Advanced

RADIO SERVICING

Methods and Ideas

A Collection of Lectures

By M. N. Beitman

Supreme Publications

CHICAGO

PRICE
$3.00

Harry E. Hedges
October 20, 1947.

Advanced

RADIO SERVICING

Methods and Ideas

THEORY
PRACTICE EXPERIENCE

A Collection of Lectures

By M. N. Beitman

Supreme Publications

CHICAGO

Objects of Supreme Publications

The purpose of all *Supreme Publications* is to help radio servicemen in their work and to aid other men to enter this profession. All of our manuals are pracfical and deal with real radio problems. Essential theory where needed is clearly explained and connected with practical radio work.

Since we first began publishing technical radio books back in 1932, almost a million various manuals, courses, books, and pamphlets issued by us have been used by radio servicemen of America. We judge by the thousands of kind and flattering letters that we have served well. We will continue to try to publish needed radio information in practical, easy-to-use form, and we will continue to sell these publications at a low price with a guarantee of satisfaction or money back.

Sincere thanks is extended to our friends and readers in the radio servicing profession. Our thanks is also given to 397 active radio jobbers and 79 book stores where *Supreme Publications* are sold.

Preface

This group of lectures is intended for technicians already doing radio work. It is true that there are men in radio servicing who need no further help. There are other radio servicemen who sorely need assistance, but who have always refused to use to their own advantage the experiences of others. We hope that you are still a different type —, a man doing radio work in a satisfactory manner, but who never-the-less does realize his own limitations and believes that additional knowledge will help to speed up repairs and make this work a better paying occupation. It is for men like you that these lectures dealing with advanced topics of radio servicing were originally delivered and now have been published in manual form.

Due thanks and acknowledgement are rendered to the firms mentioned on various pages of the text. These firms cooperated in supplying data and material on their products.

M. N. Beitman

July, 1947
Chicago

Most-Often-Needed
RADIO DIAGRAMS
and Servicing Information

☐ **1946 VOLUME 6** Newest manual covers diagrams and service instructions on practically all Post-War 1946 radio sets. 192 pages of circuits, parts lists, alignment data. Page size: 8¼x11". Price.... **$2.**

☐ **1942 VOLUME 5** You need this **Supreme Publications** Manual of servicing data on all popular 1942 sets. Repair radios quickly and properly—follow factory instructions given in these manuals. 208 fact-packed pages. Latest sets made before the War. Large size, 8½x11 inches. Low price............ **$2.**

☐ **1941 VOLUME 4** These easy-to-use, inexpensive manuals will give you 4 out of 5 circuits you will ever need. This volume covers 1941 models, with alignment data, service hints, I. F. peaks and replacement parts lists. Compiled by M. N. Beitman, radio serviceman for many years, author, and teacher. 192 pages, 8½x11 inches. Manual style binding. Each volume has an index. Price.................. **$2.**

☐ **1940 VOLUME 3** Let this important manual give you over 80% of 1940 circuits you will ever need, acquaint you with new developments, train you to service quickly and efficiently millions of sets. Data on F.M., portables, recording, etc. 417 models of 43 manufacturers. Large, clear circuits. 208 pages. 8½x11 inches. The help you need on the job........ **$2.**

☐ **1939 VOLUME 2** Another condensed manual of most-popular diagrams you need. Circuit data, hints, and information are time-savers and money-makers for you. Let these diagram manuals guide you to easier service work. 192 pages, 8½x11 inches. Diagrams of 39 manufacturers........ **$2.**

☐ **1926-38 VOLUME 1** The most popular manual of the series. Will pay for itself with time saved the first day of use. 427 diagrams of most-serviced radios, with parts list and alignment information. All popular old timers. 244 pages, 8½x11 inches. Index. Price only................ **$2.50**

☐ **INDEX** for **all** six volumes.......... **25c**

☐ RECORD PLAYERS AND RECORDERS
Just what you need to repair quickly thousands of automatic record changers, manual units, pick-ups, wireless oscillators, recorders, and combinations. Hundreds of mechanical and electrical diagrams. Instructions for adjustments and repairs. Most popular units of all makes. 132 large pages. 8½x11 inches..................... **$1.50**

☐ STEWART-WARNER MANUAL **50c**

☐ ARVIN DIAGRAM MANUAL **50c**

☐ GENERAL-ELECTRIC MANUAL
64 pages of popular circuits. 5½x8½ inches............ **50c**

☐ RADIO MATHEMATICS
Introduces and explains arithmetic and elementary algebra in connection with units, color code, meter scales, Ohm's Law, alternating currents, ohmmeter testing, wattage rating, series and parallel connections, capacity, inductance, mixed circuits, vacuum tubes, curves, the decibel, etc., and has numerous examples. Plainly written. 32 pages. Size: 5½x8½ inches............ **25c**

SUPREME PUBLICATIONS

☐ Simplified Radio Servicing by COMPARISON Method

Repair radios in minutes instead of hours. Revolutionary different COMPARISON technique permits you to do expert work on all radio sets. Most repairs can be made without test equipment or with only a volt-ohmmeter. Many simple, point-to-point, cross-reference, circuit suggestions locate the faults instantly. Plan copyrighted. Covers every radio set—new and old models. This new servicing technique presented in handy manual form, size 8½x11 inches, 72 pages. Over 1,000 practical service hints. 26 large, trouble-shooting blueprints. Charts for circuit analysis. 114 tests using a 5c resistor. Developed by M. N. Beitman. New 1945 edition. Net Price **$1.50**

☐ Practical Radio and Electronics Course
This new home-study course covers every topic of radio and electronics. Brush-up on radio fundamentals, benefit from the servicing case histories, use the practical hints, prepare for a future in Electronics and Radio.

Volume 1 contains 13 large lessons and deals with **Fundamentals of Radio.**

Volume 2, Receivers, Transmitters, Testers, covers superhets, communication receivers, oscillators, transmitters, repair, adjustment, antennas, meters, electronic test equipment, signal tracers, AFC, television, and other topics.

Volume 3, has 31 lessons on photo-cell equipment, special radio receivers, radio compass, frequency meters, life-boat transmitter, U.H.F. heating, electronic shaping circuits, aircraft direction finders, absolute altimeter, radar, metal locators, special tubes, welding controls, voltage regulators, X-rays, magnatron, electronic gages, facsimile, recording, intercomms. Contains in all 53 lessons, 332 pages in 3 volumes, 406 illustrations, diagrams, and charts, self-review questions, hints, index. Size 8½x11 inches. Price complete for all lessons.. **$3.95**

☐ ANSWER BOOK to the above course.. **25c**

☐ CYCLOPEDIA OF TELEVISION FACTS
This new television book defines and explains every term and part used in television transmitting and receiving equipment. The more important terms are described in greater detail. Well illustrated. Reprinted in 1945. 48 fact-packed pages; 5½x8½ inches............. **40c**

☐ RADIO SERVICING COURSE-BOOK

Learn new speed-tricks of radio fault finding, case histories of common troubles, servicing short-cuts, extra profit ideas. Many large lessons on the use of regular test equipment, explanation of signal tracing, television to the minute, recording dope. Many active servicemen used this reduced price radio training for brush-up and study of new service methods. Reprinted in 1946 with new information on signal-tracing, television, visual alignment, P.A., photocells, and every other fact you must know to be more expert in your work. Complete, 22 lessons, size 8½x11 inches, 224 pages. With self-testing questions and index. Greatest bargain in home-study radio training. Postpaid, only **$2.50**

☐ How to Use Diagrams in Servicing **10c**

☐ Radio Repairing with SUBSTITUTE Parts
Hints, ideas, suggestions, changes; 32 pages................ **25c**

☐ REFRIGERATION Repair, adjust, all domestic units.............. **$1.**

Book One

The Business Side of Radio Servicing

Lecture 1

Radio Servicing Basic Problem

I wish to welcome each one of you to this series of lectures on "Advanced Radio Servicing Methods and Ideas." You have shown ambition and desire to improve your servicing ability. Much time and effort have been spent in preparing this series of lectures. I will deliver these lectures, but much more than just my work went into the preparation. We believe this information will aid you in speeding up all radio repairs, operating your business in a more successful manner, and feeling greater confidence in your chosen vocation of radio servicing.

Beginning with factory production of complete radio receivers, radio found its way into the homes of non-technical individuals. These early sets were simple enough not to develop faults too often, but battery replacements, need for repairs of the antenna system, and help with tuning difficulties requred calling at frequent intervals some one with radio knowledge. In these early days, radio was a luxury from the point of cost and could be made to pay from the service side. Electricians, handy men, students taking High School Physics, and technicians who actually had some training in radio took to this new vocation. The routine was simple, see if tubes light, check battery with cheap battery meter, is the antenna connected, any wires loose; and presto the radio is fixed. But maybe on the few tough ones, the circuit would be traced. Flash-light bulb with battery, then headphones for greater sensitivity, and perhaps a 100 ohms/volt poor-sensitivity volt-meter.

Has the basic problem of radio servicing changed much? I will shock you by saying, "Not at all!"

All radio repairs are two-fold in nature: 1) the fault must be found, and 2) the repair must be made. In the old days, an entirely different technique (can you call it that) was used. It served the purpose to find the faults which developed in early radio sets. After the fault was found, the cause of the fault was removed, or a part replaced, or an adjustment carried out. Today, we use equipment to help us find faults in present day complex radio receivers. The basic problem of radio servicing is still the same — find the fault, make the repair.

So far, many interesting words, but you will ask, "How do we translate this into dollars?" Let us consider the two parts of the radio servicing basic problem: 1) to find the fault, and 2) make the repair. Both parts require time and to a serviceman time is money in the truest sense of the remark. The making of the actual repair is a mechanical task in most cases. A part is replaced, wire soldered, set screws are turned for alignment. Very little difference in time required by a novice as compared to an expert serviceman to make the actual mechanical repair. For that matter, very little time is required in most cases when this duration is compared to the time consuming task of finding the actual fault. That is the big trouble — to find the fault. We need tools to carry out the repair, but we need equipment and the know-how to find faults quickly.

The majority of these lectures will deal with the subject of finding radio faults, but we will also have material on speeding up the actual mechanical repairs. The next three lectures, however, will deal with the business side of radio servicing — this subject is badly neglected by many radio repairmen although the manner in which you run your business may spell the difference between success and failure.

We will end our first meeting by going over the outline of lectures to come. The subjects selected have been grouped in an easy to follow sequence and this material should prove of immense interest to all active radio servicemen.

<u>Outline to a Collection of Lectures</u>

Lecture 2

Setting Up a Successful Radio Repair Business

Every radio repair store or shop should sell merchandise besides offering service. The amount of effort, space, and investment to be devoted to sales will depend on each individual case, but there is a place for merchandise sales in every radio repair organization. Profit from selling radio sets, accessories, records, or electrical appliances may permit you to rent a better store on a busy street and this superior location will also benefit your service department. You will find that the merchandise section will create service business and, certainly, your service customers will buy items you offer in your store.

When we talk about location, we must keep in mind the function of our radio business in providing radio service and selling certain associated type of merchandise. Rent charged is dependent upon total space used, service offered to the tenant (heat, light, decorating), convenience to your customers, and appearance of property. Let us consider these factors.

The various illustrations included with this lecture are intended to help you visualize the suggestions. These illustrations are supplied through the courtesy of successful radio servicemen and have appeared in SYLVANIA NEWS. We extend our thanks to Sylvania Electric Products Inc. and to the individuals who cooperated with us.

The space is measured in square feet and the rent per square foot per year varies from 60¢ to $2.00. (These figures are for large cities in the present tight real estate market). A loft on the third floor of an old structure in a semi-business district, unheated, poor entrance, no elevators, no additional service, would be a poor bargain at any price. On the other hand, main floor store in the heart of the business district (where there are dime-stores, department stores, etc.) would rent very high and cannot be made to pay out as a radio business location. A good spot for your business, if you are planning to start or move, is just off the main street or section, in a good business district.

A store with heat supplied will prove economical in the long run. I am thinking of your time rather than the cost of coal. Toilet facilities must be available. Other factors are not important. If these extra services are omitted, be sure the rent is reasonable enough to permit you to spend additional sums for light, decorating, insurance, and other services sometimes furnished by the real estate owner.

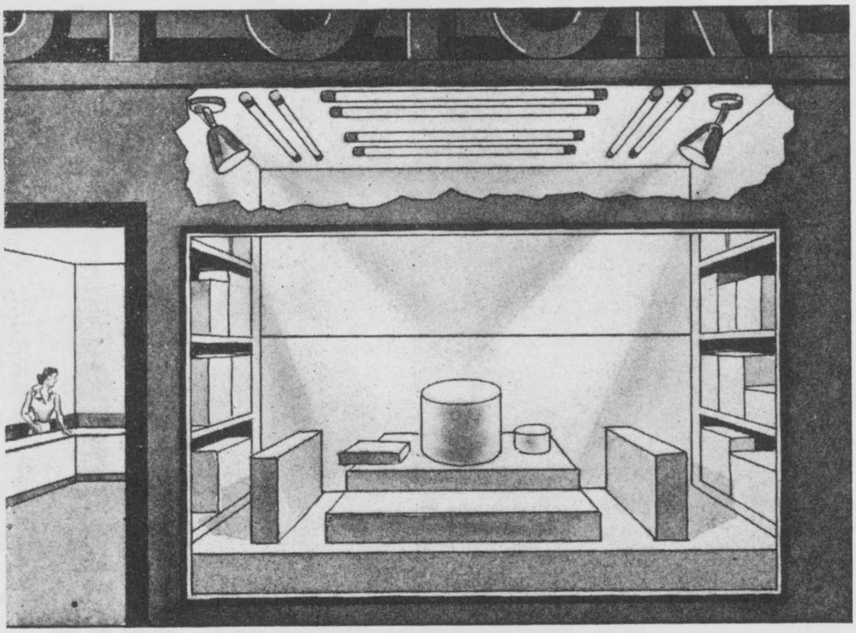
Front should be brighter than street to attract notice; Inside shop is even brighter

Convenience to your customers is important in permitting you to develop additional business and keep your old customers. If your place of business is located where your customers usually shop, attend the movies, pass on the way home from the center of the city, you have the right spot. In fact the number of people passing in front of your store (or, to a lesser degree, walking on the main street just around the corner) can be used as a measure of your store convenience.

It is hard to make an old, run-down building appear attractive. It is expensive to modernize or dress up a store front and besides the poor appearance of the neighboring stores can ruin your best efforts. People, who may become your customers, prefer to shop in an attractive, inviting place. It will be worth while, therefore, to pay a little more rent for a place of business in a well-kept, modern building. The many photographs of successful radio businesses are illustrated in connection with these lectures to help you visualize my suggestions.

Please understand that a successful radio business can be operated from the home or a garage, but I feel that if a man can do well with the handicap of a poor location, he can do wonders once he is located in a suitable business place.

Your store has a front door and probably one or two windows. These important money-making aids are usually not utilized to the best advantage of the radio business owner. And, mind you, a good part of your rent money pays for the front entrance and windows. The outside front of the store always must be clean. The door must be inviting. It must have clear glass, no advertising matter of any type, but your name and store hours can be lettered by a professional sign painter. A new brass handle, or the refinishing of the woodwork of the door in a light stain will help appearance.



Store window is amply flooded by use of concealed spots and fluorescent fixtures

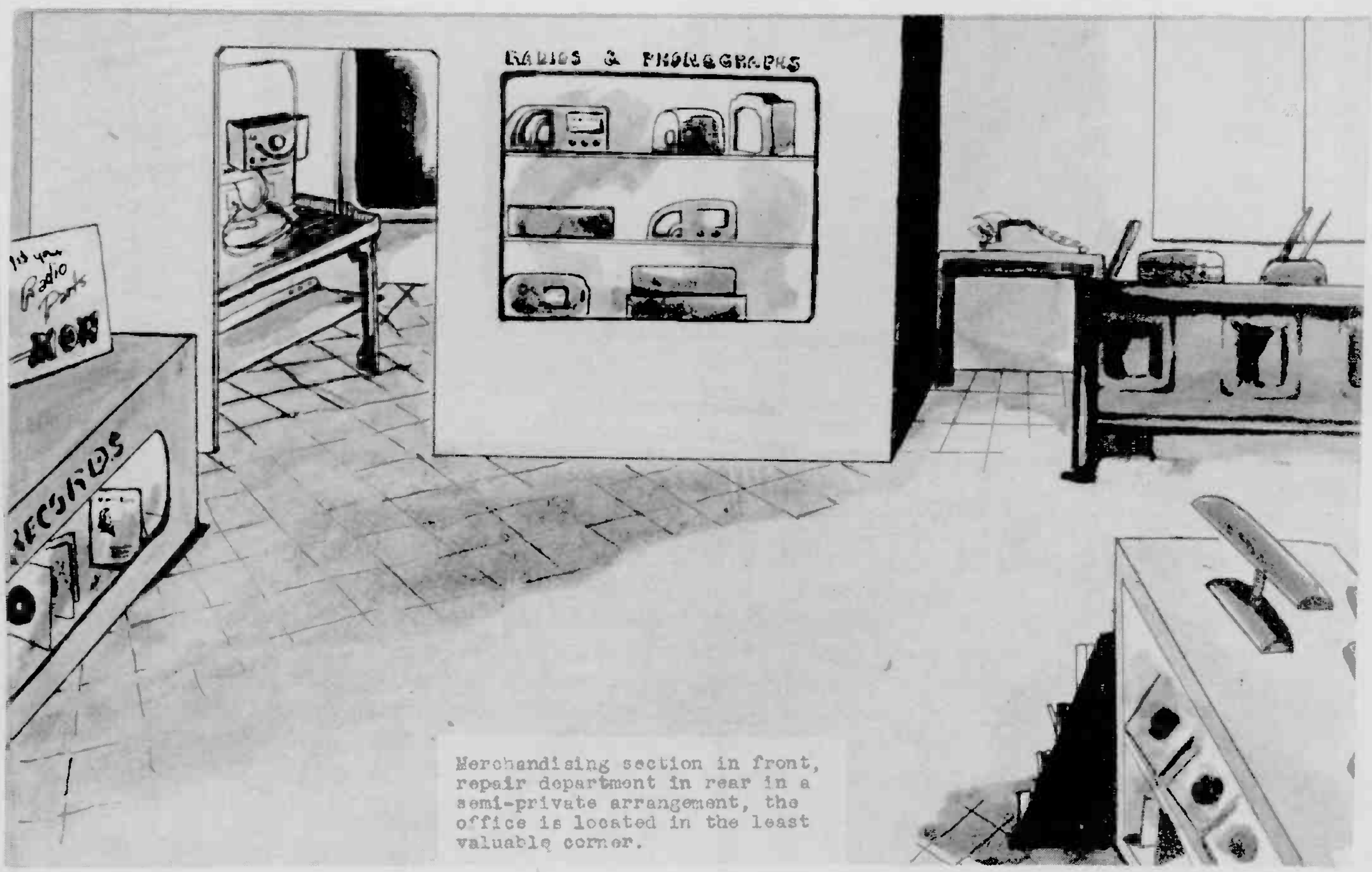
Consider your windows. Spend a few days and evening hours examining the windows of large successful businesses — not necessarily radio. What can you do to make your windows stop passerbys, and get them to come into the store? Important facts you will notice: plenty of light, interesting items cleverly arranged but not crowded, to excite interest, part of the story in the window, but offering the balance and answer inside. A few additional suggestions along this line are presented in an article, "Striking Displays Can Sell Radio Service," in December, 1946, issue of Radio News. We reproduced from this article, through the courtesy of Radio News magazine, the two illustrations below.

A neat, attractive window display. Located in a metropolitan area, this simple presentation packs a terrific selling punch. The display shown in the inset definitely lacks selling force. Merchandise occupying the most desirable positions in this window has no connection with radio or the service offered by this store.

This type of building lends itself to some type of distinguishing superstructure. This antenna mast identifies the store to both pedestrian and automobile traffic.

Divide the inside store space for merchandising, repairs, and office. Little space will be needed for the office, but a private corner should be provided for this purpose. This may be a small room or a corner set off by partitions. This office space will provide privacy for interviewing salesmen and job applicants, making personal telephone calls, examining your accounting books. The space used for the office should be least valuable; it may be in the rear, but should have a window if this is possible.

The front part of the store should be used for displaying the merchandise you will handle. Here again, a study of how large department stores arrange similar items will be the best guide. Do not crowd the items, provide chairs for the customers to relax, utilize display material supplied by the manufacturers.



Merchandising section in front, repair department in rear in a semi-private arrangement, the office is located in the least valuable corner.

It is a hard trick to get the service department in just the right place. It must be partially hidden and yet in part exposed. The benches must be hidden to a degree to give you and your service help some freedom of movement and not place you under the scrutiny of every curious customer. But, on the other hand, exposing the service department with its well arranged benches, test equipment, radios to be repaired, lets your customers know of your facilities to repair sets and instills confidence in your ability. How did some radio stores overcome these conflicting objectives?

It is possible to place the service department in a separate section and use an open arch doorway to connect it to the main merchandising section. A glimpse of the service department can be obtained as one moves about the front section of the store.

Another solution is to place the service department in the rear section, using a wall and counters for separation. The view beyond the counters will show the repair shop. This arrangement gives great flexibility if partially opaque (frosted) glass is added in parts of the wall. Mirrors are useful to give illusion of larger space and to dramatize a view. A few ideas along this line are illustrated.

Illustration of my suggestion for separating the merchandising and repair departments. Privacy is obtained for the service section, but its advertising value is not lost.

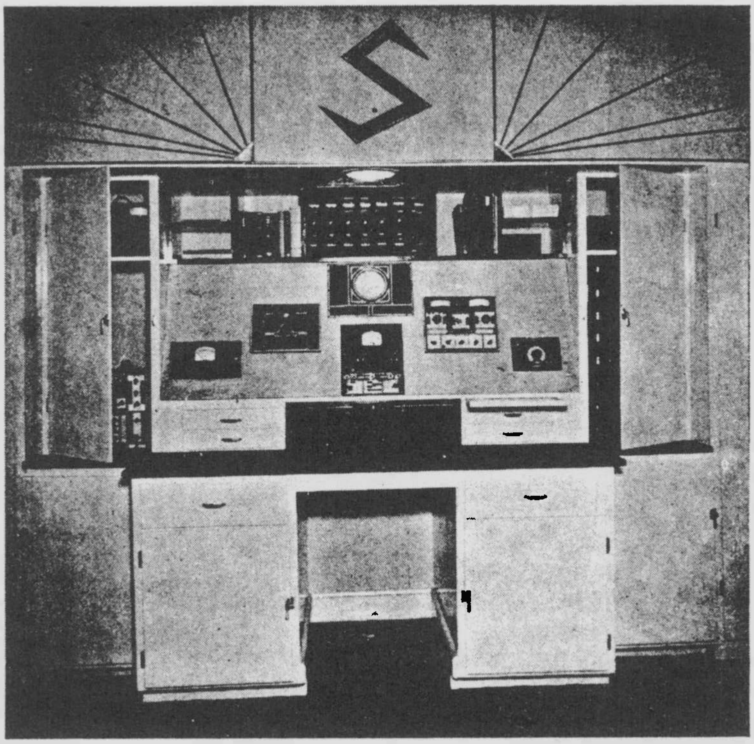
Since this lecture was delivered, I have learned of a model radio service shop, which has been designed and tested by Sylvania Electric Products Inc. There are so many excellent ideas included in this design that permission has been obtained to present the material on this shop in the few pages to follow.

Important facts are stated in the plans and description and additional information is given below.

Celotex was selected as interior finish for walls and ceiling because of its insulating properties, its moderate cost, and its adaptability for modern decorative effects. Its natural color and texture are pleasing and do not require painting or other finish.

The cabinets and finished woodwork are constructed of one-inch clear white pine. Enamel paint, in ivory with darker brown trim on counter and shelf edges, was used because it is easily kept clean by washing. The bench and counter tops are covered with Celotex hard board, stained brown and shellacked. Hinges, latches, and handles are chrome plated. Chromium-foil-covered moulding is used as trim above the analysis bench and the screen cage. This material, much less expensive than metal moulding, lends itself to many modern decorative effects and finishing treatments.

The general lighting consists of 2-lamp, 40-watt fluorescent fixtures mounted approximately 10 x 10 centers in the service area. Additional lighting calls for outlets over the work bench and the analysis bench, with possibly an additional outlet for a desk lamp in the desk space area. There are plenty of electric outlets in the repair section and analysis section, as well as at other convenient points. This lay-out is not offered as a plan to be followed exactly by every serviceman. It is hoped that servicemen will obtain ideas and suggestions for modernization and improvement of their shops, to gain both greater convenience and better appearance.



The Entrance

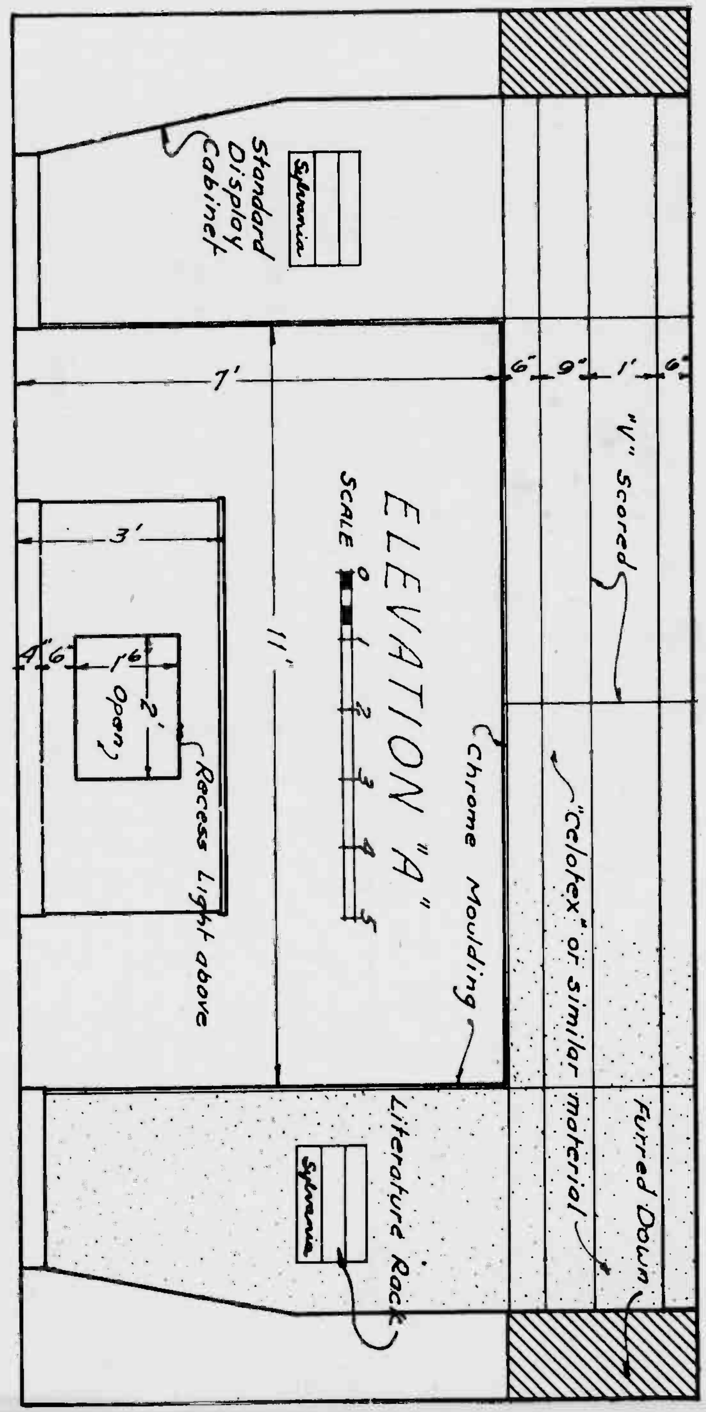
THE entrance of the Model Service Shop is a little different from ordinary store entrances, where the idea is to get the customer to walk through all parts of the shop. Here the idea is to make a good first impression, and to keep the customer out of the working space. The view on the page, Elevation A, shows how this is accomplished.

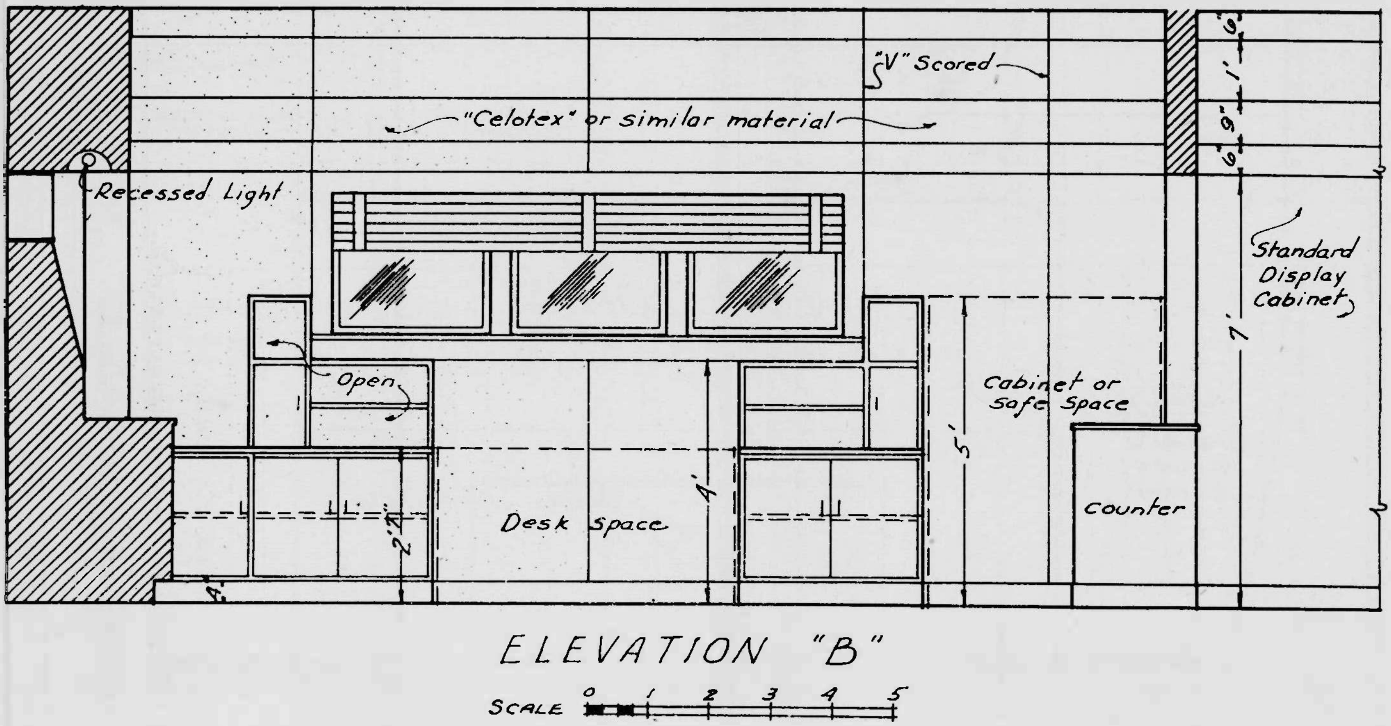
A six foot counter, directly opposite the entrance door, and flanges, or wings, built out from the walls, give the effect of a separate "reception room.". This space may be provided with comfortable chairs or settees for customers, and should be attractively lighted and decorated.

The counter, like the wood work in the shop, is painted ivory with brown trim and chrome plated moulding. A display case, 2 x 1½ feet, glass fronted and indirectly lighted, is built into the front of the counter. The rear of the counter provides convenient storage for tubes and other merchandise sold at retail, and is provided with double doors.

The wings extending from the walls, and the valance over the counter, are built of Celotex, grooved with the decorative design carried out on the walls and ceiling of the main shop. Between these wings and the display windows at the front are standard display cabinets for retail merchandise. The type of cabinet to be used is left to the judgment of the individual shop owner. If the business is only radio service and set sales the cabinets may not be necessary, and the space can be used for seating accommodations.

The display windows are a valuable part of service shop investment, and should be treated as such. Clean polished windows and frequent changes of the varied and attractive display material provided by manufacturers will make this part of the shop an invitation to come inside.





Office Section

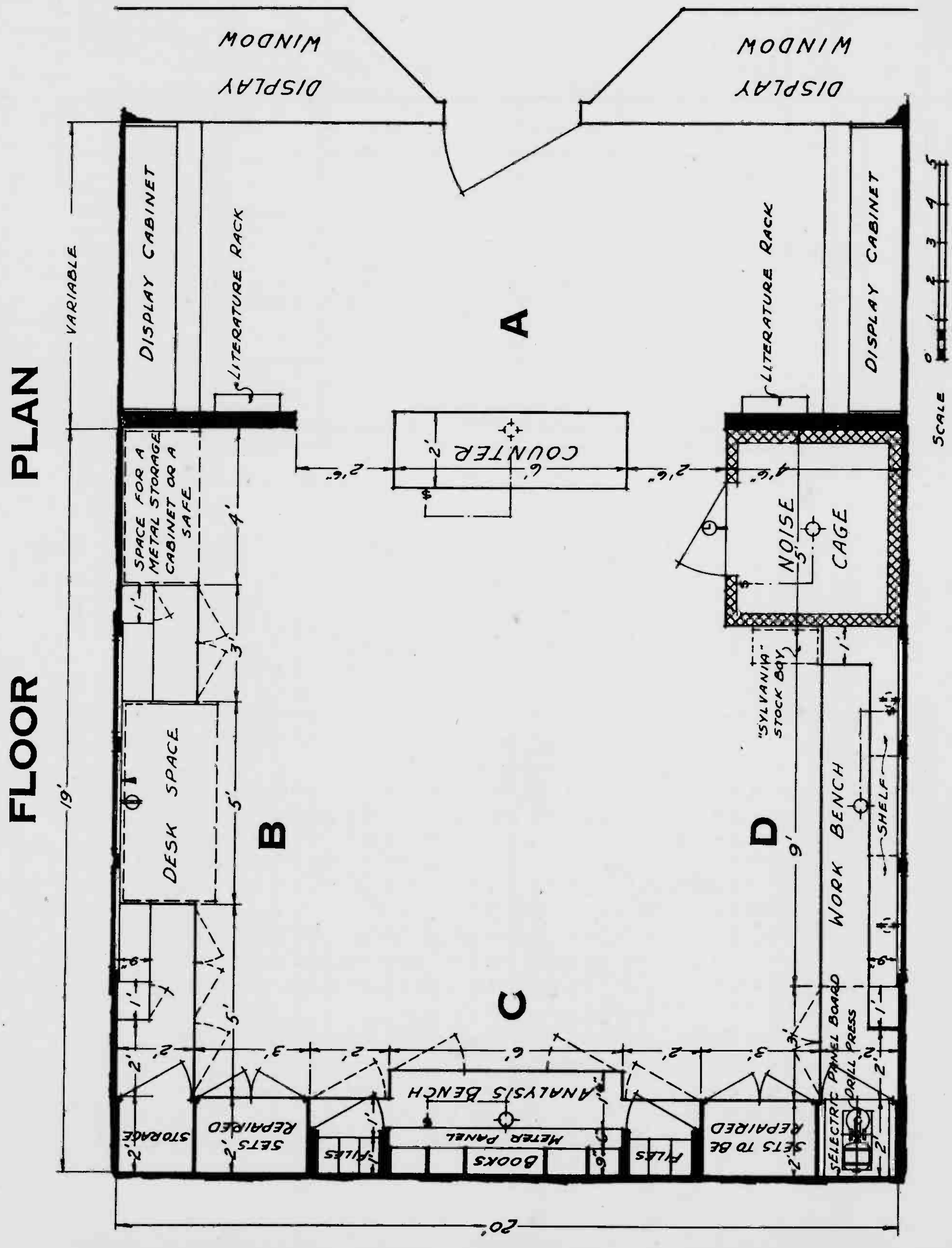
THE main object in having an office section is to segregate this part of the business so that the service shop will not have a "cluttered" appearance and so that business transactions can be carried on in a business-like manner. A well organized office section will convey an impression to customers that can not be given any other way and will instill confidence that the service shop is an organized business institution.

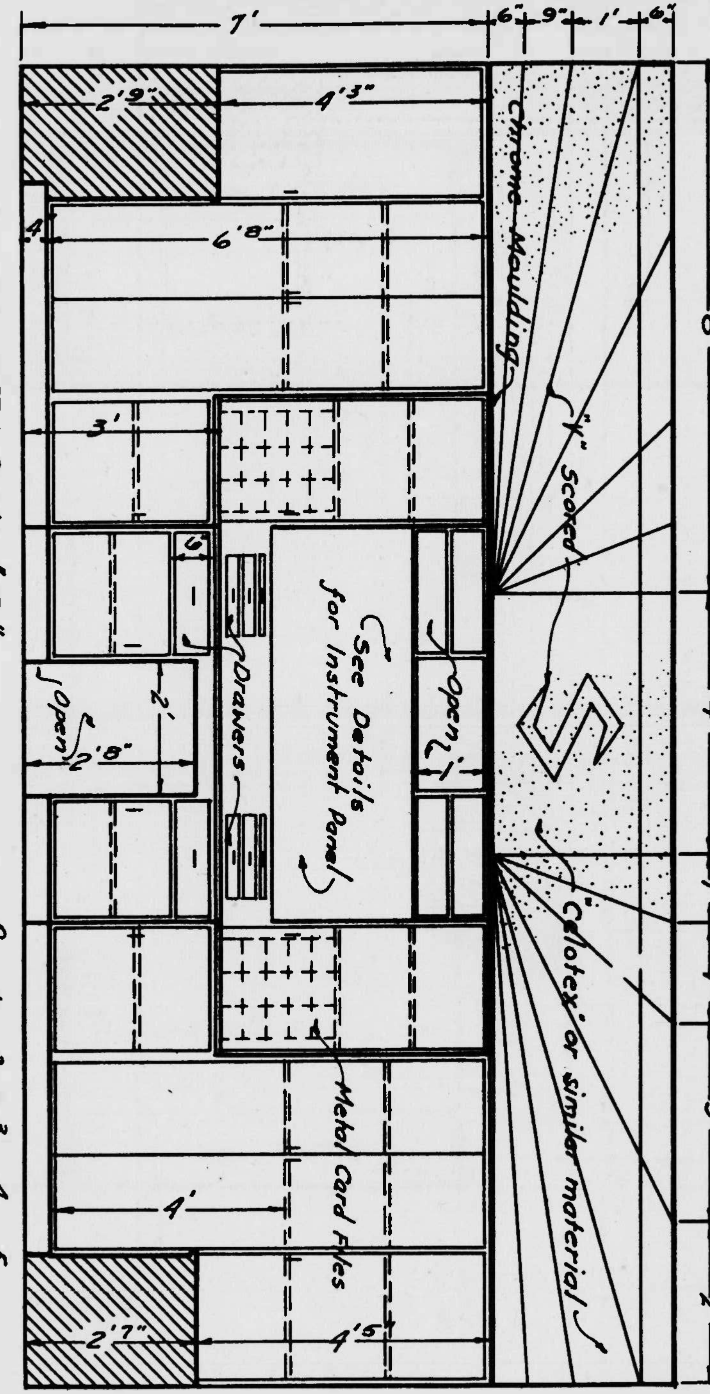
The office section of the Sylvania model service shop, shown in Elevation B, contains a standard office desk and chair, with lamp, telephone, etc. On either side are closed cupboards for office supplies. Shelves over these cabinets hold bound files of radio magazines, bulletins, and miscellaneous literature which is so valuable, yet so often contributes to the "mussy" appearance of a radio service shop. The front cover gives a good view of the lay-out of this section.

The cabinets in the office section are painted the same color as the cabinets in the other sections of the shop, ivory, trimmed with brown. The walls are covered with soft Celotex wall board with the modernistic grooved design carried out.

The windows are covered with ivory colored Venetian blinds which have brown tapes and draw-strings.

It will be noted in the elevation view that a space is provided for a cabinet or safe.


FLOOR PLAN
DISPLAY WINDOW
DISPLAY WINDOW
DISPLAY CABINET
LITERATURE RACK
LITERATURE RACK
DISPLAY CABINET
VARIABLE
A
B
C
D
COUNTER
NOISE CAGE
SPACE FOR A METAL STORAGE CABINET OR A SAFE
DESK SPACE
"SYLVANIA" STOCK BAY
WORK BENCH
SHELF
ANALYSIS BENCH
METER PANEL
BOOKS
FILES
FILES
STORAGE
SETS REPAIRED
SETS TO BE REPAIRED
SELECTRIC PANEL BOARD DRILL PRESS
19'
20'
SCALE



ELEVATION "C"

SCALE 0 1 2 3 4 5

Analysis Section

ELEVATION C, on the opposite page, shows the analysis section of the Sylvania model service shop. This section is designed for the purpose of analyzing receiver troubles. It contains an analysis bench which is located in the center with built-in book shelves above and file cabinets and storage cabinets on either side. The analysis bench in detail is shown on the last page. This is built of one-inch white pine with a sloping panel of ply-wood, five plies thick. This type of panel is used so that when future changes in equipment are necessary, the ply-wood is easy and economical to replace.

The test equipment used on the sloping panel consists of a Universal Speaker, Tube Tester, Signal Generator, small Oscilloscope, Volt-ohmmeter and a Condenser Analyzer. These instruments are considered necessary for making complete receiver tests, but the choice may vary, depending upon the owner. Below the sloping panel is a control panel made of bakelite which includes outlets for 110 volts a-c, 6 volts d-c for auto receivers, 500 volts d-c, an auto transformer, switches for the instruments in the test panel and for the light above the analysis bench. Antenna and ground outlets are also included by means of two stainless steel rods, built in an "L" shape for decorative effect. These are mounted on either end of the black bakelite panel. The rods are tapped for set screws to fasten antenna and ground connections. Connections can also be clipped to the rods since the stainless steel will not show marks.

On either side of the control panel are two drawers for holding the various connecting cables of the test sets. Above each set of drawers is a sliding shelf on which charts and operating instructions for the test equipment are fastened. On each side of the analysis bench are closed cupboards which provide storage for parts cabinets, for a set of Sylvania file cabinets, for job records, cross reference information on service hints, and plenty of room for storing sets to be repaired, and finished sets ready for delivery. The set storage cabinets are large enough to contain consoles, and also provide space for smaller sets and chassis. Above the sloping panel are shelves for Technical Manuals. As noted in the detail drawings of the analysis section shown on the last page, the center is built to hold service Manuals with space on either side built for other types of reference books. A flood light over the analysis bench gives ample light for all working conditions. The wall above the analysis section is covered with the same soft Celotex wall board as used on the other walls and ceiling. A flashing "S", grooved into the wall board, gives a pleasing effect.

The cabinet shown in the left side of the elevation view is used for the electric meter, fuse boxes and the drill press. The drill press is mounted on a sliding shelf which pulls out onto the repair bench when needed and is further described in the "Repair Section."

Repair Section

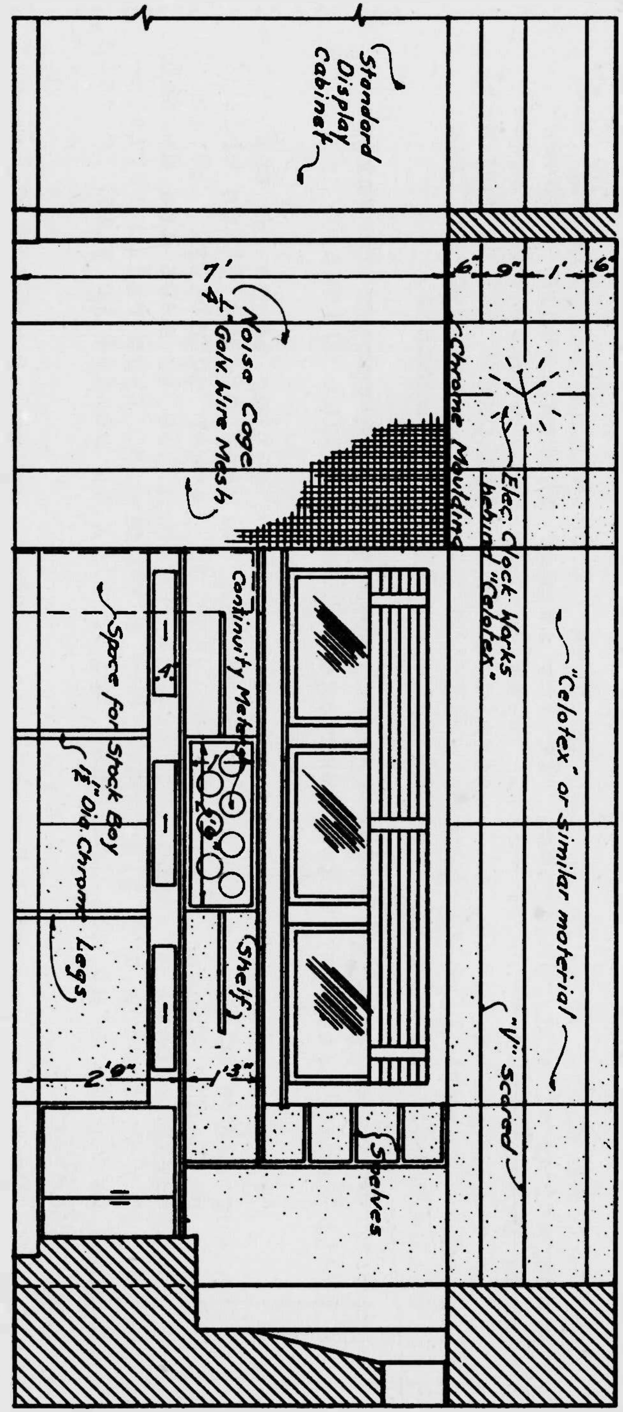
THE Repair Section, shown in Elevation D, is used for the general repair of receivers. The bench is of standard size and height, with plenty of drawer space for tools and small equipment. The top surface is covered with Celotex hard board, stained brown and shellacked. In the back center of the work bench is a series of small meters which can be used for reading currents, voltages and for continuity work. Many servicemen consider such meters of little value, but with a set of adapters this equipment will be found quite useful.

Above the repair bench are two shelves. The smaller is drilled with holes of various sizes to hold tubes and tools. Fastened on this shelf are two stainless steel rods which act as antenna and ground connections, tapped like those on the analysis panel. The larger shelf can be used to accommodate small equipment used in connection with the work bench. Under it are two 18-inch fluorescent lamps which light the repair bench.

At the right end of the bench (see Elevation C and general floor plan) is the cabinet in which the electric meter and fuse boxes are located. The interesting feature of this cabinet is a sliding shelf on which is mounted a shop drill press. When needed it slides out onto the work bench. When not in use it is out of sight in the cabinet.

At the extreme left of the work bench is a screened noise cage, 7 feet in height, used for oscillograph work and similar operations. The exterior and interior, including the ceiling and floor, are covered with ¼ inch mesh galvanized screening applied over a framework of 2 x 4 inch lumber. The inner screen is directly connected to ground, while the outer is connected to an electro static shield included in a one-to-one ratio transformer connected in the a-c circuit of the cage. This arrangement provides a workroom free of electrical interference. A different type of filtering may prove satisfactory in localities where interference is not so great a problem as in industrial areas.

The cage is equipped with a bench of standard height and a large oscillograph. Lighting is provided by a 100 watt light over and outside the screened cage. A fluorescent lamp may be used here if desired, since it is outside the shield. Celotex wall board encloses the space from the top of the cage to the ceiling. On the side facing the entrance is a built-in electric clock. The movement is a standard store-size clock mounted on a piece of aluminum which covers the original clock face. New hands of larger size were cut from aluminum and applied over the original hands. The hour divisions are simply straight grooves cut into the Celotex border. These changes give a pleasing modernistic effect at small expense.



ELEVATION "D"

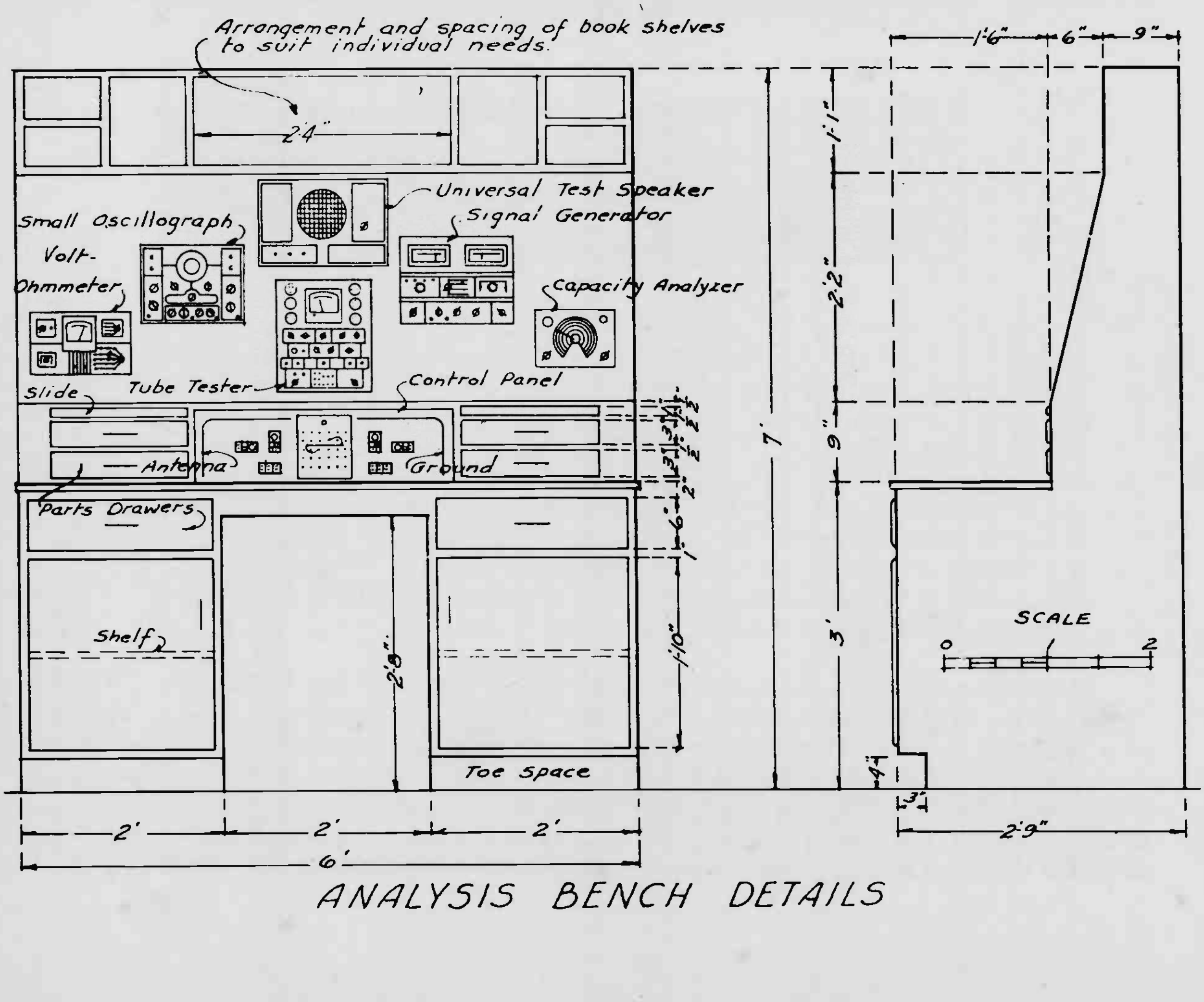
SCALE 0 1 2 3 4 5

We will now turn to the problem of obtaining supplies in the operation of your business. In the larger cities, radio jobbers can handle your requirements. Usually the same outlet will serve for radio parts, sets, and occasional test equipment which you will need. By establishing proper relationship with your jobber, you will benefit by his advice and interest in your success.

You should also study advertisements which appear in various radio magazines, and take advantage of any special offers.

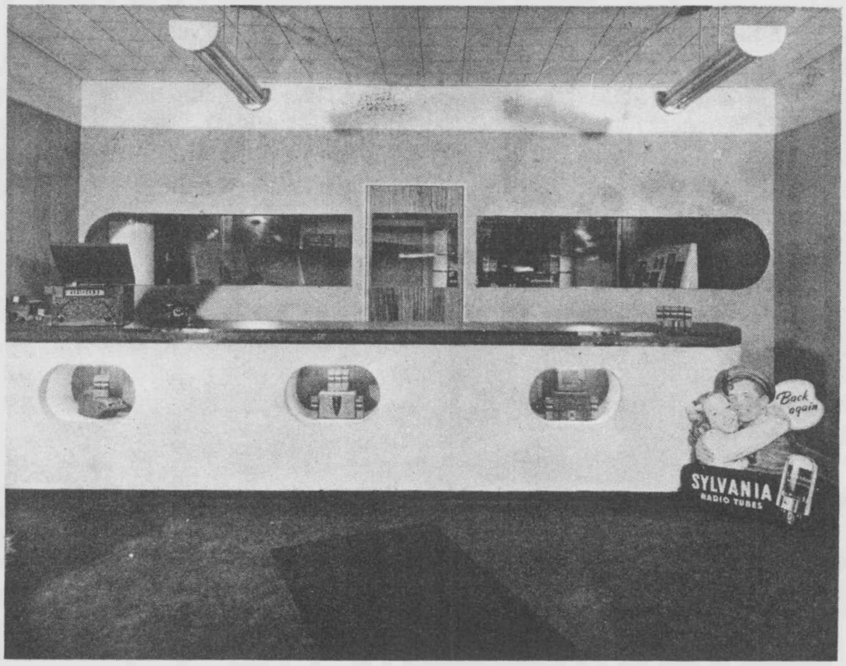
In purchasing an initial stock, it is better to be on the conservative side. Some records should be kept of the items which move best and these should be replaced in larger quantity. It is important to have on hand sufficient merchandise to meet the demand of your customers and also have the more common type radio replacement parts so that not too many trips will be needed to your sources of supply.

Probably you will be able to obtain employees needed in your business from among your acquaintances. However, if you need someone to fill a specific position and cannot contact a suitable



ANALYSIS BENCH DETAILS

person through direct knowledge, there are several means of learning of the availability of a suitable individual. Employment agencies which advertise in the telephone book may be able to help you. Small classified advertisements in your local newspaper will usually bring to you several suitable applicants. In writing this advertisement you must describe the position available and what is to be expected from the applicant. In this way, you will not waste your time and the applicant's time in discussing the position which may not be suitable for the applicant.



Suitable records should be kept in reference to the expenditures and sales so that you could tell from time to time the progress of your business. Also, these records are required for filing income tax forms and in some states for filing sales tax reports. The type of records to be kept need not be elaborate, but it is best if these are organized originally by an accountant who can get you started in the right manner and, if need be, give you occasional assistance on a fee basis. Radio stores ordinarily employ the services of an accountant once a month and the fee runs from $10.00 up, depending on the amount of work involved in checking the books and preparing needed reports.

Recently a business record book issued by Sylvania Electric Products (Emporium, Pa.) has come to my attention. This handy manual provides space for keeping complete records for one year and is especially well suited for a small radio store or shop. Complete instructions and specimen pages make the use of this manual easy for everyone. I recommend this manual for your use unless you already are using a suitable bookkeeping system.

Lecture 3

Obtaining Radio Repair Jobs

Servicemen forget that they live in a highly-competitive society. They expect Mr. Radio Owner to come to them when he has radio difficulties, to beat a path to their door, and to search high and low for their addresses if necessary. Of course, this does not happen and the fellow down the street gets the job. If you want more business, if you want the business of people who never heard of you, you must let them know of your existence, your good points, your special abilities to serve them. You must approach them many times in many different ways. Advertising does this and advertising pays!

Money invested in advertising is far from being foolishly spent. Not only do you expect to receive back every dollar spent on advertising, but on every dollar you expect a certain definite return in the form of increased business and greater profits. You will get these successful results if you plan your advertising wisely and correctly.

Among the various forms of advertising suitable for radio service business, advertising in publications such as local newspapers and telephone books is most common. When advertising is sent directly to the prospect, either by mail or messenger, this method of advertising is called direct mail.

Posters, window displays, and signs are very effective ways of obtaining additional business. See the sample illustrated. There are also certain unique methods of advertising salesmanship that get business.

Advertising in any form must get attention. Unless an advertisement or a sign attracts attention, it is not present as far as the prospective reader is concerned and it is useless. Attention is obtained in various ways. Sheer size, black type, white space, color, novelty, illustration, and catch-phrases serve to get attention.

Once attention is arrested in any suitable manner, the interest of the reader must be held. The story, the picture, the idea must "get the reader," compel him to read on. In other words, it is not merely enough to notice an advertisement, but the advertisement must actually prove interesting. With the reader expressing a not personally realized interest in your advertisement, the next step is to create a desire. A desire for a better set, a new set of tubes, or better reception.

SAMPLES OF CLASSIFIED ADS

Service, Repair, Etc.

$1 RADIO SERVICE—WORK GUARANteed. No set too complicated. Experienced men, Radio Center, 19 Yes St. BRyant 9-0553.

50c—RADIO SERVICE— Any place; work guaranteed. BRyant 9-0553.

E-Z TERMS ON ALL RADIO REPAIR. wash. mach. vacuum cleaners. BRyant 9-0558.

50c RADIO SERVICE. ALL WORK GUARanteed. Anywhere, any set. BRyant 9-0553.

Once the desire is aroused, the reader must be impressed with conviction that your tubes, your service, or your appliances are what he wants. Your items and service must appear to him as the logical solution of his desires.

At this stage, the reader is convinced that your service or products are what he wants and needs, but you must make him act. Action will make him pick up the 'phone and call you up or stop in to have his tubes tested. Do not merely tell your story in your advertisements. Finish up with action that will make the reader exclaim: "I'll phone that service man right now," and not "Well, my radio hasn't been playing right, I'll get it fixed one of these days."

In larger cities, a small advertisement in the want-ad section of the daily newspaper brings excellent results. Some outstanding points about your service must be featured. Note the few examples shown. The feature of the first ad is the fact that no set is too complicated and the work is guaranteed. In smaller city papers and in weeklies it is best to take display space, two or three inches.

The principles in the preparation of the advertising copy are therefore well defined, and of course the main objective is sales. It may seem a far cry from a two-line classified advertisement to a well-considered plan of copy preparation. Perhaps it is. The name, nature of business, solicitation, address and telephone number may take up half the space. Not much theory need be applied to creation of the seven words constituting the extra line of type. But there are at least two factors that justify exercise of skill and care, even under the extremely restricted condition outlined. First, the habit of doing things right is just as important to your grandest one, and large advertising agency businesses have been developed for handling only classified advertisements because of specialized skill; second your advertising space will grow with you, and the principles applicable to copy and art creation are in general the same for all sizes of advertising space. So address yourself to these purposes:

1. Arouse interest.
2. Create desire.
3. Impress conviction.
4. Induce action.

Telephone book advertisements offer excellent possibilities. A large number of people turn to the 'phone book when they are in need of some special commodity or service. The two examples shown demonstrate the two possibilities of such advertisements. Notice that the upper ad has much copy or reading matter. On the other hand, the second ad has white space and but a few words. Both methods have their advantages, but a happy medium will be best.

Telephone-book advertisements.

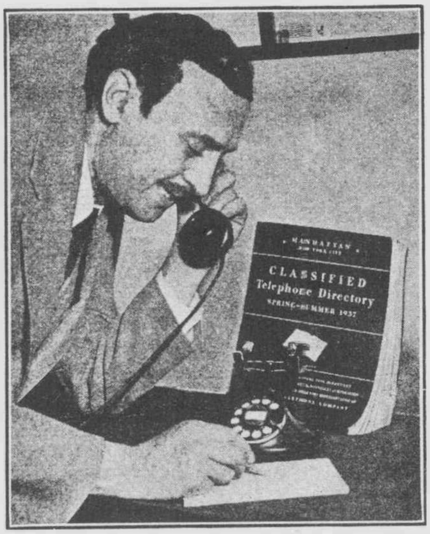
Dreams will not create successful advertisements or bring business to your store. Good advertising should make things easy for your customers.

Every serviceman should have a complete mailing list of the people he has served. Occasional mailing should be made, suggesting free check-up service on tubes, or other offer. New names may also be used for this publicity.

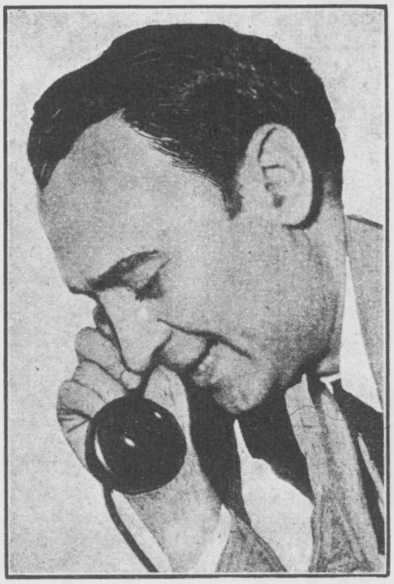
Publicity via the telephone is also adaptable for selling service. If Mr. Brown had his radio repaired ten months ago, a telephone call some evening should be made. Here is a typical conversation:

"Good evening, Mr. Brown. I repaired your radio sets ten months ago. How does it work now?"

"Fine. We haven't had a bit of trouble with it since."



"These new aerial systems bring in short-wave stations louder and also reduce noise on all stations."



"To tell the truth, I didn't hear about them. How much —". The sale is practically closed.

"I'm glad to hear that. I was wondering if you'd be interested in improving your reception by using a high-efficiency antenna system. You've probably heard about these new aerial systems that bring in short-wave stations louder and also reduce noise on all stations?"

"To tell the truth, I didn't hear about them. I'm in the sugar business and we don't hear of such things in our line."

"Well, Mr. Brown, sugar is your business but radio is your pleasure. And you do want to improve the pleasure you and your family get from the radio set, don't you? The United States Government recognizes the worth of the high-efficiency antenna, and mentions it in its book, "A Guide to Reception of Short-Wave Broadcasting Stations." I'd be glad to install one of these systems and your whole family will be delighted with the result."

"How much would it cost?"

The sale is practically closed. When it is, the "guide" may be offered, too. It is in simple language and costs a quarter.

But a sale will be the exception rather than the rule. If no immediate results are obtained, at least goodwill is established. It is vital to be good-natured even when "No" is the answer to your sales talk.

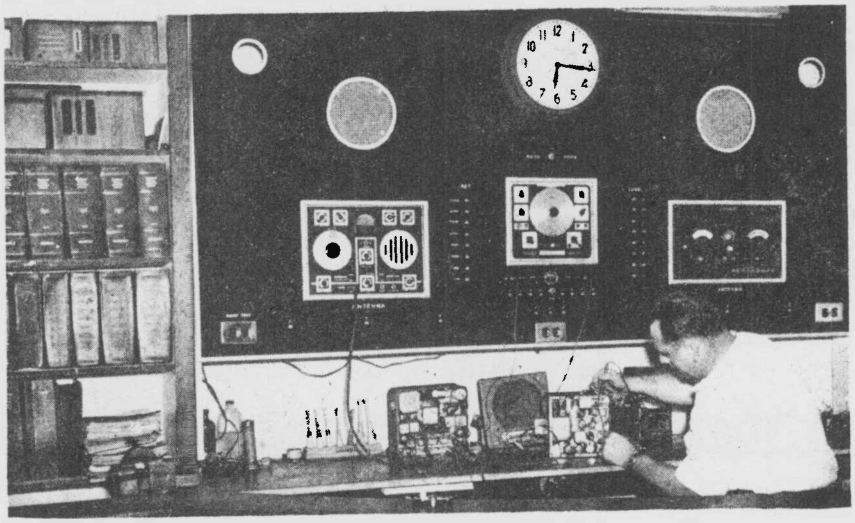
We illustrate a postal card, supplied by Sprague Products Company, and intended to help servicemen solicit noise elimination work.

Antennas are not the only topic. Nor is the report of fine reception the only answer. If the set is working satisfactorily, it is of small value to discuss tube testing or set checking. But you might inquire whether the customer plays phonograph records, and if electrical reproduction is not used, explain the better tone possible by use of a phonograph adapter. Various accessories are best plugged hard as soon as they come out, and telephone calls based on new products of that type are very helpful in extending your prestige and convincing your customer you are a live wire. It is just as vital to hold old customers as to get new ones. And the old one is a new one in a sense, when you make a sale you otherwise would not have made.

The results of different types of telephone solicitations should be checked. Perhaps some particular approach is the one you're best at, as results will prove, so largely follow that, but keep trying others also, to avoid possibility of operating in a restricted groove.

Window display advertising can be very effective. It is of prime importance, where you have a street front, to have the window dressing not only neat and orderly, but interesting. This is an art in itself and large outfits either have professional window dressers on their payroll or hire them as needed. A small operator has to do his own work, probably. So the fellow who started out as a service man finds he has to be an advertising writer of sorts, a window dresser, a bookkeeper, a buyer, a clerk, and finally a service man.

Help in a plan of window display may be obtained from the women folk. Mother, sister, or wife can suggest that "touch" a man handy with soldering iron is not likely to have.



The usual displays as received from manufacturers may serve well on counters and in windows, but the most effective method is one invoking originality. Then one's window becomes distinctive. Services that incur movement are impelling. Anything that evokes an interesting contrast is valuable for its attention value. All ideas should be definitely associated with a sales appeal. The object is to sell. Everything else is only the means.

One fellow got six dead transmitting tubes from a station and put these giants next to six receiver tubes. He cited the fact the station checked tubes hourly. Why should not the listener have his tubes checked twice a year, also for the same reason — best quality performance? The transmitting tubes cost $1,500. The six receiver tubes could be bought for less than $5.

"Let us check your tubes" is the sales appeal, because if any tubes are bad or weak, a tube sale is made, and if the tubes are in good condition, the set may not be. Or, if everything is all right, some accessory may be sold to make reception better than just "all right," or to introduce a new service from the receiver, as in the case of the phonograph pickup attachment.

Another dealer attracted large crowds of real radio prospects by offering $10 prize for the owner of the oldest radio set. Certainly the person who thinks he has the oldest radio in a community is a good prospect for a new set.

Lecture 4

The Question of Rates and Charges

The subject of the rate per hour can be calculated by considering all expenses including overhead for a period of one year and dividing this sum by the total number of productive hours in this period. This high-brow accounting technique is better suited for larger corporations. You better figure on a flat fee based on amounts others have found satisfactory. You should not make less than $1.50, but try to average $2.50 per hour. This is not too much when you consider the hours spent in travelling, buying parts, possible adjustments, holidays, and other hours spent in your business without direct earning.

I do not recommend, however, that an hourly charge is made to the customer. A charge should be made for the complete repair since this is what your customer wishes to purchase — they do not want to buy time. Parts used, at retail price which is about 66% above your cost, should also be added to the bill.

You should use the hourly charge suggestion in computing the probable charge. An estimated charge can be given in advance — make this on the high side, this will prove a good idea if the actual cost comes out about the same or lower. Charge the actual price as computed when the job is finished. If an exact price is wanted, take a guess. Make it high enough to be safe. Charge this price for the job no matter if it turns out higher or lower. Now let us consider how the price can be determined.

Brief tests to localize the source of trouble in a radio set will require about one-half to one hour. Much will depend on the difficulty of getting the chassis out of the cabinet. In the shop, the cost of time to find the fault will average between $2.00 and $3.00. If you know the fault is an intermittent, play safe with a cost figure of $5.00. To do the work in the home about $2.00 must be added to cover travel time.

The actual repair may take from a few minutes to replace a resistor to over an hour for replacing an I.F. transformer and completing the alignment. About $2.50 will cover most cases. Parts for an average job will cost $1.00, you figure $1.60. These figures indicate that an average job in your shop will be billed between $6.10 and $7.10. This gives you a figure to use if a price is wanted completely in advance; make it $10.00 for safety. If you are permitted to give the set a brief examination (your charge is $2.00 to $3.00 anyway if your customer does not want the work completed), you can give a more accurate estimate. Add a small amount anyway as a safety factor.

Be careful to quote what you believe are the correct figures. State the amount in a clear voice, make the customer realize by your actions and speech that you carefully considered the price and your quote is fair and final. If the customer wishes to think the matter over, permit him to do so, but make a record of your quotation for future reference. If the situation permits, you can go into some detail in explaining how you obtained your charge. This suggestion applies both to the occasion when you are furnishing a quotation and when you are presenting the actual bill.

Each job should be covered by a bill where labor appears as one item (no hours need be shown), and every single part used should be listed together with the net price to your customer. Any damaged parts removed from the radio should also be presented at this time. If you are told to junk these parts, try to break or mar them in some way while the customer is still present.

A suggested job ticket and receipt (sold by Sylvania Electric Products) is illustrated. You may use this as a guide in preparing your own printing.

We understand that the Superintendent of Documents, Washington, 25, D.C., has available a booklet, "Establishing and Operating an Electrical Appliance and Radio Shop." This booklet is priced at 35¢, and may be ordered direct by remitting a money order or cash.

Book Two

Equipment Used for Locating Radio Faults

Lecture 5

Visual and Aural Examination

Many of the faults which arise in radio equipment can be detected with a simple observation or with tests that do not require any equipment. I do not advocate that a radio serviceman should attempt to make repairs without the aid of test equipment he owns and has available for the job, but at times extra effort can be saved with an oral, visual, and even nasal examination.

You will agree with me that certain service jobs do not require test equipment. For example, broken dial cords, faults in the antenna lead or A.C. cord, or glass tubes actually broken. There are many other radio repair jobs where the fault can be found without test equipment. I will describe a dozen just to get you to think along our simplified fault-finding technique.

In a AC-DC set, all tubes fail to "light up." An electric lamp connected to the same power socket indicates presence of voltage. You would suspect a single bad (burned out) tube. This can be found with voltmeter (A.C.) while set is on, or ohmmeter with set off. Better yet, use 50 to 100 ohm resistor, quickly parallel each tube filament connections with this resistor while set is on. When other tubes "light," the fault lies in the tube under test.

As another example, rectifier tube shows excessive color, or is very hot, or has burned out. Disconnect filter condensers, connect a 450 volt electrolytic of any capacity at the input to filter, replace rectifier if needed, see if the set works. If operation is restored, one or both filter condensers are bad. Better replace both in any case.

In a push-pull stage, one power output tube lacks filament "light." Tone bad, but set operates. You can guess that one bad tube throws push-pull stage off balance; the cathode resistor, which is probably used, provides wrong bias with the drop of the current of but a single tube. Replace tube to complete job.

A public address system produces loud hum with mike volume control advanced. Remove mike cable at input to amplifier, short-circuit mike input channel, advance volume control. If hum is now absent, fault lies in microphone or cable picking up energy from nearby power lines. You have found the trouble. If hum continues, trouble is in amplifier and test equipment probably will be needed.

If hum develops only on strong local stations, it may be removed by connecting a 0.01 mfd. 600 volt paper condenser from one side of the transformer primary to the chassis of the radio set. This keeps the radio set from being modulated by A.C. when tuning in a strong carrier and many sets are supplied with such condenser arrangement.

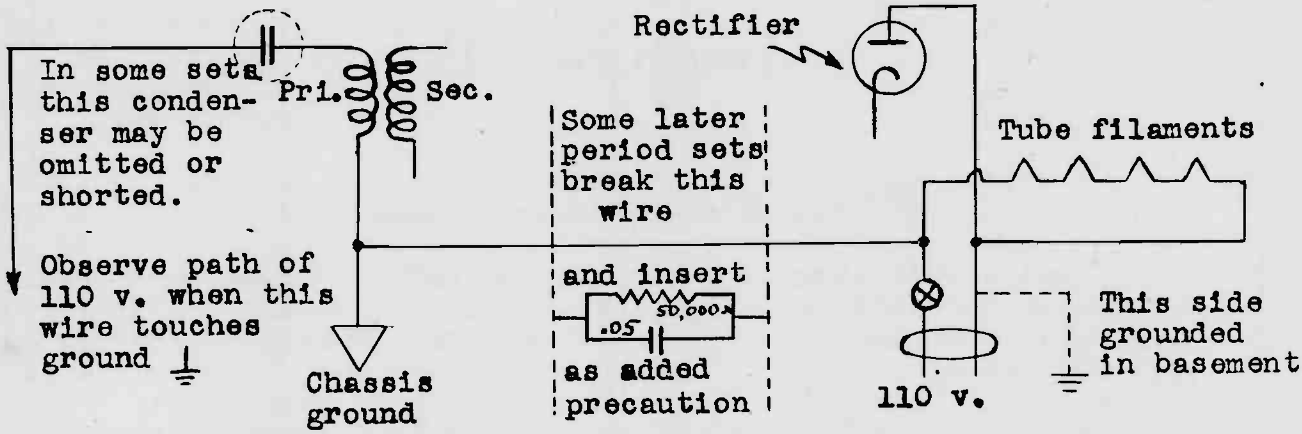
A radio set you are asked to repair, operates well on high frequencies, but is completely "dead" on the lower broadcast frequencies (say, below 1,000 KC.). Probably tuning condenser plates touch (rotor to stator) beyond this point. Examine under strong light. Use knife to bend plates back to position. Alignment may be needed, but if not required, the job is completed without test equipment.

On this type of servicing job, I want to add, an ohmmeter can be used to detect this short, but why?

Also remember that if low frequency broadcast stations are received, but set fails to operate on the "high" end of the band, the fault is not in the tuning condenser. Visualize the position of the rotor for various frequencies and you will realize the reason. This type of operation suggests lack of oscillation on "high frequencies," suggest changing oscillator tube (even if it tests OK in tube tester).

A burned out antenna coil primary in AC-DC sets is among the faults which can be discovered without test equipment. In the case of this fault, the owner usually relates a story of smoke, a flash of light, or blown fuses. Further, the appearance of the antenna coil confirms the story.

The reason for this trouble can be explained by assuming a short in the isolating condenser or complete lack of the isolating condenser (as in some older sets). Power plug is inserted so that chassis of set is on "high" side of the power line. Antenna wire makes contact with water pipe, radiator, or some other "ground." See circuit on the next page for the path of 110 volts.



This fault is so common that antenna coil primaries in various diameters are available. These replacement primaries fit around the original antenna coil. What is left of the original primary winding is removed before the replacement is installed and connected.

Many faults in radio sets distort the sound of the output. Since the loud speaker produces the actual acoustical sound, the loud speaker is suspected when the fault actually lies somewhere else. But trouble, at times, does develop in the speaker. If the speaker rattles, pressing your finger against the different parts of the speaker cone, may alter the type or pitch of rattle produced or stop the effects completely. If these changes can be obtained, the fault lies in the speaker and you need not look further.

If the complaint is, "The set has a strong hum," and the radio is of the period when wet electrolytic condensers were used, examine these condensers. You will probably find dried electrolyte deposit and corrosion on the surface of the can. Replace these condensers.

To determine if "static" noise is due to pick up from antenna or power line, short the antenna terminal or wire (making it very short) to chassis. If noise is still present, the power line is the source of interference. If the noise stops, the antenna is picking up the disturbance.

Distortion and noise produced only during the actual adjustment of the volume control may be blamed on a fault in the control which should be replaced. An open control (the rotary element not making contact) can be detected by connecting the center terminal (rotor) to each of the other terminals for test. If uncontrolled, loud operation of the radio results, the fault does lie in the control.

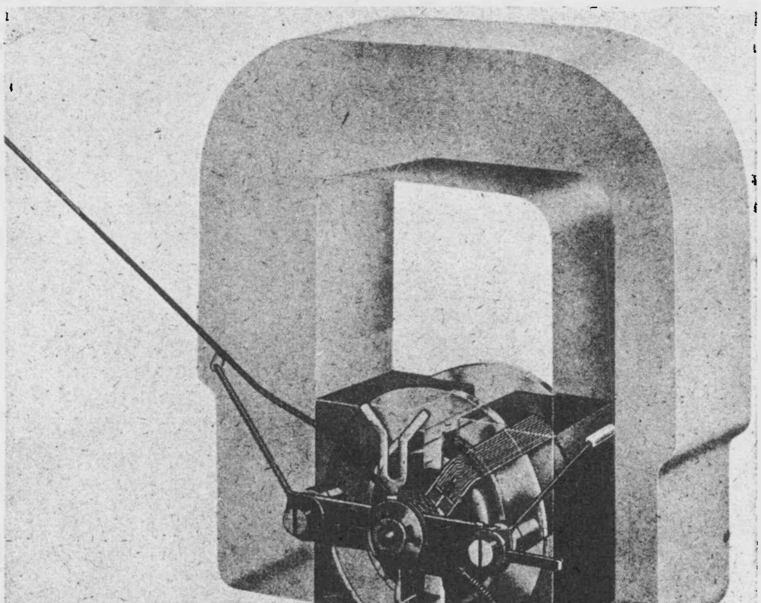
Lecture 6

Meters and Associated Networks

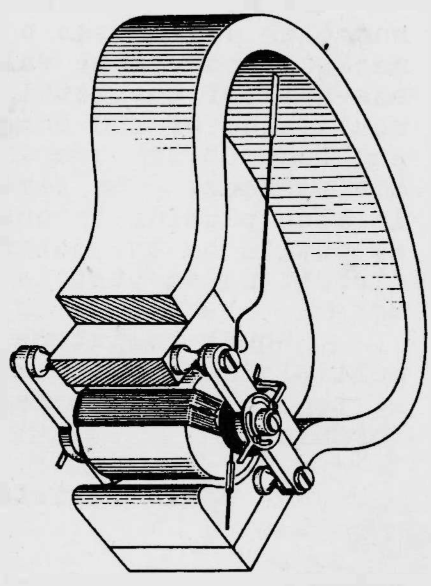
Radio servicemen use meters as an aid in discovering faults or making adjustments in radio equipment. Knowledge of circuits permits the technician to foretell what electrical values may be expected at various sections or parts under test. Considerable variation in the values of these measurements suggest the existance of a fault which is isolated with further tests.

Electric current operates all meters and, therefore, it is current that is measured. The amount of current passing through the meter, however, is a function (depends upon) other electrical quantities (voltage, for example), and the meter scale may be calibrated directly in terms of voltage, resistance, capacitance, etc. We will review some essential fundamentals of meter construction, operation, basic circuits, and scale accuracy, before we proceed to study a few popular commercial volt-ohm-milliammeters and analyzers.

The majority of today's direct current meters use D'Arsonnal type movement. This movement is sometimes called the permanent-magnet moving-coil type because of the components employed. In the two cut-away illustrations, you will notice that a large horse-shoe magnet forms the bulk of the unit. Between the pole



A PERMANENT-MAGNET MOVING-COIL MECHANISM (As used in the Weston Model 430 D-C Portable Instrument)



Courtesy Weston Electrical Instrument Corp.

pieces, a light movable coil is suspended on pivots. The springs in front and behind the coil tend to turn the coil in opposite directions and, thereby, balance the coil and the pointer in a definite position. These springs are also used to conduct current to the coil from fixed terminals.

When the meter is used for measuring and current flows in the movable coil, an electromagnetic field is produced. This field of the electromagnet is of such a polarity that it bucks the field of the fixed horse-shoe magnet. This causes the coil to rotate to the right until the magnetic force is just balanced by the additional tension produced by the springs. The intensity of this rotating (electromagnetic) effort is proportional to the current. The actual amount of rotation, of course, depends on the design of the meter besides the amount of current present. Since the same amount of current will always rotate the coil and its attached pointer needle to a specific position, a calibrated scale can be mounted on the meter frame, behind the pointer, and used to indicate the actual value of the current present.

The movement is very finely balanced and very thin wire is used for the coil, so that little current is needed for even the maximum rotation. A great many meters used in radio testers require 1 ma. for maximum deflection. For special applications, where very minute currents must be measured or circuits must not be upset, meters of greater sensitivity, 50 micro-ampere movement, are employed.

Sensitivity of a milliammeter can be decreased by connecting shunts — resistors in parallel with the meter. The D.C. resistance of a milliammeter is marked on the instructions supplied with the instrument or can be measured with a bridge or a low-resistance ohmmeter which uses a separate meter. You know that if two resistors of equal value are connected in parallel, each will pass one-half of the total current. Let us assume our meter has a D.C. resistance of 100 ohms. We parallel it with a resistor 100 ohms and connect the combination to a circuit where we want to measure the current. The same amount of current indicated on the meter is also passing through the parallel resistor. Whatever reading we obtain on the meter, the total amount of current in the circuit under test is twice this value.

Shunt resistors are usually selected on the basis of multiplying the current scale by a factor of ten, or multiples of ten. The shunt resistor value is found by using the simple formula

$$\text{Shunt resistance} = \frac{\text{Meter resistance}}{(n-1)}$$

where n is the multiplying factor wanted to increase the current reading scale.

Scales of meters are marked off in suitable divisions to help you estimate the reading obtained. Take time to read values obtained, especially on unfamiliar meters. Even experts have wasted hours on repair jobs because of such errors. I can recall the time I took a cathode current reading of 3 ma., but expecting a value of at least 30 ma., I assumed that I was using another scale. Because of this slip, many further tests were needed although the fault was obvious if I only read the meter correctly.

To produce the maximum deflection in a current-measuring meter a definite voltage will be needed. This voltage, of course, will be equal to the product of the meter internal resistance and the current required for a full scale deflection. In the case where the internal resistance of the meter is 100 ohms, and the meter has zero-to-one-milliampere movement, this voltage is 1/10 volt. (100 x .001; this second figure is one milliampere expressed in amperes).

To make this meter suitable for measuring much higher voltages, series resistors of suitable sizes are connected. If 50 volts are to be measured, as a maximum, a suitable scale is incorporated in the meter and the test prods are connected to the meter in series with a resistor of 50,000 ohms. The meter resistor of 100 ohms can be ignored since it is so small when compared to 50,000 ohms. Notice that 50 volts will just cause a current of one milliampere to pass through the circuit. This circuit has the meter and the meter will in this instance indicate full deflection. Other value resistors used with a suitable switching method will permit the same meter to be used for many additional measurements.

The same meter incorporating a battery (or other D.C. voltage source) and a series resistor which will produce full scale deflection upon the shorting of the test prods form a high resistance ohmmeter. For example, a 4½ volt battery may be used with an adjustable potentiometer which can provide an average value of 4,500 ohm resistance.

With this arrangement, when the prods are shorted, the circuit is completed. The meter shows maximum current, but the resistance between the prods is zero. So the point of maximum current (usually at the right) is marked 0 ohms on the ohmmeter scale. If a 4,500 ohm resistor is being measured by being connected between the prods, the current will drop to one half its previous value since the series circuit will be double its previous resistance. The meter needle will stop at the half-way mark. This point will correspond to 4,500 ohms.

