TRANSMITTER
PROTECTIVE
CIRCUITRY

By Norman L. Morgan, W7KCS/9

EVERY TRANSMITTER should have cir-
cuits designed into it to protect valuable
components—and especially the transmit-
ting tubes—against failure due to acci-
dental overloads. Be safe—be wise—
with these low-cost circuits by W7KCS/9.

Adequate protection of transmitting
tubes is like taking out fire in-
surance for your home—it’s pretty
inexpensive compared with the cost of
power components. Often power
tube failures happen during initial
testing when the builder is busy
checking the transmitter operation
and fails to notice damaging cur-
rents in expensive tubes.

Ideally the philosophy of protec-
tion should be that the tube can sur-
vive on only its own protective cir-
cuits, as shown in Fig. 1. With this
idea as the objective in designing
power supplies, only the usual pre-
cautions are needed to prevent ex-
tensive 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 ex-
citation; (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
bias 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 cir-
cuits. Clamp tubes usually operate
with a dropping resistor which re-
sults in undesirable screen voltage
changes so detrimental to good SSB
operation of a linear amplifier.

On the other hand, the high re-
liability and positive protection of
fixed bias to cut off currents allows
the screen grid to be operated direct-
ly 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
separately powered, which generally
results in excessive screen grid cur-
rent and rapid failure.

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 ac-
cidentally switched off during opera-
tion. This is especially true during
initial tune-out, when monitoring
when the plate power supply may
not be energized, although screen
voltage may be accidentally applied
along with power to earlier stages.

(continued on page 2)
FIG. 1. BLOCK DIAGRAM of W7RCS/8's home-built transmitter, showing where protective circuits have been incorporated to protect the RF power amplifier and modulator tubes. Details are given in the text and subsequent diagrams.

TRANSMITTER PROTECTIVE CIRCUITRY

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 voltageregulator VR tube as shown in Figure 2. The wattage limiting resistor 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 excessive current the limiting resistor drops the voltage, extinguishing the VR tube and limiting the total dissipation 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 relays 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 disconnect screen voltage when the screen grid current is excessive.

However, a less expensive method, the plate voltage sensing relay, protects the screen plate when 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 fail-safe before the screen power supply is connected to the plate screen grid. 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. However, protection against failure can be accomplished by installing relays in the plate and screen circuits which turn on these voltages only when bias voltage is present.

A push-to-talk switch can be connected in series with a voltage sensing relay which energizes the AC side of both the high voltage power supply and the screen power supply. Notice in the schematic diagram 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 present.

This relay in turn actuates the power relay which actually closes the primary AC circuits. Since the coil current of the power relay is the screen grid, 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 considerably higher than the normal primary current, since this current is largely inductive and may cause arcing and pitting of contacts on low grade AC motor starting relays should be used to minimize these difficulties.

Damage to expensive power amplifier tubes can result from excessive plate loading, and can be pre-
TABLE 1 — PARTS LIST

<table>
<thead>
<tr>
<th>Part</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1,C2,C4</td>
<td>40-mfd, 450-volt working tubular electrolytic (G.E. QT1-14)</td>
<td></td>
</tr>
<tr>
<td>C3</td>
<td>10-mfd, 450-volt working tubular electrolytic (G.E. QT1-4)</td>
<td></td>
</tr>
<tr>
<td>C5</td>
<td>10-mfd, 2000-volt working Pyralin metal oxide capacitor</td>
<td></td>
</tr>
<tr>
<td>C6</td>
<td>8-mfd, 150-volt working electrolytic (G.E. QT1-5)</td>
<td></td>
</tr>
<tr>
<td>C7</td>
<td>80-mfd, 150-volt working tubular electrolytic (G.E. QT1-20)</td>
<td></td>
</tr>
<tr>
<td>C8</td>
<td>40-mfd, 120-volt working electrolytic (G.E. QT1-12)</td>
<td></td>
</tr>
<tr>
<td>D1,D2</td>
<td>400-peak volt, 100-ma, silicon rectifier (G.E. INF691)</td>
<td></td>
</tr>
<tr>
<td>D3</td>
<td>100-peak volt, 100-ma, silicon rectifier (G.E. INF693)</td>
<td></td>
</tr>
<tr>
<td>P1</td>
<td>3-pin 10-mamp fuse and JAG type fuse holder</td>
<td></td>
</tr>
<tr>
<td>P2</td>
<td>115-volt, 60-cycle, unind. pilot-pole meter (G.E. K38-23)</td>
<td></td>
</tr>
<tr>
<td>R1</td>
<td>pilot lamp with 115-volt 4-color case set, green juice</td>
<td></td>
</tr>
<tr>
<td>R2-R4</td>
<td>47,000 ohms, 1/2-watt, metal film resistor</td>
<td></td>
</tr>
<tr>
<td>J1,J2</td>
<td>2-pin female chassis type power receptacle</td>
<td></td>
</tr>
<tr>
<td>J3</td>
<td>9-pin high voltage insulated connector</td>
<td></td>
</tr>
<tr>
<td>J4</td>
<td>6-9-volt, 10-ma, filter choke</td>
<td></td>
</tr>
<tr>
<td>J5</td>
<td>10-100, 150-ohm, swing type choke</td>
<td></td>
</tr>
<tr>
<td>J6-J8</td>
<td>4-chenery, 150-ma, filter choke</td>
<td></td>
</tr>
</tbody>
</table>

