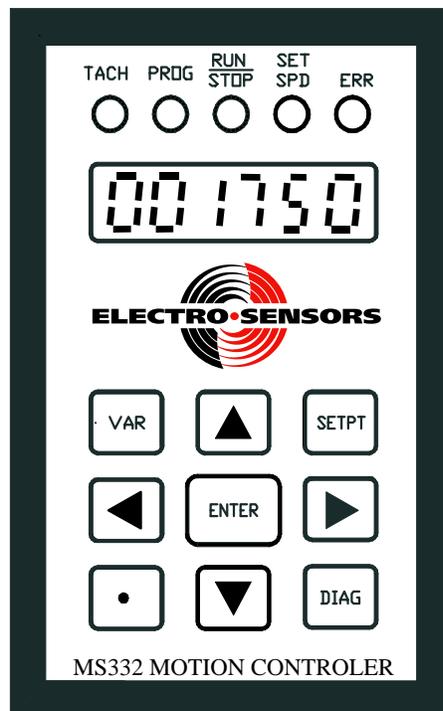




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## MS332 Motion Controller Users Manual (bA02.XX)



# MS332 Introduction

The MS332 is a powerful and versatile speed-mode motor-drive controller for building closed-loop processes. Capabilities include speed and phase control, electronic line-shaft and gearing, event synchronization and bidirectional motion.

The MS332 receives a feedback quadrature pulse signal from an incremental shaft encoder while outputting an analog control voltage signal to a variable-speed motor drive. For follower operating modes, the MS332 also receives a lead (master) quadrature pulse signal from a second incremental shaft encoder. Depending on the follower mode, the MS332 may also receive index/event pulse signals from sensors at both a lead and the follower processes.

Powerful user variables and numerous user-assignable switch-input and transistor-output functions are provided to tailor the MS332 to both the motor-drive and application requirements. The internal 32-bit processor and 1024 per second PID loop update rate make the controller precise and responsive.

## How to use this manual

This user's manual is organized to be used as follows:

- 1) **Description of Operating Modes Section (complete descriptions of each operating mode):**  
Use this section to *understand the operating modes* or to look up basic information on a particular operating mode. The descriptions in this section describe the external hardware, operation and control theory for each MS332 operating mode.
- 2) **Physical Installation Section (mounting, wiring):**  
Use this section to *look up mounting and wiring instructions, options and guidelines*.
- 3) **Set-up Section (complete step-by-step set-up procedures for setting up each operating mode):**  
Use the corresponding step-by-step procedure in this section to *set-up the MS332 for a given operating mode*. The intent of this section is to provide clear set-up procedures that avoid all nonessential information. Each procedure guides the user through all necessary steps to set-up for that operating mode.  
Note: Facility in using the keypad menus and changing user variables is required. For details, see the 'Reference Section \Keypad subsection'.
- 4) **Reference Section (a complete and detailed product reference):**  
Use this section to *look up specific information describing the function, use and operation of user variables and hardware*.  
Many details relating to the internal operation are also included in the subsections of this section.
- 5) **Specifications Section:**  
Use this section to *look up functional, operational, electrical, environmental and mechanical specifications*.
- 6) **Appendix Section:**  
Use this section to *access various information not included in the other sections* (see Table of Contents).

**Note:** The material in this manual is subject to change without notice.

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# MS332 Description of Operating Modes Section (bA02.XX)

## Master Mode

### Description:

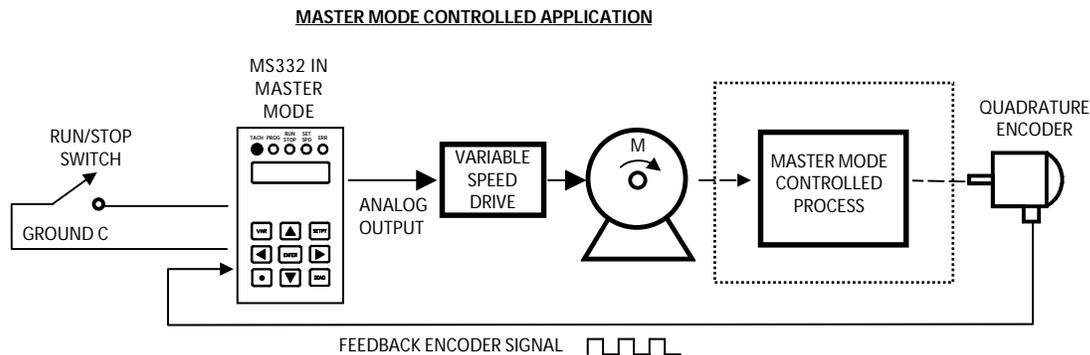
Input hardware:

- Master mode uses a single quadrature-output incremental feedback encoder on the controlled shaft.

Operation:

- Master mode controls motor speed, causing the feedback encoder to rotate at the precise set-point speed.
- When using a bidirectional drive and motor, forward and reverse Master mode operation may be achieved by utilizing the Reverse Switch Input Function.

Master mode utilizes only one encoder (connected to the MS332 feedback encoder channel inputs) as shown in the following diagram:



### Control Theory:

Closed-loop pulse-counting algorithm:

- The feedback encoder speed is controlled by forcing the number of feedback encoder pulses received (in time T) equal to the expected number determined by the master set-point and certain other variables.
- Since the MS332 time-base is controlled by an accurate, precise crystal-based clock, the speed does not significantly drift over time or vary with environmental conditions.

Feedback speed and active set-point:

- The set-point to feedback RPM relationship is given by the equation:

$$\underline{FbRPM = Set\text{-}point * (Var01.00 / Var01.01)}$$

- Var01.00 (Process Max Feedback Encoder RPM) sets the maximum feedback encoder RPM for the *process*. This is the maximum *steady state* feedback encoder RPM at which the process runs (not accounting for overspeed needed to close the loop at maximum set-point). It is the expected nominal feedback encoder RPM for Master Mode when the set-point is maximum.
- Var01.01 (Process Max Feedback Encoder RPM in User Units) configures the *user units* of feedback encoder RPM for Master Mode set-points, speed set-point scroll steps, feedback encoder velocity display and npn-output speed threshold parameters. Set Var01.01 to Var01.00's value converted to user units. To use RPM user units, set Var01.01 equal to Var01.00.
- During operation, the set-point may be set to any value from 0 to Var01.01.

# Ratio-Follower Mode

## Description:

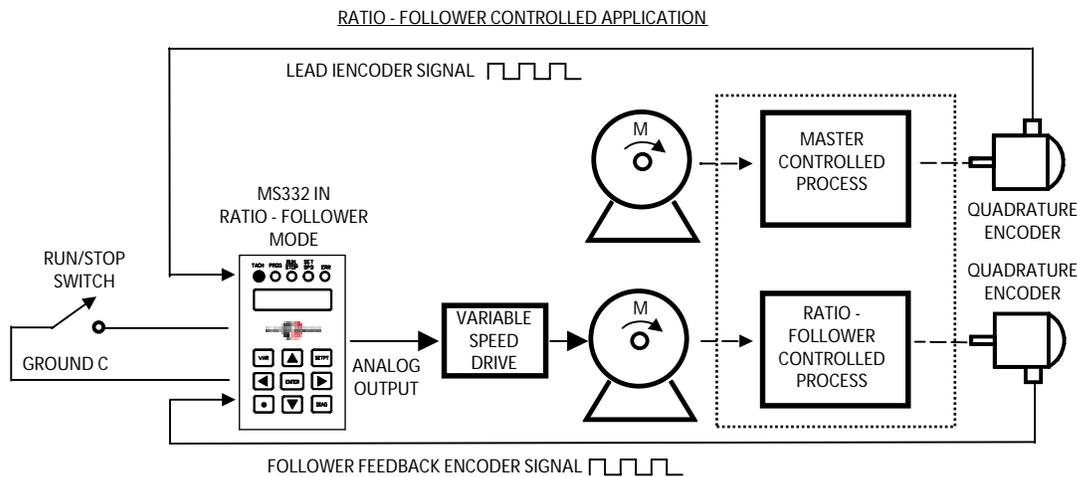
### Input Hardware:

- Ratio-Follower mode uses quadrature-output incremental encoders on both the lead and follower shafts.

### Operation:

- Ratio-Follower mode controls follower motor speed, causing the feedback encoder to precisely follow the lead encoder according to the (speed ratio) set-point. The set-point sets the proportionality between the lead and follower shaft speeds.
- When using a bidirectional drive and motor, the feedback encoder follows the lead encoder in either direction (forward or reverse). Normally, the feedback encoder follows in the same direction as the lead. When using the Reverse Switch Input Function, the feedback may be switched to follow in the *opposite* direction.

Ratio-Follower mode utilizes one lead encoder and one feedback encoder (connected to the MS332 lead and feedback encoder channel inputs) as shown in the following diagram:



## Control Theory:

### Closed-loop pulse-meshing algorithm:

- The feedback (follower) encoder speed is controlled by forcing the number of feedback encoder pulses received (in time T) equal to the expected number determined by the lead encoder pulses received (in time T), the ratio set-point and certain other variables. With this pulse-meshing algorithm the feedback encoder follows the lead encoder as though mechanically geared, with zero slippage over time.

### RPM ratio and active set-point:

- The (output) feedback follower RPM to (input) lead RPM relationship is given by the equation:

$$\underline{FbRPM / LdRPM = Set-point * [(Var01.00 / Var01.03) / Var01.04]}$$

- Var01.03 (Process Max Lead Encoder RPM) must be set to the maximum expected lead encoder RPM of the *lead process*.
- Var01.00 (Process Max Feedback Encoder RPM) sets the maximum feedback encoder RPM for the *follower process*. This is the maximum *steady state* follower process feedback encoder RPM (not accounting for overspeed to close the loop at maximum set-point). It is the expected nominal feedback encoder RPM when the lead encoder is running at process maximum RPM (Var01.03) and the Ratio-Follower set-point is maximum.
- Var01.04 ([Process Max Feedback Encoder RPM / Process Max Lead Encoder RPM] in User Units) configures the *user units* of the feedback/lead encoder RPM ratio for Ratio-Follower set-points, feedback/lead encoder velocity ratio display and npn-output velocity ratio threshold parameters. Set Var01.04 to (Var01.00 / Var01.03) converted to user units. To use "unitless" RPM ratio user units, set Var01.04 equal to Var01.00 / Var01.03.
- During operation, the Ratio Follower set-point may be set to any value from 0 to Var01.04.

# Index-Follower Mode

## Description:

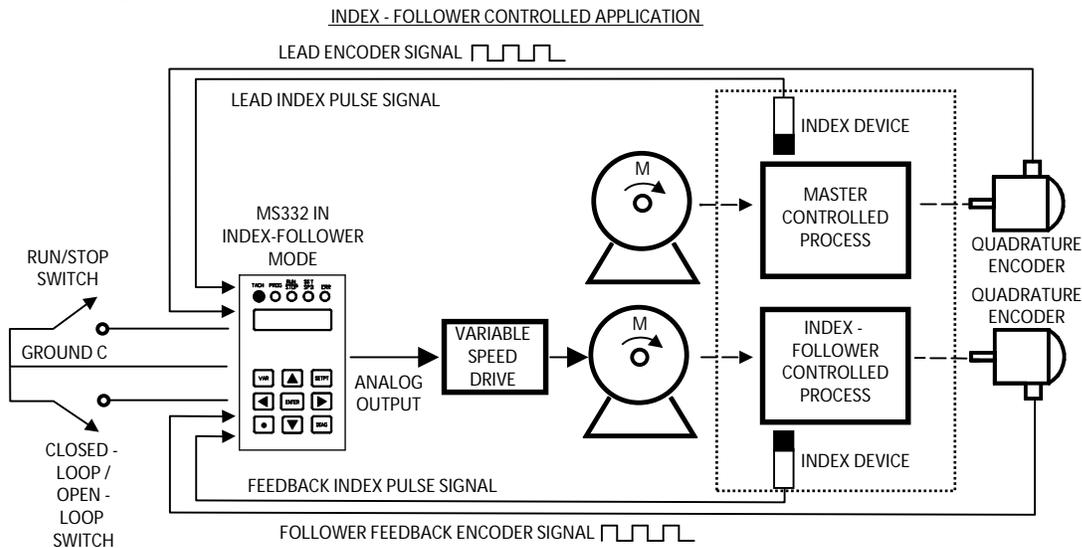
### Input Hardware:

- Index-Follower mode uses lead and follower quadrature-output incremental encoders and lead and follower index pulse devices. An Index pulse signal is usually triggered by an *event* such as an object passing by a proximity sensor.

### Operation:

- Index-follower mode controls follower motor speed, causing the feedback encoder to follow the lead encoder according to the rpm ratio while simultaneously positioning feedback index pulses relative to lead index pulses according to the index phase set-point.
- When using a bidirectional drive and motor, the feedback encoder follows the lead encoder in either direction (forward or reverse).

The connections to the MS332 lead and feedback encoder inputs, and lead and feedback index inputs are as shown in the following diagram:



## Control Theory:

### Index Phasing:

- Index phase corrections position the effective feedback index pulses relative to the effective lead index pulses according to the Index Phase set-point. In this way, a periodic feedback-process event may be precisely phased to precede, coincide with, or follow a periodic lead-process event by a desired number of feedback encoder pulses. Index phase corrections occur immediately after each effective feedback index pulse.

### RPM Ratio:

- Between index phase corrections, feedback encoder speed is controlled by forcing the number of feedback encoder pulses received (in time T) equal to the expected number determined by the lead encoder pulses received (in time T) and certain user variables (see formula below). No pulses are gained or lost between index phase corrections: the cumulative error is zero. Therefore if either index pulse source were to fail, index phase corrections would cease but the follower-to-lead phase relationship would not change.
- This closed-loop pulse-meshing algorithm is similar to that of Ratio-Follower mode. However, unlike Ratio-Follower mode, the RPM ratio derives from a feedback to lead index pulse matching ratio (Var01.10/Var01.11) and not from the set-point. The Index-Follower mode feedback/lead RPM ratio formula is shown here:

$$\underline{FbRPM / LdRPM = (FbPPI / LdPPI) * (Var01.05 / Var01.02) * (Var01.10 / Var01.11)}$$

Where FbPPI and LdPPI are the feedback and lead encoder-pulses per index-pulse, Var01.02 and Var01.05 are the feedback and lead encoder pulses per revolution, Var01.10 and Var01.11 are the desired feedback and lead index pulses per match.

## Index-Follower Mode (cont.)

PPI Measurement and Averaging:

- Although it is necessary for an application to exhibit constant or near-constant feedback and lead encoder-pulse per index-pulse counts, some variation is tolerable to the MS332. Possible causes of variation may include slippage or stretching in the medium coupling the encoder shaft and index-pulse trigger, multiple (somewhat unevenly-spaced) index-pulse triggers per mechanical cycle and multiple, irregularly shaped / oriented index-pulse triggers. In such cases this PPI variation *alone* causes periodic index-phase corrections as the MS332 maintains the set-point mandated feedback-to-lead index-pulse phase relationship.
- To mitigate the size of such index-phase corrections, MS332 provides user-configurable feedback and lead encoder PPI measurement and averaging functionality (controlled by Var01.09).  
When enabled, *averages of measured* FbPPI and LdPPI values are used in determining the FbRPM/LdRPM ratio (see the formula given above in the RPM Ratio discussion). When the RPM ratio runs on averages of measured PPI values instead of constant values that differ from the actual PPI values, the magnitude of index-phase corrections is reduced, resulting in smoother operation.  
When not enabled, the constant PPI values of Var01.07 and Var01.08 are used.

Index Matching and effective Index Pulses:

- The ratio (Var01.10/Var01.11) defines an index match pattern: Var01.10 feedback index pulses get matched with Var01.11 lead index pulses. For most applications, these two variables are each set to 1 (feedback and lead index pulses occur 1:1). In these cases, each lead pulse is *effective* and each feedback pulse is *effective*. That is to say each feedback pulse causes index phase measurement and (if necessary) correction, and each lead index pulse gets corrected to.
- In some applications, it is necessary to match index pulses in a non 1:1 pattern. Var01.10 (Feedback index pulses per match) and Var01.11 (Lead index pulse per match) accommodate these applications by accepting integer values from 1 to 21474. Generally speaking, **n** (Var01.10) feedback index pulses get matched to **m** (Var01.11) lead index pulses in a **n:m** pattern with every nth feedback index pulse and every mth lead index pulse *effective*.

# Jog Mode

## Description:

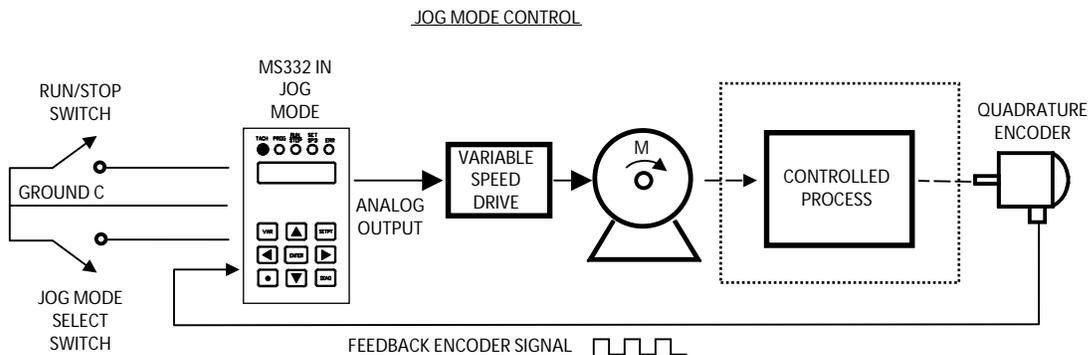
Input hardware:

- Jog mode may use a single quadrature-output incremental encoder on the driven shaft.

Operation:

- Jog mode is a simple *open-loop* mode similar to a speed pot where the output voltage is proportional to the Jog speed set-point. Although an encoder is generally connected for display purposes, Jog mode does not use encoder pulses to drive the encoder RPM to the set-point determined RPM but instead outputs a set-point determined voltage independent of actual encoder RPM.
- When using a bidirectional drive and motor, forward and reverse Jog mode operation may be achieved by utilizing the Reverse Switch Input Function.

The basic connections necessary for Jog mode (including an optional feedback encoder) are as shown in the following diagram:



## Control Theory:

Open-loop analog output formula:

- The Jog mode analog *output voltage* obeys the following formula:

$$V_{out} = [V(90\% \text{ DAC}) - V(0\% \text{ DAC})] * [(\text{Jog set-point RPM}) / (\text{Var01.00})] + V(0\% \text{ DAC})$$

Jog set-point:

- The Jog mode set-point should always be entered in feedback encoder RPM units.

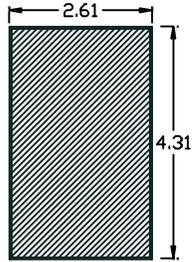
# MS332 Physical Installation Section

## Standard Panel Mount Installation

The MS332 comes standard with (2) mounting brackets for through-hole panel mounting.

### Panel-Cutout Dimensions:

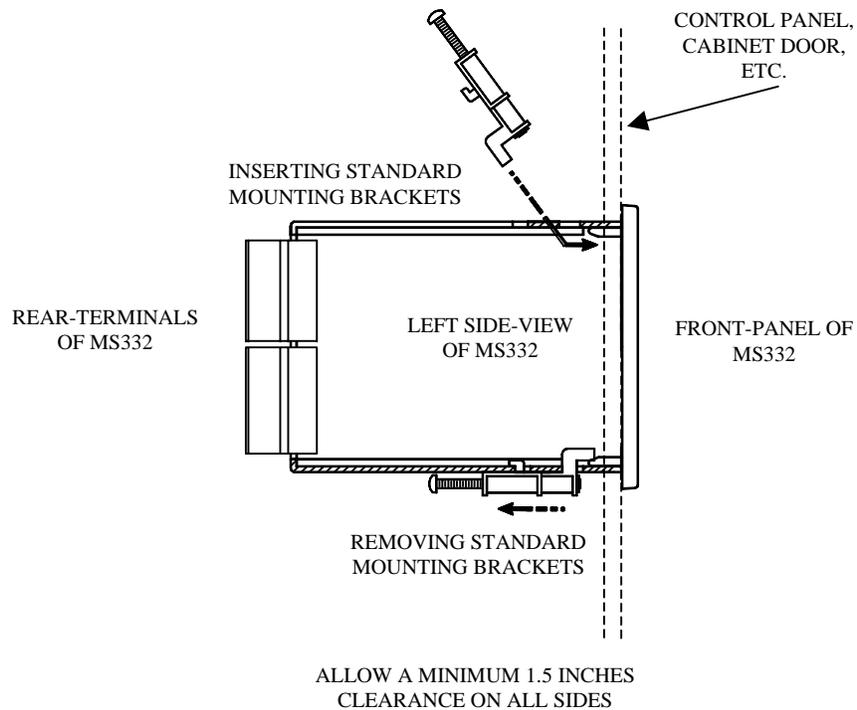
Panel-Cutout Thru-Hole Dimensions (in inches)



Note: Maximum panel thickness: 0.5 in ( 1.27 cm )

### Installation:

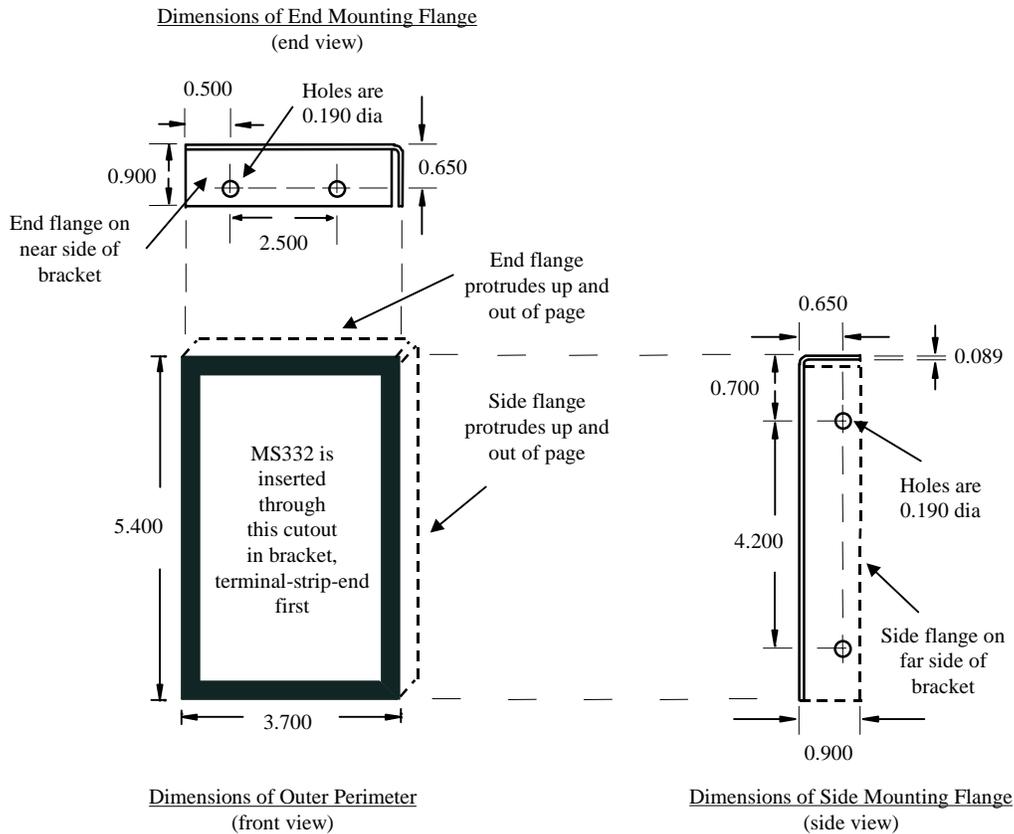
- Remove the (2) Standard Mounting Brackets from MS332.
- Slide MS332 (rear-terminals first) into the control panel cut-out.
- Replace the Standard Mounting Brackets and tighten screws (do not overtighten).



# Optional Side-Mount Bracket Installation

The optional Side-Mount Bracket provides alternatives to standard panel mounting such as attaching the MS332 to the back or inside wall of a control cabinet. With the Side-Mount Bracket, the MS332 may be installed in any orientation. One common usage is mounting the entire MS332 inside a control cabinet, away from view.

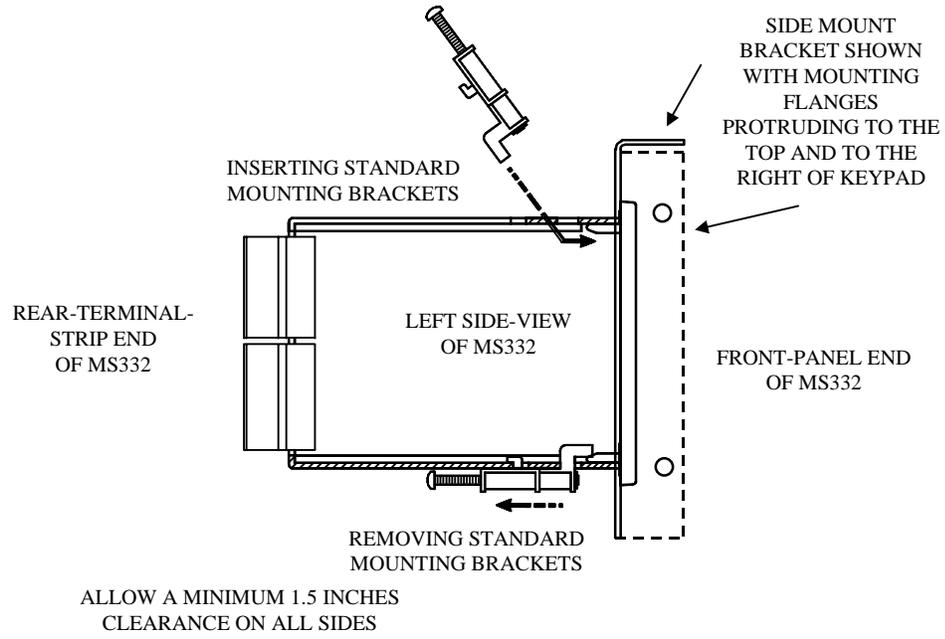
## Side-Mount Bracket Dimensions (in inches):



## Optional Side-Mount Bracket Installation (cont.)

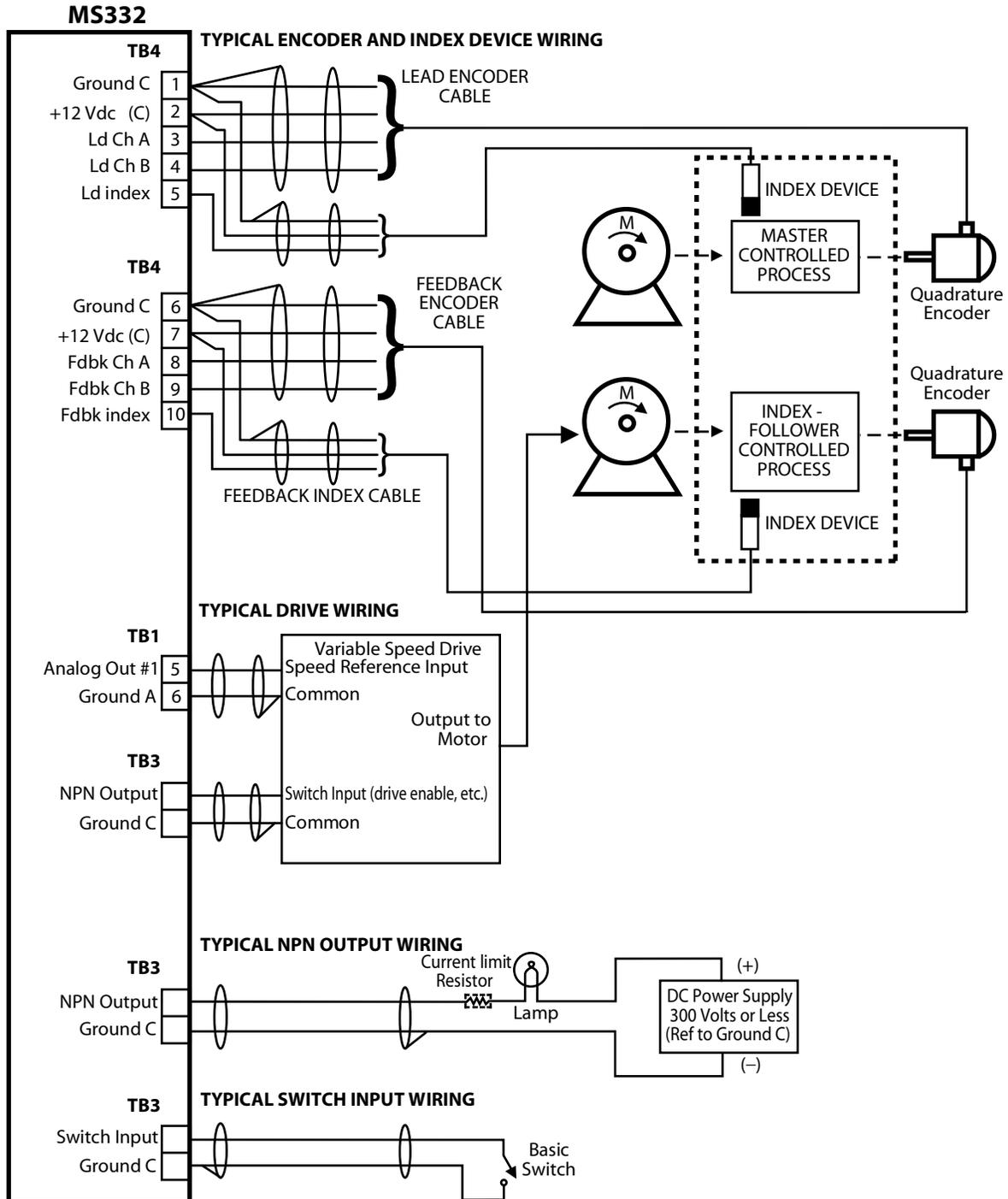
### Installation:

- The MS332 attaches to the Side-Mount Bracket using the Standard Mounting Brackets in the same way it attaches into a panel cut-out. The Side-Mount Bracket attaches to a mounting surface using the mounting screw holes in either the end or side flanges.



# Wiring

This diagram shows typical signal wiring, shielding and connections:



**Notes:** This diagram shows proper wiring of signals, devices, d.c. power, commons and cable-shields for all types of MS332 signal inputs and outputs. No specific MS332 Operating Mode or external device configuration is intentionally suggested. For a given application, the actual devices utilized depend on both the selected MS332 Operating Mode and the specific needs of the application.

## Wiring (cont.)

Wiring guidelines:

- 1) **Use shielded cable for signals.** Connect the shield to signal common at the receiving end only. See the wiring diagram on the previous page.
- 2) **Use separate cables for separate sensors.** Don't run signals from multiple sensors/sources through a shared multi-conductor cable. Each sensor/source should run its signal(s) through a dedicated cable. See the wiring diagram on the previous page.
- 3) **Never use signal cable with unused conductors.** Unused conductors can induce noise onto the signal conductors. Always use a shielded cable with the correct number of conductors.
- 4) **Physically separate signal cables from power cables.** Do not bundle signal and power cables together or route them through the same conduit or wire trays. Power wiring includes any AC or DC with current greater than 1 amp or voltage greater than 24 volts, such as 115 VAC, 230 VAC, 460 VAC, armatures, fields, and ignition wires.
- 5) **Do not run signal cables near high magnetic or electrostatic generators.** This includes motors, fans, power-switching devices, contactors and ignitors. Aluminum shielded cable does not stop magnetic noise and braided shielded cable only partially reduces magnetic noise. Neither can stop all noise or eliminate the need for good signal routing. Do not run signal cables (encoders, prox sensors, analog sensor or control signals, etc.) along a motor case or in the same conduit as motor power.
- 6) **Properly connect the input power earth ground.** Use a proper earth ground. Earth ground is used by internal noise rejection circuitry.
- 7) **Use a series resistor-capacitor type noise suppressor across the coils of contactors, solenoids and relays sharing AC power with, or in the same enclosure (panel) as the controller.** These devices greatly reduce conducted noise on the power line. They are available in two terminal packages.
- 8) **When stepping power down from a higher AC voltage, use a line filter at the transformer secondary.**
- 9) **Tighten the terminal plug screws to 2.2 lb-in (0.25 N-m) torque for all wired terminals.**

# MS332 Set-up Section (bA02.XX)

## Master Mode (Set-up Procedure)

### Description:

See 'Description of Operating Modes Section \Master Mode' for a block diagram and discussion of Master Mode Operation.

### Set-up Procedure:

#### 1) Motor-Drive adjustment settings:

- Adjust the drive settings to match the motor according to the drive instructions.
  - Set the maximum motor-drive speed to approximately 10% higher than your process maximum speed. This provides some over-speed capability to the MS332 so it can close the loop at your process maximum speed.
  - Set the acceleration/deceleration settings to the minimum time settings (fastest).
- These adjustments minimize limitations imposed on the control loop by the drive, thereby allowing the MS332 more control.

#### 2) Electrical connections:

**Note:** Do not apply power to the MS332 yet.

Connect all necessary components for Master Mode Operation. (See 'Description of Operating Modes Section \Master Mode' for a block diagram showing basic necessary components). For details about terminal connections and terminal strips, see the following:

- See 'Reference Section \Hardware Illustrations' for a general Rear-View diagram, showing the MS332 terminal strips and the individual pin-outs.
- See 'Reference Section \Encoder-Index Inputs, Power Supply Outputs \Terminal Connections' for a further detailed diagram, showing the Encoder connections.
- See 'Reference Section \Switch Inputs \Terminal Connections' for a further detailed diagram, showing the connections available for the Run/Stop switch.
- See 'Reference Section \Analog Output \Terminal Connections' for a further detailed diagram, showing the Analog Output connections.
- See 'Physical Installation Section \Wiring' for details on proper wiring, shielding, grounding, etc.

