ZiLOG

Z8 Encore! MC™ Family

Vector Control Development Kit

User Manual

UM021402-0407

Intended Use of the Vector Control Development Kit

The Vector Control Development Kit is designed for demonstration and development purposes only and must not be included in other electrical installations!

General

During operation, the Vector Control Development Kit has exposed hot surfaces, uninsulated contacts, and rotating parts when the motor is connected. If used or installed improperly, there is a danger of a serious personal injury and/or damage of property. All installation and use must be performed by skilled technical personnel!

Safeguards

The following precautions must be observed when working with the devices described in this document.

⚠️ **Caution:** Always use a grounding strap to prevent damage resulting from electrostatic discharge (ESD).

Revision History

The following table provides a revision history of this document.

Date	Revision Level	Description of Change	Page(s) Affected
February 2007	1	Original Issue	All
April 2007	2	Added warnings.	ii, 1, 5, 42

Table of Contents

Introduction

⚠️ **Caution:** The Vector Control Development Kit should only be used by technicians and engineers who are experienced in power electronics!

The Vector Control Development Kit is designed to help you develop motor control applications using the ZiLOG Z8FMC16100 Motor Control MCU. A 350-VDC, 15,000-RPM, 500-W, three-phase AC-induction motor is included with the kit if you ordered ZVECTOR0100ZCO.

Vector Control Development Kit

Kit Contents

The following items are included in the Vector Control Development Kit:

- Vector Control Unit (Control Unit)

- Optoisolated USB Smart Cable (Smart Cable)

- Six-circuit ribbon cable

- USB cable, type A to B

- USB-to-UART cable

- Vector Control CD-ROM containing demonstration code (Demo project, which is also programmed in the Control Unit) and Vector Control Panel host application

- ZDS II—Z8 Encore! 4.10.0 Development Software CD-ROM

- User manual

- Z8FMC16100 Series Motor Control MCU Easy Reference Chart

- Three-phase AC-induction motor (350 VDC, 500 W, and 15,000 RPM) is included if you ordered ZVECTOR0100ZCO

- Twenty-four-inch motor cable with six wires of 16 AWG and insulated female spade connectors (Figure 1 on page 3)
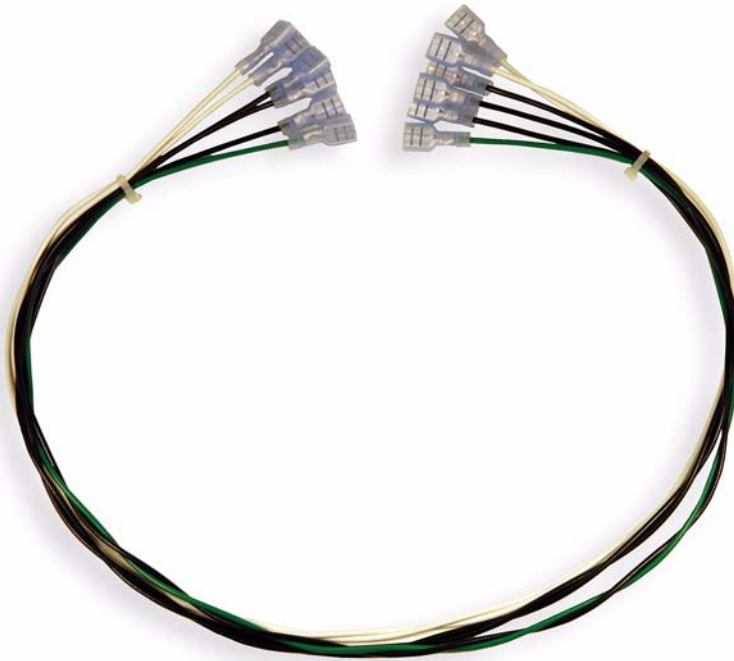
Figure 1. Motor Cable

System/Software Requirements

An IBM PC (or compatible computer) is required with the following recommended configurations:

- Windows XP Professional

- Pentium III/500-MHz processor or higher

- 128-MB RAM or more

- 135-MB hard disk space or more (includes application and documentation) or 35-MB hard disk space (application only)

- Super VGA video adapter

- CD-ROM for installation

- Two available USB high-speed ports

- Internet browser (Internet Explorer or Netscape)

Hardware/Materials Requirements

- One adjustable power supply, 1–48 VDC, 3A

- Clip-on leads to connect the Control Unit to the DC power supply

Setting up the Kit

⚠️ **Caution:** To avoid damage to the development kit, ZiLOG recommends that you use a bench DC power supply instead of AC power until your software is stable. Do not connect both the AC power cord and the DC power supply at the same time.

