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IB 16.4.1.7-2D

**Installation/Maintenance Instructions**

# I-T-E High-Speed Trip Control Assembly

## Types 76HS and 76HS-RR for use with FBK-H Direct Current Circuit Breakers

**This instruction book is to be used in conjunction with IB 16.4.1.7-1.**

Brown Boveri Electric

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# HIGH-SPEED TRIP CONTROL ASSEMBLY TYPE 76HS AND TYPE 76HS—RR

## INTRODUCTION

The high-speed trip package is a solid-state controlled system for the directional overcurrent protection of dc power systems. The system consists of current "sensors", mounted around the bus bars on the circuit breaker, a solid-state control assembly, mounted in the bottom of the breaker, and interconnecting cables. The device initiates the tripping of the breaker's high-speed latch by discharging capacitor stored energy into an impulse trip coil.

Control assembly models are available for uni-directional and duo-directional trip. For transit system applications, an optional "Rate of Rise (R-R) Detector" is available which allows tripping for fault currents below load-current levels.

When specified, an auxiliary relay contact may be provided for remote indication of a high-speed trip, or to initiate lock-out of the breaker after a high-speed trip.

## APPLICATION INFORMATION

### High-Speed (Magnitude of Current) Trip

The sensors are available in five models, with nominal current as shown in Table I. The tap block on the solid-state control assembly enables the user to select the trip current as one of four multiples of the sensor nominal rating. The multiples are 1, 2, 3 or 4.

The available trip currents, obtained by combination of sensor rating and tap-position, are listed in Table I. Allow ±20% variation.

When high-speed duo-directional trip is specified, the trip currents can be chosen independently. For example, a forward trip of 12000A (with 4000A sensor set at 3X), and a reverse trip of 500A (with 500A sensor set at 1X).

### Trip Polarity

Usually, the device trips for one polarity of fault current only. In this arrangement, only one sensor is used, and the trip direction is for fault current flow into the sensor window. The sensor(s) can be mounted on either the upper or the lower pole of the breaker, thus allowing choice of trip direction.

When dual-directional tripping is specified, two sensors are used, with the same options of mounting. (Only one (1) sensor can be mounted at each terminal location.)

The breakers are shipped with the sensor(s) nominal rating(s), and the trip polarity(s), stamped on the sensor nameplate, located on the breaker front plate, left side.

### Operating Time

The operating time of the trip device is 0.5ms, measured as the time interval between the time the fault current reaches the trip level and the time at which the high-speed impulse trip coil is energized.

### 76HS-RR Detector (Rate-of-Rise)

This function can be added to the basic high-speed current magnitude tripping function by adding a printed-circuit board to the standard units.

**NOTE:** 76HS-RR not available when high-speed duo-directional trip is specified (See Figure 1 note).

The purpose of this function is to detect relatively low-level faults. These occur commonly on transit systems, for example, as a result of short circuits remote from the rectifier.

In applying the R-R detector, a compromise must be made between its reach and security against nuisance trips on train-starts.

Knowing the values of inductance and resistance of the track circuit, the reach can be approximated from

$$D = \frac{E}{LI'} \times e^{\frac{-Tr}{L}}$$

where E = system voltage
L = system inductance in m h/mile
r = system resistance in m ohm/mile
I′ = sensor rating/sec.
T = time-delay setting in seconds.
D = distance in miles

T is selected by placement of a tap plug in a four position block on the front panel of the high-speed trip control assembly. The available settings are 1, 2, 3 or 4 multiples of the timer rating. This is stamped on the front panel.

Greatest security against nuisance trips on train-starts is provided with the longest time delay setting. To determine whether this will obtain a reach adequate for proper system protection, use this time delay value for T in the above equation. For example, with a timer rating of 0.05 seconds and tap set at 4 multiples; with a 6000A sensor:

T = 0.2 seconds
E = 650V dc
L = 3 m h per mile
r = 40 m ohm per mile
I′ = 6kA/sec.

$$D = \frac{650}{3 \times 6} \times e^{\frac{-.2 \times 40}{3}}$$

$$D = 2.5 \text{ miles}$$

This means that the detector will recognize a fault up to 2.5 miles away, and open the circuit breaker after the 0.2 second delay.

This delay time has proven adequate for trains in common service. However, for unusual system conditions, the time delay may be increased by adjusting the potentiometer as described in the circuit description. This value is set and tested at the factory. Consequently, it is not recommended that any readjustment be made unless system parameters dictate a change is definitely required and that proper test equipment is utilized.

## CONTROL POWER REQUIREMENTS

| Tripping | Nominal | Closing |
|---|---|---|
| 70–140 | 125 Vdc | 106–140 |
| 140–280 | 250 Vdc | 210–280 |

The control power source must be a stable supply, such as a battery equipped with a charger. Reasonable care must be exercised with other sources and the loads on the source so that the transient variations do not cause too much stress on the semiconductor components in the trip device. If the control line is unusually "spikey", varistors, or some other form of surge suppression must be placed across the line serving this equipment.

### Automatic Reclosing

This equipment must be coordinated with the time required to charge the energy-storage capacitor. The 76HS1 contact, in series with the circuit breaker's close circuit, is open until the capacitor is charged. Refer to IB–16.4.1.7-1 "HIGH-SPEED TRIP DEVICE (ELECTRICAL OPERATION)" for capacitor charging times and operation of 76HS contacts.

### High Speed Trip Control Assembly
**Special Auxiliary Contacts** (Optional)
(See Figure 8)

1. If current through the circuit breaker is sufficiently high to cause a high-speed trip, the level detector output will pick up relay K701 (contained in high speed control assembly 76HS).

2. Contact K701/al closes, picking up relay K702 (also contained in high speed control assembly 76HS).

3. Contacts K702/al, K702/a2 and K702/a3 close. Contact K702/al keeps relay K702 energized after relay K701 has dropped out. Contacts K702/a2 and K702/a3 may be used to energize the operating coil of a latch type lockout relay (LOR). If used, it should operate as follows:

   a. Normally closed contact LOR/b1 opens and is latched open, thus deenergizing LOR relay while normally closed contact LOR/b2 opens and is latched open, deenergizing relay K702.

   b. Any other contact of relay LOR may be used as an alarm contact signaling that a high-speed trip has occurred.

## CIRCUIT DESCRIPTION

The circuit is represented in block-diagram form, Figures 1 and 11.

### Sensors

The sensor (Figure 15) consist of a Hall device mounted in an air-gapped core. The purpose of the core is to convert the bus-bar current to a flux-density through the Hall device. By properly dimensioning the air gap, each rating of sensor (e.g. 2500 amps) will develop the same flux-density to yield the same voltage out of the sensor when the bus-bar current is the same multiple of the sensor rating.

### High-Speed Trip Control Assembly

This unit provides the following functions:

1 Control Power Converter
2a. Sensor Excitation } Fig. 4
2b. Level Detector
3a. Trip Circuit } Fig. 5
3b. Close Function
4. 76HS-RR Fault Detector (when provided), Fig. 9

**1. The Control Power Converter consists of:**

a. rectifier and regulator, PC100; Fig. 2
b. inverter, PC200; Fig. 3
c. inverter transformer, T601; Fig. 7
d. low voltage dc supply, PC500; Fig. 6
e. high-voltage dc supply, C600; Fig. 7

**1a. Rectifier and Regulator, PC100—Figure 2**

The function of the regulator is to enable the trip device system to operate at bias voltages which are relatively independent of the control voltage.

The regulator schematic is shown in Figure 2. Numerical values are given for 125 VDC control power. The operation of the circuit is explained below.

D101 fixes the base and emitter voltages of Q101 and Q102 at 56V. Thus, the emitter currents are determined by this voltage and the load resistance. The transistors are connected in Darlington for high current gain, and so the emitter current of Q102 is negligible compared to the emitter current of Q101. This is determined by D101, and the load, about 0.3 Adc.

The regulator must be capable of operating into a short circuit ($R_L$=o), to guarantee reliable starting into a capacitive load. For this reason, R120 and R121 are included, to limit the short circuit current to a safe value, about 2.5 amps.

With reference to the schematic, Figure 2, C101 and varistor RV 101 with R120 and R121 provide protection of the regulator components from control power transients, C102 aiding in this respect by appearing in shunt. C101 is lower inductance compared to C102 to take care of very fast transients. (See Control Power Requirements)

The +6V output of the regulator is used to drive the inverter transistors. This separate source is used to guarantee proper inverter operation starting into a capacitive load.

**1b. Inverter, PC200—Figure 3**

The function of the inverter is to change the dc output of the regulator to double-ended square-wave so that it may be transformed. The design is that of a conventional, astable multivibrator, with additional stages to provide the required power handling capability. The design guarantees proper starting into a capacitive load.

With reference to the schematic, Figure 3, the output stages, Q201, and Q208 are designed to saturate for collector currents of more than 3 amperes. They are required to handle only 160 ma. continuously, but the additional over-drive must be provided to ensure rapid transition through the active region.

D207 and D208 are included to remove any negative collector voltages as the transformer is switched. The Q201, Q208 emitter diodes, with the R215 and R216 returns to the positive supply provide reverse-bias for the output transistors. D205 and D206 clamp the output bases to ground when the Q203 and Q206 drivers are saturated, and the output Q201, Q208 are cut-off.

The output stage pairs, Q202–Q201 and Q208–Q207, are Darlington connected to reduce the net power dissipation on the 200 board.

**1c. Inverter Transformer, T601–Figure 7**

This is designed specifically for the application, with center tapped primary; the secondaries are two 27V, and one 2300V winding.

**1d. Low Voltage dc Supply, PC500–Figure 6**

The regulator on PC500 operates from the 27V windings of T601 to furnish plus and minus 15Vdc bias supplies to the measuring and logic circuits. The regulation function is duplicated (over that of PC100) to ensure that the 15V biases are developed before the 2300V has, so that the measuring functions perform properly on starting.

Referring to the schematic, Fig. 6, the circuit is seen to be essentially the same as that of PC100, Fig. 2, but with both positive and negative regulators.