3) **MS332 DIP Switch settings (bA02.XX):**

**Note:** Do not apply power to the MS332 until the DIP Switches have been set.

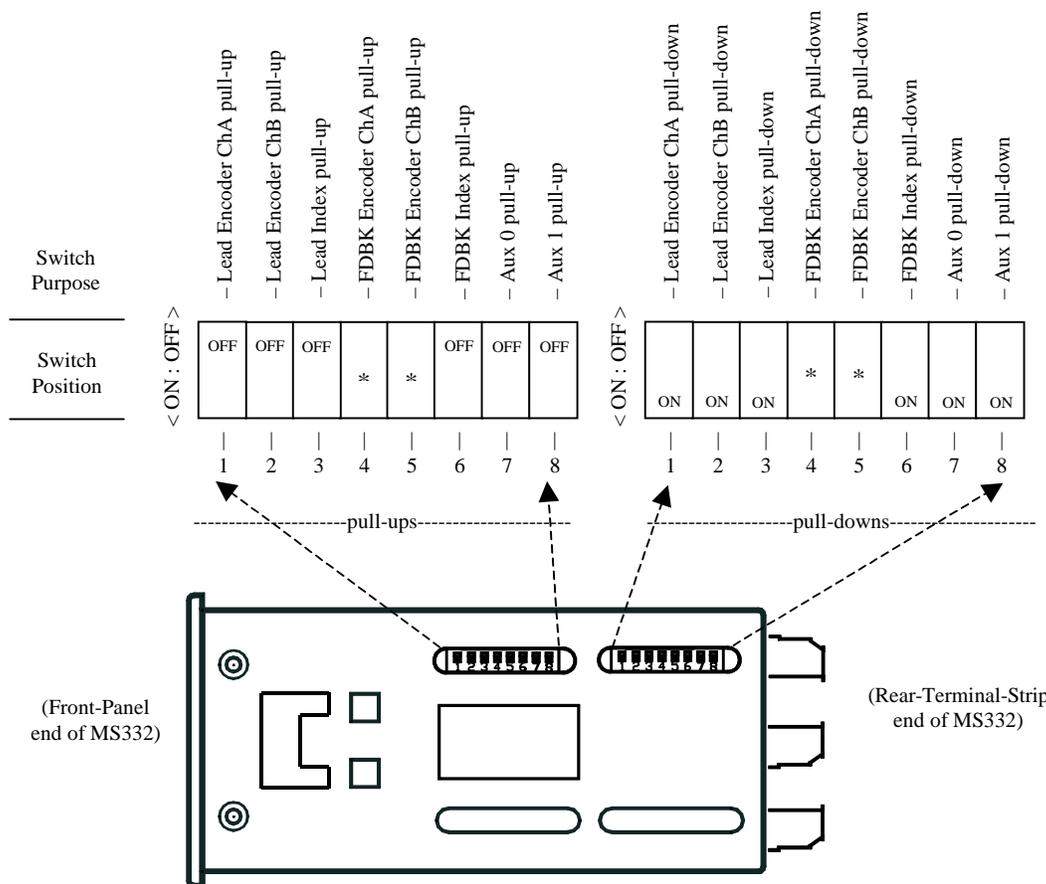
**DIP Switch Diagram for Master Mode**

This diagram shows the MS332 DIP switches (looking down on top of the MS332, front-panel on the left). Do steps (a) and (b) to set all of the MS332 DIP Switches:

- a) DIP switches corresponding to unused inputs (Leads, Indexes, Aux 0, Aux 1) are shown in this diagram in their default ON/OFF positions. Set these DIP switches to their default positions.
- b) DIP switches corresponding to inputs used by Master mode are shown in this diagram with an asterisk. Each used input must have its *Pull-up* and *Pull-down* DIP switches configured for the type of device driving it. Configure each input's DIP switches according to the following table:

Driving Device	Pull-up DIP Switch	Pull-down DIP Switch	Notes
NPN	ON	OFF	Input provides pull-up to +12C.
PNP	OFF	ON	Input provides pull-down to Ground C.
TTL/CMOS Gate	OFF	OFF	Hi-Z input.
Daisy-chained Lead encoder (any type)	OFF	OFF	Hi-Z input doesn't load signal or provide pull-up or pull-down.

See 'Reference Section \Encoder-Index Inputs, Power Supply Outputs \DIP Switches' for details on the DIP switches.



- c) Apply power to the MS332.

#### 4) Encoder PPR, Max set-point value, Max RPM:

##### a) Var01.02 - Feedback Encoder PPR

Enter the feedback encoder's pulses per revolution value into Var01.02.

##### b) Var01.01 - Process Max Feedback Encoder RPM in User Units

Enter the maximum process output RPM in user units into Var01.01. This sets the units and maximum value for the Master Mode set-point. To use RPM units, enter your process maximum feedback encoder rpm.

**Note:** Var01.01 sets the units for speed set-points, speed scroll step, certain NPN Output alarm thresholds, as well as the decimal point position of the Feedback Encoder Speed In User Units display option (Var05.00 option code 0).

##### c) Var01.00 – Process Maximum Feedback Encoder RPM

This variable must hold the encoder RPM corresponding to Var01.01 (the maximum process output). Enter this value into Var01.00.

**Note:** Var01.01 must be set to the maximum process output RPM *in user units* for the application.

- Applications using RPM user units have Var01.00 set to the *same value* as Var01.01 (the user units are RPM).

- Applications using *non-RPM* user units require entering Var01.01's value *converted to RPM units* into Var01.00. This value will be numerically different from Var01.01's value but will represent the same maximum process output. See the Example in - **Setting up Var01.00 and Var01.01 for non-RPM User Units** at the end of this Master mode set-up section.

#### 5) Set-up for Motor-Drive Compatibility:

##### a) Non-Contactor Reversing Drives (input voltage alone controls both speed and direction of rotation):

Do not assign the Contactor Reverse NPN Output function (code 14 should not be entered into any of the function assignment variables [Vars04.00 to 04.03]). This configures the MS332 analog output voltage to swing bipolar (positive or negative voltage swing from the offset voltage).

##### b) Contactor Reversing Drives (a positive voltage controls speed, a contactor input determines direction of rotation):

Assign the Contactor Reverse NPN Output function to an NPN Output (enter code 14 into one of the NPN Output function assignment variables [Vars04.00 to 04.03]). This configures the MS332 analog output voltage to swing unipolar (positive voltage swing from the offset voltage) for speed control and enables the selected NPN Output to control rotation direction (NPN Output OFF = Fwd; ON = Rev).

**Note:** There are various contactor-input configurations and polarities among the various contactor reversing type drives, so direct MS332 NPN Output to drive contact-input control may or may not be possible. For drives incompatible with direct MS332 NPN Output control, a relay can be used between the MS332 NPN Output and the drive contact-input(s) to achieve compatibility.

**See** 'Set-up Section \NPN Outputs' for details on how to set-up NPN Outputs.

**See** 'Reference Section \NPN Outputs' for more information on the Contactor Reverse Function.

**See** 'Reference Section \Analog Output' for more information on Drive Compatibility.

#### 6) Encoder Test:

To avoid wasted set-up time, it is important to verify that the Feedback encoder channel A and B (quadrature) lines are not improperly ordered (reversed).

##### a) Feedback Encoder A/B channel test

- Enter 2 into Var05.00 (display Feedback encoder frequency in Hz).

- With the MS332 Run/Stop switch OPEN (Stop), rotate the Feedback Encoder shaft in the forward direction (relative to the process) while observing the MS332 display.

- The display should show a positive value. If the display shows a negative value, swap the Feedback Encoder channel A and B wires at TB4 - 8 and TB4 - 9.

7) **Analog Output Calibration:**

- a) Use the Analog Output Calibration Utility to set the **Offset** for no feedback encoder rotation (0 RPM) while **Pc Dac** is 000.0.
- b) Use the Analog Output Calibration Utility to set the **Scale** to turn the feedback encoder at Var01.00 Process Maximum Feedback Encoder RPM while **Pc Dac** is 090.0.

**See** 'Reference Section \Keypad \Keypad Menus \Diagnostic Menu \Analog Output Calibration Utility' for details on calibration.

8) **Operational Variables:**

- a) **Var03.00 - PID Tuning-Proportional Gain**  
Enter the default value of 32 for an initial value. Adjustments can be made later in step 9.
- b) **Var03.01 - PID Tuning-Integral Time Constant**  
Enter the default value of 2.0s for an initial value. Adjustments can be made later if needed.
- c) **Var03.02 - PID Tuning-Derivative Gain**  
Enter the default value of 0 to disable derivative compensation.

**See** 'Reference Section \Operational Variables \PID Compensation' for details on PID Vars.

- d) **Var07.13 - Master/Follower Mode Select**

Enter 1 for Master mode operation.

- e) **Setting the Active Master Mode Speed Set-point:**

**Note:** Master mode set-points must be entered in the same units as Var01.01.

Master mode set-points set the speed according to this formula:

$$\text{desired Feedback RPM} = (\text{Set-point}) * (\text{Var01.00} / \text{Var01.01})$$

Enter your desired value into the active set-point (the allowed range is from 0 to Var01.01).

**Notes:**

- The active set-point may be changed via the Change Set-point Menu or by Scrolling.
- The factory-default configuration selects SP00 (the first of the four Master mode set-points) as the active set-point and sets its default value to 1000.

**See** 'Reference Section \Keypad \Keypad Menus' for details on the Change Set-point Menu.

**See** 'Reference Section \Scrolling' for details on Scrolling.

**See** 'Reference Section \Operational Variables \Active Set-point Selection' for details on using **Var06.13** to select the active set-point.

**See** 'Reference Section \Switch Inputs' for details on using Switch Inputs to select the active set-point.

- f) **Acceleration/ Deceleration Ramp Times (Vars02.00 to 02.03)**

**Notes:** Ramp times set the ramp rate and are entered in units of seconds. The time entered is the time to ramp from 0 to Var01.00 MAX RPM (acceleration) or from Var01.00 MAX RPM to 0 (deceleration).

- Var02.00, Var02.01 are acceleration time variables.
- Var02.02, Var02.03 are deceleration time variables.
- Var02.00, Var02.02 form a pair and Var02.01, Var02.03 form a pair.
- The factory-default *active pair* is Var02.00, Var02.02.

Enter your desired acceleration and deceleration ramp times.

**See** 'Reference Section \Operational Variables \Acceleration and Deceleration Ramps' for details on using **Var02.05** to select the active Acceleration/Deceleration Ramp Pair using the keypad.

**See** 'Reference Section \Switch Inputs' for details on selecting the active Acceleration/Deceleration Ramp Pair using a Switch Input.

**9) PID Proportional Gain and Integral Time adjustments:**

a) **Var05.00 - Display Selection**

Enter code 5 to choose closed-loop feedback error.

b) Close the Run/Stop switch. Observe the feedback behavior at the top of the acceleration ramp and while it runs steady-state.

- If the feedback encoder response is unstable (large, erratic displayed error, motor jerking/oscillating), try reducing Var03.00's value (proportional gain). If the feedback encoder response is sluggish (large, slow-changing displayed error), try increasing Var03.00's value.
- If the Var03.00 changes don't significantly improve the feedback encoder response, or if they get to a point of diminishing-return, try adjusting Var03.01 (integral time constant). Higher Var03.01 values will improve loop-stability, lower Var03.01 values will increase loop-responsiveness.
- Generally speaking, it is desirable to have Var03.00 as large as possible and Var03.01 as small as possible - this will result in the tightest, most responsive control. However if Var03.00 is set too high and/or Var03.01 is set too low, the feedback loop will become unstable. Open the Run/Stop switch. Repeat (b) several times.

**Notes:**

- *Higher* Proportional Gain (Var03.00) values make proportional compensation more aggressive (up to a certain max value, then causing loop instability above that value).
- *Lower* Integral Time Constant (Var03.01) values make integral compensation more aggressive (down to a certain min value, then causing loop instability below that value).
- With the PID properly adjusted, the displayed feedback error should drive towards zero at an acceptable rate (determined by Var03.01) after the ramp. After that, the feedback error should stay zero (or small and centered around zero).

**10) Display Selection:**

**Var05.00** – Enter the selection code for the desired real-time display.

**Note:** Most Master mode applications use code 0 (Feedback Encoder Speed in User Units).

**See** 'Reference Section \Display \Display Window Variables' for details on Var05.00 selection codes.

**11) Setting-up Var01.00 and Var01.01 for non-RPM User Units:**

Applications using *non*-RPM user units (such as threads/min, gallons/hr) require entering Var01.01's value *converted to RPM units* into Var01.00. This value will be numerically different from Var01.01's value but will represent the same maximum process output.

**Example (Master mode):**

An MS332 is to control a water pump. We want to use gallons-per-hour (GPH) for both the set-point and display units.

**Known:** The required process maximum flow is 90.0 GPH.

The pump is rated to deliver 100 GPH when its shaft is rotating 1500 RPM. Therefore, our conversion factor is 1500 RPM / 100 GPH.

In this example, our user units are GPH and our application's maximum process output in user units is 90 GPH.

**Steps:**

- 1) The process output is flow (measured in GPH). The maximum process output is 90.0 GPH, so enter 90.0 into Var01.01.
- 2) Determine the process maximum feedback encoder RPM (Var01.00) from the maximum process output:  
$$\text{Var01.00 value} = (90 \text{ GPH}) * (1500 \text{ RPM} / 100 \text{ GPH}) = 1350 \text{ RPM}$$
Enter 1350 into Var01.00.

Now set-points between 0 and 90.0 GPH may be used and the display will read in units of GPH.

# Ratio-Follower Mode (Set-up Procedure)

## Description:

See 'Description of Operating Modes Section \Ratio-Follower Mode' for a block diagram and discussion of Ratio-Follower Mode Operation.

## Set-up Procedure:

### 1) Follower Motor-Drive adjustment settings:

- Adjust the drive settings to match the motor according to the drive instructions.
- Set the follower motor-drive's maximum motor speed to approximately 10% higher than your process maximum speed. This provides some over-speed capability to the MS332 so it can close the loop at your process maximum follower speed.
- Set the acceleration/deceleration settings to the minimum time settings (fastest).

These adjustments minimize limitations imposed on the control loop by the drive, thereby allowing the MS332 more control.

### 2) Electrical connections:

**Note:** Do not apply power to the MS332 yet.

Connect all necessary components for Ratio-Follower Mode Operation. (See 'Description of Operating Modes Section \Ratio-Follower Mode' for a block diagram showing basic necessary components). For details about terminal connections and terminal strips, see the following:

- See 'Reference Section \Hardware Illustrations' for a general Rear-View diagram, showing the MS332 terminal strips and the individual pin-outs.
- See 'Reference Section \Encoder-Index Inputs, Power Supply Outputs \Terminal Connections' for a further detailed diagram, showing the Encoder connections.
- See 'Reference Section \Switch Inputs \Terminal Connections' for a further detailed diagram, showing the connections available for the Run/Stop switch.
- See 'Reference Section \Analog Output \Terminal Connections' for a further detailed diagram, showing the Analog Output connections.
- See 'Physical Installation Section \Wiring' for details on proper wiring, shielding, grounding, etc.

3) **MS332 DIP Switch settings (bA02.XX):**

**Note:** Do not apply power to the MS332 until the DIP Switches have been set.

**DIP Switch Diagram for Ratio-Follower Mode**

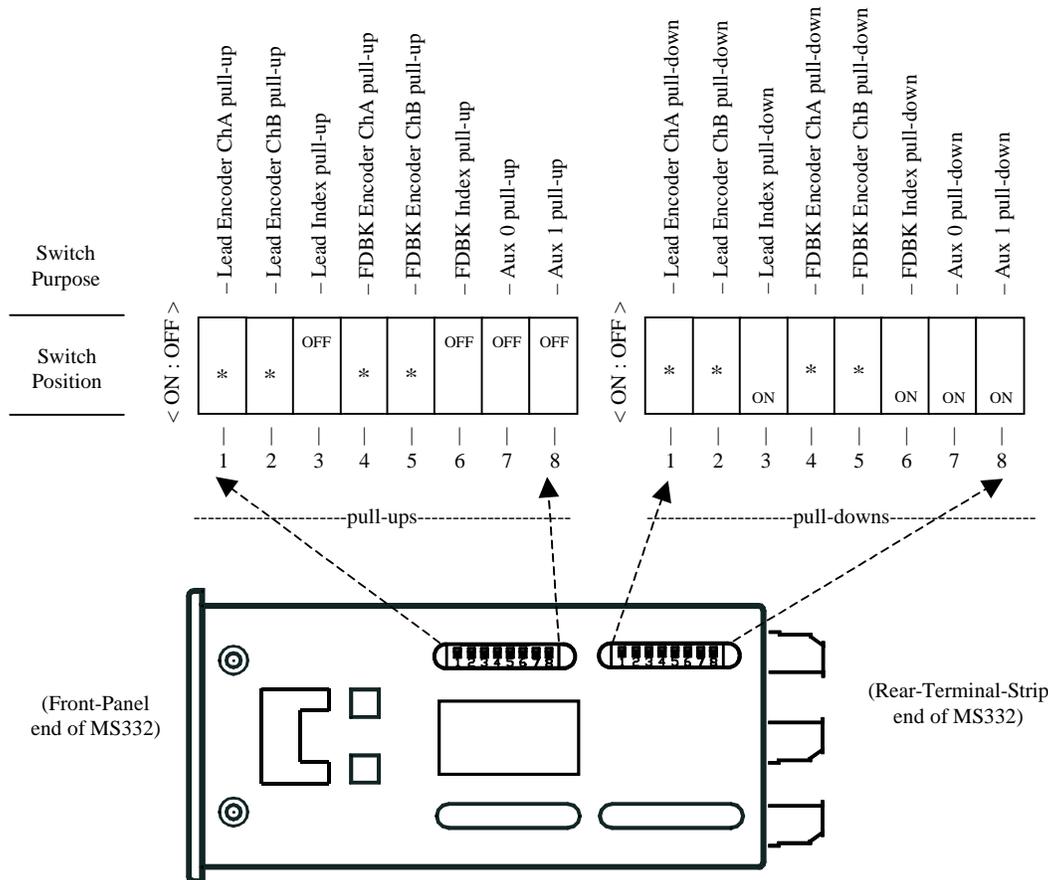
This diagram shows the MS332 DIP switches (looking down on top of the MS332, front-panel on the left).

Do steps (a) and (b) to set all of the MS332 DIP Switches:

- a) DIP switches corresponding to unused inputs (Indexes, Aux 0, Aux 1) are shown in this diagram in their default ON/OFF positions. Set these DIP switches to their default positions.
- b) DIP switches corresponding to inputs used by Ratio-Follower mode are shown in this diagram with an asterisk. Each used input must have its *Pull-up* and *Pull-down* DIP switches configured for the type of device driving it. Configure each input's DIP switches according to the following table:

Driving Device	Pull-up DIP Switch	Pull-down DIP Switch	Notes
NPN	ON	OFF	Input provides pull-up to +12C.
PNP	OFF	ON	Input provides pull-down to Ground C.
TTL/CMOS Gate	OFF	OFF	Hi-Z input.
Daisy-chained Lead encoder (any type)	OFF	OFF	Hi-Z input doesn't load signal or provide pull-up or pull-down.

See Reference Section (Encoder-Index Inputs, Power Supply Outputs \DIP Switches' for details on the DIP switches.



- c) Apply power to the MS332.

**4) Encoder PPRs, Max RPMs and Max set-point value:**

a) **Var01.05 - Lead Encoder PPR**

Enter the lead encoder's pulses per revolution value into Var01.05.

b) **Var01.03 – Process Maximum Lead Encoder RPM**

Enter the maximum expected lead encoder RPM for the process into Var01.03. This value may be known or it may have to be converted from lead process units into lead RPM. See example at end of this Ratio-Follower mode set-up section.

c) **Var01.04 – (Process Max Feedback Encoder RPM / Process Max Lead Encoder RPM) in User Units**

The (output) feedback follower RPM to (input) lead RPM relationship is given by the equation:

$$\frac{\text{FbRPM}}{\text{LdRPM}} = \text{Set-point} * [(\text{Var01.00} / \text{Var01.03}) / \text{Var01.04}]$$

This shows FbRPM/LdRPM to be the Feedback/Lead ratio of process max encoder RPMs (Var01.00 / Var01.03) scaled by the factor (Set-point/Var01.04).

Var01.04 configures the *units* in which speed ratio set-points are entered and sets the max set-point value.

To use "unitless" RPM ratio user units, set Var01.04 equal to Var01.00 / Var01.03. The set-point value may range from 0 to Var01.04.

**Notes:**

- Var01.04 also determines the units of Ratio-Follower set-point scroll steps and NPN Output speed ratio alarm threshold parameters.
- The decimal pt. position entered into Var01.04 determines the decimal pt. position for the Follower Ratio in User Units display option (Var05.00 option code 1).

Enter the [Process Max Feedback Encoder RPM / Process Max Lead Encoder RPM] in User Units into Var01.04.

d) **Var01.02 - Feedback (follower) Encoder PPR**

Enter the feedback encoder's pulses per revolution value into Var01.02.

e) **Var01.00 – Process Maximum Feedback (follower) Encoder RPM**

Generally speaking, this value must be calculated from known information. The feedback encoder will turn at the Process Maximum Feedback Encoder RPM when the *lead encoder* is running at its Process Maximum Lead Encoder RPM (Var01.03's value) *and* the ratio set-point is set to its maximum (Var01.04's value).

Enter the process maximum feedback encoder RPM into Var01.00.

**Note:** See example at end of this Ratio-Follower mode set-up section.

f) **Var01.01 - Process Max Feedback Encoder RPM in User Units**

For Ratio-Follower applications, enter the same value into Var01.01 that was entered into Var01.00.

**5) Set-up for Motor-Drive Compatibility:**

a) **Non-Contactor Reversing Drives** (input voltage alone controls both speed and direction of rotation):

Do not assign the Contactor Reverse NPN Output function (code 14 should not be entered into any of the function assignment variables [Vars04.00 to 04.03]). This configures the MS332 analog output voltage to swing bipolar (positive or negative voltage swing from the offset voltage).

b) **Contactor Reversing Drives** (a positive voltage controls speed, a contactor input determines direction of rotation):

Assign the Contactor Reverse NPN Output function to an NPN Output (enter code 14 into one of the NPN Output function assignment variables [Vars04.00 to 04.03]). This configures the MS332 analog output voltage to swing unipolar (positive voltage swing from the offset voltage) for speed control and enables the selected NPN Output to control rotation direction (NPN Output OFF = Fwd; ON = Rev).

**Note:** There are various contactor-input configurations and polarities among the various contactor-reversing type drives, so direct MS332 NPN Output to drive contact-input control may or may not be possible. For drives incompatible with direct MS332 NPN Output control, a relay can be used between the MS332 NPN Output and the drive contact-input(s) to achieve compatibility.

**See** 'Set-up Section \NPN Outputs' for details on how to set-up NPN Outputs.

**See** 'Reference Section \NPN Outputs' for more information on the Contactor Reverse Function.

**See** 'Reference Section \Analog Output' for more information on Drive Compatibility.

**6) Encoder Test:**

To avoid wasted set-up time, it is important to verify that both the Feedback and Lead encoder channel A and B (quadrature) lines are not improperly ordered (reversed).

a) **Feedback Encoder A/B channel test**

- Enter 2 into Var05.00 (display Feedback encoder frequency in Hz).
- With the MS332 Run/Stop switch OPEN (Stop), rotate the Feedback Encoder shaft in the forward direction (relative to the process) while observing the MS332 display.
- The display should show a positive value. If the display shows a negative value, swap the Feedback Encoder channel A and B wires at TB4 - 8 and TB4 - 9.

b) **Lead Encoder A/B channel test**

- Enter 3 into Var05.00 (display Lead encoder frequency in Hz).
- With the MS332 Run/Stop switch OPEN (Stop), rotate the Lead Encoder shaft in the forward direction (relative to the process) while observing the MS332 display.
- The display should show a positive value. If the display shows a negative value, swap the Lead Encoder channel A and B wires at TB4 - 3 and TB4 - 4.

**7) Analog Output Calibration:**

- a) Use the Analog Output Calibration Utility to set the **Offset** for no feedback encoder rotation (0 RPM) while **Pc Dac** is 000.0.
- b) Use the Analog Output Calibration Utility to set the **Scale** to turn the feedback encoder at Var01.00 Process Maximum Feedback Encoder RPM while **Pc Dac** is 090.0.

See 'Reference Section \Keypad \Keypad Menus \Diagnostic Menu \Analog Output Calibration Utility' for details on calibration.

**8) Operational Variables:**

a) **Var03.00 - PID Tuning-Proportional Gain**

Enter the default value of 32 for an initial value. Adjustments will be made later in step 9.

b) **Var03.01 - PID Tuning-Integral Time Constant**

Enter the default value of 2.0s for an initial value. Adjustments will be made later in step 9.

c) **Var03.02 - PID Tuning-Derivative Gain**

Enter the default value of 0 to disable derivative compensation.

d) **Var03.04 – Zero Lead Speed PID Control**

Enter the code to select desired zero lead speed PID operation. The factory-default is code 0.

See 'Reference Section \Operational Variables \PID Compensation' for details on PID Vars.

e) **Var07.13 - Master/Follower Mode Select**

Enter 0 for follower mode operation.

f) **Var01.06 - Follower Mode Configuration**

Enter 0, for Ratio-Follower mode.

g) **Setting the Active Ratio-Follower Speed Ratio Set-point:**

**Note:** Ratio-Follower mode set-points must be entered using the *user units* determined by Var01.04.

Ratio-Follower mode set-points set the *Feedback/Lead* speed ratio according to this formula:

$$\frac{\text{Feedback RPM} / \text{Lead RPM}}{(\text{Process Max Feedback RPM} / \text{Process Max Lead RPM}) * (\text{Ratio Set-point} / \text{Var01.04})}$$

Therefore:

$$\frac{\text{Ratio Set-point}}{(\text{desired Feedback RPM} / \text{Lead RPM}) * (\text{Process Max Lead RPM} / \text{Process Max Feedback RPM}) * (\text{Var01.04})}$$

Enter your desired value into the active set-point (the allowed range is from 0 to Var01.04).

**Notes:**

- The active set-point may be changed via the Change Set-point Menu or by Scrolling.
- The factory-default configuration selects SP04 (the first of the four Ratio-Follower mode set-points) as the active set-point and sets its default value to 1.000.
- See example at end of this Ratio-Follower mode set-up section.

See 'Reference Section \Keypad \Keypad Menus' for details on the Change Set-point Menu.

See 'Reference Section \Scrolling' for details on Scrolling.

**See** 'Reference Section \Operational Variables \Active Set-point Selection' for details on using **Var06.14** to select the active set-point.

**See** 'Reference Section \Switch Inputs' for details on using Switch Inputs to select the active set-point.

h) **Acceleration/ Deceleration Ramp Times (Vars02.00 to 02.03).**

**Notes:** Ramp times set the ramp rate and are entered in units of seconds. The time entered is the time to ramp from 0 to *Var01.00 MAX RPM* (acceleration) or from *Var01.00 MAX RPM* to 0 (deceleration).

- Var02.00, Var02.01 are acceleration time variables.
- Var02.02, Var02.03 are deceleration time variables.
- Var02.00, Var02.02 form a pair and Var02.01, Var02.03 form a pair.
- The factory-default *active pair* is Var02.00, Var02.02.

Enter your desired acceleration and deceleration ramp times.

**See** 'Reference Section \Operational Variables \Acceleration and Deceleration Ramps' for details on using **Var02.05** to select the active Acceleration/Deceleration Ramp Pair using the keypad.

**See** 'Reference Section \Switch Inputs' for details on selecting the active Acceleration/Deceleration Ramp Pair using a Switch Input.

9) **PID Proportional Gain and Integral Time adjustments:**

a) **Var05.00 - Display Selection**

Enter code 5 to choose closed-loop follower error.

b) Run the lead encoder at the process maximum value (Var01.03 RPM).

c) Close the Run/Stop switch (with the lead running). Observe the follower behavior at the top of the acceleration ramp and while it runs steady-state.

- If the feedback (follower) encoder response is unstable (large, erratic displayed error, motor jerking/oscillating), try reducing Var03.00's value (proportional gain). If the feedback (follower) encoder response is sluggish (large, slow-changing displayed error), try increasing Var03.00.
- If the Var03.00 changes don't significantly improve the feedback (follower) encoder response, or if they get to a point of diminishing-return, try adjusting Var03.01 (integral time constant). Higher Var03.01 values will improve loop-stability, lower Var03.01 values increase loop-responsiveness.
- Generally speaking, it is desirable to have Var03.00 as large as possible and Var03.01 as small as possible - this will result in the tightest, most responsive following. However if Var03.00 is set too high and/or Var03.01 is set too low, the follower loop will become unstable. Open the Run/Stop switch. Repeat (c) several times.

**Notes:**

- *Higher* Proportional Gain (Var03.00) values make proportional compensation more aggressive (up to a certain max value, then causing loop instability above that value).
- *Lower* Integral Time Constant (Var03.01) values make integral compensation more aggressive (down to a certain min value, then causing loop instability below that value).
- With the PID properly adjusted, the displayed following error should drive towards zero at an acceptable rate (determined by Var03.01) after the ramp. After that, the following error should stay zero (or small and centered around zero).

10) **Display selection**

Var05.00 - Enter the selection code for the desired real-time display.

**Note:** Most Ratio-Follower mode applications use code 1 (Follower Ratio in User Units) or code 5 (Closed-loop Error in feedback encoder pulses).

**See** 'Reference Section \Display \Display Window Variables' for details on Var05.00 selection codes.

**11) Example (Ratio-Follower mode):**

A continuous-duty wastewater treatment system requires that neutralizer solution be precisely dispensed in proportion to incoming wastewater flow. The maximum dispensing ratio will be 12.0 mL per L of wastewater.

The incoming wastewater flow is controlled by a motor-driven pump with an encoder on the motor shaft.

The neutralizer flow is also controlled by a motor-driven pump with an encoder on its motor shaft.

The MS332 will control the neutralizer pump with a set-point value entered in units of mL neutralizer per L wastewater.

**Known:**

Lead (wastewater) motor/encoder/pump:

Motor rated max speed: 1800 RPM  
Encoder: 60 PPR  
Pump characteristic: 0.5 L per shaft revolution.  
The lead pump will run at a maximum flow of 800 L/min

Follower (neutralizer) motor/encoder/pump:

Motor rated max speed: 1800 RPM  
Encoder: 60 PPR  
Pump characteristic: 10 mL per shaft revolution.  
The follower pump motor runs at an RPM determined by both the lead RPM *and* the selected (mL neutralizer / L wastewater) set-point.

**The Encoder PPRs, Max set-point value, and Max RPMs are set as follows for this example:**

Var01.05 - Lead Encoder PPR

Enter 60 (lead encoder PPR) into Var01.05.

Var01.03 – Process Maximum Lead Encoder RPM

We must convert the wastewater maximum flow of 800 L/min into lead RPM:

$(800 \text{ L/min}) * (1 \text{ shaft revolution} / 0.5 \text{ L}) = 1600 \text{ RPM.}$

Enter 1600 into Var01.03.

Note that this value is less than the lead motor's rated max of 1800 RPM.

Var01.04 - Max Ratio Set-point Value in User Units

We want to program the flow ratio in units of mL neutralizer per L wastewater, so we enter the required maximum of 12.0 mL neutralizer per L wastewater.

Enter 12.0 into Var01.04.

Var01.02 - Feedback (follower) Encoder PPR

Enter 60 (feedback encoder PPR) into Var01.02.

Var01.00 – Process Maximum Feedback Encoder RPM

This value must be calculated from known information. The feedback encoder will rotate at its process maximum RPM when the lead encoder rotates at its process maximum lead RPM *and* the set-point is at its maximum.

Process Max Feedback Encoder RPM =  
 $(800 \text{ L wastewater} / \text{min}) * (12.0 \text{ mL neutralizer} / \text{L wastewater}) * (1 \text{ follower rev} / 10 \text{ mL neutralizer})$   
= 960 follower rev / min.

Enter 960 into Var01.00.

Note that this value is less than the follower motor's rated max of 1800 RPM.

Var01.01 – Maximum Master Mode Set-point Value in User Units

Enter the same value into Var01.01 that was entered into Var01.00.

Now any setpoint value between 0.0 and 12.0 may be entered to set the follower pump's mL neutralizer per L wastewater dispensing ratio.

# Index-Follower Mode (Set-up Procedure)

## Description:

See 'Description of Operating Modes Section \Index-Follower Mode' for a block diagram and discussion of Index-Follower Mode Operation.

## Set-up Procedure:

### 1) Follower Motor-Drive adjustment settings:

- Adjust the drive settings to match the motor according to the drive instructions.
- Set the follower motor-drive's maximum motor speed to approximately 10% higher than your process maximum speed. This provides some over-speed capability to the MS332 so it can close the loop at your process maximum follower speed.
- Set the acceleration/deceleration settings to the minimum time settings (fastest).

These adjustments minimize limitations imposed on the control loop by the drive, thereby allowing the MS332 more control.

### 2) Electrical connections:

**Note:** Do not apply power to the MS332 yet.

Connect all necessary components for Index-Follower Mode Operation. Connect a small wire from the rear-panel TB3-3 (Switch Input 1) to TB3-5 (Ground C). This will serve as a *closed switch* to the Closed-loop/Open-loop Switch Input Function (more on this in step 7). (See 'Description of Operating Modes Section \Index-Follower Mode' for a block diagram showing basic necessary components).

For details about terminal connections and terminal strips, see the following:

- See 'Reference Section \Hardware Illustrations' for a general Rear-View diagram, showing the MS332 terminal strips and the individual pin-outs.
- See 'Reference Section \Encoder-Index Inputs, Power Supply Outputs \Terminal Connections' for a further detailed diagram, showing the Encoder/Index connections.
- See 'Reference Section \Switch Inputs \Terminal Connections' for a further detailed diagram, showing the connections available for the Run/Stop switch and the Closed-loop/Open-loop switch.
- See 'Reference Section \Analog Output \Terminal Connections' for a further detailed diagram, showing the Analog Output connections.
- See 'Physical Installation Section \Wiring' for details on proper wiring, shielding, grounding, etc.

3) **MS332 DIP Switch settings (bA02.XX):**

**Note:** Do not apply power to the MS332 until the DIP Switches have been set.

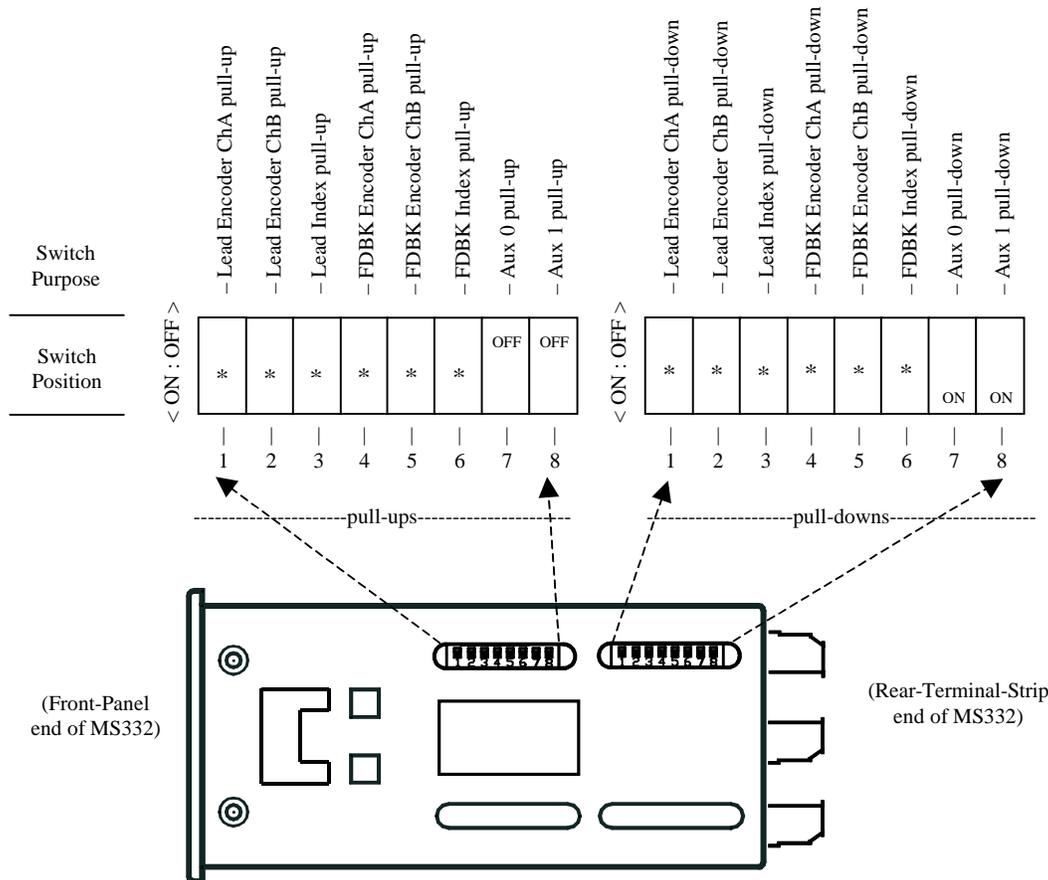
**DIP Switch Diagram for Index-Follower Mode**

This diagram shows the MS332 DIP switches (looking down on top of the MS332, front-panel on the left). Do steps (a) and (b) to set all of the MS332 DIP Switches:

- a) DIP switches corresponding to unused inputs (Aux 0, Aux 1) are shown in this diagram in their default ON/OFF positions. Set these DIP switches to their default positions.
- b) DIP switches corresponding to inputs used by Index-Follower mode are shown in this diagram with an asterisk. Each used input must have its *Pull-up* and *Pull-down* DIP switches configured for the type of device driving it. Configure each input's DIP switches according to the following table:

Driving Device	Pull-up DIP Switch	Pull-down DIP Switch	Notes
NPN	ON	OFF	Input provides pull-up to +12C.
PNP	OFF	ON	Input provides pull-down to Ground C.
TTL/CMOS Gate	OFF	OFF	Hi-Z input.
Daisy-chained Lead encoder (any type)	OFF	OFF	Hi-Z input doesn't load signal or provide pull-up or pull-down.

