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 on the system instruction leaflet before energizing the system.

For three terminal lines applications, links 1 and link 2 on amplifier and keying board must be connected C to 3. For all distance supervision relaying system, link on arming board must be open.

APPLICATION

The type SKBU-21 is a high-speed relay 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, microwave, or carrier channel.

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

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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. TCF Carrier 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, 8-3/4 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 forned 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, would on the center leg of a "F" type of lamination. The secondary taps are wired to the A, B, and C tap connections in the front of the relay (R_1 taps). Ro consists of a 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 small saturating transformer. This transformer has two secondary windings. One winding supplies the fault detector circuit 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, arming 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 pulses. 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 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.

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	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 AND circuits of 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 time circuit locks out to the relay for failure of the channel equipment. For tone channels a noise circuit is also provided to lockout the relay.

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

TYPE CHANNEL	LOCATION OF COMPONENTS	SCHEMATIC OF BOARD
TA-2	Fig.15	Fig. 16
TCF	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, OR circuits to connect the relays into the system. A 6/0 timer circuit and a signal squelch circuit, 2.5 second alarm circuit for sustained fault detector operation are also provided on this board.

Fig. 19 shows the component location for the board and Fig. 20 shows the schematic of the 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 in that compartment. The board then 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 phase comparison relaying, the phase positions 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 transfer trip system can be utilized. This means that the system can trip on either half-cycle of 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 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 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 half-cycle pulses are of the correct phase positions for an internal fault, after a fault detector operation, 4 millisecond tripping will be initiated 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 half-cycle pulses are of the correct phase positions for an internal fault, after a 4 millisecond delay tripping will be initiated 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 secrion, 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 energizes a sequence filter that varies with the type 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 the negative sequence current. These voltage 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 one 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 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 a phase-splitting network (C52, R52, R53) and a polyphase rectifier (diodes D51 to D56). The dc voltages so obtained are applied to the fault detector circuit 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 a high enough positive potential to provide base drive for transistor Q52, driving it to full conduction. With Q52 fully conducting there is no base drive to transistor Q53 and Q53 is turned off. With no Q53 collector current, the base of transistor Q54 is supplied from the 20 volt source. Thus the Q54 emitter is normally at a slightly lower potential than its base. 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 to exceed the 6.8 volt rating of Zener diode Z52, a positive bias is applied to Q51 base 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 output is applied to the arming board at terminal 12. Resistors R66 and S2 increase the voltage to Z52 to allow the fault detector to drop out 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, C9, C59 and Q61.

During the positive or negative half-cycles of the output voltage from the saturating transformer, Q55 or Q57 transistors are driven into saturation by the output of the FV transformer (T3). Transistors Q56 or Q58 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 during the start of each half-cycle. 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 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 C88 across Q59 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 by the same voltage that fires the gate of Q59, discharges timing capacitor C59, thus starting 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 thus preventing the turning off of Q60 switch. This keeps Q59 switch on to allow C60 to charge to a value to break over Zener diode Z55 to turn on Q63. Turning Q63 prevents Q53 of the fault detector from turning on thereby preventing Q54 from turning on to prevent 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 the phase delay circuit through a low pass filter of the relay board. 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. 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 to a keying transformer (T1)
2. Delayed voltages to a 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. The collection of Q1 is at positive potential which allows base current to flow from positive 20 volts dc through the base of Q2 through R6 to negative. 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.

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 voltage, terminal 8 is more negative 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. Thus on alternate half-cycles of the 60-hertz voltage from the low pass filter, Q3 turns on. By connecting Q3 through the proper interface to the channel transmitter, turning on Q3 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. 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 when 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 R15 such that Q6 is turned on. This applies negative potential to the collector of Q6 to allow 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 voltage and Q12 is conducting on the negative half-cycle of ac voltage. Turning Q5 on, puts negative potential on the collector of Q5 and turns off transistor Q6. Transistor Q6 stops conducting and its potential goes to a positive potential which turns off Q7 to place a negative potential across R19. Thus the output of the squaring amplifier is a square wave voltages 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 that its base is supplied by the opposite polarity of sine wave voltage from the squaring transformer. 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. 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. For a TCF carrier channel space squaring amplifier 3 consists of Q1 on the supervision board and Q8 and Q9 on the amplifier and keying board. Mark squaring amplifier 4 consists of Q2 on the supervision board and Q15 and Q16 on the amplifier and keying board.

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. Tone Channel

For a 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 source through R27 to negative. Q8 is turned on to provide a positive 20 volts across R123. When the channel is in service and the receiver is in a space condition, transistors Q13 and Q1 (on the supervision board) are turned on. This applies negative potential to R27. On the amplifier and keying board Q9 does not conduct and the potential of the base of transistor Q8 is raised higher than its emitter; hence, transistor Q8 stops conducting and the voltage across R23 is -20 volts. For the condition where the receiver is receiving pulses, transistors Q13 and Q1 (on supervision board) turns on and off for alternate half-cycle and the voltage across R23 is a square wave voltage varying from zero volts to a -20 volts dc. 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

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 off. This applies negative potential to the base of Q9 and Q16 (on amplifier and keying board) respectively. Transistors Q9 and Q16 turn off which applies positive potential to the base of Q8 and Q15. Negative 20 volts appears across both R23 and R43.

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 is a square wave voltage varying from zero volts to a -20 volts dc.

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 and 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 amplifier number 1. The second AND circuit (number 2) compares the mark signal with the outputs of 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 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 an internal fault fed from both line terminals, the output voltages 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 Amplifier 1 and 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 OR 1 of the arming board. The negative voltage is applied to AND 3 of the arming board to set-up one condition for activating the AND negative voltage from OR 1 circuit. The second condition to activate this AND is provided by arming the relay.

In either Fig. 21, 22, 23, or 24, with link connected on the arming board, arming occurs through OR 2 by either the operation of the distance fault detectors or the operation of the relay fault detector. The operation of either 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 31 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 18/0 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 Fault

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 can not 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 input to OR 4 operation of the fault detector will provide an input to a 0/1000 timer on the Output Board. The timer negates the signal to provide a positive input to the transient block AND. With the application of the positive 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. Eighteen milliseconds later the 18/0 timer of the transient block circuit times out to provide a negative input to the Trip AND. The Trip AND is thus desensitized 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 a negative output is obtained from the AND circuits. This output energizes OR1 which negates the signal to a negative signal. The negative signal...

1. Provides a second input to AND 3 and the 4/0 timer 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, a negative input is applied to the unblock timer. Twenty-five milliseconds later, the unblock timer will operate to apply a positive voltage to the block AND circuit. This resets the 18/0 block timer, which removes the positive input to the unblock timer and which resets 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 detectors through a 6/0 timer on the protective relay board. The operation of the distance fault detectors applies positive potential to the board. 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 12 of the arming board.

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 and provides 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.

5. PR INTER Board (Protective Relay Interface Board)

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 fault detector operation 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, C8 stops conducting and 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 Q10 turns on to turn off Q12 which removes negative potential to the keying circuit.

B. Loss-of-Potential Alarm (2500 Timer)

When arming occurs on the SKBU-21, 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 top 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.

For phase-to-phase faults AB and CA, enough negative sequence current has been introduced to allow the fault detector to pick-up at 86 percent of the tap setting. For BC faults, the fault detector will pick-up at approximately 50 percent of the tap setting. This difference in pick-up current for different phase-to-phase faults is fundamental, and occurs because of the angles at which the positive and negative sequence components of current add together.

With the sequence network arranged for positive, negative and zero sequence output, there are some applications where the maximum load current and minimum fault current are too close together to set the relay to pick-up under a minimum fault current, yet not operate under load. For these cases, a tap is available on the relay which cuts the three-phase sensitivity in half, while the phase-to-phase setting is substantially unchanged. The relay then trips at 90 percent of tap value for AB and CA faults, and at twice tap value for three-phase faults. The setting for BC faults is 65 percent of tap value. In some cases, it maybe desirable to eliminate response to positive-sequence current entirely, and operate the relay on negative-plus-zero sequence current. A tap is available to operate in this manner. The fault detector picks up at tap value for all phase-to-phase faults, but is unaffected by balanced load current or three-phase faults.

For ground faults, separate taps are available for adjustment of the ground fault sensitivity to about 1/4 or 1/8 of the left-hand tap plate setting. See Table II. For example, if the left-hand tap plate of the relay is set at tap 4, the fault detector pick-up current for ground faults can be either 1 or ½ ampere. In special applications, it may be desirable to eliminate response to zero sequence current. The relay is provided with a tap to allow such operation.

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.

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

Operating Time	15 to 32 Milliseconds
Alarm Time	2.5 seconds for FD operation 150 Milliseconds Loss-of-Channel
Transient Block Time	16 to 20 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 VA	Phase A ANGLE	Phase B VA	Phase B ANGLE	Phase C VA	Phase C 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 VA	Phase A Angle	Phase B VA	Phase B Angle	Phase C VA	Phase C Angle
C-H	11.7	2.1°	9.7	1.8°	44.	2.2°
B-H	11.4	2.0°	10.3	1.8°	46	2.2°
A-H	11.1	2.0°	11.2	1.8°	48	2.2°
C-G	8.8	2.0°	7.0	1.8°	42	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	2.2°
C-F	6.7	2.0°	7.5	1.8°	42	2.2°
B-F	6.5	2.0°	7.2	1.8°	42	2.2°
A-F	5.8	2.0°	6.6	1.8°	43	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 VA	Phase A ANGLE	Phase B VA	Phase B ANGLE	Phase C VA	Phase C 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	PHASE A		PHASE B		PHASE C	
TAPS	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.

SETTINGS

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.

Sequence Combination Taps - R1 Taps

The two halves of the right-hand tap plate are for connecting the sequence network to provide combinations of sequence current response. The upper half of the tap plate or R1 taps changes the tap on the third winding of the mutual reactor and thus changes the relative amounts of positive and negative sequence sensitivity. Operation of the relay 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	3∅ Fault	∅-∅ 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 relay pick-up currents for FD will be 10 to 15 percent higher than the indicated 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 adjusting the ground fault response of the relay. Taps G and H give the approximate ground fault sensitivities as listed in Table II. Tap F is used in applications where increased sensitivity to ground faults is not 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%

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 3B setting instead.

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 adequate keying voltage from the filter for any fault detector by remote-end relays. That is, the taps should be identical with identical 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.

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^oC.

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 instructinn should be followed when the relay is received as an integral part of the relaying system.

In those cases where the relay is not a part of a relaying system, the following procedure can be followed to 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.

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 5 and 1 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 90% of the pickup current.

2. Check of Local Squaring Amplifiers

a. With all switches of test circuit open, apply 0.5 amperes ac to terminals 1 and 5 of the SKBU-21 relay, or 5 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 Table III.

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

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 Table III should be observed.

3. Check of Keying Circuit

a. With all switches of test circuit open except A and 0.5 amperes ac applied to terminal 1 and 5 of the SKBU-21 relay, with scope check voltage across X14 and X4 (grd). (This voltage should be checked with 5 amperes into terminals 1 and 5 of SKBU-2 relay).

b. Waveform shown in Table III should be observed.

4. Check of Remote Squaring Amplifiers

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

b. Apply 0.5 amperes ac to terminals 1 and 5 of the SKBU-21 relay, or 5 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 Table III should be observed. Also for three terminal application check waveform across X13 and X17.

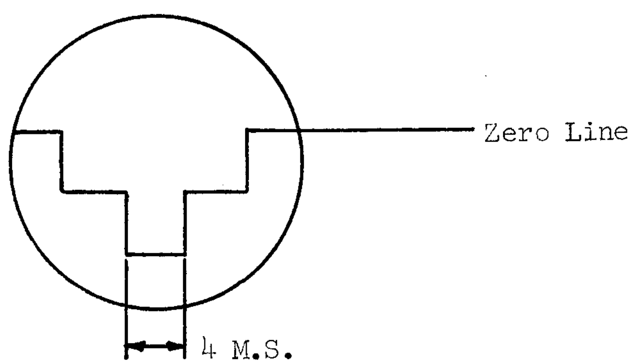
d. If scope has two traces, connect one probe to X9 and the other on X16. Connect grd. to X4. With scope set on chopped, the phase relationship to Table III **should be** observed.

5. Setting of S5 and S6

   a. Set S5 to minimum resistance and S6 to maximum resistance (fully clockwise).

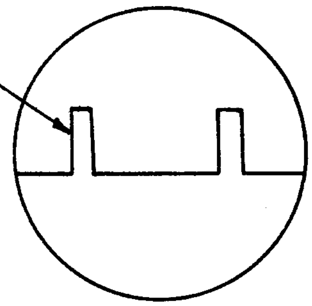
   b. Set switch L to external fault and close switches A, B, and C of the test circuit. Apply 0.5 amperes ac to terminals 1 and 5 of the SKBU-21 relay or 5 amperes ac to same terminals of SKBU-2 relay.

   c. Place scope across X10 and X2 (grd). Adjust S5 until following waveform appears on scope.



   d. Adjust S6 until the relay trips. This sets the triggering of the Trip AND after a 4 millisecond delay.

   e. Slowly increase S5 to obtain the following waveform. This will be with S5 at or near minimum resistance.



6. Transient Blocking Delay (18/0 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. Time should start and should stop between 18 and 20 milliseconds.

   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.

7. Check of Transient Unblocking Circuit

   a. With electronic timer stop connected to X7 and X4 (grd), set timer stop on positive going pulse.

   b. Connect timer start to timer start contacts of switch L. Set L on external fault, and close switches A, B, C, E and F of test circuit. Set timer start on negative going pulse.

   c. Apply 0.6 amperes ac into terminal 1 and 5 of the SKBU-21 relay, or 6 amperes into terminal 1 and 5 of the SKBU-21 relay.

   d. Close switch L to internal fault, timer should start and should stop after a time delay. Time should be 22 to 28 milliseconds. If time has to be rechecked, capacitor C4 on output board should be shorted before each reading. The short should be removed from the capacitor before the reading is taken. Time can be changed by adjusting S_7 on the front panel.

8. Fast Reset Timer (0/100)

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

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

c. Apply 0.6 to 0.8 amperes ac into terminal 5 and out terminal 1 of SKBU-21 relay. (Apply 6 to 8 amperes ac to terminals 5 and 1 of SKBU-2 relay). (Switches A, B, C, E, F closed, H and I open and 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.

9. 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. Timer should start and should stop after 6 to 8 milliseconds.

10 . Alarm on Relay Operation (2.5 Seconds)

a. With electronic timer stop connected to 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. Timer will start and should stop after 2.3 to 2.7 seconds.

d. Open PR1 switch.

11. <u>150 Timer Low Signal Clamp 1 (TCF Channel Only)</u>

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.

12. <u>150 Timer Low Signal Clamp 2 (TCF Channel Only)</u>

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 enternal 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.

13. <u>150 Timer Low Signal Clamp 1 (TA-2 Tone Only)</u>

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 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.

14. <u>150 Timer Low Signal Clamp 2 (TA-2 Tone Only)</u>

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 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.

15. <u>Signal Squelch Time (10/150)</u>

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. Timer will start and will stop after a 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 TP1 to terminal 8.

16. <u>Check of Noise Circuit (Where Used)</u>

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

b Close switch D. 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.

17. 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 5 of SKBU-21 relay. (Apply 5 amperes to terminal 1 and 5 on SKBU-2 relay).

d. Waveform of Fig. 31 should be observed.

TROUBLE SHOOTING PROCEDURE

To trouble shoot the equipment, the logic diagram voltages of Table II 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.

TABLE IV.

