Allen-Bradley

8510 AC Spindle Drive System

Programming Manual

Rockwell Automation

Important User Information

Solid state equipment has operational characteristics differing from those of electromechanical equipment. "*Safety Guidelines for the Application, Installation and Maintenance of Solid State Controls*" (Publication SGI-1.1 available from your local Allen-Bradley Sales Office or online at **http://www.ab.com/manuals/gi**) describes some important differences between solid state equipment and hard-wired electromechanical devices. Because of this difference, and also because of the wide variety of uses for solid state equipment, all persons responsible for applying this equipment must satisfy themselves that each intended application of this equipment is acceptable.

In no event will the Allen-Bradley Company be responsible or liable for indirect or consequential damages resulting from the use or application of this equipment.

The examples and diagrams in this manual are included solely for illustrative purposes. Because of the many variables and requirements associated with any particular installation, the Allen-Bradley Company cannot assume responsibility or liability for actual use based on the examples and diagrams.

No patent liability is assumed by Allen-Bradley Company with respect to use of information, circuits, equipment, or software described in this manual.

Throughout this manual we use notes to make you aware of safety considerations.

ATTENTION: Identifies information about practices or circumstances that can lead to personal injury or death, property damage, or economic loss.

Attentions help you:

- identify a hazard
- avoid the hazard
- recognize the consequences

Important: Identifies information that is especially important for successful application and understanding of the product.

Shock Hazard labels may be located on or inside the drive to alert people that dangerous voltage may be present.

Chapter 1

Introduction

Chapter Objectives

This chapter explains the programming/setup system of the 8510. Included is an explanation of the display, control features and general programming to help you use and understand the 8510 programming system.

Introduction

In addition to the standard metering and diagnostic functions explained in the 8510 User Manual, the keypad and display are also used for programming all of the drive setup parameters through the *DRIVE SETUP* menu.

Menu Format and Conventions

The menu system is based on the 16 character by 2 line display used in the 8510. The menu is arranged in a tree format to allow easy access to any item. Menu items will be shown on the display two different ways:

1) UPPER CASE letters (capitals) indicate the item is a menu heading with a group of sub-menus or parameter names below it.

2) Initial Capital letters indicate the item is the name of a parameter.

To help differentiate input/output names, programmable parameters and programmable values printed in this manual, the following conventions will be used.

Input and Output Names	will appear in Initial Capital Letters
Programming Display Text	will appear in *italics*
Menu Names	will appear with *ALL CAPITALS*
Parameter Names	will appear with *Initial Capital Letters*
Programmable Parameter Values	will appear in "quotes"

Programming Capabilities

The *DRIVE SETUP* menu is used to define the electrical configuration and tune the dynamic performance of the 8510. The drive can be programmed to provide optimum machine response for a variety of mechanical system configurations and application requirements. The following paragraphs explain some of the capabilities.

1. When used with a multi-speed spindle gearbox, a unique set of all programmable parameter values can be set for each gear range. Up to four gear ranges can be used. During drive operation, two discrete inputs are used to select the appropriate gear range parameter set.

   Tip: In applications that do not use gear boxes, the gear range data sets can be used to optimize drive performance under widely varying load conditions, to change the drive configuration for different operations, or to increase the number of parameter setpoints that are available.

2. When two speed, wide constant power range motors (1327AD series) are used, unique parameter sets are used for the low speed and high speed windings. The two speed motors can be combined with up to a three speed gearbox for a total of six unique sets of programmable parameters. During drive operation, a single discrete input will select the appropriate motor speed range and speed range parameter set.
3. Within each gear range/motor winding data set, discrete inputs can select one of three primary operating modes; spindle, servo or torque. For each of these modes there are independent sets of parameter data values to control the velocity command source and scaling along with the system dynamics. Also, within servo mode, two different velocity scaling ranges can be selected.

Gear Range Data Sets

A Gear Range Data Set is a grouping of parameters that define a gear range/motor winding configuration. A typical gear range data set consists of the following:

Data Set for Standard Motor or Low Speed Winding on a Dual Winding Motor
- Overall System Configuration
- Standard Motor or Low Speed Motor Winding Parameter Set
- Spindle Mode Configuration and Tuning
- Servo Mode Configuration and Speed Range Select
  High Range Tuning
  Low Range Tuning
- Torque Mode Configuration and Tuning
- Spindle Orient Configuration and Tuning

Data Set for High Speed Winding on a Dual Winding Motor
- Overall System Configuration
- High Speed Motor Winding Parameter Set
- Spindle Mode Configuration and Tuning
- Servo Mode Configuration and Speed Range Select
  High Range Tuning
  Low Range Tuning
- Torque Mode Configuration and Tuning
- Spindle Orient Configuration and Tuning

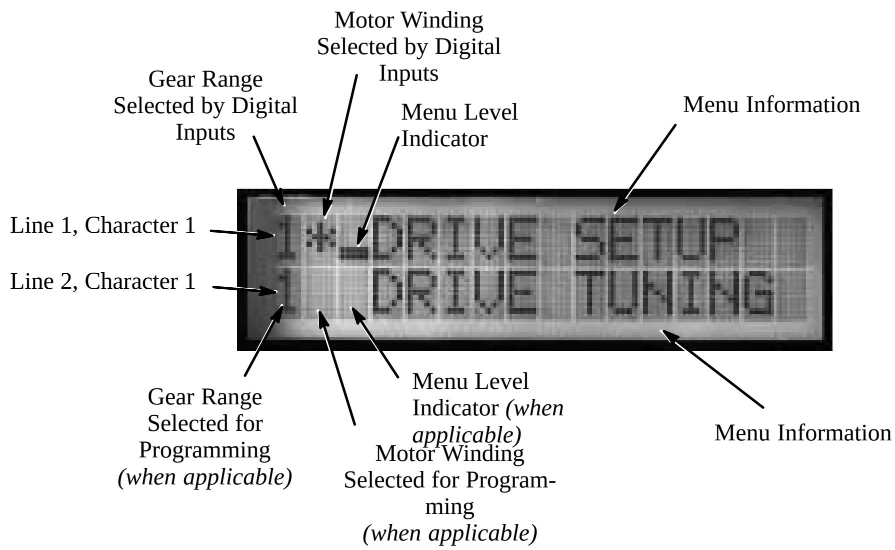
Tip: To simplify initial drive setup, a *Copy Data* command is available (*GEAR RANGES* menu). After programming a complete gear range/motor winding data set, this command can copy the data set to any other gear range/motor winding data set. The programmer then makes changes as required to the copied data set.

Refer to GEAR RANGES Menu in Chapter 2 for further information.

Display Description

The 8510 display which is used for programming, as well as status and diagnostic messages consists of a 16 character, 2 line, LCD (Liquid Crystal) display. The display is divided into several different sections as shown in Figure 1.1.

Figure 1.1
LCD Display



Line 1, characters 1 & 2 – are used to display the gear range and motor winding data set that is currently selected by the digital inputs and is being used for drive operation. Character 1 will show the selected gear range (1-4) and if a 2 speed motor is used, character 2 will show the motor winding (H = high speed winding, L = low speed winding).

Line 1, character 3 – is a variable length bar (moving from the bottom up) that represents the current depth (level) in the menu system.

Line 1, characters 4-16 – are used to display the name of the current menu level or selected parameter. The menu options or parameter value associated with the item displayed on line 1 will be displayed on line 2.

Line 2, characters 1 & 2 – are used to display the gear range and motor winding data set that is currently selected for programming. Character 1 will show the selected gear range (1-4) and with 2 speed motors, character 2 will show the motor winding (L or H).

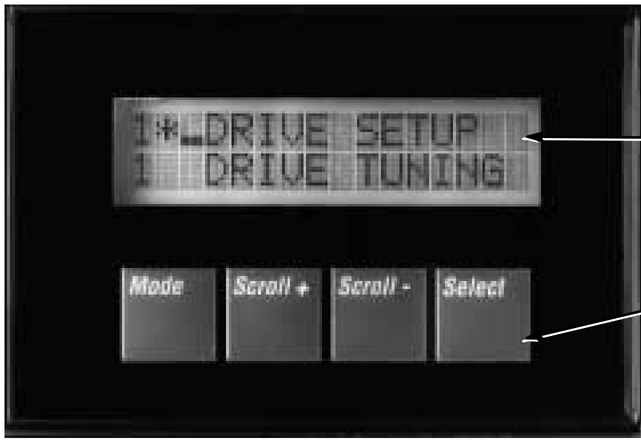
Line 2, character 3 – a variable length bar (moving from the bottom up) that represents the current depth (level) in the menu system that has been selected. For each level the user moves down, another bar is added to the display.

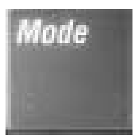
Line 2, characters 4-16 – used to display the options that are available at the current menu level or the value of the parameter that has been selected.

Keypad Description and Operation

When programming in the *DRIVE SETUP* menu, the 8510 keypad will have expanded functions not found in the *DISPLAY TYPE* menu.

Figure 1.2
8510 Keypad and Display





Pressing this key will cause the display to change to the previous menu level within the *DRIVE SETUP* menu section. If the top item of the menu (see Figure 2.2) is shown, the Mode key will have no effect. If a parameter name and value are displayed, pressing this key will cause the system to exit that parameter without saving the displayed value. This key effectively aborts a selection.

Pressing this key once will cause the parameter or sub-menu names shown on line 2 of the display to increment to the next possible choice for the menu listed on line 1. If this key is pressed and held, the display will continuously index through the possible selections until the key is released. When scrolling through a list of sub-menu or parameter names and the end of the menu list is reached, it will roll over to the beginning and continue to increment. When scrolling through parameter value selections, the incrementing will stop at the end of the list and will not roll over.

If line 2 is displaying the numerical value of a parameter, a cursor will be displayed under the least significant digit. When the Scroll + key is pressed, the value of this digit will be increased. Pressing and holding this key will cause the value to increment continuously until the maximum limit for this parameter value is reached. The scrolling stops at the maximum limit. The value will not roll over.

continued

Scroll +
(continued)

To simplify programming large values, the cursor can be moved one digit to the left by simultaneously pressing the Scroll + and Scroll – keys. Pressing and holding both keys will cause the cursor to continue indexing to the left. After reaching the most significant digit position, it will roll over to the least significant digit position.