See Reference Section (Encoder-Index Inputs, Power Supply Outputs \DIP Switches' for details on the DIP switches.



- c) Apply power to the MS332.

**4) Encoder, Index Averaging and Index Matching Variables:**

- a) **Var01.02 – Feedback (follower) Encoder PPR**  
Enter the feedback encoder's pulses per revolution.
- b) **Var01.05 - Lead Encoder PPR**  
Enter the lead encoder's pulses per revolution.
- c) **Var01.09 – Pulses per Index Measurement and Averaging Control**  
Enter 0.
- d) **Var01.07 - Feedback PPI**  
Enter the number of feedback encoder pulses per feedback index pulse.
- e) **Var01.08 - Lead PPI**  
Enter the number of lead encoder pulses per lead index pulse.

**Note:** If either (or both) the Var01.07 or 01.08 values are unknown, use the Encoder Pulses-Per-Index Learn utility to determine and enter the variable values. See 'Reference Section \Keypad \Keypad Menus \Diagnostics Menu \Encoder Pulses-Per-Index Learn Utility' for details.

- f) **Var01.10 - Feedback Index Pulses per Match**  
Enter the desired number of feedback index pulses per match.
- g) **Var01.11 - Lead Index Pulses per Match**  
Enter the desired number of lead index pulses per match.

**Note:** For 1:1 index matching, enter 1 into Var01.10, 1 into Var01.11;  
For 3:2 index matching, enter 3 into Var01.10, 2 into Var01.11; etc.

See 'Description of Operating Modes Section \Index-Follower Mode \Control Theory' for information on Index Matching.

h) **Var01.03 - Process Maximum Lead Encoder RPM**

Enter the maximum lead encoder RPM *for your process*.

**Note:** If this value is unknown, enter code 3 into Display Selection Var05.00 (display lead encoder speed in Hz), run the lead at the process maximum speed and record the lead frequency. Use the following formula to calculate the Var01.03 process maximum lead RPM:

$$\text{Var01.03 value} = (\text{measured max lead frequency in Hz}) * (60 / \text{Var01.05})$$

i) **Var01.00 - Process Maximum Feedback (follower) Encoder RPM**

**Note:** This is the feedback (follower) encoder RPM corresponding to the Process Maximum Lead Encoder RPM (Var01.03). If unknown, it can be calculated from the following formula:

$$\text{Var01.00 value} = (\text{Var01.03}) * (\text{Var01.07}/\text{Var01.02}) * (\text{Var01.05}/\text{Var01.08}) * (\text{Var01.10}/\text{Var01.11})$$

Enter this value into Var01.00.

j) **Var01.01 - Process Max Feedback Encoder RPM in User Units**

For Index-Follower applications, enter the same value into Var01.01 that was entered into Var01.00.

**5) Set-up for Motor-Drive Compatibility:**

- a) **Non-Contact Reversing Drives** (control voltage determines both speed and direction of motor rotation):  
For these drives, a positive control voltage rotates the motor in one direction while a negative control voltage rotates the motor in the opposite direction.  
Do not assign the Contactor Reverse NPN Output function (code 14 should not be entered into any of the function assignment variables [Vars04.00 to 04.03]). Leaving this function unassigned configures the MS332 analog output voltage to swing bipolar (positive or negative voltage swing from the offset voltage).
- b) **Contact Reversing Drives** (positive control voltage determines speed, contactor input determines direction of motor rotation):

Assign the Contactor Reverse NPN Output function to an NPN Output (enter code 14 into one of the NPN Output function assignment variables [Vars04.00 to 04.03]). This configures the MS332 analog output voltage to swing unipolar (positive voltage swing from the offset voltage) for speed control and enables the selected NPN Output to control rotation direction (NPN Output OFF = Fwd; ON = Rev).

**Note:** There are various contactor-input configurations and polarities among the various contactor-reversing type drives, so direct MS332 NPN Output to drive contact-input control may or may not be possible. For drives incompatible with direct MS332 NPN Output control, a relay can be used between the MS332 NPN Output and the drive contact-input(s) to achieve compatibility.

See 'Set-up Section \NPN Outputs' for details on how to set-up NPN Outputs.

See 'Reference Section \NPN Outputs' for more information on the Contactor Reverse Function.  
See 'Reference Section \Analog Output' for more information on Drive Compatibility.

**6) Encoder Test:**

To avoid wasted set-up time, it is important to verify that both the Feedback and Lead encoder channel A and B (quadrature) lines are not improperly ordered (reversed).

a) **Feedback Encoder A/B channel test**

- Enter 2 into Var05.00 (display Feedback encoder frequency in Hz).
- With the MS332 Run/Stop switch OPEN (Stop), rotate the Feedback Encoder shaft in the forward direction (relative to the process) while observing the MS332 display.
- The display should show a positive value. If the display shows a negative value, swap the Feedback Encoder channel A and B wires at TB4 - 8 and TB4 - 9.

b) **Lead Encoder A/B channel test**

- Enter 3 into Var05.00 (display Lead encoder frequency in Hz).
- With the MS332 Run/Stop switch OPEN (Stop), rotate the Lead Encoder shaft in the forward direction (relative to the process) while observing the MS332 display.
- The display should show a positive value. If the display shows a negative value, swap the Lead Encoder channel A and B wires at TB4 - 3 and TB4 - 4.

**7) Analog Output Calibration:**

- a) Use the Analog Output Calibration Utility to set the **Offset** for no feedback encoder rotation (0 RPM) while **Pc Dac** is 000.0.
- b) Use the Analog Output Calibration Utility to set the **Scale** to turn the feedback encoder at Var01.00 Process Maximum Feedback Encoder RPM while **Pc Dac** is 090.0.

See 'Reference Section \Keypad \Keypad Menus \Diagnostic Menu \Analog Output Calibration Utility' for details on calibration.

**8) Operational Variables:**

a) **Var03.00 - PID Tuning-Proportional Gain**

Enter the default value of 32 for an initial value. Adjustments will be made later in step 9.

b) **Var03.01 - PID Tuning-Integral Time Constant**

Enter the default value of 2.0s for an initial value. Adjustments will be made later in step 9.

c) **Var03.02 - PID Tuning-Derivative Gain**

Enter the default value of 0 to disable derivative compensation.

d) **Var03.04 – Zero Lead Speed PID Control**

Enter the code to select desired zero lead speed PID operation. The factory-default is code 0.

See 'Reference Section \Operational Variables \PID Compensation' for details on PID Vars.

e) **Var07.00- Switch Input 1 Function Assignment Variable**

Enter code 8 to assign the Closed-loop/Open-loop Switch Input Function to Switch Input 1.

f) **Var07.12 - Open-loop Configuration**

Enter 2 to configure the Closed-loop/Open-loop Switch Input Function to open only the index loop.

**Note:** The Closed-loop/Open-loop Switch Input Function is used here to temporarily disable index correction during set-up (PID adjustments) and troubleshooting. This switch input assignment and configuration, along with the closed-switch wire installed back in step 2 disables index correction.

g) **Var07.13 - Master/Follower Mode Select**

Enter 0 for follower mode operation.

h) **Var01.06 - Follower Mode Configuration**

Enter 1, for Index-Follower mode.

**8) Operational Variables (cont.):**

**i) Acceleration/ Deceleration Ramp Times (Vars02.00 to 02.03).**

**Notes:** Ramp times set the ramp rate and are entered in units of seconds. The time entered is the time to ramp from 0 to Var01.00 MAX RPM (acceleration) or from Var01.00 MAX RPM to 0 (deceleration).

- Var02.00, Var02.01 are acceleration time variables.
- Var02.02, Var02.03 are deceleration time variables.
- Var02.00, Var02.02 form a pair and Var02.01, Var02.03 form a pair.
- The factory-default *active pair* is Var02.00, Var02.02.

Enter your desired acceleration and deceleration ramp times.

**See** 'Reference Section \Operational Variables \Acceleration and Deceleration Ramps' for details on using **Var02.05** to select the active Acceleration/Deceleration Ramp Pair using the keypad.

**See** 'Reference Section \Switch Inputs' for details on selecting the active Acceleration/Deceleration Ramp Pair using a Switch Input.

**9) PID Proportional Gain and Integral Time adjustments (index phase correction disabled):**

**a) Var05.00 - Display Selection**

Enter code 5 to choose closed-loop follower error.

**b) Run the lead encoder at the process maximum value (Var01.03 RPM).**

**c) Close the Run/Stop switch (with the lead running). Observe the follower behavior at the top of the acceleration ramp and while it runs steady-state.**

- If the feedback (follower) encoder response is unstable (large, erratic displayed error, motor jerking/oscillating), try reducing Var03.00's value (proportional gain). If the feedback (follower) encoder response is sluggish (large, slow-changing displayed error), try increasing Var03.00's value.
- If the Var03.00 changes don't significantly improve the feedback (follower) encoder response, or if they get to a point of diminishing-return, try adjusting Var03.01 (integral time constant). Higher Var03.01 values will improve loop-stability, lower Var03.01 values will increase loop-responsiveness.
- Generally speaking, it is desirable to have Var03.00 as large as possible and Var03.01 as small as possible - this will result in the tightest, most responsive following. However if Var03.00 is set too high and/or Var03.01 is set too low, the follower loop will become unstable. Open the Run/Stop switch. Repeat (c) several times.

**Notes:**

- *Higher* Proportional Gain (Var03.00) values make proportional compensation more aggressive (up to a certain max value, then causing loop instability above that value).
- *Lower* Integral Time Constant (Var03.01) values make integral compensation more aggressive (down to a certain min value, then causing loop instability below that value).
- With the PID properly adjusted, the displayed following error should drive towards zero at an acceptable rate (determined by Var03.01) after the ramp. After that, the following error should stay zero (or small and centered around zero).

## 10) Enabling and adjusting index phase correction:

- a) **Var05.00 - Display Selection**  
Enter code 6 to display Index Phase Error.
- b) **Var07.12 - Open-loop Configuration**  
Enter code 0 to disable the Closed-loop/Open-loop Switch Input Function from opening either the index or encoder feedback loops.
- c) **Var07.14 - Phase Change Release Time**  
This variable sets the time over which index phase errors are introduced into the PID loop for correction. Longer time values cause slower (and smoother) corrections, shorter values cause faster (more abrupt) corrections. If not already set to the factory-default value of 1.0s, enter 1.0 into Var07.14. If necessary, this value may be changed later in step (e).
- d) Run the lead encoder at the process maximum value (Var01.03 RPM).
- e) Close the Run/Stop switch (with the lead running), observing the initial index phase correction that occurs after the follower ramp.
  - Index phase correction can be observed at the display. The display shows zero during and immediately after the follower ramp, then the display changes from zero to some nonzero value. This value is the index phase error and it should immediately begin shrinking towards zero as the follower motor under-speeds or over-speeds to correct the phase.
  - If the default Var07.14 value causes index phase correction to take too long, try decreasing Var07.14 to less than 1.0s. If excessive overshoot/undershoot is observed or if the follower appears to be "hunting" to get into phase, try increasing the value of Var07.14.  
When properly adjusted, the displayed error should shrink towards zero with minimal over/under-shoot and then stay zero (or small and centered around zero).
- f) Open the Run/Stop switch (the follower will ramp down to a stop).
- g) Repeat (e) and (f) several times until acceptable performance is achieved.

### Notes:

- Index phase correction does not occur during follower ramps. Index pulses occurring during the follower ramp are ignored.
- Index phase correction first occurs after the follower motor has ramped up to speed, at the first feedback index pulse *after* the first lead index pulse.

## 11) Setting the Active Index-Follower Phase Set-point

Index-follower mode set-points are entered in units of feedback (follower) encoder pulses. This sets the relative phase of the effective feedback (follower) index pulses to the effective lead index pulses.

- A positive set-point causes the effective feedback index pulses to occur *before* the effective lead index pulses.
  - A zero set-point causes the effective feedback index pulses to occur *concurrently* with the effective lead index pulses.
  - A negative set-point causes the effective feedback index pulses to occur *after* the effective lead index pulses.
- Depending on your process and the physical position of your index pulse sources, a nonzero set-point may be needed. If known, enter the desired set-point value. If unknown, try different values (by active Set-point up/down scroll or Change Set-point Menu) until the desired process phase relationship is found.

### Notes:

- In 1:1 index pulse matching, every feedback index pulse and every lead index pulse is effective.
- In 3:2 index pulse matching, every third feedback index pulse and every second lead index pulse are effective. **See** 'Description of Operating Modes Section \Index-Follower Mode \Control Theory' for information on Index Matching.
- The *active* set-point is changed via the Change Set-point Menu or by Scrolling.
- The factory-default configuration selects SP08 (the first of the four phase set-points) as the active set-point and sets its default value to zero.

**See** 'Reference Section \Keypad \Keypad Menus' for details on the Change Set-point Menu.

**See** 'Reference Section \Scrolling' for details on Scrolling.

**See** 'Reference Section \Operational Variables \Active Set-point Selection' for details on using **Var06.15** to select the active set-point.

**See** 'Reference Section \Switch Inputs' for details on using Switch Inputs to select the active set-point.

## Switch Inputs (Set-up Procedure)

For applications employing one or more MS332 Switch Input Functions, do the following for each:

- 1) Select a switch input from Switch Inputs 1->7, located on TB3.
  - See 'Reference Section \Hardware Illustrations \Rear-View' for the MS332 pin-out.
- 2) Wire your switch (or compatible device) between the selected Switch Input pin and Ground C (on TB3).
  - See 'Reference Section \Switch Inputs \Terminal Connections' for a further detailed diagram, showing the connection(s) available for the Switch Inputs.
  - See 'Reference Section \Switch Inputs \Device Compatibility' for what devices can be connected to the Switch Inputs.
- 3) Enter the desired switch input Function Code into the selected switch input's Function Assignment Variable (Var07.00->Var07.06).
  - See 'Reference Section \Switch Inputs \Functions' for a description of the Switch Input Functions.
  - See 'Reference Section \Switch Inputs \Function Assignment Variables' for the table showing which Function Code corresponds to which Switch Input Function.
  - See 'Reference Section \Switch Inputs \Function Assignment Variables' for the table showing which Function Assignment Variable **Var07.00 through Var07.06** corresponds to which Switch Input.

## NPN Outputs (Set-up Procedure)

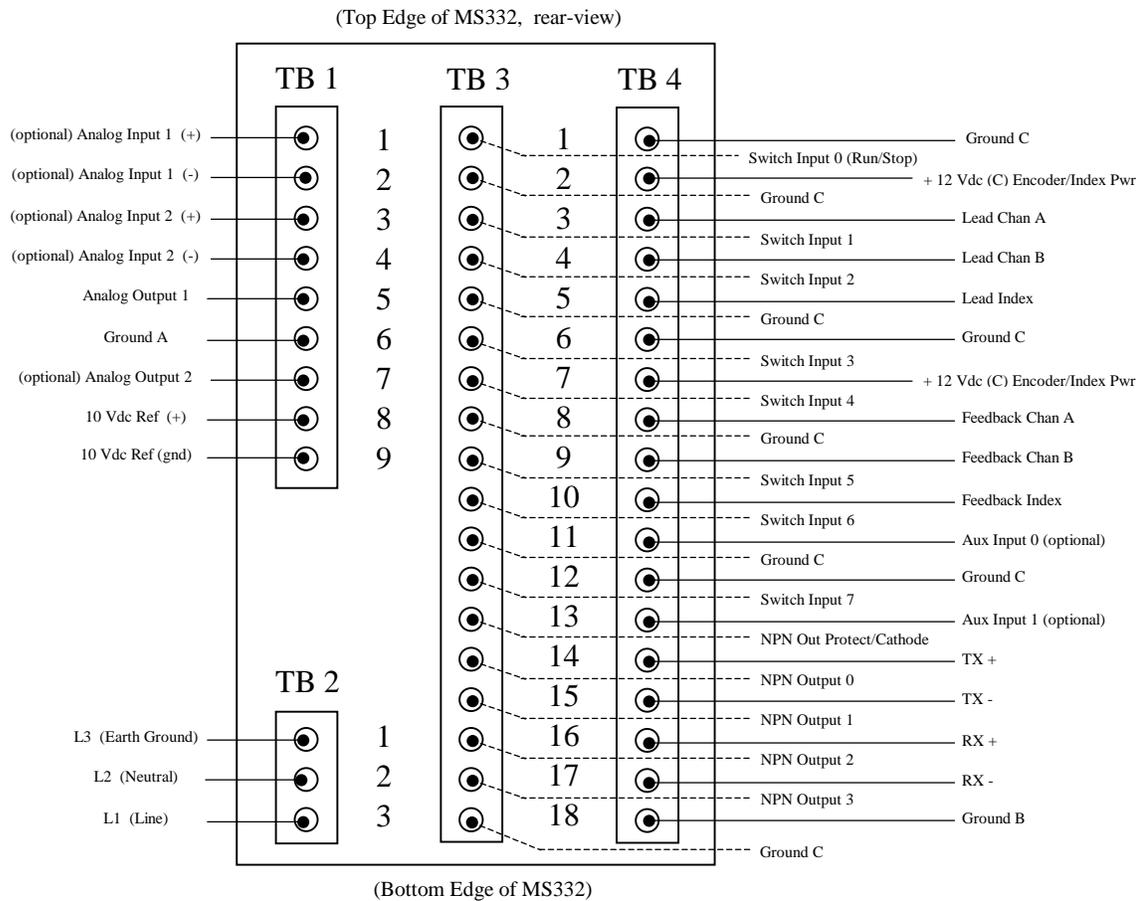
For applications employing one or more MS332 NPN Output Functions, do the following for each:

- 1) Select an NPN Output from NPN Outputs 0->3, located on TB3.
  - See 'Reference Section \Hardware Illustrations \Rear-View' for the MS332 pin-out.
- 2) Wire your device between the selected NPN Output pin (collector) and the positive (+) side of an isolated DC power-supply referenced to Ground C (on TB3).
  - **Note:** The internal +12C supply located on TB4 can be used.
  - See 'Reference Section \NPN Outputs \Terminal Connections' for a further detailed diagram, showing the connection(s) available for the NPN Outputs.
  - See 'Reference Section \NPN Outputs \Device Compatibility' for what devices can be connected to the NPN Outputs.
- 3) Enter the desired NPN Output Function Code into the selected NPN Output's Function Assignment Variable (Var04.00->Var04.03).
  - See 'Reference Section \NPN Outputs \Functions' for the table describing the NPN Output Functions.
  - See 'Reference Section \NPN Outputs \Function Variables' for the table showing which Function Code corresponds to which NPN Output Function.
  - See 'Reference Section \NPN Outputs \Function Variables' for the table showing which Function Assignment Variable **Var04.00 through Var04.03** corresponds to which NPN Output.
- 4) If the selected NPN Output function requires a parameter value, enter it into the selected NPN Output's Function Parameter Variable (Var04.04->Var04.07).
  - See 'Reference Section \NPN Outputs \Function Variables' for the table showing which Function Parameter Variable **Var04.04 through Var04.07** corresponds to which NPN Output.
  - See 'Reference Section \NPN Outputs \Function Variables' for the table showing the type and units of the Function Parameter used by the corresponding NPN Output Function.

# MS332 Reference Section (bA02.XX)

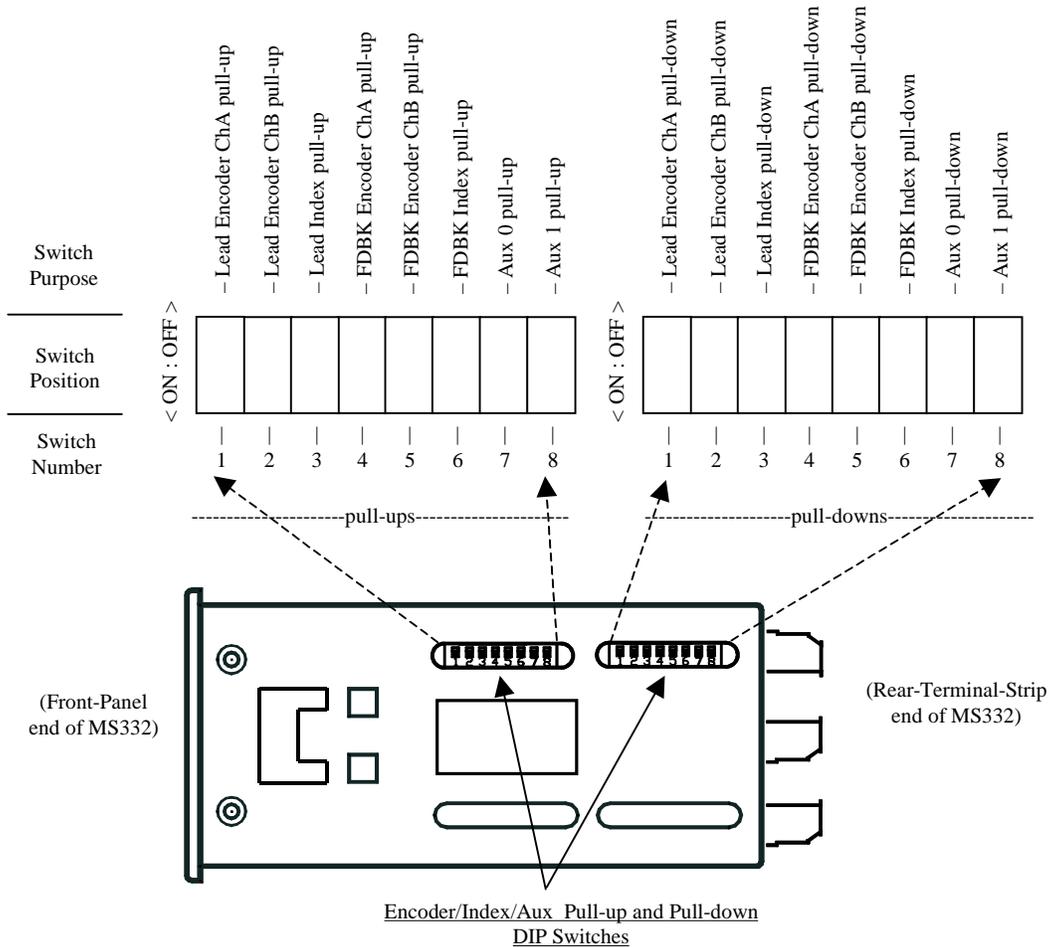
## Hardware Illustrations (Rear-View, Top-View, Block-View)

**Rear-View** (Showing all four terminal strips; TB1, TB2, TB3, and TB4):



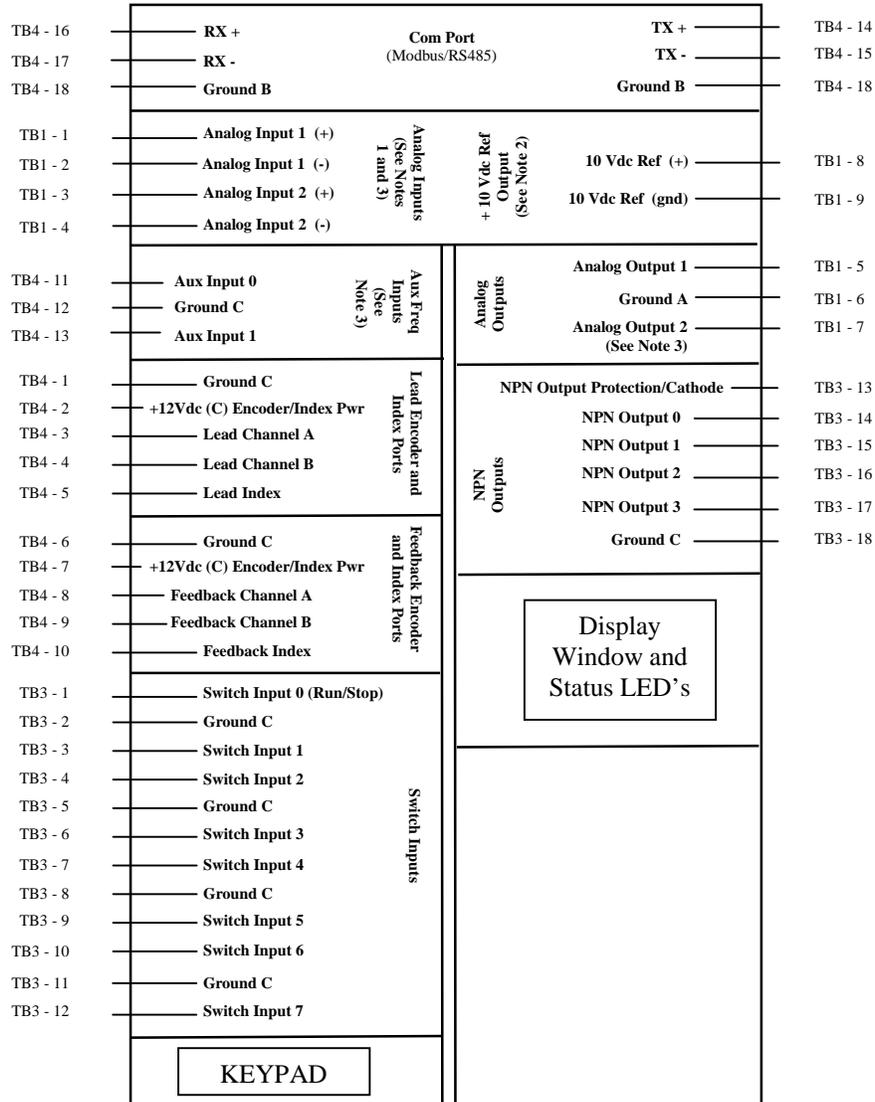
## Hardware Illustrations (cont.):

**Top-View** (Showing location of both DIP Switch banks on the MS332 package. The eight DIP Switches in each bank are also identified in this diagram):



## Hardware Illustrations (cont.):

**Block-View** (Diagram showing MS332 I/O blocks, terminals and signal commons):



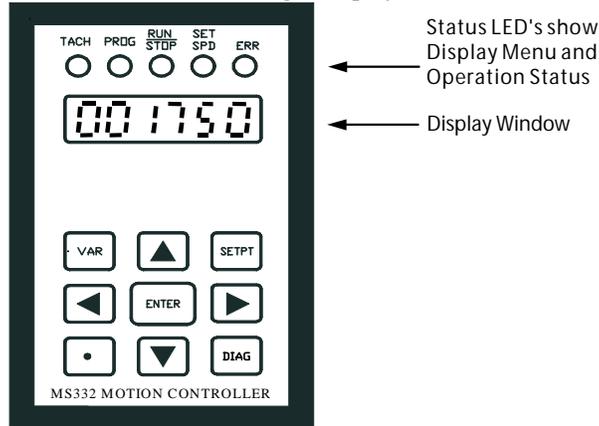
**Note 1:** The Analog Input circuitry is referenced to Ground A.

**Note 2:** The 10 Vdc Ref (gnd) is internally tied to Ground A.

**Note 3:** Not all I/O shown here in this Block-View diagram are available on the standard MS332. (Certain I/O are optional).

# Display (Status LED's, Display Window, Display Var [05.00])

The MS332 front-panel has five status LED's and a 6-digit Display Window, as shown here:



## Status LED's:

The meanings of the Status LED's and their various combinations are indicated in the following table:

TACH	PROG	RUN /STOP	SET SPD	ERR	Meaning
ON	OFF	X	OFF	X	Display shows real-time display information (according to Var05.00)
OFF	ON	X	OFF	X	Display shows Change Variable Menu information.
X	X	ON	X	X	Selected operating mode is running (Run/Stop switch closed, Fast Stop switch [if assigned] open).
OFF	OFF	X	ON	X	Display shows Change Set-Point Menu, Set-Point scroll or Advance/Retard scroll info.
X	X	X	X	ON	Indicates an error condition. (See 'Appendix Sect. \ERR led Errors').
ON	ON	ON	ON	OFF	Display shows Diagnostics Menu information.
OFF	ON	OFF	ON	X	Display shows Keypad Security Menu information.

**Note:** X indicates "don't care"; the LED can be ON or OFF.

## Display Window:

The Display Window shows real-time information as selected by Var05.00, when at Keypad Level Zero. (See 'Reference Section \Keypad' for details on Keypad Level Zero).

## Display Window Variable:

**Variable 05.00 – Display Selection** - Enter the selection code for the desired real-time display. The real-time display selection codes are summarized in this table, and described below:

Var05.00 Code	Selected real-time display information
0	Feedback encoder velocity in user units
1	Feedback / Lead velocity ratio in user units
2	Feedback encoder frequency in Hz
3	Lead encoder frequency in Hz
4	Analog output DAC value
5	Closed-loop position error in feedback encoder pulses
6	Index phase error in feedback encoder pulses
7	Index phase in feedback encoder pulses
8	Lead index frequency in Hz
9	Feedback index frequency in Hz
10	Average number of Lead Pulses per Index
11	Average number of Feedback Pulses per Index
12	Switch Input 3, 2, 1, 0 status
13	Switch Input 7, 6, 5, 4 status
14	NPN Output 3, 2, 1, 0 status
15	PID Integral Term

## Display \Display Window Variable (cont.):

Code 0: Displays the feedback encoder velocity in user units.

**Display value = (Fdbk RPM / Var01.00) \* Var01.01**

Var01.00 is the Process Max Feedback Encoder RPM.

Var01.01 is the Process Max Feedback Encoder RPM in User Units.

**Note:** A negative display value indicates reverse direction (Fdbk encoder B pulses leading A pulses).

Code 1: Displays the feedback / lead encoder velocity ratio in user units.

**Display value = [(Fdbk RPM / Lead RPM) / (Var01.00 / Var01.03)] \* Var01.04**

Var01.00 is the Process Max Feedback Encoder RPM.

Var01.03 is the Process Max Lead Encoder RPM.

Var01.04 is the process maximum encoder RPM *ratio* (Process Max Feedback Encoder RPM / Process Max Lead Encoder RPM) in User Units.

**Note:** A negative display value indicates the feedback and lead encoders running in opposite directions.

Code 2: Displays feedback encoder pulse frequency, in Hz.

**Note:** A negative display value indicates reverse direction (Fdbk encoder B pulses leading A pulses).

Code 3: Displays the lead encoder pulse frequency, in Hz.

**Note:** A negative display value indicates reverse direction (Lead encoder B pulses leading A pulses).

Code 4: Displays the current value of the output DAC. The DAC ranges from 0 up to 4095.

Code 5: Displays the closed-loop feedback encoder error in feedback encoder pulse units.

Feedback encoder error is the difference between the expected (correct) feedback encoder position and the actual feedback encoder position.

Feedback encoder error is calculated every time the PID loop executes (1024 times per second).

**Display value = (Expected feedback encoder pulse count – Actual feedback encoder pulse count)**

Code 6: Displays the feedback index phase error in feedback encoder pulse units (Index-follower mode only).

Index phase is the feedback encoder position when the lead index pulse arrives minus the feedback encoder position when the feedback index pulse arrives.

Index phase error is the difference between the actual index phase and the index phase set-point.

Index phase error is calculated upon receipt of a feedback index pulse.

**Display value = (Index phase set-point – Index phase)**

Code 7: Displays the feedback index phase in feedback encoder pulse units (Index-follower mode only).

Index phase is the feedback encoder position when the lead index pulse arrives minus the feedback encoder position when the feedback index pulse arrives.

**Display value = (Fdbk encoder pulse count at Lead index – Fdbk encoder pulse count at Fdbk index)**

**Note:** A positive value indicates the feedback index pulse leads (arrives before) the lead index pulse. A negative value indicates the feedback index pulse lags (arrives after) the lead index pulse.

Code 8: Displays the lead index pulse frequency, in Hz.

Code 9: Displays the feedback index pulse frequency, in Hz.

Code 10: Displays the average number of Lead Encoder Pulses received per Lead Index Pulse received.

Code 11: Displays the average number of Feedback Encoder Pulses received per Feedback Index Pulse received.

Code 12: Displays the status of Switch Inputs 3, 2, 1 and 0 (ordered left to right across the display digits, one digit per input). 0 indicates an open input. 1 indicates an closed input.

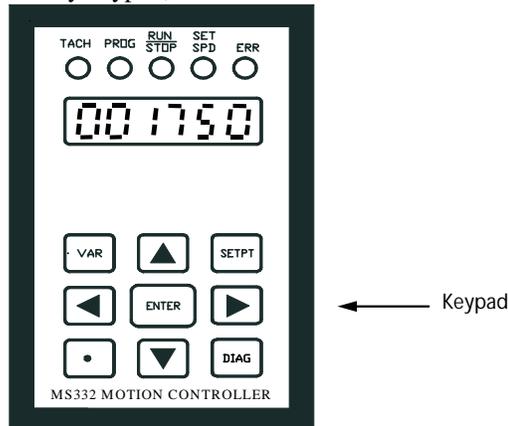
Code 13: Displays the status of Switch Inputs 7, 6, 5 and 4 (ordered left to right across the display digits, one digit per input). 0 indicates an open input. 1 indicates an closed input.

Code 14: Displays the status of NPN Outputs 3, 2, 1 and 0 (ordered left to right across the display digits, one digit per output). 0 indicates the NPN is off. 1 indicates the NPN is on.

Code 15: Displays PID Integral term.

# Keypad (Keys, Keypad Level Zero, Keypad Menus, Menu Access)

The MS332 front-panel has a 9-key keypad, as shown here:



## Keys:



**The VAR key** is used to access the Change Variable Menu. Press the “VAR” key to enter the Change Variable Menu. Press again to exit the Change Variable Menu.



**The SETPT key** is used to access the Change Set-point Menu. Press the “SETPT” key to enter the Change Set-point Menu. Press again to exit the Change Set-point Menu.



**The DIAG key** is used to access the Diagnostic Menu. Press the “DIAG” key to enter the Diagnostic Menu. Press again to exit the Diagnostic Menu. **Note:** Holding this key pressed while AC power is applied to the MS332 resets all variables to their factory default values – much the same as the Factory Default Reset Utility (see Diagnostic Menu).



**The Decimal Point “.” key** is used to access the Keypad Security Menu. Press the “.” key to enter the Keypad Security Menu. Press again to exit the Keypad Security Menu. This key is also used to change a variable or set-point’s decimal point position while in the Change Variable or Change Set-point Menus.



**The ENTER key** is used to access/save a selected security/program variable, set-point or diagnostic/utility, while in the Keypad Security, Change Variable, Change Set-point, or Diagnostic Menus.



