INSTRUCTIONS

MODULAR POSITIVE SEQUENCE OUT-OF-STEP RELAY
TYPE OST

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CONTENTS

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INTRODUCTION

The Type OST relay is a microprocessor-based positive-sequence static distance relay designed to provide out-of-step tripping, or blocking, protection. It uses three modified-mho characteristics, all with the same forward and reverse reach along a common maximum-reach angle, but each having a different shape (such as lens, circle or tomato). It includes logic and time-delay circuits that work with the modified-mho characteristics to detect an out-of-step condition.

The Type OST relay is mounted in a four rack unit (4RU) high case (one rack unit equals 1-3/4 inches), suitable for mounting in a standard 19-inch rack. The case and outline dimensions are shown in Figure 1. Both the electronics and the magnetics are contained in pluggable modules that are removable from the front of the case.

The case includes a DC-to-DC power supply and both trip and block output relays. Each relay has three normally open contacts. The OST also includes test receptacles that may be used with Type XTM test plugs to make periodic tests, plus built-in automatic self-test features.

APPLICATION

The Type OST relay provides tripping and out-of-step blocking protection when applied to either transmission lines or generators. While both tripping and blocking outputs are provided in the same relay, one or the other would be used in a specific application based on the location of the relay in the power system. For example, at a tie with a neighboring utility, out-of-step tripping (OST) might be used, with out-of-step blocking (OSB) of lines further back into the system.

Loss of synchronism or a power swing between two areas of a power system is detected by measuring the positive-sequence impedance seen by the relay over a period of time as the power swing develops. Since the OST relay measures positive-sequence impedance as seen at the relay location, there is less chance of setting up blocking for non-swing conditions (such as close-in single-phase-to-ground faults on series compensated lines where gap flashing and capacitor reinsertion can cause the fault impedance to vary greatly) than there is for a relay that measures phase impedance.

The OST relay contains circuits that produce three modified-mho distance relay characteristics. These characteristics have the same reach along a common angle of maximum reach, but have different reaches along the R axis. An out-of-step condition is detected by measuring the time it takes for the apparent impedance

* Revised since last issue

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes, the matter should be referred to the General Electric Company.

To the extent required the products described herein meet applicable ANSI, IEEE and NEMA standards; but no such assurance is given with respect to local codes and ordinances because they vary greatly.

by the relay to travel from the load impedance value to a point along the protected line. A fault on the line will cause this impedance change to occur immediately and will not set up out-of-step tripping or blocking. For a swing condition the impedance will change slowly. If the impedance passes through the three characteristics in the proper sequence, out-of-step trip and block outputs are produced.

The basic mode of operation is with all three characteristics (OUTER, MIDDLE, INNER). However, by a link arrangement, the MIDDLE characteristic can be bypassed, thereby using only the OUTER and INNER characteristics for out-of-step detection. The decision whether to use two or three characteristics depends largely on the maximum slip frequency expected during a swing condition. Three characteristics are preferred if the slip frequency is low enough to permit making the minimum recommended settings on TL61, TL62 and TL63. In some applications only two characteristics may be necessary, because the combination of a fast-moving swing locus (high-slip frequency) and a restricted OUTER characteristic (due to heavy load transfer) prevents setting up the proper logic sequence.

There is another link arrangement that provides a choice between tripping as soon as the out-of-step condition is confirmed (entering the INNER characteristic) or delaying tripping until the two system voltages are more nearly in phase (leaving OUTER chacarteristic). Some users prefer this delayed tripping to reduce the risk of damage to the breaker that does the tripping.

OPERATING PRINCIPLES

The OST uses the block-block method of producing a distance relay characteristic. In this method, the two AC quantities to be compared are converted to blocks with zero crossings that are coincident with the zero crossings of the AC waves. The angle between the two AC quantities is determined by measuring the time that the two blocks are coincident (either both positive or both negative). For example, if the two AC waves are in phase, they are coincident for 180°. If they are 60° apart, they are coincident for 120°, etc. The timers that measure this duration of coincidence are called coincidence timers. The settings are made in electrical degrees rather than milliseconds.

This relay uses positive-sequence voltage and positive-sequence current to measure positive-sequence impedance at the relay location. The three-phase voltage input is converted to a positive-sequence voltage, V_1, by a positive-sequence voltage network. The three-phase current inputs are converted to voltage signals, with output voltage leading input current by 85°, by passing through transactors. These voltages are then converted to a positive-sequence signal, IZ_1, by another positive-sequence voltage network.

OFFSET MHO CHARACTERISTIC

Figure 6 illustrates the way in which a circular offset mho characteristic is obtained by an angular measurement between the two quantities $IZ_1 - V_1$ and $IZ'_1 + V_1$. IZ'_1 is opposite in polarity to IZ_1. Z_1 determines the forward reach of the relay, and Z'_1 determines the reverse reach. They may be set to different values. The angle by which IZ_1 leads I is called the maximum reach angle of the relay characteristic, and can be adjusted from 50° to 80° in the OST1100. The maximum reach angle shown in Figure 6 is 60°.

In Figure 6, V_1 is common to both of the operating quantities, $IZ_1 - V_1$ and $IZ'_1 + V_1$. Figure 6b represents a fault on the relay characteristic (the tip of the V_1 phasor represents the fault location). Angle A between the two quantities is 90°. For any other fault location that would cause the tip of the V_1 phasor to fall on the circular characteristic, the angle A would be 90°. Therefore a 90° measurement produces the characteristic shown.

Figure 6a illustrates the angle A for one fault location that is outside the relay characteristic. The angle A is greater than 90°, which means that the two quantities would be coincident for less than 90°.

This same principle applies regardless of the angle between V_1 and IZ_1. For a swing condition, V_1 and I_1 are more nearly in phase than shown here. As long as the characteristic timer setting is 90°, the characteristic is circular as shown in Figure 6, and an angle A less than 90° represents an impedance inside the relay characteristic.

LOB CHARACTERISTICS

The shape of the offset mho characteristic may be expanded or restricted by changing the characteristic timer setting. Figure 7 shows three modified-mho characteristics that are referred to as LOB characteristics (lens out-of-step block). All three have the same forward and reverse reach along the maximum reach angle, but the OUTER characteristic is an expanded mho (tomato-shaped) while the MIDDLE and INNER characteristics are restricted mhos (lens-shaped). Note that the characteristic angle settings are: $B_1 = 70°$, $B_2 = 100°$ and $B_3 = 150°$ for the three characteristics.

In Figure 7, the line Y-Y' is a construction line perpendicular to the maximum reach angle and is used to draw the three characteristics. The dotted line, SWING LOCUS, represents one possible path that would be followed by the apparent impedance resulting from a swing, and it may travel either from left to right, or from right to left. Also, the SWING LOCUS may be above the location shown, depending on the relationship between the relay location and the electrical center of the power system.

The discrimination between a fault condition and a system swing is accomplished by checking the time that it takes for the apparent impedance to move from the load condition (far outside the OUTER characteristic) to a point within the INNER characteristic. This change occurs immediately for a fault condition, but occurs at a much slower rate for a swing.

OUT-OF-STEP DETECTION

The actual out-of-step detection in the OST relay is accomplished by a software program in the microprocessor. This software program is equivalent to the logic diagram shown in Figure 2. It should be emphasized that this logic diagram is only a functional representation, and that the AND, OR and NOT elements shown may not exist as hardware components.

There are two mode switches in this diagram to provide for two options. The function of the mode switches is explained by the notes at the bottom of the diagram.

The operation of the logic diagram in Figure 2 is explained below; this dicussion assumes that mode switch 2 is closed and that all three LOB characteristics are used.

STEP 1

The power swing enters the OUTER LOB characteristic. Thus AND61 will have one input from the OUTER LOB and a second input from OR61 since NOT61 has no input. If the swing impedance remains between the OUTER and MIDDLE characteristics for the pickup setting of TL61, TL61 operates, seals in one input of AND61 and energizes the out-of-step blocking relay, OSB.

When a fault occurs, the OUTER and MIDDLE LOBs operate almost simultaneously, and the MIDDLE LOB blocks AND61 through NOT61 thus preventing TL61 from operating.

STEP 2

The swing now enters the MIDDLE LOB characteristic but remains outside the INNER LOB characteristic. One input of AND62 is energized by TL61, a second input is proved by the MIDDLE LOB, and the last is supplied by NOT62. If the swing impedance remains between the MIDDLE and INNER LOB characteristics long enough for TL62 to pick up, TL62 seals in the lower two inputs to AND62. AND62 is therefore controlled by TL61, which, in turn is controlled by the OUTER LOB characteristic.

STEP 3

The swing now enters the INNER LOB characteristic. One input to AND63 is provided by TL62, the second by the INNER LOB. If the swing impedance remains inside the INNER LOB characteristic for the pickup setting of TL63, TL63 provides one input to AND64. At this point the decision to trip has been made and sealed-in. The out-of-step tripping output will be provided immediately if mode switch 1 is open.

STEP 4

The swing now leaves the INNER LOB characteristic (traveling in either direction), but remains inside the OUTER LOB characteristic. One input to AND64 is provided by TL63, a second input is supplied by the OUTER LOB, the third input is energized by NOT62 through OR64. If the output from AND64 lasts for the pickup setting of TL64, TL64 operates and seals in. The output of TL64 also provides one input of AND65.

STEP 5

If mode switch 1 is closed, tripping is not initiated until the swing has passed through the OUTER LOB characteristic for the second time. When the OUTER LOB resets, the second input of AND65 is supplied by NOT63. AND65, through OR65, picks up the out-of-step tripping relay, OST. This output lasts for 50 milliseconds (three cycles at 60 hertz) after the OUTER LOB resets, which is the dropout time of TL61.

Two-Characteristic Operation

Operation with two characteristics instead of three (mode switch 2 open) is essentially the same as described above, except that the MIDDLE characteristic and TL62 are taken out of the circuit. Only the OUTER and INNER characteristics are involved in the two-characteristic mode of operation.

MICROPROCESSOR OPERATION

A block diagram of the microprocessor operation, along with other components on the OLM101 digital module, is shown in Figure 9.

Eight DIP switches are used to enter timer settings and mode selection. These are shown at the top of the diagram. At start up, or after a restart, the microprocessor looks at these switches and stores their settings in memory for use later in the program.

NOTE

CHANGING ANY OF THE DIP SWITCHES ON THE OLM101 MODULE WHILE THE MICROPROCESSOR IS ON HAS NO EFFECT ON THE SETTINGS STORED IN MEMORY UNLESS THE POWER IS TURNED OFF, THEN ON, OR THE "RESTART" PUSHBUTTON IS DEPRESSED.

Signal lines from the analog module (APM) are connected to the digital module (OLM), as shown near the bottom of Figure 11. One line indicates whether 60 or 50 hertz has been selected on the analog module. This controls the step-down circuit from the microprocessor clock to generate pulses every one degree (1°) for timing purposes.

There are four monitoring LEDs (light-emitting diodes) on the face of the digital module. Three of these indicate the characteristic (OUTER, MIDDLE or INNER) that has operated. These LEDs are on only as long as the apparent impedance is within the characteristic. The fourth LED is for trip output, and this LED latches in to give a permanent display. The latch-in is mechanical so that the information is stored even if there should be a temporary loss of DC voltage. The trip output LED is reset by pressing the RESET button located next to the LED. The watchdog timer and failure LED shown on Figure 11 are part of the self-test feature described below.

SELF-TEST CIRCUITS

There are two self-test circuits in the OST. The first is controlled by the watchdog timer shown in Figure 9. The microprocessor runs continuously once it is energized by the DC supply voltage. One of its output pulses is a signal to the watchdog timer, which occurs every 10°. This pulse retriggers the timer and keeps it set. If the microprocessor should fail to execute its program correctly, it will not retrigger the watchdog timer. If the watchdog timer times out, it will disable the trip and block output signals and will light the failure LED on the front panel of the OLM101 module.

The second self-test circuit is semi-automatic and operates when the PUSH TO TEST button on the front of the APM101/102 is depressed. This test button removes the normal coincidence signal from the digital unit and replaces it with a chain of pulses of increasing width, as shown in Figure 8. It also blocks the OSB and OST output circuits. This test signal simulates a swing impedance moving first into the OUTER, then the MIDDLE and finally the INNER characteristics. The lights on the front of the digital module can be observed to see that they light in this sequence. Releasing the test switch removes the test signal and restores the normal coincidence signal input.

CAUTION

The relay is removed from service while the test button is depressed, and will not detect an out-of-step condition if one occurs while the test is being conducted.

DESCRIPTION OF HARDWARE

The OST relay consists of plug-in modules housed within an aluminum case.

* Construction

The case is fabricated from sheet aluminum. Overall case dimensions are given in the **SPECIFICATIONS** section and Figure 1.

The front cover consists of plate glass with an aluminum frame. It is hinged on the top, and opened from the bottom by way of two spring-loaded latches.

The cases are painted with a textured-finish baked enamel.

The modules are mounted vertically. The sockets within the case (towards the rear) serve as mechanical supports as well as the means of electrical connection. They hold the modules firmly in position. In addition, the front cover, when closed, provides further restraint on the modules. Proper alignment is maintained by slotted guides, one above and one beneath each module (with the exception of the MGM module, which require two guides above and two beneath).

