INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE TCF POWER LINE CARRIER FREQUENCY-SHIFT TRANSMITTER EQUIPMENT – 1 WATT/10 WATT – TRANSFER-TRIP

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 others at center frequency minus 100 cycles. The higher frequency, termed the Guard frequency, is transmitted continuously when conditions are normal. It indicates at the receiving end of the line that the channel is operative and it also serves to prevent false operation of the receiver by line noise. The lower frequency, termed the Trip frequency, is transmitted as a signal that an operation (such as tripping a circuit breaker) should be performed at the receiving end of the line.

When frequency shift carrier is used in protective relaying applications, it is recommended that the trip frequency be transmitted at a higher power level to increase reliability of the system under conditions of abnormally high channel losses or line noise. The frequency is shifted from Guard to Trip by the closing of a protective relay contact, and the same contact also shifts the transmitter from a 1 watt to a 10 watt output level.

CONSTRUCTION

The 1 watt/10 watt TCF transmitter unit is mounted on a standard 19-inch wide panel 12¼ inches (7 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, a power switch and a jack for metering the amplifier collector current are accessible from the front of the panel. See Fig. 5. All of the circuitry that is suitable for printed circuit board mounting is on two such boards, as shown in Fig. 2. The components mounted on each printed circuit board or other sub-assembly are shown enclosed by dotted lines on the internal schematic. Fig. 1. The location of components on the two printed circuit boards are shown on separate illustrations, Fig. 3 & 4.

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.

OPERATION

The transmitter is made up of four main stages and two filters. The stages include two crystal oscillators operating at frequencies that differ by the desired channel frequency, a mixer and buffer amplifier, a driver stage and a power amplifier. One filter is located between the driver and the power amplifier and the filter removes harmonics that may be generated by distortion in the power amplifier.

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 Fig. 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. 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 approxi-

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mately 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.

Crystal Y1 is connected in a circuit that is similar except for the addition of C53 and diodes CR51 and CR52. By adjustment of C52 this circuit is made to oscillate at 100 cycles above its marked frequency. Capacitor C53 is not effective until CR51 is biased in the forward direction and becomes conductive. It is biased in the reverse direction until the relay control contact is closed, which places 45 V.D.C. at terminal 3 of the printed circuit board. With CR51 conducting, C53 is effectively in parallel with C52, and adjustment of C53 will reduce the frequency by 200 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 frequencies produced by the two oscillators are coupled to the base of mixer transistor Q53 through C62 and C63. The sum of the two frequencies 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 Q54.

When the relay control, or keying, contact is closed, it increases the output power from 1 watt to 10 watts as well as changing the frequency from Guard to Trip. This is effected by reducing the emitter resistance of buffer-amplifier transistor Q54. When the keying contact is open, transistor Q55 receives no base current and is non-conducting. Emitter resistor R70 therefore is effectively open-circuited. The level of output power is adjusted to 1 watt by means of R64. When Q55 is made conductive by closing the keying contact, R70 is placed in parallel with R68 and the amount of emitter resistance unbypassed by C66 can be adjusted as required to obtain a 10-watt output level.

As is shown on the Internal Schematic, Fig. 1, the voltage for the keying circuit is obtained from the 45-volt regulated supply in the transmitter, and opening the single power switch de-energizes both the transmitter and the keying circuit. Capacitor C4 protects the transmitter from transient voltages that might be induced in the lead from terminal 8 of J3 to the keying contact, and it also effects a smoother rise in voltage from the 1-watt to the 10-watt level. Resistor R8 reduces the duty on the keying contact.

The driver 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 input level.

The driver filter, FL101, consists of a series-resonant inductor and capacitor connected between the driver and power amplifier stages by appropriate transformers T1 and T2. This filter greatly improves the waveform of the signal applied to the power amplifier.

The power amplifier uses two series-connected power transistors, Q101 and Q102, operating as a class B push-pull amplifier with single-ended output. Diodes CR101 and CR103 provide protection for the base-emitter junctions of the power transistors. Zener diodes CR105 and CR106 protect the collector-emitter junctions from surges that might come in from the power line through the coaxial cable.

The output transformer T3 couples the power 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 T4 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 power supply is a series-type transistorized d-c voltage regulator which has a very low stand-by current drain when there is no output current demand. The Zener diode VR1 holds a constant base-to-negative voltage on the series-connected power transistor Q1. Depending on the load current, the d-c voltage drop through transistor Q1 and resistors R1 and R2 varies to maintain a constant output voltage. The Zener diode VR2 serves to protect the collector-base junction of Q1 from surge voltages. Capacitor C1 provides a low carrier-frequency impedance across the d-c output voltage. Capacitors C2 and C3 bypass r.f. or transient voltages to ground, thus preventing damage to the transistor circuits.

CHARACTERISTICS

Frequency range	30-200KC
Output	1 watt guard - 10 watts trip (into 50 to 70 ohm resistive load)
Frequency stability	± 10 cycles/sec. from $-20\,^{\circ}$C to $+60\,^{\circ}$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 voltage	48 or 125 v.d.c.
Supply voltage variation	42-56 v. for nom. 48 v. supply. 105-140 v. for nom. 125 v. supply.
Battery drain	0.5 a. guard, 1.15a. trip } 48 v.d.c. 0.5 a. guard, 0.9 a. trip } 125 v.d.c.
Keying circuit current	4 ma.
Temperature range	-20 to $+60\,^{\circ}$C. around chassis.
Dimensions	Panel height - 12¼'' or 7 r.u. Panel width - 19''
Weight	12 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 $60\,^{\circ}$C.

ADJUSTMENTS

The TCF 1W/10W transmitter is shipped with the power output controls R64 and R70 set for outputs of 1 watt and 10 watts into a 60 ohm load. If it is desired to check these 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 10 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 T4 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 4 or 5 volts across the load resistor used. 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 used. Then rotate R64 farther clockwise to obtain the correct voltage for 1 watt in the load resistor, as shown in the following table.

Then change to Trip frequency by connecting together terminals 2 and 3 of the transmitter printed circuit board (which is approximately equivalent to connecting together terminals 7 and 8 of J3), and rotate R70 until the voltage across the load resistor is as shown in the following table for a 10 watt output. Recheck the adjustment of L105 for maximum output voltage and readjust R70 for a 10 watt output if necessary. Tighten the locking nut on L105. Open the power switch, remove the jumper used to key the transmitter to the 10 watt level, remove the load resistor, and reconnect the coaxial cable circuit to the transmitter.

T106 Tap	Voltage for 1 Watt Output	Voltage for 10 Watts Output
50	7.1	22.4
60	7.8	24.5
70	8.4	26.5

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 a crystal in its proper socket with the other crystal unconnected. 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.) While measurement of the oscillator crystals individually is necessary for the initial adjustment of the oscillators, generally any subsequent checks may be made with a lower range counter connected at the transmitter output. If any minor adjustment of the Guard and Trip frequencies should be needed, the Guard adjustment should be made with capacitor C52 and the Trip adjustment with C53.

MAINTENANCE

Periodic checks of the transmitter Guard and Trip power outputs 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 sinks. 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	Voltage at 10 Watts Output
TP52	20	20
TP53	5.4	5.4
TP54	3.4	3.4
TP55	21	18.5
TP56	21	18.5
TP57	* < 1.0	* < 1.0
TP58	44.3	44.1
TP59	* < 1.0	* < 1.0
TP101	0	0
TP103	21 ± 2	21 ± 2
TP105	44.3	44.0

TABLE II
TRANSMITTER RF MEASUREMENTS

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

Test Point	Voltage at 1 Watt Output	Voltage at 10 Watts Output
TP54 to TP51	0.015 - 0.03	0.015 - 0.03
TP57 to TP51	0.05 - 0.09	0.3 - 1.2
TP59 to TP51	0.05 - 0.09	0.3 - 1.2
T1-1 to TP51	1.65	5.6
T1-3 to TP51	1.45	4.9
T1-4 to Gnd.	.6	2.0
T2-1 to Gnd.	.57	1.85
TP101 to TP103	5.2	17.0
TP103 to TP105	5.2	17.0
T3-4 to Gnd.	35	112
T4-2 to Gnd.	31	110
TP109 to Gnd.	9.8	31
J102 to Gnd.	7.8	24.5

CONVERSION OF TRANSMITTER FOR CHANGED CHANNEL FREQUENCY

The parts required for converting a 1W/10W TCF transmitter for operation on a different channel frequency consist of a pair of matched crystals for the new channel frequency, new capacitors C103 and C104 on the power amplifier circuit board if the old and new frequencies are not in the same frequency group (see table on internal schematic drawing) and, in general, new or modified filters FL101 and FL102. Inductors L101, L102 and L103 in these filters are adjustable over a limited range, but thirty-two combinations of capacitors and inductors are required to cover the frequency range of 30 KC to 200 KC. The widths of the frequency groups vary from 1.5 KC at the low end of the channel frequency range to 12 KC at the upper end. A particular assembly can be adjusted over a somewhat wider range than the width of its assigned group since some overlap is necessary to allow for component tolerances. The nominal KC adjustment ranges of the group are:

30.0 – 31.5	61.0 – 64.0	113.0 – 119.5
32.0 – 33.5	64.5 – 68.0	120.0 – 127.0
34.0 – 36.0	68.5 – 72.0	127.5 – 135.0
36.5 – 38.5	72.5 – 76.0	135.5 – 143.0
39.0 – 41.0	76.5 – 80.0	143.5 – 151.0
41.5 – 44.0	80.5 – 84.5	151.5 – 159.5
44.5 – 47.0	85.0 – 89.0	160.0 – 169.5
47.5 – 50.0	89.5 – 94.5	170.0 – 180.0
50.5 – 53.5	95.0 – 100.0	180.5 – 191.5
54.0 – 57.0	100.5 – 106.0	192.0 – 200.0
57.5 – 60.5	106.5 – 112.5	

If the new frequency lies within the same frequency group as the original frequency, the filters can be readjusted. If the frequencies are in different groups, it is possible that changes only in the fixed capacitors may be required. In general, however, it is desirable to order complete filter assemblies adjusted at the factory for the specified frequency.

A signal generator, a frequency counter and a vacuum tube voltmeter are required for readjustment of FL101. The signal generator and the counter should be connected across terminals 4 and 5 of transformer T1 and the voltmeter across terminals 1 and 2 of transformer T2. The signal generator should be set at the channel center frequency and at 2 to 3 volts output. The core screw of the small inductor should be turned to the position that gives a true maximum reading on the VTVM. Turning the screw to either side of this position should definitely reduce the reading. The change in inductance with core position is less at either end of the travel than when near the center and consequently the effect of core screw rotation on the VTVM reading will be less when the resonant inductance occurs near the end of core travel.

The procedure for readjustment of the 2nd and 3rd harmonic traps of filter FL102 is somewhat similar. A signal generator and a counter should be connected to terminals 3 and 4 of transformer T3, and a 500 ohm resistor and a VTVM to the terminals of protective gap G1. The ground or shield lead of all instruments should be connected to the grounded terminal of the transformer. Set the signal generator at exactly twice the channel center frequency and at 5 to 10 volts output. Turn the core screw of the large inductor, L102, to the position that gives a definite minimum reading on the VTVM. Similarly, with the signal generator set at exactly three times the channel center frequency and 5 to 10 volts output, set the core screw of the small inductor, L103, to the position that gives a definite minimum reading on the VTVM. Then remove the instruments and the 500 ohm resistor.

After the new pair of matched crystals have been adjusted, as described under "ADJUSTMENTS", the transmitter can be operated with a 50 to 70 ohm load (depending on which tap of T4 is used) connected to its output, and inductor L105 can be readjusted for maximum output at the changed channel frequency by the procedure described in the same section.

If a frequency-sensitive voltmeter is available, the 2nd and 3rd harmonic traps may be adjusted without using an oscillator as a source of double and triple the channel frequency. Connect the frequency-sensitive voltmeter from TP109 to ground and adjust the transmitter for rated output into the selected load resistor. Set the voltmeter at twice the channel frequency and, using the tuning dial and db range switch, obtain a maximum on-scale reading of the 2nd harmonic. Then vary the core position of L102 until a minimum voltmeter reading is obtained. Similarly, tune the voltmeter to the third harmonic and adjust L103 for minimum voltmeter reading. Although the transmitter frequency will differ from the channel center frequency by 100 cycles, the effect of this difference on the adjustment of the harmonic traps will be negligible. It should be noted that the true magnitude of the harmonics cannot be measured in this manner because of the preponderance of the fundamental frequency at the voltmeter terminals. Accurate measurement of the harmonics requires use of a filter between TP109 and the voltmeter that provides high rejection of the fundamental. The insertion losses of this filter for the 2nd and 3rd harmonics must be measured and taken into account.

