INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE SKBU-2 AND TYPE SKBU-21 DUAL PHASE COMPARISON RELAYS

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

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

APPLICATION

The type SKBU-2 and SKBU-21 are high-speed relays used in conjunction with frequency shift type channels. Simultaneous tripping of the relays at each line terminal is obtained in less than 32 milliseconds for all internal faults within the limits of the relay settings.

The system is applicable to a voice-grade pilot-wire, micro-wave, or carrier channel.

In contrast to the carrier blocking scheme, this is a transfer trip system; accordingly, the blocking-start function is not required.

* The SKBU-2 and SKBU-21 relays may be applied to two-terminal or three-terminal lines. Two-terminal applications require one transmitter and one receiver per terminal. Three-terminal applications require one transmitter and two receivers per terminal.

All-distance supervision (distance relays provide the arming function for all internal faults) may be applied with both the SKBU-2 and SKBU-21 relays. For these applications, the link in the arming board must be open.

The overcurrent fault detector in the SKBU-2 relay responds to all fault types. Therefore, distance relays are not required to be used with the SKBU-2, although they may be added to improve arming sensitivity. The overcurrent fault detector in the SKBU-21 relay is not responsive to three-phase faults. Therefore, a distance relay, type SKDU-3, is required to supplement the fault detector for SKBU-21 applications.

TABLE OF CONTENTS

These instructions apply to SKBU-21 and SKBU-2 phase comparison relays for application to the following types of pilot channels.

1. TA-2 Tone Channel.
2. TA-2.1 Tone Channel.
3. ~~TCF Carrier Channel.~~
4. * TA-2.2 Tone Channel.
5. * MC-22 Microwave Channel.

CONSTRUCTION

The phase comparison relays consist of a composite positive and negative sequence current network, a saturating transformer, three isolating transformers, a 20-volt power supply, and printed circuit boards mounted on a standard 19-inch wide panel, 8¾ inches high (5 rack units). The SKBU-21 relay has a second saturating transformer in addition to these components. Edge slots are provided for mounting the rack on a standard relay rack.

Sequence Network

a. SKBU-21

The sequence filter consists of a three-legged iron core reactor and a resistor. The reactor is a four-winding reactor with two primary windings and two secondary windings. The secondary windings are connected to the resistor which consists of three tube resistors and a small formed resistor. One secondary winding and the resistor is a negative sequence current filter while the other secondary winding and the resistor is a positive sequence filter.

b. SKBU-2 Relay

The sequence filter consists of a three-legged iron core reactor and a set of resistors, R_1 and R_0. The reactor has three windings: two primary and a tapped secondary winding, wound on the center leg of an "F" type of lamination. The secondary taps are wired to the A, B and C tap con-

SUPERSEDES I.L. 41-954.5C, dated August 1972
* Denotes change from superseded issue.

EFFECTIVE JANUARY 1976

nections in the front of the relay (R_1 taps). Ro consists of three tube resistors with taps wired to F, G and H tap connections in the front of the relay. The R_0 resistor is a formed resistor associated with the tapped secondary of the reactor.

Saturating Transformer

a. SKBU-21 Relay

The voltage from the sequence network is fed into two saturating or mixing transformers. One transformer supplies a fault detector circuit and the other transformer supplies a keying circuit. Zero sequence current windings are included on the transformer.

b. SKBU-2 Relay

The voltage from the sequence network is fed into the tapped primary of a saturating transformer which has two secondary windings. One winding supplies the fault detector and the other winding supplies a keying circuit.

Isolating Transformer

Three isolating transformers are provided in the relay to isolate the dc voltages from the ac voltages. Two of the transformers are also used to energize solid-state circuit on alternate half-cycle of the power system frequency.

Power Supply

The solid-state circuits of the relays are regulated from a 20-volt supply on the relay panel. This voltage is taken from a Zener diode mounted on a heat sink. A voltage dropping resistor is provided between the source dc supply and the 20 volt regulated supply.

Printed Circuit Boards

Seven printed circuit boards are used in these relays: A fault detector board, protective relay interface board, supervision board, amplifier and keying board, output board and a relay board. The circuits of the supervision board, and the amplifier and keying boards vary with the frequency shift equipment used as a pilot channel.

All of the circuitry that is suitable for mounting on printed boards is contained in an enclosure that projects from the rear of the front panel and is accessible by opening a hinged door on the front of the panel. The printed circuit boards slide in 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 on the front of each board is labeled to identify its function in the relay.

1. **FD Board (Fault Detector Board)**

The fault detector board contains a resistor-Zener diode combination, a phase splitting network, a solid-state fault detector, and a frequency verifier circuit. The controls for setting pickup (S_1) and dropout (S_2) of the fault detector are mounted on a plate in the front of the relay. This unit operates when the fault current exceeds a definite value.

The location of components on the board is shown in Fig. 3 and the schematic of the board is shown in Fig. 4.

2. **Arming Board**

The arming board contains AND circuits that compares pulses produced by the circuits of the amplifier and keying board. An output is obtained that is proportional to the time difference in the phase. This board contains other logic circuits that will arm the trip output, set up the time delay of the trip output, and start transient blocking on external faults. A link is provided on this board such that the relay is armed by either solid state distance fault detectors or the SKBU fault detector. The link must be open for arming by the solid state distance fault detector only.

The location of components on the board is shown in Fig. 5 and the schematic of the board is shown in Fig. 6.

3. **Ampl. and Key Board (Amplifier and Keying Board)**

The amplifier and keying board contains two local squaring amplifiers, a transmitter keying circuit, and four remote squaring amplifiers. These These circuits produce the pulses that are compared by the AND circuits of the arming board to determine if the fault is external or internal. Links are provided on this board to connect the relay for two or three terminal operation. For two terminal applications, link 1 and link 2 on the Amplifier and Keyer Board must be connected C to 2. For three terminal applications, these links must be connected C to 3.

*

Because of the different keying requirements of the various pilot channels, this board varies with the different types of channels to which it is connected. The following table is with reference to the different figures that apply for the amplifier and keying board for the various type channels.

TYPE CHANNEL	LOCATION OF COMPONENTS	SCHEMATIC OF BOARD
TA-2	Fig. 7	Fig. 8
* TCF, TA2.2, MC-22	Fig. 9	Fig. 10

4. **Output Board**

The output board contains a 4-millisecond pickup and instantaneous dropout timer circuit, trip AND circuit, trip amplifier, transient blocking and unblocking circuits and two timer circuits. The trip AND operates when all the inputs to the arming board are of the correct polarity and the fault detector has operated. The transient blocking circuit operates after a time delay on external faults, and the transient unblock circuit operates after a time delay on a sequential fault (external fault followed by an internal fault).

The following figures apply to this board: Fig. 11 Component Location; Fig. 12 Schematic of the Board.

5. **Relay Board**

The relay board contains the phase delay circuit for shifting the local signals with reference to the remote signals. It also contains a low-pass filter. For the SKBU-21 relay, a Zener clipper-resistor combination is provided for protection of the solid-state circuits.

The following figures apply to this board: Fig. 13 Component Location; and Fig. 14 for the Schematic of the Board.

6. **Supervis. Board (Supervision Board)**

The number of circuits on this board varies with the application. However, for all applications interface circuits to the channel receivers and a 150 millisecond pickup and 0 millisecond dropout alarm timer circuit is provided on this board. The interface circuits connects the SKBU relay to the channel receiver, and the timer circuit locks out the relay for failure of the channel equipment. For tone channels a noise circuit is also provided to lockout the relay from information supplied by the tone equipment.

Because the board varies with the channel equipment, the following figures apply to the board.

TYPE CHANNEL	LOCATION OF COMPONENTS	SCHEMATIC OF BOARD
TA-2	Fig. 15	Fig. 16
TA-2.1	Fig. 15	Fig. 35
TCF, TA2.2, MC-22	Fig. 17	Fig. 18

7. **Pr. Inter. Board (Protective Relay Interface Board)**

The protective relay board contains logic circuits to connect the distance fault detectors, and squelch relays into the phase comparison relaying system. This board contains buffer circuits, and OR circuits to connect the relays into the system. A 6/0 timer circuit, 10/150 signal squelch circuit, and 2.5 second alarm circuit for sustained fault detector operation are also provided on this board.

Card Extender

A card extender (style no. 644B315G02) is available for facilitating circuit voltage measurements or major adjustments. After withdrawing anyone of the circuit boards, the extender is inserted into the terminal block on the front of the extender. This restores all components and test points on the boards are readily accessible.

Test Points

Test points are located on each printed circuit board for the major components on the board. Complete circuit test points are wired to the front panel of the relay for convenience in adjusting and testing the relay.

OPERATION

A. System

In a phase comparison relaying, the phase position of fault currents at the ends of a transmission line are compared over a pilot channel to determine if the fault is internal or external to the line section. When a frequency shift channel is used as the pilot channel, a dual comparison system can be utilized. This means that the system can trip on either half-cycle or power system frequency as contrasted to a blocking scheme where tripping occurs on alternate half-cycles during the absence of a carrier signal.

a. SKBU-21 Relay

The three-phase line currents energize a sequence network in the SKBU-21 relay which produces two single-phase output voltages that are proportional to either the positive sequence current or the negative sequence current. The single-phase voltages are applied to two saturating or mixing transformers, one which energizes the fault detector circuit and the other energizes the keying circuit of the SKBU-21 relay through a low-pass filter. The keying circuit shifts the frequency of the transmitter from a space frequency to a mark frequency. These frequencies are transmitted over the pilot channel to the receiver which converts the mark and space frequencies to two dc output voltages, a space output that corresponds to the mark frequency. Thus, on each half-cycle of power system frequency either a space or mark output is obtained from the receiver and applied as pulses to the remote squaring amplifiers of the SKBU-21 relay. Each of these half-cycle pulses are compared with the phase positions of each half-cycle of the voltage from the sequence network of the SKBU-21 relay at the receiver terminal. The space pulse is compared to one half-cycle of the voltage and the mark pulse to the other half-cycle. If the local and remote pulses are in an internal fault relationship and the fault detector has operated, tripping will occur 5 milliseconds later through operation of the trip AND and trip amplifier circuits on the output board of the relay.

b. SKBU-2 Relay

The three-phase line currents energize a sequence network in the SKBU-2 relay which produce a single-phase output voltage proportional to a combination of sequence components of the line current. This single-phase voltage energizes the primary of a saturating transformer with two secondary winding. One secondary winding energizes the fault detector circuit and the second secondary winding energizes the keying circuit of the relay through the low pass filter. The keying circuit shifts the frequency of the transmitter from a space frequency to a mark frequency. These frequencies are transmitted over the pilot channel to the tone receiver which converts the mark and space frequencies to two dc output voltage, a space output that corresponds to the space frequency and a mark output that corresponds to the mark frequency. Thus, on each half cycle of power system frequency either a space or mark output is obtained from the tone receiver and applied as pulses to the remote squaring amplifiers to the SKBU-2 relay. Each of these half-cycle pulses are compared with the phase positions of each half-cycle of the voltage from the sequence network of the SKBU-2 relay at the tone receiver terminal. The space pulse is compared to one half cycle of the voltage and the mark pulse to the other half-cycle. If the local and remote pulses are in an internal fault relationship and the fault detector has operated, tripping will occur 5 milliseconds later through operation of the trip AND and trip amplifier circuits on the output board.

Current transformer connections to the sequence networks at the two line terminals are such that the space and mark pulses are in phase with their respective local pulses during an internal fault to allow tripping. However, if the fault is external to the protected line section, the space and mark pulses are out-of-phase with their respective local pulses and tripping does not occur.

The four-millisecond delay previously mentioned is added to allow for differences in current transformer performance at opposite line terminals and relay coordination.

B. Relay

With reference to the logic diagram that applies to the particular relay, the three-phase line currents energize a sequence filter that varies with the type of relay.

a. SKBU-21 Relay

In the SKBU-21 relay, the sequence filter produces two single phase voltages: One voltage proportional to the positive sequence current, and the other voltage proportional to negative sequence current. These voltages are applied to primary windings of two saturating transformer where they are mixed to produce two separate secondary voltages proportional to a combination of sequence components. Zero sequence windings are included on the two transformers.

b. SKBU-2 Relay

In the SKBU-2 relay, the sequence filter produces a single phase voltage proportional to a combination of sequence components. This voltage is applied to the primary winding of a saturating transformer which produces two secondary voltages.

The secondary voltages are applied to two separate boards:

1. Fault Detector Board
2. Relay Board

1. Fault Detector Board

With reference to the schematic dwg. of Fig. 4, the ac voltage is applied to terminals 6, 5 and 3 of the fault detector board. This voltage is then applied to a phase-splitting network (C52, R52, R53) and a polyphase rectifier (diodes D51 to D56). The dc voltages obtained from the rectifier are applied to the fault detector circuit (Q51, Q52, Q53, Q54) which operates when the dc input "signal" exceeds a predetermined value.

Fault Detector (FD)

Under normal conditions, transistor Q51 has no base "signal" and is turned off. The collector of Q51 is at positive potential and provides base drive to transistor Q52, driving it to conduction. With Q52 conducting there is no base drive to transistor Q53 and Q53 is turned off. This condition keeps transistor Q54 in a non-conducting state, equivalent to an open-circuit.

When a fault causes the dc input voltage from the polyphase rectifier (across S_1 and R54) to exceed the 6.8 volt rating of Zener diode Z52, a positive input is applied to the base of Q51 causing it to conduct. In turn, Q52 stops conducting, and capacitor C54 charges, giving a few milliseconds time delay before Q53 and Q54 are switched to full conduction, thus "closing" the fault detector. When the fault detector operates, a positive input is applied to the arming board at terminal 12. The feedback path of resistors R66 and S2 increase the voltage to Z52 after the fault detector operates. This seals in the fault detector and allows the fault detector to drop at a high dropout ratio when the ac current is reduced.

Frequency Verifier (FV)

During certain switching conditions, such as energization of a transmission line, residual currents and voltages may exist of higher frequencies than 60 hertz. The frequency verifier prevents fault detector operation when frequencies 120 hertz or higher are encountered during the switching conditions. The frequency verifier circuit consists of two functional parts: Zero-crossing and commutator circuits. With reference to Fig. 4, the zero-crossing circuit consists of Q55, Q56, Q57 and Q58. The commutator circuit consists of Q59, Q60, C58, C59, Z54 and Q61.

During either the positive or negative half-cycles of the output voltage from the mixing transformer, Q55 or Q57 transistors are driven into saturation by the output of the FV transformer (T3). Transistors Q56 or Q57 conduct until capacitors C56 or C57 respectively are fully charged. While either capacitor charges, a voltage output in the form of very narrow pulse is developed across R76 and R78 resistors. This pulse triggers Q59 control switch. When transistors Q55 or Q57 are not conducting, C56 and C57 capacitors discharge respectively through D66 or D62 and the parallel combination of R73 and R74 or R69 and R70.

While Q59 is "on" its anode (TP-60) is only about 0.7 volts above negative, thus turning off transistor Q62 to allow capacitor C60 to start charging. However, a shorter time delay (consisting of R84, the capacitor C59 and the reference Zener diode Z54) of 4.3 milliseconds is also started. After 4.3 milliseconds of delay, the control switch Q60 fires applying the voltage of capacitor C58 across C59 turning it off. This raises the potential of the Q59 anode to turn on Q62 to discharge C60 before the charge reaches a value to break down Z55 to turn on Q63. After the next zero-crossing pulse Q59 switch is turned on again, and the Q60 switch is turned off by capacitor C58. Transistor Q61, when turned on and off by the same voltage that fires the gate of Q59, discharges timing capacitor C59, when on. This starts the timing cycle with close to zero charge on the capacitor. If the zero crossing period of the FV voltage is less than 4.3 milliseconds, the Q61 transistor discharges the timing capacitor to prevent Q60 from turning on. This keeps Q59 switch on to allow C60 to charge to a value to break down Zener diode Z55 to turn on Q63. Turning on Q63 prevents Q53 of the fault detector from turning on, thereby preventing Q54 from turning on and this prevents an output from the fault detector.

2. Relay Board

With reference to Fig. 14, the ac voltage from either the second saturating transformer (SKBU-21) or the second winding of the single transformer (SKBU-2) is applied to terminals 10 and 12 of the relay board. This voltage is applied to the phase delay circuit through a low pass filter. The low pass filter (C201, L201, C202) removes the harmonics from this voltage and applies a voltage that is essentially sinusoidal in waveform to R202 and R203 of the phase delay circuit. The phase delay circuit consists of R202, R203, C203 and S5 mounted on the front panel of the relay. By means of capacitor C203 and variable resistor S5, the voltage across terminal 4 and 2 can be made to lag the voltage across terminal 10 and 11 by a definite amount depending on the setting of S5. Each of these two voltages are applied to separate isolating transformers.

1. Undelayed voltages (terminals 10 and 11) to keying transformer (T1).
2. Delayed voltage (terminals 4 and 2) to local transformer (T2).

a. Keying Circuit

With no ac output (Ref. Fig. 8 or 10) voltage from the sequence network, transistor Q1 has no base current from terminals 2 and 8 of the amplifier and keying circuit. The collector of Q1 is at positive potential which allows base current to flow from positive 20 volts dc to the base of Q2 through R2 and R3. This applies negative potential to the collector of Q3 to prevent base current from flowing to Q3. Since Q2 is conducting, transistor Q3 does not conduct and the collector of Q3 is held at positive potential. As a result, transistor Q4 does not conduct.

When a sinusoidal voltage is applied to the keying transformer (T_1), the transformer steps up the voltage applied to terminals 2 and 8 of the amplifier and keying board. On the positive half-cycle of this voltage, terminal 8 is more positive than terminal 2 and transistor Q1 does not conduct.

In turn Q2 remains conducting and Q3 does not turn on. On the negative half-cycle of sine wave voltage from the keying transformer (T_1), terminal 2 is more positive than terminal 8 and base current flows in Q1. This turns Q1 on which applies negative potential to the collector of Q1. Base current to transistor Q2 is stopped and Q2 stops conducting, and its collector goes to positive potential. Positive potential is thus applied to the base of Q3 through R6 to turn on Q3. When Q3 conducts, its collector is connected to negative potential and Q4 will conduct. Thus an alternate half-cycles of the 60-hertz voltage from the low pass filter, Q4 turns on. By connecting Q4 through the proper interface to the channel transmitter, turning on Q4 keys the transmitter to a mark condition.

Q3 can be prevented from turning on and off by a negative signal applied to terminal 3 of the board. This is the input terminal from the signal squelch circuit of the protective relay board. With a negative input into terminal 3, Q3 will not turn on even though Q1 and Q2 are being turned on and off from the ac voltage applied to terminals 2 and 8.

b. Local Squaring Amplifiers (1 and 2)

There are two identical local squaring amplifiers in the SKBU-21 and SKBU-2 relays. (Number 1 Q5, Q6, Q7 and number 2 Q12, Q13 and Q14.) One is turned on and off by the positive half-cycle of voltage from the local transformer (T2) while the other one is turned on and off by the negative half-cycle of voltage from the transformer (T2). The square wave output voltages are, therefore, functions of the ac voltage input to the amplifiers. The polarity of the outputs of the two amplifiers are such that one amplifier has an output and the other one does not when ac voltage is applied to the local transformer. With no ac signal applied to the local transformer, both local amplifiers have a positive output. (This is a blocking signal to the AND circuits of the arming board.)

With reference to amplifier number 1 of either Fig. 8 or 10, with no ac input voltage, Q5 is not conducting and the collector of Q5 is at positive potential. This applies base current to transistor Q6 through R14 and R15 such that Q6 is turned on. This allows base current to flow in Q7. Q7 turns on to apply positive potential across R19 (blocking condition).

With the application of a sine wave voltage to terminals 5 and 18 of the amplifier and keying board, on the positive half-cycle of the voltage, the base of transistor Q5 is more positive than the emitter and Q5 (amplifier 1) conducts, and Q12 (amplifier 2) is turned off. On the negative half-cycle of the ac voltage, Q5 is turned off and Q12 is turned on. Therefore, Q5 is conducting on the positive half-cycle of ac voltage and Q12 is conducting on the negative half-cycle of ac voltage. Turning Q5 on, turns off transistor Q6. Transistor Q6 stops conducting and its collector goes to a positive potential which turns off Q7. Thus the output of the squaring amplifier is a square wave voltage ranging from 0 volts dc to 20 volts dc depending upon the polarity of the voltage from the phase delay circuit.

Amplifier 2 is the same as amplifier number 1 except it is supplied by the opposite polarity of sine wave voltage from the local transformer (T2) at terminals 5 and 18 of the amplifier and keying board. The output voltage from this amplifier appears across R42. By applying the same analysis of amplifier 1 to amplifier 2, the output voltage across R42 is a square wave voltage of the reversed polarity than that across R19.

c. Remote Squaring Amplifiers

As shown in Fig. 7, there are four remote squaring amplifiers in both the SKBU-2 and SKBU-21 relays (number 3 Q8, Q9, number 5 Q10, Q11, number 4 Q15, Q16 and number 6 Q17 and Q18). Two amplifiers connect the space outputs of two receivers to the relay while the other two amplifiers connect the mark outputs of the two receivers to the relay. For a TA-2 tone channel, space squaring amplifier 3 consists of transistors Q8 and Q9 on the amplifier and keying board in conjunction with an interface circuit of Q13 and Q1 on the supervision board. Mark remote squaring amplifier 4 consists of Q15 and Q16 on the amplifier and keying board and interface transistor Q14 and Q2 on the supervision board (see Fig. 37). For a TCF carrier channel, space squaring amplifier 3 consists of Q1 on the supervision board and Q8 and Q9 on the amplifier 4 consists of Q2 on the supervision board and Q15 and Q16 on the amplifier and keying board. (See Fig. 38)

The remote squaring amplifiers are in one of three states:

1. Loss-of-channel state.
2. Receiving space frequency only.
3. Receiving alternate half-cycles of space and mark frequency.

a. TA2.1 Tone Channel (See Fig. 37)

For loss of a tone channel, the receiver clamps its output to a mark condition. The space output from the receiver is zero with respect to the positive source. This means that transistor Q13 and Q1 (on the supervision board) are not conducting. On the amplifier and keying board, base drive to transistor Q9 is provided from positive 20 volts dc through R26 and R27 to negative. Q8 is turned on to provide a positive 20 volts across R23. When the channel is in service and the receiver is in a space condition, transistors Q13 and Q1 (on the supervision board) turn on. This applies negative potential to R27 on the amplifier and keying board. Hence, Q9 can not conduct and Q8 stops conducting. The voltage across R23 is –20 volts (with ref. to +20 volts). For the condition where the receiver is receiving pulses, transistors Q13 and Q1 (on supervision board) turns on and off and the voltage across R23 of the amplifier and keying board is a square wave voltage varying from zero volts to a –20 volts dc (with ref. to +20 volts). The output of the mark remote squaring amplifier is the same as the space remote amplifier except that it operates off of the mark output of the receiver. The voltage is across R43.

b. TCF Channel (See Fig. 38)

For loss of a TCF carrier channel, the carrier receiver clamps its output into both a space and a mark condition. Transistor Q1 and Q2 on the supervision board turn on. This removes base current to Q9 and Q16 (on amplifier and keying board) respectively. Transistors Q9 and Q16 turn off which turns off Q8 and Q15. Negative 20 volts (with ref. to +20 volts) appears across both E23 and R24.

This voltage enables AND 1 and AND 2 to allow tripping until the AND circuits are disabled by the 150/0 timer of the supervision board.

For the condition where the receiver is receiving pulses, transistor Q1 (on supervision board) turns on and off for alternate half cycles and the voltage across R23 (on amplifier and keying board) is a square wave voltage varying from zero volts to a –20 volts dc (with ref. to +20 volts).

c. TA2.2 Tone Channel and MC-22 Microwave Channel (See Fig. 38)

In applying the relay to the TA2.2 tone channel or MC-22 microwave channel, the channel receivers clamp their outputs into neither a space nor mark condition for a loss of channel.

Transistors Q1 and Q2 on the supervision board turn off. This allows base current to flow into Q9 and Q16 on amplifier and keying board). Transistors Q9 and Q16 turn on which turns on Q8 and Q15. Positive 20 volts (ref. to negative) appears across both R23 and R24. This positive voltage inhibits AND 1 and AND 2 of the arming board to prevent tripping during the loss of channel.

For either internal or external fault conditions the outputs of both remote squaring amplifiers are square wave voltages. Both voltages vary from zero volts to approximately −20 volts dc and are out of phase with each other: i.e., when one voltage is at zero volts the other voltage is at −20 volts.

Links are provided on the board to connect the relay for either two or three terminal lines. The connection of C to 3 on link 1 connects remote squaring amplifier 5 to AND 1 of the arming board, and link 2 (C to 3) connects remote squaring amplifier 6 to AND 2 of the arming board for three terminal operation. For two terminal operation the connection of C to 2 on the links removes the inputs of remote amplifier 5 and 6 from the AND circuits of the arming board.

3. Arming Board

The phase relationship of the outputs of the local and remote squaring amplifiers are compared by the two AND circuits of the Arming Board. One AND circuit (number 1) compares the space signal with the output from local amplifier number 1. The second AND circuit (number 2) compares the mark signal with the outputs of local amplifier number 2. Since the local signals are always 180 degrees out-of-phase with each other, and the remote signals are always 180 degrees out-of-phase with each other, a change in phase angle of one signal with respect to the other will provide one input to AND 3 through OR 1 which will activate the 4/0 timer.

A link is provided on this board for purposes of arming the relay with both distance fault detectors and the SKBU relay fault detector. Removal of the link allows arming by distance fault detector only.

a. Internal Fault Conditions

With reference to the logic drawing that applies to the particular relay for internal fault fed from both line terminals, the output voltage of the sequence filter at one line terminal is 180 degrees out-of-phase with respect to its load current condition. This changes the polarity of local Amplifier 1 and local Amplifier 2 such that their outputs are in phase with the remote signals. This means that AND 1 has a half-cycle of negative voltage and that AND 2 has a half-cycle of negative voltage (not the same half-cycle). The period of each negative voltage will be 180 degrees out-of-phase with reference to each other and a negative voltage will be produced out of OR1 of the arming board. The negative voltage is applied to AND 3 of the arming board to set-up one condition (negative voltage from OR 1 circuit) for activating the AND. The second condition to activate this AND is provided by arming the relay.

In either Fig. 21, 22, 23 or 24, with the link connected on the arming board, arming occurs through OR 2 by either the operation of the distance fault detectors or the relay fault detector will apply a voltage to OR 2 of the arming board. The output voltage from OR 2 applies a positive input to the trip AND of the output board through OR 3 and a negative input into AND 3 of the arming board. AND 3 is activated and starts the 4/0 timer. Four milliseconds later, a negative input is applied to the trip AND of the output board. Since the three conditions of trip (a negative input from the 4/0 timer, a positive input from the arm lead, and a positive signal from the 22/0 timer) is fulfilled, a trip output is obtained from the relay.

For arming by the distance fault detector only, the link on the arming board must be opened. This removes the input of the SKBU relay's fault detector from OR 2 of the arming board.

b. External Faults

Under external fault conditions, the square wave voltages from the remote squaring amplifiers and the square wave voltages from the local squaring amplifiers are out-of-phase such that zero output is obtained from the AND circuits of the arming board. The output from local 1 and remote 3 are out-of-phase to prevent an output on AND 1 and the outputs from local 2 and remote 4 are out-of-phase to prevent an output on AND 2. As a result, the outputs of the AND circuits are zero, and AND 3 cannot be activated. This blocks AND 3 and the 4/0 timer cannot be energized.