Before applying power, make sure that there are no loose wires or metal parts inside the unit. When the unit is connected to voltages above 30 VAC/60 VDC, all of the components inside the enclosed unit must be considered "hot," and any contact with the board must be avoided. The user must stay away from the unit because of the risk of projectiles of materials in case of components destruction, especially when applying high voltages.

Use the instructions below to set up the kit before running the demonstration code in standalone mode:

1. Insert the CD with the Demo project into a CD-ROM drive and follow the instructions to install the Demo project and the Vector Control Panel host application.

2. Connect the USB-to-UART cable (Figure 2 on page 6) between a PC and connector M-P3 of the Control Unit.

▶ **Note:** The UART side connector is polarized. Make sure to properly plug in the connector.

3. Follow the setup procedure in "Setting up the COM Port and Speed" on page 6 for the USB-to-UART cable (Figure 2 on page 6) to set up communication between a PC and the Control Unit.
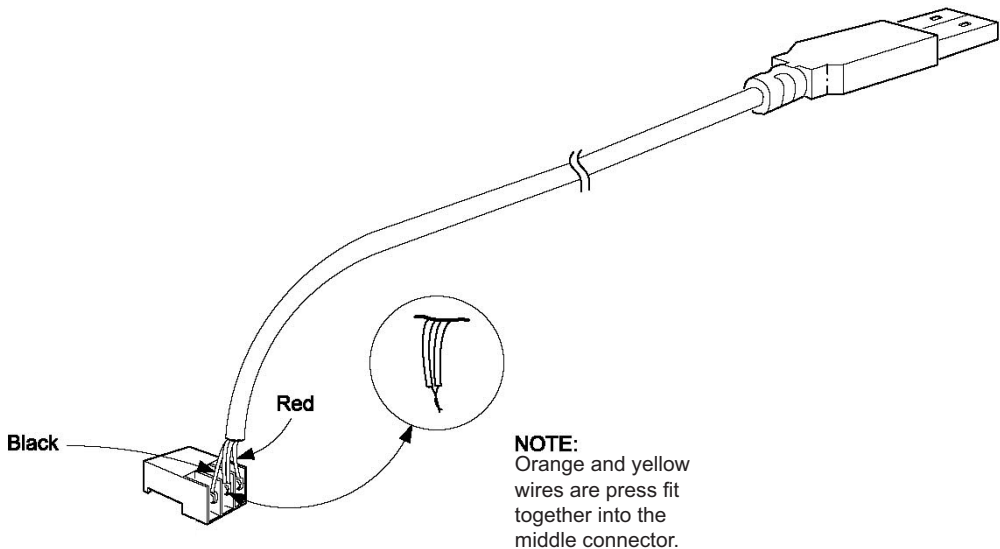
Red

Black

NOTE:
Orange and yellow
wires are press fit
together into the
middle connector.

Figure 2. USB-to UART Cable

Setting up the COM Port and Speed

To set up the COM port and speed, use the following procedure:

1. From the Start menu on the Windows desktop, select the **Control Panel**.

2. Double-click the System icon.

    The System Properties dialog box is displayed.

3. In the Hardware tab, click **Device Manager**.

    The Device Manager window is displayed.

