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QST Issue: Oct 1971
Title: CW Man's Kilowatt, A--Part 1
Author: Robert Myers, W1FBY

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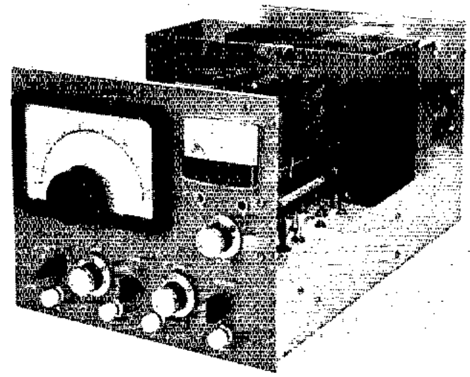
A CW Man's Kilowatt T-9er



Part I

BY ROBERT M. MYERS,* W1FBY

A CW-ONLY transmitter of modern design is difficult to find. Many circuits have been published over the years; however, building some of those older units is becoming impossible in view of today's parts-procurement problem. With the T-9er, an attempt has been made to use components which can be purchased with little difficulty. The up-to-date circuit uses techniques usually found only in ssb transmitters.

The Solid-State Oscillators

The VFO and buffer, Q1 and Q2 in Fig. 1, are an adaptation of a unit previously described in *QST*.[1] Q3, a second buffer, provides additional gain to assure adequate current to drive the base of the mixer, Q5. The VFO range is 5.0 to 5.2 MHz.

The heterodyne-frequency oscillator (HFO), Q4, operates at one of six crystal-controlled frequencies selected by the band switch. All of the crystals chosen oscillate at a frequency *above* the operating band. For this reason, the VFO dial tunes in the same direction on each band. CR13 is included to limit the oscillator voltage appearing at the mixer to 0.6.

The Mixer

Voltage from the VFO and HFO are coupled to the mixer, Q5, via C9 and C5, respectively. A tuned collector circuit operates at the *difference* frequency and provides a low-level signal to the driver stage, V1. The VFO actually tunes backwards with respect to the mixer output signal. The bottom edge of each amateur band corresponds to a VFO setting of 5.2 MHz.

Advantages of Frequency Conversion

One of the most prominent features of this system is that only one set of calibration marks is needed. The dial face is divided into 5-kHz increments to give an uncluttered appearance (1-kHz divisions can be included, if desired).

When the harmonic of a 7-MHz VFO is used on 15 and 10 meters, any drift at the fundamental frequency becomes pronounced on the higher bands. However, by heterodyning instead of multiplying the VFO energy to the higher bands, the stability of the VFO fundamental frequency is maintained. Since both the HFO and VFO are placed at frequencies far removed from the operating band, the chance of "pulling" is reduced considerably. Stability is further assured by allowing both oscillators to run continuously.

Keying

A conventional grid-block system provides clickless, chirpless operation because neither oscillator is keyed. Q6 activates the mixer only when the key is depressed. The waveform transmitted is determined by R2 and C11 in the grid circuit of V1. Since the 6GK6 keys at a slightly slower rate than the mixer, any clicks generated in the earlier stages are not heard.

The Driver Stage

Voltage from the mixer is sufficient to power the driver to nearly full output on all bands. The plate circuit uses separate slug-tuned inductors for 160 through 20 meters. The 15- and 10-meter bands are covered with one coil. Neutralization of the 6GK6 is not required.

> ***Operating a transmitter and amplifier designed with cw as an afterthought can make cw very dull. Presented here is the T-9er, a hybrid circuit built with cw as the prime mode of service. Included are such features as** full **break-in, shaped keying, linear VFO calibration, T-R switch, built-in power supply, and a solid-state heterodyne conversion scheme. The PA stage uses a pair of 6146Bs and is capable of producing up to 240-watts input on 160 through 10 meters.***

* Assistant Technical Editor, *QST.*

[1] DeMaw, "Building a Simple Two-Band VFO," *QST*, June, 1970.

