

## BE1-87T TRANSFORMER DIFFERENTIAL RELAY

The BE1-87T Transformer Differential Relay is designed as primary protection for power transformers against internal faults. Available in either single- or three-phase configurations, this solid-state relay compares the currents entering and leaving the protected transformer. If any imbalance is detected that is not attributable to other (tested) factors, the relay provides a contact closure to isolate the power transformer to limit damage.

### FEATURES

- Single- and three-phase configurations.
- Input isolation.
- Three-phase configuration includes internal phase shift compensation with zero-sequence current blocking.
- 2nd- and 5th-harmonic restraint.
- Adjustable through-current restraint.
- %  $I_{OP}$  display.
- Tap scaling covers the range of 2.0 to 8.9 amperes in 0.1-ampere increments in 5 Ampere CT models, and 0.4 to 1.78 amperes in 0.02-ampere increments in 1 Ampere CT models.
- Low sensing burden.
- Maintains proper operation when tested for interference in accordance with IECC C37.90-1989, *Trial-Use Standard Withstand Capability of Relay systems to Radiated electromagnetic Interference from Transceivers*.
- UL listed (except for 250Vdc power supply).
- 2-year limited warranty.

### ADDITIONAL INFORMATION

#### INSTRUCTION MANUAL

Request publication 9-1713-00-990

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## FUNCTIONAL DESCRIPTION

### GENERAL

The BE1-87T is a solid-state relay to protect power transformers by providing an output contact closure when the “scaled” current into the protected transformer does not equal the “scaled” current out (within defined limits). The relay is harmonically restrained to prevent tripping during initial energization and overexcitation conditions. A through-current restraint also provides security against tripping for external faults. An unrestrained tripping element is included to provide high speed tripping in the event of a severe internal fault.

The functional block diagram in Figure 1 illustrates the overall operation of the BE1-87T. Since the relay is available as either a single-phase or three-phase device, only phase A is shown in detail. Phases B and C, when present, are functionally similar to phase A.

### CURRENT TRANSFORMERS

A standard current transformer with a 5A or 1A secondary winding supplies sensing current for each input. These current transformers may be shared with other protective relays due to the isolation of individual inputs. The sensed currents are, in turn, applied to the internal input transformers of the relay.

### SCALING

Input currents are scaled by rotary switches that introduce resistances to the internal CT secondaries. The switches are calibrated in 0.1 ampere increments from 2.0 to 8.9 amperes (5 ampere CT models) and 0.02 ampere increments from 0.4 to 1.78 amperes (1 ampere CT models). The many graduations of adjustment are provided to allow each input to approach an ideal representation of its actual operating per unit value.

### SUMMING

The analog signals representing each input's contribution are electronically summed. This process produces the operating current ( $I_{OP}$ ), which is the algebraic sum of the input currents.

Ideally, with perfectly matched CTs, a transformer without an internal fault would have an  $I_{OP}$  of zero. A fault would be indicated by a nonzero  $I_{OP}$ . However, saturation caused by heavy through-currents, magnetic inrush or overexcitation can cause  $I_{OP}$  to be present

even though no fault has occurred. To prevent false tripping under such conditions, various types of restraint are used.

### RESTRAINED TRIP OUTPUT

The restrained trip output is subject to three types of restraint signals developed within the relay in response to external conditions:

- Percentage restraint
- Second-harmonic restraint
- Fifth-harmonic restraint

The “calculate max individual current” circuit determines which scaled input is receiving the greatest current. The resulting signal,  $\%I_{MAX}$  (figure 2) represents the percentage of through-current and is extended to the trip comparator, where it is compared to the operating current.

If the operating current is greater than  $\%I_{MAX}$  and there is no inhibit signal present, a restrained trip is produced; also an auxiliary output will occur (depending on relay configuration).

### Harmonic Restraints

The restrained trip output may be inhibited by either of two harmonic restraints. These are generated by filters tuned to the second- and fifth-harmonic content of the operate current. Comparators monitor these signals. When the fifth-harmonic content exceeds 35% of the operate current (indicating overexcitation of the transformer), or when the 2nd-harmonic content exceeds 12% (single-phase) or 18% (three-phase) of the operating current (indicating a magnetic inrush condition), an inhibit signal blocks operation of the Restrained output relay. The three-phase mode uses summing of the second harmonic signal to provide secure operation.

### Critical Speed Applications (Option)

On some applications, overall fault clearing time can be a major issue. The 87T can optionally be configured with a faster overall operating speed for these applications.