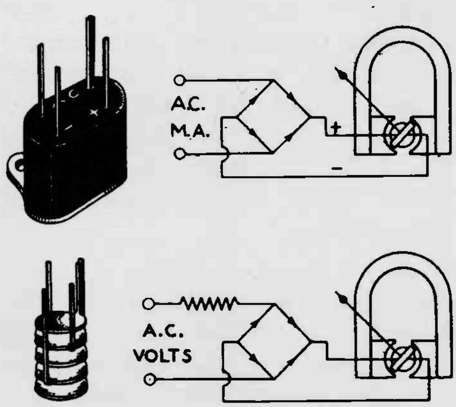
An ohmmeter scale is more spread out at the right for low values and is very congested for extremely high values. The ohmmeter we described can be read for values up to about 500,000 ohms, after that the total space of the scale remaining before the infinity mark is reached is so small that no accurate reading is possible. Some ohmmeters, of course, are made to read up to several megohms. This is accomplished by using meters of greater sensitivity or by connecting higher voltage battery. If you have an ohmmeter, for example, employing a 4½ volt battery, replacing it with 45 volt battery and connecting an additional resistor of 40,000 ohms in series will multiply your scale (on high ohms, only) by a factor of 10.

For low resistance measurements, under 50 ohms, a shunt arrangement is used. This will be explained further as we study a few commercial units.

All meters lack perfection of accuracy. In practical work very rough reading is usually sufficient and 5% accuracy is very satisfactory. The errors are due to several causes. The meter cannot be calibrated perfectly. The scales are printed from a drawing which is based on a typical meter of the type considered. However, not all bearings, springs, magnets, and coils are exactly alike and slight variations in responding to the same current always result. The same current, therefore, may give slightly different readings in several similar meters. Errors are also due to the associated resistors and to the width of the pointer.

Always use the lowest value scale which will permit measuring values obtained. It is obvious that 7 volts can be read more accurately on a 0-10 volt scale than on the 0-100 volt scale. The meter itself is usually more accurate in the center of the scale than at the edges.

The meters we have discussed so far can be used with D.C. only. It is possible to use a regular D.C. meter for measuring alternating current or voltage with the aid of a rectifier unit. The rectifier changes A.C. to D.C. and the value of A.C. voltage or current is measured on special scales. Usually these scales are calibrated for a given A.C. frequency, and considerable variation in frequency will cause additional errors. The rectifier elements are made of copper oxide and the current is permitted to pass only in one direction.

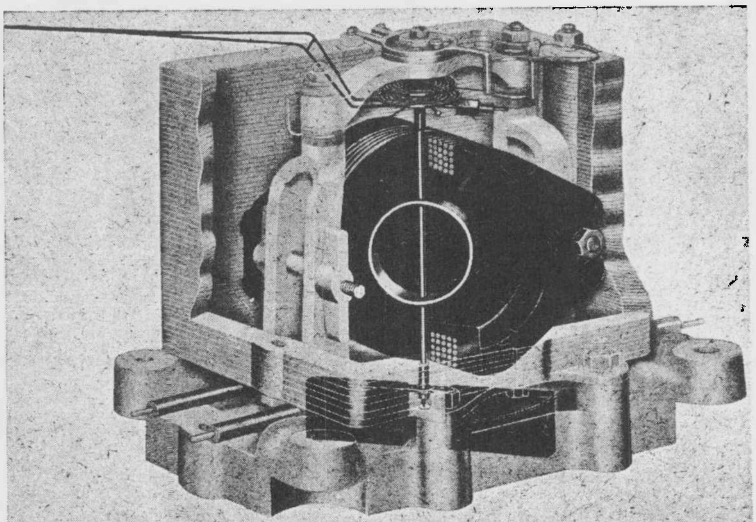


Several diagrams showing the method for connecting a four element bridge of copper oxide discs are shown on the left. These illustrations are reproduced through the courtesy of Weston Electrical Instrument Corp. It is important to realize that the sensitivity of the meter is reduced when a rectifier is used and different scales must be employed for A.C. and D.C. measurements. Any rectifier meter reads average values but is calibrated in terms of R.M.S.

The rectifier discs have a small amount of capacity associated with them which tends to by-pass currents of higher frequency and in general a rectifier meter will read low by 1/2% per 1000 cycles. This general criterion may be used up to 10,000 cycles, but may vary somewhat.

A sensitive D.C. meter may be used with a thermocouple to measure alternating currents up to R.F. The current to be measured heats a small wire which is placed near a junction of two different metals. When a point of contact of two different metals is heated, a slight voltage is produced. This voltage is D.C. and is impressed on the sensitive D.C. meter.

A meter can be constructed to operate directly from A.C. If a D'Arsonval movement meter is connected to alternating current, the needle will try to follow the variations in the current and will appear to be vibrating. No true reading will be possible. Notice the different construction of the electrodynamometer mechanism which can be used to measure A.C. directly. The large stationary coils are connected to the source of A.C., and a part of this current is conducted through the small movable coil. The small coil is mechanically connected to the pointer. Since the current in both the stationary and movable coils reverses at the same time, the torque (movement, rotation) is in the same direction and is proportional to the square of the current.

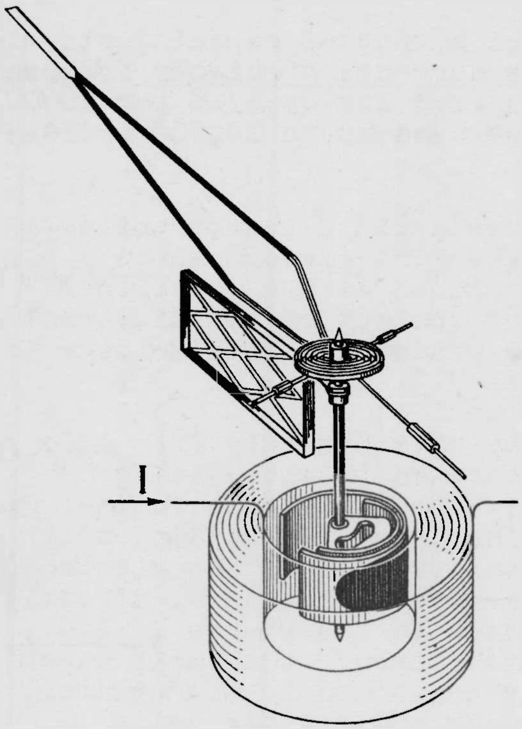


AN ELECTRODYNAMOMETER MECHANISM
(As used in the Weston Model 432 D-C and Single Phase A-C Wattmeter)

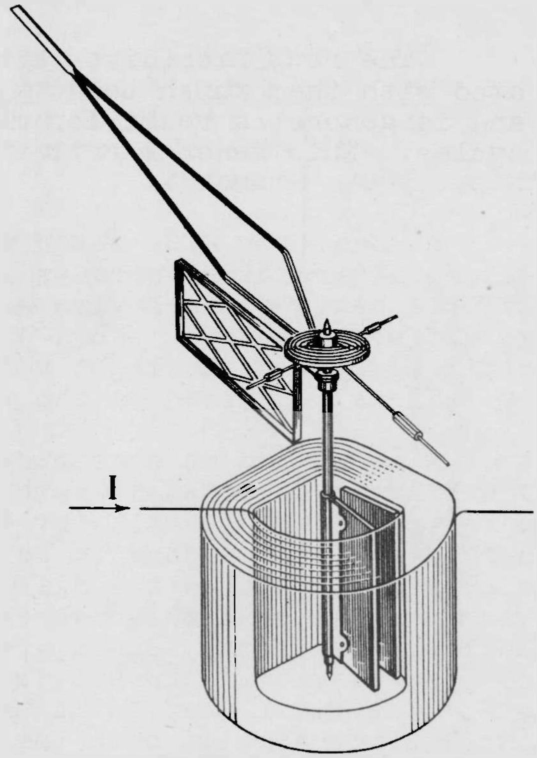
Courtesy Weston Electrical Inst. Corp.

Such meters may be used also for D.C., but they are not as sensitive as the D'Arsonval movement types. Dynamometer movements may be used in ammeters, voltmeters, or wattmeters.

Moving iron-vane meter has a fixed coil which is connected to the circuit having the current to be measured. Usually there is a fixed iron plate and a moving iron-vane. In the normal position,



Iron Vane Mechanism

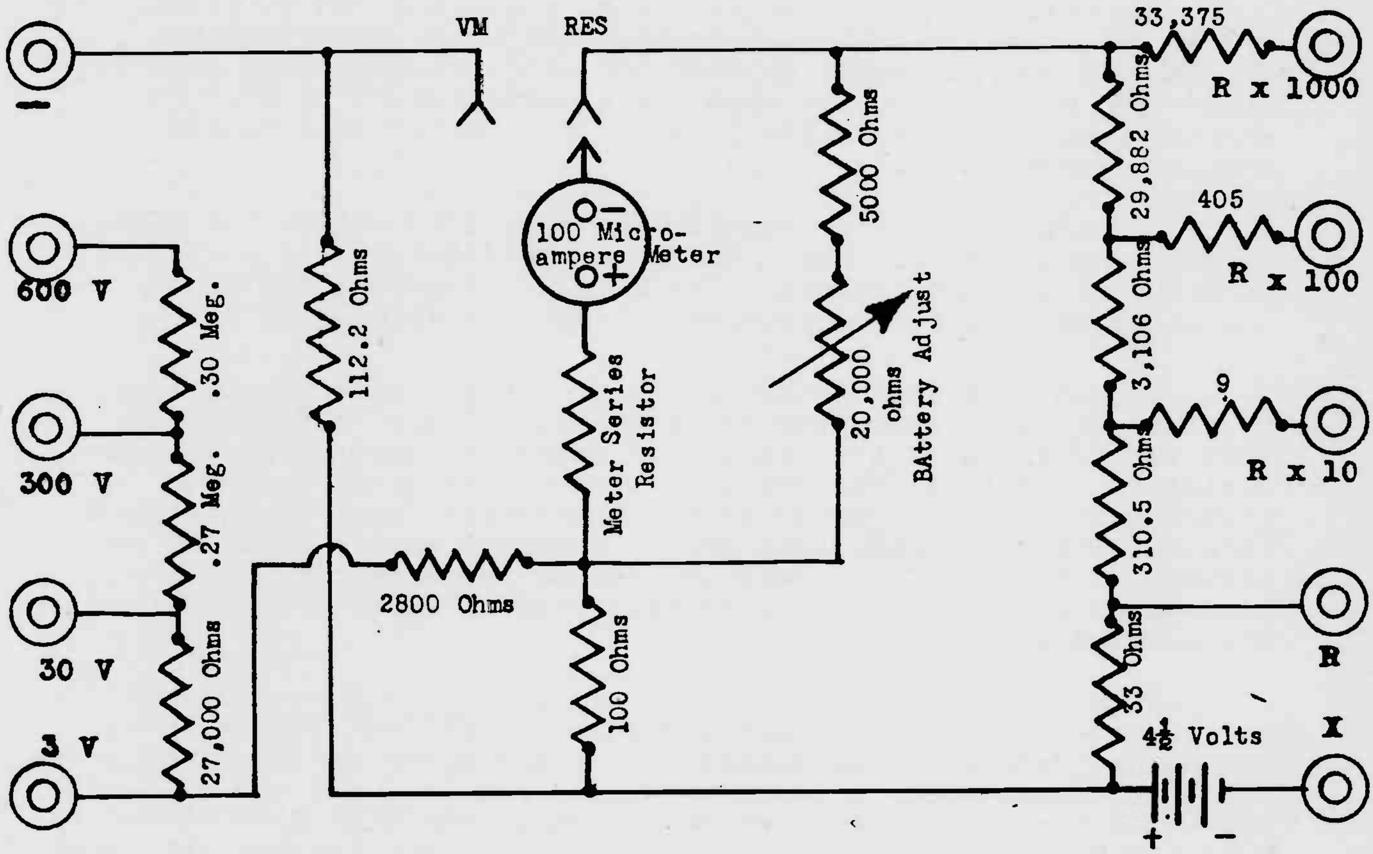


Modern Iron Vane Mechanism

these iron plates are close to each other. The moving iron-vane is connected to the pointer. When current passes through the coil, it creates an electromagnet which in turn magnetizes the iron plates. Since these plates are of the same magnetic polarity at all times, although the magnetic fields of both reverse with changes in the direction of the current, the iron plates repel each other in proportion to the current. This repelling action makes the moving-vane rotate against the tension of the spring. The amount of rotation indicates the quantity of current being measured.

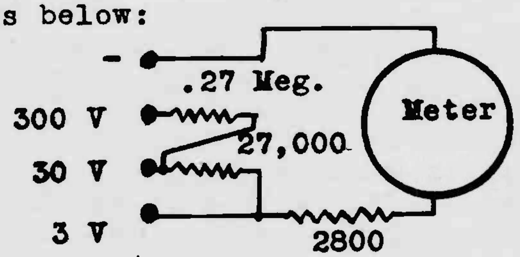
We will now discuss the circuits, operation, and use of a few popular volt-ohmmeters, multimeters, and analyzers. This explanation will aid you in understanding how all similar test instruments work and how to get the most from your equipment of this nature.

Because the Supreme Instruments Corp. Model 537 volt-ohmmeter uses an easy to trace circuit, we will introduce it first. The meter used is of 100 micro-ampere movement and for voltage measurements is switched to the left terminal marked VM. For all voltage measurements, the negative prod is inserted in the upper left hand terminal marked "—" minus. Let us consider the circuit when it is being used for measuring 300 volts maximum and the positive prod is connected to the jack marked 300 V. With this application, the .30 meg. resistor is not functioning, while the resistors marked .27 meg., 27,000 ohms, 2,800 ohms, "Meter Series Resistor,"



and the meter itself are connected in series to the prods. The meter series resistor is of a value to match the meter and give a total of 2,000 ohms. The resistors marked 100 ohms and 112.2 ohms (themselves connected in series) are in parallel with this meter circuit total resistance of 2,000 ohms. The equivalent resistance to this combination (using parallel resistance formula) is 175 ohms. The equivalent sensitivity for voltage measurements is in the order of one milliampere — if you want the exact figure it is 1.043 milliamperes. Notice also that the circuit to the right of the meter is not used when we have the tester adjusted for VM voltmeter measurements.

A simplified equivalent circuit of what we are analyzing appears below:



The meter is considered as incorporating the associated resistors and acts as the equivalent resistor of 175Ω.

The total series resistance when measuring 300 volts maximum is 299,975 ohms, but with permissible errors may vary between 294,000 and 306,000 ohms, so that 300 volts will produce full scale deflection well within the over all accuracy of 3% to 5%. In a similar manner, the circuits formed for other voltage ranges produce proper results.

For resistance measurements the switch is set to the right, to the terminal marked RES. The ohmmeter section uses a ring-type parallel adjustment circuit. The 20,000 ohm potentiometer is needed to compensate for battery voltage variation with age.

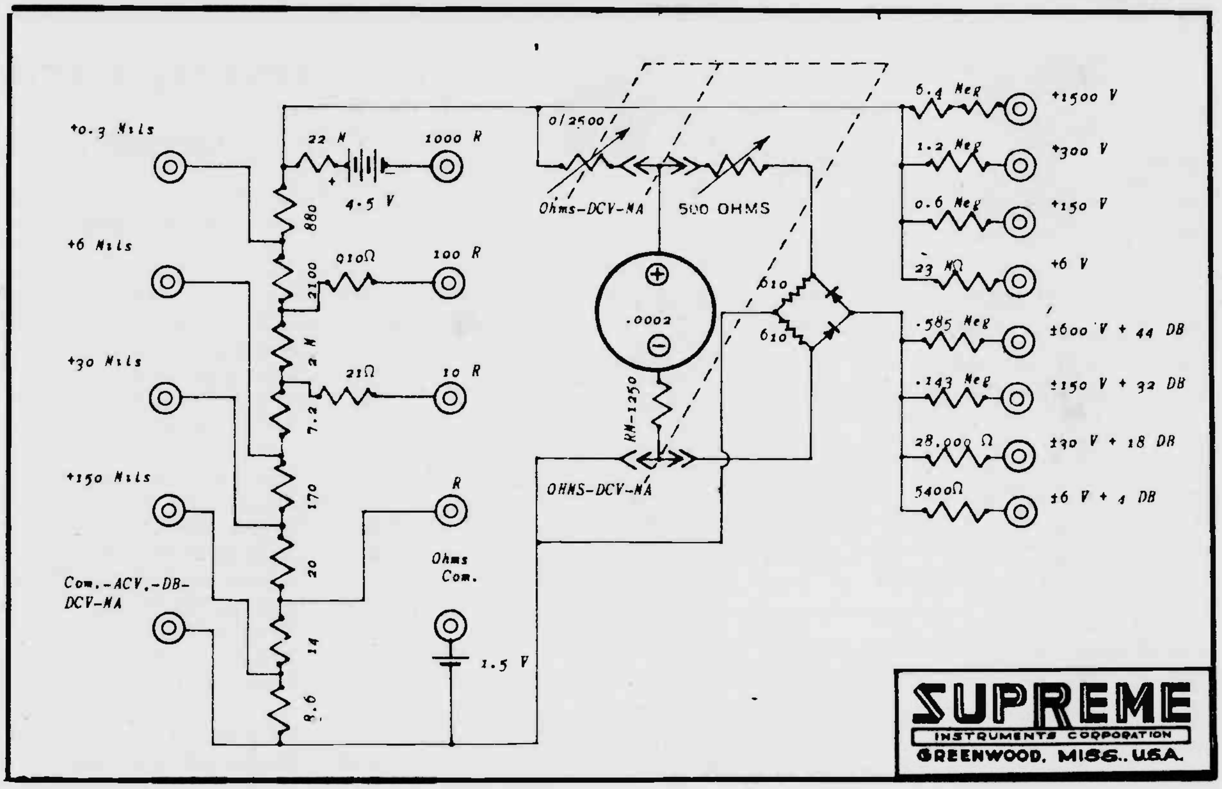
To test for resistance values of a few hundred ohms, middle of scale about 35 ohms, use jacks marked "R" and "X." Observe that the 4½ volts of the battery is impressed across the 33 ohm resistor. The total voltage if the prods are shorted (zero resistance), smaller values as the resistance under test becomes larger. The other resistors are of value to add up with the meter network to produce full scale deflection on short circuit of the test prods and corresponding correct reading when various resistors are measured.

When other resistance scales are used, the circuit is altered, but the re-arrangement is now correct for the new scale reading. The change introduces an alteration in the meter series circuit and the total resistance in series with the battery. If you calculate the meter current for each of the setting, you will find it can be made 100 micro-amperes for zero ohm testing on any scale and other correct values for other test considerations. The slight variations are compensated with the Battery Adjustment which alters the meter equivalent sensitivity and always has a minor effect on the total series resistance. The adjustment mentioned must be used to set zero ohms each time a new scale is used for measurements. The advantage of an ohmmeter circuit of this type lies in its adaptability in providing a single scale for several ranges.

The circuit of another multimeter is shown on the next page. This circuit is similar in some respects to the diagram just discussed, but there are several important differences. As you will note, many of the resistors used in connection with resistance tests serve also as shunts for current measurements. Two batteries are employed, the larger one of 4.5 volts being used for high resistance measurements.

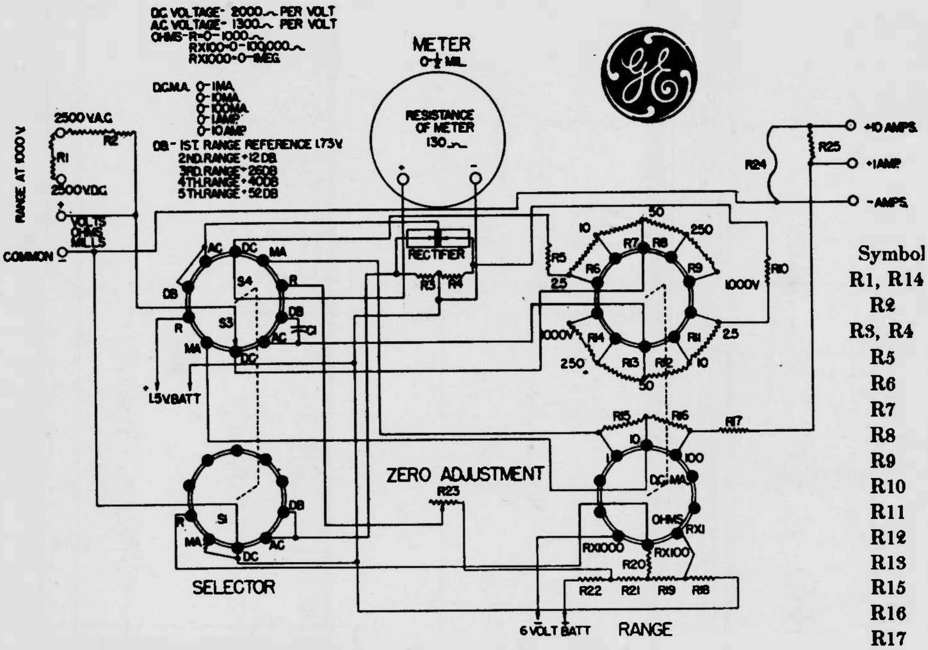
A rectifier circuit is incorporated to permit A.C. voltage measurement and an additional scale is included to give direct readings in decibels.

We include several more interesting circuits of popular test instruments. (These circuits were discussed by the attending group after the lecture and it is suggested that you take time to study and analyze the action in these circuits).



APPLICATION CHART

TYPE MEASUREMENT	RANGE OF MEASUREMENT	ROTARY CONTROL	PIN JACKS USED	READ ON METER SCALE	TO INTERPRET READING
RESISTANCE	0 to 100 ohms 100 to 1000 ohms 1000 to 10,000 ohms 10,000 ohms to 2 megohms	Adjust for zero ohms with leads shorted.	OHMS R OHMS 10R OHMS 100R OHMS 1000R	2M-0 2M-0 2M-0 2M-0	Read Direct Multiply by 10 Multiply by 100 Multiply by 1000
D-C MILLIAMPERES	0 to 0.3 MA. 0.3 to 6 MA. 6 to 30 MA. 30 to 150 MA.	D.C. V.-MA.	COM. +0.3MA. COM. +6MA. COM. +30MA. COM. +150MA.	DC 0-30 DC 0-6 DC 0-30 DC 0-150	Divide by 100 Read Direct Read Direct Read Direct
D-C VOLTS	0 to 6 volts 6 to 150 volts 150 to 300 volts 300 to 1500 volts	D.C. V.-MA.	COM. +6V COM. +150V COM. +300V COM. +1500V	DC 0-6 DC 0-150 DC 0-30 DC 0-150	Read Direct Read Direct Multiply by 10 Multiply by 10
A-C VOLTS	0 to 6 volts 6 to 30 volts 30 to 150 volts 150 to 600 volts	A.C. V.-DB.	COM. ±6V COM. ±30V COM. ±150V COM. ±600V	AC 0-6 DC 0-30 DC 0-150 DC 0-6	Read Direct Read Direct Read Direct Multiply by 100
DECIBELS	-6 to +10DB +8 to +24DB +22 to +38DB +32 to +50DB	A.C. V.-DB.	COM. +4DB COM. +18DB COM. +32DB COM. +44DB	DB-10to+6 DB-10to+6 DB-10to+6 DB-10to+6	Add+4 to reading Add+18 to reading Add+32 to reading Add+44 to reading



GENERAL ELECTRIC

UNIMETER

TYPE UM-3

Symbol	Description
R1, R14	Resistor, 1 megohm, 1 watt, ±2%
R2	Resistor, 2 megohms, 3 watts, ±2%
R3, R4	Resistor, 2000 ohms, ½ watt, ±2%
R5	Resistor, 5000 ohms, ½ watt, ±2%
R6	Resistor, 15,000 ohms, ½ watt, ±2%
R7	Resistor, 80,000 ohms, ½ watt, ±2%
R8	Resistor, 400,000 ohms, ½ watt, ±2%
R9	Resistor, 1.5 megohm, 1 watt, ±2%
R10	Resistor, 1000 ohms, ½ watt, ±2%
R11	Resistor, 10,000 ohms, ½ watt, ±2%
R12	Resistor, 53,000 ohms, ½ watt, ±2%
R13	Resistor, 265,000 ohms, ½ watt, ±2%
R15	Resistor, 117 ohms, ½ watt, ±2%
R16	Resistor, 11.7 ohms, ½ watt, wirewound, ±2%
R17	Resistor, 1.17 ohms, ½ watt, wirewound, ±2%
R18	Resistor, 11 ohms, ½ watt, wirewound, ±2%
R19	Resistor, 1134 ohms, ½ watt, ±2%
R20	Resistor, 431 ohms, ½ watt, ±2%
R21	Resistor, 1137 ohms, ½ watt, ±2%
R22	Resistor, 10860 ohms, ½ watt, ±2%
R23	Potentiometer, 2000 ohms
R24	Resistor, .013 ohm, wirewound, ±2%
R25	Resistor, .117 ohm, wirewound, ±2%
C1	Capacitor, .5 mfd, 600 volts

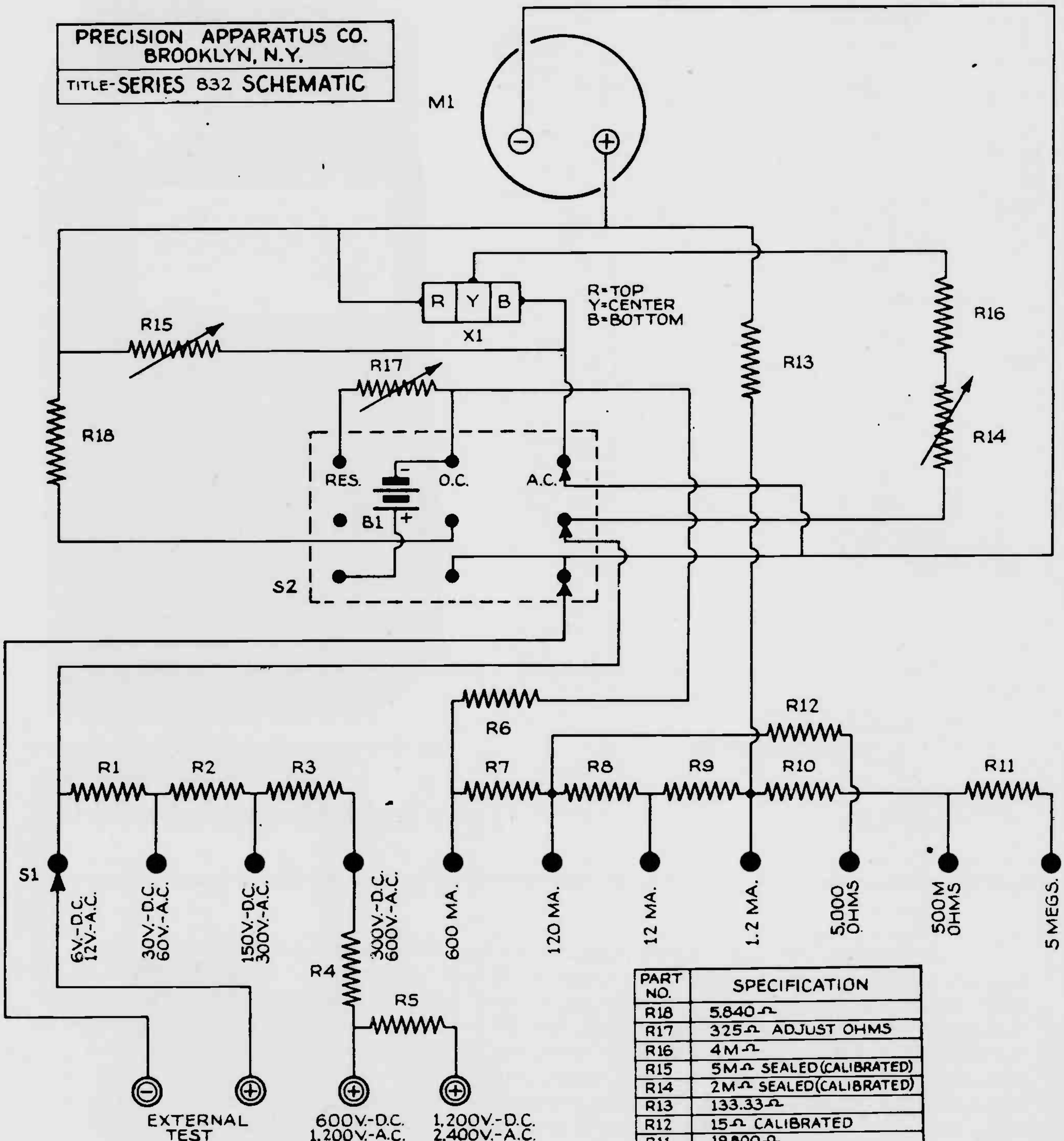
Unimeter, type UM-3, is a portable unit designed for simplicity, attractive appearance and rugged construction, for the rapid and accurate measurement of volts, ohms, current and decibels as encountered in the repair of electronic equipment. All components with the exception of the ohmmeter batteries are mounted on an aluminum panel. The unimeter is contained in a fabricated steel case with removable cover. With reasonable care the unit should give many years of service.

For operation in the normal ranges the test prods are plugged in the + and — jacks. Red test lead to +, black test lead to —. The most used ranges are changed by two selector switches. The left or SCALE switch selects the type of measurement desired. The right or RANGE switch selects the range of the desired type of measurement.

The SCALE and RANGE switch settings *must* not be changed while the test prods are in contact with the external circuit. This is particularly important in AC and Db. (Output) measurements and on DC above 100 volts. Rotating the range switch may cause transient voltages to be set up that are capable of ruining the rectifier, even though the duration of the voltage peak is so short that it doesn't show on the meter. *Never* change switch settings with 1000 or 2500 volts AC or DC applied to the test prods.

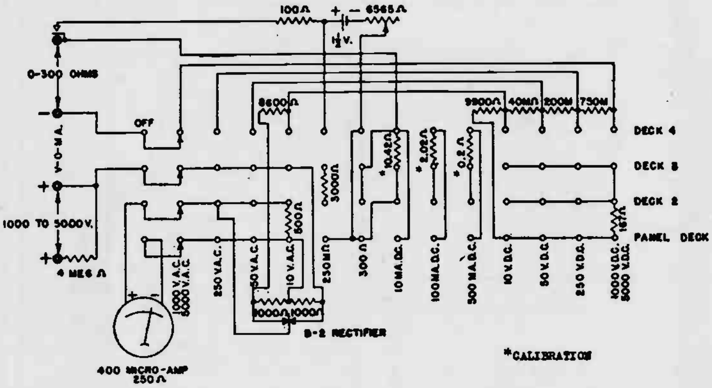
A .5 mf 600 V capacitor is switched in series with the test leads for output measurements when the SCALE switch is set to decibels.

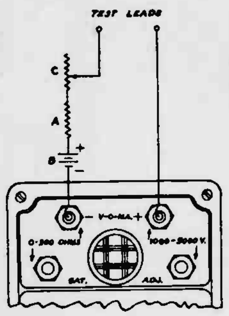
The zero adjustment knob is used to set the instrument pointer to zero ohms on the various ohms ranges.



PART NO.	SPECIFICATION
R18	5.840 Ω
R17	325 Ω ADJUST OHMS
R16	4M Ω
R15	5M Ω SEALED (CALIBRATED)
R14	2M Ω SEALED (CALIBRATED)
R13	133.33 Ω
R12	15 Ω CALIBRATED
R11	19,800 Ω
R10	1923.3 Ω
R9	600 Ω
R8	60 Ω
R7	5.333 Ω
R6	1.333 Ω
R5	600M Ω
R4	300M Ω
R3	150M Ω
R2	120M Ω
R1	24M Ω

B1	3 VOLT BATTERY
M1	800 MICROAMP. - 160 M.V.
X1	RECTIFIER
S2	3 POSITION CIRCUIT SELECTOR
S1	11 POSITION RANGE SELECTOR





To extend the 250,000 ohm range, add resistance and voltage at points A and B and multiply scale readings as shown in table.

Multiplier	Range	Volts at B	Res. at A	Rheo. at C
2	0-500,000 ohms	1.5	3,400 ohms	none required
5	0-1,250,000 ohms	6.	13,600	none required
10	0-2.5 meg-ohms	13.5	30,600 ohms	none required
100	0-25 meg-ohms	150	300,000 ohms	100,000 ohms

RANGES

A.C.-D.C. VOLTS

0-10-50-250-1000-5000 at 1000 chms per volt.

D.C. MILLIAMPERES

0-10-100-500 at 100 millivolts.

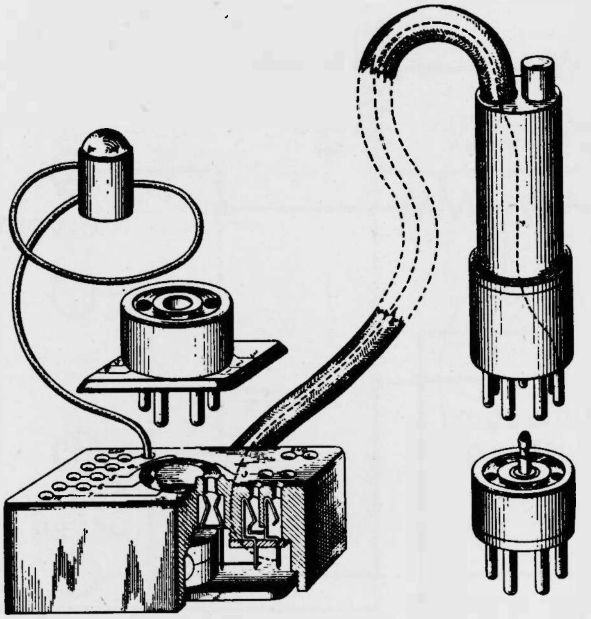
OHMS

0-300-250,000.

Tester Model 666-H shown approximately four-fifths size.

The Triplett Electrical Instrument Co.

In order to use test instruments, the serviceman must have a clear notion concerning the function of the circuit he is testing and some knowledge as to the expected correct electrical values. Voltage values can be obtained by referring to the operating conditions for the different vacuum tubes employed. Resistance values can be estimated for some parts (for example, paper condensers will show infinite resistance, coils 5 to 100 ohms) and, in the case of resistors, compared with actual markings as given. If the set is "dead," resistance tests are recommended. These usually will point to the place where the circuit is broken and prevents operation. If a radio which is being repaired has voltages at some points, the test for voltage at other points may lead to the fault which is preventing proper operation. Details on the use of meter equipment will be given in several lectures to follow, and we will now turn our attention to the description of an analyzer.



Courtesy Weston Electrical Inst. Corp.

Analyzers were popular some years ago and were intended promarily to save time in permitting the serviceman to test and discover the possible fault in a defective receiver without actually removing the chassis from the cabinet. This instrument usually had plugs for connecting to the terminals of the tube socket, while the tube itself was placed in a suitable socket on the analyzer. The various circuits coming from the tube socket could be broken for current measurements, while other switches permitted the meter incorporated in the analyzer to be employed for voltage and resistance measurements. Since, in majority of cases, in order to make the repair, the chassis had to be removed anyway, this instrument is no longer popular and majority of servicemen make the needed tests by making contact with prods of a simpler multi-tester directly to the points in the radio chassis.

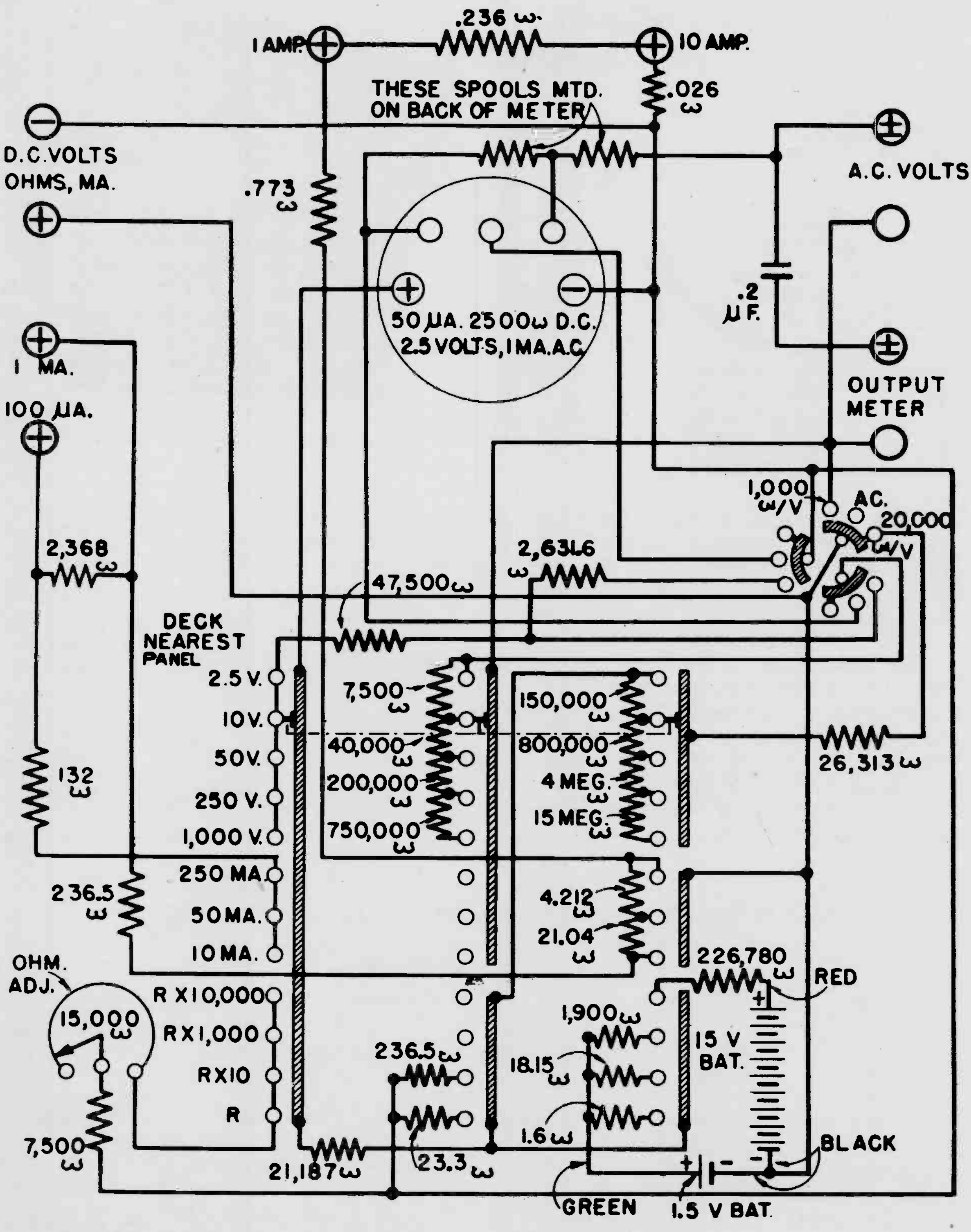
MULTI-RANGE TEST INSTRUMENT MODEL 772, TYPE 6

RANGES—all self contained

Voltage D-C and A-C	*Current D-C Only*	*Resistance*		*Decibels from 6 MW, 600 ohms*
		Full Scale	*Center Scale*	
1000	10 amps.	30 meg.	250,000 ohms	−14 to + 2
250	1 amp.	3 meg.	25,000 ohms	− 2 to +14
50	250 milliamps.	30,000 ohms	2,500 ohms	+12 to +28
10	50 milliamps.	3,000 ohms	250 ohms	+26 to +42
2.5	10 milliamps.			+38 to +54
	1 milliamp.			
	100 microamps.			

Accuracy: 2% on d-c ranges except 1000 volts, 3%
3% on a-c ranges.
Scale Length: 3.17" (80.3 mm)

Weston Electrical Instrument Corp.
Tester Model 772, Type 6
(See page 46 for Circuit Diagram)



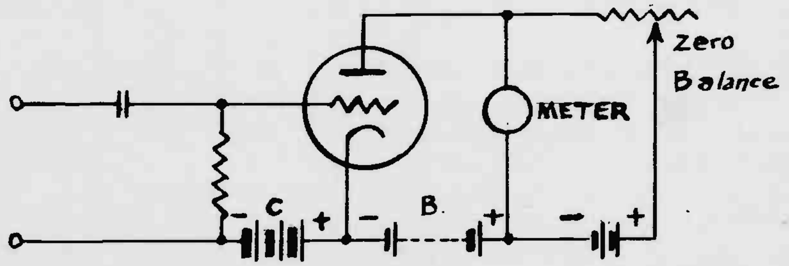
Wiring Diagram of Model 772

Lecture 7

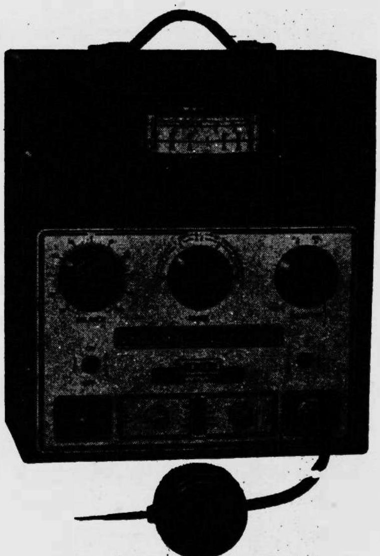
Vacuum Tube Voltmeters

As the name implies, a vacuum tube voltmeter uses a radio tube and is primarily an instrument for measuring voltage. This type of instrument falls into several different classes, each using a different basic circuit, but every type providing the main advantage of very high input impedance. The input is connected to the control grid of a vacuum tube and a theoretical infinite impedance is secured. Practically, however, a grid return path is usually provided in the instrument. This is done in case the circuit under test does not provide a D.C. return path. Further, if the vacuum tube voltmeter is intended to furnish several ranges, the voltage dividing network is included in the input grid circuit and is of finite value. In general, the input impedance to practical vacuum tube voltmeters usually has the equivalent resistance from one to ten megohms. There are also capacity effects which are of importance in making very high radio frequency measurements, but this is of no problem to radio servicemen.

The high input impedance permits the use of the vacuum tube voltmeter for practically all voltage tests in radio equipment without upsetting the voltage values existing at these points previous to the test. For example, the exact voltage at the plate of a resistance coupled tube can be obtained. Or A.V.C. voltages can be measured accurately. If the unit is designed to measure R.F., the oscillator voltage can be measured. And, of course, all normally measurable voltages can also be measured with a vacuum tube voltmeter.



One type of vacuum tube voltmeter (VTVM) employs a vacuum tube (triode or pentode) which is operated over its curved characteristic as a detector. Under such operation, the D.C. plate current will depend on the A.C. voltage applied to the control grid. It is possible, therefore, to calibrate a milliammeter placed in the plate circuit (and which will measure the plate current) in terms of the input grid voltage. The value of plate current present when the input grid voltage is zero, can be balanced out with another, separate battery and a variable resistor circuit also connected to the same meter, but passing current in reverse. A zero adjustment is made with this circuit. A basic circuit of this type is indicated. Batteries are shown for simplicity but the same general circuit can be made to operate from a single power supply.

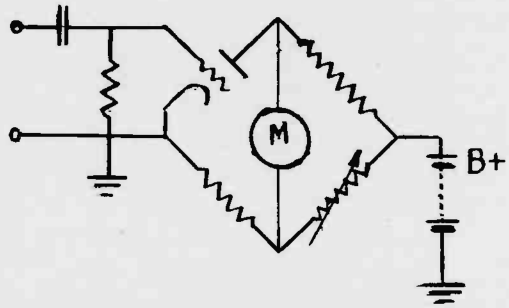


Courtesy Hickok Electrical Inst. Co.

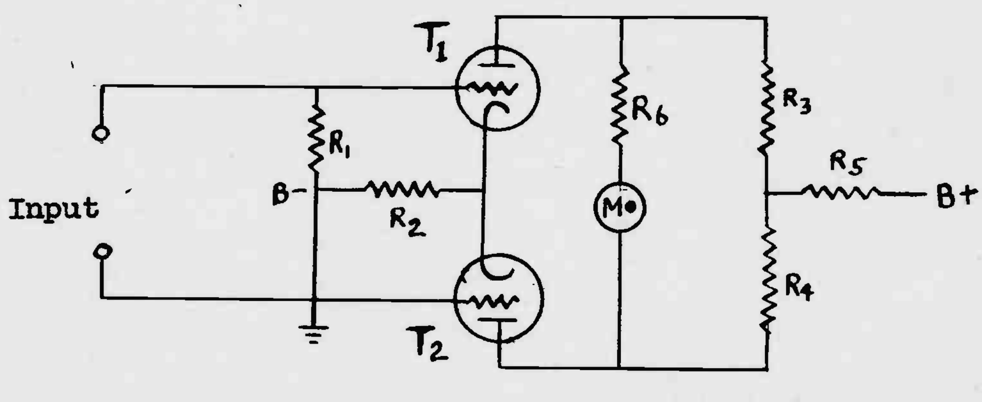
This type of VTVM is intended primarily for A.C. voltage measurements. It can be calibrated at some practical frequency (60 cycles for example) and will give accurate results even when used to measure R.F. However, D.C. voltage can be measured with this type of VTVM, provided the voltage is impressed directly on the grid (no condenser in the input) and correction charts are available for changing A.C. values read on the meter. Further, polarity must be observed, positive going to the grid terminal.

Perhaps you are wondering why equal A.C. and D.C. voltages will not produce the same plate current change. This can be answered quite easily if we realize that the triode is used with a value of grid bias (battery C) to permit plate current to flow continuously throughout the cycle of applied A.C. voltage. This is the usual case. Under these conditions, the change in plate current is almost exactly proportional to the square of the effective value of the applied voltage. Effective value is .707 of the peak and the meter is actually calibrated accordingly. A D.C. voltage of value equal to a certain effective A.C. voltage, does not have a wave shape (that is, variations, peaks) like the alternating current source and it will, therefore, produce other results. Thus, a different D.C. voltage scale or correction charts are needed.

Many special arrangements are possible to secure advantages such as increased sensitivity, stability against changes due to tube's age or voltage variations, or to obtain response in a logarithmic ratio, but these circuits are not of especial interest to a radio serviceman. We shall discuss for a few minutes the bridge-type vacuum tube voltmeter and then pass on to the electronic multimeters which are special kinds of vacuum tube voltmeters designed to provide measurements of voltage, current, and resistance values commonly encountered in radio repair work.



Later on we shall talk about bridges, but probably you already have some knowledge of bridge circuits. In the above figure, resistors are used in three arms of the bridge, while the plate resistance of a triode is used in the fourth arm. One of the resistors is made variable so that balanced condition (zero voltage across meter M) can be obtained. When an alternating voltage is impressed on the input, the plate resistance changes, unbalancing the bridge, and causing the meter to indicate a change. The meter can be calibrated to read directly in volts of input.



Almost all of the electronic type volt-ohmmeters designed for use by the radio serviceman employ a balanced vacuum tube circuit designed to measure D.C. voltages. To introduce this subject, I will present the basic vacuum tube circuit employed. As you can see in the illustration below, two similar triodes are employed in what, at first, appears to be a peculiar arrangement.

Consider the application of a D.C. voltage (of value permitted by the bias arrangement) impressed on the input terminals. For simplicity of explantion, let us further assume that the positive prod is connected to the upper terminal. This voltage will be impressed across the grid resistor R_1 of vacuum tube T_1. The grid of this tube will become positive by the amount of this voltage. Notice that the grid of T_2 remains at ground potential at all times.

For the moment, let us return to the time just before any voltage is impressed on the input. Since there is no grid current (tubes biased negatively), each grid is essentially at ground potential — resistor R_1 simply completes the circuit to ground. The steady state plate (or cathode) current passes through R_2 and produces a voltage drop here. This voltage makes the control grids of both tubes negative with respect to the corresponding cathodes, as is required. If identical tubes are selected, the operating condition described, plus the exact similarity of plate resistors R_3 and R_4, guarantees equal plate currents in each tube. If equal plate currents pass through equal plate resistors R_3 and R_4, the voltage drop across each of these two resistors will be equal. These equal drops will subtract from the power supply voltage, B+, and the voltage present at the plate of each tube used will be equal. Perhaps this value will be 80 volts in a practical circuit. If a sensitive meter M is connected to these points, as shown in the diagram, under the open input-terminal conditions described, no current will be present in the meter circuit. A difference of voltage, you understand, must exist to pass current through the meter.

After you clearly understand the conditions existing with no input voltage, we can proceed to consider the effects of the input voltage we mentioned before. This "positive" voltage will make the grid of T_1 less negative than it was before. This tube T_1 will pass greater current. A larger drop will occur across the plate resistor R_3, leaving a smaller voltage at the plate of this tube — perhaps only 78 volts.

This is not all that happens. The plate current passes through the cathode resistor R_2, and since the plate current is larger, the voltage drop across it will also be larger. This action will have a degenerative effect on the input voltage since it will produce an additional small negative bias which to a degree will nullify the application of positive input voltage to the grid of T_1.

Also, with this increase in the cathode resistor voltage, the grid bias for T_2 will become more negative and, thereby reduce its plate current. This action in turn will have a further degenerative effect (reducing) on the amount of change produced in the voltage across the cathode resistor. Reduction in plate current of T_2 will also cause a smaller drop in the plate resistor R_4, increasing the voltage at the plate of T_2, perhaps to 81½ volts. We now have a voltage difference across the meter circuit and it will indicate some new value. Resistor R_6 is used to limit the current through the meter and the meter is calibrated in terms of the input voltage.

The meter reads zero initially and is connected with proper polarity to correspond to the polarity use of the input. In some testers of this type, the meter has a center zero, and no polarity of the test prods need be observed. In other units the terminals of the meter can be reversed with a switch so that either polarity of the test prods may be used provided the corresponding setting of the switch is made.

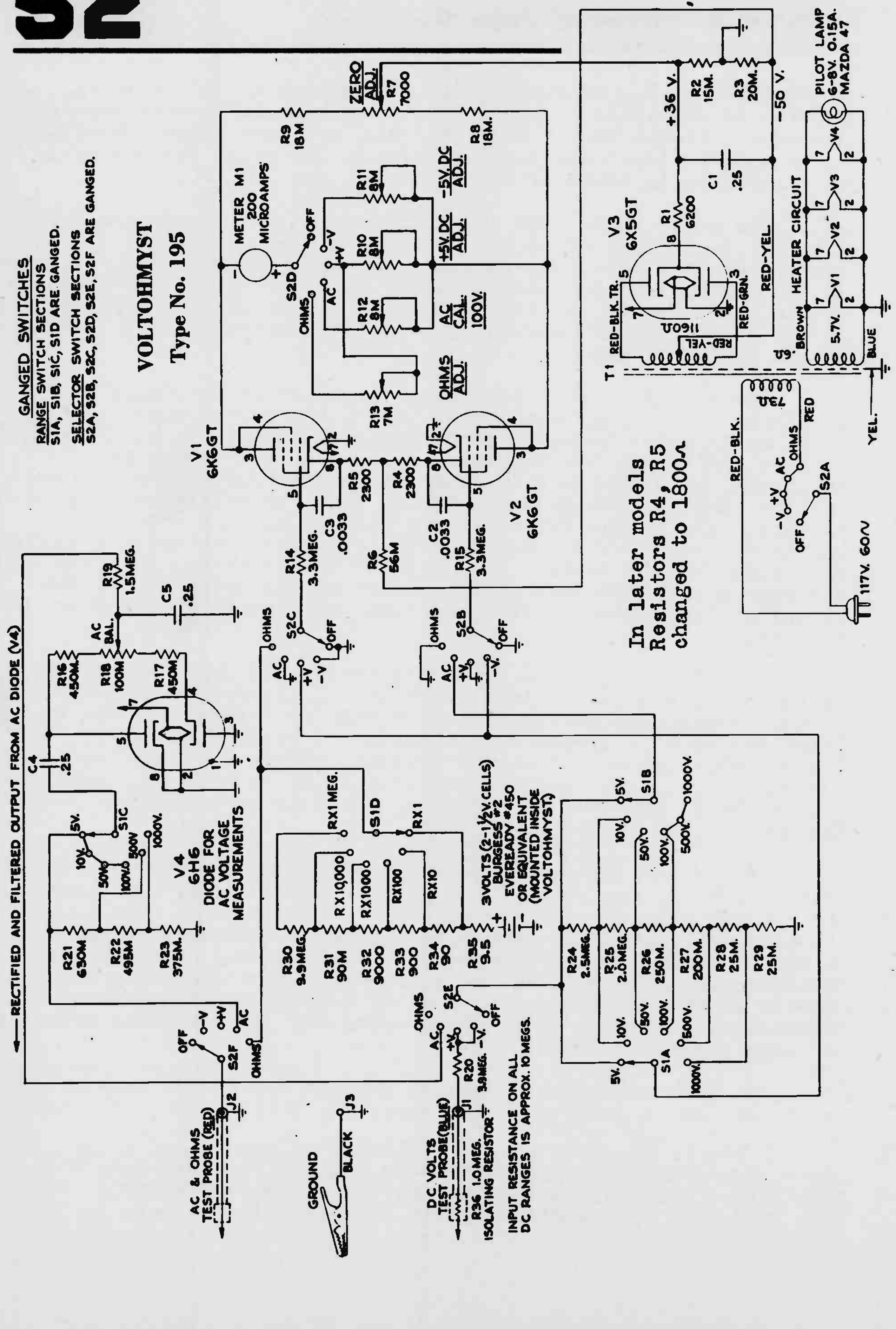
The effect of each portion of the circuit on others was mentioned as if final conditions were affected but once, actually these actions are inter-related and cause results in a multitude of ways. Although the complete analysis of the action is difficult, equalibrium is reached instantaneously for each change, and the current through the meter is directly related to the input voltage. The degenerative effects present and the use of a balanced circuit eliminate, to a large degree, the error introduced by supply voltage variations. Observe that a change in plate voltage supply will have but little effect on the operation of the circuit. The influence of aging tubes is reduced for similar reasons.

In order to use the same circuit for measuring a wide range of voltages, a voltage divider network is incorporated in the input. Resistance measurements are made by introducing the unknown resistor in series with a small dry battery across one of the voltage inputs. Since the voltage impressed on the input circuit will depend upon the resistor value under test, additional scales can be provided to indicate the value of resistors to be tested.

To measure alternating voltage a rectifier must be provided. This may be in the form of a copper-oxide unit with correspondingly reduced sensitivity. In fact, if a copper-oxide unit is used, it is usually used directly with the meter (without the tube circuit) for A.C. measurements. In the majority of commercial instruments, a diode tube is incorporated in a special probe and serves as the rectifier. The use of a diode permits voltage measurements at high radio frequencies and preserves the advantage of high impedance input.

We will now discuss several popular commercial units which will help us to understand and apply the basic theory presented.

An instrument using the basic circuit we just studied is employed in the R.C.A. VoltOhmyst. We illustrate this circuit and will call your attention to a few special features.


VOLTOHMYST
Type No. 195
GANGED SWITCHES
RANGE SWITCH SECTIONS
S1A, S1B, S1C, S1D ARE GANGED.
SELECTOR SWITCH SECTIONS
S2A, S2B, S2C, S2D, S2E, S2F ARE GANGED.
In later models
Resistors R4, R5
changed to 1800Ω
METER M1 200 MICROAMPS
ZERO ADJ. R7 7000
R9 18M
R8 18M.
R2 15M.
R3 20M.
+36 V.
-50 V.
C1 .25
V3 6X5GT
R1 6200
+5V.DC ADJ.
-5V.DC ADJ.
AC CAL. 100V.
OHMS ADJ.
R10 8M
R11 8M
R12 8M
R13 7M
V1 6K6GT
V2 6K6GT
R5 2300
R4 2300
C3 .0033
C2 .0033
R14 3.3MEG.
R15 3.3MEG.
R6 56M
PILOT LAMP 6-8V. 0.15A. MAZDA 47
HEATER CIRCUIT
117V. 60∿
RECTIFIED AND FILTERED OUTPUT FROM AC DIODE (V4)
R19 1.5MEG.
C5 .25
AC BAL.
R16 450M
R18 100M
R17 450M
C4 .25
V4 6H6 DIODE FOR AC VOLTAGE MEASUREMENTS
R21 630M
R22 495M
R23 375M.
3 VOLTS (2-1½V. CELLS) BURGESS #2 EVEREADY #450 OR EQUIVALENT (MOUNTED INSIDE VOLTOHMYST)
R30 9.9MEG.
R31 90M
R32 9000
R33 900
R34 90
R35 9.5
R24 2.5MEG.
R25 2.0MEG.
R26 250M.
R27 200M.
R28 25M.
R29 25M.
AC & OHMS TEST PROBE (RED)
GROUND
BLACK
DC VOLTS TEST PROBE (BLUE)
R36 1.0MEG. ISOLATING RESISTOR
R20 3.9MEG.
INPUT RESISTANCE ON ALL DC RANGES IS APPROX. 10 MEGS.

As you will observe, this instrument uses a D.C. electronic vacuum tube voltmeter circuit which is characterized by excellent linearity and stability. Two type 6K6-GT tubes are linked by means of a common high resistance (R_6) and because of this coupling any change in the input voltage to the grid of one tube changes the cathode bias of the other and, as a result, the change in the plate current of one is accompanied by a simultaneous opposite change in the plate current of the other. The differential voltage this action develops across the load resistors R_8 and R_9 is applied to the meter which is calibrated in terms of the voltage applied to the grid, and in terms of resistance when the instrument is being used as an ohmmeter.

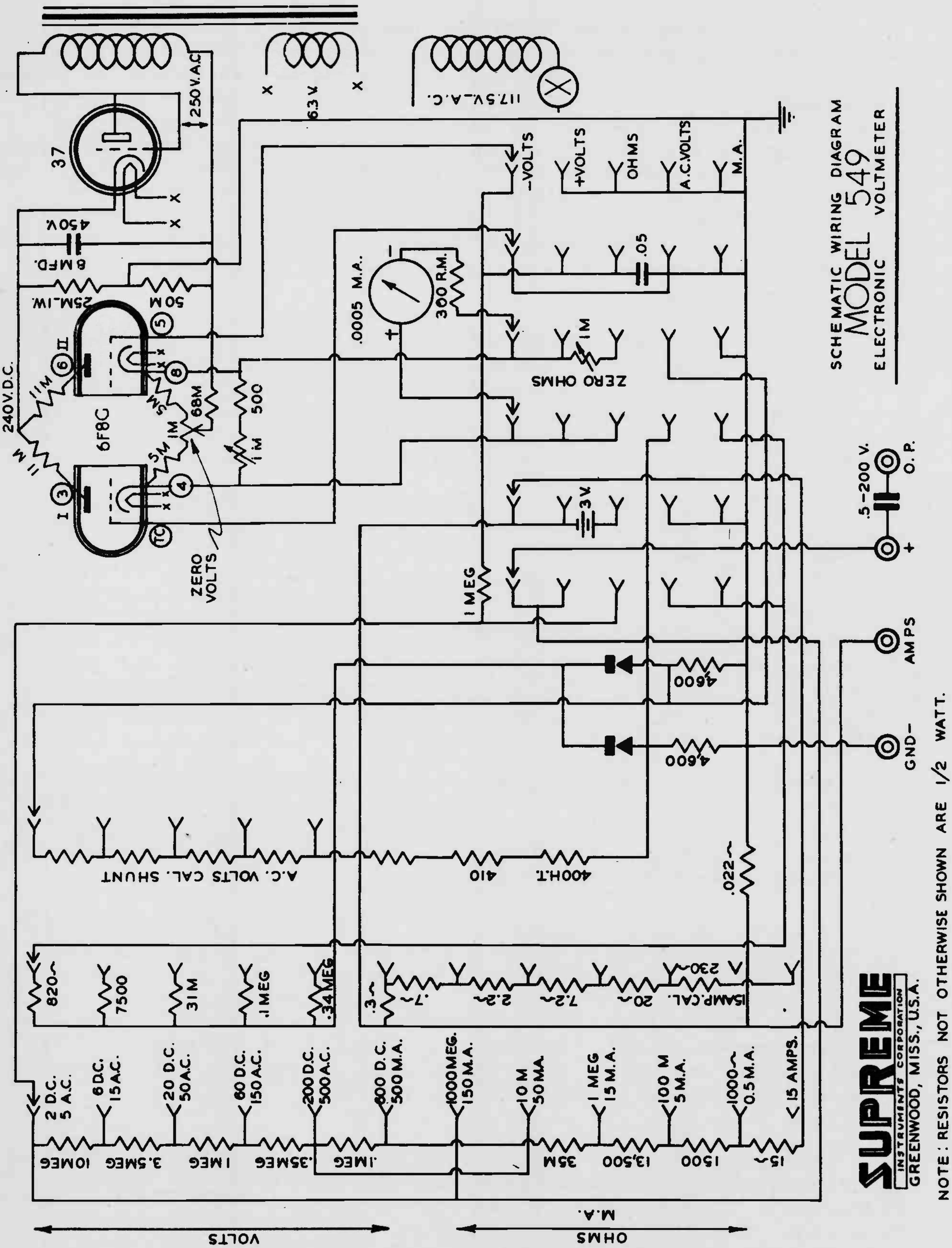
The provision of individual balance adjustments permits the switching from range to range without the need for resetting in each instance. The zero adjustment controlled by the potentiometer R_7 is employed for the initial zero setting of the meter and need be only adjusted once each time the instrument is used, unless, of course, there is considerable voltage variations.

The switching circuits at the left of the diagram employ resistance networks to provide the ranges obtainable from this instrument. Please note that the resistors in the bottom group are intended for use with D.C. ranges. The middle set of resistors is used with a small battery for resistance (ohmmeter) measurements. The circuit in the upper left hand section provides a voltage divider network to give various ranges and this circuit is used for A.C. power and audio frequency measurements. The diode 6H6 tube rectifies the alternating voltage input and places the resulting rectified voltage upon the same basic VTVM circuit which, as you recall, is intended for measuring D.C. only.

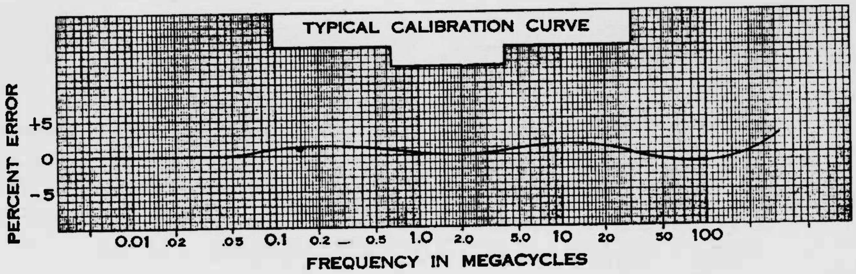
Another electronic multimeter is the Supreme Instrument Corp. Model 549. In this unit, the meter used for measuring the voltage differences in the two tube balanced circuit is placed across the cathodes. This action, however, is essentially the same as in the basic circuit we have described.

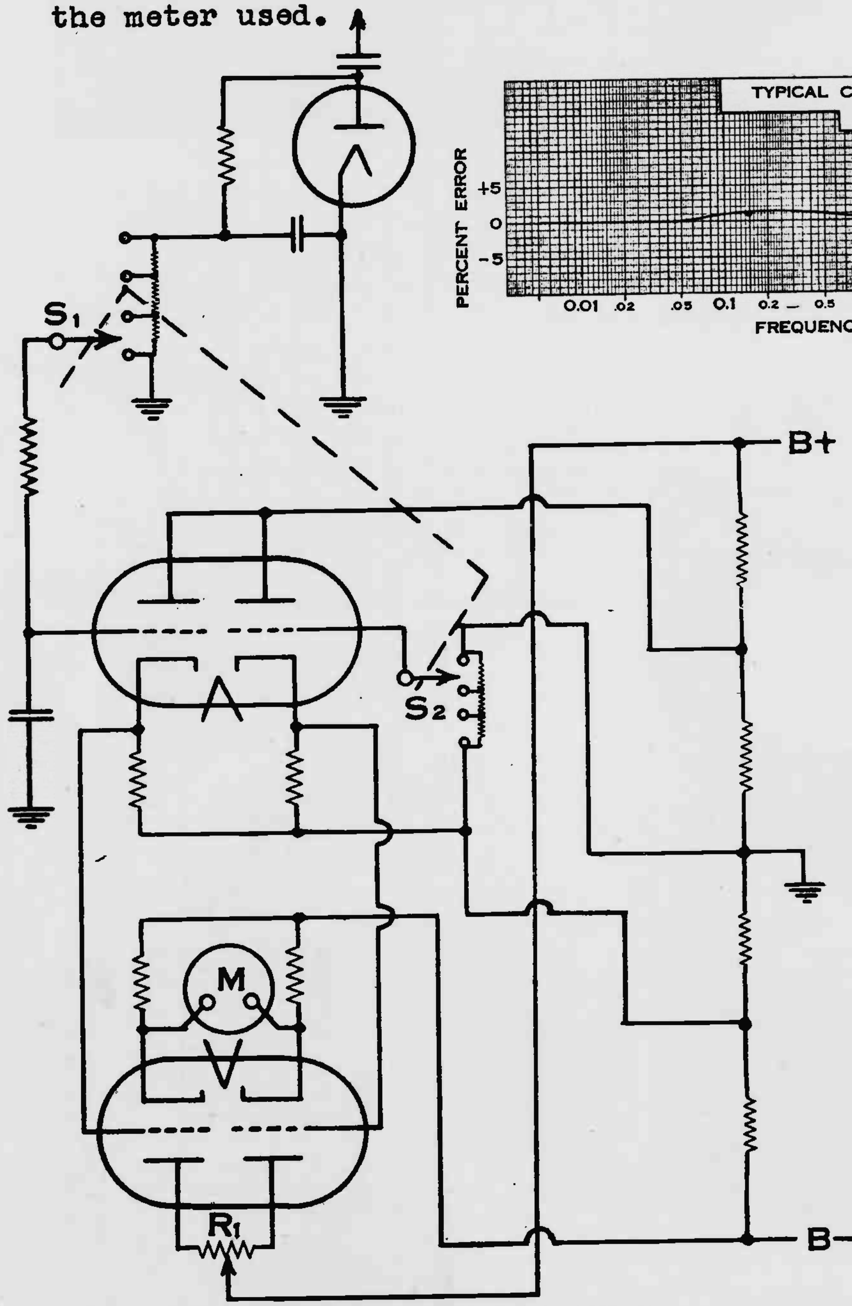
You will note in studying this circuit that it is similar and the primary singular exception is the use of copper-oxide rectifiers for A.C. measurement. For these measurements, the meter is connected directly to the voltage divider network marked A.C. VOLTS CAL. SHUNT. The electronic network is not used for these measurements. The switch elements at the right bottom of the circuit are moved in tendem "up and down" to make connections for various applications of the unit.

Sylvania Electric recently offered to servicemen a new instrument using the electronic VTVM basic circuit we have discussed. This instrument has the trade name POLYMETER, Type 134. The simplified circuit of this unit is shown on page 55, and you will observe certain important differences.


SCHEMATIC WIRING DIAGRAM
MODEL 549
ELECTRONIC VOLTMETER
SUPREME
INSTRUMENTS CORPORATION
GREENWOOD, MISS., U.S.A.
NOTE: RESISTORS NOT OTHERWISE SHOWN ARE 1/2 WATT.
250V.A.C.
6.3 V
117.5V.-A.C.
37
450V.
8MFD.
25M-1W.
50M
240V.D.C.
6F8C
68M
500
1M
ZERO VOLTS
.0005 M.A.
300 R.M.
ZERO OHMS
-VOLTS
+VOLTS
OHMS
A.C.VOLTS
M.A.
.05
3 V
1 MEG
.5-200 V.
O.P.
AMPS
GND-
4600
4,600
A.C. VOLTS CAL. SHUNT
410
400H.T.
.022~
820~
7500
31M
.1 MEG
.34 MEG
.3~
.7~
2.2~
7.2~
20~
230~
15AMP.CAL.
2 D.C. 5 A.C.
6 D.C. 15 A.C.
20 D.C. 50 A.C.
60 D.C. 150 A.C.
200 D.C. 500 A.C.
600 D.C. 500 M.A.
1000 MEG. 150 M.A.
10 M 50 M.A.
1 MEG 15 M.A.
100 M 5 M.A.
1000~ 0.5 M.A.
15 AMPS.
10 MEG
3.5 MEG
1 MEG
.35 MEG
.1 MEG
35 M
13,500
1500
15~
VOLTS
OHMS
M.A.

The diode included is intended for A.C. measurements and can be used with a good degree of accuracy up to frequencies of 300 MC. The curve illustrated below indicates the accuracy obtainable at various frequencies. The D.C. voltage obtained from the diode is impressed on a balanced electronic circuit of the type we have described. The voltage differential resulting in this instance, however, is not impressed on the meter, but instead is applied to another dual tube in a very similar circuit. A greater voltage differential is obtained from this second set of triodes and is in turn impressed upon the meter used.





FUNDAMENTAL PROBE CIRCUIT

Table

D. C. Voltages	Ohms per volt	Accuracy
0-3	5,333,333	
0-10	1,600,000	
0-30	533,333	± 3% of full scale
0-100	160,000	
0-300	53,333	
0-1000	16,000	

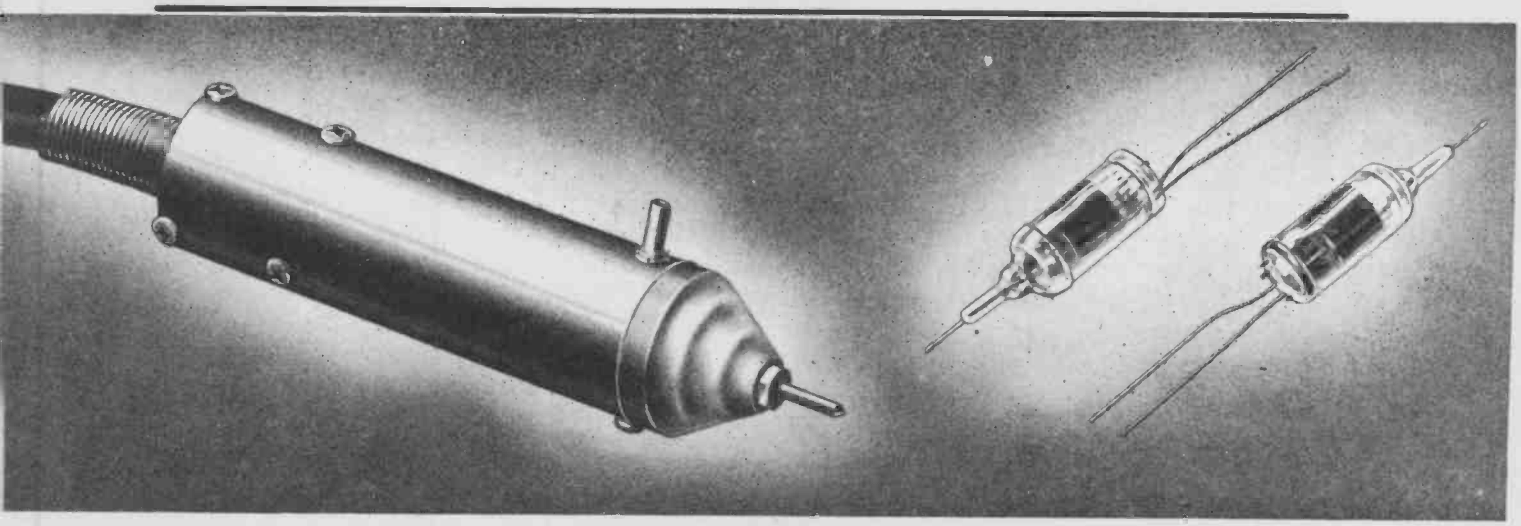
A. C. Voltages:	Audio (capacity 40 uuf.)	
0-3	900,000	
0-10	270,000	± 5% of full scale
0-30	90,000	
0-100	27,000	± 7% of full scale
0-300	9,000	

A. C. Voltages:	R.F. (at frequencies up to 300 mc with probe capacity of 3 uuf.)	
0-3	900,000	± 5% of full scale
0-10	270,000	
0-30	90,000	± 7% of full scale
0-100	27,000	
0-300	9,000	± 10% of full scale

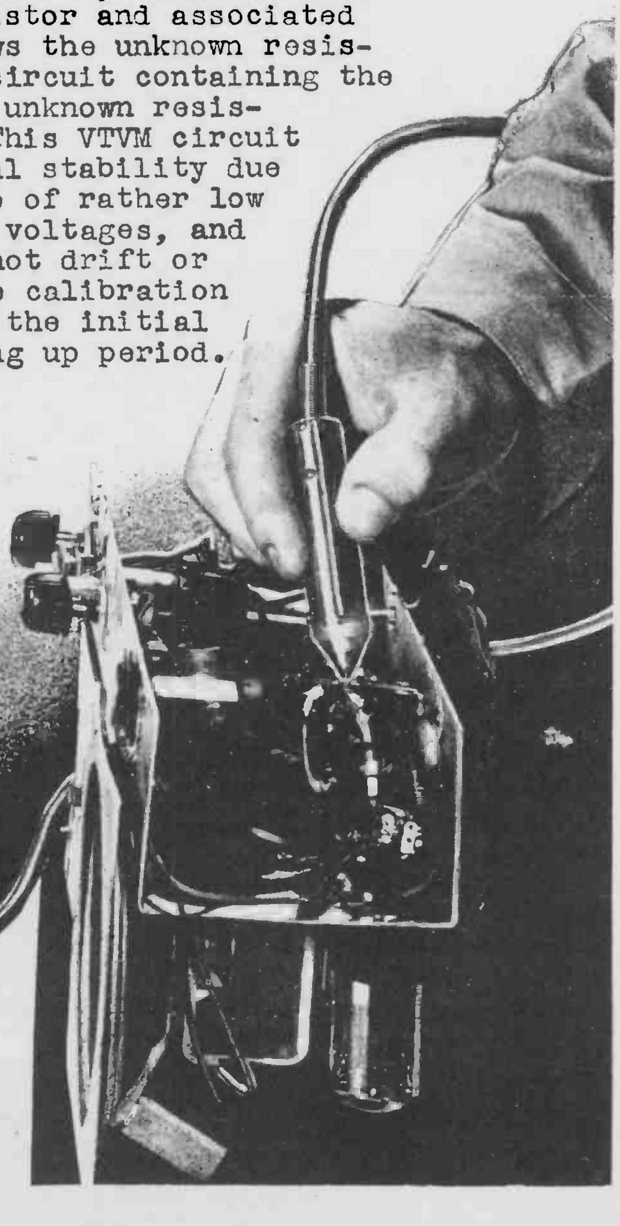
Current	Resistance	
0-10 amps	.015 ohms	± 5% of full scale
0-1000 ma	.150 ohms	
0-300 ma	.50 ohms	
0-100 ma	1.5 ohms	± 3% of full scale
0-30 ma	5.0 ohms	
0-10 ma	15.0 ohms	
0-3 ma	50.0 ohms	

Resistance	Current Required	
0-1000 ohms	300 ma @ 0 ohms	
0-10,000 ohms	30 ma @ 0 ohms	± 6%°on
0-100,000 ohms	3 ma @ 0 ohms	first half
0-1 Meg.	0.3 ma @ 0 ohms	of scale
0-10 Meg.	30 ua @ 0 ohms	
0-1000 Meg.	0.3 ua @ 0 ohms	

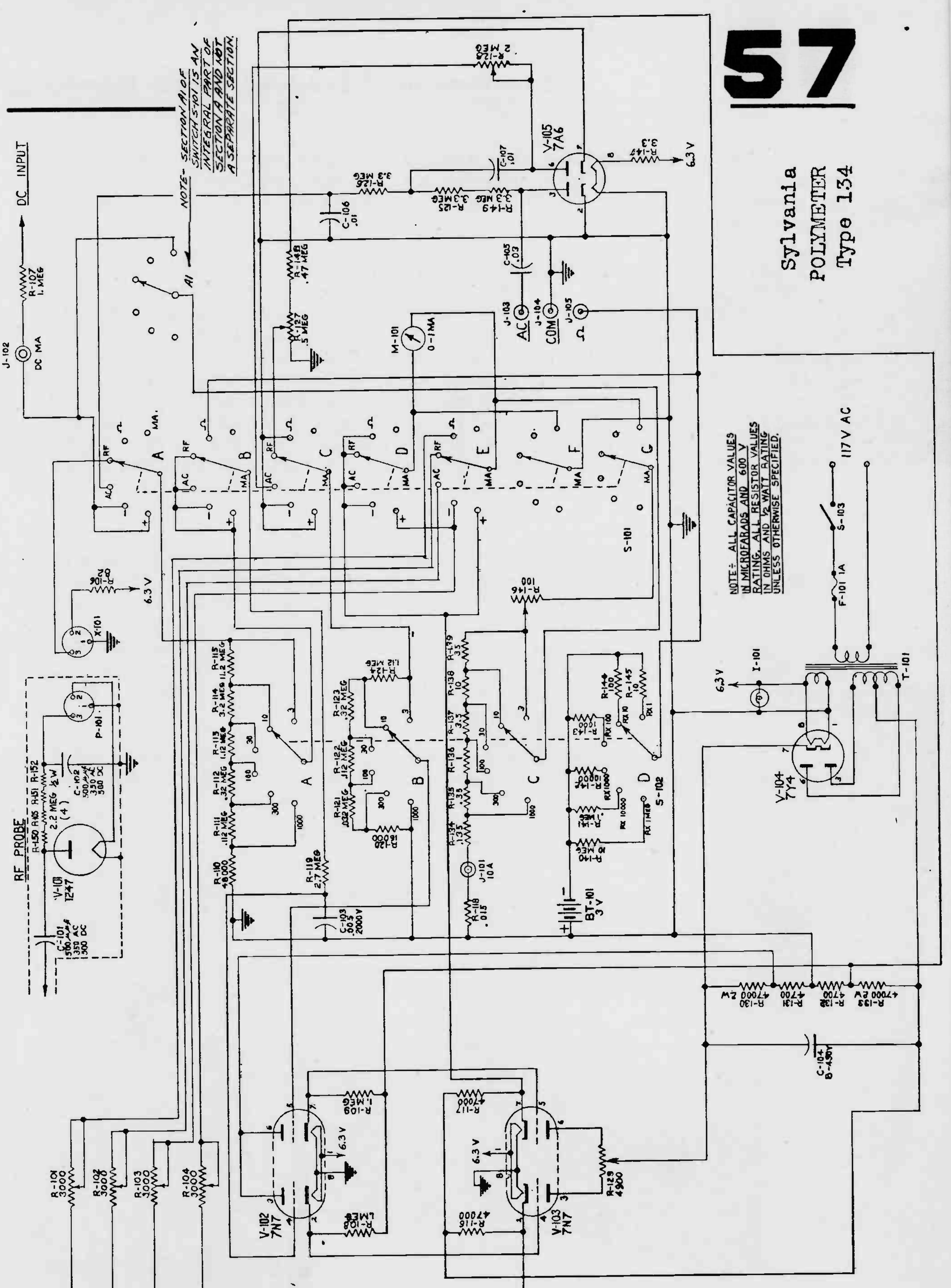
NOTE—RF accuracy from 100 to 300 mc is 5% greater than the above figures.



The ohmmeter circuit is formed from the basic voltage input circuit with the aid of a small battery which is used to supply a voltage to the unknown resistor and associated network. The reading of the meter shows the unknown resistance value when current flows in the circuit containing the known and unknown resistances. This VTVM circuit has unusual stability due to the use of rather low plate voltages, and will not drift or change calibration after the initial warming up period.



57



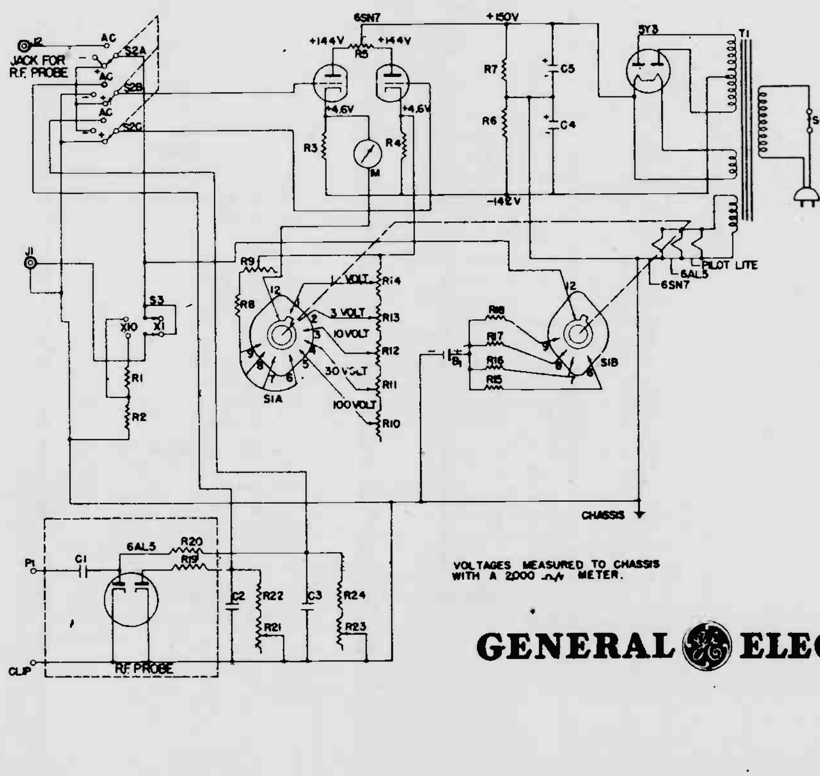
Sylvania
POLYMETER
Type 134
NOTE- SECTION A1 OF SWITCH S-101 IS AN INTEGRAL PART OF SECTION A AND NOT A SEPARATE SECTION.
NOTE: ALL CAPACITOR VALUES IN MICROFARADS AND 600 V RATING, ALL RESISTOR VALUES IN OHMS AND 1/2 WATT RATING UNLESS OTHERWISE SPECIFIED.
DC INPUT
RF PROBE
V-105 7A6
V-104 7Y4
V-102 7N7
V-103 7N7
V-101 1247
M-101 0-1 MA
S-101
S-102
BT-101 3 V
117 V AC
S-103
F-101 1A
T-101
I-101
J-101 10A
J-102 DC MA
J-103 AC
J-104 COM
J-105 Ω

A table indicating the scales available, the sensitivity obtainable, and the accuracy expected, is included to give you an idea of the results that are possible with instruments of this type.

After this preliminary study, you can refer to the general circuit. Here you will note the addition of various voltage divider networks to give the needed ranges and the switching method for changing the circuit for the measurement and range wanted. Current readings are taken directly on the meter with suitable shunt resistances, but, for this purpose, the electronic section of the unit is not employed. As you realize, the R.F. probe is employed for all A.C. measurements. Since it is not practical to design a single probe circuit to serve for high radio frequencies and at the same time measure power frequencies without error, this unit is not adaptable for A.C. frequencies below the audio spectrum.