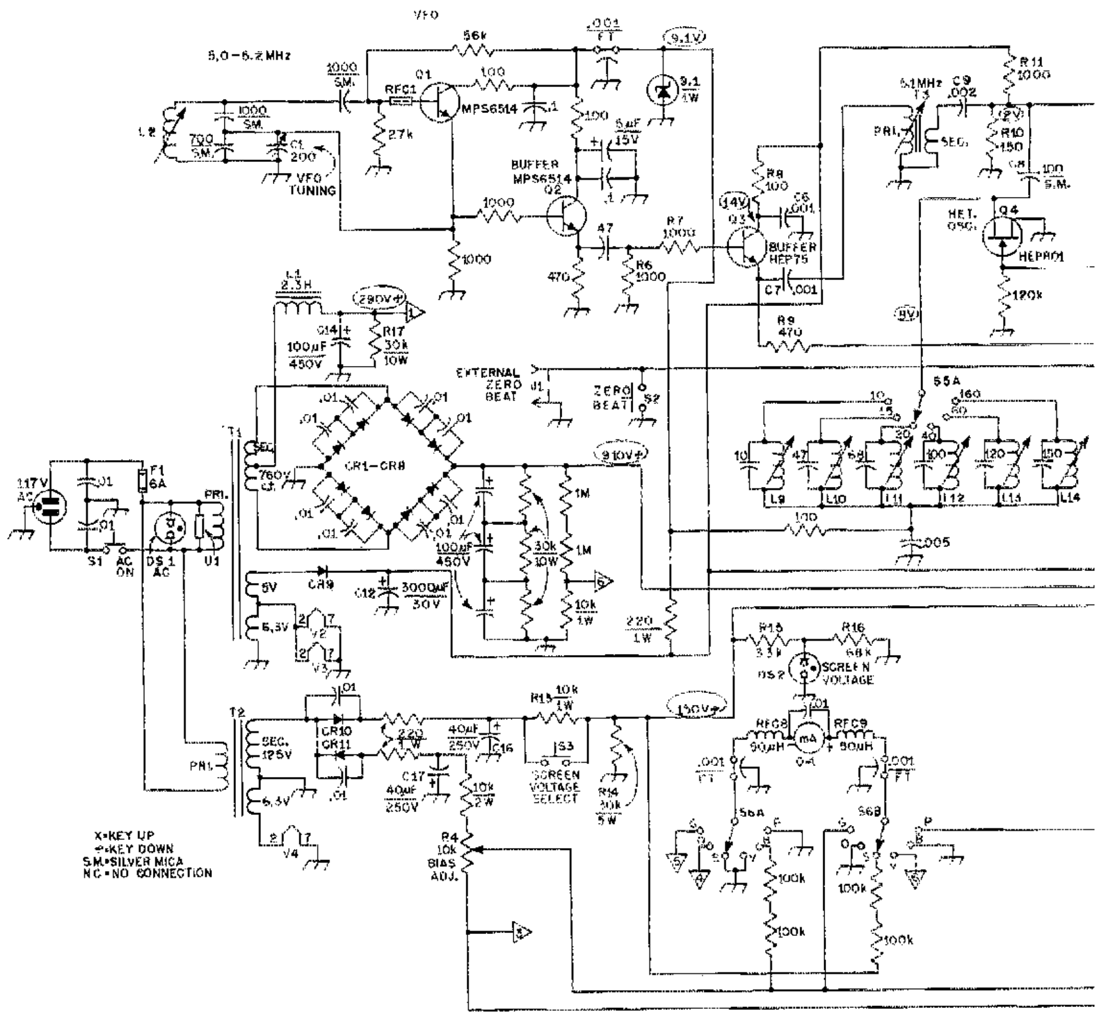
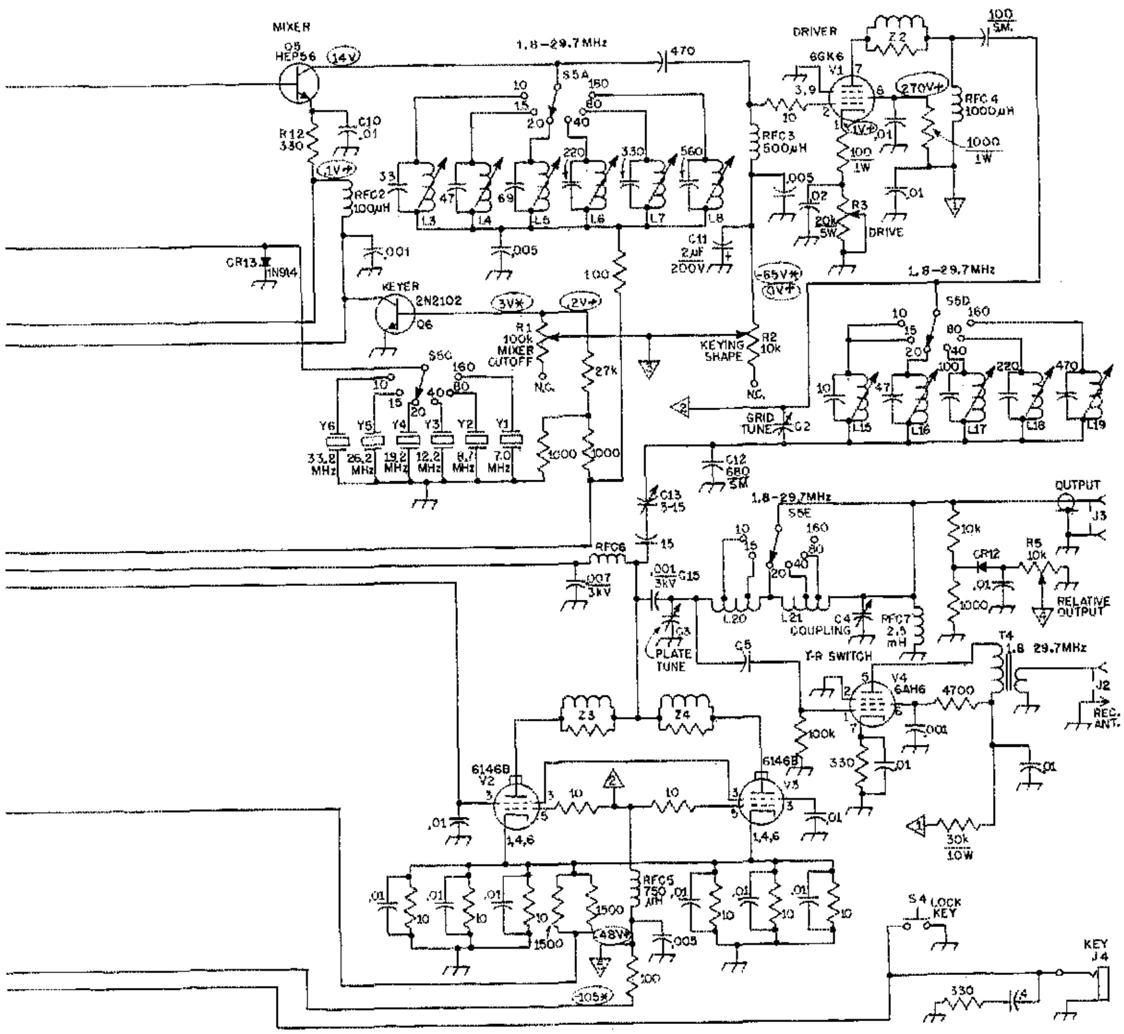


