SIEMENS-ALLIS

Switchgear

DESCRIPTION OF OPERATION

STATIC TRIP II & LimiTrip OVERCURRENT TRIP DEVICES USED WITH TYPE LA POWER CIRCUIT BREAKERS

18X4814-02
November, 1979

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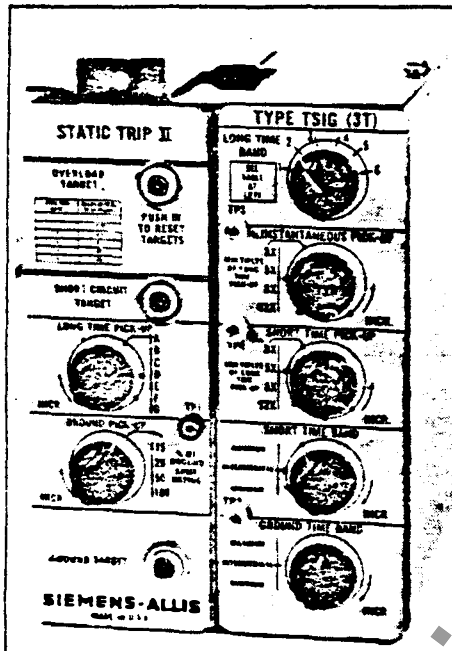
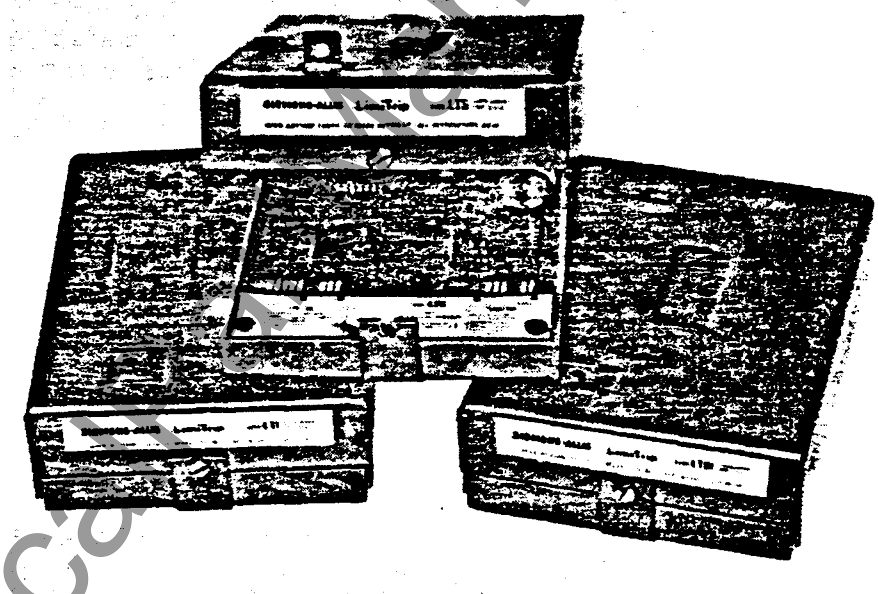


Static Trip II
Overcurrent Trip Device



LimiTrip Overcurrent
Trip Device

ILLUSTRATIONS

The information contained within is intended to assist operating personnel by providing information on the general characteristics of equipment of this type. It does not relieve the user of responsibility to use sound engineering practices in the installation, application, operation and maintenance of the particular equipment purchased.

If drawings or other supplementary instructions for specific applications are forwarded with this manual or separately, they take precedence over any conflicting or incomplete information in this manual.

General

Although not essential for the proper use and servicing of the equipment, this manual is intended to be a complete and detailed description of the circuits used in the Static Trip II and LimiTrip family of overcurrent trip devices supplied by Siemens-Allis. Refer to instruction book 18X4827 covering the Static Trip II devices and instruction book 18X10107 for the LimiTrip devices. This book is divided into two sections, describing each type of device separately.

Figure 1 is a block diagram of the basic static overcurrent trip device of the Static Trip II type (Figure 10 is a similar diagram for the LimiTrip devices). This diagram includes the Long Time delay, Short Time delay, Instantaneous and Ground Fault tripping functions. The type number of the device is significant in that it tells you in abbreviated form the circuits that are included in a particular device. A letter "L" indicates a LimiTrip type device. The first letter "T" indicates the standard long time circuits. The letter "S" stands for short time, which is a definite time delay circuit. The letter "I" is for instantaneous. "G" stands for ground, and is a definite time delay circuit that operates on ground current. The final letters "T", "2T" or "3T" indicate that the device includes targets. The targets are small electro-magnetic devices that operate at the same time as the breaker, and indicate which circuit caused tripping. They have no effect on the operation of the normal tripping circuits.

The devices are contained in metal enclosures which mount on the circuit breaker by means of a slide bracket and a single mounting screw. The Static Trip II devices can be removed from the breaker from the front while the breaker is in its cubicle (de-energized, of course). The LimiTrip devices are hardwired to their current sensors and the breaker must be out of the cubicle to remove the trip device.

Static Trip II Over Current Trip Devices

The side cover of the trip device is held by two screws and retains two circuit board assemblies in the enclosure. One of the circuit board assemblies contains transformers and other power components. This assembly is referred to as the POWER MODULE. The other circuit board assembly contains integrated circuits IC's, discrete components, and is called the LOGIC MODULE. Electrical connection is made between the modules by a "FLAT" jumper cable. They are held together mechanically by three screws. Each module has its own component designations, schematic diagrams and parts list. The modules are discussed separately.

Power Module (Figure 2 & 9)

This module contains the LONG TIME PICKUP control and, on the ground devices, the GROUND PICKUP control. All targets mount on the power module (if included). The schematic diagrams for the module are 18-398-286-401 and 402. These are the same except the ground components are omitted on mark 401.

The three phase input circuits are identical. They are made up of power transformers T1, T2, and T3 which are designed to saturate and limit the power supply output. (Saturation of these transformers does cause some difficulty when testing the trip device. They tend to chop up the current waveshape so that standard meters do not indicate properly. This requires that the testing be done with a sine-wave current source or with peak responding ammeters.) Each transformer supplies power to a bridge rectifier BR-1 thru BR-3. The rectifier outputs are connected in parallel to supply power to a filter and regulator. An RC filter comprised of the first section of R1 (10 ohms) and capacitor C1 (440 microfarad) filter the pulses of current into a fairly smooth DC. The voltage is regulated to approximately 24 volts by the Zener diode ZD-1, transistor Q-1 and the additional two sections of R-1.

THIS due to diode bridges going in and off of conduction

This approach to regulating the supply voltage is used to provide higher sink current capability and better stability for the power supply voltage. The Zener diode operates at nearly constant current which is relatively low so that self heating is minimized. Under high current the transistor turns more fully on, limiting its normal dissipation. The energy is dissipated in the 4 ohm section of R-1. As an example, at six amperes a 24 volt Zener would have an internal dissipation of 144 watts, while the transistor is turned on to around one volt and about six watts internal dissipation.

Resistor R2 provides for a slightly higher current through the Zener diode before conduction starts in Q1. This assures that the Zener is operating in its Zener mode before regulation begins. Transistor Q-1 is a Darlington device to provide high gain, so a small Zener diode can be used.

Transformers T-4, T-5 and T-6 are subassemblies consisting of a precision-wound toroidal transformer and a bridge rectifier. These assemblies convert the phase signal current into a rectified DC current. The outputs of these assemblies are connected in series, to resistor R-8 (40 ohm, 5 Watt, wire wound 1%), where the current produces a voltage drop that is used as the input signal. The toroidal transformers have a ratio of 40/1 so that with the 40 ohm resistor produce one volt of signal for each ampere of current. Since the bridge rectifiers are ahead of the sensing resistors the forward drop of the diode doesn't affect the signal magnitude. DUE TO LOW SATURATION REQUIREMENTS FOR TOROIDAL XFORMERS.

The signal voltage across R-8 is applied to the series combination of R-5, RH-1 and R-3. R-5 and R-3 set the adjustment limits for the device LONG TIME PICKUP control. In addition R-5 and Zener ZD-2 limit the maximum signal voltage to 24 volts to protect the logic circuitry.

The Ground power transformer is T-7. This is similar to transformers T-1, T-2 and T-3, except the primary is wound to provide power at a lower input current. The output of this transformer is rectified by a bridge rectifier BR-5, which is connected in parallel with the phase power rectifiers.

The Ground signal transformer is the same assembly as for the phase signals. Its output is loaded with a higher value resistor R-9 (120 ohms, 5 Watt). This provides a signal to operate the circuit at the lower values of current needed for ground fault tripping.

Resistors R-4, R-6 and potentiometer RH-2 provide the adjustment for the Ground pickup signal. R-4 and Zener ZD-3 limit the ground signal to protect the logic module circuitry. Capacitor C-2 provides a bypass to case ground for electrical noise that may be picked up in the trip device circuits.

