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MAY-JUNE, 1961

A recent series of tests on new linear amplifiers for mobile SSB operation created the demand for an RF wattmeter with which to determine their power output capabilities. After running some of these tests with a commercially built wattmeter, it was decided to build a wattmeter, so that it would be available all of the time.

The RF wattmeter is simply an extension of the basic VSWR (voltage standing wave ratio) bridge, such as the Monimatch.¹ Actually, the wattmeter to be described is like having two separate wattmeters in one box, since, in addition to measuring RF watts in the forward direction, it also measures reflected power. It consists primarily of one current transformer and two capacitive voltage dividers, plus two diodes and their filter circuits for the indicating instrument.

Looking into published information on RF wattmeters, an excellent article was found in the April, 1959 issue of *QST*.² If this article is really studied, it gives almost the complete story on the subject. However, this article also assumed that the reader would "know all of the tricks" in constructing this type of instrument. Our article gives complete constructional information.

In designing and constructing an RF wattmeter, two important design objectives must be kept in mind in order to achieve an instrument capable of accurate and consistent measurements. These are:

1. The current transformer must be *inductively* coupled to the r.f. transmission line, and not a combination of inductive and capacitive coupling; and
2. The capacitive voltage divider must consist of the ratio of capacitance in the two divider capacitors, and not a conglomeration of stray capacitances, plus some inductive coupling from long leads, and lead dress.

The first objective is accomplished with a simple electrostatic shield in the current transformer which will be described in detail later. The second is realized by selecting miniature components, and placing them in the proper physical locations.

THE CIRCUIT for the complete RF wattmeter is shown in the schematic diagram, Fig. 1. A toroidal type current transformer was designed with an electrostatic shield between the primary (the coaxial cable center conductor running straight through the box) and the secondary (L_2 , wound on the toroid form).

In the capacitive voltage dividers ($C_1 - C_3$, and $C_2 - C_4$), the smaller capacitances (C_1 and C_2) are adjustable (continued on page 2)

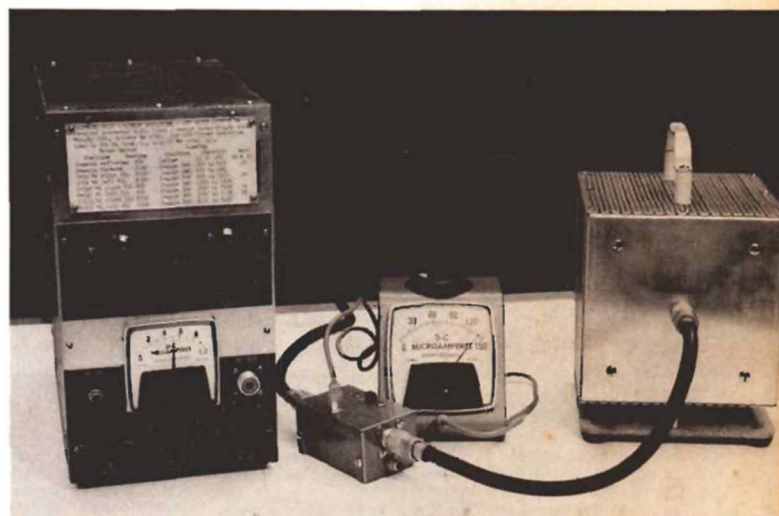
LOW-COST RF WATTMETER

By A. F. Prescott, W8DLD,
and W. C. Louden, W8WFH

THE RF WATTMETER is a highly useful item of test equipment for the amateur radio station, or the "library" of test equipment which many amateur radio clubs maintain. W8DLD and W8WFH give complete construction information here for a unit which offers a choice of meter current ranges.



W8DLD (left) and W8WFH put their RF wattmeter through its paces, checking it against the RF wattmeter built into the SSB-600 linear amplifier (center unit). Converted Command set receiver and crystal controlled converter at left of SSB-600 was described in the September-October, 1960 issue of *G-E HAM NEWS*.



CLOSEUP VIEW of the test setup for the RF wattmeter. Pickup unit is connected into coaxial cable running between SSB-600 amplifier and 500-watt, 50-ohm dummy load (right), which will be described in a coming issue.

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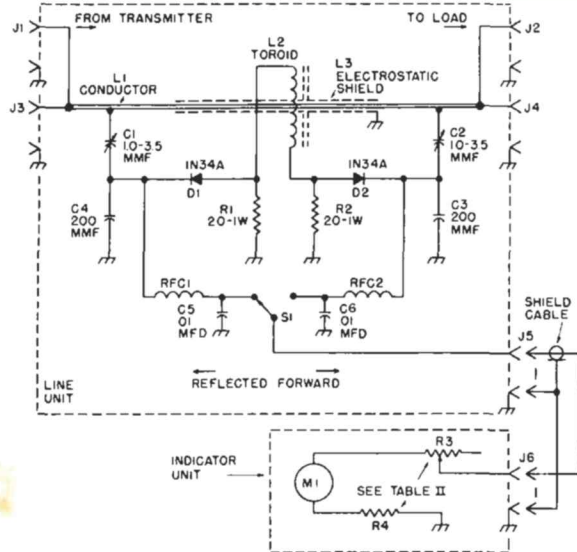


FIG. 1. SCHEMATIC DIAGRAM of the RF wattmeter. Parts with the same function in both sides of the circuit (C_1 and C_2 , etc.) should be matched in actual value, as described in the text. This circuit was used in W8DLD's SSB-600 linear amplifier described in the March-April, 1961 issue.