## FUNCTIONAL DESCRIPTION

### (Continued)

#### Unbalance Display

The 87T can be optionally configured with a front panel indication of system unbalance, to permit verification of proper relay connections. The display consists of 8 LEDs, which show the unbalance as a percent of trip.

$$\left( \frac{I_{OP}}{\% I_{MAX}} \right)$$

#### UNRESTRAINED TRIP OUTPUT

The  $I_{OP}$  signal is also compared against a reference established by the front panel UNRESTRAINED TRIP setting. When this reference is exceeded, the unrestrained trip output relay is energized. The unrestrained trip is not affected by through-current or harmonic content.

#### PHASE SHIFT AND ZERO SEQUENCE FILTER (Available only in three-phase relays)

In three-phase relays, the phase-shift jumpers may be placed to provide +30 degrees, -30 degrees or no compensation for delta-wye or wye-delta transformer configurations. The  $\pm 30$  degree phase shift will accomplish the corresponding zero sequence blocking.

In single-phase relays, the internal phase shift is not available and the phase shift compensation and zero sequence filtering must be provided by the external CT connections.

#### AUXILIARY RELAY (Option)

The auxiliary relay is controlled by two switches, S1 and S2, which allow it to respond to a restrained trip, or to an unrestrained trip, or both. The S1 and S2 switches are located on the mother board.

#### POWER SUPPLY

The solid-state power supply is a low burden, flyback switching design which delivers a nominal  $\pm 12$  Vdc to internal circuitry. The power supply inputs are not polarity sensitive. A red LED illuminates to indicate that the power supply is functioning properly.

The Type Y power supply includes a field adjustable link that is factory set for 125 Vdc input power. An alternative position is selected for 48-volt input power.

#### POWER SUPPLY STATUS OUTPUT

The power supply status output relay has a normally closed (NC) contact. This relay is energized by the presence of nominal voltage at the output of the power supply. Normal operating voltage then keeps the relay continuously energized and its contact open. However, if the power supply voltage falls below requirements, the power supply status output relay will de-energize, and close its contact.

#### TARGET INDICATOR CIRCUITS (Option)

When a target option is specified, magnetically latched indicators are included within the relay. They may be actuated by either of two methods as defined by the style chart designation.

Internally operated (type C) targets are operated by internal driver circuits that are actuated by a signal from the relay's internal logic circuits, paralleling the close signal to the output relay.

Current operated (type D) targets are actuated when a minimum of 0.2 A flows through the relay's output contacts. To accomplish this, a special reed relay is placed in series with the output contacts to enable the target indicator. (The series impedance of the reed relay is less than 0.1 ohm.)

When targets are specified, the BE1-87T relay is supplied with FUNCTION (RESTRAINED and UNRESTRAINED) targets. Three-phase styles are additionally supplied with ELEMENT (PHASE A, B, C) targets.

#### PUSH-TO-ENERGIZE OUTPUT SWITCHES (Option)

If Option 2-S has been selected, small pushbutton switches are included for the restrained and unrestrained functions. Each switch will energize the corresponding output relays for test purposes. To prevent accidental operation of these switches, they are recessed behind the front panel of the relay, and are accessed by inserting a thin non-conducting rod through access holes in the panel.