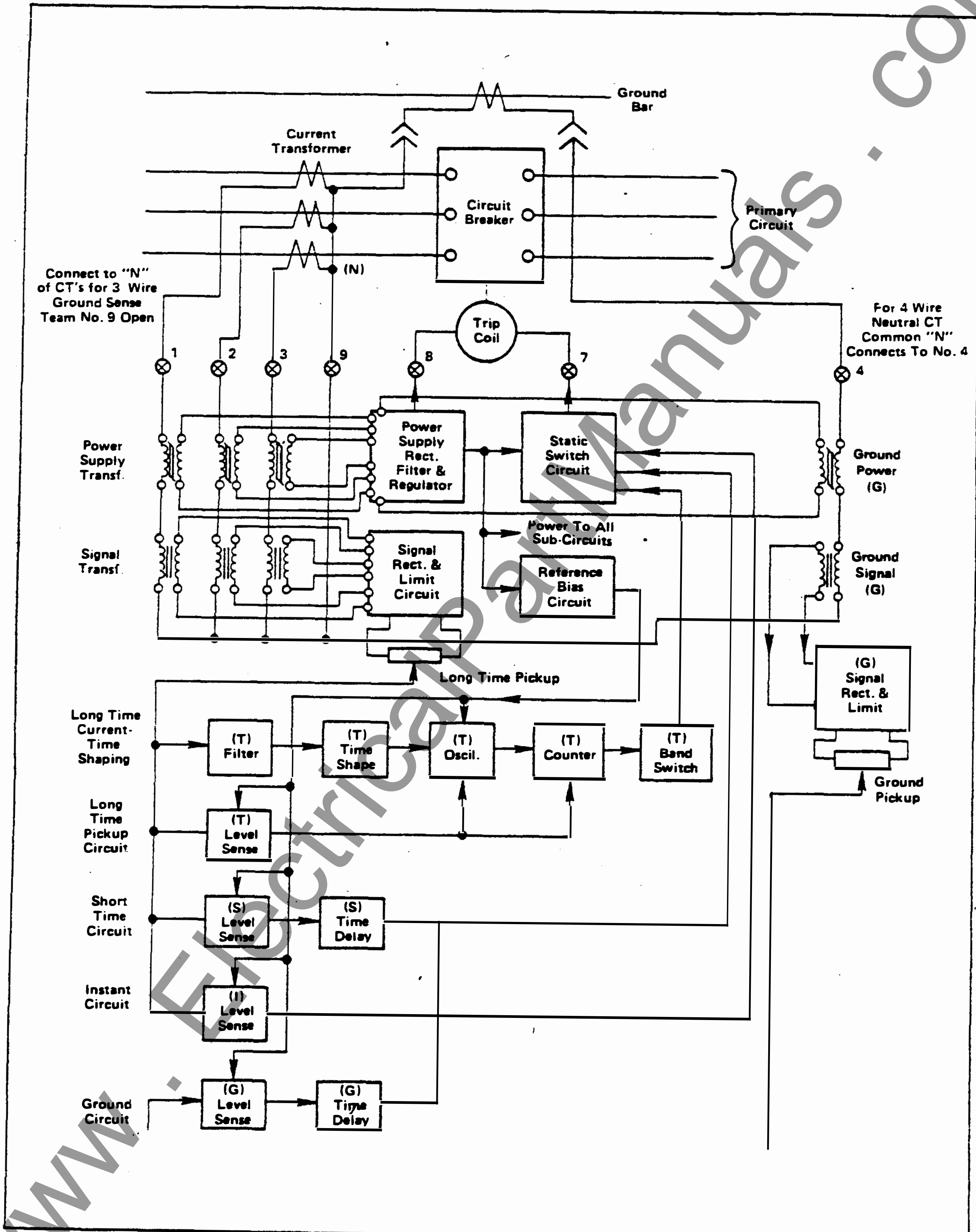


Figure 1. Basic Static Trip II

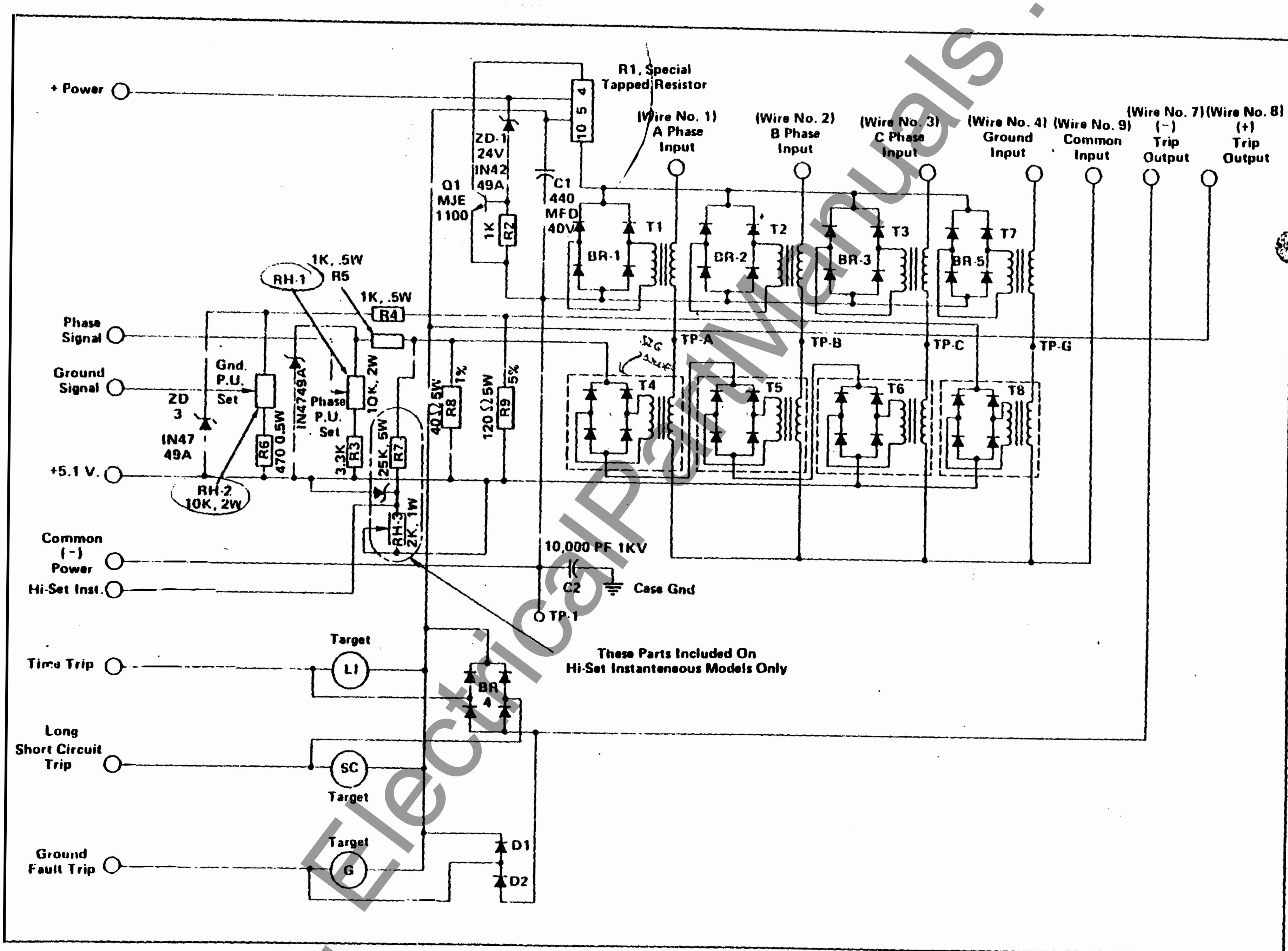


Figure 2. Power Module Static Trip II

The logic module has three output transistors. The collectors of these three devices are brought to the power module separately. Bridge rectifier BR-4 and diodes D-1 and D-2 provide steering for the output of the transistors to the appropriate target and to the common tripping actuator terminals.

Test point TP-1 (black) is the negative of the internal power supply and is used for testing the trip devices.

Logic Module (Figure 4 & 8)

This module contains the level sensing and timing circuits with their associated controls, and test points. The schematic diagrams are 18-398-286 403 through 408, the latter being the schematic of the most complicated device. The simpler devices are made up by omitting circuit elements. For example, a simple TI device omits the short time and ground circuits.

The controls on the front panel are: LONG TIME BAND, this is a small switch that selects the long time curve that the device will follow. INSTANTANEOUS PICKUP, this controls the level sensor of the instant circuit. SHORT TIME PICK-UP, this sets the current level that will start the short time delay. SHORT TIME BAND, this control determines the time from short time pickup until breaker tripping. GROUND TIME BAND, this control determines the time from ground pickup until the breaker trips.

Four test points are brought out to pin jacks. TP-3 provides an output voltage to indicate that the long time delay circuits are unclamped and allowed to operate. The voltage from TP-1 to this point will be 1 or 2 volts when current to the device is below the long time pickup setting. The voltage will increase to 20 to 24 volts when the current exceeds the pickup setting. This signals that the oscillator and counter circuits are released and can time out.

The point TP-4 provides a similar function for the short time circuits, and TP-2 does the same for ground. Test point TP-1 is the negative of the internal power supply.

The logic circuitry makes use of two types of integrated circuits. IC-1 is a CMOS binary counter, containing 12 flip-flop circuits connected in series so that each stage drives the next providing a divide by two action for each stage. The circuit provides a positive going output voltage after a set number of input pulses have been provided. The number of pulses is determined by the stage selected by the LONG TIME BAND switch. In this application only the last six stages are used. The counter includes a common reset terminal that is held "high" when the current is less than pickup. Above pickup this reset voltage is removed and the counter is allowed to operate.

The other integrated circuit used is a Quad-operational amplifier. Each package contains four operational amplifiers. The amplifiers are internally compensated, PNP input. The PNP input allows the common mode input voltage to include the negative supply line. In addition the differential voltage is rated at ± 32 volts. The outputs of the amplifiers are protected against shorts to the negative supply by internal current limiting circuits. The sink current at the output must be limited externally, however. These amplifiers are used for level sensing (signal detection and time delay), filter circuit, oscillator and buffer amplifiers.

Level Sensing Circuits (Figure 3)

Four Quad op-amps are used for signal level sensing. These

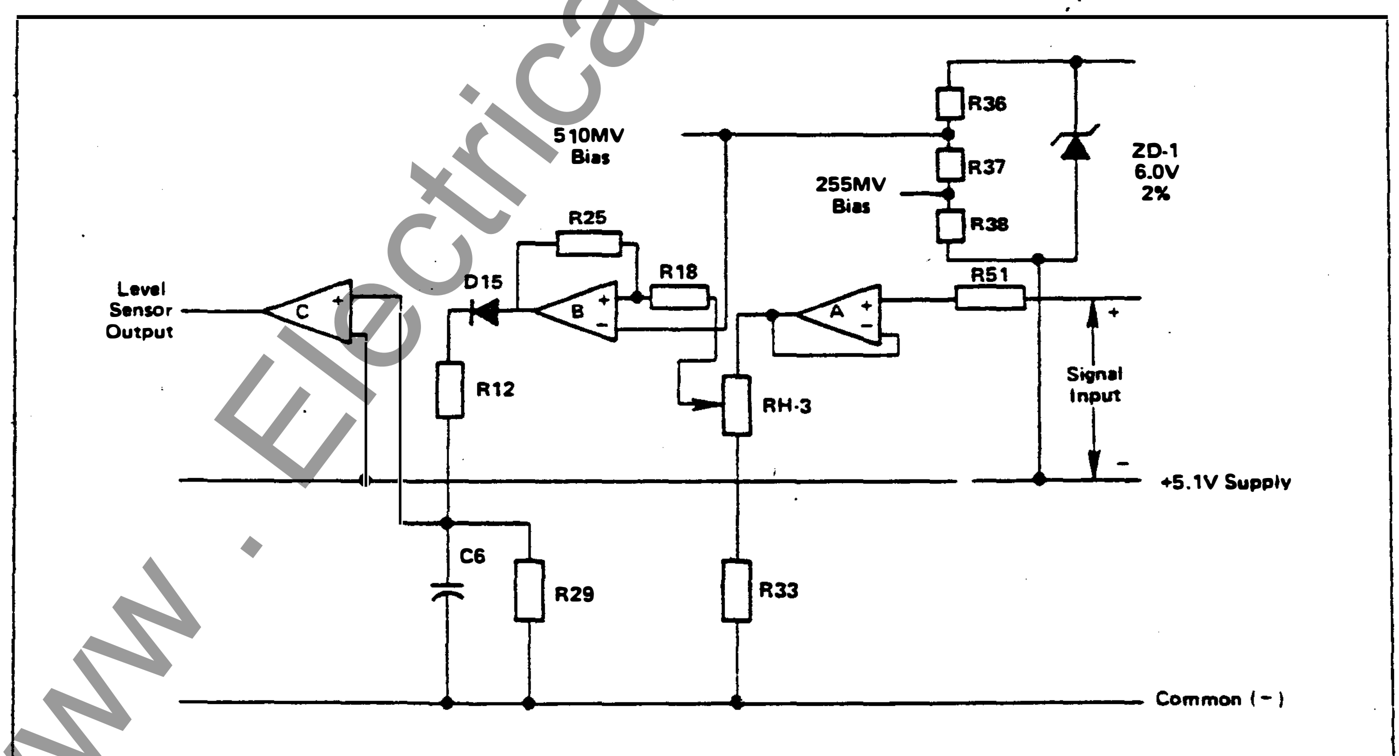


Figure 3. Level Sensing Circuits

are IC-4, IC-5, IC-6 and IC-7. These are for Long Time, Short Time, Instantaneous and Ground pickup elements. The basic pickup circuit is identical in each case with the exception of the positive feedback resistor. A typical circuit is shown in Figure 3. The Quad op-amps are redrawn in this figure to show the separate amplifiers. The two input pins of each amplifier are labeled plus and minus. If the minus input is more positive than the positive input, the output is driven negative and the amplifier can "sink" current. If the positive input is more positive than the negative input, the output will be driven in the positive direction and the output will "source" current. The amount of differential voltage required is very small. The amplifiers used have a typical voltage gain of 200000.