**1e. High Voltage dc Supply, C600–Figure 7**

The high voltage output of inverter transformer T601 is rectified by diodes D601, D602, D603 and D604. The resultant 2300V dc is the charging voltage for capacitor C-1.

**2a. Sensor Excitation, PC300–Figure 4**

This function is contained on PC300. For duo-directional models, 2–PC300 boards are supplied with two sensors (Fig. 15). The sensor excitation is obtained from the low voltage power supply through R302 and its associated components. R302 is factory set and should not be adjusted without cause.

If desired, however, the high speed trip current may be adjusted to a value other than standard, by adjusting R302 (top adjustable resistor) which may be painted red and is accessible by dropping the front panel*. CW rotation increases the current required to trip. (See Figure 16)

**2b. Level Detector–Figure 4**

The level detector is comprised of the integrated amplifier Q301, and transistors Q302 and Q303. Refer to schematic, Figure 4.

The sensor output is connected to the amplifier input in the differential mode, thus, the amplifier responds only to signals which cause a voltage between the amplifier input leads (which is the differential mode signal). The amplifier's common mode gain is less than .001 x the input signal. Thus, the response to a signal which causes both input leads to move equally from ground is virtually zero.

* The front panel may be dropped by removing the four (4) screws from the front of the high-speed trip control assembly (See Figure 14).

Using an amplifier with this capability ensures noise-free performance as long as the mutual impedance between the signal leads is kept small. For this reason, twisted pairs are used for the cable-connection between sensor and amplifier.

The sensor output is about 90 mv. per multiple of current rating. That is, with R302 as factory set, a 4kA sensor would yield 90 mv. output for 4kA through the circuit breaker.

The amplifier has a gain of 20 and the switching circuit, Q302–Q303, changes state for amplifier outputs of 1.8, 3.6, 5.4, 7.2 volts depending on the setting of the high speed trip selector plug, 26, Figure 1 (IB–16.4.1.7-1). As seen by the schematic, Figure 4, the selector plug actually selects the bias resistors R323, 4, 5 or 6.

When the amplifier output exceeds the voltages above, Q303 collector (accessible at TP2 Fig. 12 on PC300) goes to +15V, driving Q401 as described next.

For convenience, the amplifier output is available at Test Point (TP–1, Fig. 12) on PC300, accessible when the front panel is dropped.*

**3a. Trip Circuit**

The trip function is comprised of PC400 and C600. Referring to these schematics, Figure 5 and Figures 7 and 17 respectively, Q401 and Q402 switch on when the level detector output goes positive, firing Q403. This discharges C403 into the primary of T602, resulting in a secondary voltage of about 5kV, which fires spark-gap Q601. The energy storage capacitor, C1, is thus discharged into the impulse coil.

For duo-directional models, either level detector will switch Q401 and Q402 as above, resulting in a trip.

For models equipped with the R-R fault detector, the output transistor, Q806, turns on to accomplish the same function as Q303. Refer to PC800, schematic Figure 9.

**3b. Close Function**

The close function is contained on C600, Figures 7 and 17, PC400, Figures 5 and 12 and PC500, Figures 6 and 12. R610 and R603 form a voltage divider on the 2300V output of C1, down to 15V. This drives Q404; R412 is factory set to turn on Q404, when C1 is at 1800V. This level assures sufficient charge on C1 for reliable tripping. With Q404 on, Q408 is also on, driving K501 coil and closing its contacts. One set of contacts (76HS1) is in series with the X coil in the breaker's close circuit, so that the breaker can not be closed unless C1 is charged.

**4. 76HS–RR Fault Detector**

The circuit is shown in the PC800 schematic, Figure 9. The sensor output, amplified on PC300, Figure 4, is connected to the PC800 input. Q801 and its associated components form a differentiating circuit. The output of this circuit (labeled I′) is level detected by Q802 and Q803. If the rate-of-rise of the current exceeds 0.36V, Q802 turns on and Q803 turns off, allowing C804 to charge toward +15V. When it reaches 7.5V, Q804 turns on, Q805 off, and Q806 on, causing a trip through Q401 and the rest of the high-speed trip circuitry. This happens if the rate-of-rise exceeds 0.36V for the selected time period.

The level of rate-of-rise current (I′) is adjustable by R810 (Fig. 16) and the timer rating by R840 (fig. 16). These are accessible by dropping the front panel. Clockwise rotation increases each function. See Fig. 14.

**NOTE**: These values are set and tested at the factory. Consequently, it is not recommended that they be readjusted unless system parameters dictate a change is definitely required and that proper test equipment is utilized.

R852 and C852 comprise a built-in test circuit, producing an exponential voltage simulating the current resulting from a fault.

S850 is a test receptacle, with the signals as indicated on PC800 schematic, Figure 9 (See Figure 14).

## CONSTRUCTION

The sensors are encapsulated assemblies with mounting holes suitable for the FBK breaker rear molding (See Figure 15).

The high-speed trip control assembly is a sheet metal enclosure with locating pins and holes for mounting in the bottom of the breaker. Interconnections are by locking type multiple pin plugs and receptacles (See Figure 17).

The printed circuit boards are identified as PC100, PC200, PC300, PC400 and PC500 and are plug-in modules, located in the front of the unit, with PC100 to the right as viewed from the front. There may be one (1) additional PC300 or PC800 printed circuit board installed at the left of PC500 to meet the requirements for either high-speed duo-directional trip or rate-of-rise (R-R) trip respectively (See Figure 10 & Figure 12). The enclosure has two hinged covers, interlocked so that the front, or low voltage section must be opened first, allowing test or maintenance of the circuit boards without exposing the high voltage components in the rear (See Figure 13).

The energy storage capacitor, C1 (Fig. 17), is the middle subassembly. Extreme CAUTION must be used in handling of this component due to the high voltage associated with it.

BEFORE HANDLING THE CAPACITOR OR THE COMPONENTS IN THE REAR SECTION, MOMENTARILY CONNECT A JUMPER FROM THE H.V. TERMINAL TO THE CASE TO DISCHARGE THE CAPACITOR.

C600 is the rear subassembly and also contains high voltage components. Use the same care with this as with the high voltage capacitor.

Each of the printed circuit boards contains test points as indicated on the schematics (See Table II and Figure 12).

## TESTS (CONTROL POWER ON)

The push-to-test button on the front panel allows a convenient means for checking all circuits in the high-speed trip control assembly. When the button is depressed, the breaker will trip if the unit is in operable order.

A separate push-to-test button is provided with those devices containing the 76HS-RR Detector. When this button is depressed, the breaker will trip after the time delay selected.

**NOTE**: Where automatic reclosing circuitry is provided, the above two tests shall only be made when the breaker is in the TEST position or if the reclosing circuit is disconnected during the test.

Table II contains a schedule of proper test point voltages to facilitate testing within the High-Speed Trip Control Assembly.

Calibration of the magnitude of current required for a high-speed trip may be made with either AC or DC primary test current. If AC is used, the unit will trip on the peak. Assuming sinusoidal current, the RMS meter reading should be about 70% of the DC trip current.

### Load Test—Breaker Feeding Transit System

The test receptacle, S850 (see Fig. 9 & 14) allows a convenient means of testing the settings of the R-R Detector. A scope connected to S850—C will display a series of pulses (15V), corresponding to the time for which a train-starting current exceeds the set rise-rate (I′). This allows actual measurement of the timer setting required. For instance, one six-car train-start has been measured to show a string of pulses, none longer than .08 seconds. A timer setting in excess of this value would not result in a trip during the train-start.

