INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE TCF POWER LINE CARRIER FREQUENCY SHIFT RECEIVER EQUIPMENT FOR DIAL PHASE-COMPARISON CARRIER RELAYING

CAUTION: It is recommended that the user of this equipment become thoroughly acquainted 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 TCF Receiver described is for use with the SKBU Dual Phase Comparison relay. The TCF frequency-shift receiver equipment as adapted for dual phase comparison applications responds to carrier-frequency signals transmitted from the distant end of a power line and carried on the power line conductors. The space frequency is 100 hertz above the center frequency of the channel (which can be selected within the range of 30 kHz to 200 kHz), and it is transmitted continuously when no information is to be conveyed over the channel. Its reception indicates that the channel is operative. The Mark frequency is 100 hertz below the channel center frequency. Phase comparison information is conveyed over the channel during load current flow or fault conditions. The transmitter at each end of the channel is switched at a 60-Hz rate between space and mark so as to produce at the receiving end the desired operation of the SKBU relay.

CONSTRUCTION

The TCF receiver unit for dual phase-comparison applications is mounted on a standard 19-inch wide panel $10\frac{1}{2}$ inches high (6 rack units) with edge slots with edge slots for mounting on a standard relay rack. All components are mounted at the rear of the panel. An input attenuator and a jack for metering the discriminator output current are accessible from the front of the panel. Refer to Figure 3.

All of the circuitry that is suitable for mounting on printed circuit boards is contained in an enclosure that projects from the rear of the panel and is accessible by opening a hinged door on the front of the panel. Other components on the rear of the panel are located as shown in Figure 4. Reference to the internal schematic connections on Figure 1 will show the location of these components in the circuit. The dotted lines enclosing separate areas of Figure 1 indicate that the components thus enclosed are all on the same printed circuit board.

The enclosure that contains the printed circuit boards is divided into seven compartments. The partitions between compartments together with the outer walls of the enclosure provide complete shielding between adjacent boards and from external fields.

TCF receivers for transfer-trip relaying require a logic circuit board and may require a carrier level indicator circuit board, which are contained in the third-from-right and right-hand compartments respectively. These are also required for the TCF receiver for dual-phase comparison, but with a logic circuit adapted for this purpose. See Figure 13.

The printed circuit boards slide into position in slotted guides at the top and bottom of each compartment, and the board terminals engage a terminal block at the rear of the compartment. Each board and terminal block is keyed so that if a board is placed in the wrong compartment, it cannot be inserted into the terminal block. A handle of the front of each board is labeled to identify its function in the circuit.

A board extender (style # 644B315G01) is available for facilitating circuit voltage measurements or major adjustments. After withdrawing any one of the circuit boards, the extender is inserted in that compartment. The board then is inserted into the terminal block on the front of the extender. This restores all circuit connections, and all components and test points on the board are readily accessible.

A portion of the receiver operates from a regulated 20-volt dc supply, and the remainder from a regulated 45-volt dc supply. These voltages are taken from two zener diodes mounted on a common heat sink. Variation of the resistance value between the positive side of the unregulated dc supply and the 45-volt zener adapts the receiver for operation on 48, 125, or 250 volts dc.

External connections to the receiver are made through a 12-terminal receptacle, J3 on Figure 1. The r-f input connection to the receiver is made through a coaxial cable jack, J2.

OPERATION

Input Control

The signals to which the TCF receiver responds are received through a coaxial cable connected to jack J2 of Figure 1. Resistor R4 and 20-volt zener diodes CR1 and CR2 protect the receiver from abnormally high voltages received through the coaxial cable. Input attenuator R5 reduces the signal to a level suitable for best operation of the receiver. The attenuator is adjustable from the front of the panel and can be clamped at the desired setting. A scale on the panel is graduated in dB. While this scale is typical rather than individually calibrated, it is accurate within one or two dB and is useful in setting approximate levels. Settings should be made by observation of the dB scale of a suitable ac voltmeter when possible.

L-C Filter (Wide Band)

From the attenuator, the signal passes through an L-C input filter, FL-201. This filter has a relatively wide passband, and frequencies several hundred hertz above or below the center frequency (fc) of the channel are greatly attenuated. Figures 2 and 10 show a typical curve for the L-C filter, as well as a characteristic curve for the 20-kHz intermediate-frequency filter, FL-2, and for the discriminator output. The purpose of the relatively wide band of the L-C filter is to minimize the channel delay time.

Oscillator and Mixer

From the input filter, the signal enters the oscillator and mixer stage of the receiver. Crystal Y11, transistors Q12 and Q13, and their associated resistors and capacitors comprise a crystal-controlled oscillator that operates at a frequency 20 kHz above the channel frequency, fc. The output from this local oscillator if fed through transformer T11 to potentiometer R12, and the latter is adjusted to feed a suitable input to the base of mixer transistor Q11. The output of FL-201 is impressed on the emitter-collector circuit of Q11. As the result of mixing these two frequencies, the primary of transformer T12 will contain frequencies of 20 kHz, 2 fc + 20 kHz, fc, and fc + 20 kHz.

IF Amplifier

The output from the secondary of T12 is amplified by Q31, in the intermediate frequency amplifier stage, and is impressed on filter FL-2. This is a two-section filter, with both filters contained in a common case. Its passband is centered at 20 kHz; while its passband is much narrower than that of the input filter, it eliminates the frequencies present at its input that are substantially higher than 20 kHz.

Amplifier and Limiter

The output from the second section of the IF amplifier stage is fed to potentiometer R52 at the input of the amplifier and limiter stage. Sufficient input is taken from R52 so that with minimum input signal (15 mV) at J2 and with R5 set for zero attenuation, satisfactory amplitude limiting will be obtained at the output of the limiter stage.

Discriminator

The output of the limiter stage is fed to the discriminator. The discriminator is adjusted at the factory to have zero output (as measured by a milliammeter inserted in the circuit of jack J1) at fc-25 hertz approximately. The adjustment for zero output is made by capacitor C88 (bottom). C83 also is adjusted to obtain a maximum voltage reading across R84 when the current output is zero. Maximum current output, of opposite polarities, will be obtained when the frequency is 100 hertz above or below the zero output frequency. This separation of 200 hertz between the current peaks is affected by the value of C86 (the actual value of which may be changed slightly from its typical value in factory calibration if required). It should be observed that, although the higher signal frequency is fc + 100 hertz after leaving the mixer stage and as seen by the discriminator, the corresponding frequency is 20 kHz - 100 hertz. Similarly, the lower signal frequency is converted to 20 kHz + 100 hertz. After this, the discriminator is adjusted so that the mark and space outputs are of relatively equal length. This will be between 15 and 25 hertz from the center frequency towards the mark frequency.

The discriminator output is connected to the bases of transistors Q81 and Q82 in such manner that Q82 is made conductive when current flows out of terminal 4 (which occurs with mark output), and Q81 is made conductive when current flows into terminal 4. Consequently, terminal 15 is at a potential of approximately +20 volts at space frequency, and terminal 11 is at +20 volts at mark frequency.

Power Supply

The regulated 20-volt dc and 45-volt dc circuits of the receiver are supplied from zener diodes mounted on a common heat sink on the rear of the panel. Resistors (R2, R3) of suitable value are connected between the station battery supply and the 45-volt zener to adapt the receiver for use on 48, 125, or 250 volt dc battery circuits. Capacitors C1 and C2 bypass r.f. or transient voltages to ground.

Output Circuits

The output circuit consists of two printed circuit boards: the output board and the noise board.

The output board consists of two output transistors (Q102, Q104) and two driver (Q101, Q103) transistors for the space and mark outputs which are driven by the discriminator space output (Figure 13). The mark and space outputs are mutually exclusive except when there is a loss of channel (C.L.I.) or an output from the noise circuit, at which time both outputs appear.

The mark and space outputs appear together when transistors Q101 and Q103 are turned on with a current through resistors R106 and R111. The noise output current flows from Q187 collector through R116 and CR-105 into R106 and R111; the carrier level indicator output is loaded through R118 and fed through R117 into R106 and R111.

The inversion of the mark and space outputs is accomplished through the NOR function from Q101 to Q103, through R108, R109, R110, CR-102, and CR-103. Diodes CR-102 and CR-103 are provided to supply isolation from negative to the base of Q102.

The noise circuit detects a signal-to-noise ratio of the receiver signal when shifted at a 60-Hz rate. This is done by detecting the error in the discriminator output of the receiver. The noise output should appear at approximately a 3-dB signal-to-noise ratio measured in a 1000-Hz bandwidth in the transmission band.

With reference to Figure 13, when the discriminator of the TCF receiver is shifted between ± 100 Hz of center frequency, there is a 0.5-millisecond period when neither output of the discriminator appears. This generates a pulse from the negated OR, block A. The information from these pulses is then transformed through a pulse integrator into a voltage which will trigger a Schmitt trigger when it exceeds a predetermined value which indicates an intolerable noise condition.

With reference to Figure 1, the discriminator outputs are fed through R182 and R183 into transistor Q181. A lack of discriminator output will permit a flow of current into capacitor C181 through resistors R184, R185 and CR181. Diode CR181 will block the charge on capacitor C181 from flowing into transistor Q181; capacitor C181 may only discharge through R186 and R187. When the voltage across resistor R187 is enough to overcome the potential needed to turn transistor Q182 on, then transistor Q183 is turned off, and the voltage across R189 will drop proportionately to the ratio of R188 and R190 causing a drop in the voltage requirement to turn on transistor Q182. Transistor Q184 will be turned off as a result of transistor Q183 turning off, and transistor Q185 will be turned on as a result of transistor Q184 turning off. Transistors Q186 and Q187 will turn on together with Q185 giving a noise output. The Schmitt trigger is composed of transistors Q182 and Q183.

Carrier Level Indicator

The noise logic is satisfactory when the channel fails suddenly and completely. However, a measurement of signal strength is desired for providing a visual indication of the channel condition as well as providing an indication when the signal has weakened seriously but has not reached the point of complete failure.

The carrier level indicator is housed in the right-hand compartment of the enclosure that contains the circuit boards. Figure 1 shows the connections of the components of this circuit board and also the external connections of the board.

The r-f input to the carrier level indicator is taken from the collector of Q151, the first transistor in the amplifier and limiter stage. The input, which varies approximately as the signal at the receiver input, is amplified by Q151 and Q152. Diodes CR151 and CR152 together with capacitors C157 and C158 establish a dc voltage across C158 that controls the conductivity of Q153. The base current of Q153 together with the current through R164 may be measured (see Figure 5) by a milliammeter (supplied separately) located at a point convenient for observation. This current may also be metered at the receiver by means of jack J151 on the printed-circuit board. Thermistor R166 with its associated resistors, and sensistor R152 provide compensation to minimize the variation of the metered current with ambient temperature. When Q153 becomes conductive, it supplies base input to Q154 to turn it on and energizes an alarm relay AL (when supplied) or its equivalent resistance R118 (2.2K). When the signal at the input of the receiver drops sufficiently, the AL or low-signal indication will dropout. This signal level is determined by the setting of R156 in the emitter of Q151.

The input to the carrier level indicator is not greatly affected by frequency variations within the pass-band of the input filter and the I.F. filter, but mainly by the level of receiver input signal.

CHARACTERISTICS

Frequency Range: 30-200 kHz

Sensitivity (noise-free channel): 0.015 volt (55 dB below 1 watt for limiting)

Input Impedance: 5000 ohms minimum

Bandwidth (input filter): down $<$ 3 dB at 800 hertz
down $>$ 30 dB at 5000 hertz

Discriminator: Set for zero output at channel center frequency and for maximum outputs at 100 hertz above and below center frequency.

Outputs: 1 - Mark All outputs are 20 volts dc,
2 - Space 10 ma. maximum current,
3 - Noise for solid-state relaying.

Operating Time: About 4 ms channel (transmitter and receiver)

Frequency Spacing: For two-way channel -- 4000 hertz minimum between transmitter and adjacent receiver frequencies.

Ambient Temperature Range: -20°C to +60°C temperature around chassis.

Battery Voltage Variations:

Rated Voltage	Allowable Variation
48 V DC	42-56 V DC
125 V DC	105-140 V DC
250 V DC	210-280 V DC

Battery Drain: 0.20 A at 48 V DC
0.27 A at 125 or 250 V DC

Dimensions: Panel Height -- $10\frac{1}{2}$" or 6 r.u.
Panel Width -- 19"

Weight: 13 lbs.

INSTALLATION

The TCF receiver 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°.

ADJUSTMENTS

All factory adjustments of the TCF receiver have been carefully made and should not be altered unless there is evidence of damage or malfunctioning. Such adjustments are: frequency and output level of the oscillator and mixer; input to the amplifier and limiter; frequency spacing and magnitude of discriminator output peaks.

After the receiver has been installed, the input attenuator R5 must be set for the desired operating margin. The receiver should not be set with a greater margin of sensitivity than is needed to assure correct operation with the maximum expected variation in attenuation of the transmitter signal. In the absence of data on this, the receiver may be set to operate on a signal that is 15-dB below the expected maximum signal. After installation of the receiver and the corresponding transmitter, and with a normal signal being received, input attenuator R5 should be adjusted to the position at which the alarm relay drops out. R5 then should be readjusted to increase the signal voltage supplied to the receiver by 15 dB. The scale markings for R5 permit an approximate setting to be made, but it is preferable to make this setting by means of the dB scales of an ac VTVM connected from ground to the sliding contact of R5.

In case factory adjustments have been accidentally disturbed or components have been replaced, it may be necessary to readjust the oscillator and mixer, the limiter, or the discriminator, and procedures for these adjustments are described in the following paragraphs.

Potentiometer R12 in the oscillator and mixer should be set for 0.3 volt, measured with an ac VTVM connected between TP-11 and terminal 18 on the circuit board (ground terminal of voltmeter). A frequency counter can be connected to the same points for a check on the frequency, which should be 20 kHz above the channel frequency. The frequency is fixed by the crystal used, except that it may be changed a few hertz by the value of capacitor C12. Reducing C12 increases the frequency, but the capacitance should never be less than a value that insures reliable starting of oscillation. The frequency at room temperature is usually several cycles above the crystal nominal frequency as this reduces the frequency deviation at the temperature extremes.

The adjustment of the amplifier and limiter is made by potentiometer R52. An oscilloscope should be connected from the base of transistor Q54 to terminal 18 of the limiter. With 7 mV of signal frequency on the receiver input (R5 at zero), R52 should be adjusted to the point where the peaks of the oscilloscope trace begin to flatten. This should appear on the upper and lower peaks at approximately the same setting.

Adjustment of the discriminator is made by capacitors C83 and C88. Apply to the receiver input a 15-mV signal taken from an oscillator set at the center frequency of the channel. (R5 at zero). Connect a 1.5 - 0 - 1.5 milliammeter in the circuit at J1 and a VTVM across R84. Adjust C88 for zero current in the milliammeter and C83 for maximum voltage across R84, rechecking the adjustments alternately until no further change is observed. Remote the VTVM from across R84 and observe the milliammeter reading as the oscillator frequency is varied. Positive and negative peaks should occur at 100 hertz above and below center frequency of the discrimator.

Additional Adjustments

The carrier level indicator should be adjusted to operate at a 5-mV input signal with a mark or space frequency. With the input attenuator R5 set at 0, a 5-mV input signal present and the noise detector board disconnnected (pulled out) adjust potentiometer R156 from its extreme counterclockwise position until both the mark and space outputs (20 V dc) appear together on terminals 8 and 9 on J3 or terminals 19 and 1 on the output board. This is an indication that the carrier level indicator (or the noise detector board, if connected) has operated.

The discriminator bias is adjusted by capacitor C88. This capacitor should be set so that the receiver mark and space outputs for a 60-Hz keyed signal from the transmitter will appear to have equal lengths at the receiver. This may be checked by means of an oscilloscope with a calibrated triggered sweep. The zero crossing of the discriminator will appear at approximately 15 to 25 Hz below the receiver center frequency (or 15 to 25 Hz above center of the 20 kHz IF frequency).

The noise detector board is adjusted by means of R184. With a suitable input signal (above 15 mV keyed at a 60-Hz rate) and R184 to its extreme clockwise position, jumper TP-181 and TP-182; the noise output at terminal J3-6 (or terminal 7 of noise detector board) should rise to 20 volts dc now remove the jumper. Turn R184 counter clockwise until the 20-volt output at terminal J3-6 disappears, then turn R184 one more turn counterclockwise to assure dropout. The noise detector board will now pick up for a keying rate of approximately 130 Hz and drop out for a keying rate of approximately 70 Hz.

MAINTENANCE

Periodic checks of the received carrier signal and the receiver sensitivity will detect gradual deterioration and permit its correction before failure can result. An overall check can be made with the attenuation control R5. A change in operating margin from the original setting can be detected by observing the change in the dial setting required to drop out the alarm relay. If there is a substantial reduction in margin, the signal voltage at the receiver input should be checked to see whether the reduction is due to loss of signal or loss of receiver sensitivity.

All adjustable components on the printed circuit boards are accessible when the door on the front of the panel is opened. (An offset screwdriver would be required for adjusting R12). However, as described under "CONSTRUCTION", any board may be made entirely accessible while permitting electrical operation by using board extender style #644B315G01. This permits attaching instrument leads to the various test points or terminals when making voltage, oscilloscope, or frequency checks.

It is advisable to record voltage values 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. Some r-f readings may vary as much as ±20%.

TABLE I

RECEIVER DC MEASUREMENTS

NOTE: All voltage readings taken with ground of dc VTVM on terminal 9 (neg.) of any circuit board. Receiver adjusted for 15-dB operating margin with input signal down 50 dB from 1 watt. Unless otherwise indicated, voltage will not vary appreciably whether signal is high, low or fc frequency.

Collector of Transistor	Volts (+)
Q11	< 13
Q12	15 (mark or space)
Q13	15
Q31	2.5
Q32	2.5
Q51	11.5
Q52	12
Q53	15.5
Q54	2.5
Q81	20 (No signal or fc - 100 Hz)
Q81	< 0.5 (fc + 100 Hz)
Q82 and Q101	20 (No signal or Hz + 100 Hz)
Q82 and Q101	< 0.5 (fc - 100 Hz)
Q103	20 (No signal or space)
Q103	< 0.5 (No signal or mark)

TABLE II

RECEIVER RF MEASUREMENTS

Collector of Transistor	Volts (fc + 100 Hz)
Q32	0.25
Q51	0.3
Q52	0.4
Q53	2.1
Q54	4.8

Filter Response Measurements

The L-C input filter (FL-201) and the IF filter (FL-2) are in sealed containers, and repairs can be made only by the factory. The stability of the original response characteristics is such that in normal usuage, no appreciable change in response will occur. However, the test circuits of Figure 9 can be used in case there is reason to suspect that either of the filters has been damaged.

Figure 2 shows the -3 dB and -35 dB checkpoints for the IF filters, and the -3 dB checkpoints for the input filter. The response curve of the IF filter shows the combined effect of the two sections, and was obtained by adding the attenuation of each section for identical frequencies. The scale of Figure 2 was chosen to show the IF filter response, which permitted only a portion of the input filter curve to be shown. The checkpoints for the pass-band of each section of the IF filter are "down 3 dB maximum at 19.75 and 20.25 kHz, "and" for the stop band are "down 18 dB minimum at 19.00 and 21.00 kHz for each section. The signal generator voltage (Figure 9) must be held constant throughout the entire check. A value of 7.8 volts is suitable. The reading of the VM2 at the frequency of minimum attenuation should not be more than 22 dB below the reading of VM1. It should be noted that a limit measured in this manner is for convenience only and does not indicate actual insertion loss of the filter. The insertion loss would be approximately 16 dB less than the measured difference because of the input resistor and the difference in input and output impedances of the filter.

In testing the L-C filter, a value of approximately 2.45 V is suitable for the constant voltage at which to hold VM1 throughout the check. The reading of VM2 at the frequency of minimum attenuation will vary somewhat with the channel frequency, but should not be more than 18 dB below the reading of VM1. (The filter insertion loss is approximately 6 dB less than the difference in readings).

Conversion of Receiver for Changed Channel Frequency

The parts for converting a TCF receiver for operating on a different channel frequency consists of a new L-C input filter (FL201) and a new local oscillator crystal (Y11). In addition, a different feedback capacitor (C12) may be needed, depending on the need for trimming up the local oscillator frequency, as explained under ADJUSTMENTS. This conversion can be made in the field by customers who are equipped for doing this type of work.

Recommended Test Equipment

1. Minimum Test Equipment for Installation

   a. AC Vacuum Tube Voltmeter (VTVM). Voltage range 0.003 to 30 volts, frequency range 60 hertz to 230 kHz, input impedance 7.5 megohms.

   b. DC Vacuum Tube Voltmeter (VTVM).
      Voltage Range: 1.5 to 300 volts.
      Input Impedance: 7.5 megohms.

   c. Milliammeter: 0.3 ma. range (for Carrier Level Indicator).

2. Desirable Test Equipment for Apparatus Maintenance

   a. All items listed in 1.

   b. Signal Generator
      Output Voltage: up to 8 volts
      Frequency Range: 20 kHz to 230 kHz.

   c. Oscilloscope

   d. Frequency Counter

   e. Ohmmeter, Voltmeter

   f. Capacitor Checker

   g. Milliammeter, 0-1.5 or preferable 1.5-0-1.5 range, for checking discriminator.

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 and Westinghouse Designation on the Electrical Parts List.

ELECTRICAL PARTS LIST

CIRCUIT SYMBOL	DESCRIPTION	WESTINGHOUSE DESIGNATION
	Capacitors	
C1	Oil-filled; 0.5 mfd; 1500 V DC	1877962
C2	Oil-filled; 0.5 mfd; 1500 V DC	1877962
C11	Metallized paper; 0.25 mfd; 200 V DC	187A624H02
C12-C16	Mica, capacity as required; 500 V DC	
C13	Metallized paper; 0.25 mfd; 200 V DC	187A624H02
C14	Metallized paper; 1.0 mfd; 200 V DC	187A624H04
C15	Metallized paper; 1.0 mfd; 200 V DC	187A624H04
C31	Metallized paper; 0.25 mfd; 200 V DC	187A624H02
C32	Metallized paper; 0.25 mfd; 200 V DC	187A624H02
C33	Metallized paper; 0.25 mfd; 200 V DC	187A624H02
C34	Metallized paper; 1.0 mfd; 200 V DC	187A624H04
C35	Metallized paper; 0.25 mfd; 200 V DC	187A624H02
C51	Metallized paper; 0.25 mfd; 200 V DC	187A624H02
C52	Metallized paper; 0.25 mfd; 200 V DC	187A624H02
C53	Metallized paper; 0.1 mfd; 200 V DC	187A624H01
C54	Dur-Mica, 1300 pf; 500 V DC	187A584H15
C55	Metallized paper; 0.1 mfd; 200 V DC	187A624H01
C56	Metallized paper; 0.25 mfd; 200 V DC	187A624H02
C57	Metallized paper; 0.1 mfd, 200 V DC	187A624H01
C58	Metallized paper; 0.25 mfd; 200 V DC	187A624H02
C59	Metallized paper; 0.25 mfd; 200 V DC	187A624H02
C60	Metallized paper; 1.0 mfd; 200 V DC	187A624H04
C81	Mylar; 0.22 mfd; 50 V DC	762A703H01
C82	Mylar; 0.22 mfd; 50 V DC	762A703H01
C83	Variable; 4.5 - 100 pf.	762A736H02
C84	Polystyrene, 9100 pf.; 200 V DC	187A624H16
C85	Temp. compensating; 150 V DC; pf as required	
C86	100 pf.; zero temp. coef.	187A684H08
C87	Temp. compensating; 150 V DC; pf. as required	
C88	Variable; 4.5 - 100 pf.	762A736H02
C89	Polystyrene; 9100 pf.; 200 V DC	187A624H16
C90	Mylar; 0.22 mfd; 50 V DC	762A703H01
C91	Mylar; 0.22 mfd; 50 V DC	762A703H01
C151	Metallized paper; 0.25 mfd; 200 V DC	187A624H02
C152	Metallized paper; 0.25 mfd; 200 V DC	187A624H02
C153	Metallized paper; 1.0 mfd; 200 V DC	187A624H04
C154	Metallized paper; 0.25 mfd; 200 V DC	187A624H02
C155	Metallized paper; 0.25 mfd; 200 V DC	187A624H02
C156	Metallized paper; 0.25 mfd; 200 V DC	187A624H02
C157	Metallized paper; 0.25 mfd; 200 V DC	187A624H02
C158	Metallized paper; 0.25 mfd; 200 V DC	187A624H02
C181, C182	Metallized paper; 1.0 mfd; 200 V DC	187A624H04

ELECTRICAL PARTS LIST

CIRCUIT SYMBOL	DESCRIPTION	WESTINGHOUSE DESIGNATION
	Diodes	
CR51	1N457A; 60 V.; 200 MA	184A855H07
CR52	1N457A; 60 V.; 200 MA	184A855H07
CR53	1N457A; 60 V.; 200 MA	184A855H07
CR81	1N91; 100 V.; 150 MA	182A881H04
CR82	1N91; 100 V.; 150 MA	182A881H04
CR85	1N628; 125 V.; 20 MA	184A844H12
CR86	1N628; 125 V.; 30 MA	184A855H12
CR101 to CR104 CR181 to CR183	1N645 A; 225 V; 400 MA	837A692H03
CR151 to CR155	1N457A; 60 V; 200 MA	184A885H07
	Diodes - Zener	
CR1	1N3027A; 20 V.; ±10%; 1 W.	188A307H10
CR2	1N3027A; 20 V.; ±10%; 1 W.	188A307H10
CR106, CR107, CR185	1N3688A; 24 V.; ±10%, 750 MW	862A288H01
VR1	1N2828B; 45 V.; ±5%; 50 W.	184A854H06
VR2, VR3	1N2984B; 20 V.; ±5%; 10 W.	762A631H01
	Potentiometers	
R5	10K; 2 W.	185A086H10
R7	250K; 2 W.	185A086H11
R12	1K; ¼ W.	629A430H02
R52	1K; ¼ W.	629A645H04
R184	20K; 0.75 W.	629A645H08
	Resistors	
R1	400 ohms; ±5%; 25 W.	1202587
R2	26.5 ohms; ±5%; 40 W. (for 48 V. supply)	04D1299H44
R2	150 ohms; ±5%; 40 W. (for 125 V. supply)	1202499
R2	300 ohms; ±5%; 50 W. (for 250 V. supply)	763A963H01
R3	150 ohms; ±5%; 40 W. (for 125 V. supply)	1202499
R3	500 ohms; ±5%; 100 W. (for 250 V. supply)	629A843H03
R4	100 ohms; ±5%; 1 W. Composition	187A643H03
R6	10K; ±5%; ½W. Composition	184A763H51
R7	400 ohms; ±5%; 25 W.	1202587
R11	10K; ±5%; ½W. Composition	184A763H51
R13	5.6K; ±5%; ½W. Composition	184A763H45
R14	3.3K; ±5%; ½W. Composition	184A763H39
R15	330 ohms; ±5%; ½W. Composition	184A763H15
R16	10K; ±5%; ½W. Composition	184A763H51
R17	33K; ±5%; ½W. Composition	184A763H63