As shown in Figure 3 the amplifier labeled "A" is used as a unity gain buffer to isolate the particular circuit from the common input line. Resistor R-5 (10K) is provided to prevent a defective amplifier from shorting this common signal line.

The output of the "A" amplifier connects to the pickup potentiometer RH-3. RH-3 is connected through R-33 to the negative supply voltage. Note that the incoming signal is referenced to the 5.1 volt bias line. By connecting the potentiometer and resistor to negative rather than to the 5.1 volt level, the calibration dots for the potentiometer are more evenly distributed around the dial. Operation would be the same with the other connection. The output of the "A" amplifier is an exact duplicate of its input voltage since it is operating at unity gain.

In this example amplifier "B" is the actual level sensor circuit. Its negative input is connected to the 510 millivolt bias line created by Zener diode ZD-1 and voltage divider R-36, R-37 and R-38. When the voltage on the slider of RH-3 exceeds this 510 millivolts the "B" amplifier output is driven positive. Resistors R-18 and R-25 provide positive feedback, so the level sensor has some controlled amount of hysteresis. Diode D-15, resistor R-12 and capacitor C-6 provide storage for the pickup signal voltage. The diode prevents the capacitor from discharging through the "B" amplifier output. The resistor and the capacitor provide for some noise immunity. The voltage on capacitor C-6 is used as the input to the "C" amplifier. When this voltage exceeds the 5.1 volt level the "C" amplifier is driven positive. This is the output of the level sensor circuit.

Resistor R-29 in conjunction with the value of C-6 provides a discharge path for the capacitor and controls the resettable delay time of the trip device.

In the case of the long time and ground pickup circuits the "A" amplifier is not used as a buffer for the level sensor circuits.

The fourth amplifier "D" is used as the time delay switch in the case of short time and ground, and as a buffer for the long time and instantaneous circuits.

Oscillator Circuit (Figure 5)

In this circuit the "A" amplifier is used as an inverting integrator circuit. Until the long time level sensing circuit releases the oscillator the minus input pin is held negative, through diode D-6 and R-3, so the output of the "A" amplifier is held at its maximum positive voltage. When the long time circuit picks up, it releases the negative input pin and allows the integrator to come under control of its input current. The current into the negative input pin junction tends to drive the amplifier output in a negative direction. This causes a current flow into capacitor C-2. The higher the current flow into the junction the faster the output changes and the higher the charging current is for C-2. If the amplifier was ideal, with no bias current and very high gain, all of the current into the junction point would be used as charging current for the capacitor, and it would be a perfect integration of the input current. In practice the amplifiers only approach the ideal case and the results are slightly in error.

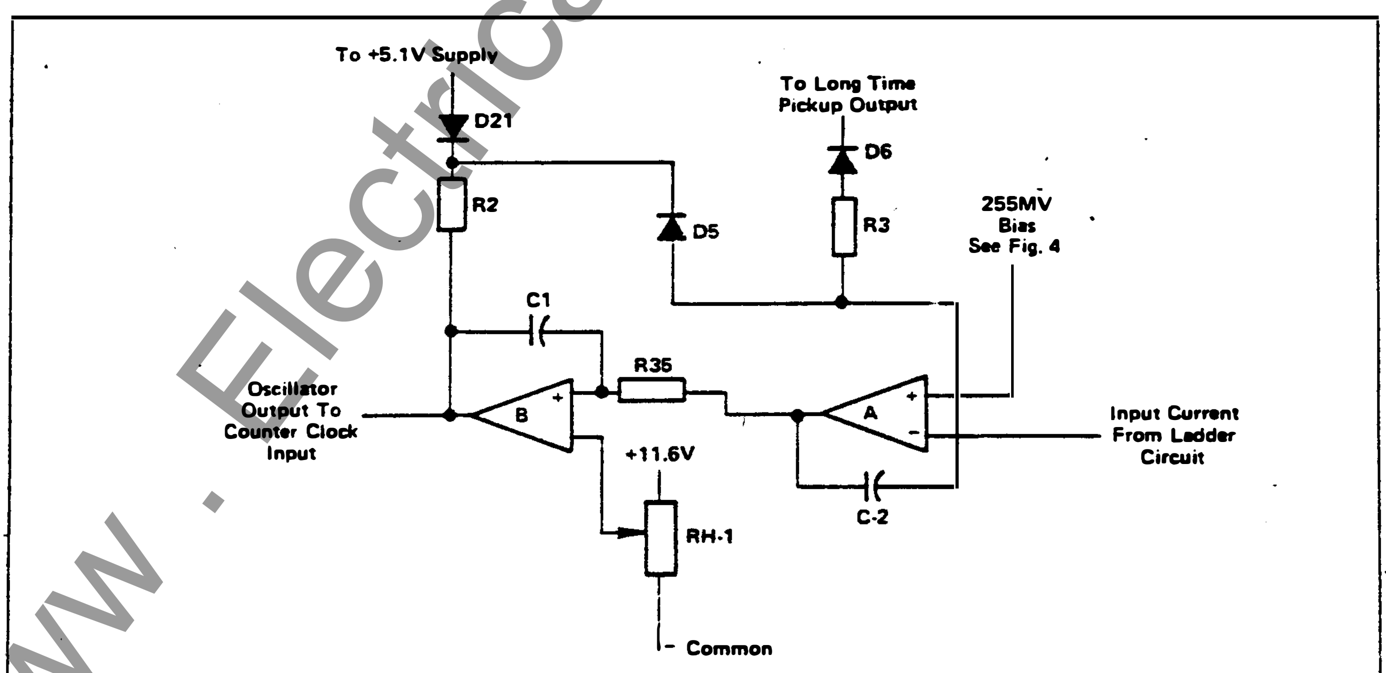


Figure 5. Oscillator Circuit

Note that the voltage at the summing junction remains within a few millivolts of the positive input terminals, as determined by the 255 millivolt bias. The change in the output of the amplifier coupled through C-2 holds the negative input terminal at this same voltage.

The output of the "A" amplifier slowly decreases from its maximum positive level. This voltage is connected to the positive input terminal of the "B" amplifier through resistor R-35. The negative input voltage at the "B" amplifier is set by the slider position of RH-1, so long as the "A" output voltage is above the voltage on the slider of RH-1 the output of the "B" amplifier is held at its maximum output voltage. When the output voltage of the "A" amplifier decreases to the slider voltage, the "B" amplifier output is driven down. Capacitor C-1 provides positive feedback for the "B" amplifier causing its output to switch to the negative supply rail. The time interval that it is held negative is determined by the time constant of R-35 and C-1. The rugged PNP input stage of the amplifiers used allows this operation without harm to the device. The output of the "B" amplifier is connected to the negative input of the "A" amplifier through resistor R-2 and diode D-5, this resets the integrator circuit for the next cycle. Diode D-21 limits the amount of overdrive for the "A" amplifier input. At the end of the reset pulse amplifier "B" switches its output back to its maximum positive voltage and the "A" amplifier again integrates the input current for the next cycle of the oscillator. The output of the "B" amplifier is also used as the clock input for the counter stage.

The oscillator circuit is operated from the 11.1 volt supply bus so the output voltage is compatable with the counter IC. This also keeps all of the oscillator switching transients well below the 32 volt limit of the amplifier input transistors. The frequency of the oscillator circuit is a linear function of the input current supplied to the negative input terminal of the "A" amplifier. The frequency is determined by the amount of current supplied the value of the integration capacitor and the voltage level set by potentiometer RH-1.

Ladder Circuit (Figures 6 and 7)

This circuit provides the input current for the oscillator. The ladder circuit output current approximates the relationship $I = KV^{2.3}$. Since the oscillator output frequency is a linear function of this current the total time delay is $T = K/V_S^{2.3}$ where V_S is the signal voltage and is proportional to the AC input current of the trip device.

It should be remembered that the input voltage level of the oscillator is determined by the voltage on its "A" amplifier positive input terminal and was not a function of the charge on the integrator capacitor or of the input current being supplied. This voltage is set by a voltage divider to be 255 millivolts above the 5.1 volt supply. The signal voltage is referenced to the 5.1 volt line as well.

With the signal voltage less than 255 millivolts there is no current flow from the ladder circuit. As the signal voltage increases above 255 millivolts current flows through R-45. The signal is also applied to a voltage divider comprised of R-39, R-40, R-41, R-42, R-43 and R-44. As the signal voltage is increased the junction between the resistors will each exceed 255 millivolts at some signal level. Each of the junction points connect to the positive input terminal of an op-amp and diode arranged as a rectifier. The cathode of each diode is returned to the negative input of its op-amp. The amplifier holds the voltage at the diode cathode at the junction voltage, so when the junction voltage exceeds 255 millivolts current flows through the appropriate series resistor.

The voltage divider sets the threshold for each line segment, and the series resistor controls the current, or slope of the line segment (see Figure 8). By careful choice of the threshold and series resistor the desired curve is generated by the addition of the straight line segments. The amount of deviation and the particular curve desired determines the number of branch circuits required. Six segments are used for the Static Trip II device.

The op-amp type ladder circuit overcomes the forward drop of the diodes and eliminates errors due to their variation due to temperature changes. In this particular circuit the diode leakage current is somewhat overcome by the bias current of the op-amp. With the op-amps used the bias current flows out of the amplifier input terminals. Resistor R-58 provides a path for the bias current to flow to the negative supply. This resistor is optional and may be omitted depending on the particular op-amps characteristics.

Signal Filter Circuit

One of the amplifiers contained in the long time pickup package (IC-4) is used as the rectifier-filter for the input to the ladder circuit. This circuit detects and holds the peak of the incoming signal, and this DC voltage is applied to the ladder circuit. Diode D-4 and capacitor C-10 provide the rectification and storage. The input of the op-amp is isolated from the incoming signal by resistor R-56. The op-amp includes the diode in its feedback loop, to eliminate the effects of its forward drop.