With a fault detector operation, an input is applied to OR 2 and OR 4 of the arming board. OR 2 will provide a positive input to the trip AND of the output board. Tripping will not occur since the 4/0 timer does not provide a negative input to the Trip AND. The fault detector input to OR 4 will provide an input to a 0/1000 timer on the Output Board. The timer negates the signal to provide a negative input to the transient block AND. With the application of the negative input from the 0/1000 timer the three conditions of transient block are fulfilled — not a negative voltage from the Trip AND, not a positive voltage from the Transient Unblock Circuit; and a negative input from the 0/1000 timer. Twenty-Two milliseconds later the 22/0 timer of the transient block circuit times out to provide a negative input to the Trip AND. The Trip AND is thus de-sensitized on the external fault to prevent undesirable operation during transients associated with power reversals on the protective line or at the clearing of an external fault.

c. Sequential Faults

If the above external fault is followed by an internal fault before the external fault is cleared, the transient unblock circuit is set up to remove the transient blocking input to the Trip AND. For the internal fault, the square wave pulses on AND 1 and AND 2 of the arming board will reverse such that an output is obtained from these AND circuits. This output energizes OR1 which negates the signal to a negative signal. The negative signal provides the second input to AND 3 which:

1. Provides an input to the 4/0 timer which times out to apply a negative input to the Trip AND.
2. Applies a negative input to the AND of the transient unblock circuit to fulfill the requirements to obtain an output from the transient unblock circuit.

As a result, an input is applied to the unblock timer. Twenty-five milliseconds later, the unlock timer will operate to apply a positive voltage to the transient block AND circuit. This resets the 22/0 block timer and removes the input to the AND of the unblock timer to reset the unblock circuit. The required three inputs are thus applied to the trip AND and a trip output is obtained from the relay. Upon operation of the relay, the 0/100 millisecond timer resets the 0-1000 transient block timer.

d. Protective Relay Operation

The phase comparison relay is armed by the distance fault detector through a 6/0 timer on the protective relay board. The operation of the distance fault detectors applies positive potential to the board at either terminal 3, 5, 5 or 7. This turns Q1 on and turns Q2 off to allow C2 to charge. Six milliseconds later the voltage on C2 reaches the breakdown of Zener diode, Z7 and base current flows into transistor Q3 to turn Q3 on. This turns on Q4 to apply a positive potential to terminal 14 of the arming board.

4. Supervision Board

The circuits on the supervision board include the interface to the channel receiver and they vary with the type of equipment used as a pilot channel. In general, though, this board contains a low signal clamp timer.

a. Low Signal Clamp (.5/150 Timer)

1. Tone Channel (See Fig. 37)

With a serviceable channel either a space frequency or an alternate space-mark frequency is received from the channel equipment. With reference to a TA-2 tone channel, Q14 and Q2 of the supervision board of Fig. 16 are either turned off or turned on and off. With Q2 turned off, base current is supplied to transistor Q3 and Q3 conduct. The collector of Q3 is thus at negative potential and capacitor C1 cannot charge.

If the channel is not serviceable, the tone receiver is clamped into a mark condition and the space output is zero. Transistor Q14 conducts and transistor Q2 is turned on. Negative potential is applied to Q3 and stops conducting. Positive potential is then applied to capacitor C1 through resistor R7 and R8. After a 150 millisecond time delay, capacitor C1 charges sufficiently to break down Zener diode Z1. When Z1 conducts, base drive is supplied to transistor Q3 and Q4 turns on. This connects the collector of Q4 to negative potential which allows base current to flow in transistor Q5 through R11. This turns on transistor Q5 to apply positive voltage to R12. This voltage is then applied to AND 1 and AND 2 of the arming board and to an alarm output. Applying the voltage to the AND circuits blocks tripping.

Under the condition of alternate mark and space outputs from the tone receiver, transistor Q3 is turned on and off every 8.3 milliseconds (half cycle of power system frequency). Every half cycle, capacitor C1 starts to charge but on the next half-cycle Q3 turns on to discharge capacitor C1. Since the charging time is not sufficient to allow capacitor C1 to break down Z1, transistor Q5 will not turn on to block tripping.

2. TCF Carrier Channel (See Fig. 38)

With reference to the supervision board of Fig. 18 for a serviceable TCF channel Q1 and Q2 either alternately turned on and off or Q1 is turned on and Q2 is turned off. Under both conditions, base current is supplied to transistor Q3 and Q3 is turned on at all times. With Q3 turned on, C1 can not charge and Q4 is turned off.

If the channel is not serviceable, the carrier receiver is clamped into both a mark and space output. This turns on transistors Q1 and Q2 and shorts the base of Q3 to negative potential and Q3 turns off. Positive potential is applied to C1 through R12 and R13 and 150 milliseconds later, Zener diode Z5 breaks down to allow base current to flow to Q4. Q4 turns on which provides a path through R16 for base current of Q5 to flow to negative. Q5 turns on to apply positive voltage to R17. This voltage is then applied to AND 1 and AND 2 of the arming board to block tripping. The voltage is also applied to an external alarm circuit.

When this relay is used on either a TA2.2 tone channel or a MC-22 microwave channel, the low signal clamp is not utilized. If these channels are not serviceable, the channel receiver is clamped into neither a mark nor a space output. This instantaneously places a blocking signal on the AND circuits of the SKBU relay. Hence, the relays will not trip on a low signal clamp. The low signal timer is not activated and will not produce an alarm output to the next device. This alarm information is supplied directly to the next device by the channel receivers.

a. **Noise Supervision (Tone Channel Only)**

The noise supervision interface consists of transistors Q17, Q11, Q12 and associated components (See Fig. 16). Under normal conditions, the output from the noise circuit of the tone receiver is zero volts. As a result, transistor Q17 is not conducting and base current is not supplied to transistor Q11. Transistor Q11 is turned off and its collector is held at positive potential to prevent base current from flowing in transistor Q12. Negative voltage (across R31) is applied to AND 1 and AND 2 of the arming board.

Under noise conditions the noise circuit of the tone equipment provides a negative output with respect to positive 48 volts dc. This negative voltage allows transistor Q17 to turn on to provide base current to Q11 through resistor R27. Transistor Q11, turns on, and its collector is connected to negative potential. Base current then flows in transistor Q12 through resistor, R30, and Q12 turns on. Positive potential is applied to resistor, R31 and to terminal 5 and 11 of the supervision board. From terminal 5, the voltage is applied to AND 1 and AND 2 of the arming board to block tripping. The voltage on terminal 11 is applied to an external alarm.

4. **PR INTER Board** (Protective Relay Interface Board) Fig. 20

The protective relay board includes the interface to the protective relays as well as the auxiliary circuits associated with the protective relays. This board contains a 6/0 timer, 2500 sustained arming timer, and a 150/10 signal squelch timer.

a. **Signal Squelch Timer**

When an input is applied to terminal 18 of the protective relay board, positive potential is applied to base of Q10, Q10 turns on to provide a discharge path for C8 through R41. 10 milliseconds after the input to terminal 18, Q11 turns off to turn on Q12. Turning on Q12 applies a negative input to the keying circuit of the amplifier and keying board which keeps the keying transistor from turning on.

Upon removal of the input to terminal 18 of the protective relay board Q10 turns off to apply positive potential to C8. 150 milliseconds later Q11 turns on to turn off Q12 which removes negative potential to the keying circuit.

b. Sustained Arming Alarm (2500 Timer)

When arming occurs, positive potential is applied to terminal 1 and capacitor C3 of the PR INTER Board from terminal 19 of the arming board. Two-and-a-half seconds later, the potential on C3 breaks down the Zener diode Z8 to allow base current to flow into Q5. This turns on Q5 which turns off Q6. Turning Q6 off applies positive potential to the base of Q7 and Q7 turns off. This removes positive potential from R26 and an external alarm is energized.

c. Arming Delay by Distance Fault Detectors (6/0 Timer)

The distance supervision arming is delayed by 6 milliseconds to allow time for the circuits feeding AND 1 and AND 2 to respond at fault inception. Operation of the distance fault detectors will apply positive potential to the protective relay board. This turns on Q1 which removes the base current to transistor Q2. Q2 turns off and positive potential is applied to capacitor C2. Six milliseconds later the voltage on C2 reaches a value to break down Zener diode Z7. This turns on Q3, which connects the base of Q4 to negative through resistor, R15. Q4 turns on to apply positive potential to resistor, R16 and terminal 2. From terminal 2 the voltage is applied to the arming board.

CHARACTERISTICS

A. SKBU-21 Relay

The type SKBU-21 relay is available for frequency shift channels, either tone or carrier. Taps are available to set different sensitivities of the fault detector to zero and negative sequence currents. These taps are as follows:

Negative Sequence Taps (I_2)

TAP SETTING	NEGATIVE SEQUENCE SENSITIVITY
A	None
B	0.4 Amperes
C	0.25 Amperes

Zero Sequence Taps (I_0)

TAP SETTING	ZERO SEQUENCE SENSITIVITY
F	None
G	0.2 Amperes
H	0.1 Amperes

The positive sequence response of the fault detector is greater than 7 amperes.

B. SKBU-2 Relay

Taps are available in the relay to set the sensitivity to different combinations of positive, negative, and zero sequence components of the line current. The T taps on the left hand tap plate indicate the balanced three phase amperes which will operate the fault detector FD. These taps are as follows:

3, 4, 5, 6, 7, 8 and 10.

For distance fault detector applications, the user should reset the SKBU-2 fault detector for a pick-up of twice tap value by means of the S1 setting.

Positive and Negative Sequence Current-R1 Taps

The upper half of the right hand tap plate of R1 taps changes the number of turns on the third winding of the mutual reactor. This reproportions the components of the sequence filter which changes the positive and negative sequence sensitivity of the fault detector. Operation of the fault detector with the various taps is given in the following table:

TABLE I

COMB.	SEQUENCE COMPONENTS IN NETWORK OUTPUT	TAPS ON RIGHT HAND TAP BLOCK		FAULT DETECTOR PICK-UP †	
		R_1	R_0 #	3ϕ FAULT	ϕϕ FAULT
1	Pos., Neg., Zero	C	G or H	Tap Value	86% Tap Value (53% on BC Fault)
2	Pos., Neg., Zero	B	G or H	2 x Tap Value	90% Tap Value (65% on BC Fault)
3	Neg., Zero	A	G or H	–	100% Tap Value

— Taps F, G and H are zero-sequence taps for adjusting ground fault sensitivity. See section on zero-sequence current tap.

† — When taps A and 3, or B and 3 are used, the fault detector will pickup 10 to 15 percent higher than the above values because of the variation in self-impedance of the sequence network and the saturating transformer.

Zero Sequence Current – R_0 Taps

The lower half of the right-hand tap plate (R_0 taps) is for setting the response of the relay to ground faults. Taps G and H give the approximate ground fault sensitivities listed in Table II. Tap F is used in applications where no response to zero sequence current is required. When this tap is used, the voltage output of the network caused by zero-sequence current is eliminated.

NOTE: Because of inherent characteristics of the sequence network, there will be small variations (from the values listed in Tables I and II) in the pick-up current for various phase or ground fault combinations.

TABLE II

COMB.	R_1 TAP	GROUND FAULT PICK-UP	PERCENT OF T TAP SETTING
		TAP G	TAP H
1	C	25%	12%
2	B	20%	10%
3	A	20%	10%

C. SKBU-2 and SKBU-21 Relay

The operating time of the fault detector of both the SKBU-2 and SKBU-21 is shown in Fig. 25. As shown in the figure, the fault detector has a maximum and minimum value. This is due to the point on the current wave that fault current is applied. Fig. 26 shows the operating times for different points on the fault wave for fault current at five amperes.

The keying response of the SKBU-21 relay is independent of the tap setting. Fig. 27 shows typical lengths of keying pulses with reference to a 60-hertz base of the SKBU-21 relay for different values of positive, negative, and zero sequence current. Fig. 32 shows the response of the SKBU-2.

The keying voltage across X_5-X_6 of the SKBU-21 Relay with reference to phase A positive, negative, and zero sequence currents is given by

$$V = 2.7\, I_{a1} \angle -125^\circ + 11.8 I_{a2} \angle 120^\circ + 31\, I_{a0} \angle 105^\circ$$

This voltage is measured with currents into the odd number terminals. X_5 is polarity terminal. 25 volts is maximum voltage obtainable from X_5-X_6.

The keying voltage across X_5-X_6 of the SKBU-2 relay with reference to phase A positive, negative and zero sequence currents is given by

$$V = K_1 I_{a1} + K_2 I_{a2} + K_0 I_{a0}$$

Where values of K_1, K_2, and K_0 are given in the following table

CONSTANT	TAP SETTING	VALUE
K_1	A – F G H	0 0
K_1	B – F G H	$\frac{1.24}{T} \angle -130^\circ$
K_1	C – F G H	$\frac{2.47}{T} \angle -155^\circ$
K_2	A – F G H	$\frac{4.35}{T} \angle 55^\circ$
K_2	B – F G H	$\frac{5.3}{T} \angle 40^\circ$
K_2	C – F G H	$\frac{5.9}{T} \angle 20^\circ$
K_0	A – H	$\frac{73}{T} \angle 50^\circ$
K_0	B – H	$\frac{73}{T} \angle 40^\circ$
K_0	C – H	$\frac{61.5}{T} \angle 25^\circ$
K_0	A – G	$\frac{41}{T} \angle 50^\circ$
K_0	B – G	$\frac{41}{T} \angle 40^\circ$
K_0	C – G	$\frac{34}{T} \angle 20^\circ$
K_0	A,B,C – F	0

This voltage is measured with currents into the odd number terminals. X_5 is polarity terminal.

Typical logic drawing for a tone channel is shown in Fig. 21 and 23 and for a TCF carrier channel in Fig. 22 and 24.

Operating Time .... 15 to 32 Milliseconds
Alarm......... 2.5 seconds for FD operation
150 Milliseconds Loss-of-Channel
Transient Block Time ....22 to 25 Milliseconds
Transient Unblock Time...23 to 27 Milliseconds
Ambient Temperature Range .... –20°C to 55°C
DC Drain .... 0.14 Amps at 48 Volts DC
Reset Time of Transient Block

1. After Fault Detector has Operated .... 1000 Milliseconds
2. When unblock time is utilized .... Instantaneous

ENERGY REQUIREMENTS

A. SKBU-21 Relay

Burdens measured at a balanced three-phase current of five amperes. (Independent of tap setting).

PHASE A		PHASE B		PHASE C	
Va	Angle	Va	Angle	Va	Angle
8.3	106°	2.2	50°	46.	0°

Burden measured at a single-phase to neutral current of five amperes.

Relay Taps	PHASE A		PHASE B		PHASE C	
	Va	Angle	Va	Angle	Va	Angle
C-H	11.7	2.1°	9.7	1.8°	44.0	2.2°
B-H	11.4	2.0°	10.3	1.8°	46.0	2.2°
A-H	11.1	2.0°	11.2	1.8°	48.0	2.2°
C-G	8.8	2.0°	7.0	1.8°	42.0	2.2°
B-G	8.7	2.0°	7.5	1.8°	43.5	2.2°
A-G	7.8	2.0°	8.5	1.8°	45.0	2.2°
C-F	6.7	2.0°	7.5	1.8°	42.0	2.2°
B-F	6.5	2.0°	7.2	1.8°	42.0	2.2°
A-F	5.8	2.0°	6.6	1.8°	43.0	2.2°

The angles above are the degrees by which the current lags its respective voltage.

B. SKBU-2 Relay

Burdens measured at a balanced three-phase current of five amperes.

Relay Taps	PHASE A		PHASE B		PHASE C	
	Va	Angle	Va	Angle	Va	Angle
A-F-3	2.4	5°	0.6	0°	2.5	50°
A-H-10	3.25	0°	0.8	100°	1.28	55°
B-F-3	2.3	0°	0.63	0°	2.45	55°
B-H-10	4.95	0°	2.35	90°	0.3	60°
C-F-3	2.32	0°	0.78	0°	2.36	50°
C-H-10	6.35	342°	3.83	80°	1.98	185°

Burdens measured at a single-phase to neutral current of five amperes.

Relay Taps	PHASE A		PHASE B		PHASE C	
	Va	Angle	Va	Angle	Va	Angle
A-F-3	2.47	0°	2.1	10°	1.97	20°
A-H-10	7.3	60°	12.5	53°	6.7	26°
B-F-3	2.45	0°	2.09	15°	2.07	10°
B-H-10	16.8	55°	22.0	50°	12.3	38°
C-F-3	2.49	0°	1.99	15°	2.11	15°
C-H-10	31.2	41°	36.0	38°	23.6	35°

The angles above are the degrees by which the current lags its respective voltage.

Continuous Ratings:

The Continuous Rating of the SKBU-2 relay is 10 amperes and the Continuous Rating of the SKBU-21 is 7 amperes. The two second overload rating or the SKBU-2 is 150 amp. phase and 125 amp. ground while the two second rating of SKBU-21 is 125 amp. phase and ground.

SETTINGS

If settings in between taps are desired, the tap screw should set in the next lowest tap. S_1 should then be adjusted for the desired pickup value. S_2 should then be adjusted to proper dropout ratio.

A. SKBU-21

The SKBU-21 relay has separate tap plates for adjustment of the zero and negative sequence sensitivity of the fault detector. The fault-detector tap markings and pickup are:

Negative Sequence Sensitivity (I_2)

A. None
B. 0.4 Amperes
C. 0.25 Amperes

Zero Sequence Sensitivity (I_0)

F. None
G. 0.2 Amperes
H. 0.1 Amperes

Two tap plates are provided: one for I_2 and the other one for I_0.

Tap A should not be used in service since this would prevent fault detector operation for phase-to-phase faults. However, tap F may be used with either B or C since negative sequence current flows for both phase-to-phase and ground faults.

The recommended settings are tap B or C as needed for the required sensitivity, and tap F. Taps G and H have been provided for applications where the negative-sequence load flow due to series impedance unbalance may be high enough to operate FD with a tap C setting. In this case, set in tap B and in tap G or H. It is not intended that taps C and H be used simultaneously due to the possibility of cancellation of the negative- and zero-sequence effects on ground faults. With a tap B setting, a tap H setting is preferred.

To summarize, the recommended setting combinations in the order of preference are:

COMBINATION	I_2 TAP	I_0 TAP
1	C	F
2	B	F
3	B	H
4	B	G

B. SKBU-2 Relay

The SKBU-2 relay has separate tap plates for adjustment of the phase and ground fault sensitivities and the sequence components included in the network output. The method of determining the correct taps for a given installation is discussed in the following paragraphs.

Setting Principles

Tap C provides the best balance between 3 phase and phase-to-phase fault sensitivity. Always use this tap where distance fault detector supervision is used. Where only the SKBU-2 fault detector is used and where the full load current (maximum through any terminal) is approximately five amperes or more, tap B will provide increased phase-to-phase fault sensitivity with little or no sacrifice in 3 phase fault sensitivity. For example, if a left-hand tap (T) of 6 is needed with tap C (6C), then use a 3 B setting instead.

NOTE: From Table I, pickup will be 105% of Tap 3 on 3B and 90% of Tap 6 for ϕA to ϕB fault. 3ϕ pickup is 6 amp. both settings.

Use tap A only where satisfactory unbalanced fault sensitivity cannot otherwise be obtained and where other protection is available for 3 phase faults. Since with Tap A no 3 phase fault protection is available.

In all cases provide identical response at all stations to insure proper phase comparison and adequate keying for any fault detected by remote-end relays. To accomplish this, the letter taps (A, B, C, F, G, H) should be identical at all stations. Also, the taps should be identical with CT ratios, or inversely proportional to CT ratios where different.

After selecting tap C or B, pick the T tap to allow reset of the fault detector in the presence of load flow. That is, fault detector pick-up should be at least 111 percent of full load current (maximum through any terminal).

Now select tap G or H for desired ground-fault sensitivity.

For distance fault detector applications, set 3C to provide the maximum sequence-filter voltage for the squaring amplifiers. The SKBU-2 current fault detector is then independently desensitized (by adjustment of S1 and S2 settings) to permit reset in the presence of full-load current. Phase faults which do not operate the SKBU-2 fault detector will be detected by the supplementary distance fault detectors.

EXAMPLE SKBU-2:

Assume a two-terminal line with current transformers rated 400/5 at both terminals. Also assume that full load current is 300 amperes, and that on minimum internal phase-to-phase faults 2000 amperes is fed in from one end and 600 amperes from the other end. Further assume that on minimum internal ground faults, 400 amperes is fed in from one end, and 100 amperes from the other end. No distance fault detectors are employed.

POSITIVE-SEQUENCE CURRENT TAP

Secondary Values:

$$\text{Load Current} = 300 \times \frac{5}{400} = 3.75 \text{ amperes} \quad (1)$$

Minimum Phase-to-Phase Fault Currents:

$$600 \times \frac{5}{400} = 7.5 \text{ amperes} \quad (2)$$

Fault detector setting (three phase) must be at least:

$\frac{3.75}{0.9} =$ 4.18 amperes (0.9 is dropout ratio of fault detector. Setting will insure that the fault detector will reset on load current.) (3)

In order to complete the trip circuit on a 7.5 ampere phase-to-phase fault, the fault detector pick-up from Table I must not be more than:
(based on a three phase fault)

$$7.5 \times \frac{1}{0.86} = 8.7 \text{ amperes} \quad (4)$$

ZERO SEQUENCE TAP

Secondary Value:

$100 \times \frac{5}{400} = 1.25$ amperes minimum ground fault current

With T, tap 6 and R1 Tap B in use, the fault detector pick-up currents for ground faults (See Table II) are as follows:

Tap G 0.2 x 6 = 1.2 amperes

Tap H 0.1 x 6 = 0.6 amperes

From the above, tap H would be used to trip for a minimum ground fault of 1.25 amperes.

SEQUENCE COMBINATION TAP

From a comparison of (3) and (4) above it is evident that the fault detector can be set to trip under minimum phase fault conditions and yet not operate under maximum load. From (3) we can select tap 5 (T). In this case, also select tap C (R_1). Current tap (6) would be used in preference to tap 5 to allow for occurrence of higher load current. However, if more margin is desired over load current, instead of setting 6C, use 3B for improved phase-to-phase fault sensitivity.

INSTALLATION

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

ADJUSTMENTS AND MAINTENANCE

NOTE: The phase comparison relay is normally supplied as part of a relaying system, and its calibration should be checked after the system has been installed and interconnected. Details are given in the instructions of the assembly. The assembly instructions and not the following instruction should be followed when the relay is received as an integral part of the relaying system.

In those cases where the relay is not part of a relaying system, the following procedure will verify that the circuits of the relay are functioning properly.

TEST EQUIPMENT

1. Oscilloscope
2. AC Current Source
3. Electronic Timer
4. AC Voltmeter
5. DC Voltmeter

ACCEPTANCE TEST

Connect the relay to the test circuit of Fig. 28 which represents the tone channel for test purposes. Fig. 29 represents the TCF carrier channel for test purposes. Connect 2, 4, 6 and 8 together on terminal block.

If a test fixture is not available, the remote pulses can be obtained from the SKBU keying circuit. This is accomplished by jumpering various circuits of the relay together as follows: (NOTE: These instructions apply where no external connections are made to the J1 block.)

1. Apply 48 volts dc to J1-2 (pos. and J1-5 (neg.). An alternate connection is to X1 and X4.
2. Jumper J1-26 to J1-27. (This replaces the external squelch test switch.)
3. Connect terminal 9 of supervision board to X14. (This connects space interface circuit to keying circuit.) As an alternate connection, J1-7 can be connected to J1-25.
4. Connect one pole of a DPST switch across TP-1 and TP-2 of amplifier and keying board. This is switch L of the tests. External fault position is with the switch open. Internal fault position is with the switch closed.
5. On the SKBU for TCF channel, connect terminal 13 to terminal 10 on the supervision board.

   (This connects mark interface to output of space interface.)

6. On the SKBU for a TA-2 tone channel:

   a. Connect terminal 10 and TP-1 of supervision board through a diode-resistor network to negative. (Connect TP-1 through the forward direction of a second diode to the junction of the first diode and resistor.)

   b. Connect J1-3 to positive 48 volts dc.

With the jumpers added as per the above information, the transistor circuits are connected together as shown in Figure 33.

If the above connections are utilized to test the relay, the reference to closing switches A, B, C, D, E, F, G, H and I of the following test procedure should be ignored.

The following tests are with reference to the relay as received. If a recalibration of the circuits is desired, the recalibration can best be obtained by setting S1, S2 and S5 to counterclockwise limit, S6 and S7 to clockwise limit, and R27 on output board to the middle of its range.

1. FD Pickup and Dropout

a. Set relay on taps C and H. Set SKBU-2 T tap 5.

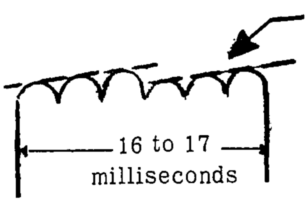
b. Connect a high resistance dc voltmeter across X_{22} and X_4 (neg.).

c. Apply 60 hertz current to terminal 1 and 3 of the relay. Gradually increase the current until the voltmeter changes reading from approximately zero volts to approximately 20 volts. This is the operating current of FD and should be 0.433±5% amperes for SKBU-21 relay and 4.33 ± 5% amperes for SKBU-2 relay.

d. Gradually lower ac test current until the dc voltmeter drops to approximately zero volts. This is the dropout current of FD and should occur at .389 to .395 amperes for SKBU-21 and 3.89 to 3.95 amperes for SKBU-2.

e. Adjustment of pickup and dropout is made by S_1, and S_2 respectively.

f. If the output of the fault detector is erratic at pickup, R53 on the fault detector should be adjusted such that the following waveform should appear across X_{21} to X_4.



peaks should be nearly equal or, if not, rising slightly to the right.

2. Check of Local Squaring Amplifiers

a. With all switches of test circuit open, apply 0.6 to 0.8 amperes ac to terminals 1 and 3 of the SKBU-21 relay, or 6 to 8 amperes ac to terminals 1 and 5 of the SKBU-2 relay.

b. Place scope probe across X12 and X4 (grd). A square wave of voltage should appear across X12 and X4 as shown in Fig. 30.

c. Place scope probe across X15 and X4 (grd). A square wave of voltage should appear across X15 and X4 as shown in Fig. 30.

d. If scope has two traces, connect one probe to X12 and second probe to X15. Connect grd. of scope to X4. The phase relationship of Fig. 30 should be observed.

3. Check of Keying Circuit

a. With all switches of test circuit open except A and 0.6 to 0.8 amperes ac applied to terminal 1 and 3 of the SKBU-21 relay, with scope check voltage across X14 and X4 (grd). (This voltage should be checked with 6 to 8 amperes into terminals 1 and 3 of SKBU-2 relay.)

b. Waveform shown in Fig. 30 should be observed.

4. Check of Remote Squaring Amplifiers

a. Close switches A, B and C of test fixture.

b. Apply 0.6 to 0.8 amperes ac to terminals 1 and 3 of the SKBU-21 relay, or 6 to 8 amperes ac to same terminals for SKBU-2 relay.

c. Using scope with grd. lead on X4, check waveshape of voltage across X9 and then X16. Waveforms of Fig. 30 should be observed. Also for three terminal application check waveform across X13 and X17.

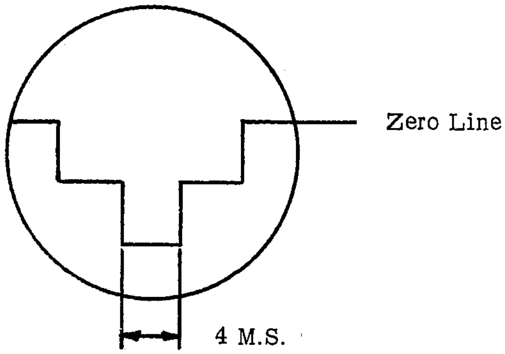
d. If scope has two traces, connect one probe to X9 and the other on X16. Connect grd. to X4. The phase relationship to Fig. 30 should be observed.

5. Setting of S6 (4/0 Timer)

a. With S5 set to minimum resistance (fully counter clockwise) and S6 to maximum resistance (fully clockwise) set switch L to external fault and close switches A, B and C, E and F. Open switch I. Apply 0.6 to 0.8 amperes ac to terminals 1 and 3 of the SKBU-21 relay or 6 to 8 amperes ac to same terminals of SKBU-2 relay.

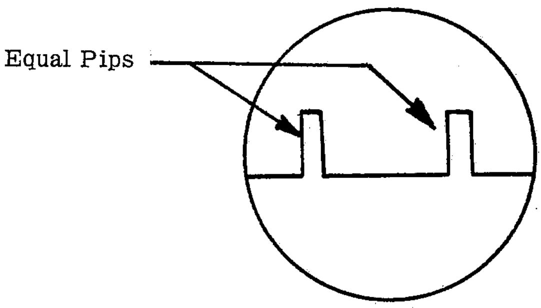
b. Place scope probe across X10 and X4 (grd).