VOLTAGE MEASUREMENTS ON PRINTED CIRCUIT BOARDS

1) Fault Detector Board Style 5312D13G01

Test Point	I_{ac} = 0	I_{ac} = Pickup of FD
54	6.5 V DC	less than 1
55	less than 1	4.5 V DC
56	less than 1	18 to 20 V DC
Term 2	less than 1	8.6 V DC
51-52	0	7.4 volts ac (Approx.)
52-53	0	7.5 volts ac (Approx.)
53-51	0	7.4 volts ac (Approx.)
Terminal 5-6	0	15 volts ac (Approx.)
TP 57	18 volts)	
TP 58	18 volts)	
TP 59	less than 1)	Pulses see **Fig. 31** for Waveform
TP 60	20 volts)	
TP 61	18 volts)	
TP 62	less than 1)	

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

TEST POINT	NORMAL CONDITION	ABNORMAL CONDITION
TP1	* 48 V DC	less than 1 with loss of channel 1
Term 13	* less than 1	16 V. with loss of channel 1
TP2	* less than 1	48 V. with loss of channel 1
Term 12	* 13.5 V DC	less than 1 with loss of channel 1
TP 3	* less than 1	7 V. with loss of channel 1
Term 18	less than 1	20 V. with loss of channel 1
Term 15	less than 1	20 V. with loss of channel 1
TP4	**48 V DC	less than 1 with loss of channel 2
Term 17	** less than 1	16 V. with loss of channel 2
TP5	* less than 1	48 V. with loss of channel 2
Term 16	* 13.5 V DC	less than 1 with loss of channel 2
TP6	* less than 1	7 V. with loss of channel 2
Term 19	less than 1	20 V. with loss of channel 2
TP7	less than 1	48 V. with noise clamp
Term 5	less than 1	20 V. with noise clamp
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
Term 13	* less than 1	less than 1 with loss of channel 1
Term 12	* 13.5 volts dc	less than 1 with loss of channel 1
TP1	* less than 1	7 V DC with loss of channel 1
Term 18	less than 1	20 V DC with loss of channel 1
Term 15	less than 1	20 V DC with loss of channel 1
Term 17	**less than 1	less than 1 with loss of channel 2
Term 16	* 13.5 Volts DC	less than 1 with loss of channel 2
TP 2	* less than 1	7 V. DC with loss of channel 2
Term 19	less than 1	20 V DC with loss of channel 2

* 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.

4. Amplifier and Keying Style, 202C551G01 for TA-2 Tones and Style 202C540G01 for TCF

TEST POINT	NORMAL ($I_{AC} = 0$)	ABNORMAL ON I_{AC} = PICKUP OF FD
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

4. <u>Amplifier and Keying Style, 202C551G01 for TA-2 Tones and Style 202C540G01, for TCF</u> (CONTINUED)

TEST POINT	NORMAL (I_{AC} = 0)	ABNORMAL ON I_{AC} = PICKUP OF FD
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

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

5. Arming Board Style 202C509G01

TEST POINT	NORMAL $I_{AC} = 0$	ABNORMAL ON I_{AC} = PICKUP OF FD
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

* Very narrow pulses would be observed on scope

6. Output Board Style 202C548G01

TEST POINT	NORMAL	
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 18 milliseconds after arming
TP9	18.5	7 Volts at trip
Term 13	less than 1	20 Volts at trip

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 the circuit symbol and the electrical value (ohms, mfd, etc.) and component style number.

ELECTRICAL PARTS LIST

Fault Detector Board Style 5312D13G01

CIRCUIT SYMBOL	DESCRIPTION	WESTINGHOUSE STYLE NUMBER
	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	1N457A	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

CIRCUIT SYMBOL	DESCRIPTION	WESTINGHOUSE STYLE NUMBER
	Resistors	
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

Supervision Board Style 202C564G01 TA-2 Tone Channel

CIRCUIT SYMBOL	DESCRIPTION	WESTINGHOUSE STYLE NUMBER
	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

Supervision Board Style 202C565G01 TCF Carrier Channel

CIRCUIT SYMBOL	DESCRIPTION	WESTINGHOUSE STYLE NUMBER
	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
	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

CIRCUIT SYMBOL	DESCRIPTION	WESTINGHOUSE STYLE NUMBER
	Diodes	
D1-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-R56	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
R36	220 K Ohm	184A763H83
	Zener Diodes	
Z2	UZ5875, 75 Volts	837A693H04

Amplifier and Keying Board Style 202C540G01 TCF Carrier Channel

CIRCUIT SYMBOL	DESCRIPTION	WESTINGHOUSE STYLE NUMBER
	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
R36	220 K Ohm	184A763H83
	Zener Diode	
Z1	1N3688A, 24 Volts	862A288H01

Arming Board Style 202C509G01

CIRCUIT SYMBOL	DESCRIPTION	WESTINGHOUSE STYLE NUMBER
	Capacitors	
C1	.27 Mfd	188A669H05
	Diodes	
D1 to D18	1N645A	837A692H03
	Transistors	
Q1-Q2-Q3-Q4- Q5-Q6-Q8	2N3417	848A851H02
Q7-Q9	2N3645	849A441H01
	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, 3 W	762A679H01
	Zener Diodes	
Z1	1N3688A, 24 Volts	862A288H01

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-R13-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
R19	47 K Ohm	629A531H72
R29	22 K Ohm	629A531H64
R42	33 K Ohm	629A531H68
	Zener Diodes	
Z1 to Z5-Z10 to Z13-Z16	1N3686B, 20 Volts	185A212H06
Z6-Z7-Z8-Z14-Z17-Z18	1N957B, 6.8 Volts	186A797H06
Z9-Z16	1N3688B	862A288H01

Output Board Style 202C548G01

CIRCUIT SYMBOL	DESCRIPTION	WESTINGHOUSE STYLE NUMBER
	Capacitors	
C1	0.047 Mfd	849A437H04
C2	22 Mfd	184A661H16
C3	2.2 Mfd	837A241H16
C4-C12	1.5 Mfd	187A508H09
C5-C7-C10	0.22 Mfd	763A219H21
C6	4.7 Mfd	184A661H12
C8-C9	500 Mfd	187A694H03
C11	0.1 Mfd	188A669H03
	Diodes	
D1 to D11	1N645A	837A692H03
	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 Volts	185A212H06
Z2-Z4-Z5-Z6-Z7	1N957B, 6.8 Volts	186A797H06
Z3-Z8	1N3688A, 24 Volts	862A288H01

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

CIRCUIT SYMBOL	DESCRIPTION	WESTINGHOUSE STYLE NUMBER
	Capacitors	
C201-C202-C203	0.25 Mfd	187A624H02
	Resistors	
R201	50 Ohms, 5 W	185A209H06
R202-R203 (SKBU-21)	3.3 K Ohms	
R202-R203 (SKBU-2)	2.2 K Ohms	
	Filter Choke	
L201	8.5 Hy, 450 Ohms	188A460H01
	Zener Diodes	
Z201 (SKBU-21 only)	1N1828C, 43 V	629A798H14

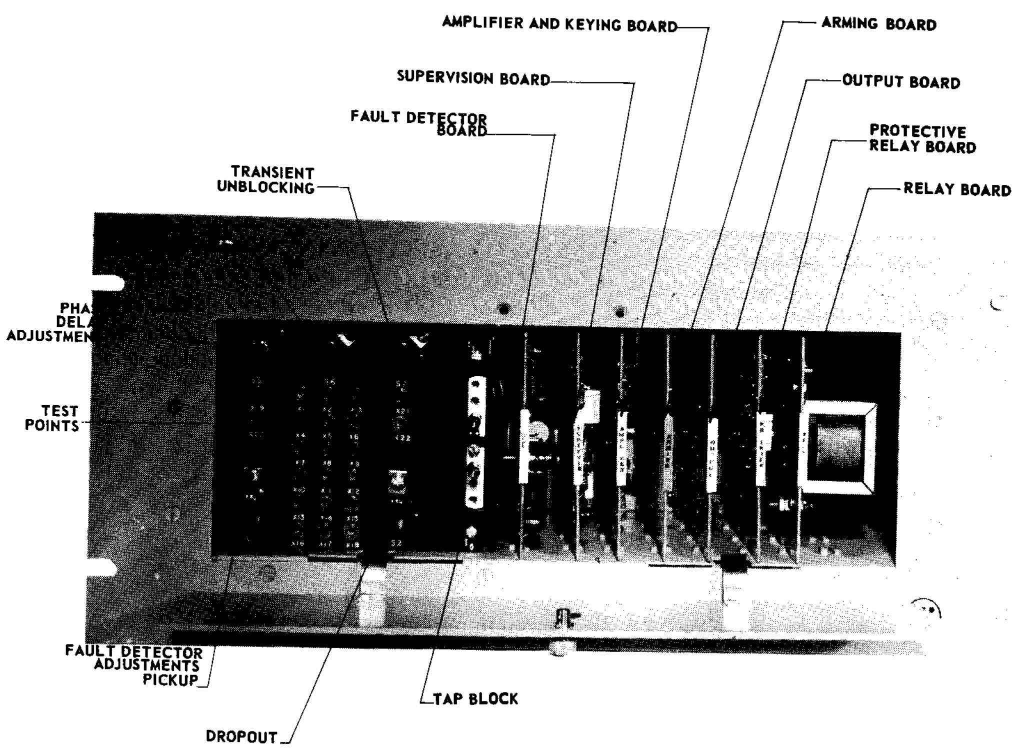


Fig. 1 Photograph (Front View).

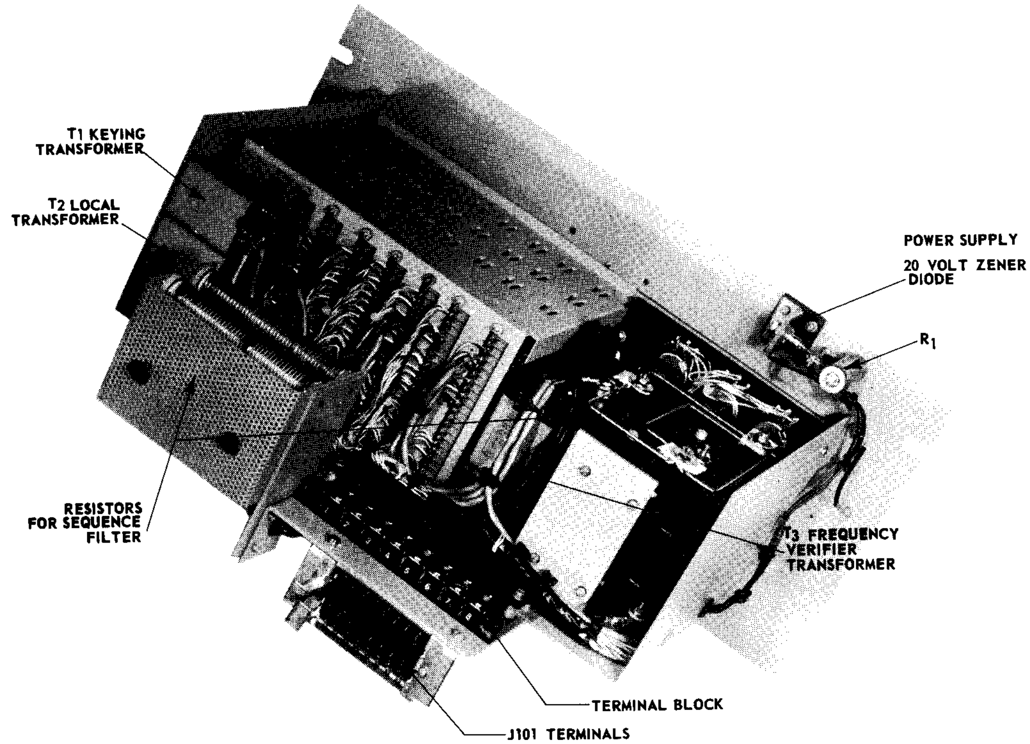


Fig. 2 Photograph (Rear View).

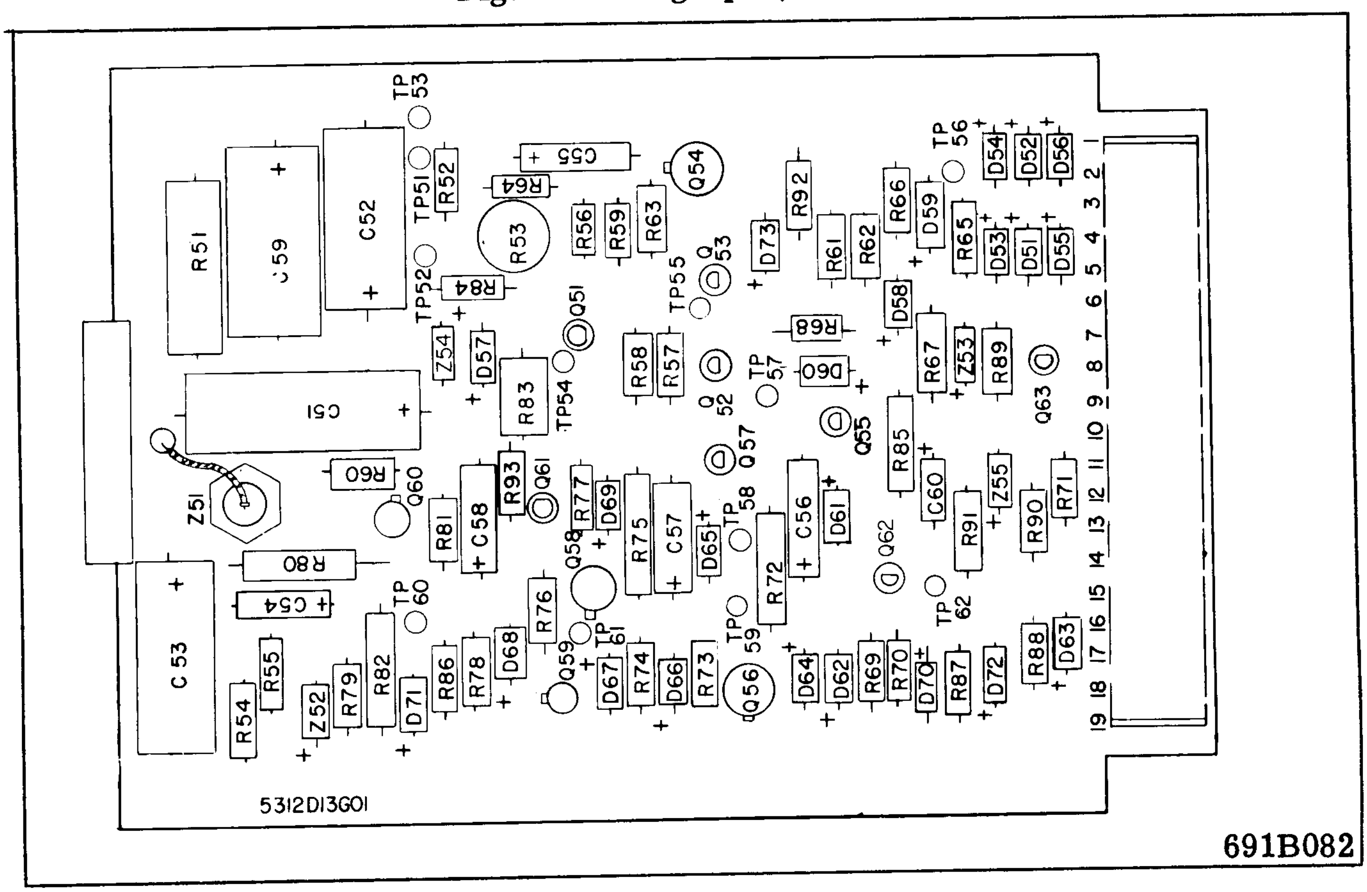


Fig. 3 Location of Components on Fault Detector Board.

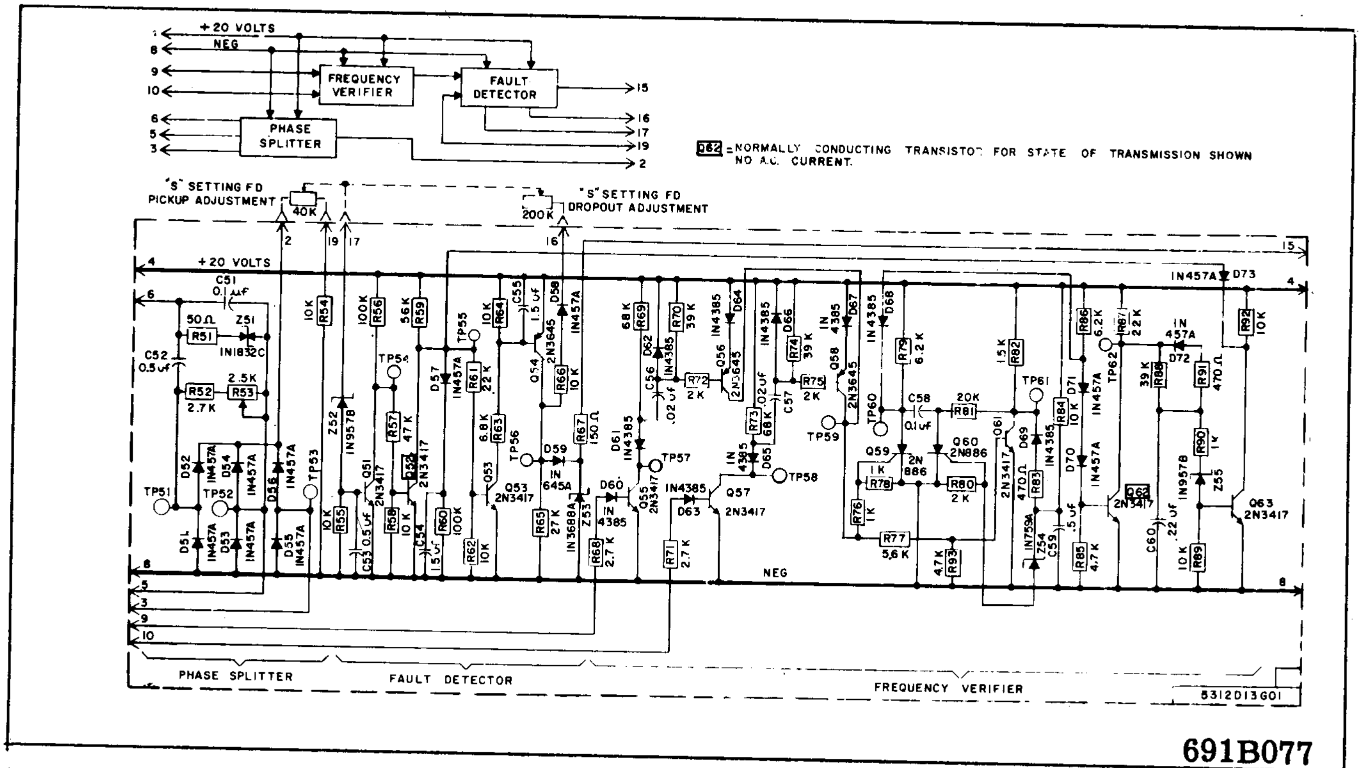


Fig. 4 Schematic of Fault Detector Board.

