INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE TCF POWER LINE CARRIER FREQUENCY-SHIFT TRANSMITTER EQUIPMENT-- 1 WATT/ 1 WATT -- VOLTAGE KEYED FOR TELEMETERING

CAUTION

It is recommended that the user of this equipment become thoroughly familiar with the information in this instruction leaflet before energizing the carrier assembly. Failure to observe this precaution may result in damage to the equipment.

If the carrier set is mounted in a cabinet, it must be bolted down to the floor or otherwise secured before swinging out the equipment rack to prevent its tipping over.

APPLICATION

The type TCF carrier transmitter equipment provides for the transmission of either of two closely controlled discrete frequencies, both within a narrow-band channel, over high-voltage transmission lines. The center frequency of the channel can vary from 30 to 200 KC in 0.5 KC steps. The two frequencies transmitted are separated by 200 cycles, one being at center frequency (fc) plus 100 cycles and the other at center frequency minus 100 cycles.

When the TCF transmitter is used in voltage-keyed telemetering applications, the transmission of the high or the low frequency in the channel is controlled by the positive and negative half cycles of an a-c voltage obtained from a telemetering transmitter. This transmitter converts a d-c millivolt signal to an a-c voltage of proportional frequency, which typically may have a range from 15 cps. at zero millivolts to 35 cps. at a selected maximum value of millivolts. The high frequency output of the TCF transmitter is carried to a TCF receiver over a power line and through coupling capacitors and line tuners at each end. The receiver converts the high frequency signal to an a-c voltage of frequency which varies identically with that which keys the transmitter, and a telemetering receiver converts this varying frequency to a proportional d-c millivolt output.

CONSTRUCTION

The 1 watt/1 watt TCF transmitter unit is mounted on a standard 19-inch wide panel 8-3/4 inches (5 rack units) high with edge slots for mounting on a standard relay rack. All components are mounted

SUPERSEDES I. L. 41-945.2
*Denotes change from superseded issue.

EFFECTIVE MARCH 1966

on the rear of the panel. Fuses, a pilot light, and a power switch are accessible from the front of the panel. See Figure No.5. All of the circuitry that is suitable for printed circuit board mounting is contained on two such boards, located as shown on Figure No. 2. The locations of the components on the voltage-keyed input board are shown on Figure No. 4, and the locations of the components on the board containing the oscillators, mixer and buffer amplifier, and final amplifier are shown on Figure No. 3. The components included on each board are indicated also by areas inclosed by dotted lines on the internal schematic, Figure No. 1. A Zener diode mounted on a heat sink provides a regulated 45-volt d-c power supply, and an output filter removes harmonics that may be generated by distortion in the amplifier. The locations of all circuit elements on the panel are shown on Figure No. 2 and their electrical connections are shown on Figure No. 1.

External connections to the assembly are made through a 12-circuit receptacle, J3. The r.f. output connection to the assembly is made through a coaxial cable jack, J2 (Figure No. 1)

OPERATION

The transmitter is made up of four main stages and an output filter. The input stage receives the a-c voltage from a telemetering transmitter and amplifies it to a level sufficient for properly shifting the frequencies of the two crystal oscillators in the next stage. The two oscillator frequencies enter the mixer and buffer amplifier stage, where the difference frequency is amplified to drive the final amplifier stage. The output of this fourth stage enters the output filter, which is tuned to the difference (fundamental) frequency and contains second and third harmonic traps for further reduction of harmonics.

The a-c output voltage from the telemetering transmitter is applied to terminals 9-10 of input jack J3, and is connected through resistors R101 and R103 to the bases of transistors Q101 and Q103. These transistors are biased by resistors R102 and R106 so that a small value of a-c voltage at terminals 9-10 will make them alternately conductive. When terminal 9 is positive with respect to terminal 10, transistor Q102 conducts and when 9 is negative with respect to 10, Q101 conducts. Consequently, current flows from terminal 2 to terminal 1 of transformer T1 when 9 is positive and from 2 to 3 when 9 is negative. Zener diode CR103 has a 15-volt rating and Zener diode CR54 (on the larger circuit board) has a 20-volt rating. Thus there is a nominal 5 volt drop across resistor R110, and for a static condition (no a-c input voltage and crystals removed from sockets) the anode of diode CR52 is held at +15 volts, thereby causing both CR51 and CR52 to be reverse biased. It will be seen that CR55 and CR56 are similarly reverse biased under this condition.

When Q101 and Q103 are turned on and off alternately by a-c voltage from the telemetering transmitter, voltage of approximately square waveform is induced in the secondary of transformer T1, and when secondary terminals 4 and 6 alternately become sufficiently positive with respect to terminal 5 diodes CR51 and CR52, or CR55 and CR56, become forward biased. The effect of this in shifting the frequencies of the oscillators will be explained in a later paragraph.

A single crystal designed for oscillation in the 30 KC to 200 KC range cannot be forced to oscillate away from its natural frequency by as much as ±100 cycles. In order to obtain this desired frequency shift, it is necessary to use crystals in the 2 MC range. The crystals are Y1 and Y2 of Figure No. 1. The frequency of Y2 is 2.00 MC when operated with a specified amount of series capacity, and the frequency of Y1 is 2.00 MC plus the channel frequency, or 2.03 MC to 2.20 MC. Capacitor C55 and crystal Y2 in series are connected between the positive side of the supply voltage and the base of transistor Q51, which operates in the emitter-follower mode. The emitter is coupled to the base through C57, and with Y2 removed the base of Q51 would be held at approximately the midpoint of the supply voltage by R51 and R52. The crystal serves as a series-resonant circuit with very high inductance and low capacitance. The circuit can be made to oscillate at other than the natural frequency of the crystal by varying the series capacitor, C55. Increasing C55 will lower the frequency of oscillations and reducing C55 will raise the frequency.

Capacitor C70 is ineffective while diode CR55 is reverse biased and therefore non-conductive, but when the diode is forward biased by sufficient positive voltage at terminal 12, it becomes conductive and C70 is effectively placed in parallel with C55. This reduces the frequency of oscillation by an amount determined by the setting of C70. The frequency of the oscillator circuit in which crystal Y1 is used will be reduced in similar manner when terminal 18 becomes sufficiently positive to forward bias diode CR51.

With diodes CR51 and CR55 both reverse biased and with C52 and C55 adjusted so that their associated crystals operate at their nominal frequencies, the sum of the two frequencies impressed on the base of mixer transistor Q53 through capacitors C62 and C63 is 4 MC+fc and the difference frequency is fc. The sum frequency is so high that a negligible amount appears on the secondary of transformer T51 but the difference frequency is accepted and amplified by Q53 and 54. However, with an a-c voltage at input terminals 9 and 10 of J3 diodes CR51 and CR55 are each alternately forward biased for substantially a full half-cycle, and by adjustment of capacitors C53 and C70 difference frequencies of fc+100 cycles and fc-100 cycles can be obtained on alternate half cycles.

The crystals taken individually have a greater variation of frequency with temperature than would be acceptable. However, by proper matching of the two crystals, the variation in their difference frequency can be kept within limits that permit holding the frequency stability of the overall transmitter to ± 10 cycles/sec. over a temperature range of -20 to +60°C.

The amplifier stage consists of transistors Q56 and Q57 connected in a conventional push-pull circuit with input supplied from the collector of Q54 through transformer T52. Thermistor R73 and resistors R74 and R75 are connected to provide a variable bias that reduces the effect of varying ambient temperatures on the output level. The output power is adjusted to 1 watt by means of R64.

The output transformer T2 couples the amplifier transistors to the output filter FL102. The output filter includes two trap circuits (L102, C_B, and L103, C_C) which are factory tuned to the second and third harmonics of the transmitter frequency. Capacitor C_D approximately cancels the inductive reactance of the two trap circuits at the operating frequency. Protective gap G1 is a small lightning arrester to limit the magnitude of switching surges or other line disturbances reaching the carrier set through the line tuner and coaxial cable. Auto-transformer T3 matches the filter impedance to coaxial cables of 50, 60, or 70 ohms.

The series resonant circuit composed of L105 and C_E is tuned to the transmitter frequency, and aids in providing resistive termination for the output stage. Jack J102 is mounted on the rear panel of FL102 and is used for measuring the r.f. output current of the transmitter into the coaxial cable. It should be noted that the filter contains no shunt reactive elements, thus providing a reverse impedance that is free of possible "across-the-line" resonances.

The regulated 45 volt power supply is obtained from a 50-watt Zener diode mounted on a heat sink and connected to the station battery supply through suitable series resistors, as shown on Figure No. 1. Capacitor C68 provides a low carrier-frequency impedance across the d-c output voltage, and capacitors C1 and C2 bypass r.f. or transient voltages to ground, thus preventing damage to the transistor circuits.

CHARACTERISTICS

Frequency Range	30-200 KC
Output	1 watt (into 50 to 70 ohm resistive load)
Frequency Stability	± 10 cycles/sec. from -20°C to +60°C.
Frequency Spacing	1. One-way channel, two or more signals - 500 cycles min. 2. Two-way channel - 1500 cycles min. between transmitter and adjacent receiver frequencies.
Harmonics	down 55 db (min.) from output level.
Input Impedance of Keying Circuit	50,000 ohms
Keying Voltage	10 to 50 volts p.-p., sine or square wave
Keying Frequency	10 to 50 cycles
Supply Voltage	48, 125 or 250 V.D.C. (Separate units)

Supply Voltage Variation	42-56 V. for nom. 48 V. supply 105-140 V. for nom. 125 V. supply 210-280 V. for nom. 240 V. supply
Battery Drain	0.12 a. at 48 V. d-c. 0.27 a. at 125 or 250 V. d-c
Temperature Range	-20 to +60°C around chassis
Dimensions	Panel height - 8-3/4" or 5 r.u. Panel width - 19"
Weight	10 lbs.

INSTALLATION

The TCF transmitter is generally supplied in a cabinet or on a relay rack as part of a complete carrier assembly. The location must be free from dust, excessive humidity, vibration, corrosive fumes, or heat. The maximum ambient temperature around the chassis must not exceed 60°C.

ADJUSTMENTS

The TCF 1W/1W transmitter is shipped with the power output control R64 set for an output of 1 watt into a 60 ohm load. If it is desired to check the adjustments or if repairs have made readjustment necessary, the coaxial cable should be disconnected from the assembly terminals and replaced with a 50 to 70 ohm non-inductive resistor of at least a 1 watt rating. Use the value of the expected input impedance of the coaxial cable and line tuner. If this is not known, assume 60 ohms. Connect the T3 output lead to the corresponding tap. Connect an a-c vacuum tube voltmeter (VTVM) across the load resistor. Turn power output control R64 to minimum (full counterclockwise). Turn on the power switch on the panel and note the d-c voltage across terminals 5 and 7 of J3. If this is in the range of 42 to 46 volts, rotate R64 clockwise to obtain 3 or 4 volts across the load resistor. At this point check the adjustment of the series output tuning coil L105 by loosening the knurled shaft-locking nut and moving the adjustable core in and out a small amount from its initial position. Leave it at the point of maximum voltage across the load resistor.

