Voltage Mode Inverter (VMI) Controller
User’s Manual
UM-0037
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1. Introduction

This document is intended to provide instruction on how to employ the Oztek Voltage Mode Inverter (VMI) firmware application on a standard Oztek OZDSP3000 controller in a hardware system. It describes the electrical connections as well as the scaling of the various signals required by the control firmware.

1.1 Referenced Documents

<table>
<thead>
<tr>
<th>Ref.</th>
<th>Document</th>
<th>Description</th>
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<tbody>
<tr>
<td>[3]</td>
<td>FS-0054</td>
<td>VMI Modbus Communications Registers</td>
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1.2 Definitions

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
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<tbody>
<tr>
<td>AFE</td>
<td>Active Front End</td>
</tr>
<tr>
<td>CAN</td>
<td>Controller Area Network</td>
</tr>
<tr>
<td>DSP</td>
<td>Digital signal processor</td>
</tr>
<tr>
<td>EEPROM</td>
<td>Electrically Erasable Programmable Read Only Memory</td>
</tr>
<tr>
<td>EMC</td>
<td>Electro-magnetic compatibility</td>
</tr>
<tr>
<td>EMI</td>
<td>Electro-magnetic interference</td>
</tr>
<tr>
<td>GND</td>
<td>Ground, low side of input power supply</td>
</tr>
<tr>
<td>GTI</td>
<td>Grid Tied Inverter</td>
</tr>
<tr>
<td>GUI</td>
<td>Graphical User Interface</td>
</tr>
<tr>
<td>HMI</td>
<td>Human Machine Interface</td>
</tr>
<tr>
<td>IPM</td>
<td>Intelligent Power Module</td>
</tr>
<tr>
<td>N.C.</td>
<td>Not connected</td>
</tr>
<tr>
<td>PCB</td>
<td>Printed Circuit Board</td>
</tr>
<tr>
<td>PCC</td>
<td>Power Control Center</td>
</tr>
<tr>
<td>PLC</td>
<td>Programmable Logic Controller</td>
</tr>
<tr>
<td>PLL</td>
<td>Phase Locked Loop</td>
</tr>
<tr>
<td>POR</td>
<td>Power On Reset</td>
</tr>
<tr>
<td>PWM</td>
<td>Pulse width modulation</td>
</tr>
<tr>
<td>SVM</td>
<td>Space Vector Modulator</td>
</tr>
<tr>
<td>VMI</td>
<td>Voltage Mode Inverter</td>
</tr>
</tbody>
</table>
2. Functional Description

A Voltage Mode Inverter is used to provide an AC voltage source from an intermediate DC circuit or Link. It can be used to produce AC power from variable power sources such as batteries, fuel cells, and windmills as well as convert from one type of AC power to another, i.e. frequency converter applications. Figure 1 and Figure 2 illustrate typical single and three phase VMI hardware configurations.

![Figure 1 - Typical Single Phase VMI Configuration](image1)

![Figure 2 - Typical Three Phase Isolated VMI Configuration](image2)

2.1 Typical Hardware Implementation

An electrical system block diagram of a typical VMI 60Hz to 400Hz Frequency Converter application is presented in Figure 3. While component values will vary from application to application depending on line voltage and power level, the overall system configuration will generally remain the same.

The three phase power is rectified and filtered to provide a DC Link voltage to the power converter. The main power converter is comprised of a three phase IGBT bridge whose output is then filtered and isolated by a transformer before being made available to the loads. A DSP control board is used to implement control of the 400Hz power electronics assembly while a PLC based HMI is provided for high level operation of the product.
2.1.1 Power Module

The power module is a three phase semiconductor bridge which controls the power transfer from the AC Line to the DC link and vice versa. Oztek control boards are designed to interface directly with Semikron SKiiP power modules. In addition to the power devices, these modules provide current sensing, DC link voltage sensing, temperature sensing, and protection features including over voltage, over current, and desaturation protection.