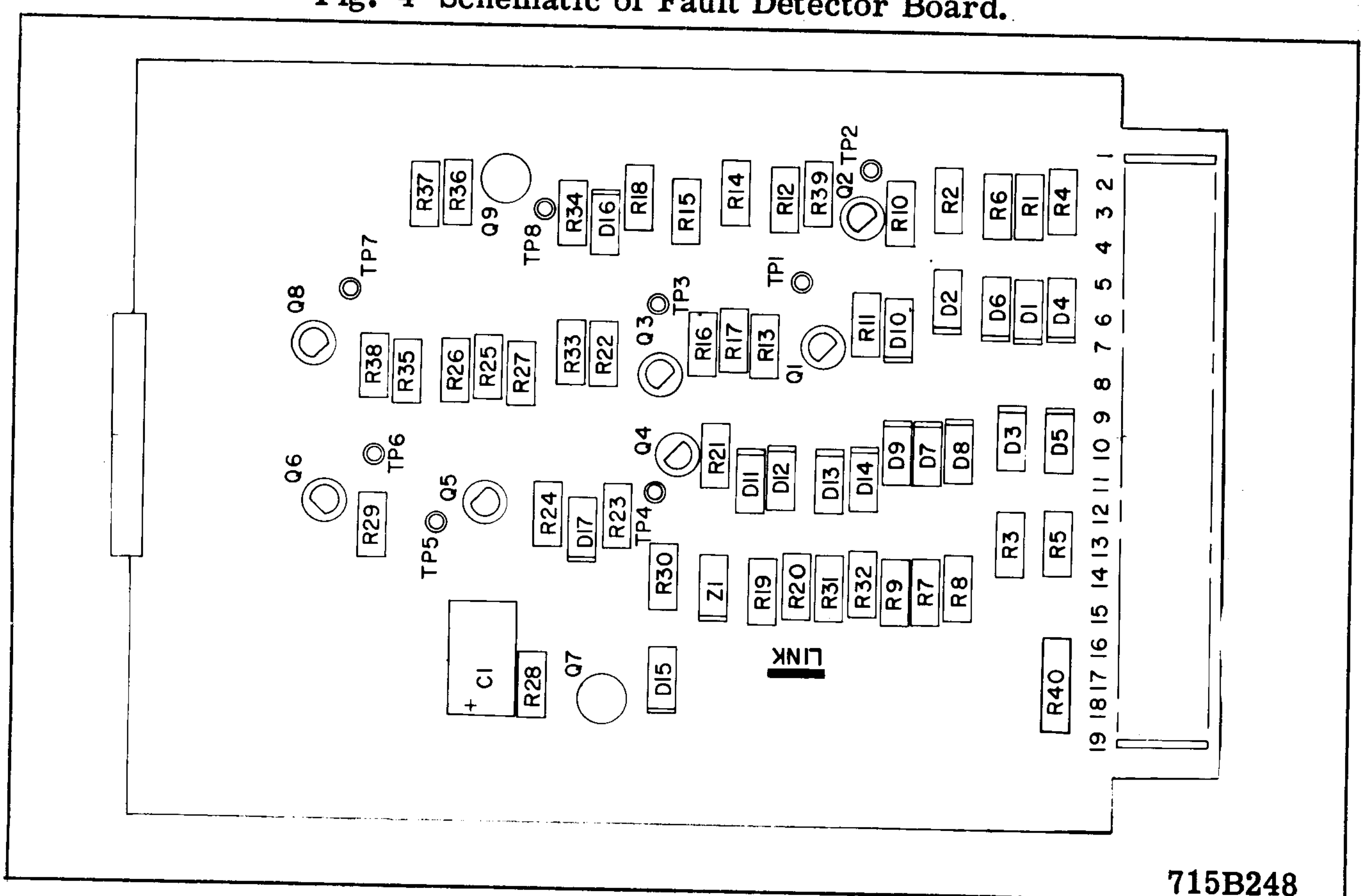


Fig. 5 Location of Components on Arming Board.

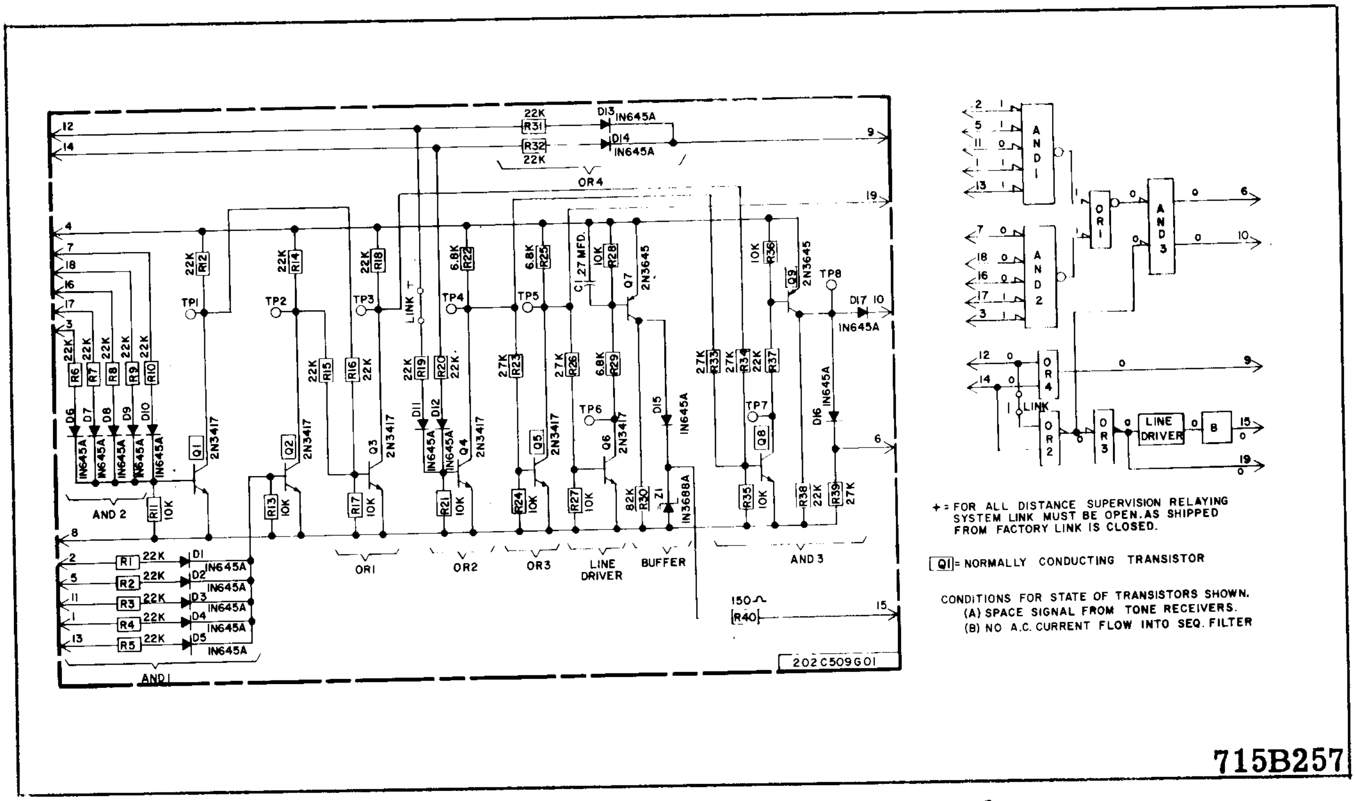


Fig. 6 Schematic of Arming Board.

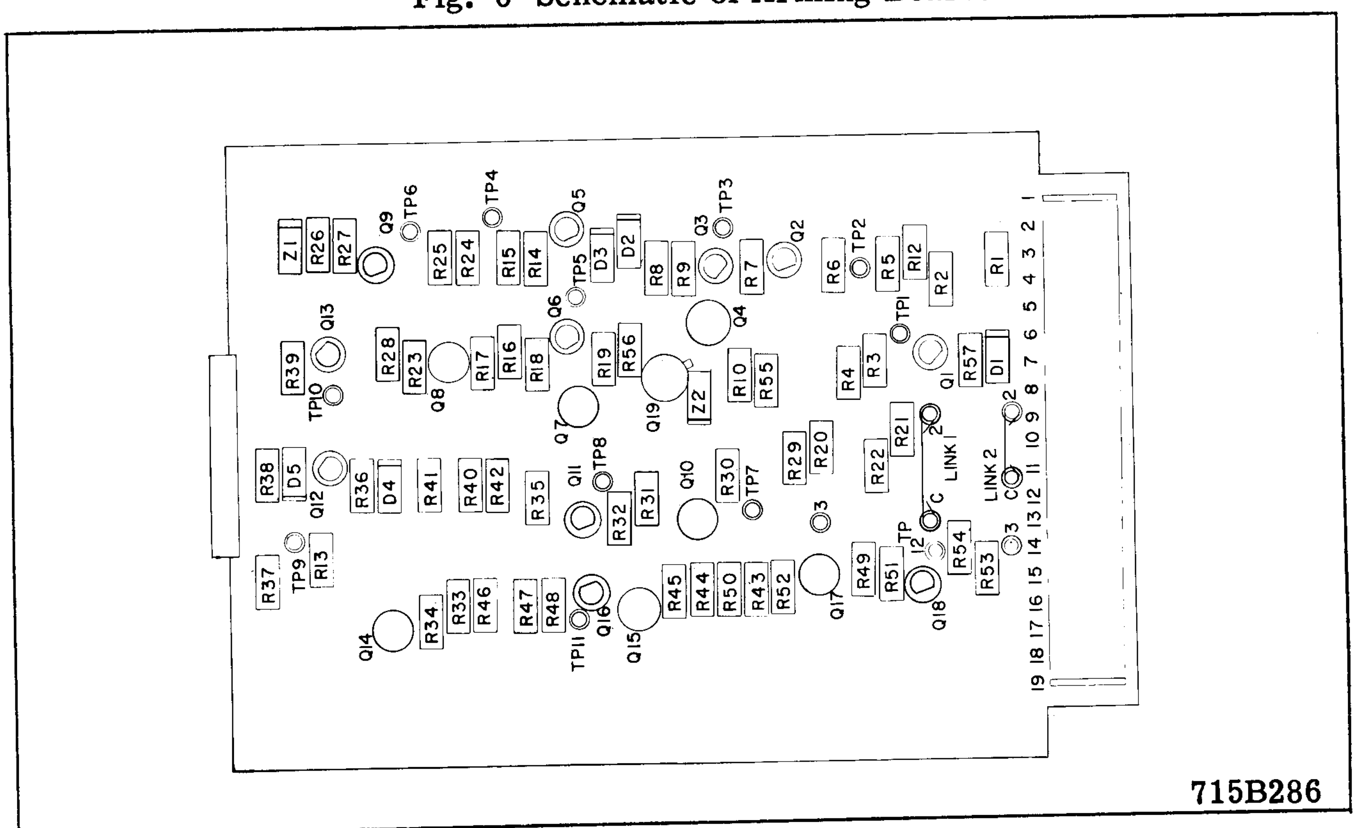


Fig. 7 Location of Components on Amplifier and Keying Board for TA-2 Tone Channel.

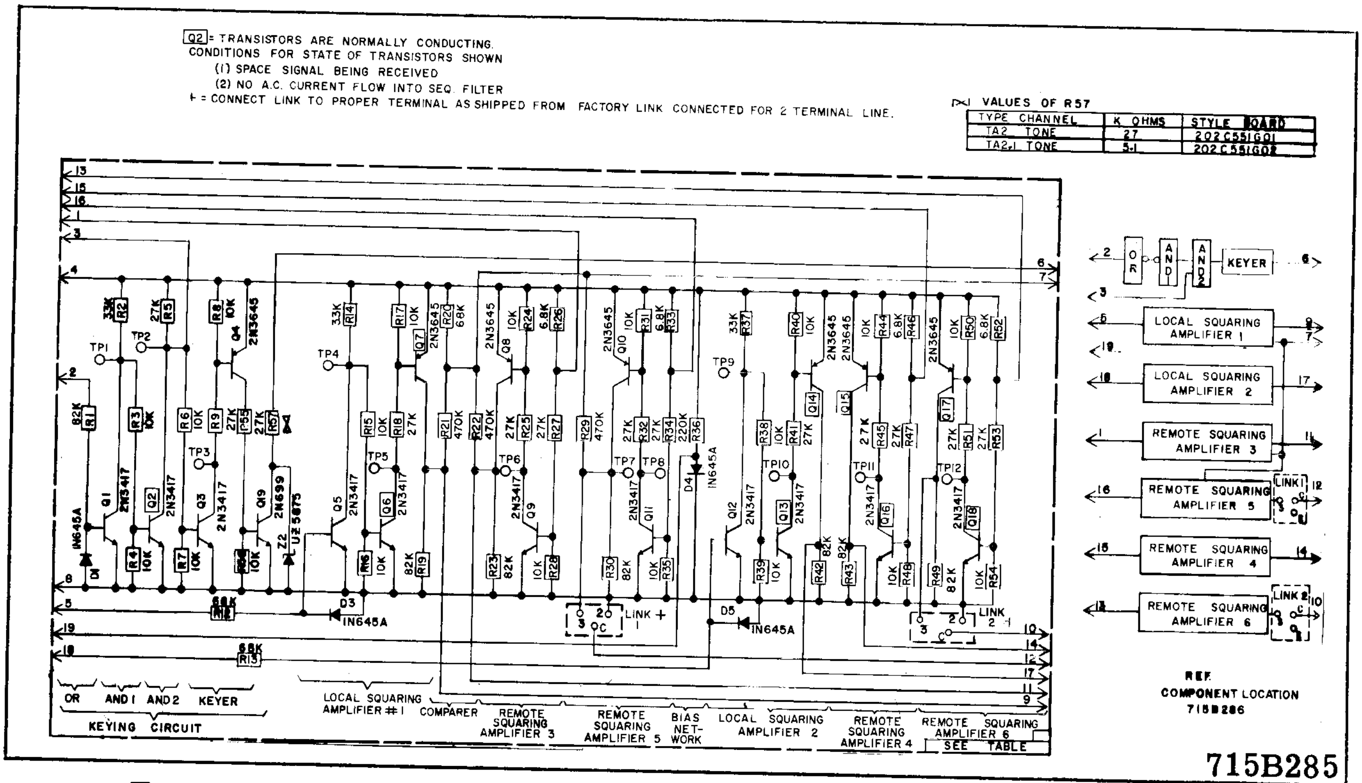


Fig. 8 Schematic of Amplifier and Keying Board for TA-2 Tone Channel.

