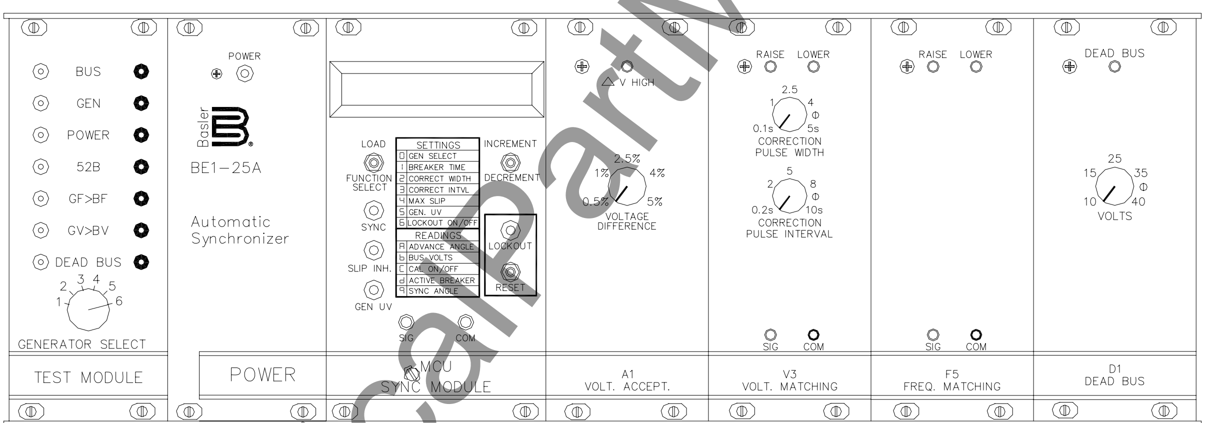
INSTRUCTION MANUAL

FOR

AUTO SYNCHRONIZER

BE1-25A



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INTRODUCTION

This instruction manual provides information about the operation and installation of the BE1-25A Auto Synchronizer. To accomplish this, the following information is provided:

- General Information and Specifications
- Controls and Indicators
- Functional Description
- Installation
- Maintenance

WARNING!

To avoid personal injury or equipment damage, only qualified personnel should perform the procedures in this manual.

NOTE

Be sure that the BE1-25A is hard-wired to earth ground with no smaller than 12 AWG copper wire attached to the ground terminal on the rear of the unit case. When the BE1-25A is configured in a system with other devices, it is recommended to use a separate lead to the ground bus from each unit.

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It is not the intention of this manual to cover all details and variations in equipment, nor does this manual provide data for every possible contingency regarding installation or operation. The availability and design of all features and options are subject to modification without notice. Should further information be required, contact Basler Electric.

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REVISION HISTORY

The following information provides a historical summary of the changes made to the BE1-25A instruction manual (9146600990). Revisions are listed in reverse chronological order.

Manual Revision and Date	Change
M, 05/08	• Corrected Max Slip Control range in Sections 1 & 2. • Corrected Breaker Operating Time range in Section 2. • Added manual part number and revision to footers.
L, 06/06	• Corrected wording in Section 2 paragraph describing F3 function. • Added metric weights to the specifications of Section 1. • Changed name of the glossary to Appendix A, *Glossary.* • Moved contents of Section 8, *Manual Change Information,* to the manual introduction and deleted Section 8.
K, 05/05	• Changed all front panel illustrations to reflect changes to the panel of the power supply module. • Updated Figure 4-1 to show new front panel and dimensions. • Updated Figure 4-2 to show height of panel cutout. • Added UL and CSA data to the specifications.
J, 11/99	• In the cutout dimensions illustration, added clearance holes for attaching the cover.
H, 08/98	• Added US patent declaration to the specifications. • Updated the manual format. • Made various, minor changes to text.
G, 10/97	• Revisions made to accommodate changes to firmware (version 5.02) which improved the performance of F1 and F3 type frequency correction.
F, 07/96	• Revised manual in response to option F5 being made standard. • Divided *Installation* and *Testing* section into two sections.
E, 03/94	• Changed all front panel illustrations to reflect changes in the controls and indicators.
D	• Changed all references to voltage difference adjustment (option A2) from 1-50 Vac to 1-10 Vac. • Corrected dead bus VOLTS control from dc to ac. • Deleted note attached to the SLIP HIGH LED. • Added manual change information section to the manual.
C	• Specification for max slip adjustment was corrected. • Specification for isolation added. • UL and CSA approval cited. • Test procedures simplified.
B	• Manual completely revised to reflect the incorporation of a microprocessor in the synchronizer module (renamed the MCU Sync module), and related changes beginning with product serial number 300. • Relay differences section added.
A	• General editorial revisions.
—, 07/85	• Initial release

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CONTENTS

SECTION 1 • GENERAL INFORMATION

DESCRIPTION

A basic BE1-25A Auto-Synchronizer consists of three rack-mounted modules that determine the proper time to initiate closing of a breaker to parallel a generator and a bus. The three standard modules are the master control unit (MCU) sync module, the test module, and the power supply. Optional plug-in modules are available for installation (at initial purchase, or at any later time) to enhance this basic capability. Among the options are the frequency matching and voltage matching modules that direct the generator control system to adjust voltage or frequency (or both) to meet system requirements. The unit is not truly an automatic synchronizer unless one or more of the matching options is incorporated.

An ideal closing is one that minimizes electrical and mechanical transients. Because the ideal closing occurs when the voltages are in phase, the initiating signal must be delivered ahead of phase coincidence by a factor equal to the operating speed of the breaker. This factor (termed the advance angle) is calculated by the MCU sync module. This module is essentially a dedicated computer that monitors the voltages on both sides of the breaker to be closed, calculates the slip frequency, and then (taking into consideration the operating speed of the breaker) calculates the required advance angle.

Closure will occur only if the slip frequency is less than the limit established by the slip setting. Once breaker closure has been initiated, the BE1-25A is inhibited from further operation for a minimum of 15 seconds. If the breaker reopens during this 15-second inhibit period, the unit enters a lockout condition that prevents further operation until the unit is reset.

OPTIONS

Plug-in options can extend the capability of the basic unit. These are briefly summarized here as to overall function. (They are explained in detail in the later sections of this manual.)

- A voltage acceptance module may be added to the basic synchronizer to assure that the oncoming generator voltage is within a pre-selected magnitude with respect to the bus voltage before breaker closure is allowed. This option is required if one of the voltage matching modules is to be used.
- Voltage matching modules provide RAISE and LOWER signals to the voltage regulator of the oncoming generator to bring the machine voltage within the limits defined by the voltage acceptance module.
- Frequency matching (i.e., speed control) module provides RAISE and LOWER signals to the governor to bring the oncoming generator speed to within the slip frequency limit that is preset into the Auto-Synchronizer. If the slip is very small and the phase angle is large, a target pulse is initiated to change the generator speed in the direction of the closest phase coincidence.
- A dead bus module allows selection of various low bus voltage conditions to enable breaker closing without synchronization. This provides a black start capability for the system.

MULTI-GENERATOR OPERATION

BE1-25A relays can control more than one generator by simultaneously switching all of the relay relevant inputs and outputs from one generator to the next. Those inputs and outputs are: the generator sensing voltage, breaker 52b and closing coil circuits, and the leads associated with options (such as the frequency and voltage matching lines to regulator or governor). All of these must be switched simultaneously by a ganged switch called the synchronizing select switch. (This switch is installed external to the BE1-25A unit, and is not supplied with the relay. Installation details are given in Section 4, *Installation*.)

In addition to the relay relevant inputs and outputs, settings for the system operational parameters are entered using the MCU front panel LOAD/FUNCTION select switch. Settings for six generator systems can be entered and stored into MCU memory.

APPLICATION

General

From large, single or multiple generators to small, multiple-unit applications, slip frequency synchronizers such as the BE1-25A provide fast, accurate, synchronization of generator-to-bus or bus-to-bus breaker closures if a slip rate exists between the two sides of the open breaker. For the BE1-25A to be capable of closing the breaker, the phase angle between the two voltage inputs must first pass through 180 electrical degrees and maintain a slip rate until the synchronizer issues a breaker close signal.

Excluded from this discussion are phase lock type synchronizers (such as the BE3-25A) that do not require – nor allow – a slip to occur between the oncoming generator and the bus.

Generator-to-Bus Application

For a slip frequency synchronizer to operate properly in a generator-to-bus application, the following listed operational parameters are entered into the memory of the synchronizer using the front panel LOAD/FUNCTION select switch.

- Generator breaker closing time (calculates advance angle)
- Generator speed correction pulse width(maximum correction pulse width)
- Generator speed correction pulse interval (maximum correction pulse interval)
- Maximum slip frequency (maximum slip frequency and still allow breaker closing)
- Generator undervoltage (inhibits synchronization below this limit)
- Lockout ON/OFF (arms or disarms lockout feature)

Synchronization is enabled when the slip frequency is less than the maximum slip setting and the generator voltage is greater than the generator undervoltage setting. Synchronization is NOT enabled (inhibited) when the slip frequency is greater than the maximum slip setting, the generator voltage is less than the generator undervoltage setting, or a lockout condition exists. If a voltage acceptance option is included, synchronization is NOT enabled if the bus voltages are out of limits, the voltage difference between generator and bus is greater than the setting, or the phase angle difference is greater than the calculated advance angle. If a dead bus option is included, immediate synchronization is enabled if the bus voltage is less than the setting and the dead bus enable input is closed.

When generator speed correction pulses are required, proportional pulses are generated based on the slip frequency and the maximum slip frequency setting. If the slip frequency is greater than four times the maximum slip frequency setting, proportional pulse are generated that are equal to 100 percent of the correction pulse width. Correction pulses proportionally reduce in duty cycle (ration of ON time to OFF time) down to zero for slip frequencies less than four times the maximum slip frequency setting. At one-half the setting, correction pulses are disabled. If the slip frequency falls below one-sixteenth of the maximum slip frequency setting for ten seconds, target pulses are generated to prevent a hung-scope or non-slip condition.

Bus-to-Bus Application

Some transmission circuits, when split apart, assume a phase angle difference that stabilizes as a steady offset. When this occurs, it is possible to reclose by supervisory means (usually supervised by a sync-check relay) if the angle is small enough or the shock to the system can be tolerated. In cases where a slip exists, re-connection can be attained using a BE1-25A. In this case, one of the following conditions must be met for the BE1-25A to initiate closure.

- A slip frequency exists the prescribed limit (i.e., within the setting adjustment of the synchronizer).
- The phase angle difference is less than three degrees, with no system slip. In this case, the phase angle between the two systems must have passed through 180 degrees to enable the synchronizer.

If either of the two conditions are met, the BE1-25A will operate in a bus-to-bus environment as it would in the case of an oncoming generator. It provides a closure command so that breaker closure occurs when the phase difference is near zero. To achieve this advance timing, the closing time of the controlled breaker must be set into the synchronizer memory.

Application Checklist

When developing the appropriate operating parameters and safeguards for synchronizing a generator with a bus, the following items should be considered.

1. Secondary potential transformer voltage waveforms should be carefully compared with the primary voltages. Consider the following:
   a. Are the secondary and primary voltages identical for both bus and generator?
   b. Is there a power transformer involved? (Suppose, for example, that the generator is operating at 2,400 volts, delta, and the bus at 34,500 volts, wye. Are the power transformer secondary voltages the same when the bus and generator voltages are proper?)
   c. Is there a phase shift?
   d. Is the phase rotation correct?
   e. Do the potential transformers reflect the actual primary voltage changes without significant delay?
2. When switching the auto-synchronizer from one generator to another, **ALL** of the auto-synchronizer/generator control inputs must be simultaneously transferred to the correct oncoming breaker and the associated generator. During this transfer, the 52b contact of the breaker must be closed. Otherwise, an interlock (in the software) prevents the auto-synchronizer from operating.

   The signals that must be switched include (but are not limited to):
   a. Breaker status signal (i.e., 52b)
   b. Generator voltage
   c. Breaker close (contact input) circuit
   d. Breaker closing time
3. Whenever frequency or voltage control options are used, their outputs must also be switched to the correct machine governor and voltage regulator.
4. The frequency correction pulse width (the amount of time a raise or lower signal remains ON) should be coordinated with the speed of response of the governor, the fuel system, and the prime mover to minimize the time required to bring the generator frequency into the required relationship with the bus frequency without excessive overshoot or hunting.
5. The voltage correction pulse width and frequency should be coordinated with the response time of the voltage regulator/exciter/generator combination to minimize the time required to correct the voltage without overshooting or hunting.
6. If a dead bus closing is desired – i.e., if the machine can be started without the bus (to which it is to be synchronized) being energized – two conditions must be met:
   a. Operating power for the synchronizer must come from a separate source (like a battery) or from the generator bus.
   b. A dead bus option must be included in the unit and be programmed to allow closure to a dead bus.
7. Some systems, where speed of synchronizing is a primary consideration, allow an oncoming generator to be closed onto the bus from either the fast or slow side, and with the voltage either high or low.
   a. Fast means that the machine is running with a positive slip (faster than the bus).
   b. Slow indicates a negative slip (i.e., slower than the bus).
   c. High is generator voltage greater that bus voltage.
   d. Low is generator voltage less than bus voltage.

Most systems include a provision to permit closing only with the speed fast and voltage high. This allows the generator to pick up some watt and var load at once, thus stabilizing the system quickly.

By contrast, when the speed is slow and the voltage low, the system must feed watts and reactive VA to the machine (to add power to the prime mover and excitation to the exciter field), thereby raising both speed and voltage. Since this action is controlled only by the sub-synchronous reactance of the machine, it can cause uncontrolled swings of both vars and watts. The resulting tendency toward destabilization may cause winding, iron, or shaft stress. Accordingly, the selection of closing direction and permissible limits should consider these and other pertinent application data.

Defining the Parameters

These application notes are not intended to cover every possible set of circumstances, but rather to provide a basic description of slip frequency synchronization. The relationship between slip, advance angle (or window), and breaker closing time is shown in Figure 1-1, and described by the formula:

$$A_A = 360(T_{CB}+T_R)F_S$$

where

A_A	=	advance angle in degrees. This is the time, measured in electrical degrees, between initiation of breaker closure and the actual closure of the breaker contacts.
360	=	degrees per slip cycle.
T_{CB}	=	the closing time of the circuit breaker in seconds. This is the time required from the closure of the synchronizer output contact to the actual closing of the circuit breaker contacts. T_{CB} is preset in synchronizer memory for each different breaker controlled by the synchronizer. EXCEPTION: In some applications, T_{CB} may represent the characteristic closing time of a group of breakers all having the same closing time.
T_R	=	response time, in seconds, of the synchronizer breaker close output relay. (A non-adjustable parameter approximately 0.008 second.)
F_S	=	slip frequency in cycles per second. This is the oncoming generator frequency minus the bus frequency: positive for a generator speed higher than bus, negative for lower.

The relationships defined above should prove helpful in determining the settings for the auto-synchronizer. Note that reducing the advance angle (or window) also reduces the absolute value of the slip frequency (which is the maximum permissible speed difference for which the machine is allowed to close onto the bus). Lower slip frequencies are softer (i.e., less liable to produce system disturbance or machine damage).

Higher frequencies, on the other hand, are quicker (i.e., allow synchronization to be accomplished faster). Again, these considerations should be balanced against others such as:

1. How fast do I need to be on line?
2. How critical is the machine?
3. How expensive is the machine as against possible outage (down) times?

A proper synchronizer application will take into account the considerations mentioned above, as well as others that may be unique to the system under consideration.

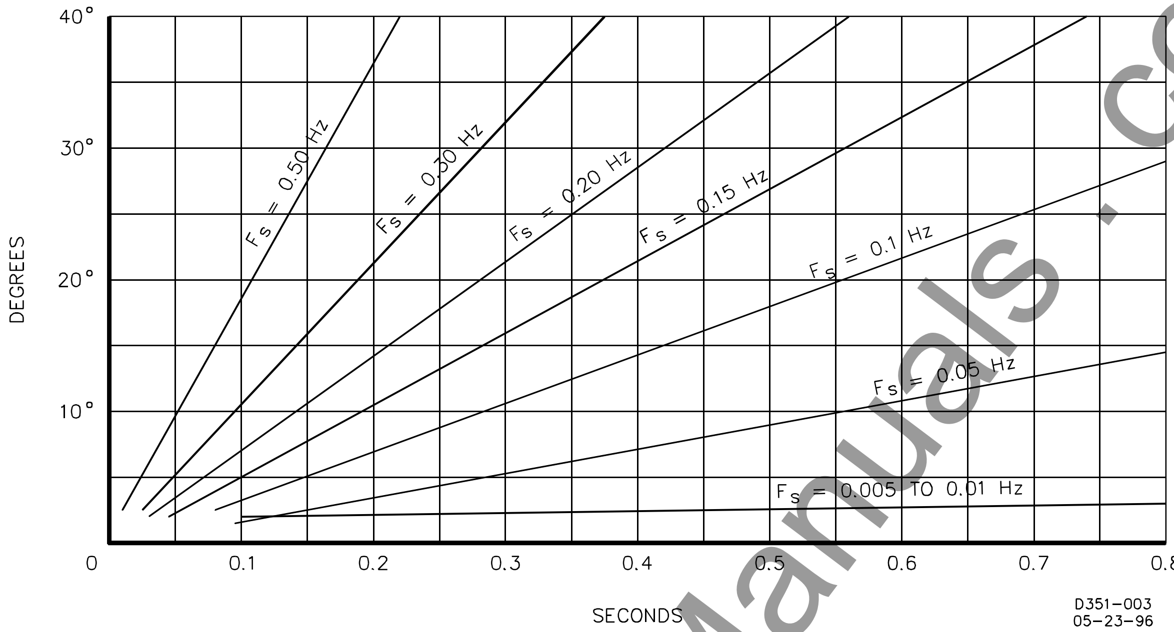

Figure 1-1. Slip, Advance Angle, and Breaker Closing Time

MODEL AND STYLE NUMBER

BE1-25A Auto-Synchronizer style numbers define the features of a specific device. Each pair of characters within the style number is associated with a specific feature or option that may be selected from the style chart on the following page.

For example, if the first two digits of the style number are A2, the unit has the capability of deferring its closure command to the breaker for any of the following reasons: (1) the bus is under a specified voltage; (2) the bus is over a specified voltage; and (3) the bus-to-generator voltage is less than a selected value. Another consideration: If a voltage matching option is desired (let assume it is), including one of the A options is essential.

The second pair of digits determines the manner in which the Auto-Synchronizer commands the generator to change speed. This relay uses option F5, which can initiate two different types of speed-change commands: (1) proportional correction pulses, that are issued when the slip frequency is above the allowable limit; and (2) target correction pulses, that automatically forces synchronization whenever an out-of-phase condition coincides with a near-zero slip rate.

The third pair of digits selects the voltage matching capabilities that are required for an application. We might look first at the voltage matching module with the most features, V3. Let examine these capabilities, and how they might be useful to a specific application.

Option V3 (like Option V2) can automatically initiate corrective pulses to bring the generator voltage to within the limits established by Option A1 or A2. However, when the voltage difference between bus and generator is less than 20.0 volts, V3 has the additional capability of reducing the width of the corrective pulses by an amount proportional to the correction required. This feature can significantly reduce overshoot where inertia is particularly high (as in the control of sluice gates). If this is beneficial to our hypothetical application (let assume it is) then the matter is decided: the third pair of digits is V3.

Finally, we choose D1 as the last pair of digits because we want the capability of obtaining a closure when a dead bus is detected. (D1 also has the means of setting a threshold voltage to define a dead bus condition.)

When ordering, it is recommended that the style number be preceded by the model number. Accordingly, the style number now looks like:

BE1-25A A2 F5 V3 D1

where

BE1-25A	=	the model number
A2	=	3-parameter voltage restraint
F5	=	both proportional correction pulse and target pulse capability
V3	=	proportional correction pulse capability
D1	=	automatic closure capability upon recognition of a dead bus.

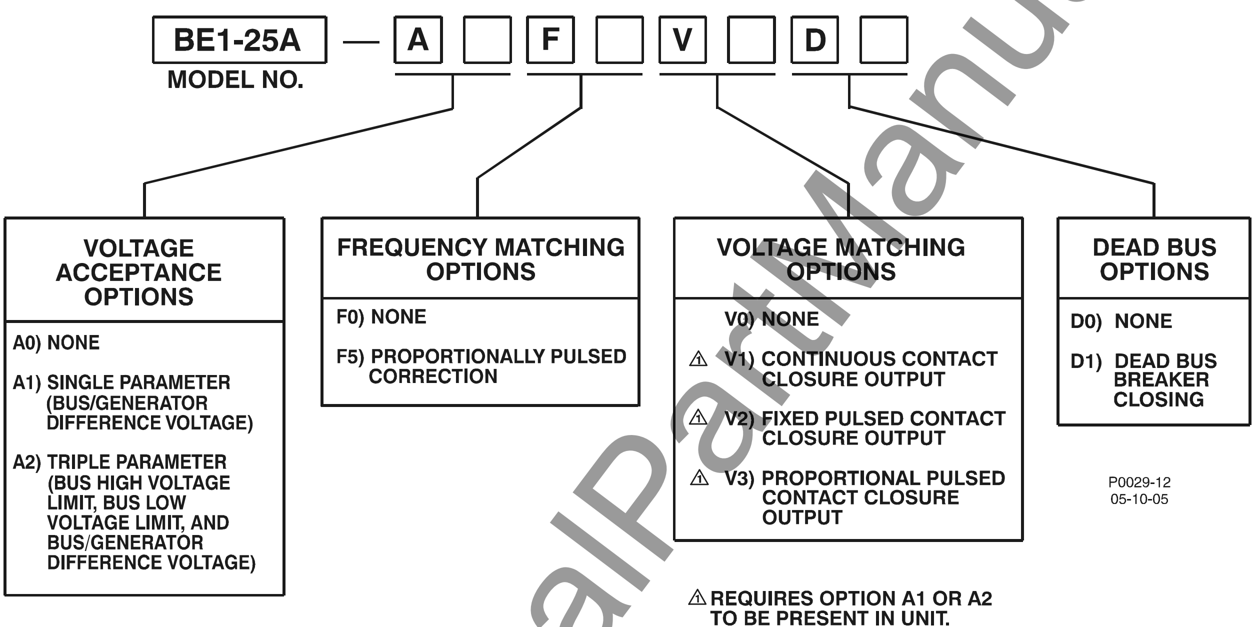

Figure 1-2. Style Number Identification Chart

SPECIFICATIONS

General specifications for the BE1-25A system are provided in the following paragraphs. For specifications that apply only to particular options, see the ensuing subsection entitled *Specifications of Options.*

Voltage Sensing Inputs (Bus and Generator)	70-150 Vac, 50/60 Hz. Burden: Less than 6 VA for the generator input; less than 2 VA for the bus input.
Contact Sensing Inputs	Requires a user-supplied contact with a minimum rating of 0.05 A at 250 Vdc.
Power Supply	Power for the internal circuitry may be derived from 90-132 Vac at 50/60 Hz (single phase), or 70-150 Vdc. Burden: Less than 20.0 VA.
Outputs	Output contacts are rated as follows. <u>Breaker Closing</u> Normally open. Make and carry 30 A at 250 Vdc for 1 second, 7 A continuously, and break 0.3 A at 250 Vdc. (L/R = 0.04). <u>Voltage, Frequency (Speed) Correction, and Lockout</u> Form C (SPDT). Make and break 5 A at 250 Vac (80% PF), 5 A at 28 Vdc (resistive), and 0.5 A at 120 Vdc (resistive).
Tolerances	
Advance Angle	The command for breaker closure occurs within ±3.0° of phase coincidence of bus and generator. (Closure will not occur if the calculated advance angle exceeds 40°.)
Lockout	Occurs when breaker reopens within 15 ±10% seconds after the initiation of breaker closure.
Slip Frequency (F_S)	±0.001 hertz.
Generator Undervoltage Inhibit	±1.0 V.
Control Ranges	The following parameters are settable over the indicated ranges.
MAX SLIP	Adjustable from 0.01 to 0.500 in steps of 0.001.
BRKR TIME	The characteristic breaker time settings are adjustable from 0.02 to 0.8 seconds.
Generator Undervoltage Inhibit	Adjustable from 40 to 110 Vac.
Generator Speed Correction Pulses	Adjustable between 0 to 99.9 seconds in 0.1 second increments.
Shock	In standard tests, the relay withstood 15 G in each of three mutually perpendicular axes without structural damage or degradation of performance.
Vibration	In standard tests the relay 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 structural damage or performance degradation.
Isolation	1,500 Vac at 60 Hz for one minute in accordance with IEC 255-5 and ANSI/IEEE C37.90-1978 (Dielectric Test).
Surge Withstand Capability	Qualified to ANSI/IEEE C37.90.1-1989 Standard Surge Withstand Capability Tests, and to IEC 255-5 Impulse Test and Dielectric Test.
Radio Frequency Interference	Field tested using a five watt, hand-held transceiver operating at random frequencies centered around 144 MHZ and 440 MHZ, with the antenna located six inches from the relay in both horizontal and vertical planes. Maintains proper operation when tested for interference in accordance with IEC C37.90-1989, *Trial-Use Standard Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers*.
Patent	Patented in U.S., 1998, Patent No. 5761073.
UL Listed	UL listed per Standard 508, UL File Number E97033.
C.S.A. Certification	CSA certified per Standard CAN/C.S.A.-C22.2 Number 14.
CE Qualification	This product meets or exceeds the standards required for distribution in the European community.
Gost R Certification	Gost R certified No. POCC US.ME05.B03391; is in compliance with the relevant standards of Gosstandart of Russia. Issued by accredited certification body POCC RU.0001.11ME05.
Temperature	
Operating	–40 to 70°C (–40 to 158°F)
Storage	–65 to 100°C (–85 to 212°F)
Weight	16.0 lb (7.26 kg) net for basic synchronizer (Includes the rack frame, MCU module, and power supply module.)

SPECIFICATIONS OF OPTIONS

To eliminate repetition, only the specifications that uniquely apply to a particular option are given below. Specifications that are applicable throughout the unit (including the options) are stated above.

Voltage Acceptance Option A1

VOLTAGE DIFFERENCE CONTROL	Minimum threshold adjustable from 0.5 to 5% of generator voltage. (Generator voltage minus bus voltage)
Weight	6.6 oz (186.0 g)

Voltage Acceptance Option A2	
BUS VOLTAGE UPPER LIMIT CONTROL	Maximum threshold adjustable from 100 to 150 Vac.
BUS VOLTAGE LOWER LIMIT CONTROL	Minimum threshold adjustable from 80 to 120 Vac.
VOLTAGE DIFFERENCE CONTROL	Minimum threshold adjustable from 1 to 10 Vac of generator voltage. (Generator voltage minus bus voltage)
Weight	8 oz (226.8 kg)
Frequency Matching Option F5	
CORRECTION PULSE WIDTH CONTROL	Adjustable from 0 to 99.9 seconds.
CORRECTION PULSE INTERVAL CONTROL	Adjustable from 0 to 99.9 seconds.
Weight	6.6 oz (186.0 g)
Voltage Matching Option V1	
Weight	5 oz (140.6)
Voltage Matching Option V2	
CORRECTION PULSE WIDTH CONTROL	Adjustable from 0.1 to 5.0 seconds.
CORRECTION PULSE INTERVAL CONTROL	Adjustable from 0.2 to 10.0 seconds.
Weight	7.0 oz (200.0 g)
Voltage Matching Option V3	
CORRECTION PULSE WIDTH CONTROL	Adjustable from 0.1 to 5.0 seconds.
CORRECTION PULSE INTERVAL CONTROL	Adjustable from 0.2 to 10.0 seconds.
Weight	8.5 oz (240.4 g)
Dead Bus Option D1	
VOLTS CONTROL	Adjustable from 10.0 to 40.0 Vac.
Weight	6.6 oz (186.0 g)

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SECTION 2 • HUMAN-MACHINE INTERFACE

CONTROLS AND INDICATORS

A basic BE1-25A Synchronizer (without options) is shown in Figure 2-1 and described in Table 2-1. Figure 2-2 shows the Test Module in its offset position as required for testing. The remaining figures describe the various options currently available.