The input impedance of 16 megohms for D.C. measurements was selected as the best compromise between the erratic behavior which may be caused through the use of a much higher value and the too low an impedance giving poor sensitivity as used in some of the earlier models of vacuum tube voltmeters. Notice that in the table the ohms-per-volt sensitivity varies with the scale used. This is not the case with some other instruments of this nature, but is of little consequence in radio service work.

The General Electric electronic volt-ohmmeter type PM-17 circuit and parts list are next presented for your study.



GENERAL ELECTRIC

SPECIFICATIONS

D-C VOLTS: ×1 range—0–1, 3, 10, 30, 100 volts. Input impedance from 30 to above 200 megohms. ×10 range—0–10, 30, 100, 300, 1000 volts. Input impedance constant at 10 megohms. Input capacity on both ×1 and ×10 ranges 2 mmf.

A-C VOLTS: 0–1, 3, 10, 30, 100 volts. Input capacity, using test leads, approximately 100 mmf. Usable at audio and low radio frequencies. Response drops below 200 cycles to a value of 5% low at 60 cycles.

R-F VOLTS: 0–1, 3, 10, 30, 100 volts. (Same as a-c scale.) R-f measurements made using the r-f probe. Input capacity using the r-f probe is 6.6 mmf at 70 megacycles.

OHMS: R×1, ×100, ×10K, ×100K (K=1000). Basic scale .2 to 1000 ohms, 10 ohms center scale. Applied voltage, all ranges, 1.5 volts.

POWER SUPPLY: 105–120 volts, 60 cycles, 30 watts input.

ACCESSORIES: (Supplied) Two alligator clips. Two pairs of leads and an r-f probe.

CASE: Steel, 8½″ by 8″ by 8″. Sloping panel of aluminum. Instrument accessible as a unit by removing panel screws.

WEIGHT: 15 pounds.

A 6AL5 tube mounted in a probe is used for audio and radio frequency voltage measurements from 200 cycles to beyond 100 megacycles. Response drops below 200 cycles to a value of 5% low at 60 cycles. In audio frequency measurements the probe can be mounted in the top of the case and the test leads from the panel used instead. An ohmmeter circuit is included for convenience in measuring high and low ohmic values of resistance.

LIST OF ELECTRICAL COMPONENTS

Symbol	Description	Rating	Tolerance
B1	No. 2 Flashlight battery	1.5 volt	
C1	Capacitor	.01 mfd	
C2	Capacitor, paper	.05 mfd, 400 volt	
C3	Capacitor, paper	.05 mfd, 400 volt	
C4	Capacitor, electrolytic	8 mfd, 250 volt	
C5	Capacitor, electrolytic	8 mfd, 250 volt	
R1	Resistor, carbon precision	1 w. 8 megohm	2%
R2	Resistor, carbon precision	1 w. 1 megohm	2%
R3	Resistor, carbon	1 w. 51K ohm	5%
R4	Resistor, carbon	1 w. 51K ohm	5%
R5	Potentiometer (zero set)	5K ohm	
R6	Resistor, carbon	1 w. 47K ohm	5%
R7	Resistor, carbon	1 w. 51K ohm	5%
R8	Resistor, carbon	½ w. 8.2K ohm	10%
R9	Potentiometer (ohms adjust)	5K ohm	
R10	Potentiometer	750K ohm	
R11	Potentiometer	350K ohm	
R12	Potentiometer	50K ohm	
R13	Potentiometer	50K ohm	
R14	Potentiometer	15K ohm	
R15	Resistor, carbon precision	½ w. 9 ohm	2%
R16	Resistor, carbon precision	½ w. 1K ohm	2%
R17	Resistor, carbon precision	½ w. 100K ohm	2%
R18	Resistor, carbon precision	¼ w. 1 megohm	2%
R19	Resistor, carbon	¼ w. 3.3 megohm	5%
R20	Resistor, carbon	¼ w. 3.3 megohm	5%
R21	Potentiometer (AC zero)	10 megohm	
R22	Resistor, carbon	½ w. 6.8 megohm	10%
R23	Potentiometer	10 megohm	
R24	Resistor, carbon	½ w. 6.8 megohm	10%
R25	Resistor, carbon precision (in DC test prod)	1 megohm	2%
M	Meter	100 microammeter	2% accuracy
T1	Power transformer		

Due to the self-balancing type of circuit and the high degree of degeneration, fluctuations in line voltage and changing of tubes has little or no effect on calibrations.

In all AC-DC volts and ohms measurements, the test leads are plugged in the jack on the front panel. The 6AL5 probe is used for R.F. measurements. All functions of the instrument are obtained through the use of two selector switches. The polarity switch controls the polarity of the test prods and also switches the instrument to the ohms and A.C. circuits. The range switch selects the range of the desired measurement.

Other controls are: a zero adjustment knob to set the instrument pointer to zero, an ohms adjustment knob to set the instrument pointer to full scale on the ohms ranges, a toggle switch which acts as a power switch.

The toggle switch in the lower right corner of the panel controls the 10 to 1 voltage divider which is switched across the input to secure the higher ranges of D.C. volts. This voltage divider also provides a convenient means of securing a grid return when D.C. loading of this instrument is obtained by using an open grid input on D.C. volts X1. The grid return is through the circuit being measured.

Voltage measurements made between two points, both above ground potential, should be made using the following procedure. Measure each point separately to ground, then subtract to find the difference in potentials. This method of measuring causes no appreciable disturbance in the circuit being measured. If the negative lead, which is grounded to the instrument case, were connected to a point above ground, inaccurate readings would result due to the A.C. loading effect of the chassis and the test leads. There is also the possibility of shorting to ground.

The operating instructions supplied with this instrument contain excellent application suggestion and I am quoting from this material through the courtesy of General Electric Co.

The automatic volume control voltage developed in a receiver by the incoming signal can be measured at a number of places. Most common places are the grids of the IF amplifier tubes and the signal grid of the converter tube. This D.C. voltage, if measured anywhere along the grid return circuit on the AVC line, is a convenient output indication during receiver alignment. Resonance will produce the highest negative voltage. Polarity will be negative with respect to ground.

The D.C. voltage developed by the oscillator is always directly proportional to the strength of the oscillation. This D.C. voltage can be measured readily at the oscillator grid of the converter tube. Polarity will be negative with respect to ground.

All voltages encountered in radio service work, of course, can be measured with electronic voltmeters. Even bias cell voltage can be measured — a thing which cannot be accomplished with an ordinary voltmeter.

The discriminator voltage developed in radio receivers employing automatic frequency control can be measured directly at the discriminator and also at the grid of the oscillator control tube.

By switching to the regular D.C. voltage ranges and connecting to the limiter grid circuit, a useful means of indicating proper antenna orientation and position as well as adjusting antenna matching sections may be found. Maximum readings indicate proper antenna positions and correct matching.

The instrument is useful for measuring the D.C. voltage developed in the picture channel of a television receiver across the second detector load resistor. This measurement is most useful when adjusting antenna orientation and position as well as when adjusting antenna matching sections. Maximum readings indicate proper antenna position and correct matching.

The effect of a gassy tube is to put a positive charge on its control grid instead of the negative charge or no charge at all that would normally be found between grid and ground. A gassy tube will cause the entire AVC system to run positive, resulting in loss of sensitivity. You can measure the voltage directly at the control grid of the tube to determine the polarity of the charge.

The R.F. probe is useful in tracing an R.F. signal from the antenna through to the diode detector plate. After rectification by the diode tube, only the audio frequency component of the signal is left, but the R.F. probe can still be used to trace the signal through to the loud speaker. Gains or losses between stages can readily be measured.

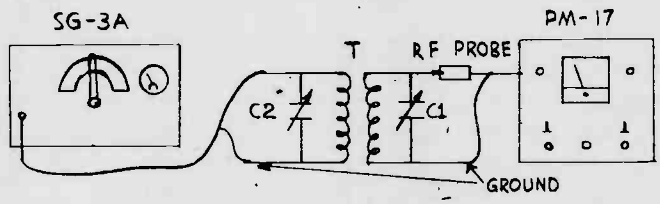
As an example of what might be expected in the R.F. portion of a small AC-DC receiver, the following figures are given. With 100,000 microvolts of R.F. fed to the receiver through a standard I.R.E. dummy antenna, AVC voltage on the control grid of the 12SA7 tube was 5.8 volts D.C. R.F. appeared on the various tubes as follows:

12SA7 converter grid	.13	volts R.F.
12SA7 converter plate	.7	volts R.F.
12SK7 IF grid	.2	volts R.F.
12SK7 IF plate	6.4	volts R.F.
12SQ7 diode plate	3.6	volts R.F.

These figures will, of course, vary with different receivers and circuits, but in general, a minimum of 3 volts should always be found at the diode plate of the second detector.

With the aid of an R.F. signal generator, such as the General Electric SG-3A, the relative merit of similar IF., R.F. and ANT. coils and wave traps, or the frequencies to which they will tune can easily be determined.

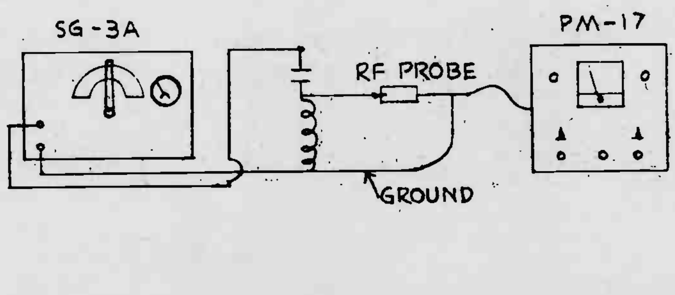
The PM-17 electronic VTVM is set up to measure R.F. voltage and is connected to the signal generator and coil as shown in the circuit. The circuit is drawn showing an IF. coil "T." R.F. and ANT. coils are connected in the same manner.

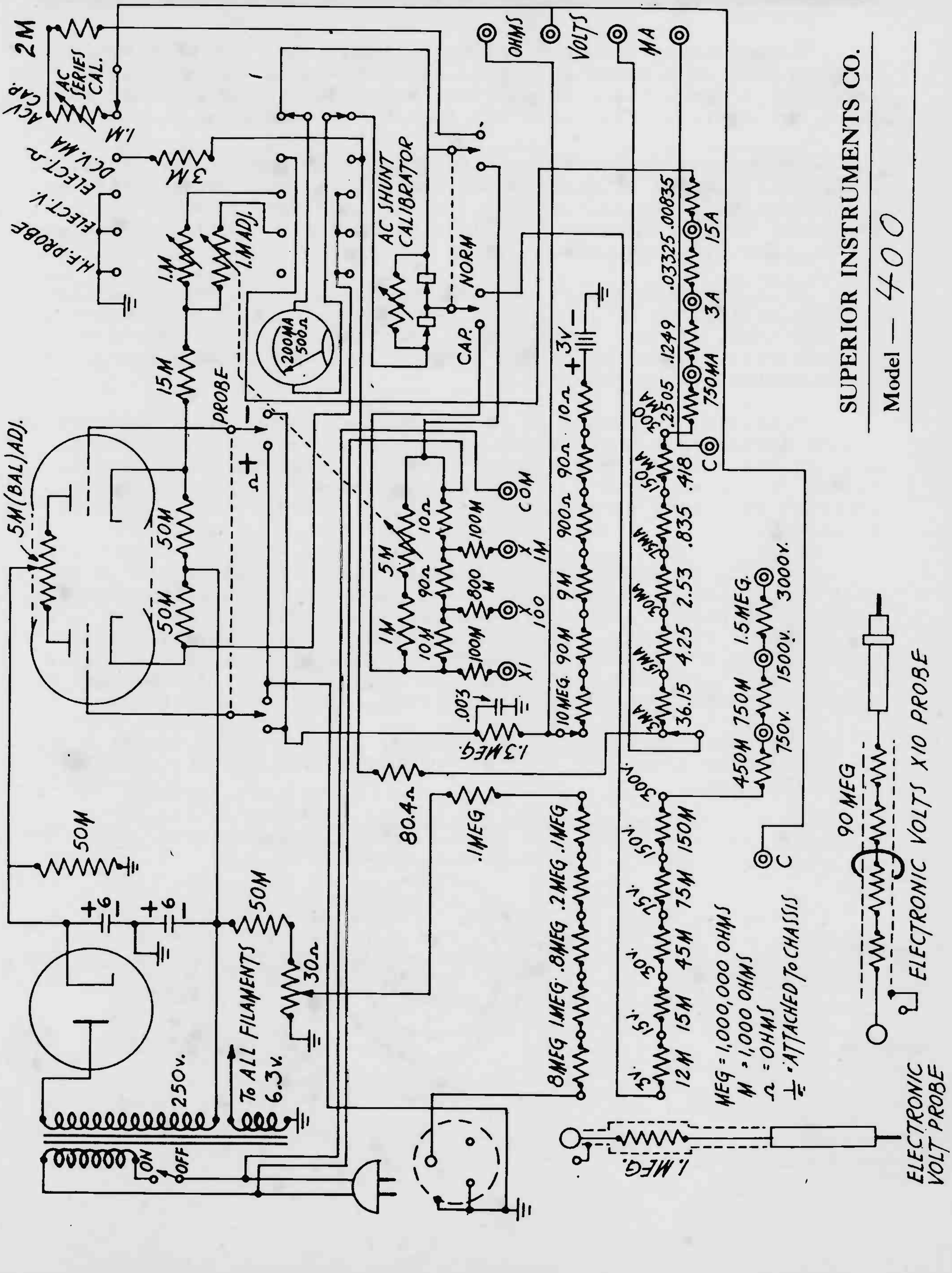


If the frequency of the coil is known, the signal generator is set on that frequency and adjusted to give an output of from 1 to 2 volts. Adjust trimmer C_1 on the coil to give the highest reading on the meter of VTVM. This reading should be noted. Trimmer C_2 will have little or no effect on the frequency, so it can be disregarded. By connecting another similar coil in place of "T," and keeping the signal generator settings the same and peaking C_1 on the second coil, the relative merits of the two coils can be determined and the better one selected. The coil with the best "Q" produces the highest reading on the meter.

If the frequencies of the coils are unknown, connect the apparatus as before and tune the signal generator until the highest reading is obtained on the meter. The frequency can then be read on the scale of the signal generator.

The frequency or relative merit of wave traps can be determined by connecting it as shown in the circuit below and tuning the signal generator until the highest reading is obtained. The frequency of the wave trap can then be read directly on the scale of the signal generator.




SUPERIOR INSTRUMENTS CO.
Model — 400
OHMS
VOLTS
MA
COM
AC SHUNT CALIBRATOR
NORM
CAP.
AC SERIES CAL.
ACV CAP.
D.C.V. MA ELECT.-Ω
ELECT.-V.
H.F. PROBE
1.M ADJ.
200MA 500Ω
PROBE
5M (BAL) ADJ.
To ALL FILAMENTS 6.3V.
250V.
ON
OFF
750MA
3A
15A
3000V.
1500V.
750V.
ELECTRONIC VOLTS X10 PROBE
90 MEG
ELECTRONIC VOLT PROBE
.1 MEG.
MEG = 1,000,000 OHMS
M = 1,000 OHMS
Ω = OHMS
⏚ = ATTACHED TO CHASSIS

By adjusting the trimmers on various coils and wave traps from minimum to maximum capacity and readjusting the signal generator to obtain the highest reading, the frequency range to which the coils can be tuned can easily be determined.

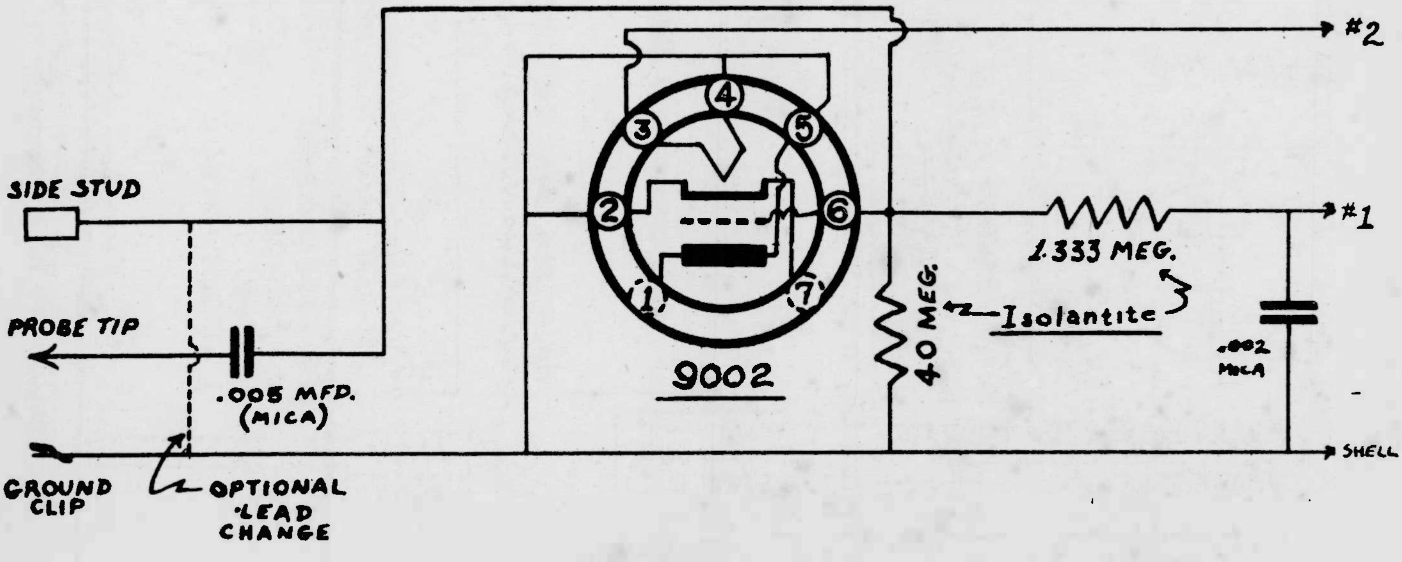
We include the circuit of Superior Instruments Co. Model 400 instrument because it has several variations from the circuits we have discussed. In this model, the 200 microampere meter is connected in the balanced cathode circuit for electronic measurements. The input resistance is 11 megohms.

This instrument also permits the use of the meter directly at the sensitivity of 1,000 ohms per volt. The A.C. measurements are also made at this sensitivity. Facilities are incorporated so that with a suitable chart, capacity and reactance measurements at 60 cycles can be obtained.

Precision Apparatus Co. Model EV-10-S vacuum tube multi-range tester defers from the circuit we have discussed in the arrangement of the electronic voltmeter circuit. Your examination will permit you to see that a bridge circuit uses a single triode. Greatest stability is achieved by using a voltage regulator tube VR-150-30.

In this type of circuit, a center-zero voltage scale is used for electronic measurements and, therefore, polarity of the probes need not be observed. The electronic circuit is also used for ohmmeter readings. Two zero adjustments at both ends of the scale are made for ohmmeter readings. This instrument may also be used as a standard 1,000 ohms per volt device by connecting proper networks by means of the switches directly to the meter.

For radio frequency measurements, a probe which contains a vacuum tube is connected to the equipment. The circuit of this probe is shown.

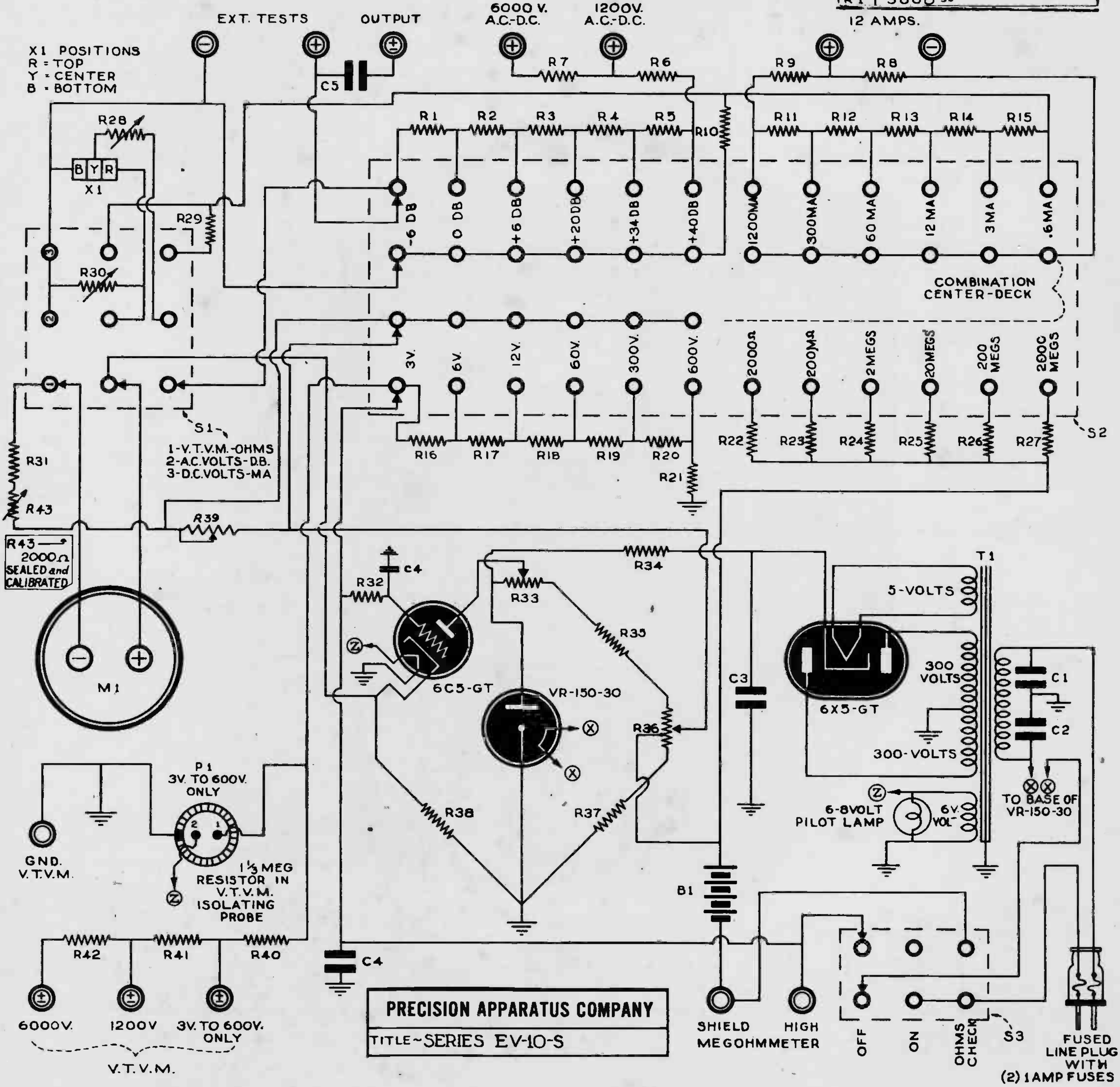


S1	3 POSITION CIRCUIT SELECTOR
S2	12 POSITION RANGE SELECTOR 3 DECKS BELOW SERIAL #6380 - 4 DECKS ABOVE.
S3	3 POSITION LINE & OHMS CHECK
P1	ISOLATING PROBE CONNECTOR —ALSO PROVIDES FILAMENT VOLTAGE FOR RF-10 RADIO FREQ. PROBING UNIT
B1	6 VOLT BATTERY-(4) 1.5V. CELLS EVEREADY #950 OR EQUIVALENT
M1	400 μ AMPS - 160 M.V.
T1	POWER TRANSFORMER
X1	METER RECTIFIER
C5	.1 MFD - 600 W.V.
C4	.002 MFD - 400 W.V.

C3	16 MFD - 450 W.V.
C2	.01 MFD - 400 W.V.
C1	.01 MFD - 400 W.V.
R42	106 2/3 MEGOHMS
R41	13 1/3 MEGOHMS
R40	1 1/3 MEGOHMS
R39	4100 Ω - OHMS ZERO ADJUST
R38	6000 Ω
R37	330 Ω
R36	225 Ω - V.T.V.M. ZERO ADJUST
R35	11,950 Ω
R34	4715 Ω - 10 WATTS
R33	3000 Ω - SEALED CALIBRATED
R32	500 MΩ

R31	8500 Ω
R30	12 MΩ - SEALED CALIBRATED
R29	2840 Ω
R28	3000 Ω - SEALED CALIBRATED
R27	20 MEGOHMS
R26	2 MEGOHMS
R25	200 MΩ
R24	20 MΩ
R23	2000 Ω
R22	20 Ω
R21	60 MΩ
R20	60 MΩ
R19	480 MΩ
R18	2.4 MEGOHMS
R17	3.0 MEGOHMS

R16	6.0 MEGOHMS
R15	640 Ω
R14	120 Ω
R13	32 Ω
R12	6.4 Ω
R11	1.2 Ω
R10	267 Ω CALIBRATED
R9	.36 Ω
R8	.04 Ω
R7	4.8 MEGOHMS
R6	600 MΩ
R5	300 MΩ
R4	240 MΩ
R3	48 MΩ
R2	6000 Ω
R1	3000 Ω



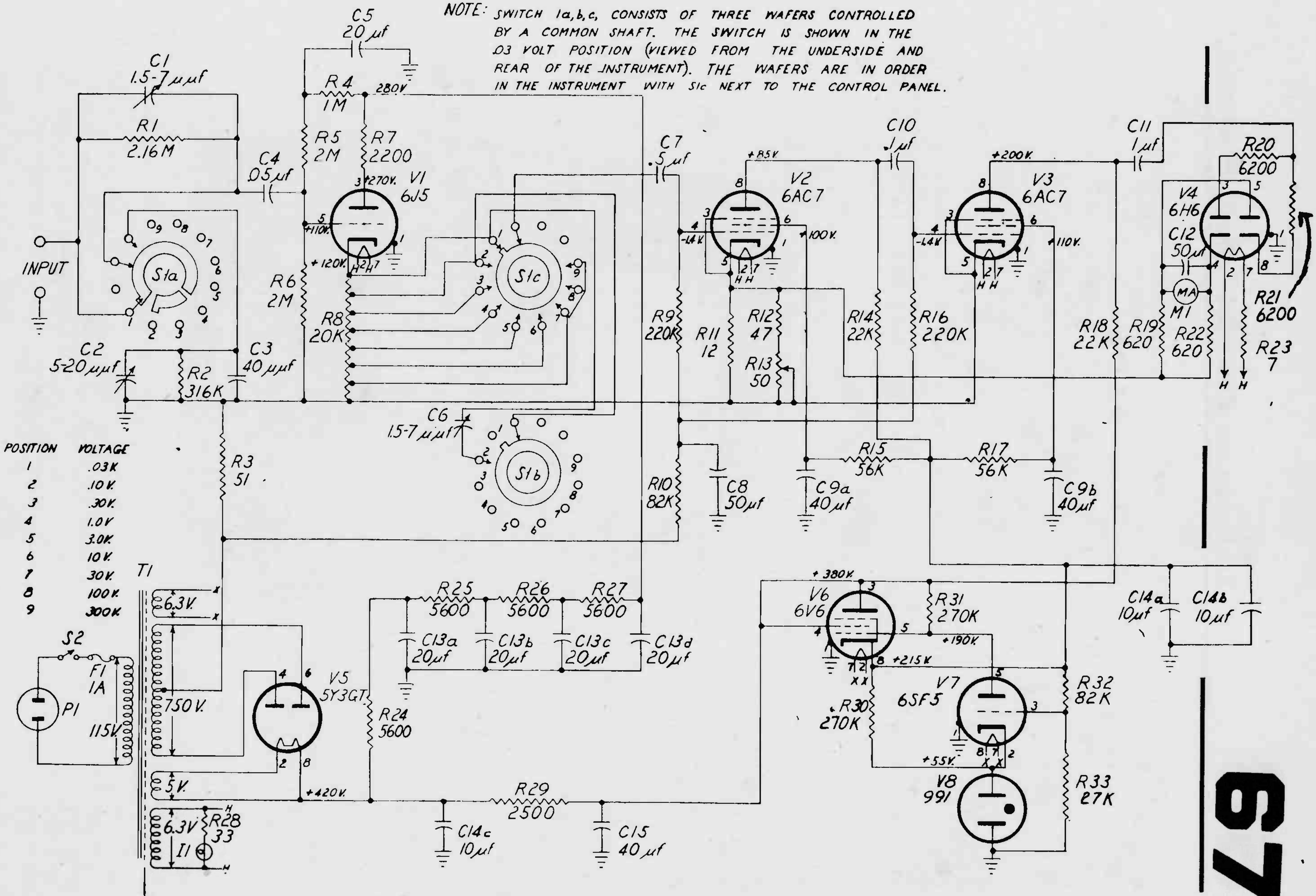
Many servicemen find occasion to use laboratory equipment, and we are including the circuit and brief description of Hewlett-Packard Co. Model 400A vacuum tube voltmeter.

This instrument is intended for A.C. use and is accurate within 3% from 10 cycles to 100 kilocycles. The accuracy is correct within 5% to frequency of 1 megocycle.

On all ranges except the 100 and 300 volt ranges, the input resistance of the instrument is one megohm. On the 100 volt range, the input resistance is 3 megohms, and on the 300 volt range the input resistance is 2.4 megohms. The input capacity is approximately 15 mmfd. in parallel with the input resistance.

The instrument is calibrated to indicate the RMS value of a sine wave, but the instrument responds to the average value of the rectified full wave applied. Because both the positive and negative portions of the applied wave thus influence the meter, "turn-over" effects are negligible and errors caused by the presence of harmonics in the applied voltage are minimized.

NOTE: SWITCH 1a,b,c, CONSISTS OF THREE WAFERS CONTROLLED BY A COMMON SHAFT. THE SWITCH IS SHOWN IN THE .03 VOLT POSITION (VIEWED FROM THE UNDERSIDE AND REAR OF THE INSTRUMENT). THE WAFERS ARE IN ORDER IN THE INSTRUMENT WITH S1c NEXT TO THE CONTROL PANEL.



POSITION	VOLTAGE
1	.03V
2	.10V
3	.30V
4	1.0V
5	3.0V
6	10V
7	30V
8	100V
9	300V

SCHEMATIC DIAGRAM FOR -hp- MODEL 400A VACUUM TUBE VOLTMETER

In addition to its voltage calibration, the unit is calibrated in decibels from the accepted standard of zero level at 1 milliwatt at 600 ohms. Therefore, the instrument can be used very conveniently as a gain-measuring device. Although true power levels are limited to a 600 ohm basis (unless calculated), the instrument will show voltage comparisons directly in terms of decibels regardless of the impedance of the device under test, as long as the readings are taken across the same impedance.

Large overloads even of 100 times the scale reading of the voltmeter will not damage the meter, owing to the limiting action of the amplifier. In general, however, overloads are undesirable and should be avoided.

Referring to the schematic diagram, it may be seen that voltages applied to the input terminals are passed through a blocking capacitor to the grid of the 6J5 cathode-follower input stage. The cathode resistor is a tapped precision wire-wound resistor which serves as the voltmeter multiplier on all but the two highest ranges. On the latter two ranges a high-resistance frequency-compensated voltage divider is switched across the input terminals and ahead of the grid of the first tube.

The cathode-follower feeds into a broad-band resistance coupled amplifier using 6AC7 tubes. Negative feedback is used in this amplifier in order to obtain high stability and uniform response over a wide frequency range, and to make the amplifier more independent from variations in tube characteristics.

From this amplifier the voltage is passed to a full-wave rectifier using a 6H6 duo-diode tube. The indicating meter is connected from one plate to the opposite cathode of the tube and, therefore, is actuated by a portion of the plate current of the two diodes.

Direct current for the plate supply of the tubes in the instrument is obtained from a conventional full-wave rectifier feeding into a resistance-capacity filter. A voltage-regulating circuit across the output of the rectifier keeps the plate supply voltage constant over a wide range of line voltages.

Throughout the circuit large resistance-capacity filters are used to isolate the individual stages and to prevent any feedback from currents flowing through the common power supply impedance.

The subject of vacuum tube voltmeters was given considerable space because these instruments are becoming of primary importance in servicing and are relatively new to radio men.

Lecture 8

Voltage Point-to-Point Servicing

While the presence of correct voltage values at all points cannot guarantee the proper operation of the radio under examination, a wide discrepancy of even a single voltage value may suggest the cause of the existing fault. This is true in equipment which has been properly operating up to the time of the failure, and a singular fault may be rightly expected to be the cause of the trouble. Radio sets which you repair fall into this class, but newly designed laboratory models do not.

When a radio set is properly operating, it may be considered to consist of several separate inter-connected stages, each stage operating in a correct fashion. For a stage to give expected operation, certain voltage values must exist at various points. Many faults commonly causing radio failure also have a pronounced effect upon voltages present at associated junction points. The existance of these facts permits the successful application of voltage point-to-point servicing technique.

For review purposes only (you probably know this information well), we will state the type of voltages present in various sections of modern receivers. In all stages, including the power supply, D.C. voltages varying from 2 to 400 volts are to be found. Majority of tests are made to detect the presence and correctness of these voltages. Many voltage values can be measured accurately only with a very sensitive voltmeter and the errors occuring in measurements introduced by less sensitive meters will be discussed later.

Power line frequency A.C. voltages may need checking (measurement) in the power supply input and at filament terminals — the only places where these voltages exist in most A.C. operated sets. Measurements from 2½ to 450 volts may be needed. Radio frequency measurements are helpful in determining the degree of oscillation in a superhet, the signal strength, the stage gain, and the power output.

The preference of voltage point-to-point servicing over other methods depends on many factors which in turn depend on equipment available, fault suspected after a preliminary examination, and your personal choice. Further, a change to this servicing method may be made after another technique of radio fault finding did not lead to any conclusive results and suggested voltage point-to-point method as being more adaptable in this instance. I hardly need to add that the power supply must be functioning and voltages must be present for this method to be applied.

In general, it is best to start voltage tests by determining if correct plate voltage exists at the output of the rectifier. The various types of power supplies are discussed in a later lecture and we will, at this time, only mention at what points this test can be made and what value of voltages can be expected.

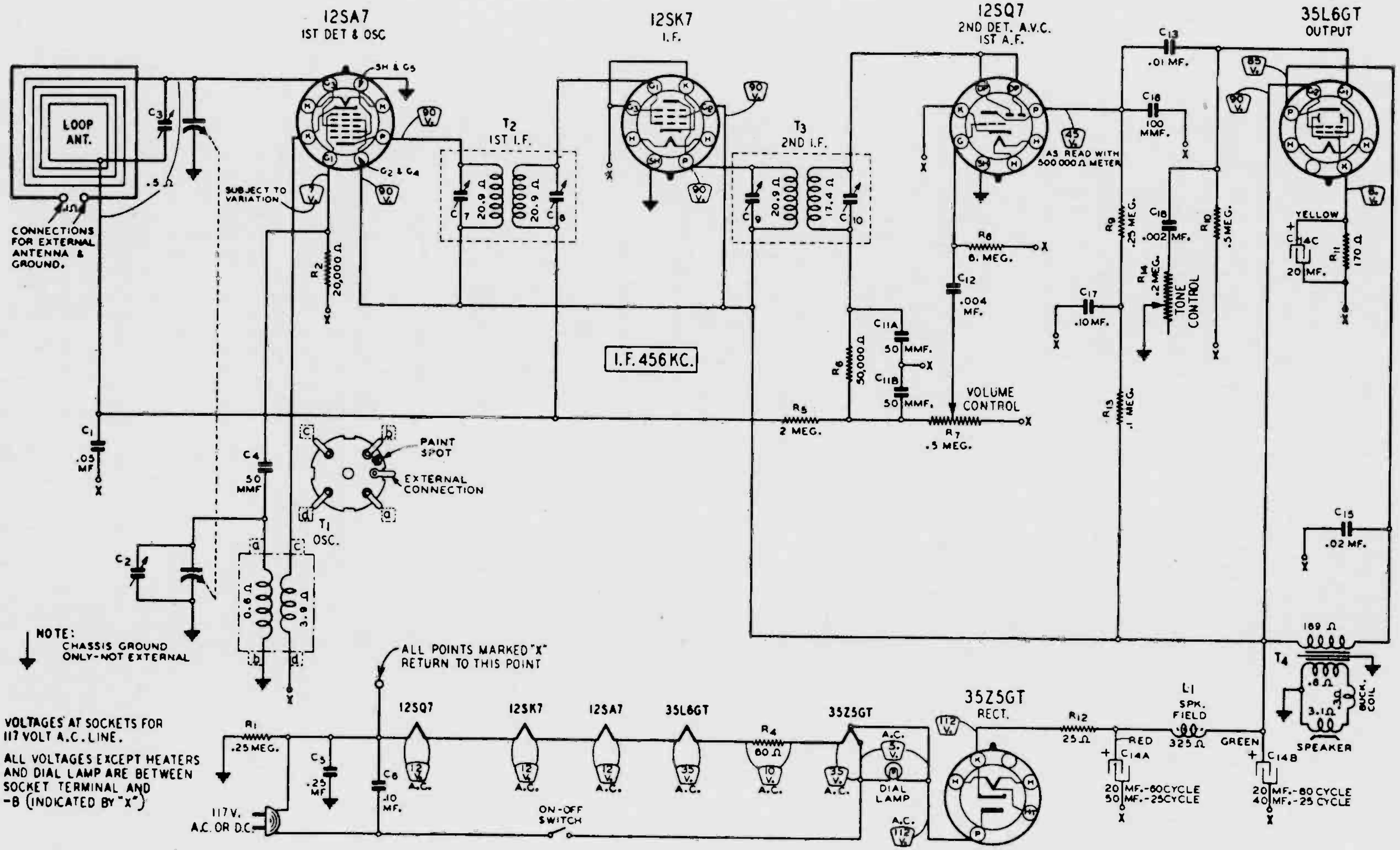
The negative prod of your voltmeter (this applies to all types) is in contact with the most negative point — this is usually the chassis. An alligator clip is handy for making this connection to the negative side, and there are clips of this type which hook into regular phone-tips of the test prods.

In some A.C. and automobile sets, the most negative point may not be the chassis. This matter may be checked easily by noting where the center-tap of the high-voltage winding is connected. This center-tap, of course, is the negative point. In the more modern AC-DC radios, the chassis is not connected directly to the negative side of the power supply. In such sets (and also in all other AC-DC types), the negative prod of your voltmeter may be connected to the power switch which is usually on the side of the power line used as the negative side. However, this is not always the case and in some sets the switch is on the positive side. The side of the line in AC-DC sets which leads to the plate of the rectifier tube is positive, so the other side of the line is negative. In battery sets, the negative B battery lead is used as the point for attaching the negative voltmeter prod. If you know that A+ is connected to B-, use A- terminal for this purpose.

The most positive point is at the cathode of the rectifier. In directly heated tubes, the filament serves as the cathode, and one side of the filament is used as the positive point before the filter. In battery sets, B+ of the battery is the point. Test at these points to determine if proper voltage is being delivered by rectifier. Here is a list of typical voltages to be expected:

Old style A.C. sets	300 to 400 volts
Recent A.C. and Auto sets	250 to 325 volts
AC-DC sets (half-wave rectifier)	115 to 135 volts

Now we can go further. Test for voltage after filter and then proceed to each tube testing for voltage at various terminals. Values expected become familiar to you from experience. A tube manual is of great help since it gives ordinary operating voltages under various conditions. Circuit diagrams include data on voltages to be expected at points used for tests.



The circuit of Series 5A25-S, Wells-Gardner receiver is illustrated. You will note the helpful voltage values given at various points which can be used as a guide in conducting point-to-point voltage tests. You will observe that these values are measured between the points indicated, and any point marked X. A.C. socket voltages are measured between the terminals, as indicated.

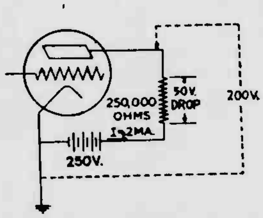
Besides voltage values indicated, others can be measured, but it is not probable that they will give any additional aid not offered by the suggested tests. In measuring unknown voltage, a high enough voltage scale should be selected so that no damage results even if the maximum possible voltage is encountered. If the voltage is smaller than expected, a lower scale may be selected for more accurate measurement.

To be efficient in using the point-to-point voltage tracing technique, you must watch for two limitations of this method and overcome them with collaborating tests or use another test technique. One limitation is wide variation in permissible values. If 200 to 300 volts is correct for a certain point in the circuit and you obtain a reading of 200, is this value to be accepted as correct? Perhaps, the set was designed to give 300 volts at the point considered, but you do not know this fact; you know that 200 to 300 is commonly used.

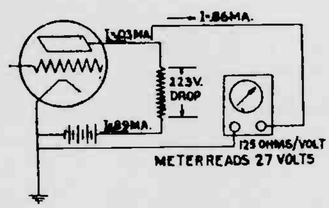
An answer to this type of problem is found in making further voltage measurements. If the voltage is low, something is causing it to be so, and probably voltages in the associated circuits will be definitely on the low side.

Another way to analyze this question is to ask yourself: "If this voltage really should be 300, but now measures only 200, would the set show the faults which exist?" Perhaps, this voltage difference should have little effect on the operation.

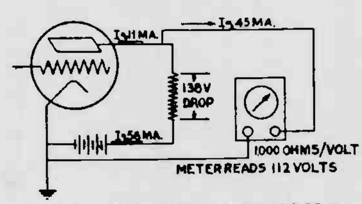
Meter Range—250 Volts Full Scale in All Cases



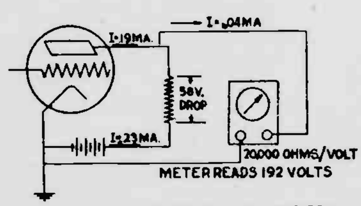
Normal Operation No Meter In Circuit



Conditions Using 125 Ohms Per Volt Meter



Conditions Using 1,000 Ohms Per Volt Meter



Conditions Using 20,000 Ohms Per Volt Meter

The second limitation is due to the voltmeter used and causes the circuit under test to be upset by the load imposed by the meter network. A voltmeter connected to make a voltage measurement is always across a circuit containing resistance. It is when the value of this circuit resistance is in the same order as the voltmeter resistance that appreciable errors are introduced. This fact will be made clear with illustrations above showing values of voltage measured in a resistance loaded plate circuit when using meters of various sensitivity. A plate voltage supply of 250 volts is indicated. The current passing through the 250,000 ohm resistor and plate circuit of the tube is 0.2 ma., or .0002 amperes. You can easily calculate the voltage drop across the plate resistor as 50 volts. This leaves 200 volts at the plate of the tube as measured to ground. The tube is actually a pentode with a plate resistance of about one megohm.

Let us see what happens when we use a none too sensitive voltmeter of 125 ohms/volt to make the measurement of voltage from the plate to ground. Because the meter has such low internal resistance, it will pass a great deal of current. The IR drop in the circuit leading to the plate will increase to 223 volts. The current through the tube will be smaller, and the voltage at the plate under these conditions will be only 27 volts. The value will be closer to the actual voltage with more sensitive meters, but in all cases will be somewhat smaller than the value actually present without the meter being connected in the circuit.

You must remember when making voltage tests in circuits where high resistance is present, that the reading will be off. By considering the circuit with the meter connected, you can estimate whether a much lower value obtained with the meter implies that the actual voltage is correct (without the meter being in the circuit), or that a fault exists.

A.C. measurements are made in testing the power supply or the existence of continuous filament circuits. In A.C. sets, voltages of various secondaries may be measured. The primary connections should indicate about 115 volts. In the "on" position, no voltage should be present across the switch; in the "off" position, you will obtain a reading almost equal to the line voltage. Filament voltage readings may be taken at the socket terminals. The voltage values should be as expected, but may be slightly higher with tube(s) out of sockets.

In AC-DC sets, filament voltage will be equal to correct value for tube employed. If the tube is burned out, your voltmeter will complete the series circuit with other tubes and will indicate the line voltage. Under this condition, the voltmeter relatively high resistance is not across any smaller resistance (filament of a tube), and almost the total drop will be across the voltmeter.

The process of translating an incorrect voltage indication to the actual fault which produces it, requires extensive understanding of the function of components included in the circuit. Normally, every component leading to the point under test is suspected and those components which could produce the results indicated by the measurement are individually tested to determine if they are the items at fault. Sometimes voltage tests at other points can be utilized for this additional testing. At other times, the parts in question may have to be tested by other methods or replaced with new components in an effort to locate the actual fault. In general, voltage point-to-point testing is best adaptable when the fault is suspected to lie in those sections of the receiver where D.C. voltage actually exists. The effect of such faults is to produce a "dead" receiver.

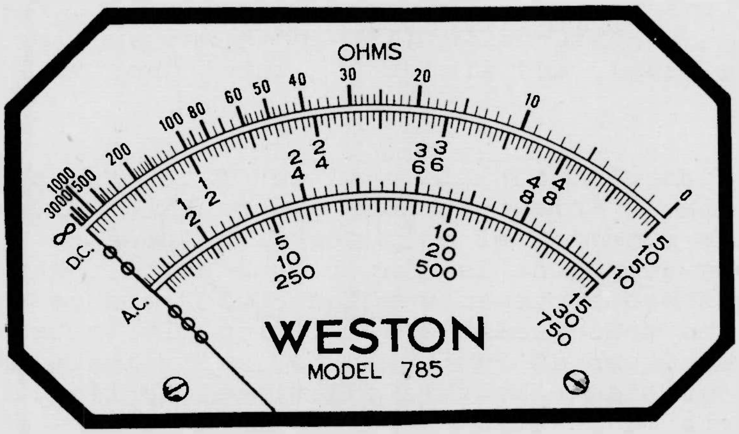
Lecture 9

Resistance Point-to-Point Servicing

Resistance point-to-point testing is especially useful in determining the source of trouble in case voltage is not present in some particular section. This method, however, is adaptable for radio fault finding under other conditions and is a basic technique. The failure of a part or circuit to function properly is accompanied with a pronounced change of some resistance value. Therefore, the finding of a considerable variation from normal in a resistance measurement usually suggests what item is at fault.

To use resistance servicing method successfully, knowledge of expected resistance values for various circuit elements and their combinations is essential. Realization of equivalent resistance values obtained with elements in series and parallel must also be known. These subjects will be discussed.

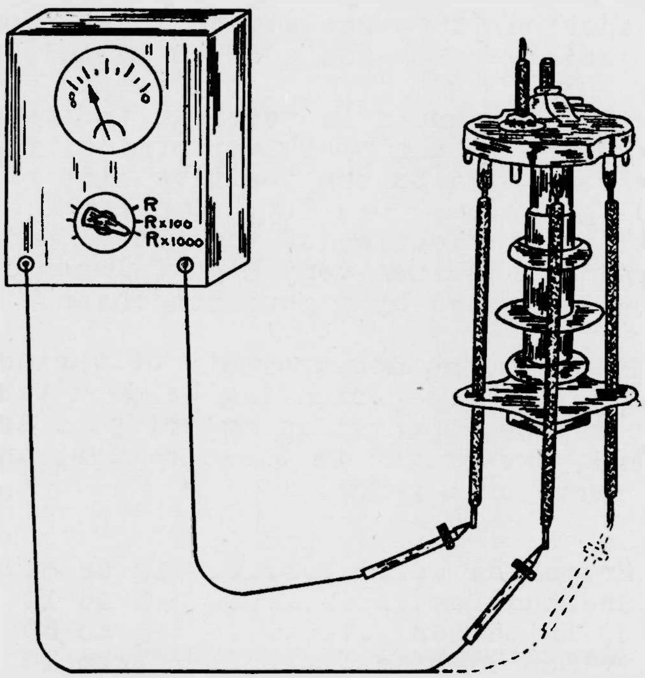
An ohmmeter is employed for resistance point-to-point testing, and, for safety sake, the power in the radio under test should be shut off (or batteries disconnected) when this testing is conducted. Actually, many tests could be made with an ohmmeter while the radio power is on, but there is always a possibility of making contact across points of voltage difference and thereby damaging the meter.

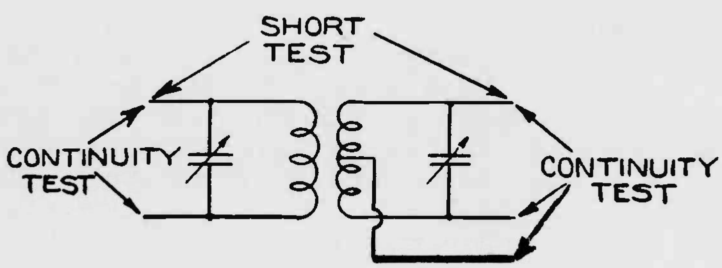


FACSIMILE SCALE

An ohmmeter should provide means for determining values commonly encountered in radio service work. However, the more popular instruments will not measure accurately above 1/2 megohm, and higher values if present cannot be tested.

Let us review what values of resistance various components used in radio receivers will indicate when tests are made. Resistors, of course, should indicate their correct values within the expected accuracy of about 10%. You should exercise care in making certain that the resistor you are measuring is not actually shunted by others, for in that case, the combination is in parallel and an entirely different value may be obtained. This subject of parallel effects will be discussed in greater detail. If you are not certain concerning possible shunts, disconnecting one side of the resistor to be tested will eliminate this possibility.





A volume control (potentiometer) can be measured from the center tap to each side. The two values so obtained for any one setting should add up to the total resistance of the control. A control may also be tested for proper operation by connecting the ohmmeter to the center tap and one side, and rotating the shaft. The resistance should vary as the control is adjusted.

Paper and mica condensers should indicate infinite resistance implying open circuit for D.C. At times, if you test a condenser in a circuit shortly after shutting off the set, the condenser still may have a charge and will cause the meter needle to move. However, this movement will be of a temporary nature and an open circuit condition should be indicated shortly thereafter.

Variable condensers are usually shunted by coils of small resistance and will require wires to be disconnected if high resistance range of the ohmmeter is to be used for test purposes. If low resistance range is employed, you will be able to tell if the condenser is shorted (zero resistance) or if you are obtaining the value of the resistance of the coil connected in parallel.

Polarity must be observed in testing electrolytic condensers. The probe wired closest to the positive terminal of the ohmmeter battery should be connected to the positive side of the electrolytic condenser being tested. Usually, upon first being connected, there will be a slight inflection of the meter needle while the condenser is charging, and then very high (almost infinity) resistance will be indicated by a good condenser.

In connection with the measurements of various coil and transformer windings, we are presenting below a table which gives values that may be expected in majority of cases. There are, you understand, exceptions to these values, and the table is given only to serve as a guide.

R.F. Coils,	Primaries	10 to 65 ohms
	Secondaries	1 to 10 "
Antenna Coils,	Primaries	3 to 50 "
	Secondaries	1 to 10 "
I.F. Coils,	Primaries	20 to 200 ohms
	Secondaries	20 to 200 "
Power Transformer,	Primary	1 to 15 ohms
	H.V. Winding	200 to 600 ohms
	Filament Winding	Very low
Output Transformers,	Primaries	300 to 800 ohms
	Secondaries	1/5 to 8 ohms

A radio tube in good operating condition will give a value of resistance approximately equal to its filament voltage rating, divided by its current rating. The information to compute this can be obtained from your tube manual. Tests between the different tube elements should indicate open circuit, unless, of course, some of these elements are connected directly with each other or through other parts in the circuit.

The majority of individuals doing radio service work already know what variations from the expected can be considered as indications of existence of faults. Additional suggestions to aid you in judging results obtained in tests will be presented later in this lecture.

You must watch for combination paths and either allow for the effects of items shunting each other, or break the circuit at proper points to eliminate these effects. You probably recall that resistors in series produce equivalent resistance which is equal to the sum of the individual values. When several resistors are connected in series and parallel combination, you should first combine the series values mentally, replacing resistors in series with their single equivalent series resistor. After this, the items may be combined in parallel. The formula for combining resistors in parallel is given below:

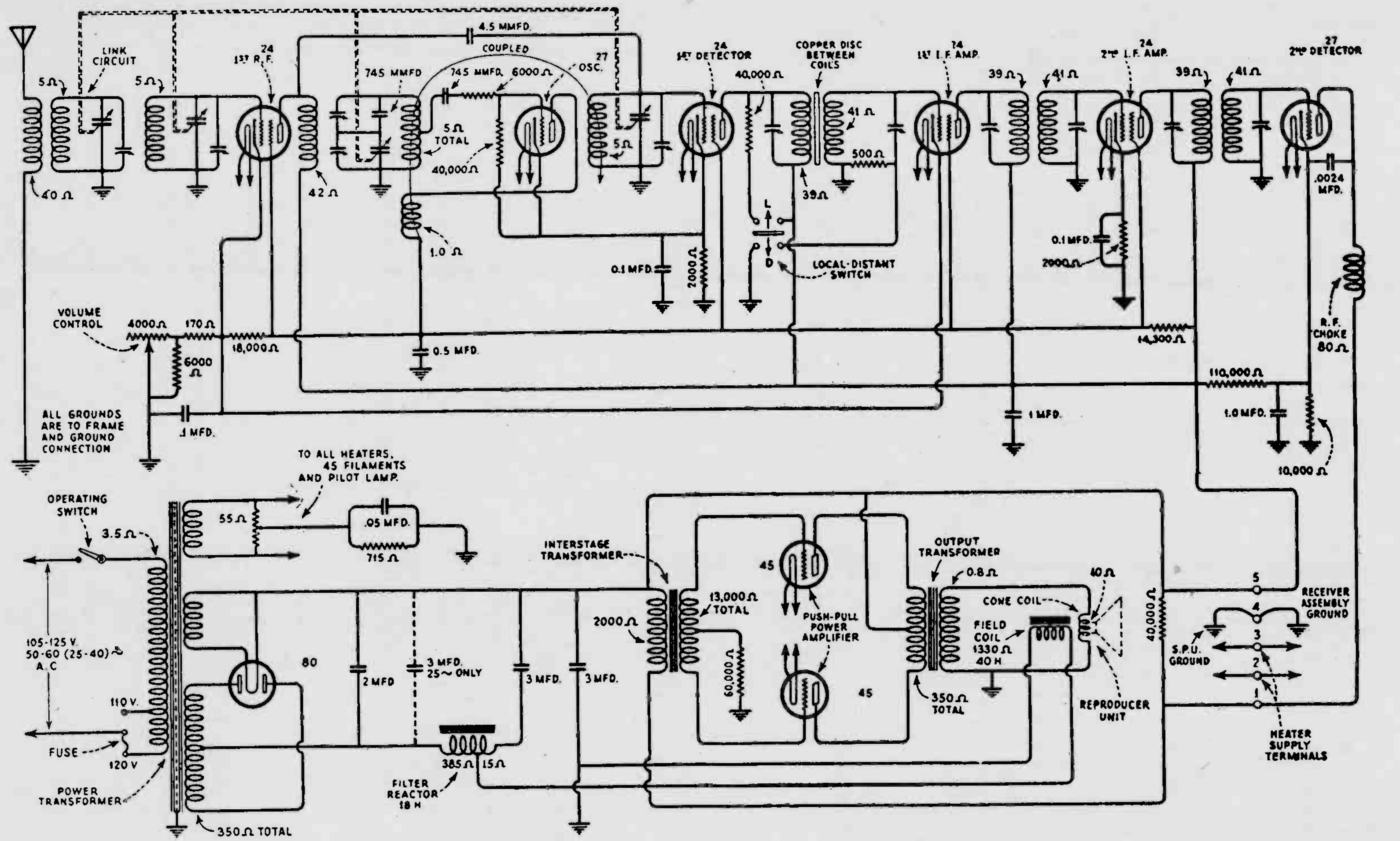
$$\text{Equivalent resistance} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots\cdots}$$

In majority of cases, a practical parallel circuit has but two equivalent resistances. For this purpose, a much simpler formula is used:

$$\text{Equivalent resistance} = \frac{R_1 \times R_2}{R_1 + R_2}$$

and this formula should be applied. Please note that the equivalent parallel resistance is always smaller than the smaller of the two resistors, and, if there is considerable difference in value between resistances (for example, one is 100 ohms and the other 1,000,000), this equivalent resistance may be assumed to be equal of the smaller one.

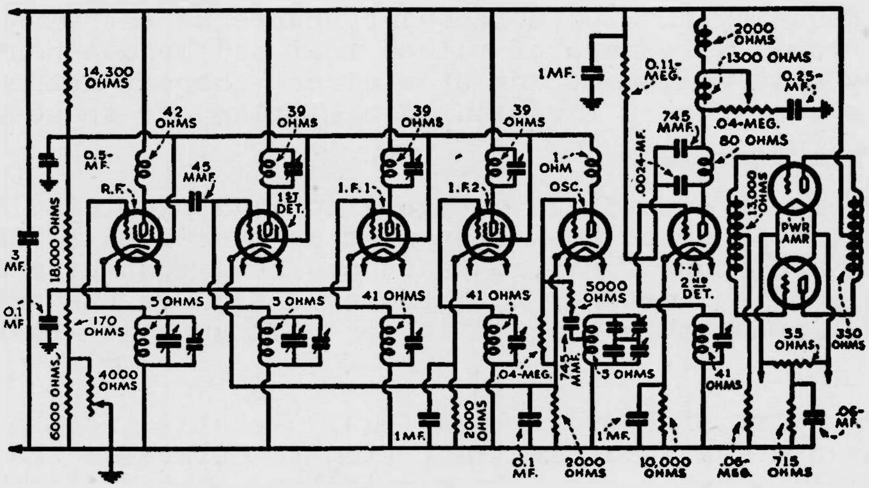
In using point-to-point resistance testing, the usual accuracy of commercial resistors must be kept in mind. Normally, resistors employed in radio receivers are accurate to plus or minus 10%, but there are units where the degree of accuracy varies up to 20%. These figures mean that values of resistors as indicated in a diagram or on the units themselves may vary plus or minus by as much as 1/5 of indicated values. Naturally, this does not imply that the operation of the receiver will be correspondingly upset. As you can understand, considerable variation in resistors as used in majority of circuits will have little effect upon proper operation.



We illustrate circuit of R.C.A. Model 80 radio receiver to offer some suggestion for resistance point-to-point testing. Please note that this diagram includes many resistance values for components other than resistors. This additional information is helpful for detecting variations which may be the cause of existing fault.

On the adjacent page you will find the same circuit simplified for resistance analysis. The real purpose behind this simplified circuit is to illustrate and indicate the resistance values which will be obtained when a complete resistance point-to-point test is conducted for the radio set.

The understanding of these facts, however, is important, since when you are actually measuring resistors, you must realize that variations mentioned are normal and do not indicate possible faults. You must further understand that certain resistors may vary even a greater amount due to other causes, but even a larger variation in some circuits will not influence proper operation. In particular, resistors used in plate, grid, filter, and AVC circuits are not critical, while resistors used in voltage divider



networks and cathode circuits to provide needed bias should not vary more than about 10%.

In proceeding to test a radio receiver, the ohmmeter should be located for easy visibility and you should hold one prod in each hand. In this manner, you can quickly make the needed contacts, and firmly holding the tips of the prods in place, observe the indication on the ohmmeter. We again caution you to watch for round about paths which may shunt the item you are intending actually to measure and may introduce errors in reading.

The circuit included above on this page is an illustration of values obtained in a typical radio set. You will note that the values of actual resistors are indicated. In the case of measuring a parallel combination, such as the 6,000 ohms fixed resistor, and the 4,000 ohms potentiometer (both located in the lower left hand corner of the schematic), one of these items has to be disconnected in order to obtain individual values and not a value for the two units in parallel.

If a condenser is to be tested with an ohmmeter, it will have to be disconnected on one side, unless, of course, you are certain that no resistor or coil shunts it in the circuit.

Lecture 10

When to Take Current Readings

Current measurements in the process of radio service work are used to a limited degree. To an extent, this limitation is due to the nature of currents existing in radio circuits. It is very difficult to measure with ordinary equipment the minute radio frequency and audio frequency currents encountered. The only currents which are of values that can be measured with ordinary test equipment are of a direct current nature. These currents vary from a fraction of a milliampere to about 100 milliamperes.

There is some disadvantage also in measuring direct current in a radio set since the meter must be placed in series with the circuit, and, therefore, at least one lead must be broken for insertion of the meter. This process requires the unsoldering and resoldering of a connection for each current measurement taken.

In spite of these limitations, certain direct current measurements are practical in trying to determine the fault existing in a radio set. In particular, current measurements are helpful when it is obvious that the current consumption is high in some one section. The symptoms of high current are usually associated with heat and can be detected by a visual examination. Such tests are also in order if a rectifier tube requires replacement after brief periods of operation.

Current measurement for the "total" radio can be taken anywhere in the positive or negative plate supply lead coming from the power supply. Care must be exercised in connecting the milliammeter with the correct polarity. Determine which side of the break you have made is most positive and connect the positive prod of the meter (test instrument) to this side. Always use the highest current scale in your equipment to begin measurement. If a change to a lower scale is in order, disconnect the meter while making the change. This is an important rule, since in many meters when changing current measuring scales by means of a switch, the shunts are temporarily disconnected and, in that instance, the meter may be burned out by the excessive current.

Information on possible faults can be obtained by measuring plate and screen grid currents. These currents together should be equivalent to the cathode current. To make these measurements, as well as for all current measurements, the circuit must be broken. Suggestions when to make current measurements will now be presented.

The presence of unusually low voltage suggests the drain of excessive current. To check your suspicion, it is worth while to measure the current in the circuit and compare the value obtained with a value to be expected in a normal circuit. A current measurement in this instance may save the need for additional voltage measurement and may lead directly to finding the existing fault.

Many volt-ohm-milliammeter units do not provide a suitable scale for very small voltage measurements. Other units of this type are not very sensitive and have a tendency to upset the circuit under the voltage test. In such cases, current measurement may be in order for test purposes. Even the lower priced testers incorporate a 0-1 ma. scale and, therefore, as little as 0.02 ma. can be accurately read.

The erratic behavior of tubes is best checked with current measurements. Even a tube tester is not as adaptable as current measurements in detecting faults which develop after a period of operation and lasts but a short interval each time the fault occurs. These faults may be due to a partial short circuit, insulation leakage, or presence of gas in the tube. In general, for testing such faults, it is best to connect the milliammeter, using a suitable scale, into the plate circuit. The insertion of the meter into the circuit should have but little effect on whatever operation can be obtained from the radio. In some instances, the meter can supply even more information if connected to the screen grid or the cathode.

The amount of leakage in electrolytic condensers may be tested with a milliammeter. In a good condenser, this leakage should be small, being about 0.1 ma. per mfd. It is interesting to observe the amount of leakage when the radio is first turned on after standing idle for some time. If the condenser does not form quickly (within 10 minutes) and high leakage continues for some time, you may assume that the condenser is defective.

In battery operated radios, the amount of current drained from batteries is a useful indicator of proper operation. Also in testing the voltage of batteries, the batteries should be under load equal to the usual current drain taken by the radio set for which the battery is intended.

In some of the older radios, the balancing arrangement is provided for adjusting the push-pull output stage. Most accurate adjustment can be made by measuring the static current for each of the tubes and then making these currents equal.

These suggestions should prove useful in illustrating that current measurements are of importance in radio service work. You should not hesitate to take current measurements as a further aid in detecting faults in a radio being repaired.

Lecture 11

Finding Faults in Tubes

Every radio receiver employs several vacuum tubes. Because of their nature, tubes have a limited life and are a common cause of radio failure. To detect a radio tube at fault, a suitable test procedure is required. We will first review the important parameters in grid controlled vacuum tubes.

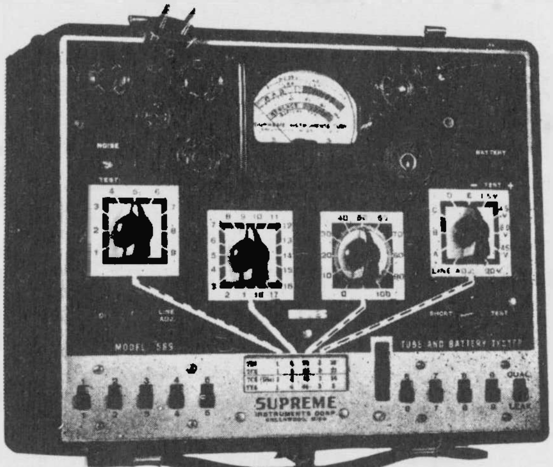
Because a diode vacuum tube will conduct electric current in a single direction, it can be used for detection and as a rectifier. The insertion of a grid permits the tube to serve as an amplifier. This means that a small grid voltage change will produce the same variation in the plate current as a much larger plate voltage change. The ratio of these two changes in voltage that will produce the same change in current when expressed mathematically is equal to the amplification factor or μ, (mu). The electron-circuit inside the tube itself (from plate to cathode) offers resistance to the passage to alternating current. In order to find the impedance to A.C., the grid voltage must be held constant and the effect of a small change in plate voltage is compared to the resulting change in the plate current. The ratio of these two changes when expressed mathematically is equal to the plate resistance for which the symbol r_p is used.

An important parameter which tells us much about the quality of a particular tube is known as transconductance, for which the symbol G_m is used. This is really the most important indicator for comparison purposes. The value of transconductance is obtained by holding the plate voltage at a constant value and noticing the change in the plate current which will result from a corresponding small change in grid voltage. In this instance, we take the ratio of the change in current to the change in voltage to obtain the value of transconductance. In general, any conductance is measured in mhos.

As we have already stated, faults in tubes are a common cause of radio failure and means for testing tubes must be found. If you have a replacement tube which you know is in good operating condition, it may be used to replace the tube you suspect. In this manner, a practical test will be conducted to determine if the fault lies in the vacuum tube. In some radio sets, several identical tubes are employed and it may be possible to eliminate one of the stages, thereby, utilizing the tube used in the stage omitted for substitution-test of other tubes. This suggestion applies particularly to the older TRF radios.

In general, however, tubes are properly tested with special equipment designed for this purpose, and the larger portion of this lecture will deal with this subject.

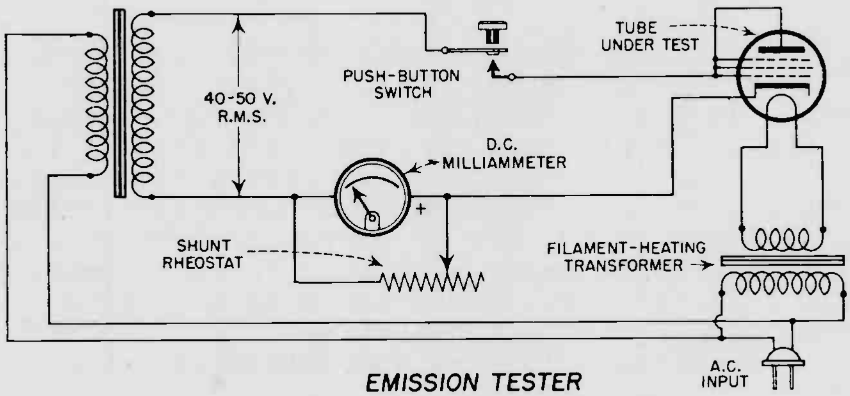
Adaptable bridge circuits may be set up to measure these important tube parameters and this is often done in the laboratory. A serviceman has but little time to allow for checking tubes and the tests for field use must be simplified even at the sacrifice of perfect results. Commercially available tube testers check either emission or transconductance in grid type tubes. The refinements of these tests vary in different brands of testers, as you will see when we discuss several different commercial models. Rectifier tubes and diodes are checked by measuring the plate current resulting from the application of a given voltage. For all types, a check is made for inter-electrode short circuits.



We will now present fundamental material on various types of tube testers. The limitations and special advantages of each type will be discussed. We are indebted to the Aerovox Corporation for their courtesy in permitting us to use material from a recent issue of their publication, "Research Worker." We will draw upon this material in presenting fundamental facts. This lecture will be completed with descriptions and illustrations of several commercial tube testers.

For easier judgment of results obtained and as a merchandising aid, a so called ENGLISH reading meter is incorporated. This meter may be graduated to read BAD-FAIR-GOOD or REPLACE-?-GOOD. Proper circuit adjustments are made for each different type of tube to be tested and, in this way, the same meter readings can be used for all tubes.

The emission type tester, as its name implies, attempts to appraise tube condition in terms of the cathode ability to emit electrons. The test is made by measuring the rectified current flow when a potential of 40 to 50 volts R.M.S. is applied between the tube cathode and all of the other electrodes tied together. The tube filament or heater is operated at its rated voltage. In this way (see figure), the tube being tested is operated as a diode rectifier, all of its elements except the cathode being connected in parallel to form a multiple plate.



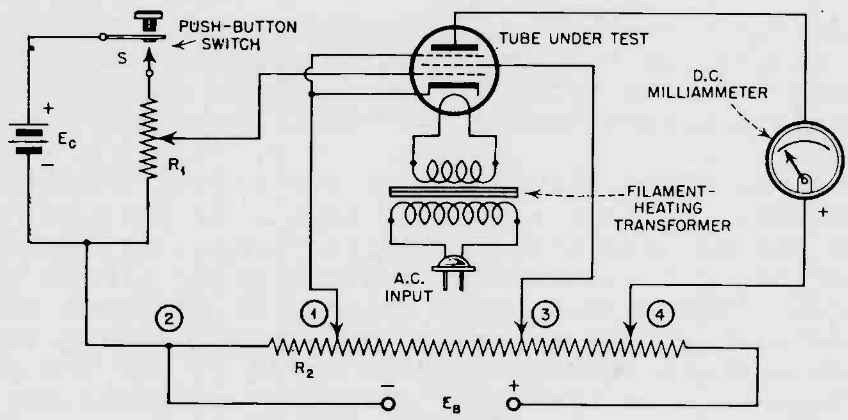
EMISSION TESTER

To enable a milliammeter to cover the wide range of current values encountered with the numerous receiving tubes (0.1 to 100 ma.), a shunt rheostat is connected in parallel with this meter. The rheostat must be set to a specific resistance for each type of tube tested. After the power is switched on, readings may be taken by depressing the push-button switch. The latter serves to protect the milliammeter from over-load while the shunt rheostat is being set.

The emission test cannot be altogether conclusive, since, as tube manufacturers point out, there is no definite 100% emission point which may be used for reference. Also high emission does not necessarily indicate a good tube, since this condition might be present, for instance, in a tube with a faulty grid structure or with a highly emissive spot on its cathode. Very high emission has been observed just before complete tube failure. Nor does fairly low emission necessarily indicate in all cases that the tube is near its end-of-life.

A further disadvantage of the emission testers is the liberation of gas within the tube by application of the A.C. test voltage unless the test is made quickly. Because the tube is not operated with its recommended D.C. electrode voltages in the emission test, it is not tested under actual operating conditions.

Calibration of privately-built emission testers presents a problem. There is no simple way to calibrate the shunt rheostat in an emission tester. This is because there are no data available on emission values to be expected for the various types of tubes. The most satisfactory method of obtaining a calibration for a specific type of tube consists of adjusting the shunt rheostat with a bad tube of that type in the tester. This tube must have just reached the poor performance stage, as indicated by a transconductance type of tester, but must not be burned out. The push-button is depressed and the rheostat adjusted for exact center-scale deflection of the milliammeter (this point on the meter scale should be the top of the BAD or REPLACE region). The rheostat setting then is recorded for that particular tube type.



STATIC TRANSCONDUCTANCE TESTER

The emission tester accepts or rejects tubes on the basis of readings obtained along this "English" scale. In all service testers, the entire left-hand half of the scale is marked BAD or REPLACE, and the entire right-hand half GOOD. The question mark (?), indicating questionable tubes, marks a line at center scale.

The laboriousness of the "calibration" process and the necessity that a large stock of bad tubes be available for the operation tend to discourage the private construction of emission testers, although the simplicity of the circuit offers a strong initial appeal. The emission tester has the advantage that the same simple circuit is used, without alterations, for checking every type of tube — diodes, triodes, tetrodes, pentodes, converters, dual-purpose types, etc. It is necessary merely to supply a sufficient number of sockets to accommodate the various tube bases.

Static transconductance testers are commonly called the "grid-shift testers." In this test, the grid-type tube is supplied with all of its recommended D.C. electrode voltages, and its filament or heater is operated at its rated voltage. A D.C. milliammeter indicates the plate current resulting from application of the D.C. plate voltage. To make the test, the D.C. grid voltage (bias) is increased by exactly 1 volt in the positive direction, and this causes the plate current to rise to a new value. The transconductance of the tube then may be determined simply by multiplying by 1000 the difference between the two plate current readings. Voltage amplifier and power amplifier tubes are considered defective when their transconductances, as indicated by a test of this sort, fall to 70% of the values stated in standard tube tables. Oscillator sections of converter tubes are defective when their transconductances fall to 60% of values stated in tables.

When making a static transconductance test, the plate, screen, and suppressor voltages must be checked both before and after shifting the grid voltage. Any voltage change resulting must be corrected before taking the final plate current reading.

A practical circuit arrangement for static transconductance testing is shown. E_B is a source of high D.C. voltage, to which is connected the voltage divider resistor, R_2. Sliders along this resistor tap off recommended control grid, screen grid, and plate voltages. The grid-cathode voltage is measured by means of a high-resistance D.C. voltmeter connected between taps 1 and 2, the screen-cathode voltage between 1 and 3, and the plate-cathode voltage between 1 and 4. A single voltmeter may be switched between cathode and the other electrodes, or three separate potentiometers might be provided with calibrated dials.

The potentiometer R_1 is adjusted so that exactly 1 volt is obtained from the low-voltage D.C. source, E_c. When the push-button, S, is depressed, the control grid voltage is shifted in value.

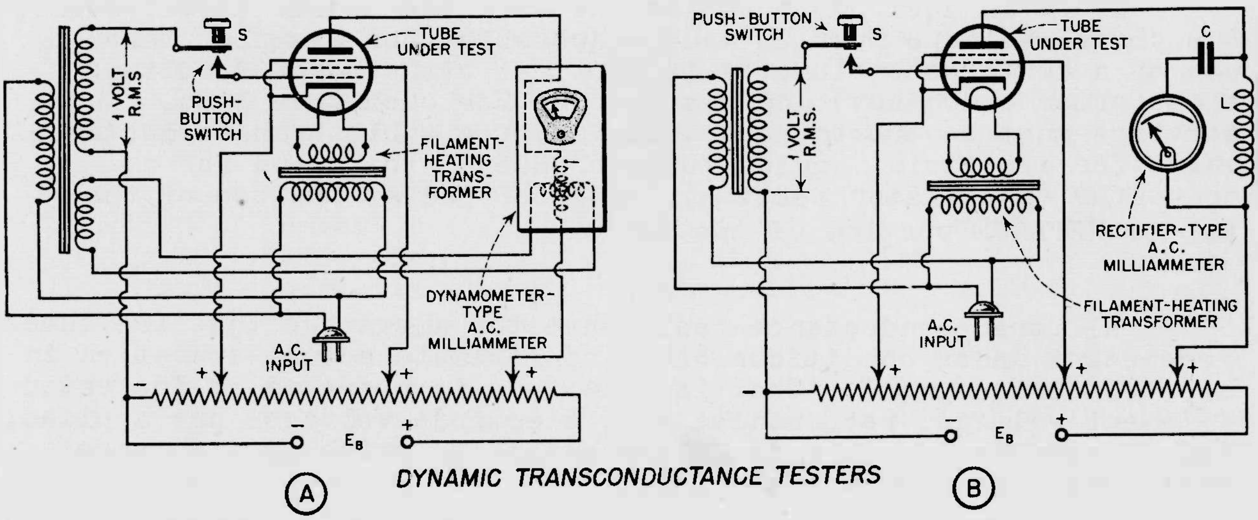
For the test, slider 2 is set on the voltage divider resistor for a grid voltage 1/2 volt lower than recommended bias for the tube under test. When push-button S is depressed, the grid voltage accordingly will be shifted from 1/2 volt lower than recommended bias to 1/2 volt higher than this bias. A net shift of 1 volt thus is obtained in the region of recommended bias, without moving too far up the characteristic curve of the tube.

For testing of the wide variety of receiving tubes, the plate milliammeter must have at least three ranges; 0-1, 0-10, and 0-100 ma.

The static transconductance test has the disadvantage that it often requires that small plate current increments be read on relatively high current scales. This leads to inaccuracy in results. If some means is provided for bucking out the initial plate current through the meter, a lower-range instrument then may be employed to read only plate current change, and may be made to read direct in transconductance (micromhos).

A further, often questioned, disadvantage of the static transconductance test is the fact that the test voltage applied to the control grid is D.C., and in the actual operation of a tube in equipment this is seldom the case; A.C. grid signals being usual. The argument is that here again the tube is not being tested under actual conditions encountered in application.

The static transconductance test is not so widely used at this time. It may be found today perhaps only as the "grid-shift" feature of radio set analyzers. Occasionally, however, an experimenter who has no tube tester and desires to check a single tube will rig up a grid-shift meter for the purpose.



DYNAMIC TRANSCONDUCTANCE TESTERS

The dynamic transconductance tester like the previous one, applies recommended D.C. voltages to each tube electrode. These voltages are obtained and checked in the same manner as before. But, unlike the static test, the dynamic transconductance test requires an A.C. grid signal, which more closely approximates tube operating conditions. A 60-cycle voltage from the secondary winding of a step-down transformer is a satisfactory signal.

Practical circuits for dynamic checking of transconductance are shown in the figure. In each case, the plate circuit instrument is an A.C. milliammeter. There accordingly is no deflection of this instrument until an A.C. signal is applied to the control grid of the tube under test.

In figure A, the indicating instrument is a dynamometer-type A.C. milliammeter with one coil connected in the tube plate circuit, and the other to a winding of the signal transformer. But since this instrument is rather costly, it never is employed for transconductance testing outside of the laboratory. For service tube tests, the arrangement shown in figure B is favored. Here a standard rectifier-type A.C. milliammeter is connected through a large capacitance, C, (1 mfd. or higher) across a low-resistance, high-impedance choke coil, L. This arrangement is not as accurate an indicator of A.C. plate current as that of figure A, unless the entire combination (meter with capacitor and choke) is calibrated against another A.C. milliammeter and a special scale is drawn.

Upon application of the A.C. grid signal (by depressing push-button S), the plate meter will indicate the resulting A.C. plate current. If the grid signal is exactly 1 volt R.M.S., the tube transconductance in micromhos will be equal to the meter reading multiplied by 1000. The A.C. milliammeter thus easily may be made a direct-reading micromho meter. The same tube rejection values may be employed as indicated in the description of the static transconductance test.

If it is desired to employ the "English" scale (BAD-?-GOOD), the signal voltage must be made adjustable (for example, through use of a small potentiometer in parallel with the grid-voltage transformer secondary) and must be set for each tube type. These settings must be chosen such that 70% of a table transconductance value for a certain regular tube, or 60% of the value for a converter (oscillator section), will be read at the top of the BAD or REPLACE portion of the scale.

All transconductance tests have the advantage that the tube is checked under conditions which approximate actual operation in electronic equipment. That is, the tube is operated at its rated filament voltage, recommended D.C. electrode voltages are applied, and an examination is made of the extent to which grid voltage will control plate current flow.

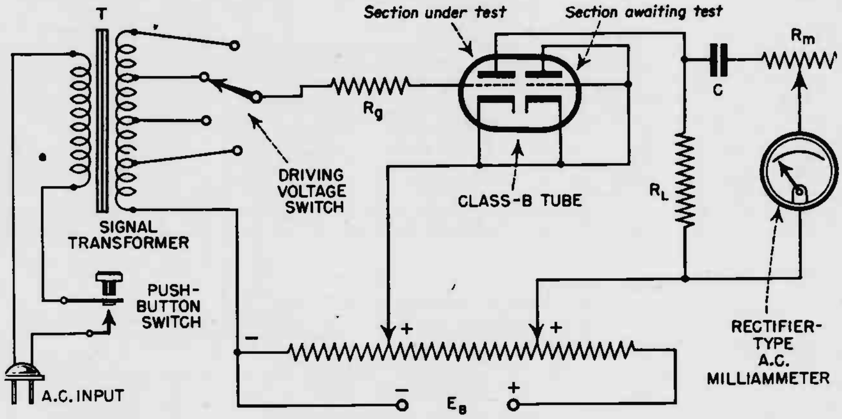
If the tube has defective electrodes, its transconductance will be affected. The effectiveness of the tube to function as a grid-controlled amplifier is revealed by the correlation of plate current and grid voltage increments by this test.

The dynamic transconductance test has the advantage that it is rapid, gives direct indications, and more closely approximates actual operating conditions than does the static transconductance test.

Class B amplifier tubes, such as 6A6, 6N7, 46, 53, and others are checked for power output, since it is not convenient to check these types for transconductance. A circuit of a tester shown in the figure on the next page may be used.

A 60-cycle signal voltage is applied to the control grid of the tube under test by means of transformer T. Taps on the secondary winding of this transformer enable the operator to obtain the recommended driving voltage for each tube type. The series grid resistor R_g, simulates the reflected impedance of the driver stage found in class-B amplifiers. When a dual tube is being tested, electrodes of the "floating" section are connected to the cathode of the section under test, as shown.

A.C. output voltage (E_o) is developed across the load resistor, R_L, which is selected to have the proper ohmic value for the tube under test. This voltage, which is proportional to power output (E_o/R_L) falls to about 55% of its rated value. When the tube under test is operated at its recommended grid driving voltage and rated load resistance, the "English" scale of the tester may be standardized for a specific Class-B tube in the following manner: Rheostat R_m is set to bring that deflection of the meter corresponding to 55% of rated power output to the top of the BAD or REPLACE section of the scale.