TABLE I — PARTS LIST

- C_1, C_21.0-3.5 mmf ceramic trimmers (Centralab 820-D, or equivalent).
 C_3, C_4200-mmf 600-volt miniature disc ceramic.
 C_5, C_601-mfd. 600-volt disc ceramic.
 D_1, D_2general purpose diodes (1N34A, 1N48, etc.).
 J_1, J_2, J_3, J_4midget phono jacks.
 J_5, J_6chassis type coaxial cable jack (SO-239).
 L_1No. 10 or 12 bare copper wire, 3 inches long, covered with $\frac{1}{8}$ -inch O.D. copper tubing $\frac{1}{2}$ inches long.
 L_2Approximately 48 turns of No. 22 enameled wire on toroid form; see footnote (3).
 L_335 turns, No. 22 enameled wire over L_1 ; see text for details.
 M_10 — 150-microampere DC meter; or, see TABLE II for other meter ranges (G. E. DW-91, $2\frac{1}{2}$ inches; DO-91, $3\frac{1}{2}$ inches, or equivalent).
 R_1, R_220 ohms, 1 watt composition.
 R_3linear taper potentiometer; see TABLE II for value.
 R_41-watt composition resistor; see TABLE II for value.
 RFC_1, RFC_21 mh single pi-wound RF choke (Miller No. 72F103AP, or equivalent).
 S_1single pole, double throw slide switch (H. H. Smith No. 516, or equivalent).
MECHANICAL PARTS NEEDED:
 Box, wattmeter — Bud Minibox No. CU-2101A.
 Box, meter — Bud sloping meter case No. CMA-2065 or CMA-2066.
 Dial plate for R_3 — 0-10 markings, 300 degrees, Mallory No. 380.
 8-connection terminal strip — Cinch-Jones No. 56A.

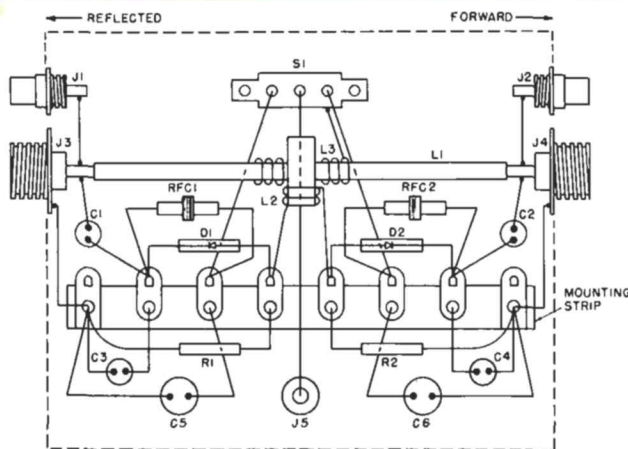


FIG. 2. PARTS LAYOUT for the RF wattmeter. This layout should be followed closely to achieve accurate reflected power readings. NOTE: Either end of the pickup unit may be connected to the transmitter or load, since the circuit is bilateral. The ends have been labelled here for discussion purposes.

LOW-COST RF WATTMETER (continued from page 1)

able. This makes possible physically small fixed larger capacitances for C_3 and C_4 to overcome the problem of stray RF voltage pickup by these capacitors.

It was previously mentioned that this device is really two wattmeters in one case. Obviously this suggests that any time two components with the same value are specified in TABLE I — PARTS LIST they should match each other closely in value. For example, the 20-ohm, 1-watt diode load resistors (R_1 and R_2) may measure from 15 to 30 ohms, but they must both read the same resistance. This also applies to the 200-mmf ceramic capacitors. From 150 to 250 mmf will work fine if the capacitances are matched. Although 1N34A diodes are specified, more important than the type of diode, they should match each other in forward and reverse characteristics. This will enable the RF wattmeter to read the same regardless of which direction it is connected in the coaxial line.

The toroid wound current transformer is a problem to shield by any ordinary method, so why not shield the primary of the transformer from its secondary? This is almost quicker done than said! Slip a piece of tubing or put some tape on the center conductor. Wind a tight winding of

¹"The Monimatch," by L. G. McCoy, W1ICP, QST, October, 1956, page 11. Also, "The Monimatch — Mork II," L. G. McCoy, QST, February, 1957, page 38.
²"An Inside Picture of Directional Wattmeters," by W. B. Bruene, W8TKK, QST, April, 1959, page 24.
³Part No. 57-1541, Radio Cores, Inc., 9540 South Tulley, Oak Lawn, Ill.
⁴"Not Just a Navalty," — by Davis A. Helton, W8PME, QST, January, 1961, pages 21 to 25.

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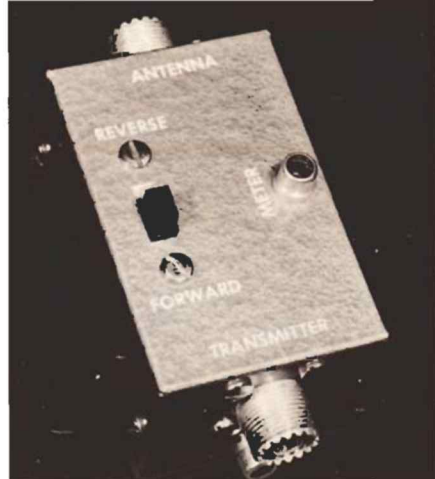
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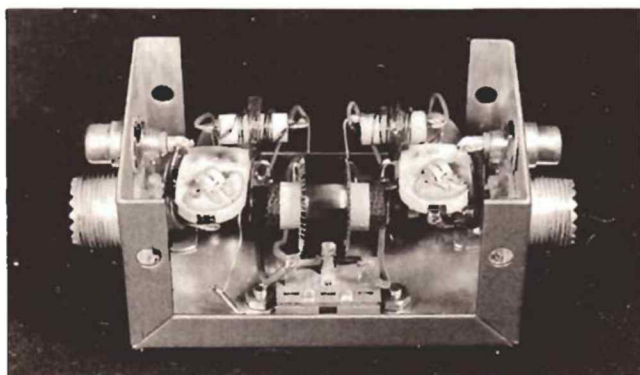
TABLE II — METER SELECTION CHART