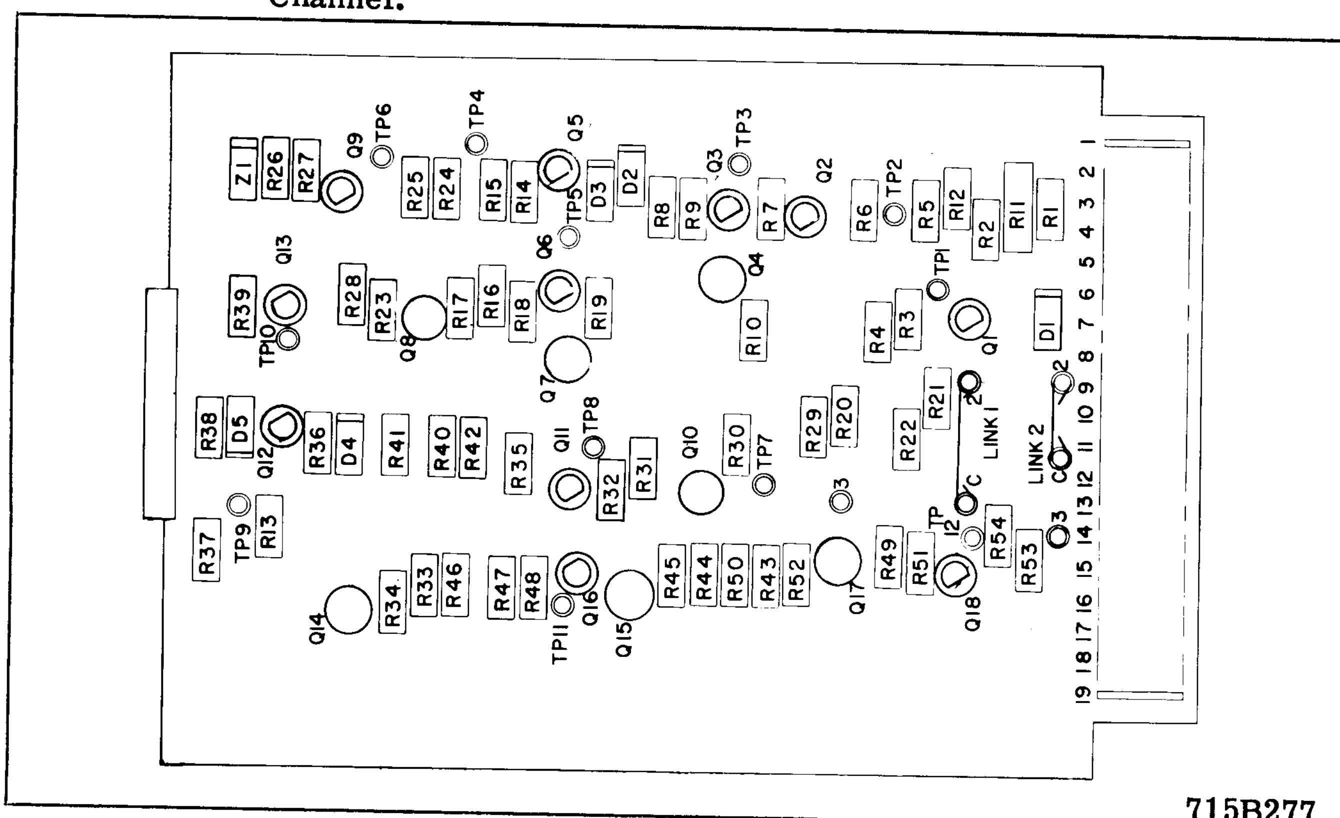


Fig. 9 Location of Components on Amplifier and Keying Board for TCF Carrier Channel.

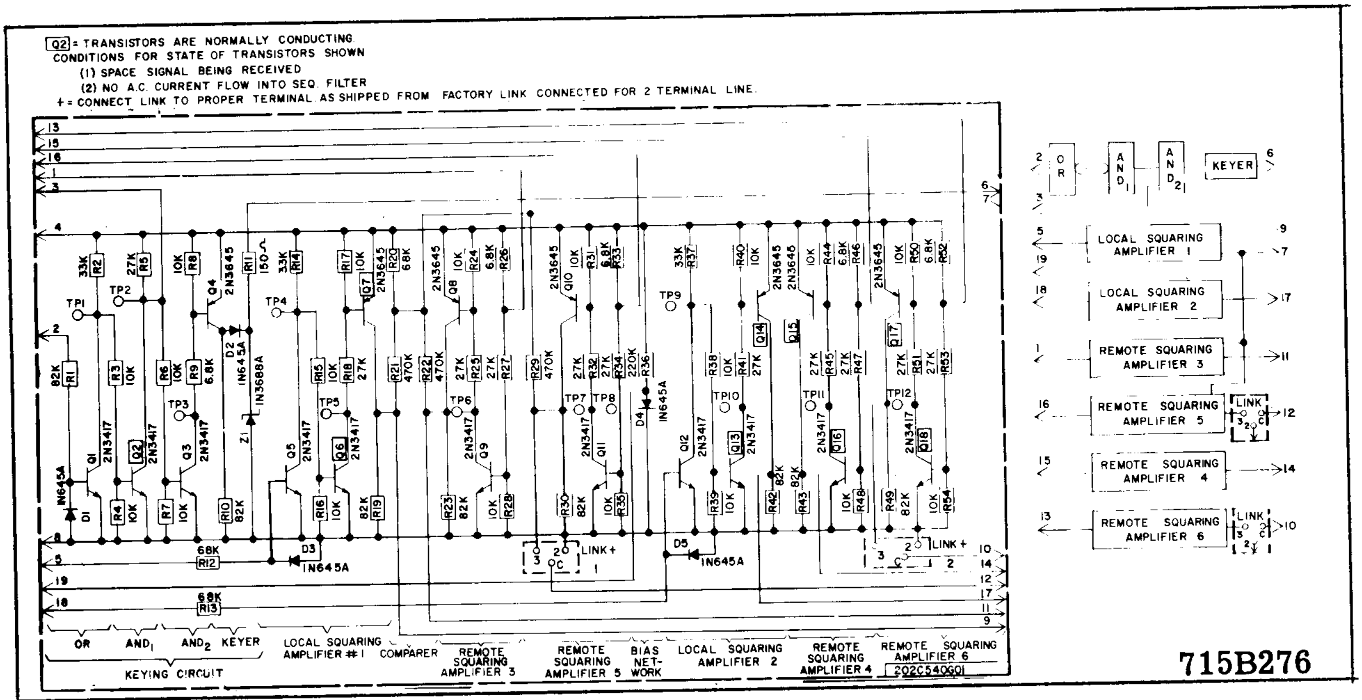


Fig. 10 Schematic of Amplifier and Keying Board for TCF Carrier Channel.

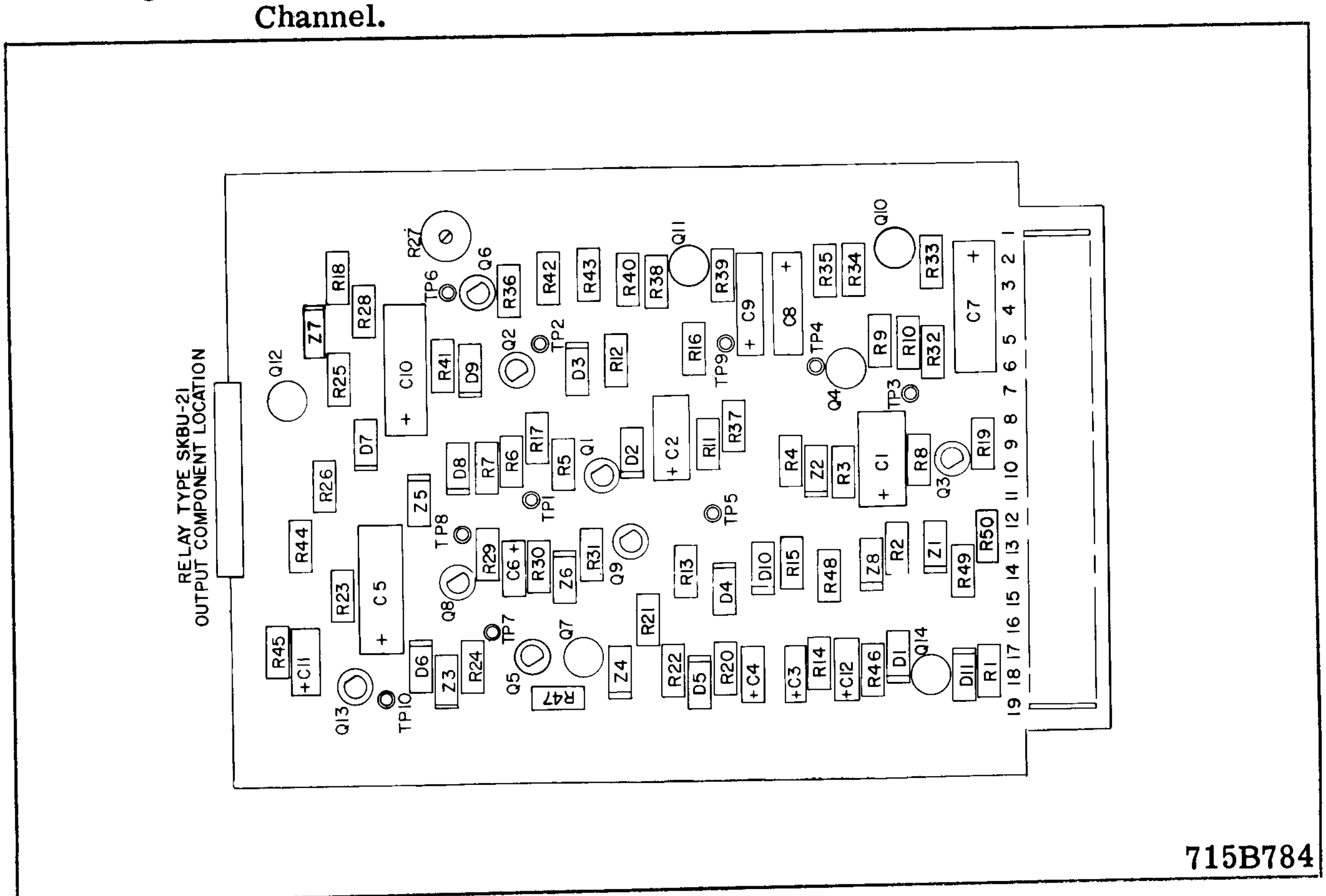


Fig. 11 Location of Components on Output Board.

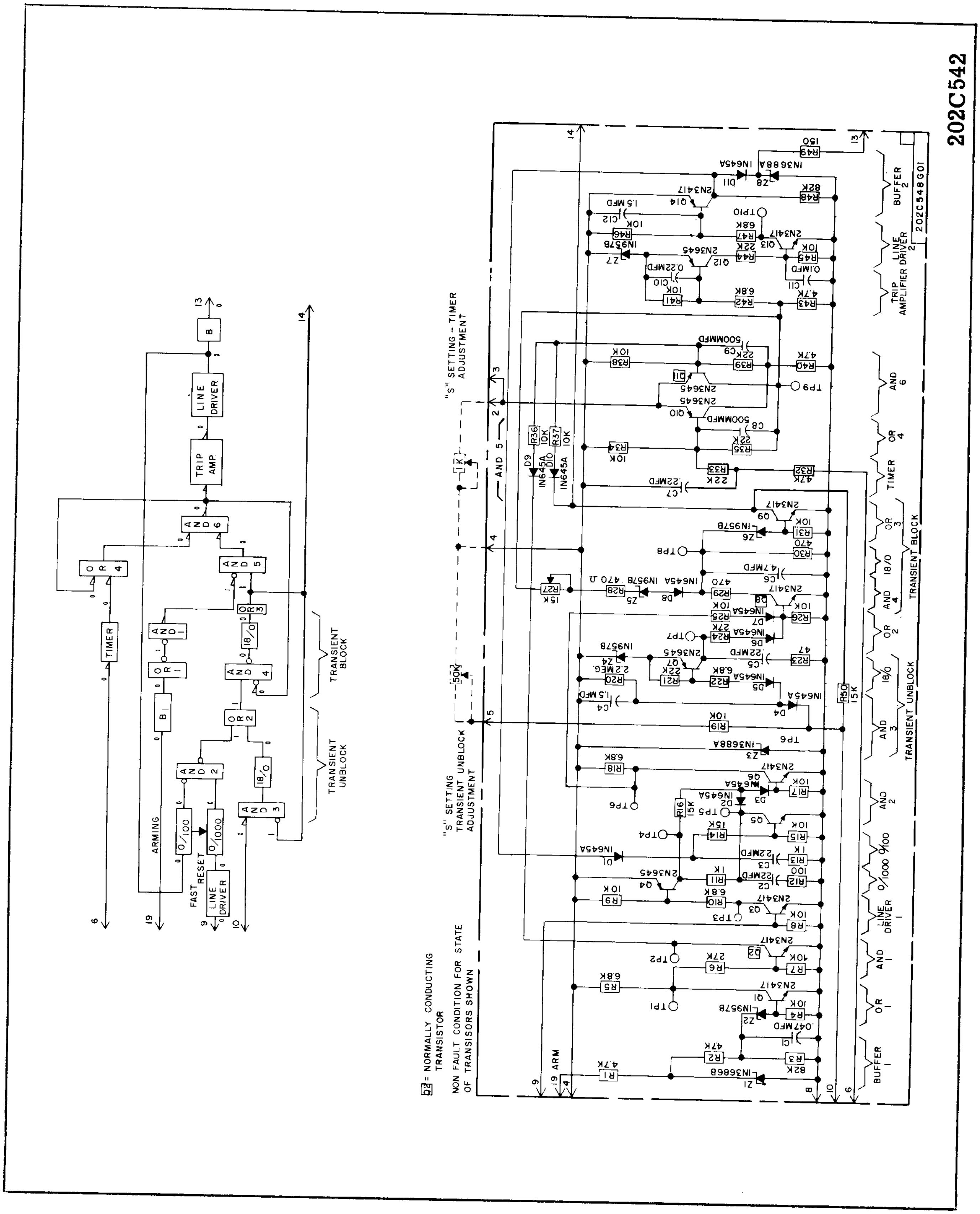


Fig. 12 Schematic of Output Board.

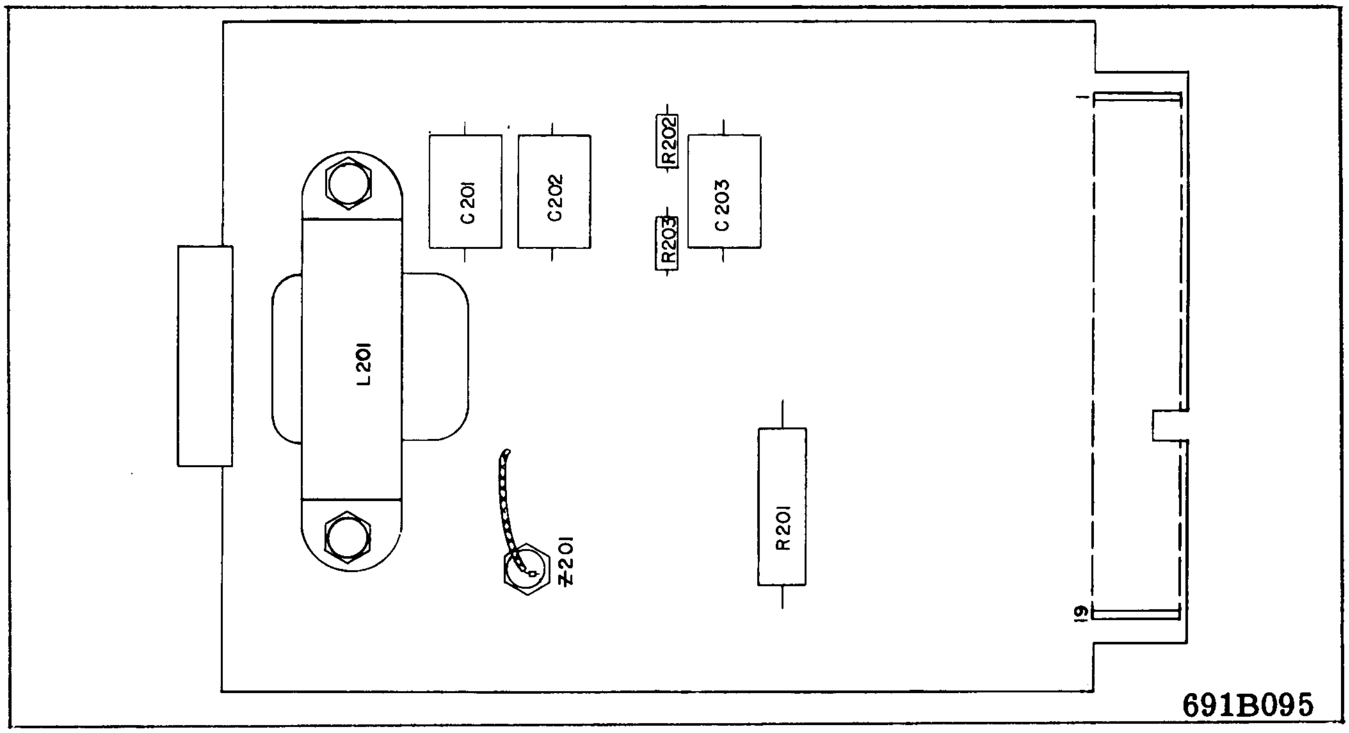


Fig. 13 Location of Components on Relay Board.