Continue to advance R64 until the output voltage shown in the following table is obtained across the load resistor. Recheck the setting of L105 to be sure it is at its optimum point for 1 watt output. Tighten the locking nut.

T3 * Tap	Voltage for 1 Watt Output
50	7.1
60	7.8
70	8.4

With no a-c voltage impressed on terminals 9 and 10, the output frequency of the transmitter is fc. When the output filter is adjusted for maximum output at this frequency, the output voltage at the operating frequencies of fc ± 100 cycles will not be appreciably lower.

Follow the procedure outlined in the line tuner instructions for its adjustment.

Normally the output filter (FL102) will require no readjustment except as noted above. It is factory tuned for maximum second and third harmonic rejection, and for series resonance (maximum output at the fundamental frequency) with a 60-ohm load. A small amount of reactance in the transmitter output load circuit may be tuned out by readjustment of the movable core of L105. This may be necessary with some types of line coupling equipment. The adjustable cores of L102 and L103 have been set for maximum harmonic rejection and no change should be made in these settings unless suitable instruments are available for measuring the second and third harmonic present in the transmitter output.

The operating frequencies of crystals Y1 and Y2 have been carefully adjusted at the factory and good stability can be expected. If it is desired to check the frequencies of the individual crystals, this can be done by turning the matched pair 180° and inserting Y1 crystal in its proper socket with the other crystal unconnected. Because of proximity to capacitor C70, the crystal pair cannot be reversed to permit checking Y2 alone, but this can be done by partially withdrawing Y2 from its socket and tilting it sufficiently to open-circuit the Y1 crystal. A sensitive frequency counter with a range of at least 2.2 megacycles can be connected from TP51 to TP54. (Connection to TP54 rather than to TP53 provides a better signal to the counter and avoids some error from the effect of the counter input capacitance on the oscillator circuit.)

If for any reason, it should be necessary to replace a matched crystal pair, the following adjustments should be made.

With rated d-c voltage on the transmitter, with R64 fully clockwise to increase input to frequency counter, and with terminals 9-10 of J3 open, the frequency of Y1 alone should be its marked frequency (±3 cycles). If adjustment is necessary, loosen locking nut of capacitor C52 and set for correct frequency. Next, apply 45v. d-c from terminal 7 of J3 (or terminal 2 of transmitter circuit board) to TP104 (on input circuit board). The frequency should drop to the marked frequency minus 85 cycles (±3 cycles), and should be adjusted to this value by C53 if necessary. If capacitor settings are changed, both steps should be rechecked until the oscillator operates at the marked frequency of Y1(±3 cycles) before applying 45 volts to TP104, and at 85 cycles (±3 cycles) less than the marked frequency after applying 45 volts.

Similarly, check the oscillator frequency with Y2 alone in circuit, and if necessary, adjust C55 for 2 MC(±3 cycles). Then apply 45 volts from terminal 7 to TP101. The frequency should be 2 MC minus 85 cycles (±3 cycles). If capacitor settings are changed, recheck both steps as before. Tighten locknuts on all capacitors. Turn R64 full counterclockwise, and after inserting both crystals in their sockets, readjust R64 for 1 watt output.

With adjustments made as described, the difference frequency of the two oscillators will be fc + 100 cycles on one half-cycle of an a-c voltage on terminals 9-10, and will be fc - 100 cycles on the next half-cycle. The frequency cannot be measured when it is being continually shifted by an a-c keying voltage, and adjustments must be made by using d-c voltage for biasing diodes CR51, CR52, CR55 and CR56. However, when an a-c keying voltage is present, the connections to the mid-tapped secondary of T1 cause the reverse bias voltage that is present alternately on each set of diodes to be much greater than when a d-c voltage is applied on TP101 or TP104. The oscillator frequency with this high reverse bias voltage shifts upward approximately 15 cycles when the other oscillator with forward bias voltage shifts downward 85 cycles. The resultant difference frequencies therefore are fc + 100 cycles and fc - 100 cycles for alternate half cycles at terminals 9 - 10.

For routine maintenance the frequencies of the individual oscillators need not be checked. The difference frequencies can be measured directly at the transmitter output, using the proper load resistor to match the T3 tap used. With terminals 9-10 open, C52 should be adjusted for a frequency of fc ±3 cycles. Then with +45 V.d-c applied to TP104, C53 should be adjusted for fc minus 85(±3) cycles. With 45 volts applied to TP101 instead of TP104, C70 should be adjusted for fc plus 85(±3) cycles. A similar final adjustment should be made after making the individual adjustments required when a matched pair of crystals is replaced.

MAINTENANCE

Periodic checks of the transmitter power output will detect impending failure so that the equipment can be taken out of service for correction. At regular maintenance intervals, any accumulated dust should be removed, particularly from the heat sink. It is also desirable to check the transmitter power output at such times, making any necessary readjustments to return the equipment to its initial settings.

Voltage values should be recorded after adjustment in order to establish reference values which will be useful when checking the apparatus. The readings will remain fairly constant over an indefinite period unless a failure occurs. However, if transistors are changed, there may be considerable difference in these readings without the overall performance being affected.

Typical voltage values are given in the following tables. Voltages should be measured with a VTVM. Readings may vary as much as ±20%.

TABLE I

TRANSMITTER D-C MEASUREMENTS

Note: All voltages are positive with respect to Neg. 45 V. (TP51). All voltages read with d-c VTVM.

Test Point	Voltage at 1 Watt Output
TP 52	20
TP 53	5.4
TP 54	3.4
TP 55	21
TP 56	21
TP 57	.65
TP 58	44.3
TP 59	.65
TP102	20
TP103	20
TP105	15

TABLE II

TRANSMITTER RF MEASUREMENTS

Note: Voltages taken with transmitter set to indicated output across 60 ohms. These voltages are subject to variations, depending upon frequency and transistor characteristics. T51-3 = Terminal 3 of transformer T51. Other transformer terminals identified similarly. All voltages read with a-c VTVM.

Test Points	Voltage at 1 Watt Output
TP 54 to TP 51	0.12
TP 57 to TP 51	0.8
TP 59 to TP 51	0.8
T2-1 to TP 51	26
T2-3 to TP 51	26
T2-4 to Gnd.	36
T3-2 to Gnd.	30
TP109 to Gnd.	9.8
J102 to Gnd.	7.8

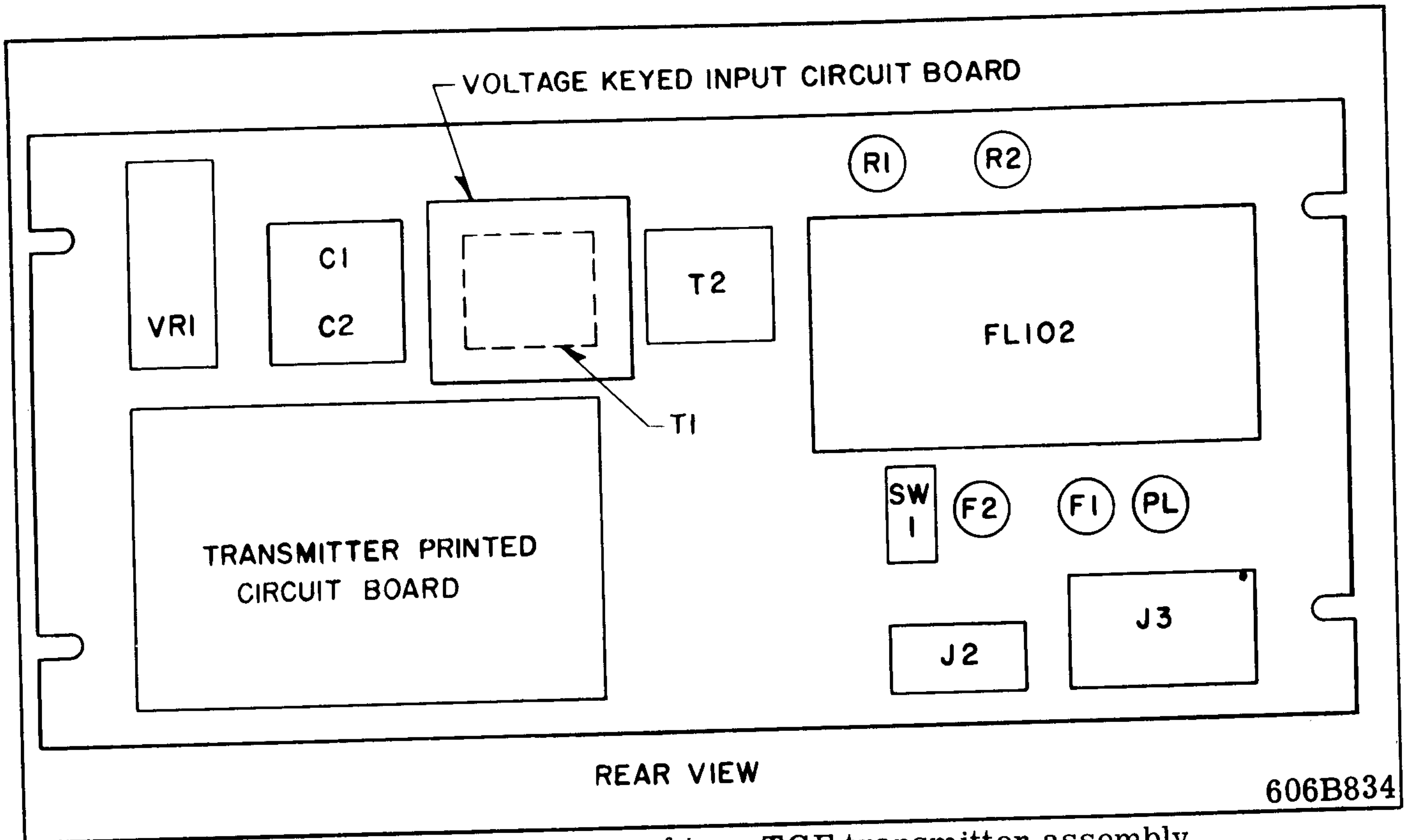

Fig. 2 Component locations of type TCF transmitter assembly.

