Innovative Thinking for Power Control

OZip AFE/GTI Inverter

User's Manual

UM-0056

11 Continental Blvd
Merrimack NH 03054

(603) 546-0090
oztekcorp.com

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Oztek Corp. is a proven innovator of power and control 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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Contact Information

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

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1. Introduction

This document is intended to provide instruction on how to configure, operate, troubleshoot, and maintain an OZip AFE/GTI Inverter. 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. For details regarding inverter installation and hardware ratings, see reference documents UM-0058 – *OZip-AFE Integrated Power Solution Hardware User's Manual* and UM-0055 – *OZip-R Intelligent Power Module Hardware User's Manual*.

1.1 Referenced Documents

Ref.	Document	Description
[1]	UM-0055	OZip-R Intelligent Power Module Hardware User's Manual
[2]	UM-0058	OZip-AFE Integrated Power Solution Hardware User's Manual
[4]	FS-0046	OzCAN CAN Communication Protocol Functional Specification
[5]	FS-0053	Modbus Communication Module Functional Specification
[6]	FS-0091	OZip AFE/GTI Inverter OzCAN Message Profile
[7]	FS-0092	OZip AFE/GTI Inverter Modbus Register Profile
[8]	UM-0052	Oztek Power Studio™ User's Manual

1.2 Definitions

Acronym	Description
ADC	Analog-to-Digital Converter
AFE	Active Front End
CAN	Controller Area Network
CRC	Cyclic Redundancy Check
DSP	Digital Signal Processor
EEPROM	Electrically Erasable Programmable Read Only Memory
EMC	Electro-Magnetic Compatibility
EMI	Electro-Magnetic Interference
ESTOP	Emergency Stop
FPGA	Field Programmable Gate Array
GND	Ground, low side of input power supply
GTI	Grid Tie Inverter
GUI	Graphical User Interface
HMI	Human Machine Interface
IGBT	Insulated-Gate Bipolar Transistor

Acronym	Description
IPM	Intelligent Power Module
NC	Not Connected
PCB	Printed Circuit Board
PI	Proportional and Integral Compensator
PID	Parameter Identifier
PLL	Phase Locked Loop
POR	Power On Reset
PWM	Pulse Width Modulation
RMS	Root Mean Square
SVM	Space Vector Modulator
THDI	Total Harmonic Distortion - Current

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 connected system. Specific Warnings, Cautions and Notes 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 Inverter 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 AFE/GTI Inverter, are typically connected to hazardous voltages. When servicing the OZip Inverter, 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 Inverter is connected to its power source.***
4. ***Never work on the OZip Inverter, power cables, or load when input power is applied.***

WARNING

1. **After disconnecting the input power, residual charge will remain on the OZip Inverter 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 Inverter 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 and other components within the inverter assembly. Even so, power range capabilities will allow the power terminals and the heatsink of the OZip IPM and other inverter components 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 On/Off signals before resetting system faults to prevent an unintentional restart of the OZip Inverter, 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 OZip 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. Functional Description

The OZip AFE/GTI Inverter is used to transfer power between an AC power input and an intermediate DC circuit or link. It generally has the ability to transfer power in both directions, operating as a rectifier when transferring power from the AC line to the DC link and as an inverter in the opposite direction. The OZip AFE/GTI Inverter provides very low current distortion (THDI) when compared to other front end rectifier solutions. Advantages of the OZip AFE/GTI Inverter solution include:

- Low AC Input Harmonics – The OZip AFE/GTI Inverter provides low harmonic distortion to meet IEEE-519 at the AC line inputs.

- Improved Power Factor – The OZip AFE/GTI Inverter provides power factor correction resulting in unity power factor operation for energy savings and system efficiency.

- Voltage Boost Capability – The pulse width modulated control scheme behaves as a boost regulator, providing regulated DC voltages higher than the rectified AC line. This isolates the load electronics from the effects of AC line voltage sags.

- Regenerative Capability – OZip AFE/GTI Inverter based applications achieve considerable savings in terms of power savings and the related costs. The ability to transfer power from the DC link to the AC line provides a direct interface with regenerative loads, transforming the kinetic energy of the inertial loads into electrical energy. This eliminates the need for braking resistors and saves the wasted energy, instead returning it to the line to be used by other equipment.

CAUTION

While the OZip AFE/GTI Inverter can be used for voltage boost, it cannot be used to lower the DC link voltage. The minimum DC link voltage is limited by the rectified AC line voltage.

Typical OZip AFE/GTI Inverter applications include renewable energy systems as well as power systems with high inertial loads such as centrifuges, test benches, rolling systems, high power servo systems, mixers etc.

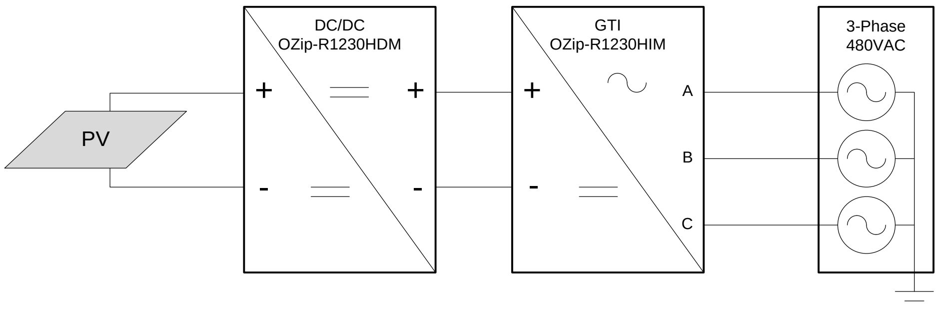


Figure 1 – Typical Renewable Energy PV Solar Application

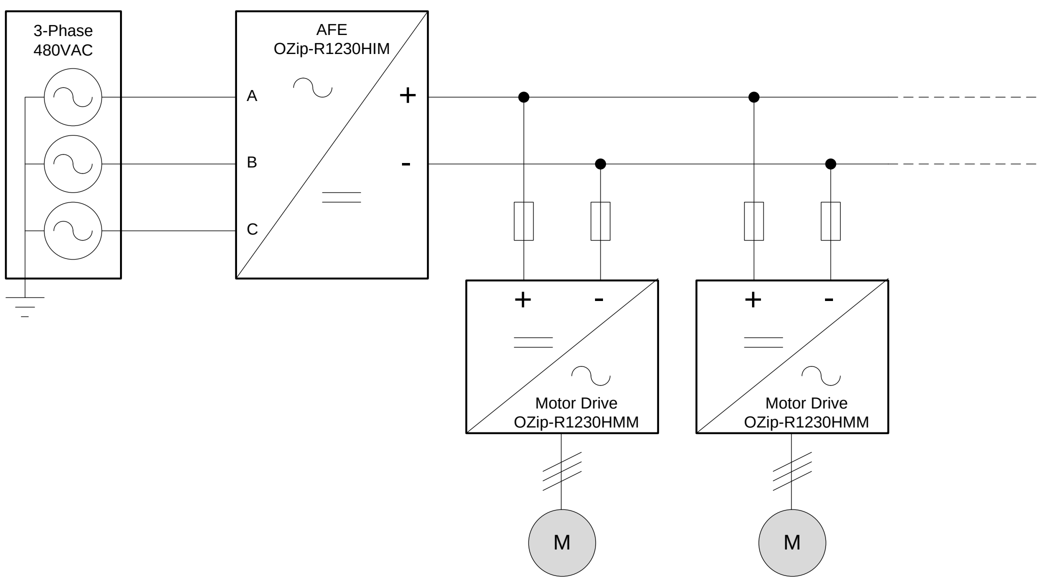


Figure 2 – Typical Regenerative Motor Drive Application

Figure 3 illustrates a typical OZip AFE/GTI Inverter electrical system implementation. While component values will vary from application to application depending on line voltage and power level, the overall system configuration will generally remain the same. The diagram shows optional interfaces including a high voltage DC link pre-charge circuit as well as controls for an optional contactor on the DC input.

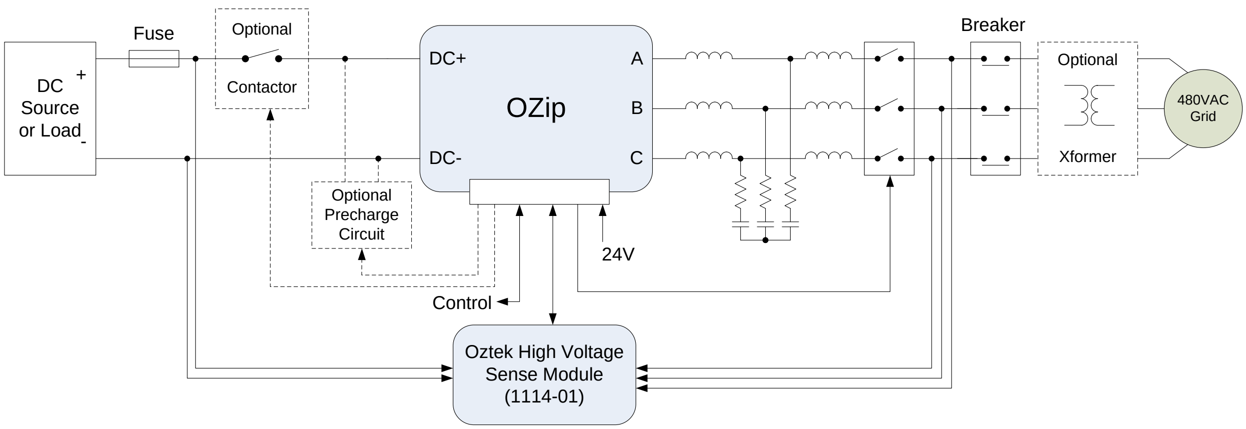


Figure 3 – Typical Inverter Electrical System Schematic

2.1 DC Link Pre-Charge Control (Optional)

CAUTION

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

The OZip contains a significant amount of internal capacitance on the high voltage DC link. When DC input power is applied to the OZip, 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 in the OZip model being used and the rate of change of the input voltage $(d\mathrm{V}/d\mathrm{T})$. Similarly, when an AC input is applied to the OZip, the diodes in the IGBT-based power stage behave like a passive rectifier when the DC link voltage is below the rectified AC voltage being applied, again causing the link capacitors to charge.

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 in-rush current.

The inverter provides the ability to control a pre-charge circuit based on ***PID 0x8080 – DC Link Pre-charge Mode.*** Additionally, the pre-charge control can be configured to charge the link from either the AC grid side or the DC input side based on ***PID 0x8081 – DC Link Pre-charge Reference.***

For typical AFE-based systems where the inverter is controlling the DC link voltage, it is common for the inverter to first pre-charge its DC link up to the rectified grid voltage. Figure 4 below shows an example of a *passive* inverter-controlled pre-charge circuit where the AC input lines are fed through a small pre-charge contactor, current limiting resistors, and a diode rectifier tied to the DC link. Upon detecting a valid grid input, the inverter will close the pre-charge contactor and wait for the local DC link voltage to charge to the measured rectified grid voltage. It then opens the pre-charge contactor and then closes the main AC input contactor once it is safe to do so. Alternatively, an *active* pre-charge circuit may be employed where the inverter's pre-charge control output can be used to enable a slow charging circuit that uses the 24V bias supply to charge the DC link until it is equal or above the rectified AC voltage.

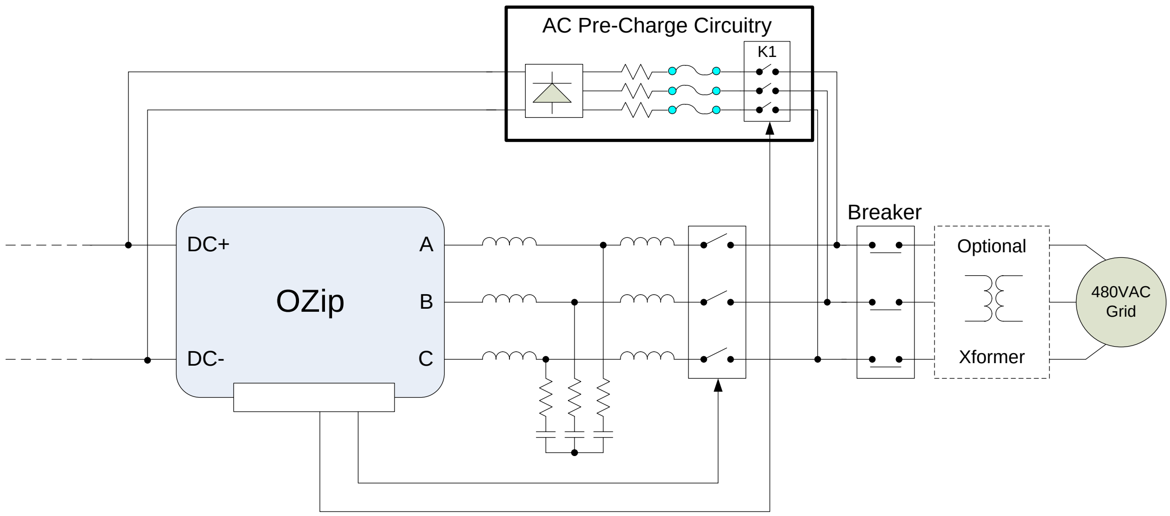


Figure 4 – AC Pre-charge Example

For typical grid-tied inverter applications where the inverter is simply moving current or power between the DC link and the grid, and an external DC source will be attached to the DC link, it may be desirable or necessary to charge the OZip's internal DC link to match the external DC source prior to making the DC connection. Figure 5 below shows an example of a *passive* inverter-controlled pre-charge circuit where the DC input is fed through a small pre-charge contactor and current limiting resistor to the DC link. Once the inverter detects that the DC link has charged up to the DC input voltage, it will then open the pre-charge contactor and safely close the main DC input contactor. Alternatively, an active circuit may be employed to charge the DC link to the input voltage using the 24V bias supply.

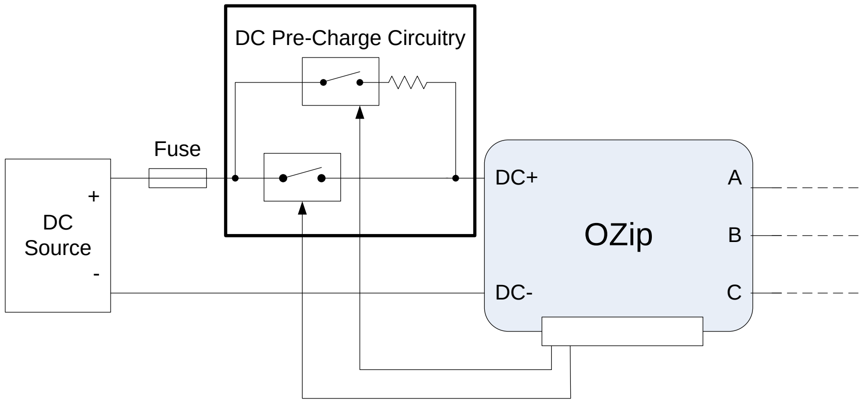


Figure 5 – DC Pre-charge Example

CAUTION

When charging the inverter's DC link up to an external DC source input voltage, the DC source must provide a voltage greater than the rectified AC grid voltage for proper inverter operation. Otherwise, the inverter will prevent connecting to the AC grid and will remain inoperable.