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: 1.5 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.

ELECTRICAL PARTS LIST

CIRCUIT SYMBOL	DESCRIPTION	WESTINGHOUSE DESIGNATION
CAPACITORS		
C1	Oil-filled; 0.45 mfd.; 330 V.A.C.	1723408
C2	Oil-filled; 0.5 mfd.; 1500 V.D.C.	1877962
C3	Oil-filled; 0.5 mfd.; 1500 V.D.C.	1877962
C4	Oil-filled; 0.5 mfd.; 1500 V.D.C.	1877962
C51	Dur-Mica, 1500 pf.; 500 V.D.C.	762A757H03
C52	Variable, 3-75 pf.	762A736H01
C53	Variable, 3-75 pf.	762A736H01
C54	Metallized paper, Oil mfd.; 200 V.D.C.	187A624H01
C55	Variable, 3-75 pf.	762A736H01
C56	Dur-Mica, 2000 pf.; 500 V.D.C.	187A584H01
C57	Dur-Mica, 2000 pf.; 500 V.D.C.	187A584H01
C58	Metallized paper, 0.25 mfd.; 200 V.D.C.	187A624H02
C59	Dur-Mica, 100 pf.; 500 V.D.C.	762A757H01
C60	Dur-Mica, 100 pf.; 500 V.D.C.	762A757H01
C61	Metallized paper, 0.25 mfd.; 200 V.D.C.	187A624H02
C62	Dur-Mica, 4700 pf.; 500 V.D.C.	762A757H04
C63	Dur-Mica, 1000 pf.; 500 V.D.C.	762A757H02
C64	Metallized paper, 0.25 mfd.; 200 V.D.C.	187A624H02
C65	Metallized paper, 0.25 mfd.; 200 V.D.C.	187A624H02
C66	Metallized paper, 0.25 mfd.; 200 V.D.C.	187A624H02
C67	Metallized paper, 0.25 mfd.; 200 V.D.C.	187A624H02
C68	Metallized paper, 0.5 mfd.; 200 V.D.C.	187A624H03
C69	Metallized paper, 0.25 mfd.; 200 V.D.C.	187A624H02
C70	Dur-Mica, 300 pf.; 500 V.D.C.	187A584H09
C101	Metallized paper, 0.25 mfd.; 200 V.D.C.	187A624H02
C102	Metallized paper, 0.25 mfd.; 200 V.D.C.	187A624H02
C103 & C104	(30-50 KC) – Extended foil, 0.47 mfd.; 400 V.D.C.	188A293H01
C103 & C104	(50.5 - 75 KC) – Extended foil, 0.22 mfd.; 400 V.D.C.	188A293H02
C103 & C104	(75.5 - 100 KC) – Extended foil, 0.15 mfd.; 400 V.D.C.	188A293H03
C103 & C104	(100.5 - 150 KC) – Extended foil, 0.10 mfd.; 400 V.D.C.	188A293H04
C103 & C104	(150.5 - 200 KC) – Extended foil, 0.047 mfd.; 400 V.D.C.	188A293H05
DIODES – GENERAL PURPOSE		
CR51	IN628; 125 V.; 30 MA.	184A885H12
CR52	IN628; 125 V.; 30 MA.	184A885H12
CR53	IN457A; 60 V.; 200 MA.	184A885H07
CR101	IN538; 200 V.; 750 MA.	407C703H03
CR102	IN91; 100 V.; 150 MA.	182A881H04
CR103	IN538; 200 V.; 750 MA.	407C703H03
CR104	IN91; 100 V.; 150 MA.	182A881H04

ELECTRICAL PARTS LIST (Cont'd.)

CIRCUIT SYMBOL	DESCRIPTION	WESTINGHOUSE DESIGNATION
	DIODES - ZENER	
VR1	IN2828B; 45 V. ±5%; 50 W.	184A854H06
VR2	IN3009A; 130 V. ±10%; 10 W.	184A617H12
VR3	IN1789; 56 V. ±10%; 1 W.	584A434H08
CR54	IN3686B; 20 V. ±5%; 750 MW.	185A212H06
CR105	IN2999A; 56 V. ±10%; 10 W.	184A617H13
CR106	IN2999A; 56 V. ±10%; 10 W.	184A617H13
	RESISTORS	
R1	26.5 ohms ±5%; 40 W.	04D1299H44
R2	26.5 ohms ±5%; 40 W.	04D1299H44
R3	26.5 ohms ±5%; 40 W. (For 48 V. Supply)	04D1299H44
R3	500 ohms ±5%; 40 W. (For 125 V. Supply)	1268047
R4	100 ohms ±10%; 1 W. Composition	187A644H03
R5	1K ±10%; ½ W. Composition	187A641H27
R6	3K ±5%; 5 W. Wire Wound	188A317H01
R7	15K ±10%; 2 W. Composition	187A642H55
R8	100 ohms ±5%; 2 W. Composition	185A207H03
R9	10K ±5%; ½W. Composition	184A763H51
R51	10K ±5%; ½W. Composition	184A763H51
R52	10K ±5%; ½ W. Composition	184A763H51
R53	10K ±5%; ½ W. Composition	184A763H51
R54	10K ±5%; ½ W. Composition	184A763H51
R55	100 ohms ±5%; ½ W. Composition	184A763H03
R56	3.3K ±5%; ½ W. Composition	184A763H39
R57	3.3K ±5%; ½ W. Composition	184A763H39
R58	100 ohms ±5%; ½ W. Composition	184A763H03
R59	10K ±5%; ½ W. Composition	184A763H51
R60	5.6K ±5%; ½ W. Composition	184A763H45
R61	15K ±5%; ½ W. Composition	184A763H55
R62	10K ±5%; ½ W. Composition	184A763H51
R63	1K ±5%; ½ W. Composition	184A763H27
R64	Potentiometer, 1K; ¼ W.	629A430H02
R65	1.8K ±5%; ½ W. Composition	184A763H33
R66	8.2K ±5%; ½ W. Composition	184A763H49
R67	3.3K ±5%; ½ W. Composition	184A763H39
R68	330 ohms ±5%; ½ W. Composition	184A763H15
R69	800 ohms ±5%; 3 W. Wire Wound	184A859H06
R70	Potentiometer, 1K; ¼ W.	629A430H02
R71	4.7K ±5%; ½ W. Composition	184A763H43
R72	3.9K ±5%; ½ W. Composition	184A763H65

ELECTRICAL PARTS LIST (Cont'd.)

CIRCUIT SYMBOL	DESCRIPTION	WESTINGHOUSE DESIGNATION
	RESISTORS (Cont'd.)	
R73	Thermistor, 30 ohms, Type 3D202 (G.E.C.)	185A211H06
R74	180 ohms ±5%; ½ W. Composition	184A763H02
R75	100 ohms ±5%; ½ W. Composition	184A763H03
R76	2K ±5%; ½ W. Composition	184A763H34
R77	10 ohms ±5%; ½ W. Composition	187A290H01
R78	10 ohms ±5%; ½ W. Composition	187A290H01
R101	10 ohms ±5%; ½ W. Composition	187A280H01
R102	2.2K ±10%; 1 W. Composition	187A644H35
R103	2.7 ohms ±10%; ½ W. Wire Wound	184A636H14
R104	0.27 ohms ±10%; 1 W. Wire Wound	184A636H18
R105	10 ohms ±5%; ½ W. Composition	187A290H01
R106	4.7K ±10% 1 W. Composition	187A644H43
R107	2.7 ohms ±10%; ½ W. Wire Wound	184A636H14
R108	0.27 ohms ±10%; 1 W. Wire Wound	184A636H18
	TRANSFORMERS	
T1	Driver Output Transformer	606B410G01
T2	Power Amp. Input Transformer	292B526G01
T3	Power Amp. Output Transformer	292B526G02
T4	Load-Matching Auto-Transformer	292B526G03
T51	Buffer Amplifier Transformer	606B537G01
T52	Driver Input Transformer	606B537G02
	TRANSISTORS	
Q51	2N697	184A638H18
Q52	2N697	184A638H18
Q53	2N697	184A638H18
Q54	2N699	184A638H19
Q55	2N697	184A638H18
Q56	2N657	184A638H15
Q57	2N657	184A638H15
Q101	2N1908 (Use in Matched Pairs)	187A673H02
Q102	2N1908 (Use in Matched Pairs)	187A673H02
	MISCELLANEOUS	
Y1-Y2	Supplied for Desired Channel Frequency in Pair Matched Per Specifications on Drawing	408C743
FL101	Driver Filter	408C261 + (Req. Freq.)
FL102	Output Filter	541D214 + (Req. Freq.)
PL	Pilot Light Bulb - For 48 V. Supply	187A133H02
	Pilot Light Bulb - For 125 or 259 V. Supply	183A955H01
F1, F2	Fuse, 1.5 A.	11D9195H26

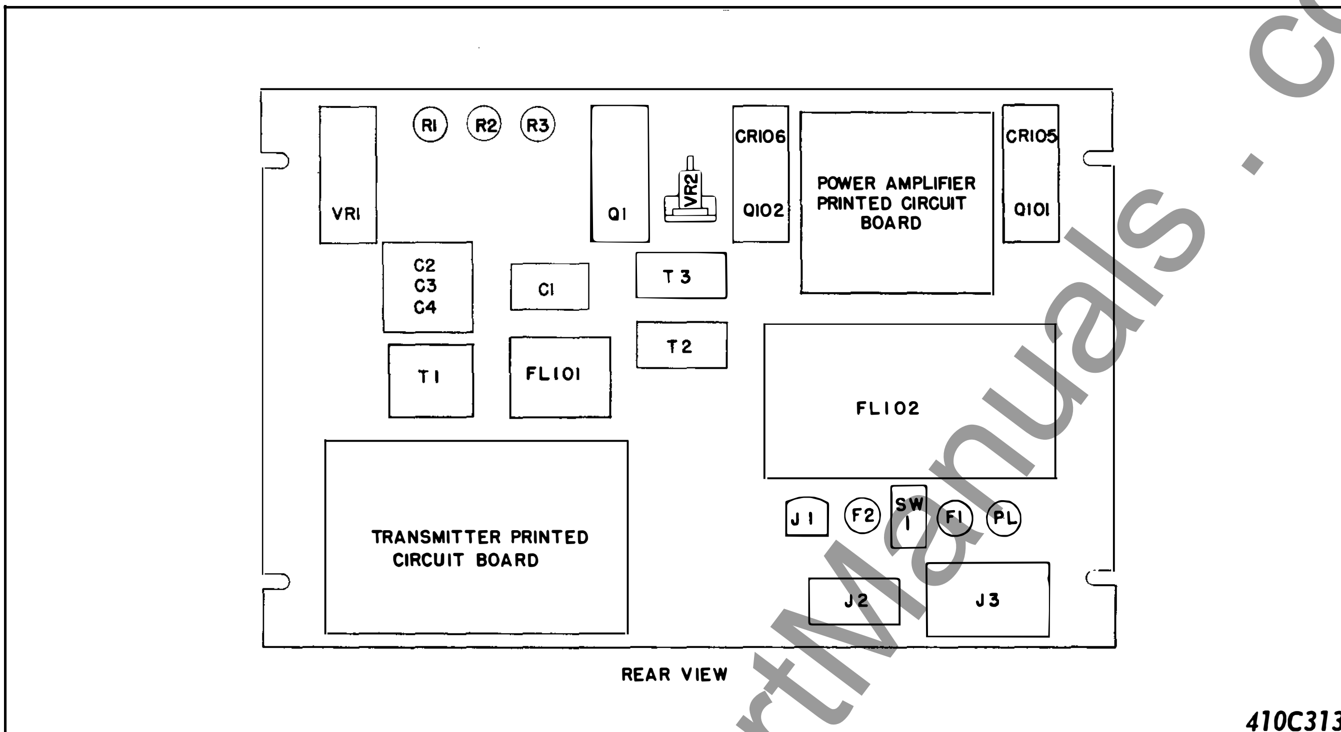

Fig. 2 Component locations of the type TCF transmitter assembly.

