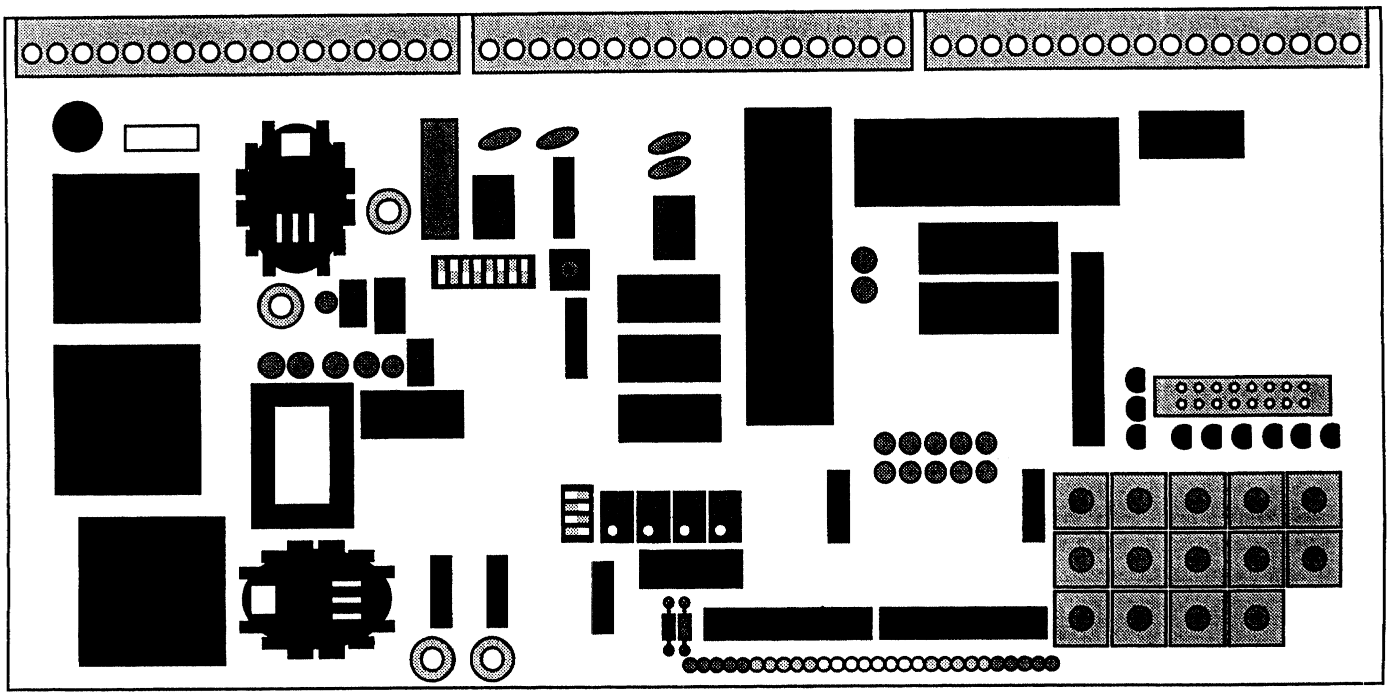
# SDC-2 Synchronizer
## Installation and Operation Manual



Version 1.4


**Drive Control Systems**
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# Proper Wiring for Industrial Controls



1. **All Control Signals must be shielded cable.** The shield must be tied at the receiving end only to earth ground or signal common. In some environments earth ground may contain excessive electrical noise. If you have noise problems using earth ground as a shield tie point, switch the shields to signal common. All connections to a controller are considered signal unless they carry AC power.

2. **Never use a shielded cable with leftover conductors.** These act as antennas. Attempting to tie them to ground or other signals just creates different antenna configurations. In many cases unshielded wire would have received less electrical noise. Always insure that a shielded cable with the correct number of conductors is pulled.

3. **All control signals must be separated from power wiring.** Power wiring includes any AC and DC voltages with a current potential of greater than 1 amp or voltage greater than 24 volts, such as 115Vac, 230Vac, 460Vac, Armatures, Fields, and Ignition wires. Do not bundle cables and power wiring within the same Panduit, Conduit, or Wire Trays.

4. **Do not run signal cables along high magnetic or electrostatic generators** such as motors, fans, contactors, ignitors, etc. Aluminum shielded cable does not stop magnetic noise, and braided cable only partially reduces magnetic noise. Neither can stop all noise or be a cure-all. Using shielded cable does not mean you can ignore proper signal routing techniques. **Do not run** feedback signal wires (Encoders, Hall-Effect Sensors, Magnetic Pickups, etc.) along a motor case or in the same conduit as power to the motor.

5. **An Earth Ground wire must be installed on microprocessor based controllers when it is specified.** Do not rely on enclosure contact with the panel for earth ground. Earth ground is often used in the noise rejection circuitry and is not just a safety factor.

6. **Contactors, solenoids,** and **relay coils** on the same AC power or in the same enclosure (panel) as the controller **must be suppressed** with resistor and capacitor filters across the coil. These filters can be made with a 1KV capacitor and a 1/4-watt resistor in a series, or they can be purchased in a package called "quencharc". Use a capacitance value of .1mf or larger and a resistance value of 500 ohms or less.

7. When power is stepped down from a higher AC voltage for the controllers, a quencharc should be placed on the secondary.

8. After the above precautions have been taken to ensure clean power and control signal lines, **do not** route these lines alongside noisy power.

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## I. GENERAL DESCRIPTION

The SDC-2 provides for synchronization of process machinery which utilizes electronic drives and motors. This synchronization can be either absolute, meaning that the angular position and shaft speed are identical, or relative, meaning that the synchronizer can act as an "electronic gear" causing the slave shaft to rotate at an angle or speed that is directly related to the angle and speed of the master shaft but not identical to the master shaft. Because the SDC-2 synchronization is rotational, angular, and linear, no drift between the drives powering the machinery can occur. The rotational error is absolute zero.

Under dynamic conditions (acceleration and deceleration) a small "twisting" action may be observed. This "twisting" action will be eliminated when the machinery is running at proper speed.

The SDC-2 operates with AC and DC drives of any horsepower and includes full reversibility (4 quadrant operation).

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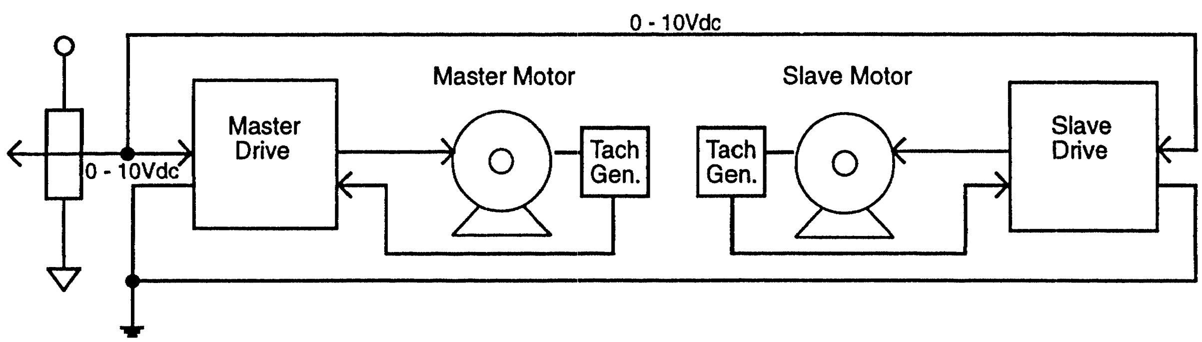
## II. BASIC TECHNOLOGY

To provide a better understanding of the function and capabilities of the SDC-2 synchronizer, this section provides an explanation of "traditional" speed synchronization followed by an explanation of synchronization as provided by the SDC-2.

The diagram below demonstrates the circuit used to achieve "traditional" analog speed synchronization:



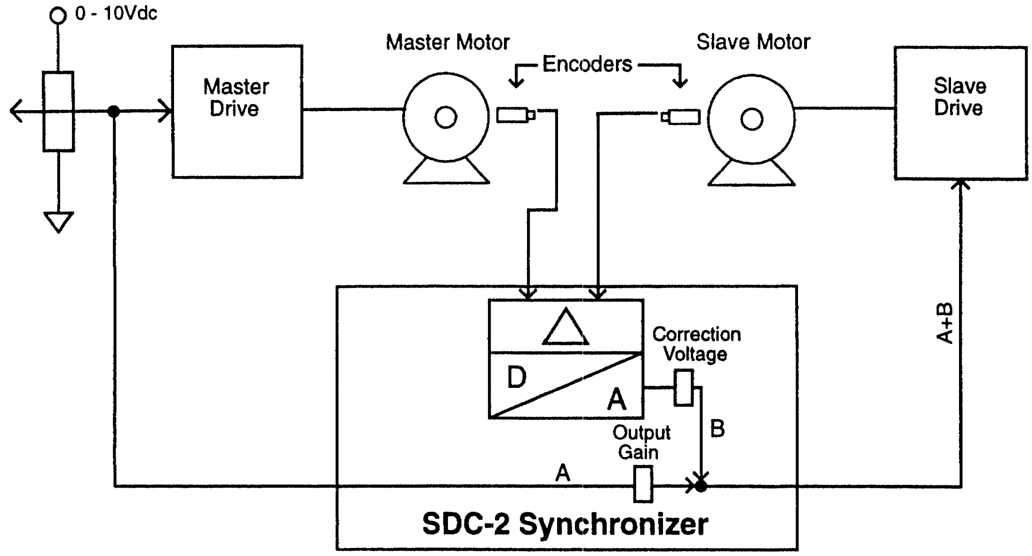

In our diagram, the Master motor speed is adjusted from 0 to maximum motor speed by the Master drive. The speed at which the master drive will run the motor is adjusted using a 0 to 10Vdc reference voltage, usually supplied by a potentiometer. Tach feedback from the motor to the drive can be utilized to achieve better dynamic response and stability.

The Slave motor speed should be synchronized with respect to the speed of the Master. This is done by supplying the Slave drive with the same reference voltage that is supplied to the Master drive. Any change in reference voltage (causing a change in motor speed) to the Master drive will simultaneously occur as a change in reference voltage to the Slave drive. The Master and Slave drives can then be matched to provide the same speed using the maximum speed trim on the drives. This means that the Master and Slave speeds will be "synchronized" over the full speed range. Using voltage dividers on the reference inputs, ratios other than 1:1 could be achieved.