Fig. 1 — Circuit diagram for the T-9er. Component designations not listed below are for text reference.

C1 — 200-pF air variable (Hammarlund HFA-200A).
C2 — 100-pF air variable (Hammarlund MAPC-100B).
C3 — 300-pF air variable (Hammarlund RMC-325-S).
C4 — 1200-pF air variable (J. W. Miller 2113).
CR1-CR12, incl. — 1000-PRV, 2.5-A (Mallory M2.5A or equiv.).
CR13 — Silicon small-signal switching diode (1N914 or equiv.).
DS1, DS2 — Neon indicator lamp, 117-V (Leecraft 32-211).
J1, J2 — Phono jack, single hole mount.
J3 — Coax chassis connector, type SO-239.
J4 — Open-circuit key jack.
L1 — 2.3-H filter choke (Stancor C-2304 or equiv.).
L2 — 2.2- to 4.1-µH slug-tuned inductor (J. W. Miller 42A336CBI).
L3, L16 — 1.0- to 4.1-µH slug-tuned inductor (J. W. Miller 42A156CBI). Both coils are rewound with the wire supplied: 3 turns spaced over a 3/4-inch length.
L4, L9, L10, L11, L15 — 1.0-µH slug-tuned inductor (J. W. Miller 21A106RBI).
L5 — 2.2- to 4.1-µH slug-tuned inductor (J. W. Miller 42A336CBI).
L6 — 1.6- to 2.7-µH slug-tuned inductor (J. W. Miller 21A226RBI).
L7, L8, L13, L14, L18, L19 — 6.8- to 8.5-µH slug-tuned inductor (J. W. Miller 21A686RBI).
L12, L17 — 1.5- to 1.8-µH slug-tuned inductor (J. W. Miller 21A156RBI).
L20 — 9 1/2 turns, 8 tpi, 1 1/2-inch dia tapped from tube end at 2 1/2 turns for 10 meters and at 4 3/4 turns for 15 meters (B&W 3018).
L21 — 38 turns, 6 tpi, 2-inch dia tapped from J3 end at 18 turns for 40 meters (B&W 3027).
M1 — 1-mA dc.
R1 — 100,000-ohm, linear-taper, 2-watt carbon control (Allen Bradley).
R2, R4, R5, R6 — 10,000-ohm, linear-taper, 2-watt carbon control (Allen Bradley).



