Silicon Controlled Rectifier Drivers

OZSCR2000(2100)
SCR Firing Board

USER MANUAL
UM-0054

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1. Introduction

This document is intended to provide instruction on how to employ the Oztek OZSCR2000 & OZSCR2100 driver boards in an application environment. The two driver boards differ from one another in that the OZSCR2000 operates off universal AC input power while the OZSCR2100 operates off DC input power. Most this manual applies to both products, which will be referred to as the OZSCR2x00. Those sections that only apply to one product or the other will call out the specific model by name.

1.1 Referenced Documents

Ref.	Document	Description
[1]	FS-0053	Modbus Communication Module Functional Specification
[2]	UM-0052	Oztek Power Studio User's Manual

1.2 Part Numbers and Descriptions

Product Family	Orderable Part Number	Description
OZSCR2000	11205-01	AC Power Input
	11205-02	Conformal Coated, AC Power Input
OZSCR2100	11206-01	DC Power Input
	11206-02	Conformal Coated, DC Power Input

1.3 Definitions

DSP	Digital signal processor
GND	Ground, low side of input power supply
GUI	Graphical User Interface
N.C.	Not connected
PCB	Printed Circuit Board
PLC	Programmable Logic Controller
PLL	Phase Locked Loop
POR	Power On Reset
SCR	Silicon Controlled Rectifier

2. Functional Description

The OZSCR2x00 is a state of the art, multifunction, universal, digitally controlled SCR firing and control board. In addition to generating the line synchronized SCR gate drive signals, the OZSCR2x00 incorporates advanced features and functions that provide closed loop control options, eliminating the need for external hardware and system complexity. It is ideally suited for a wide range of system applications including:

- Three Phase AC Switch
- Multiple Independent Single Phase AC Switches
- Single Phase Rectifiers
- Three Phase Rectifiers

Configuration and operating parameters can easily be changed in the field using the RS485 Modbus interface and supplied Graphical User Interface (GUI). Systems operating from AC mains voltages up to 1000VAC are supported using the integrated, transformer isolated, "picket fence" firing circuitry. Dedicated high voltage and current measurement interfaces are provided to implement closed loop digital control of both DC current and DC voltage.

The single board OZSCR2x00 has been designed to address numerous SCR power system challenges, allowing fast and economical product development and support. With nearly every system parameter adjustable in software over an almost unlimited range, implementation possibilities are endless. Pre-designed control algorithms can quickly be selected using a PC based GUI. A digital PLL synchronizes to the AC line voltage, and can quickly report and respond to abnormal line conditions. Intelligent fault handling minimizes down time and protects the system from damage. Field updates are fast and easy using the RS485 boot loader. For complex systems requiring control of more than six SCRs multiple OZSCR2x00 boards can easily be combined using the expansion interface.

2.1 Input Power

2.1.1 OZSCR2000

The OZSCR2000 is designed to operate off a universal, single phase AC input (85-265 V_{AC}). The AC input is used to generate isolated bias voltages for the control circuitry to operate from. All the circuitry on the control board is reference to a single common point. This common is isolated from the AC Mains and the DC high voltage by 2MOhm sense resistors.

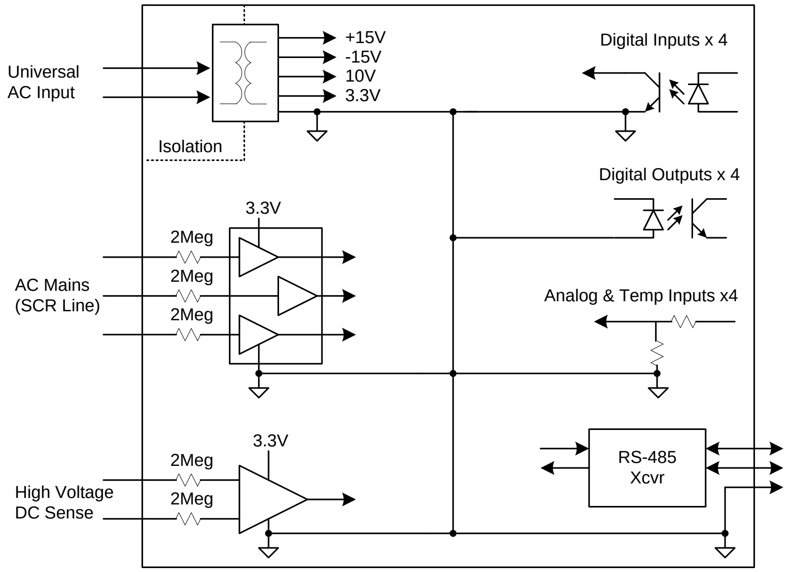


Figure 1 - OZSCR2000 Power and Grounding Block Diagram

2.1.2 OZSCR2100

The OZSCR2100 is designed to operate off a DC input voltage (18-32 V_{DC}). The DC input is used to generate isolated bias voltages for the control circuitry to operate from. All the circuitry on the control board is reference to a single common point. This common is isolated from the AC Mains and the DC high voltage by 2MOhm sense resistors.

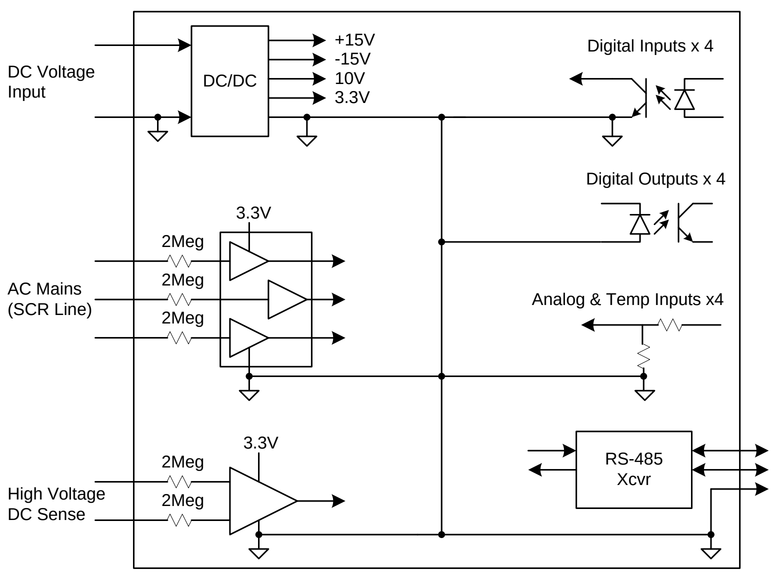


Figure 2 - OZSCR2100 Power and Grounding Block Diagram

2.2 Line Synchronization

The OZSCR2x00 implements a proprietary, digital phase locked loop to precisely track the AC mains voltage. Two separate methods of sensing the AC mains voltage are provided; either directly from the SCR cathode connections or using low voltage inputs to the board that have been stepped down elsewhere in the user's system. The desired synchronization input is specified in the ***Line Synch Input*** configuration register (0x10FD).

2.2.1 Direct Cathode Line Sense

In this configuration, the AC mains voltage is sensed directly at the SCR driver connections of the three line-connected cathode drivers, J1, J2, and J3.

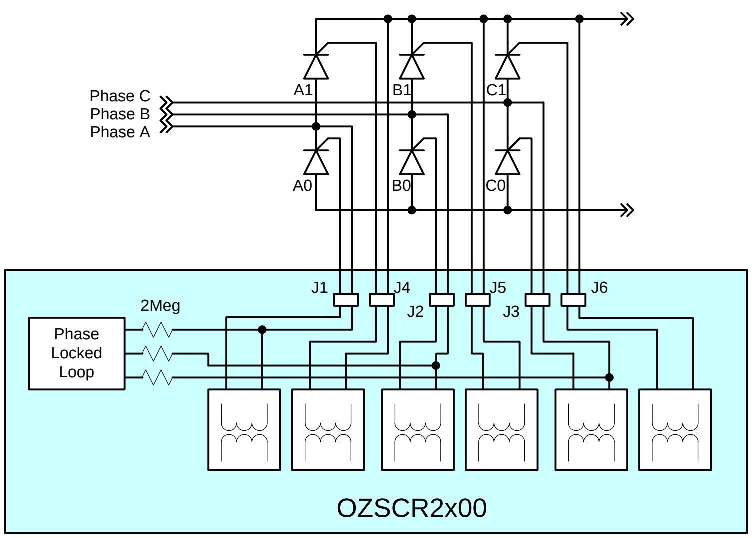


Figure 3 - Direct Line Synchronization Block Diagram

The high voltage sensing circuit incorporates a programmable gain amplifier (PGA) to optimize the circuit attenuation to the application. The ***AC Line Sense Gain*** configuration parameter (0x10FE) can be used to set the PGA gain to a value of 2, 4, 8, 16, 32, or 64. The maximum sensed AC voltage is given by:

$$\mp\frac{3660.04}{PGA\ Gain}V$$

2.2.2 Low Voltage Line Sense

This configuration provides a low voltage line synchronization interface intended to interface to +/-10V transformer isolated signals (7.07V_{rms} line-to-line).

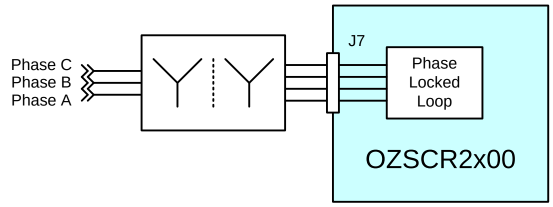


Figure 4 - Low Voltage Line Synchronization Interface

Note that any phase offsets that may occur in the process of externally stepping down the line sense inputs must be programmed into the ***PLL Phase Lag Adjustment*** register (0x1083). For example, if the step-down transformer is not a Y/Y transformer but rather a Delta/Y type, a 30-degree (or minus 30 degree) offset must be written to register 0x1083.

For proper line synchronization, the phase connections to the low voltage line sense connector J7 *MUST* match the SCR phase connections shown in the table below.

Table 1 - Low Voltage Line Sense Phases

LV Connector J7 Pin #	Corresponding SCR Phase
1	J1 - Pin 2
2	J2 - Pin 2
3	J3 - Pin 2

2.3 Fast Inhibit

The fast inhibit function allows the user to immediately terminate the SCR gate drive signals by de-asserting a digital input or by writing to the ***Fast Inhibit*** register (0x0000). The circuitry is designed such that the signal must be asserted for normal operation, ensuring that the drive is disabled should the connector become dislodged or the cable severed.

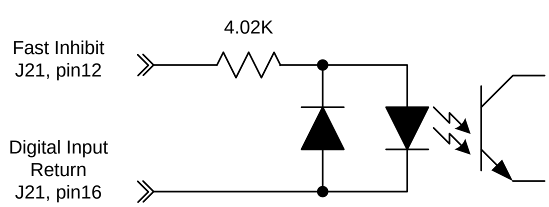


Figure 5 - Fast Inhibit Electrical Interface

CAUTION: When the fast inhibit hardware input is asserted, it will over-ride the FAST_INHIBIT Modbus register value.

Upon removing the fast inhibit condition, the SCR gate drive firing pulses will be immediately enabled if a soft inhibit condition is not present (see next section).

2.4 Soft Inhibit

The soft inhibit function causes the firing angle to ramp prior to enabling or disabling the SCR gate drive signals. Soft inhibit is controlled by asserting or deserting a digital input or by writing to the ***Soft Inhibit*** register (0x0001). The circuitry is designed such that the signal must be asserted for normal operation, ensuring that the drive is disabled should the connector become dislodged or the cable severed.

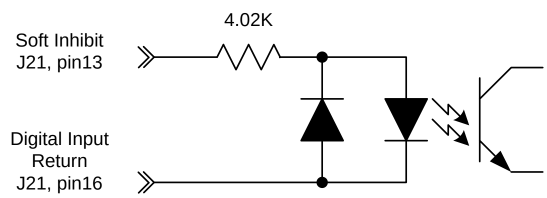


Figure 6 - Soft Inhibit Electrical Interface

In applications that do not intend to use the soft inhibit hardware input feature, it can be disabled by setting the ***Soft Inhibit Digital Input Enable*** configuration register (0x1010) appropriately.

> ⚠ **CAUTION:** When the soft inhibit hardware input is enabled and asserted, it will over-ride the SOFT_INHIBIT Modbus register value.

When asserting the Soft Inhibit condition, the firing pulse angle ramps from the user-commanded value to the angle specified in the ***Soft Stop Final Firing Angle*** configuration register (0x1014) and then the firing pulses will be disabled. The rate at which the angle is ramped is specified in the ***Soft Stop Ramp Rate*** configuration register (0x1013).

When removing the Soft Inhibit condition, the firing pulse angle will initially start at the value specified in the ***Soft Start Initial Firing Angle*** configuration register (0x1012) and then ramp to the user-commanded phase angle at a rate specified in the ***Soft Start Ramp Rate*** configuration register (0x1011). If the user-commanded phase angle happens to be a smaller conduction angle compared to the ***Soft Start Initial Firing Angle***, the soft start ramp will be skipped and instead the firing pulses will simply be turned on at the user-commanded phase angle.

When asserting the Soft Inhibit condition, the user may optionally enable a “Keep Firing” mode. In this mode, the firing pulses are not actually disabled at the end of the soft stop ramp. Instead, firing continues and the phase angle remains at the specified ***Soft Stop Final Firing Angle***. When removing the Soft Inhibit condition in this mode, the firing angle is then ramped from this angle to the user-commanded angle using the specified ***Soft Start Ramp Rate***. “Keep

Firing" mode is configured using the ***Soft Inhibit Keep Firing Enable*** configuration register (0x1015).

The soft inhibit function is only applicable for open-loop phase angle control and zero cross firing modes of operation. When operating in DC Voltage or DC Current control modes (see the ***Operating Mode*** configuration register, 0x1000), the soft inhibit digital input and the ***Soft Inhibit*** command register (0x0001) are ignored.

2.5 Analog Control Input

The OZSCR2x00 can be controlled from either one of the three analog inputs or the Modbus ***Control Setpoint*** registers (0x0005, 0x0006, 0x0007). When using one of the analog inputs, the user must configure which of the three inputs (J21, pins 7, 8, and 9) should serve as the control using the appropriate register for the desired operating mode, as summarized in Table 2.

Table 2 - Analog Control Selection Registers

Mode	Register #	Register Name
Phase Angle Control	0x1026	Phase Angle Control Analog Input Select
Zero Crossing Control	0x103C	Zero Cross Control Analog Input Select
Voltage Control	0x1042	Voltage Setpoint Analog Input Select
Current Control	0x105A	Current Setpoint Analog Input Select

The three analog inputs must also be configured for the desired interface type: 0-10Vdc, 0-5Vdc, 4-20mA, or 0-20mA. The inputs are configured using the ***Analog Input Configuration*** register (0x1001).

The analog control input is used to specify the user's desired command as a percentage of the full-scale value specific to the selected operating mode. The lower the analog input, the lower the input command (i.e. for the 0-10V option, 0V = 0% command, 10V = 100% command). For phase angle control, a 0% command is treated as an angle command of 180 degrees (no conduction) and a 100% command is treated as a zero-degree command (full conduction). For zero cross control, the input command is used to set the duty cycle of the firing bursts (the number of cycles to fire relative to the total number of cycles specified). For DC voltage or DC current control, the input command is used to define the desired setpoint as a percentage of the specified feedback range for the selected control mode.

2.5.1 Analog Control Input Trim Adjust

The analog control input can be optionally adjusted using a second "trim" analog input pin. The trim value is a bi-polar adjustment that is added to the user's analog setpoint command. This feature is enabled using the ***Analog Setpoint Trim Enable*** configuration register (0x1008). This trim enable register provides the ability to use one of the spare digital input pins as an enable pin for the trim feature. When using a digital input as an enable pin, the user must drive the input pin high to enable the trim input. Driving the input pin low or leaving the pin disconnected will cause the trim input to be ignored.

Any of the analog input pins can be selected as the source for the trim adjust value using the ***Analog Setpoint Trim Input Select*** configuration register (0x1009). When using an analog input, the trim value is centered about the mid-point of the selected analog input range. Alternatively, the ***Analog Setpoint Trim Adjust*** command register (0x0013) can be used instead of an analog input pin by selecting Modbus register control in the ***Analog Setpoint Trim Input Select*** register. The adjustment range is specified in the ***Analog Setpoint Trim Full Scale*** configuration register (0x100A).

For example, if the trim input is enabled, set to use analog input #2, analog input #2 is configured for 0-10V operation, and the full-scale trim value is set to 10%, then an input of 0V on the trim pin would add -10% to the analog command, 5V would add 0% to the analog command, and 10V would add +10% to the analog command.

If the user-selected operating mode is configured to use Modbus register control for setpoints instead of analog pin control, the ***Analog Setpoint Trim*** configuration parameters are not used.

2.5.2 Analog Input Offset Calibration

Offset corrections can be applied to any of the three analog inputs. These offsets can be user-supplied through the ***Analog Input 1-3 Offset*** configuration registers (0x10F0-0x10F2) or automatically calculated using the ***Auto Calibrate Analog Input Midscale*** command register (0x000D). These values are intended as generic offsets for the input pins themselves and are not application specific.

> **CAUTION:** These offsets will persist and values will remain the same when changing the analog input configuration (0x1001) which may cause unintended behavior. Make sure to reset or update the offset values when changing the analog input configuration.

2.6 Voltage Feedback

When operating in voltage control mode, the rectified DC output voltage must be sensed and provided to the OZSCR2x00 for the control loop to operate. For those applications that do not require this signal to be isolated, the high voltage sense circuit on J13 can be used for this purpose.

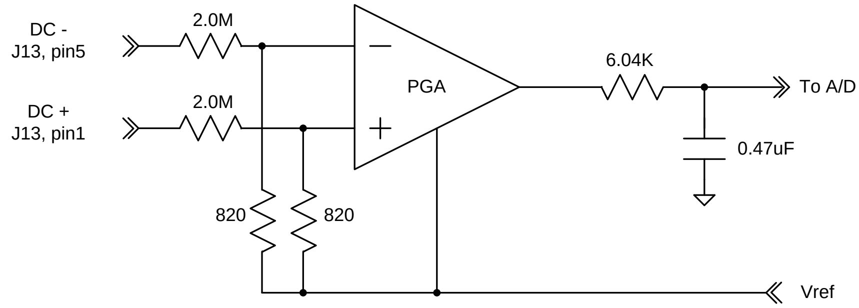


Figure 7 - J13 High Voltage Sense Interface Circuitry

The sensing circuit incorporates a programmable gain amplifier (PGA) to optimize the circuit attenuation to the application. The ***DC Link Sense Gain*** configuration parameter (0x10FF) can be used to set the PGA gain to a value of 2, 4, 8, 16, 32, or 64. Considering the 2.0M/820 Ohm divider, the maximum sensed DC Link voltage is:

$$\mp \frac{3660.04}{PGA\ Gain} V$$

If the application requires that this voltage is isolated from the OZSCR2x00 signal ground, then the circuit interface in Figure 8 can be used.

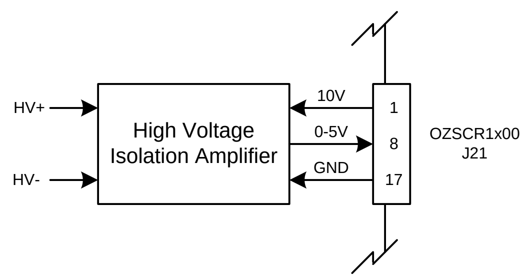


Figure 8 - Isolated High Voltage Sense Interface Circuitry

2.7 Current Feedback

When operating in DC current control mode, the applicable current must be sensed and provided to the OZSCR2x00 for the control loop to operate.