ELECTRICAL PARTS LIST

CIRCUIT SYMBOL	DESCRIPTION	WESTINGHOUSE DESIGNATION
	Resistors (Cont'd)	
R18	3.3K; +5%; ½W. Composition	184A763H39
R19	3.3K; +5%; ½W. Composition	184A763H39
R20	10K; +5%; ½W. Composition	184A763H51
R21	33K; +5%; ½W. Composition	184A763H63
R22	330 ohms; +5%; ½W. Composition	184A763H15
R23	10K; +5%; ½W. Composition	184A763H51
R31	3.3K; +5%; ½W. Composition	184A763H39
R32	22K; +5%; ½W. Composition	184A763H59
R33	680 ohms; +5%; ½W. Composition	184A763H23
R34	68 ohms; +5%; ½W. Composition	187A290H21
R35	10K; +5%; ½W. Composition	184A763H51
R36	330 ohms, +5%; ½W. Composition	184A763H15
R37	3.3K; +5%; ½W. Composition	184A763H39
R38	1000 ohms; +5%; ½W. Composition	184A763H27
R39	22K; +5%; ½W. Composition	184A763H59
R40	680 ohms; +5%; ½W. Composition	184A763H23
R41	68 ohms; +5%; ½W. Composition	187A290H21
R42	10K; +5%; ½W. Composition	184A763H51
R51	4.7K; +5%; ½W. Composition	184A763H43
R53	27K; +5%; ½W. Composition	184A763H61
R54	2.2K; +5%; ½W. Composition	184A763H35
R55	27 ohms; +5%; ½W. Composition	187A290H11
R56	10K; +5%; ½W. Composition	184A763H51
R57	4.7K; +5%; ½W. Composition	184A763H43
R58	27K; +5%; ½W. Composition	184A763H61
R59	1.5K; +5%; W. Composition	184A763H31
R60	180 ohms; +5%; ½W. Composition	184A763H09
R61	4.7K; +5%; ½W. Composition	184A763H43
R62	1.5K; +5%; ½W. Composition	184A763H31
R63	3.3K; +5%; ½W. Composition	184A763H63
R64	2.7K; +5%; ½W. Composition	184A763H37
R65	680 ohms; +5%; ½W. Composition	184A763H23
R66	68 ohms; +5%; ½W. Composition	187A290H21
R67	4.7K; +5%; ½W. Composition	184A763H43
R68	2.7K; +5%; ½W. Composition	184A763H37
R69	18K; +5%; ½W. Composition	184A763H57
R70	220 ohms; +5%; ½W. Composition	184A763H11
R71	270 ohms; +5%; ½W. Composition	184A763H13
R72	330 ohms; +5%; ½W. Composition	184A763H15
R81	4.7K; +5%; ½W. Composition	184A763H43
R82	4.7K; +5%; ½W. Composition	184A763H43
R83	2.2K; +5%; ½W. Composition	184A763H35
R84	2.2K; +5%; ½W. Composition	184A763H35
R85	220 ohms; +5%; ½W. Composition	184A763H11
R86	12K; +5%; ½W. Composition	184A763H31
R101, R113, R104, R109	10K; +5%; ½W. Composition	187A763H51

ELECTRICAL PARTS LIST

CIRCUIT SYMBOL	DESCRIPTION	WESTINGHOUSE DESIGNATION
	Resistors (Cont'd.)	
R102, R105, R114	82K; ±2%; ½W. Metalfirm	629A531H78
R103, R112	6.8K; ±5%; ½W. Composition	184A763H47
R106, R111	5.6K; ±5%; ½W. Composition	184A763H45
R107, R115	150 ohms; ±2%; 2 W. Metalfilm	762A679H01
R108	47K; ±5%; ½W. Composition	184A763H67
R110	33K; ±5%; ½W. Composition	184A763H39
R116, R117	22K; ±5%; ½W. Composition	184A763H35
R151	2.7K; ±5%; ½W. Composition	184A763H37
R152	2.2K; Sensistor Type TM¼ (Tex. Inst. Co.)	187A685H01
R153	220 ohms; ±5%; ½W. Composition	184A763H11
R154	2.2K; ±5%; ½W. Composition	184A763H35
R155	15K; ±5%; ½W. Composition	184A763H55
R157	4.7K; ±5%; ½W. Composition	184A763H43
R158	4.7K; ±5%; ½W. Composition	184A763H43
R159	15K; ±5%; ½W. Composition	184A763H55
R160	560 ohms; ±5%; ½W. Composition	184A763H21
R161	1.2K; ±5%; ½W. Composition	184A763H29
R162	180 ohms; ±5%; ½W. Composition	184A763H09
R163	180 ohms; ±5%; ½W. Composition	184A763H09
R164	470 ohms; ±5%; ½W. Composition	184A763H19
R165	1000 ohms; ±5%; ½W. Composition	184A763H27
R166	3K Thermistor Type ID201 (GE Co.)	185A211H08
R167	18K; ±5%; ½W. Composition	184A763H57
R168	10K; ±5%; ½W. Composition	184A763H51
R181, R191, R194, R196, R199	10K; ±5%; ½W. Composition	184A763H51
R182, R183	47K; ±5%; ½W. Composition	184A763H67
R185	3.9K; ±5%; 1W. Composition	187A643H41
R186	82K; ±2%; ½W. Metalfilm	629A531H78
R187, R188 R193	15K; ±2%; ½W. Metalfilm	629A531H60
R189	330 ohms; ±5%; ½W. Composition	184A763H15
R190	13K; ±2%; ½W. Metalfilm	629A531H59
R192	22K; ±5%; ½W. Composition	184A763H59
R195, R198	6.8K; ±5%; ½W. Composition	184A763H47
R197	56K; ±5%; ½W. Composition	184A763H69
R200	150; ±2%; 3W. Metalfilm	762A679H01
	Transformers	
T11	Toroidal Type, 10000/400 ohms	1962797
T12	Toroidal Type, 25000/300 ohms	1962697
T81	Pot. Core Type	606B533G01
T82	Pot. Core Type	606B533G02

ELECTRICAL PARTS LIST

CIRCUIT SYMBOL	DESCRIPTION	WESTINGHOUSE DESIGNATION
	Transistors	
Q11	2N652A	184A638H16
Q12, Q13	2N1396	848A892H01
Q31, Q32	2N274	187A270H01
Q51, Q52, Q53, Q54, Q151, Q152 Q153	2N396	762A575H03
Q81, Q82, Q102, Q104, Q184, Q185, Q187	2N3645	849A441H01
Q101, Q103, Q186	2N3417	848A851H02
Q154, Q181 Q182, Q183	2N699	184A638H19
	Miscellaneous	
Y11	Oscillator Crystal (freq. 20 kHz above channel freq.)	762A800H01 + (reg. freq.)
FL-201	L-C Input Filter	(reg. freq.)
FL-2	IF Filter	762A613G01

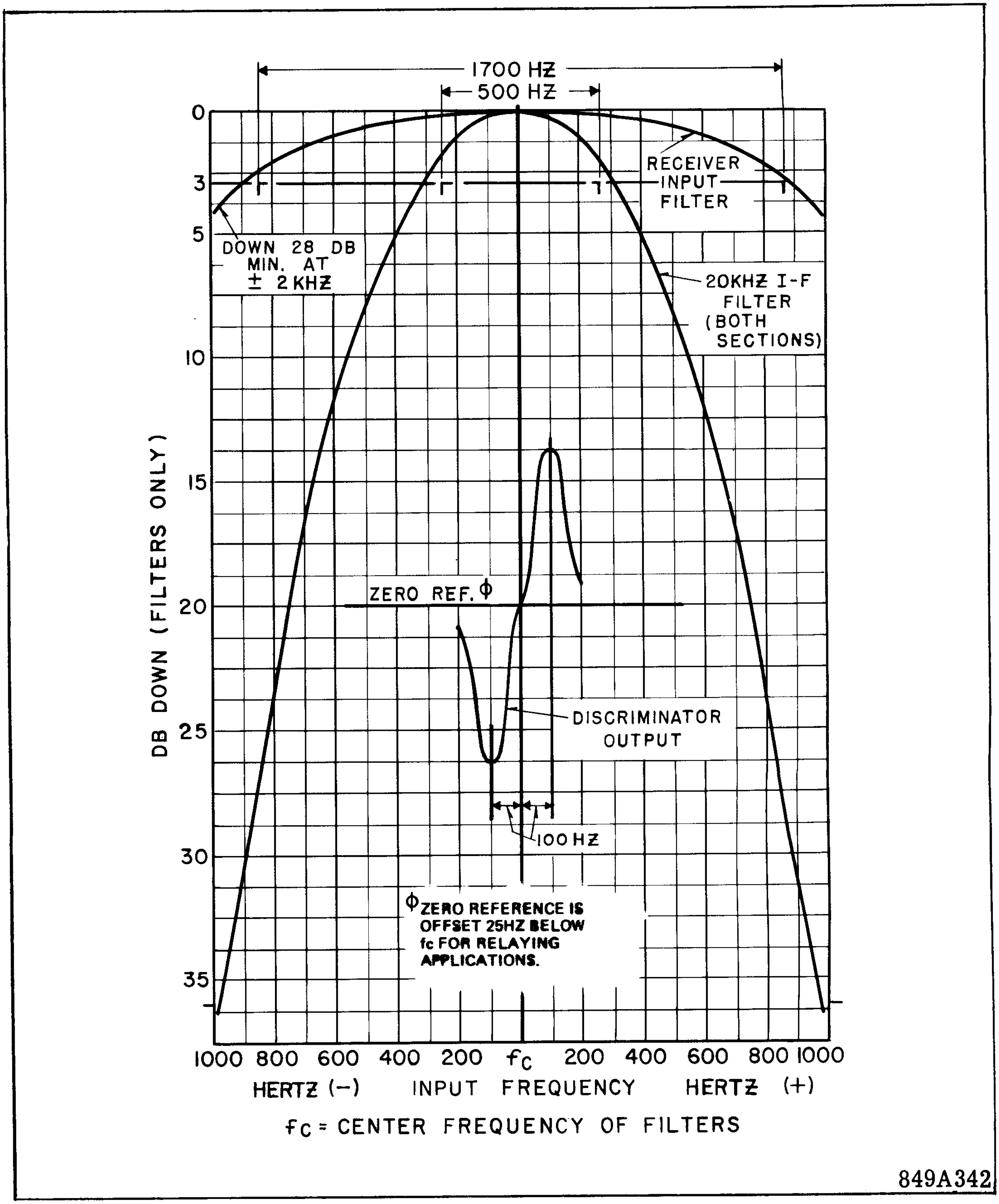

Fig. 2 Filter and Discriminator Characteristics of the Type TCF Receiver.

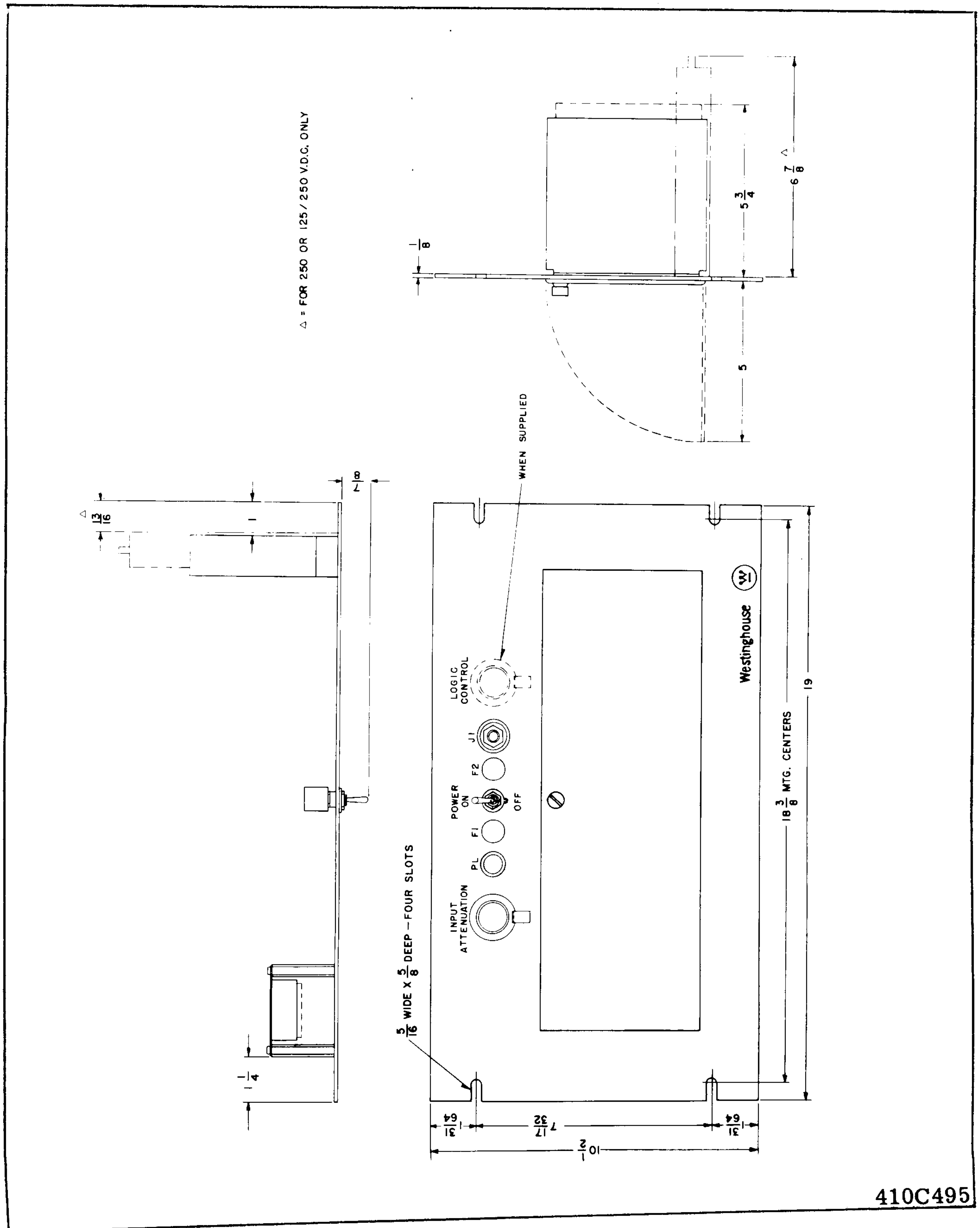

Fig. 3 Outline and Drilling Plan for the Type TCF Receiver Assembly.

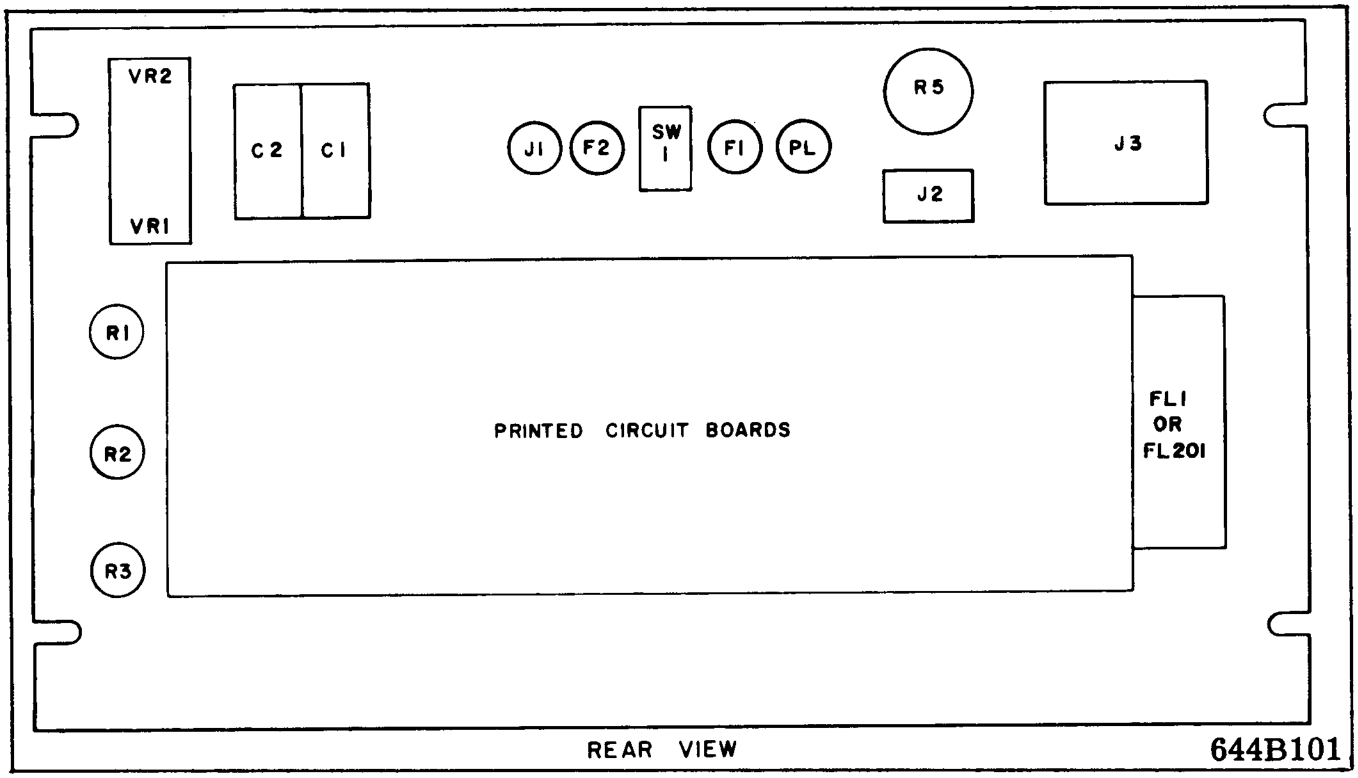

Fig. 4 Component Locations on the TCF Receiver Panel.

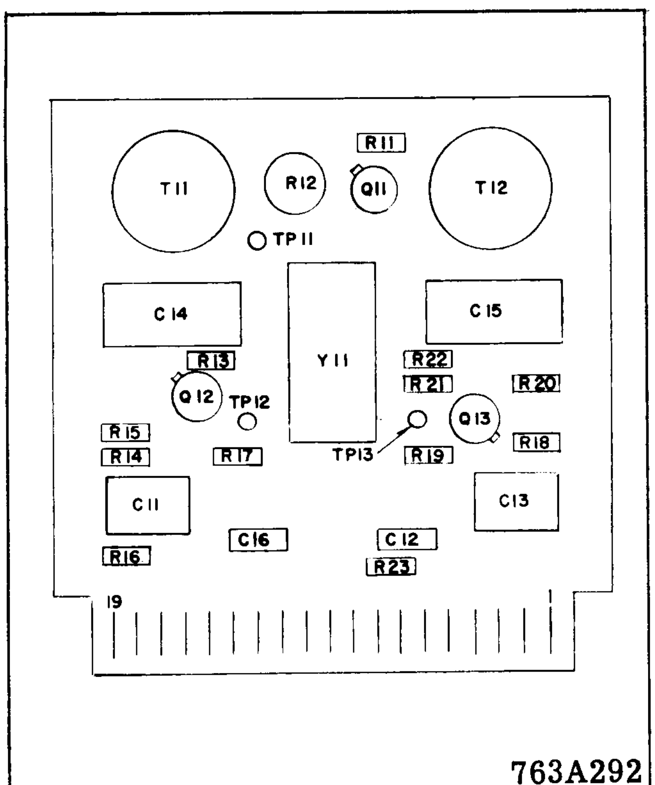

Fig. 5 Component Locations on the Oscillator and Mixer Printed Circuit Board.

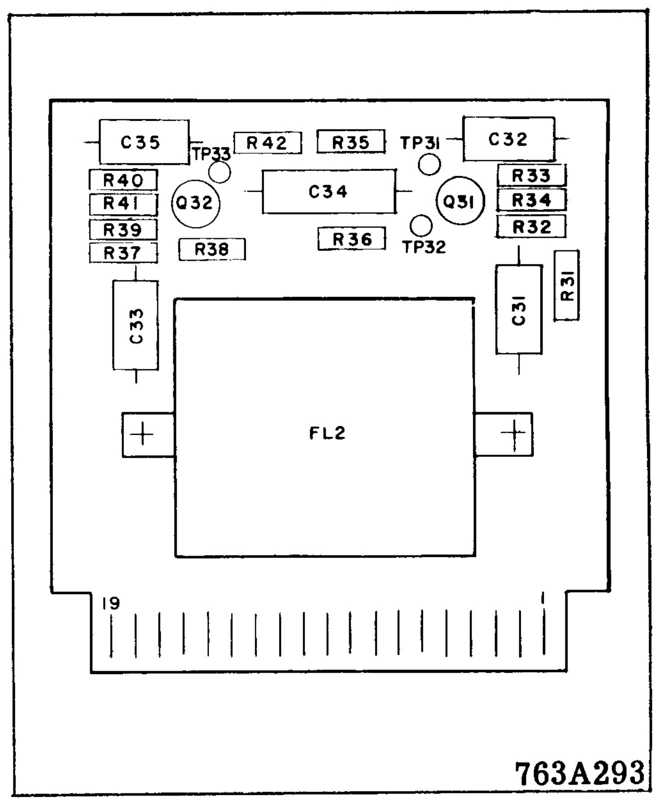

Fig. 6 Component Locations on the I. F. Amplifier Printed Circuit Board.

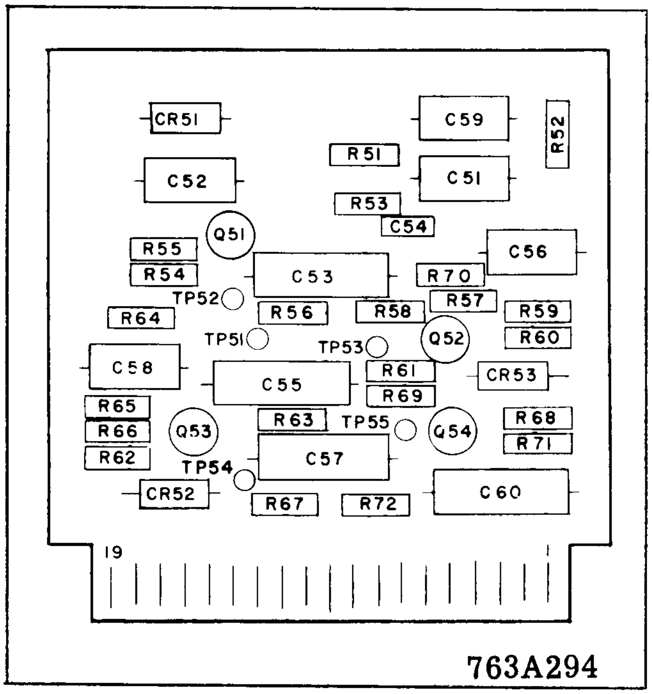

Fig. 7 Component Locations on the Amplifier and Limiter Printed Circuit Board.

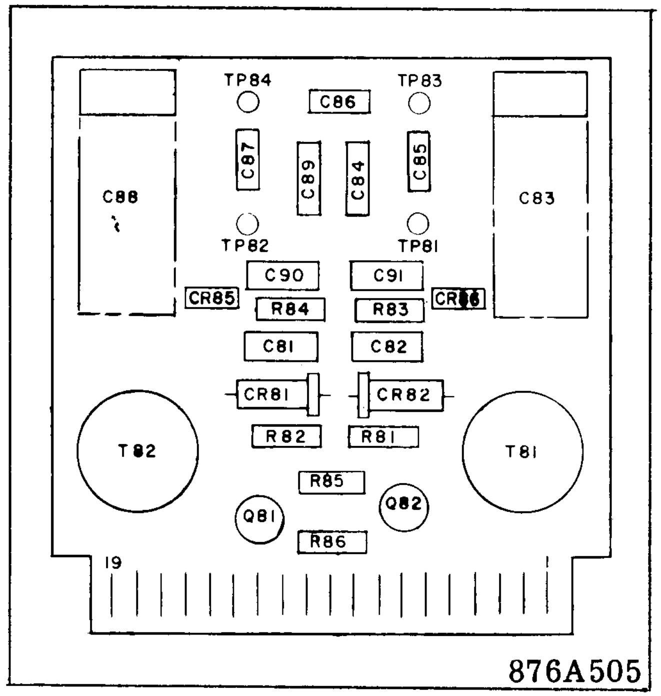

Fig. 8 Component Locations on the Discriminator Printed Circuit Board.

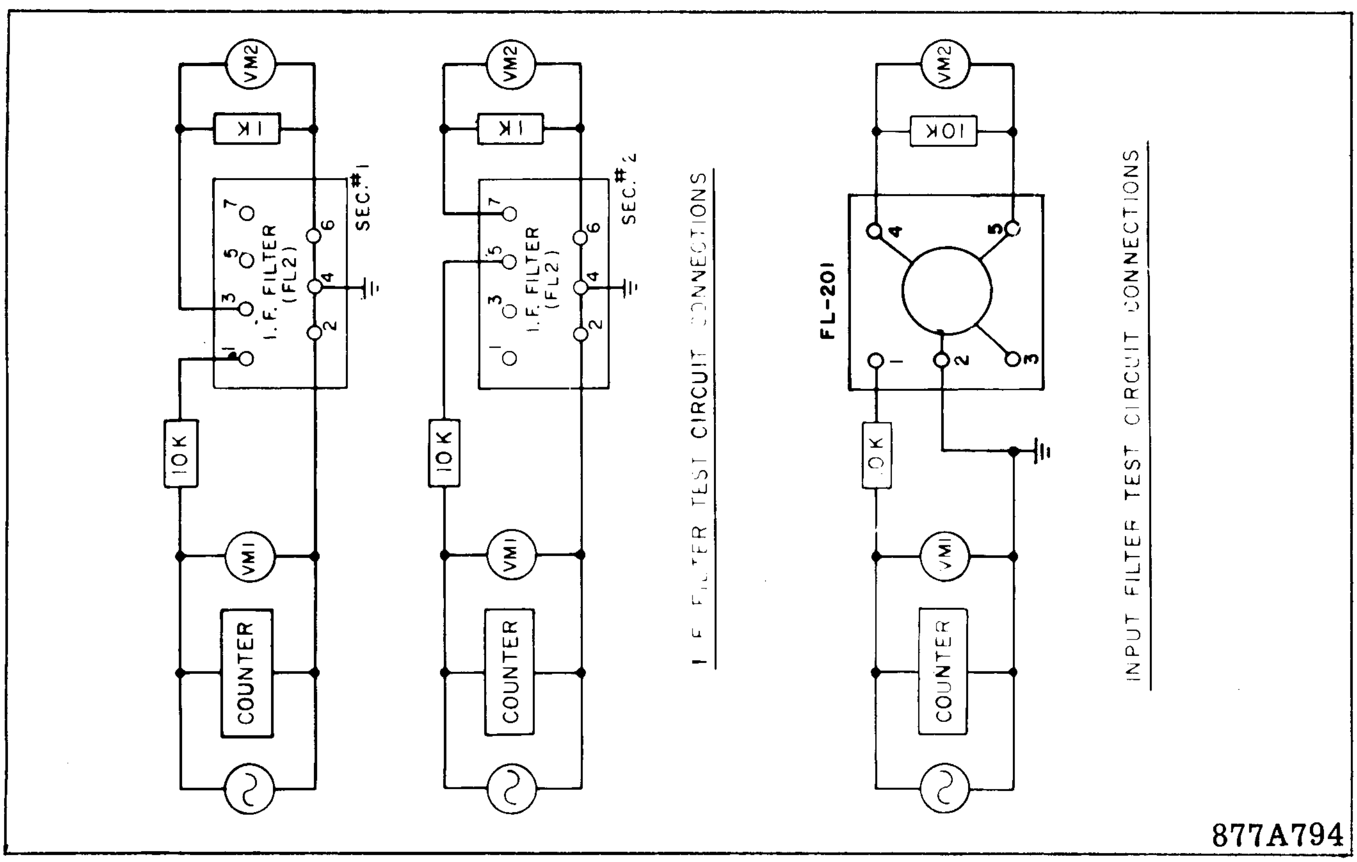

Fig. 9 Test Circuits for TCF Frequency Shift Receiver Filters.