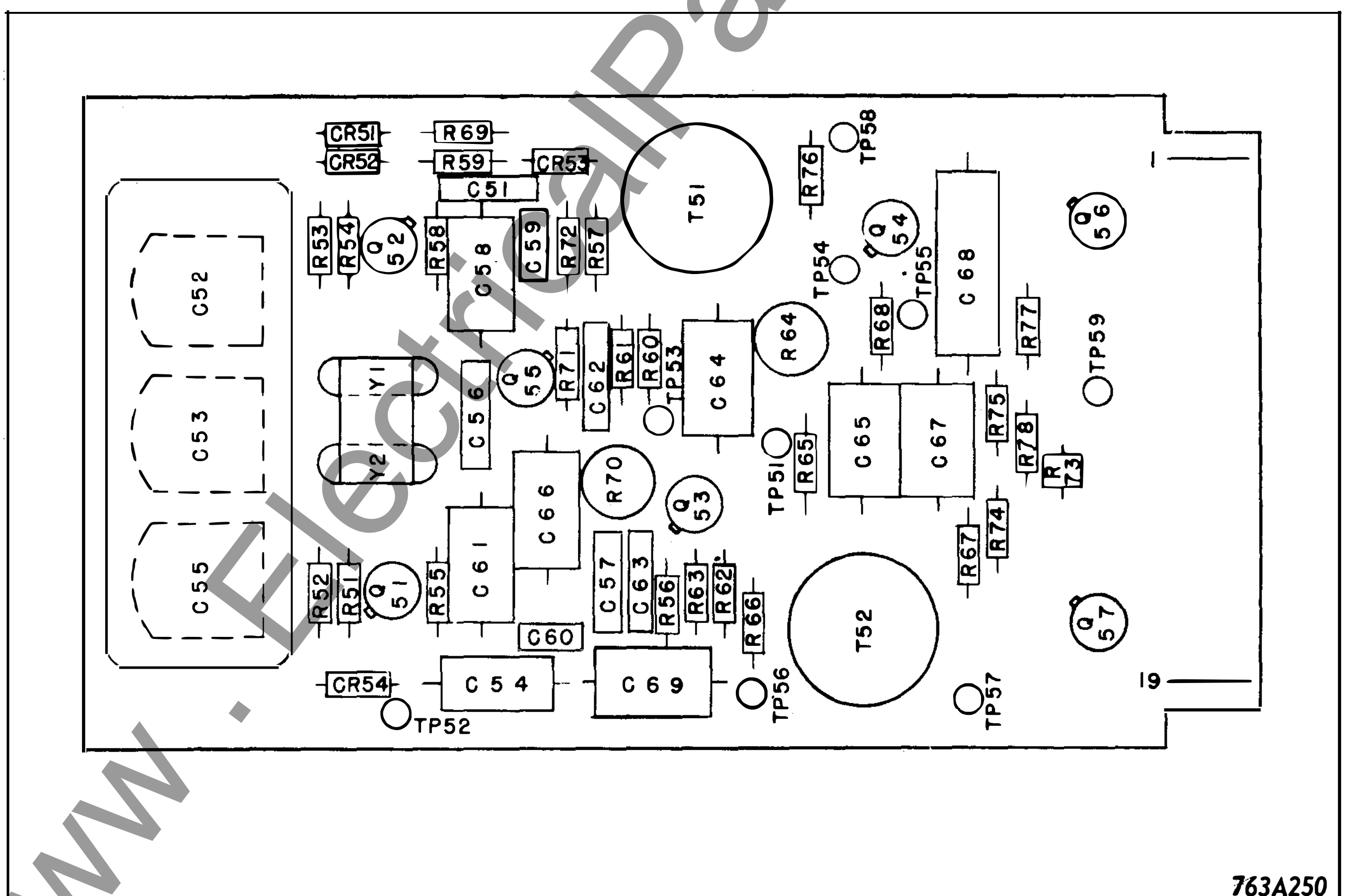

Fig. 3 Component locations of the transmitter printed circuit board.

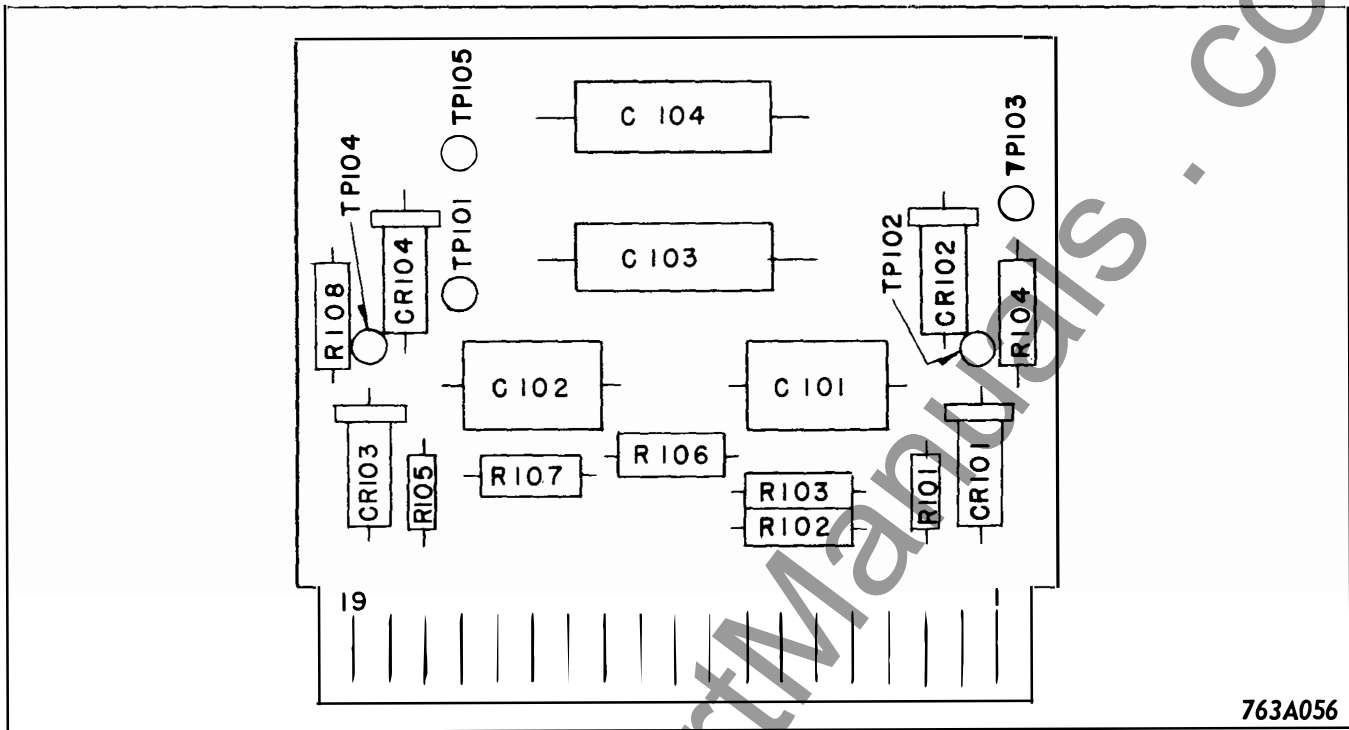

Fig. 4 Component locations of the power amplifier printed circuit board.

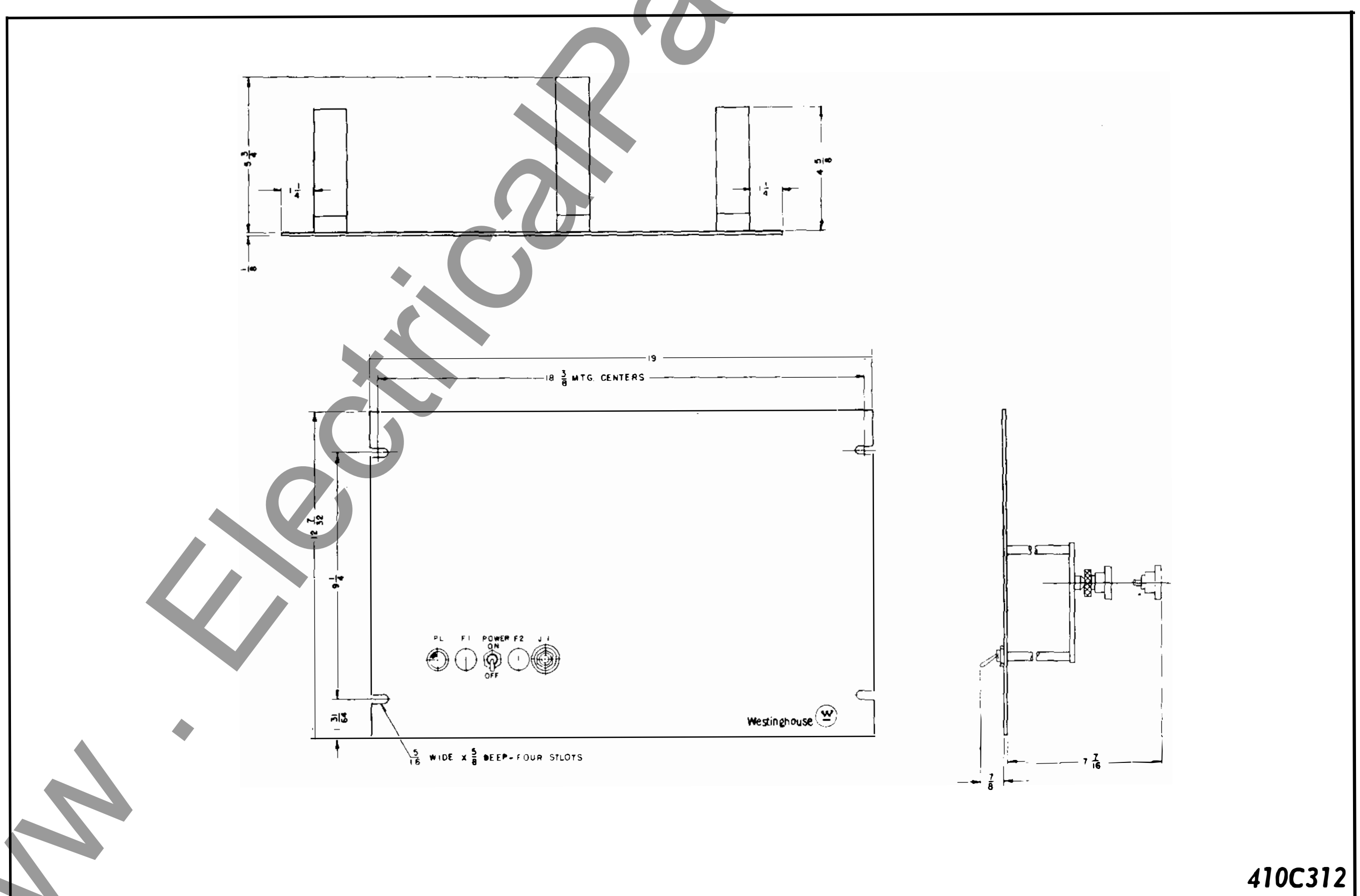

Fig. 5 Outline and drilling plan for the type TCF transmitter assembly.

WESTINGHOUSE ELECTRIC CORPORATION

RELAY-INSTRUMENT DIVISION **NEWARK, N. J.**

Printed in U.S.A.

INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE TCF POWER LINE CARRIER FREQUENCY-SHIFT TRANSMITTER EQUIPMENT – 1 WATT/10 WATT – TRANSFER-TRIP

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 freqeuncy (fc) plus 100 cycles and the others at center frequency minus 100 cycles. The higher frequency, termed the Guard frequency, is transmitted continuously when conditions are normal. It indicates at the receiving end of the line that the channel is operative and it also serves to prevent false operation of the receiver by line noise. The lower frequency, termed the Trip frequency, is transmitted as a signal that an operation (such as tripping a circuit breaker) should be performed at the receiving end of the line.

When frequency shift carrier is used in protective relaying applications, it is recommended that the trip frequency be transmitted at a higher power level to increase reliability of the system under conditions of abnormally high channel losses or line noise. The frequency is shifted from Guard to Trip by the closing of a protective relay contact, and the same contact also shifts the transmitter from a 1 watt to a 10 watt output level.