However, in this example "synchronous" and "same speed" mean only that the speed difference may be kept in a range of +/- 1%.

The SDC-2 synchronizer fully compensates for the remaining error in this "analog synchronization" to achieve error and drift free absolute speed and position synchronization.

The following diagram describes the function of the SDC-2:




In this diagram, a rotary shaft encoder mounted on the Master motor shaft transmits pulses to the SDC-2 whenever the shaft is turning. Each pulse from the encoder represents a given number of degrees of rotation (i.e. one pulse from a 360 Pulse Per Revolution encoder mounted on the motor shaft represents one degree of rotation). A second rotary shaft encoder is mounted on the Slave motor shaft. The incoming pulses from both encoders are counted by a differential counter. The count difference is continuously calculated digitally. The digitally calculated number is converted to an analog correction signal. By adding the correction signal to the Slave's reference voltage, the Slave will be accelerated or decelerated so that the error is eliminated, bringing the count differential to zero. Because the conversion time from the pulse input to the analog correction output is only a matter of a few microseconds, the Slave shaft is forced to follow any motion of the Master shaft without any error.

## III. STANDARD FEATURES

**Pulse Scaling and Speed Ratios:**

The SDC-2 provides pulse scaling for each channel (Master and Slave) separately. The scaling factors, "F1" for the Master and "F2" for the Slave, are adjusted on the SDC-2 using digital numeric switches. The scaling range for each channel is 0.0001 to 9.9999 (5 decades each). This scaling factor allows the speed ratio between the Master and Slave drives to be set to a resolution of .01% per revolution. This is the "electronic gear" function.

The practical application of this scaling factor is to allow the Slave channel (F2) to compensate for plant specific conditions such as differences in numbers of pulses per revolution provided by encoders, differences in shaft sizes on synchronized machinery, or differences in gear ratios on synchronized machinery. The Master channel (F1) can then be programmed directly in the desired "engineering units" of production.

The Master channel (F1) can be used as a parameter to be adjusted by the operator during production. This Master channel (F1) is also accessible remotely, using a parallel interface, to provide remote ratio setting via external thumbwheel switches, PLC's, or computers with BCD coded parallel outputs.

**Note:** The information in the following paragraphs is depicted in the diagram labeled "SDC-2 Block Diagram."

In Section II it was shown that "analog synchronization" has to be performed. The reference voltage of the Master, or an externally generated 0 to 10Vdc signal proportional to Master speed, must be connected to terminal Z16 on the SDC-2 (+/- 0 to 10 Vdc maximum). Using a combined analog/digital multiplier circuit, this input voltage (the Master Voltage) is scaled in relation to F1. As a result, on terminal Z17 the output voltage to the Slave drive appears as: Output Voltage = Output Gain (F1 x Master Voltage). Output Gain is adjusted using the R64 potentiometer. It prescales the output (range is 0.77 to 2.13). The offset of this circuit can be adjusted using the Output Offset potentiometer.

By using the Output Voltage as the reference voltage for the Slave drive, the required analog pre-synchronization is guaranteed under all ratio conditions. On terminal Z15 the inverted (negative) value of the Output Voltage is present for Slave units with complementary reference inputs or for other control purposes. The voltage multiplier is capable of handling positive or negative input levels, so full four quadrant operation is possible.

The analog error signal is created by a digital to analog (D/A) conversion of the pulse difference from the Master and Slave encoders. The resulting Correction Voltage is found with the following formula:

Correction Voltage = Correction Gain x Count Difference

**Note:** Count Difference is incoming pulses from the Master encoder after F1 scaling minus the incoming pulses from the Slave encoder after F2 scaling (F1 x PL) - (F2 x PF). The Count Difference is referred to in "increments." One Count Difference is equal to one increment.

Correction Gain is the position of the trim potentiometer labeled R41, which can be adjusted from 1mV per increment to 100mV per increment. Full level analog output occurs when there is a difference of +/- 255 increments. However, the internal memory has a counting range of up to +/- 32000 error pulses. Any pulse difference up to this value will be trimmed back to zero by the system if the drives have been forced out of synchronization by external events. The offset of the Correction Voltage Output can be adjusted separately by the Correction Offset potentiometer (R37). The Correction Voltage Output is on terminal X3. The inverse of this output is available on terminal Z14.

All analog signals are provided with common terminals. The Analog Common terminals are X4 and Z13.

**Summing Amplifier:**

Usually, the method of synchronizing the Slave drive to the Master is to provide one unique reference voltage to the Slave drive. This Reference voltage consists of the Master Voltage and the superimposed Correction Voltage (described above). Therefore, the SDC-2 controller provides an internal summing circuit to add the Correction Voltage to the Master Voltage so that a unique Output Voltage is available to control the Slave drive on terminal Z17, or the inverted signal on Z15.

Summation of the signals is provided via resistor RX (200K) which is mounted in a plug in socket. The total Output Voltage when the 200K resistor is in socket RX is expressed by the formula:

Output Voltage = (Master Reference x F1) + Correction Voltage

i.e. the Correction Voltage signal is added to the scaled Master Reference Voltage.

In a few cases, it may be preferable to sum the Master Reference and the Correction Voltage before scaling with the F1 factor. To do this, the 200K resistor is removed from RX and plugged into the RY socket (next to the RX socket). When this is done, the total Output Voltage is expressed by the formula:

Output Voltage = (Master Reference + Correction Voltage) x F1

In some sophisticated applications it may be useful to convert the Correction Voltage to a different level or characteristic. To achieve this, the 200K resistor in the RX socket must be removed. When this is done the output on Z17 provides only the Master Reference voltage and output X3 provides only the Correction Voltage. When using this configuration, drives with two separate inputs must be used.

**Alarm Relays:**

Many industrial applications cannot - even as a temporary condition - accept a linear or angular deviation from synchronization, particularly if the deviation is caused by external events. An emergency stop is required for both drives if, for example, one drive should be clogged or overloaded for mechanical reasons.

For this reason, the SDC-2 supplies two relays to signal unacceptable synchronizing conditions. The relays are used to indicate that the phase error (count differential between encoders) has exceeded a preselected level. One relay will respond if the phase error occurs in a positive direction, the other responds when the phase error occurs in a negative direction. The amount of error needed to actuate the relays is selected using the 10 position rotary switch marked REL on the SDC-2 Location diagram. The switch positions corresponding to the phase error required to actuate the relays is as follows:

| | | | |
|---|---|---|---|
| Switch Position | 0 = 4 increments | Switch Position | 5 = 128 increments |
| | 1 = 8 increments | | 6 = 256 increments |
| | 2 = 16 increments | | 7 = 512 increments |
| | 3 = 32 increments | | 8 = 1024 increments |
| | 4 = 64 increments | | 9 = 2048 increments |

**LED Bar Graph Display:**

The LED Bar Graph Display provides a visual indication of the state of the internal pulse differential level, which means it is an indication of the Correction Voltage level. Zero error is indicated by two green LED's illuminated simultaneously in the center of the display. In all other states, only one LED is on.

When the display is moving to the right on the bar, it means that the "analog pre-synchronization" is too low and the SDC-2 is supplying a positive Correction Voltage in order to speed up the Slave drive.

When the display is moving to the left on the bar, it means that the "analog pre- synchronization" is too high and the SDC-2 is supplying a negative Correction Voltage in order to slow the Slave drive.

This right / left description is valid for positive input reference voltages only. If the input reference is a negative voltage, the situation is reversed.

Each LED signifies an error of 4 increments (pulses) between the shafts. There are 16 LED's up from zero and 16 LED's down from zero which supply a visible error range of +/- 64 increments.

**Note:** Having the LED display out of zero position never means a fault in the speed of the shafts. The indication deals only with phase displacement between the shafts, not that one shaft or the other is actually turning at a slower or faster RPM and is off by complete revolutions.

**Phase Integrator:**

As explained earlier in this manual, the SDC-2 supplies an analog correction voltage proportional to the differential of the pulse count. This means that the correction voltage is zero when there is no difference in increment count.

Under dynamic conditions the phase lock (exact angular positioning of the shafts) may be temporarily lost. Since all drives have areas where they are not linear, the normal Correction Voltage may not immediately bring the phase lock back. When this occurs, a correction must be made immediately to compensate for the phase offset and drive it back to zero. The Phase Integrator provides a "boost" to the Correction Voltage to help it compensate for the non-linearities in the drive.

The Phase Integrator adds small additional corrections until the phase difference is returned to zero. The speed at which this correction takes place is controlled by a 10 position switch, marked INT (see diagram). The correction rates and corresponding switch positions are:

| | |
|---|---|
| Switch Position | 0 = No integration, fully proportional operation |
| | 1 = 10 msec / 1 pulse |
| | 2 = 20 msec / 1 pulse |
| | 3 = 30 msec / 1 pulse |
| | 4 = 40 msec / 1 pulse |
| | 5 = 50 msec / 1 pulse |
| | 6 = 60 msec / 1 pulse |
| | 7 = 70 msec / 1 pulse |
| | 8 = 80 msec / 1 pulse |
| | 9 = 90 msec / 1 pulse |

* The integrator range is limited to +/- 128 increments and can compensate 50% of the full scale correction signal.

* The integrator can be disabled by external command. Switch terminal Y16 to common to disable. This must be done when stopped.

* Index pulse tracking is its own integration, so the normal phase integration is not applicable when index pulse tracking is used.

* If unsteady motion or oscillation occurs on the Slave when using the integrator, set the switch to a higher position (i.e. slower integration).

**External Reset and Inhibit Switch Gear:**

The Reset and Inhibit inputs must be switched to common with external, potential free, contacts to activate their function. The switches must be activated for a period no less than 50 msec. due to the internal filtering of these lines.

The Reset line resets the error memory to zero counts and the Correction Voltage to zero volts. Pulse counting is disabled for the duration of Reset.

The Inhibit line disables the pulse counting while leaving the error memory and Correction Voltage at the level attained before the Inhibit was activated.

When activating either Reset or Inhibit, the processor reads all internal and external digital switch settings (such as the ratio setting) and writes them into memory.

