



 **MULTILIN**

**139 SERIES  
MOTOR  
PROTECTION  
RELAY**

**INSTRUCTION MANUAL**

# INSTRUCTION MANUAL

## 139 SERIES MOTOR PROTECTION RELAY

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**139 SERIES RELAY  
HORIZONTAL MOUNTING**



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# 1. INTRODUCTION

## 1.1 MULTILIN RELAY FEATURES

The Multilin relay is designed to fully protect three phase AC motors against conditions which can cause damage. In addition to motor protection, the relay has features that can protect associated mechanical equipment, give an alarm before damage results from a process malfunction, diagnose problems after a fault and allow verification of correct relay operation during routine maintenance.

One relay is required per motor. Since phase current is monitored through current transformers, motors of any line voltage can be protected. The relay is used as a pilot device to cause a contactor or breaker to open under fault conditions; that is, it does not carry the primary motor current.

**TABLE 1-1 MULTILIN RELAY PROTECTION FEATURES**

PROTECTION	FEATURES
Overload (Selectable Curves)	Trip/Alarm Outputs
Locked Rotor	Status Indication
Stall—Mechanical Jam	Fault Diagnosis
Repeated Starts	Memory Lockout
Single Phase/Unbalance	Simple Adjustment—No Tools
Ground Fault	Easy to Retrofit
Over Temperature	Field Testable
Undercurrent	CSA Approval

## 1.2 TYPICAL APPLICATIONS.

Versatile features and controls allow the relay to protect associated mechanical equipment as well as the motor. In addition to the basic electrical protection for motors listed in table 1-1, the relay can protect against common faults due to process problems such as:

- 1) Personal safety and mechanical protection of pumps using the undercurrent feature to detect loss of suction or a closed discharge valve.
- 2) Personnel safety and mechanical protection of fans against loss of air flow in mines or flow in steam generating boilers using the undercurrent feature.
- 3) Electrical protection of compressor motors from excessive run-up time caused by an open outlet using the start timer.
- 4) Mechanical protection of gears, pumps, fans, saw mill cutters and compressors against mechanical jam using the rapid trip feature.
- 5) Safety to personnel from shock hazard using the ground fault feature to detect winding shorts or leakage currents from moisture in mines.
- 6) Protection of motors and equipment from operator abuse using the thermal memory lockout feature.

### 1.3 RELAY SELECTION

The Model 139 relay is available in horizontal or vertical mount versions and is equipped with a number of standard features that are programmed for a specific application by means of selector switches. Although these can be changed in the field, they will be factory preset if specified according to the relay order code of Table 1-2. Each relay is shipped with a yellow product specification card which shows installed options and factory switch settings. Consult this card and Table 1-2 to determine how the relay has been equipped.

Relays are available for use with 1 or 5 amp current transformers (CTs) which must be specified with the order. Since the relay only sees secondary current, any CT ratio can be used with the relay providing it has the correct secondary rating to match the relay (i.e. 1 amp or 5 amp type).

Although many features are standard and field selectable, the following options will not be provided unless specifically ordered:

- 1) Ground Fault
- 2) RTD Overtemperature
- 3) Thermal Capacity Meter
- 4) 4-20mA Full Load Output

Stocking of spare relays is simplified since many features are field programmable allowing a relay to be set up for different applications. Those features that must be specified at time of order are indicated in Table 1-2.

# TABLE 1-2 RELAY ORDER CODE

139 / H / 5 / 6 / 200 / C / 10110101 / D - GF / 8 / Y / A / RTD / H / 110 / 130 - TC

**Model 139 Relay**

**Mounting**

H - Horizontal  
V - Vertical

**CT Inputs**

1 - 1 amp  
5 - 5 amp

**\*Overload Levels**

1 - 15 Overload Curve Number

**\*Mechanical Jam Level**

150% - 150  
200% - 200  
250% - 250  
300% - 300  
Off - A

**\*Short Circuit**

B - Short Circuit Disable  
C - Short Circuit Enable

0 = DEFEAT  
1 = ENABLE

**\*OPTION SWITCH SETTINGS**

0/1	Cyclic Overload Compensation
0/1	Immediate Overload Warning
0/1	Undercurrent Override
0/1	Emergency Restart
0/1	Memory Override
0/1	Motor Temperature Compensation
0/1	Voltage Compensation
0/1	Feeder Protection

Specify with order: 1) Motor Full Load Current  
2) Drive Equipment eg. Crusher, Pump

**Output Options (One only)**

TC - Thermal Capacity Meter Option  
FLC - 4 - 20mA Full Load Current

**RTD Trip Temperature °C**

**RTD Alarm Temperature °C**

**Sensor Type**

H - 100 Ohm Platinum  
J - 10 Ohm Copper  
K - 120 Ohm Nickel  
L - 100 Ohm Nickel

Thermistor - consult factory

**RTD Option**

**Ground Fault Alarm**

A - Alarm Enable  
B - Alarm Disable

**\*Ground Fault Time Delay**

X - No Delay  
Y - 100mS Delay  
Z - 2 Second Delay

**\*Ground Fault Sensitivity**

0.5, 1, 4, 8, 12 amps

**Ground Fault**

**Supply Power**

D - 120 V AC  
E - 240 V AC

† F - DC

† Requires Separate DC Power Supply Type:

Control Voltage	Multilin Part No.
48V DC:	DCS4-48
125V DC:	DCS4-125
250V DC:	DCS4-250

\*Field Programmable - Other features must be specified with order.



**TABLE 1-4 TECHNICAL SPECIFICATIONS**

**OVERLOADS:**

INPUT 0-20 TIMES RATED CT SECONDARY  
AMPS CONTINUOUS

**FREQUENCY:**

50-60 HZ

**MAXIMUM LOAD CONTROL — % CT AMPS**

ACCURACY  $\pm 3\%$  OF DIAL SETTING TO 10 TIMES

FULL LOAD (50-95% DIAL SETTING)

DETECTION LEVEL  $\pm 1\%$  PICKUP

CALIBRATED VALUE RMS AMPS SINEWAVE  
INPUT

RANGE 10-100% 0.1-1 AMP 1 AMP CT MODEL

10-100% 0.5-5 AMP 5 AMP CT MODEL

RESPONSE AVERAGE OF 3 PHASE RMS VALUES

OVERLOAD TIMES  $\pm 15\%$  OF CURVE VALUES

**OVERLOAD**

RAPID TRIP: 150/200/250/300

TIME DELAY: NOMINAL 1 SEC.

**MAXIMUM UNBALANCE**

CALCULATION

$$a) \frac{I_{0n} - I_{avl}}{FLC} = UB\%$$

LESS THAN MAXIMUM LOAD CONTROL SETTING

$$b) \frac{I_{0n} - I_{avl}}{I_{av}} = UB\%$$

GREATER THAN MAXIMUM LOAD CONTROL  
SETTING

WHERE  $I_{0n}$  = RMS VALUE OF ANY PHASE

$I_{av}$  = AVERAGE OF PHASES 1 2 3

FLC = MAXIMUM LOAD CONTROL  
SETTING

RANGE 4-50%

ACCURACY  $\pm 5\%$  DIAL POINTS

TRIP DELAY 5 SECONDS  $\pm 2$  SECONDS

**SHORT CIRCUIT**

TRIP LEVEL: 10 TIMES MAXIMUM LOAD  
CONTROL SETTING

ACCURACY  $\pm 10\%$

MAXIMUM TIME DELAY:

100mS @ 14 TIMES MAXIMUM

LOAD CONTROL SETTING

**START TIMER**

RANGE 4-60 SECONDS

ACCURACY (VOLTAGE COMP B7 OFF):  $\pm 10\%$

(VOLTAGE COMP B7 ON: INPUT 5-7

TIMES MAX. LOAD):  $\pm 20\%$

ACTIVATION INRUSH RISES FROM 10% TO

101% OF MAXIMUM LOAD

CONTROL SETTING IN ONE SECOND

DEACTIVATION LOAD CURRENT DROPS BELOW

MAXIMUM LOAD CONTROL

SETTING

**MINIMUM LOAD**

RANGE 0-100% OF MAXIMUM LOAD CONTROL  
SETTING

RESPONSE RELATED TO AVERAGE OF  
3 PHASE RMS

ACCURACY:  $\pm 10\%$

RESPONSE TIME 1 SECOND

**RESET LOCKOUT**

LOCKOUT TIME: 30 MINUTES  $\pm 20\%$   
(AC POWER ON)

LOCKOUT TIME: 30 MINUTES  $\pm 30\%$   
(AC POWER OFF)

**GROUND FAULT**

TRIP LEVEL: 0.5, 1, 4, 8, 12 AMPS THROUGH CT.

LEVEL ACCURACY:  $\pm 0 - 25\%$

TRIP DELAY: 50mS  $\pm 0 - 25$ mS

100mS  $\pm 0 - 25$ mS

2 SECONDS  $\pm 0.5$  SECONDS.

**RTD INPUT**

SENSOR USER SUPPLIED PLATINUM

COPPER NICKEL RTD

ALARM TEMPERATURE: 0-180°C

110°C NOMINAL

TRIP TEMPERATURE: 0-180°C, 130°C NOMINAL

ANALOG OUTPUT: 10mV/°C, 0V @ 0°C

**FULL LOAD OUTPUT OPTION**

NO LOAD OUTPUT: 4mA

FULL LOAD OUTPUT: 20mA

MAXIMUM LOAD RESISTANCE: 300 $\Omega$

OVERLOAD SATURATION: 30mA MAXIMUM

**MAIN RELAY CONTACTS**

TYPE: SINGLE FORM C

RATINGS: 120VAC RESISTIVE 7 AMPS

240VAC RESISTIVE 5 AMPS

125VDC RESISTIVE 0.25 AMPS

28VDC RESISTIVE 5 AMPS

**CONTROL POWER**

STANDARD: 120/240 VAC

OPTIONAL: 125 VDC

POWER: 5 VA

FREQUENCY: 50/60 HZ

120VAC INPUT RANGE: 90-150 VAC

240VAC INPUT RANGE: 176-270 VAC

125VDC INPUT RANGE: 80-150 VDC

BURDEN: 1 VA

**ENVIRONMENT**

OPERATING TEMPERATURE RANGE:

-10°C to +60°C

OUTSTPOOF CASE

**CERTIFICATION**



APPROVED



RECOGNIZED COMPONENT

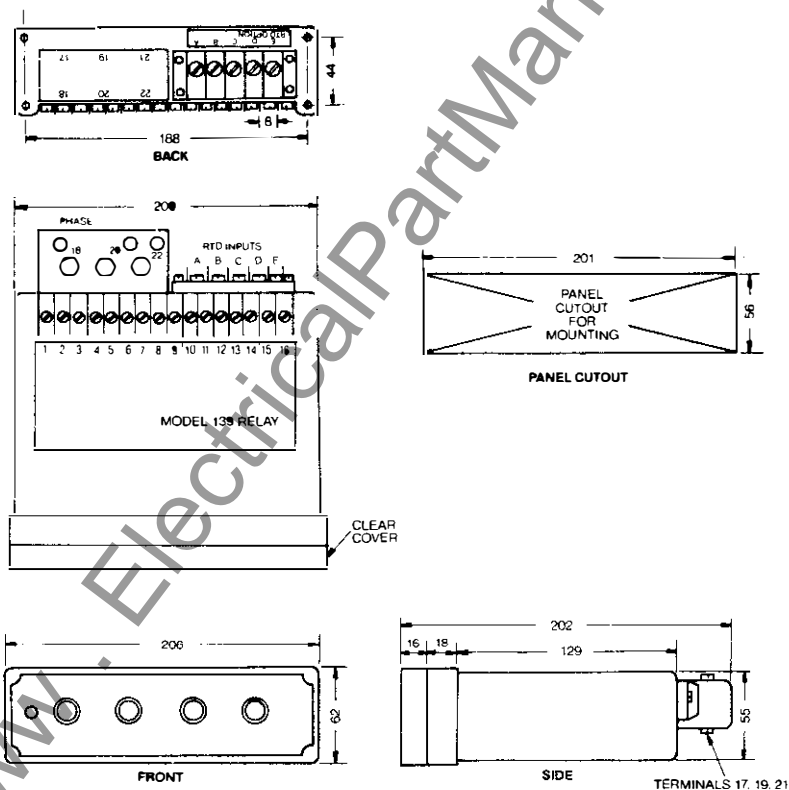
## 2. INSTALLATION

### 2.1 PHYSICAL DIMENSIONS

The relay circuitry is housed in a high impact plastic case with a clear dust proof cover for viewing indicators and control settings. The clear cover is screwed on and seals are available to prevent tampering with controls.