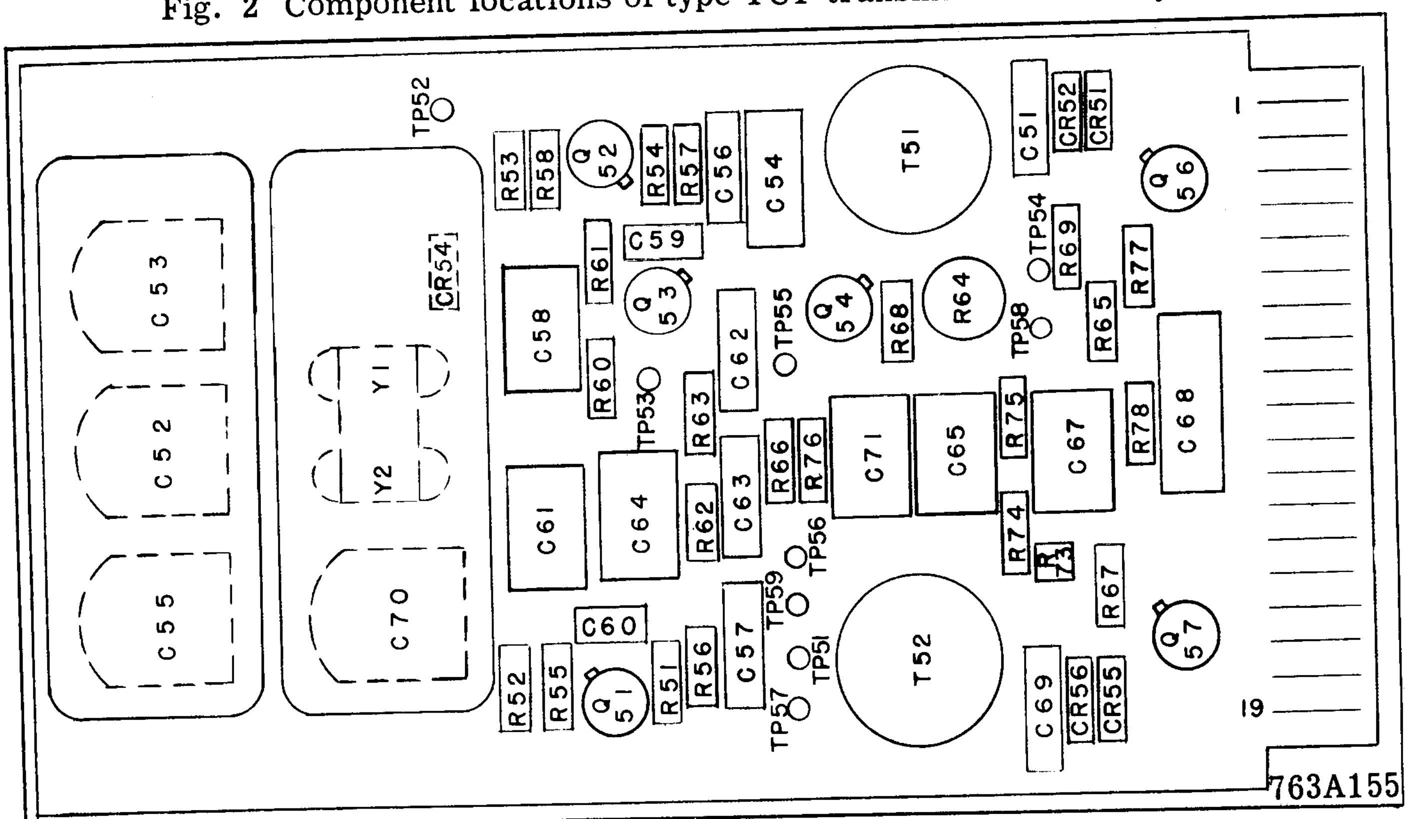

Fig. 3 Component locations of transmitter printed circuit board.

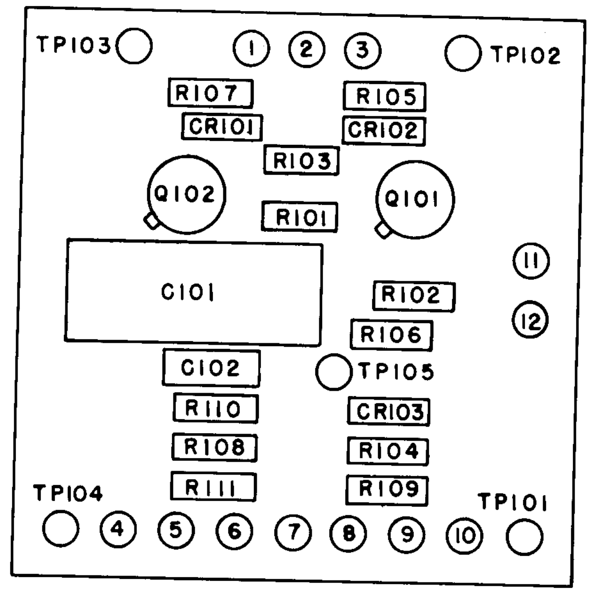

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Fig. 4 Component locations of voltage keyed input board.

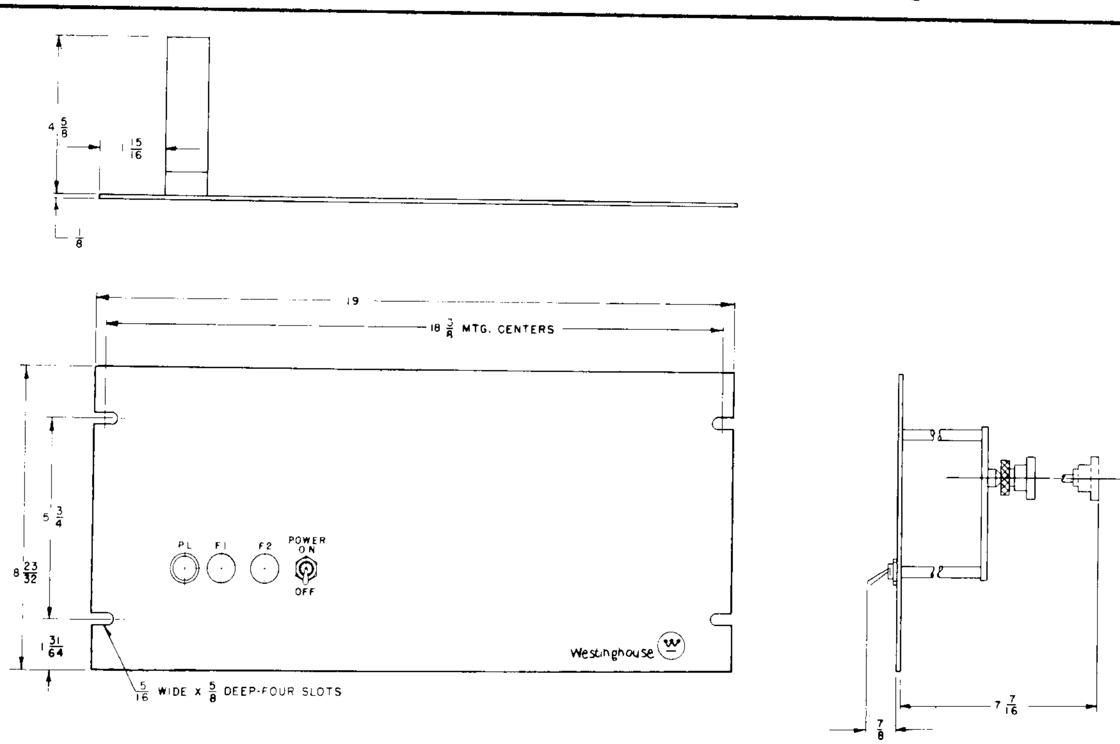

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Fig. 5 Outline of type TCF transmitter assembly.

RECOMMENDED TEST EQUIPMENT

I. Minimum Test Equipment for Installation
   a. 60-ohm 10-watt non-inductive resistor.
   b. A-C vacuum tube voltmeter (VTVM). Voltage range 0.003 to 30 volts, frequency range 60 cycles/sec. to 230-kc. input impedance 7.5 megohms.
   c. D-C vacuum tube voltmeter (VTVM).
      Voltage Range: 0.15 to 300 volts
      Input Impedance: 7.5 megohms.

II. Desirable Test Equipment for Apparatus Maintenance
   a. All items listed in I.
   b. Signal Generator

      Output Voltage: up to 8 volts
      Frequency Range: 20-kc to 230-kc

   c. Oscilloscope
   d. Frequency counter
   e. Ohmmeter
   f. Capacitor checker

Some of the functions of the recommended test equipment are combined in the type TCT carrier test meter unit, which is designed to mount on a standard 19" rack but also can be removed and used as a portable unit.

RENEWAL PARTS

Repair work can be done most satisfactorily at the factory. However, replacement parts can be furnished, in most cases, to customers who are equipped for doing repair work. When ordering parts, always give the complete nameplate data and identify the part by its designation on the Internal Schematic Drawing.

WESTINGHOUSE ELECTRIC CORPORATION

RELAY-INSTRUMENT DIVISION

NEWARK, N. J.

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NEW INFORMATION

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The series resonant circuit composed of L105 and C_E is tuned to the transmitter frequency, and aids in providing resistive termination for the output stage. Jack J102 is mounted on the rear panel of FL102 and is used for measuring the r.f. output current of the transmitter into the coaxial cable. It should be noted that the filter contains no shunt reactive elements, thus providing a reverse impedance that is free of possible "across-the-line" resonances.

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Input Impedance of Keying Circuit	50,000 ohms
Keying Voltage	10 to 50 volts p.-p., sine or square wave
Keying Frequency	10 to 50 cycles
Supply Voltage	48, 125 or 250 V.D.C. (Separate units)

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The TCF transmitter is generally supplied in a cabinet or on a relay rack as part of a complete carrier assembly. The location must be free from dust, excessive humidity, vibration, corrosive fumes, or heat. The maximum ambient temperature around the chassis must not exceed 60°C.

ADJUSTMENTS

The TCF 1W/1W transmitter is shipped with the power output control R64 set for an output of 1 watt into a 60 ohm load. If it is desired to check the adjustments or if repairs have made readjustment necessary, the coaxial cable should be disconnected from the assembly terminals and replaced with a 50 to 70 ohm non-inductive resistor of at least a 1 watt rating. Use the value of the expected input impedance of the coaxial cable and line tuner. If this is not known, assume 60 ohms. Connect the T3 output lead to the corresponding tap. Connect an a-c vacuum tube voltmeter (VTVM) across the load resistor. Turn power output control R64 to minimum (full counterclockwise). Turn on the power switch on the panel and note the d-c voltage across terminals 5 and 7 of J3. If this is in the range of 42 to 46 volts, rotate R64 clockwise to obtain 3 or 4 volts across the load resistor. At this point check the adjustment of the series output tuning coil L105 by loosening the knurled shaft-locking nut and moving the adjustable core in and out a small amount from its initial position. Leave it at the point of maximum voltage across the load resistor.

Continue to advance R64 until the output voltage shown in the following table is obtained across the load resistor. Recheck the setting of L105 to be sure it is at its optimum point for 1 watt output. Tighten the locking nut.

T2 Tap	Voltage for 1 Watt Output
50	7.1
60	7.8
70	8.4

With no a-c voltage impressed on terminals 9 and 10, the output frequency of the transmitter is fc. When the output filter is adjusted for maximum output at this frequency, the output voltage at the operating frequencies of fc ± 100 cycles will not be appreciably lower.

Follow the procedure outlined in the line tuner instructions for its adjustment.

