STARTCO
ENGINEERING LTD.

406 Jessop Avenue Saskatoon, Saskatchewan Canada S7N 2S5 Ph: (306) 373-5505 Fx: (306) 374-2245 www.startco.ca

FPU-16 MANUAL

FEEDER PROTECTION UNIT

REVISION 2

NOVEMBER 1997

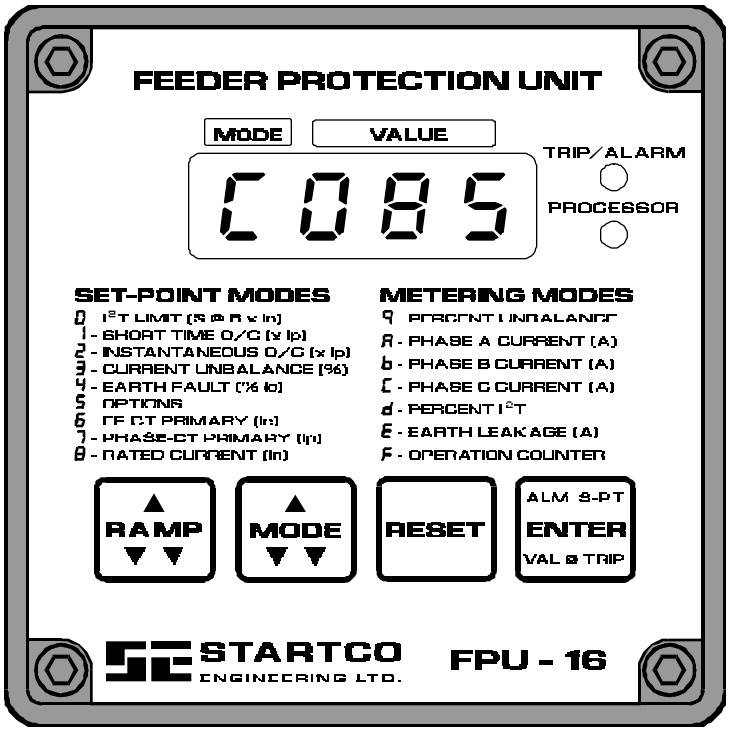

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TABLE OF CONTENTS

PAGE

TABLE OF CONTENTS

PAGE

LIST OF FIGURES

FIGURE **PAGE**

LIST OF TABLES

TABLE **PAGE**

1. INTRODUCTION

1.1 FEATURES AND OPTIONS

— I^2t thermal protection.
— Overcurrent protection.
— Current-unbalance protection.
— Earth-fault protection.
— Operation counter.
— Front-panel programming.
— Program-change lockout.
— Nonvolatile memory for programmed values and values-at-trip.
— Parameter-selectable, isolated analog output.
— Digital display of:
    Load current for Phase A, B, or C
    Percent current unbalance
    Earth-leakage current
    Percent I^2t
    Meter values-at-trip
    Minutes-to-reset
    CT-primary ratings
    Trip-and-alarm set points
    Operation counter.
— Provision for 5-A or 1-A CT's.
— -40°C to 60°C operating temperature.
— Optional dc supply voltage.
— Optional electroluminescent backlit display.
— Optional remote-keypad input.
— Optional RS-485 communications interface.

1.2 ORDERING INFORMATION

— Determine FPU-16 model number from Table 1.
— Supplied with ICT-2, ICT-2 interconnection cable (6 m, 20 ft), and mounting hardware.
— Order window-type CT (EFCT-1, EFCT-2, or other) for zero-sequence earth-fault detection.
— Order TU-16 test unit for training or functional testing.

FPU-16 MODEL NUMBER

FPU-16 - P126 - 000 - 42 - 00

Mount
- P Panel
- S Surface

Supply Voltage
- 12 120 Vac
- 24 240 Vac
- SW Switch Selectable 120/240 Vac
- AD 120/240 Vac/dc
- D1 12 Vdc
- D2 24 Vdc
- D4 48 Vdc

Note 3

Load Frequency
- 5 50 Hz (IEC Fusing)
- 6 60 Hz (CSA/UL Fusing)

Signal-Output Configuration
- 000 Analog Output Only
- 010 Communications Interface Only, Specify Analog-Output Type 00
- 011 Communications Interface and Analog Output, Output Parameter is CURRENT
- 012 Communications Interface and Analog Output, Output Parameter is I^2t
- 013 Communications Interface and Analog Output, Output Parameter is EARTH LEAKAGE

Note 1

Note 2

Analog-Output Type
- 42 4–20 mA
- 05 0–5 Vdc
- 01 0–10 Vdc
- 00 None

Options
- 00 No options
- 01 Electroluminescent Backlit Display
- 02 Remote-Keypad Input
- 03 Electroluminescent Backlit Display and Remote-Keypad Input
- 10 RS-485 Communications Interface, A-B Protocol
- 11 RS-485 Communications Interface, Modicon Protocol
- 20 RS-485 Communications Interface c/w Data Logging, A-B Protocol
- 21 RS-485 Communications Interface c/w Data Logging, Modicon Protocol

Notes:
1. Panel mount only.
2. Communications protocol must be specified. See Options.
3. CSA certification pending.

TABLE 1

2. FRONT-PANEL ANNUNCIATION, INDICATION, AND PROGRAMMING

2.1 GENERAL (See Figure 1)

FPU-16 modes are listed on the front panel. Modes 0 to 4 are used to enter trip-and-alarm set points and to annunciate trips and alarms. Mode 5 is used to select options. Modes 6, 7, and 8 are used to enter CT-primary ratings and rated current. Modes 9 to F are used to display metered values and values-at-trip.

2.2 LIQUID-CRYSTAL DISPLAY

The left digit of the four-digit liquid-crystal display uses a hexadecimal format (0 to F) to indicate the mode displayed. The remaining digits (designated from left to right as value digits 1, 2, and 3) display set-point values, meter readings, and trip-and-alarm codes.

For value digits greater than 999, the last value digit is replaced by E to indicate an extended range. To obtain the actual value, multiply the reading by 100. For example, 30E is read as 3000.

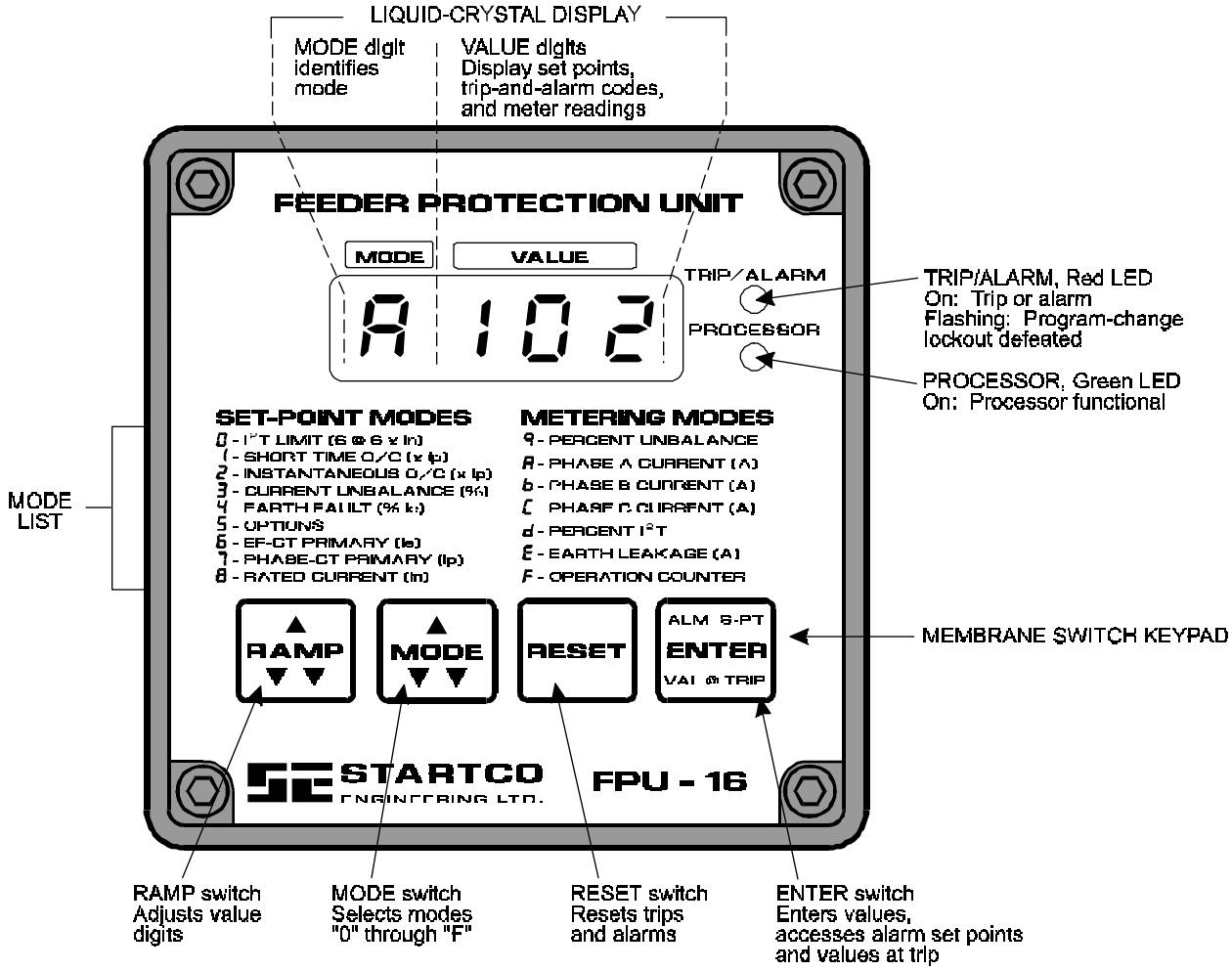
2.3 KEYPAD

Four keypad switches provide the operator interface to the FPU-16. Tactile-feedback switches are used to provide positive indication that switch contact has been made:

RAMP — This switch is used to adjust values in Modes 0 to 8. Under normal operation this switch is inoperative. To make the RAMP switch operative, the program-change lockout must be defeated by connecting FPU-16 terminals 20 and 21. To change a set point, ENTER must be pressed within three seconds after RAMP is released. If ENTER is not pressed within three seconds, the display will return to its pre-adjusted value. One arrow up and two arrows down indicate that the RAMP switch is bidirectional. To ramp up: press and hold. To reverse: release, press again within one second and hold.

MODE — This switch is used to select the mode displayed. Bidirectional operation is the same as for RAMP.

RESET— This switch is used to reset trips and alarms and it is used with ENTER to reset latched alarms in modes 0 to 4, to do an emergency thermal reset in Mode d, and to reset the operation counter in Mode F. It is also used to display current in percent of rated current (Modes A, b, and C) and time-to-reset (Mode d).



FPU-16 FRONT PANEL

FIGURE 1

ENTER — This switch is used to enter values in Modes 0 to 8, and to access a second level in modes 0 to 5 and 8 to F. Values can be entered only when the program-change lockout is defeated. This prevents unauthorized or unintentional program changes during normal operation. When the program-change lockout is defeated, the value displayed in Modes 0 to 8 will be entered if ENTER is pressed within three seconds after RAMP is released.

In Modes 0 to 5, the second-level set point will be displayed while ENTER is pressed. In Modes 9 to E, the value immediately prior to the most recent trip will be displayed while ENTER is pressed. If the program-change lockout is defeated, the second level in Modes 0 to 5 will remain displayed for three seconds after ENTER is released to allow RAMP to be pressed to initiate a second-level program change.

2.4 LED INDICATORS

The red TRIP/ALARM LED is on if a trip or alarm has occurred. It flashes when the program-change lockout is defeated (program enable active); however, ON has priority over FLASH. The green PROCESSOR LED is on when the processor is functional.

2.5 PROGRAMMING

The FPU-16 has individual trip-and-alarm control relays and all trip-and-alarm set points can be individually adjusted or deleted. At the top of each set-point range, the delete code "ddd" is displayed. If "ddd" is entered, the set point is deleted and the associated protection is disabled.

To enable program changes, the program-change lockout must be defeated by connecting FPU-16 terminals 20 and 21. Remove this connection when programming is completed. This will prevent unauthorized or unintentional program changes.

To program trip set points in Modes 0 to 4 and the first level in Modes 5 to 8:

- Press MODE to select the mode,
- press RAMP to adjust, and within three seconds of release,
- press ENTER.