The OZSCR2x00 provides an input for a LEM style current sensor input on J20. This interface provides +/-15V to power the sensor and is scaled to accept a +/-4V input signal proportional to current. Table 3 provides a list of some of the compatible LEM sensor products.

Table 3 - Compatible LEM Current Sensors

LEM Product Series	Product Sense Range	Accuracy	Mount
HAL	50A to 1000A	1%	Panel
HTA	100A to 1000A	1%	Panel
HTY	50A to 300A	1%	PCB
HTB	50A to 600A	1%	PCB

HAC	100A to 1800 A	1%	Panel
HAS	50A to 900A	1%	Panel/PCB

2.8 Phase Angle to Output Voltage Linearization

By default, the OZSCR2x00 controller provides firing pulses to the SCR devices using a phase angle provided directly by the user or from one of the internal controllers used for regulating current or voltage. For many typical systems, the transfer function from phase angle input command to average output voltage is not linear. In many situations, this transfer function resembles a cosine shape as illustrated in the figure below, where the conduction angle is plotted on the X-axis (0 degrees = maximum conduction angle, 180 degrees = minimum conduction angle) and the expected output voltage is plotted on the Y-axis as a percentage of maximum expected output.

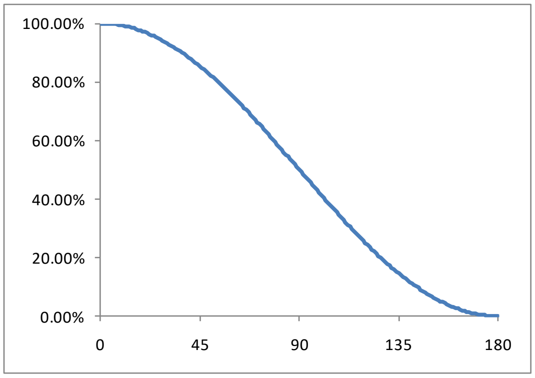


Figure 9 - Example Non-linear Conduction Angle vs. Output Voltage

The OZSCR2x00 provides a feature to modify the commanded phase angle such that the resulting phase angle to average output voltage transfer function is linear. To do so, the controller adjusts the commanded phase angle using an arccosine shape as shown in the figure below. In this figure the input angle is plotted on the X-axis, the modified output angle is plotted on the left Y-axis and shown in blue, and the resulting linear output voltage is plotted on the right Y-axis and is shown in red.

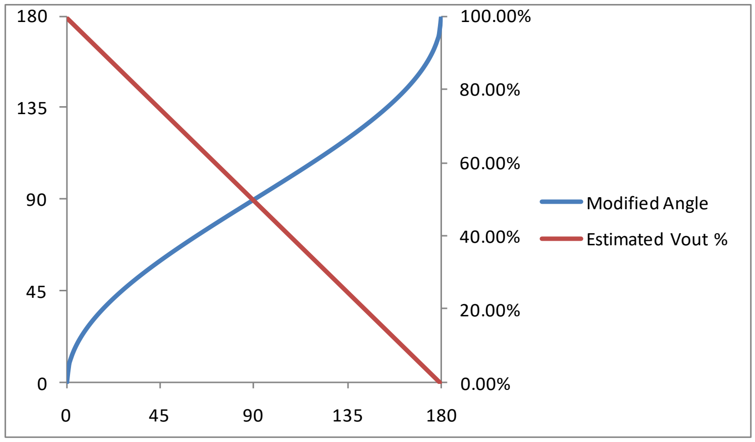


Figure 10 - Modified Conduction Angle vs. Output Voltage

This phase angle linearization feature is enabled using the ***Linearization Control Enable*** configuration register (0x100C). In addition, the actual commanded angle range that can be modified with the arccosine shape is also configurable using the ***Linearization Angle Range – Lower/Upper Angle*** configuration registers (0x100D/0x100E). For example, the illustrations above are representative of a single-phase system where the useful conduction range is from 0 to 180 degrees. However, for a three-phase system, the conduction range may be from 0 to 120 degrees. By setting the angle range to these values, the arccosine shape is applied across the 0 to 120-degree range, and any angle outside of this would simply be passed directly through to the firing controls. This scenario is shown in the following figure.

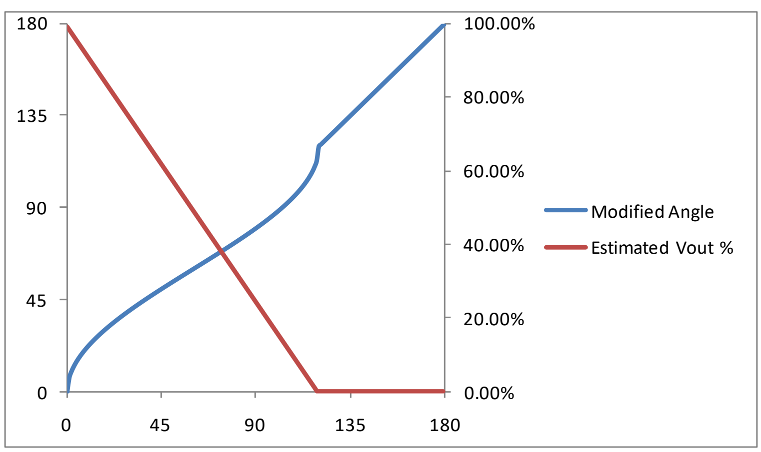


Figure 11 - Example Non-linear Conduction Angle vs. Output Voltage

2.9 Visual Indicators

The board has four LEDS used to provide a visual indication of the operating status. A description of the LEDs and their meaning is provided in Table 4.

Table 4 - Visual Indicator Descriptions

Ref Des	Label	Color	Description
D20	SYS_OK	Green	Software blinks this LED when properly executing.
D22	INHIBIT	RED	Illuminated if a Fast or Soft Inhibit source is active.
D19	PHASE_LOSS	RED	Illuminated if the PLL is unable to synchronize.
D21	FAULT	RED	Illuminated if any Fault condition exits.

The INHIBIT LED behavior varies depending on the configured operating mode (see next section). When configured for three separate single-phase controllers (specifically, modes 6 and 7), the INHIBIT LED behavior is as follows:

- If all 3 single-phase controllers are being inhibited, the LED will remain lit
- If all 3 single-phase controllers are *not* inhibited, the LED will remain unlit
- Otherwise, the LED will blink such that the number of flashes equals the number of inhibited channels (either one or two)

For all other modes where only a single controller is being used, the LED will simply remain lit when the controller is being inhibited or unlit when not inhibited.

3. Operating Modes

The OZSCR2x00 can operate in four different open or closed loop control modes; Phase Angle Control Mode, Zero Cross Control Mode, Closed Loop DC Voltage Control Mode, and Closed Loop DC Current Control Mode. For flexibility, the operating mode can be selected by setting the ***Operating Mode*** configuration register (0x1000) accordingly.

In addition, the OZSCR2x00 provides Field Flashing capability for the purposes of starting generators.

3.1 Phase Angle Control

When operating in Phase Angle control mode, the user can directly set the point on the AC input waveform at which the SCRs will be switched on, which in turn varies the output voltage of the converter.

3.1.1 Typical 3-Phase Converter Hardware Configuration

Figure 12 illustrates a typical open loop, phase control, converter application hardware configuration. While all the features, e.g. soft inhibit, command interface, etc., are completely configurable by the user, this diagram illustrates a single, basic configuration using the default setup with no configuration changes.

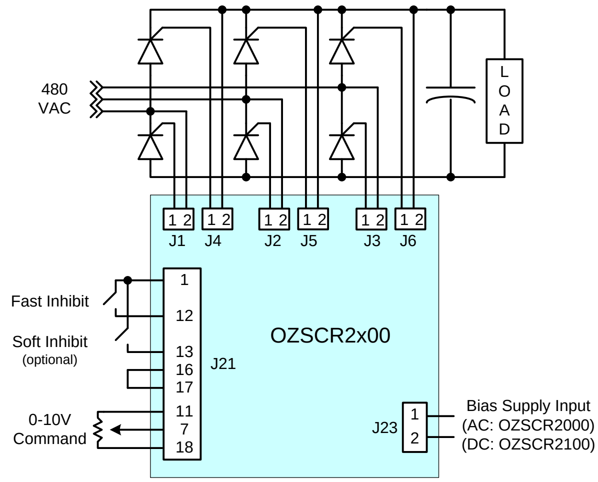


Figure 12 - Typical Phase Control 3-Phase Converter Application

3.1.2 Typical 3-Phase Controller Hardware Configuration

Figure 13 illustrates a typical open loop, phase control, controller application hardware configuration. While all the features, e.g. soft inhibit, command interface, etc., are completely configurable by the user, this diagram illustrates a single, basic configuration using the default setup and a single configuration register change. When operating in 3-Phase AC Controller mode, the ***Operating Mode*** register (0x1000) must be set to a value of zero.

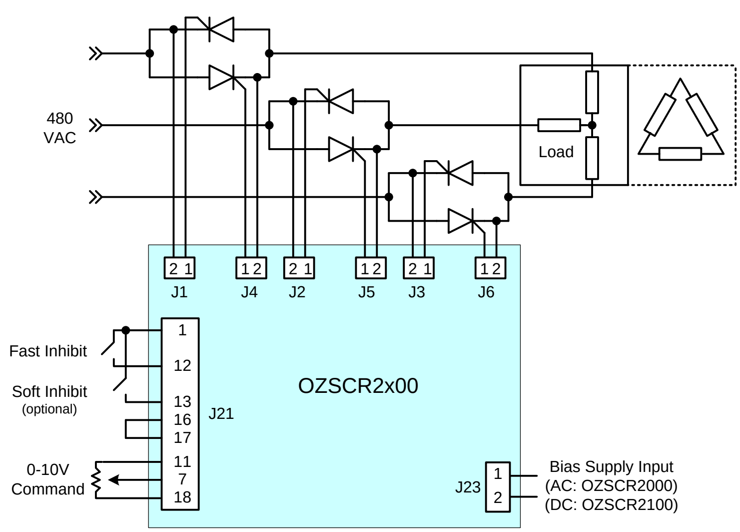


Figure 13 - Typical Phase Control 3-Phase Controller Application

3.1.3 Typical Single Phase Converter Hardware Configurations

Figure 14 illustrates typical open loop, phase controlled converter hardware configuration for single phase H-bridge topologies. The figure shows both a 4-SCR and a 2-SCR H-Bridge configuration. For proper line synchronization when operating as a 2-SCR converter, it is necessary to wire the cathode terminals of J1 (pin 2) and J2 (pin 2) to the AC line connections as shown in Case B of the figure. For 2-SCR converters where the SCRs are in the top of the bridge, they should be driven from drive connections J4 and J5 and separate line sense paths provided to the cathodes at J1 and J2.

While all the features, e.g. soft inhibit, command interface, etc., are completely configurable by the user, this diagram illustrates the basic configurations using the default setup and the following configuration register changes:

- ***Operating Mode*** (0x1000) must be set to a value of 8 (single phase bridge converter with open loop phase control).
- ***Firing Channel Enable*** (0x10A2) must have a '1' in each of the bit positions corresponding to each of the populated SCR connections and the remaining bits should be '0' (where bit 0 = connector J1, bit 1 = connector J2, and so on up to bit 5 = connector J6). Disabling the unused channels isn't required, but doing so will reduce the controller's power consumption as well as reduce the risk of inadvertently firing SCRs that may be connected to the unused driver channels.

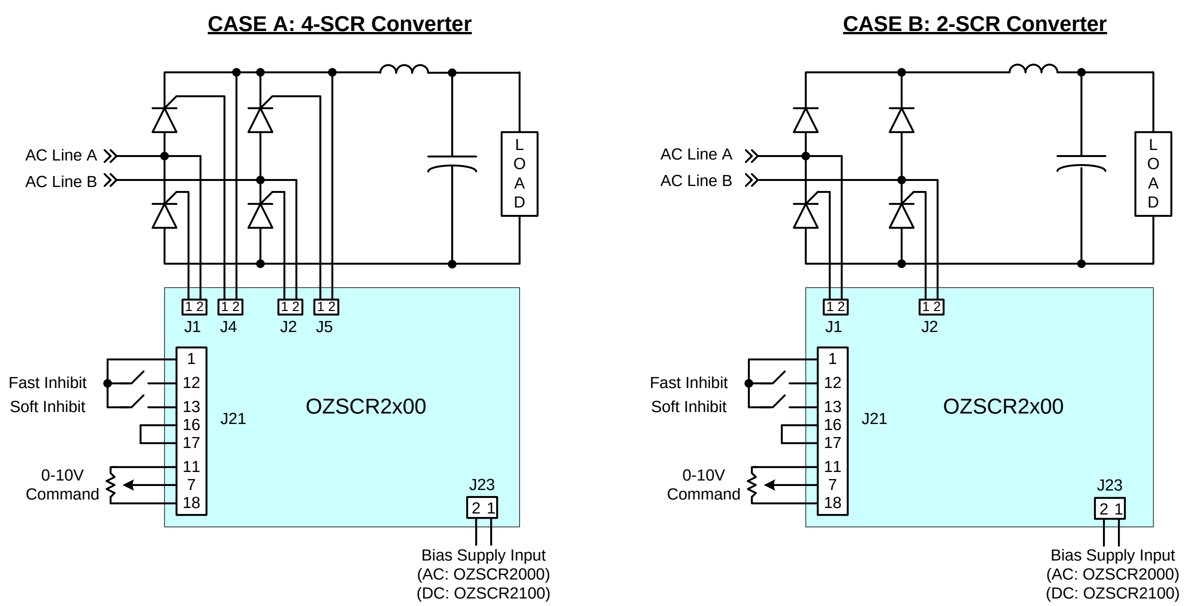


Figure 14 - Typical Single Phase H-Bridge Converter Applications

3.1.4 Typical Single Phase Controller Hardware Configurations

Figure 15 illustrates the typical open loop, phase control, single phase controller application hardware configurations. As the figure shows, the OZSCR2000 supports up to three independent single phase controllers. For proper line synchronization when operating a single controller, it is necessary to wire the cathode terminal of J2 (pin 2) to the AC line "B" connection as shown in Case A of the figure.

While all the features, e.g. soft inhibit, command interface, etc., are completely configurable by the user for each of the three controllers, this diagram illustrates the basic configurations using the default setup and the following configuration register changes:

- ***Operating Mode*** (0x1000) must be set to a value of 6 (single phase AC controller with open loop phase control).
- ***Firing Channel Enable*** (0x10A2) must have a '1' in each of the bit positions corresponding to each of the populated SCR connections and the remaining bits should be '0' (where bit 0 = connector J1, bit 1 = connector J2, and so on up to bit 5 = connector J6). Disabling the unused channels isn't required, but doing so will reduce the controller's power consumption as well as reduce the risk of inadvertently firing SCRs that may be connected to the unused driver channels.

When operating 2 or 3 controllers, the Fast Inhibit input will affect all controllers (i.e. firing on all channels is inhibited). For independent inhibit control of each controller, the soft inhibit input pin for the corresponding controller must be enabled in the ***Soft Inhibit Digital Input Enable*** register (0x1010). If fast per-controller inhibit operation is required, the soft start and soft stop ramp rates should be increased to their maximum values.

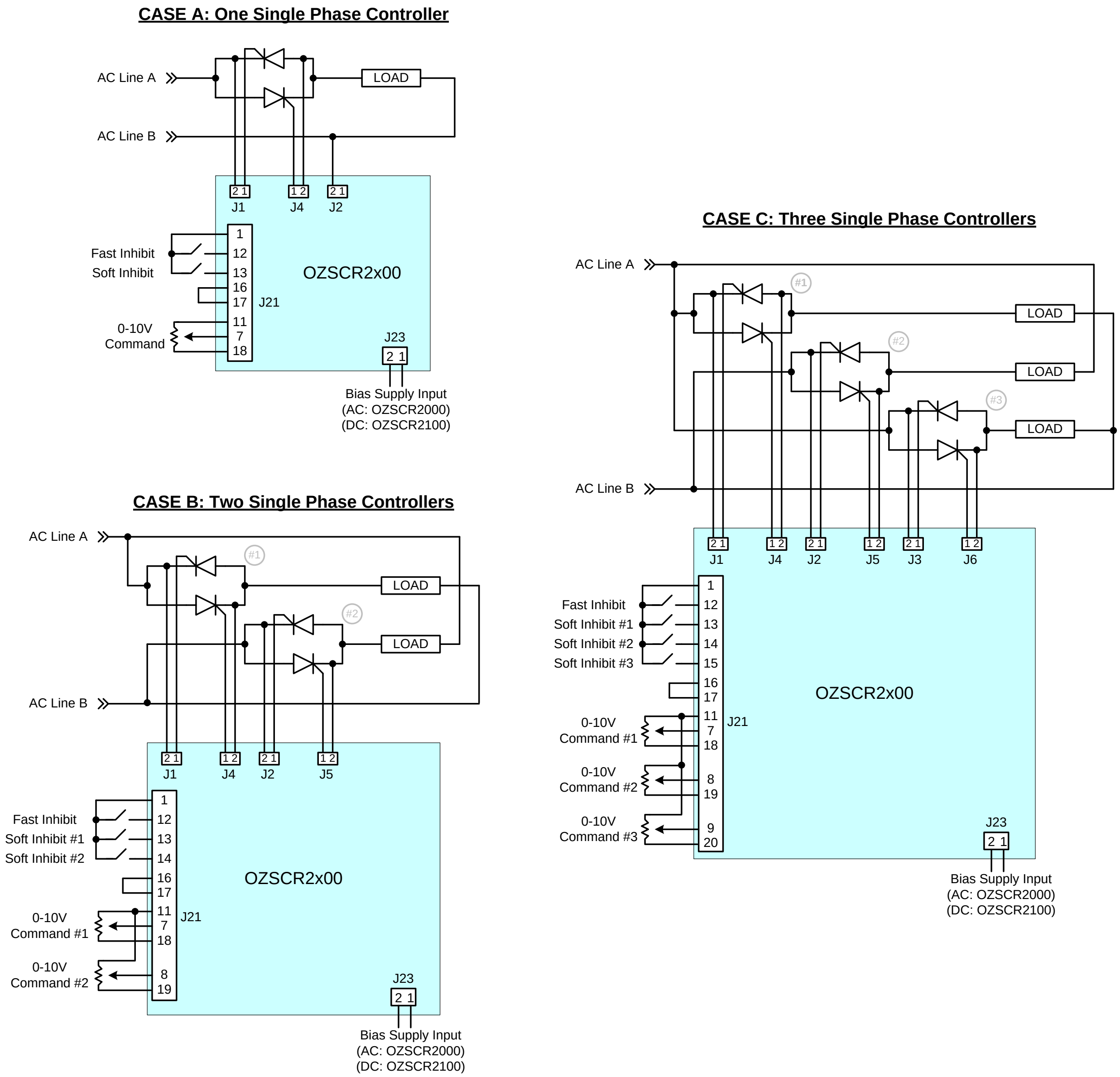


Figure 15 - Typical Single Phase Controller Applications

3.1.5 Phase Control Configuration Options

Either an analog input or the ***Control Setpoint*** register (0x0005) can be used to set the conduction angle, α, as determined by the ***Phase Angle Control Mode*** register (0x1020), for three phase configurations. Figure 16 provides a block diagram of Phase Angle Control Mode.

