May 1965

Dynamic Gain Transistor Tester

Frequency Sub-Standard ★ Improving the AR88 ★ Transistor P.A. Amplifier ★ Simple Echo Unit

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Here is proof positive of the power and quality that a Sinclair Pulse Width Modulated Amplifier can give you. The new X-20 which is complete with integrated pre-amplifier uses silicon epitaxial planars in the output stage, better than anything ever before offered to constructors in transistorised equipment. Many other refinements have been introduced into this latest Sinclair design. For example, absolute constant amplitude is maintained in the output square wave form irrespective of the extent of the modulation applied. Building this amplifier is unusually easy and the results to be obtained from it are completely rewarding. Unlike many hi-fi amplifiers, the X-20 has power and power to spare. It has superb quality, too, all from a unit measuring only 8½” x 3½” x 1”—dimensions which will inspire constructors to build to entirely new concepts of design and layout.

X-10 P.M.W. AMPLIFIER WHERE LESS POWER IS REQUIRED

Although the X-10 has been superseded in power by the X-20, this superb Sinclair integrated P.W.M. amplifier and pre-amp gives you all the advantages of quality and efficiency which makes these Sinclair designs so outstanding in every way. It is the ideal hi-fi amplifier where superb quality is wanted, with a more moderate output.

£5.19.6 Ready built
£6.19.6 X-10 power supply built
£7.19.6 X-20 Power Unit
For 12-15V operation. Tone control system is added to choice.

Complete kit of parts and manual £7.19.6
X-20 Power Unit £9.19.6

SINCLAIR RADIONICS LTD.,
COMBERTON, CAMBRIDGE Telephone: COMBERTON 682

THE RADIO CONSTRUCTOR

654

www.americanradiohistory.com
WHAT YOU SHOULD KNOW ABOUT THIS BRILLIANT NEW SINCLAIR DESIGN

CONSTANT AMPLITUDE

Pulse Width Modulation requires a perfectly formed square wave to carry the audio signal and it must be of a frequency well above the highest level of the audio spectrum. In the X-20, the peak-to-peak amplitude of the square wave is constant at all times, no matter to what extent it is modulated by the A.F. The result is that distortion figures are lower than ever.

PULSE REPETITION FREQUENCY

In the interests of quality, the P.R.F. must be as high as possible without extending into the region of radio frequencies. In the X-20, the pulse repetition frequency is between 65 and 75 kc/s, a value which is found to satisfy the most stringent demands likely to be made upon it in terms of uncompromising quality. This frequency is generated within the circuitry of the X-20 itself and the output has rise-fall times of less than 0.2 micro-seconds.

OUTPUT STAGE — 95% EFFICIENT

Rise and fall times of less than 0.2 micro-seconds are achieved by using silicon epitaxial planar output transistors which makes the efficiency of the output stage at least 95%. Thus only 1 watt is dissipated in the output stage when the amplifier is giving an output of 20 watts R.M.S. The complete linearity of the integrator and careful modulator design ensure absolutely negligible distortion right up to the maximum output.

LOW-PASS FILTER

A low-pass filter cutting off above 20 kc/s built into the output of the X-20 ensures that the output transistors always "see" a high impedance at the P.R.F., making the amplifier widely tolerant of the type of load to which it is connected.

PRE-AMPLIFIER

This consists of three transistors with two negative feedback loops which define the gain and ensure an absolutely flat frequency response. The sensitivity is sufficient for all types of pick-ups. Provision is also made for connecting high-output devices such as F.M. Tuners and Tape Pre-amps.

TONE CONTROL SYSTEMS

The Manual included with the X-20 Amplifier details a variety of tone and volume control systems, any one of which may be added to the amplifier for very little outlay. Full information on stereo operation is also provided, of course.

POWER SUPPLY

A special A.C. Mains operated power supply unit is available for the X-20, delivering 36 volts D.C. Full wave rectification is used and the unit will power up to two X-20's. The power unit is supplied ready built in a completely enclosed steel case.

OTHER SPECIAL FEATURES

Because of the high energy conversion factor of the X-20, it requires no heat sink in the output stage when the amplifier is giving an output of 20 watts R.M.S. music power. Using a 15 ohms loudspeaker, the output is 15 watts R.M.S. music power.

Please send me

NAME

ADDRESS

for which I enclose Cash/Cheque/Money Order

value £ s. d.

Guarantee

Should you not be completely satisfied with your purchase when you receive it from us, your money will be refunded in full and at once without question. Please quote R.C.S should you prefer to write your order instead of cutting out this coupon.

MAY 1965

OTHER SINCLAIR DESIGNS

MICRO-6

THE SMALLEST ON EARTH

Smaller than a matchbox, this world-famous receiver brings in stations from all over Europe. It performs with fantastic efficiency in cars, buses, trains and steel-framed buildings, yet measures only 1¼" x 1¾" x ½". The highly stable six-stage circuit provides A.G.C. and handspread for easy Luxembourg reception. Tunes over medium waveband. Building this smart minute set is easy. Its performance is wonderful.

All parts inc. 3 M.A.T. transistors, case, lightweight earpiece and instructions come to £5.96.

MALLORY MERCURY CELL ZM.312 (2 required), each 1/11

TR.750 POWER AMP

MEASURES ONLY 2" x 2"

With built-in switch and volume control. Output 750mW for feeding into standard 25 to 35 ohm speaker. Input 10mV into 2 kilo. Operates from 9V d.c.

All parts and "I.Q./A Ready built AC/DC, instructions 3/96 and tested 4/96

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MULTIMINOR Mk 4

The newly improved model of this famous AVO pocket size multi-range instrument has been enthusiastically acclaimed in all parts of the world for its high standards of accuracy and dependability as well as for its modern styling, its highly efficient internal assemblies, and its resistance to extremes of climatic conditions.

It is simple to use, one rotary switch for instant range selection, only one pair of sockets for all measurements, and a 2½ inch clearly-marked scale-plate. It is supplied in an attractive black carrying case complete with interchangeable test prods and clips, and a multi-lingual instruction booklet.

RESISTANCE: 0-2MΩ in 2 ranges, using 1.5V cell
SENSITIVITY: 10,000Ω/V on d.c. voltage ranges 1,000Ω/V on a.c. voltage ranges

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AVOCET HOUSE, 92-96 VAUXHALL BRIDGE ROAD,
LONDON, S.W.1 Telephone: Victoria 3404 (12 lines)

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2-TRANSISTOR RECEIVER for M.W. and L.W. reception. Uses ferrite rod aerial, with provision for external aerial.

AUTOMATIC CONTROL SYSTEM FOR HAMS
Fully automatic changeover system—'Press-to-talk' switch for listening through—adjustable time delay from a few m/s to 1 sec.

PRACTICAL WIRELESS
JUNE ISSUE Out May 6th — 2/-
ORDER YOUR COPY NOW!

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Trawler Band Transistor Receiver. A compact 4 transistor, semi-conductor receiver, complete with the stations that can be received on this set. Works from standard batteries. Price 4/6, p/p 2/6.

CARAVAN RADIOS
These well made radios were designed for the Government for forces entertainment. Contains 6K8, 6K7, 6Q7, and 6V6 output. Has choke smoothing and slow motion tuning. Printed government for forces entertainment. Contains wooden cabinet. Ideal for use with your caravan or car. Will work from standard 6V car battery or directly connected for mains operation. Price £13.6, p/p 10/-.

TYPE 19 SHORT WAVE RECEIVING SET
Works straight off the mains. An excellent short wave radio receiver. Only wholes for immediate operation. Price £5.19.6, p/p 10/-.
During an evening's testing of this excellent receiver, we obtained clear reception from stations many of them thousands of miles distant, including ship stations, government transmissions, maritime broadcasts, etc. Ideal for fixed or mobile authorised operation. Limited number left. Price 12 gns per pair. Post free.

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20,000 ohm per volt, 1½% resistance used throughout. Single control system for all ranges. Accurate. £5.10.0, p/p 3/6.
Compact and lightweight. Highly accurate. £10.10.0, p/p 3/6.

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CRYSTAL SET
A wonderful educational kit for all children. Provides hours of amusement while following the easy step by step instructions. Educational, fun and without the expense of batteries. No soldering required. Receives all main stations. Price 45/-, p/p 2/6.

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1555 Instruction Handbook 3/6 each, p/p 6d.
H.R.O. Instruction Handbook 1/6, p/p 5d.
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R.F. Unit 25 Circuit Diagram and Details Price 1/6, p/p 3d.
R.F. Unit 26 Circuit Diagram and Details Price 1/6, p/p 3d.
Receiver R1223A Circuit Diagram and Details Price 1/6, p/p 3d.
Receiver R1224A Circuit Diagram and Details Price 1/6, p/p 3d.
W.R. Meter Class D Handbook, Mk. 1, 111 Price 3/6, p/p 6d.

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A lightweight walkie-talkie with transmitting range 5 to 10 miles and frequency coverage 7.4 to 9 mc/s. Operates from 12V and 120V external dry batteries. Large, clearly numbered tuning control, with chucking lock, in good condition. ONLY 4/ per pair, p/p ½.

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A compact V.H.F. trans/rec., that can be held in the hand. Size approx. 12 x 3 x 2½. Range up to 3 miles under favourable conditions. Uses 3 miniature valves and self contained standard batteries. Easy operation, economical to run. Ideal for fixed or mobile authorised operation. Limited number left. Price 12 gns per pair. Post free.

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A high Impedance Personal Listening Earpiece. Suitable for all types of crystal sets and transistor sets. Complete with lead and plug. Price 4/11, p/p 6d.

SENSEF MULTIMETER
A high quality 30-watt amplifier developed for mike or pick-up. Valve line-up; two EF86; one ECC83; one GZ34; two EL34. Four separate inputs are provided with two volume controls. Bass and Treble controls are incorporated. Amplifier operates on standard 500 G.A. mains. 1 ohm and 15 ohm speakers may be used. Perforated cover with carrying handles can be provided if required, price now 25/-.
Customers are invited to see and hear this amplifier at our shop premises at Lambert’s Arcade or our new York shop. Send S.A.E. for illustrated leaflet. 16 gns. cash. Carriage 15/- to be sent with order.

THE GOLDENAIR “THIRTY” HI-FI AMPLIFIER
A high quality 30-watt amplifier developed for use in large halls and clubs etc. Ideal for bass, lead or rhythm guitars, schools, dance halls, theatres and public address. Suitable for any type of mike or pick-up. Valve line-up: two EF66; one ECC83; one GZ34; two EL34. Four separate inputs are provided with two volume controls. Bass and Treble controls are incorporated. Amplifier operates on standard 500 G.A. mains. 1 ohm and 15 ohm speakers may be used. Perforated cover with carrying handles can be provided if required, price now 25/-.
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Customers are invited to see and hear this amplifier at our shop premises at Lambert’s Arcade or our new York shop. Send S.A.E. for illustrated leaflet. 16 gns. cash. Carriage 15/- to be sent with order.

OPERATORS UNIT
Huge purchase enables us to offer at give away price operators unit containing standard jack socket 250 mfd electrolytic condenser, 4-way telephone socket, midget selenium rectifier, etc. Price 3/6 post free, or 2 for 6/6 post free.

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Enables you to determine value of a resistor at a glance. A must for the constructor. Saves time. Price 1/6 each, p/p 3d.

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Edoxan XZ202 Germanium diodes. Price 1/11, p/p 3d.
Mullard OA79. Price 1/11, p/p 3d.
Transistor holder 3-pin. Price 1/6 each, p/p 6d.

Valve Set. 2/6 each, p/p 9d. 2 for 5/- post free. 6V6, 807, 6H6, 6B8G, EF86, EL4.


DYNAMOTOR
Run all your mains A.C./D.C. equipment from your car battery. 6V input gives 250V output, or 12V input gives 500V output at 30 wats. Very low battery drain. Size only 5½ X 3½. A must for the caravanner. ONLY 25/-, p/p 3/6.

Tank Aerials. Fully interlocking copper sections one foot in length. Will make ideal dipoles, car or scooter aerials. Price 6 sections complete with canvas carrying case 3/6, p/p 1/6. Additional sections 6d. each. Please include sufficient postage.

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No C.O.D. under 30/-

SONA ELECTRONIC CO (DEPT RC4) BRIGGATE HOUSE, 13 ALBION PL. LEEDS 1.

MAY 1965
From time to time we have shown you pages from our Components Catalogue, to whet your appetite! We usually pick out pages that we consider photogenic or particularly interesting. This month we show one of the Resistor pages—after all, resistors are a basic requirement of any electronic circuit. If we tell you that our Resistor section runs to six pages, and that we list, and stock, some 22 different types and some 890 different values—are you interested? You are? Then send in 6s. (5s. plus 1s. p. and p.) and we will send you a copy by return. Incidentally in the catalogue you will find five coupons, each worth 1s. if used as directed.

RESISTORS

Metal Oxide High Stability Resistors

The general rating of these resistors is 1 watt at 70° C. At the maximum working load the drift figures are 2% and 4% for 2,000 and 25,000 hours operation respectively. Derating to 1 watt at 70° C will improve the stability to 1% and 2%, and still further derating to 1/2 watt at 70° C will bring these resistors into the Laboratory Standard with a stability rating of 0.1% and 1% for the operation periods mentioned.

The temperature coefficient is within the limits ± 150 parts in 10^6 over the range —55° C to + 150° C.

The noise is less than 0.1μV. per volt.

R9M Metal oxide resistors 1 watt 2% HSY. 2s. 3d. each.

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Miniature Resistors

R1A. ±10% 8d. each (Make as available). 1/8 in x 1/8 in. 1/8 watt. Tolerance 10%. 8d. each.

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CARBON RESISTORS

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Radio Topics, by Recorder 710

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MAY 1965
FREQUENCY SUB-STANDARD

By CRAIG MACKAY

This article describes a 100 kc/s sub-standard frequency generator which may be set up against standard frequency transmissions. Optional extras are multivibrators offering outputs at 10 kc/s and 1 kc/s, these being locked to the basic 100 kc/s signal.

All measurement must have as its basis a unit (usually arbitrary) in terms of which the quantity to be measured is expressed. It must be possible, also, to have some sub-standard which bears a certain relation to the standard unit, and which can be used for comparison with the quantity to be measured.

Clearly, the accuracy with which the quantity can be measured is directly dependent upon the accuracy of the sub-standard.

For the person concerned with electronics in its widest sense, time or frequency is a most important quantity, and the accuracy of the sub-standard which is used will largely determine the accuracy and value of any work which might be done.

This article is intended to describe the construction of a frequency sub-standard which has a basic long-term accuracy of 0.002%, and a short-term stability of one part in 250,000 (over any half-hour period) or better.

The General Circuit

The sub-standard oscillator circuit (see Fig. 1) uses a crystal mounted in an evacuated envelope with a B7G base, this oscillating at 100 kc/s in a modified Colpitts oscillator circuit. Such a crystal is marketed by the Quartz Crystal Company, and is known as crystal unit type Q7/100. Provision is made for slight adjustment of the frequency of oscillation by means of C2.

V3 is a buffer amplifier stage to isolate the oscillator from succeeding stages, and, like V1, is an EF91.

V3 is a double triode type ECC83 connected in the familiar multivibrator configuration and synchronised with the 100 kc/s oscillator to operate at 10 kc/s. The signal thus produced has exactly the same accuracy as the original 100 kc/s signal.

Fig. 2 shows the output stages. V4 amplifies the 100 kc/s signal, or amplifies and limits the 10 kc/s signal. This produces a square wave for the 10 kc/s signal.

Fig. 1. The 100 kc/s sub-standard crystal oscillator, together with the buffer amplifier and 10 kc/s multivibrator.
signal. The output from V4 is fed to V5, which is connected as a cathode follower giving a relatively low impedance output. Both V4 and V5 are type EF91.

It is often necessary to be able to pick out the signal from the chaos present these days in the amateur bands and a neon modulator is incorporated which produces a most distinct “bleeping” note which is very easy to recognize. The modulation on-off switch S1(a) is incorporated in the frequency selector switch.

V6 is a power rectifier type EZ80. The power supply circuit is given in Fig. 3.

Additions

Different people will obviously have varying requirements for an instrument of this type. If the 10 kc/s facility is not required, then V3 and V4 (with their associated circuitry) may be omitted. The grid of V5 is then connected, through a 100pF capacitor, to the anode of V2. This, of course, considerably simplifies the instrument.

However if, in addition to the 10 kc/s facility, a signal at 1 kc/s is required with the same very high accuracy, then the circuit of Fig. 4 may be added. This consists of a buffer stage V7, and a synchronised multivibrator operating at 1 kc/s (V8). V7 is type EF91, and V8 is type ECC81.*

The switching circuit shown in Fig. 2 assumes that both 10 kc/s and 1 kc/s multivibrators are employed. When only the 10 kc/s multivibrator is used, a 2-pole 4-way switch may be fitted instead of the 6-way component shown.

If more than one additional output channel is required, the circuit of Fig. 2 may be duplicated as necessary. In this way, more than one frequency may be made available at the same time.

If different sub-multiples of the synchronising frequency are required then the value of the multivibrator coupling capacitors between the anode and “opposite” grid of V8 will have to be altered. This can easily be done as the frequency of oscillation is inversely proportional to the values of these

* In the multivibrator circuits shown in Figs. 1 and 4, the sync level controls (R9 and R23) serve also as frequency controls, in that they vary the grid leak values of the associated triodes. In consequence, these controls may vary the mark/space ratio of the square wave. The circuit is, however, designed to give approximately 50:50 square waves when the controls are set to the position at which synchronising occurs.—Editor.
capacitors, e.g. halving their value doubles the frequency of oscillation. Both capacitors should have, of course, the same value.

Building the Instrument
The constructor must first make up his mind exactly what his requirements are, or are likely to be in the future, and build accordingly.

Because of the large number of variations possible, no definite layout will be given, and only a few "rules" will be mentioned.

The final layout depends to some extent on the size of the mains transformer, which must be chosen to deliver the required currents. The basic circuit, with the 1 kc/s frequency divider requires an h.t. current of 55mA.

The chassis to be used is very much a matter of personal preference. The author used one of the "Universal Chassis" sold by Home Radio (Mitcham) Ltd., which can be supplied with a baseplate as well as the usual top plate. This, with a few ventilation holes suitably drilled, met all requirements.

The crystal has a low temperature coefficient (less than 2 parts per million per degree C temperature change at normal room temperature), but it should nevertheless be kept well away from all sources of heat. As it is mounted in a B7G glass valve envelope, it helps if a screening can is used, and this should preferably be polished aluminium. The can considerably reduces the effect of valve heat generation. The valves should be mounted well away from the crystal, and should be positioned so that no unwanted feedback occurs. Use under-chassis screening, if necessary. If feedback does occur, it is unlikely that it will affect the oscillator frequency very much, but it will certainly cause some confusion when the output signals come to be sorted out.

Setting Up the Instrument
Once the instrument has been built and thoroughly tested, it will require to be adjusted for correct operation.

First, set \( S_1 \) to 100 kc/s and couple the oscillator to a receiver receiving one of the standard frequency transmissions. In Britain, the most convenient station is the B.B.C. Light Programme 200 kc/s transmitter, which is maintained very accurately at this frequency. Elsewhere, one of the WWV transmissions could be employed.

Coupling may take the form of a lead from the sub-standard output loosely wound around the aerial lead to the receiver. This will give enough signal, and the two signals should be heard beating against each other. If they are not heard, adjust \( C_2 \) until they are. \( C_2 \) is then adjusted so that the beat frequency is reduced to a minimum, this being done, preferably, after the instrument has reached its working temperature after, say, 45 minutes.

It is easier to "see" the beat frequency by measuring the receiver a.g.c. voltage and watching it vary. Do not try to make the beat frequency zero; this will be very difficult to achieve and will only be maintained for a matter of a few seconds.

Once the crystal oscillator has been adjusted it will be necessary to set up the multivibrators (if they are included). For the 10 kc/s multivibrators, first set \( S_1 \) to 100 kc/s with modulation on and, with the output coupled to a receiver working this time, on the medium waveband, vary the receiver tuning control until two adjacent points are found where the "bleeps" are coming through loud and clear. Then switch to 10 kc/s, modulation on, and count the number of points where the bleeps are heard between, but not including, the two chosen endpoints. Adjust \( R_9 \) until they are nine in number and evenly spaced between the two 100 kc/s endpoints.
The 1 kc/s multivibrator is not quite as easy to set up because, unless a very narrow band communications receiver is available, the above method (scaled down by 10) will be of little use. Probably the easiest method is to feed the output of the instrument into an audio amplifier and compare the frequency with either a piano or some other source whose frequency is known within about 5%.

If the sync control for this multivibrator, R28, is varied, the oscillator may be heard to switch from one sub-multiple of the basic frequency (in this case 10 kc/s) to another; i.e. from 833 c/s to 909 c/s to 1,000 c/s to 1,111 c/s to 1,250 c/s, etc., as the sync level is adjusted.

The multivibrators should stick to their frequency permanently, but it is advisable to carry out the above procedure from time to time just to check that everything is working correctly.

Using the Instrument
The three oscillators will produce a signal which is very rich in harmonics. The 2,000th harmonic (200 Mc/s) of the 100 kc/s oscillator has been detected with the prototype, and it will produce signals at 100 kc/s intervals which will be readily found at least up to 30 Mc/s. By using these harmonics it is possible to calibrate receivers, signal generators, etc., with very high accuracy. The 100 kc/s and 10 kc/s harmonics may be used as standard markers throughout the commonly used radio frequency spectrum for precision calibration, while the 10 kc/s and 1 kc/s oscillators may be used for precision calibration of audio generators.