**Important** - Any change in the digital switch settings or of the parallel input must be followed by one of the following actions:

- Activating the Reset function
- Activating the Inhibit function
- Recycling power to the SDC-2

This feature can be an advantage when using a PLC parallel BCD port to control the F1 ratio setting of several SDC-2 systems. A common 20 line data bus from the PLC to the SDC-2 units can be utilized to send ratio settings to the synchronizers. Activating the Inhibit function on only the addressed unit will cause the F1 ratio of that unit to be changed while all others retain their previous setting.

**Remote Control of Speed Ratios (Option):**

Option FE allows the operator to adjust the ratio from a remote location. The BY 206-5 remote thumbwheel switches are required when using this option. The BY 206-5 provides a multiplexed BCD output of switch settings and opto couplers on all remote lines. Connections are provided on the "Remote Switch Connection (Option FE)" diagram.

Option PSS is a full parallel interface for remote control of the F1 factor. Option PSS can be used with either remote thumbwheel switches BY 106-5 or a BCD output from a PLC.

An unlimited number of SDC-2 units can be controlled by wiring the parallel interfaces in parallel (Bus structure). Reset or Inhibit functions can be used as a device address strobe to activate reading by a certain unit, while the others remain unaffected (see Reset and Inhibit Switch Gear above).

**Note:** Both Option FE and Option PSS perform a "Logical OR" function from internal and remote switch data. Therefore, it is necessary to set the internal F1 switches to 0.0000 when F1 is addressed remotely.

**Prescaling of the Correction Signal:**

In some applications, such as when using high resolution encoders, correcting after 1 increment is too fast for the synchronizer/drive system. The result can be oscillation on the Slave drive. In cases such as this, the Pulse Scaling Switch must be used. This switch scales both the Master and Slave pulse inputs by the selected factor, giving a lower error authority to an increment.

When using the Pulse Scaling Switch, the definition of one increment can be found by using the following formula:

$$\frac{(F1 \times PL) - (F2 \times PF)}{\text{Scaling}} = 1 \text{ Increment}$$

The scaling factors are as follows:

| Pulse Scale Setting | Scaling | Pulse Scale Setting | Scaling |
|---|---|---|---|
| 0 | 1:1 | 5 | 1:32 |
| 1 | 1:2 | 6 | 1:64 |
| 2 | 1:4 | 7 | 1:128 |
| 3 | 1:8 | 8 | 1:256 |
| 4 | 1:16 | 9 | 1:512 |

The most appropriate setting, in typical applications is 0. Other settings are used in special applications.

Use of the Pulse Scaling Switch will also effect the light bar, relays, and the advance and retard rate since it changes the "size" of an increment.

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## IV. MODES OF OPERATION

There are 3 modes available which can be selected with the Mode Selection Switch. These modes are: Normal Operation, Operation with Phase Adjustment (Advance/Retard), and Operation with Index (Reference) Pulses.

**Important:** In normal operation mode the maximum frequency input is 30kHz. In modes 1 - 9 the maximum frequency is 28kHz.

**Normal Operation (Mode Switch in Position 0):**
In this mode, all functions and features are available except "external phase adjustment (+/- trim)" and Index Pulse Tracking. Terminals Y17 and Y13 are not used in this mode.

The angular positioning of the shafts relative to one another is determined by their position on power up or by their position after the Reset Function.

**Operation with Phase Adjustment - Advance / Retard (Mode Switches 1 - 5):**
SDC-2 controllers provide the capability to properly position machines by advancing or retarding the Slave with respect to the Master.

In many industrial applications it is necessary to align the controlled shafts in a particular angular position, one shaft relative to the other, so that mechanisms fit together. One way to do this would be to position the shafts manually. The phase adjustment feature of the SDC-2 allows you to accomplish this via a contact closure input to the controller either with the shaft stopped or while running.

Two external contacts (Y17 and Y13) allow you to add "artificial pulses" to the Master count register or to the Slave count register in order to change the angular position of the Slave with regard to the Master.

Connecting terminal Y17 to Common produces an "artificial count" added to the Master count register which moves the Slave position forward with regard to the Master. Connecting terminal Y13 to Common produces an "artificial count" added to the Slave count register which results in the Slave position moving backward with regard to the Master. If both contacts are Off, the shafts will remain in whatever position they were in upon start-up or reset.

The speed at which the shift takes place can be selected through switch positions 1 - 5 on the Mode Select Switch:

| | | |
|---|---|---|
| Position | 1 = | 27 encoder pulses per second (fast) |
| | 2 = | 14 encoder pulses per second |
| | 3 = | 7 encoder pulses per second |
| | 4 = | 4 encoder pulses per second |
| | 5 = | 1 encoder pulse per second (slow) |

**Operation with Index (Reference) Pulses (Mode Switches 6 - 9):**
This mode provides automatic adjustment of the phase, or mechanical, position upon start-up. In this mode it is necessary to use encoders with an index pulse (zero pulse) output or to create reference pulses for the Master and Slave with a proximity switch, photo electric switch, etc.

This mode of operation is only possible when the number of pulses between reference (index) pulses is the same for both the Master and Slave encoders, unless the B12 option is specified. See Appendix A for B12 option information.

The Master reference pulse is wired to terminal Y17. The Slave reference pulse is wired to terminal Y13. The position of the Mode Selection switch determines the number of reference pulses needed to have absolute phase matching (which means that the reference pulses are occurring in the proper position).

| | | |
|---|---|---|
| Position | 6 = | phase control after 1 reference pulse |
| | 7 = | phase control after 3 reference pulses |
| | 8 = | phase control after 10 reference pulses |
| | 9 = | phase control after 30 reference pulses |

The optimum switch setting depends on the motor speeds and the dynamic response of the Slave. Position 6 would result in immediate phase calibration upon start-up, however, at a speed of 3000 RPM this setting would not be appropriate. In position 6 at 3000 RPM, there would be 50 index pulses per second. This means that 20 msec. after the first analog command the next attempt would be made to get the motors into phase which is much too fast for the drive to respond. Consequently, unstable conditions could result.

In practical tests, the following settings have been proven to produce optimum results:

| | | |
|---|---|---|
| Position | 6 : | up to 400 RPM |
| | 7 : | up to 1200 RPM |
| | 8 : | up to 4000 RPM |
| | 9 : | over 4000 RPM |

In index mode, the phase integrator is automatically switched off and the INT switch provides a special function. The INT switch is used to control how hard the error correction signal will react to an out of phase condition and how much phase error tolerance is allowed. The chart below shows the switch position and the corresponding amount of error correction signal that will be used to correct and the error tolerance window.

| **INT Position** | **Correction** | **Window** |
|---|---|---|
| 0 | 100% | +/- 0 Pulses |
| 1 | 50% | +/- 2 Pulses |
| 2 | 25% | +/- 4 Pulses |
| 3 | 12.5% | +/- 8 Pulses |
| 4 | 6.25% | +/- 16 Pulses |
| 5 | 3.125% | +/- 32 Pulses |
| 6 | 1.5625% | +/- 64 Pulses |
| 7 | 0.7812% | +/- 128 Pulses |
| 8 | 0.3906% | +/- 256 Pulses |
| 9 | 0.1953% | +/- 512 Pulses |

In position 0, the response to a phase error will be a 100% error output for each detected phase error. No tolerance is left for any small phase error.

In position 1, the phase error will be eliminated in steps of 50% and a window of 1 pulse will be allowed where no phase error correction will take place. It has been found that this position is optimum for most applications.

**Factor F2 - Pulses Between Indexes:** Operating in the reference pulse mode requires that the number of encoder pulses between reference pulses be set into the internal "F2" switches. Example: if encoders with 360 PPR and index (reference) pulse outputs were used, the number 00360 would be dialed into the "F2" switches.

**Factor F1 - Phase Offset:** In some applications a certain phase offset between the reference pulses may be required. The offset occurs as a specific number of encoder pulses between index pulses. The pulse offset is programmed directly into the F1 switch set on the front panel, or it can be programmed remotely. Example: If 600 pulse per revolution encoders with an index (reference) pulse are used, an F1 setting of 00150 would result in a 90 degree phase shift.

**Note:** When operating in the reference pulse mode, perform the set-up procedure in Mode 0 and then switch to the reference pulse mode (switch positions 6 through 9).

## V. CHOICE OF ENCODERS AND INVERTERS OR DRIVES

Attention to these points can be essential for proper and trouble free operation of the SDC-2 and the complete system.

**Encoders:**

- For systems requiring angular synchronization, the Master and Slave encoders must be quadrature (A and B channels, 90 degree phase shift).
- For speed synchronization only, single channel encoders may be used. If single channel encoders are used, the drives must be immediately disabled after stopping to avoid erroneous motion of the Slave.
- Higher encoder resolution (more pulses per revolution) results in reduced twisting action and smaller temporary phase errors. Under dynamic conditions (acceleration and deceleration) phase errors increase based on drive response, pulses per revolution, and Correction Voltage calibration. Increasing the number of pulses per revolution from the encoders reduces this error, but care must be taken not to exceed the maximum frequency limits.
- Encoders should have a supply range of 10 to 30Vdc. They can be supplied by the on-board +12Vdc power supply or any appropriate external 10 to 30Vdc power source.
- Encoders with 5Vdc outputs or Line Driver outputs must use our level conversion module model PU100.

**Inverters and Drives:**

- The SDC-2 Synchronizer can be used with any size A.C. or D.C. drive systems. To provide proper synchronization the drive must be sized correctly to handle dynamic and load conditions on the motor.
- Only drives with potential free "isolated" 0 to 10V reference inputs can be used. Others may cause serious damage to the synchronizer or may require external analog isolators (such as our model CVI-50).
- In applications requiring tight dynamic response and angular precision, use of 4 quadrant (regenerative) drives is required.
- Linearity and response time of the drives are responsible for twisting actions and temporary phase errors. This should be considered when the system is being designed.

## VI. ELECTRICAL CONNECTIONS

- For electrical connection of the drive, follow the drive manufacturer's instructions and cautions as well as applicable electrical codes.
- The Synchronizer must be connected according to the wiring diagram in this manual. Do not connect the analog input (Z16), the analog output (Z17) or the remote thumbwheel switches at this time.
- ALL lines, except the main power line, must be properly SHIELDED. The cable shields must be connected to one of the Common terminals on the Synchronizer. Do not connect the shield on the other end. - Supply power to the Synchronizer directly from 110Vac or 220Vac power and not from a transformer. A direct and separate power cable eliminates noise and interference.
- When using single channel NPN encoders use terminals X10 and X6. Leave terminals X9 and X5 unconnected. When using single channel PNP encoders connect terminals X9 and X5 to +12 V supply (terminals X8 or X12).
- Connect Reset and Inhibit only if a remote F1 factor is used or if the differential counter needs to be

reset during operation. In all other cases, the Reset push button on the circuit board can be used. The SDC-2 resets the differential counter automatically on power up.