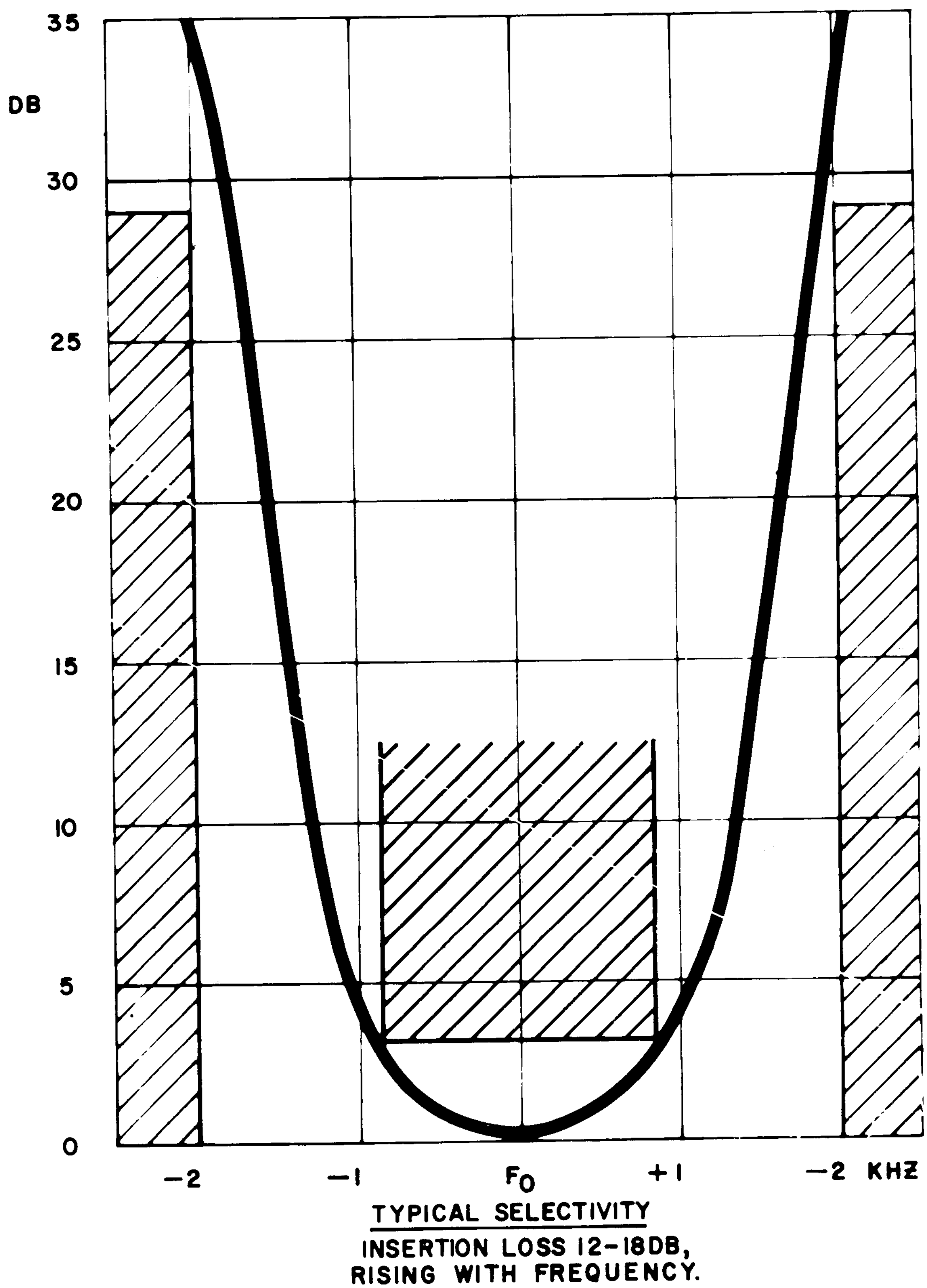

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Fig. 10 FL-201 Filter Response.

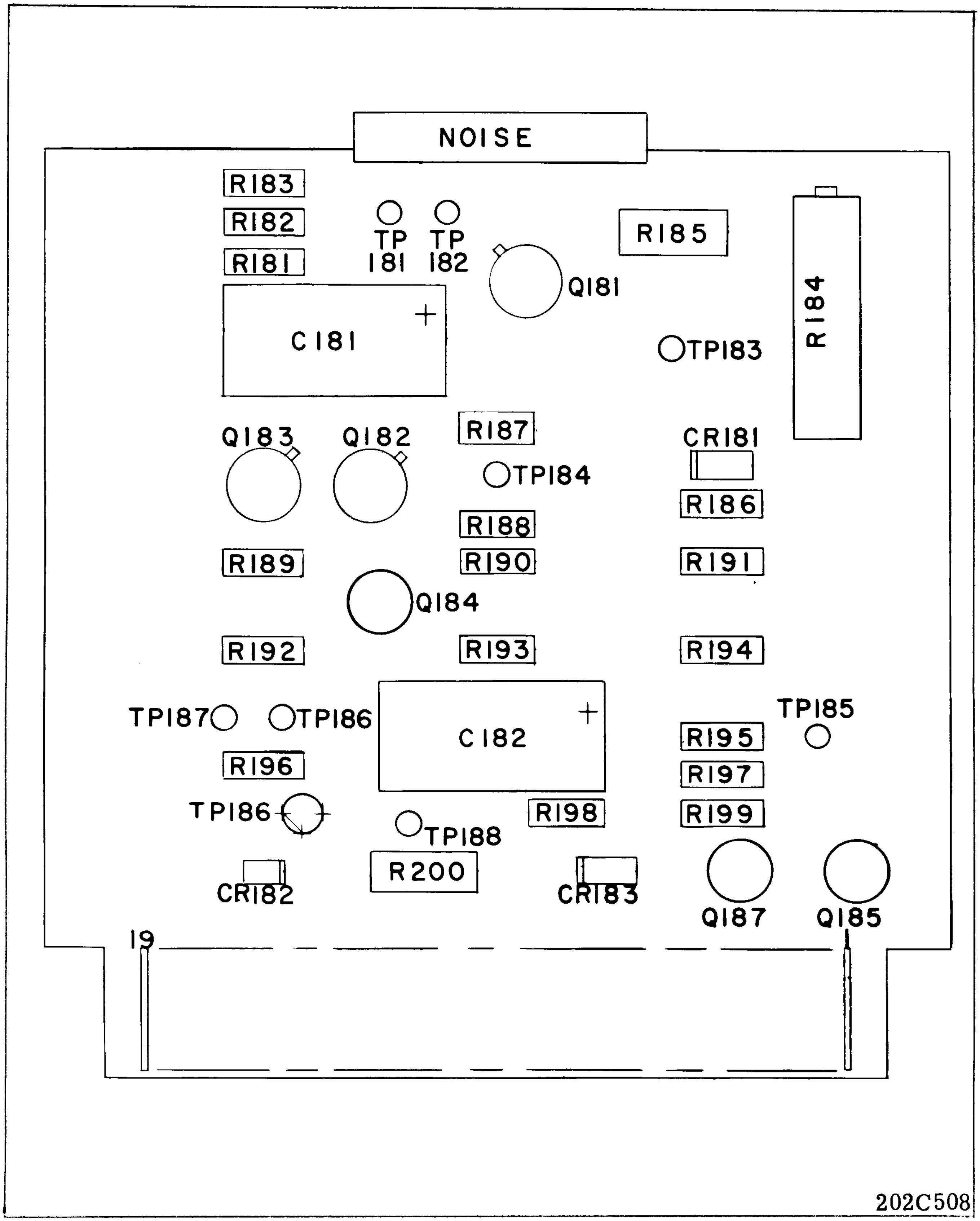

Fig. 11 Component Locations on the Noise Detector.

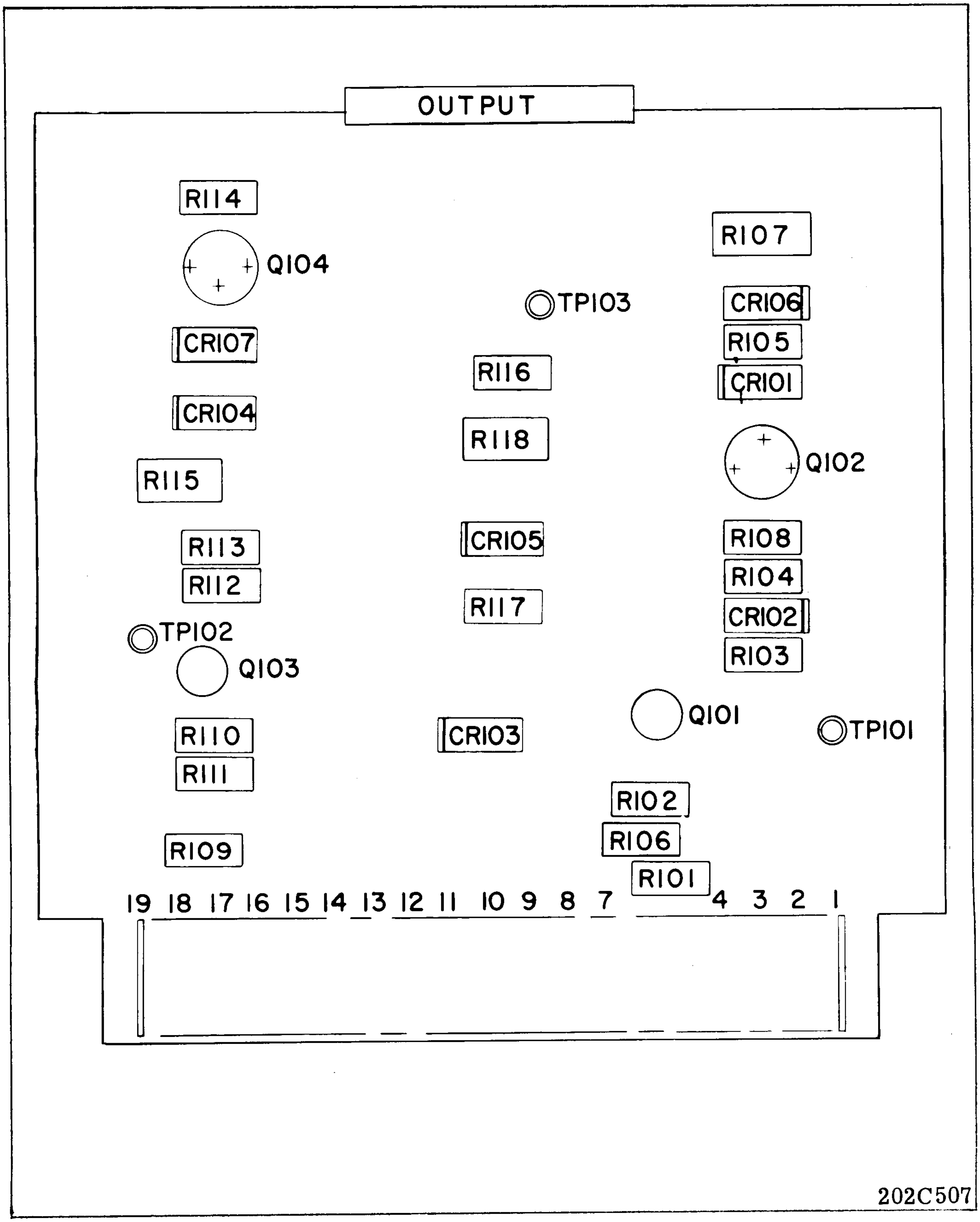

Fig. 12 Component Locations on Output Board for Phase Comparison.

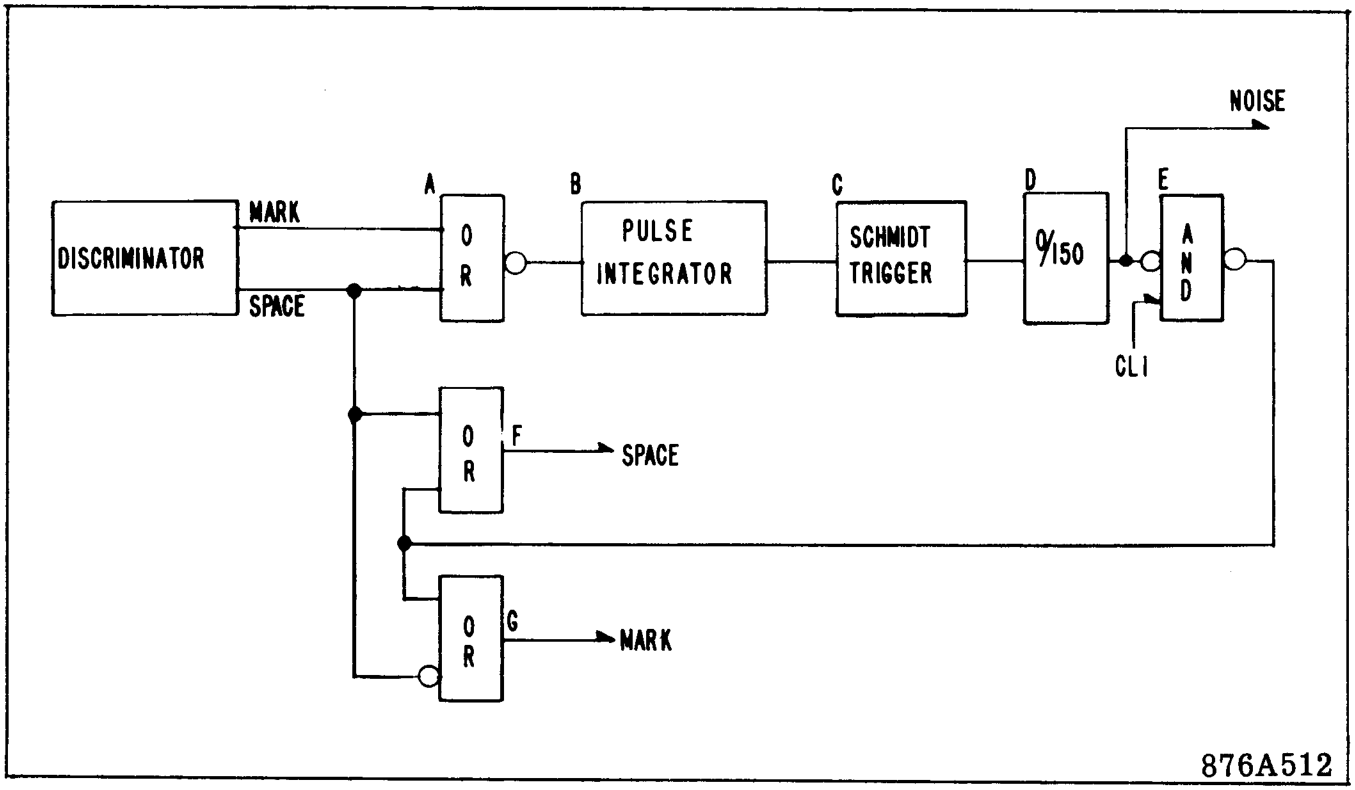

Fig. 13 Logic Diagram for Dual Phase Comparison TCF.

INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE TCF POWER LINE CARRIER FREQUENCY SHIFT RECEIVER EQUIPMENT FOR DUAL PHASE-COMPARISON CARRIER RELAYING

Caution: It is recommended that the user of this equipment become acquainted with the information in this instruction leaflet and in the system instruction leaflet before energizing the system.

Printed circuit modules should not be removed or inserted when the relay is energized. Failure to observe this precaution can result in an undesired tripping output and cause component damage.

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 tripping over.

APPLICATION

The TCF Receiver described is for use with the SKBU Dual Phase Comparison relay. The TCF frequency-shift receiver equipment as adapted for dual phase comparison applications responds to carrier-frequency signals transmitted from the distant end of a power line and carried on the power line conductors. The space frequency is 100 hertz above the center frequency of the channel (which can be selected within the range of 30 kHz to 300 kHz), and it is transmitted continuously when no information is to be conveyed over the channel. Its reception indicates that the channel is operative. The Mark frequency is 100 hertz below the channel center frequency. Phase comparison information is conveyed over the channel during load current flow or fault conditions. The transmitter at each end of the channel is switched at a 60-Hz rate between space and mark so as to produce at the receiving end the desired operation of the SKBU relay.

CONSTRUCTION

The TCF receiver unit for Dual-Phase-Comparison applications is mounted on a standard 19-inch wide panel 10½ inches high (6 rack units) with edge slots for mounting on a standard relay rack. All components are mounted at the rear of the panel. An input attenuator and a jack for metering the discriminator output current, are accessible from the front of the panel. See Fig. No. 14.

All of the circuitry that is suitable for mounting on printed circuit boards is contained in an enclosure that projects from the rear of the panel and is accessible by opening a hinged door on the front of the panel. Other components on the rear of the panel are located as shown on Fig. No. 6. Reference to the internal schematic connections on Fig. 1 will show the location of these components in the circuit. The dotted lines enclosing separate areas of Fig. 1 indicate that the components thus enclosed are all on the same printed circuit board.

The enclosure that contains the printed circuit board is divided into seven compartments. The partitions between compartments together with the outer walls of the enclosure provide complete shielding between adjacent boards and from external fields. Frequency shift receivers for dual phase-comparison relaying utilize all compartments if a carrier level indicator is provided. If this is omitted, the compartment on the extreme right, front view, is left vacant.

The printed circuit boards slide into position in slotted guides at the top and bottom of each compartment, and the board terminals engage a terminal block at the rear of the compartment. Each board and terminal block are keyed so that if a board is placed in the wrong compartment, it cannot be inserted into the terminal block. A handle on the front of each board is labeled to identify its function in the circuit.

A board extender (Style No. 644B315G01) is available for facilitating circuit voltage measurements or major adjustments. After withdrawing any one of the circuit boards, the extender is inserted in that compartment. The board then is inserted into the terminal block on the front of the extender. This

SUPERSEDES I.L. 41-945.55B, dated May 1972
*Denotes change from superseded issue.

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restores all circuit connections, and all components and test points on the board are readily accessible.

A portion of the receiver operates from a regulated 20 VDC supply, and the remainder from a regulated 45 V.D.C. supply. These voltages are taken from two Zener diodes mounted on a common heat sink. Variation of the resistance value between the positive side of the unregulated D.C. supply and the 45 volt Zener adapt the receiver for operation on 48, 125, or 250 V.D.C.

External connections to the receiver are made through a 12 terminal receptacle, J3 (see Fig. 1). The r-f input connection to the receiver is made through a coaxial cable jack, J2.

OPERATION

Input Control

The signals to which the TCF receiver responds are received through a coaxial cable connected to jack J2 of Fig. No. 1. Resistor R4 and 20-volt Zener diodes CR1 and CR2 protect the receiver from abnormally high voltages received through the coaxial cable. Input attenuator R5 reduces the signal to a level suitable for best operation of the receiver. The attenuator is adjustable from the front of the panel and can be clamped at the desired setting. A scale on the panel is graduated in db. While this scale is typical rather than individually calibrated, it is accurate within one or two db. and is useful in setting approximate levels. Settings should be made by observation of the db. scale of a suitable a-c voltmeter when possible.

L-C Filter (Wide Band)

From the attenuator, the signal passes through an L-C filter, FL201. This filter has a relatively wide pass band, and frequencies several kHz above or below the center frequency (fc) of the channel are greatly attenuated. Fig. 4 shows a typical curve for the L-C filter, as well as a characteristic curve for the immediate frequency filter, FL2 and for the discriminator output. This apparently wide bandwidth is necessary to achieve high speed relaying by minimizing channel delay.

Oscillator and Mixer

From the input filter, the signal enters the oscillator and mixer stage of the receiver. Crystal Y11, transistors Q12 and Q13, or IC201 (Fig. 16) and their associated resistors and capacitors, comprise a crystal-controlled oscillator that operates at a frequency 20 kHz above the channel frequency, fc. The output from this local oscillator is fed through transformer T11 to potentiometer R12, and the later is adjusted to feed a suitable input to the base of mixer transistor Q11. The output of FL1 is impressed on the emitter-collector circuit of Q11. As a result of mixing these two frequencies, the primary of transformer T12 will contain frequencies of 20kHz, 2fc + 20kHz, fc + 20kHz and fc.

If Amplifier

The output from the secondary of T12 is amplified by Q31, in the intermediate frequency amplifier stage, and is impressed on filter FL2. This is a two-section filter, with both filters contained in a common case. Its pass band is centered at 20kHz. Since its passband is narrower than that of the input filter, it eliminates the frequencies present at its input that are substantially higher than 20 kHz.

Amplifier and Limiter

The output from the second section of the IF amplifier stage is fed to potentiometer R52 at the input of the amplifier and limiter stage. Sufficient input is taken from R52 so that with minimum input signal (15 mv.) at J2 and with R5 set for zero attenuation, satisfactory amplitude limiting will be obtained at the output of the limiter stage.

Discriminator

The output of the limiter stage is fed to the discriminator. The discriminator is adjusted at the factory to have zero output (as measured by a milliammeter inserted in the circuit at jack J1) at fc hertz. The adjustment for zero output at fc hertz is made by capacitor C88. C83 also is adjusted to maximum voltage reading across R84 when the current output is zero. Maximum current output, of opposite polarities, will be obtained when the frequency is 100 hertz above or below the zero output frequency. This separation of 200 hertz between the current peaks is affected by the value of C86, (the actual value of which may be changed slightly from its typical value in factory calibration if required.)

It should be observed that although the space frequency is fc + 100 hertz, after leaving the mixer stage and as seen by the discriminator the space frequency is 20 kHz-100 hertz. Similarly, the mark frequency is 20 kHz + 100 hertz. The intermediate frequency at which the discriminator has zero output then is 20 kHz. The discriminator is adjusted so that the mark and space outputs are of equal lengths for equal periods of mark and space signal frequencies.

The discriminator output is connected to the bases of transistors Q81 and Q82 in such manner that Q82 is made conductive when current flows out of terminal 4 (which occurs with mark output) and Q81 is made conductive when current flows into terminal 4. Consequently, terminal 15 is at a potential of approximately + 20 volts at space frequency and terminal 11 is at + 20 volts at mark frequency.

Output Circuits

The output circuit consists of two printed circuit boards: the output board and the noise board.

The output board consists of two output transistors (Q102, Q104) and two driver (Q101, Q103) transistors for the space and mark outputs which are driven by * the discriminator space output (Figure 3). The mark and space outputs are mutually exclusive except when there is a loss of channel (C.L.I.) or an output from the noise circuit, at which time both outputs appear.

The mark and space outputs appear together when transistors Q101 and Q103 are turned on with a current through resistors R106 and R111. The noise output current flows from Q187 collector through R116 and D105 into R106 and R111; the carrier level indicator output is loaded through R118 and fed through R117 into R106 and R111.

The inversion of the mark and space outputs is accomplished through the NOR function from Q101 to Q103, through R108, R109, R110, D-102 and D103. Diodes D102 and D103 are provided to supply isolation from negative to the base of Q102.

The noise circuit detects an unsatisfactory noise condition of the receiver signal when shifted at a 60-Hz rate. This is done by detecting the error in discriminator output of the receiver. The noise output should appear at approximately a 3-db signal-to-noise ratio measured in a 1000-Hz bandwidth in the transmission band.

With reference to Figure 3, when the discriminator * of the TCF receiver shifted between + 100 Hz of center frequency, there is a 0.5 millisecond period when neither output of the discriminator appears. This generates a pulse from the negated OR, block A. The information from these pulses is then trans-- formed through a pulse integrator into a voltage which will trigger a Schmitt trigger when it exceeds a predetermined value which indicates an intolerable noise condition.

With reference to Figure 1, the discriminator outputs are fed through R182 and R183 into transistor Q181. A lack of discriminator output will permit a flow of current into capacitor C181 through resistors R184, R185 and CR181. Diode CR181 will block the charge on capacitor C181 from flowing into transistor Q181; capacitor C181 may only discharge through R186 and R187. When the voltage across resistor R187 is enough to overcome the potential needed to turn transistor Q182 on, then transistor Q183 is turned off, and the voltage across R189 will drop proportionately to the ratio of R188 and R190 causing a drop in the voltage requirement to turn on transistor Q182. Transistor Q184 will be turned off as a result of transistor Q183 turning off, and transistor Q185 will be turned on as a result of transistor Q184 turning off. Transistors Q186 and Q187 will turn on together with Q185 giving a noise output. The Schmitt trigger is composed of transistors Q182 and Q183.

Carrier Level Indicator

The noise logic takes care of the situation when the channel fails suddenly and completely. However, a measurement of signal strength is desired for providing an indication when the signal has weakened seriously but has not reached the point of complete failure.

The carrier level indicator is housed in the right-hand compartment of the enclosure that contains the circuit boards. Figure 1 shows the connections of this circuit board and also the external connections of the board.

The r-f input to the carrier level indicator is taken from the collector of Q151, the first transistor in the amplifier and limiter stage. The input, which varies approximately as the signal at the receiver input, is amplified by Q151 and Q152. Diodes D151 and D152 together with capacitors C157 and C158 establish a dc voltage across C158 that controls the conductivity of Q153. The base current of Q153 together with the current through R164 may be measured (see Figure 5) by a milliammeter (supplied separately) located at a point convenient for observation. This current may also be metered at the receiver by means of jack J151 on the printed-circuit board. Thermistor R166 with its associated resistors, and sensistor R152 provide compensation to minimize the variation of the metered current with ambient temperature. When Q153 becomes conductive, it supplies base input to Q154 to turn it on and energizes an alarm relay AL (when supplied) or its equivalent resistance R118 (2.2K). When the signal at the input of the receiver drops sufficiently, the AL or low-signal indication will drop out. This signal level is determined by the setting of R156 in the emitter of Q151.

The input to the carrier level indicator is not greatly affected by frequency variations within the pass-band of the input filter and the I.F. filter, but mainly by the level of receiver input signal.

Fig. 5 is typical of the variation of the carrier level indicator current with the receiver input level. With space signal being received, the signal level just below which the discriminator space output drops to zero is the minimum operating level of the receiver. The CLI alarm should clamp the output of the receiver into both a mark and space output at a signal level somewhat above this. For usual operating conditions it should be satisfactory to set the input attenuator (R5) 15 db, above the minimum operating level and set the CLI (by means of R156) to drop out at a signal 5 db. above the minimum operating level. Fig. 5 shows that with such settings the carrier level indicator current would be approximately 2.5 ma. with the normal input signal. The CLI alarm would be energized when the indicator current dropped to slightly less then 0.75 ma.

Power Supply

The regulated 20 V.D.C. and 45 V.D.C. circuits of the receiver are supplied from Zener diodes mounted on a common heat sink on the rear of the panel. Resistors (R2, R3) of suitable value are connected between the station battery supply and the 45 volt Zener to adapt the receiver for use on 48, 125 or 250 V.D.C. battery circuits. The receiver is connected to the external supply through a switch and fuses, and a pilot light indicates whether the D.C. circuits are energized. Capacitors C1 and C2 bypass r.f. or transient voltages to ground. Chokes L1 and L2 isolate the receiver from transient voltages that may appear on the D.C. supply.

CHARACTERISTICS

Frequency range	30-300 kHz
Sensitivity (noise-free channel)	0.015 volt (55 db below 1 watt for limiting)
Input Impedance	5000 ohms minimum
Bandwidth (L-C filter	down < 3 db at ±800 hertz down > 30 db at 5000 hertz
Operating time	4 ms. channel (transm. and receiver)
Frequency spacing For two-way channel	 3000 hertz minimum between transmitter and adjacent receiver frequencies.
Ambient temperature range	−20°C to +55°C temperature around chassis.
Battery voltage variations	
Rated voltage	Allowable variation
48 V.D.C.	42 – 56 V.D.C.
125 V.D.C.	105 – 140 V.D.C.
250 V.D.C.	210 – 280 V.D.C.
Battery drain	0.20 a. at 48 V.D.C. 0.27 a. at 125 or 250 V.D.C.
Dimensions	Panel height-10½'' or 6 r.u. Panel width – 19''
Weight	13 lbs.

INSTALLATION

The TCF receiver 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

All factory adjustments of the TCF receiver have been carefully made and should not be altered unless there is evidence of damage or malfunctioning. Such adjustments are: frequency and output level of the oscillator and mixer; input to the amplifier and limiter; frequency spacing and magnitude of discriminator output peaks. The adjustment that must be made at time of installation is the setting of input attenuator R5. The input attenuator adjustment is made by a knob on the front of the panel.