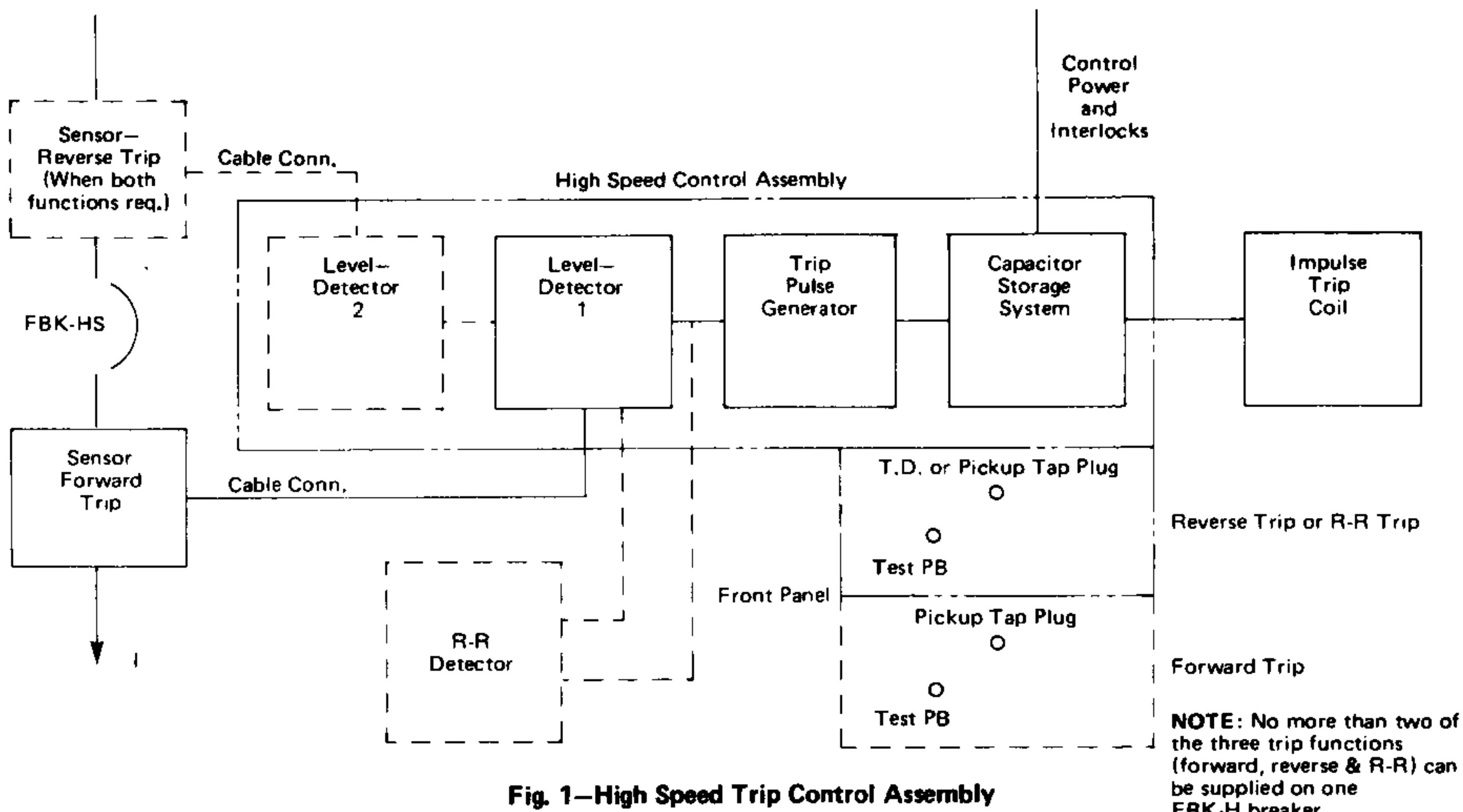



**Fig. 1—High Speed Trip Control Assembly Block Diagram**

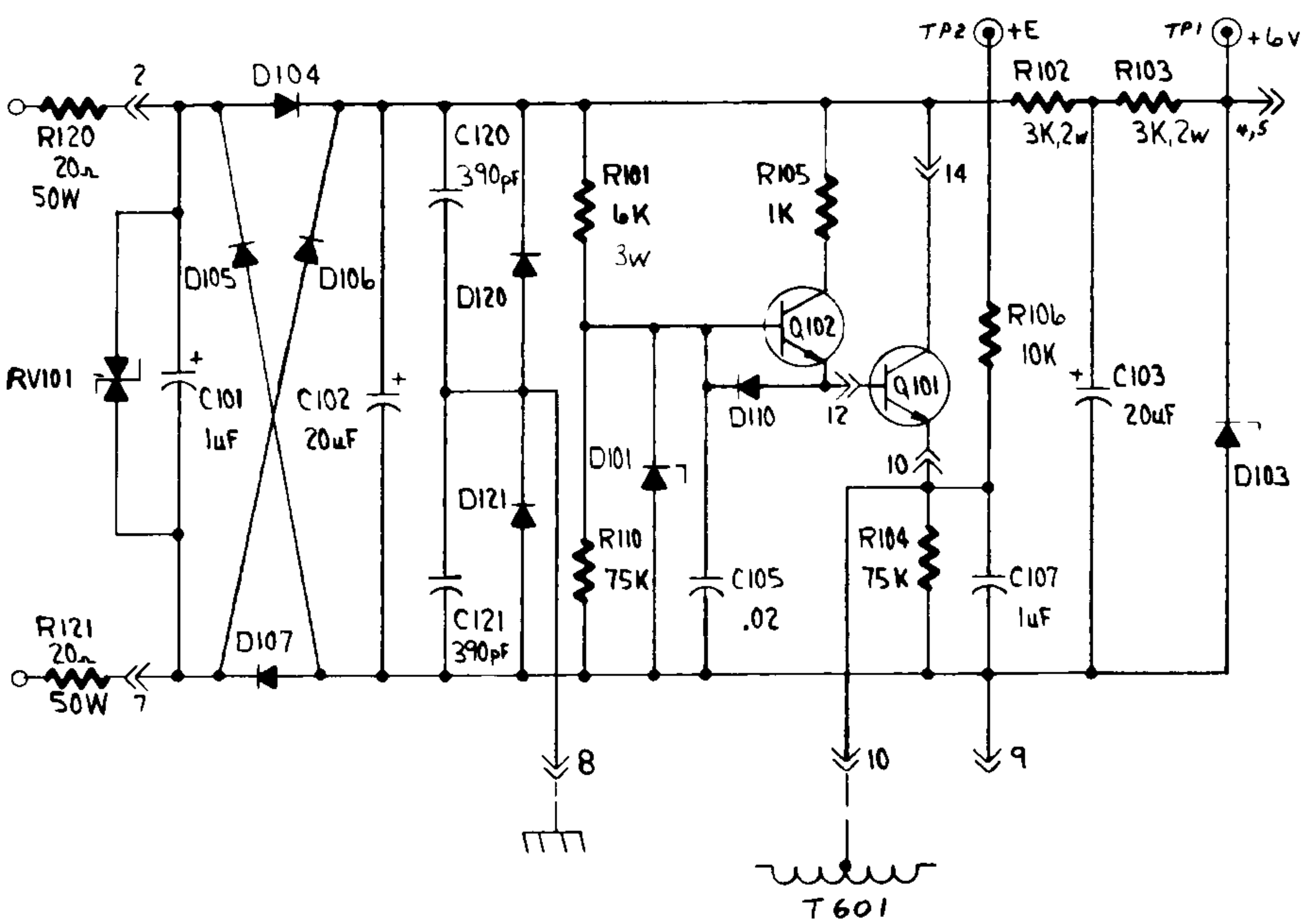



**Fig. 2—PC100 Regulator**
**Std. FBK-H**

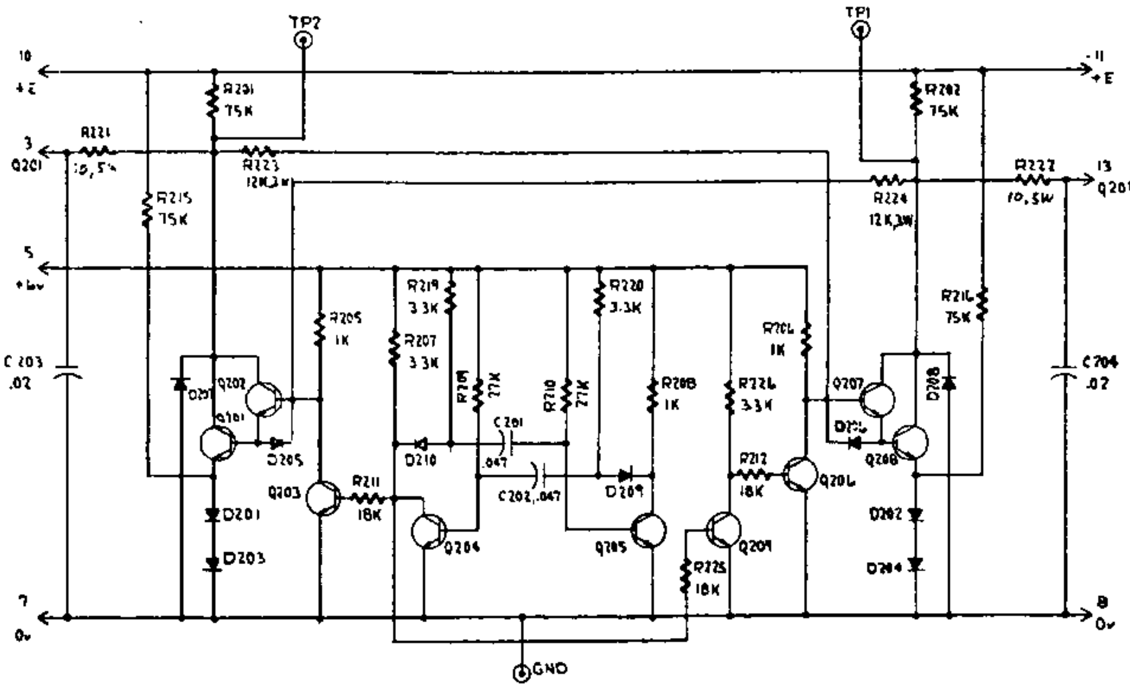



Fig. 3—PC200 Inverter
Std. FBK-H