- A battery back-up option is available by connecting a 12V / 1amp hour battery to the X1 and X2 terminals. When using the battery back-up the total system, including encoders, will remain powered for approximately 10 seconds upon power loss, allowing the motors to coast to a stop. After this period, the system will go to standby mode and the SDC-2 will hold angular position information in memory. Upon return of power, the analog signal will bring the Slave back into its position relative to the Master prior to power failure. When using the battery back-up, remove the VGG-C jumper from the SDC-2.
- All cables should be run in a dedicated conduit, separate from power and motor lines.
- Avoid creating ground loops or earth loops through multiple connection of shields or GND lines.
- The inputs for Advance (Y17) and Retard (Y13) can remain unconnected as long as those functions are not used and the encoder type is set to NPN. If the encoders are PNP, connect unused terminals Y17 and Y13 to +12Vdc.
- In applications where index pulses are used, terminal Y17 receives the Master index and terminal Y13 receives the Slave.

The following is a list of terminal locations and connections:

| | | | | | |
|---|---|---|---|---|---|
| Terminal | X1 | Battery Option + | Terminal | Y1 | Common |
| | X2 | Battery Option - | | Y2 | + Relay N.O. |
| | X3 | Error Output | | Y3 | + Relay N.C. |
| | X4 | Analog Common | | Y4 | Common |
| | X5 | Slave Enc. Channel B | | Y5 | - Relay N.O. |
| | X6 | Slave Enc. Channel A | | Y6 | - Relay N.C. |
| | X7 | Slave Enc. Common | | Y7 | Common |
| | X8 | Slave Enc. Supply (+12V) | | Y8 | Common |
| | X9 | Master Enc. Channel B | | Y9 | Common |
| | X10 | Master Enc. Channel A | | Y10 | +12V |
| | X11 | Master Enc. Common | | Y11 | +5V |
| | X12 | Master Enc. Supply (+12V) | | Y12 | N/A |
| | X13 | Reset | | Y13 | Slave Index |
| | X14 | Inhibit | | Y14 | Common |
| | X15 | Common | | Y15 | Common |
| | X16 | Neutral (110V or 220V) | | Y16 | Integration Stop |
| | X17 | Line (110V or 220V) | | Y17 | Master Index |

| | | |
|---|---|---|
| Terminal | Z1 | FE Option BCD 8 |
| | Z2 | FE Option BCD 4 |
| | Z3 | FE Option BCD 2 |
| | Z4 | FE Option BCD 1 |
| | Z5 | N/A |
| | Z6 | N/A |
| | Z7 | N/A |
| | Z8 | FE Option LSD Strobe |
| | Z9 | FE Option LSD+1 Strobe |
| | Z10 | FE Option LSD+2 Strobe |
| | Z11 | FE Option MSD-1 Strobe |
| | Z12 | FE Option MSD Strobe |
| | Z13 | Analog Common |
| | Z14 | Inverted Error Output |
| | Z15 | Inverted Slave Output |
| | Z16 | Master Drive Analog Input |
| | Z17 | Slave Drive Analog Output |

**Note: References made in this manual to Common and Analog Common are not Earth Ground.**

## VII. SWITCH SETTINGS

Prior to the set-up procedure all switches on the unit must be set to their proper positions.

**Single Channel or Quadrature Encoders:**

To select the encoder types being used switches on DIP switch set S16 are used. The Master Encoder setting is selected with S16 - 1 and 2. The Slave Encoder setting is selected with S16 - 3 and 4.

| | | |
|---|---|---|
| Master, Single Channel | 1 ON | 2 OFF |
| Master, Quadrature | 1 OFF | 2 ON |
| Slave, Single Channel | 3 ON | 4 OFF |
| Slave, Quadrature | 3 OFF | 4 ON |

**Encoder Outputs: PNP / NPN**

The encoder output type is programmed using positions 1 through 4 on the 8 position S15 DIP switches. Positions 1 and 2 control the Master and positions 3 and 4 control the Slave.

Definitions:

| | |
|---|---|
| PNP: | Switching toward + |
| NPN: | Switching toward - |

Switch Settings:

| | | |
|---|---|---|
| Master, PNP | 1 ON | 2 OFF |
| Master , NPN | 1 OFF | 2 ON |
| Slave, PNP | 3 ON | 4 OFF |
| Slave, NPN | 3 OFF | 4 ON |

**Reset and Inhibit PNP / NPN:**

Usually these functions will be used in the NPN mode and the inputs will be switched to Common to make the function active. If a PLC is used, it may be more convenient to use the PNP mode and switch the lines to +24Vdc. The Reset and Inhibit are "Active Low" so, if a PLC is used in the PNP mode, it must hold the signal high for normal operation.

The Reset and Inhibit switch selection are made on the 8 position S15 DIP switches. Switches 5 and 6 control the Inhibit function and switches 7 and 8 control the Reset function.

| | | |
|---|---|---|
| Inhibit, NPN | 5 OFF | 6 ON |
| Inhibit, PNP | 5 ON | 6 OFF |
| Reset, NPN | 7 OFF | 8 ON |
| Reset, PNP | 7 ON | 8 OFF |

**Function Switches INT (Phase Integrator), MODE, PULSE SCALING, and REL (Relays):**

These switches MUST be set to the following positions during the initial set-up procedure. The final switch settings are programmed after completing all set-up steps.

| | |
|---|---|
| INT | 0 |
| MODE | 0 |
| Pulse Scaling | 0 |
| Relays | 5 |

**Scaling Factors F1 and F2:**

For 1:1 synchronization using encoders with the same number of pulses per revolution and equal mechanical conditions on the Master and Slave, both F1 and F2 are set to 1.0000. This setting will perform both speed and angular synchronization.

If only speed synchronization is needed in an application where mechanical conditions (gear ratios, shaft sizes, etc.) are different, the encoder frequencies for the Master and Slave must be determined and the difference is entered into F2. First, set the F1 factor to 1.0000. Then, find the result of the following formula to determine the F2 setting:

$$F2 = 1.0000 \times \frac{\text{Master frequency}}{\text{Slave frequency}}$$

Using this formula, the speed of the Slave can be increased or decreased by varying the F1 Factor. For example: if F1 is changed from 1.0000 to 1.0250 the Slave will increase speed by 2.5%. Factor F2 is determined with consideration to all mechanical conditions in the plant and is usually set only once and not altered. Changes in speed are made using F1 adjustments.

In applications where mechanical conditions on the Master and Slave are different, yet angular or position synchronization is required, a calculation of the F1 and F2 factors must be made with a result that contains no remainders which will cause cumulative tracking errors. In other words, there are 5 digits in the Factor Switches (F1 and F2) and any numbers with more than five digits will produce a cumulative error. Because of this, a formula is used that produces no cumulative errors. The formula is:

Master PPR x Master RPM x F1 = Slave PPR x Slave RPM x F2

An example of this formula is as follows:

Master PPR = 360; Master RPM = 1730; Slave PPR = 360; Slave RPM =1910*

* Note: Master RPM and Slave RPM are used assuming that the RPM's represent equal distance traveled in one minute. The purpose of the equation is to find a result that provides whole numbers representing equal angular position; depending on gearing, shaft sizes, etc. the number of pulses that occur in the period it takes the Slave to travel the same distance that the Master travels in one revolution may not be a perfect whole number, so we use this formula. Other equally effective methods would be to figure the number of pulses on the Master and Slave for each complete machine cycle or for a specific distance travelled. If the machine cycle method was used, the formula would be: Master Pulses per Machine Cycle x F1 = Slave Pulses per Machine Cycle x F2.

Our formula would be:

360 x 1730 x F1 = 360 x 1910 x F2

622800 x F1 = 687600 x F2

We see by this formula that for 622800 x F1 to equal 687600 x F2 then F1 = 687600 and F2 = 622800.

622800 x 687600 (i.e. F1) = 687600 x 622800 (i.e. F2)

We can eliminate the trailing zero from each Factor and we have an F1 Factor of 68760 and an F2 Factor of 62280; each Factor is a five digit whole number.

IMPORTANT - the setting for Factor F1 is best when it is a number between 0.5000 and 2.0000. Because of this, we can divide BOTH F1 and F2 by 4 (because both numbers are evenly divisible by 4).

68760 / 4 = 17190 and 62280 / 4 = 15570

F1 = 17190 (or 17190 / 10000 since the F1 Factor is X.XXXX), so 1.7190 is entered in the F1 switches.

F2 = 15570 (or 15570 / 10000 since the F2 Factor is X.XXXX), so 1.5570 is entered in the F2 switches.

---

## VIII. INITIAL SET-UP PROCEDURE:

First, verify that the drives work properly without the SDC-2 (Terminals Z16 and Z17 open. Run both the Master and Slave drives up to full speed with 9 Volts applied; leave 1 Volt of reserve for analog correction. Use the drives' maximum speed potentiometers to adjust for full speed. All drive adjustments that cause a delay in response (ramp times, integration times, etc.) must be set at their absolute minimum values. Anything other than minimum values will impede the performance of synchronization. Set the proportional gain of the Slave drive as high as possible.

---

**Encoder Test:**

- Enter 1.0000 into F1 and F2.

- Switch power to the SDC-2 ON.

- Keep the Slave stationary and run the Master in the working direction. The LED light bar should immediately move to the right. If it moves left, interchange the X9 and X10 encoder leads.

- Press the on-board Reset to re-center the LED Light Bar display.

- Next, keep the Master stationary and run the Slave in its working direction. The LED should move immediately to the left. If it moves right, interchange the X5 and X6 encoder leads.

- Press the on-board Reset to re-center the LED Light Bar display.

Note: This is valid for a Positive input voltage from the Master on terminal Z16. If the Master provides a Negative voltage, the reverse is true.

**Correction and Output Potentiometers:**

The offset potentiometers (Output Offset = R61 and Correction Offset = R37) on the SDC-2 are set at the factory but should still be checked.