EXCEPT AS INDICATED, DECIMAL VALUES OF CAPACITANCE ARE IN MICROFARADS (µF); OTHERS ARE IN PICOFARADS (pF OR µµF); RESISTANCES ARE IN OHMS; k = 1000, M = 1000000.

R3 — 20,000-ohm, linear-taper, 4-watt, wire-wound control (Mallory M20MPK).

RFC1 — Three Amidon ferrite beads threaded on a 1/2-inch length of No. 22 wire. A 15-ohm 1/2-watt resistor may serve as a substitute. (Amidon Assoc., 12033 Otsego St., N. Hollywood, CA 91607.)

RFC2 — 100-µH rf choke (Millen 34300-100).

RFC3 — 500-µH rf choke (Millen J300-500).

RFC4 — 1000-µH rf choke (Millen 34300-1000).

RFC5 — 750-µH rf choke (Millen 34300-750).

RFC6 — 1-mH rf choke (E. F. Johnson 102-752).

RFC7 — 2.5-mH rf choke (Millen 34300-2500).

RFC8, RFC9 — 50-µH rf choke (Millen 34300-50).

S1-S4, incl. — Spst push button (Calectro E2-144).

S5 — Ceramic rotary switch, 5 poles, 6 positions, 5 sections (Centralab PA-272 index with 5 type XD wafers).

S6 — 2-pole, 6-position, single-section rotary (Centralab PA-2003).

T1 — 117-volt primary; secondary 760 volts at 220-mA, center tapped; 5-V at 3-A; 6.3-V at 5-A (Stancor P-8170 or equiv.).

T2 — 117-volt primary; secondary 125 volts at 50 mA; 6.3-V at 2-A (Stancor PA-8421 or equiv.).

T3 — Primary: 8.2- to 8.9-µH slug-tuned inductor (J. W. Miller 46A826CPC). Secondary: 2 turns No. 22 enameled wire wound on the cold end of the primary.

T4 — 20 turns, No. 24 enameled wire wound on a 1-inch long, 1/2-inch dia iron core from a slug-tuned coil form. The secondary is 3 turns No. 24 enameled wire wound over the cold end of the primary.

U1 — Transient voltage suppressor, 120-volt (General Electric 6RS20SP4B4).

Z2 — 3 turns No. 22 wire space-wound on a 100-ohm, 1-watt composition resistor.

Z3, Z4 — 5 turns No. 18 wire space-wound on a 100-ohm, 2-watt composition resistor.

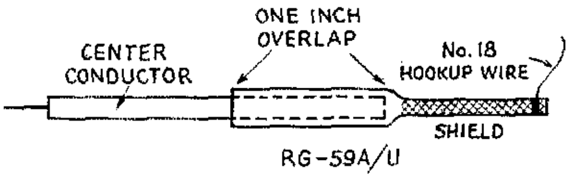


Fig. 2 — A high-voltage capacitor is constructed from a 3-inch piece of RG-59A/U. A 1-inch overlap between the braid and center conductor provides the correct amount of coupling for the T-R switch.

The Power Amplifier

A pi-network output circuit is employed with a pair of parallel-connected 6146Bs. Six 10-ohm resistors are connected between the cathodes and ground. Voltage developed across these resistors is used to indicate cathode current on the meter.

The amount of screen voltage is determined by the position of S3. When this switch is closed, the screen voltage is 150. Releasing S3 places R13 in series with the screen bus, lowering the voltage to 50. This lower voltage limits the transmitter input to approximately 60 watts. A neon lamp, DS2, has been included to indicate the position of S3. R15 and R16 form a voltage divider which allows ignition of DS2 during high screen-voltage conditions only.