Table 2-1. BE1-25A, Controls and Indicators (Refer to Figures 2-1 and 2-2)

Locator	Control or Indicator	Function
A	**GENERATOR SELECT** Control	When the Test Module is in the test position (as in Figure 2-2), this control selects one of the six possible generator operation times that are stored in the memory of the MCU Sync module. This selection process allows the stored constant for a particular generator to be employed as a reference for test purposes. This control has no function when the Test Module is in the operate position (as shown in Figure 2-1.)
B	Test Jacks	When the Test Module is in the test position (Figure 2-2), the tip jacks facilitate testing in the following described manner. When the Test Module is in the normal position (Figure 2-1), certain jacks serve as monitoring points as described in the following paragraphs. Starting from the top, the seven pairs of jacks are: 1. **BUS** voltage. When test module is in test position, a simulated bus voltage can be injected for test purposes. In normal position, monitors the bus voltage. 2. **GEN**erator voltage. When test module is in test position, allows a simulated generator voltage to be injected for test purposes. In normal position, allows the generator voltage to be monitored. 3. **POWER**. When the test module is in test position, allows the specified operating power (i.e., 85-135 Vac @ 50/60 Hz, or 70-150 Vdc) to be supplied to the BE1-25A relay. (This power was automatically disconnected by the act of placing the module into the test position.) In the normal position, allows the supply voltage to be monitored (i.e., terminals 21 and 22 of TB1). 4. **52b**. When the test module is in test position, provides a means of simulating a 52b contact closure (by applying a jumper or closing a switch across these jacks). In the normal position, allows the 52b contact input to be monitored. (Measures approximately 100 Vdc when the 52b contact input is open, 0 Vdc otherwise.)

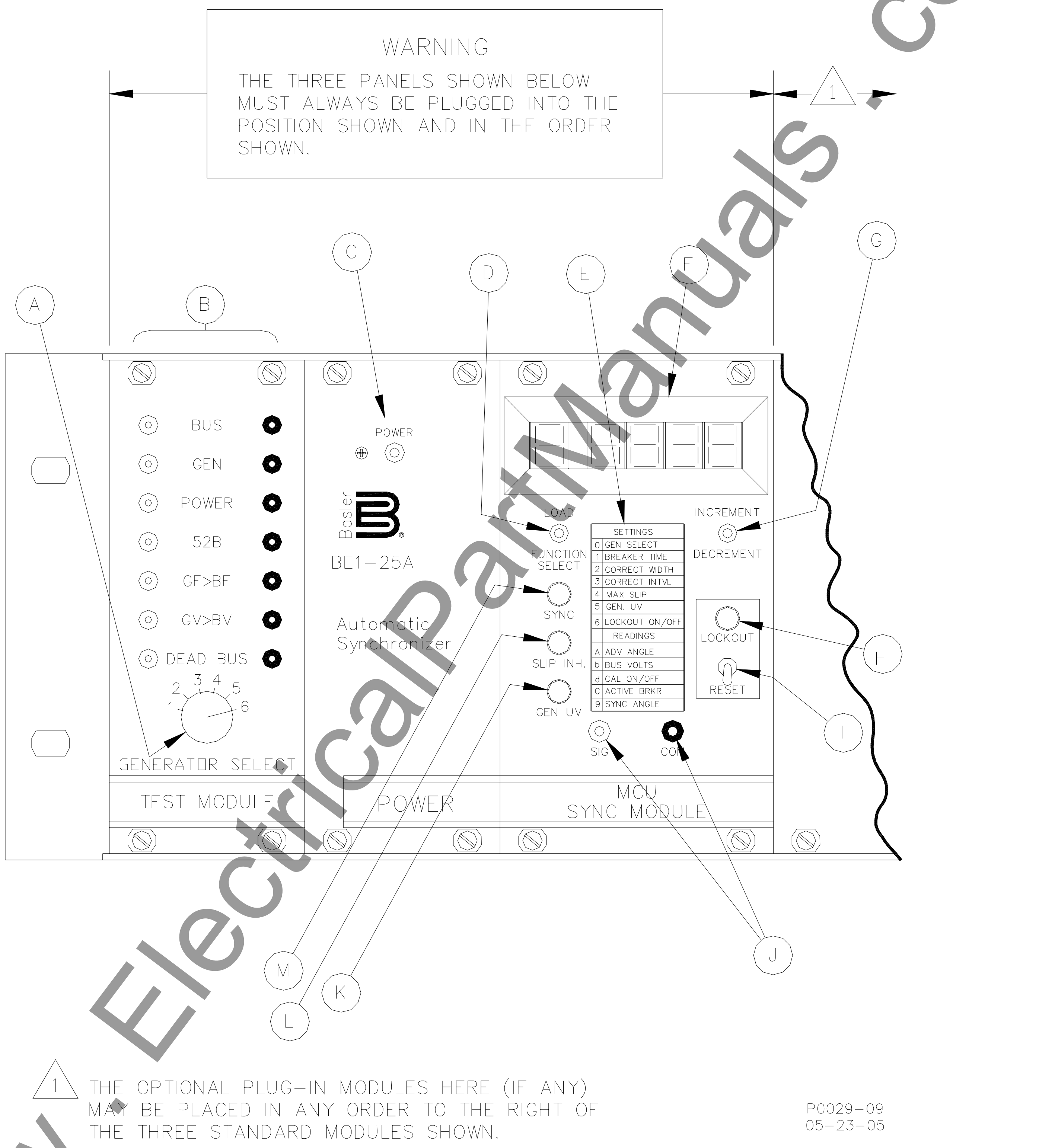


Figure 2-1. Location of Controls and Indicators

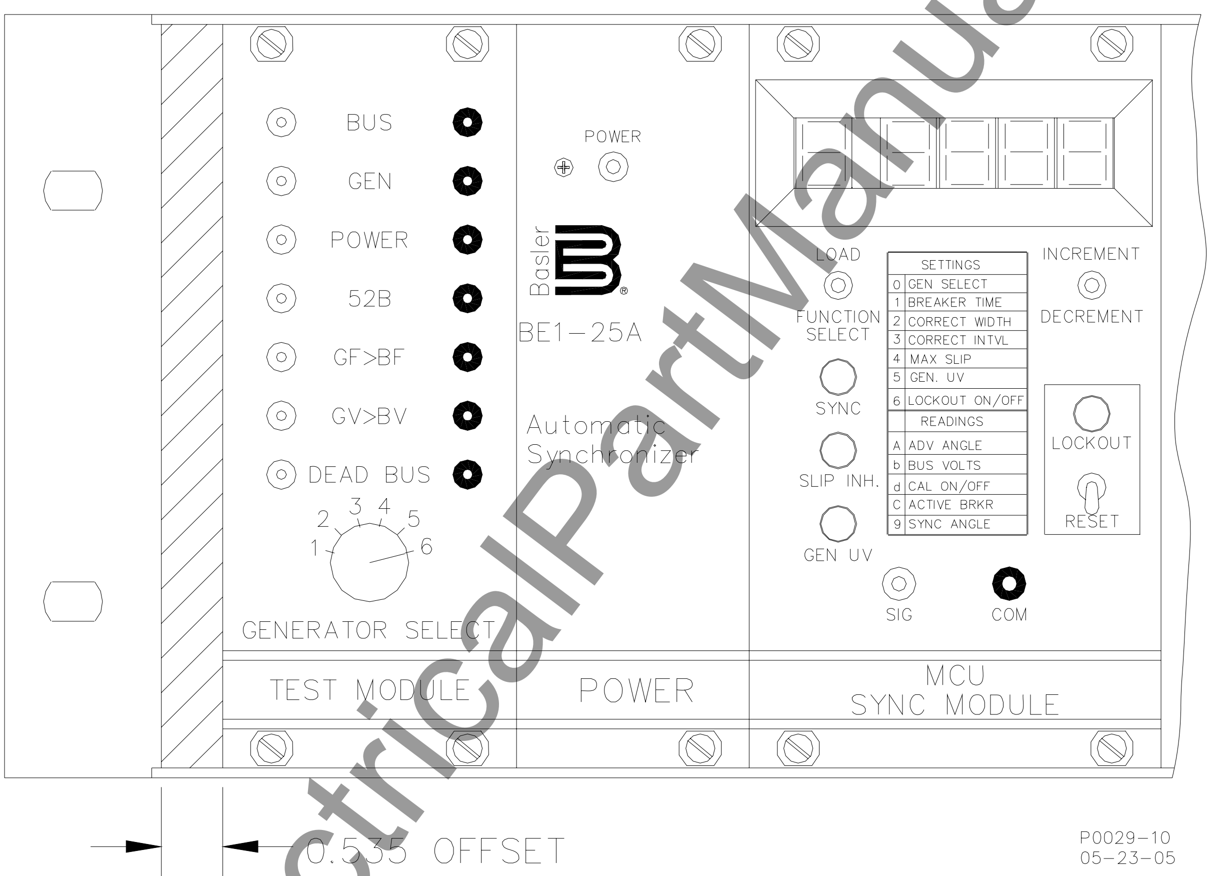


Figure 2-2. Test Module In Test Position

Table 2-1. Sync Acceptor, Controls and Indicators - Continued

Locator	Control or Indicator	Function
B	Test Jacks - Continued	5. **GF>BF**. When the module is in test position, provides the input terminals for a simulated GF>BF contact closure. In the normal position, these jacks have no function. 6. **GV>BV**. When the test module is in test position, provides the input terminals for a simulated GV>BV contact closure. In the normal position, these jacks have no function. 7. **DEAD BUS**. When the module is in test position, provides the input terminals for a simulated Dead Bus Enable signal. (This signal is useful only if the Dead Bus option is present.) In the normal position, these jacks have no function.
C	**POWER** LED	LED lights to indicate that the power supply is operating correctly.
D	**LOAD/FUNCTION** SELECT SWITCH	A three-position switch with the following two active positions. (The switch is spring loaded to the center position.) **FUNCTION SELECT**: Each time the switch is depressed, it advances the display (F) to show the next register (in the sequence listed in SETTINGS/READINGS chart (E)). The leftmost character of the display may be found in the left column of SETTINGS/READINGS chart which describes the use of each register. **LOAD**: Used to store data into memory. To do so, hold the switch in the raised position until the display flashes (disappears and reappears) (takes approximately 1 second). The data showing in the four rightmost digits of the display is now recorded in memory.
E	**SETTINGS/READINGS** Chart	This chart lists various computer registers that control the synchronizer or monitor the system. Each register is identified by the associated character in the left-hand column of the chart. This digit also appears as the left-most digit of display F whenever that register has been accessed by switch D — i..e., the characters displayed in the rightmost digits of the display represent the generator selected or status of the particular register identified by the character in the left column of the chart. The **SETTINGS** registers are: 0 (**GEN SELECT**): When function 0 is selected, a — or a digit (1 thru 6) appears as the rightmost character. After powering up or after reset, a — appears, but once a generator is selected, a digit appears. The appropriate character appears until the INCREMENT/DECREMENT switch is incremented. The INCREMENT/DECREMENT switch must be held for approximately one-half second for the change to occur. The sequence is from — to 1 and incrementing to 6, and then wrapping around to 1.

Table 2-1. Sync Acceptor, Controls and Indicators - Continued

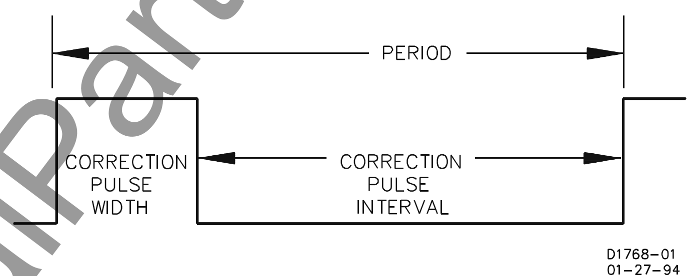
Locator	Control or Indicator	Function
E	**SETTINGS/READINGS** Chart - Continued	0 (**GEN SELECT**): - continued After a generator is selected and the FUNCTION SELECT switch is depressed, the display changes to indicate the setting number (1 thru 6) in the leftmost position and the constant (value) in the four rightmost display characters. If a setting is changed, it must be loaded by operating the LOAD switch. 1 (**BREAKER TIME**): These registers hold the characteristic operating times of the various breakers in the system. Numbers may be entered to represent breaker operating time over the range of 0.02 to 0.800 seconds. 2 (**CORRECT WIDTH)**: The number in this register represents the raise and lower speed correction pulse width. The pulse width is settable from 0 to 99.9 seconds in 0.1 second increments. (Refer to Figure 2-3.) 3 (**CORRECT INTVL)**: The number in this register represents the raise and lower speed correction pulse interval. The pulse interval is settable from 0 to 99.9 seconds in 0.1 second increments. (Refer to Figure 2-3.)  *Figure 2-3. Proportional Correction Pulses* 4 (**MAX SLIP**): The number in this register represents the maximum slip rate that is acceptable for closure of any breaker that is under the supervision of the Sync Acceptor Relay. When the slip rate exceeds this setting, the sync acceptor closure output is inhibited. The maximum slip limit is adjustable over the range of 0.01 to 0.500 Hz in 0.001 Hz increments. 5 (**GEN. UV**): The number in this register represents the minimum voltage output that the generator must have before an operator breaker closure attempt is enabled. This value is adjustable over the range of 40 to 110 Vac in 1.0 volt increments. If the generator voltage is below this setting, voltage correction pulses are inhibited.

Table 2-1. Sync Acceptor, Controls and Indicators - Continued

Locator	Control or Indicator	Function
E	**SETTINGS/READINGS** Chart - Continued	6 (**LOCKOUT ON/OFF**): This register indicates whether or not the lockout feature is enabled. When enabled, the BE1-25A Relay will automatically enter LOCKOUT whenever the breaker reopens within 15 seconds after closure by the synchronizer. This prevents another closure of the breaker from this source until LOCKOUT is terminated by (1) manually resetting the unit, using either the front panel RESET control or an external (remote) contact; or (2) by removing, then reapplying power. The **READINGS** registers are: A (**ADVANCE ANGLE**): This represents the number of degrees that the breaker closure signal must precede actual closure so that the latter will occur at, or close to, a phase difference of zero degrees. This compensation takes into consideration the operating speed of the breaker, as well as the armature operation time of the output relay. (This register performs a monitoring function only. No provision for adjusting the data.) b (**BUS VOLTS**): A digital voltmeter with a range of 0 to 135 Vac that reads the bus voltage. (This register performs a monitoring function only. No provision for adjusting the data.) C (**GEN VOLTS**): A digital voltmeter with a range of 0 to 135 Vac that reads the output voltage of the generator being addressed. (This register performs a monitoring function only. No provision for adjusting the data.) d (**ACTIVE BREAKER**): Displays an identifying digit (1 through 6) that represents the particular breaker whose operating time, b-contact, closing circuit, and associated generator voltage is being addressed by the BE1-25A Relay. (In some situations this number can represent a group of breakers having an identical operating time.) P (**SYNC ANGLE**): This variable indicates the instantaneous phase angle difference across the open breaker. (This register performs a monitoring function only.
F	Five-Digit, 7-Segment Display	The leftmost digit indicates the function selected, while the remaining four digits indicate the present value held in memory for that function.
G	**INCREMENT/DECREMENT** Switch	The constants and generators (SETTINGS) that may be viewed in Display E (but not the READINGS, such as bus voltage, etc.) may be altered in value by means of this switch. When the switch is raised for approximately one-half second and released, the number on the display is incremented. But when held raised, incrementation occurs repeatedly – at first slowly, then much faster. Similarly, when the switch is depressed, a decrement occurs, then repeats slowly, then faster—as long as the switch is held down. The switch is spring loaded to return to the center position from both directions.

Table 2-1. Sync Acceptor, Controls and Indicators - Continued

Locator	Control or Indicator	Function
H	**LOCKOUT** LED	This LED lights to indicate the occurrence of a lockout condition. During lockout, the output of the relay is inhibited from signaling the breaker to close. Lockout may be cleared by the front panel RESET switch, by a (continued)remotely located contact, or by powering down and then powering up.
I	**RESET** Switch	When momentarily raised, this switch restores the Relay to operation after a lockout has occurred.
J	**SIGnal/COMmon** Test Points	Used to monitor the output breaker closure signal during testing or calibration.
K	**GENerator UnderVoltage** LED	An LED that lights when the generator voltage is below an acceptable range of the synchronizer. Under this circumstance, the synchronizer is not allowed to close the breaker. (The acceptable range is defined by the GEN UV setting of register 5.)
L	**SLIP INH** LED	An LED that lights when the slip frequency exceeds the paralleling tolerance established by the MAX SLIP setting. The breaker close output is inhibited whenever this LED is ON.
M	**SYNC** LED	This LED is in parallel with the coil of the sync output relay. When the sync output relay coil is energized, the LED lights.

ADDITIONAL MODULES

Controls and indicators of the additional plug-in modules for the BE1-25A Relay, are described in the following paragraphs.

Voltage Acceptance Module A1

Option A1 introduces an additional enabling factor for the breaker closing signal. This additional parameter, ΔV, represents the difference in voltage on the two sides of the circuit breaker. I.e., if ΔV is greater than the setting established by the VOLTAGE DIFFERENCE control (Figure 2-4), the closure command output of the BE1-25A unit is inhibited.

Note that the magnitude of the VOLTAGE DIFFERENCE setting is expressed as a percentage of the bus voltage: the voltage difference (in %) = $|\Delta V|*100/V_{BUS}$.

An LED indicator, ΔV HIGH, illuminates when the voltage difference exceeds the setting and the synchronizer is inhibited.

As will be seen later, this option or option A2 is a prerequisite of, and a controller of, any Voltage Matching option that may be present.

Voltage Acceptance Module A2

Voltage Acceptance Module A2 can use as many as three voltage parameters to add constraints to the issuance of breaker command signals. This option or option A1 is a prerequisite of, and a controller of, any voltage matching option that may be present. Figure 2-5 illustrates the following descriptions.

1. The UPPER LIMIT control establishes a maximum bus voltage. No closure is to be attempted when the bus voltage is above the upper limit.
2. The LOWER LIMIT control establishes a minimum bus voltage. No closure is to be attempted when the bus voltage is below the lower limit.
3. The VOLTAGE DIFFERENCE control establishes the maximum acceptable voltage difference between the two sides of the circuit breaker (generator voltage minus bus voltage). No closure is to be attempted when the circuit breaker voltage difference is greater than the set limit. The voltage difference is continuously variable over the range of 1 to 10 Vac.

An LED to the left of each control lights whenever the associated parameter is beyond the range set by the control. As a result, the breaker closure is inhibited.

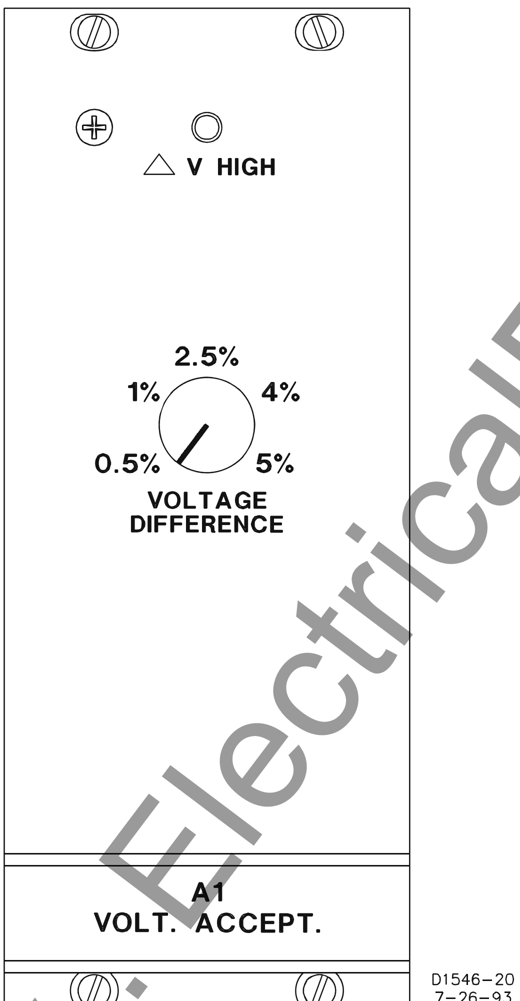


Figure 2-4. Module A1

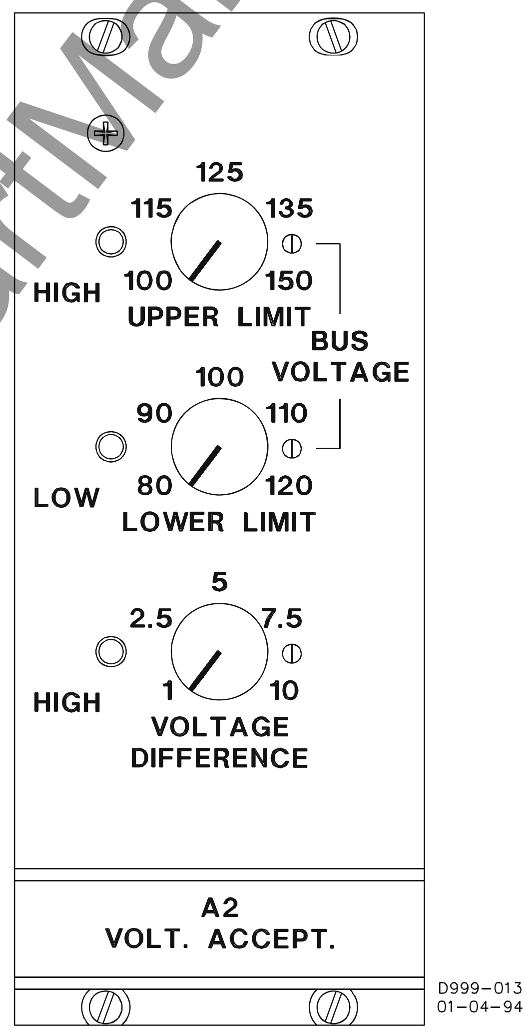


Figure 2-5. Module A2

Frequency Matching Module F5

Option F5 (Figure 2-6) provides frequency-corrective (speed) and phase-corrective signals that are compatible with motor-operated machine speed controls. Effective with BE1-25A relays, revision R and subsequent (April 30, 1996), option F5 includes the functions of options F1 and F3. Available are: (F1 function) fixed width pulses, fired inversely proportional to the slip rate; (F3 function) continuous correction signal until measured slip is less than the slip setting; and (F5 function) proportional and pulsed correction modes.

F1 Function, Pulse Contact Closure

A pulse contact closure generates a fixed-width correction pulse (pulse width of 0.1 to 99.9 seconds, in 0.1 second increments) once each cycle. These pulses, though fixed in pulse width, are sent more often at higher slip frequencies and less often as the slip decreases. In this (F5) implementation, the fixed width pulse is fired inversely proportional to the slip rate. However, no pulses are created at specific phase angle differences. The F1 function is implemented by setting the correction pulse width to any non-zero value and setting the correction pulse interval to zero. It is possible, at high slip frequencies, to have no correction pulse interval. For example, if the correction pulse width is set to 0.5 seconds and the pulse interval is set to zero, and the slip frequency is 2 hertz, the pulse width is equal to the inverse of the slip frequency (0.5). Therefore, the correction pulse is continuous. Correction pulses are issued until the slip frequency is within 0.5 of the slip setting. Sync closure can occur any time below the slip setting if no correction pulses are being issued.

Figure 2-6. Module F5

F3 Function, Continuous Correction Pulse

F3 function provides a continuous correction signal until the measured slip is less than the slip setting. The F3 function is implemented by setting the correction pulse width to any non-zero value and the correction pulse interval to zero. The correction pulse is continuous (full-on) as long as the slip frequency is greater than the slip setting. No corrections are issued if the slip frequency is less than the slip setting. One exception would be to bump the target pulse if the slip frequency is very close to zero. Figure 2-7 shows the F3 function correction pulse and slip frequency relationship.

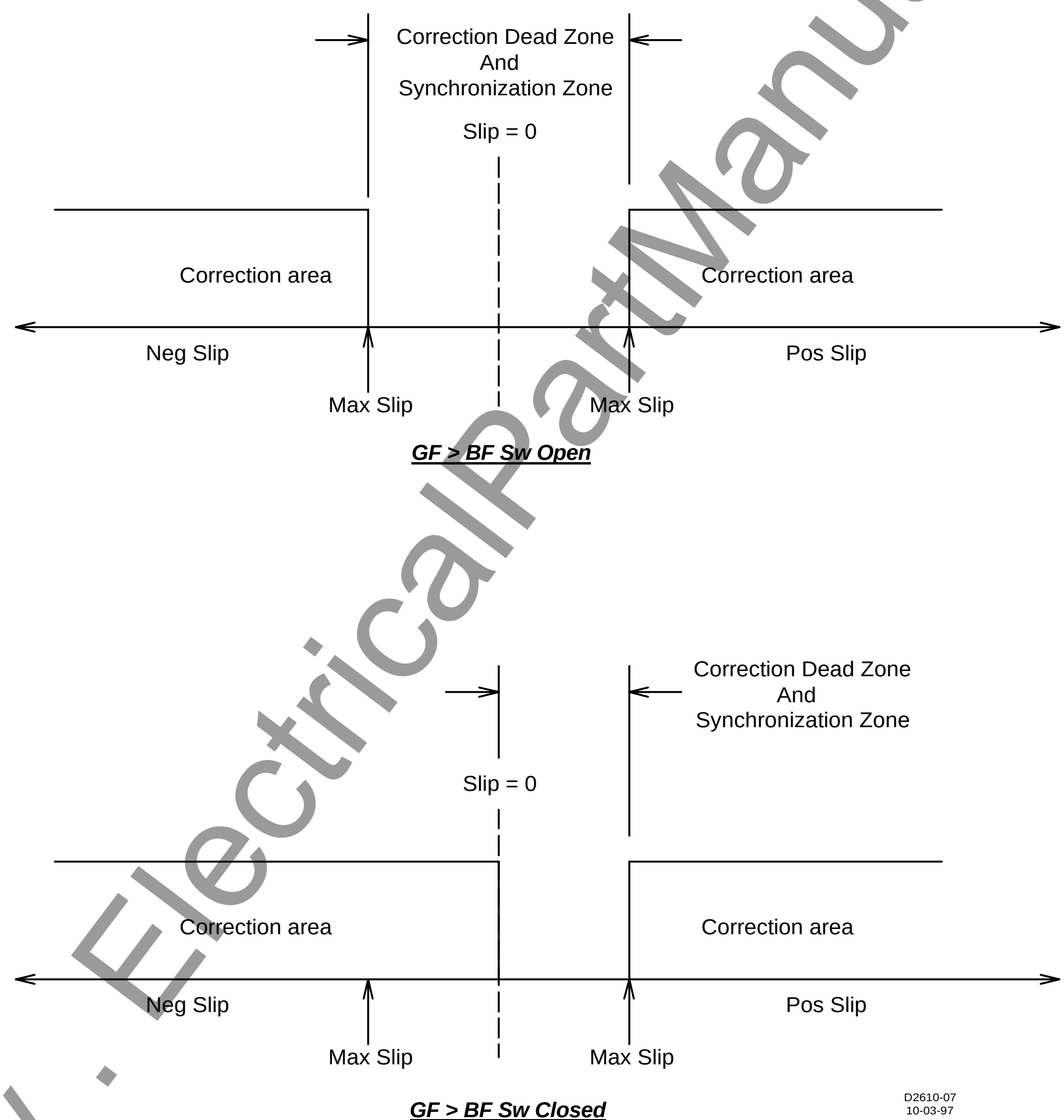


Figure 2-7. F3 Function Correction Pulse And Slip Frequency Relationship

F5 Function, Proportional Frequency Correction

A proportional correction pulse train is issued when the slip frequency is greater than 50 percent of the maximum slip frequency setting. The pulses are steered (as appropriate) to operate one of the two speed-adjust output relays. The contacts of one relay are used to signal the generator to raise speed, while the contacts of the other relay are used to signal the generator to lower its speed. The period of the correction pulses is determined by the settings loaded into the microprocessor. That is, the period is equal to the sum of the correction pulse interval plus the correction pulse width. The period remains constant once the correction pulse width and correction pulse interval are set. The proportional correction pulse is determined by the percent of correction required. If the slip frequency is greater than four times the maximum slip allowed, the proportional correction pulse train is at 100 percent of the setting (correction pulse interval setting plus correction pulse width setting). If the slip frequency is equal to the maximum slip setting, the proportional correction pulse width is at 25 percent of the original setting. The correction pulse interval (wait time) will increase to maintain a consistent correction pulse period (total of the pulse interval and pulse width). Figure 2-8 shows the proportional relationship when the GF>BF switch is open.