The receiver should not be set with a greater margin of sensitivity than is needed to assure correct operation with the maximum expected variation in attenuation of the transmitter signal. In the absence of the transmitter signal. In the absence of data on this, the receiver may be set to operate on a signal * that is 25 db below the expected maximum signal. After installation of the receiver and the corresponding transmitter, and with a normal space signal being received, input attenuator R5 should be adjusted to the position at which the receiver clamps into both mark and space outputs. R5 then should be readjusted to increase the voltage supplied to the * receiver by 20 db. The scale markings for R5 permit approximate setting to be made but it is preferable to make this setting by means of the db scales of an a-c VTVM connected from ground to the sliding * contact of R5. With this setting, a 20 db drop in signal will drop out the carrier level indicator logic to lock the output in both mark and space while the receiver is still 5 db above its dropout.

FACTORY ADJUSTMENTS

In case the factory adjustments have been altered or there is evidence of damage or malfunctioning, then the following procedures can be used.

Potentiometer R12, where applicable, in the oscillator and mixer should be set for 0.3 volt, measured with an a-c VTVM connected between TP11 and terminal 18 on the circuit board (ground terminal of voltmeter). A frequency counter can be connected to the same points for a check on the frequency, which should be 20 kHz above the channel frequency. The frequency is fixed by the crystal used, except that it may be changed a few cycles by the value of capacitor C12. Reducing C12 increases the frequency, but the capacity should never be less than a value that insures reliable starting of oscillation. The frequency at room temperature is usually several cycles above the crystal nominal frequency as this reduces the frequency deviation at the temperature extremes.

The adjustment of the amplifier and limiter is made by potentiometer R52. An oscilloscope should be connected from the base of transistor Q54 to terminal 18 of the limiter. With 10 mv. of space frequency on the receiver input (R5 at zero), R52 should be adjusted to the point where the peaks of the oscilloscope trace begin to flatten. This should appear on the upper and lower peaks at approximately the same setting.

The Carrier Level Indicator adjustment is set by the control R156 on the CLI module. The procedure is as follows:

1. Set input attenuator R5 to 0.
2. Remove noise detector board.
3. With 18 mv. of space frequency applied, adjust R156 until the receiver just clamps into both space and mark outputs. This indicates that the CLI has just dropped out.

Adjustment of the discriminator is made by capacitors C83 and C88. Apply to the receiver input a 10 mv. signal taken from an oscillator set at fc Hertz (R5 at zero.) Connect a 1.5-0-1.5 milliammeter in the circuit at J1 and a VTVM across R84. Adjust C88 for zero current in the milliammeter and C83 for maximum voltage across R84, rechecking the adjustments alternately until no further change is observed. Remove the VTVM from across R84 and observe the milliammeter reading as the oscillator frequency is varied. Positive and negative peaks should occur at fc + 100 Hertz and fc- 100 Hertz,

An alternate method of adjusting the carrier level Indicator and the input attenuator R5 in the field is described below. However this should be done only if there is doubt that the carrier level indicator is set wrong. Normally the only field adjustment necessary is that of R5 described under previous section "adjustments".

1. With a normal guard signal being received, connect an oscilliscope from the base of Q54 (probe) to terminal 18 (shield lead) of the amplifier-limiter board.
2. Set input attenuator R5 for the start of clipping (flattening of 20KHz signal peaks).
3. Note the R5 dial reading in dB, then reduce the attenuation by 5dB.
4. Set R156 on the carrier level indicator (CLI) board just to dropout. This is accomplished by first turning the screw-driver control of R156 clockwise until at least 2 ma. current is indicated on the associated milliammeter, then backing off until the receiver clamps into both

space and mark outputs. This indicates that the CLI has dropped out which occurs at approximately 0.75 ma.

5. Reduce the R5 dial reading by another 10 dB and tighten the locking screw. With this setting, the CLI current will be between 2.5 ma and 2.75 ma.

With the foregoing receiver setting, a 10 db drop in receiver signal will drop out the CLI for low signal indication while the receiver limiter still has a margin of 5dB before it drops out of saturation (clipping).

In case a check is desired of any of the delay times of the receiver (such as channel time), this can be done most conveniently by means of an oscilloscope with a calibrated triggered sweep. A two-pole toggle switch, checked to have less than 1 ms. interval between pole closures, can be used to impress the signal and trigger the sweep.

MAINTENANCE

Periodic checks of the received carrier signal and the receiver sensitivity will detect gradual deterioration and permit its correction before failure can result. The carrier level indicator, when provided, permits ready observation of the received signal level. With or without a carrier level indicator, an overall check can be made with the attenuation control R5. A change in operating margin from the original setting can be detected by observing the change in the dial setting required to drop out the alarm relay. If there is a substantial reduction in margin, the signal voltage at the receiver input should be checked to see whether the reduction is due to loss of signal or loss of receiver sensitivity.

All adjustable components on the printed circuit board are accessible when the door on the front of the panel is opened. (An offset screwdriver would be required for adjusting R12.) However, as described under "CONSTRUCTION", any board may be made entirely accessible while permitting electrical operation by using board extender Style No. 644B315G01. This permits attaching instrument leads to the various test points of terminals when making voltage, oscilloscope or frequency checks.

It is advisable to record voltage values 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 Table I and II. Voltages should be measured with a VTVM. Some readings may vary as much as ± 20%.

TABLE I
RECEIVER D-C MEASUREMENTS

Note: All voltage readings taken with ground of d-c VTVM on terminal 9 (neg. d.c.). Receiver adjusted for 15 db operating margin with Guard signal down 50 db. from 1 watt and Trip signal down 40 db. Unless otherwise indicated, voltage will not vary appreciably whether signal is Guard, Trip or zero.

Collector of Transistor	Volts (+)	
Q11	< 13	
Q12	15	(Mark or Space)
Q13	15	(Mark or space)
Q31	2.5	
Q32	2.5	
Q51	11.5	
Q52	12	
Q53	15.5	
Q54	2.5	
Q81	< 1	(No Sig. or Mark)
Q81	19.5	(Space)
Q82	< 1	(No sig. or Space)
Q82	19.5	(Mark)
Q101	< 1	(No Sig. or Space)
Q101	20	(Mark)
Q102	20	(No Sig. or Space)
Q102	< 1	(Mark)
Q103	20	(No. Sig. or Space)
Q103	< 1	(Mark)
Q104	< 1	(No Sig. or Space)
Q104	20	(Mark)
Q181	34	(No Signal)
Q181	< 1	(Space or Mark)
Q182	< 1	(No Signal)
Q182	20	(Space or Mark)
Q184	45	(No Signal)
Q184	20	(Space or Mark)
Q185	< 1	(No signal)
Q185	45	(Space or Mark)

Collector of Transistor	Volts (+)	
Q186	20	(No Signal)
Q186	< 1	(Space or Mark)
Q187	< 1	(No Signal)
Q187	20	(Space or Mark)
Q151	6	(No Signal)
Q151	6	(Space)
Q152	9.8	(No Signal)
Q152	10	(Space)
Q153	< 1	(No Signal)
Q153	19	(Space)
Q154	45	(No Signal)
Q154	< 1	(Space)

TABLE II
RECEIVER RF MEASUREMENTS

Note: Voltmeter readings taken between receiver input and Q32 are not meaningful or feasible because of waveform or effect of instrument loading. Receiver adjusted as in Table I.

Collector of Transistor	Volts at 10 watts
Q32	.8
Q51	.9
Q52	.65
Q53	2.2
Q54	4.5

FILTER RESPONSE MEASUREMENTS

The L-C input filter (FL-201) and the IF filter (FL-2) are in sealed containers, and repairs can be made only by the factory. The stability of the original response characteristics is such that in normal usuage, no appreciable change in response will occur. However, the test circuits of Figure 15 can be used in case there is reason to suspect that either of the filters has been damaged.

Figure 4 shows the -3 dB and -35 dB checkpoints for the IF filters, and the -3 dB checkpoints for the input filter. The response curve of the IF filter shows the combined effect of the two sections, and was obtained by adding the attenuation of each section for identical frequencies. The scale of Figure 4 was chosen to show the IF filter response, which permitted only a portion of the input filter curve to be shown. The checkpoints for the pass-band of each section of the IF filter are down 3 dB maximum at 19.75 and 20.25 kHz, and for the stop band are down 18 dB minimum at 19.00 and 21.00 kHz for each section. The signal generator voltage (Figure 15) must be held constant throughout the entire check. A value of 7.8 volts is suitable. The reading of the VM2 at the frequency of minimum attenuation should not be more than 22 dB below the reading of VM1. It should be noted that a limit measured in this manner is for convenience only and does not indicate actual insertion loss of the filter. The insertion loss would be approximately 16 db less then the measured difference because of the input resistor and the difference in input and output impedances of the filter.

In testing the L-C filter, a value of approximately 2.45 V· is suitable for the constant voltage at which to hold VM1 throughout the check. The reading of VM2 at the frequency of minimum attenuation will vary somewhat with the channel frequency, but should not be more than 18 dB below the reading of VM1. (The filter insertion loss is approximately 6 dB less than the difference in readings).

CONVERSION OF RECEIVER FOR CHANGED CHANNEL FREQUENCY

The parts required for converting a TCF receiver for operating on a different channel frequency consist of a new L-C input filter (FL201), a new local oscillator crystal (Y11) and probably a different feedback capacitor (C12). Because the wide range of channel frequencies precludes maintaining a factory stock of the various crystals, immediate shipment of the filter and the oscillator crystal cannot be made. After the crystals have been procured and the filter has been completed, it is recommended that the receiver be returned to the factory for the conversion and for complete test and adjustment. However, if the time that the receiver can be out of service must be kept to a minimum, the conversion may be made by customers who are equipped for this work.

RECOMMENDED TEST EQUIPMENT

I. Minimum Test Equipment for Installation.

a. A-C vacuum Tube Voltmeter (VTVM). Voltage range 0.003 to 30 volts, frequency range 60 Hz to 330 kHz, input impedance 7.5 megohms.

b. D-C Vacuum Tube Voltmeter (VTVM).

Voltage Range: 1.5 to 300 volts
Input Impedance: 7.5 megohms

c. Milliammeter, 0-3 range (if receiver has carrier level indicator).

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 330-kHz.

c. Oscilloscope

d. Frequency counter

e. Ohmmeter

f. Capacitor checker

g. Milliammeter, 0-1.5 or preferably 1.5-0-1.5 range for checking discriminator.

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, the electrical value, style number, and identify the part by its designation on the Internal Schematic drawing.

* ADDENDUM

With shipments of sets starting in early 1973, the germanium transistors used in the various modules were replaced with silicon transistors. In addition, due to the nature of silicon transistors, some resistor values in the circuits had to be changed in order to correctly bias these transistors. Therefore the transistors are not replaceable on a pin for pin basis throughout the receiver. Before attempting to replace a germanium transistor with a silicon transistor on older sets using germanium, please check the schematics on the following pages to see if the location where the replacement is desired has additional component changes. If that is the case, then the replacement can only be made by the same designation transistor or the additional component changes must also be made. It should be pointed out that the modules containing the silicon transistors are completely interchangeable with the modules containing germanium transistors. Therefore, there is no problem with intermixing the silicon transistor modules in the same receiver. Thus complete new modules containing silicon transistors can be ordered and used as replacements in older receivers having germanium transistor modules. The new modules have the same style numbers as the old germanium transistor modules they replace.

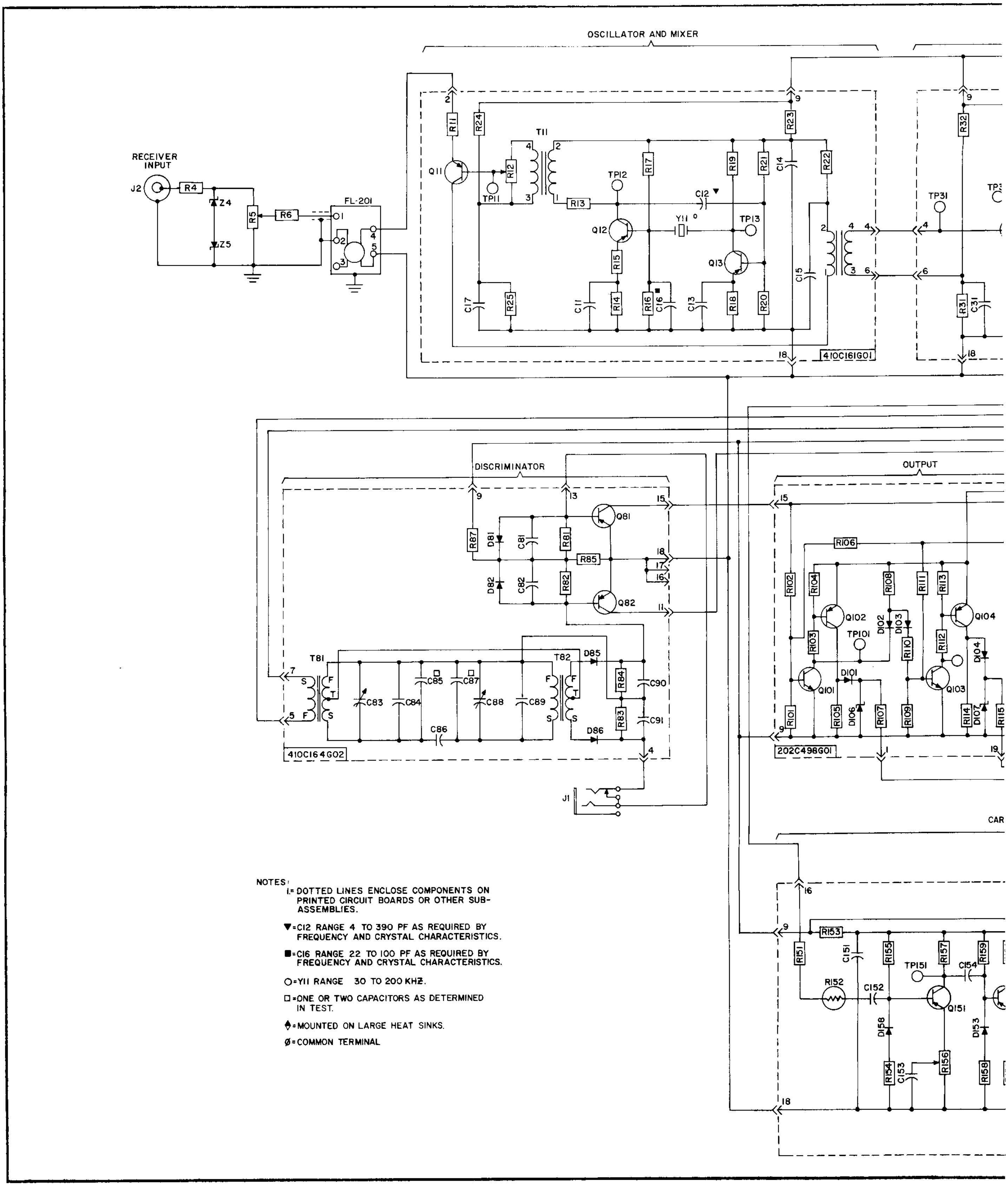
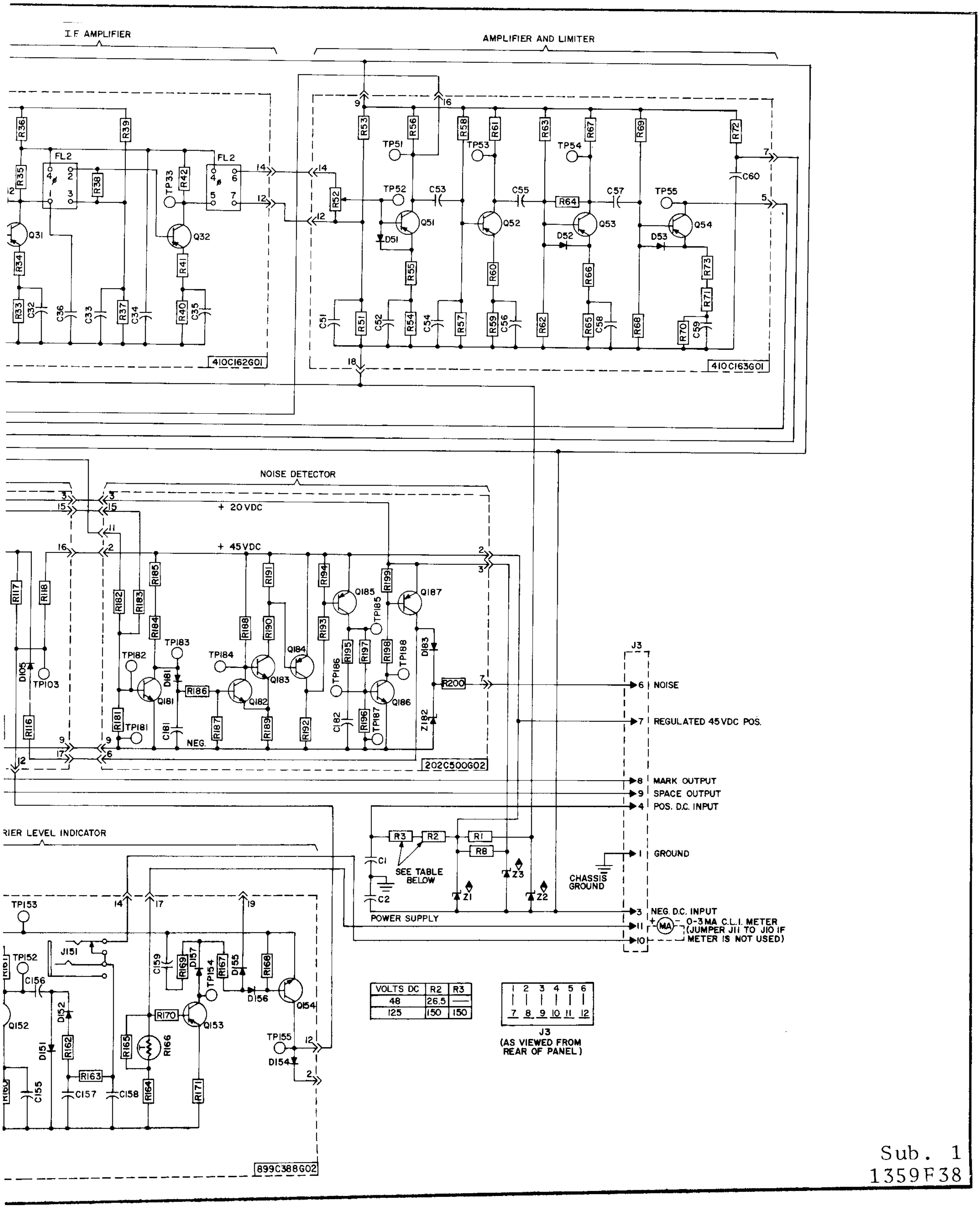


**Fig. 1 Internal schematic of the type TCF receiver under 20*



VOLTS DC	R2	R3
48	26.5	—
125	150	150

0kHz (See pages 23-26 for electrical parts list)

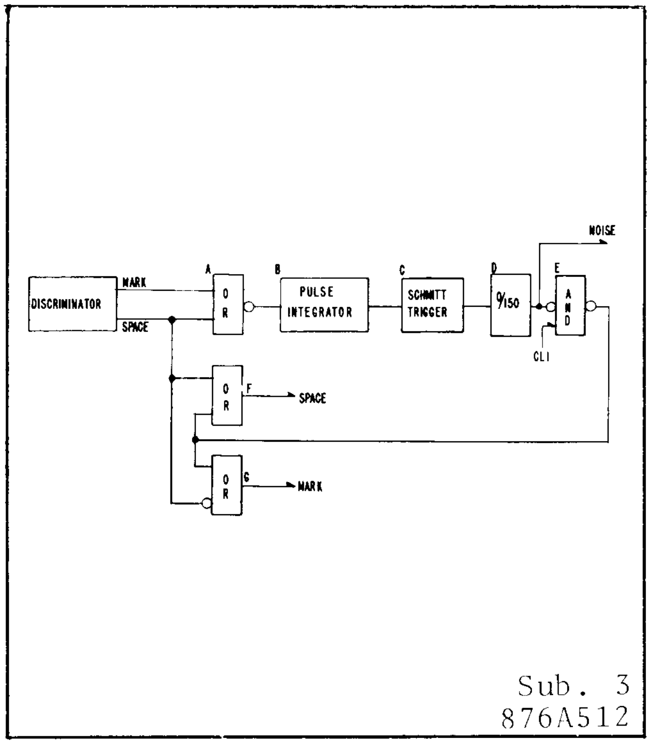
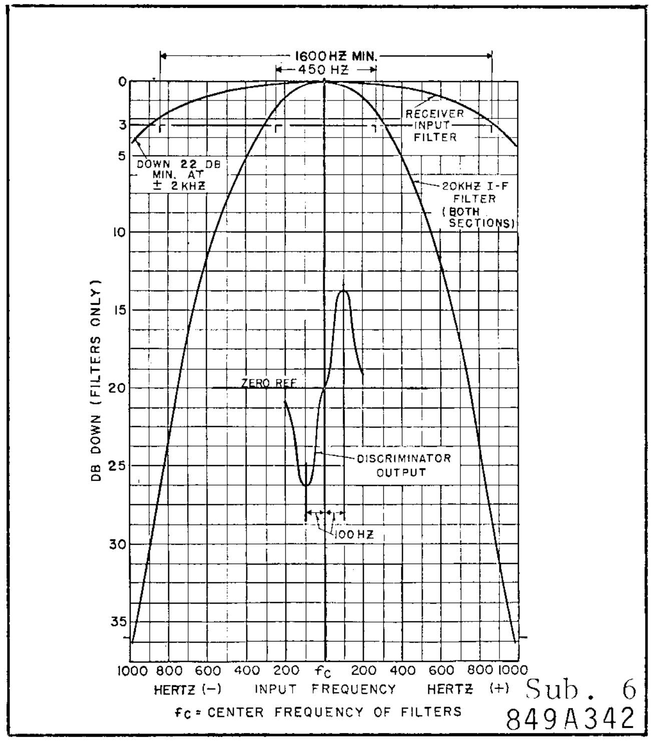
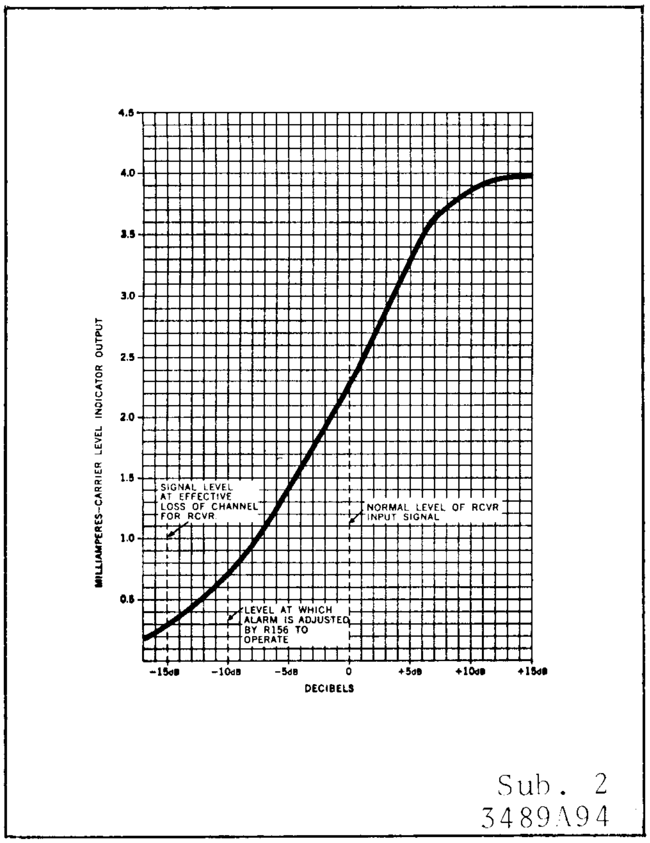


Fig. 3 Logic Diagram of Output Circuit



* Fig. 4 Filter and discriminator characteristics of the type TCF receiver



* Fig. 5 Typical curve of the carrier level indicator current vs. receiver margin above minimum operating level.