Internal Bias Supply

The power supplied to the logic module is regulated and filtered DC at approximately 24 volts. This power is supplied to the logic module through a diode D-1 and a small filter capacitor C-9. This capacitor and diode supports the power supply for the logic module during tripping when the 24 volt source is loaded by the tripping actuator. The internal bias supply consists of resistor R-1, diode D-2 and two Zener diodes ZD-1 and ZD-2 in series. ZD-1 is 6.0 volts 2%. A voltage divider R-36, R-37 and R-38 provides 510 millivolts bias for the pickup circuits, and 255 millivolts for the oscillator bias. Diode D-2 isolates the 11.6 volt power bus from the bias network. The 11.6 volt power is used to operate the CMOS counter and oscillator IC, and is filtered by capacitor C-3.

During startup R-1 and C-3 provide a delay for the 11.6 volt power. A constant current diode CLD-1 provides 4 milliamperes to the Zener diodes so the bias voltages are supplied before the IC power is available. Resistor R-57 insures that the 6 volt supply is the first to be established.

Counter Circuit

A twelve stage CMOS counter IC-1 provides a means of greatly reducing the size of the timing components in the long time delay circuit. By switching to different stages in the counter the multiple time bands are provided without

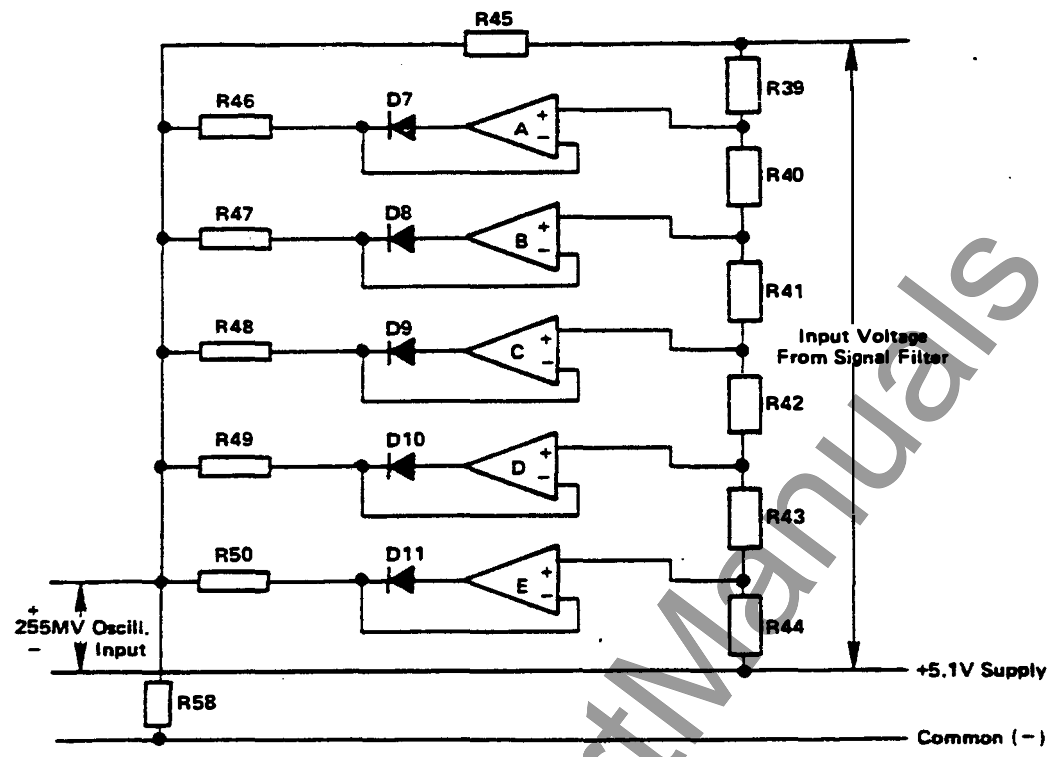


Figure 6. Ladder Circuit

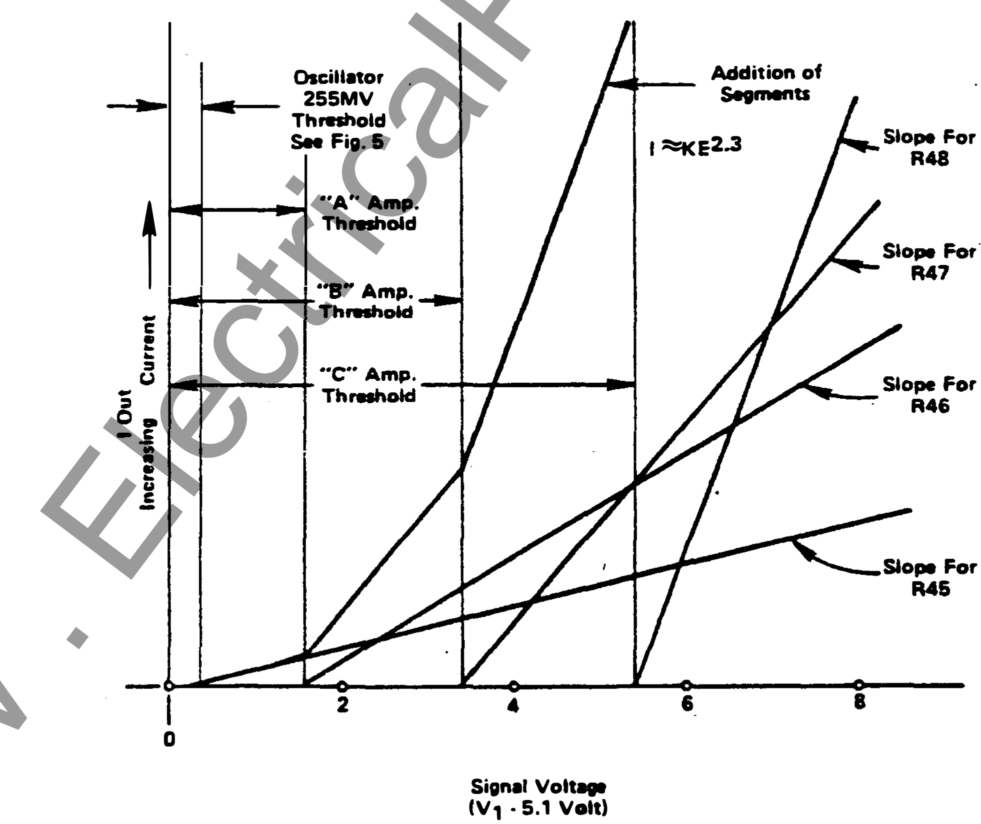


Figure 7. Ladder Circuit

changing the timing components. The output of the counter does not have enough current to drive the output transistors directly so one section of IC-2 is used as an amplifier.

The differential input of this amplifier is used to interlock the long time circuit and the short time circuit. If the short time circuit is picked up, its output voltage is coupled through diode D-16. This increases the voltage on the negative input of the op-amp so the counter does not have enough voltage to produce an output. This prevents the long time circuit from tripping when the device is in the definite delay mode of the short time circuit.

Diodes D-14 and D-13 provide a similar function for the ground trip circuit, this is intended to prevent false ground signals produced by current transformer saturation during short circuit conditions.

Definite Delay Circuits

Short time and ground trip circuits are of the definite delay type. When the level sensor circuits operate, the output voltage is applied to a series RC circuit. In the case of the short time circuit this is potentiometer RH-5, resistor R-16 and capacitor C-11. The level of voltage is detected by one section of IC-5, the 5.1 volt supply is used as a reference. When the capacitor voltage reaches 5.1 volts the op-amp output is driven positive and in turn drives the base of the appropriate output transistor, in this case Q-2 through R-5. Diode D-19 prevents the capacitor C-11 from being charged to more than the 11.6 volt bus plus the forward drop of D-19. The ground circuit is the same as short time except for the interlocking provisions mentioned earlier. The voltage applied through D-13 and or D-14 referenced to the pickup bias line (5.1 plus 510 millivolts) connects to the negative input of an op-amp in IC-7. Capacitor C-8 and R-32 provide storage for this signal. When this voltage is "high" the output of the op-amp is driven low sinking the current from C-12 through D-18, thus preventing the ground circuit from timing out.

Output Stages

The output devices are Darlington transistors, Q-1, Q-2, and Q-3. The Darlington configuration minimizes the base drive requirements. Transistor Q-1 is driven from the long time delay circuit. Q-2 by either the short time or the instantaneous circuit. Q-3 is driven from the ground fault circuit. The power module contains steering diodes for the three transistors to operate the appropriate target as well as the common tripping actuator on the circuit breaker.