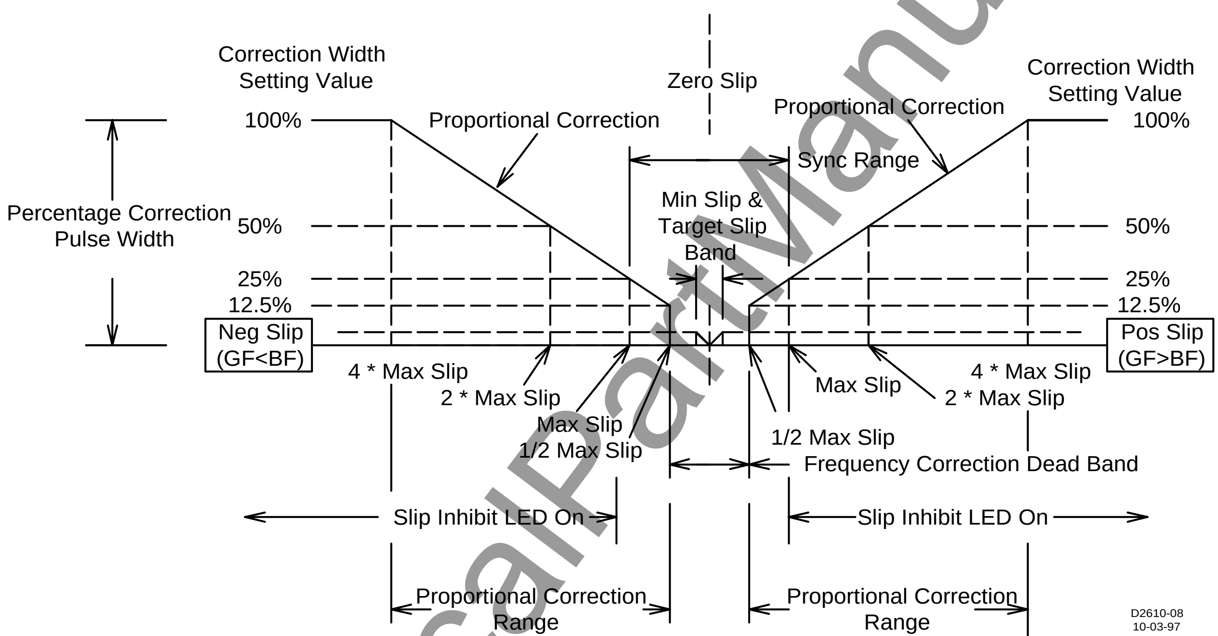


Figure 2-8. Proportional Relationship When GF>BF Switch Is Open

Proportional correction is linear between 100 percent (four times maximum slip frequency setting) and 12.5 percent (equal to one-half maximum slip frequency setting). Synchronization is enabled at slip frequencies less than the maximum slip setting. Although synchronization is enabled at slip frequencies below 50 percent of the maximum slip allowed, no correction pulses are issued. The pulses issued by this option (to direct the output relays) may be monitored at the SIG and COM jacks. (+12 Vdc = raise pulse; -12 Vdc = lower pulse.) Figure 2-9 shows the proportional relationship when the GF>BF switch is closed.

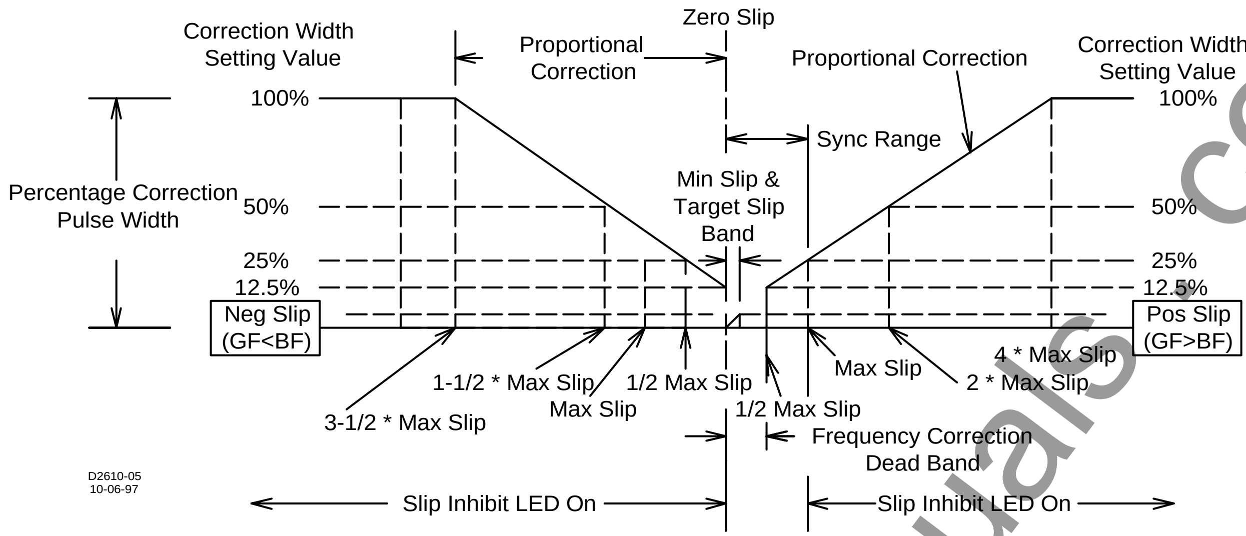


Figure 2-9. Proportional Relationship When GF>BF Switch Is Closed

<u>Phase Correction</u>

A target pulse is issued to the correction pulse train when the bus and generator are frequency matched (within approximately six percent of the maximum slip setting) but not phase matched. The pulses are steered to induce a slip frequency that may be adjusted to fall within the allowable limits of the correction pulse train. The contacts of one relay are used to signal the generator to raise speed, while the contacts of the other relay are used to signal the generator to lower its speed. The width of the target pulses is approximately 1.5 percent of the correction pulse width setting loaded into the microprocessor. The target pulses issued may be monitored at the SIG and COM jacks and are additional pulses to the correction pulse train. (+12 Vdc = raise pulse; -12 Vdc = lower pulse.)

> **NOTE**
>
> If the generator voltage is less than the generator undervoltage setting, correction pulse are inhibited.

Voltage Matching Module V1

Option V1 (Figure 2-10) issues a corrective signal whose purpose is to increase or decrease the generator terminal voltage to within the voltage difference limit determined by the setting of the Voltage Acceptance Option A1 or A2 (whichever is present). The signal is in the form of a **continuous** closed-contact output.

Controls and indicators are limited to:

a. RAISE LED, that lights when a raise voltage signal is being output (at which time the raise output contact is closed).

b. LOWER LED, that lights when a lower voltage signal is being output (at which time the lower output contact is closed).

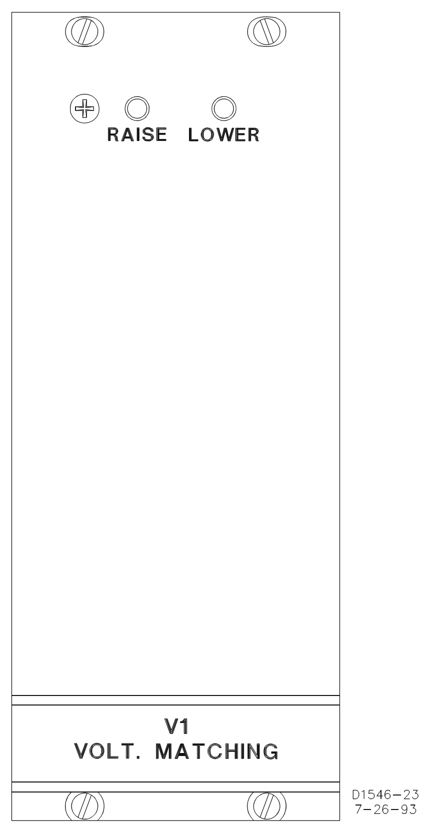


Figure 2-10. Module V1

Voltage Matching Module V2
Option V2 (Figure 2-11), like option V1, issues corrective signals that increase or decrease the generator voltage to within the voltage difference limit determined by the setting of whichever Voltage Acceptance option is present (A1 or A2). In the case of this option, however, the corrective signal is not continuous (as in V1), but rather is in the form of a pulsing output contact.

Pulse duration and interval are independently controlled by the CORRECTION PULSE WIDTH control, and by the CORRECTION PULSE INTERVAL control.

When correction pulses are issued, the direction of the correction is indicated by either the RAISE or the LOWER LED. This also indicates which of the two output relays (and which set of output contacts) is delivering the pulses: the raise output relay or the lower output relay.

The pulses issued by this option (to direct the output relays) may be monitored at the SIG and COM jacks. (+12 Vdc = relay deenergized; 0 Vdc = relay energized.)

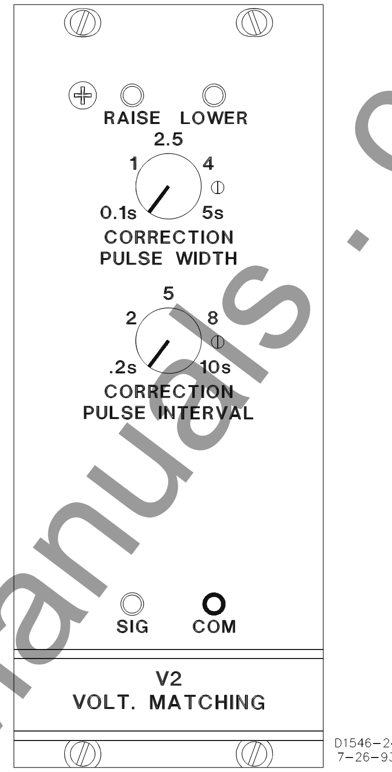


Figure 2-11. Module V2

Voltage Matching Module V3
Option V3 (Figure 2-12) is similar to Option V2, in that it initiates corrective pulses that are used to increase or decrease the generator voltage to within the voltage difference limit as determined by the Voltage Acceptance module (either A1 or A2). Both V2 and V3 are functionally identical when the voltage difference between generator and bus is equal to or greater than 20.0 Vac.

But when the voltage difference is less than 20.0 Vac, Option V3 differs in this respect: the duration of the corrective pulses no longer follows in lockstep with the setting of the CORRECTION PULSE WIDTH control. Instead, the duration of the corrective pulses is reduced by an amount proportional to the correction required (Figure 2-13). Note that the minimum pulse duration is 0.1 seconds.

The CORRECTION PULSE INTERVAL control determines the period of the pulse train. (Unlike the PULSE WIDTH control, the INTERVAL control does **NOT** vary from the setting as a function of voltage difference.)

The pulses issued by this option (to direct either the raise or the lower output relay) may be monitored at the SIG and COM jacks. (+12 Vdc = relay de-energized; 0 Vdc = relay energized.)

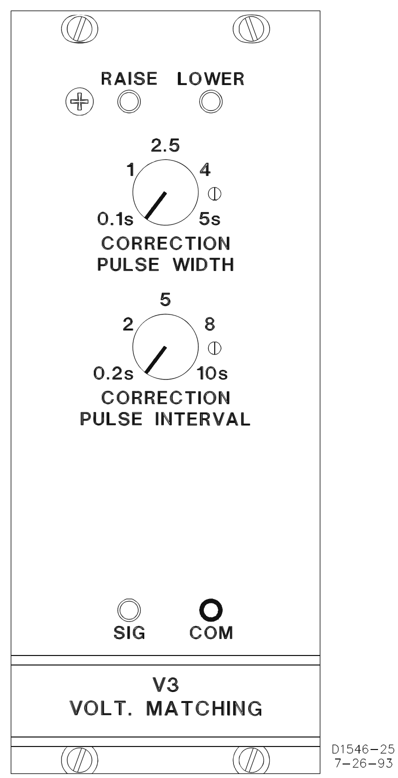


Figure 2-12. Module V3

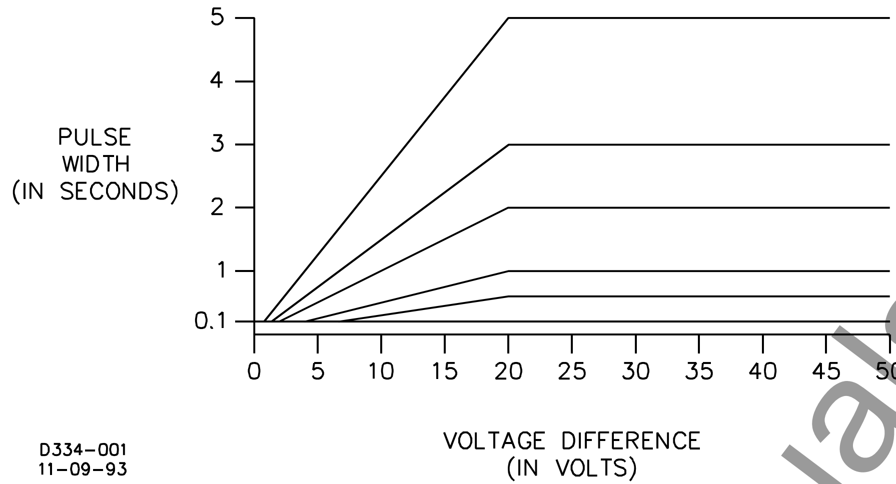


Figure 2-13. Pulse Duration Timing for Option V3

Dead Bus Module D1

When the external dead bus contact is closed, module D1 (Figure 2-14) determines when the bus is dead, and acts upon this determination (if the breaker is detected open) by initiating a close breaker signal. This signal is terminated as soon as the sync acceptor recognizes the breaker as having closed, or when 100 milliseconds has passed (whichever occurs first).

The VOLTS control defines a dead bus condition by establishing a voltage threshold between 10 and 40 Vac.

The DEAD BUS indicator is an LED that lights whenever the bus voltage is below the control setting.

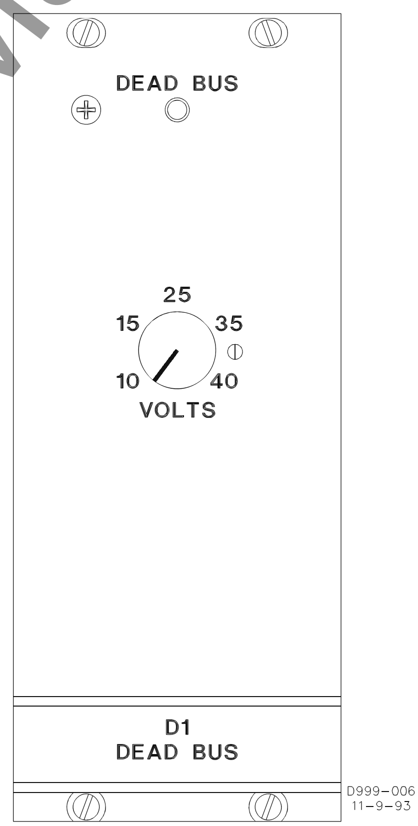


Figure 2-14. Module D1

SECTION 3 • FUNCTIONAL DESCRIPTION

SYSTEM OPERATION

As the prime mover brings the oncoming generator up to speed, the BE1-25A Auto-Synchronizer (Figure 3-1) compares the generator output with the bus. When the monitored frequency and phase angle (and, optionally, the voltage) are within preset limits – as described below – the BE1-25A Auto-Synchronizer signals the controlled breaker to close.

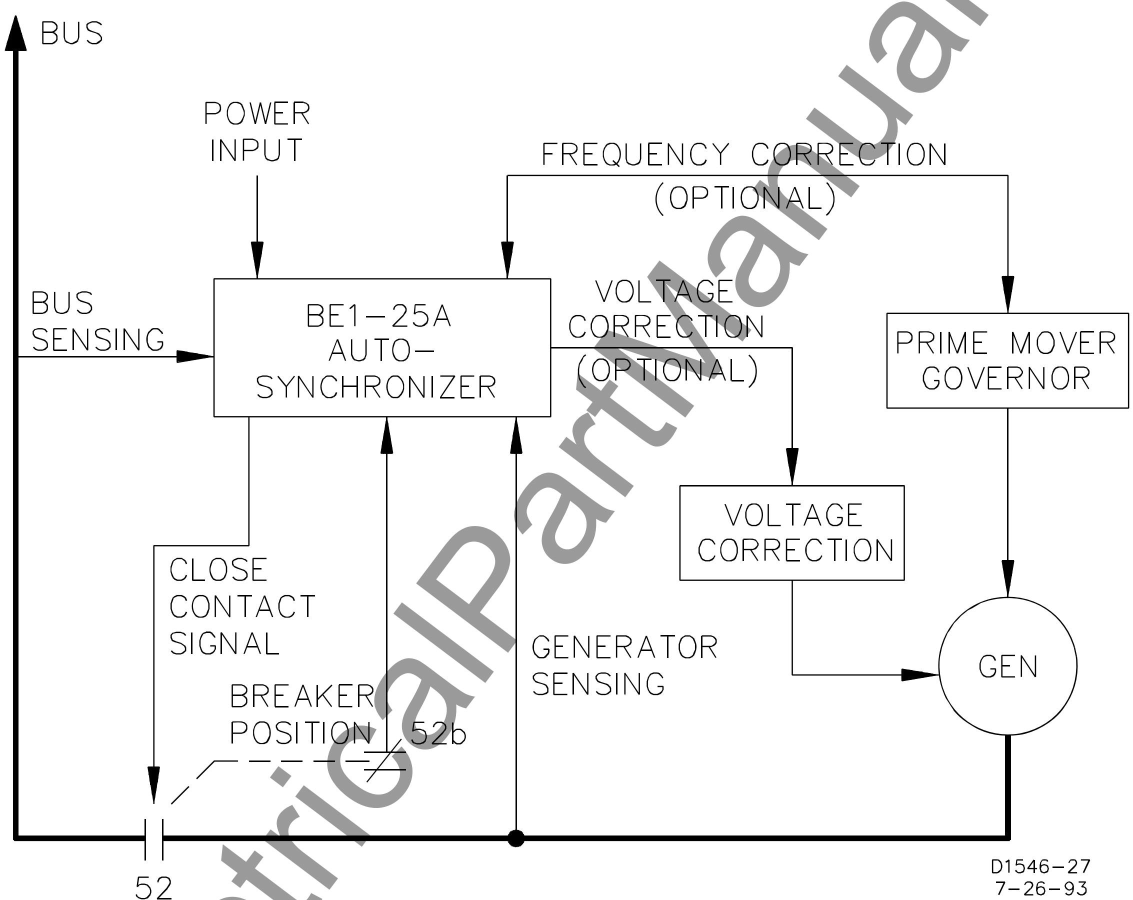


Figure 3-1. System Block Diagram

To accomplish closure quickly and with the least stress on the system, a microprocessor in the MCU sync module calculates (and thus anticipates) the advance angle necessary to compensate for breaker closure time, as well as for operation time of the output relay. To do so, it utilizes data stored in memory concerning the characteristic closing times of the generator breaker to which it is connected.

As detailed in Section 4, the BE1-25A Auto-Synchronizer can be set-up to control multiple generators. Each generator may be associated with a breaker whose closing time may be different from the others. The various closing times are stored in the synchronizer memory and called up according to which generator/breaker combination the BE1-25A Auto-Synchronizer is connected. (The connecting is performed by user-installed switches.)

After breaker closure has been initiated, the Auto-Synchronizer is inhibited from further operation for 15 ±1.5 seconds.

A functional block diagram of the Auto-Synchronizer is given in Figure 3-2, and is referred to in the circuit descriptions that follow. A black box approach is taken, with the emphasis on the inputs and outputs to the external world. Omitted from the diagram are the internal signals that communicate between the various modules of the system. Note that the output relays shown in the lower right corner of the figure are not present unless the controlling options are installed.

Later in this section, additional functional diagrams are provided that describe the options.

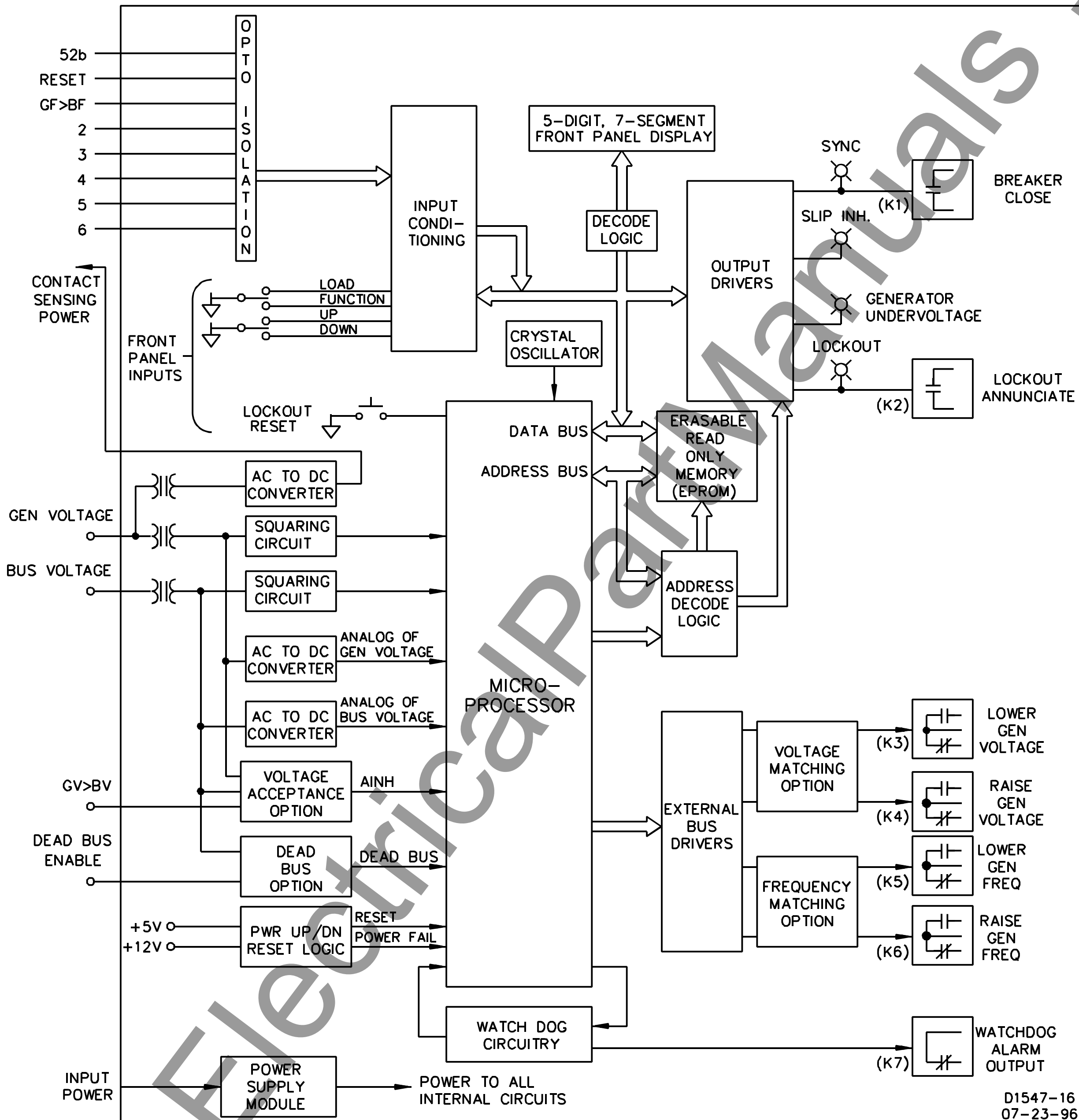


Figure 3-2. Auto-Synchronizer Block Diagram

INPUT CIRCUITS

Contact Inputs

At the upper left corner of Figure 3-2 are the contact sensing inputs. Note that opto-isolators protect the internal circuits from the unwanted noise that is present on unconditioned lines. The inputs are:

- **52b** – An input that monitors the 52b auxiliary contact of the controlled breaker. (The 52b contact, when closed, indicates that the breaker is open.)
- **Reset** – An input that may be used to monitor a remotely located reset switch. (Not to be confused with the RESET switch on the front panel of the unit.)
- **GF>BF** – An input that may be used to monitor a remotely located switch, that when closed, enables the closure output of the Auto-Synchronizer if (and only if) the generator frequency is greater than the bus frequency. When this contact is open, closure is allowed from both directions.
- **2, 3, 4, 5, 6** – These five input contacts, in conjunction with the common contact, provide a means of informing the Auto-Synchronizer which generator (and which generator breaker) has been connected to the Auto-Synchronizer. A sixth generator/breaker combination (generator/breaker 1) may be recognized by opening all five inputs, 2 through 6. This is a default input that addresses the first generator/breaker combination.

The various contact input signals are directed to input-conditioning circuitry, where they are translated into binary notation and strobed into the microprocessor. Notice that power for the contact inputs is isolated by means of a transformer supplied by the generator voltage sensing input.

At the lower left corner of Figure 3-2 are two inputs that go directly to optional modules. They are also translated into binary notation and strobed into the microprocessor. They are:

- **GV>BV** – If one of the voltage acceptance options is present, this input may be used to monitor a remotely located switch, that when closed, enables the closure output of the Auto-Synchronizer if (and only if) the generator voltage is greater than the bus voltage. When this contact is open, closure is allowed from both directions.
- **Dead Bus Enable** – If the dead bus enable option is installed, the closure of this contact input coupled with a dead bus condition will bring about an immediate breaker close output.

Front Panel Inputs

Front panel inputs (Figure 3-2, about one-third down at the left), represent (1) the LOAD & FUNCTION switch, (2) the INCREMENT-DECREMENT switch, and (3) the LOCKOUT RESET switch of the MCU sync module. Switches (1) and (2) control the display and the memory of the Auto-Synchronizer. Switch (3), when momentarily raised, restores the operation of the Auto-Synchronizer to the initialized condition.

Analog Inputs

Generator and bus voltage inputs together monitor both sides of the breaker, and have a nominal rating of 150 Vac at 50/60 Hz. Internal transformers provide isolation and scaling. After the transformers, the analog inputs enter squaring circuits. These circuits allow the phase information to be represented by precise square waves needed to accurately determine the zero crossings. Additional circuitry provides a dc-analog representation of voltage magnitude for evaluation by the microprocessor and associated circuits.

To conclude the input description, a source of power for the digital circuits is required. Internal diodes steer these voltages so that no polarity needs to be observed in making connections. These terminals will accept either ac or dc, provided that it is within the voltage range of 70-150 V (and 50/60 Hz if ac).

MICROPROCESSOR CIRCUITRY

The microprocessor, with the associated memory and decoding logic, performs all calculations, makes all decision, and controls the display and output circuitry. These functions are for the most part, determined by the software in the manner illustrated by the flow diagram of Figure 3-3.

Returning to Figure 3-2, a crystal oscillator provides a precise time reference for determining frequency and phase relationships.

The power up/down reset logic (at the lower left corner) monitors the internal logic voltages. If any of the voltages fall below a critical threshold, the microprocessor is placed in a park mode. All decision making is then inhibited until such time as all vital voltages return to normal. (Because all settings and vital, programming instructions are held in non-volatile memory (EEPROM), and are not erased if power is lost.)

Microprocessor operation is monitored by the watchdog circuitry. If some transient condition has disrupted the normal pattern of operation, the watchdog operates the alarm output, resets the microprocessor and initializes the program. The reset restarts the microprocessor. After the third such reset operation (perhaps indicative of some hardware failure), the microprocessor is stopped and shuts down the entire unit. This condition remains until operating power is disconnected, then reapplied. (An inoperative microprocessor usually appears as a display that is frozen and – probably – inappropriate or meaningless.)

OUTPUTS

Again referencing Figure 3-2, the Output Drivers provide the interface required between the logic circuits and the final outputs, which are the LED indicators and the output relays. The Breaker Close relay provides a normally open contact. The other output relays are of the plug-in type, and are only incorporated into the unit upon the addition of the relevant option(s). Note that these supplementary relays provide both normally open and normally closed contacts for each function represented. (For the terminal numbers of these contacts see the last page of Section 4.)

OPTIONS

The various options available for the BE1-25A Auto-Synchronizer Relay are described on the following pages. Note that they are grouped into four categories: *Voltage Acceptance, Voltage Matching, Frequency Matching*, and *Dead Bus*. Only one option from each category can be used at one time.

The basic Synchronizer may be upgraded to Automatic Synchronizer status by incorporating one of the voltage matching options and/or one of the frequency matching options. This may be accomplished at any time – i.e., at original purchase or at any time thereafter.

Legend for Figure 3-3.