Tip: The quickest method to program large values is to scroll the first digit to the correct value, index the cursor one digit to the left and scroll to set the value of the second digit, and repeat the process for the other digits. Scrolling the value of a specific digit will only change the value of digits at or to the left of the cursor.

The function of this key is identical to the Scroll+ key except that it causes the display to decrement rather than increment.

If a menu name is shown on line 1, pressing this key will cause the sub-menu or parameter shown on line 2 of the display to become the active menu or parameter. This sub-menu or parameter name will move to line 1 and the new menu choices or parameter value will be shown on line 2.

If a parameter name is shown on line 1 and the parameter value is on line 2, pressing Select will cause the displayed parameter value to be stored in RAM. This value is also used as the current operating parameter value. After the parameter value has been stored in RAM, the display will return to the previous menu display with the parameter name on line 2 of the display.

If the Mode key is used to return the display to the previous menu display, any parameter value changes will not be stored in RAM.

Important: All parameter value changes are initially stored in RAM. To save the data to EEPROM it is necessary to exit the *DRIVE SETUP* menu and return to the *DISPLAY TYPE* menu. Upon exiting *DRIVE SETUP*, all parameter changes are automatically stored into EEPROM. If power is removed from the drive or the drive is reset before the changes have been stored in EEPROM, these changes will be lost. When data is being written to the EEPROM, the "←" symbol will momentarily show as character 3 on line 2 of the display.

continued

Select
(continued)

Any time a parameter name is selected, the parameter value that is initially shown on line 2 is the value that is currently stored in RAM as the operating parameter value.

To speed system setup, it is possible to change the value of any parameter while the drive is operating. When a parameter value is changed and the Select key is pushed, there is a time delay of about 0.75-1.0 second before the value is used in drive operation. Changes to the specified motor or drive type or to the analog output definition will only become effective when the value changes are actually stored in EEPROM the next time the Enable input is energized.

Important: When trying to change parameters while the drive is operating and then observe the resultant operation, verify that the actual operating gear range and motor winding selected by the drive inputs (and shown in characters 1 & 2 of line 1 of the display) matches the programming gear range and motor winding shown by characters 1 & 2 of line 2. If they do not match, any parameter changes will be made to a different gear range data set, resulting in no effect on current drive operation and possible erratic operation when the other data set is used.

ATTENTION: Changing certain parameter values can result in significantly different drive operation characteristics, such as reversing direction of rotation or changing the motor speed for a specific input command level. If parameters are changed while the drive is operating, the user is responsible for assuring that the changes in operating characteristics that result from these changes will not result in unsafe machine operating conditions

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Accessing the DRIVE SETUP Menu

To help guard against access to the drive setup programming parameters by untrained personnel, a special key combination is required to access the *DRIVE SETUP* menu. To access this menu, simultaneously press and hold the Mode, Scroll + and Scroll – keys for about 3 seconds. The *DRIVE SETUP* menu and a second bar at character 3 of line 1 will be displayed. This menu allows access to all of the drive setup parameters that are needed to integrate the motor and drive to the machine. The programmer will be able to:

- Select and define gear ranges
- Select the motor
- Select the drive and set basic configuration parameters
- Dynamically tune the drive
- Setup spindle orient
- Configure the analog outputs

Exiting the *DRIVE SETUP* Menu

Upon completion of setup, pressing and holding the Mode and Scroll – keys will return the display to the *DISPLAY TYPE* menu.

Important: Exiting *DRIVE SETUP* and returning to the *DISPLAY TYPE* menu is the <u>only</u> way to cause all parameter value changes to be written to EEPROM for permanent storage.

Default Data

When the drive is shipped from the factory, default values are programmed for most of the drive configuration data. The values that are chosen will result in relatively low performance operation up to about half speed with most types of systems.

Important: There are three parameters that have no default value assigned. Two of these parameters **must** be programmed by the user before trying to enable the drive or the drive will fault. These parameters are l) *MOTOR SELECT– Catalog Num* and 2) *PARAMETER SET – ELECT CONFIG – Drive Cat Num*. The third parameter, *ORIENT SETUP – FEEDBACK DEFN – Encoder Lines*, must be programmed before attempting to use the drive to perform spindle orient.

Programming Key Combinations

Several functions are implemented through the use of specific combinations of multiple keys.

- Access to the *DRIVE SETUP* menu is accomplished by simultaneously pressing and holding the Mode, Scroll +, and Scroll – keys for about 3 seconds.
- Pressing Mode and Scroll – simultaneously will cause the system to change to the first display screen in the *DRIVE SETUP* menu. Pressing these keys again will exit the *DRIVE SETUP* menu and return the display to the *DISPLAY TYPE* menu.

  Important: Exiting *DRIVE SETUP* and returning to the *DISPLAY TYPE* menu is the only way to cause all parameter value changes to be written to EEPROM for permanent storage.
- When programming numerical values for a programmable parameter, the cursor can be indexed one digit to the left by simultaneously pressing Scroll + and Scroll –.

Remote Programming

Program Upload/Download
Initially, during normal drive integration, the drive is programmed using the integral keypad and display and all programmed data is stored in the EEPROM on the I/O Board. The I/O board contains an RS-232 port that allows offline software to access this EEPROM data.

A file transfer utility, Catalog Number 8510SA-SFTU, that runs on a DOS based, IBM® compatible personal computer, will allow the contents of the EEPROM to be uploaded through the RS-232 port and stored in a file in the computer. This same utility can download this data file to the EEPROM of another drive to duplicate the original drive setup. This allows rapid setup of machines that are in series production by simply downloading the drive setup from a master file. Also, a user can maintain files for each drive in the facility and quickly duplicate the original drive setup in case the setup is accidentally changed.

Offline Programming
A spindle drive configuration software package, Catalog Number 8510SA-SSDC, allows complete offline configuration programming of the 8510 drive. This software runs as part of the Allen-Bradley Offline Development System (ODS) software that is used to configure the 9/Series CNC and IMC motion controller hardware. It also requires a DOS based, IBM compatible personal computer. Rather than using the integral keypad and display on the drive, a full screen display and complete keyboard can be used to enter all drive configuration data. The data file is then downloaded via the RS-232 port into the 8510 drive. To make the final adjustment of the analog input calibration and the drive gains, it may be necessary to use the integral drive programming keypad.

Chapter 2

Programming

Chapter Objectives

Chapter 2 provides a detailed look at the programming associated with the *DRIVE SETUP* menu found in the 8510. Included are complete descriptions of the various parameters that can be programmed during drive setup.

DRIVE SETUP Menu

The *DRIVE SETUP* menu (see Figure 2.1) is the top level of the setup parameters. The menu is accessed by simultaneously pressing and holding the Mode, Scroll +, and Scroll – keys for about 3 seconds.

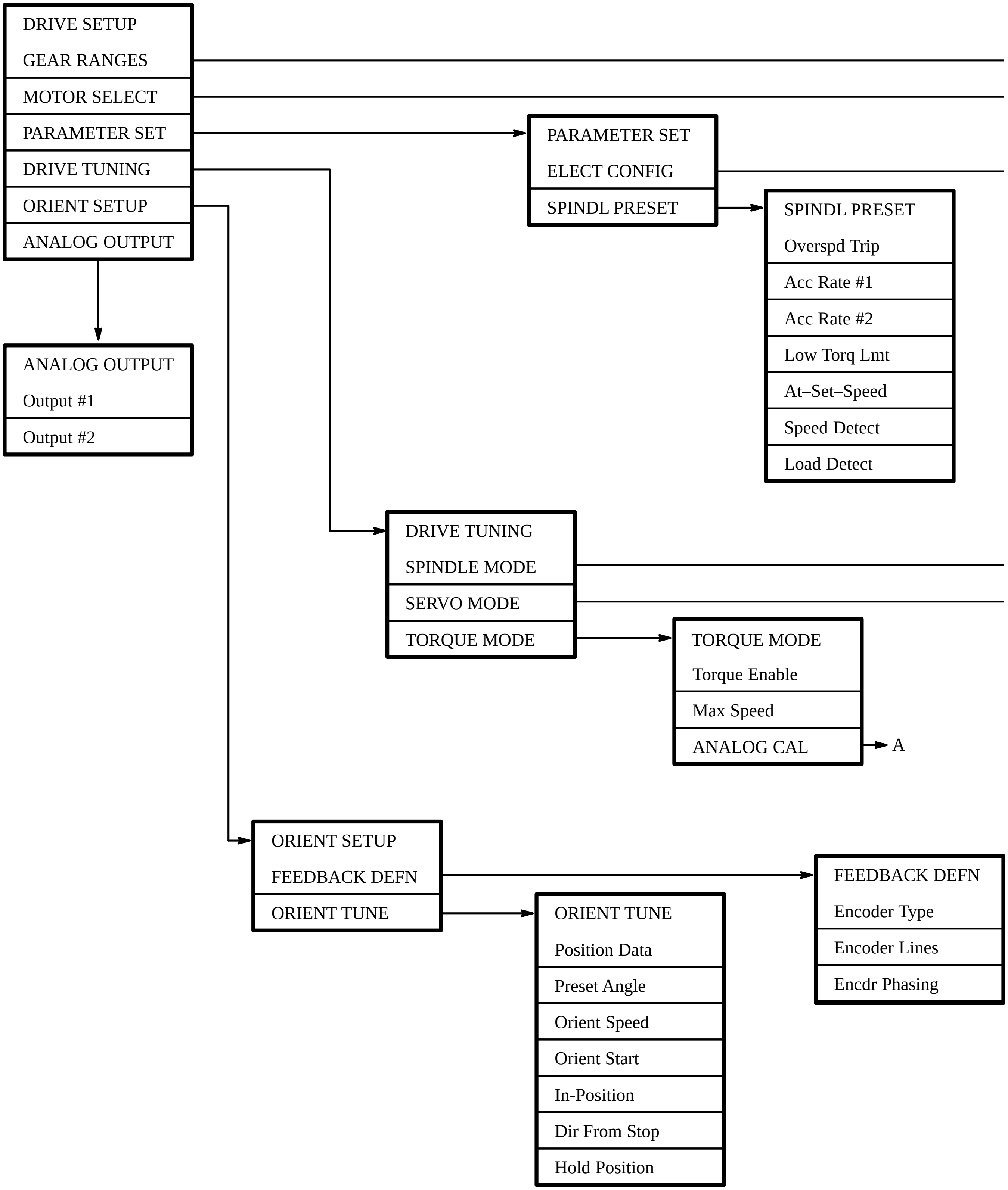
An overall view of the complete *DRIVE SETUP* menu is shown in Figure 2.2.