For really good stability it is necessary to put the completed instrument on a quiet shelf in the workshop where it can be used without being moved or bumped. The final adjustments should be carried out on this shelf, and the instrument should be left in peace and never mechanically disturbed. It should, nevertheless, be periodically checked for drift in the manner described above.

Components List
(Note.—As explained in the text, some components are not required if one or both of the multivibrators are omitted.)

**Resistors**
(All fixed resistors are 1 watt 10% unless otherwise specified)

| R1  | 10kΩ | R18 | 470kΩ |
| R2  | 470kΩ| R19 | 100kΩ |
| R3  | 100kΩ| R20 | 150Ω |
| R4  | 22kΩ 1/2 watt | R21 | 1MΩ |
| R5  | 470kΩ| R22 | 150Ω |
| R6,7| 100kΩ| R23 | 10kΩ potentiometer |
| R8  | 22kΩ 1/2 watt | R24 | 100kΩ |
| R9  | 20kΩ pre-set | R25 | 470kΩ |
| R10,11| 10kΩ | R26 | 100kΩ |
| R12 | 5.6kΩ | R27 | 22kΩ 1/2 watt |
| R13 | 4.7kΩ 20% | R28 | 20kΩ pre-set |
| R14 | 10ΜΩ | R29,30 | 10kΩ |
| R15 | 18kΩ | R31 | 22kΩ |
| R16,17| 1MΩ | |

**Capacitors**

| C1  | 1,000pF |
| C2  | 100pF air-spaced variable |
| C3  | 0.1μF |
| C4  | 8μF electrolytic 300V wkg |
| C5  | 100pF |
| C6  | 1,000pF |
| C7,8| 5,600pF |
| C9  | 100pF |
| C10 | 0.1μF |
| C11 | 1,000pF |
| C12 | 0.1μF |
| C13 | 25μF electrolytic 25V wkg. |
| C14 | 0.01μF |
| C15 | 25μF electrolytic 25V wkg. |
| C16 | 0.1μF |
| C17 | 16μF electrolytic 300V wkg. |
| C18 | 32μF electrolytic 300V wkg. |
| C19 | 1,000pF |
| C20 | 22,000pF |
| C21 | 1,000pF |
| C22,23 | 56,000pF |

**Inductors**

| L1  | Smoothing choke, 10H 60mA |
| T1  | Mains transformer. Secondaries (all currents minimum rating required when both divider circuits are incorporated) 250–0–250V at 55mA; 6.3V at 0.6A; 6.3V at 2.1A |

**Valves**

| V1,2 | EF91, 6AM6, Z77 |
| V3   | ECC83, 12AX7 |
| V4,5 | EF91, 6AM6, Z77 |
| V6   | EZ80 |
| V7   | EF91, 6AM6, Z77 |
| V8   | ECC81, 12AT7 |

**Crystal**

100 kc/s crystal type Q7/100 (Quartz Crystal Co., Wellington Crescent, New Malden, Surrey)

**Switches**

| S1(a)(b) | 2-pole 6-way (see text) |
| S2      | d.p.s.t. toggle |

**Fuse**

1/2 amp cartridge fuse

**Neon**

Neon bulb, MES (Radiospares)

**Sockets**

6 B7G valveholders (one with screen, see text)
3 B9A valveholders
1 coaxial output socket
1 cartridge fuse holder
1 socket for neon bulb

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IN THE PRECEDING ARTICLE IN this series (published in last month's issue of The Radio Constructor) the writer discussed several simple methods of employing moving-coil meters as add-on tuning indicators for conventional medium and long wave a.m. transistor superhets. He also stated that he had devised a somewhat more complex circuit which enabled tuning indication to be given by varying illumination in a small m.e.s. bulb, but that considerations of space necessitated that this be described in the following article. In consequence, the present "Suggested Circuit" describes the bulb tuning indicator referred to.

Before proceeding further, it should be pointed out that the circuit described this month is of an experimental nature. This is for two reasons. Firstly, the circuit may, in some cases, necessitate the selection of transistors to obtain satisfactory results. Secondly, the circuit is intended to be added to existing receivers whose individual performances cannot be accurately assessed, with the result that success may not always be achieved. The circuit requires a basic knowledge of transistor operation and its assembly should preferably be tackled by constructors who understand the principles involved. The writer suggests that the circuit be initially checked in a temporary experimental manner with the particular transistor receiver with which it will be employed before any permanent installation is carried out.

A.M. Receiver A.G.C. Circuits

To understand how the tuning indicator circuit functions it is first of all necessary to examine the a.g.c. circuits employed in conventional a.m. transistor superhets. As was checked by the writer (who examined a large number of commercial receiver circuits to verify the point) it is conventional practice, with medium and long wave transistor superhets, to connect the diode detector following the last i.f. transformer in such a manner that the non-earthly end of the diode load goes positive as signal strength increases. This positive-going voltage is applied, as an a.g.c. potential, to a potentiometer which provides bias for the first i.f. transistor. The potentiometer is shown, in Fig. 1, as R1, R2. In the absence of signal, R1 and R2 bias the i.f. transistor such that maximum i.f. amplification is given. When a signal is received the positive-going voltage from the diode load causes the transistor base to go positive also, thereby reducing its gain. Thus, an a.g.c. loop is set up.

A small standing forward current flows through the diode detector, with the result that the a.g.c. potential from its load is slightly negative of chassis in the absence of signal, and only swings positive of chassis on reception of a signal of sufficient strength. The small forward bias can result in an apparent delay in the a.g.c. characteristic of the receiver, since very weak signals can be detected and reproduced at acceptable loudspeaker strength without causing any appreciable positive excursion of the a.g.c. voltage. This effect (which will vary in degree between receivers of different manufacture and design) prevents any tuning indicator operated by a.g.c. potential from giving indications with very weak signals, and represents a limitation in performance which has to be accepted if simple circuits are to be used for coupling the indicator to the receiver.

These points summarise the receiver features which are applicable to the present circuit. They were dealt with in greater detail in last month's "Suggested Circuit", and readers requiring further information should turn to that article.

Adding A Tuning Indicator

The preceding article also gave details of several methods in which a meter could be employed as a tuning indicator. However, such a meter cannot be mounted on the restricted panel space available with the smaller transistor radios, and an alternative means of indication is required. The lack of a suitable h.t. supply makes it impossible to fit a conventional type of tuning indicator (as is employed with valve receivers), and it was this which prompted the writer to investigate the possibilities of a tuning indicator employing a small m.e.s. bulb.

The result is shown in Fig. 2. In this diagram the input emitter of a pair of directly coupled transistors, TR1, TR2, is connected, via the contacts of press-switch S1, to the junction of R1 and R2 of Fig. 1. A low-consumption pilot lamp appears in the collector circuit of TR2. The remaining contacts of S1 cause the receiver battery supply to be applied to TR1 and TR2 when it is depressed, with the result that these transistors are only connected to the receiver battery when it is required to use the tuning indicator. Additional battery consumption is, in consequence, kept at a low level. A 9 volt supply is assumed in Fig. 2, but the circuit could be readily adapted to operate from a 12 volt supply.

The functioning of the circuit is quite simple. In the absence of signal, maximum negative voltage appears at the junction of R1 and R2. In addition to providing bias

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for the i.f. transistor, this condition allows sufficient current to flow in the base circuit of TR1 to cause the bulb in the collector circuit of TR2 to be fully illuminated. On reception of a signal the junction of R1 and R2 goes positive, this resulting in a reduction in the base current for TR1 and the dimming of the lamp. Receiver tuning is, therefore, carried out for minimum illumination in the bulb. Checks of the circuit made by the writer with a standard 6-transistor medium and long wave superhet gave quite impressive results, the bulb illumination changing from full brilliance in the absence of signal to almost complete extinction on reception of local stations. Signals of intermediate strength (apart from very weak signals, which did not cause the appearance of a.g.c. voltage) gave corresponding amounts of dimming in the bulb.

Component Details

Despite the simple manner of circuit operation, there are a number of points which have now to be dealt with in detail, and these can be conveniently approached by discussing the individual components specified in Fig. 2.

TR2 is an ACY18. This is a small wire-ended transistor which is readily available, and it is capable of controlling the bulb illumination for short periods, as is anticipated in the present application, without distress. It should be pointed out, nevertheless, that the circuit causes it to be operated at a fairly high dissipation figure, and it would be advisable to fit it with a well-coupled cooling fin if the indicator is to be switched on for anything longer than occasional short periods.

The remaining transistor in the direct-coupled pair, TR1, may be any small p.n.p. type whose maximum Vce is greater than 9 volts. It may, however, be necessary to select this transistor for adequate gain. The operating current available from the receiver for the direct-coupled pair depends upon conditions in the first i.f. transistor base circuit and, in particular, upon the value of R1. As shown in Fig. 1, the value of R1 in most receivers likely to be encountered ranges from 33 to 68kΩ. In the receiver used with the prototype circuit it

The transistor chosen for the TR1 position can be any small p.n.p. type whose maximum Vce is greater than 9 volts. It may, however, be necessary to select this transistor for adequate gain. Under correct operating conditions, a direct-coupled pair such as is given by TR1 and TR2 can offer an overall gain which is equal to the product of the gains in each transistor. Thus, very high overall gain figures are feasible. To give an idea of what may be done, the writer initially checked the direct-coupled pair in the prototype circuit (with R3 set to zero resistance) by the delightfully simple process of holding the unconnected base lead-out of TR1 between thumb and forefinger, and touching a finger of the other hand to the negative terminal of the battery. The small base current which then flowed was more than sufficient to cause the bulb to become fully illuminated!
was 39k\(\Omega\), and the writer found that he could obtain satisfactory operation of the bulb with any of several transistors of the OC71 class in the TR\(_1\) position. He then increased the value of R\(_1\) in the receiver to 75k\(\Omega\) (this representing a slightly worse case than the maximum of 68k\(\Omega\) shown in Fig. 1) and found it necessary to select transistors for gain in order to obtain satisfactory results. This selection gave rise to little trouble in practice, however, and several OC44's which happened to be on hand all gave the desired results in the TR\(_1\) position.

It is the fact that selection of transistors for gain may be required, and that it is impossible to predict circuit conditions in the particular receiver to be modified, which puts this circuit in the experimental category. As was mentioned above, it should be tried out experimentally before making a permanent installation.

The changes in TR\(_1\) carried out by the author assumed, of course, adequate gain in TR\(_2\), and a low gain transistor in the latter position will naturally require a higher gain transistor in the TR\(_1\) position to compensate. However, the writer felt that there was little point in going to exceptional lengths in investigating gain requirements because of the inability to predict receiver circuit conditions. It should be added that, in all cases checked, connecting up the indicator circuit (with R\(_3\) correctly adjusted) caused no significant drop in the negative voltage at the junction of R\(_1\) and R\(_2\).

Since carrying out his experiments, the writer has encountered a commercial receiver circuit having a value of 120k\(\Omega\) in the R\(_3\) position. If a value as high as this is employed in the receiver it is intended to modify, more careful selection of transistors in the direct-coupled pair may be needed. The writer has not checked the circuit for a value, in R\(_1\), above the 75k\(\Omega\) figure just referred to.

Variable resistor R\(_3\) is inserted between TR\(_1\) and TR\(_2\) to provide a sensitivity control. An alternative position for such a sensitivity control would be given by a variable resistor in series with the input connection to TR\(_1\) base, but the writer found that indications for weak signals appeared to be marginally better with the sensitivity control inserted between TR\(_1\) and TR\(_2\), as shown.

The press-switch, S\(_1\), requires two sets of contacts since it is necessary to disconnect the direct-coupled pair from R\(_1\) and R\(_2\) when its supply circuit is broken. If this is not done, the base-emitter junctions of TR\(_1\) and TR\(_2\) operate as diodes, and draw the junction of R\(_1\) and R\(_2\) towards chassis potential when their collector supplies are removed. The switch may be any spring-loaded rotary or toggle type having two poles.

The lamp is a Radiospares 6 volt 0.06 amp m.e.s. type, and its low current consumption makes it particularly useful in the present application. Resistor R\(_4\) limits the voltage across the bulb to approximately 6 volts when TR\(_2\) is fully conductive. If it is intended to use the circuit with a 12 volt supply, R\(_4\) should be increased to 82\(\Omega\), ½ watt. In this instance, TR\(_2\) should be a transistor having a maximum V\(_ce\) greater than 12 volts.

**Setting Up**

After the circuit has been assembled in experimental fashion it should be coupled up to the receiver. At this stage it may prove helpful to use a separate battery for the tuning indicator circuit proper and to dispense with S\(_1\), connecting the base of TR\(_1\) direct to the point in the receiver corresponding to the junction of R\(_1\) and R\(_2\) in Fig. 1. The fact that this point is bypassed by a large value capacitor (see Fig. 1) allows the connecting lead to be routed through any section of the receiver without undue risk of instability. R\(_3\) should be set to insert maximum resistance.

The receiver should then be switched on and tuned to a blank section of the dial. If there is sufficient gain in TR\(_1\) and TR\(_2\), and if the receiver circuit permits sufficient input base current for the direct-coupled pair, the lamp should reach full brilliance as the resistance inserted by R\(_3\) is decreased. R\(_3\) should then be left at the setting at which the lamp just reaches full brilliance under no-signal conditions, and the receiver tuning control adjusted to check the performance of the indicator with various received signals. If necessary, R\(_3\) should then be given a final slight readjustment to give optimum performance with all signal strengths received.

As has already been mentioned, results with the prototype were very satisfactory for values in R\(_1\) of 39k\(\Omega\) and 75k\(\Omega\), the bulb illumination responding to all signals which caused the appearance of an a.g.c. potential. In the writer's case, the most powerful local station caused the bulb to be very nearly completely extinguished whilst, under no-signal conditions, it glowed at full brilliance.
NEWS AND COMMENT . . .

Oscar III

Attention was drawn to the Orbital Satellite Carrying Amateur Radio projects in “News and Comment”, in our February 1964 issue. Oscar III was successfully launched from a rocket launching site in California on 9th March last at 18.30 G.M.T.

This satellite is a far more ambitious project than the previous two. It is designed so that it can receive amateur radio signals directed at it and then re-transmit them, in much the same manner as the relay satellites of the Telstar type. This type of satellite is known as a translator satellite. It receives amateur transmissions in the approximate range 144.1 Mc/s, amplifies them and then re-transmits them at approximately 145.9 Mc/s. It also carries normal beacon transmitters similar to those in previous satellites; one on 145.85 Mc/s sending the Morse signal “HI” and the other a continuous signal for tracking purposes on 145.95 Mc/s. The satellite measures approximately 18 x 12 x 6 in and weighs about 30 pounds. It has four aerials, one for receiving and three for transmitting, and extensive use is made of transistors. Solar cells provide part of the power supply.

The successful launching naturally produced much excitement in the amateur radio world, particularly amongst v.h.f. enthusiasts. Its characteristic “HI” signal was being reported, within an orbit or two, from amateur stations all over the world. The orbit time was found to be 103J minutes and the orbit path, from pole to pole, almost circular; its height was about 575 miles.

Reports soon came in, too, of the reception of amateur radio signals from it. Experience so far has shown that whilst it is comparatively easy to pick up amateur signals from it, two way communication is extremely difficult, and we will watch with keen interest for the official reports on this use of the satellite to appear.

May we add our congratulations to the many which have already been extended to the band of enthusiasts in the U.S.A. who saw this project through to success. We hope they will go on to even more ambitious projects in the future. The success of Oscar III speaks very highly indeed for the scientific and technical ability which is to be found within the sphere of amateur radio, and shows, once again, in a new field this time, that amateur radio can still play a part in promoting technical advances.

Quote

“If the Drury Lane Theatre were filled for eight performances a week, it would take 27 years to reach the audience which Septoe and Son attracted in one night.”—Lord Willis, during a debate in the House of Lords on television.

Radio Energy from Distant Galaxy

Radio energy which originated more than 300 million years ago was harnessed to open a curtain during the dedication ceremonies in the United States of, it is claimed, the world’s most sensitive radio aerial. The aerial, known as the Haystack Radar Facility, stands on a hill near Tyngsboro, Massachusetts. The aerial is designed for tracking spacecraft and for exploring radio waves spontaneously emanating from still little-understood sources in the universe.

During the dedication ceremonies, the aerial was focused on the Cygnus A galaxy, one of the “brightest”—most powerful—radio sources in the universe, which few optical telescopes can observe.

Cygnus A is believed to have originated from the collision of two galaxies at about the same time the earth was in its early stages of development. The collision sparked radio energy which has been travelling ever since towards the earth and is only now arriving after traversing 300 million light years.

(A light year is the distance over which light—moving at a speed of about 186,000 miles a second—travels in a year's time—about six million million miles.)

The radio energy picked up by the aerial was translated into static noise which was broadcast over the public address system for the audience at the ceremony. The noise then triggered a relay which slowly opened a curtain on the stage, unveiling the dedication plaque for the Haystack facility.

The aerial is so sensitive that it can track an object the size of a needle orbiting 500 miles above the earth!

Solder Remover

An effective solder remover is an invaluable aid to the radio and electronic engineer enabling speedy and efficient repairs or replacements of components to be carried out.

W. Greenwood Electronic Limited has introduced a precision tool for the instant removal of solder from printed circuits and all other solder joints.

The tool is an invaluable aid to the radio and electronic engineer. It enables much quicker and more efficient repair or replacement to be carried out and completely eliminates the risk of damage to either unit or component.

The nozzle of the tool is placed adjacent to the solder joint and on depression of the release button the hot solder is immediately and completely sucked into the nozzle. Re-loading is easily carried out by pressing the piston knob and the tool is then ready for the next operation.

This new and patented device costs 7s. 6d.
Improving the Performance of the AR88

By J. HOLLINGWORTH

As a general purpose communications receiver, the AR88 is excellent in most respects, but by present-day standards the signal/noise ratio and sensitivity leave much to be desired. It was therefore decided to attempt a modification to improve the performance in this respect.

Design Considerations

At this stage, a few words about the basic design considerations for an r.f. amplifier may not be amiss.

The first point to consider is noise. Any receiving system generates some noise, and unless the wanted signal is stronger than this noise, no amount of amplification will make it audible. Sources of noise are the aerial system, the components in the grid circuit of the first stage, the first amplifier valve itself and, to some extent, the second r.f. stage or mixer stage.

The noise generated by the valve itself is due to a number of effects, generally lumped together as a factor "$R_{eq}$" which is simply the value of resistance which would generate the same value of noise as the valve, under the conditions specified. This value of $R_{eq}$ should ideally be as small as possible.

A second matter to consider is a.g.c. and its application. The method of applying a.g.c. to an r.f. stage is extremely important. Consider for example a receiver tuned to a weak signal, and giving a reasonable signal-to-noise ratio. With a high gain receiver, it is possible to generate quite large a.g.c. voltages for comparatively small input signals. Thus, if our weak signal is slightly increased, the a.g.c. could bias back the r.f. stage to a point on its characteristic which gives a low value of $g_m$ and hence a low gain. Under these circumstances it would be possible for the noise generated by the second r.f. stage or mixer to be significant compared to the noise output of the first r.f. stage, leading to a deterioration in signal/noise ratio as the input signal is increased.

The solution to this problem is to delay the application of a.g.c. to the first r.f. stage until the input signal is sufficiently strong to overcome the effect, relying on i.f. gain control alone up to this point.

Lastly, the problem of stability must be considered. This is most important, since even if actual oscillation does not take place, feedback may cause undesirable effects on the tracking of the grid and anode tuned circuits. Apart from reducing anode-to-grid capacitance by the choice of a valve with low $C_{a-g}$, and careful screening, it is necessary to avoid having impedances common to input and output circuits. For example, a.g.c. lines, heater lines, portions of the chassis carrying currents from tuned circuit or bypass components, cathode circuit components and even the shafts of variable capacitors can all contribute to this type of coupling between input and output circuits.

Modifications

Considering, now, the AR88 itself, the r.f. stage uses a 6SG7 variable-mu r.f. pentode. This has the following approximate characteristics: $R_{eq}=3,000\Omega$, $g_m=3.5\text{mA/V}$ and $C_{a-g}=3\text{ mpF}$. The EF183, a readily obtainable modern pentode, has $R_{eq}=490\Omega$, $g_m=12-15\text{mA/V}$, sufficiently high to make its noise output large compared with the noise generated by the next stage.

Fig. 1. The existing aerial r.f. amplifier stage in the AR88
and \( C_{a-g} = 5.5 \ \text{mpF}. \)

As the actual noise voltage generated is roughly proportional to \( R_{eq} \) an improvement of about 2.5:1 can be obtained using the EF183. The stability however will be reduced, due to the increase in gain of around four times and the almost doubled \( C_{a-g}. \) It would be possible to operate the EF183 at reduced gm but, as the noise has been reduced, an increase in gain is desirable to take full advantage of this. It is simpler to provide this gain in the r.f. stage, as part of the modification, than elsewhere.

Fig. 1 shows the original circuit and Fig. 2 the modified version. As can be seen, the a.g.c. and heater supplies have been rearranged, and the decoupling components and cathode circuit rewired to reduce feedback.