Normally the output filter (FL102) will require no readjustment except as noted above. It is factory tuned for maximum second and third harmonic rejection, and for series resonance (maximum output at the fundamental frequency) with a 60-ohm load. A small amount of reactance in the transmitter output load circuit may be tuned out by readjustment of the movable core of L105. This may be necessary with some types of line coupling equipment. The adjustable cores of L102 and L103 have been set for maximum harmonic rejection and no change should be made in these settings unless suitable instruments are available for measuring the second and third harmonic present in the transmitter output.

The operating frequencies of crystals Y1 and Y2 have been carefully adjusted at the factory and good stability can be expected. If it is desired to check the frequencies of the individual crystals, this can be done by turning the matched pair 180° and inserting Y1 crystal in its proper socket with the other crystal unconnected. Because of proximity to capacitor C70, the crystal pair cannot be reversed to permit checking Y2 alone, but this can be done by partially withdrawing Y2 from its socket and tilting it sufficiently to open-circuit the Y1 crystal. A sensitive frequency counter with a range of at least 2.2 megacycles can be connected from TP51 to TP54. (Connection to TP54 rather than to TP53 provides a better signal to the counter and avoids some error from the effect of the counter input capacitance on the oscillator circuit.)

If for any reason, it should be necessary to replace a matched crystal pair, the following adjustments should be made.

With rated d-c voltage on the transmitter, with R64 fully clockwise to increase input to frequency counter, and with terminals 9-10 of J3 open, the frequency of Y1 alone should be its marked frequency (±3 cycles). If adjustment is necessary, loosen locking nut of capacitor C52 and set for correct frequency. Next, apply 45v. d-c from terminal 7 of J3 (or terminal 2 of transmitter circuit board) to TP104 (on input circuit board). The frequency should drop to the marked frequency minus 85 cycles (±3 cycles), and should be adjusted to this value by C53 if necessary. If capacitor settings are changed, both steps should be rechecked until the oscillator operates at the marked frequency of Y1(±3 cycles) before applying 45 volts to TP104, and at 85 cycles (±3 cycles) less than the marked frequency after applying 45 volts.

Similarly, check the oscillator frequency with Y2 alone in circuit, and if necessary, adjust C55 for 2 MC(±3 cycles). Then apply 45 volts from terminal 7 to TP101. The frequency should be 2 MC minus 85 cycles (±3 cycles). If capacitor settings are changed, recheck both steps as before. Tighten locknuts on all capacitors. Turn R64 full counterclockwise, and after inserting both crystals in their sockets, readjust R64 for 1 watt output.

With adjustments made as described, the difference frequency of the two oscillators will be fc + 100 cycles on one half-cycle of an a-c voltage on terminals 9-10, and will be fc - 100 cycles on the next half-cycle. The frequency cannot be measured when it is being continually shifted by an a-c keying voltage, and adjustments must be made by using d-c voltage for biasing diodes CR51, CR52, CR55 and CR56. However, when an a-c keying voltage is present, the connections to the mid-tapped secondary of T1 cause the reverse bias voltage that is present alternately on each set of diodes to be much greater than when a d-c voltage is applied on TP101 or TP104. The oscillator frequency with this high reverse bias voltage shifts upward approximately 15 cycles when the other oscillator with forward bias voltage shifts downward 85 cycles. The resultant difference frequencies therefore are fc + 100 cycles and fc - 100 cycles for alternate half cycles at terminals 9 - 10.

For routine maintenance the frequencies of the individual oscillators need not be checked. The difference frequencies can be measured directly at the transmitter output, using the proper load resistor to match the T3 tap used. With terminals 9-10 open, C52 should be adjusted for a frequency of fc ±3 cycles. Then with +45 V.d-c applied to TP104, C53 should be adjusted for fc minus 85(±3) cycles. With 45 volts applied to TP101 instead of TP104, C70 should be adjusted for fc plus 85(±3) cycles. A similar final adjustment should be made after making the individual adjustments required when a matched pair of crystals is replaced.

MAINTENANCE

Periodic checks of the transmitter power output will detect impending failure so that the equipment can be taken out of service for correction. At regular maintenance intervals, any accumulated dust should be removed, particularly from the heat sink. It is also desirable to check the transmitter power output at such times, making any necessary readjustments to return the equipment to its initial settings.

Voltage values should be recorded after adjustment in order to establish reference values which will be useful when checking the apparatus. The readings will remain fairly constant over an indefinite period unless a failure occurs. However, if transistors are changed, there may be considerable difference in these readings without the overall performance being affected.

Typical voltage values are given in the following tables. Voltages should be measured with a VTVM. Readings may vary as much as ±20%.

TABLE I

TRANSMITTER D-C MEASUREMENTS

Note: All voltages are positive with respect to Neg. 45 V. (TP51). All voltages read with d-c VTVM.

Test Point	Voltage at 1 Watt Output
TP 52	20
TP 53	5.4
TP 54	3.4
TP 55	21
TP 56	21
TP 57	.65
TP 58	44.3
TP 59	.65
TP102	20
TP103	20
TP105	15

TABLE II

TRANSMITTER RF MEASUREMENTS

Note: Voltages taken with transmitter set to indicated output across 60 ohms. These voltages are subject to variations, depending upon frequency and transistor characteristics. T51-3 = Terminal 3 of transformer T51. Other transformer terminals identified similarly. All voltages read with a-c VTVM.

Test Points	Voltage at 1 Watt Output
TP 54 to TP 51	0.12
TP 57 to TP 51	0.8
TP 59 to TP 51	0.8
T2-1 to TP 51	26
T2-3 to TP 51	26
T2-4 to Gnd.	36
T3-2 to Gnd.	30
TP109 to Gnd.	9.8
J102 to Gnd.	7.8