2.2 Control Interface

The primary method for configuring and controlling the inverter is through the OZip's serial interface (CAN or RS-485, depending on the selected OZip model). 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.

The user may optionally use the dedicated *On/Off* hardware pin to turn the inverter ON or OFF if this pin has been enabled in ***PID 0x8061 – Hardware On/Off Pin Enable***. When the hardware *On/Off* pin is enabled, the soft ***PID 0x0000 – On/Off*** command is ignored and only the hardware pin is used. Likewise, when the hardware pin is not enabled, it is ignored and only the soft *On/Off* command is recognized.

2.3 Operating Modes

The inverter provides three main modes of operation:

1. **DC Voltage Control** - the DC link voltage is regulated to the user-defined value
2. **Grid Current Control** - real and reactive current to/from the grid is controlled to the user-defined set points
3. **Grid Power Control** - real and reactive power to/from the grid is controlled to the user-defined set points

Figure 6 presents a simplified block diagram of the control scheme employed by the inverter firmware. For typical AFE applications, the inverter regulates the DC link voltage using a standard proportional and integral (PI) controller. The commanded reference to this PI controller is the desired DC link voltage as specified by the user in ***PID 0x811E – DC Voltage Command***. The PI controller compares this reference to the measured DC link voltage and generates the real current command to the inner current loops.

For the inner current loop, PI controllers are used to control both the real and reactive current components using current feedback calculated from the three phase current measurements (I_a, I_b, I_c). The current controllers are implemented in the voltage-oriented synchronous DQ reference frame. A digital phase locked loop (PLL) is used to synchronize to the AC line voltage and provide a phase reference needed to transform to/from the DQ reference frame. The outputs of the real and reactive PI regulators generate a desired inverter voltage output needed to achieve the commanded currents. A third PI controller may be optionally used to control the zero sequence current to zero. This is particularly useful for avoiding DC current offsets on the inverter output when multiple OZip inverters are connected in parallel.

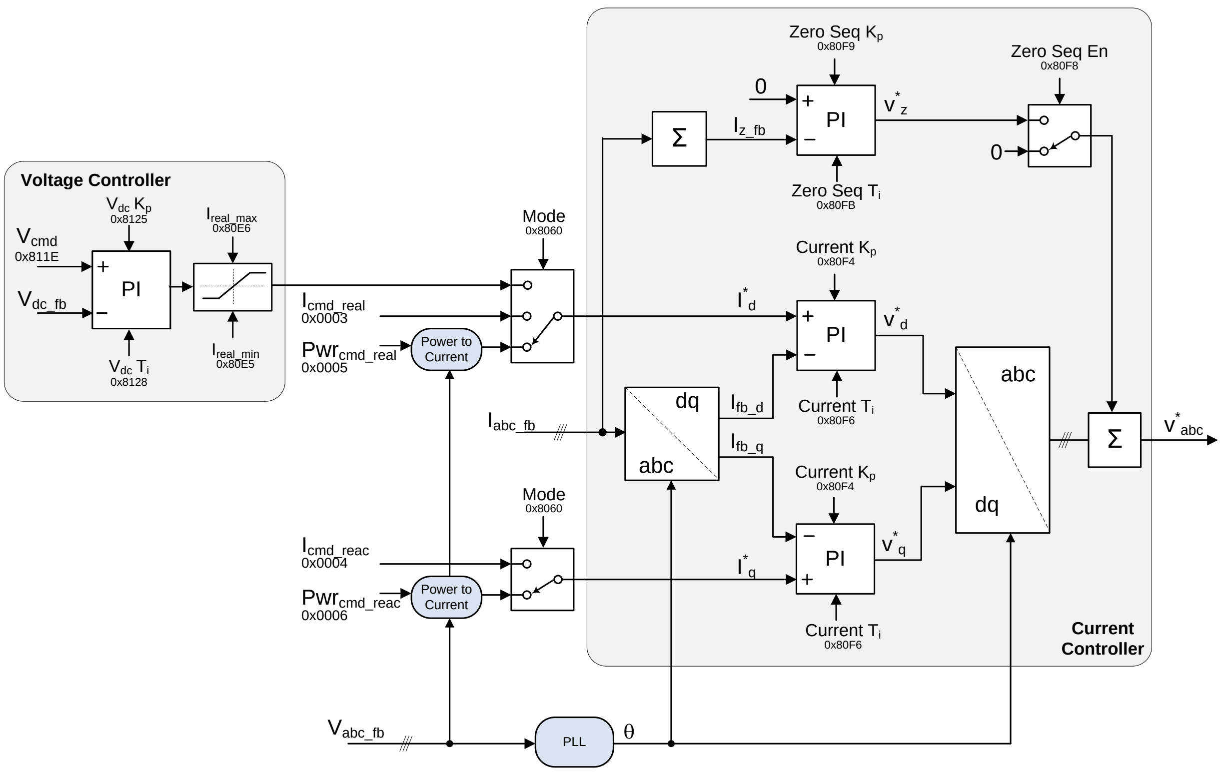


Figure 6 – Inverter Control Software Functional Block Diagram

For typical grid tie applications, the inverter is used to simply control the real and reactive current or power to or from the grid. In this case, the outer voltage controller is not used and an external source is responsible for controlling the DC link. In Grid Current Control mode, the user can directly command the real and reactive grid current references to the inverter's current controller as shown in Figure 6 above. In Grid Power Control mode, the inverter uses the real and reactive power commands provided by the user, along with the measured grid voltages to determine the appropriate real and reactive grid current commands.

CAUTION

Operation in Grid Current or Power Control modes assumes there is an external means to control the DC link voltage. DC link voltage control is required when commanding current or power into the inverter. Otherwise the DC link voltage will likely rise to high over-voltage conditions on the DC link, causing the inverter to trip off and become inoperable.

2.4 External Temperature Sensor

The OZip inverter hardware provides a 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 by the user. When enabled, this temperature input may be monitored by reading ***PID 0x4014 – External Temperature***. It may also be configured to generate a high temperature warning and/or an over-temperature fault shutdown event if desired (see section 4.4.12 - *External Temperature Sensor Parameters* 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 thermistors in the range of 1kΩ to 10kΩ with beta constants between 3500K and 3900K.

2.5 State Sequencing

A state machine is used to provide deterministic control and sequencing of the inverter hardware. Figure 7 illustrates the operating states as well as the transition logic employed in the system state machine. Each state is then described in further detail below. As Figure 7 below illustrates, the inverter is disabled and the power stage hardware will be inoperable until the inverter reaches the ***Standby*** state. Any attempts to turn the inverter ON, either with ***PID 0x0000 – On/Off Control***, or with the optional ON/OFF hardware pin control, will be ignored until the inverter reaches the ***Standby*** state.

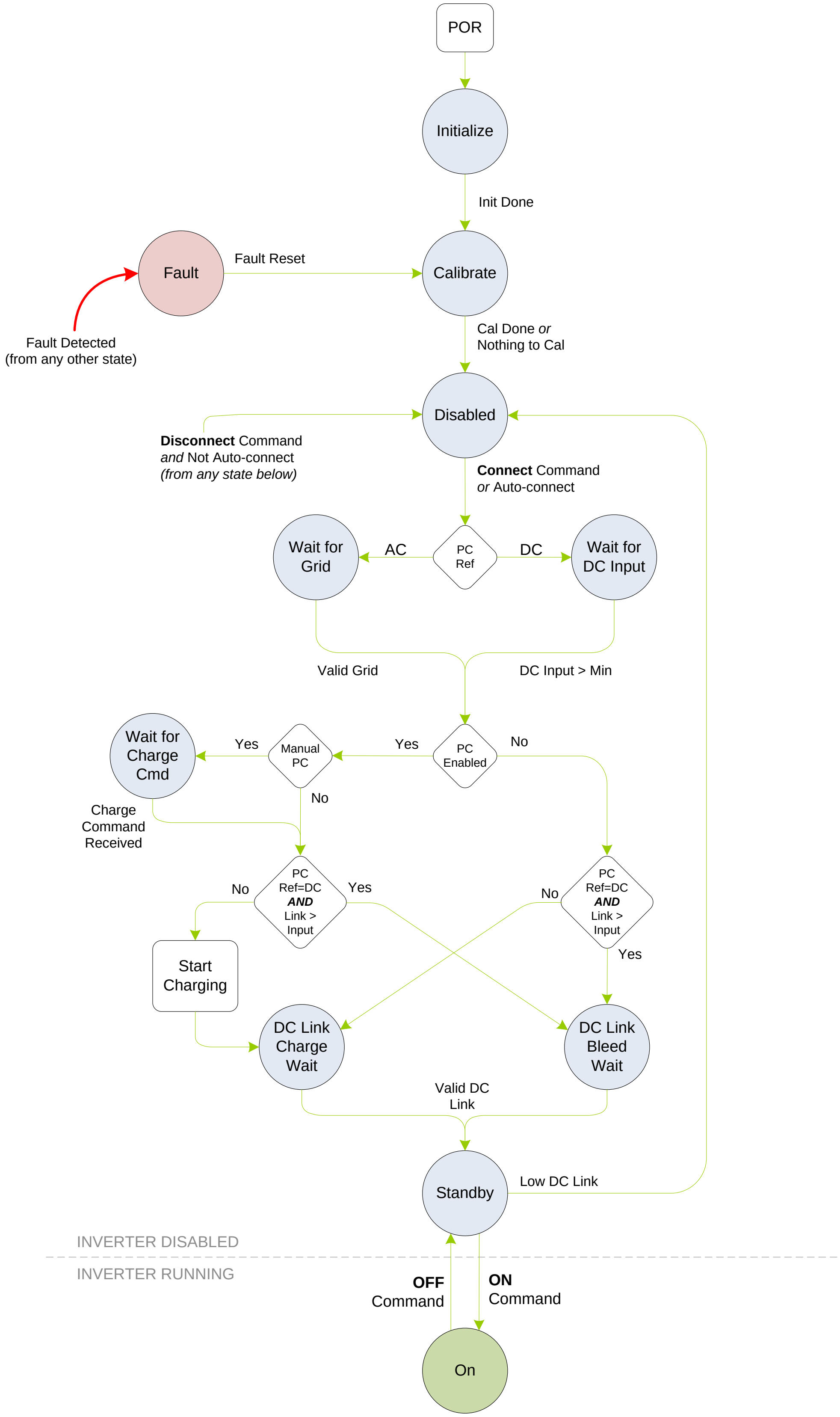


Figure 7 – Inverter Control State Machine

2.5.1 Initialize

The state machine resets to the ***Initialize*** state following a power-on-reset (POR) event. The firmware is initializing hardware peripherals, configuring variables, and performing self-health tests while in this state. Upon successful initialization, the inverter will auto-transition to the ***Calibrate*** state.

2.5.2 Calibrate

The ***Calibrate*** state is used to calibrate the inverter controller's internal analog-to-digital converter (ADC) at power up. Following successful calibration, or if no calibration is necessary because it has already been performed, the inverter will then transition to the ***Disabled*** state.

2.5.3 Disabled

The inverter will wait in this state until a connect command is sent by the user using ***PID 0x0001– Connect Control***. Alternatively, if ***PID 0x8064 – Auto Connect Enable*** is set to true, no connect command is needed by the user and the inverter will automatically transition to the next state. When transitioning out of this state, the inverter will go to the ***Wait for Grid*** state or ***Wait for DC Input*** state based on ***PID 0x8081 – DC Link Pre-charge Reference***.

When operating in any state downstream from this ***Disabled*** state, the inverter will transition back to this state if ***PID 0x8064 – Auto Connect Enable*** is set to false *AND* a disconnect command is sent by the user using ***PID 0x0001– Connect Control***. If Auto-Connect is enabled, disconnect commands from the user are ignored. When transitioning back to the ***Disabled*** state, the controller will handle turning off the inverter, opening contactors, disabling pre-charge, etc, as necessary.

2.5.4 Wait for Grid

The inverter waits in this state until a valid grid connection is detected per the voltage and frequency tolerances specified in ***PIDs 0x802A – 0x8036***. Once the sensed grid is within tolerance, the inverter then uses ***PID 0x8080 – DC Link Pre-Charge Mode*** to determine if it should start charging the local DC link, transition to the ***Wait for Charge Command***, or transition to the ***DC Link Charge Wait*** state.

2.5.5 Wait for DC Input

The inverter waits in this state until adequate DC voltage is present on the DC input. The inverter will remain in this state until the sensed DC input voltage is above the value specified in ***PID 0x8047 – DC Link Under Voltage Warning Threshold***. Once adequate DC voltage is present, the inverter then uses ***PID 0x8080 – DC Link Pre-Charge Mode*** to determine if it should start charging the local DC link, transition to the ***Wait for Charge Command***, or transition to one of the ***DC Link Charge Wait*** or ***DC Link Bleed Wait*** states.

2.5.6 Wait for Charge Command

The inverter will wait in this state until a charge command is sent by the user using ***PID 0x0002 – Charge Command***, indicating that it is OK to begin the DC link pre-charge process. Once the charge command is received, the inverter starts charging immediately and will transition to the ***DC Link Charge Wait*** state. If the charge reference is set to the *DC Input* and the DC link voltage happens to be greater than the DC input, the inverter does not perform pre-charge, and instead will transition to the ***DC Link Bleed Wait*** state.

2.5.7 DC Link Charge Wait

The inverter waits in this state until the local DC link has been charged to an appropriate level as determined by ***PID 0x8081 – DC Link Pre-charge Reference***. If the pre-charge reference is set to the AC grid, then the inverter will wait in this state until the DC link voltage is near or above the rectified AC grid voltage. If the reference is set to the DC input, the inverter will wait until the DC link voltage matches the DC input voltage (within approximately 15V). Once the DC link has reach an acceptable level, the inverter will transition to the ***Standby*** state. During this transition, the inverter will close the contactor on either the AC or DC side (or both) based on the behavior specified in ***PIDs 0x8084-0x8085 – AC/DC Contactor Action***.

If ***PID 0x8080 – DC Link Pre-Charge Mode*** is set to *Disabled*, the inverter will wait in this state until some external resource brings the DC link up to the appropriate level.

While in this state, the DC link must charge within the time specified by ***PID 0x8082 – DC Link Charge Timeout***. If the timeout period is reached and the DC link has not finished charging, the pre-charge function will be turned OFF (if enabled) and the inverter will transition to the ***Fault*** state. This timeout fault checking can be disabled by setting the timeout value to zero.

