TRANSMITTER PROTECTIVE CIRCUITRY

By Norman L. Morgan, W7KCS/9

EVERY TRANSMITTER should have circuits designed into it to protect valuable components—and especially the transmitting tubes—against failure due to accidental overloads. Be safe—not sorry—with these low-cost circuits by W7KCS/9.

Adequate protection of transmitting tubes is like taking out fire insurance for your home—it's pretty inexpensive compared with the cost of power components. Often power tubes failures happen during initial testing when the builder is busily checking the transmitter operation and fails to notice damaging currents in expensive tubes.

Ideally the philosophy of protection should be that the tube can survive on only its own protective circuits, as shown in Fig. 1. With this idea as the objective in designing power supplies, only the usual precautions are needed to prevent extensive tube and component damage.

Electrical failures are caused by excessive element heating or element overvoltage. Excessive dissipation is generally a result of (1) loss of excitation, (2) failure of plate or bias supplies, or (3) excessive loading. Overvoltage is mainly a result of low voltage drop in series resistors when power is correctly applied to the tube.

Loss of excitation in unprotected circuits can cause damaging screen and plate currents. Protection is generally supplied by clamp tubes or fixed bias to cut off these currents. Although clamp tube operation is quite popular and is extensively used by many amateur designers, it must be realized that screen grid voltage variation is built in with these circuits. Clamp tubes usually operate with a dropping resistor which results in undesirable screen voltage changes so detrimental to good SSB operation of a linear amplifier.

On the other hand, the high reliability and positive protection of fixed bias to cut off currents allows the screen grid to be operated directly from a stiff power source to achieve the good voltage regulation necessary for class AB (triodes in class B) operation of the power amplifier.

Loss of plate voltage in tetrode or pentode tube essentially transfers plate current to the screen if it is separated from screen grid current by protection circuits described in this article. Actual failure of the plate power supply is a rare phenomenon, but its effect is the same as when the high voltage power supply switch is accidentally switched on with the transmitter operating. This is especially true during initial tune-up, neutralizing, or retuning. Even when the plate power supply may not be energized, although screen voltage may be accidentally applied along with power to exciter stages.

(continued on page 2)

NEAT STATION AT W7KCS/9, including the compact 500-watt CW and AM transmitter in which the protective circuits described in this article are installed. Transmitter covers 2.5 to 29.7 megacycles, and, except for commercial VFO and dial, is completely home made. Norm Morgan operates ¾ transmitter mainly on the 21 and 28-megacycle bands. He is an Application Engineer with General Electric's Specialty Motor Department in Fort Wayne, Indiana. Norm has also authored several articles on electronic control circuits in trade magazines.

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The two most used methods of preventing screen damage due to these circumstances are (1) screen dropping resistors or screen wattage limiting resistors, and (2) various current relays. The dropping resistor alone can cause screen grid failure through overvoltage resulting from low screen current.

The undesirable effects of poor screen grid voltage regulation through a dropping resistor can be partially offset by connecting a volt-

age regulator VR tube as shown in Figure 2. The wattage limiting re-
sistor is chosen so that the screen grids cannot draw more than rated dissipation no matter what current they demand. The voltage regulating tubes maintain the 256 volt screen voltage for all normal values of screen current.

Should the screen grid begin ex-
cessive current the limiting resistor drops the voltage, extinguishing the VR tubes and limiting the total dis-
sipation of the screen grid to a safe level. Note that the screen grid should be operated somewhat less than maximum allowable wattage in order to leave some reserve for this action.

SCREEN GRID OVER-CURRENT RELAYS or plate voltage sensing screen re-
lays allow the screen voltage to be supplied by a stiff power source. The screen grid current sensitive relay is probably the most positive method of preventing failure. It will dis-
connect screen voltage when the

screen grid current is excessive.

However, a less expensive method, the plate voltage sensing relay, pro-
tects the screen when the plate voltage is not present and can be connected from the high voltage bleeder resistor to ground, as shown in Figure 2. The plate voltage will thus approach its full value before the screen power supply is connected to the plate circuit. Unless there is plate voltage present, no screen voltage can be applied to the power amplifier or modulator tubes.

Failure of the negative control grid bias supply when it is used, is fortunately a rare occurrence. How-

ever, protection against this failure can be accomplished by installing re-

lays in the plate and screen circuits which turn on these voltages only when bias voltage is present.

A push-to-talk switch can be con-

nected in series with a voltage sens-
ing relay which energizes the AC side of both the high voltage power supply and the screen power sup-
plies. Notice in the schematic dia-

gram of Fig. 2 that the voltage sensing relay is operated directly from the power amplifier grid bias source. Thus, plate and screen power cannot be applied unless grid bias is pres-
ent. This relay in turn actuates the power relay which actually closes the primary AC circuits.