ADVANCE ANGLE	-	Number of degrees that the **close breaker** signal must precede actual closure of the breaker so that the closure occurs at (or very close to) zero degrees of phase difference.
BF	-	Bus frequency.
CLOSE BREAKER	-	Represent the closure of the BE1-25A output contact to provide closing current to the breaker.
DEAD BUS	-	A condition where the bus voltage is less than the setting of module D1, VOLTS control.
GF	-	Generator frequency.
GV	-	Generator voltage.
MAX SLIP	-	Maximum slip frequency setting.
F_S	-	Slip frequency.
UV	-	Undervoltage Setting

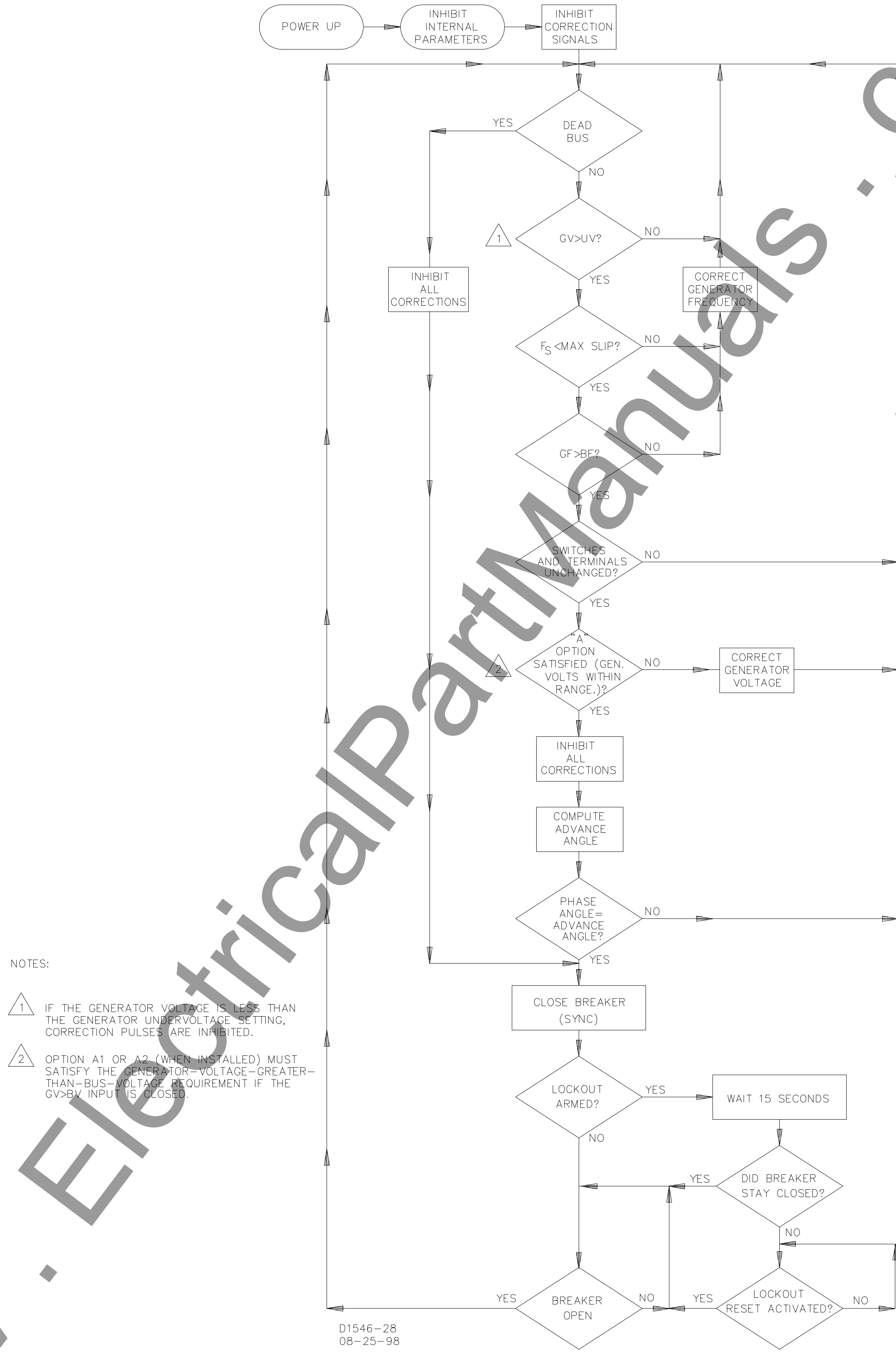


Figure 3-3. Synchronizer Flow Diagram

VOLTAGE ACCEPTANCE MODULE A1

With reference to Figure 3-4: The sensed bus and generator voltages are rectified and output to the balance circuit. Any inequality detected in the balance circuit represents the voltage difference (ΔV) between the bus and the generator. And the polarity of the difference represents the direction required for any corrective signal to the generator.

The balance error signal (or output) is amplified and directed to the precision full wave rectifier and to the output gates. The output gates provide a signal (utilized by any voltage matching module present) that indicates the desired direction that any speed-corrective command should have. This takes the form of either a raise signal or a lower signal, according to the polarity of the error.

A comparator monitors the VOLTAGE DIFFERENCE control. If the voltage difference between the two sides of the breaker (ΔV) is found to be greater than the setting of the control, the breaker closure command of the synchronizer is inhibited. (This information is also used by any voltage matching module in the system to determine whether corrective signals are required.)

Additional circuitry monitors the external enable contact. The presence of a GV>BV signal (i.e., contact closed) inhibits the synchronizer closure output unless the generator voltage is indeed greater than the bus voltage.

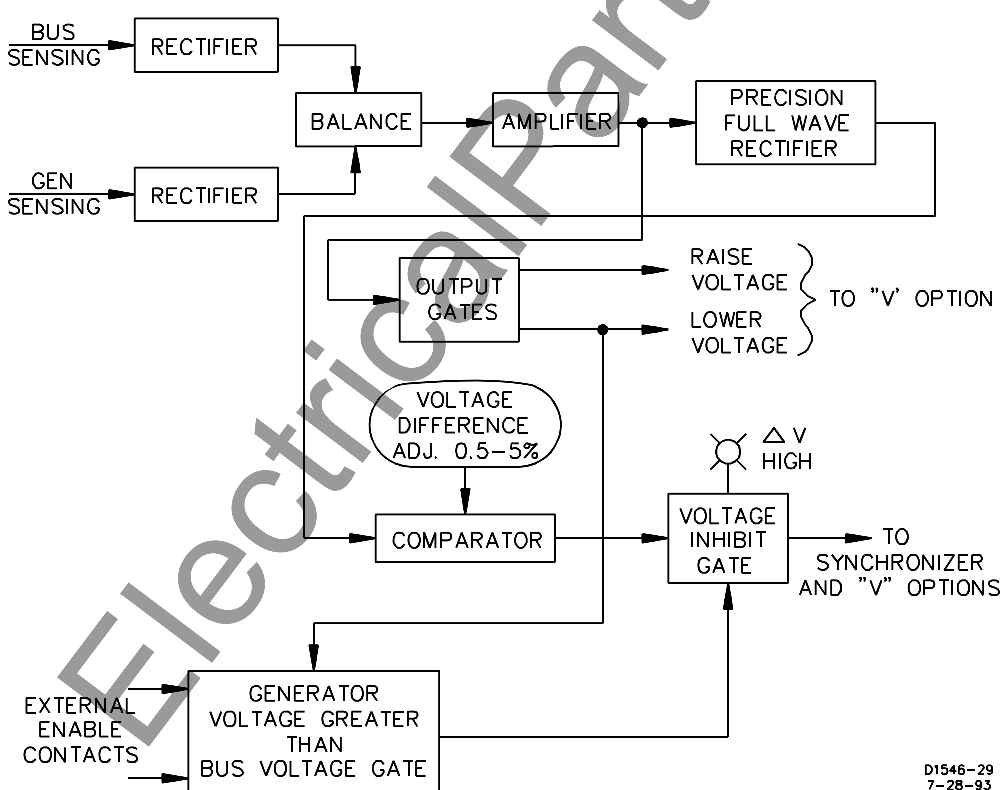


Figure 3-4. Voltage Acceptance Module A1 Block Diagram

VOLTAGE ACCEPTANCE MODULE A2

Note: The first three paragraphs below repeat the material on the previous page.

The sensed bus and generator voltages are rectified and output to the balance circuit. Any inequality detected in the balance circuit represents the voltage difference (ΔV) between the bus and the generator. And the polarity of the difference represents the direction required for any corrective signal to the generator.

The balance error signal (or output) is amplified and directed to the precision full wave rectifier and to the output gates. The output gates provide a signal (utilized by any voltage matching module present) that indicates the desired direction that any speed-corrective command should have. This takes the form of either a raise signal or a lower signal, according to the polarity of the error.

A comparator monitors the VOLTAGE DIFFERENCE control. If the voltage difference between the two sides of the breaker (ΔV) is found to be greater than the setting of the control, the breaker closure command of the synchronizer is inhibited. (This information is also used by any voltage matching module in the system to determine whether corrective signals are required.)

Module A2 differs from A1 by having additional comparators that monitor the UPPER LIMIT and the LOWER LIMIT controls. The added circuitry serves to inhibit operation unless the bus voltage is less than the upper limit, and greater than the lower limit. Additional circuits monitor the external enable contact. The presence of a GV>BV signal (i.e., contact closed) inhibits the synchronizer closure output unless the generator voltage is indeed greater than the bus voltage.

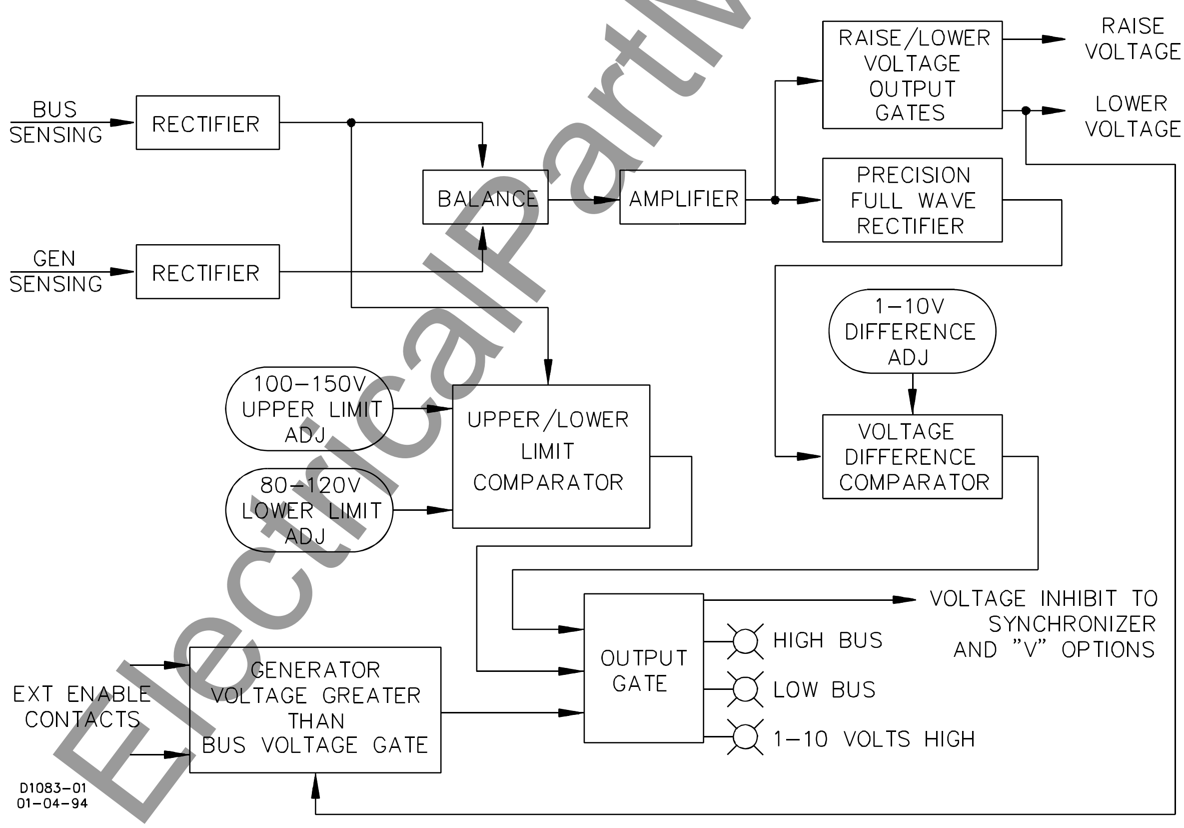


Figure 3-5. Voltage Acceptance Module A2 Block Diagram

FREQUENCY MATCHING MODULE F5

Frequency Correction

A proportional correction pulse train is issued when the slip frequency is greater than 50 percent of the maximum slip frequency setting. The pulses are steered (as appropriate) to operate one of the two speed-adjust output relays. The contacts of one relay are used to signal the generator to raise speed, while the contacts of the other relay are used to signal the generator to lower the speed. The period of the correction pulses is determined by the settings loaded into the microprocessor. That is, the period is equal to the sum of the correction pulse interval plus the correction pulse width. The period remains constant once the correction pulse width and correction pulse interval are set. The proportional correction pulse is determined by the percent of correction required. If the slip frequency is greater than four times the maximum slip allowed, the proportional correction pulse train is at 100 percent of the setting (correction pulse interval setting plus correction pulse width setting). If the slip frequency is equal to the maximum slip setting, the proportional correction pulse width is at 25 percent of the original setting. The correction pulse interval (wait time) will increase to maintain a consistent correction pulse period (total of the pulse interval and pulse width).

Proportional correction is linear between 100 percent (four times maximum slip frequency setting) and 12.5 percent (equal to one-half maximum slip frequency setting). Synchronization is enabled at slip frequencies less than the maximum slip setting. Although synchronization is enabled at slip frequencies below 50 percent of the maximum slip allowed, no correction pulses are issued. The pulses issued by this option (to direct the output relays) may be monitored at the SIG and COM jacks. (+12 Vdc = raise pulse; -12 Vdc = lower pulse.)

Phase Correction

A target pulse is issued to the correction pulse train when the bus and generator are frequency matched (within approximately six percent of the maximum slip setting) but not phase matched. The pulses are steered to induce a slip frequency that may be adjusted to fall within the allowable limits of the correction pulse train. The contacts of one relay are used to signal the generator to raise speed, while the contacts of the other relay are used to signal the generator to lower the speed. The frequency of the target pulses is approximately 1.5 percent of the correction pulse width setting loaded into the microprocessor. The target pulses issued may be monitored at the SIG and COM jacks and are additional pulses to the correction pulse train. (+12 Vdc = raise pulse; -12 Vdc = lower pulse.)

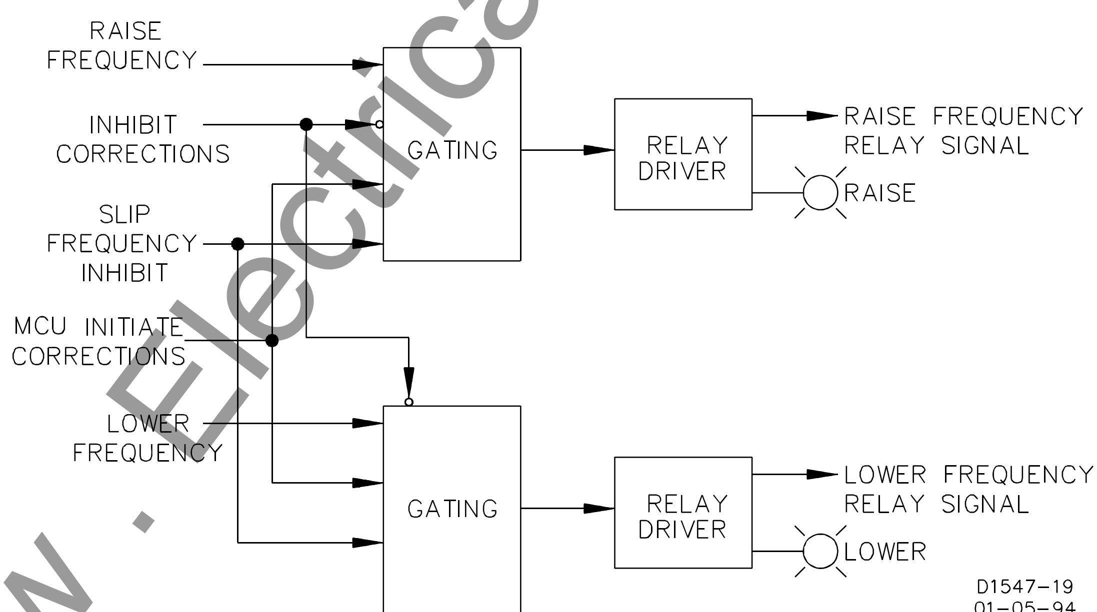


Figure 3-7. Frequency Match (Module F5) Block Diagram

VOLTAGE MATCHING MODULE V1

Module V1 issues corrective signals to the generator control system that cause the voltage to approach the voltage of the bus. The corrective output signal is in the form of a continuous contact closure.

This module is, in turn, controlled by whichever voltage acceptance module is in the system. (One of these, either A1 or A2, must be present in order for module V1 to function.)

An inhibit signal from the A module, AINH, will disable the V1 output (Figure 3-8). Additional A-module signals, raise and lower, determine whether the output will raise or lower the generator voltage.

If the generator voltage is less than the generator undervoltage setting, voltage correction pulses are inhibited.

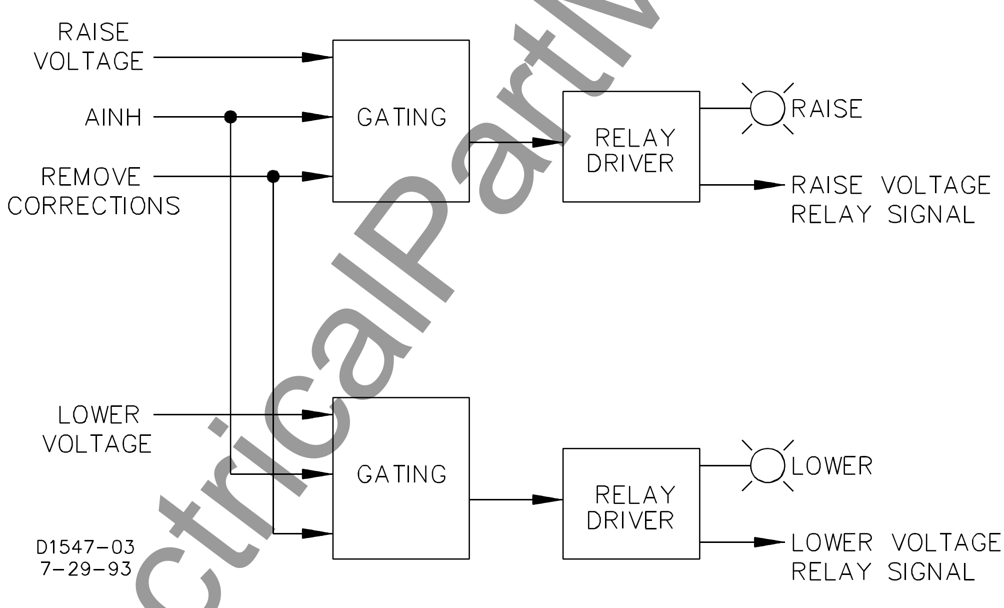


Figure 3-8. Voltage Matching Module V1 Block Diagram

VOLTAGE MATCHING MODULE V2

Like the V1 module, module V2 issues corrective signals to the generator control system that cause the generator voltage to approach the voltage of the bus. In the case of this module, however, the corrective signal is not continuous, but rather a train of pulses. The pulse width and pulse frequency are adjusted by front panel controls.

Module V2 (Figure 3-9) is controlled by whichever voltage acceptance module (A1 or A2) is in the system. (Either A1 or A2 must be present in order for this module to function.)

An Inhibit signal from the A module, AINH, will disable the V2 output (Figure 3-9). Additional A-module signals, raise and lower, determine whether the output will raise or lower the generator voltage.

If the generator voltage is less than the generator undervoltage setting, voltage correction pulses are inhibited.

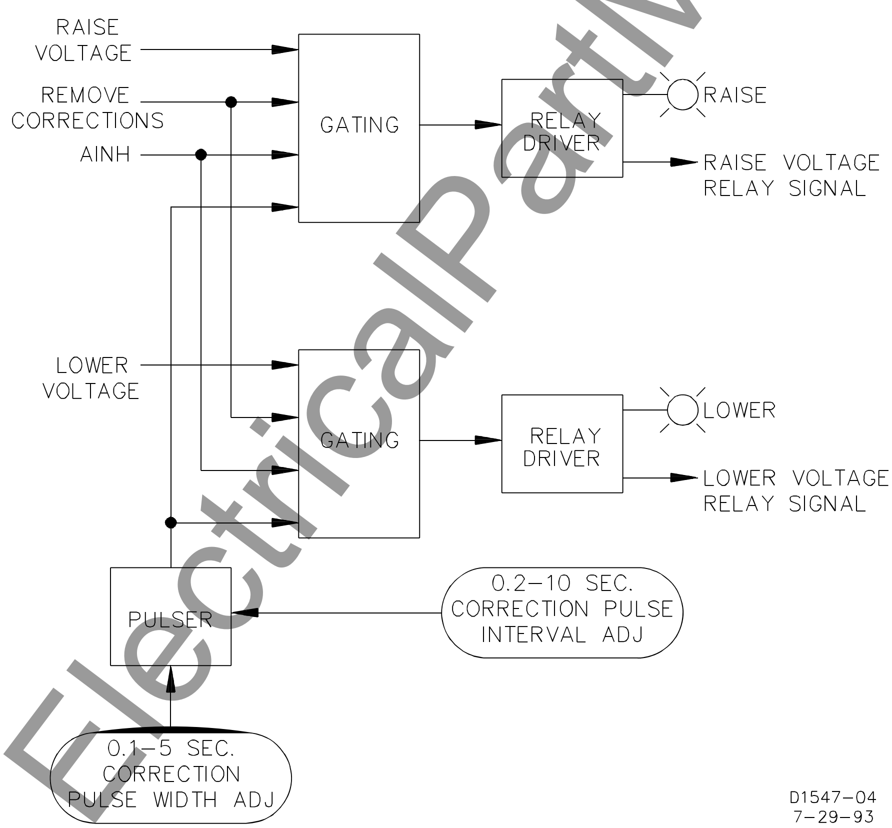


Figure 3-9. Voltage Matching Module V2 Block Diagram

VOLTAGE MATCHING MODULE V3

Like the V2 module, module V3 issues corrective signals in the form of pulses to the generator control system. The corrective signals are used to adjust the generator voltage toward the voltage of the bus. In fact, this module is functionally identical to module V2 so long as the voltage difference between the two sides of the breaker is greater than 20.0 Vac.

However, when the voltage difference is less than 20.0 Vac, the duration of the corrective pulses is proportionally reduced from the duration called for by the setting of the CORRECTION PULSE WIDTH control. I.e., the duration falls off by a ratio that is directly proportional to the reduced difference between the two voltages.

A constant current generator (Figure 3-10, bottom left) outputs a current that is used to charge a capacitor. (The magnitude of the current is established by the CORRECTION PULSE WIDTH control.) The comparator weighs the capacitor rising charge against the output of the precision full wave rectifier. The interval pulser will then have the duration trimmed by an amount directly proportional to the capacitor charge. This additional constraint is then input to the gate.

For other circuit features, refer to the functionally similar module V2 description on the previous page.

Module V3 is controlled by whichever voltage acceptance module (A1 or A2) is in the system. (Either A1 or A2 must be present in order for this module to function.)

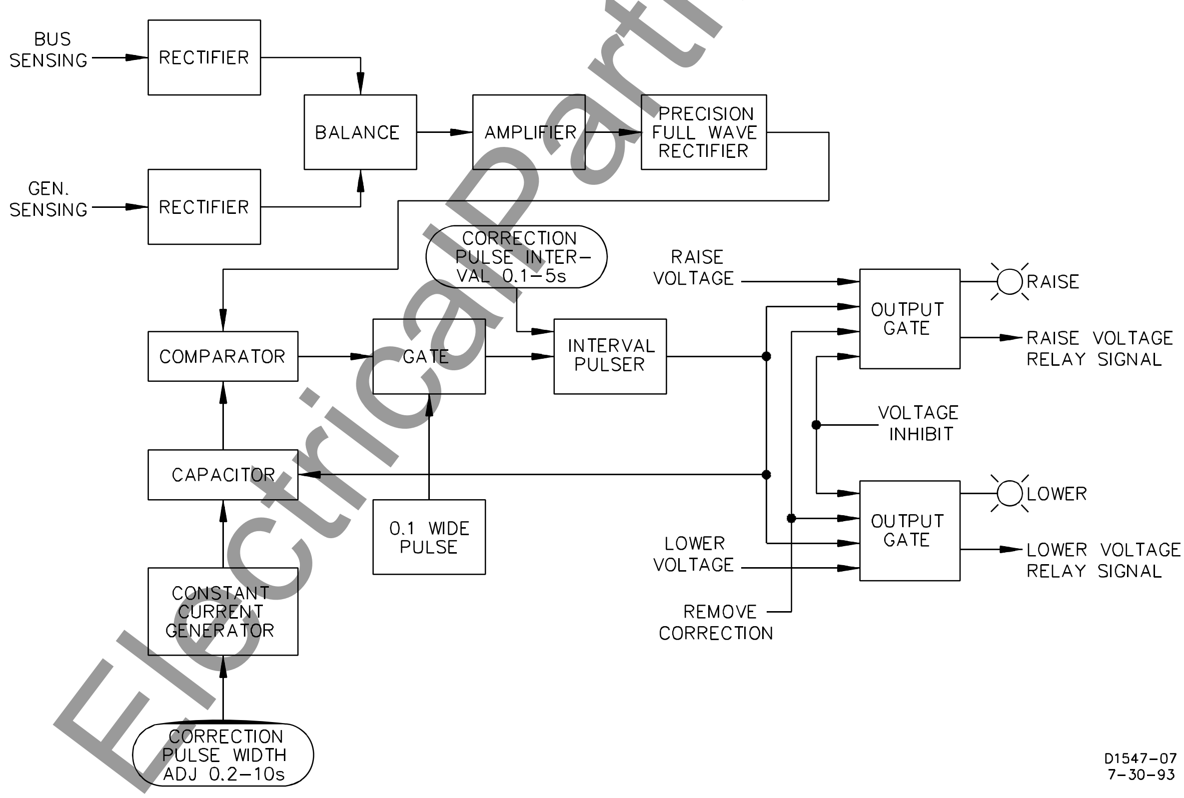


Figure 3-10. Voltage Matching Module V3 Block Diagram

DEAD BUS MODULE D1

Sensed bus voltage (upper left of Figure 3-11) is rectified, scaled to logic levels, then presented to the comparator. The comparator determines whether or not the bus is dead, as defined by the setting of the VOLTS control. Note that this control can define dead as any condition under a threshold setting in the range of 10 to 40 volts.

If the bus voltage is less than the VOLTS control setting, the output gate logic is enabled. At this point, if the output gate logic detects an enabling jumper (described below) and an undervoltage signal, the DEAD BUS indicator is illuminated and the 1-second timer is started. If, for the ensuing second, the 1-second timer continues to receive a qualifying signal from the output gate logic (and a lockout state is not evidenced), a DB (dead bus) signal is passed to the MCU sync module, that causes the MCU sync module to generate a breaker close signal.

This module is enabled by an external contact closure in one of three ways:

1. By an external jumper across the terminals 9 and 10 of terminal strip TB1 (on the rear of the case);
2. By a manually-controlled external switch (same terminals);
3. By an automatically controlled enabling signal (same terminals).

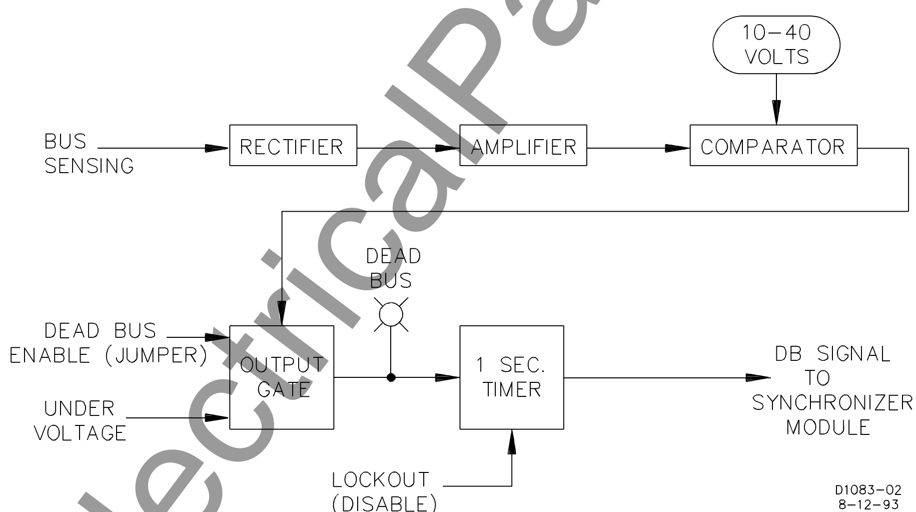


Figure 3-11. Dead Bus Module Block Diagram

SECTION 4 • INSTALLATION

GENERAL

When not shipped as part of a control or switchgear panel, the BE1-25A Auto-Synchronizer is shipped in a sturdy carton to prevent damage during transit. Immediately upon receipt, check the model and style number against the requisition and packing list to see that they agree. Visually inspect it for damage that may have occurred during shipment. If there is evidence of damage, immediately file a claim with the carrier and notify the Regional Sales Office, or contact the Customer Service Representative at Basler Electric, Highland, Illinois.

In the event the unit is not to be installed immediately, store it in its original shipping carton in a moisture and dust free environment. It is strongly recommended that an operational test (described in Section 5, *Testing*), always be performed prior to installation.

OPERATING PRECAUTIONS

Before installation, note the following precautions.

- BE1-25A Auto-Synchronizers are solid-state devices and have been type tested in accordance with the requirements defined below under Dielectric Test. If a wiring insulation test is required on the switchgear or panel assembly of which this unit is a part, see *Dielectric Test* below.
- Be sure that the BE1-25A case is hard wired to earth ground using the ground terminal (A1) on the rear of the unit.
- When the unit is installed, the controls should be protected by the plastic cover supplied. This limits access to the control settings.