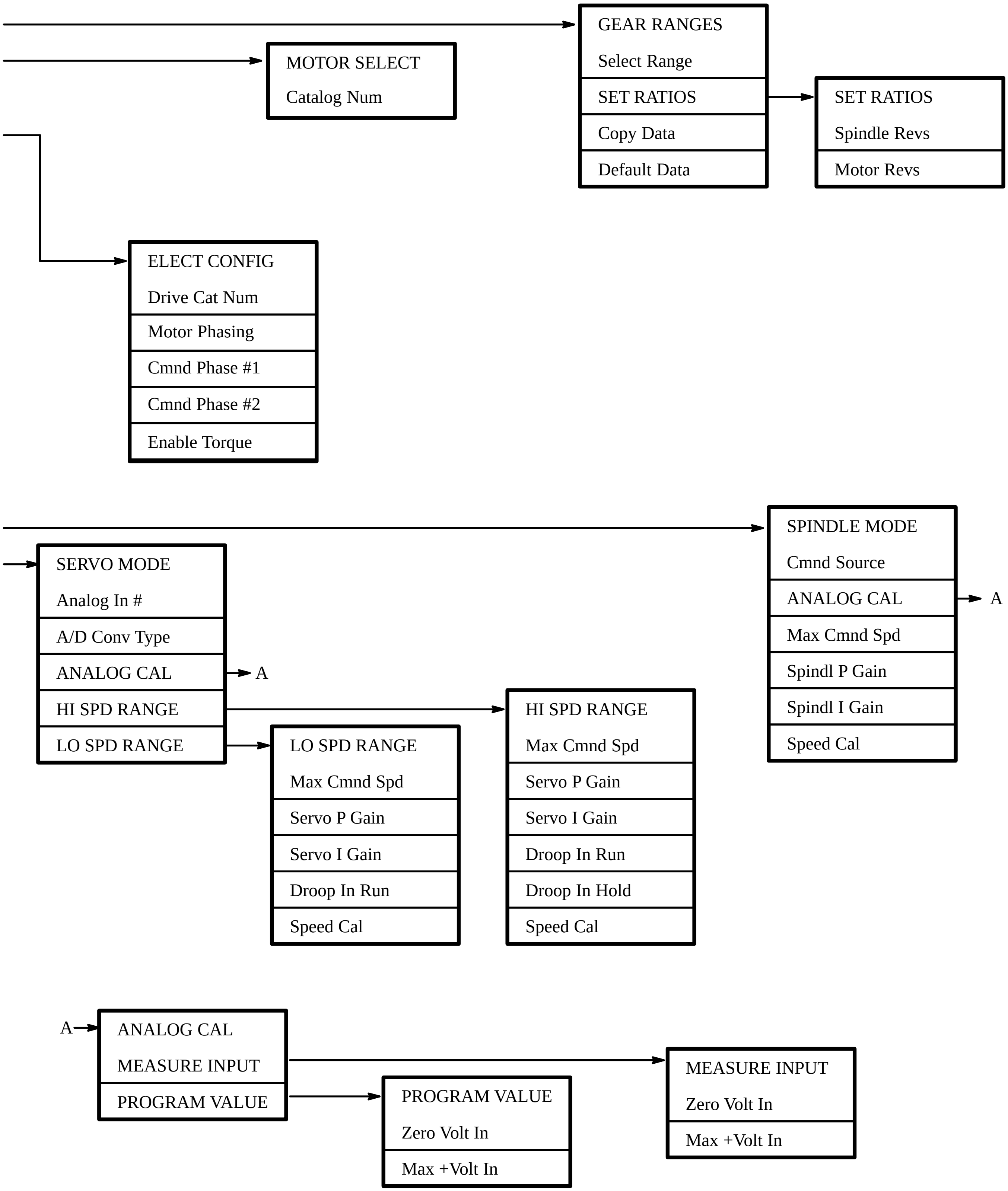
The remaining sections in this chapter provide detailed parameter descriptions used when programming. After most descriptions, a data format will be provided. This indicates the entry format expected by the programming system or the scroll choices that are available. Refer the page numbers provided in Figure 2.1 to help locate specific programming information.

Figure 2.1
Drive Setup Menu Tree

DRIVE SETUP	
GEAR RANGES	→ See Page 2-12
MOTOR SELECT	→ See Page 2-14
PARAMETER SET	→ See Page 2-14
DRIVE TUNING	→ See Page 2-18
ORIENT SETUP	→ See Page 2-29
ANALOG OUTPUT	→ See Page 2-32

Figure 2.2
DRIVE SETUP Menu Tree

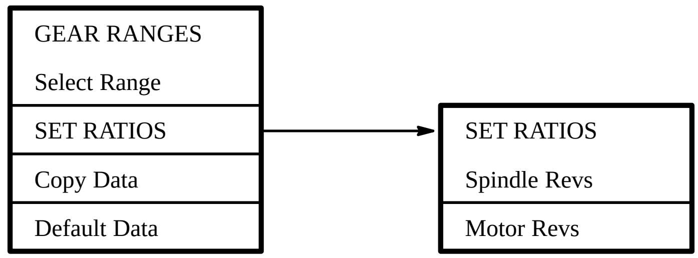



GEAR RANGES
Select Range
SET RATIOS
Copy Data
Default Data
SET RATIOS
Spindle Revs
Motor Revs
MOTOR SELECT
Catalog Num
ELECT CONFIG
Drive Cat Num
Motor Phasing
Cmnd Phase #1
Cmnd Phase #2
Enable Torque
SPINDLE MODE
Cmnd Source
ANALOG CAL
A
Max Cmnd Spd
Spindl P Gain
Spindl I Gain
Speed Cal
SERVO MODE
Analog In #
A/D Conv Type
ANALOG CAL
A
HI SPD RANGE
LO SPD RANGE
LO SPD RANGE
Max Cmnd Spd
Servo P Gain
Servo I Gain
Droop In Run
Speed Cal
HI SPD RANGE
Max Cmnd Spd
Servo P Gain
Servo I Gain
Droop In Run
Droop In Hold
Speed Cal
A
ANALOG CAL
MEASURE INPUT
PROGRAM VALUE
PROGRAM VALUE
Zero Volt In
Max +Volt In
MEASURE INPUT
Zero Volt In
Max +Volt In

GEAR RANGES Menu

This menu allows the gear ranges to be defined and selected for programming. Refer to Figure 2.3 for an example of the *GEAR RANGES* menu and the paragraphs that follow for parameter explanations.

Figure 2.3
GEAR RANGES Menu Tree



The two Gear Range Active inputs define which gear range data set is currently being used for motor control. However, these inputs do not select the gear range data set that can currently be programmed. The *GEAR RANGES* menu is used to select the gear range data set to program.

- The first character of the first line of the display shows the gear range data set that is selected as the operating data set.
- The first character of the second line of the display shows the gear range data set that has been selected for programming.

Select Range
This parameter allows selection of the gear range data set that is to be programmed. The programming gear range has two parts - the physical gear range and the motor winding. If dual winding motors are used, the parameters must be programmed for both the low and high speed windings in each gear range.

The physical gear range is shown in character 1, line 2 of the display, with the motor winding (dual winding motors only) shown in character 2. Dual winding motors use an L or an H to designate the Low and High speed windings. The second position will be blank if a motor is not selected or a single speed motor is being used. A scroll sequence is used to select the low speed and high speed motor windings for a particular gear range before advancing to the next gear (i.e. 1L, 1H, 2L, 2H, etc.). With dual winding motors, only three physical gear ranges can be used since only 6 data sets are stored.

Possible Choices: 1, 2, 3, 4, 1L, 1H, 2L, 2H, 3L, 3H
Default Value 1

SET RATIOS

This item defines the gear range ratio.

Spindle Revs

This parameter defines half of the gear ratio. The gear ratio must be expressed as a ratio of two whole numbers and is stated as the number of spindle revolutions for a certain number of motor revolutions. Enter the number of spindle revolutions here.

Data Range:	00000 to 30000
Default Value:	00001

Motor Revs

The *Motor Revs* parameter programs the other half of the gear ratio. This parameter defines the number of motor revolutions required for the number of spindle revolutions specified above. For Example: a 4.3333:1 speed reduction would be specified as *Spindle Revs* = 3 and *Motor Revs* = 13.

Data Range:	00000 to 30000
Default Value:	00001

Copy Data

This parameter allows data from a previously programmed gear range to be copied to the gear range that is currently selected for programming. When selected, the bottom line can be scrolled through the gear ranges starting at “RANGE: 1.”

Possible Choices:	NO COPY, RANGE: 1, RANGE: 2, . . ., RANGE: 3H
Default Value:	NO COPY

Default Data

Default Data will cause all data stored in the gear range currently selected for programming to be reset to the factory default values. This parameter is used to confirm that reset is desired.

Possible Choices:	NO, YES
Default Value:	NO

MOTOR SELECT Menu

This menu (Figure 2.4) selects the motor that will be used with this drive.

Figure 2.4
MOTOR SELECT Menu Tree

Catalog Num
This parameter lists the available spindle motors. Simply select the catalog number of the motor being used. If a motor was previously selected, that number will be displayed. If a motor was not previously selected, the display will show "NONE SELECTED."