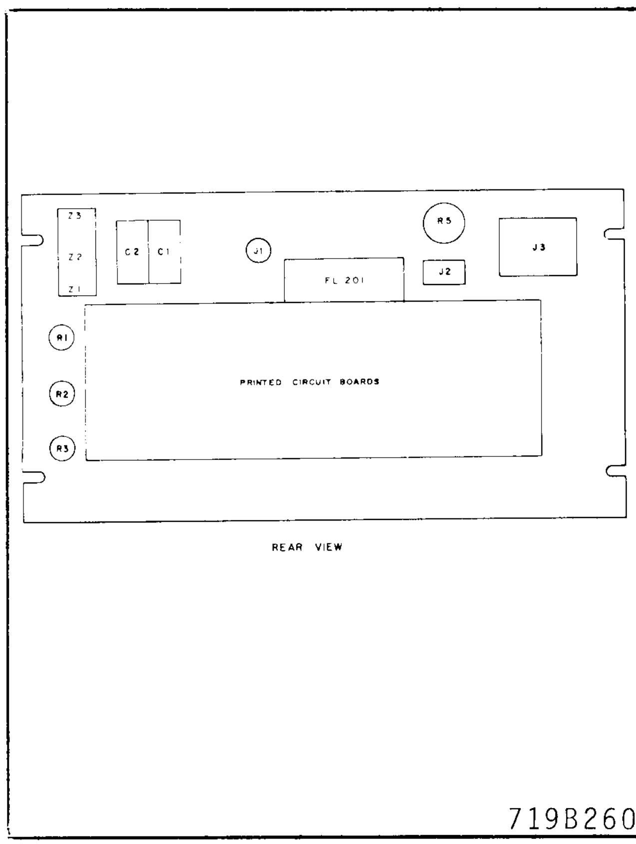
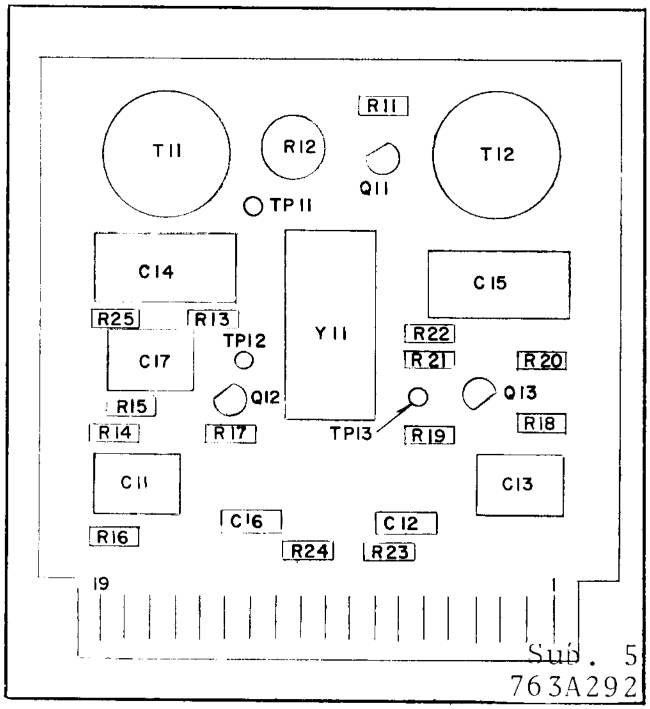
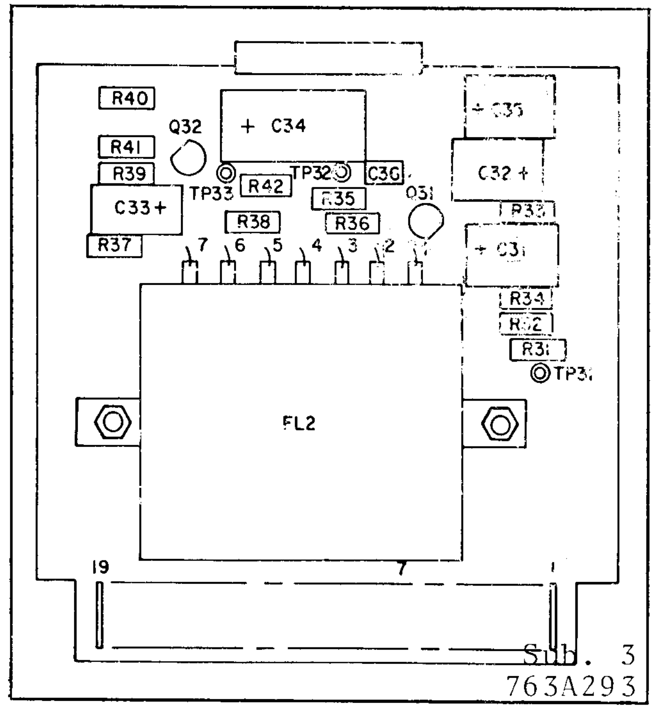


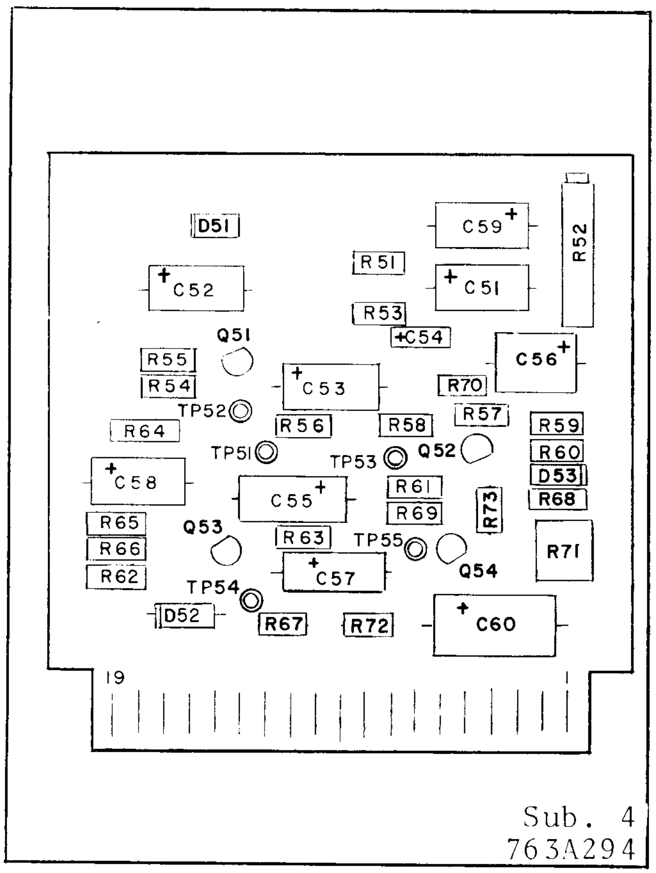
Fig. 6 Component locations on the type TCF receiver panel



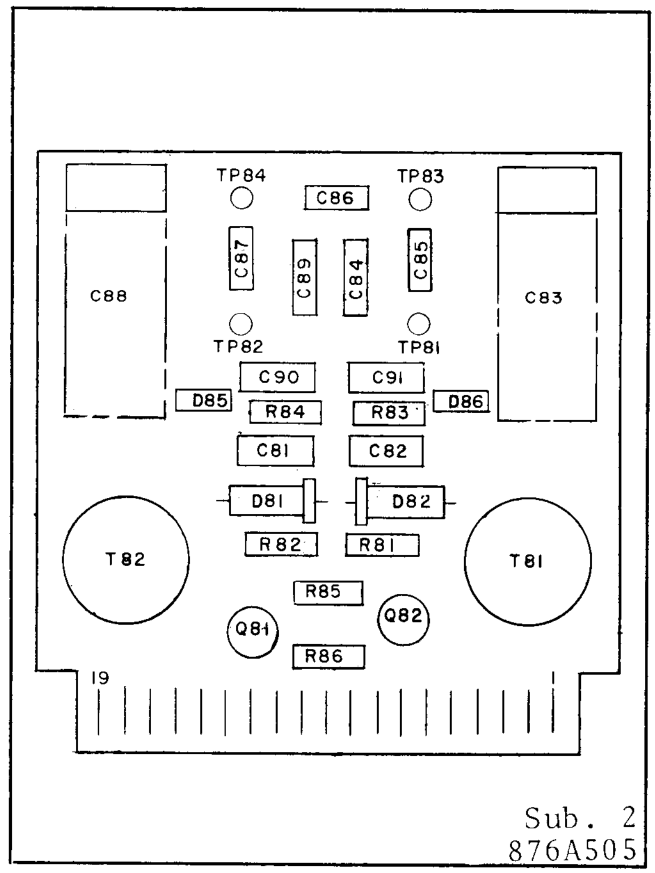
* *Fig. 7 Component locations on the oscillator and mixer printed circuit board.*



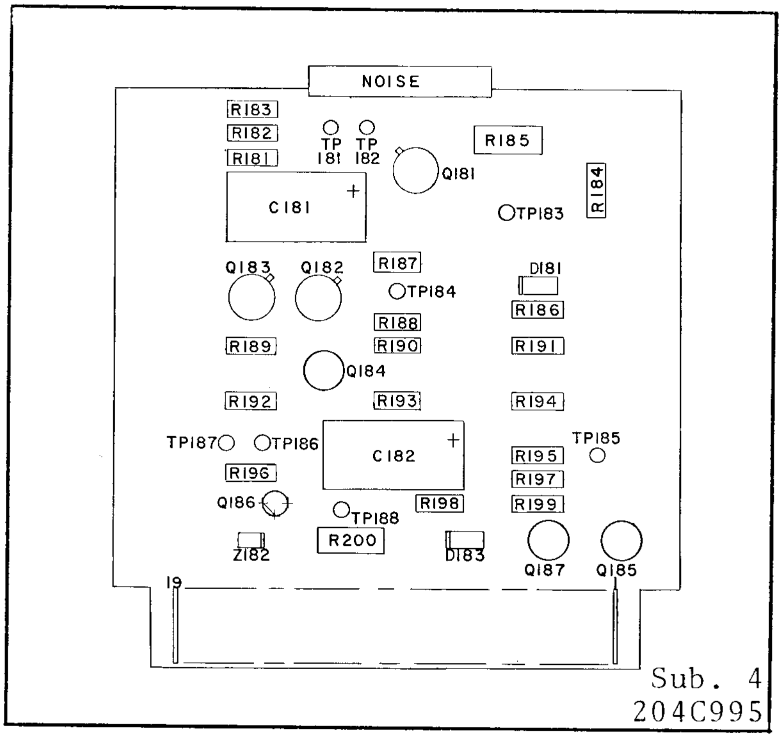
* *Fig. 8 Component locations on the I.F. amplifier printed circuit board.*



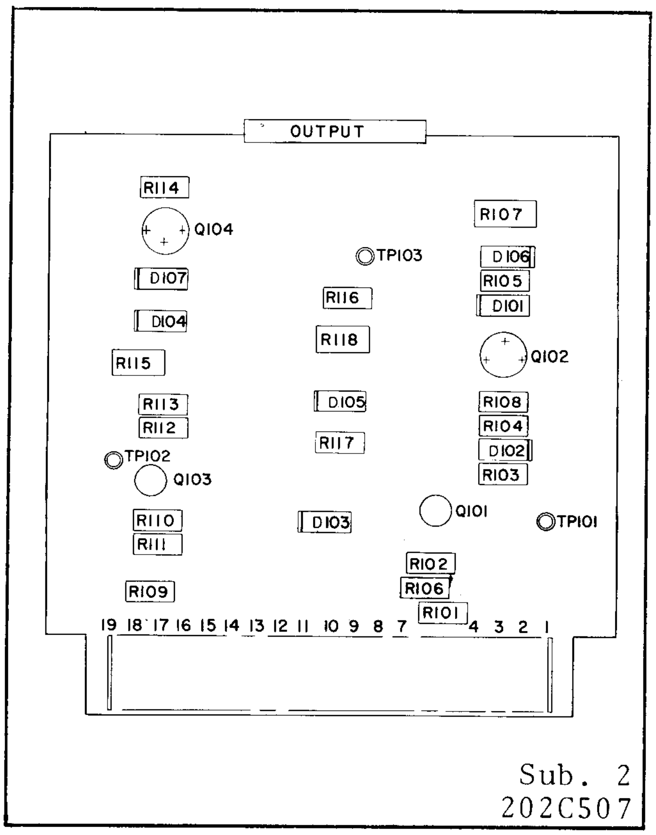
* *Fig. 9 Component locations on the amplifier and limiter printed circuit board.*



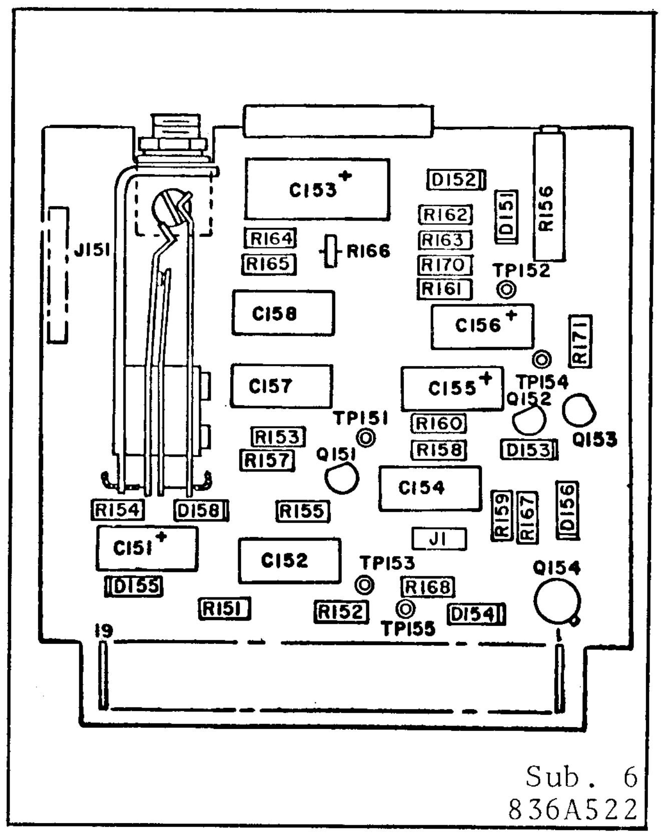
* *Fig. 10 Component locations on the discriminator printed circuit board.*



* *Fig. 11 Component Locations on the Noise Detector Printed Circuit Board.*



* *Fig. 12 Component Locations on the output printed circuit board.*



* *Fig. 13 Component Locations on the carrier level indicator printed circuit board.*

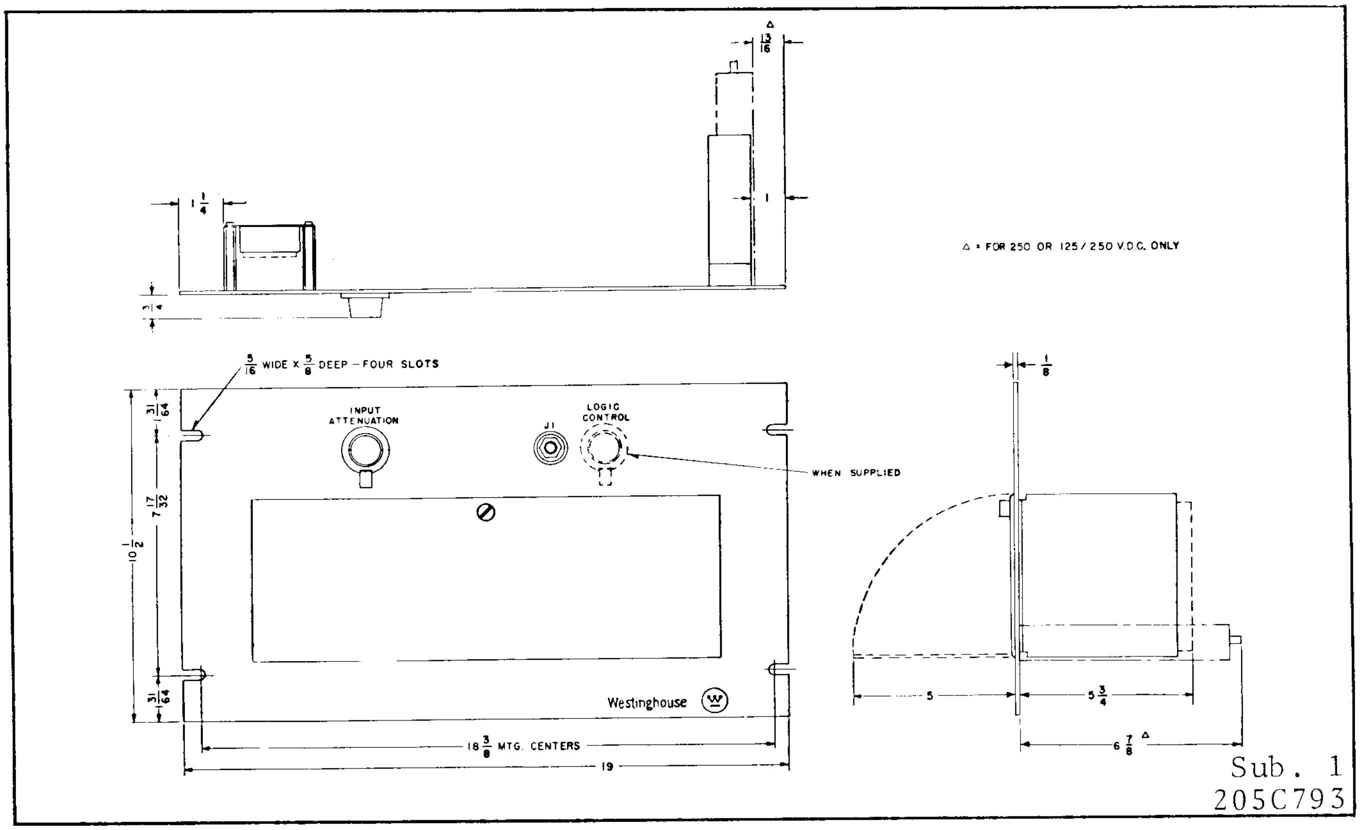


Fig. 14 Outline and drilling plan for the type TCF receiver assembly.

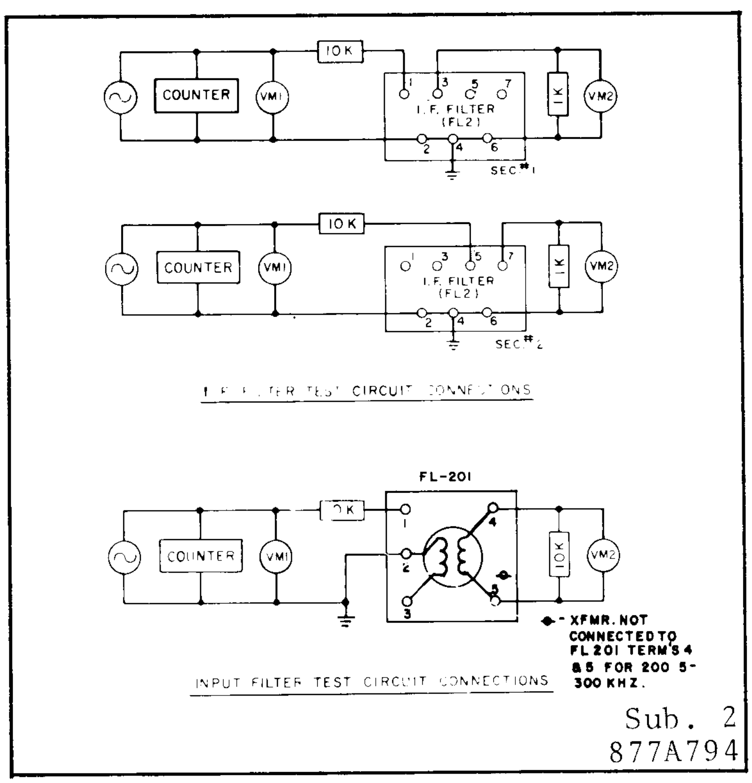
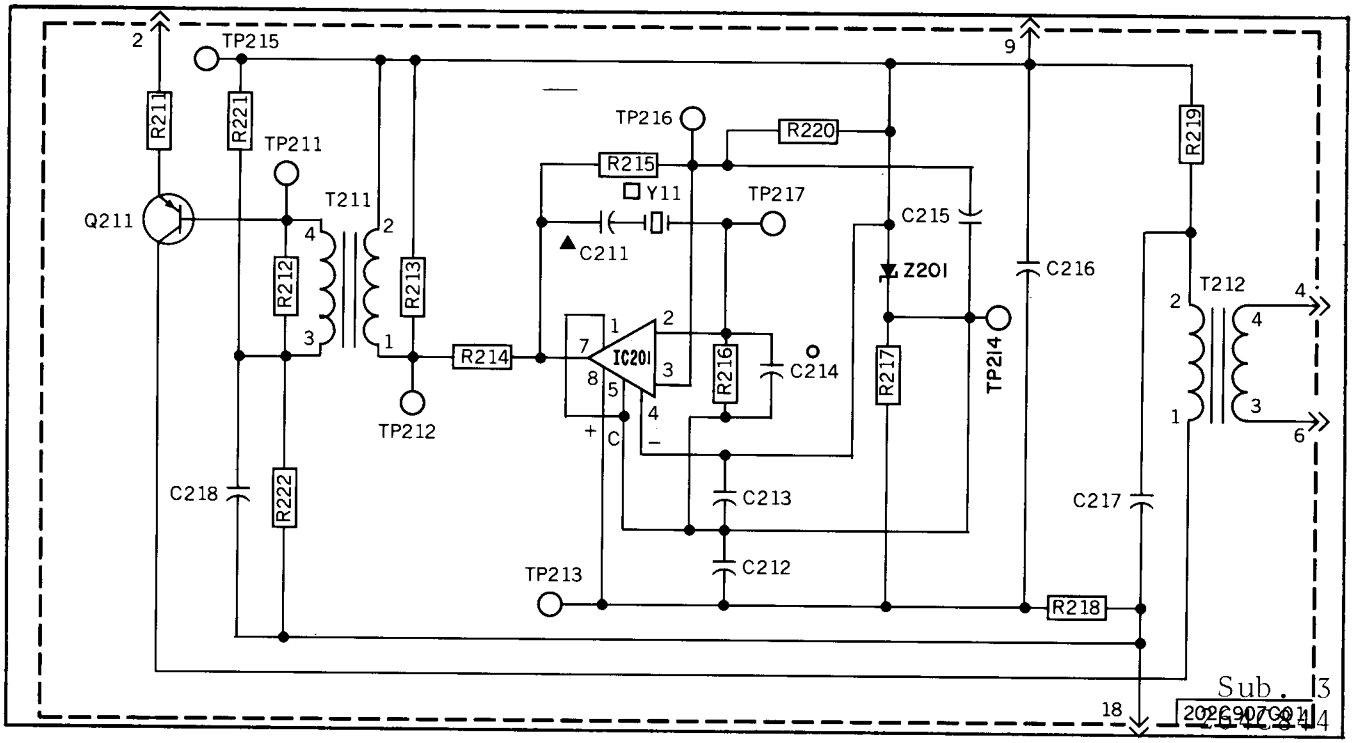
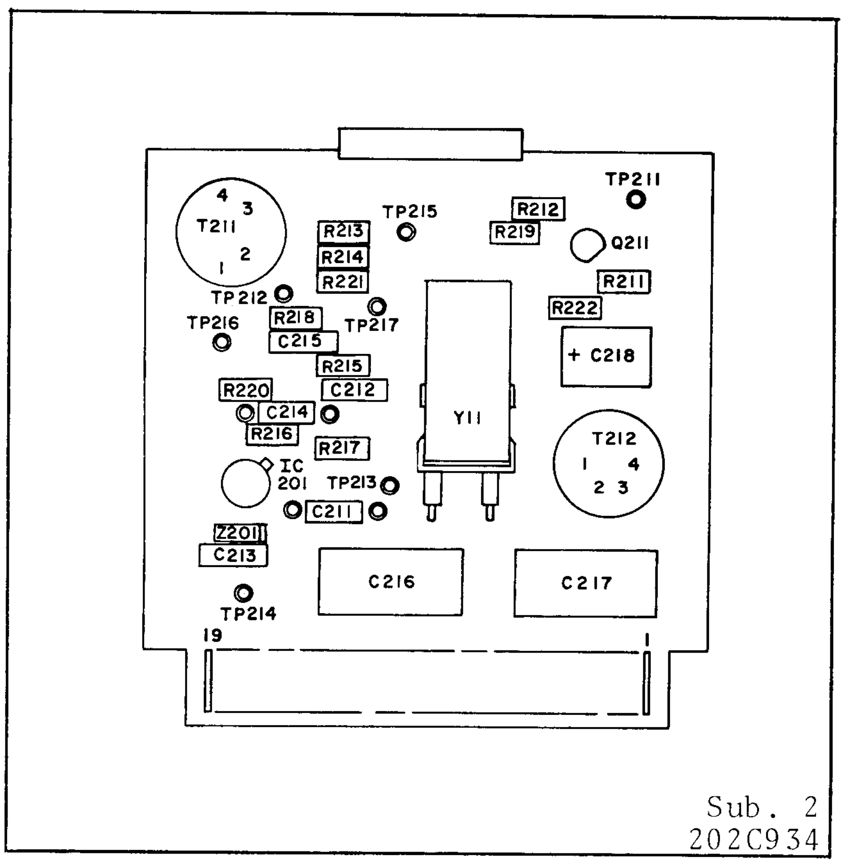


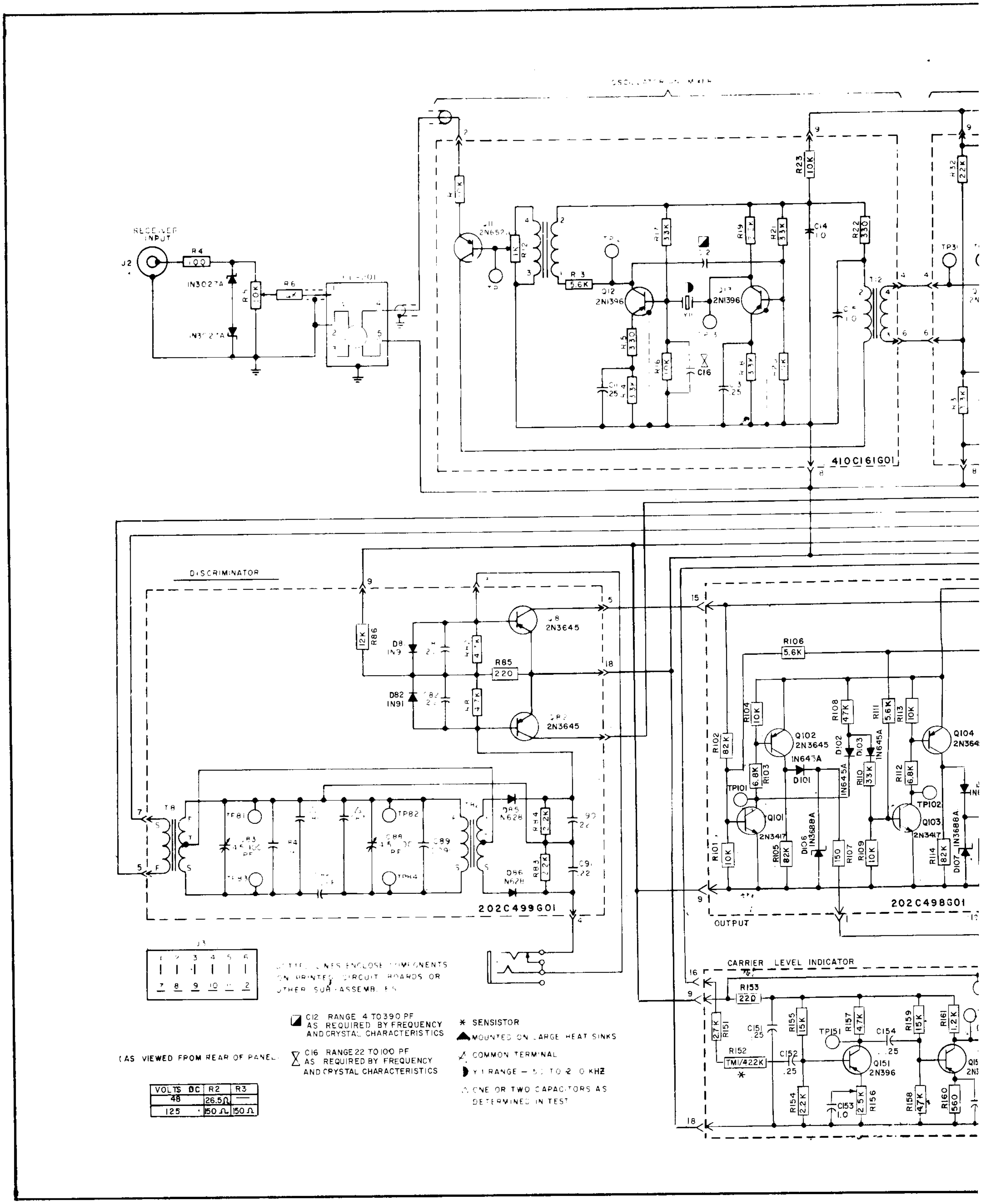
Fig. 15 Test Circuits for TCF Frequency Shift Receiver Filters.