Minimum Watt Range Desired	Maximum Watt Range Desired	Meter Range	Potentiometer R ₂ Ohms
0-3	1000	0-75 μ A	*50,000 + R ₁ Fixed
0-6	1000	0-150 μ A	25,000 + R ₁ Fixed
0-12	1000	0-300 μ A	15,000
0-25	1000	0-500 μ A	7,500
0-50	1000	0-1 MA	4,000

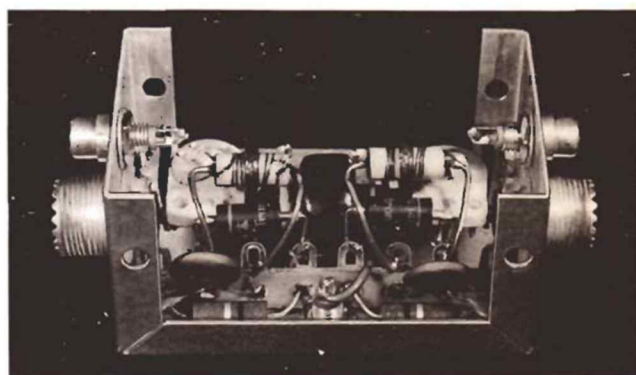
*Zero to three watts range is possible but it would be desirable to use the proper fixed resistance to limit this range for zero to seven and one half watts to go with the full scale marking on a 0 — 75 microammeter. When using this low range R₂ is set at zero resistance and R₁ is chosen to calibrate desired range.



TOP VIEW of the RF pickup unit. Compact size and complete shielding contribute to maintaining 50-ohm impedance through unit, minimizing disturbance in line. Box size is 3¼ x 2½ x 1½ inches.



INTERIOR VIEW of the switch side of the pickup unit. Trimmer capacitors C₁ and C₂ are adjusted through ¼-inch diameter holes in the other half of the box, and then plugged with snap-in buttons.



DETAIL VIEW of the terminal strip area of the pickup unit. Parts can be identified from the layout diagram, Fig. 2, which is drawn from the same position as this photo.

enameled wire over the tape. Ground one end of this winding and it forms a good electrostatic shield.

CONSTRUCTION of the RF wattmeter is not difficult, but to assure success, study the parts layout diagram, Fig. 2, and the interior illustrations carefully before starting assembly. Complete the drilling on the part, so put everything in its place please! Complete the drilling on the Minibox and mount the parts in this order: Switch S₁, coaxial cable chassis connectors (J₃ and J₄) and the phono jacks (J₁ and J₂).

Solder a short piece of No. 14 bare copper wire to each center conductor of J₃ and J₄. Connect this wire to the center contact on the adjacent phono jack. The parts mounting strip goes in next, with the outer lugs on each end soldered to an SO-239 connector mounting screw. This grounds the outer two terminals which will later be used as common grounds. This mounting strip may be 1/16" too long, so file 1/32" off each end to make it fit inside the Minibox.

Wire the switch and remaining phono jack (J₅) to the proper tie points (these connections are hard to reach later so don't forget). Now mount the two 20 ohm resistors (R₁ and R₂) and two 220 mmf capacitors (C₃ and C₄), followed by the two .01 mfd. bypass capacitors (C₅ and C₆).

The IN34A diodes now go in, keeping their leads short. Hold each lead with longnose pliers, to act as a heat sink, while soldering. Put in the two RF chokes (RFC₁ and RFC₂) and the main work is done.

The current transformer should be built as a subassembly which will literally fall in place with five connections to be soldered. Here's how it is done: Cut to the exact length a piece of No. 10 or 12 copper wire that will connect the two center conductors in the SO-239 coaxial cable connectors. This wire is used to mount the entire transformer assembly, and forms the primary of the current transformer. This model has a piece of copper tubing 1/8" I.D. x 1½" long slipped over the No. 10 wire and soldered.

Then put on a layer of spaghetti tubing and wind the electrostatic shield (L₂). Put on more than 35 turns so it can later be pruned to length, and dope the wire with radio cement. When dry, adjust the turns to approximately 35 and clean one end of the wire. Cut off the other wire close to the coil. The cleaned wire will later be tied to ground.

A commercially available form¹ for the toroid coil (L₂) can be used; or, a suitable toroid form can be made from the iron tuning slug inside the amplifier plate coil in the Command

Set transmitters, as described by WØPME in *QST*.¹

Wind the toroid with a full winding, dope with radio cement, and allow to dry. Leave 1-inch leads on this coil for connections and clean the leads at this time. Wind enough tape over center of the shield winding so that the toroid fits snugly at the center of the shield. Cement the toroid in place and, when dry, solder this assembly in place.

Construct the indicator unit, using the desired range of meter and power level potentiometer shown in TABLE II — METER SELECTION CHART. A sloping front meter case (*Bud* CMA-2066, or equivalent) was used on the model pictured.

ADJUSTMENT of the completed RF wattmeter is simple, once the wiring has been given a final check. The test setup, pictured in the view on page 1, shows the RF power source, line pickup unit, indicator unit, and 50-ohm dummy antenna load. RG-8/U or other 50-ohm coaxial cable should be used for interconnections between units. Sufficient RF power output to give a full-scale forward reading for the meter range selected, should be available.

Set switch S₁ toward the load, set R₂ at maximum resistance, turn on the transmitter and tune it for opti-

(continued on page 6)

TWO-TUBE DIFFERENTIAL KEYER

By S. E. Johnson, Jr., W2FBS

A GOOD-SOUNDING CW SIGNAL usually results from a transmitter keying system that applies and removes the keying voltages with a smooth waveform, without sharp peaks that can result in key clicks and thumps; or chirps from too-slow application of these keying voltages.