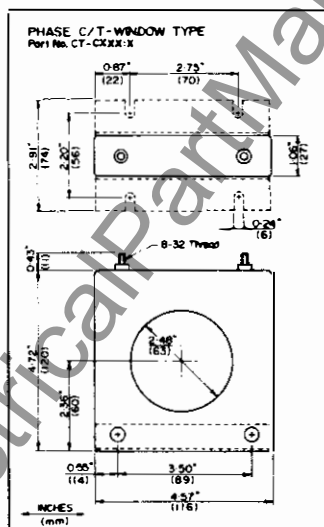
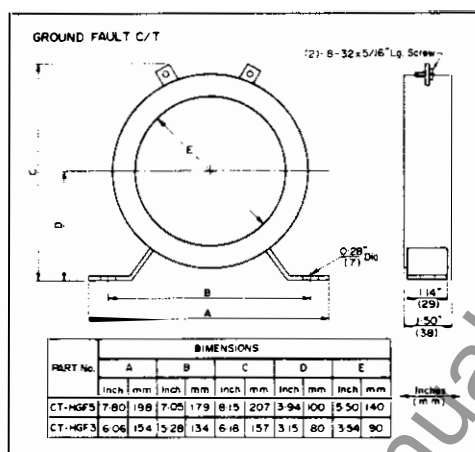
Dimensions for the relay are given in Figure 2-1. Phase and ground fault CTs are available from Multilin. The dimensions of these CTs are shown in Figure 2-2.

FIGURE 2-1 -- RELAY DIMENSIONS



ALL DIMENSIONS IN MILLIMETERS

**FIGURE 2-2 CT DIMENSIONS**



## 2.2 OPTION SELECTION

In addition to the front panel controls, there are selector switches inside the relay used to program user requirements. Consult the yellow product specification card supplied with the relay to ensure that the factory switch settings match the order requirements. Field changes can be made by removing the cover and altering the switch settings. These changes should be noted on the product specification card and kept on file or mounted near the relay.

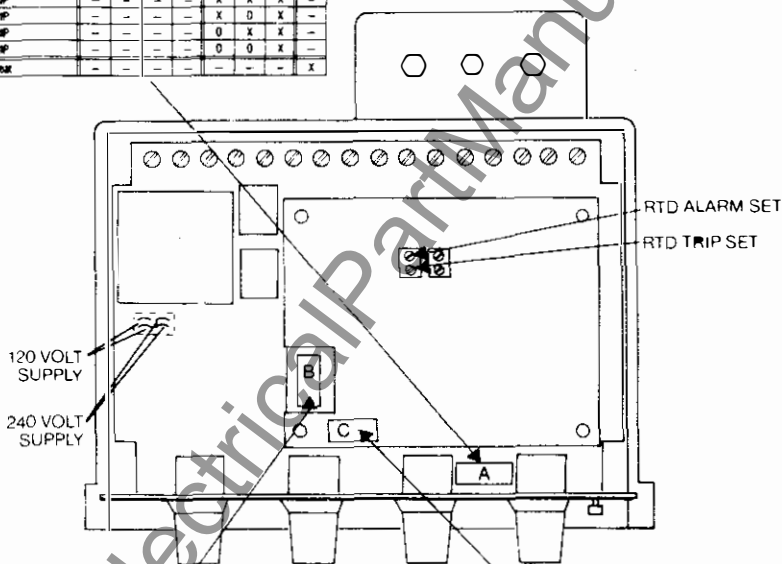
Figure 2-3 shows switch locations. A description of each switch function will be found in sections 3-8, 3-10 and 3-11. Ensure switches are firmly pushed in when changing settings.

Once the switches are set, the cover can be replaced ready for installation.

# FIGURE 2-3

## OVERLOAD LEVEL SWITCH SETTINGS A1 to A8

FUNCTION		OVERLOAD LEVEL SWITCH SETTINGS							
		A1	A2	A3	A4	A5	A6	A7	A8
X = Switch On									
0 = Switch Off									
- = No Effect									
Run Curve No.	Locked Motor Time (Seconds)	Run Curve Selection				Rapid Trip		S/C	
1	2.5	0	X	X	X	-	-	-	-
2	5	X	0	X	X	-	-	-	-
3	7.5	0	0	X	X	-	-	-	-
4	10	X	X	0	X	-	-	-	-
5	12.5	0	X	0	X	-	-	-	-
6	15	X	0	0	X	-	-	-	-
7	17.5	0	0	0	X	-	-	-	-
8	20	X	X	X	0	-	-	-	-
9	22.5	0	X	X	0	-	-	-	-
10	25	X	0	X	0	-	-	-	-
11	27.5	0	0	X	0	-	-	-	-
12	30	X	X	0	0	-	-	-	-
13	32.5	0	X	0	0	-	-	-	-
14	35	X	0	0	0	-	-	-	-
15	37.5	0	0	0	0	-	-	-	-
NO RAPID TRIP		-	-	-	-	-	-	0	-
150% RAPID TRIP		-	-	-	-	X	X	X	-
200% RAPID TRIP		-	-	-	-	X	0	X	-
250% RAPID TRIP		-	-	-	-	0	X	X	-
300% RAPID TRIP		-	-	-	-	0	0	X	-
Short Circuit Delay		-	-	-	-	-	-	-	X



## OPTION SWITCH SETTINGS B1 to B8

FUNCTION		OPTION SWITCH SETTINGS							
		B1	B2	B3	B4	B5	B6	B7	B8
X = Switch On									
0 = Switch Off									
- = No Effect									
Cyclic Overload Compensation		X	-	-	-	0	-	-	-
Immediate Overload Warning		-	X	-	-	-	-	-	-
Disable Undercurrent		-	-	X	-	-	-	-	-
Emergency Restart		-	-	-	X	-	-	-	-
Memory Defeat		-	-	-	-	X	-	-	-
Motor Temperature Compensation		-	-	-	-	-	X	-	-
Voltage Compensation		-	-	-	-	-	-	X	-
Enable Feeder Protection		-	-	-	-	X	-	-	X

## GROUND FAULT SWITCH SETTINGS C1 TO C8

FUNCTION		TRIP AMPS					TRIP TIME		ALARM
		C1	C2	C3	C4	C5	C6	C7	C8
X = Switch On									
0 = Switch Off									
- = No Effect									
12 Amp Trip		X	0	0	0	0	-	-	-
8 Amp Trip		0	X	0	0	0	-	-	-
4 Amp Trip		0	0	X	0	0	-	-	-
1 Amp Trip		0	0	0	X	0	-	-	-
0.5 Amp Trip		0	0	0	0	X	-	-	-
No Trip Delay		-	-	-	-	-	X	X	-
100ms Trip Delay		-	-	-	-	-	0	X	-
2 Second Trip Delay		-	-	-	-	-	0	0	-
Enable Ground Fault Alarm		-	-	-	-	-	-	-	X

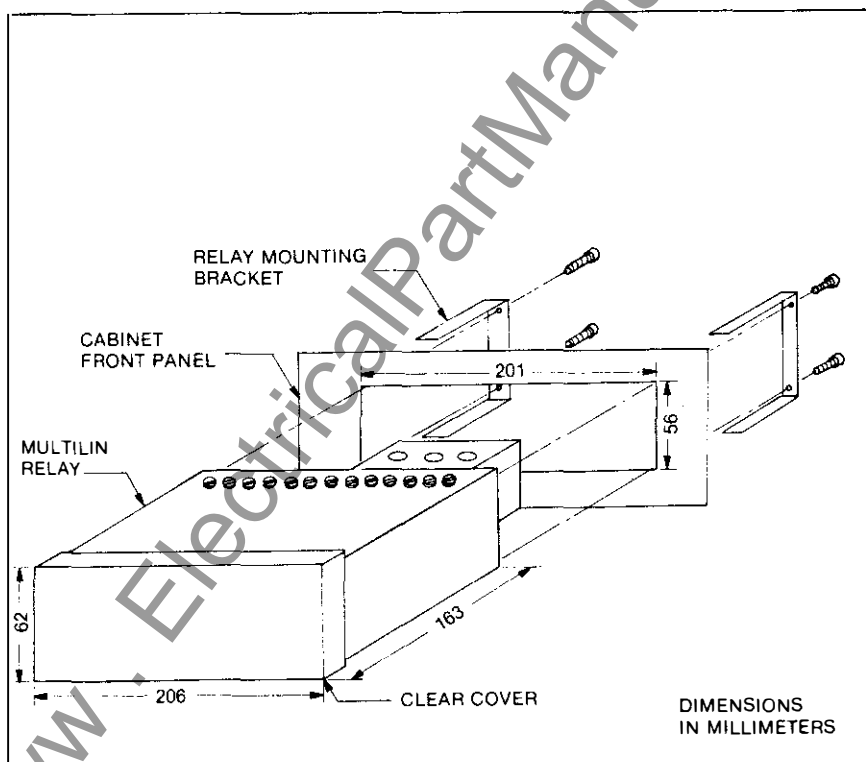
## 2.3 MOUNTING

Flush mounting of the relay on a panel or switchgear door is shown in Figure 2-4. Both the horizontal and vertical faceplate versions of the relay require the same size rectangular panel cutout although the latter will be rotated 90 degrees from that shown in Figure 2-1. Once the rectangular slot is cut, the relay is held in place by two U-shaped clamps, ready for wiring.

Connections to the relay are through 16 terminals on the upper surface near the back. CT connections are made to the interposing transformer module mounted on the back of the relay. CT wires are passed directly through the holes in the module or connected to the terminals supplied as described in Section 2-6. If the RTD option is supplied, 5 extra terminals will be provided on the back of the relay. The mounting scheme used should allow for access to the terminals.

Before mounting and connecting the relay check the yellow product specification card to ensure that all options and switch settings are set as desired.

FIGURE 2-4



## 2.4 EXTERNAL CONNECTIONS

The complexity of wiring to the relay will vary with the number of options used. A minimal configuration would require supply power, 3 phase current CT inputs and the main relay contacts wired in series with the contactor control relay or circuit breaker shunt trip coil.

Extra terminals will be provided on the back of the relay when the RTD over-temperature option is ordered. Terminals for other extra options will be marked if they have been supplied with the relay. Consult the yellow product specification card to verify which options have been provided. A summary of all the external connections that can be used appears below. Items marked as optional are standard on all relays but not necessary for correct operation. Items marked as optional extra are supplied only if ordered with the relay.

**TABLE 2-1 EXTERNAL RELAY CONNECTIONS**

INPUTS
1) Supply power 120/240 V AC or 80–150 V DC (Optional Extra) 2) Phase 1 current CT 3) Phase 2 current CT 4) Phase 3 current CT 5) Ground fault current CT (Optional Extra) 6) External reset switch (Optional) 7) Emergency restart keyswitch (Optional) 8) RTD temperature sensor (Optional Extra)
OUTPUTS
1) Contactor/breaker trip —main relay contacts (N.O. & N.C.) 2) Alarm —auxiliary relay contacts (N.O. & N.C.) 3) Analog temperature output (Optional Extra with RTD) 4) 4–20mA output of full load current (Optional Extra) 5) Thermal capacity used meter (Optional Extra)

## 2.5 POWER SUPPLY

Control power to the relay is normally 120V AC or 240V AC at 50HZ/60HZ. The voltage is selected by means of soldered jumpers or switch. Power consumption is 5VA.

Terminals 15 and 16 will be marked with the supply voltage for which the relay has been set. If the voltage is changed, the extra voltage identification label supplied with the relay should be placed next to terminals 15 and 16 so that the correct value is marked. Wiring connections are shown in Figure 2-5a (A.C. CONTROL POWER) or Figure 2-5b (D.C. CONTROL POWER). It is essential that the relay receive control power before the motor is energized and recommended that the relay remain powered after a motor has been shut down.

An optional 80–150V DC power supply is also available.