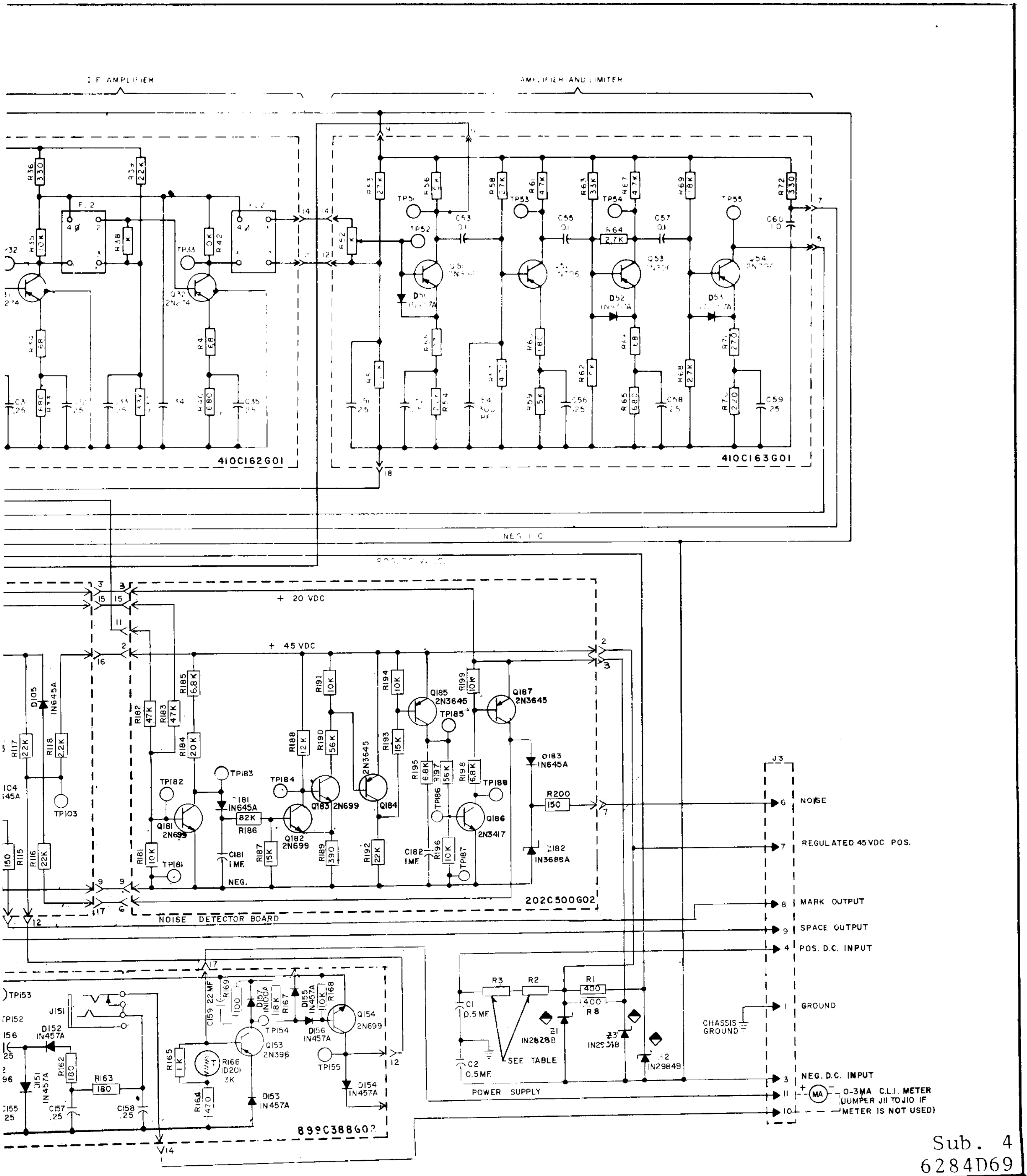
* *Fig. 16. 200.5 to 300 kHz oscillator mixer board*



* *Fig. 17. Component Location 200.5 to 300 kHz oscillator mixer board.*



** Fig. 19 Internal schem*
through early 1



tic of the type TCF receiver - 1971

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ELECTRICAL PARTS LIST FOR FIGURES 1 AND 2 (Cont'd)

AMPLIFIER & LIMITER-410C163G01

COMPONENT	STYLE	REQ	REF
TRANSISTOR			
Q51-Q52-Q53-Q54	849A441H03	4	2N4249
RESISTOR			
R66	187A290H21	1	68Ω 1/2W ±5%
R55	187A290H11	1	27Ω 1/2W ±5%
R70	184A763H11	1	220Ω 1/2W ±5%
R72	184A763H15	1	330Ω 1/2W ±5%
R65	184A763H23	1	680Ω 1/2W ±5%
R59	184A763H31	1	1.5K 1/2W ±5%
R54-R62	184A763H35	2	2.2K 1/2W ±5%
R64-R68	184A763H37	2	2.7K 1/2W ±5%
R51-R57-R61-R67	184A763H43	4	4.7K 1/2W ±5%
R56	184A763H51	1	10K 1/2W ±5%
R69	184A763H57	1	18K 1/2W ±5%
R53-R58	184A763H61	2	27K 1/2W ±5%
R63	184A763H63	1	33K 1/2W ±5%
R71	**629A531H04**	1	**68Ω 1/2W** ±2%
R60	184A763H09	1	180Ω 1/2W ±5%
R73	629A531H02	1	56Ω 1/2W ±2%
CAPACITOR			
C54	187A584H15	1	1300MMF. 500V.
C51-C52-C56-C58-C59	187A624H02	5	.25MFD. 200V.
C53-C55-C57	187A624H01	3	0.1MFD. 200V.
C60	187A624H04	1	1.0MFD. 200V.
DIODE			
D51-D52-D53	184A855H07	3	1N457A
POTENTIOMETER			
R52	629A645H04	1	1K

NOISE DETECTOR-202C500G02

COMPONENT	STYLE	REQ	REF
TRANSISTOR			
Q181-Q182-Q183	184A638H19	3	2N699
Q184-Q185-Q187	849A441H01	3	2N3645
Q186	848A851H02	1	2N3417
RESISTOR			
R181-R191-R194-R196-R199	184A763H51	5	10K, -1/2W, ±5%
R182-R183	184A763H67	2	47K, 1/2W, ±5%
R184	184A763H58	1	20K, 1/2W, ±5%
R185	184A763H47	1	6.8 K, -1/2W, ±5%
R186	629A531H78	1	82K, 1/2W, ±2%
R187-R193	629A531H60	2	1.5K, -1/2W, ±2%
R188	184A763H53	1	12K, 1/2W, ±5%
R189	184A763H17	1	390 1/2W, ±5%
R190	184A763H69	1	56K, 1/2W, ±5%
R192	184A763H59	1	22K, 1/2W, ±5%
R195-R198	184A763H47	2	6.8K, 1/2W, ±5%
R197	184A763H69	1	56K, 1/2W, ±5%
R200	762A679H01	1	150 3W
CAPACITOR			
C181-C182	187A624H04	2	1MFD 200 V DC
ZENER DIODE			
Z182	862A288H01	1	1N3688A
DIODE			
D181-D183	837A692H03		1N645A

OUTPUT-202C498G01

COMPONENT	STYLE	REQ	REF
Q101-Q103	848A851H02	2	2N3417
Q102-Q104	849A441H01	2	**2N3645**

I.F. AMPLIFIER-410C162G01

COMPONENT	STYLE	REQ	REF
TRANSISTOR			
Q31-Q32	849A441H03	2	2N4249

RESISTOR			
R101-R104-R109-R113	184A763H51	4	10K, 1/2W, 5%
R102-R105-R114	629A531H78	3	82K, 1/2W, 2%
R103-R112	194A763H47	2	6.8K, 1/2W, 5%
R106-R111	184A763H45	2	5.6K, 1/2W, 5%
R107-R115	762A679H01	2	150 3W
R108	184A763H67	1	47K, 1/2W, ±5%
R110	184A763H63	1	33K, 1/2W, ±5%
R116-R117	184A763H59	2	22K, 1/2W, ±5%
R118	763A127H11	1	2.2K, 3W, ±5%
DIODE			
D101-D102-D103-D104-D105	837A692H03	5	1N645A
ZENER DIODE			
D106-D107	862A288H01	2	1N3688A

RESISTOR			
R34-R41	187A290H21	2	68Ω 1/2W ±5%
R36	184A763H15	1	330Ω 1/2W ±5%
R33-R40	184A763H23	2	680Ω 1/2W ±5%
R38	184A763H27	1	1K 1/2W ±5%
R31-R37	184A763H39	2	3.3K 1/2W ±5%
R35-R42	184A763H51	2	10K 1/2W ±5%
R32-R39	184A763H59	2	22K 1/2W ±5%
CAPACITOR			
C31-C32-C33-C35	187A624H02	4	25MFD. 200V
C34	187A624H04	1	1MFD. 200V.
C36	762A757H01	1	100 Pf.
FILTER			
FL2	762A613G01	1	

OTHER-THIS DWG. SEE SHEET 1.

COMPONENT	STYLE	REQ	REF.
RESISTOR			
R1	1202587	1	400, 25W, ±5%
R2	04D1299H44	1	26.5, 40W, ±5%
R2	1202499	1	150, 40W, ±5%
R3	1202499	1	150, 40W, ±5%
R4	187A643H03	1	100, 1W, ±5%
R6	184A763H51	1	10K, 1/2W, ±5%
R8	1202537	1	400, 25W, ±5%
POTENTIOMETER			
R5	185A086H10	1	0-10K, 2W, ±10%
CAPACITOR			
C1-C2	1877962	2	0.5MFD, 1500V
ZENER DIODE			
Z1 (1N2828B)	184A854H06	1	45V, 50W, ±5%
Z2-Z3 (1N2934B)	762A631H01	2	20V, 10W, ±5%
Z4-Z5 (1N3027A)	188A302H07	2	20V, 1W, ±10%
TELEPHONE JACK			
J1	187A606H01	1	
CONNECTOR			
J3	187A336H03	1	12 TERMS.
CRYTAL FILTER	*	1	

*= PER S.O.

INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE TCF POWER LINE CARRIER FREQUENCY SHIFT RECEIVER EQUIPMENT FOR DUAL PHASE-COMPARISON CARRIER RELAYING

Caution: It is recommended that the user of this equipment become acquainted with the information in this instruction leaflet and in the system instruction leaflet before energizing the system.

Printed circuit modules should not be removed or inserted when the relay is energized. Failure to observe this precaution can result in an undesired tripping output and cause component damage.

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 tripping over.

APPLICATION

The TCF Receiver described is for use with the SKBU Dual Phase Comparison relay. The TCF frequency-shift receiver equipment as adapted for dual phase comparison applications responds to carrier-frequency signals transmitted from the distant end of a power line and carried on the power line conductors. The space frequency is 100 hertz above the center frequency of the channel (which can be selected within the range of 30 kHz to 300 kHz), and it is transmitted continuously when no information is to be conveyed over the channel. Its reception indicates that the channel is operative. The Mark frequency is 100 hertz below the channel center frequency. Phase comparison information is conveyed over the channel during load current flow or fault conditions. The transmitter at each end of the channel is switched at a 60-Hz rate between space and mark so as to produce at the receiving end the desired operation of the SKBU relay.

CONSTRUCTION

The TCF receiver unit for Dual-Phase-Comparison applications is mounted on a standard 19-inch wide panel 10½ inches high (6 rack units) with edge slots for mounting on a standard relay rack. All components are mounted at the rear of the panel. An input attenuator and a jack for metering the discriminator output current, are accessible from the front of the panel. See Fig. No. 14.

All of the circuitry that is suitable for mounting on printed circuit boards is contained in an enclosure that projects from the rear of the panel and is accessible by opening a hinged door on the front of the panel. Other components on the rear of the panel are located as shown* on Fig. No. 6. Reference to the internal schematic connections on Fig. 1 will show the location of these components in the circuit. The dotted lines enclosing separate areas of Fig. 1 indicate that the components thus enclosed are all on the same printed circuit board.

The enclosure that contains the printed circuit board is divided into seven compartments. The partitions between compartments together with the outer walls of the enclosure provide complete shielding between adjacent boards and from external fields. Frequency shift receivers for dual phase-comparison relaying utilize all compartments if a carrier level indicator is provided. If this is omitted, the compartment on the extreme right, front view, is left vacant.

The printed circuit boards slide into position in slotted guides at the top and bottom of each compartment, and the board terminals engage a terminal block at the rear of the compartment. Each board and terminal block are keyed so that if a board is placed in the wrong compartment, it cannot be inserted into the terminal block. A handle on the front of each board is labeled to identify its function in the circuit.

A board extender (Style No. 644B315G01) is available for facilitating circuit voltage measurements or major adjustments. After withdrawing any one of the circuit boards, the extender is inserted in that compartment. The board then is inserted into the terminal block on the front of the extender. This

SUPERSEDES I.L. 41-945.55B, dated May 1972
*Denotes change from superseded issue.

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restores all circuit connections, and all components and test points on the board are readily accessible.

A portion of the receiver operates from a regulated 20 VDC supply, and the remainder from a regulated 45 V.D.C. supply. These voltages are taken from two Zener diodes mounted on a common heat sink. Variation of the resistance value between the positive side of the unregulated D.C. supply and the 45 volt Zener adapt the receiver for operation on 48, 125, or 250 V.D.C.

External connections to the receiver are made through a 12 terminal receptacle, J3 (see Fig. 1). The r-f input connection to the receiver is made through a coaxial cable jack, J2.

OPERATION

Input Control

The signals to which the TCF receiver responds are received through a coaxial cable connected to jack J2 of Fig. No. 1. Resistor R4 and 20-volt Zener diodes CR1 and CR2 protect the receiver from abnormally high voltages received through the coaxial cable. Input attenuator R5 reduces the signal to a level suitable for best operation of the receiver. The attenuator is adjustable from the front of the panel and can be clamped at the desired setting. A scale on the panel is graduated in db. While this scale is typical rather than individually calibrated, it is accurate within one or two db. and is useful in setting approximate levels. Settings should be made by observation of the db. scale of a suitable a-c voltmeter when possible.

L-C Filter (Wide Band)

From the attenuator, the signal passes through an L-C filter, FL201. This filter has a relatively wide pass band, and frequencies several kHz above or below the center frequency (fc) of the channel are greatly attenuated. Fig. 4 shows a typical curve for the L-C filter, as well as a characteristic curve for the immediate frequency filter, FL2 and for the discriminator output. This apparently wide bandwidth is necessary to achieve high speed relaying by minimizing channel delay.

Oscillator and Mixer

From the input filter, the signal enters the oscillator and mixer stage of the receiver. Crystal Y11, transistors Q12 and Q13, or IC201 (Fig. 16) and their associated resistors and capacitors, comprise a crystal-controlled oscillator that operates at a frequency 20 kHz above the channel frequency, fc. The output from this local oscillator is fed through transformer T11 to potentiometer R12, and the later is adjusted to feed a suitable input to the base of mixer transistor Q11. The output of FL1 is impressed on the emitter-collector circuit of Q11. As a result of mixing these two frequencies, the primary of transformer T12 will contain frequencies of 20kHz, 2fc + 20kHz, fc + 20kHz and fc.

If Amplifier

The output from the secondary of T12 is amplified by Q31, in the intermediate frequency amplifier stage, and is impressed on filter FL2. This is a two-section filter, with both filters contained in a common case. Its pass band is centered at 20kHz. Since its passband is narrower than that of the input filter, it eliminates the frequencies present at its input that are substantially higher than 20 kHz.

Amplifier and Limiter

The output from the second section of the IF amplifier stage is fed to potentiometer R52 at the input of the amplifier and limiter stage. Sufficient input is taken from R52 so that with minimum input signal (15 mv.) at J2 and with R5 set for zero attenuation, satisfactory amplitude limiting will be obtained at the output of the limiter stage.

Discriminator

The output of the limiter stage is fed to the discriminator. The discriminator is adjusted at the factory to have zero output (as measured by a milliammeter inserted in the circuit at jack J1) at fc hertz. The adjustment for zero output at fc hertz is made by capacitor C88. C83 also is adjusted to maximum voltage reading across R84 when the current output is zero. Maximum current output, of opposite polarities, will be obtained when the frequency is 100 hertz above or below the zero output frequency. This separation of 200 hertz between the current peaks is affected by the value of C86, (the actual value of which may be changed slightly from its typical value in factory calibration if required.)

It should be observed that although the space frequency is fc + 100 hertz, after leaving the mixer stage and as seen by the discriminator the space frequency is 20 kHz-100 hertz. Similarly, the mark frequency is 20 kHz + 100 hertz. The intermediate frequency at which the discriminator has zero output then is 20 kHz. The discriminator is adjusted so that the mark and space outputs are of equal lengths for equal periods of mark and space signal frequencies.

The discriminator output is connected to the bases of transistors Q81 and Q82 in such manner that Q82 is made conductive when current flows out of terminal 4 (which occurs with mark output) and Q81 is made conductive when current flows into terminal 4. Consequently, terminal 15 is at a potential of approximately + 20 volts at space frequency and terminal 11 is at + 20 volts at mark frequency.

Output Circuits

The output circuit consists of two printed circuit boards: the output board and the noise board.

The output board consists of two output transistors (Q102, Q104) and two driver (Q101, Q103) transistors for the space and mark outputs which are driven by * the discriminator space output (Figure 3). The mark and space outputs are mutually exclusive except when there is a loss of channel (C.L.I.) or an output from the noise circuit, at which time both outputs appear.

The mark and space outputs appear together when transistors Q101 and Q103 are turned on with a current through resistors R106 and R111. The noise output current flows from Q187 collector through R116 and D105 into R106 and R111; the carrier level indicator output is loaded through R118 and fed through R117 into R106 and R111.

The inversion of the mark and space outputs is accomplished through the NOR function from Q101 to Q103, through R108, R109, R110, D-102 and D103. Diodes D102 and D103 are provided to supply isolation from negative to the base of Q102.

The noise circuit detects an unsatisfactory noise condition of the receiver signal when shifted at a 60-Hz rate. This is done by detecting the error in discriminator output of the receiver. The noise output should appear at approximately a 3-db signal-to-noise ratio measured in a 1000-Hz bandwidth in the transmission band.

With reference to Figure 3, when the discriminator * of the TCF receiver shifted between + 100 Hz of center frequency, there is a 0.5 millisecond period when neither output of the discriminator appears. This generates a pulse from the negated OR, block A. The information from these pulses is then transformed through a pulse integrator into a voltage which will trigger a Schmitt trigger when it exceeds a predetermined value which indicates an intolerable noise condition.

With reference to Figure 1, the discriminator outputs are fed through R182 and R183 into transistor Q181. A lack of discriminator output will permit a flow of current into capacitor C181 through resistors R184, R185 and CR181. Diode CR181 will block the charge on capacitor C181 from flowing into transistor Q181; capacitor C181 may only discharge through R186 and R187. When the voltage across resistor R187 is enough to overcome the potential needed to turn transistor Q182 on, then transistor Q183 is turned off, and the voltage across R189 will drop proportionately to the ratio of R188 and R190 causing a drop in the voltage requirement to turn on transistor Q182. Transistor Q184 will be turned off as a result of transistor Q183 turning off, and transistor Q185 will be turned on as a result of transistor Q184 turning off. Transistors Q186 and Q187 will turn on together with Q185 giving a noise output. The Schmitt trigger is composed of transistors Q182 and Q183.

Carrier Level Indicator

The noise logic takes care of the situation when the channel fails suddenly and completely. However, a measurement of signal strength is desired for providing an indication when the signal has weakened seriously but has not reached the point of complete failure.

The carrier level indicator is housed in the right-hand compartment of the enclosure that contains the circuit boards. Figure 1 shows the connections of this circuit board and also the external connections of the board.

The r-f input to the carrier level indicator is taken from the collector of Q151, the first transistor in the amplifier and limiter stage. The input, which varies approximately as the signal at the receiver input, is amplified by Q151 and Q152. Diodes D151 and D152 together with capacitors C157 and C158 establish a dc voltage across C158 that controls the conductivity of Q153. The base current of Q153 together with the current through R164 may be measured (see Figure 5) by a milliammeter (supplied separately) located at a point convenient for observation. This current may also be metered at the receiver by means of jack J151 on the printed-circuit board. Thermistor R166 with its associated resistors, and sensistor R152 provide compensation to minimize the variation of the metered current with ambient temperature. When Q153 becomes conductive, it supplies base input to Q154 to turn it on and energizes an alarm relay AL (when supplied) or its equivalent resistance R118 (2.2K). When the signal at the input of the receiver drops sufficiently, the AL or low-signal indication will drop out. This signal level is determined by the setting of R156 in the emitter of Q151.

The input to the carrier level indicator is not greatly affected by frequency variations within the pass-band of the input filter and the I.F. filter, but mainly by the level of receiver input signal.

Fig. 5 is typical of the variation of the carrier level indicator current with the receiver input level. With space signal being received, the signal level just below which the discriminator space output drops to zero is the minimum operating level of the receiver. The CLI alarm should clamp the output of the receiver into both a mark and space output at a signal level somewhat above this. For usual operating conditions it should be satisfactory to set the input attenuator (R5) 15 db, above the minimum operating level and set the CLI (by means of R156) to drop out at a signal 5 db. above the minimum operating level. Fig. 5 shows that with such settings the carrier level indicator current would be approximately 2.5 ma. with the normal input signal. The CLI alarm would be energized when the indicator current dropped to slightly less then 0.75 ma.

Power Supply

The regulated 20 V.D.C. and 45 V.D.C. circuits of the receiver are supplied from Zener diodes mounted on a common heat sink on the rear of the panel. Resistors (R2, R3) of suitable value are connected between the station battery supply and the 45 volt Zener to adapt the receiver for use on 48, 125 or 250 V.D.C. battery circuits. The receiver is connected to the external supply through a switch and fuses, and a pilot light indicates whether the D.C. circuits are energized. Capacitors C1 and C2 bypass r.f. or transient voltages to ground. Chokes L1 and L2 isolate the receiver from transient voltages that may appear on the D.C. supply.

CHARACTERISTICS

Frequency range	30-300 kHz
Sensitivity (noise-free channel)	0.015 volt (55 db below 1 watt for limiting)
Input Impedance	5000 ohms minimum
Bandwidth (L-C filter	down < 3 db at ±800 hertz down > 30 db at 5000 hertz
Operating time	4 ms. channel (transm. and receiver)
Frequency spacing For two-way channel	3000 hertz minimum between transmitter and adjacent receiver frequencies.
Ambient temperature range	−20°C to +55°C temperature around chassis.
Battery voltage variations	
Rated voltage	Allowable variation
48 V.D.C.	42 – 56 V.D.C.
125 V.D.C.	105 – 140 V.D.C.
250 V.D.C.	210 – 280 V.D.C.
Battery drain	0.20 a. at 48 V.D.C. 0.27 a. at 125 or 250 V.D.C.
Dimensions	Panel height-10½'' or 6 r.u. Panel width – 19''
Weight	13 lbs.

INSTALLATION

The TCF receiver 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

All factory adjustments of the TCF receiver have been carefully made and should not be altered unless there is evidence of damage or malfunctioning. Such adjustments are: frequency and output level of the oscillator and mixer; input to the amplifier and limiter; frequency spacing and magnitude of discriminator output peaks. The adjustment that must be made at time of installation is the setting of input attenuator R5. The input attenuator adjustment is made by a knob on the front of the panel.

The receiver should not be set with a greater margin of sensitivity than is needed to assure correct operation with the maximum expected variation in attenuation of the transmitter signal. In the absence of the transmitter signal. In the absence of data on this, the receiver may be set to operate on a signal * that is 25 db below the expected maximum signal. After installation of the receiver and the corresponding transmitter, and with a normal space signal being received, input attenuator R5 should be adjusted to the position at which the receiver clamps into both mark and space outputs. R5 then should be readjusted to increase the voltage supplied to the * receiver by 20 db. The scale markings for R5 permit approximate setting to be made but it is preferable to make this setting by means of the db scales of an a-c VTVM connected from ground to the sliding * contact of R5. With this setting, a 20 db drop in signal will drop out the carrier level indicator logic to lock the output in both mark and space while the receiver is still 5 db above its dropout.

FACTORY ADJUSTMENTS

In case the factory adjustments have been altered or there is evidence of damage or malfunctioning, then the following procedures can be used.

Potentiometer R12, where applicable, in the oscillator and mixer should be set for 0.3 volt, measured with an a-c VTVM connected between TP11 and terminal 18 on the circuit board (ground terminal of voltmeter). A frequency counter can be connected to the same points for a check on the frequency, which should be 20 kHz above the channel frequency. The frequency is fixed by the crystal used, except that it may be changed a few cycles by the value of capacitor C12. Reducing C12 increases the frequency, but the capacity should never be less than a value that insures reliable starting of oscillation. The frequency at room temperature is usually several cycles above the crystal nominal frequency as this reduces the frequency deviation at the temperature extremes.

The adjustment of the amplifier and limiter is made by potentiometer R52. An oscilloscope should be connected from the base of transistor Q54 to terminal 18 of the limiter. With 10 mv. of space frequency on the receiver input (R5 at zero), R52 should be adjusted to the point where the peaks of the oscilloscope trace begin to flatten. This should appear on the upper and lower peaks at approximately the same setting.

The Carrier Level Indicator adjustment is set by the control R156 on the CLI module. The procedure is as follows:

1. Set input attenuator R5 to 0.
2. Remove noise detector board.
3. With 18 mv. of space frequency applied, adjust R156 until the receiver just clamps into both space and mark outputs. This indicates that the CLI has just dropped out.

Adjustment of the discriminator is made by capacitors C83 and C88. Apply to the receiver input a 10 mv. signal taken from an oscillator set at fc Hertz (R5 at zero.) Connect a 1.5-0-1.5 milliammeter in the circuit at J1 and a VTVM across R84. Adjust C88 for zero current in the milliammeter and C83 for maximum voltage across R84, rechecking the adjustments alternately until no further change is observed. Remove the VTVM from across R84 and observe the milliammeter reading as the oscillator frequency is varied. Positive and negative peaks should occur at fc + 100 Hertz and fc-100 Hertz,

An alternate method of adjusting the carrier level Indicator and the input attenuator R5 in the field is described below. However this should be done only if there is doubt that the carrier level indicator is set wrong. Normally the only field adjustment necessary is that of R5 described under previous section "adjustments".

1. With a normal guard signal being received, connect an oscilliscope from the base of Q54 (probe) to terminal 18 (shield lead) of the amplifier-limiter board.
2. Set input attenuator R5 for the start of clipping (flattening of 20KHz signal peaks).
3. Note the R5 dial reading in dB, then reduce the attenuation by 5dB.
4. Set R156 on the carrier level indicator (CLI) board just to dropout. This is accomplished by first turning the screw-driver control of R156 clockwise until at least 2 ma. current is indicated on the associated milliammeter, then backing off until the receiver clamps into both

space and mark outputs. This indicates that the CLI has dropped out which occurs at approximately 0.75 ma.

5. Reduce the R5 dial reading by another 10 dB and tighten the locking screw. With this setting, the CLI current will be between 2.5 ma and 2.75 ma.

With the foregoing receiver setting, a 10 db drop in receiver signal will drop out the CLI for low signal indication while the receiver limiter still has a margin of 5dB before it drops out of saturation (clipping).

In case a check is desired of any of the delay times of the receiver (such as channel time), this can be done most conveniently by means of an oscilloscope with a calibrated triggered sweep. A two-pole toggle switch, checked to have less than 1 ms. interval between pole closures, can be used to impress the signal and trigger the sweep.

MAINTENANCE

Periodic checks of the received carrier signal and the receiver sensitivity will detect gradual deterioration and permit its correction before failure can result. The carrier level indicator, when provided, permits ready observation of the received signal level. With or without a carrier level indicator, an overall check can be made with the attenuation control R5. A change in operating margin from the original setting can be detected by observing the change in the dial setting required to drop out the alarm relay. If there is a substantial reduction in margin, the signal voltage at the receiver input should be checked to see whether the reduction is due to loss of signal or loss of receiver sensitivity.

All adjustable components on the printed circuit board are accessible when the door on the front of the panel is opened. (An offset screwdriver would be required for adjusting R12.) However, as described under "CONSTRUCTION", any board may be made entirely accessible while permitting electrical operation by using board extender Style No. 644B315G01. This permits attaching instrument leads to the various test points of terminals when making voltage, oscilloscope or frequency checks.

It is advisable to record voltage values 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 Table I and II. Voltages should be measured with a VTVM. Some readings may vary as much as ± 20%.

TABLE I
RECEIVER D-C MEASUREMENTS

Note: All voltage readings taken with ground of d-c VTVM on terminal 9 (neg. d.c.). Receiver adjusted for 15 db operating margin with Guard signal down 50 db. from 1 watt and Trip signal down 40 db. Unless otherwise indicated, voltage will not vary appreciably whether signal is Guard, Trip or zero.

Collector of Transistor	Volts (+)	
Q11	< 13	
Q12	15	(Mark or Space)
Q13	15	(Mark or space)
Q31	2.5	
Q32	2.5	
Q51	11.5	
Q52	12	
Q53	15.5	
Q54	2.5	
Q81	< 1	(No Sig. or Mark)
Q81	19.5	(Space)
Q82	< 1	(No sig. or Space)
Q82	19.5	(Mark)
Q101	< 1	(No Sig. or Space)
Q101	20	(Mark)
Q102	20	(No Sig. or Space)
Q102	< 1	(Mark)
Q103	20	(No. Sig. or Space)
Q103	< 1	(Mark)
Q104	< 1	(No Sig. or Space)
Q104	20	(Mark)
Q181	34	(No Signal)
Q181	< 1	(Space or Mark)
Q182	< 1	(No Signal)
Q182	20	(Space or Mark)
Q184	45	(No Signal)
Q184	20	(Space or Mark)
Q185	< 1	(No signal)
Q185	45	(Space or Mark)

Collector of Transistor	Volts (+)	
Q186	20	(No Signal)
Q186	< 1	(Space or Mark)
Q187	< 1	(No Signal)
Q187	20	(Space or Mark)
Q151	6	(No Signal)
Q151	6	(Space)
Q152	9.8	(No Signal)
Q152	10	(Space)
Q153	< 1	(No Signal)
Q153	19	(Space)
Q154	45	(No Signal)
Q154	< 1	(Space)

TABLE II
RECEIVER RF MEASUREMENTS

Note: Voltmeter readings taken between receiver input and Q32 are not meaningful or feasible because of waveform or effect of instrument loading. Receiver adjusted as in Table I.