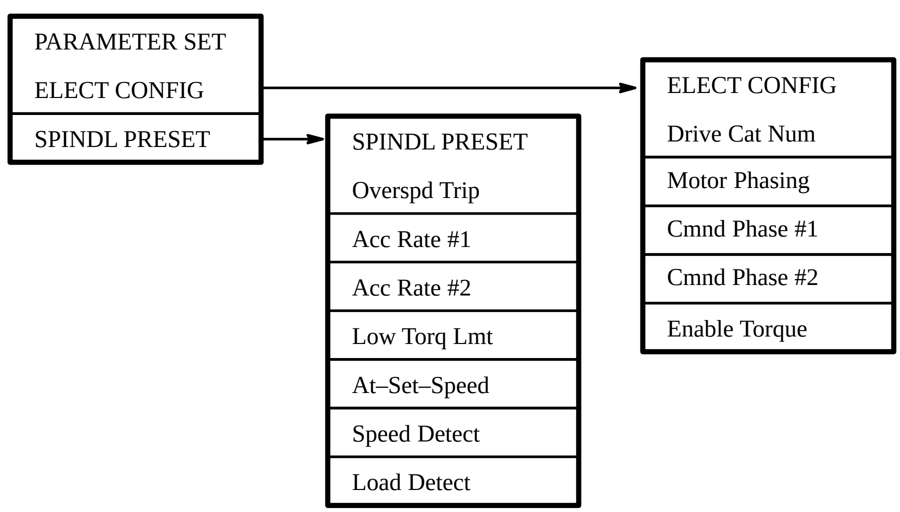
Important: The default parameters do not include the motor type. This parameter must be programmed before attempting to enable the drive or a fault will occur.

Data Format: 1327AB-AFL-15
Default Value: NONE SELECTED

PARAMETER SET Menu

The *PARAMETER SET* menu allows the selection and programming of basic drive configuration parameters and preset parameters.

Figure 2.5
PARAMETER SET Menu Tree



ELECT CONFIG

This menu allows the user to select electrical configuration parameters for programming.

Drive Cat Num

This parameter lists the available drive catalog numbers for selection. Simply select the catalog number of the drive being used. If a catalog number had previously been entered, it will be displayed. If a catalog number was not previously selected, the display will show “NONE SELECTED.”

Important: The default parameters do not include the drive type. This parameter must be programmed before attempting to enable the drive or a fault will occur.

Possible Choices: NONE SELECTED, 8510A-A04, 8510A-A06, 8510A-A11, 8510A-A22
Data Format: 8510A-A04
Default Value: NONE SELECTED

Motor Phasing

This parameter allows the electrical phase sequence of the motor control loops to be reversed without physically changing the wiring to the motor. If incorrectly set, the motor may run slowly or oscillate between forward and reverse rotation.

Possible Choices: FORWARD, REVERSE
Default Value: FORWARD

Cmnd Phase #1

Cmnd Phase #1 allows the polarity of Analog Input #1 to be reversed inside the drive without reversing the actual wiring.

Possible Choices: FORWARD, REVERSE
Default Value: FORWARD

Cmnd Phase #2

Cmnd Phase #2 allows the polarity of Analog Input #2 to be reversed inside the drive without reversing the actual wiring.

Possible Choices: FORWARD, REVERSE
Default Value: FORWARD

Enable Torque

Determines whether or not the drive will produce motor holding torque when the Drive Enable command is On, but the Forward and Reverse Run commands are both Off or On. The “With Run” selection means that one of the Run commands must be present before the motor will produce torque.

Possible Choices: WITH RUN, WITHOUT RUN
Default Value: WITH RUN

SPINDL PRESET

Selects the various Spindle Mode parameters and performance detectors.

Overspd Trip

Sets the overspeed trip point . The drive will shut down at this point and cause the motor to coast to a stop. Set this parameter at least 10% higher than expected maximum speed to avoid nuisance trips.

Data Range: RPM 00000 to 30000
Default Value: 08000

Acc Rate #1

Sets the acceleration rate ramp generator for the ramp rate that is used in spindle mode when the Accel/Decel Rate Select input is turned Off. The rate is defined in seconds/1000 rpm of speed change. This accel/decel rate is achieved only if the required torque does not exceed the torque limit level.

Data Range: S/KRPM 000.00 to 009.99
Default Value: 001.00

Acc Rate #2

Sets the acceleration rate ramp generator for the ramp rate that is used in spindle mode when the Accel/Decel Rate Select input is On. The rate is defined in seconds/1000 rpm of speed change. This accel/decel rate is achieved only if the required torque does not exceed the torque limit level.

Data Range: S/KRPM 000.00 to 009.99
Default Value: 001.00

Low Torq Lmt

This parameter sets the level of torque limit used when the Low Torque Limit Select input is On. The torque is defined as a percent of the continuous rated torque of the specific motor/drive combination and cannot exceed the peak torque capacity of the motor (1.2 x 30 minute motor rating).

Data Range: % 000 to 250
Default Value: % 025

At-Set-Speed

This parameter determines how close the actual speed must be to the commanded speed before the At Speed Indicator output is On. The data is stated as a percent of the commanded speed. If the percent of commanded speed gives a value less than 25 rpm, then a fixed ±25 rpm band is used for the test.

Data Range: % 000 to 100
Default Value: % 010

Speed Detect

The *Speed Detect* parameter determines the speed at which the Speed Level Indicator output changes state. If the motor speed is above this programmed level, the output is Off.

Data Range:	RPM 00000 to 30000
Default Value:	00300

Load Detect

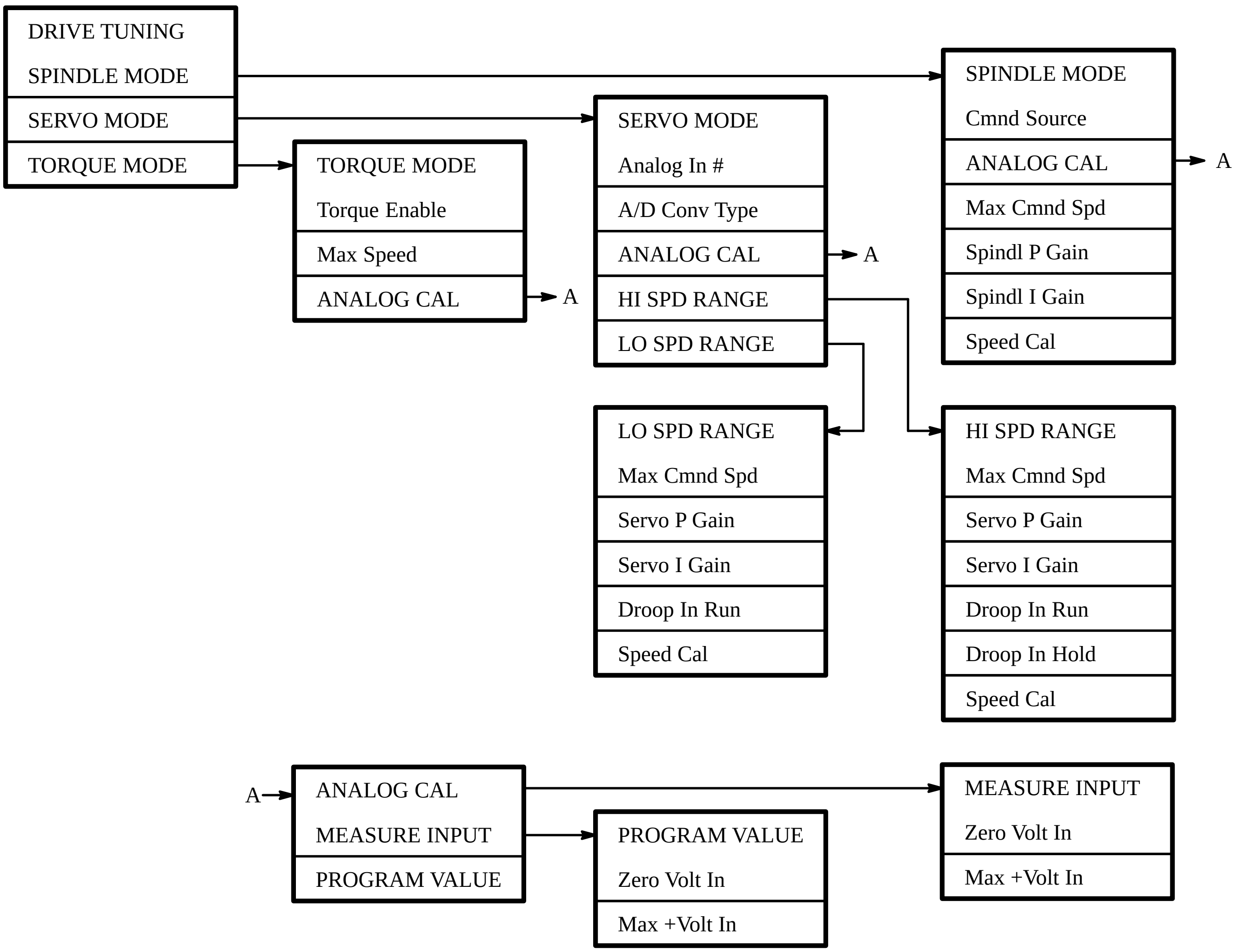
The *Load Detect* parameter determines the commanded torque level at which the Load Level Indicator output changes state. If the torque command exceeds this programmed level, the output is On. The data defines the torque as a percent of the continuous rated torque of the specific motor/drive combination and cannot exceed the peak torque capacity of the motor (1.2 x 30 minute motor rating).

Data Range:	% 000 to 250
Default Value:	% 125

DRIVE TUNING Menu

This menu allows selection of the drive setup and tuning procedure for each of the different operating modes. Refer to Figure 2.6.

Figure 2.6
DRIVE TUNING Menu Tree



SPINDLE MODE

This menu selects the various setup and tuning procedures needed to set the operating parameters that are used when the Spindle/Servo Mode Select input is Off.

Cmnd Source

This parameter is used to specify the source of the speed command. The command can be from Analog Input #1 or from the optional 16 Bit Digital Speed Command/Orient Position inputs on connector CN10. If the digital inputs are used, the data can be in binary or BCD format. In binary mode, maximum speed equals $2^{16} – 1$ or 65,535 counts. 1 LSB = *Max Cmnd Spd* / 65535. In BCD mode, maximum speed equals 9,999 counts. In this mode, 1 LSB = *Max Cmnd Spd* / 9999. The digital inputs can be used for either orient position command or spindle speed command, but not both.

Possible Choices: ANALOG, 4 DIGIT BCD, 16 BIT BINARY
Default Value ANALOG

ANALOG CAL

This menu allows selection of two alternative methods to calibrate the analog input channel. This sequence is not required if digital speed commands are being used.

MEASURE INPUT

Allows selection of the steps required to calibrate the analog input by actually measuring the value of the applied signal voltages. This is the preferred method for calibrating the analog input.