FIGURE 2-5a—RELAY WIRING DIAGRAM / AC CONTROL POWER

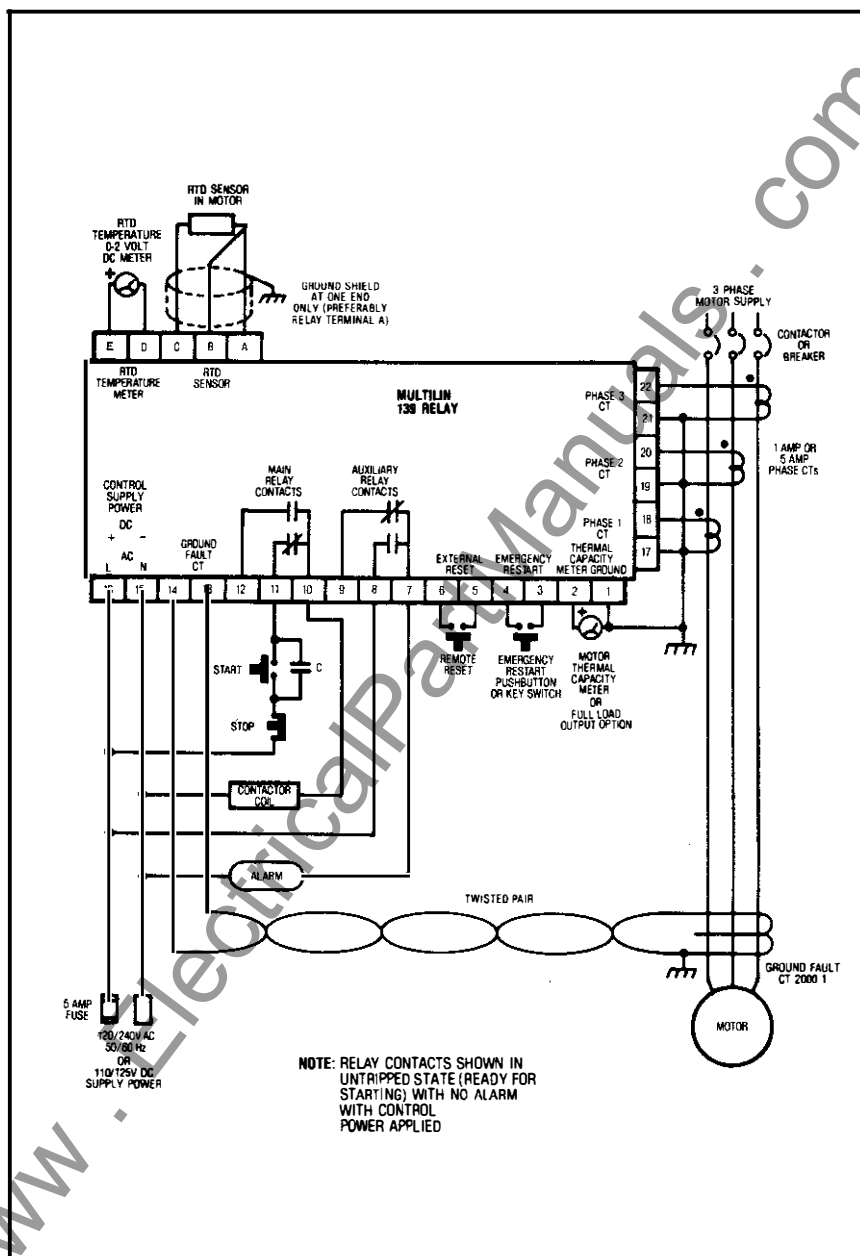
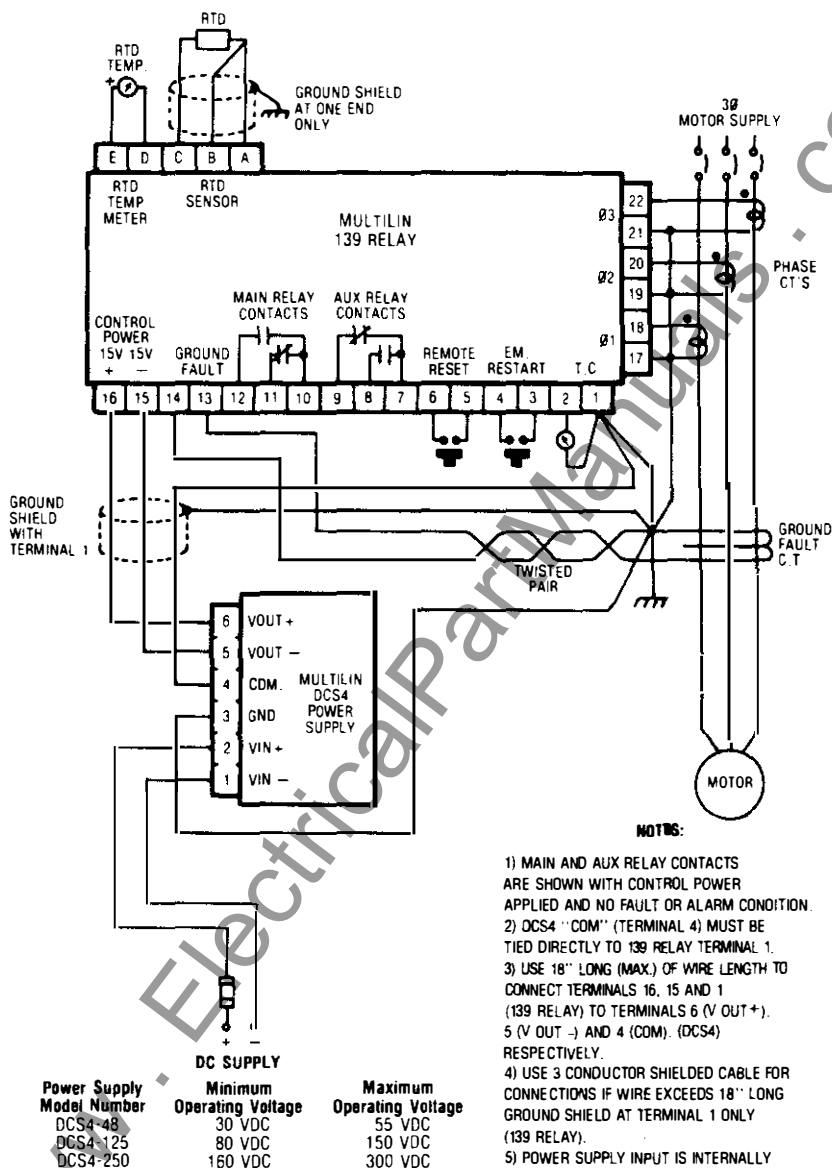


FIGURE 2-5b—RELAY WIRING DIAGRAM / DC CONTROL POWER





## 2.6 PHASE CTs

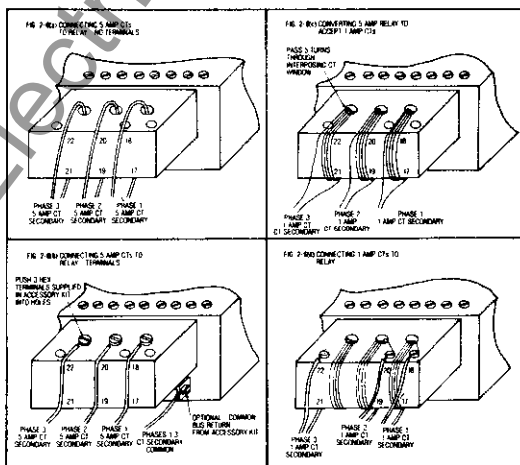
One CT for each of the three motor phases is required to input a current into the relay proportional to the motor phase current. Although polarity is not important, it is recommended that the polarity markings shown in Figure 2-5 be observed in accordance with standard practice. The CT used can either have a 1 amp or 5 amp secondary and should be sized so that the motor full load current is between 50-95% of the rated CT primary amps. When ordering the relay, it is necessary to specify whether 1 amp or 5 amp CTs are being used. The CT ratio should be typed on the CT ratio label supplied and fastened to the front panel as shown in Fig. 3-1. The maximum load control is specified as a percentage of the CT value so the relay will work with any CT ratio. Conventional current transformers will work with the relay which presents negligible burden or CTs can be purchased directly from Multilin.

Five amp current transformers are connected to the CT module on the back of the relay as shown in figure 2-6b by connecting the CT secondary wires to the screw terminals provided. If desired, the CT common wires can be connected to a single terminal using the common bar provided in the accessory kit. It is also possible to remove the three brass terminals and pass the CT wires directly through holes in the CT module as shown in figure 2-6a.

A relay designed for 5 amp CTs can be used with 1 amp CTs by removing the brass terminals and wrapping 5 turns through the holes as shown in figure 2-6c or 2-6d. If the relay is ordered for use with 1 amp CTs these turns will already be installed as shown in figure 2-6d. Otherwise, a conversion kit is available on request. Use of the common bar with the 1 amp version is not recommended as it may cause the windings to short.

Each of the CT secondaries is isolated from the relay but one side should be grounded for safety reasons. Terminal 1 of the relay is the circuit ground which will also normally be tied to an external ground.

FIGURE 2-6 PHASE CT WIRING



## 2.7 GROUND FAULT CT

All current carrying conductors must pass through the ground fault CT window. If a safety ground is used, it should pass outside the CT window. Terminals 13 and 14 are connected to the external ground fault CT. Polarity is not important and one of the CT terminals should be grounded for safety reasons.

A specially designed CT is used that is capable of outputting low level signals which allows for sensitive ground fault detection. **It is recommended that the two CT leads be twisted together to minimize noise pickup.** If it is desired to use a different ground fault CT, consult the factory.

## 2.8 MAIN RELAY CONTACTS

The control relay or shunt trip coil of the starter or circuit breaker is connected to the main relay contacts which are available as normally open or normally closed. Contact ratings are 7 amps maximum at 115V AC. Silver cadmium oxide contacts are used because of their ability to withstand high inrush currents on inductive loads. Consult the factory if these contacts are to be used for carrying low currents since these contacts are not recommended for use below 0.1 amps.

**When the relay is ready for motor starting the contacts for terminals 10, 11, 12 will be as shown in Figure 2-5. When the relay trips, or if control power is lost, the contacts will change to the opposite condition. However, if this change occurred from lost control power, the main relay will return to its normal operating state when power is re-applied, without having to reset the relay. A change in state due to a relay lockout trip, requires that the reset button be pushed, or the external reset terminals shorted, in order to reset the relay. A motor start/stop scheme is indicated in Figure 2-5. Use terminals 10 and 11 in conjunction with a contactor starter and terminals 10 and 12 for a breaker shunt trip coil.**

On special order the relay can be equipped so that the main relay picks up only on a fault; that is, it is in the untripped state whenever power is lost. If the relay is purchased this way, the contact state will be opposite to that shown in Figure 2-5; that is, 10 and 11 will be open when the motor is ready for starting while 10 and 12 will be closed. The yellow product specification card will be marked "Non fail-safe Operation" if the relay is ordered this way.

## 2.9 AUXILIARY RELAY CONTACTS

An extra set of contacts which operate independently of the main relay contacts, is provided in normally open and normally closed formats. These contacts have the same ratings as the main relay contacts.

Internal selector switches are used to program which conditions will activate the auxiliary relay. This normally will be one of the following: Undercurrent, immediate overload warning, ground fault alarm or RTD overtemperature alarm. When the alarm condition is not present, the contacts of terminals 7, 8, 9 will be as shown in Figure 2-5. These contacts are normally used for alarm purposes to signal a fault condition before the motor is shut down.

## 2.10 EXTERNAL RESET

An external reset switch, which operates in parallel with the front panel reset switch, can be connected to terminals 5 and 6 for remote reset operation. The

normally open contacts of this external switch are closed to reset the relay. Auto resetting of the relay after a fault has cleared can be obtained by permanently connecting a jumper across terminals 5 and 6

## 2.11 EMERGENCY RESTART OPTION

If it is desired to sometimes override the memory after a lockout trip, a keyswitch can be connected across terminals 3 and 4. This keyswitch, which can be purchased from Multilin, should be located close to the relay to avoid long wire runs. Shorting the terminals allows the memory to be discharged for motor restarting. Emergency restart enable switch B4 (Section 3.10) must be on if this feature is to be used.

A temporary jumper placed across these terminals is also a useful way to test the relay or reset it from a lockout condition allowing restarting after a trip.

## 2.12 TEMPERATURE SENSING

When the temperature sensing option is ordered, 5 terminals are added to the back of the relay. Terminals A, B, C are connected to the customer supplied RTD sensor in the motor as shown in Figure 2-5. The RTD sensor used should agree with that indicated on the yellow product specification card. Consult the factory if thermistors are to be used.

The motor temperature can be monitored if desired by connecting a standard voltmeter across terminals D and E. The output from these terminals is 0 volts @ 0°C, 10mV/°C. A digital voltmeter with a 0–2 volt DC range will give a direct readout of motor temperature in degrees celcius. A suitable digital meter with °C markings is available from Multilin for panel mounting.

The RTD sensor changes its resistance in proportion to temperature; consequently, lead resistance compensation is employed. To prevent errors, each lead must have the same resistance. Thus, identical length runs of the same wire are required in connecting the sensor. Shielded 3 wire cable of #18 wire is recommended. **This should be routed away from wires carrying large currents and the shield grounded at only one end, preferably at relay terminal A.**

If the RTD leads are brought from the relay to a terminal block in the switch-gear cabinet and an RTD is not to be connected immediately, the terminals A, B, C should be left disconnected at the relay to prevent the wires from acting as an antenna and causing nuisance tripping.

## 2.13 CONNECTING THE THERMAL CAPACITY METER

On relays equipped with the thermal capacity meter option a 0–1mA output from terminals 1 and 2 (+VE) is provided to drive the meter supplied with this option. It may be desirable to place this meter away from the relay near the operator controlling the motor since accuracy is not affected by lead length. This allows the user to determine how close the relay is to tripping the motor.