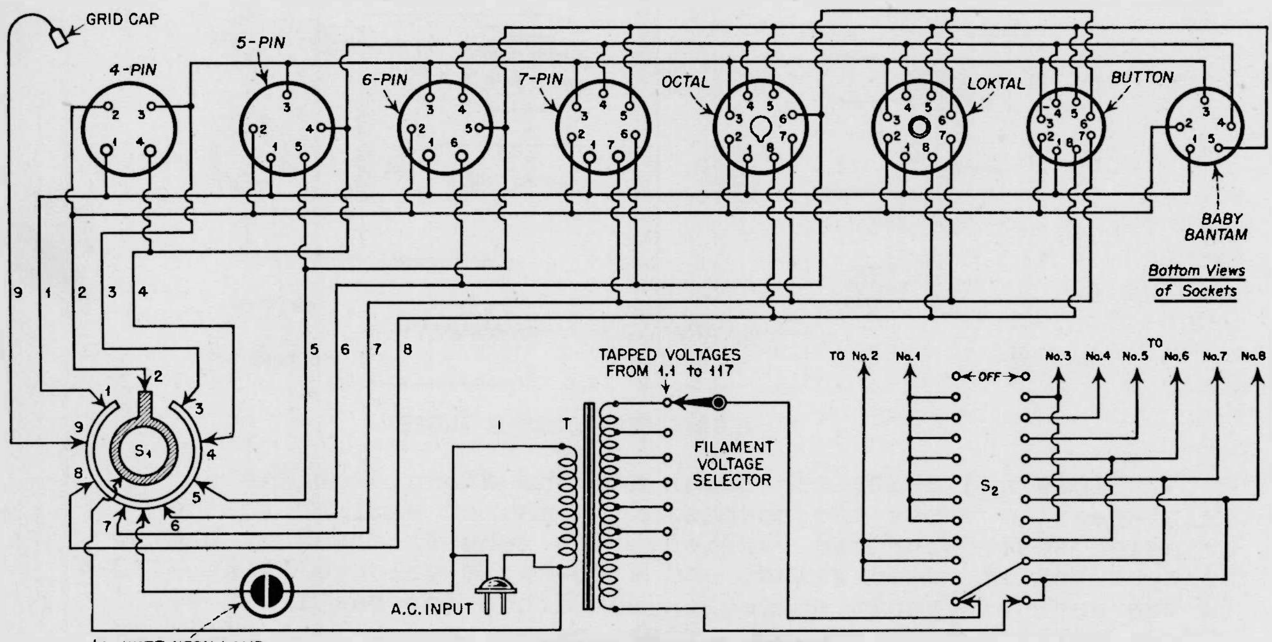
TESTER FOR CLASS-B TUBES

Diode and rectifier tubes and the diode sections of multi-section tubes are checked in a manner similar to the emission test described earlier. The tube filament or heater is operated at rated value, and a 60-cycle voltage is applied to the series circuit embracing the diode (or rectifier section), a D.C. milliammeter of appropriate range. and a load resistor. Such circuits are incorporated in testers. The load resistor is shunted by a capacitor. Each type of tube is rejected when its rectified current, as indicated by the milliammeter, falls to 80% of the rated value for the R.M.S. voltage applied. Current and voltage data for this test are obtained from the graphs and tables supplied by tube manufacturers.

A meter shunt rheostat (R_m) is set to bring the meter deflection corresponding to 80% of rated current for a specific type of tube to the top of the BAD or REPLACE section of the "English" reading scale.

Several schemes have been devised for locating inter electrode short circuits in a tube. One of the simpler circuits, often incorporated in complete tube testers, is shown. In this arrangement, a 115-volt potential is applied in series with a 1/4-watt neon lamp between any one electrode of the tube and all of the others in parallel. As the switch is rotated, different parallel combinations of electrodes are checked against other single electrodes. The tube is operated at its rated filament or heater voltage. A continuous glow of the neon lamp indicates a short circuit.

The electrode combination to be checked for short circuit is selected by means of a rotary switch, S_1. The points of this switch have been numbered in the figure, to correspond to numbering of the tube socket terminals. Thus, when pole A of switch S_1 is in position 2, as shown, the short-circuit test is made between socket terminal 2 and the parallel connection of terminals 1, 3, 4, 5, 6, 7, 8, and 9. Terminal 9 is the top-cap grid connection.



SHORT-CIRCUIT TESTER

If the lamp should glow with switch S_1 in the position shown, a short circuit would be indicated between either 1 & 2, 2 & 3, 2 & 4, 2 & 5, 2 & 6, 2 & 7, 2 & 8, or 2 & 9. In order to locate exactly the second electrode contributing to the short circuit, the switch is rotated, noting that the lamp glows for a second time when the pole is set to the second electrode. Thus, a 2-9 short circuit will be indicated by glowing of the lamp when S_1 is at settings 2 and 9. If more than one inter electrode short circuit is present at any switch setting, the individual ones may be located, as just explained, by successive settings.

Sockets are included to accommodate all tube bases. Filament voltage is supplied by the tapped transformer, T, to all tubes, and is applied to the proper socket terminals by means of the 11-position switch S_2. Socket filament terminal combinations selected by this switch are 1-3, 1-4, 1-5, 1-6, 1-7, 1-8, 2-3, 2-6, 2-7, 2-8, and 7-8.

In order to prevent switch S_1 from short circuiting and extinguishing the tube heater during operation, an auxiliary set of contacts is provided on S_2 which open one leg of the leads between S_1 and the filament or heater terminals of the sockets. One leg of the heater line is still left accessible to S_1 for short circuit test against all other electrodes. These auxiliary contacts have been omitted from the schematic, in order to minimize confusion in reading the drawing. The lines opened by the contacts are No. 1 when S_2 is in one of the seven topmost positions, No. 2 when S_2 is in the next three positions, and No. 8 when S_2 is in the lowermost position. By setting S_2 to its OFF position, heater voltage is removed from the tube and the short-circuit test may be applied (for continuity indication) between the heater terminals.

When making a complete short-circuit test, the operator must be familiar with the tube base connections in order best to interpret the flash lamp indications. Some tubes, for example, have two base connections to a single electrode. An example is type 45Z3 where the plate is connected to pins 2 and 6. Such base connections will yield a continuity test which might be taken erroneously as a short circuit between terminals 2 and 6. From standard tube data, it will be easy to identify all terminals (such as filament or heater connections, and cases such as the one just cited) between which continuity should be expected, and to determine corresponding switch positions.

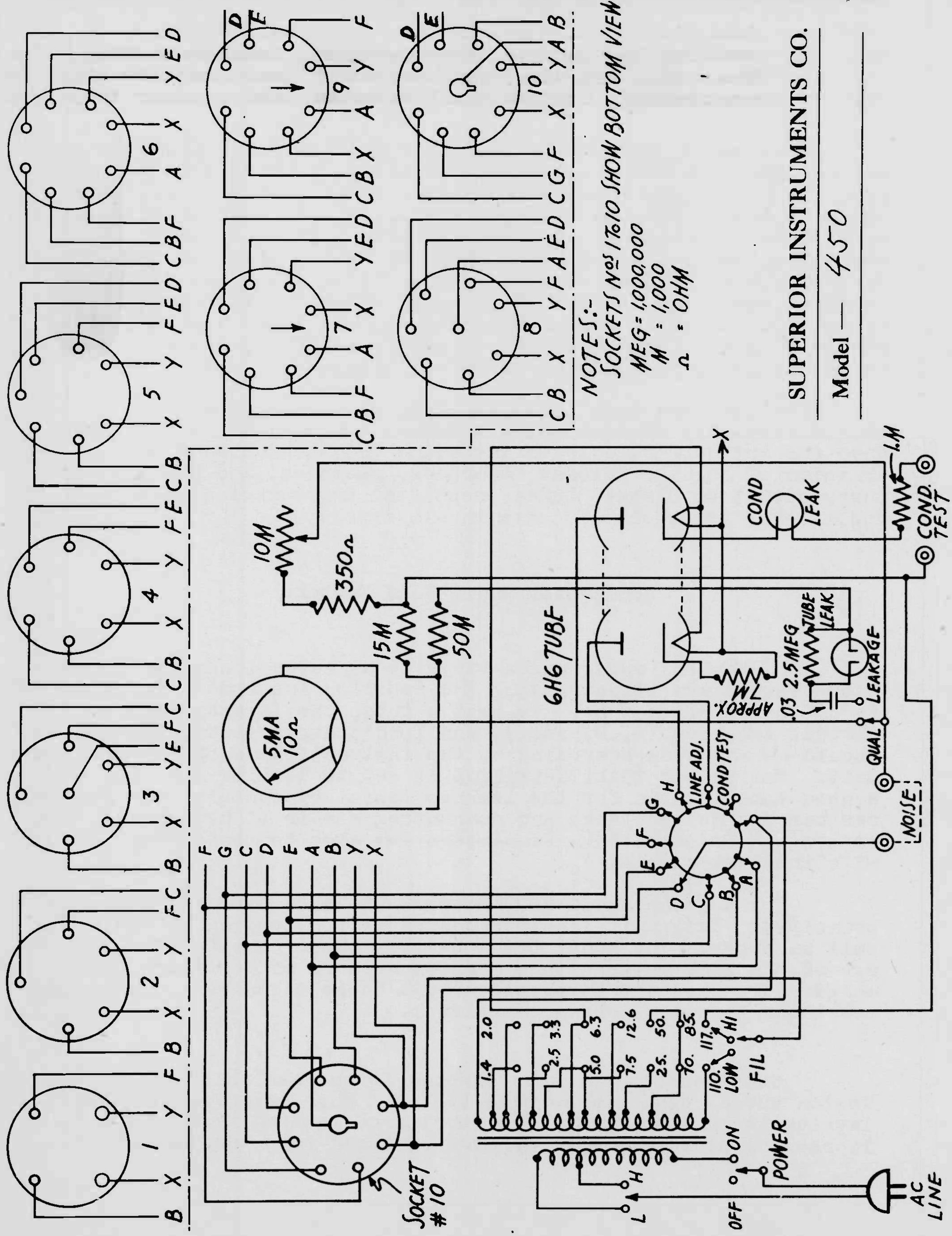
The separate test circuits shown may be combined into a single complete, field-type instrument. This instrument may be used for complete tube tests including transconductance or emission of regular triodes, tetrodes, pentodes, and converters; power output of Class-B tubes; rectified current of diodes and rectifiers; and short circuits in all types.

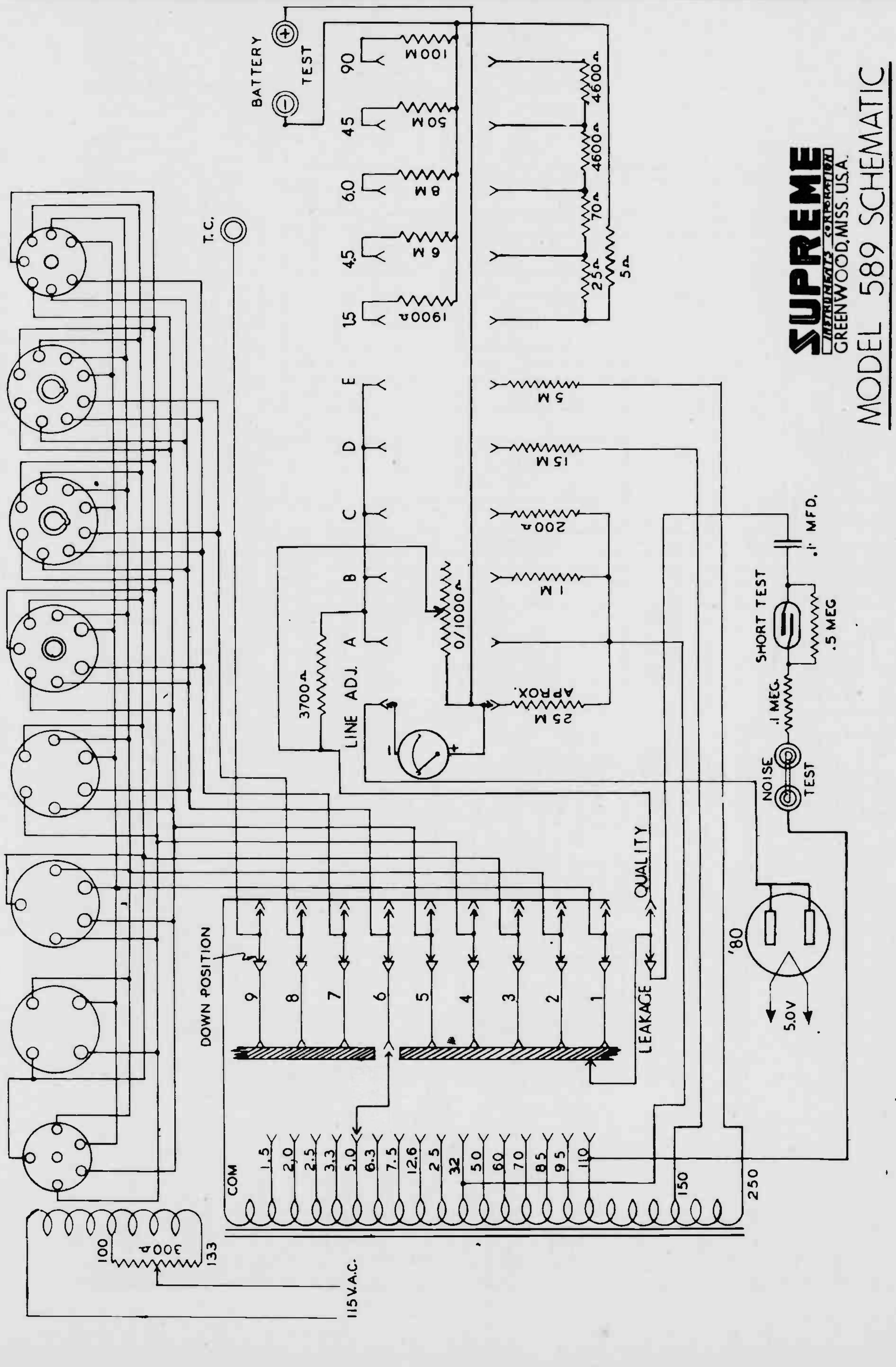
Commercial Radio Tube Testers

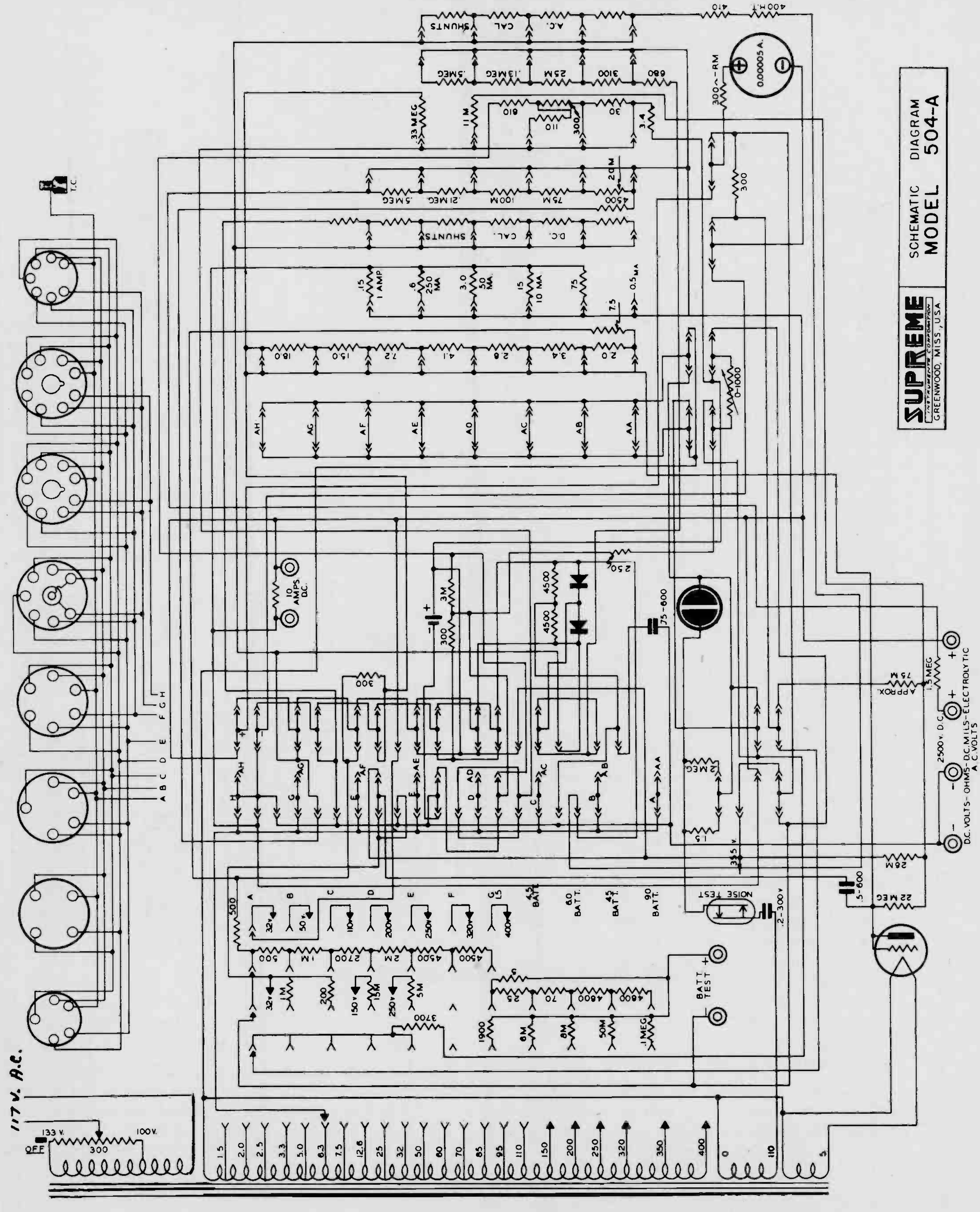
On the following pages circuits of several popular commercial tube testers are illustrated. The Superior Instrument Co. Model 450 is of the emission type. To test a tube, the filament switch, circuit selector (A, B, etc.), and load control (10M potentiometer) should be adjusted according to the instructions supplied with the unit. The switch QUALITY-LEAKAGE is set to QUALITY for this test. A neon tube is used for the leakage test. By removing the shorting bar across "noise" jacks and connecting a pair of headphones, tube noises can be detected. Condensers may also be tested for leakage with this instrument.

The Supreme Model 589, on page 93, also uses the emission principle. This unit incorporates means for testing batteries as well as tubes. The Model 504-A besides these functions permits the use of the same meter with a correct network of resistors as a multimeter. You should trace through these circuits to understand how these functions are accomplished.

Considerable space is devoted to the explanation of the Weston mutual conductance tube tester. This material will prove invaluable in clarifying laboratory tube testing technique and in increasing your knowledge of more advanced tube testing methods.


SUPERIOR INSTRUMENTS CO.
Model — 450
NOTES:-
SOCKETS NOS 1 TO 10 SHOW BOTTOM VIEW
MEG = 1,000,000
M = 1,000
Ω = OHM
6H6 TUBE
COND LEAK
COND TEST
.1M
5MA 10Ω
10M
350Ω
15M
50M
7M APPROX.
2.5 MEG
TUBE LEAK
LEAKAGE
.03
QUAL
NOISE
LINE ADJ.
COND TEST
SOCKET #10
FIL
LOW
HI
POWER
ON
OFF
AC LINE


SUPREME
INSTRUMENTS CORPORATION
GREENWOOD, MISS. U.S.A.
MODEL 589 SCHEMATIC
BATTERY
TEST
T.C.
LINE ADJ.
SHORT TEST
NOISE
TEST
QUALITY
LEAKAGE
DOWN POSITION
COM
115 V.A.C.
'80


SCHEMATIC DIAGRAM
MODEL 504-A
SUPREME INSTRUMENTS CORPORATION
GREENWOOD, MISS., U.S.A.
117 V. A.C.
OFF
10 AMPS D.C.
NOISE TEST
BATT TEST
DC. VOLTS - OHMS - D.C. MILS - ELECTROLYTIC A.C. VOLTS
2500 V. D.C.

WESTON

MODEL 686 TYPE 9

True Mutual Conductance Vacuum Tube Analyzer

GENERAL DESCRIPTION

The Model 686 Type 9 is a complete direct reading True Mutual Conductance Vacuum Tube Analyzer designed to operate from any 105 to 125 volt 50-60 cycle outlet. It has three mutual conductance ranges with full scale readings of 3,000, 6,000 and 15,000 micromhos. Instruments are provided for accurately measuring all electrode voltages and for reading electrode currents including low order grid currents. Internal power supplies and a signal source provide all necessary potentials to panel controls, wherein adjustments can be made in accordance with meter readings. Tube sockets for all commercial type receiving tubes are mounted on a removable socket panel across the top front section of the equipment. These in turn connect through short-test switches to patch cord jacks which are marked with R.M.A. pin numbers and are used with patch cords for any or all electrode connections. Thus with complete connector flexibility and complete voltage control, all kinds of static characteristics can be plotted, in addition to the measurement of G_m under any or all applied potential conditions.

DETAILED DESCRIPTION OF EQUIPMENT

THE G_m METER: The fan shaped instrument in the top center of the main panel is the G_m meter. The scale is calibrated in two arcs each reading zero to thirty. These arcs indicate 0 to 3,000 or *Micromhos* x 100 as noted on the small plate just below the scale glass. The top scale arc is printed with black lines and figures, while the lower arc is printed in red. The top or black arc is used for G_m readings on all tubes with an amplification factor (μ) up to and including 19. The red scale is used in measuring G_m on all types with amplification factors of 20 or over.

This meter operates with a multiplier switch marked *Micromhos* directly below it, and a compensator switch directly to the left marked *Set To Nearest Amp Factor* (Refer to Fig. 1).

On low mu tubes with low plate resistance, the meter resistance is a reasonable part of the total tube and tube tester plate circuit impedance; measurements on these tubes would be in error unless this was taken into consideration. The compensator switch, therefore, must be set to the nearest amplification factor up to a value of 19 and readings should be taken on the black scale.

The extreme right hand position on the compensator switch is marked *Red Scale*. On tube types with an amp factor of 20 or over, the *"Red Scale"* switch position is always used because on these

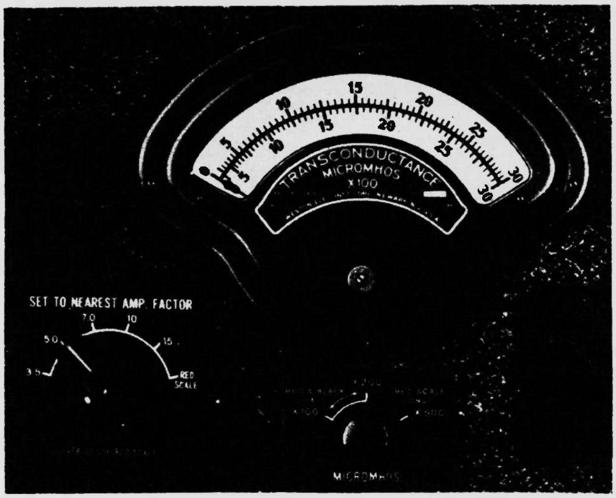
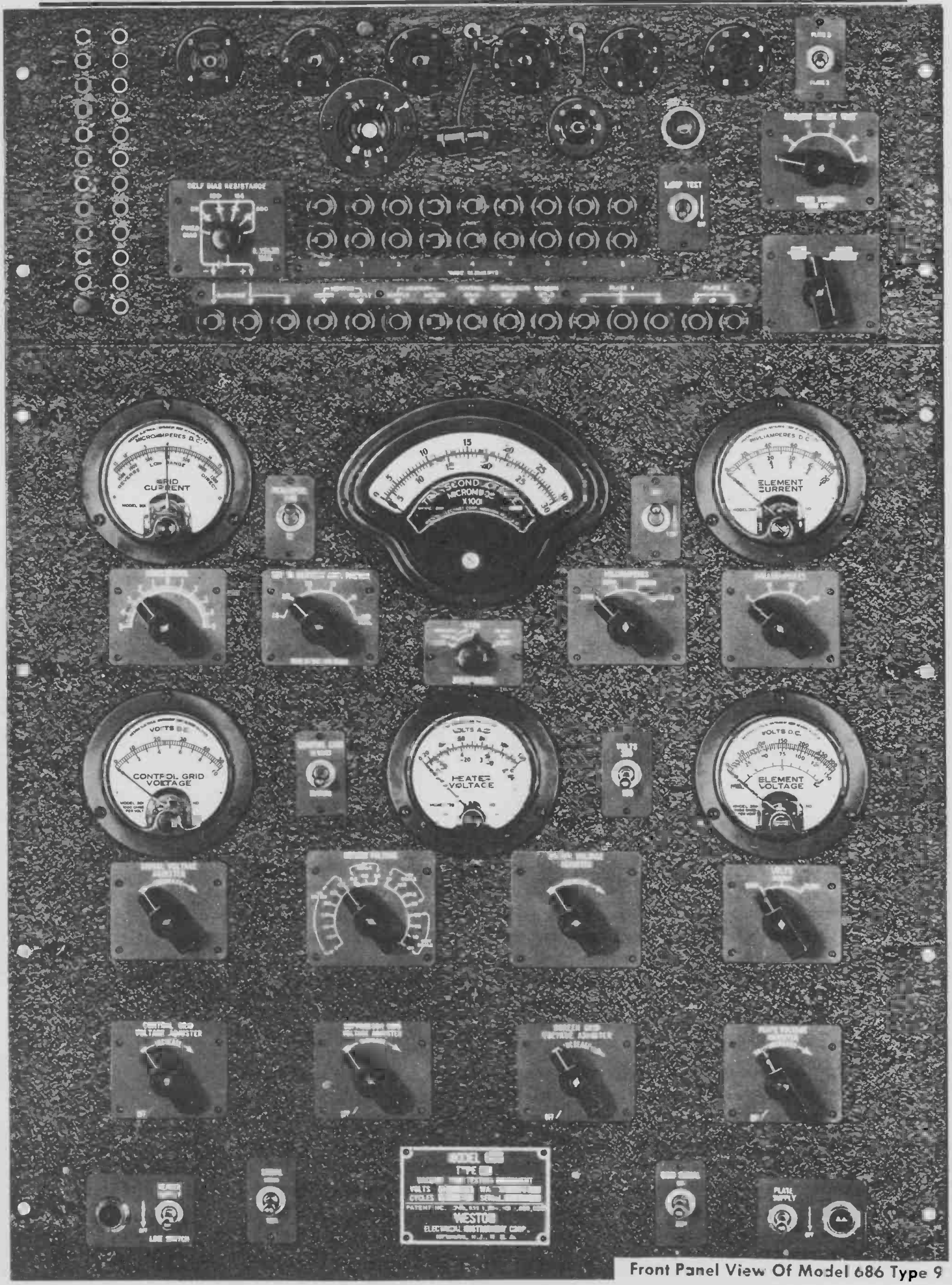


FIG. 1

types the instrument resistance is a negligible part of the tube plate resistance. On this switch position, all G_m readings are taken on the *Red Scale* arc.

The *Micromhos* switch is used for selecting the 3,000, 6,000 or 15,000 micromhos range as required. Since the arcs on the G_m meter are calibrated 0 to 30, the G_m meter readings should be multiplied by 100 for the 3,000 range, 200 for the 6,000 range, and



Front Panel View Of Model 686 Type 9

500 for the 15,000 range. This switch does not change the meter sensitivity on *"Red Scale"* setting of the compensator switch but selects 3 different signal voltages. These are 1 volt r.m.s. for the 3,000 range, 0.5 volts r.m.s. for the 6,000 range, and 0.2 volts r.m.s. for the 15,000 range. This method has a definite advantage over a system wherein the G_m meter is shunted for the various ranges and the signal voltage maintained constant. The low signal voltages available on the two higher ranges make it possible to maintain peak signal potentials well within the grid bias voltage on high mu triodes and other types where bias voltages in the region from 0.8 to 3 volts are specified. The above is necessary in the case of all low bias tubes operated and tested as Class A amplifiers. If too great a signal amplitude is used, the tube may operate in the grid current region during a part of the signal voltage cycle. In such a case the tube being tested is not operating under true class A conditions, and G_m readings will not agree with the tube manufacturer's listings.

It is advisable for the operator to select the highest G_m range that will render reasonable pointer deflection when testing all low bias high mu tubes.

Since low mu tubes do not have G_m ratings over 6,000 micromhos, the 15,000 micromhos range is used only with *Red Scale* readings. It will be noted that the *Micromhos* switch plate is marked *"Red Scale Only"* on this range.

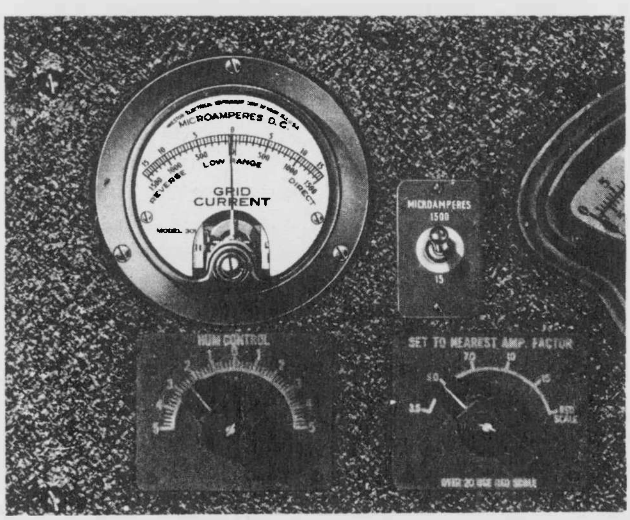


FIG. 2

GRID CURRENT METER: A two range microammeter for grid current readings is mounted to the left of the G_m meter. This instrument has a range of 15-0-15 microamperes. Readings down to and including one-half microampere are easily read. The meter is normally shunted to 1500-0-1500 microamperes and is switched to the low range by manipulation of a momentary toggle switch located to the right of the meter (Refer to Fig. 2).

The meter is a zero center instrument to indicate any or all components of grid current resulting from gas, leakage resistance, or secondary emission. Grid current readings are especially important in segregating defective power tubes such as the type 6L6 where a limit of 3 microamperes is specified.

In taking grid current readings, the operator will note that there is a red line on each side of the center scale zero mark. This red line indicates 15 microamperes on the 1500 microampere range. If the pointer does not deflect beyond the red line after the tube is heated, then the *Microamperes* switch can be shifted to the 15 microampere position, and readings taken on this low range. The instrument is in series with the control grid patch cord jack at all times and, therefore, will indicate grid current under all operating conditions.

ELEMENT CURRENT METER: A four range milliammeter is mounted to the right of the G_m meter with the marking *Element Current* on the scale. This meter is used in conjunction with a range *Milliamperes* switch located below the meter and an element *Milliamperes* switch to the left of the range switch (Refer to Fig. 3).

By rotating the element *Milliamperes* switch, the meter may be connected into the cathode, anode grid, screen grid, or plate circuit. The right hand switch is used to select the required milliampere range.

The *Element Current* meter picks up the millivolt drop across low resistance shunts in the 4 different electrode circuits. Since any resistance in the cathode circuit will cause degeneration, the switch is designed so that the shunt used for cathode current readings is short-circuited on all other positions. It is advisable to have this switch indexed to one of the other three positions when taking G_m readings. Cathode current may be measured before or after taking the actual micromhos indications.

CONTROL GRID VOLTMETER: The double range *Control Grid Voltage* meter is mounted below the *Grid Current* meter, and is used for measuring the control grid bias potential.

To the right of the meter (Refer to Fig. 4) is a toggle switch indicating the meter range. This switch may be indexed to either the 10 or 50 volt range as required. The operator should be sure to note the position of the switch when setting grid bias potentials on the *Control Grid Voltage* meter. This switch also changes the bias network, decreasing the drop across the control grid poteniometer on the 10 volt range, providing better voltage control when adjusting low voltage bias potentials.

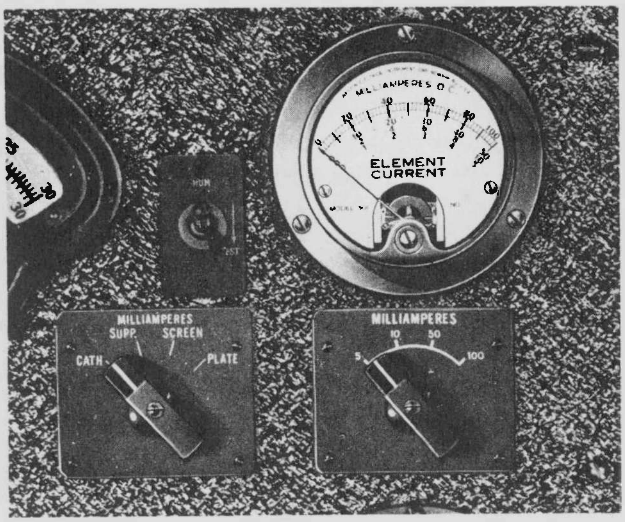


FIG. 3

HEATER VOLTMETER: Filament potentials from 1 to 120 volts may be selected by means of a rotary switch and potentiometer. These potentials are measured on a multirange a-c voltmeter (Refer to Fig. 5).

Note that the *Heater Voltage* switch is used to select the nominal voltage, and exact adjustment is made by rotating the *Heater Voltage Adjuster* which controls the primary potential on the filament transformer. An interlock circuit is used on the rotary switch to automatically shift ranges on the filament voltmeter as the switch is rotated. Thus the operator always has this meter on the correct range, and the possibility of instrument overload is eliminated. The particular range connected into the circuit is marked for each group of potentials on the *Heater Voltage* switch plate. The voltmeter connections are brought back through separate leads directly from the tube socket thus providing a more accurate reading of filament potential at the tube pins. Any voltage drop in the leads from the filament transformer to the tube socket will not be in the meter circuit.

FIG. 4

ELEMENT VOLTMETER: This is a two range voltmeter, 150 and 300 volts full scale, mounted below the *Element Current* meter. This reads plate, screen, or suppressor grid potential as selected by the rotary switch below the meter (Refer to Fig. 6).

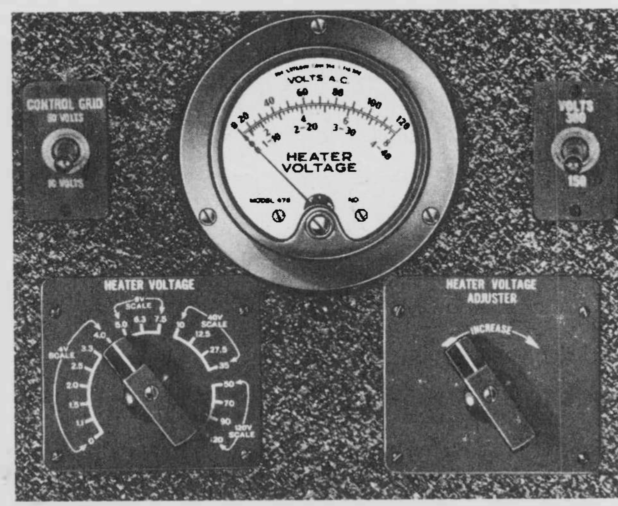


FIG. 5

The voltmeter range is selected by the toggle switch directly to the left of the meter. A red arc on the scale plate indicates true voltmeter current which can be subtracted from low range milliammeter readings where this current may be an appreciable part of the total element current. In other words the *Element Current* meter reads true element current plus voltmeter current when the voltmeter and milliammeter are switched to the same electrode position.

D-C POWER SUPPLY CONTROLS: Individual control grid, suppressor grid, screen grid, and plate adjusters are mounted in line across the lower section of the Model 686 panel. These are 150 watt or 100 watt vitreous type potentiometers connected in the d-c supply circuit. While these high wattage ratings are not required, controls of this size provide a long peripheral length of contact travel, thus giving accurate potential settings on the tube electrodes. The element voltages should be adjusted in the following order to prevent damage to the screen and cathode due to excessive currents: (1) control grid (2) plate (3) screen. All electrode potentials can then be re-adjusted and any changes due to tube loading of the power supply can be corrected. The accuracy of the mutual conductance readings depend to a great extent on the accuracy of these electrode potential adjustments.

SIGNAL VOLTAGE ADJUSTER: It is mounted directly below the *Control Grid* voltmeter. This potentiometer controls the a-c current through a series of accurately adjusted resistors developing the signal potential for each G_m range. To eliminate possible temperature errors in the rectifier type G_m meter and to compensate for line voltage changes, the signal potential is

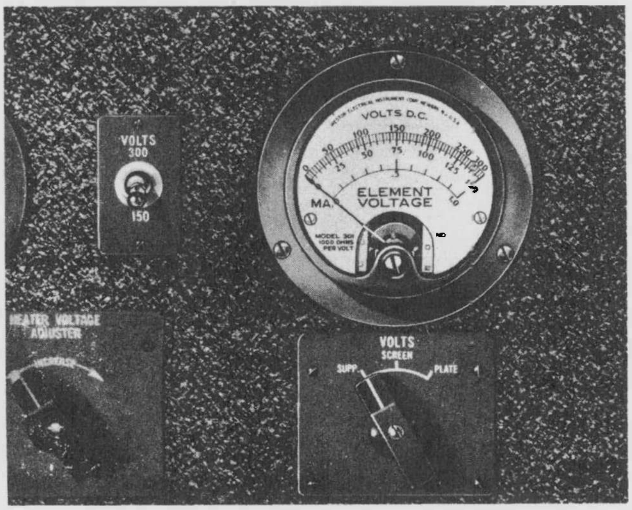


FIG. 6

checked against full scale deflection on the G_m meter. Any necessary correction is then made with this control. The *Signal* switch should be placed on the *"Check"* position and the *Signal Voltage Adjuster* rotated to obtain full scale deflection on the G_m meter.

HUM CONTROL: It is used only on directly heated or filament type tubes. This is a low resistance potentiometer which is switched across the heater leads on the low ranges up to and including 10 volt heater potentials. The *Hum Control* is mounted below the *Grid Current* meter and is used to provide an accurate electrical center tap return on filament type tubes. After the tube is in position and all electrode potentials have been adjusted to the specified values, the *Hum* toggle switch to the right of the G_m meter should be operated and the *Hum Control* set for a minimum or zero reading on the G_m meter.

SELF BIAS RESISTANCE SWITCH: The Model 686 Type 9 is equipped with a *Self Bias Resistance* switch mounted on the left side of the top panel section. This switch provides for checking certain tube types such as the 6J4, 6J6 and 1231 where self bias is definitely specified by the manufacturer. These tubes tend to draw grid current under equivalent fixed bias conditions, wherein errors in G_m readings would be encountered.

The switch is wired for 50, 100, 150 and 200 ohm positions, with one spare position, now shorted, and one marked *"Fixed Bias,"* which is also a short circuit position. Since the circuit includes a low voltage 1,000 microfarad 3 volt by-pass condenser, this switch does not open circuit on any position, and it must be indexed to the *"Fixed Bias"* position for measurements on all types except those where self bias is specified. On self bias types the *Control Grid Voltmeter* must be set to the zero position so that additional fixed bias will not be applied to the tube over and above the self bias potential. To prevent damage to the 1,000 microfarad condenser, a simple calculation should be made to see that the product of the expected cathode current, and the resistance in the self bias circuit does not exceed 3 volts: $V = I \times R \times .001$

Where V = Voltage appearing across 1,000 microfarad condenser.

I = Expected cathode current in mill-amperes.

R = Resistance selected by *Self Bias* switch position.

SHORT TEST-METER READING AND ELEMENT SHORT TEST SWITCHES: The *Short Test-Meter Reading* and *Element Short Test* switches mounted on the right side of the top panel section provide the necessary means for short checking tubes with a d-c potential. Tubes may be short checked with a filament or heater, either hot or cold. The *Short Test-Meter Reading* switch disconnects the d-c potential and meters from the tube elements and connects a small d-c power supply and a neon lamp into a group of circuits controlled by the *Element Short Test* switch. This switch segregates the element to be short checked, leaving all the other elements tied together.

The filament or heaters should be at normal operating temperature when hot short checking, and the *Short Test-Meter Reading* switch should be indexed to *"Short Test"* position. The *Element Short Test* switch is then rotated through its six positions, stopping at each position to tap the tube.

If the patch cords have been connected so as to use both P_1 and P index the P_1 and P_2 toggle switch located on the upper right top panel section to its other position and rotate the *Element Short Test* switch through its six positions again. A slight flicker of the neon lamp between positions on the *Element Short Test* switch does not indicate a short in the tube.

HEATER SUPPLY TOGGLE SWITCH: This toggle switch is located at the bottom left side of the panel with its associated green jewel pilot lamp. It is used to turn on the heater potential. This switch may be operated first, which permits the tube to warm up after the filament leads have been patched. Thus the tube can come to temperature while the operator is completing the patching operation.

PLATE SUPPLY TOGGLE SWITCH: This toggle switch is located at the bottom right hand side of the panel and operates the internal d-c supply for plate, screen and other electrode potentials. The switch should be indexed to the *"Off"* position when the operator is changing or removing the patch cords.

GRID SIGNAL TOGGLE SWITCH: This switch is located to the left of the *Plate Supply* switch and is of the momentary type. It is used to apply the signal voltage when the operator is ready to take a G_m reading. No signal is applied to the tube until this switch is indexed to the *"On"* position.

LAMP TEST TOGGLE SWITCH: Located to the left of the *Element Short Test* switch, providing a ready means for checking the neon lamp. If a tube shows no short and there is some doubt as to the condition of the neon lamp, lift the toggle to its upper position and if it does not glow replace with a new neon lamp.

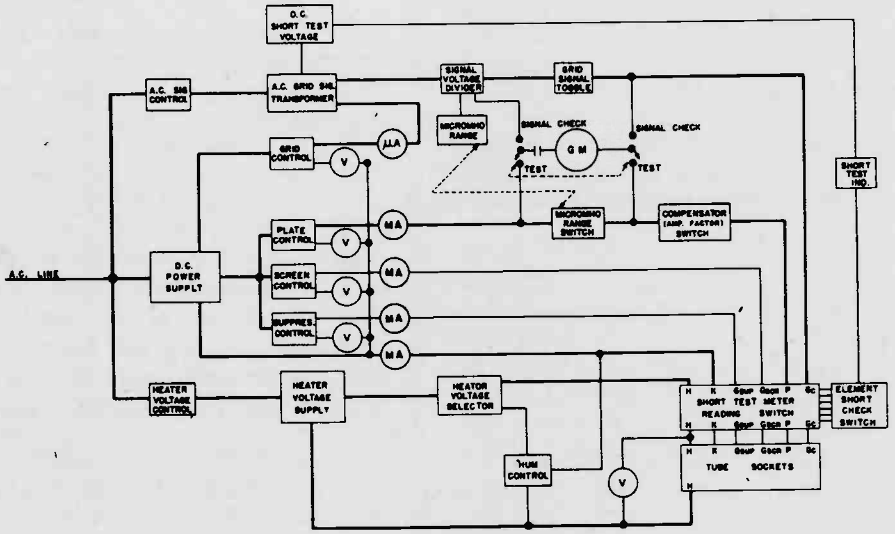
THEORY OF OPERATION

Reference to the Simplified Block Diagram shown below will aid the reader in understanding the functioning of the various controls and parts of this equipment. Only those parts having important functions in the measuring of G_m have been included in this diagram so that the theory may be more readily understood.

Essentially the Model 686 Type 9 is a low impedance power supply metered for potentials and currents and provided with a means of introducing an a-c signal into the grid bias line and measuring the a-c component in the plate circuit.

The incoming a-c line energizes the d-c power supply, the heater voltage supply and the a-c grid signal transformer. The filament and grid signal transformers have their controls located in the primary leads thus providing proper adjustment to take care of varying line voltage conditions. A rotary switch selects secondary taps to give the necessary heater voltages for all tubes.

The d-c power supply delivers potentials to the plate, screen and suppressor controls. Following these controls the potentials are metered and the circuit is so arranged that the element milliammeter



Simplified Block Diagram Of Model 686 Type 9

can be placed in each of the lines. A resistance in the low side of the power supply develops the voltage for grid bias. This potential is likewise controlled by a potentiometer. A separate voltmeter is used to measure this potential and a microammeter is placed in the circuit to detect the presence of grid current.

The a-c grid signal winding together with a signal voltage divider is placed in series with the control grid circuit to the tube. The proper signal voltages are selected by one section of the *Micromhos* switch which is connected to the signal voltage divider. The injection of the a-c grid signal into the grid bias circuit is a function performed by the *Grid Signal* toggle switch.

The G_m meter is a rectifier type a-c instrument which is switched into the plate circuit for measuring the a-c component of plate current or into the signal circuit for measuring signal voltage. The *Micromhos* range switch selects the proper shunt for the G_m meter or the proper signal voltage in the case of high mu tubes.

A compensator network supplies the necessary correction in the plate circuit to give a true G_m indication. The introduction of an instrument into the plate circuit increases the plate circuit resistance to a point wherein it becomes an appreciable part of the tube plate resistance on low amp factor tubes. Hence a compensating resistance network based on sound mathematical calculations is necessary to provide accurate mutual conductance indications.

The element potentials are fed to a multi-circuit *Short Test-Meter Reading* switch. This switch provides the necessary circuit connections so that tube elements may be either short checked by means of the *Element Short Test* switch or energized by the potentials from the power supply.

The a-c grid signal transformer has a separate winding feeding a type 3A4 tube which supplies the necessary d-c voltage for high sensitivity short check.

The *Hum Control* is simply a potentiometer placed across the filament winding to provide the necessary balance on the filament return when checking these types. This is to prevent an additional signal (which may either add to or subtract from the true grid signal) from appearing in the grid circuit causing a modification in the a-c plate current component. The *Hum Control* is switched out of the circuit on heater voltages above 10.

In checking a tube, the d-c potentials are applied to the tube through the various controls. The a-c grid signal is applied in series with the grid bias voltage, and is measured by switching the G_m meter to "*Signal Check*" and held to a fixed value by rotating the *Signal Voltage Adjuster*. To measure a-c component of plate current, the compensator switch is set to the proper Amp Factor position and the G_m meter switched to the *Test* position. Inasmuch as the value of the grid signal and the a-c component of plate current are known, the mutual conductance is the ratio of the two. Since the ratio $\frac{\Delta I_p}{\Delta E_g} = G_m$ consists of one known value and one measured quantity, the scale can be calibrated directly in micromhos.

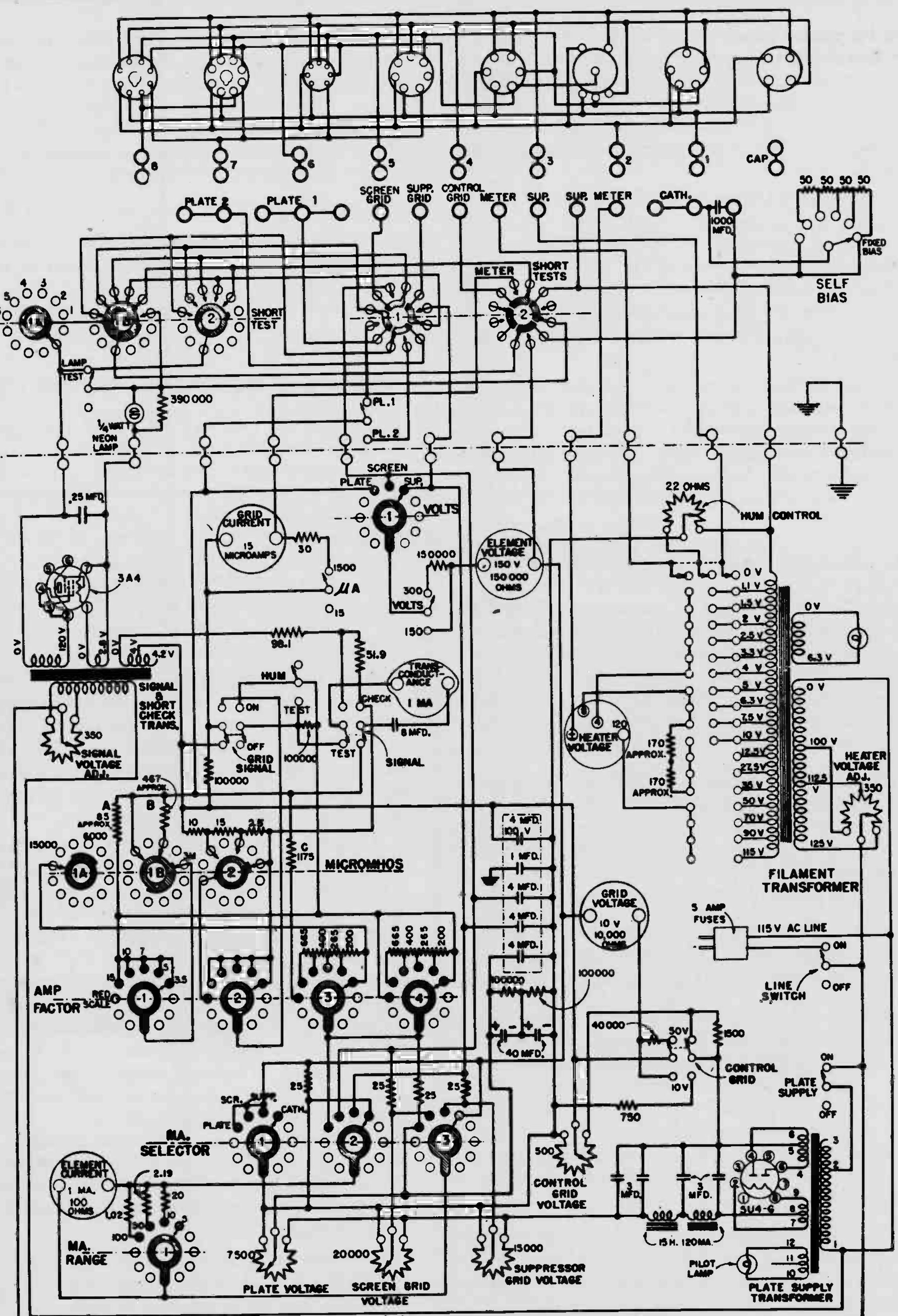
HELPFUL SUGGESTIONS IN TUBE TESTING

GRID CURRENT: In using the Model 686 Type 9 care should be exercised to see that the grid current in microamperes indicated on the *Grid Current* meter does not exceed three to four microamperes. This value changes somewhat between tube types, but the above value can be assumed in general, to be satisfactory. Excessive grid current will cause an error in the G_m readings and it is advisable that a limit of 4 microamperes be strictly adhered to and that some means of eliminating this condition should be tried as outlined below.

If the *Grid Current* meter deflects to the left of zero the tube is either gassy or the element potentials applied are not correct. Check the manufacturer's specification and note whether the proper potentials have been applied. If the potentials are correct and the meter indicates 4 microamperes or more to the left of zero the tube should be rejected.

If the *Grid Current* meter indicates to the right of the zero with the correct potentials applied, the tube is oscillating. This condition must be eliminated before accurate G_m indications can be obtained. Usually a 15 to 20 ohm resistor placed in some one of the electrode leads, except filament and cathode, will eliminate the tendency to oscillate. There are some tubes requiring low bias and if the signal voltage applied is too high, the tube will oscillate causing the *Grid Current* meter to indicate to right of zero. This condition can be readily detected by noting the increase in *Grid Current* meter deflection when the *Grid Signal* toggle switch is indexed to the "On" position and the *Microamperes* toggle switch is indexed to the "15" position. Any attempt to check certain tubes under *Fixed Bias* conditions that should be checked under *Self-Bias* conditions, usually results in tube oscillation.

The *Grid Current* meter will also indicate to the right of zero when the plate supply and grid bias potentials are extremely low or zero.

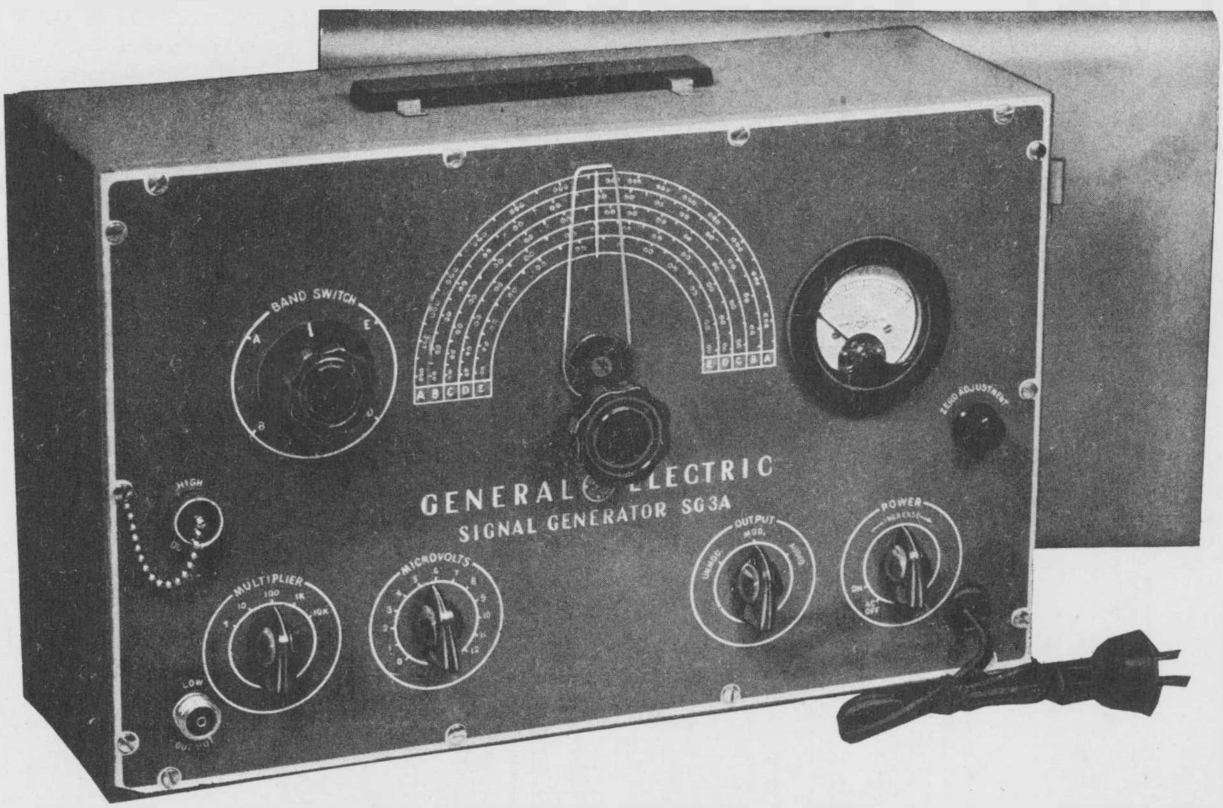


WIRING DIAGRAM OF MODEL 686 TYPE 9

Lecture 12

Signal Generator As A Service Instrument

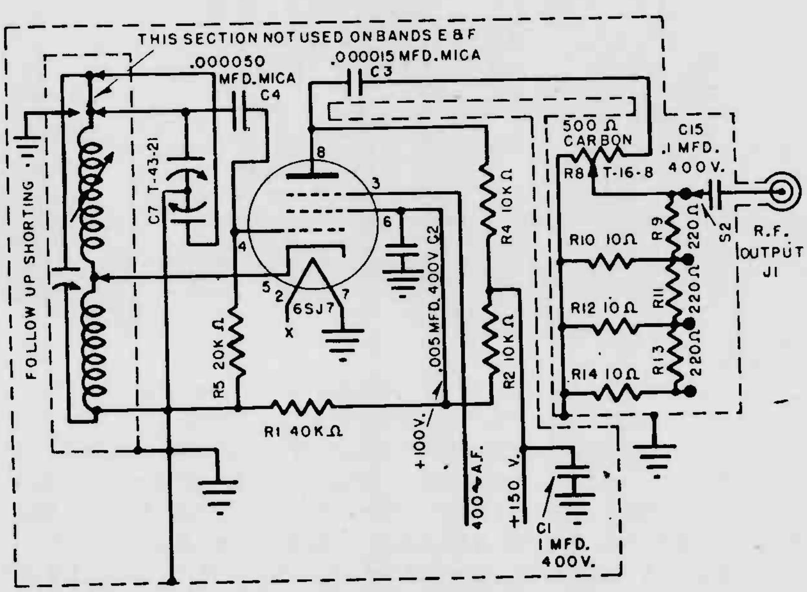
A signal generator is essentially a small transmitter designed to produce various frequencies required for service and laboratory work. Important design details, circuits, limitations, and applications will be considered in describing several actual commercial units. At this time, I want to remind you that a good signal generator produces needed frequencies calibrated to a high degree of accuracy and the attenuator used permits adjustment of the output power down to a zero level. The power output and stability of a signal generator of acceptable quality should be influenced very little by the type of load connected.



Primarily, signal generators have been used by radio servicemen for alignment work, and the many additional functions of this versatile instrument have been ignored by the servicing profession. Considerable time of this lecture will be devoted to the explanation on the use of signal generators in solving service problems other than alignment. A separate lecture on alignment will be presented at a later time.

To mention briefly, a signal generator may be used for localizing the source of trouble in a radio receiver, detecting the stage producing distortion, testing individual parts, measuring gain, various audio and fidelity tests, and many other applications which can be used to simplify the job of a radio serviceman. We will first discuss types of generators available commercially and will then return to explain how these units are applied to special problems.

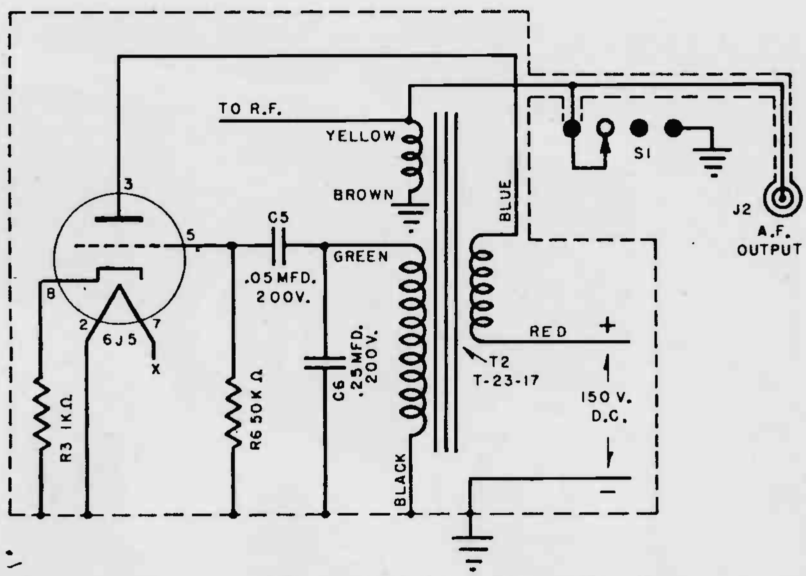
Audio frequency signal generators are designed to produce signal frequencies between 30 to 15,000 cycles per second. Some of these units employ standard type of oscillators with the components designed to produce the required audio frequencies. Suitable inductors and capacitors for this purpose would be quite large and could be made variable only with the greatest difficulty. However, it is possible to produce audio frequencies by beating (combining in a non-linear impedance) two radio frequencies differing in frequency by the number of cycles required to produce the audio frequency. In practice, two R.F. signal generators and associated equipment are built-in a single case. One generator circuit produces a fixed R.F., while the second has its frequency variable and easily altered with a regular tuning condenser. If the frequencies of the two R.F. generators, for any one adjustment, differ (for example) by 800 cycles, then an 800 cycle audio signal is produced. R.C.A. audio oscillator Model 154 is of this type and is described later on. A few lately developed types of sine wave audio signal generators use circuits without any inductance. The required wave form is produced with novel R-C vacuum tube circuits.



Simplified R. F. Oscillator Circuit

Part of Circuit of Triplett Model 2432 Signal Generator

In a R.F. signal generator, an electron-coupled oscillator circuit is employed to produce adjustable radio frequencies. With this type of oscillator, the variations in the load have little effect upon the frequency. Tuning (adjustment of the frequency produced) is accomplished with a variable condenser. To my knowledge no signal generator using permeability tuning has been announced to date, but this idea presents strong possibilities. The control dial is carefully calibrated and is usually accurate to within 1%. The frequencies available are generated with several different coil-arrangements which are selected and connected to the tuning condenser of the circuit by means of a band-switch. A practical R.F. signal generator may cover frequencies from 100 KC. to 90 MC. This includes all I.F. frequencies used and also the usually employed communications frequencies. The coverage may be obtained in six or seven steps. In most units, the higher frequencies are not actually generated as fundamentals, but are obtained as harmonics of the highest frequency band for which L-C is actually provided.



Simplified A. F. Oscillator Circuit

Part of Circuit of Triplett Model 2432 Signal Generator

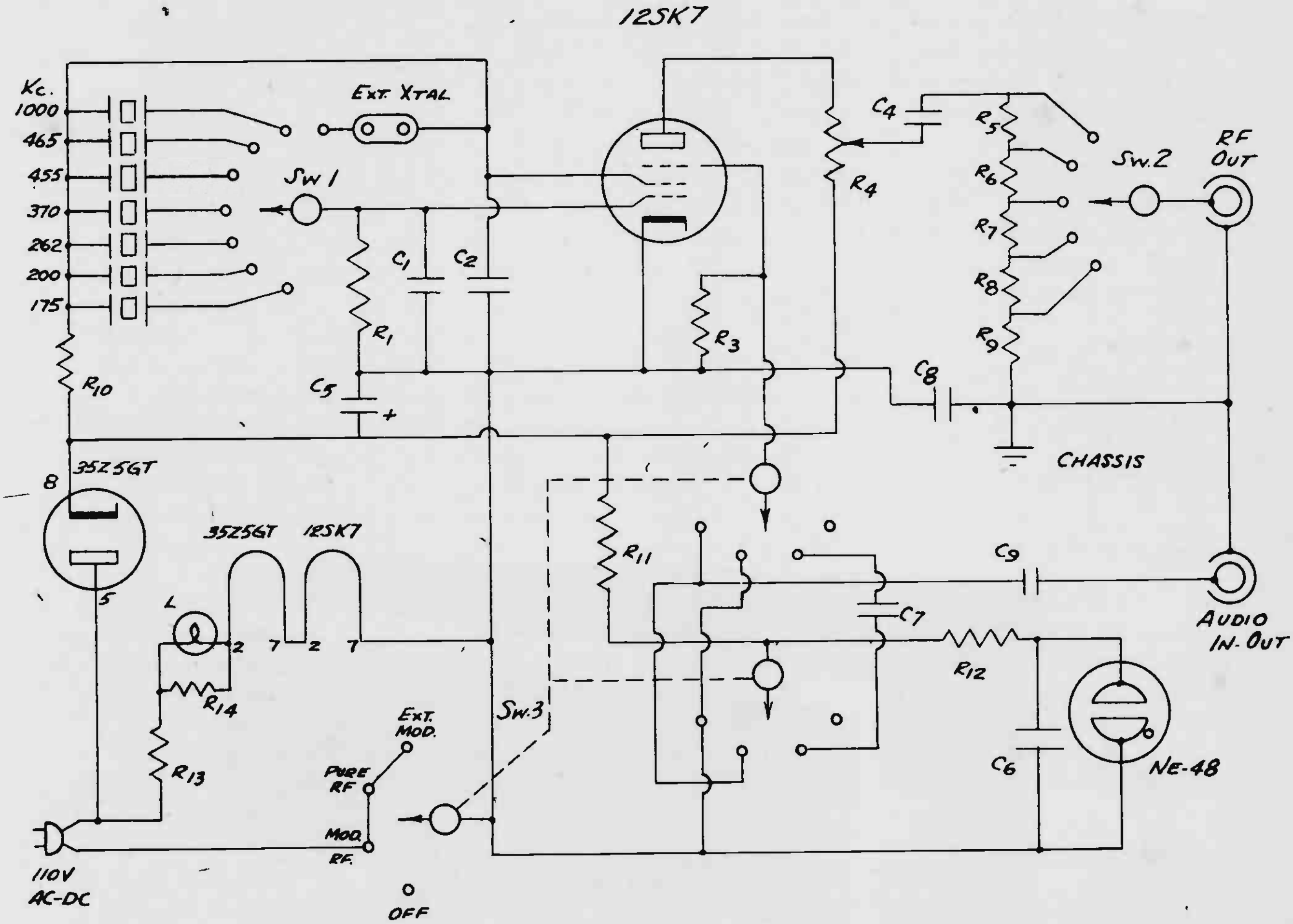
A separate audio signal generator circuit is usually included in conjunction with the R.F. signal generator circuit. The audio signal produced may be of a single frequency (400 cycles commonly used), or several different frequencies may be available for selection. The intensity of the audio signal superimposed on the R.F. carrier may be controlled. This is known as the percentage of modulation and 30% is popular. Also the audio frequency output may be used separately if need arises.

A great deal of care must be exercised in design to prevent stray radiation from the signal generator. This shortcoming would prevent the attenuator from being perfectly effective. To eliminate this unwanted radiation, the cabinet of the signal generator is made of heavy metal, and the coils and tuning condenser are further shielded inside of the cabinet. Since radio frequency energy at high power levels exist at the input to the attenuator, this control is also shielded in the better made signal generators.

A square wave generator produces a wave of a shape which gives it its name. The frequency of the signal and the fraction of energy time to off-energy time can be controlled. Since a square wave contains a great many harmonics, this instrument is especially useful for testing the audio response of radio and amplifier equipment. By observing in an oscilloscope the amount of distortion produced in a square wave signal by the associated equipment under test, the frequency response qualities of this equipment can be estimated.

Recently a crystal controlled signal generator for service use has been placed on the market. This instrument uses a number of fixed frequency crystals designed to give commonly needed frequencies and to permit selection by means of a rotary switch. A high degree of stability is obtained and all commonly needed frequencies for I.F. and broadcast band alignment are included. Short wave alignment can be carried out by using a higher harmonics or by purchasing external crystals for this purpose. Details on this instrument are illustrated.

BLILEY CRYSTAL CONTROLLED OSCILLATOR

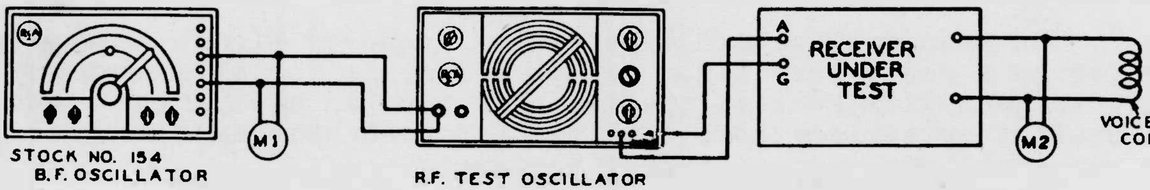


			(all 20% tolerance)
R_1	220 M ohms ½ W.	C_1	50 mmf. mica 10%
R_3	470 M ohms ½ W.	C_2	100 mmf. mica 10%
R_4	25 M ohms Potentiometer	C_4	.002 mfd. mica 20%
R_5	100 M ohms ½ W.	C_5	16.0 mfd. 250 v. Electrolytic
R_6	47 M ohms ½ W.	C_6	.002 mfd. mica 20 %
R_7	1000 ohms ½ W.	C_7	.02 mfd. 400 v. 20%
R_8	100 ohms ½ W.	C_8	.1 mf. 400 v. 20%
R_9	4.7 ohms ½ W.	C_9	.02 mfd. 400 v. 20%
R_{10}	33 M ohms 1 W.	Sw. 1	1 Circuit 8 Positions
R_{11}	1 megohm ½ W.	Sw. 2	1 Circuit 5 Positions
R_{12}	1 megohm ½ W.	Sw. 3	3 Circuits 4 Positions
R_{13}	500 ohms 20 W.	L	6.3 v. .15 amp. Lamp
R_{14}	100 ohms 1 W.		

A signal generator may be used for locating faults in radio receivers and as an aid for properly aligning all types of sets. With a signal generator, you can produce a similar signal to the one which can be handled by any stage of the receiver. For example, you can generate a powerful audio signal to drive the output stage. Or you can produce a relatively weak I.F., of the correct frequency and with about 30% modulation, to excite the input of the first I.F. transformer. The signal is applied to any one stage, and if the output is present in the loudspeaker, this stage and the balance of stages leading to the speaker may be assumed to be operating.

With the aid of a signal generator, each stage of a radio receiver can be tested individually and distortion can be detected. A higher accuracy in judging results can be obtained with the aid of an oscilloscope connected first to the signal generator direct and then to the output of the stage to observe effects produced on the signal. If intead of an oscilloscope, a vacuum tube voltmeter is used, stage gain can be measured.

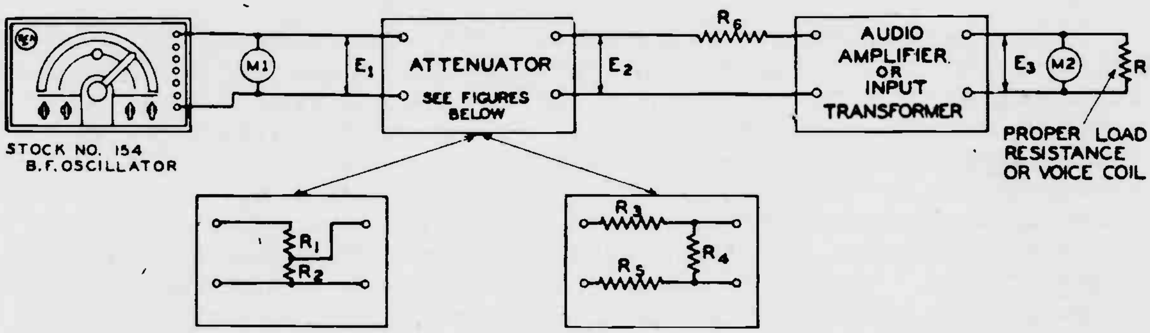
Radio receiver audio fidelity tests are used to determine the over-all electrical fidelity characteristics of the complete receiver. This test is accomplished by applying a modulated R.F. signal to the input of the receiver and measuring the output voltage (at various modulating audio frequencies) across the loudspeaker voice coil. See sketch below which is reproduced through the courtesy of R.C.A. Manufacturing Company.



Connections for Radio Receiver Fidelity Measurements

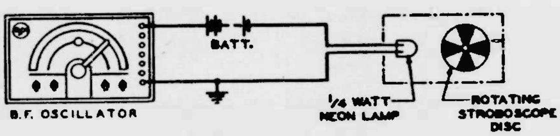
In testing the quality of the audio frequency response of an audio amplifier, the test procedure is generally the same as described above for fidelity test, but no R.F. signal generator is required. The output of the beat-frequency oscillator may be fed directly into the input of the audio amplifier, or, when the input voltage required for the amplifier is so low that it is practically impossible to measure it with an ordinary voltmeter, an attenuator should be used. This will establish a definite ratio between the output voltage of the beat-frequency oscillator and the input voltage fed to the amplifier.

Normally, either of two types of attenuators may be used, and each type has its particular advantage. If one side of the amplifier input is grounded, the arrangement shown at the left may be used. The value of $R_1 + R_2$ should be equal to or greater



Connections for Measurement of Audio Amplifier Frequency Response

than the impedance across the output terminals of the beat-frequency oscillator to which they are connected



An audio signal generator may also be used for determining audio transformer and filter characteristics, for testing percentage modulation of amateur transmitters, for audio frequency measurements with the aid of an oscilloscope, and for stroboscopic speed measurements using a neon bulb connected to the output (see figure, also courtesy of R.C.A.).

The main application of a radio frequency signal generator, as far as a radio serviceman is concerned, is for alignment and this subject will receive special attention in a separate lecture. Several other applications will be described briefly to suggest to you additional uses for your equipment.

First we will consider how to determine the over-all sensitivity of a radio receiver. The Standards Committee of the Institute of Radio Engineers recommends that a standard output power of 50 milliwatts be used (optional values in special fields) while determining receiver characteristics.

Thus after alignment the sensitivity at any frequency may be measured by setting the generator to that frequency, tuning the receiver accurately to that frequency and noting the attenuator setting required to produce 50 milliwatts in the output circuit.

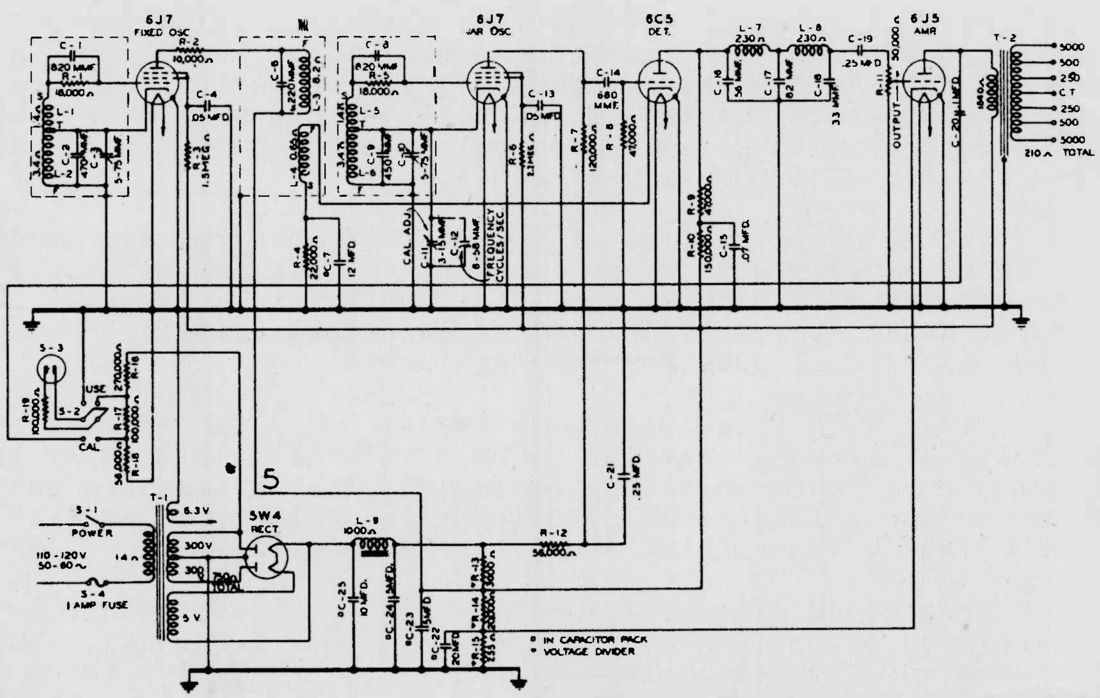
To determine any single stage contribution to gain, the previously described technique is applied in turn to the grids of the first and second I.F. amplifier tubes, for example; the ratio of the two attenuator adjustments required for standard output would be assumed in most quarters.

In like manner, if the sensitivity is determined at signal frequency at the grid of the first detector and at intermediate frequency at the grid of the first I.F. amplifier tube, the ratio of the two sensitivities is the conversion gain of the first detector circuit at the signal frequency used.

To determine the image ratio, first determine the sensitivity (as described) at the frequency at which the image ratio is wanted. Then, leaving the receiver tuning undisturbed, turn the generator frequency to a new frequency higher by twice the value of the I.F. frequency of the receiver and determine what output is necessary (use the high output jack if in excess of .1 volt) to produce standard output. The ratio of this voltage to the sensitivity is the image ratio.

After determining the sensitivity, if the attenuator readings are increased by discrete steps and the resulting power output plotted, the curve portrays the performance of the automatic volume control circuit.

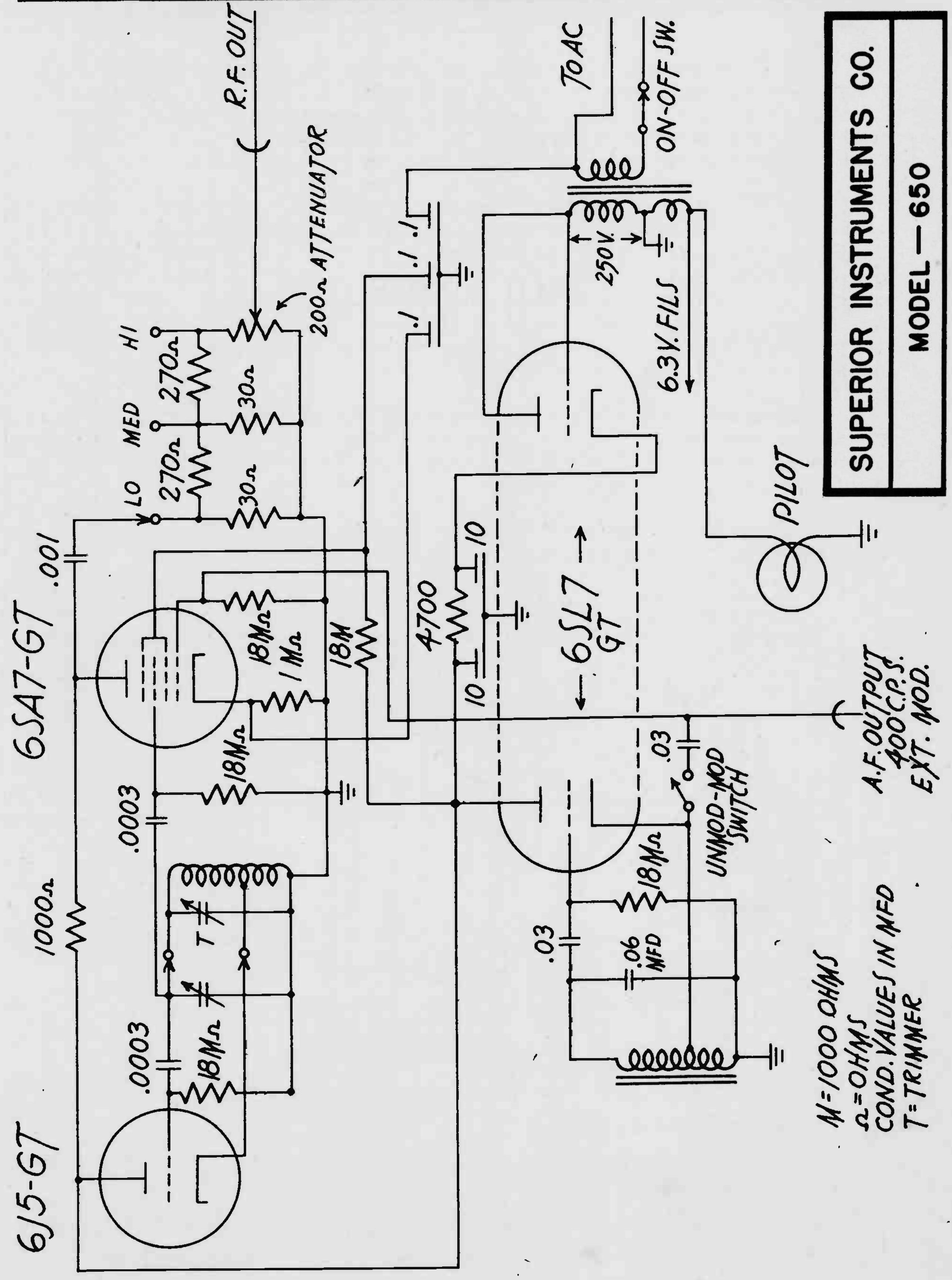
Circuits of several popular signal generators will be illustrated to complete this lecture.

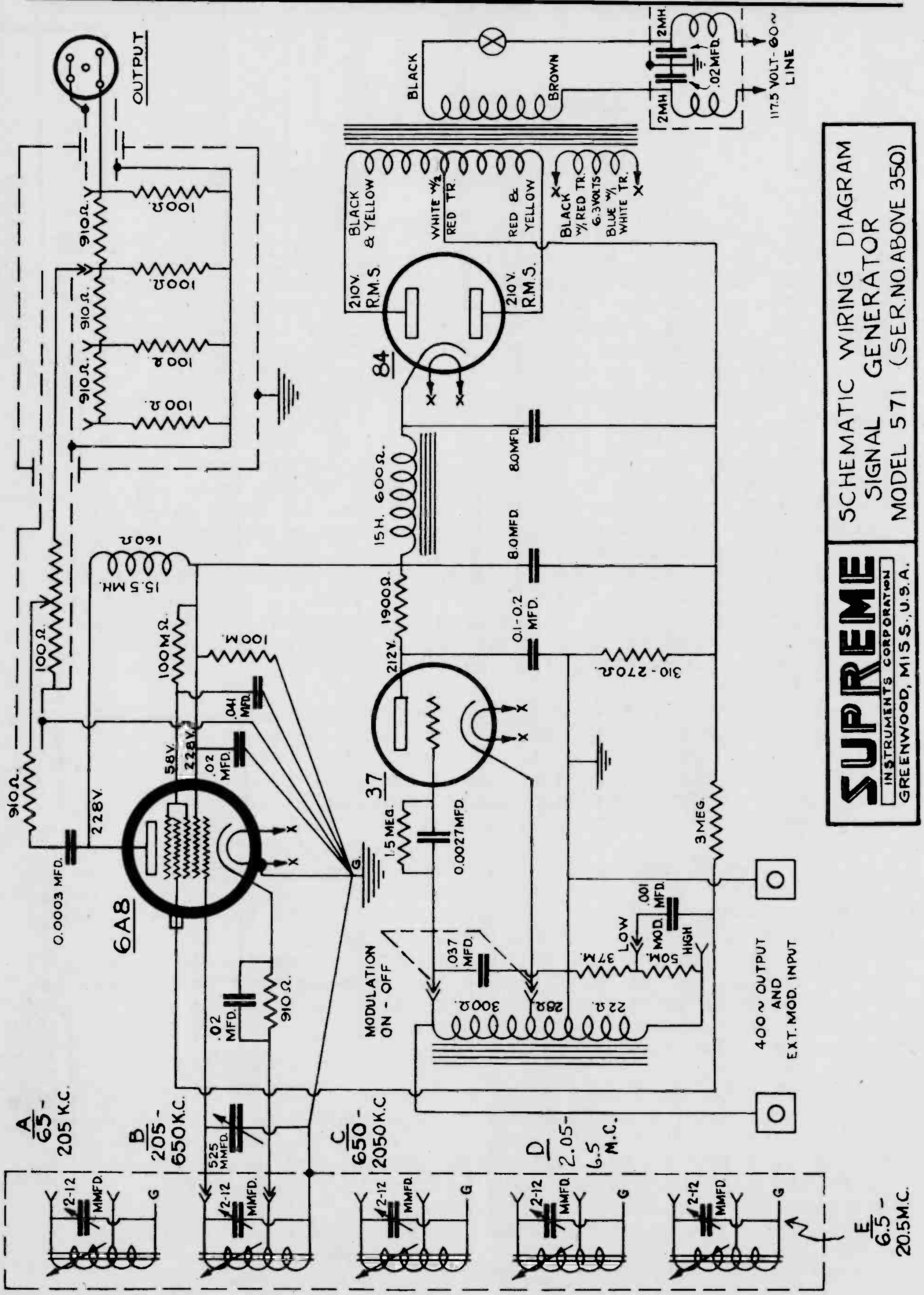


Frequency Range .... 30 to 15,000 cycles
Power Output .... 125 milliwatts
Voltage Output:

Load Impedance	Output Voltage
Open Circuit	37.5 volts
5,000 ohms	25.0 volts
500 ohms	7.5 volts
250 ohms	5.2 volts

R.C.A. Manufacturing Co.
Beat-Frequency Oscillator
Model 154


SUPERIOR INSTRUMENTS CO.
MODEL — 650
R.F. OUT
200Ω ATTENUATOR
HI
MED
LO
270Ω
270Ω
30Ω
30Ω
.001
6SA7-GT
18MΩ
1MΩ
18M
18MΩ
.0003
1000Ω
T
.0003
18MΩ
6J5-GT
TO AC
ON-OFF SW.
250V.
6.3V. FILS
PILOT
4700
10
10
6SL7 GT
.03
UNMOD-MOD SWITCH
A.F. OUTPUT 400 C.P.S. EXT. MOD.
18MΩ
.03
.06 MFD
M=1000 OHMS
Ω=OHMS
COND. VALUES IN MFD
T=TRIMMER


SCHEMATIC WIRING DIAGRAM
SIGNAL GENERATOR
MODEL 571 (SER. NO. ABOVE 350)
SUPREME
INSTRUMENTS CORPORATION
GREENWOOD, MISS., U.S.A.
OUTPUT
6A8
37
84
117.5 VOLT-60~ LINE
400~ OUTPUT AND EXT. MOD. INPUT
MODULATION ON - OFF
A 65-205 K.C.
B 205-650 K.C.
C 650-2050 K.C
D 2.05-6.5 M.C.
E 6.5-20.5 M.C.
BLACK
BROWN
BLACK & YELLOW
WHITE W/ RED TR.
RED & YELLOW
BLACK W/ RED TR. 6.3 VOLTS BLUE W/ WHITE TR.
210 V. R.M.S.
15 H. 600 Ω.
8.0 MFD.
0.1-0.2 MFD.
1900 Ω.
212 V.
310-270 Ω.
3 MEG.
.001 MFD.
LOW
MOD. 50 M.
HIGH
37 M.
.037 MFD.
300 Ω.
28 Ω.
22 Ω.
1.5 MEG.
0.0027 MFD.
160 Ω.
15.5 MH.
100 M Ω.
100 M.
.041 MFD.
.02 MFD.
58 V.
228 V.
910 Ω.
100 Ω.
0.0003 MFD.
525 MMFD.
2-12 MMFD.
2MH
.02 MFD.