Connect a second scope probe to X11. Adjust S5 until following waveform appears on scope.



c. Adjust S6 until the relay trips as indicated in a change in voltage on X11.

* d. Change S5 to obtain the following waveform. This will be with S5 at minimum resistance.

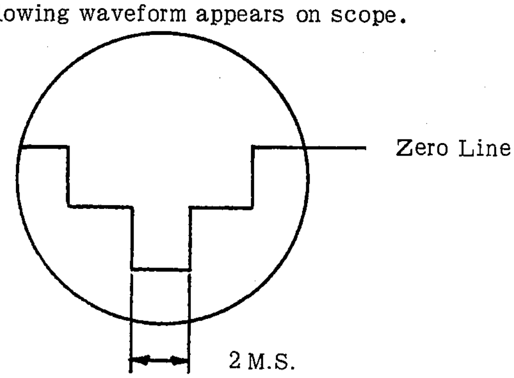


e. Close and open switch H, and slowly turn S5 until the relay operates. Waveform should be same as step b. If necessary, readjust S6 and repeat d and c.

* 6. Setting of S7 (Transient Unblock)

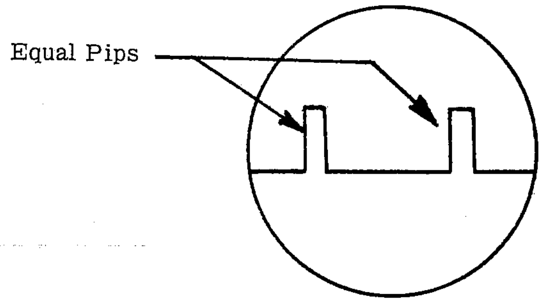
a. With S5 set to minimum resistance (fully counter clockwise) and S7 to maximum resistance (fully clockwise) set switch L to external fault and close switches A, B and C, E and F. Open switch I. Apply 0.6 to 0.8 amperes ac to terminals 1 and 3 of the SKBU-21 relay or 6 to 8 amperes ac to same terminals of SKBU-2 relay.

b. Place scope probe across X10 and X4 (grd). Connect a second probe to X7. Adjust S5 until following waveform appears on scope.



Slowly turn S7 until a voltage begins to show on X7. NOTE: This voltage is NOT a sudden charge but a small pulse of voltage that charges back to zero volts.

c. Change S5 to obtain the following waveform. This will be with S5 at minimum resistance. (NOTE: This will not be true if the relay is connected in a system.)



If relay is connected in a system, pips will change when remote terminal is adjusted. Readjust bottom terminals such that the pips remain equal.

7. Transient Blocking Delay (22/0 and 0/1000 Timer)

a. Connect electronic timer stop to X7 and X4 (grd). Set timer stop on negative going pulse. Relay not to be energized with ac current.

b. Connect timer start to X3. Set timer start to positive going pulse.

c. Close PR1 switch. (Represents 20 volts input to terminal 7 of PR board.) Timer should start and should stop between 22 and 25 milliseconds. If necessary, adjust R27 on output board to obtain timing.

d. Set timer start on a negative pulse and timer stop on a positive pulse.

e. Open PR1 switch. Timer should start and should stop after a time delay of 980 to 1020 milliseconds.

8. 6/0 Timer Distance Fault Detector

a. Connect timer start to timer start of PR1 switch. Set timer start on positive pulse. Connect timer stop to X3 and X4 (comm). Set timer stop on positive pulse.

b. Close PR1 switch (Represents 20 volts input to terminal 7 of PR board.) Timer should start and should stop after 6 to 8 milliseconds.

9. Sustained Arming Alarm

a. With electronic timer stop connected to X20 X20 and X4 (grd), set timer stop on negative going pulse.

b. Connect timer start to X3. Set timer start on positive pulse.

c. Close PR1 switch. (Represents 20 volts input to terminal 7 of PR board.) Timer will start and should stop after 2.2 to 2.8 seconds.

d. Open PR1 switch.

10. Recheck steps 5, 6 and 7. Readjust S6, R27 and S7 if necessary.

11. Fast Reset Timer (0/100)

a. Connect jumper from TP4 to terminal 4 on output board.

b. Connect start timer to X11. Set timer start on positive pulse. Connect timer stop to TP6 and terminal 8 (neg.) of output board. Set timer stop on positive pulse.

c. Apply 0.6 to 0.8 amperes ac into terminal 1 and out terminal 3 of SKBU-21 relay. (Apply 6 to 8 amperes ac to terminals 1 and 3 of SKBU-2 relay.) (Switches A, B, C, E, F closed, H and I open. Switch L on external fault position.)

d. Close switch L to internal fault position. Relay should trip and timer should start and stop in less than 2.5 milliseconds.

e. Set timer start on negative pulse and timer stop on negative pulse.

f. Close switch L to external fault position and de-energize relay. Timer should start and stop after 80 to 120 milliseconds.

g. Open all switches on test fixture, set L on external fault. Remove jumper from TP4 to terminal 4.

12. 150 Timer Low Signal Clamp 1 (TCF Channel Only)

a. Connect timer stop to X19 and X4 (comm). Set timer stop to positive pulse.

b. Set switch L to internal fault position.

c. Connect timer start to timer start of switch L. Set timer start to positive pulse.

d. Close switches B, C and G. Close switch L to external fault position. Timer will start and should stop in 130 to 170 milliseconds.

e. Open switches B, C and G. Set L on internal fault position.

13. 150 Timer Low Signal Clamp 2 (TCF Channel Only)

a. Connect timer stop to X19 and X4 (comm). Set timer stop to positive pulse.

b. Set switch L to internal fault position.

c. Connect timer start to timer start of switch L. Set timer start to positive pulse.

d. Close switches E, F and G. Close switch L to internal fault position. Timer will start and should stop in 130 to 170 milliseconds.

e. Open switches E, F and G and set L to internal fault position.

14. 150 Timer Low Signal Clamp 1 (TA-2 Tone Only)

a. Connect timer stop to X19 and X4 (comm). Set timer stop to positive pulse.

b. Set switch L to internal fault position.

c. Connect timer start to timer start of switch L. Set timer start to negative pulse.

d. Close switches B and C. Close switch L to external fault position. Timer will start and should stop in 130 to 170 milliseconds.

e. Open switches B and C. Set L on internal fault position.

15. 150 Timer Low Signal Clamp 2 (TA-2 Tone Only)

a. Connect timer stop X19 and X4 (comm). Set timer stop to positive pulse.

b. Set switch L to internal fault position.

c. Connect timer start to timer start of switch L. Set timer start to negative pulse.

d. Close switches E and F. Close switch L to external fault position. Timer will start and should stop in 130 to 170 milliseconds.

e. Open switches E and F and set switch L on internal fault position.

16. Signal Squelch Time (10/150)

a. Connect timer stop to X14 and X4 (comm). Set timer stop on negative pulse. Close switch A. Connect a jumper from TP1 to terminal 8 of the amplifier and keying board. This turns off Q2 to turn on Q3.

b. Connect timer start to pilot trip switch. Set timer start on positive pulse. Close switch I.

c. Close pilot trip switch. (Represent 20 volt input to terminal 14 of PR board.) Timer will start and will stop after an 8 to 12 millisecond delay.

d. Set timer stop on negative pulse, and timer start to negative pulse.

e. Open pilot trip switch. Timer should start and stop after a time delay of 125 to 185 milliseconds.

f. Remove jumper from TP to terminal 8.

17. Check of Noise Circuit (Where Used)

a. Connect dc voltmeter to X18 and X4 (grd). Voltage must read zero.

b. Close switch D. (Connects terminal 7 of supervision board to negative for TA-2 tone channel, and represents a 20 volt input to terminal 7 of supervision board for TA-2.1 tone channel. Switch D can be connected to +20 volts instead of −12 volts.) Voltage must rise to 20 volts. Open switch D. Voltage must change to zero volts. Close switch G. Voltage must rise to 20 volts. Open switch G.

18. Check of Frequency Verifier

a. Open all switches of test circuit.

b. Connect scope across TP60 and terminal 8 of the FD board.

c. Apply 0.5 amperes to terminal 1 and 3 of SKBU-21 relay. (Apply 5 amperes to terminal 1 and 3 on SKBU-2 relay).

d. Waveform of Fig. 31 should be observed.

TROUBLE SHOOTING PROCEDURE

To trouble shoot the equipment, the logic diagram voltage of Table III (Fig. 30) should be used to isolate the circuit that is not performing correctly. The schematic of the individual board, and the voltages of Table IV should then be used to isolate the faulty component.

RENEWAL PARTS

Repair work can be done most satisfactorily at the factory. However, interchangeable parts can be furnished to the customers who are equipped for doing the repair work. When ordering parts, always give the complete nameplate data. For components mounted on the printed circuit board, give circuit symbol and the electrical value (ohms, mfd., etc.) and component style number.

TABLE IV

VOLTAGE MEASUREMENTS ON PRINTED CIRCUIT BOARDS

1. Fault Detector Board Style 5312D13G01

Test Point	$I_{ac} = 0$	I_{ac} = Pickup of FD	Test Point	$I_{ac} = 0$	I_{ac} = Pickup of FD
54	6.5 V. DC	less than 1	Term. 5-6	0	14.5 volts ac (Approx.)
55	less than 1	4.5 V. DC	TP 57	18 volts)	
56	less than 1	18 to 22 V.DC	TP 58	18 volts)	
Term.2	less than 1	8.6 V. DC	TP 59	less than 1)	Pulses see Fig. 31 for Waveform
51-52	0	7.4 volts ac (Approx.)	TP 60	20 volts)	
52-53	0	7.5 volts ac (Approx.)	TP 61	18 volts)	
53-51	0	7.4 volts ac (Approx.)	TP 62	less than 1)	

2. Supervision Board, 202C564G01, TA-2 Tones

TEST POINT	NORMAL CONDITION	ABNORMAL CONDITION	TEST POINT	NORMAL CONDITION	ABNORMAL CONDITION
TP1	*48 V. DC	less than 1 with loss of channel 1	Term. 17	**less than 1	16 V. with loss of channel 2
Term. 13	*less than 1	16 V. with loss of channel 1	TP5	*less than 1	48 V. with loss of channel 2
TP2	*less than 1	48 V. with loss of channel 1	Term. 16	*13.5 V DC	less than 1 with loss of channel 2
Term. 12	*13.5 V. DC	less than 1 with loss of channel 1	TP 6	*less than 1	7 V. with loss of channel 2
TP 3	*less than 1	7 V. with loss of channel 1	Term. 19	less than 1	20 V. with loss of channel 2
Term. 18	less than 1	20 V. with loss of channel 1	TP7	less than 1	48 V. with noise clamp
Term. 15	less than 1	20 V. with loss of channel 1	Term. 5	less than 1	20 V. with noise clamp
TP4	**48 V. DC	less than 1 with loss of channel 2	Term. 11	less than 1	20 V. with noise clamp

*Normal condition could be square wave pulses.

**Normal condition could be square wave pulses. On two terminal line application normal condition of TP4—less than 1 and term 17—16 volt dc.

3. Supervision Board, 202C565G01, TCF Channel

TEST POINT	NORMAL CONDITION	ABNORMAL CONDITION	TEST POINT	NORMAL CONDITION	ABNORMAL CONDITION
Term. 13	*less than 1	less than 1 with loss of channel 1	Term. 17	**less than 1	less than 1 with loss of channel 2
Term. 12	*13.5 volts dc	less than 1 with loss of channel 1	Term. 16	*13.5 volts DC	less than 1 with loss of channel 2
TP1	*less than 1	7 V. DC with loss of channel 1	TP 2	*less than 1	7 V. DC with loss of channel 2
Term. 18	less than 1	20 V. DC with loss of channel 1	Term. 19	less than 1	20 V. DC with loss of channel 2
Term. 15	less than 1	20 V. DC with loss of channel 1			

*Normal condition could be square wave pulses.

**Normal condition could be square wave pulses. On two terminal line applications normal condition of terminal 17 is 13.5 volts dc.

TABLE IV (Con't.)
VOLTAGE MEASUREMENTS ON PRINTED CIRCUIT BOARDS

TEST POINT	NORMAL (I_{AC} = 0)	ABNORMAL ON I_{AC} = PICKUP OF FD
4. Amplifier and Keying Style, 202C551G01 for TA-2 Tones and Style 202C540G01 for TCF		
TP1	4.5 volts	4.5 volt pulses at FD pickup
TP2	less than 1	5.5 volt pulses at FD pickup less than 1 with squelch
Term.6 (TA-2 Tones)	48 volts	-12 volt pulses at FD pickup 48 V DC with squelch
Term.6 (TCF Carrier)	less than 1	20 volt pulses at FD pickup less than 1 with squelch
TP4	4.5 volts	4.5 volt pulses at FD pickup
Term.9	20 volts	20 volt pulses at FD pickup
Term.11	less than 1 or 20 volt pulses	20 volts with loss of TA-2 channel 1 less than 1 with loss of TCF channel 1
Term.1	less than 1 or 16 volt pulses TA-2, 13.5 volt pulses TCF	16 volts with loss of TA-2 channel 1
Term.12	**less than 1 or 20 volt pulses	20 volts loss of TA-2 channel 2 less than 1 with loss of TCF channel 2
Term.16	**less than 1 or 16 volt pulses TA-2, 13.5 volts TCF	16 volts with loss of TA-2 channel 2 less than 1 with loss of TCF channel 2
TP9	4.5 volts	4.5 volt pulses at FD pickup
Term.17	20 volts	20 volt pulses at FD pickup
Term.14	20 volts or 20 volt pulses	less than 1 with loss of channel 1
Term.15	13.5 volts or 13.5 volt pulses	less than 1 with loss of channel 1
Term.10	**20 volts or 20 volt pulses	less than 1 with loss of channel 2
Term.13	**13.5 volts or 13.5 volt pulses	less than 1 with loss of channel 2
5. Arming Board Style 202C509G01		
TP1	less than 1	10 volt pulses on internal fault *less than 1 on external fault less than 1 on loss of channel
TP2	less than 1	10 volt pulses on internal fault *less than 1 on external fault less than 1 on loss of channel
TP3	10 volts	*less than 1 on internal fault *10 volts on external fault 10 volts on loss of channel
TP4	13.5 volts	less than 1 at FD pickup
TP5	less than 1	13.5 volts at FD pickup
Term.15	less than 1	20 volts at FD pickup
TP8	20 volts	*less than 1 on internal faults *20 volts on external fault 20 volts on loss of channel
6. Output Board Style 202C548G01		
TP1	16	less than 1 when armed
TP2	less than 1	20 volts when armed
TP3	20 volts	less than 1 when armed
TP4	less than 1	20 volts when armed
TP5		less than 1 at trip
TP6	20 volts	less than 1 when armed
TP7	less than 1	Applies to sequential fault and is a pulse of short duration
TP8	less than 1	7 volts 22 milliseconds after arming
TP9	18.5	7 volts at trip
Term.13	less than 1	20 volts at trip

*Very narrow pulses would be observed on scope

**Values for three terminal line applications. On two terminal line applications—Term 12 and 10 are zero volts, Term. 16 volts TA-2 Tones, 13.5 volts TCF and Term. 13 13.5 volts dc for TA-2 tones and TCF.

ELECTRICAL PARTS LIST

Circuit Symbol	Description	Westinghouse Style Number
Fault Detector Board Style 5312D13G01		
	Capacitors	
C51	0.1 Mfd.	1544920
C52-C53-C59	0.5 Mfd.	187A624H11
C54-C55	1.5 Mfd.	187A508H09
C56-C57	0.02 Mfd.	187A624H09
C58	0.1 Mfd.	187A624H01
C60	0.22 Mfd.	762A703H01
	Diodes	
D51 to D58-D70 to D73	IN457A	184A855H07
D59	1N645A	837A692H03
D60 to D69	1N4385	184A855H14
	Transistors	
Q51-Q52-Q53-Q55 Q57-Q61-Q62-Q63	2N3417	848A851H02
Q54-Q56-Q58	2N3645	849A441H01
	Switches	
Q59-Q60	2N886	185A517H03
	Resistors	
R51	50 Ohms, 5W	185A209H06
R52-R68-R71	2.7 K Ohms	629A531H42
R53 (POT)	2.5 K Ohms	629A430H03
R54-R55-R58-R62 R64-R66-R84-R89 -R92	10 K Ohms	629A531H56
R56-R60	100 K Ohms	184A763H75
R57	47 K Ohms	629A531H72
R59	56 K Ohms	184A763H69
R61-R87	22 K Ohms	629A531H64
R63	6.8 K Ohms	629A531H52
R65	27 K Ohms	629A531H66
R67	150 Ohms, 3W	762A679H01
R69-R73	68 K Ohms	629A531H76
R70-R74-R88	39 K Ohms	629A531H70
R72-R75-R80	2 K Ohms	836A503H33
R76-R78-R90	1 K Ohm	629A531H32
R77	5.6 K Ohm	629A531H50
R79-R86	6.2 K Ohms	629A531H51
R81	20 K Ohms	629A531H63
R82	1.5 K Ohms	836A503H30
R83-R91	470 Ohms	629A531H24
R85-R93	4.7 K Ohms	629A531H48
	Zener Diodes	
Z51	1N1832C, 62 V	184A617H06
Z52-Z55	1N957B, 6.8 V	186A797H06
Z53	1N3688A, 24 V	862A288H01
Z54	1N759A, 12V	837A693H01

Circuit Symbol	Description	Westinghouse Style Number
Supervision Board Style 202C564G01 TA-2 Tone Channel		
	Capacitors	
C1-C3	6.8 Mfd.	184A661H10
C2-C4-C6	0.27 Mfd.	188A669H05
C5	0.47 Mfd.	188A669H01
	Diodes	
D1 to D7	1N645A	837A692H03
	Transistors	
Q1 to Q4 Q6 to Q9-Q11	2N3417	848A851H02
Q5-Q10-Q12	2N3645	849A441H01
Q13 to Q17	2N4356	849A441H02
	Resistors	
R1-R3-R7-R14 R16-R20-R27	47 K Ohm	629A531H72
R2-R4-R6-R9-R10-R15-R17-R19-R22-R23-R28-R29-R34 R36-R38-R40-R41-R42-R43	10 K Ohm	629A531H56
R5-R18	27 K Ohm	629A531H66
R8-R21	470 Ohm	629A531H24
R11-R24-R30	6.8 K Ohm	629A531H52
R12-R25-R31	82 K Ohm	629A531H78
R13-R26-R32	150 Ohm, 3 W	762A679H01
R33-R35-R37-R39	2 K Ohm	629A531H39
	Zener Diode	
Z1-Z3	1N957B, 6.8 volt	186A797H06
Z2-Z4-Z5-Z6	1N3688A, 24 volt	862A288H01
Z7	UZ5875, 75 volt	837A693H04

Circuit Symbol	Description	Westinghouse Style Number
Supervision Board Style 202C565G01 TCF Channel, TA2.2 Channel, and MC-22 Channel		
	Capacitors	
C1-C3	6.8 Mfd.	184A661H10
C2-C4	0.27 Mfd.	188A669H05
	Diodes	
D1 to D8	1N645A	837A692H03
	Transistors	
Q1-Q2-Q3-Q4 Q6-Q7-Q8-Q9	2N3417	848A851H02
Q5-Q10	2N3645	849A441H01

ELECTRICAL PARTS LIST (Cont'd.)

Circuit Symbol	Description	Westinghouse Style Number
Supervision Board Style (Cont'd.)		
	Resistors	
R1-R2-R5-R6-R19-R20-R23-R24	4.7 K Ohm	629A531H48
R3-R7-R17-R21-R25-R35	82 K Ohm	629A531H78
R4-R8-R11-R14-R15-R22-R26-R29-R32-R33	10 K Ohm	629A531H56
R9-R10-R27-R28	27 K Ohm	629A531H66
R12-R30	47 K Ohm	629A531H72
R13-R31	470 Ohm	629A531H24
R16-R34	6.8 K Ohm	629A531H52
R18-R36	150 Ohm, 3W	762A679H01
	Zener Diodes	
Z1-Z3-Z7-Z9	1N3686B, 20 V	185A212H06
Z2-Z4-Z5-Z8-Z10-Z11	1N957B, 6.8 V	186A797H06
Z6-Z12	1N3688A, 24 V	862A288H01
Amplifier and Keying Board Style 202C551G01 TA-2 Tones		
	Diodes	
ΔD1-D3-D4-D5	1N645A	837A692H03
	Transistors	
Q1-Q2-Q3-Q5-Q6-Q9-Q11-Q12-Q13-Q16-Q18	2N3417	848A851H02
Q4-Q7-Q8-Q10 Q14-Q15-Q17	2N3645	849A441H01
Q19	2N699	184A638H19
	Resistors	
R1-R19-R23-R30 R42-R43-R49	82 K Ohm	629A531H78
R2-R14-R37	33 K Ohm	629A531H68
R3-R4-R6-R7-R8-R15-R16-R17-R24-R28-R31-R35-R38-R39-R40-R44-R48-R50-R54-R-56	10 K Ohm	629A531H56
R5-R9-R18-R25-R27-R32-R34-R41 R45-R47-R51-R53 R55-R57	27 K Ohm	629A531H66
R12-R13-R20	68 K Ohm	629A531H76
R21-R22-R29	470 K Ohm	184A763H91
R26-R33-R46-R52	6.8 K Ohm	629A531H52
ΔR36	220 K Ohm	184A763H83
	Zener Diodes	
Z2	UZ5875, 75 V	837A693H04

Circuit Symbol	Description	Westinghouse Style Number
Amplifier and Keying Board Style 202C540G01 TCF Channel, TA2.2 Channel, and MC-22 Channel		
Δ	**Diodes**	
D1 to D5	1N645A	837A692H03
	Transistors	
Q1-Q2-Q3-Q5 Q6-Q9-Q11-Q12-Q13-Q16-Q18	2N3417	848A851H02
Q4-Q7-Q8-Q10-Q14-Q15-Q17	2N3645	849A441H01
	Resistors	
R1-R10-R19-R23-R30-R42-R43-R49	82 K Ohm	629A531H78
R2-R14-R37	33 K Ohm	629A531H68
R3-R4-R6-R7-R8-R15-R16-R17-R24-R28-R31-R35-R38-R39-R40-R44-R48-R50-R54-	10 K Ohm	629A531H56
R5-R18-R25-R27-R32-R34-R41-R45-R47-R51-R53	27 K Ohm	629A531H66
R9-R26-R33-R46-R52	6.8 K Ohm	629A531H52
R11	150 Ohm 3 Watts	762A679H01
R12-R13-R20	68 K Ohm	629A531H76
R21-R22-R29	470 K Ohm	184A763H91
ΔR36	220 K Ohm	184A763H83
	Zener Diode	
Z1	1N3688A, 24 V	862A288H01
Arming Board Style 202C509G01		
	Capacitors	
C1	.27 Mfd.	188A669H05
	Diodes	
D1 to D18	1N645A	837A692H03
	Transistors	
Q1-Q2-Q3-Q4-Q5-Q6-Q8	2N3417	848A851H02
Q7-Q9	2N3645	849A441H02
	Resistors	
R1 to R10-R12-R14 R15-R16-R18-R19-R20-R31-R32-R37-R38	22 K Ohm	629A531H64
R11-R13-R17-R21-R24-R27-R28-R35 R36	10 K Ohm	629A531H56
R22-R25-R29	6.8 K Ohm	629A531H52
R23-R26-R33-R34-R39	27 K Ohm	629A531H66
R30	82 K Ohm	629A531H78
R40	150 Ohm, 3W	762A679H01
	Zener Diodes	
Z1	1N3688A, 24 V	862A288H01

Δ R36 and D4 not used on boards style 202C551G03 and style 202C540G02. * Jumper used in place of D4.

ELECTRICAL PARTS LIST (Cont'd.)

Protective Relay Board Style 202C563G01

Circuit Symbol	Description	Westinghouse Style Number
	Capacitors	
C1-C5-C7	0.047 Mfd.	849A437H04
C2	0.47 Mfd.	188A669H01
C3	68 Mfd.	187A508H02
C4-C6	0.27 Mfd.	188A669H05
C8	6.8 Mfd.	184A661H10
	Diodes	
D1 to D8	1N645A	837A692H03
	Transistors	
Q1-Q2-Q3-Q5-Q6-Q8-Q10-Q11-Q12	2N3417	848A851H02
Q4-Q7-Q9	2N3645	849A441H01
	Resistors	
R1-R2-R3-R4-R5-R27-R28-R30-R36 R37	4.7 K Ohm	629A531H48
R6-R16-R26-R31 R35-R38	82 K Ohm	629A531H78
R8-R15-R25-R34-R40-R44	6.8 K Ohm	629A531H52
R7-R9-R10-R14-R20-R21-R23-R24-R32-R33-R39-R41-R43-R46	10 K Ohm	629A531H56
R11-R22-R45	27 K Ohm	629A531H66
R12-R18	470 Ohm	629A531H24
°R29 (48 Vdc)	22 K Ohm	629A531H64
°R29 (125 Vdc)	68 K Ohm	187A643H71
R42	33 K Ohm	629A531H68
	Zener Diodes	
Z1 to Z5-Z10 to Z13-Z16	1N3686B, 20 V	185A212H06
Z6-Z7-Z8-Z14-Z17-Z18	1N957B, 6.8 V	186A797H06
Z9-Z15	1N3688A	862A288H01

Output Board Style 202C548G01

Circuit Symbol	Description	Westinghouse Style Number
	Capacitors	
C1	0.047 Mfd.	849A437H04
C2	22 Mfd.	184A661H16
Δ C3	3.3 Mfd.	867A530H01
C4-C12	1.5 Mfd.	187A508H09
C5-C7-C10	0.22 Mfd.	763A219H21
C6	4.7 Mfd.	184A661H12
C8-C9	500 Mmfd.	187A694H03
C11	0.1 Mfd.	188A669H03
	Diodes	
D1 to D11	1N645A	837A692H03

Output Board Style 202C548G01 (Cont'd.)

Circuit Symbol	Description	Westinghouse Style Number
	Transistors	
Q1-Q2-Q3-Q5-Q6-Q8-Q9-Q13	2N3417	848A851H02
Q4-Q7-Q10-Q11-Q12-Q14	2N3645	849A441H01
	Resistors	
R1-R2-R32-R40-R43	4.7 K Ohm	629A531H48
R3-R48	82 K Ohm	629A531H78
R4-R7-R8-R9-R15-R17-R19-R26-R31-R34-R36-R37-R38-R41-R45-R46	10 K Ohm	629A531H56
R5-R10-R18-R22-R42-R47	6.8 K Ohm	629A531H52
R6-R24-R25	27 K Ohm	629A531H66
R11-R13	1 K Ohm	629A531H32
R12	100 Ohm	629A531H08
R14-R16-R50	15 K Ohm	629A531H60
R20	220 K Ohm	187A641H83
R21-R33-R35-R39 R44	22 K Ohm	629A531H64
R23	47 Ohm	187A290H17
R27 (Pot)	15 K Ohm	629A430H08
R28-R29	470 Ohm	629A531H24
R30	470 K Ohm	184A763H91
R49	150 Ohm, 3 Watts	762A679H01
	Zener Diodes	
Z1	1N3686B, 20 V	185A212H06
Z2-Z4-Z5-Z6-Z7	1N957B, 6.8 V	186A797H06
Z3-Z8	1N3688A, 24 V	862A288H01

Relay Board Style 5312D80G01 – SKBU-2
5312D78G01 – SKBU-21

Circuit Symbol	Description	Westinghouse Style Number
	Capacitors	
C201-C202-C203	0.25 Mfd.	187A624H02
	Resistors	
R201	50 Ohms, 5W	185A209H06
* R202-R203 (SKBU-21)	3.3 K Ohms	629A531H44
* R202-R203 (SKBU-2)	2.2 K Ohms	187A641H35
	Filter Choke	
L201	8.5 H , 450 Ohms	188A460H01
	Zener Diodes	
Z201 (SKUB-21 only)	1N1828C, 43 V	629A798H14

Δ C3 – 2.2 MFD. on some board.