Zero Volt In

This parameter requires the user to input the command voltage that is equal to the zero speed command. When the Select key is pressed, the control will read the input voltage on Analog Input #1 and use that as the zero speed reference value. The display will function as a voltmeter to show the voltage being read on the analog input.

Data Range: VOLT 00.000 to ±09.999
Default Value 0.000

Max +Volt In

This parameter requires the user to input the positive command voltage that is equal to the maximum speed command. When the Select key is pressed, the control will read the input voltage on Analog Input #1 and use that as the maximum speed command reference value. The display will function as a voltmeter to show the voltage being read on the analog input.

Data Range: VOLT 00.000 to 10.000
Default Value 10.000

PROGRAM VALUE
This menu allows selection of the steps required to calibrate the analog input by presetting the display as a normal scrolled variable. Use this calibration method if the actual command voltages are not available.

Zero Volt In
This parameter requires the user to program the value of the command voltage that is equal to the zero speed command.

Data Range: VOLT 0.000 to ±9.999
Default Value 0.000

Max +Volt In
This parameter requires the user to program the value of the command voltage that is equal to the maximum speed command.

Data Range: VOLT 00.000 to 10.000
Default Value 10.000

Max Cmnd Spd
Defines the maximum motor speed that is to correspond to the maximum input command. The maximum motor speed can be programmed to any level required by the application (but less than the maximum allowable for the motor/drive combination) and achieve full scale speed command resolution at that speed.

Data Range: RPM 00000 to 30000
Default Value 03000

The tuning parameters in the 8510 drive are based on the “per unit” system. For this drive the base quantities are defined as follows:

1 p.u. Torque = Peak Motor Torque
1 p.u. Velocity or Velocity Error = Motor Base Speed
1 p.u. Inertia = Time to accelerate to 1 p.u. Velocity with 1 p.u. Torque

Refer to Chapter 3 for a detailed description of drive tuning and the use of the “per unit” system in determining optimum drive tuning parameters.

Spindl P Gain
The velocity loop proportional gain used in the spindle mode is set with this parameter. This data is programmed in Per Unit Torque / Per Unit Velocity Error or % Torque / % Velocity Error.

Data Range: 000.0 to 200.0
Default Value 005.0

Spindl I Gain

The velocity loop integral gain used in the spindle mode is set with this parameter. This data is programmed in Per Unit Torque / Per Unit Velocity Error/second or % Torque / % Velocity Error / second. The units for this parameter are 1/seconds.

Data Range:	1/S 00.00 to 50.00
Default Value	00.20

Speed Cal

This parameter allows exact matching of the speed command to the actual motor speed. When an analog input equal to the maximum spindle speed command is supplied from the CNC, the Scroll keys can be used to adjust the motor speed until the displayed actual speed matches the commanded speed. Press the Select key to store the setting.

This could be considered a fine tuning of the *Max Cmnd Spd* parameter. As the appropriate Scroll key is pressed, a multiplier factor for the *Max Cmnd Spd* parameter is incremented in 0.04% steps. There is a time delay of approximately one second after the multiplier is changed until it can be observed in the system operation. During this operation, the display is operating as a digital speed meter showing current motor speed. Reprogramming the *Max Cmnd Spd* parameter will reset this multiplier to zero.

Data Range:	RPM 00000 to 30000
Default Value	0.00%

SERVO MODE

This menu selects the various setup and tuning procedures needed to set the operating parameters that are used when the Spindle/Servo Mode Select input is On.

Analog In

Analog In # determines which analog input is going to be used for the velocity command in servo mode. If the drive is to operate in torque mode, Analog Input #1 must be used for the velocity command.

Possible Choices:	INPUT #2, INPUT #1
Default Value	INPUT #2

A/D Conv Type

This parameter determines which A/D converter will be used with the servo mode analog input signal. The standard A/D converter is a 10 bit converter with auto-ranging capabilities that gives an effective 14 to 17 bits resolution for positioning applications.

However, for large command changes, the autoranging function introduces a time delay. The full input range of +10 volts to –10 volts is broken into 32 equal steps of 0.625 volts. Within one increment, A/D conversions are made in 0.8 ms. To shift the input level one increment requires 0.8 ms. For a maximum input change from +10 volts to –10 volts, the maximum delay is 26.4 ms. The optional A/D converter is a full 14 bit, high speed converter providing an input sample every 0.8 ms. This converter must be used for precision continuous path contouring applications and very high response positioning applications.

Possible Choices:	STANDARD, 14 BIT LINEAR
Default Value	STANDARD

ANALOG CAL

This menu allows selection of two alternative methods to calibrate the analog input channel.

MEASURE INPUT

Allows selection of the steps required to calibrate the analog input by actually measuring the value of the applied signal voltages. This is the preferred method for calibrating the analog input.

Zero Volt In

This parameter requires the user to input the command voltage that is equal to the zero speed command. When the Select key is pressed, the control will read the input voltage on the input selected by the *Analog Input #* parameter and use that as the zero speed reference value. The display will function as a voltmeter to show the voltage being read on the analog input.

Data Range:	VOLT 00.000 to ±09.999
Default Value	0.000

Max +Volt In

This parameter requires the user to input the positive command voltage that is equal to the maximum speed command. When the Select key is pressed, the control will read the input voltage on the input selected by the *Analog Input #* parameter and use that as the maximum speed command reference value. The display will function as a voltmeter to show the voltage being read on the analog input.

Data Range:	VOLT 00.000 to 10.000
Default Value	10.000

PROGRAM VALUE
This is a menu title that allows selection of the steps required to calibrate the analog input by presetting the display as a normal scrolled variable. Use this calibration method if the actual command voltages are not available.

Zero Volt In
This parameter requires the user to program the value of the command voltage that is equal to the zero speed command.

Data Range:	VOLT 0.000 to ±9.999
Default Value	0.000

Max +Volt In
This parameter requires the user to program the value of the command voltage that is equal to the maximum speed command.

Data Range:	VOLT 00.000 to 10.000
Default Value	10.000

HI SPD RANGE
This menu selects the various setup and tuning parameters that are used when the Spindle/Servo Mode Select input is On and the Servo Input Scaling Low/High input is On. Also, the velocity loop tuning parameters set for this mode will be used when the drive is performing the spindle orient operation.

Max Cmnd Spd
Defines the maximum motor speed that will correspond to the maximum input command. The maximum motor speed can be programmed to any level required by the application (but less than the maximum allowable speed for the motor/drive combination) and achieve full scale speed command resolution at that speed. Typically this parameter would be used for C axis rapid traverse, solid tapping operation, or possibly precision spindle orient operations from the CNC and would be set to a relatively low speed.

Data Range:	RPM 00000 to 30000
Default Value	00084

The tuning parameters in the 8510 drive are based on the “per unit” system. For this drive the base quantities are defined as follows:

1 p.u. Torque = Peak Motor Torque
1 p.u. Velocity or Velocity Error = Motor Base Speed
1 p.u. Inertia = Time to accelerate to 1 p.u. Velocity with 1 p.u. Torque

Refer to Chapter 3 for a detailed description of drive tuning and the use of the “per unit” system in determining optimum drive tuning parameters.

Servo P Gain

The velocity loop proportional gain used in the servo mode is set with this parameter. This data is programmed in Per Unit Torque / Per Unit Velocity Error or % Torque / % Velocity Error.

Data Range: 000.0 to 200.0
Default Value 5.00

Servo I Gain

The velocity loop integral gain used in the servo mode is set with this parameter. This data is programmed in Per Unit Torque / Per Unit Velocity Error/second or % Torque / % Velocity Error / second. The units for this parameter are 1/seconds.

Data Range: l/S 00.00 to 50.00
Default Value 00.20

Droop In Run

Droop In Run sets a maximum limit on the effective low frequency velocity loop gain that the integrator can generate during normal running mode operation. This parameter limits stick-slip motion during very low speed C axis operation. The data is expressed in Per Unit Velocity Error / Per Unit Torque or % Velocity Error / % Torque.

Data Range: 0.000 to 7.999
Default Value 0.001

Droop In Hold

Sets a maximum limit on the effective low frequency velocity loop gain that the integrator can generate when the spindle is within the in-position error band limit during spindle orient operation. This can allow accurate positioning without excess stick-slip motion. The data is expressed in Per Unit Velocity Error / Per Unit Torque or % Velocity Error / % Torque.

Data Range: 0.000 to 7.999
Default Value 0.001

Speed Cal

The *Speed Cal* parameter allows exact matching of the speed command to the actual motor speed in order to precisely set position loop gain. When the velocity command from a closed position loop move commanded by the CNC is input to the drive, the Scroll keys can be used to adjust the motor speed until the exact following error value required in the CNC is achieved. Press the Select key to store the setting.

This could be considered a fine tuning of the *Max Cmnd Spd* parameter. As the appropriate Scroll key is pressed, a multiplier factor for the *Max Cmnd Spd* parameter is incremented in 0.04% steps. There is a time delay of approximately one second after the multiplier is changed until it can be observed in the system operation. During this operation, the display is operating as a digital speed meter showing current motor speed. Reprogramming the *Max Cmnd Spd* parameter will reset this multiplier to zero.

Data Range:	RPM 00000 to 30000
Default Value	0.00 %

LO SPD RANGE

This menu selects the various setup and tuning parameters that are used when the Spindle/Servo Mode Select input is On and the Servo Input Scaling Low/High input is Off.

Max Cmnd Spd

Defines the maximum motor speed that will correspond to the maximum input command. The maximum motor speed can be programmed to any level required by the application (but less than the maximum allowable speed for the motor/drive combination) and achieve full scale speed command resolution at that speed. Typically this parameter would be used to obtain maximum resolution for C axis contouring mode and would be set to a very low speed.

Data Range:	RPM 00000 to 30000
Default Value	00030

The tuning parameters in the 8510 drive are based on the “per unit” system. For this drive the base quantities are defined as follows:

1 p.u. Torque = Peak Motor Torque
1 p.u. Velocity or Velocity Error = Motor Base Speed
1 p.u. Inertia = Time to accelerate to 1 p.u. Velocity with 1 p.u. Torque

Refer to Chapter 3 for a detailed description of drive tuning and the use of the “per unit” system in determining optimum drive tuning parameters.