To program alarm set points in Modes 0 to 4 and the second level in Mode 5:
- Press MODE to select the mode,
- press ENTER, and within three seconds of release,
- press RAMP to adjust, and within three seconds of release,
- press ENTER.

All programmed values and values-at-trip are stored in a nonvolatile memory that retains its data indefinitely—even if supply voltage is lost. It is not necessary to reprogram the unit when supply voltage is restored.

2.6 TRIPS AND ALARMS

When a trip occurs:
- The trip relay operates,
- the red TRIP/ALARM LED comes ON,
- the display automatically switches to the mode that initiated the trip, and
- the mode digit is followed by a trip code.

With the exception of autoreset which can be enabled for Mode 0, all trips must be individually reset.

When an alarm occurs:
- The alarm relay operates,
- the red TRIP/ALARM LED comes ON, and
- the display does not switch to the mode that initiated the alarm; however,
- an alarm code is displayed if the mode that initiated the alarm is selected.

Unless latching alarms are selected in Mode 5, alarms automatically reset when conditions return to normal. See Section 3.7.2 and Table 2.

2.7 DEFAULT VALUES

A set of default values are preprogrammed at the factory. Default values are listed in their respective mode descriptions in Section 3.

To reload factory default values:
- Remove the supply voltage,
- connect FPU-16 terminals 20 and 21 to enable program changes, and
- with RESET pressed, apply the supply voltage.

3. MODE DESCRIPTIONS

3.1 GENERAL

This section contains a description of each mode. It explains operational characteristics, describes special functions, and lists set-point ranges, display codes, and default values.

3.2 MODE 0 — I^2t LIMIT

This mode is used to enter long-time overcurrent set points and to annunciate long-time overcurrent alarms and trips.

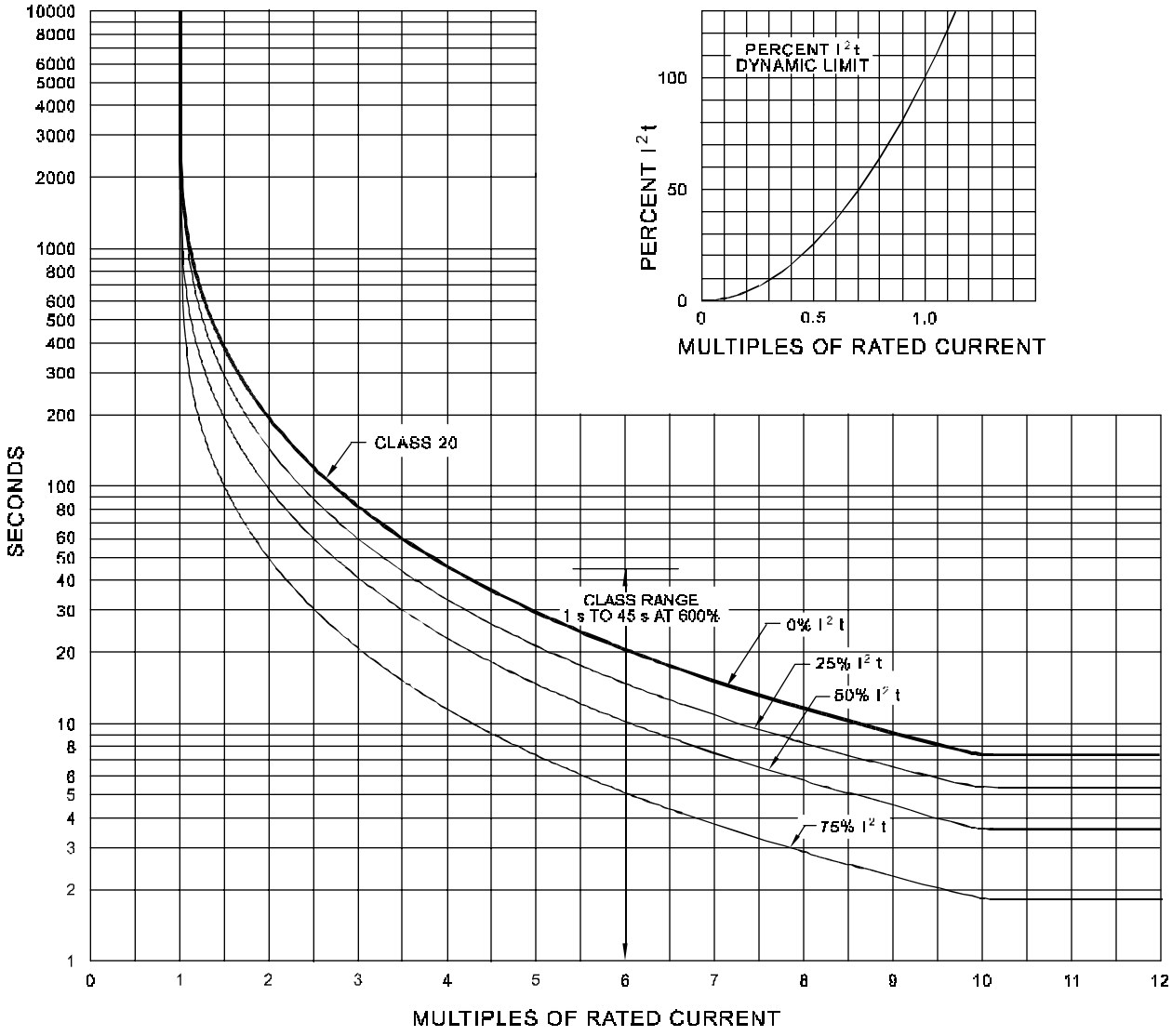
Thermal protection provided by the FPU-16 is based upon a constant I^2t characteristic that is defined by the Mode-0 set point and the rated current (I_n) programmed in Mode 8. The Mode-0 set point is the time, in seconds, required for the FPU-16 to trip at 6 x I_n. The Mode-0 set point is determined by equating I^2t at 6 x I_n to the allowable thermal rating. For example, if the allowable thermal rating is 2 x I_n for 3 minutes, the I^2t limit is:

$6^2 \times t = 2^2 \times 180$, and
t = 20 seconds—this is the Mode-0 set point.

One of the 45 available protection curves is shown in Figure 2. The largest of the three phase currents is used for the I^2t thermal model and the 0%-I^2t curve is the maximum-time-to-trip curve for current above I_n. Current above I_n causes I^2t to tend toward a limit above 100%, and current below I_n causes I^2t to tend toward a limit that is less than 100% as shown in the inset graph in Figure 2. In all cases, I^2t responds exponentially toward its final value with a time constant derived from the Mode-0 set point so that I^2t tracks used thermal capacity.

Used thermal capacity determines the time-to-trip for excursions above I_n. For the Class-20 example shown in Figure 2, sustained operation at 0.87 x I_n will ultimately result in a used thermal capacity of 75% and the time to trip for current above I_n will be reduced as shown by the 75%- I^2t curve.

The FPU-16 trips in Mode 0 when I^2t reaches 100%. A Mode-0 trip cannot be reset until I^2t has decreased to 30% unless Mode 5 has been programmed to allow an immediate reset. See Section 3.7.3 and Table 2. If Mode 5 has not been programmed to allow an immediate reset, the time required for I^2t to decrease to 30% is a function of the derived time constant. Percent I^2t and minutes-to-reset are displayed in Mode d. The FPU-16 can be programmed in Mode 5 to automatically reset when I^2t decreases to 30%. See Section 3.7.1 and Table 2.



FPU-16 CLASS-20 THERMAL CURVE

FIGURE 2

All programmed values and values-at-trip are stored in nonvolatile memory. When data are retrieved from this memory, error-detection techniques check for corrupted data. If data are suspect, the unit will trip, "0bAd" will be displayed, and default values will be loaded. If "0bAd" is displayed, defeat the program-change lockout, reprogram the unit, and reset Mode 0.

Set-Point Range..... 1 s to 45 s @ 6 x I_n
Set-Point Step Size..... 1 s
Display Codes:
- Trip..... 0FFF
- Alarm..... 0AAA*
- Set Point Deleted..... 0ddd*
- Memory Error..... 0bAd

Default Values:
- Trip..... 10 s @ 6 x I_n
- Alarm..... 9 s @ 6 x I_n

* Alarm is on when $I^2t \geq$ (Alarm Set Point/Trip Set Point) x 100%. Deleting the TRIP function automatically deletes the ALARM function.

3.3 MODE 1 — SHORT-TIME OVERCURRENT

This mode is used to enter short-time overcurrent set points and to annunciate short-time overcurrent alarms and trips.

The short-time overcurrent trip-and-alarm time is selected in Mode 5. Four trip-and-alarm times are available as 3-, 6-, 12-, and 24-cycle minimums. See Table 2.

Set-Point Range..... 1 to 9 x CT-Primary Rating
Set-Point Step Size..... 0.1 x CT-Primary Rating
Trip-and-Alarm Times..... 3, 6, 12, or 24 cycles
Trip-and-Alarm Time Accuracy..... +3, -0 cycles
Display Codes:
- Trip..... 1FFF
- Alarm..... 1AAA
- Set Point Deleted..... 1ddd

Default Values:
- Trip Time..... 3 cycles
- Trip Level..... 7 x CT-Primary Rating
- Alarm Level..... 5 x CT-Primary Rating

3.4 MODE 2 — INSTANTANEOUS OVERCURRENT

This mode is used to enter instantaneous overcurrent set points and to annunciate instantaneous overcurrent alarms and trips. The instantaneous overcurrent trip-and-alarm time is fixed.

Set-Point Range..... 1 to 9 x CT-Primary Rating
Set-Point Step Size..... 0.1 x CT-Primary Rating
Trip-and-Alarm Time..... 0.25 to 3 cycles
Display Codes:
- Trip..... 2FFF
- Alarm..... 2AAA
- Set Point Deleted..... 2ddd

Default Values:
- Trip..... Deleted
- Alarm..... Deleted

3.5 MODE 3 — CURRENT UNBALANCE

This mode is used to enter current-unbalance set points and to annunciate current-unbalance alarms and trips. Two equations are used to calculate current unbalance.

For $I_{max} \leq 0.5 \times I_n$:

$$\text{Unbalance} = \left[\left(I_{max} - I_{min} \right) / I_n \right] \times 100\% \qquad (3.1)$$

For $I_{max} > 0.5 \times I_n$:

$$\text{Unbalance} = \left[\left(I_{max} - I_{min} \right) / I_{max} \right] \times 100\% \qquad (3.2)$$

Where: I_{max} = maximum phase current
I_{min} = minimum phase current
I_n = rated current

Set-Point Range..... 5% to 75%
Set-Point Step Size..... 1%
Trip Time..... 5 s
Alarm Time..... 1 s
Alarm Hysteresis..... 2%
Display Codes:
- Trip..... 3FFF
- Alarm..... 3AAA
- Set Point Deleted..... 3ddd

Default Values:
- Trip 25%
- Alarm 15%

3.6 MODE 4 — EARTH FAULT

This mode is used to enter earth-fault set points and to annunciate earth-fault alarms and trips. Set points are expressed in percent of the earth-fault-CT-primary rating entered in Mode 6.

Optional CT's (EFCT-1 or EFCT-2) with 5-A-primary ratings are available for sensitive earth-fault detection in applications where earth-fault current is less than 100 A and surge current is less than 2.5 kA. If surge current is greater than 1 kA but less than 2.5 kA, a flux conditioner should be used to prevent nuisance tripping. If earth-fault current is greater than 100 A, surge current is greater than 2.5 kA, or if a trip level greater than 5 A is required, use a 5-A- or 1-A-secondary earth-fault CT that will not saturate at the prospective currents.

Earth-fault current can be derived from the phase currents by using the ICT-2 residual connection. See Section 4.5.2. When this connection is used, the primary rating of the earth-fault CT is the same as the phase CT's. Due to CT errors, trip set points should be greater than 10% with the residual connection.

Earth-fault detection in a two-CT configuration requires an earth-fault CT. Do not use a residual-type connection with two phase-CT's because an earth fault in the derived phase will not be detected.

Four earth-fault-trip times are available. See Section 3.7.5 and Table 2.

- Set-Point Range ..... 1% to 100% of Earth-Fault-CT-Primary Rating
- Set-Point Step Size 1%
- Trip Time ..... 3, 6, 12, or 24 cycles
- Alarm Time ..... 12 cycles
- Trip-and-Alarm-Time Accuracy ..... +3, -0 cycles
- Display Codes:
  - Trip 4FFF
  - Alarm 4AAA
  - Set Point Deleted 4ddd
- Default Values:
  - Trip Time ..... 3 cycles
  - Trip Level 40%
  - Alarm Level 20%

3.7 MODE 5 — OPTIONS (See Tables 2 & 3)

This mode is used to select special program options. Any combination in Tables 2 and 3 can be selected by entering the appropriate hexadecimal numbers in Mode 5 in the same way that trip-and-alarm set points are entered in Modes 0 to 4.