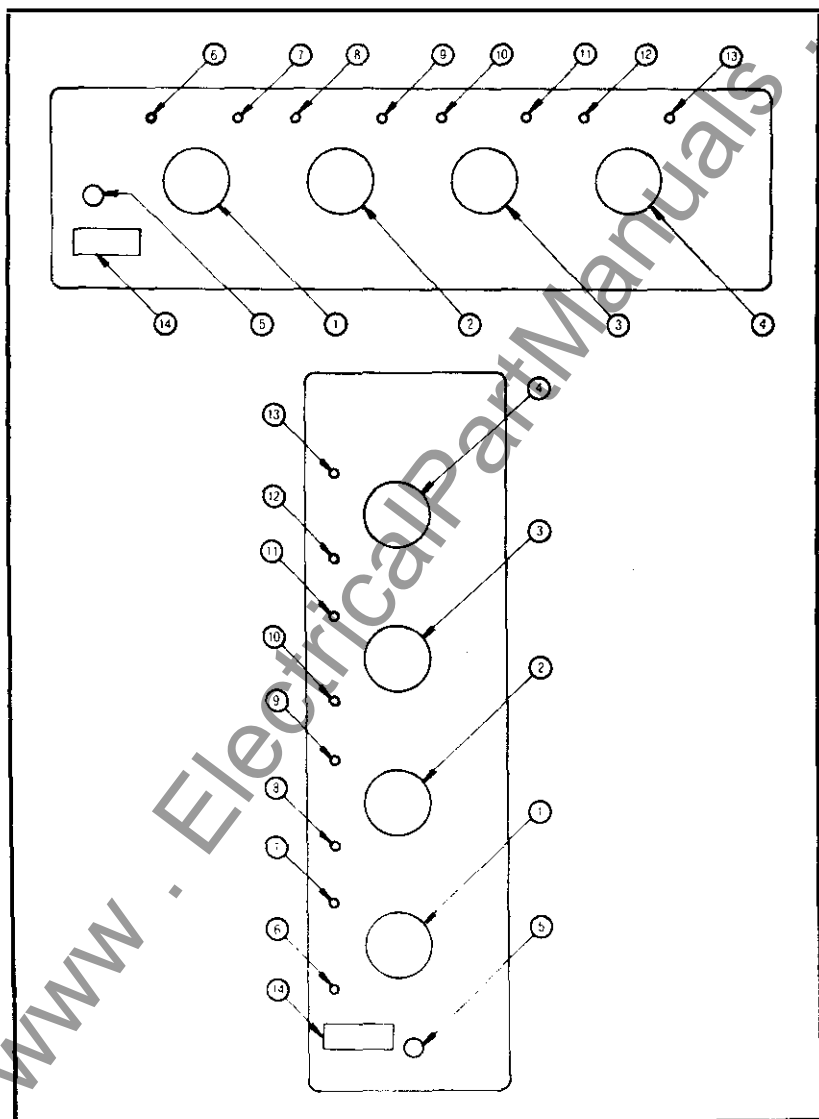
## 2.14 CONNECTING THE CURRENT OUTPUT OPTION

When the relay has been ordered with this option a 4–20mA output from terminals 1 and 2 (+VE) proportional to the percentage of full load motor current

is provided. Current levels are not affected by wire length and are suitable for driving chart recorders, programmable controllers or a computer interface. Output current saturates below 30mA on overloads. The wire connected to terminal 1 may also be grounded at the receiver.

### 3. SETUP AND USE

FIGURE 3-1 FRONT PANEL LAYOUT



### 3.1 CONTROLS AND INDICATORS

Once the relay has been wired and the internal selector switches programmed for the desired options (Sections 3.8, 3.10, 3.11) all that remains is to set the front panel controls for the required application. Table 3-1 provides a summary of controls and indicators. Indicators come on whenever the corresponding condition is present and remain latched after the relay trips.

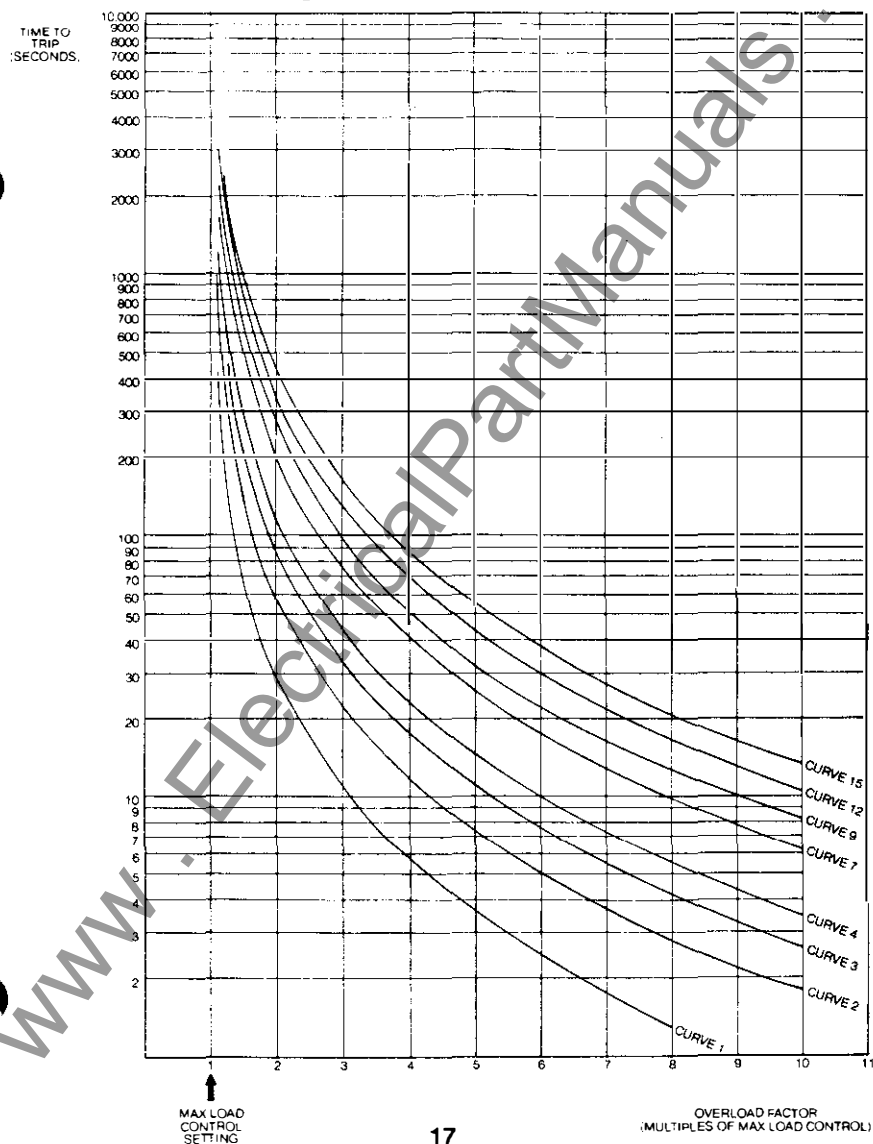
**TABLE 3-1 CONTROLS AND INDICATORS**

NO.	NAME	FUNCTION
1	Maximum load control	Sets the maximum average RMS current to the motor at which overload occurs. Calibrated in % of CT amps.
2	Unbalance control	Sets the level of unbalance between phases for indication of an unbalance fault.
3	Undercurrent control	Sets the current level at which loss of load will be detected. Calibrated as percentage of maximum load current amps.
4	Start time	Sets maximum time motor can take to attain normal running mode. Calibrated in seconds.
5	Reset push button	Resets relay after a trip. If relay in memory lockout condition reset does not function.
6	Unbalance light	Indicates that the actual current phase unbalance exceeds the set value (Control 2).
7	Overload light	Indicates the motor current exceeds the set value (Control 1).
8	Start light	Indicates motor in a start up mode.
9	Overtemperature light	Indicates the external RTD sensor in the motor exceeds the internally set RTD alarm temperature.
10	Ground fault light	Indicates ground fault (earth leakage) current exceeds 50% of internally preset value.
11	Trip light	Indicator flashes when relay has tripped.
12	Undercurrent light	Indicates motor current has dropped below minimum load setting (Control 3).
13	Power on	Indicates relay energized by supply power.
14	CT Ratio sticker	Customer to mark existing CT ratio on this sticker (in accessory kit) and affix to front panel.

## 3.2 MAXIMUM LOAD CONTROL

To set the maximum load control, determine from the motor nameplate the full load current and the service factor, e.g. 1.0, 1.15. Set the maximum load current control to the nameplate rating, or this value times the service factor. If the current rises above this value the overload light will come on and the relay will shutdown the motor after a time determined by the run curve selected, degree of overload and cumulative effect of previous overloads when the memory is active. Selection of the appropriate run curve is outlined in Section 3.8. As explained in Section 3.4 the run curve is not active during a startup.

FIGURE 3-2 RUN CURVES



### 3.3 UNBALANCE CONTROL

An unbalance in the three motor phase currents will result when a voltage unbalance exists in a plant, if the resistance of one phase increases due to a pitted contactor or if loose connections develop. This results in a rapidly rotating field which induces severe heating in the rotor. It is difficult to predict the exact effect on rotor heating from a given amount of unbalance because of the problems in measuring rotor current directly and different types of rotor construction used in induction motors. Consequently there is no single recommended setting for the unbalance control.

A suggested procedure for setting this control is to initially dial it fully clockwise to 50%. After the motor is powered on, dial back until the unbalance indicator (U/B) comes on. The scale reading at this point is the residual motor current unbalance, typically 4-50%. Increase the setting a few percent to avoid nuisance tripping. If the motor unbalance now increases above the normal setting the relay will trip within 5 seconds and the unbalance light will remain on. Unbalance levels exceeding the dial value do not affect the memory nor is the effect of previous unbalances cumulative. The condition must persist for a full 5 seconds for a trip to occur. In this way the motor is shut down before it can overheat while nuisance tripping is avoided. Periodic flashes of the unbalance light due to surges from other plant loads are normal and will not cause any problems. If an unbalance condition exists at a dial setting above 20% the plant distribution and motor connections should be checked.

Measurement of the negative sequence component of current which results in rotor heating is difficult to do reliably because both phase and magnitude calculations are involved and as such the output is prone to nuisance tripping from harmonics. An approximation to this component is used in the Multilin relay to give effective unbalance protection. The actual dial value is calculated as follows:

**1) Average 3 phase RMS current below maximum load control value.**

$$\frac{U/B\%}{(\text{Dial Setting})} = \frac{|\phi_n - \phi_{av}|}{\phi_{FLC}} \times 100$$

Example running:

$$\phi_1 = 120 \text{ amps} \quad \phi_{av} = \frac{120 + 110 + 108}{3} = 113 \text{ amps}$$

$$\phi_2 = 110 \text{ amps}$$

$$\phi_3 = 108 \text{ amps}$$

$$\phi_{FLC} = 120 \text{ amps} \quad U/B = \frac{|120 - 113|}{120} \times 100 = 6\%$$

**2) Average 3 phase RMS current above maximum load control value.**

$$\frac{U/B\%}{(\text{Dial Setting})} = \frac{|\phi_n - \phi_{av}|}{\phi_{av}} \times 100$$

Example: During Start

$$\phi_1 = 600 \text{ amps} \quad \phi_{av} = \frac{600 + 550 + 400}{3} = 516 \text{ amps}$$

$$\phi_2 = 550 \text{ amps}$$

$$\phi_3 = 400 \text{ amps} \quad U/B = \frac{|400 - 516|}{516} \times 100 = 22\%$$

$$\phi_{FLC} = 120 \text{ amps}$$

Where  $\phi_n$  = RMS value of phase with max. deviation from  $\phi_{av}$ .

$\phi_{av}$  = average of 3 RMS phase values

$\phi_{FLC}$  = maximum load control setting converted to amps.  
(i.e. control setting in %  $\times$  phase CT primary rating).

The relay relates unbalance to the full load control setting for normal loads to prevent nuisance tripping on very lightly loaded motors where large unbalances have a small effect. During starting and overloads, the unbalance is related to the average to give a more accurate approximation to motor heating.

### 3.4 START TIMER

Induction motors will draw an inrush current while running up to speed on starting which is greater than the full load current. For across the line starting the current will typically be 5-7 times the normal running current. The start timer, with a range of 4-60 seconds, is used to provide protection against locked rotor, excessive loading during start-up and multiple starts. This control is only active when power is first applied to the motor.

To set the start timer determine the actual measured run-up time of the motor, the specified locked rotor time and the number of consecutive starts allowed by the manufacturer. Set the start time control to a time less than the maximum locked rotor time but greater than the total time required for the maximum number of consecutive starts allowed. A high start timer setting corresponds to a large motor thermal capacity.

When the relay first senses a motor current greater than 15% of the maximum load current setting it goes into start mode; that is, the run curve and rapid trip are ignored during start-up. When the motor current drops back down below the maximum load setting, the relay switches to the normal run curve. Subsequent overloads will time out on the inverse time run curve (Figure 3-2). If the motor current does not drop below the maximum load setting within the start time, the relay will trip with a start and overload indication.

When using the memory feature, the heat build up within the motor is accurately simulated and kept within safe limits. Since heat is dissipated in the motor during starting, the available overload time during running after a start will be reduced accordingly.

If the relay is to be used for an application other than rotating machinery the start timer can be defeated (Section 3-10). In this mode, the relay will always respond to overloads according to the run curve. Operating in this mode may be useful for protecting transformers, feeder cables or motors that have multitap reduced voltage starters which allow the load current to fall below the full load value during acceleration.