# FUNCTIONAL DESCRIPTION (Continued)

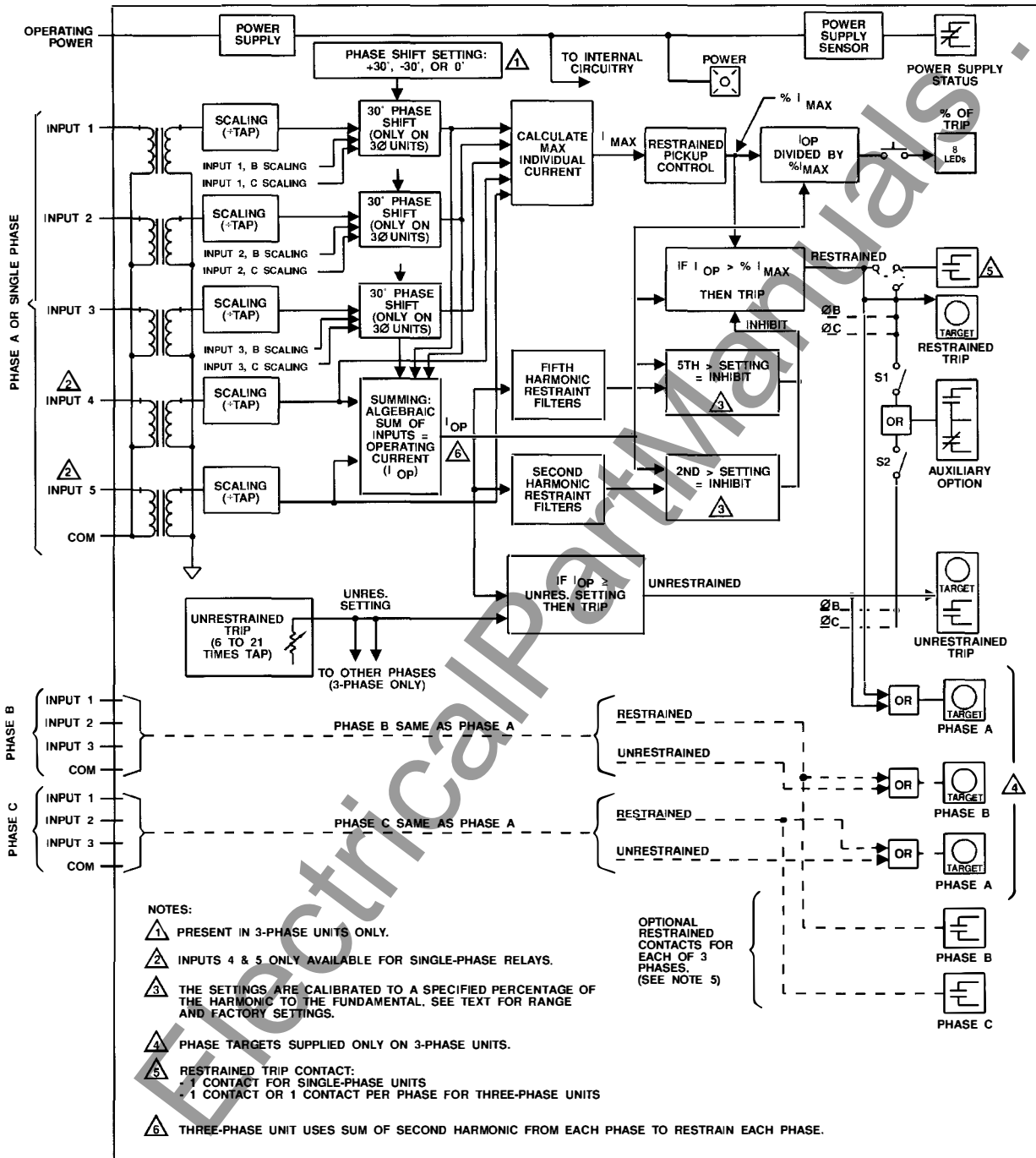


Figure 1 - Functional Block Diagram

## FUNCTIONAL DESCRIPTION (continued)

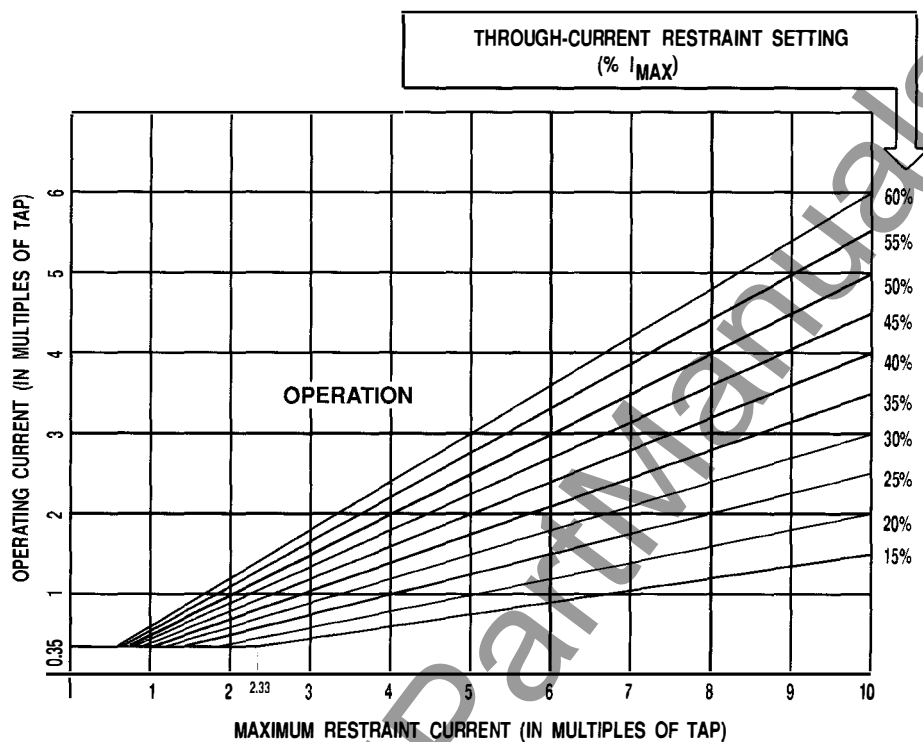


Figure 2.