Although it is not explicitly shown in the state diagram, if the charge reference (either the AC grid voltage or the DC input) is no longer valid, the inverter will turn off the pre-charge function (if enabled) and go back to the respective ***Wait for Grid*** or ***Wait for DC Input*** state until the reference is once again valid. The charge timeout timer is also reset in this case so that the next pre-charge attempt has the full timeout period to attempt charging again.

2.5.8 DC Link Bleed Wait

This state is used if ***PID 0x8081 – DC Link Pre-charge Reference*** is set to the *DC Input* and the DC link voltage happens to be greater than the DC input voltage. In this scenario, the DC link does not require pre-charging. Instead, the inverter will wait in this state until the DC link voltage bleeds down and matches the DC input voltage (i.e. safe to close the DC contactor if enabled). When the two voltages match (within approximately 15V), the inverter will transition to the ***Standby*** state. During this transition, the inverter will close the contactor on either the AC or DC side (or both) based on the behavior specified in ***PIDs 0x8084-0x8085 – AC/DC Contactor Action***.

While in this state, the DC link must bleed down within the time specified by ***PID 0x8083 – DC Link Bleed Timeout***. If the timeout period is reached and the DC link has not finished discharging, the inverter will transition to the ***Fault*** state. This timeout fault checking can be disabled by setting the timeout value to zero.

Although it is not explicitly shown in the state diagram, if the DC input is no longer valid, the inverter will go back to the ***Wait for DC Input*** state until the input is once again valid.

2.5.9 Standby

Once in the ***Standby*** state the inverter is ready for use. If a fault occurs while waiting in this state, the inverter will open any enabled contactors and transition to the ***Fault*** state. If the charge reference is set to the DC input and the DC link drops below the ***PID 0x8047 – DC Link Under Voltage Warning Threshold***, or if the charge reference is set to the AC grid voltage and the DC link drops below the minimum acceptable rectified line voltage based on ***PID 0x8031 – Grid Slow Under-Voltage Threshold***, the inverter will open any enabled contactors and go back to the ***Disabled*** state. Otherwise, the inverter will wait in this state indefinitely until the user sends a turn-on command (either with ***PID 0x0000 – On/Off Control*** or with the hardware ON/OFF pin if enabled), at which point it will inverter will turn ON and transition to the ***On*** state.

2.5.10 On

While in the ***On*** state the inverter is processing power and controlling either the AC line current/power or the DC link voltage depending on the configuration (***PID 0x8060 – Control Mode)***. If a fault occurs while in this state, the inverter will immediately turn OFF, open any enabled contactors, and transition to the ***Fault*** state. Otherwise, the inverter will remain in this state indefinitely until a turn-off command is received (either with ***PID 0x0000 – On/Off Control*** or with the hardware ON/OFF pin if enabled), at which point the inverter will quickly ramp the inverter current down to zero, turn OFF, and transition to the ***Standby*** state.

2.5.11 Fault

If a fault is detected in any of the operating states, the power stage is immediately turned OFF (if running), any enabled contactors will be opened, and the inverter will transition to the ***Fault*** state. The inverter will remain in this state until the latched fault information is explicitly cleared using ***PID 0x0003 – Fault Reset*** or a rising edge is detected on the FLT_RST hardware pin (if enabled in ***PID 0x8063 – Hardware Fault Reset Pin Enable***). If any fault conditions still exist when the fault reset occurs, the inverter will remain in the ***Fault*** state. All attempts to turn the inverter ON are ignored while in the ***Fault*** state.

The only exception to the above description is if ***PID 0x803E – Grid Fault Auto-Reconnect Enable*** is set to TRUE. If the only fault condition(s) that has occurred is a grid voltage or frequency tolerance fault (see section 4.4.4 – *Grid Monitor and Protection Parameters*), and the grid comes back within the specified tolerance for a period greater than ***PID 0x803F – Grid Reconnect Delay Time***, the grid faults will be automatically cleared and the inverter will go back to the ***On*** state if the inverter On/Off command was left ON by the user.

If grid fault auto-reconnect is not enabled, or if the inverter was subsequently turned OFF, and the faults are successfully cleared by the user, the inverter will transition back to the ***Calibrate*** state.

2.6 Fault and Warning Conditions

The inverter 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 inverter are listed and described in the following sections.

2.6.1 Warnings

The inverter provides the warning indicators listed below. These warning conditions do not prohibit operation of the inverter; they are merely reported for informational purposes only. Each warning condition described below is reported in ***PID 0x4015 – Warning Status*** and is also reported on the CAN bus in the Warning Alarm Status message (see FS-0091 – *OZip AFE/GTI Inverter OzCAN Message Profile*).

2.6.1.1 DC Link High Voltage

The inverter monitors the DC link voltage and will set a warning flag if it exceeds the value in ***PID 0x8045 – DC Link Over Voltage Warning Threshold***. This flag will remain set until the voltage falls below the warning threshold minus the delta amount specified in ***PID 0x8052 – DC Link Over Voltage Warning Recover Delta***.

2.6.1.2 DC Link Low Voltage

The inverter monitors the DC link voltage and will set a warning flag if it falls below the value in ***PID 0x8047 – DC Link Under Voltage Warning Threshold***. This flag will remain set until the voltage rises above the warning threshold plus the delta amount specified in ***PID 0x8053 – DC Link Under Voltage Warning Recover Delta***.

2.6.1.3 DC Link Under Voltage

The inverter checks for DC link under voltage fault conditions as described in the next section. However, the under voltage fault is only triggered if the DC link is too low while the inverter is ON. This warning is used to indicate that DC link is below the fault threshold specified in ***PID 0x8046 – DC Link Under Voltage Fault Threshold***, regardless of whether the inverter is actually ON or OFF.

2.6.1.4 High Inverter Current

The inverter monitors the RMS inverter currents for each of the three phases and will set a flag (one per phase) if the current exceeds the value specified in ***PID 0x8049 – Grid Over Current***

Warning Threshold. These flags remain set until the respective current falls below the warning threshold minus the delta value specified in ***PID 0x8054 – Grid Over Current Warning Recover Delta***.

2.6.1.5 Grid Frequency Out of Tolerance

The inverter monitors the AC line and will set a warning flag if the frequency is not within the tolerances specified in ***PIDs 0x8034-0x8036 – Grid Fast/Slow Over/Under Frequency Thresholds***. The warning flag will be cleared once the grid frequency is within the required limits.

2.6.1.6 Grid Voltage Out of Tolerance

The inverter monitors the three RMS phase-to-phase AC line voltages and will set a warning flag (one per phase-to-phase voltage) if the voltage is not within the tolerances specified in ***PIDs 0x8030-0x8033 – Grid Fast/Slow Over/Under Voltage Thresholds***. The warning flags are cleared once the associated voltage is within the required limits.

2.6.1.7 High Grid Voltage

The inverter monitors the three RMS phase-to-phase AC line voltages and will set a warning flag (one per phase-to-phase voltage) if the voltage exceeds the value specified in ***PID 0x804B – Grid Over Voltage Warning Threshold***. These flags remain set until the respective voltage falls below the warning threshold minus the delta value specified in ***PID 0x8055 – Grid Over Voltage Warning Recover Delta***.

2.6.1.8 High Inverter Temperature

The OZip power module provides temperature sensors at the IGBT modules for each of the AC phases. The inverter monitors these temperatures and will set a warning flag if any exceed 110°C. These warning flags will remain set until the temperature(s) fall below 105°C.

2.6.1.9 High PCB Temperature

The OZip power module provides a temperature sensor on the internal controller PCB. The inverter monitors this temperature and will set a warning flag if it exceeds 85°C. This warning flag will remain set until the temperature falls below 80°C.

2.6.1.10 High External Temperature

If ***PID 0x80BC – External Thermistor Enable*** is set to TRUE, the inverter will monitor the external temperature and will set a warning flag if it exceeds the value specified in ***PID 0x80C4 – External Temperature Warning Threshold.*** This flag will remain set until the temperature falls below the warning threshold minus the delta value specified in ***PID 0x80C5 – External Temperature Warning Recover Delta***.

2.6.1.11 PLL Not Locked

The inverter monitors the status of the internal phase lock loop (PLL) module that is providing synchronization to the AC line and will set a warning flag if the PLL is not locked. This flag is cleared when the PLL regains lock.

2.6.1.12 Local Bias Supply Tolerance Warnings

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

2.6.2 Faults

The inverter provides the fault detection listed below. Whenever a fault occurs the inverter will automatically turn the power stage hardware OFF, open any contactors that may be enabled (see ***PIDs 0x8084-0x8085 – AC/DC Contactor Action***), and transition to the ***Fault*** state. Any attempt to turn the inverter ON while it is in the ***Fault*** state will be ignored. Each fault condition is latched and reported in ***PIDs 0x4016/0x4017 – Fault Status Word 0/1*** and is also reported on the CAN bus in the Fault Alarm Status message (see FS-0091 – *OZip AFE/GTI Inverter OzCAN Message Profile*). The inverter also indicates the presence of a fault condition by asserting the dedicated FLT_OUT hardware pin any time one or more latched fault bits are present.

The inverter will remain in the ***Fault*** state and any latched fault flags remain set until explicitly cleared using ***PID 0x0003 – Fault Reset*** or a rising edge is detected on the FLT_RST hardware pin (if enabled in ***PID 0x8063 – Hardware Fault Reset Pin Enable***). Upon receiving the fault reset command, the inverter will attempt to clear all latched fault bits. It then examines the sources of all fault conditions and if none are active the inverter will either transition back to the ***Calibrate*** state or the ***Wait for DC Input*** state depending on whether or not the firmware had finished executing its power-on calibration routines. If upon re-examination any sources of faults are still active, their respective fault flags will remain latched and the inverter will remain in the ***Fault*** state.

The inverter may be optionally configured to automatically recover from grid voltage and frequency faults and turn back ON (if previously enabled) as described in ***PID 0x803E – Grid Fault Auto-Reconnect Enable***.

2.6.2.1 Inverter Hardware Faults

The inverter software, along with the OZip power state hardware, provides a means for recognizing hardware-based IGBT de-saturation and gate drive faults. These two hardware fault conditions are detected and latched separate for each of the three AC phases.

2.6.2.2 Hardware DC Link Over-Voltage

The inverter software, along with the OZip power stage hardware, provides a means for detecting and reporting a hardware-based DC link over-voltage fault condition. See the OZip hardware manual for the model being used to determine the over-voltage fault trip threshold.

2.6.2.3 DC Link Over-Voltage

The inverter monitors the measured DC link voltage and will assert a fault if it exceeds the value specified in ***PID 0x8044 – DC Link Over Voltage Fault Threshold***.

2.6.2.4 DC Link Under-Voltage

The inverter monitors the measured DC link voltage and will assert a fault if it drops below the value specified in ***PID 0x8046 – DC Link Under Voltage Fault Threshold***. This fault is only generated if the inverter is ON.

2.6.2.5 Software Inverter Over-Current

The inverter monitors the RMS current for each of the three AC phases and asserts a fault if any exceed value specified in ***PID 0x8048 – Grid Over Current Fault Threshold***.

2.6.2.6 Grid Frequency Fault

The inverter measures the AC line frequency and will assert a fault if exceeds the tolerances specified in ***PIDs 0x8034-0x8036 – Grid Fast/Slow Over/Under Frequency Thresholds*** for the durations specified in ***PIDs 0x803B-0x803D – Grid Frequency Fault Clear Times***. This fault is only generated if the inverter is ON or if an attempt is made to turn it ON while the frequency is out of tolerance. Otherwise, this condition is only reported as a warning.

2.6.2.7 Grid Voltage Fault

The inverter monitors the three RMS AC phase-to-phase line voltages and will assert a fault if any of these voltages are not within the tolerances described in ***PID 0x8030-0x8033 – Grid Fast/Slow Over/Under Voltage Threshold*** for the durations specified in ***PIDs 0x8037-0x803A – Grid Voltage Fault Clear Times.*** These faults are only generated if the inverter is ON or if an attempt is made to turn it ON while the voltage is out of tolerance. Otherwise, these are only reported as warning conditions.

2.6.2.8 Grid Over-Voltage Fault

The inverter monitors the three RMS AC phase-to-phase line voltages and will immediately assert a fault if any of rise above the value specified in ***PID 0x804A – Grid Over Voltage Fault Threshold.*** These faults are only generated if the inverter is connected to the AC line (i.e. AC contactor is closed). Otherwise, these are only reported as warning conditions.

2.6.2.9 Inverter Over-Temperature

The firmware monitors the IGBT module temperatures in the inverter power stage and will assert a fault if any exceed 115°C.

2.6.2.10 PCB Over-Temperature

The firmware monitors the temperature on the inverter’s internal control PCB and will assert a fault if it exceeds 90°C.

2.6.2.11 External Over-Temperature

If ***PID 0x80BC – External Thermistor Enable*** is set to TRUE, the inverter will monitor the external temperature sensor and assert a fault if the temperature exceeds the value specified in ***PID 0x80C3 – External Temperature Fault Threshold***.

2.6.2.12 Hardware Interlock

If the hardware interlock pin is enabled in ***PID 0x8062 – Hardware Interlock Pin Enable***, the inverter will assert a fault if the ILOCK hardware pin is driven low or unconnected. If this pin is not enabled, or if it is driven high, no hardware interlock faults will be generated. This pin is typically tied to the inverter's 24V supply through an emergency stop (ESTOP) switch or a contactor controlled by the system's master controller.

2.6.2.13 DC Input Error

If the use of a DC contactor has been enabled (***PID 0x8081 – DC Link Pre-charge Reference*** is set to *Charge to DC Input* and ***PID 0x8084-0x8085 – AC/DC Contactor Action*** is not set to *None*), the inverter will monitor the voltages at the DC input and the local DC link. If the two ever differ by more than 25V when the contactor is supposed to be closed, the inverter will assert a fault.

2.6.2.14 AC/DC Contactor Error

If one or both of the contactor feedback monitors have been enabled in ***PID 0x808A – Contactor Monitor Enables***, the inverter will continuously compare the state of the contactor feedback status against the commanded contactor states and will assert a fault if they ever differ.

2.6.2.15 DC Link Charge Timeout Error

The inverter monitors the amount of time spent in the ***DC Link Charge Wait*** state. A fault will be asserted if the elapsed time exceeds the value specified in ***PID 0x8082 – DC Link Charge Timeout***.

2.6.2.16 DC Link Bleed Timeout Error

The inverter monitors the amount of time spent in the ***DC Link Bleed Wait*** state. A fault will be asserted if the elapsed time exceeds the value specified in ***PID 0x8083 – DC Link Bleed Timeout***.