Electrical Connections and Internal Wiring

External connections are made to terminal blocks mounted on the rear cover plates. Each block contains 14 terminal points, which consist of a Number 6 screw threaded into a flat contact plate.

Connection to the printed-circuit-board modules is made by means of 60-pin edge connectors. Conection to the MGM module is made by means of two connector sockets: an eight (8) contact current block and a 104-pin signal block. The current block contacts are rated to handle current transformer (CT) secondary currents.

* The primary DC control power feeding the power supply module (PSM) may be disconnected by removing the magnetics module.

TEST PROVISIONS

The test receptacle and connection plug for the OST relay are located to the far left of the modular package. When the connection plug is removed, shorting bars in the current circuits prevent open-circuiting CTs. The Type-XTM test plug may be inserted in place of the connection plug so that test signals can be injected into the OST from the front of the relay.

*Revised since last issue

XTM TEST PLUGS

Description

The XTM test plugs are designed specifically for periodic (post-installation) testing of modular relay systems. In this package, there are two test receptacles at the far left, but only one of these, the left-hand receptacle, is used in the OST. The test plug XTM28L1 (left-hand plug) provides access to fourteen (14) relay and fourteen (14) system points. The system points are located on the outer edge of the relay.

The plugs are fitted with a sliding handle that swings out to facilitate wiring to the terminals. The terminals consist of number 8 screws threaded into flat contact plates. The handles each have a tab on the outside edge to guide the wire dress of the test leads.

CAUTION

Not all contact circuits go through the test device (see Figure 13).

Terminal Designation

The terminals on the test plug are labelled 1 through 14. These points are designated on the elementary diagram (Figures 4 and 5) as TP1 through TP14.

On the test plug itself, the terminals are labeled 1R through 14R for the relay side and 1S through 14S for system side, with the system side labeled in red.

XTM Test Circuit Connections

Test-circuit connections, designated as TP points in the elementary diagrams, should be made to the relay side of the test plug. Connections should be made to the test plugs **prior** to insertion into the OST.

Test-Plug Insertion

To insert the test plug, the connection plug must first be removed. In so doing, electrical continuity is broken betweem the power system and the OST for those signals that are wired through the test receptacle (refer to TP points on elementary diagrams). For the terminals connected to the current-transformer secondaries, shorting bars are included on the system side of the test receptacle. These are clearly visible through the transparent plastic face plate on the receptacle. The shorting bars make contact before the connection plug contacts break during removal, so that the CT secondaries are never open-circuited.

WARNING

WHEN THE TEST PLUG IS INSERTED INTO THE RECEPTACLE, THE POWER SYSTEM IS ISOLATED FROM THE OST AS FAR AS INPUT AC QUANTITIES ARE CONCERNED. HOWEVER, THE OUTPUT CONTACT CIRCUITS ARE NOT COMPLETELY ISOLATED, AND THE CONNECTION OF ANY TEST EQUIPMENT INTO THESE OUTPUT CIRCUITS SHOULD BE DONE WITH EXTREME CAUTION.

WARNING

IT IS CRITICAL THAT JUMPERS BE INSERTED ON THE SYSTEM SIDE TEST PLUG TERMINALS THAT ARE CONNECTED TO THE CT SECONDARIES. IF THESE JUMPERS ARE LEFT OUT, THE RESULTING HIGH VOLTAGES DEVELOPED PRESENT A SERIOUS HAZARD TO PERSONNEL AND MAY SEVERELY DAMAGE CONNECTED EQUIPMENT.

IDENTIFICATION

The OST relay model number is indicated on a label located on the inside of the front cover in the lower left-hand corner.

A marking strip that indicates the name and position of every module in a given case is included on the lower inside edge of the front cover. It is placed to be read when the front cover is fully opened.

The terminal blocks located on the rear of the modular case are uniquely identified by a two-letter code, which is found directly beneath the outermost edge (rear view) of each terminal block. Also, the terminal points (1 through 14) are identified by stamped numbers.

PRINTED CIRCUIT BOARD MODULES

Basic Construction

Each module consists of a printed circuit board and front panel. Two knobs are provided on the front panel for removing and inserting the module. Electrical connection is made by contact pads at the back of the board. Not all module locations within the case have a printed-circuit board. Some locations have a blank board and front panel.

Figure 14 shows the interconnections between the various modules, terminal boards and the test receptacles.

Identification

Each module has its own identification number, consisting of a three-letter code followed by a three-digit number. These are found at the bottom of each front panel and may be read when the case cover is opened.

MODULE DESCRIPTION

MGM114, MGM115, MGM118, MGM119

* The MGM114 and 118 magnetics modules are for one ampere (1 amp) operation, while the MGM115 and 119 are for five ampere (5 amp) operation. Links (see Figure 16) are provided on the magnetics module to select either 50 or 60 hertz operation.

The magnetics module contains three potenial transformers to transform the input voltage to a convenient level for the electronics. Three transactors provide a similar function for the input currents. The transactor output voltage is shifted 85° leading with respect to the input current.

* The OST relay uses two telephone relays that are mounted in the magnetics module. One provides the trip output contacts and the other the blocking output contacts. The MGM114 and 115 magnetics modules provide "A" type contacts for blocking outputs. The MGM118 and MGM119 provide "B" type contacts for blocking outputs.

APM101/102

The analog module contains all of the circuitry used to process the IZ_1 and V_1 signals in an analog form. This includes the following functions:

1. Positive-sequence networks
2. Phase shifter on IZ_1 signal to produce 50° - 80° range of adjustment
3. Current supervision and adjustment
4. Reach settings, forward and reverse
5. Summing amplifiers, to add IZ and V quantities
6. Coincidence circuit, to produce coincidence blocks
7. Self-test circuit, to produce train of pulses of increasing width

* Revised since last issue

OLM101

The digital module contains a microprocessor and auxiliary chips. Figure 9 shows the overall function of the digital module in block diagram form; operation of the microprocessor is described in the section, **OPERATING PRINCIPLES**.

PSM

* This module provides power to operate the OST relay. The power supply is self-protecting and will not be damaged by a continuous short circuit. The output voltage will recover when the fault is removed. An output alarm is provided to indicate voltage outside the desired limits. A green light-emitting diode on the front panel indicates normal output voltage. A switch mounted on the front panel removes the internal voltage from the OST. A 3 amp, 250 volt fuse is provided on the board to protect the printed-circuit board.

*

CAUTION
Battery voltage is still present when the PSM switch is off.

CALCULATION OF SETTINGS

RELAY REACH

Figure 7 shows a simple system with an equivalent 5 ohm source impedance behind the local bus, and a 6 ohm source impedance beyond the remote bus. For the relay location shown, the forward reach is made equal to the sum of the line impedance and the remote end source impedance, while the reverse reach is made equal to the source impedance behind the relay.

OUT-OF-STEP BLOCKING

Out-of step blocking occurs when the swing locus stays in the outer characteristic (before entering the MIDDLE characteristic) for a time equal to or greater than the setting of the TL61 timer. Ideally, the MIDDLE characteristic should surround the largest tripping characteristic (of another relay) to be blocked. In some cases it may not be the possible for the MIDDLE characteristic to completely surround this tripping characteristic. In that case, the setting of the TL61 timer should be based on the time it takes the swing to pass from the OUTER LOB characteristic to the trip characteristic. The minimum recommended setting of TL61 is 540^{o}, which is equal to 25 milliseconds at 60 hertz, or 30 milliseconds at 50 hertz.

OUT-OF-STEP TRIPPING

The preferred sequence of determining characteristic reach and characteristic timer setting begins with the INNER characteristic. The INNER characteristic is set as narrowly as possible; the maximum recommended characteristic timer setting is 150^{o}. Note that the timer setting is equal to the included angle (Figure 5). A second consideration for the INNER characteristic is that it should be set inside any swing from which the system could recover. The 150^{o} unstable point is usually the limiting case.

*Revised since last issue

The reason for setting the INNER characteristic to be as narrow as possible is so that an adequate separation-angle differential between the OUTER and INNER characteristics can be selected, allowing reasonable TL62, TL63 and TL64 timer settings for possible fast swings. The setting of the OUTER characteristic is now determined from system swing studies and a consideration of maximum load current and breaker interrupting capability. Assuming that tripping should be delayed until the swing locus leaves the OUTER characteristic, that characteristic should be set large enough so that when it resets, the breaker that is tripped will not have to interrupt an out-of-phase condition greater than 90° between the two ends of the system. The dotted lines adjacent to angle B_1 in Figure 7 are an indication of the angle between the two ends of the system when the swing leaves the OUTER characteristic.

On the basis of system swing studies, the known setting of the INNER characteristic, and the range of settings on the TL61,TL62 and TL63 timers, the included angle of the OUTER characteristic must be selected to permit reasonable TL61, TL62 and TL63 timer settings. If the swing is fast, the OUTER characteristic must have a smaller included angle (larger characteristic). However, the OUTER characteristic should not be set so large that it picks up on maximum load transfer across the line.

The MIDDLE characteristic is between the INNER and OUTER, and if TL62 and TL63 pickup times allow, it should be set to surround the largest tripping characteristic for which out-of-step blocking is desired.

With all the characteristic shapes determined, the TL61, TL62, TL63 and TL64 pickup times should be selected. The approximate pickup values have already been considered in selecting characteristic shapes in conjunction with system swing values. The minimum recommended values of TL62, TL63 and TL64 are given in TABLE I.

TABLE I

Timer	Degrees	Milliseconds	
		At 60 Hertz	At 50 Hertz
TL62	360	16.7	20
TL63	180	8.3	10
TL64	360	16.8	20

SAMPLE CALCULATIONS

Considering the simplified system of Figure 7, the sequential procedure is as follows:

(a) Choose a maximum reach angle of 80°.

(b) Establish LOB and LOB* reaches
For the example, assume that the best values of LOB and LOB* are:
LOB = 15 (forward reach)
LOB* = 5 (reverse reach)

(c) This establishes the reach settings near the end points of the system. Determine the value of the included angle, B_3, of the inner characteristic. For this example the stability limit criterion of $B_3 = 150^{\circ}$ is selected.

$$B_3 = 150^{\circ}$$

(d) Set the inner characteristic timer angle to $B_3 = 150^{\circ}$

(e) Determine the value of the included angle, B_1, of the outer characteristic. Here it is assumed that system swing studies and load considerations have dictated an angle of

$$B_1 = 70^{\circ}$$

(f) Set the outer characteristic timer angle to $B_1 = 70^{\circ}$

(g) Determine the value of the included angle, B_2, of the middle characteristic. Here the angle B_2 is choosen as 100° to position the middle characteristic approximately half way between the inner and outer characteristics on the RX diagram.

$$B_2 = 100^{\circ}$$

(h) Set the middle characteristic angle to $B_2 = 100^{\circ}$

(i) Set the pickup times of the TL61, TL62, TL63 and TL64 timers based on system swing studies.

(j) Choose a current supervision setting of 0.4 per unit, based on minimum expected load and swing currents.

RECEIVING, HANDLING AND STORAGE

CAUTION

This relay contains electronic components that could be damaged by electrostatic discharge currents if those currents flow through certain terminals of the components. The main source of electrostatic discharge currents is the human body, and the conditions of low humidity, carpeted floors and isolating shoes are conducive to the generation of electrostatic discharge currents. Where these conditions exist, care should be exercised when removing and handling the modules to make settings on the internal switches. The persons handling the module should make sure that their body charge has been discharged by touching some surface at ground potential before touching any of the components on the modules.

Immediately upon receipt, the equipment should be unpacked and examined for any damage sustained in transit. If damage resulting from rough handling is evident, file a damage claim at once with the transportation company and promptly notify the nearest General Electric Sales Office.

If the equipment is not to be installed immediately, it should be stored indoors in a location that is dry and protected from dust, metallic chips, and severe atmospheric conditions.

SETTINGS PROCEDURES

Some of the switches used to make settings are on the front panel of the APM (analog) module and the others are internal switches on both modules, which may be reached by removing the APM or the OLM (digital) module. Figures 10 and 11 show the location of these switches. See the Caution in the **RECEIVING,HANDLING and STORAGE** section.

The method of making settings is described below:

APM MODULE

Front-Panel Switches

Forward-Reach Range (X.25 or X1):

Moving switch to the right (X1) gives reach shown by numbers below, while moving the switch to the left (X.25) gives one-fourth the reach shown below.

Reverse Reach Range (X.25 or X1):

Similar to forward reach range.

Forward Reach:

The forward reach is set by positioning the eight (8) toggle switches. The reach, in ohms, for the X1 range selection is given by the following expression, which appears on the module front panel:

$$Z_F = [3 + (\ )] \times 5/I_N$$

Where: I_N is the current rating, either 1 or 5 amperes

The value in parentheses represents the composite setting of the eight (8) toggle switches. This number is arrived at by summing all the values corresponding to the switches in the closed (right-hand) position.

Example:

If the 9 and the 1.2 switches are closed, and the rest are open, the value of the closed switches is

$$9 + 1.2 = 10.2$$

If the range switch is in the X1 position, and the current rating is 5 amperes, then the forward reach is

$$Z_F = [3 + 10.2] \times 5/5 = 13.2 \text{ ohms}$$

Reverse Reach:

The setting procedure for the reverse reach is the same as for forward reach.