A T-R switch, V4, permits using the same antenna for transmitting and receiving. The theory and operation of this unit was described in an earlier *QST*.[2] An antenna relay is not required.

Metering

The operating conditions of the final-amplifier stage may be checked with the panel meter, M1. A 6-position switch allows monitoring of grid current, relative output, screen, plate and bias voltages, and cathode current. The range and typical values are listed in Table I.

The Power Supply

A silicon-diode full-wave bridge rectifier is used in the secondary of T1 to produce slightly over 1000 V dc during no-load conditions. Although this is somewhat high for 6146Bs, it has not shortened tube life. A choke-input filter is connected in the transformer center-tap lead to obtain 300 volts for powering the driver tube and the T-R switch. Sixteen volts of dc for operating the solid-state circuitry are obtained by rectifying and filtering the combined output of the two filament windings, which are connected in series. If the windings buck each other, producing no voltage, one set of leads should be reversed.

Final-amplifier screen and bias voltages are developed by T2. This part of the supply uses one half-wave rectifier for each voltage.

[2] Myers, "Stepping Up TR Switch Performance," *QST*, December, 1967.

TABLE I

Meter Switch Positions

Panel Designation	*Function*	*Range*	*Relative Readings Key Up*	*Key Down*
G	Grid Current	0-10 mA	0	2
O	Relative Output	–	0	*
S	Screen Voltage	0-200 V	155	150
V	Plate Voltage	0-2 kV	990	910
B	Bias Voltage	0-200 V	105	60
P	Cathode Current	0-500 mA	0	260

* R5 should be adjusted for a 3/4-scale reading during full-power-output conditions.

TABLE II

Measuring point to ground	*Resistance (ohms)*	*Voltage*
V1 – Pin 7	20,000	335
Pin 8	21,000	330
Pin 2	7,100	–47
V2 – Pin 3	25,000	155
Pin 5	10,000	–92
plate cap	30,000	980
V4 – Pin 5	20,000	335
C12	300	16