2.6.2.17 AC/DC Contactor Interlock Error

The inverter's contactor controller provides an interlock feature that protects against closing a contactor under potentially hazardous scenarios. Prior to closing the AC contactor, the firmware compares the measured DC link voltage against the calculated rectified AC voltage. If the DC link voltage is less than the rectified AC voltage, the firmware will not attempt to close the contactor, and will instead assert an AC contactor interlock error. This could occur if the pre-charge reference is set to the DC Input, the link has charged to a value that matches the specified valid DC input level, and this value is less than that needed to connect to the grid (i.e. less than the rectified grid voltage).

Similarly, if a DC contactor has been enabled (***PID 0x8084 – DC Contactor Action*** is not *None*), prior to closing this contactor, the firmware will compare the measured DC input voltage against the measured local DC link voltage, and if the two do not match, it will assert a DC contactor interlock error rather than closing the contactor. This scenario should be rare, since the DC contactor is intended to be used only when the inverter needs to charge the DC link to match an external DC source (i.e. ***PID 0x8081 – DC Link Pre-charge Reference*** is set to *Charge to DC Input*), in which case the inverter would only attempt to close the contactor after a successful pre-charge operation.

2.6.2.18 PLL Lost Lock

The inverter monitors the status of the internal phase lock loop (PLL) module that is providing synchronization to the AC line. A fault is asserted if the PLL loses lock while inverter is ON or when an attempt is made to turn the inverter ON when the PLL is not locked.

2.6.2.19 Communications Error

This fault will be asserted if ***PID 0x0008 – Host Heartbeat*** hasn't incremented by 1, or been reset to zero, within ***PID 0x804C – Host Heartbeat Timeout***. This fault check can be disabled by setting the Host Heartbeat Timeout to 0.

2.6.2.20 Configuration Memory Error

This fault occurs any time a read from the inverter'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 0x0003 – Fault Reset*** or the FLT_RST hardware pin because this fault condition indicates the possibility that the inverter'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 - *Oztek Power Studio™ Tool*). If the error persists after attempting both of these actions, there may be an issue with the inverter'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.

2.6.2.21 Calibration Error

This error is asserted if the inverter is unable to perform any required internal calibrations when powering up. There is likely an issue with the inverter's internal control board hardware if this error occurs. 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.

2.6.2.22 Invalid Factory Configuration

The inverter stores certain key factory parameters such as the OZip IPM model number, serial number, inverter model information, and factory-calibrated current sensor offsets in a local non-volatile memory. This information is programmed at the factory at the time that the unit is manufactured. This error is asserted to indicate that the factory data is invalid, either because it was not properly programmed or has been corrupted. If this error 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.

2.6.2.23 Invalid OZip Model

Using the firmware download features in the Oztek Power Studio™ tool (see section 5), the inverter's software and default configuration parameters may be upgraded in the field. When a new configuration parameter set is loaded into the inverter, it will contain information regarding the specific OZip IPM model that the configuration file was intended to work with. If the OZip IPM model information does not match the actual OZip IPM model information stored in the factory configuration registers, the inverter will assert this error, indicating that the default, minimum, and maximum configuration parameter values are not appropriate for the OZip IPM model being used. If this error should occur, contact Oztek for assistance with diagnosing the cause.

2.6.2.24 Invalid Inverter Model

This is similar to the previous error; when a new configuration parameter set is loaded into the inverter, it will contain information regarding the specific inverter model that the configuration file was intended to work with. If the inverter model information does not match the actual inverter model information stored in the factory configuration registers, the inverter will assert this error, indicating that the default, minimum, and maximum configuration parameter values are not appropriate for the inverter hardware being used. If this error should occur, contact Oztek for assistance with diagnosing the cause.

3. Hardware Interface

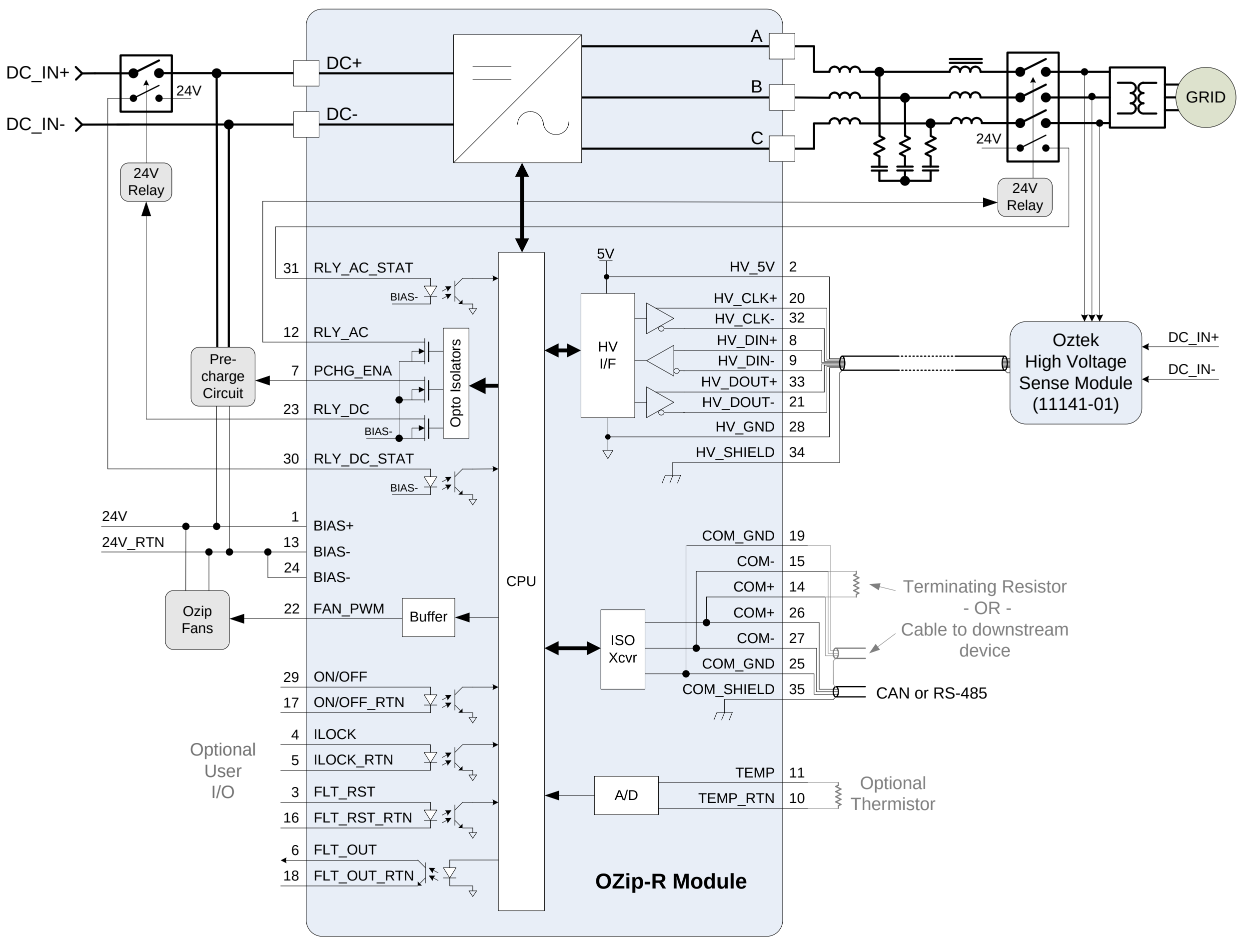


Figure 8 – Hardware Connections Overview

3.1 Control Signal Wiring

Bias voltage and control signal connections are made using a 35-pin AMPSEAL connector. The figure below shows the pin orientation for this connector. This is followed by a table with the specific pin assignments and descriptions. Reference UM-0055 - *OZip-R Intelligent Power Module Hardware User's Manual* for detailed electrical specifications.

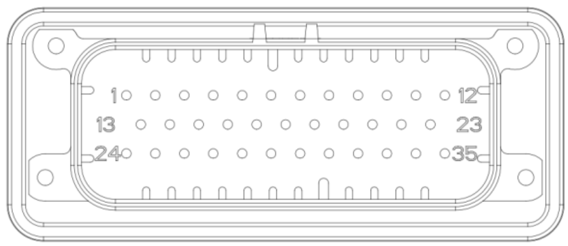


Figure 9 – Control Signal Connector Pin Orientation

Table 1 – Control Interface Pin Descriptions

Pin	Signal	Description
1	BIAS+	Input bias voltage
2	HV_5V	5V supply to high voltage sense interface
3	FLT_RST	Fault Reset – when enabled (***PID 0x8063***) a low-to-high transition on this isolated input pin will attempt to clear any latched fault conditions ①
4	ILOCK	Hardware Interlock (emergency stop) – when enabled (***PID 0x8062***) and this isolated pin is low or unconnected, the inverter is forced into the ***Fault*** state and immediately turned OFF ①
5	ILOCK_RTN	Hardware Interlock Return①
6	FLT_OUT	Fault Output – this isolated open-collector output is driven low any time the inverter is in the ***Fault*** state, otherwise it will be undriven (high impedance)
7	PCHG_ENA	Pre-charge Enable – when enabled (***PID 0x8080***) this low side inductive load driver output is used to control local DC link pre-charge hardware
8	HV_DIN+	Differential data inputs from the high voltage sense interface
9	HV_DIN-	
10	TEMP_RTN	Thermistor temperature sensor return ①
11	TEMP	Thermistor temperature sensor ①
12	RLY_AC	AC Relay Control – this low side inductive load driver output is used to control an AC contactor that interfaces to the grid
13	BIAS-	Input bias voltage return
14	COM+	Redundant serial interface connections - used for daisy-chained connections to other devices if this unit is not at the end of the bus or for connecting termination resistor if this is the end of the bus
15	COM-	
16	FLT_RST_RTN	Fault Reset Return ①
17	ON/OFF_RTN	On/Off Return ①
18	FLT_OUT_RTN	Fault Output Return ①

Pin	Signal	Description
19	COM_GND	Isolated serial interface ground reference
20	HV_CLK+	Differential "+" clock output to the high voltage sense interface
21	HV_DOUT-	Differential "-" data output to the high voltage sense interface
22	FAN_PWM	OZip pulse width modulated fan control output – connect to fan interface on OZip module if present ①
23	RLY_DC	DC Relay Control – this low side inductive load driver output is used to control an optional DC contactor ①
24	BIAS-	Input bias voltage return
25	COM_GND	Isolated serial interface ground reference
26	COM+	Isolated differential serial interface (can be either CAN or RS-485 depending on OZip model)
27	COM-	
28	HV_GND	Ground reference to high voltage sense interface
29	ON/OFF	On/Off – when enabled (***PID 0x8061***), driving this isolated input high will attempt to turn the inverter ON and low or disconnected will turn the inverter OFF ①
30	RLY_DC_STAT	DC Relay Status Input – when enabled (***PID 0x808A***), this pin should be tied to an auxiliary normally-open contact on the DC contactor with the other side tied to BIAS+ to indicate the actual state of the DC contactor ①
31	RLY_AC_STAT	AC Relay Status Input – when enabled (***PID 0x808A***), this pin should be tied to an auxiliary normally-open contact on the AC contactor with the other side tied to BIAS+ to indicate the actual state of the AC contactor ①
32	HV_CLK-	Differential "-" clock output to the high voltage sense interface
33	HV_DOUT+	Differential "+" data output to the high voltage sense interface
34	HV_SHIELD	Chassis ground connection for high voltage sense cable shield
35	COM_SHIELD	Chassis ground connection for CAN/RS-485 cable shield

① Can be left unconnected if not used

3.2 Serial Communications

The OZip is available with either a CAN or RS-485 isolated serial interface, depending on which model is being used. 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. For details on the specific CAN messages and Modbus registers implemented in the inverter firmware, reference FS-0091 and FS-0092 respectively.

To allow for easy daisy chaining of multiple OZips or termination of the serial network, redundant serial interface pins have been provided. Figure 10 illustrates how to use the pins to daisy chain multiple OZips on a single multi-drop network (CAN or RS-485), as well as proper termination of the end nodes on the network. Termination resistors are typically **120Ω** for CAN bus and **100Ω** for RS-485 based on typical cable impedances and drivers used for each.

CAUTION

If the inverter is located at the end of the serial bus, a termination resistor ***must*** be connected for reliable bus operation.

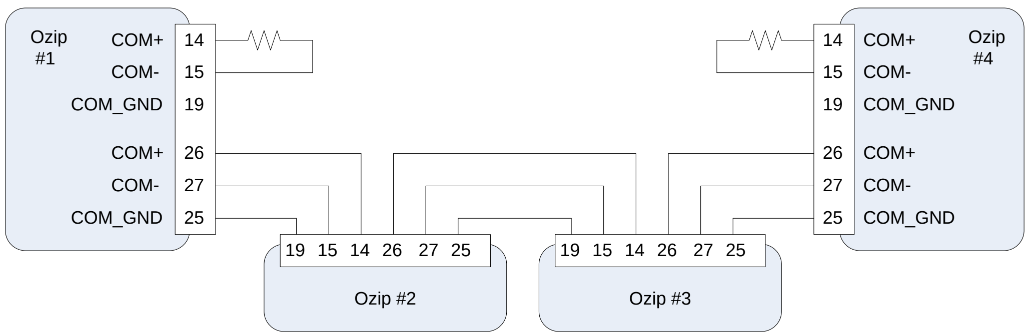


Figure 10 – Serial Interface Daisy Chain and Termination

3.3 High Voltage Sense Module

The OZip AFE/GTI inverter requires the use of Oztek's High Voltage Sense module (11141-01) as shown in Figure 8. This module provides isolated high voltage measurement circuits that are capable of measuring both the AC grid-side voltages as well as an external DC bus voltage (optional). The OZip inverter's control interface is designed to directly connect to the low-voltage serial interface on the High Voltage Sense module.

CAUTION

If a DC contactor is not present, the DC inputs to the High Voltage Sense module ***must*** be connected to the DC link of the OZip module for proper operation.

3.4 DC Link Pre-charge Circuit

As described in section 2.1 – *DC Link Pre-Charge*, the inverter provides features to control charging the local DC link up to the rectified AC grid voltage or up to an external DC bus voltage when a DC contactor is employed. The pre-charge function is controlled using the PCHG_ENA low side driver switch output. The pre-charge circuit may be an active circuit that charges the link from the 24V bias supply as shown in Figure 8 above. Alternatively, a passive charging scheme may be employed using a charging resistor and a relay/contactor to either the rectified AC grid voltage or the external DC bus.