Internal Switches

Current Supervision Level:

The current supervision switch (SW7) has five (5) toggle switches marked "0.1, 0.2, 0.4, 0.8 and 1.6." The current supervision, in per unit of rated current, is 0.2 plus the sum of the switches that are in the closed (right-hand) position.

Example:

If the 0.4 and 0.2 switches are closed, the setting is

$$0.2 + 0.2 + 0.4 = 0.8 \text{ per unit}$$

Frequency Switch:

This switch is marked with 50 hertz and an arrow. If the switch is in the left-hand position, the setting is 60 hertz; if moved to the right in the direction of the arrow, the setting is 50 hertz.

Phase Angle Set:

This switch sets the maximum reach angle of the modified-mho characteristics. It is a rotary switch marked with numbers 1 through 10. The corresponding maximum reach angles are shown in TABLE II:

TABLE II

DIAL	ANGLE
1	50°
2	55°
3	60°
4	65°
5	70°
6	75°
7	80°
8	85°

CAUTION

The OST relay will not operate properly if this switch is left in the 9 or 10 position. Check that one of the first eight positions is opposite the index mark on the printed-circuit board.

OLM MODULE

Internal Switches

OUTER Characteristic Angle:

This switch is an eight-stage miniature toggle switch, with the value of each switch marked on the printed-circuit board to the left of the switch. The angle setting is the sum of the switches that are closed (in the ON position).

Example:

If 64, 32, 8, 4 and 2 are closed, the setting is

$$64 + 32 + 8 + 4 + 2 = 110^{\circ}$$

MIDDLE Characteristic Angle:

Same procedure as for OUTER Characteristic Angle.

INNER Characteristics Angle:

Same procedure as for OUTER Characteristic Angle.

TL61, TL62, TL63, TL64:

These are time delay switches, but settings are made in terms of slip cycles per second, expressed in degrees. Also, the angle is ten (10) times the marked value.

Example:

If the 32 and 4 switches are closed, the setting is

$$10(32+4) = 360°$$

NOTE: Logic timers TL61, TL62, TL63, and TL64 must NOT be set to their maximum value. If any of these four timers are set to the maximum value (all switches to the ON position), the timer will never produce an output. This effectively prevents the OST relay from detecting an out-of-step condition!

For a given timer (TL61, TL62, TL63, or TL64), at least one of the eight 'dip switches' located on the OLM101 module MUST be set to OFF.

Mode Switch:

This is an eight-stage toggle switch, but only the first two switches are used.

(a) With the "1" switch in the ON position, the relay trips when leaving the OUTER characteristic. With this switch in the OFF position, the relay trips when the swing enters the INNER characteristic.

(b) With the "2" switch in the ON position, all three modified-mho characteristics must be crossed in the proper sequence to produce a trip output. With this switch in the OFF position, only two of the characteristics are used.

(c) The other six (6) toggle switches on this mode switch are not used and may be left in either the ON or the OFF position.

TESTING

See the Caution in the **RECEIVING, HANDLING AND STORAGE** section.

DIELECTRIC TESTS

Dielectric tests may be performed (1) between all terminals (tied together) and the case, and (2) between independent circuit groups (refer to elementary diagram, Figure 4).

ACCEPTANCE TESTS

The tests described in this section should be conducted prior to installation of the OST relay. These may be done on a bench-top basis.

FUNCTIONAL TESTS

This test simulates a swing impedance moving through the three characteristics in the proper sequence. Connect the relay and test generator as shown in Figure 12 (single phase test circuit). Set the three currents to a value equal to rated current (I_N) with angles as shown in Figure 12. Use the settings of TABLE III on the relay:

Function	Setting	Location
Phase Angle	85°	APM - Internal
Current Supervision	0.2 per unit	APM - Internal
Forward Reach	[$15/I_N$] ohms	APM - Front
Reverse Reach	[$15/I_N$] ohms	APM - Front
Reach Range	X1	APM - Front
OUTER Angle	70°	OLM - Internal
MIDDLE Angle	90°	OLM - Internal
INNER Angle	120°	OLM - Internal
TL61	72 (720°)	OLM - Internal
TL62	72 (720°)	OLM - Internal
TL63	36 (360°)	OLM - Internal
TL64	36 (360°)	OLM - Internal
Mode Switch	Any desired combination (see TABLE IV)	OLM - Internal

Begin the test with the variance at the maximum setting. Reduce the voltage slowly and observe LED indication on the front of the OLM101 module, and also observe trip or block contact operation. Check the results against the voltage values of TABLE IV.

NOTE

TABLE IV SHOWS ONLY THE CHANGE IN LED OR CONTACT OPERATION AS EACH CHARACTERISTIC IS PASSED. IT DOES NOT SHOW THOSE LEDs THAT REMAIN LIT OR THOSE THAT REMAIN CLOSED.

TABLE IV

VOLTAGE	MODE SWITCH SETTING: 1 - Open, 2 - Open	1 - Closed, 2 - Open	1 - Open, 2 - Closed	1 - Closed, 2 - Closed
	Two Characteristics		Three Characteristics	
	TRIP: Entering INNER	TRIP: Leaving OUTER	TRIP: Entering INNER	TRIP: Leaving OUTER
Maximum	None	None	None	None
Below 65 volts Above 55 volts	OUTER LED OSB Contact	OUTER LED OSB Contact	OUTER LED OSB Contact	OUTER LED OSB Contact
Below 47 volts Above 38 volts	-- --	-- --	MIDDLE LED	MIDDLE LED
Below 33 volts Above 28 volts	INNER LED OST Contact +TRIP LED	INNER LED	INNER LED OST Contact +TRIP LED	INNER LED
Above 55 volts Below 65 volts	OSB resets OST resets	+TRIP LED OSB resets, momentary OST contact as OSB resets	OSB resets OST resets	+TRIP LED OSB resets, momentary OST contact as OSB resets

+Front panel TRIP LED latches. Reset after each test.

LOB Characteristic Plotting

As an optional test, each of the three LOB characteristics may be checked over a 360° range using the test procedure described on the following page. This may be done on a three-phase basis, using the circuit of Figure 13, or with single-phase voltage control, using the circuit of Figure 12. A test generator that provides the ablitiy to change all three voltages while maintaining a balanced three-phase relationship is preferred, as it better stimulates real conditions. However, if this three-phase control is not available, the single-phase test circuit of Figure 12 may be used.

Follow this procedure to obtain the points for plotting the relay characteristics:

1. Choose settings of relay reach, maximum reach angle, current supervision and characteristic angles, and make these settings on the relay.
2. Set three-phase current to values equal to rated current, with phase angles as shown in Figure 12 and 13.
3. Begin with three-phase voltage equal to rated value, and with all three voltages in phase with the corresponding currents. If the single phase test circuit is used, begin with V_B in phase with I_B.
4. Reduce the voltage until the OUTER LED on the front panel indicates that the OUTER characteristic has been crossed. Measure the line-to-neutral voltage. If the three-phase circuit is used, this voltage divided by the current is the reach in ohms along the R-axis. If the single-phase test circuit is used, the reach is V/3 divided by the test current. For example, for a test current of five (5) amperes, and a reach of six (6) ohms, the test voltage would be 30 volts three phase, or 90 volts single phase.
5. Change the angle between the test voltage and current to the condition where the voltage leads the current by 30^o. Observe the voltage that causes the OUTER LED to come on, and calculate reach. This value is plotted as $+30^o$ on the R-X diagram.
6. Continue to increase the angle between the voltage and current, measure the balance point, calculate the reach and plot the points for the OUTER characteristic. Connect the points to draw the OUTER characteristic.
7. Starting again with voltages and currents in phase, reduce the voltage until the MIDDLE LED comes on. Follow the procedure above to plot the MIDDLE characteristic.
8. Repeat this procedure for the INNER characteristic.

PERIODIC TESTS

Automatic Self-Tests

The simplest test to make on a periodic basis is the automatic self-test, controlled
* by the PUSH TO TEST button on the front of the APM101/102 module. When this button is depressed, it disables the trip and block outputs, removes the normal coincidence block input to the digital module, and supplies a train of pulses that gradually increase in width, as shown in Figure 8. This will cause the OUTER, MIDDLE and INNER lights to come on in sequence if the characteristic timer circuit is working correctly.

Functional Test

For a more precise test, the functional test described in **ACCEPTANCE TESTS** may be performed. In order to check the voltage values in TABLE IV, the reach settings will have to be changed to those shown in **ACCEPTANCE TESTS.** To check the relay at the reach settings being used, the actual reach that is measured for each characteristic can be calculated by dividing (V/3) by the test current. If V_B is in phase with I_B, this is the reach along the R-axis on the R-X diagram.

*Revised since last issue

When testing the relay in place (mounted on a panel) the XTM test plug may be used to inject test signals from the front of the relay. See the **DESCRIPTION OF HARDWARE** section for a description of the XTM test plug. The TP terminal markings on Figure 12 and 13 indicate the test point connections to be used when using the test plug.

NOTE

FOR THE TRIP AND BLOCK CONTACT OUTPUTS, ONLY ONE SIDE OF EACH CONTACT IS BROUGHT THROUGH A TEST POINT, AND THEREFORE THESE CONTACTS ARE NOT COMPLETELY ISOLATED FROM THE REST OF THE EXTERNAL CIRCUIT WHEN THE TEST PLUG IS INSERTED.

INSTALLATION

ENVIRONMENT

The location should be clean and dry, free from dust and excessive vibration, and well lighted to facilitate inspection and testing.

MOUNTING

The OST case has been designed for standard rack mounting. The case measures four rack units in height. The unit may also be flush mounted on a panel. Refer to Figure 1.

Provision has been made for surface panel mounting as well. This is accomplished by removing and reversing the side brackets so that the mounting wings are in the rear. For surface mounting, cutouts must be made in the panel to allow for the terminal blocks.

EXTERNAL CONNECTIONS

External connections are made according to the elementary diagram (Figures 4 and 5). This is a general diagram incorporating all of the available options. Connection need not be made to those terminals associated with options not required.

PERIODIC CHECKS AND ROUTINE MAINTENANCE

Relays in operation should be tested by repeating the **ACCEPTANCE TEST** procedures. Relays stored for a year or more should be tested, using the **ACCEPTANCE TEST** procedures, prior to installation.

RENEWAL PARTS

Sufficient quantities of renewal parts should be carried in stock to enable the prompt replacement of any that are worn, broken or damaged. Should a printed-circuit board become inoperative, this board should be replaced with a spare. In most instances, the insertion of a spare board represents the most expeditious means of returning the equipment to service. The faulty board can then be returned to the factory for repair or replacement.

When ordering renewal parts, address the nearest Sales Office of the General Electric Company, specify quantity required, name of part wanted, and give the complete model number of the relay for which the part is required.

SPECIFICATIONS

RATINGS

Rated Frequency	- 50 or 60 hertz (requires correct form)
AC Voltage	- 100 to 120
AC Current	- I_N = 1 or 5 amperes
DC Control Voltage	- 48 - Operating Range: 34-60 110/125 - Operating Range: 88-150 220/250 - Operating Range: 176-300
Maximum Permissible Currents	
Continuous	- 2 x I_N
Three Second	- 50 x I_N
One Second	- 100 x I_N
Maximum Permissible AC Voltage	
Continuous	- 2.0 x rated
One Minute (one per hour)	- 3.5 x rated
Ambient Temperature Range	
For Storage	- -20° to +60° Celsius
For Operation	- The OST has been designed for continuous operation between -20° and +55°C per ANSI/IEEE C37.90-1978. In addition, this relay will not malfunction nor be damaged by operation at temperatures up to +65°C.
Insulation Test Voltage	- 2 kV 50/60 hertz, one minute
Impulse Voltage Withstand	- 5 kV peak, 1.2/50 microseconds, 0.5 joule
Interference (SWC) Test	- ANSI/IEEE C37.90 and IEC 255-5

BURDENS

Current Circuits	- 0.03 ohm $\angle 5^\circ$, I_N = 5 amps - 0.14 ohm $\angle 30^\circ$, I_N = 1 amp

Voltage Circuits	- 0.2 VA $\angle 49^{\circ}$, 60 hertz
Current Circuits	- 0.24 VA $\angle 48^{\circ}$, 50 hertz

DC Battery (for Power Supply and Telephone Relays)	Normal	Tripped
All voltage ratings	6 watts	11 watts

Contact Data

Trip Outputs
- Continuous rating = 3 amperes
- Make and carry for tripping duty (per ANSI C37.90) 30 amps
- Break 180 VA resistive at 125/250 VDC
- Break 60 VA inductive at 125/250 VDC

ACCURACY

Reach	- Plus and minus (±) 5% of setting at angle of maximum reach. Plus and minus (±) 10% at other angles
Angle of Maximum Reach	- Plus and minus (±) 3° of setting
Zone Timers	- Plus and minus (±) 3% of setting
Characteristic Timers	- Plus and minus (±) 1°

SETTINGS AND RANGES OF ADJUSTMENT

Angle of Maximum Reach:

On-board adjustment, 50° to 85° in five (5°) degree steps

Forward and Reverse Reach	X1 Tap	X.25 Tap
5 ampere relay	3 - 75 ohms (in 0.3 ohm steps)	0.75 - 18.75 ohms (in 0.075 ohm steps)
1 ampere relay	15 - 375 ohms (in 1.5 ohm steps)	3.75 - 93.75 ohms (in 0.375 ohm steps)

Current Supervision Level:

On board adjustment, 0.2 to 2 per unit in 0.1 steps

Characteristic Timers: (determine shape of modified-mho characteristics)

Recommended range - 65° to 155° in one degree (1°) steps (actual range is much wider). Three switches are provided: One for OUTER, one for MIDDLE and one for INNER characteristic

Logic Timers: (TL61, TL62, TL63, TL64)

The range of all four timers, expressed in degrees, is 10° to 2,550° in 10° steps.
This is equivalent to a range of 0.46 to 118 milliseconds for hertz relays, or 0.55 to 142 milliseconds for 50 hertz relays.