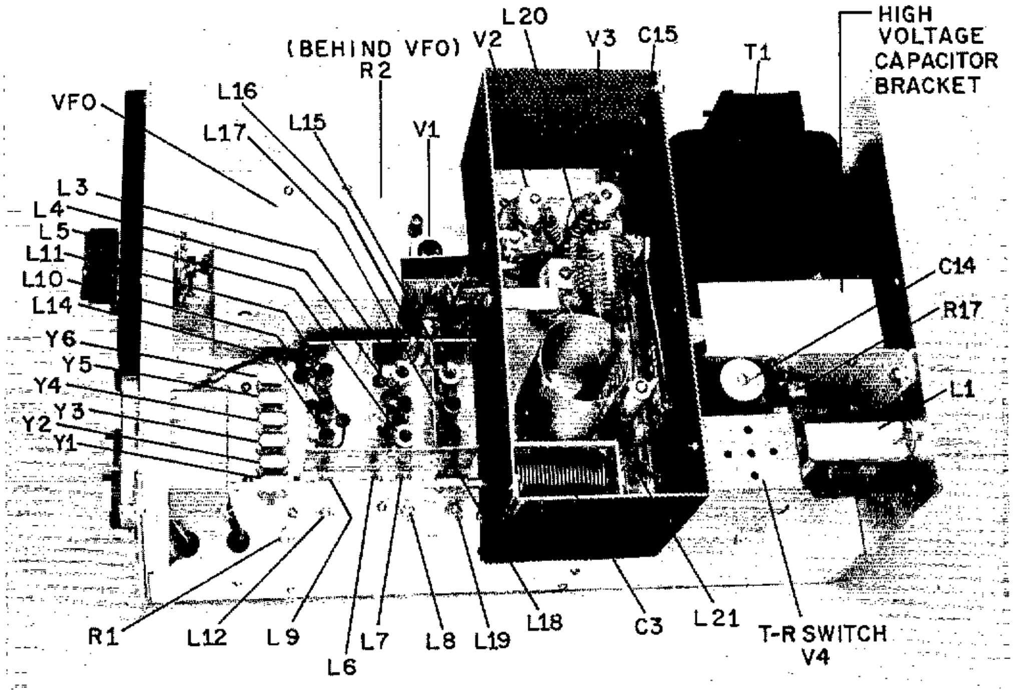
Construction

The transmitter is completely self-contained. It is built on a 10 × 17 × 3-inch chassis with an 8 1/2-inch-high front panel. Shielding is used between each stage and between each band-switch wafer as shown in the photograph. The final-amplifier section on top of the chassis is completely enclosed in a perforated aluminum shield. Small pieces of circuit board are soldered together to form a compartment for the slug-tuned coils. The etched circuit board for the buffer, Q3, and the mixer, Q5, is mounted vertically between the slug-tuned coil compartment and the driver tube, V1. An aluminum box measuring 2 1/2 × 2 1/4 × 1 3/4 inches is used as a meter enclosure.

Most of the power-supply components are mounted on the rear quarter of the chassis. The bracket located next to the power transformer supports the three filter capacitors for the high-voltage supply. Accidental contact with the 1000-volt line is prevented by the top lip.

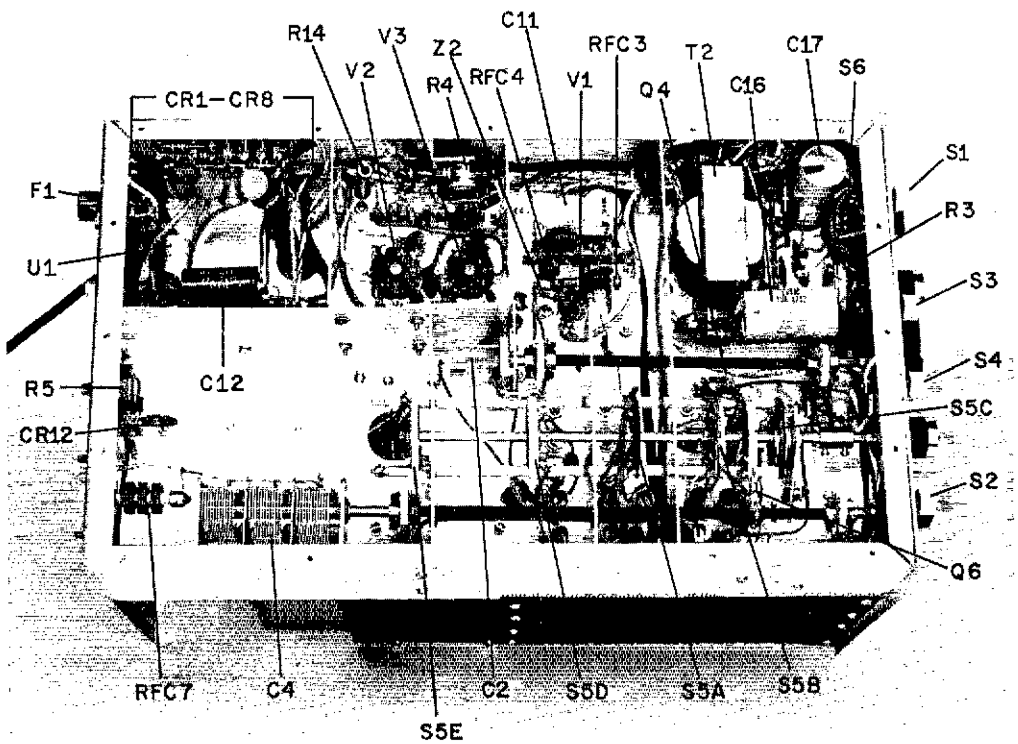
The T-R switch, V4, is mounted inside a Minibox attached to the rear of the amplifier shield compartment. The signal-input connection to V4 is made through the shield. Five holes in the top of the Minibox cover provide ventilation for the 6AH6.

