Innovative Thinking for Power Control

OZip Motor Drive

User's Manual

UM-0057

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Oztek Corp. is a proven innovator of power, control, and instrumentation solutions for the most demanding industrial applications. Oztek products include variable motor drives, grid tie inverters, frequency converters, stand alone inverters, DC/DC converters, and DSP based control boards for power control applications.

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Table of Contents

Table of Figures

Table of Tables

1. Introduction

This document is intended to provide instruction on how to install, configure, startup, troubleshoot, and maintain an OZip Motor Drive. In order to provide for safe installation and operation of the equipment, please read the safety guidelines at the beginning of this manual and follow the procedures outlined before connecting power to the OZip IPM.

1.1 Referenced Documents

Ref.	Document	Description
[1]	UM-0055	OZip Intelligent Power Module Hardware User's Manual
[2]	FS-0046	OzCAN Protocol Function Specification
[3]	FS-0053	Modbus Communication Module Functional Specification
[4]	FS-0093	OZip Motor Drive OzCAN Message Profile
[5]	FS-0094	OZip Motor Drive Modbus Register Profile
[6]	UM-0052	Oztek Power Studio™ User's Manual

1.2 Definitions

CAN	Controller Area Network
CRC	Cyclical Redundancy Check
EEPROM	Electrically Erasable Programmable Read Only Memory
FOC	Field Oriented Control
GUI	Graphical User Interface
HMI	Human Machine Interface
H/W	Hardware
IGBT	Insulated Gate Bipolar Transisitor
IPM	Intelligent Power Module
NC	Not Connected
NOP	No Operation
NTC	Negative Temperature Coefficient
PCB	Printed Circuit Board
PI	Proportional and Integral Compensator
PID	Parameter Identifier
POR	Power On Reset
PMSM	Permanent Magnet Synchronous Machine
PWM	Pulse Width Modulation
RMA	Return Material Authorization
RMS	Root Mean Square
RPM	Revolutions per Minute

1.3 Safety Notices

The following safety notices are provided for your safety and as a means of preventing damage to the product or components in the application. Specific Dangers, Warnings, and Cautions that apply to particular activities are listed at the beginning of the relevant sections and are repeated or supplemented at critical points throughout these sections. Please read the information carefully, since it is provided for your personal safety and will also help prolong the service life of your OZip Motor Drive and the equipment you connect to it.

1.3.1 Definitions and Symbols

DANGER	***This symbol indicates high voltage. It calls your attention to items or operations that could be dangerous to you and other persons operating this equipment. Read the message and follow the instructions carefully.***
WARNING	**Indicates a potentially hazardous situation which, if not avoided, can result in serious injury or death.**
CAUTION	Indicates a potentially hazardous situation which, if not avoided, can result in minor to moderate injury, or serious damage to the product. The situation described in the CAUTION may, if not avoided, lead to serious results. Important safety measures are described in CAUTION (as well as WARNING).

1.3.2 Electrical Safety

DANGER

Power inverters, such as the OZip IPM, are typically connected to hazardous voltages. When servicing the OZip IPM, there may be exposed terminals at or above line potential, as well as residual charge in place for some time after the removal of the input source. Extreme care should be taken to protect against shock.

1. ***Before startup, observe the warnings and safety instructions provided throughout this manual. All power terminals should be considered to be at utility AC or high DC potential unless verified to be otherwise. These voltages are extremely dangerous and may cause death or severe injury if contacted.***
2. ***All power terminals should be considered live with the application of input voltage regardless of operating mode of the load.***
3. ***Do not make any connections when the OZip IPM is connected to its power source.***

4. ***Never work on the OZip IPM, power cables, or load when input power is applied.***

WARNING

1. **After disconnecting the input power, residual charge will remain on the OZip IPM absent any external load through which that charge can dissipate. It is the customer's responsibility to develop and implement a means at the application level to assure that charge is dissipated in a limited and controlled fashion for operator safety and product longevity.**
2. **Do not make any insulation or voltage withstand tests on the OZip IPM.**
3. **Always ensure by measuring with a multimeter that:**
   a. **There is no voltage between the AC terminals (A, B, & C) and the heatsink, considered chassis ground.**
   b. **There is no voltage between the DC terminals (+ & -), nor between either DC terminal and the heatsink, considered chassis ground.**

CAUTION

1. The OZip Intelligent Power Module operates on several electrical reference points, whether these be earth ground, communication ground, signal ground, etc. Proper system design with regard to equipotential bonding must be employed so that all simultaneously accessible conductive parts are electrically connected to prevent hazardous voltages appearing between them. This is accomplished by a proper factory grounding.
2. Ensure sufficient cooling for safe operation of the OZip IPM. Even so, power range capabilities will allow the power terminals and the heatsink of the OZip IPM to reach and maintain temperatures high enough to burn skin on contact. Allow adequate time for cooling before attempting to service the unit.
3. Remove any External Start signals before resetting system faults to prevent an unintentional restart of the OZip IPM, which could result in personal injury or equipment damage.
4. The OZip IPM is not field repairable. Never attempt to repair a malfunctioning unit; contact Oztek for a replacement.
5. Each IPM is sealed with a warranty void sticker across the top cover which will tear if the cover is removed. A torn warranty void sticker shall be interpreted as unauthorized access to the internal contents of the OZip IPM, in violation of warranty terms, thereby terminating any remaining warranty otherwise in effect.

2. Electrical Interface

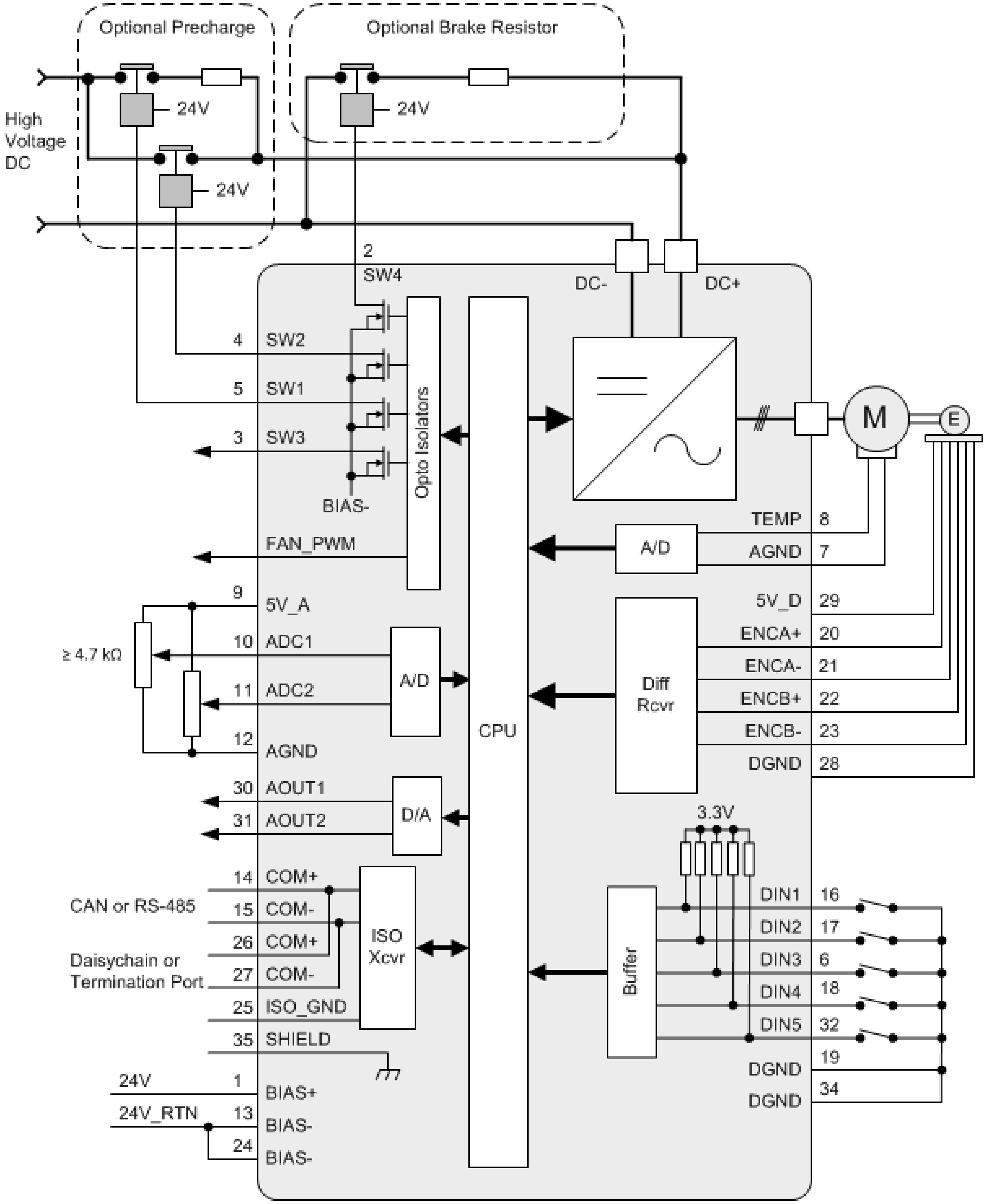
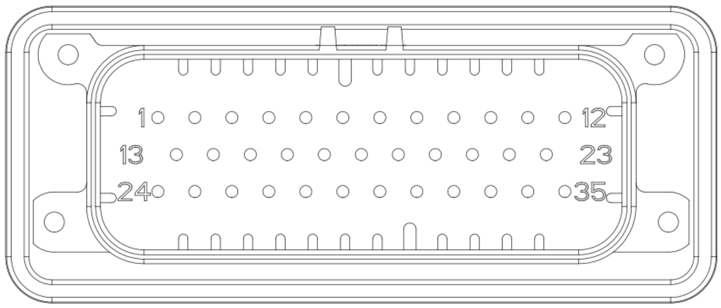


Figure 1 - OZip Motor Drive Block Diagram

2.1 Signal Wiring

Bias voltage and signal connections are made using a 35pin AMP Seal connector. Reference the OZip IPM Hardware User's Manual (UM-0055) for detailed interface specifications.



Pin	Signal	Description	Function
1	BIAS+	Input bias voltage	Power control & interface electronics
2	SW4	Low side inductive load driver	Brake contactor
3	SW3	Low side inductive load driver	Fault indication
4	SW2	Low side inductive load driver	Pre-charge contactor
5	SW1	Low side inductive load driver	Pre-charge bypass contactor
6	DIN3	Logic level digital input	Optional control interface input
7	AGND	Analog ground	Return for motor thermistor
8	TEMP	Thermistor temperature sensor	Motor thermistor input
9	5V_A	Analog 5V supply output	Voltage ref for potentiometer
10	ADC1	0-5V Analog input	Optional analog reference
11	ADC2	0-5V Analog input	Not used
12	AGND	Analog ground	Return for ADC1 input
13	BIAS-	Input bias voltage return	Return for bias voltage
14	COM+	Serial Interface "+" differential input.	CAN or RS-485 option
15	COM-	Serial Interface "-" differential input.	CAN or RS-485 option
16	DIN1	Logic level digital input	Optional control interface input
17	DIN2	Logic level digital input	Optional control interface input
18	DIN4	Logic level digital input	Optional control interface input
19	DGND	Digital ground	Return for DIGIN1-5
20	ENCA+	Encoder A "+" differential input	Motor shaft position feedback
21	ENCA-	Encoder A "-" differential input	Motor shaft position feedback
22	ENCB+	Encoder B "+" differential input	Motor shaft position feedback
23	ENCB-	Encoder B "-" differential input	Motor shaft position feedback
24	BIAS-	Input bias voltage return	Return for bias voltage
25	ISO_GND	Isolated serial port ground	Isolated communications
26	COM+	Serial Interface "+" differential input.	CAN or RS-485 option

27	COM-	Serial Interface "-" differential input.	CAN or RS-485 option
28	DGND	Digital ground	Encoder power return
29	5V_D	Digital 5V supply output	Encoder power
30	AOUT1	Analog output	Debug signal
31	AOUT2	Analog output	Debug signal
32	DIN5	Logic level digital input	Optional control interface input
33	FAN_PWM	Pulse Width Modulated output	Cooling fan control
34	DGND	Digital ground	Return for DIGIN1-5
35	SHIELD	Chassis ground connection for shield	Shield termination

2.2 Serial Communications

The OZip is available with either a CAN or RS-485 isolated serial interface. The CAN interface utilizes the OzCAN serial protocol whereas the RS-485 option utilizes Modbus. For detailed information on either of these protocols reference FS-0046 and FS-0053 respectively.

To allow for easy daisy chaining of multiple OZip motor drives or termination of the serial network, redundant serial interface pins have been provided. Figure 2 illustrates how to use the pins to daisy chain multiple OZip motor drives on a single multi-drop network (CAN or RS-485), as well as proper termination of the end nodes on the network. Termination resistors for CAN and RS-485 are typically **120Ω** and **100Ω**, respectively, based on typical cable impedances and drivers used for each.

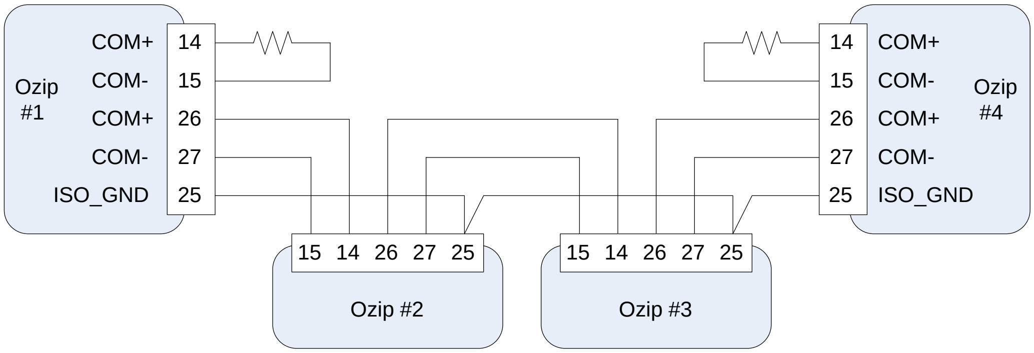


Figure 2 - Serial Interface Daisy Chain and Termination

3. Functional Description

The OZip motor drive can be used to provide speed or torque control for AC induction or permanent magnet motors by converting DC power to AC power as required by the application. The DC/AC inverter controls are bidirectional, being able to not only provide power to the motor, but also able to absorb power during regeneration. Typical OZip applications include:

- Renewable energy systems such as wind turbines.
- Flywheel energy storage systems.
- Traction motor drives for vehicle applications.
- Servo application for industrial controls.

Figure 3 illustrates a typical OZip based motor drive system. The diagram shows several optional interfaces including a high voltage DC Link pre-charge circuit, as well as a brake chopper module.

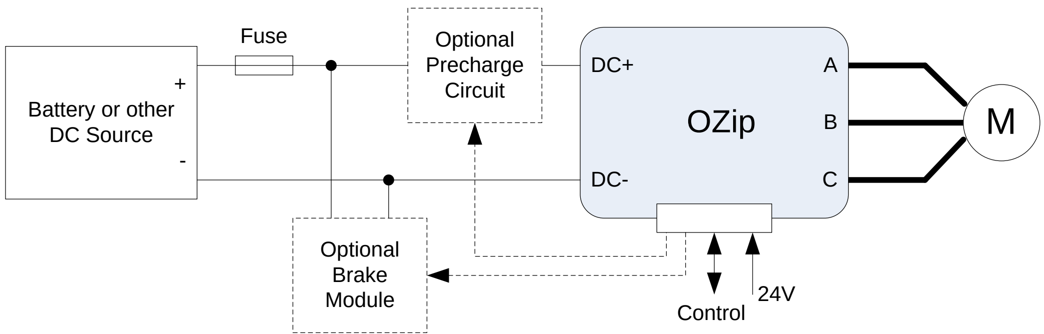


Figure 3 - Typical Drive Electrical System Schematic

3.1 Pre-Charge Circuit (Optional)

CAUTION

Failure to control the DC link inrush current to acceptable limits can cause catastrophic damage to the OZip and void the warranty.

The OZip contains significant internal capacitance on the high voltage DC link. When DC input power is applied to this capacitance, the step response of the voltage input will cause the capacitance to charge. The capacitor charging starts with an inrush current defined by $I = C(d\mathrm{V}/d\mathrm{T})$ and ends with an exponential decay down to the steady state condition. The peak inrush current will depend upon the capacitance C and the rate of change of the voltage $(d\mathrm{V}/d\mathrm{T})$.

If the system provides a means to limit the initial inrush current during power up to 10A or less, there is no need for additional pre-charge circuitry. If the inrush current is greater than 10A, a pre-charge circuit should be used to limit the inrush current.

The drive provides the ability to control a pre-charge circuit if ***PID 0x813A - DC Link Pre-charge Enable*** = 1. Figure 4 illustrates the typical pre-charge circuit. Refer to section *Pre-charge Parameters* 4.4.19 for details on configuring the pre-charge controller.

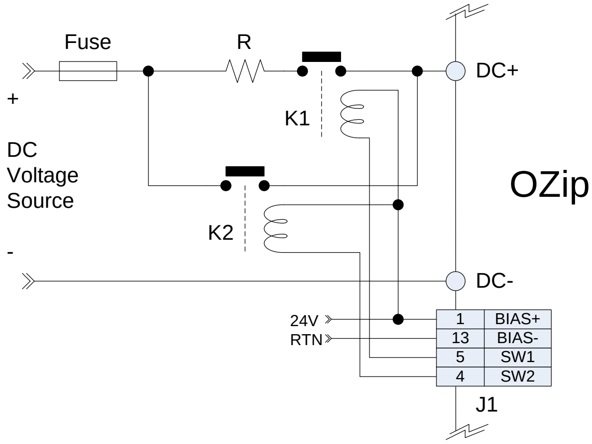


Figure 4 - DC Link Precharge Circuit

3.2 Dynamic Brake Control (Optional)

The optional Dynamic Brake controller can be used to switch in or out a brake resistor to dissipate power from the DC bus when operating with regenerative loads. When ***PID 0x8136 – Brake Controller Enable*** is TRUE, the Brake Control signal on pin SW4 is asserted whenever the DC bus voltage rises above ***PID 0x8137 – Brake Controller Voltage Threshold***. The SW4 output remains asserted until the DC bus voltage falls below ***PID 0x8138 – Brake Controller Recover Voltage Threshold***. The SW4 signal is intended to control an external switching device and power resistor, providing a basic hysteretic voltage control mode to bleed off excess energy from the DC bus and prevent it from rising to unsafe levels, as shown in Figure 5.

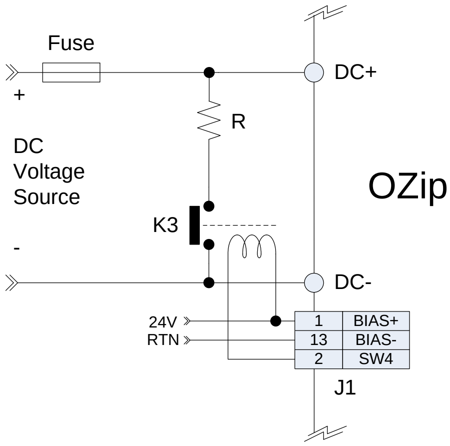


Figure 5 - Dynamic Brake Control Interface

3.3 Control Interface

The OZip can be controlled either through the serial interface (CAN or RS-485) or the hardware control inputs, Digital Inputs 1-5 and Analog Input 1. The desired interface is selected using ***PID 0x08048 - Control Interface***. Table 1 provides a summary of the available control interfaces and their associated hardware assignments.