**The RIGHT and LEFT ARROW keys** select which digit to edit on the display while in the Change Variable, Change Set-point and Keypad Security Menus. These keys are also used in a few places of the Diagnostic Menu. When running closed-loop without index correction and not in one of the four menus, these keys are used to Advance/Retard the feedback encoder (RIGHT arrow advances, LEFT arrow retards).



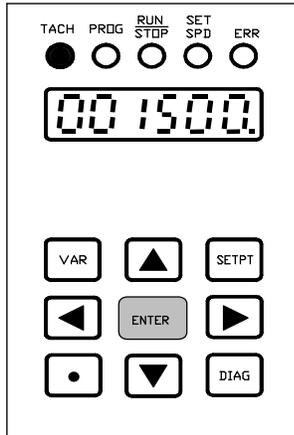
**The UP and DOWN ARROW keys** are used to increase or decrease the value of the flashing (selected) display digit while in the Change Variable, Change Set-point and Keypad Security Menus. These keys are also used in many places of the Diagnostic Menu. When not in one of the four menus, these keys are used to increase/decrease the mode-determined active set-point: the Master mode speed, the Ratio-Follower mode speed ratio, the Index-Follower mode phase, or the Jog mode speed.

### Keypad Level Zero (Real-time Display):

This is the base keypad level (not in a menu) where the display window shows real-time information according to Var05.00 and real-time status (Status LED's).

### Real-time display, select menu, scroll active set-point, scroll advance/retard:

Use this level to display real-time measurements and status, enter keypad menus, scroll\* the active set-point and scroll\* the (phase) advance/retard.



#### LED's / Display Window:

- TACH led lit.
- Display Window shows information according to Var05.00.  
(Ex. A feedback speed of 1500 RPM).

#### Valid Keys:

- Press **VAR** key to enter level one of the Change Variable Menu.  
(See the Change Variable Menu).
- Press **SETPT** key to enter level one of the Change Set-point Menu.  
(See the Change Set-point Menu).
- Press **DIAG** key to enter level one of the Diagnostic Menu.  
(See the Diagnostic Menu).

**Note:** The Run/Stop switch must be open and the DAC must be at zero before the Diagnostic Menu can be accessed. (If the DAC is ramping to zero, then the Diagnostic Menu cannot be entered until the DAC reaches zero). Pressing **DIAG** while the Run/Stop switch is closed - or even while the Run/Stop switch is open and the DAC is still not zero - results in no action other than lighting the ERR (error) led.

- Press **•** key to enter level one of the Keypad Security Menu.  
(See the Keypad Security Menu).
- Press **▲** and **▼** arrows to increase/decrease the mode-determined active set-point. (See 'Reference Section \Scrolling' for details on the Set-point Scroll feature).
- Press **▶** and **◀** arrows to Advance/Retard the feedback encoder.  
(See 'Reference Section \Scrolling' for details on the Advance/Retard Scroll feature).

**Invalid Keys:** (**Note:** Any invalid keys are shaded in the keypad diagram to the left).

- Pressing the **ENTER** key results in no action other than lighting the ERR (error) led.

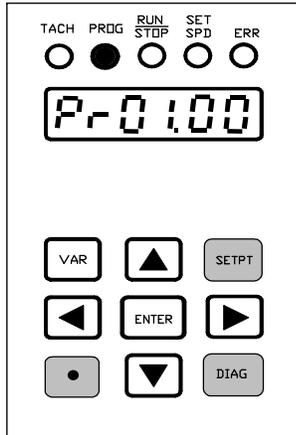
\* **Note:** Here at Keypad Level Zero, the active set-point may be changed by Scrolling with the **▲** and **▼** keys; and the feedback encoder may be Advance/Retard Scrolled using the **▶** and **◀** keys. These changes take effect immediately and without pressing the **ENTER** key.

## Keypad Menus:

**Change Variable Menu:** Follow these steps to access the Change Variable Menu:

**Level One - Select variable:** Use this level to select which user program variable to change. This is the first level of the Change Variable Menu.

**Note:** Enter level one by pressing **VAR** while at level zero. (See level zero above).



### LED's / Display Window:

- PROG led lit.
- Display Window initially shows the last variable changed, with the right-most digit flashing. (Ex. Showing "Pr 01.00" for Var01.00).

### Valid Keys:

To select desired variable:

- Press **▲** or **▼** to change the flashing (selected) digit.
- Press **◀** or **▶** to select which digit to change.
- When the desired variable is displayed, press **ENTER** to confirm and enter level two of the Change Variable Menu.

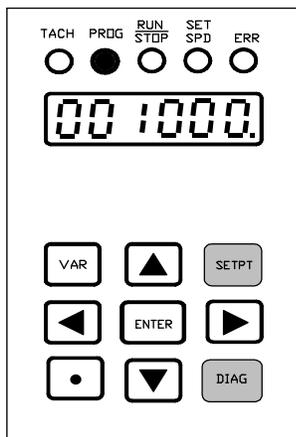
**OR**

Press **VAR** to exit from Change Variable Menu and return to level zero.

### Invalid Keys:

- Pressing **SETPT**, **DIAG** or **●** results in no action other than lighting the ERR (error) led.

**Level Two - Change variable value:** Use this level to change the value of the selected variable. This is the second level of the Change Variable Menu.



### LED's / Display Window:

- PROG led remains lit.
- Display Window shows the selected variable's value, with the right-most digit flashing. (Ex. Showing "1000" for a Var01.00 value of 1000 RPM).

### Valid Keys:

To change variable value:

- Press **▲** or **▼** to change the flashing (selected) digit.
- Press **◀** or **▶** to select which digit to change.
- Press **●** to change the decimal point position.
- When the desired new value is displayed, press **ENTER** to save the new variable value and to return to level one.

**OR**

Press **VAR** to exit from Change Variable Menu and return to level zero (without saving any changes).

### Invalid Keys:

- Pressing **SETPT** or **DIAG** results in no action other than lighting the ERR (error) led.

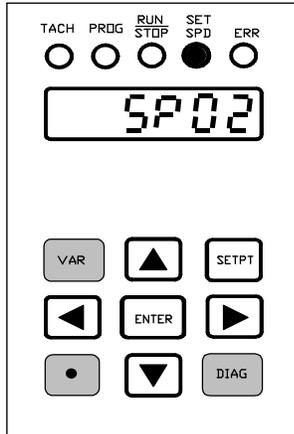
## Keypad Menus (cont.):

**Change Set-point Menu:** Follow these steps to access the Change Set-point Menu.

**Note:** The Change Set-point Menu is used to change any set-point. However, the active set-point can also be Scrolled. (See both 'Reference Section \Operational Variables \Active Set-point Selection' and 'Reference Section \Switch Inputs \Functions' for details on active set-point selection. See 'Reference Section \Scrolling' for details on the Scroll feature).

**Level One - Select set-point:** Use this level to select which set-point to change. This is the first level of the Change Set-point Menu.

**Note:** Enter level one by pressing **SETPT** while at level zero. (See level zero above).



### LED's / Display Window:

- SET SPD led lit.
- Display Window initially shows the active set-point, with the right-most digit flashing. (Ex. Showing "SP 02" for master mode speed setpt 2).

### Valid Keys:

To select desired set-point:

- Press **▲** or **▼** to change the flashing (selected) digit.
- Press **◀** or **▶** to select which digit to change.
- When the desired set-point is displayed, press **ENTER** to confirm and enter level two of the Change Set-point Menu.

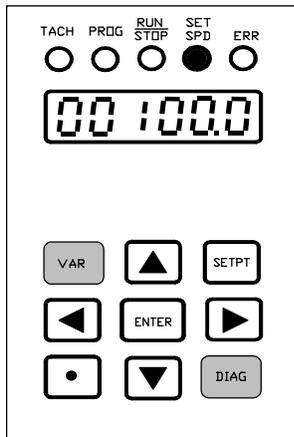
**OR**

Press **SETPT** to exit from Change Set-point Menu and return to level zero.

### Invalid Keys:

- Pressing **VAR**, **DIAG** or **●** results in no action other than lighting the ERR (error) led.

**Level Two - Change set-point value:** Use this level to change the value of the selected set-point. This is the second level of the Change Set-point Menu.



### LED's / Display Window:

- SET SPD led remains lit.
- Display Window shows the selected set-point's value, with the right-most digit flashing. (Ex. Showing "100.0" for a master mode speed setpt value of 100.0 feet/min).

### Valid Keys:

To change set-point value:

- Press **▲** or **▼** to change the flashing (selected) digit.
- Press **◀** or **▶** to select which digit to change.
- Press **●** to change the decimal point position.
- When the desired new value is displayed, press **ENTER** to save the new set-point value and to return to level one.

**OR**

Press **SETPT** to exit from Change Set-point Menu and return to level zero (without saving any changes).

### Invalid Keys:

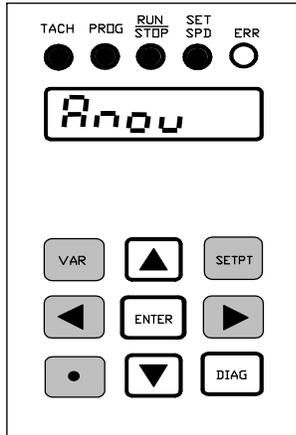
- Pressing **VAR** or **DIAG** results in no action other than lighting the ERR (error) led.

## Keypad Menus (cont.):

**Diagnostic Menu:** Follow these steps to access the Diagnostic Menu:

**Level One - Select diagnostic/utility:** Use this level to select which diagnostic/utility to perform. This is the first level of the Diagnostic Menu.

**Note:** Enter level one by pressing **DIAG** while at level zero. (See level zero above).



### LED's / Display Window:

- All of the status led's are lit except for the ERR led.
- Display Window initially shows the diagnostic/utility last performed, with all the digits flashing.  
(Ex. Showing "Anou" for the Analog Output Calibration utility).

### Valid Keys:

To select diagnostic:

- Press **▲** or **▼** to select which diagnostic/utility to perform. Choose from SInPu, nPnou, Anou, KEYPAd, dISP, FACdEF, PPILrn, or UErrEU.

**Note:** The eight diagnostics/utilities are abbreviated in the Display Window in this manner:

- "SInPu" for Switch Inputs diagnostic.
- "nPnou" for NPN Outputs diagnostic.
- "Anou" for Analog Output Calibration utility.
- "KEYPAd" for Keypad diagnostic.
- "dISP" for Display Window diagnostic.
- "FACdEF" for Factory Defaults Reset utility.
- "PPILrn" for Encoder Pulses Per Index Learn utility.
- "UErrEU" for Product-Version-Revision diagnostic.

(See the remaining pages here in 'Diagnostic Menu' for the descriptions of each individual diagnostic/utility).

- When the desired diagnostic/utility is displayed, press **ENTER** to confirm and enter level two of that particular diagnostic/utility.

**Note:** Levels two and three (if applicable) are specific to the particular diagnostic/utility selected in level one. This means for example, that level two in the Switch Input Diagnostic is completely separated from level two in the NPN Outputs Diagnostic. Jumping from level two in one diagnostic/utility to level two in another diagnostic/utility is not possible.

### OR

Press **DIAG** to exit the Diagnostic Menu and return to level zero.

### Invalid Keys:

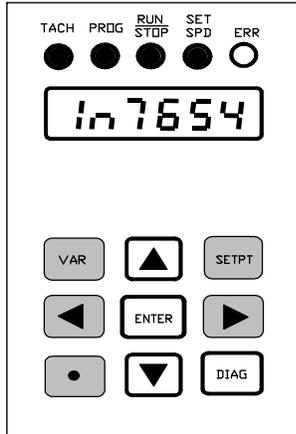
- Pressing **VAR**, **SETPT**, **◀**, **▶** or **•** results in no action other than lighting the ERR (error) led.

## Keypad Menus \Diagnostic Menu (cont.):

### Switch Inputs Observation Diagnostic:

**Level Two – Select Switch Input group:** Use this level to select which group of Switch Inputs to observe. This is on the second level of the Diagnostic Menu.

**Note:** Enter level two by selecting “SInPu” in the display window while at level one of the Diagnostic Menu. (See level one above).



#### LED's / Display Window:

- All of the status led's are lit except for the ERR led.
- Display Window initially shows the group of Switch Inputs observed last, with all the digits flashing.  
(Ex. Showing “In 7654” for switch inputs 7, 6, 5, and 4).

#### Valid Keys:

To select which group of inputs to observe:

- Press or to select between “In 3210”, “In 7654”, etc.  
(**Note:** The standard MS332 has only the two groups).
- When the desired group of inputs is displayed, press to confirm and enter level three of the Switch Inputs diagnostic.

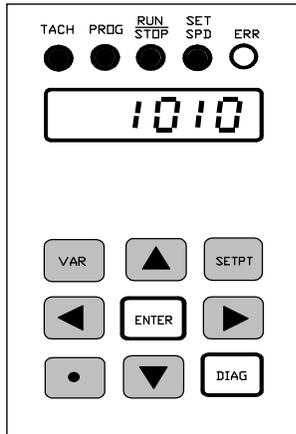
#### OR

Press to exit the Diagnostic Menu and return to level zero.

#### Invalid Keys:

- Pressing , , , or results in no action other than lighting the ERR (error) led.

**Level Three – Observe Switch Input statuses:** Use this level to display the status of each Switch Input in the selected group. This is used to observe whether the Switch Inputs are **OFF** or **ON** (open or closed). This is on the third level of the Diagnostic Menu.



#### LED's / Display Window:

- All of the status led's are lit except for the ERR led.
  - Display Window shows the status of each Switch Input in the selected group:
    - A switch input is **ON** if the status is a “1”. (The switch is closed connecting the input to Ground C).
    - A switch input is **OFF** if the status is a “0”. (The switch is open disconnecting the input from Ground C).
- (Ex. Showing “1010” for the statuses of switch inputs 7, 6, 5, and 4. This shows that input 7 is ON, input 6 is OFF, input 5 is ON and input 4 is OFF).

#### Valid Keys:

- Press to return to level two.

#### OR

Press to exit the Diagnostic Menu and return to level zero.

#### Invalid Keys:

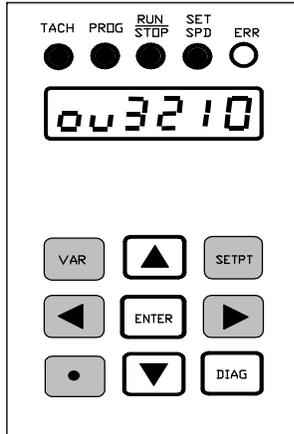
- Pressing , , , , , or results in no action other than lighting the ERR (error) led.

## Keypad Menus \Diagnostic Menu (cont.):

### NPN Outputs Test Diagnostic:

**Level Two – Select NPN Output group:** Use this level to select which group of NPN Outputs to test. This is on the second level of the Diagnostic Menu.

**Note:** Enter level two by selecting “nPnou” in the display window while at level one of the Diagnostic Menu. (See level one above).



#### LED's / Display Window:

- All of the status led's are lit except for the ERR led.
- Display Window initially shows the group of NPN Outputs tested last, with all the digits flashing.  
(Ex. Showing “ou 3210” for NPN outputs 3, 2, 1, and 0).

#### Valid Keys:

To select which group of outputs to test:

- Press or to select “ou 3210”, etc.  
(**Note:** The standard MS332 has only the one group).
- Press to confirm and enter level three of the NPN Outputs diagnostic.

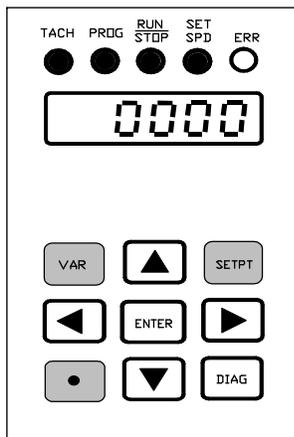
#### OR

Press to exit the Diagnostic Menu and return to level zero.

#### Invalid Keys:

- Pressing , , , or results in no action other than lighting the ERR (error) led.

**Level Three – Test NPN Output statuses:** Use this level to test and display the status of each NPN Output in the selected group. This is used to temporarily (only for the duration of this diagnostic) control the state of each NPN Output for the purpose of testing. This is on the third level of the Diagnostic Menu.



#### LED's / Display Window:

- All of the status led's are lit except for the ERR led.
- Display Window initially shows all the NPN Outputs in the selected group are **OFF**, with the right-most digit flashing.

When an Output is **OFF** then the status is a “0”.

When an Output is **ON** then the status is a “1”.

#### Valid Keys:

To test an NPN Output:

- Press or to select which individual output to test from the group.
- Press or to toggle **ON/OFF** the selected (flashing) output.
- Press to save (only for the duration of the diagnostic) the status of each NPN Output in the group and return to level two.

#### OR

Press to exit the Diagnostic Menu and return to level zero (without saving the temporary statuses of the NPN Outputs).

#### Invalid Keys:

- Pressing , or results in no action other than lighting the ERR (error) led.

## Keypad Menus \Diagnostic Menu (cont.):

### Analog Output Calibration Utility:

This utility facilitates changing the Analog Output's offset voltage and DAC code voltage sensitivity. When invoked, the analog output voltage (Vout) obeys the following formula:

$$\text{Vout} = \text{oFFSET volts} + (\text{SCALE volts}) * (\text{Pc dAC} / 100)$$

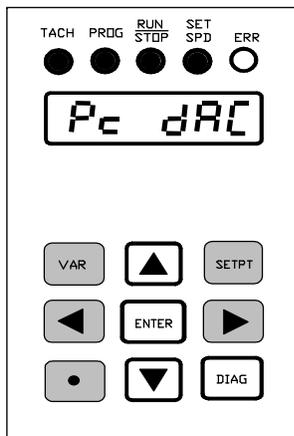
- Pc dAC sets a temporary DAC code for the duration of this utility. The units of Pc dAC are +/- % of full-scale DAC (4095 for the 12-bit DAC). Pc dAC may range from -100.0 to 100.0%.
- oFFSET sets the Vout component that is independent of DAC code. It is the Vout present when Pc dAC is 000.0 (DAC code 0). oFFSET is typically adjusted to produce *no feedback encoder rotation* when Pc dAC is 000.0. Once changed, this calibration setting will remain until explicitly changed again.
- SCALE sets the *sensitivity* of the DAC-code-dependent Vout component. SCALE should be adjusted to turn the feedback encoder at (+/-) Var01.00 Process Max Feedback Encoder RPM when Pc dAC is (+/-) 090.0 (DAC code 3686). Once changed, this calibration setting will remain until explicitly changed again.

### Notes:

- Usually, the Analog Output is calibrated in the feedback encoder's *forward* direction (the direction produced by a positive Pc dAC). However, it *can* be calibrated in the *reverse* direction (the direction produced by a negative Pc dAC). Although the MS332 can run the feedback encoder/motor in both directions regardless of the direction in which it was calibrated, it is recommended that the Analog Output be calibrated in the direction produced in your application.
- In order to run your motor in the reverse direction, the MS332 must first be properly configured and wired to your drive according to your drive's reversing method (negative voltage input or contact closure). See the 'Set-up for Motor-Drive Compatibility' step, in your selected operating mode's set-up procedure for details ('Set-up Section \your mode \Set-up for Motor-Drive Compatibility').
- The variables **Var01.00** (Process Max Feedback Encoder RPM) and **Var01.02** (Feedback Encoder PPR) must both be written with correct values before running this Analog Output Calibration Utility.

**Level Two – Select Analog Output calibration characteristic:** Use this level to select from among Pc dAC, oFFSET, and SCALE. This is on the second level of the Diagnostic Menu.

**Note:** Enter level two by selecting "Anou" in the display window from level one of the Diagnostic Menu. (See Keypad Menus \Diagnostics Menu \ Level One for a discussion of level one).



### LED's / Display Window:

- All of the status led's are lit except for the ERR led.
- Display Window initially shows the last-changed Analog Output characteristic, with all the display characters flashing. (Ex. Showing "Pc dAC" for temporary Percent of DAC code).

### Valid Keys:

To select which Analog Output characteristic to adjust:

- Press or to select Pc dAC, oFFSET or SCALE.
- When the desired selection is displayed, press to confirm and enter level three of the Analog Output Calibration Utility.

OR

Press to exit the Diagnostic Menu and return to level zero.

### Invalid Keys:

- Pressing , , , or results in no action other than lighting the ERR (error) led.

### Notes on Feedback Encoder Reverse Operation:

Operating in the Reverse (or opposite) direction requires using a bidirectional motor/drive.

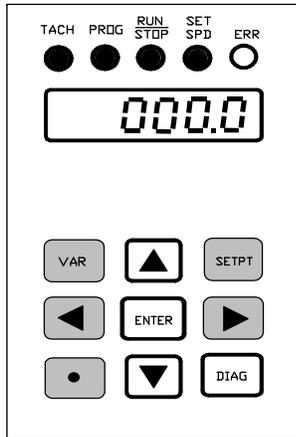
See 'Reference Section \Analog Output' for related information on Drive Compatibility.

See 'Reference Section \NPN Outputs' for related information on the Contactor Reverse NPN Output Function.

## Keypad Menus \Diagnostic Menu (cont.):

### Analog Output Calibration Utility (continued):

**Level Three – Change Analog Output calibration setting:** Use this level to change settings.



#### LED's / Display Window:

- All of the status led's are lit except for the ERR led.
- Display Window shows the numerical Pc dAC setting if Pc dAC is selected.  
**Note:** Pc dAC is initially 000.0 upon entering this utility.
- Display Window shows the present feedback encoder RPM if oFFSET or SCALE are selected. Note that numeric oFFSET and SCALE settings are not displayed: Instead, the feedback encoder RPM is displayed to show the immediate *effect* of oFFSET and SCALE settings and adjustments.

#### Valid Keys:

To change the selected Analog Output calibration setting:

- Press or to scroll the selected setting up or down. Note that Pc dAC is the only selection whose numerical setting is displayed. The oFFSET and SCALE selections display real-time feedback encoder RPM measurements so the immediate *effect* of calibration settings and adjustments may be observed.
- When the desired adjustment is achieved, press to save the new setting and return to level two.

**OR**

Press to exit the Diagnostic Menu and return to level zero.

**Note:** Level three changes to Pc dAC, oFFSET and SCALE settings take immediate effect at the Analog Output but remain temporary (for the duration of this utility) until is pressed to store the new setting. The effect of pressing for any one of the three selections is described below:

- Pc dAC is stored, remaining in effect for the duration of the Analog Output Calibration utility. This gives the user control over the DAC for the purpose of setting SCALE.
- oFFSET is stored in non-volatile memory and remains in *permanent* effect at the Analog Output until it is deliberately changed again.
- SCALE is stored in non-volatile memory and remains in *permanent* effect at the Analog Output until it is deliberately changed again. (The oFFSET and SCALE values together comprise the Analog Output calibration).

#### Invalid Keys:

- Pressing , , , or results in no action other than lighting the ERR led.

## Keypad Menus \Diagnostic Menu (cont.):

### Analog Output Calibration Utility (continued):

#### Step-By-Step Analog Output Calibration Procedure

Note: Before calibrating the analog output, your system's Process Maximum Feedback Encoder RPM must be entered into Var01.00 and Feedback Encoder PPR must be entered into Var01.02.

Enter the Analog Output Calibration Utility:

1. Open the MS332 RUN switch (open the contact across TB3 pins 1 and 2).
2. From keypad level 0 (not in a menu), press **DIAG** (enter the Diagnostics menu).
3. Press **▲** or **▼** several times until "Anou" appears on the display. Press **ENTER** (enter Analog Output calibration).

Adjust Analog Output Offset:

4. Press **▲** or **▼** until "oFFSE" appears on the display. Press **ENTER** (enter Offset voltage adjustment).
5. Observe the follower system and listen to its motor.

If it is completely still (not even slightly rotating), press **▲** until the follower creeps forward, then press **▼** until it stops, then press **ENTER** (save the adjusted offset voltage) and proceed to step 6.

If it is rotating forward (even slightly creeping), press **▼** until it stops, then press **ENTER** (save the adjusted offset voltage) and proceed to step 6.

If it is rotating reverse (even slightly creeping), press **▲** until it the follower creeps forward, then press **▼** until it stops, then press **ENTER** (save the adjusted offset voltage) and proceed to step 6.

Adjust Analog Output Scale:

6. Press **▲** or **▼** until "Pc dAC" appears on the display. Press **ENTER** (enter % DAC adjustment ).
7. The display will initially show "000.0".  
Press and hold **▲** until the display shows 090.0 (DAC at 90.0 % of full-scale). This will take about 70 seconds. The follower motor should start rotating, steadily increasing in speed.  
If you scroll past 90.0, just press **▼** and **▲** to get exactly "090.0".  
When the display shows exactly "090.0", press **ENTER** (temporarily keep the DAC at 90.0% of full-scale).
8. Press **▲** or **▼** until "SCALE" appears on the display. Press **ENTER** (enter Scale adjustment).
9. Observe the display, it will show the RPM at which the follower encoder is presently rotating.  
Press **▲** or **▼** until the displayed RPM is equal to your follower process maximum RPM of \_\_\_\_\_ (the value in Var01.00).  
If the displayed RPM is too high, press **▼** to reduce it.  
If the displayed RPM is too low, press **▲** to increase it.  
When the displayed RPM is equal to your follower process maximum RPM, press **ENTER** (save the scale).

Exit the Analog Output calibration utility:

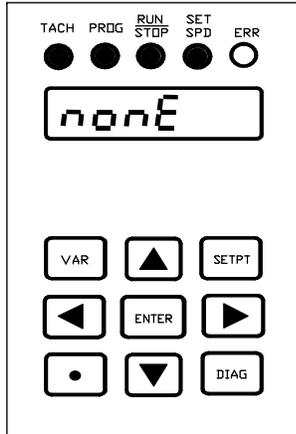
10. Press **DIAG** (exit the Diagnostics menu). The follower motor will stop. Calibration is complete.

## Keypad Menus \Diagnostic Menu (cont.):

### Keypad Diagnostic:

**Level Two – Test keypad keys:** Use this level to individually test each key on the keypad. This is on the second level of the Diagnostic Menu.

**Note:** Enter level two by selecting “KEYPAD” in the display window while at level one of the Diagnostic Menu. (See level one above).



### LED's / Display Window:

- All of the status led's are lit except for the ERR led.
- Display Window initially shows the mnemonic “nonE”, with all the digits flashing.  
(The mnemonic “nonE” is displayed when no keys are pressed).

### Valid Keys:

Press the desired key to test it:

(If the key is working properly, then the respective mnemonic is displayed in the Display Window).

- Press **VAR**; the mnemonic “VAR” is displayed.
- Press **▲**; the mnemonic “UP” is displayed.
- Press **▼**; the mnemonic “dn” is displayed.
- Press **SETPT**; the mnemonic “SP” is displayed.
- Press **◀**; the mnemonic “LEF” is displayed.
- Press **▶**; the mnemonic “rI9h” is displayed.
- Press **ENTER**; the mnemonic “En” is displayed.
- Press **●**; the mnemonic “dP” is displayed.
- Press **DIAG** to exit the Diagnostic Menu and return to level zero.

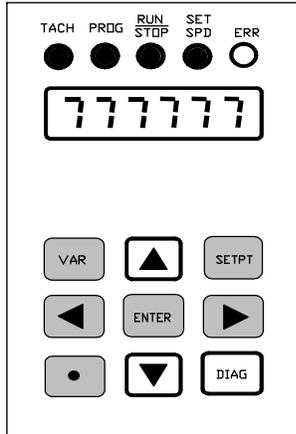
**Invalid Keys: NONE**

## Keypad Menus \Diagnostic Menu (cont.):

### Display Window Diagnostic:

**Level Two – Test the Display Window:** Use this level to test if the Display Window is working properly by correctly displaying the numbers **0 through 9**. This is on the second level of the Diagnostic Menu.

**Note:** Enter level two by selecting “dISP” in the display window while at level one of the Diagnostic Menu. (See level one above).



### LED's / Display Window:

- All of the status led's are lit except for the ERR led.
- Display Window initially shows the last number tested, with all the digits flashing. (Ex. Flashing “777777” in all the digits).

### Valid Keys:

To test the Display Window for the digits 0 through 9:

- Press to increment the Display Window digits: “111111”, “222222”, “333333”, etc., is displayed when the key is repeatedly pressed.
- Press to decrement the Display Window digits: “999999”, “888888”, “777777”, etc., is displayed when the key is repeatedly pressed.

**Note:** The decimal point position of each digit is tested when the number **0** is tested. The digits all flash with zeros but the decimal points are displayed without flashing.

- Press to exit the Diagnostic Menu and return to level zero.

### Invalid Keys:

- Pressing , , , , or results in no action other than lighting the ERR (error) led.

## Keypad Menus \Diagnostic Menu (cont.):

### Factory Default Reset Utility:

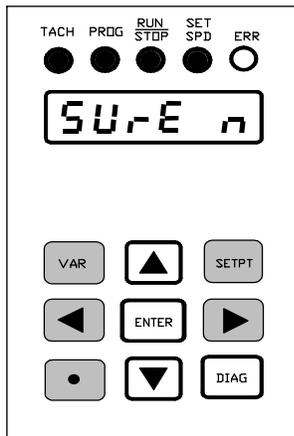
Use this utility to reset all the variables (the user program variables, the Analog Output calibration values, and the security variables) to their factory default values.

**Level Two – Confirm intent to reset:** To avoid inadvertent execution of this utility, level two prompts for confirmation of intent by offering two options:

- 1) When entering level two, the initial option is Do Not Proceed (indicated by the “SUrE\_n” display mnemonic). Pressing  while “SUrE\_n” is displayed gives no action other than lighting the ERR led.
- 2) To confirm and proceed with reset, press  or  to select “SUrE\_y”. Then press  to proceed to level three and reset.

Option	Display mnemonic	Response to pressing 
Do Not Proceed	SUrE_n	No action other than lighting ERR led.
Proceed	SUrE_y	Proceed to level three and reset.

**Note:** Enter level two by selecting “FACdEF” in the display window while at level one of the Diagnostic Menu. (See level one above).



### LED's / Display Window:

- All of the status led's are lit except for the ERR led.
- Display Window shows the mnemonic “SUrE\_n” or “SUrE\_y”, with the right-most digit flashing. (The initial display mnemonic upon entering level two is “SUrE\_n”).

### Valid Keys:

Press the following keys to confirm:

- Press  or  to toggle between “SUrE\_n” or “SUrE\_y”.
- Press  while “SUrE\_y” is displayed to proceed to level three and reset.

**Note:** Pressing  while “SUrE\_n” is displayed results in no action other than lighting the ERR led.

### OR

Press  to exit the Diagnostic Menu and return to level zero.

### Invalid Keys:

- Pressing , , ,  or  results in no action other than lighting the ERR (error) led.

## Keypad Menus \Diagnostic Menu (cont.):

### Factory Default Reset Utility (cont.):

**Level Three – EXECUTE RESET:** This level resets all the variables to their factory defaults. Pressing **ENTER** in level two while “SUrE\_y” is displayed advances the menu to level three and commences reset.

Two mnemonics are displayed in level three:

- First, the mnemonic “PrOCES” is displayed (flashing) while the variables are resetting.

**Note:** “PrOCES” is displayed for only a very brief time (since reset only takes a second or so).

- Then, the mnemonic “dOnE” is displayed, indicating the variables have been reset to their factory default values and the utility has finished executing.

#### Display mnemonic

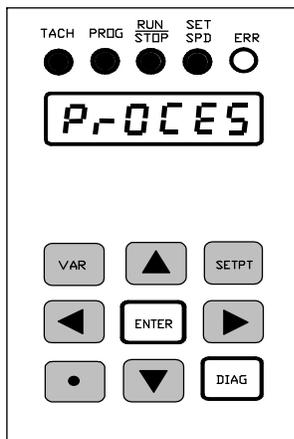
PrOCES

dOnE

#### Interpretation

Reset executing (writing factory default values to variables).

Reset done (done writing factory default values to variables).



#### **LED's / Display Window:**

- All of the status led's are lit except for the ERR led.
- Display Window first flashes “PrOCES”, then displays “dOnE”.

#### **Valid Keys:**

**Note:** Any key pressed while “PrOCES” is flashing will be ignored.

When “dOnE” is displayed, these two keys are valid:

- Press **ENTER** to return to level two.

**OR**

Press **DIAG** to exit the Diagnostic Menu and return to level zero.

#### **Invalid Keys:**

- Pressing **VAR**, **SETPT**, **▲**, **▼**, **◀**, **▶** or **●** results in no action other than lighting the ERR (error) led.

## Keypad Menus \Diagnostic Menu (cont.):

### Encoder Pulses Per Index Learn Utility (Index-Follower mode applications only):

This utility determines your system's encoder pulses per index pulse (PPI) values and writes them into Var01.07 (Feedback PPI) and Var01.08 (Lead PPI). When invoked, the selected feedback or lead encoder is rotated while the PPI value is automatically measured then written into the appropriate PPI variable. This utility is useful for setting up applications where these values are not initially known.

#### Notes:

- To learn the Var01.08 (Lead PPI) value, the lead encoder must first be turning. Turning the lead motor and encoder is accomplished at the lead drive control, apart from the MS332.
- To learn the Var01.07 (Feedback PPI) value, the feedback (follower) encoder must first be turning. This is accomplished with the FbSpd (Feedback Speed) selection from inside this utility (explained below).

**Level Two - Select PPI learn operation:** Use this level to select one of three PPI learn operations. The operations and their mnemonics are described below. This is on the second level of the Diagnostic Menu.

#### PPI learn operations:

1) LdLrn (Lead Learn)

This operation measures the Lead PPI value and writes it into Var01.08.

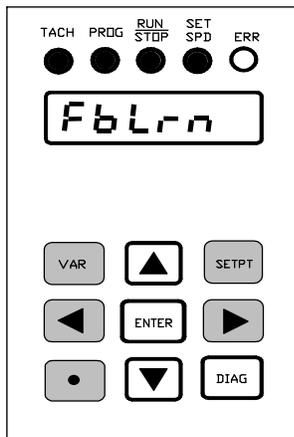
2) FbLrn (Feedback Learn)

This operation measures the Feedback PPI value and writes it into Var01.07.

3) FbSPd (Feedback Speed)

This operation allows scrolling the DAC up or down, setting the feedback encoder speed for FbLrn.

**Note:** Enter level two by selecting “PPI<sub>Lrn</sub>” in the display window while at level one of the Diagnostic Menu. (See Keypad Menus \Diagnostics Menu \Level One for a discussion of level one).



#### LED's / Display Window:

- All of the status led's are lit except for the ERR led.
- Display Window initially shows the PPI Learn Operation last selected, with all the digits flashing. (Ex. Showing “FbLrn” for the Feedback Learn operation).

#### Valid Keys:

To select Index Learn Operation:

- Press or to select LdLrn, FbLrn or FbSPd.
- When the desired selection is displayed, press to confirm and enter level three of the Encoder Pulse Per Index Learn utility.

**Note:** Pressing while LdLrn or FbLrn is displayed automatically begins the PPI learn process in level three.

OR

Press to exit the Diagnostic Menu and return to level zero.

#### Invalid Keys:

- Pressing , , , or results in no action other than lighting the ERR (error) led.

## Keypad Menus \Diagnostic Menu (cont.):

### Encoder Pulses Per Index Learn Utility (cont.):

**Level Three - Learn PPI value or set temporary speed:** Use this level to execute the PPI learn operation selected in level two.

The feedback encoder RPM is displayed when the FbSPd operation is selected.