2.1.2 Pre-Charge Circuit

A pre-charge circuit is used to limit the inrush current associated with charging the DC link capacitance when applying line voltage to the VMI. Lack of a pre-charge circuit can result in extremely high, potentially damaging inrush currents.

2.1.3 Power Rectifier

A three phase diode bridge is used to rectify the AC input into a DC Link voltage for the VMI frequency converter to operate off of. The rectifier is fed by a three phase contactor controlled by the control board firmware, allowing the firmware to pre-charge the DC Link.

2.1.4 Output Filter

A second order, three phase L-C filter is used to remove the PWM switching components from the switch-mode voltage output. Resistors and inductors are used in series with the capacitors to provide damping of resonances.
2.1.5 Isolation Transformer

A three phase transformer is used to provide galvanic isolation and voltage translation on the output of the converter. In addition, the transformer's leakage inductance, together with additional discrete capacitors, forms a secondary output filter to help meet the output THD requirements.

2.1.6 Current Sensors

The VMI firmware expects to sense current both at the primary and secondary sides of the output transformer.

2.1.6.1 Primary Current Sensors
Primary current is sensed via current sensors incorporated in to the Power Modules.

2.1.6.2 Secondary Current Sensors
LEM type current sensors are included on the output of the transformer to provide feedback for controlling the magnetization current in the isolation transformer.

2.1.7 OZDSP3000 Controller

The OZDSP3000 is an Oztek “off the shelf” control solution intended for rapid prototyping and low volume production of power control systems. It has been designed to specifically interface with Semikron Power Modules and provides all of the necessary interfaces for controlling a VMI including isolated, high voltage line sensing, RS-485 communication port, relay drivers etc.

2.2 Description of Operation

Figure 4 presents a simplified block diagram of the control scheme employed in the VMI firmware. This block diagram illustrates the controls for a single output phase. Each phase is independently controlled allowing the controller to operate in single or multiphase applications. The voltage controller is a resonant mode type regulator whose reference sets the value of the output voltage. This reference is adjusted by the line drop compensator to account for IR drops in long output cable runs. The adjusted reference is then compared to the measured output voltage providing the voltage error input to the resonant mode controller.

The output of the voltage controller is adjusted by a DC Link Voltage feed forward term, limited, and used to control a pulse width modulator which generates the gating commands to the power switches.
2.3 State Sequencing

A state machine is used to provide deterministic control and sequencing of the VMI hardware. If a fault is detected in any of the operating states, the hardware is placed into a safe condition and the state machine is latched into the Fault state. Figure 5 illustrates the operating states as well as the transition logic employed in the system state machine.
2.3.1 Initialize

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

2.3.2 Calibrate

The *Calibrate* state is used to calibrate system hardware as applicable. Power hardware is not operable while in the *Calibrate* state. Following successful calibration, the state machine will auto-transition to the *Precharge* state.

2.3.3 Precharge

The *Precharge* state is used to wait for a valid AC line interface before attempting to begin the DC link charging process. The state machine will remain in the *Precharge* state indefinitely.
transitioning either on a fault or upon detecting a valid AC line. Power hardware is not operable while in the *Precharge* state.

### 2.3.4 Charge

The *Charge* state is used to charge the DC link capacitance in a controlled manner before directly connecting to the AC line. Once the DC link is charged, the state machine will sequence to the *Idle* state. Power hardware is not operable while in the *Charge* state.

### 2.3.5 Idle

Once in the *Idle* state the VMI is ready for use. The state machine will remain in the *Idle* state indefinitely, transitioning either on a fault, a turn-on command, or upon detecting an invalid AC line.

### 2.3.6 On

While in the *On* state the VMI is processing power and will remain in the *On* state indefinitely, transitioning either on a fault or a turn-off command.