Mode Switch:

Switch 1 chooses between trip when entering the INNER characteristic, or trip when leaving the OUTER characteristic (see Figure 7).

Switch 2 chooses between the use of three characteristics (OUTER, MIDDLE, INNER) or two characteristics (OUTER, INNER).

DIMENSIONS

Standard rack-mounted unit:
- 6-15/16 inches/176 millimeters high
- 19-1/16 inches/484 millimeters wide (standard 19-inch rack)
- 16 inches/406 millimeters deep (including terminal blocks and interconnection cables)

WEIGHT

Standard rack mounted unit weighs approximately 33 pounds/15 kilograms net.

	FIGURE	DRAWING NO.		TITLE
	1	0138B7600, Sh. 1		OST Case and Outline Dimensions
*	2	0138B7771, Sh. 1	3	Functional Logic Diagram for OST1000 Relay
*	3	0138B7771, Sh. 2		Functional Logic Diagram for OST1100 Relay
*	4	0138B7770, Sh. 1	1	Elementary Diagram for OST1000, 1100 Relay
*	5A	0138B7770, Sh. 2	2	Elementary Diagram for OST1000 Relay
*	5B	0138B7770, Sh. 3		Elementary Diagram for OST1100 Relay
	6	0285A9129		Offset Mho Characteristics, V_1 and I_1Z Quantities
	7	0246A7983-1		Typical Set of LOB Chacteristics
	8	0285A8845		Self-Test Waveforms
	9	0285A8846		Microprocessor Block Diagram
	10	0285A8848-1		Settings, Adjustments - APM101/102 Module
	11	0285A8849-1		Settings, Adjustments - OLM101 Module
	12	0285A9127		Single-Phase Test Circuit
	13	0285A9128		Three-Phase Test Circuit
	14	0179C6366, Sh. 1	5	OST1000 Case Internal Wiring
*	15	0179C6366, Sh. 2		OST1100 Case Internal Wiring
	16	0285A9130		Magnetics Module - Rear View

*Revised since last issue

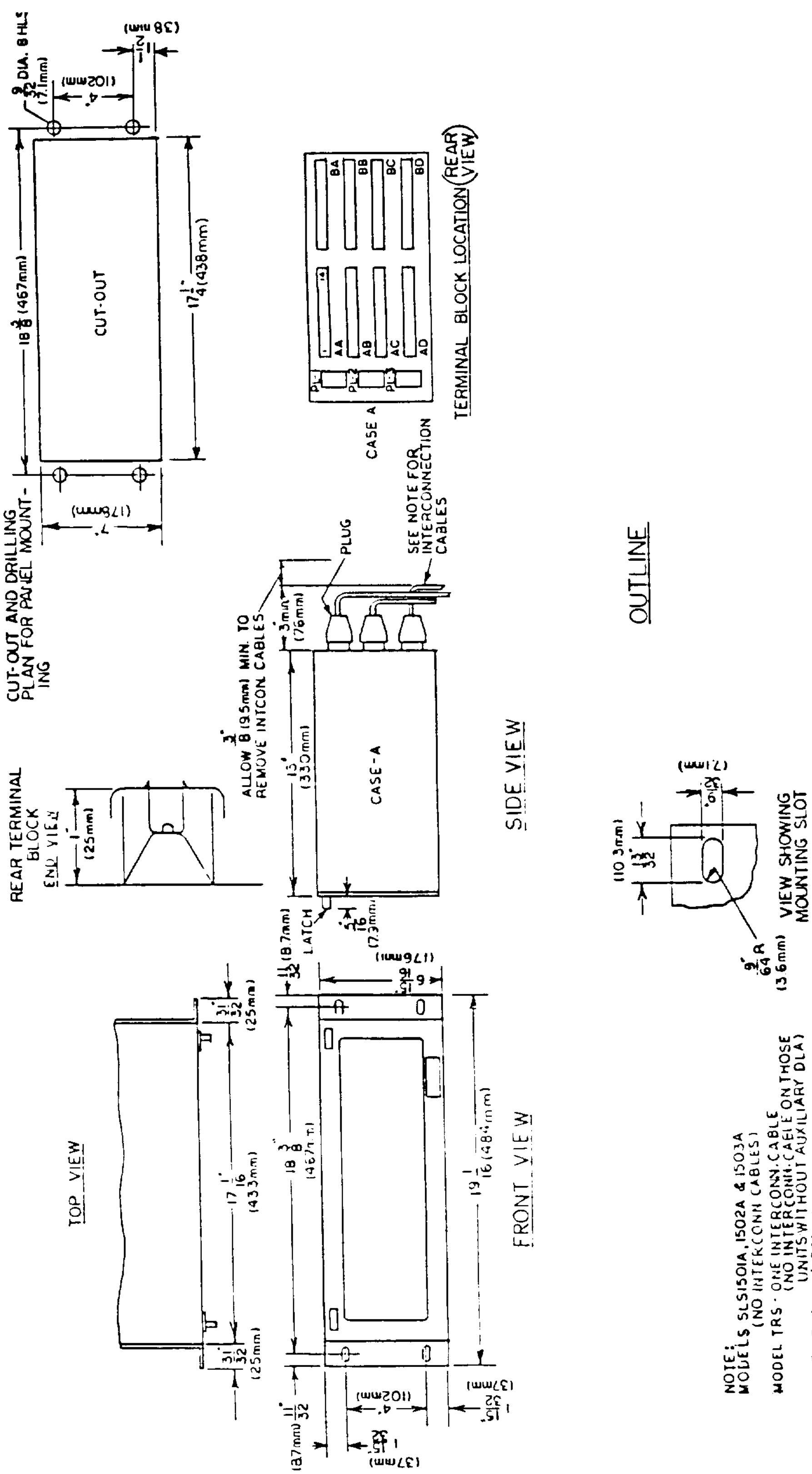
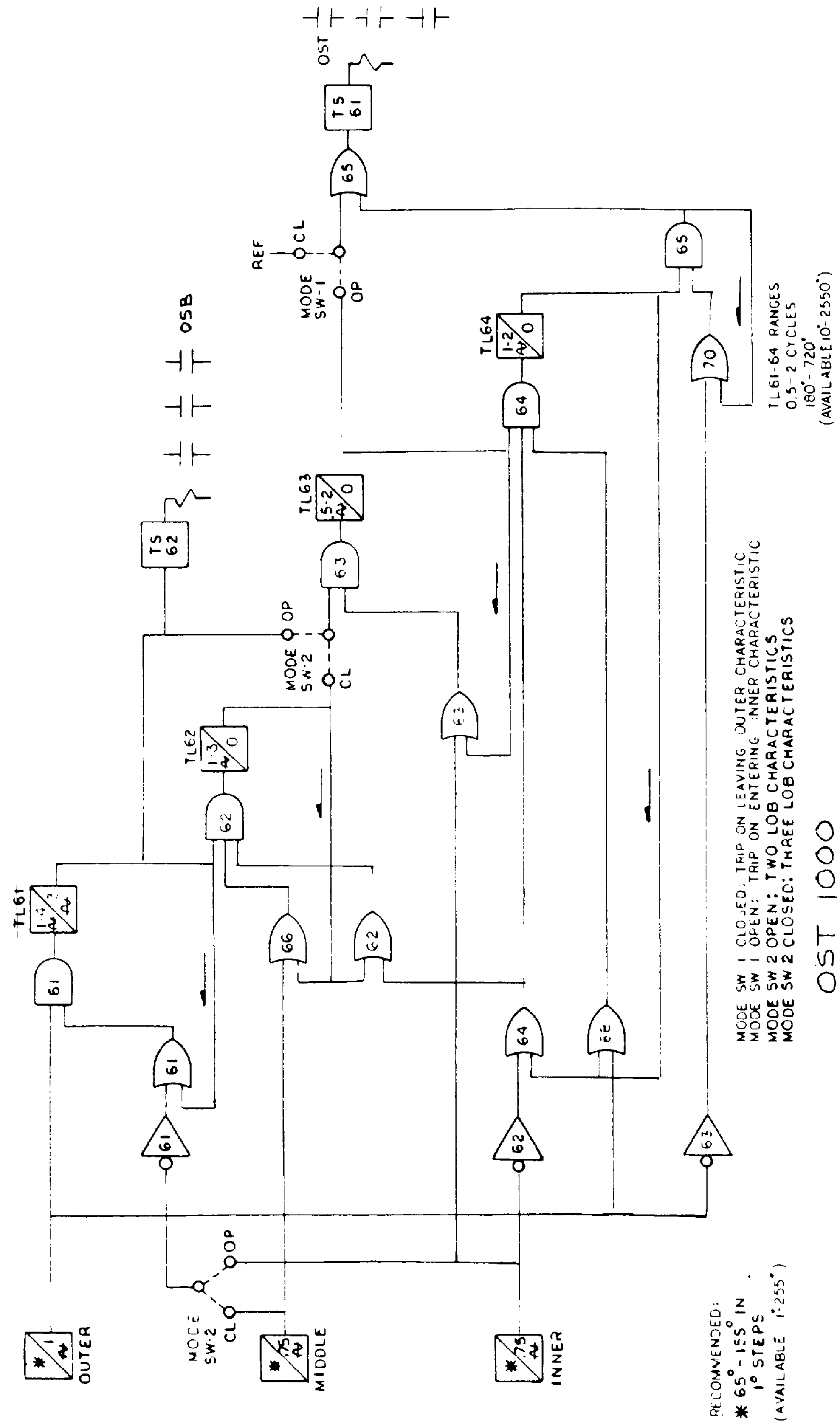