Two mnemonics are displayed when either the LdLrn or FbLrn operations are selected:

- First, "PrOCES" displays (flashing) while the MS332 measures the PPI.
- Then "dOnE" displays, indicating the Feedback PPI or Lead PPI value has been measured and stored in Var01.07 or Var01.08 respectively.

#### Display mnemonic/value

PrOCES (LdLrn or FbLrn selected)

dOnE (LdLrn or FbLrn selected)

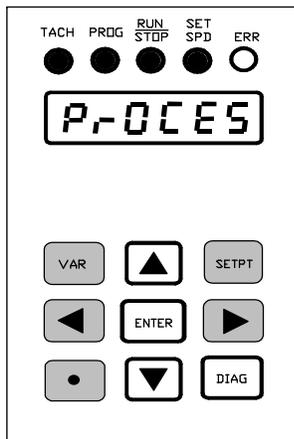
Numeric value (FbSPd selected)

#### Interpretation

LdLrn or FbLrn executing

LdLrn or FbLrn done

Display shows the real-time feedback encoder speed in RPM



#### **LED's / Display Window:**

- All of the status led's are lit except for the ERR led.
- Display Window:
  - shows feedback speed in RPM (if FbSPd is selected).
  - flashes "PrOCES", then displays "dOnE" (if LdLrn or FbLrn are selected).

#### **Valid Keys:**

If FbSPd is selected:

- Press or to scroll the feedback motor (and encoder) speed.
- When the desired RPM is reached, press to temporarily save the DAC code (for the duration of this utility) and return to level two.

**OR**

Press to exit the Diagnostic Menu and return to level zero.

If LdLrn or FbLrn are selected:

- Press to return to level two.

**OR**

Press to exit the Diagnostic Menu and return to level zero.

**Note:** Only these two keys are valid while "PrOCES" is flashing or while "dOnE" is displayed. (However, pressing either key while "PrOCES" is flashing interrupts the Learn operation and no new value is stored into Var01.07 or Var01.08).

#### **Invalid Keys:**

- Pressing , , , or results in no action other than lighting the ERR (error) led.

## Keypad Menus \Diagnostic Menu (cont.):

### Encoder Pulses Per Index Learn Utility (cont.):

#### Step-By-Step PPI Learn Procedure

Note: The feedback encoder Pulses Per Revolution value should be entered into Var01.02 before executing this utility.

Enter the Pulse Per Index learn utility:

1. Open the MS332 RUN switch (open the contact across TB3 pins 1 and 2).
2. From keypad level 0 (not in a menu), press **DIAG** (enter the Diagnostics menu).
3. Press **▲** or **▼** several times until the display flashes "PPILrn". Press **ENTER** (enter PPI learn).

Determine Lead PPI:

4. Run the lead system (to generate lead encoder and index pulses). The exact speed is not important.
5. Press **▲** or **▼** until the display flashes "LdLrn". Press **ENTER** (begin Lead PPI learn).  
The display will flash "PrOCES" (process) while the MS332 counts the lead encoder pulses per lead index pulse. When finished, the display shows "dOnE" (the measured lead PPI value has been written into variable 1.08).
6. Stop the lead system.
7. Press **ENTER**. The display will flash "LdLrn" again.

Determine Feedback PPI:

8. Press **▲** or **▼** until the display flashes "FbSPd". Press **ENTER** (enter feedback speed adjustment).
9. The display will initially show "000000." (feedback encoder stopped).  
Press and hold **▲**. The follower system should start moving, steadily increasing in speed. The display shows the feedback encoder rpm.
10. When the follower system is moving at a moderate speed (the exact speed is not important), remove your finger from **▲**.
11. Press **ENTER**. The display will flash "FbSPd" again. The follower system will continue moving (allowing the MS332 to receive feedback encoder and index pulses).
12. Press **▲** or **▼** until the display flashes "FbLrn" (feedback learn). Press **ENTER**.  
The display will flash "PrOCES" (process) while the MS332 counts the feedback encoder pulses per feedback index pulse. When finished, the display shows "dOnE" (the measured feedback PPI value has been written into variable 1.07).

Exit the Pulse Per Index learn utility:

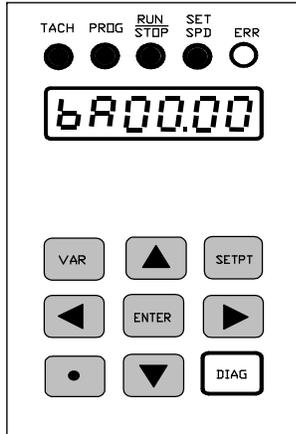
13. Press **DIAG** (exit the Diagnostics menu). The follower system will stop. PPI Learn is complete.

## Keypad Menus \Diagnostic Menu (cont.):

### Product-Version-Revision Diagnostic:

**Level Two – Observe Product-Version-Revision code:** Use this level to observe the MS332 product/version/revision code.

**Note:** Enter level two by selecting “UErrEU” in the display window while at level one of the Diagnostic Menu. (See level one above).



### LED's / Display Window:

- All of the status led's are lit except for the ERR led.
- Display Window shows the Product-Version-Revision code.  
(Ex. Showing bA00.00: Basic MS332, Version 00, Revision 00).

### Valid Keys:

- Press **DIAG** to exit the Diagnostic Menu and return to level zero.

### Invalid Keys:

- Pressing **VAR**, **SETPT**, **▲**, **▼**, **ENTER**, **◀**, **▶** or **●** results in no action other than lighting the ERR (error) led.

## Keypad Menus (cont.):

### Keypad Security Menu:

**Keypad Security** allows selective disabling of keypad menu editing and level-zero scrolling *when the keypad is locked*. The effect of each selected *disable* is as follows:

<u>Keypad feature disabled:</u>	<u>Effect when disabled:</u>
Change Variable Menu editing	Menu may be entered, variables may be observed but not changed.
Change Set-point Menu editing	Menu may be entered, variables may be observed but not changed.
Diagnostic Menu	Menu may not be entered.
Set-point Scroll	Attempts to scroll the active set-point from the keypad have no effect.
Advance/Retard Scroll	Attempts to Advance or Retard scroll from the keypad have no effect.

### Keypad Security Variables:

Security is controlled by three Keypad Security Variables (found in the Keypad Security Menu):

1) **PASIn** (PASsword code **I**nput):

This 6-digit variable is where a code is entered to *lock or unlock* the keypad. To unlock the keypad, enter the password code value into **PASIn**. Any other code locks the keypad. This variable may be thought of as a *keyhole* for which only one *key* or code (the password code) will unlock the keypad.

2) **PASdEF** (PASsword **dE**Finition):

This 6-digit variable *defines* the password code for unlocking. To unlock the keypad, the numerical value of **PASdEF** (the password code) must be entered into **PASIn**. This variable may be thought of as defining the *key* to the keypad. Therefore, changing this variable may be thought of as *changing the lock*.

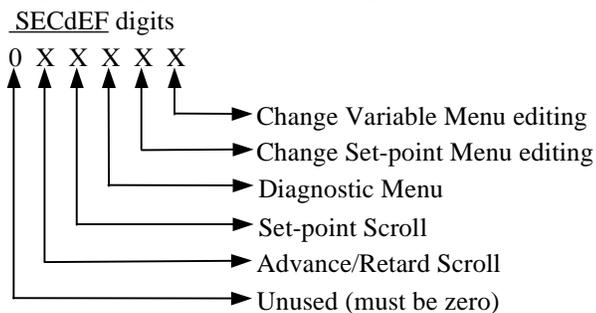
**Note:** When **PASIn**'s value is *different* from **PASdEF**'s value, the keypad is *locked*.

Conversely, when **PASIn**'s value is *identical* to **PASdEF**'s value, the keypad is *unlocked*.

3) **SECdEF** (keypad **SEC**urity **dE**Finition):

This 6-digit variable defines the *effect* of keypad-lock. This is where the previously mentioned selective disabling is defined. When the keypad is locked, **SECdEF**'s five right-most digits define which (if any) keypad features are *lock-disabled*.

**SECdEF**'s digit to keypad-lock-effect correspondence is as follows:



The allowed **SECdEF** digit values and their effects are as follows:

**Digit value**    **Effect on corresponding keypad feature when keypad is locked**

1	Disabled
0	Enabled

**Note:** Each **SECdEF** digit will accept a **1** or a **0** only. The left-most digit is unused and must be **0**.

**Note:** When the keypad is unlocked, each of the three keypad security variables may be observed and changed in the Keypad Security Menu. The effects of keypad-lock on the security variables are as follows:

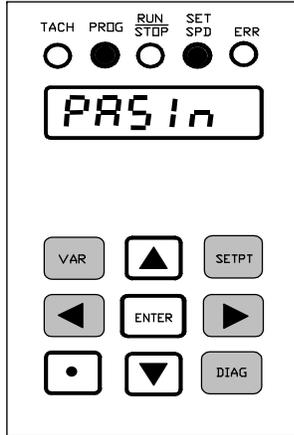
<b>Keypad security variable:</b>	<b>Effect of keypad-lock:</b>
<u>PASIn</u>	None (always observable and changeable).
<u>PASdEF</u>	May not be observed or changed.
<u>SECdEF</u>	May be observed <i>but not changed</i> .

## Keypad Menus \Keypad Security Menu (cont.):

Follow these steps to access the Keypad Security Menu:

**Level One - Select security variable:** Use this level to select from among PASIn, PASdEF and SECdEF. This is the first level of the Keypad Security Menu.

**Note:** Enter level one by pressing  while at level zero. (See level zero above).



### LED's / Display Window:

- PROG and SET SPD led's are lit.
- Display Window shows the selected security variable, with all the digits flashing.  
(Ex. Showing "PASIn" for the Password code Input variable).

### Valid Keys:

To select which security variable to access:

- Press  or  to select PASIn, PASdEF or SECdEF.
- When the desired variable is displayed, press  to confirm and enter level two of the Keypad Security Menu.

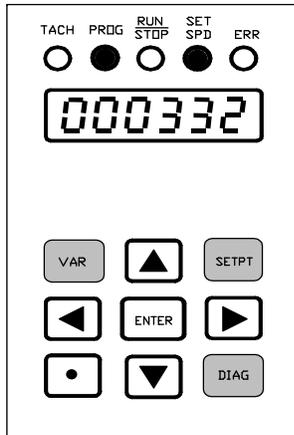
**OR**

Press  to exit the Keypad Security Menu and return to level zero.

### Invalid Keys:

- Pressing , , ,  or  results in no action other than lighting the ERR (error) led.

**Level Two – Change security variable value:** Use this level to observe and/or change the value of the selected security variable. This is on the second level of the Keypad Security Menu.



### LED's / Display Window:

- PROG and SET SPD led's remain lit.
- Display Window shows the value of the selected security variable, with the right-most digit flashing.  
(Ex: Showing "000332" for the factory default value of PASIn).

**Exception:** When PASdEF is selected while keypad is locked, the mnemonic "HlddEn" is displayed, concealing PASdEF's value.

### Valid Keys:

To change the value of the selected security variable:

**Note:** When the keypad is locked (i.e., PASIn's value does match PASdEF's value) PASdEF or SECdEF can't be changed. Trying to do so results in no action other than lighting up the ERR led.

- Press  or  to change the flashing (selected) digit.
- Press  or  to select which digit to change.
- When the desired value is reached, press  to save the new value and return to level one.

**OR**

Press  to exit the Keypad Security Menu (without saving) and return to level zero.

### Invalid Keys:

- Pressing ,  or  results in no action other than lighting the ERR led.

## Keypad Menus \Keypad Security Menu (cont.):

### Using Keypad Security:

**Note:** The state of the keypad (locked or unlocked) may be observed by viewing the PASdEF variable:

- If unlocked, then the numerical password value is displayed.
- If locked, then the "HlddEn" mnemonic is displayed.

### Unlocking:

1) Enter the password code into PASIn. An unlocked keypad can be verified by observing PASdEF's value.

### Defining the effect of keypad-lock:

- 1) Unlock the keypad by entering the password code into PASIn.
- 2) Enter the SECdEF settings (digit values for desired disables during keypad-lock).

### Locking:

1) Enter a number *other than the password code* into PASIn. A locked keypad can be verified by attempting to observe PASdEF's value.

### Changing the password code:

- 1) Unlock the keypad by entering the current password code into PASIn.
- 2) Enter the new password code into PASdEF.

### Important note regarding Keypad Security:

In any environment where tampering is a concern, it is strongly suggested that the keypad be kept locked with knowledge of the password code limited to the intended individuals. This is suggested even if no keypad features are set for lock-disable in SECdEF (i.e., when SECdEF is set to 000000). This is because anyone who changes the "lock" also changes the "key". When the keypad is unlocked (i.e., PASIn and PASdEF hold the same values) anyone can change PASdEF, thereby changing the lock with a new and unknown (to you) password code.

Leaving the keypad unlocked is similar to removing the lock from a door: Anyone can put on a new lock (change PASdEF), and unless the individual is thoughtful enough to leave the new *key* in the new lock (enter PASdEF's new value into PASIn), you are locked out!

### Keypad Menu Access:

The Keypad Security, Change Variable and Change Set-point Menus can be entered at any time - even when the MS332 is running (i.e., when the Run/Stop Switch is closed and the Fast Stop Switch is open, if assigned). However, the selective keypad security determines if variables or set-points are changeable or not, once inside the respective menus. The MS332 continues all real-time control operations when in the Keypad Security, Change Variable and Change Set-point Menus. Changed security variables, changed program variables and changed set-points take immediate effect.

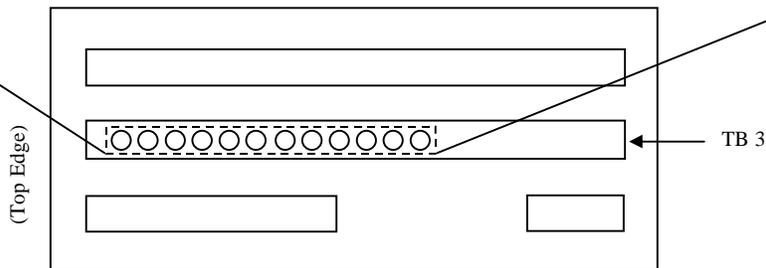
Assuming the selective keypad security is disabled, the Diagnostic Menu can be entered only if the Run/Stop Switch is open and the DAC is at zero. Therefore, no real-time control operations occur while in the Diagnostic Menu.

# Switch Inputs (Terminal Connections, Device Compatibility, Functions, Switch Input Vars [07.00 to 07.06])

The MS332 has eight Switch Inputs. One (Switch Input 0) is dedicated to the Run/Stop Function. Each of the other seven Switch Inputs may have one of twelve different Switch Input Functions assigned to them by the user or they may be left with no functions assigned to them. For ON/OFF type functions, the function is turned ON (or active) by connecting the Switch Input to Ground C, and turned OFF (or inactive) by disconnecting the Switch Input from Ground C. MS332 Switch Inputs are compatible with mechanical ON/OFF switches, relays and open-collector NPN transistors. (See 'Device Compatibility' diagram below).

## Terminal Connections:

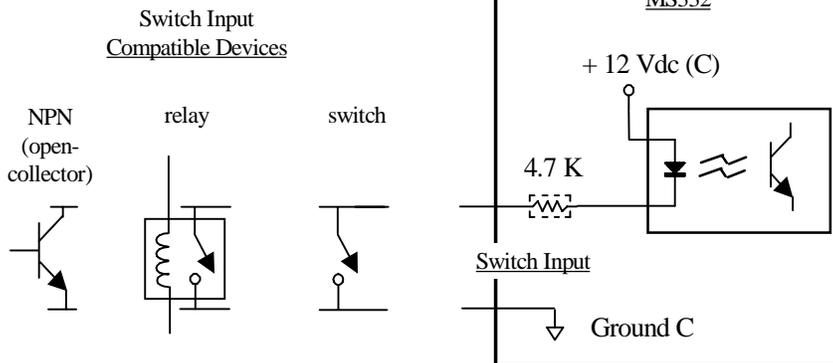
-----Switch Inputs-----											
Switch Input 0 (Run/Stop)	Ground C	Switch Input 1	Switch Input 2	Ground C	Switch Input 3	Switch Input 4	Ground C	Switch Input 5	Switch Input 6	Ground C	Switch Input 7
TB3 - 1	TB3 - 2	TB3 - 3	TB3 - 4	TB3 - 5	TB3 - 6	TB3 - 7	TB3 - 8	TB3 - 9	TB3 -10	TB3 -11	TB3 -12



MS332 Rear-View

See 'Reference Section \Hardware Illustrations \Rear-View' for a complete diagram showing the details of terminal strip TB3 (containing the Switch Inputs) on the back of the MS332 package.

## Device Compatibility:



## Switch Inputs \Functions:

### Run/Stop Function:

The Run/Stop function is permanently assigned to Switch Input 0. When Switch Input 0 is closed, the MS332 will drive its Analog Output to the set-point/calibration/lead-speed (if follower) determined voltage and then begin decoding encoder inputs. When Switch Input 0 is opened, the MS332 will cease decoding encoder inputs and drive the Analog Output to the zero DAC (offset) voltage.

If the Run/Stop switch is:	Then the <b>command</b> is:
Open	STOP
Closed	RUN

**Note:** In Master or Follower modes, the Analog Output will ramp. In Jog mode, the Analog Output will ramp or step, depending on the Jog Mode Configuration Var07.11.

### Jog Mode Function:

Selects Jog mode when the assigned Switch Input is closed. The feedback encoder then runs at the Jog mode set-point when the Run/Stop switch is closed. Var06.12 sets the Jog mode speed. (See 'Reference Section \Operational Variables \Set-points and Set-point Units' for details on Var06.12).

**Note:** Selecting Jog mode (by closing the Jog mode function-assigned Switch Input) overrides the Master/Follower operating mode selection.

### Set-point Scroll-down Function:

Accesses the Set-point Scroll-down feature when the assigned Switch Input is closed, and de-accesses this feature when the Switch is opened. (See 'Reference Section \Scrolling' for details on Set-point Scroll).

### Set-point Scroll-up Function:

Accesses the Set-point Scroll-up feature when the assigned Switch Input is closed, and de-accesses this feature when the Switch is opened. (See 'Reference Section \Scrolling' for details on Set-point Scroll).

### Active Set-point Select Function(s):

Selects different set-points when assigned Switch Input(s) are open/closed. If only one of the set-point select functions is assigned to a Switch Input, then that function selects from only two mode-determined set-points, as shown in the top half of the table. If both set-point select functions are assigned to Switch Inputs, then both functions work together to select from all four mode-determined set-points, as shown in the bottom half of the table: (**Note:** Code '4' and '5' refer to Switch Input function codes).

If the <b>code 4-assigned</b> Switch Input is:	<u>And</u> if the <b>code 5-assigned</b> Switch Input is:	Then the selected mode-determined <b>Active Set-point</b> is:
Open	(not assigned)	setpt 0
Closed	(not assigned)	setpt 1
(not assigned)	Open	setpt 0
(not assigned)	Closed	setpt 2
Open	Open	setpt 0
Closed	Open	setpt 1
Open	Closed	setpt 2
Closed	Closed	setpt 3

**Note:** Assigning codes **4 and/or 5** to Switch Inputs overrides the Master mode set-point select Var06.13, the Ratio-Follower mode set-point select Var06.14 and the Index-Follower mode set-point select Var06.15. (Vars 06.13, 06.14 and 06.15 have no effect when codes **4 and/or 5** are assigned to Switch Inputs).

### Advance Scroll Function:

Accesses the Advance Scroll feature when the assigned Switch Input is closed, and de-accesses this feature when the Switch is opened. (See 'Reference Section \Scrolling' for details on Advance Scroll).

### Retard Scroll Function:

Accesses the Retard Scroll feature when the assigned Switch Input is closed, and de-accesses this feature when the Switch is opened. (See 'Reference Section \Scrolling' for details on Retard Scroll).

## Switch Inputs \Functions (cont.):

### Closed-loop/Open-loop Select Function:

Selects operating mode to run closed-loop or open-loop when the assigned Switch Input is open/closed:

If the assigned Switch Input is:	Then the Master/Follower operating mode <b>runs in:</b>
Open	Closed-loop
Closed	Open-loop (per Var07.12)

**Note:** See 'Reference Section \Operational Variables \Open-loop Configuration' for details on Var07.12.

### Master/Follower Mode Select Function:

Selects Follower or Master operating mode when the assigned Switch Input is open/closed:

If the assigned Switch Input is:	Then the selected <b>operating mode</b> is:
Open	Follower mode
Closed	Master mode

#### Notes:

- 1) Assigning this function to a Switch Input overrides the Master/Follower Mode Select Var07.13. (Var07.13 then has no effect).
- 2) When using this function to select Follower mode, you must further configure which Follower mode is actually desired (Ratio-Follower or Index-Follower). See 'Reference Section \Encoder-Index Inputs, Power Supply Outputs \Encoder Variables \Variable 01.06' for details on Follower Mode Configuration.
- 3) This Master/Follower Mode Select Function is overridden if Jog mode is selected (by closing a Jog mode function-assigned Switch Input).

### Active Ramp Pair Select Function:

Selects the active ramp pair when the assigned Switch Input is open/closed:

If the assigned Switch Input is:	Then the selected <b>Active Ramp Pair</b> is:
Open	Accel 0 and Decel 0
Closed	Accel 1 and Decel 1

**Note:** Assigning this function to a Switch Input overrides the Active Ramp Pair Select Var02.05. (Var02.05 then has no effect).

### Fast Stop Function:

Fast Stops the feedback motor/encoder when the assigned Switch Input is closed. The Fast Stop Decel Ramp Var02.04 determines how quickly to ramp down the Analog Output under this condition.

**Note:** The Fast Stop function (when enabled) overrides and disables the Run/Stop Switch Input function.

- If the feedback motor/encoder is running or jogging, closing the Fast Stop switch overrides the Run/Stop switch and ramps the encoder to a stop using the Var02.04 ramp.
- The Run/Stop Switch Input will remain disabled as long as the Fast Stop switch is closed. To re-enable the Run/Stop Switch Input, open up the Fast Stop switch.

### Reverse Function:

Selects the feedback encoder's reverse (or opposite) direction when the assigned Switch Input is closed. The feedback encoder then runs in the reverse (or opposite) direction when the Run/Stop switch is closed:

If the assigned Switch Input is:	Then the Jog or Master mode <b>direction</b> is:	Then the Follower mode (Ratio or Index) <b>direction</b> is:
Open	Forward (Chan A leads Chan B)	Same as lead encoder direction
Closed	Reverse (Chan A lags Chan B)	Opposite of lead encoder direction

#### Notes:

- 1) The Reverse function requires using a bidirectional motor/drive. See 'Reference Section \Analog Output', and 'Reference Section \NPN Outputs \Contactor Reverse Function' for related information.
- 2) If the Reverse function is not assigned to a Switch Input, then the direction is always *Forward* in Jog or Master modes, and *Same as lead encoder direction* in the Follower modes.
- 3) If the Reverse function-assigned Switch Input changes state while the feedback encoder is running, then the feedback encoder speed ramps through zero to the same speed in the opposite direction.

## Switch Inputs \Function Assignment Variables:

**Function Assignment Variables 07.00 -> 07.06:** Each Switch Input has a Function Assignment Variable for selecting the desired function. These variables correspond to the Switch Inputs as shown in this table:

Switch Input	Function Assignment Variable
0	None (Reserved for Run/Stop)
1	Variable 07.00
2	Variable 07.01
3	Variable 07.02
4	Variable 07.03
5	Variable 07.04
6	Variable 07.05
7	Variable 07.06

To assign a certain Switch Input function to a certain Switch Input:

- First find the desired Switch Input function from the table below.
- Then enter the corresponding function code into the Switch Input's Function Assignment Variable.

To un-assign a Switch Input function from a certain Switch Input:

- Enter code **0** into the Switch Input's Function Assignment Variable.

The Switch Input Functions and their corresponding Codes are shown in this table:

Switch Input Function	Function Code
Run/Stop	None (permanently assigned to Switch Input 0)
Unused Switch Input	0
Jog mode	1
Set-point Scroll-down	2
Set-point Scroll-up	3
Active Set-point select 0 or 1	4
Active Set-point select 0 or 2	5
Advance	6
Retard	7
Closed-loop or Open-loop select	8
Follower mode or Master mode select	9
Active Ramp Pair select 0 or 1	10
Fast Stop	11
Reverse	12

**Note:** Each function code (except code **0**) can be assigned to only one Switch Input at a time. If you attempt to assign a function code that is already assigned to another Switch Input, the front-panel **ERR** led lights up and your code is not accepted. To proceed with the change, the desired function code must first be un-assigned from the other Switch Input.

**Note:** The statuses of the Switch Inputs 0 through 7 can be displayed on the Display Window.  
(See 'Reference Section \Display \Display Window Variable' for details).

## Scrolling (Scroll Vars 07.07 to 07.10, Set-point Scroll, Advance/Retard Scroll)

Scrolling allows the user to continuously increment or decrement certain quantities in real-time without entering the Change Variable/Change Set-point Menus. Scrolled quantities take immediate effect: when the MS332 is running (Run/Stop switch closed, Fast Stop switch open [if assigned]), the Analog Output responds as the quantity changes.

When Scroll is accessed, the display window changes from displaying real-time information (as selected by Var05.00) to the scrollable quantity's value. This quantity then begins to periodically increase or decrease by the appropriate mode-determined scroll step. For the first 2 seconds of scroll the quantity is 'stepped' once per 250 msec. After the first 2 seconds the quantity is 'stepped' once per 20 msec. The quantity continues to scroll for as long as Scroll is accessed or until it reaches its limit. When Scroll is de-accessed, the display window reverts back to real-time information (as selected by Var05.00).

### Scroll Variables:

**Variable 07.07 – Master Speed Scroll Step** – Enter the desired scroll step for scrolling the active Master mode speed set-point. (Var07.07 values must be entered in the same units as Var01.01).

**Variable 07.08 – Ratio-Follower Speed Ratio Scroll Step** – Enter the desired scroll step for scrolling the active Ratio-Follower mode ratio set-point. (Var07.08 values must be entered in the same units as Var01.04).

**Variable 07.09 – Phase Scroll Step** – Enter the desired scroll step for scrolling either the current phase-offset or the active Index-Follower mode phase set-point. (Var07.09 values must be entered in units of feedback encoder pulses).

**Variable 07.10 – Jog Speed Scroll Step** – Enter the desired scroll step for scrolling the Jog mode speed set-point. (Var07.10 values must be entered in units of RPM).

### Set-point Scroll:

Set-point Scroll-up/down changes only the active set-point (i.e. the selected set-point from the current operating mode): Master mode Speed, Ratio-Follower mode Ratio, Index-Follower mode Phase, or Jog mode Speed.

There are two ways to access Set-point Scroll-up or Scroll-down:

- 1) From the Keypad; by pressing the UP or DOWN arrow keys (if not security-locked) when at Keypad Level Zero.
- 2) From a remote switch; by remotely closing a Switch Input that has the Set-point Scroll-up or Set-point Scroll-down Switch Input function assigned to it.

### Advance/Retard Scroll:

Use Advance to speed up - and Retard to slow down - the feedback encoder when running closed-loop without index phase correction.

There are two ways to access Advance Scroll or Retard Scroll:

- 1) From the Keypad; by pressing the RIGHT(Advance) or LEFT(Retard) arrow keys (if not security-locked) when at Keypad Level Zero.
- 2) From a remote switch; by remotely closing a Switch Input that has the Advance Scroll or Retard Scroll Switch Input function assigned to it.

When either Advance/Retard Scroll is accessed, the current \*phase-offset is displayed (expressed in feedback pulses) and is then scrolled up or down in Phase Scroll Step (Var07.09) increments. As the phase-offset changes, the feedback motor speed increases or decreases accordingly, effecting the displayed phase-offset.

### Scrolling \Advance-Retard Scroll (cont.):

When Advance/Retard Scroll is de-accessed, scrolling terminates and the motor speed returns to the mode-determined active speed or ratio set-point (as the case may be). At this point, everything is as it would otherwise have been, except that the feedback encoder has advanced a certain number (= current phase-offset - previous phase-offset) of feedback pulses more or less than would have been the case if the advance or retard had not occurred.

Advance/Retard Scroll is enabled for Master, Ratio-Follower, or Index-Follower modes if both of the following requirements are met (Advance/Retard Scroll is never enabled for Jog mode):

- 1) The feedback encoder loop is closed (applies to all three modes).
- 2) The feedback index loop is open (applies to Index-Follower mode only).

The conditions for meeting these requirements are listed in the rows of this table:

Operating Mode	Var01.06 Code (Fol Mod Config)	Any Var07.00->.06 Code 8 (Open-loop)?	Open-loop switch:	Var07.12 Code (Open-loop Config)
Master	---	No	---	---
Master	---	Yes	Open	---
Master	---	Yes	Closed	0 or 2 (enable encoder loop)
Follower	0: (NoIndex)	No	---	---
Follower	0: (NoIndex)	Yes	Open	---
Follower	0: (NoIndex)	Yes	Closed	0 or 2 (enable encoder loop)
Follower	1: (Index)	Yes	Closed	2 (enable encoder loop disable index loop)

**\*Note:** The term “phase-offset” is not to be confused with the term “Phase Set-point”.

- **Phase Set-point:** In Index-Follower mode (with index loop closed), the **absolute** position of the feedback encoder relative to the lead encoder is measured and corrected per the active Phase Set-point **each time** the selected pair (lead and feedback) of index pulses is received. In between such index pulse pairs, the phase from the previous correction is maintained. In Index-Follower mode (with index loop closed) there is no phase-offset or Advance/Retard Scroll feature: phase changes in this mode are accomplished by changing the active phase set-point. (Advance/Retard Scroll has no effect on Phase Set-points and is not enabled in Index-Follower mode unless the feedback index loop is open).
- **Phase-offset:** In Master and Ratio-Follower modes (i.e., closed-loop modes without index phase correction), the position of the feedback encoder is dictated solely by its starting position, phase-offset, Master speed set-point or Follower (ratio set-point)\*(lead speed), and time. The phase-offset may be changed only through the Advance/Retard mechanism. Unlike Phase Set-points, the phase-offset defaults to zero at power-up and mode changes.

**See** 'Reference Section \Keypad \Keypad Level Zero' for details on keypad level zero.

**See** 'Reference Section \Switch Inputs' for details on assigning and using any of the Scroll Switch Input Functions.

**See** 'Reference Section \Operational Variables \Active Set-point Selection' for details on the active set-point.

**See** 'Reference Section \Operational Variables \Set-points and Set-point Units' for information on changing any (active or non-active) set-point.

# Encoder-Index Inputs, Power Supply Outputs

(Terminal Connections, DIP Switches,

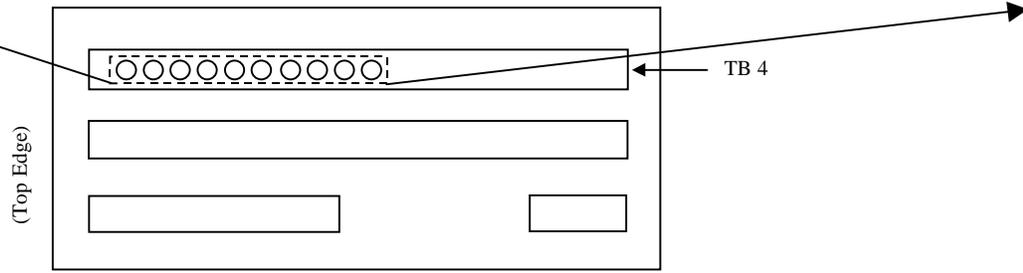
Encoder Vars [01.00, 01.02, 01.03, 01.05 to 01.08, 01.12],

Index Averaging-Matching Vars [01.09 to 01.11])

The MS332 takes input signals from a lead encoder, a feedback encoder, a lead index device and a feedback index device. The encoders must be incremental quadrature output type. Outputs from encoder and index devices may be NPN, PNP, TTL logic-gate or CMOS logic-gate types. The MS332 also provides an unregulated +12 Vdc power supply for powering encoder and index devices.

## Terminal Connections:

Lead Encoder/Index Power Supply		Lead Encoder/Index Signal			Feedback Encoder/Index Power Supply		Feedback Encoder/Index Signal		
-----Outputs-----		-----Inputs-----			-----Outputs-----		-----Inputs-----		
Ground C	+12 (C) volt	Lead ChA	Lead ChB	Lead Index	Ground C	+12 (C) volt	Fdbk ChA	Fdbk ChB	Fdbk Index
TB4 - 1	TB4 - 2	TB4 - 3	TB4 - 4	TB4 - 5	TB4 - 6	TB4 - 7	TB4 - 8	TB4 - 9	TB4 - 10

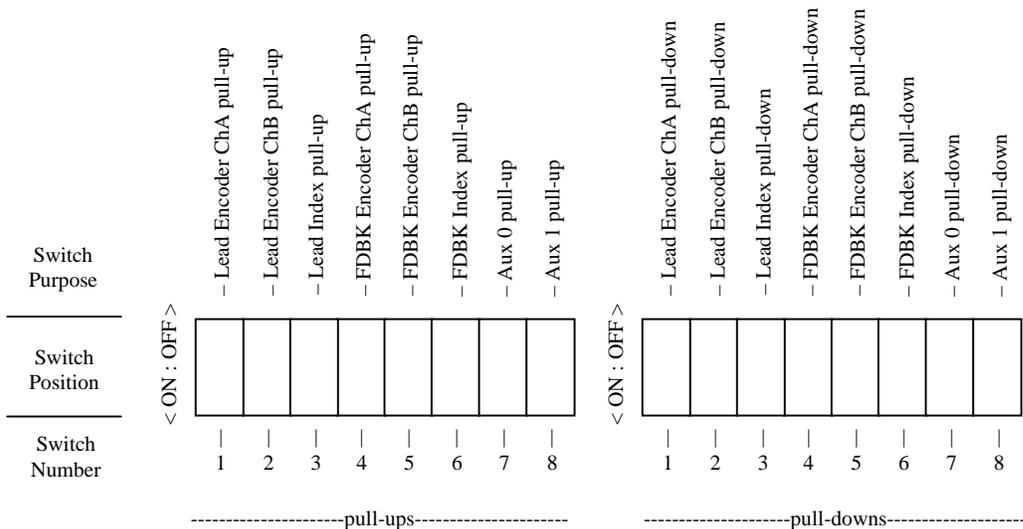


MS332 Rear-View

See 'Reference Section \Hardware Illustrations \Rear-View' for a diagram showing the details of terminal strip TB4 (containing the encoder/index signal and power terminals) on the back of the MS332 package.

## DIP Switches:

This diagram shows the Pull-up and Pull-down DIP Switches for the Encoders and Indexes. (View looking down on top of the MS332 package, with the front-panel on left). There are two banks of switches. (See 'Reference Section \Hardware Illustrations \Top-View' for a diagram showing the location of the DIP Switches on the MS332 package).