Collector of Transistor	Volts at 10 watts
Q32	.8
Q51	.9
Q52	.65
Q53	2.2
Q54	4.5

FILTER RESPONSE MEASUREMENTS

The L-C input filter (FL-201) and the IF filter (FL-2) are in sealed containers, and repairs can be made only by the factory. The stability of the original response characteristics is such that in normal usuage, no appreciable change in response will occur. However, the test circuits of Figure 15 can be used in case there is reason to suspect that either of the filters has been damaged.

Figure 4 shows the -3 dB and -35 dB checkpoints for the IF filters, and the -3 dB checkpoints for the input filter. The response curve of the IF filter shows the combined effect of the two sections, and was obtained by adding the attenuation of each section for identical frequencies. The scale of Figure 4 was chosen to show the IF filter response, which permitted only a portion of the input filter curve to be shown. The checkpoints for the passband of each section of the IF filter are down 3 dB maximum at 19.75 and 20.25 kHz, and for the stop band are down 18 dB minimum at 19.00 and 21.00 kHz for each section. The signal generator voltage (Figure 15) must be held constant throughout the entire check. A value of 7.8 volts is suitable. The reading of the VM2 at the frequency of minimum attenuation should not be more than 22 dB below the reading of VM1. It should be noted that a limit measured in this manner is for convenience only and does not indicate actual insertion loss of the filter. The insertion loss would be approximately 16 db less then the measured difference because of the input resistor and the difference in input and output impedances of the filter.

In testing the L-C filter, a value of approximately 2.45 V· is suitable for the constant voltage at which to hold VM1 throughout the check. The reading of VM2 at the frequency of minimum attenuation will vary somewhat with the channel frequency, but should not be more than 18 dB below the reading of VM1. (The filter insertion loss is approximately 6 dB less than the difference in readings).

CONVERSION OF RECEIVER FOR CHANGED CHANNEL FREQUENCY

The parts required for converting a TCF receiver for operating on a different channel frequency consist of a new L-C input filter (FL201), a new local oscillator crystal (Y11) and probably a different feedback capacitor (C12). Because the wide range of channel frequencies precludes maintaining a factory stock of the various crystals, immediate shipment of the filter and the oscillator crystal cannot be made. After the crystals have been procured and the filter has been completed, it is recommended that the receiver be returned to the factory for the conversion and for complete test and adjustment. However, if the time that the receiver can be out of service must be kept to a minimum, the conversion may be made by customers who are equipped for this work.

RECOMMENDED TEST EQUIPMENT

I. Minimum Test Equipment for Installation.

a. A-C vacuum Tube Voltmeter (VTVM). Voltage range 0.003 to 30 volts, frequency range 60 Hz to 330 kHz, input impedance 7.5 megohms.

b. D-C Vacuum Tube Voltmeter (VTVM).

Voltage Range:	1.5 to 300 volts
Input Impedance:	7.5 megohms

c. Milliammeter, 0-3 range (if receiver has carrier level indicator).

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 330-kHz.

c. Oscilloscope

d. Frequency counter

e. Ohmmeter

f. Capacitor checker

g. Milliammeter, 0-1.5 or preferably 1.5-0-1.5 range for checking discriminator.

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, the electrical value, style number, and identify the part by its designation on the Internal Schematic drawing.

* ADDENDUM

With shipments of sets starting in early 1973, the germanium transistors used in the various modules were replaced with silicon transistors. In addition, due to the nature of silicon transistors, some resistor values in the circuits had to be changed in order to correctly bias these transistors. Therefore the transistors are not replaceable on a pin for pin basis throughout the receiver. Before attempting to replace a germanium transistor with a silicon transistor on older sets using germanium, please check the schematics on the following pages to see if the location where the replacement is desired has additional component changes. If that is the case, then the replacement can only be made by the same designation transistor or the additional component changes must also be made. It should be pointed out that the modules containing the silicon transistors are completely interchangeable with the modules containing germanium transistors. Therefore, there is no problem with intermixing the silicon transistor modules in the same receiver. Thus complete new modules containing silicon transistors can be ordered and used as replacements in older receivers having germanium transistor modules. The new modules have the same style numbers as the old germanium transistor modules they replace.

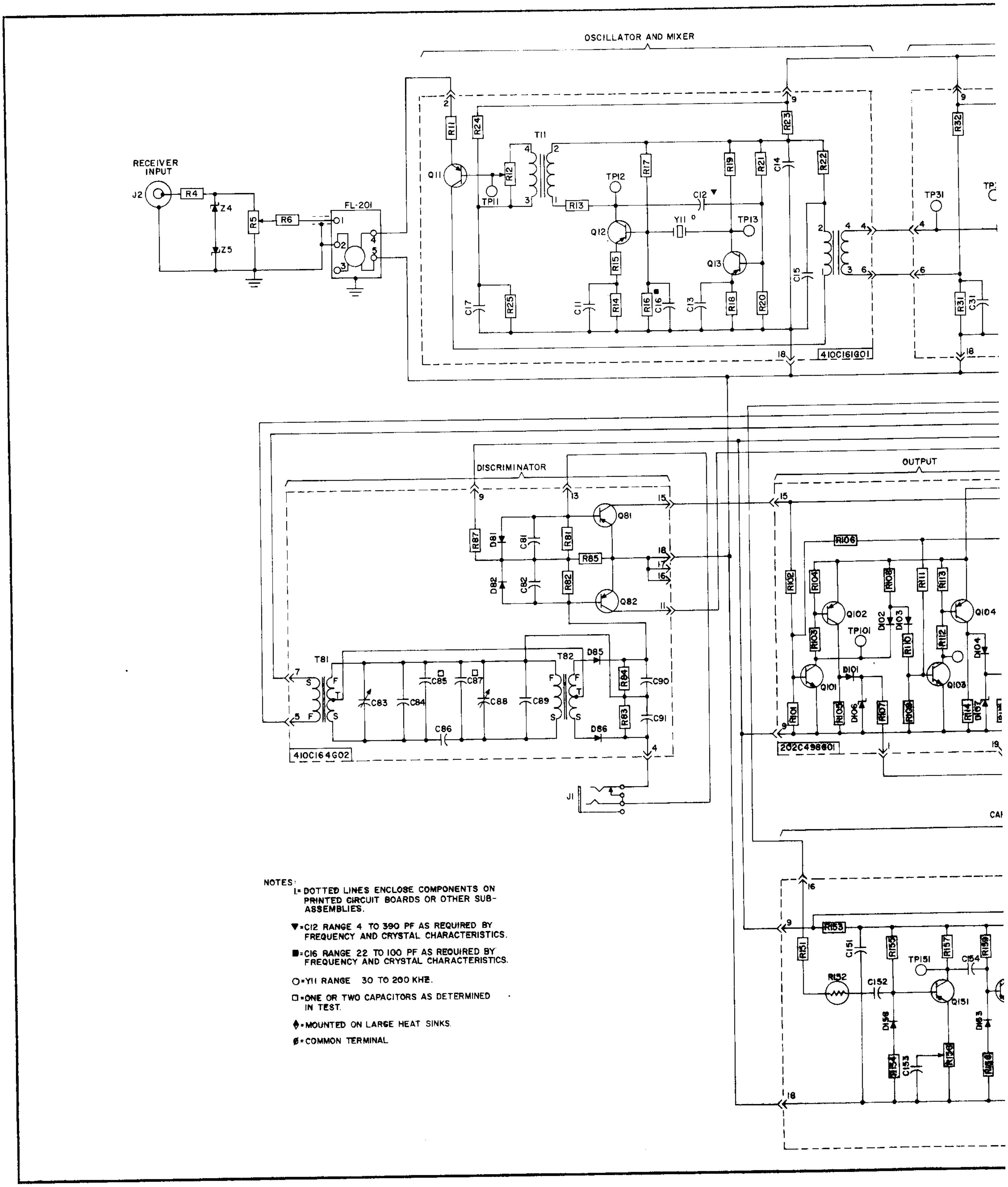
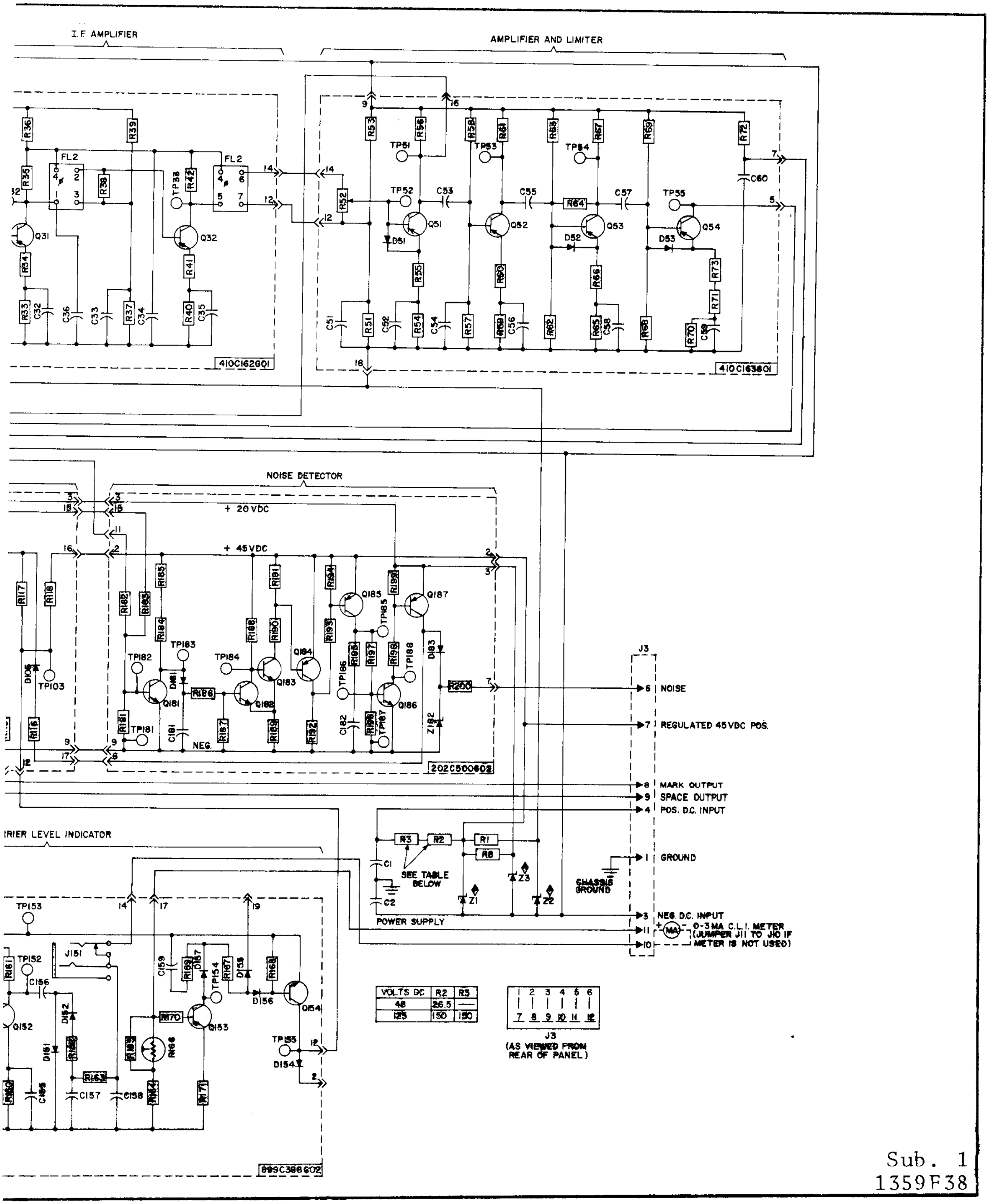


**Fig. 1 Internal schematic of the type TCF receiver under 2*



VOLTS DC	R2	R3
48	26.5	—
125	150	150

)0kHz (See pages 23-26 for electrical parts list)

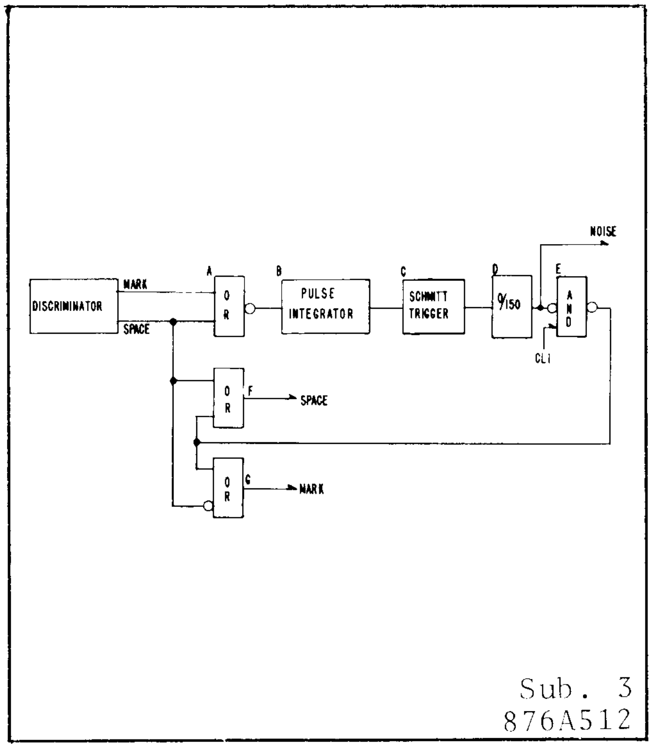
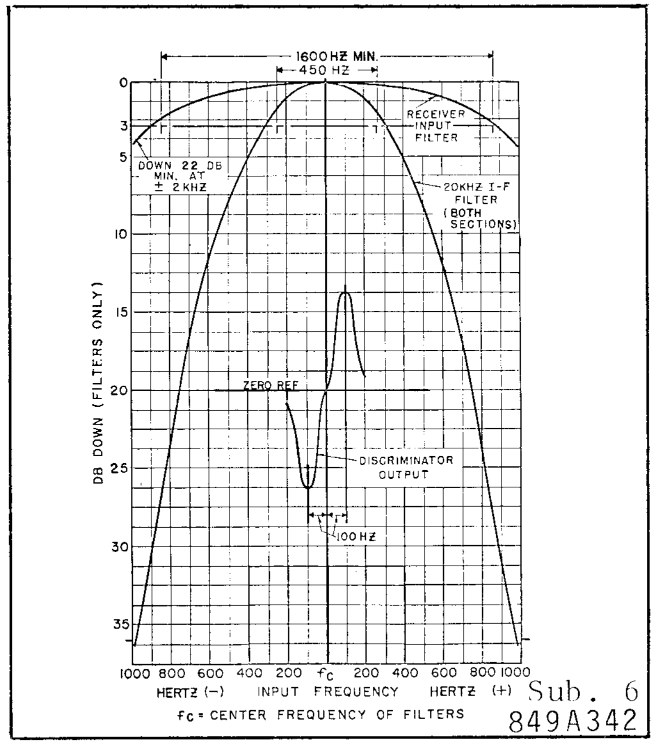
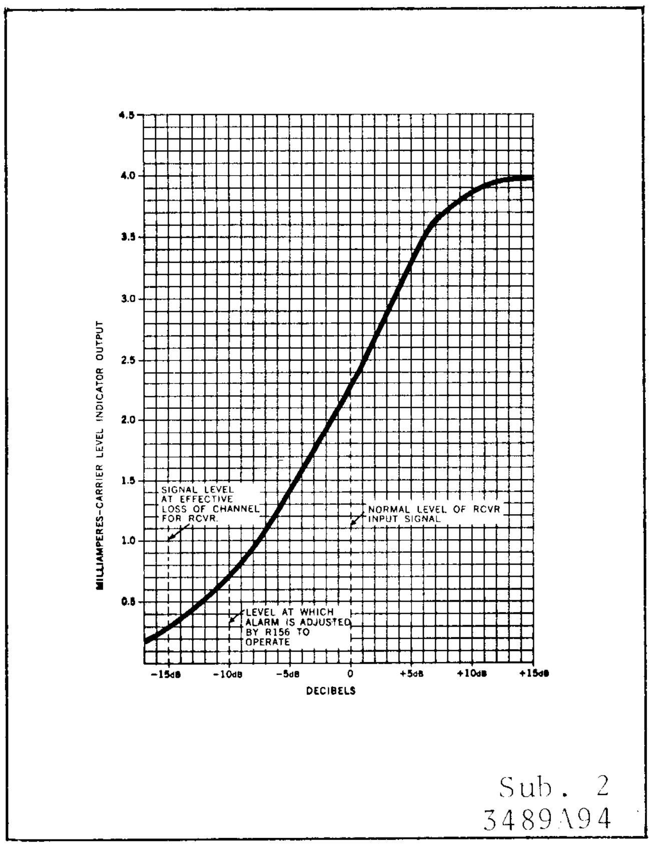


Fig. 3 Logic Diagram of Output Circuit



* *Fig. 4 Filter and discriminator characteristics of the type TCF receiver*



* *Fig. 5 Typical curve of the carrier level indicator current vs. receiver margin above minimum operating level.*

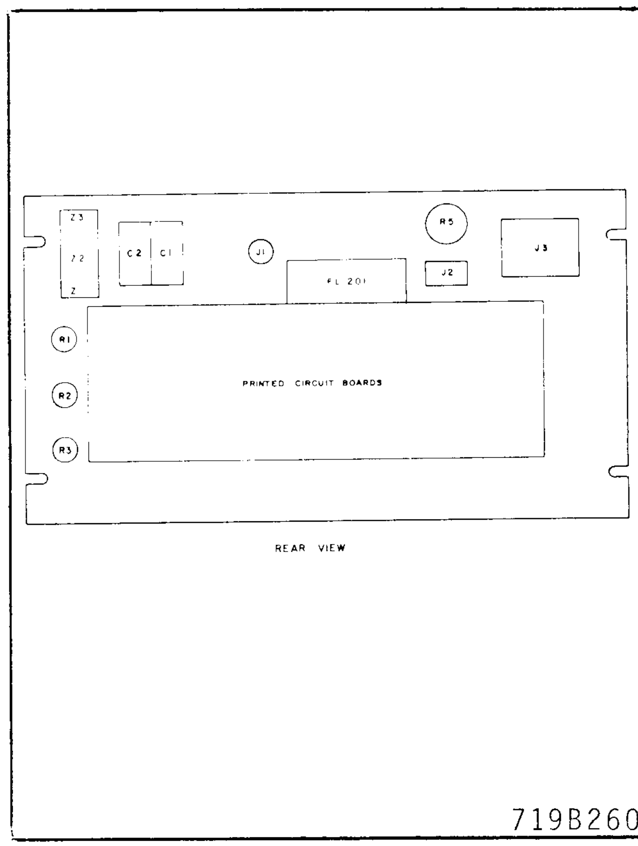
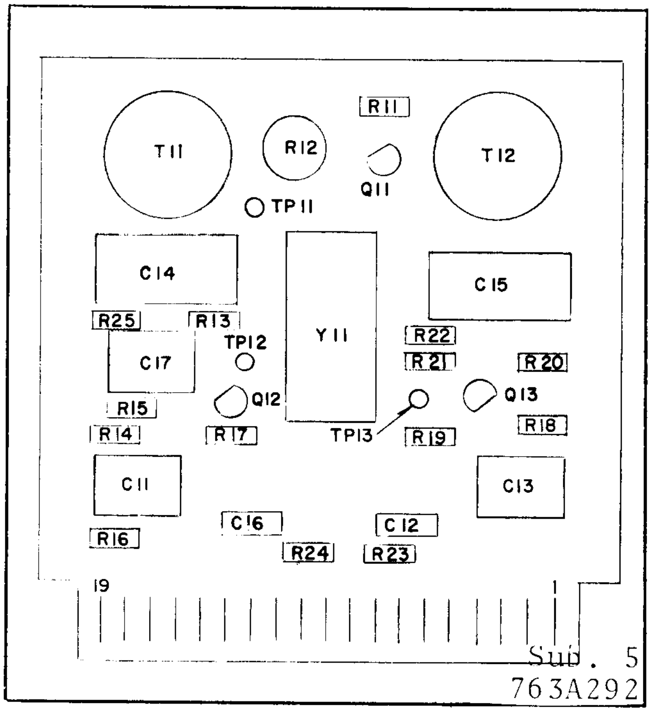
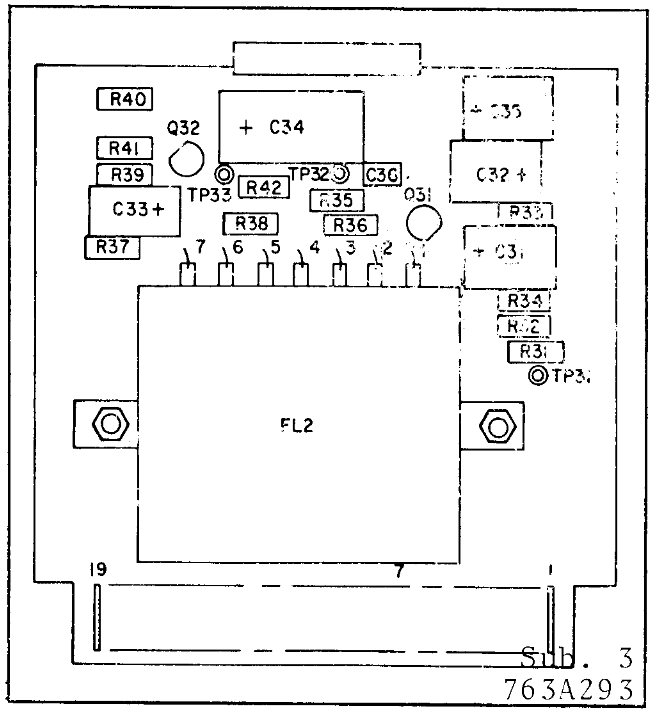


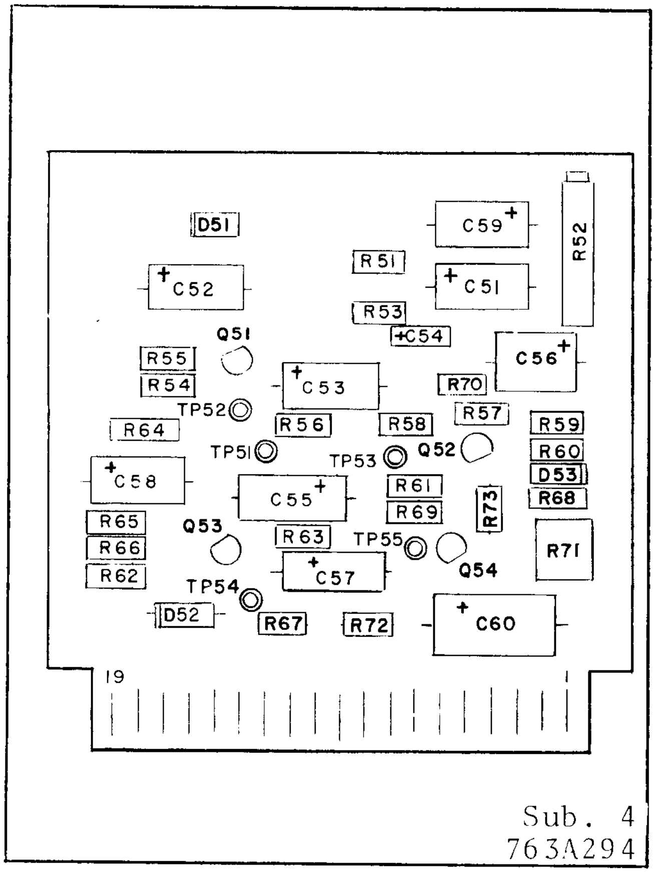
Fig. 6 Component locations on the type TCF receiver panel



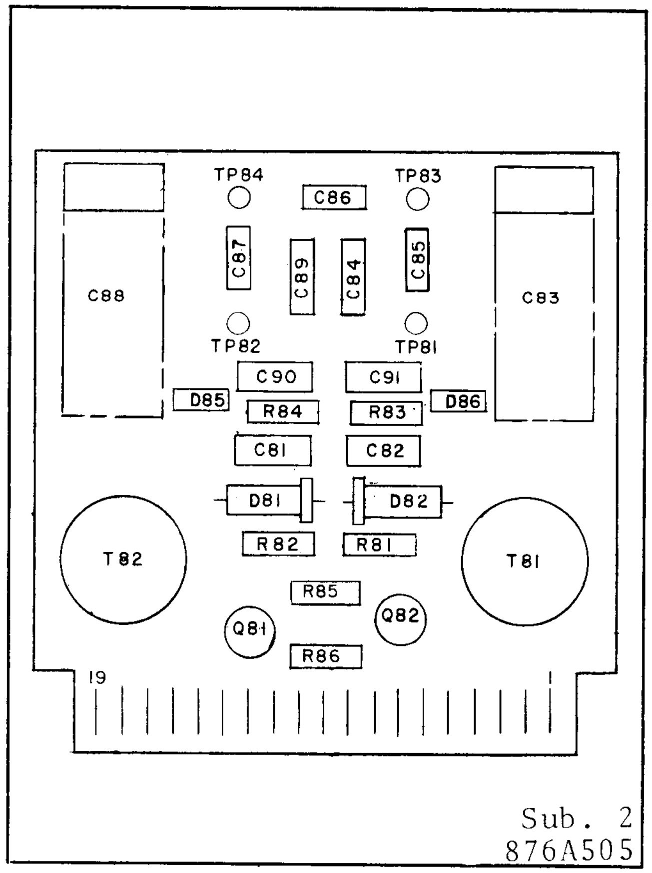
* *Fig. 7 Component locations on the oscillator and mixer printed circuit board.*



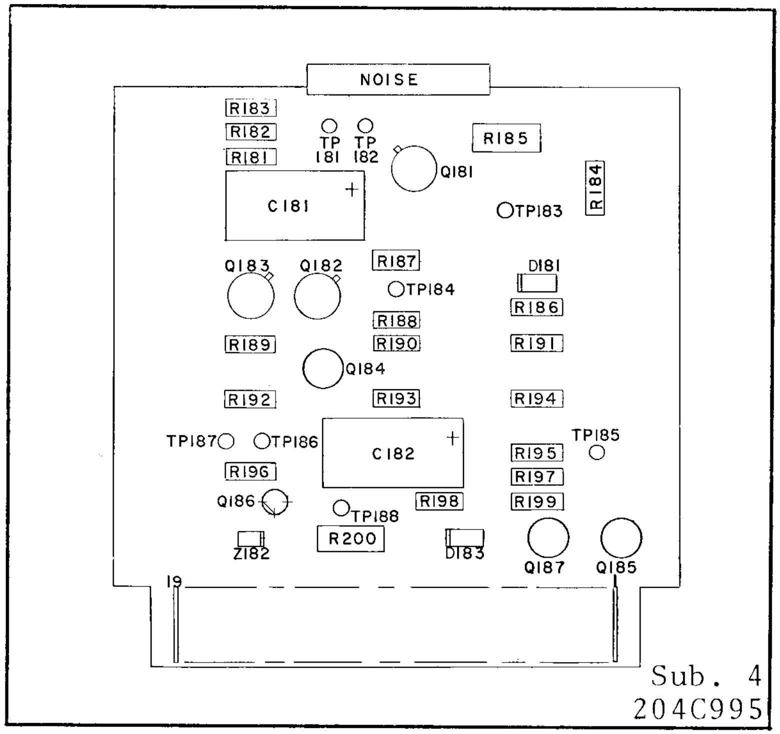
* *Fig. 8 Component locations on the I.F. amplifier printed circuit board.*