Default Values:
Table 2 5000
Table 3 5000

3.7.1 AUTORESET

When autoreset is ON, a Mode-0 trip will automatically reset when I^2t decreases to 30%. See Section 3.2. Autoreset will not occur if I^2t IMMEDIATE RESET is selected. If autoreset is required, disable I^2t IMMEDIATE RESET.

Default ..... OFF

3.7.2 ALARM LATCH

When the alarm latch is ON, all alarms that occur in Modes 0 to 4 will latch and must be individually reset. To reset a latched alarm, use MODE to select the alarm and press ENTER and RESET simultaneously.

Default ..... OFF

3.7.3 I^2t IMMEDIATE RESET

When I^2t IMMEDIATE RESET is ON, I^2t will be cleared when a Mode-0 trip occurs. This will allow an immediate Mode-0 reset when RESET is pressed. When OFF, Mode-0 reset is not allowed until I^2t has decreased to 30%.

3.7.4 SPARE

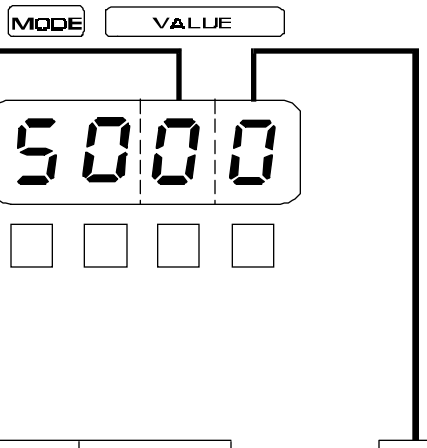
Not used.

3.7.5 EARTH-FAULT TRIP TIME

Four earth-fault trip times (3, 6, 12, or 24 cycles) are available. See Section 3.6.

Default ..... 3 cycles

MODE 5 — OPTIONS



Default Value 5000

This indicates:
Short-Time-Trip Time. . . . . 3 cycles
Earth-Fault-Trip Time. . . . . 3 cycles
I^2t Immediate Reset . . . . . OFF
Alarm Latch . . . . . OFF
Autoreset (Mode 0). . . . . OFF

DEFAULT

VALUE DIGIT 2	SHORT-TIME-TRIP TIME 00 = 3 CYCLES 01 = 6 CYCLES 10 = 12 CYCLES 11 = 24 CYCLES		EARTH-FAULT-TRIP TIME 00 = 3 CYCLES 01 = 6 CYCLES 10 = 12 CYCLES 11 = 24 CYCLES	
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
A	1	0	1	0
b	1	0	1	1
C	1	1	0	0
d	1	1	0	1
E	1	1	1	0
F	1	1	1	1

VALUE DIGIT 3	SPARE	I^2t IMMEDIATE RESET 0=OFF 1=ON	ALARM LATCH 0=OFF 1=ON	AUTORESET (MODE 0) 0=OFF 1=ON
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
A	1	0	1	0
b	1	0	1	1
C	1	1	0	0
d	1	1	0	1
E	1	1	1	0
F	1	1	1	1

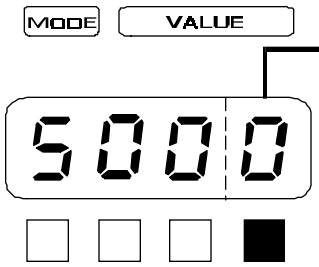
TABLE 2

MODE 5 — OPTIONS

(2nd Level Without Communications Interface)

Default Value 5000

This indicates:
Trip Relay . . . . . Fail Safe
Alarm Relay . . . . . Fail Safe
Analog-Output Parameter. . . Current



DEFAULT	VALUE DIGIT 3	TRIP RELAY	ALARM RELAY	ANALOG-OUTPUT PARAMETER 00=CURRENT 01= I^2t 10=NO SELECTION 11=EARTH LEAKAGE	
		RELAY OPERATING MODE 0=FAIL SAFE 1=NON FAIL SAFE		FULL SCALE 1.25 x I_n 100% I_e	
◄	0	0	0	0	0
	1	0	0	0	1
	2	0	0	1	0
	3	0	0	1	1
	4	0	1	0	0
	5	0	1	0	1
	6	0	1	1	0
	7	0	1	1	1
	8	1	0	0	0
	9	1	0	0	1
	A	1	0	1	0
	b	1	0	1	1
	C	1	1	0	0
	d	1	1	0	1
	E	1	1	1	0
	F	1	1	1	1

NOTE:

Not applicable to units with RS-485 communications interface. See FPU-16 RS-485 Communications Interface Manuals.

TABLE 3

3.7.6 SHORT-TIME TRIP-AND-ALARM TIME

Four short-time trip-and-alarm times (3, 6, 12, or 24 cycles) are available. See Section 3.3.

Default ..... 3 cycles

3.7.7 ANALOG-OUTPUT PARAMETER

For units without RS-485 communication interface, the analog output parameter is selectable as shown in Table 3. When CURRENT is selected, the maximum of the three phase currents is used.

Current (Mode A, b, or C) ..... 0 to 1.25 I_n
I^2t (Mode d) ..... 0 to 100%
Earth Leakage (Mode E) ..... 0 to 1 x I_e

Default ..... Current

3.7.8 RELAY OPERATING MODE

Each output-relay driver can be independently operated in a fail-safe or non-fail-safe mode. In the fail-safe mode, the output relays are energized when supply voltage is on and the unit is not in a trip-or-alarm condition. The output relays are de-energized if supply voltage is off or if a trip-or-alarm condition occurs. FPU-16 labelling shows the relays de-energized. In the non-fail-safe mode, the output relays are energized only during a trip-or-alarm condition.

Default Values:
Trip Relay ..... Fail Safe
Alarm Relay ..... Fail Safe

3.8 MODE 6 — EARTH-FAULT-CT-PRIMARY RATING (I_e)

This mode is used to enter the earth-fault-CT-primary rating. All four digits are displayed when the earth-fault-CT-primary rating is being adjusted. When the new rating is entered, the display returns to the three-value-digit format and the extended-range notation applies for values above 999 A. See Section 2.2.

The primary rating for the EFCT-1 and EFCT-2 is 5 A. If a 5-A- or 1-A-secondary earth-fault CT is used, the primary rating of the earth-fault CT must be entered. If the residual connection is used, enter the primary rating of the phase CT's in both Modes 6 and 7.

Earth-Fault-CT-Primary Ratings:
EFCT-1 and EFCT-2 ..... 5 A
5-A- or 1-A-Secondary CT ..... 50 A to 2000 A in 50-A increments

Default Value ..... 5 A (EFCT-1 or EFCT-2)

3.9 MODE 7 — PHASE-CT-PRIMARY RATING (I_p)

This mode is used to enter the phase-CT-primary rating. All four digits are displayed when the phase-CT primary rating is adjusted. When a new rating is entered, the display returns to the three-value-digit format and the extended-range notation applies for values above 999 A. See Section 2.2.

If I_p is greater than 1200 A or if I_n is greater than 800 A, enter 0.1 x I_p and multiply readings in Modes A, b, and C by 10.

Phase CT's should be selected so that rated current is approximately 70% of the primary rating. The rated-current programming range in Mode 8 is 45% to 93% of the phase-CT-primary rating. Mode 7 must be programmed before Mode 8 because Mode 8 is set to the bottom of the rated-current range when the phase-CT-primary rating is entered.

CT-Primary-Rating Range ..... 20 A to 1200 A in 5-A increments

Default Value ..... 150 A

3.10 MODE 8 — RATED CURRENT (I_n)

This mode is used to enter rated current (I_n) and to indicate the firmware revision level. Rated-current range is a function of the phase-CT-primary rating entered in Mode 7. It is necessary to enter I_p in Mode 7 before I_n is entered in Mode 8 because Mode 8 is set to the minimum value of the I_n range when I_p is entered. The firmware revision level is displayed by pressing ENTER.

If I_p is greater than 1200 A or if I_n is greater than 800 A, enter 0.1 x I_n and multiply readings in Modes A, b, and C by 10.

Set-Point Range..... 9 A to 800 A
Set-Point Step Size ..... 1 A
Rated-Current Range..... 0.45 to 0.93 x I_p
Default Value ..... 100 A

3.11 MODE 9 — PERCENT UNBALANCE

This mode is used to display percent current unbalance. The unbalance value is calculated using equations 3.1 and 3.2. See Section 3.5.

The pre-trip current unbalance value can be recalled by pressing ENTER.

Range..... 0 to 100%
Resolution..... 1%

3.12 MODES A, b, and C — AMMETERS

These modes display the phase currents. Mode A is automatically displayed when supply voltage is applied. For currents above 999 A, the last value digit is replaced by E to indicate an extended range. To obtain the actual value, multiply the reading by 100. For example, 30E is read as 3000 A.

If the 0.1 multiplier was used in Modes 7 and 8, multiply readings in Modes A, b, and C by 10. Current as a percentage of rated current is displayed by pressing RESET. Pre-trip ammeter values can be recalled by pressing ENTER.

Range..... 0 to 10 x I_n
Resolution..... 1 A for I < 1000 A
100 A for I ≥ 1000 A
Accuracy..... ± 0.3% Full Scale or
± 3% Reading

See Technical Specifications in Section 6 for metering accuracy vs ICT interconnection cable length.

3.13 MODE d — PERCENT I^2t / TIME-TO-RESET / EMERGENCY THERMAL RESET

This mode is used to display percent I^2t which is a measure of used thermal capacity. See Section 3.2. If a Mode-0 trip has occurred, Mode d is also used to display time in minutes until a Mode-0 reset will be allowed. Reset time is a function of the time constant and reset time is displayed when RESET is pressed.

EMERGENCY THERMAL RESET will set I^2t to 0% and reset Mode 0. For EMERGENCY THERMAL RESET:

- Defeat program-change lockout by connecting FPU-16 terminals 20 and 21,
- select Mode d, and
- press RESET and ENTER simultaneously.

When I^2t IMMEDIATE RESET is selected in Mode 5, pressing RESET in Mode d will set I^2t to 0%.

The pre-trip percent I^2t value can be recalled by pressing ENTER.

Percent I^2t:

Range	0 to 100%
Resolution	1%
Trip Value	100%
Reset Value	30%

Time-to-Reset:

Range	0 to 85 minutes
Resolution	1 minute

3.14 MODE E — EARTH LEAKAGE

This mode is used to display earth-leakage current. For currents above 999 A, the last value digit is replaced by E to indicate an extended range. To obtain the actual value, multiply the reading by 100. For example, 10E is read as 1000 A.

The pre-trip earth-leakage value can be recalled by pressing ENTER.

Range	0 to 1.25 x I_e
Accuracy	± 3% I_e
Resolution With:	
EFCT-1 or EFCT-2	0.02 A
5-A- or 1-A-Secondary CT	1 A for I < 1000 A, 100 A for I ≥ 1000 A

3.15 MODE F — OPERATION COUNTER

The counter increments by one each time an external contact closes. The maximum count is 65535 and the counter returns to zero on the next count.

The value digits display the three least-significant digits of the counter. When ENTER is pressed, the two most-significant digits are displayed.

To reset the counter, defeat the program-change lockout by connecting FPU-16 terminals 20 and 21 and press RESET and ENTER simultaneously in Mode F.

4. INSTALLATION

4.1 GENERAL

A basic feeder-protection system consists of a FPU-16 feeder protection unit, an ICT-2 interface CT, and three customer-supplied phase CT's. An earth-fault CT is usually required for earth-fault detection.

4.2 COMPONENT MOUNTING

4.2.1 PANEL-MOUNT CONFIGURATION

Outline dimensions and mounting details for the panel-mount FPU-16 are shown in Figure 3. The FPU-16 mounts in a 92-mm (3.62-in) square cutout (1/4 DIN) and is secured to the panel by the panel-mount clamp. To mount the FPU-16, insert it through the panel cutout and slip the panel-mount clamp over the FPU-16 body. Slide the clamp forward until the latch tabs snap into the mating holes. Lock the unit in place by tightening the four clamp screws against the mounting panel.