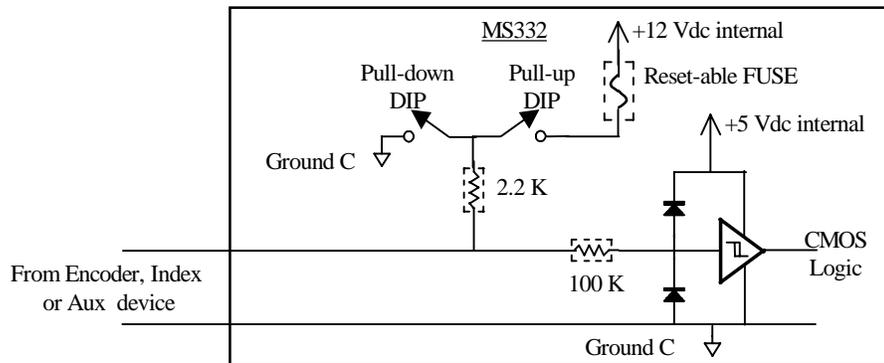
## Encoder-Index Inputs \Dip Switches (cont.):

### Encoder, Index and Aux input DIP Switches:

Each used input must have its pull-up and pull-down DIP switches configured for the type of device driving it. Each unused input must also be properly configured. Configure each Encoder, Index and Aux input DIP switch according to the following table:

Driving Device	Pull-up DIP Switch	Pull-down DIP Switch	Notes
NPN	ON	OFF	Input provides pull-up to +12C.
PNP	OFF	ON	Input provides pull-down to Ground C.
TTL/CMOS Gate	OFF	OFF	Hi-Z input.
Daisy-chained Lead encoder (any type)	OFF	OFF	Hi-Z input doesn't load signal or provide pull-up or pull-down.
None (unused input)	OFF	ON	Pulls unused input to Ground C.

### Encoder/Index/Aux input circuitry:



### Special notes on DIP Switches:

- 1) The DIP switches should be changed only while the MS332 is powered down.
- 2) Pull-up/pull-down DIP switch pairs should never be configured both ON while the MS332 is powered-up. If any pull-up/pull-down switch pair is configured both ON while the MS332 is powered-up, the internal protective device (reset-able fuse) may trip, disconnecting all pull-up switches from the internal +12Vdc supply. If this happens, the protective device may be reset by powering-down the MS332 for a few seconds.

## Encoder Variables:

### Variable 01.00 – Process Maximum Feedback Encoder RPM –

- (For Master mode). Enter the feedback encoder RPM corresponding to Var01.01 (Process Max Feedback Encoder RPM in User Units).
- (For Ratio-Follower mode). Enter the feedback encoder RPM corresponding to Var01.03 (Process Maximum Lead Encoder RPM) and Var01.04 ([Process Max Feedback Encoder RPM / Process Max Lead Encoder RPM] in User Units). This is the expected feedback encoder RPM when the lead encoder is running at the process max and the set-point is max.
- (For Index-Follower mode). Enter the feedback encoder RPM corresponding to Var01.03 (Process Maximum Lead Encoder RPM). This can be calculated from the formula:

$$\text{Var01.00 value} = (\text{Var01.03}) * (\text{Var01.07}/\text{Var01.02}) * (\text{Var01.05}/\text{Var01.08}) * (\text{Var01.10}/\text{Var01.11})$$

### Variable 01.01 – Process Max Feedback Encoder RPM in User Units –

See 'Reference Section \Operational Variables \Set-points and Set-point Units' for details on Var01.01.

**Variable 01.02 – Feedback Encoder PPR** - Enter the feedback encoder's Pulses Per Revolution value.

**Encoder-Index Inputs \Encoder Variables (cont.):**

**Variable 01.03 - Process Maximum Lead Encoder RPM** - (Ratio-Follower and Index-Follower modes). Enter the maximum expected lead encoder RPM for the process. This value may be known or it may have to be converted from lead process units into lead RPM.

**Variable 01.04 – [Process Max Feedback Encoder RPM / Process Max Lead Encoder RPM] in User Units** – See ‘Reference Section \Operational Variables \Set-points and Set-point Units’ for details on Var01.04.

**Variable 01.05 – Lead Encoder PPR** - (Ratio-Follower and Index-Follower modes). Enter the lead encoder’s Pulses Per Revolution value.

**Variable 01.06 – Follower Mode Configuration** – (Ratio-Follower and Index-Follower modes). The user must select the Follower mode (Ratio or Index) needed for their application. Select from the table:

Var01.06 CODE	Selected Follower mode
0	Ratio-Follower mode
1	Index-Follower mode

**Variable 01.07 - Feedback PPI** – (Index-Follower mode). Enter the number of Feedback Encoder Pulses per Feedback Index Pulse.

**Variable 01.08 - Lead PPI** - (Index-Follower mode). Enter the number of Lead Encoder Pulses per Lead Index Pulse.

**Variable 01.12 - No-Feedback Response Configuration** (Master, Ratio-Follower and Index-Follower modes). Variable 01.12 configures the MS332's response to a failed (or otherwise unresponsive) feedback encoder.

Var01.12 CODE	Response to No-Feedback condition
0	Let Position Error grow to max, remain closed-loop
1	Clear Position Error, run open-loop

**Index Averaging and Matching Variables (Index-Follower mode only):**

**Variable 01.09 - Pulses per Index Measurement and Averaging Control**

In Index-Follower mode, the Feedback/Lead RPM ratio between index phase corrections is given by the following relationship:

$$FbRPM/LdRPM = (FbPPI / LdPPI) * (Var01.05/Var01.02) * (Var01.10/Var01.11)$$

Where FbPPI and LdPPI are the effective Feedback and Lead Pulses Per Index values used in determining the RPM ratio. Var01.09 determines the values used for FbPPI and LdPPI as shown in the following table:

Var01.09 CODE	PPI Measurement	PPI Averaging	FbPPI, LdPPI values used for RPM ratio
0	disabled	disabled	Var01.07, Var01.08
1	enabled	disabled	Most recent measured Feedback Pulses Per Feedback Index and Lead Pulses Per Lead Index
2...32	enabled	enabled	Average of last (2...32) measured Feedback Pulses Per Feedback Index and Lead Pulses Per Lead Index

**Variable 01.10 – Feedback Index Pulses per Match** – Enter the number of feedback index pulses to be matched with Var01.11, the number of Lead Index Pulses per Match.

**Variable 01.11 – Lead Index Pulses per Match** - Enter the number of lead index pulses to be matched with Var01.10, the number of Feedback Index Pulses per Match.

**Note:** See ‘Description of Operating Modes Section \Index-Follower Mode’ for a more complete description of the usage and effect of PPI measurement and averaging, and of index matching.

## Analog Output (Terminal Connections, Calibration Vars [OFFSET, SCALE], Drive Compatibility)

The standard MS332 provides one Analog Output signal. This is the analog speed reference voltage signal sent to the motor-drive. The Analog Output voltage swings positive or negative as needed.

Functionally, the Analog Output behaves like a 12-bit plus sign DAC with adjustable offset and scale voltage. The Analog Output voltage obeys the following relationship:

$$\text{Analog Output voltage} = \text{OFFSET volts} + \text{SCALE volts} * (\text{DAC code} / 4095)$$

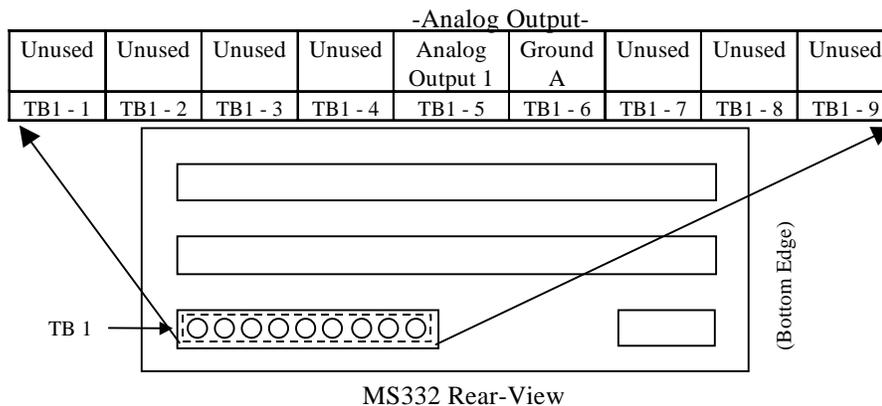
OFFSET volts range: -2.1Vdc to +2.1Vdc,

SCALE volts range: 0 to 11Vdc

DAC code range: -4095 to +4095

**Note:** The Analog Output voltage is limited to a maximum possible range of -11.0 to +11.0 Vdc.

### Terminal Connections:



See 'Reference Section \Hardware Illustrations \Rear-View' for a complete diagram showing the details of terminal strip TB1 (containing the Analog Output) on the back of the MS332 package.

### Calibration Variables:

The OFFSET and SCALE volts are adjusted with the OFFSET and SCALE calibration variables. The MS332 has no pots: all calibration is done from the keypad.

#### OFFSET:

The OFFSET variable adjusts the OFFSET volts. This sets the Analog Output voltage component that is insensitive to the DAC code. The OFFSET volts are the Analog Output volts when DAC code is zero. Offset adjustment is sometimes called "Zero" adjustment.

#### SCALE:

The SCALE variable adjusts the SCALE volts. This sets the Analog Output voltage sensitivity to nonzero DAC codes. Scale adjustment is sometimes called "Span" adjustment.

### Drive Compatibility:

**Non-Contactor Reversing Drive:** This type of drive uses an analog speed reference where voltage controls both speed and direction (+ Vdc = Fwd; - Vdc = Rev). By default, the MS332 is programmed for this type of drive. In this case, the MS332 Analog Output has a possible bipolar range from the OFFSET voltage to -11.0 and +11.0 Vdc.

**Contactor Reversing Drive:** This type of drive uses an analog speed reference where a positive voltage controls the speed and a contactor input determines direction of rotation. The MS332 may be programmed for this type of drive by assigning the Contactor Reverse Function to one of the NPN Outputs. The state of the Contactor Reverse function-assigned NPN Output sets the encoder/motor direction (NPN Output OFF = Fwd; ON = Rev). In this case, the MS332 Analog Output is restricted to a possible unipolar range from the OFFSET voltage to +11.0 Vdc.

See 'Ref. Section \Keypad \Keypad Menus \Diagnostic Menu' for details on the Analog Output Calibration Utility.

See 'Reference Section \NPN Outputs' for details on assigning/using the Contactor Reverse NPN Output Function.

See 'Reference Section \Switch Inputs' for related information about the Reverse Switch Input Function.

## Operational Variables (Vars [07.11 to 07.14], [06.13 to 06.15], [06.00 to 06.12 and 01.01, 01.04], [02.00 to 02.05], [03.00 to 03.04])

### Jog Mode Ramp Configuration:

**Variable 07.11** enables/disables the acceleration and deceleration ramps in any combination for Jog mode. Enter the code to select desired configuration:

Var07.11 CODE	Jog Deceleration	Jog Acceleration
0	OFF	OFF
1	OFF	ON
2	ON	OFF
3	ON	ON

**Note:** In Jog mode, acceleration means ramping to the Jog mode set-point Dac value; deceleration means ramping to the 0 Dac value.

### Open-loop Configuration:

**Variable 07.12** defines the effect of *open-loop* when a Closed-loop/Open-loop function-assigned Switch Input is closed. Enter the code to select desired configuration:

Var07.12 CODE	Open-loop Effect:	
	Ignore (cut) Feedback Encoder Pulses	Ignore (cut) Feedback Index Pulses
0	No	No
1	Yes	No
2	No	Yes
3	Yes	Yes

**Note:** See 'Reference Section \Switch Inputs \Functions' for details on the Closed-loop/Open-loop Switch Input Function.

### Master/Follower Mode Selection:

The Master or Follower operating mode is selected by remote switch or from the keypad.

#### Master/Follower Mode Selection by remote switch:

See 'Reference Section \Switch Inputs' for details on assigning and using the Master/Follower Mode Select Switch Input Function.

#### Master/Follower Mode Selection from the keypad:

**Variable 07.13 - Master/Follower Mode Select** - Enter the code to select between Master and Follower operating modes:

Var07.13 CODE	Selected operating mode
0	Follower mode
1	Master mode

#### Notes:

- 1) Var07.13 is overridden (has no effect) when the Master/Follower Mode Select Switch Input Function is assigned to a Switch Input. See 'Reference Section \Switch Inputs' for details on this method.
- 2) Var07.13 is also overridden if a Jog mode function-assigned Switch Input is closed. (Jog mode over-rides Master or Follower modes). See 'Reference Section \Switch Inputs \Functions' for details on the Jog mode function.
- 3) When Var07.13 is set to select Follower mode, it is necessary to further configure which of the two Follower modes is actually desired (Ratio-Follower or Index-Follower). See 'Reference Section \Encoder-Index Inputs, Power Supply Outputs \Encoder Variables \Variable 01.06' for details on configuring for Ratio-Follower or Index-Follower mode.

## Operational Variables (cont.):

### Phase Change Release Time:

The MS332 accomplishes phase changes by introducing *externally-determined phase difference errors* into the closed-loop PID algorithm\*. To ensure smooth phase difference error correction, the error is not introduced to the PID all at once, but is instead time-released (spread out over time). This is accomplished by dividing the error into  $(1024) \cdot (\text{Var07.14})$  pieces and adding the pieces, one-per-loop-update, into the PID's phase difference error (PID loop is updated 1024 times per second).

Externally-determined phase difference errors arise by two mechanisms:

- 1) Index-Follower mode index phase measurement.
- 2) Master and Ratio-Follower mode Advance/Retard Scroll mechanism.

**Variable 07.14 - Phase Change Release Time** – Enter the time over which the phase difference error is introduced into the PID. The allowed range for Var07.14 values is 0.01->100.0 (in seconds).

**Note:** The Phase Change Release Time is not the same as Var03.01 (Integral Time Constant):

- Var07.14 (Phase Change Release Time) sets the time over which an externally-determined phase difference error is smoothly introduced into the PID.
- Var03.01 (Integral Time Constant) determines the PID's phase difference error correction rate.

**\*Note:** In this context, phase changes refers to changes apart from the corrections made in the normal course of maintaining correct speed and phase. Similarly, *externally-determined phase difference error* refers to mechanisms of determining error apart from the normal cumulative mechanism based on encoder quadrature phases. The closed-loop PID performs its normal phase error measurements and corrections 1024 times per second.

## Operational Variables (cont.):

### Active Set-point Selection:

The Master, Ratio-Follower, and Index-Follower modes each have four set-points. The Jog mode has only one set-point. For the Master, Ratio-Follower, and Index-Follower modes, the active set-point is selected by remote switch or from the keypad.

### Active Set-point Selection by remote switch:

See 'Reference Section \Switch Inputs' for details on assigning and using the Active Set-point Select Switch Input Function(s).

### Active Set-point Selection from the keypad:

If the Active Set-point Select Switch Input Function(s) are not assigned to any Switch Inputs, then Var06.13 selects the Master mode speed set-point. Similarly, Var06.14 selects the Ratio-Follower mode ratio set-point, and Var06.15 selects the Index-Follower mode phase set-point.

**Variable 06.13 – Master Mode Active Set-point Select** – Enter the corresponding code to select the active Master mode speed set-point:

Var06.13 CODE	Master Mode Active Set-point
0	Speed setpt 0
1	Speed setpt 1
2	Speed setpt 2
3	Speed setpt 3

**Variable 06.14 – Ratio-Follower Mode Active Set-point Select** – Enter the corresponding code to select the active Ratio-Follower mode speed ratio set-point:

Var06.14 CODE	Ratio-Follower Mode Active Set-point
0	Speed Ratio setpt 0
1	Speed Ratio setpt 1
2	Speed Ratio setpt 2
3	Speed Ratio setpt 3

**Variable 06.15 – Index-Follower Mode Active Set-point Select** – Enter the corresponding code to select the active Index-Follower mode phase set-point:

Var06.15 CODE	Index-Follower Mode Active Set-point
0	Phase setpt 0
1	Phase setpt 1
2	Phase setpt 2
3	Phase setpt 3

**Note:** Vars 06.13, 06.14 and 06.15 are overridden (have no effect) when the Active Set-point Select Switch Input Function(s) are assigned to Switch Inputs. See 'Reference Section \Switch Inputs' for details on this method.

## Operational Variables (cont.):

### Set-points and Set-point Units:

The MS332 has four Master mode speed set-points, four Ratio-Follower mode speed ratio set-points, four Index-Follower mode phase set-points, and one Jog mode speed set-point.

**Set-points:** Set-points are stored in **Variables 06.00** through **06.12** (a.k.a., **Pr 06.00** to **Pr06.12**). The set-point description and their Change Variable Menu/Change Set-point Menu (level one) mnemonics are given for each in the following table:

Set-point Description	Change Variable Menu mnemonic (level one)	Change Set-point Menu mnemonic (level one)
Master mode speed setpt 0	Pr 06.00	SP 00
Master mode speed setpt 1	Pr 06.01	SP 01
Master mode speed setpt 2	Pr 06.02	SP 02
Master mode speed setpt 3	Pr 06.03	SP 03
Ratio-Follower mode speed ratio setpt 0	Pr 06.04	SP 04
Ratio-Follower mode speed ratio setpt 1	Pr 06.05	SP 05
Ratio-Follower mode speed ratio setpt 2	Pr 06.06	SP 06
Ratio-Follower mode speed ratio setpt 3	Pr 06.07	SP 07
Index-Follower mode phase setpt 0	Pr 06.08	SP 08
Index-Follower mode phase setpt 1	Pr 06.09	SP 09
Index-Follower mode phase setpt 2	Pr 06.10	SP 10
Index-Follower mode phase setpt 3	Pr 06.11	SP 11
Jog mode speed setpt	Pr 06.12	SP 12

**Note:** All set-points can be set and changed by using either the Change Variable or the Change Set-point Menus. Also, the active set-point can be changed directly (without entering a menu) by using the Set-point Scroll feature. (See 'Reference Section \Scrolling' for details on the Scroll feature. See 'Reference Section \Keypad \Keypad Menus' for details on the Change Variable and Change Set-point Menus. See 'Reference Section \Operational Variables \Active Set-point Selection' for details on the active set-point).

**Set-point Units:** Master mode speed set-points are in units set by Var01.01. Ratio-Follower mode speed ratio set-points are in units set by Var01.04. Index-Follower mode phase set-points are in units of Feedback Encoder Pulses. Jog speed set-point is in units of RPM.

**Variable 01.01 - Process Max Feedback Encoder RPM in User Units** – This variable configures the *units* in which speed set-points are entered and sets the max speed set-point value. Set-points may be entered in (your) user units or entered as RPM user units. In either case, the set-point value may range from 0 to the Var01.01 value:

- To configure for set-points given in *non*-RPM user units, set Var01.01 to the maximum process output value in (your) user units. See 'Set-up Section \Master Mode \Setting up Var01.00, Var01.01 for non-RPM User Units' for an example.
- To configure for set-points given in RPM user units, set Var01.01 equal to the Process Max Feedback Encoder RPM (*same numerical value* as Var01.00).

**Note:** Var01.01 sets the units for Master mode speed set-points, Master mode speed scroll step, certain NPN Output alarm thresholds, as well as the decimal point position of the Feedback Encoder Speed In User Units display option (Var05.00 option code 0).

## Operational Variables \Set-points and Set-point Units (cont.):

### Variable 01.04 - [Process Max Feedback Encoder RPM / Process Max Lead Encoder RPM] in User Units

This variable configures the *user units* of the feedback/lead encoder RPM ratio for Ratio-Follower set-points, feedback/lead encoder velocity ratio display and npn-output velocity ratio threshold parameters.

- To configure for set-points given in user units, set Var01.04 to  $(\text{Var01.00} / \text{Var01.03})$  converted to user units. See 'Set-up Section \Ratio-Follower Mode \Step 10' for an example that includes setting up Var01.04 for user defined *user units*.
- To use "unitless" RPM ratio user units, set Var01.04 equal to  $(\text{Var01.00} / \text{Var01.03})$ .

**Note:** Var01.04 also sets the decimal point position of the Follower Ratio In User Units display option (Var05.00 option code 1).

**Index-Follower Phase Set-point Units:** Index-Follower mode phase set-points set the position/phase relationship between each effective feedback index pulse and each effective lead index pulse. Index-Follower mode phase set-points must be entered in units of Feedback (follower) Encoder Pulses.

**Note:** See 'Description of Operating Modes Section \Index-Follower Mode' for a more complete description of index phase set-points, index phasing and effective index pulses.

## Operational Variables (cont.):

### Acceleration and Deceleration Ramps:

Under certain circumstances, the MS332 uses linear volts-verses-time ramp functions to transition the analog output to a new voltage. This linear voltage transition produces a corresponding motor speed transition.

It is important to understand what is (and isn't) meant by ramps in this manual. Ramps in the context of this manual are linear volts-verses-time functions *executed by the MS332, apart from the normal closed-loop speed, speed-ratio and phase control mechanisms.*

For example, a follower-mode scenario where the *lead encoder* speed transitions from one speed to another while the MS332 follows is *not* a ramp in the sense of the MS332's ramp mechanisms and variables. Here the MS332 *follows the lead*, never suspending its normal following mechanism.

Similarly, a scenario invoking a motor-drive's independent speed control / ramping functionality is also *not* a ramp in the sense of the MS332's ramp mechanisms and variables because speed control is taken away from the drive's analog input (and therefore away from the MS332).

### Ramp time variables (Var02.00 - Var02.04)

*Time* values are entered into the ramp variables Var02.00 - Var02.04. These ramp variables work together with Var01.00 (Process Max Feedback Encoder RPM) to determine the ramp rates (RPMs per second). The acceleration and deceleration ramp rates are (Var01.00/Var02.0X).

### Acceleration Ramp Variables:

Enter the desired time (in seconds) to ramp the feedback encoder RPM from 0 to Var01.00. The value may range from 0.1 to 3600.0 seconds.

**Variable 02.00 - Accel Ramp 0**

**Variable 02.01 - Accel Ramp 1**

### Deceleration Ramp Variables:

Enter the desired time (in seconds) to ramp the feedback encoder RPM from Var01.00 to 0. The value may range from 0.1 to 3600.0 seconds.

**Variable 02.02 - Decel Ramp 0**

**Variable 02.03 - Decel Ramp 1**

**Variable 02.04 – Fast Stop Decel Ramp** - (See 'Reference Section \Switch Inputs \Functions' for details on the Fast Stop Switch Input Function).

**Note:** The time values entered into Var02.00 - Var02.04 define ramp *rates* of RPM change per second (slopes). The time the feedback encoder speed spends ramping depends on the initial (pre-ramp) RPM, the ramp rate and the final (post-ramp) RPM. Speed changes less than the *maximum* 0 RPM to Var01.00 ramp-up or Var01.00 to 0 RPM ramp-down spend less time ramping but still ramp at the same *rate* as these maximum speed changes.

## Operational Variables \Acceleration and Deceleration Ramps (cont.):

### Ramp selection

Accel/Decel ramps are selected together. Ramp pairs may be selected by either Var02.05 (Active Ramp Pair Select) or by a Switch Input.

#### **Variable 02.05 selected Accel/Decel Ramp pair:**

Enter the code to select the desired active ramp pair.

Var02.05 CODE	Selected Active Ramp Pair
0	Accel 0 and Decel 0
1	Accel 1 and Decel 1

**Note:** Var02.05 is overridden (has no effect) when the Active Ramp Pair Select Switch Input Function is assigned to a Switch Input. See 'Reference Section \Switch Inputs' for details on this method.

#### **Switch Input selected Accel/Decel Ramp pair:**

See 'Reference Section \Switch Inputs' for details on assigning and using the Active Ramp Pair Select Switch Input Function.

### Causes and Criterion for Ramping

In a given operating mode, certain events *enable* ramping in the MS332.

When one such *enabling event* occurs, the MS332 checks the *ramp criterion* to decide whether or not to ramp. If the ramp criterion is true, the MS332 *ramps* to the Target Feedback RPM; otherwise the MS332 achieves the Target Feedback RPM by normal means.

In most cases, the ramp criterion is whether the Current Feedback RPM to Target Feedback RPM *difference* is greater than 10% of the process maximum Feedback RPM.

Current Operating Mode	Enabling Event	Ramp Criterion
All	Run/Stop Switch Input Change (open or close)	$ Current\ RPM - Target\ RPM  > (0.1 * Var01.00)$
All	Fast Stop Switch Input Change (open or close)	$ Current\ RPM - Target\ RPM  > (0.1 * Var01.00)$
Jog, Master, Ratio-Follower	Setpoint (value or selection) Change	$ Current\ RPM - Target\ RPM  > (0.1 * Var01.00)$
All	Operating Mode Change	$ Current\ RPM - Target\ RPM  > (0.1 * Var01.00)$
All	Fwd/Rev Switch Input Change (open or close)	Always ramp (change direction by ramping through zero RPM)

**Note:** In Jog mode, acceleration or deceleration ramps are further qualified by Var07.11 (Jog Mode Ramp Configuration). If Var07.11 disables acceleration ramps, the Analog Output voltage will *step* up to the new voltage. Similarly, if Var07.11 disables deceleration ramps, the Analog Output voltage will *step* down to the new voltage.

## Operational Variables (cont.):

### PID Compensation:

Each of the MS332's closed-loop control modes utilize PID compensation to help achieve and maintain precise, accurate speed and phase control. The MS332 control-loop reads the encoders, recalculates the PID terms and writes the Analog Output DAC 1024 times per second. Four user programmable PID variables are provided for tuning the closed-loop system. When adjusting these variables, it is best to test the dynamic performance (start/stop, load changes, set-point changes) in addition to the steady-state performance (running at set-point, constant load) of the system. MS332 PID compensation and the four PID variables are described in the following:

#### MS332 Proportional Compensation

The MS332 proportional compensation maintains accurate speed control. In Master mode, the proportional compensation drives the difference between the active speed set-point and the feedback encoder speed to zero. In the Follower modes, the proportional compensation drives the difference between the *\*(ratio-scaled)lead encoder* and feedback encoder speeds to zero.

**Variable 03.00 – Proportional Gain – Var03.00 controls how hard speed difference errors are driven to zero.** This is done by controlling the amount or "strength" of the proportional compensation. The allowed range is 1-1024. Generally speaking, larger values result in tighter, stiffer speed control over the motor's range of loads. If the Proportional Gain is set too high for the drive/motor/load/encoder subsystem, instability will result (ranging from small speed oscillations after a set-point or load change to continuous, violent jerking). Generally speaking, a higher-resolution encoder will require less Proportional Gain than a lower-resolution encoder.

#### MS332 Integral Compensation

The MS332 Integral Compensation maintains an accurate average feedback encoder phase (or position). This is particularly important in Follower mode applications such as electronic-gearing and event-synchronizing, where a particular phase difference from the *(ratio-scaled)lead encoder* must be maintained. The phase (or position) difference is the cumulative difference, in feedback encoder quadrature counts, between the *(ratio-scaled)lead encoder* and the feedback encoder.

Proportional Compensation achieves and maintains speed accuracy by maintaining a stable (unchanging) phase (or position) difference between the feedback encoder and the *(ratio-scaled)lead encoder* under steady-state conditions. However, a stable phase difference cannot be maintained under dynamic conditions with Proportional Compensation alone: if the set-point or load changes, a new phase difference will be established to maintain speed accuracy.

Integral Compensation maintains an accurate average phase difference by driving the average difference between the desired and actual phase difference to zero. So while Proportional Compensation maintains accurate speed at the expense of creating a certain phase difference to fit the set-point/drive/motor/load/encoder conditions, Integral Compensation drives the average phase difference to the desired value by driving the average phase difference error to zero.

**Variable 03.01 – Integral Time Constant – Var03.01 controls how quickly any average phase difference errors are driven to zero.** Var03.01 is the phase (or position) correction rate time constant. The allowed range is 0.0 to 100.0 seconds. A nonzero value is the time to reduce phase difference error to approximately 37% of its previous value (exponential response). Phase difference error is reduced to less than 0.25% after six Var03.01 time spans have passed. Generally speaking, smaller nonzero values result in faster phase correction over the motor's range of loads. If the Integral Time Constant is set too low (i.e., too fast) for a system's drive/motor/load/encoder combination, instability will result (ranging from small phase/speed oscillations after a set-point or load change to continuous, violent jerking). A zero value disables (turns off) Integral Compensation.

## Operational Variables \PID Compensation (cont.):

### MS332 Derivative Compensation

The MS332 Derivative Compensation together with Integral Compensation, attempts to maintain an accurate instantaneous feedback encoder phase (or position).

It was previously explained how Integral Compensation drives the average phase difference error to zero. This means that with Proportional and Integral Compensation only, the Follower phase (or position) difference at any given instant may not be the exact desired value, but on average the Follower phase difference will be the desired value. Viewed over time, the phase difference error may be described as a sum of the average value plus an instantaneous deviation (+ or -) from the average value.

It is this instantaneous error component that Derivative Compensation attempts to drive to zero. If Integral Compensation is viewed as reducing "slow", cumulative errors, Derivative Compensation may be viewed as reducing "fast", non-cumulative errors. In many systems, Proportional and Integral Compensation alone are fully adequate to achieve the desired system performance and in many systems Derivative Compensation produces little or no noticeable effect due to the response-time limitations of the drive/motor/load/encoder subsystem. For these reasons Derivative Compensation is used less often than Proportional and Integral Compensation.

**Variable 03.02 – Derivative Gain** – Var03.02 controls how hard any instantaneous phase difference errors are driven to zero. This is done by controlling the amount or "strength" of the Derivative Compensation. The allowed range is 1->100. Generally speaking, larger values result in tighter, stiffer phase control. If the Derivative Gain is set too high for the drive/motor/load/encoder subsystem, phase control will worsen (resulting in phase oscillations). Generally, a higher-resolution encoder will require less Derivative Gain than a lower-resolution encoder. A zero value disables (turns off) Derivative Compensation.

**Variable 03.03 – Derivative Sample Period** – This is the time between re-calculations of the Follower phase difference error deviation for Derivative Compensation. The allowed range is 0.001->1.000 seconds. Generally speaking, setting this variable to smaller values makes the Derivative more effective, but for any system that benefits from Derivative Compensation there will be a point of diminishing (or even counterproductive) returns, below which no more (or even less) phase difference accuracy is achieved.

\* **Note:** (*ratio-scaled*)lead encoder is a lead encoder speed or count value multiplied by a 'ratio' factor. This 'ratio' factor is determined by the Follower mode used:

In Ratio-Follower mode,                      ratio = the selected Follower Speed Ratio Set-point.  
In Index-Follower mode,                      ratio = (var01.10 / var01.11)    i.e., the Index Match Ratio.

### MS332 Zero Lead Speed PID Operation

The MS332 is factory-configured to control follower position (or phase) under all lead speed conditions: from a dead-stop, up to the maximum lead RPM. When used with a bidirectional motor-drive, a factory-default MS332 will maintain the follower at the correct stopped position even against attempts to manually move it in either direction (lead encoder stopped).

However, some follower applications have special requirements or restrictions for a stopped-lead situation. Some systems may require that the follower never correct its position when the lead is stopped. Some may additionally require that the follower position error be cleared to zero and not measured (accumulated) until the lead starts up again. Others may not tolerate follower reversing for any reason, under any circumstances. Variable 03.04 is included for these special cases.

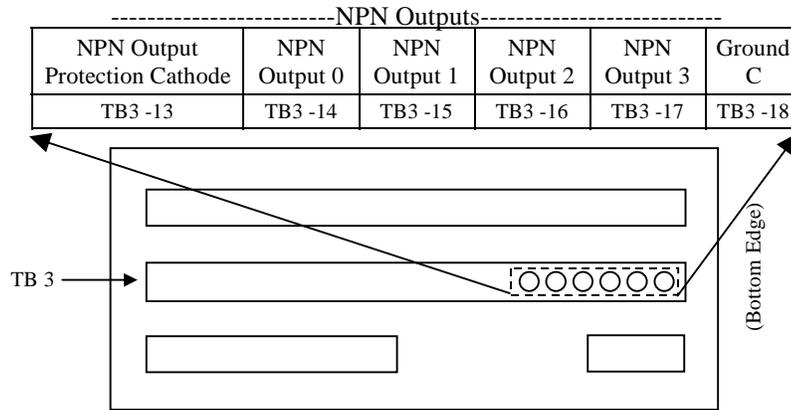
**Variable 03.04 – Zero Lead Speed PID Control** – (Ratio-Follower and Index-Follower modes only). Enter the code to select desired zero lead speed PID operation:

Var03.04 CODE	Measure Position Error	Correct Position Error	Forward only motion	Notes:
0	Yes	Yes	No	Factory-default (always correct)
1	Yes	No	No	Correct when lead starts
2	Yes	No	Yes	Same as 1, except forward only
3	No	No	No	Same as 1, except zero out error
4	No	No	Yes	Same as 3, except forward only

# NPN Outputs (Terminal Connections, Device Compatibility, Functions, NPN Output Vars [04.00 to 04.08])

The MS332 has four NPN Transistor Outputs. Each of the four NPN Outputs may have one of seventeen different NPN Output Functions assigned to them by the user, or they may be left with no functions assigned to them. The NPN Output Functions are ON/OFF type alarm/indicator functions. An alarm/indicator function is true when the MS332 turns its assigned NPN Output ON, driving the output voltage down near Ground C. An alarm/indicator function is false when the MS332 turns its NPN Output OFF. MS332 NPN Output compatibility includes relay coils, diodes, DC lamps, and logic inputs. (See 'Device Compatibility' diagrams below).

## Terminal Connections:

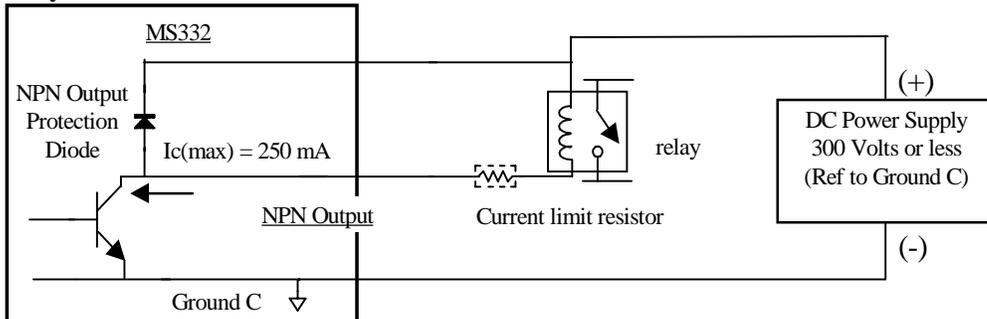


MS332 Rear-View

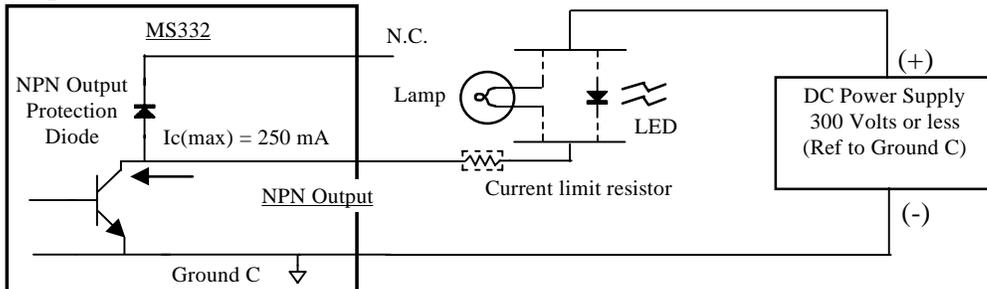
See 'Reference Section \Hardware Illustrations \Rear-View' for a complete diagram showing the details of terminal strip TB3 (containing the NPN Outputs) on the back of the MS332 package.