The un-bypassed cathode resistors serve to keep the input capacitance more constant with a.g.c. voltage variations, thus preventing detuning. With the layout shown in Fig. 3, and the adaptor plate and screen shown in Figs. 4 and 5, the amplifier remains stable at all frequencies for

\[ C_{a-g} \text{ up to 25 mpF, thus retaining a good margin of safety when } C_{a-g} \text{ is 5.5 mpF.} \]

The operation of the transistorised a.g.c. delay circuit is as follows. For low a.g.c. voltages \( T_R_1 \) is cut off, the valve grid being returned to earth via the 10k\( \Omega \) resistor, \( R. \) As the a.g.c. voltage increases \( T_R_1 \) conducts, the emitter following the base, with \( V_{be} \) in the order of 0.6 volts. Most of the voltage between emitter and earth is dropped across the zener diode, which exhibits a high reverse resistance up to the zener voltage. After this point, the drop across the zener diode remains substantially constant, any further increase in emitter voltage appearing across \( R. \) Thus, when a.g.c. is applied progressively, very little bias is applied to the r.f. stage until a voltage (determined by the zener voltage) is reached. The \(-20V\) supply is derived from a convenient point in the receiver bias circuit (at the junction of \( R_43 \) and \( R_44)).\)

The zener diode is a Ferranti KS56 having a nominal zener voltage of 5.6.*

**Realignment**

The only adjustment necessary is the re-trimming of the pre-set capacitors in the first r.f. anode circuit. This is best done at the correct frequencies using a signal generator, but can be carried out quite successfully on received signals at the high frequency end of each range.

**Performance**

Accurate measurements of noise performance require a correctly matched noise generator and an output meter capable of reading r.m.s. noise, preferably before the

\[ * \text{ An OAZ202, with a zener voltage of 5.6 at 1 mA, should provide a satisfactory alternative.—Editor.} \]

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**Fig. 3. The new layout around the EF183 valveholder**

**Fig. 4. The valveholder adaptor plate which takes the new B9A valveholder. The dimensions are the same as for the octal adaptor removed, and the B9A valveholder is sweated to the plate.**
INEXPENSIVE TRANSISTOR SUPERHET

By G. F. PARKER

How does one build a transistor superhet really cheaply? In this article our contributor approaches the ultimate because not only are most component values not critical but all inductors, including the i.f. transformers, are home-wound! A further saving is given by the use of a complementary output stage which requires no a.f. transformers. The result is a medium wave receiver which gives excellent results on local stations and on Luxembourg, combined with quite an adequate performance with other transmitters.

The radio to be described in this article is a 7-transistor portable giving good quality sound with adequate volume on the medium waveband. A large 3Ω speaker, 5in diameter, is used, and the reproduction compares favourably, both in volume and quality, with that of commercial types costing many times as much as the original.

The first aim in construction was to produce at superhet at the absolute minimum of cost. In fact the author built the prototype with parts found in the spares box, and bought no components specifically for this set. This was possible because most of the parts, except the coils and the components associated with the tuned circuits, are not critical.

Fig. 1. The r.f. and i.f. section of the receiver. The numbers on L₁ to L₄ indicate the leads identified in the layout diagram of Fig. 5. Also indicated are the start (S) and finish (F) of each winding. It is most important that the oscillator coil, in particular, be connected as shown here.
Fig. 2. The a.f. section of the receiver. The output stage employs a complementary pair of transistors.

Components List
(Figs. 1 and 2)

Resistors
(All fixed values 20% ±1 watt)
- R₁ 68kΩ
- R₂ 10kΩ
- R₃ 3.9kΩ
- R₄ 100kΩ
- R₅ 4.7kΩ
- R₆ 100kΩ
- R₇ 4.7kΩ
- R₈ 22kΩ
- R₉ 100kΩ
- R₁₀ 10 or 20kΩ potentiometer, log track
- R₁₁ 2.2kΩ
- R₁₂ 1kΩ
- R₁₃ 10kΩ
- R₁₄ 100Ω
- R₁₅ 1kΩ
- R₁₆ 100Ω
- R₁₇ 1kΩ
- R₁₈ 4.3kΩ
- R₁₉ 4.3kΩ
- R₂₀ 10kΩ

Capacitors
(Electrolytics may be sub-miniature types. Working voltages should be at least 12)
- C₁₁ 10μF, electrolytic
- C₁₂ 100μF, electrolytic
- C₁₃ 30 to 100μF, electrolytic
- C₁₄ 10μF, electrolytic
- C₁₅ 30 to 100μF, electrolytic
- C₁₆ 100μF, electrolytic
- C₁₇ 500pF trimmer
- C₁₈ 50pF trimmer

Semiconductors
(Alternative transistors are discussed in the text)
- TR₁ OC44, SB305, AF115, surplus r.f. transistors
- TR₂,₃ OC45, AF117, surplus r.f. or i.f. transistors
- TR₄ OC71, GET113, surplus a.f. transistors
- TR₅ OC71, GET113, OC81D, surplus a.f. transistors
- TR₆ XA701, OC140, OC139
- TR₇ OC72, OC81, surplus a.f. transistors

Loudspeaker
See text

Inductors
(All inductors are home-wound, and construction is described in the text)
- L₁,₂ Ferrite rod aerial
- L₁₄ Oscillator coil
- IFT₁,₂,₃ I.F. transformers

Switch
- S₁ s.p.s.t. (may be ganged with R₁₀)

Battery
- 9V type PP9 or similar

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The Circuit

The circuit, which is shown in Figs. 1 and 2, was evolved after considerable experiment towards obtaining good results with the materials to hand at the time. It was essential, therefore, to hand-wind the i.f. and oscillator coils. The a.f. amplifier was also constructed with little expenditure. It does not contain the usual push-pull output stage having two transformers and a matched pair of transistors, but the less common complementary circuit. In this the p.n.p. transistor, TR7, conducts for the negative half, and the n.p.n. transistor, TR6, for the positive half of the signal. A matched pair of transistors is not required in this circuit. The main drawback of this circuit, so far as the home constructor is concerned, is the fact that an n.p.n. transistor is used. Most constructors will probably not have one of these in their spares box, and it will have to be purchased. Any n.p.n. transistor, such as the Ediswan XA701, OC139 or OC140, should be suitable in this position. The author used an XA701.

TR1 is the frequency changer, oscillation being achieved by coupling the emitter of this transistor to the collector by means of L4. Any r.f. transistor will work in this position. The author has tried OC44, SB305, surplus white spot and various surplus Ediswan transistors, and all were found to be satisfactory. However, new transistors, as would be expected, gave slightly better results than surplus types. The 3.9kΩ bias resistor, R3, is shunted by the 0.01μF capacitor, C3, this being tapped into the earthy end of L3 (the emitter impedance of TR1 is very low). The bias resistors for the first transistor are R1 and R2, and these are not critical.

The intermediate frequency resulting from mixing the oscillator and signal frequencies is selected by the tuned i.f. circuit represented by the primary of IFT1 and C5. It should be noted that the values of C5, C7 and C9 are critical. The intermediate frequency is then fed into the emitter of TR2 by a low impedance coupling coil. TR2 is connected in the common base mode rather than in the more usual common emitter circuit, even though it gives slightly less gain as a result. It was thought, however, that some gain could be spared in the interest of stability.

TR3 amplifies the i.f. signal in similar manner. The signal at the collector of TR3 is demodulated by diode D1, which may be of any type (even surplus) and it is then fed via C11 to the slider of the 10 or 20kΩ volume control R10. This potentiometer forms part of the potential divider supplying the base of TR4 and its value is not very critical. The bypass capacitors in the emitter leads of TR4 and TR5 need to be fairly large, about 30 to 100μF.

TR4 and TR5 amplify the a.f. signal, this appearing at the collector of TR5. TR6 and TR7 provide further amplification, these transistors being connected in the common-collector mode. This arrangement gives a high current gain and faithful reproduction of the signal.

For TR4 and TR5, OC71, GET113 and various surplus transistors have been found to be satisfactory. An OC81D would probably be satisfactory for TR5, with an OC72 or OC81 for TR7. In the original, TR7 was a surplus Ediswan transistor selected for its high gain and low leakage.

R14 (100Ω) and C12 (100μF) form the decoupling circuit for the receiver. If decoupling is found to be unsatisfactory, R14 may be increased to, say, 300Ω.

The loudspeaker may be any type, preferably of slightly higher impedance than the 2–3Ω employed in the prototype. Smaller speakers than the 5in diameter used in the original may be employed, but quality of reproduction will, however, suffer.

The Ferrite Aerial

Details of the ferrite aerial are given in Fig. 3. This was wound on two pieces of ferrite rod 3in in diameter, the complete assembly being approximately 6in in length. The size is not critical, and any available piece of rod of reasonable size may be used, the larger the better. If rods of different
dimensions are used the number of turns on \( L_1 \) may have to be changed slightly. In the original, the two pieces of ferrite were bound together with Sellotape, and the coils were wound over this material.

\( L_1 \) consisted of 35 turns of 30 or 32 s.w.g. cotton covered or enamelled wire, slightly spaced at one end. \( L_2 \) was one turn of the same wire wound in the same sense at the earthy end of \( L_1 \).

The coils should not be fixed permanently in place yet, as they may have to be adjusted when alignment is commenced.

If a smaller rod than that used by the author is to hand, several more turns may have to be added to \( L_1 \). If a larger diameter rod is available, several turns may need to be removed from \( L_1 \).

The Coils

The coils comprise the three i.f. transformers and the oscillator coil, and these are all wound on coil formers having an approximate diameter of \( \frac{1}{4} \) in. In one version of this radio made by the author, small TV i.f. coil formers were used. Some further notes on these formers are given at the end of this article.

The oscillator coil \( L_3, L_4 \), consists of two windings. The first, \( L_4 \), has 30 turns of 30 s.w.g. enamelled or cotton-covered wire close-wound on the \( \frac{1}{4} \) in former. This winding is covered with Sellotape, and the second winding, \( L_3 \), which consists of 80 turns of a thinner wire, around 36 s.w.g. enamelled or cotton-covered, and tapped at 70 turns, is wound in the same sense over this. The winding should be done neatly, but does not have to be close-wound. When the coil is finished, \( L_3 \) should be sealed in place with Sellotape, or polystyrene cement.

The first and second i.f. transformers come next. (See Fig. 4.) Each of these, again, consists of two separate windings. The first has 33 turns of 30 to 32 s.w.g. cotton-covered or enamelled wire close-wound on the former. This is then covered with a layer of Sellotape, and the second winding is started. The second winding consists of 330 turns of 36 s.w.g. enamelled or cotton-covered wire random-wound, and is fixed with a second layer of adhesive tape. Both windings must be in the same sense. The 330 turn winding is that which is tuned.

The third i.f. transformer has a single tuned winding only. This consists of 330 turns of 36 s.w.g. enamelled or cotton-covered wire wound directly on to the former in the same manner as the other i.f. transformers. The windings are sealed in place with adhesive tape or cement.

Construction

The original was built for convenience in two parts, these being the r.f. and i.f. section, and the a.f. section. The r.f. and i.f. section (Figs. 1 and 5) was constructed on a piece of \( \frac{1}{4} \) in plywood. Four holes were drilled in the wood to take four bolts which held solder tags in place. To these tags were soldered parallel bus-bars of 20 s.w.g. tinned copper wire. Components were then soldered to these bus-bars, using the layout shown. If some alternat-
tive arrangement of the components is preferred by the constructor, he must ensure that the coils are not too close together or the connecting wires too long, as instability may occur in the form of oscillations when stations are tuned in.

It is important to note that, for correct results, the oscillator coil and i.f. transformers must be connected as shown in Fig. 1. This indicates the start (S) and finish (F) of each winding.

The a.f. section (Figs. 2 and 6) is built in the same way as the i.f. section, a piece of ¼-in plywood, with bus-bars, again being used. The layout of this section is shown in Fig. 6.

With both sections, care should be taken, when soldering transistors and other delicate components, to use heat shunts on the lead-out wires.

Alignment and Testing

Before the set is switched on for the first time, the circuit should be checked to ensure correct connections of the transistors, the electrolytic capacitors and the diode. The polarity of the battery should be double-checked, as reversal of the battery connections could damage the transistors.

If possible, a meter reading up to 50 or 100mA should be inserted in one of the battery leads, whereupon the set should be switched on. If a high current passes (above 20mA) switch off immediately and again check the circuit. Current consumption should be about 10mA with no signal. If the consumption is more than 5mA greater, or about 3mA less than this, something is probably wrong. If the set goes into violent oscillation when it is switched on, the decoupling components C12 and R14 should be suspected. If necessary, increase the value of R14 as mentioned above.¹

If all is satisfactory so far the tuning capacitor should be rotated throughout its range, whereupon some stations may be heard faintly. If nothing is heard, an aerial should be connected temporarily via a 50pF capacitor to the non-earthly end of L1. At least the local station should now be heard, even if only at low level. The cores of the i.f. transformers are then adjusted for best results. These adjustments should preferably be made with an insulated tool. The cores of the transformers should not be fully in nor fully out. During final adjustments the volume control should be turned up, the signal level being kept down by tuning in to a weak station or by using the directional effect of the aerial. Small increases in signal strength during alignment can then be checked more easily.

Alignment of the aerial and oscillator sections may next be carried out.

Radio Luxembourg on 208 metres should be tuned in, and TC1 and TC2 adjusted so that this station is received at almost minimum capacitance of the two-gang capacitor. If the tuning capacitor is then rotated throughout its entire range, several stations should be heard. Select a station near the maximum capacitance end of the tuning capacitor range. The core of the oscillator coil is then adjusted for maximum volume, readjusting the tuning capacitor as necessary to keep the station tuned in. Spacing the turns of L1, the tuned coil, may have a similar effect at this end of the tuning range. At the high frequency end of the scale results will now probably have deteriorated, and adjustment of TC2 will again be necessary.

By repeating this procedure several times—varying the trimming at the high frequency end, and the inductances at the low frequency end—good results can be obtained.

¹ If instability is particularly troublesome, it may prove helpful to insert a further 100Ω resistor in the negative supply line. This can be inserted between R4 and the primary of IFT1, it being bypassed on its left hand side to the positive line by a 0.5μF capacitor. —Editor.
results should be obtained over the whole tuning scale.

Results

Although the hand-wound coils used in this set must necessarily be less efficient than the manufactured article, the original gave very good results. Selectivity was excellent. During the daytime, about five or six stations were received at good volume, and after dark many more, about thirty, were picked up. At full volume, several stations were too loud to listen to in comfort.

Battery consumption at normal volume was about 15mA, but at maximum volume went up to about 50mA. A PP9 9-volt battery was used by the author and this can be expected to last about a month, depending obviously upon the amount of use. Smaller batteries can be used if miniaturisation is attempted, but these cannot be expected to last as long as the PP9.

Further Details

Before concluding, some further details are now given to clear up any points not fully covered earlier in this article.

It will be noticed that no a.g.c. circuit is employed. A number of circuits were tried, but the complication introduced in what is intended to be a simple receiver for local station reception did not make their inclusion attractive.

As was mentioned earlier, several versions of the receiver have been made up using different types of former for the oscillator coil and i.f. transformers. The great advantage of this radio is the fact that components are not critical, and that latitude is possible in almost all sections. Almost any former with a diameter of approximately \( \frac{3}{4} \) in and having a dust core may be employed, provided that the number of turns specified is closely observed. In one version, small formers of the type shown in Fig. 7 (a) were used and it was even found possible to employ them without screening cans. In another version, TV i.f. coil formers, as in Fig. 7 (b), were employed, these using screening cans.\(^2\)

The intermediate frequency is about 300 kc/s.

The tuning capacitor specified for \( C_1, C_4 \) has a value of 500+500pF. Normally, a 208+176pF tuning capacitor is used in transistor circuits but the writer has found that the 500+500pF component offers wider coverage and includes all stations on the medium waveband.\(^3\)

The author has also tried transistors type AF115 in the TR\(_1\) position and transistors type AF117 in the TR\(_2\) and TR\(_3\) positions. These gave extremely good results. There was, however, a tendency to squegging which was completely cured by inserting a 39\( \Omega \) resistor between \( C_3 \) and the tap in the oscillator coil.

Fig. 7. Coil former dimensions are not critical. As a guide, both the types shown in (a) and in (b) have been used successfully. The coil former assemblies of (b) were taken from a TV set and a readily-obtainable alternative is discussed in the text.

REDESIGNED STUDIOS TO HAVE MARCONI MARK V CAMERAS

Granada Television Network Ltd., one of the largest of the British independent programme contractors, is to be among the first users of the Marconi Mark V camera.

The Marconi Company are engineering consultants for a major re-development of the principal Granada Centre at Quay Street, Manchester. The new studios will provide Granada with the most up-to-date production facilities, including full 625-line capability. Marconi's, acting on behalf of Granada, will undertake all aspects of the work involved in providing Granada with this entirely new installation.

The Mark V camera, smallest and lightest 4\( \frac{3}{4} \) in image orthicon camera available in the world, is as simple to operate as an ordinary amateur photographic camera. With its integrated zoom lens, it brings a new degree of freedom to television production, by eliminating the restriction of having a number of lenses of fixed focal length on each camera. The zoom lens can frame each scene accurately at the producers direction, and either manual or servo control can be provided. With the servo control, up to four zoom positions can be pre-set.

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Super-Regenerative

Transistor Circuit for Medium and Long Waves

Sir Douglas Hall, K.C.M.G., B.A. Oxon

Daylight reception on medium and long waves can be considerably enhanced by the use of super-regenerative detection. In this article our contributor describes a complete receiver, based on his "Spontaflex" circuit, which offers super-regenerative reception during the day and normal reception after dark. An additional feature is that one transistor serves the dual function of a.f. amplifier and quench oscillator.

Super-regeneration is a means of obtaining a very high degree of radio frequency amplification with the minimum of components and power. The processes involved are complicated, but basically the system can be described as a means of quenching oscillation so that regeneration can be used far beyond the point which would otherwise be possible. A regenerative detector or radio frequency amplifier is taken beyond the point where oscillation starts, and an external oscillation at a frequency of about 10 kc/s is injected into its circuit. This quenches the radio frequency oscillation so that the amplified signal is available without the distortion which would otherwise render it useless. The radio frequency amplifier or detector is moved in and out of oscillation, the resistance of the tuned circuit becoming alternatively positive and negative at the frequency of the quench oscillation.

If the radio frequency oscillations are allowed to reach the highest point made possible by the circuit constants and direct voltage before they are quenched, the output will be logarithmically proportional to the input and so no use for the reception of speech or music. But if they are quenched before the maximum is reached the output will be arithmetically proportional to the input, and all will be well. Whether the one set of circumstances or the other prevails depends on the frequency and amplitude of the quench oscillation. It should be as far removed from the radio signal, in frequency, as possible; and design should allow for the amplitude to be adjusted, once and for all, when the receiver is set up.

Producing the Quench Oscillation

There are various ways in which the quench oscillation can be produced. The simplest is to make use of the time constant of a capacitor and resistor so that the quench frequency is produced by the detector or radio frequency oscillator, the quench oscillation being caused by the capacitor charging up and discharging through the resistor. This is attractive, as (assuming transistors instead of valves) one transistor can be used to do both jobs. But in the author's experience the result is logarithmic in nature and therefore unsatisfactory. A second method is to use a tuned circuit resonant at 10 kc/s and by means of a feedback coil produce the necessary oscillation, again using the radio frequency transistor. But here again it is difficult, if not impossible, to obtain the maximum results which super-regeneration can give. The most effective arrangement, and at the same time the easiest to set up and most stable in operation, is to use a separate transistor for quench oscillation. Experiments have shown that this need not, in practice, mean the use of an extra transistor in the overall circuit, as it is possible to use an audio frequency amplifier to double up as quench oscillator without any loss in efficiency or quality.

The gain which can be obtained is very great. It is proportional to the frequency of the signal being received, and at very high frequencies can only be described as phenomenal. On the medium wave band the extra gain is such as to increase the output from a station which can only just be received with normal regeneration at the critical point to an output which is ample for a large room. Even on the long wave band reception of the Light programme can be stepped up from being too quiet for comfortable listening to a point where a simple Class A output transistor is overloaded.

If this were the whole of the story, there might be no need for any other circuits. But super-regeneration has its snags. Background noise on weak stations is very loud—though the stations might be inaudible without super regeneration—and there is a 10 kc/s whistle which, oddly enough, is not nearly such a nuisance as it might appear, and on some loudspeakers may be inaudible! There is also radiation if an aerial is used. However an aerial is not necessary and with a frame or rod aerial, the receiver described in this article can be used within a few feet of another without any interference being caused.

The most serious fault is lack of selectivity. This is not as bad as often described, since it is seldom that two programmes, as such, are heard together. In fact there is less spread from a powerful station than with ordinary regeneration. But after dark, when many stronger signals are available, there is scarcely a station on the medium waveband which can be received.
Daylight Reception

It is during the hours of daylight that the circuit excels. The really weak signals do not produce their whistles, and stations in the middle distance, which would be too weak to be of use with a normal simple receiver, can be brought up to excellent strength. In fact the receiver can be brought up to sensitivity becomes at least as good as at anything like programme value at distances which would be too weak for powerful stations for which the extra sensitivity is not really required.

Components List (Fig. 1)

Resistors
(All fixed resistors 10% ± 0.1 watt)
R1 47kΩ
R2 27Ω
R3 75Ω
R4 1kΩ
*R5 100Ω
*VR1 2MΩ potentiometer, log track

Capacitors
C1 100μF electrolytic, 6V wkg.
C2 0.01μF
C3 1.000μF
C4 0.1μF
C5 100μF electrolytic, 6V wkg.
*C6 0.05μF
VC1 500μF variable
*VC2 500μF pre-set

Inductors
L1,2,3,4 (see text)
T1 Output transformer. Type LT700 (Rex) or type T15 (Repanco)
T2 Output transformer. Type TT46 (Repanco)

Semiconductors
TR1 MAT101
TR2,3 OC72
D1 OA81

Switches
S1 3-pole 3-way
*S2 s.p.s.t.

Speaker
3Ω moving-coil

Battery
9 volt battery

*Only these components are needed if the original three-transistor “Sportaflex” circuit is to be modified.