DIELECTRIC TEST

In accordance with IEC 255-5 and ANSI/IEEE C37.90-1978, one-minute dielectric (high potential) tests up to 1500 Vac (45-65 hertz) may be performed. Note that:

- Decoupling capacitors are employed from all terminals to ground. Accordingly, a leakage current of approximately 20 milliamperes is to be expected when high potting at 1500 Vac, 60 hertz.
- Varistors are connected across all terminal-pairs of terminal strip TB1, and across terminals 21/22 of TB2. Do NOT high pot from terminal to terminal across these varistors. Normal high pot procedures (high potting from terminal to frame) are not affected by these varistors.
- A one megohm resistor is used in the contact sensing input circuit between the minus supply and the chassis. High potential testing on these contact sensing inputs (TB1, terminals 3, 4, 5, 6, 9, 10, 11, 12, 13, 14, 15, and 16), (TB2, terminals 21 and 22) may damage the internal resistor. Use a high resistance tester (megger) or alternate means to test these contacts.

MOUNTING

BE1-25A Synchronizers are designed to be rack-mounted. The overall dimensions are shown in Figure 4-1. Alternatively, the unit may be panel mounted, using the cutout dimensions of Figure 4-2 as a guide. The unit may be mounted at any convenient angle.

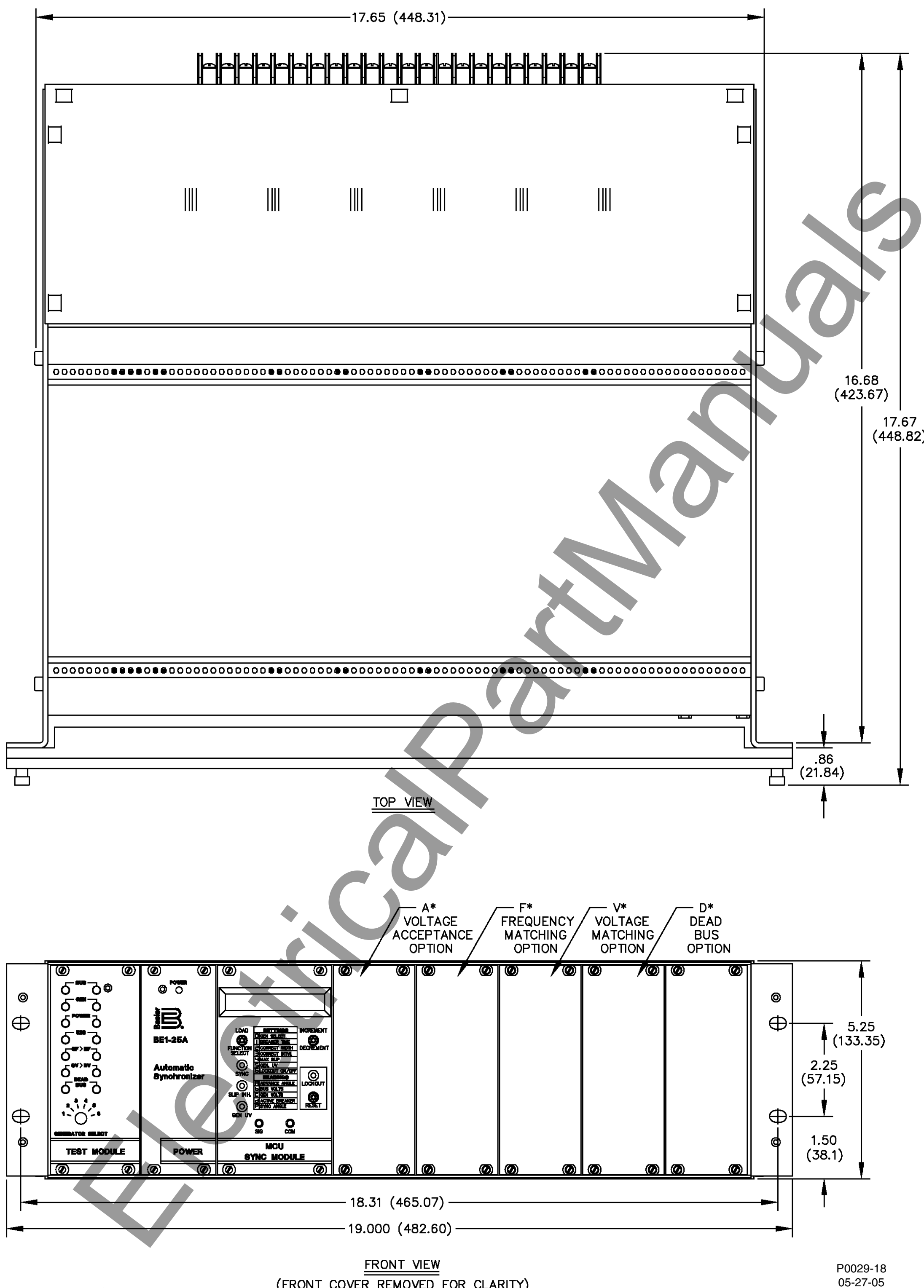


Figure 4-1. Overall Dimensions

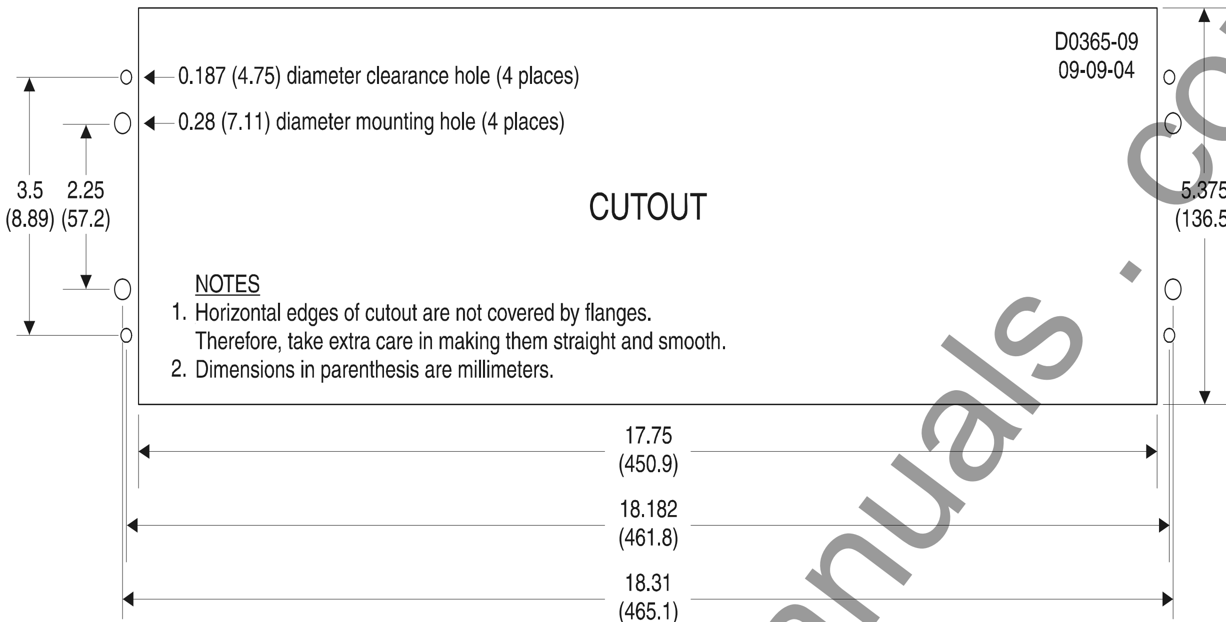


Figure 4-2. Cutout Dimensions (for Non-Rack Mounting)

CONNECTIONS

General

Incorrect wiring may result in damage to the unit. Connections for Auto-Synchronizer terminals are identified in Figure 4-3. Terminals are suitable for use with wire sizes 14 AWG or larger.

When one BE1-25A unit is used to control more than one generator, refer to *Multi-Generator Operation* in this section for a connection diagram.

Multi-Generator Operation

BE1-25A Auto-Synchronizers can be used on multiple-generator systems by simultaneously switching all relevant inputs and outputs from one generator to the next. Figure 4-4 is an interconnect diagram for a typical multiple-generator system controlled by one BE1-25A. This includes the generator sensing voltage, the breaker 52b and closing coil circuits, and any leads associated with options (such as the frequency and voltage matching lines to regulator or governor). Note that the closing time of each generator breaker is entered into the memory of the BE1-25A, and is recalled by positioning the SYNCHRONIZING SELECT SWITCH accordingly.

> **NOTE**
> Be sure the relay is hard-wired to earth ground with no smaller than 12 AWG copper wire attached to the ground terminal on the rear of the relay case. When the relay is configured in a system with other protective devices, it is recommended to use a separate lead to the ground bus from each relay.

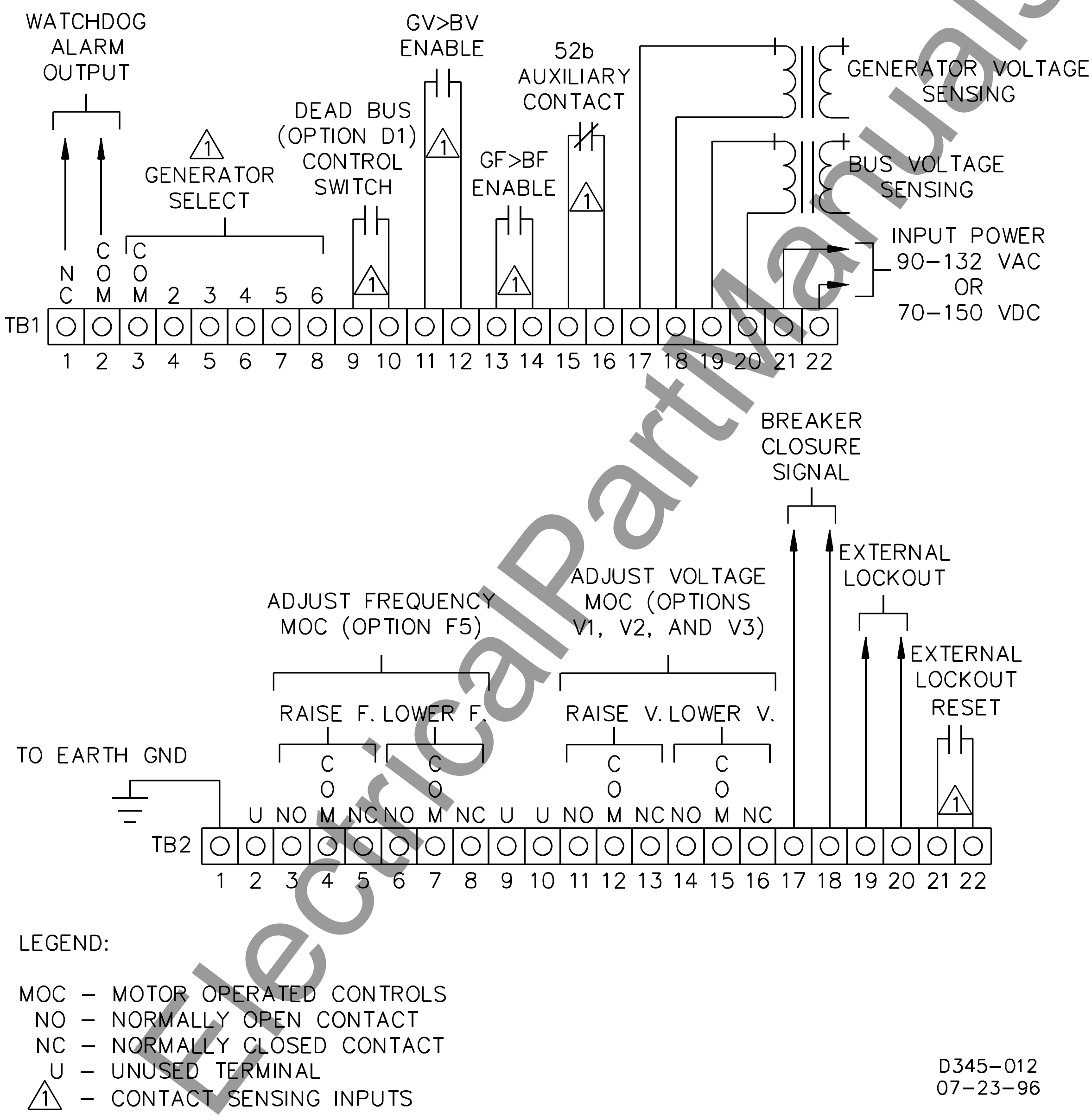


Figure 4-3. Connection Diagram (Units Serial Number 546 And Higher)

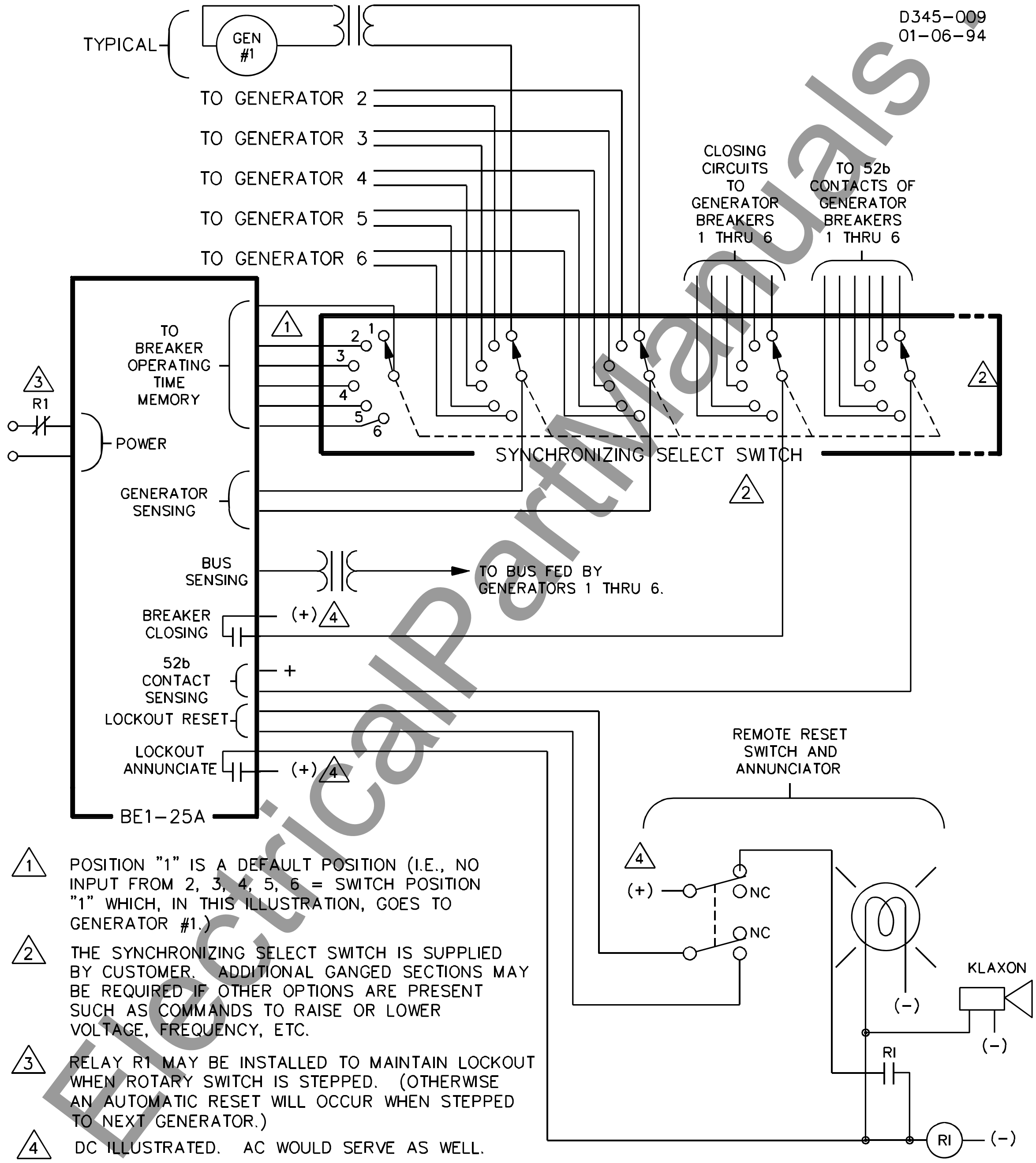


Figure 4-4. Controlling 6 Breakers With One BE1-25A

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SECTION 5 • TESTING

GENERAL

BE1-25A Auto-Synchronizers are calibrated and tested for correct operation at the factory and all calibration pots are sealed. Immediately upon receipt of the relay, or after extended service, it is recommended that the *VERIFICATION TESTS* in this section be performed. These comprehensive tests verify all operating parameters.

OPERATING PRECAUTIONS

Before operation, note the following precautions.

- Always be sure that external operating (monitored) conditions are stable before removing a BE1-25A unit from service.
- The BE1-25A is a solid-state device and has been type tested in accordance with the requirements defined below under Dielectric Test. If a wiring insulation test is required on the switchgear or panel assembly of which this unit is a part, see *Dielectric Test* below.
- Be sure that the BE1-25A case is hard wired to earth ground using the ground terminal (A1) on the rear of the unit.
- When the unit is in service, the controls should be protected by the plastic cover supplied. This limits access to the control settings.

DIELECTRIC TEST

In accordance with IEC 255-5 and ANSI/IEEE C37.90-1978, one-minute dielectric (high potential) tests up to 1500 Vac (45-65 hertz) may be performed. Note that:

- Decoupling capacitors are employed from all terminals to ground. Accordingly, a leakage current of approximately 20 milliamperes is to be expected when high potting at 1500 Vac, 60 hertz.
- Varistors are connected across all terminal-pairs of terminal strip TB1, and across terminals 21/22 of TB2. Do NOT high pot from terminal to terminal across these varistors. Normal high pot procedures (high potting from terminal to frame) are not affected by these varistors.
- A one megohm resistor is used in the contact sensing input circuit between the minus supply and the chassis. High potential testing on these contact sensing inputs (TB1, terminals 3, 4, 5, 6, 9, 10, 11, 12, 13, 14, 15, and 16), (TB2, terminals 21 and 22) may damage the internal resistor. Use a high resistance tester (megger) or alternate means to test these contacts.

APPLICATION

General Information

Although operation of BE1-25A Auto-Synchronizers is straightforward, the following suggestions are offered.

- When using the LOAD switch, there is a built-in delay before the display responds to the command. This delay is for the purpose of security — so that a deliberate action is required to effect a change, not an accidental bump. (If the switch is released before display acknowledgment, the original setting is retained.)
- Dashes in the display indicate an open input or out-of-range condition.
- When power is first applied to the unit, the display defaults to Function P, at which position the display functions as a digital synchroscope. This default also occurs whenever the unit is RESET.
- In an ideal system, a smoother closing results when the generator speed and voltage are exactly in synchronism with the system. Depending on the system, this usually is not possible. Closing from the high side with GF > BF usually results in less stress on system components. Contact sensing inputs can be set so that the synchronizer only allows closing when GF > BF and/or GV > BV.
- Setting MAX SLIP too low can result in excessive hunting by the governor. A low inertia system driven by an internal combustion prime mover is especially prone to this, since the power strokes can (prior to breaker closure) modulate the fundamental frequency of the generator output. If the resulting

sidebands (or jitter) exceed the MAX SLIP frequency, overshoot and prolonged delay in reclosing will likely occur.
- Because installations may have different characteristics, there is no standard value for the generator speed correction pulse width and interval settings. Refer to the following paragraph *Maximizing Auto-Synchronizer Performance* for a recommended procedure to achieve values for the generator speed correction pulse width and interval settings.
- Whenever the LOAD switch is raised, the BE1-25A becomes inactive (non-functional) for 1.0 second.

Maximizing Auto-Synchronizer Performance

Disconnect the breaker from the Auto-Synchronizer output. Select a pulse width and interval setting based on governor sensitivity. Record the synchronizing time (that time from when the Auto-Synchronizer initiates correction pulses to when the Auto-Synchronizer issues the breaker close signal).

If excessive overshooting occurs, reduce the correction pulse width and increase the correction pulse interval. If the generator speed increases too slowly, then increase the correction pulse width and reduce the correction pulse interval.

Maximum performance is achieved if synchronization occurs within one to two minutes providing that the Auto-Synchronizer takes control of the generator within a two hertz slip frequency window.

APPLICATION EXAMPLE

Example Parameters

- A generator breaker whose characteristic closing time is 385 milliseconds.
- A maximum allowable slip rate of 0.1 hertz. (This slip rate suggests that our hypothetical generator is of greater than average size.)
- A generator undervoltage of 65 Vac. (I.e., at this voltage or below, no effort shall be made by the Auto-Synchronizer to control the generator voltage.)
- For this example, the generator is designated West. This generator breaker closing time is to be stored as generator breaker 2 in the Auto-Synchronizer memory.

Recommended Procedure

Step 1. Bring the memory register for the test generator into view by depressing the FUNCTION switch once (MCU display should show 0 in the left-most digit and—in the right-most digit), and then depress the increment switch twice to select generator breaker 2 (MCU display shows 2 in the right-most digit).

Step 2. Depress the FUNCTION switch once and observe that the display left-most digit shows 1. Change the display to read 1.385, the .385 represents the new breaker-closing time in seconds. This is done by holding and/or stepping the INCREMENT/DECREMENT switch until the desired number is displayed. (Note the two-speed response as the switch is held depressed. This feature greatly speeds up the selection process.) Raise the LOAD switch, and hold it raised for at least two seconds. The display will blank out and then, after about one second, will read 1.385. This is to acknowledge that the characteristic closing time for the breaker that controls the West generator has been recorded.

Step 3. Depress the FUNCTION switch once and observe that the display left-most digit shows 2. Use the INCREMENT/DECREMENT switch to select a value/setting for the correction pulse width. Raise the LOAD switch, and hold it raised for about two seconds. The display will blank out and then return, indicating that the new correction pulse width has been stored in MCU memory.

Step 4. Depress the FUNCTION switch once and observe that the display left-most digit shows 3. Use the INCREMENT/DECREMENT switch to select a value/setting for the correction pulse interval. Raise the LOAD switch, and hold it raised for about two seconds. The display will blank out and then return, indicating that the new correction pulse interval has been stored in MCU memory.

Step 5. Depress the FUNCTION SELECT switch twice to cause the figure 4 to appear as the left-most digit of the display. As indicated on the front panel chart, this is the register that stores the maximum slip rate. Using the INCREMENT/DECREMENT switch, adjust the display digits to read .100, then raise the LOAD switch and hold it raised for about two seconds until the display goes from blank to 4 .100. The maximum slip rate is now loaded.

Step 6. Step the display to the next register which is 5 (GENerator UnderVoltage). Enter and load 65, using the previous procedures.

CAUTION

Before placing the Auto-Synchronizer into service, be sure that the LOCKOUT ON/OFF register (6) is set to system requirements. When OFF, the Auto-Synchronizer is free to repeatedly close the breaker into a fault.

Step 7. To change the LOCKOUT condition (i.e., from ON to OFF to ON, etc.): Select function 6 and raise the LOAD switch for approximately two seconds. The display will toggle to the opposite condition that it held. (Lon stands for lockout ON, Lof for lockout OFF.)

The setup procedure is complete. If you wish to place the relay into service, you can park the display at a parameter that you wish to monitor, such as ADVANCE ANGLE or BUS VOLTS.

VERIFICATION AND CALIBRATION

General

This paragraph is an introduction to the specific verification and calibration procedures given later in this section.

Equipment Required

- Two dynamic frequency sources calibrated to 1.0% accuracy
- One scope
- One digital voltmeter
- One counter
- One stopwatch
- One phase angle meter

Preliminary Instructions

The various verification tests may be done independently. However, certain assumptions and blanket instructions apply as given in the steps that follow.

CAUTION

To test the BE1-25A Auto-Synchronizer requires that it be isolated from the system that it controls. For a bench-test setup that would be appropriate before installation, see Figure 5-1.

After installation, it is inconvenient to remove the many connections on the back of the unit. For this reason, special provisions for testing have been incorporated that require the following procedures of steps 1 through 5 .

Step 1. To isolate the BE1-25A unit from the electrical environment, first loosen the 4 screws of the test module. Then pull the module completely out of the case.

Step 2. Note that two sets of tracks have been provided for the test module. Carefully enter the module into the right-hand tracks (upper and lower), and gently push the module forward. (If a bind or obstruction is felt, pull the module back slightly and check that it is properly entered into the right-hand pair of tracks.) Figure 5-2 shows the module fully entered into the offset—or test mode—position.

WARNING!

Do **NOT** apply Test power to tip-plugs until the power tip-plugs are inserted into the test module POWER jacks.

Step 3. With the BE1-25A now electrically isolated, supply operating power to the unit by connecting 70-150 Vdc or 90-132 Vac (50/60 hertz) to the POWER jacks of the test module. The power supply module POWER LED should be ON to indicate that the BE1-25A unit is functioning.

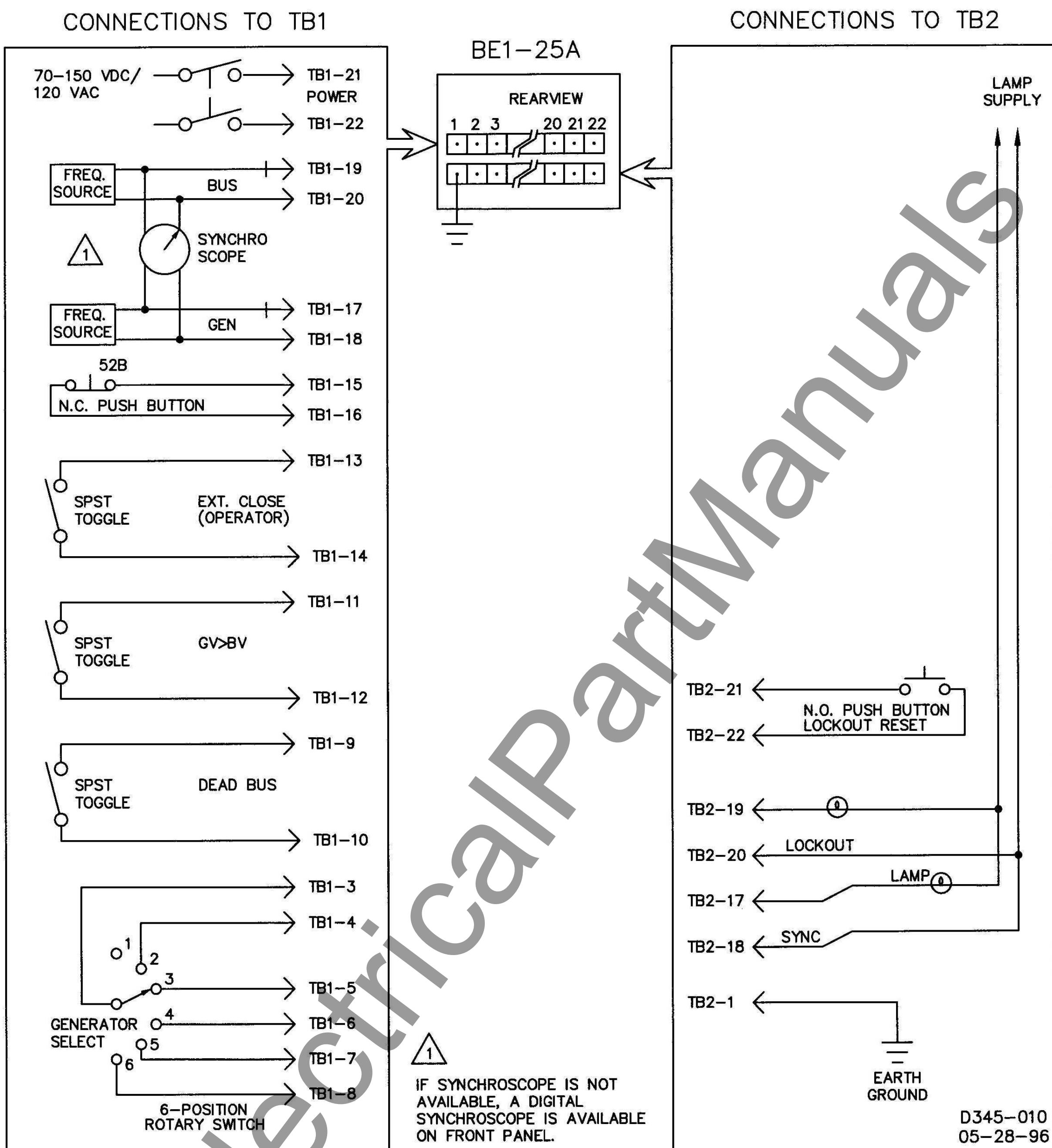

Figure 5-1. Bench Test Setup

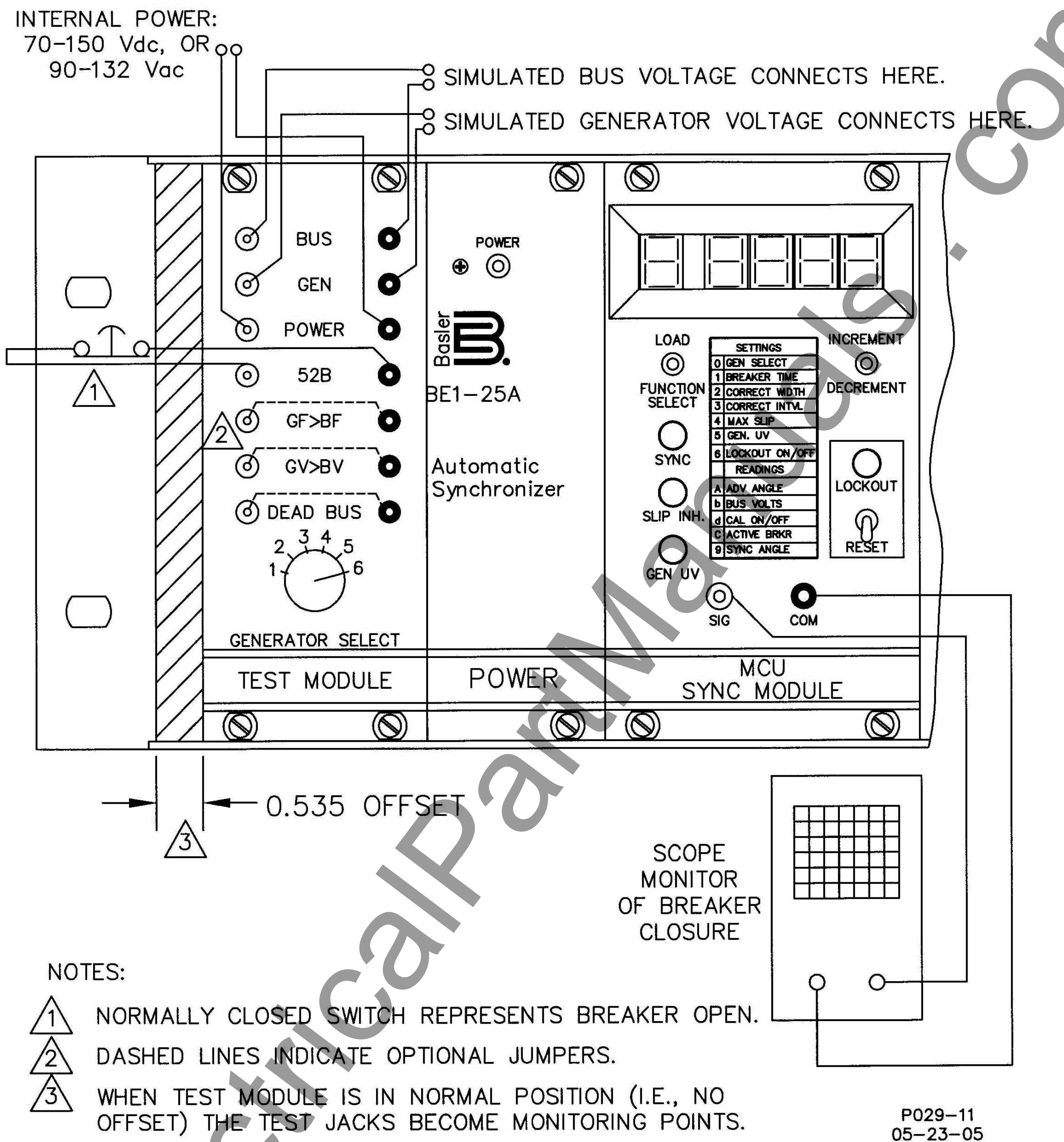

Figure 5-2. Test Setup For Installed Unit

Step 4. With the sensing connections to the BE1-25A (via the rear case terminals) now disconnected, all inputs for testing must be supplied by the jacks of the test module. At this time the jacks have the following functions (functions are illustrated in Figure 5-2).