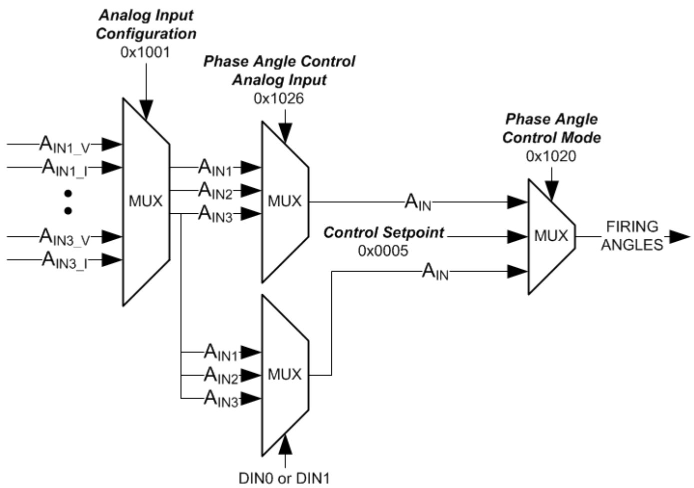


Figure 16 – Three Phase, Phase Angle Control Block Diagram

The analog input can be configured either as a 0-5V, 0-10V, 4-20mA, or a 0-20mA input, via the ***Analog Input Configuration*** register (0x1001). When the analog input is configured for a voltage interface, 0V corresponds to maximum phase angle (minimum conduction angle) or zero output while 5V or 10V corresponds to minimum phase angle (maximum conduction angle) or maximum output.

When the analog input is configured for a current interface, 0mA or 4mA corresponds to maximum phase angle (minimum conduction angle) for zero output while 20mA corresponds to minimum phase angle (maximum conduction angle) for maximum output.

The analog input pin to control firing in three phase configurations can either be set statically or chosen based on the state of a digital input pin. A digital input pin can be used to dynamically change between two analog input pins during operation.

When operating multiple independent single phase controllers with Modbus register control, all three ***Control Setpoint*** registers, ***Phase Angle Control*** registers, and ***Phase Angle Control Mode*** registers are used.

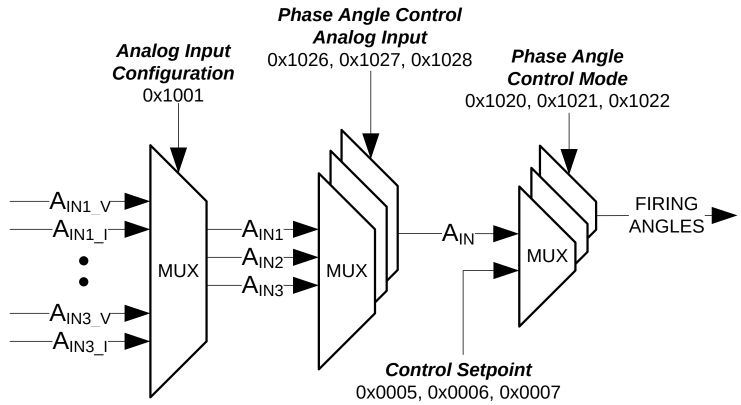


Figure 17 – Single Phase, Phase Angle Control Block Diagram

3.2 Zero Cross Control

When operating in Zero Cross control mode, the user can configure the control period as a total number of AC line cycles using the ***Zero Cross Control Total Line Cycle Count*** register (0x1032). This register defaults to a value of 60, for a 1 second (60-cycle) control period on 60Hz systems.

The selected control input is then used to directly control the number of cycles that the SCRs will conduct within the defined control period. For example, if a control period of 60 cycles is specified, a 10% duty cycle command causes the driver board to fire for 6 line cycles and inhibit for 54 cycles.

The default firing angle is set to maximum conduction angle for the "on" cycles. If soft inhibit is enabled, the "on" firing angle will be slewed accordingly. Either an analog input or the ***Control Setpoint*** register (0x0005) is used to set the duty cycle, as determined by the ***Zero Cross Control Mode*** register (0x1033), when configured for three phase operation. Figure 18 provides a block diagram of Zero Crossing control mode.

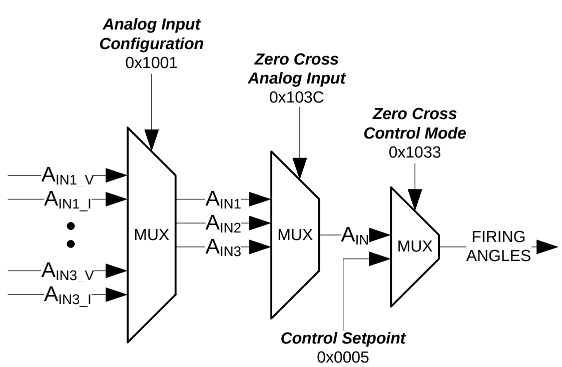


Figure 18 – Three Phase Zero Crossing Control Block Diagram

The analog input can be configured either as a 0-5V, 0-10V, 4-20mA, or a 0-20mA input via the ***Analog Input Configuration*** register (0x1001). When operating in voltage mode, 0V corresponds to 0% duty cycle while 5V or 10V corresponds to 100% duty cycle. When operating in current mode, 0mA or 4mA corresponds to 0% duty cycle while 20mA corresponds to 100% duty cycle.

For single phase zero cross control, up to three separate controllers may be used with the restriction that they must all use the same control period specified in the ***Zero Cross Control Total Line Cycle Count*** register (0x1032). The hardware configuration requirements are the same as those shown in Figure 15 for the phase controlled single phase switch applications. When operating with Modbus register control, the three ***Control Setpoint*** registers, ***Zero Cross Analog Input*** registers, and ***Zero Cross Control Mode*** registers are used.

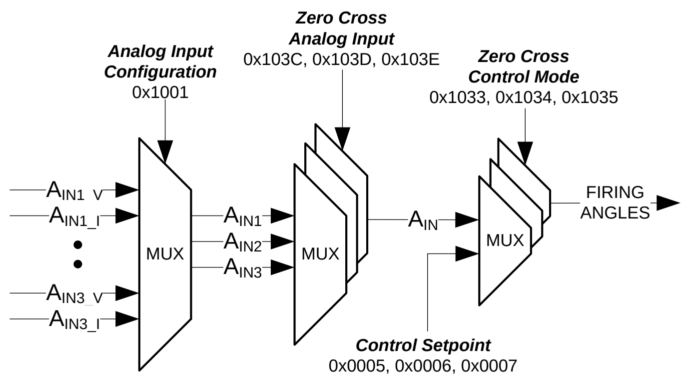


Figure 19 – Single Phase Zero Crossing Control Block Diagram

3.3 Voltage Control Mode

When operating in voltage control mode, the OZSCR2x00 provides closed loop control of rectified output voltage. Figure 20 illustrates a typical three phase voltage controller hardware configuration. While all the features, e.g. fast inhibit, command interface, etc., are completely configurable by the user, this diagram illustrates a single, basic configuration using the default setup with minimum configuration register changes. In this application, the non-isolated, high voltage sense interface is used as the feedback for the voltage controller. For those customers requiring isolated feedback, please consult Oztek application engineers for isolated sense solutions.

In this configuration, 0V command corresponds to 0% output voltage while 5V or 10V corresponds to 100% output voltage. Percentages are with respect to the maximum voltage measured on the configured voltage sense interface. This is described in section 2.6.

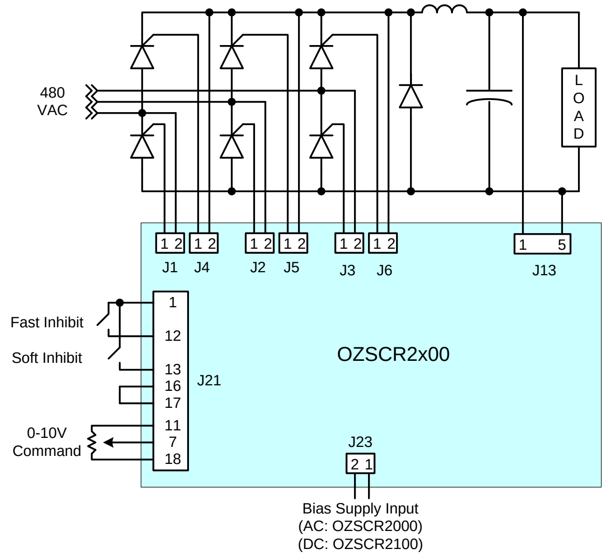


Figure 20 - Typical 3-Phase Voltage Control Hardware Configuration

Voltage control mode is also supported for single phase applications as shown in the following figure.

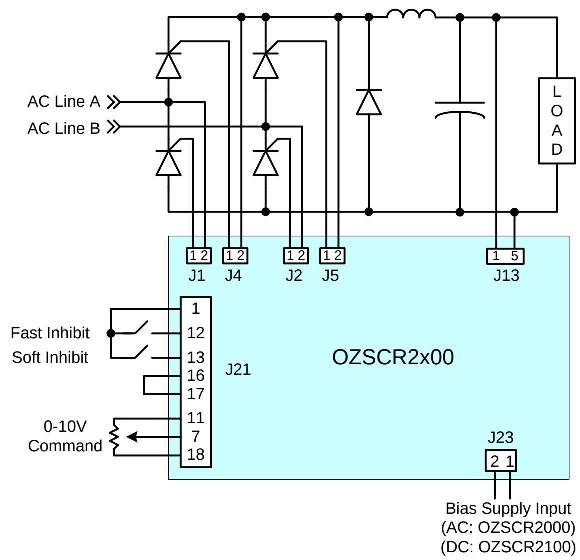


Figure 21 - Typical Single Phase Voltage Control Hardware Configuration

Either an analog input or the ***Control Setpoint*** register (0x0005) can be used to set the output voltage, as determined by the ***Voltage Control Mode*** register (0x1040). The analog input can be configured either as a 0-10V, 0-5V, 4-20mA, or a 0-20mA input, via the ***Analog Input Configuration*** register (0x1001).

The voltage controller is implemented as a classical Proportional plus Integral (PI) controller. All the PI controller gain settings are configurable using the Modbus interface. In addition, the voltage controller can be configured for multi-loop control using an inner current controller. Figure 22 provides a block diagram of the voltage mode controller. Figure 24 provides details on the voltage PI controller and Figure 24 illustrates the inner current controller implementation.

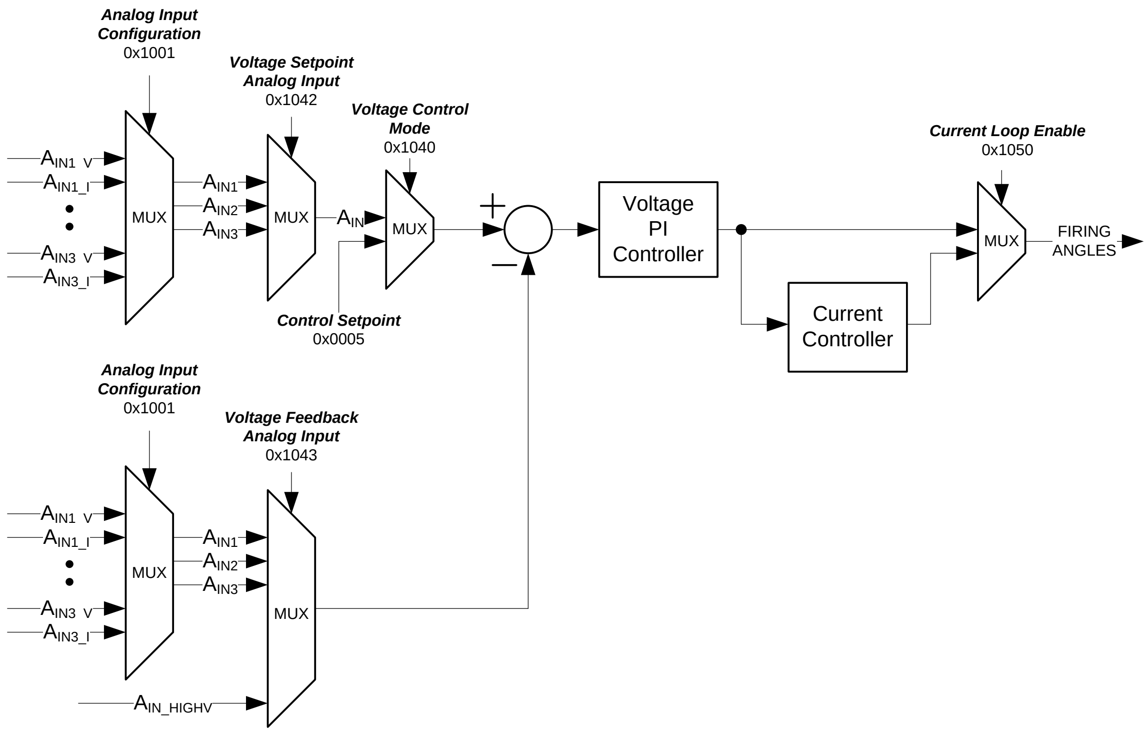


Figure 22 - Voltage Control Mode Block Diagram

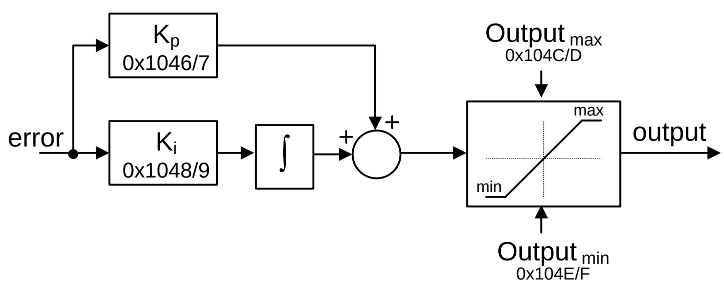


Figure 23 - Voltage PI Controller Block Diagram

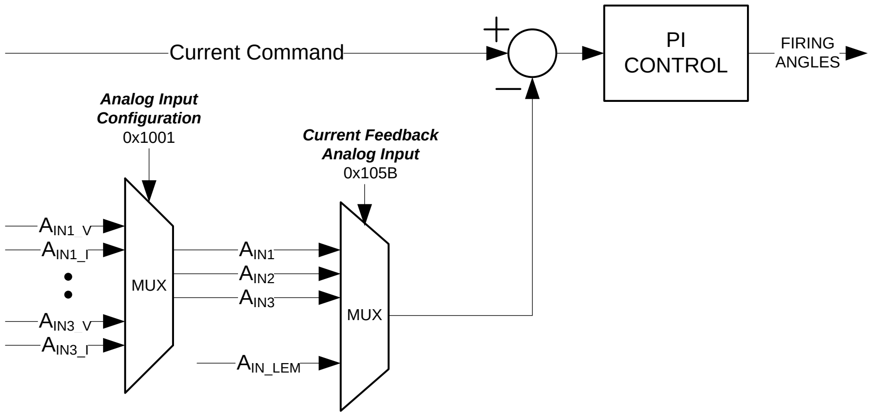


Figure 24 - Inner Current Loop Block Diagram

The voltage loop max output can be changed dynamically using either the ***Voltage Loop Max Output*** command register (0x12) or an analog input pin based on the ***Voltage Loop Max Output Mode*** configuration register (0x1051). The default settings use the Modbus command register which defaults to the ***Voltage Control Max Output*** configuration register value (0x104C-0x104D).

3.4 DC Current Control Mode

When operating in DC current control mode, the OZSCR2x00 provides closed loop control of the converter's output current. Either an analog input or the ***Control Setpoint*** register (0x0005) can be used to set the output current, as determined by the ***Current Control Mode*** register (0x1058).

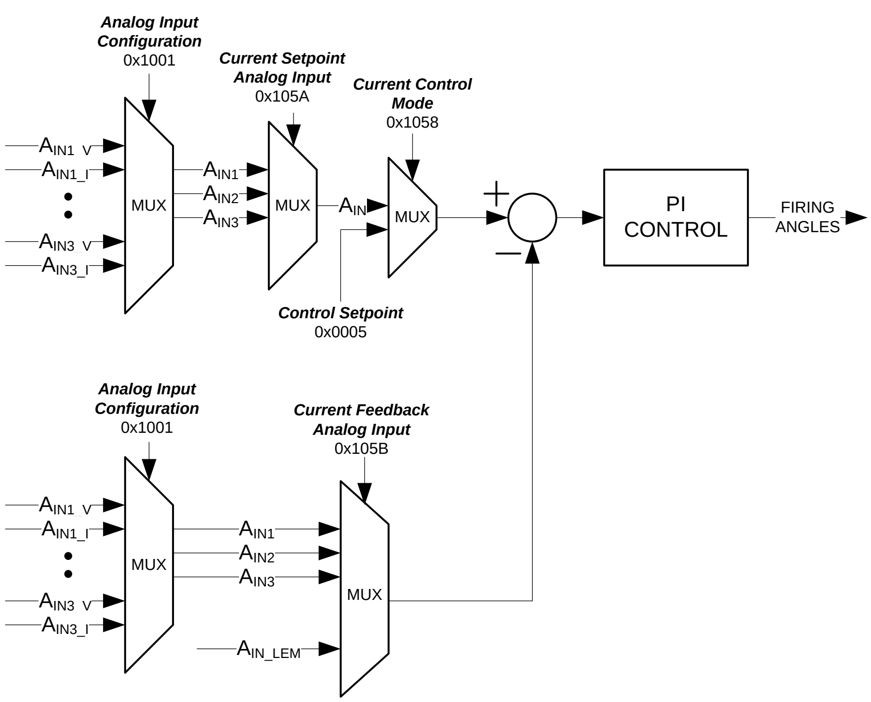


Figure 25 - DC Current Control Mode Block Diagram

The analog input can be configured either as a 0-10V, 0-5V, 4-20mA, or a 0-20mA input, via the ***Analog Input Configuration*** register (0x1001). When operating in voltage mode, 0V corresponds to 0% output current while 5V or 10V corresponds to 100% output current. When operating in current mode, 0mA or 4mA corresponds to 0% output current while 20mA corresponds to 100% output current. The feedback input for the control loop is determined by the ***Current Feedback Analog Input Select*** register (0x105B).

3.5 Field Flashing Mode

In some generator applications, if the machine does not have enough residual magnetism to build up to full voltage, a provision is usually made to inject current into the rotor from another source. This may be a battery, a *house unit* providing direct current, or rectified current from a source of alternating current power. Since this initial current is required for a very short time, it is called "field flashing".

Field flashing can be controlled via one of the digital inputs or a Modbus register, as determined by the ***Motor Field Flashing Control*** register (0x10A3). When enabled, a continuous stream of lower-current "B" firing pulses is driven out simultaneously on all enabled channels. The higher-current "A" pulses are disabled when operating in this mode. The ***Firing Pulse Width*** register (0x10A0) is used to determine the time that the pulse is "on". However, unlike normal firing control where the "B" pulse duty cycle is 50%, a 25% duty cycle is used when field flashing is enabled - the "off" time is set to three times the "on" time resulting in a pulse frequency of half the normal picket fence "B" pulse frequency. This is used to reduce the overall power dissipated by the gate drive circuits when they are continuously generating current pulses on all channels simultaneously.

As discussed in section 5.4.12.1, the nominal ***Firing Pulse Width*** value is set to 21.7 microseconds to match the intended use of the local gate drive hardware. This value can be set to a higher value when not using local gate drive hardware and instead using the external gate drive interface to drive logic-level gate drive signals to off-board gate drive hardware. The maximum firing pulse supported by the field flashing controls is 136 microseconds. Care must be taken to not exceed this firing pulse width when using field flashing mode as higher values will result in unpredictable and shorter "off" times.