Table 1 – Control Interface Hardware Assignments

Control Interface	AIN	D1	D2	D3	D4	D5
Serial Link	n/a	Fault Ilock	n/a	n/a	n/a	n/a
Analog - Unipolar	Setpt	Start/Stop	n/a	Fault Ilock	Flt Rst	Fwd/Rev
Analog - Bipolar	Setpt	Start/Stop	n/a	Fault Ilock	Flt Rst	n/a
Digital Potentiometer	n/a	Start/Stop	Ref Up	Ref Dwn	Flt Rst	Fwd/Rev
Binary Set Points A	n/a	Start/Stop	Bit 0	Bit 1	Flt Rst	Fwd/Rev
Binary Set Points B	n/a	Fault Ilock	Bit 0 + On	Bit 1 + On	Flt Rst	Fwd/Rev
Binary Set Points C	n/a	Bit 0 + On	Bit 1 + On	Bit 2 + On	Flt Rst	Fwd/Rev

3.3.1 Serial Interface Control

Figure 6 illustrates the hardware interface configuration when operating the OZip via the serial communications link. When operating the OZip via the serial interface, all control references etc. are provided over the serial communications link (either CAN or RS485). The h/w input DIN1 serves as a Fault Interlock input. This input must be tied to digital ground to enable the outputs. When operating in this mode the frequency reference is initialized to ***PID 0x0809E – Freq Ref Min*** and the direction is initialized to ***PID 0x0804A – POR Reset Direction.***

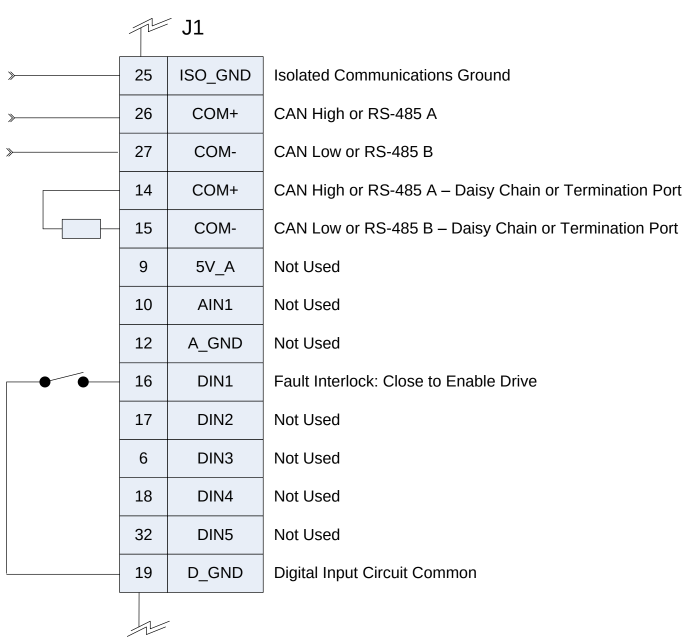


Figure 6 - Serial Interface Control H/W Interface

3.3.2 Unipolar Analog Control

The Unipolar Analog Control interface provides reference magnitude control using an analog potentiometer with a digital input used for direction; forward or reverse. In addition, Start/Stop, Fault Interlock, and Fault Reset functions are provided by digital inputs. Figure 7 illustrates the hardware interface configuration. In this mode the serial interface is not required for control purposes, although it can be used for configuration and/or instrumentation as desired. To enable this mode set ***PID 0x08048 - Control Interface*** = 1*.*

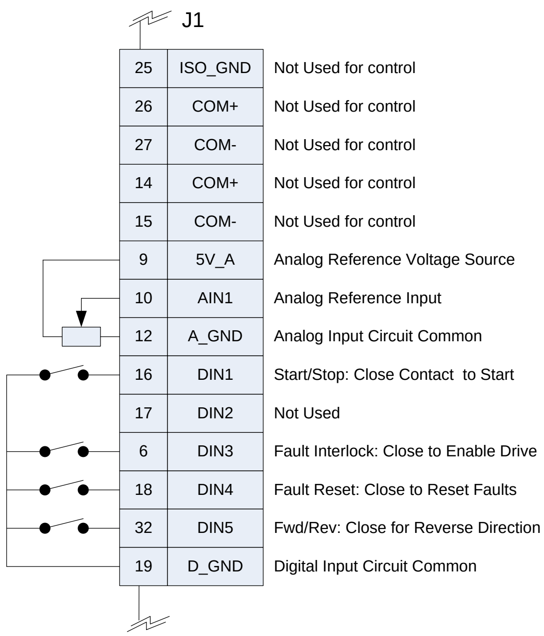


Figure 7 - Unipolar Analog Control H/W Interface

3.3.3 Bipolar Analog Control

The Bipolar Analog Control interface provides both reference magnitude and direction control using a single analog potentiometer. In addition, Start/Stop, Fault Interlock, and Fault Reset functions are provided by digital inputs. Figure 8 illustrates the hardware interface configuration. In this mode the serial interface is not required for control purposes, although it can be used for configuration and/or instrumentation as desired. To enable this mode set ***PID 0x08048 - Control Interface*** = 2*.*

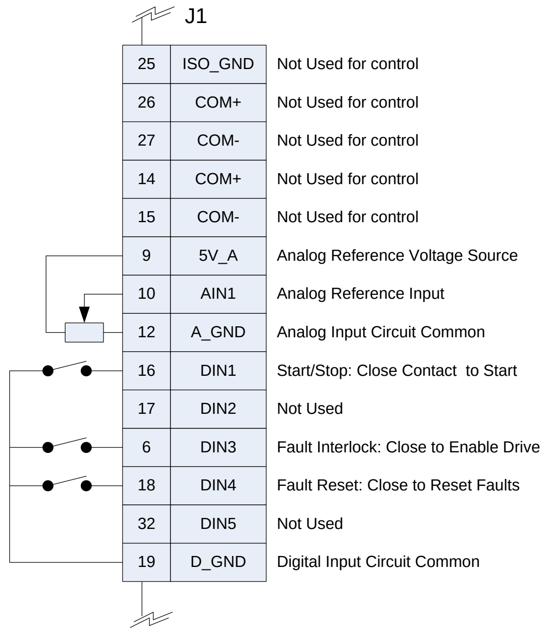


Figure 8 - Bipolar Analog Control H/W Interface

3.3.4 Digital Potentiometer Control

The Digital Potentiometer Control interface is intended for use when the drive is controlled using momentary push buttons. Digital Input 2 provides an “increase” reference function. While this input is connected to digital common, the internal reference is increased according to either the ***Speed Reference Slew Rate*** or the ***Frequency Reference Slew Rate,*** depending on the ***Control Mode*** setting.

Similarly, if Digital Input 3 is connected to digital common, the internal reference is decreased according to the slew rates described above. Note: the decrease function has priority. If both inputs are asserted (i.e. grounded) the reference is decreased according to the slew rates described above.

In addition, Start/Stop, Direction (Fwd/Rev), and Fault Reset functions are provided by digital inputs. Figure 9 illustrates the hardware interface configuration. In this mode the serial interface is not required for control purposes, although it can be used for configuration and/or instrumentation as desired. To enable this mode set ***PID 0x08048 - Control Interface*** = 3***.***

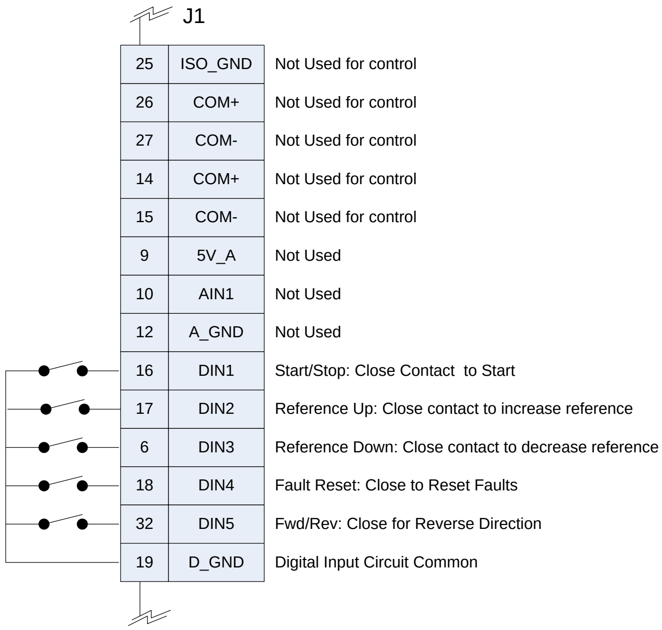


Figure 9 - Digital Potentiometer Control H/W Interface

3.3.5 Binary Setpoints (A) Control

The Binary Setpoints (A) Control interface allows operation at four fixed speeds, selectable using Digital Inputs 2 and 3 according to the following table:

Table 2 – Binary Setpoints (A) Decode

DIN3	***DIN2***	***Selected Reference***	***Reference PID***
Open	Open	Preset Freq(Spd) Reference 1	0x80A0(0x80BD)
Open	Closed	Preset Freq(Spd) Reference 2	0x80A1(0x80BE)
Closed	Open	Preset Freq(Spd) Reference 3	0x80A2(0x80BF)
Closed	Closed	Preset Freq(Spd) Reference 4	0x80A3(0x80C0)
Notes: (1) The selected reference depends on ***Control Mode*** setting.			

In addition, Start/Stop, Direction (Fwd/Rev), and Fault Reset functions are provided by digital inputs. Figure 10 illustrates the hardware interface configuration. In this mode the serial interface is not required for control purposes, although it can be used for configuration and/or instrumentation as desired. To enable this mode set ***PID 0x08048 - Control Interface*** = 4***.***

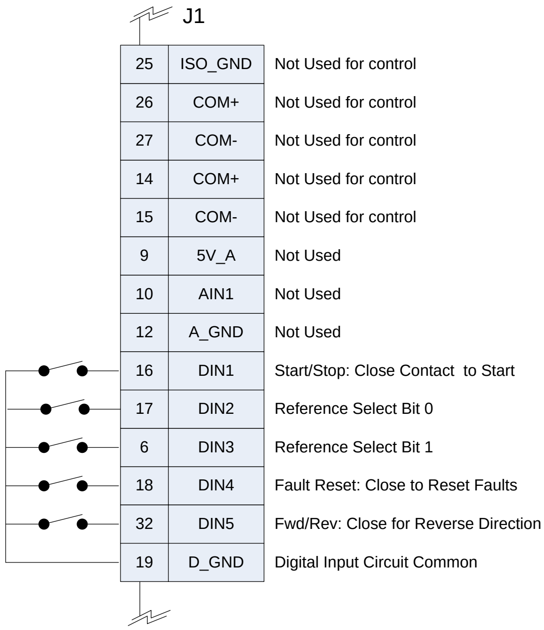


Figure 10 - Binary Setpoints (A) Control H/W Interface

3.3.6 Binary Setpoints (B) Control

The Binary Setpoints (B) Control interface is similar to the Binary (A) mode except that it replaces the Start/Stop function with a Fault Interlock function. As such, the start and stop function is controlled by the set point switches themselves; when either or both of the setpoint switches are closed, the corresponding reference is selected and the drive is started.

Table 3 – Binary Setpoints (B) Decode

DIN3	***DIN2***	***Selected Reference***	***Reference PID***
Open	Open	Drive Off	n/a
Open	Closed	Preset Freq(Spd) Reference 1 & Drive On	0x80A0(0x80BD)
Closed	Open	Preset Freq(Spd) Reference 2 & Drive On	0x80A1(0x80BE)
Closed	Closed	Preset Freq(Spd) Reference 3 & Drive On	0x80A2(0x80BF)
Notes: (1) The selected reference depends on ***Control Mode*** setting.			

In addition, Direction (Fwd/Rev) and Fault Reset functions are provided by digital inputs. Figure 11 illustrates the hardware interface configuration. In this mode the serial interface is not required for control purposes, although it can be used for configuration and/or instrumentation as desired. To enable this mode set ***PID 0x08048 - Control Interface*** = 5***.***

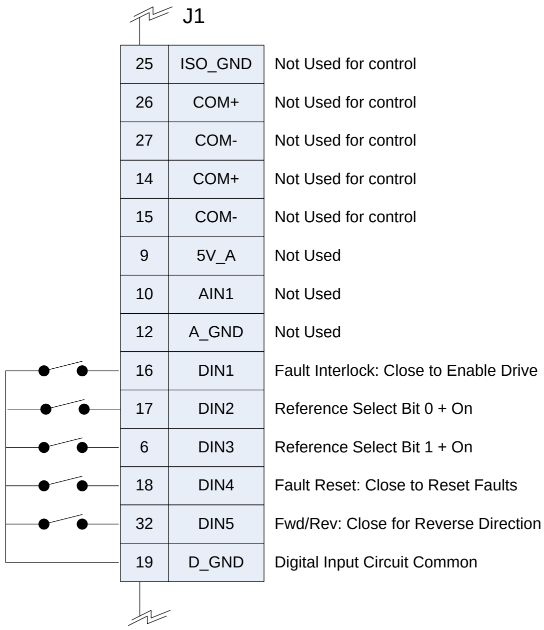


Figure 11 - Binary Setpoints (B) Control H/W Interface

3.3.7 Binary Setpoints (C) Control

The Binary Setpoints (C) Control interface allows operation at seven fixed speeds, selectable using Digital Inputs 1, 2 and 3 according to the following table. The start and stop function is controlled by the set point switches themselves; when any or all of the setpoint switches are closed, the corresponding reference is selected and the drive is started.

Table 4 – Binary Setpoints (C) Decode

DIN3	***DIN2***	***DIN1***	***Selected Reference***	***Reference PID***
Open	Open	Open	Drive Off	n/a
Open	Open	Closed	Preset Freq(Spd) Reference 1 & Drive On	0x80A0(0x80BD)
Open	Closed	Open	Preset Freq(Spd) Reference 2 & Drive On	0x80A1(0x80BE)
Open	Closed	Closed	Preset Freq(Spd) Reference 3 & Drive On	0x80A2(0x80BF)
Closed	Open	Open	Preset Freq(Spd) Reference 4 & Drive On	0x80A3(0x80C0)
Closed	Open	Closed	Preset Freq(Spd) Reference 5 & Drive On	0x80A4(0x80C1)
Closed	Closed	Open	Preset Freq(Spd) Reference 6 & Drive On	0x80A5(0x80C2)
Closed	Closed	Closed	Preset Freq(Spd) Reference 7 & Drive On	0x80A6(0x80C3)
Notes: (1) The selected reference depends on ***Control Mode*** setting.				

In addition, Direction (Fwd/Rev) and Fault Reset functions are provided by digital inputs. Figure 12 illustrates the hardware interface configuration. In this mode the serial interface is not required for control purposes, although it can be used for configuration and/or instrumentation as desired. To enable this mode set ***PID 0x08048 - Control Interface*** = 6***.***

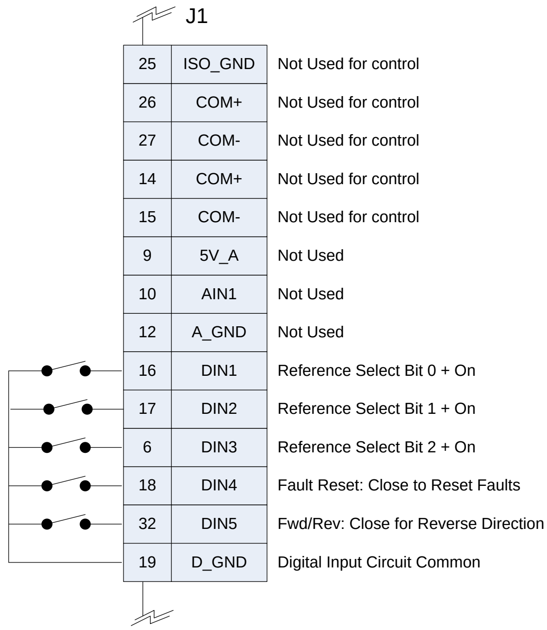


Figure 12 - Binary Setpoints (C) Control H/W Interface

3.4 Volts/Hertz Control Mode

Figure 13 illustrates the basic V/Hz block diagram. Volts/Hertz control mode is intended for AC induction motor applications that do not require the advanced control and performance of the closed-loop field oriented current controller. In addition to using the general motor parameters specified in ***PIDs 0x8064 – 0x8068***, this controller is configured using V/Hz-specific parameters in ***PIDs 0x8091 – 0x8095***. These parameters are used to determine the desired relationship between the applied line-to-line RMS voltage and the electrical frequency. More specifically, the controller can be configured to operate with one of three different V/Hz profiles: Linear, Squared, or Custom (***PID 0x8091 – V/Hz Control Type***).

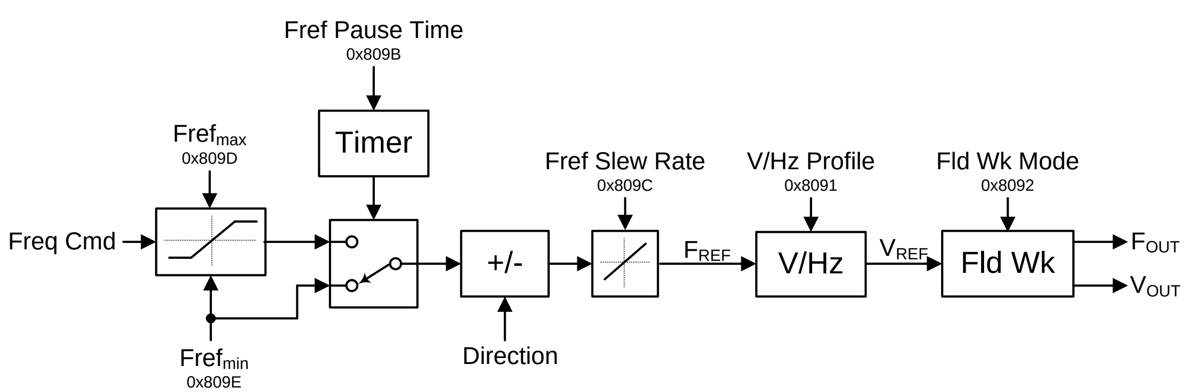


Figure 13 - V/Hz Control Block Diagram

The drive provides minimum and maximum clamps on user frequency commands (***PIDs 0x809D, 0x809E***). Commands outside of these limits are clamped to these limits. The commands are then slew rate limited based on ***PID 0x809C – Freq Ref Slew Rate***.

When starting, the drive will output the ***Frequency Ref Minimum*** (***PID 0x809E***). This "starting" frequency will be held for the ***Freq Ref Startup Pause Time (PID 0x809B)***, before slewing to the commanded frequency.

3.4.1 Linear Volts/Hertz Profile

The linear Volts/Hertz profile is the default setting and should be used unless there is a special application need for another mode. With a linear profile the voltage applied to the motor changes linearly with the frequency reference and is ideal for constant torque applications. The ratio is set by ***PID 0x8065 Motor Rated Voltage*** and ***PID 0x8066 – Motor Rated Frequency***, as illustrated in Figure 14.

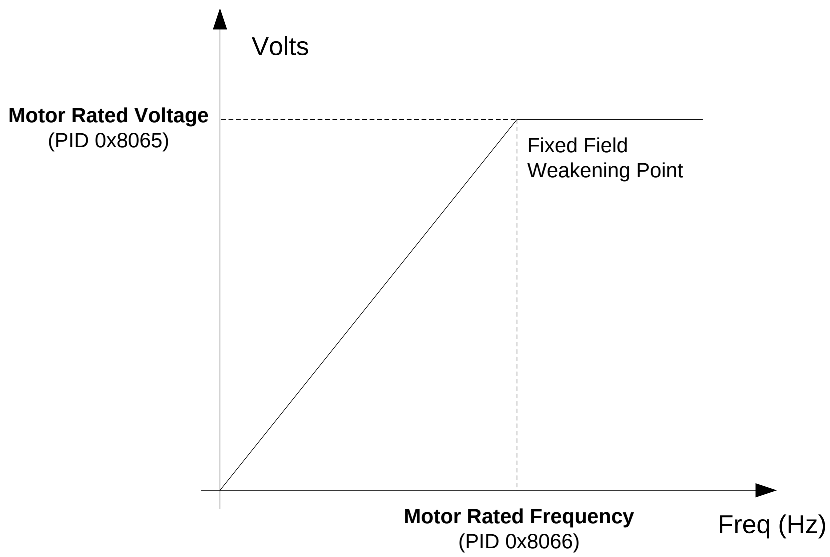


Figure 14 - Linear V/Hz Profile

3.4.2 Squared Volts/Hertz Profile

With a squared Volts/Hertz profile the voltage applied to the motor follows a squared function of frequency. The motor runs under magnetized below the field weakening point, producing less torque and electromechanical noise. This profile can be useful in fan and pump applications where the torque demand of the load is proportional to the square of the speed. The ratio is configured using ***PID 0x8065 Motor Rated Voltage*** and ***PID 0x8066 – Motor Rated Frequency***, as illustrated in Figure 15.