CONSTRUCTION

The 1 watt/10 watt TCF transmitter unit is mounted on a standard 19-inch wide panel 12¼ inches (7 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, a power switch and a jack for metering the amplifier collector current are accessible from the front of the panel. See Fig. 5. All of the circuitry that is suitable for printed circuit board mounting is on two such boards, as shown in Fig. 2. The components mounted on each printed circuit board or other sub-assembly are shown enclosed by dotted lines on the internal schematic, Fig. 1. The location of components on the two printed circuit boards are shown on separate illustrations, Fig. 3 & 4.

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.

OPERATION

The transmitter is made up of four main stages and two filters. The stages include two crystal oscillators operating at frequencies that differ by the desired channel frequency, a mixer and buffer amplifier, a driver stage and a power amplifier. One filter is located between the driver and the power amplifier and the final filter removes harmonics that may be generated by distortion in the power amplifier.

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

SUPERSEDES I.L. 41-945.1A
*Denotes change from superseded issue

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Fig. 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.

Crystal Y1 is connected in a circuit that is similar except for the addition of C53 and diodes CR51 and CR52. By adjustment of C52 this circuit is made to oscillate at 100 cycles above its marked frequency. Capacitor C53 is not effective until CR51 is biased in the forward direction and becomes conductive. It is biased in the reverse direction until the relay control contact is closed, which places 45 V.D.C. at terminal 3 of the printed circuit board. With CR51 conducting, C53 is effectively in parallel with C52, and adjustment of C53 will reduce the frequency by 200 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 frequencies produced by the two oscillators are coupled to the base of mixer transistor Q53 through C62 and C63. The sum of the two frequencies 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 Q54.

When the relay control, or keying, contact is closed, it increases the output power from 1 watt to 10 watts as well as changing the frequency from Guard to Trip. This is effected by reducing the emitter resistance of buffer-amplifier transistor Q54. When the keying contact is open, transistor Q55 receives no base current and is non-conducting. Emitter resistor R70 therefore is effectively open-circuited. The level of output power is adjusted to 1 watt by means of R64. When Q55 is made conductive by closing the keying contact, R70 is placed in parallel with R68 and the amount of emitter resistance unbypassed by C66 can be adjusted as required to obtain a 10-watt output level.

As is shown on the Internal schematic, Fig. 1, the voltage for the keying circuit is obtained from the 45-volt regulated supply in the transmitter, and opening the single power switch de-energizes both the transmitter and the keying circuit. Capacitor C4 protects the transmitter from transient voltages that might be induced in the lead from terminal 8 of J3 to the keying contact, and it also effects a smoother rise in voltage from the 1-watt to the 10-watt level. Resistor R8 reduces the duty on the keying contact.

The driver 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 input level.

The driver filter, FL101, consists of a series resonant inductor and capacitor connected between the driver and power amplifier stages by appropriate transformers T1 and T2. This filter greatly improves the waveform of the signal applied to the power amplifier.

The power amplifier uses two series-connected power transistors, Q101 and Q102, operating as as a class B push-pull amplifier with single-ended output. Diodes CR101 and CR103 provide protection for the base-emitter junctions of the power transistors. Zener diodes CR105 and CR106 protect the collector-emitter junctions from surges that might come in from the power line through the coaxial cable.

The output transformer T3 couples the power 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 T4 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 power supply is a series-type transistorized d-c voltage regulator which has a very low standby current drain when there is no output current demand. The Zener diode VR1 holds a constant base-to-negative voltage on the series-connected power transistor Q1. Depending on the load current, the d-c voltage drop through transistor Q1 and resistors R1 and R2 varies to maintain a constant output voltage. The Zener diode VR2 serves to protect the collector-base junction of Q1 from surge voltages. Capacitor C1 provides a low carrier-frequency impedance across the d-c output voltage. Capacitors C2 and C3 bypass r.f. or transient voltages to ground, thus preventing damage to the transistor circuits.

CHARACTERISTICS

Frequency range	30-200 KC
Output	1 watt guard — 10 watts trip (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 voltage	48 or 125 v.d.c.
Supply voltage variation	42-56 v. for nom. 48 v. supply. 105-140 v. for nom. 125 v. supply.
Battery drain	0.5 a. guard, 1.15a. trip } 48 v.d.c. 0.5 a. guard, 0.9 a. trip } 125 v.d.c.
Keying circuit current	4 ma.
Temperature range	−20 to + 60°C. around chassis.
Dimensions	Panel height - 12¼" or 7 r.u. Panel width - 19"
Weight	12 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/10W transmitter is shipped with the power output controls R64 and R70 set for outputs of 1 watt and 10 watts into a 60 ohm load. If it is desired to check these 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 10 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 T4 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 4 or 5 volts across the load resistor used. 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 used. Then rotate R64 farther clockwise to obtain the correct voltage for 1 watt in the load resistor, as shown in the following table.

Then change to Trip frequency by connecting together terminals 2 and 3 of the transmitter printed circuit board (which is approximately equivalent to connecting together terminals 7 and 8 of J3), and rotate R70 until the voltage across the load resistor is as shown in the following table for a 10 watt output. Recheck the adjustment of L105 for maximum output voltage and readjust R70 for a 10 watt output if necessary. Tighten the locking nut on L105. Open the power switch, remove the jumper used to key the transmitter to the 10 watt level, remove the load resistor, and reconnect the coaxial cable circuit to the transmitter.

T106 Tap	Voltage for 1 Watt Output	Voltage for 10 Watts Output
50	7.1	22.4
60	7.8	24.5
70	8.4	26.5

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 a crystal in its proper socket with the other crystal unconnected. 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.) While measurement of the oscillator crystals individually is necessary for the initial adjustment of the oscillators, generally any subsequent checks may be made with a lower range counter connected at the transmitter output. If any minor adjustment of the Guard and Trip frequencies should be needed, the Guard adjustment should be made with capacitor C52 and the Trip adjustment with C53.

MAINTENANCE

Periodic checks of the transmitter Guard and Trip power outputs 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 sinks. 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	Voltage at 10 Watts Output
TP52	20	20
TP53	5.4	5.4
TP54	3.4	3.4
TP55	21	18.5
TP56	21	18.5
TP57	* < 1.0	* < 1.0
TP58	44.3	44.1
TP59	* < 1.0	* < 1.0
TP101	0	0
TP103	21 ± 2	21 ± 2
TP105	44.3	44.0

TABLE II
TRANSMITTER RF MEASUREMENTS

Note: Voltages taken with transmitter set to indicated output across 60 ohms. These voltages 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 Point	Voltage at 1 Watt Output	Voltage at 10 Watts Output
TP54 to TP51	0.015 – 0.03	0.015 – 0.03
TP57 to TP51	0.05 – 0.09	0.3 – 1.2
TP59 to TP51	0.05 – 0.09	0.3 – 1.2
T1-1 to TP51	1.65	5.6
T1-3 to TP51	1.45	4.9
T1-4 to Gnd.	.6	2.0
T2-1 to Gnd.	.57	1.85
TP101 to TP103	5.2	17.0
TP103 to TP105	5.2	17.0
T3-4 to Gnd.	35	112
T4-2 to Gnd.	31	110
TP109 to Gnd.	9.8	31
J102 to Gnd.	7.8	24.5

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.

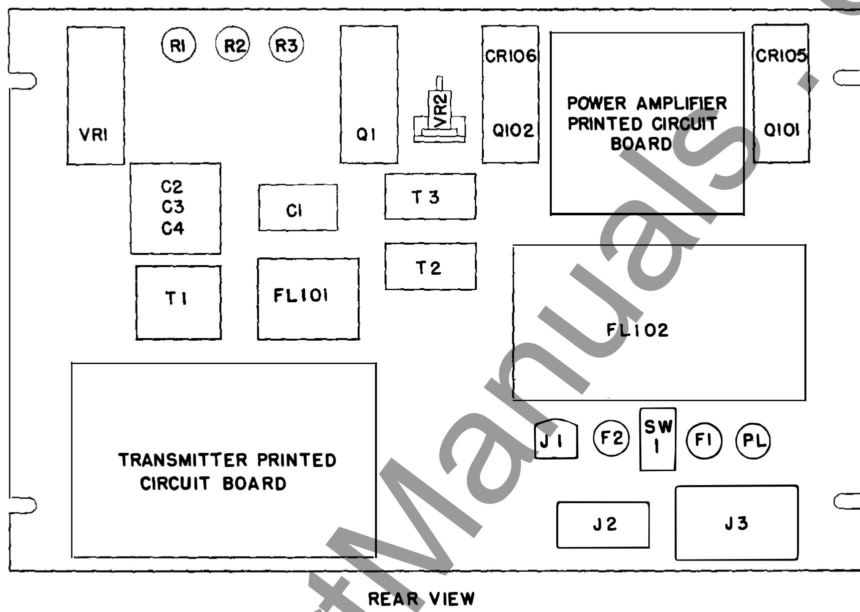

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Fig. 2 Component locations of the type TCF transmitter assembly.

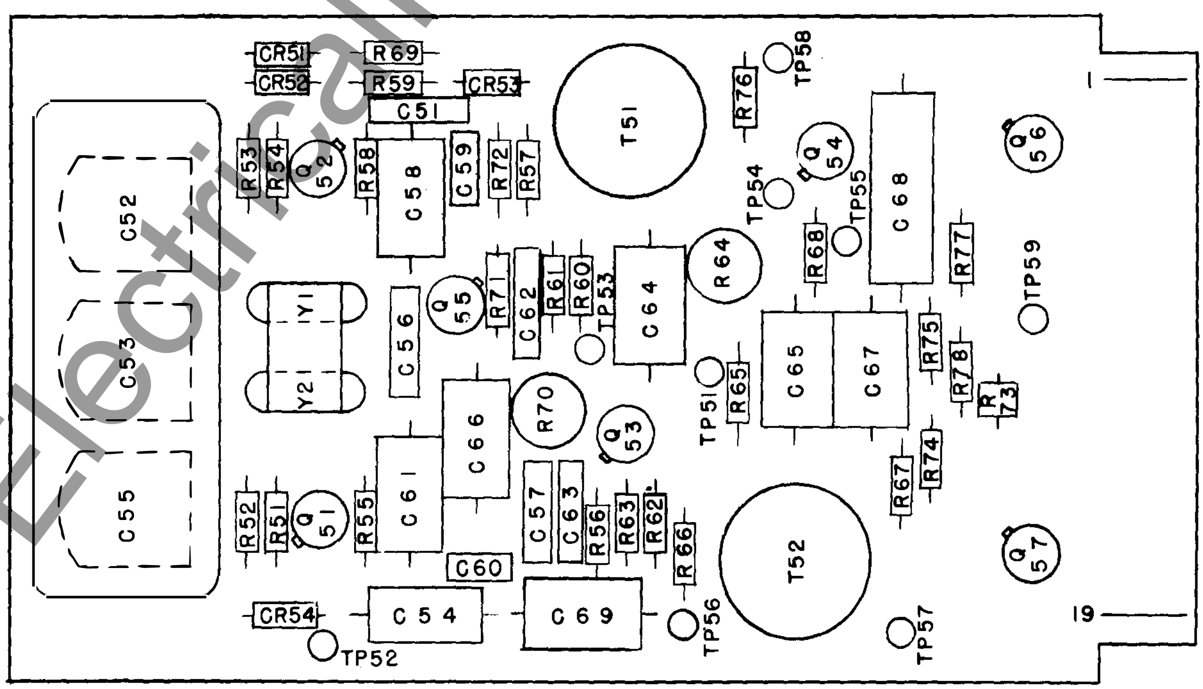

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Fig. 3 Component locations of the transmitter printed circuit board.