Figure 1 (0138B7600, Sh. 1) OST Case and Outline Dimensions



* Figure 2 (0138B7771, Sh. 1 3) Functional Logic Diagram for OST1000 Relay

*Revised since last issue

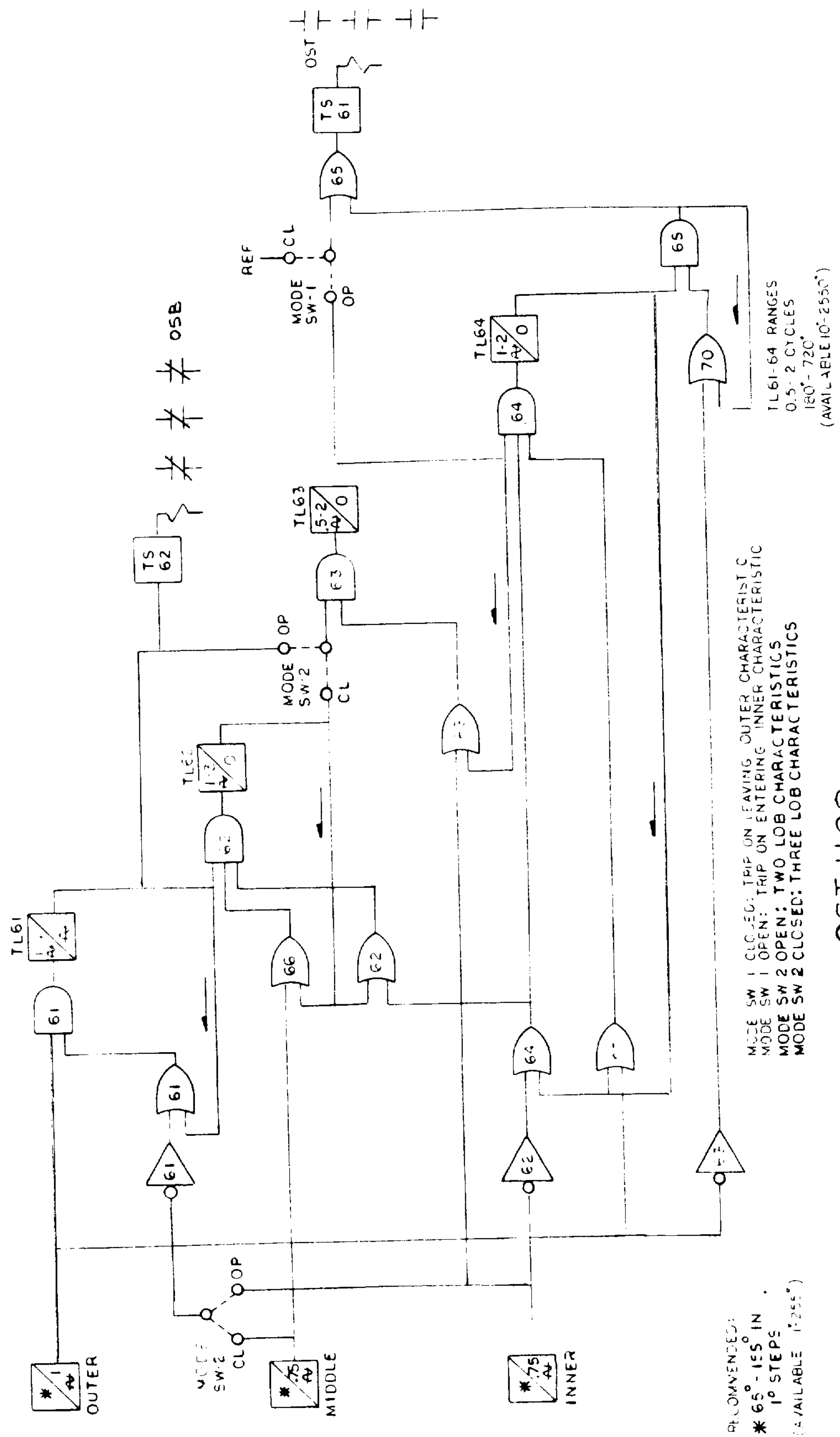
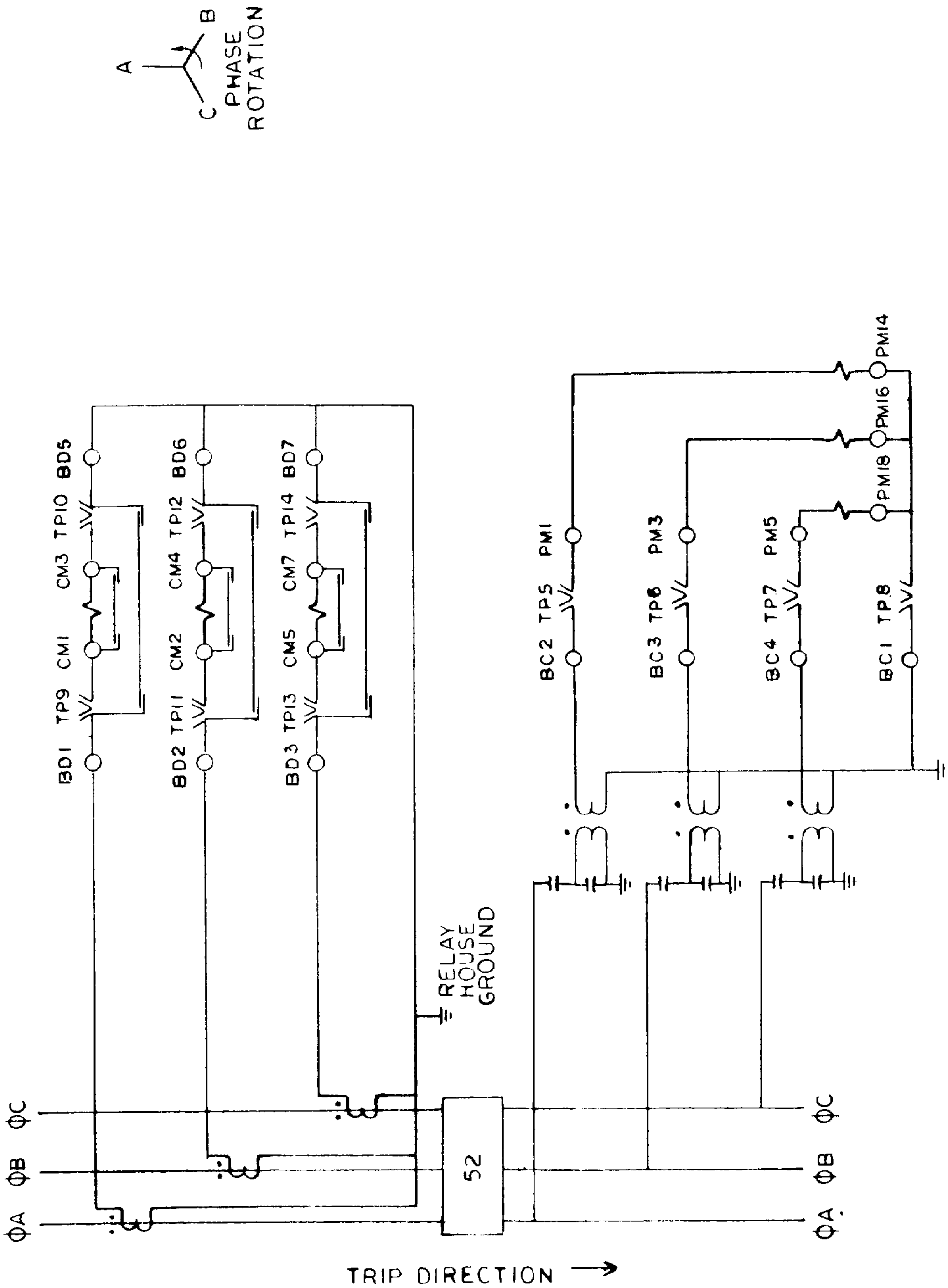
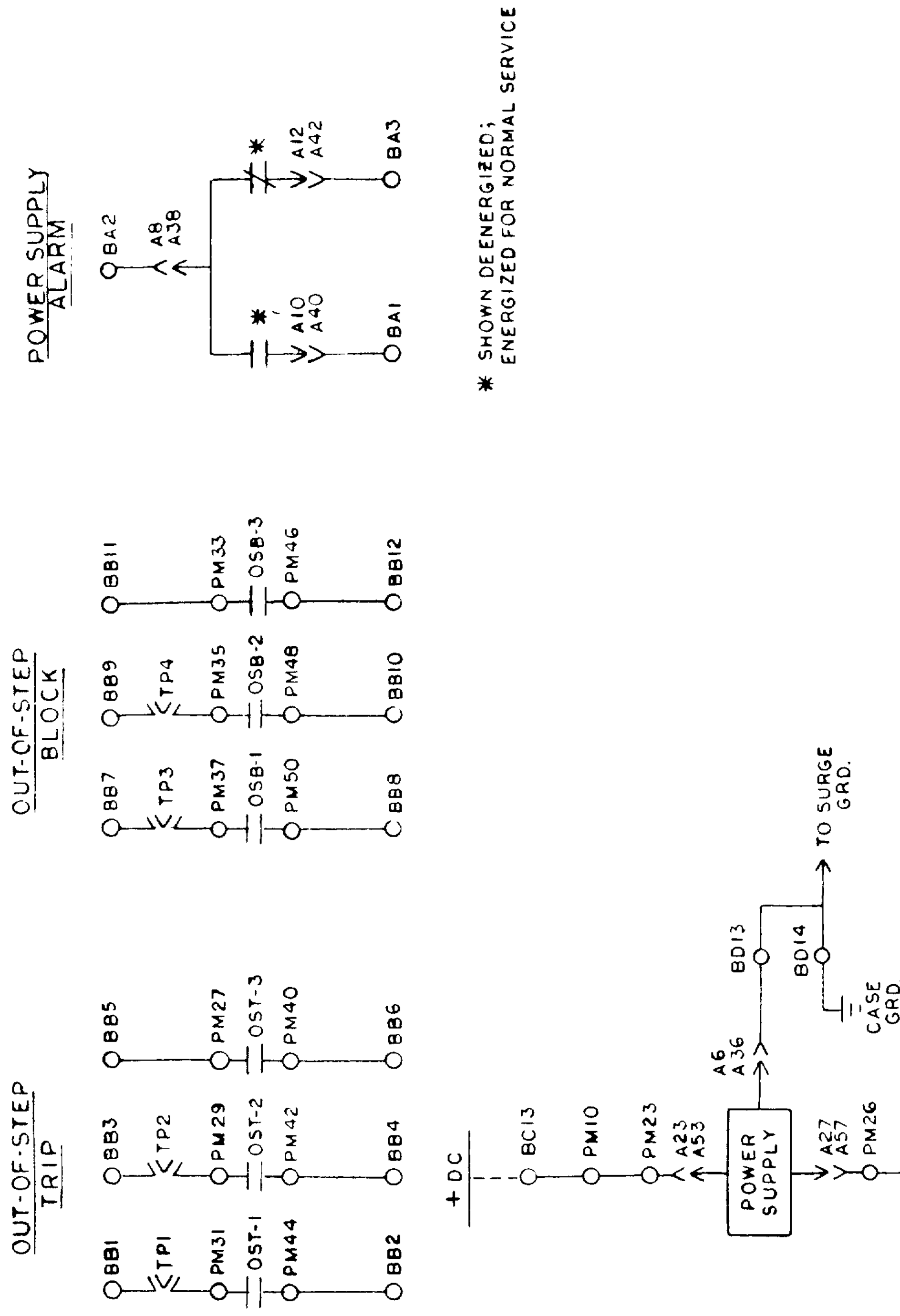


Figure 3 (0138B7771, Sh 2) Functional Logic Diagram for OST1100 Relay
*Revised since last issue

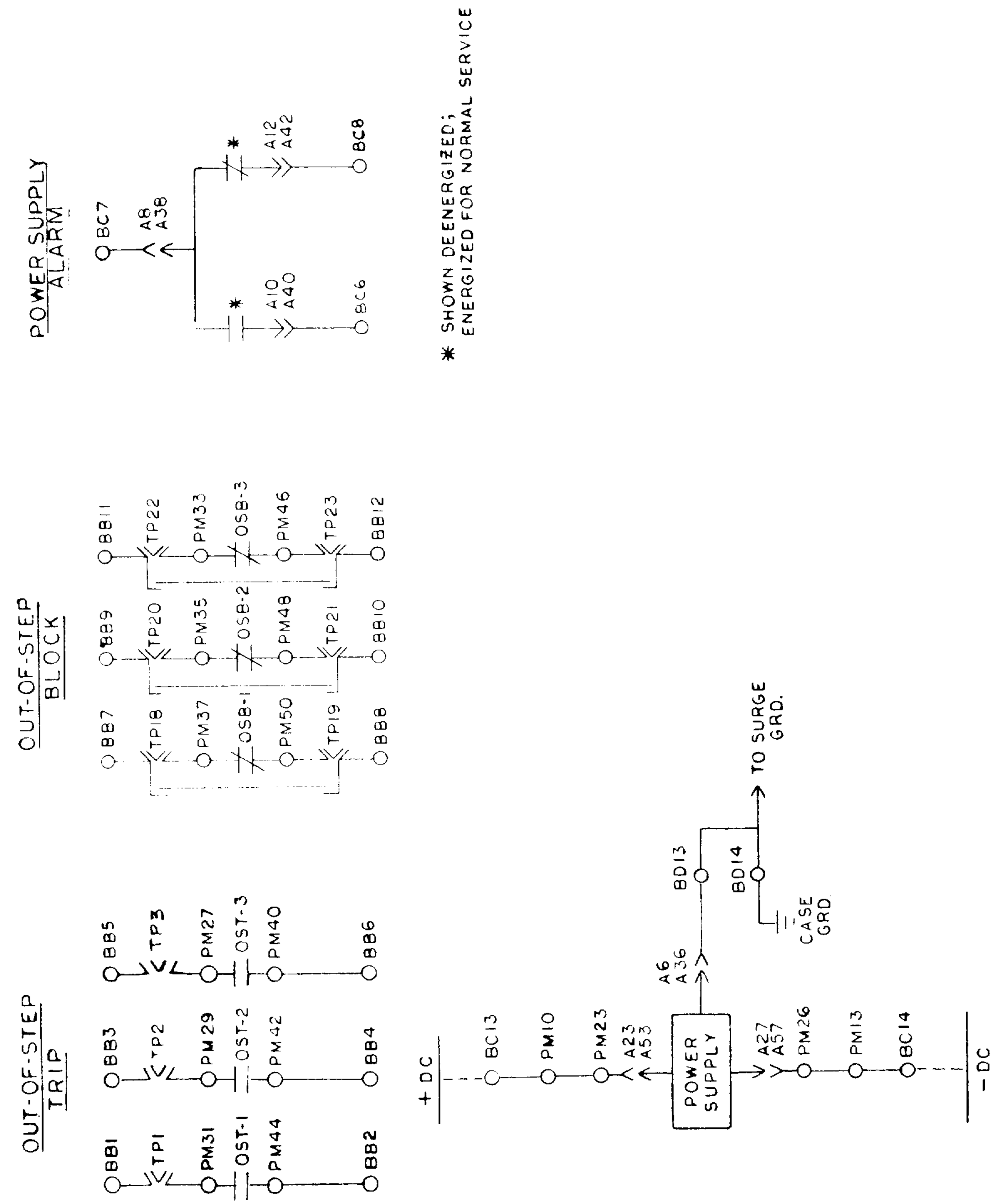


* Figure 4 (0138B7770, Sh. 1 2) Elementary Diagram for OST Relay
*Revised since last issue