Note that field flashing operation is overridden and disabled if **Fast Inhibit** or **Soft Inhibit** (if enabled) is asserted. When field flashing operation is enabled, the **Fast Inhibit** control will behave the same as with normal firing, meaning the firing pulses will start or stop immediately. In addition, the ***Motor Field Flashing Status*** register (0x0808) returns a Boolean value representing the status of the field flashing enable logic signal.

4. OZSCR2x00 Interface

4.1 Electrical Interfaces

The approximate location of the connectors, jumper blocks, LEDs, and test hooks are illustrated in Figure 26.

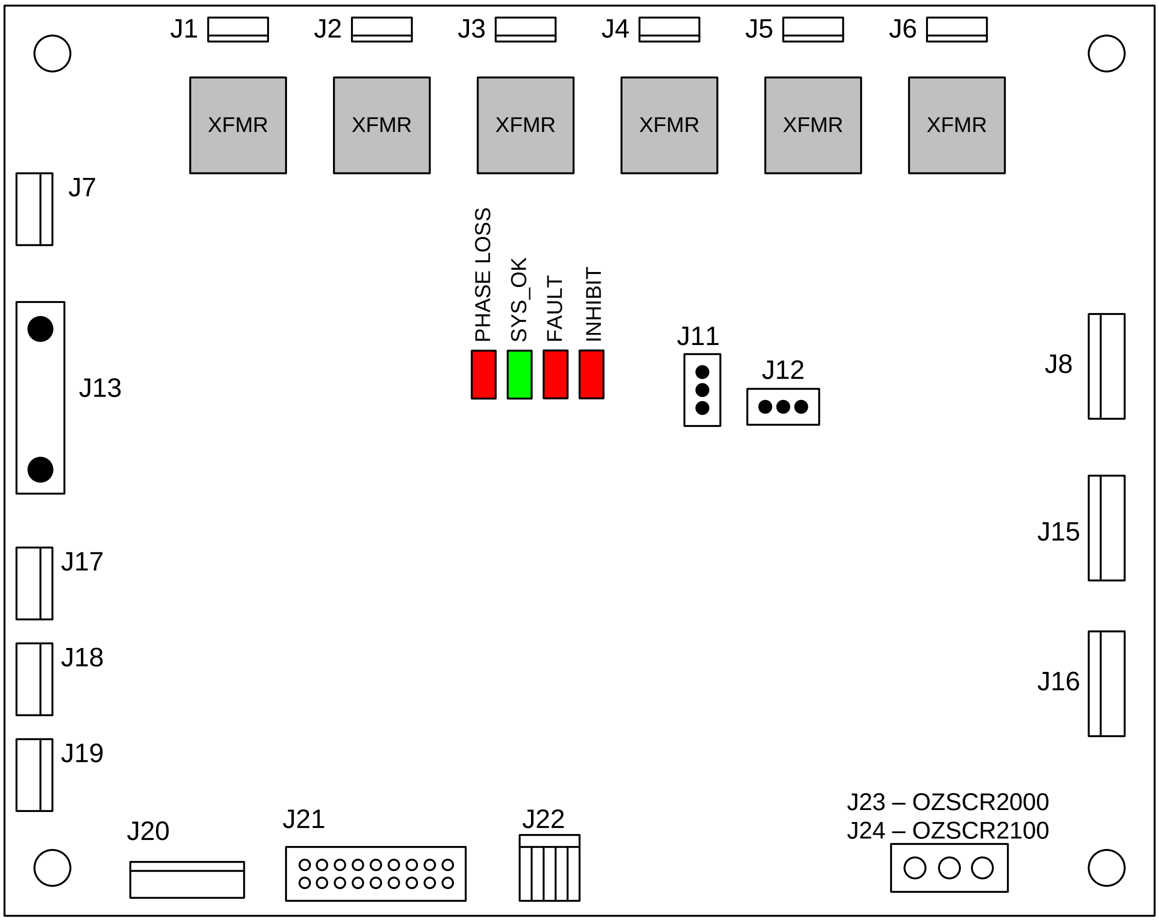


Figure 26 - Approximate Connector, Jumper, LED, and Test Hook Locations

4.1.1 J1/J2/J3/J4/J5/J6 - SCR Gate Interfaces

Connectors J1, J2, J3, J4, J5, and J6 provide the gate drive signals to the SCR devices.

Table 5 - J1/J2/J3/J4/J5/16 SCR Gate Drive Pin Assignment

Pin #	Description
1	Gate
2	Cathode

- **OZSCR2x00 Connector Part Number:** (Waldom/Molex) 39-29-9022
- **Mating Connector Part Number:** (Waldom/Molex) 39-01-3022
- **Crimp Terminal:** (Molex) 39-00-0047 or 39-00-0060

⚠ **CAUTION:** High voltage may be present on these terminals when the system is connected and in operation.

4.1.2 J8 - Board to Board Slave Interface

J8 provides an interface for linking together multiple OZSCR2x00s in more complex control architectures.

Table 6 - J8 Board to Board Slave Interface Pin Assignment

Pin #	Description
1	n/c
2	n/c
3	Slave SCR Enable -
4	Slave SCR Enable +
5	Slave Fault Out -
6	Slave Fault Out +
7	RS485 B
8	RS485 A
9	Ground
10	Ground

- **OZSCR2x00 Connector Part Number:** (Tyco) 1761608-3
- **Mating Connector Part Number:** (Tyco) 1658527-3

4.1.3 J11 - RS485 Host Port Termination Jumper

J11 is a three-pin header that provides a means to terminate the differential RS485 Host port lines.

Table 7 - J11 RS485 Host Port Termination Jumper Assignment

Jumper Installed on Pin #	Description
1-2	No Termination
2-3	121 Ohm Termination

4.1.4 J12 - RS485 Slave Port Termination Jumper

J12 is a three-pin header that provides a means to terminate the differential RS485 Host port lines.

Table 8 - J12 RS485 Slave Port Termination Jumper Assignment

Jumper Installed on Pin #	Description
1-2	No Termination
2-3	121 Ohm Termination

4.1.5 J13 - High Voltage Sense Input

Connector J13 provides high voltage sense circuitry for measuring rectified, DC voltages.

Table 9 - J13 HV Sense Input Pin Assignment

Pin #	Description
1	DC +
5	DC -

- **OZSCR2x00 Connector Part Number:** (Tyco) 640445-5
- **Mating Connector Part Number:** (Tyco) 640250-5
- **Crimp Terminal:** (Tyco) 3-640706-1
- **Input Range:** 1830 V_{DC} maximum, see section 2.6 for the gain calculation using the ***DC Link Sense Gain*** configuration register (0x10FF).

CAUTION: High voltage may be present on these terminals when the system is connected and in operation.

4.1.6 J15 - Board to Board Master Interface

J15 provides an interface for linking together multiple OZSCR2x00s in more complex control architectures.

Table 10 - J15 Board to Board Master Interface Pin Assignment

Pin #	Description
1	n/c
2	n/c
3	Master SCR Enable -
4	Master SCR Enable +
5	Master Fault Out -
6	Master Fault Out +
7	RS485 B
8	RS485 A
9	Ground
10	Ground

- **OZSCR2x00 Connector Part Number:** (Tyco) 1761608-3
- **Mating Connector Part Number:** (Tyco) 1658527-3

4.1.7 J16 - External Gate Drive Interface

Connector J16 provides logic level gate drive signals for interfacing with medium voltage gate drivers.

Table 11 - J16 External Gate Drive Interface Pin Assignment

Pin #	Description
1	+15V
2	+15V
3	SCR-A0+
4	SCR-A0-
5	SCR-A1+
6	SCR-A1-
7	SCR-A2+
8	SCR-A2-
9	SCR-A3+
10	SCR-A3-
11	SCR-A4+
12	SCR-A4-
13	SCR-A5+
14	SCR-A5-
15	Ground
16	Ground

- **OZSCR2x00 Connector Part Number:** (Tyco) 1761608-6
- **Mating Connector Part Number:** (Tyco) 2-1658526-9

4.1.8 J22 - RS485 ModBus Interface

Connector J22 provides a 2-wire, RS-485 serial interface. Pinout is in accordance with "MODBUS over Serial Line Specification and Implementation Guide V1.02".

Table 12 - J22 RS-485 Pin Assignment

Pin #	Description
1	n/c
2	n/c
3	n/c
4	EIA/TIA-485 - B Signal
5	EIA/TIA-485 - A Signal
6	n/c
7	n/c
8	Common

- **OZSCR2x00 Connector Part Number:** (AMP) RJLSE4238101T
- **Mating Connector Part Number:** RJ45 Plug

4.1.9 J21 - Control and Feedback Interface

Connector J21 provides an interface to the various low voltage analog and digital I/O signals.

Table 13 - J21 Control and Feedback Pin Assignment

Pin #	Description
1	+10V
2	Digital Output 1
3	Digital Output 2
4	Digital Output 3
5	Digital Output 4
6	Digital Output Return
7	Analog Input 1
8	Analog Input 2
9	Analog Input 3
10	Thermistor Input *(not yet supported)*
11	+10V
12	Fast Inhibit
13	Soft Inhibit
14	Digital Input 0
15	Digital Input 1
16	Digital Input Return
17	Ground
18	Ground
19	Ground
20	Ground

- **OZSCR2x00 Connector Part Number:** (Waldom/Molex) 39-29-9203
- **Mating Connector Part Number:** (Waldom/Molex) 39-01-2205
- **Crimp terminals:** (Molex) 39-00-0047 or 39-00-0060

4.1.10 J20 - LEM Sensor Interface

Connector J20 provides an interface to a LEM style current sensor.

Table 14 - J20 LEM Sensor Interface Pin Assignment

Pin #	Description
1	+15V
2	-15V
3	LEM_OUT
4	LEM_RTN

- **OZSCR2x00 Connector Part Number:** (Molex) 22-04-1041
- **Mating Connector Part Number:** (Molex) 22-01-1042
- **Crimp Terminal:** (Molex) 08-50-0114

- **Input Range:** +/- 4V

Consult Section 7.2, Table 38 for operating constraints while using bias voltage at J20.

4.1.11 J23 - AC Power Input (OZSCR2000 Only)

Connector J23 provides AC input power to operate the on board bias supply on the OZSCR2000.

Table 15 - J23 AC Input Pin Assignment

Pin #	Description
1	AC Hot
2	AC Neutral
3	Ground

- **OZSCR2000 Connector Part Number:** (Waldom/Molex) 39-30-2030
- **Mating Connector Part Number:** (Waldom/Molex) 39-01-4031
- **Crimp Terminal:** (Molex) 39-00-0047 or 39-00-0060
- **Input Range:** 85-265 V_{AC}

CAUTION: High voltage may be present on these terminals when the system is connected and in operation.

4.1.12 J24 - DC Power Input (OZSCR2100 Only)

Connector J24 provides DC input power to operate the on-board bias supply on the OZSCR2100.

Table 16 - J24 DC Input Pin Assignment

Pin #	Description
1	DC Positive
2	DC Return

- **OZSCR2100 Connector Part Number:** (Waldom/Molex) 39-29-9022
- **Mating Connector Part Number:** (Waldom/Molex) 39-01-3022
- **Crimp Terminal:** (Molex) 39-00-0047 or 39-00-0060
- **Input Range:** 18-32 V_{DC}

4.1.13 J7 - Low Voltage AC Line Synch Interface

Connector J7 provides an alternative line voltage sensing interface. It is designed to accept +/-10 V_{AC} peak (7.07 V_{AC} RMS) from a sense transformer. For proper line synchronization, the sensed voltage phases wired to this connector *MUST* match the SCR phases as shown in the table below.

For sense transformers that do not provide a neutral connection, pin 4 of this connector should be left unconnected.

Table 17 – J7 Low Voltage Line Sense Interface Pin Assignment

Pin #	Description	Corresponding SCR Phase
1	Phase A	SCR Cathode at J1
2	Phase B	SCR Cathode at J2
3	Phase C	SCR Cathode at J3
4	Neutral	n/a

- **OZSCR2x00 Connector Part Number:** (Molex) 22-04-1041
- **Mating Connector Part Number:** (Molex) 22-01-1042
- **Crimp Terminal:** (Molex) 08-50-0114

4.2 Mechanical Interface

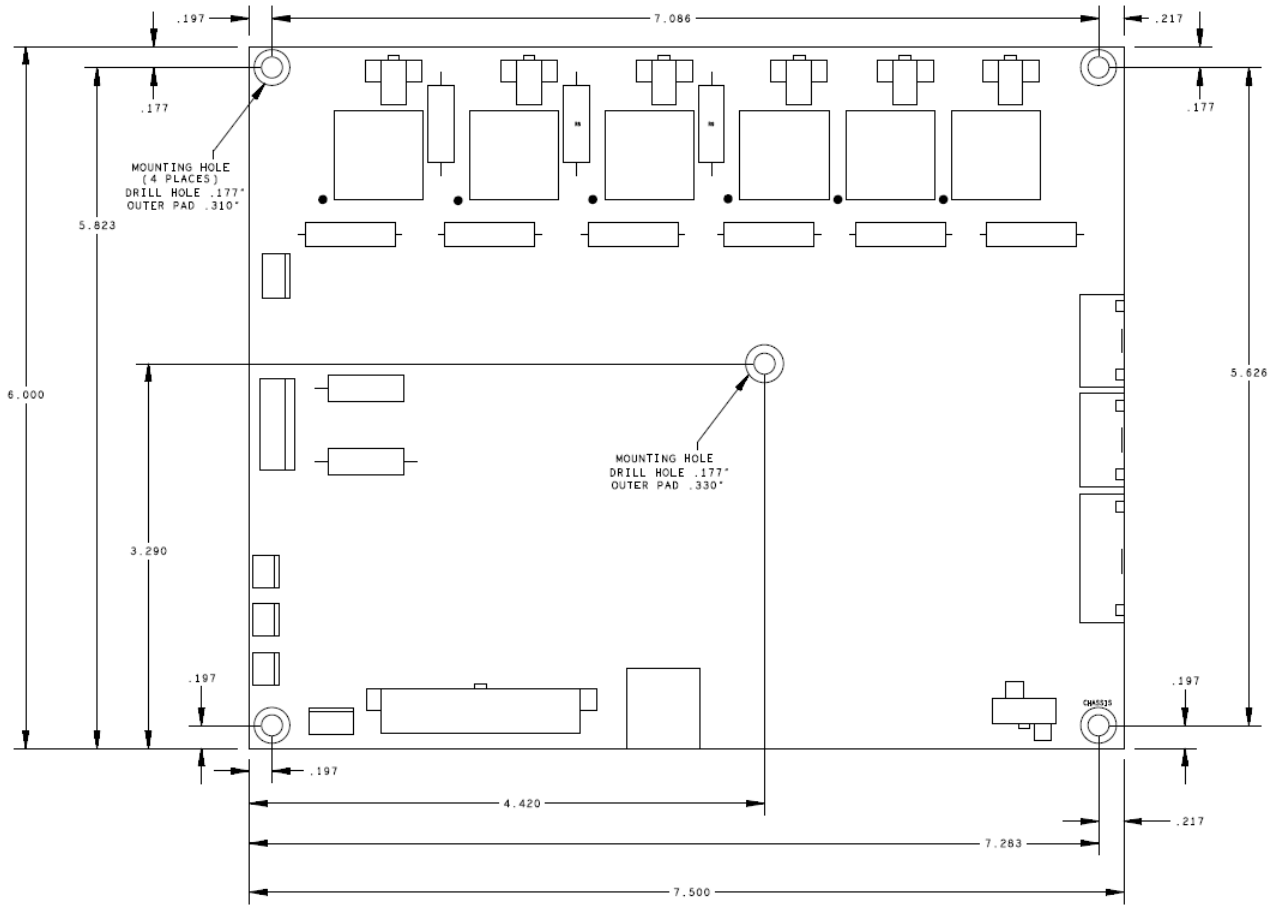


Figure 27 - OZSCR2x00 Mechanical Dimensions

5. Modbus Interface

The Modbus protocol implemented in the OZSCR2x00 is a simplified version of the industry standard Modbus protocol. It provides support for a 2-wire, RS-485 physical layer and the RTU transmission mode. More specifically, it provides the following functions:

- Control
- Configuration
- Instrumentation/Monitoring

The OZSCR2x00 defaults to using the following communications port properties:

- Baud Rate: 19200 bits per second
- Data Bits: 8
- Parity: None
- Stop Bits: 1
- Flow Control: None

It is important that the RS-485 bus connected to the target OZSCR2x00 board be properly terminated at both ends. If the OZSCR2x00 board is located on one end of the bus, the board provides a jumper (J11) that can be used to enable an on-board 120-ohm terminator (see section 4.1.3 for details). The controller located on the other end of the RS-485 bus should also be similarly terminated.

5.1 Register Properties

5.1.1 Data Types

By protocol, each addressable Modbus register holds a 16-bit quantity. In order to write or read 32-bit quantities, the least significant (LSW) and most significant words (MSW) must be written independently.

The actual parameters are stored internally as either 16-bit or 32-bit quantities and can be treated as either 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 entity
- U32 – Parameter is an unsigned 32-bit entity
- S16 – Parameter is a signed 16-bit entity
- S32 – Parameter is a signed 32-bit entity

Parameters that are specified as Boolean are stored as 16-bit entities – a value of all zeros indicates FALSE and any non-zero value indicates TRUE. Unless otherwise specified in the parameter description, the parameters are stored and treated as 16-bit unsigned values.

5.1.1.1 Specifying Fixed-Point Parameters

Some parameters listed in the following sections are specified as 32-bit signed numbers with the units specified as Q16 fixed point numbers. Using this data format, the lower 16-bits (LSW) represents the fractional portion of the parameter and the upper 16-bits (MSW) represent the integer portion of the parameter. For example, the number 10.25 would be entered as 0x000A4000, where the MSW = 0x000A (hex) = 10 (decimal) and the LSW = 0x4000 (hex) = 0.25 (0x4000/0xFFFF). Similarly, some numbers are specified as Q24 fixed point numbers. In this case, the lower 24-bits represent the fractional portion of the parameter and the upper 8-bits represent the integer portion of the parameter.

There are also cases where some of the command registers are specified as signed 16-bit values with units specified as Q15. In this case, bit 15 represents the sign bit and the lower 15 bits represent the integer portion. The allowable range for numbers in this format are -1.0 (0x8000) to 0.999 (0x7FFF / 2^{15}).