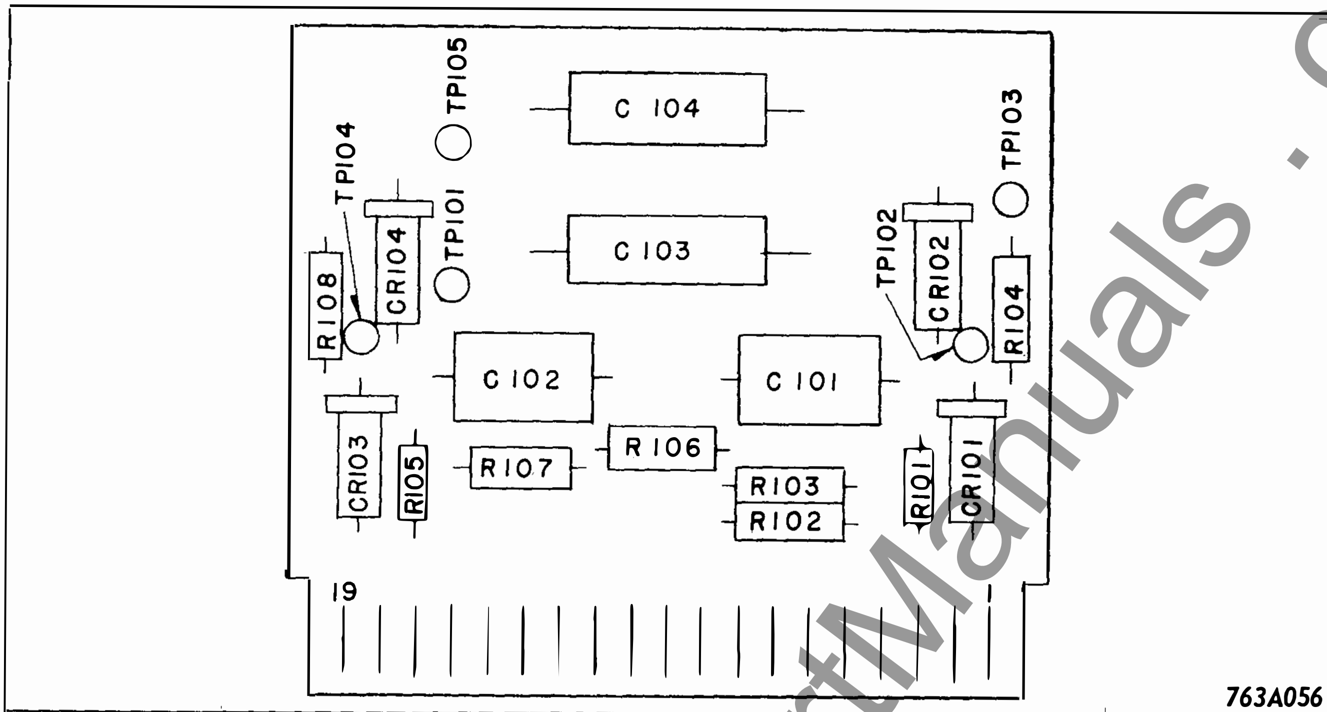

Fig. 4 Component locations of the power amplifier printed circuit board.

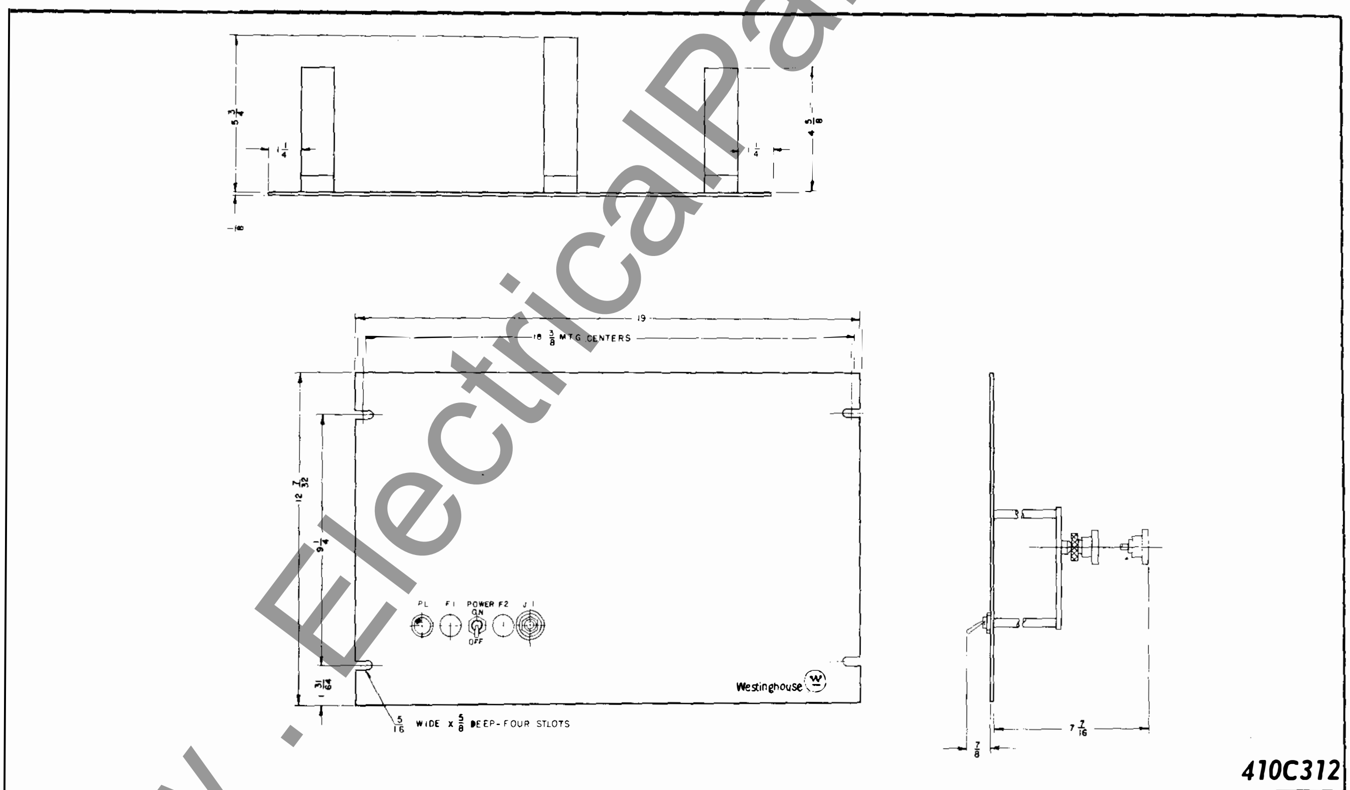

Fig. 5 Outline and drilling plan for the type TCF transmitter assembly.

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INSTRUCTIONS

TYPE TCF POWER LINE CARRIER FREQUENCY-SHIFT TRANSMITTER EQUIPMENT – 1 WATT/10 WATT – TRANSFER-TRIP

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 others at center frequency minus 100 cycles. The higher frequency, termed the Guard frequency, is transmitted continuously when conditions are normal. It indicates at the receiving end of the line that the channel is operative and it also serves to prevent false operation of the receiver by line noise. The lower frequency, termed the Trip frequency, is transmitted as a signal that an operation (such as tripping a circuit breaker) should be performed at the receiving end of the line.

When frequency shift carrier is used in protective relaying applications, it is recommended that the trip frequency be transmitted at a higher power level to increase reliability of the system under conditions of abnormally high channel losses or line noise. The frequency is shifted from Guard to Trip by the closing of a protective relay contact, and the same contact also shifts the transmitter from a 1 watt to a 10 watt output level.

CONSTRUCTION

The 1 watt/10 watt TCF transmitter unit is mounted on a standard 19-inch wide panel 12¼ inches (7 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, a power switch and a jack for metering the amplifier collector current are accessible from the front of the panel. See Fig. 5. All of the circuitry that is suitable for printed circuit board mounting is on two such boards, as shown in Fig. 2. The components mounted on each printed circuit board or other sub-assembly are shown enclosed by dotted lines on the internal schematic, Fig. 1. The location of components on the two printed circuit boards are shown on separate illustrations, Fig. 3 & 4.

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.

OPERATION

The transmitter is made up of four main stages and two filters. The stages include two crystal oscillators operating at frequencies that differ by the desired channel frequency, a mixer and buffer amplifier, a driver stage and a power amplifier. One filter is located between the driver and the power amplifier and the final filter removes harmonics that may be generated by distortion in the power amplifier.

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

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*Denotes change from superseded issue

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Fig. 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.

Crystal Y1 is connected in a circuit that is similar except for the addition of C53 and diodes CR51 and CR52. By adjustment of C52 this circuit is made to oscillate at 100 cycles above its marked frequency. Capacitor C53 is not effective until CR51 is biased in the forward direction and becomes conductive. It is biased in the reverse direction until the relay control contact is closed, which places 45 V.D.C. at terminal 3 of the printed circuit board. With CR51 conducting, C53 is effectively in parallel with C52, and adjustment of C53 will reduce the frequency by 200 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 frequencies produced by the two oscillators are coupled to the base of mixer transistor Q53 through C62 and C63. The sum of the two frequencies 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 Q54.

When the relay control, or keying, contact is closed, it increases the output power from 1 watt to 10 watts as well as changing the frequency from Guard to Trip. This is effected by reducing the emitter resistance of buffer-amplifier transistor Q54. When the keying contact is open, transistor Q55 receives no base current and is non-conducting. Emitter resistor R70 therefore is effectively open-circuited. The level of output power is adjusted to 1 watt by means of R64. When Q55 is made conductive by closing the keying contact, R70 is placed in parallel with R68 and the amount of emitter resistance unbypassed by C66 can be adjusted as required to obtain a 10-watt output level.

As is shown on the Internal schematic, Fig. 1, the voltage for the keying circuit is obtained from the 45-volt regulated supply in the transmitter, and opening the single power switch de-energizes both the transmitter and the keying circuit. Capacitor C4 protects the transmitter from transient voltages that might be induced in the lead from terminal 8 of J3 to the keying contact, and it also effects a smoother rise in voltage from the 1-watt to the 10-watt level. Resistor R8 reduces the duty on the keying contact.

The driver 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 input level.

The driver filter, FL101, consists of a series resonant inductor and capacitor connected between the driver and power amplifier stages by appropriate transformers T1 and T2. This filter greatly improves the waveform of the signal applied to the power amplifier.

The power amplifier uses two series-connected power transistors, Q101 and Q102, operating as as a class B push-pull amplifier with single-ended output. Diodes CR101 and CR103 provide protection for the base-emitter junctions of the power transistors. Zener diodes CR105 and CR106 protect the collector-emitter junctions from surges that might come in from the power line through the coaxial cable.

The output transformer T3 couples the power 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 T4 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 power supply is a series-type transistorized d-c voltage regulator which has a very low standby current drain when there is no output current demand. The Zener diode VR1 holds a constant base-to-negative voltage on the series-connected power transistor Q1. Depending on the load current, the d-c voltage drop through transistor Q1 and resistors R1 and R2 varies to maintain a constant output voltage. The Zener diode VR2 serves to protect the collector-base junction of Q1 from surge voltages. Capacitor C1 provides a low carrier-frequency impedance across the d-c output voltage. Capacitors C2 and C3 bypass r.f. or transient voltages to ground, thus preventing damage to the transistor circuits.

CHARACTERISTICS

Frequency range	30-200 KC
Output	1 watt guard — 10 watts trip (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 voltage	48 or 125 v.d.c.
Supply voltage variation	42-56 v. for nom. 48 v. supply. 105-140 v. for nom. 125 v. supply.
Battery drain	0.5 a. guard, 1.15a. trip } 48 v.d.c. 0.5 a. guard, 0.9 a. trip } 125 v.d.c.
* Keying circuit current	4 ma.
Temperature range	−20 to + 60°C. around chassis.
Dimensions	Panel height - 12¼" or 7 r.u. Panel width - 19"
Weight	12 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/10W transmitter is shipped with the power output controls R64 and R70 set for outputs of 1 watt and 10 watts into a 60 ohm load. If it is desired to check these 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 10 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 T4 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 4 or 5 volts across the load resistor used. 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 used. Then rotate R64 farther clockwise to obtain the correct voltage for 1 watt in the load resistor, as shown in the following table.

* Then change to Trip frequency by connecting together terminals 2 and 3 of the transmitter printed circuit board (which is approximately equivalent to connecting together terminals 7 and 8 of J3), and rotate R70 until the voltage across the load resistor is as shown in the following table for a 10 watt output. Recheck the adjustment of L105 for maximum output voltage and readjust R70 for a 10 watt output if necessary. Tighten the locking nut on L105. Open the power switch, remove the jumper used to key the transmitter to the 10 watt level, remove the load resistor, and reconnect the coaxial cable circuit to the transmitter.