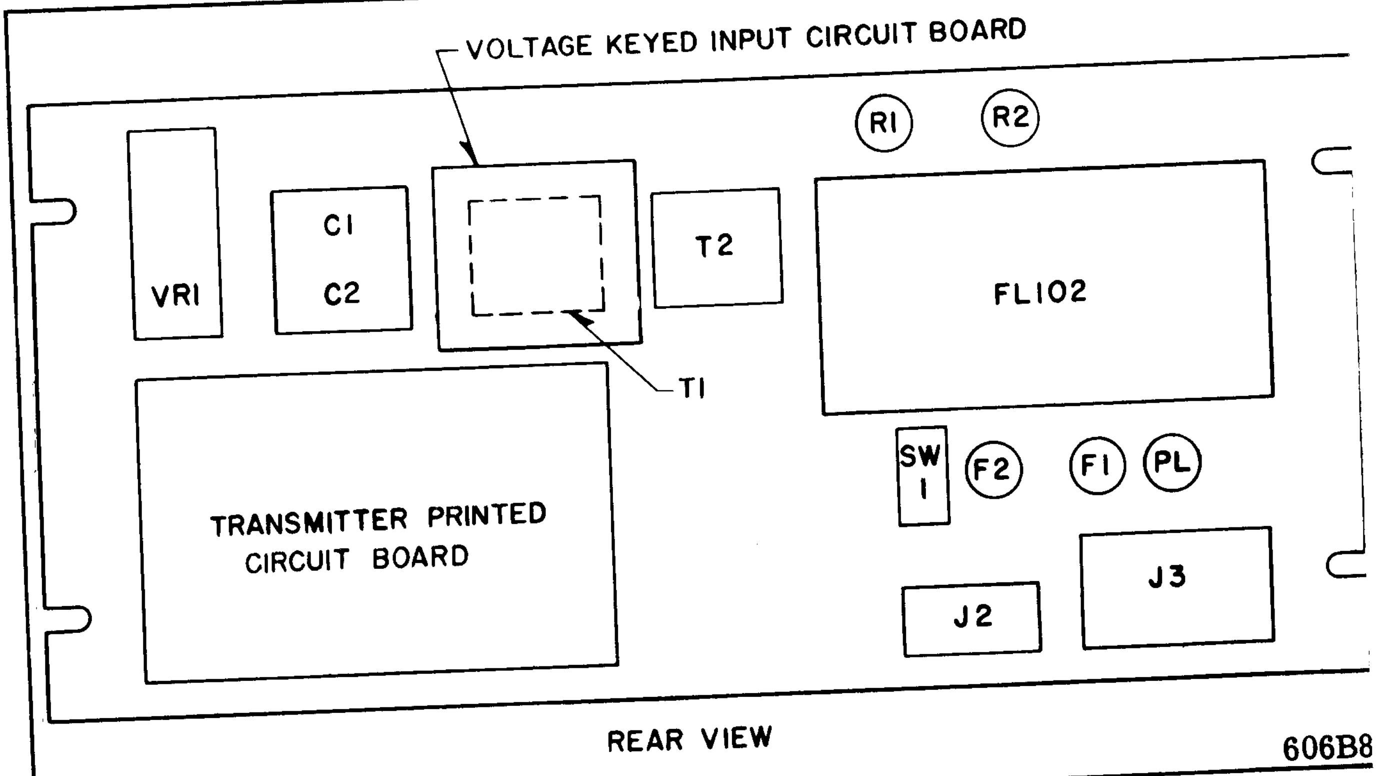

Fig. 2 Component Locations of Type TCF Transmitter Assembly

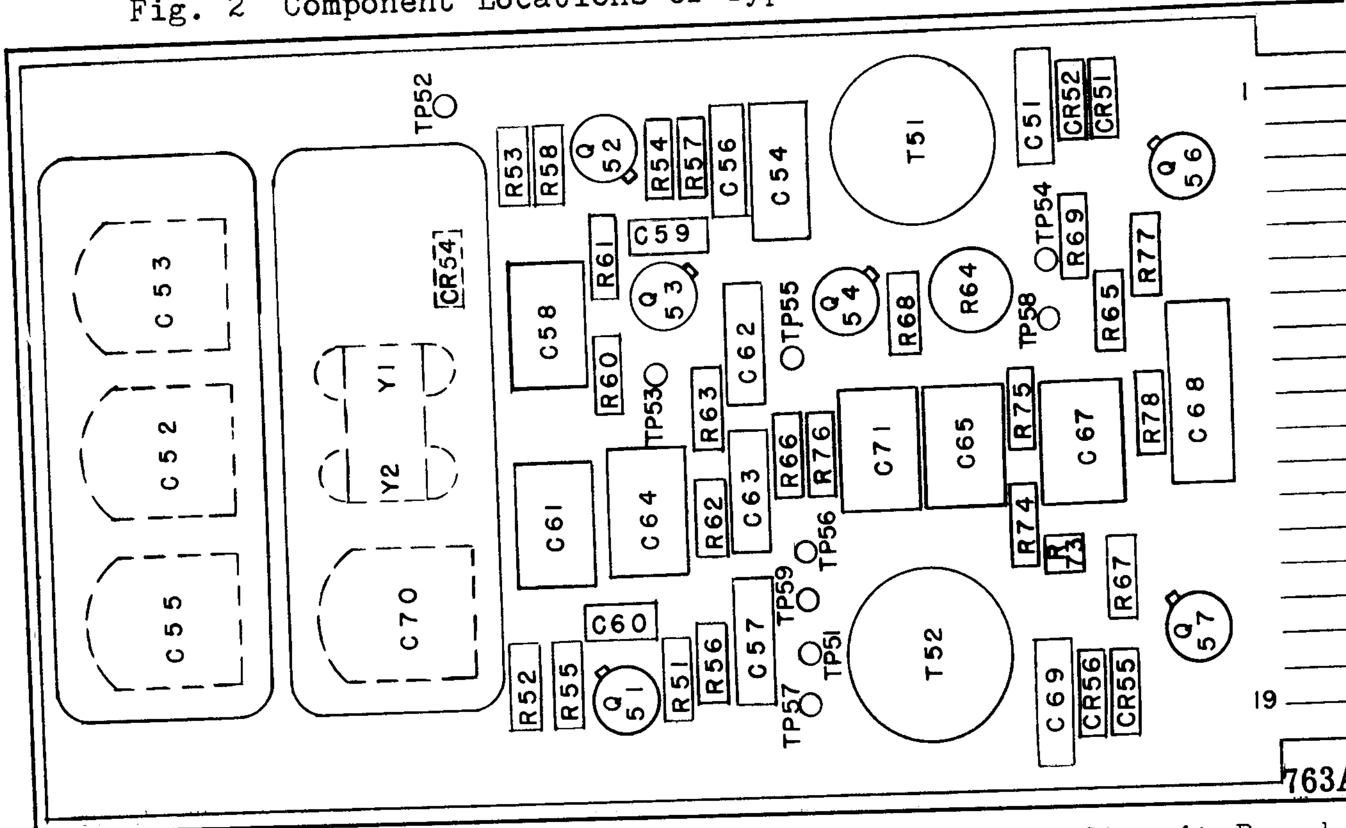

Fig. 3 Component Locations of Transmitter Printed Circuit Board

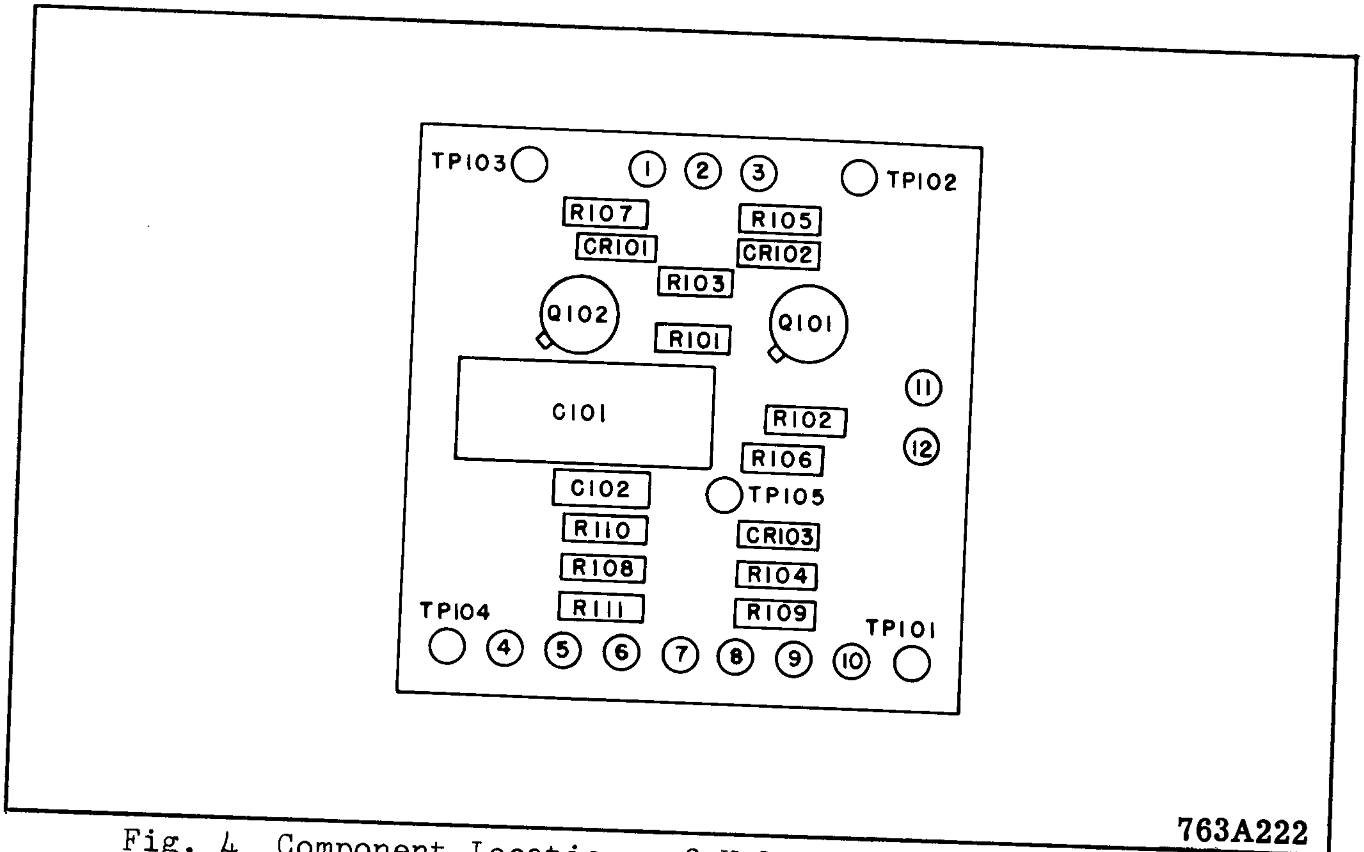

Fig. 4 Component Locations of Voltage Keyed Input Board

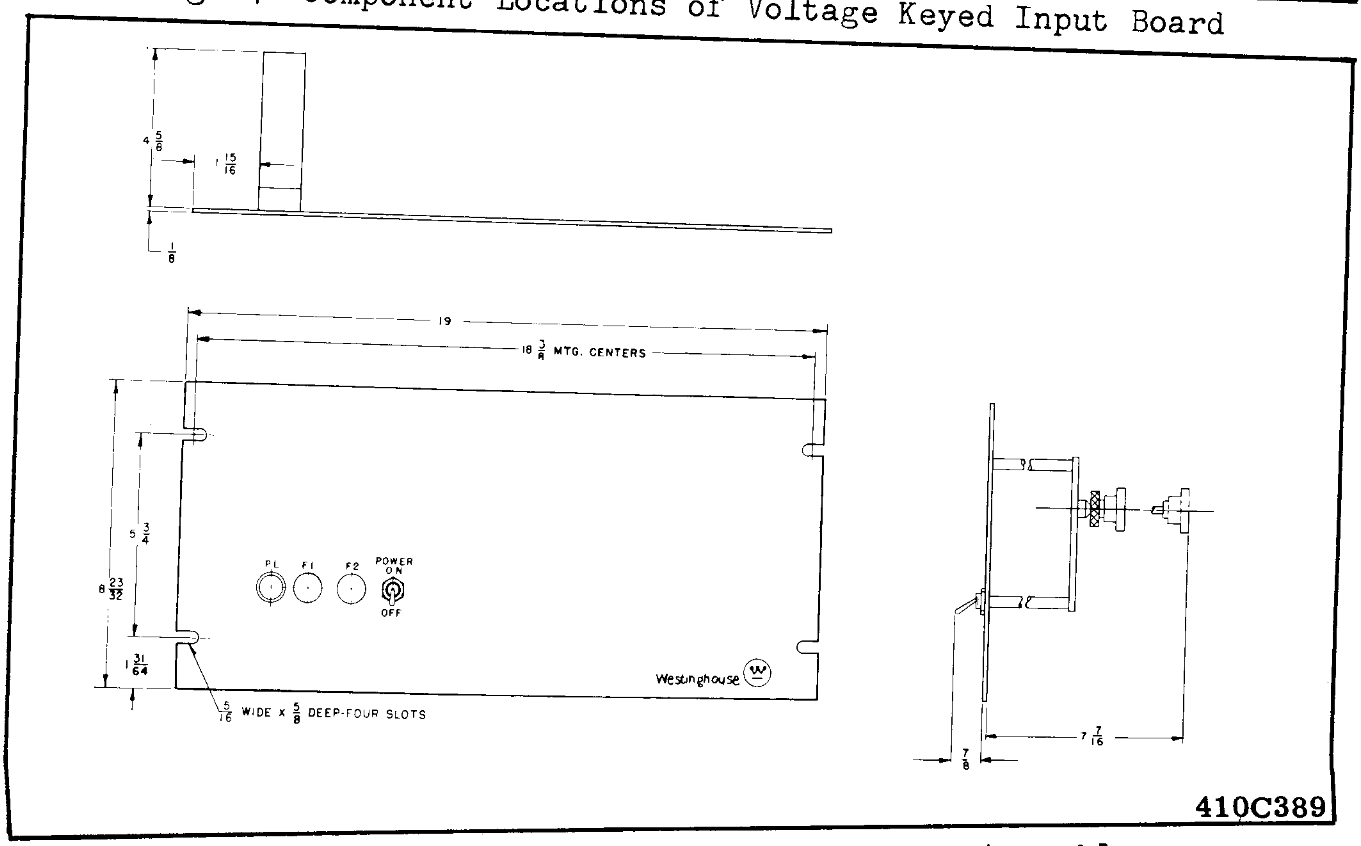

Fig. 5 Outline of Type TCF Transmitter Assembly

RECOMMENDED TEST EQUIPMENT

I. Minimum Test Equipment for Installation
   a. 60-ohm 10-watt non-inductive resistor.
   b. A-C vacuum tube voltmeter (VTVM). Voltage range 0.003 to 30 volts, frequency range 60 cycles/sec. to 230-kc. input impedance 7.5 megohms.
   c. D-C vacuum tube voltmeter (VTVM).
      Voltage Range: 0.15 to 300 volts
      Input Impedance: 7.5 megohms.

II. Desirable Test Equipment for Apparatus Maintenance
   a. All items listed in I.
   b. Signal Generator
      Output Voltage: up to 8 volts
      Frequency Range: 20-kc to 230-kc
   c. Oscilloscope
   d. Frequency counter
   e. Ohmmeter
   f. Capacitor checker

Some of the functions of the recommended test equipment are combined in the type TCT carrier test meter unit, which is designed to mount on a standard 19" rack but also can be removed and used as a portable unit.

RENEWAL PARTS

Repair work can be done most satisfactorily at the factory. However, replacement parts can be furnished, in most cases, to customers who are equipped for doing repair work. When ordering parts, always give the complete nameplate data and identify the part by its designation on the Internal Schematic Drawing.