5.1.2 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
- **P** (password-protected) – the parameter may only be accessed by supplying a password

5.1.3 Duplicate Registers

Some of the registers listed in the following sections are split into three identical registers with ***'A'***, ***'B'***, and ***'C'*** suffixes. These duplicate registers are provided for operating modes that support multiple single-phase controllers. For 3-phase operational modes, only the ***'A'*** register is used; the ***'B '*** and ***'C '*** registers are not used and are not enabled for Modbus access. For single-phase operational modes, all three registers are enabled for Modbus access and are used to control the SCR channel pairs as follows:

Register	Affected SCR Channels
A	SCR Connections J1 & J4
B	SCR Connections J2 & J5
C	SCR Connections J3 & J6

5.2 Command Registers

Table 18 - Command Register Set

Address		Register Name	Data Type	Units	Default	Min	Max	Access Level
Decimal	Hex							
0	0x0000	Fast Inhibit	U16	Boolean	0 or 1	0	1	R/W
1	0x0001	Soft Inhibit A	U16	Boolean	0 or 1	0	1	R/W
2	0x0002	Soft Inhibit B	U16	Boolean	0 or 1	0	1	R/W
3	0x0003	Soft Inhibit C	U16	Boolean	0 or 1	0	1	R/W
4	0x0004	*Reserved*	n/a	n/a	n/a	n/a	n/a	n/a
5	0x0005	Control Setpoint A	S16	% (Q15)	0	0	0.999	R/W
6	0x0006	Control Setpoint B	S16	% (Q15)	0	0	0.999	R/W
7	0x0007	Control Setpoint C	S16	% (Q15)	0	0	0.999	R/W
8	0x0008	Configuration Password	U16	Integer	n/a	0	65535	R/W
9	0x0009	Configuration Reset	U16	Boolean	n/a	0	1	P/W
10	0x000A	Configuration Reload	U16	Boolean	n/a	0	1	R/W
11	0x000B	*Reserved*	n/a	n/a	n/a	n/a	n/a	n/a
12	0x000C	Field Flashing Enable	U16	Boolean	0	0	1	R/W
13	0x000D	Auto Calibrate Input Midscale	U16	Integer	0	0	7	R/W
14	0x000E	Voltage Controller Kp Scaling	U16	0.01	100	1	10000	R/W
15	0x000F	Voltage Controller Ki Scaling	U16	0.01	100	1	10000	R/W
16	0x0010	Current Controller Kp Scaling	U16	0.01	100	1	10000	R/W
17	0x0011	Current Controller Ki Scaling	U16	0.01	100	1	10000	R/W
18	0x0012	Voltage Loop Max Output	S16	% (Q15)	n/a	0	0.999	R/W
19	0x0013	Analog Setpoint Trim Adjust	S16	% (Q15)	0	-1.0	0.999	R/W

5.2.1 Fast Inhibit

This register is used to enable or disable the firing pulses as follows:

0 – Fast Inhibit is removed: Firing pulses are immediately enabled if Soft Inhibit is not asserted
1 – Fast Inhibit is asserted: This causes the firing pulses to immediately terminate

The power-on default value for this register is determined by the ***Inhibit Registers Default Value*** configuration register (0x1016).

5.2.2 Soft Inhibit (A, B, C)

These registers are used to enable or disable the firing pulses as follows:

0 – Soft Inhibit is de-asserted: Firing pulses are enabled and firing angle is then soft started
1 – Soft Inhibit is asserted: Firing angle is soft stopped and firing pulses are then disabled

The soft inhibit function is only applicable for open-loop phase angle control and zero cross firing modes of operation. These registers have no affect when operating in DC Voltage or Current control modes (see the ***Operating Mode*** configuration register, 0x1000).

The power-on default values for these registers is determined by the ***Inhibit Registers Default Value*** configuration register (0x1016).

5.2.3 Control Setpoint (A, B, C)

These registers are used to adjust the setpoint while the controller is operating. The desired command variable is determined by the ***Operating Mode*** configuration register (0x1000).

The value written to these registers specifies the command as a percentage of the full-scale value specific to the selected operating mode. For phase angle control, a 0% command is treated as an angle command of 180 degrees (no conduction) and a 100% command is treated as a zero-degree command (full conduction). For zero cross control, the input command is used to set the duty cycle of the firing bursts (the number of cycles to fire relative to the total number of cycles specified). For voltage or current control, the input command is used to define the desired setpoint as a percentage of the specified feedback range for the selected control mode.

5.2.4 Configuration Password

This Command register is used to supply a password for those configuration operations that are password protected. The password is cleared to zero each time an attempt is made to execute a password protected operation.

5.2.5 Configuration Reset

This Command register causes the system to restore itself to the factory default configuration. Successful execution of this command requires the following conditions be met:

- ***To avoid unintentionally resetting the configuration memory to the factory default values, this command requires that the "Configuration Password" register be previously loaded with 0x795A (or 31066 decimal) prior to issuing this command.***
- ***The system must be in a non-operation state, i.e. the power outputs must be disabled.***

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

5.2.6 Configuration Reload

This Command register causes any modifications to the Configuration register space to be loaded from the non-volatile configuration space. Successful execution of this command requires the following conditions be met:

- ***The system must be in a non-operation state, i.e. the power outputs must be disabled.***

> ⚠ **CAUTION:** Either execution of this command or a Power-On Reset (POR) is required before changes to the configuration space are used for operation.

5.2.7 Field Flashing Enable

This register is used to enable or disable field flashing mode as follows:

0 – Field Flashing is disabled (turned off if previously enabled)
1 – Field Flashing is enabled

This register has no effect unless the ***Motor Field Flashing Control*** configuration register (0x10A3) is set to Modbus register control.

Note that field flashing operation is overridden and disabled if **Fast Inhibit** or **Soft Inhibit** (if enabled) is asserted. When field flashing operation is enabled, the **Fast Inhibit** control will behave the same as with normal firing, meaning the firing pulses will start or stop immediately.

Similarly, the **Soft Inhibit** control also behaves the same as with normal firing. This means that when asserting **Soft Inhibit** (if enabled), the controller will first slew the angle command from the user's present command to the stop angle before turning off. Although the angle has no meaning when field flashing operation is in progress, the slew time is still enforced, so the field flashing operation will continue during this slew period. When removing the **Soft Inhibit** condition, the field flashing pulses will begin immediately. It is important to note that if the user has enabled the **Soft Inhibit Keep Firing Enable** feature (0x1015), firing is not actually disabled (including field flashing pulses) when asserting the **Soft Inhibit** condition.

5.2.8 Auto Calibrate Analog Input Midscale

This command is used to automatically calculate the ***Analog Input 1/2/3 Offset*** (0x10F0-0x10F2) configuration register values based on a user-supplied half scale input voltage or current for the selected input channel(s). The difference between the measured user-provided midscale value and the expected theoretical midscale value is then automatically stored in the corresponding configuration registers.

The user can specify which analog input(s) to calibrate through the value supplied to this command. Writing a value that contains a '1' in the following bits will trigger a calculation for the corresponding inputs:

Bit	Affected Analog Input
0	Analog Input 1
1	Analog Input 2
2	Analog Input 3

5.2.9 Voltage Controller Kp, Ki Scaling

These registers are used to dynamically and temporarily modify the gains of the voltage controller. The default voltage control gains specified in the ***Voltage Control Proportional Gain Kp*** and ***Voltage Control Integral Gain Ki*** configuration registers (0x1046-0x1049) are multiplied by their respective scaling values from these registers. This results in the ability to adjust the gains up or down by as much as two orders of magnitude (i.e. multiply by 100 or 0.01). For example, if the proportional gain (Kp) is set to a value of 2.7 and the ***Voltage Controller Kp Scaling*** register is set to 1000, the resulting Kp used by the controller will be 2.7 x (1000 x 0.01), or 27.0.

The power-on default for these registers results in a multiplier of 1.0, or no adjustment to the default gains. These register values are stored in volatile memory and will return to their default values upon a device reset or when the controller is power cycled.

5.2.10 Current Controller Kp, Ki Scaling

These registers are used to dynamically and temporarily modify the gains of the current controller. The default current control gains specified in the ***Current Control Proportional Gain Kp*** and ***Current Control Integral Gain Ki*** configuration registers (0x105E-0x1061) are multiplied by their respective scaling values from these registers. This results in the ability to adjust the gains up or down by as much as two orders of magnitude (i.e. multiply by 100 or 0.01). For example, if the proportional gain (Kp) is set to a value of 3.6 and the ***Current Controller Kp Scaling*** register is set to 10, the resulting Kp used by the controller will be 3.6 x (10 x 0.01), or 0.36.

The power-on default for these registers results in a multiplier of 1.0, or no adjustment to the default gains. These register values are stored in volatile memory and will return to their default values upon a device reset or when the controller is power cycled.

5.2.11 Voltage Loop Max Output

This register is used to dynamically change the maximum output of the voltage loop if running in Voltage Control Mode. If the inner current loop is enabled, this modifies the current limit. If the inner current loop is disabled, this modifies the maximum phase angle. The value of this register is specified as a percentage of full scale in Q15 format.

The power-on default for this register is loaded from the ***Voltage Loop Max Output*** configuration register (0x104C-0x104D).

5.2.12 Analog Input Trim Adjust

This register is used to set the trim value when the trim feature is enabled and the ***Analog Setpoint Trim Input Select*** configuration register is set to take input from this register.

The value of this register is specified as a percentage of full scale (***Analog Setpoint Trim Full Scale*** configuration register value) in Q15 format.

The power-on default for this register is 0, meaning no trim will be applied.

5.3 Instrumentation Registers

Table 19 - Instrumentation Register Set

Address		Register Name	Data Type	Units	Access Level
Decimal	Hex				
2048	0x0800	Configuration Command Status	U16	ENUM	R
2051	0x0803	Operating State	U16	ENUM	R
2052	0x0804	Fast Inhibit Status	U16	Boolean	R
2053	0x0805	Soft Inhibit Status A	U16	Boolean	R
2054	0x0806	Soft Inhibit Status B	U16	Boolean	R
2055	0x0807	Soft Inhibit Status C	U16	Boolean	R
2056	0x0808	Motor Field Flashing Status	U16	Boolean	R
2060	0x080C	AC Voltage AB	U16	0.01Vrms	R
2061	0x080D	AC Voltage BC	U16	0.01Vrms	R
2062	0x080E	AC Voltage CA	U16	0.01Vrms	R
2063	0x080F	Analog Input 1	S16	0.01%	R
2064	0x0810	Analog Input 2	S16	0.01%	R
2065	0x0811	Analog Input 3	S16	0.01%	R
2066	0x0812	DC Voltage	S16	0.01V	R
2067	0x0813	DC Current	S16	0.01%	R
2068	0x0814	AC Line Frequency	U16	0.1 Hz	R
2069	0x0815	Firing Angle A	S16	0.0001	R
2070	0x0816	Firing Angle B	S16	0.0001	R
2071	0x0817	Firing Angle C	S16	0.0001	R
2072	0x0818	Voltage Command Input	S16	0.01%	R
2073	0x0819	Current Command Input	S16	0.01%	R
4080	0x0FF0	Software Revision – Major	U16	Integer	R
4081	0x0FF1	Software Revision – Minor	U16	Integer	R
4082	0x0FF2	Programmable Logic Revision	U16	Integer	R
4083	0x0FF3	Board Hardware Revision	U16	Integer	R
4084	0x0FF4	Software Part #	U16	Integer	R
4085	0x0FF5	Bootloader Part #	U16	Integer	R
4086	0x0FF6	Bootloader Revision – Major	U16	Integer	R
4087	0x0FF7	Bootloader Revision – Minor	U16	Integer	R

5.3.1 Configuration Command Status

This register is used to determine if the last Configuration Reload or Reset command completed successfully. The command status value is encoded as follows:

Value	Description
0	Command executed successfully
1	Command ignored, system is 'ON'
2	Command ignored, invalid password specified
3	Command failed, nonvolatile memory CRC error
4 - 15	*Reserved*

5.3.2 Operating State

This register returns an enumerated value detailing the OZSCR2x00's current operating state. The enumerated types are defined in the table below.

Value	Description
0	POR
1	Initialization
2	Standby
3	On
4	Fault
5	Test (Factory use only)
6 - 15	***Reserved for future use***

5.3.3 Fast & Soft Inhibit Status

These registers return a Boolean value representing the status of the fast and soft inhibit logic signals. A value of True represents an inhibited condition. Soft inhibit statuses may return non-Boolean values when not used due to the operating mode.

5.3.4 Motor Field Flashing Status

This register returns a Boolean value representing the status of the field flashing enable logic signal. A value of True indicates that field flashing is enabled.

5.3.5 AC Voltage AB, BC, CA

These registers return the measured RMS line-to-line AC voltages. These values are reported in units of 0.01 Vrms. The maximum measured voltage is described in section 2.2. BC and CA voltages may return meaningless values for certain single-phase operating modes.

5.3.6 Analog Input 1, 2, 3

These registers return the measured analog input values. These values include any offset adjustments from the **Analog Input 1/2/3 Offset** configuration registers (0x10F0-0x10F2).

Values are reported as a percentage (in 0.01% increments) of the full-scale input range specified in the ***Analog Input Configuration*** register (0x1001).

5.3.7 DC Voltage

This register returns the DC voltage measured at J13 in units of 0.01V. The maximum measured voltage is described in section 2.6.

5.3.8 DC Current

This register returns the DC current measured at J20 as a percentage (in 0.01% increments) of the full-scale input range. See section 4.1.10 for details.

5.3.9 AC Line Frequency

This register returns the measured AC line frequency. It returns 0 if the PLL is not locked.

5.3.10 Firing Angle A, B, C

These registers return the active normalized firing angles being presently used on the controller. These normalized values are reported in 0.0001 increments and are scaled such that a value of zero indicates full conduction (i.e zero-degree phase command) and a value of 0.5 indicates no conduction (i.e. 180-degree phase command). For example, reading a value of 4500 would represent a normalized firing angle of 0.45, or an angle of 162 degrees ((0.45 * 2) x 180 degrees). Note that Firing Angles B and C are only used while operating in single phase controller modes; for all other modes, these registers are unused and will report zero.

5.3.11 Voltage Command Input

This register reports the active voltage setpoint into the voltage controller. This value is reported as a percentage (in 0.01% increments) of full scale, where the full scale is defined by the selected feedback input (either a general-purpose analog input or the high voltage DC sense input - see section 3.3 for more details). This register is only used when operating in Voltage Control Mode; for all other modes, this register will return zero.

5.3.12 Current Command Input

This register reports the active current setpoint into the current controller. This value is reported as a percentage (in 0.01% increments) of full scale, where the full scale is defined by the selected feedback input (either a general-purpose analog input or the LEM current sense input - see section 5.4.8.4 for more details). This register is only used when operating in Current Control Mode or in Voltage Control Mode with the inner current loop enabled; for all other modes, this register will return zero.

5.3.13 Software Revision

These registers provide a means to read the Major and Minor revisions of the embedded software.

5.3.14 Programmable Logic Revision

This register provides a means to read the revision of the programmable logic device on the OZSCR2x00 controller.

5.3.15 Board Hardware Revision

This register provides a means to read the hardware revision lines located on the OZSCR2x00 controller board.

5.3.16 Software Part Number

This register returns the Oztek software part number for the main controller software. It should always return a value of 217.

5.3.17 Bootloader Part Number

This register returns the Oztek software part number for the bootloader. It should always return a value of 190.

5.3.18 Bootloader Revision

These registers provide a means to read the Major and Minor revisions of the embedded bootloader software.

5.4 Configuration Registers

When one or more configuration parameters have been updated by writing to the memory space using the associated communication message, the actual operating configuration variables remain unaffected until one of two events occur: either the user cycles power on the control board (turning the input power off then on) or the user sends a “Configuration Reload” command. In the second case, the communication-initiated reload is only allowed if the controller is ***not*** enabled. Attempts to reload the system configuration while the controller is in operation will result in the message being ignored and the appropriate status being set in the **Configuration Command Status** register (0x0800).

The “Configuration Reset” message is used to reset the configuration memory back to the original Factory Default values. The user should take care when using this command as any custom configuration settings will be lost as the entire contents of the configuration memory is overwritten with the specified factory defaults. This command is only allowed if the controller is ***not*** enabled. Attempts to reset the configuration data while the controller is in operation will result in the message being ignored and the appropriate status being set in the **Configuration Command Status** register (0x0800).

5.4.1 Control Configuration Parameters

Table 20 - Configuration Register Set – Control Configuration Parameters

Address		Register Name	Data Type	Units	Factory Default	Min	Max	Access Level
Decimal	Hex							
4096	0x1000	Operating Mode	U16	ENUM	2	0	15	R/W
4097	0x1001	Analog Input Configuration	U16	ENUM	0x15	0	0x3F	R/W
4099	0x1003	Line Voltage Under-Voltage Threshold	U16	0.1 %	50	50	1000	R/W
4100	0x1004	Line Voltage Over-Voltage Threshold	U16	0.1 %	950	0	1000	R/W
4101	0x1005	Line Voltage Phase Imbalance Threshold	U16	0.1 %	100	50	1000	R/W

5.4.1.1 Operating Mode

This register defines the desired operating mode as follows:

Value	Description
0	3-Phase AC Switch Controller with Open Loop Phase Angle Control
1	3-Phase AC Switch Controller with Zero Cross Control
2	3-Phase Bridge Converter with Open Loop Phase Angle Control
3	3-Phase Bridge Converter with Zero Cross Control
4	3-Phase Bridge Converter with Closed Loop DC Voltage Control
5	3-Phase Bridge Converter with Closed Loop DC Current Control
6	Single-Phase AC Switch Controller with Open Loop Phase Angle Control
7	Single-Phase AC Switch Controller with Zero Cross Control
8	Single -Phase Bridge Converter with Open Loop Phase Angle Control
9	Single -Phase Bridge Converter with Zero Cross Control
10	Single -Phase Bridge Converter with Closed Loop DC Voltage Control
11	Single -Phase Bridge Converter with Closed Loop DC Current Control
12 - 15	***Reserved for future use***

5.4.1.2 Analog Input Configuration

This register configures the three analog input circuits for the desired operating mode where:

0 – Input is configured for 0-5V operation
1 – Input is configured for 0-10V operation
2 – Input is configured for 4-20mA operation
3 – Input is configured for 0-20mA operation

The 2-bit analog input configuration is independently programmable for each analog input. Each channel's configuration bits are assigned to the register bits shown below:

Bit	Description
0-1	Analog input #1 Configuration
2-3	Analog input #2 Configuration

Bit	Description
4-5	Analog input #3 Configuration
6 - 15	***Reserved for future use***

5.4.1.3 Line Voltage Under-Voltage Threshold

This register defines the under-voltage threshold for the AC line. If any of the AC line sense inputs drop below this threshold, the controller will report a phase loss condition and will cease firing.

This value is entered as a percentage of the full-scale line sense voltage as described in section 2.2. For example, if the input full scale value is set to 1830V, and this register is set to 50 (5.0%), then the under-voltage threshold will be set to 1830V * 5% = 91.5V peak, or 65.3V rms.

5.4.1.4 Line Voltage Over-Voltage Threshold

This register defines the over-voltage threshold for the AC line. If any of the AC line sense inputs rises above this threshold, the controller will report a phase loss condition and will cease firing.

Similar to the under-voltage threshold parameter, this value is entered as a percentage of the full scale line sense voltage.

5.4.1.5 Line Voltage Phase Imbalance Threshold

This register defines the phase imbalance threshold for the AC line when operating in any of the 3-phase operational modes. If the difference between any of the three AC line-to-line sense inputs rises above this threshold, the controller will report a phase loss condition and will cease firing.

Similar to the over and under voltage parameters, this value is entered as a percentage of the full-scale line sense voltage.

This register is not used when operating in one of the single-phase operational modes.

5.4.2 Analog Setpoint Trim Control Parameters

Table 21 - Configuration Register Set – Analog Trim Control Parameters

Address		Register Name	Data Type	Units	Factory Default	Min	Max	Access Level
Decimal	Hex							
4104	0x1008	Analog Setpoint Trim Enable	U16	ENUM	0	0	3	R/W
4105	0x1009	Analog Setpoint Trim Input Select	U16	ENUM	2	0	3	R/W
4106	0x100A	Analog Setpoint Trim Full Scale	U16	%	100	0	100	R/W
4336	0x10F0	Analog Input 1 Offset	S16	Integer	0	-32768	32767	R/W
4337	0x10F1	Analog Input 2 Offset	S16	Integer	0	-32768	32767	R/W
4338	0x10F2	Analog Input 3 Offset	S16	Integer	0	-32768	32767	R/W

5.4.2.1 Analog Setpoint Trim Enable

This parameter is used to enable one of the analog inputs as a “trim” adjust for the analog setpoint command. The enumerated values for this register are as follows:

Value	Description
0	Trim Input is Disabled
1	Trim Input is Enabled
2	Trim Input is Enabled by Digital Input #0 (J21, Pin 14)
3	Trim Input is Enabled by Digital Input #1 (J21, Pin 15)

When using one of the digital input pins to enable the trim input, the user must drive the input pin high to enable the trim input. Driving the selected digital input pin low or leaving the pin disconnected will cause the trim input to be ignored.