T106 Tap	Voltage for 1 Watt Output	Voltage for 10 Watts Output
50	7.1	22.4
60	7.8	24.5
70	8.4	26.5

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 a crystal in its proper socket with the other crystal unconnected. 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.) While measurement of the oscillator crystals individually is necessary for the initial adjustment of the oscillators, generally any subsequent checks may be made with a lower range counter connected at the transmitter output. If any minor adjustment of the Guard and Trip frequencies should be needed, the Guard adjustment should be made with capacitor C52 and the Trip adjustment with C53.

MAINTENANCE

Periodic checks of the transmitter Guard and Trip power outputs 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 sinks. 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	Voltage at 10 Watts Output
TP52	20	20
TP53	5.4	5.4
TP54	3.4	3.4
TP55	21	18.5
TP56	21	18.5
TP57	.65	.65
TP58	44.3	44.1
TP59	.65	.65
TP101	0	0
TP103	21±2	21±2
TP105	44.3	44.0

TABLE II
TRANSMITTER RF MEASUREMENTS

Note: Voltages taken with transmitter set to indicated output across 60 ohms. These voltages 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 Point	Voltage at 1 Watt Output	Voltage at 10 Watts Output
TP54 to TP51	0.015 – 0.03	0.015 – 0.03
TP57 to TP51	0.05 – 0.09	0.3 – 1.2
TP59 to TP51	0.05 – 0.09	0.3 – 1.2
T1-1 to TP51	1.65	5.6
T1-3 to TP51	1.45	4.9
T1-4 to Gnd.	.6	2.0
T2-1 to Gnd.	.57	1.85
TP101 to TP103	5.2	17.0
TP103 to TP105	5.2	17.0
T3-4 to Gnd.	35	112
T4-2 to Gnd.	31	110
TP109 to Gnd.	9.8	31
J102 to Gnd.	7.8	24.5

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.

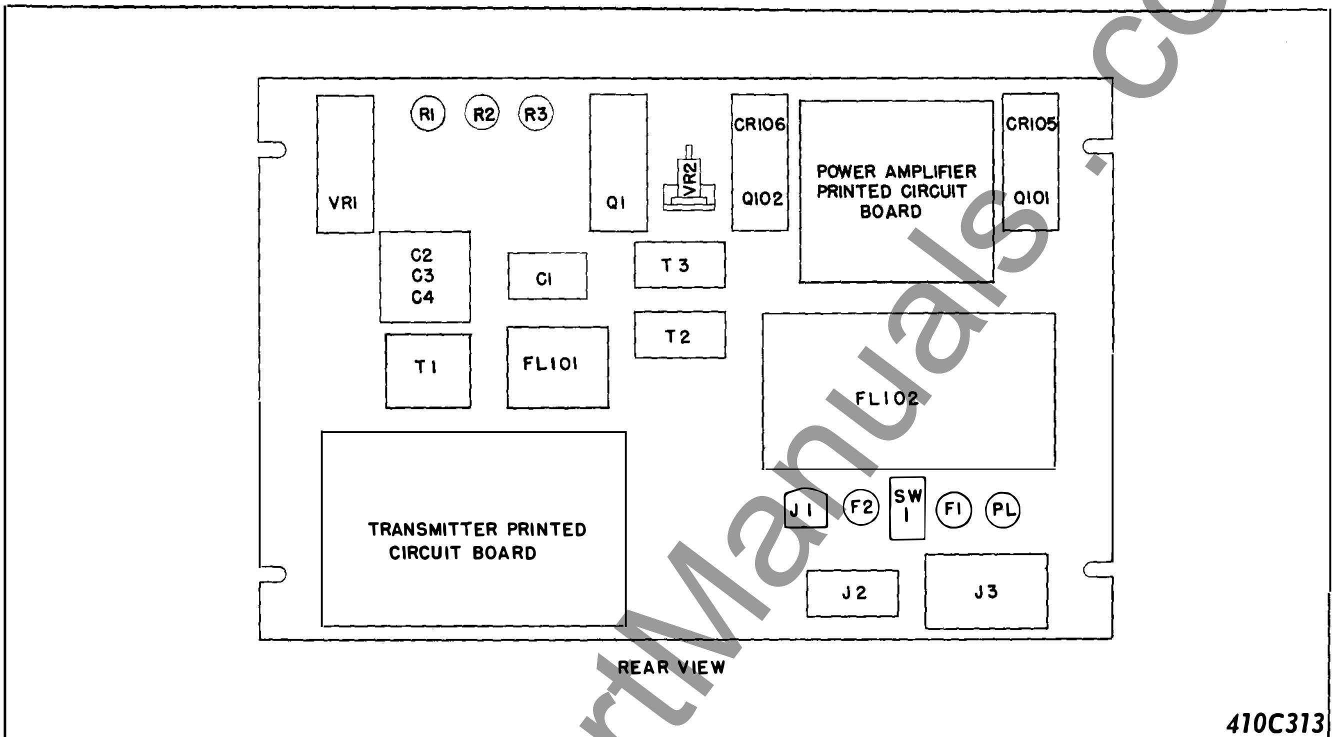

Fig. 2 Component locations of the type TCF transmitter assembly.

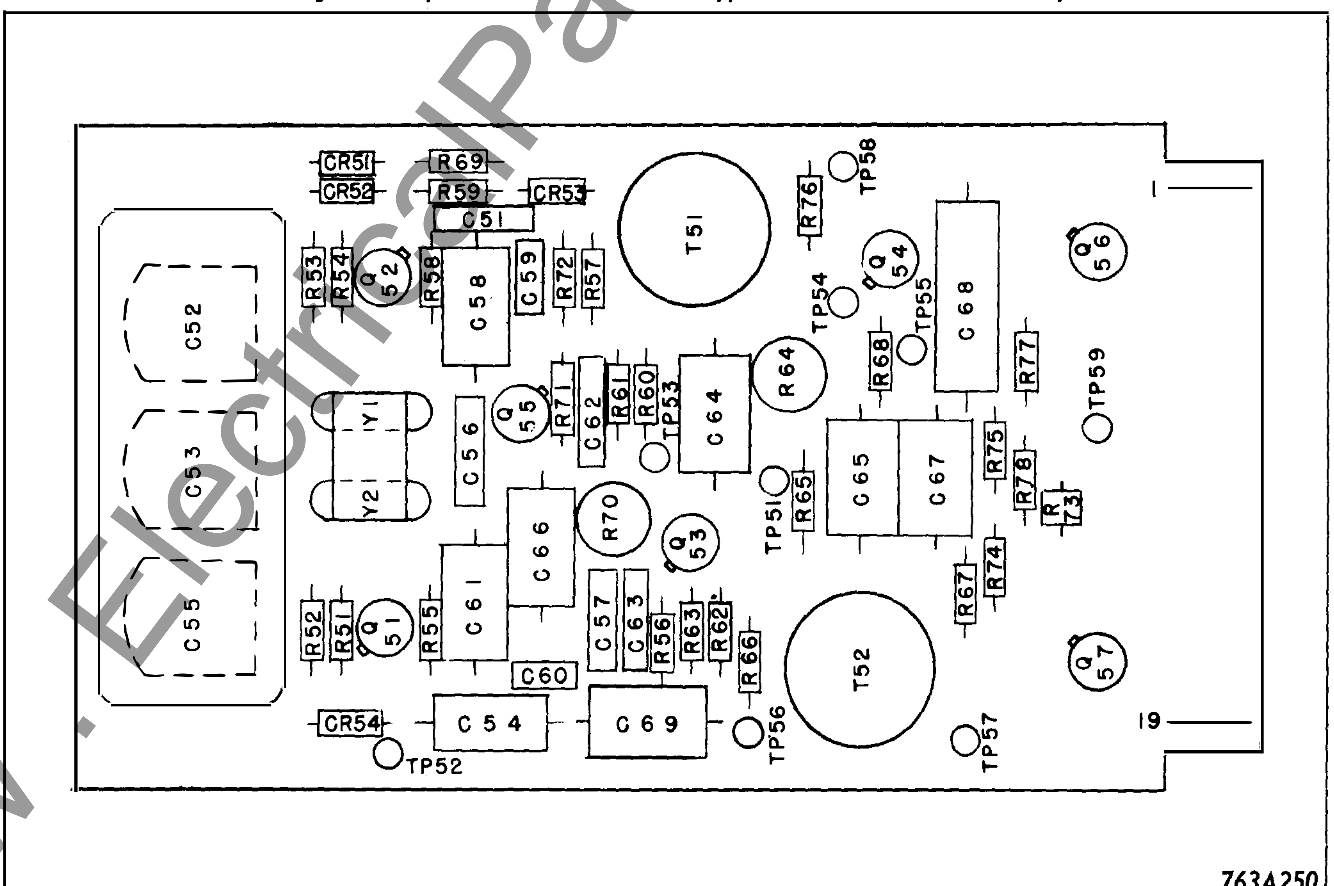

Fig. 3 Component locations of the transmitter printed circuit board.

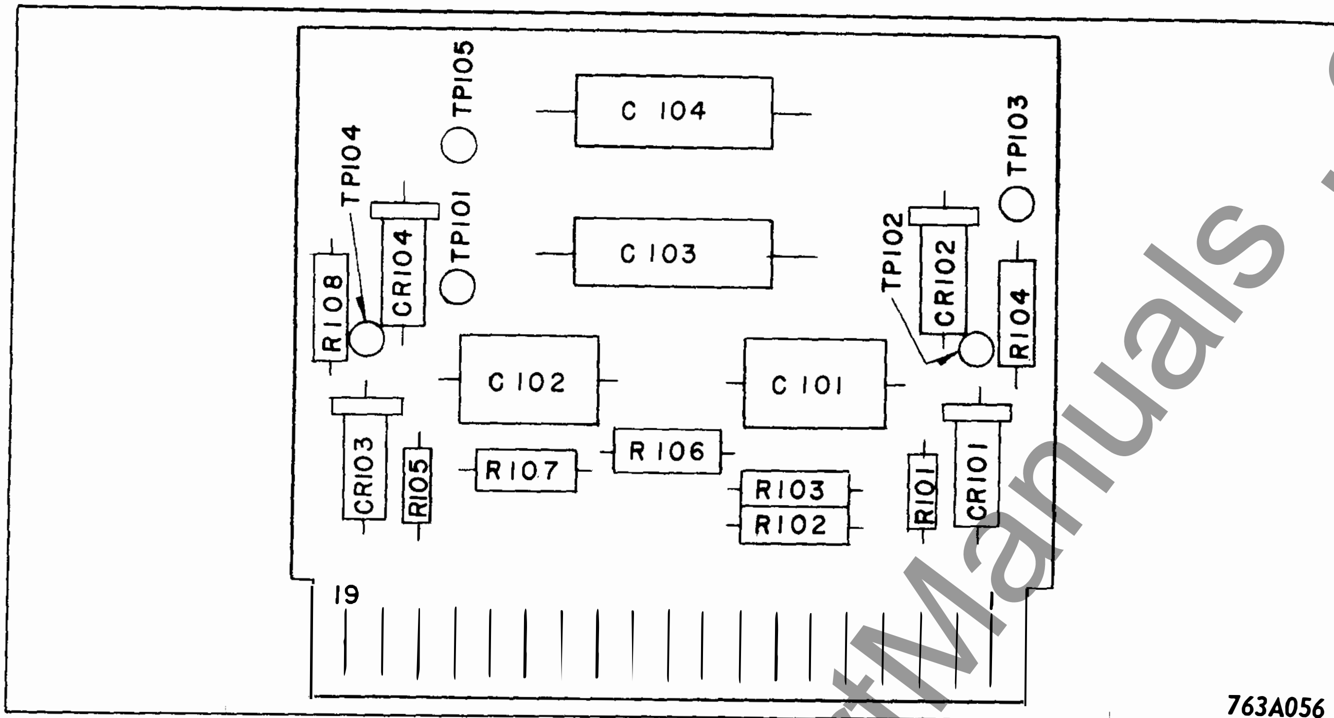

Fig. 4 Component locations of the power amplifier printed circuit board.