Lecture 13

Using an Oscilloscope for Servicing

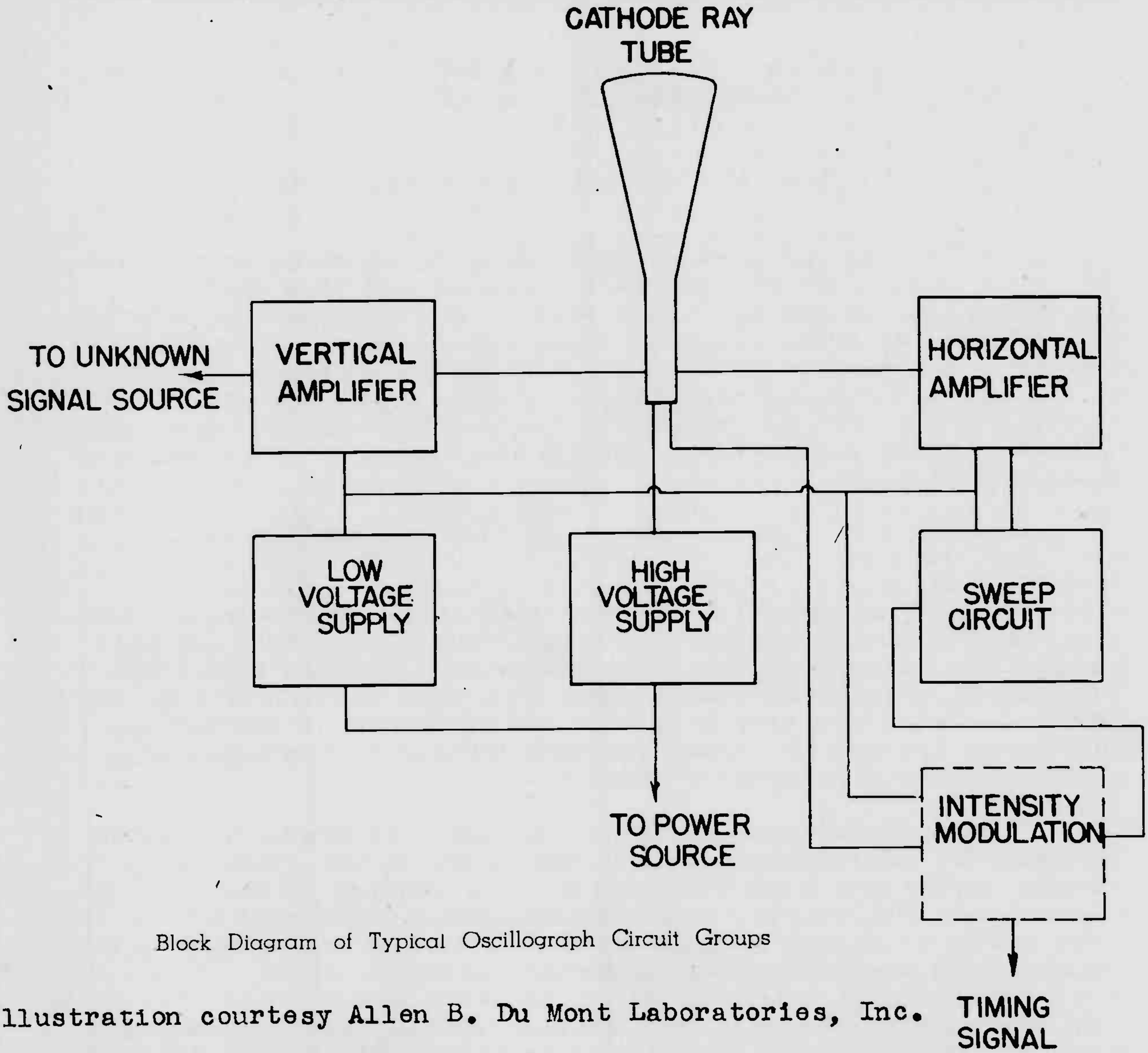
The cathode ray oscilloscope is an indispensable tool for the radio laboratory and can be a valuable aid to a radio serviceman in performing repair work. The heart of the unit is the cathode ray tube. This we will discuss first. The need for the associated circuits then will become obvious. Sweep circuits, flat-response amplifiers, focusing arrangements will be explained before we review the technique of operating a cathode ray oscilloscope and interpretation of visual results obtained.

A cathode ray tube is a vacuum tube so designed that electrons emitted from a cathode (located at one end) are concentrated into a narrow beam. This beam is influenced by electrostatic or magnetic fields and is caused to impinge upon a screen at the opposite (wide) end of the tube. This screen becomes fluorescent at the place where the electron beam makes the impact and, as the beam varies from side to side and up and down, the image produces a pattern. The nature of the pattern depends on changes of intensity taking place in the associated electrostatic or magnetic fields.

A cathode ray tube in itself is not a complete indicating device. In order to produce a simple spot on the fluorescent screen, the proper high voltages must be applied to the various electrodes. Familiarity with power supplies used will be obtained in studying the schematic diagrams of commercial units described at the end of the lecture.

As pointed out in the "Reference Manual" copyrighted by Allen B. Du Mont Laboratories, a source from which we will quote at length on the subjects of sweep circuits and amplifiers, the combination of the cathode ray tube and suitable power supply is enough to form the indicator element. Since the cathode ray tube is relatively an insensitive device requiring potentials of several hundred volts for full deflection, a suitable amplifier is needed to increase the usual input voltage of much lower magnitude to acceptable value.

While the amplifier will permit the study of small voltages, it will also impose limitations on the character of signals that can be transmitted by the amplifier. With the unknown signal applied directly to the deflection plates, the maximum amplitude observable will be limited only by the full scale deflection of the beam; the maximum frequency which can be applied is limited by the transit time of the beam passing between the deflection



Block Diagram of Typical Oscillograph Circuit Groups

Illustration courtesy Allen B. Du Mont Laboratories, Inc.

plates, and also by the shunt capacitance between deflection plate terminals. Transit time effects generally restrict usefulness to below 200 megacycles in commercial tubes operated at accelerating potentials of about 1500 volts. Low capacitive reactance at higher frequencies may load down the signal sourse.

Applying a direct current voltage to the plates will deflect the beam proportionally to the magnitude of that voltage, and the beam will remain fixed in its deflected position until that D.C. deflection voltage is removed. Therefore, there is no low frequency limitation when direct connection is used. In fact, it is the application of a direct current voltage, controllable in magnitude, that is used to position the beam in both horizontal and vertical directions in the complete oscillograph unit.

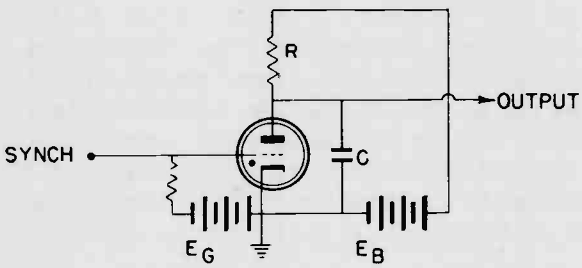
When an amplifier is interposed between signal source and deflection plates, the signal will be faithfully reproduced only if the limitations of the amplifier are not exceeded. These limitations include frequency discrimination both in the amplifier and input attenuator circuits, phase distortion, and the maximum allowable direct current and peak input voltages. The minimum signal voltage is determined by the least amount of beam deflection which can be tolerated for effective study, and therefore by the gain of the deflection amplifier. The maximum voltage which can be applied is limited by the voltage rating of any input coupling capacitances and the voltage range of the input amplifier stage. Of course, a radio frequency signal will not be passed by an audio frequency amplifier, nor will a direct current signal be amplified by an alternating current amplifier. Attention must also be directed towards the gain or attenuation control, since the effects of the variable distributed capacitance depending on the setting of the rotor in a high resistance potentiometer can cause extreme phase and frequency distortion.

A very important consideration in choosing an oscillograph is the frequency response characteristic of the vertical axis amplifier. Many applications of an oscillograph require the observation of pulses, square waves and other non-sinusoidal waveforms. Therefore, not only must the sinusoidal response be uniform, but the transient response must permit undistorted amplification of irregular wave shapes.

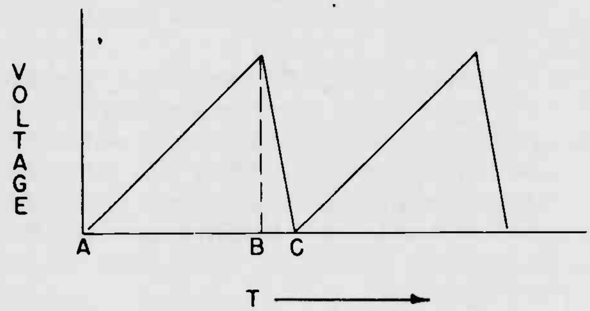
This amplifier discussion thus far has been restricted largely to the vertical axis. Similarly, these considerations apply to the horizontal amplifier. For most applications, the signal applied to the horizontal deflecting plates provides for the movement of the spot at a uniform rate with respect to time. Such a signal provides the time-axis along which is plotted the unknown variable voltage. After the spot has traveled the width of the screen, it snaps back to its starting position and the process is repeated. Without going into a detailed discussion of the generator which supplies the horizontal voltage, it will suffice to say that the waveform of this time-axis deflecting voltage is usually of a saw-tooth nature, and therefore, is rich in harmonic content. Since this saw-tooth voltage is amplified by the horizontal amplifier, the frequency and phase characteristics of that amplifier should permit undistorted amplification of sinusoidal signals of frequencies extending both far above and below the saw-tooth recurrence rates. Frequently, the saw-tooth frequency range is from a few cycles per second to over 50,000 cycles per second, so that quite stringent requirements are imposed on the frequency response characteristic of this amplifier.

It is also desirable for the horizontal and vertical amplifier to have identical phase characteristics to facilitate accurate study of the relationship between two different signals, each being applied to a separate axis. Such a connection will produce a pattern called a "Lissajou Figure." A detailed discussion of these figures is given later in this lecture.

The linear time-base generator or sweep oscillator is the integral part of the oscillograph unit which generates the saw-tooth voltage producing the linear time-base referred to above. The time-base is not restricted to a linear function, but can also be a sinusoidal, circular or spiral function or any other shape that may be desirable for particular applications.



Basic gas triode sweep oscillator circuit



Linear time-base voltage waveform

The saw-tooth wave is generally developed by a relaxation oscillator in which a gas discharge tube is used.

A feature of the sweep oscillator is its ability to synchronize its frequency of oscillation with the frequency of the unknown signal so that in cases of recurrent phenomena the spot begins its excursion each period at the same point on the wave of the unknown. The resulting luminescent pattern is a stabilized wave. With the pattern "locked in," the rapid re-trace of the wave many times a second will give the appearance to the human eye of a "still photograph" because of the persistence of the fluorescent-phosphorescent screen on the cathode-ray tube coupled with the persistence of human vision.

For some applications it is necessary to record a phenomenon which does not continually recur, but exists for a short time interval and then disappears. Such a phenomenon is known as a transient. If the ordinary sweep oscillator were used, the horizontal spot travel would be entirely independent of the transient, and the observer would have no assurance that the beginning of the unknown wave would occur at the beginning of the spot excursion on the screen. This condition is nicely provided for by a single sweep circuit which generates a time-base only when a transient initiates it. Initiation of the single sweep may be effected either by the transient itself, in case that transient cannot be controlled at will by the observer, or by an independent voltage applied to the synchronizing terminal which can also control the initiation of the transient.

For applications involving rotating machinery, it is often desirable to use a sinusoidal sweep, which can be obtained from either an external sinusoidal oscillator, or from a small generator mounted on the rotating shaft so that the frequency will correspond to the speed of the shaft.

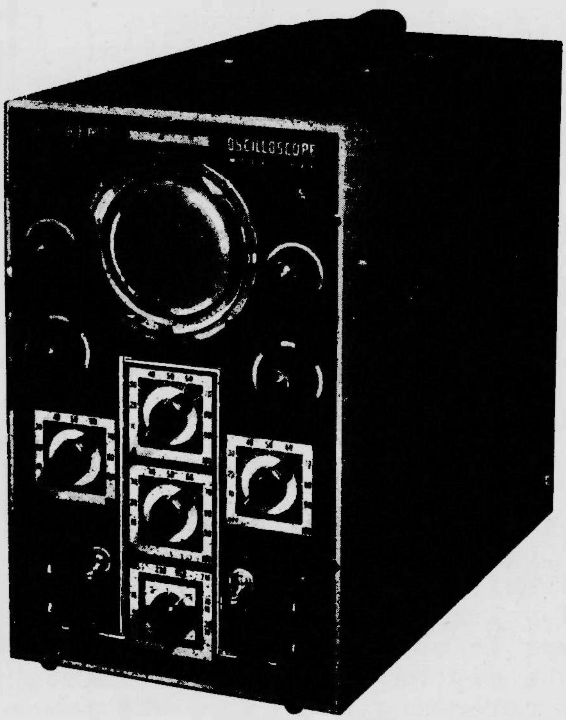
Where photographic recording of transients is involved, the travel of the continuously exposed film very often provides the linear time-base, and the horizontal deflection circuits are not used at all. In such an arrangement the shutter of the motion picture camera must be removed.

Reference was made above to the time required for the beam to return to its original starting position. In some studies, the appearance of that return trace is objectionable, and means are usually provided to blank it out. This blanking out process is accomplished by applying a negative pulse at the grid of the cathode ray tube during the return trace interval. The negative pulse is derived from the saw-tooth wave generated by the sweep oscillator.

The subject of blanking or intensifying the beam naturally brings to mind the application of beam intensity modulation for other purposes. In the case of television, the grid of the cathode ray tube is modulated by a voltage which causes the spot or trace to become lighter or darker in accordance with the voltage variations. This same principle may be used in oscillographs to provide timing demarcations, or reference points on the trace or pattern. These timing marks can be provided by an external oscillator or pulse generator whose frequency is known. Other times, the signal available for beam modulation is less than that needed for extinguishing the beam, and therefore, an amplifier is needed. This amplifier is commonly known as the Z-axis amplifier. A further use for this provision is to intensify the beam over portions of the trace where the writing rate of the spot is so great that the fluorescent screen is not sufficiently excited. Thus, the intensity is more uniform throughout the entire trace and photographic exposure is facilitated. Furthermore, the portion of the trace which is most interesting is often the least visible. This provision will prevent burning and damage to the fluorescent-phosphorescent screen caused by operation of the intensity control at maximum (i. e., zero bias) in an attempt to improve the total visibility.

Focusing of the fluorescent spot is accomplished by varying the ratio of the voltages applied to the two anodes. Regulation of the spot size and intensity is accomplished in some tubes through the variation of anode current of one of the plates. Variation in the bias voltage applied to the control grid will permit this adjustment. In practical equipment, of course, these adjustments are made by means of variable resistors (potentiometers) mounted on the control panel.

Facts presented so far plus your previous theoratical knowledge of cathode ray oscilloscopes should permit us now to review the actual method of operating such units. For this purpose, I will talk about a Supreme Instruments Corp. Model 546 Oscilloscope.



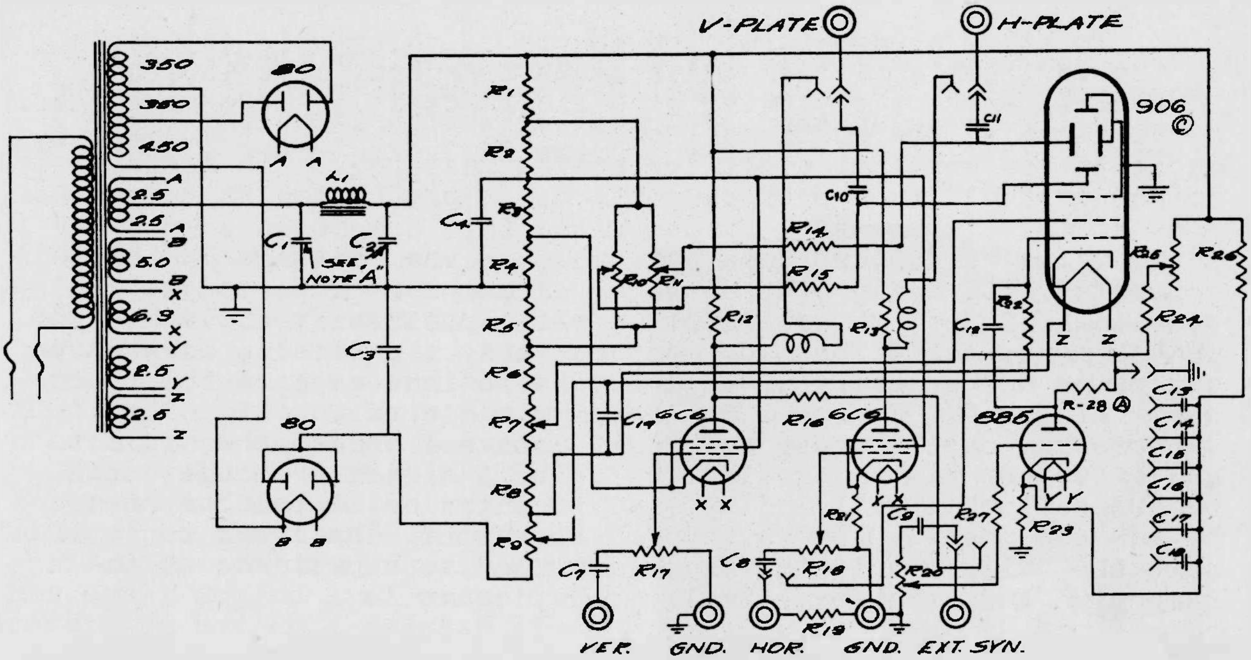
The illustration of this instrument will suggest to you the physical position of the various controls, which are also indicated in the schematic diagram. The intensity control varies the brilliance of the spot. Usually this control also has the on-off switch. The focus control is used to adjust the resulting picture to a bright image and is dependent on the adjustment of anode voltages for proper electron-optical focus.

Bearing in mind that any picture or trace obtained consists of a moving dot of light, you can understand that it may be required to shift the position of the dot or the complete picture. For this purpose, the vertic__ position and horizontal position controls are employed. These adjustments are accomplished by varying D.C. voltages applied to both sets of deflecting plates; potentiometers R_{10} and R_{11} are used for this purpose.

The gain controls are potentiometer voltage divider networks at the input to the vertical and horizontal amplifiers. These parts are marked R_{17} and R_{18}. In the unit described, these controls are not connected unless the respective amplifier gain controls are placed in operation.

Means are provided for using the internal sweep or for changing the circuit so that an external sweep can be employed. Provisions are also incorporated for eliminating the horizontal amplifier when external sweep is employed.

In using the internal sweep, a special saw-tooth oscillator becomes connected to the circuit and produces a changing voltage which sweeps the beam across at an adjustable frequency and returns the beam from extreme right to left in a very short fraction of the total cycle. Since it is not practical to produce all frequencies in the saw-tooth oscillator with a one set of components, in the oscilloscope described, six steps are employed



Symbol	Ohms	R-9	200,000	R-18	4 megohms	R-23	1,000	Symbol	Mfd.		
R-1	25,000	R-10	4 megohms	R-19	1 megohm	R-24	1 megohm	C-3	0.5	C-12	50 mmfd.
R-2	10,000	R-11	4 megohms	R-20	15 megohms	R-25	4 megohms	C-4	8.0	C-13	0.37
R-3	10,000	R-12	50,000	R-21	1,000	R-26	100,000	C-7	0.1	C-14	0.04
R-4	220	R-13	100,000	R-22	500,000	R-27	100,000	C-8	0.1	C-15	0.01
R-5	250,000	R-14	1 megohm			R-28	500			C-16	0.0025
R-6	750,000	R-15	500,000			Symbol	Mfd.	C-9	0.05	C-17	600 mmfd.
R-7	500,000	R-16	1 megohm			C-1	4.0	C-10	0.5	C-18	200 mmfd.
R-8	100,000	R-17	1 megohm			C-2	4.0	C-11	0.25	C-19	0.5

covering from 15 to 30,000 cycles per second and overlapping each other for easy adjustment. Once the band of sweep frequencies, which include the frequency required is selected, the fine frequency control (potentiometer R_{25}) is used to achieve the exact adjustment.

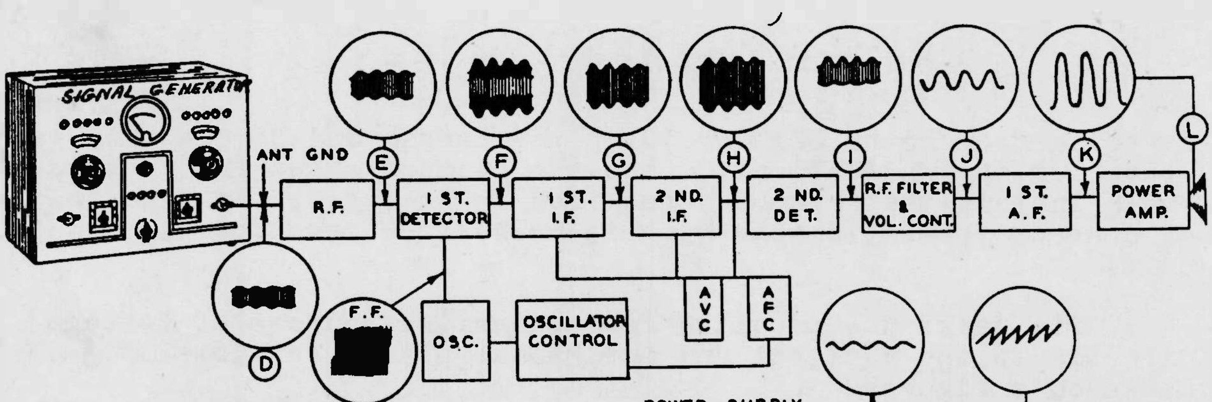
Pin jacks are provided for connecting sources of voltage directly to the vertical and horizontal plates for obtaining Lissajou's figures.

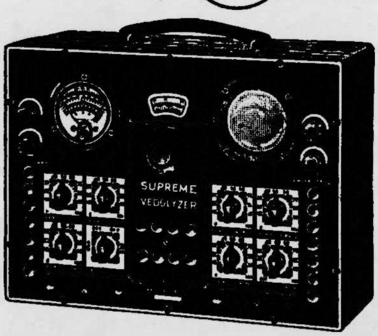
The understanding what the various controls do will permit you to make the necessary adjustment to view any pattern obtainable from equipment under test. It is important to have the spot moving at all times in order not to burn out the fluorescent screen.

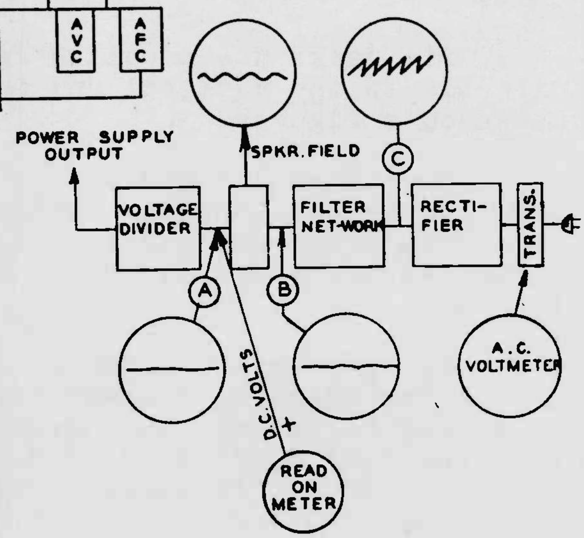
For a serviceman, a cathode ray oscilloscope is especially useful for checking voltage wave forms, as an aid in alignment, as a peak voltmeter, for measuring phase shift, for detecting and measuring distortion, for frequency measurements, and as a visual indicator in signal tracing. We will briefly describe these applications.

To study a wave form, the source of voltage is connected to the vertical amplifier and a sweep frequency is selected that will permit the viewing of a single cycle or several cycles. By eliminating the horizontal sweep from operating, the voltage input to the vertical amplifier can be measured. The actual height of the "line" produced will be in proportion to twice the peak voltage impressed. By comparing this height to some other known value of A.C. voltage, the unknown peak voltage can be estimated. In using D.C. voltage for comparison purposes, please bear in mind that the visual line will appear only above the center mark, while for A.C. measurements, the line appears above and below and actually gives twice the height as compared to the same value D.C. A signal can be examined with the aid of a cathode ray oscilloscope before it enters a piece of equipment, and a further visual examination of this signal from the output of the equipment will indicate any changes or distortion produced by the equipment. For this purpose, special apparatus is available that will permit the examination of both patterns at the same time and, thereby, simplify the comparison.

In alignment work, with the aid of a proper sweep arrangement, the response curve can be viewed on the scope and exact adjustments carried out for best operation. This type of alignment is especially beneficial in high fidelity radio receivers and in frequency modulation equipment.





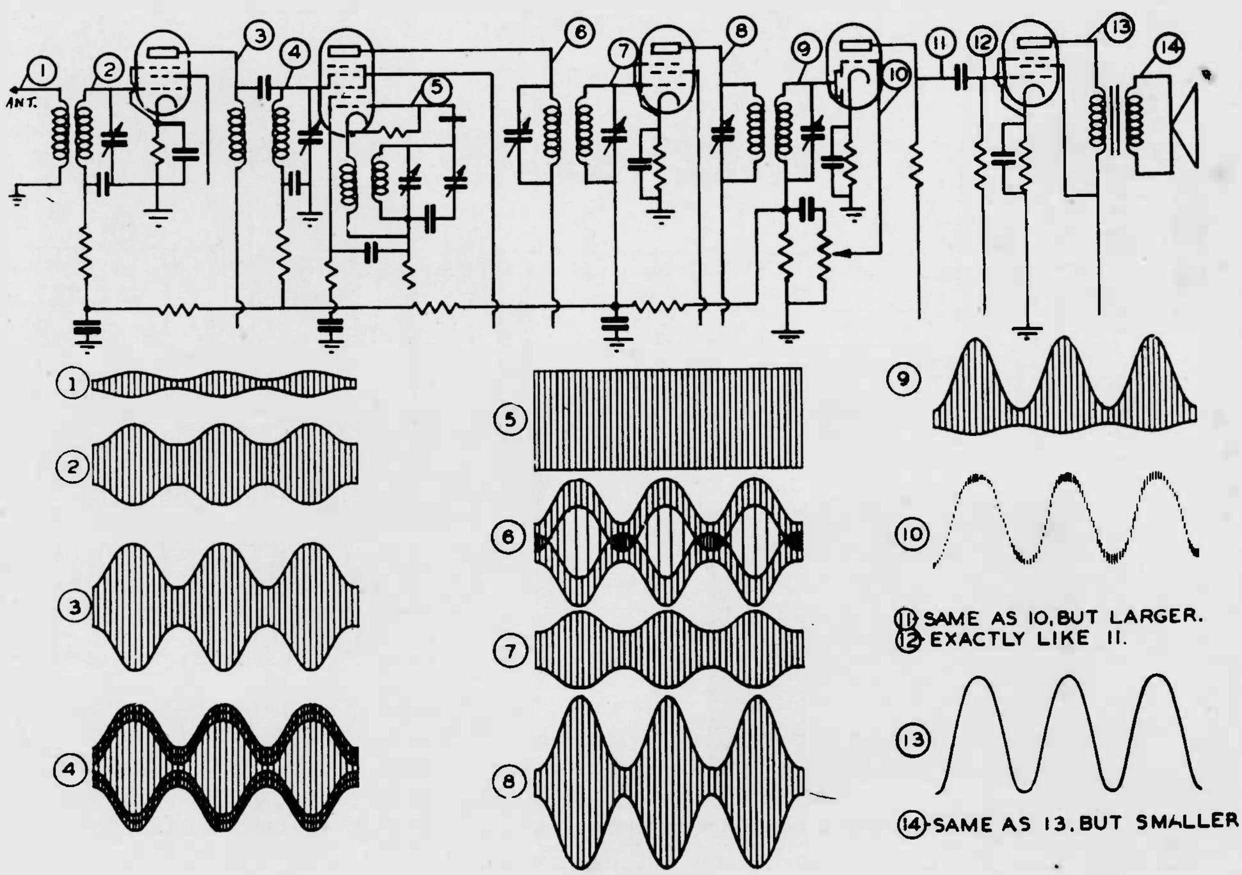


Positions for testing a typical superhetrodyne with the aid of a *Supreme* Vedolyzer. Illustrations indicate types of patterns to be expected from properly operating circuits.

While the majority of signal tracers depend on hearing an audio signal or measuring voltage values, as indicated on a tuning-eye tube or a standard meter, additional information can be supplied by a cathode ray oscilloscope used in conjunction with the signal tracer. In fact, Supreme Instruments have built a visual type signal tracer, which is illustrated below together with a chart showing its application and the type of patterns obtained when a typical receiver is tested at various points.

The shape of a pattern obtained on the cathode ray tube depends on the value and phase relationship of the voltages applied to the deflecting plates. These patterns are useful for the study of voltage and phase relationship and supply information about the unknown voltage applied to one set of plates when the character of voltage applied to the other set of deflecting plates is known.

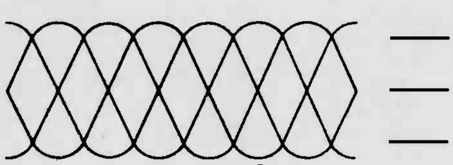
It is important to understand that the electron beam of the cathode ray tube is influenced by both sets of deflecting plates at the same time. For example, if equal sine wave voltages are applied to both sets of plates, the pattern obtained will be a line of 45 degree slope, provided the voltages are in phase. The



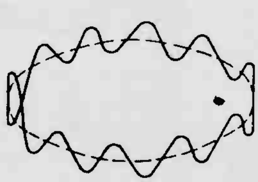
reason for this result becomes clear, if you bear in mind that the instantaneous values of both voltages are equal at all times and the beam is shifted equally towards one of the horizontal plates and one of the vertical plates.

If two identical voltages of the same amplitude, but out of phase by 90 degrees are used instead, a circle pattern is produced. If the amplitudes are not equal, an ellipse will result. If besides the difference in amplitude, the phase differs by 45 degrees, a figure similar to an ellipse, but slanting to one side, will be produced. Figures so far considered are of the simpler Lissajou's types. From the pattern obtained on the screen of the scope, the frequency and phase relationship of the two voltages can be determined. In cases where the wave form for one of the deflecting voltages is known, the wave form of the other voltage can be readily obtained by graphical means.

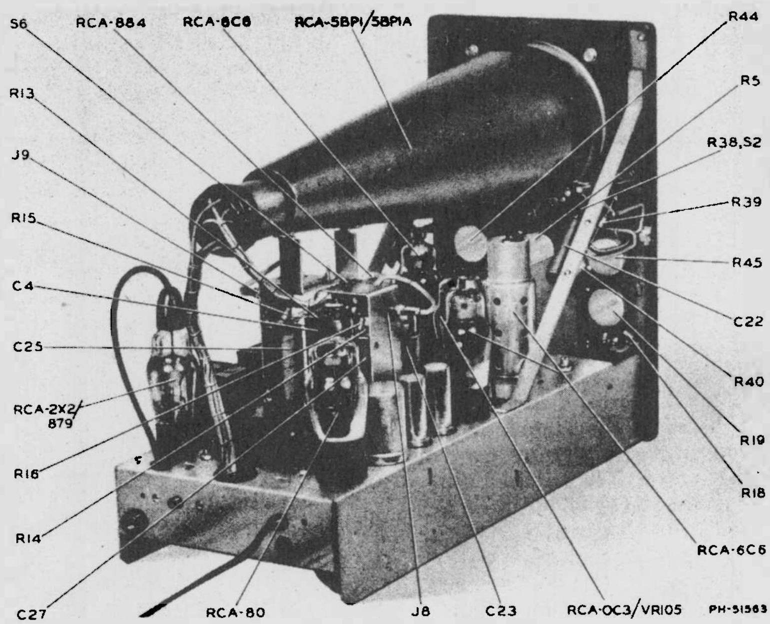
As the ratio of the frequencies increase, the pattern obtained becomes more complex. Ratios under 10 to 1, can be determined without difficulty. In general, it is difficult to judge the ratio directly from the picture without the knowledge of some tricks. One such tricky method is to count the number of horizontal lines of intersection, see illustration. Add one to this number and the result is one number of the required ratio. The other number of the ratio is obtained by counting the peaks at the top (or bottom, but not both) of the pattern.



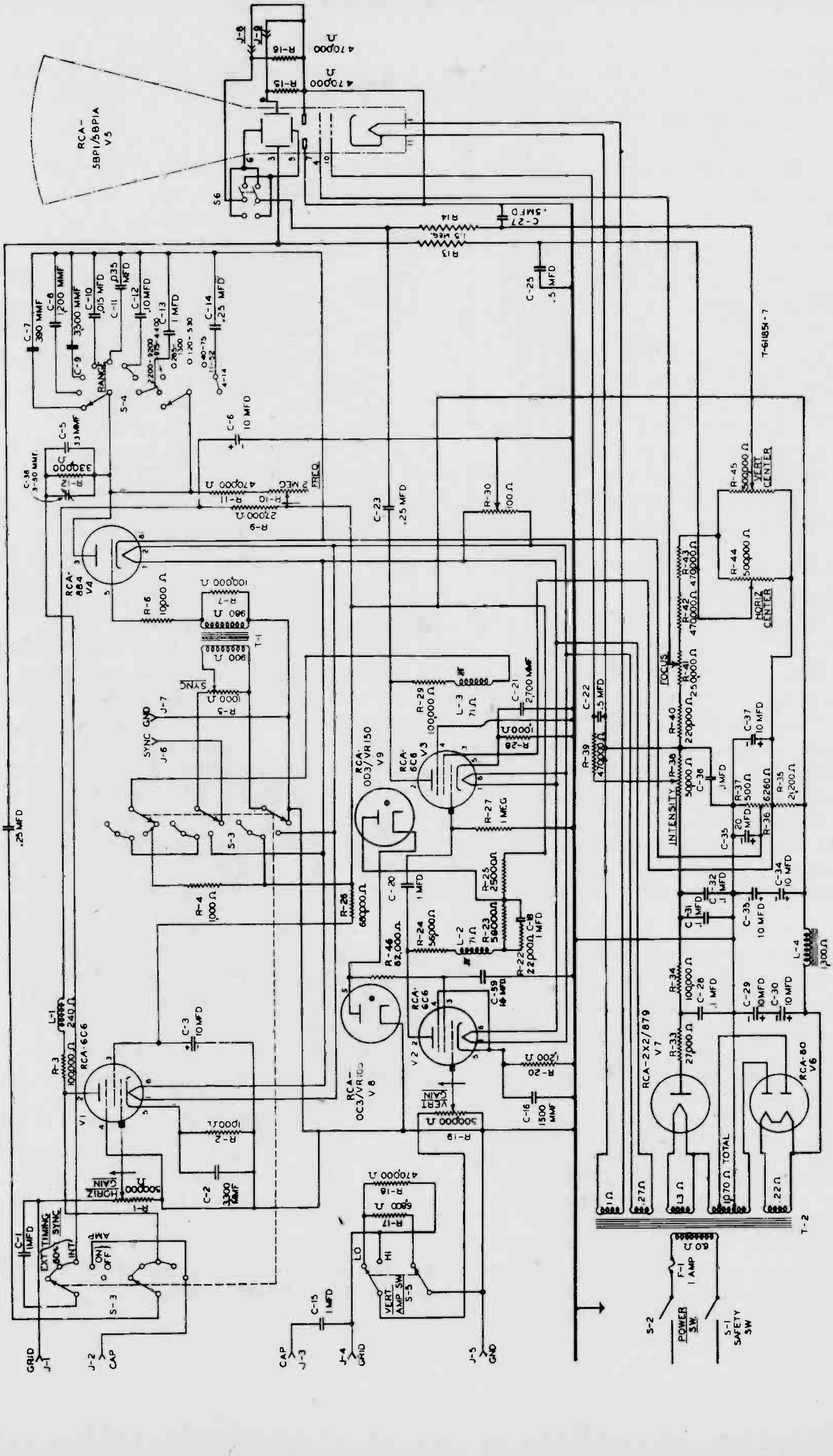
7:4 $1\frac{3}{4}$:1



10:1



For the study of ratios greater than 10 to 1, the wave form is produced on a circle or ellipse. A phase splitting circuit consisting of a condenser across one set of deflecting plates and a resistor across the other plates will displace the pattern around the ellipse for easy analysis.



To complete this lecture we include the circuit diagram and other data on a 5 inch type R.C.A. Model 160-B oscilloscope.

Lecture 14

Signal Tracing Technique

Until this lecture, we have considered servicing methods that depended on indications of electrical values to suggest and locate faults existing in radio equipment. Although it was actually the lack of the signal or some peculiarity of the signal that forced the radio owner to call the serviceman, it was not until 1938 that test equipment was released that depended primarily on the signal for finding radio faults. The existance of the signal in various forms permits the use of signal tracing equipment to test for failure or distortion of the signal at some one stage. Indeed, this service technique has great merit since it tests the signal directly instead of associated electrical values that may influence the circuit handling the signal.

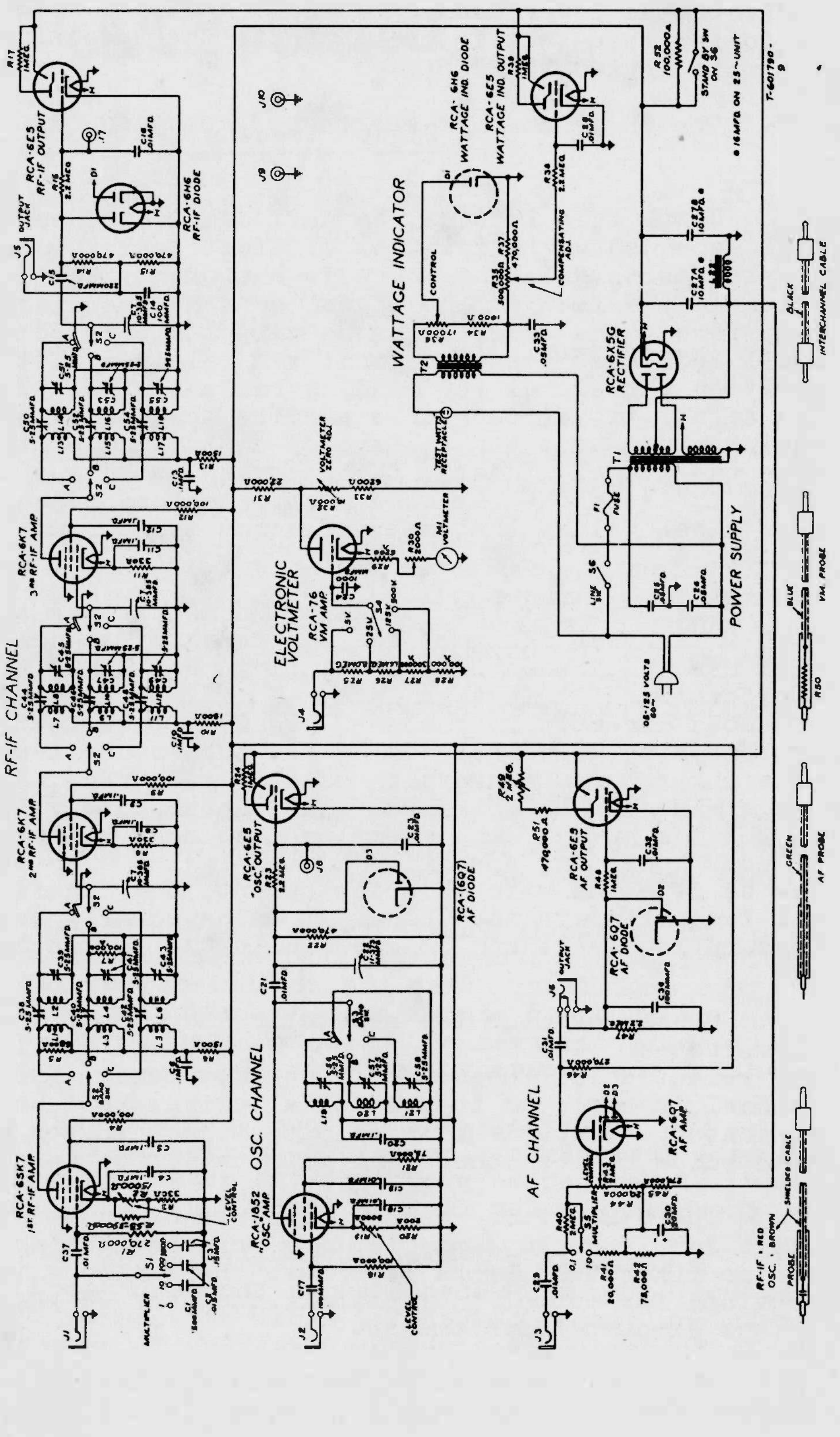
Historically the RCA-Rider Chanalyst was the first commercial instrument designed for servicing by signal tracing. We will use the present day model (Type No. 162C) to illustrate the application of this technique. This instrument permits testing of tubes directly in the set. Usually this test is accomplished by measuring gain produced by the tube under test. In the case of a mixer tube, conversion gain is measured. Gain of each stage also can be obtained. The vacuum tube voltmeter included in the instrument can be employed to make voltage measurements without upsetting operation of the radio. The usual radio faults can be detected with this instrument, but for finding distortion and intermittents the Chanalyst is especially useful. Power consumption tests can be made while the set is under examination.

Please examine the schematic diagram of the RCA-Chanalyst illustrated. The RF-IF channel is a tuned amplifier permitting the selection of the needed frequency band. The output of this channel is employed to control a tuning-eye tube used as an indicator. There is also an output jack J5 for high-impedance headphones or for connecting this output to an audio channel.

The oscillator channel consists of an oscillator-amplifier stage and is employed in testing or substituting for the oscillator or mixer tubes in a superhet. Here also a tuning-eye tube is provided for output indication. The jack J8 permits connection to the electronic voltmeter.

The audio channel is employed for audio tests or for audio amplification of the output produced in the RF-IF channel.

RCA-RIDER CHANALYST
TYPE No. 162C



A tuning-eye tube is incorporated in a special circuit to indicate the power used by a radio receiver under test. The radio for this test is connected to the special receptacle of the unit marked "TEST WATTS."

The RF-IF channel has three frequency bands as follows:

Band A	96 KC. to 260 KC.
Band B	240 KC. to 630 KC.
Band C	600 KC. to 1700 KC.

A special cable is provided for connecting the probe to the input jack, J1. When the signal is properly tuned in and is at its maximum, the shadow angle of the tuning-eye will be minimum.

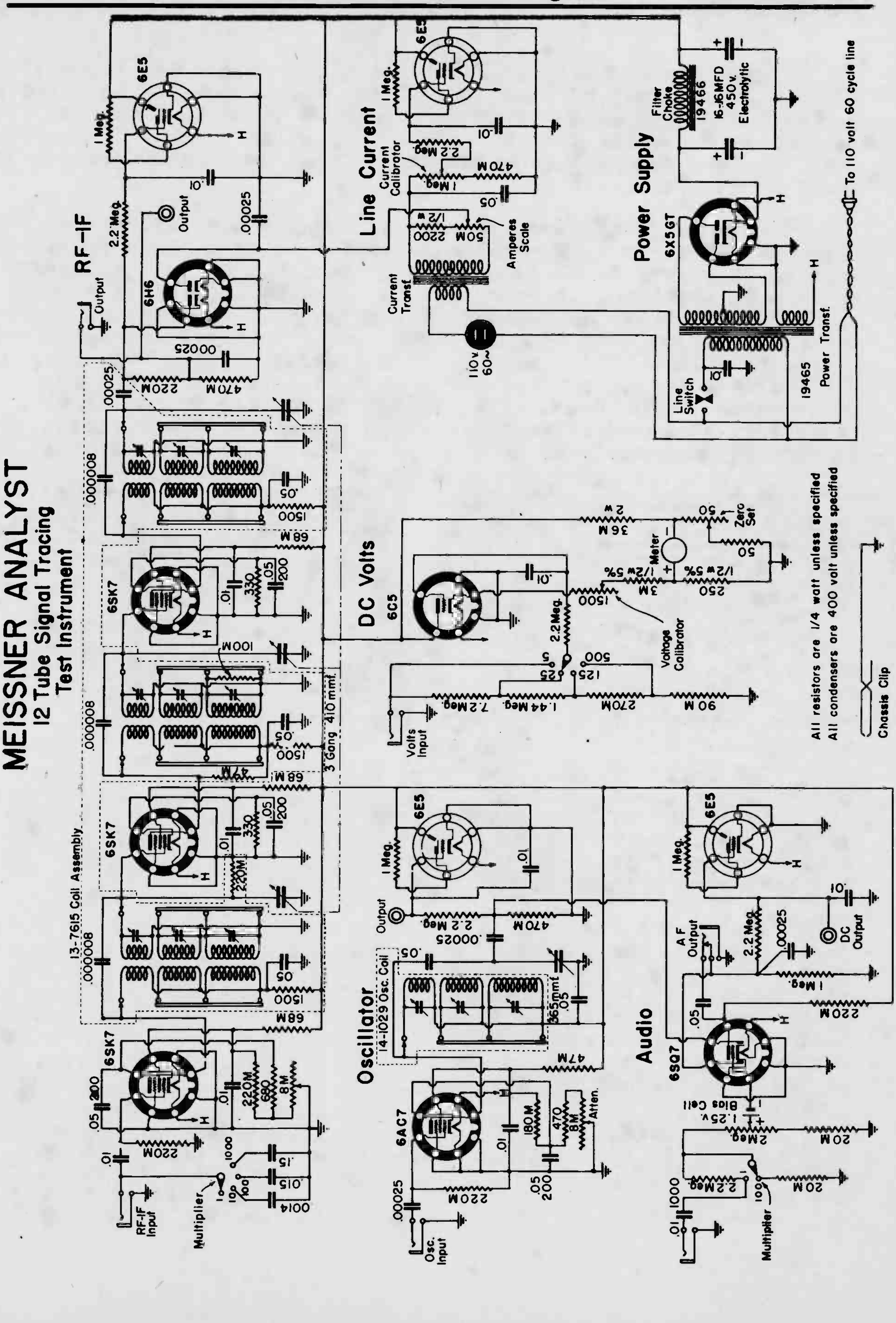
One of the applications of this channel is to use it as a comparison broadcast receiver, since it is actually capable of receiving signals from 96 to 1,700 KC. This channel also may be used for checking antenna pickup, determining frequency of an incoming signal, or as a resonated vacuum tube voltmeter to measure and compare gain of R.F., I.F., and oscillator signals. This channel is also used for testing for the presence of signals, for determining presence of hum, distortion, or noise, and for general alignment, as well as a means of checking automatic frequency control adjustment on sets where AFC is used.

The oscillator channel is useful for comparing signal voltage levels from oscillators, for checking the frequency of signals, and as a frequency monitor of signals secured from a signal generator or other oscillator.

In conducting audio tests, the audio frequency channel is employed. This channel may be used as a separate high gain voltage amplifier. Also the channel may be left connected to a source of audio signal and the intensity of the signal can be continually observed on the associated tuning-eye tube or by means of the vacuum voltmeter.

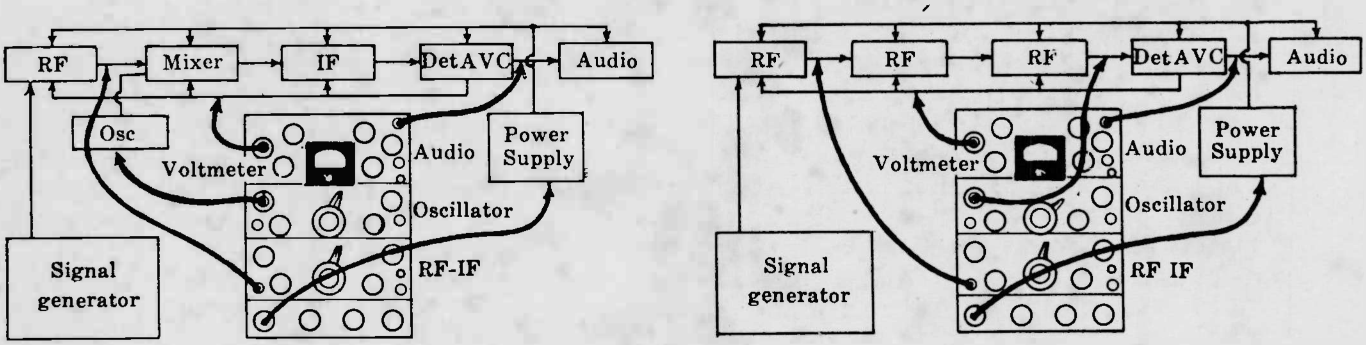
The electronic vacuum tube voltmeter may be used separately to make measurements in several ranges up to 500 volts D.C. By means of the cables provided, the meter may be connected to any of the channels for further tests.

A somewhat similar instrument is the Meissner Analyst which has its schematic reproduced on the next page. As in the case of other analyzers, it permits radio servicemen to measure and listen in (with headphones) to the signal as it passes through each of the components in a receiver, regardless of the level of the signal and in spite that the signal may be in R.F. or I.F. form.


MEISSNER ANALYST
12 Tube Signal Tracing
Test Instrument
RF-IF
Line Current
Power Supply
DC Volts
Oscillator
Audio
13-7615 Coil Assembly
14-1029 Osc. Coil
3 Gang 410 mmf.
RF-IF Input
Osc. Input
Volts Input
Multiplier
Output
AF Output
DC Output
Current Calibrator
Amperes Scale
Current Transf.
Voltage Calibrator
Zero Set
Meter
Filter Choke
19466
16-16MFD 450v. Electrolytic
Power Transf.
19465
Line Switch
To 110 volt 60 cycle line
110v 60~
Atten.
1.25v. Bias Cell
Chassis Clip
All resistors are 1/4 watt unless specified
All condensers are 400 volt unless specified

The audio channel consists of a single stage amplifier with a suitable attenuator. The output from this stage may be detected on the tuning-eye tube indicator or may be heard in a pair of headphones for which an output jack is provided. In this instrument, we have also the other sections which were described in our study of the Chanalyst.

Instruments of this type are especially adapted for finding intermittent faults. The method used for locating such faults will be described in conjunction with the Analyst. If intermittent fault servicing is attempted by ordinary methods, the mere connection of test instruments frequently restores the set to its normal operating condition and many hours of effort are sometimes necessary before it is possible to locate the fault. By means of the Meissner Analyst, which has five indicators to check the performance of the receiver at as many strategic points simultaneously, it is possible to localize the fault to a certain portion of the receiver the first time that the signal fades.



The figure at the left shows a block diagram of a conventional superheterodyne receiver and the points where the various channels of the Analyst are normally connected for the first test on an intermittent receiver. The figure at the right shows, in a similar type of diagram, the most logical places to connect the indicators to a conventional T.R.F. receiver.

The controls can be set so that all four indicator shadows just close and the voltmeter reads the AVC voltage. Then, if a fault occurs, the appearance of some, or all, of the indicators will change, indicating the portion of the receiver in which operation is not normal. In other words, all of the necessary test instruments are connected to the receiver before the fault occurs so that they may be observed during the faulty operation of the receiver without disturbing the set.

If the last indicator that shows normal signal, and the first indicator that shows abnormal signal, are separated by several circuits or stages, it is usually possible to attach the test prods to points closer together for the second test and, thereby, to restrict the part of the receiver under test so that on the second fade the defective part can be located more closely. Sometimes a third operation is possible, narrowing down still more the region that must be closely inspected for the faulty unit, but usually the region is so restricted by the second test that it is a simple matter to locate the defective part.

The Supreme Instruments Model 562 Audolyzer falls into the group of instruments we are now discussing, although it is greatly simplified when used for signal tracing and incorporates, besides the vacuum tube voltmeter, an ohmmeter and output indicator. We illustrate the circuit of this instrument and quote from its instruction manual the general description and function of this instrument.

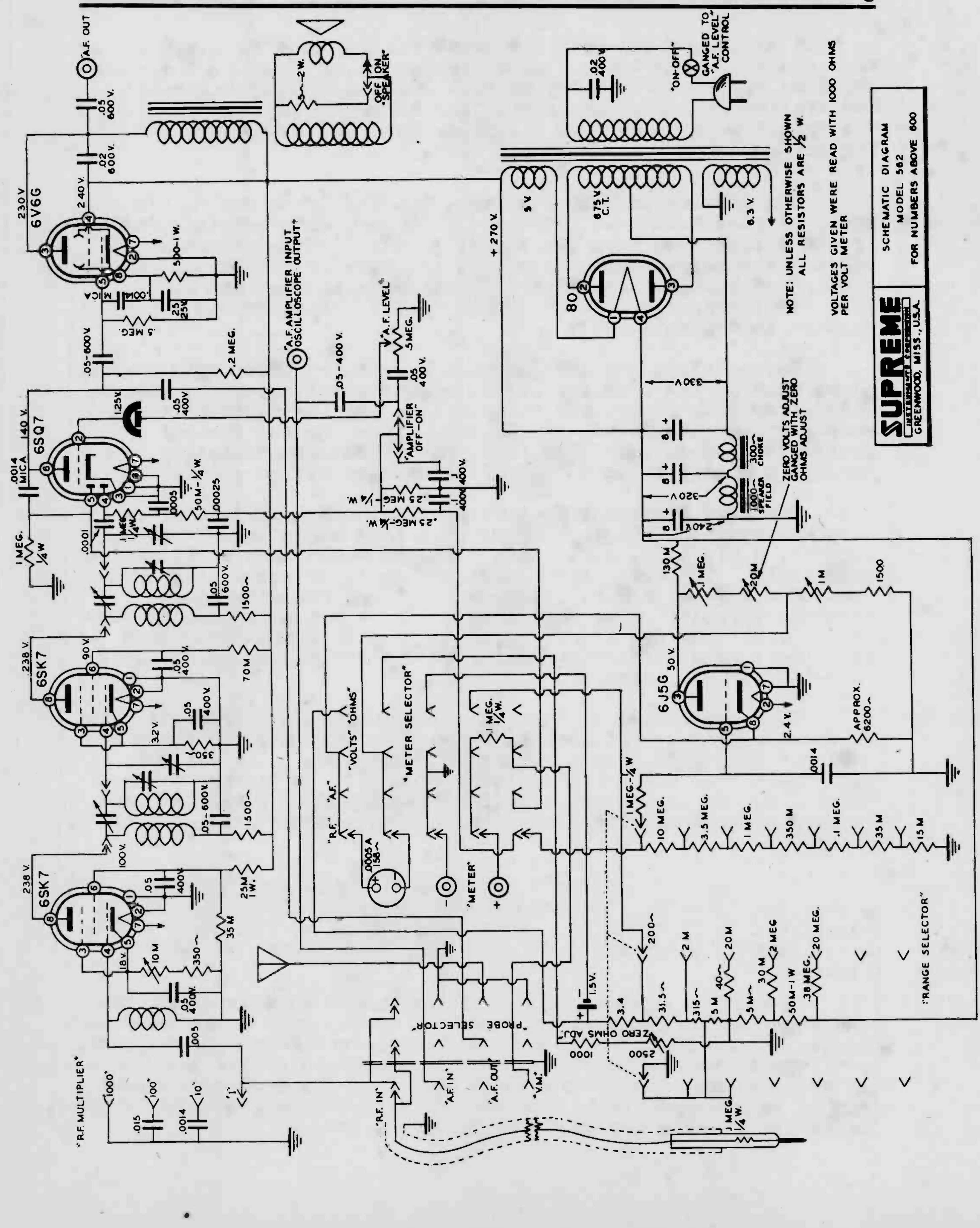
Essentially, the Audolyzer is a radio receiver with provisions whereby the operator may eliminate any stage or section under suspicion in the customer's radio and use sections of the Audolyzer for substitution. All functions for the general procedure used in servicing radio receivers are accessable through a single probe and a multi-function switch selector.

The most important feature of the instrument is that it is a signal monitor. Regardless of what type signal you want to explore, R.F., I.F., A.F., or oscillator, means are provided for such tests. The radio frequency section is composed of one untuned and two tuned R.F. stages which terminate at a diode detector circuit. This amplifier covers a range from 95 KC. to 14.5 MC. in five overlapping bands. The audio amplifier uses two stages of amplification to provide aural indication on a five-inch dynamic speaker.

The vacuum-tube voltmeter is designed with characteristics of the single-tube bridge type which provides good stability of calibration. This unit covers a wide range and will measure potentials from 0.1 volts to 1000 volts D.C. A feature of this section is the center scale dial calibration which permits both forward or backward indication to be read without reversing the probes.

The ohmmeter is of the conventional ring type described in a previous lecture. Resistance may be measured from 0.1 ohm to 20 megohms in five ranges. This function is particularly useful in confirming short and open circuits, continuity, and other tests.

A word of caution is in order to close this lecture. The ownership of an advanced type of instrument, such as we have just discussed, does not imply that such equipment should be used on every radio repair job. You should attempt to locate the fault in the minimum of time using the technique and equipment which may be best adaptable in the particular instance. Advanced type of signal tracers are best for the tough jobs.

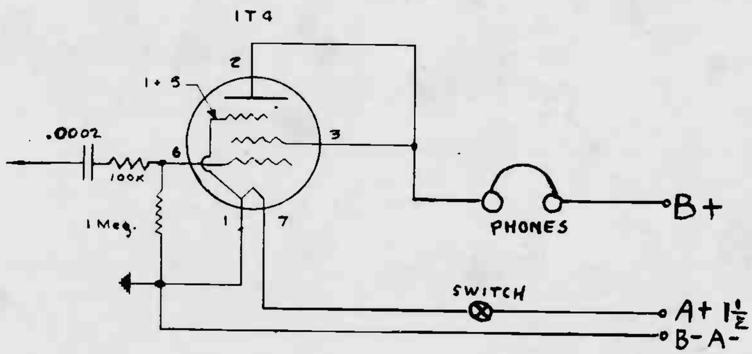

SCHEMATIC DIAGRAM
MODEL 562
FOR NUMBERS ABOVE 600
SUPREME
GREENWOOD, MISS., U.S.A.
NOTE: UNLESS OTHERWISE SHOWN ALL RESISTORS ARE 1/2 W.
VOLTAGES GIVEN WERE READ WITH 1000 OHMS PER VOLT METER
"METER SELECTOR"
"RANGE SELECTOR"
"PROBE SELECTOR"
"R.F. MULTIPLIER"

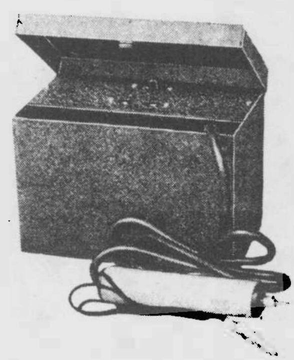
Lecture 15

Simplified Signal Tracers

In 1945, simplified versions of signal tracing instruments were released. These lower priced instruments permitted one to listen to the existing signal at various points in the radio under test, and either incorporated a meter or had provisions for connecting a meter for comparative measurements.

The Feiler Model TS-1 is a very simple instrument and an examination of its basic schematic below will suggest its mode of operation. The capacitance-resistance input network will not upset or de-tune the circuit under test. When operated at R.F. or I.F. frequencies, this network provides correct values to convert the type 1T4 (pentode connected as a triode) to a grid leak type detector. Because of the small value condenser, the unit will produce louder signals from higher frequencies. This is just what is wanted since by operating more efficiently at R.F. than I.F., the unit can automatically adjust for the greater signal level of I.F. signal obtained from a radio under test.

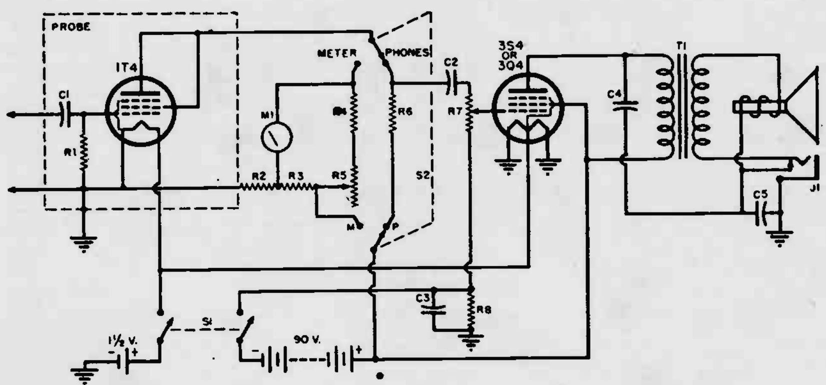




In using the unit for audio tests, no special adjustments are needed; in fact, there is no adjustments needed for any test and the probe can be touched safely to any point of the circuit. In this application, the impedance of the grid condenser and grid leak form a voltage divider network, and only a fraction of the strong incoming audio signal is impressed on the grid. The impedance of a small condenser at audio frequencies is very high; for example, at 1,000 cycles, a .0002 mfd. condenser will have an impedance of about 750,000 ohms. This automatic action is also what is wanted and the signal is reduced to a value that can be handled by the tube with its very small bias obtained from a voltage drop in the filament and from contact potential voltage.

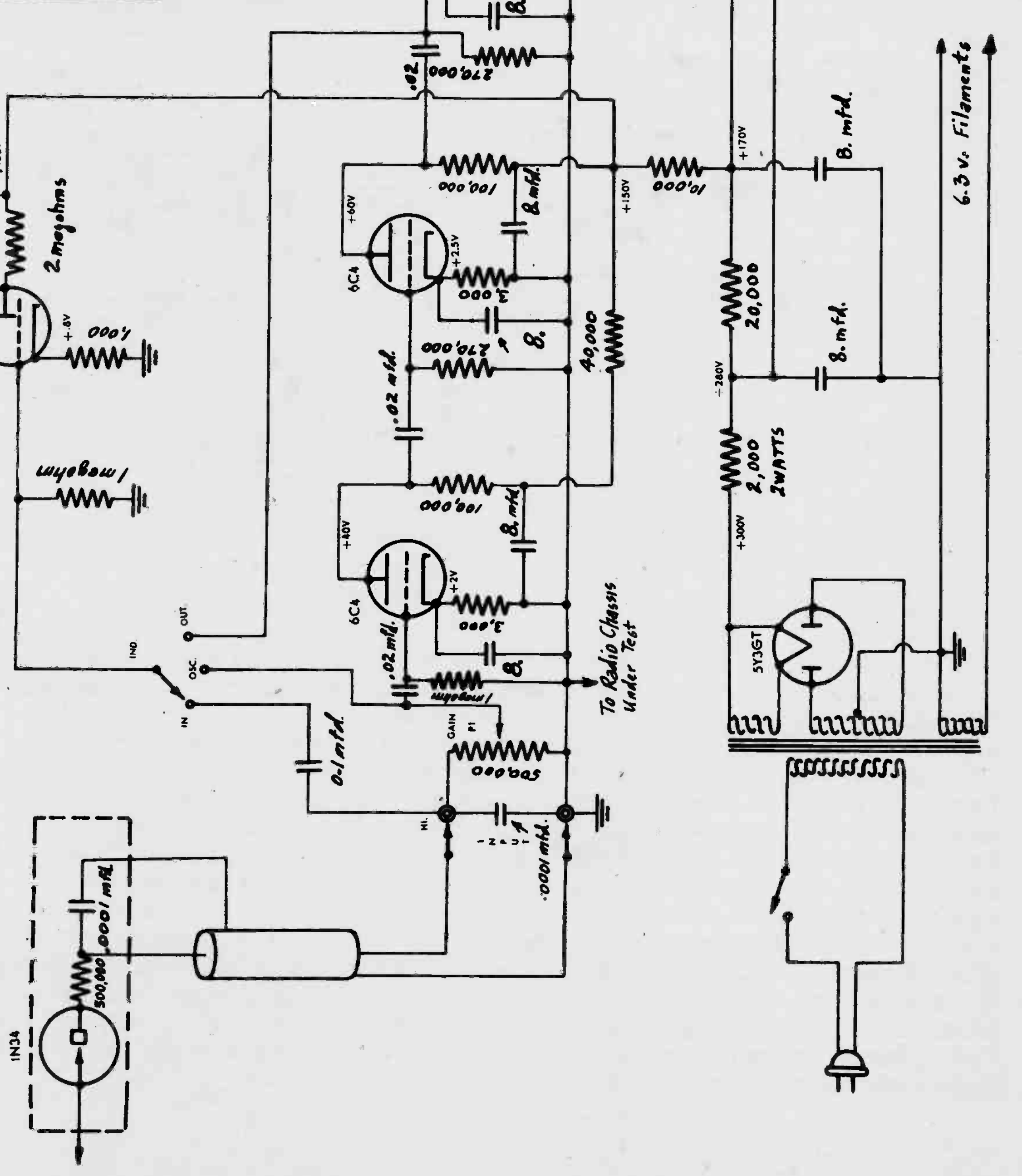
The output from this single stage (when used with a $67\frac{1}{2}$ volt plate battery) is sufficient to operate a pair of headphones. In this manner, it is possible to test for the signal at all points of a radio receiver without any adjustments at all and without risk of damaging the test unit or the radio.

The Superior Model CA-12 signal tracer was described in a past issue of RADIO NEWS and we reproduce the schematic of this unit through the courtesy of this magazine. The input arrangement is similar to the unit we just described. A meter is incorporated in the plate circuit and permits the use of the instrument as a vacuum tube voltmeter to measure input signal strength. To obtain audio output from the loudspeaker of the tester or separate phones, a double-pole double-throw switch is used to connect the output of the probe-tube to an audio amplifier stage employing either a 3S4 or 3Q4 pentode.



R_1—20 megohm, ½ w. res.
R_2—20,000 ohm, ½ w. res.
R_3—1000 ohm, ½ w. res.
R_4, R_8—500 ohm, ½ w. res.
R_5—500 ohm rheostat
R_6—50,000 ohm, ½ w. res.
R_7—500,000 ohm pot.
C_1—.0002 μfd. mica cond.
C_2, C_4—.025 μfd., 200 v. cond.
C_3—4 μfd., 10 v. elec. cond.
C_5—.002 μfd., 200 v. cond.
S_1—S.p.d.t. sw.
S_2—2-pole, 2-pos. sw.
M_1—0-1 d.c. milliammeter
T_1—Output trans., 10,000 ohms plate to voice coil
J_1—Closed circuit jack
1—1T4 tube
1—3S4 or 3Q4 tube
1—4" PM Speaker

The operation of the vacuum tube voltmeter may be described briefly as follows: When there is no signal applied to the grid, current flows in the plate circuit because there is no bias on the grid. When a signal is applied to the grid, rectification takes place and the current flowing through the grid resistor biases the tube, causing the plate current flowing to drop. In order to make the meter give positive current readings for decreases in tube plate current, the meter is connected in reverse (plus terminal to plate, and minus to B+) and a bucking voltage applied across the meter to bring the reading to zero when there is no signal. Meter current is adjusted to zero for no signal by means of the 500 ohm balancing potentiometer. Then, when a signal is applied to the grid, the meter reads up scale in the conventional manner. The calibration is not in volts, but in relative signal strength.


MODEL 905 "SPARX"
P
B+
6AK6
6C4
6C4
6E5
5Y3GT
1N34
OUTPUT
INT
AMP
SPK
IND
OSC
IN
OUT
GAIN
HI.
2 megohms
1 megohm
1,000
510
270,000
100,000
10,000
20,000
2,000 2 WATTS
40,000
3,000
500,000
.02
.02 mfd.
8. mfd.
0.1 mfd.
.0001 mfd.
+170V
+270V
+150V
+60V
+40V
+280V
+300V
To Radio Chassis Under Test
6.3 v. Filaments

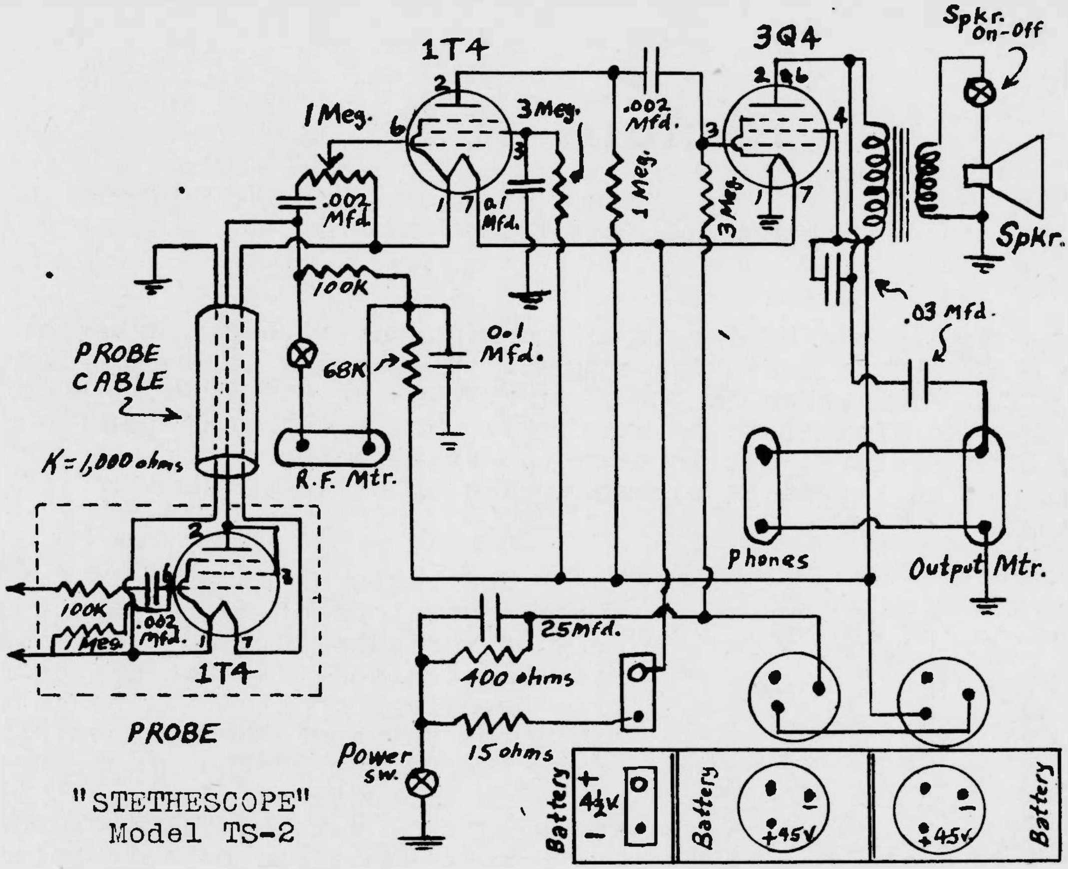
The Silver "Sparx" tester is an aural-visual signal tracer. This unit uses a new type 1N34 crystal diode rectifier. This rectifier, a 500,000 ohm anti-loading resistor, and an R.F. by-pass condenser are housed in a test prod which is connected to the main cabinet through a flexible shielded cable. With the probe, a test for existing signal may be made at all points in a radio and in this manner the stage at fault can be isolated. The tuning-eye indicator can be connected directly across the input jacks of the instrument and in this position the size of the shadow will indicate the relative value of the signal voltage. The position marked OSC. is for estimating R.F. voltages generated by oscillators in superhet sets and for comparing D.C. voltages. In this position, the 6E5 shadow is controlled by the gain potentiometer.

The indicator tube may also be connected, by means of the same switch, to the output of the second audio stage and can then be used for comparing the strength of audio signals. The gain potentiometer P1 is linear and is calibrated to show percentage of the input voltage impressed upon the audio amplifier input.

This instrument may be used for checking oscillator tube operation, for tracing hum and noise, for testing AVC function, for gain estimation, and as a voltmeter. This last application of measuring voltage is approximate and depends on establishing a suitable reference level with a known voltage. Phonograph pickups may be tested by being connected to the input jacks. Loudspeakers can be tested with the Sparx and the speaker of the service instrument may be employed with other equipment. The instrument, of course, may be used as a complete receiver if some simple tuning arrangement is connected to the input of the probe.

From the schematic diagram of the Feiler "Stethescope" Model TS-2, you will observe that the unit incorporates the probe section and an additional two-stage audio amplifier to produce the output from the loudspeaker included. The unit is battery operated and, in this way, is self-contained and is adaptable for portable use. There is also an A.C. model which has a built-in power supply. A regular 0-1 ma. meter can be connected for observing the intensity of the R.F. signal. Phone terminals are also provided.

We will now outline the general servicing procedure in using signal tracers of the type described. With the aid of a signal tracer it is possible to locate quickly the section of the radio receiver which is causing the difficulty. For this purpose, the ground lead of the tester is connected to the radio chassis and the probe is touched to points where signal is expected, progressing from antenna to speaker. The point beyond which the signal is no longer obtainable is in the section which contains the fault.



"STETHESCOPE"
Model TS-2

As you progress with the test suggested, the signals should become stronger. Should any of the tests indicate a weakening of the signal, the stage preceeding this point is not operating properly and is producing a loss instead of a gain.

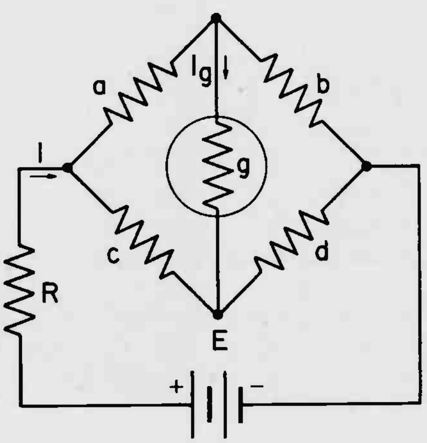
To locate an intermittent fault, the probe is placed on points where signal is to be expected, progressing from antenna to speaker. For each test made, try to obtain the intermittent failure, so that you can determine where the fault producing this failure lies ahead of the point under test or beyond this point. For example, if you are testing at the plate of the first I.F. tube, the turning the set on and off, shaking it, touching and pushing various parts, or doing similar things which ordinarily produce the intermittent condition, in this case do not cause the intermittent to appear in the output of the signal tracer, you can form the following deduction. Since in the test described, portions of the radio set ahead of the point under test were in the circuit serving the signal tracer output, but did not produce any intermittent indication, then these sections (ahead of the point) must be in good operating condition. The fault lies beyond the point at which you are testing. Further, tests after this point will isolate the stage and suggest the parts that may be at fault.

Test for noise, hum, or distortion is carried out in a similar manner. In alignment work, a signal tracer may be employed as the audio output indicator.

Lecture 16

Advanced Test Equipment

The Wheatstone Bridge is an arrangement of components to provide a sensitive measuring system. The bridge is ordinarily drawn in the form shown in the figure. One of the arms is supplied by the unknown element to be measured. The other arms usually consist of resistors, but in case the voltage source is alternating the arms may be impedance elements made up of capacitors or inductances.



The ratio of resistance (or impedance) values of two adjacent arms may be variable so that a balance can be obtained. It is then possible for practical application to calculate the value of the unknown element from the values of the other three. In some circuits no adjustment is carried out, but the value of the unknown element can be calculated from the current of the measuring galvanometer, item g, and other known components. In fact, the scale of the measuring instrument can be graduated to read the value of the element directly in ohms of resistance (or impedance).

Below is reprinted the mathematical development in obtaining the relationship between the factors mentioned. This material is reproduced from "Weston Engineering Notes" of February, 1946, through the courtesy of Weston Electrical Instrument Corp.

The general solution for the galvanometer current follows:

$$I_g = \frac{E(bc-ad)}{R(a+c)(b+d)+Rg(a+b+c+d)+ab(c+d)+cd(a+b)+g(a+b)(c+d)} \quad (1)$$

where I_g is the galvanometer current in amperes, E the applied battery voltage in volts and g the galvanometer resistance in ohms.

With the battery polarity shown, a positive value of I_g indicates that galvanometer current will flow as indicated.

In many bridge networks the effective series resistance, R is non-existent or can be considered so in view of the very much larger values of resistance in the bridge arms, giving effectively a constant voltage bridge. If R is considered as zero, the equation reduces somewhat and

$$I_g = \frac{E(bc-ad)}{g(a+b)(c+d)+ab(c+d)+cd(a+b)} = \frac{E(bc-ad)}{ab(c+d)+(a+b)(cd+gc+gd)} \quad (2)$$

Note that the equation is presented in two forms since sometimes one form is easier to solve than the other.

If R is very large so as to dominate the network or, if due to some other circuit condition the current entering the bridge is fixed and known, we have a constant current bridge. The galvanometer current may then be calculated in terms of the current entering the bridge.

$$I_g = \frac{I\ (bc+ad)}{(a+c)(b+d)+g(a+b+c+d)} \quad (3)$$

The resistance of the bridge presented to the battery is given by

$$Res. = \frac{(a+b)cd+g(a+b)(c+d)+ab(c+d)}{(a+c)(b+d)+g(a+b+c+d)} \quad (4)$$

This will allow for obtaining the total current taken by the bridge from the battery for any set of conditions.

In the selection of a galvanometer the resulting damping of the galvanometer pointer is usually governed by the resistance in shunt to it and this shunt resistance is given by the equation

$$R_s = \frac{(b+d)ac+bd(a+c)+R(b+d)(a+c)}{(a+b)(c+d)+R(a+b+c+d)} \quad (5)$$

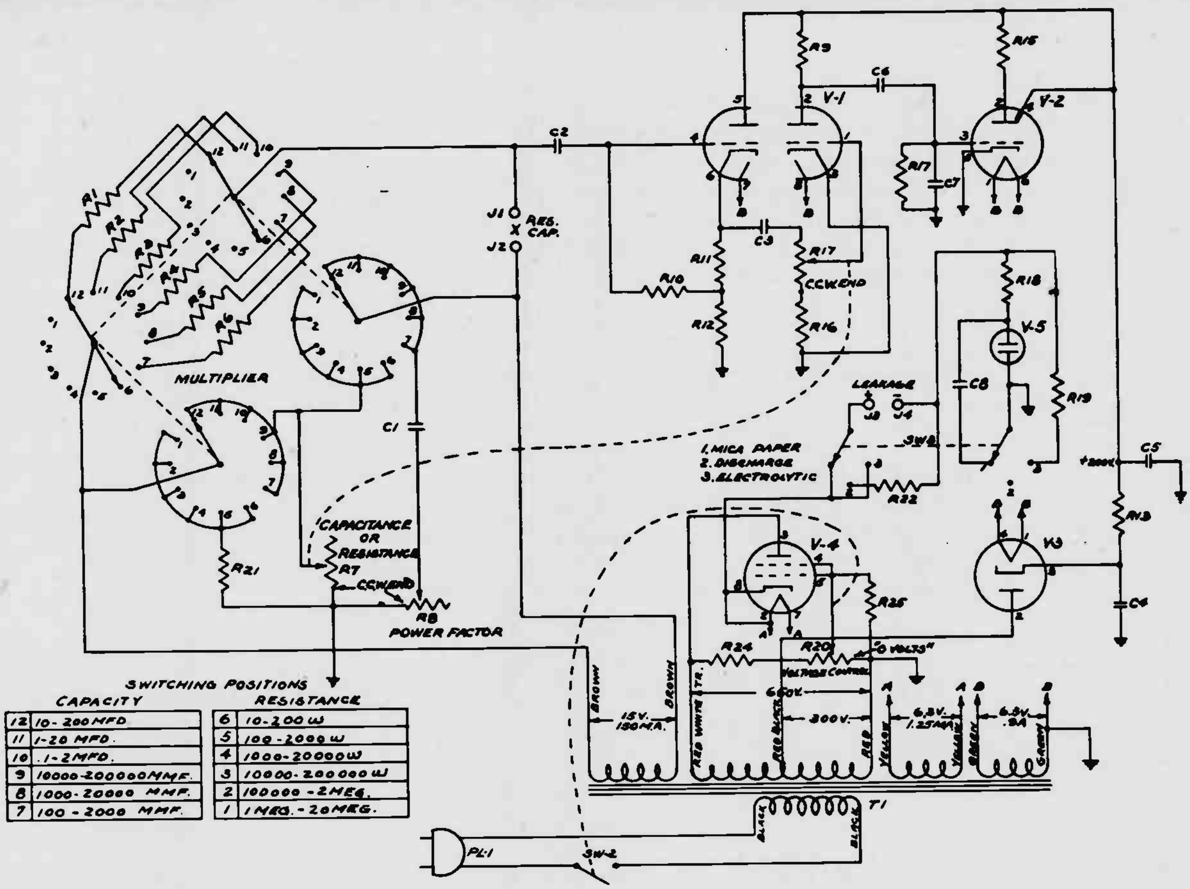
If R equals zero, or, if the bridge is very nearly balanced, the equation simplifies to

$$R_s = \frac{(b+d)(a+c)}{a+b+c+d} \quad (6)$$

Bridges of various types are used in laboratory work and also form important sections in some test units used by radio servicemen. We have already observed the use of bridge networks in balanced vacuum tube voltmeter circuits. Capacity testers depend on a bridge arrangement for their function and these instruments will be discussed now.

The Aerovox Model 76 capacity and resistance bridge can be employed to measure capacitors ranging in value from 100 mmfd. to 200 mfd., and resistors from 10 ohms to 20 megohms. Provisions are also included for the measurement of the power factor as well as a qualitative test for leakage in all types of capacitors. Please examine the complete schematic of this instrument. The description of the function and operation to follow is taken from the instruction booklet supplied with the instrument and thanks is extended to the Aerovox Corporation for their permission.