4. Under Ports (COM & LPT), check which COM port was mapped to the USB-to-UART cable.

5. Select **Exit** from the File menu to close the Device Manager window.

6. Click **OK** to close the System Properties dialog box.

7. If the Control Panel application is not running, start the Control Panel (Start > Programs > ZiLOG Vector Control > Control Panel).
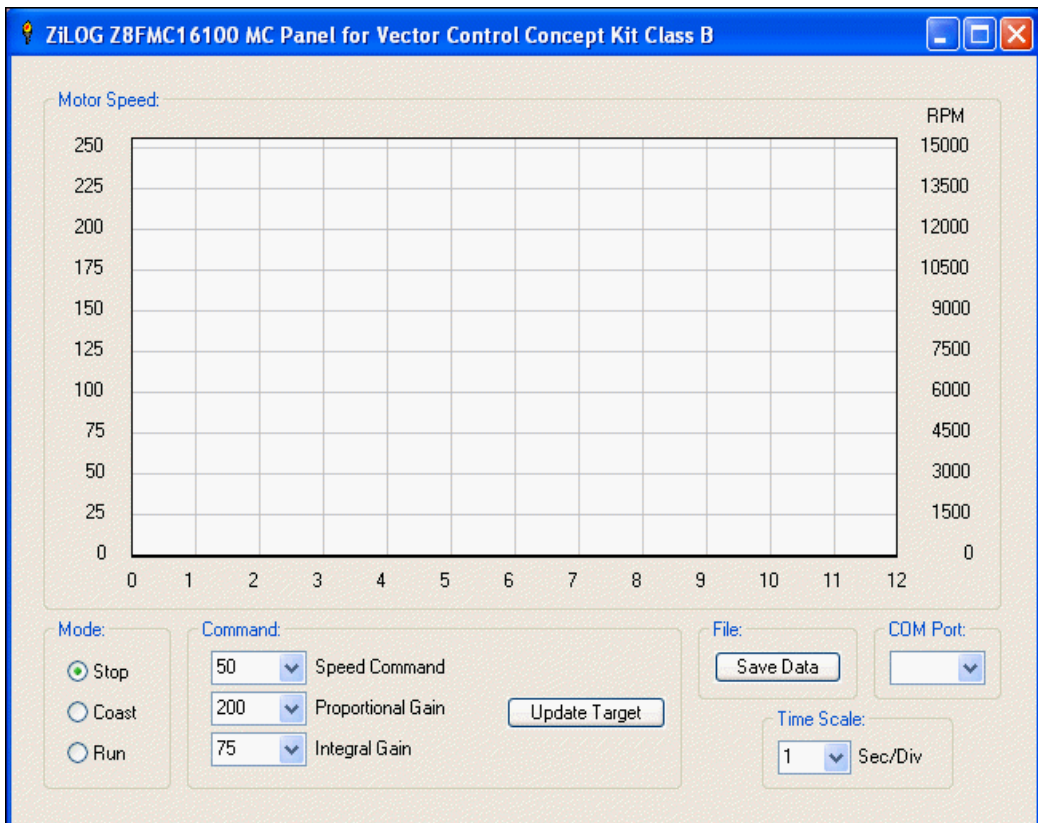
   See Figure 3.

Figure 3. Control Panel

8. In the Control Panel, select the same COM port that Windows mapped the USB-to-UART cable to (see Step 3).

9. Connect the motor to the Control Unit using the motor cable as shown in Figure 4 on page 8, Figure 5 on page 9, and Figure 6 on page 10.
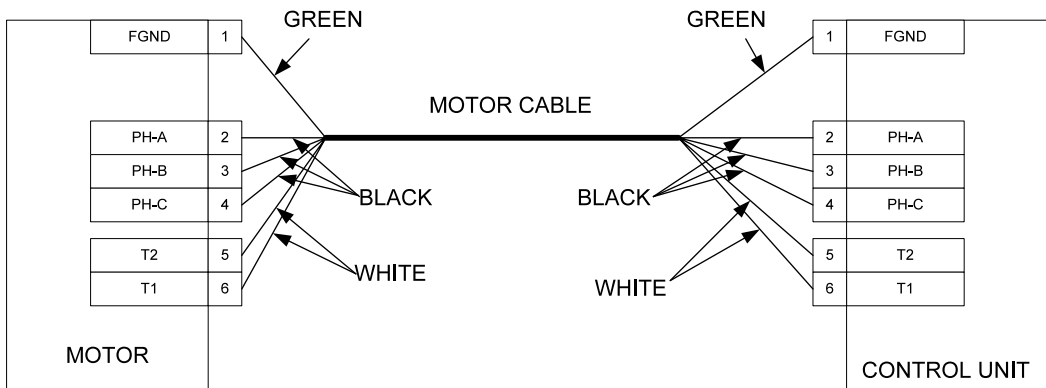
Figure 4. Control Unit and Motor Connection Diagram