The trim value is a bi-polar adjustment that is added to the user's analog setpoint. This value is centered on the mid-point of the trim input pin selected in the ***Analog Setpoint Trim Input Select*** configuration register. The adjustment range is specified in the ***Analog Setpoint Trim Full Scale*** configuration register.

For example, if the trim input is set to use analog input #1, that pin is configured for 0-10V operation, and the full-scale value is set to 10%, then an input of 0V would add -10% to the analog command, an input of 5V would add 0% to the analog command, and a value of 10V would add +10% to the analog command.

This parameter should be set to *False* if the user-selected operating mode is configured to use Modbus register control and not analog pin control.

5.4.2.2 Analog Setpoint Trim Input Select

This parameter specifies the analog input pin or Modbus ***Analog Setpoint Trim Adjust*** command register (0x0013) to use for the trim signal as follows:

Value	Description
0	Analog input #1
1	Analog input #2
2	Analog input #3
3	Modbus register

5.4.2.3 Analog Setpoint Trim Full Scale

This parameter specifies the bi-polar trim adjustment range for the trim input.

5.4.2.4 Analog Input 1, 2, 3 Offset

These registers are used to apply an offset to the corresponding analog inputs. These values are directly added to the processor's raw ADC input values. Positive values increase the analog input measurement and negative values decrease the analog input measurement.

The following table gives the corresponding register scaling relative to each of the analog input configuration modes.

Input Mode	Offset Register Bit Weight
0-5V	308.5 uV/bit
0-10V	308.5 uV/bit
4-20mA	624.8 nA/bit
0-20mA	624.8 nA/bit

Table 22 - Configuration Register Set – Linearization Control Parameters

> ⚠ **CAUTION:** These offsets will persist and values will remain the same when changing the analog input configuration (0x1001) which may cause unintended behavior. Make sure to reset or update the offset values when changing the analog input configuration.

5.4.3 Phase Angle to Output Voltage Linearization Control Parameters

Address		Register Name	Data Type	Units	Factory Default	Min	Max	Access Level
Decimal	Hex							
4108	0x100C	Linearization Control Enable	U16	Boolean	False	False	True	R/W
4109	0x100D	Linearization Angle Range – Lower Angle	U16	Degree	0	0	180	R/W
4110	0x100E	Linearization Angle Range – Upper Angle	U16	Degree	180	0	180	R/W
4374	0x1116	Linearization Angle Min Clamp	U16	Degree	0	0	180	R/W
4375	0x1117	Linearization Angle Max Clamp	U16	Degree	180	0	180	R/W

5.4.3.1 Linearization Control Enable

This Boolean parameter is used to enable the use of the phase angle to output voltage linearization feature. When this parameter is set to zero, output linearization is disabled. When set to 1, output linearization is enabled.

5.4.3.2 Linearization Angle Range – Lower/Upper Angles

These two parameters determine the firing angle range across which to apply the linearization correction. Angles outside of this range are used directly by the firing controls. Angles within this range are adjusted using an arccosine wave shape as described in section 2.8.

Typical settings for these registers would be 0 to 180 degrees for a single-phase application and 0 to 120 degrees for a 3-phase application (i.e. purely resistive loads). Having programmability of both the lower and upper angles allows the linearization scheme to work across other angle ranges in the event that an angle offset needs to be applied or if the range needs to be increased or decreased depending on the end actual system constraints.

5.4.3.3 Linearization Angle Min/Max Clamp

These two parameters specify the minimum and maximum values in degrees that the firing angles can be set. Any commands outside of these values will be treated as if commanding the clamp values.

5.4.4 Soft Inhibit Control Parameters

Table 23 - Configuration Register Set – Soft Inhibit Control Parameters

Address		Register Name	Data Type	Units	Factory Default	Min	Max	Access Level
Decimal	Hex							
4112	0x1010	Soft Inhibit Digital Input Enable	U16	ENUM	0	0	7	R/W
4113	0x1011	Soft Start Ramp Rate	U16	Deg/sec	180	1	65535	R/W
4114	0x1012	Soft Start Initial Firing Angle	U16	Degree	180	0	180	R/W
4115	0x1013	Soft Stop Ramp Rate	U16	Deg/sec	360	1	65535	R/W
4116	0x1014	Soft Stop Final Firing Angle	U16	Degree	180	0	180	R/W
4117	0x1015	Soft Inhibit Keep Firing Enable	U16	Boolean	False	False	True	R/W
4118	0x1016	Inhibit Registers Default Value	U16	ENUM	0	0	3	R/W

5.4.4.1 Soft Inhibit Digital Input Enable

This register is used to enable or disable the soft inhibit input pins. The soft inhibit input pins are dedicated inputs located on connector J21. For all 3-phase operational modes, only pin 13 is used as the soft inhibit pin. For single-phase operational modes, up to three soft inhibit pins may be implemented as follows:

Soft Inhibit Pin	Affected Single-Phase SCR Channels
J21 Pin 13	SCR Connections J1 & J4
J21 Pin 14	SCR Connections J2 & J5
J21 Pin 15	SCR Connections J3 & J6

This register contains three bits; one for each soft inhibit pin listed above. Bit 0 in this register enables the use of pin 13, bit 1 enables pin 14, and bit 2 enables pin 15. Writing a ‘1’ to a particular bit will enable that particular soft inhibit digital input; writing a ‘0’ will disable that input.

When the soft inhibit pin is enabled and asserted, the firing angle is ramped to the ***Soft Stop Final Firing Angle*** before gating is inhibited. Conversely, the firing angle is ramped from the ***Soft Start Initial Firing Angle*** to the commanded angle when the soft inhibit pin is de-asserted.

5.4.4.2 Soft Start Ramp Rate

When using the soft inhibit feature, this register sets the rate at which the firing angle is slewed from the ***Soft Start Initial Firing Angle*** to the user-commanded angle when firing pulses are enabled.

5.4.4.3 Soft Start Initial Firing Angle

When using the soft inhibit feature and the inhibit pin is de-asserted, this register specifies the initial firing angle to use when enabling the firing pulses. The firing angle is then slewed to the user-commanded angle at a rate specified in the ***Soft Start Ramp Rate*** register.

If the user-commanded firing angle is a smaller conduction angle than the value specified in this register, the firing pulses will simply turn on at the user-commanded angle and no soft start ramping will occur.

5.4.4.4 Soft Stop Ramp Rate

When using the soft inhibit feature, this register sets the rate at which the firing angle is slewed from the user-commanded angle to the ***Soft Stop Final Firing Angle*** before the firing pulses are disabled.

5.4.4.5 Soft Stop Final Firing Angle

When using the soft inhibit feature and the inhibit pin has been asserted, this register specifies the final delay angle to ramp to before firing is disabled. The firing angle is slewed to this final angle at a rate specified in the ***Soft Stop Ramp Rate*** register.

5.4.4.6 Soft Inhibit Keep Firing Enable

When using the soft inhibit feature and "Keep Firing" mode is enabled, if the inhibit pin is asserted, the firing angle will be ramped to the ***Soft Stop Final Firing Angle***. Once at this final angle, the firing pulses will continue to fire rather than being disabled. While the inhibit pin remains asserted, the firing angle will remain at the specified ***Soft Stop Final Firing Angle***. Once the inhibit pin is de-asserted, the firing angle will soft start to the user-commanded angle at the specified ***Soft Start Ramp Rate,*** but rather than starting at the ***Soft Start Initial Firing Angle***, the angle will be ramped from the present angle (i.e. the ***Soft Stop Final Firing Angle***).

If the firing pulses are inhibited due to the assertion of the Fast Inhibit line, upon removing the Fast Inhibit condition, if the Soft Inhibit pin is asserted the firing angle will first turn on at the ***Soft Start Initial Firing Angle*** and then ramp to the ***Soft Stop Final Firing Angle*** at the ***Soft Start Ramp Rate***.

5.4.4.7 Inhibit Registers Default Value

This register is used to define the default state of the ***Fast Inhibit*** and ***Soft Inhibit*** command registers when the controller is first started up (either following a power-up or when the application is restarted following a ***Configuration Reload*** command). This register contains four bits, one for the default fast inhibit state and one for each of the three soft inhibit states. The bit assignments are mapped as follows:

Register Bit	Affected Inhibit Condition
0	Fast Inhibit
1	Soft Inhibit A
2	Soft Inhibit B
3	Soft Inhibit C

Setting a bit to a '1' will assert the corresponding inhibit condition; a value of '0' indicates that the corresponding inhibit condition is not asserted at power-up. This register should be set to zero for any application that does not intend to use Modbus register control of the SCR controller. Instead, the user must set the state of the Fast and Soft Inhibit digital input pins to the desired behavior at startup.

5.4.5 Phase Angle Control Parameters

Table 24 - Configuration Register Set – Phase Angle Control Parameters

Address		Register Name	Data Type	Units	Factory Default	Min	Max	Access Level
Decimal	Hex							
4128	0x1020	Phase Angle Control Mode A	U16	ENUM	0	0	4	R/W
4129	0x1021	Phase Angle Control Mode B	U16	ENUM	0	0	2	R/W
4130	0x1022	Phase Angle Control Mode C	U16	ENUM	0	0	2	R/W
4131	0x1023	Phase Angle Default Setpoint A	U16	Degree	180	0	180	R/W
4132	0x1024	Phase Angle Default Setpoint B	U16	Degree	180	0	180	R/W
4133	0x1025	Phase Angle Default Setpoint C	U16	Degree	180	0	180	R/W
4134	0x1026	Phase Angle Control Analog Input Select A	U16	ENUM	0	0	2	R/W
4135	0x1027	Phase Angle Control Analog Input Select B	U16	ENUM	1	0	2	R/W
4136	0x1028	Phase Angle Control Analog Input Select C	U16	ENUM	2	0	2	R/W
4137	0x1029	Phase Angle Command Slew Rate	U16	Deg/sec	180	1	65535	R/W
4138	0x102A	Phase Angle Minimum Firing Angle	U16	Degree	0	0	180	R/W
4139	0x102B	Phase Angle Maximum Firing Angle	U16	Degree	180	0	180	R/W

5.4.5.1 Phase Angle Control Mode (A, B, C)

When operating in phase angle control mode, these registers select the source of the phase angle setpoints as follows:

Value	Description
0	Use analog input for phase angle setpoint
1	Use Modbus register for phase angle setpoint
2	Disable this controller
3	Use Digital Input #0 (J21, Pin 14) to select between ***Analog Input Select A*** (4134) and ***Analog Input Select B*** (4135) – input select “A” is used if digital input pin is low or undriven, select “B” is used if digital input pin is driven high
4	Use Digital Input #1 (J21, Pin 15) to select between ***Analog Input Select A*** (4134) and ***Analog Input Select B*** (4135) – input select “A” is used if digital input pin is low or undriven, select “B” is used if digital input pin is driven high

Values 3 and 4 only apply to Three Phase operating modes and will be treated as Disabled if used in Single Phase modes.

5.4.5.2 Phase Angle Default Setpoint (A, B, C)

If configured to receive the phase angle setpoint from a Modbus register, these parameters are used to set the default firing angles to use after a POR.

5.4.5.3 Phase Angle Control Analog Input Select (A, B, C)

If configured to receive the phase angle setpoint from an analog input, these parameters specify the analog input pin to use.

Value	Description
0	Analog input #1
1	Analog input #2
2	Analog input #3

5.4.5.4 Phase Angle Command Slew Rate

This register sets the rate at which the firing angle is slewed when the user's angle command is changed (regardless of whether the angle command is coming from an analog input pin or by the corresponding Modbus register).

5.4.5.5 Phase Angle Minimum Firing Angle

This register sets the minimum firing angle allowed. When the user commands an angle less than this value, the actual firing angle will be clamped to this value.

5.4.5.6 Phase Angle Maximum Firing Angle

This register sets the maximum firing angle allowed. When the user commands an angle greater than this value, the actual firing angle will be clamped to this value.

5.4.6 Zero Cross Control Parameters

Table 25 - Configuration Register Set – Zero Cross Control Parameters

Address		Register Name	Data Type	Units	Factory Default	Min	Max	Access Level
Decimal	Hex							
4146	0x1032	Zero Cross Control Total Line Cycle Count	U16	Integer	60	0	255	R/W
4147	0x1033	Zero Cross Control Mode A	U16	ENUM	0	0	2	R/W
4148	0x1034	Zero Cross Control Mode B	U16	ENUM	0	0	2	R/W
4149	0x1035	Zero Cross Control Mode C	U16	ENUM	0	0	2	R/W
4150	0x1036	Zero Cross Default Operating Angle A	U16	Degree	0	0	180	R/W
4151	0x1037	Zero Cross Default Operating Angle B	U16	Degree	0	0	180	R/W
4152	0x1038	Zero Cross Default Operating Angle C	U16	Degree	0	0	180	R/W
4153	0x1039	Zero Cross Default Line Cycle On Count A	U16	Integer	0	0	255	R/W
4154	0x103A	Zero Cross Default Line Cycle On Count B	U16	Integer	0	0	255	R/W
4155	0x103B	Zero Cross Default Line Cycle On Count C	U16	Integer	0	0	255	R/W
4156	0x103C	Zero Cross Control Analog Input Select A	U16	ENUM	0	0	2	R/W
4157	0x103D	Zero Cross Control Analog Input Select B	U16	ENUM	1	0	2	R/W
4158	0x103E	Zero Cross Control Analog Input Select C	U16	ENUM	2	0	2	R/W

5.4.6.1 Zero Cross Control Total Line Cycle Count

This register determines the total number of line cycles to use when operating in Zero Cross mode. The number of 'On' cycles to be controlled is determined by multiplying the user's commanded duty cycle by the total count specified by this register.

5.4.6.2 Zero Cross Control Mode (A, B, C)

When operating in zero cross control mode, these registers select the source of the duty cycle setpoint as follows:

Value	Description
0	Use analog input for zero-x duty cycle setpoint
1	Use Modbus register for zero-x duty cycle setpoint
2	Disable this controller

5.4.6.3 Zero Cross Default Operating Angle (A, B, C)

These parameters determine the delay angle to use when firing the 'On' cycles.

5.4.6.4 Zero Cross Default Line Cycle Count (A, B, C)

If configured to receive the zero-cross duty cycle setpoints from Modbus registers, these parameters determine the default number of 'On' cycles to use when turning on in zero cross mode after a POR.

5.4.6.5 Zero Cross Control Analog Input Select (A, B, C)

If configured to receive the zero-cross duty cycle setpoints from analog inputs, these parameters specify the analog input to use as follows:

Value	Description
0	Analog input #1
1	Analog input #2
2	Analog input #3

5.4.7 Voltage Control Parameters

Table 26 - Configuration Register Set – DC Voltage Control Parameters

Address		Register Name	Data Type	Units	Factory Default	Min	Max	Access Level
Decimal	Hex							
4160	0x1040	Voltage Control Mode	U16	ENUM	0	0	1	R/W
4161	0x1041	Default Voltage Setpoint	U16	0.1%	0	0	1000	R/W
4162	0x1042	Voltage Setpoint Analog Input Select	U16	ENUM	0	0	2	R/W
4163	0x1043	Voltage Feedback Analog Input Select	U16	ENUM	3	0	3	R/W
4164	0x1044 (LSW)	Voltage Setpoint Slew Limit	S32	Q24	0.0606	0.0	100.0	R/W
4165	0x1045 (MSW)							
4166	0x1046 (LSW)	Voltage Control Proportional Gain Kp	S32	Q16	1.0	0.0	10000.0	R/W
4167	0x1047 (MSW)							
4168	0x1048 (LSW)	Voltage Control Integral Gain Ki	S32	Q16	0.0	0.0	10000.0	R/W
4169	0x1049 (MSW)							
4172	0x104C (LSW)	Voltage Control Max Output, Vo_{max}	S32	Q16	1.0	0.0	10000.0	R/W
4173	0x104D(MSW)							
4174	0x104E (LSW)	Voltage Control Min Output, Vo_{min}	S32	Q16	0.0	0.0	10000.0	R/W
4175	0x104F (MSW)							
4176	0x1050	Inner Current Loop Enable	U16	Boolean	False	False	True	R/W
4177	0x1051	Voltage Loop Max Output Mode	U16	ENUM	0	0	1	R/W
4178	0x1052	Voltage Loop Max Output Analog Input Select	U16	ENUM	0	0	2	R/W

5.4.7.1 Voltage Control Mode

When operating in closed loop voltage control mode, this register selects the source of the voltage setpoint; either an analog input or a Modbus register as follows:

Value	Description
0	Use analog input for voltage setpoint
1	Use Modbus register for voltage setpoint

5.4.7.2 Default Voltage Setpoint

If configured to receive the voltage setpoint from a Modbus register, this parameter will be set as the default voltage setpoint after a POR. This parameter is specified as a percentage of full scale voltage.

5.4.7.3 Voltage Setpoint Analog Input Select

If configured to receive the voltage setpoint from an analog input, this parameter specifies the analog input to use as follows:

Value	Description
0	Analog input #1
1	Analog input #2
2	Analog input #3

5.4.7.4 Voltage Feedback Analog Input Select

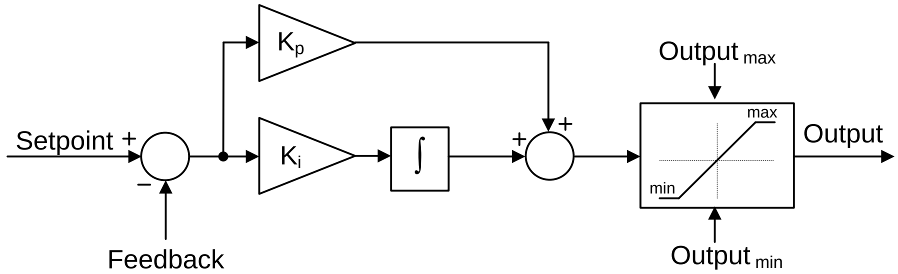
When operating in closed loop voltage control mode, this register selects the source of the voltage feedback as follows:

Value	Description
0	Analog input #1
1	Analog input #2
2	Analog input #3
3	High Voltage DC Input

5.4.7.5 Voltage Setpoint Slew Limit

This parameter defines the slew rate to use when operating in voltage control mode and the output voltage setpoint is changed. This slew rate is used both at initial turn-on and when the programmed set point is changed after the controller has already been turned on. It is specified as a percentage of full scale voltage per second in Q24 format (10% per second would be entered as 0.1).

5.4.7.6 Voltage Controller Constants (K_p, K_i, Vo_{max}, Vo_{min})



These parameters define the gain constants for the PI controller that is used to regulate the output DC link voltage when operating in voltage control mode. K_p is the proportional gain term and K_i is the integral gain. The integral gain (K_i) parameter should be entered as the continuous gain (or sometimes referred to as the "analog" gain). The firmware handles converting this to the discretized gain by automatically dividing this by the sample frequency at which the controller is updated.