## Device Compatibility:

### Driving relays and other inductive loads:

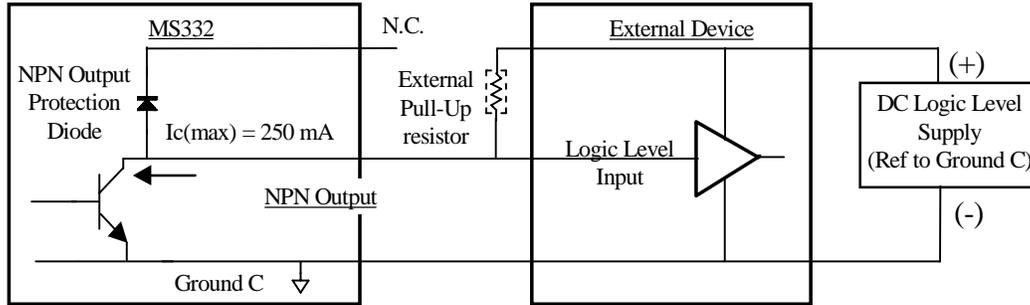


### Driving lamps, LED's, and other non-inductive loads:



## NPN Outputs \Device Compatibility (cont.):

Driving logic inputs:



## NPN Outputs \Functions:

The NPN Output Functions operate as described in the following table:

NPN Function	Function Input	Turns ON the NPN Output when the function input is...	Turns OFF the NPN Output when the function input is...
High Alarm	Feedback speed or speed ratio	$> \text{Threshold} * (1 + [\% \text{Hysteresis}/100])$	$< \text{Threshold} * (1 - [\% \text{Hysteresis}/100])$
Low Alarm	Feedback speed or speed ratio	$< \text{Threshold} * (1 - [\% \text{Hysteresis}/100])$	$> \text{Threshold} * (1 + [\% \text{Hysteresis}/100])$
Deviation Alarm	Feedback speed or speed ratio	$> (\text{Setpoint} + \text{SetpointDev}) * (1 + [\% \text{Hysteresis}/100])$ -or- $< (\text{Setpoint} - \text{SetpointDev}) * (1 - [\% \text{Hysteresis}/100])$	$< (\text{Setpoint} + \text{SetpointDev}) * (1 - [\% \text{Hysteresis}/100])$ -and- $> (\text{Setpoint} - \text{SetpointDev}) * (1 + [\% \text{Hysteresis}/100])$
Zero Speed	Feedback speed	$< \text{Fraction} * \text{Var01.00} * (1 - [\% \text{Hysteresis}/100])$	$> \text{Fraction} * \text{Var01.00} * (1 + [\% \text{Hysteresis}/100])$
Contactor Reverse	Reverse Switch, and/or Lead Encoder direction (See Note 2 below)	Jog or Master modes: - Reverse Switch closed. Ratio or Index Follower modes: - Lead running forward <u>and</u> Reverse Switch closed. - Lead running backward <u>and</u> Reverse Switch open (or not assigned).	Jog or Master modes: - Reverse Switch open (or not assigned). Ratio or Index Follower modes: - Lead running forward <u>and</u> Reverse Switch open (or not assigned). - Lead running backward <u>and</u> Reverse Switch closed.
Drive Enable	Run/Stop Switch, and Analog Output Dac	Run/Stop Switch closed	OpCode = 1: Run/Stop Switch open OpCode = 2: Run/Stop Switch open and Dac=0
Index Sync	Index Phase Error   (See Note 3 below)	$\leq \text{Threshold} * (1 - [\% \text{Hysteresis}/100])$	$> \text{Threshold} * (1 + [\% \text{Hysteresis}/100])$
Encoder Position Error Alarm	Closed-loop Position/Phase Error	$> \text{Threshold} * (1 + [\% \text{Hysteresis}/100])$ -or- $< -\text{Threshold} * (1 + [\% \text{Hysteresis}/100])$	$< \text{Threshold} * (1 - [\% \text{Hysteresis}/100])$ -and- $> -\text{Threshold} * (1 - [\% \text{Hysteresis}/100])$

**Note 1:** Active NPN functions are recalculated 51.2 times per second. Therefore, the maximum delay from an event to an NPN Output change will be less than 19.6 mS.

**Note 2:** Assigning the Contactor Reverse Function to an NPN Output also changes the Analog Output signal from a bipolar to a unipolar swing. See 'Reference Section \Analog Output' for details on Drive Compatibility.

See 'Reference Section \Switch Inputs' for details on assigning/using the Reverse Switch Input Function.

**Note 3:** Index Sync exists when the Index Phase Error between the appropriate lead and feedback indexes is within  $\pm$  Threshold feedback encoder pulses. Index Sync ceases to exist when the Index Phase Error falls outside the Threshold window. As long as the magnitude of the Index Phase Error is less than the Threshold window the index pulses are said to be in sync, as seen according to this formula:

$$(| \text{Index Phase Error} |) \leq (\pm \text{Threshold window})$$

See 'Reference Section \Display \Display Window Variable \Variable 05.00 \Codes 6 and 7' for details on the Index Phase Error and Index Phase.

## NPN Outputs \Function Variables:

**Function Assignment Variables 04.00 -> 04.03:** Each NPN Output has a Function Assignment Variable for entering the desired function code. The code determines the:

- 1) Function
- 2) Operating mode in which the function will be active
- 3) Input to the function.

**Function Parameter Variables 04.04 -> 04.07:** Each NPN Output has a Function Parameter Variable for entering a... Threshold, Setpoint Deviation or Fraction (for threshold-type functions) or an option code (OpCode) for selecting function options.

The Variables 04.00 -> 04.07 correspond to the NPN Outputs as shown in this table:

NPN Output	Function Assignment Variable	Function Parameter Variable
0	Var04.00	Var04.04
1	Var04.01	Var04.05
2	Var04.02	Var04.06
3	Var04.03	Var04.07

To assign a certain NPN function to a certain NPN Output:

- First find the desired function, active operating mode, and function input from the table below.
- Enter the corresponding function code into the NPN Output's Function Assignment Variable.
- Enter a desired value (in the indicated units) into the NPN Output's Function Parameter Variable.

To un-assign an NPN function from a certain NPN Output:

- Enter code **0** into the NPN Output's Function Assignment Variable.

The NPN Output Functions and their corresponding Codes are shown in this table:

NPN Function	Active Operating Mode	Function Input	Function Code	Function Parameter Type and Units
None (unused)	-----	-----	0	-----
High Alarm	Master	Feedback RPM	1	Threshold in Var01.01 Feedback Units
High Alarm	Ratio-Follower	Feedback RPM	2	Threshold in Var01.01 Feedback Units
High Alarm	Ratio-Follower	Follower ratio	3	Threshold in Var01.04 Follower Units
High Alarm	Master & Ratio-Fol.	Feedback RPM	4	Threshold in Var01.01 Feedback Units
Low Alarm	Master	Feedback RPM	5	Threshold in Var01.01 Feedback Units
Low Alarm	Ratio-Follower	Feedback RPM	6	Threshold in Var01.01 Feedback Units
Low Alarm	Ratio-Follower	Follower ratio	7	Threshold in Var01.04 Follower Units
Low Alarm	Master & Ratio-Fol.	Feedback RPM	8	Threshold in Var01.01 Feedback Units
Deviation Alarm	Master	Feedback RPM	9	SetpointDev in Var01.01 Feedback Units
Deviation Alarm	Ratio-Follower	Follower ratio	10	SetpointDev in Var01.04 Follower Units
Zero Speed	Master	Feedback RPM	11	Fraction of Var01.00 (ex: 1%, enter 0.01)
Zero Speed	Ratio-Follower	Feedback RPM	12	Fraction of Var01.00 (ex: 1%, enter 0.01)
Zero Speed	Master & Ratio-Fol.	Feedback RPM	13	Fraction of Var01.00 (ex: 1%, enter 0.01)
Contactor Reverse	Master, Ratio-Fol., Index-Fol., Jog	Reverse Switch, and/or Lead Encoder direction	14	Uses no parameter
Drive Enable	Master, Ratio-Follower, Index-Follower, Jog	Run/Stop Switch, and Dac	15	Unitless OpCode (select per NPN Output turn-OFF requirement): <b>1:</b> OFF when Run/Stop switch open. <b>2:</b> OFF when Run/Stop open <u>and</u> Dac = 0.
Index Sync	Index-Follower	Index Phase Error	16	Threshold in Feedback Encoder Pulses
Encoder Position Error Alarm	Master, Ratio-Follower, Index-Follower	Closed-loop Position/Phase Error	17	Threshold in Feedback Encoder Pulses

**Note:** Each function code (except code **0**) can be assigned to only one NPN Output at a time. If you attempt to assign a function code that is already assigned to another NPN Output, the front-panel **ERR** led lights up and your code is not accepted. To proceed with the change, the desired function code must first be un-assigned from the other NPN Output.

## **NPN Outputs \Function Variables (cont.):**

### **Variable 04.08 – NPN Output %Hysteresis:**

Threshold-type NPN Output functions have hysteresis to prevent the NPN Output from chattering ON/OFF when the function input is at the threshold. Hysteresis breaks a threshold into two thresholds for changing function state: one for the function input going high and one for the function input going low.

Low to High *effective* threshold = (Threshold) \* (1 + [%Hysteresis / 100])

High to Low *effective* threshold = (Threshold) \* (1 - [%Hysteresis / 100])

Hysteresis is entered in units of %, so the allowed range of Var04.08 is 0 -> 100. The %Hysteresis is always applied to the threshold.

The %Hysteresis applies to all active threshold-type NPN Output functions (all NPN Output functions except for the Contactor Reverse Function and the Drive Enable Function). **See** the table in the **NPN Outputs \Functions** discussion for a mathematical description of each function with hysteresis.

**Note:** The statuses of the NPN Outputs 0 through 3 can be displayed on the Display Window.  
(**See** 'Reference Section \Display \Display Window Variable' for details).

# Serial Communications (Interface Port, Serial Protocol, Serial Communications Vars [08.00 to 08.04], Modbus Implementation, Data Types, Remote Analog Output Calibration Procedure, Remote Encoder PPI Variable Determination Procedure, Addendum)

MS332 Serial Communications provide an alternative to the Front Panel Keypad/Display whereby User Variables (including Setpoints), real-time Display Values, Switch Inputs, Keypad buttons, and NPN Outputs may be remotely accessed.

## Interface Port:

The Interface Port consists of one balanced EIA-485 tri-state driver, one balanced EIA-485 receiver and their reference common (Ground B).

The Interface Port is electrically isolated from all other MS332 circuits and terminals. If desired, reference common (Ground B) may be tied to an external reference potential.

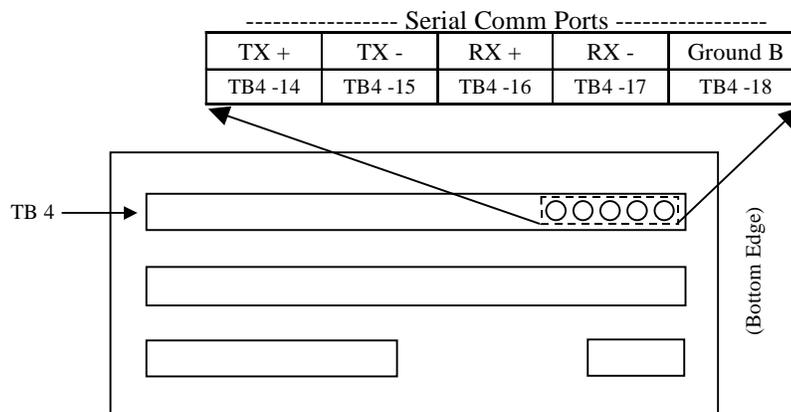
Separate terminals are provided for the driver, receiver and reference common (Ground B).

The driver tri-state outputs (TX+, TX-) are transmitter-controlled, remaining in Hi-Z state when not transmitting.

The interface port is compatible with both "4-wire" (TX+, TX-, RX+, RX- all separate) and "2-wire" (TX+, RX+ connected; TX-, RX- connected) network configurations.

The interface port is multi-slave compatible in both "2-wire" and "4-wire" network configurations.

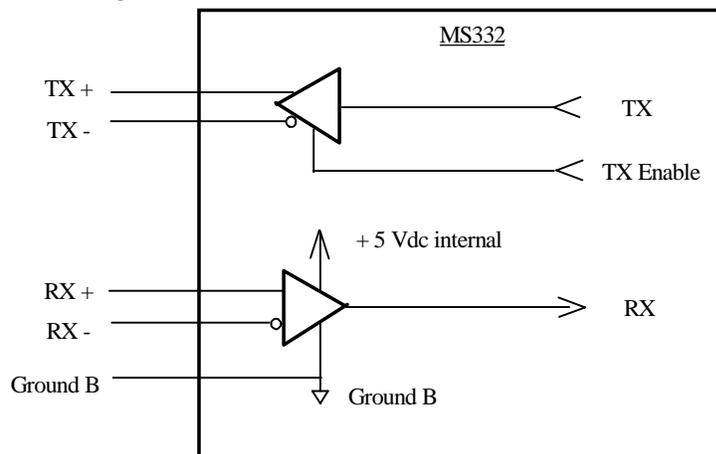
## Interface Port Terminal Connections:



MS332 Rear-View

See 'Reference Section \Hardware Illustrations \Rear-View' for a complete diagram showing the details of terminal strip TB4 (containing the Serial Communication Ports) on the back of the MS332 package.

## Interface Port Electrical Diagram:



## Serial Communications (cont.)

### Serial Protocol:

MS332 Serial Communications use the Modbus RTU protocol, configured as a Slave.  
Modbus is a trademark of Modicon, Inc.

### Serial Communications User Variables:

MS332 class 8 (Var08.0X) User Variables configure serial communications. These variables are accessible from the Front Panel Keypad/Display only (serial communications User Variables are not accessible with serial communications). All other User Variables are accessible with serial communications. Do not change these variables in a networked MS332 while the Master is transmitting queries. The Master should be disabled (or MS332 disconnected) before any of these variables are changed.

<u>User Var</u>	<u>Values</u>	<u>Usage</u>	<u>Notes</u>
Var08.00	1-247	Slave Address	Sets the MS332's Modbus slave address.
Var08.01	0-4	Baud Rate	Selects Baud Rate
Var08.02	0-2	Parity	Selects or Disables Parity
Var08.03	1	Mode	Modbus mode (RTU only)
Var08.04	0-5	Data Type	Select Data Type, 16-bit word ordering

<b>Var08.00</b>	<b>Value</b>	<b>Slave Address</b>	<b>Slave Address = Var08.00 value.</b>	
	1	1		
	2	2		
	...	...		
	247	247		
<b>Var08.01</b>	<b>Value</b>	<b>Baud Rate</b>	<b>Baud rate selected by Var08.01 value.</b>	
	0	1200		
	1	2400		
	2	4800		
	3	9600		
	4	19200		
<b>Var08.02</b>	<b>Value</b>	<b>Parity</b>	<b>Parity enabled/disabled, selected by Var08.02 value.</b>	
	0	Disabled	2 stop bits when parity is disabled.	
	1	Enabled-Odd	1 stop bit when parity is enabled.	
	2	Enabled-Even	1 stop bit when parity is enabled.	
<b>Var08.03</b>	<b>Value</b>	<b>Mode</b>	<b>Message framing selected by Var08.03 value.</b>	
	0	ASCII	Not implemented	
	1	RTU		
<b>Var08.04</b>	<b>Value</b>	<b>Data Type</b>	<b>Address XXXX0 Access</b>	<b>Address XXXX1 Access</b>
	0	float (32 bit)	High 2-bytes (32 of 3210)	Low 2-bytes (10 of 3210)
	1	float (32 bit)	Low 2-bytes (10 of 3210)	High 2-bytes (32 of 3210)
	2	long int (32 bit)	High 2-bytes (32 of 3210)	Low 2-bytes (10 of 3210)
	3	long int (32 bit)	Low 2-bytes (10 of 3210)	High 2-bytes (32 of 3210)
	4	int (16-bit)	2-bytes (entire value)	Illegal (exception code 02)
	5	unsigned int (16 bit)	2-bytes (entire value)	Illegal (exception code 02)

**Note:** The RTU-mode character frame format is always 11 bits (total):

- 1 Start Bit.
- 8 Data Bits.
- 1 Parity Bit and 1 Stop Bit (parity enabled) -or- 2 Stop Bits (parity disabled).

## Serial Communications (cont.)

### Modbus Implementation:

#### 1) MS332 / Modbus Address Mapping

Modbus defines separate address spaces for Coils (0XXXX), Discrete Inputs (1XXXX), Input Registers (3XXXX) and Holding Registers (4XXXX). MS332 outputs, inputs, Display Values and User Variables are mapped into these spaces as indicated in the following tables:

#### NPN Outputs: Modbus Coil (0XXXX) mapping

NPN Output	Modbus Address	Description	Range
0	01000	NPN output 0	0: OFF, 1: ON
1	01001	NPN output 1	0: OFF, 1: ON
2	01002	NPN output 2	0: OFF, 1: ON
3	01003	NPN output 3	0: OFF, 1: ON

#### Switch Inputs, Front Panel Keypad: Modbus Discrete Input (1XXXX) mapping

Switch Input	Modbus Address	Description	Range
0	11000	Switch Input 0 (Run/Stop)	0: OFF, 1: ON
1	11001	Switch Input 1	0: OFF, 1: ON
2	11002	Switch Input 2	0: OFF, 1: ON
3	11003	Switch Input 3	0: OFF, 1: ON
4	11004	Switch Input 4	0: OFF, 1: ON
5	11005	Switch Input 5	0: OFF, 1: ON
6	11006	Switch Input 6	0: OFF, 1: ON
7	11007	Switch Input 7	0: OFF, 1: ON
<b>Keypad Key</b>			
	11024	Variable Menu Key	0: OFF, 1: ON
	11025	Up Key	0: OFF, 1: ON
	11026	Setpoint Menu Key	0: OFF, 1: ON
	11027	Left Key	0: OFF, 1: ON
	11028	Enter Key	0: OFF, 1: ON
	11029	Right Key	0: OFF, 1: ON
	11030	Decimal Point Key	0: OFF, 1: ON
	11031	Down Key	0: OFF, 1: ON
	11032	Diagnostics Menu Key	0: OFF, 1: ON

#### Display Values: Modbus Input Register (3XXXX) mapping

Display Value	Modbus Address	Description	
0	31000	Feedback speed in user units	
1	31010	Fol speed ratio in user units	
2	31020	Feedback pulse freq in Hz	
3	31030	Lead pulse freq in Hz	
4	31040	Current DAC value	
5	31050	Feedback encoder position error	
6	31060	Index phase error	
7	31070	Index phase	
8	31080	Lead index pulse freq in Hz	
9	31090	Feedback index pulse freq in Hz	
10	31100	Ave Lead encoder PPI	
11	31110	Ave Feedback encoder PPI	
15	31150	PID Integral term	

## Serial Communications \Modbus Implementation \Address Mapping (cont.)

User Var:

Modbus Holding Register (4XXXX) mapping

User Var	Modbus Address	Description	Range
01.00	41000	Max process RPM - Feedback	1.00000->99999.
01.01	41010	Var01.00 in user units	0.0001->99999.
01.02	41020	Feedback encoder PPR	1->4096
01.03	41030	Max process RPM - Lead	1.00000->99999.
01.04	41040	Var01.00/Var01.03 in user units	0.0001->99999.
01.05	41050	Lead encoder PPR	1->4096
01.06	41060	Follower mode configuration	0: Ratio, 1: Index
01.07	41070	Feedback encoder PPI	0->99999
01.08	41080	Lead encoder PPI	0->99999
01.09	41090	PPI measure/average control	0:off, 1-32: ave last 1-32
01.10	41100	Feedback index pulse/match	1->21474
01.11	41110	Lead index pulse/match	1->21474
02.00	42000	Accel ramp 0	0.1->3600.0 s
02.01	42010	Accel ramp 1	0.1->3600.0 s
02.02	42020	Decel ramp 0	0.1->3600.0 s
02.03	42030	Decel ramp 1	0.1->3600.0 s
02.04	42040	Fast stop decel ramp	0.1->3600.0 s
02.05	42050	Active ramp pair select	0, 1
03.00	43000	Proportional gain	1->1024
03.01	43010	Integral time constant	0.0 (off) -> 100.0 s
03.02	43020	Derivative gain	1->1024
03.03	43030	Derivative sample period (sec)	0.001->1.000
03.04	43040	Zero lead speed PID control	0->4
04.00	44000	NPN output 0 function assign	0->17
04.01	44010	NPN output 1 function assign	0->17
04.02	44020	NPN output 2 function assign	0->17
04.03	44030	NPN output 3 function assign	0->17
04.04	44040	NPN output 0 function param	.00000->99999.
04.05	44050	NPN output 1 function param	.00000->99999.
04.06	44060	NPN output 2 function param	.00000->99999.
04.07	44070	NPN output 3 function param	.00000->99999.
04.08	44080	NPN output % hysteresis	0 -> 100
05.00	45000	Display selection	0 -> 15
06.00	46000	Master mode speed setpoint 0	.00000->99999.
06.01	46010	Master mode speed setpoint 1	.00000->99999.
06.02	46020	Master mode speed setpoint 2	.00000->99999.
06.03	46030	Master mode speed setpoint 3	.00000->99999.
06.04	46040	Ratio fol mode ratio setpoint 0	.00000->99999.
06.05	46050	Ratio fol mode ratio setpoint 1	.00000->99999.
06.06	46060	Ratio fol mode ratio setpoint 2	.00000->99999.
06.07	46070	Ratio fol mode ratio setpoint 3	.00000->99999.
06.08	46080	Index fol mode phase setpoint 0	-99999->99999
06.09	46090	Index fol mode phase setpoint 1	-99999->99999
06.10	46100	Index fol mode phase setpoint 2	-99999->99999
06.11	46110	Index fol mode phase setpoint 3	-99999->99999
06.12	46120	Jog mode speed setpoint	.00000->99999.
06.13	46130	Master mode active setpoint	0 -> 3
06.14	46140	Ratio fol mode active setpoint	0 -> 3
06.15	46150	Index fol mode active setpoint	0 -> 3

## Serial Communications \Modbus Implementation \Address Mapping (cont.)

**User Var (cont.): Modbus Holding Register (4XXXX) mapping (cont.)**

User Var	Modbus Address	Description	Range
07.00	47000	Switch input 1 function assign	0->12
07.01	47010	Switch input 2 function assign	0->12
07.02	47020	Switch input 3 function assign	0->12
07.03	47030	Switch input 4 function assign	0->12
07.04	47040	Switch input 5 function assign	0->12
07.05	47050	Switch input 6 function assign	0->12
07.06	47060	Switch input 7 function assign	0->12
07.07	47070	Master speed scroll step	.000001->100.000
07.08	47080	Ratio fol speed ratio scroll step	.000001->100.000
07.09	47090	Phase scroll step	0->100
07.10	47100	Jog speed scroll step	.000001->100.000
07.11	47110	Jog mode ramp configuration	0->3
07.12	47120	Open-loop configuration	0->3
07.13	47130	Master/Follower mode select	0: Follower, 1: Master
07.14	47140	Phase change release time (sec)	0.01->100.0
08.00	Not serially accessible	Modbus Slave Address	-----
08.01	Not serially accessible	Baud Rate select	-----
08.02	Not serially accessible	Parity select	-----
08.03	Not serially accessible	Modbus mode (RTU/ASCII)	-----
08.04	Not serially accessible	Data type select	-----
09.00	49000	Aout calibrate: OFFSET	-734 -> +734
09.01	49010	Aout calibrate: SCALE	0 -> 1150

### Notes:

- Each Display Value Input Register address includes the corresponding User Var 05.00 Display Selection code (XX in address 31XX0 is the selection code 0->15).
- Each User Variable Holding Register address includes the Class Var code of that User Variable (address 4XXX0 accesses User Var 0X.XX).

## 2) Supported Modbus Function Codes and their use

<u>Function Code</u>	<u>Use</u>
01 (Read Coil Status)	Read NPN Outputs
02 (Read Input Status)	Read Switch Inputs
03 (Read Holding Registers)	Read User Variable
04 (Read Input Registers)	Read Display Value
05 (Force Single Coil)	Write single NPN
06 (Preset Single Register)	Write User Variable
15 (Force Multiple Coils)	Write multiple NPNs
16 (Preset Multiple Registers)	Write User Variable

### Note on function codes 05 and 15:

- These function codes allow forcing NPN outputs ON or OFF, regardless of assigned NPN Output Functions.
- Outputs without an assigned NPN Output Function remain in their forced state until forced to the opposite state.
- Outputs with an assigned NPN Output Function remain in their forced state only until the next function execution (19.2 mS or less), after which each follows its function.

## Serial Communications \Modbus Implementation (cont.)

### 3) Supported Modbus Exception Responses

<u>Code</u>	<u>Name</u>	<u>Meaning</u>
01	ILLEGAL FUNCTION	Function code received not supported by slave.
02	ILLEGAL DATA ADDRESS	Data address received not supported by slave.
03	ILLEGAL DATA VALUE	Data value received is not valid.

### 4) Response Message Delay

A maximum 30mS delay occurs from the end of Query Message reception to the start of Response Message transmission. This time interval is independent of Baud Rate and is required for Query Message error-checking and validation, task-processing synchronization, function execution and Response Message construction.

This delay time should be used in determining the Master's Receiver Timeout Period.

It is necessary that the Master's Receiver Timeout Period be set sufficiently long to ensure the Master does not time-out and re-transmit a Query Message to an MS332 or query any other device before the MS332 has had sufficient time to transmit the Response Message.

## **Data Types:**

### User Variables and Display Values

The Data Type for accessing User Variables and Display Values is selectable.

16-bit signed integer, 16-bit unsigned integer, 32-bit signed integer and 32-bit IEEE floating-point data types are supported.

Integer types allow writing whole numbers (numbers with no fractional part) only. When real numbers (numbers with a fractional part) are read using an integer type, only the whole number part is returned (the fractional part is truncated).

IEEE floating-point allows reading and writing both whole numbers and real numbers.

Although IEEE floating-point is the most versatile data type for MS332 serial communications, it is usually unnecessary because most applications don't require User Variable and Set-Point values with fractional resolution.

Since the Master and Slave data types must match, only those data types supported by both Master and Slave may be used.

**See** 'Addendum - Accessing User Vars and Display Values' at the end of this section for a complete discussion of issues related to accessing MS332 data using the various Data Types.

## Serial Communications (cont.)

### Procedure: Remote Analog Output Calibration.

Notes:

- The MS332 Analog Output must be calibrated to the motor-drive and the process.
- This procedure provides a Serial Communications alternative to the Keypad method given in the 'Reference Section \Keypad Menus \Diagnostic Menu \Analog Output Calibration Utility'.
- To execute this procedure, the MS332 must first be wired for optional Jog Mode operation.  
Jog Mode is an *open-loop* speed control mode: the actual encoder speed has no effect on the Analog Output DAC, only the Jog speed set-point determines the DAC value.  
When the Analog Output is calibrated open-loop to your process, closed-loop performance is improved because less compensation is required.

Connect an unused MS332 Switch-Input to Ground C either through a closed switch or a wire.

This Switch-Input will enable Jog Mode selection for calibrating the Analog Output.

Example: Connect TB3 pin 7 (Switch-Input 4) to TB3 pin 8 (Ground C).

#### Modbus addresses accessed

This procedure requires accessing certain MS332 Display Values and User Variables over Serial Communications. The Modbus address, type of access (read/write) and description of each is listed below.

<u>Address</u>	<u>Access</u>	<u>Description</u>
31000	Read	Feedback encoder speed (Display option 0)
41000	Read	Process max. feedback encoder RPM (Var01.00)
41010	Write	Process max. feedback encoder RPM in user units (Var01.01)
46120	Write	Jog Mode speed set-point (Var06.12)
470X0	Write	Switch-input function-assignment (X: 0...6, depending on input)
49000	Write	Analog Output offset calibration (Var09.00)
49010	Write	Analog Output scale calibration (Var09.01)

#### Configure Jog Mode

- 1) Open the MS332 Run switch.
- 2) Set the feedback speed user units to RPM by setting Var01.01 (address 41010) equal to Var01.00 (address 41000), your Process Maximum Feedback Encoder RPM.
- 3) Assign the Jog function to a Switch-Input (as mentioned above) by writing 1 (Jog) to the corresponding Switch-Input function assignment variable.  
Example: To use Switch-Input 4, write 1 to Var07.03 (address 47030).
- 4) Set the Jog Speed set-point to zero: Write zero (0) into Var06.12 (address 46120).
- 5) Close the MS332 Run Switch.

#### Offset adjustment

- 1) Slowly increase the Aout Offset by incrementing the Var09.00 (address 49000) value until the motor creeps forward (if not already doing so).
- 2) Next, slowly decrease the Aout Offset by decrementing the value in Var09.00 (address 49000) by increments of 1 until it stops.

This sets the Analog Output base voltage (0 Dac) just below the voltage at which the motor creeps forward.

#### Scale adjustment

- 1) Set the Jog Speed set-point equal to your Process Maximum Feedback Encoder RPM by setting Var06.12 (address 46120) equal to Var01.00 (address 41000). The motor should turn.
- 2) Monitor Display Value 0 (address 31000). This is the real-time feedback encoder RPM.
- 3) Slowly adjust the Aout Scale (Var09.01 / address 49010) until the real-time feedback encoder RPM is equal (or as close as possible) to the Jog Speed set-point.  
If the displayed RPM is *higher* than setpoint, *reduce* Aout Scale (Var09.01 / address 49010).  
If the displayed RPM is *lower* than setpoint, *increase* Aout Scale (Var09.01 / address 49010).

This sets the Analog Output's voltage-output / DAC-input sensitivity.

## Serial Communications \Remote Analog Output Calibration Procedure (cont.)

### Exit Jog Mode

- 1) Open the MS332 Run Switch
- 2) Un-assign the Jog Switch-Input function from the Switch-Input by writing 0 to the corresponding Switch-Input function assignment variable.

Example: If you previously wrote 1 (Jog) to Var07.03 (address 47030) assigning Jog to Switch-Input 4, write 0 to it now to un-assign Jog from it.

## Procedure: Remote Encoder PPI Variable Determination and Initialization (Index-Follower mode)

Notes:

- Index-Follower Mode setup requires determining values for and writing Var01.07 (Feedback PPI: Feedback Encoder pulses per Feedback Index pulse) and Var01.08 (Lead PPI: Lead Encoder pulses per Lead Index pulse).
- This procedure provides a Serial Communications alternative to the Keypad method given in the 'Reference Section \Keypad Menus \Diagnostic Menu \Encoder Pulses Per Index Learn Utility'.
- This procedure consists of measuring the average encoder pulses per index pulse values for both Feedback and Lead and writing these values into Var01.07 and Var01.08 respectively.
- To execute this procedure, the MS332 must first be wired for optional Jog Mode operation.  
Connect an unused MS332 Switch-Input to Ground C either through a closed switch or a wire.  
This Switch-Input will enable Jog Mode selection.  
Example: Connect TB3 pin 7 (Switch-Input 4) to TB3 pin 8 (Ground C).

### Modbus addresses accessed

This procedure requires accessing certain MS332 Display Values and User Variables over Serial Communications. The Modbus address, type of access (read/write) and description of each is listed below.

<u>Address</u>	<u>Access</u>	<u>Description</u>
31100	Read	Average Lead PPI (Display option 10)
31110	Read	Average Feedback PPI (Display option 11)
41000	Read	Process max. feedback encoder RPM (Var01.00)
41010	Write	Process max. feedback encoder RPM in User Units (Var01.01)
41070	Write	Feedback PPI (Var01.07)
41080	Write	Lead PPI (Var01.08)
41090	Write	PPI Measurement and Averaging Control (Var01.09)
46120	Write	Jog Mode speed set-point (Var06.12)
470X0	Write	Switch-input function-assignment (X: 0...6, depending on input)

### Configure Jog Mode, PPI measurement/averaging

- 1) Open the MS332 Run switch.
- 2) Set the feedback speed user units to RPM by setting Var01.01 (address 41010) equal to Var01.00 (address 41000), your Process Maximum Feedback Encoder RPM.
- 3) Assign the Jog function to a Switch-Input (as mentioned above) by writing 1 (Jog) to the corresponding Switch-Input function assignment variable.  
Example: To use Switch-Input 4, write 1 to Var07.03 (address 47030).
- 4) Set the Jog Speed set-point to zero: Write zero (0) into Var06.12 (address 46120).
- 5) Write 32 into Var01.09 (address 41090). This causes Display Options 10 (address 31100) and 11 (address 31110) to display real-time averages of the last 32 measured Lead PPI and Feedback PPI values respectively.
- 6) Close the MS332 Run Switch.

### Measure Average Lead PPI, write Var01.08 (address 41080)

- 1) Rotate the Lead Encoder by starting the Lead process. Leave the Lead process running.
- 2) View the Average Lead PPI (address 31100). This is the average of the last 32 measured Lead PPI values. The displayed Average Lead PPI will initially change as more measured Lead PPI values are included in the running average (if the measured values are not equal to Var01.08).  
Wait for at least 33 Lead Index pulses to occur. This ensures the Lead PPI averaging buffer contains only *measured* Lead PPI values. At this point, the displayed Lead PPI value should have settled down to a stable value.
- 3) Write the displayed Average Lead PPI value (address 31100) into Var01.08 (address 41080).
- 4) Stop the Lead process.

## Serial Communications \Remote Encoder PPI Var Procedure (cont.)

### Measure Average Feedback PPI, write Var01.07 (address 41070)

- 1) Write a nonzero Jog Mode speed setpoint value into Var06.12 (address 46120). The value is not important as long as it is no larger than the Process Maximum Feedback Encoder RPM of Var01.00 (address 41000). The Feedback Encoder should turn.
- 2) View the Average Feedback PPI (address 31110). This is the average of the last 32 measured Feedback PPI values.  
The displayed Average Feedback PPI will initially change as more measured Feedback PPI values are included in the running average (if the measured values are not equal to Var01.07).  
Wait for at least 33 Feedback Index pulses to occur. This ensures the Feedback PPI averaging buffer contains only *measured* Feedback PPI values. At this point, the displayed Feedback PPI value should have settled down to a stable value.
- 3) Write the displayed Average Feedback PPI value (address 31110) into Var01.07 (address 41070).

### Un-configure Jog Mode, restore previous PPI measurement/averaging

- 1) Open the MS332 Run Switch
- 2) Un-assign the Jog Switch-Input function from the Switch-Input by writing 0 to the corresponding Switch-Input function assignment variable.  
Example: If you previously wrote 1 (Jog) to Var07.03 (address 47030) assigning Jog to Switch-Input 4, write 0 to it now to un-assign Jog from it.
- 3) Restore the previous PPI measurement/averaging setting by writing the previous value into Var01.09 (address 41090).

## Serial Communications (cont.)

### Addendum: Accessing User Vars and Display Values (function codes, data types and addressing)

#### MS332 - Modbus Master compatibility

Significant flexibility is built into the MS332 Serial Communications for compatibility with virtually all Modbus RTU Masters.

One example is the MS332's ability to communicate using various 16-bit and 32-bit data types.

Although the Modbus standard is oriented towards 16-bit "registers" and does not explicitly support any data type, widely used Modbus adaptations exist for supporting 32-bit types.

The following explains in detail how the MS332 utilizes these adaptations for supporting both 16-bit and 32-bit data types.

#### Background

- 1) Although the MS332 User Variables and Display Values are stored internally using 32-bit floating-point format, many (in most cases all) of them can be *represented* in 16-bit integer format because...
  - a) In most cases these values don't have a fractional part (nonzero value to the right of the decimal point).
  - b) In most cases, these values fall within the range -32768 -> 32767 (the range of 16-bit integers).
- 2) To provide both data-type flexibility and compatibility with various Modbus Masters, the data type for accessing User Vars and Display Values using Serial Communications is selectable. The available data types are 32-bit float, 32-bit long-int, 16-bit int and 16-bit unsigned int.
- 3) Modbus data is addressed in 16-bit increments, not by the more common 8-bit (byte) increments. For example, address 41000 (holding register 1000) and address 41001 (holding register 1001) access separate 16-bit data with no overlap.
- 4) The Modbus address of each MS332 User Var (4XXX0) or Display Value (3XXX0) refers to:
  - a) One 16-bit half for 32-bit data types.
  - b) The entire value for 16-bit data types.