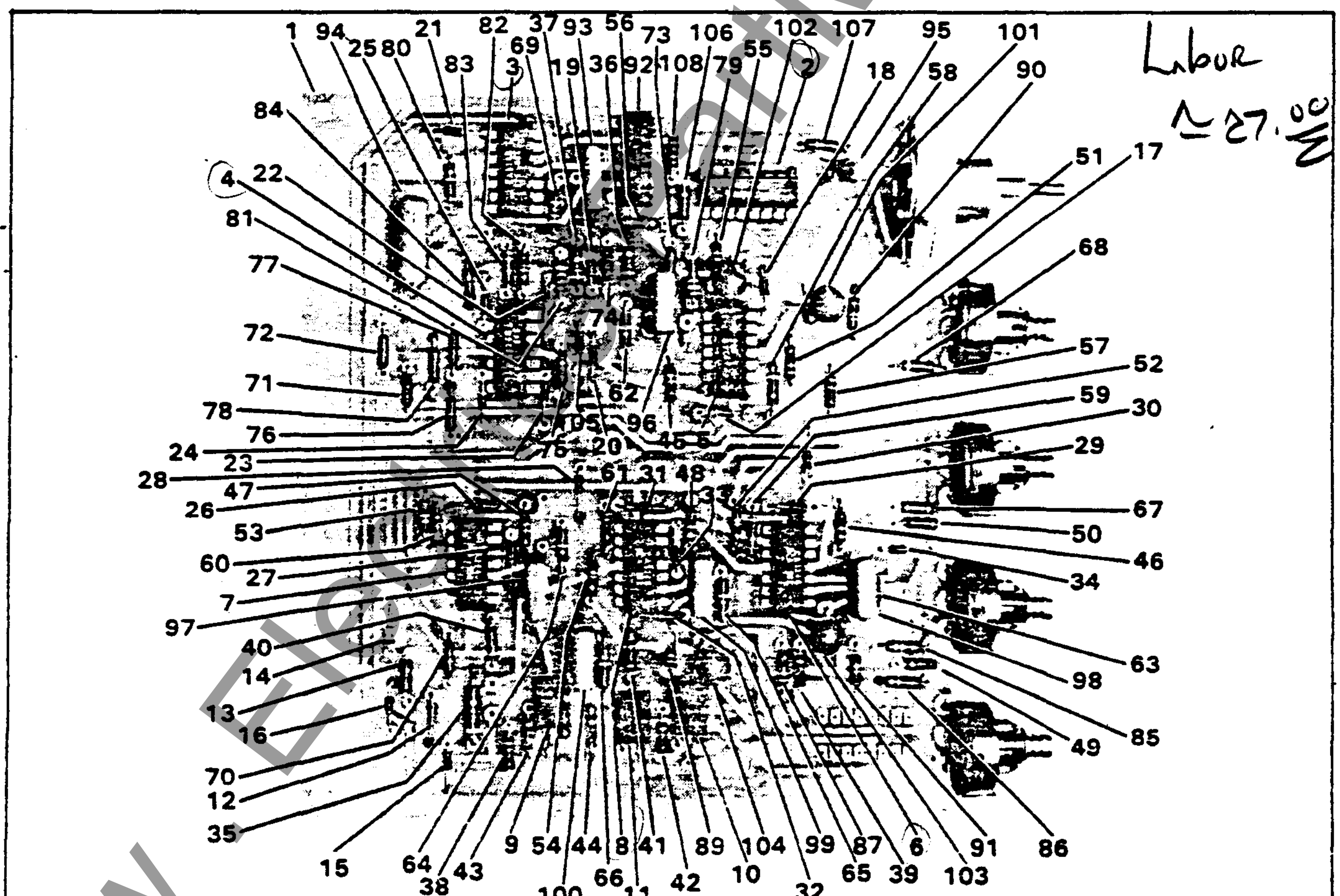


Figure 8. Static Trip II Logic Board

Item	Symbol		Description	Part Number
1	—	4.00	✓Circuit Board	18-387-923-004
2	IC-1	.90	Counter, 4040 (MC14040BCP)	15-171-282-009
3	IC-2	.70	Op-Amp (LM324N)	15-171-282-008
4	IC-3	.70	Op-Amp LM324N	15-171-282-008

(continued on next page)

Item	Symbol	Description	Part Number
5	IC-4	Op-Amp	15-171-282-008
6	IC-5	Op-Amp	15-171-282-008
7	IC-6	Op-Amp	15-171-282-008
8	IC-7	Op-Amp	15-171-282-008
9	Q1	Transistor	15-875-075-010
10	Q2	Transistor	15-875-075-010
11	Q3	Transistor	15-875-075-010
12	CLD-1	Current Limit Diode	15-875-155-011
13	ZD-1	Zener Diode, 6.0V	15-875-155-015
14	ZD-2	Zener Diode, 5.1V	15-171-281-009
15	D-1	Diode	15-875-155-017
16	D-2	Diode	15-875-155-017
17	D-3	Diode	15-875-155-017
18	D-4	Diode	15-875-155-017
19	D-5	Diode	15-875-155-017
20	D-6	Diode	15-875-155-017
21	D-7	Diode	15-875-155-017
22	D-8	Diode	15-875-155-017
23	D-9	Diode	15-875-155-017
24	D-10	Diode	15-875-155-017
25	D-11	Diode	15-875-155-017
26	D-12	Diode	15-875-155-017
27	D-13	Diode	15-875-155-017
28	D-14	Diode	15-875-155-017
29	D-15	Diode	15-875-155-017
30	D-16	Diode	15-875-155-017
31	D-17	Diode	15-875-155-017
32	D-18	Diode	15-875-155-017
33	D-19	Diode	15-875-155-017
34	D-20	Diode	15-875-155-017
35	R-1	Resistor, 470 ohm, 1/2W	00-875-397-058
36	R-2	Resistor, 470 ohm, 1/4W	15-171-279-040
37	R-3	Resistor, 470 ohm, 1/4W	15-171-279-040
38	R-4	Resistor, 1K, 1/4W	15-171-279-044
39	R-5	Resistor, 1K, 1/4W	15-171-279-044
40	R-6	Resistor, 1K, 1/4W	15-171-279-044
41	R-7	Resistor, 1K, 1/4W	15-171-279-044
42	R-8	Resistor, 1K, 1/4W	15-171-279-044
43	R-9	Resistor, 1K, 1/4W	15-171-279-044
44	R-10	Resistor, 1K, 1/4W	15-171-279-044
45	R-11	Resistor, 10K, 1/4W	15-171-279-056
46	R-12	Resistor, 10K, 1/4W	15-171-279-056
47	R-13	Resistor, 10K, 1/4W	15-171-279-056
48	R-14	Resistor, 10K, 1/4W	15-171-279-056
49	R-15	Resistor, 1K, 1/4W	15-171-279-044
50	R-16	Resistor, 1K, 1/4W	15-171-279-044
51	R-17	Resistor, 10K, 1/4W	15-171-279-056
52	R-18	Resistor, 10K, 1/4W	15-171-279-056
53	R-19	Resistor, 10K, 1/4W	15-171-279-056
54	R-20	Resistor, 10K, 1/4W	15-171-279-056
55	R-21	Resistor, 10K, 1/4W	15-171-279-056
56	R-22	Resistor, 10K, 1/4W	15-171-279-056
57	R-23	Resistor, 10K, 1/4W	15-171-279-056
58	R-24	Resistor, 4.7 Meg, 1/4W	15-171-279-088
59	R-25	Resistor, 4.7 Meg, 1/4W	15-171-279-088
60	R-26	Resistor, 1 Meg, 1/4W	15-171-279-080
61	R-27	Resistor, 1 Meg, 1/4W	15-171-279-080
62	R-28	Resistor, 180K, 1/4W	15-171-279-071
63	R-29	Resistor, 180K, 1/4W	15-171-279-071
64	R-30	Resistor, 180K, 1/4W	15-171-279-071
65	R-31	Resistor, 180K, 1/4W	15-171-279-071
66	R-32	Resistor, 180K, 1/4W	15-171-279-071
67	R-33	Resistor, 7500 ohm, 1/4W	15-171-280-094

(continued on next page)

Item	Symbol	Description	Part Number
68	R-34	Resistor, 7500 ohm, 1/4W	15-171-280-094
69	R-35	Resistor, 4.7K, 1/4W	15-171-280-089
70	R-36	Resistor, 21.5K, 1%	15-873-139-017
71	R-37	Resistor, 1.0K, 1%	15-873-139-015
72	R-38	Resistor, 1.0K, 1%	15-873-139-015
73	R-39	Resistor, 10.0K, 1%	15-873-139-024
74	R-40	Resistor, 2150 ohm, 1%	15-873-139-025
75	R-41	Resistor, 1470 ohm, 1%	15-873-139-026
76	R-42	Resistor, 1K, 1%	15-873-139-015
77	R-43	Resistor, 681 ohm, 1%	15-873-139-027
78	R-44	Resistor, 953 ohm, 1%	15-873-139-028
79	R-45	Resistor, 390K, 5%	15-171-280-135
80	R-46	Resistor, 120K, 5%	15-171-280-123
81	R-47	Resistor, 47K, 5%	15-171-280-113
82	R-48	Resistor, 27K, 5%	15-171-280-107
83	R-49	Resistor, 3.3K, 5%	15-171-280-085
84	R-50	Resistor, 1K, 5%	15-171-280-073
85	R-51	Resistor, 10K, 1/4W	15-171-279-056
86	R-52	Resistor, 10K, 1/4W	15-171-279-056
87	R-53	Resistor, 1 Meg, 1/4W	15-171-279-080
88	R-54	Resistor, 1 Meg, 1/4W	15-171-279-080
89	R-55	Resistor, 1 Meg, 1/4W	15-171-279-080
90	R-56	Resistor, 10K, 1/4W	15-171-279-056
91	R-57	Resistor, 10K, 1/4W	15-171-279-056
92	RH-1	P.C. Pot, 10K	15-171-315-010
93	C1	Capacitor, .056 μfd	00-875-347-008
94	C2	Capacitor, .22 μfd	15-171-838-005
95	C3	Capacitor, 4.7 μfd, 25V	15-171-029-018
96	C4	Capacitor, 0.1 μfd	15-171-838-003
97	C5	Capacitor, 0.1 μfd	15-171-838-003
98	C6	Capacitor, 0.1 μfd	15-171-838-003
99	C7	Capacitor, 0.1 μfd	15-171-838-003
100	C8	Capacitor, 0.1 μfd	15-171-838-003
101	C9	Capacitor, 33 μfd, 25 Vdc	15-875-347-011
102	C10	Capacitor, 33 μfd, 25 Vdc	15-875-347-011
103	C11	Capacitor, 68 μfd, 15V	15-171-029-012
104	C12	Capacitor, 68 μfd, 15V	15-171-029-012
105	D21	Diode	15-875-155-017
106	R58	Resistor, 22 Meg	15-171-280-177