## SPECIFICATIONS

### CURRENT SENSING INPUTS

The unit is designed to operate from the secondary of current transformers rated at either 5A or 1A. Frequency range is  $\pm 5$  Hz of nominal. Maximum current per input (5 Ampere CT Models) 20A continuous; 250A or 50 X tap (whichever is less) for 1 second; (1 Ampere CT Models) 4A continuous; 50A or 10 X tap (whichever is less) for 1 second. For ratings other than one second, the rating may be calculated as:

$$I = \frac{K}{\sqrt{t}}$$

where t is the time (in seconds) that the current flows, and K = 250A or 50 times tap, whichever is less (5A CT Models); or K = 50A or 10 times tap, whichever is less (1A CT Models).

### CURRENT SENSING BURDEN

Less than 0.1 ohm per phase.

### SCALING CONTROL (or Tap Setting)

Front panel rotary switches permit scaling the sensed input current (or Tap Setting) over the range of:

(5 Ampere CT Models) 2.0 to 8.9A, in 0.1A increments

(1 Ampere CT Models) 0.4 to 1.78A, in 0.02A increments

### RESTRAINED OUTPUT PICKUP CONTROL

Front panel thumbwheel switches permit adjustment of the restrained pickup as a percentage of through current, and over the range of 15 to 60% in increments of 5%. (Figure 2)

### MINIMUM PICKUP

$I_{OP} = 0.35 \times \text{tap setting} \pm 6\%$ . (Figure 2)

### SECOND-HARMONIC RESTRAINT

Inhibit of the restrained output occurs when the second-harmonic component exceeds the pickup setting which is internally adjustable over the range of 8% to 15% of the operating current for single-phase units, or 11% to 27% three-phase units. The factory setting is 12% for single-phase units and 18% for three-phase units.

### FIFTH-HARMONIC RESTRAINT

Inhibit of the restrained output occurs when the fifth-harmonic component exceeds a pick-up setting which has an internally adjustable range of 25% to 45% of the operating current. The factory setting is 35%.

### UNRESTRAINED OUTPUT PICKUP CONTROL

Front panel thumbwheel switches provide adjustment of the desired pickup point for the unrestrained element of the relay from 6 to 21 times the tap setting in increments of 1x tap.

### OUTPUTS

Output Contacts are rated as follows.

#### Resistive

120/240 Vac: Make 30A for 0.2 seconds, carry 7A continuously, break 7A.

250 Vac: Make and carry 30A for 0.2 seconds, carry 7A continuously, break 0.3A.

500 Vdc: Make and carry 15A for 0.2 seconds, carry 7A continuously, break 0.1A.

#### Inductive

120/240 Vac, 125 Vdc, 250 Vdc: break 0.3A (L/R = 0.04).

### TARGET INDICATORS

Internally operated and current operated targets are available (in accordance with the style number).

Internally operated targets utilize the internal trip signal to energize the output relay and the target drivers. Current operated targets are energized by a minimum of 0.2A flowing through the output contacts.

The series impedance of the current operated target is 0.1 ohms or less. The current operated targets are rated at 30A for 0.2 seconds, 7A for 2 minutes and 3A continuous. **Note: This is less than the rating of the output contact and can constrain the control circuit.**

*Single-phase Units* - When specified, either an internally operated or a current operated target will be supplied for the relay.

*Three-phase Units* - When targets are specified, either internally operated or current operated targets indicate the function (Restrained or Unrestrained) that caused the trip as well as the associated phase element (A,B,C).

## SPECIFICATIONS (continued)

### POWER SUPPLY SPECIFICATIONS

| Typ | Nomina<br>Input<br>Voltage | Input<br>Voltage<br>Range      | Burden at<br>Nominal<br>(Energize) | Burden at<br>Nominal<br>(De-Energiz) |
|-----|----------------------------|--------------------------------|------------------------------------|--------------------------------------|
| J   | 125 Vdc<br>120 Vac         | 62 - 150 Vdc<br>90 - 132 Vac   | 9.0 W<br>21.0 VA                   | 6.5 W<br>16.0 VA                     |
| K   | 48 Vdc                     | 24 - 60 Vdc                    | 8.5 W                              | 6.0 W                                |
| L   | 24 Vdc                     | 12 - 32 Vdc                    | 9.0 W                              | 6.5 W                                |
| Y   | 48 Vdc<br>125 Vdc          | 24 - 60 Vdc<br>62 - 150 Vdc    | 7.5 W<br>8.5 W                     | 6.0 W<br>6.5 W                       |
| Z   | 250 Vdc<br>230 Vdc         | 140 - 280 Vdc<br>190 - 270 Vac | 9.5 W<br>28.0 VA                   | 7.7 W<br>26.6 VA                     |

### WEIGHT

22.3 pounds (three-phase unit)  
19.5 pounds (single-phase unit)

### CASE SIZE

M1 case (double ended).  
Refer to Bulletin SDA for dimensions.