BUS – Apply simulated bus voltage here.

GEN – Apply simulated generator voltage here.

POWER – These jacks are used to supply operating power. (Reference step 4.)

52b – Plug in a normally closed momentary pushbutton switch into these jacks to simulate a 52b signal from the auxiliary contact of the breaker.

GF>BF – Short these jacks together to simulate the closing of the GF>BF contact sensing input terminals 13 & 14 of TB1 (reference Figure 5-2). When shorted, the BE1-25A will not issue a breaker closure signal unless the generator frequency is greater than the bus frequency.

GV>BV – (Only used when an A option is installed.) Short these jacks together to simulate the closing of the GV>BV contact sensing input terminals 11 & 12 of B1 (reference Figure 5-2). When shorted, the BE1-25A will not issue a breaker closure signal unless the generator voltage is greater than the bus voltage.

DEAD BUS—(Only used when a D option is installed.) Short these jacks together to simulate the closing of the dead bus contact input terminals 9 & 10 of TB1 (reference Figure 5-2). When shorted —AND if the dead bus option is incorporated—the BE1-25A will issue a breaker-closure signal when the bus voltage drops below the set threshold that defines a dead bus.

Step 5. Monitor the outputs as follows:

With test module in the test position— Operation of the Breaker Closure (i.e., SYNC) relay may be monitored at the SIG & COM jacks of the MCU sync module, using an oscilloscope, as illustrated in Figure 5-2. Each time the SYNC LED turns ON, the SIG voltage should be the same as the COM jack voltage. At all other times there should be 12 Vdc between these jacks (with SIG +). (Note that this monitoring procedure only confirms that an operating voltage is being extended to the output relay. It does not confirm a contact closure by this relay.)

When the test module is in test position, the +12 Vdc supply is blocked from all output relays to prevent their operation.

For bench testing (with test module in normal operating position)— If any of the plug-in (option) relays are present, the pull-in of the relay armature(s) may be observed by opening the hinged door at the rear of the unit.

Sync output — For many test purposes, the most convenient monitor of the sync output is the SYNC LED. (Lit when sync relay is closed.) However, the bench test setup of Figure 5-1 has the advantage of acknowledging the passage of current through the output contacts.

VERIFICATION TESTS

General

Five test procedures cover the three basic modules (MCU sync module, test module, and power supply). Those five procedures are:

- Undervoltage (UV) Inhibit Verification Test
- Slip Frequency Verification Test
- Sync Signal Verification Test
- Lockout And Reset Verification Test
- Advance Angle Verification Test

Testing of the optional modules is covered in individual verification tests.

NOTE

Verification test procedures for Auto-Synchronizers prior to serial number 300, and for discontinued Options B3, B5, F1, F2, F3, F4, and V4, are given in Section 7.

All option modules should **NOT** be installed when performing the basic verification tests because they affect the basic unit effective parameters.

Undervoltage (UV) Inhibit Verification Test

Step 1. For a bench test, connect the unit as in Figure 5-1. Otherwise connect the unit as described previously in steps 1 through 4, and illustrated in Figure 5-1. Leave GF>BF, GV>BV, and dead bus open (i.e., OFF) at this time. Set the simulated bus and generator voltages at 120 Vac, 60 hertz.

Step 2. Set the GEN UV register to 40 Vac. Reduce the simulated generator voltage until the GEN UV LED turns ON. This should occur as the simulated generator voltage goes below 40 ±1.5 Vac. (Beginning here, the word simulated shall be understood without repeating it.)

Step 3. Return the GEN UV register to 110 Vac: the GEN UV LED should remain ON. Increase the generator input voltage until the GEN UV LED turns OFF. This should occur as the input voltage rises above 110 ±1.5 Vac.

> **NOTE**
>
> If there is a slip rate, the SYNC LED will begin flashing (instead of extinguishing) as synchronization is detected.

Slip Frequency Verification Test

Step 4. Set the GEN UV register to 40 Vac. Set the MAX SLIP register for 0.500 hertz.

Step 5. Adjust the bus input and the generator input to 120 Vac at 60.00 hertz.

Step 6. Slowly adjust the generator input frequency lower. At 59.49 ±0.01 hertz, the SLIP HIGH LED should turn ON. Slowly move the generator frequency above and below the threshold and observe that the LED acknowledges the slip frequency status within the stated tolerance.

Sync Signal Verification Test

Step 7. With the bus input at 120 Vac, 60.00 hertz, adjust the generator input to 120 Vac at 59.90 hertz. Set MAX SLIP (the #4 register) for 0.250 hertz. Rotate the GENERATOR SELECT control knob to the generator position of choice. Set the register of the active breaker to 0.40 seconds.

> **NOTE**
>
> Always load in all new breaker timer settings, and always verify the active breaker by momentarily selecting item d from the MCU readings menu. (Breaker settings, unlike other settings, must be loaded before they can take effect.)

Step 8. Using an external synchroscope, check that the SYNC LED turns ON at 14 ±3°, and OFF at 0°. The breaker closure output (as monitored by a lamp (Figure 5-1), or an by oscilloscope (Figure 5-1)) should follow the SYNC LED.

Step 9. Install a jumper at the GF>BF jacks of the test module. The SYNC LED should immediately stop flashing. Remove jumper to bring back the flashing SYNC LED. (The flashing is caused by the slip rate. Note that (with this jumper applied) the generator frequency must be greater than that of the bus for a sync output to be initiated.)

Step 10. Return the display to MAX SLIP (the #4 setting). Use the DECREMENT switch to reduce the setting from the initial (0.250) value to 0.090. Use the LOAD switch to save the new MAX SLIP setting into memory. Raise the LOCKOUT RESET switch: the SYNC LED should cease flashing and the SLIP HIGH LED should turn ON.

Step 11. Return the MAX SLIP setting to 0.250 and use the LOAD switch to save the new MAX SLIP setting into memory. The SYNC LED should resume flashing and the SLIP HIGH LED should turn OFF.

Step 12. Vary the bus and generator inputs over the range of 70-150 Vac. Vary the power supply over the range of 90-132 Vac. Neither operation should affect the flashing rate of the LED.

Step 13. Set the GENerator UnderVoltage setting (5) to 80 Vac. Reduce the generator output to 70 Vac, then raise it until the UV LED just turns OFF. This should occur at 80 ±1.5 Vac.

Step 14. Raise the generator voltage to 120 Vac, then reduce it to the value where the GEN UV LED just turns ON. At this point, the generator input voltage should be 79 ±1.5 Vac.

Lockout and Reset Verification Test

Step 15. Set the bus input to 120 Vac at 60.00 hertz; the generator input to 120 Vac at 60.04 hertz; the MAX SLIP setting to 0.250 hertz; the generator 2 breaker time to 0.40 seconds; the GENERATOR SELECT control to 2; and LOCKOUT ON/OFF (setting 6) to ON.

NOTE
A stopwatch is recommended for the following steps.

Step 16. Simulate a breaker trip using a normally-closed pushbutton switch in series with the 52b test jacks. After the SYNC LED turns ON, depress the 52b pushbutton switch and release the switch within 15 seconds. The LOCKOUT LED should turn ON, and the SYNC LED should quit flashing.

Step 17. Pressing the front panel LOCKOUT RESET pushbutton switch should clear the lockout and enable the sync output.

Step 18. Repeat step 16, but depress the switch for a minimum of 17 seconds. No lockout should occur.

Step 19. Set the LOCKOUT (enable) setting to OFF, then repeat step 16. This time the LOCKOUT LED should not turn ON. Return the LOCKOUT setting to ON.

Advance Angle Verification Test

Step 20. Set the bus input to 120 Vac at 60.0 hertz; set the generator input to 120 Vac at 60.1 hertz.

NOTE
Always load in all new breaker timer settings, and always verify the active breaker by momentarily selecting item d from the MCU readings menu. (Breaker settings, unlike other settings, must be loaded before they can take effect.)

Step 21. Connect a counter or an oscilloscope to the front panel SIG/COM jacks. Adjust the counter or scope to measure negative pulse width. Set generator 3 breaker time for a characteristic closing time of 0.800 seconds. Turn the GENERATOR SELECT knob to 3.

Step 22. Short out the 52b jacks to induce a closure cycle. At closure (or sync), the length of the negative 12 V pulse at the SIG/COM jacks should be 800 ±5.0 ms.

Step 23. Repeat step 22 except, while the SIG/COM pulse is still negative, open and immediately close the 52b jacks. This should terminate the sync pulse. Lockout will occur if automatic lockout (setting 6) is enabled. The lockout can be canceled by raising the RESET switch.

Step 24. Set the generator 4 breaker time to 0.020 seconds. Turn the GENERATOR SELECT knob to 4. Repeat step 22. The SIG/COM pulse width should be 250 ±2 ms (minimum pulse duration).

Step 25. A 40°-inhibit feature prevents a closure output for any advance angle intern-ally calculated to be greater than 40°. Arrange a test for this as follows. (a) Increase the generator input to 60.2 hertz. (b) Set generator 5 breaker time to the maximum value — 0.800 seconds. (c) Turn the GENERATOR SELECT knob to 5. (d) Set the display to read setting A (ADV ANGLE).

Step 26. Short the 52b jacks to simulate breaker open. There should be no illumination of the SYNC LED, and the ADV ANGLE setting should display dashes to indicate that the required advance angle is beyond range.

Step 27. While monitoring the phase difference between generator and bus with a phase angle meter, set generator 5 breaker time 0.500. Set the display to read ADVance ANGLE and wait 15 seconds. The SYNC LED should pulse ON/OFF, and the ADVance ANGLE setting should read 36 ±3° at sync.

Step 28. To check that the advance angle is within specified accuracy, use the set up parameters given in Table 5-1. When running the tests, the phase angle meter should provide the indicated readings within ±3°. Note that no Breaker Closure output will occur when the parameters are such that the advance angle is beyond 40°.

Table 5-1. Advance Angle Test Parameters
(Maximum slip rate must be set at 0.500 hertz.)

Sensed Generator Frequency (With Bus at 60.00 hertz.)		**Advanced Angle (±3°) for Indicated Breaker Closing Times**		
Gen. Under	**Gen. Over**	**100 ms**	**400 ms**	**700 ms**
59.6	60.4	14.4	No Sync	No Sync
59.8	60.2	7.2°	28.8°	No Sync
59.98	60.02	0.72°	2.88°	5.04°
59.995	60.005	0.18°	0.72°	1.26°

VERIFICATION TESTING OPTIONS

General

Before performing any of the following procedures for the first time, be sure to review the paragraphs entitled *VERIFICATION AND CALIBRATION, General*. There you will find preliminary instructions that are common to virtually all test and calibration procedures. Also, you will find many terms defined, a list of recommended equipment, and two basic setup diagrams. Test procedures for discontinued options B3, B5, F1, F2, F3, F4, and V4 are provided in Section 7.

Voltage Acceptance Module A1 Verification Test

The VOLTAGE DIFFERENCE control is calibrated in terms of percentage, using the bus voltage as a reference. The following definitions apply.

$\Delta\Delta V = |V_{BUS} - V_{GENERATOR}|$

$\Delta V_{\%}$ = the setting of the VOLTAGE DIFFERENCE control
$= 100|V_{BUS} - V_{GENERATOR}|/V_{BUS}$

Step 1. Perform the test setup illustrated in Figure 5-1, and move the test module into the offset (i.e., test) position.

Step 2. Set the simulated bus voltage and the simulated generator voltage (at the voltage sensing inputs) to 120 V, 60 hertz. Rotate the VOLTAGE DIFFERENCE control of the A1 module to the minimum setting (0.5%).

Step 3. Slowly adjust the generator voltage to 0.6 ±0.3 V above, and then to 0.6 ±0.3 V below the initial 120 Vac setting. The ΔV HIGH LED should turn ON whenever above or below this range.

Step 4. Repeat steps 2 and 3 with the VOLTAGE DIFFERENCE control at maximum (5%). The ΔV HIGH LED should turn ON whenever the generator voltage swings 6 V (±1%) above or below the initial 120 Vac position.

Step 5. Test the GV>BV function by setting the generator voltage to a value 2.0% lower than that of the bus. Set the VOLTAGE DIFFERENCE control to 5%. Shorting the GV>BV jacks on the test module should inhibit SYNC LED operation. Removing the short should restore the output.

Voltage Acceptance Module A2 Verification Test

Step 1. Provide the test setup illustrated in Figure 5-1, and move the test module into the offset (i.e., test) position.

Step 2. Set the bus voltage to 120 Vac at 60.0 hertz, and the generator voltage to 120 Vac at 60.10 hertz. Set the UPPER LIMIT control to 150, and the LOWER LIMIT control to 80. Set the VOLTAGE DIFFERENCE control to 10.

Step 3. Increase the generator voltage until the HIGH LED turns ON (approximately 130 Vac).

Step 4. Decrease the generator voltage towards 120 Vac and observe that the HIGH LED turns OFF.

Step 5. Set the bus voltage to 120 Vac at 60.0 hertz, and the generator voltage to 120 Vac at 60.10 hertz. Set the VOLTAGE DIFFERENCE control to 1.

Step 6. Increase the generator voltage until the HIGH LED turns ON (approximately 121 Vac).

Step 7. Decrease the generator voltage towards 120 Vac and observe that the HIGH LED turns OFF.

Step 8. Set the simulated bus voltage to the desired upper limit. Adjust the UPPER LIMIT control until the HIGH LED just turns OFF. The high limit is now set.

Step 9. Set the simulated bus voltage to the desired lower limit. Adjust the LOWER LIMIT control until the LOW LED just turns OFF. The low limit is now set.

Step 10. Verify that the SYNC LED will not operate whenever the bus voltage is above or below the UPPER LIMIT or LOWER LIMIT settings. A LIMIT HIGH LED or a LIMIT LOW LED will confirm that the bus voltage is out of range.

Frequency Matching Module F5 Verification Test

Step 1. Provide the test setup illustrated in Figure 5-2, and move the test module into the offset (i.e., test) position.

Step 2. Establish a slip rate of 1 hertz using the following parameters for generator 1.

On MCU display, set the following parameters and load them into MCU memory.

- Generator select (register 0) = 1.
- Breaker time (register 1) = 0.200 second.
- Correction pulse width (register 2) = 5.0 seconds.
- Correction pulse interval (register 3) = 5.0 seconds.
- Maximum slip (register 4) = 0.250 hertz.
- Generator undervoltage (register 5) = 90 volts.
- Lockout ON/OFF (register 6) = Lon.

On the test setup, set the following parameters.

- Generator voltage = 120 Vac at 59 hertz.
- Bus voltage = 120 Vac at 60 hertz.
- GF > BF switch to OPEN.
- 52b contacts CLOSED.
- Activate RESET switch.

Step 3. Measure the correction pulse width by timing the ON time of the F5 module RAISE LED (time should be approximately 5.0 seconds). Measure the correction pulse interval by timing the OFF time of the F5 module RAISE LED (time should be approximately 5.0 seconds). Total time for ON and OFF is approximately 10.0 seconds. Observe that the SLIP INH LED is ON.

Step 4. Set the generator voltage = 120 Vac at 59.5 hertz.

Step 5. Measure the correction pulse width by timing the ON time of the F5 module RAISE LED (time should be approximately 2.5 seconds). Measure the correction pulse interval by timing the OFF time of the F5 module RAISE LED (time should be approximately 7.5 seconds). Total time for ON and OFF is approximately 10.0 seconds. Observe that the SLIP INH LED is ON.

Step 6. Increase the generator frequency until the SLIP INH LED goes OUT (should be approximately 59.75 hertz). This should be the point at which synchronization is enabled.

Step 7. Continue to increase the generator frequency until the SYNC LED flashes. Observe that the generator frequency is greater than 59.75 hertz.

Step 8. Increase the generator frequency to 60 hertz. Observe the SYNC ANGLE (register P) on the MCU display. If the display indicates a negative angle, then raise pulses are issued. If the display indicates a positive angle, then lower pulses are issued. The pulse period (total time for ON and OFF) should be approximately 10.0 seconds.

Voltage Matching Module V1 Verification Test

An A1 or A2 module must be installed to perform this test.

Step 1. Provide the test setup illustrated in Figure 5-1, and move the test module into the offset (i.e., test) position.

Step 2. Set the simulated generator voltage to a value that is higher than the bus by an amount that exceeds the option A VOLTAGE DIFFERENCE control setting. The LOWER LED should be ON.

Step 3. Set the simulated generator voltage to a value that is lower than the bus by an amount that exceeds the Option A VOLTAGE DIFFERENCE control setting. The RAISE LED should be ON.

Step 4. Randomly check one or two points where the difference is less than the option A voltage difference. Neither of the LEDs should be ON.

Voltage Matching Module V2 Verification Test

An A1 or A2 module must be installed to enable this option.

Step 1. Provide the test setup illustrated in Figure 5-1, and move the test module into the offset (i.e., test) position.

Step 2. Set the simulated generator voltage to a value that is higher than the bus by an amount that exceeds the option A VOLTAGE DIFFERENCE control setting.

Step 3. Connect an oscilloscope or frequency counter to the jacks on the front panel of the V2 module. Observe the following waveform (Figure 5-3).

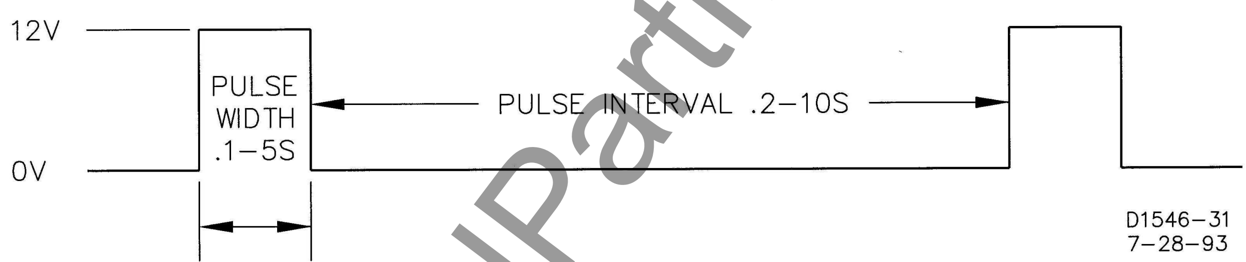

Figure 5-3. Option V2 Waveform

Step 4. Adjust the PULSE WIDTH control for the desired pulse width. The LOWER LED should be ON for the duration of the pulse width.

Step 5. Adjust the PULSE INTERVAL control for the desired interval. The LED should **NOT** be ON during the interval.

Step 6. Set the simulated generator voltage to a value that is lower than the bus by an amount that exceeds the Option A VOLTAGE DIFFERENCE control setting. The RAISE LED should be ON for the duration of the pulse width.

Voltage Matching Module V3 Verification Test

An A1 or A2 module must be installed to enable this option. Use average-reading voltmeters scaled in RMS.

Step 1. Provide the test setup illustrated in Figure 5-1, and move the test module into the offset (i.e., test) position.

Step 2. Set bus voltage to 120 Vac, and generator voltage to 130 Vac. Adjust the A1 or A2 option as follows.

Option A1:
Set VOLTAGE DIFFERENCE to minimum.

Option A2:
Set VOLTAGE DIFFERENCE to minimum, UPPER LIMIT to 135, and LOWER LIMIT to 100.

Step 3. Connect an oscilloscope or frequency counter to the front panel jacks of the V3 module. Note that the pulse width generated by this module <u>for differences of less than 20 volts</u> is determined by the following formula.

Pulse Width = ΔV(PULSE WIDTH control setting)/20

where

ΔV = the absolute voltage difference between bus and generator.

Step 4. With reference to the waveform (Figure 5-9), adjust the PULSE WIDTH control for a pulse width of two seconds. The LOWER LED will turn ON for the duration of the pulse width if the voltage difference exceeds the VOLTAGE DIFFERENCE setting on the option A module.

Step 5. Note that increasing the voltage difference between generator and bus will cause the pulse width to increase. Decreasing the voltage difference will cause the pulse width to decrease.

Step 6. Adjust the CORRECTION PULSE INTERVAL control to the desired interval. (The interval is not affected by the voltage difference.)

Step 7. Set the generator voltage lower than the bus; the RAISE LED should be ON for the duration of the pulse width if the voltage difference exceeds the VOLTAGE DIFFERENCE setting on the option A module.

Dead Bus Module D1 Verification Test

Step 1. Provide the test setup illustrated in Figure 5-1, and move the test module into the offset (i.e., test) position.

Step 2. Turn ON the dead bus option by installing a jumper across the DEAD BUS terminals on the test module.

Step 3. Complete the setup by providing the following adjustments.

- Set GENerator UnderVoltage (Setting 5) to 110 Vac;
- Set bus at 120 Vac, 60 hertz;
- Set generator at 120 Vac, 60.4 hertz;
- Set MAX SLIP to 0.2 hertz, and verify that the SLIP HIGH LED is ON.

Step 4. Reduce the bus voltage to a point below the VOLTS control setting (on the dead bus option). The SYNC LED should turn ON within 1 second after the DEAD BUS LED turns ON.

Step 5. Set the generator voltage to 100 Vac. Disable the automatic lockout feature (by setting the LOCKOUT ON/OFF setting to OFF). Actuate the LOCKOUT RESET switch. Turn OFF the bus voltage: The DEAD BUS LED should not turn ON. (Note that when a generator undervoltage condition is in force, the breaker closure output is inhibited.)

Step 6. Enable the automatic lockout feature (by setting the LOCKOUT ON/OFF setting to ON). Set the generator to 120 Vac; actuate the LOCKOUT RESET switch; and turn ON the bus voltage (120 Vac). To get sync activity, turn bus voltage OFF, and wait 1 second. Immediately after the SYNC LED turns ON, depress and immediately release the momentary pushbutton that represents a 52b input – signifying the opening of the breaker. (Reference Figures 5-2.) Verify that the LOCKOUT LED is ON. Actuate the LOCKOUT RESET switch.

Step 7. Repeat step 6, only this time wait 17 seconds after the SYNC LED turns ON before opening and closing the simulated 52b input. This time, lockout should not occur.

SECTION 6 • MAINTENANCE

GENERAL

BE1-25A Auto-Synchronizer Relays require no preventive maintenance other than a periodic operational test (refer to Section 4 for test procedures). If the relay fails to function properly, and factory repair is desired, contact the Customer Service Department of the Power Systems Group, Basler Electric, for a return authorization number prior to shipping.

IN-HOUSE REPAIR

In-house replacement of individual components may be difficult and should not be attempted unless appropriate equipment and qualified personnel are available.

> **CAUTION**
>
> Substitution of printed circuit boards or individual components does not necessarily mean the relay will operate properly. Always test the relay before placing it in operation.

When complete boards or assemblies are needed, the following information is required.

1. Relay model and style number
2. Relay serial number
3. Board or assembly
    a) Part number
    b) Serial number
    c) Revision letter
4. The name of the board or assembly.

STORAGE

This protective relay contains aluminum electrolytic capacitors which generally have a life expectancy in excess of 10 years at storage temperatures less than 40°C. Typically, the life expectancy of the capacitor is cut in half for every 10°C rise in temperature. Storage life can be extended if, at one-year intervals, power is applied to the relay for a period of thirty minutes.

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SECTION 7 • RELAY DIFFERENCES

GENERAL

This section contains information concerning previous versions of the BE1-25A Auto-Synchronizer Relays.

PRODUCT DESIGN CHANGES

Synchronizer Modules are the primary control modules of the original BE1-25A Auto-Synchronizer. However, beginning with serial number 300, a redesigned module was introduced that featured a microprocessor. The redesigned module was renamed the MCU sync module to distinguish it from the old module. It is theoretically possible to upgrade the original version of the BE1-25A by replacing the synchronizer module with an MCU sync module. However, this is definitely not recommended. When a microprocessor based synchronizer system is wanted, an entirely new unit – with improved accessibility and numerous other refinements – would be the most cost-effective choice.

Because of the greater power of the MCU sync module over the original module, it was possible to incorporate the functions of several options. Those options were the breaker time equalization options B3 and B5. In addition to these, several other former options are no longer supported in the new design. They are the F2, F4, and V4 options. The discontinued options, B3, B5, F2, F4, and V4 are not to be used when the new MCU sync module is installed.

Effective with BE1-25A relays, revision R and subsequent (April 30, 1996, serial number 9616002N and later), options F1 and F3 became obsolete. Options F0 and F5 are the only frequency matching options available. The functions of options F1 and F3 were made available as part of the F5 frequency matching option.

The software of revision U BE1-25A relays was changed to Version 5.02. These software changes improved the performance of the F1 and F3 types of frequency correction which are available as part of the F5 option.

Options that are compatible with the both the new and the old versions of the BE1-25A system, are described in the main section of the manual along with the standard modules. Those modules are the test module, the mcu sync module, and the power supply module. Discontinued options are described later in this section.

The power supply was redesigned for the new series beginning with S/N 300. Both the old and new designs of the power supply are of the switching type, and operate from the same nominal voltages. Therefore, because this manual is not involved with minute details of the internal circuitry, no special coverage of the old version is detailed here.

While the two power supply designs are theoretically interchangeable, any such substitution has not been subjected to the extensive verification testing that is necessary to ensure that the published specifications are supported. Accordingly, we strongly recommend against any reverse substitution.