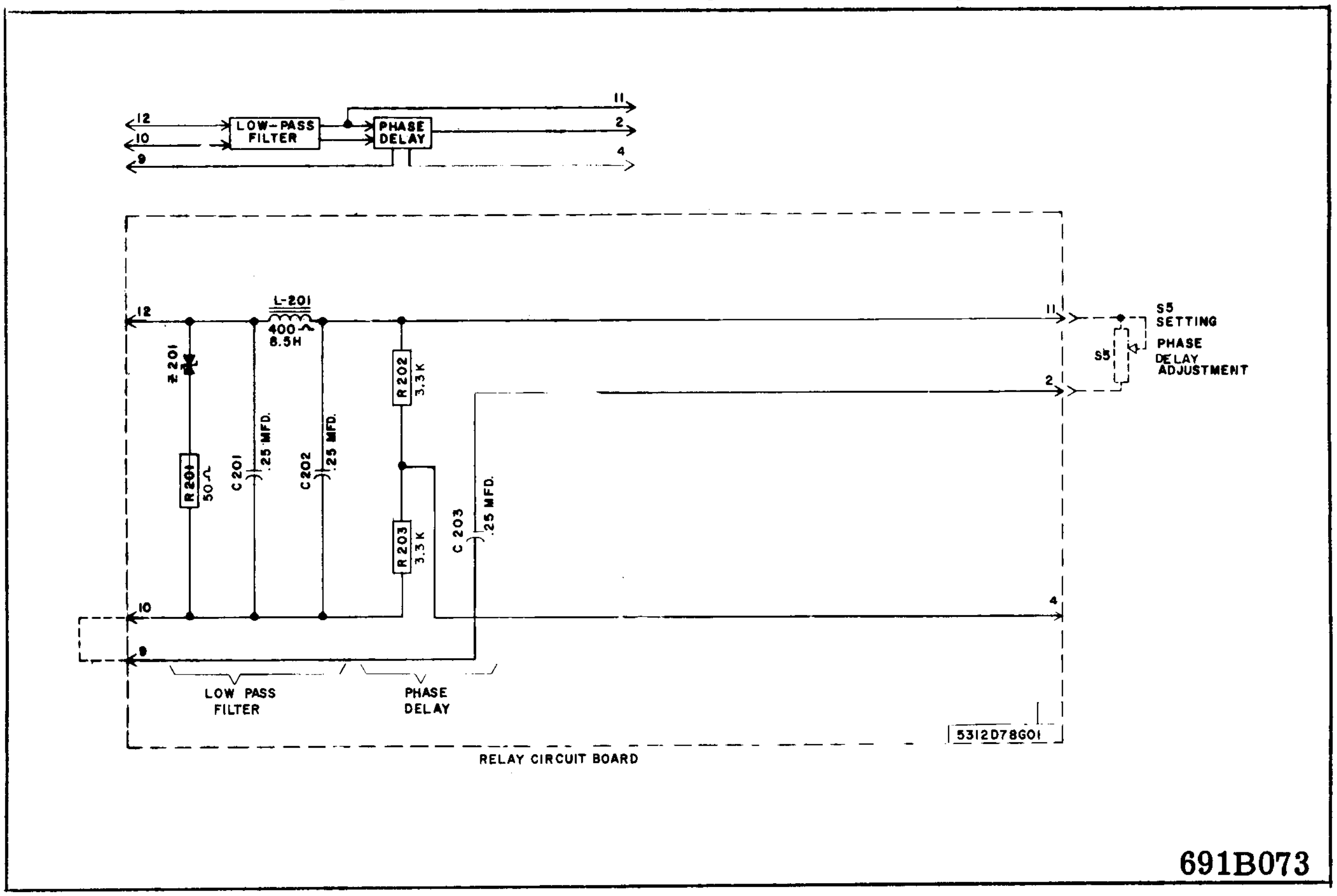


Fig. 14 Schematic of Relay Board

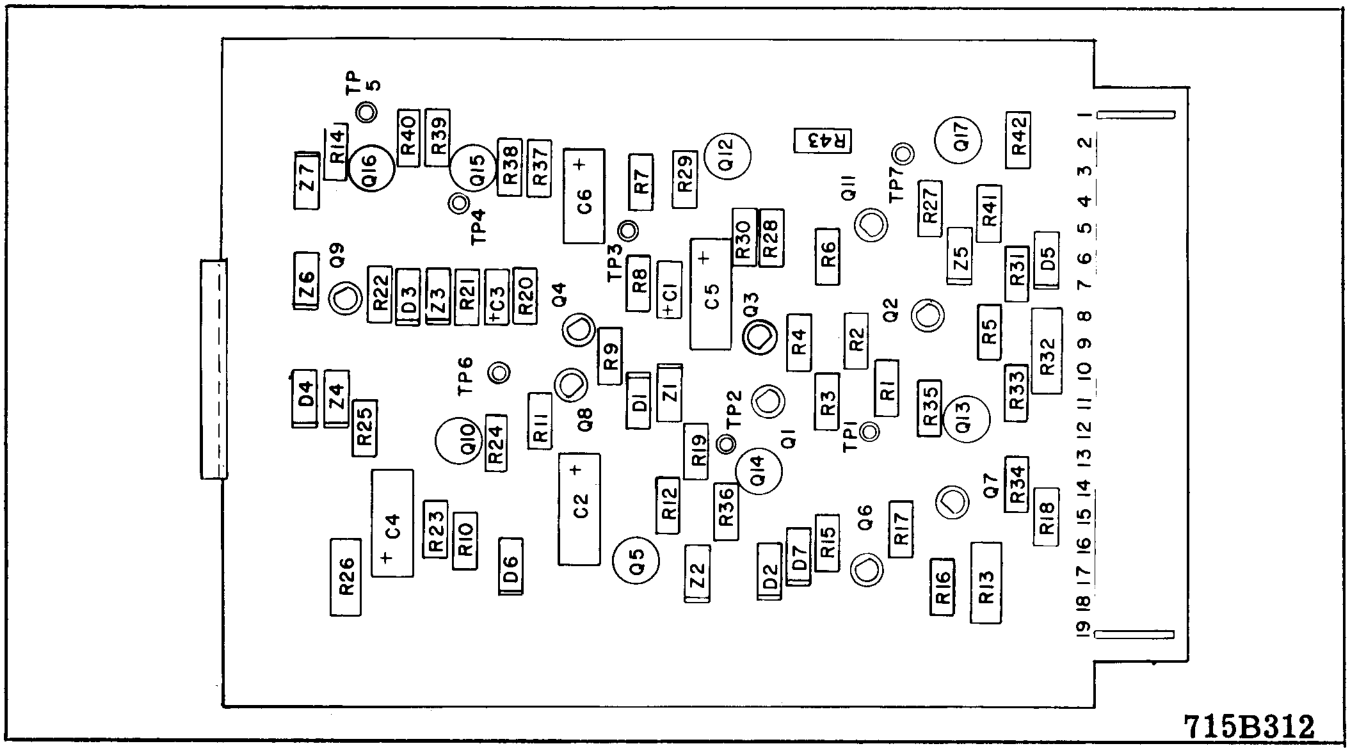


Fig. 15 Location of Components on Supervision Board for TA-2 Tone Channel.

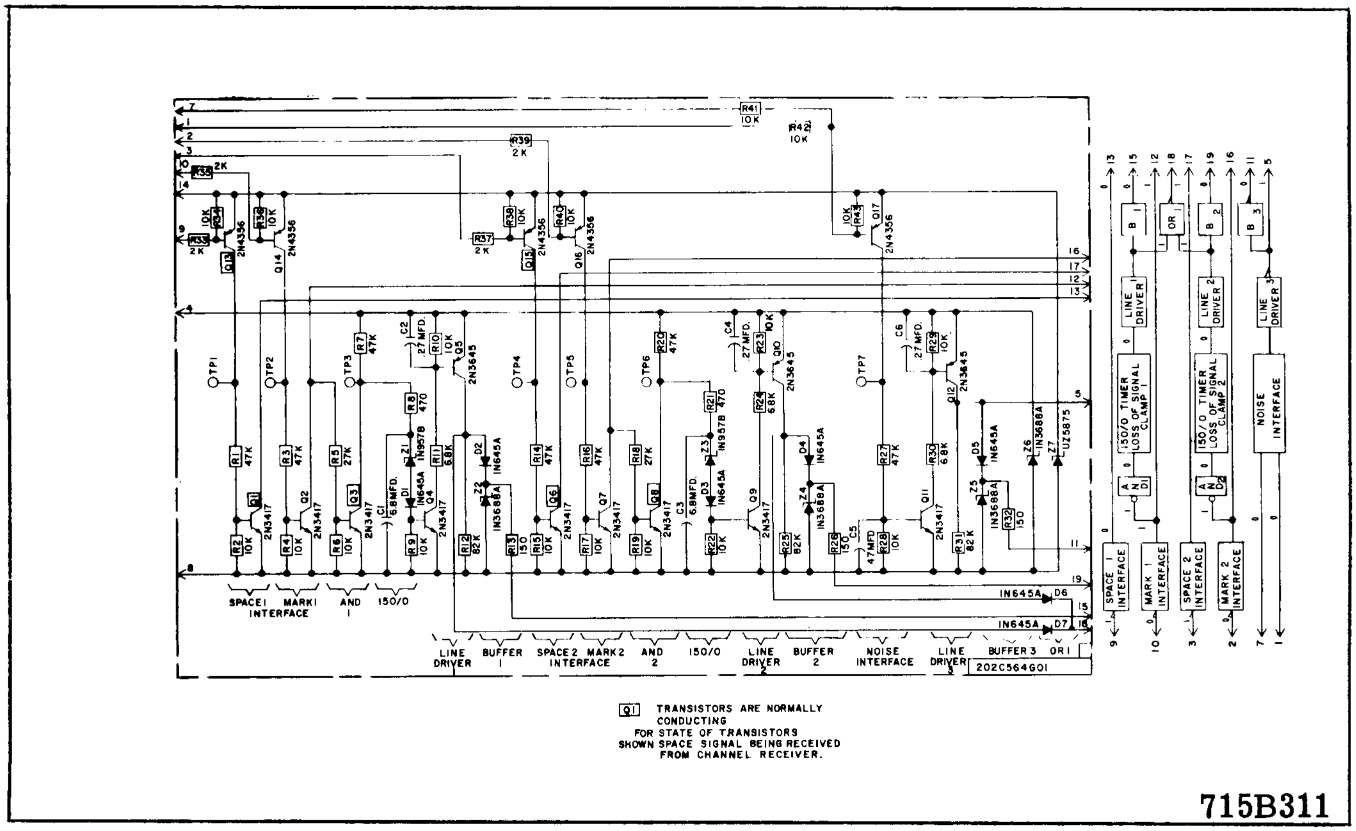
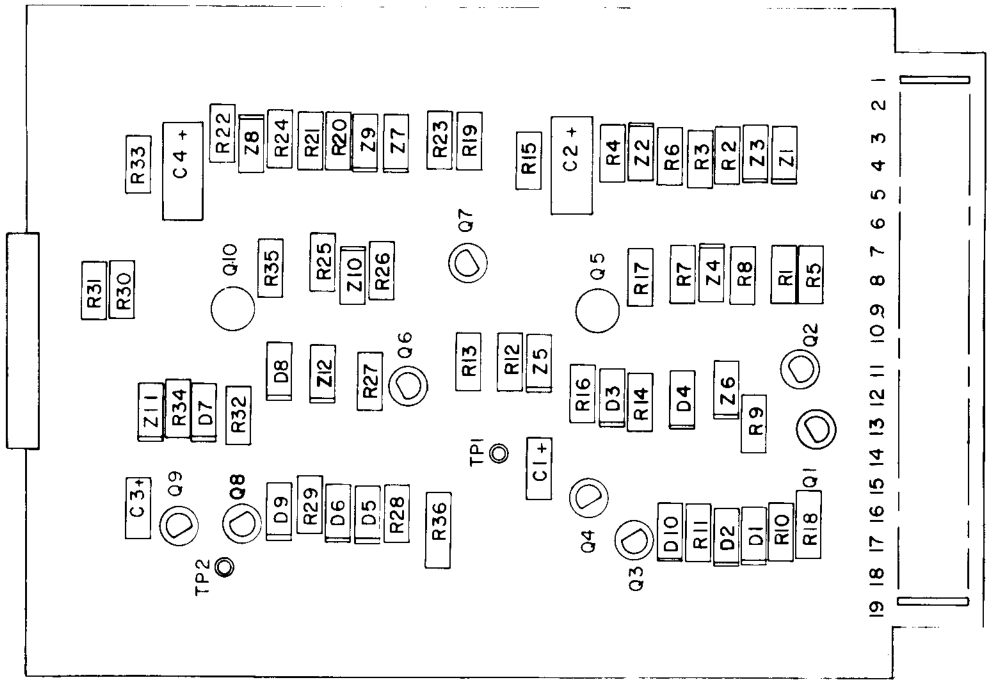
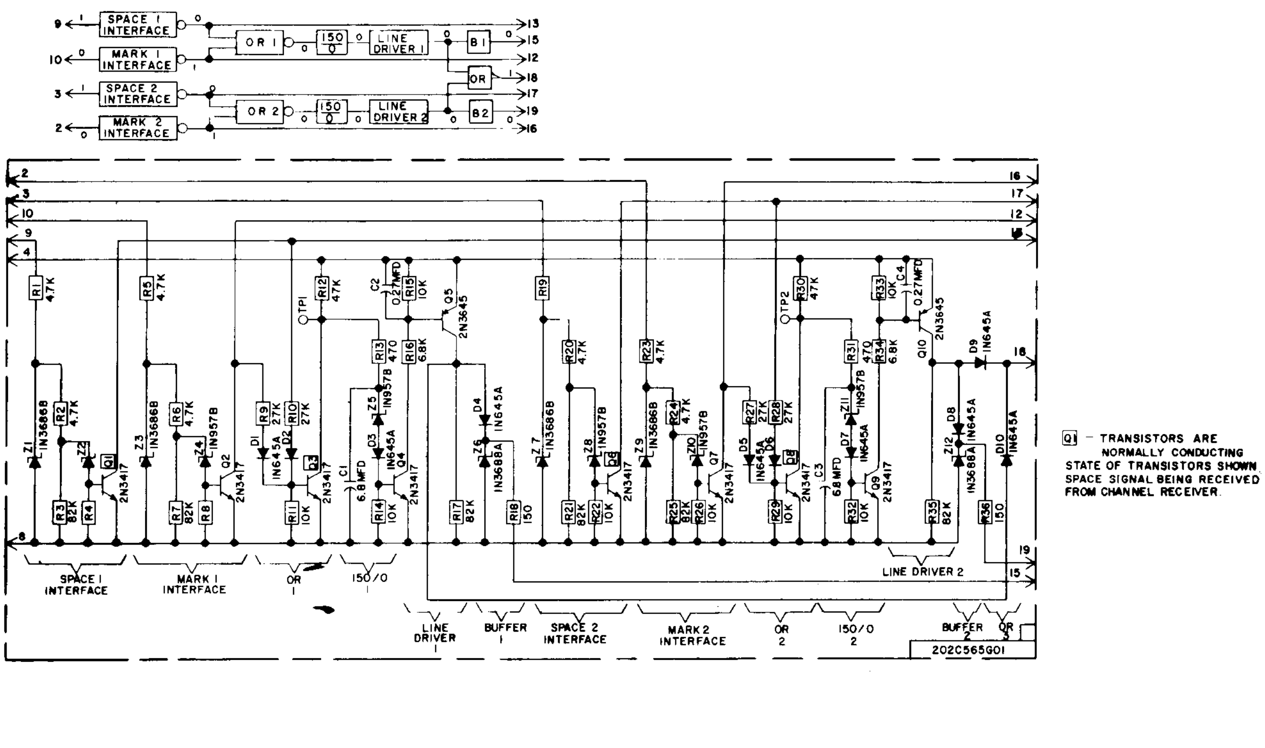


Fig. 16 Schematic of Supervision Board for TA-2 Tone Channel.



715B314

Fig. 17 Location of Components on Supervision Board for TCF Carrier Channel.



715B313

Fig. 18 Schematic of Supervision Board for TCF Carrier Channel.