Switch
1.50 Panel Pot, CERMET
1.50 Panel Pot.,
1.50 Panel Pot.,
1.50 Panel Pot.,

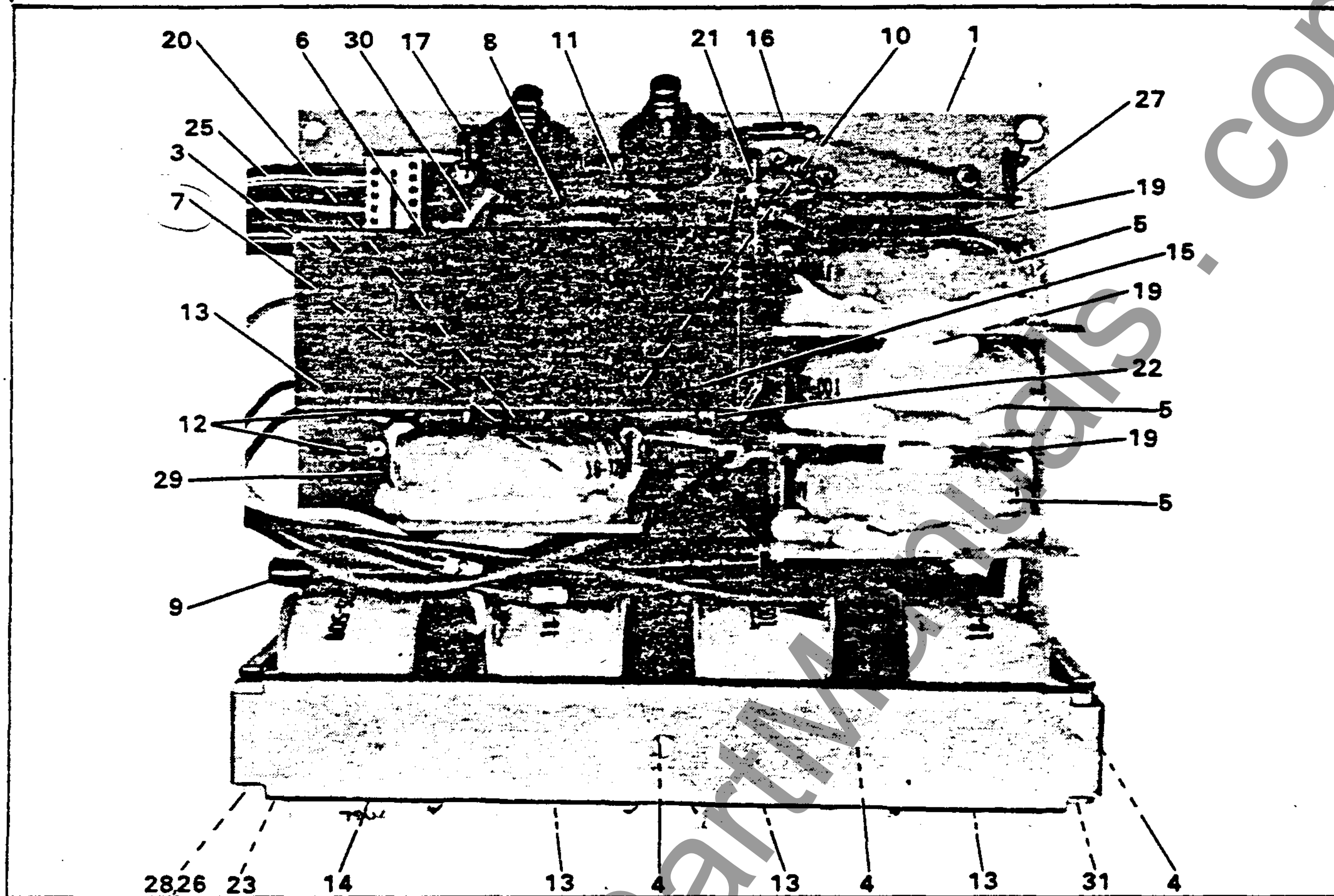


Figure 9. Static Trip II Power Module

Item	Symbol		Description	Part Number
1		$4.00	Circuit Board	18-387-923-005
2				
3			Tape (.0035 x .5 wide, yellow scotch #57)	00-475-511-047
4	T1, T2, T3	18.00	Transformer	18-721-004-501
5	T4, T5, T6	18.00	Transformer Assembly	18-721-484-502
6	Q1	2.00	Heatsink Assembly (MJE1100)	18-721-482-501
7	ZD-1	.07	Zener Diode, 24V, 1N4749A	15-875-155-016
8	C1	1.00	Capacitor, 440 µfd, ELECT	15-171-278-007
9	R1	1.50	Resistor (3-65-7) ohm (WW)	18-657-463-019
10	R2	.01	Resistor, 1K, 1/4W	15-171-279-044
11	R3	.01	Resistor, 3.3K, 1/4W	15-171-279-050
12	D1, D2	.05	Diode, 1N459A	15-875-155-017
13	LR-1-BRA	.75	Bridge, VM88 (800V)	15-171-857-007
14	BA-5	.75	Bridge, VM88 (800V)	15-171-857-007
15	R4	.02	Resistor, 1K, 1/2W	00-875-397-007
16	R5	.02	Resistor, 1K, 1/2W	00-875-397-007
17	R6	.01	Resistor, 470, 1/4W	15-171-279-040
18	R7	.50	Resistor, 25K, 5W, 11a, WW	15-873-139-012
19	R8	.50	Resistor, 40 ohm, 5W, 11a, WW	15-873-139-010
20	R9	.50	Resistor, 120 ohm, 5W, 5a, WW	15-171-046-010
21	Z0, Z3, D4	.25	Zener, 1N4749A	15-875-155-016
22	ZD3	.08	Zener, 1N4749A	15-875-155-016
23		.50	Transf. Bracket	18-724-507-001
24	RH-3	1.50	PC Pot, 2K	15-873-139-012
25		.02	#6-32 Screw	15-171-074-010
26		.25	Spacer	18-657-825-056
27	C2	.10	Capacitor, CERAMIC	15-171-029-021
28	T7	6.00	Transformer	18-721-005-501
		1.50	Panel Pot,	
		1.50	Panel Pot,	

Item	Symbol		Description	Part Number
29	T8	$6.00	✓Transformer Assembly	18-721-484-502
30			Wire #22 (6 inch)	15-171-783-010
31			Insulator	18-657-939-201
32		1.50	Cord Set	18-721-488-502
33	ZD4	.08	✓Zener, 1N4749A	15-875-155-016
34			Pwr Board Pix	18-398-285-401
35			Schematic Diag.	18-398-286-401
36			Schematic Dia.	18-398-286-402
37		.20	✓Flat Cable	

LimiTrip Overcurrent Trip Device

The trip device enclosure is made with a hinged bottom portion that is held shut by one screw. By loosening the screw the bottom can be opened for access to the circuit board and the control switches. One circuit board assembly is used in the LimiTrip device. The operation of the circuits are quite similar to those used in the Static Trip II device, with some notable exceptions. The LimiTrip device does not contain any transformers. The function of the transformers has been designed into special current sensors. The sensor transformers contain two cores each wound with the appropriate winding. One core is wound to supply power to operate the device and is made with few turns and a small cross section core to limit the power under short circuit current conditions. The other core is wound with the turns needed to establish the correct current ratio for the sensor. In keeping with past practice the 100% rating of the trip device signal current is one ampere. The signal winding is designed to work with 0.707 ohm resistive load, and saturation is designed for essentially linear operation to 12 amperes. Above about 12 amperes the transformer saturates to limit the power dissipation in the sensing resistors of the trip device.

Power Supply Circuit (Figure 11 & 12)

The power winding of the sensor provides short pulses of current at each zero crossing of the load current wave. These pulses of current charge capacitor C-1 (440 microfarad) through the rectifier bridges BR-1 through BR-3. Resistors R-1 through R-3 provide loading for the sensor power winding to control the saturation of the sensor core. The power to operate IC-1, IC-2 and IC-4 is supplied from C-1 through resistor R-20 and regulated by ZD-1 to 24 volts.

11.6 volts is supplied to IC-3, IC-5, IC-6 and when used IC-7. Resistor R-19 is a series dropping resistor for this supply. The supply is filtered by C-3. The voltage is regulated by connecting through D-24 to the series connection of ZD-2 and ZD-3. These two Zeners supply the bias voltages for the level sensor circuits and oscillator. A constant current diode CLD-1 supplies current to the series Zener so that the bias levels are established at a lower level of input current to the device than is required for circuit operation.

A voltage divider is made up of R-16 and R-17. The junction between the two connects to the positive input of one of the op-amps in IC-3. The negative input of this op-amp is referenced to the 5.1 volt level of ZD-2. When the voltage of the divider exceeds 5.1 volts the op-amp output is driven positive. Resistor R-27 and capacitor C-11 provide positive feedback to cause the op-amp to switch rapidly from one state to the other. The output of the op-amp drives the base of transistor Q-1 through resistor R-29. Q-1 is connected through R-70 to the positive power bus. The circuit forms a switching regulator for the positive bus voltage set to approximately 30 volts.

The pickup level reference voltage is provided by the 6.0 volt Zener diode ZD-3 and voltage divider resistor R-18, R-14 and R-15. The voltage across R-15 is used as the bias voltage for the long time oscillator circuit while the voltage across both R-14 and R-15 is used as the reference for the long time pickup circuit. These voltages are 255 and 510 millivolts. Since the Zener diode is ± 2% tolerance and the resistors are all ± 1 percent these voltages are reasonably accurate. This provides long time pickup at essentially 510 milliamperes of current. The 6.0 volt Zener also directly provides the reference voltage to the instantaneous and short circuits at 12X pickup level. Resistor networks RN-2 and RN-3 in conjunction with switches SW-3 and SW-4 form voltage dividers for the lower trip settings.

Signal Input Circuit

The signal windings of the sensors supply current proportional to the current flowing in the circuit breaker. For one phase the sensor secondary current flows through resistors R-4, R-5. The other two phases use R-6, R-7 and R-8, R-9. These are special 1.41 ohm resistors 1% tolerance. The voltage across the resistors is applied to an op-amp rectifier through series resistors R-10, R-11 or R-12. Diodes D-8 through D-13 limit the signal voltage applied to the op-amp input.

Three amplifiers in IC-1 are used as rectifiers, in conjunction with diodes D-14, D-15 and D-16. The diodes are included in the feedback of the op-amps so their forward drop is overcome. The voltage at the cathodes of the diodes is a nearly exact duplicate of the positive portion of the incoming signal. The circuit is basically a halfwave rectifier for each phase. The phasing of the sensor transformers provides the equivalent of full wave for all but ground current or four wire neutral systems. IC-1 operates at the full 24 volt supply so that the rectifier signal at its output can exceed the level required for 12X signals. The input signal uses the 5.1 volt supply as the common, so 12 times the 1.125 setting requires a minimum output voltage of 18.6 volts. The output of the rectifier is applied to a voltage divider RN-1 and R-13. Switch SW-1 selects taps on this divider for higher pickup current settings for the device. The voltage tapped