The *next higher* address from each User Var (4XXX1) or Display Value (3XXX1) refers to:

- c) The *other* 16-bit half for 32-bit data types.
- d) Nothing (Illegal Data Address) for 16-bit data types.

Note: Var08.04 selects the data type (32 bit long int or float, 16-bit int or unsigned int) and the ordering of 16-bit halves of 32-bit data types.

#### Accessing User Vars and Display Values

##### Function codes 03, 04 and 16 (multiple contiguous access):

Since the Modbus addresses for MS332 User Vars and Display Values are non-contiguous (they are separated by increments of 10, not 1), function codes 03 and 16 *cannot* access multiple User Vars and function code 04 *cannot* access multiple Display Values.

However, function codes 03, 04 and 16 are supported for accessing *single* User Vars and Display Values when using 32-bit data types:

- a) Access 2 adjacent registers *together* starting at 4XXX0 or 3XXX0 (both 16-bit halves accessed together in one query-response transaction):

User Vars	One 16-bit half at 4XXX0, other 16-bit half at 4XXX1 (1 query-response cycle).
Display Values	One 16-bit half at 3XXX0, other 16-bit half at 3XXX1 (1 query-response cycle).

## Serial Communications \Addendum \Access User Vars and Display Values (cont.)

- b) Access 2 adjacent registers *separately* at 4XXX0 and 4XXX1 or 3XXX0 and 3XXX1 (16-bit halves are accessed separately, each in a separate query-response transaction):

User Vars           First access one 16-bit half at one address (first query-response cycle).  
                      Then access the other 16-bit half at the adjacent address (second query-response cycle).

Display Values     First read one 16-bit half at one address (first query-response cycle).  
                      Then read the other 16-bit half at the adjacent address (second query-response cycle).

Notes: Coherency of the two 16-bit halves is ensured if the two 16-bit transactions occur together with no other transactions to that MS332 between them:

- User Variable writes do not take effect until the second half is written.
- Second 16-bit halves of User Variable or Display Value reads come from the same 32-bit values as the first.
- The order in which the 16-bit halves are accessed does not matter.
- If the second 16-bit query contains a different function code, address the same 16-bit half or addresses a different User Var or Display Value than the first, a new access is begun and the previous access begun by the first 16-bit query is discontinued.

Function codes 03, 04 and 16 are also supported for accessing *single* User Vars and Display Values using 16-bit data types as follows:

Access 1 register at 4XXX0 or 3XXX0.

User Vars           All 16-bits at 4XXX0 (1 query-response cycle).

Display Values     All 16-bits at 3XXX0 (1 query-response cycle).

### Function code 06:

Function code 06 (Preset Single Register) is supported for writing User Variables using 32-bit data types as follows:

Two function code 06 write transactions. One each to the addresses 4XXX0 and 4XXX1:

First write one 16-bit half to one address (first query-response cycle).

Then write the other 16-bit half to the other address (second query-response cycle).

Notes: Coherency of the two 16-bit halves is ensured if the two 16-bit transactions occur together with no other transactions to that MS332 between them:

- 32-bit User Variable writes do not take effect until the second half is written.
- The order in which the 16-bit halves are written does not matter.
- If the second 16-bit query contains a different function code, address the same 16-bit half or addresses a different User Var than the first, a new access is begun and the previous write begun by the first 16-bit query is discontinued.

Function code 06 (Preset Single Register) is also supported for writing User Variables using 16-bit data types as follows:

One function code 06 write to address 4XXX0 (one query-response cycle).

# MS332 Specification Section (bA02.XX)

## Functional

### Encoder/Index Inputs:

2 ports (Lead and Feedback/Follower), each receiving 2 quadrature incremental encoder signals (A, B) and one index pulse signal.

### Switch Inputs:

8 switch inputs (1 dedicated Run/Stop, 7 user-programmable).  
12 user-assignable switch input functions.

### Keypad:

9 button, tactile.  
6 user-selectable lockout options.

### Analog Output:

1 dedicated motor-drive control analog, configurable for Bipolar input ( $\pm$  volts) and Contactor Reversing (+ volts with contactor-reverse input) type motor-drives.

### NPN Transistor Outputs:

4 user-programmable open-collector NPN outputs.  
8 user-assignable NPN output functions (Alarm, Annunciator and Control functions).

### Display:

6 character, 7-segment alphanumeric LED display for real-time, menu and error information.  
16 user-selectable real-time display options.  
5 discrete annunciator LEDs.

### Encoder/Index Power Supply:

+12Vdc, 300mA for powering incremental encoders and event/index sensors.

### Serial Communications Interface Port:

Modbus RTU protocol.  
1 Balanced EIA-485 tri-state driver.  
1 Balanced EIA-485 receiver.

## Operational

### Accuracy:

### Master mode maximum speed set-point error:

0.004% (0°C)  
0.002% (25°C)  
0.010% (70°C)

### Follower mode cumulative error:

Zero (0 - 70°C)

### Processor:

16MHz, 32 bit

### PID loop update rate:

1024 per second (977  $\mu$ S)

### NPN Output update rate:

51.2 per second (19.5 mS)

### Switch Input read rate:

51.2 per second (19.5 mS)

### Keypad read rate:

51.2 per second (19.5 mS)

### Display update rate:

2.56 updates per second (391 mS)

# Electrical

Line Voltage:	115 Vac (230 Vac optional) $\pm$ 10%, 50/60 Hz
Line Power:	15 W (max)
Fuse (internal)	
115 Vac:	200 mA, 5x20mm, slo-blo
230 Vac:	100 mA, 5x20mm, slo-blo
Encoder/Index/Aux Inputs	
Compatibility:	NPN, PNP, TTL, CMOS single-ended outputs
Encoder Type:	Incremental
Encoder Signaling:	Quadrature squarewaves (A & B channels)
Index Sensor Type:	Proximity sensor, encoder index line
Index Signaling:	Pulse (1 per cycle/event), rising-edge triggered
Frequency range:	1Hz to 70KHz
Input resistance:	2.2 k $\Omega$ (pull-up or pull-down switched in) $\geq$ 100 k $\Omega$ (pull-up/down switched out)
Signal (logic) Levels:	Low: 0 to 1Vdc High: 4 to 28 Vdc
Isolation:	2500 Vrms (Ground C referenced circuit)
Switch Inputs	
Polarity:	Closed switch (to Ground C): ON Open switch: OFF
Compatibility:	Mechanical ON/OFF switches, Relays, NPN open-collector transistors
Source current (ON state):	3.5 mAdc (switching device must sink a maximum 3.5 mA when ON.)
Isolation:	2500 Vrms (Ground C referenced circuit)
Analog Output	
Signal Range:	-11.5 to +11.5 Vdc (max swing)
Calibration method:	From Keypad, stored in non-volatile memory
Offset Adjust:	-2 Vdc to +2 Vdc (programmable, 0 DAC)
Scale Adjust:	0 to $\pm$ 11.5 Vdc (programmable, full-scale DAC)
Output Resistance:	0 $\Omega$
Settling Time:	150 $\mu$ S (to $\leq$ 1 DAC bit @ 0.1 $\mu$ F load)
Resolution:	12-bit plus sign (8192 steps)
Isolation:	2500 Vrms (Ground A referenced circuit)
Short-circuit Protection:	Yes
NPN Outputs (each output)	
Vce (max):	300 Vdc
Vce (@ Ic = 20 mA):	0.5 Vdc (max)
Pd (power dissipation):	625 mW (max)
Isolation:	2500 Vrms (Ground C referenced circuit)
Encoder/Index Power Supply	
Power Output:	+12 Vdc @ 300mA (max), unregulated
Short-circuit Protection	Polyfuse® type (cycle power to reset)
Isolation:	2500 Vrms (Ground C referenced circuit)
RS485 Communications Port	
RX input resistance:	12 k $\Omega$ (min)
RX differential threshold:	$\pm$ 0.2V (max)
RX common-mode range:	-7 Vdc to +12 Vdc
TX differential voltage:	1.5 Vdc differential (minimum, @ 54 $\Omega$ load)
TX common-mode volts:	3 Vdc (max)
Isolation:	2500 Vrms (Ground B referenced circuit)

## Electrical (cont.)

Isolation Configuration (4 circuits, 2500 Vrms isolation each)

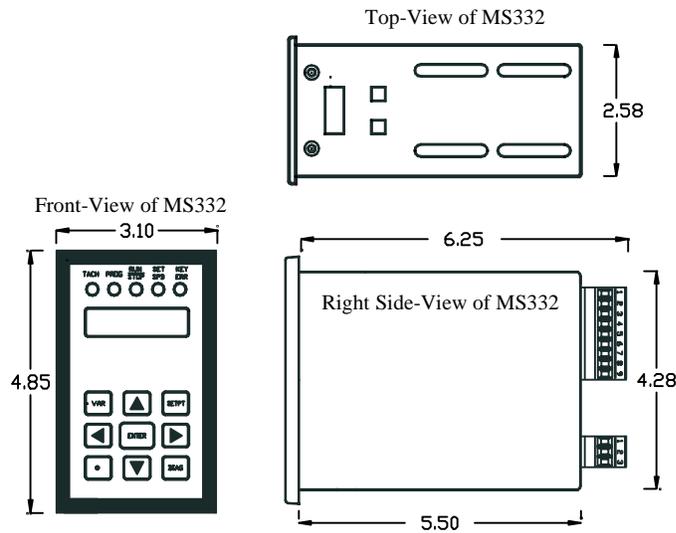
Ground A referenced:	Analog Output
Ground B referenced:	RS485 Com Port
Ground C referenced:	Encoder, Index, Aux and Switch Inputs;
En	coder-supply and NPN Outputs
Digital Gnd referenced:	Internal digital circuitry

## Environmental

Temperature:	0	- 70 C
Humidity:		0 - 90% Non-Condensing

## Mechanical

Terminal Plug screw torque:	2.2 lb-in (0.25 N-m)
Enclosure material:	ABS Plastic 94V-0
Keypad:	Polycarbonate tactile switch pad, chemical resistant, splash-proof
Weight:	2 .2 Lb (1.0 Kg)
Dimensions:	



# MS332 Appendix Section

## Front-panel ERR led

The front-panel ERR status led is a general alarm alerting the user to errors and potential fault conditions. The following lists the conditions under which the ERR status led is lit.

### Invalid Keypress:

Invalid keypresses are those not supported at a given Keypad menu and level. An invalid keypress results in no action other than lighting the front-panel ERR led.

**See** 'Reference Section \Keypad \Keypad Level Zero and Keypad Menus' for details on when keys are valid/invalid for each menu and level.

Example: When in keypad level one of the Change Set-point Menu, pressing the VAR key is invalid and results in no action other than lighting the ERR led.

### Invalid Variable Values:

Each user program variable has a permitted range of values. Any attempt to enter a value outside a user program variable's permitted range is rejected, resulting in no action other than lighting the front-panel ERR led.

**See** 'Appendix Section \User Records \User Program Vars' for details on ranges of variable values.

Example: Var05.00 (Display Selection) has a range of 0 to 15. If the user attempts to enter 16, the value is rejected and the ERR led lights up.

### Previously assigned Switch Input or NPN Output Function Codes:

Each Switch Input function is exclusive and may be assigned to only one Switch Input at a time. Attempts to assign a Switch Input function code to a second Switch Input are rejected and result in no action other than lighting the ERR led.

Each NPN Output function is exclusive and may be assigned to only one NPN Output at a time. Attempts to assign an NPN Output function code to a second NPN Output are rejected and result in no action other than lighting the ERR led.

**See** both 'Reference Section \Switch Inputs \Function Assignment Variables' and 'Reference Section \NPN Outputs \Function Variables' for details.

### Keypad Security Protection:

Keypad operations may be selectively disabled by Keypad Security. Attempts to change a user program variable or set-point using a disabled keypad menu or execute a disabled keypad scroll will result in no action other than lighting the ERR led.

**See** 'Reference Section \Keypad \Keypad Menus \Keypad Security Menu' for details on Keypad Security.

Example: When the front-panel Set-point Scroll is disabled by Keypad Security, pressing the scroll UP/DOWN keys result in no action other than lighting the ERR led.

### Loss of Feedback Encoder Signal (no-feedback condition):

When the feedback encoder signal fails (or stops) while the MS332 attempts to run closed-loop, the ERR led lights and the display flashes "noFbAC" (no feedback). Restoring the feedback encoder signal, stopping the lead (if follower mode) or opening the Run switch will clear the "noFbAC" message and turn off the ERR led.

### Stopped Lead (Follower mode, Display option 1):

When in follower mode and displaying the follower speed ratio (code 1 in Var05.00), the ERR led lights and the display flashes "LEAD = 0" when the lead encoder stops (or fails).

# Mnemonics-Glossary

## Display Window messages:

'Anou':	Flashes when selecting the <u>A</u> nalog <u>O</u> utput Calibration utility (Diagnostic Menu).
'dISP':	Flashes when selecting <u>D</u> isplay <u>W</u> indow diagnostic (Diagnostic Menu).
'dn':	Flashes when testing the <u>D</u> own arrow key in the Keypad diagnostic (Diagnostic Menu).
'dOnE':	1) Displayed when <u>done</u> resetting the variables in the Factory Default Reset utility (Diagnostic Menu). 2) Displayed when <u>done</u> learning/teaching a Pulses per Index value in the Encoder Pulses per Index Learn utility (Diagnostic Menu).
'dP':	Flashes when testing the <u>D</u> ecimal <u>P</u> oint key in the Keypad diagnostic (Diagnostic Menu).
'dSPSEL':	Flashes when choosing an <u>err</u> oneous Var05.00 <u>display</u> <u>selection</u> code (the <b>ERR</b> status led also lights up). Indicates the selected Var05.00 code doesn't apply to present operating mode.
'En':	Flashes when testing the <u>E</u> nter key in the Keypad diagnostic (Diagnostic Menu).
'FACdEF':	Flashes when selecting the <u>F</u> actory <u>D</u> efault <u>R</u> eset utility (Diagnostic Menu).
'FbLrn':	Flashes when selecting the <u>F</u> eedback <u>L</u> earn operation in the Encoder Pulses per Index Learn utility (Diagnostic Menu).
'FbSPd':	Flashes when selecting the set temporary <u>F</u> eedback <u>S</u> peed operation in the Encoder Pulses per Index Learn utility (Diagnostic Menu).
'HEYPAD':	Flashes when selecting the <u>K</u> eypad diagnostic (Diagnostic Menu).
'HiddEn':	Displayed when trying to see the value of the <u>PASdEF</u> variable while the keypad is locked; <u>PASdEF</u> 's value is 'hidden' during keypad-lock (Keypad Security Menu).
'LdLrn':	Flashes when selecting the <u>L</u> ead <u>L</u> earn operation in the Encoder Pulses per Index Learn utility (Diagnostic Menu).
'LEAd = 0'	Flashes when the Display Window is set (via Var05.00) to display the follower speed ratio <u>and</u> there are no lead encoder pulse received at terminals TB4 -3 and TB4 -4 (can't calculate speed ratio if lead speed is zero).
'LEF':	Flashes when testing the <u>L</u> eft arrow key in the Keypad diagnostic (Diagnostic Menu).
'In XXXX':	Flashes when selecting the Switch <u>I</u> nput group in the Switch Inputs Observation diagnostic (Diagnostic Menu).
'noFbAC':	Flashes when feedback encoder pulses are not received (when they should be), indicating a <u>no-feedback</u> condition.
'nonE':	Flashes when testing <u>none</u> of the keys in the Keypad diagnostic (Diagnostic Menu).
'nPnou':	Flashes when selecting the <u>NPN</u> <u>O</u> utputs diagnostic (Diagnostic Menu).
'oFFSE':	Flashes when selecting the <u>OFFSET</u> variable in the Analog Output Calibration utility (Diagnostic Menu).
'ou XXXX':	Flashes when selecting the NPN <u>O</u> utput group in the NPN Output test diagnostic.
'PASdEF':	Flashes when selecting the <u>P</u> assword <u>D</u> efinition variable (Keypad Security Menu).
'PASIn':	Flashes when selecting the <u>P</u> assword <u>I</u> nput variable (Keypad Security Menu).
'Pc dAC':	Flashes when selecting the temporary <u>P</u> ercent of <u>D</u> AC variable in the Analog Output Calibration utility (Diagnostic Menu).
'PPILrn':	Flashes when selecting the Encoder Pulses per Index Learn utility - i.e., <u>P</u> ulses <u>p</u> er <u>I</u> ndex <u>L</u> earn (Diagnostic Menu).
'Pr XX.XX':	'Pr' is displayed along with the selected variable's mnemonic, and the right-most digit flashes (Change Variable Menu).
'PrOCES':	1) Flashes when <u>processing</u> - i.e., resetting - the variables in the Factory Default Reset utility (Diagnostic Menu). 2) Flashes when <u>processing</u> - i.e., learning/teaching - a Pulses per Index value in the Encoder Pulses per Index Learn utility (Diagnostic Menu).
'ri9h':	Flashes when testing the <u>R</u> ight arrow key in the Keypad diagnostic (Diagnostic Menu).
'SCALE':	Flashes when selecting the <u>SCALE</u> variable in the Analog Output Calibration utility (Diagnostic Menu).
'SECdEF':	Flashes when selecting the <u>S</u> ecurity <u>D</u> efinition variable (Keypad Security Menu).
'SInPu':	Flashes when selecting the <u>S</u> witch <u>I</u> nputs diagnostic (Diagnostic Menu).
'SP XX':	'SP' is displayed along with the selected set-point's mnemonic, and the right-most digit flashes (Change Set-point Menu).
'SP':	Flashes when testing the <u>SETPT</u> (Set-point) key in the Keypad diagnostic (Diagnostic Menu).

## Mnemonics-Glossary \Display Window messages (cont.):

'SUrE_n':	Displayed with the right-most character flashing, when first entering the Factory Default Reset utility (Diagnostic Menu). 'SUrE_n' is the mnemonic for <u>not sure</u> .
'SUrE_y':	Displayed with the right-most character flashing, when selecting to reset all the variables in the Factory Default Reset utility (Diagnostic Menu). 'SUrE_y' is the mnemonic for <u>yes sure</u> .
'UP':	Flashes when testing the <u>Up</u> arrow key in the Keypad diagnostic (Diagnostic Menu).
'VAr':	Flashes when testing the <u>VAR</u> (Variable) key in the Keypad diagnostic (Diagnostic Menu).

### Acronyms-abbreviations:

Accel	Acceleration (as in acceleration ramps).
Advance	Increase (add to) the feedback encoder phase-offset by a certain number of pulses, using the Advance/Retard feature.
Algorithm	A mathematical routine.
Aux	Auxiliary (as in optional Aux 0 and Aux 1 inputs).
Bipolar	Analog voltage signal capable of positive and negative voltage relative to its base (or offset) voltage.
Cathode	Cathode-end of the NPN Output protection diode.
ChA, Chan A	Quadrature encoder Channel A.
Chan	Encoder channel
ChB, Chan B	Quadrature encoder Channel B.
Closed-loop	Method of control where process output measurements (feedback) are used to control the process output.
Config	Configuration (as in Open-loop Configuration).
DAC	Digital-to-Analog Converter (used in Analog Output circuitry).
De-accesses	To no longer access (as in de-accessing a Switch Input function).
Decel	Deceleration (as in deceleration ramps).
DIAG	Diagnostic mode, or Diagnostic key on MS332 keypad.
DIP Switches	Dual-inline-package switches (as in Encoder/Index Pull-up and Pull-down DIP Switches).
Encoder pulses	Pulses received from an encoder, or ring kit.
ENTER	Enter key on MS332 keypad.
ERR	Error (as in the front-panel ERR led).
Fast Stop	A Switch Input function for quickly stopping the feedback encoder/motor ( <u>not</u> an emergency stop).
Fb, Fdbk	Feedback (as in feedback encoder, or feedback signal/pulses).
FbPPI	Feedback encoder Pulses Per Index pulse (Index-Follower mode).
FbRPM	Feedback encoder RPM.
Feedback	1) Pulses from the encoder or index sensor at the MS332-controlled process. 2) Term sometimes used in place of the term 'follower'; (as in 'feedback encoder' - meaning the same as 'follower encoder').
FOL MOD	Follower mode (as in Follower Mode Configuration variable).
Follower	An MS332-controlled process that tracks (or follows) an independent (lead or Master) process.
Ratio-Follower	An MS332 follower mode where the follower encoder rotates at a setpoint ratio of lead encoder rpm (i.e. electronic gearing).
Index-Follower	An MS332 follower mode where follower index pulses are positioned (or phased) relative to lead index pulses according to a phase setpoint.
Funct	Function (as in NPN Output or Switch Input functions).
Gnd	Circuit common (as in the encoder/index/switch-input/npn-output circuit common, GndC).
I/O	Input/Output (as in the I/O Connection Block View Diagram).
Index pulses	Pulses received from an encoder (Z output), proximity sensor, etc. in Index-Follower mode.
Ld, Lead	Pulses from the encoder or index sensor at the independent process (Follower mode).
LdPPI	Lead encoder Pulses Per Index pulse (Index-Follower mode).
LdRPM	Lead encoder RPM.
LED	Light-emitting-diode (as in status indicator LED's).

## Mnemonics-Glossary \Acronyms-abbreviations (cont.):

Master	1) An MS332 control mode where the feedback encoder rotates at a setpoint rpm. 2) The independent encoder in a follower-mode process. Same as Lead.
MaxFbRpm	Maximum Feedback encoder RPM (for a given process).
Max Lead RPM	Var01.03 Process Maximum Lead Encoder RPM.
mS, ms, msec	millisecond
NPN Output	The NPN Outputs of the MS332 are open-collectors of NPN transistors.
NPN, PNP, Logic-gate	Encoder or Index device output types.
OpCode	Function option code (as in NPN Output function option code).
Open-loop	A control method where process feedback (e.g. encoder pulse, index sensor pulses) is either nonexistent or ignored.
Phase-offset	The difference of follower encoder position relative to lead encoder position expressed in units of follower encoder pulses (Ratio-Follower mode). Phase offset is controlled by the Advanced/Retard feature.
Phase set-point	The desired position difference of the Feedback Index pulse relative to the Lead Index pulse, expressed in units of feedback encoder pulses (Index-Follower mode only).
PID	Proportional-Integral-Derivative (The MS332 uses PID compensation to achieve and maintain accurate speed and position control).
PPR	Pulses per revolution (as in encoder pulses per revolution).
PROG	A status LED. Lights up to indicate when the MS332 is in the Change Variable Menu (i.e., program variable).
Pull-down	A resistor (or other device) that pulls an undriven signal line down to signal common.
Pull-up	A resistor (or other device) that pulls an undriven signal line up to a positive DC voltage.
Pwr	Power (as in +12 Vdc encoder Pwr supply at terminals TB4-2).
Quadrature	Encoder with two output squarewave signal lines (A and B). Frequency signals speed, A to B phase relationship signals direction.
Real-time	Not delayed (as in real-time display of encoder RPM during a controlled process).
Retard	Decrease (subtract from) the feedback encoder phase-offset by a certain number of pulses, using the Advance/Retard feature.
RPM	Revolutions per minute (as in encoder RPM).
Sec	second
SET SPD	A status LED. Lights up to indicate when the MS332 is in the Change Set-point Menu (i.e., set the speed).
SetpointDev	Set-point Deviation threshold (as in NPN Output Deviation Alarm function).
Setpt	Set-point (as in master mode speed setpt 1).
SETPT	Change Set-point Menu key on MS332 keypad.
Single Channel	Encoder with one channel, used to detect only speed. (MS332 uses quadrature encoders).
Slave	Term sometimes used in place of the term 'follower'; (as in 'slave encoder' - meaning the same as 'follower encoder').
TACH	A status LED. Lights up to indicate when the MS332 is showing real-time information selected by the Var05.00 code.
TB1	Terminal strip TB1 on back of MS332 (analog inputs and outputs).
TB2	Terminal strip TB2 on back of MS332 (AC line power input).
TB3	Terminal strip TB3 on back of MS332 (switch-inputs, npn-outputs).
TB4	Terminal strip TB4 on back of MS332 (pulse-output sensor inputs, sensor power, serial communications).
uF	microfarad (as in 0.1 uF capacitance).
Unipolar	Analog voltage signal capable of positive (and zero) voltage relative to its base (or offset) voltage.
usec	microsecond (as in 150 usec for Analog Output Settling Time).
Var(s)	MS332 user-variables (setup parameters).

# User Records (User Program Vars, Analog Output Calibration, DIP Switch Settings, Keypad Security Vars)

MS332 User Program Variable Record: Record your values in the “Your value” column.

Var	Description	Range	(units- if any)	Comments	Ref. Sect. page #	Default value	Your value
01.00	Process Max Feedback Encoder RPM	1.0000->99999.	Rev per minute		32	1750.	
01.01	Process Max Feedback Encoder RPM in User Units	0.0001->99999.		Sets units for Feedback speed display, Master mode set-points, etc.	38	1750.	
01.02	Feedback Encoder PPR	1->8192	Pulses per rev		32	60.	
01.03	Process Max Lead Encoder RPM	1.0000->99999.	Rev per minute		33	1750.	
01.04	(Proc. Max Feedback Enc. RPM / Proc. Max Lead Enc. RPM) in User Units	0.0001->99999.		Sets units for feedback/lead speed ratio display, Ratio-Follower mode set-points, etc.	39	1.000	
01.05	Lead Encoder PPR	1->8192	Pulses per rev		33	60.	
01.06	Follower Mode Configuration	0, 1		0: Ratio-Follower mode 1: Index-Follower mode	33	0.	
01.07	Feedback PPI	0->99999	Pulses per index		33	60.	
01.08	Lead PPI	0->99999	Pulses per index		33	60.	
01.09	Pulses per Index Measurement and Averaging Control	0->32		0: Uses Var01.07 and Var01.08 Pulse per Index values. 1-32: Use average of last Var01.09 measured feedback and lead Pulse per Index values.	33	0.	
01.10	Feedback Index Pulses per Match	1 -> 21474	Indexes per match		33	1.	
01.11	Lead Index Pulses per Match	1 -> 21474	Indexes per match		33	1.	
01.12	No-Feedback Response Configuration	0, 1		0: closed-loop, 1: clear pos error, open-loop	33	0.	
02.00	Accel Ramp 0	0.1->3600.0	sec		40	1.0	
02.01	Accel Ramp 1	0.1->3600.0	sec		40	1.0	
02.02	Decel Ramp 0	0.1->3600.0	sec		40	1.0	
02.03	Decel Ramp 1	0.1->3600.0	sec		40	1.0	
02.04	Fast Stop Decel Ramp	0.1->3600.0	sec		40	0.5	
02.05	Active Ramp Pair Select	0, 1		0: enables Ramp Pair 0 1: enables Ramp Pair 1	41	1.	
03.00	PID Proportional Gain	1->1024			42	32.	
03.01	PID Integral Time Constant	0.0 -> 100.0	sec	0.0 disables integral	42	2.0	
03.02	PID Derivative Gain	0 -> 100		0 disables derivative	43	0.	
03.03	PID Derivative Sample Period	0.001->1.000	sec		43	0.01	
03.04	Zero Lead Speed PID Control	0->4		See Reference Section for Selection Codes	43	0	

Var	Description	Range	(units- if any)	Comments	Ref. Sect. page #	Default value	Your value
04.00	NPN Output 0 function assign	0->17		See Reference Section for Function Codes	46	0.	
04.01	NPN Output 1 function assign	0->17		See Reference Section for Function Codes	46	0.	
04.02	NPN Output 2 function assign	0->17		See Reference Section for Function Codes	46	0.	
04.03	NPN Output 3 function assign	0->17		See Reference Section for Function Codes	46	0.	
04.04	NPN Output 0 function parameter	.00000->99999			46	0.	
04.05	NPN Output 1 function parameter	.00000->99999			46	0.	
04.06	NPN Output 2 function parameter	.00000->99999			46	0.	
04.07	NPN Output 3 function parameter	.00000->99999			46	0.	
04.08	NPN Output %Hysteresis	0->100	%		47	1.	
05.00	Display Selection	0->15		See Reference Section for Display Codes	4	0.	
05.01	Display Update Time			unimplemented			
06.00	Master speed seupt 0	.00000->99999	in Var01.01 units		38	1000.	
06.01	Master speed seupt 1	.00000->99999	in Var01.01 units		38	1000.	
06.02	Master speed seupt 2	.00000->99999	in Var01.01 units		38	1000.	
06.03	Master speed seupt 3	.00000->99999	in Var01.01 units		38	1000.	
06.04	Ratio-Follower speed ratio seupt 0	.00000->99999	in Var01.04 units		38	1.000	
06.05	Ratio-Follower speed ratio seupt 1	.00000->99999	in Var01.04 units		38	1.000	
06.06	Ratio-Follower speed ratio seupt 2	.00000->99999	in Var01.04 units		38	1.000	
06.07	Ratio-Follower speed ratio seupt 3	.00000->99999	in Var01.04 units		38	1.000	
06.08	Index-Follower phase seupt 0	-99999->99999	in Fb encoder pulses		38	0.	
06.09	Index-Follower phase seupt 1	-99999->99999	in Fb encoder pulses		38	0.	
06.10	Index-Follower phase seupt 2	-99999->99999	in Fb encoder pulses		38	0.	
06.11	Index-Follower phase seupt 3	-99999->99999	in Fb encoder pulses		38	0.	
06.12	Jog speed seupt	.00000->99999	Rev per minute		38	175.	
06.13	Master Mode Active Set-point Select	0->3		0: speed seupt 0 1: speed seupt 1 2: speed seupt 2 3: speed seupt 3	37	0.	
06.14	Ratio-Follower Mode Active Set-point Select	0->3		0: speed ratio seupt 0 1: speed ratio seupt 1 2: speed ratio seupt 2 3: speed ratio seupt 3	37	0.	
06.15	Index-Follower Mode Active Set-point Select	0->3		0: phase seupt 0 1: phase seupt 1 2: phase seupt 2 3: phase seupt 3	37	0.	

Var	Description	Range	(units- if any)	Comments	Ref. Sect. page #	Default value	Your value
07.00	Switch Input 1 function assign	0->12		See Reference Section for Function Codes	28	0.	
07.01	Switch Input 2 function assign	0->12		See Reference Section for Function Codes	28	0.	
07.02	Switch Input 3 function assign	0->12		See Reference Section for Function Codes	28	0.	
07.03	Switch Input 4 function assign	0->12		See Reference Section for Function Codes	28	0.	
07.04	Switch Input 5 function assign	0->12		See Reference Section for Function Codes	28	0.	
07.05	Switch Input 6 function assign	0->12		See Reference Section for Function Codes	28	0.	
07.06	Switch Input 7 function assign	0->12		See Reference Section for Function Codes	28	0.	
07.07	Master Speed Scroll Step	0->100	in Var01.01 units		29	1.	
07.08	Ratio-Follower Speed Ratio Scroll Step	0->100	in Var01.04 units		29	1.	
07.09	Phase Scroll Step	0->100	in Fb encoder pulses		29	1.	
07.10	Jog Speed Scroll Step	0->100	Rev per minute		29	1.	
07.11	Jog Mode Ramp Configuration	0->3		0: disable ramps 1: enable Accel ramp only 2: enable Decel ramp only 3: enable Accel and Decel ramps	35	3.	
07.12	Open-loop Configuration	0->3		0: enable Fb encoder and Fb index feedback. 1: disable Fb encoder feedback. 2: disable Fb index feedback. 3: disable Fb encoder and Fb index feedback	35	3.	
07.13	Master/Follower Mode Select	0, 1		0: Follower mode 1: Master mode	35	0.	
07.14	Phase Change Release Time	0.01->100.0	sec	Release-time for entering phase changes into PID Position Error.	36	1.	
08.00	Serial Comm. Slave Address	1->247			49	1	
08.01	Serial Comm. Baud Rate Select	0->4		See Reference Section for Selection Codes	49	3	
08.02	Serial Comm. Parity Select	0->2		See Reference Section for Selection Codes	49	0	
08.03	Serial Comm. Mode Select	0, 1		0: ASCII (unimplemented) 1: RTU	49	1	
08.04	Serial Comm. Data Type Select	0->5		See Reference Section for Selection Codes	49	4	
09.00	Analog output calibrate: OFFSET	-734 -> +734			34	0.	
09.01	Analog output calibrate: SCALE	0->1150			34	1027.	

# User Records (cont.):

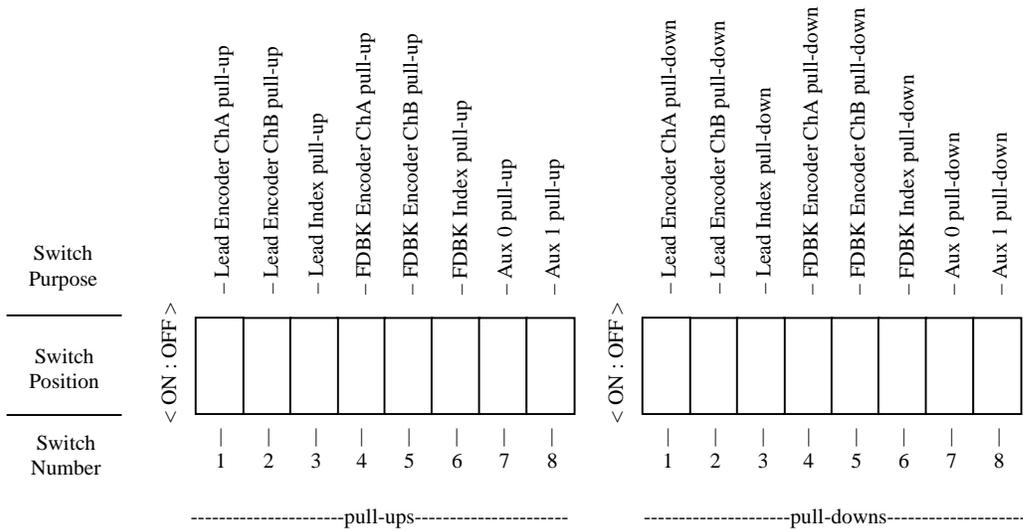
## Analog Output Calibration Record:

Record your Calibrated Analog Output Voltage when the Pc dAC is 000.0: \_\_\_\_\_ Vdc

Record your Calibrated Analog Output Voltage when the Pc dAC is 090.0: \_\_\_\_\_ Vdc

## DIP Switch Settings Record:

Record both your left bank and right bank DIP Switch Settings by writing **ON** or **OFF** in the switch locations in the diagram below:



## Keypad Security Variable Record:

Record your values in the “Your value” column:

Var	Description	Range	Comments	Ref. Sect. page #	Default value	Your value
PASIn	Keypad password code input	000000- >999999	Enter code to lock/unlock. (view/change at any time)	22	000332	
PASdEF	Keypad password code define	000000- >999999	Define unlock code. (view/change only when unlocked)	22	000332	
SECdEF	Keypad security define	000000- >011111	Define <i>lock-disabled</i> keypad features. (view at any time, change only when unlocked)	22	000000	

# Rear-View (Showing all four terminal strips; TB1, TB2, TB3, and TB4):