W2FBS describes here a vacuum-tube screen grid keying system that will key tetrode or pentode power amplifier stages in 20 to 300-watt transmitters. It will provide the following functions:

1. Keyed screen grid voltage for a power amplifier, with adjustable keying waveform;
2. Negative screen grid voltage when the key is open to cut off amplifier plate current;
3. Adjustment of screen voltage to the power amplifier to set the r.f. power output of that stage to the optimum level;
4. Negative blocking bias voltage with which to cut off an oscillator or mixer when the screen grid keying function is idle;
5. Adjustable negative bias voltage for the r.f. power amplifier.

This keyer contains a series screen voltage keyer tube, a control triode tube for the keyer tube, a diode-connected tube section to apply the blocking bias, and a 200-volt negative bias power supply.

Function of the keyer timewise is shown in the waveform chart, Fig. 1. When keying starts, screen voltage rises from a negative value to the operating value for the amplifier tube each time the key is pressed. The negative blocking bias on the os-

cillator or mixer grid is removed at the instant the key is pressed, and remains off until keying stops. The blocking bias then returns gradually, cutting off the oscillator or mixer shortly after keying of the amplifier screen grid stops. The oscillator or mixer thus will continue to operate during normal sending, but stops when the operator stops sending briefly to listen for incoming signals.

A 6BL7-GT TWIN TRIODE is the screen grid keyer tube as shown in the schematic diagram, Fig. 2. Both sections are connected in parallel, thus reducing its internal resistance to less than 1,000 ohms at zero control grid bias. The screen voltage of one, two or three small transmitting pentode tubes (807, 1625, 6146, 6L6-GC, 7581, GL-829B, etc.) thus can be controlled. Screen grid current flows from the cathode to screen grid of this amplifier tube, then to the cathode of the keyer tube, through this tube to the plate, and to the high voltage supply of 400 volts.

Section one of a 12AU7-A twin triode serves as a control tube for the grid bias voltage applied to the 6BL7-GT. With the key open, grid pin 7 has minus 90 volts applied, but the cathode, pin 8, is at minus 110 volts. This 12AU7-A section thus draws plate current through the 100,000-ohm resistor and potentiometer, R₁. This holds the control grid in the 6BL7-GT sufficiently negative with respect to its cathode, so that no plate current (and r.f. amplifier screen grid current) flows.

About minus 100 volts is applied

to the amplifier screen grid from the keyer bias supply through the 47,000-ohm, 2-watt resistor. At the same time, a minus 100 volts is applied to the oscillator or mixer control grid through the diode-connected section two of the 12AU7-A triode.

When the key is closed, cathode pin 8 of the 12AU7-A is grounded, and the minus 90 volts on control grid pin 7 cuts off plate current flow through this section. This causes the plate, pin 6, of this 12AU7-A section, and the control grids of the 6BL7-GT, pins 1 and 4, to rise to a positive voltage determined by the setting of R₁, the "Amplifier Screen Voltage Control." The 6BL7-GT then conducts, and the cathodes, pins 3 and 6, rise to a positive value approaching the positive voltage applied to pins 1 and 4.

Since closing the key also removes the negative voltage from the plate (pin 1) of the diode-connected 12AU7-A section, negative blocking bias no longer is presented to the grid circuit of the oscillator or mixer in the transmitter and it can operate. Capacitor C₁ in the cathode of the 12AU7-A diode-connected section prevents this bias from reappearing during the brief intervals the key is open between characters. But C₁ charges through R₁ and the blocking bias to returns in from 1/2 to 1 1/2 seconds after keying stops.

The setting of potentiometer R₁ adjusts the positive voltage applied to the control grids of the 6BL7-GT, and thus the voltage drop through it. This permits setting the screen voltage applied to the r.f. power amplifier tube (or tubes), when the key is closed, to the positive value which results in the desired r.f. power output. This feature is most helpful when only a portion of the normal power output of the trans-

TOP VIEW showing keyer constructed by W2FBS in a Minibox. Heater voltage for the 6BL7-GT in this model was obtained from one of two 6.3-volt windings on filament transformer T₁, with 6.3 volts fed into other winding. Only 6 terminals were thus needed on strip TS₁ for external connections.

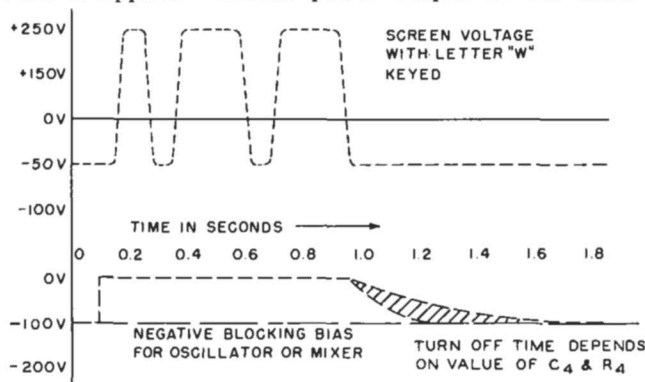
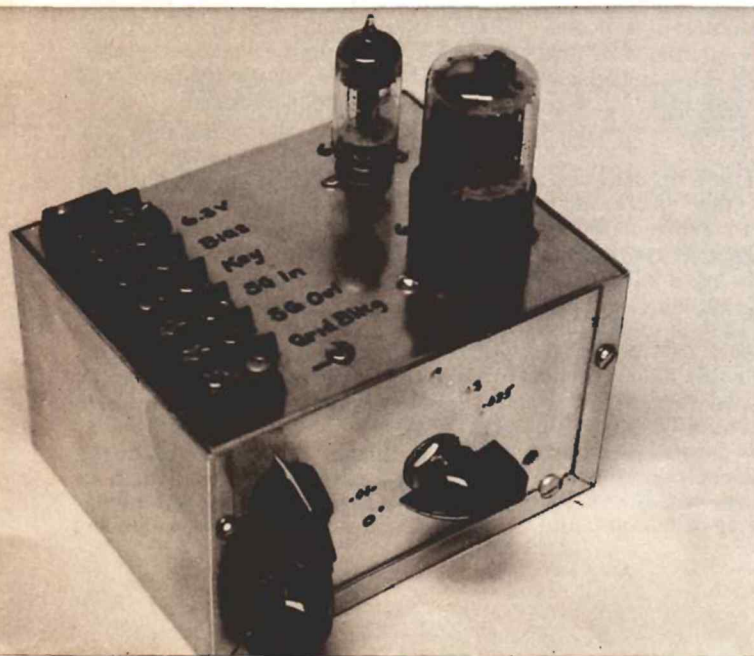