Since the coil current of the pow-

er relay is less than the normal primary current, it is advisable to use a small, low current relay in the push-to-talk circuit to actuate the power relay. Also, the power relay should be rated con-

siderably higher than the normal primary current, since this current is largely inductive and may cause arcing and pitting of contacts on low value AC motors. Ideally AC motor starting relays should be used to minimize these difficulties.

Damage to the power amplifier tubes can result from exces-

sive plate loading, and can be pre-
vented by plate over-current relays, other element relays, or by careful tune-up procedure. Normally, during initial tune-up a wary eye is kept on the plate currents so that excessive loading of these circuits is generally only a result of careless procedure. At first glance these schematic diagrams (Figs. 2 and 3) appear to contain several electro-mechanical elements; however, it is surprising how inexpensively voltage-sensitive relays can be obtained. The two voltage-sensitive relays used in the WTKCS transmitter were less than $\$1.00$ each.

Low-cost silicon diodes have greatly simplified the construction of grid bias supplies because they provide extremely low resistance in the forward direction. This is important in bias supplies since the over-all equivalent resistance of the supply adds to the grid leak resistance to determine the total grid bias under excitation.

In the WTKCS transmitter it is necessary to provide two values of bias voltage: namely, minus 105 volts power amplifier, and minus 35 volts for the modulator. Ninety of the 135 volts are obtained across the 90-volt regulator tube in the circuit of the dual bias supply, Fig. 3.

The AC side of the circuit is two 110/35 volt transformers connected primary to secondary and secondary to primary. With the low current drawn on the bias supply it is possible to maintain a DC voltage nearly the same as the input AC RMS voltage — or, the output voltage can be greater than the AC input voltage by using input filter capacitance. In addition, the high capacitance improves the normally poor regulation of half-wave rectifier supplies. Current limiting resistors are used (the 100 ohm resistor in the 90 volt supply) in order to reduce the transient currents during the first rise-cycle of the rectifier. These small rectifiers cannot handle an extremely high current for an extended length of time; consequently, the impedance looking toward the source must sometimes be artificially made higher. In the low voltage (35 volts) supply the in-rush current was well within the approximately 20 amperes one cycle limit on these rectifiers.
THE ADVANTAGES of inductive tuning in high stability oscillators (VFO's) have long been recognized by manufacturers of radio equipment. Unfortunately, the construction of a precision, high stability variable inductance is beyond the capabilities of the average radio amateur, and he has had to be content with capacitive tuning for his home built VFO. These VFO's are capable of excellent stability, but such stability is achieved only through meticulous attention to mechanical as well as electrical construction.

The pros and cons of the most popular types of capacitance-tuned oscillators — the Clapp and the high "C" Colpitts — have been exhaustively discussed in the amateur journals in recent years. The Clapp circuit is capable of excellent stability but mechanical problems of anchoring down the large, high "Q" inductance, together with variations in output over wide frequency changes remain bugaboos.

The high "C" Colpitts does away with the inductance mounting problem because the required coil is small and can be made mechanically sturdy. Large values of voltage di- vider capacities are required, however, and these, in turn, call for the use of extremely large values of tuning capacitances to cover the lower frequency bands. Such tuning capacitances are generally available only as replacement two or three section broadcast types, which are not designed for precision tuning. The flimsy construction and large mass of such units again lead to mechanical stability problems.

In the Clapp, this large amount of capacity is extremely sensitive to humidity changes because the major portion of the dielectric is air. A gentle breath into the tuning capacitor of the high "C" Colpitts VFO can cause a frequency shift of several hundred cycles. While the average ham doesn't make a practice of breathing into his VFO, changes in the humidity content of the shack can cause short-term instability, particularly on "muggy" summer days.

The majority of high stability VFO's require some degree of temperature compensation and here again, the capacitively tuned oscillator is at a disadvantage because perfect compensation can be obtained only at one setting of the tuning capacitor. This problem is minimized in the inductively tuned circuit because the amount of capacity in the circuit remains fixed.

Most of the above mentioned problems are licked in this VFO exciter through use of an inductively tuned high "C" Colpitts oscillator tuned with a Mallory "Inductuner." Amateurs with a background in television will recognize the Inductuner as the front-end tuning device used in many TV receivers manufactured ten years or so back. The unit was manufactured in two, three and four section units and was used to provide continuous tuning of the TV and FM spectrum from 64 to 220 Mc. Each section of the tuner consists of a spirally wound, silver plated inductance firmly bedded in low-loss plastic.

A silver plated slider driven by the tuning shaft rides along the inductance under tension. The excellent high frequency, electrical and mechanical characteristics of this tuner make it a good choice for use in a VFO and enable relatively simple construction of a tuned circuit which results in superb stability.