° – Breaker Failure Inputs.

* Typical Value

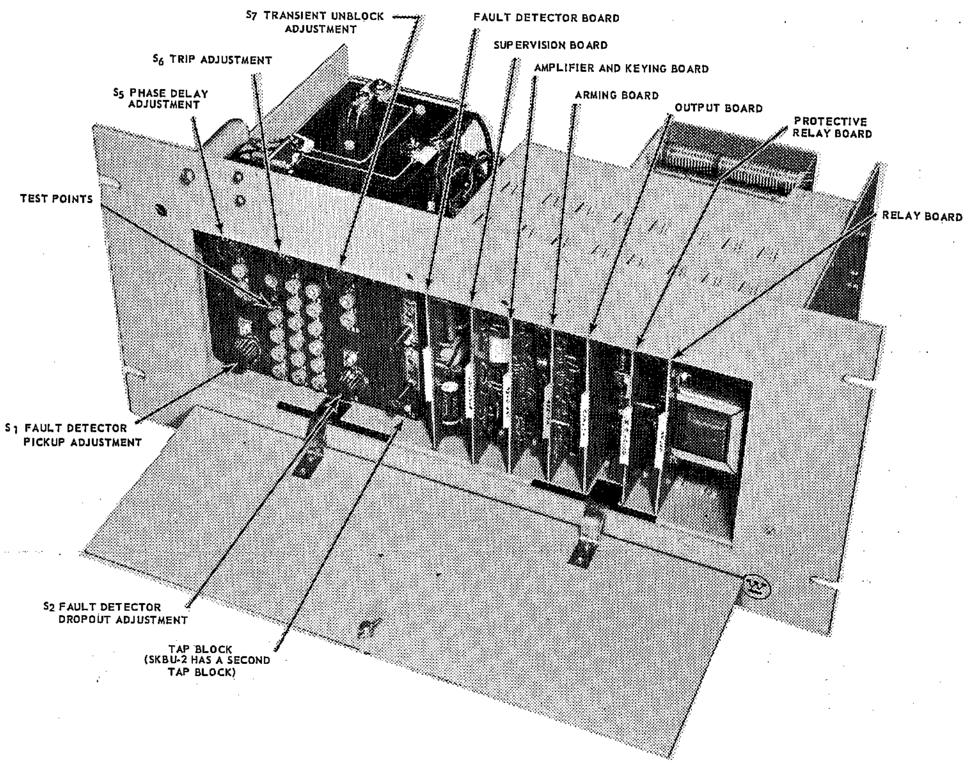


Fig. 1. Photograph (Front View).

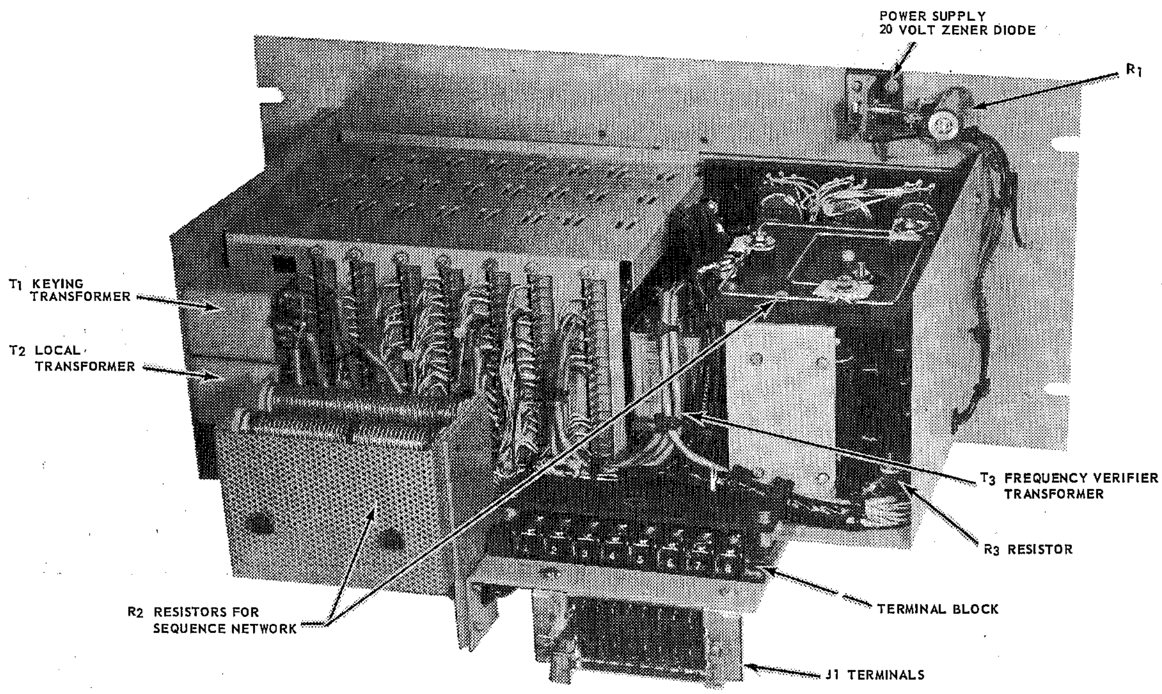


Fig. 2. Photograph (Rear View).

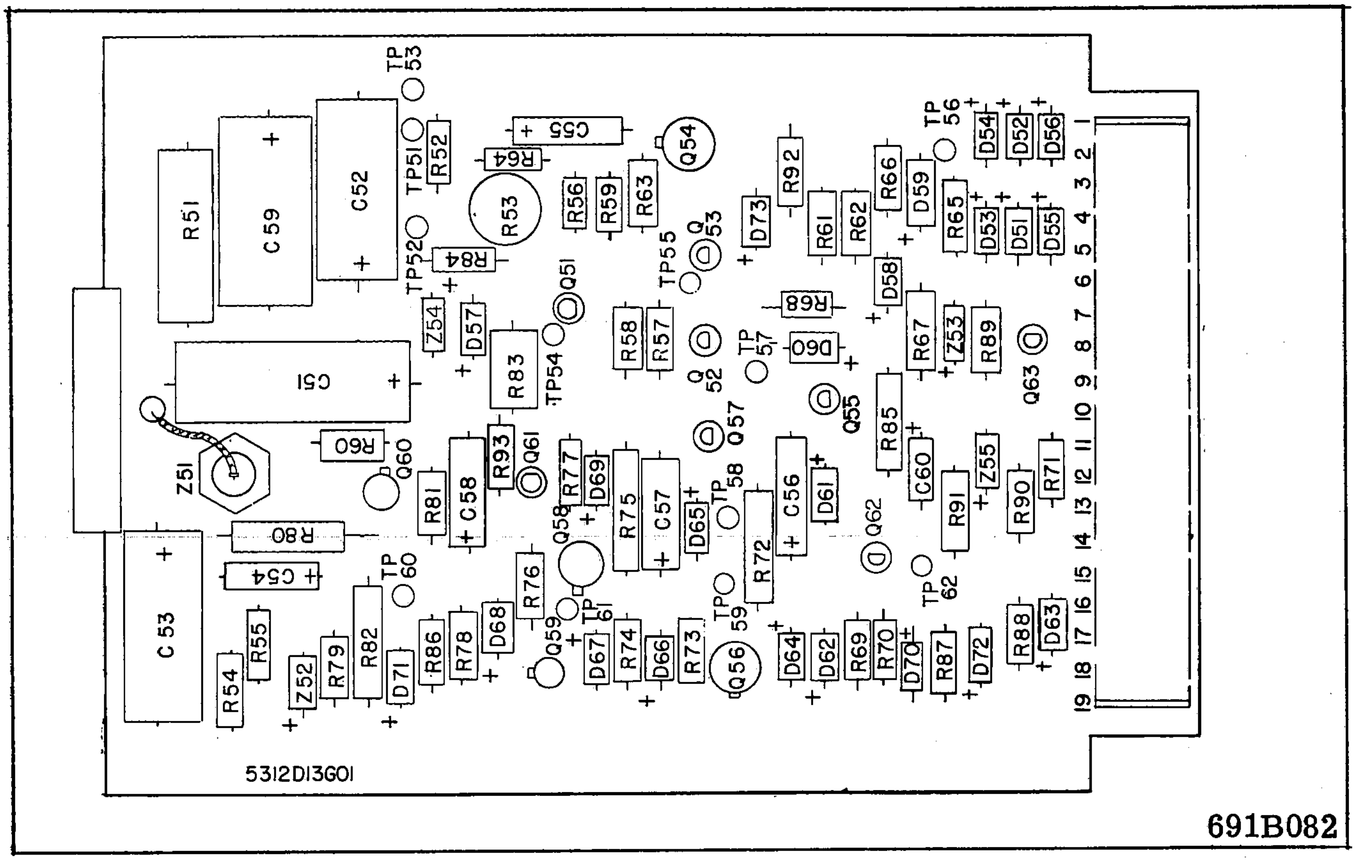


Fig. 3. Location of Components on Fault Detector Board.

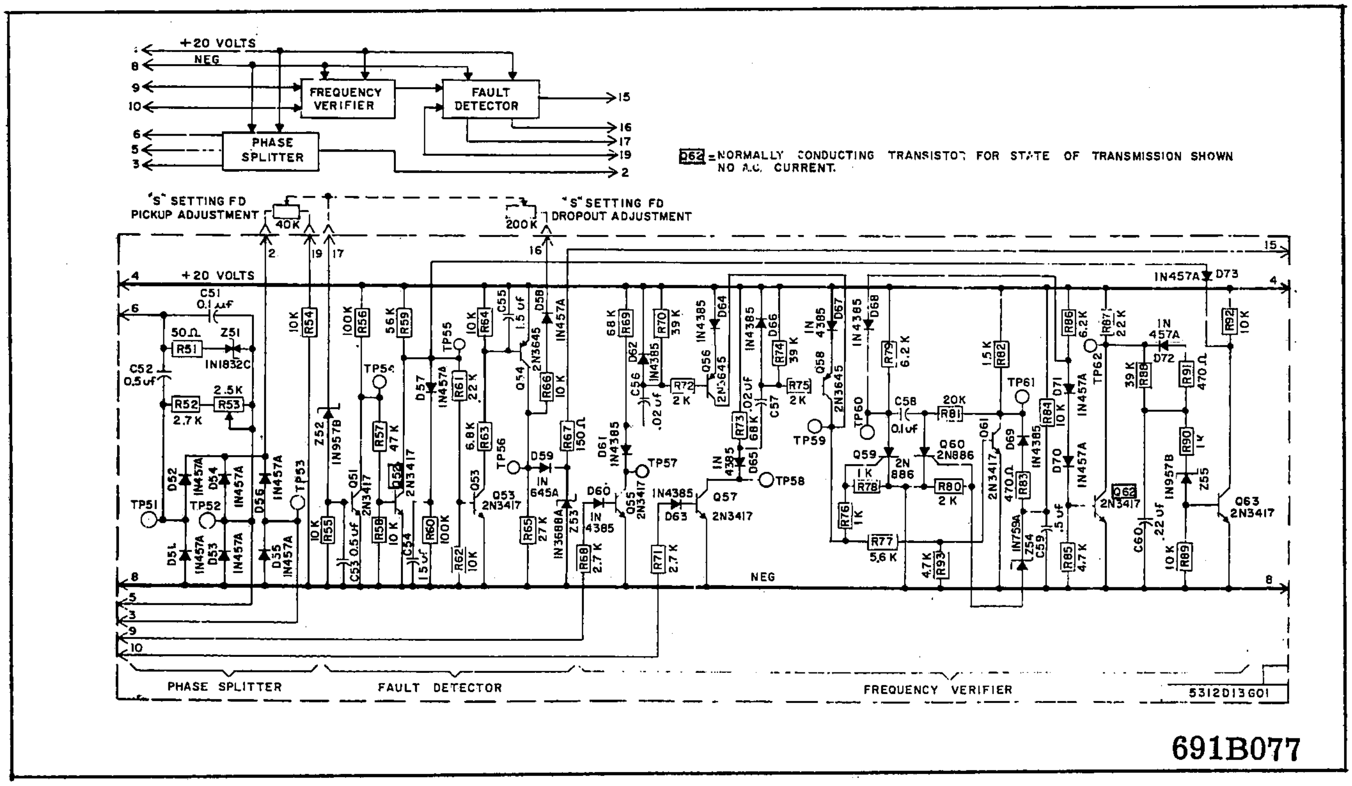


Fig. 4. Schematic of Fault Detector Board.

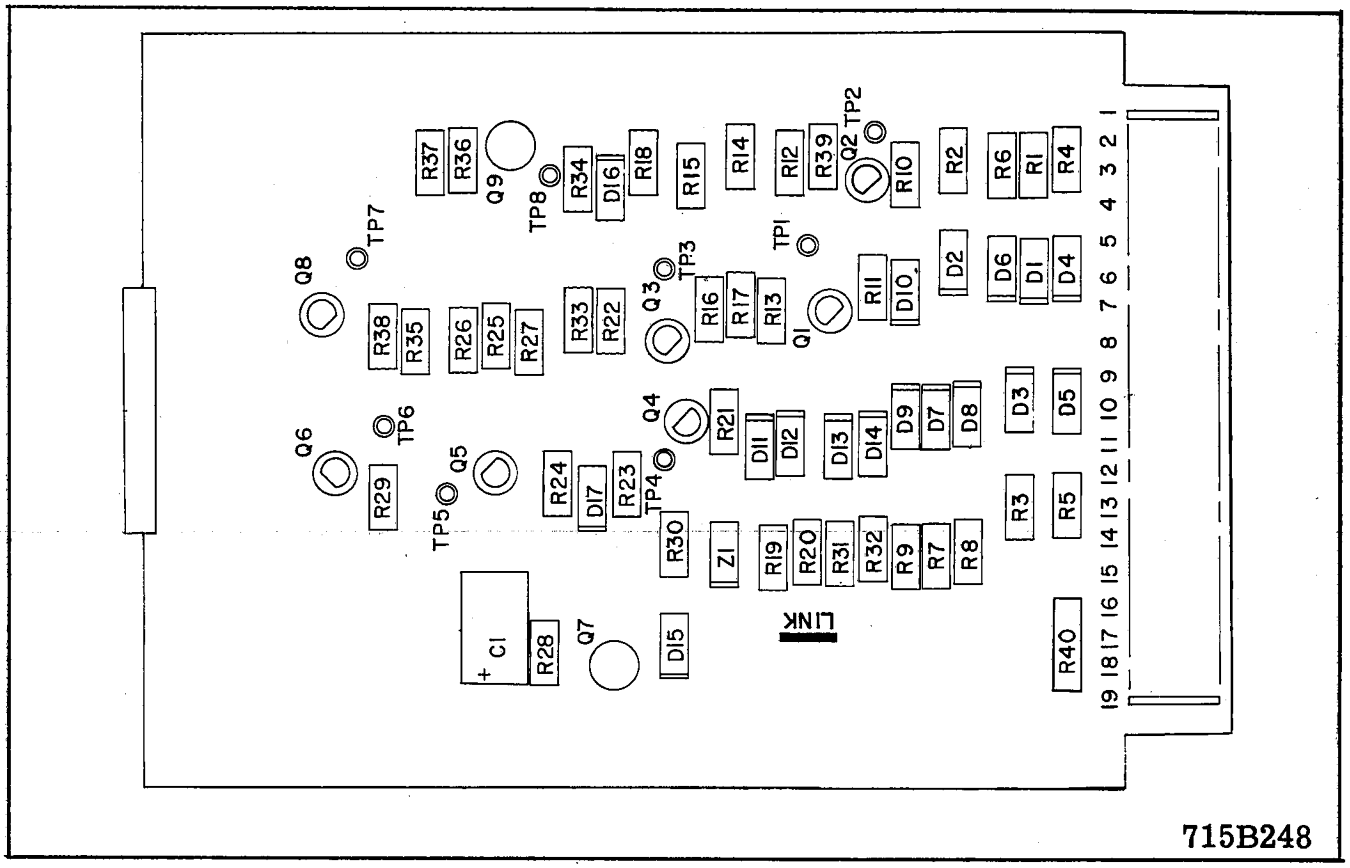


Fig. 5. Location of Components on Arming Board.

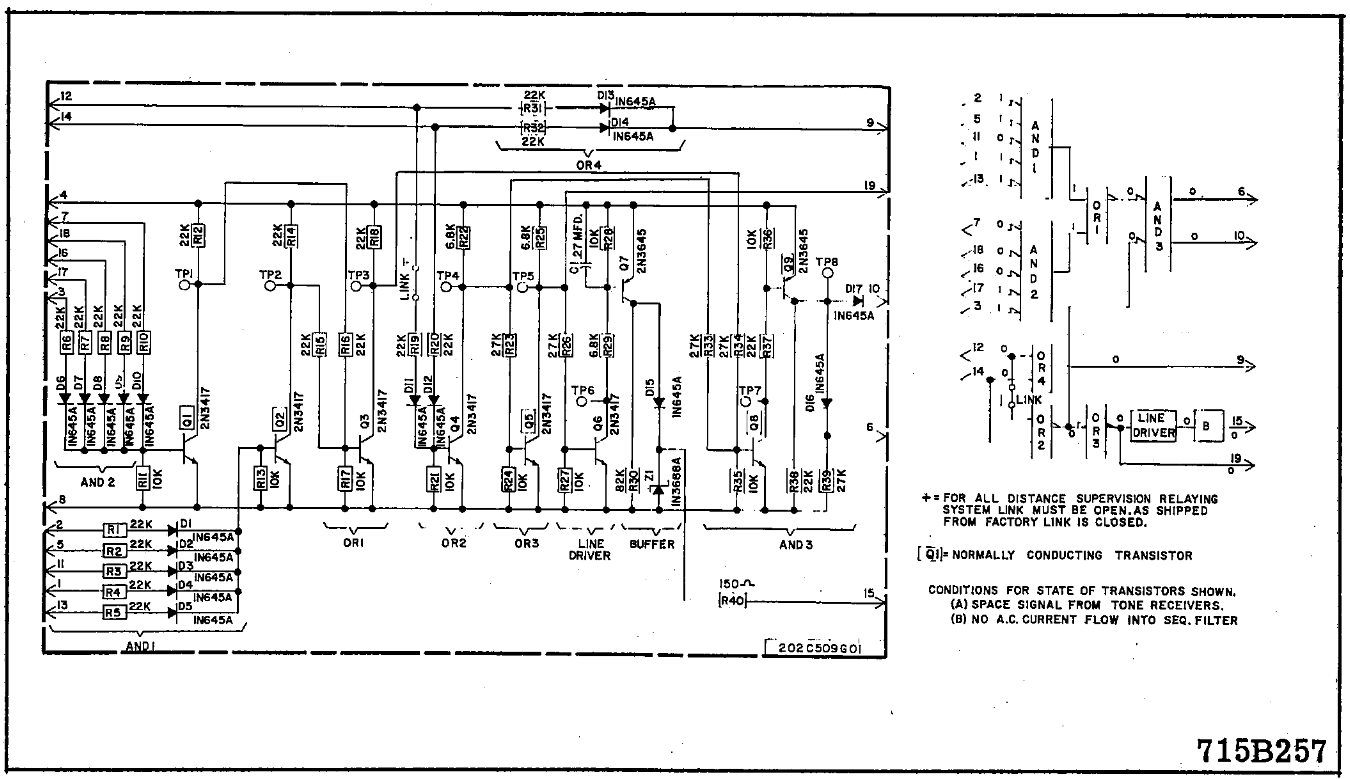
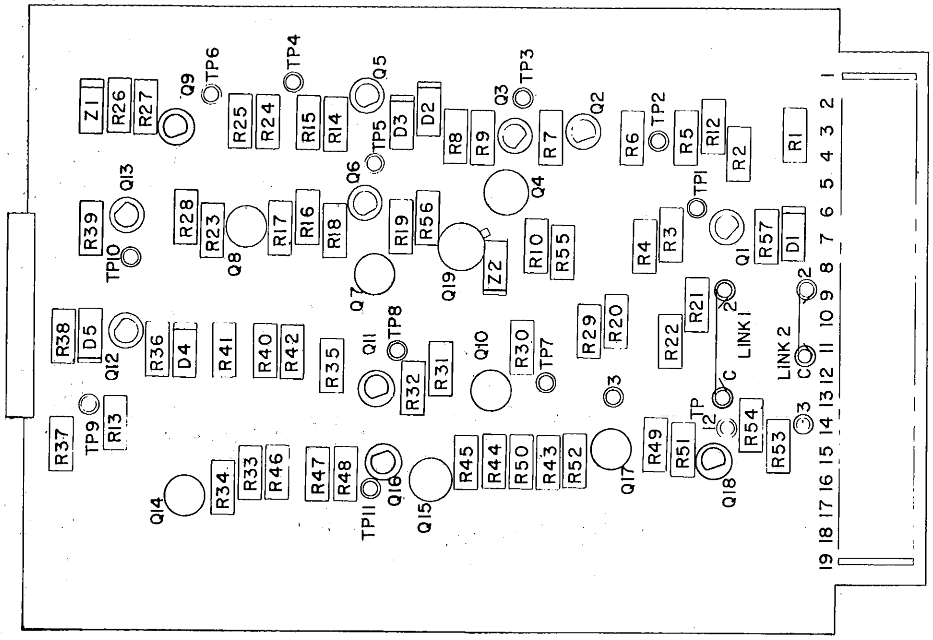


Fig. 6. Schematic of Arming Board.

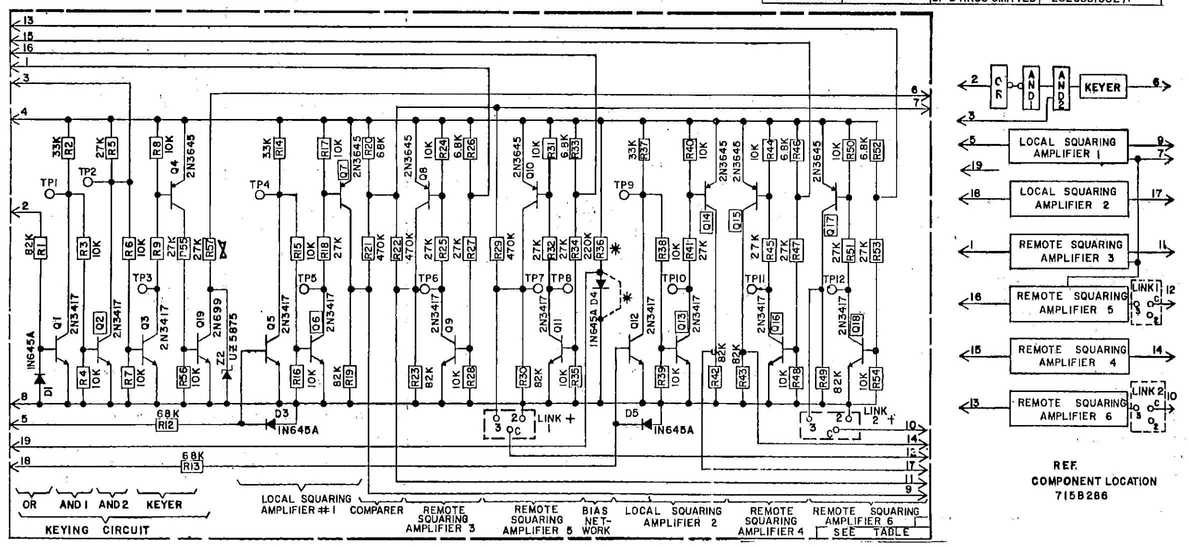


715B286

Fig. 7. Location of Components on Amplifier and Keying Board for TA-2 Tone Channel.

[Q2] = TRANSISTORS ARE NORMALLY CONDUCTING.
CONDITIONS FOR STATE OF TRANSISTORS SHOWN
I (1) SPACE SIGNAL BEING RECEIVED
(2) NO A.C. CURRENT FLOW INTO SEQ. FILTER
+ = CONNECT LINK TO PROPER TERMINAL. AS SHIPPED FROM FACTORY LINK CONNECTED FOR 2 TERMINAL LINE

TYPE RELAY	TYPE CHANNEL	REMARKS	STYLE BOARD
SKBU-2	TA2 TONE	⋈ = 27 K	202C551G01
SKBU-2	TA2.1 TONE	⋈ = 5.1 K	202C551G02
SKBU-2 SKBU-21	TA2 TONE	⋈ = 27 K ✱=JUMPER IN PLACE OF D4. R36 OMITTED	202C551G03 (SUPERSEDES 202C551G01)
SKBU-2 SKBU-21	TA2.1 TONE	⋈ = 5.1 K ✱=JUMPER IN PLACE OF D4. R36 OMITTED	202C551G04 (SUPERSEDES 202C551G02).



715B285

Fig. 8. Schematic of Amplifier and Keying Board for TA-2 Tone Channel.

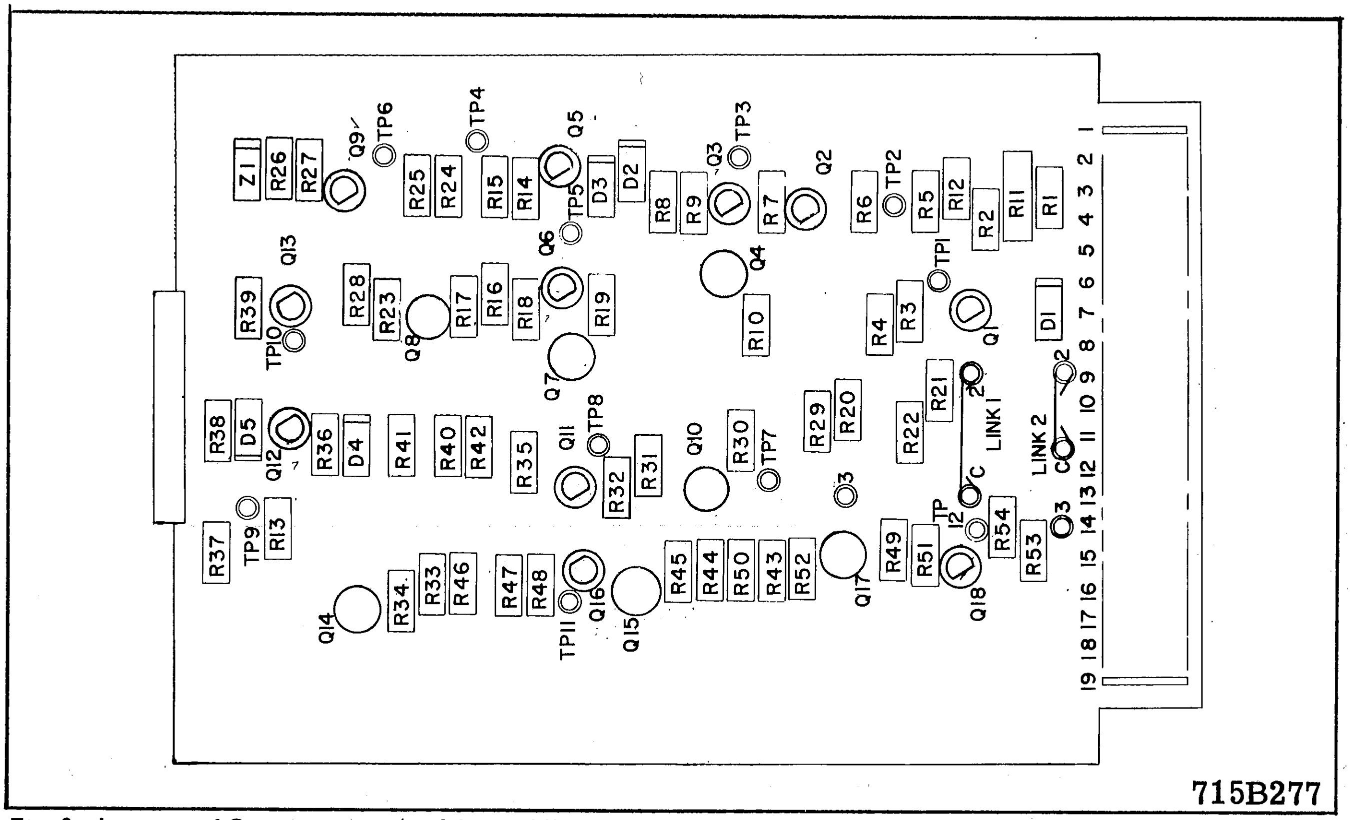


Fig. 9. Location of Components on Amplifier and Keying Board for TCF Carrier Channel, TA2.2 Tone Channel, and MC-22 Microwave Channel.