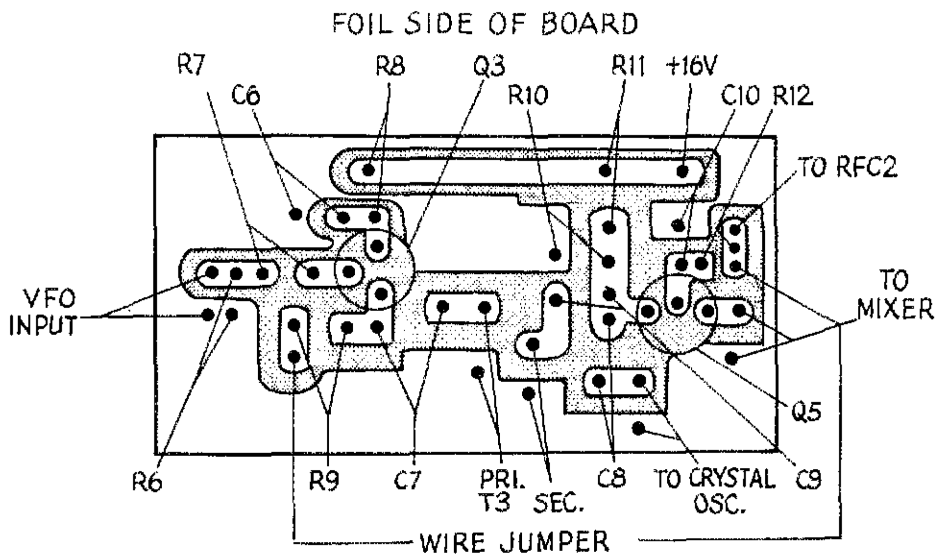
The VFO is built on an etched circuit board and is completely enclosed in the shield cover behind the tuning dial. In order to enhance mechanical stability, the cover is made of 3/16-inch-thick aluminum. A small hole is drilled in the side of the cover to allow for adjustment of L1.



▲ Top view of the T-9er.

▼ Chassis bottom view. The opening next to S5E is needed to make connections to L20 and L21.





A full-size template of the mixer board.

All of the wiring between stages is done with shielded cable. Additionally, all leads to the meter-switch compartment are shielded.

A capacitor constructed from a short piece of RG-59A/U is used for C5 (Fig. 2). The shield and inner conductor overlap approximately 1 inch. If a ceramic capacitor is used at this point, it should have a capacitance of roughly 3 pF, and a voltage rating of 3 kV.

A full-size template of the mixer board is shown in Fig. 3. Shielded wire must be used between it and the other points in the circuit, as well as for the jumper lead.

Adjustments

Aligning a complex transmitter is difficult without the use of test gear, so a grid-dip oscillator, a VTVM, and a general-coverage receiver are required here.

Before power is applied to the T-9er, resistance measurements should be made at several points to assure there are no wiring errors which could cause damage to the power supply. Typical resistance values are given in Table 2. Caution! When primary power is applied, lethal voltages are present at all times. Allow several minutes for the bleeder resistors to discharge the capacitors after the power is removed. Then, it is a wise practice to "screwdriver test" (short circuit) the capacitor bank. All of the voltage points listed on the circuit diagram, Fig. 1, should be checked.

The general-coverage receiver is used to check the operation of the heterodyne oscillator on each crystal frequency. Then, the receiver antenna is coupled to pin 2 of V1 through a 100-pF capacitor. By setting the band switch at 160 meters and adjusting the VFO signal to 5.2 MHz, a signal should appear at 1.8 MHz when the spotting switch is depressed. Adjust L3 for maximum S-meter reading. Tune L4 (80 meters) through L8 (10 meters) in a similar manner. All of the tubes should be removed for these tests.

The biggest pitfall in aligning the mixer is tuning the output circuit to something other than the desired frequency. For instance, on 20 meters, the mixer can be tuned to the third harmonic of the VFO, producing output at 15.6 MHz! There are a few similar combinations which might be encountered.

After determining that the solid-state circuitry is functioning correctly on each band, the tubes are installed and the driver coils are adjusted. To set the final-amplifier bias, set the drive control at minimum (ccw), depress the key, and adjust R4 for a PA cathode current of 5 mA.

The entire alignment must be "touched up" under full-power-output conditions. The heterodyne oscillator coils should be detuned to a point where the power output drops approximately 2 percent. This procedure assures proper oscillator injection at the mixer. When the rf alignment is completed, a receiver should be connected to J2. If any backwave is heard under key-up conditions, adjustment of R1 should eliminate it.

In a transmitter of this type, leads to the band-switch lugs contribute stray inductance and capacitance. For this reason, the builder is advised to "tack" the mica capacitors across the inductors until it is determined that the various circuits will resonate at the proper frequencies. Only then should the capacitor leads be soldered permanently in place.

Performance

Power output from the T-9er is roughly 150 watts on 160 through 20 meters. On 15 meters the output drops to 125 watts, and on 10 meters it is slightly over 100 watts. The reduced output on the higher bands is caused by marginal drive to the 6GK6. It is not considered important enough to add another buffer stage with its associated coils and band-switch wafer.