3 See the article by Sir Douglas Hall in the June 1964 issue, and our note on page 36 of the August 1964 issue.—Editor.

Fig. 1. The circuit of the receiver with optional super-regeneration
impedance consisting of $R_1$ and part of $VR_1$. Further audio frequency amplification is given by $TR_3$ as a common collector amplifier. At the same time, this transistor oscillates at about 10 kc/s due to the presence of $T_2$. $T_2$ is a small output transformer with the large winding (half the primary) in the base circuit, and the small winding (the secondary) in the emitter circuit. The frequency of the oscillation is determined by the inductance of the half-primary and the capacitance of $C_3$. $VC_2$ controls the amplitude of the oscillation. It is necessary to use a variable capacitor here, though it may be preset, because of varying characteristics in different OC72's. It will be found that the correct setting with most specimens is about half-way.

$R_5$ prevents spurious oscillation at unwanted frequencies in $TR_2$. $S_2$ can short-circuit the secondary of $T_2$ and thereby prevent quench oscillation taking place when super-regeneration is not needed. The circuit then becomes a fairly normal three-transistor "Spontaflex" except for the modified volume control.

The receiver should be tested in daylight. $S_2$ should be closed and $VC_2$ turned to about the half-way position. It should then be checked that the receiver works properly without super-regeneration, tuning with $VC_1$ and bringing the strength up with $VR_1$. When this has been done $S_2$ should be opened and, if $VC_2$ is set approximately correctly, it should be found possible to advance $VR_1$ considerably with a great increase in volume. There will be a lot of noise between stations but this will disappear completely with a loud signal, and particularly with weaker ones.

The right setting for $VC_2$ should be found by trial and error, first choosing a weakish station near the low wavelength end of the medium waveband, and then a similar station near the high wavelength end. The correct setting will be fairly critical, but not exasperatingly so. Next switch to the long waveband and check that all is well. Provided $L_3$ and $L_4$ are in correct proportion there should be no difficulty, as quench oscillation amplitude is less critical on the long wave band.

As an aid to adjusting $VC_2$, it may be said that if the capacitance is too low there will be whistles, as $VC_1$ is rotated, of the kind produced by normal regenerative receivers when reaction is advanced too far. If capacitance is too high there will be a loud growling type of instability. The right position, between these two extremes, will result in good, sensitive reception, unless $VR_1$ is advanced too near to maximum.

Modifying the "Spontaflex"

Constructors who have built the three-transistor version of the "Spontaflex" circuit, described in the previous article and who wish to modify it will find that they can use nearly all the components specified for the earlier receiver, the original volume control, $VR_1$, being the only surplus item. It may prove necessary to remove a turn or two from the reaction windings of the frame aerials in order to prevent a loss of amplification resulting from the tighter coupling. The tighter coupling may cause the new $VR_1$ to be turned back to a point which seriously reduces the current flowing through $TR_1$. It may also be necessary to rearrange the switching to the method shown in this article, in order to keep the two aerials separate. As a double-pole switch was specified for wave changing, (coupled with a third pole for the battery) no new switch, apart from $S_2$, should be required.

Referring to Fig. 2 in the previous article, $VR_1$ will have to be removed,
C\textsubscript{2} being taken straight to S\textsubscript{1}. The emitter of TR\textsubscript{2} will need to be disconnected from R\textsubscript{4}, C\textsubscript{3} disconnected from the positive line, R\textsubscript{i} disconnected from the base of TR\textsubscript{2}, and the base of TR\textsubscript{3}, the emitter of TR\textsubscript{2} and R\textsubscript{4} all disconnected from each other. VR\textsubscript{1} can take up the physical position occupied by its predecessor, though this and other new components will be wired up as shown in Fig. 3 of the present article. Fig. 2 shows how the original three-transistor receiver circuit should appear when modified for inclusion of the new components, whilst Fig. 3 shows the new part of the circuit required for super-regeneration.

VR\textsubscript{1} should be wired so that volume increases in an anti-clockwise direction, with the slider approaching the negative line. Control will then be very smooth with oscillation starting in the second half of the movement, and nearly the whole of the movement being of use with super-regeneration. VC\textsubscript{2} can be tucked away, as it is adjusted once and for all, but S\textsubscript{2} must be mounted in an accessible position.

Finally, the author would reiterate that the circuit should only be used as a super-regenerator during daylight, as it will give disappointing results on stations other than the locals after dark (except, possibly, in a very bad reception area). After dark plenty of programmes will be available without super-regeneration. During daylight the extra amplification available is really useful.

**SIMPLE MIXER UNIT**

By S. G. WOOD, G5UJ

From time to time the need is felt for a "fader" or mixer unit, and the circuit described here may be of interest.

As will be evident from the diagram, few components are required. In fact, most of the parts needed may be found in the junk box. The main item, the valve, can be of the 6SN7 or 12AU7 class, which is well suited to this particular application.

The two potentiometers are of the small carbon variety and the fixed resistors are standard \(\frac{1}{2}\) watt types. The bias capacitor in shunt with the 1.2k\(\Omega\) biasing resistor is of 25\(\mu\)F 10 volt rating.

Little is needed in the way of power supplies, and 6.3V at 0.6 amp (6SN7) or 0.3 amp (12AU7) together with around 200 volts h.t. are the total requirements here. In most cases the main amplifier power unit could provide the power required. In any case, neither the cost of building, nor the running of this little unit can be regarded as expensive.

The construction of the unit should not raise any difficulties, owing to the small number of components required. The two input circuits are shown in the diagram as being screened. Such screening will be necessary in most instances to obviate hum.

Components List

**Resistors**

(All fixed resistors \(\frac{1}{2}\) watt 10\%)

\[
\begin{align*}
R_{1,2} & = 250k\Omega \text{ potentiometer, log track} \\
R_3 & = 1.2k\Omega \\
R_{4,5} & = 1M\Omega \\
R_{6,7} & = 100k\Omega \\
R_8 & = 1M\Omega
\end{align*}
\]

**Capacitors**

\[
\begin{align*}
C_1 & = 25\mu\text{F electrolytic 10V wkg.} \\
C_2 & = 0.05\mu\text{F paper}
\end{align*}
\]

**Valve**

\[
V_1 = 6\text{SN7 or 12AU7}
\]

MAY 1965

www.americanradiohistory.com
Understanding

AMPLITUDE MODULATION AND THE DIODE DETECTOR

By W. G. Morley

In last month's issue we concluded our consideration of the diode when employed as a rectifier for power supply circuits. We shall now carry on to its use as a detector of amplitude modulated signals.

It is interesting to note, in the discourse which follows, that we shall be calling on a wide range of subjects which were covered in previous "Understanding Radio" articles, these including such things as audio and radio frequencies, r.f. transformers and tuned circuits, and sound reproducing devices.

Transmitting Information

In an earlier article in this series we saw that radio waves may be assumed to travel from a transmitter to a receiver by way of the "ether" (a medium which pervades all space and matter) and that they may be described as radio frequency (or r.f.) signals. Also that it is difficult, in practice, to transmit radio waves having frequencies lower than 10 kc/s, with the result that the radio frequency range may, in general, be assumed to commence at this figure. So far as domestic equipment is concerned, the highest frequency currently envisaged for radio reception in the U.K. is 854 Mc/s, this being the highest frequency in the range allocated for 625-line television.

Another point noted in the previous article is that, since radio waves travel through the "ether" at almost exactly 300,000,000 metres per second, with the result that the radio frequency range may, in general, be assumed to commence at this figure. So far as domestic equipment is concerned, the highest frequency currently envisaged for radio reception in the U.K. is 854 Mc/s, this being the highest frequency in the range allocated for 625-line television.

Also transmitted in this country are the v.h.f. sound-only signals in Band II. Band II extends from 87.5 to 100 Mc/s and it is common practice to refer to Band II signals in terms of their frequency rather than their wavelength, as is our custom on medium and long waves.

The previous article also referred to audio frequency (or a.f.) signals, these being signals which may be heard by the human ear when the air is set in vibration. The audio frequencies range from some 30 c/s to 20 kc/s.

Let us now turn our attention to the manner in which a radio signal may be used to transmit information from the transmitter to the receiver.

The easiest method of passing such information is by connecting a Morse key to the transmitter in such a manner that the latter only gives an output when the key is depressed. (See Fig. 276 (a).) If the Morse key is operated to send the letter "L" (· − ·) the resultant signal from the transmitter may then look like that shown in Fig. 276 (b). At the receiver, it is normal practice to employ a circuit

\[
\frac{f}{\lambda} = 300,000
\]

where \( f \) is frequency in \( \text{kc/s} \); and

\[
\frac{f}{\lambda} = 300
\]

where \( f \) is frequency in \( \text{Mc/s} \). In both cases, \( \lambda \) is wavelength in metres.

Thus, the "medium waveband" of about 200 to 600 metres may also be expressed as 1,500 to 500 kc/s, and the "long waveband" of about 1,000 to 2,000 metres as 300 to 150 kc/s. Some domestic sound receivers have a short wave range of about 20 to 60 metres, this corresponding, in terms of frequency, to 15 to 5 Mc/s.

\[1\] Published in the March 1963 issue.

\[2\] The upper and lower limits in the audible range vary slightly for different individuals.
which enables an audible a.f. tone to be heard from a loudspeaker or pair of headphones when the transmitter signal is present, with the result that this tone is given when the key at the transmitter is pressed. The overall effect, therefore, is that depressing the key at the transmitter causes an audible tone to be heard at the receiver, whereupon a workable system for sending a signal in Morse code is set up. In the instance shown in Fig. 276 (b), the a.f. tone at the receiver will follow the sequence sent from the transmitter.

The circuit at the receiver which causes an audible tone to be heard on reception of the transmitted signal is desirable because the transmitted signal is not otherwise capable of being readily understood. The operator at the receiver could not "listen" to the r.f. cycles in the transmitted radio signal because these will have a frequency which is much higher than the upper limit of human hearing. This explanation ignores the possibility that the transmitted signal may have a frequency lower than 20 kc/s and be, therefore, within the audible range. However, unless he is undertaking specialised work, it is extremely unlikely that the amateur will encounter transmissions below about 100 kc/s, whereupon all the transmitted signals he works with will be well above the upper limits of audibility. It should be added that, for purposes of illustration, Fig. 276 (b) shows the r.f. cycles as having a much lower apparent frequency than would in actual fact be possible. In practice there would be so many cycles in each section of the Morse character that the lines representing them in the diagram would merge together and could not be reproduced. (In the diagrams which follow, the r.f. cycles will similarly be shown as representing a much lower frequency than would actually be the case.)

The transmitted wave shown in Fig. 276 (b) is quite satisfactory for the transmission of Morse code signals because it can be controlled by a Morse key. But this is only a "switching on and off" process, and it is obvious that a different approach is needed if we want to transmit speech and music by way of a radio frequency signal. The r.f. signal is itself inaudible, but we can employ it for the transmission of a.f. signals in a manner which is very easy to understand.

**Modulation**

Fig. 277 (a) shows the radio frequency signal as it appears when the transmitter is continually switched on. At the same time, Fig. 277 (b) shows a cycle of an audio frequency signal which we wish to transmit. In order to transmit this audio frequency signal we now apply it to the transmitter in such a way that it regulates the amplitude of the radio frequency signal. This process is known as modulation, and the result is shown in Fig. 277 (c). As may be seen, the radio frequency signal now has greatest amplitude when the audio frequency waveform is at its uppermost peak, and has lowest amplitude when the audio frequency waveform is at its lowermost trough. The modulation process has allowed the transmitted radio frequency signal to convey audio frequency signals to a receiver.

Since the audio frequency signals imposed on the radio frequency signal vary its amplitude, the process is known as amplitude modulation (or a.m.). It is usual to show an amplitude modulated wave in the manner shown in Fig. 277 (d), in which lines are drawn along the outside of the waveform joining the peaks of the r.f. signal, and these lines constitute the modulation envelope. (In practice, there would be far more radio frequency cycles than are shown in Fig. 277 (d), with the result that the distance between peaks would be almost negligibly small when compared with the length of a single cycle of the modulating audio frequency signal.)

The process of modulation causes the maximum peak-to-peak amplitude of the radio frequency signal to be greater than occurs in the unmodulated state, resulting in the effect shown in Fig. 278 (a). In this diagram a modulating audio frequency signal is applied, starting at line XY, to a previously unmodulated radio frequency signal. The degree of modulation is referred to as modulation depth, and is equal to the ratio of dimension P or dimension Q to dimension R. In Fig. 278 (a) dimensions P and Q are one-half of dimension R, and so the modulation depth is 50%. If no modulation were applied there would be no dimensions P and Q, and modulation depth would be zero. Fig. 278 (b) shows the case where dimensions P and Q are equal to R, giving 100% modulation depth. This is the maximum modulation depth which may be employed without introducing serious distortion of the modulating signal. The effect of over-modulation, given by too great a modulating audio frequency signal, is shown in Fig. 278 (c). As may be seen, the radio frequency signal now disappears completely during part of the audio frequency cycle.

The modulated radio frequency signal is described as the carrier, this being a well-chosen term since

![Morse key](a)

![Transmitter](b)

Fig. 276. By suitably connecting a Morse key to a transmitter, (a), so that it controls the output, Morse characters may be transmitted. The transmitter output for the letter "L" is shown in (b)
The output of an unmodulated radio transmitter

(a) An audio frequency waveform

(b) The r.f. signal of (a) modulated in amplitude by the a.f. waveform of (b)

(c) Two outside lines joining the peaks of the modulated waveform constitute the "modulation envelope"

(d) Fig. 277 (a). The output of an unmodulated radio transmitter

(b) An audio frequency waveform

(c) The r.f. signal of (a) modulated in amplitude by the a.f. waveform of (b)

(d) Two outside lines joining the peaks of the modulated waveform constitute the "modulation envelope"
Fig. 279 (a). Coupling an aerial and earth to an r.f. transformer whose secondary is tuned to a station in the medium wave band (b). Attempting, unsuccessfully, to hear the transmitter modulation by adding a pair of headphones.

Fig. 280. The modulation of the signal selected by the tuned circuit of Fig. 279 becomes audible if we insert a diode, as in (a). But it is necessary to add the self-capacitance of the headphones to the overall circuit, (b), if the functioning of the diode is to be fully understood.

Fig. 281. The effect of the diode of Fig. 280 (b) in terms of the voltage on the upper headphone terminal with respect to the lower terminal. The voltage across the capacitor (the self-capacitance of the headphones) is shown in heavy line, as also is the average a.f. voltage. The positive half-cycles of the carrier, shown in light line, are included to demonstrate the manner in which the voltage across the capacitor is developed.

The A.M. Detector

In two other preceding articles we described r.f. transformers and showed that these could be used for tuning over, for example, the medium or long waveband. We employ such an r.f. transformer in Fig. 279 (a), the primary winding being coupled to an aerial and an earth connection. The secondary has an inductance such that, when a variable capacitor of suitable value is connected across it, the pair may resonate at (or become "tuned to") any desired frequency in the medium waveband. The secondary tuned circuit offers maximum impedance at the frequency at which it is resonant, with the result that signals at this frequency may be passed on to a subsequent circuit at greater amplitude than other signals of different frequency.

Let us now adjust the variable capacitor of Fig. 279 (a) so that the secondary circuit is tuned to an amplitude modulated transmitter in the medium waveband. The result is that a wave-form similar to that of Fig. 277 (d) appears at the output terminals. How are we to make the modulating signal audible to us?

3 In the September and October 1963 issues.

4 This diagram also introduces us to the circuit symbol for an aerial.

Fig. 282. Reversing the Diode
We could commence by experimentally connecting a pair of headphones across the output terminals, as in Fig. 279 (b). We should, preferably, use high-resistance headphones, (say 2,000Ω for earphones) so that the secondary tuned circuit offers a signal at high impedance. But, however acutely we listened, we would hear nothing. It is obvious, of course, that the headphones cannot respond to the high frequency of the r.f. carrier, but we could at least expect them to respond to variations in the average value of the waveform if these occurred at an audible frequency. As is evident from Fig. 277 (d), however, the sections of the waveform which appear on either side of the central zero voltage line are, at all points along the waveform, equal and opposite; with the result that the average value of the waveform remains constant at zero volts and does not vary. Thus, our headphones will not reproduce any audible signal.

In Fig. 280 (a) we introduce a diode, whereupon we at once hear, in the headphones, the modulation of the transmitted signal. The reason for this dramatic change in performance is that the diode acts as a rectifier but, before finally evaluating the manner in which it works, we must first take the intermediary step of adding the self-capacitance of the headphones to the circuit, as is done in Fig. 280 (b). As we may now see, the diode functions in much the same manner as the half-wave power supply rectifier with reservoir capacitor which we have discussed in the last few issues. The diode causes the capacitor to charge during peaks of the applied alternating voltage (which in this case is the carrier signal) and to discharge between these peaks. The resultant effect, and the consequent average a.f. voltage, are shown in Fig. 281. The average a.f. voltage varies in sympathy with the modulating voltage at the transmitter, and the headphones can now reproduce the sound signal which originally modulated the carrier. It should be added that, in practice, the peaks of the carrier signal will be much closer together than is shown in Fig. 281, whereupon, assuming sufficient capacitance in the capacitor, there will be only a small difference between the average a.f. voltage and the voltage appearing across the capacitor. Fig. 281 shows also the positive half-cycles which are applied to the anode of the diode, in order to illustrate the manner in which the rectified voltage is formed.

If we reverse the diode, as in Fig. 282, we will still be able to hear the original modulating signal. This is because a rectified signal once more appears, the only difference being that it has opposite polarity to the one shown in Fig. 281. It will still have an average a.f. voltage varying in sympathy with the sound signal which originally modulated the transmitter, and the headphones will once more reproduce the signal.

The rectified signal of Fig. 281 has an average direct voltage as well, this direct voltage being the average over all portions of the audio frequency cycle. With the circuit of Fig. 280 (b) the average direct voltage has a polarity such that the upper terminal of the headphones is positive relative to the lower terminal. If we reverse the diode, as we did in Fig. 282, the upper terminal of the headphones becomes negative with respect to the lower terminal. The presence of the average direct voltage will not affect operation in the simple headphone circuits we are discussing here, but it can be of considerable importance in more complex arrangements.

The diode of Figs. 280 (b) and 282 is normally described as a detector, this being a term dating from the early days of radio in which any device which enabled radio signals to be “detected” was so called. It is also, but less frequently, referred to as a demodulator.

Next Month

In next month’s issue we shall continue to discuss the diode detector.

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**Simple Shorted Turns Detector**

By A. C. NORMAN

**THE UNIT DESCRIBED HERE WILL PROVIDE, IN** conjunction with an oscilloscope, either a convincing demonstration of damped oscillations or a shorted turns indicator for air-cored coils up to 3in in diameter.

**Pulse Generator**

A pulse generator using two OC71's in a multivibrator circuit energises a tuned circuit consisting of L1 and C3. R5 is a preset damping resistor. (See Fig. 1.)
Components List

Resistors
(All fixed resistors ½ watt 20%)
- R1 3.3kΩ
- R2 22kΩ
- R3 1kΩ
- R5 5kΩ, pre-set potentiometer, log track

Capacitors
- C1 0.02µF paper
- C2 0.1µF paper
- C3 500pF silver-mica or ceramic

Inductor
- L1 Coil on ferrite rod (see text)

Transistors
- TR1,2 OC71 (see text)

Switch
- S1 s.p.s.t. on-off switch

Battery
- 9-volt battery

---

Fig. 1. The circuit of the shorted turns detector

Fig. 2 (a). The output from the pulse generator
(b). The voltage across L1 when no shorted turn is present
(c). The waveform across L1 changes, typically, to that shown here if a shorted turn is passed over the ferrite rod

---

Frequency
In the prototype the multivibrator offered 500 pulses per second but, using components of 20% tolerance, this figure could be anything between 350 and 700. As L1 and C3 resonate at a frequency of about 15 kc/s, 30 cycles of damped oscillations can be seen. This is enough to give a well defined envelope but not enough for individual cycles to merge with each other.

A logarithmic track in R5 is desirable, although not essential, as it gives closer control over the damping of the tuned circuit. R5 should be connected so that it offers minimum resistance to the circuit when adjusted fully anticlockwise.

The current drain is fairly low at 10mA, so a small battery can be used. Excluding the ferrite rod, the complete prototype was built on a chassis less than 3in square. By using miniature components it could have been considerably smaller.

Care should be taken in the construction of L1 as it will “detect” short-circuits in itself as well as in any metallic mounting components that encircle it.

The detector is very simple to use on any air-cored coil. It will be found particularly useful when winding the bobbins for home-made transformers as the coil can be tested every 50 or so turns, thus minimising the amount of unwinding if a short-circuit is discovered.

Testing Large Coils
The detector can be used, without adjustment, to test coils with from 1 to 10,000 turns. With the larger coils it may be found that the resonant frequency of the coil being tested (given by its inductance and stray capacitance) is near the resonant frequency of L1 and C3. In this case a second train of damped oscillations will be set up in the coil being tested and these will beat with the oscillations in L1. With practice it is still easy to distinguish between good and faulty coils.

In some circumstances it may be necessary to test coils which are too small to fit on the ¼in ferrite rod. For these a smaller version of L1 could be wound on a thinner piece of rod. This would, however, be less sensitive to the larger diameter short-circuits.

Cheap, low gain surplus transistors work well in this circuit as all frequencies are low, and plenty of drive is available at the bases. If these are used, the total cost of the detector can be kept to quite a low figure.

---

May 1965
An experimental design intended for the more experienced constructor.

The amplifier described in this article was designed for public address purposes and can provide 20 watts into a 1.5Ω load or 10 watts into a 3Ω load. A suitable power supply would consist of two 12 volt accumulators connected in series to form a centre-tapped 24 volt supply. If a centre-tapped supply is not available one side of the load can be connected to the positive supply line and the other connected to the output terminal via a 5,000μF 25V working electrolytic capacitor.