### 3.5 UNDERCURRENT CONTROL

This control, used to detect loss of load, is calibrated in percentage of the maximum load control. When the motor current drops below the control set point the undercurrent indicator (U/C) comes on and the auxiliary relay closes (if selected, Section 3-10). This auxiliary relay operates a separate set of contacts from the main relay and is used for warning or process control functions.

Typical uses for the undercurrent control include protection of pumps from loss of suction, fans from loss of airflow due to a closed damper or conveyor system from a broken belt.

For example, if the maximum load control is set to cause an overload condition when a pump draws 100 amps, setting the undercurrent control to 60% will cause the auxiliary relay to activate an alarm when the current drops below 60 amps which might represent loss of suction.

A further use of this control is as a preoverload warning. Suppose a fan normally drew 90 amps and the maximum load control was set to give an overload condition at 100 amps which was the maximum rating for the fan motor. If the undercurrent control was set at 95% the relay would always sense an undercurrent condition with the auxiliary relay energised. Bearing wear would cause the current to increase above 95 amps causing the undercurrent condition to drop out. If an alarm was wired across the normally closed contacts terminals 7 and 9, the alarm would sound above the normal current but before an overload occurred signalling an abnormal condition prior to actual shut down.

### 3.6 MEMORY

Heat build-up in the motor is simulated electronically by means of a memory circuit which integrates the phase currents over time. Motor start-ups or previous overloads are remembered by the circuit and reduce the remaining time available for future overloads. The memory will be fully discharged if no overloads occurred during the previous 30 minutes.

When a motor trips due to overheating, the relay will prevent restarting by locking out for 30 minutes to allow the motor to cool. Conditions which will not cause motor overheating do not lock out the relay. Table 3-2 shows which conditions will allow immediate reset and which require a 30 minute wait before reset.

**TABLE 3-2 MEMORY LOCKOUT CONDITIONS**

TRIP CONDITION	MEMORY LOCKOUT
Start	Yes
Overload	Yes
Jam-Rapid Trip	No
Short Circuit	No
Unbalance	No
Ground Fault	No
RTD High Temperature	No — Reduces Memory Capacity

Memory lockout can be defeated by setting option switch B5 on (Section 3-10) allowing immediate resetting after any trip condition. Since no memory can allow a motor burnout for multiple starts or overloads, this setting should only be used with caution where production considerations are more important than motor protection.

During loss of control power the memory discharges at the same rate as when power is applied. When power is restored the relay will automatically revert to a lockout/trip state if it was in this condition before loss of power and sufficient cooling time has not elapsed. However the lockout condition causing the trip is not indicated after power is re-applied.

### 3.7 EMERGENCY RESTART

During testing of the relay or when production and safety considerations override motor protection needs, it may be desirable to reset the relay from a memory lockout condition. Placing a wire across terminals 3 and 4 for several seconds when emergency restart is enabled (Section 3-10) will discharge the memory. It is now possible to reset the relay by pushing the reset button. A key switch wired across these terminals can be left in the memory mode (contacts open) then switched to discharge the memory whenever it is required to set the relay from a lockout mode. Since previous starts and overloads are ignored, lack of caution using this feature could lead to a motor burnout.

### 3.8 RUN CURVE SELECTION

Fifteen different run curves are provided to tailor the relay to the exact thermal requirements of the motor being protected. These curves are numbered in Figure 3-2 and are selected by 4 switches according to Table 3-3. These switches are located on the large circuit board as shown in Figure 2-3. Curve numbers that are not shown in Figure 3-2 for clarity lie in between curves of adjacent numbers.

If the manufacturer's data for the motor is available this can be plotted directly on the run curve figure and the next lower curve chosen. In absence of this information the curve which has the closest value to the locked rotor time at 6 times full load current would be the best choice.

If short circuit protection is enabled the relay will trip in approximately 100ms when the phase current exceeds about 10 times the full load setting. Short circuit protection should only be selected if the motor breaker or contactor is capable of opening safely under short circuit conditions. If switch A8 is turned off, short circuit protection will be enabled.

**TABLE 3-3 OVERLOAD LEVEL SWITCH SETTINGS**

FUNCTION		OVERLOAD LEVEL SWITCH SETTINGS							
X = Switch On 0 = Switch Off — = No Effect		A1	A2	A3	A4	A5	A6	A7	A8
Run Curve No.	Locked Rotor Time (Seconds)	Run Curve Selection				Rapid Trip			S/C
1	2.5	0	X	X	X	—	—	—	—
2	5	X	0	X	X	—	—	—	—
3	7.5	0	0	X	X	—	—	—	—
4	10	X	X	0	X	—	—	—	—
5	12.5	0	X	0	X	—	—	—	—
6	15	X	0	0	X	—	—	—	—
7	17.5	0	0	0	X	—	—	—	—
8	20	X	X	X	0	—	—	—	—
9	22.5	0	X	X	0	—	—	—	—
10	25	X	0	X	0	—	—	—	—
11	27.5	0	0	X	0	—	—	—	—
12	30	X	X	0	0	—	—	—	—
13	32.5	0	X	0	0	—	—	—	—
14	35	X	0	0	0	—	—	—	—
15	37.5	0	0	0	0	—	—	—	—
NO RAPID TRIP		—	—	—	—	—	—	0	—
150% RAPID TRIP		—	—	—	—	X	X	X	—
200% RAPID TRIP		—	—	—	—	X	0	X	—
250% RAPID TRIP		—	—	—	—	0	X	X	—
300% RAPID TRIP		—	—	—	—	0	0	X	—
Short Circuit Defeat		—	—	—	—	—	—	—	X

### 3.9 MECHANICAL JAM RAPID TRIP

In protecting driven equipment such as pumps, gearboxes, compressors and bandsaws, it is often desirable to have an immediate trip in the event of a locked rotor during running. Table 3-3 shows switch settings for current surge levels from 150-300% of the maximum load current at which the relay will trip after 1 second. During startup the rapid trip is disabled because a typical inrush of 600% is normal. Use of this feature with loads that experience overloads as part of normal operation such as crushers is not recommended.

Rapid trip selection can be shown on the run curves of figure 3-2 by plotting a line horizontally at a time to trip of one second, and vertically from the rapid trip overload factor until it intersects with the selected curve.

## 3.10 OPTION PROGRAMMING

Each relay can be programmed for a particular application using a group of selector switches. This provides flexibility since only the desired features are used and the settings can be changed at any time. Table 3-4 is a summary of the switch options.

**TABLE 3-4 OPTION SWITCH SETTINGS**

FUNCTION	OPTION SWITCH SETTINGS							
	B1	B2	B3	B4	B5	B6	B7	B8
X = Switch On O = Switch Off — = No Effect								
Cyclic Overload Compensation	X	—	—	—	O	—	—	—
Immediate Overload Warning	—	X	—	—	—	—	—	—
Disable Undercurrent	—	—	X	—	—	—	—	—
Emergency Restart	—	—	—	X	—	—	—	—
Memory Defeat	—	—	—	—	X	—	—	—
Motor Temperature Compensation	—	—	—	—	—	X	—	—
Voltage Compensation	—	—	—	—	—	—	X	—
Enable Feeder Protection	—	—	—	—	X	—	—	X

### Switch B1—Cyclic Overload Compensation

In applications where the motor periodically goes into overloads such as crushing, switches B1 should be on and B5 off. Motors of this type are designed for frequent short overloads but the relay memory would accumulate the overloads and eventually trip. Cyclic overload compensation causes the memory to discharge every time the motor recovers from an overload but still allows repeat start protection from jogging. A continuous overload will still trip according to the run curves (Figure 3-2).

### Switch B2—Immediate Overload Warning

Turning this switch on will cause the auxiliary relay to be activated whenever the relay senses an overload providing a useful warning signal. Since overloads are normal during start up, this function is not active when the relay is in start mode.

### Switch B3—Undercurrent Detection

An undercurrent condition will activate the auxiliary relay if this switch is off. When the auxiliary relay is to be activated by a condition other than undercurrent this switch should be set on.

### Switch B4—Emergency Restart

It may be necessary to disable the emergency restart terminals 3 and 4 to prevent unauthorised reset of the relay after a lockout. Turning switch B4 off disables the emergency restart feature.

### Switch B5—Memory Defeat

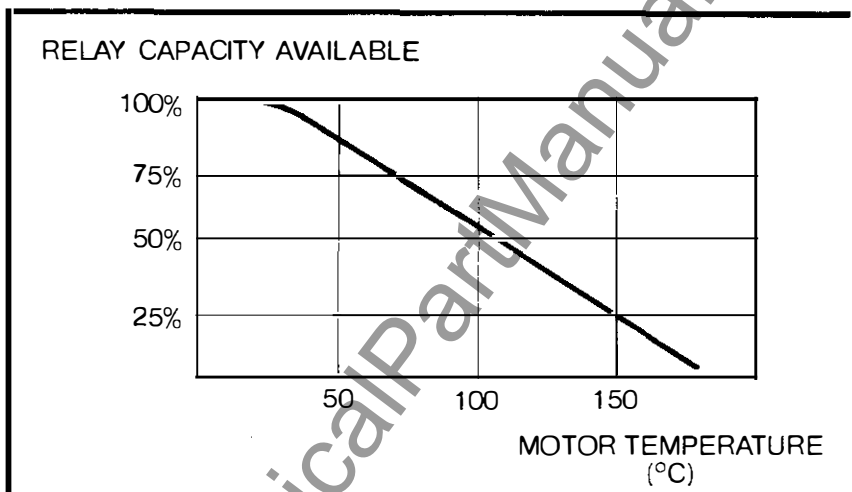
Each relay incorporates a memory which simulates heat buildup in the motor by accumulating previous overloads and start-ups reducing the time available for future overloads. When the memory is defeated by turning switch B5 on, the unit can be reset immediately after a trip instead of the normal 30 minute lockout. Only a continuous overload or start will cause a trip when the memory is defeated. Previous overloads and starts will have no effect.

### Switch B6—Motor Temperature Compensation

When the relay is equipped with the overtemperature option, the memory capacity available in the relay can be reduced proportional to the temperature of the motor winding RTD by turning this switch on. An improvement in motor protection results because the effects of a hot motor due to factors like blocked ventilation which can't be predicted from phase currents alone are compensated for. The available relay trip time reduces linearly so that at approximately 100°C the start timer setting and overload time available (from run curves Fig. 3-2) are reduced 50% to represent a hot motor. Figure 3-3 shows the relationship between RTD temperature and derating of start and overload times.

This switch has no effect on relays that aren't equipped with the over temperature option.

**FIGURE 3-3—RTD HOT MOTOR COMPENSATION**



### Switch B7—Voltage Compensation

When the supply voltage to the motor drops from its normal value, the run-up time of the motor will increase by the square of the change but the heating effect will be the same despite the longer time because of the decreased current. By turning this switch on, the start timer value will be multiplied by:

$$\frac{(\text{normal starting current})^2}{(\text{actual starting current})^2}$$

$$\frac{6^2}{5^2} \times 20 = 28.8 \text{ seconds.}$$

It is assumed that the normal inrush current is 6 times full load. If the actual inrush current was only 5 times full load because of reduced supply voltage and the start timer had been set to 20 seconds, the actual start time allowed would be:

$$\frac{6^2}{5^2} \times 20 = 28.8 \text{ seconds.}$$

Similarly for an overvoltage condition the start time would be reduced. This feature is only active during starting because the effects of a change in supply voltage will automatically show up in the current during running which will adjust the trip time according to the run curve.

If the supply voltage fluctuates significantly and a fixed start time is not required this feature is useful. Note that the motor inrush current must be approximately 6 times full load when using this compensation; otherwise set the start timer as follows:

$$\text{Actual Start Timer} = \frac{(\text{Normal Start})}{(\text{Time})} \times \frac{(\text{Actual start current multiples of full load})^2}{6}$$

Example—Normal start time—20 seconds.

Full voltage actual inrush current—4.5 times full load.

$$\text{Set start timer to} = \frac{(20)(4.5)^2}{(6)^2} = 11.3 \text{ seconds.}$$

### Switch B8—Feeder Protection

The relay can be used to protect loads other than rotating machinery by turning this switch on which defeats the start timer. In this case, the run curve selected is always active and the relay behaves as an inverse/time overload device with the following features:

- (i) 3 phase overcurrent protection—The time/overload characteristic of the relay is matched to the device being protected by suitable adjustment of the maximum load control and selection of the appropriate run curve (Section 3.8).
- (ii) Rapid trip at high currents—Using the mechanical jam levels (Section 3.9) or short circuit an immediate cutout at high fault currents can be obtained.
- (iii) Phase Unbalance Protection—the desired level of phase unbalance that is acceptable can be selected by the unbalance control.
- (iv) Ground Fault Protection—Ground faults between the protected device and ground can be detected to obtain first an alarm and then a shutdown. Fault current level and time delay to trip are adjustable.