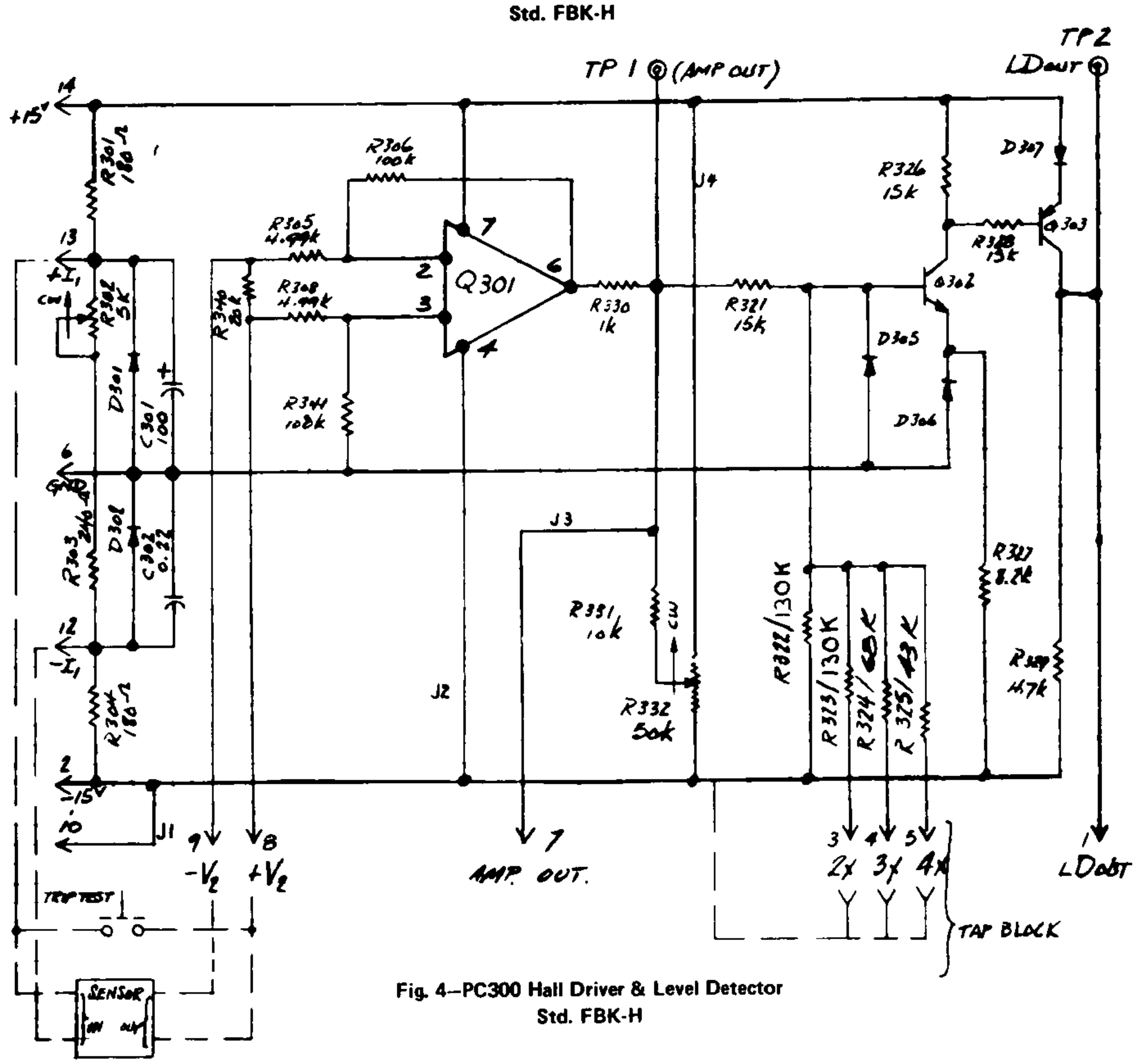



Fig. 4—PC300 Hall Driver & Level Detector
Std. FBK-H

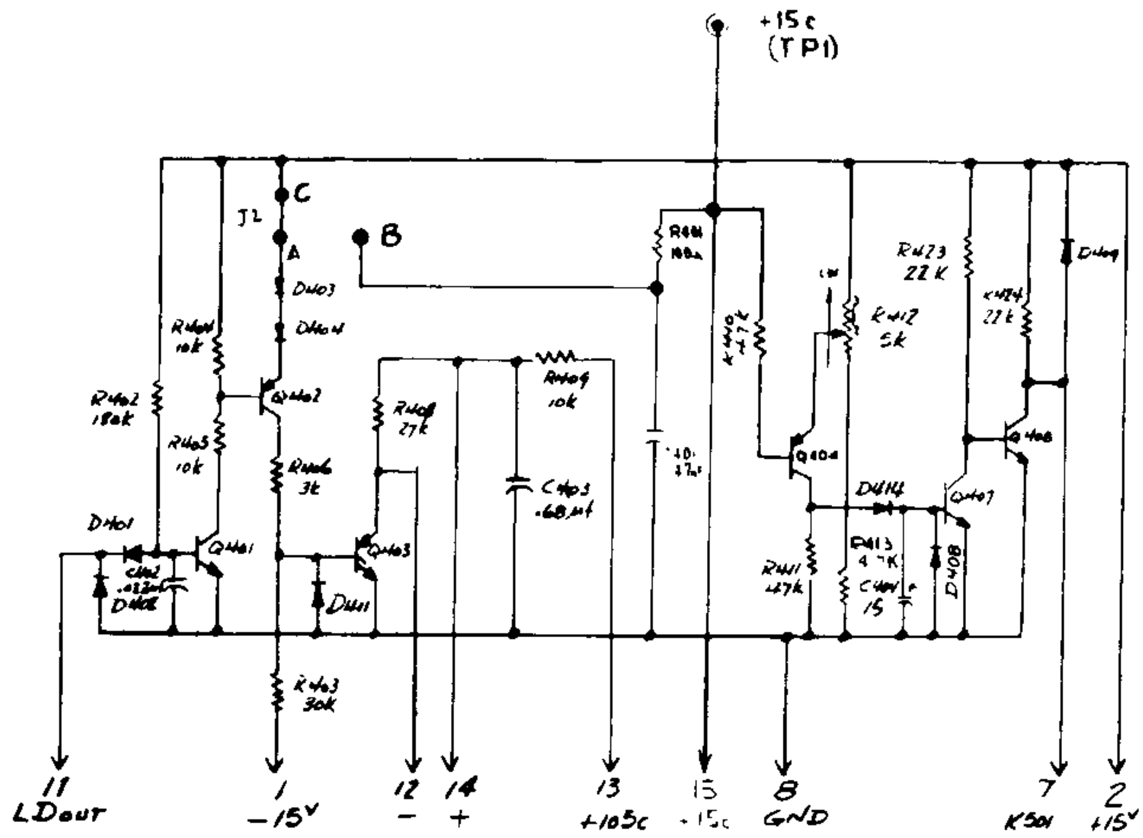



**Fig. 5—PC400 Trip Ckt. & C1 Voltage Detector**
**Std. FBK-H**

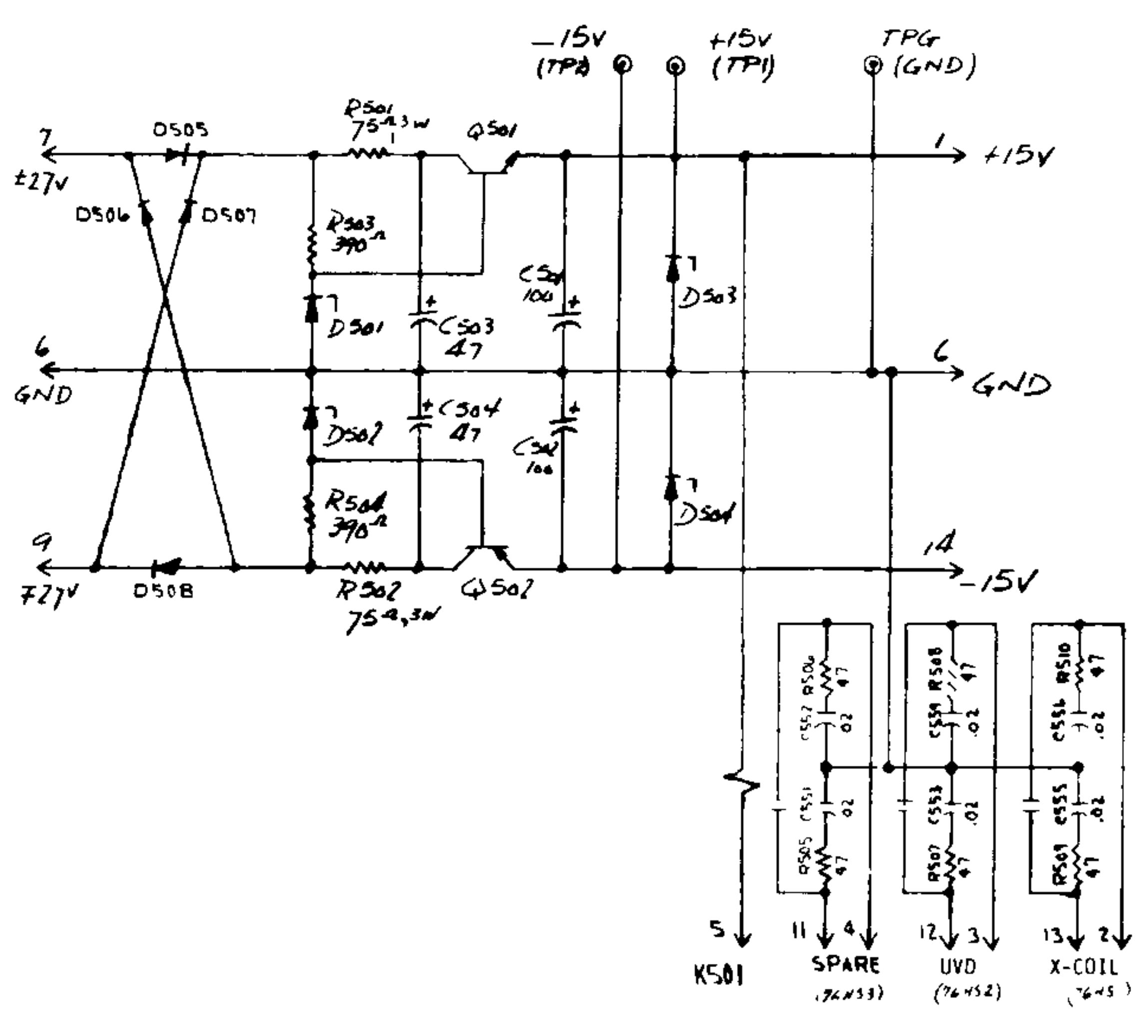



**Fig. 6—PC500 Low Voltage Power Supplies**
**Std. FBK-H**