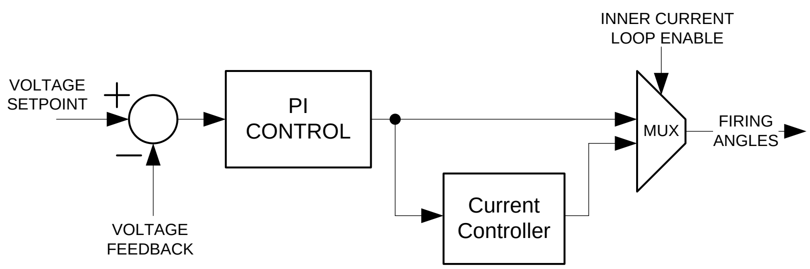
As the figure above illustrates, the implemented PI topology sums the proportional and integral correction terms and then clamps the output to the specified limits based on the ***Voltage Control Min/Max Output*** configuration registers (0x104C – 0x104F). In the event that the output of the regulator is clamped, the integrator is also clamped using the same limits in order to prevent the integrator from winding up.

When using the voltage loop by itself (i.e. the inner current loop is disabled), the output of the PI controller is the commanded phase angle. The PI output is scaled such that an output of zero indicates no conduction (i.e. 180-degree phase command) and an output of 0.5 indicates full conduction (i.e. zero-degree phase command). When operating in this scenario, the ***Voltage Control Min/Max Output*** clamp values are used to clamp the phase command using this same scaling.

When the inner current loop is enabled, the output of the voltage loop's PI controller is the commanded current to the inner current loop. In this case, the PI output is scaled such that an output of zero indicates no current and an output of 1.0 indicates the full-scale current. When operating in this scenario, the ***Voltage Control Min/Max Output*** clamp values are used to clamp the current command using this same scaling. This effectively acts as the active current limit for voltage control mode.

5.4.7.7 Inner Current Loop Enable

This parameter enables the inner current loop when operating in voltage control mode. As described in the previous section, with the current loop disabled the output of the voltage loop is used to modify the SCR trigger angle to regulate the output DC link voltage. With the inner current loop enabled, the output of the voltage loop commands a DC current output to regulate the DC link voltage. The current loop, in turn, modifies the SCR trigger angle to regulate the output current.



5.4.7.8 Voltage Loop Max Output Mode

This parameter selects the input method for setting the maximum voltage loop output as described in section 3.3. This register can be set as follows:

Value	Description
0	Max output is controlled via the ***Voltage Loop Max Output*** Modbus command register (0x12)
1	Max output is controlled via analog input as defined by the ***Voltage Loop Max Output Analog Input Select*** configuration register (0x1052)

5.4.7.9 Voltage Loop Max Output Analog Input Select

This parameter selects the analog input pin to use to set the maximum voltage loop output when ***Voltage Loop Max Output Mode*** (0x1051) is configured to use an analog input pin. The parameter values are enumerated as follows:

Value	Description
0	Analog input #1
1	Analog input #2
2	Analog input #3

5.4.8 DC Current Control Parameters

Table 27 - Configuration Register Set – DC Current Control Parameters

Address		Register Name	Data Type	Units	Factory Default	Min	Max	Access Level
Decimal	Hex							
4184	0x1058	Current Control Mode	U16	ENUM	0	0	1	R/W
4185	0x1059	Default Current Setpoint	U16	0.1%	0	0	1000	R/W
4186	0x105A	I Setpoint Analog Input Select	U16	ENUM	0	0	2	R/W
4187	0x105B	I Feedback Analog Input Select	U16	ENUM	3	0	3	R/W
4188 4189	0x105C (LSW) 0x105D (MSW)	Current Setpoint Slew Limit	S32	Q24	0.1	0.0	100.0	R/W
4190 4191	0x105E (LSW) 0x105F (MSW)	Current Control Proportional Gain Kp	S32	Q16	1.0	0.0	10000.0	R/W
4192 4193	0x1060 (LSW) 0x1061 (MSW)	Current Control Integral Gain Ki	S32	Q16	0.0	0.0	10000.0	R/W
4196 4197	0x1064 (LSW) 0x1065 (MSW)	Current Control Max Output, Io_{max}	S32	Q16	1.0	0.0	10000.0	R/W
4198 4199	0x1066 (LSW) 0x1067 (MSW)	Current Control Min Output, Io_{min}	S32	Q16	0.0	0.0	10000.0	R/W

5.4.8.1 Current Control Mode

When operating in closed loop current control mode, this register selects the source of the current setpoint; either an analog input or a Modbus register. This register has no effect when the current loop is being used as an inner current loop in DC Voltage Mode, as the current setpoint is the output of the voltage loop.

Value	Description
0	Use analog input for current setpoint
1	Use Modbus register for current setpoint

5.4.8.2 Default Current Setpoint

If configured to receive the current setpoint from a Modbus register, this parameter specifies the default setpoint to use after a POR. This parameter is specified as a percentage of full scale current.

5.4.8.3 Current Setpoint Analog Input Select

If configured to receive the current setpoint from an analog input, this parameter specifies the analog input to use as follows:

Value	Description
0	Analog input #1
1	Analog input #2
2	Analog input #3

5.4.8.4 Current Feedback Analog Input Select

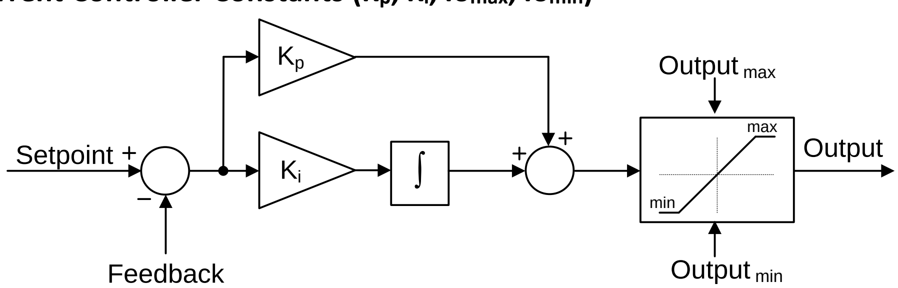
When operating in closed loop current control mode, this register selects the source of the current feedback as follows:

Value	Description
0	Analog input #1
1	Analog input #2
2	Analog input #3
3	LEM Input

5.4.8.5 Current Setpoint Slew Limit

This parameter defines the slew rate to use when operating in current control mode and the output current setpoint is changed. This slew rate is used both at initial turn-on and when the programmed set point is changed after the controller has already been turned on. It is specified as a percentage of full scale current per second in Q24 format (10% per second would be entered as 0.1).

5.4.8.6 Current Controller Constants (K_p, K_i, Io_{max}, Io_{min})



These parameters define the gain constants for the PI controller that is used to regulate the output current when operating in DC current control mode or in voltage control mode with the inner current loop enabled. K_p is the proportional gain term and K_i is the integral gain. The integral gain (K_i) parameter should be entered as the continuous gain (or sometimes referred to as the "analog" gain). The firmware handles converting this to the discretized gain by automatically dividing this by the sample frequency at which the controller is updated.

As the figure above illustrates, the implemented PI topology sums the proportional and integral correction terms and then clamps the output to the specified limits based on the ***Current Control Min/Max Output*** configuration registers (0x1064 – 0x1067). If the output of the regulator is clamped, the integrator is also clamped using the same limits to prevent the integrator from winding up.

The PI output is scaled such that an output of zero indicates no conduction (i.e. 180-degree phase command) and an output of 0.5 indicates full conduction (i.e. zero-degree phase command). The ***Current Control Min/Max Output*** clamp values are used to clamp the phase command using this same scaling.

5.4.9 Modbus Interface Parameters

Table 28 - Configuration Register Set – Modbus Interface Parameters

Address		Register Name	Data Type	Units	Factory Default	Min	Max	Access Level
Decimal	Hex							
4208	0x1070	Modbus Baud Rate	U16	ENUM	2	2	4	R/W
4209	0x1071	Modbus Device Address	U16	Integer	2	1	255	R/W

5.4.9.1 Modbus Baud Rate

This register sets the Modbus serial baud rate as follows:

Value	Baud Rate (bits per second)
2	19200 *(default)*
3	38400
4	57600

5.4.9.2 Modbus Device Address

This register sets the Modbus device address for the OZSCR2x00 controller. If more than one OZSCR2x00 controller is present on the same Modbus network, each controller **MUST** be configured with a unique address.

5.4.10 Digital Output Status Parameters

Table 29 - Configuration Register Set – Digital Output Status Masks

Address		Register Name	Data Type	Units	Factory Default	Min	Max	Access Level
Decimal	Hex							
4216	0x1078	Digital Output 0 Mask	U16	ENUM	0	0	0xFFFF	R/W
4217	0x1079	Digital Output 1 Mask	U16	ENUM	0	0	0xFFFF	R/W
4218	0x107A	Digital Output 2 Mask	U16	ENUM	0	0	0xFFFF	R/W
4219	0x107B	Digital Output 3 Mask	U16	ENUM	0	0	0xFFFF	R/W
4220	0x107C	Digital Output Polarity	U16	ENUM	0	0	0x000F	R/W

5.4.10.1 Digital Output Mask (0, 1, 2, 3)

These registers are used to select the various conditions that may be used to assert the digital output pins. These output pins are optically isolated open-collector outputs, all of which share a common ground return (J21 pin 6). When an output is asserted, the corresponding output may be driven low or put in a high impedance state depending on the selected polarity in the **Digital Output Polarity** register (see next section). There is one register for each of the four digital output pins (J21 pins 2, 3, 4, and 5) as follows:

Register #	Corresponding Output Pin
0	J21 Pin 2
1	J21 Pin 3
2	J21 Pin 4
3	J21 Pin 5

These registers contain a bit for each possible condition that may be reported on the output pin. Setting a particular bit to a 1 will enable the corresponding condition to be driven on the output. For bits set to 0, the corresponding conditions will not be used to drive the output pin. More than one bit may be set to a 1, in which case all enabled conditions will be logically OR'ed together and then reported on the output pin. The register bit assignments and the corresponding conditions are as follows:

Bit	Condition	Description
0	PLL Unlocked	The PLL is unable to lock to the AC line
1	AC Line Low	One or more line sense inputs is below the ***Line Voltage Under-Voltage Threshold*** register value
2	AC Line High	One or more line sense inputs is above the ***Line Voltage Over-Voltage Threshold*** register value
3	AC Line Imbalance	The line-to-line sense inputs differ by more than the ***Line Voltage Imbalance Threshold*** register value
4	Board Fault	The control board has experienced a hardware failure that may require factory diagnosis and possible repair
5	Fast Inhibit	Fast Inhibit is presently asserted
6	Soft Inhibit A	Soft Inhibit A is presently asserted
7	Soft Inhibit B	Soft Inhibit B is presently asserted
8	Soft Inhibit C	Soft Inhibit C is presently asserted
9	Angle Setpoint A Is Used	Asserted if 3-Phase Open Loop Phase Angle Control Mode is being used and Analog Input Select "A" (4134) is being used for control, otherwise not asserted
10	Angle Setpoint B Is Used	Asserted if 3-Phase Open Loop Phase Angle Control Mode is being used and Analog Input Select "B" (4135) is being used for control, otherwise not asserted
11-15	*N/A*	*Reserved for future use*

5.4.10.2 Digital Output Polarity

This register is used to select the output polarity for each individual digital output pin. This register contains four bits, one for each digital output, mapped as shown in the table below. For bits set to zero, the corresponding digital output pin will be active low. In this case, any time an unmasked condition in the corresponding **Digital Output Mask (0/1/2/3)** register is active, the output pin will be driven low. For bits set to one, the corresponding digital output pin will be active high. In this case, any active unmasked condition will result in the output pin being set to a high impedance state.

Bit #	Corresponding Output Pin
0	Digital Output 0 - J21 Pin 2
1	Digital Output 1 - J21 Pin 3
2	Digital Output 2 - J21 Pin 4
3	Digital Output 3 - J21 Pin 5

5.4.11 Phase Locked Loop (PLL) Parameters

Table 30 - Configuration Register Set – PLL Parameters

Address		Register Name	Data Type	Units	Factory Default	Min	Max	Access Level
Decimal	Hex							
4227	0x1083	PLL Phase Lag Adjustment	S16	0.01 Deg	0	-18000	18000	R/W

5.4.11.1 PLL Phase Lag Adjustment

This register can be used to manually add or subtract a phase angle bias to the PLL output.

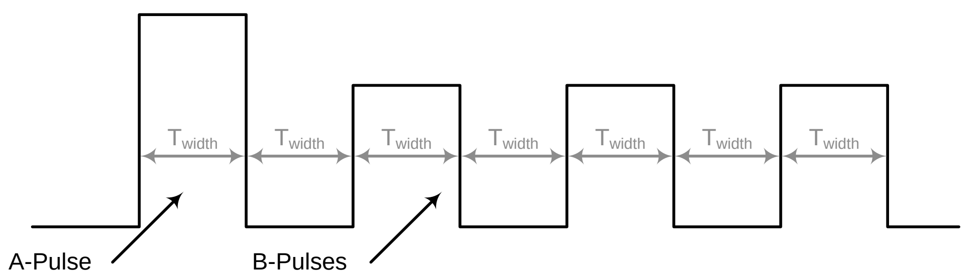
5.4.12 SCR Gate Drive Pulse Control Parameters

Table 31 - Configuration Register Set – SCR Gate Drive Pulse Control Parameters

Address		Register Name	Data Type	Units	Factory Default	Min	Max	Access Level
Decimal	Hex							
4256	0x10A0	Firing Pulse Width	U16	100ns	217	0	8191	R/W
4257	0x10A1	Firing Pulse Duration	U16	0.01 Degrees	12000	0	18000	R/W
4258	0x10A2	Firing Channel Enable	U16	Integer	0x3F	0	0x3F	R/W
4259	0x10A3	Motor Field Flashing Control	U16	ENUM	0	0	3	R/W
4260	0x10A4	Local/External Pulse Enable	U16	ENUM	1	0	3	R/W
4261	0x10A5	Double Pulse Mode	U16	Boolean	False	False	True	R/W

5.4.12.1 Firing Pulse Width

This parameter specifies the duration of the firing pulse high and low times. The first pulse is always the higher-current "A" firing pulse; all subsequent pulses are the lower-current "B" firing pulses.



The gate drive circuits local to the OZSCR2x00 board have been designed for optimal operation at the default pulse width of 21.7 microseconds. It is recommended that this default value be used whenever using the local gate drive hardware. This parameter is meant to provide flexibility for those applications that may elect to use the external gate drive interface to drive logic-level gate drive signals to off-board gate drive hardware (see sections 4.1.7 and 5.4.12.5 for details on using the external interface). The local gate drive hardware is not meant to be driven with pulse widths greater than 25 microseconds. As such, if this parameter is set to a value above 25 microseconds, the controller will automatically disable the local gate drive pulse drivers.

When using the ***Field Flashing*** feature (see section 3.5), the maximum firing pulse width supported by the controller is 136 microseconds. Otherwise, setting firing pulse widths greater than this value will result in higher than expected pulse duty cycles.

5.4.12.2 Firing Pulse Duration

This parameter determines the duration of the firing pulses in terms of the number of degrees out of a complete 360-degree electrical cycle. The controller dynamically monitors the electrical frequency and will fire an integer number of pulses using the ***Firing Pulse Width*** to achieve the required number of degrees specified by this register. Setting this register to a value of '0' will cause the controller to only generate a single firing pulse rather than a series of picket fence pulses.

5.4.12.3 Firing Channel Enable

This parameter is used to disable firing on any unused output channels. Setting a bit to ‘0’ will disable the corresponding SCR output channel. The register bit to SCR output channel assignments are as follows:

Bit	SCR Connection
0	J1
1	J2
2	J3
3	J4
4	J5
5	J6

5.4.12.4 Motor Field Flashing Control

This parameter is used to enable the Motor Field Flashing feature and to determine which control is used to turn field flashing on or off as follows:

Value	Description
0	Disabled
1	Use Digital Input #0 (J21, Pin 14)
2	Use Digital Input #1 (J21, Pin 15)
3	Use Modbus Register

When using a digital input, the user must drive the input pin high to enable field flashing. Driving the input pin low or leaving the pin disconnected will turn off field flashing.

Note that when field flashing is enabled, a continuous stream of lower-current “B” firing pulses is driven out simultaneously on all enabled channels. The higher-current “A” pulses are disabled when operating in this mode. Also, the ***Firing Pulse Width*** register (0x10A0) is used to determine the time that the pulse is “on”. However, unlike normal firing control where the “B” pulse duty cycle is 50%, a 25% duty cycle is used when field flashing is enabled - the “off” time is set to three times the “on” time resulting in a pulse frequency of half the normal picket fence “B” pulse frequency. This is used to reduce the overall power dissipated by the gate drive circuits when they are continuously generating current pulses on all channels simultaneously.

5.4.12.5 Local/External Pulse Enable

This parameter is used to control whether SCR firing pulses are driven out on the local gate drive pulse transformer outputs (connectors J1 – J6), on the external gate drive interface (J16), or both. Note that the ***Firing Channel Enable*** register (0x10A2) will determine which of the six individual channels are enabled. The enumerated values for this register are as follows:

Value	Description
0	All pulse outputs are disabled
1	Local pulse outputs are enabled
2	External pulse outputs are enabled
3	Local *and* external pulses are enabled

5.4.12.6 Double Pulse Mode

This Boolean parameter is used to enable 'double pulse mode'. Setting this register to TRUE will cause the controller to fire twice in one line cycle. In this mode the second firing pulse(s) is generated 60° after the initial firing pulse(s).

This feature is meant to support applications that require picket fence pulsing for 30 degrees followed by 30 degrees of no pulses and then another 30 degrees of firing pulses. For this reason it is recommended that the ***Firing Pulse Duration*** register (0x10A1) be set to 30 degrees in this mode. Alternatively, the ***Firing Pulse Duration*** register may be set to zero, resulting in a single pulse at the intended firing angle followed by a second pulse 60 degrees later.

The double pulse mode feature is meant to be used for fixed frequency applications (50Hz/60Hz). Although the OZSCR2x00 controller is also suitable for variable frequency applications up to 500Hz, double pulse mode is not intended to operate at these higher rates. Care must be taken to not use this mode above approximately 250Hz. Otherwise the local gate drive hardware will be operating above its intended power ratings, potentially resulting in damage to the controller.

5.4.13 Configuration Parameters

Table 32 - Configuration Register Set – Configuration Parameters

Address		Register Name	Data Type	Units	Factory Default	Min	Max	Access Level
Decimal	Hex							
4265	0x10B0	Factory Configuration Major Rev	U16	Integer	8	0	65535	R
4266	0x10B1	Factory Configuration Minor Rev	U16	Integer	1	0	65535	R
4267	0x10B2	Application Configuration Rev	U16	Integer	0	0	65535	R/W

5.4.13.1 Factory Configuration Major/Minor Revision

These registers represent the major and minor revisions of the Configuration registers. Generally, the Major revision is incremented if a Configuration register is added or is no longer supported. The Minor revision indicates changes to factory defaults, min/max values, or scaling.

5.4.13.2 Application Configuration Revision

This is a generic writable register provided to the user to allow for a means of tracking the application's configuration revision.

5.4.14 Instrumentation LPF Cutoff Parameters

These parameters are used to filter data for reporting on instrumentation registers. These do not affect the values used by the controller.