* Figure 5A (0138B7770, Sh. 2 [2]) Elementary Diagram for OST1000 Relay

*Revised since last issue



* Figure 5B (0138B7770, Sh. 3 [3]) Elementary Diagram for OST1100 Relay

*Revised since last issue

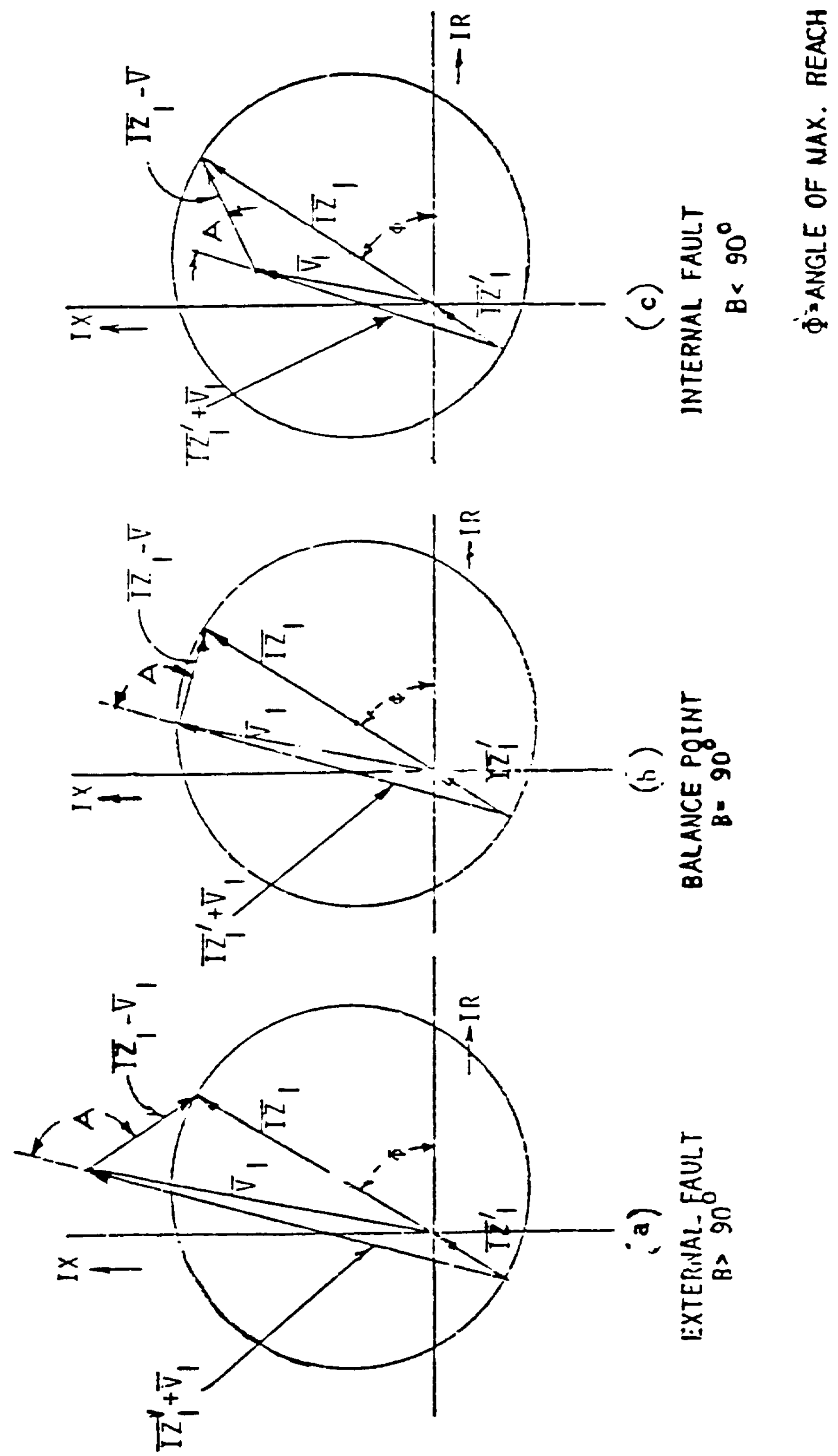


Figure 6 (0285A9129) Offset MHO Characteristics, V_1 and I_1Z Quantities

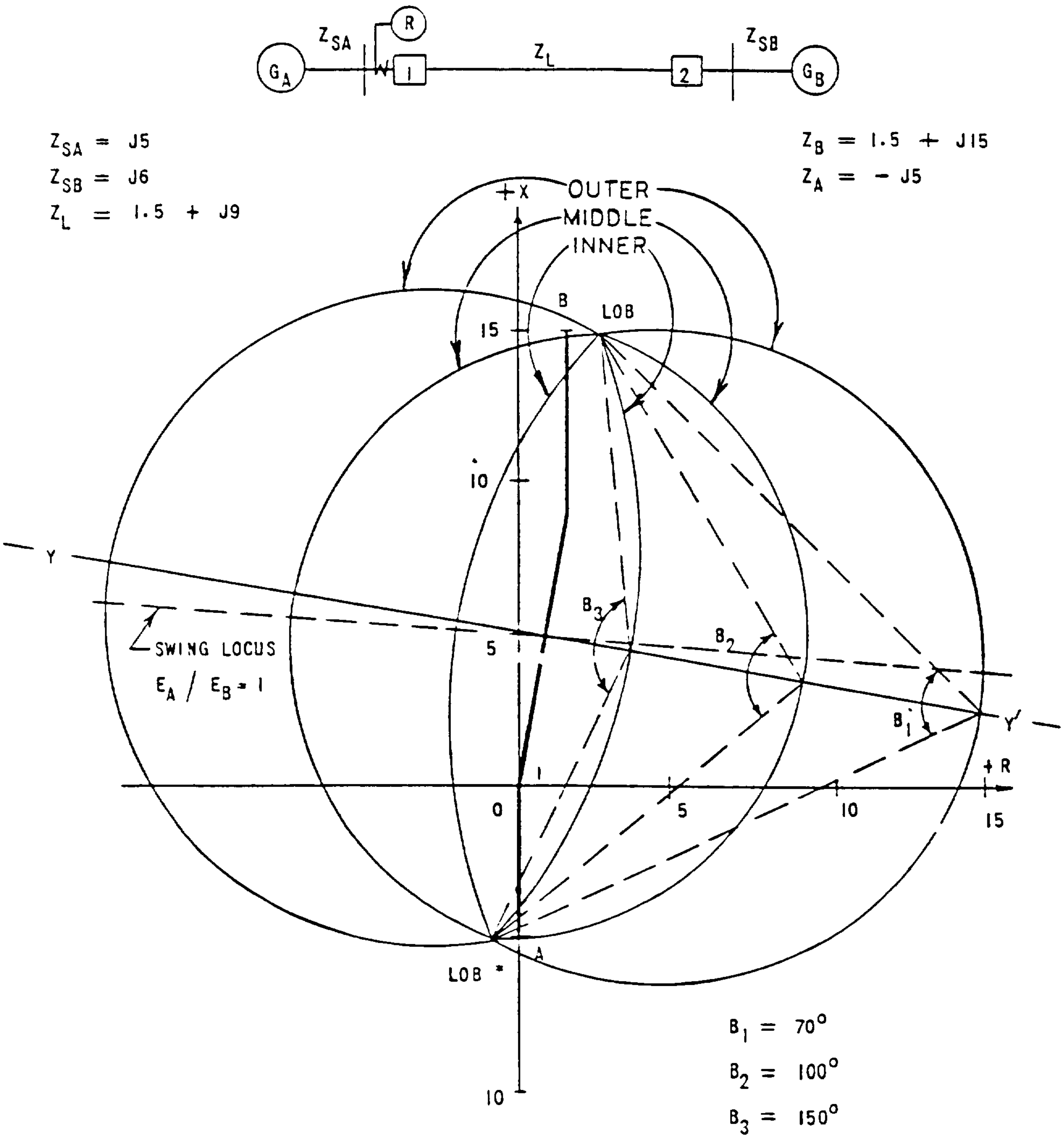


Figure 7 (0246A7983-1) Typical Set of LOB Characteristics

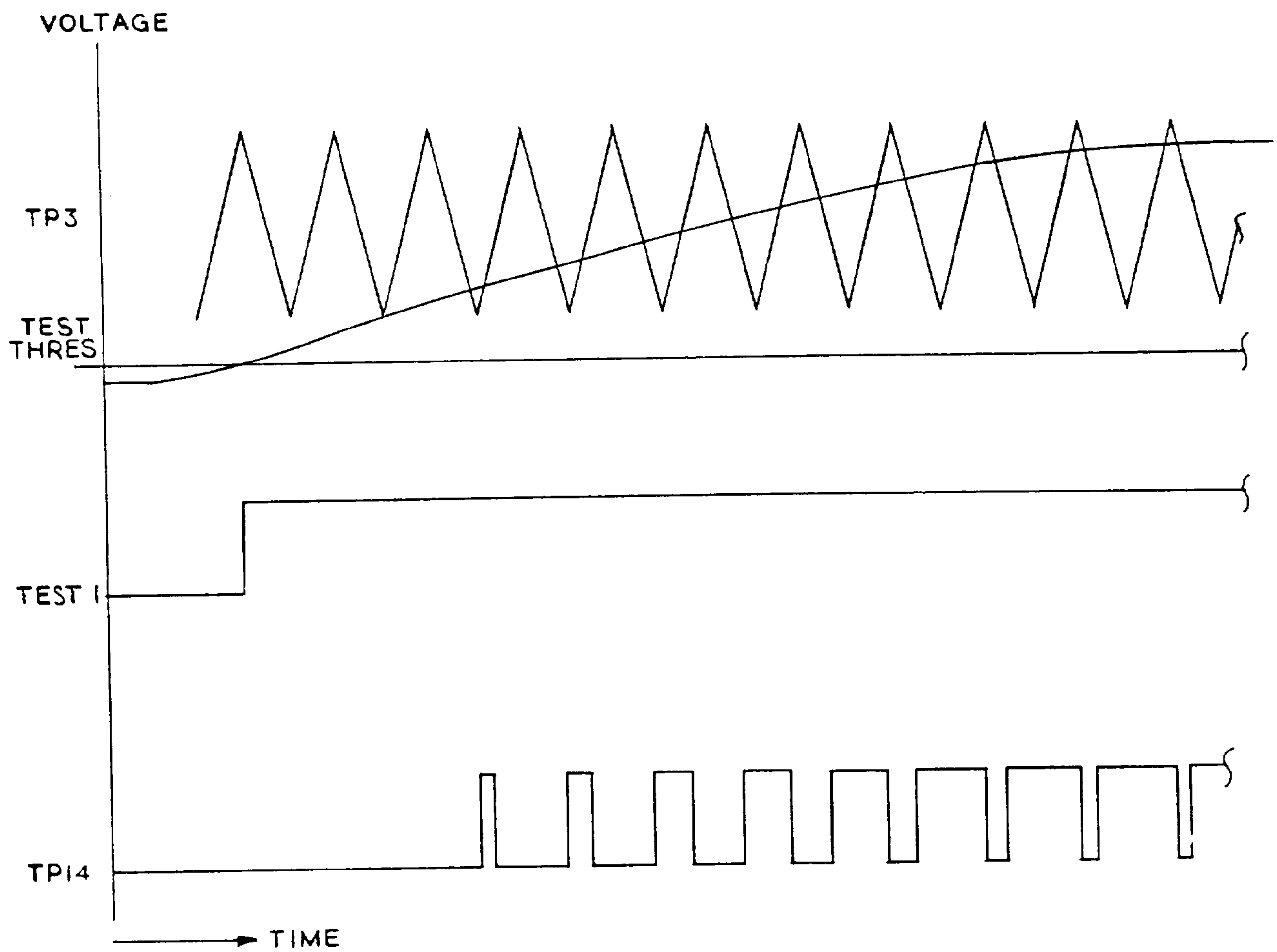