- - - CAUTION - - -

OVER TIGHTENING THE CLAMP SCREWS WILL DEFORM THE CLAMP AND CAUSE THE LATCH TABS TO RELEASE.

4.2.2 SURFACE-MOUNT CONFIGURATION

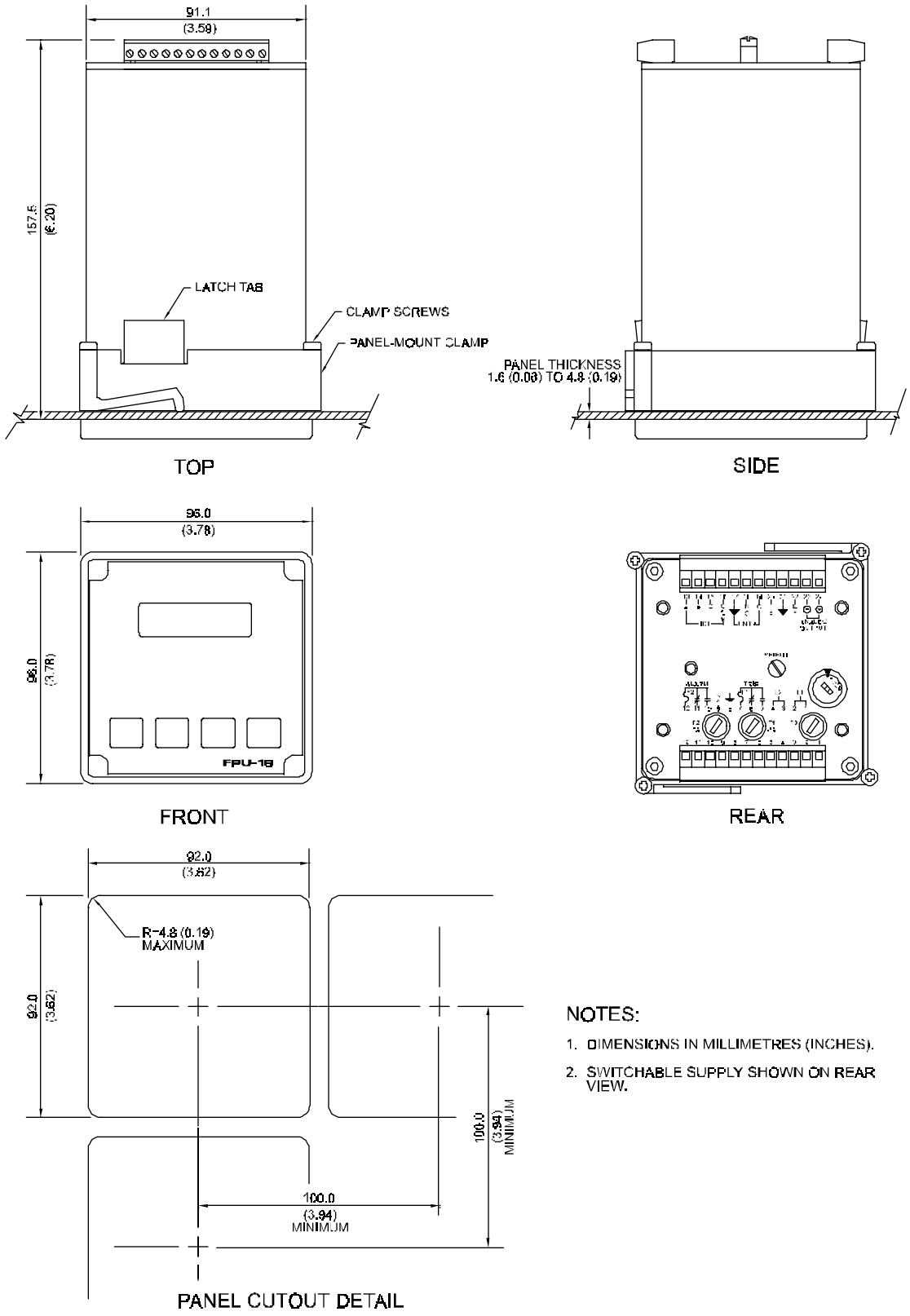
Outline dimensions and mounting details for the surface-mount FPU-16 are shown in Figure 4. Mount the FPU-16 using M4 (No. 8) screws and external-tooth lockwashers. Surface-mount FPU-16's have panel-mount-clamp latch holes and are supplied with panel-mount clamps and hole plugs. This allows surface-mount units to be panel mounted as described in Section 4.2.1; however, 100-mm (3.94-in) mounting centres cannot be maintained. If the unit is surface mounted, insert hole plugs in the latch holes.

4.2.3 ICT-2 INTERFACE CT

Outline dimensions and mounting details for the ICT-2 interface CT are shown in Figure 5. Locate the ICT-2 near the phase CT's.

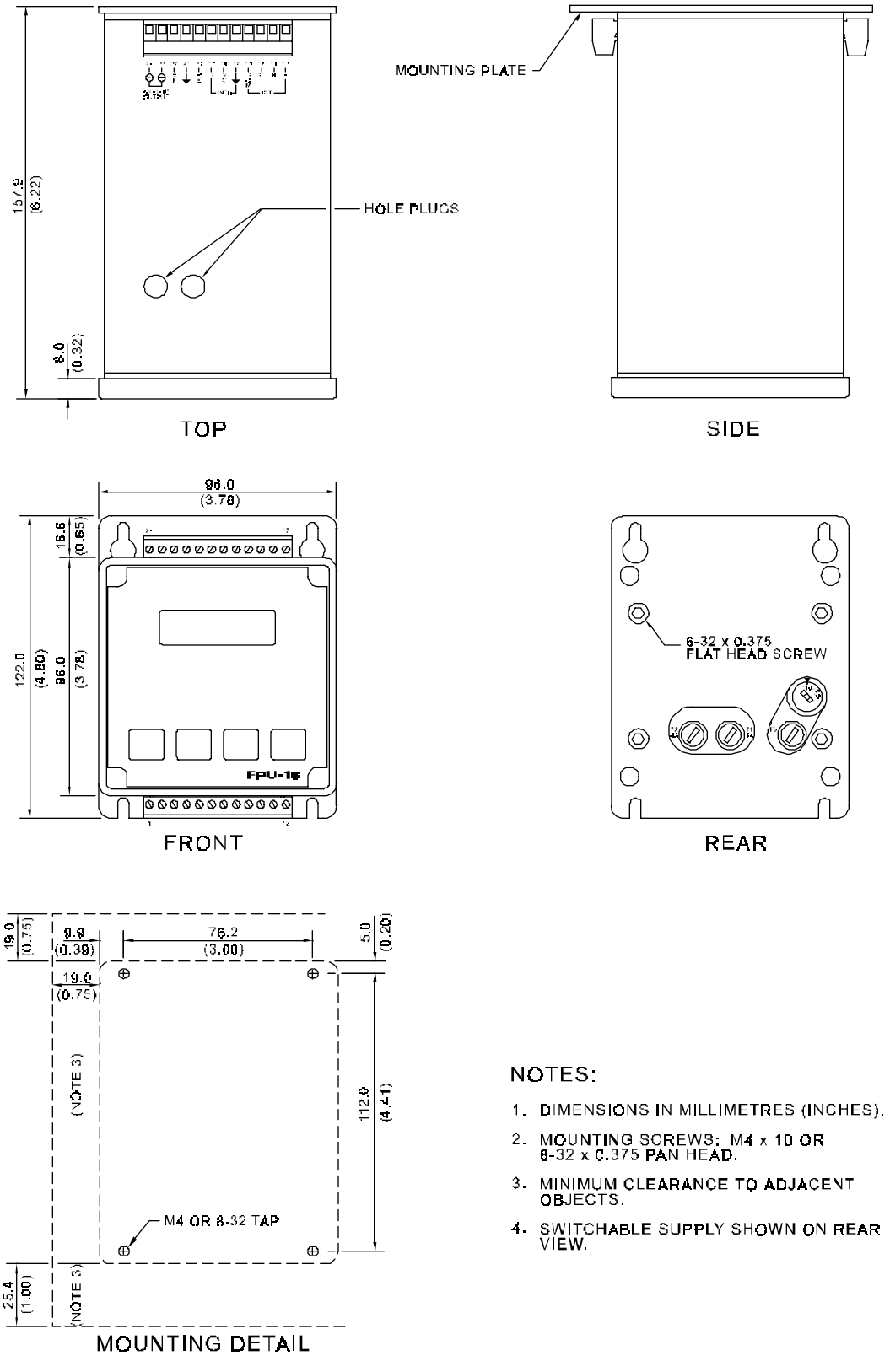
4.2.4 EFCT-1 AND EFCT-2 EARTH-FAULT CT'S

Outline dimensions and mounting details for the EFCT-1 and EFCT-2 earth-fault CT's are shown in Figures 6 and 7.



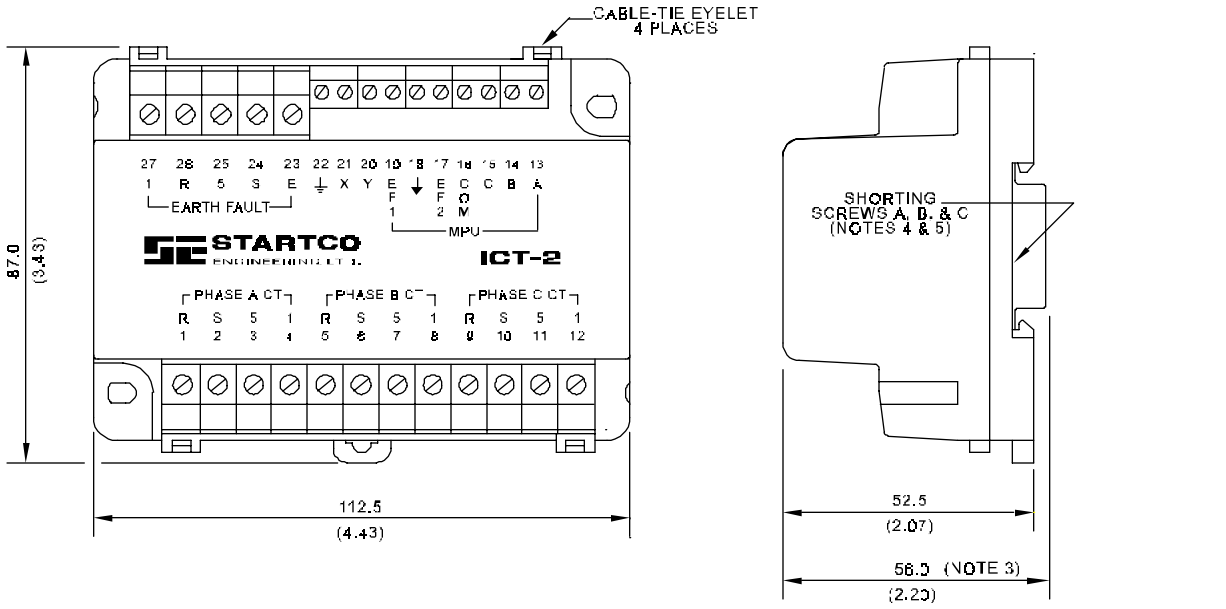
PANEL-MOUNT FPU-16 OUTLINE AND MOUNTING DETAILS

FIGURE 3



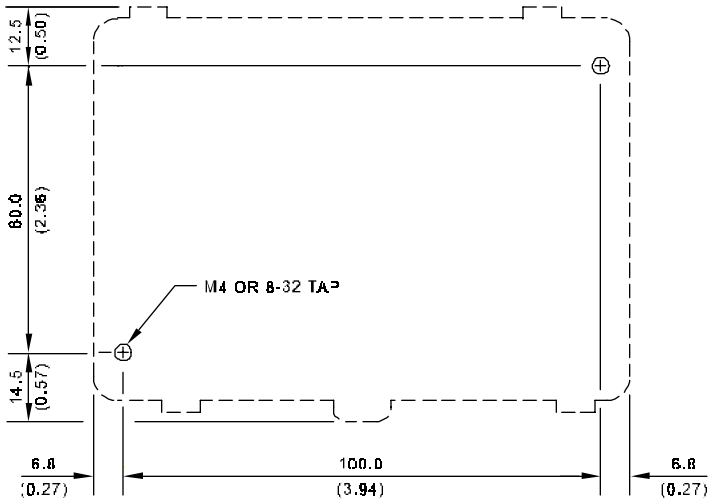
SURFACE-MOUNT FPU-16 OUTLINE AND MOUNTING DETAILS