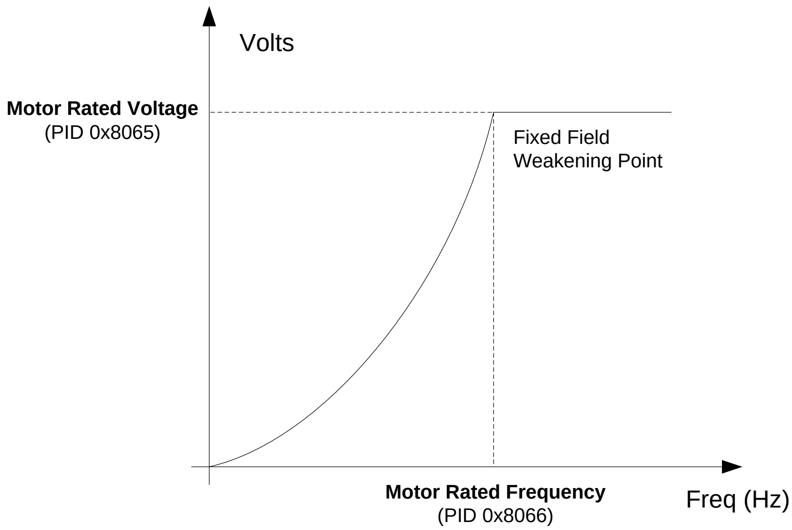


Figure 15 - Squared V/Hz Profile

3.4.3 Custom Volts/Hertz Profile

The custom Volts/Hertz profile is a two-slope profile programmed with three points. It can be particularly useful in applications that require higher starting torque by boosting the applied voltage in the lower frequency range.

For low speed operation, the drive provides a "voltage boost" feature to avoid stalling the motor. This feature allows the user to modify the low speed portion of the Volts/Hertz curve based on two additional parameters. First, the voltage at zero hertz can be specified (***PID 0x8095)*** to be a value greater than zero volts, typically 1.3% of rated voltage. An "inflection point" is then specified by ***PID 0x8093 and 0x8094***, typically 5Hz and 10% of the rated voltage, as illustrated in Figure 16.

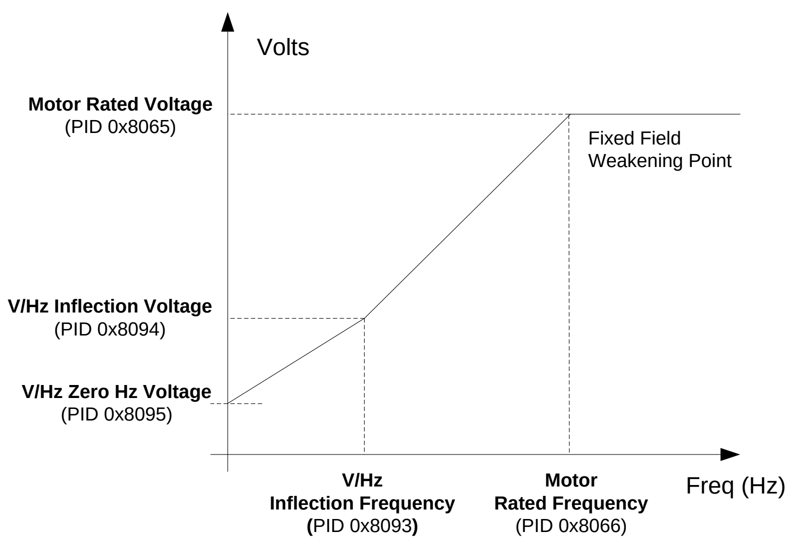


Figure 16 - Custom V/Hz Profile

3.4.4 V/Hz Field Weakening and Frequency Foldback

The controller provides three different types of field weakening behavior when commanded above the rated frequency: Fixed, Variable, and None. In Fixed mode the controller will output the rated motor voltage (***PID 0x8065***) for all frequency commands greater than the motor rated frequency (***PID 0x8066***).

In Variable mode the controller will continue to follow the configured V/Hz profile for frequency commands greater than the motor rated frequency (***PID 0x8066***) until the output voltage exceeds the DC Link capability. The output voltage is then limited by the available DC Link voltage while the frequency is allowed to increase.

When the field weakening mode is set to "None", frequency foldback is implemented to protect the motor. In this scenario the drive will never allow the configured V/Hz profile to be violated. If the output voltage required by the V/Hz profile isn't achievable, due to inadequate DC Link voltage, the drive will output the maximum achievable voltage and back calculate the resulting output frequency according to the V/Hz profile.

3.4.5 Skip Frequencies

In some applications, it may be necessary to avoid operation at certain frequencies due to mechanical resonance issues in the system. The drive provides the ability to configure three separate "skip" frequencies along with an adjustable range (+/- hysteresis) around each, as illustrated in Figure 17. Refer to ***PIDs 0x80AF-0x80B2*** for configuration details.

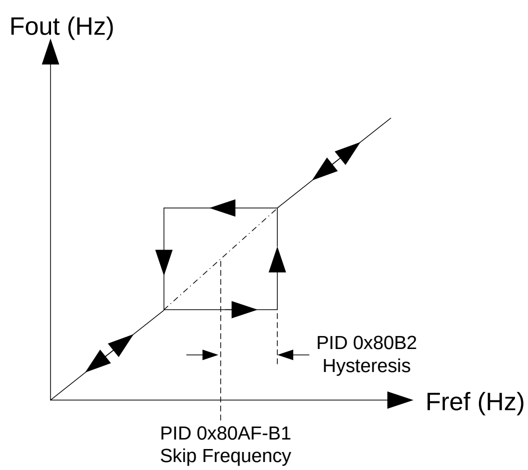


Figure 17 - Skip Frequency Operation

3.5 Field-Oriented Control Mode (Future Feature)

Closed-loop, field-oriented control mode provides both speed and direct torque control options. Figure 18 presents a simplified block diagram of the field-oriented control scheme employed in the motor drive firmware. PI regulators are used to control both the torque (I_q) and field (I_d) current components using current feedback calculated from the three phase current measurements ($I_{fb\ a,b,c}$) from the inverter. The current regulators are implemented in the synchronous DQ reference frame.

When operating in direct torque control mode, the torque producing current (I_q) is calculated from the torque command provided by the user. In closed-loop speed control mode, the output of the speed control PI regulator serves as the torque current command for the inner current controller.

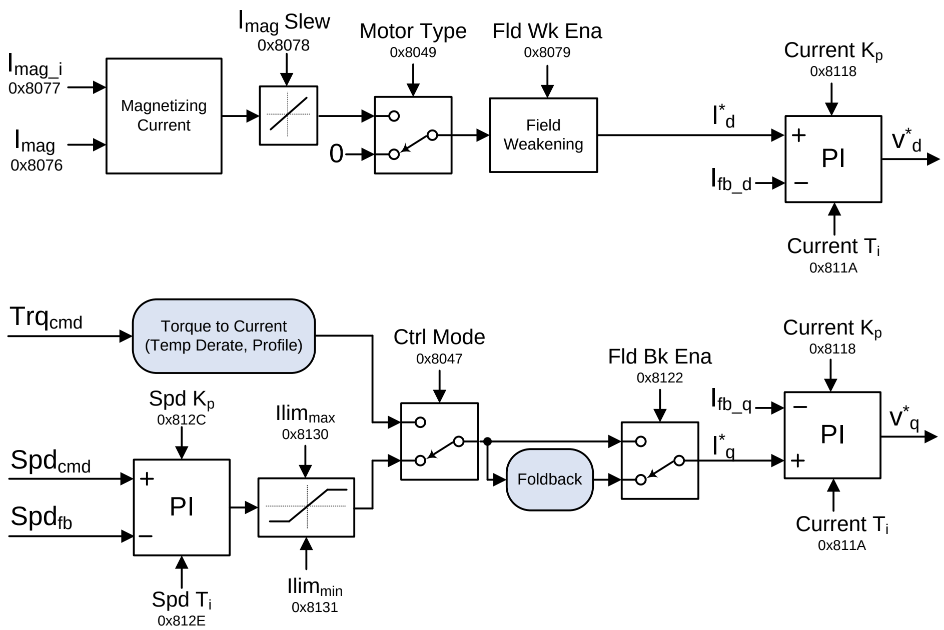


Figure 18 - FOC Controller Functional Block Diagram

The field current (I_d) reference depends on which type of motor has been selected (see ***Motor Type***, ***PID 0x8049***). For AC induction motors, the field current is set to the specified magnetizing current (***PID 0x8076***). An optional field weakening controller may be enabled (***PID 0x8079***) to reduce the magnetizing current based on the available DC link voltage and motor speed. When initially turning on the drive, the magnetizing current may optionally be increased (***PID 0x8077***) to reduce the time it takes to develop the corresponding magnetic field in the rotor. This may be useful in applications that want to be able to turn on quickly but are using motors with large rotor time constants.

The generation of the electrical angle also depends on the specified motor type. For AC induction motor applications, the relative changes in position from the feedback device are used to calculate the mechanical speed of the motor. This speed is used in conjunction with a "slip estimator" block to determine the desired electrical speed from which the desired electrical angle is derived. The "slip estimator" requires accurate motor parameters to be specified for the induction motor (***PIDs 0x806E – 0x8074***).

For permanent magnet motor applications, the electrical angle must be synchronous with the rotating field from the rotor. In this case, knowledge of the rotor position and field is necessary. When configured to operate with a quadrature encoder, the drive supports an "automatic alignment" procedure at startup. Using this procedure, the controller specifies a DC alignment current (***PID 0x8084***) and duration (***0x8085***) for which it is applied to the motor at startup. Once the specified time has passed, it is assumed that the rotor has rotated into alignment with the applied current, and the drive stores the necessary position offset required to then operate the drive.

For proper alignment operation, it is required that the rotor be able to move freely. If enabled, this process is only executed the first time the drive is enabled following a power on reset of the controller. Thereafter, the controller will use the stored position offset for subsequent "turn on" events.

3.5.1 Temperature Based Torque Derating (Future Feature)

To prevent the inverter and/or motor from overheating and causing an over-temperature fault shutdown, the drive provides a mechanism to limit the available torque at high temperatures. Two separately enabled and configurable thermal derating blocks exist: one based on inverter temperature and one based on motor temperature.

A low and a high temperature threshold define the temperature range in which to limit the user's torque command. When the temperature is below the low threshold, the user torque command is not affected by thermal derating. When the temperature is between the low and high thresholds, the user torque command is multiplied by a derating factor that is calculated as follows:

$$DerateFactor = 1 - \left(\frac{(T_{meas} - T_{low})}{(T_{high} - T_{low})} \cdot (1 - Derate_{\min}) \right)$$

The minimum derating value ($Derate_{min}$) is configurable and it determines how much the drive is allowed to reduce the torque command. Above the high threshold, the derating factor will be set to this minimum value. If derating is enabled based on both inverter temperature *and* motor temperature, the derating factor is configured and calculated separately for each. The lower of the two derating factors is then chosen to reduce the user torque command. For example:

Inverter Motor Derate$_{min}$ = 10%
Inverter low threshold = 90 °C
Inverter high threshold = 100 °C
Inverter measured temp = 94 °C
Inverter Derating factor = 0.64

Motor Derate$_{min}$ = 10%
Motor low threshold = 85 °C
Motor high threshold = 105 °C
Motor measured temp = 91 °C
Motor Derating factor = 0.73

User command = 50% of Torque$_{max}$

Derated user command = 50% * 0.64 = 32%

A warning flag is reported to indicate when the user torque command is being reduced due to thermal derating.

This feature is only available when operating the drive in direct torque control mode. When operating in Volts/Hertz mode or closed-loop speed control mode, the thermal derating controller is not used.

3.5.2 Maximum Torque Profile (Future Feature)

The maximum available motor torque and power is affected by the present value of the DC Link and the operating motor speed. For systems with fixed/regulated DC links, the maximum torque and power curves will be deterministic. However, for systems in which the DC Link is allowed to vary (such as with battery-based systems), the maximum torque and power will vary as the DC link varies. Depending on the motor application, it may be undesirable to make the user be aware of this fluctuation in torque or power. For example, in a vehicle application it may be desirable to limit the allowable torque/power based on the minimum expected DC link voltage. In doing so, the operator (i.e. driver) will not notice these fluctuations in available torque due to DC link voltage variations even when they maintain a constant position with the accelerator pedal.

To facilitate the ability to restrict the maximum torque as a function of speed, the controller provides a configurable maximum torque profile feature. This feature is enabled using the ***PID 0x80D9 - Torque Profile Enable*** configuration parameter. The profile consists of three speed regions as follows:

- **Region 1** (Torque Limit) – This is the low speed region of the profile, and it starts at 0 RPM. In this region, the torque command will be limited to the value specified by ***PID 0x80DA - Torque Profile Maximum Torque***. Any commands from the user that exceed this value will be ignored and this value will be used instead.

- **Region 2** (Power Limit) – This is the mid speed region. In this region, the motor power is limited to the value specified by ***PID 0x80DB - Torque Profile Maximum Power***. The speed at which this region begins can be calculated based on the fact that motor power equals torque times speed. Therefore, the speed at which the motor will reach this maximum power threshold can be calculated as the specified maximum power divided by the specified maximum torque. This speed (ω_{base}) will be in units of radians/second when using units of Watts for power and Nm for torque.

When the user commands a torque that would result in a motor power that exceeds the specified maximum power, the controller will automatically limit the torque so that the resulting power is clamped to the maximum value.

- **Region 3** (Power*Speed Limit) – This is the high speed region. This region begins at the motor speed specified by ***PID 0x80DC - Torque Profile Constant Power*Speed Region Start***. This speed value is used along with the specified maximum power to calculate a maximum "Power*Speed" value. As the motor speed increases, the controller will calculate the power * speed value and compare it to the maximum value specified. If the maximum is exceeded, the torque will then be reduced such that the power is reduced to maintain the maximum "Power*Speed" value.

Figure 19 shows a pictorial summary view of the three regions created by the torque profile. Note that the ω_{cps} represents the speed at which Region 3 starts, as specified by parameter ***PID 0x80DC***.

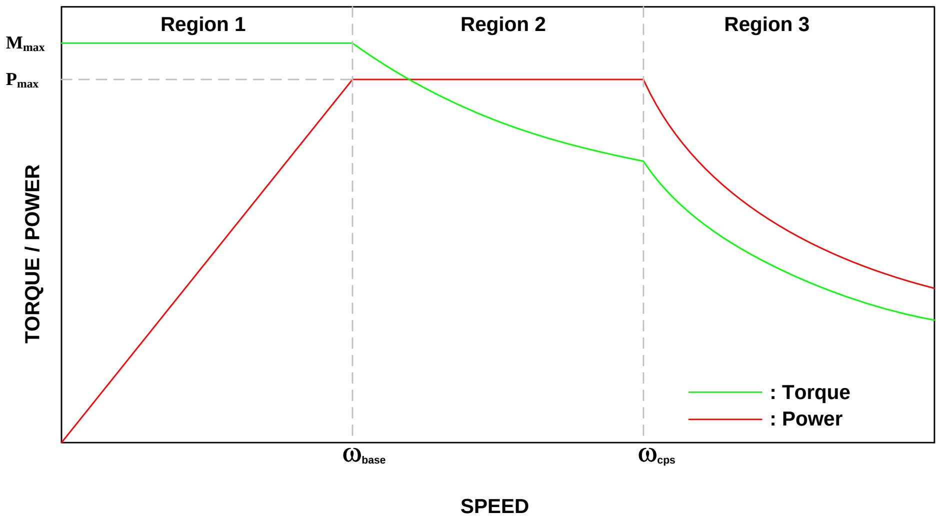


Figure 19 - Torque and Power in the Three Speed Regions

This torque profile feature is only available when operating the drive in direct torque control mode. When operating in Volts/Hertz mode or closed-loop speed control mode, the torque profile is not used.

3.5.3 Current Fold Back (Future Feature)

For protection purposes, the drive supports a current fold back feature for the torque (I_q) current command in the event that the applied stator voltage gets too close to the maximum achievable level dictated by the DC link voltage. The ***I_q Current Foldback Modulation Index***

Threshold (***PID 0x8123***) defines the maximum modulation index (percent of applied voltage relative to the DC link voltage), above which the current will be reduced.

For most applications the system should be designed such that the DC link voltage provides ample voltage headroom to achieve the desired speed and torque from the motor. In this case the fold back controller is not required and can be disabled (***PID 0x8122***). Otherwise, for systems with minimal voltage headroom the fold back controller may be employed to prevent losing current regulation and potentially faulting off the drive.

To limit the torque producing current (I_q), a simple PI regulator is used to decrease the current in order to maintain an applied voltage below the specified modulation index. The output of the PI regulator is a "limit factor", a value between 0 and 1.0 that is multiplied with the desired current command. When the DC link voltage is high enough to produce the desired torque without exceeding the specified modulation index, the current will not be reduced (the compensator output will be 1.0). If the DC link were to drop, causing the modulation index to increase to the specified limit, the commanded current will be linearly reduced based on the compensator output. When this condition occurs, a warning flag is asserted that indicates to the user that the current is presently being limited by this controller.

This feature is only available when operating the drive in closed-loop field-oriented control (i.e. not Volts/Hertz mode). This feature is mainly targeted at applications that are running in direct torque control mode, where the torque command is simply reduced. This feature may also be enabled and used when the drive is operated in closed-loop speed control mode. However, if the fold back feature is engaged, the speed loop will no longer be in regulation and the resulting motor speed will change based on the load conditions.

3.5.4 Skip Speeds (Future Feature)

In some applications, it may be necessary to avoid operation at certain speeds due to mechanical resonance issues in the system. The drive provides the ability to configure three separate "skip" speeds along with an adjustable range (+/- hysteresis) around each, as illustrated in Figure 20. Refer to ***PIDs 0x80CD-0x80D0*** for configuration details.

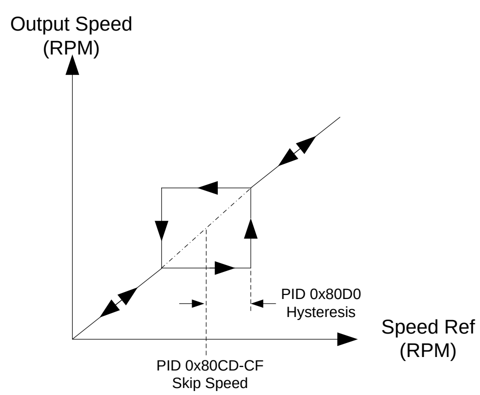


Figure 20 - Skip Speed Operation

3.6 External Temperature Sensor

The OZip hardware provides a motor temperature sensing circuit designed to interface with a standard thermistor style temperature sensor, i.e. negative temperature coefficient, variable resistance device. This interface is optional and can be enabled or disabled using ***PID 0x80E8 - Motor Temperature Sensor Enable***. When enabled, this temperature input may be monitored by reading ***PID 0x400D – Motor Temperature***. It may also be configured to generate a high temperature warning and/or an over-temperature fault shutdown event if desired (see section 4.4.14 for details).

Given the non-linear resistance versus temperature behavior of thermistor devices, the inverter's internal hardware circuit has been designed to provide as linear a response as possible over a nominal temperature range of -40°C to +125°C for typical NTC thermistors in the range of 1kΩ to 10kΩ with beta constants between 3500K and 3900K.

3.7 State Sequencing

A state machine is used to provide deterministic control and sequencing of the motor drive states. If a fault is detected in any of the operating states, the inverter is immediately disabled, and the state machine is latched into the FAULT state. Figure 21 illustrates the operating states as well as the transition logic employed in the controller's state machine.

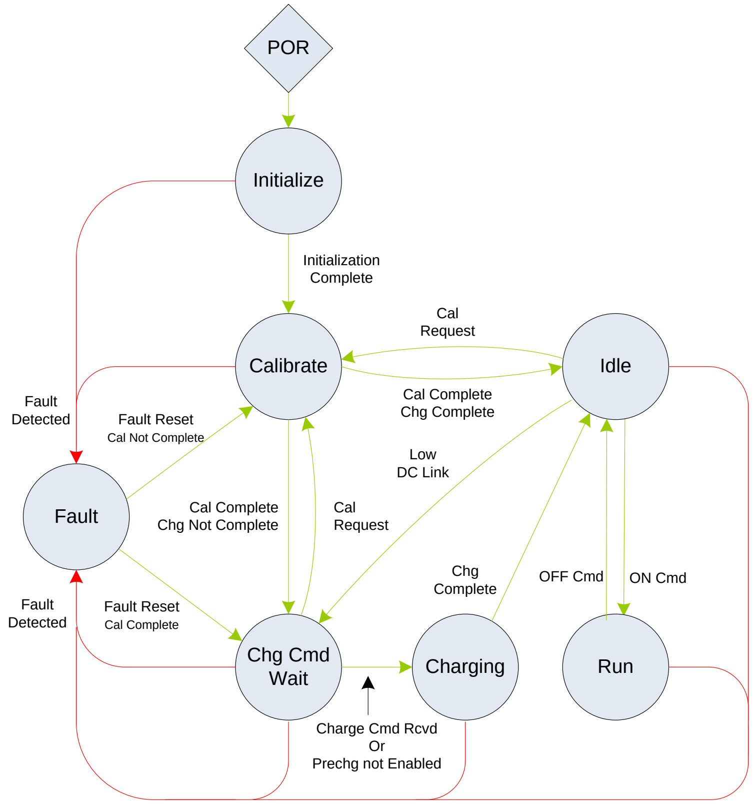


Figure 21 - Controller State Machine

3.7.1 Initialize

The state machine resets to the *Initialize* state following a power-on-reset (POR) event. While in this state the power hardware is not operable; the firmware is initializing hardware peripherals, configuring variables, and performing self-health tests. Upon successful initialization the state machine will auto-transition to the *Calibrate* state.