Output Stage
The output stage is a Class B transformerless push-pull type, the load being provided directly by the speaker or speakers. The 1Ω emitter resistors improve thermal stability and frequency response whilst lessening crossover distortion. The upper resistors of the potential dividers which bias the output transistors, R11, R13, are connected directly to the transistor bases so that they provide negative feedback. The 6Ω preset resistors are adjusted to set the quiescent current in the output transistors to the lowest value consistent with low crossover distortion. The voltage at the output terminal (at the collector of TR5) should be half the supply voltage, i.e. there should be an equal voltage across each output transistor under quiescent conditions. The peak current on full drive is about 6 amps.

In the prototype amplifier the output and driver transistors were mounted with mica washers and insulating bushes on a heat sink made up of two 12 x 8in 18 s.w.g. aluminium plates. These were bolted together to give twice the thickness, and sprayed matt black. This was found to be adequate for speech and music at ordinary room temperatures (about 25°C).

The driver stage is an OC35 transistor operating in Class A at a current of 0.3 amp. It provides more power than is necessary to fully drive the output stage. It is thus possible to increase the local negative feedback in the output stage or to increase the output power by replacing the OC35 output transistors with other types having a higher current rating. The output could, of course, be increased by raising the supply voltage, but this would make it difficult to provide a “non-mains” power supply for outdoor use.

Fig. 1. The circuit of the main amplifier. The 1.5Ω load could conveniently consist of two 3Ω speakers connected in parallel.
Components List (Fig. 1)

Resistors
(All fixed values ½ watt 10% unless otherwise stated)

- \( R_1 \) 2.2\( \Omega \)
- \( R_2 \) 1.8\( \Omega \)
- \( R_3 \) 220\( \Omega \)
- \( R_4 \) 82\( \Omega \)
- \( R_5 \) 10\( \Omega \)
- \( R_6 \) 470\( \Omega \)
- \( R_7 \) 470\( \Omega \)
- \( R_8 \) 1\( \Omega \) wirewound
- \( R_9 \) 4\( \Omega \) 1 watt wirewound
- \( R_{10} \) 4\( \Omega \) 1 watt wirewound
- \( R_{11} \) 180\( \Omega \) 1 watt wirewound
- \( R_{12} \) 6\( \Omega \) wirewound preset potentiometer
- \( R_{13} \) 100\( \Omega \) 1 watt wirewound
- \( R_{14} \) 6\( \Omega \) wirewound preset potentiometer
- \( R_{15} \) 4\( \Omega \) 5 watt wirewound
- \( R_{16} \) 3\( \Omega \) 5 watt wirewound
- \( R_{17} \) 1.8\( \Omega \)

Capacitors
- \( C_1 \) 10\( \mu \)F electrolytic 25V wkg.
- \( C_2 \) 250\( \mu \)F electrolytic 25V wkg.
- \( C_3 \) 200\( \mu \)F electrolytic 6V wkg.
- \( C_4 \) 1,000\( \mu \)F tubular ceramic
- \( C_5 \) 1,000\( \mu \)F electrolytic 12V wkg.
- \( C_6 \) 500\( \mu \)F electrolytic 6V wkg.

Transistors
- \( TR_1 \) ACY21
- \( TR_2 \) ACY21
- \( TR_3 \) OC35
- \( TR_4 \) OC35
- \( TR_5 \) OC35

Transformer
- \( T_1 \) 1.3+1.3:1+1, Type TT24 (Repanco)

Pre-Amplifier
The pre-amplifier stage and the gain control are separate from the main amplifier and are intended to be sited near the microphone. The writer is, at the time of writing, employing a grounded base stage as shown in Fig. 2, but this can be rearranged as a grounded base stage, if desired, by connecting \( C_1 \) to the positive rail and connecting the microphone between \( C_2 \) and the positive rail. An OC81D is used in the pre-amplifier because of its low cost. If noise is evident when the OC81D is used as a grounded emitter amplifier, \( R_1 \) and \( R_2 \) should be replaced by new, high stability, resistors before any blame is cast on the transistor. Noise caused by the base biasing resistors is avoided when a grounded base stage is employed.

Construction
The main amplifier was constructed on a 26-way tagboard, with \( TR_1 \), \( C_1 \), \( R_1 \), \( R_2 \) and \( C_3 \) enclosed in a flat tin-plate box on which was mounted the coaxial input socket.

![Fig. 3. Connections to the Repanco TT24 transformer](image3)

![Fig. 4. A suitable power supply for operation from the mains](image4)

The Repanco transformer type TT24 is a 1.3+1.3:1+1 component, and is used here as a 2.6:1 transformer. As is indicated by Fig. 1, the primary offers a 2.6:1 ratio to both secondaries, i.e. the 1.3 sections of the primary are connected in series. External physical connections to the transformer, as used in the prototype, are shown in Fig. 3. If, by any chance, there is a reversal in phase in the signal fed to the output transistors, \( R_{17} \) will provide positive feedback instead of negative feedback, and this may be corrected by reversing the connections to the primary.

The transistor heat sink is mounted vertically to allow cooling by convection.

![Fig. 5. Output waveforms given by square wave inputs at the frequencies indicated](image5)
Mains Power Supply
The circuit of a suitable mains power supply is given in Fig. 4. The hum level is low with this power unit, and 20 watts of "speech and music power" are available. A 5 amp fuse is inserted between the transformer and the rectifier. There may be transient currents greater than 5 amps, but these are unlikely to blow the fuse.

With the mains power supply, the load is coupled to the output terminal via a 5,000µF capacitor, as mentioned in the opening paragraph.

Output Waveforms
A selection of output waveforms is illustrated in Fig. 5. These were taken with a 24 volt supply having no centre-tap, the load being a 3Ω speaker coupled to the output terminal via a 5,000µF capacitor. The oscilloscope was a Solaroscope type CD711S.2 on the 3 volt Y range, and the generator an Advance H1. The oscilloscope was connected between the output terminal and the positive supply line. Input signals were square waves at the frequencies indicated.

2-TRANSISTOR MINIATURE A.F. AMPLIFIER
KENNETH JONES

A very simple circuit design which, at the expense of increased battery consumption, offers reproduction superior to that given by the normal Class B transistor output stage.

This amplifier was designed by the writer to be reasonably small and to have a higher output quality than usual. It was decided that a transformerless circuit should be employed, using only a driver and output transistor. Direct coupling between stages, and to the speaker, was used to ensure good quality.

Power Transistor
In order that the output should be reasonably loud, a single power transistor was used. The Mullard AD140 was chosen here because of its high gain and output, but in this circuit no heat sink is required. A high gain driver using an OC44 was employed, and an OC45 was also successfully used in the prototype.

Connection between the amplifying stages is made via the driver's emitter, so the base of the AD140 has the correct polarity bias when using p.n.p. driver transistors. This also allows for the use of a higher impedance input than usual, because of the impedance step-down effect of a grounded collector stage. Further, the d.c. coupling reduces the number of components required for the complete circuit. Only two transistors, two resistors and one capacitor are needed, making the complete circuit inexpensive even though the output transistor may not be obtainable cheaply.

The prototype amplifier was built on a small Paxolin sheet, on to which the AD140 and remaining components were mounted, including miniature input and output sockets. If miniature components are used throughout, a really small and powerful amplifier may be constructed.

Soldering
Care must be taken when soldering in the transistors, and a heat shunt must be used. The author found a pair of fly-tying pliers extremely useful when soldering transistor leads. The pliers are spring-loaded, and may be clipped on to the leads, leaving the two hands free. They may be obtained from most large fishing tackle shops, the larger size being the best investment.

The amplifier requires a potential of 4 to 5 volts at up to 90mA, but if more output is required, at a correspondingly higher current, a 6 volt battery

Components List

<table>
<thead>
<tr>
<th>Resistors</th>
<th></th>
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<tbody>
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<td>$R_1$</td>
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<td>$R_2$</td>
<td>33kΩ 1/4 watt 20%</td>
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<td>10µF electrolytic 3V wkg.</td>
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<td>$TR_2$ AD140</td>
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<table>
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<tr>
<td>Output sockets</td>
</tr>
<tr>
<td>Transistor holder for $TR_1$ (optional)</td>
</tr>
</tbody>
</table>
may be used. After 6 volts, the current consumption rises sharply.* A flat torch battery containing three single cells at 1s. 3d. should give reasonable life. The amplifier could be used as the audio and output stages following a 3-transistor superhet tuner, and will give full output straight off the diode. Such a radio may be used as a car radio in cars having 6 volt systems.

The amplifier gives an output power commensurate with a 2 x OC81 push-pull circuit, and has an excellent frequency response together with (because of the negative feedback taken from TR2 to the base of TR1) little distortion even at full output. The quality was much preferred to that given by two OC81's in push-pull with a similar sized speaker. There is no reason why really good quality reproduction should not be obtained, especially when a large 15Ω speaker is used.

*Due to the d.c. flowing in the speaker and the absence of a heat sink, it would probably be preferable not to employ supplies considerably in excess of 6 volts.—EDITOR.

SIMPLE ECHO UNIT

By P. F. EXETER

An inexpensive sound delay unit employing readily obtainable parts

Commercially manufactured echo units are expensive to buy and so the writer tried to find a simpler method which could be constructed cheaply. Several attempts were made, and the most successful is described in this article. The author's unit can be easily fitted to any radio or small a.f. amplifier and, when used, gives the effect of being in a large hall.

As shown in Fig. 1, the amplifier drives the speaker in the normal way, but a portion of the output is fed into the echo unit, which is an electro-mechanical time delay device. This includes two 2,000Ω headphones placed approximately 15in apart with a metal spring coupling the two diaphragms together.

Construction

To commence construction, a small hook is first soldered on to the diaphragm of each headphone, as shown in Fig. 2. Before soldering it is necessary to scrape and clean the central area of the diaphragm, as this has an enamelled surface. The writer used a penknife and fine glass paper to prepare the surface and obtained a satisfactory joint with resin-cored solder. The diaphragm is then refitted to the headphone and the cap screwed on. The latter must, of course, have a hole in its centre to allow the hook to pass through.

The headphones are then fixed to the ends of a wooden box, as illustrated in Fig. 3, rubber grommets being placed between the inside surface of the box and the headphones to act as shock absorbers and prevent vibrations being transmitted along the wooden sides. The dimensions of the box used by the writer were 16 x 3 x 3in, and it was
constructed from plywood. These measurements may need to be adjusted to suit different headphones.

The component which provides the time delay is the spring, and this is attached to the hooks on the headphones at each end of the box. The size and tension of the spring depend upon the amount of time delay required. The writer obtained best results with an electric fire spiral element of the type which can be obtained from hardware and electrical shops for several shillings. Home-made springs using copper or steel wire were not as successful.

The output of the headphone at the other end of the box is then fed back into an early stage of the amplifier or, if desired, into a separate amplifier.

Operation

The echo unit operates in the following manner.

When a signal is fed from the amplifier output to the echo unit it is passed through a matching transformer to match the speaker impedance to the impedance of the headphone. This signal causes the diaphragm to vibrate in sympathy with the signal fed to the headphone. As the spring is connected to the diaphragm by the hook, the diaphragm vibrations are transmitted along the spring to the other headphone. Again, the spring is connected to the diaphragm, and vibrations in this cause an alternating voltage to develop across the coils in the second headphone, this voltage being fed back into the amplifier for further reproduction by the speaker. As there is a time delay along the spring the voltage fed back into the amplifier will appear at the speaker shortly after the original sound, giving hence the effect of an echo.

The headphones and spring are fitted in a sealed wooden box to prevent “outside” sounds being picked up.

Further Points

Originally, the output of the amplifier was fed to the first headphone of the echo unit without a gain control but, as there was evidence of overloading, the control was then inserted. A standard speaker transformer with its secondary connected to the speaker and its primary to the headphone (so that it acts as a step-up transformer) should give a reasonable match. The gain control may be a 10kΩ or 20kΩ potentiometer and should be wire-wound. If the amplifier has a high output power, the matching transformer should be of appropriate size. Also, further resistance may need to be inserted between its high impedance winding and the gain control to prevent excessive dissipation here and in the headphone.

The output from the second headphone is at high impedance, and may be coupled directly to any grid circuit without a transformer.

Due to the simplicity of the device some distortion must be expected, but this was not found to be very noticeable with the prototype. A correct setting in the gain control helps in the reduction of distortion.

The time delay offered by the unit is fairly short but is readily discernible. An increased time delay would be given by using a longer box and a longer length of spring between the headphones, but this was not checked by the writer.

TELEVISION AND RADAR

An interesting demonstration of how radar and closed circuit television can be linked as a navigational teaching aid was recently mounted at the Navigation School of Hull Trinity House.

A Marconi Marine “Radiolocator IV”, with 9in P.P.I., is installed on the second floor of the School for radar training purposes, and for the demonstration the new Marconi V322 television camera was linked to a 27in receiver in the main hall two floors below. The radar “picture”, enlarged from 9in in diameter to 27in, could be seen in comfort by a number of viewers at one time—an obvious boon in class teaching where a large television picture could be employed as a lecturer uses a projected lantern slide.
Dynamic Gain Transistor Tester

By D. BOLLEN

An inexpensive instrument which gives comparative tests of transistor performance at 2 Mc/s, 10 Mc/s and 30 Mc/s.

IT IS WELL KNOWN THAT TRANSISTORS EXHIBIT A "spread" in their characteristics, this being especially true of the cheaper surplus types. Current gain is easy enough to check at zero frequency, but it bears little relation to the actual gain given in a grounded emitter circuit operating near the transistor's cut-off frequency. Now that r.f. transistors are readily available to the home-constructor some simple means of checking their gain at working frequency is particularly desirable in order to avoid the wasted time and inconsistent results obtained from "try it and see" methods.

Components List

Resistors
- \( R_1 \) 12k\( \Omega \) 10% 1/2 watt
- \( R_2 \) 6.8k\( \Omega \) 10% 1/2 watt
- \( R_3 \) 2.5k\( \Omega \) potentiometer, preset, linear track
- \( R_x \) Series meter resistor (see text)

Capacitors
- \( C_1 \) 1,000pF ceramic or silver-mica
- \( C_2 \) 120pF ceramic or silver-mica
- \( C_3 \) 8\( \mu \)F electrolytic, 12V wkg.

Inductors
- \( L_{1,2,3} \) See text

Diodes
- \( D_{1,2} \) OA81

Switches
- \( S_{(a,b)} \) 2-pole, 3-way
- \( S_2 \) s.p.s.t. on-off

Miscellaneous
- Meter (see text)
- Transistor holder
- 3 coil formers, \( \frac{3}{4} \) in by 1\( \frac{1}{4} \)in (see Fig. 2)
- 3 dust cores
- Tagstrip
- Paxolin panels

The easily built tester described here has shown that surprising variations do exist between transistors in respect of gain. In some cases ordinary audio transistors will give useful gain at higher than 2 Mc/s, while types designed to operate at 10 Mc/s sometimes show only a small gain at 2 Mc/s and will not amplify much beyond that. An old XA123 drift transistor, scrapped by the writer because its beta was less than 15, was found to out-perform a new alloy-diffused transistor with a beta of 100. Subsequent "in circuit" tests confirmed its usefulness.

The Circuit

The circuit is shown in Fig. 1, and it incorporates a straightforward inductance-coupled oscillator. Switch tuning is employed for simplicity with feedback between collector and base, the transistor under test operating in the common emitter mode.

There are three ranges, chosen to suit the p.n.p. r.f. transistors which are most commonly encountered, i.e. i.f. amplifiers, m.w. r.f. amplifiers and self-oscillating mixers, and transistors operating in s.w. circuits up to 30 Mc/s. With the coils specified the transistor under test oscillates at 2 Mc/s on range 1, 10 Mc/s on range 2, and 30 Mc/s.
The coils were mounted on a smaller piece of Paxolin measuring 3 x 2in, together with a slim tagstrip sawn from Veroboard, which was then screwed to the back of the meter. The three resistors, three capacitors, and two diodes can all be soldered direct to this tagstrip.

When connecting the coil leads to the tagstrip it is important to observe the lead numbering sequence shown in Figs. 1 and 2.

As the consumption of the unit does not exceed 2.5mA, and then only for short periods, the smallest type of 9 volt battery (such as the PP4) can be used. This is clamped to the Paxolin panel by a thin strip of aluminium. The battery was removed for the photographs so that construction could be more easily seen.

**Operation**

Insert a transistor and check that the battery consumption does not exceed 2.5mA. Set $R_3$ to mid-point and insert a good high frequency transistor with the range set at 2 Mc/s. An OC171 is ideal for this purpose. Adjust $R_3$ until the meter reads slightly less than full-scale, then switch to the other two ranges. The meter reading should remain approximately the same if all is well. If no reading is obtained on one of the ranges check the coil connections and reverse one winding if necessary.

All that remains is to try various transistors. An OC45 should read high on range 1, with no reading at all on ranges 2 and 3, indicating that its gain has fallen steeply between 2 and 10 Mc/s. An OC44 will show a fair reading on range 2, but nothing on range 3. Transistors of the same type can be compared with one another by noting the meter reading for each one. Only the higher frequency transistors will give a reading on range 3. To increase the range frequencies unscrew the dust cores, or completely remove them. The exact frequency of oscillation can be checked by finding the fundamental on a short wave receiver, but if the coils are wound according to the instructions they should be near enough to the specified frequencies for practical purposes.

Obviously the flexibility of the instrument could be increased by extending the ranges to include 300 kc/s for audio transistors, and 100 Mc/s or more to suit the very high frequency transistors now available.
The “Athenian” 4-Band Superhet Receiver

Part 2—A Design for the Beginner, 16—2,000 Metres

By James S. Kent

HAVING DECIDED TO CONSTRUCT THE “ATHENIAN” receiver, whose circuit was described last month, and having obtained the parts as listed in the Components List, the intending constructor will have no doubt be waiting for this issue so that operations can commence.

The first step is probably the least exciting but nevertheless it must be carried out accurately if every panel and chassis mounted component is to fit in the correct place.

Drilling the Chassis and Panel

Fig. 2 (a) shows the front panel measurements, this having an overall size of 14 x 8in. Holes A, B, C, D, and E are all $\frac{1}{4}$in diameter. They should first be marked out with a centre-punch on the rear of the panel before drilling, and the dimensions double-checked. The reason for marking the rear of the panel is that any error in measurement, or false markings, will not show on the front. Hole A is for the wavechange switch; B for the b.f.o. pitch control; C for the function control; D for the audio gain control; and E for the phone jack.

Next, mark and drill holes F and G to $\frac{1}{4}$in diameter, these being the apertures for the handset and bandspread spindles respectively. Refer to Fig. 2 (d) for the remaining drilling details required for holes F and G in order that the two dials may be fitted correctly, as is done at a later stage.

The drilling details for the pilot lamp assembly and the “Athenian” motif have not been given in Fig. 2 (a) as these will depend on the type of fitment obtained. In the prototype, the drilling measurements for the lamp assembly are 1in from the edge of the right-hand side of the panel (looking at the front) and 1\(\frac{3}{4}\)in down from the top edge of the panel. Those for the medallion are exactly the same except that it is 1in from the left-hand side of the panel.

Next, place the front panel against the front apron of the chassis, and clamp (or secure by other means) these together in exactly their final relative position, the two edges and bottom of both panel and chassis being square and level.

Centre-punch in the centre of holes A to E inclusive, remove the panel and drill the same size holes as hitherto in the chassis apron. The holes in the panel and front apron of the chassis should now coincide. If not, then a small amount of filing with a round or half-round file will be necessary when these two parts are later fitted together.

Fig. 2 (b) shows the main details for the chassis deck. Holes H, K, M and O are for V1, V3, V2 and V4 respectively. These should be marked out first and circular holes having a diameter of $\frac{1}{2}$in made in the chassis deck. The easiest method of accomplishing this is to obtain a Q Max chassis punch complete with Allen key,1 this tool cutting a smooth round hole in one operation after a centre hole has been initially drilled. Failing this, it will be necessary to mark out a circle of the diameter stated and to drill holes round this mark, finally removing the unwanted centre by a slight tap with a ball-pane hammer and filing clean with a half-round file. The latter is a most laborious business and the small investment involved in obtaining the Q Max tool is well worthwhile—particularly as it will last a lifetime and be constantly in use during constructional operations. Do not drill any of the valveholder mounting holes yet.

1 Home Radio Cat. No. TL10 with key Cat. No. TL12, 17s. 9d. post paid.

Above-chassis view of the completed prototype receiver. The components, from left to right at bottom, are V1, bandset capacitor, b.f.o. coil, IFT2, bandspread capacitor, V3 and pilot lamp assembly. Left to right, above, IFT1, V2, C28, 29, V4 and mains transformer T2.
Holes I, J and L should now be marked, these being the centre points for the transformer hole groups; I being that for the b.f.o. coil, L for IFT₁ and J for IFT₂. The three centre holes should have a diameter of \( \frac{1}{8} \) in. Six other holes are now required at positions I, J and L, and details of these are given in Fig. 5 (a). Before marking and drilling, however, ensure that with IFT₁ (hole L) pins 1 and 6 are positioned nearest the rear edge of the chassis and pins 3 and 4 are nearest the front edge. (See Fig. 5 (b).) A useful dodge here consists of marking the metal cans with a pencilled number corresponding to the various pins, this helping to ensure that the orientation of these components is correct. IFT₂ (hole J) should now be similarly drilled (see Fig. 5 (a)) with pins 1 and 3 nearest the rear and pins 4 and 6 nearest the front of the chassis. The b.f.o. coil is next dealt with in a similar manner, pins 1 and 3 being nearest the front and pins 4 and 6 being nearest the rear edge of the chassis.