These features make the relay particularly useful for protection of transformers, feeder cables in portable substations and arc furnace electrodes. Normally the memory will be defeated (Switch B5 on) when operating in this mode to prevent a lockout or nuisance trip from repeated short overloads.

## 3.11 GROUND FAULT (EARTH LEAKAGE)

An insulation breakdown in the motor windings can provide a current path between the motor casing (ground) and the high voltage supply. When this occurs, not only is it desirable to shut the motor down before severe structural damage occurs but also the motor casing may be above ground potential, thus presenting a safety hazard to personnel.

A separate current transformer which encircles all the motor conductors is also required to provide the sensing signal. Ground fault detection is only suitable for systems that have a path from the supply neutral to ground either through a resistance or by direct connection. The current transformer ratio, required for ground fault detection on the 139 is 2000:1.

By means of an internally mounted selector switch the relay can be set to trip for ground fault currents of 0.5, 1, 4, 8, 12 amps with instantaneous trip, 100 millisecond delay or two second delay. On solidly grounded systems the instantaneous trip should be used. The 100 millisecond delay is provided for applications where the relay has to be co-ordinated with other protective devices or a short delay is desired because of transients. The two second time delay is provided for use on high resistance grounded systems where nuisance tripping may be a problem.

An alarm is provided to activate the auxiliary relay when the ground fault current exceeds 50% of the selected value. This is especially useful in mines where moisture buildup in the windings may start to cause excessive leakage.

**If ground fault detection is not being used (ie. ZSCT not connected), ensure that switch C1 is on and switches, C2-C8 are off.**

The eight ground fault selector switches control ground fault functions according to Table 3-5. Figure 2-3 shows the location of these switches.

**TABLE 3-5 GROUND FAULT SWITCH SETTINGS**

FUNCTION	GROUND FAULT SWITCH SETTINGS							
	TRIP AMPS					TRIP TIME		ALARM
	C1	C2	C3	C4	C5	C6	C7	C8
X = Switch On O = Switch Off — = No Effect								
NOT USED	X	O	O	O	O	O	O	O
12 Amp Trip	X	O	O	O	O	—	—	—
8 Amp Trip	O	X	O	O	O	—	—	—
4 Amp Trip	O	O	X	O	O	—	—	—
1 Amp Trip	O	O	O	X	O	—	—	—
0.5 Amp Trip	O	O	O	O	X	—	—	—
No Trip Delay	—	—	—	—	—	X	X	—
100 mS Trip Delay	—	—	—	—	—	O	X	—
2 Second Trip Delay	—	—	—	—	—	O	O	—
Enable Ground Fault Alarm	—	—	—	—	—	—	—	X

**EXAMPLE (NOMINAL FACTORY SETTING):**

Required sensitivity 8 amps ground fault current—Switch No. 2 on.

Required trip delay 100mS—Switch 7 on.

Enable ground fault alarm—Switch 8 on.

### 3.12 OVERTEMPERATURE OPTION

Protection against excessive motor temperature due to loss of ventilation or high ambient temperatures is provided by the RTD option which must be ordered with the relay if required. A resistance temperature detector (RTD) supplied by the customer, is placed in the motor stator slots or air stream and provides the sensing signal to the relay. The standard sensor is a 3 wire, 100 ohm platinum RTD although other types can be accommodated upon request. If temperature sensing from a thermistor is required consult factory.

Two additional terminals are provided to give a direct readout of temperature using any standard voltmeter. The output voltage changes 10mV/°C from 0 volts at 0°C. Thus, 85°C would cause a voltage of 0.85 volts between terminals D and E. Any digital voltmeter with a 0-2 volt range would be suitable as a readout device although a panel mount model marked in °C is available from Multilin. Even if no permanent display meter is used, the terminals can be probed after a trip to detect heat build-up within the motor.

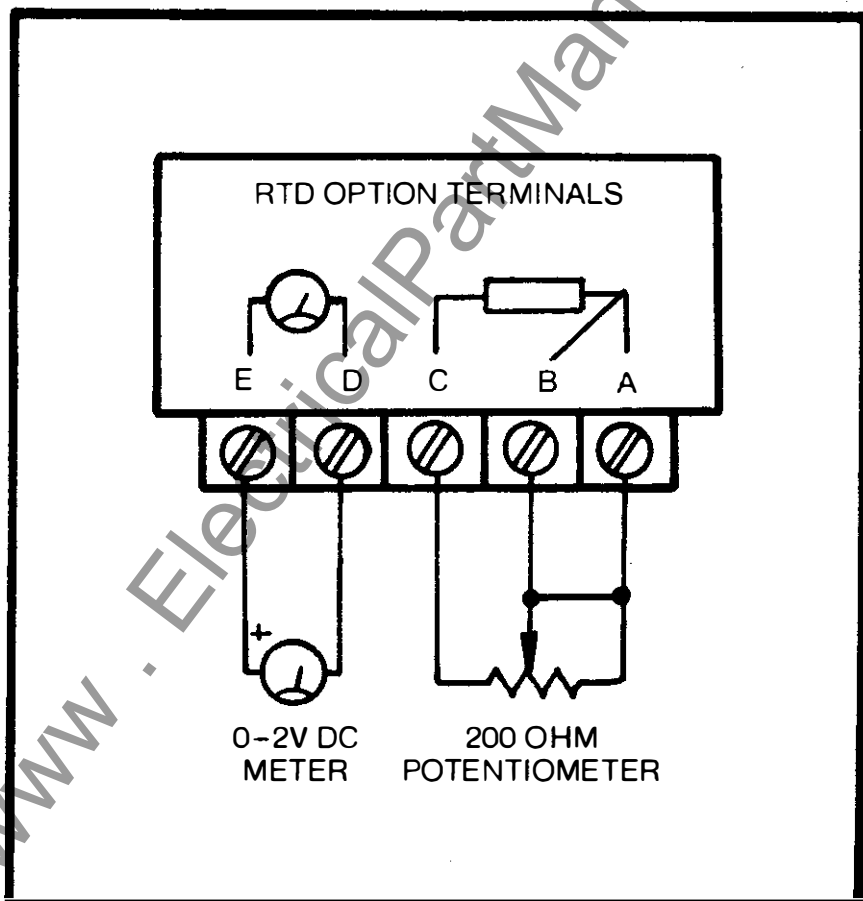
The RTD circuitry is factory calibrated to operate the auxiliary relay at 110°C unless otherwise specified. Connecting an alarm to the output of this set of contacts would give a warning but still allow the motor to run. The RTD indicator will come on when the temperature exceeds the preset alarm value. When the

sensor temperature reaches 130°C the main relay trips shutting down the motor. The relay cannot be reset until the RTD temperature falls below the trip value.

Different alarm and trip temperatures can be factory preset upon request. The nominal factory settings are recommended for use with class B winding insulation or class F insulation with class B temperature use. It is possible to change the alarm and trip temperatures in the field if required. To make these changes a 200 ohm potentiometer is connected across terminals A, B, C as shown in Figure 3-4 to simulate the RTD sensor

The potentiometer is varied until a voltmeter across terminals D and E reads the desired alarm or trip temperature. The preset alarm or trip temperature trimpot in the relay as shown in Figure 2-3 is then adjusted until the auxiliary relay (alarm) or main relay (trip) just picks up. There is a short time delay after the threshold temperature is reached before the relay is activated. Care should be taken to ensure the settings of the RTD calibration trimpots are not altered.

**FIGURE 3-4 SETTING RTD TRIP/ALARM TEMPERATURES**





### 3.13 THERMAL CAPACITY

In processes where the motor loads are varied and operated at near the motor full load such as in grinding or in conveyor systems it is useful to know how close the relay is to tripping so the load may be adjusted accordingly. When the thermal capacity option is ordered with the relay a remote meter, calibrated from 0-100% of motor capacity used, is available to be situated near the operator and connected to the relay. The meter indicates how much the memory has charged corresponding to heat buildup in the motor. When the relay is about to trip, the meter will approach 100% capacity used. After a trip, the meter will indicate how much charge is left in the memory to give a rough idea of the lockout time remaining.

### 3.14 4-20mA FULL LOAD OUTPUT

If the relay is to be used in conjunction with programmable controllers, automated equipment, or a chart recorder, this option can be ordered. A 4-20mA current corresponding to 0-100% of the motor full load current as set on the maximum load control is output. Thus a computer can be used to automatically shed loads as the motor current increases or a chart recorder can be used to plot the loading of a motor in a particular process.

Other output ranges of motor full load current can be obtained on special factory order.

### 3.15 FAULT DIAGNOSIS

A valuable feature of the relay is its ability to record the fault condition which caused the motor to be shut down for later analysis. All the conditions present at the moment of tripping except for undercurrent continue to be displayed on the front panel indicators until the relay is reset. The Multilin Fault Finder shown in Figure 3-5 allows the user to determine the likely cause of trouble by examining the relay display.

### 3.16 CONTROL POWER

Control power should always be applied to the relay before the motor is started. Even if control power is removed the memory will remain active discharging at a rate proportional to an idle motor. If control power is removed from a relay in the lockout condition, it will remain locked out after power is reapplied unless sufficient time has elapsed. Whenever control power is removed and reapplied, the condition causing the trip will not come on. If control power is removed when in an untripped state, it is not necessary to press the reset button in order to restart the motor, when control power is reapplied.

Relays are normally supplied with fail safe contacts so that the output reverts to a trip condition when control power is lost. It is possible to obtain the relay on special order with a contact configuration which allows motor starting if control power is lost.

FIGURE 3-5 MULTILIN FAULT FINDER



TRIPPED RELAY INDICATION								PROBABLE CAUSE OF TRIP
U/B	O/L	START	RTD	G/F	TRIP	U/C	ON	
<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<b>START TIMER EXCEEDED</b> – locked rotor – too many starts – start timer set too low
<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<b>OVERLOAD</b> – excessive overloads during running – mechanical jam rapid trip – short circuit
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<b>HIGH TEMPERATURE (RTD OPTION)</b> – blocked ventilation – cooling fans blocked – high ambient temperature
<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<b>BLOWN FUSE START</b> – check fuses
<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<b>EXCESSIVE UNBALANCE</b> – blown fuses – single phase supply – loose wiring connection – short between motor windings
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<b>GROUND FAULT</b> – motor winding to case short – wiring touching metal ground
<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<b>GROUND FAULT</b> – motor winding to case short – wiring touching metal ground
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<b>MEMORY LOCKOUT</b> – memory still locked out after power is applied
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<b>UNDERCURRENT ALARM</b> – pump loss of suction – pump closed discharge valve – blower loss of airflow – conveyor overload warning

## 4 RELAY TESTING

### 4.1 SECONDARY INJECTION TEST EQUIPMENT

Although it is possible to verify correct relay operation after installation without any special equipment it may be desirable to check all relay functions before commissioning. Basic operation of the relay can be checked using a commercial secondary injection set capable of supplying up to 15 amps. Since the relay operates on average RMS current values, a single phase current source is adequate. Figure 4-1 is the schematic of a simple test circuit that can be built to perform all the tests described in the following sections.

### 4.2 COMMISSIONING RELAY TESTS

Prior to applying power to a new installation, system operation can be verified by applying currents through the relay current transformers using a primary (high current) injection test set. Alternately, operation of all system components except the phase CTs can be checked by disconnecting the current transformer secondaries and applying an input signal to the relay using a secondary injection test set similar to that shown in Figure 4-1.

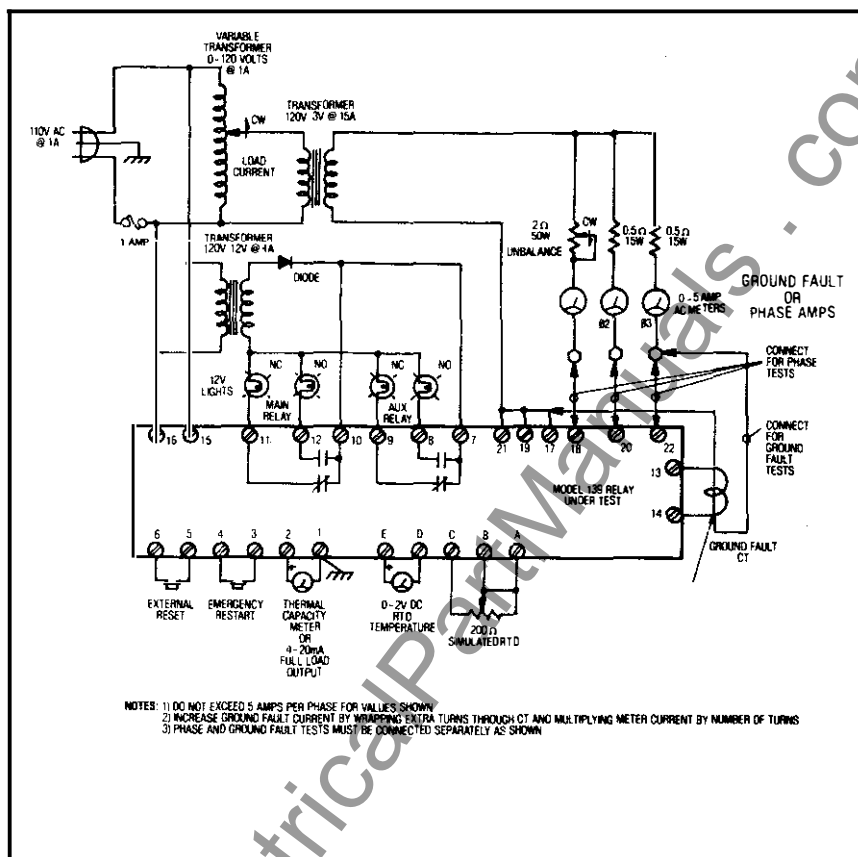
### 4.3 OVERLOADS

Determine from the yellow product specification card whether the relay is designed for 1 amp or 5 amps CTs. Set the maximum load control to 50% of CT amps. The overload light should come on when injecting equal currents in all three phases of 0.5 amps (1 amp CT's) or 2.5 amps (5 amp CTs). Other points across the scale can also be checked. Verification of the overload/time curve (Figure 3-2) is possible by setting a known amount of overload and determining the time to trip. For example, with a 5 amp CT relay and the maximum load control set at 50%, injecting 5 amps in each phase will cause the relay to trip within 117 seconds if run curve number 4 has been selected. To get accurate measurements it is necessary to know which run curve has been selected (Section 3.8), to ensure that the memory is fully discharged by using the emergency restart feature (Section 3.7), and to ensure that the relay does not go into start mode by slowly increasing the current to the overload level.