FIGURE 4



TOP

SIDE



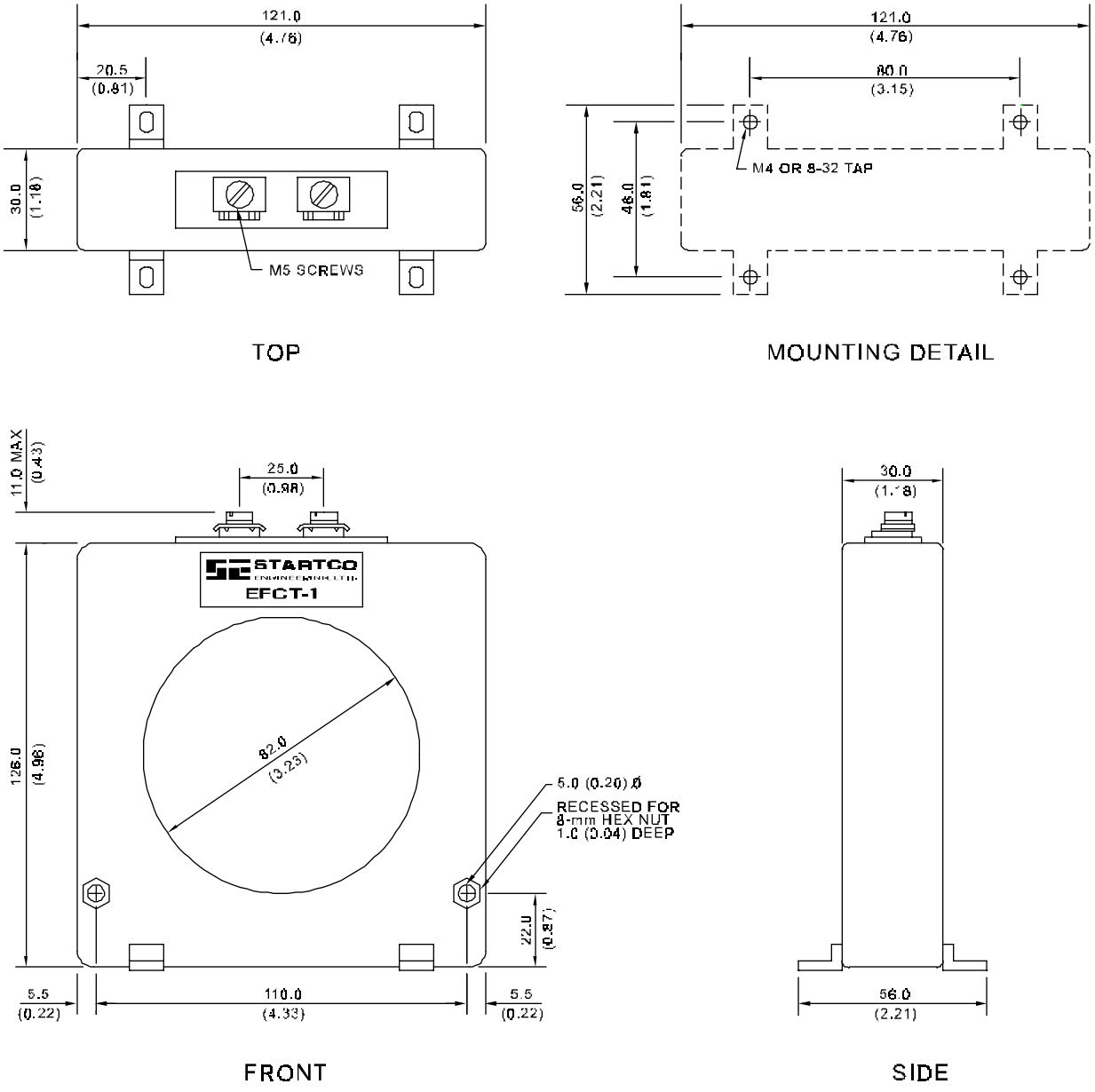
MOUNTING DETAIL

NOTES:

1. DIMENSIONS IN MILLIMETRES (INCHES).
2. MOUNTING SCREWS: M4 x 20 OR 8-32 x 0.875.
3. OVERALL HEIGHT WHEN MOUNTED ON DIN EN50022 35-mm x 7.5-mm TOP-HAT RAIL.
4. SHORTING SCREWS ARE ACCESSIBLE FROM BOTTOM OF ICT-2.
5. SHORTING SCREWS: 6-32 x 0.375 NICKEL-PLATED-BRASS BINDING HEAD. DO NOT SUBSTITUTE.

ICT-2 OUTLINE AND MOUNTING DETAILS

FIGURE 5

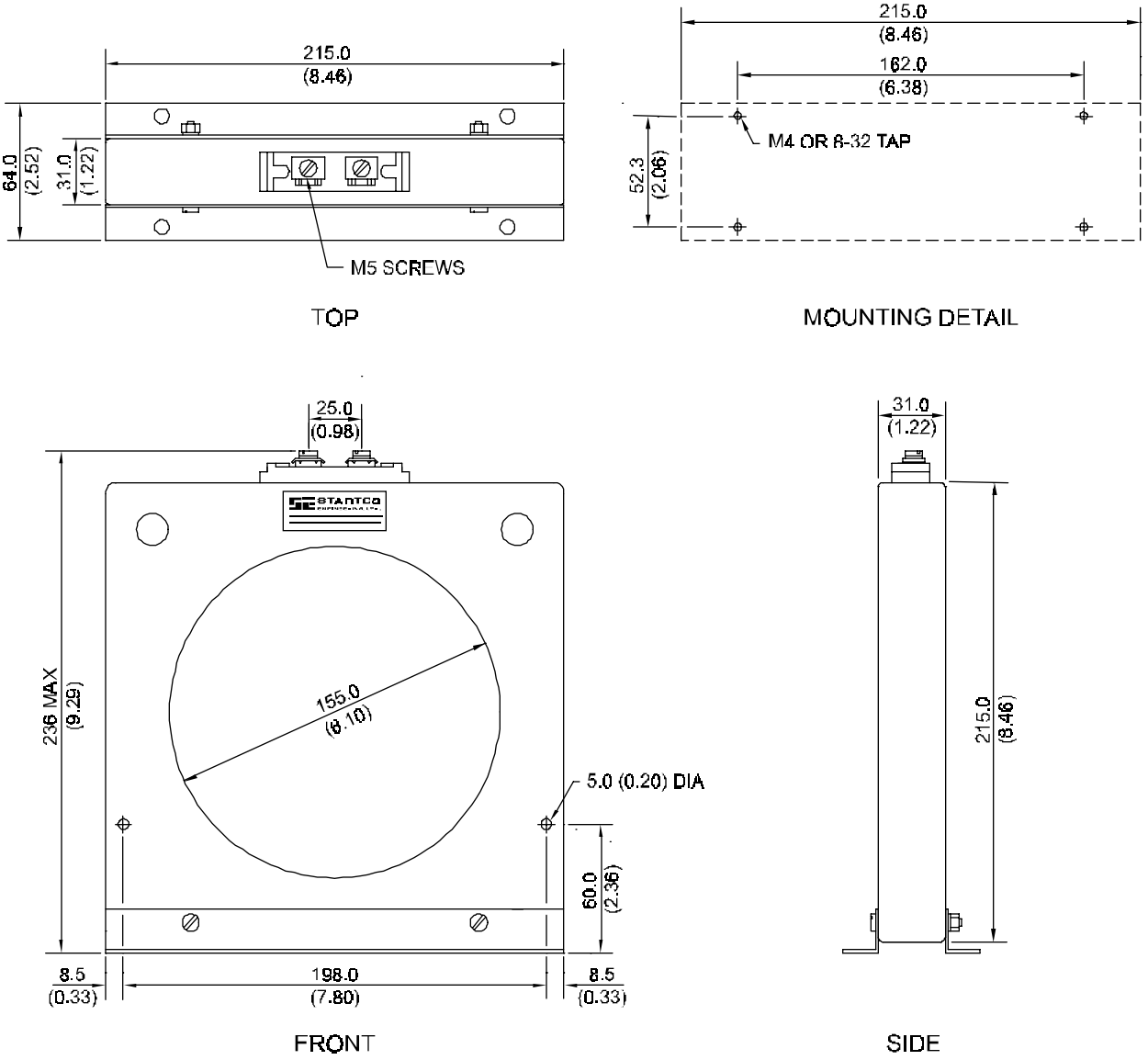


NOTES:

1. DIMENSIONS IN MILLIMETRES (INCHES).
2. MOUNTING SCREWS: M4 x 12 OR 8-32 x 0.50.

EFCT-1 OUTLINE AND MOUNTING DETAILS

FIGURE 6



NOTES:

1. DIMENSIONS IN MILLIMETRES (INCHES).
2. MOUNTING SCREWS: M4 x 12 OR 8-32 x 0.50.

EFCT-2 OUTLINE AND MOUNTING DETAILS

FIGURE 7

4.3 SHIELDED CABLES

Feeder protection equipment must operate in electrically noisy environments. Use shielded, twisted cables for all low-level signals to minimize electrostatic and electromagnetic coupling. The shield must enclose the signal conductors as completely as possible and the shield must have only one connection to ground.

Input-cable shields from the ICT-2, the operation-counter switch, and the remote program-enable switch must be grounded at the FPU-16 end only. Analog- and communications-output cables should be grounded at the receiver end only.

Terminate foil-shielded input cables as shown in Figure 8:

1. Strip 150 mm (6") of outer jacket from the cable.

2. Peel and strip the foil shield from the drain and insulated wires.

3. Trim the insulated wires to 50 mm (2"), and strip 6 mm (1/4") of insulation from each wire. Leave the drain wire full length.

4. Connect the insulated wires to the terminal block.

5. Group the drain wires from all shielded input cables and twist them together. Trim the drain wires to length and attach the crimp-type ground lug provided. For panel-mount units, fasten the lug with the shield screw. For surface-mount units, install the lug between the screw head and the lockwasher on one of the FPU-16 mounting screws.

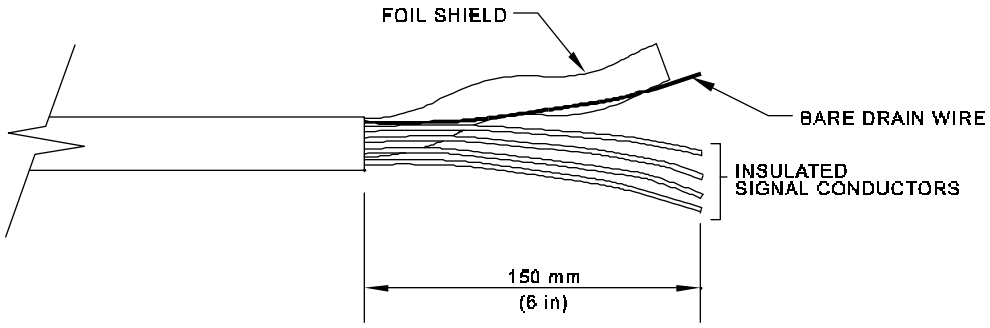
6. Repeat steps 1 and 2 at the other end of the cable. Cut off the drain wire and use heat-shrink sleeving or tape to insulate the shield from ground.

Terminate output cables in the same manner. Ground the drain wires at the receiver ends only.

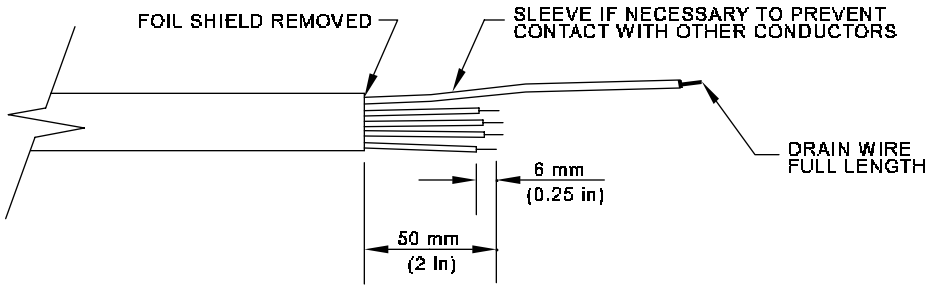
4.4 FPU-16 CONNECTIONS

All connections to the FPU-16 are made through two plug-in, wire-clamping terminal blocks. Each terminal will accept one No. 14 AWG conductor. The supply-voltage terminal block has a keying pin blocking terminal 9 so that supply voltage cannot be accidentally applied to the signal terminals. See Figure 9 for a typical connection diagram.