The next task is to mark out and drill the holes required for mounting the mains transformer. These are not shown in Fig. 2 (b) but a glance at the accompanying illustration (above chassis) shows the location and orientation of this component. The thin red, yellow, green, black, brown and black/yellow leads, together with the two yellow heater wires, should be nearest the rear edge of the chassis. Mark and drill the four 2BA holes required to hold the transformer in position using the mounting lugs as a template. Mark and drill two \( \frac{1}{4} \) in holes mid-way between the fixing lugs and fit these with suitably sized rubber grommets.

Hole N should next be dealt with, and this should have a diameter of \( 1 \frac{1}{8} \) in (the same size as is required for an octal valveholder). A Q Max chassis cutter is also available for this size.²

² Home Radio Cat. No. TL14, with Allen key Cat. No. TL15C, 19s. 6d. post paid.

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Holes I, J and L should now be marked, these being the centre points for the transformer hole groups; I being that for the b.f.o. coil, L for IFT₁ and J for IFT₂. The three centre holes should have a diameter of \( \frac{1}{8} \) in. Six other holes are now required at positions I, J and L, and details of these are given in Fig. 5 (a). Before marking and drilling, however, ensure that with IFT₁ (hole L) pins 1 and 6 are positioned nearest the rear edge of the chassis and pins 3 and 4 are nearest the front edge. (See Fig. 5 (b).) A useful dodge here consists of marking the metal cans with a pencilled number corresponding to the various pins, this helping to ensure that the orientation of these components is correct. IFT₂ (hole J) should now be similarly drilled (see Fig. 5 (a)) with pins 1 and 3 nearest the rear and pins 4 and 6 nearest the front of the chassis. The b.f.o. coil is next dealt with in a similar manner, pins 1 and 3 being nearest the front and pins 4 and 6 being nearest the rear edge of the chassis.

The next task is to mark out and drill the holes required for mounting the mains transformer. These are not shown in Fig. 2 (b) but a glance at the accompanying illustration (above chassis) shows the location and orientation of this component. The thin red, yellow, green, black, brown and black/yellow leads, together with the two yellow heater wires, should be nearest the rear edge of the chassis. Mark and drill the four 2BA holes required to hold the transformer in position using the mounting lugs as a template. Mark and drill two \( \frac{1}{4} \) in holes mid-way between the fixing lugs and fit these with suitably sized rubber grommets.

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Fig. 2 (a). Panel drilling details. The wavechange switch is positioned at A, the b.f.o. pitch control at B, the function switch at C, the volume control at D, the phone jack at E, the bandset capacitor at F and the bandspread capacitor at G.

(b). Chassis drilling details. V₁ is fitted at H, the b.f.o. coil at I, IFT₂ at J, V₃ at K, IFT₁ at L, V₂ at M, C₃8.29 at N and V₄ at O.

(c). Rear chassis apron details. The mains input lead passes through P, the mains filter unit is fitted at Q, the power outlet socket at R and the aerial input socket at S.

(d). Drilling details required for fitting the bandset and bandspread dials, together with their associated slow motion drives.
The 9-way tagstrip should now be fitted (see illustration) and this should occupy a position midway between $V_1$ and $1F_1$ at one end and $V_2$ and $L_4$ (b.f.o. coil) at the other end. This tagstrip has two earthed tags (tags 2 and 8) and each of these must be reliably secured to the chassis.

The 4-way tagstrip can now be fitted and this should occupy a position to the left of $V_3$ (looking from the rear of the chassis) such that tag 1 (see Fig. 13) is level with pin 9 of the valveholder.

The hole for the aerial i.f. filter unit should now be drilled, this being 1 in from the left-hand edge of the chassis and 2 in from the rear edge. Do not secure any component into position as yet.

Refer now to Fig. 2 (c) and mark and drill the holes P, Q, R and S. Hole P should have a diameter of $\frac{3}{4}$ in, and is fitted with a rubber grommet. This is for the mains input lead. Hole Q is 4BA clearance to take the mains input filter unit. Hole R is for the power outlet socket and should be $1\frac{1}{4}$ in diameter to take an octal socket. Finally, hole S is for the coaxial aerial input socket and should have a diameter of $\frac{3}{4}$ in.

The next task is to drill and bend the two variable capacitor mounting platforms (see Fig. 3 (a) and (b)). In each case, the components themselves may be used as templates for marking out the fixing holes, 4BA nuts, bolts and shakeproof washers being used for securing purposes. Dealing with Fig. 3 (a) first, it will be noted that there is a cut-out portion on the right-hand side of the metalwork, this being required to give clearance for the b.f.o. transformer, the depth of this cut-out being $\frac{3}{4}$ in. Drill the platform as shown, not forgetting the two 4BA chassis securing holes and the $\frac{3}{8}$ in hole required beneath each solder tag of the capacitor (two in all); fit these two holes with small rubber grommets. Each corner of the platform should be trimmed as shown, this avoiding possible cuts on the hands at a later stage. Bend along the two lines as shown in the side view of Fig. 3 (a). Similarly deal with the platform shown in Fig. 3 (b). Here, no connections pass through the platform from the variable capacitor, and no cut-out is required in the metalwork. Having drilled the metalwork, bend along the lines as shown. Both of the capacitors should be mounted on the metalwork such that the spindles protrude as much as possible, $\frac{3}{4}$ in of spindle being required to extend beyond the front panel for dial fixing purposes. Mount the capacitors to the metalwork but do not secure to the chassis as yet.

To the right-hand apron of the chassis, on the outside, place the output transformer $T_1$ into position. Mark the fixing holes with a centre-punch and drill the four holes. The position of this transformer is such that its centre is $3\frac{1}{2}$ in from the front of the chassis and $1\frac{1}{2}$ in from the top of the chassis. The transformer is used as a template on
Fig. 5 (a). Drilling details for the i.f. transformers and b.f.o. coil. (b). Underside view of these components.

the outside of the chassis for the reason that it is almost impossible to employ it in this manner from inside the chassis.

Midway between this transformer and the rear edge of the chassis, place the speaker output Paxolin strip upright, mark out, drill and secure into position. Mount under one of the fixing nuts an earth tag. (See below-chassis illustration and Fig. 16.)

Refer next to Fig. 4, which shows the mounting bracket for the smoothing choke. Mark out, drill and bend as shown, using the component itself as a template for its four mounting holes, then mount the choke in position on the bracket.

Returning again to the chassis deck, position V₁ valveholder (which requires a screening can) such that pins 1 and 9 are nearest the front of the chassis, drill the two fixing holes and mount into position, placing an earthed solder tag under the nut nearest the front of the chassis. With V₂ valveholder, (which also requires a screening can) place this with pins 1 and 9 nearest aperture N, and secure with a solder tag under the nut nearer the same hole. For V₃, position so that pins 4 and 5 are nearest the side of the chassis and, with V₄, so that pins 1 and 9 are nearest hole N. Secure these two valveholders and ensure that a solder tag is mounted under the nut nearer the centre of the chassis in each case. Mount the smoothing capacitors C₂₈, C₂₉ into position by using the metal clip as a template, ensuring that the red tag is nearest the V₄ valveholder. Secure into position the i.f. filter unit; the aerial input socket; the international octal valveholder used as the power outlet socket, mounting an earthed solder tag under one of its nuts; the mains input filter; IFT₁ (pins 1 and 6 nearest the rear of the chassis) and the mains transformer.

Place temporarily into position firstly the handset variable capacitor on its platform, mark on the chassis deck the two positions for feeding the two connecting leads required, remove the mounting, drill the two holes and fit two 3⁄16in rubber grommets. Similarly deal with the bandspread capacitor. In this case the connecting leads pass through two holes in the chassis between the bandspread capacitor bracket and IFT₂. The two platforms are now

Fig. 6. Point-to-point diagram of the power stage at V₄. Note that the spigot earth tag appears between pins 1 and 9.
ready for mounting but, first of all, a small soldering process is required.

When dealing with the handset two-gang capacitor, it will be found much easier to solder to the respective tag of each fixed vane section a 3in length of p.v.c. covered wire before securing the assembly into position, feeding the two wires through the platform and the chassis prior to mounting into position. The two platforms may now be mounted.

Mount and secure into position the b.f.o. coil (pins 4 and 6 nearest the rear of the chassis) and IFT2 (pins 1 and 3 nearest the rear edge of the chassis). Under the right-hand fixing bolt of the b.f.o. coil (that nearer IFT2) secure an earth solder tag.

Secure into position the smoothing choke assembly using the metalwork as a template for the two fixing holes to the chassis deck. The illustration shows the position for this assembly, the screen protruding beyond hole N and being placed midway between this hole and V2 valveholder.

**Fig. 8. Point-to-point wiring diagram of the first stage (V1 and IFT1). In all the point-to-point diagrams, where a resistor or capacitor is designated within a rectangle, that component should be soldered into circuit at that particular stage of construction**

Next, fit the panel to the chassis by feeding the two variable capacitor spindles through their respective holes, and securing into position in hole A the coilpack, hole B the 25pF variable b.f.o. pitch capacitor, hole C the 4-pole, 3-way function switch, hole D the volume control and E the phone jack. Note from the below-chassis illustration the orientation of these components.

Finally, fit the pilot lamp assembly and drill through the chassis, directly underneath, a ½in hole, which is fitted with a small rubber grommet. Secure the assembly into position. If using the medallion, drill the panel as previously described but do not fit the medallion as yet. The drilling and fixing of components is complete and wiring-up may now commence.

**Wiring-up the Circuit—V4**

The best method of carrying out this task is to commence at V4 and to follow this by connecting up all the respective valve heater supplies. In this manner, heater leads may be so positioned and routed that they do not run near tuned or “hot” leads, thereby reducing the risk of induced 50 c/s mains hum.

**Fig. 9. Wiring-up details of the 9-way tagstrip. Note that both tags 2 and 8 must be secured to chassis**

**Fig. 10. Point-to-point wiring details at V2 valveholder**
The diagram of Fig. 6 shows the required connections from the mains transformer T2 to the rectifier V4, the smoothing capacitors C28, C29 and the mains filter unit (shown in inset).

Commence by soldering into position the following leads connecting to V4: red 250V to pin 1; green 6.3V to pins 3 and 4; white to pin 5; black to the centre metal spigot and from there to the spigot tag and chassis, and red 250V to pin 7. Note that both of the 6.3V leads (green and white) will have to be scraped in order to remove the protective enamel covering prior to soldering. From pin 4, a length of p.v.c. covered wire is taken to the tag of C29 (red). To this latter point, one of the smoothing choke leads (it does not matter which one) is also soldered.

Dealing next with the wires from the other grommet, the black (yellow), green, yellow wires will have to be taped separately in such a manner that their bare ends are covered and will not make contact with each other or the chassis. These wires should now be folded, taped so that they are retained in the fold, and tucked away under the other wires once these are connected. The two yellow 6.3V wires should now be scraped and connected, one to pin 4 of V3 (output stage) and one to the earth tag. The black 0V a.c. input wire and the red 250V a.c. input wire should now be soldered to the two lower tags of the mains filter unit (see inset to Fig. 6). The brown wire is connected to the earth tag. The remaining smoothing choke wire should now be connected to the tag of C28 (yellow). Other connections to this tag are: a p.v.c. covered wire to pin 4 of the power outlet socket; a p.v.c. covered lead to tag 9 of tagstrip 1 (Fig. 9) and to tag 4 of tagstrip 2 (Fig. 13). The connection to R11 will be dealt with later. Carefully check to ensure that the correct connections have been made and constantly refer to the circuit diagram in Fig. 1, published last month.

Next connect a small length of bare wire from pin 2 of the power outlet socket to its adjacent earth tag.

From pin 4 of V3, continue the heater supply to pins 4 of both V2 and V1. Place the heater lead as close to the chassis deck as possible.

The Circuit of V1

The wiring-up details for this arc shown in Figs. 7 and 8. Fig. 7 is for the coilpack but it will be found easier to commence by wiring the circuit of V4 and make the necessary connections to the coilpack as they become necessary.

With a short length of bare wire, connect pin 5, the central metal spigot and the spigot tag to the earth tag. To pin 1, solder one end of R1 (33kΩ, orange, orange, orange) and C6 (0.1µF), the other end of R1 being soldered to tag 1 and the other end of C6 to tag 2 of tagstrip 1 (see Fig. 9). To pin 2 of V1 connect one end of both R6 (1MΩ, brown, black, green) and C1 (100pF); the other end of R6 being soldered to tag 3 of tagstrip 1 and the other end of C1 to the green tag of the coilpack (see Fig. 7). From the green tag of the coilpack connect a length of p.v.c. covered wire to C2(a) (bandspread capacitor section nearest the front panel, feeding this wire through the associated rubber grommet in the chassis deck). Also to the green tag of the coilpack connect the length of p.v.c. covered wire previously connected to C2(a) (front section of the handset capacitor nearest the front panel).

To pin 3 of V1, connect one end of both R5 (47kΩ, yellow, violet, orange) and R7 (220Ω, red, red, brown). The other end of R5 connects to pin 9 and that of R7 to pin 5 (chassis). C4 (0.01µF) is also connected to pin 3, its other end connecting to tag 2 of tagstrip 1. Pin 4 has already been dealt with (6.3V a.c.). Pin 6 is connected directly to pin 3 of IFT1.

Pin 7 of V1 has soldered to it one end of C9 (50pF) the other end of which is connected to tag 6 of tagstrip 1; also a short length of wire, the other end of which connects to pin 9 of V1.

To pin 8 connect one end of both R3 (33kΩ, orange, orange, orange) and C8 (200pF). The other end of R3 connects to pin 9 and that of R7 to pin 5 (chassis). C4 (0.01µF) is also connected to pin 3, its other end connecting to tag 2 of tagstrip 1. Pin 4 has already been dealt with (6.3V a.c.). Pin 6 is connected directly to pin 3 of IFT1.

The connections to pin 9 of V1 have already been completed.

The next step is that of completing the wiring to IFT1. To pin 1, connect one end of both R2 (10kΩ brown, black, orange) and C7 (0.1µF). The other

3The connections to the mains input filter unit assume a 240–250 volt a.c. mains supply, as will be in existence in most instances. For lower mains voltage supplies, the appropriate primary leads should be selected, following the circuit diagram shown last month in Fig. 1 — EDITOR.
end of R2 now connects to tag 1 and that of C7 to tag 2 of tagstrip 1 (see Fig. 9). Pin 4 of IFT1 is soldered direct to tag 4 of tagstrip 1 and pin 6 is connected to pin 2 of V2.

Return now to the coilpack and complete the following wiring. The yellow tag (this is a stand-off pillar with wire insert, the latter being, in effect, the tag) is now connected to tag 8 of tagstrip 1. This yellow tag connection constitutes the coilpack earth and is shown in the circuit diagram of Fig. 1 (published last month) as such. The blue lead of the coilpack connects to tag 6 of tagstrip 1 and the black lead to L1 (aerial filter unit, if included) and yellow tag connection constitutes the coilpack earth tag) is now connected to tag 8 of tagstrip 1. This is connected to pin 2 of V2.

Fig. 7 shows, in addition to the various connections, the positions of the various coils, both aerial and oscillator, and also the trimmer capacitors for each range.

The Circuit of V2

Before commencing with this part of the circuit, beginners should check with the foregoing instructions and the circuit of Fig. 1 to ensure that all connections have been made as described, whereupon the various components of the circuit completed may be “blacked in” on the circuit diagram with the aid of a ball-point pen. It should be noted, however, that the tags of tagstrip 1 are used as junction points and in case some confusion arises when checking and “blacking out” the circuit, a reference to Fig. 9 will assist in ensuring that the correct connections have been made. For instance, R5 in the V1 circuit (pin 8) is shown in Fig. 8 as being connected between that pin and tag 1 of tagstrip 1 whereas in the circuit it is shown as being connected at one end to tags 2 and 3 of S2(a). A reference to Fig. 9 will show that it is, in fact, so connected to S2(a) whilst a further reference to Fig. 11 (S2(a), (b), (c), (d)) will show that tag 5 of the tagstrip is connected to S2(d).

In all the point-to-point diagrams, it has been so arranged that where a component is actually shown, i.e. designation within a rectangle, it should be wired in at that stage.

Referring to Fig. 9, complete the following wiring. Connect tag 1 of the tagstrip to tag 5 with a length of p.v.c. covered wire. To tag 2 connect one end of C5 (0.01µF), the other end of this capacitor going to tag 3. To tag 3 connect one end of R8 (220kΩ red, red, yellow) and C10 (0.1µF), the other end of R9 connecting to tag 7 and that of C18 to tag 8. To tag 4 also connect a length of p.v.c. covered wire, the other end of which is soldered to one end of R16 (100Ω brown, black, brown). The free end of R16 is then connected to tag C of S2(a)—see Fig. 11.

To tag 5 of tagstrip 1 solder a length of p.v.c. covered wire, the other end of which connects to tags 2 and 3 of S2(a). To tag 6 of tagstrip 1 connect a length of p.v.c. covered wire, the other end of which is connected to C3(0) (bandspread capacitor section nearest the rear of the chassis). One end of the wire previously soldered to C2(0) should now also be connected to tag 6 of the tagstrip.

With a short length of p.v.c. covered wire, connect tag 7 of the tagstrip to pin 6 of IFT2. To tag 8 of the tagstrip, connect one end of C16 (140pF), leaving the other end free for the moment. To tag 9 connect a length of p.v.c. covered wire, the other end of which is now connected to tag D of S2(d)—see Fig. 11. The remaining connections to the tagstrip will be completed later as the wiring process continues.

We deal next with the connections to the valveholder of V2. (See Fig. 10.) With a short length of bare wire, connect pin 5 to the central metal spigot and the spigot tag to the earthed tag. A small metal screen should now be soldered across the valveholder as shown by the dotted line. This screen should be soldered to both the central metal spigot and the spigot tag and care should be taken to ensure that the screen does not make contact with any other valve pin. A suitable metal screen may be made by cutting out a piece of tin from a discarded cocoa tin or similar with the aid of a pair of tinsnips, and trimming to shape.

To pin 1 of V2 connect one end of both R10 (100Ω brown, black, yellow) and C10 (0.1µF), the other end of R10 being connected to tag 9 of tagstrip 1 and that of C10 to the earth tag as shown. To pin 3 of V2 solder one end of R14 (220Ω red, red,
join tag A to tag D of S2(d) — Dealing with S2(b)

control. (See Fig. 15). To complete S2(c), connect tag 3 to pin 3 of the b.f.o. coil L4. This completes the section, connect tag 2 to tag 1 of the volume control, that of C26 to tag B of the phone jack—see Fig. 15 (b). From tag 3 solder a length of p.v.c. covered wire and connect the other end to tag 2 of the volume control R19—see Fig. 15 (b). Pin 2 of V3 should now be connected to tag 2 of the volume control R19—see Fig. 15 (b) — and this connection should be made by using a short length of coaxial cable, the metal outer braiding of which is connected to chassis by soldering to the central metal spigot of V3 valveholder. Note that of C15 (b.f.o. pitch control variable capacitor). With a short length of bare wire, join pins 3 and 6 of L4 and connect these to the chassis earth tag.

Dealing next with IFT2, connect to pin 1 one end of both R11 (10kΩ, brown, black, orange) and C11 (0.1μF), the other end of R11 being connected to the tag of C24 (32μF electrolytic) and that of C11 to chassis (tag 1 of the volume control R19—see Fig. 15). To pin 4 of IFT2 solder the black end of the diode, using a pair of pencils as a heat shunt. The other end of this component (red) is now soldered to the earth tag as shown (using a heat shunt). Obtain R17 (270kΩ, red, violet, yellow), C19 (100μF), C20 (100μF) and a length of p.v.c. wire, suitably shorten one wire end of each component and twist these and the wire together and solder. Place the pliers against the red end wire of the diode to form a heat shunt and connect the twisted ends of the components mentioned above to the earth tag as shown in Fig. 12.

Connect the other end of the p.v.c. covered wire to tag 1 of the volume control, that of C19 to pin 6 of IFT2, C20 and R17 to the ends of R16 (22kΩ, red, red, orange) and C21 (0.01μF), cutting the wires forming this latter junction as short as possible, twist them together and solder. The other end of R16 connects to pin 6 of IFT2 and that of C21 to tag 3 of the volume control R19.

The Circuit of V3

This is the last stage to be dealt with and operations should commence with wiring-up tagstrip 2, as shown in Fig. 13.

Connect R23 (1.5kΩ 5 watts) between tags 1 and 4 of this tagstrip as shown. Solder the end of C24 (8μF electrolytic) which is marked with a plug sign or is coloured red to tag 1, the other end of this component being connected to tag 3. Join tags 1 and 2 of the tagstrip as shown. From tag 2 connect a length of p.v.c. covered wire and connect the other end of this wire to pin 8 of V3. From tag 3 connect a short length of p.v.c. covered wire and connect the other end to tag C of the phone jack—see Fig. 15 (b). From tag 4 solder a length of p.v.c. covered wire, the other end of which connects to the tag of C23 (32μF electrolytic). The remaining connections will be made to this tagstrip as the wiring-up process of V3 continues.