WESTINGHOUSE ELECTRIC CORPORATION
RELAY-INSTRUMENT DIVISION
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INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE TCF POWER LINE CARRIER FREQUENCY-SHIFT TRANSMITTER EQUIPMENT– 1 WATT/1 WATT–VOLTAGE KEYED FOR TELEMETERING

CAUTION
It is recommended that the user of this equipment become thoroughly familiar with the information in this instruction leaflet before energizing the carrier assembly. Failure to observe this precaution may result in damage to the equipment.

If the carrier set is mounted in a cabinet, it must be bolted down to the floor or otherwise secured before swinging out the equipment rack to prevent its tipping over.

APPLICATION

The type TCF carrier transmitter equipment provides for the transmission of either of two closely controlled discrete frequencies, both within a narrow-band channel, over high-voltage transmission lines. The center frequency of the channel can vary from 30 to 200 kHz in 0.5 kHz steps. The two frequencies transmitted are separated by 200 hertz, one being at center frequency (fc) plus 100 hertz and the other at center frequency minus 100 hertz.

When the TCF transmitter is used in voltage-keyed telemetering applications, the transmission of the high or the low frequency in the channel is controlled by the positive and negative half cycles of an a-c voltage obtained from a telemetering transmitter. This transmitter converts a d-c millivolt signal to an a-c voltage of proportional frequency, which typically may have a range from 15 Hz at zero millivolts to 35 Hz at a selected maximum value of millivolts. The high frequency output of the TCF transmitter is carried to a TCF receiver over a power line and through coupling capacitors and line tuners at each end. The receiver converts the high frequency signal to an a-c voltage of frequency which varies identically with that which keys the transmitter, and a telemetering receiver converts this varying frequency to a proportional d-c millivolt output.

CONSTRUCTION

The 1 watt/1 watt TCF transmitter unit is mounted on a standard 19-inch wide panel 8-3/4 inches (5 rack units) high with edge slots for mounting on a standard relay rack. All components are mounted on the rear of the panel. Fuses, a pilot light, and a power switch are accessible from the front of the panel. See Figure No. 5. All of the circuitry that is suitable for printed circuit board mounting is contained on two such boards, located as shown on Figure No. 2. The locations of the components on the voltage-keyed input board are shown on Figure No. 4, and the locations of the components on the board containing the oscillators, mixer and buffer amplifier, and final amplifier are shown on Figure No. 3. The components included on each board are indicated also by areas inclosed by dotted lines on the internal schematic, Figure No. 1. A Zener diode mounted on a heat sink provides a regulated 45-volt d-c power supply, and an output filter removes harmonics that may be generated by distortion in the amplifier. The locations of all circuit elements on the panel are shown on Figure No. 2 and their electrical connections are shown on Figure No. 1.

External connections to the assembly are made through a 12-circuit receptacle, J3. The r.f output connection to the assembly is made through a coaxial cable jack, J2 (Figure No. 1).

OPERATION

The transmitter is made up of four main stages and an output filter. The input stage receives the a-c voltage from a telemetering transmitter and amplifies it to a level sufficient for properly shifting the frequencies of the two crystal oscillators in the next stage. The two oscillator frequencies enter the mixer and buffer amplifier stage, where the difference frequency is amplified to drive the final amplifier stage. The output of this fourth stage enters the output filter, which is tuned to the difference (fundamental) frequency and contains second and third harmonic traps for further reduction of harmonics.

The a-c output voltage from the telemetering transmitter is applied to terminals 9-10 of input

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EFFECTIVE AUGUST 1969

jack J3, and is connected through resistors R101 and R103 to the bases of transistors Q101 and Q102. These transistors are biased by resistors R102 and R106 so that a small value of a-c voltage at terminals 9-10 will make them alternately conductive. When terminal 9 is positive with respect to terminal 10, transistor Q102 conducts and when 9 is negative with respect to 10, Q101 conducts. Consequently, current flows from terminal 2 to terminal 1 of transformer T1 when 9 is positive and from 2 to 3 when 9 is negative. Zener diode CR103 has a 15-volt rating and Zener diode CR54 (on the larger circuit board) has a 20-volt rating. Thus there is a nominal 5 volt drop across resistor R110, and for a static condition (no a-c input voltage and crystals removed from sockets) the anode of diode CR52 is held at +15 volts, thereby causing both CR51 and CR52 to be reverse biased. It will be seen that CR55 and CR56 are similarly reverse biased under this condition.

When Q101 and Q103 are turned on and off alternately by a-c voltage from the telemetering transmitter, voltage of approximately square waveform is induced in the secondary of transformer T1, and when secondary terminals 4 and 6 alternately become sufficiently positive with respect to terminal 5 diodes CR51 and CR52, or CR55 and CR56, become forward biased. The effect of this in shifting the frequencies of the oscillators will be explained in a later paragraph.

A single crystal designed for oscillation in the 30 kHz to 200 kHz range cannot be forced to oscillate away from its natural frequency by as much as ±100 hertz. In order to obtain this desired frequency shift, it is necessary to use crystals in the 2 MHz range. The crystals are Y1 and Y2 of Figure No. 1. The frequency of Y2 is 2.00 MHz when operated with a specified amount of series capacity, and the frequency of Y1 is 2.00 MHz plus the channel frequency, or 2.03 MHz to 2.20 MHz. Capacitor C55 and crystal Y2 in series are connected between the positive side of the supply voltage and the base of transistor Q51, which operates in the emitter-follower mode. The emitter is coupled to the base through C57, and with Y2 removed the base of Q51 would be held at approximately the midpoint of the supply voltage by R51 and R52. The crystal serves as a series-resonant circuit with very high inductance and low capacitance. The circuit can be made to oscillate at other than the natural frequency of the crystal by varying the series capacitor, C55. Increasing C55 will lower the frequency of oscillations and reducing C55 will raise the frequency.

Capacitor C70 is ineffective while diode CR55 is reverse biased and therefore non-conductive, but when the diode is forward biased by sufficient positive voltage at terminal 12, it becomes conductive and C70 is effectively placed in parallel with C55. This reduces the frequency of oscillation by an amount determined by the setting of C70. The frequency of the oscillator circuit in which crystal Y1 is used will be reduced in similar manner when terminal 18 becomes sufficiently positive to forward bias diode CR51.

With diodes CR51 and CR55 both reverse biased and with C52 and C55 adjusted so that their associated crystals operate at their nominal frequencies, the sum of the two frequencies impressed on the base of mixer transistor Q53 through capacitors C62 and C63 is 4 MHz + fc and the difference frequency is fc. The sum frequency is so high that a neglibible amount appears on the secondary of transformer T51 but the difference frequency is accepted and amplified by Q53 and 54. However, with an a-c voltage at input terminals 9 and 10 of J3 diodes CR51 and CR55 are each alternately forward biased for substantially a full half-cycle, and by adjustment of capacitors C53 and C70 difference frequencies of fc + 100 hertz and fc-100 hertz can be obtained on alternate half cycles.

The crystals taken individually have a greater variation of frequency with temperature than would be acceptable. However, by proper matching of the two crystals, the variation in their difference frequency can be kept within limits that permit holding the frequency stability of the overall transmitter to ±10 hertz over a temperature range of -20 to +55°C.

The amplifier stage consists of transistors Q56 and Q57 connected in a conventional push-pull circuit with input supplied from the collector of Q54 through transformer T52. Thermistor R73 and resistors R74 and R75 are connected to provide a variable bias that reduces the effect of varying ambient temperatures on the output level. The output power is adjusted to 1 watt by means of R64.

The output transformer T2 couples the amplifier transistors to the output filter FL102. The output filter includes two trap circuits (L102, C_B, and L103, C_C) which are factory tuned to the second and third harmonics of the transmitter frequency. Capacitor C_D approximately cancels the inductive reactance of the two trap circuits at the operating frequency. Protective gap G1 is a small lightning arrester to limit the magnitude of switching surges or other line disturbances reaching the carrier set through the line tuner and coaxial cable. Autotransformer T3 matches the filter impedance to coaxial cables of 50, 60, or 70 ohms.

The series resonant circuit composed of L105 and C_E is tuned to the transmitter frequency, and aids in providing resistive termination for the output stage. Jack J102 is mounted on the rear panel of FL102 and is used for measuring the r.f. output current of the transmitter into the coaxial cable. It should be noted that the filter contains no shunt reactive elements, thus providing a reverse impedance that is free of possible "across-the-line" resonances.

The regulated 45 volt power supply is obtained from a 50-watt Zener diode mounted on a heat sink and connected to the station battery supply through suitable series resistors, as shown on Figure No. 1. Capacitor C68 provides a low carrier-frequency impedance across the d-c output voltage, and capacitors C1 and C2 bypass r.f. or transient voltages to ground, thus preventing damage to the transistor circuits.

CHARACTERISTICS

Frequency Range	30-200 kHz
Output	1 watt (into 50 to 70 ohm resistive load)
Frequency Stability	±10 hertz from -20°C to +55°C.
Frequency Spacing	1. One-way channel, two or more signals – 500 hertz min. 2. Two-way channel – 1500 hertz min. between transmitter and adjacent receiver frequencies.
Harmonics	down 55 db (min.) from output level.
Input Impedance of Keying Circuit	50,000 ohms
Keying Voltage	10 to 50 volts p.-p, sine or square wave
Keying Frequency	10 to 50 hertz
Supply Voltage	48, 125 or 250 V.D.C. (Separate units)
Supply Voltage Variation	42-56 V. for nom. 48 V. supply, 105-140 V. for nom. 125 V. supply, 210-280 V. for nom. 250 V. supply
Battery Drain	0.12 a. at 48 V. d-c. 0.27 a. at 125 or 250 V. d-c
Temperature Range	-20 to +55°C around chassis
Dimensions	Panel height – 8-3/4" or 5 r.u. Panel width – 19"
Weight	10 lbs.

INSTALLATION

The TCF transmitter is generally supplied in a cabinet or on a relay rack as part of a complete carrier assembly. The location must be free from dust, excessive humidity, vibration, corrosive fumes, or heat. The maximum ambient temperature around the chassis must not exceed 55°C.

ADJUSTMENTS

The TCF 1W/1W transmitter is shipped with the power output control R64 set for an output of 1 watt into a 60 ohm load. If it is desired to check the adjustments or if repairs have made readjustment necessary, the coaxial cable should be disconnected from the assembly terminals and replaced with a 50 to 70 ohm non-inductive resistor of at least a 1 watt rating. Use the value of the expected input impedance of the coaxial cable and line tuner. If this is not known, assume 60 ohms. Connect the T3 output lead to the corresponding tap. Connect an a-c vacuum tube voltmeter (VTVM) across the load resistor. Turn power output control R64 to minimum (full counterclockwise). Turn on the power switch on the panel and note the d-c voltage across terminals 5 and 7 of J3. If this is in the range of 42 to 46 volts, rotate R64 clockwise to obtain 3 or 4 volts across the load resistor. At this point check the adjustment of the series output tuning coil L105 by loosening the knurled shaft-locking nut and moving the adjustable core in and out a small amount from its initial position. Leave it at the point of maximum voltage across the load resistor.