- Frame
  Ground/Motor
  Case
    - **FGND**
- 3 Motor Leads
    - **PH-A**
    - **PH-B**
    - **PH-C**
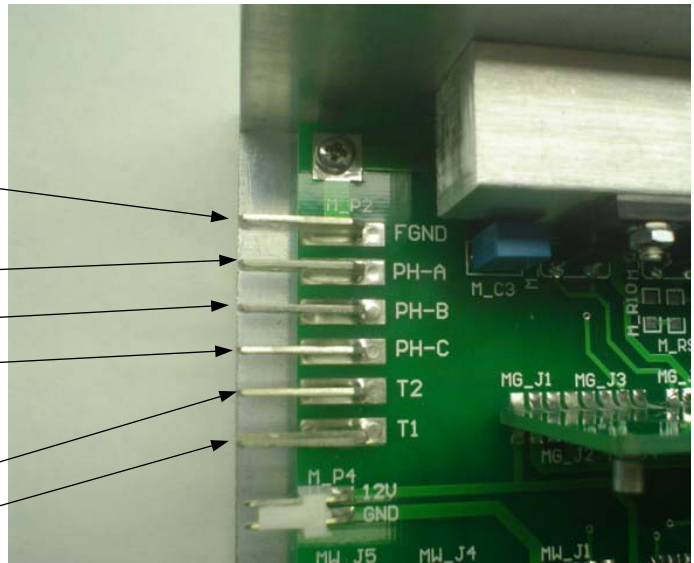- Tachogenerator
  Inputs
    - **T2**
    - **T1**

Figure 5. Control Unit Connection

Frame
Ground/Motor
Case
- **FGND**

3 Motor Leads
- **PH-A**
- **PH-B**
- **PH-C**
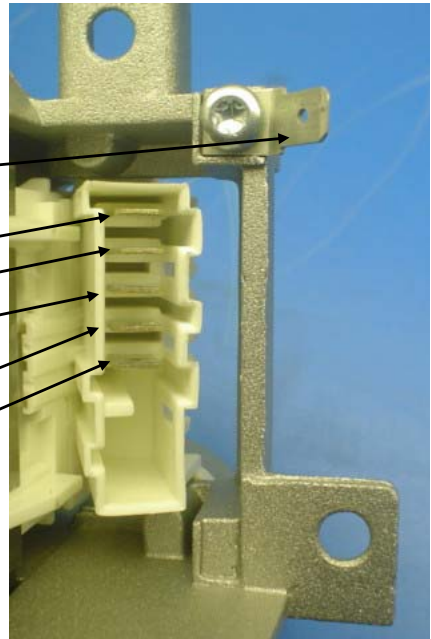
Tachogenerator
outputs
- **T2**
- **T1**

Figure 6. Motor Connection

10. Set the adjustable power supply to 0 VDC and connect it to the Control Unit using clip-on leads as following

    a. Connect the negative (-) lead of your adjustable power supply to spade lug connector AC-2 on the Vector Control Unit.

    b. Connect the positive (+) lead of your adjustable power supply to spade lug connector AC-1 on the Vector Motor Control Unit.

11. Gradually increase the voltage on the DC Power Supply to ~48VDC.

12. In the Control Panel (Figure 3 on page 7), click **Update Target**.

13. In the Control Panel, select the Run button in the Mode area and observe as the motor starts spinning.

▶ **Note:** If the motor does not start, click **Update Target** and select the Run button in the Mode area again.

> Bringing up the DC supply to 48 V is enough to power up the HV power module. It is a good practice to program the FMC16100 MCU with the input voltage at 48 V. Vector Control is a current regulator, so it can be run at this low voltage.

14. Now you can start changing speed, proportional gain, and integral gain on the Vector Control Panel and observe how the motor reacts to the changes.