FIG. 1. WAVEFORM GRAPH showing (top) the screen voltage applied to the transmitter power amplifier when the letter "W" is keyed. Peak voltage will be from plus 25 to 300 volts, depending upon setting of R₁. Bottom graph shows sharp rise of negative blocking voltage for oscillator or mixer control grid from minus 100 to 0 volts, and slow decrease back to minus 100 volts after keying is stopped.

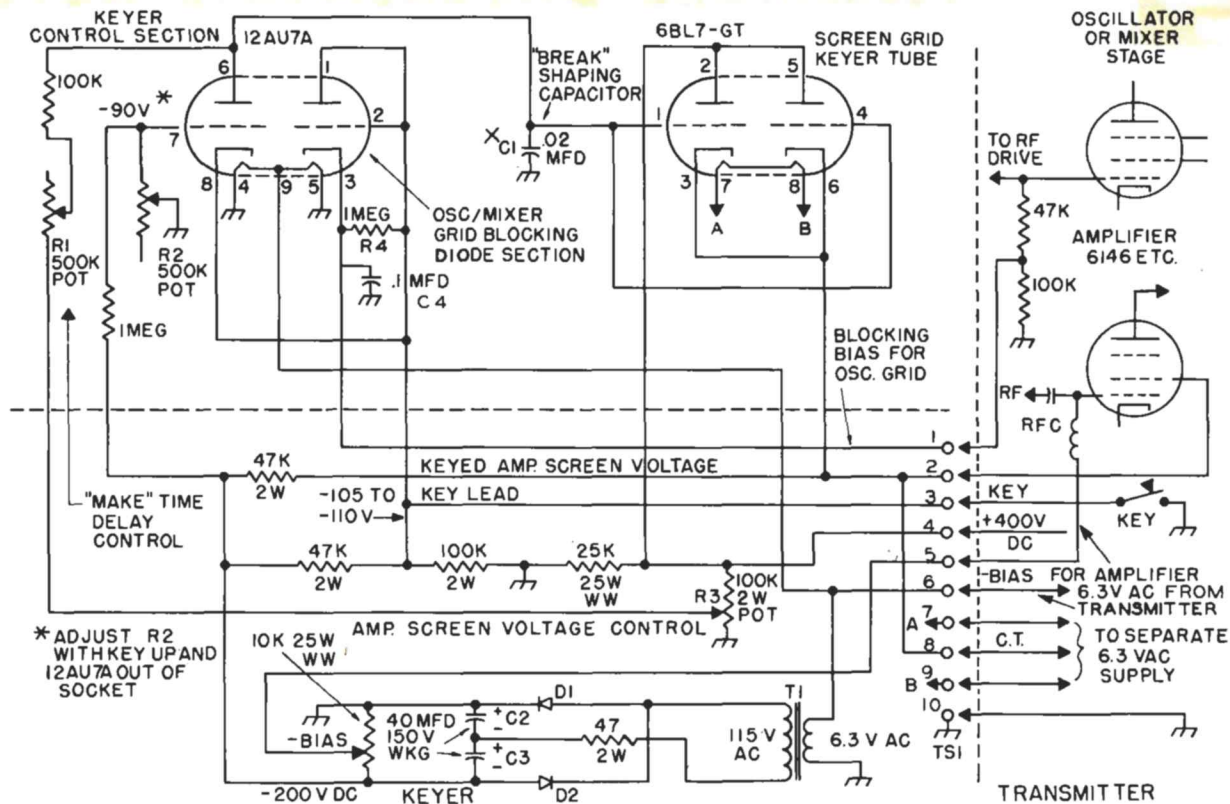


TABLE I — PARTS LIST DIFFERENTIAL KEYS

- C₁.....Paper capacitor, .02 mfd, 400 V. DC working (try values from .01 to .05 mfd for fast or slow "break" in keying).
 C₂, C₃.....40 mfd, 150-volt working electrolytic capacitors.
 C₄.....0.1-mfd, 400-volt paper, see text.
 D₁, D₂.....Selenium, Germanium or silicon diode rectifiers, 380-volt peak inverse rating, 50 milliampere DC current rating.
 R₁, R₂.....500,000-ohm, 2-watt potentiometer.
 R₃.....100,000 ohm, 2-watt potentiometer.
 R₄.....1 megohm, ½ watt, see text.
 T₁.....6.3-volt, 1 ampere filament transformer, 115-volt Primary (Thardarson T-21F08 or equivalent).

FIG. 2. SCHEMATIC DIAGRAM of complete keyer. Connections to typical oscillator or mixer control grid, negative bias for power amplifier control grid, and keyed screen grid voltage for power amplifier, are shown at right side of diagram. All resistances are in ohms, ½-watt rating, unless otherwise specified. All capacitances are in microfarads.