4. Parameter Register Interface

The inverter 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 by the control software:

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

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 inverter is ON, writes to any parameter without this indicator will be ignored if the inverter is ON

4.2 Command Registers

Table 2 – Command Register Set

PID	Data Type	Description	Units	Min	Max	Access Level
0x0000	U16	On/Off Control	ENUM	0	1	RWO
0x0001	U16	Connection Control	Boolean	0	1	RWO
0x0002	U16	Charge Command	ENUM	0	1	RW
0x0003	U16	Fault Reset	ENUM	0	1	RW
0x0004	S16	Grid Current, Real	0.1 A_{rms}	①	①	RWO
0x0005	S16	Grid Current, Reactive	0.1 A_{rms}	①	①	RWO
0x0006	S16	Grid Power, Real	0.1 kW	①	①	RWO
0x0007	S16	Grid Power, Reactive	0.1 kvar	①	①	RWO
0x0008	U16	Host Heartbeat	Integer	0	65535	RWO
0x0009	U16	Restore Default Configuration	Integer	0	65535	RW

① See parameter descriptions below for allowable Min/Max values

PID 0x0000 On/Off Control

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

0 = OFF - This turns the inverter OFF
1 = ON - This turns the inverter ON

If ***PID 0x8061 - Hardware On/Off Pin Enable*** is set to TRUE, this command register will be ignored. Instead, the inverter is turned ON or OFF using the dedicated ON/OFF hardware pin.

PID 0x0001 Connect Control

This register is used to control when the inverter is connected or disconnected to the AC and DC bus interfaces as follows:

0 = DISCONNECT – This causes the inverter to shut down and disconnect
1 = CONNECT – This instructs the inverter to attempt to connect once the AC and DC bus voltages are valid.

If ***PID 0x8064 – Auto-Connect Enable*** is set to TRUE, this command register will be ignored.

PID 0x0002 Charge Command

This register is used to issue a manual charge command to the inverter to initiate the DC link pre-charge process. This command is only used when the inverter is in the ***Wait for Charge Command*** state, otherwise this command will be ignored. Legal registers values are as follows:

0 = NOP - No charge action requested
1 = CHARGE - Start charging the DC link

PID 0x0003 Fault Reset

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

0 = NOP - No reset action requested
1 = RESET - Attempt a fault reset

PID 0x0004 Grid Current, Real

This register sets the desired real grid current while the inverter is operating in Grid Current Control mode. When the inverter is turned on in Grid Current Control mode, the current will be set to zero - this register is then used to dynamically change the commanded current to the desired value. A positive command indicates current flowing from the inverter to the grid; a negative command indicates current flowing from the grid to the inverter. The allowable minimum and maximum real current commands are configured with ***PID 0x80E5-0x80E6***.

PID 0x0005 Grid Current, Reactive

This register sets the desired reactive grid current while the inverter is operating in Grid Current Control mode. When the inverter is turned on in Grid Current Control mode, the current will be set to zero - this register is then used to dynamically change the commanded current to the desired value. A positive command indicates a capacitive reactive current; a negative command indicates an inductive reactive current. The allowable minimum and maximum reactive current commands are configured with ***PID 0x80E7-0x80E8***.

PID 0x0006 Grid Power, Real

This register sets the desired real grid power while the inverter is operating in Grid Power Control mode. When the inverter is turned on in Grid Power Control mode, the power will be set to zero - this register is then used to dynamically change the commanded power to the desired value. A positive command indicates power delivered from the inverter to the grid; a negative command indicates power delivered from the grid to the inverter. The allowable minimum and maximum real power commands are configured with ***PID 0x810E-0x810F***.

PID 0x0007 Grid Power, Reactive

This register sets the desired reactive grid power while the inverter is operating in Grid Power Control mode. When the inverter is turned on in Grid Power Control mode, the power will be set to zero - this register is then used to dynamically change the commanded power to the desired value. A positive command indicates capacitive reactive power; a negative command indicates inductive reactive power. The allowable minimum and maximum reactive power commands are configured with ***PID 0x8110-0x8111***.

PID 0x0008 Host Heartbeat

This register serves as a heartbeat monitor for the host controller. It is expected that the host controller increments this register at a defined rate, with periodic resets to zero. The inverter will monitor this register and assert a fault if it hasn't incremented by 1 or been reset to zero within the timeout period defined by ***PID 0x804C – Host Heartbeat Timeout***. This fault check can be disabled by setting the Host Heartbeat Timeout to 0.

PID 0x0009 Restore Default Configuration

This register causes the system to restore its non-volatile configuration memory to the factory default configuration. Successful execution of this command requires the following conditions be met:

- ***A 16-bit key value of 0xAA55 must be written to this register***
- ***The system must be in a non-operation state, i.e. the inverter must be 'OFF'***

CAUTION

Upon execution, all currently stored configuration data will be permanently destroyed and over written with the factory default configuration data.

4.3 Instrumentation Registers

Table 3 – Instrumentation Register Set

PID	Data Type	Description	Units	Access Level
0x4000	U16	Operating State	ENUM	R
0x4001	U16	Operating Mode	ENUM	R
0x4002	U16	DC Link Voltage	0.1 V	R
0x4003	U16	DC Input Voltage	0.1 V	R
0x4004	U16	AC Line Voltage, Phase A-to-B	0.1 V_{rms}	R
0x4005	U16	AC Line Voltage, Phase B-to-C	0.1 V_{rms}	R
0x4006	U16	AC Line Voltage, Phase C-to-A	0.1 V_{rms}	R
0x4007	U16	AC Current, Phase A	0.1 A_{rms}	R
0x4008	U16	AC Current, Phase B	0.1 A_{rms}	R
0x4009	U16	AC Current, Phase C	0.1 A_{rms}	R
0x400A	U16	AC Line Frequency	0.01 Hz	R
0x400B	U16	Power Factor	0.1 %	R
0x400C	S16	AC Power, Real	0.1 kW	R
0x400D	S16	AC Power, Reactive	0.1 kvar	R
0x400E	U16	PLL Status	ENUM	R
0x400F	U16	Contactor Status	ENUM	R
0x4010	U16	IGBT Temperature, Phase A	1° C	R
0x4011	U16	IGBT Temperature, Phase B	1° C	R
0x4012	U16	IGBT Temperature, Phase C	1° C	R
0x4013	U16	PCB Temperature	1° C	R
0x4014	U16	External Temperature	1° C	R
0x4015	U32	Warning Status	n/a	R

PID	Data Type	Description	Units	Access Level
0x4016	U32	Fault Status – Word 0	n/a	R
0x4017	U32	Fault Status – Word 1	n/a	R
0x4018	U16	Register Operation Status	ENUM	R
0x4019	U16	Inverter Software Revision – Major	Integer	R
0x401A	U16	Inverter Software Revision – Minor	Integer	R
0x401B	U16	Bootloader Revision – Major	Integer	R
0x401C	U16	Bootloader Revision – Minor	Integer	R
0x401D	U16	HV Sense FPGA Revision – Major	Integer	R
0x401E	U16	HV Sense FPGA Revision – Minor	Integer	R
0x401F	U16	AFE Controller Heartbeat	Integer	R

PID 0x4000 Operating State

The present inverter operating state is enumerated as follows (see section 2.5 - *State Sequencing* for details on each of these operating states):

Value	State
0	Initializing
1	Fault
2	Calibrating
3	Disabled
4	Wait for DC Input
5	Wait for Valid Grid
6	Wait for Charge Command
7	DC Link Charge Wait
8	DC Link Bleed Wait
9	Standby
10	On
11	Unknown

PID 0x4001 Operating Mode

The present inverter operating mode is enumerated as follows:

0 = DC Voltage Control
1 = Grid Current Control
2 = Grid Power Control

PID 0x4002 DC Link Voltage

This register reports the DC link voltage measured at the power module terminals.

PID 0x4003 DC Input Voltage

This register reports the DC input voltage measured at the input to the DC contactor, if present. If a DC contactor is not present, this will report the DC voltage measured at the power module terminals.

PID 0x4004-0x4006 AC Line Voltage

These registers report the RMS phase-to-phase line voltages measured at the input to the AC contactor.

PID 0x4007-0x4009 AC Current

These registers report the RMS inverter phase currents measured at the power module terminals.

PID 0x400A AC Line Frequency

This register reports the measured line frequency.

PID 0x400B Power Factor

This register reports the estimated power factor at the grid interface.

PID 0x400C AC Power, Real

This register reports the real power at the grid interface. A positive value indicates power delivered from the inverter to the grid; a negative value indicates power delivered from the grid to the inverter.

PID 0x400D AC Power, Reactive

This register reports the reactive power at the grid interface. A positive value indicates capacitive reactive power; a negative value indicates inductive reactive power.

PID 0x400E PLL Status

This register reports PLL locked status as follows:

0 = PLL not locked
1 = PLL locked to grid reference

PID 0x400F Contactor Status

This register reports the state of the AC and DC contactors as follows:

Bit	Status
0	AC Contactor: 0 = Open, 1 = Closed
1	DC Contactor: 0 = Open, 1 = Closed

PID 0x4010-0x4012 IGBT Temperature

These registers report the IGBT temperatures measured for each phase within the power module.

PID 0x4013 PCB Temperature

This register reports the temperature measured on the controller PCB within the power module.

PID 0x4014 External Temperature

This register reports the external temperature if an external thermistor has been configured by the user (see ***PIDs 0x80BC-0x80C2***). If an external device is not enabled, this register will return zero.

PID 0x4015 Warning Status

This register reports all warning status bits. Warning bits are active when set to '1', and not present when set to '0'. See section 2.6.1 - *Warnings* for details on each warning. The warning bits are mapped as follows:

Bit	Warning
0	High DC Link Voltage
1	Low DC Link Voltage
2	High AC Current, Phase A
3	High AC Current, Phase B
4	High AC Current, Phase C
5	Grid Frequency Out of Tolerance
6	Grid Voltage Out of Tolerance, A-to-B
7	Grid Voltage Out of Tolerance, B-to-C
8	Grid Voltage Out of Tolerance, C-to-A
9	High IGBT Temperature, Phase A
10	High IGBT Temperature, Phase B
11	High IGBT Temperature, Phase C
12	High PCB Temperature
13	High External Temperature
14	PLL Not Locked
15	5V Supply Out of Tolerance
16	15V Supply Out of Tolerance
17	DC Link Under Voltage
18	High Grid Voltage, A-to-B
19	High Grid Voltage, B-to-C
20	High Grid Voltage, C-to-A
21-31	*Reserved*

PID 0x4016-0x4017 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 ***PID 0x0003 - Fault Reset***. When a fault occurs, the inverter will immediately turn OFF and go to the ***Fault*** state. The inverter will stay in the ***Fault*** state until the fault reset command is received. See section 2.6.2 - *Faults* for details on each fault condition. ***Fault Word 0*** bits are mapped as follows:

Bit	Fault
0	IGBT Desaturation Error, Phase A
1	IGBT Desaturation Error, Phase B
2	IGBT Desaturation Error, Phase C
3	IGBT Drive Error, Phase A
4	IGBT Drive Error, Phase B
5	IGBT Drive Error, Phase C

Bit	Fault
6	DC Link Over Voltage H/W Error
7	DC Link Over Voltage S/W Error
8	DC Link Under Voltage S/W Error
9	Over Current, Phase A
10	Over Current, Phase B
11	Over Current, Phase C
12	Grid Monitor Frequency Fault
13	Grid Monitor Voltage Fault, A-to-B
14	Grid Monitor Voltage Fault, B-to-C
15	Grid Monitor Voltage Fault, C-to-A
16	IGBT Over Temperature, Phase A
17	IGBT Over Temperature, Phase B
18	IGBT Over Temperature, Phase C
19	PCB Over Temperature
20	External Over Temperature
21	Hardware Interlock Error
22	AC Contactor Feedback Error
23	DC Contactor Feedback Error
24	*Reserved*
25	PLL Lost Lock
26	Communications Error
27	Configuration Memory Error
28	Calibration Error
29	DC Input Measurement Error
30	AC Contactor Interlock Error
31	DC Contactor Interlock Error

Fault Word 1 bits are mapped as follows:

Bit	Fault
0	Grid Over Voltage Fault, A-to-B
1	Grid Over Voltage Fault, B-to-C
2	Grid Over Voltage Fault, C-to-A
3	DC Link Charge Timeout
4	DC Link Bleed Timeout
5-38	*Reserved*
29	Invalid Factory Configuration
30	Invalid OZip Model
31	Invalid Inverter Model

PID 0x4018 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 enumerated as follows:

Value	Status
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 write 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 inverter is ON
> 8	*Unknown – Reserved for future use*

PID 0x4019-0x401A Inverter Software Revision – Major/Minor

These values report the major and minor revisions of the inverter control software.

PID 0x401B-0x401C Bootloader Revision – Major/Minor

These values report the major and minor revisions of the embedded bootloader software.

PID 0x401D-0x401E HV Sense FPGA Revision – Major/Minor

These values report the major and minor revisions of the FPGA code used on the high voltage sense module.

PID 0x401F AFE Controller Heartbeat

This value is incremented by 1 at the period defined by ***PID 0x804D – Heartbeat Period***, and periodically resets to zero. It can be used by the host controller to monitor the integrity of the communication link to the inverter.

4.4 Configuration Registers

These registers are used to configure the various operational modes and settings for the inverter. 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 typically handle over 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.

When performing inverter 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 build of the firmware, then the previous configuration memory map is considered incompatible and will be automatically reset to the new factory defaults.

CAUTION

The user must take care when updating the firmware to understand whether the configuration memory will be reset, and if so, 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 inverter 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 inverter controls.

4.4.1 Configuration Control Parameters

Table 4 – Basic Configuration Control Parameters

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

PID 0x8000-0x8001 Factory Configuration Revision – Major/Minor

These read-only values represent the major and minor revision of the default factory configuration stored in the configuration 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 configuration space that are required for proper inverter operation, or if existing parameters change locations or formats. At startup, the firmware will read this value from 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 configuration parameters to the present factory default values.

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 parameter or the addition of a new parameter that is not needed for proper inverter operation.

PID 0x8002 User Configuration Revision

This is a generic register 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 Interface Parameters

The following set of parameters are provided to allow for customizing the Modbus interface for the end 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-0092.

Table 5 – 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 ①
0x800E	U16	Modbus Baud Rate	ENUM	2	0	5	RWO ①

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

PID 0x800D Modbus Device Address

This parameter specifies the Modbus Device Address used by the inverter.

PID 0x800E Modbus Baud Rate

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

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

Table 6 – 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 This register may be written at any time, but it will not take effect until the inverter is power cycled

PID 0x800F Modbus Parity

This parameter is used to configure the parity mode used by the Modbus interface. 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 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-0091.

Table 7 – Basic CAN Interface Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x8014	U16	CAN Group ID	Integer	2	1	15	RWO ①
0x8015	U16	CAN Module ID	Integer	1	1	31	RWO ①
0x8016	U16	CAN Baud Rate	ENUM	2	0	5	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 inverter.

PID 0x8015 CAN Module ID

This parameter specifies the Module ID used by the inverter.