Continue to advance R64 until the output voltage shown in the following table is obtained across the load resistor. Recheck the setting of L105 to be sure it is at its optimum point for 1 watt output. Tighten the locking nut.

T3* TAP	VOLTAGE FOR 1 WATT OUTPUT
50	7.1
60	7.8
70	8.4

With no a-c voltage impressed on terminals 9 and 10, the output frequency of the transmitter is fc. When the output filter is adjusted for maximum output at this frequency, the output voltage at the operating frequencies of fc ± 100 hertz will not be appreciably lower.

Follow the procedure outlined in the line tuner instructions for its adjustment.

Normally the output filter (FL102) will require no readjustment except as noted above. It is factory tuned for maximum second and third harmonic rejection, and for series resonance (maximum output at the fundamental frequency) with a 60-ohm load. A small amount of reactance in the transmitter output load circuit may be tuned out by readjustment of the movable core of L105. This may be necessary with some types of line coupling equipment. The adjustable cores of L102 and L103 have been set for maximum harmonic rejection and no change should be made in these settings unless suitable instruments are available for measuring the second and third harmonic present in the transmitter output.

The operating frequencies of crystals Y1 and Y2 have been carefully adjusted at the factory and good stability can be expected. If it is desired to check the frequencies of the individual crystals, this can be done by turning the matched pair 180° and inserting Y1 crystal in its proper socket with the other crystal unconnected. Because of proximity to capacitor C70, the crystal pair cannot be reversed to permit checking Y2 alone, but this can be done by partially withdrawing Y2 from its socket and tilting it sufficiently to open-circuit the Y1 crystal. A sensitive frequency counter with a range of at least 2.2 megahertz can be connected from TP51 to TP54. (Connection to TP54 rather than to TP53 provides a better signal to the counter and avoids some error from the effect of the counter input capacitance on the oscillator circuit.)

If for any reason, it should be necessary to replace a matched crystal pair, the following adjustments should be made.

With rated d-c voltage on the transmitter, with R64 fully clockwise to increase input to frequency counter, and with terminals 9-10 of J3 open, the frequency of Y1 alone should be its marked frequency (±3 hertz). If adjustment is necessary, loosen locking nut of capacitor C52 and set for correct frequency. Next, apply 45v. d-c from terminal 7 of J3 (or terminal 2 of transmitter circuit board) to TP104 (on input circuit board). The frequency should drop to the marked frequency minus 85 Hz (±3 Hz), and should be adjusted to this value by C53 if necessary. If capacitor settings are changed, both steps should be rechecked until the oscillator operates at the marked frequency of Y1 (±3 hertz) before applying 45 volts to TP104, and at 85 hertz (±3 hertz) less than the marked frequency after applying 45 volts.

Similarly, check the oscillator frequency with Y2 alone in circuit, and if necessary adjust C55 for 2 MHz (±3 hertz). Then apply 45 volts from terminal 7 to TP101. The frequency should be 2 MHz minus 85 hertz (±3 hertz). If capacitor settings are changed, recheck both steps as before. Tighten locknuts on all capacitors. Turn R64 full counterclockwise, and after inserting both crystals in their sockets, readjust R64 for 1 watt output.

With adjustments made as described, the difference frequency of the two oscillators will be fc + 100 hertz on one half-cycle of an a-c voltage on terminals 9-10, and will be fc − 100 hertz on the next half-cycle. The frequency cannot be measured when it is being continually shifted by an a-c keying voltage, and adjustments must be made by using d-c voltage for biasing diodes CR51, CR52, CR55 and CR56. However, when an a-c keying voltage is present, the connections to the mid-tapped secondary of T1 cause the reverse bias voltage that is present alternately on each set of diodes to be much greater than when a d-c voltage is applied on TP101 or TP104. The oscillator frequency with this high reverse bias voltage shifts upward approximately 15 hertz when the other oscillator with forward bias voltage shifts downward 85 hertz. The resultant difference frequencies therefore are fc + 100 hertz and fc − 100 hertz for alternate half cycles at terminals 9 − 10.

For routine maintenance the frequencies of the individual oscillators need not be checked. The difference frequencies can be measured directly at the transmitter output, using the proper load resistor to match the T3 tap used. With terminals 9-10 open, C52 should be adjusted for a frequency of fc ±3 hertz. Then with +45V.d-c applied to TP104, C53 should be adjusted for fc minus 85 (±3) hertz. With 45 volts applied to TP101 instead of TP104, C70 should be adjusted for fc plus 85 (±3) hertz. A similar final adjustment should be made after making the individual adjustments required when a matched pair of crystals is replaced.

MAINTENANCE

Periodic checks of the transmitter power output will detect impending failure so that the equipment can be taken out of service for correction. At regular maintenance intervals, any accumulated dust should be removed, particularly from the heat sink. It is also desirable to check the transmitter power output at such times, making any necessary readjustments to return the equipment to its initial settings.

Voltage values should be recorded after adjustment in order to establish reference values which will be useful when checking the apparatus. The readings will remain fairly constant over an indefinite period unless a failure occurs. However, if transistors are changed, there may be considerable difference in these readings without the overall performance being affected.

Typical voltage values are given in the following tables. Voltages should be measured with a VTVM. Readings may vary as much as ±20%.

TABLE I

TRANSMITTER D-C MEASUREMENTS

Note: All voltages are positive with respect to Neg. 45 V. (TP51). All voltages read with d-c VTVM.

TEST POINTS	VOLTAGE AT 1 WATT OUTPUT
TP 52	20
TP 53	5.4
TP 54	3.4
TP 55	21
TP 56	21
TP 57	.65
TP 58	44.3
TP 59	.65
TP102	20
TP103	20
TP105	15

TABLE II

TRANSMITTER RF MEASUREMENTS

Note: Voltages taken with transmitter set to indicated output across 60 ohms. These voltages are subject to variations, depending upon frequency and transistor characteristics. T51-3 = Terminal 3 of transformer T51. Other transformer terminals identified similarly. All voltages read with a-c VTVM.

TEST POINTS	VOLTAGE AT 1 WATT OUTPUT
TP 54 to TP 51	0.12
TP 57 to TP 51	0.8
TP 59 to TP 51	0.8
T2-1 to TP 51	26
T2-3 to TP 51	26
T2-4 to Gnd.	36
T3-2 to Gnd.	30
TP109 to Gnd.	9.8
J102 to Gnd.	7.8

RECOMMENDED TEST EQUIPMENT

I. Minimum Test Equipment for Installation
   a. 60-ohm 10-watt non-inductive resistor.
   b. A-C vacuum tube voltmeter (VTVM). Voltage range 0.003 to 30 volts, frequency range 60 hertz to 230-kHz. input impedance 7.5 megohms.
   c. D-C vacuum tube voltmeter (VTVM).
      Voltage Range: 0.15 to 300 volts
      Input Impedance: 7.5 megohms.

II. Desirable Test Equipment for Apparatus Maintenance
   a. All items listed in I.
   b. Signal Generator
      Output Voltage: up to 8 volts
      Frequency Range: 20-kHz to 230-kHz
   c. Oscilloscope
   d. Frequency counter
   e. Ohmmeter
   f. Capacitor checker

Some of the functions of the recommended test equipment are combined in the type TCT carrier test meter unit, which is designed to mount on a standard 19'' rack but also can be removed and used as a portable unit.

RENEWAL PARTS

Repair work can be done most satisfactorily at the factory. However, replacement parts can be furnished, in most cases, to customers who are equipped for doing repair work. When ordering parts, always give the complete nameplate data and identify the part by its designation on the Internal Schematic Drawing.

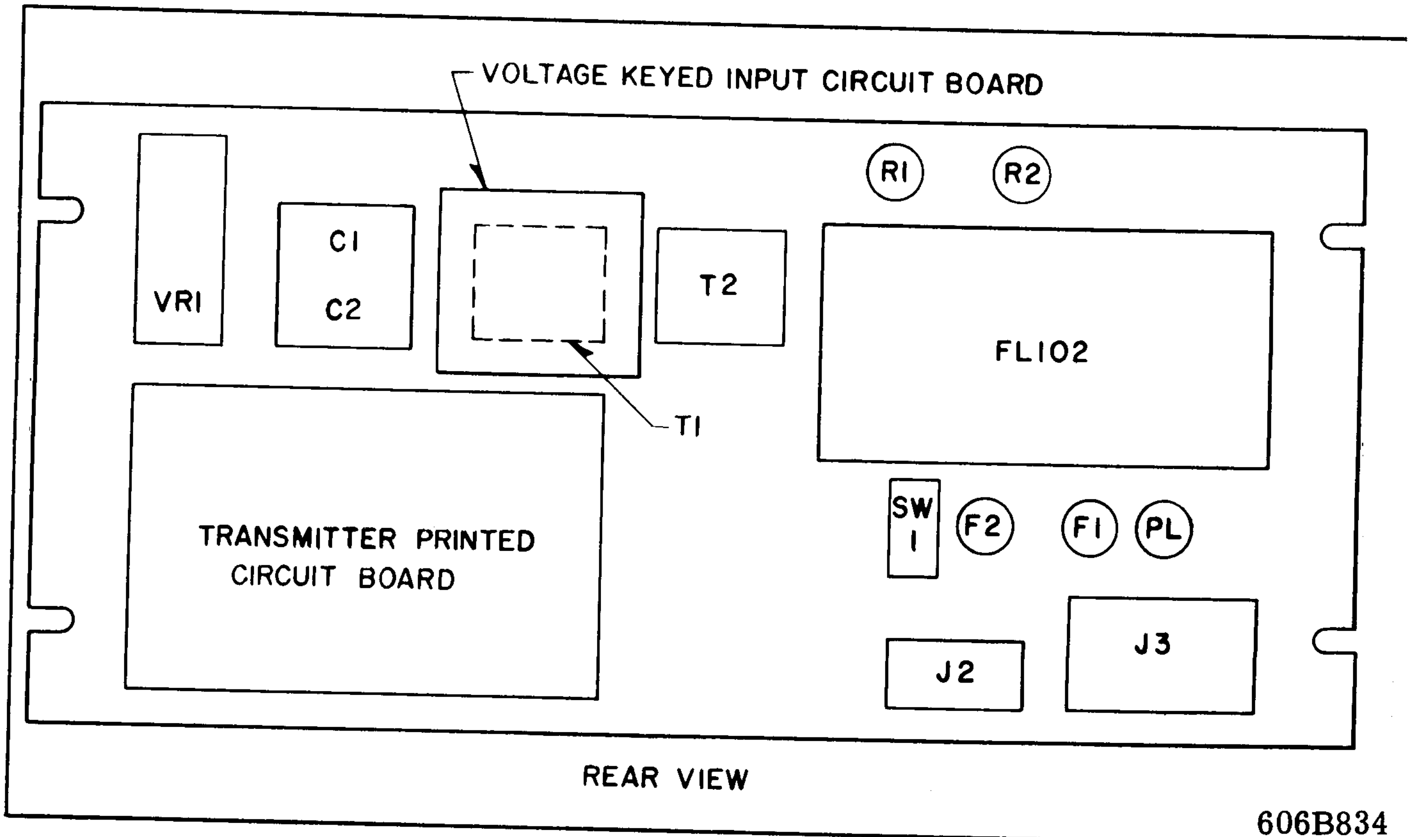

Fig. 2. Component locations of type TCF transmitter assembly.