At first glance it would seem this VHF tuner could not possibly have enough inductive range to be useful at the lower frequency at which VFO's generally operate. The high "C" Colpitts circuit, however, requires very little inductance, even in the two megacycle range. Each section of the Inductuner has a maximum inductance of approximately 3 microhysteres and in the circuit shown one section of the tuner is used in conjunction with a fixed inductance and fixed capacitors to cover the 1.76-2.0 Mc. range. By properly proportioning the fixed inductance and capacitors the desired range is made to occupy almost the complete six turn tuning spread of the Inductuner as shown in Fig. 1. Some form of turn counting type dial is required for the Inductuner. The dial shown in the photographs is a Model 1220 series Microdial manufactured by Borg Corporation, Janesville, Wisconsin. This dial has provisions for ten turns broken down into 100 divisions per turn, and while it was designed for Microtaps, it works fine in this application.

The two section Inductuner in the unit shown in the pictures was salvaged from an old TV booster. Most TV receivers employing this unit were equipped with the three section unit and some scrapping in the back stairs basements of TV service shops should turn up this little gem. It may also be available on some of the surplus market. While only one section is used in this particular design there is no reason why two or more sections cannot be connected in series or parallel to provide more

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**INDUCTIVE TUNING FOR HIGH-C RF OSCILLATORS**

By Jack Nolajki — KYODE

KYODE TUNES UP HIS VFO EXCITER after completing construction. Exciter is housed in perforated metal case shown left. Closer Corner of home-built transmitter appears on shelf above station re- turn light. Jack Nolajki received his 5TH license in 1954 and became KYODE in 1958. He operates mostly on CW, with some voice operating on double sidetone and 144 megacycles.

KYODE is District Sales Manager in Chicago for General Electric's Communication Products Department, which manufactures and sells G. E.'s famous Progress Line two-way mobile radio. He formerly was located in Syracuse, N. Y., where he was an engineer on electronic test equipment, and later a field engineer for the radio and television repair department. Jack Nolajki writes a number of articles describing his home-built equipment for amateur radio and other electronics publications.
The exciter is keyed in the doubler, multiplier and external buffer cathode circuits. If desired, the keying circuit can be adapted to a different keying system. The current transmitter driven by this exciter consists of a 6L6 buffer driving four 6146’s in DSB and when this mode of operation is used the push-to-talk relay also keys the exciter. For frequency spotting, the control switch activates the exciter stages only. The fixed inductance used in conjunction with the inductance is a home-made toroid wound on a toroid form sliced from a Command transmitter tuning slug as described by WFPME. Dimensions of the core are shown in Fig. 3. Although a conventional coil wound on a ceramic form can be used in place of the toroid, the toroid is strongly recommended because its smaller mass and electrical field contribute to both electrical and mechanical stability.

(continued on page 6)
INDUCTIVE TUNING

(continued from page 5)

CONSTRUCTION of the complete VFO-excitier was accomplished on a standard 4 x 6 x 2-inch deep alumi-
num chassis (Bad AC-431, or equiv.

lent). The odd-size panel on KoDGE's model shown in the pictures was
made to fit an available cabinet in
which the unit was housed. Major
parts were fastened in the locations
shown in the chassis diagram, Fig 4.

By following good construction
practices the aluminum chassis will
be found to be adequate for excel-

lent mechanical stability (as much as
the rugged Inductuner eliminates most
of the common mechanical problems.
All frequency components should be
mounted on one surface of the chas-

sis so that flexing of the chassis
sides will not change their relative
positions. As hammered home many
times: anchor everything solidly.

All wiring and components in
and around the oscillator circuit should be

cemented or waxed to the chassis
to prevent movement and vibration.
The author used low melting point
wax of the type used in ingot molds.
It is easy to flow around com-
ponents and does a good job of hold-
ing things in place.

TUNEUP — With the components
shown in TABLE 1 — PARTS LIST
the VFO tuning range will be close to
1.75 — 2.0 megacycles. Some ad-
justment of inductance or capacity
may be required. A considerable var-
iation in toroid inductance can be
made by simply spreading or com-
pressing the turns on the form. To
increase the tuning range, reduce
the inductance by spreading
the toroid turns. This will also move
the range higher in frequency and it
may be necessary to add fixed capac-
ity across the inductances to bring
the range down to the desired fre-
quency. If the frequency spread is

too great, increase the toroid induct-
ance and decrease the fixed capacity
across the inductances to bring
the range back to the desired fre-
quency.

The slug-tuned coils used in the
oscillator plate and doubler plate

circuits were made from a 4.5-mega-
cycle interleaver transformer found
in the Jack box. Standard commer-
cial counterparts can be used, of
course.