- Turn the Correction Gain (R41, 30 turn) Potentiometer completely counterclockwise then five (5) full turns clockwise.

- Press the on-board Reset and verify that the LED Light Bar display is centered (two green LED's in the middle of the bar are illuminated).

- Connect a digital voltmeter to terminals X3 (Correction Output) and X4 (Analog Common). The reading should be 0 (zero) Volts or just a few millivolts (positive or negative). If not, use the Correction Offset (R37) potentiometer to calibrate to zero.

- With Z16 (Analog Input) unconnected, connect a voltmeter to terminals Z17 (Analog Output) and Z13 (Analog Common). The reading should be 0 Volts or just a few millivolts. If not, use the Output Offset (R61) potentiometer to calibrate to zero.

- During all offset adjustments the two green LED's in the center of the Light Bar should be illuminated. Once they are properly adjusted do not make any further adjustment to the Output and Correction Offset potentiometers.

**Achieving Analog Synchronization:**

These steps will set-up the analog synchronization discussed in Section II.

- Disconnect external reference sources from the drive and connect Z16 (Master Input) and Z17 (Slave Output) according to the wiring diagram in this manual.

- Turn the Correction Output potentiometer (R41) fully counterclockwise (until it clicks) to switch off the correction voltage.

- Enter your calculated values for F1 and F2 and press the Reset button.

- With both drives enabled, run the Master. The Slave will follow. Watch the LED light bar. If it moves to the right, the Slave is too slow; to the left, it is too fast (or vice versa when using a negative voltage).

- Turn the Slave drive's maximum speed potentiometer to achieve synchronization (evidenced by the 2 center LED's being illuminated on the light bar), pushing the reset button on the SDC-2 after each adjustment. The center LED's should be illuminated or moving as slowly as possible. The Output Gain (R64) potentiometer on the SDC-2 can be used for fine tuning after getting the synchronization as close as possible with the maximum speed potentiometer on the Slave drive.

**Digital Synchronization:**

The next step will bring the correction signal into the system, achieving digital synchronization.

- Turn the Correction Voltage (R41) potentiometer clockwise. The stronger the correction signal is, the closer the system will synchronize. A correction signal that is too strong can result in improper motion or oscillation of the Slave. If this happens, reduce the Correction Voltage by turning R41 counterclockwise a few turns. The typical position of the Correction Voltage potentiometer is 5 turns from the zero position.

- Run the drives over their full speed range to test the synchronization. The LED Light Bar should move in its green area or just touch the yellow through all speeds. Use the Output Gain (R64) potentiometer to make minor adjustments.

**Setting the Function Switches:**

After the synchronization steps are complete, set the Mode, Relay, and Phase Integration switches to the positions selected for operation (switch functions are described in prior sections in this manual). The Pulse Scaling switch is typically set at zero (0). If another setting is needed, set it at this time.

**Note:** Remember to cycle the Reset button on the board after adjusting the switches.

---

## IX. REVERSING

Basically, all combinations of reversals are possible. However, to maintain the logic of the system the encoder leads or analog lines may have to be switched. The steps taken to reverse depend on the type of encoders and drives being used.

**4-Quadrant Drives (+/- 10V input), Quadrature Encoders:**

A) Master Forward, Slave Reverse:
- Use analog output Z15 instead of Z17
- Switch the A and B lines of the Slave encoder

B) Master Reverse, Slave Forward:
- Invert analog input Z16
- Switch the A and B lines of the Master encoder

C) Master Reverse, Slave Reverse
- No steps necessary

**4-Quadrant Drives (+/- 10V input), Single Channel Encoders:**

A) Master Forward, Slave Reverse
- Use analog output Z15 instead of Z17

B) Master Reverse, Slave Forward
- Invert analog input Z16

C) Master Reverse, Slave Reverse
- Invert analog input Z16
- Use analog output Z15 instead of Z17

**Contactor Reversing Drive (+ 10V input), Quadrature Encoders:**

A) Master Forward, Slave Reverse
- Switch the A and B lines of the Slave encoder

B) Master Reverse, Slave Forward
- Switch the A and B lines of the Master encoder

C) Master Reverse, Slave Reverse
- Switch the A and B lines of both encoders

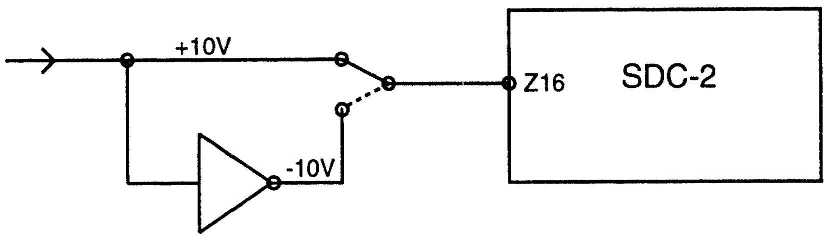
**Contactor Reversing Drive (+ 10V input), Single Channel Encoders:**

Any combination of reversals possible without additional steps.

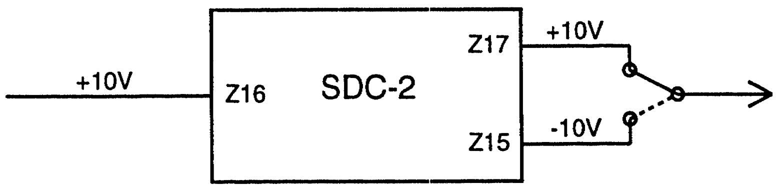
Note: Whenever analog or digital signals must be switched by relays, use relays with gold contacts suitable for switching low voltage / low current signals.

Reversal steps can be made by using the following circuits:

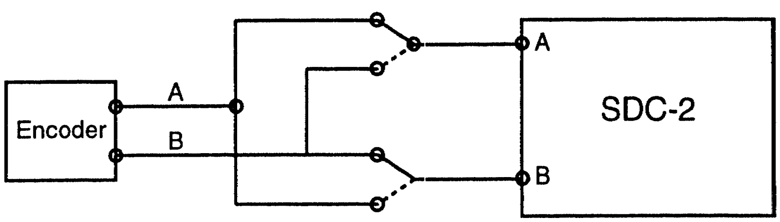
Inverting the Analog Input




Inverting the Analog Output




Switching Encoder Leads




## X. NOISE IMMUNITY

The technology and noise immunity of the SDC-2 is proven in tens of thousands of applications worldwide. With proper wiring and consideration of the recommendations in this manual, no noise or other problems should occur.

If any problems occur which may seem to be caused by electrical noise we recommend the following:

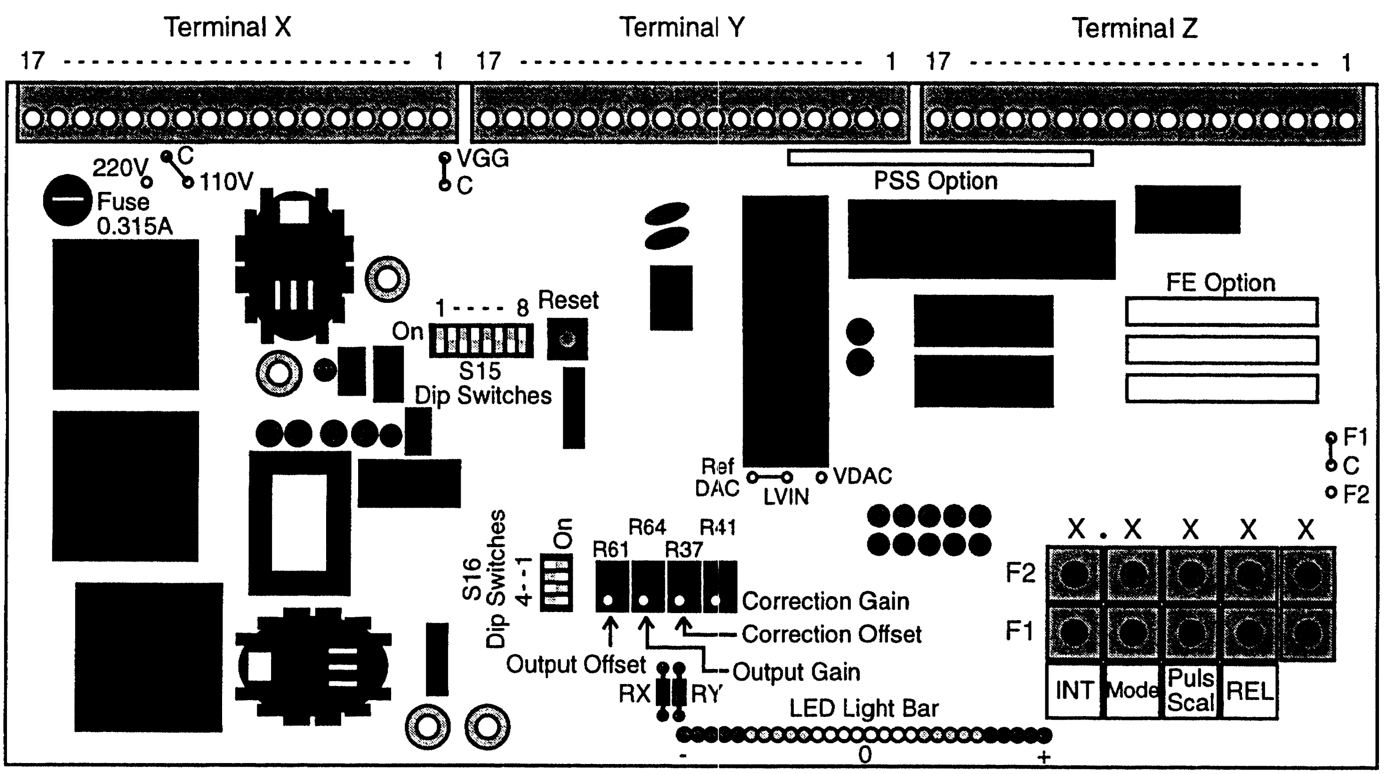
- Carefully check all cables, leads, shields, etc.
- If AC contactors are being used, put RC components (0.1 µF/100 Ohms or others) parallel to the coils.
- If DC inductive loads are switched, put diodes parallel to the coils.
- Install a power line filter on the SDC-2 supply line (close to the device).
- Disconnect AC power from the internal alarm relays. Use auxiliary low power relays.