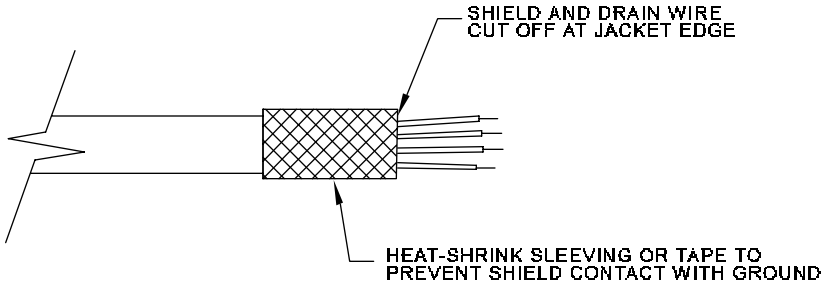
a) OUTER JACKET REMOVED AND FOIL SHIELD PEELED



b) CONDUCTORS PREPARED FOR TERMINATION



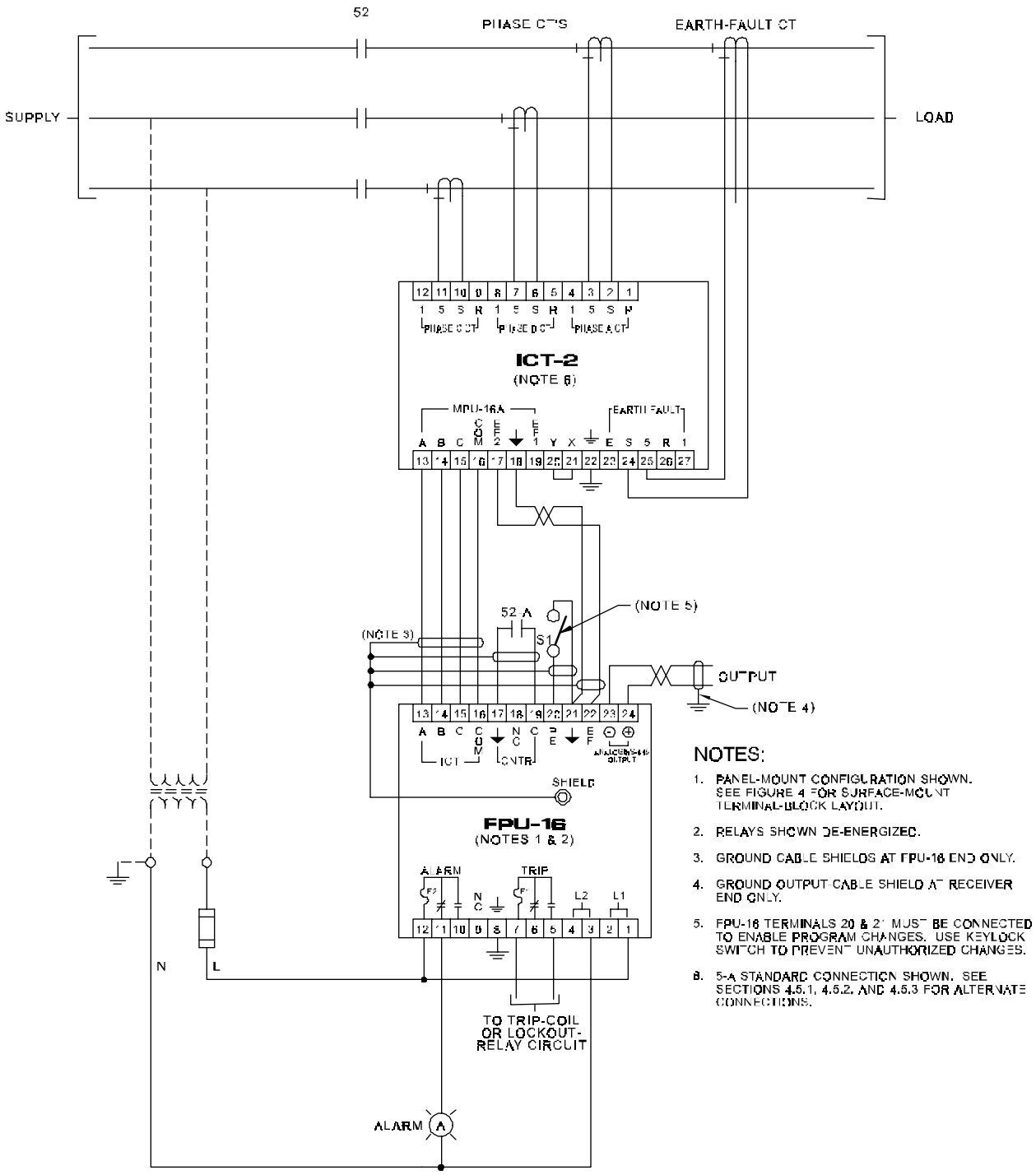
SHIELD-GROUND END



UNGROUNDED END

SHIELDED-CABLE PREPARATION

FIGURE 8



TYPICAL FPU-16 CONNECTION DIAGRAM

FIGURE 9

4.4.1 ICT-2 INTERCONNECTION CABLE

Connect the FPU-16 to the ICT-2 with the interconnection cable supplied. See Figures 11 and 12. Prepare the shielded-conductor groups as outlined in Section 4.3. The following colour code is recommended:

A B C COM	Black White Red Green	Shielded-Group 1
EF(1,2)	Blue Brown	Shielded-Group 2

Ground the cable shields at the FPU-16 only.

4.4.2 POWER SUPPLY

The FPU-16 power supply is protected by a time-delay fuse, F3, which is externally accessible only on units with SW, D1, D2, and D4 power supplies. SW units are supplied with fuses for 120-Vac operation. D1, D2, and D4 units are fused for 12, 24, and 48 Vdc operation respectively. All other units are internally fused for the supply indicated on the FPU-16 nameplate. See Section 6 for recommended F3 fuses.

Derive supply voltage from the line side of the breaker or from an independent source. Connect supply voltage to terminals 1 and 3 (L1 and L2) as shown in Figure 9. In 120-Vac systems, L2 is usually designated as the neutral conductor. Direct-current power supplies use L1 for the positive terminal and L2 for the negative terminal. Ground terminal 8.

4.4.3 TRIP-RELAY CONTACTS

A set of Form C relay contacts are provided for use in a control circuit. These contacts are designated TRIP and are available at terminals 5, 6, and 7. The trip contacts are rated 8 A resistive at 250 Vac and are protected by an 8-A fuse, F1. The trip relay is shown de-energized.

4.4.4 ALARM-RELAY CONTACTS

A set of Form C relay contacts are provided for use in an indication or supervisory-control circuit. These contacts are designated ALARM and are available at terminals 10, 11, and 12. The alarm contacts are rated 8 A resistive at 250 Vac and are protected by an 8-A fuse, F2. The alarm relay is shown de-energized.

NOTE: USE No. 14 AWG CONDUCTORS FOR SUPPLY VOLTAGE AND OUTPUT RELAY CONNECTIONS.

4.4.5 OPERATION COUNT INPUT

Contact closures can be counted by connecting the contact between terminals 17 and 19. Shielded cable is recommended for cable lengths greater than 1 m (3 ft). If shielded cable is used, ground the shield at the FPU-16 only.

4.4.6 PROGRAM-CHANGE LOCKOUT

As explained in Sections 2.3 and 2.5, program-change lockout prevents unauthorized or unintentional changes. It is recommended that a keylock switch be connected to FPU-16 terminals 20 and 21 to allow programming. If the switch is mounted more than 1 m (3 ft) from the FPU-16, use shielded cable and ground the shield at the FPU-16 end only.

4.4.7 ANALOG OUTPUT

An isolated analog output is available at terminals 23 and 24. Terminal 23 is negative. Use shielded cable and ground the cable shield at the receiver.

4.4.8 COMMUNICATIONS INTERFACE

The optional RS-485 communications interface replaces the analog output at terminals 23 and 24. See communications interface manuals.

4.5 ICT-2 CONNECTIONS

The FPU-16 uses an ICT-2 interface CT to simplify wiring and to minimize CT burden. The ICT-2 contains four signal-conditioning interface transformers which are interconnected as shown in Figure 10. These transformers isolate the FPU-16 from the phase and earth-fault CT's. Also, they eliminate the need for CT shorting contacts when the FPU-16 is disconnected. Phase-CT and earth-fault-CT secondaries can be simultaneously grounded through terminal 22 and a jumper to terminal 20. For in-line applications, the CT secondaries can be isolated by removing shorting screws A, B, and C through holes in the bottom of the ICT-2. See Figure 5.

4.5.1 STANDARD CONNECTION

Standard connections with three, phase CT's and an earth-fault CT are shown in Figure 11. Dotted lines indicate 1-A-CT connections. Use shielded cable for EFCT-1 or EFCT-2 connections. Ensure that only current-carrying phase conductors pass through the earth-fault CT window and that ground conductors do not. For applications where the CT secondaries must be grounded at another location, remove shorting screws A, B, and C.

4.5.2 RESIDUAL EARTH-FAULT CONNECTION

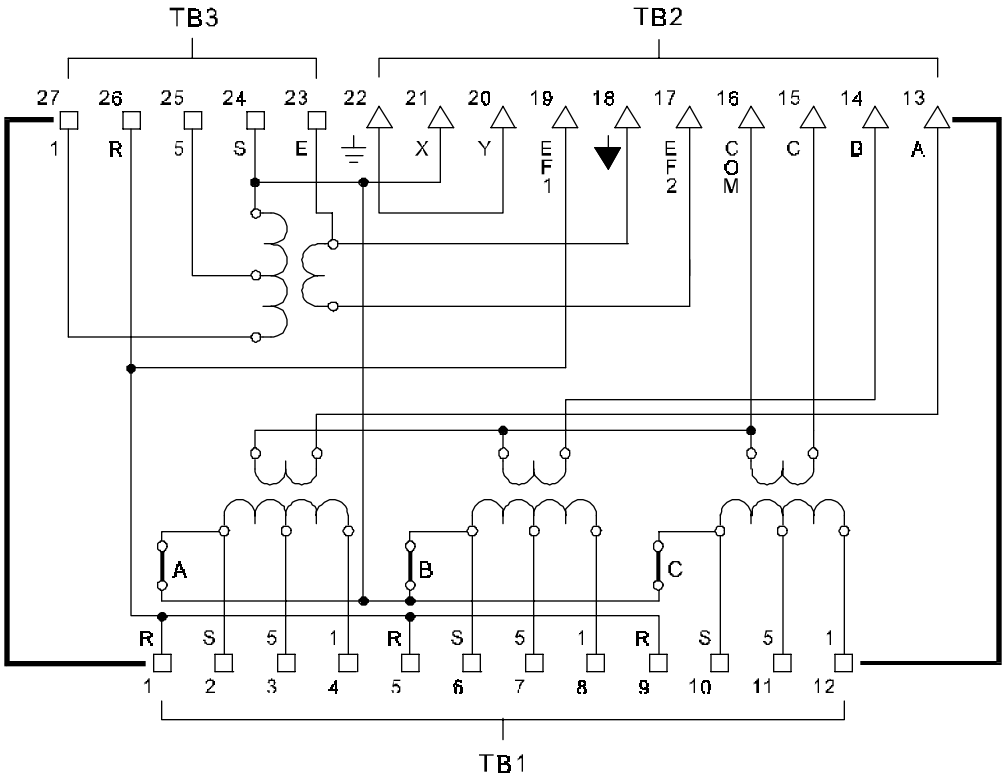
The residual earth-fault connection is shown in Figure 12a. Dotted lines indicate 1-A-CT connections. Use identical phase CT's for this connection.

4.5.3 TWO-CT CONNECTIONS

The two-CT connections are shown in Figures 12b and 12c. Dotted lines indicate 1-A-CT connections. Two-CT connections are not recommended and are used only in retrofit applications where the third phase CT is not available.

4.6 CABLE RESTRAINT

All conductors should be restrained within 100 mm (4") of the terminal blocks as shown in Figure 13. Three sizes of adjustable "P" clips are provided for this purpose. For surface-mount units, restrain the conductors by fastening the "P" clips to the mounting surface. For panel-mount units, secure the "P" clips to the FPU-16 rear panel. Secure cables to the ICT-2 using the cable-tie eyelets and the cable ties provided.