15. After seeing how the demonstration operates, turn the adjustable power supply to 0 VDC and unplug the power supply from the board.

Downloading and Running the Sample Demonstration Code

Downloading and running the demonstration code involves some or all of the following general steps:

1. Install ZDS II—Z8 Encore! 4.10.0 development software, the USB device drivers, and the demonstration code.

2. Configure and connect the target hardware.

3. Use ZDS II to build, download, and run/debug the demonstration code and project.

The sections below provide the details needed to complete these steps.

Install the ZDS II—Z8 Encore! 4.10.0 Development Software

Perform the following steps to install the software tools:

a. Insert the provided ZDS II CD into your computer's CD-ROM drive.

    If the installation program does not start automatically, execute the `launch.exe` file from the root of the CD-ROM.

b. Select "Install ZiLOG Developer Studio" to install.

    Other software and accompanying documentation can be installed later.

c. Follow the instructions on the screen to complete the installation.

Install the USB Smart Cable Driver Software and USB Smart Cable

The USB Smart Cable connects the development kit to a high-speed or full-speed USB port on your ZDS II host system. Its internal optoisolator electrically isolates the development kit circuitry from the USB Smart Cable.

The USB Smart Cable is enclosed in a black box that connects to the host PC using a USB cable (included in kit). The USB Smart Cable housing connects to the development kit using a six-circuit ribbon cable.

The steps to install the USB Smart Cable are included with ZDS II. The file can be found at one of the following locations:

- *<ZiLOG Developer Studio II Installation Directory>*
  device drivers\USB

- *<ZiLOG Developer Studio II Installation CD>*
  Device Drivers\USB

Follow the instructions for the appropriate operating system.

▶ **Note:** Do not connect power to the application board before connecting a USB Smart Cable to both the host PC and development board.

Configure and Connect the Target Hardware

1. Stop the preloaded demonstration code, set the power supply to 0 VDC, and disconnect the power supply from the Control Unit.

2. Using the six-pin ribbon cable (Figure 7 on page 14), connect the Smart Cable to the connector that is available on the Control Unit through the opening in the clear cover. Make sure that the red strip on the ribbon cable (pin1) is oriented toward the power connector of the Control Unit.

Figure 7. Six-Pin Ribbon Cable

3. Connect and apply power to the development kit as described in "Setting up the Kit" starting on page 5.

▶ **Note:** This sets the voltage to 48 VDC.

⚠ **Caution:** Do not apply power to the application board unless the USB Smart Cable is connected both to the host PC and to the development board's DBG port.

Build, Download, and Run the Demonstration Code

Perform the following procedure to open the DemoApp.zdsproj sample project and run the code:

1. Run the ZDS II software using the Start menu shortcut. By default, ZDS II can be found at Start → Programs → ZiLOG ZDS II - Z8Encore! 4.10.0.

2. Select **Open Project** from the File menu and browse to the Vector Control demonstration code, which is located by default at

   C:\Program Files\ZiLOG\VectorControl_1.0\DemoApp

3. Select the DemoApp.zdsproj file and click **Open** to load the project.

4. Ensure that the USB Smart Cable is the selected debug tool.

   a. Select **Settings** from the Project menu to display the Project Settings dialog box.

    b.   In the Project Settings dialog box, select the Debugger tab and make certain that the target selected in the Target area is DemoApp.

    c.   Select the Debugger tab and ensure that USBSmartCable is the selected debug tool.

    d.   Click **Setup** under the debug tool selection field and ensure that a valid serial number is selected.

    e.   To save changes, click **OK** to close all dialog boxes.

5.   In the upper left corner of the Project Settings dialog box, make certain that the Debug build mode is selected.

6.   Build the demonstration project by selecting Rebuild All from the Build menu.The build output is displayed in the Output window at the bottom of the ZDS II window.

7.   Select **Reset** from the Debug menu to initiate a debug session and to connect and download the code to the development board.