PID 0x8016 CAN Baud Rate

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

0 = 1 Mbps
1 = 500 kbps
2 = 250 kbps
3 = 125 kbps
4 = 100 kbps
5 = 50 kbps

Table 8 – Advanced CAN Interface Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x801C	U16	CAN Update Rate – DC Link Status	1 ms	0	0	65535	RWO
0x801D	U16	CAN Update Rate – Grid Voltage Status	1 ms	0	0	65535	RWO
0x801E	U16	CAN Update Rate – Inverter Current Status	1 ms	0	0	65535	RWO
0x801F	U16	CAN Update Rate – Grid Status	1 ms	0	0	65535	RWO
0x8020	U16	CAN Update Rate – System Status	1 ms	0	0	65535	RWO
0x8021	U16	CAN Update Rate – Alarm Status	1 ms	0	0	65535	RWO
0x8022	U16	CAN Status Destination Group ID	Integer	1	0	15	RWO ①
0x8023	U16	CAN Status Destination Module ID	Integer	1	0	31	RWO ①
0x8024	U16	CAN Automatic Alarm Transmit Enable	Boolean	FALSE	FALSE	TRUE	RWO
0x8025	U16	CAN Broadcast Message Receive Enable	ENUM	0	0	3	RWO ①

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

PID 0x801C-0x8021 CAN Update Rates

These parameters are used to set the rate at which the corresponding status messages will be automatically transmitted by the firmware. These values specify the period between message transmissions. Setting a parameter to zero disables automatic/periodic transmission for the corresponding message. See reference document FS-0091 for details regarding specific CAN status message formats used by this inverter.

PID 0x8022 CAN Status Destination Group ID

This parameter specifies the Destination Group ID that the inverter will use when sending the periodic status messages.

PID 0x8023 CAN Status Destination Module ID

This parameter specifies the Destination Module ID that the inverter will use when sending the periodic status messages.

PID 0x8024 CAN Automatic Alarm Transmit Enable

This parameter is used to enable automatic transmission of the Warning and Fault Alarm Status messages upon a change 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 from when the offending event occurs to when the Warning or Fault Alarm Status message is sent. When disabled (parameter is set to

FALSE), a change in any warning or fault bit does not cause automatic transmission of the Warning or Fault Alarm Status messages.

PID 0x8025 CAN Broadcast Message Receive Enable

This parameter determines whether the inverter will accept broadcast messages from the host controller. Legal values for this parameter are encoded as follows:

0 = Do not accept broadcast messages
1 = Accept group-wide broadcast messages (Module ID = 0)
2 = Accept system-wide broadcast messages (Group ID = 0)
3 = Accept both group-wide and system-wide broadcast messages

4.4.4 Grid Monitor and Protection Parameters

Table 9 – Basic Grid Monitor Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x802A	U16	Nominal Grid Voltage	0.1 V_{rms}	4800 ①	0	6900 ②	RWO
0x802B	U16	Nominal Grid Frequency	0.01 Hz	6000	4500	6500	RWO

① *Factory Default* value will be preset for inverters provided by Oztek, refer to inverter hardware manual for details
② *Max* value may vary based on the selected OZip model, refer to OZip hardware manual for details

PID 0x802A Nominal Grid Voltage

This parameter is used to specify the expected nominal grid voltage.

PID 0x802B Nominal Grid Frequency

This parameter is used to specify the expected nominal grid frequency.

Table 10 – Advanced Grid Monitor Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x8030	U16	Grid Fast Under-Voltage Threshold	0.1 %	500	0	2000	RWO
0x8031	U16	Grid Slow Under-Voltage Threshold	0.1 %	880	0	2000	RWO
0x8032	U16	Grid Fast Over-Voltage Threshold	0.1 %	1200	0	2000	RWO
0x8033	U16	Grid Slow Over-Voltage Threshold	0.1 %	1100	0	2000	RWO
0x8034	U16	Grid Fast Under-Frequency Delta	0.01 Hz	300	0	1000	RWO
0x8035	U16	Grid Slow Under-Frequency Delta	0.01 Hz	70	0	1000	RWO
0x8036	U16	Grid Over-Frequency Delta	0.01 Hz	50	0	1000	RWO
0x8037	U16	Grid Fast Under-Voltage Clear Time	1 ms	50	1	65535	RWO
0x8038	U16	Grid Slow Under-Voltage Clear Time	1 ms	1500	1	65535	RWO
0x8039	U16	Grid Fast Over-Voltage Clear Time	1 ms	50	1	65535	RWO
0x803A	U16	Grid Slow Over-Voltage Clear Time	1 ms	500	1	65535	RWO
0x803B	U16	Grid Fast Under-Frequency Clear Time	1 ms	50	1	65535	RWO
0x803C	U16	Grid Slow Under-Frequency Clear Time	1 ms	500	1	65535	RWO
0x803D	U16	Grid Over-Frequency Clear Time	1 ms	50	1	65535	RWO
0x803E	U16	Grid Fault Auto-Reconnect Enable	Boolean	FALSE	FALSE	TRUE	RWO
0x803F	U16	Grid Reconnect Delay Time	1 sec	1	1	1000	RWO

PID 0x8030-0x8033 Grid Fast/Slow Over/Under Voltage Thresholds

These parameters define the allowable grid voltage thresholds as a percentage of the specified ***PID 0x802A – Nominal Grid Voltage*** value. When the grid voltage exceeds a particular parameter, the corresponding “clear time” parameter is used to define a period of time to wait before declaring a grid voltage fault condition.

Grid voltage fault conditions are only asserted when the inverter is ON or an attempt is made to turn the inverter ON. If the inverter is OFF and a voltage threshold has been exceeded, a warning bit will be asserted for the corresponding high phase-to-phase voltage. If the inverter is ON and a voltage threshold has been exceeded and the corresponding clear time has not yet been met, a warning bit will be asserted for the corresponding high phase-to-phase voltage.

PID 0x8034-0x8036 Grid Fast/Slow Over/Under Frequency Thresholds

These parameters define the allowable grid frequency range in terms of delta values relative to the specified ***PID 0x802B – Nominal Grid Frequency*** value. When the grid frequency exceeds a particular parameter, the corresponding “clear time” parameter is used to define a period of time to wait before declaring a grid frequency fault condition.

Grid frequency faults are only asserted when the inverter is ON, otherwise when the grid frequency exceeds one or more of the thresholds, an associated warning bit will be asserted.

PID 0x8037-0x803D Grid Voltage/Frequency Fault Clear Times

The “clear time” parameters define the period of time to wait before declaring the corresponding voltage or frequency fault condition. Each specific voltage or frequency fault condition has its own corresponding clear time register.

The “slow” clear times are intended to be used to check for moderate voltage or frequency deviations from the nominal grid value, and to define an appropriately “slow” time to wait prior to declaring a fault. The “fast” clear times are intended to be used for checking gross voltage or frequency deviations from the nominal grid value, and to define a relatively “fast” fault assertion time.

PID 0x803E Grid Fault Auto-Reconnect Enable

This parameter is used to determine if the inverter should automatically reconnect and continue operating after a grid voltage or frequency fault occurs. If the inverter is ON and any grid voltage or frequency fault occurs, the inverter will transition to the ***Fault*** state and force the inverter OFF. If this parameter is set to TRUE, once the grid voltage and frequency have been within tolerance for the period specified by ***PID 0x803F - Grid Reconnect Delay Time***, the inverter will automatically clear the associated grid fault bits and transition back into the ON state. This is only true if no other fault conditions exist and if the inverter was left ON (i.e. the last ***PID 0x0000 - On/Off Control*** command sent was the ON command). If this parameter is set to FALSE, then any grid voltage or frequency related faults will be latched and the inverter will remain in the ***Fault*** state with the inverter OFF until the faults are explicitly cleared using the ***PID 0x0003 - Fault Reset*** command.

PID 0x803F Grid Reconnect Delay Time

This parameter is used to define the period of time to wait when automatically reconnecting to the grid and turning ON following a grid voltage or frequency fault. This parameter is only used if ***PID 0x8030E– Grid Fault Auto-Reconnect Enable*** is set to TRUE and the inverter was left ON.

4.4.5 Fault and Warning Parameters

Table 11 – Basic Fault and Warning Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x8044	U16	DC Link Over Voltage Fault Threshold	0.1 V	8500 ①	0	9000 ①	RWO
0x8045	U16	DC Link Over Voltage Warning Threshold	0.1 V	8400 ①	0	9000 ①	RWO
0x8046	U16	DC Link Under Voltage Fault Threshold	0.1 V	5000 ①	0	9000 ①	RWO
0x8047	U16	DC Link Under Voltage Warning Threshold	0.1 V	5100 ①	0	9000 ①	RWO
0x8048	U16	Grid Over Current Fault Threshold	0.1 A_{rms}	1400 ①	0	3000 ①	RWO
0x8049	U16	Grid Over Current Warning Threshold	0.1 A_{rms}	1200 ①	0	3000 ①	RWO
0x804A	U16	Grid Over Voltage Fault Threshold	0.1 V_{rms}	6000 ①	0	6500 ①	RWO
0x804B	U16	Grid Over Voltage Warning Threshold	0.1 V_{rms}	5750 ①	0	6500 ①	RWO
0x804C	U16	Host Heartbeat Timeout	1 ms	0	0	65535	RWO
0x804D	U16	Heartbeat Period	1 ms	1000	1	65535	RWO

① *Factory Default* and *Max* values may vary based on the selected OZip model, refer to OZip hardware manual for details

PID 0x8044 DC Link Over Voltage Fault Threshold

If the DC link voltage rises above this value the inverter will automatically transition to the ***Fault*** state and the inverter will be forced OFF. Refer to the inverter hardware manual for model-specific ratings.

PID 0x8045 DC Link Over Voltage Warning Threshold

If the DC link voltage rises above this value the inverter will report a high voltage warning. Once above this warning threshold, the voltage must drop below this value minus the value in ***PID 0x8052 – DC Link Over Voltage Warning Recover Delta*** before the inverter will clear the high voltage warning.

PID 0x8046 DC Link Under Voltage Fault Threshold

If the DC link voltage falls below this value while the inverter is ON, the inverter will automatically transition to the ***Fault*** state and the inverter will be forced OFF. If the DC link is below this value and the inverter is OFF, a fault is not generated, but the *DC Link Under Voltage* warning bit will be set. Refer to the inverter hardware manual for model-specific ratings.

PID 0x8047 DC Link Under Voltage Warning Threshold

If the DC link voltage falls below this value the inverter will report a low voltage warning. Once below this warning threshold, the voltage must rise above this value plus the value in ***PID 0x8053 – DC Link Under Voltage Warning Recover Delta*** before the inverter will clear the low voltage warning.

PID 0x8048 Grid Over Current Fault Threshold

If any of the AC phase currents rise above this value the inverter will automatically transition to the ***Fault*** state and the inverter will be forced OFF. Refer to the inverter hardware manual for model-specific ratings.

PID 0x8049 Grid Over Current Warning Threshold

If any of the AC phase currents rise above this value, the inverter will report a high AC current warning for the corresponding phase(s). Once above this warning threshold, the current must drop below this value minus the value in ***PID 0x8054 – Grid Over Current Warning Recover Delta*** before the inverter will clear the high current warning.

PID 0x804A Grid Over Voltage Fault Threshold

If any of the AC phase-to-phase voltages rise above this value the inverter will automatically transition to the ***Fault*** state and the inverter will be forced OFF. Refer to the inverter hardware manual for model-specific ratings.

PID 0x804B Grid Over Voltage Warning Threshold

If any of the AC phase-to-phase voltages rise above this value, the inverter will report a high AC voltage warning for the corresponding phase(s). Once above this warning threshold, the voltage must drop below this value minus the value in ***PID 0x8055 – Grid Over Voltage Warning Recover Delta*** before the inverter will clear the high voltage warning.

PID 0x804C Host Heartbeat Timeout

This parameter defines the fault timeout for the host heartbeat. It is expected that the host controller increments ***PID 0x0008 – Host Heartbeat*** at a rate faster than this timeout value. The inverter will assert a fault if ***PID 0x0008 – Host Heartbeat*** hasn’t incremented by 1 or been reset to zero within this timeout period. Host heartbeat timeout fault checking is disabled when this register is set to 0.

PID 0x804D Heartbeat Period

This parameter defines how often the inverter increments the ***PID 0x401F – AFE Controller Heartbeat*** register.

Table 12 – Advanced Fault and Warning Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x8052	U16	DC Link Over Voltage Warning Recover Delta	0.1 V	100	10	1000	RWO
0x8053	U16	DC Link Under Voltage Warning Recover Delta	0.1 V	100	10	1000	RWO
0x8054	U16	Grid Over Current Warning Recover Delta	0.1 A_{rms}	100	10	1000	RWO
0x8055	U16	Grid Over Voltage Warning Recover Delta	0.1 V_{rms}	50	10	1000	RWO

PID 0x8052 DC Link Over Voltage Warning Recover Delta

This parameter defines the voltage delta below the value in ***PID 0x8045 – DC Link Over Voltage Warning Threshold*** that the DC link must fall below in order to clear the corresponding warning bit.

PID 0x8053 DC Link Under Voltage Warning Recover Delta

This parameter defines the voltage delta above the value in ***PID 0x8047 – DC Link Under Voltage Warning Threshold*** that the DC link must rise above in order to clear the corresponding warning bit.

PID 0x8054 Grid Over Current Warning Recover Delta

This parameter defines the current delta below the value in ***PID 0x8049 – Grid Over Current Warning Threshold*** that an AC phase current must fall below in order to clear the corresponding warning bit.

PID 0x8055 Grid Over Voltage Warning Recover Delta

This parameter defines the voltage delta below the value in ***PID 0x804B – Grid Over Voltage Warning Threshold*** that an AC phase-to-phase voltage must fall below in order to clear the corresponding warning bit.

4.4.6 Inverter Control Parameters

Table 13 – Basic Inverter Control Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x8060	U16	Control Mode	ENUM	0	0	2	RW
0x8061	U16	Hardware On/Off Pin Enable	Boolean	FALSE	FALSE	TRUE	RW
0x8062	U16	Hardware Interlock Pin Enable	Boolean	FALSE	FALSE	TRUE	RWO
0x8063	U16	Hardware Fault Reset Pin Enable	Boolean	FALSE	FALSE	TRUE	RWO
0x8064	U16	Auto-Connect Enable	Boolean	FALSE	FALSE	TRUE	RWO

PID 0x8060 Control Mode

This register is used to set the desired operating mode. This register may not be changed while the inverter is ON. The control mode is encoded as follows:

0 = DC Voltage Control - the DC link voltage is controlled
1 = Grid Current Control - the real and reactive grid current is controlled
2 = Grid Power Control - the real and reactive grid power is controlled

PID 0x8061 Hardware On/Off Pin Enable

When this parameter is set to TRUE, the inverter is turned 'ON' and 'OFF' using the dedicated On/Off hardware pin. When hardware pin control is enabled, the ***PID 0x0000 - On/Off Control*** register is not used and any writes to this register will be ignored.