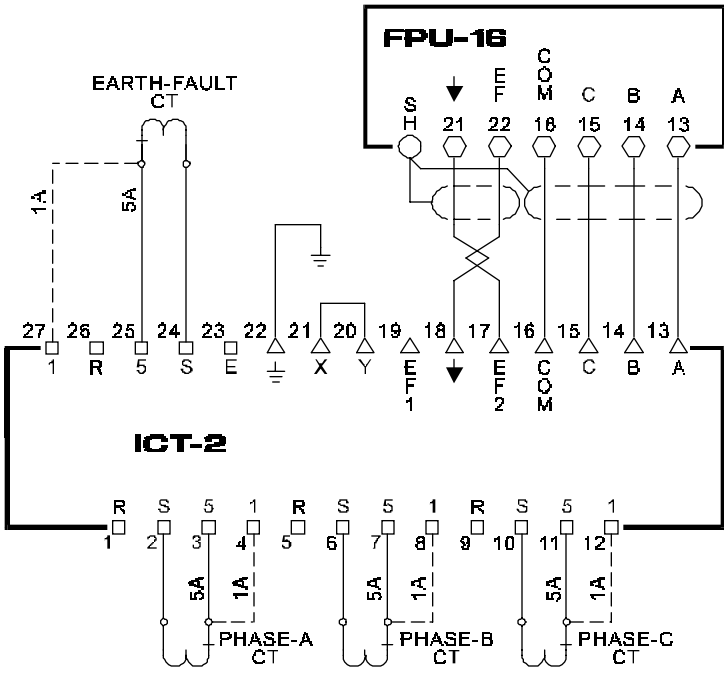
NOTES:

1. REMOVE SHORTING SCREWS A, B, AND C TO ISOLATE PHASE-CT AND EARTH-FAULT-CT SECONDARIES FOR IN-LINE APPLICATIONS.
2. SHORTING SCREWS A, B, AND C: 6-32 x 0.375 NICKEL-PLATED-BRASS BINDING HEAD. **DO NOT SUBSTITUTE**
3. SHORTING SCREWS A, B, AND C MUST NOT BE REMOVED FOR RESIDUAL OR TWO-CT CONNECTIONS.
4. EACH TERMINAL ON TB1 AND TB3 WILL ACCEPT ONE NO. 10 AWG CONDUCTOR

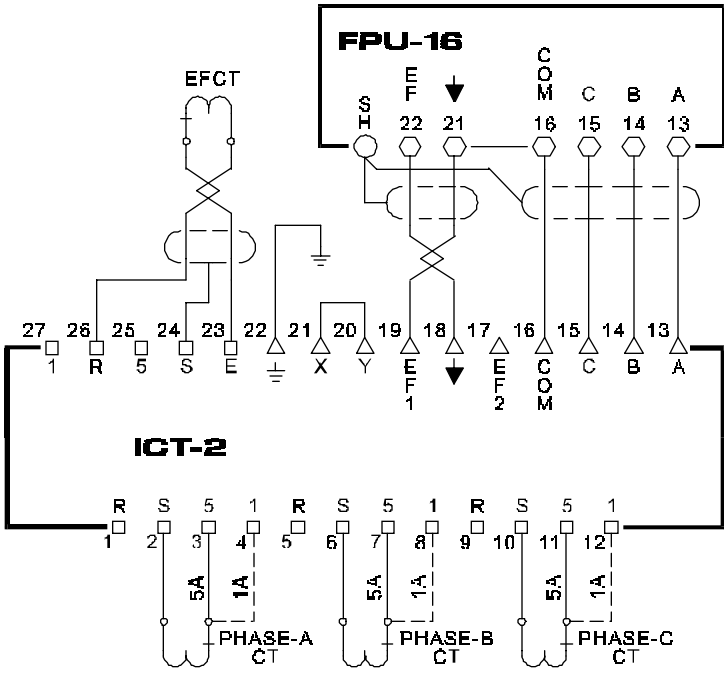
ICT-2 SCHEMATIC

FIGURE 10

a) STANDARD CONNECTION



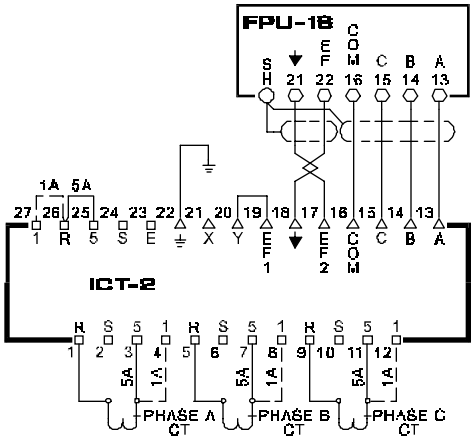
b) STANDARD CONNECTION WITH EFCT



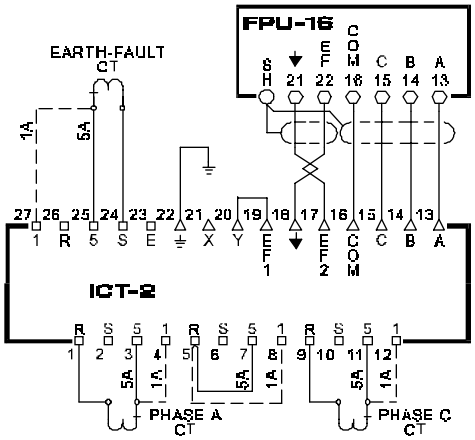
ICT-2 STANDARD CONNECTIONS

FIGURE 11

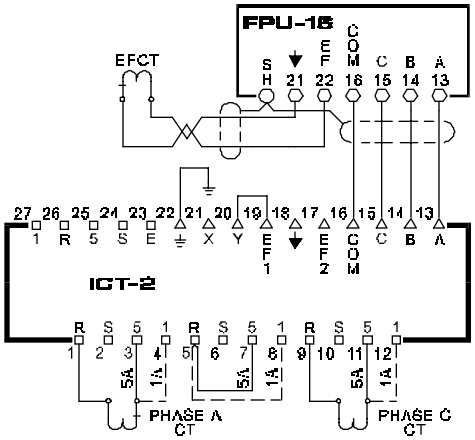
a) RESIDUAL CONNECTION



b) TWO-CT CONNECTION



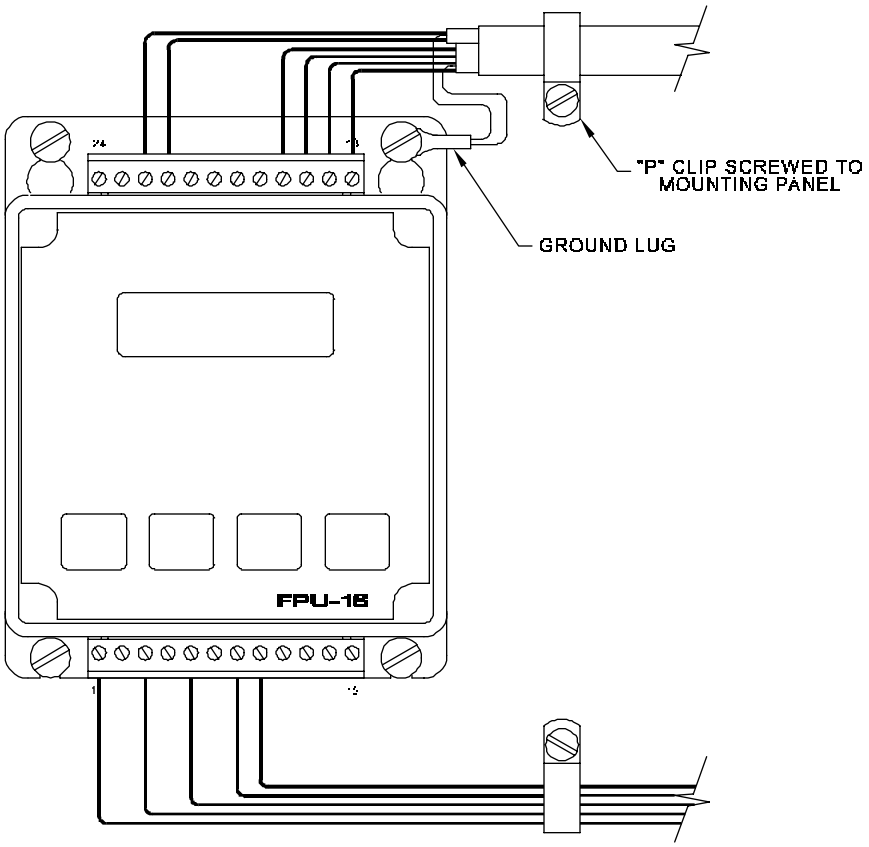
c) TWO-CT CONNECTION WITH EFCT



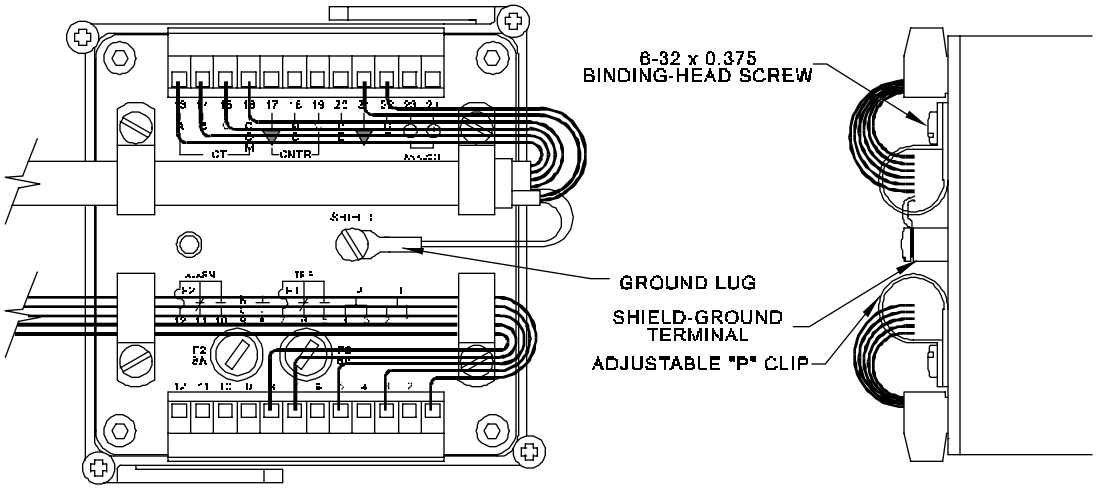
OTHER ICT-2 CONNECTIONS

FIGURE 12

a) SURFACE MOUNT



b) PANEL MOUNT



CABLE TERMINATION AND RESTRAINT

FIGURE 13

5. THEORY OF OPERATION

5.1 GENERAL (See Figure 14)

A basic FPU-16 consists of a display module, a power-supply module, a processor module, and an analog module. The display module is a "motherboard" for the other modules.

5.2 DISPLAY MODULE

The display module has two functions. It is the operator interface and it provides the main bus network for the system. The display module contains the LCD, LCD driver, LED indicators, and bus connectors. The power-supply, processor, analog, and option modules plug into the bus connectors. A sealed-membrane-switch keypad containing four switches and an ESD shield also connect to the bus. A direct-drive LCD allows operation to -40°C.