Table 33 - Configuration Register Set – Instrumentation LPF Cutoff Parameters

Address		Register Name	Data Type	Units	Factory Default	Min	Max	Access Level
Decimal	Hex							
4339	0x10F3	AC Voltages Instr LPF Cutoff Frequency	U16	1 Hz	10	1	555	R/W
4340	0x10F4	DC Voltage Instr LPF Cutoff Frequency	U16	1 Hz	10	1	555	R/W
4341	0x10F5	AC Freq Instr LPF Cutoff Frequency	U16	1 Hz	10	1	555	R/W
4342	0x10F6	LEM Current Instr LPF Cutoff Frequency	U16	1 Hz	10	1	555	R/W
4343	0x10F7	Analog Input 1 Instr LPF Cutoff Frequency	U16	1 Hz	10	1	555	R/W
4344	0x10F8	Analog Input 2 Instr LPF Cutoff Frequency	U16	1 Hz	10	1	555	R/W
4345	0x10F9	Analog Input 3 Instr LPF Cutoff Frequency	U16	1 Hz	10	1	555	R/W

5.4.14.1 AC Voltages LPF Cutoff Frequency

This register is used to supply a cutoff frequency to the low pass filters that filter the AC voltages (AB, BC, and CA) for use with reporting on instrumentation registers 0x080C-0x80E.

5.4.14.2 DC Voltage LPF Cutoff Frequency

This register is used to supply a cutoff frequency to the low pass filter that filters the DC voltage for use with reporting on instrumentation register 0x0812.

5.4.14.3 AC Frequency LPF Cutoff Frequency

This register is used to supply a cutoff frequency to the low pass filter that filters the AC Frequency for use with reporting on instrumentation register 0x0814.

5.4.14.4 LEM Current LPF Cutoff Frequency

This register is used to supply a cutoff frequency to the low pass filter that filters the LEM for use with reporting on instrumentation register 0x0813.

5.4.14.5 Analog Input 1 LPF Cutoff Frequency

This register is used to supply a cutoff frequency to the low pass filter that filters the Analog Input 1 for use with reporting on instrumentation register 0x080F.

5.4.14.6 Analog Input 2 LPF Cutoff Frequency

This register is used to supply a cutoff frequency to the low pass filter that filters the Analog Input 2 for use with reporting on instrumentation register 0x0810.

5.4.14.7 Analog Input 3 LPF Cutoff Frequency

This register is used to supply a cutoff frequency to the low pass filter that filters the Analog Input 3 for use with reporting on instrumentation register 0x0811.

5.4.15 High Voltage Gain Parameters

Table 34 - Configuration Register Set – High Voltage Gain Parameters

Address		Register Name	Data Type	Units	Factory Default	Min	Max	Access Level
Decimal	Hex							
4349	0x10FD	Line Sync Input	U16	Enum	0	0	1	R/W
4350	0x10FE	AC Line Sense Gain	U16	Enum	2	1	6	R/W
4351	0x10FF	DC Link Sense Gain	U16	Enum	1	1	6	R/W

5.4.15.1 Line Sync Input

This register is used to select the line sense input used for the PLL. A value of “0” selects the direct cathode sense, high voltage input. A value of “1” selects the low voltage sense input.

5.4.15.2 AC Line and DC Link Sense Gain

These registers set the AC Line and DC Link sense PGA gain as follows:

Value	Gain
1	2
2	4
3	8
4	16
5	32
6	64

Note that the AC Line Sense gain is forced to a value of 1 when using the low voltage sense input (i.e. ***Line Sync Input*** is set to 1) and the ***AC Line Sense Gain*** parameter will have no effect.

5.4.16 Analog Input LPF Cutoff Parameters

These parameters are for filtering analog input signals used by the controller.

Table 35 - Configuration Register Set – Analog Input LPF Cutoff Parameters

Address		Register Name	Data Type	Units	Factory Default	Min	Max	Access Level
Decimal	Hex							
4355	0x1103	Input Low Pass Filter Enable	U16	ENUM	0	0	0x1F	R/W
4356	0x1104	Analog Input 1 Input Frequency	U16	1 Hz	500	1	500	R/W
4357	0x1105	Analog Input 2 Input Frequency	U16	1 Hz	500	1	500	R/W
4358	0x1106	Analog Input 3 Input Frequency	U16	1 Hz	500	1	500	R/W
4359	0x1107	DC Voltage Input Frequency	U16	1 Hz	500	1	500	R/W
4360	0x1108	LEM Current Input Frequency	U16	1 Hz	500	1	500	R/W

5.4.16.1 Input Low Pass Filter Enable

This register is used to specify which Analog Input filters are enabled and disabled. A value of 0 in a filter’s bit position means no filter is used and a value of 1 filters the input at the specified cutoff frequency. The bit positions are specified in the table below.

Bit	Filter
0	AIN1
1	AIN2
2	AIN3
3	DC Voltage
4	LEM Current

.

5.4.16.2 Analog Input 1 LPF Cutoff Frequency

This register is used to supply a cutoff frequency to the low pass filter that filters the Analog Input 1 signal used by the controller.

5.4.16.3 Analog Input 2 LPF Cutoff Frequency

This register is used to supply a cutoff frequency to the low pass filter that filters the Analog Input 2 signal used by the controller.

5.4.16.4 Analog Input 3 LPF Cutoff Frequency

This register is used to supply a cutoff frequency to the low pass filter that filters the Analog Input 3 signal used by the controller.

5.4.16.5 DC Voltage LPF Cutoff Frequency

This register is used to supply a cutoff frequency to the low pass filter that filters the DC voltage signal used by the controller.

5.4.16.6 LEM Current LPF Cutoff Frequency

This register is used to supply a cutoff frequency to the low pass filter that filters the LEM signal used by the controller.

5.4.17 Digital Input Debounce Parameters

Table 36 - Configuration Register Set – Digital Input Debounce Parameters

Address		Register Name	Data Type	Units	Factory Default	Min	Max	Access Level
Decimal	Hex							
4380	0x111C	Fast Inhibit Debounce Count	U16	Integer	2	0	15	R/W
4381	0x111D	Slow Inhibit Debounce Count	U16	Integer	2	0	15	R/W
4382	0x111E	DIN0 Debounce Count	U16	Integer	2	0	15	R/W
4383	0x111F	DIN1 Debounce Count	U16	Integer	2	0	15	R/W

5.4.17.1 Debounce Counts

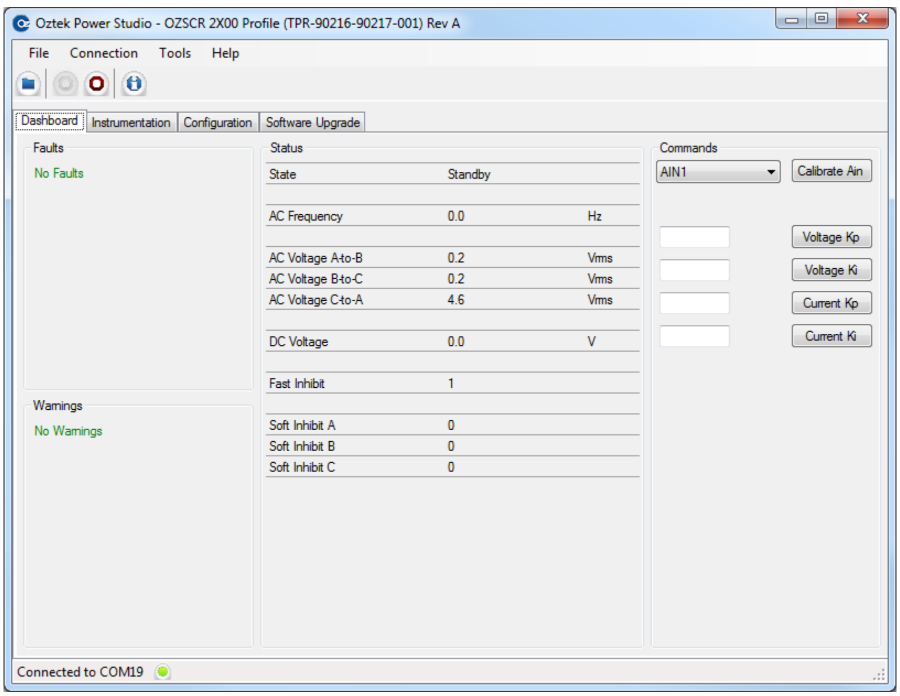
These registers are used to set the debounce counts for digital inputs. The debouncing takes place every 200us. A value of 0 disables debouncing and the unit uses the pin value directly. The default value is 2, meaning the pin has to read the same value 3 consecutive times (once, followed by 2 debounces) for a state change to take effect.

6. Oztek Power Studio

The Oztek Power Studio is a Microsoft Windows GUI which provides any easy to use method to configure the OZSCR2x00, as well as serve as an operating dashboard. Features include individual parameter configuration as well as application configuration management and production line configuration capability. The installer for this tool can be downloaded from the Oztek website (see Oztek part number SW-90216). This tool supports many different standard Oztek controllers. When using Power Studio to configure and control an OzSCR2X00 product, the TPR-90216-90217-001_rev*.xml Target Profile must be loaded. This file is also available for download on the Oztek website. For more information about the tool, see User Manual UM-0052, available from the Oztek website or the tool itself using the "Help→User Manual" menu item.

6.1 Dashboard

The Dashboard shows high level system data and provides an overview of the controller state.



6.1.1 Status

The status section shows instrumentation data that affects how the system operates. This data corresponds with the related descriptions in section 5.3 and is scaled to real world values.

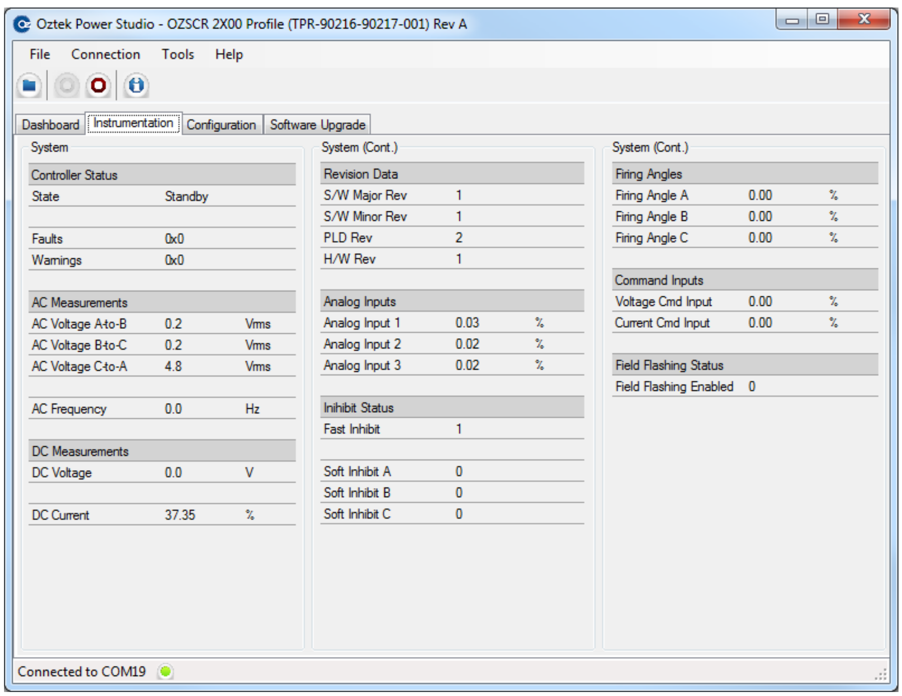
6.1.2 Commands

The command section allows the user to send commands to the controller which are described below:

- Calibrate AIN: This command provides a dropdown list to calibrate a single analog input at a time. This calibration is used to calculate and store an offset to correct analog input measurements as described in section 5.2.8.
- Voltage and Current Kp and Ki gains: These textboxes provide the means to change the voltage and current loop gains on the fly. These gains are volatile and will be reset to defaults upon POR. These are further described in sections 5.2.9 and 5.2.10.

6.2 Instrumentation

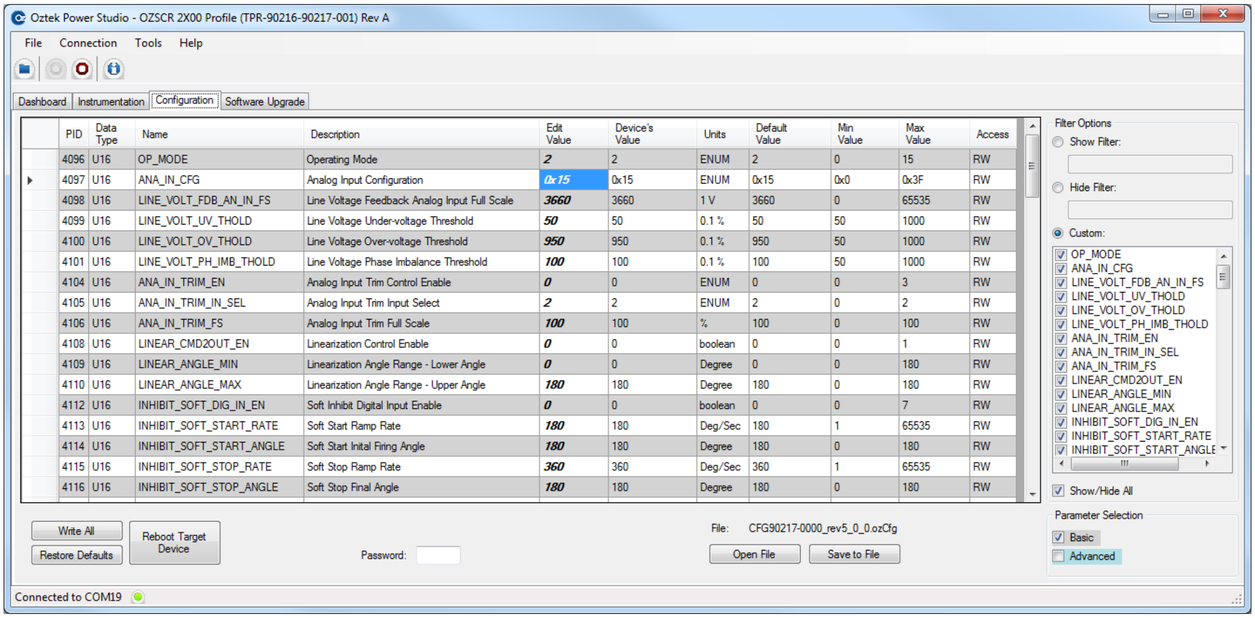
The Instrumentation tab displays detailed data from the controller.



Most of the data is scaled from the descriptions in section 5.3 to be shown as percentages of full scale or real world values.

6.3 Configuration

The Configuration tab provides access to configuration parameters. The factory default configuration file CFG-90217-0000_rev#_#_#.ozCfg must be loaded to access the parameters which can be downloaded from the Oztek website. Changes made within Power Studio can be saved to create configuration files for specific applications.



Once the ozCfg file is opened and the target is connected, the parameters are read from the target device. Values can be written individually via the “Edit Value” column or en masse using the “Write All” button.

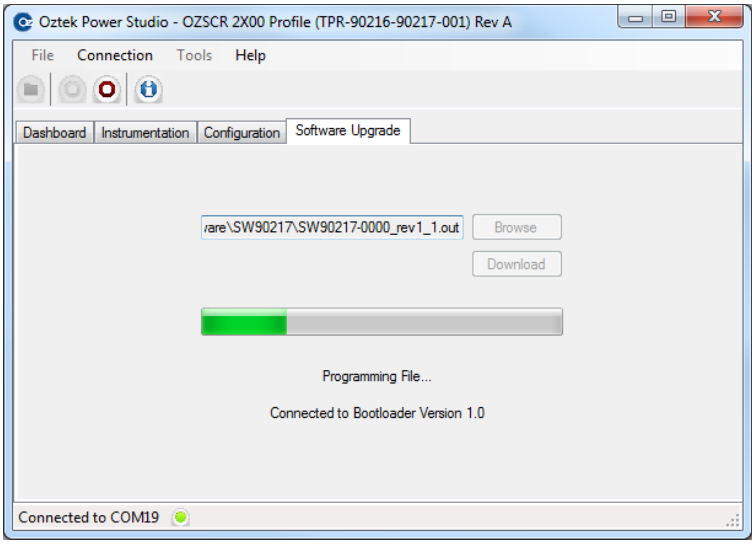
The “Restore Defaults” button issues the “Configuration Reset” command described in section 5.2.5. The password textbox is used to supply the password for the command as well as any parameters that may require a password.

The “Reboot Target Device” button issues the “Configuration Reload” command described in section 5.2.6.

The “Parameter Selection” checkboxes do not need to be changed to use the OzSCR2X00.

6.4 Software Upgrade

The Software Upgrade tab uses the target’s embedded bootloader to download a new flash image to the target. The bootloader is launched automatically by Power Studio so power cycling to launch the bootloader is not required. The latest version of the OzSCR software SW90217-0000_rev#_#.out can be downloaded from the Oztek website.



While downloading the image, the other tabs and Power Studio features will be disabled. Once the download process is complete, the downloaded image will be run and the other tabs will become unlocked.

7. Specifications

> ⚠ **CAUTION: Equipment Damage**
> Operation of the OZSCR2x00 in a manner other than specified in this manual may cause damage to the OZSCR2x00 and other system components and will void the terms of the warranty.

7.1 Environmental Specifications

Table 37 - Environmental Specifications

Operating Temperature	-40°C to 85°C
Storage Temperature	-65°C to 85°C
Relative Humidity	90%, Non-condensing
Dimensions	6 in x 8 in

7.2 Electrical Specifications

Table 38 - Electrical Specifications

Input Power	
Input Voltage (OZSCR2000)	85 – 265 V_{AC} 120 – 375 V_{DC}
Input Voltage (OZSCR2100)	18 – 32 V_{DC}
Power	15 W
Line Voltage Sense (Direct Cathode)	
Voltage Range	50 – 1000 V_{AC}
Frequency Range	10 – 500 Hz
Line Voltage Sense (Low Voltage)	
Voltage Range	0 – 7 V_{AC}
Frequency Range	10 – 500 Hz
Gate Drive	
Initial short circuit gate current	3 A
Sustaining short circuit gate current	600 mA
Initial gate pulse rate of rise	6 A/us
Open circuit voltage	15 V
Picket fence frequency	25 kHz
Analog Inputs (Voltage Mode)	
Input Voltage Range	0-10V
Input Impedance	14.22k Ohm

Analog Inputs (Current Mode)	
Input Current Range	0-20mA
Digital Inputs	
Input Voltage Range	0-24V
Low Input	< 1.0 V
High Input	> 4.0 V
Input Impedance	4k Ohm
Digital Outputs (Open Collector)	
Maximum Voltage	24V
Maximum Sink Current	10mA
Bias Output	
Minimum Input Voltage Necessary for Use of ±15V Bias Voltage at J20	22.5V_{DC} (SCR2100) 85V_{AC}/120V_{DC}(SCR2000)
J20 ±15V Bias Maximum Load Current	30mA
Serial Interface	
Physical Layer	RS-485 2-wire
Protocol	MODBUS

7.3 Regulatory Specifications

Table 39 - Regulatory Specifications

PCB designed to UL standards	
Creepage	UL480, VDE0110

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 OZSCR2x00 controller. This Warranty Period lasts for 18 months from the date of purchase at the point of sale to you, the original end user customer, unless otherwise agreed in writing. You will be required to demonstrate proof of purchase to make warranty claims. This Limited Warranty is transferable to subsequent owners but only for the unexpired portion of the Warranty Period. Subsequent owners also require original proof of purchase as described in "What proof of purchase is required?"

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

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

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

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

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

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

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

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

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

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

Disclaimer

Product

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

Return Material Authorization Policy

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

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

Return Procedure

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

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

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

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

Out of Warranty Service

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

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

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