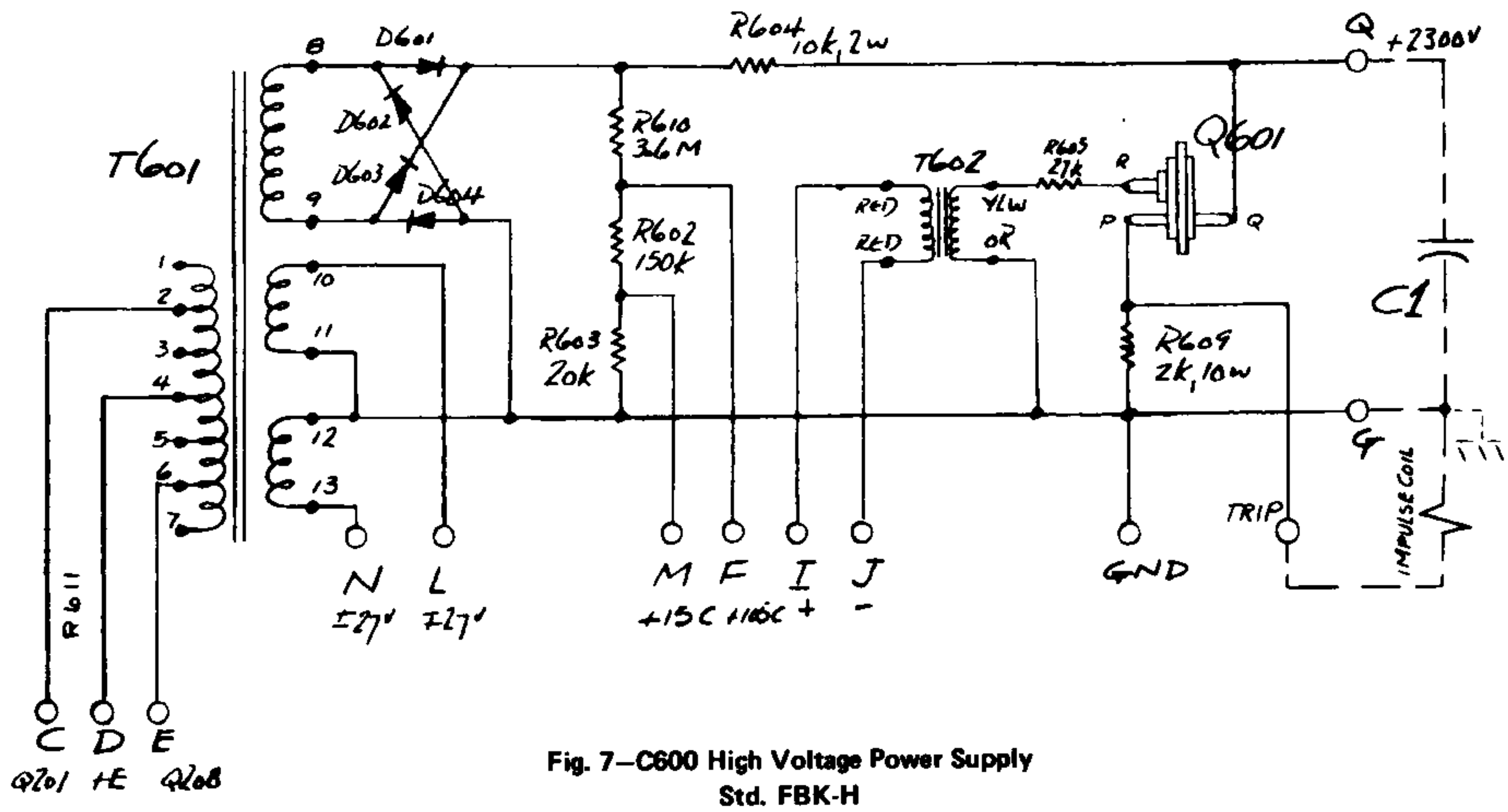



Fig. 7—C600 High Voltage Power Supply
Std. FBK-H

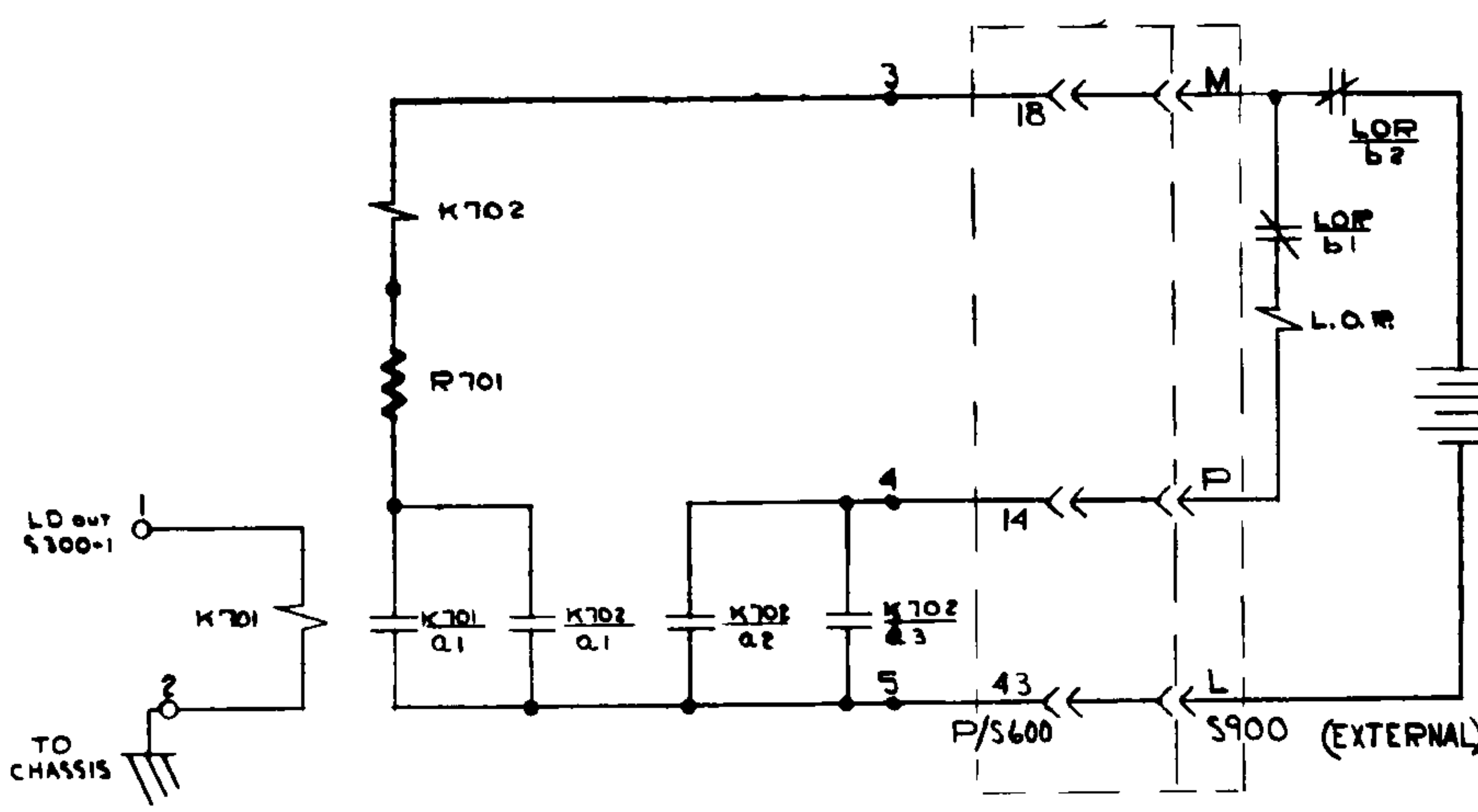



Fig. 8—C700 Auxiliary Relay Circuit
FBK-H (Optional)

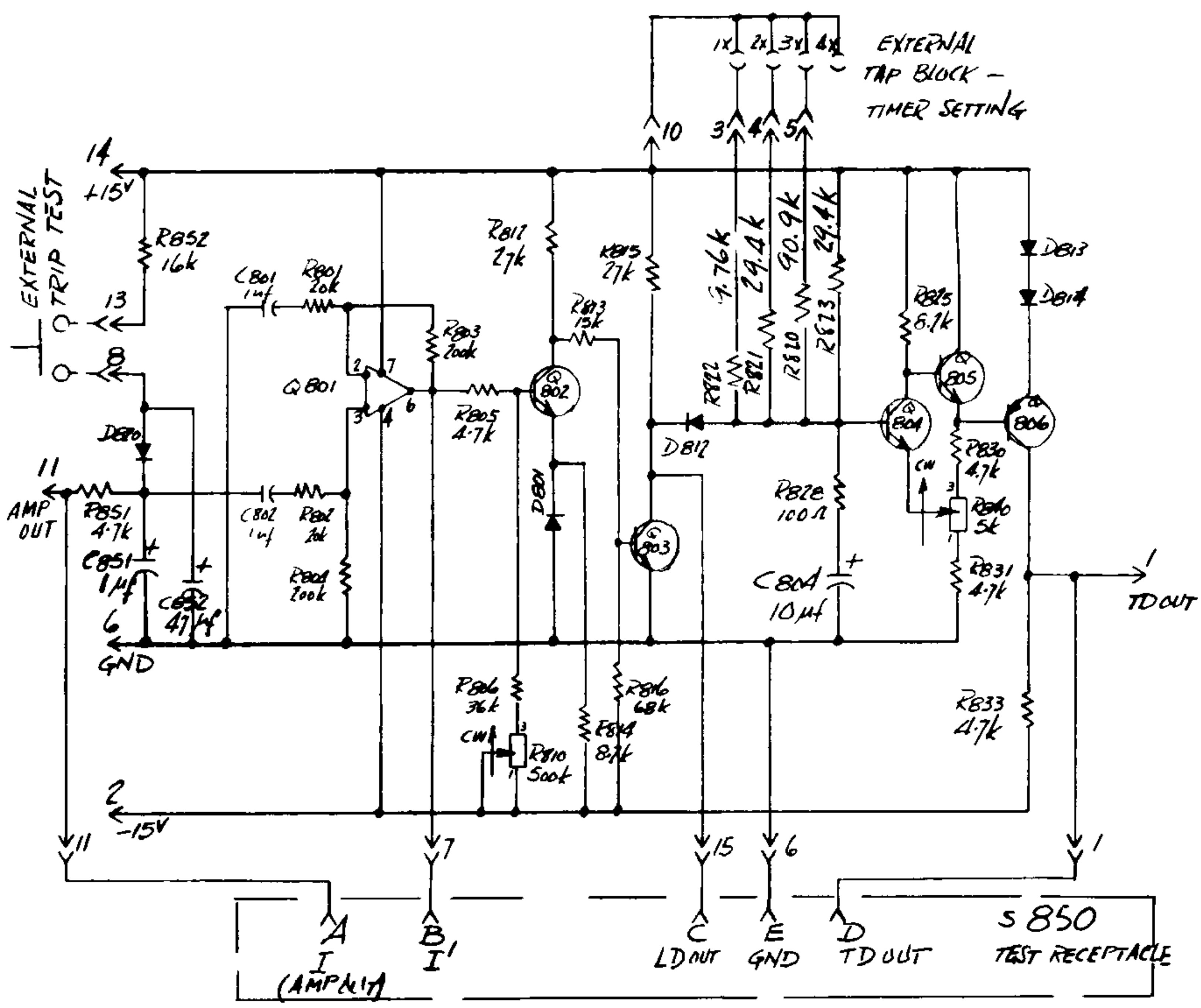



Fig. 9—PC800 Rate of Rise Runction
FBK-H (Optional)