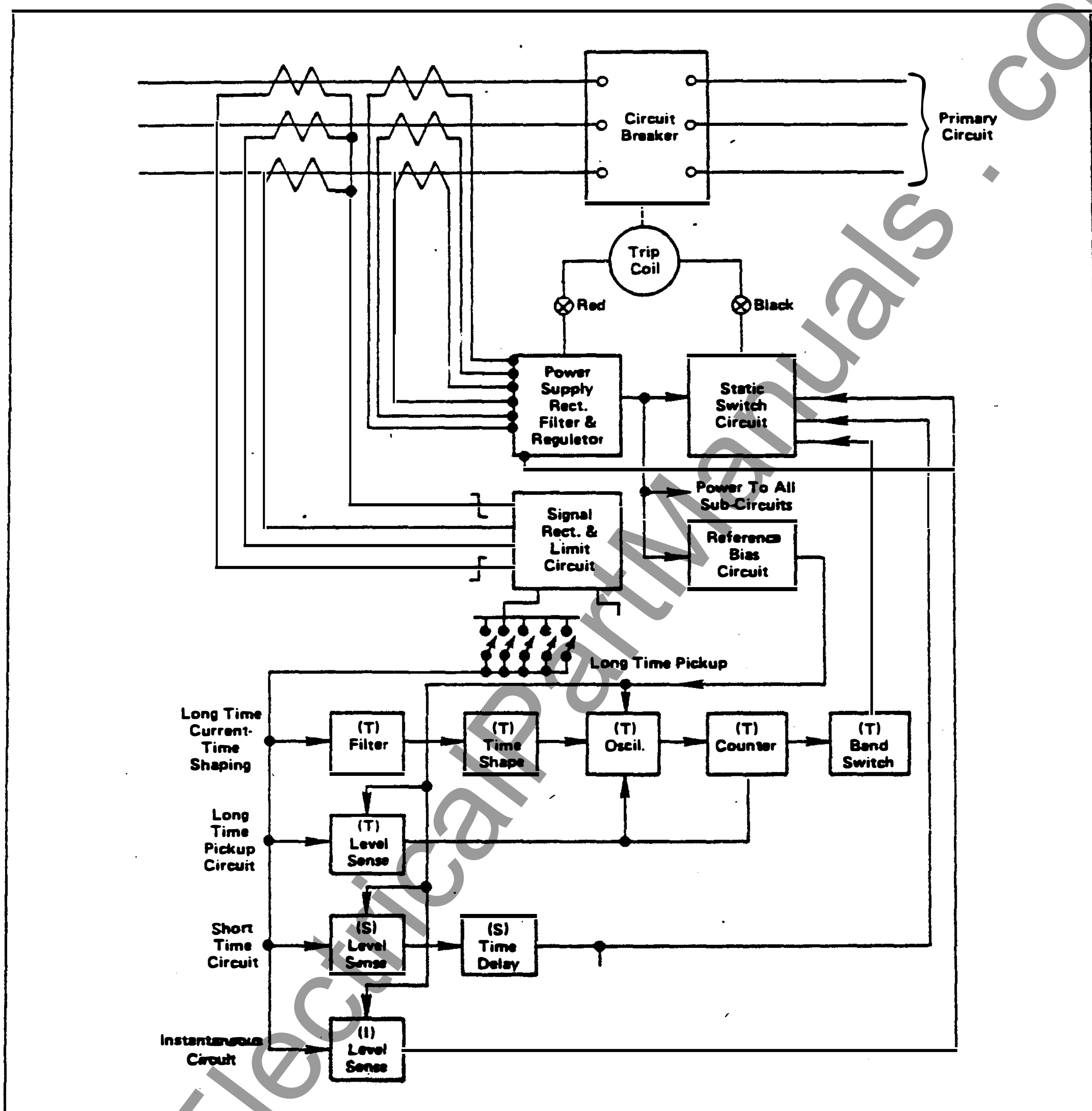
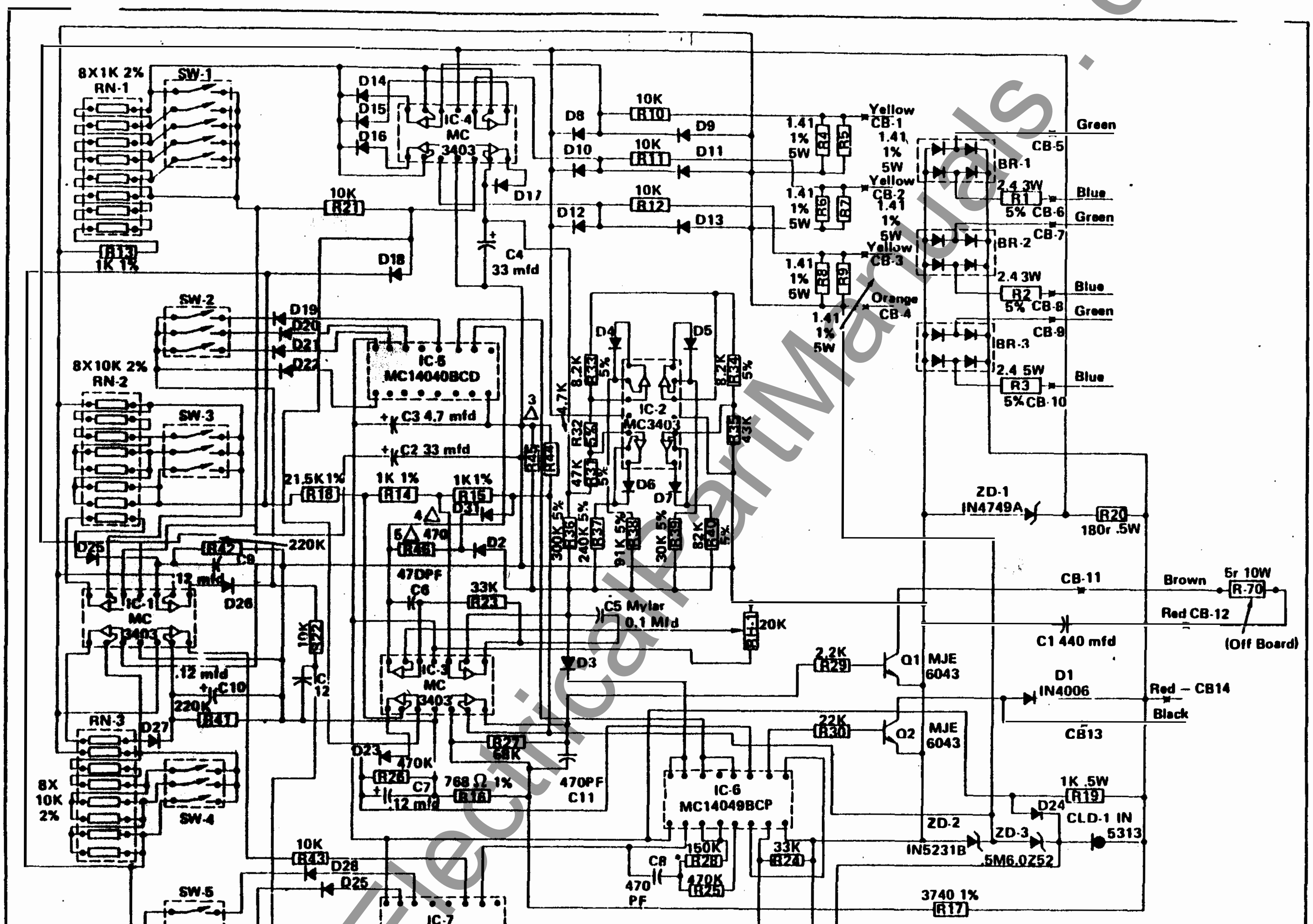


Figure 10. Basic LimiTrip System Block Diagram

off is compared to the 510 millivolt reference. The reference is set slightly high so that the tolerance of the parts will not degrade the breaker rating below nominal.

The voltage set by SW-1 is applied to the input of the fourth op-amp in IC-1 through resistor R-21. Capacitor C-4 is charged to the peak of the signal through diode D-17. This voltage is used as the input of the ladder circuit for the long time oscillator.

The same voltage is also applied to the input of the instantaneous pickup circuit and the short time pickup circuit (both of these circuits are in IC-4) and to the input of the long time pickup circuit in IC-3. Diode D-18 and R-21 limits the magnitude of the signal applied to the ladder circuit. This prevents the minimum long time curve from being decreased to a value less than the maximum short time band. The signals for the instantaneous and short time circuits are picked off ahead of R-21 so are not limited, appreciably.



*Select R28, if needed to meet timing on short time.

1 Use 120K for units when time is long.

1 Use 180K for units when time is short.

Figure 11. LimiTrip Circuit Diagram

As mentioned previously, the reference voltage for the long time circuit is the 510 millivolts across R-14 and R-15. When the signal exceeds this value the op-amp output is driven in a positive direction charging C-7 through diode D-23. R-26 controls the resettable delay of the circuit. The voltage on C-7 is applied to the input of an inverting buffer in IC-6. The output of this buffer then goes negative. This signal is connected to the reset input of the long time delay counter IC-5. The signal is positive when the long time circuit is not picked up and is removed above long time pickup. This allows the counter to operate. The output of the first buffer stage connects to the input of another buffer. The output of the second buffer goes positive above long time pickup. The second buffer connects to the input of the oscillator through diode D-3. At current less than pickup this prevents the oscillator from operating.

Instantaneous Pickup

The signal selected by SW-1 is applied to the positive input of an op-amp in IC-4. The reference voltage on the negative input is a voltage set by RN-2 and SW-3. When the signal exceeds the selected reference voltage the op-amp output voltage is driven positive. This output is rectified by D-25 and stored in C-9. The voltage on C-9 is applied to the positive input terminal of another op-amp. Its negative input is referenced to the 5.1 volt line so when the voltage on C-9 exceeds 5.1 volts its output voltage is driven high. This voltage is applied to the common trip signal line through D-26. This line connects to the input of an inverting buffer in IC-6 that is in turn inverted and used as the base drive for transistor Q-2. The buffers in this case are used to provide higher current for the base of Q-2.

Short Time Circuit

The two additional amplifiers in IC-4 are used as the pickup circuit for short time delay tripping. The pickup portion of the circuit is the same as previously described for instantaneous trip, except the second op-amp stage is inverted. The output of the second stage is normally positive and goes negative at short time pickup. This signal is connected to the reset input of the short time delay counter IC-7. When the reset voltage is removed the counter is allowed to operate. The clock input for this counter is a continuously running oscillator made up of two stages of the inverting buffer IC-6, R-25, R-28 and capacitor C-8. When the reset voltage is removed the counter responds to the oscillator. The appropriate counter stage output is selected by switch SW-5 through diodes D-28, D-29 or D-30 and applied to the common trip signal line. This drives the buffers and output transistor. Two switch poles are used for switching. When both switches are open the longest time delay is selected through D-30. Resistor R-43 protects the reset input of IC-7 from the higher level output voltage of IC-4.

Ladder Circuit and Long Time Oscillator

This circuit is described in detail in the Static Trip II section of this book. The difference between the LimiTrip circuit and the other is that there are fewer line segments used to fabricate the desired time current curves, and the 5.1 volt supply level is used as part of the voltage divider circuit. The longest band for the LimiTrip is equal to the second longest band of the Static Trip II device. For this reason the integrating capacitor of the oscillator is half as large, and some of the other circuit elements are adjusted in size to match.

The desired output stage of the long time delay counter IC-5 is selected by diodes D-19 through D-22 and switch SW-2. The last stage in the counter is permanently connected through D-22 so that if all the switches ar open the device will still operate on the longest time band.

Sensor Transformers - LimiTrip Device

The sensors contain two isolated cores per phase. These are carefully matched to the breaker current rating and the LimiTrip input capability. The sensor rating is derived from the ratio of the signal winding. The signal input for the trip device is one ampere for 100% of rating. As an example a 600 ampere sensor would have 600 turns on the signal winding. The LimiTrip device has limited thermal capacity so these transformers are designed to saturate at around twelve times rated current. For this example 600 turns of #22 AWG on a core cross section of .375 by .5 inches is used. Larger cores should not be used because short circuits on the breaker could cause damage to the trip device.

Similarly, for the 600 ampere example power winding is 120 turns #22 AWG on a core of .25 by .5 cross section. The sensor also contains a 5 ohm resistor (in addition to the 2.4 ohm resistor in the trip device). The operating voltage of the trip device is 30 volts DC rectified. If larger cores are used in the power winding the trip device may be damaged at normal operating current.