Refer now to Fig. 14 in which is shown the connections to V3. With a short length of bare wire connect pin 5 to the central metal spigot, the spigot tag and the earth tag. To pin 1 connect one end of R24 (100kΩ, brown, black, yellow), C25 (0.01μF) and C26 (0.1μF). Connect the other end of R24 to tag 2 of tagstrip 2, that of C25 to pin 9 of V3 and that of C26 to tag B of the phone jack—see Fig. 15 (b). Pin 2 of V3 should now be connected to tag 2 of the volume control R19—see Fig. 15 (b) — and this connection should be made by using a short length of coaxial cable, the metal outer braiding of which is connected to chassis by soldering to the central metal spigot of V3 valveholder. Note that of C15 (b.f.o. pitch control variable capacitor). With a short length of bare wire, join pins 3 and 6 of L4 and connect these to the chassis earth tag.
here that in the photograph of the prototype (below chassis view) this coaxial cable is shown connected incorrectly, being soldered to tag 3 of R19 instead of tag 2.

To pin 3 of V3, connect one end of both R20 (1.8kΩ, brown, grey, red) and C22 (10μF electrolytic) the positive end of the capacitor being that connected to this pin. The other wires of these two components should now be cut to a suitable length, twisted together and soldered to tag C of the phone jack (chassis). To pin 4 of V3, to which two connections have already been made when dealing with V4, solder a length of p.v.c. covered wire, the other end of which connects to pin 7 of the power outlet socket. Next, obtain two lengths of p.v.c. covered wire of similar length (sufficient to reach from V3 valveholder to the pilot lamp assembly via the rubber grommet when twisted together) and solder one end of each length of wire to a tag of the pilot lamp assembly. The other end of one length of this wire is now connected to pin 4 of V3 and the remaining end to tag C (chassis) of the phone jack.

To pin 6 of V3 solder one end of C27 (0.01μF), the other end connecting to tag C of the phone jack. Connect the orange wire of T1 (output transformer) to pin 6 of V3. To pin 7 of V3 connect one end of R21 (470kΩ, yellow, violet, brown) and the positive end of C23 (25μF electrolytic), the other ends of R21 and C23 being connected to tag 3 of tagstrip 2. To pin 8 of V3 connect the white wire of T2 and a short length of p.v.c. covered wire, the other end of which connects to tag 2 of tagstrip 2. To pin 9 connect one end of R22 (220kΩ, red, red, yellow) the other end being soldered to tag 3 of tagstrip 2.

One connection now remains to be made to the volume control and that is the coupling of tag 1 to chassis. The connection may be made by connecting a length of wire to tag 3 of S2(c)—see Fig. 11.

To tag D of the phone jack solder the black wire of T1.

The yellow and green wires of T1 should be taped separately to ensure that the wire ends do not make contact with each other or the chassis and these wires should then be tucked away. The red wire from T1—see Fig. 16—should now be soldered to the lower tag of the speaker output socket, the upper tag of this strip being soldered to the chassis earth tag.

R25 (10Ω, brown, black, black) is now wired between the lower speaker output socket tag and tag D of the phone jack. To accomplish this it will be necessary for one of the resistor leads (that connecting to the phone jack) to be extended by soldering on an additional length of insulated wire, the joint being covered by sleeving. The resistor is positioned near the speaker output socket.

Finally, complete the mains input circuit. This consists of fitting the mains input lead and com-
Completing the wiring between this and the on-off switch, and between the on-off switch and the mains filter unit. (See Figs. 6 and 15 (a).) Ensure that switch tags A, B, C and D are those which correspond to the switching circuit shown in the inset in Fig. 15 (a).

The wiring of the receiver is now complete. Carefully check all the wiring against the circuit diagram of Fig. 1 and the foregoing textual instructions to ensure that all connections have been made correctly.

Part 3, the conclusion of this series, is to be published next month, and will deal with treating the front panel, testing and operation of the receiver.

(To be concluded)

This month Smithy the Serviceman, aided as always by his able assistant, Dick, turns away from the more complex aspects of servicing to consider the simpler problems involved in meter series resistors and shunts.

The nominal resistance per yard," called out Smithy, "is 1.13Ω.

"Fine," declared Dick, jotting the figure down in his notebook. "That's got 22 s.w.g. Eureka wire sorted out! Now, what about 24 s.w.g. Eureka?"

Smithy consulted his tables once more.

"That," he pronounced gravely, "has a nominal resistance of 1.83Ω per yard."

"Good," said Dick enthusiastically, "and 26 s.w.g.?"

"The nominal resistance there," Smithy replied, "is 2.73Ω per yard."

"Excellent," said Dick, scribbling in his notebook. "Well, that's got me sorted out so far as resistance wire is concerned. Incidentally, why did you keep referring to nominal resistance values just now? Why not just say what the actual value is?"

"It's necessary," replied Smithy, "to refer to nominal resistance values with resistance wire because of the inevitable tolerances which are involved. To start off with, there's a tolerance on the diameter of the wire itself."

Smithy returned to his wire tables. "For instance," he continued, "the diameter of 22 s.w.g. wire is nominally 0.028 inches, but it has top and bottom limits of 0.0283 and 0.0277 inches. With 24 s.w.g. wire, the nominal diameter is 0.022 inches, with top and bottom limits of 0.0222 and 0.0218 inches. Again, with 26 s.w.g. wire the nominal is 0.018 inches, with top and bottom limits of 0.0182 and 0.0178 inches. These tolerances on wire diameter are just one reason why you have to refer to resistance values in resistance wire as being nominal."

A Simple Power Unit

Dick groaned. "This tolerance business," he complained, "doesn't half make life complicated. Why can't people make things exact?"

"Because it's impossible," replied Smithy. "What you have to do is make things to tolerances which are sufficiently tight for the job in hand."

"I suppose," grumbled Dick, "that tolerances are just one of those things I must learn to put up with."

"Since everyone else in any other branch of engineering," commented Smithy sarcastically, "has to work with tolerances, it would seem reasonable for you to join in as well. I assume, incidentally, that you won't need any help in working out the correct value for this meter shunt you're making up?"

Dick's jaw dropped. "How on earth?" he gasped incredulously, "did you know I was making up a meter shunt?"

"You don't need," grinned Smithy, "to be a Sherlock Holmes to work that one out. Whenever anyone starts nattering about resistance wire, it's a 99.8 to 100% chance that he's going to make up a meter shunt!"

"I can see," said Dick quickly, "that even that chance has a ±0-1% tolerance on it!"

Smithy chuckled, and leaned back lazily against his bench. Both he and Dick were spending a relaxed half-hour before leaving the Workshop for the evening. They had managed to clear all receivers which were in for repair, and had now assumed the postures of men who had worked well and who were very well aware they had worked well. Smithy squatted comfortably on his stool, tilting it negligently backwards towards his bench. Dis-
daining the conventional, his youthful assistant had perched himself on the surface of his bench, taking up an attitude reminiscent of the Lotus Position in Yoga. There had been no squabbles during the day to disrupt the harmony of Workshop operations, and the pair were now in complete rapport.

"Are you," asked Smithy, returning to the resistance wire theme, "knocking up a multi-testmeter, or something like that?"

"Nothing so complicated," replied Dick. "I'm just finishing off a little power supply unit I've made up in my bedroom at home."

"In your bedroom?"

"There's nowhere else in the house," replied Dick mournfully, "where they'll let me do any experimenting. Anyway, all this power unit consists of is a mains transformer giving two lots of 6.3 volts and 250-0-250 volts at 70mA, together with a rectifier, a choke and a double electrolytic. I'll be using this power pack to run a few odd bits of valve equipment I'm dreaming up, and I'll be fitting a meter to it to read h.t. current and voltage."

"Hrm," commented Smithy. "All this seems nice and straightforward."

Dick fished a sheaf of papers out of an inside pocket, selected a sheet, and tossed it over to the Serviceman.

"There you are," he announced. "That's the circuit. Dead simple, isn't it?"

Smithy unfolded the paper and examined the circuit carefully.

"Very good," he remarked. "Your meter switching is quite neat, too. On one switch position, the meter is connected across a 100mA shunt in the h.t. positive line. In the other switch position it's in series with a resistor which allows it to read h.t. current and voltage."

"That's the circuit. Dead simple, isn't it?"

"Incidentally, I thought I'd do the current reading bit in the h.t. positive line rather than the h.t. negative line for several reasons. If I'd put the shunt in the h.t. negative line I would have had to make the power unit chassis connection to one side of it. A chassis connection at the output terminal side of the shunt (Fig. 2(a)) would mean that the can of the double electrolytic in the power unit would need insulating from chassis. At the same time, a chassis connection on the transformer side (Fig. 2(b)) would have meant that the power unit chassis wouldn't have been common with the h.t. negative output terminal nor, as a result, with the chassis of any gear I connected it up to. So it seemed easier in the long run to put the shunt in the h.t. positive line instead."

"Very sensible," pronounced Smithy approvingly. "I can see that you've given some consideration to this little power pack of yours."

"I'm not," said Dick modestly, "just a pretty face, you know."

"Perhaps not," replied Smithy hurriedly. "Anyway, what is the full-scale deflection of your meter?"

"It's a 0-1mA movement," said Dick, "with an internal resistance of 75Ω. It's one of those surplus 2½ inch jobs which still seem to be knocking around these days."

"Fair enough," said Smithy. "Have you worked out the value of the shunt?"

"Of course," said Dick proudly, as he ruffled through the sheaf of papers he had extracted from his pocket. "I started off by assuming that, with the shunt, I wanted the meter to give a full-scale deflection of 100mA. (Fig. 3.) This meant that 1mA would flow through the meter and 99mA would flow through the shunt. So the shunt resistance needed to be one ninety-ninth of the meter resistance, or 75 x 1/99 ohms."

And you don't need to be Einstein to find that that comes to 0.758Ω!

"I would jolly well think you shouldn't," snorted Smithy, who had been scribbling out a quick calculation. "Especially when the correct answer is 0.758Ω!"

"Well, I'm dashed," said Dick mildly. "Come to think of it, my answer must have had something queer about it. I'd have needed a
Making a Shunt

"I should hate," said Smithy, "to think of you attempting any real design work. Anyway, hadn't you better start working out the length of resistance wire you need for the shunt?"

"I'm beginning to wonder whether it will be O.K. to work to wire a multi-testmeter which you knew to have made up the resistance value I got!"

Smithy raised an eyebrow. "You don't," he commented reprovingly, "seem particularly worried about your calculation being wrong."

"Why should I be?" replied Dick airily. "It was only the decimal point in the wrong position. That can happen to anyone!"

Fig. 3. A shunt which converts a 0-1mA meter to give an f.s.d. of 100mA must pass 99mA when the meter passes 1mA. Its resistance is, therefore, \( \frac{1}{7} \) of the internal resistance of the meter.

It will be O.K. to work to wire dickens of a lot of that Eureka wire to have made up the resistance value I got!"

"That," remarked Dick, "sounds interesting. How would you tackle it?"

"I'd begin," replied Smithy, "by making a very approximate calculation for the length of wire required. Let's assume we're going to use the 22 s.w.g. wire, which has a nominal resistance of 1.13 \( \Omega \) per yard. The present shunt requires 0.7580 \( \Omega \), which is a little less than three-quarters of 1.13. So I'd start off by cutting myself three-quarters of a yard of the resistance wire with some four inches or so spare."

"Which," chimed in Dick, "would come to 31 inches."

"Right," confirmed Smithy. "I'd then pass a current through this wire with a standard meter in series, if possible adjusting the current by a variable series resistor so that the standard meter reads a nice round value near f.s.d. (Fig. 4 (a).) You could obtain this current from the power unit itself, but its maximum transformer rating of 70mA means that you'd have to choose a current which didn't exceed this value. The next process would consist of connecting one terminal of your 0-1mA meter to one end of the resistance wire, and sliding a flexible lead from the other terminal up and down the resistance wire at the other end. (Fig. 4 (b).) When the 0-1mA meter gave a reading corresponding to that in the standard meter, say 0.6mA to correspond with 60mA, then you'd know that the length of resistance wire across which the meter was connected was exactly that needed for the 100mA shunt."


"I've used it on quite a few occasions," replied Smithy. "The main advantage is that there is no risk of damage to the meter movement because the heavy current always flows through the shunt wire. If you're going to find the length of resistance wire experimentally, the method I've described is a far safer idea than another that is occasionally advised, and which consists of applying the heavy current to the meter terminals with a variable length of shunt resistance wire across them."

"With your method," said Dick critically, "there is the disadvantage that you need a standard meter for comparison purposes."

"True enough," agreed Smithy. "But some sort of standard meter would also be desirable if you worked all the way through by calculations of resistance wire length. It would still be preferable to check the final result with another meter, if only to assure yourself that you'd got everything right. The standard meter I referred to would, normally, be a multi-testmeter which you knew to be reliable."

"I see," said Dick, "Well, having found the length of resistance wire..."
needed, what’s the next job?”

“Making up the shunt,” replied Smithy. “Usually, this process will consist of winding the wire round a strip of Paxolin or something similar, and anchoring the ends at solder tags. (Fig. 5 (a).) Don’t forget that the effective length of the resistance wire is that between the points at which the solder joints start. (Fig. 5 (b).) If you’re aiming at a very high level of accuracy, it’s a good plan to make this effective length very slightly longer than that you actually need. You can then ‘trim’ the shunt when it’s finally mounted in position by extending the solder joint along the wire by the requisite amount. (Fig. 5 (c).) You do this, of course, whilst checking against the standard meter as before.”

With these words, Smithy came to a stop. Surprised at a lack of audible response from his assistant the Serviceman glanced up, to see that Dick’s face had become contorted in the scowl which signified that he was about to indulge in one of his occasional outbursts of doggerel. His heart sinking, Smithy prepared for the worst.

Suddenly Dick’s face cleared.

“Here we are, Smithy,” he announced proudly. “Just listen to this!

“A serviceman living in Beckenham
Makes meters read high without wrecking ‘em,
He’s developed a stunt
Where the shunt bears the brunt
Of the current which flows when he’s checking ‘em!”

Series Resistors

“Well,” said Smithy after an embarrassed silence, “I can see you’ve achieved your old form once more.”

“I’m glad you liked it,” replied Dick, pleased. “It seems to be quite a long time since I last gave you one of my offerings.”

“Perhaps,” offered Smithy hopefully, “you’re getting out of practice?”

Dick considered this question carefully.

“I don’t think so,” he remarked eventually. “At the same time, though, I mustn’t let the old Muse get all rusty and clogged up. I think I’d try my hand at this sort of thing a little more often in the future.”

“I can,” commented Smithy, “hardly wait. In the meantime, I see that we’ve now cleared up the shunt resistor for the meter in your little power supply. What about the series resistor?”

“That’s easy,” said Dick promptly, as he consulted his sheaf of papers once more. “What I need there is a 1% high-stability resistor having a value of 499,925Ω!”

“You’re in luck,” said Smithy, with heavy irony. “It was only last week that I got in a box of resistors with that particular value and tolerance.”

“That’s great,” said Dick enthusiastically, taking out a pen and ticking off an item on his papers with a flourish. “If I can scrounge one of those resistors off you, then, Smithy, I can get my power pack finally completed tonight.”

Smithy swallowed.

“Well,” said Dick confidently, “there we are then.”

“You thundering twit,” exploded Smithy. “Where the dickens are you going to find a resistor like that? You said a tolerance of 1%, which means plus or minus 5kΩ out of 500kΩ. So, if you state a tolerance of 1%, all you need is any resistor whose actual value lies between 495 and 505kΩ.”

“What about the 75Ω resistance in the meter?”

“Well, compared,” snorted Smithy, “with resistances of the order of 500kΩ, 75Ω is just a fle-

“And that,” queried Smithy, “is 499,925Ω?”

“Isn’t it?”

“Of course it is.”

“Well,” said Dick confidently, “there we are then.”

“Where the dickens are you going to find a resistor like that? You said a tolerance of 1%, which means plus or minus 5kΩ out of 500kΩ. So, if you state a tolerance of 1%, all you need is any resistor whose actual value lies between 495 and 505kΩ.”

“What about the 75Ω resistance in the meter?”

“When compared,” snorted Smithy, “with resistances of the order of 500kΩ, 75Ω is just a flea-

Fig. 5 (a). When the requisite length of resistance wire has been found, the shunt may be made up as shown here
(b). An enlarged cross-sectional view of one of the solder joints, illustrating that the effective length of the resistance wire extends only to the start of the solder in the joint
(c). Extending the solder from the joint along the wire reduces the effective length of the latter

Fig. 6. Fitting a series resistor to enable a 0-1mA meter to read 500 volts full-scale

May 1965
"Then how," wailed Dick, "am I going to get this power unit of mine finished?"

"You can always," suggested Smithy, "buy the resistor."

"What," exclaimed Dick, aghast. "Buy a resistor? When I work in a servicing shop!"

"I can see," said Smithy resignedly, "that you're quite definitely a product of the New Morality. Anyway, it shouldn't be too hard to fix you up from my resistor stock, even if it doesn't include 500kΩ at 1%. All that's required is to find any low tolerance high-stability resistor that's near to the value you want and trim it up a bit."

"Trim it up?"

"That's right," confirmed Smithy. "What I would do, in the present case, is to start off by connecting up a standard voltmeter across the meter and series resistor points in your power pack, and then trying a few low tolerance 470kΩ resistors in the series resistor position. (Fig. 7 (a)). If you're lucky you may even find a 470kΩ resistor which gives you a reading in the meter corresponding almost exactly with that in the standard voltmeter, whereupon all you do is to wire that particular resistor permanently into circuit and all your troubles are over. It is much more probable, however, that you'll be unlucky, whereupon you select a 470kΩ resistor which is just a little too low in value, so that the reading in your meter is just a wee bit high. All you then have to do is find a low value resistor which you can pop in series with the first one to bring the meter reading right. (Fig. 7 (b)). The low value resistor will probably be in the region of 1kΩ to 33kΩ and, provided you have a reasonable stock of such resistors on hand to choose from, you should be able to get a meter reading which agrees almost exactly with that shown by the standard voltmeter. It will be easy to select the second resistor because quite large relative changes in value here will correspond to low changes in meter reading. For instance, changing from a 10kΩ to a 15kΩ resistor will cause the meter reading to shift by about 1% only."

"That's quite a snazzy idea," remarked Dick appreciatively. "So far as I can see, the only disadvantage is that you have to fit two resistors into circuit instead of one."

"That's right," confirmed Smithy. "I've used this approach myself on occasion and I don't need them, because He combines 20 percenters to stick in 'em!"

There was silence as the last echoes died away.

"That last line," commented Smithy dispassionately, "doesn't even scan."

"What do you mean, doesn't scan?"

"It doesn't," explained Smithy, "agree with the rules of metre."

"I wouldn't know about that," commented Dick cheerfully, "I leave all that sort of thing to the professionals, like Patrick Strong and John Betjeman. So long as the lines more or less rhyme at the ends they're good enough for me!"

**Bypass Electrolytics**

"Well, that," remarked Smithy, hastily changing the conversation, "seems to have buttoned up your little power unit. There's one thing that worries me about it, though."

"Oh yes," said Dick, "and what's that?"

"The question of limiting resistance for the rectifier. It's one of those things that so many home constructors seem to forget about."

"You mean," queried Dick, "en-
suring that there is sufficient resistance in each rectifier anode circuit to meet the valve manufacturer’s requirements?”

“That’s right.”

“In that case,” said Dick condescendingly, “I can set your mind at complete rest. I’ve been following the recent ‘Understanding Radio’ articles, which have been all about things like rectifier limiter resistors, and I’m not so big-headed as to refuse to pick up a few points from some other geyser in the electronics game!”

“You’re not so what?” spluttered Smithy.

“So big-headed,” added Dick, “I confess, I gasped the Serviceman, and it was only two months ago that you were going around upsetting G. A. French. What I can’t understand is why, at that last statement of yours, the heavens didn’t open up and a great streak of forked lightning come down and hit you on the bone!”

“I can’t see,” said Dick carelessly, “what you’re making all the fuss about. Anyway, since the rectifier anodes need a limiting resistance I checked up in the valve book. I’m using an EZ80 which, with 250-0-250 volts applied, requires minimum limiting resistances in each anode of 125Ω when the reservoir capacitor is 50μF. I measured the resistance of each half of the mains transformer h.t. secondary and these came to slightly more than 200Ω. So the effective limiting resistance in each rectifier anode must be well above the minimum of 125Ω. Also, I’m using a 16μF electrolytic instead of a 50μF component, so that makes things easier still.”

“Fair enough,” commented Smithy, “but why shouldn’t I look upon the reduction in reservoir capacitance as necessarily arguing that limiting resistance may be reduced below the valve-manufacturer’s minimum figures. One thing the limiter resistor does is to keep the current down if you switch on with the rectifier cathode hot, and at a time when the mains voltage is at a peak and the reservoir capacitor is discharged. Under these conditions, even the 16μF electrolytic will still act more or less as a dead short at the instant of switching on. The same applies also, of course, to any limiting resistor values quoted for silicon and selenium rectifiers, with the exception that these don’t require a hot cathode to operate.”

But Smithy’s words fell on deaf ears, and Dick offered no reply when the Serviceman finished.

“What’s up?” asked Smithy.

“There’s something,” said Dick pensively, “which has just occurred to me. I think I’ll have to change that meter switching circuit.”

“What on earth for?” asked Smithy.

“It seems perfectly good to me.”

“There’s a snag in it,” pronounced Dick. “The meter shunt resistance appears between the smoothing electrolytic and the h.t. positive terminal. This means that the h.t. lines to equipment run from the supply won’t be as well bypassed as they would be if the smoothing electrolytic connected directly to the h.t. positive terminal.”

“You’ve got a minor point there,” admitted Smithy. “But I shouldn’t worry too much about it, if I were you.”

“Why not?”

“Because,” explained Smithy, “if your power unit is going to supply any equipment which needs a well bypassed h.t. supply, I’d strongly advise you not to fit another electrolytic across the h.t. lines on the equipment itself.”

“What’s the reason for that?”