### 2.4 Precharge Process

The application software is capable of controlling external precharge components for use in precharging the DC Link capacitors from the AC line. Figure 6 illustrates the logic used to implement the precharge process.
2.5 Fault and Warning Conditions

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

2.5.1 Warnings

The VMI provides the warning indicators listed below. These warning conditions do not prohibit operation of the VMI; they are merely reported for informational purposes only.
2.5.1.1 Local Bias Supply Tolerance Warnings
The VMI firmware monitors the local bias supplies (24V, 15V, 5V, 3.3V, and -15V) on the control board and will set a warning flag if the corresponding supply voltage is not within the range required by the on-board hardware. The various warning flags will remain set while the supply voltages are out of tolerance and will be cleared when the supply is found to be within the required limits.

2.5.1.2 DC Link High Voltage
The VMI firmware monitors the DC link voltage and will set a warning flag if it exceeds the **DC Link Over-Voltage Warning Threshold** configuration parameter. This flag will remain set until the voltage falls below the **DC Link Over-Voltage Recover Threshold** configuration parameter.

2.5.1.3 DC Link Low Voltage
The VMI firmware monitors the DC link voltage and will set a warning flag if it falls below the **DC Link Under-Voltage Warning Threshold** configuration parameter. This flag will remain set until the voltage exceeds the **DC Link Under-Voltage Recover Threshold** configuration parameter.

2.5.1.4 Line Frequency Out of Tolerance
The VMI firmware monitors the AC Line frequency and will set a warning flag if it falls below the **AC Line Low Frequency Warning Threshold** or exceeds the **AC Line High Frequency Warning Threshold** configuration parameters. These flags will remain set until the frequency exceeds the **AC Line Low Frequency Recover Threshold** or the **AC Line High Frequency Recover Threshold** configuration parameters respectively.

2.5.1.5 Line Voltage Out of Tolerance
The VMI firmware monitors the AC Line voltage and will set a warning flag if it falls below the **AC Line Low Voltage Warning Threshold** or exceeds the **AC Line High Voltage Warning Threshold** configuration parameters. These flags will remain set until the voltage exceeds the **AC Line Low Voltage Recover Threshold** or the **AC Line High Voltage Recover Threshold** configuration parameters respectively.

2.5.1.6 Inverter & Cabinet High Temperature
The VMI firmware monitors the inverter power module and cabinet temperatures and will set warning flags if they exceed the **Inverter Temperature Warning Threshold** or **Cabinet Temperature Warning Threshold** configuration parameters. These flags will remain set until the temperature falls below the **Inverter Temperature Recover Threshold** or **Cabinet Temperature Recover Threshold** configuration parameters respectively.

2.5.2 Faults
The VMI provides the fault protection listed below. Whenever a fault occurs the VMI will automatically turn the converter OFF, open the main line contactor and transition to the FAULT state.
The controller remains in the FAULT state and the latched fault flags remain set until explicitly reset with a Fault Reset command. This is true even if the source(s) of the fault(s) are no longer active. Upon receiving the Fault Reset command, the VMI will attempt to clear all latched fault bits. It then examines the sources of all fault conditions and if none are active the VMI controller will transition to the Precharge state. If upon re-examination any sources of faults are still active, their respective fault flags are latched again and the VMI will remain in the FAULT state.

2.5.2.1 Precharge Timeout Error
The VMI Firmware monitors the amount of time spent in the CHARGE State. A fault will be asserted if the DC Link Precharge Enable configuration parameter is set to TRUE (i.e. the VMI is controlling the precharge function) and the elapsed time exceeds the Precharge Timeout Threshold configuration parameter.

2.5.2.2 Precharge Contactor Error
The VMI monitors the status of the precharge contactor feedback signal if the precharge contactor monitor is enabled in the Contactor Monitor Enables configuration parameter. If, after the time specified in the Contactor Debounce Time configuration parameter has passed, the precharge contactor is not in the state commanded by the VMI, a fault will be asserted.