As you have observed, a Wheatstone Bridge is used at the input to the capacitor tester. Such a bridge is simple to operate and requires but one adjustment for balance (i.e., zero current through the galvanometer if one is employed). The bridge used in this tester is operated on A.C., and for resistance measurements all four arms are pure resistances. When the controls of the tester are set for resistance measurements, the bridge is connected as shown in the adjacent figure. This is a simple resistance bridge operated on A.C. The equation for Rx, the unknown resistor, is:



SWITCHING POSITIONS

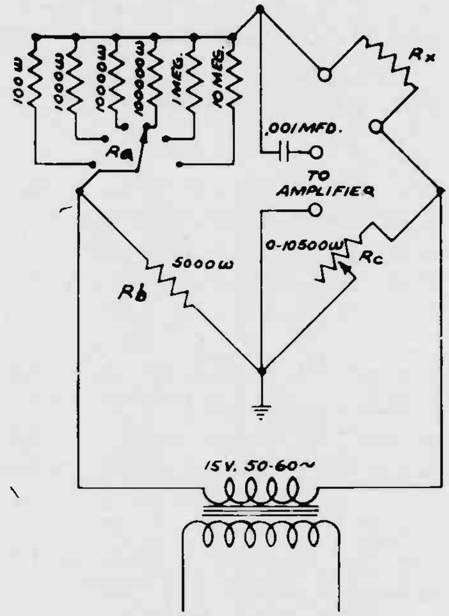
CAPACITY		RESISTANCE	
12	10-200 MFD	6	10-200 ω
11	1-20 MFD.	5	100-2000 ω
10	.1-2 MFD.	4	1000-20000 ω
9	10000-200000 MMF.	3	10000-200000 ω
8	1000-20000 MMF.	2	100000-2 MEG.
7	100-2000 MMF.	1	1 MEG.-20 MEG.

Symbol	*DESCRIPTION*
R1	100 ohms resistor, 1 watt ±2%
R2	1,000 ohms resistor, ½ watt ±2%
R3	10,000 ohms resistor, ½ watt ±2%
R4	100,000 ohms resistor, ½ watt ±2%
R5	1 megohm resistor, ½ watt ±2%
R6	10 megohm resistor, ½ watt ±2%
R7, R14	5 megohm and 10,500 watt potentiometer
R8	1,000 ohms potentiometer
R9, R13	100,000 ohms resistor, ½ watt 20%
R10	5 megohm resistor, ½ watt 20%
R11	1,500 ohms resistor, ½ watt 20%
R12	70,000 ohms resistor, ½ watt 20%
R15, R16, R17	1 megohm resistor, ½ watt 20%
R18, R22	30,000 ohms resistor, ½ watt 20%
R19	5,100 ohms resistor, 2 watts, 5%
R20-SW2	1 megohm carbon potentiometer with single-pole, single-throw switch
R21	5,000 ohms wire-wound resistor ±1%
R24	330,000 ohms ½ watt resistor 20%
R25	2 megohm resistor, ½ watt, 20%

C1	2 mfd. capacitor (1 mfd.-1 mfd.)
C2	.001 mfd. 400 volt capacitor
C3, C6, C7	.01 mfd. 400v. capacitor
C4, C5	4 x 4 mfd. dual capacitor 450v.
C8	.1 mfd. 200v. capacitor
V1	6SL7 Tube
V2	6E5 Tube
V3	1V Tube
V4	6V6G Tube
V5	991 Tube
SW1	Range Selector Switch
SW3	2-pole, 2-position Switch
T1	Transformer
J1, J3	Jack
J2, J4	Jack
PL-1	Line Cord

AEROVOX

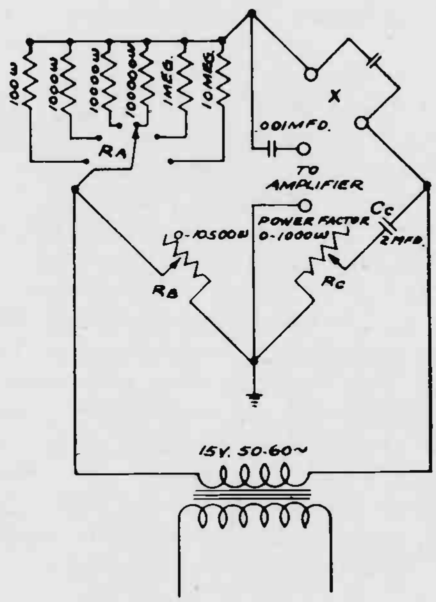
Model 76



$$R_x = \frac{R_a}{R_b} R_c$$

Ra is chosen by the multiplier switch which is marked with the appropriate multiplication factors. Rc is the variable resistor which has been adjusted so as to be variable from 0 to 10,500 ohms. Its setting is controlled by the main calibrated dial on the instrument panel. The bridge source voltage is provided by a special winding on the power transformer and delivers 15 volts at the power line frequency.

The output of the bridge is applied to the input of a 6SL7 twin-triode high gain amplifier. The output of this stage is applied to the grid of a 6E5 indicator tube which is very sensitive to the balance point of the bridge, indicated by maximum opening of the eye.



Two balances are required in the measurement of capacitance. First, the bridge indicator should connect two points of equal potential and satisfy the equation

$$\frac{R_x}{R_a} = \frac{R_c}{R_b}$$

second, the alternating potentials at the two points must be in phase with each other to satisfy the equation

$$\frac{C_x}{C_c} = \frac{R_b}{R_a}$$

The first equation indicates a balance of resistance components, the second a balance of reactance components. In the bridge circuit shown, the value of Cx is:

$$C_x = \frac{R_b}{R_a} C_c$$

$$\text{POWER FACTOR} = \frac{100\,R_c}{\sqrt{R_c^2 + \left(\frac{1}{\omega C_c}\right)^2}}\ \text{PERCENT}$$

From this it is apparent that the balance adjustments for capacity and power factor are not interlocking and that Rc can be directly calibrated in percent power factor, since the value of Cc is a constant.

A D.C. polarizing potential continuously variable from 0-600 volts is provided for the leakage test. The "Voltage Control" R20 is a 1 megohm potentiometer for adjusting the control voltage on the grid of the 6V6G, a grid controlled type of rectifier tube well suited for the purpose.

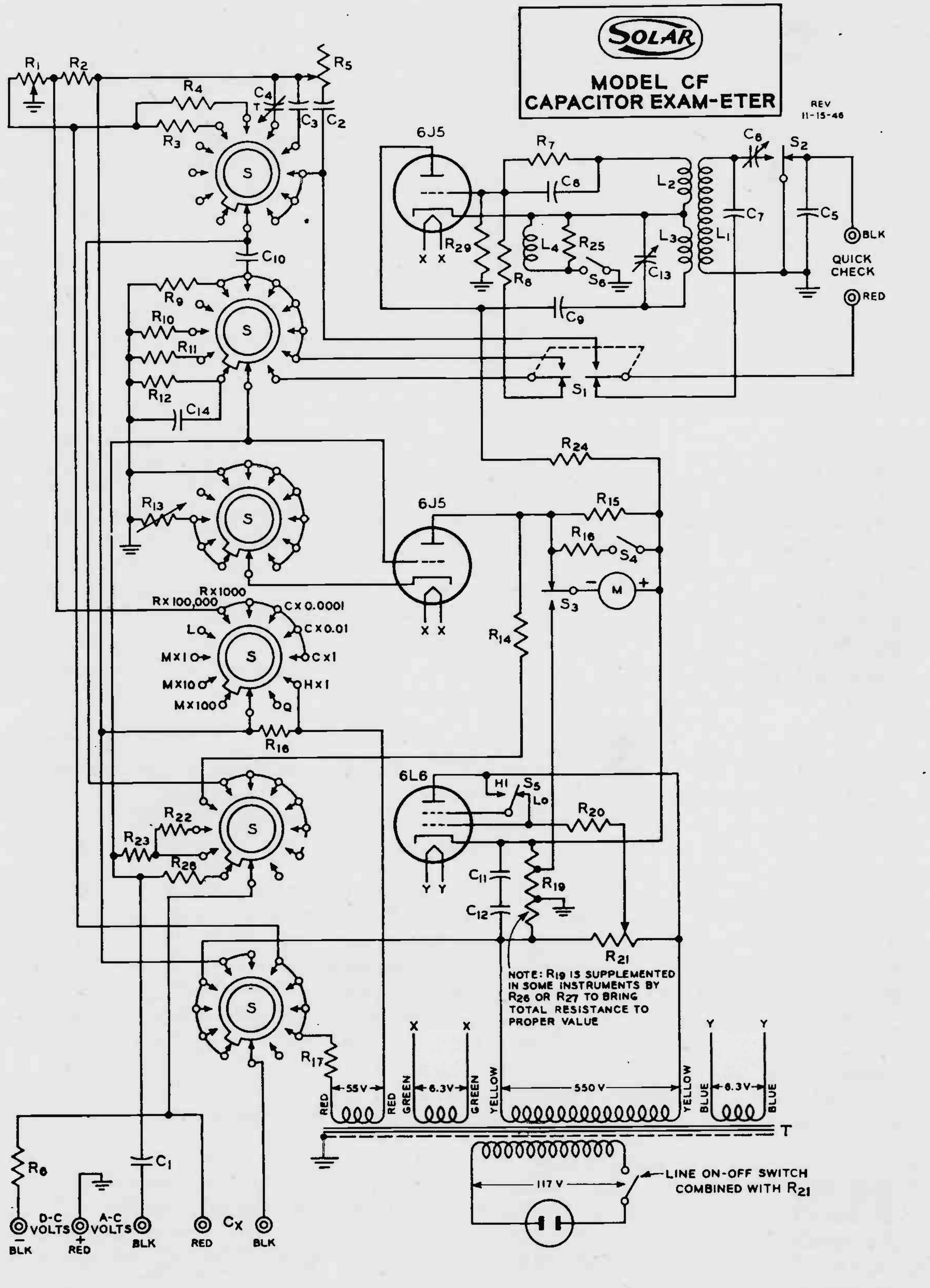
A two-circuit 3-position knife switch SW3 chooses the proper circuit for indicating leakage of electrolytic capacitors in one position and that of all mica and paper capacitors in another. The neutral position of the switch serves to safely discharge the capacitor under test through resistor R22.

A neon filled type 991 tube serves as an indicator for the leakage tests. The characteristics of the 991 are such that it will glow when the voltage across it rises above a certain point. R18 serves to limit the current thru the 991 tube to a safe value when it is conducting.

With an electrolytic capacitor connected to the leakage test terminals and SW3 thrown to the "Elec" position, the existing circuit consists of the polarizing voltage in series with the capacitor under test and resistor R19. The current flow through this circuit is then dependent on the magnitude of the polarizing potential and the leakage merit of the electrolytic under test. When the current flow becomes large enough, the voltage drop across R19 is sufficient to cause the 991 tube to conduct. Proper choice of R19 and the calibration of the "Voltage Control" dial furnish the necessary parameters for determining the leakage merit of any electrolytic capacitor.

With the knife switch thrown to the "All M-P" position, R19 is replaced by a capacitor, C8. If a leaky mica or paper capacitor is connected across the leakage test terminals, the circuit acts as a relaxation oscillator, as follows: C8 will tend to charge to the polarizing potential through leakage resistance of the test capacitor. When the charge of C8 reaches the voltage sufficient to start the 991 tube conducting, C8 will discharge through the now conducting 991. The 991 will extinguish when C8 discharges to a potential insufficient to maintain conduction in the 991 tube. C8 will start to charge up again and the process will repeat itself at a constant rate. Since C8 is constant, the leakage resistance in the capacitor under test determines the rate of flash of the indicator tube. A leakage resistance of 100 megohms will cause the tube to flash at a rate of from 20 to 40 times per minute. Higher leakage resistance causes a lower flash rate, while a lower leakage resistance will increase the flash rate.

A tester adaptable for measuring and analyzing condensers and for measuring the value of resistors, which depends on an entirely different principle, will be described next. This unit is made by Solar Manufacturing Corp., and we are indebted to this firm for much of the material on their Model CF as stated below.


SOLAR
MODEL CF
CAPACITOR EXAM-ETER
REV 11-15-46
NOTE: R19 IS SUPPLEMENTED IN SOME INSTRUMENTS BY R26 OR R27 TO BRING TOTAL RESISTANCE TO PROPER VALUE
LINE ON-OFF SWITCH COMBINED WITH R21
QUICK CHECK
D-C VOLTS
A-C VOLTS
6J5
6J5
6L6
117 V
550 V
55 V
6.3 V
6.3 V
RX100,000
RX1000
CX0.0001
CX0.01
CX1
HX1
MX1
MX10
MX100

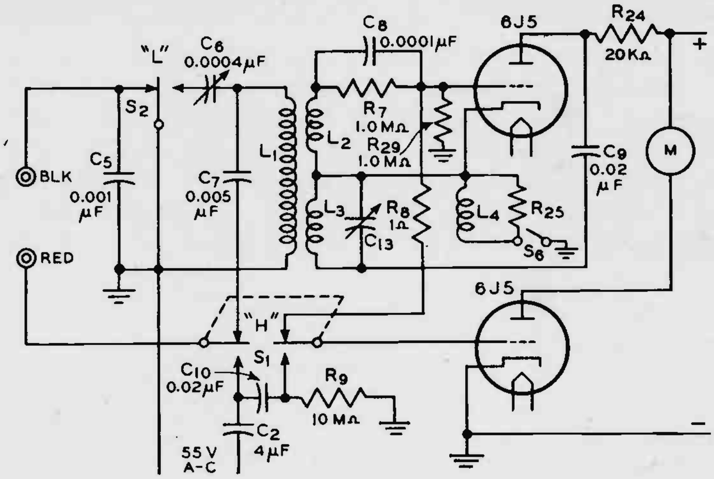
The complete circuit is shown on page 141 and the list of parts is included at the bottom of page 142. The circuit has been patented and consists essentially of a balanced R.F. oscillator, a source of A.C. voltage, and a vacuum tube voltmeter intended to measure A.C. Under normal conditions, the circuit is balanced and will not oscillate when the test leads are connected. This condition will produce full scale deflection (5 ma.) on the meter included in the plate circuit of the 6J5 tube used in the vacuum tube voltmeter.

If the test clips are placed across an open-circuited capacitor, there will be no change in circuit conditions and the meter needle will not deflect. If the capacitor is intermittent, the needle will fluctuate violently as the oscillator goes in and out of oscillation. If the unknown capacitor causes the needle to drop downscale, the capacitor is not open-circuited and further "Quick-Check" tests must be performed. Pressing the "L" button for capacitors from .0001 mfd. to approximately .003 mfd. will stop the oscillation if the capacitor is short-circuited and the meter will return to full-scale. Capacitors from approximately .003 mfd. to 50 mfd. can be checked for shorts by pressing the "H" button. This places the unknown capacitor in series with a 4 mfd. capacitor across an A.C. source and connects the vacuum tube voltmeter across the unknown capacitor. If it is short-circuited, the meter needle will return to full-scale since there will be no voltage drop across the capacitor under test. These tests may be applied with the condenser under test still wired in its circuit and the radio being repaired turned "on."

Description

C1, C9, and C10 .02 mfd., 200 v.
C2 4 mfd., 100 v.
C3 .04 mfd., 100 v.
C4, C6 250-500 mmfd., adj. mica
C5 .001 mfd., 500 v.
C7 .005 mfd., 500 v.
C8, C14 .0001 mfd., 500 v.
C11, C12 8 mfd., 350 v.
C13 15-130 mmfd., adj. mica
R1 10,000 ohms potentiometer
R2 119,500 ohms, ± 2%
R3 400,000 ohms, ± 2%
R4 4,000 ohms, ± 2½%
R5 400 ohms potentiometer
R6, R11, R22 1 megohm, ± 2%
R7, R8, R20, R-29 1 megohm
R9, R25 10 megohms
R10 100,000 ohms, ± 2%
R12 10 megohms, ± 2%
R13 1,000 ohms, ± 5%, adj.
R14 5,000 ohms
R15 510 ohms, ± 5%
R16 2.8 ohms, ± 2%
R17, R18 220 ohms
R19 Special resistor, total 120,000 ohms, tapped at 500 and 60,000 ohms
R21 500,000 ohms potentiometer
R23 2 megohms
R24 20,000 ohms
R26 4,000 ohms, ± 5%
R27 8,000 ohms, ± 5%
R28 9 megohms, ± 2%

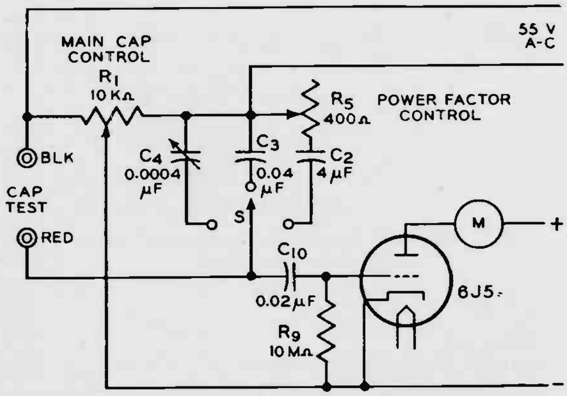
The above description and value of parts given is for study of the circuit and is not intended to serve as a complete description in case replacement parts are needed.



THE "QUICK-CHECK" CIRCUIT

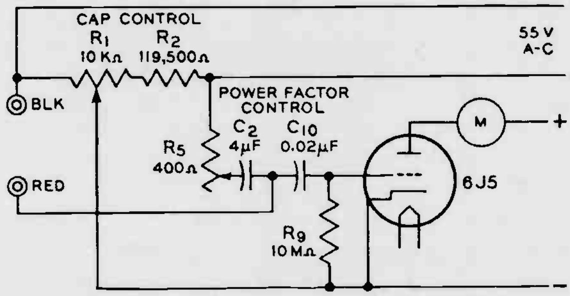
The "Quick-Check" section is comprised essentially of an a-c voltage supply source, an a-c vacuum tube voltmeter and a balanced radio-frequency oscillator. For diagrammatic simplicity, the switching system and power supply have been omitted.

An intermittent capacitor may be the result of a pressure contact only between the capacitor section and the terminals. The connection may be broken as the result of mechanical vibration or displacement of the capacitor, or as the result of expansion of section leads, etc., under temperature rise. Slight rocking of a capacitor will often detect intermittents since it will cause the needle to fluctuate on the "Quick-Check" test as described, or when the short test buttons are held down. Where heat-caused intermittents are suspected (wax-end seals may hold defective parts together when set is first turned on), the test leads can be placed across the suspected capacitor and other work attended to while the tester stands guard over the set, waiting for it to fail. When fading or other defects appear, a glance at the unit tells whether the capacitor under test is faulty.



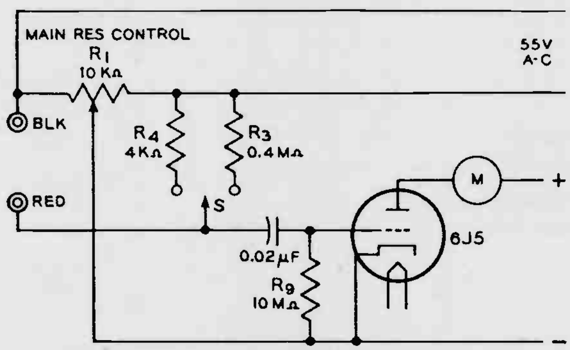
LOW CAPACITANCE BRIDGE CIRCUIT

Quantitative capacitance measurements from 10 mmfd. to 2,000 mfd. are made on a 4-range line-frequency capacitance bridge. The figure shows a simplified schematic diagram of the DeSauty bridge employed by the Cx.0001 and Cx.01 ranges and the Wien bridge used on the Cx1 range. It will be seen that the main dial potentiometer acts as the continuously adjustable ratio arm of the bridges. Consequently, a highly accurate linear-taper wire-wound variable resistor must be used for the main bridge element in order to assure accurate matching of the calibrated scale. The standard capacitor for the CX.0001 range is a mica trimmer, which is adjusted to take into account variations in wiring capacitance. A simple vacuum-tube voltmeter is used as the bridge null detector. The bottom figure shows the circuit variation to extend the range of the Wien Bridge of the first



HIGH CAPACITANCE BRIDGE CIRCUIT

figure. Here R1 and R2 together comprise the calibrated adjustable ratio arm of the bridge. R5 is the power-factor balance rheostat in both figures.

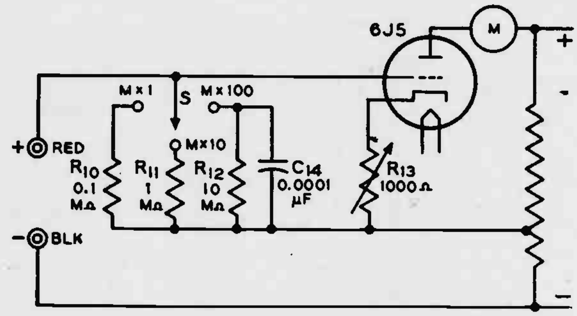


RESISTANCE TEST CIRCUIT

Dual range a-c Wheatstone bridge used for resistance measurements.

Resistance measurements are made on a conventional 2-range A.C. Wheatstone bridge. A simplified schematic diagram is shown. It will be seen at a glance that it is quite similar to the DeSauty capacitance bridge arrangement described.

Insulation resistance measurements are made by the electronic test circuit shown. Leakage current through the capacitor or circuit element under test causes an increase in the negative bias on the triode grid and a consequent drop in plate current. The plate circuit milliammeter is calibrated directly in megohms.



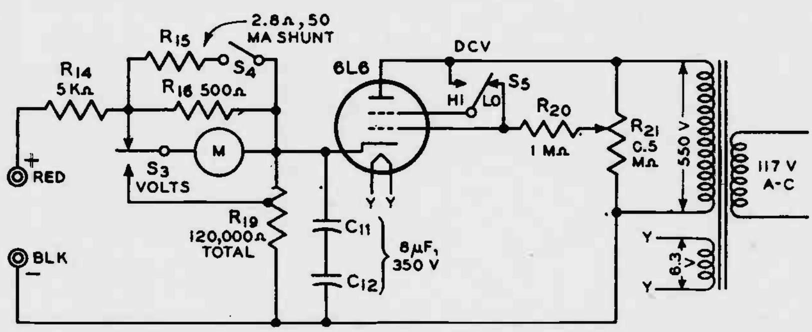
FUNCTIONAL INSULATION-RESISTANCE TEST CIRCUIT

I-R measurements are read in megohms directly from the calibrated milliammeter (M).

The leakage current of electrolytic capacitors may be measured at rated D.C. voltage by the test circuit shown. The circuit consists basically of a continuously adjustable voltage supply and a milliammeter to indicate the leakage current. The milliammeter current range may be increased by closing Switch S4, or it may be made to act as a voltmeter, indicating the impressed voltage across the capacitor under test, by depressing Switch S3. The test voltage is determined by the continuously adjustable voltage-divider resistor R21, which sets the control grid voltage on the rectifier tube. Plate and screen grids of the rectifier are normally connected together by Switch S5. When making

ELECTROLYTIC CAPACITOR LEAKAGE CURRENT TEST CIRCUIT

Simplified drawing showing continuously adjustable voltage power supply and instrumentation.



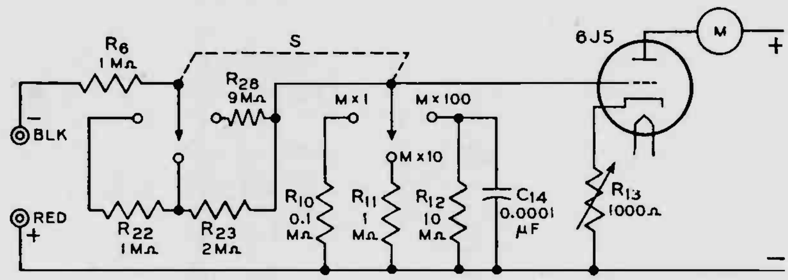
measurements on capacitors rated at 100 volts D.C. working or less, closer control of the test voltage is secured by throwing S5 to connect the rectifier tube screen grid to the control grid instead of the plate (Lo position of switch).

The leakage current of most dry electrolytic capacitors should come down to 2 ma. or less when 30 minutes of continuous rated voltage application has elapsed. If it does not, the capacitor should be replaced. If there is appreciable fluctuation in the leakage current, the capacitor is probably intermittent and should be replaced.

This Solar tester provides a 3-range overload-proof D.C. vacuum tube voltmeter. A simplified circuit is illustrated. It will be seen that application of a negative voltage through

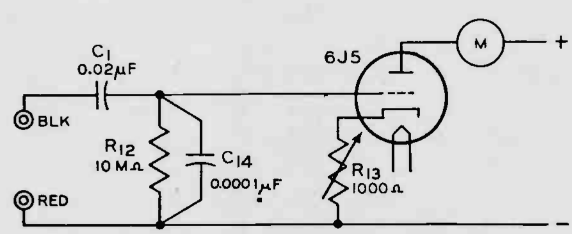
D-C VACUUM TUBE VOLTMETER CIRCUIT

Excessive applied potential biases tube beyond cutoff, thereby preventing meter overload.



the voltage divider network to the triode grid will cause a reduction in plate current of the tube. Special scales on the plate circuit milliammeter have been calibrated accordingly. Note that application of excessive potential will merely bias the tube beyond cutoff, the meter dropping back to zero ma. or full voltage deflection without the possibility of bending the pointer. The input resistance on the 30 volt range is 700,000 ohms per volt, on the 60 volt range 70,000 ohms per volt, and on the 600 volt range 3,500 ohms per volt.

The A.C. vacuum tube voltmeter may be used as an audio output indicator for output alignment. Figure below shows the circuit to be essentially that of a simple triode detector with a milliammeter in the plate circuit. As the signal strength increases, the plate current drops off in accordance with the tube characteristics. Since tubes may not be uniform, each tester is individually calibrated. The meter has a range of approximately 5 to 50 volts A.C.

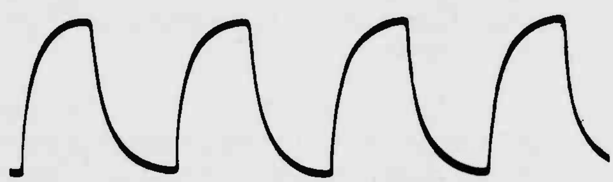


A-C VACUUM TUBE VOLTMETER CIRCUIT

A square wave generator is used as a source of square waves for production, experimental, and service purposes. The Hewlett-Packard Model 210A square wave generator can produce square waves of frequencies from 20 to 10,000 cycles per second, and a reasonable square wave can be obtained at frequencies as high as 100 KC. An outside source of signal is needed and usually an audio signal generator capable of supplying a driving voltage of two volts is employed. A few facts about the operation of this unit and the practical applications of square waves for test purposes are restated from the Hewlett-Packard catalog.

Square waves are formed in this generator by amplifying and clipping the tops of a sine wave, and thus converting it into a wave which has vertical sides and a flat top. The square wave voltage is applied to the amplifier or network under test; the shape of the output wave immediately shows up any distortion present. Because a sharp wavefront contains a large number of frequencies, this wavefront is distorted when all of the frequencies originally present are not transmitted. The frequencies contained in a uniform square wave are the fundamental and odd harmonics.

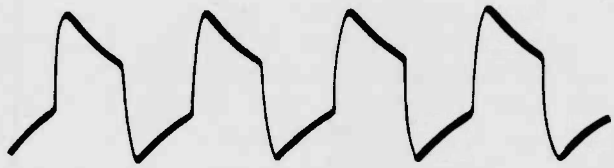
In practice, a wave which appears to be perfectly square will contain 30 or more harmonics, and when the amplitude or phase relation of the harmonics is disturbed, the square wave will be distorted. Thus, the application of a square wave to a circuit shows up any irregularities in amplitude or phase transmission not only at the square wave frequency but also at frequencies far removed from the test point.



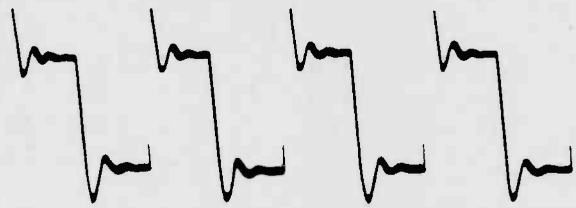
1. Square wave distortion from poor high frequency response.

When a square wave is applied to an amplifier, the top of the wave will show distortion if the frequency response of the amplifier does not extend to at least one-tenth the frequency of the square wave applied. Likewise, the sides of the wave will be distorted if the response of the amplifier does not extend to at least 10-times the frequency of the square wave applied. Thus, one observation with a square wave applied to an amplifier will check a wide frequency range, a range of 100 to 1, or even more. This is an extremely important fact because once the proper criteria have been established a production test can be set up with one or at the most two observations with a square wave. A square wave may also be employed to study phase shift effects in an amplifier. An amplifier will not produce a square wave faithfully unless both the amplitude and phase shift characteristics are correct. Thus, if the amplitude response is known to be good, phase shift effects can be determined with a square wave observation.

Peaks or deficiencies in amplification of an amplifier can readily be detected with a square wave generator. Tendency to oscillate will appear as damped oscillations on top of the amplified square wave and these oscillations can be measured both in frequency and amplitude with a given observation. A square wave is also very useful in determining the transient response of networks. Time constants of circuits can be easily observed, damped oscillations of resonant circuits can be checked, and the transient behavior of complicated networks can be studied by the application of a square wave to the network, making observations of the voltage or current with an oscilloscope.



2. Square wave distortion from poor response at both high and low frequencies (A typical amplifier response).



3. Square wave test on a feedback amplifier showing amplifier peak at 9 times square wave frequency (This characteristic would not be detected by normal measurements).

Before we study an important laboratory instrument, known as the Q-Meter, we will review the significance of the factor Q. This symbol is used to designate the ratio of reactance to the R.F. resistance of a coil, a condenser, or any two terminal network.

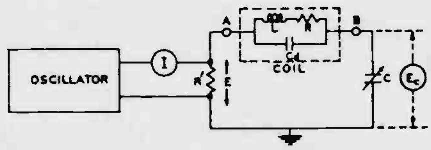
Usually reactance is the desired characteristic of a coil or condenser while resistance is not. For example, a figure of merit for coils is needed to enable us to judge between various coils. We call this figure of merit for comparative purposes, Q and it is equal to the inductive reactance divided by the R.F. resistance.

$$Q = \frac{\text{Reactance}}{\text{Resistance}} = \frac{X_L}{R} = \frac{6.28 \times f \times L}{R}$$

Since both the reactance and resistance increase with frequency, but not in the same order, the Q of coils will vary with the frequency used for the test. In the broadcast band, 540 to 1,750 kilocycles, the Q of coils increases for higher frequencies and special methods are used to "even it out" for the entire band. The Q determines the gain one obtains from a coil. The voltage step-up is approximately equal to the Q of the coil. Broadcast coils have a value of Q between 75 and 200. In general, the higher the Q of any reactive elements the better will be the performance of the circuit.

A Q-Meter is used primarily for measuring Q, but it is also employed for determining the dissipation factor, power factor, phase angle, and phase difference. The general explanation of the Boonton Radio Q-Meter Model 160A is taken from the instruction booklet supplied with this instrument.

The oscillator furnishes a current, measured by means of the ammeter I, which flows through the special resistor R'. This



resistance R′ (0.04 ohm) will usually be small compared with the other resistances in the circuit and can be neglected, or, if the circuit resistance is especially low, corrected for. In practice, a given value of I is obtained by initial design. A known voltage E is thus introduced into the series circuit comprising the variable condenser C and the inductive reactor under measurement, connected across the terminals AB. The condenser C is contained in the instrument and its effective resistance is negligible.

By way of illustration we shall consider the measurement of the Q of a coil having inductance L, resistance R, and distributed capacitance C_d, as shown connected to the terminals AB.

In general, any two-terminal inductive reactor which might be connected across AB can be represented by an effective series inductance L_e (not exactly equal to L) and an effective series resistance R_e. At resonance the condenser reactance will balance the effective series reactance between A and B and the current will be (neglecting R′):

$$I = \frac{E}{R_e}$$

The voltage E_c across the condenser C is measured by means of a vacuum tube voltmeter having negligible power consumption. Then:

$$\frac{E_c}{E} = Q_e = \frac{1}{\omega C R_e}$$

At resonance $1/\omega C = \omega L_e$, hence:

$$\frac{E_c}{E} = Q_e = \frac{\omega L_e}{R_e}$$

This is defined as the effective Q of the coil or other impedance connected to AB.

The method of measurement thus yields the "effective Q." This differs somewhat from the true Q, which is defined by:

$$Q = \frac{\omega L}{R}$$

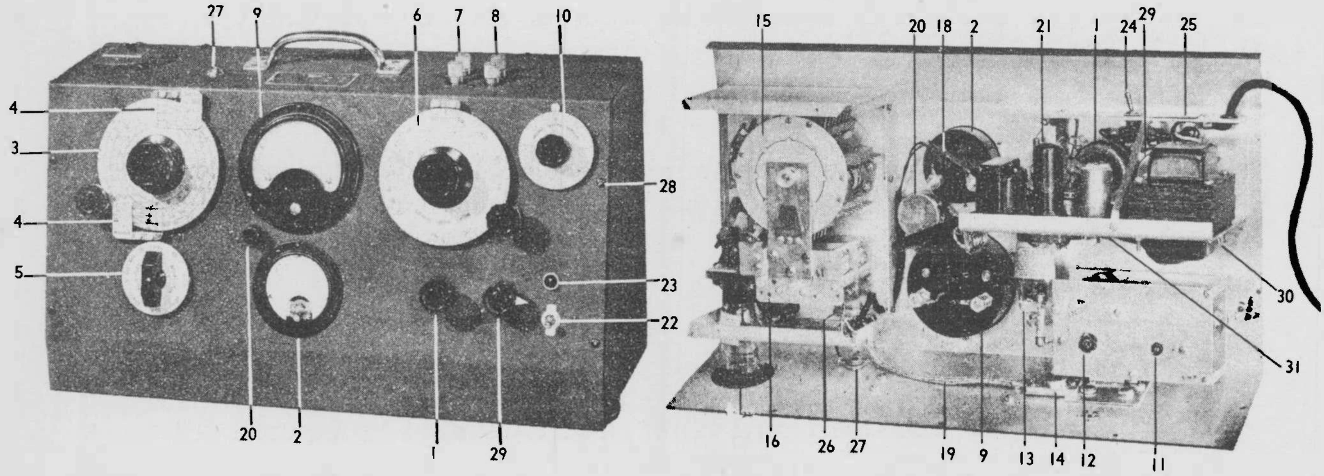
A detailed analysis shows that in the case of a coil, the difference between the true Q and effective Q depends on the distributed capacitance of the coil, and may be expressed very closely by:

$$Q = Q_e\left(1 + \frac{C_d}{C}\right)$$

except for frequencies very near the natural frequency of the coil. Thus, the effective Q approaches true Q as the ratio of tuning capacitance to distributed capacitance increases.

From the practical viewpoint, this difference is of little importance since in the design of tuned circuits the minimum capacitance used to tune a coil is usually 10 to 20 times the distributed capacitance of the coil so that the maximum difference between effective and true Q will be 5 to 10 per cent when measured with the minimum tuning capacitance.

The frequency range of the Model 160A Q-Meter is continuously variable from 50 KC. to 75 MC. in eight ranges. The Q voltmeter is calibrated directly in Q, 20-250. The "Multiply Q by" meter, which measures the oscillator voltage injected in the Q measuring circuit, is calibrated in tenths from x1 to x2, and also at x2.5. The reading of the Q voltmeter scale is to be multiplied by the setting of the "Multiply Q by" meter. Thus the total range of the circuit Q measurements is from 20-625. The Q's of condensers, dielectrics, etc., which may be as high as 5,000, are measured by placing these in parallel with the measuring circuit.



1 Oscillator Output Control.
2 Osc. Out. VM. (Mult. Q By Meter).
3 Oscillator Frequency Dial.
4 Oscillator Frequency Indicator.
5 Oscillator Range Switch.
6 Q Tuning Condenser Dial.
7 Coil Terminals.
8 Condenser Terminals
9 Q Voltmeter
10 Vernier Tuning Condenser Dial.
11 Vernier Tuning Condenser
12 Q Tuning Condenser.
13 Q Voltmeter Tube.
14 Thermocouple Unit.
15 Oscillator Range Switch Assembly.
16 Oscillator Tuning Condenser.
18 Thermocouple Calibrating Resistor.
19 Oscillator Output Cable.
20 VTVM Zero Adjust.
21 Rectifier Tube.
22 ON—OFF Switch.
23 Pilot Light.
24 HI—LO Switch.
25 Power Unit Nameplate.
26 Thermocouple Filter.
27 Jack.
28 Panel Securing Screws.
29 Oscillator Output Control, Vernier.
30 Dual-Voltage Switch (115-230 volts).
31 VTVM Calibration Control.

Book Three

Radio Circuits and Trouble-Shooting

Lecture 17

Audio Frequency Voltage Amplifiers

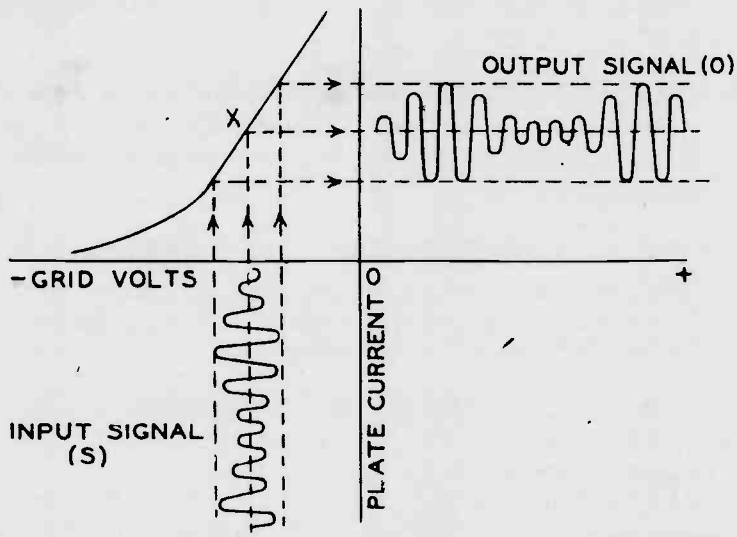
The voltage amplifying action of a vacuum tube is due to the fact that a small voltage applied to the control grid is equivalent in effect to a much larger voltage acting in the plate circuit of this tube. Greater amplification than that obtainable from a single stage can be secured by connecting several stages in cascade.

In this lecture we are considering voltage amplifiers used at audio frequencies and this application will confine the tube operation to Class A. Class B and intermediate mode of Class AB amplifiers will be discussed in the next lecture on power amplifiers; while Class C amplifiers are used primarily in transmitters, although oscillator tubes in superhets are operated in modified Class C circuits.

A Class A amplifier is operated in such a manner that the plate-output wave form is essentially the same as that of the exciting grid voltage. By the phrase "essentially the same" we mean only a constant multiplication factor increase in amplitude, no change in shape, phase relationship, or ratio of intensity of different points. If the original and the reproduced signals are viewed on a cathode ray oscilloscope, they will appear the same with the singular exception that the height (amplitude) of each corresponding point of the two oscilloscope traces will be in a definite ratio to each other, i.e. magnified in height only. This ratio figure represents the amplification obtained in the Class A amplifier being examined and should be exactly the same for each set of corresponding points considered.

A vacuum tube operated in Class A requires a negative grid bias of a value to keep the grid negative under all operating conditions. This means that the grid bias value must be greater than the peak positive signal voltage.

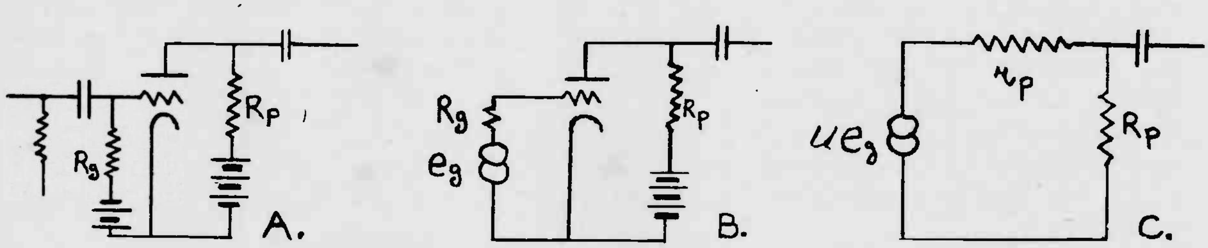
The plate current under such operation is present at all times, increasing when the signal is positive and decreasing during the negative cycle of the signal.



Courtesy RCA

The operating conditions must be so selected that the dynamic characteristic curve over the operating range is essentially linear. This requirement is in accord with the need for the grid not to go positive and the plate current not to rise to the curved part of the characteristic curve.

Examine the illustration of the characteristic curves of a triode and note that the operating portion so marked will meet these conditions.



The main distortion present in Class A amplifier is due to operation over curved sections of the characteristic curve and results primarily in creation of second harmonic distortion. Since this distortion is so much larger than other forms, it may be used by itself as a measure of quality, or lack of quality, in the amplifier.

Under "A" we illustrate a typical circuit of a triode voltage amplifier. Batteries have been included for simplicity. Notice that in circuit "B" we have replaced the incoming signal by a generator producing the equivalent alternating current voltage marked e_g. As long as the grid remains negative, this "generator" is working into an infinite impedance and no current will be flowing in the grid circuit. Should the grid become positive at any time, this circuit will be completed and grid current present will upset the operation of the amplifier.

A further equivalent type of circuit is shown in "C" drawing. Here the generator has been placed in the plate circuit, but the value of the signal voltage has been altered by a factor μ, the amplification factor of the tube.

The resistor r_p is the actual plate resistance of the vacuum tube. This is connected with the balance of the circuit, since the tube is really in series with the plate resistor R_p as far as the plate current is concerned.

Distortion of varying degrees is present in all amplifiers. Amplitude distortion is due to the production of new frequencies in the output signal which were not present in the input. This distortion is mainly due to the non-linearity of the operating characteristic curve. If you are interested in the mathematical proof of this we refer you to any one of the three references stated below. These will require the knowledge of trigonometry.

Chaffee, "Theory of Thermionic Vacuum Tubes," 1st ed., pp. 286-287;
Glasgow, "Principles of Radio Engineering," 1st ed., pp. 146-147;
Staff of M.I.T., "Applied Electronics," 1st ed., pp. 413-415.

Amplitude distortion will also result if the grid draws current (becomes positive) and an impedance, such as a grid resistor, is present in the circuit. This is due to a non-linear relationship between the grid current so resulting and the actual potential on the grid. To get this idea clearly in mind, refer to drawing "B" of the illustration on the previous page. While there is no grid current, the potential on the grid will be the instantaneous voltage supplied by the generator e_g. But when grid current is present the value of the total grid potential will be the sum of the IR voltage drop across R_g and the signal voltage e_g.

Any change in the relative phase relationship of the different frequency components of the signal gives rise to phase distortion. This type of distortion is not important in audio frequency amplifiers, because the human ear does not detect phase shifts among the several component vibrations. However, phase shift distortion cannot be tolerated in an amplifier designed for use with an oscilloscope tube, to give but a single example.

In any amplifier where harmonics are produced, their ill effects will be exaggerated by the presence of phase distortion. To a large degree, the input and output circuits are the causes of phase distortion and also of frequency distortion about which we will talk next. A serviceman will have little trouble with phase distortion in audio amplifiers, but you may detect this trouble in your oscilloscope or in the video circuits of a television set.

The unequal amplification of the various frequencies making up the signal gives rise to frequency distortion. As we have just stated, this is due entirely to input and output circuits associated with the tube.

Most present day audio frequency voltage amplifiers use a resistance plate load. As the value of the plate resistor is increased, the characteristic curve is straightened and amplitude distortion, thereby, is reduced. However, the plate current must pass through this resistor and the voltage drop across it is in proportion to the resistance value. The use of a very high value resistance will require extremely large plate voltage. The values used, 100,000 to 1,000,000 ohms, are a compromise for best practical results.

The actual amplification obtainable from a single stage is a function of the amplification factor of the tube (μ) and the value of the plate resistor employed. Referring to the previously mentioned drawing, part "C," we realize that the voltage across R_p, which is the signal supplied to the next stage, is the

$$\text{Output voltage} = \frac{\mu e_g R_p}{r_p + R_p}$$

and since the input voltage is e_g, by dividing output voltage (above) by the input voltage e_g, we obtain

$$\text{Stage gain} = \frac{\mu R_p}{r_p + R_p}$$

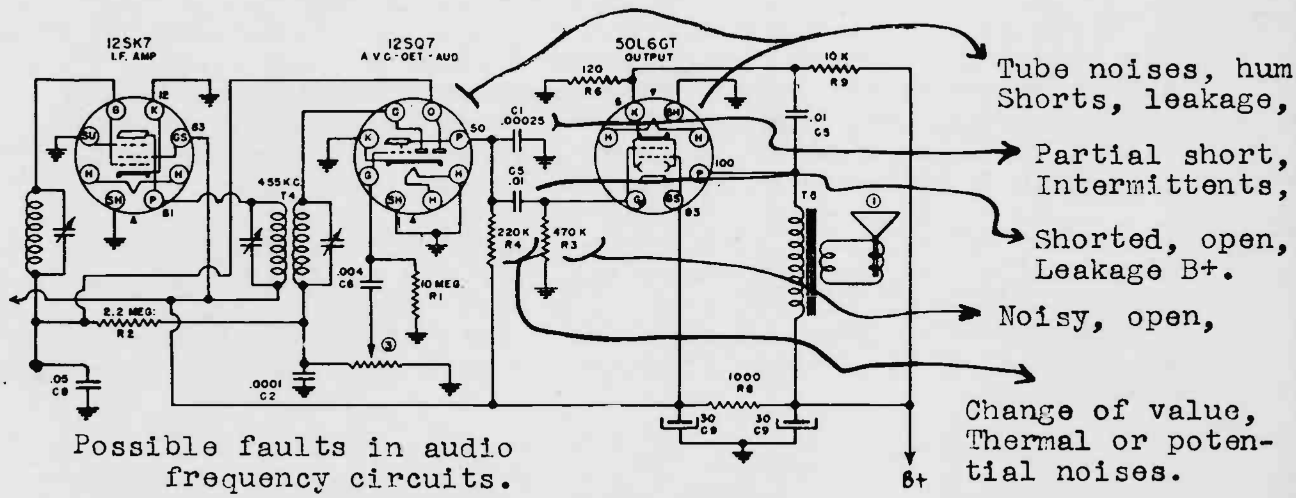
If R_p is much larger than r_p, the gain is almost equal to the tube amplification factor. If R_p and r_p are equal, the gain of the stage is one-half of μ.

The theory presented will help you in understanding the limitations and possible faults in audio frequency voltage amplifier stages. Progress has been made in circuits of this type, but since many of the old fashion radios are still in use, we will deal with the circuits in the historical order.

In the type of circuits used in early A.C. power operated radios, we find low gain triode type tubes employing audio transformers for coupling the stages. The transformers employed had a turns ratio of about 3 to 1 and stepped up the signal voltage in this proportion. Further, since the older type triodes have low plate impedance, in the order of 10,000 ohms, the transformer served also as an impedance matching device. The impedance ratio is always the square of the turns ratio and the plate impedance of 10,000 ohms was reflected into the grid circuit of the next stage as a 90,000 ohm impedance.

It is very difficult to make audio transformers to have uniform response in the audio band. This was the main limitation and served to hamper the popularity of such interstage arrangement. With the high gain triode or pentode type tubes, a much higher plate load is required, and, therefore, a resistor can be employed. While resistance coupling produces a certain loss of voltage instead of gain, the amount lost is easily made up by the higher gain of the tubes employed, and excellent frequency response is obtainable with a simpler arrangement. The values of plate resistor, plate coupling condenser, and grid resistor for the next stage are not critical, but formulas have been worked out which permit the calculation for most advantageous operation, and suggested values of these parts are given in tube manuals.

With the use of pentodes in the output stage and with the high gain obtainable in the stages of the radio preceding the detector, very little additional audio voltage amplification is needed. In most of the modern sets, this is obtained with the aid of a single triode having a mu of 20 to 100. This triode may be incorporated with a diode detector in a single tube envelope.



Possible faults in audio frequency circuits.

The majority of faults in audio voltage amplifiers lie in the tube itself or in the coupling condenser. Generally, this stage gives little trouble. Plate coupling condensers must be of high quality, since even the slightest amount of leakage may cause the grid of the next tube to become positive.

Lecture 18

Audio Frequency Power Amplifiers

Since a loudspeaker is an electro-acoustical device, actual power is required to operate it. For this reason, the output stage of a radio receiver uses a tube intended for power amplifier amplification. Such tubes are designed with the object of developing power, in contrast with voltage amplifier tubes in which the object is to obtain as much voltage gain as possible.

Because triode tubes in Class A are commonly used in receivers, and also for reasons of simplicity, we will first consider such an application. For any given operating condition of negative grid bias and a suitable value of plate voltage, the plate current will be of some value that can be measured or found from characteristic curves of the tube under consideration. Without a load in the plate circuit, the plate current would vary as the signal voltage would alter the instantaneous grid potential above and below the fixed bias value. This variation would follow along one of the lines (known as the static characteristic line) of the grid-voltage-plate-current curves.

The connection of a load alters these results. As the grid becomes more negative (on a negative cycle of the signal), the plate current is reduced, but not as much as under the conditions of no load. The reasons for this change is due to the fact that a reduction in the plate current reduces the voltage drop across the load and accounts for a higher voltage at the plate. This higher voltage, of course, to a degree counteracts the plate current reduction. The exact reverse of this action takes place with a positive signal. In such instance, the plate current rises less with a load connected then without.

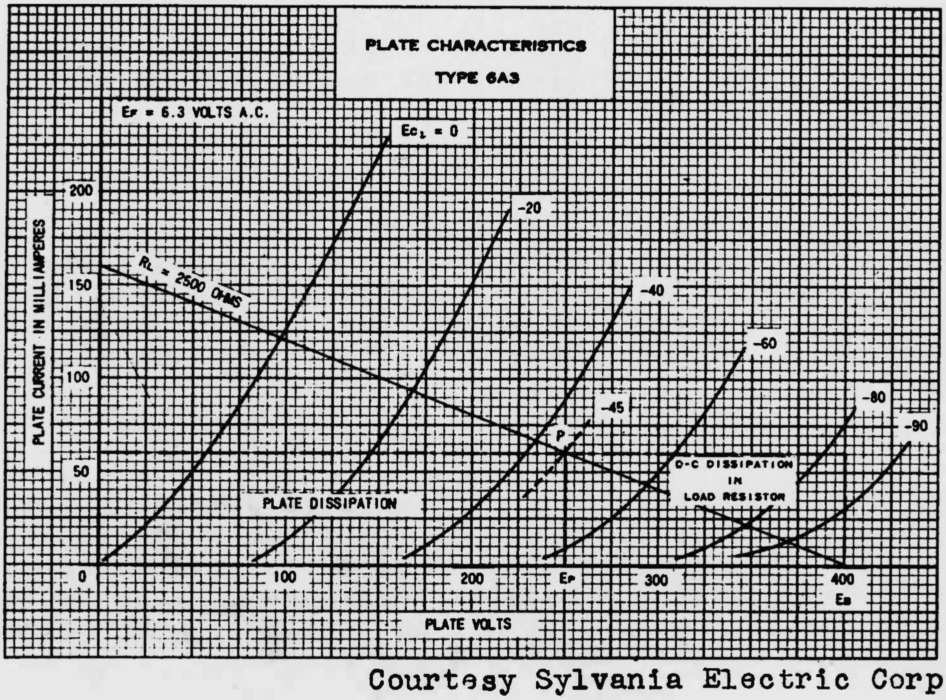
The effect of a load is to change the operating line to a line called the dynamic characteristic and having a smaller slope. The dynamic characteristic is also more nearly linear than are the characteristic curves of the tube. This linear factor is important in minimizing distortion produced by the curvature of the characteristic curve.

To keep distortion to a minimum, the practical limiting factors are the excessive curvature of the dynamic characteristic at low plate currents and the need to keep positive peaks of the signal smaller in value than the negative bias used. This latter fact is important, for if the grid is driven positive, grid current will result and will distort the input signal.

In order to obtain the maximum power output without producing distortion for reasons just stated, it is necessary to maintain a careful balance between grid bias, load impedance, plate resistance of the tube, and plate voltage. For the serviceman, this problem has been solved by tube engineers and tube manuals give the operating information required.

Distortion arises primarily from operating the tube over the curved part of its characteristics. It usually resolves itself into harmonics. Of all the harmonics, the second are of the greatest magnitude. The push-pull amplifier by cancellation reduces the even order harmonics to a very negligable figure, requires less filtering of its plate supply, and permits somewhat larger input voltage without causing distortion due to overloading.

In Class B operation the tubes are biased or designed with a sufficiently high amplification factor to cut off the plate current with no input signal. When a signal sufficient to swing the grid is introduced, the negative portion of the cycle will add only to the bias and, therefore, plate current will flow only during the positive half of the cycle. A large amount of even order harmonics will of course be produced. However, by using two similar tubes in a balanced circuit, the harmonics may be eliminated from the output. Since at times the grids are driven positive, the preceding stage must be capable of supplying the power drawn by the grids under this condition. This is accomplished by using for a driver stage a Class A power amplifier of suitable size, coupled by a transformer possessing the proper characteristics. The transformer is usually of the step down type.



Courtesy Sylvania Electric Corp.

With Class B it is possible to obtain high power output with comparatively small tubes operating at ordinary plate potentials. Since very little power is consumed with no signal, economy is another advantage. To offset these, the distortion present is always somewhat larger than for the same power for Class A operation and the power supply must have very good regulations to maintain proper operating voltage with considerable current variations.

Many modern amplifiers employ output stages using tubes in an arrangement intermediary between Class A and Class B commonly called Class A-prime or Class AB. On low signals the circuit behaves as a Class A, while on powerful signals the Class B action allows the handling of large power. In this manner, the advantage of both classes is combined.

Because tubes operated in Class B cannot be self biased, it is an advantage to design these tubes so that they take almost zero current at no-signal. If tubes are employed for this class of operation that do require considerable negative grid bias, a separate power supply for this purpose is recommended. While it is best for this additional power supply to have a separate power transformer, the required power may be obtained from separate windings on the power transformer used in the main supply.

In the early days of A.C. radios, single triodes were used in the power output stage. Many of these older sets, which still find their way to your shop, used type 71-A or 45 triodes. Push pull operation has considerable advantage in producing a greater power output than twice obtainable from a single corresponding tube, and, therefore, found its use in the better sets. As we have already mentioned, push pull operation also reduces certain types of distortion and simplifies the filtering requirements in the power supply.

The development of the type 47 pentode permitted a much greater power output with less amplification in other sections of the radio. This type of pentode requires relatively small signal voltage in comparison to the triodes previously in use. Most pentodes, of course, produce larger amounts of distortion, but at the time of their popularity this distortion was tolerated. Class B application for home radios was introduced with type 46 tubes, and while the amount of power these tubes are capable of delivering is never required in the home, the public was "sold" this new development. In the case of a Class B radio using type 46 or similar tubes, should you have a customer requiring better fidelity, I recommend the changing of the output circuit and operating these tubes as regular Class A power output amplifiers. This change can be brought about by changing one of the grid connections, providing the correct bias, and seeing that the output transformer employed properly matches the resulting new impedance of these tubes.

The type 2A3 tubes were employed in Class A when used in radio receivers, although the same tubes are adaptable for Class AB operation for greater power output needed in public address work.

The pentode power output tube was a natural component in the lower priced AC-DC radio sets, which made their appearance in 1931. The type 43 tube was among the first adaptable for such sets and was followed by others of corresponding type.

The latest in power output tubes, of course, is the beam power type of which 6L6 was first developed. This tube is still employed in power amplifier requirements, but in home radios, beam power tubes of smaller output are better adapted. Modern AC-DC radios and battery sets also employ beam power tubes with suitable filaments.

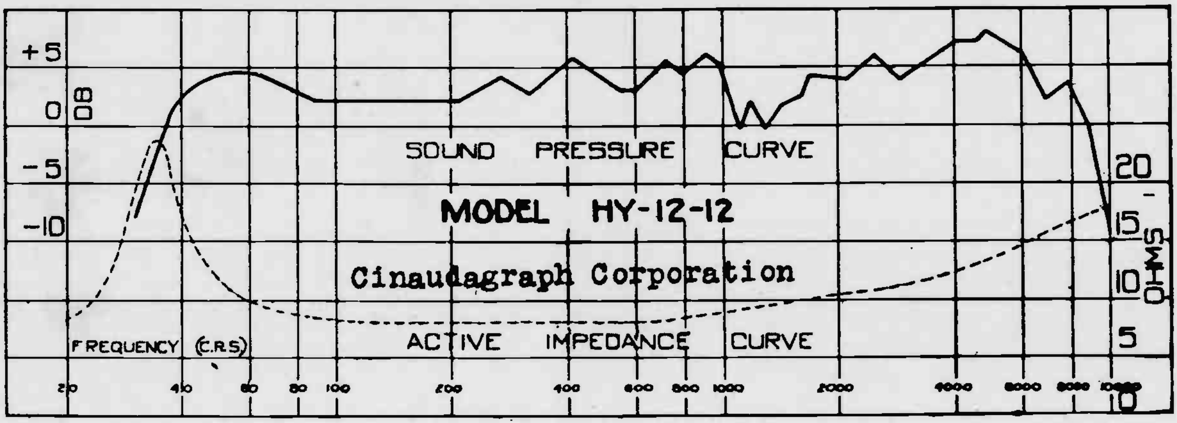
Since the power output stage has considerable voltage and current present in its circuits, tests are easily conducted. Voltage tests can be easily made and current tests are useful for detecting faults in the tube itself which may not be readily observed in the tube tester.

Lecture 19

Audio Corrective Networks

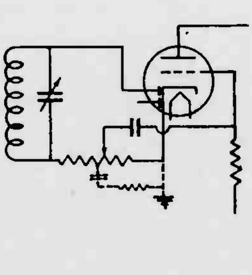
The majority of radio receivers handled by you at your shop have little in the way of special circuits to correct the audio response. For one thing, the audio output from the detector has good fidelity from an average, properly aligned receiver. Further, the loudspeaker response, even in the better sets, is such that it proves the weakest link in the chain of stages influencing the fidelity of output. Consider the curves of the characteristics of a high grade speaker, as shown below, and you will understand that with an average-priced speaker our statement is certainly true. However, many sets do have corrective networks and with better fidelity possible with F.M., modern P.A. amplifiers, and improved speakers, this subject is of interest and importance to radio servicemen.

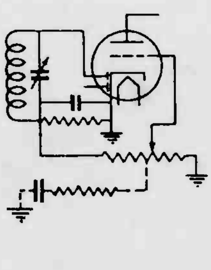
The chart below will give you an idea of the response of a good quality 12 inch speaker. Also notice the dotted curve which indicates the change of the voice coil impedance.



You are familiar with a plate by-pass condenser used with a pentode output tube. This condenser compensates to a degree for the tendency of a pentode to favor in.amplification the higher audio frequencies. This is a simple application of a single condenser for tone correction. A variable tone control circuit consists of a fixed condenser and a variable resistor (potentiometer) connected in series. These components are shunted across the power tube input or output circuit. The values of capacity and resistance are so selected that with total resistance in the circuit almost no by-pass action takes place, and the adjustment of the resistance causes the circuit to by-pass the higher frequencies. These circuits are not true tone correction networks since they are only capable of changing the response by reducing the output of higher audio frequencies.

The sound output from a radio receiver will appear more natural to a listener at lower volume levels if the middle range of audio frequencies are reduced in a larger amount than the low frequencies and to a lesser difference from the higher frequencies. This action is the result of the human ear sensitivity becoming less for low and high frequencies as the level of the reproduced sound is reduced. A degree of tone compensation to overcome this peculiarity can be introduced automatically with a tone compensated volume control — accomplished in practice with a tapped volume control. See sketch below.





In public address amplifiers, tone controls are not only used for the simple purpose of cutting down high frequency output, but, with additional circuit arrangement to permit variation of the low frequency response, are employed for special sound effects, to correct for acoustical limitations of auditoriums, to reduce hum and hiss, and to reduce phonograph pickup scratch. In designing such tone corrective networks for public address and radio receiver applications, an attempt is made to keep the circuits simple and to permit a wide degree of frequency response adjustment at both the high and low end without disturbing the middle frequencies.

So far we discussed non-resonant tone correction circuits. Such circuits may involve inductance and resistance or capacitance and resistance, but in practice C-R combinations are used. Inductance of a value adaptable for a tone correction circuit must be made especially for the application and would be priced much higher than a stock condenser adaptable for the same purpose. Further, the distributed (stray) capacities of the inductance and associated circuit would resonate at frequencies that may upset the uniformity of the response. Also, inductances may pick up hum voltages from a power transformer, while this problem does not come up with condensers.

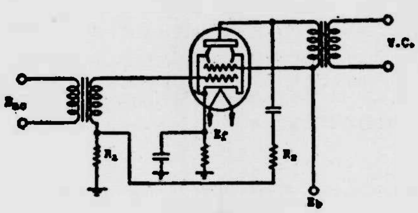
We have already considered the use of a shunt capacitance as a means of reducing high frequency output. Low audio frequency attenuation may be simply achieved by using a plate coupling condenser of a low capacity. You may try an interesting experiment with almost any radio using a plate coupling condenser, by observing the difference in bass response when using a .05 mfd. and .0005 mfd. condensers. A bass tune control may consist of two condensers connected in series and used in place of the plate coupling condenser. One condenser is large in capacity (0.1 mfd. is suggested), the other may be .0005 mfd. shunted by a variable resistor of 1 or 2 megohm value. The degree of the low frequency loss will depend on the adjustment of the variable condenser.

Limited bass attenuation results from a low value of cathode by-pass condenser. You probably observed that while some audio tubes have by-pass condensers in the order of 10 mfd., other sets have capacities of .05 mfd. in the same type of circuit. Low value screen by-pass condenser will also produce bass attenuation provided the screen is fed from a high resistance dropping resistor.

Resonant type tone control circuits incorporate values of inductance and capacity which resonate at audio frequencies which are either to be reduced or increased in intensity. A parallel arrangement of L-C has no effect on frequencies far removed from their natural frequency. At its natural frequency, an L-C tuned circuit has an exceptionally high impedance. By connecting such an arrangement into a plate load (in series with a regular plate resistor), the apparent load as it will appear to the tube will become much greater at frequencies close to the resonant frequency of the L-C circuit and, thereby, produce greater amplification at such frequencies. Connecting this parallel combination of inductance and capacity into a wire carrying the audio signal, will produce extra attenuation around the resonant frequency, and reduce the response from the group of frequencies close to the resonant frequency.

Inverse feedback introduced in audio amplifiers has several desirable effects and may be accomplished in a single stage or over several stages in cascade. The advantages of degeneration produced by inverse feedback circuits may be summarized as follows:

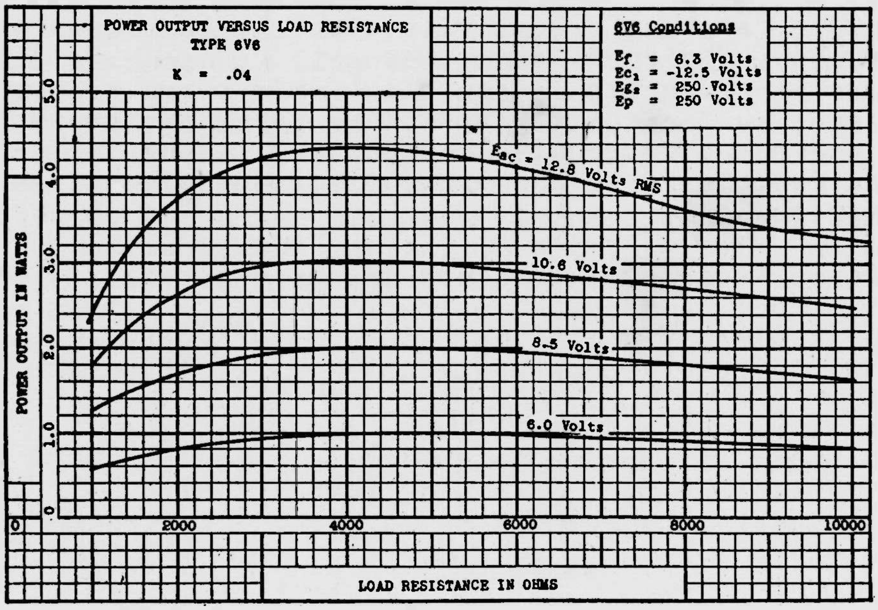
1. Power output remains more constant.
2. Audio distortion is decreased.
3. Frequency response is improved.
4. Signal voltage must be larger.



$$K = \frac{R_1}{R_1 + R_2}$$

Audio degeneration is obtained by feeding part of the output signal back, in proper relationship, to be exactly out of phase. Due to the effects of reactances in the circuit, exact phase shift is difficult to accomplish in practice. The feedback path may be such as to include several tubes in the circuit, but is usually confined to one or two tubes.

Let us consider a simple feedback circuit. The figure is published through the courtesy of P.R. Mallory & Co. In the figure, we have a beam power output tube. It is excited by a signal, marked E_{ac} in the drawing, and is a basic circuit except for R_1, R_2 and the coupling condenser. For the moment, we will study the regular function of this circuit. The input signal is induced in the secondary of the interstage audio transformer and excites the control grid of the tube. The resistor R_1, is small and need not be considered for the moment. The tube is self biased with the resistor in the cathode circuit. This resistor is by-passed with a large capacity (about 20 mfd.) electrolytic condenser which is not marked in the drawing. The screen grid of the tube receives the plate voltage directly, terminal E_b. The plate current for the tube is supplied through the primary of the output transformer. This transformer matches the tube to the voice coil. The required size of this transformer,



Courtesy P. R. Mallory & Co.

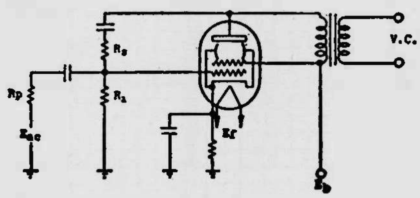
The power output of a radio tube varies less with changing load resistance if inverse feedback is employed. The curves show the results with different excitation voltages.

by the way, will be different with degeneration, in the case of most vacuum tubes than would be used with the same tube in an ordinary circuit.

Now let us consider the additional circuit which produced degeneration. Trace this circuit from the plate of the tube, through the blocking condenser, and through the two resistor R_1 and R_2. The blocking condenser, we mentioned, is used only to keep D.C. of the plate supply out of the resistor network. This condenser may be considered as having zero impedance to the audio signals. You can see that the audio signals coming out of the tube, divide themselves across the two resistors. The amount of signal across R_1, in terms of the total available signal at the plate, will be a factor K, equal to the simple formula stated under the illustration. Since only a small amount of signal is fed back, K will be much less than 1.

Another way to analyze this action is to realize that if R_2 is large, and R_1 is small, little voltage will develope across resistor,' By changing the size of these resistors, the voltage across R_1 may be made any value required in terms of the total voltage available at the plate of the tube. Notice that the voltage across R_1, adds in series with any voltage induced across the secondary of the input transformer, and both of these voltages are impressed on the control grid.

Now, it is a well known fact that a vacuum tube shifts the phase of the signal 180°. When the grid is becoming more positive, the plate current is increased, the impedance of the load causes a larger voltage drop, and less of the total battery voltage is left for the tube. This means that while the signal is becoming more positive, the voltage fed back by the degenerative system is negative in relationship. When signal is either positive or negative, the voltage fed back is just the opposite. This is degeneration and produces the effects we described.



$$K = \frac{R_T}{R_T + R_2}$$

Where R_T = Parallel Resistance of R_p and R_1

$$K = \frac{R_1 R_p}{R_1 R_p + R_1 R_2 + R_2 R_p}$$

Another negative feedback circuit is shown and this type of circuit is well suited for use with resistance coupled stages. Please notice that only R_2 and the blocking condenser form the degenerative system. The action is very similar to the one described. Many commercial circuits not having audio degeneration, can be converted to include this feature by the simple addition of this condenser and resistor. The condenser may be .01 mfd., 600 volt type, the resistor should be about 5 megohms. However, bear in mind that the same output transformer will no longer correctly match the output tube and should also be replaced.

Tone control correction can be accomplished in circuits having negative feedback, by returning voltages of certain frequencies in greater or lesser magnitudes to produce wanted results.

The voltage required for feedback in some units is obtained from the voice coil or an extra winding on the output transformer. This is a convenient method for obtaining a voltage of the correct value, in the proper phase as needed, and completely isolated from other sections of the circuit. The feedback voltage may be returned to one of the first audio stages and, thereby, cause several stages to function in the feedback amplifying circuit.

Lecture 20

Phase Inverters

The material on the subject of phase inverters as presented below is reprinted from an article, "Phase Inverter Circuits," by J. Richard Johnson, published in the April 1947 issue of "Radio Maintenance" magazine. We express our sincere thanks to the editors of this magazine for their kind permission which permits us to reprint this article.

WITH THE TRANSITION from transformer coupled audio amplifiers to those of the resistance type, the phase inverter has become increasingly more important. This importance will continue to grow as more and more frequency modulation receivers demand high fidelity amplifiers with resistance coupled output stages. Consequently, it is felt that a full explanation of the theoretical and practical aspects of this type of circuit will be found useful to the service engineer.

First, why is a phase inverter necessary? To understand this, it is important that we clarify the difference between a single-ended or "unbalanced" circuit and a double-ended or "balanced" type. Fig. 1 shows two simple load circuits. Suppose in each of these circuits we assume that a signal voltage is applied between points X and Z. In Fig. 1a, let's assume that at a given instant X is positive and Z is negative. This means that they have these polarities with respect to each other, and either one could be used as a reference. As soon as we ground Z as shown, however, we establish a fixed reference, or starting point. We then have only one "phase" or direction of voltage available since signal voltages are measured with respect to ground. Point Z will now coincide with ground and our one phase exists at X (above ground) producing the single-ended type of circuit. Ordinary voltage amplifiers and detectors put out this type of signal.

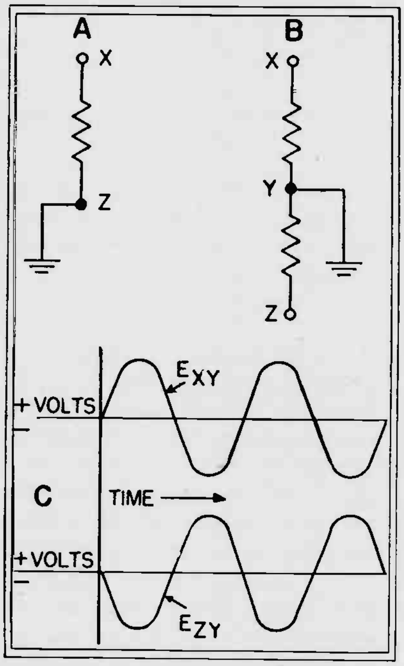


Fig. 1 A representation of single- and double-ended circuits. A represents the load circuit of a single-ended amplifier and B represents the load circuit of a double-ended amplifier. C shows the phase relationships of the voltage present in B when a sine wave signal is applied across points X and Y.

Let us now take the same circuit and move the ground up to the midpoint of the resistor as shown in Fig. 1b without disturbing the source of the signal. Point X will still be above ground, but at only one-half of the previous potential. But point Z still differs from point X by the full potential. This means that when point X is positive with respect to point Y, point Z will be the same amount negative with respect to Y. Thus, with point Y grounded, we now have two voltages, both above ground and 180 degrees out of phase with each other. This relation is shown graphically in Fig. 1c, and is representative of the double-ended type of circuit.

A push-pull amplifier is a double-ended circuit in which each tube works against ground and is 180 degrees out of phase with its companion tube in the stage. Fig. 1c could represent the voltages in the plate circuit of a push-pull amplifier, or the voltages applied to the push-pull grids.

Since a great majority of voltage amplifiers and all ordinarily used AM second detectors are single-ended, it becomes necessary to convert from one type of circuit to the other. One way to do this is by use of a push-pull audio transformer. With a transformer, one can run the primary single ended and the secondary double-ended and thus solve the problem. But a transformer is expensive, bulky, and subject to resonance effects. That is why the phase inverter is the logical alternative since it overcomes these disadvantages.

One of the basic principles upon which phase inverter circuits are founded is the fact that the plate voltage of a vacuum tube is 180 degrees out of phase with the grid voltage of that tube.

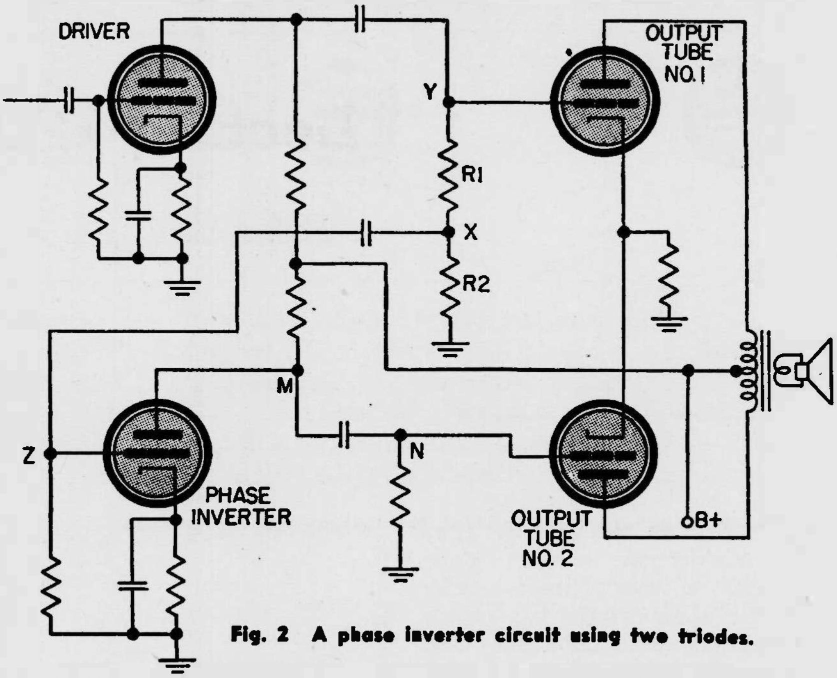


Fig. 2 A phase inverter circuit using two triodes.

Probably the most popular inverter circuit is the type shown in Fig. 2. An ordinary single-ended resistance coupled amplifier is used in conjunction with an additional tube which gives the phase shift needed for the second output tube grid. Notice that except for the tap at point X and the use of a push-pull output transformer, the upper portion of Fig. 2 is simply a conventional resistance coupled amplifier.

Now some of the signal voltage applied to the output grid at point Y is tapped off at point X and fed into the grid of the phase inverter tube at point Z. The phase inverter grid now has a signal voltage of exactly the same phase as the grid of the top output tube but a lower voltage because it is tapped down on R1.

Because of the fundamental phase shifting property of a vacuum tube described above, the signal will appear in the plate circuit at M, not only amplified, but 180 degrees out of phase with the signal at point Z. This voltage is then passed on to point N, the grid of the lower output tube. Thus points Y and N have the opposite phase necessary for proper operation of the output stage. The only components which could change the exactness of the 180 degree relation are the coupling condensers. Since these are always chosen to have negligence reactance at the frequencies used, they do not disturb the relation.

But there is another important requirement. The voltages on the two output grids must be balanced; they must be equal. If balance is not obtained, the output wave form will not be symmetrical and third harmonic distortion will appear. To preserve balance, the ratio of the signal voltages at points X and Y must be carefully adjusted in conjunction with the gain of the phase inverter tube. Since the voltage at X is amplified to produce the voltage at N, which should be equal to that at Y, it becomes clear that the ratio of the voltage at Y to that at X should equal the gain of the phase inverter tube.

An important variation of this circuit is shown in Fig. 3. This is known as the *self-balancing* type of phase inverter. Since the main portion of the diagram would be the same as that described above, only the grid circuit of the push-pull amplifier is shown. Notice that the only difference here is that the low side of the grid resistor of output tube No. 2 now goes to the point X in Fig. 2, instead of directly to ground. This means that part of the voltage applied to the grid at point N is fed back (along with part of the voltage at point Y) through point X to the phase inverter tube through point Z. Since the voltages at points N and Y are out of phase with each other, the portion of the N voltage appearing at point X is degenerative feedback. This degeneration has a balancing effect on the two voltages. As soon as the voltage at N gets too large, the portion of it at X reduces the signal voltage on point Z, reducing the voltage at N, where it was originally too large. This design has the advantage that the division between the X and Y portions of the grid resistor of output tube No. 1 is not as critical as in the case of the first circuit described. It can be seen that if the three resistors involved in the grid circuit of the push-pull stage are all made the same resistance, there will be 50 per cent negative feedback. This feedback not only helps to balance the signals on the two grids, but also

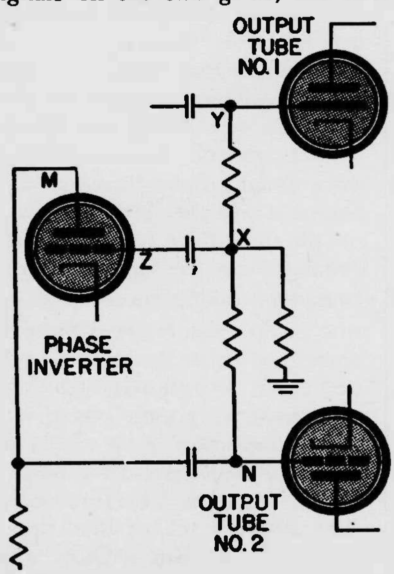


Fig. 3 A partial circuit diagram of the self-balancing type of phase inverter.

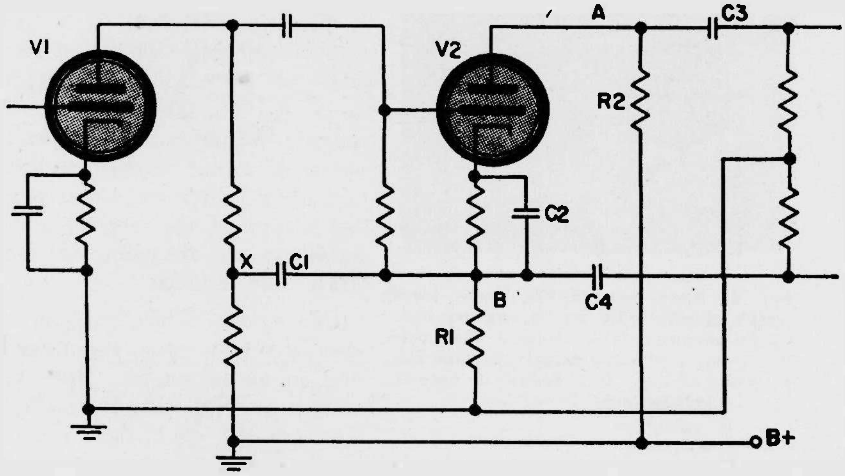


Fig. 4 A phase inverter utilizing the cathode follower principle.

gives the other advantages of degeneration in an audio amplifier.

The cathode follower type of circuit is utilized as a phase inverter since it has the proper phase relation between plate and cathode voltages. The tube is connected as shown in Fig. 4. Two plate circuit resistors, R1 and R2, are used, both of which carry the fluctuating plate current. One is connected between the plate and B+, the other between B— (ground) and the cathode resistor. Since a triode is normally used, there is no screen current and the same currents flow through R1 and R2. With ground connected between the resistors as shown, equal voltages with respect to ground will exist at points A and B. But, since the electron flow is toward ground through R1 and away from ground through R2, the voltages will be 180 degrees out of phase with each other. These voltages can be applied through coupling condensers to the grids of the push-pull stage. Notice that since the cathode of the inverter tube must be operated with a signal voltage above ground, the grid signal voltage must vary with respect to cathode, rather than ground. An extra resistor is therefore added to the plate circuit of the previous stage to keep point X above ground potential. Condenser C1 ties point X to the cathode of V2 since C1 and C2 are chosen to have negligible reactance at the signal frequency. This keeps the grid voltage from having to work against the signal voltage appearing across R1. As explained above, the voltages across R1 and R2 are out of phase and are coupled through C3 and C4 to the output stage grids.

The big advantage of this circuit and ones similar to it is the fact that it requires one tube while those previously described require two. However, since dual triodes of the 6N7 and 6SC7 variety are readily obtainable, this is not always such a powerful argument in its favor. A disadvantage of the single-tube inverter is that the circuit values are more critical than those of the two-tube type, and therefore can get out of balance more easily.

Another type of one-tube inverter is shown in Fig. 5. Here again, two resistors (R1 and R2) are used in the external plate-to-cathode circuit, but this time both are placed between B+ and the plate. The distinctive feature of this circuit is the fact that the grid of tube V3 is grounded. This may seem an impossible condition at first thought. It must be remembered, however, that the input voltage to a tube exists between the grid and the cathode. This means that we may run the grid at ground signal potential providing the cathode runs "hot" or at a voltage above ground. This gives the same effect as does running the grid at a negative potential with respect to ground when the cathode is as in Fig. 5.

The input audio signal is applied at point A and is amplified in the normal manner by tube V1. The amplified signal appears across the load resistors R1 and R2. This signal is fed to the grid of tube V2 through coupling condenser C1 and appears at point Y. The bottom of resistor R1 goes through condenser C2 to point N and ground. Thus, the signal between the top and bottom of resistor R1 is applied across

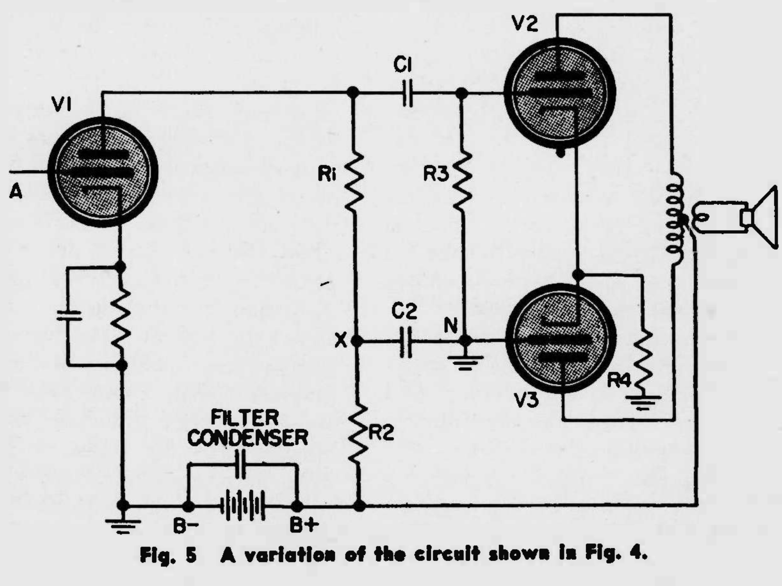


Fig. 5 A variation of the circuit shown in Fig. 4.

resistor R3, and between grid of tube V2 and ground. Now V2 amplifies the signal and it appears as fluctuating plate current which is conducted through half of the output transformer, through the power supply, and back to the cathode of V2 through cathode resistor R4. Since no cathode by-pass condenser is used, these fluctuations produce a signal voltage across resistor R4. But R4 is connected between the grid and the cathode of tube V3 (through ground). This voltage is therefore the input signal to tube V3. Suppose we now check the phase relationships. When point Y gets more positive, more plate current flows through tube V2; this increase in current flows through R4 in such a way as to make the cathode more positive than ground. Since the cathode is more positive than the grid, the grid thus becomes more negative than the cathode. In this manner, we have opposing voltages at points Y and N at any given time—which is what we want to get from the phase inverter.