5.3 POWER-SUPPLY MODULE

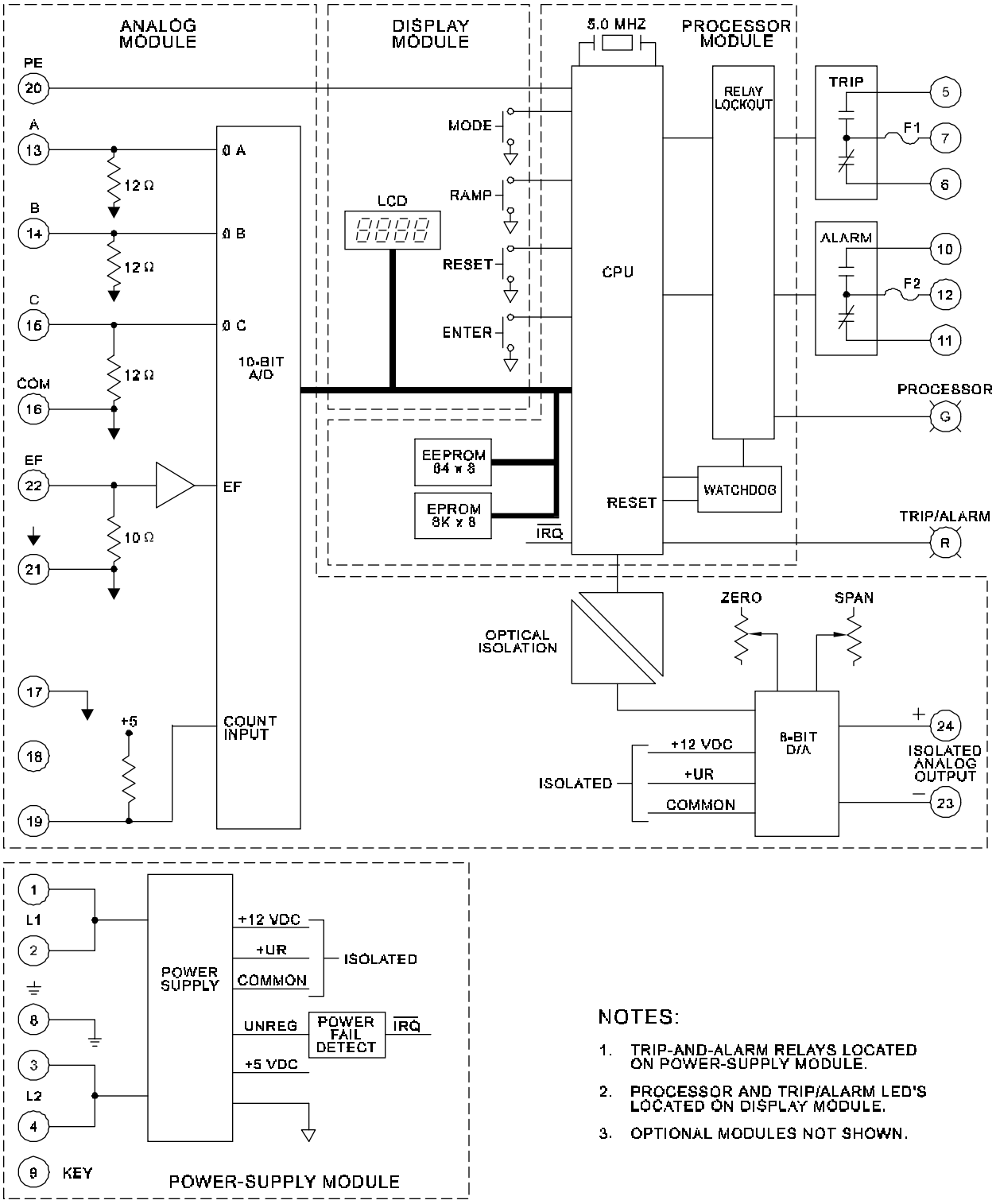
A transformer-isolated power supply provides 5, 12, and 20 Vdc for the other modules. The transformer primary can be connected for 120- or 240-Vac operation. A dc-to-dc converter is used for 120/240 Vac/dc operation or for 12-, 24-, or 48-Vdc operation. The power-supply module also contains the trip-and-alarm relays.

5.4 PROCESSOR MODULE

The processor module contains the CMOS 6805 microprocessor, EPROM memory, nonvolatile EEPROM memory, and watchdog circuit.

The EEPROM memory provides 64, 8-bit memory locations to store programmed values and values-at-trip. When the supply voltage drops below its minimum rated value, a power-fail circuit generates an interrupt and data are written into the EEPROM memory. Hysteresis in the power-fail circuit ensures that the FPU-16 will not attempt to operate unless the supply voltage is within specifications.

The watchdog connected to the CPU reset line will reset the CPU if a watchdog pulse has not been detected for 0.25 second. The watchdog prevents changes to the EEPROM contents until the CPU is reset. If the CPU does not reset, the trip-and-alarm relays are de-energized and the green PROCESSOR LED is turned off.



NOTES:

1. TRIP-AND-ALARM RELAYS LOCATED ON POWER-SUPPLY MODULE.
2. PROCESSOR AND TRIP/ALARM LED'S LOCATED ON DISPLAY MODULE.
3. OPTIONAL MODULES NOT SHOWN.

FPU-16 FUNCTIONAL BLOCK DIAGRAM

FIGURE 14

5.5 ANALOG MODULE

The analog module contains input circuits for phase current, operation counter, and earth-leakage current. It also contains an eight-channel, multiplexed, ten-bit, A/D converter and an isolated analog-output circuit. All inputs and outputs have MOV protection against electrical transients.

Serial data are transferred to the isolated analog-output circuit through a dual-channel optical isolator. The analog signal is scaled and buffered to provide the required current or voltage output.

5.6 OPTION MODULES

A 50-pin bus connector on the display module accepts a backlighting, remote input, or RS-485 communications interface module.

5.7 FIRMWARE

The FPU-16 has a two-cycle sampling interval followed by a one-cycle calculation interval.

In each sampling interval, the multiplexed A/D converter obtains 200 samples of the earth-fault and phase-current signals. The multiplexer sequences these four signals so that each measurement is a digital integration of 50 samples uniformly spaced throughout the sampling interval.

6. TECHNICAL SPECIFICATIONS

SPECIFICATIONS APPLY TO FIXED-FREQUENCY APPLICATIONS.

Specify supply voltage and frequency in FPU-16 model number. See Table 1.

Supply:
- AC (supply voltage codes: 12, 24, SW, and AD*):
  - 120/240 Vac, 50/60 ± 1 Hz ..... 10 VA
  - Maximum Continuous ..... 135/265 Vac
  - Minimum Continuous ..... 85/170 Vac
  - Power-up Voltage ..... 100/200 Vac
- DC (supply voltage code: AD): *
  - 100 to 240 Vdc..... 10 W
  - Maximum Continuous ..... 340 Vdc
  - Minimum Continuous ..... 90 Vdc
- DC (supply voltage codes: D1, D2, and D4): *
  - 12, 24, or 48 Vdc..... 10 W
  - Maximum Continuous ..... +50%
  - Minimum Continuous ..... -25%
- Fuse (F3)..... See Fuse-Selection Chart

Interface-CT Inputs:
- Thermal Withstand
  - Continuous ..... 5 x CT-Secondary Rating
  - 1-Second ..... 80 x CT-Secondary Rating
- Burden ..... < 0.01 Ω

Metering Accuracy vs ICT Interconnection Cable Length:

No. 22 AWG	No. 18 AWG	Accuracy
< 18 m (60 ft)	< 45 m (150 ft)	± 3%
< 30 m (100 ft)	< 75 m (250 ft)	± 4%
> 30 m (100 ft)	> 75 m (250 ft)	± 5%

Operation Counter Input:
- Maximum Count Rate..... 4 counts/s
- Count Method ..... Contact Closure
- Open-Contact Voltage..... 5 Vdc
- Closed-Contact Current ..... 18 mA

Output Relays:
- CSA/UL Contact Rating..... 8 A Resistive, 250 Vac or 24 Vdc. B300 Pilot Duty 0.25 hp @ 120 Vac

* CSA certification pending on AD, D1, D2, and D4.

Supplemental Contact Ratings:
- Make/carry 0.2 s ..... 30 A
- Carry Continuous..... 8 A
- Break:
  - dc..... 50 W resistive
    25 W inductive (L/R = 0.04 s)
  - ac..... 2000 VA resistive
    1500 VA inductive (PF = 0.4)
  - Subject to maximums of 8 A and 250 V (ac or dc).

Contact Configuration ..... Form C
Fuse Rating (F1 & F2) ..... 8 A, 250 Vac
Fuse Type ..... See Fuse-Selection Chart

Analog Output:
- Parameter..... 0 to 1.25 x I_n,
  0 to 100% I^2t, or
  0 to 1 x I_e
- Drive:
  - 4–20 mA..... 700 Ω max
  - 0–5 Vdc ..... 25 mA max
  - 0–10 Vdc ..... 25 mA max
- Isolation to Ground ..... 300 Vac Continuous
- Dielectric Strength ..... 1500 Vac
- Resolution ..... ± 1% Full Scale

Accuracies:
- Ammeter Accuracy [1, 2] ..... ± 0.3% Full Scale or
  ± 3% Reading
- Earth-Leakage Accuracy [2] ..... ± 3% I_e

[1] Ammeter Full Scale = 10 x I_n
[2] Interface-CT accuracy included

Environment:
- Operating Temperature..... -40°C to 60°C
- Storage Temperature ..... -55°C to 80°C

Terminal Block Ratings:
- FPU-16..... 10 A, 300 Vac, No. 14 AWG
- ICT-2, CT Inputs ..... 25 A, 500 Vac, No. 10 AWG

Compliance:
- Impulse Voltage Withstand to IEC 255-4,
  Appendix E, Class III
- High-Frequency Disturbance to IEC 255-4,
  Appendix E, Class III
- Dielectric to IEC 255-5, Clause 6
- Insulation Resistance to IEC 255-5, Clause 7

Fuse-Selection Chart:

FUSE	HZ	VOLTAGE	RATING	DESCRIPTION
F1, F2	60	120/240	8 A, 250 Vac	¼" x 1¼" CSA/UL Normal
	50			IEC 127/I F Quick Acting
F3	60	120	100 mA, 250 Vac	¼" x 1¼" CSA/UL Time
		240	62 mA, 250 Vac	Delay
SW	50	120	160 mA, 250 Vac	IEC 127/III T Time Lag
		240	80 mA, 250 Vac	
F3 D1		12 Vdc	2A, 250 Vac	¼" x 1 ¼" CSA/UL Time Delay 5 x 20 mm IEC 127/III TD
F3 D2		24 Vdc	1 A, 250 Vac	¼" x 1 ¼" CSA/UL Time Delay 5 x 20 mm IEC 127/III TD
F3 D4		48 Vdc	0.5 A 250 Vac	¼" x 1 ¼" CSA/UL Time Delay 5 x 20 mm IEC 127/III TD

All specifications are subject to change without notice.

FPU-16 MANUAL COMPATIBILITY

Startco Engineering Ltd. constantly strives to improve its products. These product improvements are upwardly compatible so that a unit can be replaced by a unit of more recent manufacture. As features or enhancements are incorporated, the manual is revised to reflect the changes made. It is important that the manual revision corresponds to both the FPU-16 revision level and the firmware revision level.

The FPU-16 revision level is shown on its nameplate and the firmware revision level is accessed by selecting Mode 8 and pressing ENTER. The manual revision level is listed on the manual title page.

MANUAL REVISION LEVELS

REVISION LEVELS					COMMENTS
FPU-16		FIRMWARE		MANUAL	
60 Hz	50 Hz	60 Hz	50 Hz		
0	50	0	50	0	Initial release.
0	50	0	50	1	Minor manual changes.
0	50	0	50	2	Manual changes, dc power supply added.

TABLE 4

WARRANTY

The Startco Engineering FPU-16 feeder protection unit is warranted to be free from defects in material and workmanship for a period of 12 months from installation, or 18 months from date of invoice, whichever comes first. Startco Engineering Ltd. will (at Startco's option) repair, replace, or refund the original purchase price of a unit which is determined by Startco to be defective if it is returned to Startco, prepaid, within the warranty period. This warranty does not apply to any feeder protection unit which has been subjected to misuse, negligence, or accident, or has been misapplied, modified, or improperly installed.

The foregoing provisions are the sole obligation of Startco Engineering Ltd. and exclude all other warranties or guarantees. No warranty or representation is to be taken to have been given or implied from anything said or written in the negotiations between the customer and Startco Engineering Ltd., or their respective representatives, prior to the granting of this warranty, and any statutory or other warranty or condition, expressed or implied, as to the state, quality, or fitness of the goods subject to this warranty is hereby expressly excluded. No agent, distributor, or employee is authorized to extend or enlarge upon this warranty by any verbal or written statement or advertisement.

Under no circumstances shall Startco Engineering Ltd. be liable to the customer or to any person for injury to person, or damage to or loss of property or value caused by unit malfunction, misapplication, modification, or adjustment. Under no circumstances shall Startco Engineering Ltd. be liable for any incidental, consequential, or special damages, losses or expenses in connection with the use of, or inability to use the product for any purpose whatsoever. Disclaimers apply both during and after the term of this warranty.

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FPU-16 WARRANTY REGISTRATION

Completed warranty registration must be returned within 30 days of purchase.

MODEL NO. FPU-16 _____ SERIAL NO._____

PURCHASED FROM _____

PURCHASE DATE _____ INSTALLATION DATE _____

PURCHASED BY _____

ADDRESS _____

CITY _____ PROV. OR STATE _____

POSTAL OR ZIP CODE _____ SIGNATURE _____