The 6CL6 plate circuit components
are tailored to take into considera-
tion the capacity introduced by 18"
of RG8U cable feeding the grid of
a 6L6 stage in the transmitter. If a
short, direct connection is used from
the 6CL6 plate to the following grid,
the inductances will have to be in-
creased in value to resonate at the
desired bands. If low impedance out-
put is required, links can be wound
over the plate coils and switched
by an additional section of the band-
switch.

PERFORMANCE — Many tests of
the high "C" Colpitts oscillator show
that short-term instability, or drift,
is caused by two factors. The first is
RF heating of the voltage divider
capacitors which results in approxi-
mately 200 cycles positive (lower
frequency) drift during the first ten
minutes of operation.

The second cause is thermal heat-
ing of the tuned circuit caused by
heat from the oscillator tube socket
reaching these components via the
connecting leads. This second effect
can be minimized by using an oscil-
lator circuit and tube which require
a minimum of heater and plate pow-
er. In addition, components are lo-
cated far enough away from the socket to prevent efficient thermal trans-
fer. This thermal heating effect is
most pronounced on the induct-
ance in the tuned circuit and in this
design the Inductuner plus the to-
roid are positioned so very little,
if any, heat can be conducted to them
from the oscillator tube socket.

Heating of the voltage divider

presents HOW-TO-DO-IT IDEAS
from the 999 radio amateurs at

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ship arising from the use of such information by others.

502 inches of toroid will come
used for oscillator Inductance is.
Material is powdered iron.

Fig 2. DIMENSIONS of toroid will come
used for oscillator Inductance is.
Material is powdered iron.
TRANSMITTER PROTECTIVE CIRCUITRY

THE COMPLETE POWER SUPPLY for the transmitter at W7KCS is shown in the schematic diagram of Fig. 4. Note that all of the foregoing features have been included in this circuit. Power is fed into the power supply through a 3-prong AC line plug which provides for automatic grounding of the transmitter cabinet and chassis. A time-delay switch is included in the high voltage supply primary circuit to provide 60 seconds delay after the GL-3B28 filaments are energized, before the high voltage transformer can be energized.

Good construction practice should be followed in this unit, including adequate insulation in high voltage circuits, fastening small parts securely to prevent movement, etc. The

photographs of W7KCS's transmitter and power supplies on these pages show many of these construction details. Readers are also referred to the "Power Supply Construction" chapter of the ARRL Radio Amateurs' Handbook for further suggestions.

Although W7KCS's protective circuits have been utilized in his AM transmitter, they are also excellent for the bias, screen grid and plate voltage power supplies for linear amplifiers. They can be easily added as subassemblies to existing power supplies.

It's smart to protect the lives of your transmitting tubes — not to mention your own life — by including these simple, but effective circuits in your transmitter.
MEET RADIO AMATEURS AMONG G-E TUBE DISTRIBUTORS

Harry A. Tummonds, W3BAH, owner of Northern Ohio Laboratories in Cleveland, Ohio, recently received the 1961 Public Service Award of the Ohio Council of Amateur Radio Clubs at the Dayton Hamvention. The award plaque reads, "Presented to Harry A. Tummonds, W3BAH, by the Ohio Council of Amateur Radio Clubs for Meritorious Journalistic Public Relations on Behalf of Amateur Radio, April 25, 1961." Harry recently completed two years of writing a weekly newspaper column on amateur radio, "Ham Antenna," for the Cleveland Plain Dealer.

An enthusiastic amateur since 1920, Harry specializes in distributing amateur radio equipment, and sees that his customers regularly receive copies of G-E HAM NEWS.

ANNOUNCING 10TH ANNUAL EDISON RADIO AMATEUR AWARD

Nominations for the 1961 Edison Radio Amateur Award are now open. This year marks the tenth anniversary of General Electric’s annual Edison Award, established in 1952.

The Award is presented annually to a licensed radio amateur who, while pursuing his or her hobby within the limits of the United States, has performed an outstanding and meritorious public service in behalf of a group, the general public, or an individual.

Full details on the Award, and nomination forms, are available from the G-E HAM NEWS office. Complete the public service record of your candidate now and mail it well before the deadline, January 2, 1962.

Available FREE from your G-E Tube Distributor

COMPIILATION of the 3rd Bound Volume of G-E HAM NEWS has been finished and the completed books are being shipped from our bindery starting in September. This 340-page book contains copies of all issues from January-February, 1956 (Vol. 11, No. 1), to November-December, 1960 (Vol. 15, No. 6), totalling 260 pages.

In addition, the 3rd Bound Volume contains an 80-page supplement with additional information, circuits and comments on many of the articles in the above issues; and a Cross Index of all articles published in G-E HAM NEWS from 1946 (Vol. 1) to the end of 1960 (Vol. 15).

The price to radio amateurs in the United States and possessions is $3.00, postpaid. The 3rd Bound Volume should be ordered from the G-E HAM NEWS office, and remittance payable to "General Electric Company" enclosed with order.

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