“You’re bound,” said Smithy in reply, “to have fairly long leads between the equipment and the power supply, and these will act as a common impedance to all h.t. circuits in your equipment, with a consequent risk of instability. It’s almost always desirable to use short wiring to any h.t. bypass capacitor. So far as this particular problem is concerned, what I’ve usually done in the past, when making up a power unit of the type you’ve got here, is to omit the smoothing capacitor altogether. I’ve then fitted h.t. bypass electrolytics in all the pieces of equipment which are intended to connect to the supply, whereupon these also act as smoothing capacitors.”

“That’s a neat idea,” commented Dick. “I wish I’d used it with my own power unit now. The trouble is that I can’t take out the smoothing capacitor because it’s in a double electrolytic with the reservoir capacitor.”

“Not to worry,” replied Smithy soothingly. “Every microfarad on the h.t. line makes the ripple smoother!”

Time To Go

“There’s another thought that’s occurred to me,” said Dick, who seemed to have entered into a mood of despondency. “I haven’t made any provision for discharging the electrolytics in the power pack when there’s no equipment connected to it. You can get some nasty shocks from charged electrolytics, you know!”

“You’ve forgotten something.”

“Have I?”

“You’ve forgotten,” said Smithy, “your built-in voltmeter circuit. If the electrolytics in the power pack are charged up, and no external equipment is connected, all you’ve got to do is to switch in the voltmeter. You can then sit down and watch its needle go slowly down to zero as it bleeds the charge off the electrolytics.”

“Oh of course I can,” exclaimed Dick, reverting to his usual optimistic self. “I’d forgotten all about the voltmeter circuit.”

He paused for a moment.

“Oh no,” said Smithy, watching his assistant with the helpless fascination of a rabbit before a snake, “not again!”

But it was too late.

“Our serviceman’s fees are essentially

The lowest you’ll find, confidentially

Since all his voltmeters

Work also as bleeders,

His charges reduce exponentially!”

Despite himself, Smithy couldn’t help but grin at his assistant’s latest excursion on the sea of verse.

“All right, boy,” he chuckled.

“I’ll allow that that one wasn’t quite as corny as the previous ones.”

“All my stuff,” pronounced Dick, with the air of Royalty unbending graciously to accept a small favour, “is good. Even though middle-aged Philistines such as yourself may not always understand its greater depths!”

Whereupon Smithy’s assistant, seeing from the Workshop clock that it was time to leave for the day, and forgetting all about the resistors he had intended to borrow, nipped smartly through the door, leaving a wrathful Serviceman to switch off and lock up.

But Smithy’s indignation soon changed into more purposeful contemplation as, later, he drove home in his car. If, he meditated, the gods that be couldn’t get organised on that business of opening up the heavens for the streak of forked lightning, perhaps a little mortal assistance might not come amiss. Mentally considering the number of kilovolts he could conjure up from his stock of line output transformers, together with their possible effect on his assistant, Smithy the Serviceman drove happily away into the gentle May evening.
The Use of Heat Sinks with Power Transistors

A. FOORD, Grad. I.E.R.E.

How to calculate heat sink dimensions

For almost every transistor the manufacturer specifies a maximum junction temperature which must not be exceeded under normal operating conditions. This temperature is denoted by the symbol \( T_{j\text{ max}} \). For a silicon transistor this may be of the order of 150°C, and for a germanium transistor about 90°C.

Thermal Equilibrium

The heat generated inside a transistor is conducted away to the case and absorbed by the surroundings. When the transistor is operated continuously the device must reach a thermal equilibrium with its immediate surroundings; with the result that the collector junction remains at a steady temperature above the ambient value. Since almost all the internal heat dissipation is at the collector junction, power transistors have the collector in contact with the mounting base. Thus, conduction of heat from the semiconductor wafer to the case takes place over a large cross-section. By attaching a cooling fin to the case, or by mounting the case on a heat sink, the effective surface area is increased. This gives a considerable improvement on the speed of heat transfer to the air.

Where no potential exists on the heat sink which might affect the collector voltage, the transistor is bolted directly to the heat sink. In other instances the transistor is isolated electrically from the heat sink by means of a mica washer and two bushes. Since this washer is thin, there is very little resistance to the flow of heat. If possible, it is better to isolate the heat sink electrically from the chassis and mount the transistor directly on the heat sink, since this gives the least possible thermal resistance from the transistor mounting base to the sink.

Thermal Resistance

From the junction to the air we have a temperature gradient, this extending from junction temperature (say 90°C) to air temperature (say 25°C). The temperature gradient is shown in Fig. 1, and it will be noted that we have a temperature drop from the junction to the mounting base, from the base to the heat sink, and from the sink to the air.

The terms “air temperature” and “ambient temperature” are used as synonyms, although for equipment working in a confined space ambient temperature may be 45°C and not the 25°C normally associated with air temperature. Ambient temperature simply means the temperature of the air surrounding the heat sink. The various temperature gradients will depend on the power dissipated in the transistor, and are given as thermal resistances in degrees per watt. The symbols used for the various thermal resistances are given in Fig. 1.

Example 1

To take an example, let us suppose that the maximum rated junction temperature of a transistor is 90°C. The thermal resistance from the junction to the mounting base is quoted as 1.5°C per W. If we wish to dissipate 10W, what is the maximum temperature we can allow the mounting base to attain?

Then: \( T_{j\text{ max}} = 90°C \), \( P_{\text{tot}} = 10W \)
\( \theta_m = 1.5°C/W \), \( T_{\text{case}} = ? \)

If we dissipate 10W, the temperature drop from the junction to the mounting base is given by:

\[
T_{j\text{ max}} - T_{\text{case}} = P_{\text{tot}} \times \theta_m
\]
\[
90 - T_{\text{case}} = 10 \times 1.5
\]
\[
T_{\text{case}} = 90 - 15
\]
\[
T_{\text{case}} = 75°C
\]

We must, therefore, keep the mounting base temperature below 75°C.

In this example we saw how to work out the mounting base temperature for a given power dissipation and junction thermal resistance. If we wish to work out the heat sink temperature we can deal with \( \theta_i \) by adding it on to \( \theta_m \) in our calculations.

If a mica washer is employed \( \theta_i \) is, typically, equal to 0.5°C/W and, with a lead washer, to 0.2°C/W. A lead washer is sometimes used between the transistor case and the heat sink since it moulds itself to the contours of the two surfaces and causes good thermal contact between them. With a mica washer the transistor mounting base is sometimes smeared with high thermal conductivity silicone grease before mounting in order to minimise any air gaps due to surface irregularities.

Up to now we have considered the thermal resistance to the case, and the thermal resistance
of the lead or mica washer (if used). These two values are fixed by the manufacturer, and are beyond our control. We therefore only have control over one part of the system—the heat sink or cooling fin.

Heat Sink Design for Natural Air Cooling

The thermal resistance of a flat heat sink or fin supported in free air depends on its thickness, shape, orientation, surface area, temperature, material, nature of its surface, and the temperature of the cooling air. The curve given in Fig. 2 may be used to determine the fin area required for a given value of \( \theta_h \). This curve applies under the following conditions:

1. The fin is vertically mounted.
2. It is made of bright aluminium or copper \( \frac{1}{4} \) in. thick or thicker.
3. The ratio of length to breadth should be less than 2:1.
4. The hottest point is at least 25°C above the surrounding air temperature.
5. The transistor is mounted near the centre of the fin.

In the curve the heat dissipated due to radiation is neglected since the surface is assumed to be bright. If appreciable radiation occurs, the fin area can be reduced. For a single fin with a matt black surface, the area can be reduced to 0.7 times the value calculated from Fig. 2.

Our heat sink must, then, have a thermal resistance given by:

\[
\theta_h = \frac{T_{\text{case}} - T_{\text{ambient}}}{P_{\text{tot}}} \quad \text{°C/W}
\]

or, if we work from the heat sink temperature, then:

\[
\theta_h = \frac{T_h - T_{\text{ambient}}}{P_{\text{tot}}} \quad \text{°C/W}
\]

If we work directly from the junction temperature, we have:

\[
\theta = \frac{T_j - T_{\text{ambient}}}{P_{\text{tot}}} \quad \text{°C/W}
\]

where \( \theta \) is the total thermal resistance from the junction to air, and is given by:

\[
\theta = \theta_m + \theta_j + \theta_h
\]

Thus:

\[
\theta_h = \frac{T_j - T_{\text{ambient}}}{P_{\text{tot}}} - \theta_m - \theta_j \quad \text{°C/W}
\]

Example 2

If \( T_j = 90^\circ \text{C}, \theta_j = 2.2^\circ \text{C/W}, \) \( P_{\text{tot}} = 10 \text{W}, \theta_m = 0.5^\circ \text{C/W}, \) \( \theta_m = 1.5^\circ \text{C/W}, \)

Calculate \( T_{\text{case}}, T_h \) and \( T_{\text{ambient}} \). From the junction to the case the temperature drops by:

\[
T_{\text{case}} - T_j = P_{\text{tot}} \times \theta_m
\]

\[
T_{\text{case}} - T_j = 10 \times 0.5 = 5 \text{°C}
\]

\[
T_{\text{case}} = 75^\circ \text{C}
\]

Example 3

If \( T_j = 90^\circ \text{C}, \theta_j = 0.5^\circ \text{C/W}, \) \( P_{\text{tot}} = 5 \text{W}, \theta_m = 1.5^\circ \text{C/W}, \)

\[
T_{\text{ambient}} = 25^\circ \text{C},
\]

what is the minimum size of heat sink required? If it were painted matt black, what size would it need to be?

Now:

\[
\theta_h = \frac{T_j - T_{\text{ambient}}}{P_{\text{tot}}} - \theta_m - \theta_i
\]

\[
= 90 - 25 - 0.5 = -1.5
\]

\[
\theta_h = 11^\circ \text{C/W}.
\]

1 This curve is taken from the booklet The Use of Semiconductor Devices, published by the Electronic Valve and Semiconductor Manufacturers’ Association. Acknowledgements are due to the Association for permission to reproduce the curve here.—Editor.

2 The value for \( \theta_h \) chosen for this example (2.2°C/W) is a little lower than the range covered by the curve of Fig. 2, which indicates heat sink dimensions that may under normal conditions be safely applied. The figure of 2.2°C/W is quoted by Mullard, in their literature on the OC28 series, as the \( \theta_h \) for an air-cooled heat sink of 7 x 7 x \( \frac{1}{4} \) in made of blackened aluminium.—Editor.
Isolation by Capacitors

One of the minor difficulties which beset audio enthusiasts is the problem of coupling the sound channel of a mains-operated television receiver to a high fidelity amplifier or to a tape recorder. The reason for the difficulty is that, whereas the high fidelity amplifier or tape recorder chassis are fully isolated from the mains supply, that of the television receiver is not. Practically all the exposed metalwork on high fidelity equipment is at chassis potential and, because of the mains isolation, offers no shock hazard at all. On the other hand, television chassis are connected to one side of the mains supply and must not, under domestic conditions, be touched at all.

Isolation by Capacitors

How, then, can the sound channel of a television receiver be safely coupled to the input of a high fidelity amplifier? It might at first sight be thought that the coupling could be made by means of isolating capacitors as shown in my accompanying diagram, Fig. 1 (a). In this, the television receiver is connected to the mains supply such that its chassis is at neutral potential. An a.f. signal is taken, for the purpose of illustration, from the sound detector load, and it is assumed that the high fidelity amplifier chassis is at earth potential. But there is a hidden snag in this arrangement. The neutral line of the mains supply is rarely at true earth potential, and it normally carries a volt or so with respect to earth. For instance, in my own house at the moment (I've just got out the testmeter to check it!) the a.c. potential between the neutral line and earth is 0.7 volts. This small alternating voltage appears across C2 in Fig. 1 (a), whereupon this component can be replaced by a generator offering the same voltage, as in Fig. 1 (b). The result is that the voltage applied to the high fidelity amplifier input is the sum of the signal voltage plus the alternating voltage between the neutral side of the mains and earth, and reproduction from the hi-fi loudspeaker will be marred by a continuous, and probably very loud, hum. If, due to incorrect connection to the mains, the television chassis assumes live mains potential, the generator of Fig. 1 (b) will be churning out some 240 volts a.c., and there will then be a prodigious hum, to say the least, from the hi-fi amplifier!

Even if the hi-fi amplifier chassis is not connected directly to earth, the hum problem will still exist. This is because the hi-fi chassis will be coupled capacitively to the mains via stray capacitances in its mains transformer and any anti-mains-modulation capacitors which may be fitted, and will then take up an a.c. potential relative to earth which will almost inevitably be different from that on the TV chassis. Increasing the value of C2 doesn't provide an answer under these conditions, either. For safety reasons, the sum of C1 and C2 should not be allowed to exceed 0.02 uF.

Isolation by Transformers

Isolation between the two chassis by way of capacitors offers, therefore, no help at all towards solving the present problem. The only other simple means of isolation is by way of transformers and here, fortunately, there are two very simple solutions to the problem. One of these solutions, the cheaper, has the disadvantage that the circuitry involved is not quite hi-fi. The other allows full hi-fi techniques to be followed but at much greater expense.
Fig. 2 (a) shows how an isolating transformer may be coupled to the existing output transformer in the receiver, the secondary of the added transformer coupling to the high fidelity equipment. The isolating transformer is a special type which is specifically designed to offer full isolation, at mains voltages, between its primary and secondary. Two transformers in this category are manufactured by Radiospares Ltd., and I must hasten to add that they can only be obtained through radio retailers. Radiospares do not supply components direct to members of the public.

The two Radiospares transformers are known as the "Universal" Speaker Isolating Transformer and the "Midget" Speaker Isolating Transformer. As a guide to prospective purchasers these transformers are available from Home Radio (Mitcham) Ltd. under Cat. No. T070 for the "Universal" and Cat. No. T071 for the "Midget". Alternatively, you can obtain them from your own local component supplier.

The main function of these transformers is to isolate extension loudspeakers or headphones when employed with live chassis radio and television receivers. They may also be used to provide isolated feeds for tape recorders and the like. The "Universal" has the further advantage of being able to match loudspeakers to various impedances. Both transformers are flash-tested at 2.000 volts a.c., and the insulation between primary and secondary is completely adequate for mains isolation. The "Universal" measures 2.12in wide by 1.87in high by 1.62in deep, and has fixing centres at 2.5in. Both the primary and secondary are tapped at 3, 7 and 15Ω to provide any particular speaker matching which may be required. The transformer has a "snap-on" cover to guard the terminals when mounted in accessible positions, and its power rating is 5 watts maximum. The "Midget" is a smaller and more inexpensive component which is intended to give a 1:1 ratio in the isolating transformer, the fixed resistor has the same value as the loudspeaker impedance.

The switch wiring of Fig. 2 (b) should be inside the television cabinet so that none of the connection points can be inadvertently touched, and it will probably be found that the switch, itself, may be readily mounted on the back cover of the TV set. A rotary type with insulated knob is preferable. High a.f. voltages can be developed across the primary of a valve speaker transformer if its secondary is unloaded, whereupon the switch should, ideally, be of the make-before-break type. However, the ordinary type of switch should suffice in practice if the output transformer is not carrying high level signals at the moment of switching over.

The circuits of Fig. 2 represent the instance I mentioned earlier where the circuitry is not quite hi-fi. This is because the detected sound signal has to pass through the a.f. stages of the receiver, which are almost certain to include a single-ended output pentode, and two transformers. Fig. 2 (a) is a little worse than Fig. 2 (b) because the output valve load is a loudspeaker whose impedance will vary quite considerably with frequency. Nevertheless, if the volume control in the television receiver is kept at a low level (mainly to keep down distortion introduced in the receiver a.f. stages) reproduction over the hi-fi system should be quite acceptable and should be noticeably better than occurs with the TV receiver speaker on its own. If the output from the secondary of the isolating transformer is coupled to a tape recorder, the results obtained will, of course, be streets ahead of what is given by such artifices as placing the tape recorder microphone in front of the TV loudspeaker.

The voltage available across the secondary of the output transformer should be more than adequate for normal purposes. If, for instance, the TV volume control is set to produce an output of 50mW, this corresponds to nearly 0.4 volts across an impedance of 3Ω. The secondary of the isolation transformer could, therefore, be plugged direct into the "radio tuner" socket of any normal high fidelity amplifier. No trouble should be given by
feeding the "radio tuner" input of the amplifier from the very low source impedance offered by the isolation transformer.

These last comments assume that the TV volume level will be turned well down when coupling up to the hi-fi equipment. This should satisfy most instances likely to be encountered in practice, but it may occasionally be found that, with some TV sets, the level of background noise (hiss, "frame tick", etc.) relative to sound level increases at low volume control settings. If this occurs, a compromise setting of the TV volume control is needed which causes these background noises to be over-ridden by signal level, without the latter being too high to introduce excessive (by hi-fi standards) distortion.

**Isolating the TV Set**

The use of an isolating output transformer offers a safe, inexpensive, and very simple method of coupling a mains-operated TV set to high fidelity equipment. But it may not satisfy the seeker after perfection, who will want to take his output direct from the sound detector circuit in the television receiver. There is, however, one completely practicable answer for the perfectionist, and it consists of isolating the entire TV set!

A suitable component for carrying out this function is the Radiospares 200 Watt Mains Isolating Transformer, and I must once again state that this component can only be ordered through a retailer and not direct from Radiospares Ltd. This transformer is primarily intended to isolate a.c./d.c. equipment being serviced on the test bench, and its power rating of 200 watts is quite adequate for any conventional television receiver. The transformer has a 1:1 ratio and can handle the full rated load at any voltage in the range of 200 to 250. Its width is 4in, its height is 4.75in, its depth is 4.5in, and its fixing centres (four holes) are 3.5 by 3.31in. The weight is a good solid 12lb. As is to be expected, this transformer is considerably more expensive than the two output isolating transformers of Fig. 2, and readers contemplating its use should ascertain its cost before ordering. It offers, nevertheless, an extremely tidy solution to the problem of obtaining really high fidelity coupling from the sound channel of a mains operated TV set. The transformer is connected up between the mains supply and the TV receiver in the manner shown in Fig. 3.

One final point needs to be resolved. When the circuit of Fig. 3 is used, the constructor may find difficulty, even with the service manual of the TV receiver before him, in finding a suitable take-off point for the hi-fi amplifier input. This is because the television sound detector is normally followed by a sound interference limiter, whereupon the circuitry tends to become rather complicated. Further complexity is introduced if the TV receiver is a dual-standard model, in

---

**Fig. 2 (a).** Incorporating an isolating transformer between the TV receiver and the amplifier.

(b). An alternative way of using the isolating transformer. The load resistor should have a wattage rating equal to the output power of the output valve.

**Fig. 3.** Isolating the TV set. S2 is the on-off switch installed in the television receiver, whilst S1 is an external switch. The outer conductor of the screened cable now connects direct to the TV chassis.
which the 405-625 switching arrangements cause an output to be taken either from the 38.15 Mc/s a.m. detector on 405 lines, or the 6 Mc/s f.m. detector on 625 lines. Yet another pitfall for the unwary is that the input resistance of the amplifier should not cause the a.c./d.c. a.m. diode load ratio to be seriously upset. (For the record, the d.c. diode load is the resistor immediately following the a.m. detector, and the a.c. diode load is this resistor in parallel with any other resistors coupled to it by way of capacitors. The ratio should not be too far removed from unity if distortion on certain types of modulation is not to occur.)

Fortunately, these problems may all be overcome with nearly every type of TV set by the simple process of taking the detected a.f. from the slider of the television receiver volume control, as in Fig. 4. This should ensure that the take-off point is after the sound interference limiter and the 405-625 switching circuits. Also, provided that the television volume control is not advanced more than about one-third of full travel when the high fidelity equipment is connected, the input resistance at the “radio tuner” input socket of a conventional amplifier should not unduly upset the a.c./d.c. diode load ratio. Although unlikely in conventional TV receiver circuits, it is possible that a direct voltage may appear on the track of the volume control due to a.g.c. circuits and the like. If such a voltage is present, a 0.01 μF capacitor may be inserted at the point marked with a cross in Fig. 4.

A.C./D.C. Receivers

Up to now we have concerned ourselves mainly with the problem of taking an a.f. output for high fidelity equipment from a TV receiver. The techniques used will also, of course, apply equally well to taking a similar output from an a.c./d.c. sound receiver. In this case, it should be possible to use a smaller and more inexpensive mains isolating transformer if a similar circuit to that of Fig. 3 is to be employed, and the Radiospares range includes a 75 Watt Mains Isolating Transformer which is ideal for this purpose. This has a 1:1 ratio and can operate at full load for input voltages from 200 to 250. The dimensions are 3.12in wide, 4in high, 3.80in deep, with fixing centres (four holes) at 2.62 x 2.51in. The weight is 5½lb.

Camera Tube Assembly

I seem to have taken up nearly all my space this month discussing isolating transformers, but I would just like to slip in a few more words before finishing on the subject of the accompanying photograph.

This shows an operator spot-welding the electrodes of a 4¼in image orthicon TV camera tube, one of the processes carried out at the Hayes plant of E.M.I. Electronics Ltd. The particular electrode assembly shown is quite a “handful”, as you can see, and it constitutes, in fact, the image transfer system between the photo-cathode and the glass storage target of the E.M.I. tube. The upper welding contact protrudes vertically downwards from the block above the girl’s right hand, the heavy welding current flowing through the six flexible copper straps connecting to this block from the main body of the spot-welding jig.

The electrode assembly shown is of particular importance so far as the quality of focus and accuracy of geometry of the resulting TV picture is concerned, and it is necessary to observe careful alignment of its constituent parts.

Spot-welding the electrodes of the image transfer system for a 4¼in image orthicon television camera tube at the Hayes plant of E.M.I. Electronics Ltd.
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**Continued on page 717**

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