PID 0x8062 Hardware Interlock Pin Enable

This parameter is used to enable the external Hardware Interlock input pin. This pin can be used as a fast, emergency 'OFF' input or to prohibit inverter operation. When this parameter is set to TRUE and the input pin is low (0V or not connected), the inverter will immediately transition to the ***Fault*** state and the inverter will be forced 'OFF' of it was previously 'ON'.

PID 0x8063 Hardware Fault Reset Pin Enable

When this parameter is set to TRUE, the dedicated Fault Reset hardware pin may be used for resetting any fault conditions. This hardware pin is edge sensitive. When enabled and the input pin is transitioned from a low input (0V or not connected) to a high input, an attempt will be made to clear all faults. When this parameter is FALSE, the Fault Reset hardware pin is ignored. The use of the dedicated Fault Reset hardware pin does not affect the use of the ***PID 0x0003 – Fault Reset*** register; this command register may still be used to clear faults even if the hardware pin is enabled.

PID 0x8064 Auto-Connect Enable

When this parameter is set to FALSE, the user has direct control over when the inverter can connect and when it should disconnect from the AC and DC bus interfaces using ***PID 0x0001 – Connect Control***. When this parameter is set to TRUE, the inverter controller will automatically attempt to connect (and stay connected) when the AC and DC bus connections are valid. In this case, the ***PID 0x0001 – Connect Control*** command registers is not used and is ignored. Refer to the system state diagram in Figure 7 for more details on connection controls.

Table 14 – Advanced Inverter Control Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x806A	U32	Inductance – Inverter Side	1 nH	8.1E+05 ①	0	1E+09	RWO
0x806C	U32	Inductance – Grid Side	1 nH	0 ①	0	1E+09	RWO
0x806E	U32	Filter Capacitance	1 nF	60000 ①	0	1E+09	RWO
0x8070	U16	Pulse Width Modulation Frequency	1 Hz	8000 ②	1000	12000 ②	RW

① *Factory Default* values will be preset for inverters provided by Oztek, refer to inverter hardware manual for details
② *Factory Default* and *Max* values will vary based on the selected OZip model, refer to OZip hardware manual for details

PID 0x806A-0x806C Inductance

These parameters are used to specify the inductance between the OZip power module and the point of grid attachment. The *Inverter Side* inductance should be set to the inductance between the OZip's AC terminals and the point at which the grid voltage is sensed by the Oztek High Voltage Sense module. The *Grid Side* inductance should be set to the inductance between the high voltage sense connection and the point of grid attachment. For example, in the arrangement shown below, the *Inverter Side* inductance would be set to L1 + L2, and the *Grid Side* inductance would be set to L3. If no transformer is present, the *Grid Side* inductance would be set to zero. If L2 is not present (i.e. transformer inductance is used as part of the LCL filter), the *Inverter Side* inductance would be set to just L1.

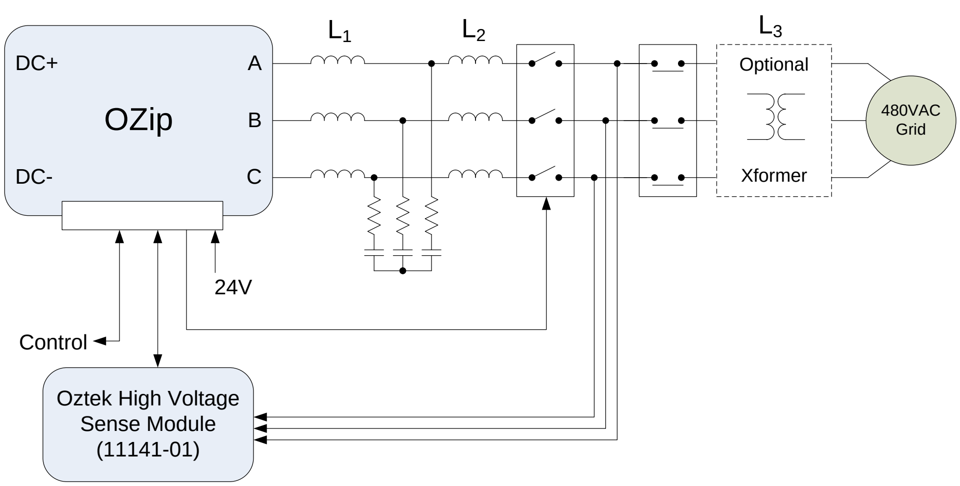


Figure 11 – Inverter vs Grid Side Inductance Example

PID 0x806E Filter Capacitance

This parameter is used to specify the filter capacitance. This value is used to correct for the reactive filter current that flows through the capacitor when an LC grid interface filter is used and inverter current is used for feedback as opposed to grid current. By doing so, the resulting grid side current and power factor will better correspond to the desired commands. If the filter capacitance is unknown, or to disable the reactive current offset, this parameter should be set to zero.

PID 0x8070 Pulse Width Modulation Frequency

This parameter defines the PWM switching frequency used by the inverter.

4.4.7 Pre-charge and Contactor Parameters

Table 15 – Basic Pre-charge and Contactor Control Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x8080	U16	DC Link Pre-charge Mode	ENUM	1	0	2	RW
0x8081	U16	DC Link Pre-charge Reference	ENUM	0	0	1	RW
0x8082	U16	DC Link Charge Timeout	0.1 s	300	0	65535	RWO
0x8083	U16	DC Link Bleed Timeout	0.1 s	300	0	65535	RWO
0x8084	U16	AC Contactor Action	ENUM	1	0	2	RW
0x8085	U16	DC Contactor Action	ENUM	0	0	2	RW

PID 0x8080 DC Link Pre-charge Mode

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

0 = Disabled - the pre-charge function is performed by another piece of equipment attached to the same DC link as the inverter. In this case, the inverter will simply monitor the DC link voltage and wait for it to be within an acceptable voltage range (see ***PID 0x8081 – DC Link Pre-charge Reference*** below) before attempting to close any contactors and transition from the ***DC Link Charge Wait*** or ***DC Link Bleed Wait*** states to the ***Standby*** state.

1 = Automatic - the inverter will automatically attempt to pre-charge the DC link once it detects either a valid grid connection or a valid DC input (see ***PID 0x8081 – DC Link Pre-charge Reference*** below).

2 = Manual - the inverter will transition to the ***Wait for Charge Command*** state once it detects a valid grid connection or a valid DC input (see ***PID 0x8081 – DC Link Pre-charge Reference*** below). It will then wait in this state until the user sends a charge command using ***PID 0x0002 – Charge Command***. Upon receiving this command, the inverter will then attempt to pre-charge the DC link.

PID 0x8081 DC Link Pre-charge Reference

This parameter determines the reference to which the DC link should be charged to. Legal values are as follows:

0 = Charge to AC input
1 = Charge to DC input

When charging relative to the AC input, the pre-charge controller first waits for a valid grid based on the parameters discussed in section 4.4.4 - *Grid Monitor and Protection Parameters.* Once the grid is within the specified voltage and frequency tolerances, it will then enable the pre-charge hardware. When the DC link is above the rectified AC voltage the pre-charge hardware will be disabled and the inverter will connect to the grid by closing the main AC contactor. This charging mode is typically used when the inverter is operating in DC Voltage Control mode, where there is no other stiff source attached to the DC link and the inverter must first charge the DC link above the rectified grid voltage to avoid large inrush currents when closing the main AC contactor. In this scheme, the use of a DC contactor is optional and is typically not employed.

When charging relative to the DC input, the pre-charge controller first waits for the measured DC input to be above ***PID 0x8047 – DC Link Under Voltage Warning Threshold***. Once above this threshold, it will then enable the pre-charge hardware. When the DC link reaches the DC input voltage the pre-charge hardware will be disabled and the inverter will connect to the DC input by closing the main DC contactor. This charging mode must be used any time a DC contactor is used to connect to an external DC source. This is typically the case when operating in Grid Current Control or Grid Power Control modes and the DC input is fed from batteries or another power converter. In these cases, it is necessary to charge the DC link to match the DC input voltage to avoid large inrush currents when closing the main DC contactor.

PID 0x8082 DC Link Charge Timeout

This parameter specifies the maximum amount of time to wait before reporting a charge timeout fault. If the DC link has not charged to the appropriate level within this amount of time, the inverter will disable the pre-charge hardware and transition to the ***Fault*** state. This timeout function may be disabled by setting this parameter to zero.

PID 0x8083 DC Link Bleed Timeout

This parameter specifies the maximum amount of time to wait before reporting a bleed timeout fault. If the DC link has not discharged to the same voltage as the DC input within this amount of time, the inverter will transition to the ***Fault*** state. This timeout function may be disabled by setting this parameter to zero.

PID 0x8084-0x8085 AC/DC Contactor Action

These parameters determine the behavior of the AC and DC contactor drive outputs from the inverter as follows:

0 = None
1 = Close when pre-charge completes
2 = Close when inverter is turned 'ON'

By default, both contactors are configured to close when the DC link has been charged to the specified input (***PID 0x8081 – DC Link Pre-charge Reference***). In this mode, the inverter is generally always connected to the grid and DC input whenever they are within tolerance. The contactor for the specified pre-charge reference should generally be set to this mode (i.e. if charging to the DC input, the DC contactor action should be set to '1', and likewise, when charging to the AC input, the AC contactor action should be set to '1').

The contactors may also be programmed to close only when the inverter has been turned 'ON'. This should only be used for the contactor not associated with the pre-charge operation (i.e. always close the contactor on the pre-charge side when pre-charge is complete).

If no contactors are to be controlled by the inverter itself, these parameters may be set to *None* to disable the associated contactor drive output(s).

Table 16 – Advanced Contactor Control Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x808A	U16	Contactor Monitor Enables	ENUM	1	0	3	RWO

PID 0x808A Contactor Monitor Enables

This parameter is used to determine if the contactor feedback monitors are enabled as follows:

0 = No monitoring - i.e. no contactor feedback is provided or checked
1 = Monitor AC Contactor only
2 = Monitor DC Contactor only
3 = Monitor Both Contactors

4.4.8 AC Current Control Parameters

Table 17 – Basic AC Current Control Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x80E4	U16	Rated Current	0.1 A_{rms}	1300 ①	0 ①	3000 ①	RWO
0x80E5	S16	Real Current Command Minimum	0.1 A_{rms}	-1300 ①	-3000 ①	3000 ①	RWO
0x80E6	S16	Real Current Command Maximum	0.1 A_{rms}	1300 ①	-3000 ①	3000 ①	RWO
0x80E7	S16	Reactive Current Command Minimum	0.1 A_{rms}	-1300 ①	-3000 ①	3000 ①	RWO
0x80E8	S16	Reactive Current Command Maximum	0.1 A_{rms}	1300 ①	-3000 ①	3000 ①	RWO

① Values may vary based on the selected OZip model, refer to OZip hardware manual for details

PID 0x80E4 Rated Current

This parameter defines the rated AC current supported by the inverter hardware.

PID 0x80E5-0x80E6 Real Current Command Minimum/Maximum

These parameters are used to set the allowable range for real current commands sent using ***PID 0x0004 – Grid Current, Real***.

PID 0x80E7-0x80E8 Reactive Current Command Minimum/Maximum

These parameters are used to set the allowable range for reactive current commands sent using ***PID 0x0005 – Grid Current, Reactive***.

Table 18 – Advanced AC Current Control Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x80F1	U16	Current Command Slew Rate	A_{rms}/s	100	1	65535	RWO
0x80F2	U16	Current Foldback Mode Select	ENUM	0	0	2	RWO
0x80F3	S16	Current Control K_p Scale	none	-3 ①	-12	12	RWO ③
0x80F4	U16	Current Control Proportional Gain (K_p)	none	640 ①	0	65535	RWO
0x80F5	S16	Current Control T_i Scale	none	-3 ①	-12	12	RWO ③
0x80F6	U16	Current Control Integral Time Constant (T_i)	sec	240 ①	0	65535	RWO
0x80F7	U16	Zero Sequence Control Enable	boolean	FALSE	FALSE	TRUE	RWO
0x80F8	S16	Zero Sequence K_p Scale	none	-3 ①	-12	12	RWO ③
0x80F9	U16	Zero Sequence Proportional Gain (K_p)	none	640 ①	0	65535	RWO
0x80FA	S16	Zero Sequence T_i Scale	none	-3 ①	-12	12	RWO ③
0x80FB	U16	Zero Sequence Integral Time Constant (T_i)	sec	240 ①	0	65535	RWO

① *Factory Default* values will be preset for inverters provided by Oztek, refer to inverter hardware manual for details
② *Min/Max* values may vary based on the selected OZip model, refer to OZip hardware manual for details
③ Changes in *Scale* values do not take effect until associated gain/time constant is changed or power is cycled

PID 0x80F1 Current Command Slew Rate

This parameter defines the current slew rate when operating in Grid Current Control mode and the commanded real or reactive current is changed.

PID 0x80F2 Current Foldback Mode Select

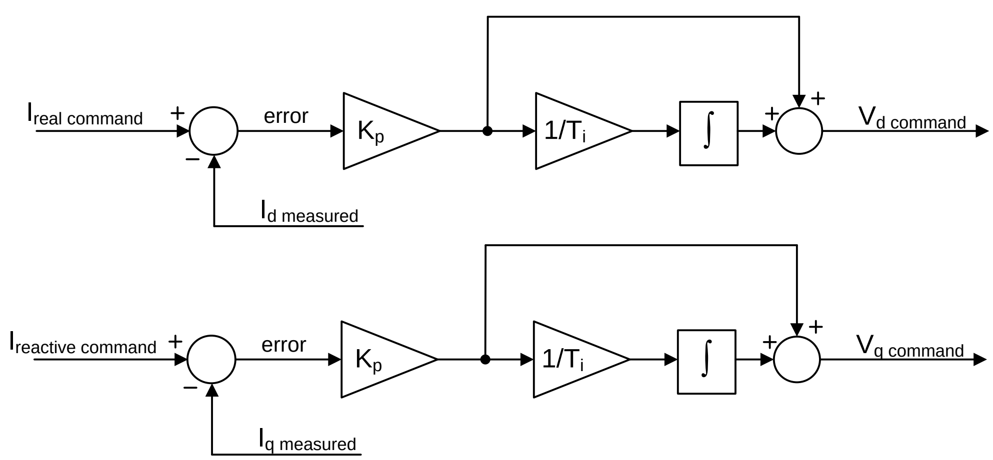
This parameter determines how the inverter will limit the real and reactive currents when operating in Grid Current Control or Grid Power Control modes. When operating in either of these modes, if the total commanded grid current (vector sum of the Real and Reactive currents) exceeds the value in ***PID 0x80E4 – Rated Current***, the inverter will limit the total current to the specified rated value. To do so, the inverter will reduce either the real, reactive, or both currents as follows:

0 = Fold Back Real and Reactive (Id & Iq) Currents Proportionally
1 = Fold Back Reactive (Iq) Current
2 = Fold Back Real (Id) Current

For the latter two cases where only the reactive or real currents are being reduced, the specified current will be reduced to zero if necessary, at which point the complementary current component will then be reduced if it is still greater than the rated current.