NOTE: A tap switch with several positions and a set of paper capacitors from .01 to .05 microfarads, can be inserted at point "X" in place of C₁. This provides adjustable sharpness of "break" characteristic of keyer.

mitter or exciter being controlled with this keyer is needed to drive a large r.f. power amplifier.

The rise of the amplifier screen grid voltage is delayed by C₁ charge-exponentially through R₁ and the 100,000 ohm resistor. The sharpness of the keying on the front of the keying characters is thus adjusted by the setting of R₁. Increased resistance increases the rise time and softens the keying.

The value of C₁ also shapes the tail of each keying character; more capacitance here softens the "break." Several values of capacitance can be cut in by a tap switch at this point to provide easy adjustment of both "make" and "break." Either a set of capacitors ranging from .01 to .05 microfarads, in steps of .005 microfarads; or, several .005 microfarad capacitors can be added to the circuit with a progressive shorting switch.

Negative bias for the keyer and r.f. amplifier is provided by connecting a 6.3-volt filament transformer (T₁) to the 6.3 volt supply for the 12AU7-A tube, and rectifying the 115-volt winding output. A voltage doubler provides about minus 200 volts bias. A lower bias voltage for the r.f. amplifier is obtained from the voltage divider. The 6BL7-GT keyer tube should be run from a separate 6.3-volt AC source, with the center tap connected to the amplifier screen voltage lead to keep the heater-cathode voltage of the 6BL7-GT within its rating.

CONSTRUCTION of W2FBS's keyer is in a 4 x 5 x 3-inch Minibox (Bud CU-3005, or Premier MC-1005). All parts except the terminal strip and tubes are inside the box, as shown in the photo on this page. Controls were mounted on one side, and the bias transformer was mounted in-

side on the opposite wall. This model has the tap switch added to select different values of C₁ for soft or sharp "break" characteristics.

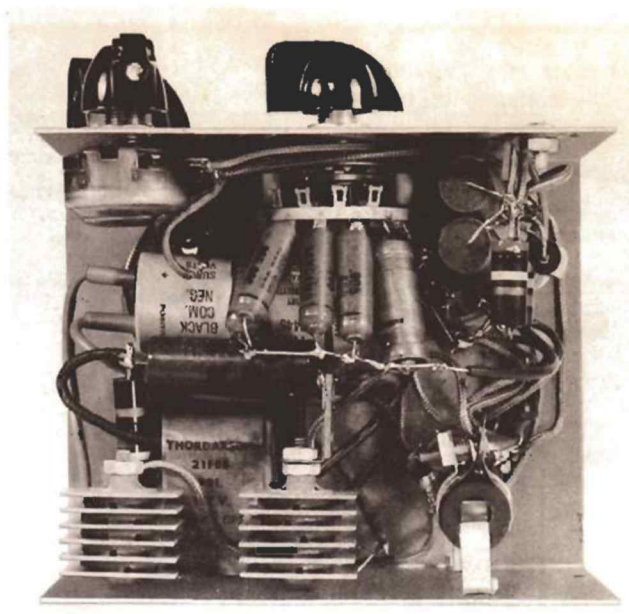
W2FBS has constructed another model of this keyer for the heterodyne exciter in his transmitter. All parts above the horizontal dotted line in the schematic diagram, Fig. 2, are inside a 2½ x 2½ x 5-inch Minibox (Bud CU-3004). The box is mounted on the main chassis of the exciter, with the other keyer parts located inside the main chassis below the Minibox. This complete exciter will be described in the July-August, 1961 (Vol. 16, No. 4) issue of *G-E HAM NEWS*.

ADJUSTMENT, after a check of the wiring, is simply a matter of applying 6.3 volts AC and measuring the output of the bias supply. With the 12AU7-A tube out of the socket and

(continued on page 6)



MODERN HETRODYNE EXCITER in W2FBS's attractive station console has the two-tube differential keyer unit built right into it. Exciter will be described in the July-August, 1961 issue. In addition to four one-kilowatt power amplifiers for the DX bands, the station also has a **PI-NETWORK ANTENNA TUNER** at right (see *G-E HAM NEWS*, May-June, 1960, page 3). World map in background contains 260-odd pins representing the present DXCC score on CW at W2FBS.



BOTTOM VIEW showing locations of major components: T_1 , D_1 and D_2 , and the bias voltage divider on rear wall; potentiometers R_1 and R_2 , and tap switch for selecting different values of capacitance for C_2 on front wall; and other components in middle of Minibox type chassis.

TWO-TUBE DIFFERENTIAL KEYER (continued from page 5)

the key open, adjust R_2 until minus 80 to 90 volts is measured at grid pin 7 of this socket. Use a voltmeter with a resistance of at least 5 megohms (scale of 250 volts or higher on a 20,000-ohm per volt meter, or vacuum tube voltmeter.

Plug in the 12AU7-A and 6BL7-GT tubes and, with the key still open, minus 105 to 110 volts should be read at cathode pin 3 on the 12AU7-A socket. The screen voltage to the power amplifier should be about minus 50 volts with the key open. With the keyer connected to the amplifier screen grid circuit in

the transmitter (or with a 10,000-ohm, 10-watt resistor from the screen grid voltage terminal to ground), check the screen voltage with key up and key down. Adjust R_1 over its range with the key closed, and a screen voltage from about plus 25 to 300 volts should be read.

This keyer can be built into an existing exciter if desired. It is ideal for replacing less satisfactory keying systems in transmitters in the 20 to 300-watt power input class. A keyer of this type has been operated with excellent results on the 150-watt **SINGLE BANDER** transmitter

models (See *G-E HAM NEWS*, November-December, 1957; and January-February, 1958, Vols. 12, No. 6, and 13, No. 1 issues).