## XI. SPECIFICATIONS

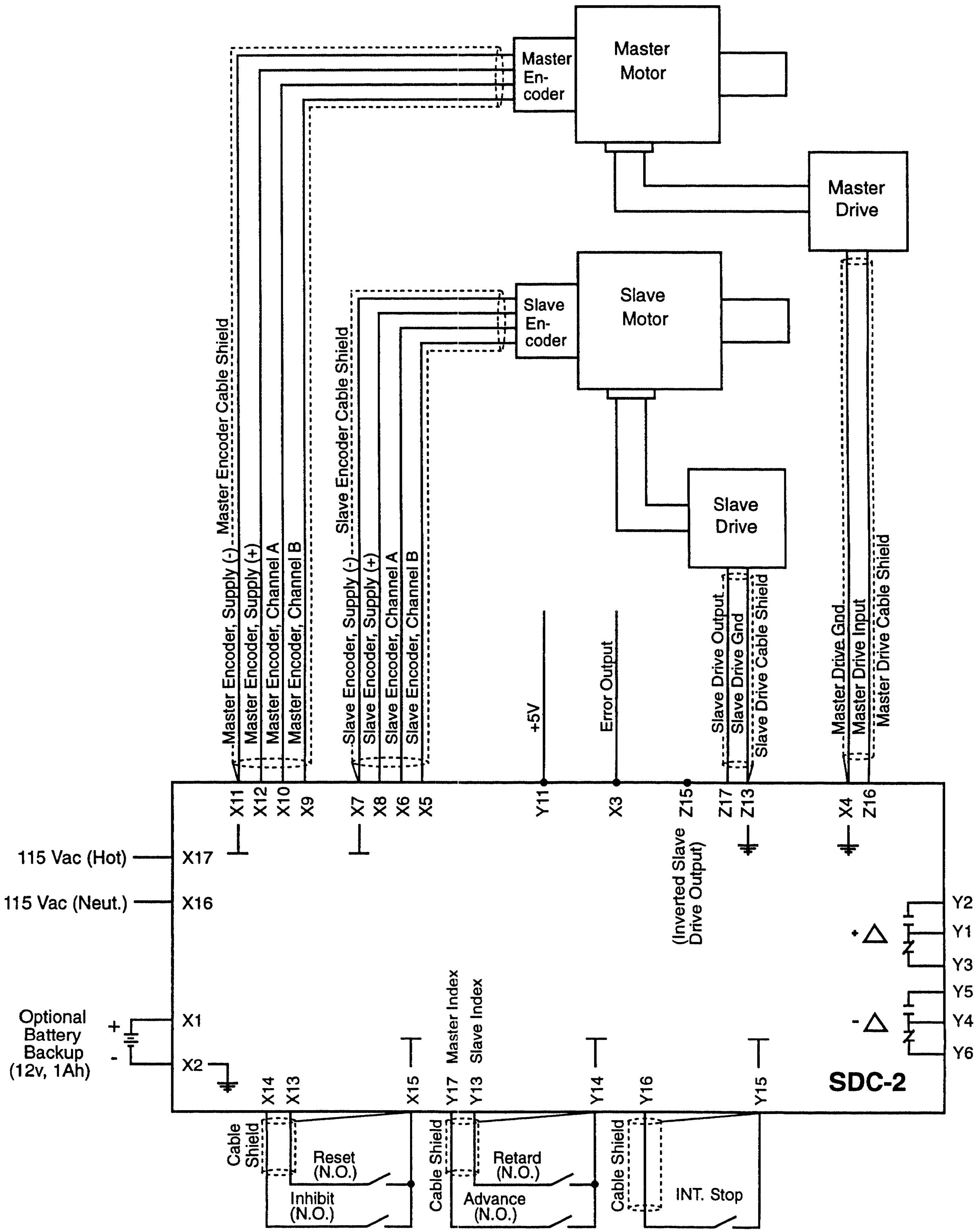
| | |
|---|---|
| Power Supply | 110 Vac or 220 Vac;15 VA |
| Fuse | 5 x 20mm type, 0.3 Amps |
| Encoder Supply | 12Vdc / 240 mA; 5Vdc / 240mA available |
| Technology | N Mos Processor 68701 with C Mos and TTL peripheral components |
| Clock Frequency | 5 MHz |
| Digital Inputs | 2 x channels A and B for encoders<br>2 x channel C (Index pulse)<br>2 x Reset and Inhibit<br>20 x BCD parallel input (Option)<br>All inputs: logical low = -30 to +5V<br>logical high = +10 to +30V<br>Ri = 2.7 KOhms |
| Max. Frequency (Encoder Inputs and Index) | Mode 0 = 30 KHz<br>Modes 1 - 9 = 28 KHz |
| Maximum Pulses Between Indexes | 16,383 |
| Reset, Inhibit, Parallel Inputs | Minimum signal duration 50 msec |
| Analog Input | 1 for Master Voltage; +/- 10V, Ri = 10 KOhms |
| Analog Outputs | 1 output for Slave<br>1 output for Inverted Slave<br>1 output for Correction<br>1 output for Inverted Correction<br>all: +/- 10V, 5mA max. |
| Analog Resolution | 12 bit; 4096 steps |
| Analog Accuracy (without digital correction) | +/- 0.3% |
| Slave Speed Accuracy | +/- 0.00% (Absolute) |
| Response time: Encoder input/ Analog Output | Typical = 150 µsec<br>Max. = 250 µsec |
| Pulse Scaling | Separate for Master and Slave<br>Adjustable from 0.0001 to 9.0000 |
| Count Capacity | +/- 255 increments for full scale error correction<br>+/- 32000 pulse memory range |
| Battery Back-up | External lead battery; 12 V/1.1 Ah (Option) |
| Back-up Time (Full Power) | 10 seconds after power failure |
| Back-up Time (Memory) | Approximately 200 hours |

| | |
|---|---|
| Alarm Relays | Potential free contacts; max. 220V / 100VA<br>Recommended: 24 Vdc / 100mA only<br>Inductive loads require a protection circuit such as RC component or diodes |
| Serial Line | 20 mA current loop bidirectional<br>or RS 232, 1200 to 2600 baud |
| Temperature Range | -10°C to +40°C |
| Dimensions | see drawings |
| Weight | 1100g (approx.) |

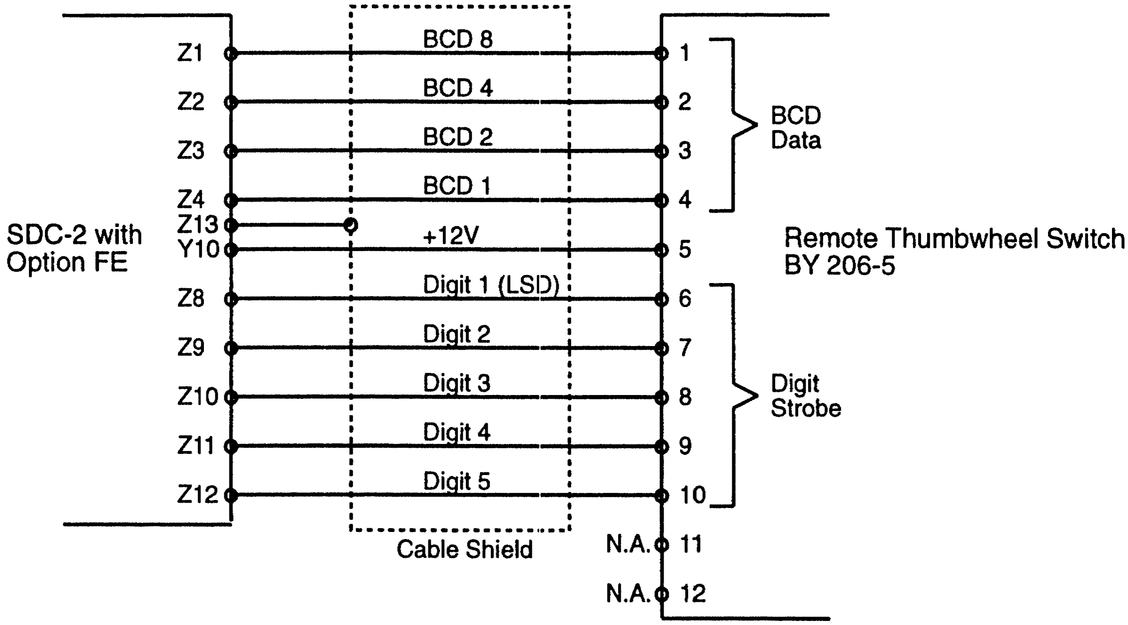
## SDC-2 TERMINAL, SWITCH, AND POTENTIOMETER LOCATION DRAWING:

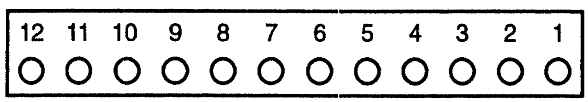


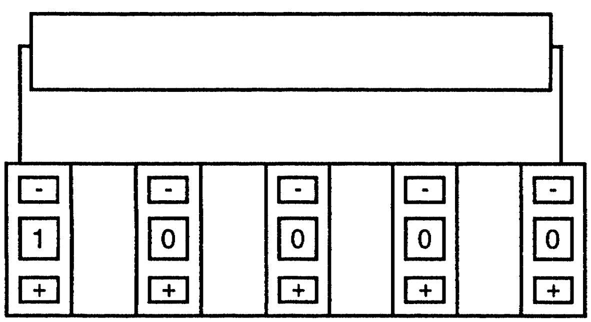
# SDC-2 Connection Diagram

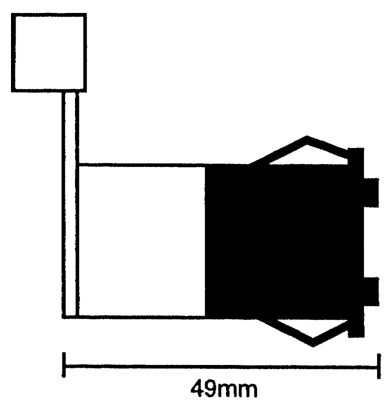


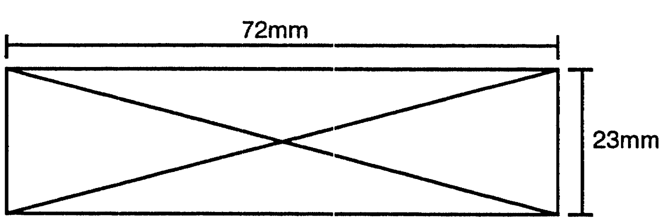
# Remote Switch Connection (Option FE)