### AGENCY RATINGS

UL listed (except for 250Vdc power supply).  
U.S. Patent #5014153. Patented in Canada,  
1993.

### ISOLATION

1500 Vac at 60 Hz for one minute in accordance  
with IEC 255-5 and ANSI/IEEE C37.90-1989  
(Dielectric Test).

### SURGE WITHSTAND CAPABILITY

Qualified to: ANSI/IEEE C37.90-1989, *Standard  
Surge Withstand Capability Test and Fast Tran-  
sient Test*, and IEC 255-5 *Impulse Test and  
Dielectric Test*.

### RADIO FREQUENCY INTERFERENCE (RFI)

Maintains proper operation when tested for  
interference in accordance with IECC C37.90-  
1989, *Trial-Use Standard Withstand Capability of  
Relay systems to Radiated electromagnetic  
Interference from Transceivers*.

### SHOCK

In standard tests, the relay has withstood 15 g in  
each of three mutually perpendicular axes without  
structural damage or degradation of performance.

### VIBRATION

In standard tests, the relay has withstood 2 g in  
each of three mutually perpendicular axes swept  
over the range of 10 to 500 Hz for a total of six  
sweeps, 15 minutes each sweep, without struc-  
tural damage or degradation of performance.

### OPERATING TEMPERATURE

-40°C to +70°C (-40°F to +158°F)

### STORAGE TEMPERATURE

-65°C to +100°C (-85°F to +212°F)

## EXTERNAL CONNECTION

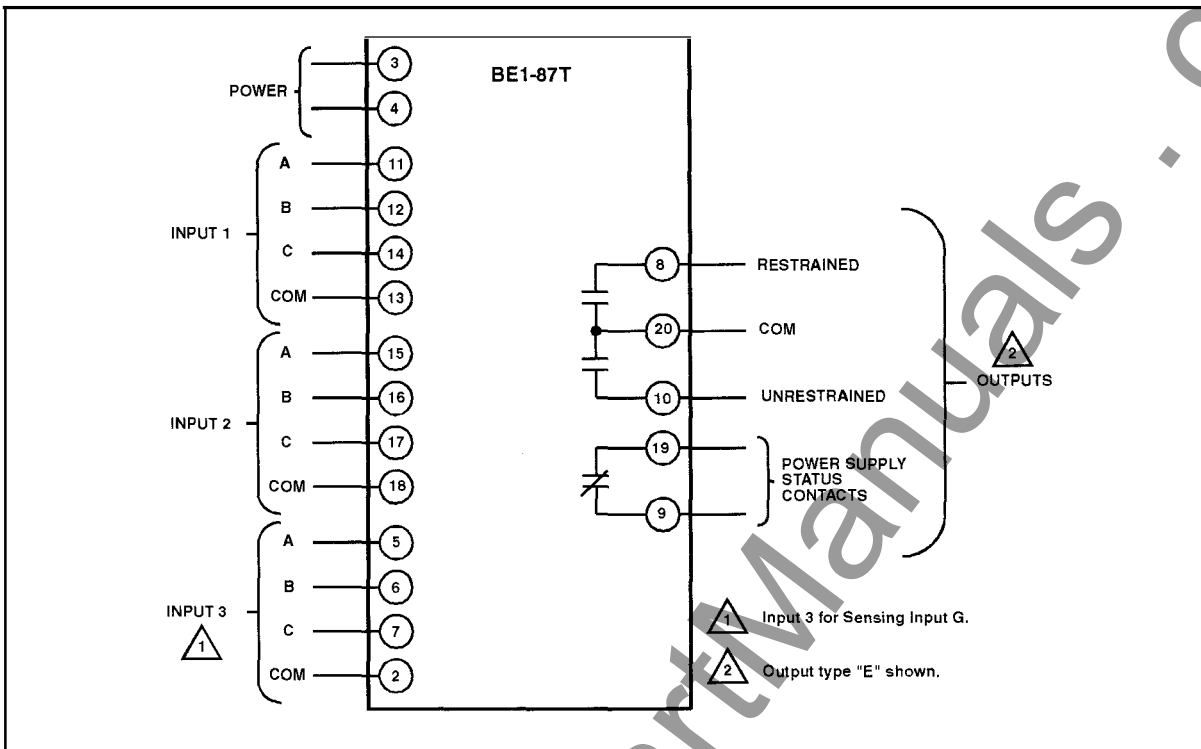


Figure 3 - Sensing Connections for Three-Phase Unit with Two Normally Open Contacts