3.7.2 Calibrate

The *Calibrate* state is used to calibrate system hardware as applicable. Power hardware is not operable while in the *Calibrate* state. Following successful calibration, the state machine will auto-transition to either the *Idle* or *Charge Cmd Wait* state, depending on the DC Link state of charge.

3.7.3 Charge Cmd Wait

If ***PID 0x80B0 - DC Link Pre-charge Enable*** is TRUE, the drive will remain in this state until it receives a command to begin charging the DC Link, at which point it will transition to the *Charging* state. If ***DC Link Pre-charge Enable*** is False, it is assumed the user is responsible for charging the DC Link and the drive will auto transition to the *Charging* state.

3.7.4 Charging

In the *Charging* state, the drive waits for the DC Link to reach ***PID 0x80B1 - Pre-charge DC Link Connect Voltage***, after which the pre-charge circuit is disabled and the drive transitions to the *Idle* state.

3.7.5 Idle

Once in the *Idle* state the controller is ready for use. The state machine will remain in the *Idle* state indefinitely, transitioning either due to a fault condition (*Fault* State), a turn-on command (*Run* State), or a Calibrate command (*Calibrate* State).

3.7.6 Run

While in the *Run* state the motor drive is enabled and processing either frequency, speed or toque commands from the user. The state machine will remain in the *Run* state indefinitely, transitioning either on a fault or a turn-off command. When a turn-off command is received, the state machine will immediately disable the inverter and go to the *Idle* state.

3.7.7 Fault

The *Fault* state indicates that a latched fault condition has occurred and that the drive is inoperable. The various fault conditions are reported in ***PID 0x4010 - Fault Status*** and also reported on the CAN bus in the Alarm Status CAN message. The SW3 output is set when in the Fault state as well.

The controller remains in the *Fault* state and the latched fault flags remain set until explicitly reset with a ***Fault Reset*** command (***PID 0x0007***), or a h/w fault clear input. This is true even if the source(s) of the fault(s) is(are) no longer active. Upon receiving the ***Fault Reset*** command, the firmware will attempt to clear all latched fault bits. It then examines the sources of all fault conditions and if any sources of faults are still active, their respective fault flags are latched again, and the controller will remain in the *Fault* state. Otherwise, if no faults remain active, the controller will transition either back to the *Calibrate* state if a calibration request is pending, or back to the *Charge Cmd Wait* state if calibration is complete.

3.8 Fault and Warning Conditions

The drive provides warning indicators and fault protection in the event of conditions that may cause damage to the equipment or injure personnel. The various conditions that are monitored by the controller are listed and described in the following sections.

3.8.1 Warnings

The drive provides the warning indicators listed below. These warning conditions do not prohibit operation of the drive; they are merely reported for informational purposes only. Each warning condition described below is reported in ***PID 0x400F - Warning Status*** and also reported on the CAN bus in the Alarm Status CAN message.

3.8.1.1 High Inverter Temperature

The firmware will monitor the inverter temperature and will set a warning flag if it exceeds 110°C. The flag will remain set until the temperature falls below 105°C

3.8.1.2 High PCB Temperature

The firmware will monitor the internal OZip ambient temperature and will set a warning flag if it exceeds 85°C. The flag will remain set until the temperature falls below 80°C

3.8.1.3 High Motor Current

The firmware monitors the RMS inverter current going to the motor and will set a flag if it exceeds ***PID 0x802B - Motor Over Current Warning Threshold***. Once above this warning threshold, the current must drop below this value minus the value in ***PID 0x8033 – Motor Over Current Warning Recover Delta*** before the inverter will clear the warning.

3.8.1.4 High Motor Temperature

If ***PID 0x80EA - Motor Temp Enable*** is TRUE, the firmware will monitor the motor's temperature sensor and set a warning flag if the temperature exceeds ***PID 0x8028 - Motor Temperature Warning Threshold***. Once above this warning threshold, the temperature must drop below this value minus the value in ***PID 0x8032 – Motor Temperature Warning Recover Delta*** before the inverter will clear the warning.

3.8.1.5 High Motor Speed

The firmware monitors the motor's speed and will set a warning flag if the speed exceeds ***PID 0x802D - Motor Over Speed Warning Threshold***. Once above this warning threshold, the speed must drop below this value minus the value in ***PID 0x8034 – Motor Over Speed Warning Recover Delta*** before the inverter will clear the warning.

3.8.1.6 Clamped Torque Command

If ***PID 0x80D9 -Torque Profile Enable*** is set to TRUE and the user attempts to operate the drive in torque control mode with a torque command above the maximum allowed by the profile, the firmware will limit the applied torque to the maximum value from the profile. When this is the case, the motor drive will set this flag to indicate that the requested torque command is not being used and that a lower torque is actually being commanded. This warning flag is automatically cleared when the motor torque returns to being controlled to the requested torque value from the user.

3.8.1.7 Motor Torque Reduced Due to Thermal Derating

If the controller has been configured to enable thermal derating from either a high motor temperature (***PID 0x80F1***) or a high inverter temperature (***PID 0x80E6***), the firmware will reduce the user torque command applied to the motor when the corresponding temperature is too high. When this occurs, the controller will set this warning flag to indicate to the upper-level controller that the requested torque command is not being used and that a lower torque is actually being commanded due to thermal derating. The warning flag will be cleared when no thermal derating is being performed (i.e. the temperature(s) is(are) below their minimum derating values).

3.8.1.8 I_q Current Foldback

If ***PID 0x80122 - I_q Current Foldback Enable*** is TRUE, the firmware will reduce the I_q current if the voltage applied to the motor gets too close to the full utilization of the DC Link voltage (i.e. a high modulation index). When this is the case, the motor drive will set this bit to indicate that the current is actively being reduced. This warning flag is automatically cleared when the current is no longer being clamped.

3.8.1.9 High DC Link Voltage

The firmware monitors the DC link voltage and will set a warning flag if it exceeds ***PID 0x802F - DC Link Over Voltage Warning Threshold***. Once above this warning threshold, the voltage must drop below this value minus the value in ***PID 0x8035 – DC Link Over Voltage Warning Recover Delta*** before the inverter will clear the warning.

3.8.1.10 Skip Zone

This bit is set if the drive's frequency or speed command falls inside one of the pre-configured skip zones. This bit is automatically cleared when the frequency or speed transitions out of the configured skip zone. See sections 4.4.10 and 4.4.12.

3.8.1.11 Local Bias Supply Tolerance Warnings

The firmware monitors the internal 15 and 5V bias supplies and will set a warning flag if the corresponding supply voltage is not within the range required by the on-board hardware. These flags will remain set while the supply voltages are out of tolerance and will be cleared when each supply is within the required limits.

3.8.2 Faults

The drive provides the fault protection listed below. Whenever a fault occurs the firmware will automatically turn the inverter OFF and transition to the FAULT state. Each fault condition is latched and reported in ***PID 0x4010 - Fault Status*** and also on the CAN bus in the Alarm Status CAN message.

The controller remains in the FAULT state and the latched fault flags remain set until explicitly reset with a ***Fault Reset*** command (***PID 0x0007***) or a h/w fault clear input. This is true even if the source(s) of the fault(s) are no longer active. Upon receiving the ***Fault Reset*** command, the firmware will attempt to clear all latched fault bits. It then examines the sources of all fault conditions and if any sources of faults are still active, their respective fault flags are latched again and the controller will remain in the *Fault* state. Otherwise, if no faults remain active, the controller will transition either back to the *Calibrate* state if a calibration request is pending, or back to the *Charge Cmd Wait* state if calibration is complete.

3.8.2.1 IGBT De-Saturation & Drive Faults

The firmware provides a means to recognize hardware-based IGBT de-saturation and Drive Fault signals from the gate driver modules.

3.8.2.2 DC Link Hardware Over-Voltage

The firmware provides a means to recognize hardware-based DC Link Over Voltage faults.

3.8.2.3 Inverter Over Temperature

The firmware will monitor the inverter temperature and will assert a fault if it exceeds 115°C.

3.8.2.4 PCB Over Temperature

The firmware will monitor the internal OZip ambient temperature and assert a fault if it exceeds 90°C.

3.8.2.5 Motor Over Current

The firmware monitors the RMS motor current and asserts a fault if it exceeds ***PID 0x802A - Motor Over Current Fault Threshold***.

3.8.2.6 Motor Over Temperature

If ***PID 0x80EA - Motor Temp Enable*** is TRUE, the firmware will monitor the motor’s temperature sensor and assert a fault if the temperature exceeds ***PID 0x8028 - Motor Temperature Fault Threshold***.

3.8.2.7 Motor Over Speed

The firmware monitors the motor's speed and will assert a fault if the speed exceeds ***PID 0x802C - Motor Over Speed Fault Threshold***.

3.8.2.8 Motor Align Error

This fault is used to indicate when the drive is configured to operate as a permanent magnet motor drive and the user attempted to turn on when the motor was spinning faster than the allowable maximum align speed (***PID 0x8086***).

3.8.2.9 Pre-Charge Timeout

A pre-charge timeout fault is asserted if the DC Link does not reach ***PID 0x80B1 – Pre-charge DC Link Connect Voltage*** within the ***PID 0x80B4 – Precharge Timeout Threshold***.

3.8.2.10 DC Link Over-Voltage

The firmware monitors the DC link voltage and will assert a fault if it exceeds ***PID 0x802E - DC Link Over-Voltage Fault Threshold***.

3.8.2.11 Configuration EEPROM Error

This fault occurs any time a read from the drive's on-board configuration memory (EEPROM) is performed and the CRC for the block of data being read does not match the CRC that is stored in the memory. Unlike all other fault sources, this fault condition is not clearable with ***PID 0x0007 – Fault Reset*** or the fault reset hardware pin because this fault condition indicates the possibility that the drive's configuration parameters may be corrupted. If this fault occurs, the user may try cycling the power to the control board. If this error remains, the user may try reloading their configuration parameters using the Power Studio™ tool (see section 5). If the error persists after attempting both of these actions, there may be an issue with the drive's control board hardware. If this should occur, contact Oztek for further diagnostic tips or to determine if the unit should be returned using the RMA process described at the end of this document.

3.8.2.12 Calibration Error

This error is asserted if the controller is unable to perform any required internal calibrations. There is likely an issue with the drive hardware if this error occurs, in which case the user should contact Oztek for further diagnostic tips or to determine if the unit should be returned using the RMA process described at the end of this document.

3.8.2.13 Communications Timeout

If ***PID 0x8017 - CAN Timeout*** is set to a non-zero value, the firmware will monitor the amount of time elapsed between received CAN messages. A fault will be asserted if the specified timeout threshold is exceeded.

3.8.2.14 Hardware Interlock

This fault is asserted anytime the hardware interlock input is asserted.

3.8.2.15 Configuration Error

Configuration errors can occur if configuration registers have been programmed with in-compatible settings. For instance an "Illegal Control Mode" error can occur if the user sets ***PID 0x8049 – Motor Type*** to PMSM and attempts to operate in V/Hz mode by setting ***PID 0x8047 – Control Mode*** = 0.

4. Parameter Register Interface

The motor drive is controlled, monitored, and configured via a parameter register set. This register set can be accessed through several different interfaces including RS-485 and CAN bus serial communication links, depending on the model of the OZip power module being used. There are three types of registers implemented in the drive:

- **Command Registers** – Writes to these registers will command the drive to perform a specific action, such as turning on/off or changing an operational set point, such as speed, torque, etc.
- **Instrumentation Registers** – These read-only registers are used to return various measurements and status information from the drive.
- **Configuration Registers** – These are non-volatile registers that are used to configure the various operational modes and settings for the drive. In general, writes to these registers will take effect immediately and will also be stored in non-volatile memory so their values will be retained when power is removed from the drive.

4.1 Register Properties

4.1.1 Parameter ID

The Parameter ID (PID) listed in the tables below represents a numerical identifier for each parameter.

4.1.2 Data Types

Parameters are specified as either 16-bit or 32-bit quantities and may be signed or unsigned entities. The tables below indicate this information using the following abbreviations for the *Data Type*:

- U16 – Parameter is an unsigned 16-bit value.
- U32 – Parameter is an unsigned 32-bit value.
- S16 – Parameter is a signed 16-bit value.
- S32 – Parameter is a signed 32-bit value.

Parameters that are specified as Boolean are stored as unsigned 16-bit values – a value of all zeros indicates FALSE and any non-zero value indicates TRUE.

4.1.3 Access Level

The access level for each register is defined as follows:

- **W** (writeable) – the parameter is writable by the user.
- **R** (readable) – the parameter is readable by the user.
- **O** (operating) – the parameter may be written while the drive is enabled, writes to any parameter without this indicator will be ignored if the drive is enabled.

Note that any registers with a colored background are not currently implemented and will be released in a future revision.

4.2 Command Registers

Table 5 – Command Register Set

PID	Data Type	Description	Units	Min	Max	Access Level
0x0001	U16	On/Off Control	ENUM	0	1	RWO
0x0002	S16	Reference – Percent	0.1%	-1000	1000	RWO
0x0003	U16	Reference – Frequency	0.1 Hz	0	5000	RWO
0x0004	U16	Reference – Speed	RPM	0	30000	RWO
0x0005	U16	Direction	ENUM	0	1	RWO
0x0006	U16	Charge Command	ENUM	0	1	RW
0x0007	U16	Fault Reset	ENUM	0	1	RW

PID 0x0001 On/Off Control

This register is used to turn the motor drive ON or OFF as follows:

0 – OFF: This turns the drive OFF.
1 – ON: This turns the drive ON.

Note that ***PID 0x8048 – Control Interface*** must be set to 0 (Serial Interface) for this command to work. For settings other than 0, dedicated h/w pins are used for control. Reference section 3.3 for additional information.

PID 0x0002 Reference - Percent

This register is used to adjust the control reference in any of the three operating modes by commanding a percentage of the full-scale configuration value. The following table provides the full-scale references that correspond to each of the operating modes. Note that in V/Hz or FOC Speed mode the command is internally limited to 0-100% and the direction command (PID 0x0005) is used to determine "sign". In FOC Torque mode, the direction command is ignored and the full -100-100% range is used.

Mode	*Full Scale Reference*
Open-loop AC Induction Volts/Hertz Control	PID 0x809D - Freq Ref Max
Closed-loop Field Oriented Speed Control	PID 0x80BA - Speed Ref Max
Closed-loop Field Oriented Torque Control	100%

PID 0x0003 Reference - Frequency

This register can be used to set the frequency reference when operating in Open-loop AC Induction Volts/Hertz mode. It allows a command in units of Hz as opposed to percent.

PID 0x0004 Reference - Speed

This register can be used to set the speed reference when operating in Closed-loop Field Oriented Speed mode. It allows a command in units of RPM as opposed to percent.

PID 0x0005 Direction

This register can be used to control the direction of rotation as follows:

0 – FWD
1 – REV

Note that ***PID 0x8048 – Control Interface*** must be set to 0 (Serial Interface) for this command to work. For settings other than 0, dedicated h/w pins are used for control. Reference section 3.3 for additional information.

PID 0x0006 Charge Command

If pre-charge has been enabled, ***PID 0x80B0 - DC Link Pre-charge Enable*** = TRUE, writing a "1" to this register will begin the pre-charge process. See section 3.1 for detailed information.

PID 0x0007 Fault Reset

This register is used to reset any latched fault. Any faults that still exists will remain latched after this command is executed. Legal registers values are as follows:

0 – NOP: No reset action requested
1 – RESET: Attempt to reset all fault conditions

4.3 Instrumentation Registers

Table 6 – Instrumentation Register Set

PID	Data Type	Description	Units	Access Level
0x4000	U16	Operating State	ENUM	R
0x4001	U16	Control Mode	ENUM	R
0x4002	U16	Motor Speed	RPM	R
0x4003	U16	Motor Power	10 W	R
0x4004	U16	Motor Current	0.1 A_{rms}	R
0x4005	U16	Motor Frequency	0.1 Hz	R

PID	Data Type	Description	Units	Access Level
0x4006	U16	Motor Voltage	0.1 V	R
0x4007	U16	Control Status	ENUM	R
0x4008	U16	Brake State	ENUM	R
0x4009	U16	Inverter A Temperature	°C	R
0x400A	U16	Inverter B Temperature	°C	R
0x400B	U16	Inverter C Temperature	°C	R
0x400C	U16	PCB Temperature	°C	R
0x400D	U16	Motor Temperature	°C	R
0x400E	U16	DC Link Voltage	0.1 V	R
0x400F	U32	Warning Status	ENUM	R
0x4010	U32	Fault Status	ENUM	R
0x4011	U16	Configuration Error	ENUM	R
0x4012	U16	Frequency Reference	0.1 Hz	R
0x4013	U16	Id Reference	0.1 A_{rms}	R
0x4014	U16	Iq Reference	0.1 A_{rms}	R
0x4015	U16	Motor State	ENUM	R
0x4016	U16	Nominal Slip	0.1 Hz	R
0x4017	U16	Register Operation Status	ENUM	R
0x4018	U16	Application Software Revision – Major	Integer	R
0x4019	U16	Application Software Revision – Minor	Integer	R
0x401A	U16	Bootloader Revision – Major	Integer	R
0x401B	U16	Bootloader Revision – Minor	Integer	R

PID 0x4001 Operating State

The present operating state is reported as shown below. See section 3.7 for details on each of these operating states.

Value	State
0	Initializing
1	Calibrating
2	Charge Cmd Wait
3	Charge
4	Idle
5	Run
6	Fault
7-255	***Unknown: Reserved for future use***

PID 0x4002 Control Mode

The present control mode is reported as follows:

Value	State
0	Open-loop AC Induction Volts/Hertz Controller
1	Closed-loop Field Oriented Speed Control
2	Closed-loop Field Oriented Torque Control
3-255	***Reserved for future use***

PID 0x4003 Motor Speed

This register reports the present motor speed.

PID 0x4004 Motor Power

This register reports the estimated motor power.

PID 0x4005 Motor Current

This register reports the measured RMS motor current.

PID 0x4006 Motor Frequency

This register reports the inverter output frequency.

PID 0x4007 Motor Voltage

This register reports the inverter output voltage.

PID 0x4008 Control Status

Controller status bits are reported as shown in the table below.

Bit	Status	Description
0	Ready	This bit is set if the Operating state = “Idle” or “Run”
1	Run/Stop	This bit is set if the Operating state = “Run”
2	Direction	This bit reflects the current direction, 0=FWD, 1=REV
3	Faulted	This bit is set if the Operating state = “Fault”
4	Warning	This bit is set if one or more warnings are asserted
5	V/Hz Field Weakening	This bit is set if the drive is operating in the Field Weakening region
6	V/Hz Saturated	This bit is set if the V/Hz output voltage is saturated
7-31	***Reserved for future use***	

PID 0x4009 Brake State

The present state of the brake is reported as follows:

Value	State
0	Disabled
1	Off
2	On
3-255	***Reserved for future use***

PID 0x4009-400C Inverter Temperature A, B, C, PCB

These registers report the measured inverter temperatures and PCB temperature.

PID 0x400D Motor Temperature

This register reports the measured motor temperature if a sensor has been enabled in the ***Motor Temp Enable*** configuration parameter (***PID 0x80EA***). This register will return zero when a temperature sensor is not enabled.

PID 0x400E DC Link Voltage

This register reports the measured voltage on the DC link.

PID 0x400F Warning Status

Warning bits are active when set to ‘1’, and not present when set to ‘0’. See section 3.8 for details on each warning. The warning bits are mapped into the register as follows.