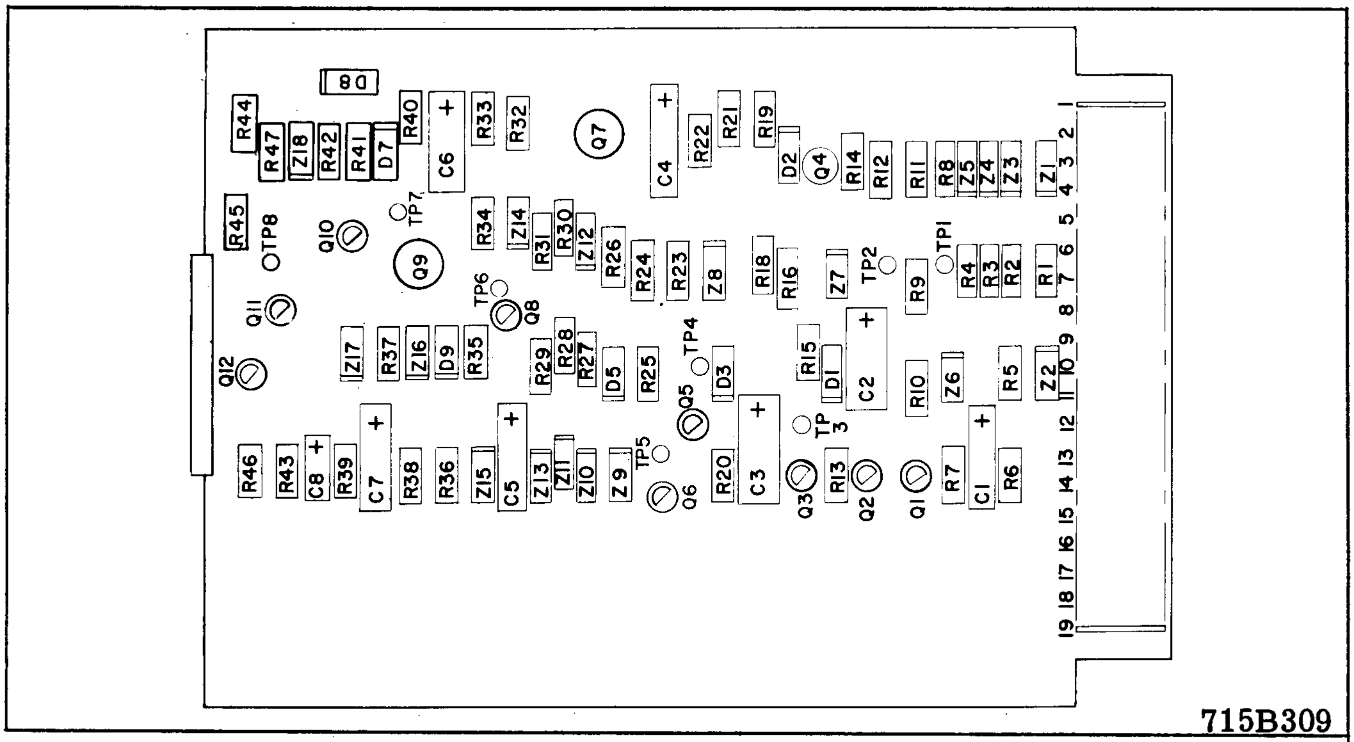


Fig. 19 Location of Components on Protective Relay Board.

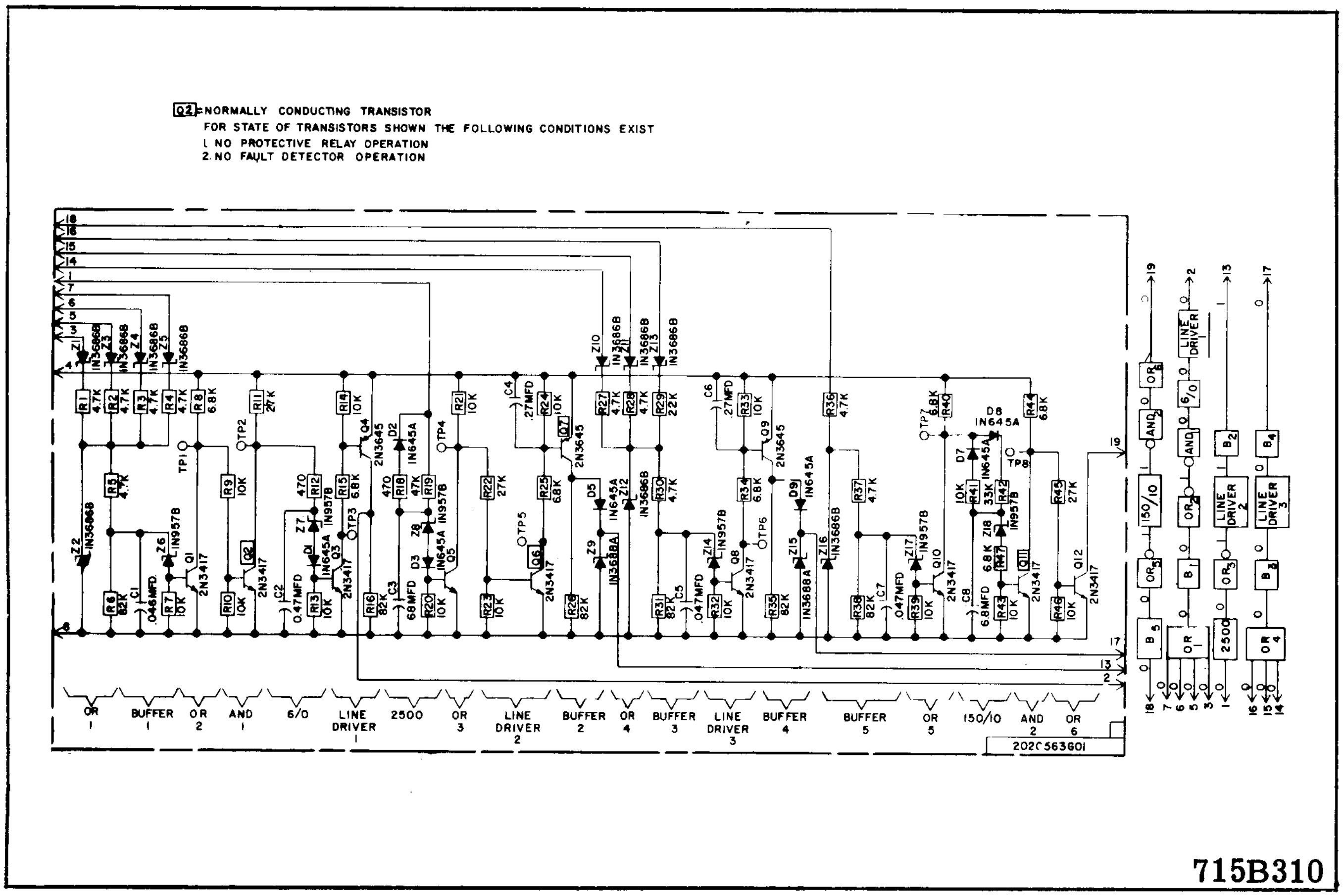


Fig. 20 Schematic of Protective Relay Board.

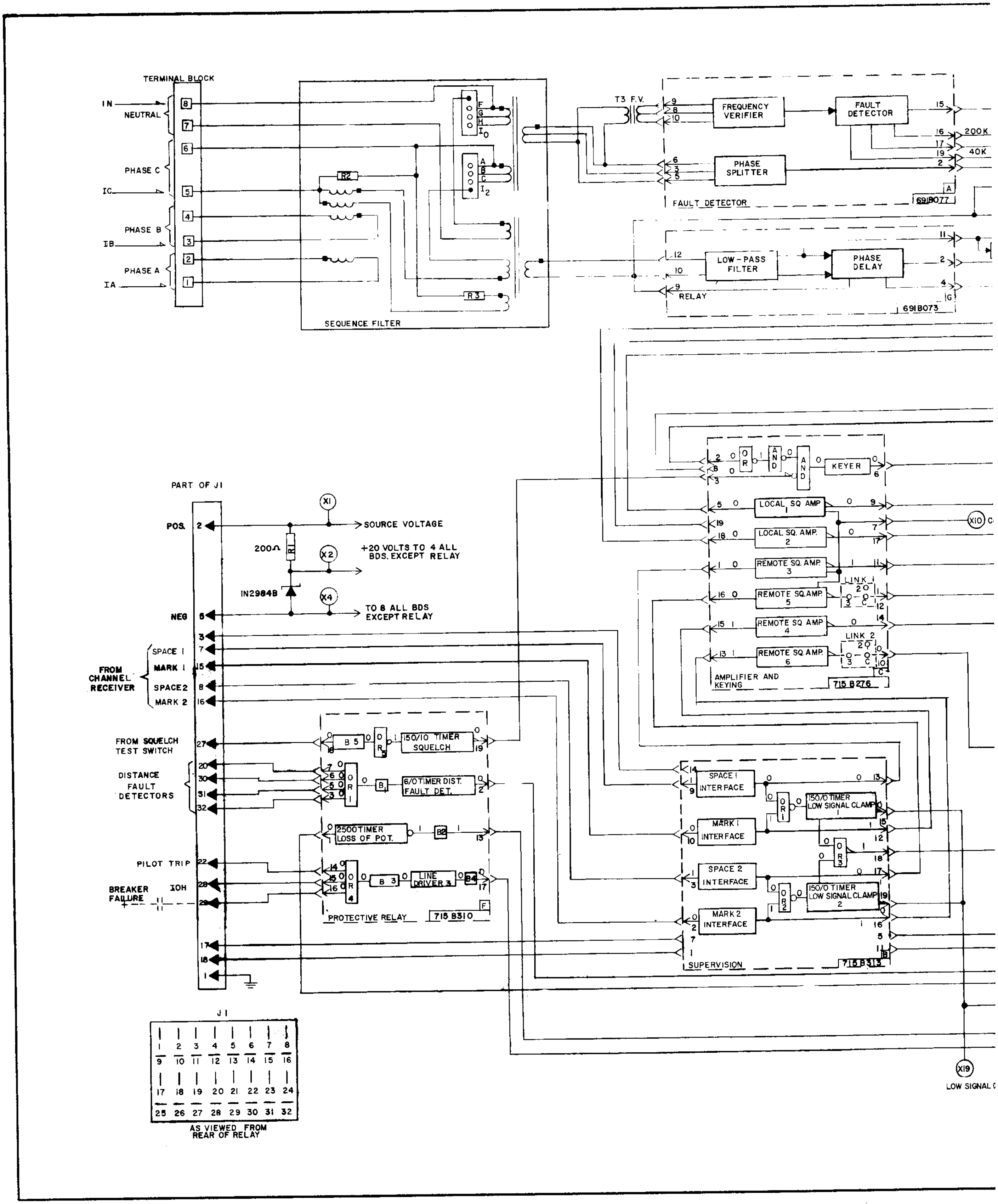
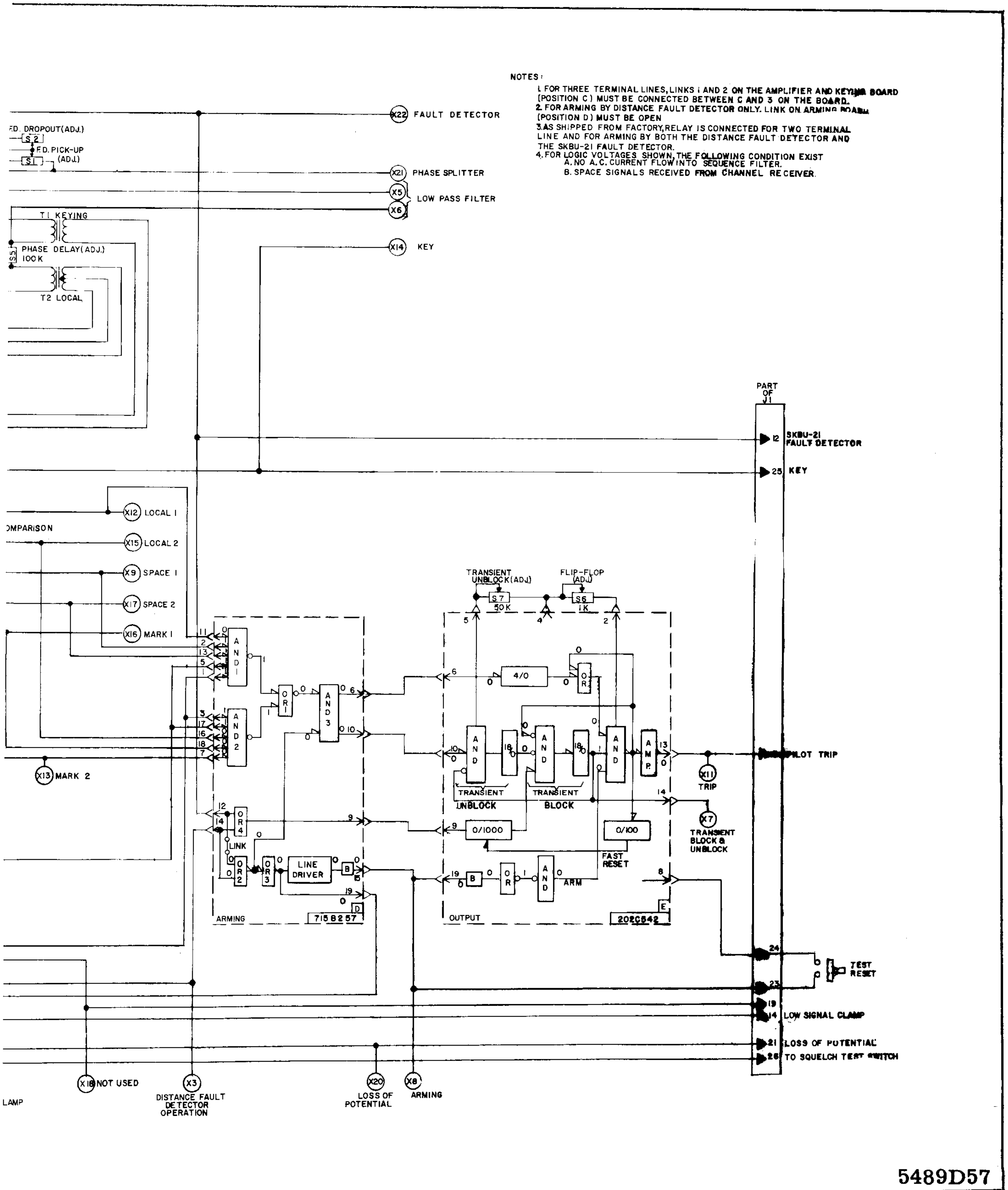


Fig. 22 Logic Diagram o



: SKBU-21 for TCF Carrier Channel.