CONNECTIONS

Terminals are suitable for use with wire sizes 14 AWG or larger. Incorrect wiring may result in damage to the unit. Terminal connections for Automatic Synchronizers with serial numbers 299 and lower are identified in Figure 7-1. Note that this diagram (unlike the diagram in Section 4 and Figure 7-2) does not provide a ground terminal at TB2-1. Instead, a direct ground connection may be secured by any of the rack-attachment screws. Terminal connections for Automatic Synchronizers with serial numbers 300 to 9616001N are identified in Figure 7-2.

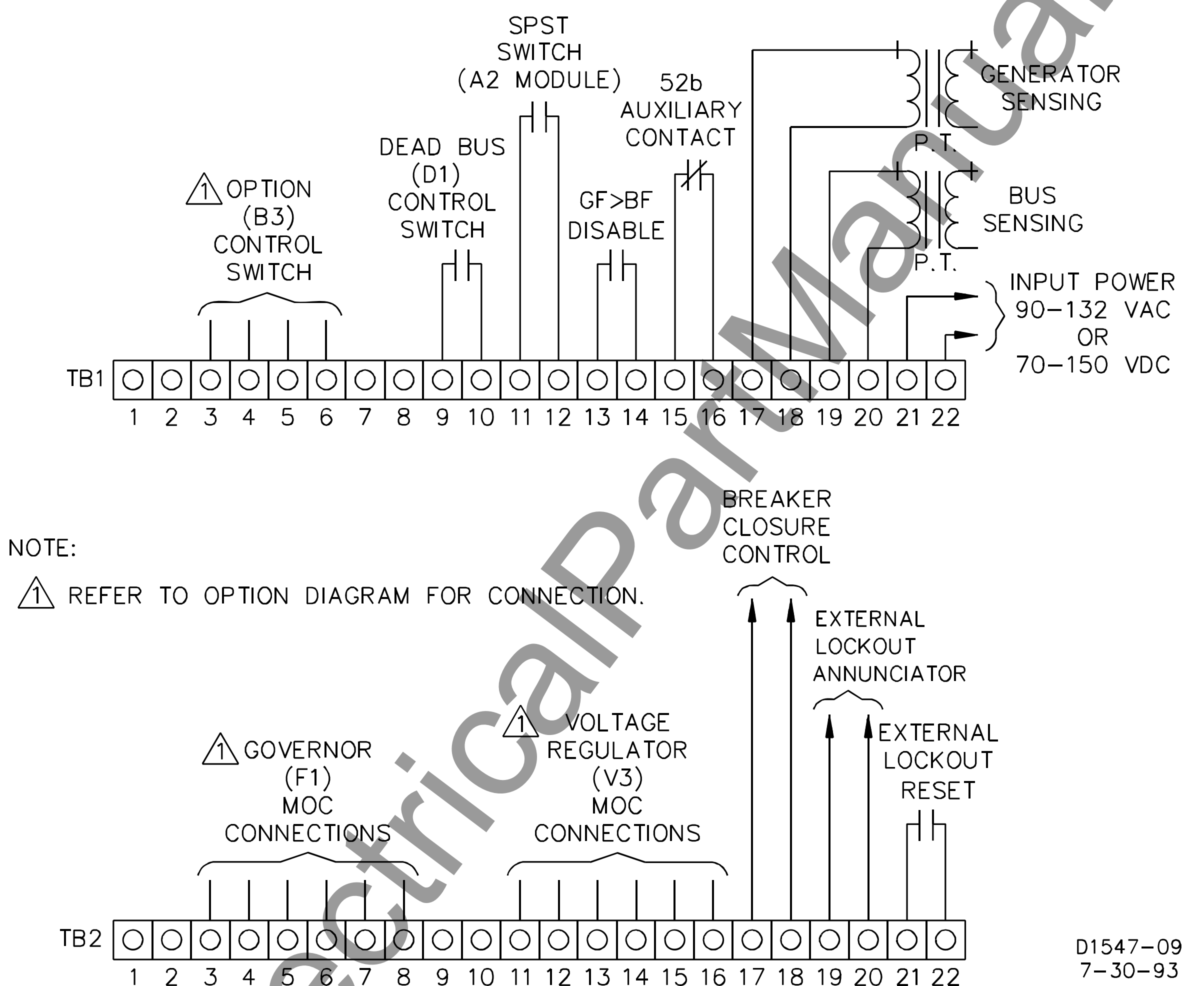

Figure 7-1. BE1-25A Connection Diagram (Serial Numbers 299 and Lower)

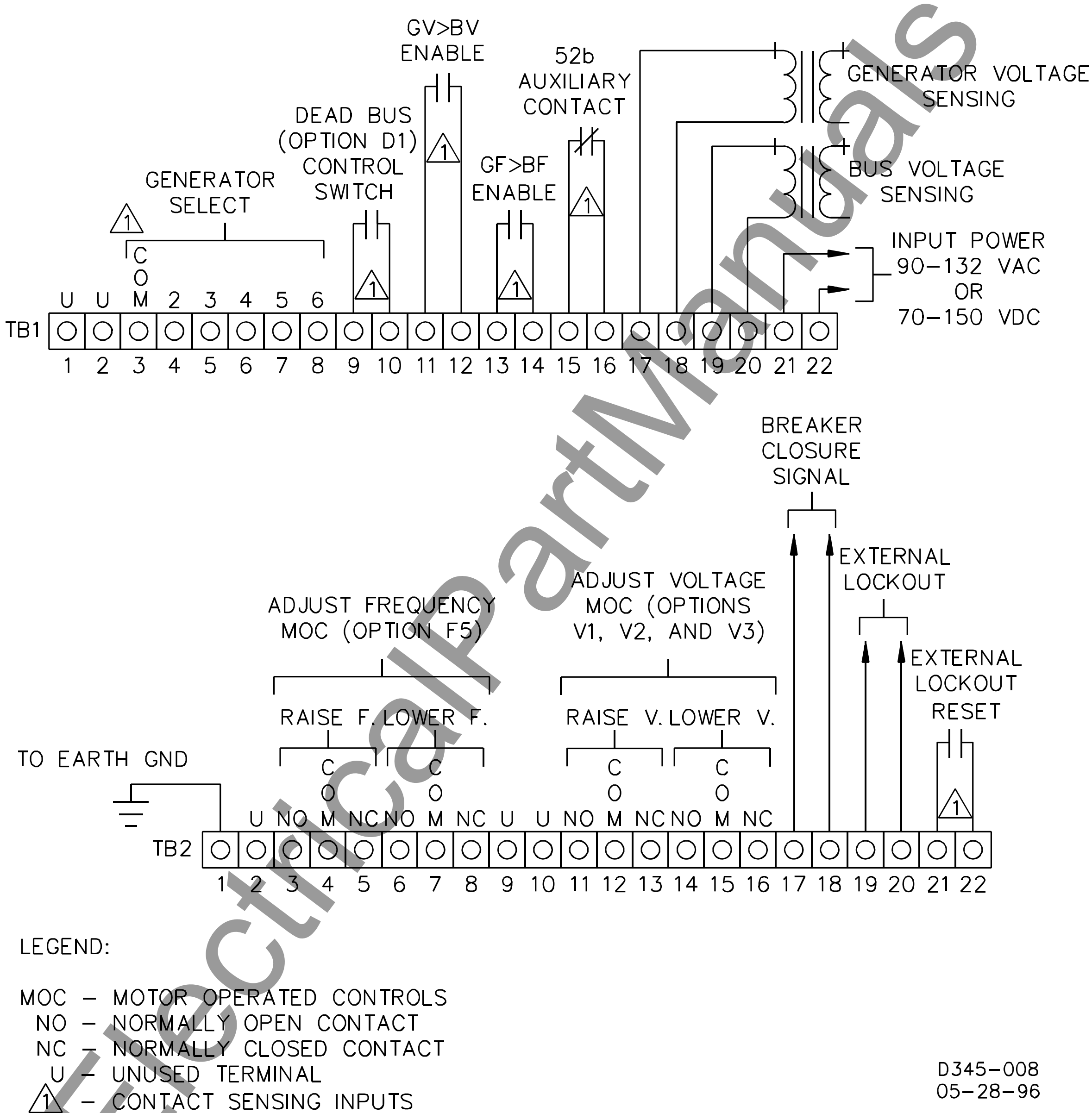

Figure 7-2. BE1-25A Connection Diagram (Serial Numbers 300 To 9616001N)

AUTOMATIC SYNCHRONIZER

BE1-25A Auto-Synchronizers, serial number 299 and previous use the synchronizer module shown in Figure 7-3. A functional description and calibration instructions are provided in the following paragraphs.

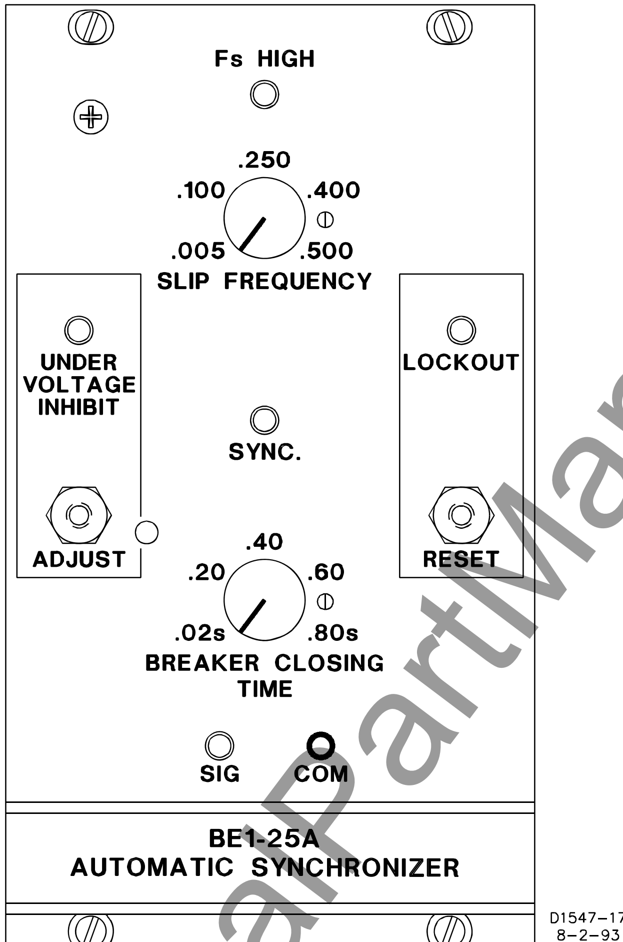

Figure 7-3. Synchronizer Module

Functional Description

See figure 7-4 to follow the functional description. The sensed bus and generator sine wave voltages are input to the separate Square Wave Generators.

The square wave generators' outputs are used by the generator frequency greater than bus frequency circuit. The generator and bus frequencies are compared and, if the external GF>BF switch is closed and the bus frequency is higher, the GF>BF signal is output to inhibit the sync circuits until the generator frequency is greater than the bus frequency. This allows the generator to pick up load more quickly.

The exclusive-or circuit outputs a pulse that has a width proportional to the phase difference. The pulse is then input to a low pass filter and converted to a triangular waveform whose instantaneous amplitude is proportional to the phase difference of the input squarewaves. The low pass filter waveform is input to the breaker time compensation circuit, the 40° inhibit sync circuit, and the differentiator.

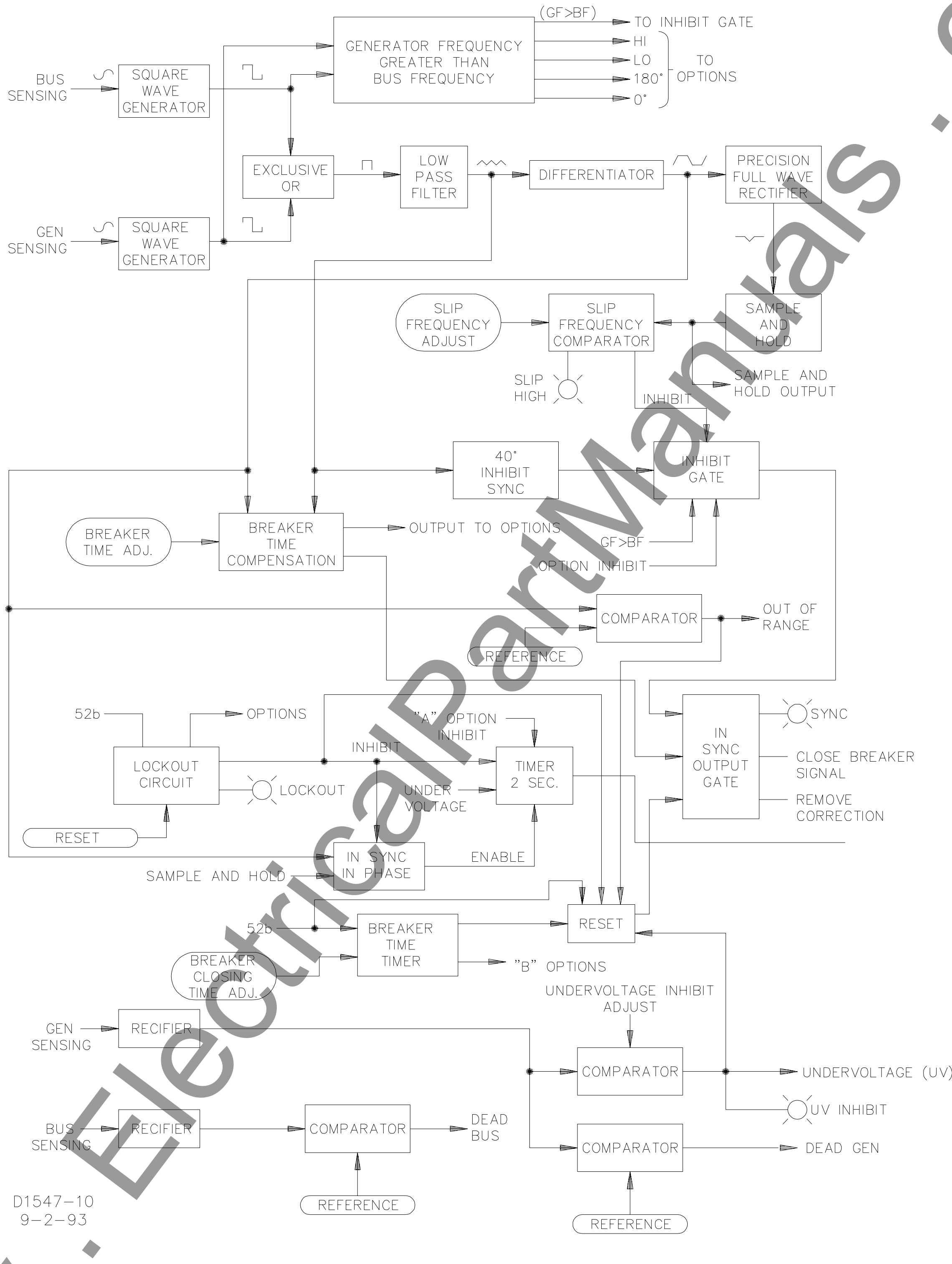

Figure 7-4. Synchronizer Module (Relays Serial Number 299 And Lower)

The differentiator produces a dc voltage proportional to the rate of change of the input triangular waveform, and outputs this voltage to the breaker time compensation circuit, the in sync/in phase circuit, the comparator and the precision full wave rectifier. The dc output of the precision full wave rectifier is further smoothed by the sample and hold circuit. The sample and hold circuit output is input to the in sync/in phase circuit and to the slip frequency comparator.

If the input signal to the slip frequency comparator exceeds the front panel SLIP FREQUENCY adjustment setting (i.e. the reference), an inhibit signal is delivered to the output gate and the front panel FS HIGH indicator illuminates. When the input slip frequency signal is less than the front panel SLIP FREQUENCY setting, an enable signal is sent by the inhibit gate to the in-sync output gate to permit breaker closure when the other conditions are met.

If the phase angle is greater than 40°, the 40° inhibit sync circuit outputs an inhibit signal to the inhibit gate.

The lockout circuit will generate an inhibit signal such that if the generator breaker opens within 15 seconds after closing, the synchronizer will not attempt to reclose the relay. The lockout circuit outputs are sent to the sync circuits, the timer, and to any options. In addition, the front panel LOCKOUT indicator will illuminate. This function may be reset by use of the LOCKOUT RESET switch, or by an external contact closure. A circuit-board-mounted switch (S2 of the circuit board) can be used to disable or enable this function.

The inhibit gate receives the generator frequency greater than bus frequency (GF>BF) signal, the differentiator output, and any option outputs. These are compared, and when the generator frequency, bus frequency, and phase angle are within limits, an enable signal is output to the in sync output gate. This is acknowledged by the illumination of the SYNC indicator.

The breaker time timer will start timing as soon as the close signal is sent to the generator breaker. The period of this timer is adjusted by the BREAKER CLOSING TIME control. When the timer times out (at 0°), a reset signal is output to the in sync output gate to remove the close breaker signal, and a remove correction signal is output to the V and F options.

When the in sync/in phase circuit inputs (from the differentiator circuit and the sample and hold circuit) indicate less than 0.008 Hz frequency difference and less than a 3° ±1° phase angle difference, the timer will time out provided there are no inhibits present. After two seconds, a 100 msec pulse is output to the relay driver to close the controlled breaker.

The sensed bus voltage is rectified and output to the comparator shown at bottom left of Figure 7-4, where it is compared to a reference level that is controlled at the front panel. If the bus is below the front panel setting, a dead bus signal is output.

Sensed generator voltage is rectified and output to two comparators shown at bottom right of Figure 7-4. One comparator compares the generator voltage to the front panel UNDERVOLTAGE INHIBIT ADJUST reference. When the generator voltage is below the reference, it produces an undervoltage signal and illuminates the UNDERVOLTAGE INHIBIT indicator. The other comparator compares the generator voltage to a fixed reference. If the generator voltage is below the fixed reference, a dead generator signal is output.

An out-of-range signal (right center of Figure 7-4) is generated if the differentiator output indicates that the bus and generator frequency difference is greater than a preset value, thereby inhibiting synchronization.

Calibration Instructions

Equipment Required

(1) Two frequency-adjustable voltage sources for the generator and bus sensing inputs. Requires a low-distortion output with a voltage range of 70-150 Vac, and a frequency that is adjustable in 0.005 Hz increments. (The use of less accurate sources will result in less accurate settings.)

(2) Input power source capable of either 90-132 Vac at 50/60 Hz, or 70-150 Vdc.

(3) Oscilloscope or counter for measuring pulse width.

(4) Ac Voltmeter.

(5) Synchroscope.

(6) Switches or jumpers for enabling the 52b, GF>BF, GV>BV, and dead bus functions.

Pre-Calibration Procedure

(1) Verify that all external interconnections are correct according to Figure 7-1 or 7-2.

(2) Verify that all modules are properly installed.

(3) Install the test module into the test position.

(4) Connect the input power source to the POWER pin jacks on the test module.

(5) Connect the bus voltage source to the BUS pin jacks on the test module.

(6) Connect the generator voltage source to the GEN pin jacks on the test module.

(7) Connect a normally closed switch to the 52b pin jacks on the test module.

(8) Connect a normally open switch to each of the following pin jacks on the test module:

(a) GF>BF
(b) GV>BV
(c) DEAD BUS

> **NOTE**
>
> Perform only those procedures that apply to your synchronizer and its installed options, and in the order the procedures are given.

Basic Synchronizer Calibration

(1) Turn on Input Power. The POWER LED (on the power supply module) should be ON.

(2) Turn the bus sensing voltage and the generator sensing voltage on.

(3) Adjust magnitude of the generator sensing voltage to the level at which synchronization should be inhibited. Adjust the UNDERVOLTAGE INHIBIT ADJUST control to the point where the front panel LED just illuminates.

(4) Set the BREAKER CLOSING TIME control to 0.02 (CCW).

(5) Adjust the bus and generator voltage source frequencies to provide the maximum desired slip frequency.

(6) Adjust the front panel SLIP FREQUENCY control so that the F_s HIGH LED just turns off.

(7) Connect the frequency counter or oscilloscope to the synchronizer module front panel pin jacks. Set the trigger to pick up negative going (+12 to O V) pulses. Set up a suitable slip frequency (with the generator and bus sensing voltages being equal), so that a sync signal is generated.

(8) Adjust the BREAKER CLOSING TIME (front panel) control for the desired closing time. Note that this does not include the pickup time of the internal relay (a nominal 15 ms).

(9) To test the lockout function: Immediately after a sync is generated, open the 52b switch (or remove the jumper). The LOCKOUT LED should illuminate. Press the RESET pushbutton to clear the lockout function. Repeat, but this time wait 15 ±1.5 seconds before opening the 52b switch. The LOCKOUT LED should not illuminate.

(10) To test the GF>BF function, close the switch (or install a jumper). Set up a suitable slip frequency with the generator frequency higher than the bus frequency. Sync signals should be generated. By setting the generator frequency lower than the bus frequency, sync signals should be inhibited.

> **NOTE**
>
> If an installation includes machines of diverse vintage or manufacture, attempts to adjust the frequency and/or voltage matching options for optimum performance of every machine may not be possible. In an installation of this type, some machines may not respond as quickly as others because the front panel settings are a compromise.

BREAKER TIME EQUALIZATION MODULES (OPTIONS B3 AND B5)

Beginning with serial number 300, options B3 and B5 were discontinued. For reference purposes, portions of an earlier edition of this manual that covered these discontinued options are reprinted in the following paragraphs.

Description and Application

Two breaker time equalization options (Figures 7-4 and 7-5) provide individually adjustable time delays that may be adjusted to match the characteristic closing times of the controlled breakers. Option B3 provides three additional time delays, while option B5 provides five additional delays (i.e., additional to the one that is present without any option).

These options are not currently offered because their function was incorporated in the MCU synchronizer module (beginning with chassis serial number 300).

Functional Description

(Refer to Figures 7-6 and 7-7.) A remote selector switch is used to select and enable the Transmission Gate to be used. All gates are inhibited except the one selected.

The signal from the Breaker Time Timer (of the Synchronizer Module) is delivered to the front panel TIME SET controls, and then to the Transmission Gates.

The Advance Angle signal (from the Breaker Time Compensation circuit of the Synchronizer Module) is delivered to the front panel TIME SET controls, and then to the Transmission Gates. The Transmission Gate output of the selected breaker is then used to determine when the Breaker Close signal is generated.

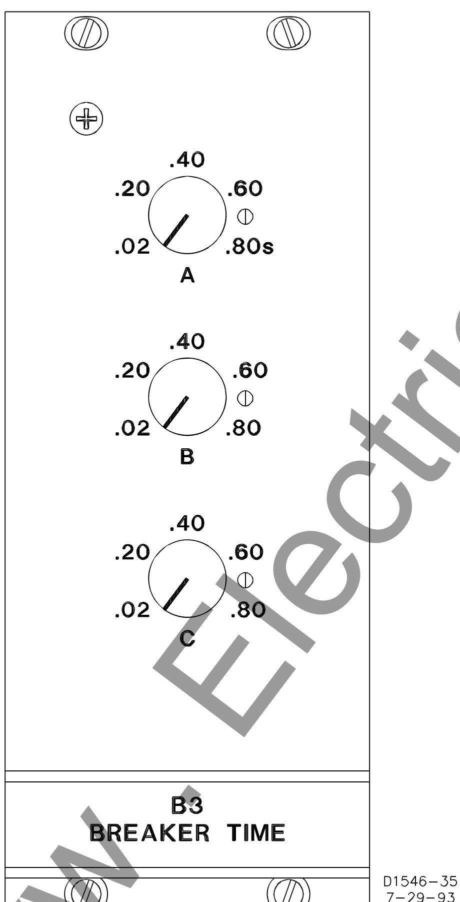

Figure 7-5. Module B3

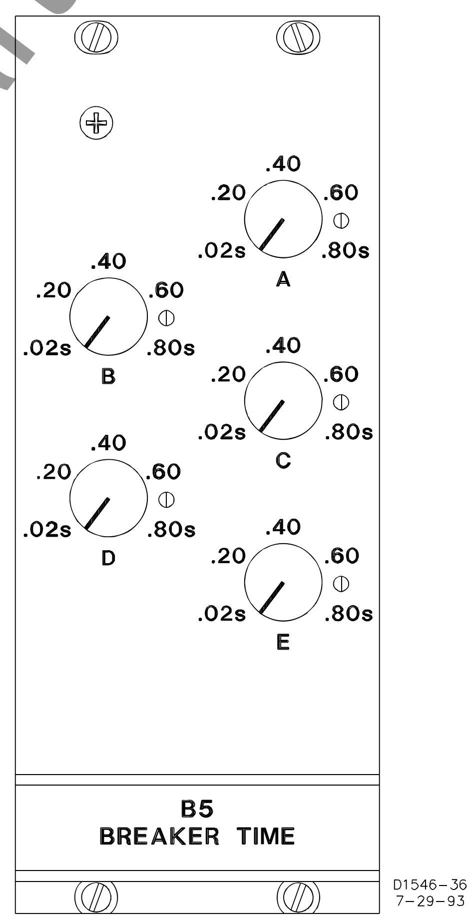

Figure 7-6. Module B5

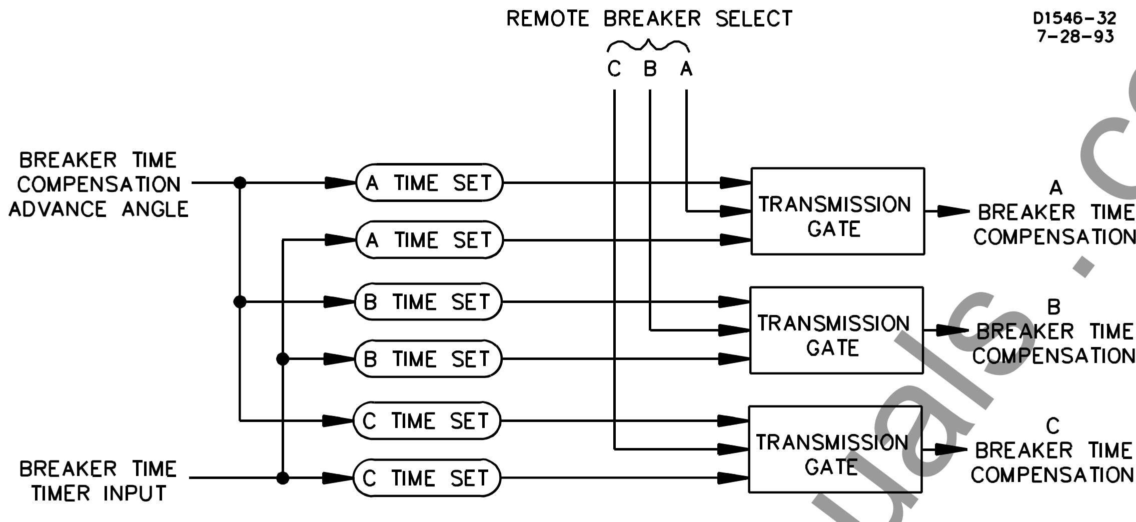

Figure 7-7. Module B3 Block Diagram

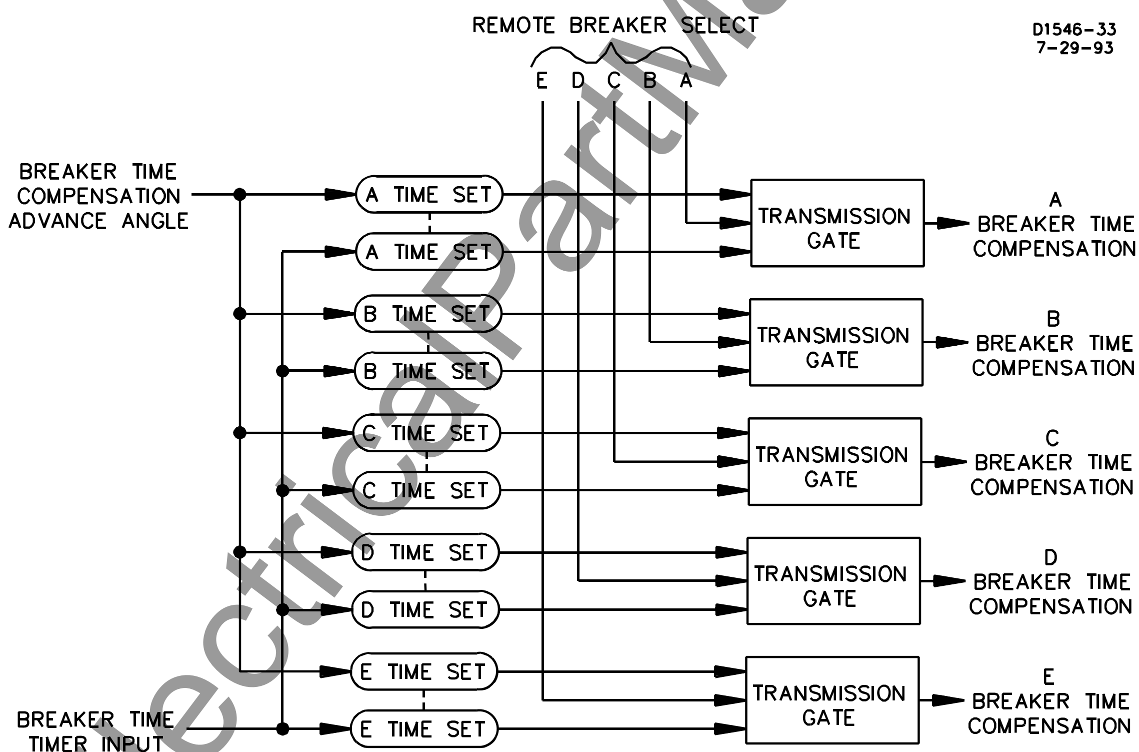

Figure 7-8. Module B5 Block Diagram

B3 and B5 Calibration

(1) Connect the oscilloscope or frequency counter to the synchronizer module front panel pin jacks. Set the trigger to detect negative going (+12 to O V) pulses.