Servo P Gain

The velocity loop proportional gain used in the servo mode is set with this parameter. This data is programmed in Per Unit Torque / Per Unit Velocity Error or % Torque / % Velocity Error.

Data Range: 000.0 to 200.0
Default Value 5.00

Servo I Gain

The velocity loop integral gain used in the servo mode is set with this parameter. This data is programmed in Per Unit Torque / Per Unit Velocity Error/second or % Torque / % Velocity Error / second. The units for this parameter are 1/seconds.

Data Range: l/S 00.00 to 50.00
Default Value 00.20

Droop In Run

Droop In Run sets a maximum limit on the effective low frequency velocity loop gain that the integrator can generate during normal running mode operation. This parameter limits stick-slip motion during very low speed C axis operation. The data is expressed in Per Unit Velocity Error / Per Unit Torque or % Velocity Error / % Torque.

Data Range: 0.000 to 7.999
Default Value 0.001

Speed Cal

The *Speed Cal* parameter allows exact matching of the speed command to the actual motor speed in order to precisely set position loop gain. When the velocity command from a closed position loop move commanded by the CNC is input to the drive, the Scroll keys can be used to adjust the motor speed until the exact following error value required in the CNC is achieved. Press the Select key to store the setting.

This could be considered a fine tuning of the *Max Cmnd Spd* parameter. As the appropriate Scroll key is pressed, a multiplier factor for the *Max Cmnd Spd* parameter is incremented in 0.04% steps. There is a time delay of approximately one second after the multiplier is changed until it can be observed in the system operation. During this operation, the display is operating as a digital speed meter showing current motor speed. Reprogramming the *Max Cmnd Spd* parameter will reset this multiplier to zero.

Data Range: RPM 00000 to 30000
Default Value 0.00 %

TORQUE MODE

This menu selects the steps needed to set up torque mode operation. When operating in torque mode, the motor must be connected to a speed controlled load or an external speed regulator must be used. Otherwise, the motor will be accelerated at a constant commanded torque level until the drive faults on overspeed.

Important: Torque Mode operation requires the use of the 14 bit A/D converter that is part of I/O Board versions -Cx or -Dx. To make Torque Mode work, it is necessary to set the *SERVO MODE – A/D Conv Type* parameter to “14 BIT LINEAR.”

Torque Enable

This parameter is used to enable or disable torque mode operation. When torque mode is enabled, the drive can operate in torque mode whenever the proper input command is given to activate it. When torque mode is programmed to the enabled condition, the internal low accel/decel ramp control will be disabled and the Accel/Decel Rate Select input will be assigned a new function. Torque mode will now be activated when the Accel/Decel Rate Select is On. Otherwise, when this input is Off, the drive operates as a normal velocity control drive in the selected mode.

Possible Choices:	DISABLE, ENABLE
Default Value	DISABLE

Max Speed

Defines the motor speed that will cause an overspeed fault when in torque mode. It is determined by the speed requirements of the application.

Data Range:	RPM 00000 to 30000
Default Value	03000

ANALOG CAL

This menu allows selection of two alternate methods to calibrate Analog Input #2. The torque mode *Torque Command* can only be applied to this input. The spindle mode or servo mode velocity commands must be applied to Analog Input #1.

MEASURE INPUT

Allows selection of the steps required to calibrate the analog input by actually measuring the value of the applied signal voltages. This is the preferred method for calibrating the analog input.

Zero Volt In

This parameter requires the user to input the command voltage that is equal to the zero torque command. When the Select key is pressed, the control will read the input voltage on Analog Input #2 and use that as the zero torque reference value. The display will function as a voltmeter to show the voltage being read on the analog input.

Data Range:	VOLT 00.000 to ±09.999
Default Value	0.000

Max +Volt In

This parameter requires the user to input the positive command voltage that is equal to the maximum torque command. When the Select key is pressed, the control will read the input voltage on Analog Input #2 and use that as the maximum torque command reference value. The display will function as a voltmeter to show the voltage being read on the analog input.

Data Range: VOLT 00.000 to 10.000
Default Value 10.000

PROGRAM VALUE

This menu allows selection of the steps required to calibrate the analog input by presetting the display as a normal scrolled variable. Use this calibration method if the actual command voltages are not available.

Zero Volt In

This parameter requires the user to program the value of the command voltage that is equal to the zero torque command.

Data Range: VOLT 0.000 to ±9.999
Default Value 0.000

Max +Volt In

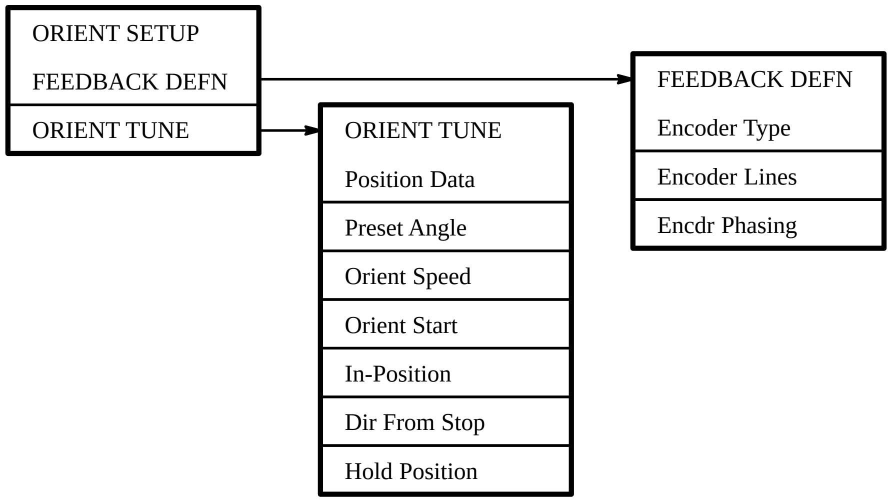
This parameter requires the user to program the value of the command voltage that is equal to the maximum torque command.

Data Range: VOLT 00.000 to 10.000
Default Value 10.000

ORIENT SETUP Menu

The *ORIENT SETUP* menu (Figure 2.7) is used for configuring and tuning the drive to properly perform the spindle orient function. If spindle orient is being performed by the CNC, this setup is not required.

Figure 2.7
Orient Setup Menu Tree



FEEDBACK DEFN
This is a menu title for defining the feedback type and electrical configuration for use in spindle orient.

Encoder Type
The basic type of feedback device that is being used to provide spindle position data is determined with this parameter. If a normal encoder with quadrature A and B channel square wave outputs and a marker channel is being used, select “OPTICAL PULSE.” The encoder must meet the electrical specifications defined in the 8510 User Manual. If the high resolution magnetic feedback offered with the 8510 is being used, select “MAGNET ANALOG.” The alternate choices are not currently valid.

Important: When this parameter has been changed and stored, it will not become effective until AC power is removed from the drive and then reapplied.

Possible Choices: OPTICAL PULSE, MAGNET PULSE, MAGNET ANALOG
Default Value: OPTICAL PULSE

Encoder Lines

The number of lines or primary counts per revolution from the feedback device is defined with this parameter. For an optical encoder, this is the number of lines on the A channel of the encoder disk. For the high resolution magnetic feedback, it is the number of teeth on the gear. This parameter must be specified or spindle orient will not function.

Data Range: 0000 to 8192
Default Value 0000

Encdr Phasing

Allows the polarity of the feedback data to be reversed without physically reversing the wires from the feedback device.

Possible Choices: FORWARD, REVERSE
Default Value FORWARD

ORIENT TUNE

This menu selects the items needed to setup encoder based spindle orient operation. Refer to Chapter 3 for a more detailed description of orient mode tuning.

Position Data

Defines the source of orient position angle command. If a preset angle is chosen, the actual angle is specified with the following parameter. The other choices define the format of the optional 16 bit digital input data. Either BCD or binary formats can be chosen. If “BCD” is chosen, one LSB = 360 degrees / 10,000 or 0.036 degrees. If binary is chosen, one LSB = 360 degrees / 2^{16} or 0.0055 degrees. The data read at the inputs is defined in degrees of angular displacement from the zero reference of the spindle encoder. Also, if either “BCD” or “BINARY” are selected, it is not possible to use digital velocity commands.

Possible Choices: PRESET ANGLE, BCD INPUT, BINARY INPUT
Default Value PRESET ANGLE

Preset Angle

This parameter specifies a preset, internally stored orient position. The data variable is expressed in degrees of angular displacement from the zero reference of the spindle encoder.

Data Range: DEG 000.000 to 359.999
Default Value 000.000

Orient Speed

Defines the spindle rpm from which the orient sequence will start. When the Orient Command is input, the spindle will decelerate to this speed before beginning the orient operation.

Data Range: RPM 000 to 999
Default Value 060

Orient Start

Specifies how far before the target position that the orient deceleration begins. The data variable is expressed in spindle degrees prior to the target.

Data Range: DEG 000.0 to 359.9
Default Value 45.0

In-Position

In-Position specifies how close the actual spindle position must be to the target position before the In-position output is energized. If the spindle were to move outside of this in-position range after the output was initially energized, the output would again turn Off. The data is expressed in spindle degrees away from the target.

Data Range: +DEG 000.000 to 359.999
Default Value 000.250

Dir From Stop

This parameter specifies the direction of spindle rotation when performing an orient operation from stop. The scroll selection for this variable specifies the direction of rotation if the Zero Speed output was On when the Orient Command was input.

If “SHORTEST” is selected, the spindle will rotate in the direction that gives the shortest distance to the orient position. It may rotate either clockwise or counterclockwise.

If the spindle is rotating (the Zero Speed output is not On) when the Orient Command is input, the orient operation always continues in the same direction of rotation as it was moving prior to receiving the command.

Possible Choices: CCW, CW, SHORTEST
Default Value CCW

Hold Position

Determines whether or not the motor will continue to produce torque to hold the spindle within the in-position band once the orient function has been completed.

Possible Choices: TORQUE HOLD, TORQUE OFF
Default Value TORQUE HOLD

ANALOG OUTPUT Menu

The *ANALOG OUTPUT* menu (see Figure 10.1) allows the analog output signals to be properly configured. These selections will not become active until the data has been stored in EEPROM by transitioning the Drive Enable input from Off to On.