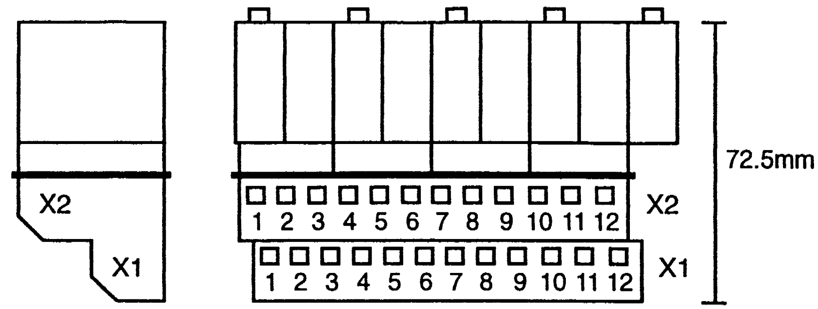



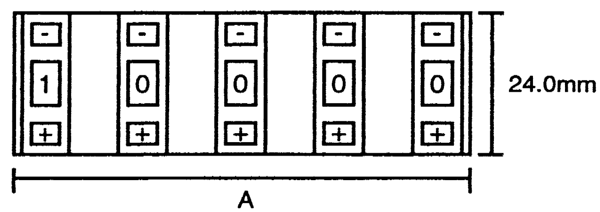



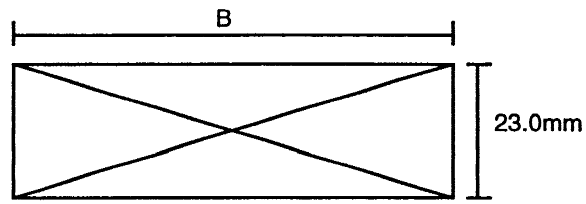




Panel Cutout

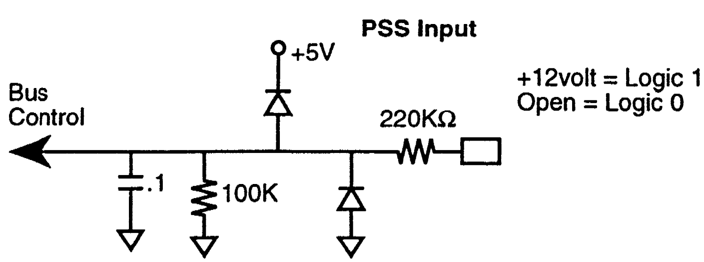
# Option PSS



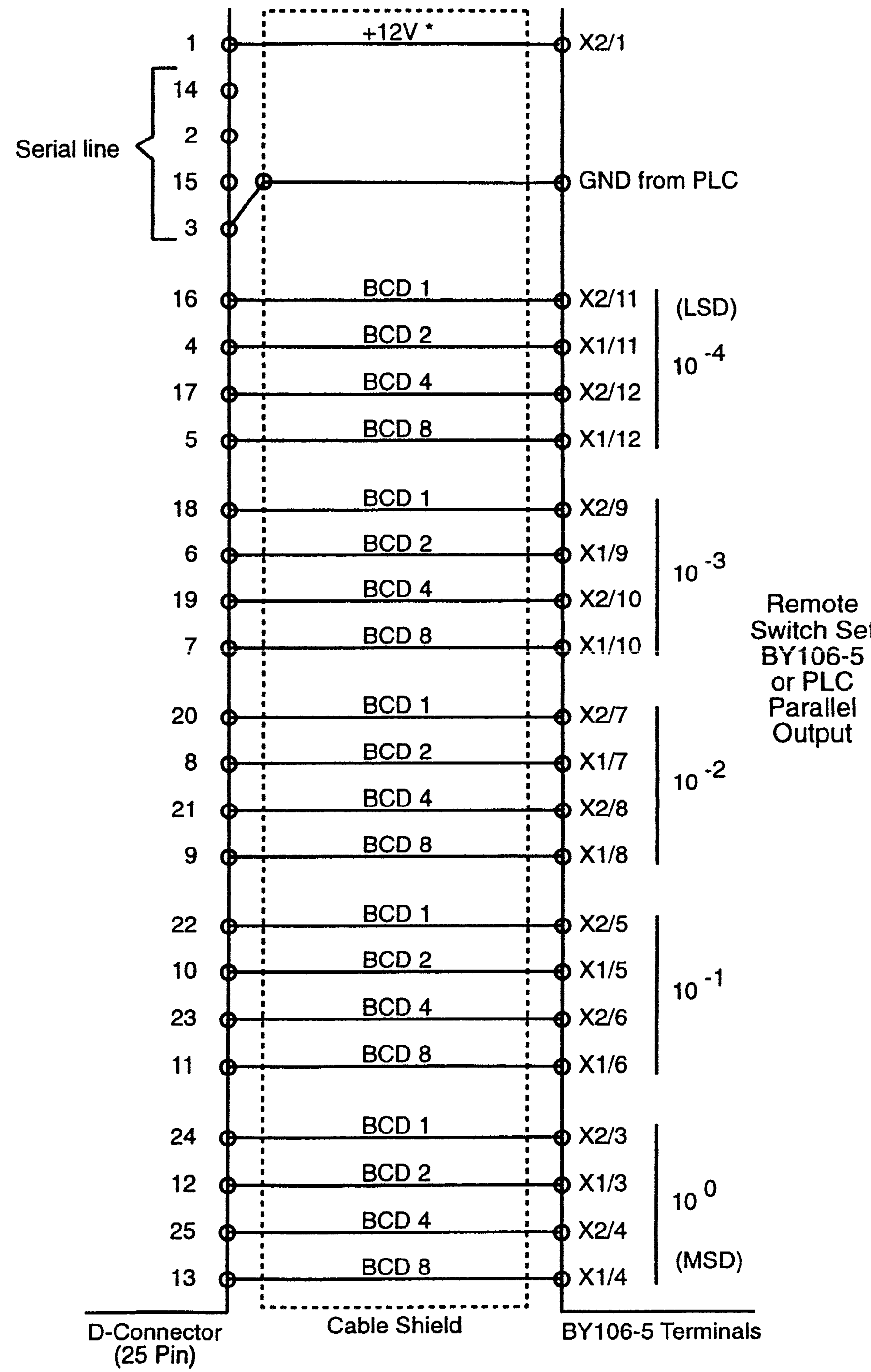



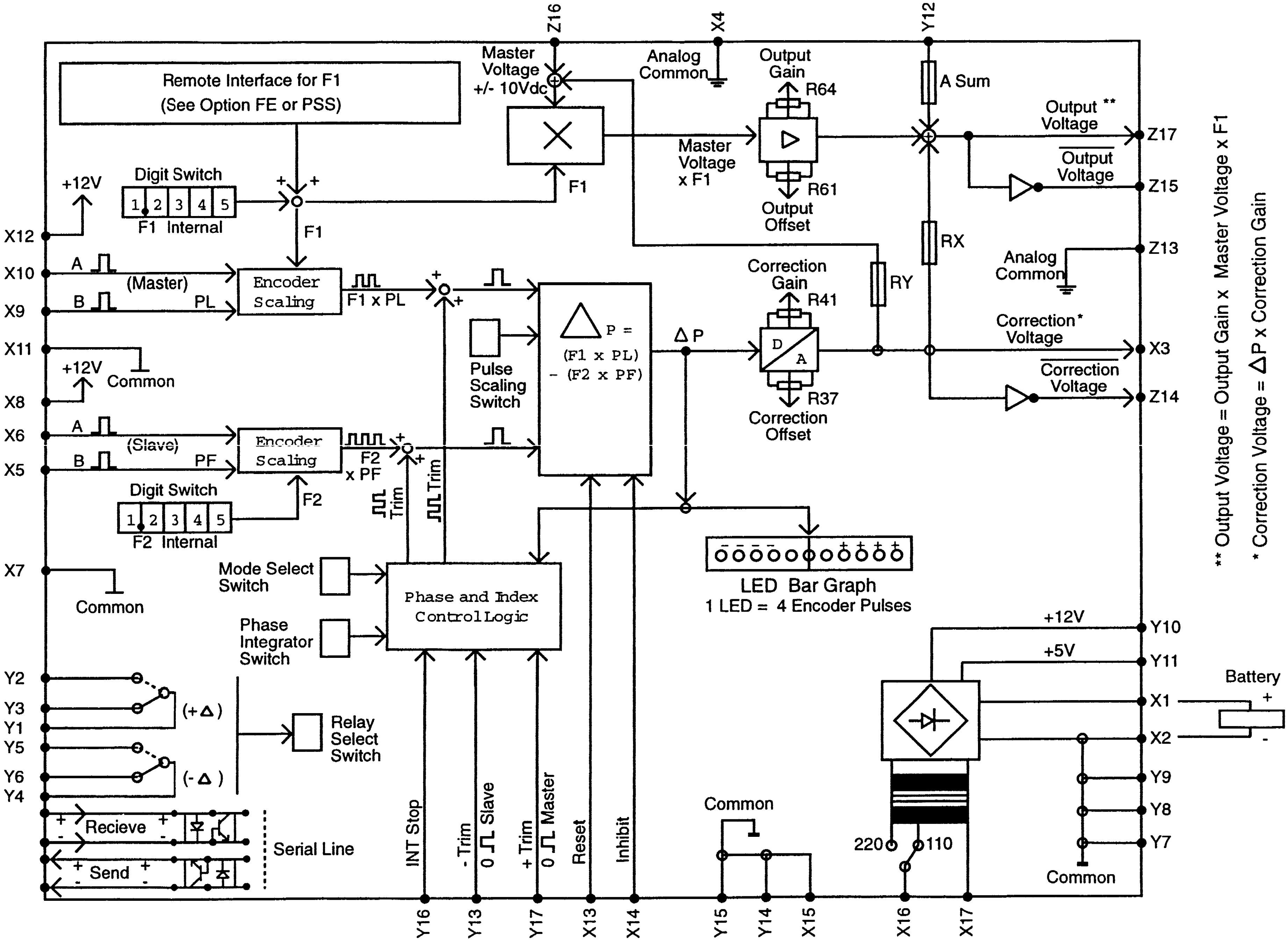

Panel Cutout




| Switch Type | Decades | A (mm) | B (mm) |
|---|---|---|---|
| BY106-3 | 3 | 44.5 | 42 |
| BY106-4 | 4 | 59.5 | 57 |
| BY106-5 | 5 | 74.5 | 72 |