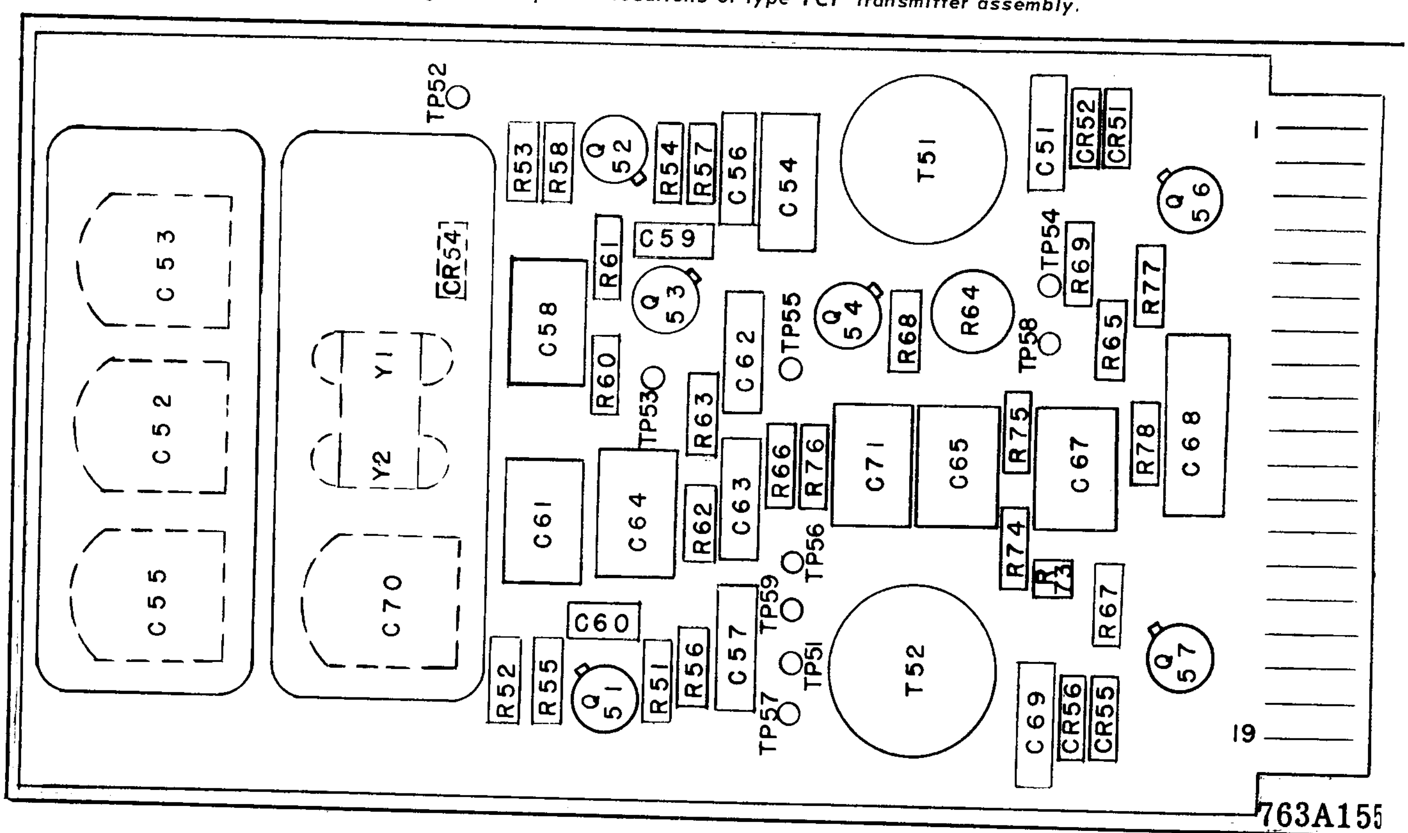

Fig. 3. Component locations of transmitter printed circuit board.

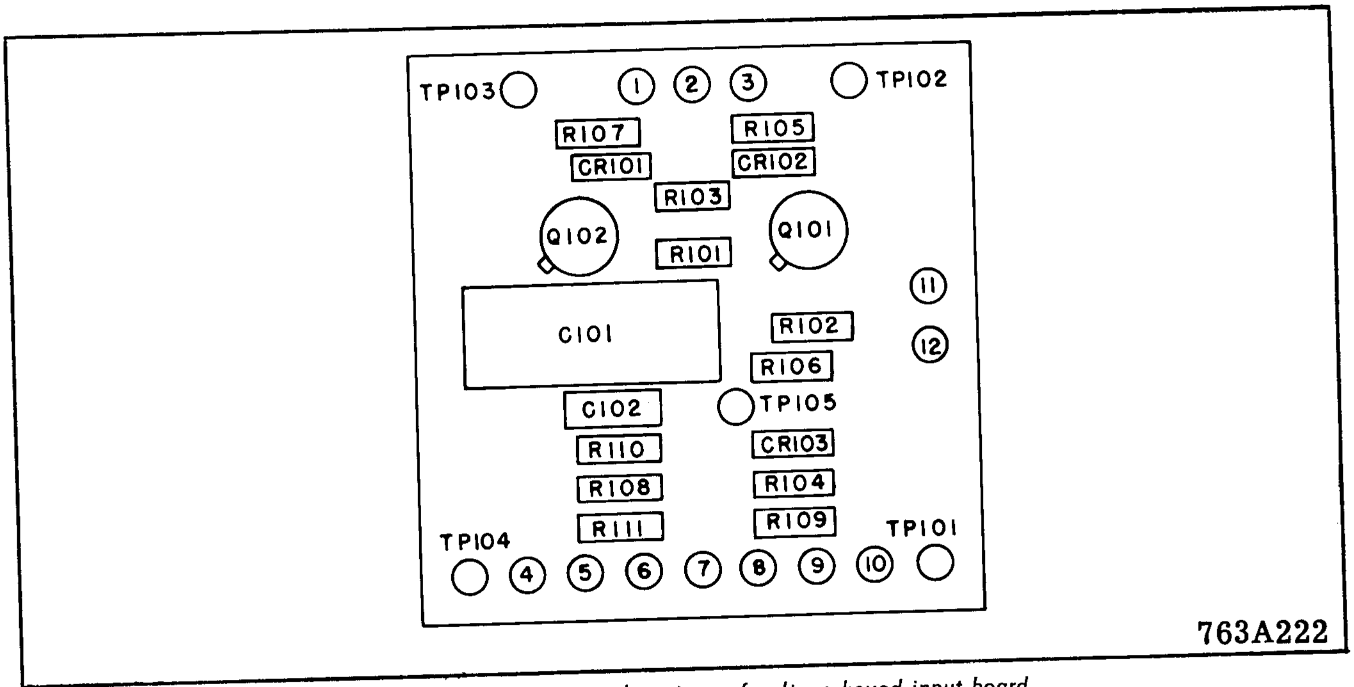

Fig. 4. Component locations of voltage keyed input board.

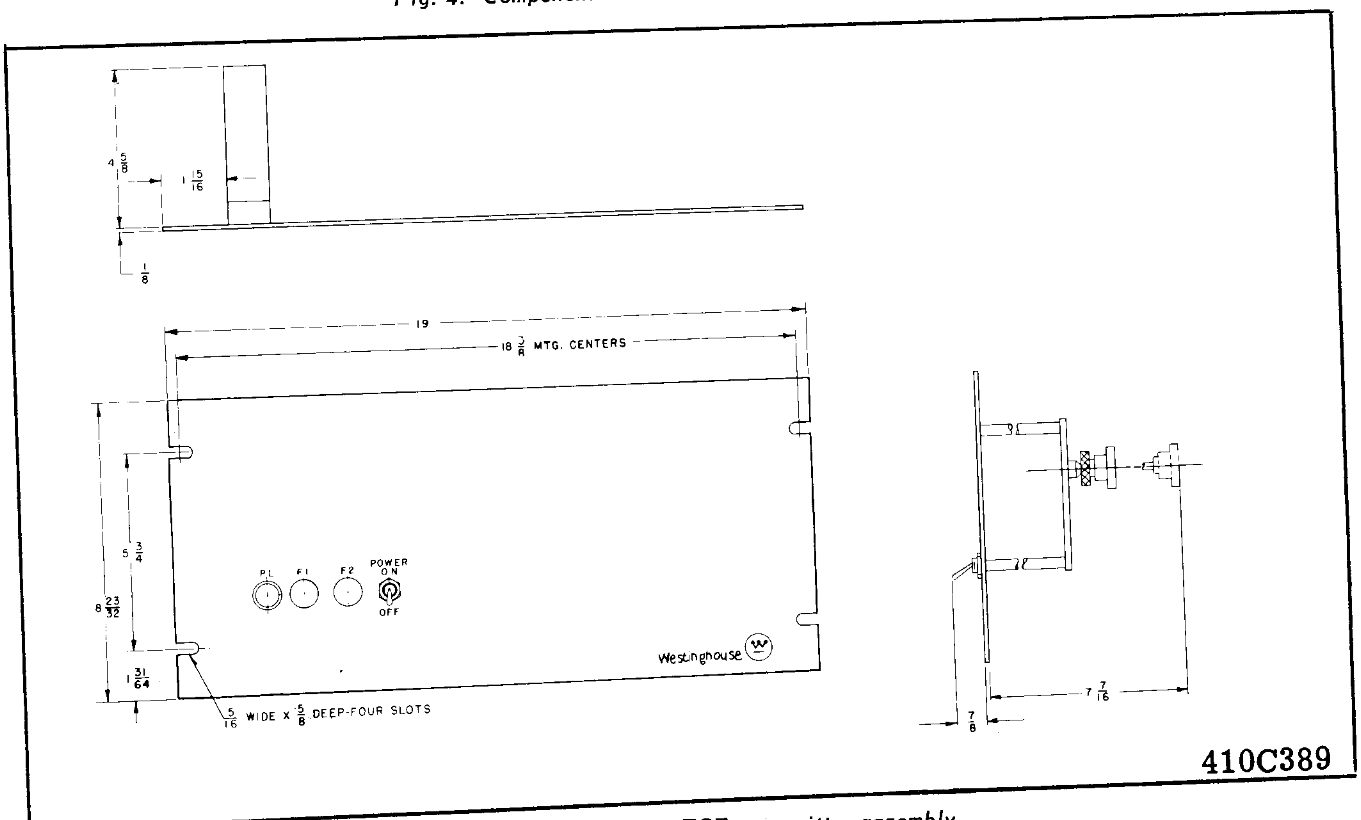

Fig. 5. Outline of type TCF transmitter assembly.

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