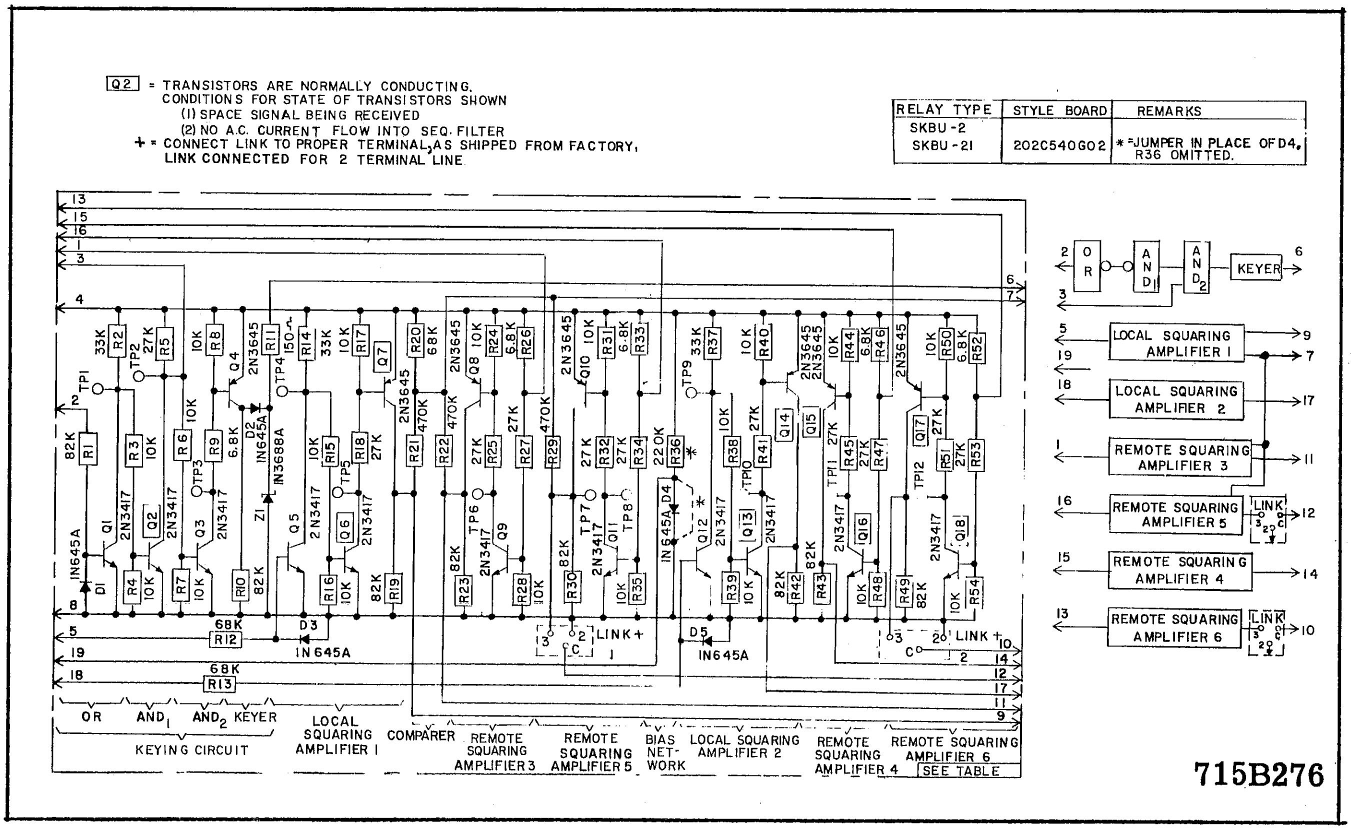


Fig. 10. Schematic of Amplifier and Keying Board for TCF Carrier Channel, TA2.2 Tone Channel, and MC-22 Microwave Channel.

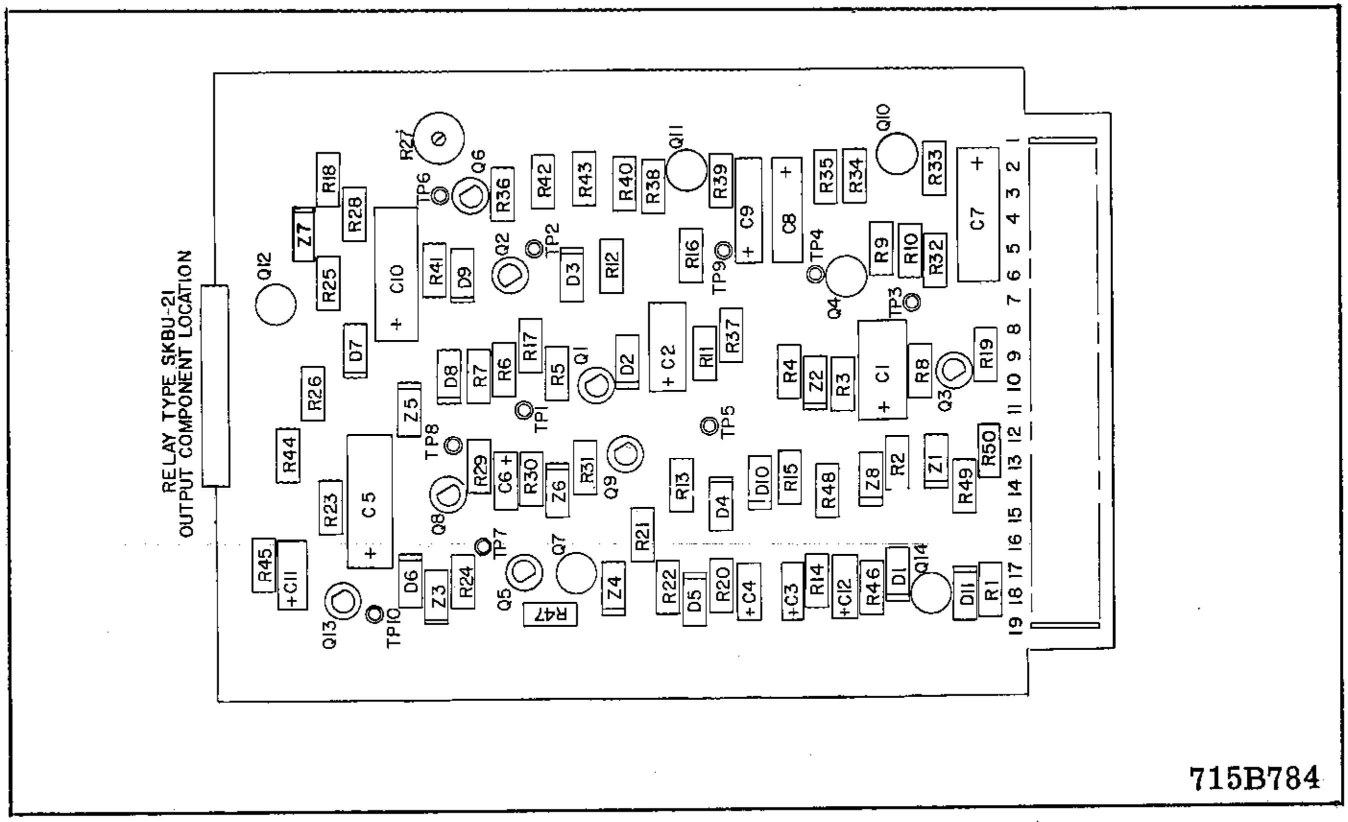


Fig. 11. Location of Components on Output Board.

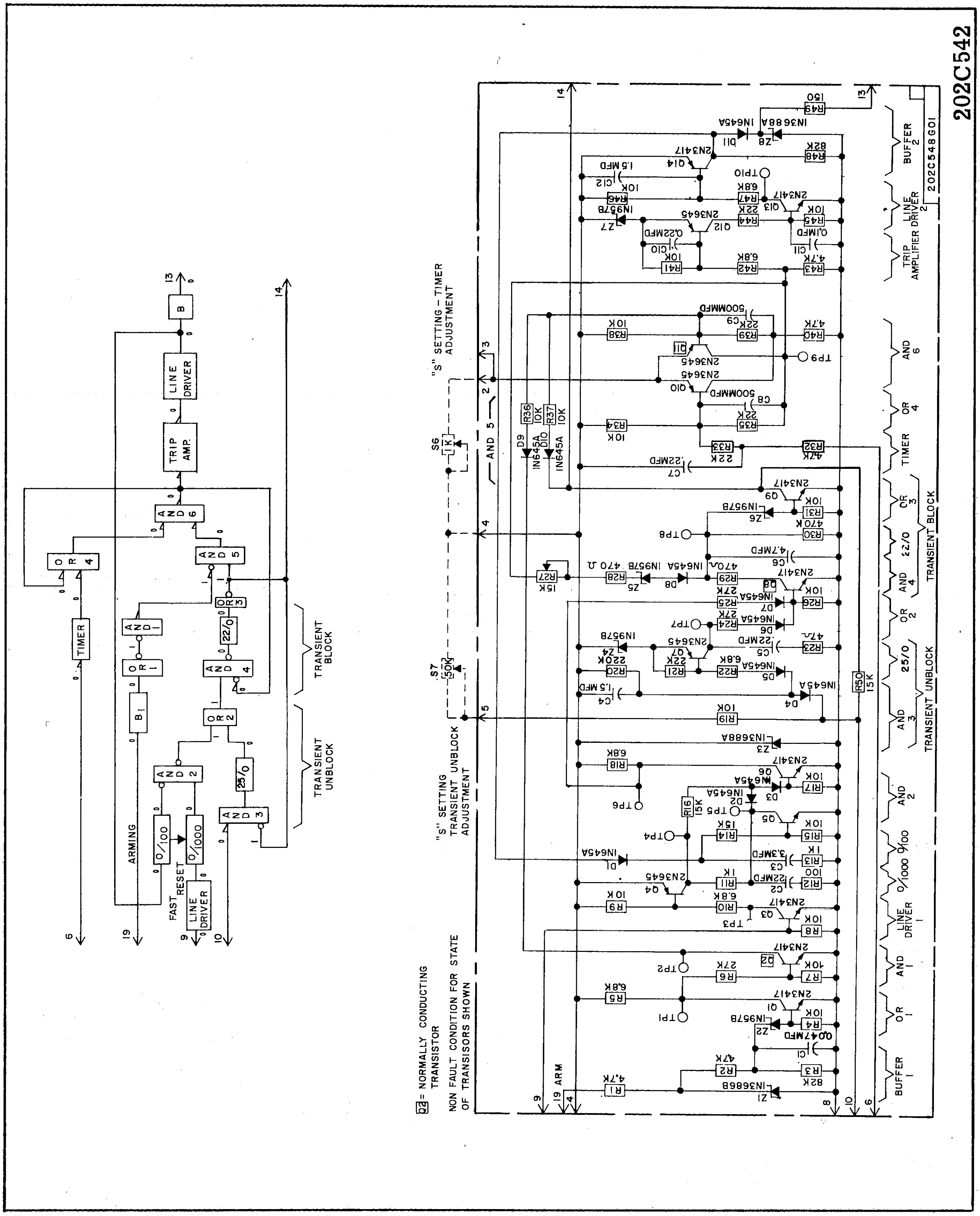


Fig. 12. Schematic of Output Board.

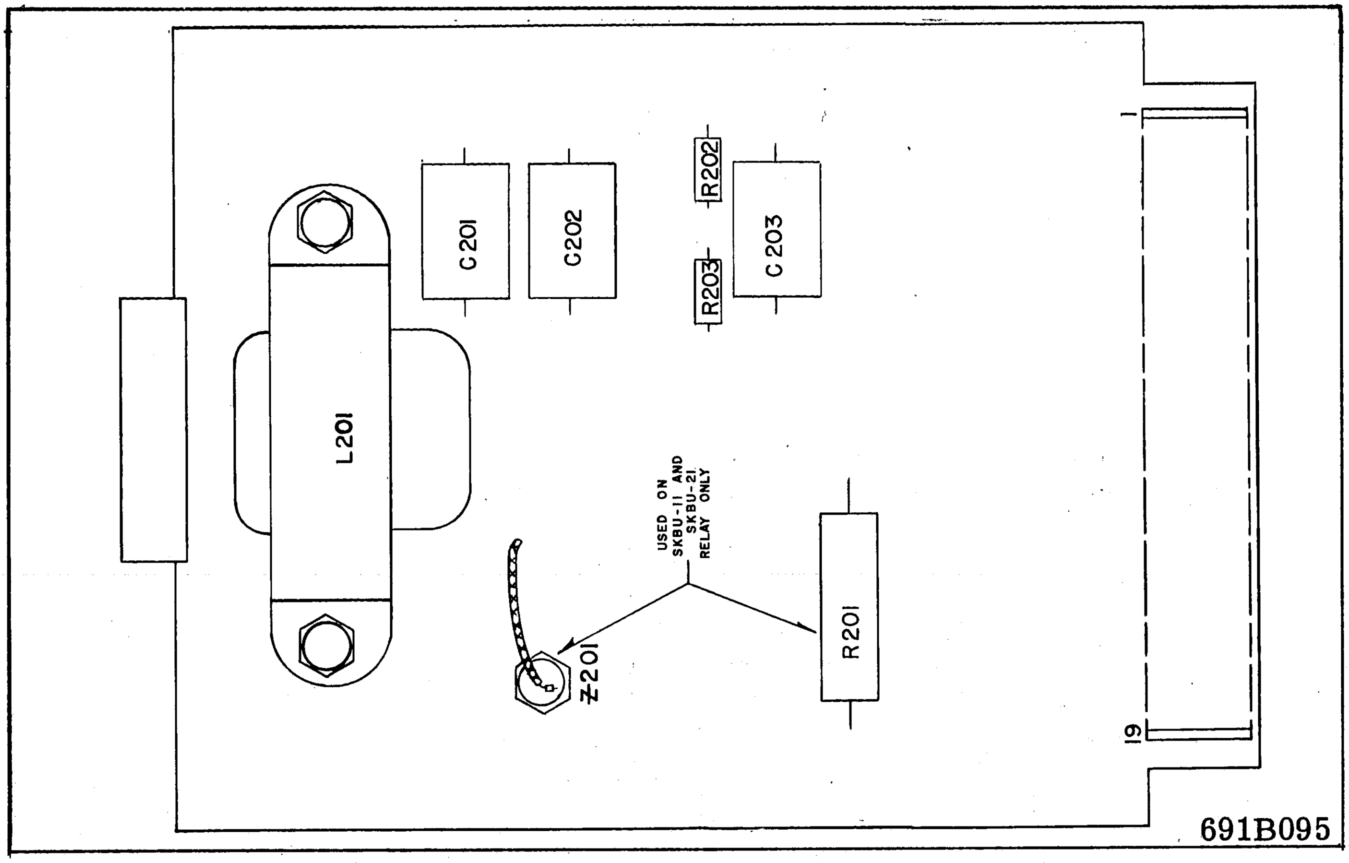
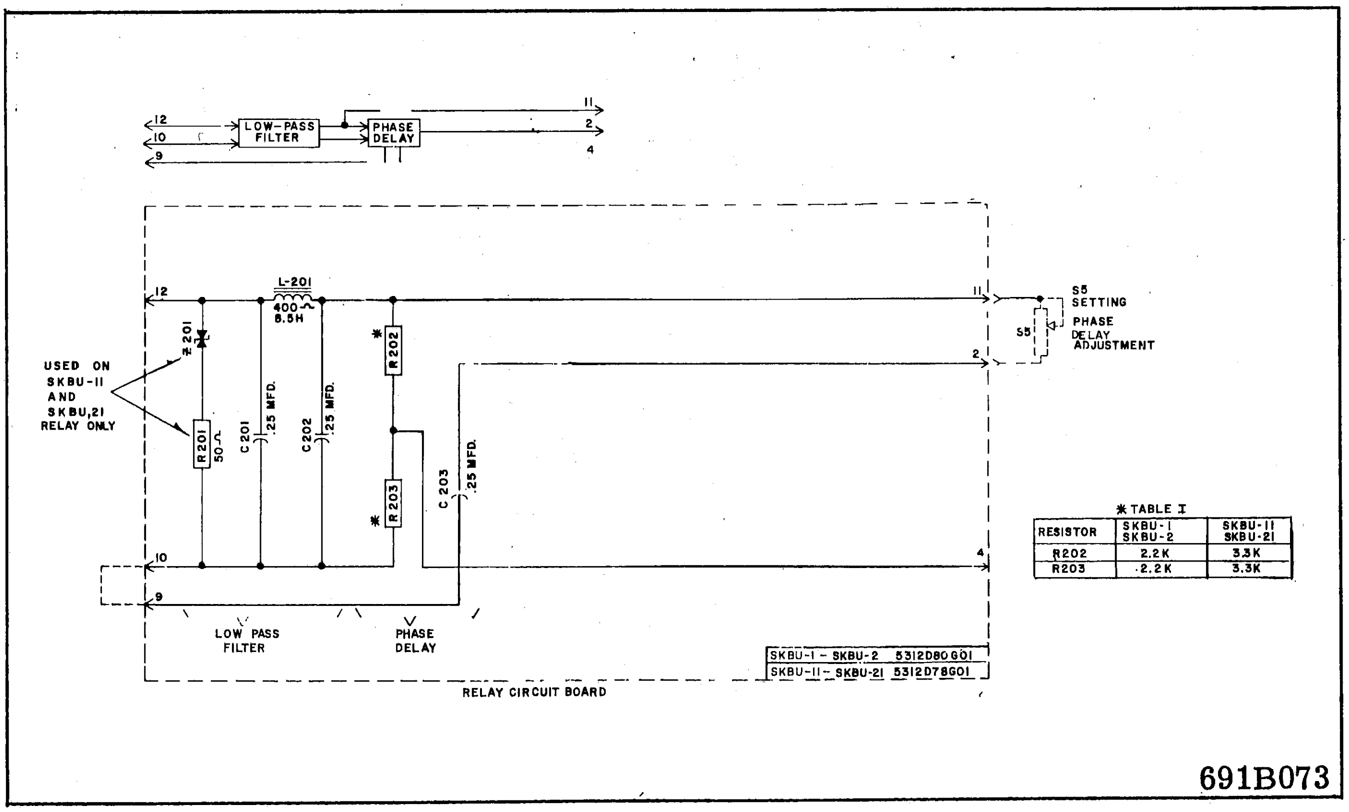


Fig. 13. Location of Components on Relay Board.



✱ TABLE I

RESISTOR	SKBU-1 SKBU-2	SKBU-11 SKBU-21
R202	2.2K	3.3K
R203	2.2K	3.3K

Fig. 14. Schematic of Relay Board.

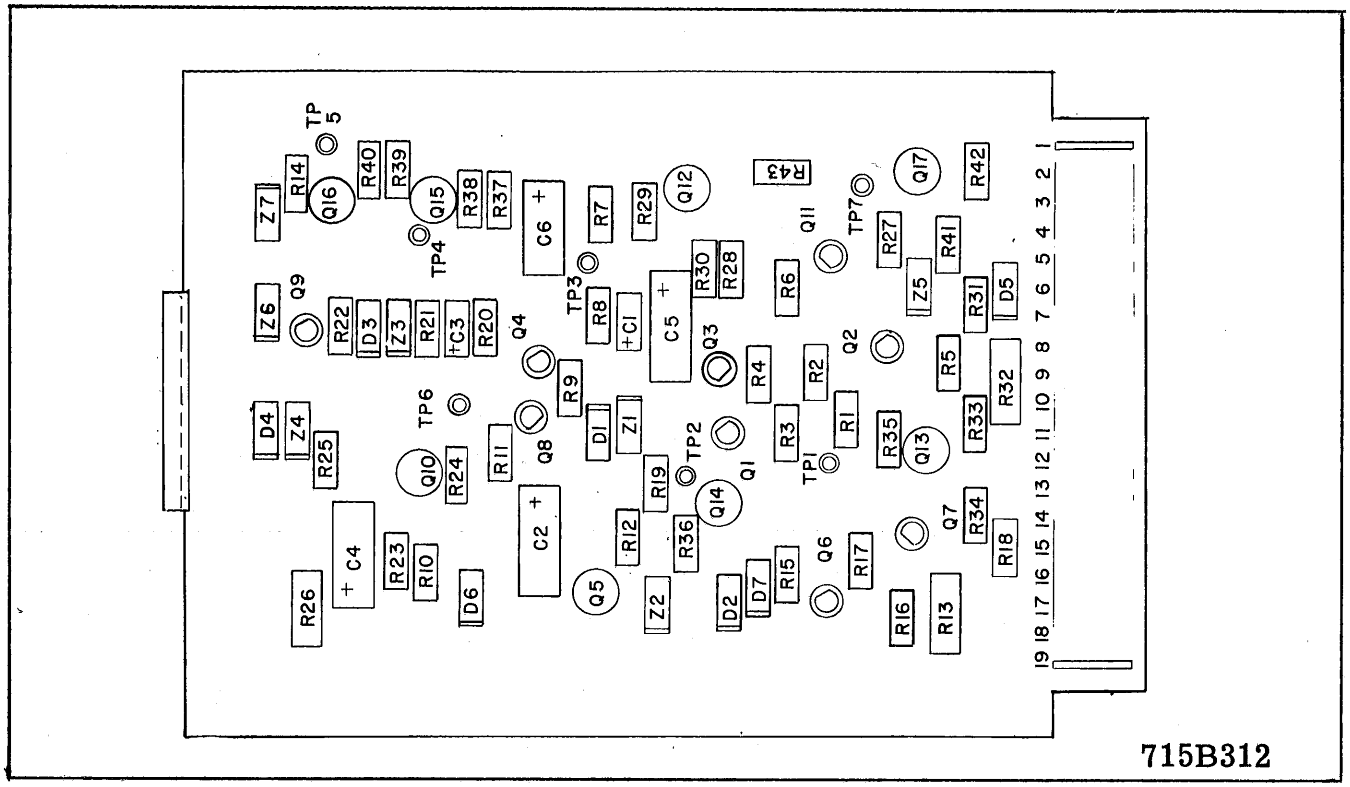


Fig. 15. Location of Components on Supervision Board for TA-2 Tone Channel.

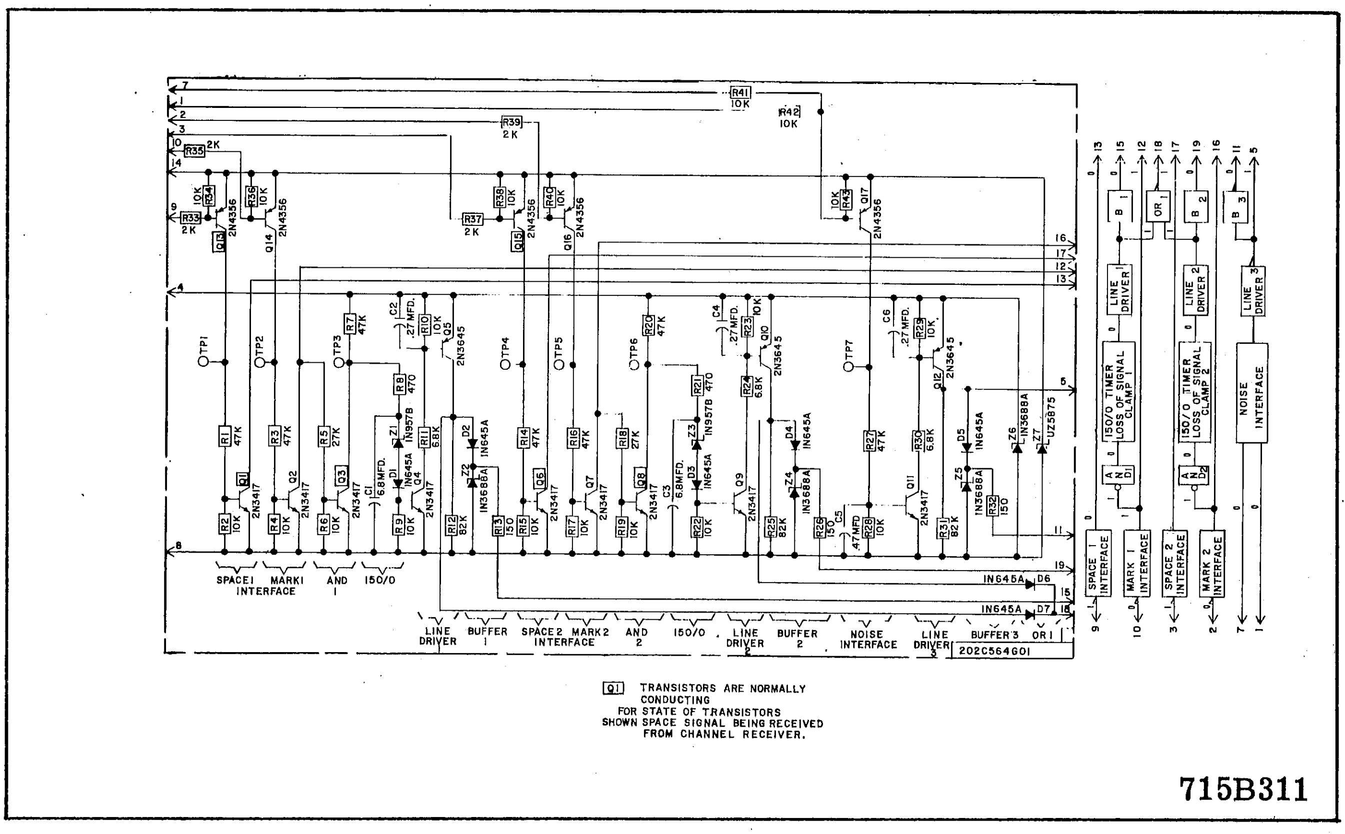


Fig. 16. Schematic of Supervision Board for TA-2. Tone Channel.

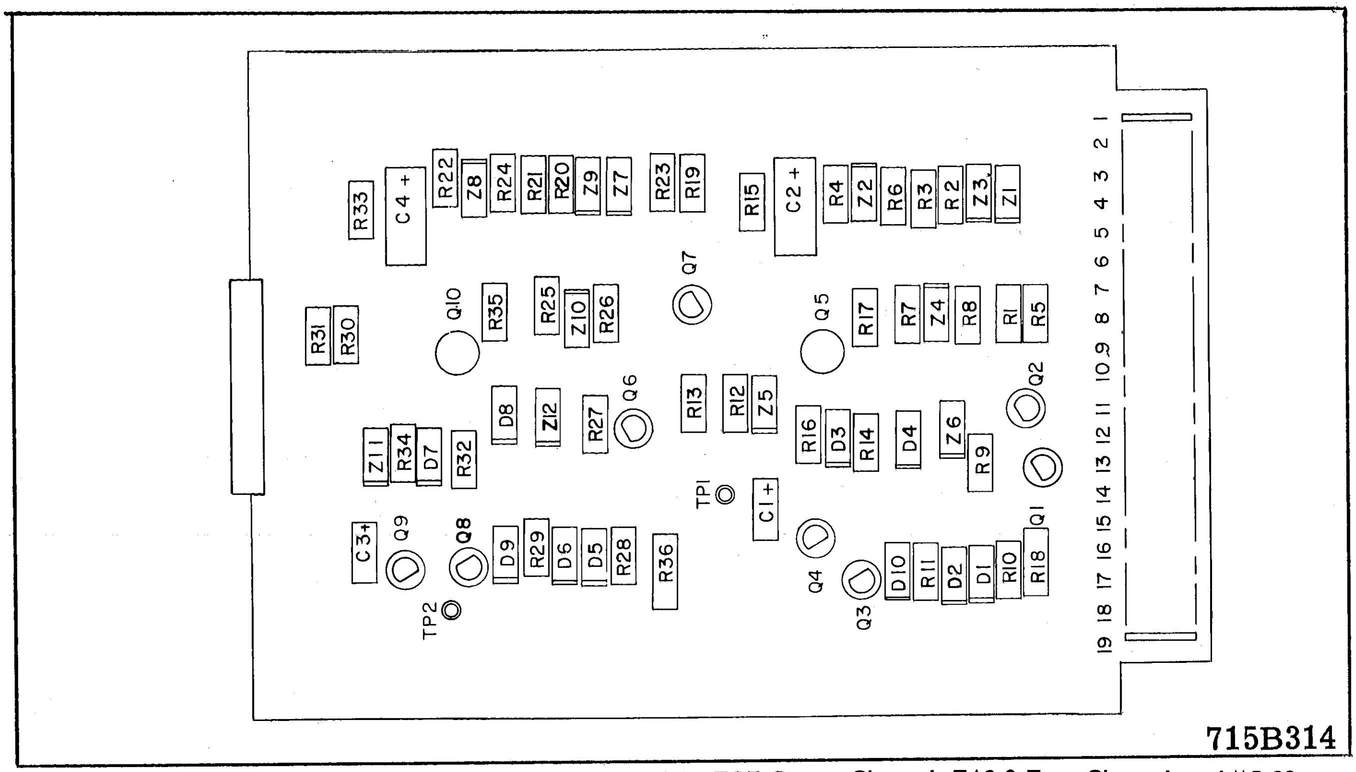


Fig. 17. Location of Components on Supervision Board for TCF Carrier Channel, TA2.2 Tone Channel, and MC-22 Microwave Channel.