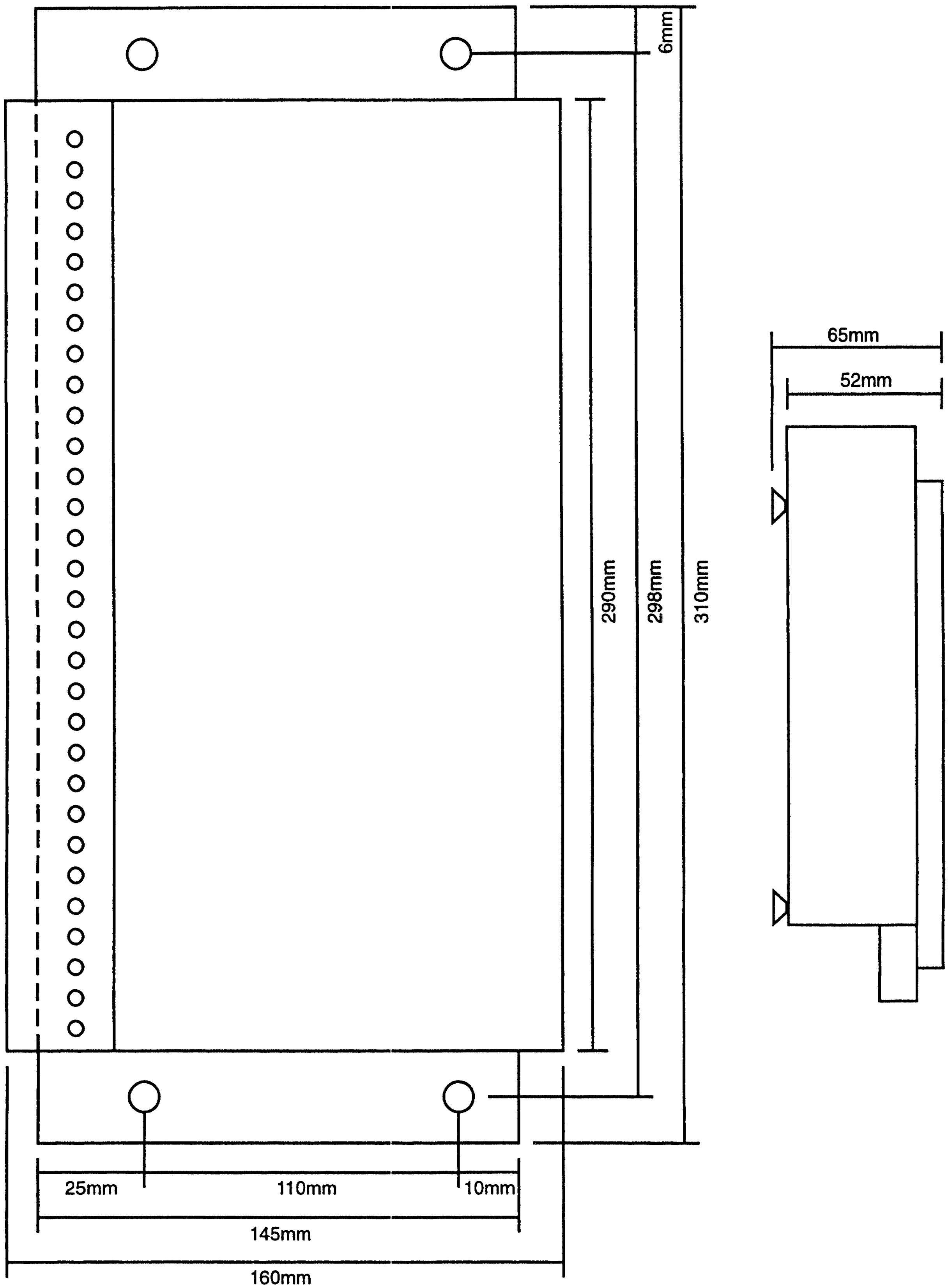
# SDC-2 BLOCK DIAGRAM




** Output Voltage = Output Gain x Master Voltage x F1

* Correction Voltage = ΔP x Correction Gain

# SDC-2 Dimensions



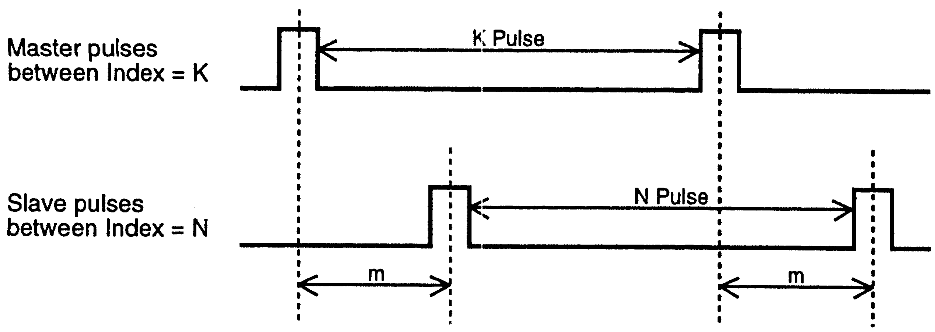
# Appendix A: SDC-2 with B12 Option (SDC-2-PSSB12)

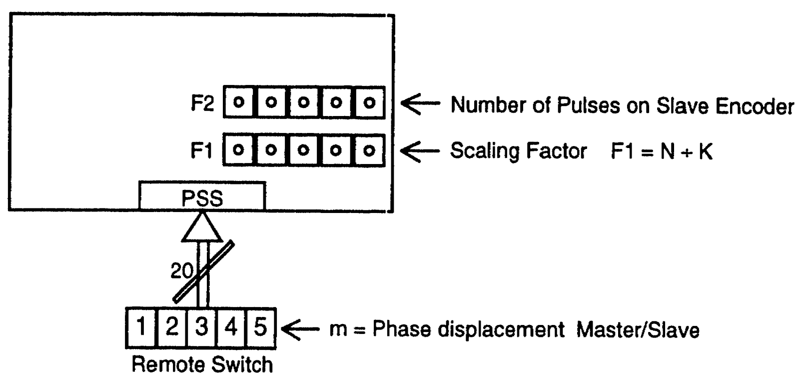
**Note: When using the an SDC-2 with the B12 option installed (SDC-2-PSSB12) the PSS option card must be installed and the Microcontroller chip on the SDC-2 will be labled with the numbers BY20022.**

### Principle of Operation:

Many applications require not only synchronization, but also a defined position or phase condition between the driven shafts. This can be done by using encoders and index pulses. Detailed information about this can be found in the SDC-2 manual.

Standard Synchronizers require a pulse ratio of 1:1 when operating in index mode, i.e. the numbers of encoder pulses between index pulses must be the same for the Master and the Slave. With version B 12, index mode can be used when there are different numbers of pulses between indexes on the Master and Slave encoders.




### Special Operation of Version B 12:

1) The version requires the use of the PSS option.
2) The F2 switches must be set to the number of pulses between index (N) of the **SLAVE** encoder.
   Range: 00000 - 65535.
3) The pulse ratio between the Master pulses and the Slave pulses must be set on the F1 switches.
   F1 = Pulses between index Slave ÷ Pulses between index Master.
4) The remote switch set (option PSS) adjusts the phase displacement (m) between the index pulses with reference to the Slave pulses. Example: If n = 1000, a setting of m = 500 on the remote switch set results in a 180° phase offset.
5) See the wiring section of this manual for all connections and adjustments.

# SDC-2 PROGRAM & CALIBRATION RECORD

Software # _______________ (Written on large chip with label)
Remote Thumbwheel PSS(BY106-5,4,3) or the Standard FE(BY206-5)

## Switch Settings:

Control Name or Location ________________________

F2 _______________
F1 _______________ (calibrated at)
T.W. Range______to________
Intergration ________
Mode ________
Pulse Scale ________
Relay ________

Sw 15 Dip Switch, Circle On or Off

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| On | On | On | On | On | On | On | On |
| Off | Off | Off | Off | Off | Off | Off | Off |

Sw 16 Dip Switch, Circle On or Off

| 1 | 2 | 3 | 4 |
|---|---|---|---|
| On | On | On | On |
| Off | Off | Off | Off |

## Analog Calibration:

### Step 1

Jumper terminal X15 to terminal X13 (reset held). Disconnect the Master Analog Input (Z16) and jumper to Z13 (common). Using a Digital DC Voltmeter measure and record the the volts from Z17 (Slave Drive Output, positive lead) to Z13(Common, negative lead). This is your R61 Calibration Value.

R61 Calibration Value is ______________ with zero volts input.

---

### Step 2

Remove the jumber from Z16 to Z13 and reconnect the Master Analog Input to Z16. Run the master motor at maximum speed. Measure and record the Master Analog Input voltage Z16 to Z13. Measure and record the R64 Calibration Value across Z17 to Z13 (Slave Drive Output).

Note: If the mode switch is between 0 and 5 use highest F1 setting without exceeding 10 volts on Z17.

R64 Calibration Value is ______________ with Master Analog Input of _____________ volts.

---

### Step 3

Remove the jumper between X15 and X13, and disconnect the Slave Encoder. Measure and record the R41 Calibration Value between Terminals X3 (positive lead) and X4 (negative lead). Note: the master motor must be running. If the voltage is greater than 10 volts, use alternate method.

R41 Calibration Value is ______________ volts

### Step 3 Alternate Method

With the Master Motor stopped, press the Reset button. With the meter on terminals X3 to X4, slowly turn the master motor until the light is near the end of the light bar or the meter reads 10volts. Record the light and voltage. Count lights by left or right of light bar center, color and number.

Example: Right Yellow #4 = right from center, yellow band, fourth light counting from center.

R41 Alternate Calibration Value is _________ volts, Light = R or L, Color ______, # _______

---

### Step 4

Record Drive or Inverter Calibration: Accel\Decel, Max Speed (Hz),

________Volts in = Speed ____________