2.5.2.3 Line Contactor Error
The VMI monitors the status of the main line contactor feedback signal if the line contactor monitor is enabled in the Contactor Monitor Enables configuration parameter. If, after the time specified in the Contactor Debounce Time configuration parameter has passed, this contactor is not in the state commanded by the VMI, a fault will be asserted.

2.5.2.4 Relay Driver Hardware Error
The VMI monitors the status of the relay drive circuit on the control board that is used to drive the precharge and main line contactors. This hardware circuit provides the ability to detect open load, short circuit, over-voltage and over-current conditions. A fault is asserted if any of these conditions are reported.

2.5.2.5 Configuration Memory Error
This fault occurs any time a read from the configuration memory is performed and the CRC for the block being read does not match the CRC stored in the memory. This may occur if the data was corrupted in transmission during the read or this may occur if the data stored in memory was corrupted. Unlike all other fault sources, this fault condition is not cleared with the Fault Reset command as the fault condition indicates the possibility that the control parameters are not as intended. Instead, this fault is considered a major system fault and needs to be addressed as follows:

1. Attempt to reload the system configuration using the Configuration Reload command or cycle power to the control board. Either of these actions will reset the CPU on the control board which then forces a re-initialization of the application, including reading the configuration parameters from the external configuration memory. If this
completes without error, this implies the previous error occurred while the data was being read.

2. If after executing step 1 above a configuration error is still present, this may indicate bad data in the configuration memory. In this case, the memory will need to be reset to the factory defaults using the Configuration Reset command. Once the memory contents have been reset and any values changed to their customized settings, step 1 above should be executed to force a reload of the system variables.

3. If neither of the above result in clearing the configuration error, then there is likely an issue with the control board hardware. At this point the board should be sent back to the factory for diagnosing and repairing of any defects (see the RMA process described at the end of this document).

2.5.2.6 Calibration Error
When first powering up the control board the VMI software attempts to calibrate the controller’s internal ADC. This error is asserted if the controller is unable to perform the required calibration. There is likely an issue with the control board hardware if this error occurs, in which case the board should be sent back to the factory for diagnosing and repairing of any defects (see the RMA process described at the end of this document).

2.5.2.7 DC Link Faults
The VMI firmware monitors the DC link voltage and will assert a fault if it exceeds the **DC Link Over-Voltage Fault Threshold** or falls below the **DC Link Under-Voltage Fault Threshold** configuration parameters.

2.5.2.8 Line Frequency Fault
The VMI firmware monitors the AC Line frequency and will assert a fault if it exceeds the **AC Line Frequency High Fault Threshold** or falls below the **AC Line Frequency Low Fault Threshold** configuration parameters.

2.5.2.9 Line Voltage Fault
The VMI firmware monitors the AC Line voltage and will assert a fault if it exceeds the **AC Line Voltage High Fault Threshold** or falls below the **AC Line Voltage Low Fault Threshold** configuration parameters.

2.5.2.10 Inverter Hardware Over-Temperature
The VMI firmware provides a means to recognize a hardware-based over-temperature error signal from the inverter interface (as is present on a typical Semikron SKiiP interface).

2.5.2.11 Inverter IGBT Error
The VMI firmware provides a means to recognize a hardware-based IGBT error signal from the inverter interface (as is present on a typical Semikron SKiiP interface).
2.5.2.12 Software Inverter Over-Temperature
The VMI monitors the inverter and cabinet temperatures and will assert a fault if they exceed the \textit{Inverter Temperature Fault Threshold} or the \textit{Cabinet Temperature Fault Threshold} configuration parameters respectively.

2.5.2.13 Output Overload
The VMI firmware monitors the RMS output current for each of the three phases and asserts a fault if any phase exceeds the \textit{Output Over-Current Fault Threshold} configuration parameter.