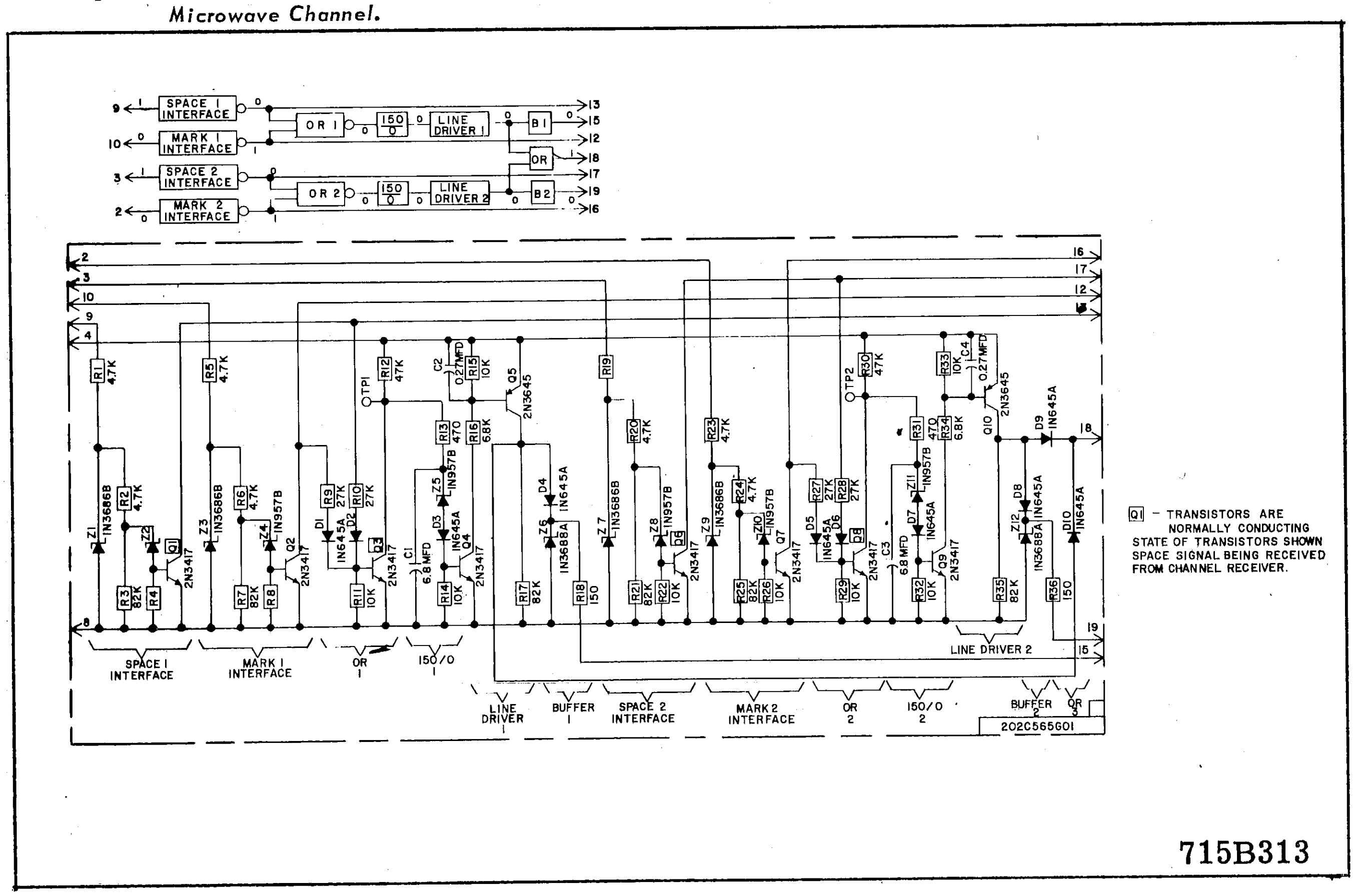


Fig. 18. Schematic of Supervision Board for TCF Carrier Channel, TA2.2 Tone Channel, and MC-22 Microwave Channel.

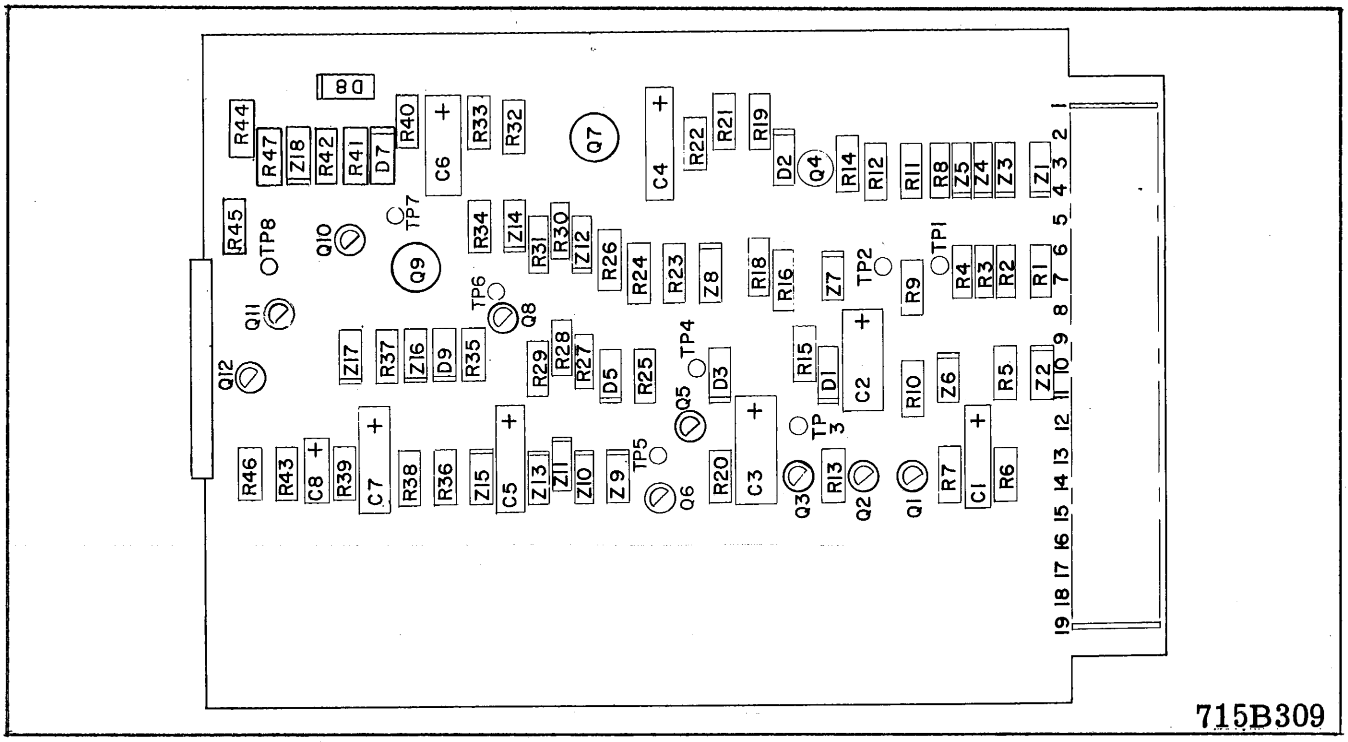


Fig. 19. Location of Components on Protective Relay Board.

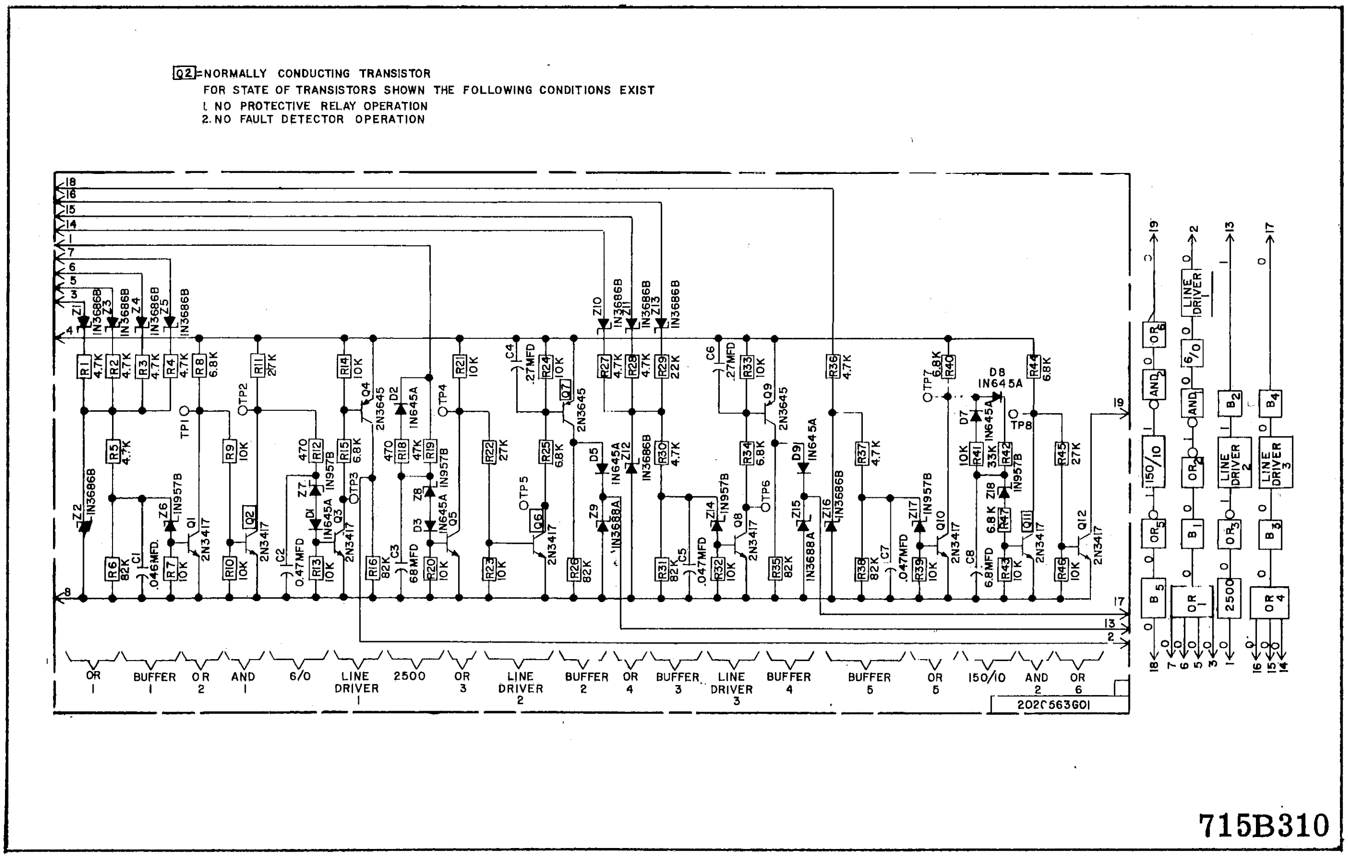
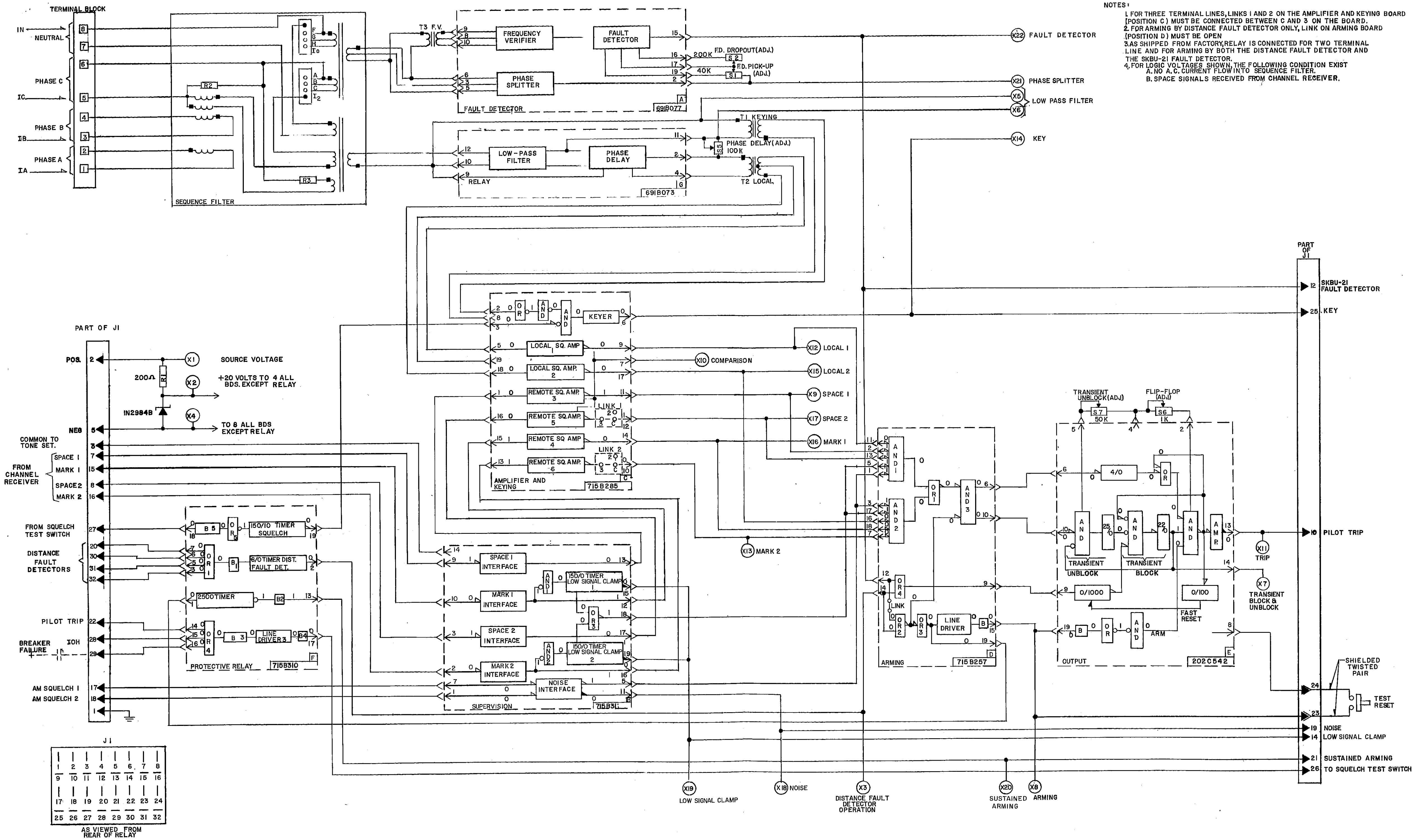


Fig. 20. Schematic of Protective Relay Board.



NOTES:

1. FOR THREE TERMINAL LINES, LINKS 1 AND 2 ON THE AMPLIFIER AND KEYING BOARD (POSITION C) MUST BE CONNECTED BETWEEN C AND 3 ON THE BOARD.
2. FOR ARMING BY DISTANCE FAULT DETECTOR ONLY, LINK ON ARMING BOARD (POSITION D) MUST BE OPEN
3. AS SHIPPED FROM FACTORY, RELAY IS CONNECTED FOR TWO TERMINAL LINE AND FOR ARMING BY BOTH THE DISTANCE FAULT DETECTOR AND THE SKBU-21 FAULT DETECTOR.
4. FOR LOGIC VOLTAGES SHOWN, THE FOLLOWING CONDITION EXIST
   A. NO A.C. CURRENT FLOW INTO SEQUENCE FILTER.
   B. SPACE SIGNALS RECEIVED FROM CHANNEL RECEIVER.

Fig. 21. Logic Diagram of SKBU-21 for TA-2 Tone Channel.

5489D85

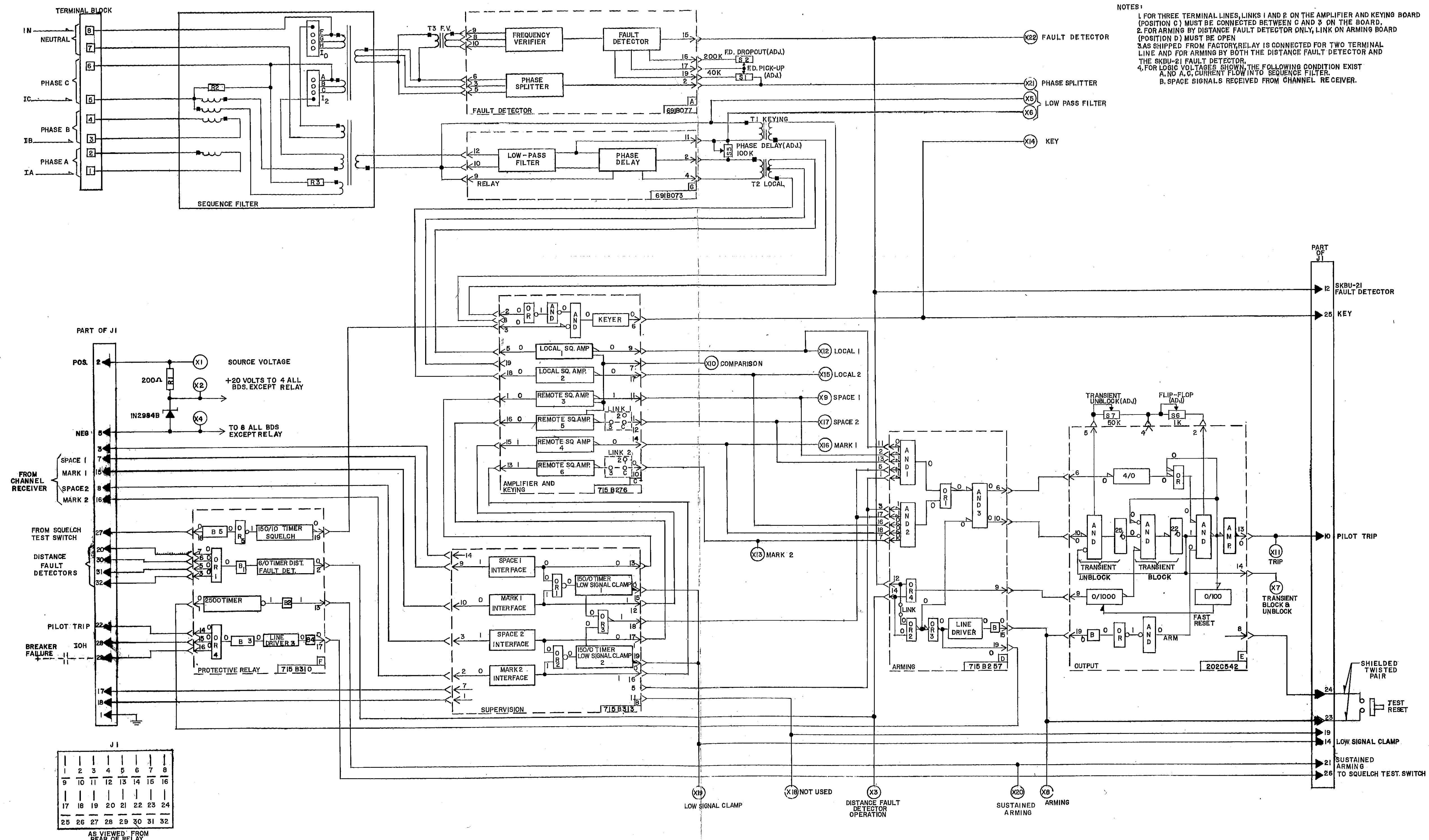


Fig. 22. Logic Diagram of SKBU-21 for TA2.2 Channel, MC-22 Microwave Channel and TCF Carrier Channel.

5489D57

NOTES:

1. FOR THREE TERMINAL LINES, LINKS 1 AND 2 ON THE AMPLIFIER AND KEYING BOARD (POSITION C) MUST BE CONNECTED BETWEEN C AND 3 ON THE BOARD.
2. FOR ARMING BY DISTANCE FAULT DETECTOR ONLY, LINK ON ARMING BOARD (POSITION D) MUST BE OPEN
3. AS SHIPPED FROM FACTORY, RELAY IS CONNECTED FOR TWO TERMINAL LINE AND FOR ARMING BY BOTH THE DISTANCE FAULT DETECTOR AND THE SKBU-2 FAULT DETECTOR.
4. FOR LOGIC VOLTAGES SHOWN, THE FOLLOWING CONDITION EXIST
   A. NO A.C. CURRENT FLOW INTO SEQUENCE FILTER.
   B. SPACE SIGNALS RECEIVED FROM CHANNEL RECEIVER

TABLE I (SUPERVISION BD.)

TYPE CHANNEL	NOISE INPUT	SCHEMATIC REF.	NOTE
TA-2	NEGATIVE	715B311	WHERE NO LOCKOUT ON LOW SIGNAL CLAMP IS DESIRED, OR 3 OMITTED AND OUTPUT OF LOW SIGNAL CLAMP 1 DISABLED
TA-2.1	POSITIVE	716B364	

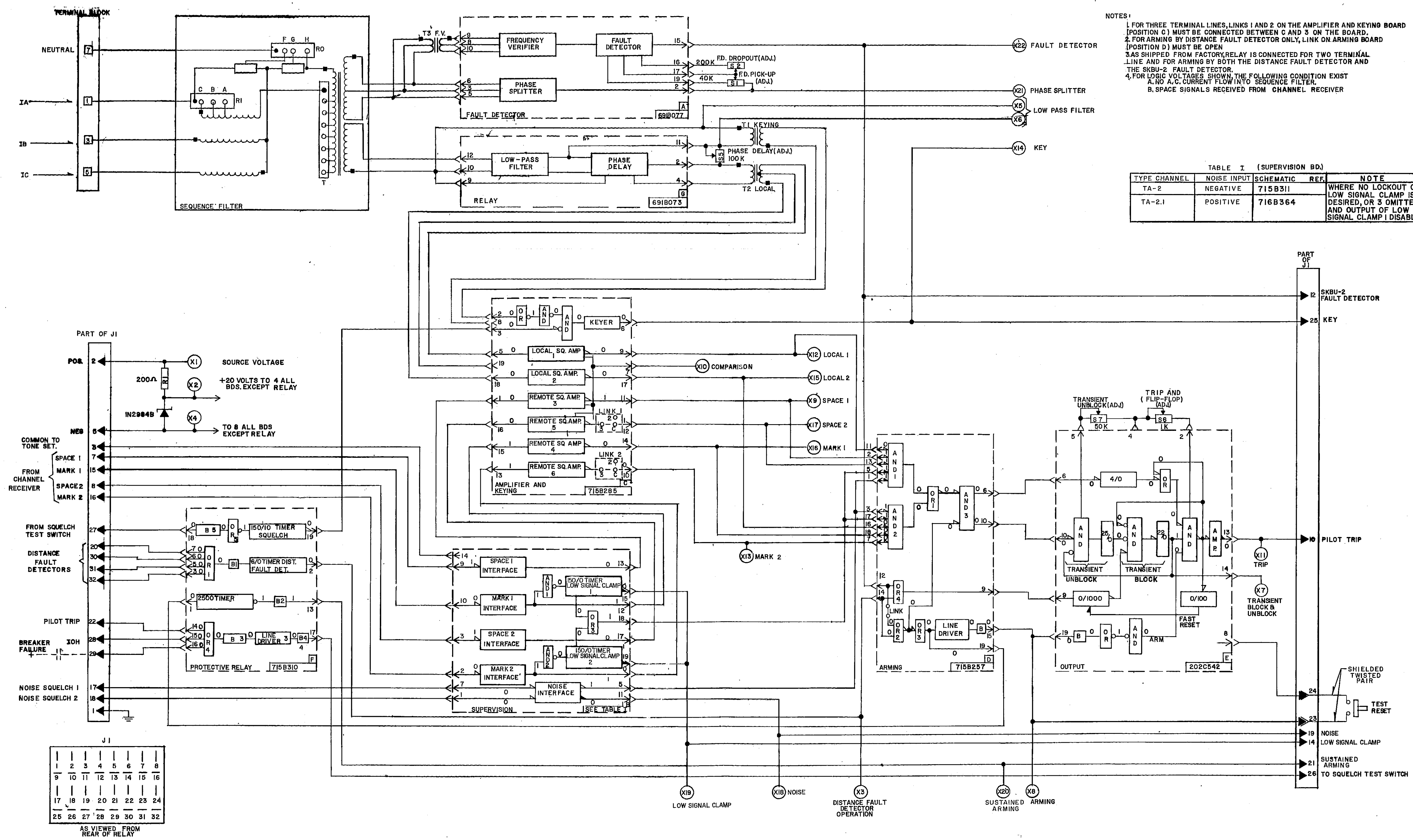


Fig. 23. Logic Diagram of SKBU-2 for TA-2 Tone Channel.

5489D83

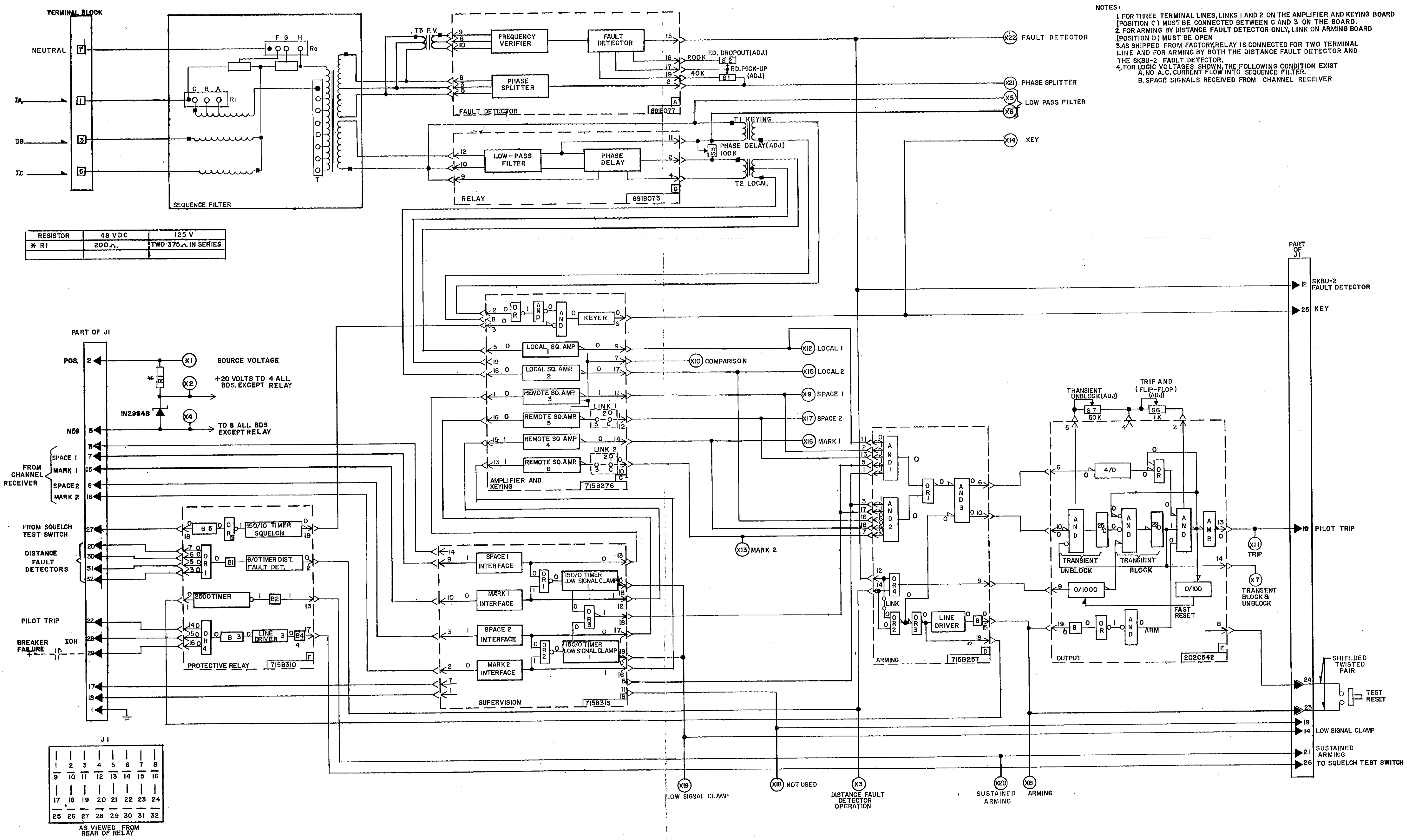


Fig. 24. Logic Diagram of SKBU-2 for TA2.2 Tone Channel, MC-22 Microwave Channel and TCF Carrier Channel.