The screen voltage (SV) switch is included to provide a low-power tune-up function. It is best not to operate (on the air) in the low-voltage position. If low power operation is desired, the drive can be reduced during normal screen-voltage conditions.

Every effort has been made to produce a TVI-free transmitter. The addition of a low-pass filter should make harmonic radiation almost immeasurable.

Keying Wave-Form Adjustment

A wide range of keying characteristics is available. R2 should be adjusted while observing the transmitted signal on an oscilloscope. Typical patterns are shown in *The Radio Amateur's Handbook*. If an oscilloscope is not available, keying adjustment could be made on the air with the help of a local amateur. These tests should be made on a dead band, however, thus preventing needless QRM!

Adequate Planning

It is worth mentioning that this is not a beginner's project. Building the T-9er should not be attempted by someone who lacks experience in constructing amateur gear.

One of the biggest problems these days is that of obtaining parts. The builder should arm himself with several parts catalogs and be familiar with the minimum billing requirements of each.[3] A project such as the T-9er requires as much planning in the parts procurement phase as in the layout work.

Part II

An accompanying kW amplifier – The S-9er – will be presented in a subsequent issue of *QST*. It uses a single 3-500Z triode in a grounded-grid circuit. QST

3 DeMaw, "The Ham Builder's Nightmare," *QST*, October, 1970.

Strays

The article by Moore, "Homebrew DX Prediction" (*QST*, August, 1971, p. 53), was scheduled for publication just as we received the Office of Telecommunication's announcement that their monthly publication, *Ionospheric Predictions*, was being discontinued. (See "Publication of Ionospheric Predictions," Technical Correspondence, same *QST* issue, p. 40.) The appearance of both of these items in the same issue of *QST* may be confusing to some of our readers.

Advance information has been obtained from the Institute for Telecommunication Sciences, Boulder, Colo., regarding the new volumes. Volume 1, titled *The Estimation of Maximum Usable Frequencies from World Maps of MUF (ZERO) F2, MUF (4000) F2 and MUF (2000) F*, describes the maps of the remaining three volumes and describes their usage in the estimation of maximum usable frequencies (MUF). In effect, this new volume takes the place of *Handbook 90*, described by Moore in his article, although the precedure to be used for making estimations manually will not be the same.

To use the predictions for estimating MUFs, at least one of the three remaining volumes is required – the one applicable to the level of sunspot activity for which predictions are to be made. Volume 2 presents maps for a predicted Zurich smoothed relative sunspot number of 10 (minimum solar activity), Volume 3 for 110 (maximum solar activity period of an average solar cycle), and Volume 4 for 160 (maximum solar activity period of an above average solar cycle). For periods such as exist now (the predicted number for October, 1971, is 57.8) it would be necessary to use both Volumes 2 and 3, making a linear interpolation of the data obtained from each. Thus, the 4-volume set will permit estimations to be made for any period of solar activity, once the relative sunspot number is known or predicted. In the future, information on predicted relative sunspot numbers will be contained in Propagation Forecast Bulletins, transmitted by W1AW and many Official Bulletin stations.

The new *Ionospheric Predictions* report, available approximately October 1, 1971, will be distributed through the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. The price for a complete set is $9.30. Individual volumes may be purchased at the following prices: Vol. 1 – 30 cents; Vols. 2, 3, and 4 – $3.00 each volume. Stock numbers are: Vol. 1 – 0300 0318; Vol. 2 – 0300 0319; Vol. 3 – 0300 0320; and Vol. 4 – 0300 0321. These are volumes of the OT Telecommunications Research and Engineering Report *Ionospheric Predictions*, OT-TRER 13.

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QST has twice run warnings about possible radio transmitter interference to electronic anti-skid and braking systems in certain luxury automobiles. The more we "learn" of the matter, however, the less concrete the information seems to become. Will any readers who have had *first-hand* experience with RFI to these systems please write to W1UED at Hq? We'd like the following details: 1 Type of automotive electronic system involved. 2 Year and make of automobile. 3 Power and frequency of transmitter and antenna location. 4 What operator action or equipment condition was necessary to cause a problem? 5 What happened that shouldn't have, or what didn't happen that should have? 6 Comments. Specifically, anything unusual about the situation; e.g., being near a broadcast station, or no trouble in humid weather, etc.