Notice that here again we have introduced some negative feedback as a by-product of our phase inverting process. This is true because the plate current of tube V3, as well as that of tube V2, flows through resistor R4. Since these two plate currents are 180 degrees out of phase with each other, they tend to balance out the voltage drops across R4 as far as signal fluctuations are concerned. Thus, a considerable amount of degeneration is taking place. It now becomes clear that this is another *self-balancing* circuit. But notice that it cannot be perfectly balanced because the input voltage to tube V3 is obtained as a result of unbalance of currents through resistor R4. Since the input voltage necessary for the tube is usually very small, this unbalance is not serious, and this circuit is used successfully in several sets now on the market.

Now that we have covered the theoretical aspects of the subject, let us investigate the practical realm of servicing technique.

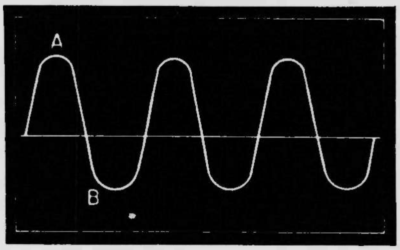


Fig. 6 Distortion of the wave form which results from an improperly balanced phase inverter circuit. The positive peak is of higer amplitude than the negative peak. This condition results in harmonic distortion.

First, there is the possibility that the relatively critical relations between bias resistors and plate and grid resistors, as well as coupling condensers, might be upset by a change in value of one or more of these components. A number of these parts have a dual purpose, and thus small changes which would not necessarily be noticed in an ordinary amplifier can cause trouble. Carbon resistors will often age and change their value; this fact must be kept in mind when searching for trouble in these circuits. Don't let a qualitative reading on an ohmmeter give you a false sense of security about a resistor. Make sure it has the correct value within the tolerance required by the parts list. Condensers are not quite as critical as resistors; but if one of them is leaking excessively, the result may be distortion and loss of signal strength.

Second, there is the matter of balance. Aging of resistors can, of course, seriously affect the balance of the two voltages on the grids of the output stages. Even if all other things in the circuit are working perfectly, this factor will produce distortion in the output. Fig. 6 shows the type of wave form which results from unbalance of the phase inverter circuit. One peak of the wave (A) has a higher value of voltage than the other peak (B). Thus harmonics, or voltages having twice, three times, etc., the fundamental frequency are produced in the output.

Having analyzed in a general way the possible causes of trouble, let's get more specific about symptoms and remedies. Since we are talking about phase inverters only, we must asume that the trouble has already been traced to that particular section of the receiver and that is where we are going to concentrate our efforts.

No signal: Trace with an audio oscillator or a signal generator having an audio output. Start at the output grids, placing the audio voltage on one grid, then the other. Audio output from the speaker should be heard from either tube, although the gain of the power tubes is quite low so don't be alarmed if the output sounds quite weak. If the set itself is dead, it is quite unlikely that one of the output tubes will be any different from the other in this test since the proper operation of either one would produce some sort of signal. An exception to this, of course, would be the case of a short in the common B+ lead. If the signal through the output stage seems to be okay, then we can move back a stage and try applying our signal to the grid of the inverter itself.

Distorted Signal: First, use the same method as described above, except that now we try to find the point at which the distortion starts. We should, of course, check all bias resistors and make sure that power supply voltages are proper. If none of these normal measures produces results, we should look for unbalance. If an audio oscillator with a good wave form is available, as well as an oscilloscope, we can follow the wave form through the circuit until we find the point at which distortion shows up in the wave shape.

Low output: All the ordinary causes of low output in an audio amplifier *except* those which would also cause unbalance are to be suspect in this case. Weak tubes in self-balancing types or low supply voltages are possible causes.

Lecture 21

A Few Words About Impedance

The term impedance appears in practical literature intended for radio servicemen, but the meaning and effects of this quantity is not at all clear to the average radio man. This lecture will attempt to clarify and to give correct concepts of impedance without resorting to extensive mathematics.

In general, impedance is the effects produced by components upon the distribution of electrical potentials and current in any network. In the simplest case, a single resistor may be considered an impedance. This resistor produces a certain voltage change, and, in particular, the voltage measured from one side of the resistor to some reference point in the circuit is different, by the voltage drop produced, from the voltage measured from the other side of the same resistor. This simple illustration indicates that voltage distribution is influenced by the presence of an impedance in the form of a resistor.

The current is also dependent on the resistor we are using for illustration. This current can be changed in value by increasing or decreasing the resistance. In the case of a simple resistor, whether the source of voltage is A.C. or D.C., the phase relationship between voltage and current remains the same.

A practical inductance has a certain amount of actual D.C. resistance, but in trying to explain its reactance, we will assume that the actual wire resistance can be ignored. The current first entering an inductance begins to form an electromagnet and this magnetic field opposes any further current increase by inducing a back-electromotive force (opposite voltage) in the inductance. In this way, a certain opposition exists to the passage of current. In the case the source is D.C., this action will simply delay the rising of the current to its normal value, but in a very short time with a practical inductance connected to a source of D.C., the current will rise to a value limited only by the resistance of this coil. From this effect, it is obvious that inductive reactance effects are important only at the first instant when D.C. source is connected and not after a period of time elapses. The study of initial effects in any circuit deals with transient conditions.

In an A.C. circuit, there is a constant changing potential and the conditions are not steady at any time. The effect of inductive reactance to A.C. is much more important and interesting. As the voltage is applied, and in the case the source supplies sine wave voltage form, the voltage may at first be rising. Because of the opposition of the inductance to changes of the current and because the current is zero initially, the current will not rise in step with the increases in voltage values, but will lag behind it, and will assume values of corresponding sine wave distribution at a definite period behind the voltage values. In a perfect inductance (one not having any resistance), the current will lag behind the voltage by 90° or 1/4 of the cycle period.

In a pure inductance, there is no power consumed since any energy taken is returned at another part of the cycle. Any practical inductance, of course, has some wire-resistance and certain other losses are present which act as if the equivalent resistance is greater. Under a theoretical consideration, one would have to assume that the resistance and other losses are associated with each small section of the inductance, but, for practical considerations, very little error occurs if these infinitesimal resistance elements are lumped and are considered equivalent to a single series connected resistor.

The presence of resistance and losses causes an inductance to consume power. These losses also change the current lag from the maximum of 90° for a pure inductance to a smaller value. If you will bear in mind that a pure resistance does not produce any lag; i.e., the phase angle is zero. It is readily understood that the combination of inductance and resistance would produce a phase angle somewhere between these two values — less than 90° and greater than 0°. There are mathematical formulas for calculating this angle, but any component used to produce the effect of inductance (chokes, coils) may be considered as having a phase angle close to 90°.

From the explanation we have given, you will readily understand that an impedance of a circuit containing an inductance is made up of inductive reactance and resistance which in part may be due to the coil itself or may be a coil and resistor connected in series as a part of the circuit. For the moment, we will consider the meaning and method of calculating inductive reactance (assuming it has zero resistance) to an alternating current of a given frequency as the value measured in ohms which would compare to a resistor of the same value producing similar effects. From considerations given earlier, it is clear that this opposition, known as inductive reactance, will depend on the actual inductance of the coil and also on the frequency of the alternating current source. The higher the frequency the less chance will the current have to build up to a high value before the cycle is reversed, and, therefore, it will be limited to a smaller measurable current. The effects produced depend on the size of the inductance and the opposition is greater for a larger inductance. Development of the actual formula for measuring inductive reactance, symbol X_L, requires knowledge of higher mathematics, but, as you have expected, the inductive reactance increases with frequency and value of inductance L. The formula is:

$$X_L = 6.28 \cdot f \cdot L$$

A capacitor, after a very short period of time, will act as an open circuit when connected to a source of D.C. Some current will move through the circuit until the condenser becomes charged to the voltage of the source. When the condenser is charged, it has the equivalent counter-voltage to the source voltage. This is a condition similar to equal batteries being connected with positive terminals together and negative terminals together. No current then will move in the circuit.

When a condenser is connected to a source of A.C., entirely different events occur, since the same D.C. steady state condition cannot be reached with constantly changing voltage values provided by A.C. When a condenser is first connected to a circuit and before it begins to charge, it takes a very high current which, as it passes through the condenser, begins to charge the condenser to small potentials at first and increasing in value with time. The effect of this is that the voltage across the condenser is lagging behind the current and in a perfect condenser this lag angle is 90°. Please observe that the phase angle effects with a capacitor are exactly opposite from those obtained in an inductance.

Capacitance reactance also depends on the size of the capacitor and the frequency of the voltage supplied. However, these factors influence the capacitive reactance value in an entirely different manner from the case of inductive reactance. The larger the capacity the longer it takes for the condenser to become charged to some specific value, and, therefore, the current passing will be of greater magnitude. This fact will imply that the larger the capacity the smaller is the capacitive reactance (opposition to current).

Let us consider the effect of frequency variation on the capacitive reactance of a given condenser. If the frequency is very high, the current will be quite large, since many times during each second the condenser will be under its initial conditions as the current of the high frequency source returns to zero at each half cycle. The fact that the current is high would indicate that opposition, capacitive reactance, is small. As the frequency becomes smaller, the capacitive reactance increases. An interesting example to keep in mind is the case of D.C., which may be considered having zero frequency. This is the least frequency possible, and, therefore, the capacitive reactance should be the highest which it is, acting as an open circuit.

The formula for capacitive reactance, symbol X_C, is:

$$X_C = \frac{1}{6.28\, f\, C}$$

The various losses in a condenser may be considered as being equivalent to a series resistor and this assumption is used in analyzing practical circuits.

To fix these ideas in mind, we will now refer to practical circuits involving the calculation of reactance. In a power supply, a choke (or field coil) has a small D.C. resistance and this factor is considered in calculating the actual D.C. voltage drop produced. A full wave rectifier produces "hum" frequency of 120 cycles A.C. and the choke acts as the inductance to this alternating voltage. An inexpensive choke used in some sets when operated at its rated current may have actual inductance of 3 henries. Applying these figures to the inductive reactance formula, we obtain 2260.8 ohms. From this you can see that the inductive reactance is much greater than the D.C. resistance which may be in the order of 200 ohms. As you probably understand, and as will be explained in a few minutes, the total opposition to A.C. involves both the inductance and resistance calculated in a special manner to give the value of impedance, but in the example cited, the value of impedance will not be much different from the inductive reactance value.

A cathode biasing resistor is used to produce a voltage drop. This voltage drop places the grid at a negative potential in respect to the cathode. This potential difference must be relatively constant and must not vary with the signal in a standard type of circuit. However, the plate current of the radio tube passing through this resistor does vary and would have an effect on the bias voltage, unless means are provided for eliminating the A.C. (signal) variations across this cathode resistor. This requirement is easily accomplished with a condenser shunting the cathode resistor. To direct current, this condenser acts essentially as an open circuit. To the average signal frequency, however, the capacitive reactance of this condenser is much smaller than the value of the resistor and, thereby, provides an easy path for the signal, eliminating the signal's effects on the average current passing through the resistor. Consider, for example, a by-pass condenser of 10 mfd. when operating with a signal of 1,000 cycles per second. Substituting these parts we obtain a capacitive reactance of about 16 ohms. This is much smaller than a cathode resistor of 500 ohms.

As we have stated, in majority of practical radio circuits L-C components employed have little resistance when compared with their reactance, and, because of this, the calculated value for reactance gives results almost equivalent to the true impedance. There are occasions, however, where resistance of the part, or separate resistor connected in the circuit itself, is of such value that impedance must be calculated from special formulas developed for that purpose. Because reactance produces a phase shift of 90° between voltage and current, while resistance does not, these factors must be combined in a manner that considers their effects. The formula for absolute impedance does this automatically and is stated below:

$$Z = \sqrt{R^2 + X^2}$$

Please note that this formula is correct for circuits involving either capacity-resistance or inductance-resistance, but no other combination of these elements.

We have already stated that inductive reactance and capacitive reactance have opposite effects on phase displacement, and by themselves do not consume any power. Therefore, you can understand that when both inductive and capacitive reactances appear in a circuit, they will have a tendency to neutralize each other. Keeping in mind the fact that inductive reactance increases as a frequency increases, while capacitive reactance increases as the frequency decreases, it is obvious that there must be some frequency for which any capacity reactance can be made equal to any inductive reactance. This frequency, as you suspected, is the natural frequency of the circuit involving the inductance and capacity. The expression is developed for it below, since it involves but simple mathematics and is of great interest.

At resonance X_C equals X_L,

Setting their formulas equal, $6.28\,fL = \frac{1}{6.28\,fC}$

Solving for f^2 we have:

$$f^2 = \frac{1}{(6.28)^2}\,\frac{1}{LC}$$

From which the resonant frequency f can be found,

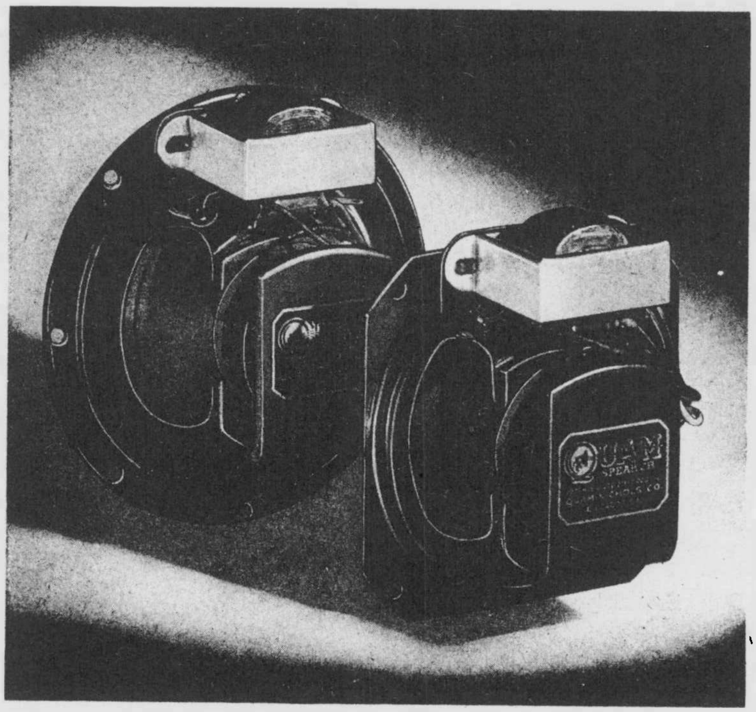
$$f = \frac{1}{6.28\sqrt{LC}}$$

Lecture 2 2

Loud Speakers, Output Transformers, and Baffles

Dynamic speakers are used almost universally in radio sets which may require your attention and our discussion will be confined to such types. In a dynamic speaker, a paper cone is attached to the frame around its periphery and creates acoustical sound with its movement. At the vertex of this cone is mounted a light-weight, small cylindrical coil having flexible leads connected to terminals supported by the frame. The voice coil has an impedance of about 4 to 8 ohms in majority of speakers. This impedance varies to a degree with the frequency of the signal impressed, but such low impedance will not vary much with the range of audio frequencies encountered. Such low impedance requires but a limited number of turns and, not only improves the response for the reason just mentioned, but also keeps the weight of the cone mass small, making the speaker more efficient.

The voice coil physically surrounds a magnetic pole piece, but is free to move longitudenally to this pole. The pole piece is magnetized by means of D.C. current flowing in an associated electro-magnetic coil (field coil) which is placed so that the pole piece is one of its poles. This type of speaker is known as an electro-dynamic type, while the type which has a strong fixed magnet (alnico or similar material) instead of the electro-magnet is called a permanent magnet speaker.



The position of the voice coil in relationship to the pole piece will depend primarily on the initial suspension of the cone, the constant magnetic strength of the field, and the current flowing in the voice coil. As the current changes in the voice coil, the coil and the attached vertex of the cone will be attracted and repelled, with or against tension produced by the cone. This physical movement (or vibration since the rate will be high corresponding to audio frequencies) will be imparted to the cone which will vibrate the air at essentially the same audio frequencies and produce sounds.

Although many faults in the circuit proper of the radio are assigned incorrectly to the loud-speaker, occasionally you will find the speaker actually causing the trouble. The existance of the magnetic field can be determined with an iron blade of a screw driver. Break and tears in the paper cone can be detected. A very tiny hole or a small break can be patched up with paper tape, but for major breaks a new cone should be installed. The new cone, of course, must be of the correct diameter, proper depth, and having correct physical and electrical size voice coil.

In mounting the cone, the voice coil is correctly centered to clear the pole piece at all points with the aid of a few matches and tooth-picks. These items are left in place while the glue dries and assures the correct positioning of the cone and voice coil. On cheap speakers do not attempt to make a repair, but replace the entire speaker.

Moisture may cause the cone to warp and push the voice coil against the pole. The rubbing action resulting will prevent proper operation and may produce audible distortion. Steaming the cone while trying to re-center the voice coil may solve this problem. In some cases, you may be able to remove the cone almost at all points on its periphery and then re-glue it in a slightly moved position to eliminate the effect of the warping.

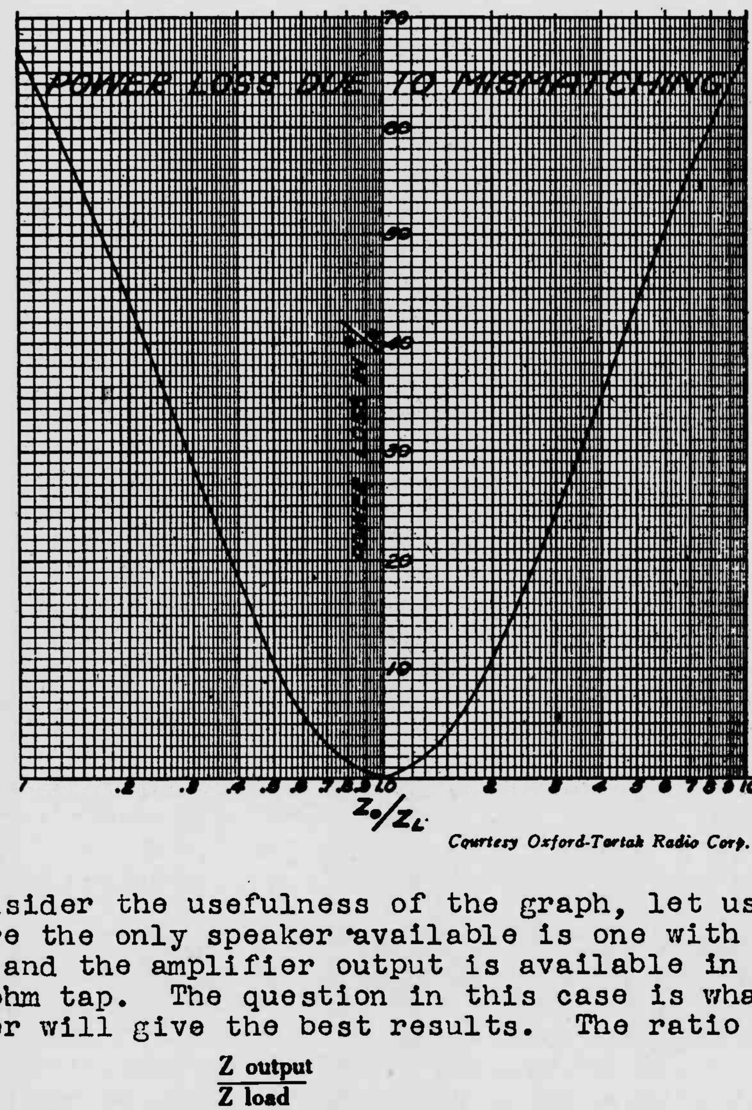
Pig tail leads may break, or the voice coil may open at a solder-contact. These faults are easily detected with an ohm-meter test.

As you probably know, to reduce distortion and to obtain maximum power, a vacuum tube in the output stage of a set or amplifier must be correctly loaded. The impedance required for this purpose varies from 1,000 to 10,000 ohms for majority of tubes. This impedance is much greater than is possible to obtain from a well designed voice coil, and a matching transformer is needed to interconnect these components. A transformer is a device for matching impedances, although you may have considered it mainly as a voltage changing part. When a transformer is placed into a circuit, the impedance connected to the primary will appear to the secondary circuit as a changed value, depending on the turns ratio. For example, if the turns ratio is 5 to 1 from primary to secondary, the impedance ratio will be the square of this quantity, or 25 to 1, and all impedances connected to the primary will appear to the secondary circuit as being 1/25th of their original size. On the other hand, any impedance connected to the secondary of this particular transformer, will appear to the primary circuit as being 25 times as large. Should the voice coil connected to the secondary have a value of 8 ohms, it will be reflected to the primary as a 2,000 ohm impedance (8 X 25 = 2,000). In this way, the transformer we have used as an example will correctly match an 8 ohm voice coil to a power tube requiring a 2,000 ohm load. Similar transformers can be made to produce any required match.

In a practical circuit, an output transformer can be tested by observing the voltage on each terminal of the primary as measured to ground. There should be a small voltage drop produced in this winding, so that if the B+ connection gives a voltage indication of 120 volts, the PLATE connection of the transformer primary will give a value of somewhat less, or about 115 volts. If these measurements are obtained, usually you can assume that there is no fault in the primary. The secondary may be measured with a low resistance ohmmeter, and for this purpose one lead to the voice coil must be disconnected. The resistance value obtained should be a few ohms.

A great deal of stress has been placed on the necessity of exact matching from source to load. While this generally holds true when the mismatching is considerable, a slight mismatch is not serious. This is quite obvious by referring to the chart.

In order to properly determine correct matching, the impedance of the voice coil must be known. This impedance is not a constant figure, but varies with frequency. For all general applications, however, the impedance is measured at 400 cycles. In the event that the impedance of a speaker is not known, the approximate value can be obtained by multiplying the D.C. resistance by a factor of 1.25.



Courtesy Oxford-Tartak Radio Corp.

To consider the usefulness of the graph, let us take the problem where the only speaker available is one with a 6 ohm voice coil, and the amplifier output is available in either a 4 ohm or 8 ohm tap. The question in this case is what tap on the amplifier will give the best results. The ratio of

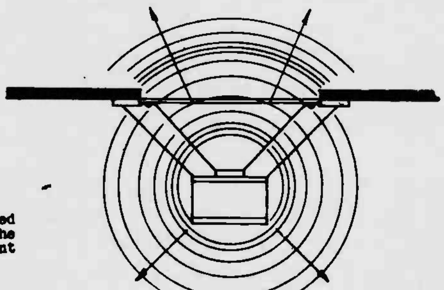
$$\frac{\text{Z output}}{\text{Z load}}$$

in the case of the 4 ohm tap is .666, and in the case of the 8 ohm tap is 1.33. In checking these figures on the graph, we find that in the case of the 4 ohm tap where the ratio is .666,

ERROR IN MATCHING OUTPUT Z / LOAD Z	APPROXIMATE LOSS OF POWER IN DB	APPROXIMATE LOSS OF POWER IN %	APPROXIMATE EFFECT ON QUALITY AND SENSITIVITY
.5	.5	11	NOTICEABLE
.6	.35	7	SLIGHTLY NOTICEABLE
.7	.2	4	BARELY NOTICEABLE
.8	.1	2	BARELY NOTICEABLE
.9	.05	1	NEGLIGABLE
1.0	0	0	NONE
1.25	.05	1.5	NEGLIGABLE
1.50	.2	4	BARELY NOTICEABLE
1.75	.35	7	SLIGHTLY NOTICEABLE
2.0	.5	11	NOTICEABLE

the loss is approximately 4%, and similarly, on the 8 ohm tap, the loss is only 2½%. It is quite obvious that the best results will be obtained if the speaker is connected to the 8 ohm tap. Generally, the results are better if the speaker is mismatched to a higher rather than a lower impedance.

However, if the speaker has only a 2 ohm voice coil, and the only tap available on the amplifier is 8 ohms, the ratio of the two impedances is 4. From observation on the graph, the loss is 35%, which is quite serious and this mismatching is not recommended.



A cross section of a speaker mounted in a baffle. Note how the baffle prevents the inter-action of the waves set up by the front and rear of the cone.

The speakers must always be used with some form of baffle to prevent the tendency of the front and rear sound waves from cancelling-out each other. If the baffle were omitted, sound compression produced in front of the speaker cone, when the cone moves forward, would cause the air to rush around the edges and relieve the rarefaction in the rear. To be equally effective to the middle and lower frequencies, a baffle must be fairly large. In practice, a 6" or 8" speaker will require a baffle with 40 inch sides. This is somewhat reduced in the case of a cabinet.

A speaker mounted in a flat baffle made of ply-wood, celotex, or masonite will radiate sound almost uniformly in all directions. If the installation requires the projection of the sound forward, directional flares or special horn baffles must be employed.

Lecture 23

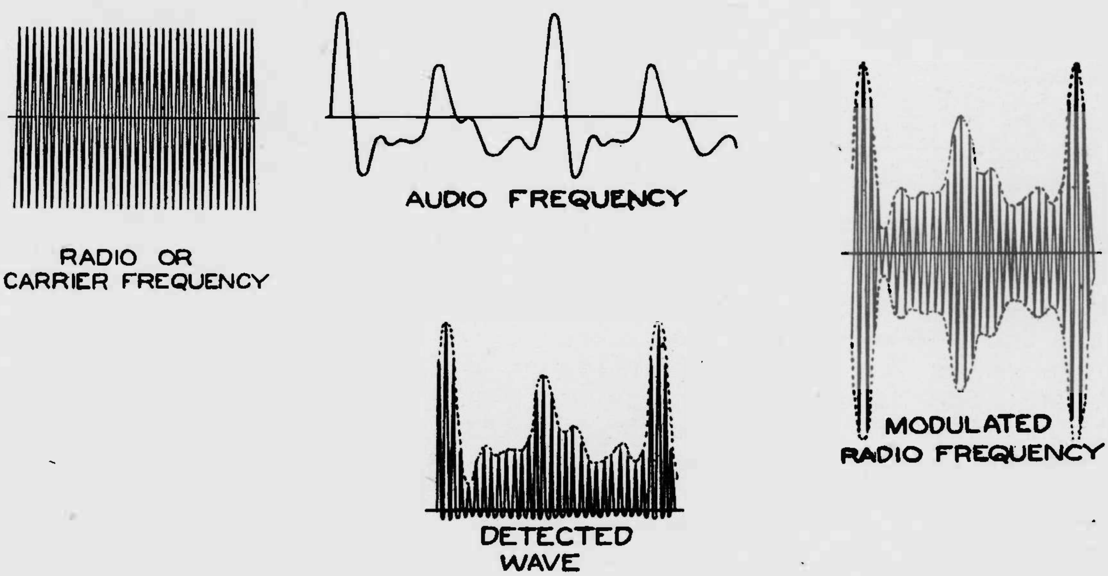
Detectors

Detectors for amplitude modulation type receivers differ from F.M. types, and will be the ones discussed in this lecture. Frequency modulation will be an important method of radio transmission, but at this time almost every receiver that finds its way into your shop is intended to receive amplitude modulation.

The study of detection is so closely associated with the modulation process at the broadcasting station that a brief explanation of modulation is in order. The amplified radio frequency energy to be transmitted must be altered in some manner by the speech or music to be broadcast. In amplitude modulation, the intensity of the audio signal is employed to vary the amplitude (intensity, strength) of the R.F. energy. Besides the carrier frequency, two side bands are created by this modulation process. The upper side band has at any one instant a new frequency equal in value to the carrier frequency plus the audio frequency existing at the same moment. The lower side band correspondingly has a new frequency equal to the difference of the carrier and audio frequency. As the audio frequencies vary and several different audio frequencies may exist at the same time, similar conditions are created in the two side bands. If the highest audio frequency transmitted is 5,000 cycles per second, the maximum variation of the side bands will also be 5 KC. This indicates that a 10 KC. channel is used for transmission.

Among all other signals, the antenna of our receiver is having a voltage induced upon it corresponding to the frequency of the station we wish to receive. This radio frequency signal is varying in intensity (amplitude) in accordance with the audio variations of the sound being transmitted. This wanted radio frequency of varying amplitude is amplified by the R.F. and I.F. section of the receiver. The resulting voltage delivered to the detector stage is similar to the varying voltage received by the receiving antenna but is much larger in value. The job now is to remove the audio variations which were placed on the radio frequency carrier at the transmitting station. The detector performs this function of removing the audio signals. Since the process of placing the audio on the carrier is called modulation, the removal of the audio may be called demodulation.

It is possible to visualize the appearance of the voltage produced by the radio wave from instant to instant. A transmitter, when no modulation is present, impresses pulses on a parallel inductance-capacity circuit tuned to resonance, and sine waves of the natural frequency of this circuit are produced. There are as many such waves per second as the numberical value of the frequency in cycles per second. Audio modulation increases or decreases the intensity of the pulses delivered to the L-C circuit, and the resulting wave-form will be increasing or decreasing in accordance with these audio variations. Since a larger voltage of the pulse, shocking the circuit, will produce a sine wave which will be larger, both the lower and upper sections of the train of sine waves will increase. As the illustration shows, the constant maximum amplitude R.F. carrier is increased or decreased in voltage (height, amplitude, intensity) in accordance with the audio signal. The envelope of the modulated R.F. wave forms a pattern above and below the wave train, and this pattern is the representation of the audio



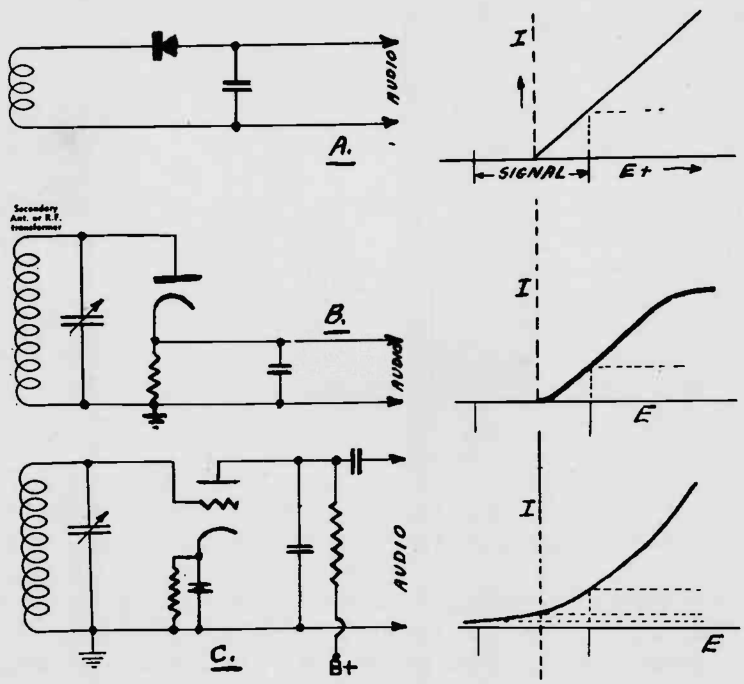
frequency which is modulating the signal. Notice that the lower envelope is this audio frequency also, but in reverse.

With any varying signal, the average voltage over several cycles will be zero. This is so because the voltage of the wave increases and decreases by the same amount over the adjacent R.F. cycles. The detector must eliminate (or greatly reduce) the lower portion of the R.F. voltage train (as modulated by the audio frequency) must be smoothed out so that an average audio signal will remain.

Although in modern radio sets, vacuum tubes are used as the detectors, in the early days of radio and for micro-wave work at present, crystal detectors found a ready application. A crystal detector consists of a mounted crystal of some special material such as galena, iron pyrites, or carborundum, and uses a thin copper wire to make the needed contact. When an alternating current of any frequency is applied to the crystal, it flows in one direction only. When the voltage reverses its polarity, the crystal presents a very high resistance. Since the upper portion of the wave train of the R.F. represents polarity in the opposite direction, detection will take place.

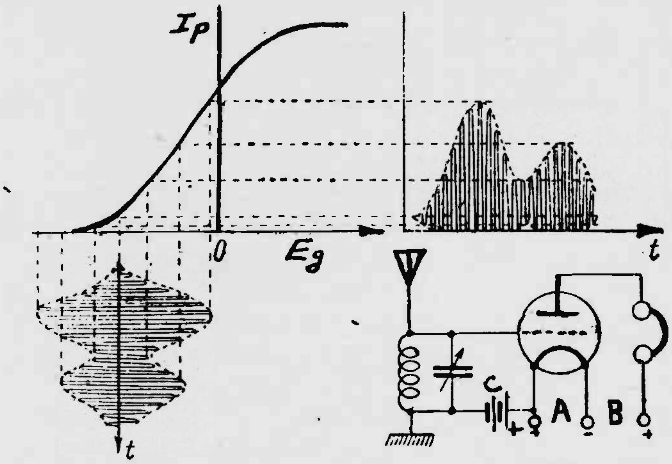
A small capacity condenser (about .0003 mfd.) is placed across the crystal output circuit. This condenser must not be so large as to by-pass audio signals, but it must be large enough to smooth out the gaps between the half-sine-waves and produce an average value of voltage which will correspond to the audio voltage originally used to modulate the wave at the transmitter.

A diode vacuum tube can be used in place of the crystal detector. A diode, of course, conducts only when the plate is made positive. This fact will permit detection to take place. The voltage is developed across the load resistor, and then is impressed on the audio amplifier. The small condenser shunts this load resistor and smooths out R.F. variations. In practice, the load resistor may be 500,000 ohms, while the condenser may be .0001 mfd. mica type.

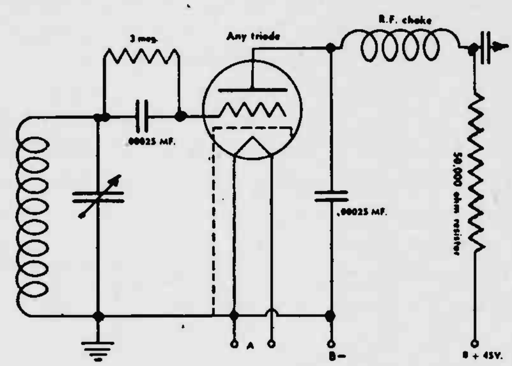


A crystal detector circuit is shown in (A). This detector is essentially linear to the signal in one direction and has infinite resistance to the signal in the opposite direction. In illustration (B) a diode detector is shown. The principle of operation is similar. A power detector, using a self biasing resistor, is shown schematically in (C).

It is possible to adjust the bias of a triode tube, so that the plate current is near cut-off. The grid bias required may be obtained from a separate voltage divider or the tube may use a cathode-resistor circuit. In the usual practical circuit, the cathode resistor is between 10,000 and 50,000 ohms. As you can see from the illustration, the positive portions of the R.F. will be amplified a great deal, while the negative portions will reduce the minute-minimum (no signal) current very little. The plate current passing through the tube, therefore, will depend primarily



A biased or power detector is operated at that point of its characteristic curve where a much greater plate current change occurs on positive peaks than on the negative peaks.



A grid leak detector is especially useful in circuits requiring considerable sensitivity. It is not used in modern radio sets.

on the positive portion of the R.F. and will reproduce this wave-shape greatly amplified.

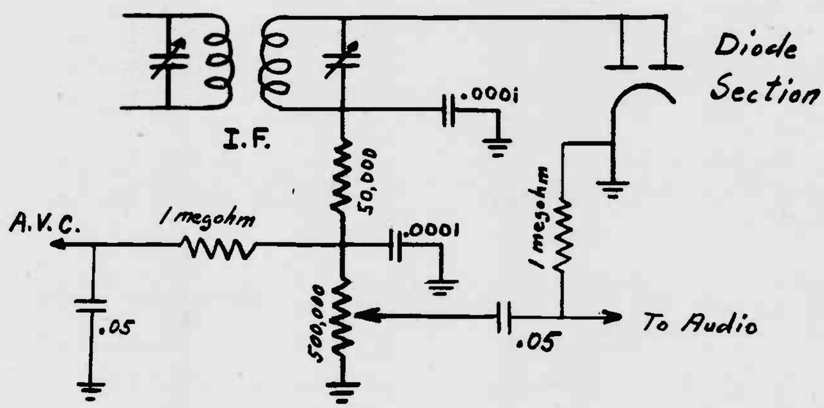
The result is similar to what we have obtained from other type detectors, but here we not only produced detection but have amplified the signal at the same time. This type of detector employs a process called plate detection. Plate detection is especially useful for handling large signals and may be used to drive the final power output audio tube directly, therefore, these detectors are used in cheaper sets where economy factor is of importance.

In a grid leak type detector, see illustration, the control grid and cathode act as a diode and the control grid voltage varies at the audio signal rate. At the same time, the grid bias varies from some negative value close to zero to larger negative values as the signal increases. With strong signals, the grid circuit (acting as a diode) will conduct on the positive cycles of the R.F., and produce larger average voltage drop across the grid leak.

The grid leak detector is more sensitive than other types, has limited power handling ability, and is seldom used in modern receivers.

In majority of modern sets, the function of detection and of production of A.V.C. voltage is combined. For this purpose, a diode type tube such as 6H6, or dual purpose tube such as 6Q7 is used. The dual purpose tube provides a triode voltage amplifier in the same envelope and is used to amplify the audio output from the detector. The diode plates may be tied together or used separately to produce the audio signal and A.V.C. distinctly. In such combination, tubes have their common cathode at ground potential as is required for the diode detector circuit. The bias for the triode section is produced by using external bias cells in the grid circuit or is obtained from the contact potential of the tube and grid leak bias produced by using a large value grid resistor.

In a practical circuit, the secondary of an output type I.F. transformer has one connection to the diodes and the other connection to the diode load resistor.



The diode load may be in the form of a smaller R.F. filter resistor of 50,000 ohms by-passed on each side by small condensers which offer low impedance to R.F. (or I.F.) and do not pass audio frequencies which exist across this resistor in series with the 500,000 ohm volume control. At the junction of these two resistors, is connected an audio filter so that the A.V.C. voltage applied to various other tubes is essentially D.C. changing in value with carrier intensity and not audio variations.

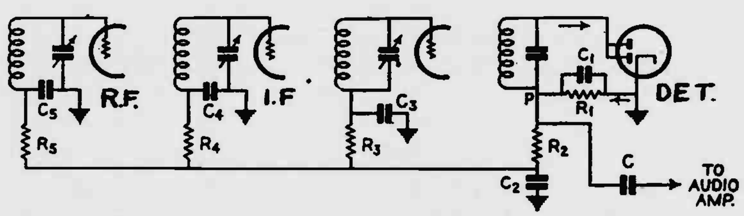
In another type diode detector circuit, only one diode is used in a similar detector circuit, but the A.V.C. is obtained from the second diode, connected to the first diode through a small condenser, and connected to ground through a high resistance.

Faults developing in detector circuit, outside of the A.V.C., are not very common since the components employed are not subject to large potential variations. The R.F. by-pass condensers may be at fault and should be suspected. For better high fidelity response, one of these condensers may be omitted, or smaller capacity condensers used. Lack of proper operation may be due to open I.F. transformer winding, open volume control, shorted I.F. transformer trimmer, or bad tube.

Automatic volume control attempts to bring all signals to a uniform level regardless of intensity. The value of A.V.C. voltage applied to the grid return of tubes so controlled depends on the rectified current at the detector and this, in turn, depends on the signal strength. If the signal is strong, the A.V.C. voltage will be large and will reduce the gain of the tubes so controlled. This action will even out the value of the signal reaching the detector.

One type of fault in A.V.C. circuits is due to poor filtering action. In the detector, the R.F. (or I.F.) component must be filtered, but such R-C filter used should have little effect on audio frequencies. The audio signals should not reach the A.V.C. controlled tubes and, for this purpose, we have another R-C filter in the A.V.C. circuit. This R-C filter must be of value not to reduce to any degree the audio signals developed across the volume control. Also the value of the resistance and condenser in this R-C filter determine the time constant of A.V.C. action, and this is equal to a value in seconds obtained by multiplying resistance used expressed in megohms by capacity in microfarads. There are also in some circuits additional R-C filters in the A.V.C. distribution network.

Improper speed in the operation of the A.V.C. showing up as a reduction in audio volume a period of time after tuning in the station, is due to a high time constant. This may be caused by the condenser or resistor in the A.V.C. filter changing values. Try lower values to obtain proper operation.



The basic circuit showing the voltage distribution in a modern AVC system.

Overloading or distortion traced to A.V.C. is usually due to leaky filter condenser in A.V.C. circuit. Remove old condenser and connect a new one to test for fault — do not shunt the new one across the old condenser.

Motorboating and oscillations are produced by feedback, insufficient by-pass, or improper dressing of the leads. Try moving leads with a small stick or pencil. By-pass a few points of the A.V.C. circuit with a .05 mfd. test condenser.

Lecture 24

Tuned Circuits

Radio servicemen successfully adjust, repair, and replace elements of tuned circuits used in radio receivers, but in all frankness the knowledge of servicemen on this important subject is not on a very satisfactory plane. This lecture will attempt to correct this shortcoming and you will be surprised with what ease this matter can be understood.

Tuned circuits consist of required inductance and capacity, and associated inherent resistance which is not wanted in most applications, but cannot be eliminated. Every radio coil has a certain amount of distributed capacity produced by small amount of capacitance between adjacent turns, between each turn and every other turn, and from each turn to the ground or shield. These various individual capacities are equivalent to a small condenser shunted across the terminals of the coil. In multilayer coils, bank or honeycomb windings are employed to reduce distributed capacity effects since these effects limit the tuning range of the coil when used with a given variable condenser.

Dielectric losses in a coil increase with frequency. These losses are due to materials used for tubing, wire insulation, and terminal strips. However, these losses are not as important or as large as the loss produced by skin effect. The magnetic flux distribution around a conductor at radio frequencies is such as to force almost the entire current to move on the surface of the conductor. So little current travels within the conductor that a hollow wire (tubing) can be used instead of a solid wire without introducing any additional R.F. resistance loss. Litz wire consists of a number of strands of fine wire which is woven so that each strand is on the outside of the resulting cable an equal amount with other strands. This placement of the strands will result in an uniform current distribution throughout the conductor and the much larger surface area of many small conductors, as compared to one large one of equal cross-sectional area, will reduce the resistance to radio frequencies. Coils using Litz wire are especially useful at frequencies below 1,500 KC. and are, therefore, used for broadcast frequencies.

Capacity exists when a potential difference is possible between two conducting bodies. For adjusting radio tuned circuits, air dielectric movable plate condensers are employed. Where adjustment is needed only at times of alignment, semi-adjustable, mica dielectric condensers are used. The capacity of a condenser (a measurement expressed in microfarads for practical units) depends directly on the size of the plates, distance between these plates, and the type of dielectric material placed between the plates. Mica has a dielectric constant about six times larger than air and this explains why small mica trimmers of only two plates may have maximum capacities in the order of .00005 mfd.

Variable tuning condensers are constructed with a set of fixed plates within which a group of additional plates revolve. The stationary plates are connected together and in a practical condenser have two terminals, one at each side. The rotor plates are connected to the frame and become grounded to the chassis when the unit is mounted. In the better sets, a ground lead is also provided for assuring a good ground connection. In the present day radio receivers, the condensers are of straight-line capacity type, meaning that equal degree of rotation produce approximately equal changes of capacity. Several gangs may be constructed on one frame and have their stator plate sections insulated from each other, while the rotors are on a common shaft.

For superhet application, the required difference in frequency of one tuned circuit is obtained through the use of an extra padder, or, in a cut-section condenser, one section is made of smaller size rotor plates so that the required frequency difference in the tuned circuits exists at all settings.

The capacity of a tuned circuit influences the frequency as the square root of its variation. Therefore, a practical condenser, which has capacity change from maximum to minimum in the ratio of 9 to 1, will produce a frequency range in the order of 3 to 1. These figures include in the minimum capacity of the condenser plus stray capacities of the associated circuit and inductance.

During the shortages resulting in the post-war period, iron core slug tuning was employed and produced frequency changes in a tuned circuit by alternating the value of inductance. Necessary capacity was provided in a fixed form and by the stray capacities of the circuit.

The majority of coils used in radio receivers involve common coupling, and an explanation of mutual inductance is in order. Mutual inductance is present whenever two coils have some of their magnetic flux linking each other. If all the magnetic lines are common to both coils, the mutual inductance,

$M = \sqrt{L_1 L_2}$, where L_1, and L_2 are the individual inductances.

The coupling between the coils is never perfect and is of a small percentage in radio frequency coils.

The transfer of energy will take place between two coils if there exists between them some mutual inductance. This transformer action is not as simple in radio frequency coils as it is in the case of iron core transformers used for power frequencies.

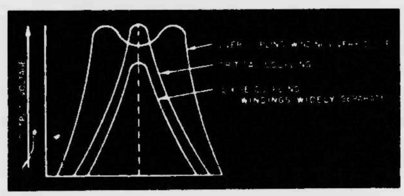
Mutual impedance is the term that explains the inter-relationship between two coupled circuits. In a practical case of an antenna or R.F. coil, the value of mutual impedance will depend on the impedance of the primary and secondary, and on the degree of coupling. In an air core coil, the mutual impedance is very nearly a pure reactance.

The secondary impedance and the load coupled to it, may appear to the primary as being of another value. This reflection depends in a mathematical manner on the impedance of the secondary, the load, and mutual impedance. Of particular interest to you as practical radio men are several facts influencing alignment. If the coupled coils (i.e., primary and secondary) are loosely coupled with the coefficient of coupling small, very little effect will be carried from one coil to the other. This will result from the reflected impedance being very small as compared to the impedance of the coil itself. If the coupling is increased, the reflected impedance must be considered and either coil will be influenced by the adjustment of the other.

If, for example, the secondary of an I.F. transformer is adjusted above the signal frequency, this secondary will have its inductive reactance of value slightly greater than its capacitance reactance. When properly adjusted, at resonance, these factors would be equal. An L-C circuit with resistance losses having a greater value of inductive reactance behaves as if it had but a small inductance and resistance — the capacity effects are balanced out by part of the inductance. The interesting fact is that this equivalent inductance of the secondary is reflected to the primary of the I.F. transformer as capacitance of value depending on factors already mentioned and has an influence as a capacity on this coupled circuit. It becomes clear to you, by following this explanation, why in I.F. alignment it may be necessary to go over the alignment several times. As you can see, a slight error in adjustment in the secondary reflect capacity into the primary which may then be adjusted slightly off and reflect reactance into the secondary. As you know, in practice, these adjustments are not too difficult since minor variations do not have bad effects.

In most practical cases, the antenna coil primary is not naturally resonant to the frequency of the station wanted. Therefore, when this station is tuned in for best operation, the secondary of this antenna coil and the tuning condenser (adjusted to this station) are somewhat detuned from the frequency of the station. This detuning of the secondary reflects the right reactance to the antenna primary for improvement of reception. In tuning a radio, this step is carried out automatically in obtaining maximum signal.

The degree of coupling in modern coils cannot be altered, but is selected by engineers who design coils to produce desired effects. Close coupling (above a certain critical value) will produce double peak response. Very close coupling (of 5% in a typical broadcast frequency R.F. coil) will produce peaks of maximum current at 975 and 1025 KC., when adjustment is carried out for 1000 KC., and a dip between these peaks to about one half maximum current value at the center. As the coupling is reduced, the two peaks approach each other and merge into each other at the critical coupling value. In the example we have used, critical coupling may represent a value of 1%, and the peak in such case will be at 1000 KC., giving suitable selectivity for 10 KC. broadcast channel. The response curve resulting has a



flatter top and steeper sides than would be possible from a simple parallel or series tuned circuit.

If coupling is reduced beyond the critical value, the current peak is reduced and response curve is made narrower and the sides less steep, conditions definitely not wanted for good radio reception. Practical circuits are usually adjusted to produce coupling slightly in excess of critical coupling.

Lecture 25

Radio Frequency and I.F. Amplifiers

Radio frequency amplifiers increase the voltage of the wanted signal while rejecting to a large degree frequencies of adjacent stations. In the older radio sets, before the superheterodyne circuit was adopted for general use, the entire selectivity and practically all of the sensitivity of the receiver were provided by R.F. stages. At first, triode tubes were employed and required neutralization to prevent oscillations. The screen grid tube (type 24-A and then 35) increased the gain possible and eliminated the need for neutralization. You still may be called on to service such circuits, and additional theory and service hints will be presented to help you. In modern sets, you will find R.F. amplifiers in small T.R.F. sets or as a pre-selector stage before the mixer tube in the better superhets.

In general, any R.F. stage consists of a tuning arrangement before and after a vacuum tube employed as a voltage amplifier. The L-C combinations provided are tuned to the frequency of the wanted station and are sufficiently selective to pass the band of frequencies of this station and, to a large degree, reject frequencies of other stations somewhat removed on the frequency spectrum.

In considering a circuit used with a triode tube, we observe a coil (usually in the form of an air core R.F. transformer) tuned with a variable condenser at the input. The secondary is connected to the control grid and cathode return of the triode and a voltage gain of a value almost equal to the Q of this coil is produced and impressed on the grid. The grid potential is fixed at a sufficiently negative value so that it remains negative under all operating conditions and does not draw current. The plate of the tube is loaded with the primary of another R.F. coil and presents a very high impedance at the wanted frequency. Since this impedance is high as compared to the plate resistance of a triode, the amplification produced by this tube is almost equal to the amplification factor and is in the order of 7 to 20. The R.F. coil secondary, in turn, is connected to another R.F. stage or the detector.

With triodes, means of neutralizing the R.F. stage is provided. Various arrangements are employed and one such method is to connect a small semi-variable condenser from a top of the secondary to the control grid of the tube of the preceding stage. At this time, you will be called upon to repair very few such old fashion radios.

In modern type superhets, a pentode type tube, similar to 78-6D6-6K7-12SK7, is used. In A.C. radios, the plate voltage may have a value from 180 to 250 volts, with about one-half the plate voltage applied to the screen. The lower voltage is obtained in most sets by means of a voltage divider and not just a series dropping resistor. In AC-DC sets, the plate and screen have the same potential of 80 to 120 volts. The negative grid bias is obtained with a cathode resistor. This resistor provides only minimum bias in case AVC is incorporated. In sets without AVC, a variable resistor may be used to give needed control of the volume.

If the radio is used for reception of several bands, a band switch connects proper coils but the circuit remains the same. In some of the cheaper midget radios, the police band can be received by providing a tap on the coil to reduce the inductance of the secondary remaining in the circuit.

Intermediate frequency (I.F.) amplifiers are special kind of radio frequency amplifiers and may be considered as such. The tuned circuits used are not variable but are adjusted for best operation at the I.F. frequency which is usually below the frequencies used with the R.F. amplifier. The tuning arrangement consists of an air core transformer and usually has both primary and secondary tuned (adjusted) with small mica dielectric trimmers. The majority of superhets you will be called on to service will use pentode tubes in the I.F. stage.

In the superhetrodyne receiver, the frequency of any wanted station is changed to a fixed frequency usually between 450 KC. and 480 KC. The original side-bands of the station being received become corresponding side-bands of this new intermediate frequency. The I.F. coil used to couple such stages may be designed to give better results than the R.F. coil which is tuned to resonance for each station to be received. Let us consider the limitations of R.F. transformers, which are used to receive many frequencies, and see how the I.F., which is a single frequency transformer, eliminates these faults.

The shape of the response curve obtained depends on the Q of the coil. If the Q is large, the curve is narrow and has steep sides. If the Q is small, the selectivity curve spreads out and is almost flat over a large frequency variation. Since the value of Q is computed by multiplying the fixed quantity 6.28 by the inductance of the coil in henries by the frequency of the circuit, and dividing the result by the resistance which changes but little, the Q varies primarily with frequency. In the broadcast band, the value of Q may vary by a ratio of 2½, from the lowest to the highest frequency of the band. This variation, of course, gives different degrees of response to different frequencies. If the R.F. coil is designed to give proper response at one frequency in the center of the band, the response may be too sharp at one end and too broad at the other end.

A tuned circuit made to operate at a definite single frequency may be designed to give optimum results at this frequency. This is just what is done in the case of the I.F. transformer. High gain is obtained and the output is almost flat within the required band width of 5 KC. on each side of the I.F., and falls off sharply after these frequencies.

Weak tube in R.F. or I.F. amplifier may reduce the volume level or prevent the set from operating completely. Complete failure may also be due to shorted screen or cathode by-pass condenser, open coil primary, or shorted tuning condenser. In the case of an R.F. stage, oscillations may be caused by open screen by-pass condenser, poor shielding, high screen voltage, or by poor contact of rotary plates of the variable condenser to frame.

Because of the circuit position of the I.F. amplifier in relationship to the balance of the set, special faults can exist in the I.F. stage. For example, weak signals may be due to improper alignment and in particular in using wrong I.F. frequency. The trimmer of the I.F. transformer can be the cause of trouble — it may short, screw threads become worn, or connection to the trimmer may break. Oscillation may be due to poor alignment, insufficient screen by-pass, or poor dressing of the leads. In some sets, the oscillation at many points on the dial can be best solved by segregating common B+ (or AVC) points by means of R-C filters. Use 5,000 ohms resistors and .05 mfd. condensers. In AVC circuits, the resistor should be 100,000 ohms.

Lecture 26

Superheterodyne Frequency Converters

The advantage of a superhet circuit comes from the use of pre-adjusted single frequency amplifiers (I.F. amplifiers) and means must be provided in such sets to convert the frequency of the station received to this intermediate frequency. This conversion is accomplished by generating a radio frequency higher than the signal and differing from it by the frequency of the I.F., and mixing this new frequency and the signal frequency in a non-linear impedance which can be provided by a vacuum tube operated over a non-linear part of its characteristic curve.

From this review, it is clear that an oscillator is needed to produce this new frequency and a mixer is required to combine these two frequencies. In the early types of superheterodyne receivers, a triode served as a local oscillator and another triode was used as the mixer. Since the mixer in such sets was operated as detector to obtain the non-linear characteristics, this tube in some literature is called the first detector while the detector used to "remove" audio signals is called the second detector. It is possible to obtain the combined action of oscillator and mixer with a tetrode or an ordinary R.F. type pentode and this was done in the sets built during the depression for economy reasons. You still may run across such sets and the service suggestions presented later will apply.

Pentagrid converter tubes (of which 1A7, 6A7 and 6A8 are commonly encountered examples) have the electron stream influenced by both the signal and oscillator frequencies. A common cathode serves both the oscillator and mixer sections. The output is taken from the main plate. The oscillator grid is next to the cathode and the next grid serves as the oscillator anode. These elements form a triode which is connected to the oscillator coil and effects the current passing between the cathode and the main plate. Grids three and five are connected together to serve as the screen, while grid four is between them and is the control grid for the signal frequency. The tube is operated to produce a mixing of the signal and oscillator frequencies on its non-linear curvature and produces new frequencies. In the plate circuit of the pentagrid converter (or other type of mixer tube), appear the original frequencies impressed on the tube, the sum, and the difference of these frequencies, and other minor frequencies which are related to the harmonics of the signal and oscillator frequencies. Of all these, only the difference of the oscillator and signal frequencies is of importance, and is passed and amplified by the I.F. stages.

Tubes of the single-ended types such as 6SA7 and 12SA7 have their elements connected somewhat differently from pentagrid converters we have just considered. Grid one nearest the cathode is here also used as the oscillator grid, but grids two and four are tied together and used as the screen, grid three is the R.F. input grid, and grid five nearest the plate is the suppressor. The oscillator coil used with such single-ended converter tubes has a single tapped winding. As you probably recall, in majority of sets, one end of this coil connects to the oscillator grid through a small mica condenser, the top is connected to the cathode, the remaining lead is grounded. The oscillator feed-back circuit uses cathode current which passes through a part of the oscillator coil winding.

Tubes such as 6J8 and 6K8 are really dual tubes, having some of their elements connected internally to provide required converter action. For example, type 6J8 has a triode oscillator and a section similar to a 6L7 tube. The cathode is common to these two sections, and the control grid of the triode is directly connected to the second control grid in the heptode section. The function is similar to that obtained from two tube arrangement such as using 6L7 and 6C5.

Oscillator tubes are tricky and, although appearing in good condition when tested in a tube tester, may not oscillate above a certain frequency or not at all. A signal generator may be substituted for the oscillator; simply connect to oscillator grid or other point where oscillator frequency is present normally. Adjust signal generator to frequency (unmodulated) equal to signal frequency plus I.F. This will permit operation of radio if the only fault was in the oscillator section.

The fault in the oscillator may be due to an open oscillator coil winding, defect in oscillator grid condenser or resistor, or shorted padder. If the repair was attempted by someone else before you were called, the oscillator coil connections may be reversed.

In replacing an oscillator coil, you may find the alignment difficult since the circuits may not track at all points. This limitation is due to differences in coils. Ordinarily, the coils to be used in a superhet are designed to correspond to the capacity curves of the variable condenser and to the dial calibration. For some repairs, it may prove better to replace both the antenna and oscillator coils. In multi-band sets or in case the break (or short) in the oscillator coil can be detected by unwinding some of the turns, it will be best to make an attempt at a repair. The wire removed should be replaced after the repair is made.

Lecture 27

Alignment Information

The process of alignment is the combination of adjustments carried out to permit every tuned circuit to operate properly at each setting of the dial. In a T.R.F. receiver, alignment is a relatively simple matter since every tuned stage is intended to operate at the same frequency at any one time. Each section of a multi-gang variable condenser is shunted by a trimmer and these trimmers are used to equalize the minimum capacity variations due to stray capacities of the circuit and slight differences in inductances employed.

The alignment of a T.R.F. receiver is carried out at about 1,400 KC. and adjustment of trimmers is made to produce maximum signal. Once adjustment is made at this frequency, the receiver tuned circuits will track at lower frequencies since greater amount of capacity of the variable condenser will be in effect and any small additional differences will represent only minute fractions of this capacity.

In a superhet, as you know, the several tuned circuits function at entirely different frequencies but their adjustments are interdependent. For optimum results, the adjustments must be correctly made and carried out in the proper sequence.

The I.F. transformers are usually double tuned and will give maximum gain and best selectivity response when employed at a frequency for which these coils were designed. This frequency varies in radios of various makes and the period in which the sets were produced. In modern sets, the I.F. is between 455 and 470 KC. Some of the older sets used I.F. of 175, 260 KC., and other values.

For correct tracking, the oscillator of a superhet must generate a frequency usually above the signal frequency and differing from it by the I.F. value. When the oscillator frequency is higher, the tuning capacity must be smaller to give the required frequency range. This tuning capacity is made smaller in practical circuits by employing a cut-section condenser or by connecting a padder, which is a small semi-variable condenser, in series with the gang of a regular tuning condenser that is used for the oscillator section.

The antenna and oscillator coils (in some larger sets an R.F. coil is also used) are so designed that with a given cut-section condenser (or regular condenser and correctly adjusted padder) it is possible to adjust the trimmers at the high frequency band and have correct tracking at all other frequencies. This design, of course, is based on the I.F. used, and this is another reason why correct I.F. adjustment must be made.

In the process of tuning a superhet receiver slightly out of alignment, the oscillator section has a much more pronounced effect upon the tuning adjustment since the antenna (and R.F. if used) sections are broad enough to pass the signal of a station even if slightly detuned. Under such conditions, a given station will be received at some incorrect, but not much removed, point on the dial. At this setting, the signal of the station wanted will "ride through" the detuned antenna (and R.F. if used) sections, while the particular adjustment will produce in the incorrectly adjusted oscillator a frequency higher exactly by the I.F. of the set. This suggests that the dial reading is corrected by adjusting the oscillator section trimmer.

In performing alignment, means must exist for comparing the intensity of the output as adjustments are made. Listening to the output is one method, but it is not very reliable since the human ear is not critical to very small changes in sound intensity. If the set is equipped with a tuning indicator such as an electron-ray tube, shadow-meter, or plate milliammeter, these devices can be employed to indicate resonance. A vacuum tube voltmeter may be connected across the A.V.C. junction point and ground; with this arrangement, resonance will be indicated by maximum voltage. An A.C. voltmeter of low range can be connected across the voice coil, or a higher range of such a meter in series with a paper dielectric condenser can be inserted across the primary of the output transformer.

In sets with A.V.C., steps must be taken to nullify this action while carrying out alignment work. If you are able to carry out the alignment while feeding a very weak signal, the A.V.C. will not produce any effect under such a weak signal and the response will be directly related to accuracy of the alignment. When using a weak signal, you should have the volume control of the receiver wide open.

In sets where a stronger signal is needed, the A.V.C. by trying to keep the output intensity constant will prevent you from judging true effects of the adjustments, and in such sets A.V.C. must be prevented from operating during alignment. Where a separate A.V.C. tube is used, this tube may be removed without impairing the operation of the receiver except for lack of automatic volume control action. In other sets, it is permissible and quite a simple matter to ground A.V.C. bus to remove this action. There are sets where this simple means of nullifying A.V.C. cannot be made and in such sets you can disconnect I.F. stages grid returns from the A.V.C. and connect these returns to ground or similar point.

A signal generator is essential if the I.F. stages are out of alignment to a considerable degree. If you have another set properly operating and having the same I.F., you can couple these to carry out the I.F. adjustment without a signal generator. If the I.F. amplifier is not too far out of alignment, a signal generator lead may be connected to the signal input grid of the oscillator. A small mica condenser is wired in series with this lead and also the ground lead. The I.F. trimmers may be adjusted in any order in such case.

In some sets, where the owner may have attempted the repair himself, you may find it impossible to get the signal through both transformers of the I.F. amplifiers. The best procedure under such circumstances is to adjust one transformer at a time. Connect the signal generator to the grid of the I.F. tube preceding the output I.F. transformer and adjust the trimmers of this transformer. You may find it necessary to find a signal generator frequency which will get through. If this frequency is above the correct I.F., turn the trimmers clockwise to increase capacity and lower the adjusted frequency of the I.F. transformer. In this manner, you can approach the correct adjustment. Then return to the converter tube and complete the adjustment of the I.F. amplifier.

There are receivers having the trimmers located apart from the coils of the I.F. transformer. A few transformers you encounter may be triple tuned, while many midgets have the second I.F. transformer of the single tuned type. In all these cases, the alignment practice is as described. As the volume output increases with improvement of gain obtained by adjusting the circuits to resonance, the volume should be reduced with the attenuator of the signal generator and not with the volume control of the set.

In carrying out the alignment of the I.F. amplifier, the turning of every trimmer should have a noticeable effect on the volume of the output or the indicator employed. Lack of such action will suggest an open coil, shorted trimmer, or a stripped adjusting screw. The factory engineers design I.F. coils so that the trimmers can give considerable variation from the optimum I.F. If you find that the trimmer adjusting screw must be tightened completely or left very loose, suspect trouble.

Although high frequency adjustment in most superhets should be performed at 1,400 KC., many manufacturers specify different frequencies and you should watch for such variations. If a station operates in your locality at the very frequency suggested for alignment, a slightly different value should be employed. In a few sets, the manufacturer's instructions give a high frequency at the end of the dial calibration for setting the oscillator trimmer and another high frequency for completing this alignment.

High frequency adjustments are made after the I.F. is aligned. A signal generator set at the correct frequency is connected to the antenna or coupled loosely to the loop of the radio with the aid of three turns of hook up wire about 8 inches in diameter. In alignment work if your signal generator provides for percentage modulation adjustment, a value between 30% and 50% will give best results.

The radio receiver dial is adjusted to a frequency corresponding to the frequency being produced by the signal generator. This is usually about 1,400 KC., but, as we have mentioned, other frequencies may be suggested by a manufacturer for certain radio sets. The adjustment of the oscillator trimmer should permit you to obtain proper response without changing the dial setting. The antenna trimmer need not be touched at this time since this circuit is broad enough to pass the signal frequency even if considerably detuned.

After the oscillator section is adjusted, the antenna trimmer adjustment is made. In radio sets using R.F. pre-selector, this stage is adjusted at the very end. You may find it advisable to go back and recheck all points of alignment including I.F. trimmers. Sometimes slight additional adjustment is possible for further improvement of response.

In superhet receivers using a cut-section condenser, no other adjustment is needed and the set should now work properly at all frequencies. In case you cannot obtain successful results at low frequencies and are certain that the alignment work has been correctly carried out with a good signal generator, adjustment at the low frequency end can be made by bending the outside plates of the variable condenser, which are notched for this purpose. You can understand that bending these plates slightly, no effective change will be produced on your high frequency adjustments, since these plates engage the stationery plates only at the lower frequencies.

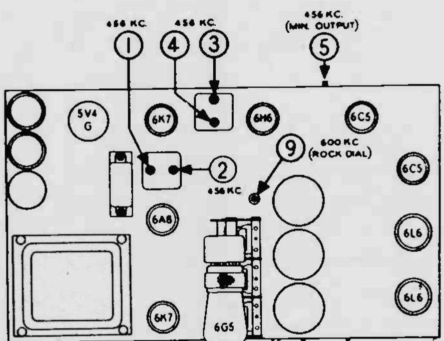
In case an ordinary gang condenser is used, a padder is provided for adjustment at about 600 KC. This frequency is not critical but is recommended by most manufacturers.

In low frequency adjustment, the signal generator is set to produce 600 KC., and while the radio dial is rocked up and back past the 600 KC. point on the dial, the padder is adjusted for maximum signal. The rocking action need not be employed and the adjustment may be carried out at 600 KC. with the objective of having the signal intensity drop above and below this frequency.

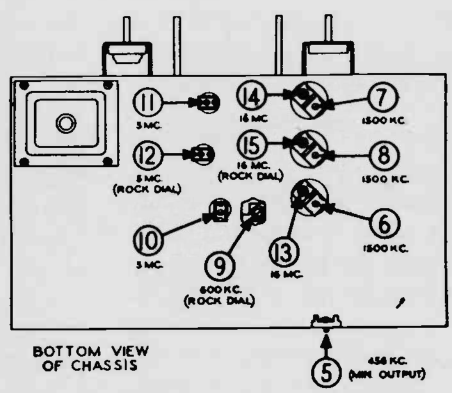
A word of caution is in order to those who have not yet handled receivers that incorporated a fixed mica condenser in series with the padder. Many times this fixed condenser is the one that causes the trouble and this difficulty is not easily detected.

In radio sets providing reception on more than one band, the same procedure for adjustment of the I.F. is carried out first of all. Unless there are manufacturer's instructions to the contrary, the broadcast band is aligned next. In multi-band receivers, the trimmers may not be supplied on the variable condenser or, if they are included, may not be employed for alignment. Usually each set of coils has its own separate trimmers mounted near corresponding coils.

If the short wave bands included have "independent" trimmers, these can be adjusted with the lowest frequency band first. In some sets, the adjustment of some one trimmer may effect an adjacent band and in such cases the alignment procedure must be carried out in the proper order.



TOP VIEW OF CHASSIS



BOTTOM VIEW OF CHASSIS

In general, the alignment of multi-band receivers is involved because it is difficult to find the proper trimmers that correspond to the various bands. Charts similar to that illustrated are provided with circuit diagrams to permit easy location of these trimmers. Another problem is the possibility of adjusting the oscillator to produce an incorrect frequency which nevertheless will have a value that will result in new frequencies (due to harmonics) which may pass through the I.F., but not permit the receiver to operate at its maximum efficiency.

In carrying out alignment on short-wave bands, it is also helpful to know the correct frequencies for the high and low positions of the alignment. If these frequencies are not available, it is usually possible to guess by using the corresponding variable condenser position for each band after the broadcast band, but changing the wavelength switch and adjusting the signal generator to the corresponding frequency.

We will now consider a few possible troubles. The failure of any of the trimmers to have an effect on the response may be due to an open secondary or broken lead to the trimmer. Should you experience an improvement in response as any one trimmer is tightened, but find it impossible to tighten beyond a certain point, this shortcome will suggest that the oscillator trimmer has been tightened too far, and probably the dial scale does not read correctly. Similar trouble may occur at the other extreme when you are forced to loosen the trimmer to a point where the set screw no longer engages the threaded bushing.

Lecture 28

Radio Receiver Power Supplies

The discussion of radio receiver power supplies will cover facts on transformer A.C. operated types, AC-DC half-wave types, and voltage doubler circuits. Test procedures and service hints will also be given.

Filaments used in vacuum tubes can be manufactured most easily for operation from relatively low voltages. In directly heated tubes, low filament voltage eliminates the problem of voltage distribution along the filament, and permits higher current for the equivalent power consumption. The higher current has a thermal (temperature) stabilizing effect and reduces possibilities of hum. The geometry of elements in the tube and physical properties of radio receiving circuits are such that plate voltages above the usual 110 volt line supply give best results. This fact was particularly so with early tubes and circuits.

This introduction shows why a power transformer was a natural device to provide voltages of applicable values for the purposes described. In general, transformers in older receivers using directly heated tubes in some positions, provide the high voltage for the plate supply and have several filament secondaries of correct voltages which permit isolation of the filament circuits as needed. In some of these older sets, for example, a separate 5 volt filament winding served a type 80 rectifier, a 2½ volt filament served a directly heated type 45 tube, and another (separate) 2½ volt winding supplied the balance of the tubes which were of cathode types. Perhaps the reason for two separate 2½ volt winding is not clear to you. Separate windings were required for if all the 2½ volt tubes were connected to a single winding, the potential difference between the filament and cathode of a tube such as a type 27 would be almost equal to the bias voltage of the power tube. This could cause a direct short or leakage condition.

The high voltage winding has two identical secondaries (actually these two secondaries are one continuous winding with a center tap) so connected to a dual-plate rectifier so that current from each secondary winding is taken during one-half time of the alternating cycle. The center tap is ordinarily connected to chassis, but in any case is the most negative point of the power supply. In respect to this center point, as the end point of one secondary winding becomes positive, the other secondary end point becomes negative. The two plates of the rectifier assume these potentials and only one conducts at a time. In this manner, full wave rectification is obtained. Full wave rectification produces a 120 cycle ripple when operated from a 60 cycle power source. This higher frequency is easier to filter permitting the use of smaller filter condensers and choke.

The majority of power supplies use a brute-force filter. The older radio sets employed a two-section filter and this requirement was primarily due to the use of small capacitors of the paper dielectric type — electrolytic condensers were not commercially available at that time. To obtain proper filtering, a certain combination of inductance (may be resistance) and capacity is needed, and since electrolytic condensers for a given filtering action costs so much less than required inductance, the trend has been to use very little inductance and to obtain the needed filtering effects with very large electrolytic condensers.

The first filter condenser has a pronounced influence on the voltage output. It is, therefore, made large in radio sets where no transformer is employed, but in the case of a transformer type power supply, it is better to have this first condenser of small capacity. The reason for this suggestion is that the use of large capacity produces peak currents which may damage the rectifier tube if the supply voltage is above a recommended value. Further, no matter how large, within reason, the first condenser is made, it cannot reduce the ripple below 10%.

The capacitor used after the inductance (or resistor) has much more influence on reducing the ripple, but has little effect on the output voltage. In general, if there is sufficient voltage and you have a choice of two different sizes of condensers to be used in the first and second positions, it is better to put the larger one in the second position.

The voltage drop in an ordinary rectifier tube varies with the current demand. It is best to have the change in current of small value as compared to the total average current supplied. This suggests the use of a bleeder to stabilize operation. Mercury vapor rectifiers, such as type 82, have a constant drop of about 15 volts within their operating range.

The older types of power supplies incorporated a voltage divider which not only served as a bleeder, but also supplied voltage values less than the maximum for various circuits. In practical work, these taps are adjusted with the aid of a voltmeter and no calculation is needed to obtain the resistance value for each tap setting. Modern sets do not use voltage dividers, but may employ small carbon resistors wired in series to supply reduced voltage for the screen grid of R.F. pentodes.

It is possible to place a filter choke, speaker field, or a fixed resistor in the negative connection of the power supply and use the voltage drop produced for grid bias purposes. This practice was carried out in many sets, and the grid return lead connected to such an arrangement must have an additional filter consisting of resistance and capacity.

The discussion presented so far deals primarily with the A.C. operated power supply and tests for quickly determining the faults will now be given. First determine if the power supply voltage reaches the transformer. This can be done by testing for voltage (A.C.) at the primary connections of the power transformer. Lack of voltage will suggest broken cord, poor connection at the socket, or defective switch. Next test for filament voltage, using your voltmeter or simply momentarily shorting one of the low filament windings and watching for a spark. Lack of voltage on any secondary will suggest a burned out primary winding, and this winding can be tested with an ohmmeter while the power is shut off.

Further tests may be conducted by breaking the B+ lead at the filament or cathode of the rectifier tube and measuring the amount of current consumed by the radio. If this current is very high, one filter condenser may be disconnected at a time and observing the effects produced. In case you are told by the owner of the radio that the rectifier tube needed replacements many times, suspect the input filter condenser.

The successful design of radio tubes with high voltage filaments and efficient operation with relatively low plate voltages permitted extensive use of AC-DC power supplies. In the older sets of this type, the heater voltage added up to a value considerably below the line voltage of 110 volts, and a voltage drop was produced with a line cord resistor or ballast tube. In more modern AC-DC sets, the tubes are selected so that the heater voltage adds up to the value of the line voltage and no dropping resistor is necessary. For the plate supply, use was made of half-wave rectifier or voltage-doubler circuits, and each of these will be treated from an advanced servicing point of view.

For a brief analysis of the half-wave rectifier power supply, let us first consider the action at the rectifier tube and input condenser which is made quite large in practice. While the plate of the rectifier tube is negative, it does not conduct and the current for the radio is supplied by the condenser which has been charged during the previous positive half of the cycle. When the alternating line voltage passes through the zero point and begins to supply an increasing positive potential to the plate, no conduction takes place until the sine wave positive value rises above the voltage-charge remaining in the filter condenser. Once started, this conduction lasts until the peak of the positive lobe of the sine wave is passed. When the sine wave value drops below the charge-voltage remaining in the condenser, and this occurs a short fraction of the cycle after the peak, the tube stops conducting although the positive half of the cycle is still in effect.

From this explanation, we can realize that the tube conducts over a small fraction of the cycle near the maximum point of the positive cycle. Fluctuations in the output voltage from the first condenser are less pronounced with large capacity, but a large condenser places a higher momentary load on the rectifier tube. The peak current through the rectifier tube may be many times the average of the D.C. current you may measure with a milliameter.

Electrolytic condensers exhibit a series resistance characteristic which is not important in considering filtering efficiency, but cannot be disregarded from the stand point of heating effect. The ripple current flowing through the condenser, and therefore through the series resistance, causes a temperature rise. If the temperature of the condenser is permitted to rise above 200° F., the condenser may be completely ruined. This problem can be solved in a practical manner by always using a capacitor of not less than 20 mfd. in the first section of the filter when carrying out a repair. Also, condenser of metal can construction will radiate heat more efficiently than a cardboard unit. Placement away from parts which radiate heat should be your guide. The 150-volt condensers are adaptable for AC-DC supplies operated from 60 cycle A.C., but for 25 cycle use 200-volt or higher working voltage condensers will provide required safety factor.

The newly developed selenium rectifier is a natural replacement for half-wave rectifier tubes and presents several advantages. The technical facts about this new rectifier have been taken from a description of Sylvania type NC-5, but units of other makes are very similar. The actual size of the unit is 1-1/4 inches square and 11/16 inches thick and it mounts anywhere on the chassis by one bolt. Selenium rectifiers are similar in construction and performance to the copper-oxide disc rectifiers. When made for radio application, 5 discs are used in series as the maximum operating voltage is only about 76 volts per disc. This is the factor that so far has made their use as replacements for type 80 and similar tubes too expensive.

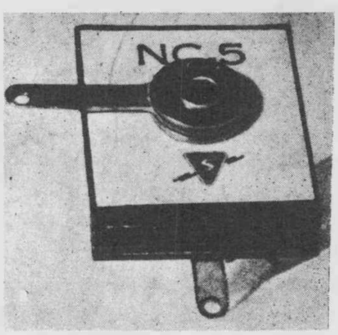
When the performance of a selenium rectifier is compared to a type 35Z3 rectifier, the same filter capacity will produce about 20 volts greater output.

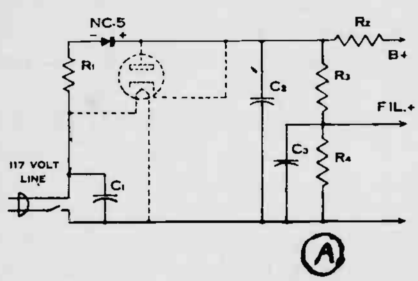
These units show a gradual improvement in rectification efficiency for the first few hundred hours and from then on the performance seems to be perfectly flat for 10,000 hours or more.

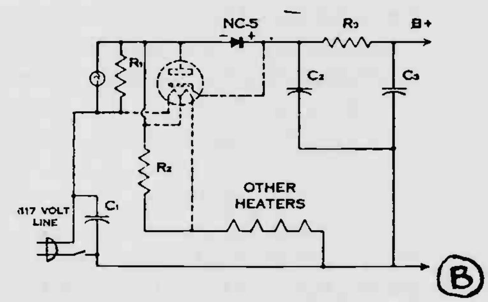
They can be considered good for the life of the radio unless accidents happen. Failure of the first filter condenser or other accidental short will damage the selenium rectifier just as much as a tube in a similar situation. They are perhaps a little more tolerant of occasional short overloads than a tube, but are more critical with regard to the temperature of the space in which they operate. Confinement in too small a space which results in a temperature about 168° F. will cause very short life. When bolted under a typical small chassis, the metal conducts the heat away sufficiently to keep the temperature down to 120° F.

When used in sets properly designed to take full advantage of the good features of the selenium rectifier, the outstanding improvement will be the increased volume obtainable by reason of the greater voltage available to the output tube. With the new rectifier, set designers will probably completely rearrange the tube complement rather than use a dropping resistor in place of the rectifier heater. In the type of AC-DC sets which used a 117 volt rectifier and battery type tubes in series, very few design changes will be required. Another minor advantage is that in circuits using battery tubes the radio will start to play the instant it is turned on.

The figures below show changes required when substituting a selenium rectifier for an ordinary rectifier tube in half-wave power supplies.







In Figure A, the heater circuit of the former 117 volt tube can be completely removed and the + side of the selenium rectifier connected to the cathode terminal and the minus side to the plate terminal. It is important to increase the value of the resistor R1 to restore the voltage on the tube filaments to the proper value. It would be inadvisable in this case to connect the resistor in such a place as to use additional plate voltage since the tubes are already being operated at the maximum rated voltage. The added resistance should be about 25 to 30 ohms, but may require adjusting slightly for different sets. The best way of making this adjustment is to use a 1000 ohm-per-volt meter to read the voltage across a 1.4 volt tube when the line voltage is exactly 117 volts. Adjust the resistance to get 1.3 volts under this standard condition.

Figure B shows the changes required when using the Sylvania type NC-5 as a replacement for a 35Z5 or 35Y4 rectifier tube. The important item here is R2 which must replace the rectifier tube heater in the series string. Be sure to place this so as not to overheat other parts as it will dissipate considerable heat. Table I gives the values of R2 recommended for the most common rectifier tubes.

TABLE I

Type	Heater Current	R2 Ohms	Watts	R1 Ohms
25Z5	.300	85	15	Not required
25Z6	.300	85	15	Not required
35W4	.150	200	10	10 to 25
35Y4	.150	200	10	10 to 25
35Z3	0.150	230	10	Not required
35Z4GT	0.15	230	10	Not required
35Z5GT	0.15	200	10	10 to 25
45Z5GT	0.15	270	10	10 to 25
50Y6GT	0.15	330	15	Not required
50Z7GT	0.15	300	15	10 to 25

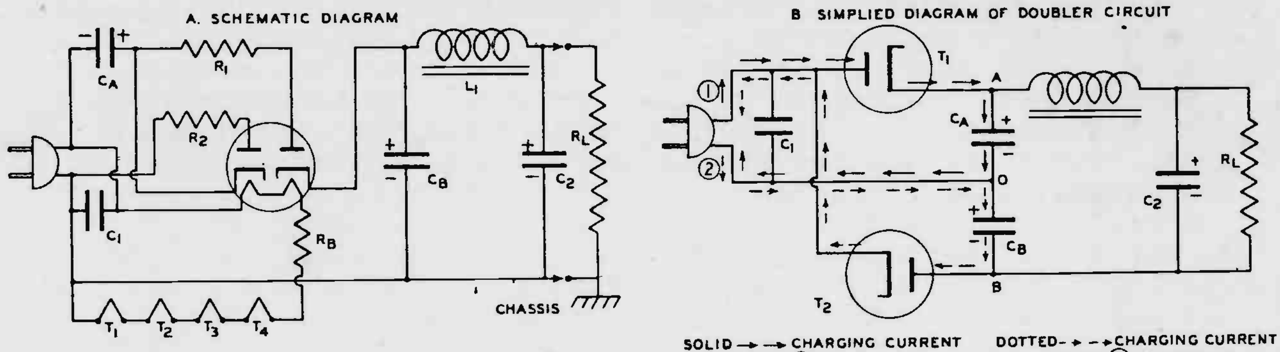
The values given for R1 are for use with one type 47 panel lamp and a total B+ supply drain of 60 ma. A lower value will be required if the drain is higher than this.

In using this substitution, we are allowing the added efficiency of the selenium rectifier to be used in increasing the available plate voltage. This increase of approximately 20 volts may be more than the filter condenser can stand, particularly as the no-load voltage will be applied until the cathode type tubes warm up. The higher voltage may throw the set into oscillation which may need to be taken out by a little improvement in the screen by-passing by adding a screen dropping resistor. In most cases, however, the customer will be very pleased with the increased sensitivity obtained.

For use in the few sets where voltage doubling is employed, two units will be required for replacement, each connected as explained above.

Voltage doubler rectifier circuits have been used in many popular models. Basically there are two different circuits which produce a D.C. voltage approximately twice the A.C. line voltage. In the symmetrical type, two large capacity condensers are connected in series across the input to the filter section. Each of these condensers is also connected to a separate diode section (may be a part of 25Z5, or a separate diode rectifier) in such a manner that each half-cycle charges a different condenser. For best results, the two condensers employed should be of equal capacity or a strong 120 cycle hum will be noticed. To test for equality, shunt one condenser at a time with a 4 mfd. electrolytic and see if 120 cycle hum is reduced. If the original condensers in the set are balanced, any added capacity will increase the hum level. For added future safety when you are repairing a voltage doubler of the symmetrical type, add 25 ohm resistors in series with plate leads. Input condensers should be at least 20 mfd., 150 working volt rating. The output condenser of the filter should be rated at 250 volts.