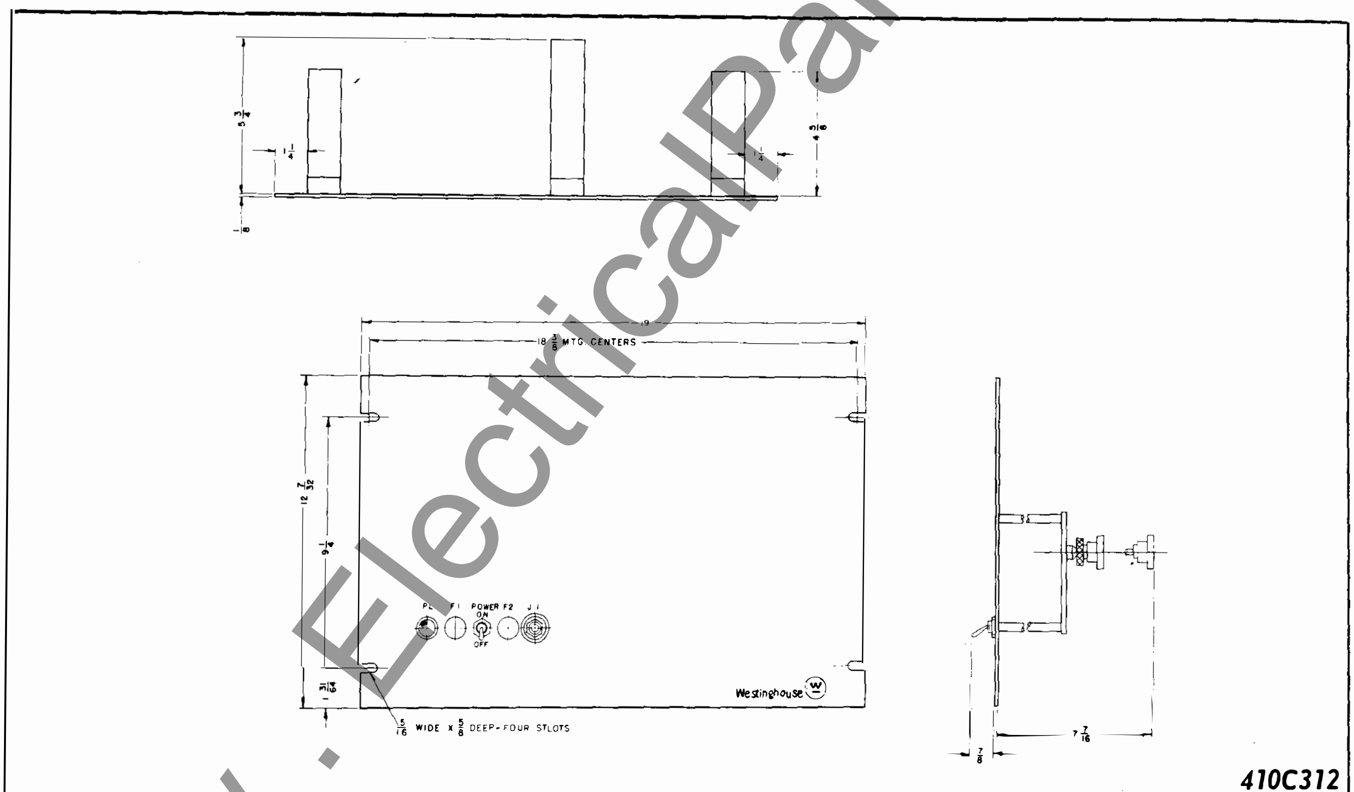

Fig. 5 Outline and drilling plan for the type TCF transmitter assembly.

WESTINGHOUSE ELECTRIC CORPORATION

RELAY-INSTRUMENT DIVISION

NEWARK, N. J.

Printed in U.S.A.

INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE TCF POWER LINE CARRIER FREQUENCY-SHIFT TRANSMITTER EQUIPMENT – 1 WATT/10 WATT – TRANSFER-TRIP

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 others at center frequency minus 100 cycles. The higher frequency, termed the Guard frequency, is transmitted continuously when conditions are normal. It indicates at the receiving end of the line that the channel is operative and it also serves to prevent false operation of the receiver by line noise. The lower frequency, termed the Trip frequency, is transmitted as a signal that an operation (such as tripping a circuit breaker) should be performed at the receiving end of the line.

When frequency shift carrier is used in protective relaying applications, it is recommended that the trip frequency be transmitted at a higher power level to increase reliability of the system under conditions of abnormally high channel losses or line noise. The frequency is shifted from Guard to Trip by the closing of a protective relay contact, and the same contact also shifts the transmitter from a 1 watt to a 10 watt output level.

CONSTRUCTION

The 1 watt/10 watt TCF transmitter unit is mounted on a standard 19-inch wide panel 12¼ inches (7 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, a power switch and a jack for metering the amplifier collector current are accessible from the front of the panel. See Fig. 5. All of the circuitry that is suitable for printed circuit board mounting is on two such boards, as shown in Fig. 2. The components mounted on each printed circuit board or other sub-assembly are shown enclosed by dotted lines on the internal schematic. Fig. 1. The location of components on the two printed circuit boards are shown on separate illustrations, Fig. 3 & 4.

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.

OPERATION

The transmitter is made up of four main stages and two filters. The stages include two crystal oscillators operating at frequencies that differ by the desired channel frequency, a mixer and buffer amplifier, a driver stage and a power amplifier. One filter is located between the driver and the power amplifier and the final filter removes harmonics that may be generated by distortion in the power amplifier.

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

Fig. 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.

Crystal Y1 is connected in a circuit that is similar except for the addition of C53 and diodes CR51 and CR52. By adjustment of C52 this circuit is made to oscillate at 100 cycles above its marked frequency. Capacitor C53 is not effective until CR51 is biased in the forward direction and becomes conductive. It is biased in the reverse direction until the relay control contact is closed, which places 45 V.D.C. at terminal 3 of the printed circuit board. With CR51 conducting, C53 is effectively in parallel with C52, and adjustment of C53 will reduce the frequency by 200 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 frequencies produced by the two oscillators are coupled to the base of mixer transistor Q53 through C62 and C63. The sum of the two frequencies 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 Q54.

When the relay control, or keying, contact is closed, it increases the output power from 1 watt to 10 watts as well as changing the frequency from Guard to Trip. This is effected by reducing the emitter resistance of buffer-amplifier transistor Q54. When the keying contact is open, transistor Q55 receives no base current and is non-conducting. Emitter resistor R70 therefore is effectively open-circuited. The level of output power is adjusted to 1 watt by means of R64. When Q55 is made conductive by closing the keying contact, R70 is placed in parallel with R68 and the amount of emitter resistance unbypassed by C66 can be adjusted as required to obtain a 10-watt output level.

As is shown on the Internal schematic, Fig. 1, the voltage for the keying circuit is obtained from the 45-volt regulated supply in the transmitter, and opening the single power switch de-energizes both the transmitter and the keying circuit. Capacitor C4 protects the transmitter from transient voltages that might be induced in the lead from terminal 8 of J3 to the keying contact, and it also effects a smoother rise in voltage from the 1-watt to the 10-watt level. Resistor R8 reduces the duty on the keying contact.

The driver 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 input level.

The driver filter, FL101, consists of a series resonant inductor and capacitor connected between the driver and power amplifier stages by appropriate transformers T1 and T2. This filter greatly improves the waveform of the signal applied to the power amplifier.

The power amplifier uses two series-connected power transistors, Q101 and Q102, operating as as a class B push-pull amplifier with single-ended output. Diodes CR101 and CR103 provide protection for the base-emitter junctions of the power transistors. Zener diodes CR105 and CR106 protect the collector-emitter junctions from surges that might come in from the power line through the coaxial cable.

The output transformer T3 couples the power 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 T4 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 power supply is a series-type transistorized d-c voltage regulator which has a very low standby current drain when there is no output current demand. The Zener diode VR1 holds a constant base-to-negative voltage on the series-connected power transistor Q1. Depending on the load current, the d-c voltage drop through transistor Q1 and resistors R1 and R2 varies to maintain a constant output voltage. The Zener diode VR2 serves to protect the collector-base junction of Q1 from surge voltages. Capacitor C1 provides a low carrier-frequency impedance across the d-c output voltage. Capacitors C2 and C3 bypass r.f. or transient voltages to ground, thus preventing damage to the transistor circuits.

CHARACTERISTICS

Frequency range	30-200 KC
Output	1 watt guard — 10 watts trip (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 Voltage	48 or 125 v.d.c.
Supply voltage variation	42-56 v. for nom. 48 v. supply. 105-140 v. for nom. 125 v. supply.
Battery drain	0.5 a. guard, 1.15a. trip } 48 v.d.c. 0.5 a. guard, 0.9 a. trip } 125 v.d.c.
Temperature range	−20 to + 60° C. around chassis.
Dimensions	Panel height - 12¼" or 7 r.u. Panel width - 19"
Weight	12 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/10W transmitter is shipped with the power output controls R64 and R70 set for outputs of 1 watt and 10 watts into a 60 ohm load. If it is desired to check these 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 10 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 T4 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 the correct voltage for 1 watt in the load resistor used.

Then change to trip frequency by connecting together terminals 2 and 3 of the printed circuit board (or terminals 7 and 8 of J3), and rotate R70 until about 10 volts is obtained 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 R70 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 10 watts output. Tighten the locking nut. Open the power switch, remove the jumpers used to key the transmitter to the 10 watt level, remove the load resistor, and reconnect the coaxial cable circuit to the transmitter.

T106 Tap	Voltage for 1 Watt Output	Voltage for 10 Watts Output
50	7.1	22.4
60	7.8	24.5
70	8.4	26.5

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 a crystal in its proper socket with the other crystal unconnected. 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.) While measurement of the oscillator crystals individually is necessary for the initial adjustment of the oscillators, generally any subsequent checks may be made with a lower range counter connected at the transmitter output. If any minor adjustment of the Guard and Trip frequencies should be needed, the Guard adjustment should be made with capacitor C52 and the Trip adjustment with C53.

MAINTENANCE

Periodic checks of the transmitter Guard and Trip power outputs 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 sinks. 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	Voltage at 10 Watts Output
TP52	20	20
TP53	5.4	5.4
TP54	3.4	3.4
TP55	21	18.5
TP56	21	18.5
TP57	.65	.65
TP58	44.3	44.1
TP59	.65	.65
TP101	0	0
TP103	21±2	21±2
TP105	44.3	44.0

TABLE II
TRANSMITTER RF MEASUREMENTS

Note: Voltages taken with transmitter set to indicated output across 60 ohms. These voltages 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 Point	Voltage at 1 Watt Output	Voltage at 10 Watts Output
TP54 to TP51	0.015 – 0.03	0.015 – 0.03
TP57 to TP51	0.05 – 0.09	0.3 – 1.2
TP59 to TP51	0.05 – 0.09	0.3 – 1.2
T1-1 to TP51	1.65	5.6
T1-3 to TP51	1.45	4.9
T1-4 to Gnd.	.6	2.0
T2-1 to Gnd.	.57	1.85
TP101 to TP103	5.2	17.0
TP103 to TP105	5.2	17.0
T3-4 to Gnd.	35	112
T4-2 to Gnd.	31	110
TP109 to Gnd.	9.8	31
J102 to Gnd.	7.8	24.5

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.