The wiring diagram also includes the construction of the 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 WTKS transmitter it is necessary to provide two values of bias voltage: namely, minus 155 volts power amplifier, and minus 35 volts for the modulator. Ninety of the 135 volts are obtained across the OB1 90-volt regulator tube in the circuit of the bias 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 drain 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 normal 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 on-cycle of the rectifier. These small rectifiers cannot handle an extremely high current for an extended period of time; consequently, the impedance looking toward the source must sometimes be artificially made higher. In the low voltage (35 volt) supply the in-rush current was well within the approximately 20 ampere one cycle limit on these rectifiers. (continued on page 7)
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 burdensome.

The high "C" Colpitts does away with the inductance mounting problems. As the required coil is small and can be made mechanically sturdy. Large values of voltage divider 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. A large inductance construction and large mass of such units again lead to mechanical stability problems.

In addition, 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" VFO can cause a frequency shift of several hundred cycles. While the average ham may not 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 at only 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 excited through use of an inductively tuned high "C" Colpitts oscillator tuned with a Malory "Inducuter." Amateurs with a background in television will recognize the Inducuter as the front-end tuning device used in many TV receivers manufactured ten years or so back. The Inducuter 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 Inducuter consists of a spirally wound, silver plated inductance firmly imbedded 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 perfectly satisfactory in use in a VFO and enable relatively simple construction of a tuning 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 frequencies at which VFO's generally operate. The high "C" Colpitts circuit, however, requires very little inductance, even in the two million range. Each section of the Inducuter has a maximum inductance of approximately .8 microhenries 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 Inducuter as shown in Fig. 1. Some form of turn counting type dial is required for this Inducuter. The dial shown in the photographs in a Model 1220 series Microdial manufactured by Zorg Corporation, Janesville, Wisconsin. This dial has provisions for ten turns broken down into 100 divisions per turn, and while it was designed for Microcrite, it works fine in this application.

The two section Inducuter 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 scrounging in the basements and basements of TV service shops should turn up this little gem. It may also be available on the surplus market. A 1620 type unit with one section is used in this particular design, but there is no reason why two or more sections cannot be interconnected in series or parallel to provide more

FIG. 1. TUNING CURVE FOR THE INDUCUTER Tuned oscillator as constructed by KYODE.
or less tuning range or bandspread for different bands. For mobile ap- plications and others where space is a problem it is possible to cut away all but the first section of the tuner.

THE SCHEMATIC DIAGRAM for the inductive-tuned VFO is shown in Fig. 2. The tube line-up consists of a 6A8G pentode oscillator with the grid circuit tuning 1.76 - 2.0 megacycles, and plate circuit tuning to 3.5 - 4.0 megacycles. This drives a 6A6 doublet on 7 megacycles which in turn drives the 6C6E multiplier. Although drive to the 6C6E is at 7 megacycles, enough 3.5 megacycle energy leaks through the tube to permit the 6C6E to deliver plenty of output on this band. The 6C6E operates straight through on 7 megacycles and multiplies as required to hit 14, 21, and 28 megacycles. To equalize output one section of the bandswitch is used to select 6C6E screen resistors of appropriate values. If desired, a potentiometer can be substituted in the screen to permit continuous output control.

Those accustomed to strings of multiplier tubes may raise eyebrows at the sight of a single 6C6E tripping and quadraplying to output on 21 and 28 megacycles. The high transconductance of this tube makes it an extremely efficient multiplier, however, and the circuit, as shown, easily drives a 6L6 buffer on all bands. With voltages and constants shown in the schematic diagram, the 6C6E operates well within its maximum plate dissipation rating and considerably more output can be obtained by reducing the value of the cathode resistance.

The control circuit switching arrangement permits the oscillator to run continuously. An RF signal is heard from the oscillator on the 60 meter band and this can be cut off, if necessary, by throwing the control switch to "OFF."
INDUCTIVE TUNING (continued from page 7)

CONSTRUCTION of the complete VFO-excitcrr was accomplished on a standard 4 x 6 x 2-inch deep alumi-
nium chassis (Rud AC-431, or equiva-
lent). The odd-size panel on KGOOE's model shown in the pictures was
made to fit an available cabinet in
which the unit was housed. Major
parts were fastencred 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
excellent mechanical stability inasmuch as
the rugged Inducton reduces most
of the common mechanical problems.
All frequency components should be
mounted on surface of the chassis
so that flexing of the chassis sides
will not change their relative
positions. As hammered home many
instances: 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 to impregnate
coils. It is easy to flow around
components and does a good job of hold-
ing things in place.