Figure 8 (0285A8845) Self-Test Waveforms

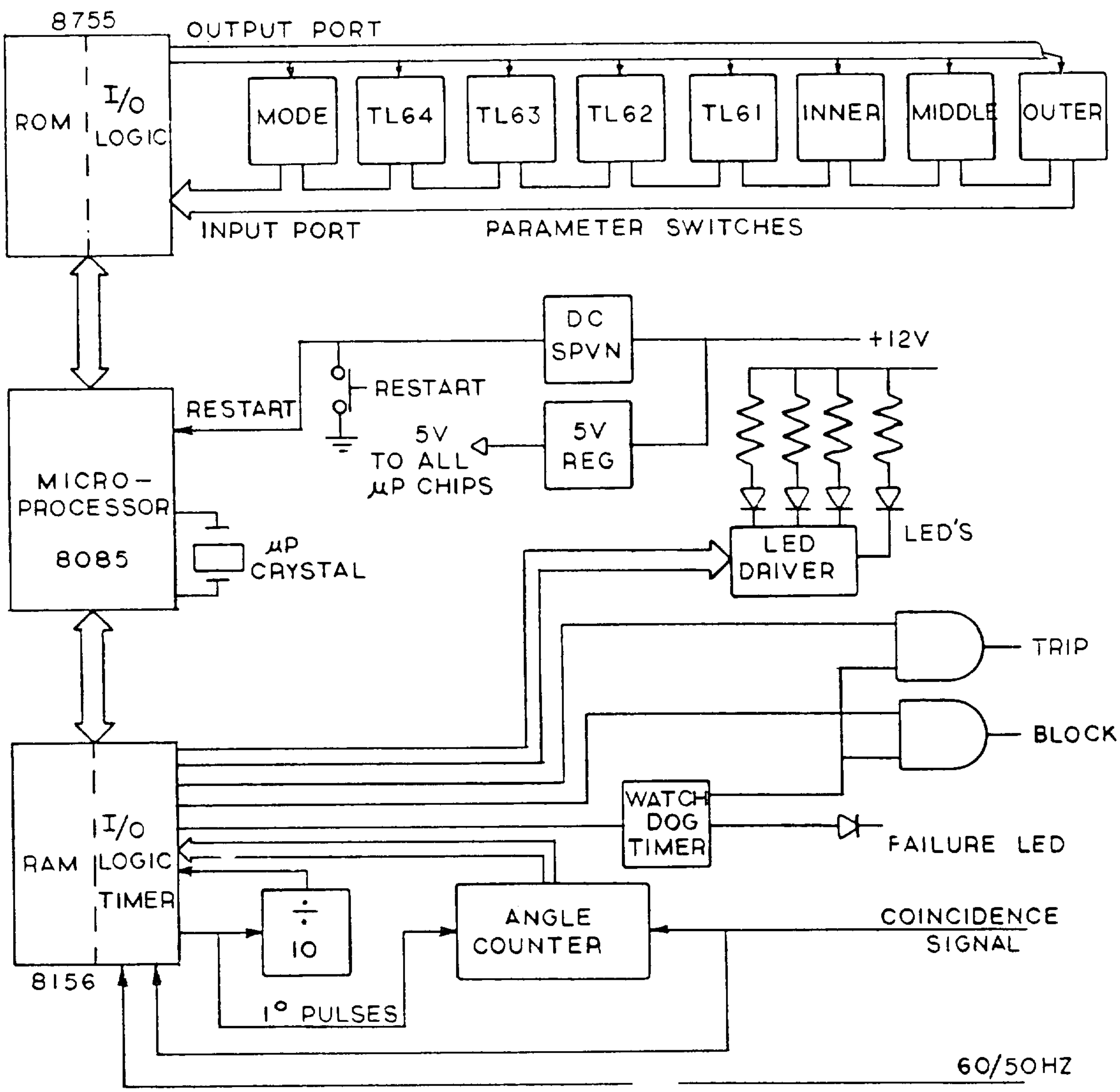


Figure 9 (0285A8846) Microprocessor Block Diagram

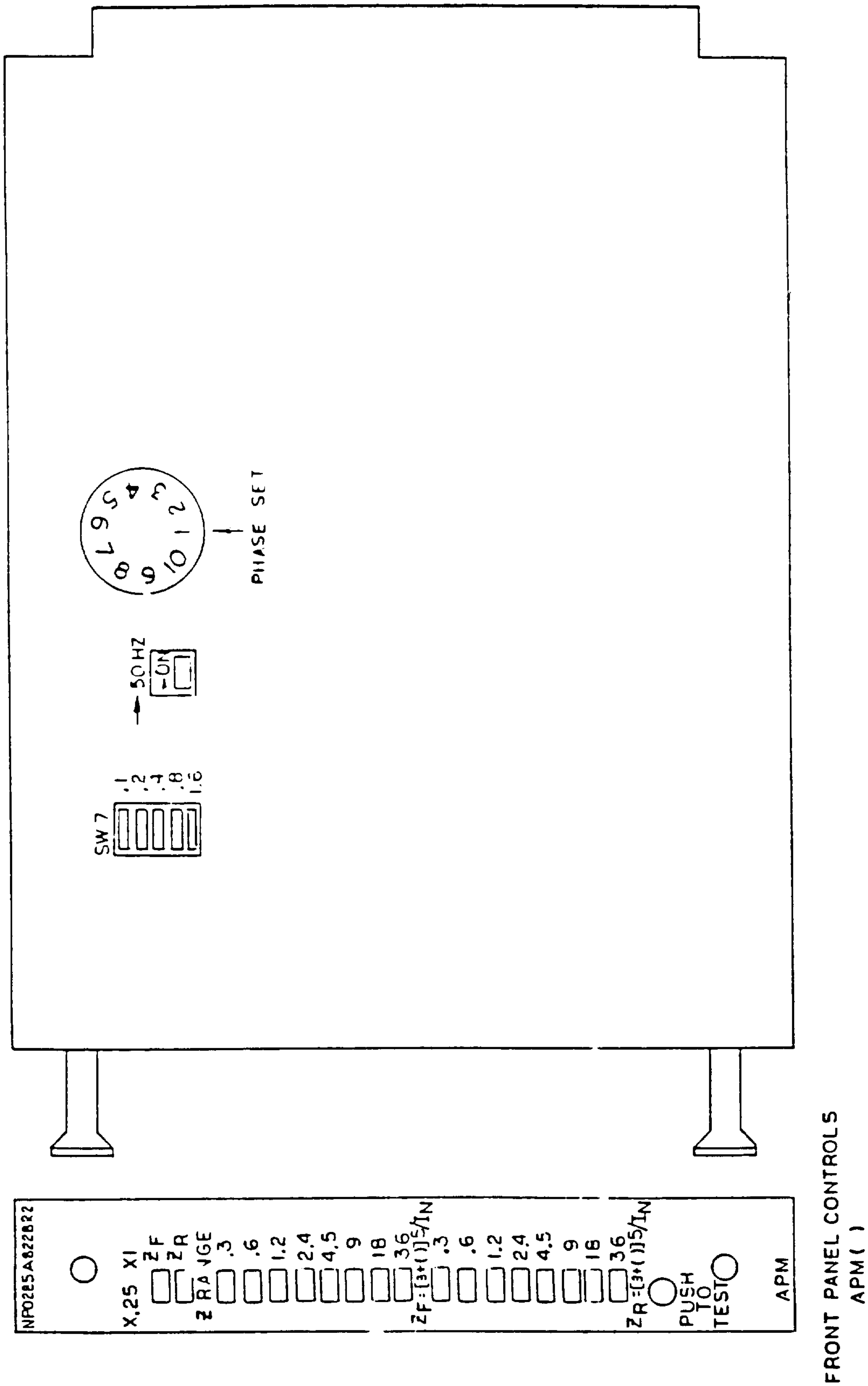


Figure 10 (0285A8848-1) Settings, Adjustments - AMP101/102 Module

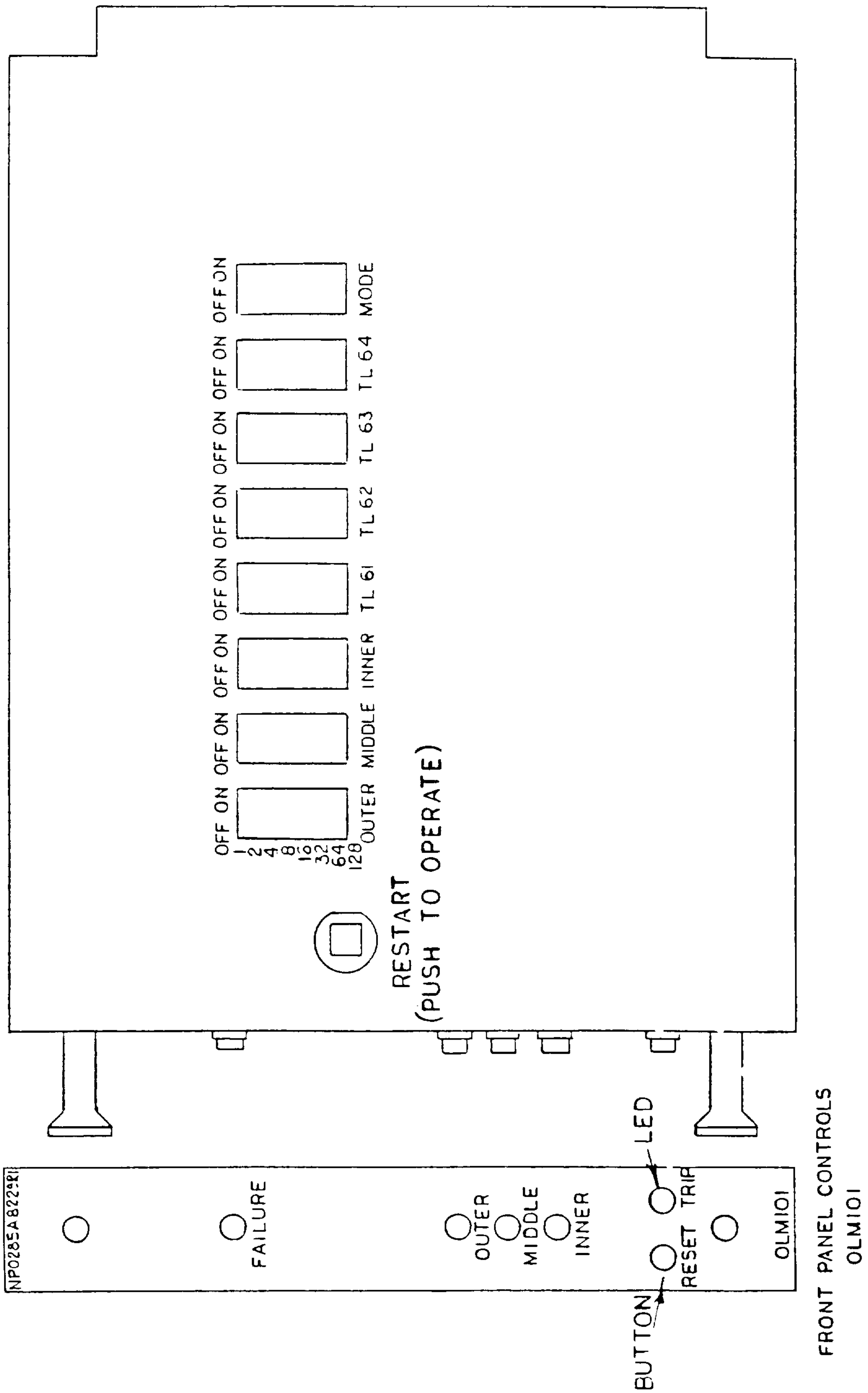


Figure 11 (0285A8849-1) Settings, Adjustments - OLM101 Module

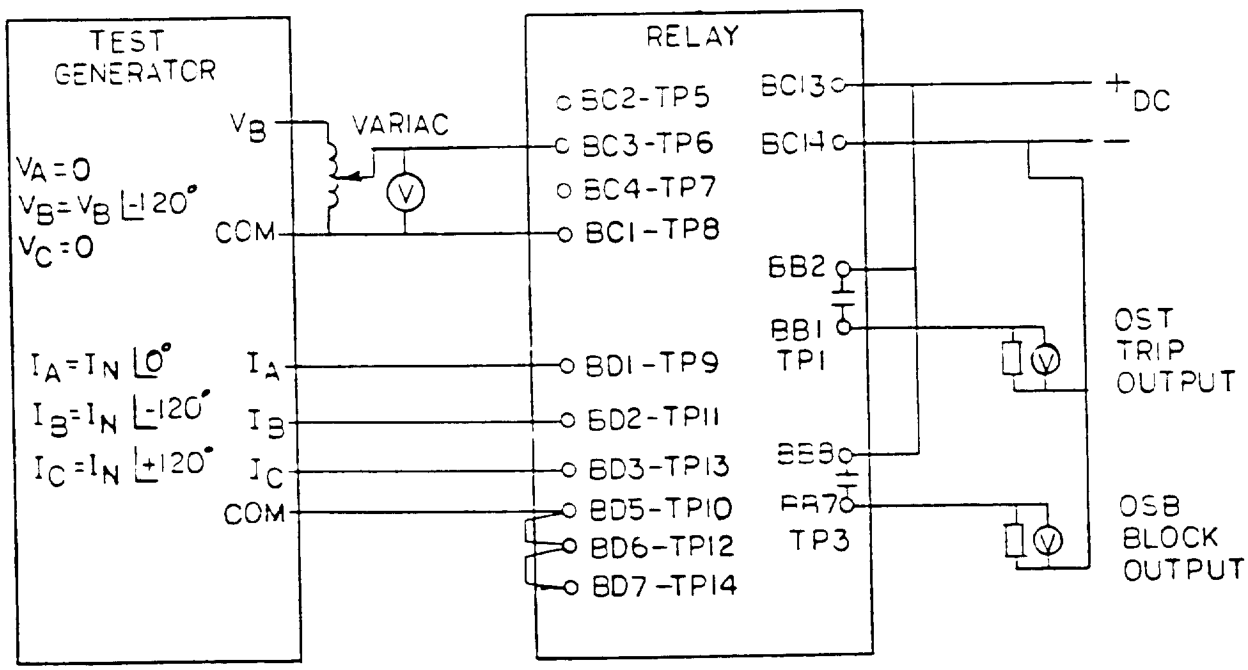


Figure 12 (0285A9127) Single-Phase Test Circuit