Bit	Warning
0	Phase A High Temperature
1	Phase B High Temperature
2	Phase C High Temperature
3	PCB High Temperature
4	Motor High Current
5	Motor High Temperature
6	Motor High Speed
7	Torque Limited to Maximum
8	Reserved
9	Torque Limited by High Temp
10	Iq Current Foldback
11	Reserved
12	DC Link High Voltage
13	Skip Zone
14-29	Reserved
30	15V Supply Out of Tolerance
31	5V Supply Out of Tolerance

PID 0x4010 Fault Status

Fault bits are active when set to a ‘1’ and not present when set to a ‘0’. If a fault occurs, the corresponding bit is set to a ‘1’ and remains set until a “1” is written to the ***Fault Reset*** command register (***PID 0x0007***), or a h/w fault clear input. When a fault occurs, the controller will go to the FAULT state and the drive will stop operating. The controller will stay in the FAULT state until the ***Fault Reset*** command is received. See section 3.8 for details on each fault condition. The fault bits are mapped as follows:

Bit	Fault
0	Phase A H/W Desat
1	Phase B H/W Desat
2	Phase C H/W Desat
3	Phase A H/W Drive Fault
4	Phase B H/W Drive Fault
5	Phase C H/W Drive Fault
6	H/W DC Link Over Voltage
7	Phase A S/W Over Temp
8	Phase B S/W Over Temp
9	Phase C S/W Over Temp
10	PCB S/W Over Temp
11	Motor Over Current
12	Motor Over Temp

Bit	Fault
13	Motor Over Speed
14	Motor Align Error
15	Reserved
16	Charge Timeout
17	S/W DC Link Over Voltage
18	EEPROM Error
19	Calibration Error
20	Communications Timeout
21	H/W Interlock
22	Configuration Error
23-31	Reserved

PID 0x4011 Configuration Error

This register provides and enumerated description of an existing configuration fault:

Value	Error	Description
0	No Error	
1	Illegal Control Mode	***PID 0x8049 – Motor Type*** = 1 (PMSM) and ***PID 0x8047 – Control Mode*** = 0 (V/Hz).
2	Illegal Position Feedback	***PID 0x804A – Motor Speed Fdbk Device Select*** = 0 (None) and ***PID 0x8047 – Control Mode*** = 1 or 2 (FOC Modes).
3-15	Reserved	

PID 0x4012 Frequency Reference

This register reports the current frequency reference.

PID 0x4013 Id Reference

This register reports the current Id reference.

PID 0x4014 Iq Reference

This register reports the current Iq reference.

PID 0x4015 Motor State

This register reports the present state of the motor:

Value	State
0	Idle
1	Magnetizing
2	Aligning
3	Running
4-15	Reserved

PID 0x4016 Nominal Slip

This register reports the present estimated slip for an AC induction motor.

PID 0x4017 Register Operation Status

This register is updated after every parameter read or write operation and indicates whether the operation was completed successfully. The status is reported as follows:

Value	State
0	Operation completed successfully
1	Error – Illegal/unsupported Parameter ID was supplied by the user
2	Error – A write was attempted to a Read-Only Parameter
3	Error – A read was attempted from a Write-Only Parameter
4	Error – User-provided data is not within legal range
5	Error – Configuration Memory Hardware Error
6	Error – Configuration Memory CRC Mismatch
7	Error – Invalid password provided for operation
8	Error – Operation not allowed when the drive is "ON"
9-255	*Unknown: Reserved for future use*

PID 0x4018-19 Application Software Revision – Major/Minor

These registers report the major and minor revisions of the application software.

PID 0x401A-1B Bootloader Software Revision – Major/Minor

These registers report the major and minor revisions of the bootloader software.

4.4 Non-Volatile Configuration Registers

These registers are used to configure the various operational modes and settings for the drive. Unless stated otherwise, writes to these registers will take effect immediately. Additionally, these register values are stored in local non-volatile EEPROM so that their values are retained between power cycles.

CAUTION

EEPROM devices have limited write cycle capability. While they can handle 1 million write cycles, care should be taken not to continuously write to Configuration Registers. Poorly designed HMI and master controller applications that needlessly update configuration registers in a continuous fashion serve no purpose and will result in premature EEPROM failure.

CAUTION

When performing firmware updates, the software *may* automatically reset the values of the configuration registers and the associated contents of the EEPROM to their factory default values. This will occur if the configuration memory map for the newly installed firmware is not compatible with the previously programmed version of the firmware. The firmware determines this condition at power up by reading ***PID 0x8000 – Factory Configuration***

Revision - Major. If the major revision value stored in the EEPROM does not match the default major revision for that particular build of the firmware, then the previous configuration memory map is considered incompatible and will be automatically reset to the new factory defaults.
The user must take care when updating the firmware to understand whether or not the configuration memory will be reset and to save a copy of any custom settings prior to performing the firmware update.

The configuration registers presented below have been organized by functional groups. Within each functional group, the registers have been separated into two categories: *Basic* and *Advanced*. As the names suggest, *Basic* configuration registers are those that are used to configure the drive for common applications that do not require any special setup or tuning; *Advanced* registers are provided for more experienced users who may wish to modify the basic behavior or system tuning of the various drive controls.

Note that any registers with a colored background are not currently implemented and will be released in a future revision.

4.4.1 Configuration Control Parameters

Table 7 – Basic Configuration Control Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x8000	U16	Factory Revision - Major	Integer	1	0	0xFFFF	R
0x8001	U16	Factory Revision - Minor	Integer	0	0	0xFFFF	R
0x8002	U16	User Configuration Data Revision	Integer	0	0	0xFFFF	RWO

PID 0x8001 Factory Configuration Revision – Major

This is a read-only value that represents the major revision of the factory default configuration stored in memory. Major revision changes to the default factory configuration are those that are not compatible with previous configurations, such as when new parameters are added to the memory that are required for proper drive operation, or if existing parameters change locations or formats. At startup the firmware will read this value from the memory and compare it against the factory default for the present build of the firmware. If the two values do not match, the firmware will automatically reset the memory to the factory default values built into that version of the firmware. Updates to the major factory revision value are expected to increment the previous value by +1.

PID 0x8002 Factory Configuration Revision – Minor

This is a read-only value that represents the minor revision of the default factory configuration stored in memory. Minor revisions are those that do not require reloading the memory to the factory default values. This could be a result of a minor value change to the default value for a particular parameter or the addition of a new parameter that is not needed for proper drive operation. Updates to the minor factory revision value are expected to increment the previous value by +1.

PID 0x8003 User Configuration Revision

This is a generic parameter that is provided to allow the user or a higher-level controller to maintain revision information for custom settings to the configuration memory. The firmware does not use this value. The protocol for numbering and maintaining custom configurations is left up to the user.

4.4.2 Modbus Parameters

The following set of parameters are provided to allow for customizing the Modbus interface for the end-user's application. Refer to the OZip hardware manual to determine which models support the RS-485 Modbus interface. For more information regarding Oztek's implementation of the Modbus serial protocol, see reference document FS-0053. All the parameter registers implemented in the inverter firmware are accessible through the Modbus interface. For a list of specific Modbus register addresses, reference document FS-0094.

Table 8 – Basic Modbus Interface Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x800D	U16	Modbus Device Address	Integer	1	1	247	RWO
0x800E	U16	Modbus Baud Rate	ENUM	2	0	5	RWO

PID 0x800D Modbus Device Address

This parameter defines the device address for Modbus messaging.

PID 0x800E Modbus Baud Rate

This parameter is used to configure the serial baud rate for the Modbus interface. The legal values are as follows:

- 0 = 2400 bps
- 1 = 4800 bps
- 2 = 19200 bps
- 3 = 38400 bps
- 4 = 57600 bps
- 5 = 115200 bps

Table 9 – Advanced Modbus Interface Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x800F	U16	Modbus Parity	ENUM	0	0	2	RWO ①

① These registers may be written at any time, but they will not take effect until the inverter is power cycled

PID 0x800F Modbus Parity

This parameter is used to configure the parity for the Modbus interface. The legal values are as follows:

- 0 = None
- 1 = Odd
- 2 = Even

4.4.3 CAN Interface Parameters

The following set of parameters are provided to allow for customizing the CAN interface for the end-user's application. Refer to the OZip hardware manual to determine which models support the CAN interface. For more information regarding the Oztek OzCAN protocol, see reference document FS-0046. For details on the specific CAN messages implemented in the inverter firmware, see reference document FS-0093.

Table 10 – CAN Interface Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x8014	U16	CAN Group ID	Integer	3	1	15	RWO ①
0x8015	U16	CAN Module ID	Integer	1	1	31	RWO ①
0x8016	U16	CAN Baud Rate	ENUM	250kbps	50kbps	1Mbps	RWO ①
0x8017	U16	CAN Timeout	1 ms	0	0	65535	RWO ①

① These registers may be written at any time, but they will not take effect until the inverter is power cycled

PID 0x8014 CAN Group ID

This parameter specifies the Group ID used by the firmware. For more information see FS-0047.

PID 0x8015 CAN Module ID

This parameter specifies the Module ID used by the firmware. For more information see FS-0047.

PID 0x8016 CAN Baud Rate

This parameter is used to configure the serial baud rate for the CAN interface. The legal values are as follows:

- 0 = 1 Mbps
- 1 = 500 kbps
- 2 = 250 kbps

- 3 = 125 kbps
- 4 = 100 kbps
- 5 = 50 kbps

PID 0x8017 CAN Timeout

This parameter specifies the timeout period to use when checking for CAN communications errors. This value specifies the timeout period in terms of milliseconds. Setting this parameter to zero disables checking for CAN communications timeouts. When CAN timeout checking is enabled (parameter is set to a legal non-zero value), a timeout counter is used to time the period of inactivity on the CAN bus. This timer is reset upon the receipt of any of the valid receive messages supported by this application.

Table 11 – Advanced CAN Interface Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x8018	U16	CAN Status Destination Group ID	Integer	1	0	15	RWO ①
0x8019	U16	CAN Status Destination Module ID	Integer	1	0	31	RWO ①
0x801A	U16	CAN Automatic Alarm Transmit Enable	Boolean	FALSE	FALSE	TRUE	RWO
0x801B	U16	CAN Update Rate – Motor Status	1 ms	0	0	65535	RWO
0x801C	U16	CAN Update Rate – Drive Status	1 ms	0	0	65535	RWO
0x801D	U16	CAN Update Rate – System Status	1 ms	0	0	65535	RWO
0x801E	U16	CAN Update Rate – Alarm Status	1 ms	0	0	65535	RWO

① These registers may be written at any time, but they will not take effect until the inverter is power cycled

PID 0x8018 CAN Status Destination Group ID

This parameter specifies the Destination Group ID that this firmware will use when sending the Status messages. Note that the Illegal CAN Message and Configuration Response messages use the Group/Module information from the sending device as the Destination Group/Module when responding, so this parameter is not used for those messages. For more information see FS-0047.

PID 0x8019 CAN Status Destination Module ID

This parameter specifies the Destination Module ID that this firmware will use when sending the Status messages. Note that the Illegal CAN Message and Configuration Response messages use the Group/Module information from the sending device as the Destination Group/Module when responding, so this parameter is not used for those messages. For more information see FS-0047.

PID 0x801A CAN Automatic Alarm Transmit Enable

This is a Boolean parameter that is used to enable automatic transmission of the Alarm Status message upon a change of value of any warning or fault bit. Note that when enabled (parameter is set to *true*), the checks for whether an automatic transmission should be sent occur on 1ms boundaries, so there may be up to 1ms of latency between when the offending event occurs and when the Alarm message is sent. When disabled (parameter is set to *false*), a change in any warning or fault bit does not cause an automatic transmission of the Alarm Status message.

PID 0x801B CAN Update Rate – Motor Status Message

This parameter specifies the rate at which the Motor Status CAN message will be automatically transmitted by the firmware. This value specifies the period between message transmissions in terms of milliseconds. Setting this parameter to zero disables automatic/periodic transmission of this message. All other values (1ms – 65,535ms) are valid.

PID 0x801C CAN Update Rate – Drive Status Message

This parameter specifies the rate at which the Drive Status CAN message will be automatically transmitted by the firmware. This value specifies the period between message transmissions in terms of milliseconds. Setting this parameter to zero disables automatic/periodic transmission of this message. All other values (1ms – 65,535ms) are valid.

PID 0x801D CAN Update Rate – System Status Message

This parameter specifies the rate at which the System Status CAN message will be automatically transmitted by the firmware. This value specifies the period between message transmissions in terms of milliseconds. Setting this parameter to zero disables automatic/periodic transmission of this message. All other values (1ms – 65,535ms) are valid.

PID 0x801E CAN Update Rate - Alarm Status Message

This parameter specifies the rate at which Alarm Status CAN message will be automatically transmitted by the firmware. This value specifies the period between message transmissions in terms of milliseconds. Setting this parameter to zero disables automatic/periodic transmission of this message. All other values (1ms – 65,535ms) are valid.

4.4.4 Fault and Warning Parameters

Table 12 – Basic Fault and Warning Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x8028	U16	Motor Temperature Fault Threshold	°C	115	0	150	RW
0x8029	U16	Motor Temperature Warning Threshold	°C	105	0	150	RW
0x802A	U16	Motor Over Current Fault Threshold	0.1 A_{rms}	①	0	①	RW
0x802B	U16	Motor Over Current Warning Threshold	0.1 A_{rms}	①	0	①	RW
0x802C	U16	Motor Over Speed Fault Threshold	RPM	6250	0	30,000	RW
0x802D	U16	Motor Over Speed Warning Threshold	RPM	6000	0	30,000	RW
0x802E	U16	DC Link Over Voltage Fault Threshold	0.1 V	①	0	①	RW
0x802F	U16	DC Link Over Voltage Warning Threshold	0.1 V	①	0	①	RW

① *Factory Default* and *Max* values will be based on OZip model, refer to hardware manual for details

PID 0x8028 Motor Temperature Fault Threshold

This parameter defines the motor temperature fault threshold. If ***PID 0x80E8 - Motor Temperature Sensor Enable*** is set to TRUE, and the temperature rises above this value, the drive will be disabled and automatically transition to the FAULT state.

PID 0x8029 Motor Temperature Warning Threshold

This parameter defines the motor temperature threshold above which the drive will report a high temperature warning (if ***PID 0x80E8 - Motor Temperature Sensor Enable*** is set to TRUE). Once above this warning threshold, the temperature must fall below the threshold less the corresponding delta before the warning is cleared.

PID 0x802A Motor Over Current Fault Threshold

This parameter defines the motor over current fault threshold. If the current rises above this value, the drive will be disabled and automatically transition to the FAULT state.

PID 0x802B Motor Over Current Warning Threshold

This parameter defines the motor current threshold above which the drive will report a high current warning. Once above this warning threshold, the current must fall below the threshold less the corresponding delta before the warning is cleared.

PID 0x802C Motor Over Speed Fault Threshold

This parameter defines the motor speed fault threshold. If the motor speed rises above this value, the drive will be disabled and automatically transition to the FAULT state.

PID 0x802D Motor Over Speed Warning Threshold

This parameter defines the motor speed threshold above which the drive will report a high-speed warning. Once above this warning threshold, the speed must fall below the threshold less the corresponding delta before the warning is cleared.

PID 0x802E DC Link Over Voltage Fault Threshold

This parameter defines the DC link over voltage fault threshold. If the DC link voltage rises above this value, the drive will be disabled and automatically transition to the FAULT state.

PID 0x802F DC Link Over Voltage Warning Threshold

This parameter defines the DC link voltage threshold above which the drive will report a high voltage warning. Once above this warning threshold, the voltage must drop below the threshold less the corresponding delta before the warning is cleared.

Table 13 – Advanced Fault and Warning Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x8032	U16	Motor Temperature Warning Recover Delta	°C	5	0	100	RW
0x8033	U16	Motor Over Current Warning Recover Delta	0.1 A_{rms}	100	0	1000	RW
0x8034	U16	Motor Over Speed Warning Recover Delta	RPM	250	0	1000	RW
0x8035	U16	DC Link Over Voltage Warning Recover Delta	0.1 V	50	0	1000	RW

PID 0x8032 Motor Temperature Warning Recover Delta

This parameter defines the temperature delta below the value in ***PID 0x8029 – Motor Temperature Warning Threshold*** that the motor temperature must fall below in order to clear the corresponding warning bit.

PID 0x8033 Motor Over Current Warning Recover Delta

This parameter defines the current delta below the value in ***PID 0x802B – Motor Over Current Warning Threshold*** that the motor current must fall below in order to clear the corresponding warning bit.

PID 0x8034 Motor Over Speed Warning Recover Delta

This parameter defines the speed delta below the value in ***PID 0x802D - Motor Over Speed Warning Threshold*** that the motor speed must fall below in order to clear the corresponding warning bit.

PID 0x8035 DC Link Over Voltage Warning Recover Delta

This parameter defines the voltage delta below the value in ***PID 0x802F - DC Link Over Voltage Warning Threshold*** that the DC Link voltage must fall below in order to clear the corresponding warning bit.

4.4.5 Drive Configuration Parameters

Table 14 – Basic Drive Configuration Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x8046	U16	Control Mode	ENUM	0	0	2	RW
0x8047	U16	Control Interface	ENUM	0	0	6	RW
0x8048	U16	Motor Type	ENUM	0	0	1	RW
0x8049	U16	Motor Speed Feedback Device Select	ENUM	0	0	1	RW
0x804A	U16	POR Direction	ENUM	0	0	1	RW
0x804B	U16	Reverse Inhibit	ENUM	1	0	2	RW
0x804C	U16	Filter Inductance – Per Phase	µH	0	0	100,000,000	RW

PID 0x8046 Control Mode

This parameter is used to select the control mode as follows:

- 0 = Open-loop AC Induction Volts/Hertz Controller
- 1 = Closed-loop Field Oriented Speed Control
- 2 = Closed-loop Field Oriented Torque Control

PID 0x8047 Control Interface

This parameter is used to select the control interface as follows:

- 0 = Serial Interface
- 1 = Unipolar Analog
- 2 = Bipolar Analog
- 3 = Digital Potentiometer
- 4 = Binary Set Points (A)
- 5 = Binary Set Points (B)

- 6 = Binary Set Points (C)

PID 0x8048 Motor Type

This parameter is used to configure the type of motor.

- 0 = AC induction Motor
- 1 = Permanent Magnet Synchronous Motor

PID 0x8049 Motor Speed Feedback Device Select

This parameter is used to configure the type of speed feedback device being used by the controller as follows:

- 0 = None
- 1 = Digital Quadrature Encoder

PID 0x804A Power-On Reset Direction

This parameter is used when ***PID 0x8047 – Control Interface*** is set to 0, the Comm interface. The motor direction at startup is initialized to this value when using the Comm interface.

- 0 = Forward
- 1 = Reverse

PID 0x804B Reverse Inhibit

This parameter is used to select how motor rotation direction is controlled.

- 0 = None: Direction may be changed at any time.
- 1 = Operating: Direction changes are inhibited whenever the motor is running.
- 2 = All: Direction changes are not allowed. Drive operates in a single direction.

PID 0x804C Filter Inductance

This parameter is used to define any additional filter inductance used to interface with a PMSM type motor.

Table 15 – Advanced Drive Configuration Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x8050	U16	Pulse Width Modulation Frequency	1 Hz	5000	1000	①	RW

① *Factory Default* and *Max* values will be based on OZip model, refer to hardware manual for details

PID 0x8050 Pulse Width Modulation Frequency

This parameter defines the PWM switching frequency.

4.4.6 General Motor Parameters

Table 16 – Basic General Motor Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x8064	U16	Motor Pole Pair Count	Integer	2	1	10	RWO
0x8065	U16	Motor Rated Voltage	0.1 Vrms	①	1	①	RWO
0x8066	U16	Motor Rated Frequency	0.1 Hz	600	1	5000	RWO
0x8067	U16	Motor Rated Current	0.1 Arms	①	1	①	RWO
0x8068	U16	Motor Rated Speed	RPM	1765	1	65535	RWO

① *Factory Default* and *Max* values will be based on OZip model, refer to hardware manual for details

PID 0x8064 Motor Pole Pair Count

This parameter is used to indicate the number of pole pairs for the motor being controlled.

PID 0x8065 Motor Rated Voltage

This parameter is used to indicate the rated voltage for the motor being controlled.

PID 0x8066 Motor Rated Frequency

This parameter is used to indicate the rated frequency for the motor being controlled.

PID 0x8067 Motor Rated Current

This parameter is used to indicate the rated current for the motor being controlled.

PID 0x8068 Motor Rated Speed

This parameter is used to indicate the rated speed for the motor being controlled.

4.4.7 AC Induction Motor Parameters (Future Feature)

The parameters described in this section are only used if ***PID 8049 – Motor Type*** is set to "0", AC Induction Motor.