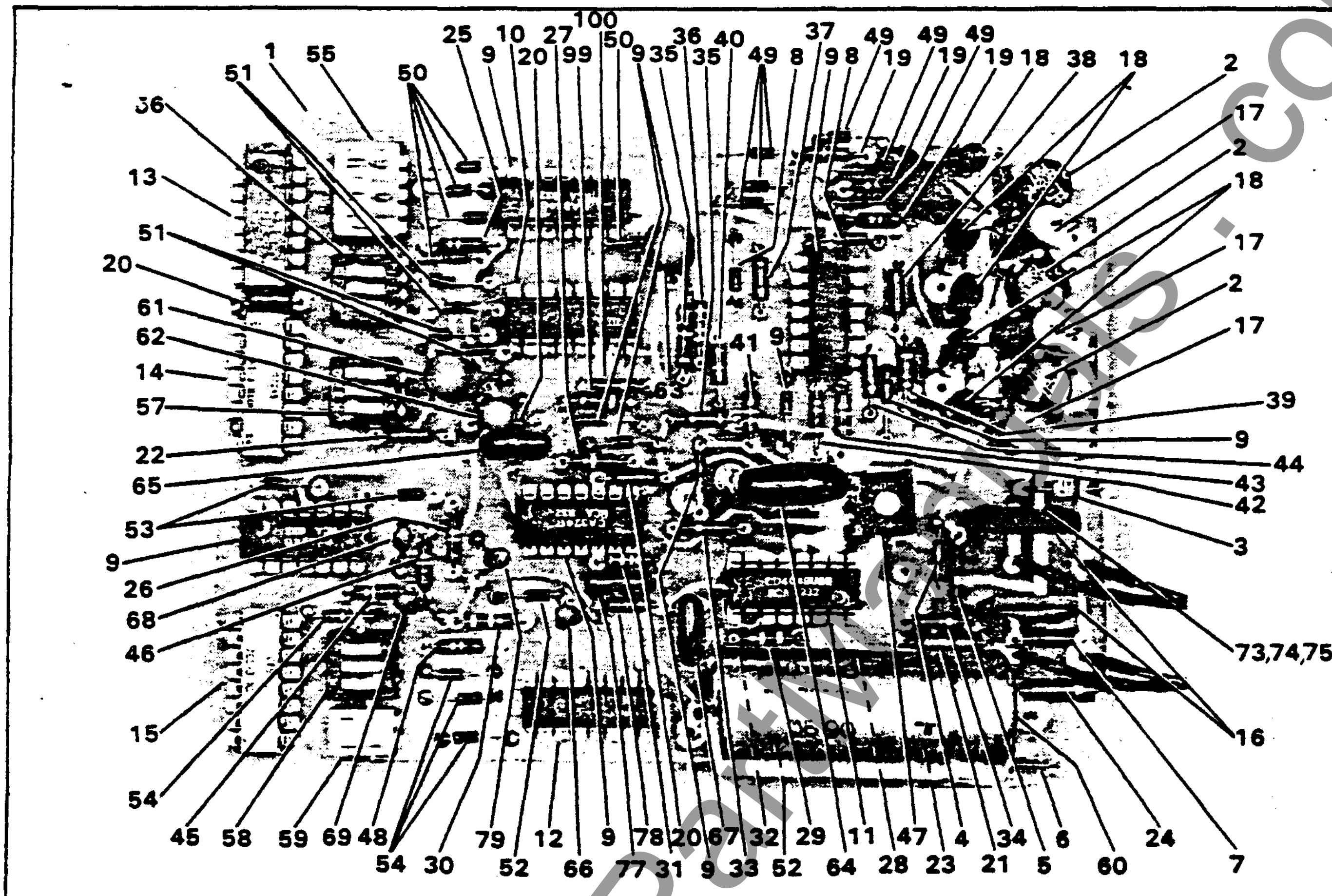


Figure 12. LimiTrip Circuit Board Module

Item	Symbol	Description	Part Number
1		Circuit Board	18-395-042-001
2	BR1, 2 & 3	Bridge Rectifier	15-171-767-003
3	ZD-1	Zener Diode, 1N4749A	15-875-155-016
4	ZD-2	Zener Diode, 1N5231B	15-171-281-009
5	ZD-3	Zener Diode, .5M6.0ZS2	15-875-155-015
6	CLD-1	Current Reg. 1N5313	15-875-155-011
7	D1	Diode, 1N4006	15-875-155-007
8	D2 thru D7 & D31	Diode, 1N457A	15-875-155-017
9	IC-1, 2, 3, 4	Op-Amp Quad, MC3403P	15-171-282-008
10	IC-5	Counter, MC14040QBCP	15-171-282-009
11	IC-6	Hex Buffer, MC14049BCP	15-171-282-010
12	IC-7	Counter, MC14040BCP	15-171-282-009
13	RN-1	Resistor Net, 8 x 1K	15-873-139-018
14	RN-2	Resistor Net, 8 x 10K	15-873-139-019
15	RN-3	Resistor Net, 8 x 10K	15-873-139-019
16	Q & Q2	Transistor, MJE6043	15-875-075-016
17	R1, R2, R3	Resistor, 2.4 ohm, 3W	15-873-139-013
18	R4 thru R9	Resistor, 1.41 ohm, 1%, 5W	15-873-139-014
19	R10, R11, R12	Resistor, 10K, .25W	15-171-279-056
20	R13 thru R15	Resistor, 1K, 1%, .25W	15-873-139-015
21	R17	Resistor 3740 ohm, 1%, .25W	15-873-139-016
22	R18	Resistor 21.5K, 1%, .25W	15-875-139-017
23	R19	Resistor 1K, .5W	00-875-397-007
24	R20	Resistor 180 ohm, .5W	00-875-397-005
25	R21	Resistor 10K, .25W	15-171-279-056
26	R22	Resistor 10K, .25W	15-171-279-056
27	R23	Resistor 33K, .25W	15-171-279-062

(continued on next page)

Item	Symbol	Description	Part Number
28	R24	Resistor 33K, .25W	15-171-279-062
29	R25	Resistor 470K, .25W	15-171-279-076
30	R26	Resistor 470K, .25W	15-171-279-076
31	R27	Resistor 68K, 10%, .25W	15-171-279-066
32	R28	Resistor 150K, 5%, .25W	15-171-280-125
33	R29	Resistor 2.2K, .25W	15-171-279-048
34	R30	Resistor 2.2K, .25W	15-171-279-048
35	R31, R44	Resistor, 4.7K, 5%, .25W	15-171-280-089
36	R32	Resistor, 4.7K, 5%, .25W	15-171-280-089
37	R33	Resistor, 8.2K, 5%, .25W	15-171-280-095
38	R34	Resistor, 8.2K, 5%, .25W	15-171-280-095
39	R35	Resistor, 43K, 5%, .25W	15-171-280-112
40	R36	Resistor, 300K, 5%, .25W	15-171-280-132
41	R37	Resistor, 240K, 5%, .25W	15-171-280-130
42	R38	Resistor, 91K, 5%, .25W	15-171-280-120
43	R39	Resistor, 30K, 5%, .25W	15-171-280-108
44	R40	Resistor, 8.2K, 5%, .25W	15-171-280-095
45	R41	Resistor, 220K, .25W	15-171-279-072
46	R42	Resistor, 220K, .25W	15-171-279-072
47	RN-1	Potentiometer, 20K, Cement 1 Turn	15-171-031-004
48	R43	Resistor, 10K, .25W	15-171-279-056
49	D8 thru D13	Diode	15-875-155-017
50	D14 thru D18	Diode	15-875-155-017
51	D19 thru D22	Diode	15-875-155-017
52	D23, D24	Diode	15-875-155-017
53	D25, D26	Diode	15-875-155-017
54	D27 thru D30	Diode	15-875-155-017
55	SW-1	Switch, 5P	15-171-766-005
56	SW-2	Switch, 3P	15-171-766-003
57	SW-3	Switch, 3P	15-171-766-003
58	SW-4	Switch, 3P	15-171-766-003
59	SW-5	Switch, 2P	15-171-766-002
60	C1	Capacitor, 440 µfd	15-171-278-007
61	C2	Capacitor, 33 µfd	15-875-347-011
62	C3	Capacitor, 4.7 µfd	15-171-029-018
63	C4	Capacitor, 33 µfd	15-875-347-011
64	C5	Capacitor, 0.1 µfd, Mylar	15-171-029-011
65	C6	Capacitor, 470 pf	15-171-029-020
66	C7	Capacitor, 0.12 µfd, Tant.	15-171-029-019
67	C8	Capacitor, 470 pf	15-171-029-020
68	C9	Capacitor, 0.12 µfd, Tant.	15-171-029-019
69	C10	Capacitor, 0.12 µfd, Tant.	15-171-029-019
70	R70	Resistor, 5 ohm, 10W	00-873-139-801
71	C70	Capacitor	15-171-029-021
72	—	Terminal	00-851-062-023
73		Screw, Rd. hd., #6-32 x .5 lg	00-615-471-124
74		Nut, Hex, #6-32	00-631-109-106
75		Torque, Washer, #6	15-171-065-003
76		Heatsink	18-657-898-229
77	C11	Capacitor, 470 pf	15-171-029-020
78	R16	Resistor, 768 ohm, 1%	15-873-139-023
79	C12	Capacitor, .12 µfd, Tant.	15-171-029-019
80		Wire, #20 Awg., Yellow	15-171-786-004
81		Wire, #20 Awg., Yellow	15-171-786-004
82		Wire, #20 Awg., Yellow	15-171-786-004
83		Wire, #20 Awg., Orange	15-171-786-003
84		Wire, #20 Awg., Green	15-171-786-005
85		Wire, #20 Awg., Blue	15-171-786-006
86		Wire, #20 Awg., Green	15-171-786-005
87		Wire, #20 Awg., Blue	15-171-786-006
88		Wire, #20 Awg., Green	15-171-786-005
89		Wire, #20 Awg., Blue	15-171-786-006

(continued on next page)

Item	Symbol	Description	Part Number
90		Wire, #20 Awg., Brown	15-171-786-001
91		Wire, #20 Awg., Red	15-171-786-002
92		Wire, #20 Awg., Black	15-171-786-010
93		Wire, #20 Awg., Red	15-171-786-002
94			
95		Circuit Board Assembly, Pix	18-396-441-401
96		Schematic Diagram, LTI	18-396-223-401
97		Schematic Diagram, LTS	18-396-223-402
98		Schematic Diagram, LTSI	18-396-223-403
99	R46	Resistor, 470 ohm, .25W	15-171-279-040
100	R45	Resistor, 22 Meg., .25W	15-171-279-096

LimiTrip Sensor Ratings (Figure 13)

Continuous Current	Signal Winding Number of Turns	Power Winding Number of Turns	Power Winding Series Resistor	Breaker Type
40-80	80	140	5	LA600A/LA800A
100-200	200	120	5	LA600A/LA800A
200-400	400	120	5	LA600A/LA800A
300-600	600	120	5	LA600A/LA800A
400-800	800	120	5	LA600A/LA800A
100-200	200	110	5	LA1600A
200-400	400	110	5	LA1600A
400-800	800	110	5	LA1600A
800-1600	1600	110	5	LA1600A
1000-2000	2000	135	2.4	LA3000A/LA3200A
1500-3000	3000	125	2.4	LA3000A/LA3200A
1600-3200	3200	125	2.4	LA3000A/LA3200A
2000-4000	4000	125	2.4	LA4000A/LA40008

Figure 13. LimiTrip Sensor Ratings