If you've been having keying problems — chirps, clicks, thumps, back-wave, etc. — try this easy-to-construct packaged keyer unit in your transmitter. Or, add it in place of a less satisfactory keying system for improved CW performance. The 6BL7-GT twin triode will pass sufficient current to key the screen grid voltage of two, three, or even four transmitter stages which require about the same screen grid voltage.

LOW-COST RF WATTMETER (continued from page 3)

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imum power output. Then set R_3 for full-scale deflection of the meter. Throw S_1 toward the RF source to read reflected power. Adjust capacitor C_1 until a definite null is observed on the meter. A false null may be indicated at minimum capacitance, so check C_1 to see that the null occurs with C_1 at greater than minimum capacitance.

Reverse the connections to the wattmeter and repeat the adjustment just described with C_2 . This will set the reflected power null for the other half of the instrument. Run through it a couple of times to be sure of

the settings. A carefully built wattmeter will show almost true zero reflected for a full scale forward reading. This assumes that a 50-ohm non-reactive load and 50-ohm coaxial cable are used.

ACCURATE CALIBRATION of the RF wattmeter is not difficult, even though the authors were able to check their results against a commercially made RF wattmeter. If a good 50-ohm dummy load with low reactance is available, an RF ammeter and Ohms Law can be used to calibrate the RF wattmeter. Either a 0—1 (for transmitters with up to

50 watts output), 0—3 (for up to 450 watts), 0—4 (for up to 800 watts) or 0—5-ampere (for up to 1,250 watts) RF ammeter can be used.

There is a trick to connecting an RF ammeter into a coaxial cable. Be careful not to disturb the 50-ohm surge impedance and this takes a bit of doing! For frequencies in the range of 3-30 megacycles a wide strip of thin copper sheet or flat copper braid can be used to connect the outside braid together at the point where you open the cable to insert the meter. Insulate the meter

terminals with tape and then bend the copper strip tight against the terminals and meter case. The thermocouple is usually between the two meter terminals just inside the case, so bending the copper strip tight against the case helps preserve the 50-ohm configuration. The acid test is to insert the meter in a line and see if the VSWR changes noticeably.

If you are suspicious of the accuracy of any RF ammeter used to calibrate the RF wattmeter, check the result as follows: Measure the true input to the RF amplifier connected to the load; be sure to check the plate current and plate voltage. From these figures calculate the DC watts input. If possible operate the amplifier under Class C conditions. Be sure the coupling is adjusted for maximum efficiency. Assume 70% efficiency when the foregoing conditions have been met. If the watts (I^2R) in the load check about 70% of the DC input, the cross check is reasonably close.

Other methods of calibration are also practical. Calibrate an oscilloscope from a 60 cycle AC voltage fed directly into the deflection plates. Then use it to measure the RF voltage across the 50-ohm dummy load. Use the measured voltage in the formula $E^2 = W R$ to find the RF output

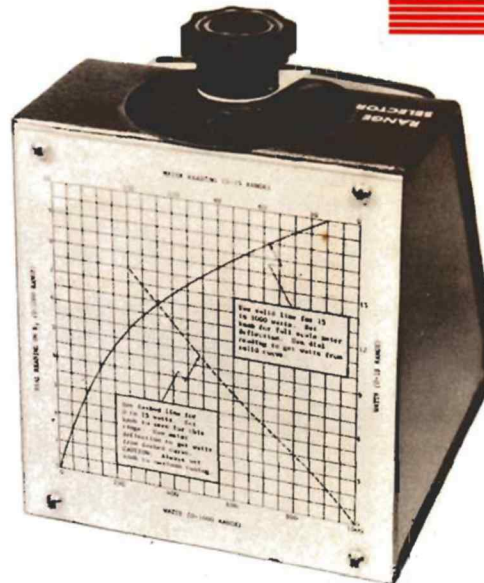
in watts. A VTVM with an RF probe, if its calibration is checked, can also be used in the same manner. Try checking power output several ways and take an average of the readings.

A good frequency to use for calibrating the RF wattmeter is 14 megacycles. It will probably then read 5% low on 4 megacycles and 5% high on 28 megacycles.

The calibration curves are attached to the back of the meter case and covered by a piece of 1/8" thick lucite sheet. The two curves can be drawn in different colors or in different type lines, as shown in the sample chart, Fig. 3. The dashed curve reads 0 to 15 watts. Set R_2 at zero resistance for this range. Read the actual meter deflection and then find this reading on the curve, move over to the other axis and read the power output in watts. The solid curve is the 15 to 1000-watt range. Always set R_2 for a full scale reading and accurately note the dial reading on R_2 . Use this figure to read watts from the 15 to 1000 watt scale on the calibration chart.

One word of caution: Always set R_2 fully clockwise, which automatically puts it on the highest range, when it is connected to an amplifier of unknown output. Obviously R_2 can