Table 17 – Basic AC Induction Motor Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x806E	U32	AC Motor Mutual Inductance	nH	4.25E+07	0	1E+09	RW
0x8070	U32	AC Motor Stator Leakage Inductance	nH	1.5E+06	0	1E+09	RW
0x8072	U32	AC Motor Rotor Leakage Inductance	nH	2.626E+06	0	1E+09	RW
0x8074	U32	AC Motor Rotor Resistance	µΩ	282.5E+03	0	1E+09	RW
0x8076	U16	AC Motor Magnetizing Current	0.1 Arms	84	1	①	RW
0x8077	U16	AC Motor Initial Magnetizing Current	0.1 Arms	100	1	①	RW
0x8078	U16	AC Motor Magnetizing Current Slew Rate	Arms/s	10	1	65535	RW
0x8079	U16	AC Motor Field Weakening Enable	Boolean	TRUE	FALSE	TRUE	RW
0x807A	U16	AC Motor Temperature Coefficient	0.001%/°C	0	0	65535	RW

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level

① *Factory Default* and *Max* values will be based on OZip model, refer to hardware manual for details

PID 0x806E AC Motor Mutual Inductance

This parameter is used to specify the motor's mutual inductance.

PID 0x8070 AC Motor Stator Leakage Inductance

This parameter is used to specify the motor's stator leakage inductance.

PID 0x8072 AC Motor Rotor Leakage Inductance

This parameter is used to specify the motor's rotor leakage inductance.

PID 0x8074 AC Motor Rotor Resistance

This parameter is used to specify the motor's rotor resistance.

PID 0x8076 AC Motor Magnetizing Current

This parameter is used to specify the nominal magnetizing current for the motor. When field weakening is not in effect, the magnetizing current to the motor will be controlled to this value.

PID 0x8077 AC Motor Initial Magnetizing Current

This parameter is used to specify the initial magnetizing current to use when first turning the drive on. For motors with long rotor time constants, it may be desirable to set this parameter to a value higher than the nominal magnetizing current parameter as this will shorten the time it takes to induce the magnetic field in the rotor. Once the drive has determined that the rotor field has reached the desired level, the magnetizing current will then be reduced to the nominal magnetizing current specified by ***PID 0x8076 – AC Motor Magnetizing Current***. This parameter should be set to the nominal magnetizing current for applications that do not require a faster initial magnetization period.

PID 0x8078 AC Motor Magnetizing Current Slew Rate

This parameter is used to set the magnetizing current slew rate when turning on the drive. The drive initially turns on with a regulated current of zero amps. It will then ramp up the magnetizing current at a rate defined by this parameter.

PID 0x8079 AC Motor Field Weakening Enable

This parameter is used to enable the field weakening controller. If this parameter is set to FALSE, the field weakening feature will be disabled and the magnetizing current will be held at the nominal specified magnetizing current. If this parameter is set to TRUE, the field weakening feature will be enabled, allowing the magnetizing current to be reduced at high motor speeds. Note that the maximum available motor torque and/or motor speed may be limited if field weakening is disabled (depending on the motor ratings and the DC link voltage).

PID 0x807A AC Motor Temperature Coefficient

This parameter is used to specify the thermal coefficient of the motor's rotor material. The controller's slip estimator uses this parameter along with the measured motor temperature to estimate the change in rotor resistance as the temperature increases above the nominal 20°C. If a motor temperature sensor is not enabled, then this parameter will not be used.

This parameter is specified in units of 0.001 % / °C. For example, the thermal coefficient of copper is approximately +0.4 %/°C, meaning that if the temperature increases by 1°C, the resistance will increase by 0.4%. This value would be stored as 400. The rotor resistance adjustment can be disabled by setting this parameter to zero.

4.4.8 Volts/Hertz Drive Parameters

The parameters described in this section are only used if the controller is configured to operate as an Open-loop Volts/Hertz Controller for AC induction motors, ***PID 0x8047 Control Mode*** = 0. See section 3.4 for more details on general Volts/Hertz operation and configuring the desired Volts/Hertz operating profile.

Table 18 – Basic Volts/Hertz Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x8091	U16	V/Hz Profile	ENUM	0	0	2	RW
0x8092	U16	V/Hz Field Weakening Mode	ENUM	0	0	2	RW
0x8093	U16	V/Hz Inflection Frequency	0.1 Hz	150	0	10000	RW
0x8094	U16	V/Hz Inflection Voltage	0.1 Vrms	100	1	10000	RW
0x8095	U16	V/Hz Zero Hertz Voltage	0.1 Vrms	50	1	10000	RW

PID 0x8091 V/Hz Profile

This parameter is used to select the desired V/Hz profile as follows:

- 0 = Linear: Voltage applied to the motor changes linearly with the frequency reference.
- 1 = Squared: Voltage applied to the motor follows a squared function of the frequency reference.
- 2 = Custom: A two-slope profile programmed with three points. It can be particularly useful in applications that require higher starting torque by boosting the applied voltage in the lower frequency range.

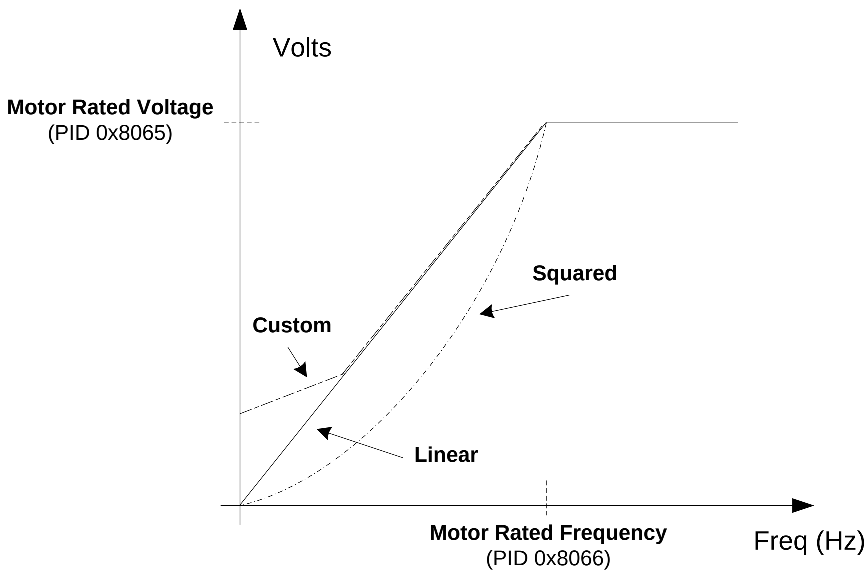


Figure 22 - V/Hz Profiles

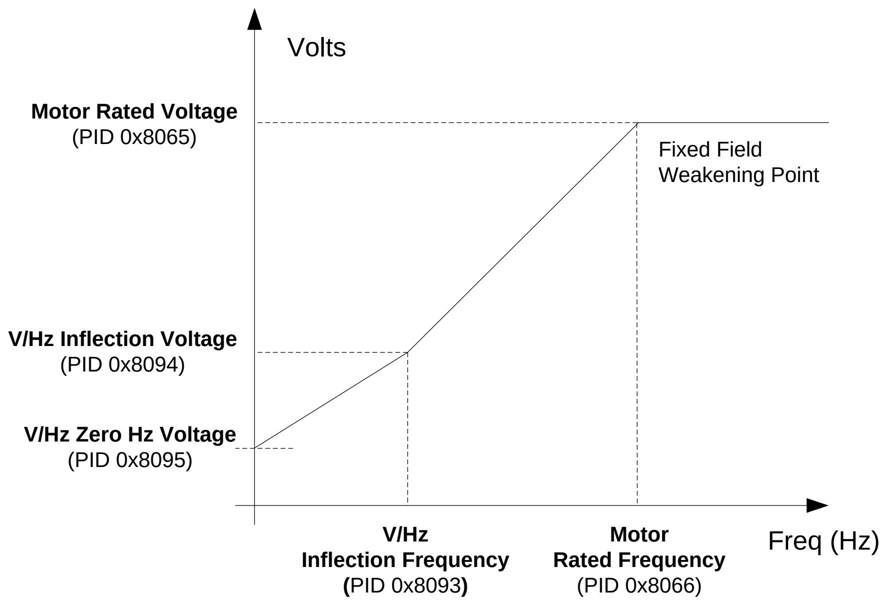
PID 0x8092 V/Hz Field Weakening Mode

This parameter is used to select the desired Field Weakening Mode.

- 0 = None: Field Weakening not allowed. Frequency fold back is used to maintain V/Hz Profile.
- 1 = Fixed: Drive will output the rated motor voltage for all frequency commands greater than the motor rated frequency. If the rated motor voltage exceeds the DC Link capability the output voltage will be limited by the available DC Link voltage while the frequency is allowed to increase.
- 2 = Variable: Drive will continue to follow the configured V/Hz profile for frequency commands greater than the motor rated frequency until the output voltage exceeds the DC Link capability. The output voltage is then limited by the available DC Link voltage while the frequency is allowed to increase.

PID 0x8093-95 V/Hz Inflection Frequency, Voltage, Zero Hz Voltage

These parameters are used to configure the custom V/Hz profile according to the following figure if ***PID 0x8091 – V/Hz Profile*** = 2 (custom).



4.4.9 Volts/Hertz Frequency References

The parameters described in this section are only used if the controller is configured to operate as an open-loop Volts/Hertz Controller for AC induction motors, ***PID 0x8047 Control Mode*** = 0. See section 3.4 for more details on general Volts/Hertz operation and configuring the desired Volts/Hertz operating profile.

Table 19 – V/Hz Frequency Reference Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x809B	U16	Freq Ref Startup Pause Time	1 ms	500	0	65535	RW
0x809C	U16	Freq Ref Slew Rate	0.1 Hz/Sec	100	1	5000	RW
0x809D	U16	Freq Ref Maximum	0.1 Hz	1200	0	10000	RW
0x809E	U16	Freq Ref Minimum	0.1 Hz	0	0	10000	RW
0x809F	U16	Freq Ref Preset 1	0.1 Hz	50	0	10000	RW
0x80A0	U16	Freq Ref Preset 2	0.1 Hz	100	0	10000	RW
0x80A1	U16	Freq Ref Preset 3	0.1 Hz	150	0	10000	RW
0x80A2	U16	Freq Ref Preset 4	0.1 Hz	200	0	10000	RW
0x80A3	U16	Freq Ref Preset 5	0.1 Hz	250	0	10000	RW
0x80A4	U16	Freq Ref Preset 6	0.1 Hz	300	0	10000	RW
0x80A5	U16	Freq Ref Preset 7	0.1 Hz	350	0	10000	RW

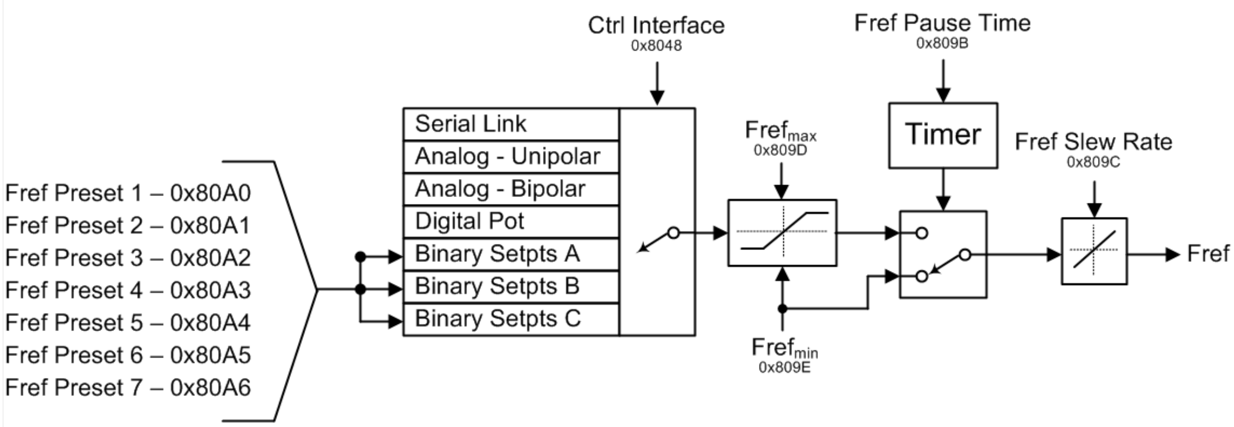


Figure 23 - Frequency Reference Generation Block Diagram

PID 0x809B Freq Ref Startup Pause Time

When first starting the motor the frequency reference is set to ***PID 0x809E – Frequency Ref Minimum***. This parameter defines the length of time to maintain this initial frequency when first turning on the motor. Once this time has expired, the controller will then go to the commanded motor frequency set by the user.

PID 0x809C Freq Ref Slew Rate

This parameter defines the slew rate to use when user changes the frequency command.

PID 0x809D Freq Ref Maximum

This parameter defines the maximum frequency reference command used by the drive.

PID 0x809E Freq Ref Minimum

This parameter defines the minimum frequency reference command used by the drive.

PID 0x809F-A6 Freq Ref Preset 0- 7

These parameters define the frequency references used by the drive when configured to operate off of preset references, ***PID 0x8048 – Control interface*** = {4..8}.

4.4.10 Volts/Hertz Skip Frequency

The parameters described in this section are only used if the controller is configured to operate as an Open-loop Volts/Hertz Controller for AC induction motors, ***PID 0x8047 Control Mode*** = 0. See section 3.4 for more details on general Volts/Hertz operation and configuring the desired Volts/Hertz operating profile.

Table 20 – V/Hz Skip Frequency Parameters

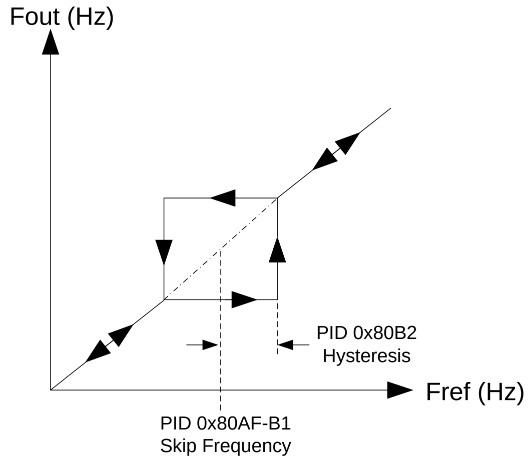
PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x80AF	U16	Skip Freq 1	0.1 Hz	0	0	10000	RW
0x80B0	U16	Skip Freq 2	0.1 Hz	0	0	10000	RW
0x80B1	U16	Skip Freq 3	0.1 Hz	0	0	10000	RW

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x80B2	U16	Skip Freq Hysteresis	0.1 Hz	1	1	1000	RW

PID 0x80AF-B1 Skip Frequency 1-3

PID 0x80B2 Skip Frequency Hysteresis

These parameters prevent prolonged operation within an adjustable range (+/- hysteresis) around particular frequencies (up to three). The feature is particularly useful to avoid certain frequencies because of mechanical resonance problems. Setting the skip frequency to zero, disables the function.



4.4.11 FOC Speed References (Future Feature)

The parameters described in this section are only used if the controller is configured to operate in Closed-loop Field Oriented Speed Control, ***PID 0x8047 Control Mode*** = 1. See section 3.5 for more details on general FOC operation and configuration.

Table 21 – FOC Speed Reference Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x80B9	U16	Speed Ref Slew Rate	RPM/Sec	10	1	65535	RW
0x80BA	U16	Speed Ref Maximum	RPM	1000	0	30000	RW
0x80BB	U16	Speed Ref Minimum	RPM	0	0	30000	RW
0x80BC	U16	Speed Ref Preset 1	RPM	500	0	30000	RW
0x80BD	U16	Speed Ref Preset 2	RPM	1000	0	30000	RW
0x80BE	U16	Speed Ref Preset 3	RPM	1500	0	30000	RW
0x80BF	U16	Speed Ref Preset 4	RPM	2000	0	30000	RW
0x80C0	U16	Speed Ref Preset 5	RPM	2500	0	30000	RW
0x80C1	U16	Speed Ref Preset 6	RPM	3000	0	30000	RW
0x80C2	U16	Speed Ref Preset 7	RPM	3500	0	30000	RW

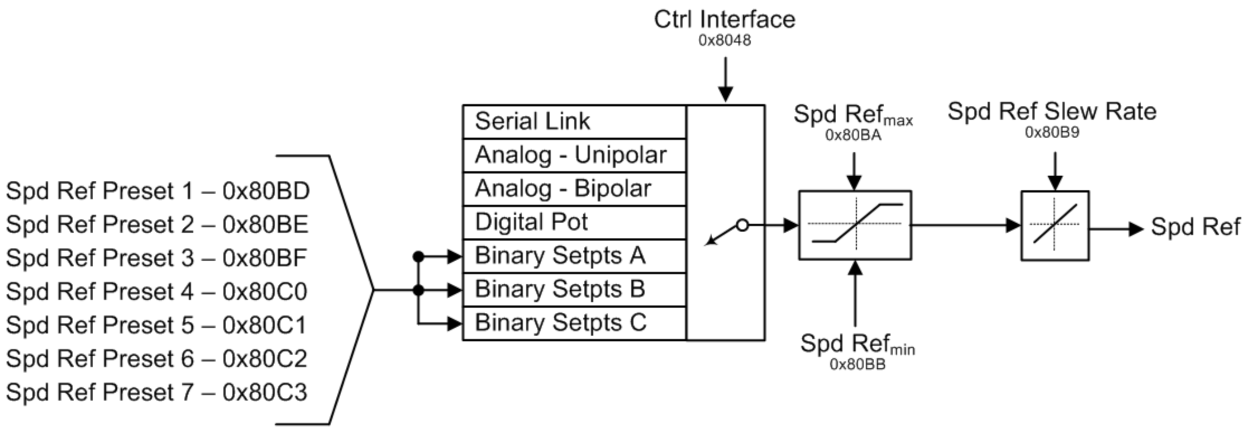


Figure 24 - Speed Reference Generation Block Diagram

PID 0x80B9 Speed Ref Slew Rate

This parameter defines the slew rate to use when user changes the commanded speed reference.

PID 0x80BA Speed Ref Maximum

This parameter defines the maximum speed reference command used by the drive

PID 0x80BB Speed Ref Minimum

This parameter defines the minimum Speed reference command used by the drive.

PID 0x80BC-0x80C3 Speed Ref Preset 0- 7

These parameters define the speed references used by the drive when the configured to operate off of preset references, ***PID 0x8048 – Control interface*** = {4..8}.

4.4.12 FOC Skip Speed (Future Feature)

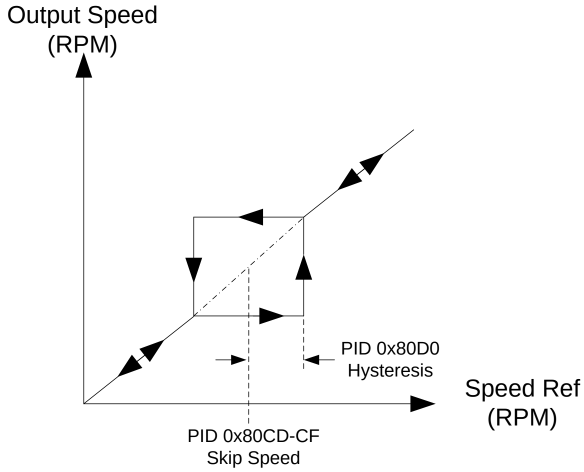
The parameters described in this section are only used if the controller is configured to operate in Closed-loop Field Oriented Speed Control, ***PID 0x8047 Control Mode*** = 1. See section 3.5 for more details on general FOC operation and configuration.

Table 22 – FOC Skip Speed Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x80CD	U16	Skip Speed 1	RPM	0	0	30000	RW
0x80CE	U16	Skip Speed 2	RPM	0	0	30000	RW
0x80CF	U16	Skip Speed 3	RPM	0	0	30000	RW
0x80D0	U16	Skip Speed Hysteresis	RPM	50	1	30000	RW

PID 0x80CD-CF Skip Speed 1-3

These parameters prevent prolonged operation within an adjustable range (+/- hysteresis, ***PID 0x80D0 – Skip Speed Hysteresis***) around particular speeds (up to three). The feature is particularly useful to avoid certain speeds because of mechanical resonance problems. Setting the Skip Speed to zero disables the function.



PID 0x80D0 Skip Speed Hysteresis

See description above.

4.4.13 FOC Torque Mode Parameters (Future Feature)

The parameters described in this section are only used if the controller is configured to operate in Closed-loop Field Oriented Torque Control, ***PID 0x8047 Control Mode*** = 2. See section 3.5 for more details on general FOC operation and configuration. See section 3.5.2 for more details on configuring the desired maximum torque operating profile.