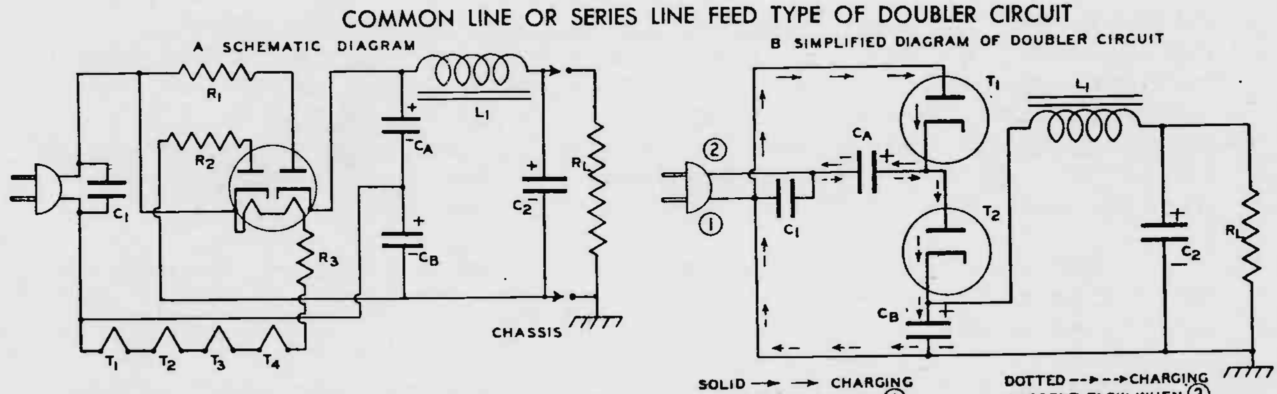
SYMMETRICAL OR BALANCED TYPE OF VOLTAGE DOUBLER



Courtesy P. R. Mallory & Co.

In power supplies of this type, there exists a potential difference between every cathode and heater even if one tube in the set has one filament connection grounded. Any cathode leakage in a tube will create much more trouble in a set using a voltage doubler circuit. You may have to try several tubes for best results and use the unsuitable tubes in a regular type AC-DC radio.

COMMON LINE OR SERIES LINE FEED TYPE OF DOUBLER CIRCUIT



Courtesy P. R. Mallory & Co.

The common line or the so called half-wave doubler operates on a somewhat different principle and permits one side of the line to be connected to the chassis or ground. In this type of circuit, a diode rectifier charges a condenser during one-half of the cycle. During the second half of the cycle, this condenser becomes connected in series with the line which now reversed its polarity. This line voltage and the charge-voltage of the condenser during this second half of the cycle pass through another diode rectifier which in turn is connected to a regular filter that employs condensers rated at 300 volts. Half-wave pulses are supplied to the filter in this type of doubler circuit, but the voltage is doubled. The first diode and condenser are used only to add voltage to the line voltage while the second diode is conducting. P. R. Mallory & Co. holds patents on a special circuit of this type that permits all condensers employed in a half-wave doubler circuit to have a common negative return.

Failure of tubes in AC-DC sets may be due to unequal voltage distribution across tube filaments while they are heating. Since in a tube the cold resistance is much smaller than the corresponding hot resistance, the sudden high current surge when the set is first turned on may cause a cathode short or open. If the short takes place in the rectifier, it places A.C. across the first condenser and usually damages this condenser also. The use of a filament dropping resistor in the older sets, and the pilot bulb arrangement across a part of the rectifier filament in the newer sets, eliminates this problem to a large degree.

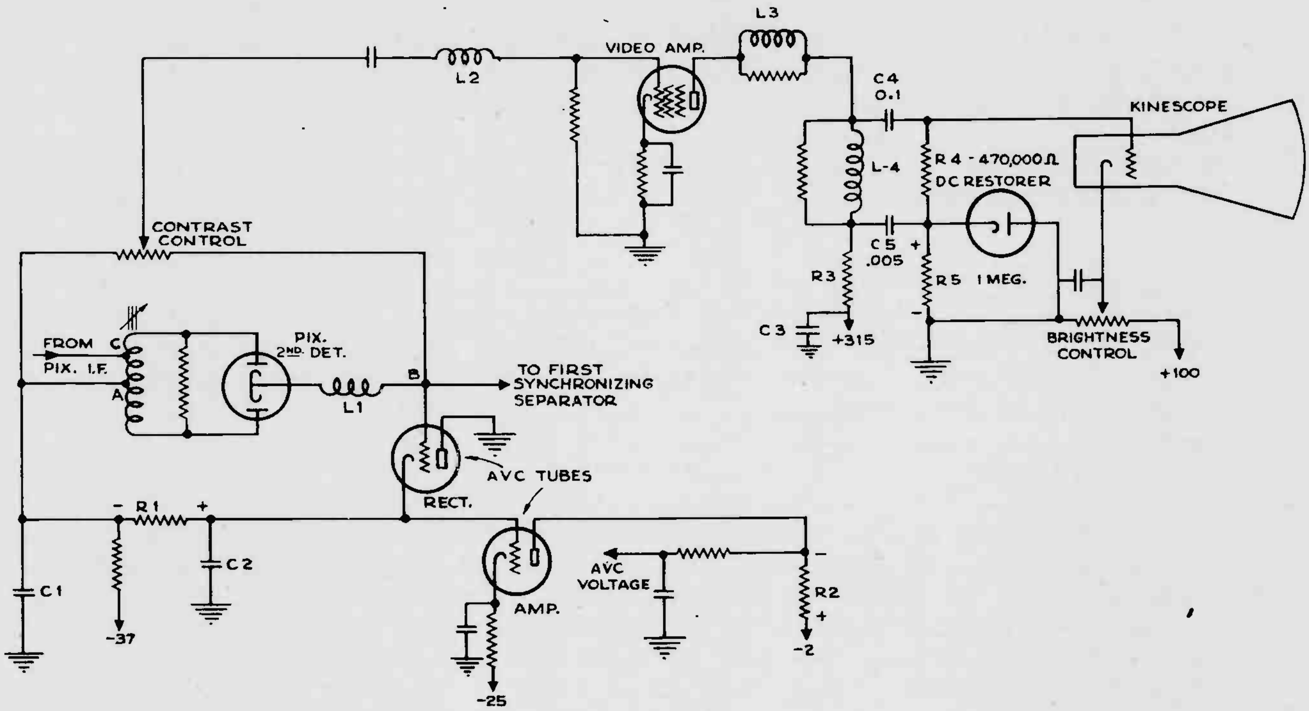
Most of the failures of the rectifier tube or filter condensers (not due to age) can be prevented from happening by connecting a 25 to 50 ohm resistor in the plate lead of the rectifier tube, and this practice is followed in most commercial sets. Should any set require your attention which does not have such limiting resistor, you should add it.

Lecture 29

Some Television Facts Not Clearly Understood

Although very few servicemen have been called upon to service television receivers up to this time, the day is not far removed when television receivers will be produced and sold in quantity. In the not toodistant future, television stations will be operated in almost all populated sections of the country and television receivers will require your attention for proper installation, adjustment, and repair.

The basic fundamentals of modern television are probably known to every radio serviceman. This lecture will deal with a few sections of television receivers which are of a little more advanced nature and are not easily understood at the first reading in an article or book. This treatment is intended as an aid in carrying out needed adjustments and repairs. We are indebted to R.C.A. Manufacturing Co. for their permission which allows us to quote and illustrate facts from their publication, "Practical Television."



Picture Second Detector, Video Amplifier and D.C. Restorer

The video second detector circuit in television receivers is different from regular superhet detectors and will receive our attention at first. Illustrated at the top of this page is a basic circuit used in some R.C.A. receivers. This circuit includes more than just the second detector, but we will first focus our attention on this section. The picture (video) input coil is, in effect, a center-tapped auto-transformer with its center tap at ground with respect to I.F. voltages because of the by-pass condenser C1.

In this coil, the primary is formed by a section of the winding between the center-tap and the connection shown directly above it. The ends of this coil feed the plates of a double diode rectifier. This arrangement provides a balanced full-wave detector. In some sets, a half-wave similar arrangement is employed.

The general operation of this circuit is similar to the action in an ordinary modern superhet with a diode second detector. When the video I.F. signals are impressed on the diode, the signal appearing across the diode load resistor (used as the contrast control in the circuit illustrated) will be essentially the same as the standard television signal usually illustrated in text books. Since negative modulation is employed, white in the picture is represented by minimum voltage across this resistor, while the black level is always represented by an amplitude equal to 75% of the total voltage range, and synchronizing pulses occupy the upper 25% of the voltage range.

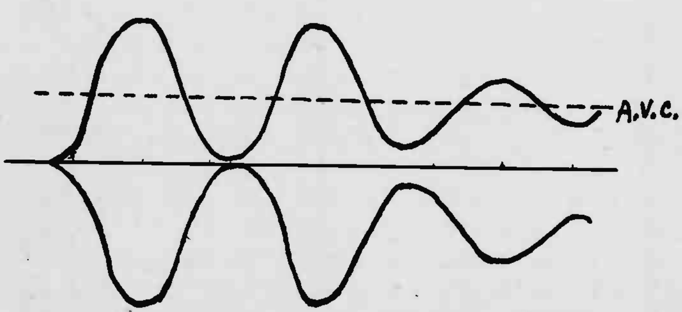
The video detector produces greater amplitude distortion than similar types audio detectors, but usually this distortion increases slightly the whiteness of the brightest portion of the picture and, therefore, can be tolerated. The phase delay in the frequencies, and the existance of this fault is evident by the blurring of the resulting pattern.

Correct polarity of the signal must be observed in video equipment. Since each vacuum tube amplifying stage following the video detector shifts the polarity (i.e., phase by 180°), the required polarity for the video signal and synchronizing pulses can be easily achieved.

Good response with a minimum of distortion can be obtained by using a small value of load resistor and using a peaking circuit incorporating an inductance. The circuits used, in general, are of low-pass filter type designed to pass without attenuation frequencies up to 5 MC. Since much of the produced distortion is in the form of harmonics above this cut-off frequency, they will be suppressed. Also, since the ratio of the I.F. to some video frequencies is in the order of only 3 to 1, the same filter arrangement will also prevent the I.F. signal from effecting the video amplifier.

The use of automatic gain control on the video channel will maintain the signal level at the second detector constant for wide variation in signal input. This action will improve reception and simplify the problem of synchronizing pulse separation.

The A.V.C. system of any sound receiver provides the needed automatic control by adjusting the gain of the I.F. (and R.F.) amplifiers. The voltage for this control purpose is obtained by filtering the D.C. drop across the diode resistor of the sound receiver detector. This works out satisfactory because the average voltage so obtained is directly proportional to carrier amplitude received. In audio transmission, the modulation process is such that the average value of the rectified signal is of a value directly related to the carrier level. See illustration.



Envelope of Audio Modulated Carrier Signal Showing Value of Filtered A.V.C. Voltage with Steady Carrier but Variable Modulation.

Envelope of Video Modulated Carrier Signal with Two Synchronizing Pulses. Average Rectified Voltage Varies a Great Deal.

In the transmission of television pictures, however, the average carrier amplitude varies greatly with the picture content and an A.V.C. system operating on this principle of maintaining a substantially uniform average carrier amplitude is not suitable. The average value of the rectified signal in picture transmission is not in constant proportion to the carrier level, but varies a great deal. The automatic gain control in a video receiver is obtained by other means. This control is commonly called video A.V.C. because of the similarity of its function to A.V.C. in sound receivers.

The A.V.C. voltage obtained in the audio circuit of a television receiver may be applied to the video tubes to serve as an automatic gain control. Since the recommended standards specify that the picture and sound transmission shall have the same power and since the two antennas used are located close together, such an arrangement for obtaining video automatic gain control can be employed in lower priced receivers. Experimental investigations, however, have indicated that sound and video input voltages may vary greatly from each other due to frequency response characteristics of the receiving antenna, the location of antenna, and other causes. These factors cause television receiver design engineers to favor automatic gain control circuits that can be made to depend on the video carrier. Such circuits are called A.V.C. (although truthfully they are automatic gain control circuits) and in conjunction with the simplified diagram of the second detector, video amplifier, and D.C. restorer, shown at the beginning of this lecture, the explanation given in "Practical Television" (published by R.C.A. Manufacturing Co., Inc.) will be quoted.

"Under the American television system, the carrier always reaches a uniform maximum amplitude during the periods when synchronizing pulses are being transmitted, and a white portion of the scene is represented by minimum or zero carrier condition. Thus, if there is no fading, the peaks of the synchronizing pulses will always represent some constant amplitude, and they, therefore, form a convenient reference for operating a satisfactory picture A.V.C. system.

"In the circuit diagram, the A.V.C. rectifier tube and its associated circuit components furnishes a D.C. voltage which is amplified by a D.C. amplifier stage designated as the A.V.C. amplifier. The voltage drop across the plate resistor of the A.V.C. amplifier is used as A.V.C. bias. The A.V.C. rectifier is essentially a peak voltmeter, i.e., the voltage across R-1 is proportional to the peak amplitude of the signal applied to the A.V.C. rectifier. The condenser C-2 assumes a charge proportional to the peak amplitude of the applied voltage because the shunting resistance is too high to appreciably discharge the condenser during the period between successive synchronizing pulses. The operation is somewhat similar to that of the first synchronizing separator tube. It differs in the fact that the time constant of the R-1, C-2 circuit is so long that the voltage across them remains substantially equal to the peak amplitude of the synchronizing pulses instead of following the amplitude-time characteristic of the synchronizing pulses as in the case of the separator tube. The cathode of the A.V.C. rectifier which in this particular illustration, is at a negative potential of 12 volts with respect to its cathode. For zero signal conditions, this effectively biases the D.C. amplifier tube to cut off and no A.V.C. action is therefore obtained until the A.V.C. voltage overcomes enough of the residual bias on the A.V.C. amplifier to cause plate current to flow. Thus, a desired amount of delayed A.V.C. action is obtained. The plate of the A.V.C. amplifier is connected to a potential of -2 volts through a load resistor R-2, and to the grids of the first detector and picture I.F. amplifier tubes through a conventional RC filter. Thus, an increase in signal beyond the point at which the A.V.C. becomes operative causes plate current to flow in the A.V.C. amplifier tube, and the voltage developed across R-2 by this current causes the plate of the A.V.C. amplifier tube, and, therefore, the grids of the video I.F. amplifier stages, to become more negative. Thus, the gain will be controlled to maintain substantially the maximum carrier amplitudes represented by synchronizing pulses."

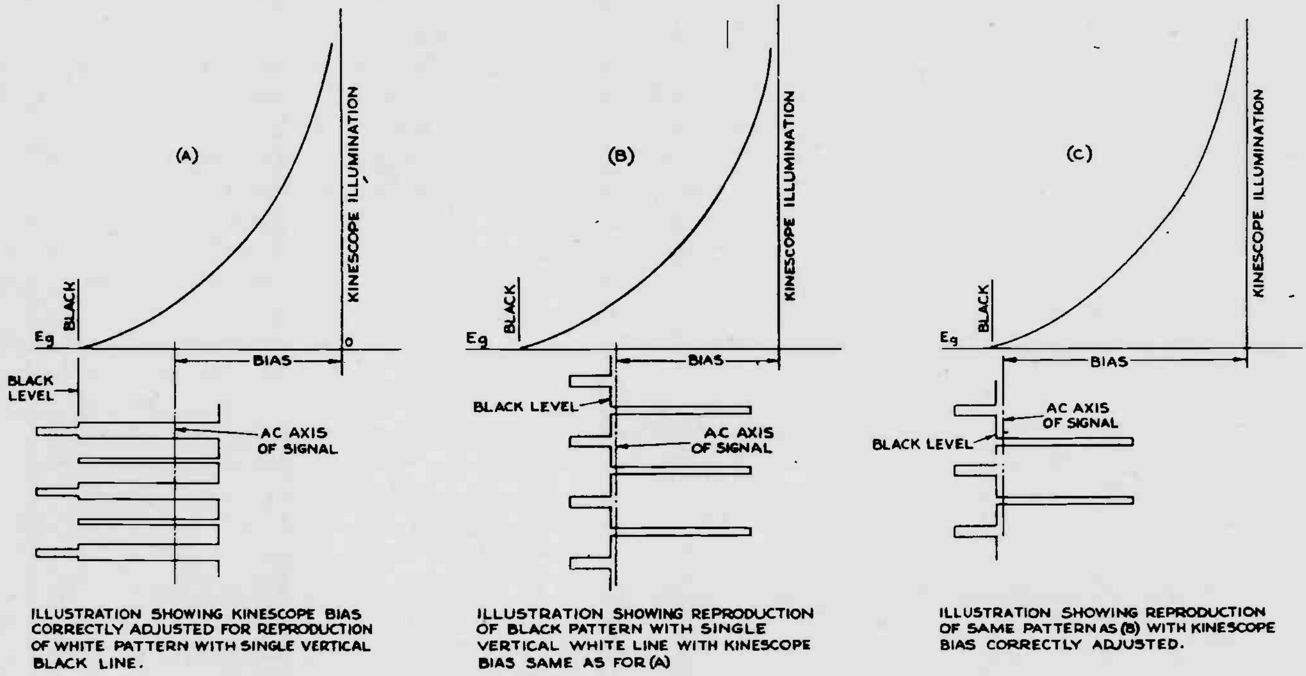
The television signal consists of D.C. and A.C. components. The D.C. component of the video signal represents the average illumination of the original scene and, since the video amplifier is an A.C. amplifier with capacity coupling, this D.C. component will not be passed. This means that while the signal and synchronizing pulses will be passed in their correct form and relationship to each other, the voltage values will not be correct in relationship to the "zero" or reference level and to the white level.

Consequently, unless some provision is made to restore the corresponding D.C. value, the picture tube or Kinescope will not receive any information on the average brightness of the televised scene and the reproduced image, therefore, will not have the correct average illumination even though the contrast between the illumination of picture elements may be correct. Furthermore, unless the residual bias on the Kinescope is adjusted to a point too negative for average conditions, the black portions of the original scene and the blanking pulses will not always drive the grid to cutoff as desired. The restoration of the D.C. component in the typical receiver under consideration is accomplished by means of a D.C. restorer tube or automatic brightness control tube as it is commonly called. Reference to the figure published on page 205 will indicate how the tube is applied. This explanation, with minor changes, is taken from "Practical Television," by R.C.A.

It will be noted that the D.C. restorer or automatic brightness control utilizes a diode rectifier. Reference to two typical conditions of transmission may best serve to illustrate how it serves the function intended. Under the recommended standards, if the scene being televised is completely black (that is dark, no light present), the amplitude of the voltage representing the picture content will be equivalent to the black level. As a result, if the D.C. component is removed, the only amplitude excursions from the A.C. axis will be those corresponding to the synchronizing peaks which will represent comparatively small amplitudes. If these small pulses are to drive the grid of the Kinescope beyond cut-off as is needed to create a condition of operation beyond the black level, it is obvious that some means must be provided whereby the bias on the grid is automatically adjusted to cut-off so that the small negative synchronizing pulses can drive it beyond cut-off.

We can assume that the initial Kinescope bias as determined by the setting of the "Brightness Control" is such that with no signal this tube operating at the point of cut-off. Assume now that the condition discussed in the previous paragraph is imposed. Because the signal voltage across the video amplifier plate load resistor is small, only a small A.C. voltage will be applied in the series A.C. circuit represented by the plate circuit decoupling condenser C-3 the plate load resistor, R-3, the 0.005 mfd. condenser C-5, and the diode rectifier. When the plate is positive with respect to its cathode, the diode rectifier passes current which charges the 0.005 mfd. condenser. During periods when the plate is negative with respect to its cathode the diode rectifier is non-conducting and the condenser discharges partially through the 1 megohm resistor, R-5. If the circuit elements are correctly proportioned, the charge across the condenser (and therefore the voltage from cathode to ground) will remain substantially constant during the picture interval between successive horizontal line synchronizing pulses. The effect is to develop across the resistor R-5 a variable bias voltage which opposes the residual bias effected by the brightness control. If the constants are correctly adjusted, this reduction in bias will always be just sufficient to enable the synchronizing pulses to drive the Kinescope beyond cut-off.

Another analysis may be made using as an example an all white scene. Under such a condition, the amplitude of the voltage corresponding to the picture content will be a minumum. Consequently, after the D.C. component is removed from the signal voltage developed across the picture second detector load resistor the voltage excursions from the A.C. axis represented by the synchronizing and blanking pulses will represent comparatively high amplitudes. Under such conditions the Kinescope bias must be automatically reduced by a considerable amount from its correct value for a black scene if the blanking pulses are to drive the tube just to the cut-off point and the synchronizing pulses beyond cut-off. An analysis of the circuit as previously made indicates that the larger voltage excursions or peak amplitudes would cause a greater amount of rectification and, therefore, a correspondingly greater reduction in bias. Thus the automatic brightness control or D.C. restorer is in reality an automatic bias control which continually

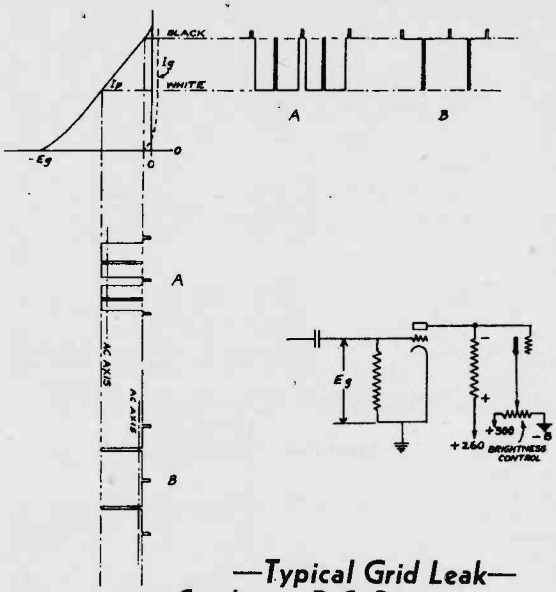


Operation of D.C. Restorer or Automatic Brightness Control

adjusts the bias so that the blanking pulses always drive the Kinescope grid to the desired cut-off point and the synchronizing pulses drive it beyond cut-off.

A reference to A, B, and C of the figure illustrated above will serve to further illustrate the need for automatic brightness control. In A, the Kinescope bias has been correctly adjusted for reproduction of a pattern which is all white with the exception of a single vertical black line. In B is shown the application of a signal from a pattern which is all black with the exception of a single vertical white line under the same Kinescope bias conditions as for A. It should be noted that in B the synchronizing pulses no longer drive the grid beyond cut-off. In other words black level now occurs at a point where the Kinescope still has a considerable amount of illumination. The white line therefore will not appear as a white line on a black background but instead will be reproduced as a white line on a slightly whiter or gray background. In C is shown the reproduction of the same pattern, but with the Kinescope bias correctly readjusted to make the black level occur at the correct or cut-off bias point.

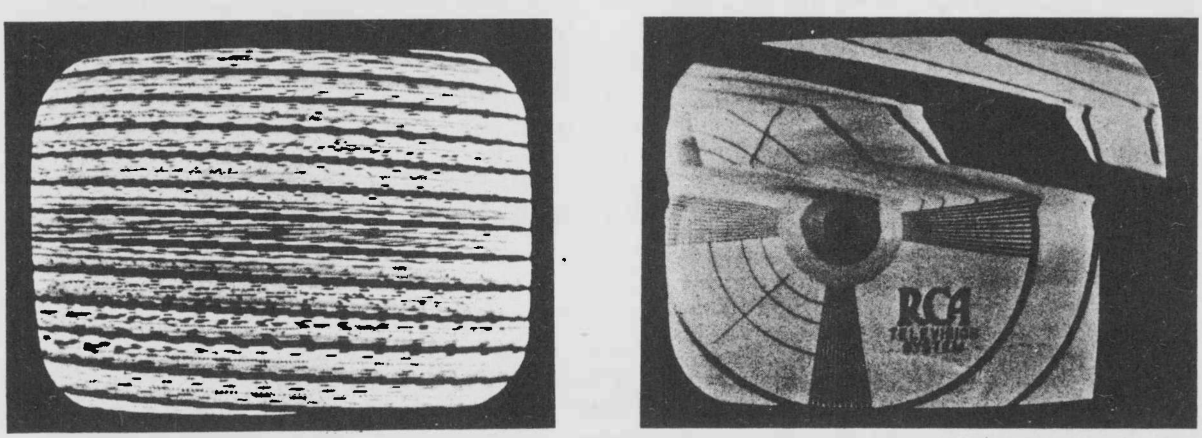
The time constant of the D.C. restorer circuit should be sufficiently long to maintain the bias substantially constant during the picture intervals between the horizontal or line synchronizing pulses but sufficiently short to enable the restorer to follow rapid variations in the average illumination such as occur in motion picture transmission.



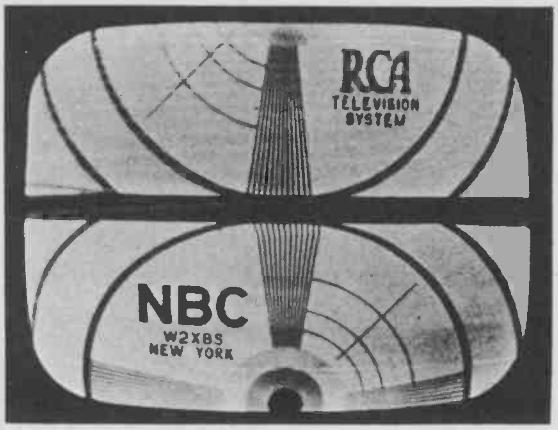
—Typical Grid Leak—
Condenser D.C. Restorer

Another method of restoring the D.C. component is by reinserting it in the signal at the grid of the video amplifier tube by operating the tube at zero fixed bias. This method is illustrated at left. The operating bias is then determined by the D.C. drop across the grid resistor caused by the grid current.

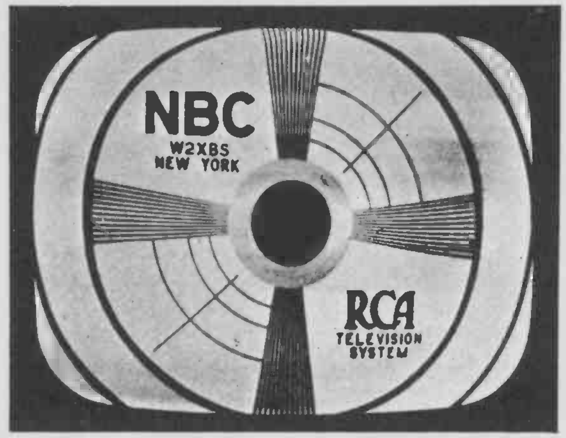
To keep the grid current small, the grid resistor should be large; a half megohm or more, depending on the tube used. The bias generated by the grid current which flows during the occurrence of the synchronizing pulses is maintained by the charge on the grid coupling capacitor. The time constant of the grid resistance-grid capacitor should be sufficiently long to maintain the bias substantially constant during the picture intervals between horizontal (line) synchronizing pulses, but sufficiently short to follow the variations introduced by the time constant of the circuits preceding this point. It will be noted in this figure that grid current flows during the peaks of the synchronizing pulses, thus maintaining them at approximately the zero bias point regardless of the position of the A.C. axis, and that black level, therefore, occurs again always at the same voltage level, as it did in the detector diode circuit before the D.C. component was lost. With this method for restoring the D.C. component, it is, of course, necessary that the plate of the video amplifier tube be direct coupled to the grid of the Kinescope. In other words, the plate resistor IR voltage drop variation, caused by the amplifier grid bias change, will raise or lower the applied Kinescope grid bias.



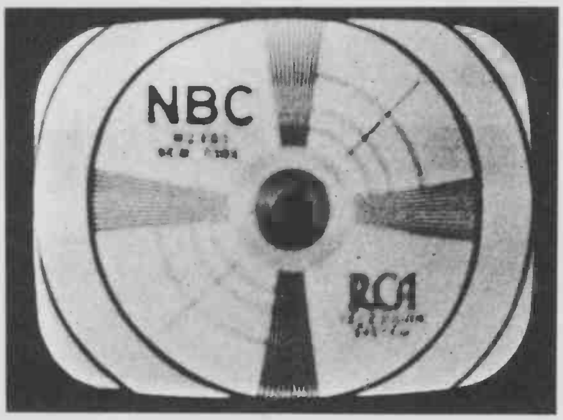
Horizontal Hold Control Incorrectly Set; Two Different Effects.



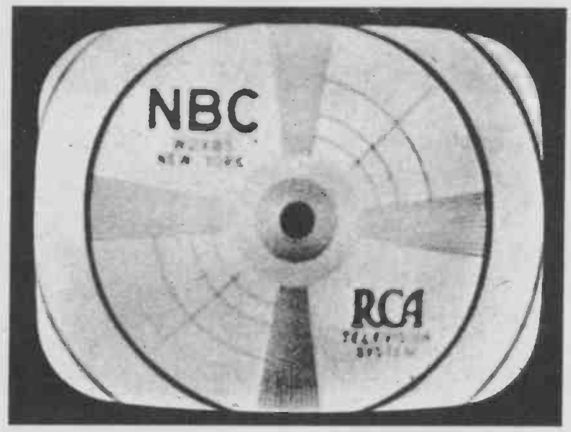
—*Vertical Hold Control Incorrectly Set*



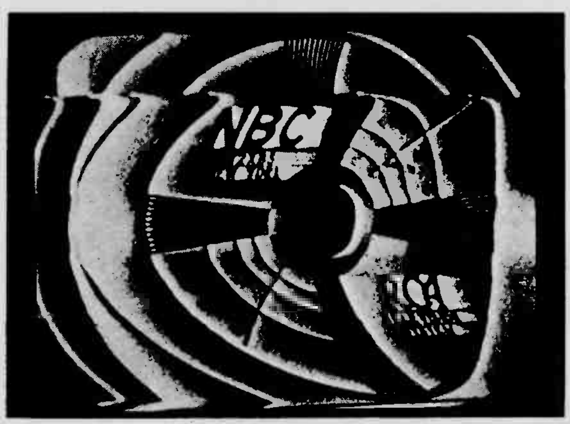
—*Contrast Control Advanced Too Far*



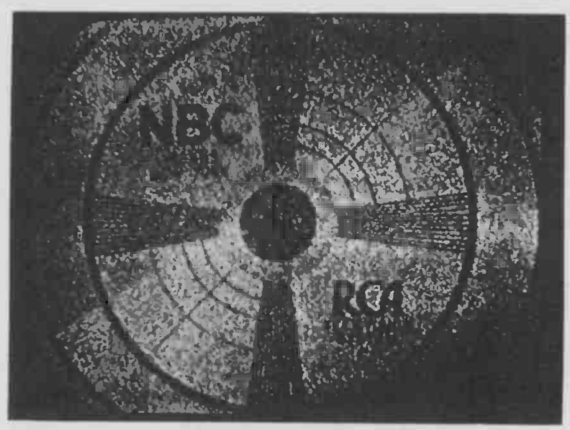
—*Focus Control Incorrectly Set*



—*Brightness Control Advanced Too Far*



—*Effect of Too Strong a Signal*



—*Effect of Too Weak a Signal*

The group of illustrations above are included to show the effect on the test pattern of various commonly encountered faults. The observation of these views will aid you in analyzing faults and making needed adjustments.

Lecture 30

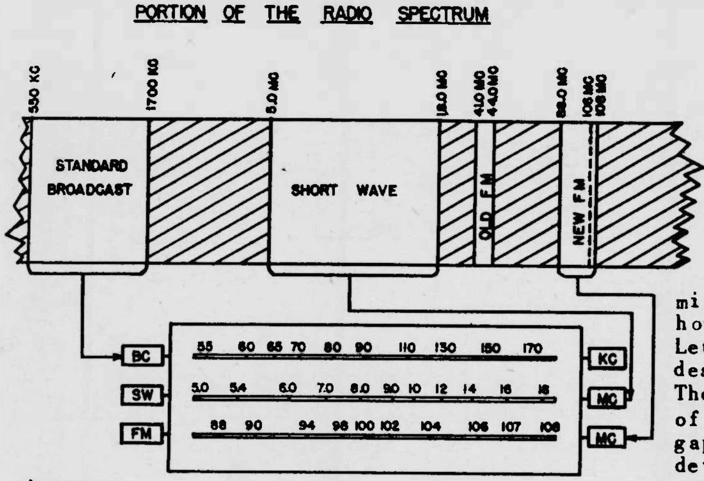
Frequency Modulation

The lecture on Frequency Modulation is reprinted through the courtesy and cooperation of Westinghouse Electric Corporation and is copyrighted by this organization. The subject matter is divided into three convenient sections dealing with (1) Band Location and VHF Characteristics, (2) F.M. Receiver Fundamentals, and (3) F.M. Receiver Alignment and Trouble Shooting. This is a natural method for treating this subject from a serviceman's point of view.

As an introduction to F.M., let us briefly review the difference between amplitude and frequency modulation. In amplitude modulation, we have mentioned the presence of two side bands. At any one instance, if the transmitter is amplitude modulated with a single frequency sine-wave at the moment, the energy radiated is made up of the carrier frequency and the two side bands. The frequencies of the side bands shift together and these side bands are always apart from the carrier frequency by an equal number of cycles. Since the side bands have their frequencies equal to the carrier frequency plus the modulating audio frequency for one and the carrier minus the audio frequency for the other, the frequencies of the two side bands shift together from moment to moment as the modulating audio frequency changes.

Now suppose we have a carrier which is frequency modulated. It is possible to swing the frequency by different amounts. The amount of frequency shift will determine the amplitude of the audio signal at the detector, while its "rate of change" or speed determines the audio frequency. Such a signal can be shown to consist of a carrier plus an infinite number of side bands. The side bands are in pairs, symmetrically placed with respect to the carrier and they are separated by the amount of the modulating frequency. A carrier of 1,000 KC. being frequency modulated at 1,000 cycles (i.e., 1 KC.) would have side bands at 1,001, 1,002, 1,003, etc., as well as at 999, 998, 997 KC. When the carrier is being swung, for instance 10 KC. to either side, the side bands situated between 990 KC. and 1,010 KC. only are of importance, the others becoming very weak. Therefore, the practical band-width of a frequency-modulated signal is equal to twice the frequency deviation employed and has no connection with the audio frequency.

The material on F.M. band location and very high frequency behavior begins on the next page.



SLIDE 1

H-119 DIAL

(1-1) The present carrier frequency band assigned to FM extends from 88 to 106 megacycles. The 106 to 108 megacycle range, which also is included on our FM receivers, is set aside for facsimile and is, so far as we are aware, not in general use at this time. Slide 1 shows the spectrum location of the new VHF FM and facsimile bands with respect to the standard broadcast and short wave band. The old prewar FM band from 41 to 44 megacycles also is shown in the spectrum chart for comparison purposes. The dial scale shown in this slide is that of the Westinghouse Model H-119 AM-FM radio and phonograph which is to be discussed in this lecture.

(1-2) As slide 2 shows, at this very-high-frequency range, propagation of radio waves tend to follow more or less optical laws as compared with the standard broadcast range from 540 to 1600 kilocycles used in present-day AM systems. Briefly, this means that the radio waves act somewhat like light waves and "line-of-sight" wave propagation plays an important part. Under ideal conditions the terrain between the transmitting and receiving antennas should have no continuous obstructions such as large buildings, hills, etc. In actual practice ideal conditions are seldom realized. Frequently, very good FM reception may be obtained under conditions which according to the "line-of-sight" theory would make reception impossible.

According to the accepted theory, the electric field intensity of the FM wave varies inversely with the *square* of the distance from the transmitting antenna to the receiver. For production of a *true frequency modulated* signal to be passed on to the discriminator in the receiver, a good husky signal at the limiter grid is an absolute necessity. Unless there is a signal of sufficient strength to saturate the limiter, amplitude signals will be passed on to the discriminator, resulting in very poor tone quality and distorted output. This requirement practically dictates the use of a good, well-elevated outside antenna.

(1-3) **FM Antenna Fundamentals.** At first glance the design of a suitable antenna for receiving FM waves might seem a very simple problem. Actually, however, a number of factors are involved. Let us examine these factors from the practical design standpoint.

The antenna input impedance determines the value of the r-f voltage developed across the dipole gap (load impedance) inasmuch as the voltage developed is determined by the values of the current flowing and the load impedance at that particular instant. It may be expressed mathematically by ohm's law for alternating current:

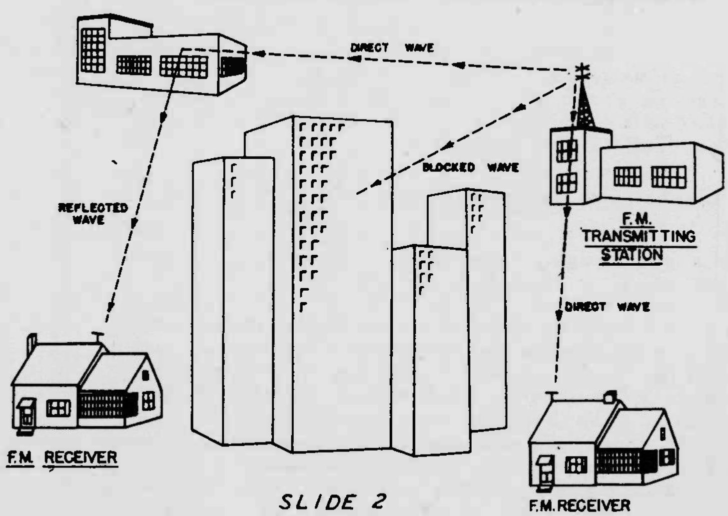
$$E = IZ \qquad (1)$$

Where E and I are the r-f voltages and currents, respectively, and Z is the impedance at the center of the dipole at any given instant. The impedance may be expressed as

$$Z = \sqrt{R^2 + X^2} \qquad (2)$$

Where R and X are the antenna input resistance and reactance, respectively.

In a half-wave antenna, *resonant to a fixed frequency*, the current is a maximum at the center and zero at the ends, while the voltage is a maximum at the ends and a minimum at the center. For this half-wave *resonant* dipole, then, the impedance varies along the antenna and is minimum at the center and maximum at the ends. For a half-wave dipole, *resonant* and *isolated in free space*, the impedance at the center is approximately 73 ohms and approximately 2500 ohms at the ends. The intermediate points between the center and each end have intermediate values of impedance. The 73 ohms impedance at the center represents the vector magnitude of the effective resistance



SLIDE 2

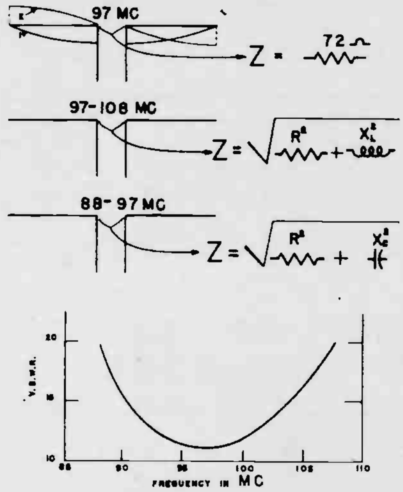
and a small residual reactance; however, for all practical purposes it may be considered a pure resistance. For *single, fixed frequency operation,* then, the transmission line should present a characteristic impedance to the center of the dipole, equal to the dipole center impedance, or, in other words, the characteristic impedance of the transmission line should be 73 ohms. But wait! Don't jump to any conclusions! We are now talking about a half-wave antenna resonant to a single frequency. For FM we have entirely different conditions.

The FM signal is constantly shifting in frequency with applied modulation. So far as the impedance value is concerned, the effect is exactly the same as would be encountered if the frequency were fixed and the length of the dipole were varied. At frequencies higher than the resonant frequency of the antenna, the dipole acts an inductive reactance and at frequencies lower than its resonant frequency it acts as a capacitive reactance. Remember that the center impedance value is equal to the square root of the sum of the squares of the resistance *and the reactance*. In short, as the signal frequency swings back and forth across resonance, the impedance value "travels" up and down its scale of values for the single FM signal. Furthermore, we are not interested in receiving only *one* FM station--we wish to receive stations all the way across the FM band. Various schemes have been brought forth for leveling out the extreme impedance values encountered at the band edges but most of these systems are too costly for anything other than certain commercial applications. For ordinary FM reception, a good compromise can be effected by making the dipole elements large in diameter, overlapping them slightly at the center and selecting the correct resonant frequency length.

(1-4) **Determination of FM antenna length.** If reception of programs from only *one* FM station is desired, the dipole elements would be cut to a half-wave length at the center or unmodulated carrier frequency according to the formula:

$$\text{Length of half-wave (inches)} = \frac{5540}{\text{Freq. (mc)}} \quad (3)$$

In a practical installation, however, reception of more than one FM station is desired. This means that the length of the elements must be cut to some intermediate frequency which will give a satisfactory response at the extreme ends of the band and yet keep the standing wave ratio (mis-match) of the transmission line between the dipole and the receiver input, to the minimum. In general, the frequency to which a broadly resonant antenna is cut, is equal to the geometric mean of the frequency extremes of the band to be covered.



VOLTAGE STANDING WAVE RATIO VS FREQUENCY
WESTINGHOUSE STRATOVISION
F.M. ANTENNA

SLIDE 3

For the 88 - 106 megacycle band, the frequency at which the antenna should equal one half-wave is

$$\text{Frequency in Megacycles} = \sqrt{88 \times 106} = 97 \text{ mc.} \quad (4)$$

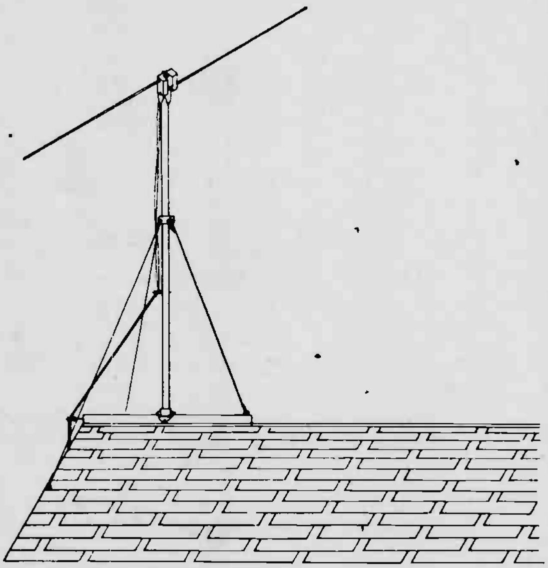
The actual length of the elements, in inches, according to the above formula, is

$$\text{Length} = \frac{5540}{97} = 57.1 \text{ inches}$$

Like most other practical applications of electrical theory, however, it is necessary to modify the actual element length for maximum efficiency across the FM band. In order to obtain a semi-broad-band characteristic in the Westinghouse Stratovision FM antenna, the two elements overlap at the center insulator. It was found necessary to increase the overall dipole length, end to end, to 62 inches to compensate for this physical characteristic.

(1-5) **FM dipole antenna transmission line characteristic impedance.** As mentioned above, the impedance at the center of an FM receiving dipole antenna cannot be stated as any given value. In actual practice it varies anywhere from 68 ohms to 1000 or 1500 ohms depending upon the length and diameter of the dipole elements and the portion of the FM band to which the receiver is tuned. It is obvious that no fixed value of transmission line impedance can be selected and matched to the center of the antenna. It is necessary to select some "happy medium" value which will operate most efficiently over the entire FM band. Due to the rather high standing wave ratios encountered at the band extremes, the transmission line must present very low-loss characteristics in the VHF range. Recent developments in low-loss transmission lines include a spaced, polyethylene-insulated, two-wire line of 300 ohms characteristic impedance. In tests with the Westinghouse Stratovision FM antenna, it was found that maximum signal level at the receiver input terminals was obtained with this new "twin-lead" line as compared with standard 50 and 70 ohm coaxial and twisted pair lines. In extremely noisy locations, however, the 300 ohm line will pick up slightly more noise than the coaxial type. In making installations in such very noisy areas, the coaxial-type transmission line may be used with some sacrifice of signal strength at the receiver input.

(1-6) Installation of the FM Antenna.



SLIDE 4

The FM antenna should be installed as high as possible and in the clear. It should be kept away from close proximity to metal roofs, eaves and other metallic objects. The dipole antenna is slightly directional and is most sensitive to FM signals when rotated to a position broadside to the FM station. The antenna can usually be mounted on a roof top or other high projection and then rotated to the position which gives best signal pickup on the various stations across the band. As the sensitivity pattern of the dipole is that of a figure 8, it will be necessary to rotate the antenna only 90° for changing from minimum to maximum sensitivity. Tests have proved that in most cases little difference in signal strength is noticed when the antenna is rotated, provided that the signal is strong. In most installations the antenna will be orientated to provide best reception on desired weak stations and left in that position.

The 300-ohm transmission line is fairly sensitive to metallic objects. The Westinghouse Stratovision FM antenna is supplied with a stand-off insulator to prevent the transmission swinging or rubbing against the metal mast. The three-foot section of transmission line between the stand-off insulator and the center of the dipole should be twisted *three times* and drawn tight through the insulator. The purpose in twisting the transmission line between the dipole center and the stand-off insulator is to maintain electrical balance between each wire of the transmission line and the metal mast. This nullifies the effect of the metal mast in the transmission line field, thus preventing loss of the r-f signal energy.

The section of transmission line between the stand-off insulator and the FM receiver, input terminals should be kept flat and drawn fairly tight. Do not permit the line to swing or rub against roof edges, walls or shrubbery. The transmission line may be dressed against a *dry* wooden baseboard or wall and the line secured by driving a small metal brad through the center of the plastic dielectric and into the wood. The brads should be spaced about one or two feet apart. Do not use thumb or carpet tacks; The large metallic head may short circuit the two wires of the line or may cause serious signal losses due to a change in the characteristic impedance of the line.

Use just sufficient length of line to reach the antenna terminals without coiling; any excess line should be cut away. At these extremely high frequencies, tests have shown that two or three turns or loops in the transmission line are sufficient to reduce the received signal strength 25 to 50 percent.

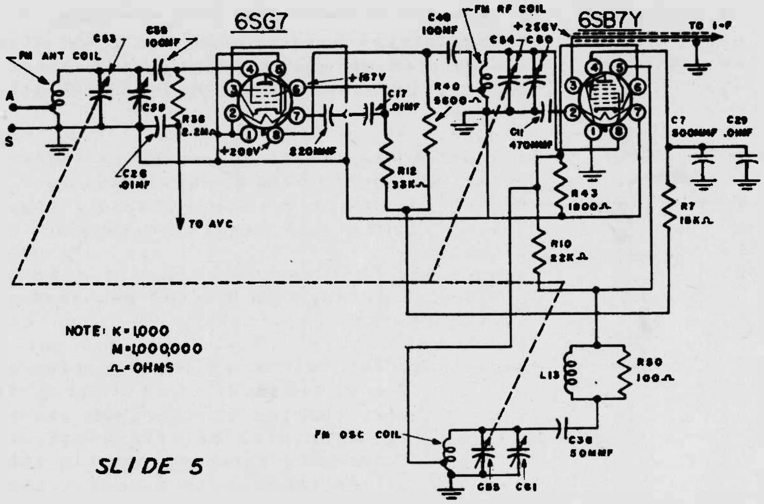
SECTION II
FM RECEIVER FUNDAMENTALS

(2-1) General - The design of a receiver for FM is similar in many respects to that employed in AM practice, but is somewhat more complex. The superheterodyne circuit is standard, but the 88 - 106 megacycle tuning range brings in some variations from the usual AM practice, and, of course, we have the special FM circuit features such as limiters, discriminators, etc. In this discussion we shall start at the FM antenna input terminals of the Westinghouse Model H-119 receiver and discuss the major differences between the FM and AM circuits.

(2-2) R.F., Mixer and Oscillator Circuits, H-119.

The r-f end of an FM receiver has somewhat the same functions to perform as in an AM receiver. I-F rejection is of less importance as the 10.7 mc. i-f is comparatively interference free. Image rejection is not a major problem as the high i-f places images of FM stations outside the band. *The major function of the r-f end of the receiver is to add as much as possible to the gain of the set so that a good signal-to-noise ratio will be obtained.*

Slide 5 shows the r-f amplifier, mixer and oscillator circuits of the Westinghouse Model H-119 AM-FM receiver. Only the FM portion of the circuit is shown; all band switches and components associated with AM have been deleted for the sake of simplicity in following the FM operation. It will be noticed that one wire of the two-wire transmission line from



SLIDE 5

R-F MIXER OSC STAGE H-119

the antenna, is connected to chassis ground; the other wire is connected to a tap on the antenna coil. The tap location has been selected for maximum signal voltage delivery to the 6SG7 r-f amplifier grid and is correct for use with transmission line impedances of from 50 to 300 ohms. The tuned circuits, both physically and electrically, are more or less conventional, as compared with regular AM circuits, except for the size of the tuning capacitors and coils. One and one-half volts of negative bias for the 6SG7 r-f amplifier tube is obtained from the voltage drop across a resistor in series with the power transformer high-voltage winding center tap and additional bias from the AVC circuit. The r-f energy from the 6SG7 plate is fed to a tap on the mixer r-f coil in order to obtain the proper impedance match between the 6SG7 plate and the 6SB7Y signal grid.

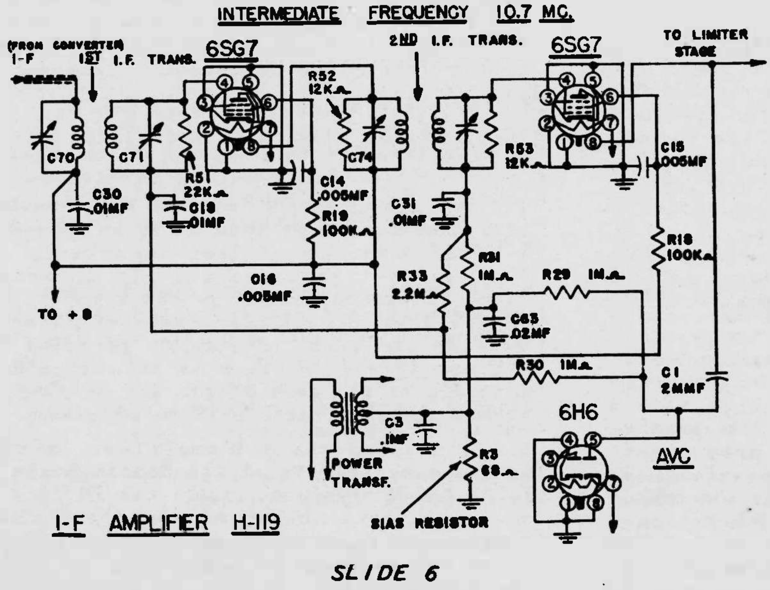
This mixer-oscillator tube is a 6SB7Y which is a special metal-shell type developed for converter service on the new 88 - 106 mc. FM band. The circuit and connections are similar to those of the ordinary 6SA7 type; however, the interelectrode capacitance of the 6SB7Y is much lower than that of the 6SA7 and the 6SB7Y is fitted with a low-loss base. The oscillator circuit is a conventional tapped-coil Hartley type. The coil and resistor network, L13 and R50, is a parasitic suppressor circuit. When the 14-tube chassis was designed it was found that a spurious oscillation appeared near the 1600 kilocycle point on the regular AM broadcast range. The coil and resistor combination effectively eliminates this condition.

(2-3) Intermediate Frequency Amplifier Circuits, H-119.

Electrically, the i-f amplifier circuits of the H-119 are more or less conventional. The 10.7 mc. i-f transformer windings are connected in series with the regular 455 kc. AM i-f windings. Due to the wide difference between the two intermediate frequencies, no interaction or ill effects are encountered. The gain and other characteristics are about the same as when separate transformers are used, In tuning such composite i-f units, the AM or 455 kc. trimmers are adjusted first and the FM or 10.7 mc. trimmers last.

It will be noticed that a 22,000 ohm loading resistor is connected across the secondary winding of the first i-f transformer and 12,000 ohm resistors across the primary and secondary windings of the second i-f transformer. The higher value of resistance in the grid circuit of the first i-f stage is used because of the comparatively low signal level at this point. If the resistance value is made very low the loss in signal level would be too great. The purpose of the resistors is to permit "peaking" of the i-f circuits; unless resistor loading is used, it would be necessary to "flat-top" the i-f circuits in order to obtain proper band-pass characteristics. There is some curvature, of course, in the top portion of the resistance-loaded frequency response curve but the limiter acts to clip off this curvature providing, in effect, a wide-band flat-top response at the discriminator input.

INTERMEDIATE FREQUENCY 10.7 MC.

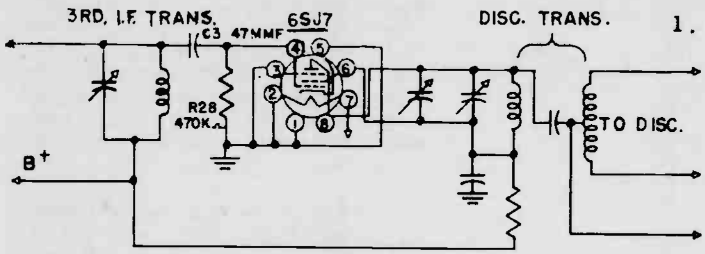


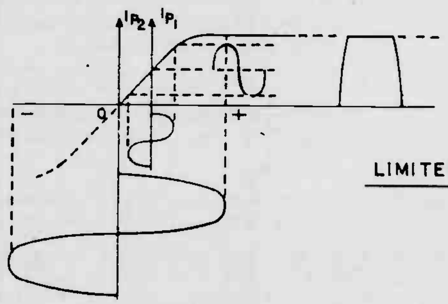
I-F AMPLIFIER H-119

SLIDE 6

This slide shows the 68 ohms voltage dropping bias resistor in the power transformer high-voltage center tap. Note that the signal for the AVC rectifier is taken directly from the plate of the 6SG7 second i-f tube through a 22 mmf fixed capacitor. This permits the same AVC circuit to function on both AM and FM without becoming involved in complex switching arrangements. In every other respect the i-f amplifier is strictly conventional. We shall now discuss the operation of the limiter stage.

(2-6) The limiter circuit, H-119





SLIDE 7

a. *The limiter is an i-f amplifier stage designed to "saturate" at a certain signal level.* It acts somewhat like a tank, which allows the water level to rise to the outflow pipe and then keeps that level constant no matter how much water is poured in.

b. In the FM set the purpose of the limiter is:

1. *To remove all amplitude variations in the i-f amplifier system ahead of the limiter.* It should pass on to the discriminator a signal of constant amplitude and varying frequency.

2. *To enable the FM set to discriminate between two stations on the same frequency* as long as the signal strength of one station is two times that of the other. (Similar to AVC.)

3. *To reject static*, both natural and man-made.

Operation of the limiter:

1. *The limiter works on the grid rectification principle.* A grid condenser and grid leak are used in the same manner as the "square law" detectors used in the radios of 15 or 20 years ago.

2. *No negative bias is supplied to the grid.* The grid swings positive and grid current flows at the moment a signal is applied. Grid current flows through the 470,000 ohm grid resistor, R28, from grid to cathode of the 6SJ7 tube. The voltage drop across R28 has a polarity which makes the grid negative with respect to cathode. The stronger the signal, the greater the bias voltage. This "automatic" bias reduces the gain of the tube and maintains a constant output.

d. The step by step operation of the limiter follows:

1. A *strong* signal is impressed on the 6SJ7 grid. The 47 mmf capacitor, C3, rapidly charges up to nearly the peak signal amplitude.

2. *The capacitor then discharges through the 470,000 ohm resistor R28.*

3. *The values of the resistor and capacitor are critical.* The discharge rate through the resistor will be *slower* than the charging rate through the tube. This results in a steady negative bias voltage being built up on the grid.

4. *This negative voltage is almost equal to peak of the signal.* The grid will swing positive only on signal peaks and for a very short period of time. The length of these periods is determined by the time constant of the grid capacitor, C3, and the grid resistor, R28.

5. Under these conditions the 6SJ7 tube then will "squash" down any changes in the strength or amplitude of the signal. From its plate circuit it will deliver a constant amplitude signal to the discriminator.

e. Precautions

Limiter tube voltages are quite critical. When replacing the grid condenser or the grid and plate resistors, the exact value specified by the manufacturer must be used.

(2-7) The Discriminator Circuit, H-119

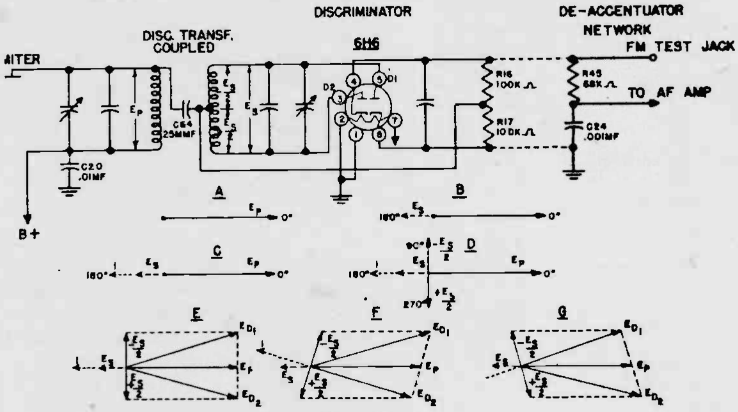
a. *The discriminator is a device which changes frequency variations into a varying audio voltage.* This varying audio voltage corresponds to the sound being transmitted by the FM station.

b. In the Westinghouse Model H-119 a more or less conventional center-tapped i-f transformer and a 6H6 tube comprise the discriminator. This circuit utilizes the phase shift between the primary and secondary voltages across the i-f transformer to produce a differential audio voltage.

c. The step by step operation of the H-119 discriminator is as follows:

1. The i-f signal voltage appears across the tuned primary of the discriminator transformer (condition A).

2. An *induced* voltage is produced across the secondary winding. This voltage is 180° out of phase with the primary voltage (condition B).



SLIDE 8

3. At resonance the *induced* secondary voltage causes an in-phase current to flow through the coil and its tuning condenser (condition C).

4. This in-phase current flows through the coil and produces a *reactive voltage drop* across the coil and condenser. This reactive voltage is out of phase with the secondary current by 90° (condition D).

5. If the resistance of the secondary winding is low, the reactive voltage drop across the secondary tuning capacitor will be many hundreds of times greater than the induced voltage due to transformer action. This "gain" is similar to that of an ordinary TRF stage when it is tuned and for all practical purposes, we can forget the induced secondary voltage and assume that the secondary voltage is equal to the reactive voltage drop across the coil and condenser.

6. The current through the secondary winding may be assumed to flow from bottom to top of the coil. One half of the reactive voltage drop appears between the center tap and the bottom of the coil; the other half appears between the center tap and the top of the coil. For purposes of explanation, we will designate the upper half of the voltage drop as "minus" Es/2 and the lower half as "plus" Es/2.

7. The primary voltage is also coupled to the *center--point of the secondary winding through the capacitor C64.* This voltage appears across resistor R17, and is the same as that across the primary winding.

8. *The resultant signal voltage which appears at diodes No. 1 or No. 2 is the vector sum* of the series voltage drop across R17 plus the upper half of the secondary voltage, or the vector sum of the series voltage plus the lower half of the secondary voltage.

9. *When the signal voltage frequency is equal to the resonant frequency* of the tuned primary and secondary discriminator transformer circuits, the signal voltages appearing at the two diode plates are equal, and equal and opposite rectified voltages will appear across resistors R16 and R17 (condition E).

10. *The audio frequency output under the conditions just mentioned,* will be zero. This would be a condition of no modulation at the FM transmitter.

11. *As the frequency varies with modulation, the voltages applied to the two diodes become unequal.*

12. *At frequencies higher than the resonant frequency of the tuned circuits,* the secondary winding presents an inductive reactance causing the current to lag the secondary voltage. As a result the voltage at diode No. 1 is greater than at diode No. 2 (condition F).

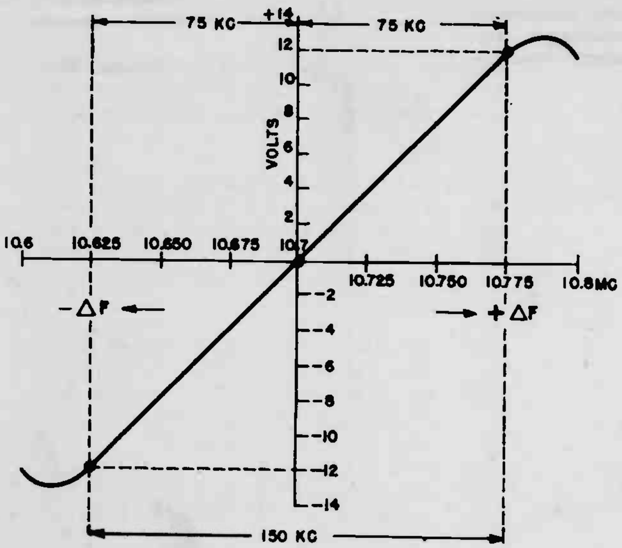
13. Diode No. 1 passes current which flows from the cathode mid-point connection through R16. The voltage drop across R16 is now greater than the drop across R17. The voltage output at the discriminator test jack will be equal to the algebraic difference between the voltage drops across R16 and R17 and will have a definite polarity, plus or minus, with respect to ground.

14. *At frequencies below resonance,* the conditions are the direct opposite of those just described. The tuned circuit now presents a capacitive reactance, the secondary current leads the voltage and the voltage at diode No. 2 is now greater than that at diode No. 1 (condition G).

15. Diode No. 2 accordingly passes current which flows from cathode midpoint connection through R17 causing a greater voltage drop across that resistor.

16. As the frequency swings from one side of resonance, through resonance and to the other side of resonance, the audio voltage output from the discriminator, will decrease to zero, reverse polarity and rise to a peak. If the voltage values appearing across R16 and R17 are plotted against the impressed frequency, a curve such as that shown in slide 9 will be obtained. The straight portion of the curve must, at least, extend over the band width covered by the FM signal.

(2-8) **Deaccentuation Network H-119.** The a-f accentuator is used at the FM transmitter network to raise the amplitude of the audio



SLIDE 9

frequencies in the upper range. At 10,000 cycles the amplitude of the audio signal is up to 15DB. The actual signal, as taken from the discriminator output is therefore distorted. It is necessary to utilize this arrangement in order to prevent the transmission of noise from the FM transmitter.

At the receiver, the a-f amplifier must be designed to present a response the direct opposite of that at the transmitter. This means that the a-f amplitude at 10,000 cycles must be *down* 15DB in order to realize reproduction of the original sound. This is accomplished by the insertion of a network of resistance and capacitance at the input of the a-f amplifier. The time constant of this network is from 70 to 100 micro-seconds and the values are quite critical. When replacing these components, be certain that the values are identical with those specified by the manufacturer.

SECTION III
FM RECEIVER ALIGNMENT AND TROUBLE SHOOTING

(3-1) Voltmeter Alignment H-119

a. Test Equipment Required:

1. Standard signal generator with provision for removal of modulation and capable of providing 10.7 mc. and 88 - 106 mc. output.

2. Vacuum tube voltmeter, such as RCA Voltohmist or Hickok 125 (must have a scale of around 2.5 volts D.C.). A 20,000 ohms per volt D.C. voltmeter, such as Simpson Model 260, may be used. However, the VTVM is recommended.

b. R-F and I-F Alignment.

1. Connect vacuum tube voltmeter across limiter grid resistor.

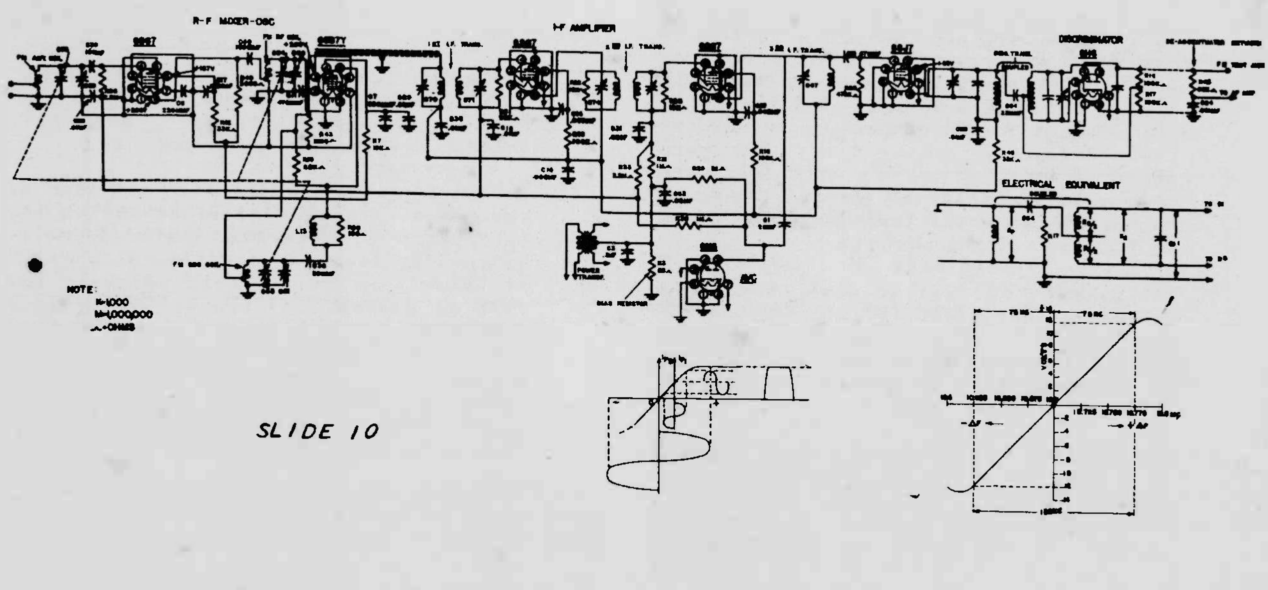
2. Connect unmodulated output signal voltage from signal generator to stage under alignment (if aligning i-f generator should be adjusted for 10.7 mc. center i-f; if aligning r-f, generator should be adjusted to some frequency in the 88 - 106 mc. band.)

3. Adjust i-f or r-f trimmers for maximum voltage indication on vacuum tube voltmeter.

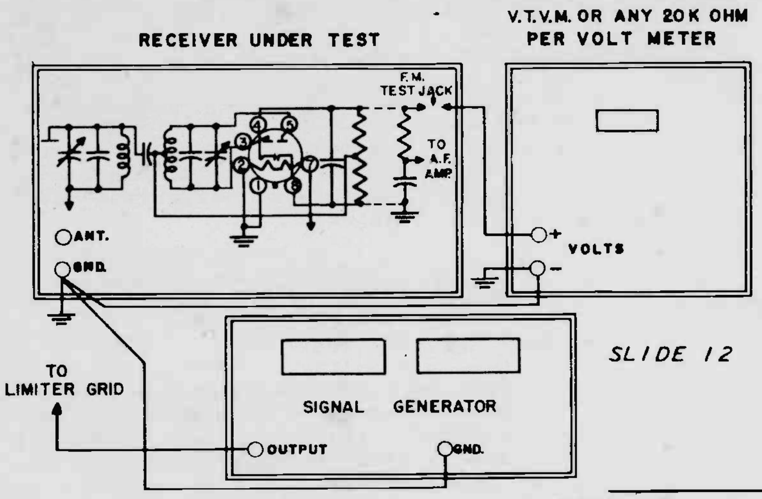
NOTE: Maintain a good common ground connection between the receiver, the vacuum tube voltmeter and the signal generator.

c. Discriminator Alignment.

1. Connect signal generator to receiver limiter grid. Keep output of signal generator *low* so that grid current will not be drawn.



SLIDE 10



F. M. BAND ALIGNMENT

Connect a 10,000 ohms-per-volt or Vacuum Tube Voltmeter between the Discriminator Test Jack and the chassis.

With the volume control set for maximum output and the signal from the generator attenuated to avoid A.V.C. action, proceed as follows

SLIDE 12

STEP	CONNECT SIGNAL GENERATOR TO--	SIGNAL GENERATOR FREQUENCY	RADIO DIAL SETTING	ADJUST
1	Set Phono-Band switch to "F.M."			
2	Detune secondary trimmer of discriminator transformer.			
3	6SG7, 2nd i-f, control grid through a .01 mfd mica capacitor	UNMODULATED 10.7mc	88 mc	10.7 mc primary trimmer of 3rd i-f trans. for maximum voltage.
4	6SG7, 1st i-f, control grid through a .01 mfd mica capacitor	UNMODULATED 10.7 mc	88 mc	10.7 mc secondary and primary trimmers of 2nd i-f trans. for maximum voltage.
5	Fixed plates of the FM converter tuning capacitor through a .01 mfd mica capacitor	UNMODULATED 10.7 mc	88 mc	10.7 mc secondary and primary trimmers of 1st i-f transformer for maximum voltage.
6	Fixed plates of the FM converter tuning capacitor through a .01 mfd mica	UNMODULATED 10.7 mc	88 mc	carefully "peak" all 10.7 mc i-f trimmers for maximum voltage.
7	FM antenna terminal through a non-inductive 300 ohm resis.	UNMODULATED 105 mc	105 mc	FM oscillator trimmer for maximum voltage.
8	FM antenna terminal through a non-inductive 300 ohm resistor	UNMODULATED 105 mc	105 mc	FM r-f and ANT trimmers for maximum voltage.
9	Fixed plates of the FM converter tuning capacitor through a .01 mfd mica capacitor	UNMODULATED 10.7 mc	88 mc	Primary trimmer of discriminator transformer for maximum voltage.
10	Fixed plates of the FM converter tuning capacitor through a .01 mfd mica capacitor	UNMODULATED 10.7 mc	88 mc	Secondary trimmer of discriminator transformer for zero voltage. The voltage will change polarity as the trimmer is tuned through resonance. Tune carefully for zero voltage.
11	Re-check steps 9 and 10.			

2. Connect vacuum tube voltmeter to discriminator output (FM test jack in H-119).

3. Detune discriminator transformer secondary trimmer.

4. Adjust discriminator transformer primary trimmer for maximum voltage indication on the VTVM.

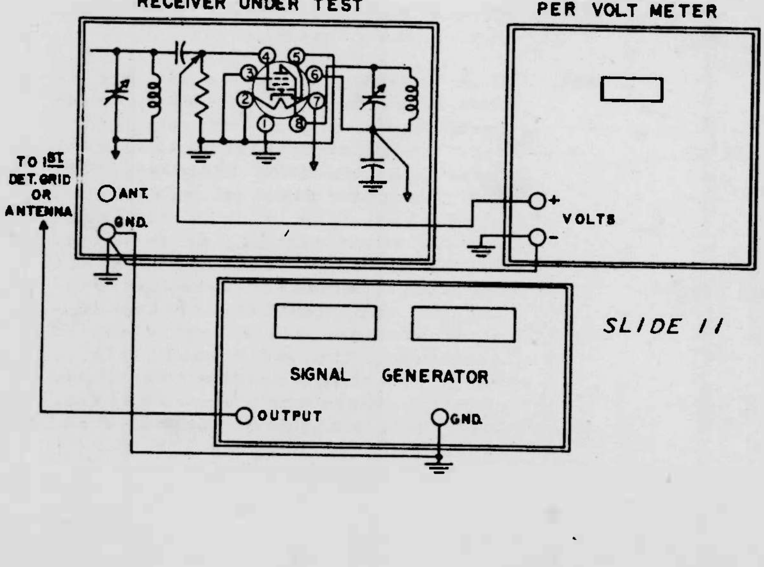
5. Adjust discriminator transformer secondary trimmer for *zero* voltage indication on the VTVM.

NOTE: As the secondary trimmer passes through resonance, the voltage indication will decrease to zero, reverse polarity, and again increase to a peak. Adjust as accurately as possible to the zero value.

6. Swing signal generator frequency to 10.775 mc. Note discriminator voltage value as indicated on VTVM.

7. Swing signal generator frequency to 10.625 mc. Note discriminator voltage value as indicated on VTVM. This voltage indication will be of opposite polarity to that observed under step 6. The two readings should be of the same value within ± 10% of the highest value.

8. If the two voltage readings are not within the tolerance specified under step 7, a slight readjustment of the primary trimmer may be necessary. The primary trimmer controls the amplitude and linearity of the discriminator output; the secondary trimmer controls the location of the zero reference point on the discriminator characteristic curve.



SLIDE 11

d. FM Alignment H-119

Service Department laboratory tests showed that the Model H-119 FM alignment could be carried out by a procedure much simpler than that just described. The FM alignment chart reproduced here is taken from the H-119 Service Notes.

(3-2) Visual Alignment H-119

a. Test Equipment Required:

1. FM signal generator, such as Hickok 288-X, capable of providing 10.7 mc and 88 - 106 mc output. Should supply synch sweep voltage for oscilloscope trace.

2. Oscilloscope, such as RCA Model 155C.

b. R-F and I-F Alignment

1. Connect oscilloscope vertical input across limiter grid resistor.

2. Connect synch sweep voltage from signal generator to horizontal input of oscilloscope.

3. Connect output signal voltage from signal generator to stage under alignment (if aligning i-f, generator should be adjusted for 10.7 mc. center i-f; if r-f, generator should be adjusted to somewhere in 88 - 106 mc. band).

4. Adjust i-f or r-f trimmers until oscilloscope pattern is similar to "A" in slide.

NOTE: Maintain a good ground common connection between the receiver, the oscilloscope and the signal generator.

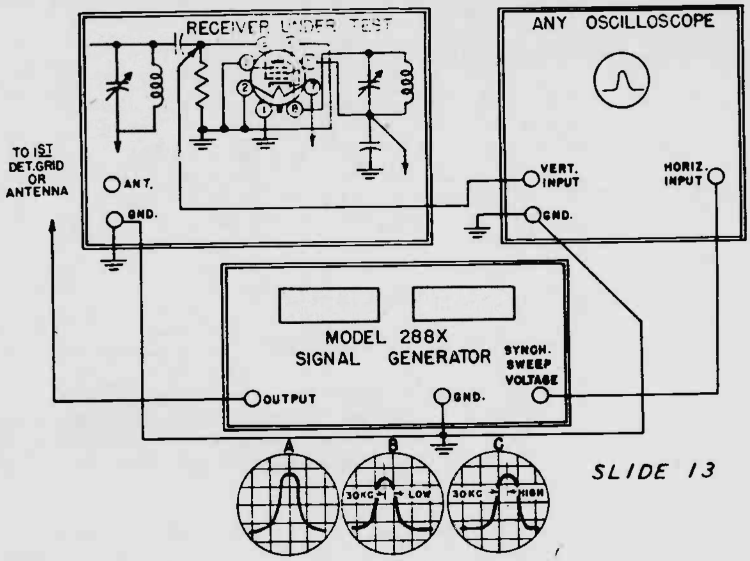
Visual Alignment Discriminator

1. Connect signal generator to receive limiter grid and to oscilloscope as outlined above.

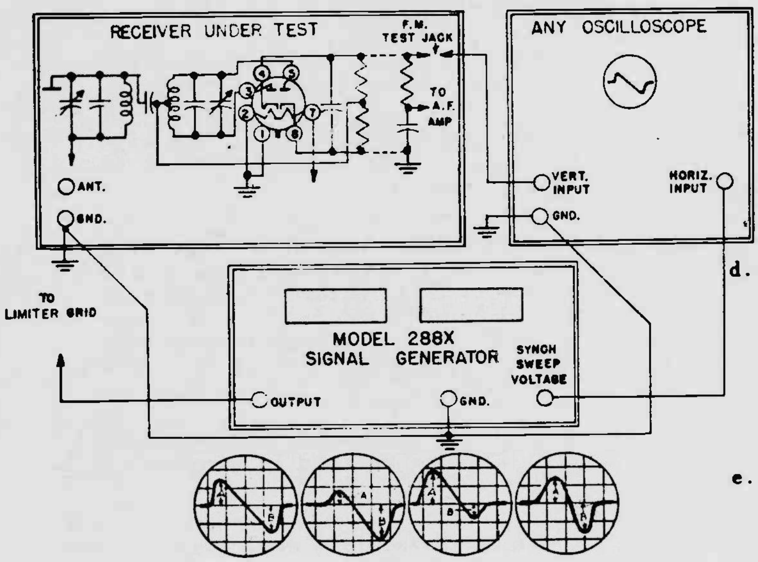
2. Connect vertical input of oscilloscope to discriminator output (FM test jack in H-119).

3. Adjust discriminator primary trimmer for *maximum pattern amplitude*.

4. Adjust discriminator secondary trimmer until pattern is correctly centered about the horizontal axis. The positive and negative peaks should be equal in amplitude and the trace between the two peaks should be linear, at least over the frequency response of the r-f and i-f circuits.



SLIDE 13



SLIDE 14

5. It may be necessary to alternately readjust the discriminator primary and the secondary trimmers to obtain linearity and symmetry in the output. The primary trimmer controls the overall amplitude and the linearity of the pattern; the secondary trimmer controls the distribution of the pattern around the horizontal axis or zero reference line.

(3-3) FM Trouble Shooting

a. Noise and Hiss

1. Noisy r-f or converter tube
2. Defective antenna system
3. Excessive plate voltage on limiter
4. Regeneration

b. Regeneration

1. Improper lead dress
2. Incorrect alignment
3. Defective shield or ground straps
4. Open bypass condenser (r-f or i-f circuits)

c. Distortion and poor Tone Quality

1. Limiter not functioning due to
   a. Bad 6SJ7 limiter tube
   b. Incorrect limiter voltage
   c. Limiter circuit not properly aligned
   d. I-F circuits not properly aligned
   e. Bad i-f amplifier tube
   f. Open loading resistor across i-f winding
   g. Open bypass condenser, i-f circuit
   h. Incorrect voltages on i-f tubes
2. Bad resistors or capacitors in de-accentuator network.
3. Insufficient signal for limiter saturation due to
   a. R-F circuits out of alignment
   b. Bad r-f tube
   c. Inefficient antenna system

d. Dynamic Range or Reproduction Poor

1. Limiter not functioning properly
2. Regeneration in i-f due to open bypass condenser or open loading resistor across i-f transformer
3. I-F circuits, limiter or discriminator not properly adjusted.

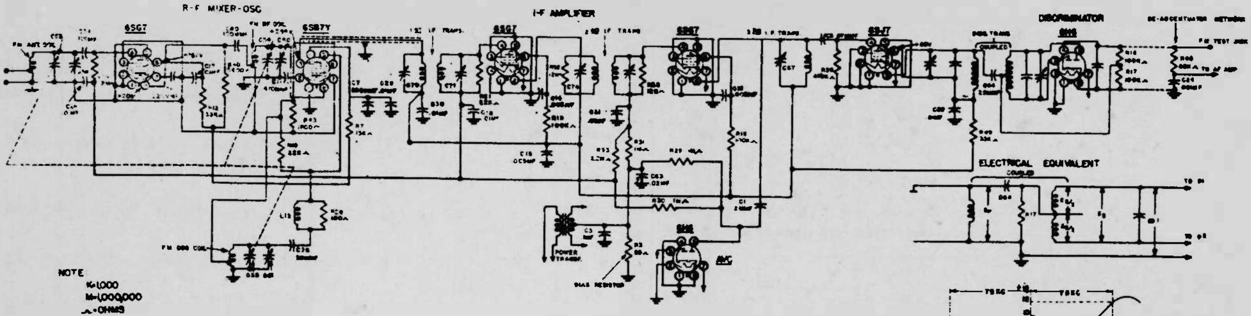
e. Lack of Highs on FM Stations

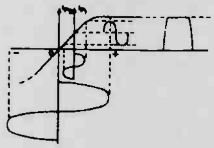
1. Check resistance-capacitance values in de-accentuator network.

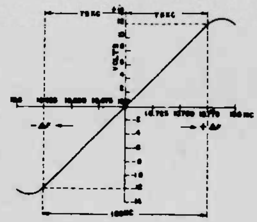
f. Trouble Shooting in the Discriminator

Trouble: Severe Amplitude Distortion During High Audio Signal Levels.

Remedy: This trouble is frequently due to poor discriminator alignment. High level audio signals correspond to wide frequency deviations around the center intermediate frequency. If the discriminator is far out of alignment, the widely deviated signal, which corresponds to a loud noise, will go over the "hump" of the characteristic curve and distortion will result. If the discriminator is only slightly out of alignment, the audio quality will be good except on the very loud passages where the response leaves the linear portion of the curve and passes over to the peak.







SLIDE 15

To correct, realign the discriminator transformer primary and secondary trimmers.

Another possibility is that one-half of the discriminator transformer secondary winding may be open; or, the phasing condenser between the primary and secondary windings may be open. Either of these troubles will cause loss of one reference voltage and thereby introduce distortion.

g. Trouble Shooting In the Limiter

Trouble: Distortion in Discriminator A-F Output

The same basic operating principle is involved in all present-day limiter circuits. In the Westinghouse H-119, a 6SJ7 sharp cut-off pentode is operated so that grid swing conditions between cut-off and zero grid volts is of the order of 3 or 4 volts. The plate and screen voltage is maintained at approximately 63 volts. Under such operating conditions, with a strong signal applied to the limiter grid, plate current saturation is quickly reached.

The most frequent trouble in limiter circuits, with the possible exception of tube trouble, is a change in plate voltage due to changes in the value of the plate load resistor or to partial short-circuit of the plate circuit bypass condenser. If the plate and screen voltages are too high, the "threshold" voltage may change as much as 50 to 150 microvolts or more. This means that the limiter will function as an i-f amplifier and little or no limiting action will take place. As the signal frequency swings with modulation, it passes over the slope of the i-f characteristic curve generating an AM signal which can be passed on to the discriminator. The discriminator will respond to AM as one-half of the 6H6 tube can act as a diode rectifier. Unless the limiter removes the AM response, this condition will occur. The i-f response curve is not linear, so considerable distortion will take place when the FM signal is converted to AM. This is not normal FM reception and the conditions just described are due to a lack of limiter action. This condition can be readily recognized by noisy and somewhat distorted reproduction.

The H-119 limiter is of the "peak-riding" type. The bias across the grid resistor is developed from current flow during the peaks of the r-f grid voltage swing. This grid current charges the capacitor and the capacitor, in turn, discharges through the grid resistor. If the grid resistor became open, there would be no leakage path for the condenser charge. A burst of noise or a strong signal will charge the grid capacitor to a large bias voltage. If the resistor is open, however, there would be no condenser discharge other than the loss leakage across the dielectric and the accumulated charge holds the 6SJ7 grid below the cut-off value. This condition will cause sharp clicks of signal or noise similar to a motor-boating effect. If the capacitor dielectric has a very low leakage factor, the set may appear dead for fairly long periods of time.

Another

Supreme Publications

Radio Book

SUPREME PUBLICATIONS, 9 SOUTH KEDZIE AVENUE, CHICAGO 12, ILLINOIS