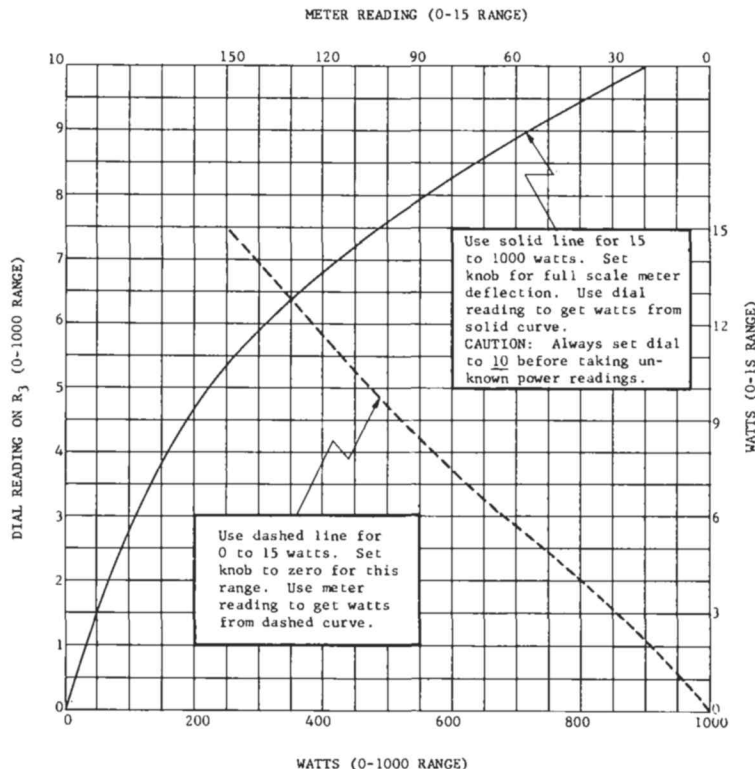
REAR VIEW of the indicator unit, showing the calibration curves fastened to the box and covered with 1/8-inch thick clear plastic. Curve is shown in Fig. 3.

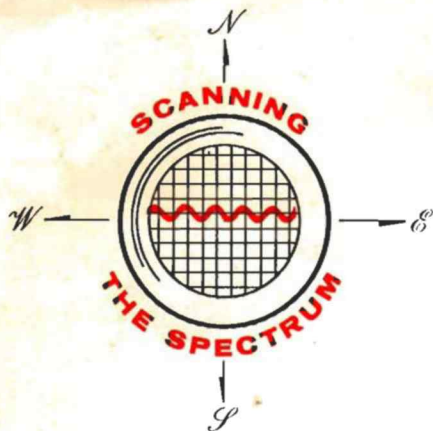


be set for 500 watts ahead of time if the power output is known to be less than 500 watts. This device will stand a 100% overload for a few minutes, but don't be the first to prove this statement.

When constructed as described, we're sure you'll find the Low-Cost RF Wattmeter an almost essential addition to your amateur radio station. In fact, you're likely to wonder how you ever got along without it.

FIG. 3. CALIBRATION CHART for the wattmeter described, for use with a 0—150-microampere meter (G. E. type DO-91) and 25,000-ohm potentiometer at R_2 . The solid line and figures at the left and bottom are for 15 to 1,000 watts; the dashed line and figures at the top and right are for the 0 to 15-watt range. Chart is shown actual size, so that it may be cut out and fastened to rear of meter box.





NEW G. E. "PACER" TWO-WAY RADIO FEATURES SIMPLIFIED TUBE CIRCUITS, 15-WATT OUTPUT, LOW BATTERY DRAIN

GENERAL ELECTRIC has engineered a new line of low-priced, lightweight, compact, two-way radios using vacuum tubes and simplified circuits to achieve lower battery drain than previously attained in tube-type equipment. Radio amateurs will find the new "PACER" a veritable "gold mine" of features.

The new G. E. "PACER" line has models covering both the low band (25-50 Mc.) and high band (150-174 Mc.). Smallest in G. E.'s entire line of two-way radios, the 15-tube unit has a panel only $4\frac{1}{4}$ x $7\frac{3}{4}$ inches, and is $12\frac{1}{2}$ inches deep, a total of only 412 cubic inches. How-

"KING-SIZE" COMMENTS —

Yes, we've received considerable "fan mail" on our increasing the page size of *G-E HAM NEWS* up to $8\frac{1}{2}$ x 11 inches this year, and 99.9 percent of it has been favorable. Most readers like the larger size of diagrams and photos. I'm also sure you'll like the additional articles we have room for, such as the **LOW-COST RF WATTMETER** and **TWO-TUBE DIFFERENTIAL KEYER** articles in this issue. Either of these would have occupied nearly an entire issue in the smaller page size.

ever, the cabinet provides ample space for optional accessories — two-channel operation, and G. E.'s "Channel Guard" device to protect against interference.

The miniaturized unit was designed to fit under the dash of even new compact cars without cramping passengers. Lightweight aluminum construction has reduced weight to only 10 pounds, including a newly designed microphone and elliptical speaker built into front of the unit.

The G. E. "Pacer" is completely American made and features the new General Electric line of 13.6-volt heater communication tubes in the 7000 series. A power pentode-high gain triode tube serves as microphone preamplifier and limiter for the transmitter, and as noise amplifier and audio output in the receiver.

One-case construction and universal mounting brackets simplify installation. A drawer-type pull-out chassis eases servicing and routine maintenance. Only one relay is used in the entire unit. There are plug-in connections to circuit boards, and plug in 0-3 volt DC metering for all critical circuits.

Look over the new G. E. "Pacer" two-way radio. You'll find it a prime example of how your new mobile should be built.

OMNIVOX PATCH TRANSFORMERS

Again from the mail basket, readers have asked some questions about the transformers used in the phone patch section of the OMNIVOX (See *G-E HAM NEWS*, January-February, 1961, page 1). The winding on T_2 marked as 1,200 ohms in the schematic diagram, Fig. 1, page 3, actually has a 4,000-ohm impedance. However, this winding is loaded by R_{17} (1,000 ohms), in combination with the primary load through R_{21} (470 ohms) and R_{20} (1,000-ohm potentiometer), and thus provides a good impedance match to the average phone line.

This 4,000-ohm winding is terminals 1 and 3 on the T_2 transformer obtained from the Signal Corps RM-52 Remote Control Unit. Although the RM-52 has been advertised by a number of surplus outlets, I notice that it has been listed regularly in flyers from Fair Radio Sales Co., P. O. Box 1105, Lima, Ohio, both as "used" and "new."

The following is a bibliography of articles that author W4PFQ referred to in designing his OMNIVOX.

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