Figure 2.8
Analog Output Menu Tree

ANALOG OUTPUT
Output #1
Output #2

Output #1

This parameter allows Analog Output #1 to be configured for the desired output parameter.

Possible Choices	| MOTOR RPM | *(Absolute Value)* MOTOR RPM *(Bipolar Value)* | SPINDLE RPM | *(Absolute Value)* SPINDLE RPM *(Bipolar Value)* % LOAD % TORQUE POWER ORIENT ERROR
Default Value	| MOTOR RPM | *(Absolute Value)*

Output #2

This parameter allows Analog Output #2 to be configured for the desired output parameter.

Possible Choices	| MOTOR RPM | *(Absolute Value)* MOTOR RPM *(Bipolar Value)* | SPINDLE RPM | *(Absolute Value)* SPINDLE RPM *(Bipolar Value)* % LOAD % TORQUE POWER ORIENT ERROR
Default Value	% LOAD

Chapter 3

Drive Tuning

Chapter Objectives

Chapter 3 provides details of the principles and process of tuning the 8510 drive for optimum operation. This chapter is designed to help the user understand the tuning process and anticipate the results of changes in tuning parameters. In addition, the Per Unit system of measure is explained in detail.

Tuning Introduction

The purpose of tuning a drive is to achieve the required stability, bandwidth, and stiffness. Stability is the ability of the drive to regulate speed or position without oscillation or excessive overshoot. Bandwidth is related to the quickness of drive response to changing commands. Stiffness is the ability of the drive to resist external load disturbances.

Tuning closed loop feedback systems can be complicated. There is however, an organized approach for the typical machine tool as described below.

- P Gain is strongly related to bandwidth
- I Gain is strongly related to stiffness
- Both P and I Gains are related to stability, if either is too high, the system will be unstable

When building identical machines in a production environment, only the first machine should require tuning. All others should perform identically by simply presetting the parameter values determined while tuning the first machine.

Tuning Requirements

The 8510 drive provides multiple parameter sets to allow optimum performance to be achieved with multi-speed gearboxes, dual winding motors, and widely varying operating conditions. Each parameter set provides unique tuning parameters for spindle, high speed servo, low speed servo, and spindle orient modes. Each parameter set and its respective operating modes used in the application will require individual tuning according to the following procedure. For best results, it is recommended that an oscilloscope be used to observe the results of drive tuning, however, acceptable results can often be achieved by simply observing the spindle and listening to the drive and motor during the tuning process.

Spindle/Servo Mode Tuning

The following steps describe the tuning process for spindle or servo mode.

ATTENTION: If an oscilloscope is used during start-up, tuning or troubleshooting, it must be properly grounded. The oscilloscope chassis may be at a potentially fatal voltage if not properly grounded. Always connect the oscilloscope chassis to earth ground.

When using an oscilloscope it is recommended that the test probe ground be connected to the test point labeled "GND."

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o 1. Program the following parameters (for the mode you are using) as follows (refer to Chapter 2 as necessary) :

P Gain (Servo or Spindl) – set to the default value (5.0)

I Gain (Servo or Spindl) – set to zero

o 2. Program *ANALOG OUTPUT – Output #1* for "± MOTOR RPM" and *ANALOG OUTPUT – Output #2* for "% TORQUE." While observing the motor rpm and per cent torque via the analog outputs or test points, adjust *P Gain* to achieve the desired speed of response with no more than one overshoot.

Ideally, *P Gain* should be adjusted with minimum load inertia. Tuning with maximum load inertia could result in instability with a smaller load inertia. Lost motion between the motor and load may intermittently decouple the load inertia from the motor. This situation could also lead to instability if the drive were tuned for maximum inertia.

Lowering *P Gain* slows response, reduces overshoot, improves stability, and reduces torque ripple. *P Gain* should not be increased beyond the required amount for acceptable system response. Too high of a *P Gain* setting will amplify digital and analog system noise and increase velocity and torque ripple. High torque ripple can overheat the motor and deteriorate surface finish. If *P Gain* is increased to extremes, the system will become unstable, oscillate at a high frequency, and produce significant audible noise.

It will not be possible to achieve high bandwidth on high inertia systems. The high *P Gain* required will cause very high torque ripple due to digital noise amplification.

o 3. Increase *I Gain* to achieve the required stiffness. Ideally, *I Gain* should be adjusted with maximum load inertia. Tuning with minimum load inertia could result in an underdamped response or instability when larger load inertia is applied.

Operating the system in its normal metal cutting mode provides a simplified method to verify stiffness. Load changes occur due to milling cutter tooth frequency, intermittent cuts, etc. Velocity disturbance can be observed by monitoring the motor rpm analog output signal. Proper stiffness can be assumed when the velocity disturbances are acceptable.

Stiffness can be measured by applying torque to the system when it is at rest. The shaft will move an amount proportional to the torque. When torque is removed, the shaft will return to its original position. Stiffness is the ratio of torque to the angle moved. The greater the stiffness, the lesser amount a given torque will disturb the shaft position, and the quicker the system will respond to counteract the disturbance.

As *I Gain* is increased, stability will gradually decrease. Frequency of oscillation will be relatively low and audible noise should be at a minimum. This suggests another method for adjusting stiffness, simply increase *I Gain* until instability is about to occur, then lower the gain until the system is well damped.

o 4. When operating the 8510 in servo mode in a closed position loop (such as during C-axis operation or spindle orient), a “stick/slip hunting” may be observed. Increasing the *Droop In Run* value can minimize this.

“Stick/slip hunting” occurs when static friction is significantly higher than running friction. As the motor approaches the final commanded position, the position and velocity error decrease until the commanded torque is less then the running friction. The motion will then stop. When the system is at zero velocity with a non-zero position error, the velocity loop integrator will slowly increase the motor torque until it builds to the point of breaking the static friction lock and causing the system to move. Once motion starts, friction immediately drops from the static level to the running level. Since the torque being generated to overcome static friction is too high for the lower running friction level, overshoot of the target position may result. When motion stops in the process of reversing, static friction again locks the system. The integrator slowly builds up torque in the opposite direction until it breaks the friction lock and overshoots in the opposite direction. Hunting now becomes a never ending process, usually in the range of 0.5 to 2 Hz.

The integral gain compensator has infinite DC gain, meaning that the smallest position error (velocity command) can be integrated up, to eventually generate maximum torque. Droop places a limit on DC gain and creates a threshold below which small position error cannot generate enough torque to break the static friction lock. The never ending cycle of stick/slip hunting is broken. Increasing the *Droop In Run* parameter setting will increase the level of this threshold.

o 5. Repeat steps 1 through 4 for each gear range, motor winding, and mode if applicable.

"Per Unit" System Description

The units used to express gain are arbitrary. When tuning analog drives by adjusting potentiometers, units are completely unknown and gain is only an arbitrary scale on the pot. Thus, it is possible to tune drives without even knowing the gain units.

With digital drives, parameter values must relate directly to mathematical or computer models of the system that are implemented in the drive. Therefore, the units must follow some defined format.

The 8510 uses the Per Unit system. This system is employed for the following reasons:

- The Per Unit system is independent of any local system of units. Units do not change among industries or locality.
- The Per Unit system yields gain values which are very similar over a wide range of motor/drive sizes. Once you become familiar with typical values for P, I, and Droop gains, nearly the same values can be expected for a very wide variety of motor/drive sizes.
- The Per Unit system is becoming the worldwide drives industry standard.

Per Unit System Defined

Unit Velocity, V, is defined as the motor base speed

Unit Torque, T, is defined as the motor peak torque

Unit Inertia, J, is defined as the time to accelerate to Per Unit speed at Per Unit torque

Unit Time, t, is defined as 1 Second

Example 1:
Unit motor speed is defined as base speed. The base speed of a certain motor is 1500 rpm. How many units of speed is the motor running at when it is rotating at 6000 rpm?

$$\frac{6000\text{ rpm}}{1500\text{ rpm}} = 4$$

Note that the Per Unit speed does not have a unit

Example 2:
The peak torque of the same motor is 200 N-m (147.5 lb.-ft.). What is the Per Unit torque when operating at 50 N-m (36.9)?

$$\frac{50\text{ N-m (36.9 lb.-ft.)}}{200\text{ N-m (147.5 lb.-ft.)}} = 0.25$$

Note that the answer is the same with torque expressed in lb.-ft. or N-m.

Gains

The variables for gain are expressed in Per Unit. Per Unit P, I, and Droop gains are defined as:

P is defined as T/V (units of torque produced for each unit of velocity error)

I is defined as T/V/s (units of torque change per second for each unit velocity error)

Droop is defined as V/T (units of velocity droop for each unit of torque being produced)

Example 3:

The same 1500 rpm, 200 N-m (147.5 lb.-ft.) motor will be used.

If the velocity error is 0.02 Per Unit and P = 20, what is the Per Unit torque?

T = P x V = 20 x 0.02 = 0.4 Per Unit Torque

What is the torque expressed in N-m (lb.-ft.)?

$$0.4 = \frac{\text{Torque}}{\text{200 N-m (147.5 lb.-ft.)}} = \text{80 N-m (59.0 lb.-ft.)}$$

Spindle Orient Mode Tuning

In the Spindle Orient Mode, the 8510 uses the Servo Mode, High Speed Range parameter settings to control the dynamics of the velocity loop. The position loop dynamics is controlled by the settings of the *ORIENT TUNE – Orient Speed* and *ORIENT TUNE – Orient Start* parameters.

The actual target position is either preset by the *ORIENT TUNE – Preset Angle* parameter or input through the 16 bit digital speed/position inputs. The actual source of the orient position data is determined by the setting of the *ORIENT TUNE – Position Data* parameter.

The *ORIENT TUNE – Orient Speed* parameter defines the spindle speed just prior to the start of the final deceleration toward the target position. The *ORIENT TUNE – Orient Start* parameter defines the number of degrees ahead of the target spindle position where the drive begins the final deceleration to the target position.

When the Orient Command is energized, the spindle is immediately decelerated to the Orient Speed. When the Orient Start position is reached, the final deceleration begins. The deceleration to Orient Speed is a simple velocity ramp without position control. Thus, the spindle may turn as much as one revolution at Orient Speed before the Orient Start position is reached.