2.5.2.14 Output Voltage
The VMI firmware monitors the RMS output voltage for each of the three phases and asserts a fault if any phase exceeds the \textit{Output Over-Voltage Fault Threshold} or falls below the \textit{Output Under-Voltage Fault Threshold} configuration parameters.
3. **OZDSP3000 Hardware Interfacing**

The OZDSP3000 is a highly integrated DSP control solution for power control applications. Typical applications include voltage mode inverters, grid-tie inverters, AC induction motor controllers, brushless DC motor controllers, and Active Front-End regulators. This section describes how to utilize the OZDSP3000 along with the VMI control firmware in a typical VMI system application.

3.1 **Application Interfaces**

![Diagram of OZDSP3000 VMI Application Electrical Connections](image)

**Figure 7 – OZDSP3000 VMI Application Electrical Connections**

3.1.1 **J1/J2/J3: Auxiliary LEM Current Sensor Interfaces**

Connectors J1, J2, and J3 provide interfaces to auxiliary LEM current sensors. +/-15V power is provided to the sensor. The LEM current transducer HAS series is recommended for use with this interface.

- **OZDSP3000 Connector Part Number:** (Waldom/Molex) 22-04-1041
- **Mating Connector Part Number:** (Waldom/Molex) 22-01-1042
- **Input Range:** +/- 4V

<table>
<thead>
<tr>
<th>J1/2/3 Pin #</th>
<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>+15V</td>
</tr>
<tr>
<td>2</td>
<td>-15V</td>
</tr>
<tr>
<td>3</td>
<td>Iout</td>
</tr>
<tr>
<td>4</td>
<td>Iout Return</td>
</tr>
</tbody>
</table>

### Table 1 – J1/2/3 LEM Sensor Pin Assignments

#### 3.1.2 J4 Cabinet Temp Thermistor Interface

Connector J4 provides an interface for a 10k cabinet thermistor style temperature sensor.

- **OZDSP3000 Connector Part Number:** (Molex) Micro-Fit 2 Position Header: 43650-0215
- **Mating Connector Part Number:** (Molex) Micro-Fit 2 Position Receptacle: 43645-0200
- **Input Range:** 0Ω to open circuit

#### 3.1.3 J8: Relay Driver Interface

The VMI firmware automatically controls both a pre-charge relay as well as a line interface relay, intended to drive the coils of higher power contactors.

<table>
<thead>
<tr>
<th>Pin #</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Line interface relay 24V drive</td>
</tr>
<tr>
<td>7</td>
<td>Line interface relay drive return</td>
</tr>
<tr>
<td>4</td>
<td>Pre-charge relay 24V drive</td>
</tr>
<tr>
<td>8</td>
<td>Pre-charge relay drive return</td>
</tr>
</tbody>
</table>

- **OZDSP3000 Connector Part Number:** (Molex) Micro-Fit 2x4 Header: 43045-0824
- **Mating Connector Part Number:** (Molex) Micro-Fit 2x4 Receptacle: 43025-0800
- **Output Range:** 24V, 2A continuous, 5A inrush

#### 3.1.4 J9: Contactor Status Feedback

The VMI firmware expects switch closure feedback from both the pre-charge as well as the line interface contactors. These switch closure, status feedback signals should be wired to the opto-coupler inputs on J9, as illustrated in Figure 7.
Table 3 – J9 Contactor Status Pin Assignment

<table>
<thead>
<tr>
<th>Pin #</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pre-charge contactor status (switched 24V)</td>
</tr>
<tr>
<td>2</td>
<td>Line contactor status (switched 24V)</td>
</tr>
<tr>
<td>5</td>
<td>24V Return</td>
</tr>
<tr>
<td>6</td>
<td>24V Return</td>
</tr>
</tbody>
</table>

- **OZDSP3000 Connector Part Number:** (Molex) Micro-Fit 2x4 Header: 43045-0824
- **Mating Connector Part Number:** (Molex) Micro-Fit 2x4 Receptacle: 43025-0800
- **Input Range:** Logic high: 0V or floating. Logic low: 3V – 25V

3.1.5 J11/J13: SKiiP Power Module Interface

Connector J11 provides an interface to SKiiP style Semikron power modules. This interface complies with Semikron's required specifications. The OZDSP3000 supplies 24V power to the power module via pins 14 and 15. PWM commands (15V logic level) are supplied to the top and bottom switches of each of the three half bridges via signals INV_TOP_U(V,W) and INV.Bot.U(V,W) respectively. Feedback of phase currents, temperature, and DC link voltage are provided on INV.IOUT_U(V,W), INV.TEMP, INV.U DC signals respectively. Error signals from the module are similarly provided via INV.ERR_U(V,W) and INV.OVT. Please refer to the Semikron datasheet for the particular module being used for more information.