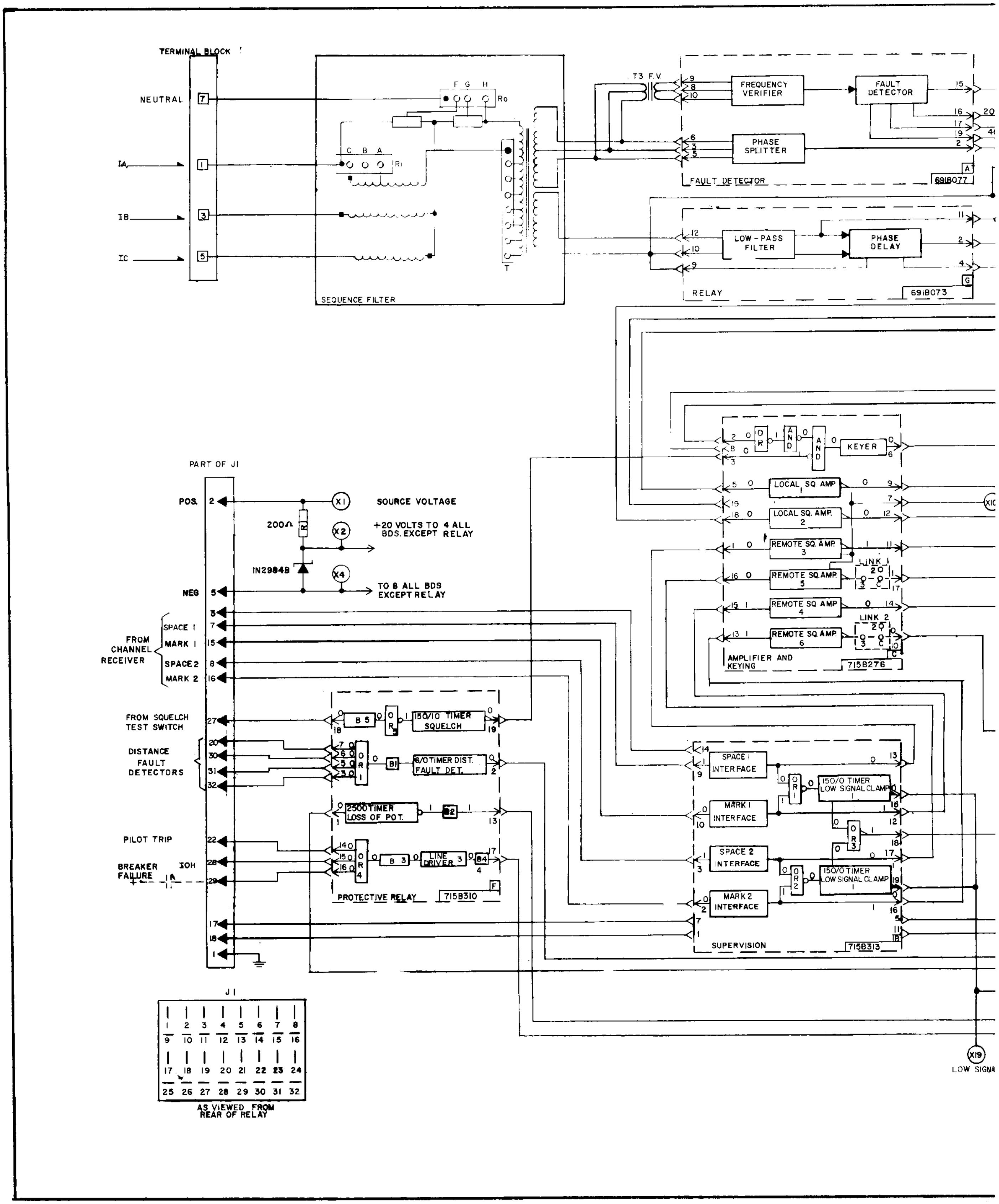
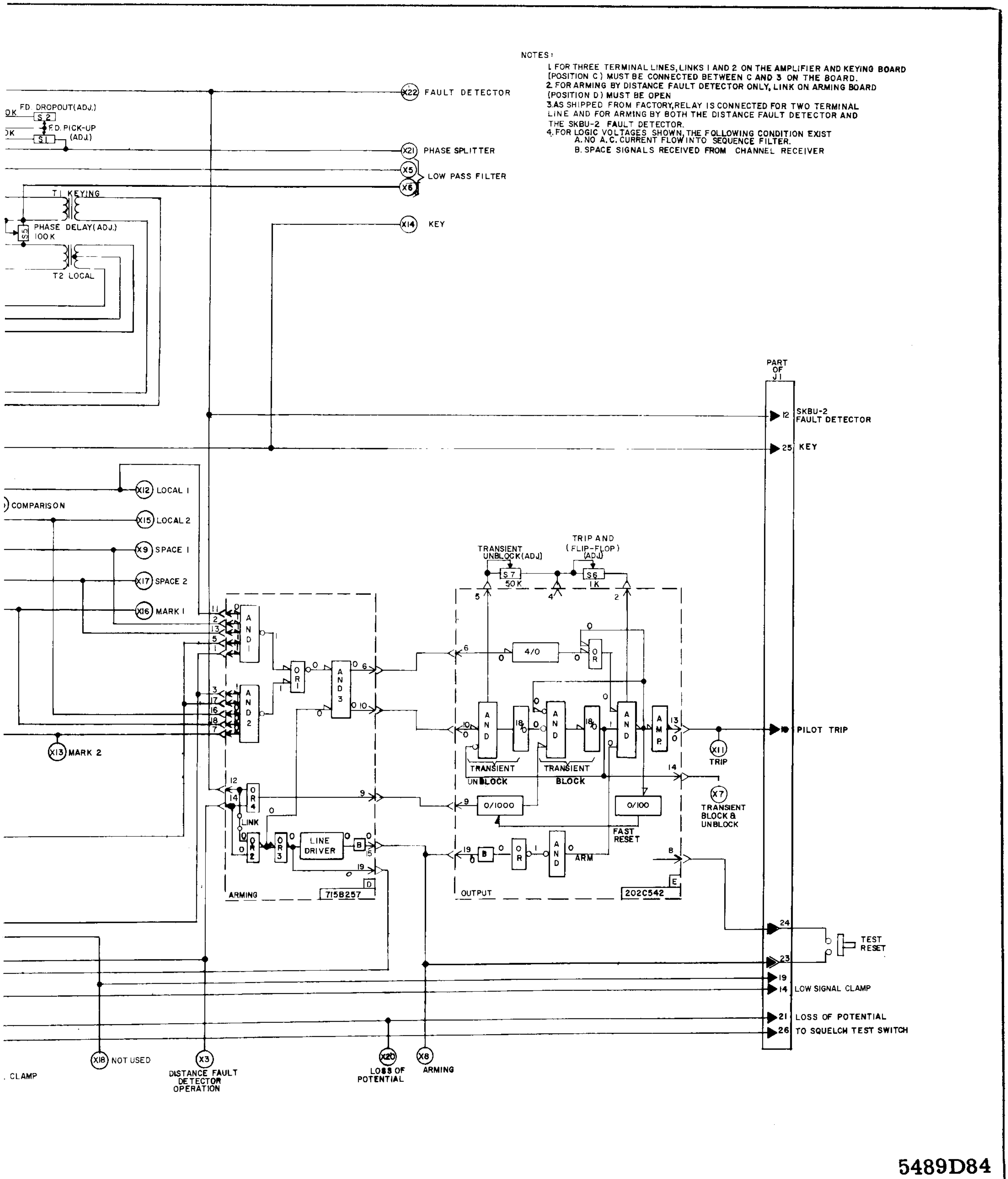


Fig. 24 Logic Diagram of S

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



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KBU-2 for TCF Carrier Channel.

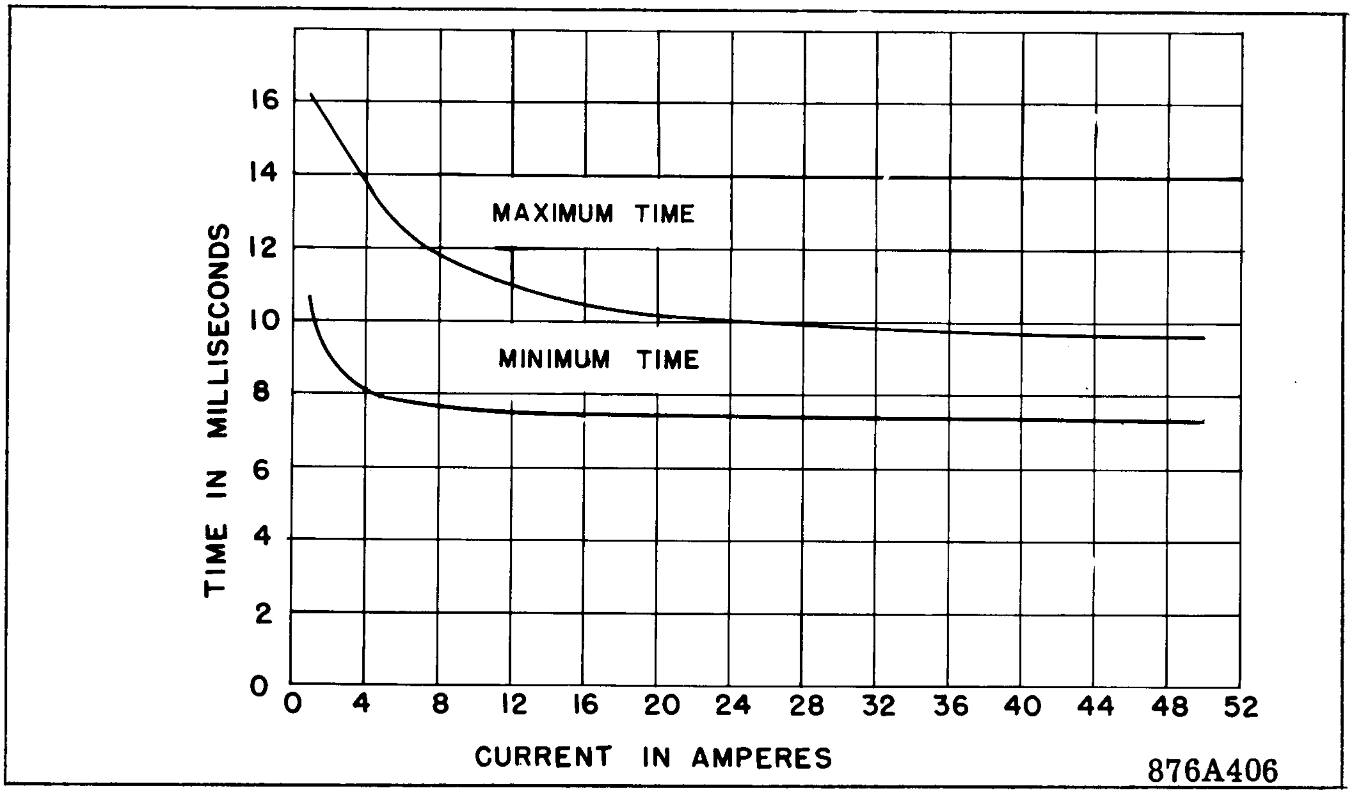

Fig. 25 Operating Times of Fault Detector of SKBU-21 Relay.

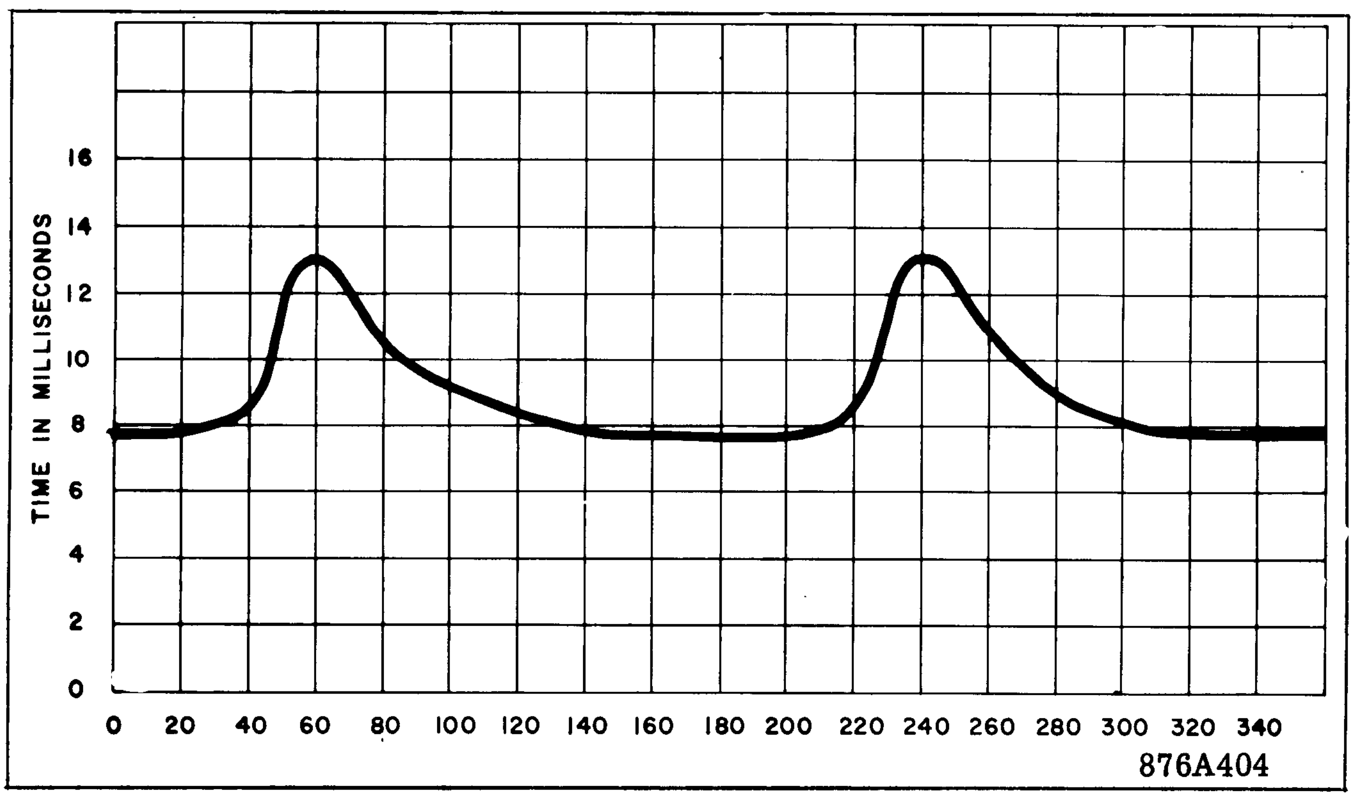

Fig. 26 Operating Times for Fault Detector of SKBU-21 Relay as a Function of Fault Incidence Angle at 5 amperes.

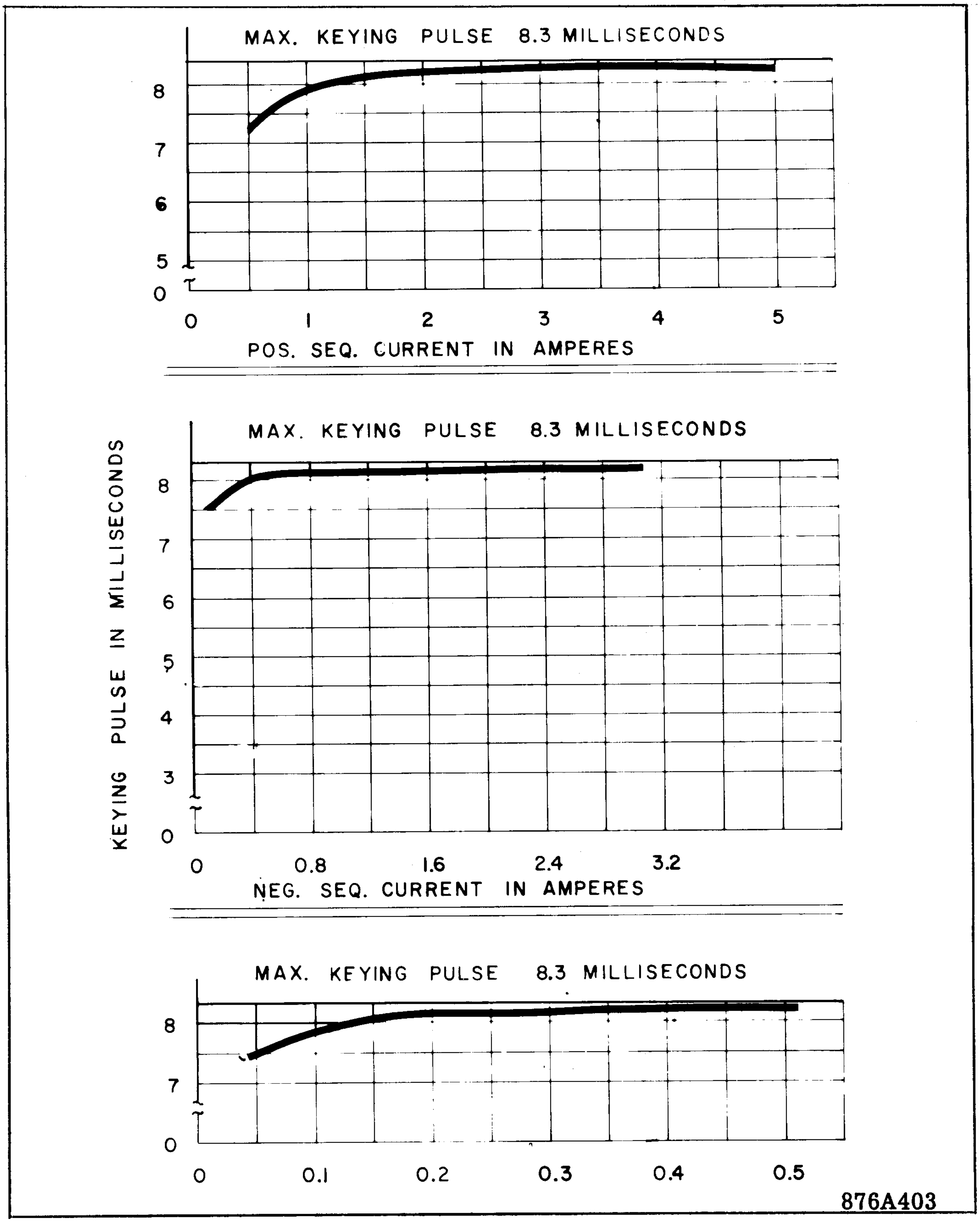

Fig. 27 Width of Keying Pulses at Different Current Levels of SKBU-21Relay.