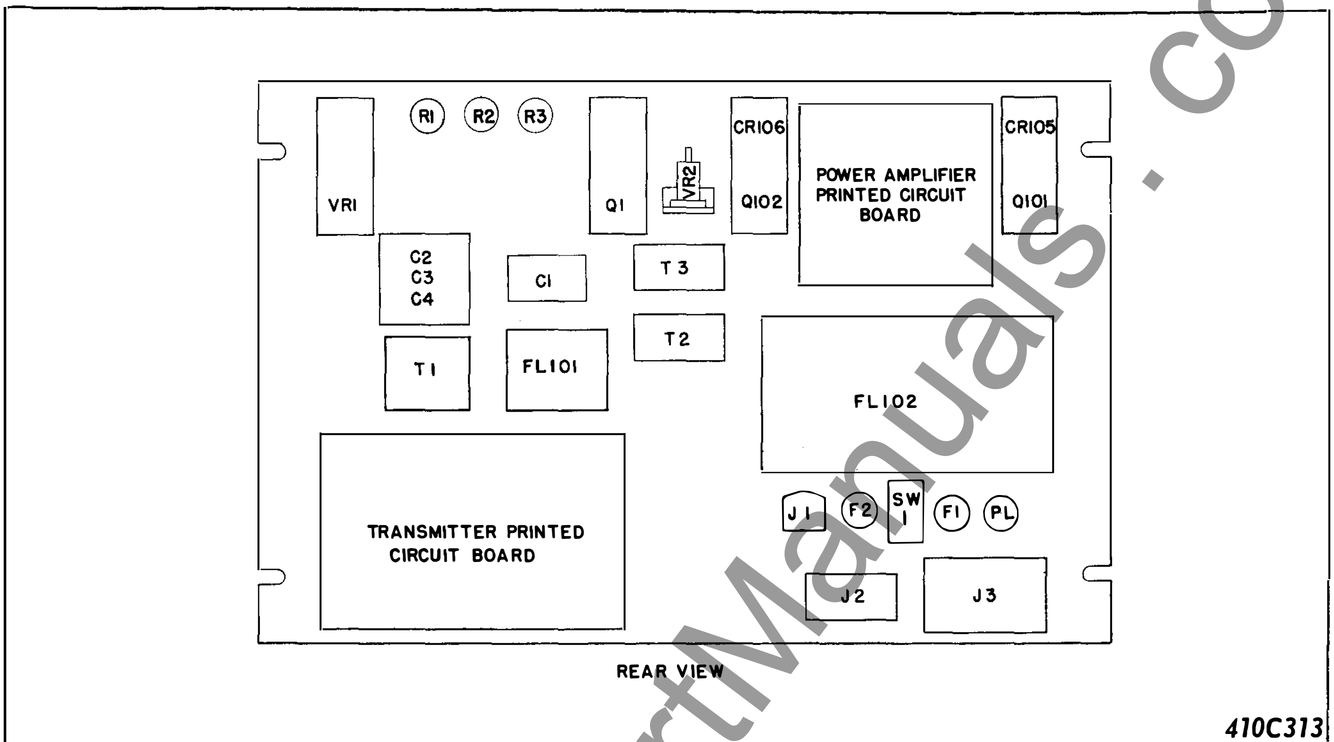

Fig. 2 Component locations of the type TCF transmitter assembly.

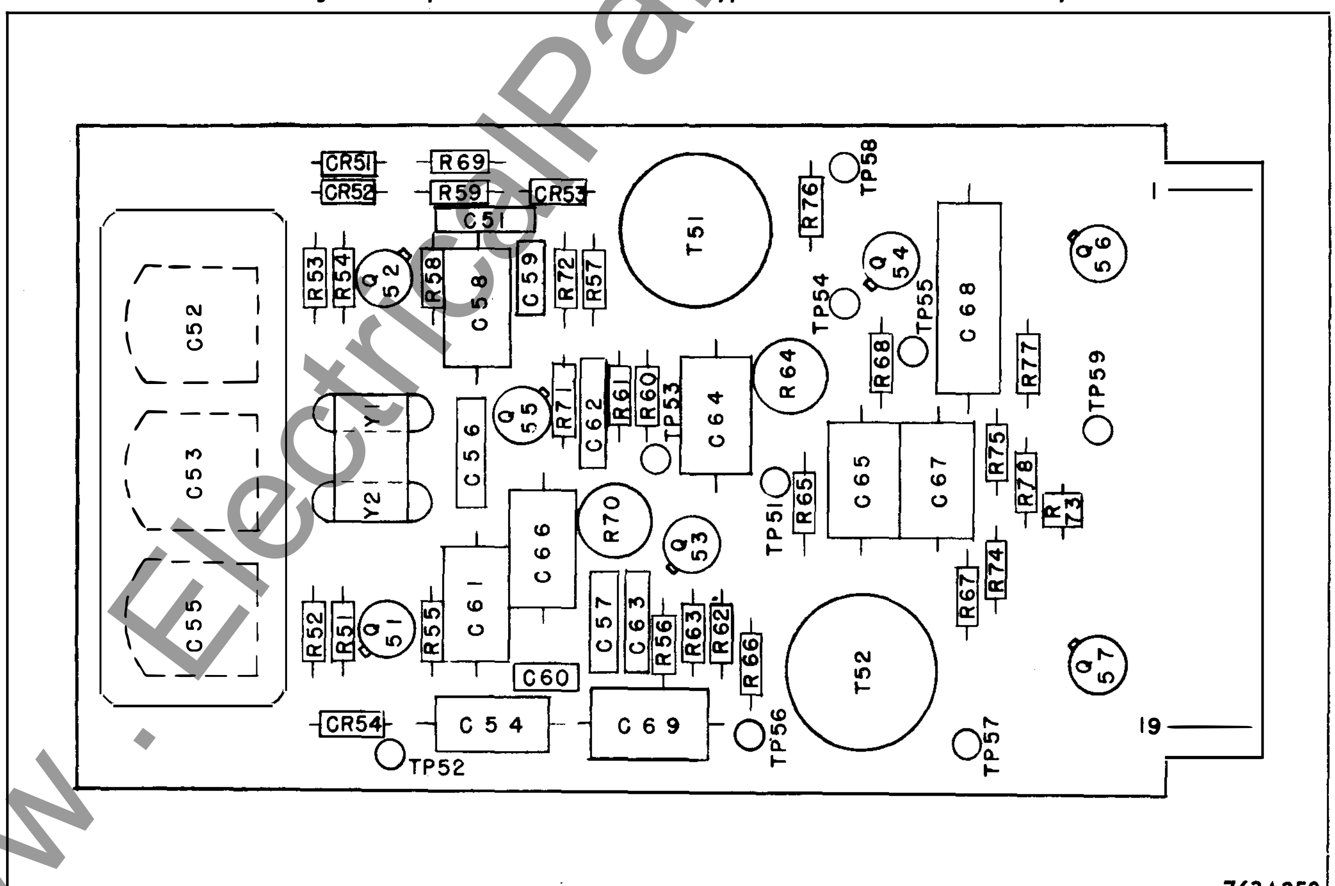

Fig. 3 Component locations of the transmitter printed circuit board.

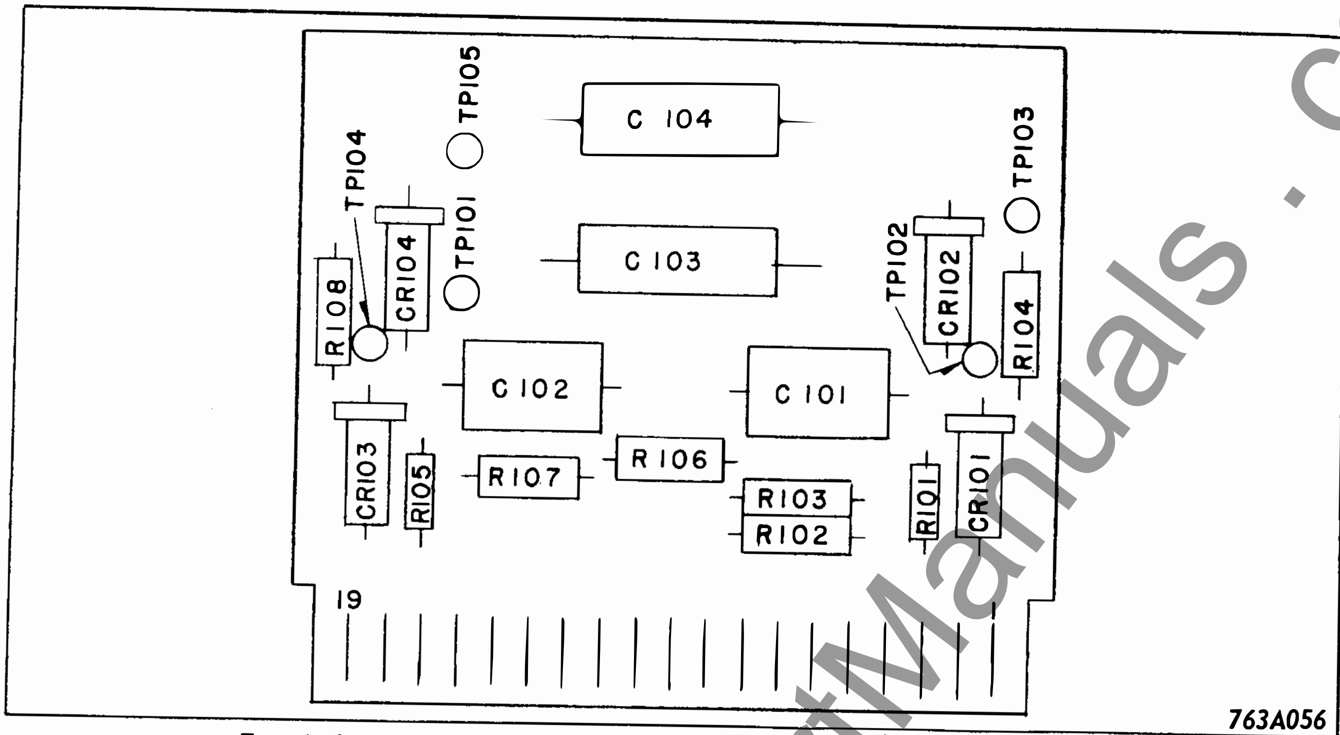

Fig. 4 Component locations of the Power Amplifier printed circuit board.

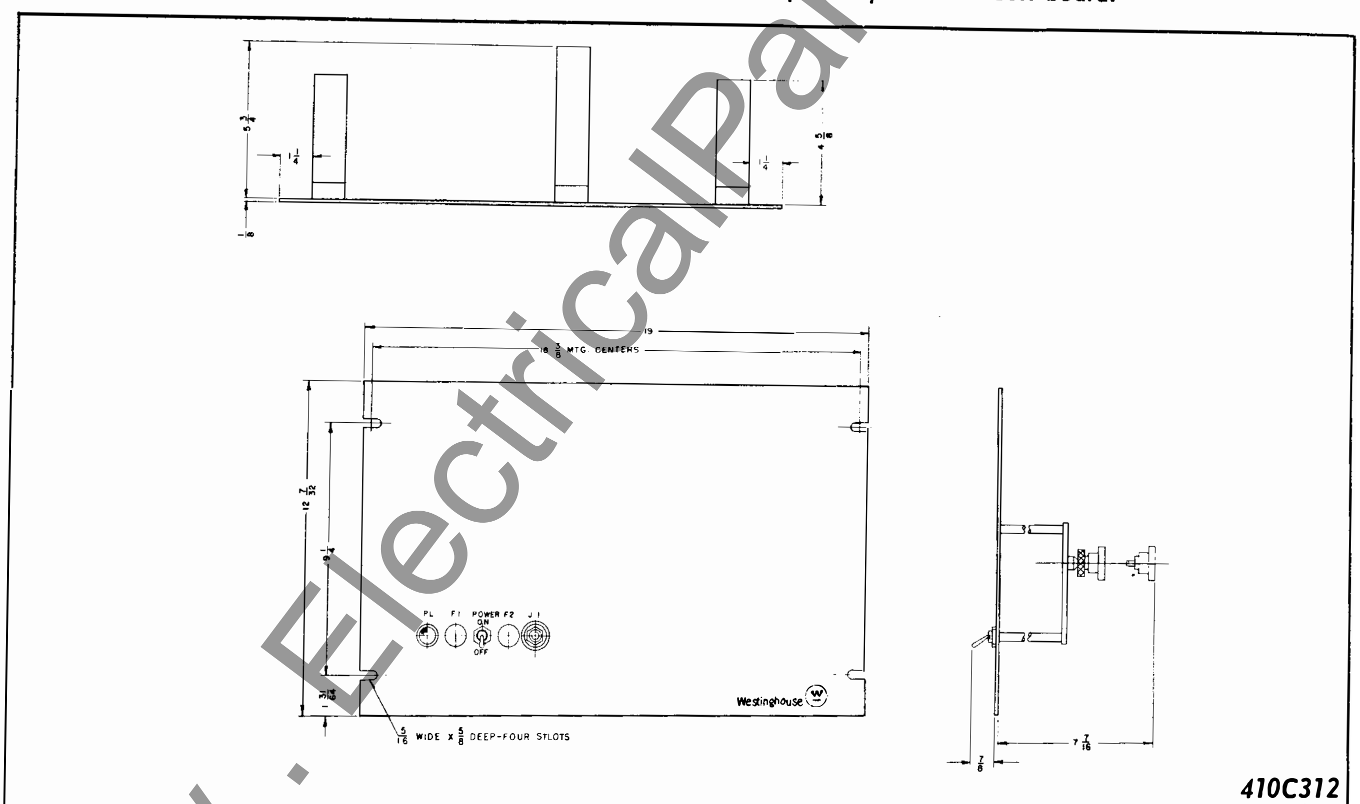

Fig. 5 Outline and drilling plan for the type TCF transmitter assembly.

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