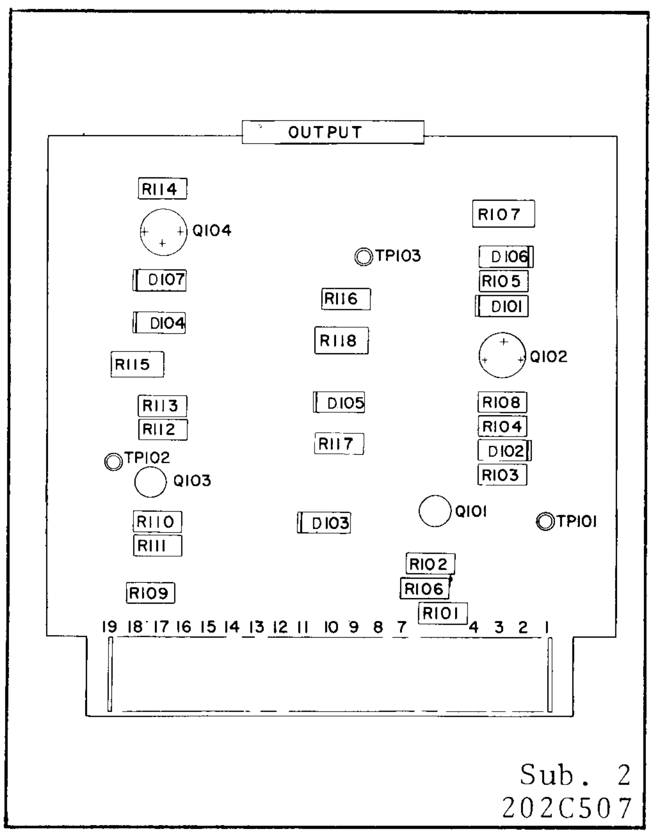
* *Fig. 9 Component locations on the amplifier and limiter printed circuit board.*



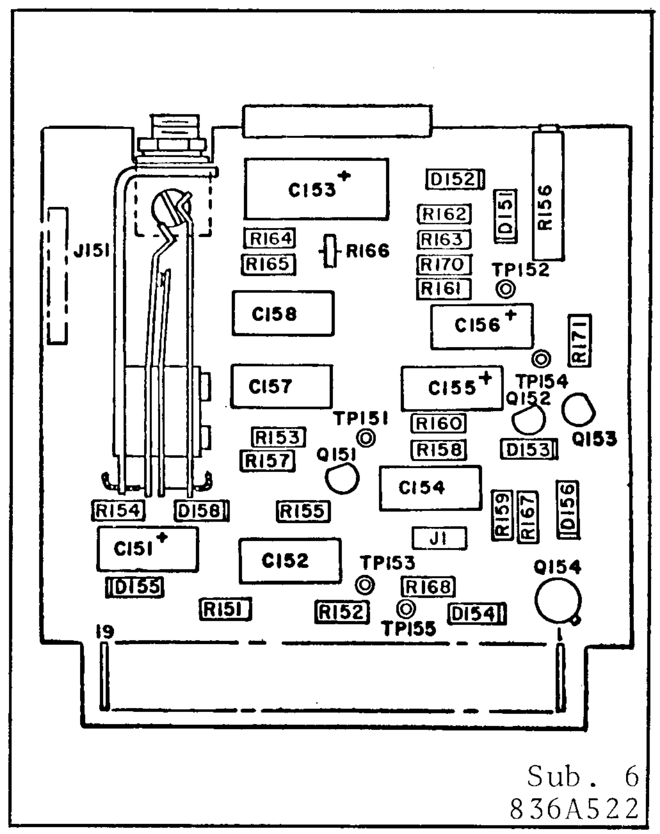
* *Fig. 10 Component locations on the discriminator printed circuit board.*



* *Fig. 11 Component Locations on the Noise Detector Printed Circuit Board.*



* *Fig. 12 Component Locations on the output printed circuit board.*



* *Fig. 13 Component Locations on the carrier level indicator printed circuit board.*

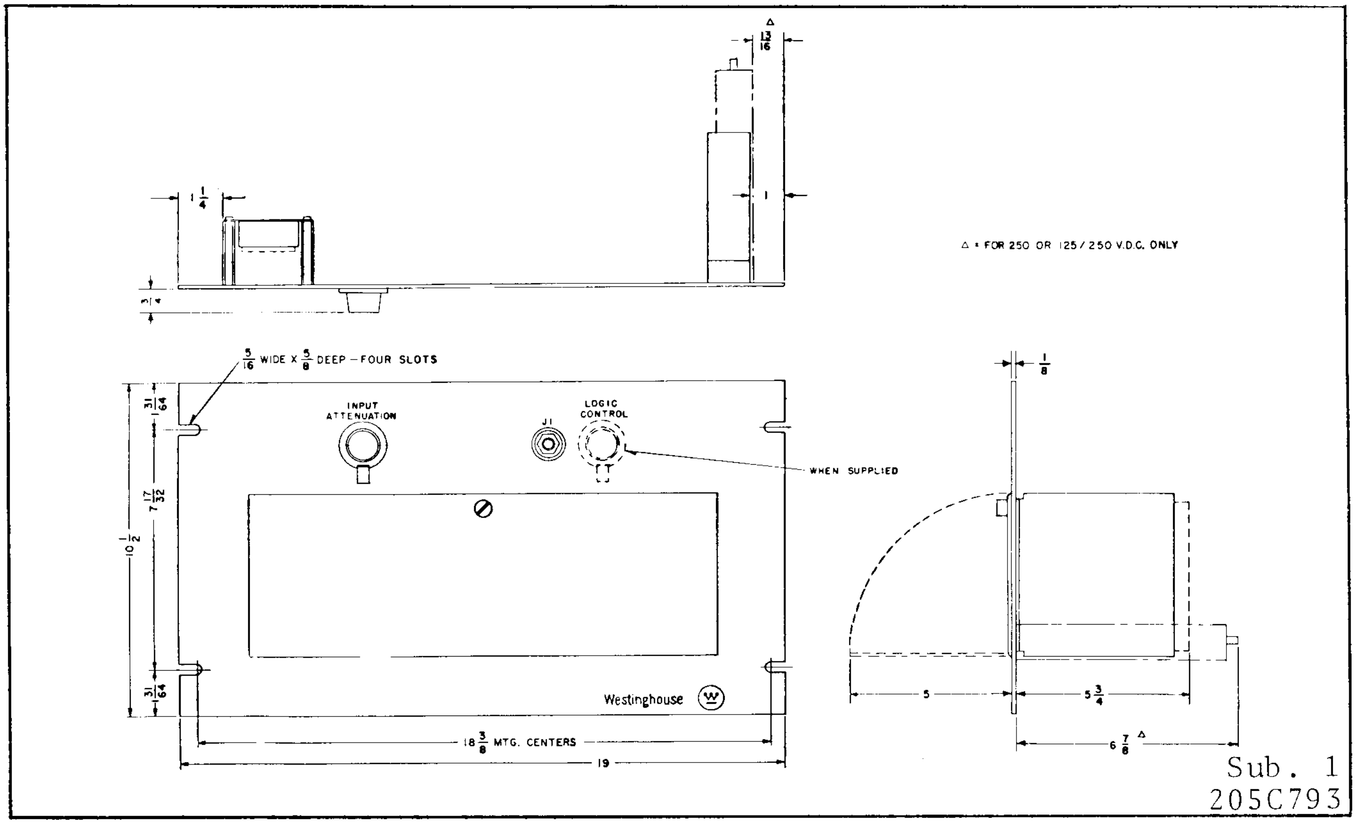


Fig. 14 Outline and drilling plan for the type TCF receiver assembly.

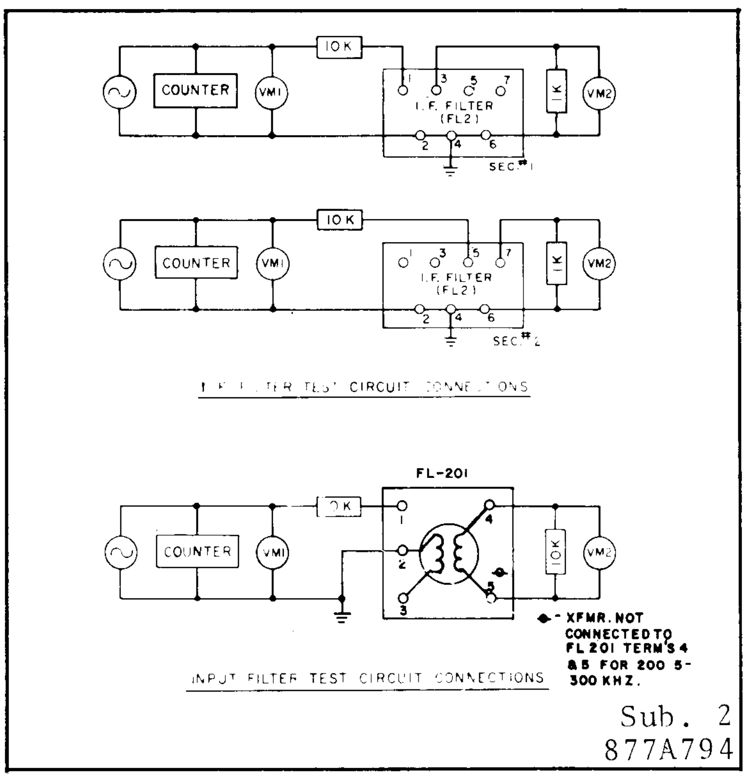
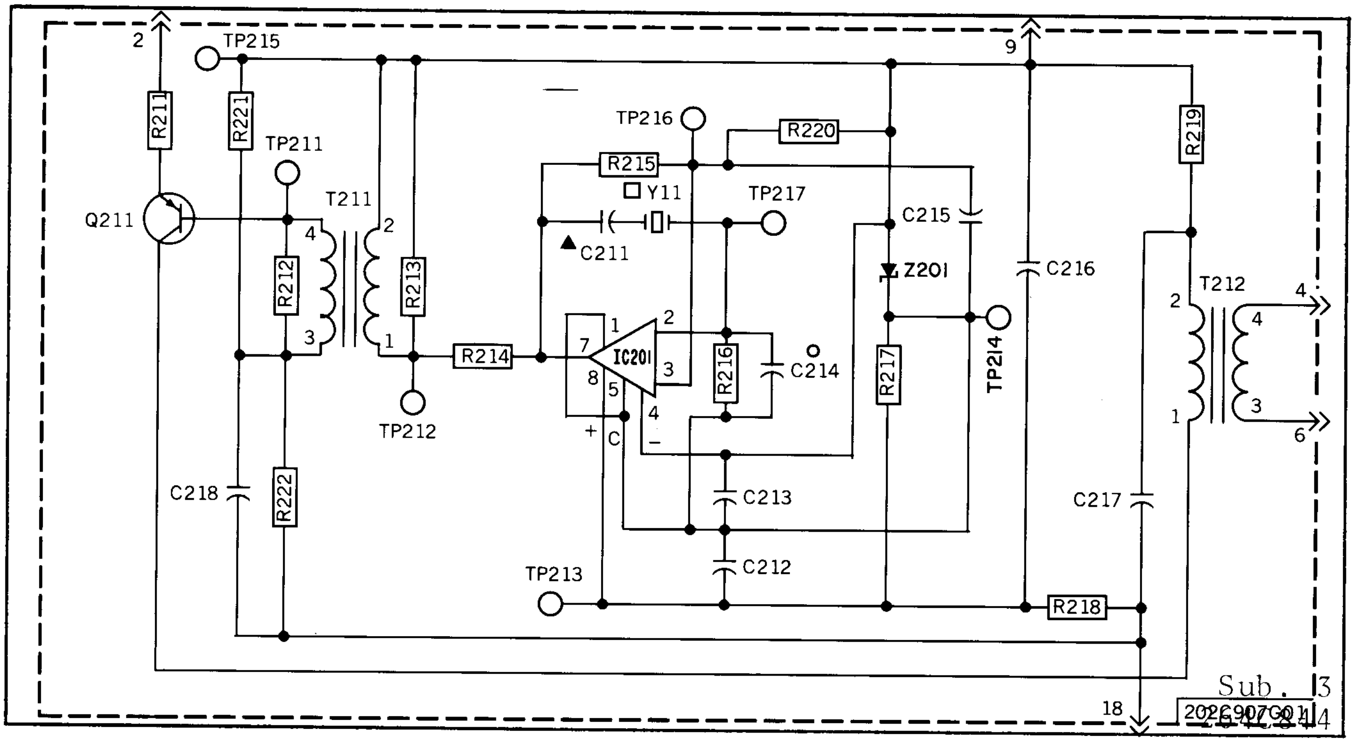
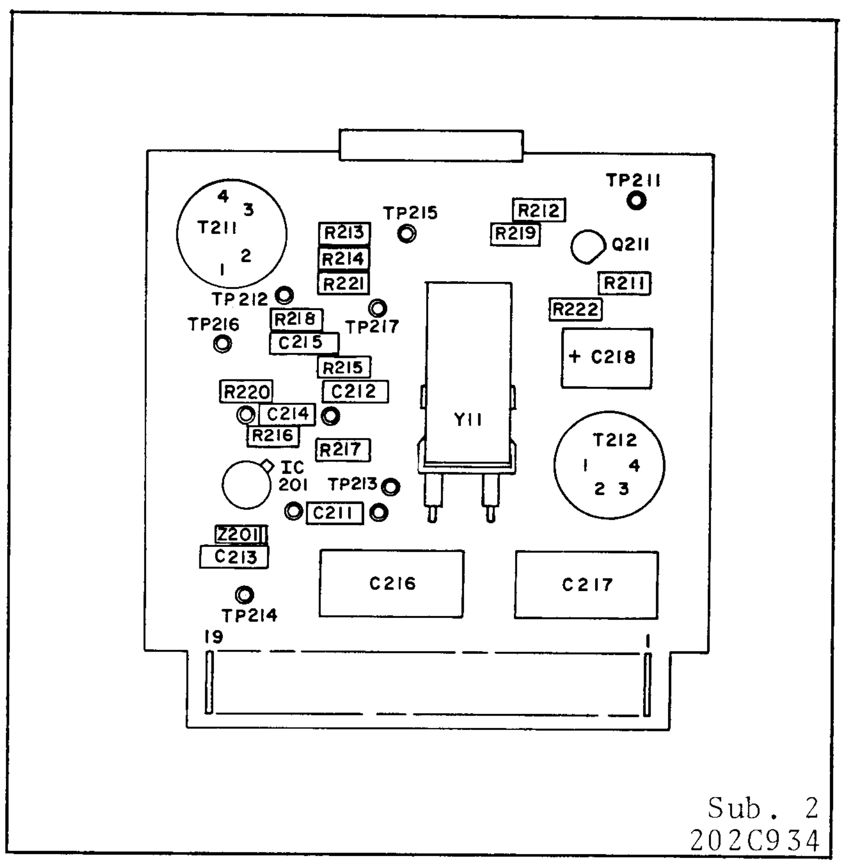


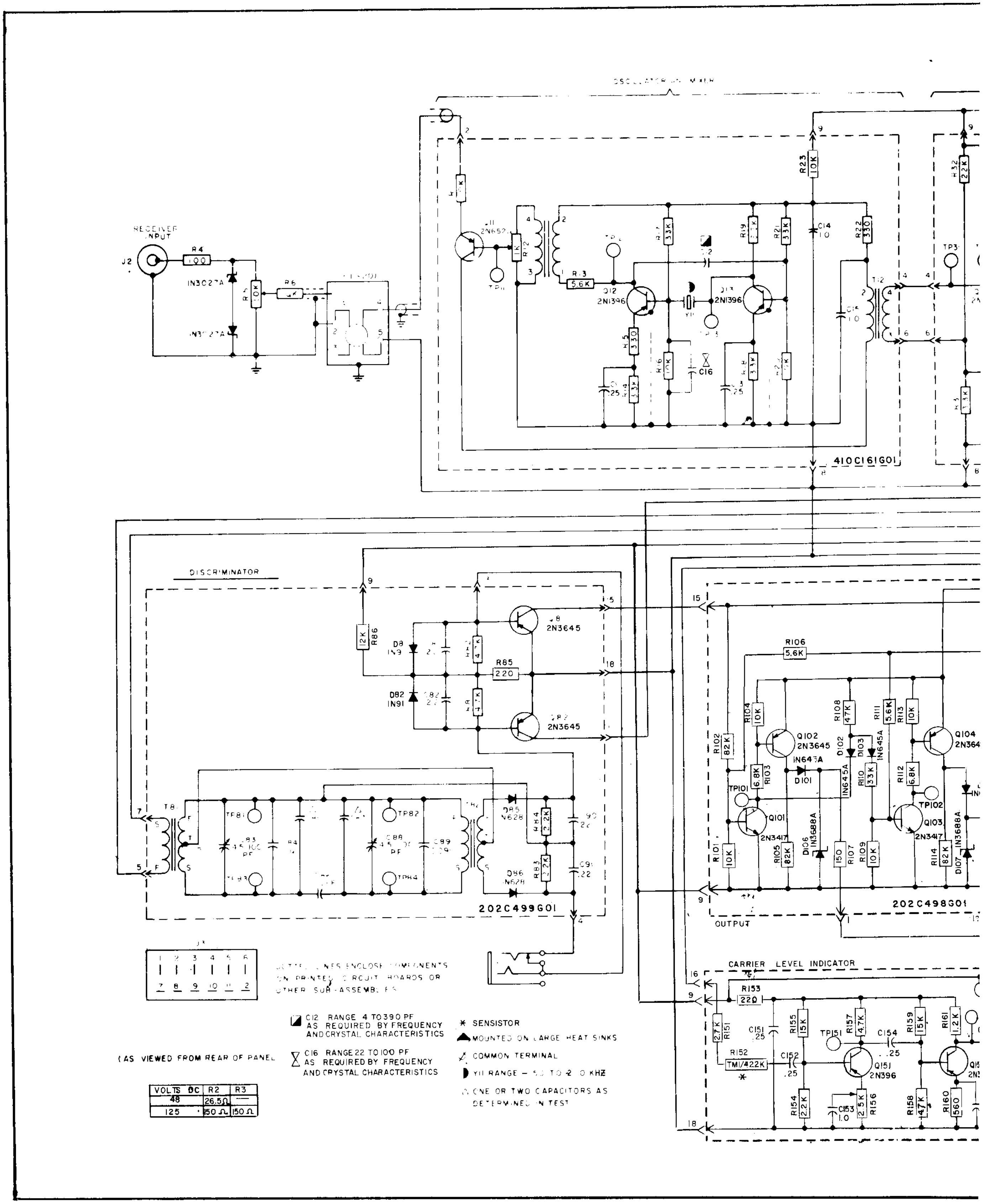
Fig. 15 Test Circuits for TCF Frequency Shift Receiver Filters.



* *Fig. 16. 200.5 to 300 kHz oscillator mixer board*

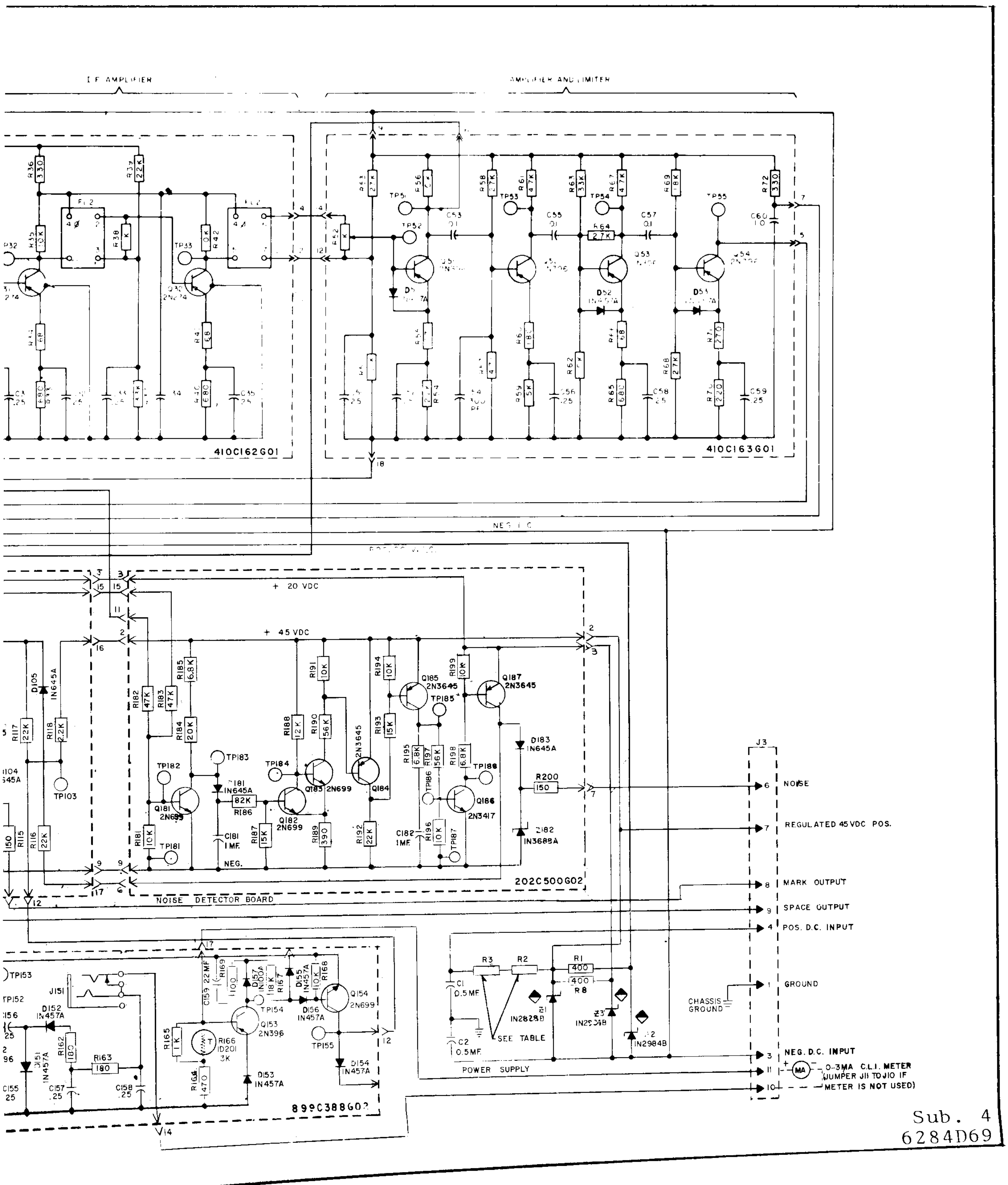


* *Fig. 17. Component Location 200.5 to 300 kHz oscillator mixer board.*



* Fig. 19 Internal schem

through early 1



...tic of the type TCF receiver - 1971

...973.

ELECTRICAL PARTS LIST FOR FIGURES 1 AND 2 (Cont'd)

AMPLIFIER & LIMITER-410C163G01

COMPONENT	STYLE	REQ	REF
TRANSISTOR			
Q51-Q52-Q53-Q54	849A441H03	4	2N4249
RESISTOR			
R66	187A290H21	1	68Ω 1/2W ±5%
R55	187A290H11	1	27Ω 1/2W ±5%
R70	184A763H11	1	220Ω 1/2W ±5%
R72	184A763H15	1	330Ω 1/2W ±5%
R65	184A763H23	1	680Ω 1/2W ±5%
R59	184A763H31	1	1.5K 1/2W ±5%
R54-R62	184A763H35	2	2.2K 1/2W ±5%
R64-R68	184A763H37	2	2.7K 1/2W ±5%
R51-R57-R61-R67	184A763H43	4	4.7K 1/2W ±5%
R56	184A763H51	1	10K 1/2W ±5%
R69	184A763H57	1	18K 1/2W ±5%
R53-R58	184A763H61	2	27K 1/2W ±5%
R63	184A763H63	1	33K 1/2W ±5%
R71	**629A531H04**	1	**68Ω 1/2W** ±2%
R60	184A763H09	1	180Ω 1/2W ±5%
R73	629A531H02	1	56 Ω 1/2W ±2%
CAPACITOR			
C54	187A584H15	1	1300MMF. 500V.
C51-C52-C56-C58-C59	187A624H02	5	.25MFD. 200V.
C53-C55-C57	187A624H01	3	0.1MFD. 200V.
C60	187A624H04	1	1.0MFD. 200V.
DIODE			
D51-D52-D53	184A855H07	3	1N457A
POTENTIOMETER			
R52	629A645H04	1	1K

NOISE DETECTOR-202C500G02

COMPONENT	STYLE	REQ	REF
TRANSISTOR			
Q181-Q182-Q183	184A638H19	3	2N699
Q184-Q185-Q187	849A441H01	3	2N3645
Q186	848A851H02	1	2N3417
RESISTOR			
R181-R191-R194-R196-R199	184A763H51	5	10K,-1/2W,±5%
R182-R183	184A763H67	2	47K, 1/2W,±5%
R184	184A763H58	1	20K, 1/2W,±5%
R185	184A763H47	1	6.8 K,-1/2W,±5%
R186	629A531H78	1	82K, 1/2W,±2%
R187-R193	629A531H60	2	1.5K,-1/2W,±2%
R188	184A763H53	1	12K, 1/2W,±5%
R189	184A763H17	1	390 1/2W,±5%
R190	184A763H69	1	56K, 1/2W,±5%
R192	184A763H59	1	22K, 1/2W,±5%
R195-R198	184A763H47	2	6.8K, 1/2W,±5%
R197	184A763H69	1	56K, 1/2W,±5%
R200	762A679H01	1	150 3W
CAPACITOR			
C181-C182	187A624H04	2	1MFD 200 V DC
ZENER DIODE			
Z182	862A288H01	1	1N3688A
DIODE			
D181-D183	837A692H03		1N645A

OUTPUT-202C498G01

COMPONENT	STYLE	REQ	REF
Q101-Q103	848A851H02	2	2N3417
Q102-Q104	849A441H01	2	**2N3645**

I.F. AMPLIFIER-410C162G01

COMPONENT	STYLE	REQ	REF
TRANSISTOR			
Q31-Q32	849A441H03	2	2N4249

RESISTOR			
R101-R104-R109-R113	184A763H51	4	10K, 1/2W, 5%
R102-R105-R114	629A531H78	3	82K, 1/2W, 2%
R103-R112	184A763H47	2	6.8K, 1/2W, 5%
R106-R111	184A763H45	2	5.6K, 1/2W, 5%
R107-R115	762A679H01	2	150 3W
R108	184A763H67	1	47K, 1/2W, ±5%
R110	184A763H63	1	33K, 1/2W, ±5%
R116-R117	184A763H59	2	22K, 1/2W, ±5%
R118	763A127H11	1	2.2K, 3W, ±5%
DIODE			
D101-D102-D103-D104-D105	837A692H03	5	1N645A
ZENER DIODE			
D106-D107	862A288H01	2	1N3688A

RESISTOR			
R34-R41	187A290H21	2	68Ω 1 2W ±5%
R36	184A763H15	1	330Ω 1 2W ±5%
R33-R40	184A763H23	2	680Ω 1 2W ±5%
R38	184A763H27	1	1K 1 2W ±5%
R31-R37	184A763H39	2	3.3K 1 2W ±5%
R35-R42	184A763H51	2	10K 1 2W ±5%
R32-R39	184A763H59	2	22K 1 2W ±5%
CAPACITOR			
C31-C32-C33-C35	187A624H02	4	25MFD. 200V
C34	187A624H04	1	1MFD. 200V.
C36	762A757H01	1	100 Pf.
FILTER			
FL2	762A613G01	1	

OTHER-THIS DWG. SEE SHEET I.

COMPONENT	STYLE	REQ	REF.
RESISTOR			
R1	1202587	1	400, 25W, ±5%
R2	04D1299H44	1	26.5, 40W, ±5%
R2	1202499	1	150, 40W, ±5%
R3	1202499	1	150, 40W, ±5%
R4	187A643H03	1	100, 1W, ±5%
R6	184A763H51	1	10K, 1/2W, ±5%
R8	1202587	1	400, 25W, ±5%
POTENTIOMETER			
R5	185A086H10	1	0-10K, 2W, ±10%
CAPACITOR			
C1-C2	1877962	2	0.5 MFD, 1500V
ZENER DIODE			
Z1 (1N2828B)	184A854H06	1	45V, 50W, ±5%
Z2-Z3 (1N2984B)	762A631H01	2	20V, 10W, ±5%
Z4-Z5 (1N3027A)	188A302H07	2	20V, 1W, ±10%
TELEPHONE JACK			
J1	187A606H01	1	
CONNECTOR			
J3	187A336H03	1	12 TERMS.
CRYTAL FILTER	*	1	

*= PER S.O.

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