Table 23 – FOC Torque Mode Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x80D7	U16	Torque Cmd Slew Rate	0.1 %/sec	1000	1	65535	RW
0x80D8	U16	Torque Profile Enable	Boolean	False	False	True	RW
0x80D9	U16	Torque Profile Max Torque	0.1 %	1000	0	1000	RW
0x80DA	U16	Torque Profile Max Power	10W	10000	1	65535	RW
0x80DB	U16	Torque Profile Cnst Pwr*Spd Start	RPM	3000	0	65535	RW

PID 0x80D7 Torque Command Slew Rate

This parameter defines the slew rate to use when the user changes the commanded torque value. This parameter is specified as a percent of the maximum torque capability of the motor (as calculated by the drive) per second. For example, if this parameter is set to 1000, this would indicate that the torque command slew rate will be zero to 100% of the specified maximum torque command in one second.

PID 0x80D8 Torque Profile Enable

This parameter is used to enable the Maximum Torque Profile feature. When this parameter is set to FALSE, the torque profile parameters are ignored and no torque limiting is performed. When set to TRUE, the motor drive enforces the maximum allowable torque versus speed profile as defined by the parameters below.

PID 0x80D9 Torque Profile Maximum Torque

This parameter defines the maximum allowable torque when operating at the lower speed range (Region 1).

PID 0x80DA Torque Profile Maximum Power

This parameter defines the maximum allowable power. The speed at which the torque profile switches from torque limiting to power limiting (Region 1 to Region 2) is determined by the combination of this parameter and the specified maximum torque described in the previous section.

PID 0x80DB Torque Profile Power*Speed Region Start

This parameter defines the speed at which the torque profile switches from power limiting to power*speed limiting (Region 2 to Region 3).

4.4.14 Temperature Measurement and Derating Parameters

Table 24 – Temperature Measurement and Derating Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x80E6	U16	Inverter Temp Derating Enable	Boolean	FALSE	FALSE	TRUE	RW
0x80E7	U16	Inverter Temp Derating Low Threshold	°C	90	0	150	RW
0x80E8	U16	Inverter Temp Derating High Threshold	°C	100	0	150	RW
0x80E9	U16	Inverter Temp Min Derating Factor	%	10	0	100	RW
0x80EA	U16	Motor Temp Sensor Enable	Boolean	FALSE	FALSE	TRUE	RW
0x80EB	U16	Motor Temp Coefficient A	n/a	1032	0	65535	RW
0x80EC	S16	Motor Temp Coefficient A Scale	n/a	-6	-12	12	RW
0x80ED	U16	Motor Temp Coefficient B	n/a	23856	0	65535	RW
0x80EE	S16	Motor Temp Coefficient B Scale	n/a	-8	-12	12	RW
0x80EF	U16	Motor Temp Coefficient C	n/a	15914	0	65535	RW
0x80F0	S16	Motor Temp Coefficient C Scale	n/a	-11	-12	12	RW
0x80F1	U16	Motor Temp Derating Enable	Boolean	FALSE	FALSE	TRUE	RW
0x80F2	U16	Motor Temp Derating Low Threshold	°C	90	0	150	RW
0x80F3	U16	Motor Temp Derating High Threshold	°C	100	0	150	RW
0x80F4	U16	Motor Temp Min Derating Factor	%	10	0	100	RW

PID 0x80E6 Inverter Temp Derating Enable

This parameter enables the thermal derating feature where the user's motor torque command can be reduced based on high inverter temperatures as described in section 3.5.1. If this parameter is set to FALSE, the inverter temperature will not be used to adjust the commanded torque.

PID 0x80E7 Inverter Temp Derating Low Threshold

This parameter specifies the lower inverter temperature threshold at which thermal derating will begin. Temperatures below this value will not cause torque derating. Temperatures above this value will cause the user's torque command to be reduced as described in section 3.5.1.

PID 0x80E8 Inverter Temp Derating High Threshold

This parameter specifies the upper inverter temperature threshold at which the user's torque command will be reduced to the minimum derating value specified by the ***Inverter Temp Min Derating Factor***, as discussed in section 3.5.1.

PID 0x80E9 Inverter Temp Min Derating Factor

This parameter is used to define the minimum derating factor to use when reducing the user's torque command due to high inverter temperatures. Normally, at low temperatures with no torque reduction the thermal derating factor is 1.0 (or 100%). This parameter specifies the maximum amount of torque reduction allowed. This parameter should be set to a value between zero (0% being the maximum derating, which reduces the torque command to zero at the maximum temperature) and 100 (100% being no derating).

PID 0x80EA Motor Temp Sensor Enable

This parameter is used to determine if there is a motor temperature sensing device present. If this parameter is set to FALSE, the motor temperature is not monitored or calculated, and the reported motor temperature will default to 0°C. When set to TRUE, the temperature is calculated according to the user-provided temperature coefficients (see next section) and is also monitored for possible over-temperature conditions according to the ***Motor Temperature Fault/Warning Threshold*** configuration parameters (***PIDs 0x8028-0x802A***).

PID 0x80EB-0x80F0 External Thermistor Coefficients

These parameters are used to define the resistance versus temperature characteristics for the selected device using the standard Steinhart-Hart equation for modeling non-linear thermistor behavior as follows:

$$\frac{1}{T} = A + B\ln(R) + C[\ln(R)]^3$$

Where:
T = temperature (in Kelvins)
R = resistance at *T* (in ohms)
$A = (\text{PID 0x80EB}) \times 10^{(\text{PID 0x80EC})}$
$B = (\text{PID 0x80ED}) \times 10^{(\text{PID 0x80EE})}$
$C = (\text{PID 0x80EF}) \times 10^{(\text{PID 0x80F0})}$

Manufacturers will often provide the three constants *A, B,* and *C*. When these constants are not available, they can be derived using resistance measurements at three temperatures and solving the simultaneous equations. There are several web-based calculators that can be used to perform this derivation including:

http://www.thinksrs.com/downloads/programs/Therm%20Calc/NTCCalibrator/NTCcalculator.htm

PID 0x80F1 Motor Temp Derating Enable

This parameter enables the thermal derating feature where the user's motor torque command can be reduced based on high motor temperatures. If this parameter is set to FALSE, the motor temperature will not be used to adjust the commanded torque. If this parameter is set to TRUE and the ***Motor Temp Sensor Enable*** parameter is TRUE, then the thermal derating feature will be enabled and will operate as discussed in section 3.5.1.

PID 0x80F2 Motor Temp Derating Low Threshold

This parameter specifies the lower motor temperature threshold at which thermal derating will begin. Temperatures below this value will not cause torque derating. Temperatures above this value will cause the user's torque command to be reduced as described in section 3.5.1.

PID 0x80F3 Motor Temp Derating High Threshold

This parameter specifies the upper motor temperature threshold at which the user's torque command will be reduced to the minimum derating value specified by the ***Motor Temp Min Derating Factor***, as discussed in section 3.5.1.

PID 0x80F4 Motor Temp Min Derating Factor

This parameter is used to define the minimum derating factor to use when reducing the user's torque command due to high motor temperatures. Normally, at low temperatures with no torque reduction the thermal derating factor is 1.0 (or 100%). This parameter specifies the maximum amount of torque reduction allowed. This parameter should be set to a value between zero (0% being the maximum derating, which reduces the torque command to zero at the maximum temperature) and 100 (100% being no derating).

4.4.15 Encoder Parameters (Future Feature)

The parameters described in this section are only used if the controller is configured to operate in Closed-loop Field Oriented Control modes, ***PID 0x8047 Control Mode*** = {1,2}. See section 3.5 for more details on general FOC operation and configuration.

Table 25 – Encoder Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x8109	U16	Encoder Line Count	Integer	1024	0	10,000	RW
0x810A	U16	Encoder Positive Direction	ENUM	1	0	1	RW
0x810B	U16	Motor Speed Low Pass Filter Cutoff	Hz	1000	1	10,000	RW

PID 0x80F4 Encoder Line Count

This parameter is used to specify the line count for the encoder being used.

PID 0x80F4 Encoder Positive Direction

This parameter is used to define the phase relationship between A and B that results in a positive speed calculation by the drive. The legal values for this parameter are as follows:

- 0 = A LEADS B – a positive speed is calculated when A leads B by 90°
- 1 = B LEADS A – a positive speed is calculated when B leads A by 90°

PID 0x80F4 Low Pass Filter Cutoff – Motor Speed

This parameter defines the cutoff frequency for the digital low pass filter used to calculate the motor speed, see Figure 27.

4.4.16 Current Regulator Parameters (Future Feature)

The parameters described in this section are only used if the controller is configured to operate in Closed-loop Field Oriented Control modes, ***PID 0x8047 Control Mode*** = {1,2}. See section 3.5 for more details on general FOC operation and configuration.

Table 26 – Basic Current Regulator Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x8118	U16	Current Controller Kp	n/a	12286	0	65535	RW
0x8119	S16	Current Proportional Gain Scale	n/a	0	-12	12	RW
0x811A	U16	Current Controller Integral Time Constant Tc	n/a	1	0	65535	RW
0x811B	S16	Current Integral Time Constant Scale	n/a	-1	-12	12	RW

PID 0x8118-0x811B Current Controller Gain Constants (Kp, Tc)

These parameters define the gain constants for the PI controllers that are used to regulate the direct field-producing current (I_d) and the quadrature torque-producing (I_q) current. The PI controllers use the following topology:

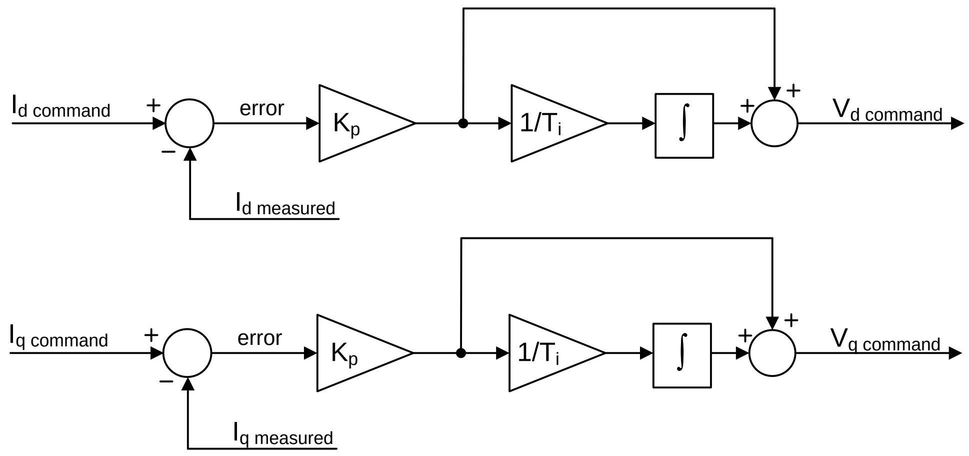


Figure 25 - Current Control PI Regulators

Where: K_p = (PID 0x8118) x $10^{(\text{PID 0x8119})}$
T_i = (PID 0x811A) x $10^{(\text{PID 0x811B})}$

For these PI controllers, the commanded and measured currents are in units of amps (peak) and the V_d/V_q commands are the drive's applied output voltages in units of volts (peak).

Table 27 – Advanced Current Regulator Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x8122	U16	Iq Current Foldback Enable	Boolean	TRUE	FALSE	TRUE	RW
0x8123	U16	Iq Current Foldback Mod Index Threshold	0.1 %	950	0	1000	RW
0x8124	U16	Iq FldBk Controller Kp	n/a	2	0	65535	RW
0x8125	S16	Iq FldBk Controller Kp Scale	n/a	-1	-12	12	RW
0x8126	U16	Iq FldBk Controller Integral Time Constant Tc	n/a	1	0	65535	RW
0x8127	S16	Iq FldBk Controller Tc Scale	n/a	-3	-12	12	RW

PID 0x8122 Iq Current Foldback Enable

This parameter is used to enable the I_q foldback mechanism. When set to FALSE, the current foldback controller is disabled. When set to TRUE, the I_q current foldback controller is enabled.

PID 0x8123 Iq Current Foldback Modulation Index Threshold

This parameter specifies the modulation index level at which the controller should start folding back the commanded current. For proper foldback operation, this parameter should be set slightly below 100% (generally in the mid 90's, see section 3.5.3 for more details).

PID 0x8124-0x80127 Iq Current Foldback Controller Gain Constants (Kp, Tc)

These parameters set the proportional gain and integral time constants for the PI regulator that is used by the foldback controller. The PI topology is the same as the main current regulators shown above except for a clamp on the integrator and output. The calculated error input to the regulator is the difference between the maximum modulation index and the actual modulation index. The output from the compensator is a number between 0 and 1.0 that is multiplied by the corresponding current command, where a value of 1.0 indicates no foldback, a value of 0.9 would indicate that the corresponding current command has been reduced by 10%.

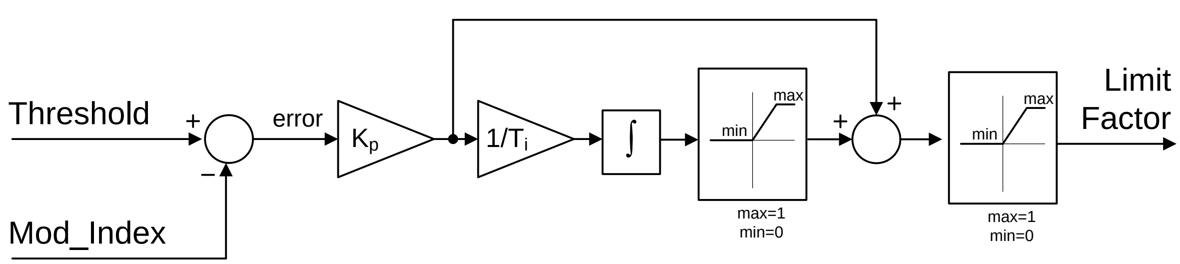


Figure 26 - Current Fold Back PI Regulator

Where: K_p = (PID 0x8124) x $10^{(\text{PID 0x8125})}$
T_i = (PID 0x8126) x $10^{(\text{PID 0x8127})}$
Threshold = (PID 0x8123)

4.4.17 Speed Regulator Parameters (Future Feature)

The parameters described in this section are only used if the controller is configured to operate in Closed-loop Field Oriented Speed Control, ***PID 0x8047 Control Mode*** = 1. See section 3.5 for more details on general FOC operation and configuration.

Table 28 – Speed Regulator Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x812C	U16	Spd Controller Kp	n/a	1	0	65535	RW
0x812D	S16	Spd Controller Kp Scale	n/a	-1	-12	12	RW
0x812E	U16	Spd Controller Integral Time Constant Tc	n/a	0	0	65535	RW
0x812F	S16	Spd Controller Tc Scale	n/a	0	-12	12	RW
0x8130	S16	Spd Controller Maximum Current	0.1 Arms	100	-32768	32767	RW
0x8131	S16	Spd Controller Minimum Current	0.1 Arms	-100	-32768	32767	RW

PID 0x812C-0x812F Speed Controller Gain Constants (Kp, Ti)

These parameters define the gain constants for the PI controller that is regulating the motor speed. The PI controller uses the following topology:

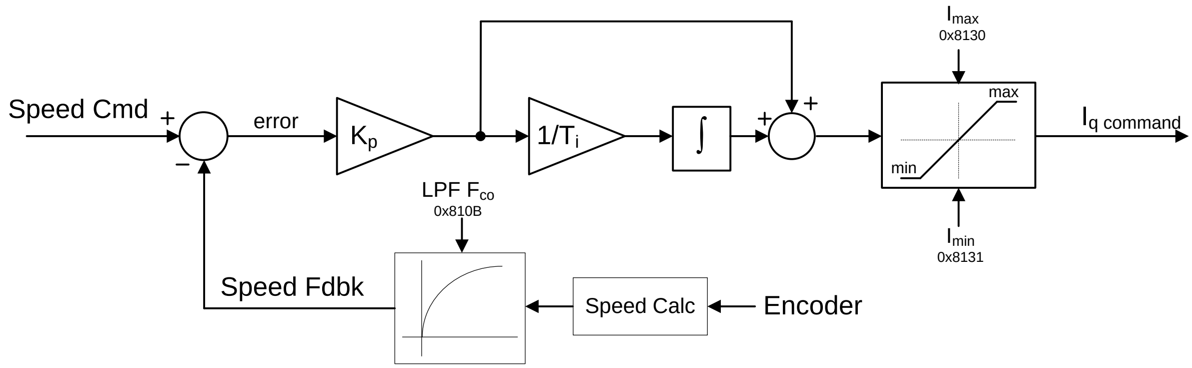


Figure 27 - Speed Control PI Regulator

Where: K_p = (PID 0x812C) x $10^{(\text{PID 0x812D})}$
T_i = (PID 0x812E) x $10^{(\text{PID 0x812F})}$

For this PI controller, the commanded and measured speed is in units of RPM and the I_q command is in units of amps (peak).

As Figure 27 illustrates, the PI topology used sums the proportional and integral correction terms and then clamps the output to the specified current limits based on the ***Speed Controller Maximum/Minimum Current*** configuration parameters (see next section).

PID 0x8130-0x8131 Speed Controller Maximum/Minimum Current

These parameters specify the current limits used by the speed controller. For flexibility, there are separate parameters provided for the positive and negative current limits. The output of the speed loop will be clamped to be within these current limits.

4.4.18 Brake Controller Parameters

Table 29 – Brake Controller Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x8136	U16	Brake Controller Enable	Boolean	false	false	true	RW
0x8137	U16	Brake Controller Voltage Threshold	0.1 V	①	①	①	RW
0x8138	U16	Brake Controller Recover Voltage Threshold	0.1 V	①	①	①	RW
0x8139	U16	Brake Gate Driver Signal Active High	Boolean	true	false	true	RW

① *Factory Default* and *Max* values will be based on OZip model, refer to hardware manual for details

PID 0x8136 Brake Controller Enable

This parameter is used to enable the brake controller. When this parameter is set to FALSE, brake operation and all related features are disabled. In this case the brake controller state will always read as OFF and the switch output will always be inactive. When this parameter is set to TRUE, the brake function operates as specified in section3.2.

PID 0x8137 Brake Controller Voltage Threshold

This parameter specifies the DC Link voltage above which the brake should engage the brake resistor. Once the brake resistor is engaged, it remains connected until the DC Link voltage drops below the value specified by the ***Brake Controller Recover Voltage Threshold***.

PID 0x8138 Brake Controller Recover Voltage Threshold

This parameter specifies the DC Link voltage at which the brake controller should disconnect the brake resistor if it is currently engaged. This value should be set to a value less than the ***Brake Chopper Voltage Threshold*** in order to provide some hysteresis between turning the brake resistor on and off.

PID 0x8139 Brake Gate Driver Signal Active High

This parameter specifies the logic level that is used to turn ON the gate driver. If the value is set to TRUE, the drive signal out of the control board is driven low when the Brake is off (i.e. the signal is treated as active high to connect the brake resistor). If this value is set to FALSE, the signal is driven high when the Brake is off.

4.4.19 Pre-charge Parameters

Table 30 – Pre-charge Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x80B0	U16	DC Link Pre-charge Enable	Boolean	True	False	True	RW
0x80B4	U16	Pre-charge Timeout Threshold	1 ms	20000	10	65535	RW
0x80B1	U16	Pre-charge DC Link Connect Voltage	0.1 V	500	0	20000	RW
0x80B2	U16	Pre-charge DC Link Disconnect Voltage	0.1 V	4500	0	20000	RW
0x80B3	U16	Pre-charge Connect Max dv/dt	0.1 V/sec	10	0	20000	RW

The drive provides the ability to control a pre-charge circuit if ***PID 0x813A - DC Link Pre-charge Enable*** = 1. Figure 28 illustrates the typical pre-charge circuit. The control logic drives two contactors: a pre-charge contactor, K1, and a bypass contactor, K2. The drive requires a "charge" command over the serial interface to start the pre-charge process. When a "1" is written to ***PID 0x0007 Charge Command***, K1 is closed and the DC Link begins to charge through the current limiting resistor R. When the DC Link voltage has charged, K1 is opened and K2 is closed.

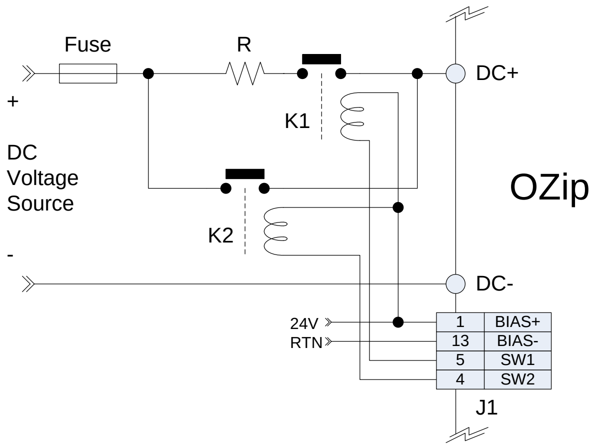


Figure 28 - External DC Link Precharge Circuit

PID 0x813A DC Link Pre-charge Enable

This parameter configures the use of the pre-charge contactor control as follows:

- **0 = Disabled**: Pre-charge control is not enabled. It is assumed that the pre-charge function is performed by another piece of equipment attached to the same DC link as the OZip. In this case, the drive will not attempt to close the pre-charge contactor when first starting up. Instead, it simply monitors the DC link voltage and waits for it to reach the configured ***Pre-charge DC Link Connect Voltage*** (see below) before it will transition from the CHARGE state to the IDLE state.