If plotted as velocity versus position, the final deceleration is a straight line from the Orient Speed/Orient Start point to the Zero Speed/Target Position point (see Figure 3.1). The orient position loop gain is essentially the slope of this curve and is defined as:

$$Kp = 6 \times \frac{\text{Orient Speed}}{\text{Orient Start}}$$

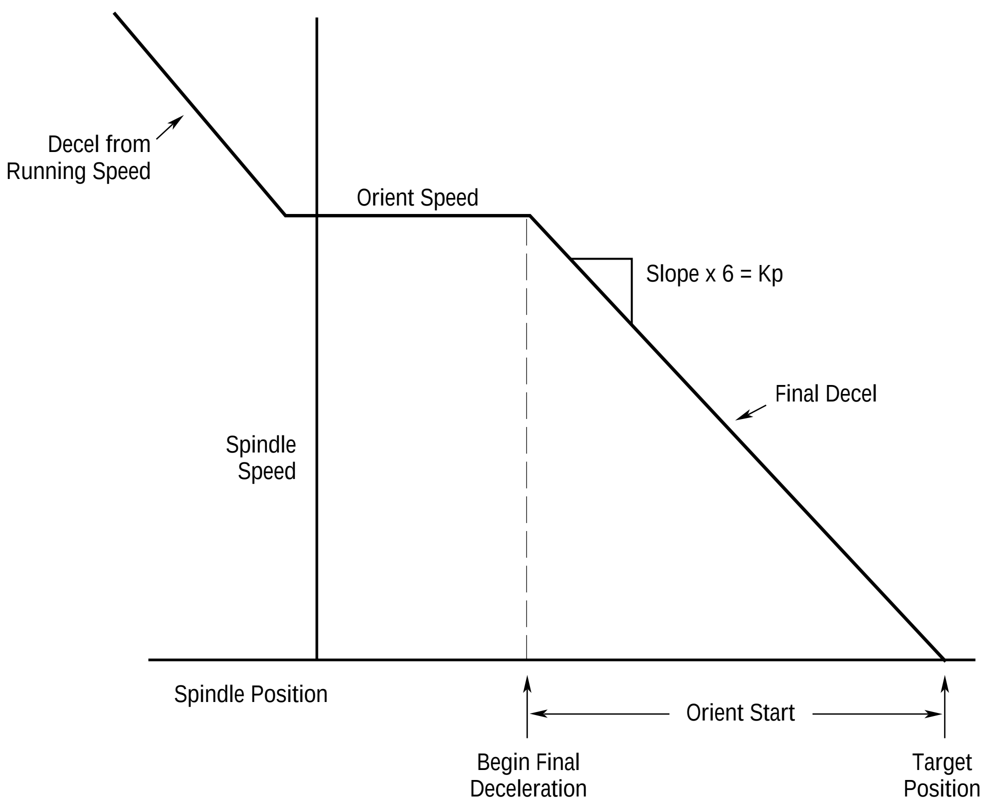
(expressed as degrees/second/degrees or radians/second)

The orient position loop gain that is achieved using the default values for *Orient Speed* and *Orient Start* is:

$$Kp = 6 \times \frac{60 \text{ rpm}}{45.0 \text{ degrees}} = 8 \text{ radians/second}$$

If the velocity or position error were plotted versus time, the deceleration would be a single exponential deceleration to the target position.

Figure 3.1
Spindle Orient Operation



Spindle Orient Tuning Process

During the final deceleration toward the target position, the drive should not be in torque limit. When the drive is in torque limit, the actual spindle position will fall behind the commanded spindle position, and the system is likely to overshoot the target position as the control loops try to recover.

The peak torque required from the drive to decelerate the spindle is directly related to the total system inertia, the orient position loop gain (Kp), and the motor speed when the deceleration is initiated.

Please note the following points:

- For any setting of *Orient Speed*, the required peak torque will increase in direct proportion to the increase in Kp (*Orient Start* setting is decreased).
- For any specific value of Kp (ratio of *Orient Speed* to *Orient Start*), the required peak torque will increase in direct proportion to the increase in value of *Orient Speed*.
- For any setting of *Orient Start*, the required peak torque will increase as the <u>square</u> of any percentage increase in the *Orient Speed* parameter value. For example, if the *Orient Speed* is increased from 100 to 200 rpm, the peak torque will increase to 400% of the previous value. Increasing *Orient Speed* without changing *Orient Start* increases both the value of Kp and the initial decel speed.

The time to perform the spindle orient is composed of three components:

1. the time to decelerate to the *Orient Speed*,
2. the time to search for the *Orient Start* spindle position, and
3. the time for the final deceleration to the target position.

The initial time to decelerate to the *Orient Speed* is determined by the actual spindle speed when the orient command is given and is not controllable by drive tuning. The time required to search for the *Orient Start* position can be minimized by increasing the setting of *Orient Speed* as much as possible, without causing the drive to be torque limited. The time for the final deceleration is minimized by increasing the value of Kp as much as possible. After selecting the *Orient Speed*, the *Orient Start* setting is made as small as possible without forcing the drive into torque limit, which will result in the highest possible setting of Kp.

On a high inertia spindle, if the *Orient Speed* is set too high, the orient position loop gain (Kp), may have to be very low to prevent the drive from going into torque limit. This low Kp setting may lengthen the deceleration time, offsetting any reduction in the time spent searching for the *Orient Start* position achieved by using the high *Orient Speed* setting. Quicker orient performance may be obtained by reducing the *Orient Speed* setting and increasing the Kp value.

In a typical system, the orient position loop gain (Kp), should be between 5 and 20 radians/second. Lower gains are usually used with gearboxes and high inertia systems. Higher gains can be used with direct drive and low inertia systems.

Spindle orient tuning should be adjusted with the maximum expected load inertia connected to the system, if possible. If this is not possible, estimate the maximum expected load inertia versus the current value of load inertia. Reduce the maximum allowed peak torque during the spindle orient tuning by this ratio. For example, if the worst case load inertia would be about twice the system inertia during setup, adjust the Orient Speed and Orient Start parameters to require no more than one half the drive peak torque capability during setup.

Orient Tuning Procedure

o 1. Verify proper orient operation using the default values for *Orient Speed* and *Orient Start*.

o 2. Program *ANALOG OUTPUT – Output #1* for "± MOTOR RPM" and *ANALOG OUTPUT – Output #2* for "% TORQUE." Use an oscilloscope to monitor the % Torque during orient.

If the system can be tested with the maximum expected load inertia connected, the peak torque during decel should not exceed 95% of maximum capability (9.5 volts on Analog Output #2). If the system is being setup without a workpiece or tooling installed, the recommended maximum torque value is 40% of peak torque capability (4 volts output) for a lathe and 70% of peak torque capability (7 volts output) for a machining center. For systems with a completely known and repeatable load inertia and torque requirement, a small amount of torque limiting is acceptable and will usually shorten the time to decelerate to the target position.

o 3. Observe the peak torque required when using the default values of *Orient Speed* and *Orient Start*. Compare this observed peak torque with the desired peak torque defined above to determine the necessary adjustments to the *Orient Speed* and *Orient Start* settings. For example, if the observed peak torque was 25% of the target value, then potential actions are to:

- Increase *Orient Speed* setting from 60 to 240 rpm and *Orient Start* from 45 to 180 degrees (maintain Kp at 8 radians/second while raising *Orient Speed* a factor of 4), or
- Reduce *Orient Start* from 45 degrees to 11.25 degrees without changing *Orient Speed* setting (quadruple Kp from 8 to 32 radians/second with the same *Orient Speed*), or
- Increase *Orient Speed* setting from 60 to 120 rpm without changing *Orient Start* setting (double Kp to 16 radians/second and double the *Orient Speed*).

o 4. Adjust *Orient Speed* and *Orient Start* to give desired levels of peak torque during orient. Assure that the spindle does not overshoot target position by viewing actual spindle motion and observing ±MOTOR RPM and % TORQUE analog outputs with the oscilloscope. If position overshoot occurs, increase value of *Orient Start* to reduce Kp.

Appendix A

Parameter Record

Introduction

The following list can be used to record final parameter values for reference at a later date. It is recommended that any changes made to the parameter values be recorded.

Machine Designation ______________________________

Location ______________________________

Date ______________________________

Name ______________________________

General Information ______________________________

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Menu 1	Menu 2	Parameter	1 or 1L	1H	2 or 2L	2H	3 or 3L	3H	4
GEAR RANGES	**SET RATIOS**	Spindle Revs							
		Motor Revs							
MOTOR SELECT									
Catalog Num									
PARAMETER SET		**ELECT**							
CONFIG	Drive Cat Num								
		Motor Phasing							
		Cmnd Phase #1							
		Cmnd Phase #2							
		Enable Torque							
	SPINDL PRESET	Overspd Trip							
		Acc Rate #1							
		Acc Rate #2							
		Low Torq Lmt							
		At-Set-Speed							
		Speed Detect							
		Load Detect							

Menu 1	Menu 2	Parameter	1 or 1L	1H	2 or 2L	2H	3 or 3L	3H	4
DRIVE TUNING	**SPINDLE MODE**	Cmnd Source							
		Max Cmnd Spd							
		Spindl P Gain							
		Spindl I Gain							
		Speed Cal							
	ANALOG CAL	Zero Volt In							
		Max +Volt In							
	SERVO MODE	Analog In #							
		A/D Conv Type							
	ANALOG CAL	Zero Volt In							
		Max +Volt In							
	HI SPD RANGE	Max Cmnd Spd							
		Servo P Gain							
		Servo I Gain							
		Droop In Run							
		Droop In Hold							
		Speed Cal							
	LO SPD RANGE	Max Cmnd Spd							
		Servo P Gain							
		Servo I Gain							
		Droop In Run							
		Speed Cal							
	TORQUE MODE	Torque Enable							
		Max Speed							
	ANALOG CAL	Zero Volt In							
		Max +Volt In							
ORIENT SETUP	**FEEDBACK DEFN**								
Encoder Type									
		Encoder Lines							
		Encdr Phasing							
	ORIENT TUNE	Position Data							
		Preset Angle							
		Orient Speed							
		Orient Start							
		In-Position							
		Dir From Stop							
		Hold Psition							
ANALOG OUTPUT									
Output #1									
		Output #2							

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