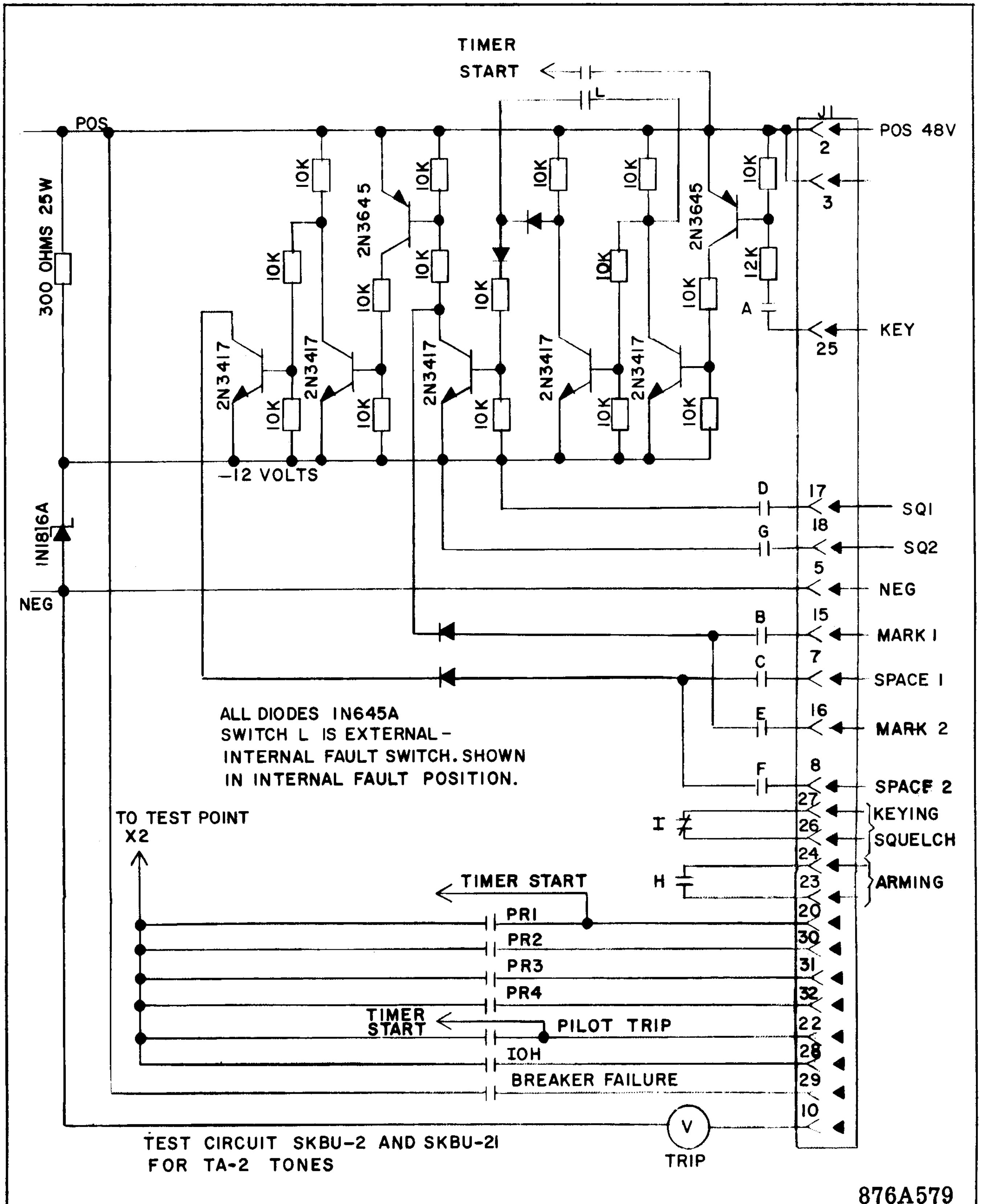

Fig. 28 Test Circuit of SKBU-21 Relay for TA-2 Tone Channel.

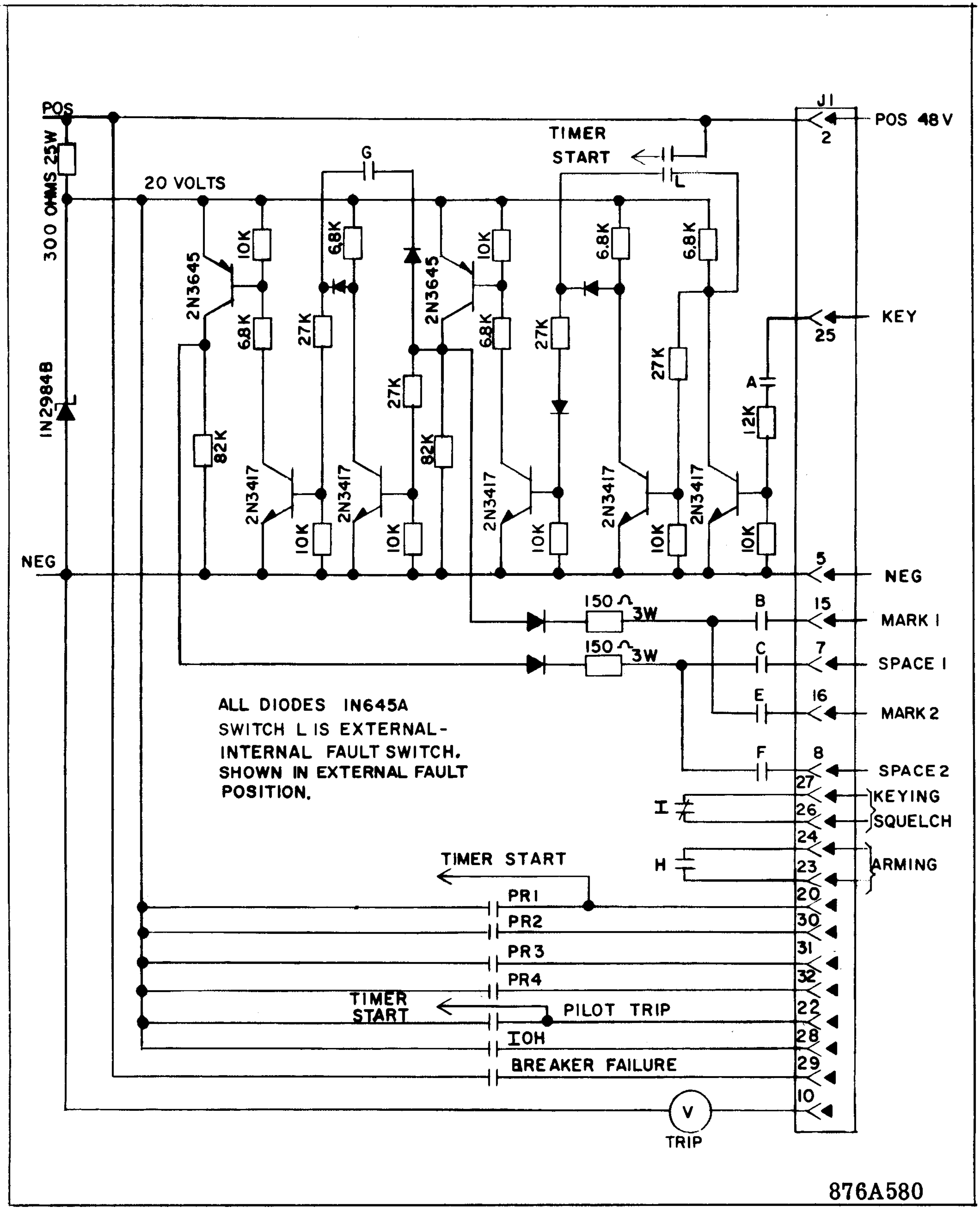

Fig. 29 Test Circuit of SKBU-21 Relay for TCF Carrier Channel.

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	LOSS OF POTENTIAL	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 3φ
X14	KEYING TA–2 TONE CHANNEL	45 / 36 — 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 — 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	

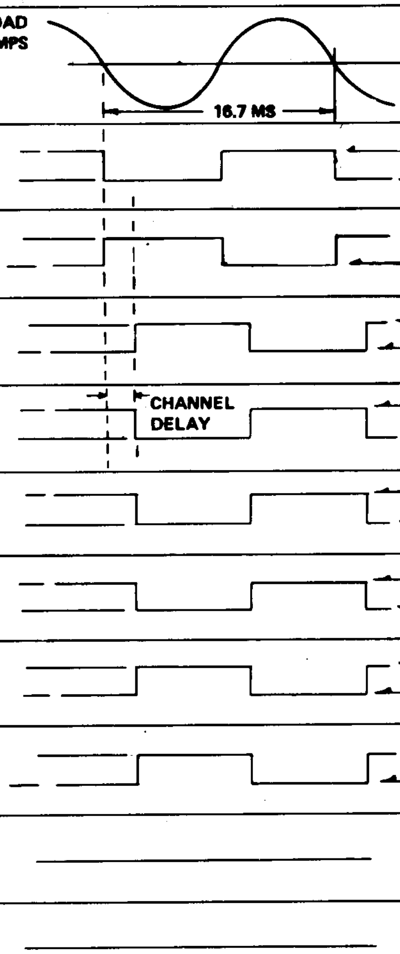

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Fig. 30 Table III Test Point Voltage.

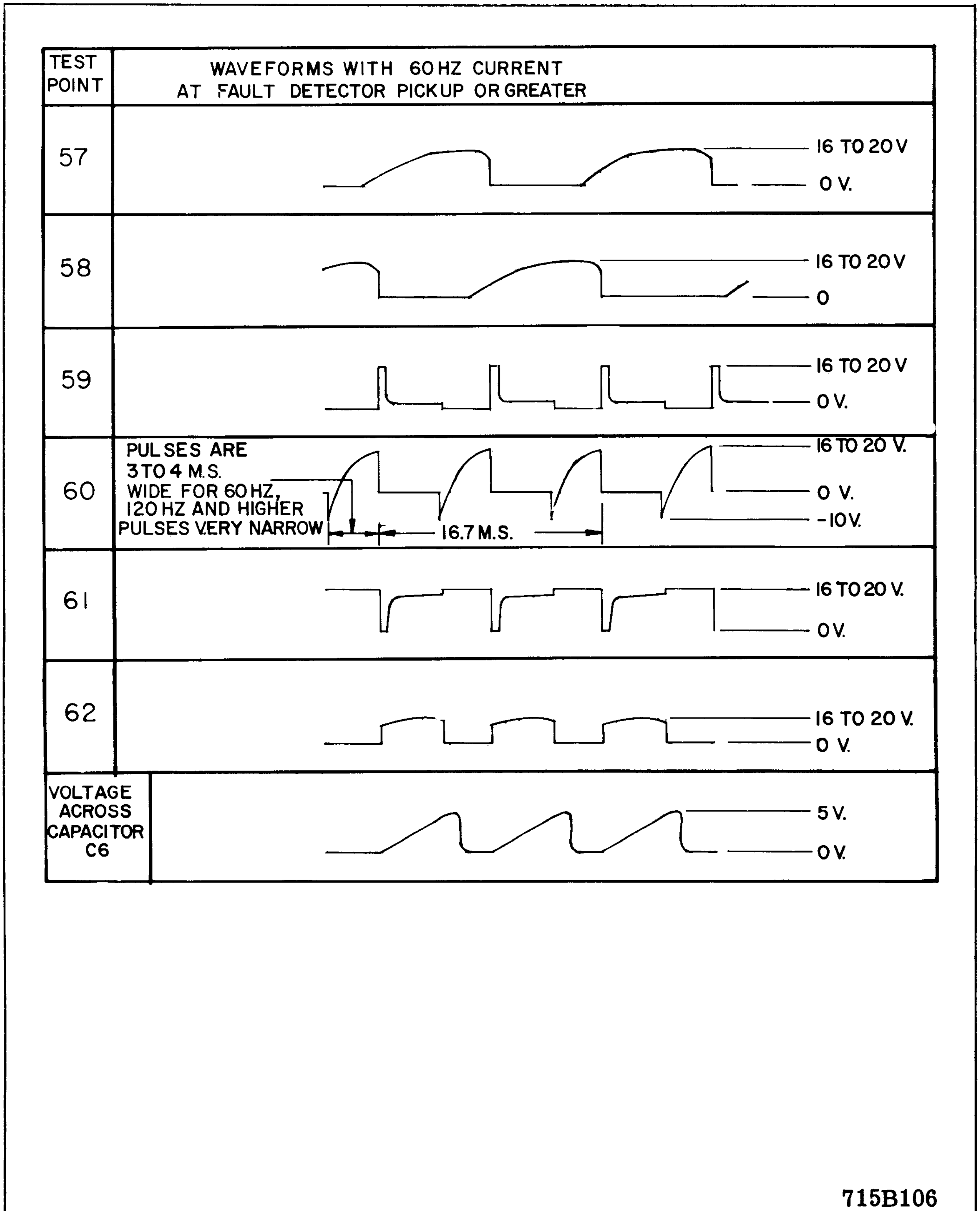

Fig. 31 Frequency Verifier Waveforms at 60 Hz.

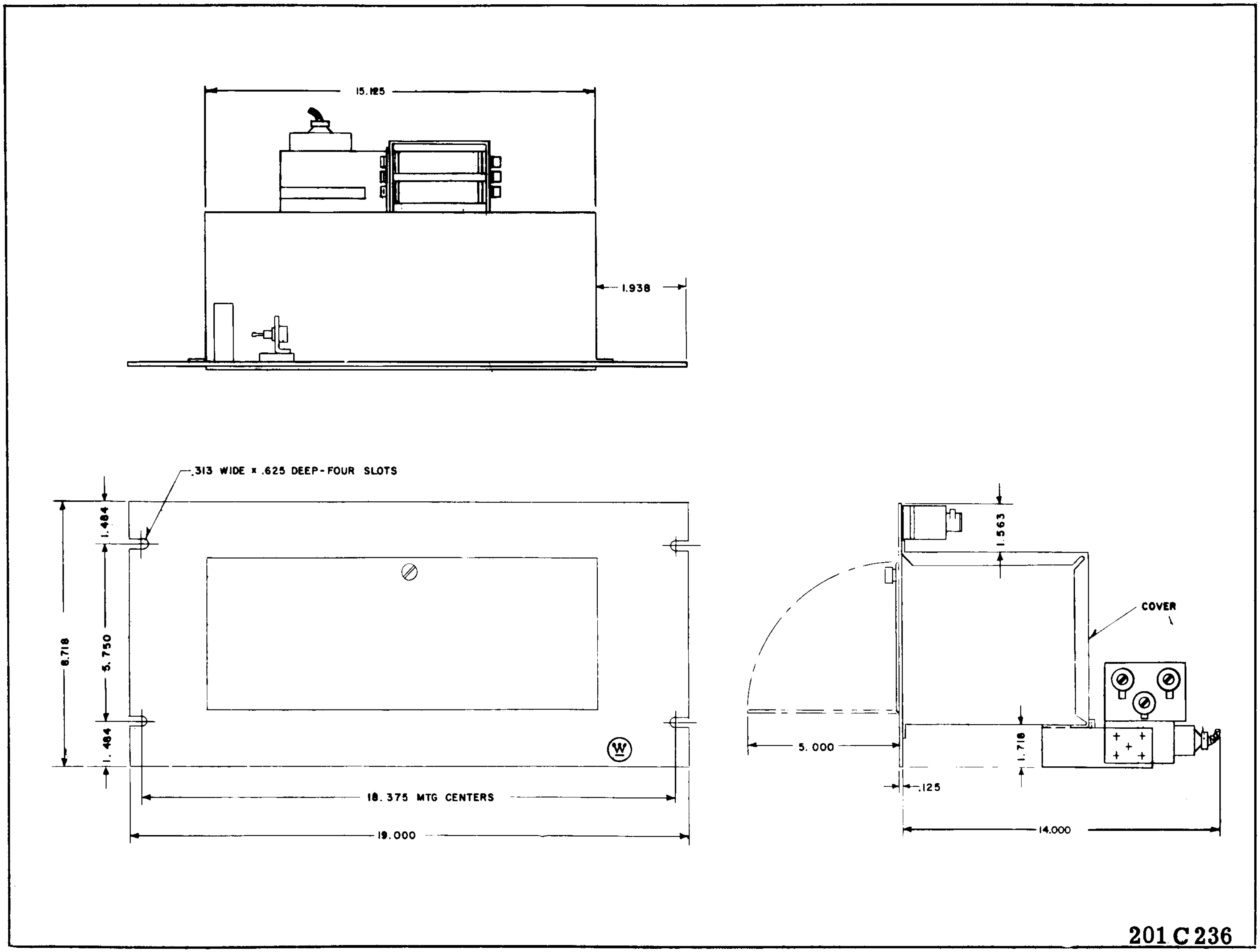

Fig. 32 Outline for the Type SKBU-21 Relay.

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