- **1 = Enabled**: The drive will transition to the ***Wait for Charge Command*** state, where it will wait for the user to send the CHARGE command in order to initiate the pre-charge function.

PID 0x813A Precharge Timeout Threshold

This parameter specifies the maximum amount of time to wait before reporting a pre-charge timeout fault. If the DC link has not charged within this amount of time, the drive will transition to the FAULT state. This parameter is only used if the ***DC Link Pre-charge Enable*** parameter (see above) is set to TRUE (i.e. the drive is controlling the pre-charge function). If the ***DC Link Pre-charge Enable*** parameter is set to FALSE, the drive will simply wait indefinitely for the DC link voltage to rise above the ***Pre-charge DC Link Connect Voltage***.

PID 0x813A Pre-charge DC Link Connect Voltage

This parameter defines the minimum DC link voltage threshold to charge to. The pre-charge controller requires the DC Link voltage to be at or above this threshold and the rate of charge to be below the ***Pre-charge Max dv/dt*** in order to close the by-pass contactor.

PID 0x813A Pre-charge DC Link Disconnect Voltage

This parameter defines the DC link voltage threshold at which the pre-charge controller will open the by-pass contactor and go back to waiting for charge command. This feature prevents the drive from operating with inadequate DC link voltage.

PID 0x813A Pre-charge Max dv/dt

This parameter defines the maximum acceptable rate of charge for the DC link at which it is safe to close the by-pass contactor. The pre-charge controller requires the DC Link voltage to be at or above the ***Pre-charge DC Link Connect Voltage*** and the rate of charge to be below this parameter in order to close the by-pass contactor.

4.4.20 Analog Input Parameters

Table 31 – Analog Input Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x8159	U16	Analog Input 1 Mode	ENUM	0	0	2	RW
0x815A	U16	Analog Input 1 Min	0.1 V	0	0	50	RW
0x815B	U16	Analog Input 1 Max	0.1 V	50	0	50	RW
0x815C	U16	Analog Input 1 Filter Cutoff	Hz	100	0	100	RW

PID 0x8159 Analog Input 1 Mode

This parameter configures the operating mode for the analog input as follows:

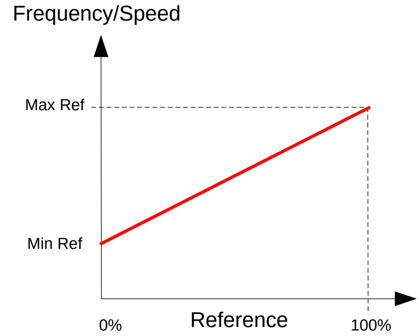
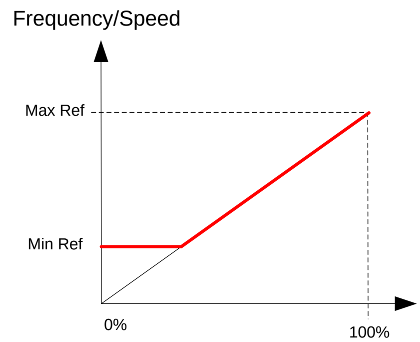
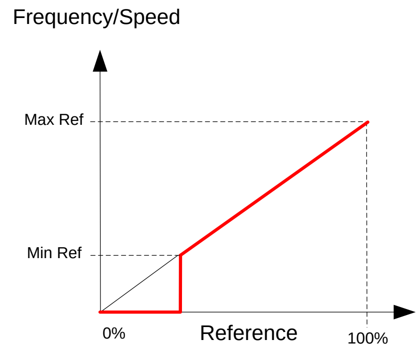
0 = Standard	At ref = 0, freq/spd = Min	
1 = Pedestal	At ref = 0 to Min, frq/spd = Min	
2 = Deadband	At ref = 0 to Min, frq/spd = 0	

Figure 29 - Analog Input Modes

PID 0x815A, 815B Analog Input 1 Min/Max

These parameters assign the input voltages that correspond to (0% -> 100%) or (-100% -> 100%) of the reference limits, depending on ***PID 0x8048 Control Interface***.

If ***Control Interface = 1,*** the range is configured for (0% -> 100%) as follows:

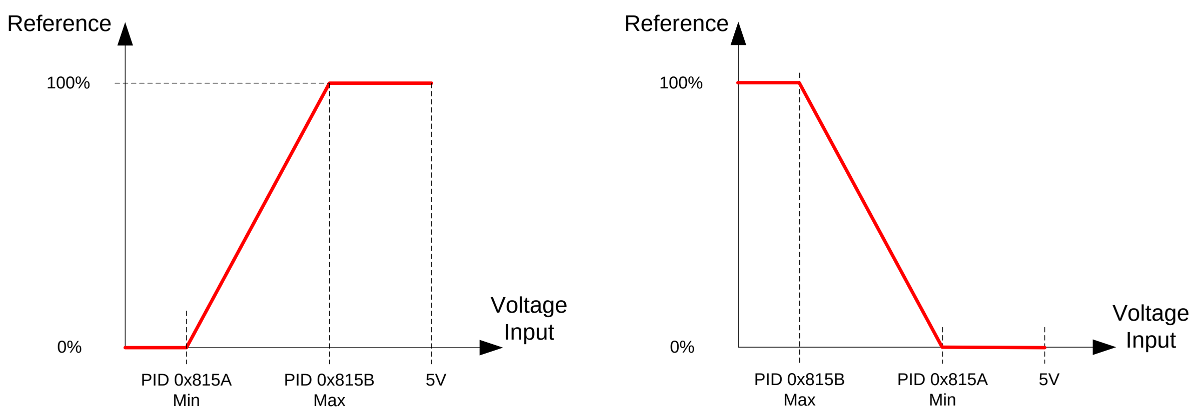


Figure 30 - Analog Input Min/Max – Control Interface = 1

If ***Control Interface = 2,*** the range is configured for (-100% -> 100%). Note that the minimum value may be greater than the maximum value, in which case the generated reference will be the inverse of the analog input as shown below.

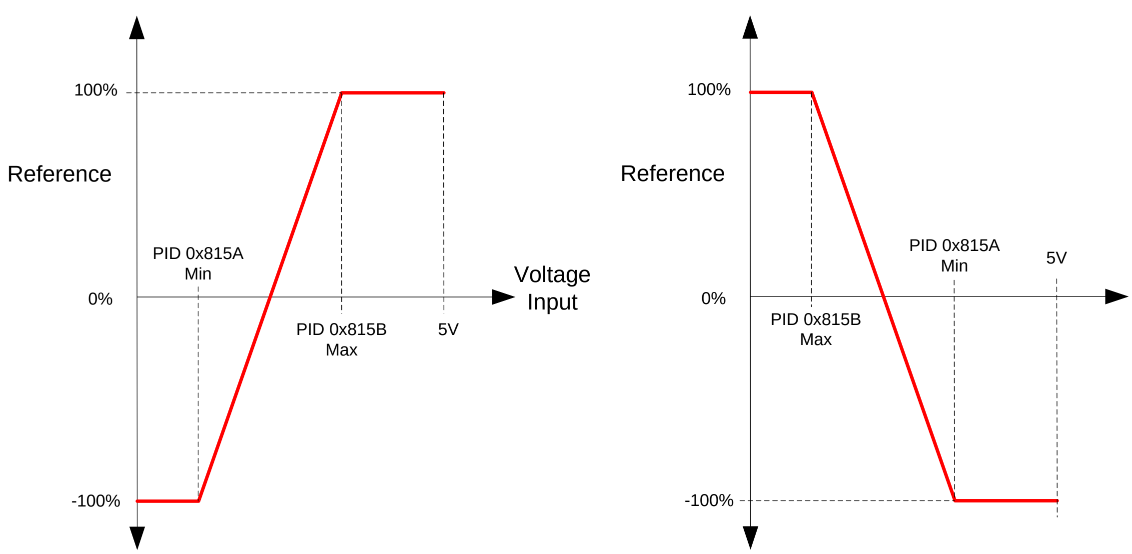


Figure 31 - Analog Input Min/Max – Control Interface = 2

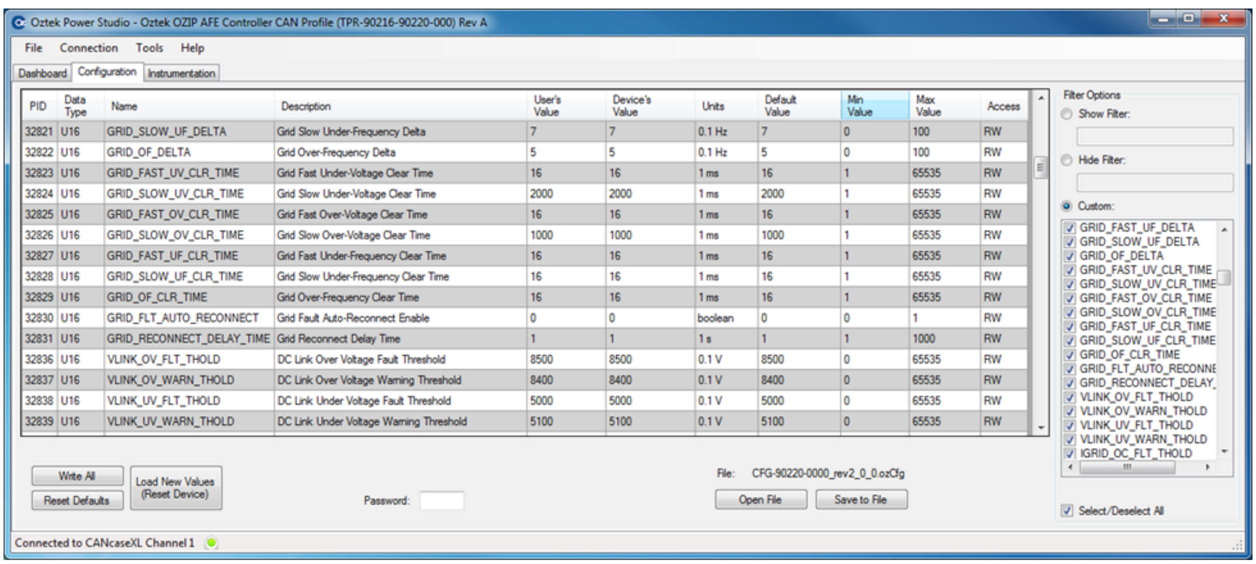
PID 0x815C Analog Input 1 Filter Cutoff

This parameter defines the cutoff frequency for the digital low pass filter used to filter the analog input.

5. Oztek Power Studio™ Tool

The Oztek Power Studio™ tool is a Microsoft Windows based Graphical User Interface (GUI) that can be used to easily configure and control the OZip Inverter. The tool communicates with the inverter over the CAN or RS-485 serial port and provides a simple, intuitive user interface. Some of the features provided by Power Studio™ include:

- Simple tabbed interfaces:
    - Dashboard
    - Configuration
    - Instrumentation
- Dashboard for inverter control and monitoring
- Inverter configuration control, including:
    - Editing configurations
    - Downloading/uploading configurations
    - Archiving multiple configuration files
- Firmware Update Utility



For detailed information and operating instructions, please refer to UM-0052 – Oztek Power Studio™ User's Manual.

Warranty and Product Information

Limited Warranty

What does this warranty cover and how long does it last? This Limited Warranty is provided by Oztek Corp. ("Oztek") and covers defects in workmanship and materials in your OZip Motor Drive. This Warranty Period lasts for 18 months from the date of purchase at the point of sale to you, the original end user customer, unless otherwise agreed in writing. You will be required to demonstrate proof of purchase to make warranty claims. This Limited Warranty is transferable to subsequent owners but only for the unexpired portion of the Warranty Period. Subsequent owners also require original proof of purchase as described in "What proof of purchase is required?"

What will Oztek do? During the Warranty Period Oztek will, at its option, repair the product (if economically feasible) or replace the defective product free of charge, provided that you notify Oztek of the product defect within the Warranty Period, and provided that through inspection Oztek establishes the existence of such a defect and that it is covered by this Limited Warranty.

Oztek will, at its option, use new and/or reconditioned parts in performing warranty repair and building replacement products. Oztek reserves the right to use parts or products of original or improved design in the repair or replacement. If Oztek repairs or replaces a product, its warranty continues for the remaining portion of the original Warranty Period or 90 days from the date of the return shipment to the customer, whichever is greater. All replaced products and all parts removed from repaired products become the property of Oztek.

Oztek covers both parts and labor necessary to repair the product, and return shipment to the customer via an Oztek-selected non-expedited surface freight within the contiguous United States and Canada. Alaska, Hawaii and locations outside of the United States and Canada are excluded. Contact Oztek Customer Service for details on freight policy for return shipments from excluded areas.

How do you get service? If your product requires troubleshooting or warranty service, contact your merchant. If you are unable to contact your merchant, or the merchant is unable to provide service, contact Oztek directly at:

USA
Telephone: 603-546-0090
Fax: 603-386-6366
Email techsupport@oztekcorp.com

Direct returns may be performed according to the Oztek Return Material Authorization Policy described in your product manual.

What proof of purchase is required? In any warranty claim, dated proof of purchase must accompany the product and the product must not have been disassembled or modified without prior written authorization by Oztek. Proof of purchase may be in any one of the following forms:

- The dated purchase receipt from the original purchase of the product at point of sale to the end user
- The dated dealer invoice or purchase receipt showing original equipment manufacturer (OEM) status
- The dated invoice or purchase receipt showing the product exchanged under warranty

What does this warranty not cover? Claims are limited to repair and replacement, or if in Oztek's discretion that is not possible, reimbursement up to the purchase price paid for the product. Oztek will be liable to you only for direct damages suffered by you and only up to a maximum amount equal to the purchase price of the product. This Limited Warranty does not warrant uninterrupted or error-free operation of the product or cover normal wear and tear of the product or costs related to the removal, installation, or troubleshooting of the customer's electrical systems. This warranty does not apply to and Oztek will not be responsible for any defect in or damage to:

a) The product if it has been misused, neglected, improperly installed, physically damaged or altered, either internally or externally, or damaged from improper use or use in an unsuitable environment
b) The product if it has been subjected to fire, water, generalized corrosion, biological infestations, or input voltage that creates operating conditions beyond the maximum or minimum limits listed in the Oztek product specifications including high input voltage from generators and lightning strikes
c) The product if repairs have been done to it other than by Oztek or its authorized service centers (hereafter "ASCs")
d) The product if it is used as a component part of a product expressly warranted by another manufacturer
e) The product if its original identification (trade-mark, serial number) markings have been defaced, altered, or removed
f) The product if it is located outside of the country where it was purchased
g) Any consequential losses that are attributable to the product losing power whether by product malfunction, installation error or misuse.

Disclaimer

Product

THIS LIMITED WARRANTY IS THE SOLE AND EXCLUSIVE WARRANTY PROVIDED BY OZTEK IN CONNECTION WITH YOUR OZTEK PRODUCT AND IS, WHERE PERMITTED BY LAW, IN LIEU OF ALL OTHER WARRANTIES, CONDITIONS, GUARANTEES, REPRESENTATIONS, OBLIGATIONS AND LIABILITIES, EXPRESS OR IMPLIED, STATUTORY OR OTHERWISE IN CONNECTION WITH THE PRODUCT, HOWEVER ARISING (WHETHER BY CONTRACT, TORT, NEGLIGENCE, PRINCIPLES OF MANUFACTURER'S LIABILITY, OPERATION OF LAW, CONDUCT, STATEMENT OR OTHERWISE), INCLUDING WITHOUT RESTRICTION ANY IMPLIED WARRANTY OR CONDITION OF QUALITY, MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE TO THE EXTENT REQUIRED UNDER APPLICABLE LAW TO APPLY TO THE PRODUCT SHALL BE LIMITED IN DURATION TO THE PERIOD STIPULATED UNDER THIS LIMITED WARRANTY. IN NO EVENT WILL OZTEK BE LIABLE FOR: (a) ANY SPECIAL, INDIRECT, INCIDENTAL OR CONSEQUENTIAL DAMAGES, INCLUDING LOST PROFITS, LOST REVENUES, FAILURE TO REALIZE EXPECTED SAVINGS, OR OTHER COMMERCIAL OR ECONOMIC LOSSES OF ANY KIND, EVEN IF OZTEK HAS BEEN ADVISED, OR HAD REASON TO KNOW, OF THE POSSIBILITY OF SUCH DAMAGE, (b) ANY LIABILITY ARISING IN TORT, WHETHER OR NOT ARISING OUT OF OZTEK'S NEGLIGENCE, AND ALL LOSSES OR DAMAGES TO ANY PROPERTY OR FOR ANY PERSONAL INJURY OR ECONOMIC LOSS OR DAMAGE CAUSED BY THE CONNECTION OF A PRODUCT TO ANY OTHER DEVICE OR SYSTEM, AND (c) ANY DAMAGE OR INJURY ARISING FROM OR AS A RESULT OF MISUSE OR ABUSE, OR THE INCORRECT INSTALLATION, INTEGRATION OR OPERATION OF THE PRODUCT. IF YOU ARE A CONSUMER (RATHER THAN A PURCHASER OF THE PRODUCT IN THE COURSE OF A BUSINESS) AND PURCHASED THE PRODUCT IN A MEMBER STATE OF THE EUROPEAN UNION, THIS LIMITED WARRANTY SHALL BE SUBJECT TO YOUR STATUTORY RIGHTS AS A CONSUMER UNDER THE EUROPEAN UNION PRODUCT WARRANTY DIRECTIVE 1999/44/EC AND AS SUCH DIRECTIVE HAS BEEN IMPLEMENTED IN THE EUROPEAN UNION MEMBER STATE WHERE YOU PURCHASED THE PRODUCT. FURTHER, WHILE THIS LIMITED WARRANTY GIVES YOU SPECIFIC LEGAL RIGHTS, YOU MAY HAVE OTHER RIGHTS WHICH MAY VARY FROM EU MEMBER STATE TO EU MEMBER STATE OR, IF YOU DID NOT PURCHASE THE PRODUCT IN AN EU MEMBER STATE, IN THE COUNTRY YOU PURCHASED THE PRODUCT WHICH MAY VARY FROM COUNTRY TO COUNTRY AND JURISDICTION TO JURISDICTION.

Return Material Authorization Policy

Before returning a product directly to Oztek you must obtain a Return Material Authorization (RMA) number and the correct factory "Ship To" address. Products must also be shipped prepaid. Product shipments will be refused and returned at your expense if they are unauthorized, returned without an RMA number clearly marked on the outside of the shipping box, if they are shipped collect, or if they are shipped to the wrong location.
When you contact Oztek to obtain service, please have your instruction manual ready for reference and be prepared to supply:

- The serial number of your product
- Information about the installation and use of the unit
- Information about the failure and/or reason for the return
- A copy of your dated proof of purchase

Return Procedure

Package the unit safely, preferably using the original box and packing materials. Please ensure that your product is shipped fully insured in the original packaging or equivalent. This warranty will not apply where the product is damaged due to improper packaging. Include the following:

- The RMA number supplied by Oztek clearly marked on the outside of the box.
- A return address where the unit can be shipped. Post office boxes are not acceptable.
- A contact telephone number where you can be reached during work hours.
- A brief description of the problem.

Ship the unit prepaid to the address provided by your Oztek customer service representative.

If you are returning a product from outside of the USA or Canada - In addition to the above, you MUST include return freight funds and you are fully responsible for all documents, duties, tariffs, and deposits.

Out of Warranty Service

If the warranty period for your product has expired, if the unit was damaged by misuse or incorrect installation, if other conditions of the warranty have not been met, or if no dated proof of purchase is available, your unit may be serviced or replaced for a flat fee. If a unit cannot be serviced due to damage beyond salvation or because the repair is not economically feasible, a labor fee may still be incurred for the time spent making this determination.

To return your product for out of warranty service, contact Oztek Customer Service for a Return Material Authorization (RMA) number and follow the other steps outlined in "Return Procedure".

Payment options such as credit card or money order will be explained by the Customer Service Representative. In cases where the minimum flat fee does not apply, as with incomplete units or units with excessive damage, an additional fee will be charged. If applicable, you will be contacted by Customer Service once your unit has been received.