Once the relay has tripped due to the overload test it should not be possible to reset it if the memory is being used. Connect a jumper across emergency restart terminals 3 and 4 for 5 seconds to discharge the memory. The relay can now be reset for further tests.

If the relay is programmed for mechanical jam rapid trip (Section 3.9) set the maximum load control to 100% and inject 5 amps (5 amp model) or 1 amp (1 amp model). Slowly dial back the maximum load control until the relay trips. The current injected should exceed the full load control setting by the jam level selected. For example, if mechanical jam rapid trip was set for 2 times full load, with 5 amps injected (5 amp CT model) the relay would trip at a maximum load setting of 50% since 5 amps represents a current level of twice full load. Furthermore, unlike prolonged overloads which cause lockout when the memory is used it should be possible to immediately reset the relay after mechanical jam.

FIGURE 4-1 SECONDARY INJECTION TEST SET SCHEMATIC



## 4.4 START TIMER

Before performing any start timer tests discharge the memory by connecting a jumper across emergency restart terminals 3 and 4 for 5 seconds. With the voltage compensation switch off (Section 3.10) turn on the injection set so that a balanced overload is immediately applied to the relay. This will simulate motor starting causing both the overload and start lights to come on. The relay should trip after the time set on the start timer. On start time and overload tests, there will be a 30 minute lockout before resetting is possible if the injected signal is removed as soon as the relay has tripped. Delaying removal of the applied signal after a trip allows the relay to continue charging and may result in a much longer lockout period.

If the voltage compensation switch is left on the actual start time will differ from the dial setting as explained in Section 3.10.

## 4.5 UNBALANCE

Unbalance detection is simulated by injecting a different current in each of the 3 phases and noting the unbalance control setting at which the unbalance light comes on. The scale value at this point should correspond to the degree of unbalance simulated according to the formulae of Section 3.3. For example, using a 5 amp CT relay with the full load control set at 60% and the unbalance control at 50% inject phase currents of 2 amps, 2 amps and 1 amp. Dial the unbalance control back until the unbalance light comes on. The value at this point should be approximately 22% as determined from:

$$\frac{|\bar{I}_n - \bar{I}_{av}|}{\bar{I}_{FLC}} \times 100$$
$$= \frac{|1 - 1.66|}{0.6 \times 5} \times 100$$
$$= 22\% \text{ Unbalance}$$

After about 5 seconds of continuous unbalance the relay should trip.

## 4.6 UNDERCURRENT

Set the full load control to 50% and the undercurrent control to 60%. When the injected current falls below 60% of the maximum load setting the auxiliary relay will be activated if this feature has been enabled (Section 3.10). Thus for a 5 amp CT relay, when the input current falls below 60% of (0.5x5 amps) = 1.5 amps the auxiliary relay will be activated with the undercurrent light on. Increasing the current clears the condition automatically.

## 4.7 GROUND FAULT

Connect a single phase through the window of the ground fault current transformer as shown in Figure 4-1. Note the required trip current and time from the yellow product specification card and Section 3.11. Increase the current from the test set until the relay trips with the ground fault light on. It should require a current equal to the setting value +0, -25% to cause a ground fault trip. If the ground fault alarm is enabled, the auxiliary relay should activate at a current approximately one half this value.

## 4.8 OVERTEMPERATURE OPTION

If the relay is equipped with the RTD option, an overtemperature can be simulated by substituting for the RTD sensor a resistance equivalent to the sensor resistance at high temperatures. A 200 ohm potentiometer is connected in place of the RTD sensor as shown in Figure 4-1. The relay can be made to alarm or trip by setting the potentiometer to the appropriate resistance corresponding to the preset temperatures which are nominally; alarm at 110°C, trip at 130°C. Table 4-1 gives temperature resistance relationships for 100 ohm platinum, 120 ohm nickel and 10 ohm copper RTD sensors.

The actual temperature the relay is measuring can be checked if a voltmeter is connected across the temperature output terminals as shown in Figure 4-1. The reading is 10mV/°C from 0 volts at 0°C.

**TABLE 4-1 RTD RESISTANCE VS TEMPERATURE**

TEMPERATURE °C	100 OHM PLATINUM	120 OHM NICKEL	10 OHM COPPER
0	100.00	120.00	9.04
10	103.90	127.17	9.42
20	107.79	134.52	9.81
30	111.67	142.06	10.19
40	115.54	149.79	10.58
50	119.39	157.74	10.97
60	123.24	165.90	11.35
70	127.07	174.25	11.74
80	130.89	182.84	12.12
90	134.70	191.64	12.51
100	138.50	200.64	12.90
110	142.29	209.85	13.28
120	146.06	219.29	13.67
130	149.82	228.96	14.06
140	153.58	238.85	14.44
150	157.32	248.95	14.83
160	161.04	259.30	15.22
170	164.76	269.91	15.61
180	168.47	280.77	16.00
190	172.16	291.96	16.39
200	175.84	303.46	16.78

## 4.9 ROUTINE MAINTENANCE VERIFICATION

Once a relay has been successfully installed, periodic tests as part of the plant maintenance program can be performed to check correct operation of the protection system. Each condition can be simulated without actually creating an overload unbalance etc. which is generally not practical. Place a jumper across emergency restart terminals 3 and 4 for 5 seconds before each test to ensure the memory is fully discharged.

**OVERLOADS** — With the motor running, dial back the full load control until the overload light comes on. The dial reading at this point should correspond to the RMS current measured in the motor leads with an ammeter. If half this current is quickly set on the full load control, the relay now sees a current of 2 times the full load setting. Consult the appropriate run curve from Figure 3-2 to determine the time to trip at this overload level. After the relay has tripped the motor it should not be possible to reset for about 30 minutes if the memory is activated.

**LOCKED ROTOR** — To simulate a locked rotor trip or excessive run up time, set the start timer to be less than the actually measured run up time of the motor. Start the motor. After the selected start time the relay should trip with the start and overload lights on. If the voltage compensation switch is on this time will be different from the dial value according to Section 3.10.

**UNBALANCED CONDITIONS** — Dial back the unbalance control until the unbalance light just stays on. This is the measured unbalance to the motor. After 5 seconds of continuous unbalance the relay should shut down the motor with the unbalance light on. If the residual plant unbalance is too low for any unbalance indication, remove one of the phase CT inputs to simulate a single phase condition after first placing a short across the phase CT terminals to prevent a shock hazard.

**UNDERCURRENT** — With the motor running slowly dial back the undercurrent control from 100% until the undercurrent light goes out. The undercurrent percentage at this point times the motor full load current setting should correspond to the actual current drawn by the motor.

**OTHER FUNCTIONS** — Routine testing of the other functions such as ground fault and overtemperature is similar to the procedures outlined in Sections 4.7 and 4.8.

## 4.10 PROBLEM TROUBLESHOOTING

Often a correctly functioning relay will appear to have a problem because switch settings or operation are not understood. Table 4-2 is a guide to help operators determine what steps are necessary to correct an apparent problem. Ensure that all switch settings are known before attempting to investigate confusing results. If problem symptoms cannot be explained after consulting Table 4-2 contact a factory service centre to determine if the relay is defective.

**TABLE 4-2 PROBLEM TROUBLESHOOTING GUIDE**

SYMPTOM	PROBABLE CAUSE	ACTION
Relay won't reset	<ul style="list-style-type: none"> <li>locked out after trip</li> <li>condition still persists, e.g. Hot RTD above trip temperature.</li> </ul>	<ul style="list-style-type: none"> <li>place short across emergency restart terminals for 5 seconds then press reset. Switch B4 must be on.</li> <li>allow motor to cool or disconnect RTD input.</li> </ul>
Excessive Unbalance	<ul style="list-style-type: none"> <li>unloaded new plant -- high voltage unbalance.</li> <li>CTs incorrectly sized.</li> <li>periodic surges</li> </ul>	<ul style="list-style-type: none"> <li>set unbalance control higher.</li> <li>change load distribution.</li> <li>check CT ratios.</li> <li>normal, will not cause nuisance tripping unless continuous.</li> </ul>
Periodic Overload Tripping.	<ul style="list-style-type: none"> <li>overload surges.</li> <li>cyclic overloads (crushers etc).</li> <li>incorrect run curve selected.</li> </ul>	<ul style="list-style-type: none"> <li>increase or defeat mechanical jam level.</li> <li>turn on cyclic overload switch or defeat memory</li> <li>use run curve with longer trip times.</li> <li>increase maximum load control setting.</li> </ul>
Start Time too short/long.	<ul style="list-style-type: none"> <li>voltage compensation switch on.</li> <li>previous overload, starts shorten time available</li> </ul>	<ul style="list-style-type: none"> <li>consult Instruction Manual Section 3.10.</li> <li>use emergency restart to discharge memory before test.</li> </ul>
Start light flickers relay trips periodically.	<ul style="list-style-type: none"> <li>lightly loaded motor causes relay to see start condition.</li> </ul>	<ul style="list-style-type: none"> <li>decrease maximum load control setting.</li> </ul>
RTD Trip — motor not running	<ul style="list-style-type: none"> <li>hot RTD above trip temperature.</li> <li>no RTD connected at motor.</li> <li>unshielded leads or noise pickup.</li> <li>if using thermistor option, no thermistor connected.</li> </ul>	<ul style="list-style-type: none"> <li>allow motor to cool.</li> <li>disconnect RTD wires running from relay to terminals in switchgear.</li> <li>shield wires, check for correct connections, reroute away from noise sources.</li> <li>place jumper across unused thermistor terminals.</li> </ul>
Alarm not working. <ul style="list-style-type: none"> <li>immediate overloads.</li> <li>RTD</li> <li>ground fault.</li> <li>undercurrent</li> </ul>	<ul style="list-style-type: none"> <li>not enabled inside relay.</li> </ul>	<ul style="list-style-type: none"> <li>check relay switch settings. (Manual Section 3.10).</li> </ul>
Ground Fault nuisance tripping.	<ul style="list-style-type: none"> <li>set too sensitive.</li> <li>noise</li> </ul>	<ul style="list-style-type: none"> <li>increase G/F trip level.</li> <li>increase G/F time delay.</li> <li>twist ground fault wires together and route away from heavy current conductors.</li> </ul>
All relay indicators off.	<ul style="list-style-type: none"> <li>no control power.</li> <li>control power applied to wrong terminals.</li> </ul>	<ul style="list-style-type: none"> <li>check for supply voltage at terminals 15 and 16.</li> <li>damaged components, return relay for repair.</li> </ul>



## 5. THEORY OF OPERATION

### 5.1 RELAY BLOCK DIAGRAM

The simplified block diagram of Figure 5-1 shows the main features of the relay. Further circuit details for troubleshooting at the component level are provided in the Model 139 Relay Service Manual available from Multilin.

Each phase is isolated through a matching current transformer. The AC RMS current is converted to the equivalent DC average voltage for each phase by 3 precision AC to DC converter/averager circuits. These three DC values are then sampled at a rate of 3KHZ by an electronic switch. Each signal is amplified according to the full load current control to normalize the signal so that 800mV is one full load regardless of the actual current this might represent. Other circuits such as short circuit, rapid trip and undercurrent then compare the actual current level to preset reference levels to determine if a fault exists.

The output of the 3 phase sampling multiplexer goes to a circuit which produces the average of each of the phase RMS values. This average is alternately subtracted from each of the 3 RMS phase values in the unbalance circuit. This normalized value is then divided either by the full load current or the average current during overloads to get the degree of unbalance. If this level exceeds the unbalance control setting, an unbalance fault signal is generated.