Table 4 – J11/13 SKiiP Power Module Pin Assignment

<table>
<thead>
<tr>
<th>Pin #</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ground</td>
</tr>
<tr>
<td>2</td>
<td>INV_BOT_U (Phase A)</td>
</tr>
<tr>
<td>3</td>
<td>INV.ERR_U (Phase A)</td>
</tr>
<tr>
<td>4</td>
<td>INV.TOP_U (Phase A)</td>
</tr>
<tr>
<td>5</td>
<td>INV_BOT_V (Phase B)</td>
</tr>
<tr>
<td>6</td>
<td>INV.ERR_V (Phase B)</td>
</tr>
<tr>
<td>7</td>
<td>INV.TOP_V (Phase B)</td>
</tr>
<tr>
<td>8</td>
<td>INV_BOT_W (Phase C)</td>
</tr>
<tr>
<td>9</td>
<td>INV.ERR_W (Phase C)</td>
</tr>
<tr>
<td>10</td>
<td>INV.TOP_W (Phase C)</td>
</tr>
<tr>
<td>11</td>
<td>INV.OVR_TEMP</td>
</tr>
<tr>
<td>12</td>
<td>n/c</td>
</tr>
<tr>
<td>13</td>
<td>INV.U DC</td>
</tr>
<tr>
<td>14</td>
<td>24V</td>
</tr>
<tr>
<td>15</td>
<td>24V</td>
</tr>
<tr>
<td>16</td>
<td>n/c</td>
</tr>
<tr>
<td>17</td>
<td>n/c</td>
</tr>
<tr>
<td>18</td>
<td>Ground</td>
</tr>
<tr>
<td>Pin #</td>
<td>Description</td>
</tr>
<tr>
<td>-------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>19</td>
<td>Ground</td>
</tr>
<tr>
<td>20</td>
<td>INV_TEMP</td>
</tr>
<tr>
<td>21</td>
<td>INV_IOUT_U_RTN (Phase A)</td>
</tr>
<tr>
<td>22</td>
<td>INV_IOUT_U (Phase A)</td>
</tr>
<tr>
<td>23</td>
<td>INV_IOUT_V_RTN (Phase B)</td>
</tr>
<tr>
<td>24</td>
<td>INV_IOUT_V (Phase B)</td>
</tr>
<tr>
<td>25</td>
<td>INV_IOUT_W_RTN (Phase C)</td>
</tr>
<tr>
<td>26</td>
<td>INV_IOUT_W (Phase C)</td>
</tr>
</tbody>
</table>

- **OZDSP3000 Connector Part Number:** (AMP) 499922-6
- **Mating Connector Part Number:** (AMP) 1658621-6
- **Power:** 24V @ 1.5A

### 3.1.6 Custom Driver Interface Considerations

When attempting to use the OZDSP3000 VMI controller with a custom designed power stage the hardware must be designed to provide the appropriate signals expected at the J11/13 interface. Generally some sort of custom printed circuit board will be required to interface the J11/13 signals to the gate drivers, current sensors, etc.

#### 3.1.6.1 Power

The OZDSP3000 supplies 24V on J11/13, pins 14 & 15. This 24V may be used to power the electronics on the interface board. The supply is capable of providing 1.5A.

#### 3.1.6.2 Switch Commands

The six switching commands are provided on pins 2, 4, 5, 7, 8, and 10. These switch command signals are driven off of the OZDSP3000 at 15V logic level using MC14504B level shifting devices.