PID 0x80F3-0x80F6 Current Control Gains (K_p, T_i)

These parameters define the gains for the PI controllers that are used to regulate the average real (I_d) and reactive (I_q) currents. The PI controllers use the following topology:



Where: K_p = (PID 0x80F4) x $10^{(\text{PID 0x80F3})}$
T_i = (PID 0x80F6) x $10^{(\text{PID 0x80F5})}$

Figure 12 – Current Controller Diagram

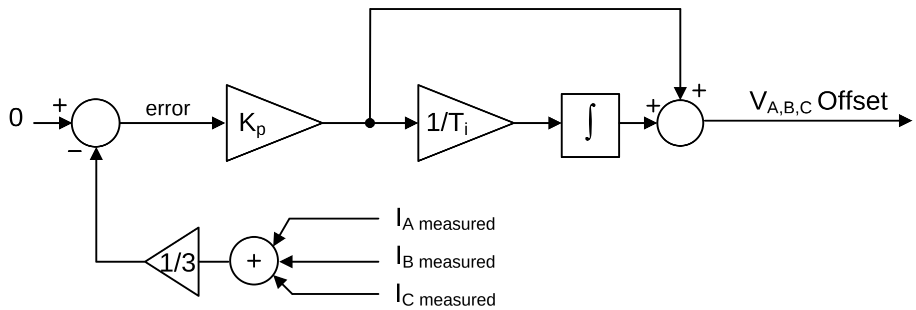
For these PI controllers, the commanded and measured currents are in units of amps (peak) and the V_d/V_q commands are the inverter's applied output voltages in units of volts (peak).

PID 0x80F7 Zero Sequence Control Enable

This parameter is used to enable the PI controller that is used to force the zero sequence current to zero. The zero sequence controller is intended to prevent a DC current offset from developing and circulating when running multiple inverters in parallel. This parameter should be set to FALSE when running the inverter by itself. This parameter should be set to TRUE if this inverter is running in parallel with other inverters, and at least one of the other inverters has its zero sequence controller disabled.

PID 0x80F8-0x80FB Zero Sequence Gains (K_p, T_i)

These parameters define the gains for the zero sequence PI controller. This PI controller uses the following topology:



Where: K_p = (PID 0x80F9) x $10^{(PID\ 0x80F8)}$
T_i = (PID 0x80FB) x $10^{(PID\ 0x80FA)}$

Figure 13 – Zero Sequence Controller Diagram

The current feedback signals ($I_{A,B,C}$ in **Error! Reference source not found.** above) are in units of a mps (peak). The output of the PI controller ($V_{A,B,C}$ Offset) is an offset voltage that is added to all three phases of the inverter's applied output voltage, in units volts (peak).

4.4.9 Grid Power Control Parameters

Table 19 – Basic Grid Power Control Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x810E	S16	Real Power Command Minimum	0.1 kW	-1000 ①	-1000 ②	1000 ②	RWO
0x810F	S16	Real Power Command Maximum	0.1 kW	1000 ①	-1000 ②	1000 ②	RWO
0x8110	S16	Reactive Power Command Minimum	0.1 kvar	-1000 ①	-1000 ②	1000 ②	RWO
0x8111	S16	Reactive Power Command Maximum	0.1 kvar	1000 ①	-1000 ②	1000 ②	RWO

① *Factory Default* values will be preset for inverters provided by Oztek, refer to inverter hardware manual for details
② *Min/Max* values may vary based on the selected OZip model, refer to OZip hardware manual for details

PID 0x810E-0x810F Real Power Command Minimum/Maximum

These parameters are used to set the allowable range for real power commands sent using ***PID 0x0006 – Grid Power, Real***.

PID 0x8110-0x8111 Reactive Power Command Minimum/Maximum

These parameters are used to set the allowable range for reactive power commands sent using ***PID 0x0007 – Grid Power, Reactive***.

Table 20 – Advanced Grid Power Control Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x8118	U16	Power Command Slew Rate	0.1 kW/s	1000	1	65535	RWO

PID 0x8118 Power Command Slew Rate

This parameter defines the power slew rate when operating in Grid Power Control mode and the commanded real or reactive power is changed.

4.4.10 DC Voltage Control Parameters

Table 21 – Basic DC Voltage Control Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x811E	U16	DC Voltage Command	0.1 V	8000 ①	0	9000 ①	RWO

① Values may vary based on the selected OZip model, refer to OZip hardware manual for details

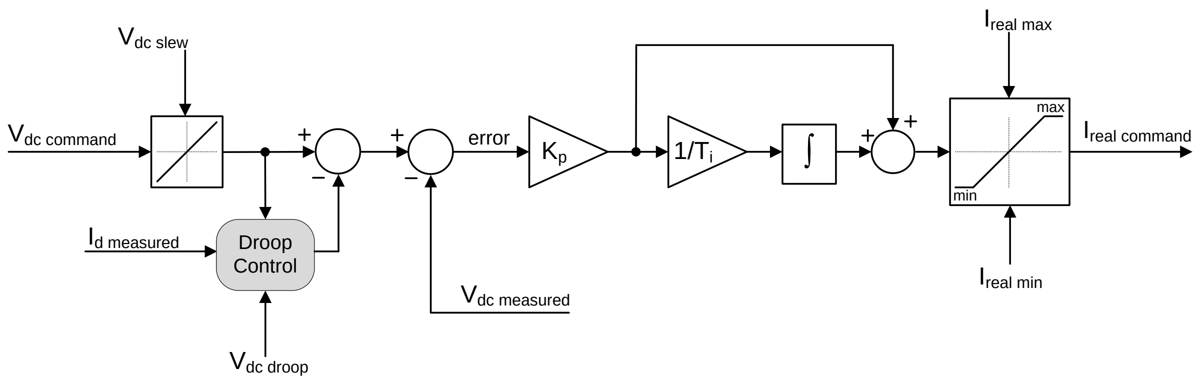
PID 0x811E DC Voltage Command

This parameter sets the desired DC link voltage while the inverter is operating in DC Voltage Control mode.

Table 22 – Advanced DC Voltage Control Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x8124	U16	DC Voltage Command Slew Rate	V/s	100	1	65535	RWO
0x8125	S16	DC Voltage Control K_p Scale	none	-3 ①	-12	12	RWO ②
0x8126	U16	DC Voltage Control Proportional Gain (K_p)	none	1517 ①	0	65535	RWO
0x8127	S16	DC Voltage Control T_i Scale	none	-6 ①	-12	12	RWO ②
0x8128	U16	DC Voltage Control Integral Time Constant (T_i)	sec	18800 ①	0	65535	RWO
0x8129	U16	DC Voltage Droop Control	0.01 %	0	0	5000	RWO

① *Factory Default* values will be preset for inverters provided by Oztek, refer to inverter hardware manual for details
② Changes in *Scale* values do not take effect until associated gain/time constant is changed or power is cycled



Where: K_p = (PID 0x8126) x $10^{(\text{PID 0x8125})}$
T_i = (PID 0x8128) x $10^{(\text{PID 0x8127})}$
$I_{real\ max}$ = (PID 0x80E6)
$I_{real\ min}$ = (PID 0x80E5)
$V_{dc\ slew}$ = (PID 0x8124)
$V_{dc\ droop}$ = (PID 0x8129)

Figure 14 – DC Voltage Controller Diagram

PID 0x8124 DC Voltage Command Slew Rate

This parameter defines the voltage slew rate when operating in DC Voltage Control mode and the commanded voltage is changed. This slew rate is used both at initial turn-on when the voltage is changed from the present value to the configured value or when the commanded value is changed after the inverter has already been turned 'ON'.

PID 0x8125-0x8128 DC Voltage Control Gains (K_p, T_i)

These parameters define the gains for the PI controller that is used to regulate the voltage when operating in DC Voltage Control mode. The PI controller uses the topology shown in Figure 14 above. For this PI controller, the commanded and measured V_{dc} voltage are in units of volts and the real current command output is in units of amps (peak).

PID 0x80129 DC Voltage Droop Control

This parameter is used to simulate a higher impedance on the regulated DC link voltage output. When running in DC Voltage Control mode, the regulated voltage will decrease based on the load current. The maximum amount that the voltage will droop occurs when the load current is at the maximum value specified in ***PID 0x80E4 – Rated Current***; at this point the voltage will be reduced by the percentage defined by this parameter. For example, if this parameter is set to 5%, the DC link voltage is set to 800V, and the rated current is specified as $100A_{rms}$, the actual DC link voltage will be reduced by 40V (800V x 5%) when the load current is $100A_{rms}$, or 20V when the load current is at $50A_{rms}$.

This feature is useful for assisting in load balancing when multiple inverters are operating in parallel in DC Voltage Control mode. This feature is disabled by setting this parameter to the factory default value of zero.

4.4.11 Instrumentation Parameters

Table 23 – Advanced Instrumentation Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x809A	U16	Filter Cutoff – DC Voltage	1 Hz	5	1	100	RWO
0x809B	U16	Filter Cutoff – Grid Voltage	1 Hz	5	1	100	RWO
0x809C	U16	Filter Cutoff – AC Current	1 Hz	5	1	100	RWO

PID 0x809A Filter Cutoff – DC Voltage

This parameter defines the cutoff frequency for the digital low pass filters used to filter the DC voltages that are reported in ***PID 0x4002 – DC Link Voltage*** and ***PID 0x4003 – DC Input Voltage***.

PID 0x809B Filter Cutoff – Grid Voltage

This parameter defines the cutoff frequency for the digital low pass filters used to filter the RMS grid voltages that are reported in ***PIDs 0x4004-0x4006***.

PID 0x809C Filter Cutoff – AC Current

This parameter defines the cutoff frequency for the digital low pass filters used to filter the RMS currents that are reported in ***PIDs 0x4007-0x4009***.

4.4.12 External Temperature Sensor Parameters

Table 24 – Advanced External Temperature Sensor Parameters

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x80BC	U16	External Thermistor Enable	Boolean	FALSE	FALSE	TRUE	RWO
0x80BD	S16	External Thermistor Coefficient A Scale	none	-7	-15	15	RWO ①
0x80BE	S16	External Thermistor Coefficient A	none	3411	-32768	32767	RWO
0x80BF	S16	External Thermistor Coefficient B Scale	none	-7	-15	15	RWO ①

PID	Data Type	Description	Units	Factory Default	Min	Max	Access Level
0x80C0	S16	External Thermistor Coefficient B	none	0	-32768	32767	RWO
0x80C1	S16	External Thermistor Coefficient C Scale	none	-10	-15	15	RWO ①
0x80C2	S16	External Thermistor Coefficient C	none	0	-32768	32767	RWO
0x80C3	U16	External Temp Fault Threshold	°C	85	20	150	RWO
0x80C4	U16	External Temp Warning Threshold	°C	75	20	150	RWO
0x80C5	U16	External Temp Warning Recover Delta	°C	5	1	100	RWO

① Changes in *Scale* values do not take effect until associated coefficient is changed or power is cycled

PID 0x80BC External Thermistor Enable

This parameter is used to enable the use of the external thermistor input. When set to FALSE, the input will be ignored and the value reported in ***PID 0x4014 – External Temperature*** will be forced to zero. When set to TRUE, the input is enabled and the temperature will be calculated based on the thermistor coefficients described below.

PID 0x80BD-0x80C2 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 = (PID 0x80BE) x $10^{(\text{PID 0x80BD})}$
B = (PID 0x80C0) x $10^{(\text{PID 0x80BF})}$
C = (PID 0x80C2) x $10^{(\text{PID 0x80C1})}$

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 0x80C3 External Temperature Fault Threshold

If the measured temperature rises above this value the inverter will automatically transition to the ***Fault*** state and the inverter will be forced OFF.

PID 0x80C4 External Temperature Warning Threshold

If the measured temperature rises above this value, the inverter will report a high external temperature warning. Once above this warning threshold, the temperature must drop below this value minus the value in ***PID 0x80C5 – External Temperature Warning Recover Delta*** before the inverter will clear the high temperature warning.

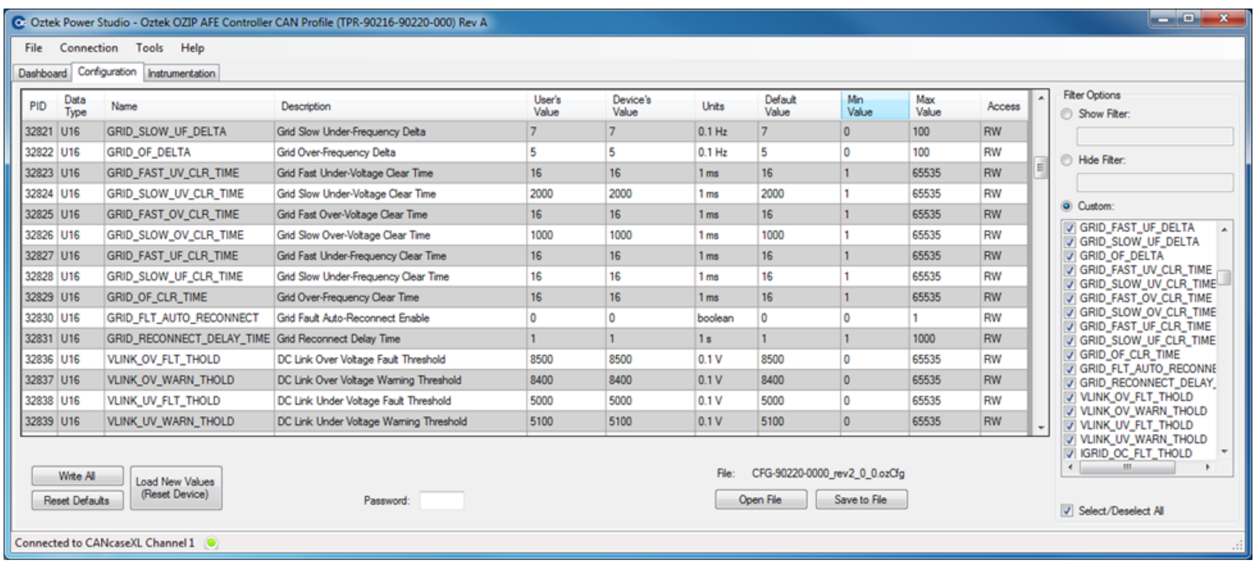
PID 0x80C5 External Temperature Warning Recover Delta

This parameter defines the temperature delta below the value in ***PID 0x80C4 – External Temperature Warning Threshold*** that the measured temperature must fall below to clear the corresponding warning bit.

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 Inverter. 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
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

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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.