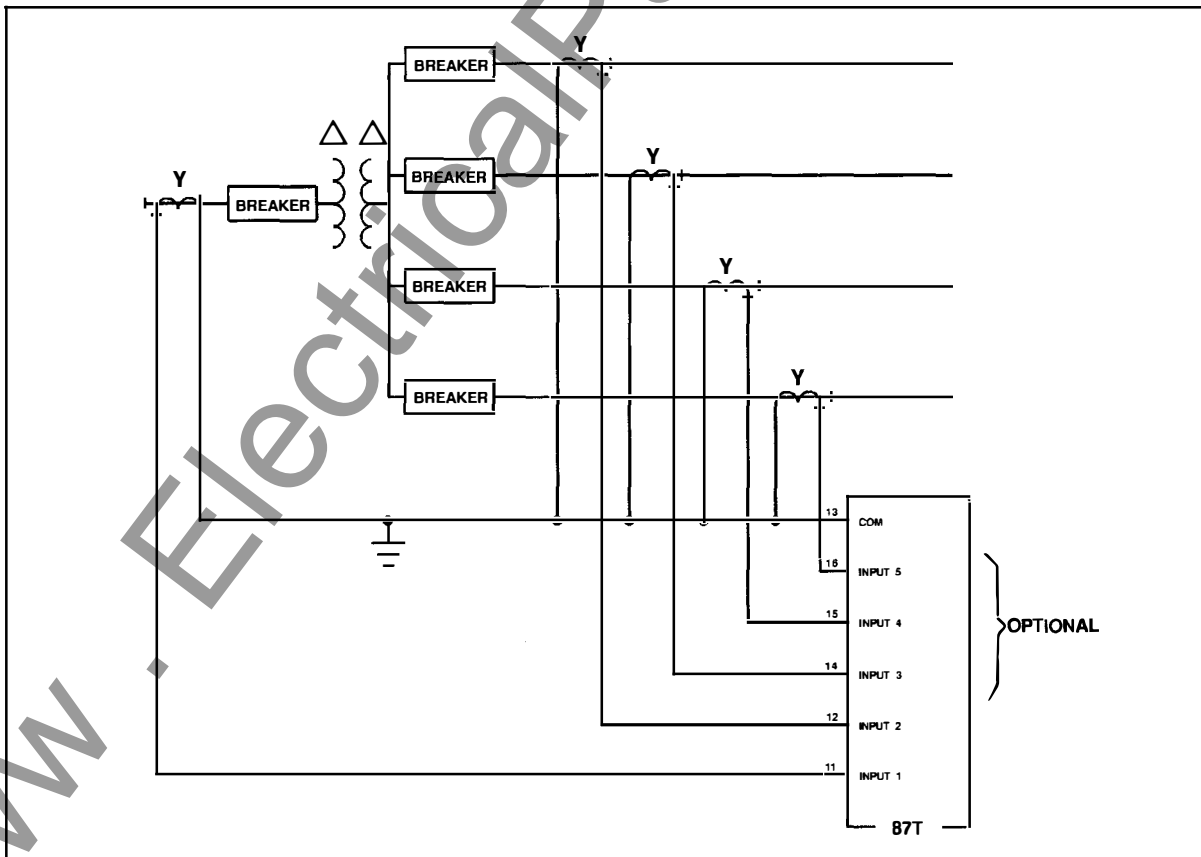


Figure 4 - Sensing Connections for Single-Phase Unit with Five Inputs



## EXTERNAL CONNECTION (Continued)

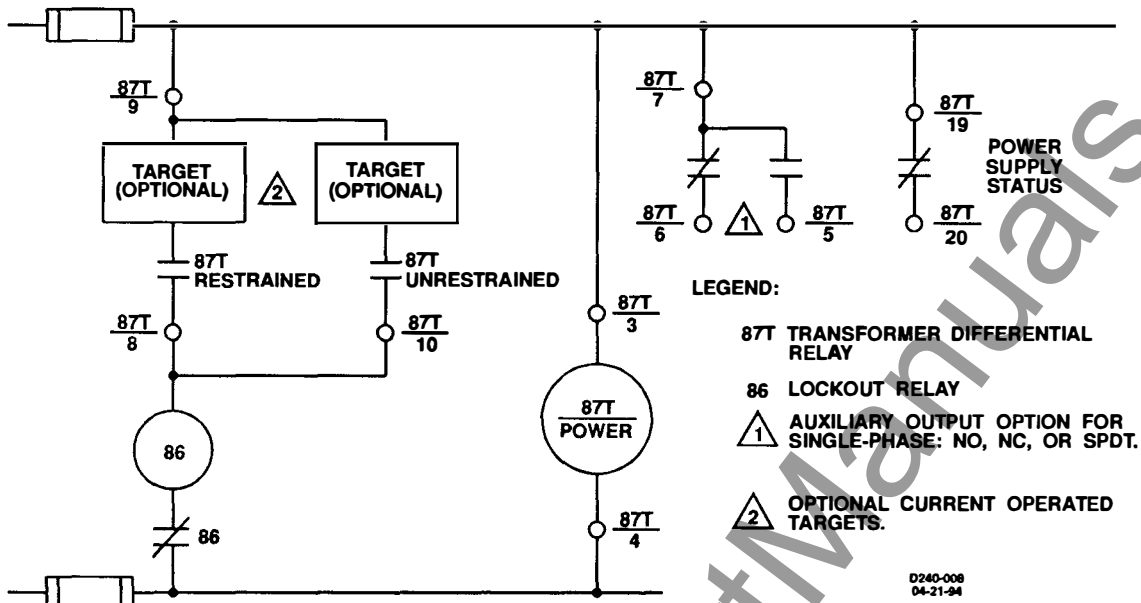


Figure 5 - Typical Control Connections for Output E:  
(Single-Phase or Three-Phase)

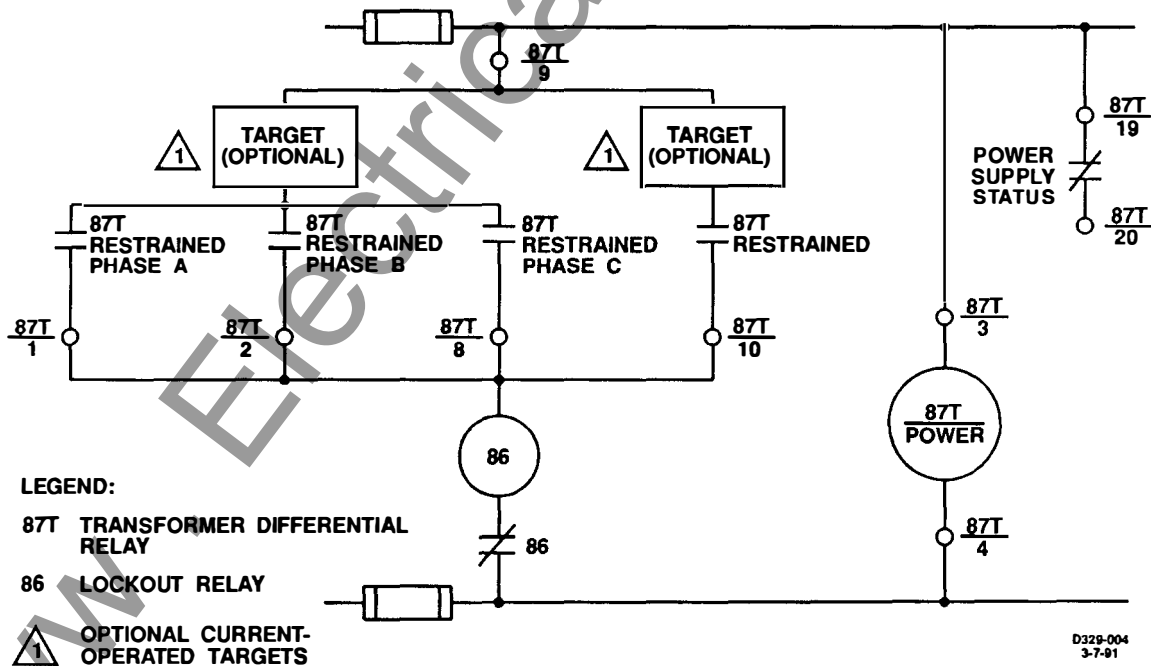


Figure 6 - Typical Control Circuit Connections for Output F

## ORDERING

### MODEL NUMBER

BE1-87T Transformer Differential Relay

### STYLE NUMBER

The style number appears on the front panel, drawout cradle, and inside the case assembly. This style number is an alphanumeric combination of characters identifying the features included in a particular unit. The sample style number below illustrates the manner in which the various features are designated. The Style Number Identification Chart (page 11) defines each of the options and characteristics available for this device.

#### SAMPLE STYLE NUMBER: BE1-87T E1E-A1J-D0S1F

The style number above describes a BE1-87T Transformer Differential relay having the following features:

- (E) Three-phase current sensing for a two winding transformer.
- (1) 2.0 to 8.9 ampere tap setting range.

- (E) One restrained and one unrestrained output contact (N.Q.)

- (A1) Instantaneous Timing.

- (J) Internal operating power is obtained from an external 125 Vdc or 100/120 Vac source.

- (D) Function targets (Restrained and Unrestrained) are current operated. Element (Phase) Targets are internally operated.

- (0) No option installed.

- (S) Push-to-energize switches are included to verify external wiring connections.

- (1) Normally open auxiliary output contacts operate concurrently with either the Restrained or Unrestrained output relays, or both.