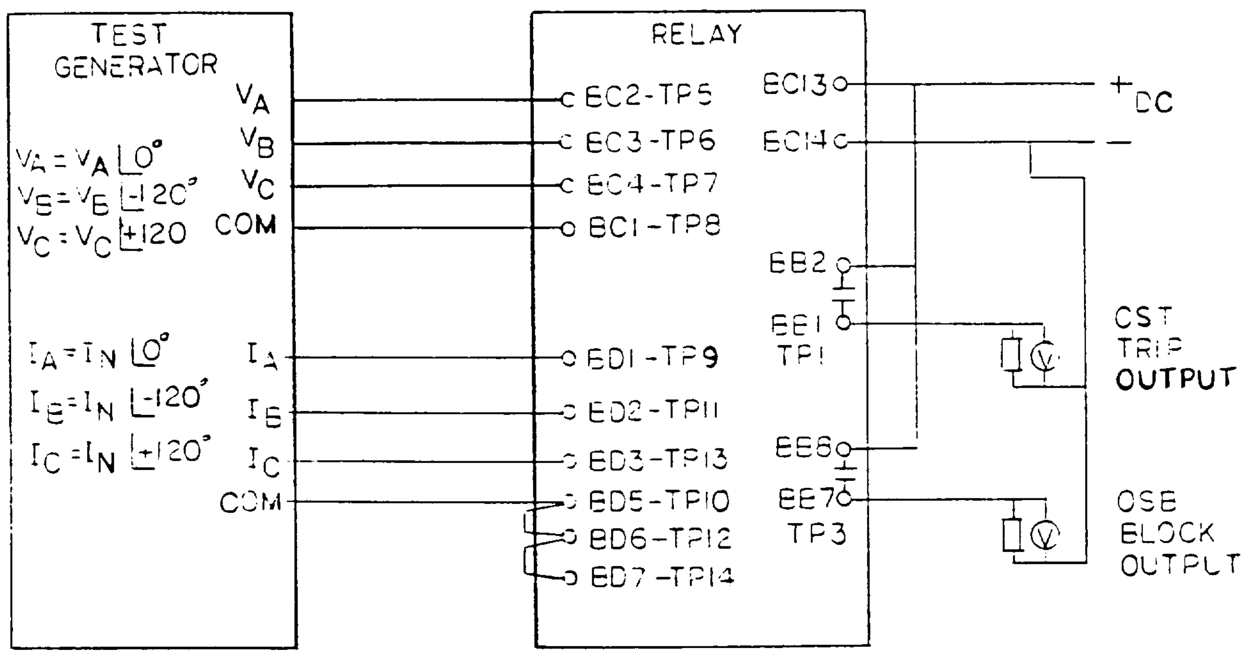


Figure 13 (0285A9128) Three-Phase Test Circuit

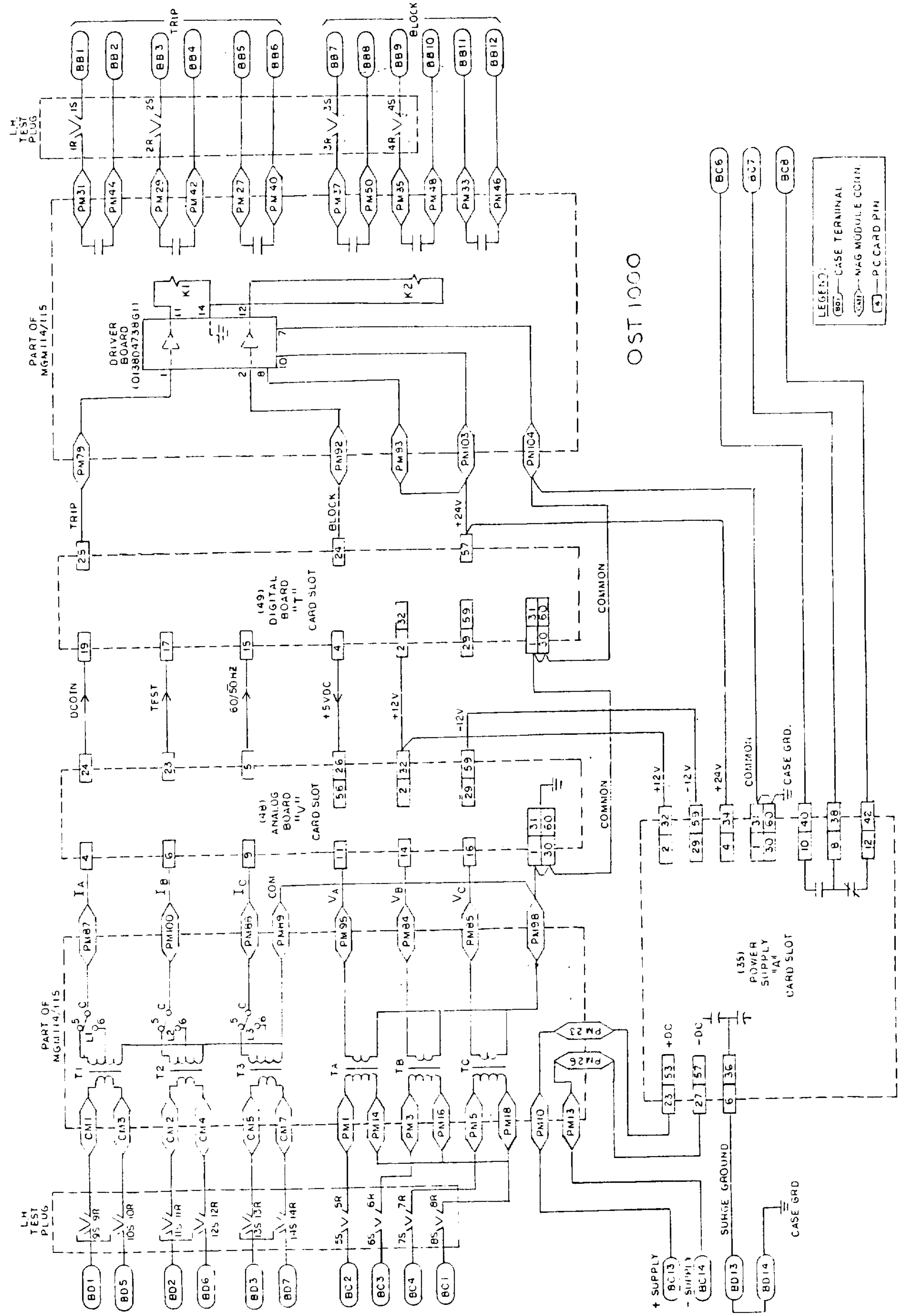
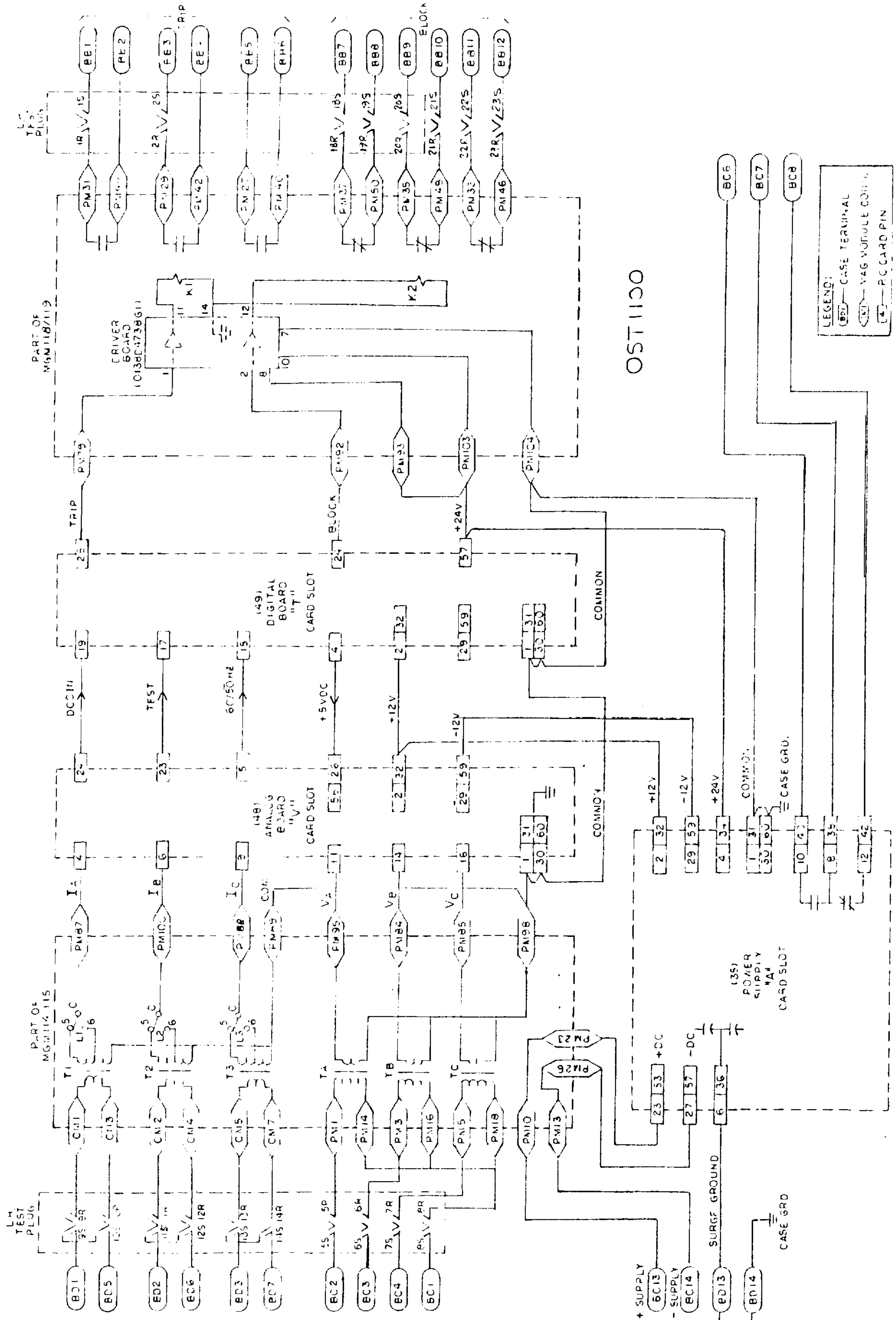


Figure 14 (0179C6366, Sh. 1 5) OST1000 Case Internal Wiring



* Figure 15 (0179C6366, Sh. 2) OST1100 Case Internal Wiring

*Revised since last issue

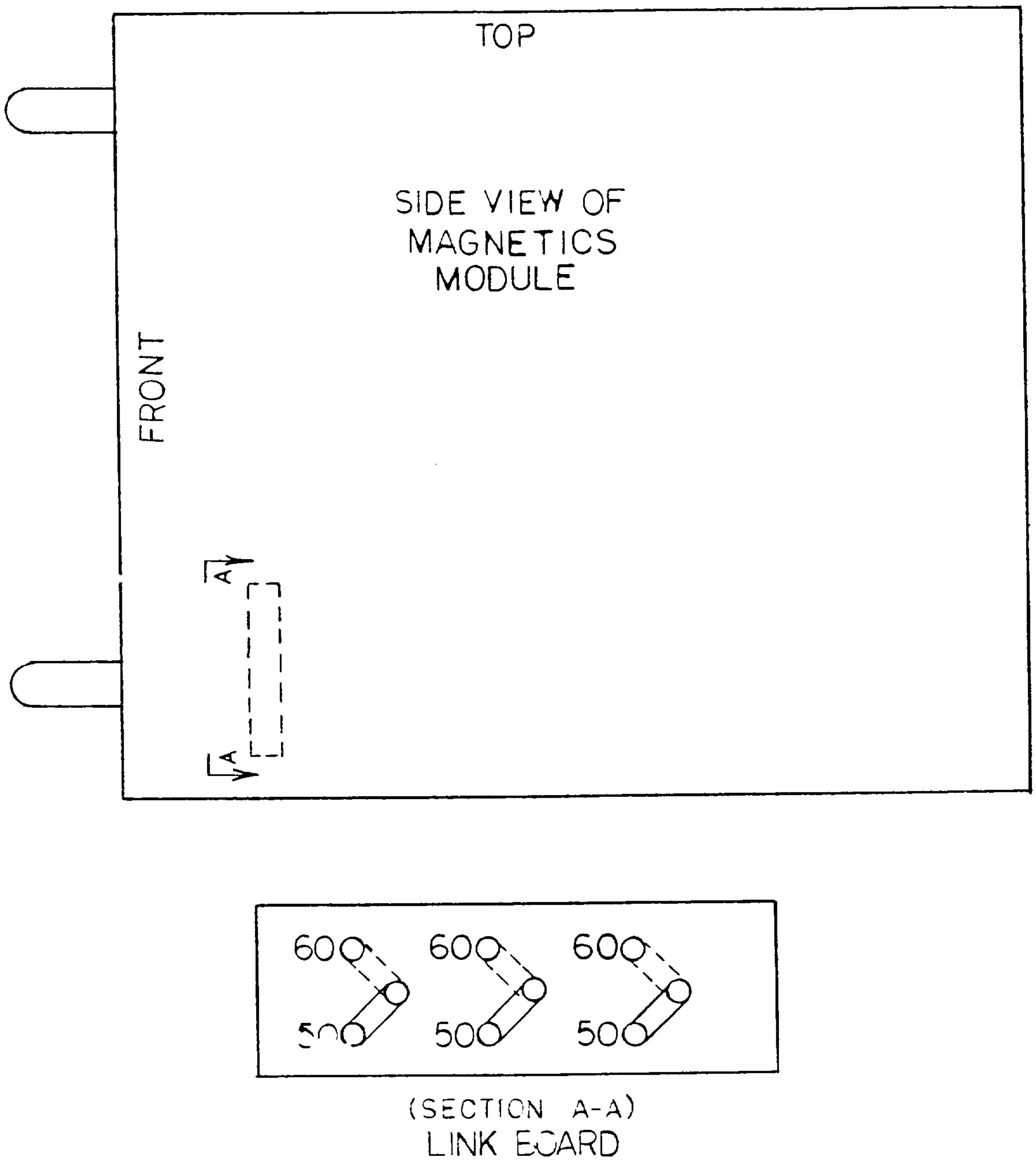


Figure 16 (0285A9130) Magnetics Module - Rear View

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