#### 3.1.6.3 Error Inputs

The OZDSP3000 expects three logic level, error inputs; one associated with each phase, on pins 3, 6, and 9. When active, these inputs cause the VMI firmware to latch the system off into the Fault state. Pull-ups to 3.3V are provided on board and the signals are active high. Depending on the features provided in the custom design, these signals can be used to interface single error sources, multiple protection circuits, or none at all.

The custom interface board should drive the pin with an open-collector style circuit. In the case where no protection is provided, the pins should be grounded to disable the faults.
3.1.6.4 DC Link Voltage Sensing
The OZDSP3000 expects a signal proportional to DC link voltage to be provided on J11, pin 13 with respect to pins 18 and 19. This signal should be scaled such that 0-10 V represents the measurable DC link voltage range.

3.1.6.5 DC Link Hardware Over-Voltage Protection
When designing a custom interface it is highly recommended that hardware over voltage protection be implemented. This can be implemented with a comparator using the DC link voltage sense output. The output of this comparator can be used to gate off the switch commands as well as assert the Error inputs on each phase.

3.1.6.6 Hardware Over-Current and Desaturation Protection
Semikron SKiiP power modules provide fast hardware over current and desaturation protection. When designing a custom power solution, these additional protection features should also be considered. When including over current, desaturation, and over voltage protection into the design, the fault flags must be logically ORed together and reported using the open collector Error signal inputs to the OZDSP3000.

3.1.6.7 Current Sense Signals
The OZDSP3000 expects to receive a current sense signal for each half bridge phase output. This should be a bipolar signal where +/-10V corresponds to the full scale current range. The current sense signals should be provided on the following pins:

<table>
<thead>
<tr>
<th>J11 Pin #</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>Current Phase A (U)</td>
</tr>
<tr>
<td>21</td>
<td>Gnd Reference for Current Phase A (U)</td>
</tr>
<tr>
<td>24</td>
<td>Current Phase B (V)</td>
</tr>
<tr>
<td>23</td>
<td>Gnd Reference for Current Phase B (V)</td>
</tr>
<tr>
<td>26</td>
<td>Current Phase C (W)</td>
</tr>
<tr>
<td>25</td>
<td>Gnd Reference for Current Phase C (W)</td>
</tr>
</tbody>
</table>

3.1.6.8 Temperature Sense Signals
The OZDSP3000 expects to receive a 0-10V temperature signal on pin 20 that corresponds to the hot spot temperature of the power devices.

3.1.7 J20 Line Voltage Line Feedback
The VMI firmware expects to sense AC line voltage on J20. This is a low voltage interface and requires an off-board attenuator.

<table>
<thead>
<tr>
<th>J20 Pin #</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Line Voltage Phase A</td>
</tr>
<tr>
<td>3</td>
<td>Line Voltage Phase B</td>
</tr>
<tr>
<td>J20 Pin #</td>
<td>Description</td>
</tr>
<tr>
<td>-----------</td>
<td>-------------------</td>
</tr>
<tr>
<td>4</td>
<td>Line Voltage Phase C</td>
</tr>
<tr>
<td>5</td>
<td>Neutral</td>
</tr>
</tbody>
</table>

- **OZDSP3000 Connector Part Number**: (Molex) Micro-Fit 6 Header: 43650-0615
- **Mating Connector Part Number**: (Molex) Micro-Fit 6 Receptacle: 43645-0600

### 3.1.8 J23: High Voltage Line Feedback

The VMI firmware expects to sense output voltage for feedback control purposes on J23. The standard hardware variant is designed to accept 115VAC voltages directly. Interfacing to other AC voltages may require a modification to the gain of the sense amplifier (consult Oztek for more information).