5489D84

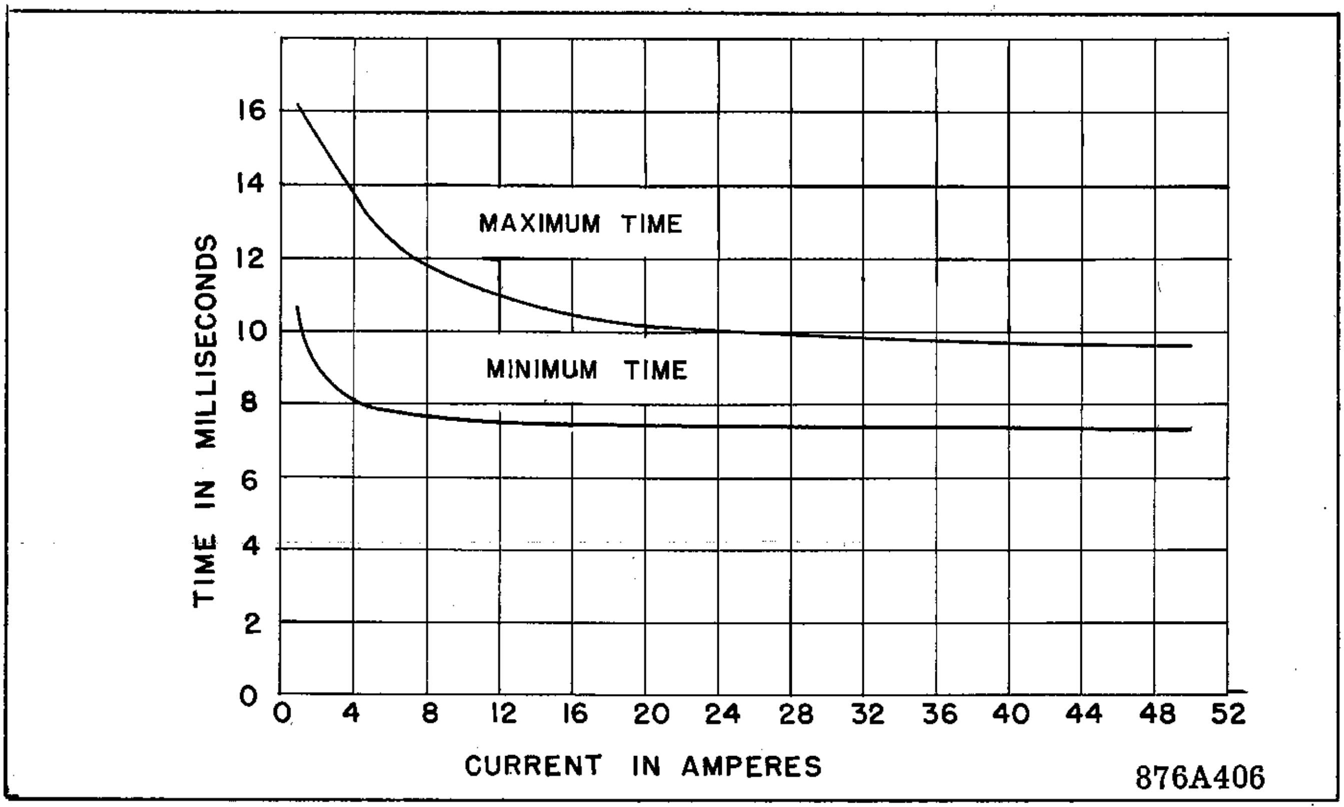


Fig. 25. Operating Times of Fault Detector of SKBU-21 Relay.

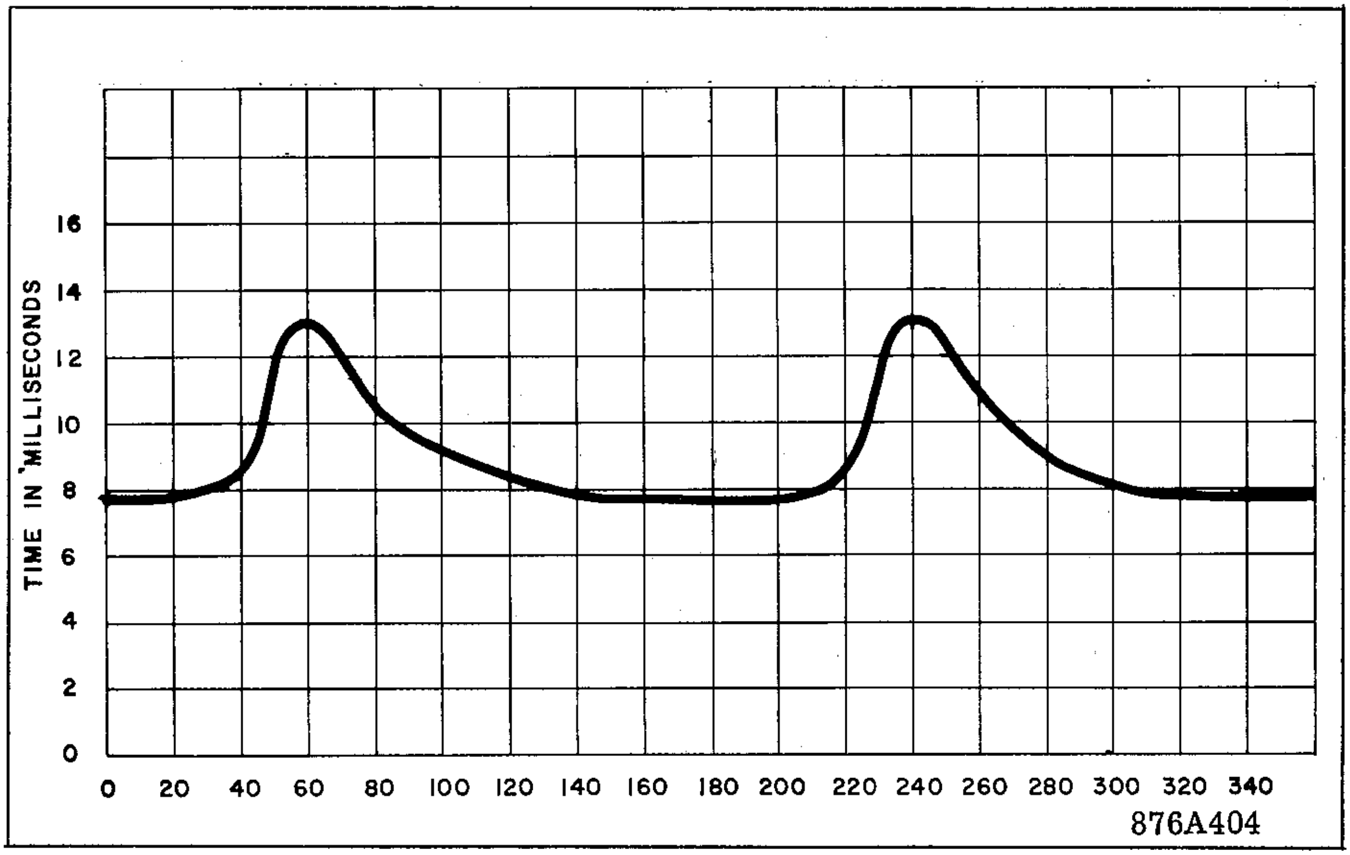


Fig. 26. Operating Times for Fault Detector of SKBU-21 Relay as a Function of Fault Incidence Angle at 5 amperes.

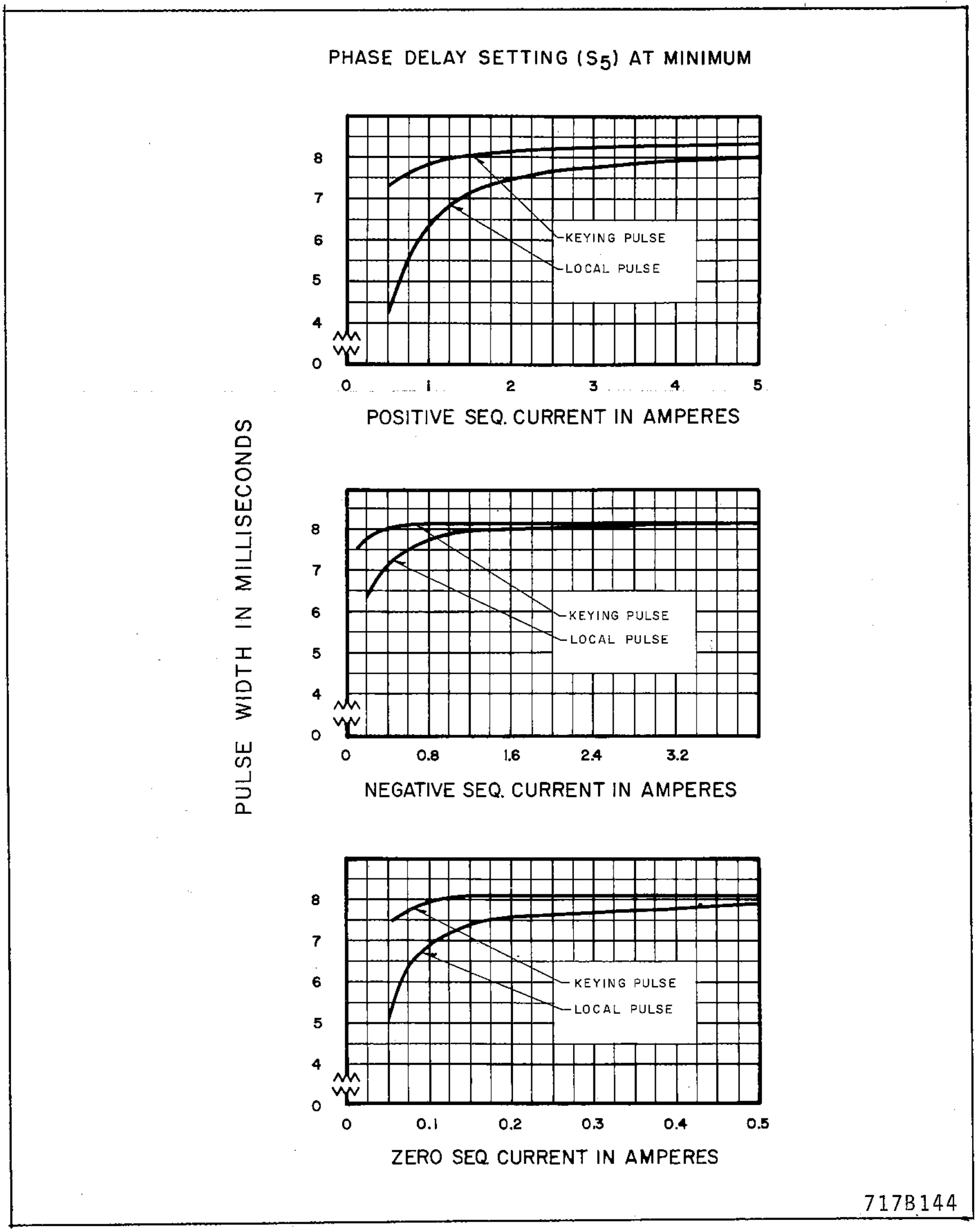


Fig. 27. Width of Keying Pulses at Different Current Levels of SKBU-21 Relay.

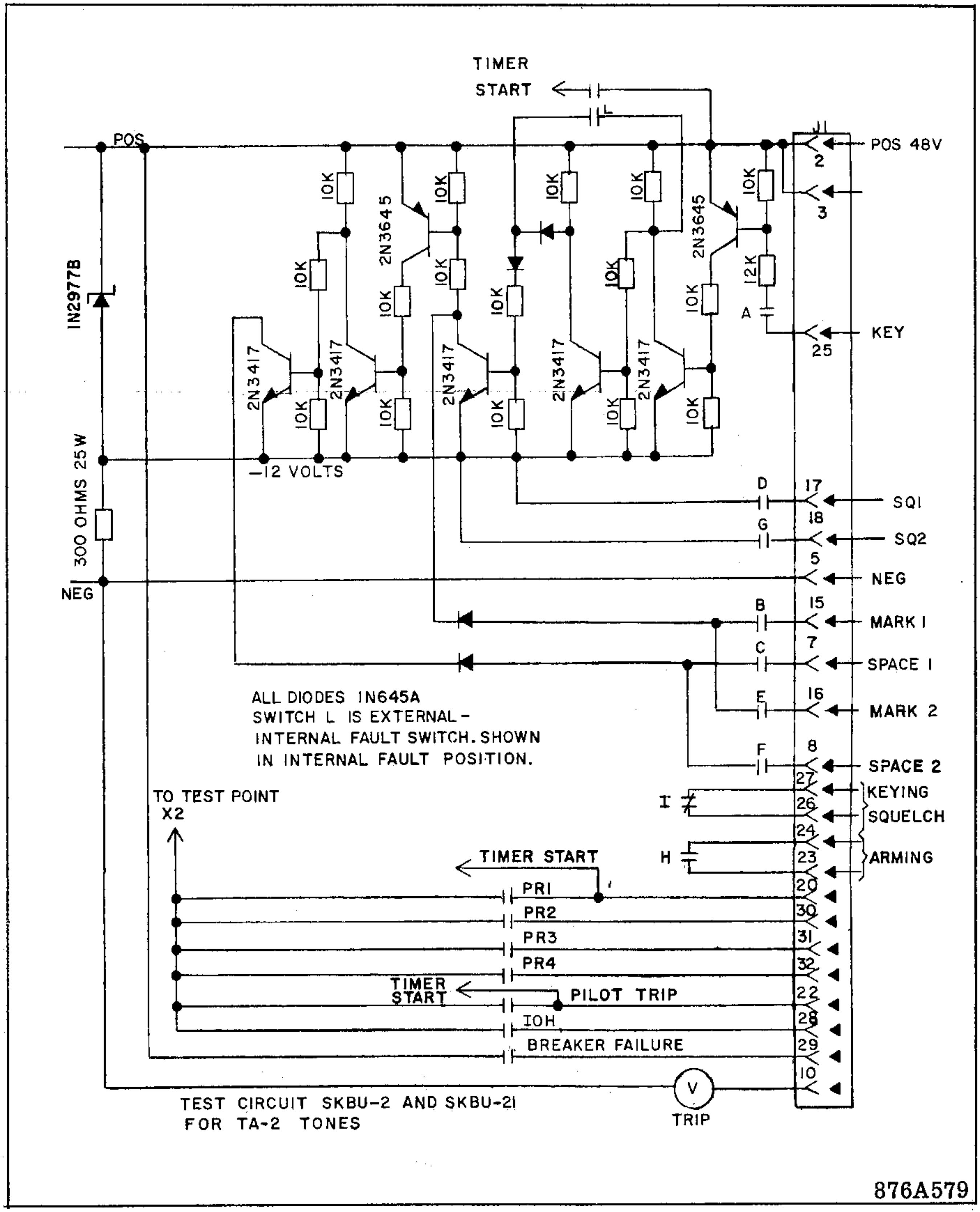


Fig. 28. Test Circuit of SKBU-21 Relay for TA-2 Tone Channel.

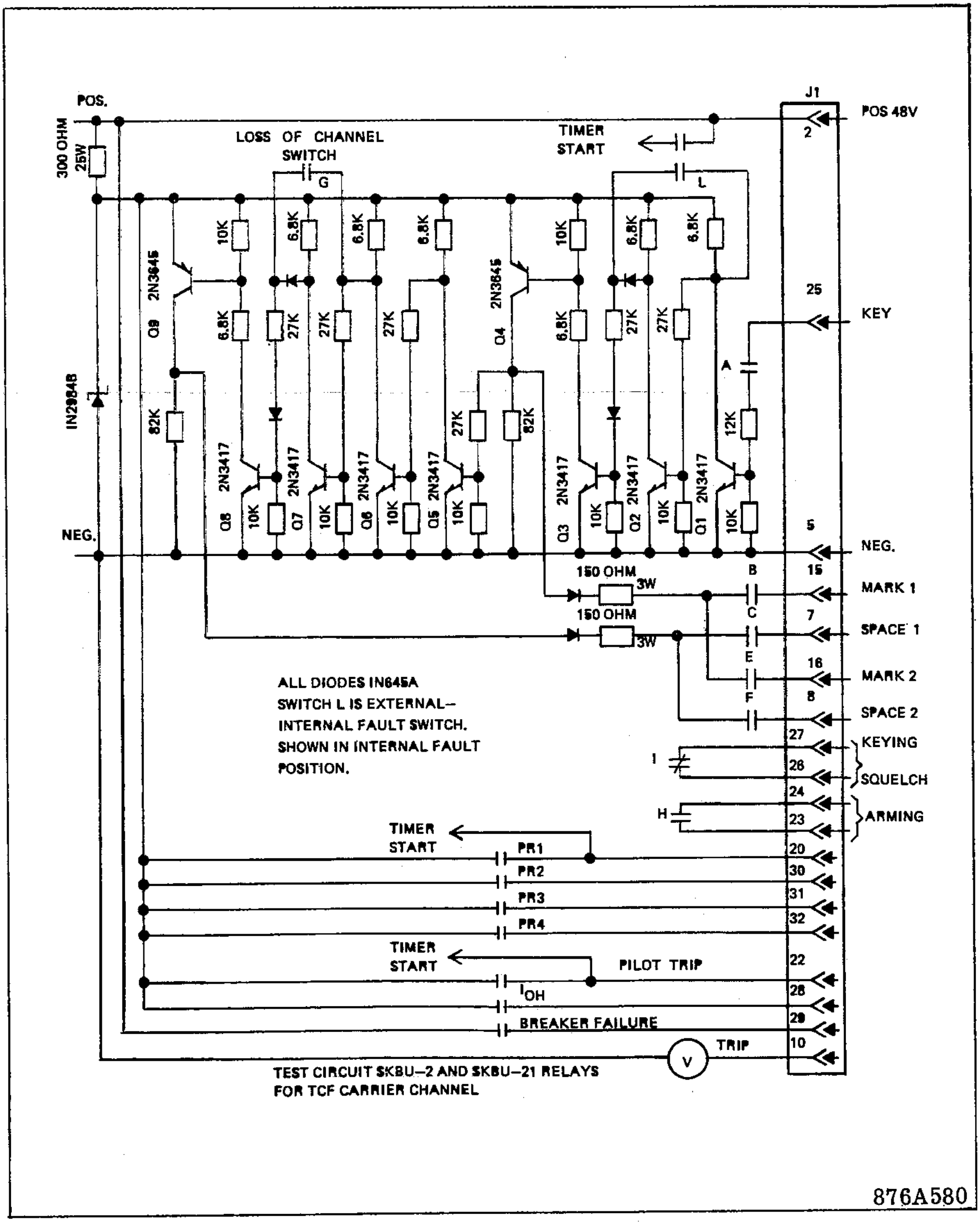


Fig. 29. Test Circuit of SKBU-21 Relay for TCF Carrier Channel, TA2.2 Tone Channel, and MC-22 Microwave Channel.

TEST POINT	CIRCUIT	VOLTAGE TO X4
X1	D.C. INPUT VOLTAGE	48 VOLTS D.C.
X2	REGULATED D.C.	20 VOLTS D.C.
X4	BATTERY NEGATIVE	
X7	TRANSIENT BLOCK	NORMAL 20 VOLTS OPERATE 0 VOLTS
X8	ARMING	NORMAL 20 VOLTS OPERATE 0 VOLTS
X11	PILOT TRIP	NORMAL 0 VOLTS OPERATE 20 VOLTS
X18	NOISE (TA-2 ONLY)	NORMAL 0 VOLTS OPERATE 20 VOLTS
X3	DISTANCE FAULT DETECTOR OPERATION	NORMAL 0 VOLTS OPERATE 20 VOLTS
X19	LOSS OF SIGNAL CLAMP	NORMAL 0 VOLTS OPERATE 20 VOLTS
X20	SUSTAINED ARMING	NORMAL 20 VOLTS OPERATE 0 VOLTS
X22	FAULT DETECTOR	NORMAL 0 VOLTS OPERATE 20 VOLTS
X5 TO X6(GND)	LOW PASS FILTER	I LOAD 5 AMPS 3 ϕ; 16.7 MS
X14	KEYING TONE CHANNEL ϕϕ	X, Y; SPACE, MARK
X14	KEYING TCF POWER LINE CARRIER CHANNEL	20, 0; MARK, SPACE
X12	LOCAL SIGNAL 1	20, 0; BLOCK, UNBLOCK
X9	SPACE SIGNAL 1 REMOTE 3	20, 0; CHANNEL DELAY; BLOCK, UNBLOCK
X17	SPACE SIGNAL 2 REMOTE 5 (3 TERMINAL LINE)	20, 0; BLOCK, UNBLOCK
X15	LOCAL SIGNAL 2	20, 0; BLOCK, UNBLOCK
X16	MARK SIGNAL 1 REMOTE 4	20, 0; BLOCK, UNBLOCK
X13	MARK SIGNAL 2 REMOTE 6 (3 TERMINAL LINE)	20, 0; BLOCK, UNBLOCK
X10	COMPARER	
X21	PHASE SPLITTER	

ϕϕ = TA 2 TONE CHANNEL X=45 VOLTS Y=36 VOLTS
TA2.1 TONE CHANNEL X=18 VOLTS Y=8 VOLTS

716B052

Fig. 30. Table III Test Point Voltage.

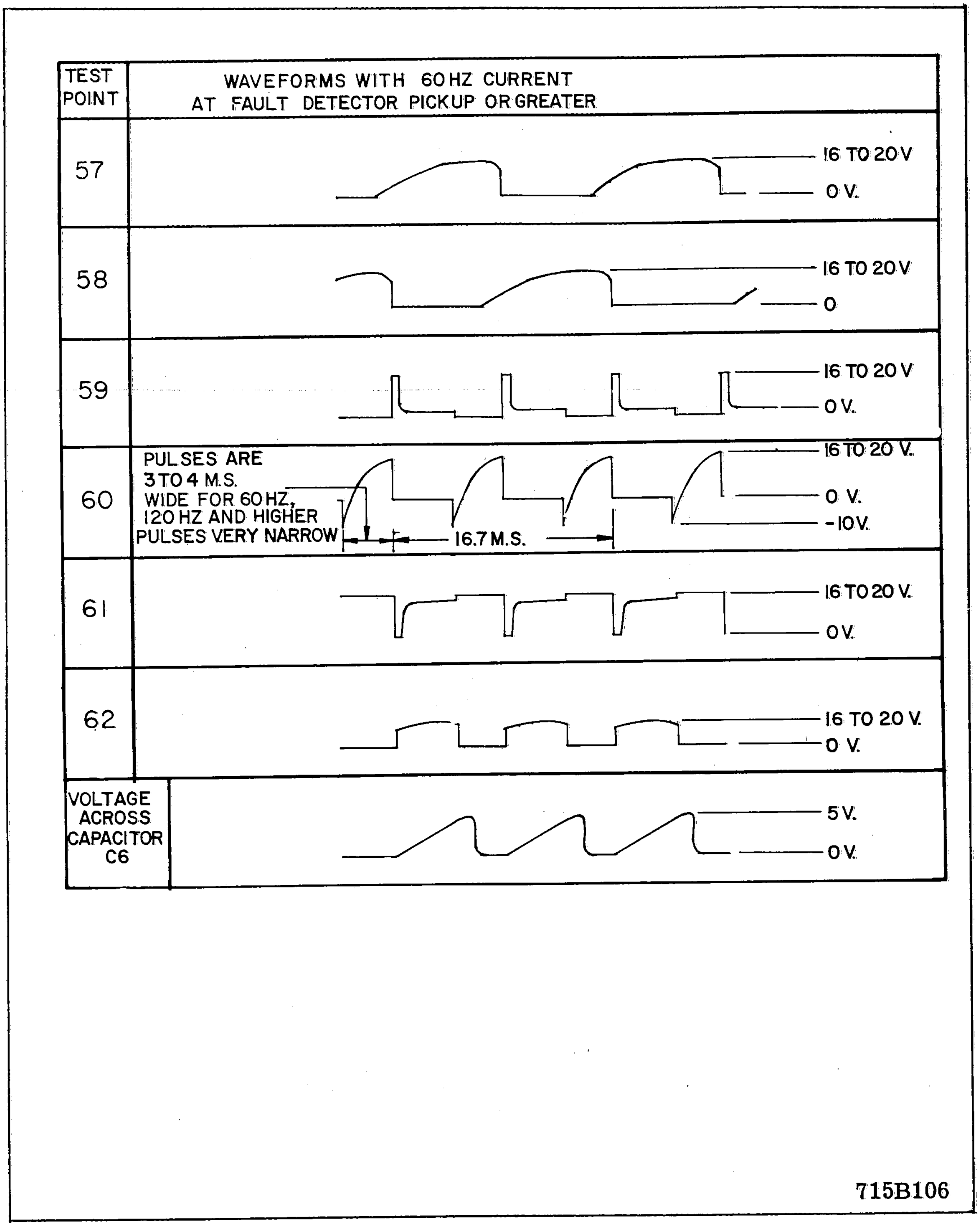


Fig. 31. Frequency Verifier Waveforms at 60 Hz.