- (F) The relay case is configured for flush mounting.

Note: Description of a relay must include both the model number (BE1-87T), and complete style number.

### HOW TO ORDER:

Designate the model number, followed by the complete Style Number:

BE1-87T Style No. □□□-□□□-□□□□□

Complete the Style Number by selecting one feature from each column of the Style Number Identification Chart and entering its designation letter or number in the appropriate square. All squares must be completed.

### STANDARD ACCESSORIES

The following standard accessories are available for use on the BE1-87T Transformer Differential Relays.

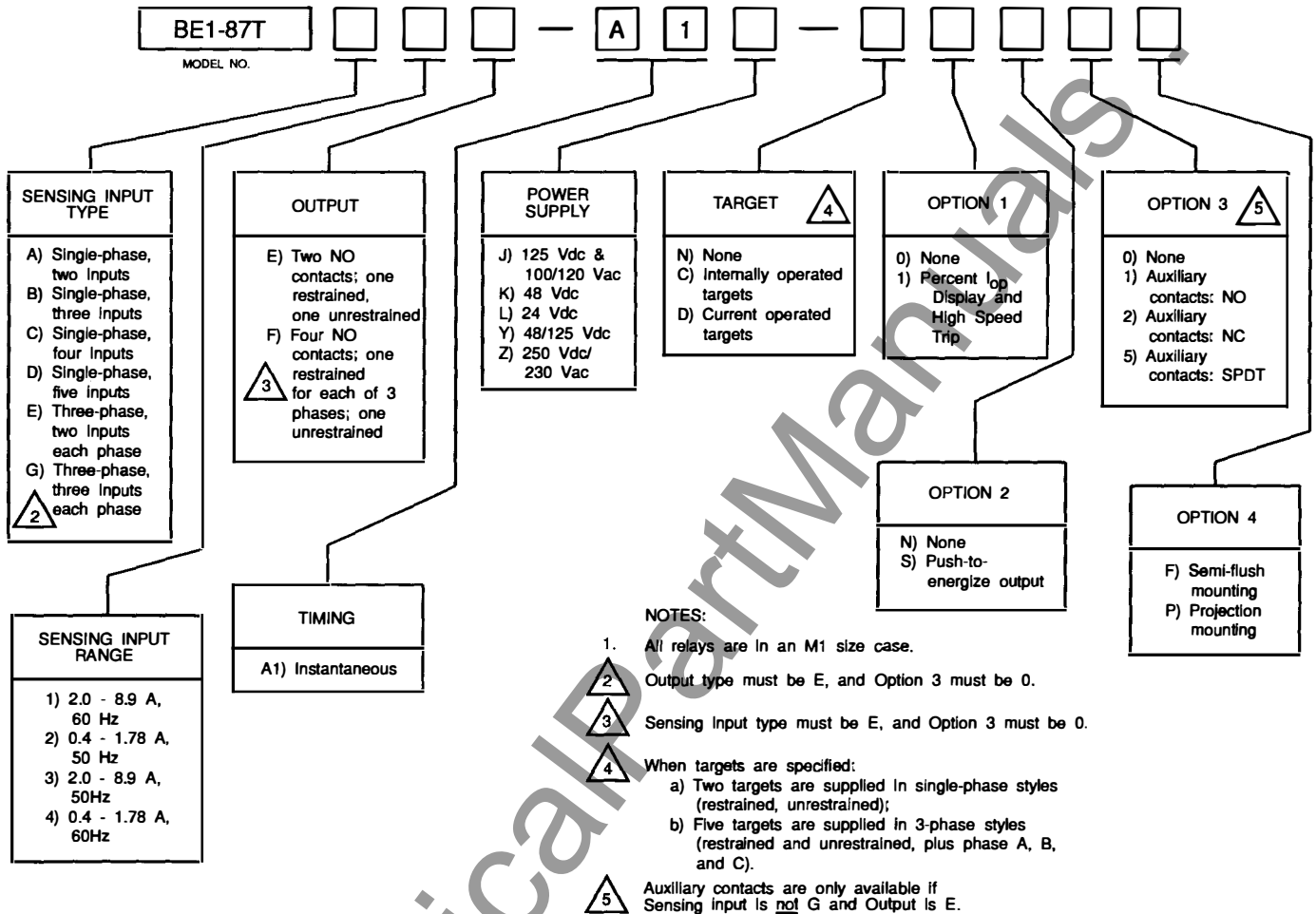
#### Test Plug

Order Test Plug, Basler Electric part number 10095. (Two plugs are required for complete testing capabilities.)

#### Extender Board

The Extender Board will permit troubleshooting of the PC boards outside the relay cradle. Order Basler part number 9 1655 00 100.

# STYLE NUMBER IDENTIFICATION CHART



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