#### Table 7 – J23 High Voltage Sense Pin Assignment

<table>
<thead>
<tr>
<th>Pin #</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Output Voltage Phase A</td>
</tr>
<tr>
<td>4</td>
<td>Output Voltage Phase B</td>
</tr>
<tr>
<td>7</td>
<td>Output Voltage Phase C</td>
</tr>
<tr>
<td>10</td>
<td>Neutral</td>
</tr>
</tbody>
</table>

- **OZDSP3000 Connector Part Number**: (Waldom/Molex) 26-60-4100
- **Mating Connector Part Number**: (Tyco) 3-644465-7

### 3.1.9 P1 Isolated RS485 ModBus Interface

Connector P1 provides an isolated RS422/485 communications interface. In RS422/485 mode jumper block J15 is used to select between the two protocols and configure termination if desired as detailed in Table 8. Figure 8 illustrates the pinout of the connector in the RS422/485 configuration.

- **OZDSP2000 Connector Part Number**: (AMP) 747844-5
- **Mating Connector Part Number**: Industry Standard DB9 Male

#### Table 8 – J15 RS422/485 Configuration Jumper Settings

<table>
<thead>
<tr>
<th>Mode</th>
<th>Jumper 1-2</th>
<th>Jumper 3-4</th>
<th>Jumper 5-6</th>
<th>Jumper 7-8</th>
</tr>
</thead>
<tbody>
<tr>
<td>RS422</td>
<td>TX Termination</td>
<td>RX Termination</td>
<td>DNP</td>
<td>DNP</td>
</tr>
<tr>
<td>RS485 Four-Wire</td>
<td>TX Termination</td>
<td>RX Termination</td>
<td>DNP</td>
<td>DNP</td>
</tr>
<tr>
<td>RS485 Two-Wire</td>
<td>Termination</td>
<td>DNP</td>
<td>Connect TX to RX</td>
<td>Connect TX to RX</td>
</tr>
</tbody>
</table>
OZDSP3000 Hardware Interfacing

3.1.10 J25: Bias Power Input

The OZDSP3000 requires 24VDC power input on terminal block J25. Note that Pin 3 is used for SPI boot enable; it should be left floating or connected to ground for normal Flash Boot operation.

<table>
<thead>
<tr>
<th>Pin #</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>24 VDC</td>
</tr>
<tr>
<td>5</td>
<td>24V Return</td>
</tr>
</tbody>
</table>

- **OZDSP3000 Connector Part Number:** (Phoenix Contact) 1733606
- **Mating Connector Part Number:** n/a (terminal block style)
- **Voltage:** 24V nominal, 18V min, 28V max
- **Current:** 4.5A maximum (Inrush current while powering three SKiiP modules)
3.2 Electrical Interfaces

The approximate location of the connectors, jumper blocks, LEDs, and test hooks are illustrated in Figure 9.

Figure 9 – Approximate Connector, Jumper, LED, and Test Hook Locations
3.3 Mechanical Interface

Figure 10 – OZDSP3000 Mechanical Dimensions
4. Maintenance and Upgrade

The firmware image on the OZDSP3000 can be upgraded in-system using the resident CAN bootloader. For detailed information on how to upgrade the firmware or directly interface with the bootloader, please reference UM-0015 Oztek TMS28x CAN Bootloader Users Manual.
Warranty and Product Information

Limited Warranty

What does this warranty cover and how long does it last? This Limited Warranty is provided by Oztek Corp. ("Oztek") and covers defects in workmanship and materials in your OZDSP3000 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.

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Product
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Return Material Authorization Policy

Before returning a product directly to Oztek you must obtain a Return Material Authorization (RMA) number and the correct factory “Ship To” address. Products must also be shipped prepaid. Product shipments will be refused and returned at your expense if they are unauthorized, returned without an RMA number clearly marked on the outside of the shipping box, if they are shipped collect, or if they are shipped to the wrong location.

When you contact Oztek to obtain service, please have your instruction manual ready for reference and be prepared to supply:

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

Return Procedure

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

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

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

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

Out of Warranty Service

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

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

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