8.   When the Option Bits Warning dialog box shown in Figure 8 displays, click **Yes** to continue.
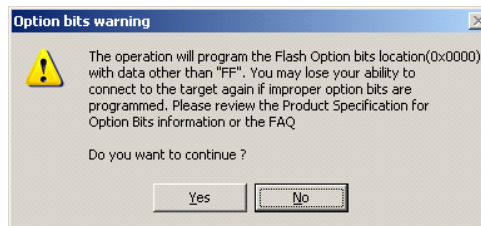

Figure 8. Option Bits Warning Dialog Box

9.   Select **Go** from the Debug menu to start the program.

10. In the Control Panel (Figure 3 on page 7), click **Update Target**.

11. In the Control Panel, select the Run button in the Mode area and observe as the motor starts spinning.

▶ **Note:** If the motor does not start, click **Update Target** and select the Run button in the Mode area again.

Bringing up the DC supply to 48 V is enough to power up the HV power module. It is a good practice to program the FMC16100 MCU with the input voltage at 48 V. Vector Control is a current regulator, so it can be run at this low voltage.

12. Now you can start changing speed, proportional gain, and integral gain on the Vector Control Panel and observe how the motor reacts to the changes.

For more information about using ZDS II and building projects for your Z8FMC16100 Series Motor Control Development Kit, refer to the *ZiLOG Developer Studio II—Z8 Encore!® User Manual* (UM0130).

Troubleshooting Tips

If you experience trouble running the demo program with the Vector Control Development Kit, check the following before contacting ZiLOG Technical Support for assistance:

- Verify that you are using the correct version of the development tools: ZDS II—Z8 Encore! version 4.10.0.

- Make sure you are using the unmodified sample project code as described in "Downloading and Running the Sample Demonstration Code" on page 12.

- Verify that you have properly connected the USB Optoisolator Smart Cable to the host PC as described in "Install the USB Smart Cable Driver Software and USB Smart Cable" on page 13. Ensure that pin 1

of the cable is properly aligned with DBG connector pin 1 (C_P18) of the development kit (see Figure 11 on page 24).

- In ZDS II (Project > Settings... > Debugger tab), verify that DemoApp is selected as the target and that USBSmartCable is the selected debug tool. Verify that the serial number for the USB Optoisolator Smart Cable interface is selected and configured using the Setup button under the Debug Tool selection field.

- Ensure that the project builds with no errors. To do so, select Rebuild All from the Build menu and view the build results in the Output window's Build tab.

- Verify that the development board is not currently running any code—the motor should not be spinning.

- Try reloading the sample project as described in "Downloading and Running the Sample Demonstration Code" on page 12.

If you perform these steps and cannot get the demonstration code to run, contact ZiLOG Technical Support at www.ZiLOG.com.

Theory of Operation

In this application, the FMC16100 microcontroller's PWM module is configured as three complementary output pairs. Each output pair controls one complementary source/drain transistor pair in the inverter bridge. The PWM module is configured to insert a 0.6 µS dead band between ON states to prevent leakage that might occur if one transistor in a pair turns on before the other is fully off.

Each PWM output pair produces a stream of complementary on/off pulses to activate the corresponding source or drain transistor in the inverter bridge. The voltage of each bridge output varies with the source/drain pulse duty cycle.

The period of each PWM cycle is configured to be 50 µS, and the PWM module generates an interrupt request at the end of each cycle. The PWM interrupt service routine (ISR) leaves the PWM interrupt disabled while it executes, and is tuned to execute within 200–250 µS. Therefore, the PWM ISR is executed every five PWM cycles, or 250 µS.

The PWM ISR controls all of the ongoing application program functions after initialization. The primary goal of the ISR is to update the duty cycle value for each PWM channel as needed to produce the desired AC waveforms at the inverter bridge outputs.

The PWM duty cycle values are derived from a feedback loop based on rotor speed and rotor flux position. The stator current waveform is determined by sampling two phases of the inverter output current and reconstructing the third phase.

The rotor speed is sampled by a counter/timer configured to measure the period of a magnetic position sensor on the motor. The measured speed is periodically compared to the requested speed received via UART from an external controller. The resulting speed command value is used to create a rotation reference frame expressed as a two-phase direct/quadrature (DQ) vector. The resulting vector is regulated to produce the necessary flux and torque amplitude in the output vector.