(2) Set the front panel BREAKER SELECT switch to A.

(3) Adjust the A control on the breaker time equalization option module for the desired time. Note that the internal relay pickup time (nominal 15 ms) is not included in the above measurement.

(4) Repeat the above steps for breaker times B, C, D, and E as desired.

FREQUENCY MATCHING MODULES (OPTIONS F1, F2, F3, and F4)

Description and Application

When the oncoming generator frequency is not within the paralleling tolerance, but is within +20% or -40% of the bus frequency, one of the frequency matching options – F1, F2, F3, or F4 – can supply a correction signal to the prime mover governor to adjust the generator speed to within the required paralleling tolerance.

Frequency Matching Module F1

Option F1 (Figure 7-9) provides a speed-corrective signal that is compatible with motor-operated controls of machine speed. The signal can operate in two modes, depending upon slip rate and phasing.

Mode 1: A correction pulse train is issued when the slip frequency is greater than the allowable limit. The pulses are steered (as appropriate) to operate one of the two speed-adjust output relays. The contacts of one relay are used to signal the generator to raise speed, while the contacts of the other relay are used to signal the generator to lower its speed. The frequency of the correction pulses is identical to the slip frequency, while the width of the pulses is governed by the CORRECTION WIDTH PULSE control that has a range of 0.1 to 1.0 seconds.

Mode 2: In the event that generator and bus are frequency matched but not phase matched, bump pulses are issued to induce a slip frequency that, in turn, may be adjusted to fall within the allowable limit by means of mode-1 correction pulses. The bump pulses are matched to system requirements by the BUMP PULSE WIDTH and the BUMP PULSE INTERVAL controls (Figure 7-9). Bump pulses and control pulses share the same output relays: one for raise speed, the other for reduce speed. They also share the same indicators. As the output commands are issued, the two LED indicators, RAISE and LOWER, illuminate accordingly. The pulses issued by this option (to direct the output relays) may be monitored at the SIG and COM jacks. (+12 Vdc = relay deenergized; 0 Vdc = relay energized.)

Frequency Matching Module F3

Option F3 (Figure 7-10) is identical to Option F1, described previously, except that the F3 mode-1 correction signal is continuous rather than pulsed.

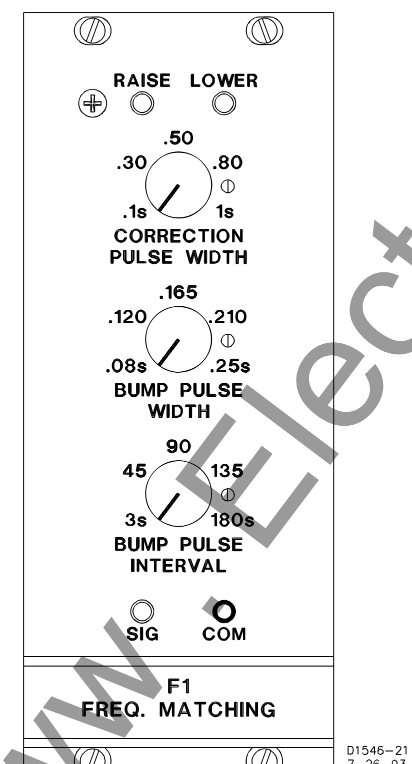

Figure 7-9. Module F1

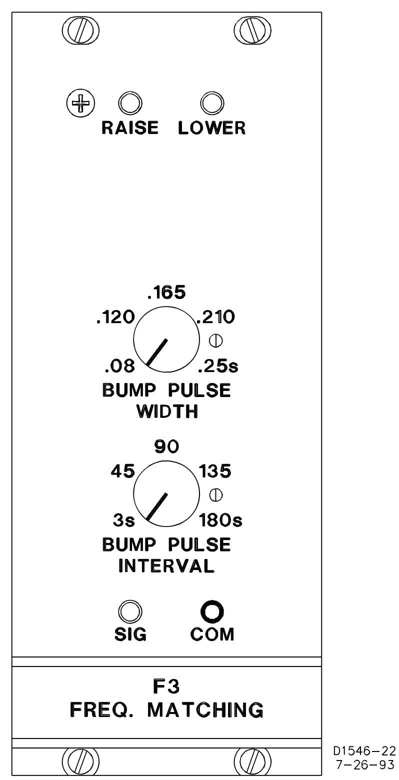

Figure 7-10. Module F3

Options F1 and F3 differ from F2 and F4 by not providing a direct signal to the summing input of the governor. Options F2 and F4 provide a bipolar dc voltage to the summing point of the prime mover governor. The magnitude of the correction signal is proportional to the slip frequency, with maximum amplitude being a nominal ±8 Vdc. The rate of change is controlled by the STABILITY control (Figures 7-10 and 7-11). The output signal is not terminated until breaker closure. To this point we have discussed features shared by all of the F options. We will now consider the differences between F2 and F4.

The F2 option (Figure 7-11), is equipped with an AMPLITUDE control that limits the output control signal to the summing point. This option is compatible with the Woodward 2301, 1712, 1724, and 2301A, as well as with the Barber Colman ILS, DYNA, and Load Commander governors.

The F4 option (Figure 7-12), instead, has an OFFSET control which is used to adjust the neutral reference of the output signal to match the neutral reference of the governor. This option is compatible with the United Technologies/American Bosch CU 673C.

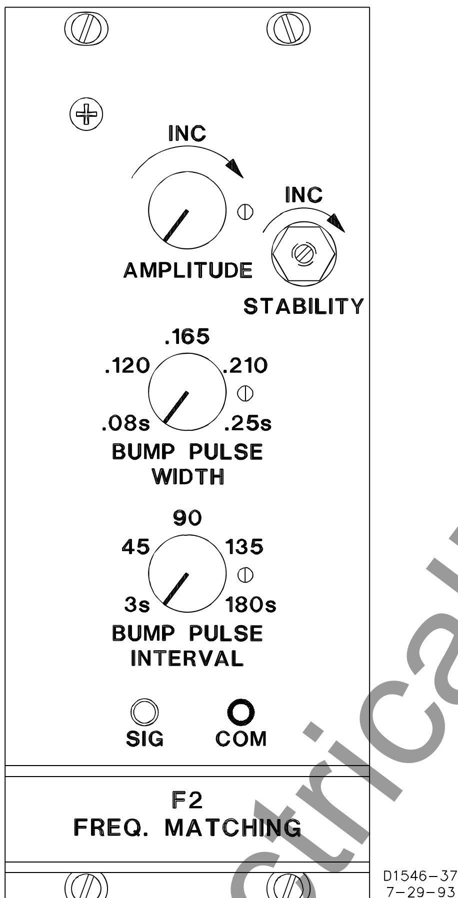

Figure 7-11. Module F2

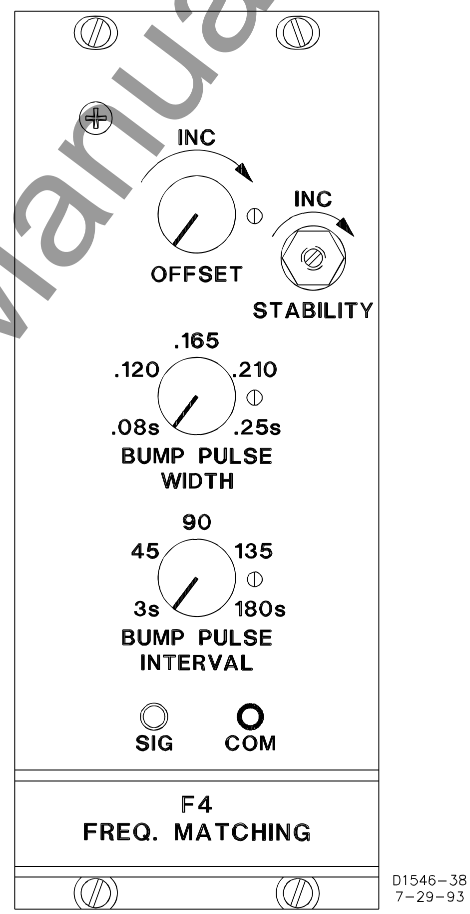

Figure 7-12. Module F4

Frequency Matching Module F2

(See Figure 7-13.) If the bump pulser circuit does not receive the 180°-out-of- phase signal before the adjustable interval has timed out, a bump pulse (whose width is determined by the front panel BUMP PULSE WIDTH control) is output to the gates to change the generator speed slightly to decrease the phase angle.

The bump pulser output, together with either the frequency low or frequency high signal, are input to the gate. Unless disabled by a slip frequency inhibit signal, the gates will then generate an output to the discriminator.

The discriminator output is modified by the stability circuit (controlled by the front panel STABILITY control) to produce the proper polarity signal for correcting the generator frequency. Unless inhibited by a dead bus or by a 52b relay contact signal input, the stability output is amplified and delivered to a summing point type governor. Note that a bump pulse is issued only when the generator is frequency matched but not phase matched.

A dead bus condition or 52b auxiliary contact closure causes the module outputs to go to zero volts.

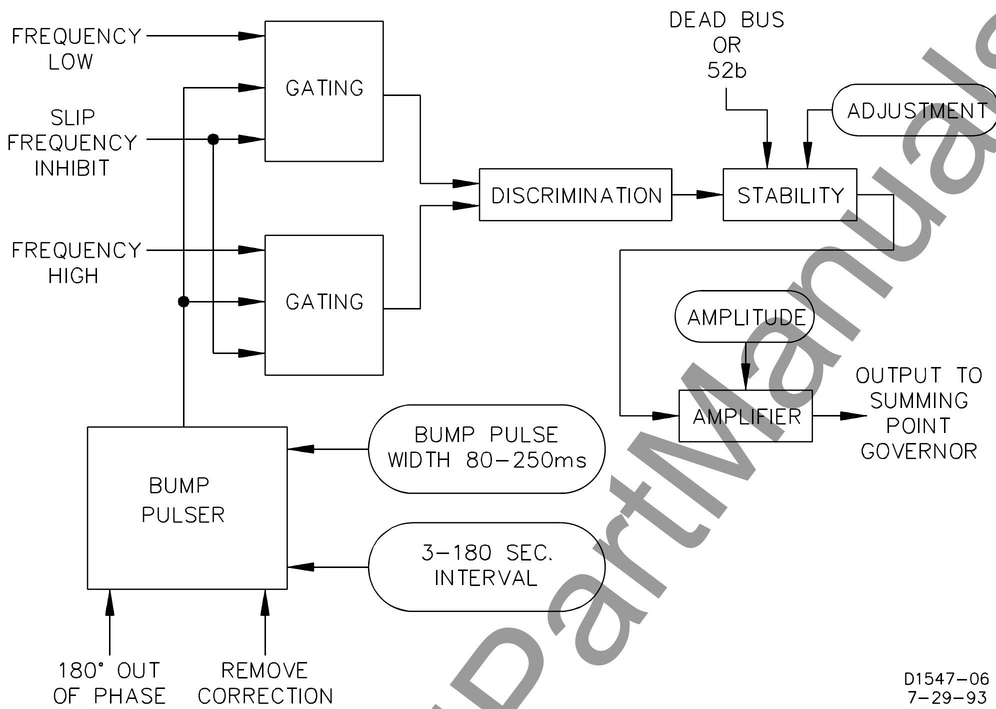

Figure 7-13. Module F2 Block Diagram

Frequency Matching Module F4

(See Figure 7-14.) If the bump pulser circuit does not receive the 180°-out-of- phase signal before the adjustable interval has timed out, a bump pulse (whose width is determined by the front panel BUMP PULSE WIDTH control) is output to the gates to change the generator speed slightly to decrease the phase angle.

The bump pulser signal, together with the frequency low or frequency high signal, are input to the gate. Unless disabled by a slip frequency inhibit signal, the gates will then generate an output to the discriminator.

The discriminator output is modified by the stability circuit (controlled by the front panel STABILITY control) to produce the proper polarity signal for correcting the generator frequency. Unless inhibited by a dead bus or by a 52b relay contact signal, the stability output is amplified and then delivered to the offset amplifier. Note that a bump pulse issued only when the generator is frequency matched but not phase matched.

The offset amplifier adds the offset (adjustable by the front panel OFFSET control) to the correction signal, and outputs the result to a summing point type governor.

A dead bus condition or 52b auxiliary contact closure causes the module outputs to go to zero volts.

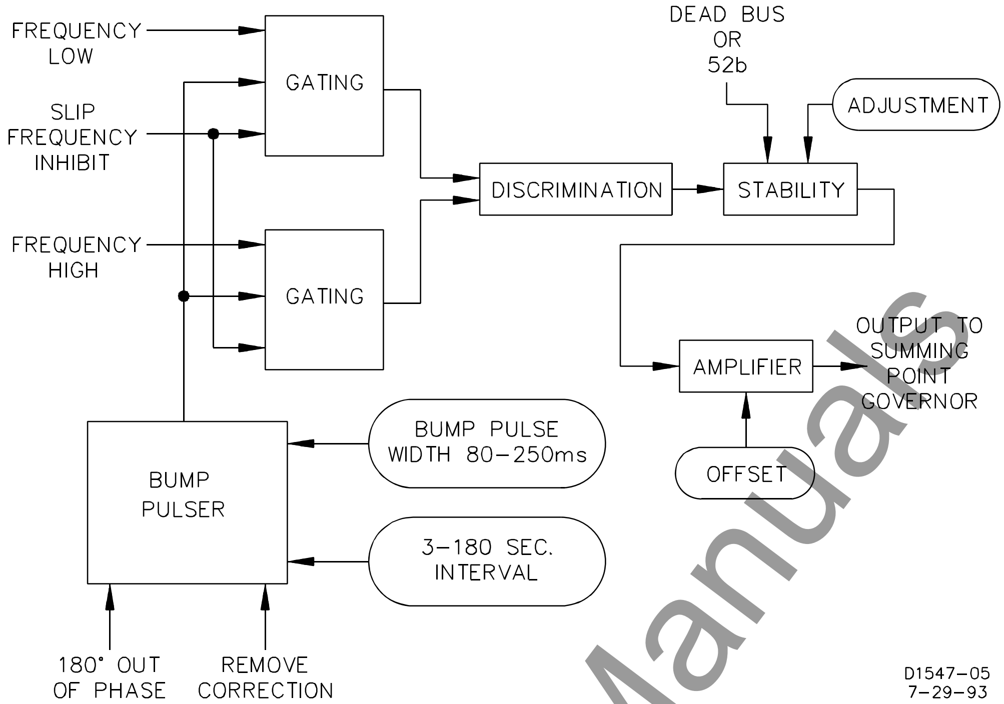

Figure 7-14. Module F4 Block Diagram

F2 and F4 Calibration

(1) Connect module F2 or F4 in accordance with Figure 7-15.

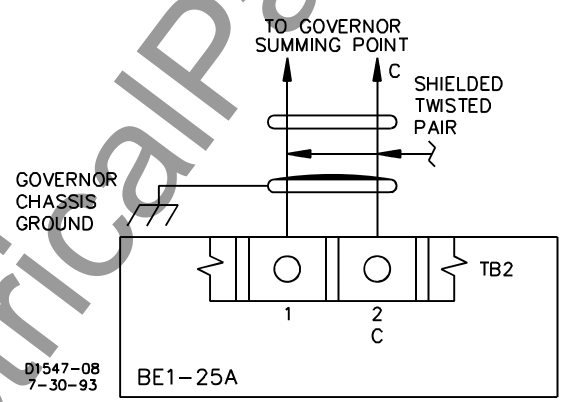

Figure 7-15. Connection Diagram For F2 and F4 Modules

WARNING
DO NOT ATTEMPT TO USE OPTIONS F2 OR F4 IN ANY CHASSIS OF SERIAL NUMBER 300 UP. ON THESE UNITS, TERMINAL 1 IS GROUND FOR THE CHASSIS.

(2) Set the bus and generator sensing voltages to equal values.

(3) Set the bus and generator sensing frequencies equal and about 90° out of phase.

(4) Connect the oscilloscope or frequency counter to the module front panel pin jacks.

(5) Confirm the following waveform (Figure 7-15).

NOTE

On the F2 and F4 modules, the waveform is not the summing point output but the input to the summing point driver.

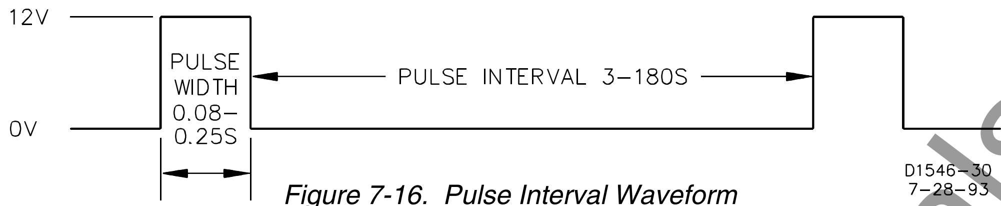

Figure 7-16. Pulse Interval Waveform

VOLTAGE MATCHING MODULE V4

Description and Application

Option V4 modules (Figure 7-17) provide an isolated, bipolar dc correction signal to a summing-input type of voltage regulator, or to generator excitation equipment. Examples of the former: Basler SSR, SR, or KR regulators. Examples of the latter: Basler SSE or SER-CB static exciter-regulators. Figure 7-18 shows the connections for V4 modules.

The STABILITY control provides a rate-of-change adjustment for the correction signal to match the correction signal to the generator regulator response.

V4 Functional Description

(See Figure 7-19.) The raise or lower voltage signal is output to the appropriate gate and, in turn, to either the positive or negative amplifier. The amplifier signal is directed first to the stability circuit (whose output is buffered by the output buffer) and then to an external summing point voltage regulator. A circuit-board-mounted switch is used to invert (if necessary) the output polarity so as to match a particular voltage regulator requirements .

A voltage inhibit signal from the A option, or a remove corrections signal from the synchronizer module will inhibit further output changes. A dead bus input or a 52b auxiliary contact closure will cause the output to go to zero volts.

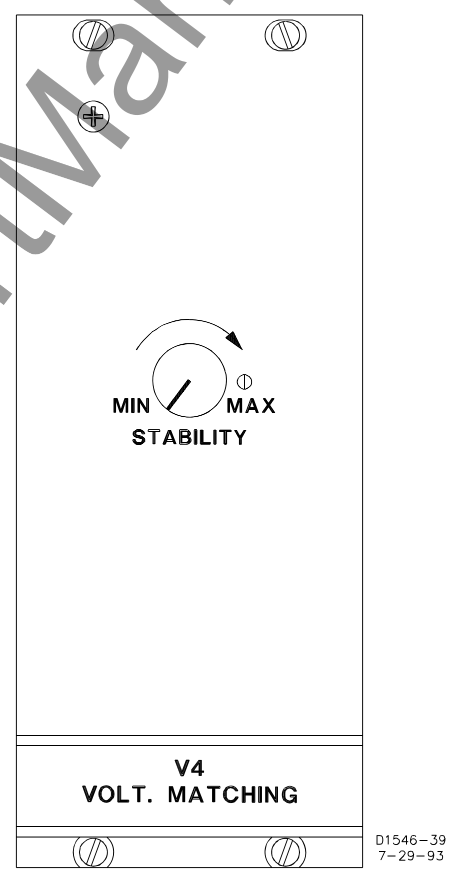

Figure 7-17. Module V4

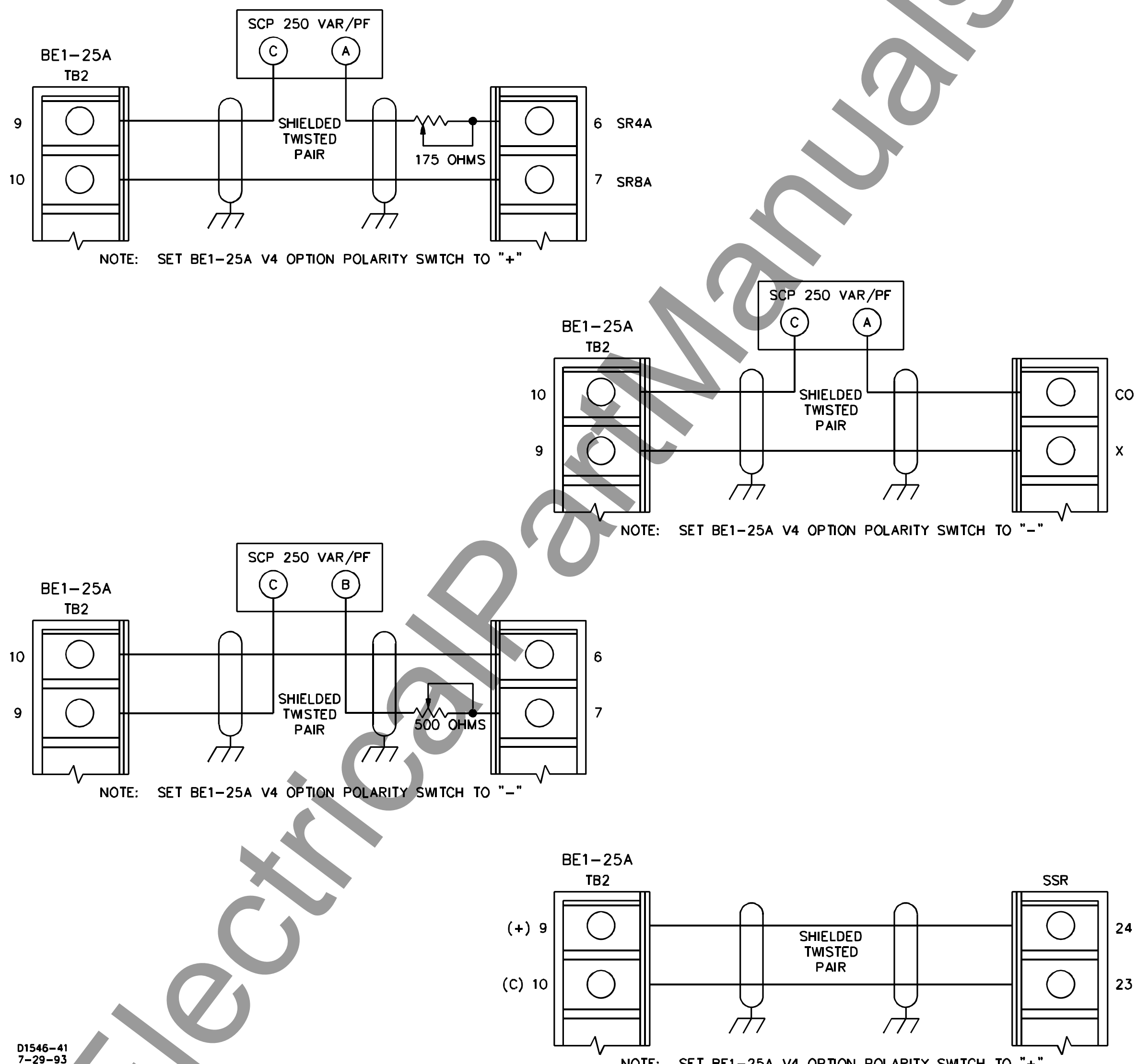

Figure 7-18. Module V4 Connection Diagram

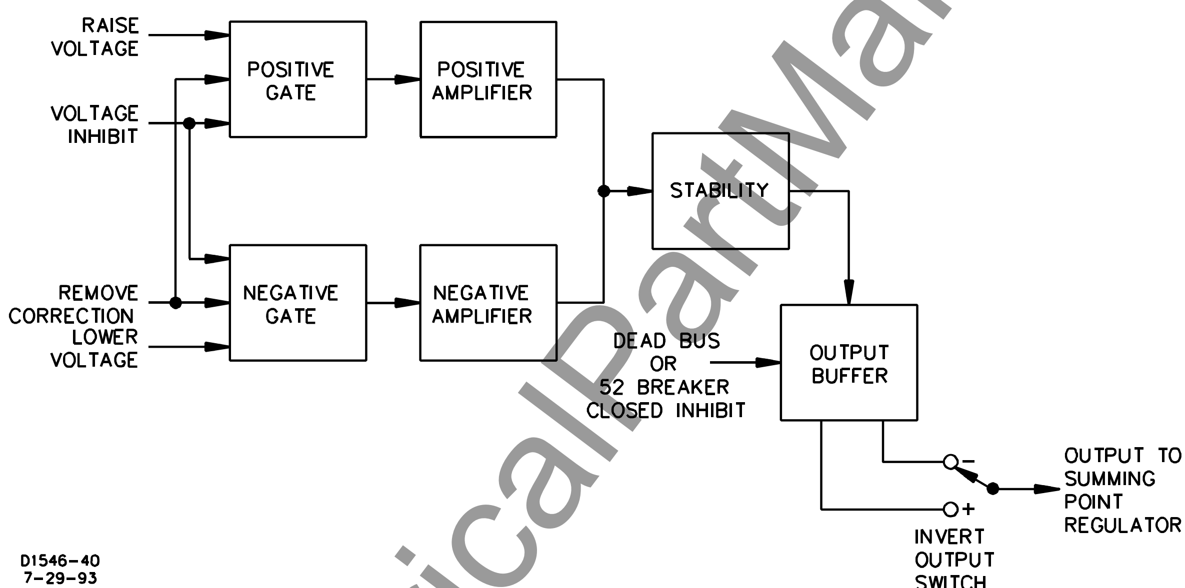

Figure 7-19. Module V4 Block Diagram

APPENDIX A • GLOSSARY

This appendix provides definitions for selected nomenclature used in this manual.

Advance Angle. The angle in degrees prior to phase coincidence that the generator voltage waveform will change relative to the bus voltage waveform during the period of time between initiation of breaker closing and the actual closing of the circuit beaker contacts. This can be expressed by the equation:

$$\Phi = 360 \times F \times T$$

Where: Φ is the advance angle in degrees
F is the slip frequency in hertz
T is the breaker closing time in seconds

Automatic Synchronizing System. A relaying scheme that uses a synchronizing relay with one or more elements that: 1) take into account the closing time of the controlled breaker to calculate when the advance angle is proper to initiate closing, 2) cause the output contacts to open when a zero phase difference between the sensed voltages occurs, and 3) monitor and control the frequency and voltage of the generator.

Bump Pulse. If the oncoming generator and the bus are frequency matched but not phase matched (and if the Auto-Synchronizer is equipped with a Frequency Matching option), these pulses (or, more precisely, contact closures) are used to alter generator speed and, in turn, to induce a slip frequency that is within the capture limits of the synchronizer.

Corrective Pulse. A contact closure initiated by the Frequency Matching Option F1 to change generator speed. A situation calls for Corrective Pulses when the slip frequency is greater than the allowable limit but within the capture range.

F_S. Slip frequency: the difference between the system frequency and the generator frequency.

GF>BF. 1 An internal signal that inhibits the breaker closure signal unless the generator frequency is greater than the bus frequency. **2** The designation of an external signal (or the terminals thereof) which causes the Auto-Synchronizer to not issue a breaker closure signal unless the generator frequency is greater than the bus frequency.

GV>BV. 1 An internal signal that inhibits the breaker closure signal unless the generator voltage is greater than the bus voltage. **2** The designation of an external signal (or the terminals thereof) which causes the Auto-Synchronizer to not issue a breaker closure signal unless the generator voltage is greater than the bus voltage.

LO, HI. Two internal signals developed by the MCU Sync module in response to the speed of an oncoming generator relative to the bus frequency. These signals are used by the various options to determine the direction of any correction or bump pulses issued by the Auto-Synchronizer.

Raise, Lower. 1 Refers to external signals delivered to the generator's control system to adjust frequency or voltage (as the case may be) in the desired direction (up or down). **2** The names of two internal signals developed by the Voltage Acceptance module to indicate to other modules the desired direction of any corrective pulses to be issued.

SYNC. An alternate name for the breaker closure signal.

ΔV. The difference voltage between the bus and the generator.

180° Out of Phase. An internal pulse that is generated when the voltage of the bus and the voltage of the generator vectorial pass each other (as components of the slip frequency). Each pulse thus generated occurs at the midpoint of the slip frequency period. These pulses are used to strobe the Correction and Bump pulses.

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