TUNEP — With the components
shown in the TUNEP - PARTS LIST
the VFO tuning range will be close
to 1.75 - 2.0 megacycles. Some ad-
j ustment of inductance or capacity
may be required. A considerable var-
iation in torted 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
torted turns. This will also move the
range higher in frequency and it
may be necessary to add fixed capaci-
ty across the inductances to bring
the range down to the desired fre-
quency. If the frequency spread
is too great, increase the torted induct-
anace and decrease the fixed capacity
across the inductances to bring
the range back to the desired frequency.

The slug-tuned coils used in the
oscillator plate and doubler plate
circuits were made from a 4.5-mega-
cycle interstage transformer found
in the junk box. Standard commer-
cial counterparts can be used, of
course.

The G6L6 plate circuit components
are tailored to take into considera-
tion the capacity introduced by 1B8
of RG8U cable feeding the grid of
a G6L6 stage in the transmitter. If a
short, direct connection is used from
the G6L6 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
transfer. This thermal heating effect
is most pronounced on the induct-
cance in the tuned circuit and in this
design the Inductor 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

FIG. 2. Dimensions of toroid coil core used for oscillator inductance. Material is powdered iron.
capacitors from RF energy can be minimized by using the lowest possible voltages on the oscillator but despite this precaution some heating and drift are inevitable. Various types and makes of mica and silver mica capacitors were tried and despite popular belief, some silver mica capacitors were no better than conventional micas in this application. A slight improvement was noted by paralleling several capacitors to provide the required 0.006 mfd. of capacitance. This VFO parallels three 0.002 mfd. capacitors for each of the voltage dividing capacitors.

The drift problem was licked in conventional fashion by the use of temperature-compensating capacitors in the oscillator grid-coupling and tuned circuit. These reduce the drift to less than 30 cycles at the fundamental frequency.

If you don't want to bother with temperature compensation you can still rate your VFO as manufacturers do by saying, "drift is negligible after ten minutes warmup." However, the true test for short-term VFO stability is the amount of drift measured from the moment plate power is applied, after two minutes of heater warmup. After all, the fellow at the other end doesn't wait ten minutes for your VFO to warm up before he starts to copy you!

Aside from the afore-mentioned drift considerations, the Inductometer VFO eliminates "peeking" on the operating table. Even on 28 megacycles the VFO can be rapped sharply with no detectable change in beat-note — provided the oscillator components have anchored down. The Inductometer completely eliminates frequency variations usually found in the average home-built VFO where a push on the front panel shifts frequency.

TRANSMITTER PROTECTIVE CIRCUITRY

THE COMPLETE POWER SUPPLY for the transmitter at WTRCS 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-3828 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 WTRCS's transmitter and power supply on these pages show many of these construction details. Readers are also referred to the "Power Supply Construction" chapter of the ARRL Radio Amateur's Handbook for further suggestions.

Although WTRCS'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.

CONTROL CIRCUIT VOLTAGE is measured by Nunn Morgan checking the protective circuits in his transmitter. Note that all parts are firmly fastened to chassis.

FIG. 4. CHASSIS LAYOUT DIAGRAM for the inductive-tuned VFO exciter. Locations for parts on chassis are shown. The small radio coil, L1, shown at the lower right corner, is housed in the chassis with insulating spacer washers and a brass machine screw. Bottom plate covers chassis for shielding.
COMING NEXT TWO ISSUES

"The LWM-3 — A Bandswitching SSB Mobile Transceiver," by W. C. (Bill) Lunden, WAWFII, and A. F. (Al) Pregott, WAWII, co-authors of the G-E HAM NEWS series on high-power mobile radio systems last year. This compact transceiver — 13 inches wide, 8 inches high, and 11 inches deep — attracted great attention at several amateur radio conventions during 1951. The LWM-3 (the letters stand for "London, William, Mobile — 3rd mod- el") covers any eleven 200-kilocycle segments of the amateur bands between 3.5 and 26.7 megacycles. It's a simple, compact design, and delivers about 5 watts ERP output sufficient to drive a mobile linear amplifier described in the November-December, 1960 issue of G-E HAM NEWS.

In order to completely cover the LWM-3, the circuit and other electrical details will be run in the November-December, 1962 issue, with the mechanical and constructional details to follow in January-February, 1963.

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 the General Electric 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 nominating 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.