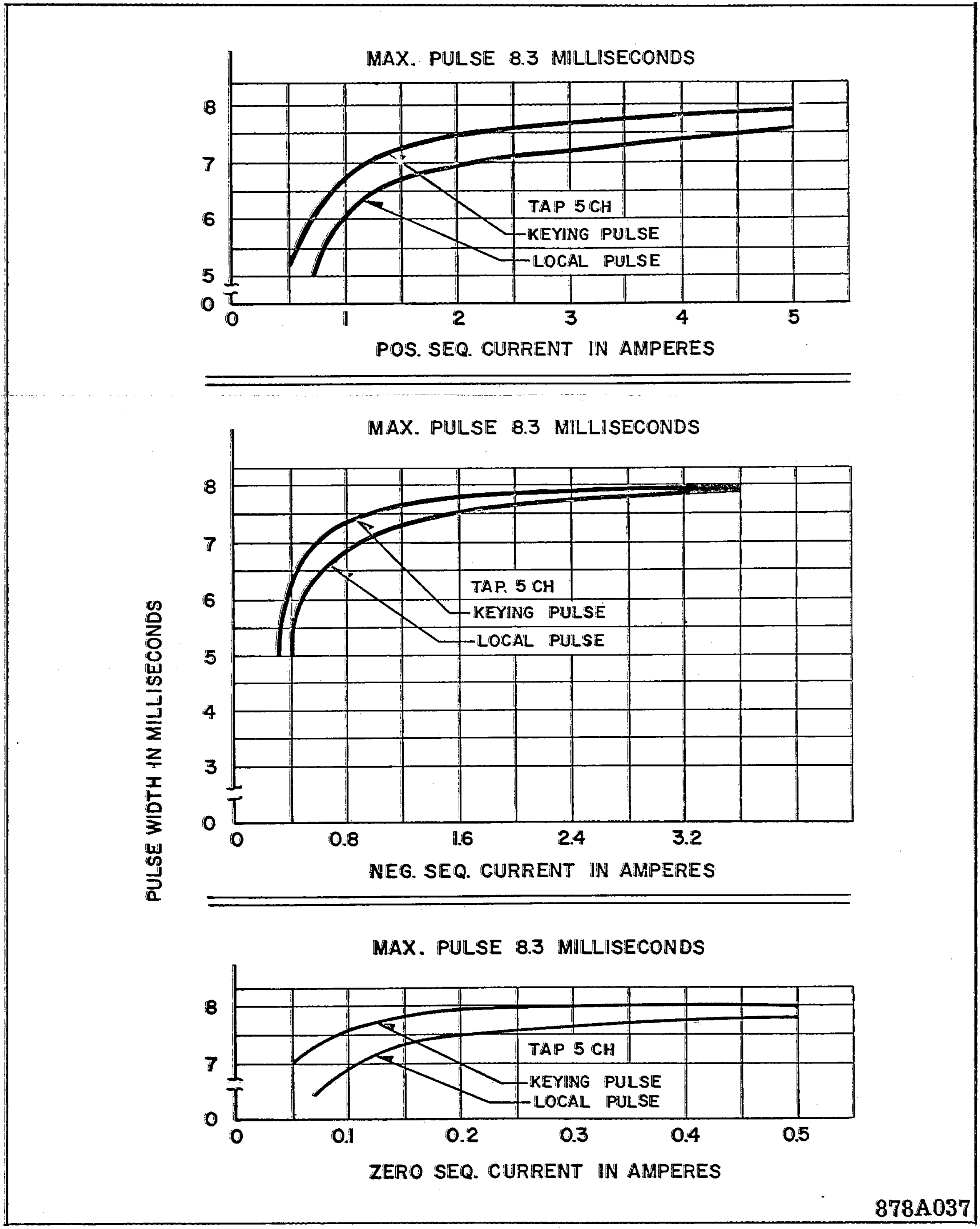


Fig. 32. Width of Keying Pulses at different current levels of SKBU-2 Relay.

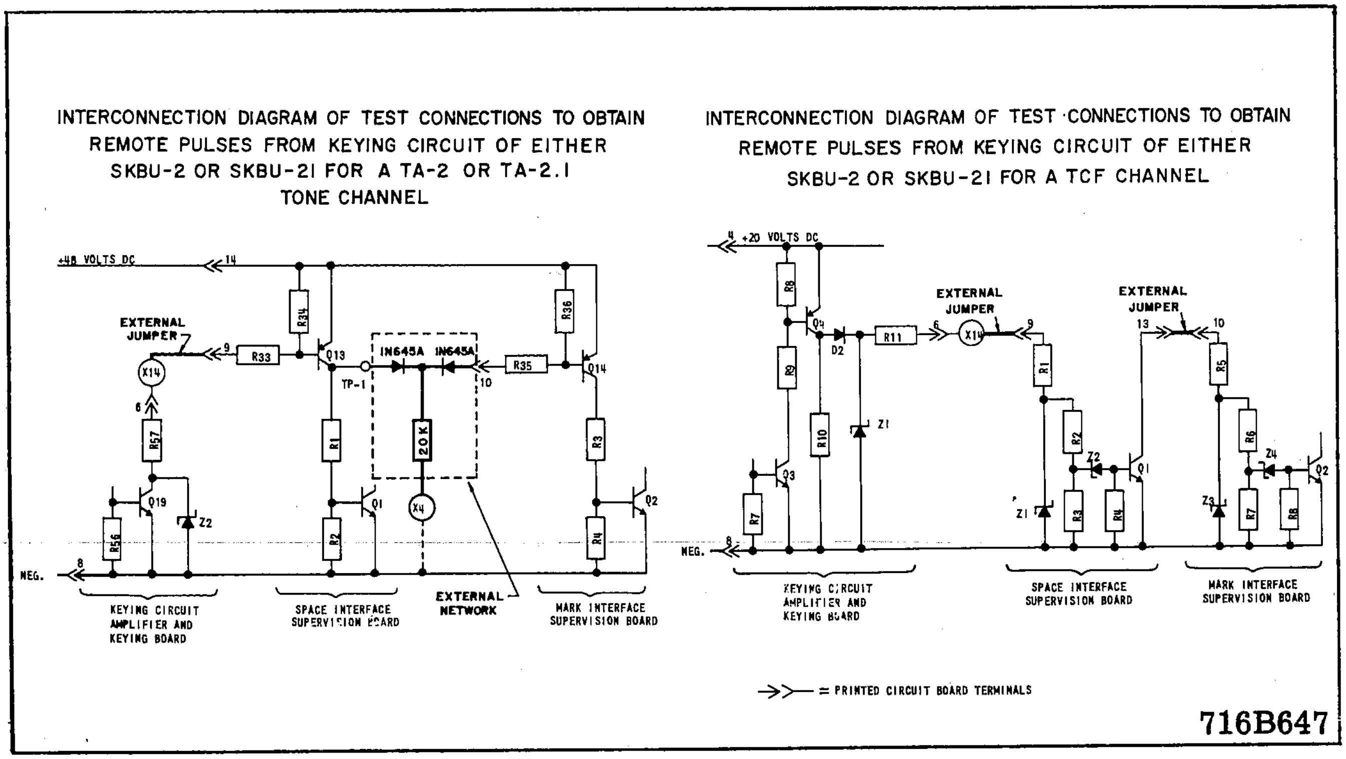


Fig. 33. Inter Connection Diagram of Test Connections to Obtain Remote Pulses from Keying Circuit.

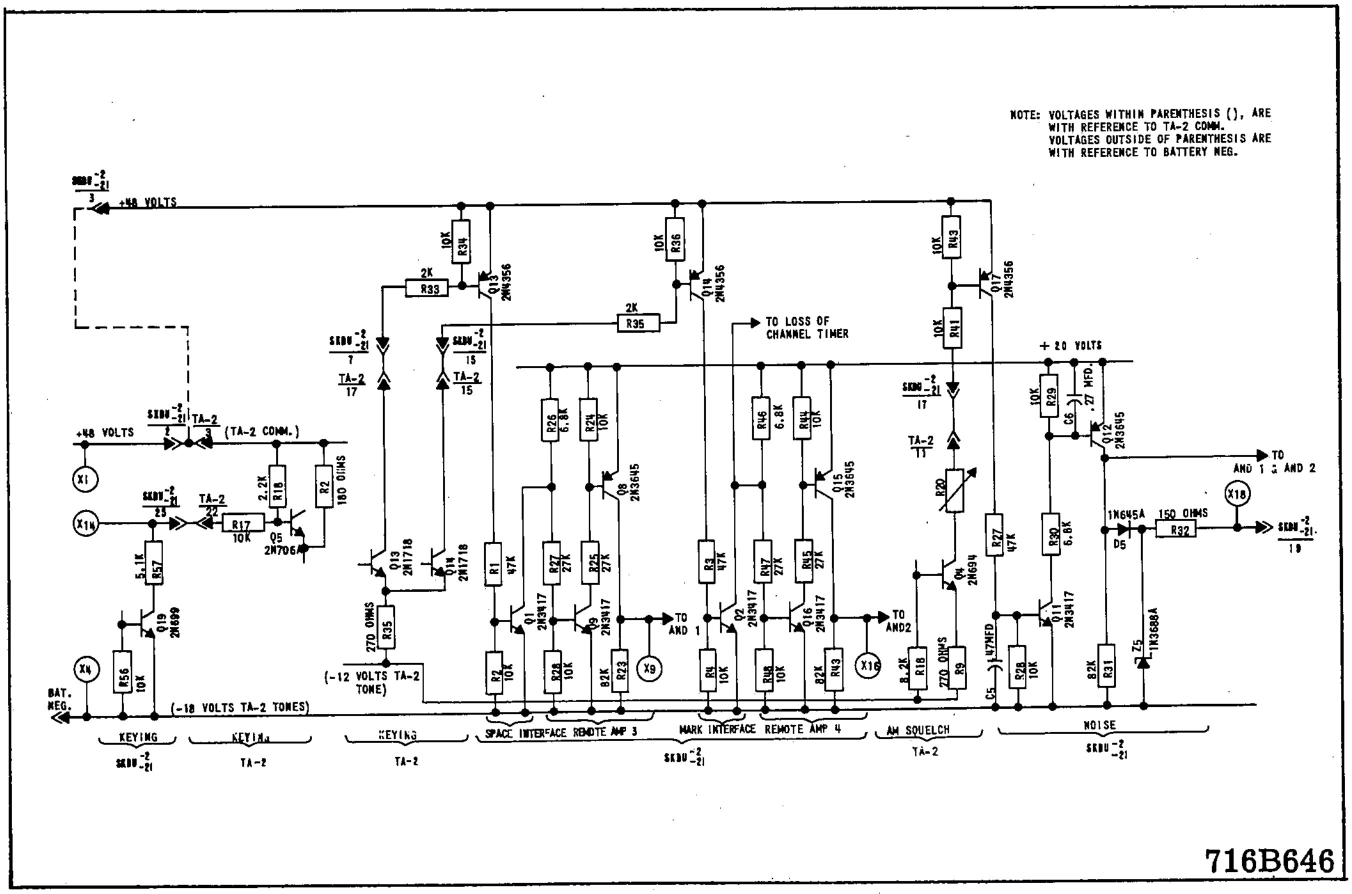


Fig. 34. Elementary Connections of SKBU to TA-2 Tone Channel.

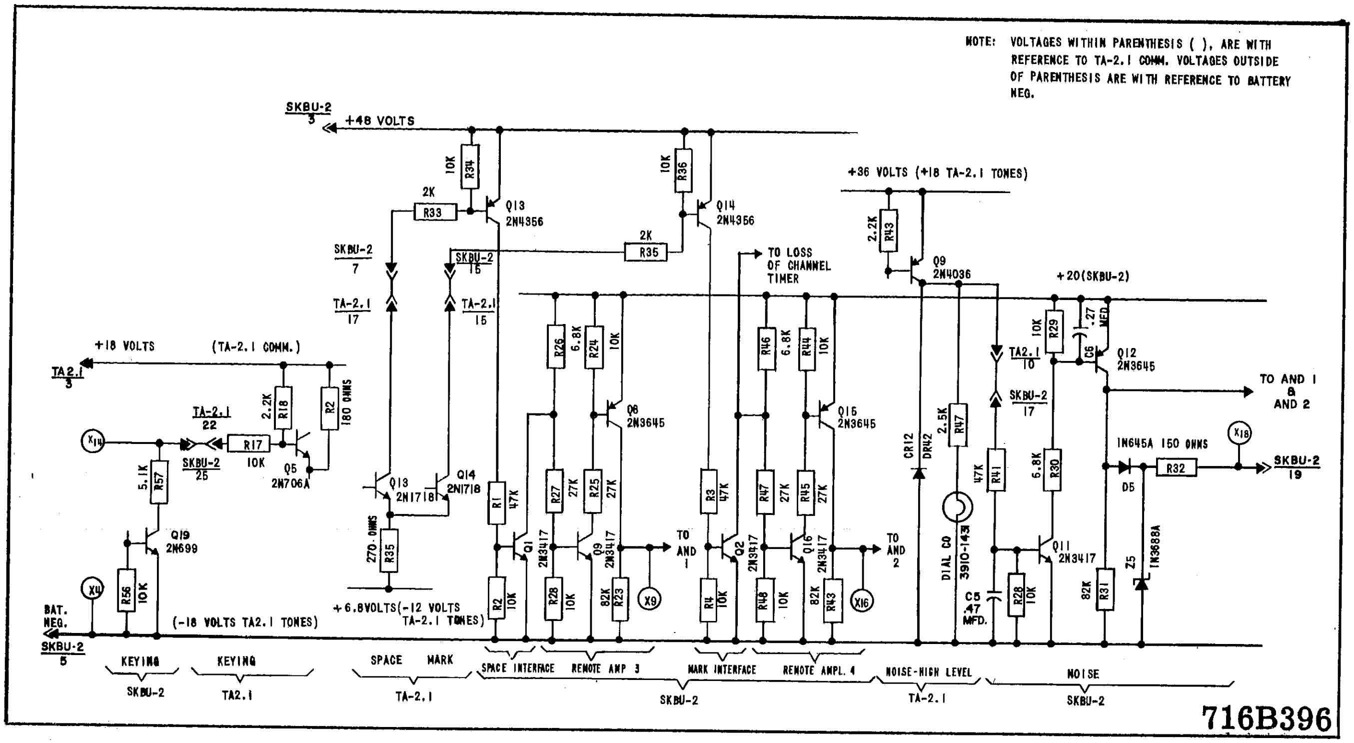


Fig. 35. Elementary Connections of SKBU to TA-2.1 Tone Channel.

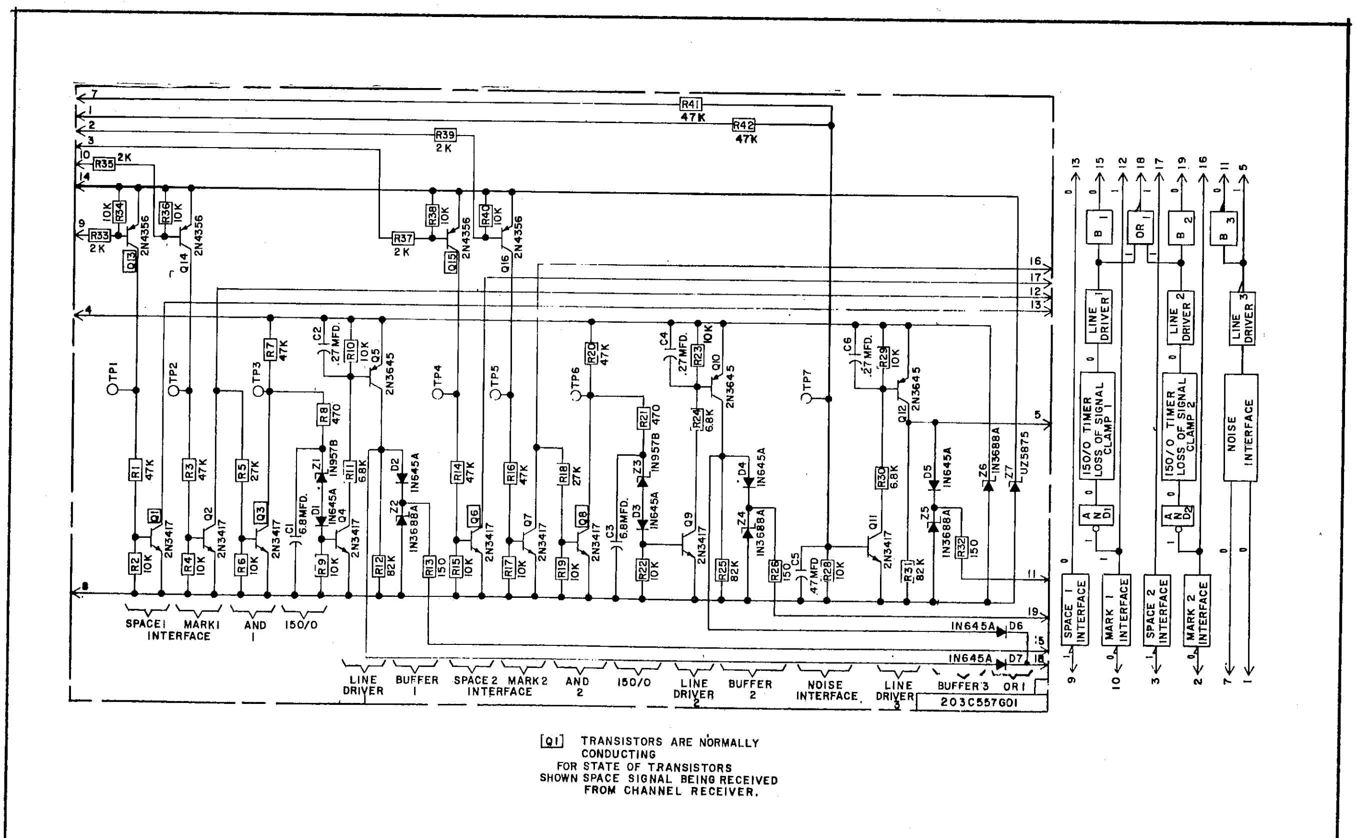


Fig. 36. Schematic of Supervision Board for TA-2.1 Tone Channel.

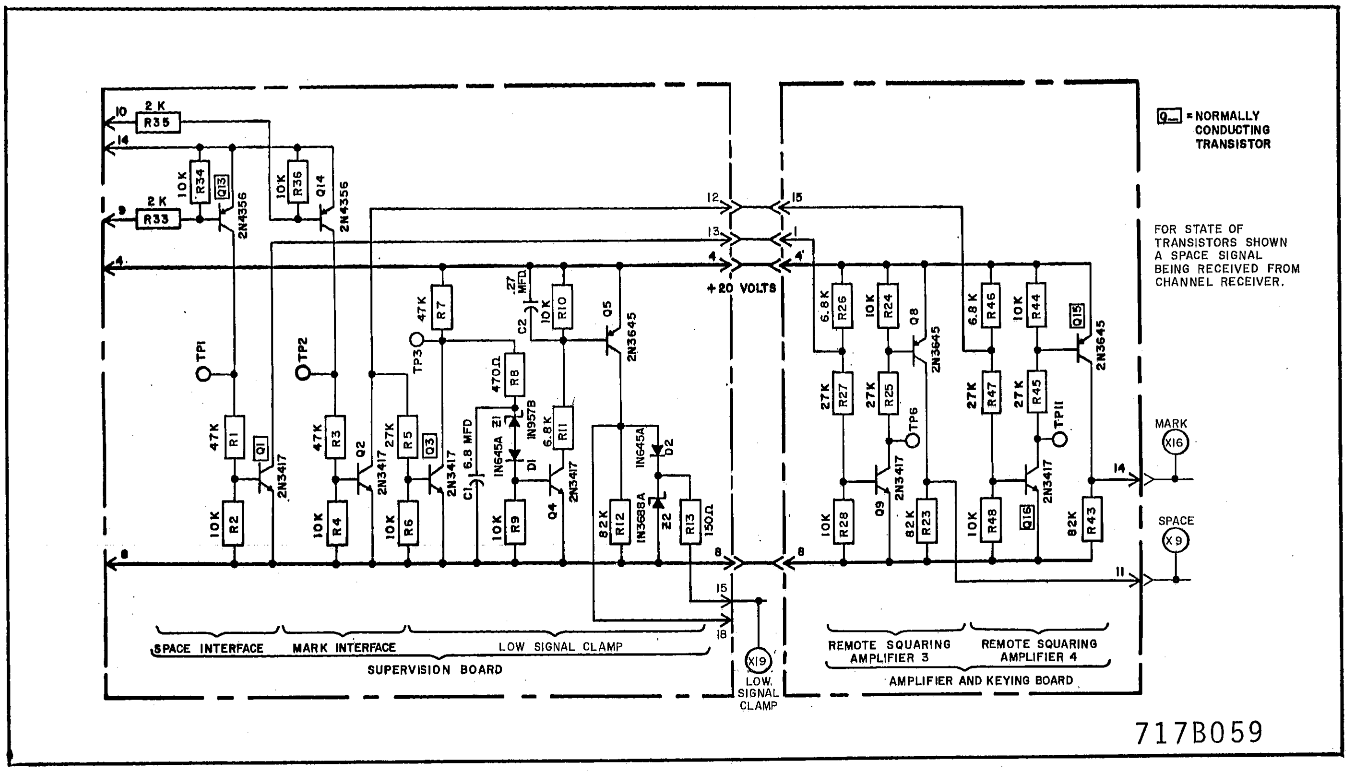


Fig. 37. Connection Diagram of Remqte Squaring Amplifiers of SKBU-2 and SKBU-21 Relays for TA-2 Tone Channel.

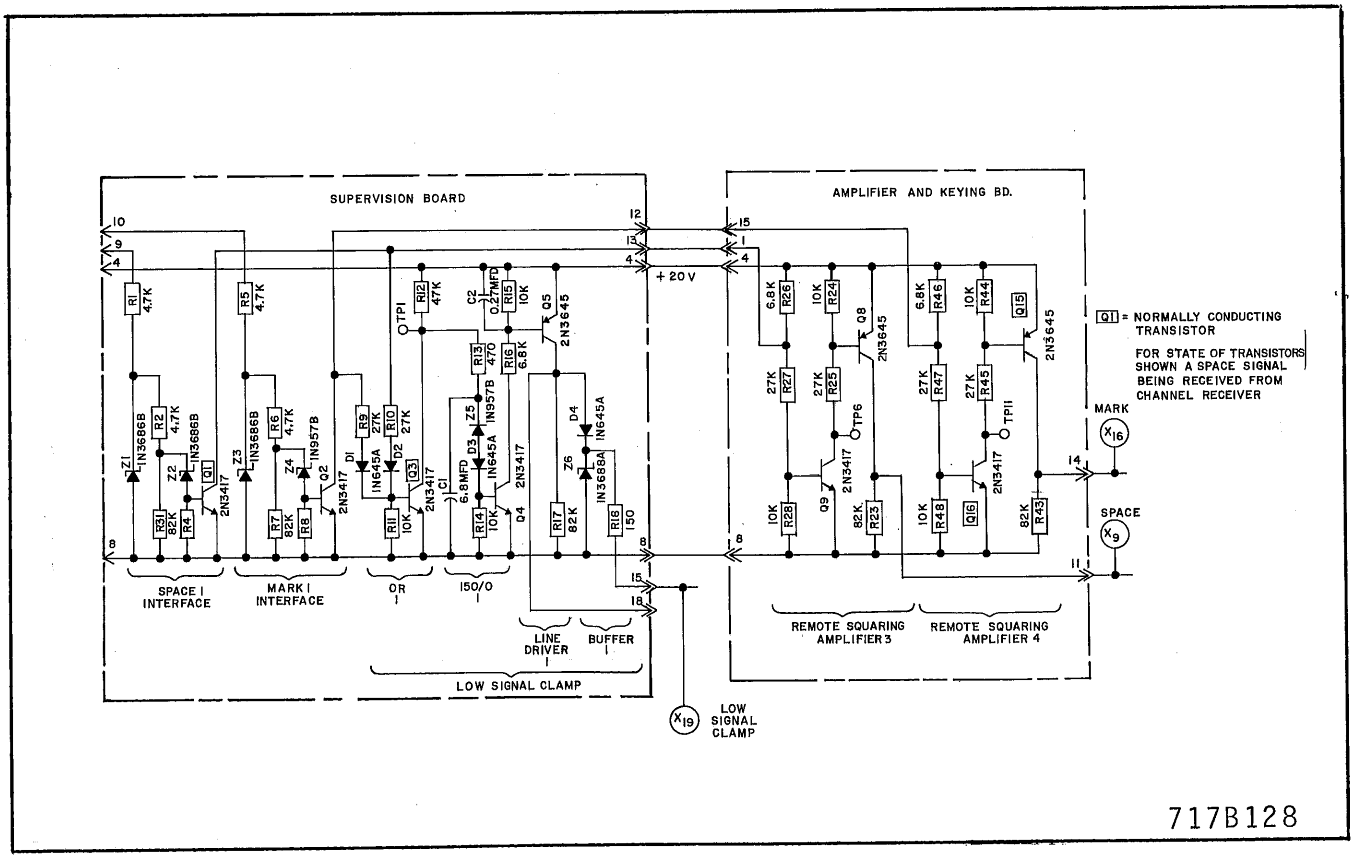


Fig. 38. Connection Diagram of Remote Squaring Amplifiers of SKBU-2 and SKBU-21 Relays for TCF Carrier Channel, TA2.2 Tone Channel and MC-22 Microwave Channel.

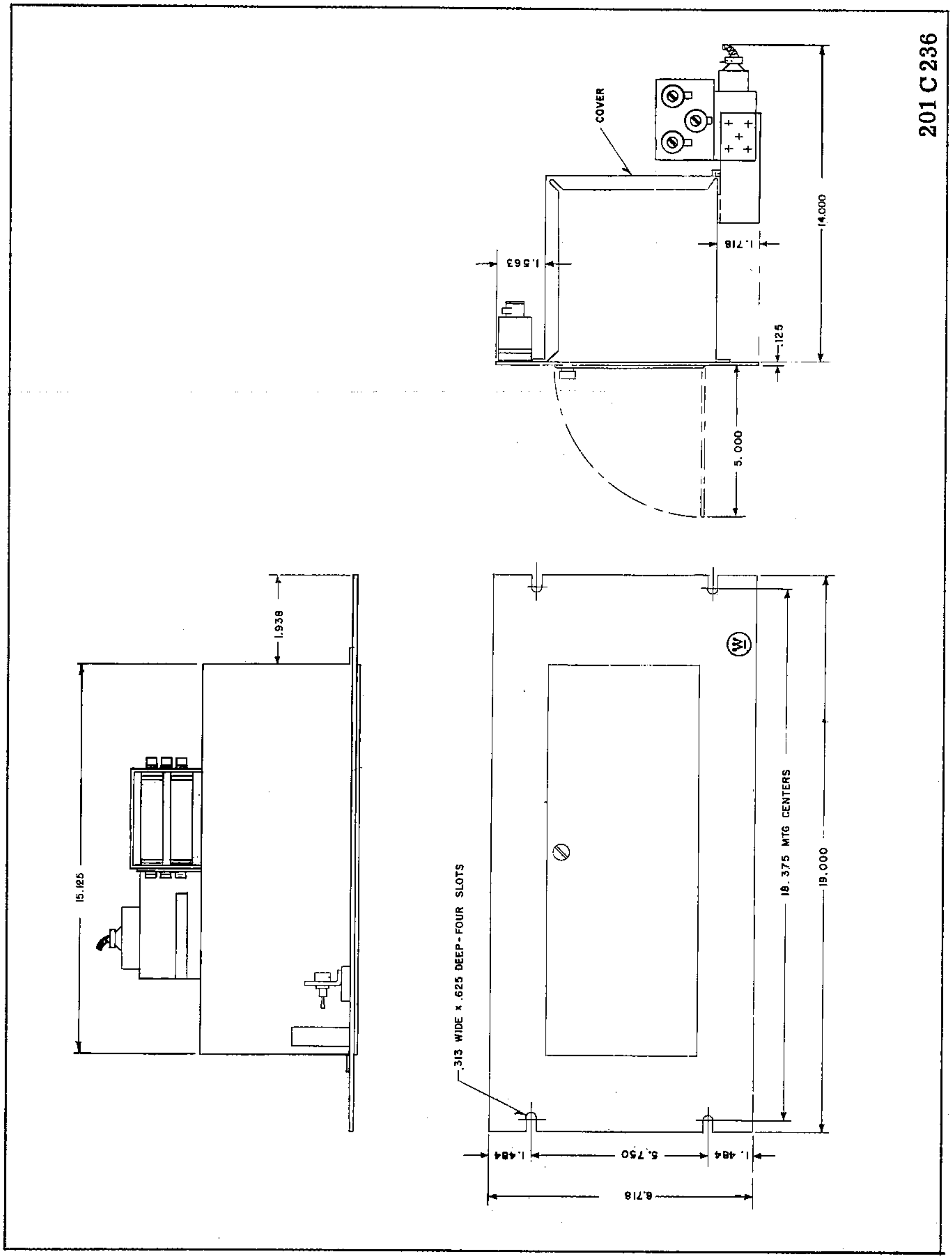


Fig. 39 Outline for the Type SKBU-21 Relay

WESTINGHOUSE ELECTRIC CORPORATION

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

Printed in U.S.A.