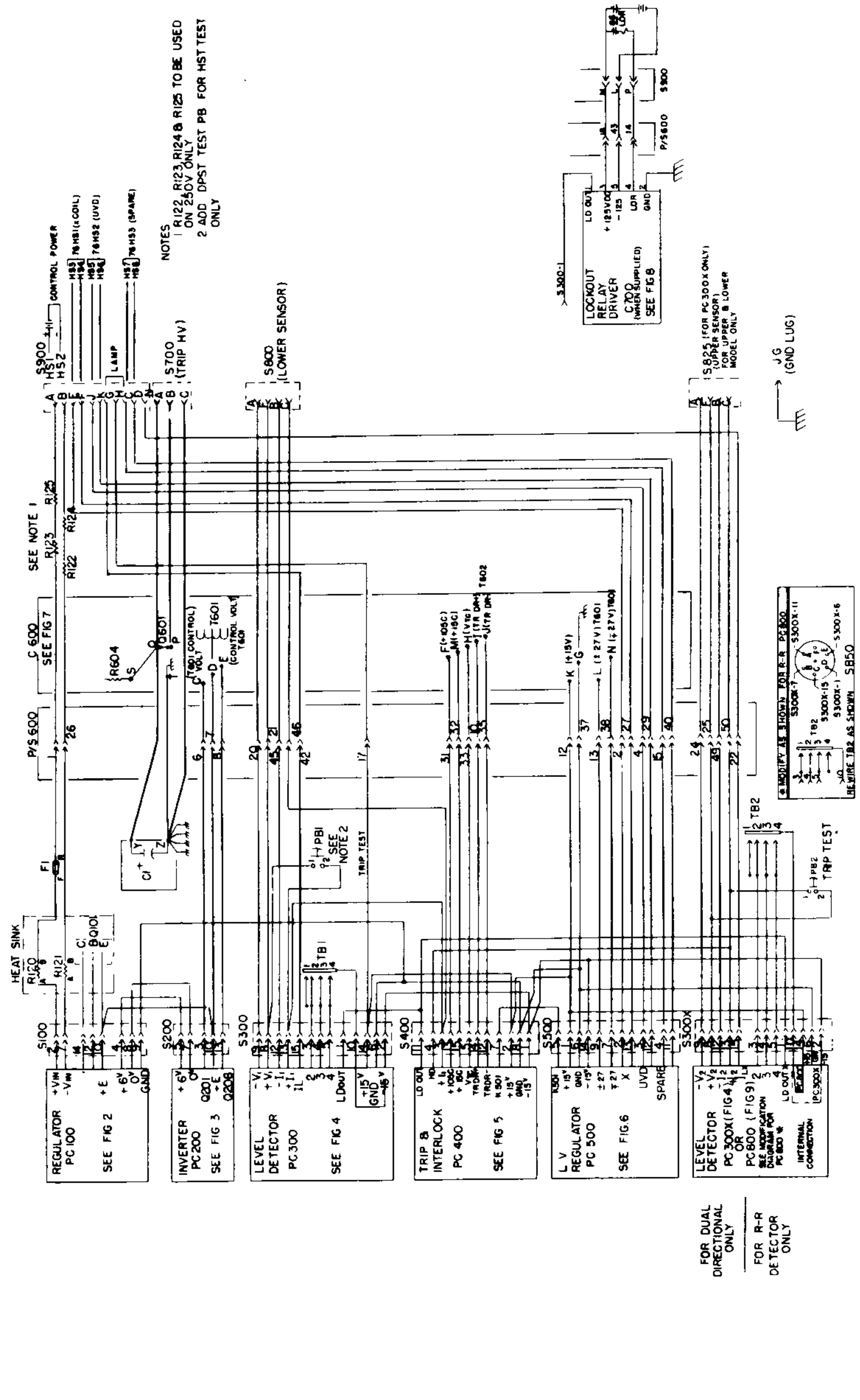



Fig. 10—FBK-H High Speed Trip Control Assembly Internal Wiring Diagram

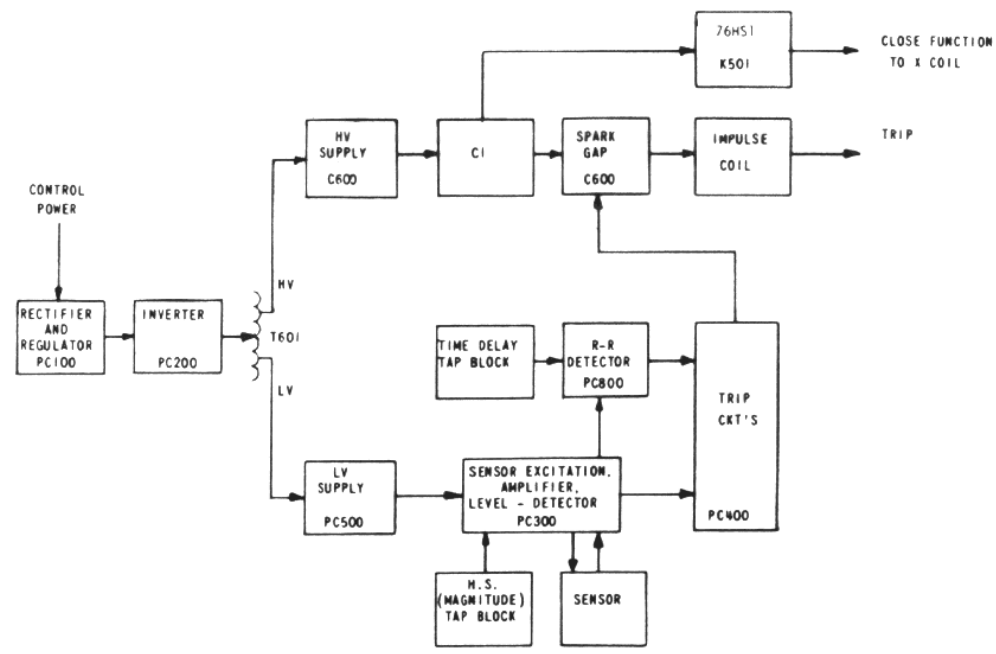



**Fig. 11—High Speed Trip Control Assembly**
**Type 76HS—RR Block Diagram**

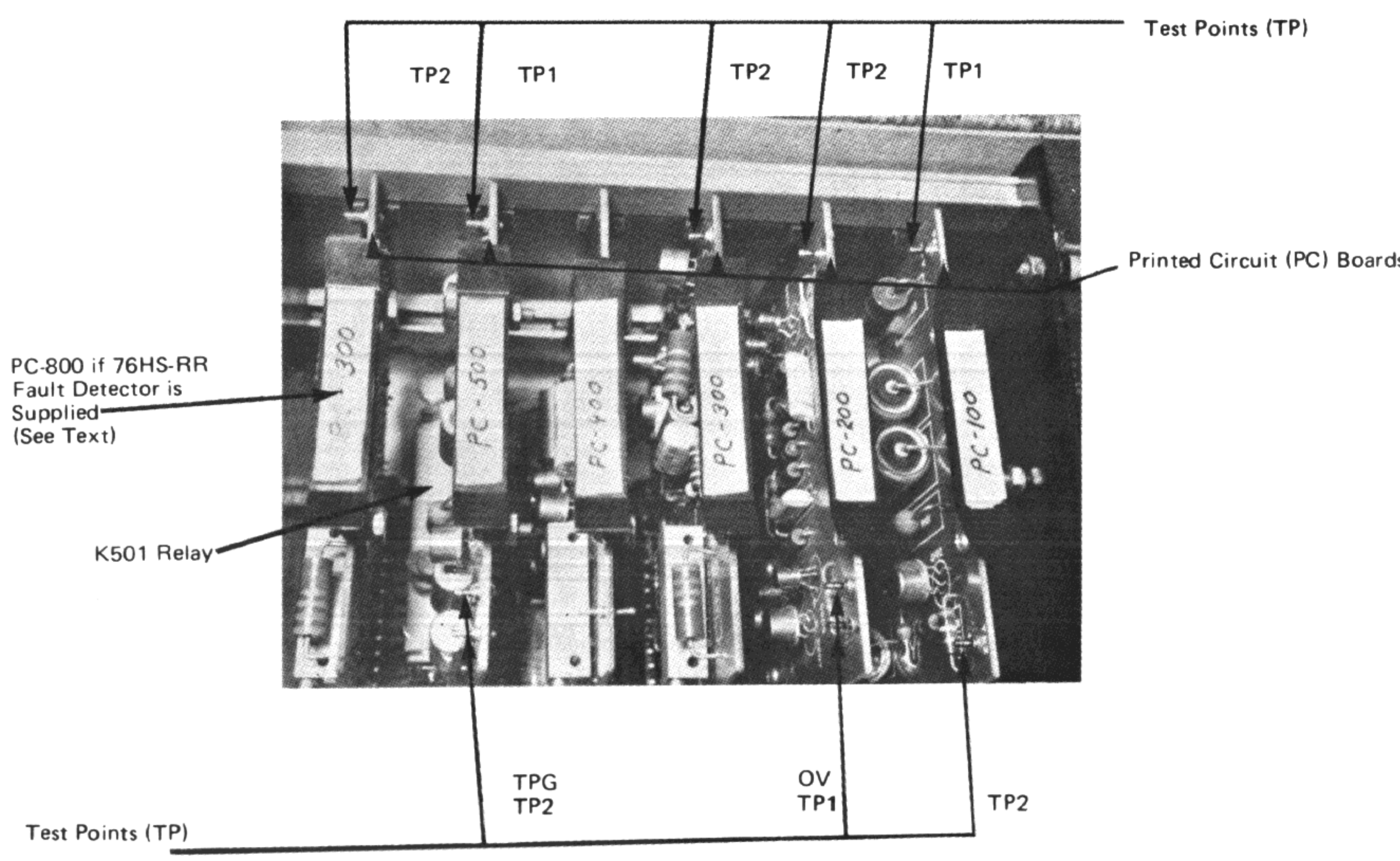