Overload timing is determined by charging an integrator memory circuit at a rate proportional to the average phase current squared. The output of the squaring circuit is placed in series with different resistor values to control the integrator charging current and hence the appropriate run curve for any given level of overload.

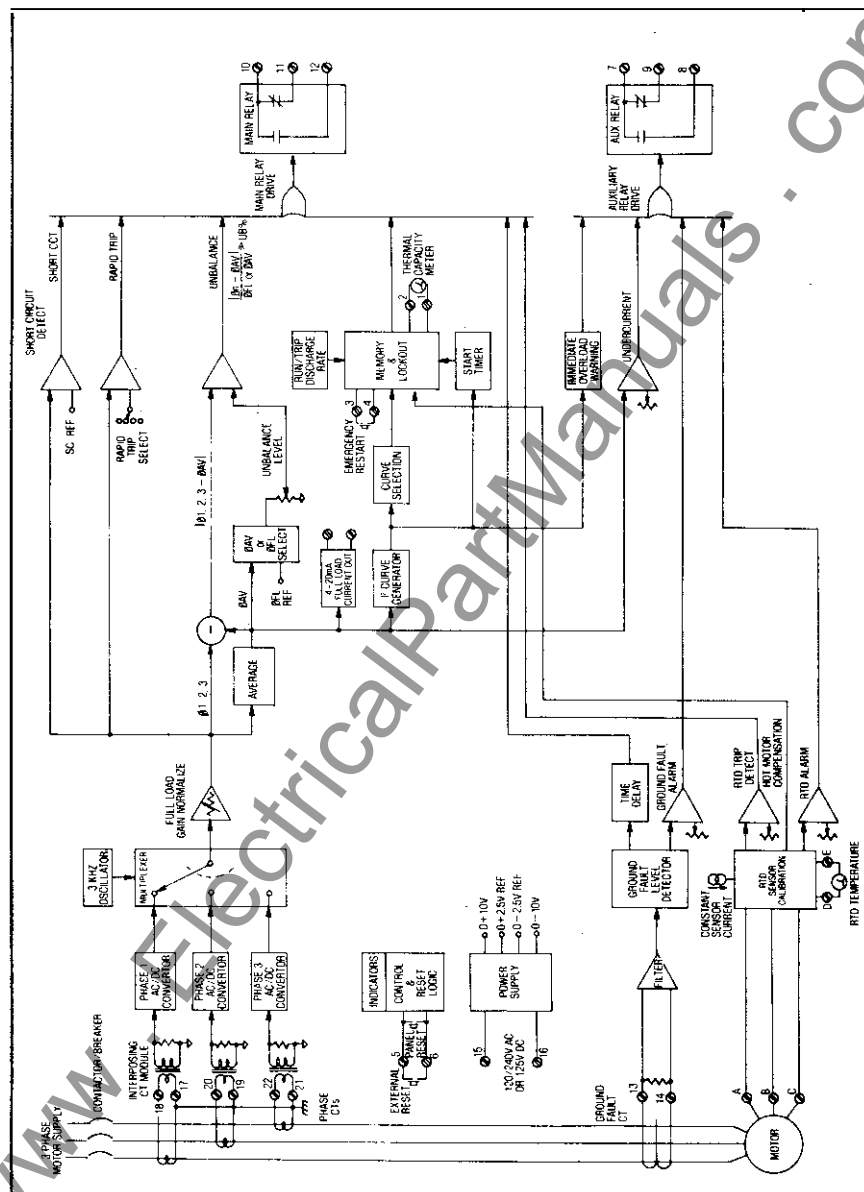
During startup mode, as determined by control circuitry, the integrator memory charges at a rate determined by the start timer. This rate is either directly in terms of the start timer settings from a reference voltage or proportional to the current squared when using the voltage compensation feature.

Only during idle operation or normal running will the memory integrator be given a chance to slowly discharge. Emergency restart or no memory options cause the memory to discharge rapidly at these times. After the integrator reaches the trip threshold, it must discharge to a much lower threshold before reset is possible producing the lockout characteristic.

A separate relay is provided for alarm functions such as immediate overload warning and undercurrent both of which are based on phase current level. RTD and ground fault alarms are also both available.

A constant current is passed through a remote RTD sensor in the overtemperature option. Three wires and a compensation circuit ensure that the temperature sensed is not affected by lead resistance. RTD circuitry converts the sensor resistance value to a voltage of 10mV/°C. Separate adjustable comparators are provided for detecting alarm and trip temperatures. A no sensor detection circuit eliminates false tripping when no sensor is connected or the RTD becomes damaged.

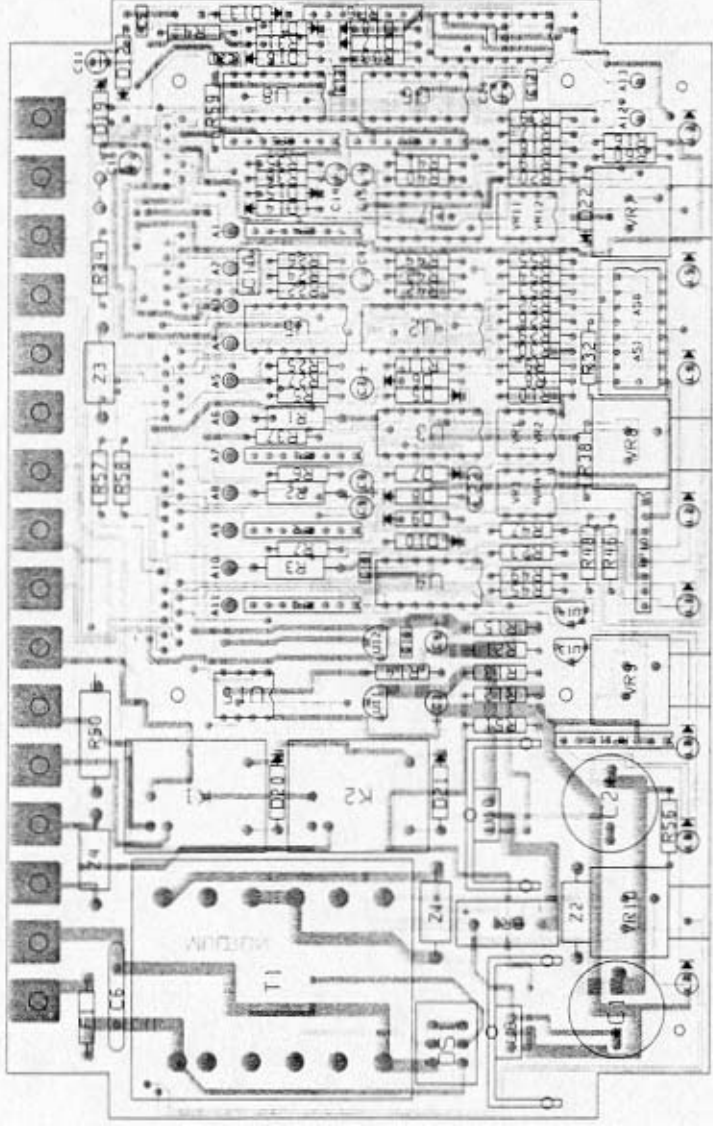
FIGURE 5.1



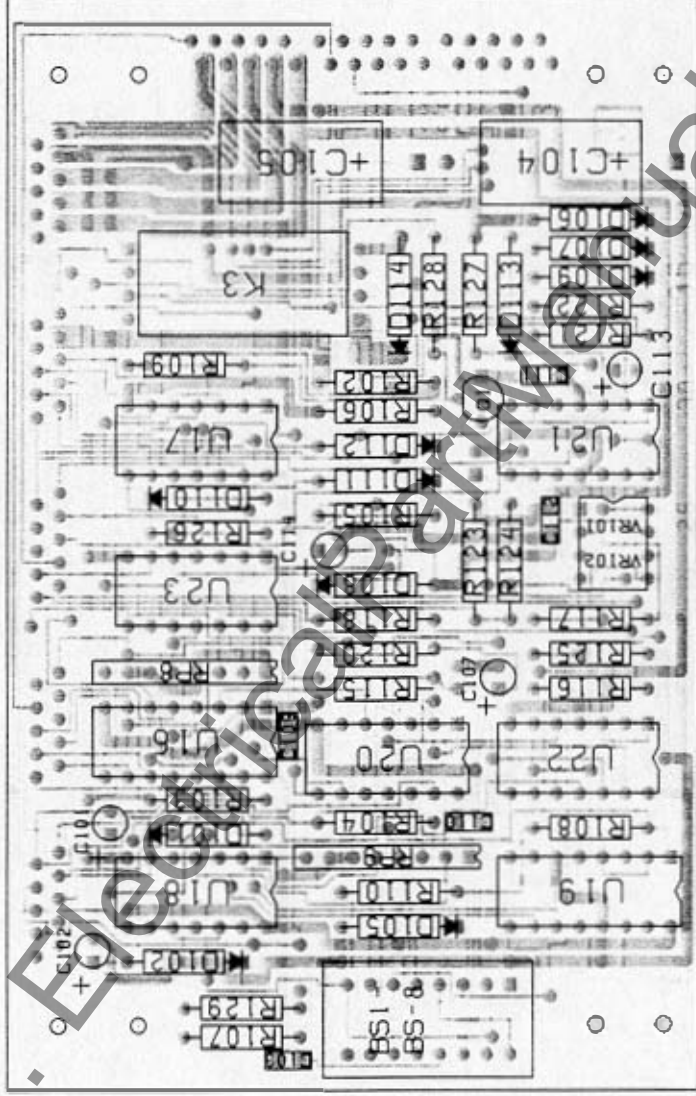
When a ground fault is detected, a 50HZ/60HZ current is generated by the ground fault current transformer. This low level signal passes through a differential amplifier and filter to remove common mode and high frequency noise. A comparator gives an output whenever this signal exceeds a selected threshold level. Further time delay of this signal can be selected before a trip signal is generated. A separate comparator generates an alarm signal at 50% of the trip level selected.

Power for the unit is provided by an AC transformer designed to accept a wide range of input signals. Solid state voltage regulators provide +10V, -10V to power the circuitry. Separate precision references provide +2.5V and -2.5V to give drift free calibration over temperature changes and time.

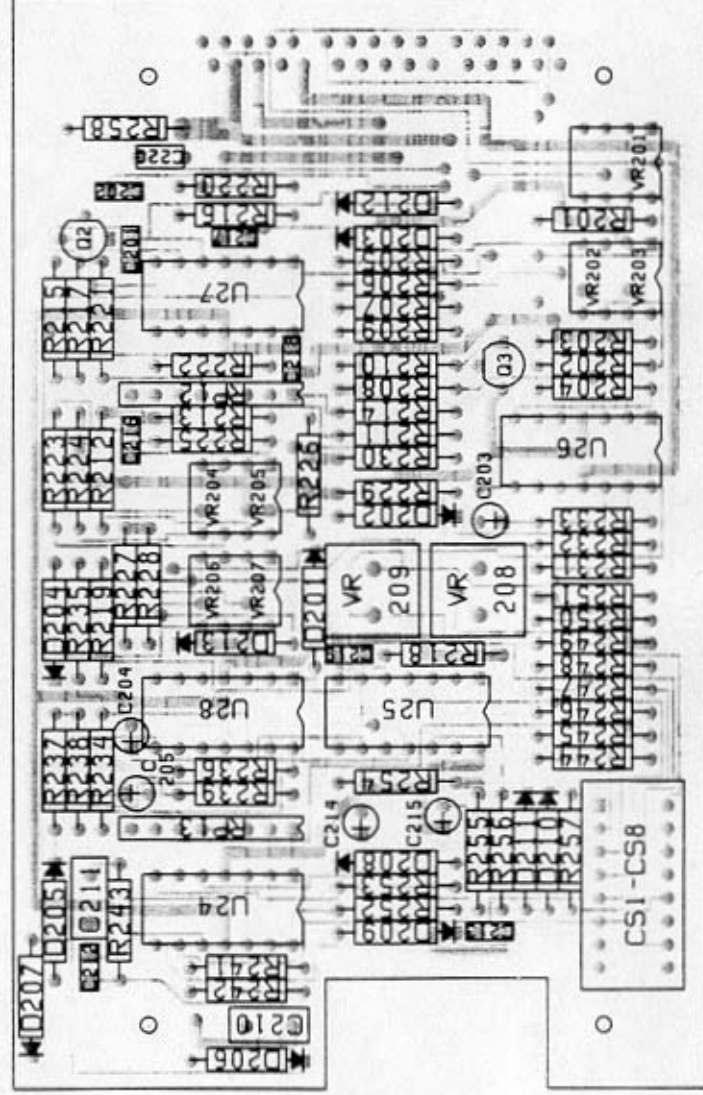




139A BOARD - COMPONENT SIDE



139B BOARD - COMPONENT SIDE



139C BOARD - COMPONENT SIDE



**MOTOR PROTECTION RELAY**



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