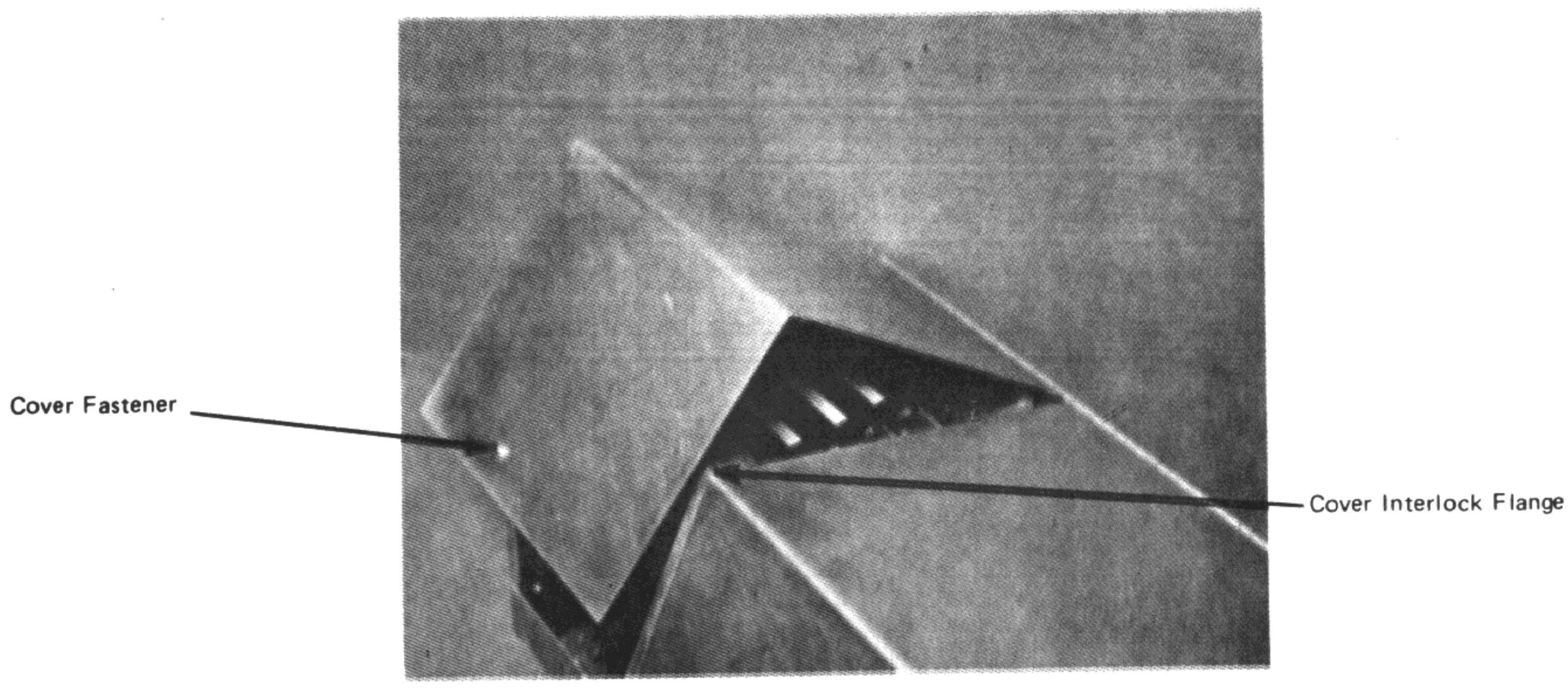



**Fig. 12—High Speed Trip Control Assembly**
**Printed Circuit Boards (top view)**



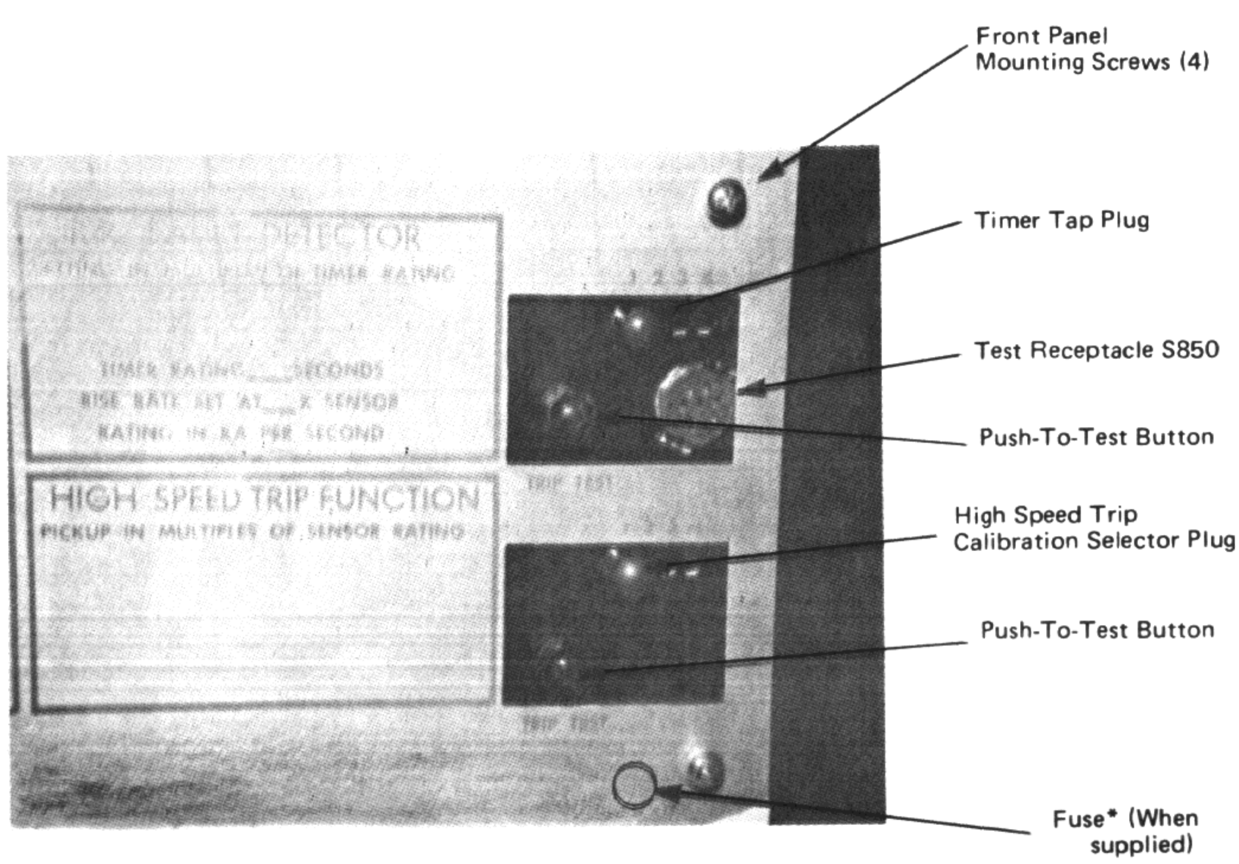




**Fig. 14—High Speed Trip Control Assembly Front View**

* Replace with slow blow types:

| 125 VDC | 250 VDC |
|---|---|
| ¾ A, 250 V, 3 AG | ½ A, 250 V, 3 AG |

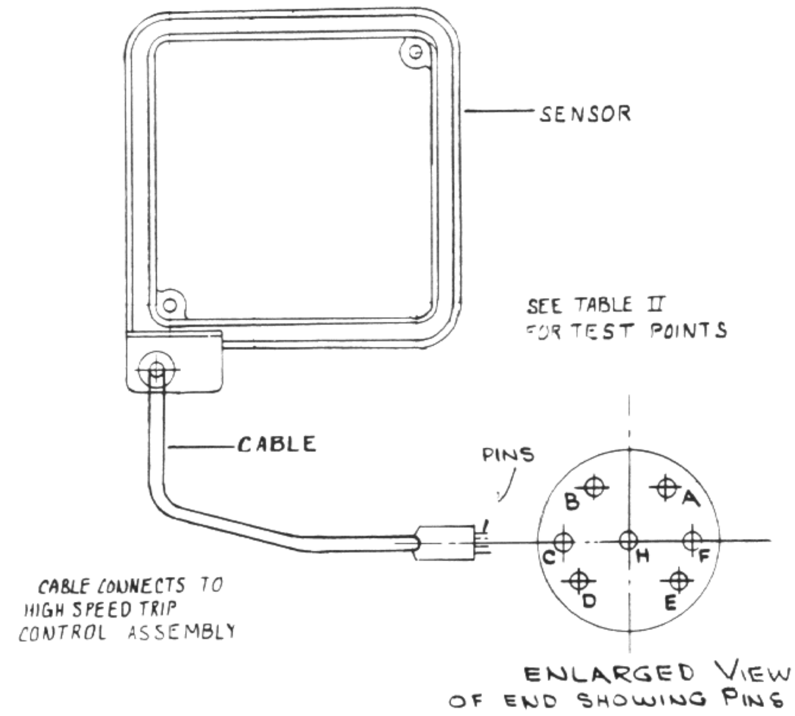



**Fig. 15—FBK-H Current Sensor and Breaker Connecting Cable**

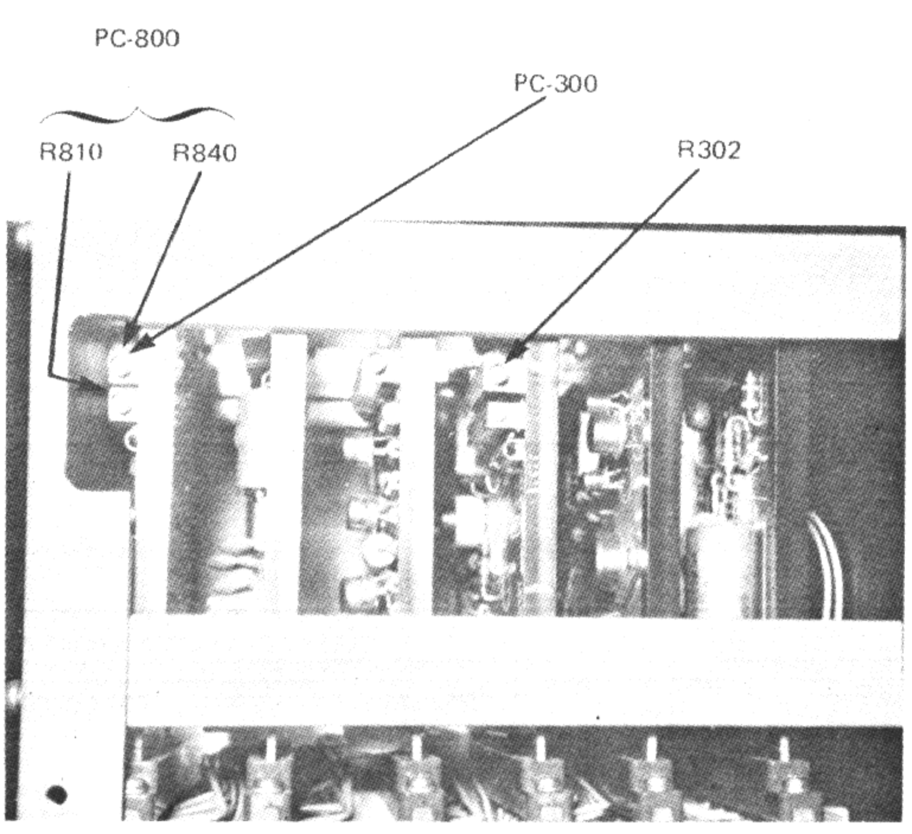



**Fig. 16—High Speed Trip Control Assembly Front View — Nameplate Removed Adjustable Resistor Locations**

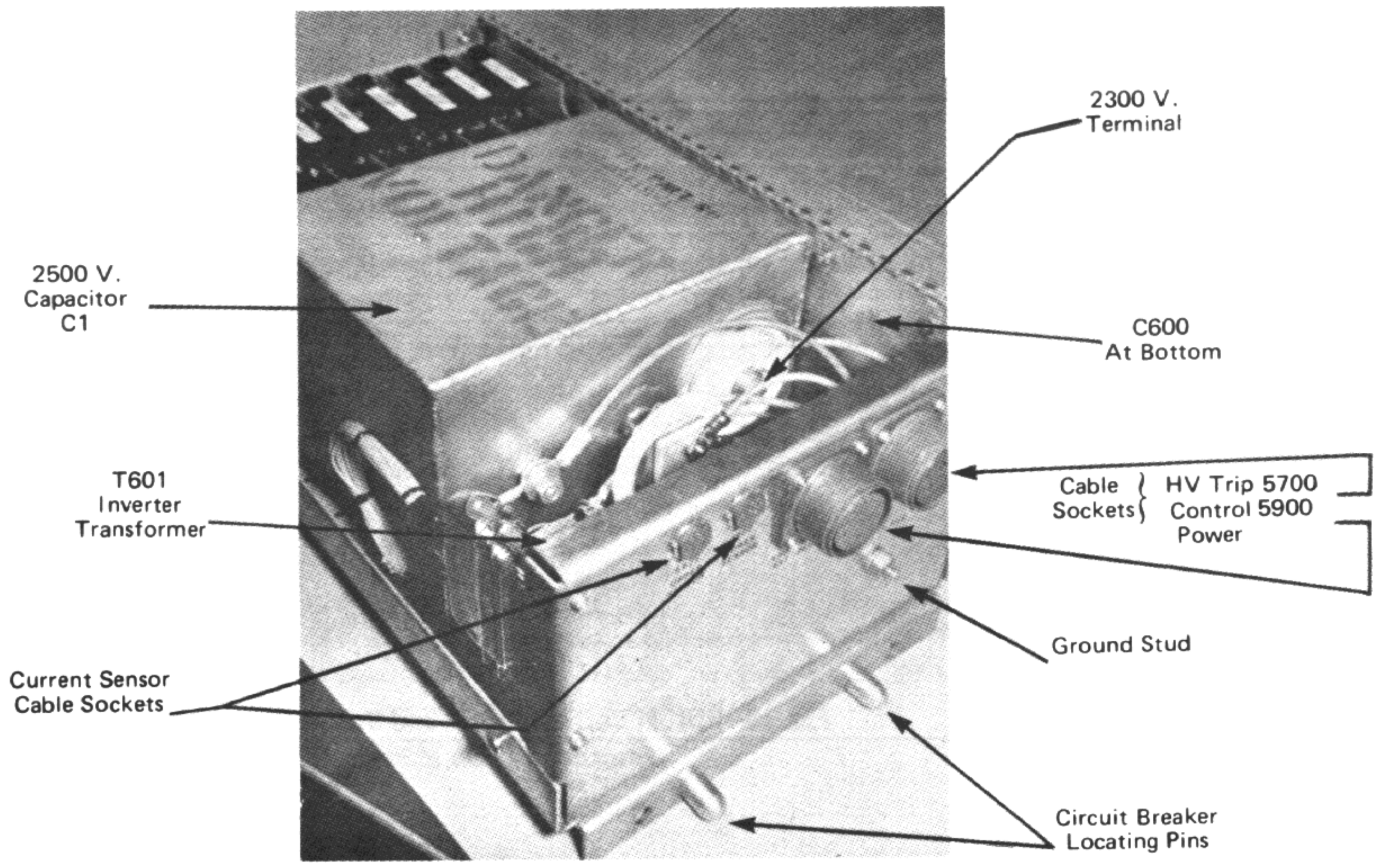


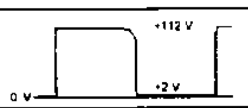
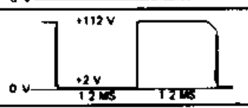
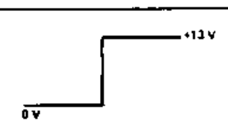
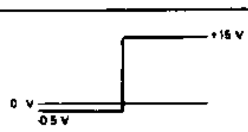

**Fig. 17—High-Speed Trip Control Assembly Top, Rear View, Covers Open**

## TABLE I
## HIGH SPEED TRIP CONTROL ASSEMBLY: TRIP CURRENTS

| Nominal Sensor Rating In Amperes | Tap-Positions (Multiples of Sensor Rating, Trip Levels) | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| 500 | 500 | 1000 | 1500 | 2000 |
| 1600 | 1600 | 3200 | 4800 | 6400 |
| 2500 | 2500 | 5000 | 7500 | 10000 |
| 4000 | 4000 | 8000 | 12000 | 16000 |
| 6000 | 6000 | 12000 | 18000 | 24000 |

## TABLE II

### HIGH-SPEED TRIP DEVICE TEST POINT VOLTAGES

| Test No. | Test Item | Location | Meter Reading | Wave Form | Scope Gnd. or $V_m$ Common at | Test Condition |
|---|---|---|---|---|---|---|
| 1 | +6V | PC 100, TP1 Fig. 2 & 12 | +6.2Vdc | | TP-Ov, PC 200 Fig. 3 & 12 | Control Power ON |
| 2 | +E | PC 100, TP2 Fig. 2 & 12 | +62Vdc | | TP-Ov, PC 200 Fig. 3 & 12 | Control Power ON |
| 3 | Q201 | PC 200, TP2 Fig. 3 & 12 | +56Vdc |  | TP-Ov, PC 200 Fig. 3 & 12 | Control Power ON |
| 4 | Q208 | PC 200, TP1 Fig. 3 & 12 | +56Vdc |  | TP-Ov, PC 200 Fig. 3 & 12 | Control Power ON |
| 5 | +15V | PC 500, TP1 Fig. 6 & 12 | +15.6Vdc | | TP-G, PC 500; Or Chassis Fig. 6 & 12 | Control Power ON |
| 6 | −15V | PC 500, TP1 Fig. 6 & 12 | −15.6Vdc | | TP-G, PC 500; Or Chassis Fig. 6 & 12 | Control Power ON |
| 7 | +2300V | HV Term, C1 | +2370Vdc | | TP-G, PC 500; Or Chassis Fig. 6 & 12 | Control Power ON CAUTION High Voltage |
| 8 | +15C | PC 400, TP1 Fig. 5 & 12 | +14.1Vdc | | TP-G, PC 500; Or Chassis Fig. 6 & 12 | Control Power ON |
| 9 | Amp Out | PC 300, TP1 Fig. 4 & 12 | +13Vdc 0Vdc |  | TP-G, PC 500; Or Chassis Fig. 6 & 12 | Control Power ON After Depress *Before P.B. |
| 10 | LD Out | PC 300, TP2 Fig. 4 & 12 | +15Vdc −0.5Vdc |  | TP-G, PC 500; Or Chassis Fig. 6 & 12 | Control Power ON After Depress *Before P.B. |
| 11 | Sensor Fig. 15 | A-B, B-C, C-F, F-A, B-F, A-C | Approx. 240 Ohms | | | Control Power OFF Ohmmeter Across Pairs Of Sensor Cable Connector Pins |

* If the RR fault detector is furnished, duplicate this test by depressing the trip test push button on the front of the RR fault detector. Do not depress both buttons at the same time. No change in scope test points are required.

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