An inverse Park transform is used to rotate the reference frame relative to the rotor position. Then an inverse Clarke transform is used to convert the rotated two-phase reference frame back into a three-phase expression. At the same time, the vector's position is classified into one of six states, each corresponding to one sixth of the vector circle.

When the ISR calculates duty cycles for the three PWM channels, one phase is left unmodulated (ON or OFF for the whole PWM cycle), and the flux vector is encoded by modulating the other two phases. This reduces switching losses by one third. The two phases to be modulated depend on the flux vector's state position. After the PWM space vector calculation is complete, the corresponding PWM registers are updated.

For an example of a vector-control application, see the *Vector Control of a
3-Phase AC Induction Motor Using the FMC16100 MCU Application
Note* (AN0247).

Block Diagram

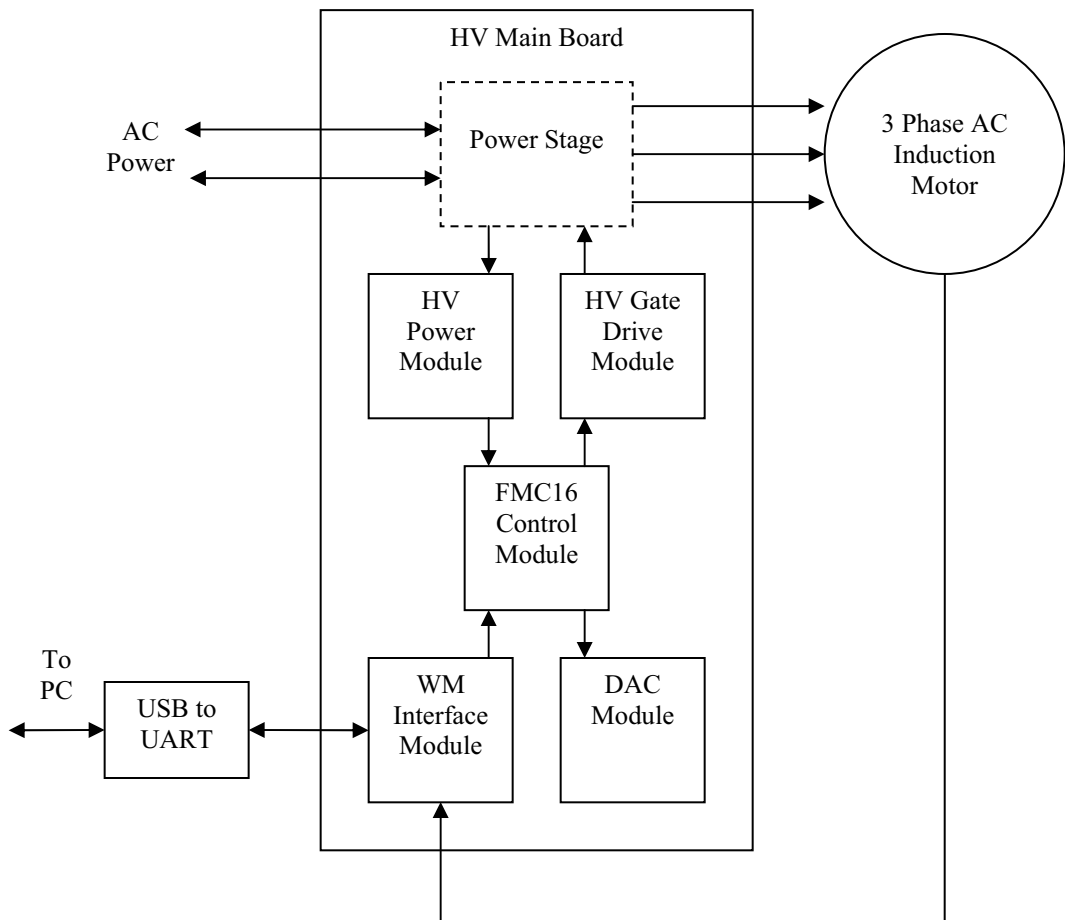A block diagram of the Vector Control Development Kit is shown in
Figure 9.

Figure 9. Vector Control Development Kit Hardware Block Diagram

Description of the Hardware

The hardware interface of the Vector Control Unit consists of the following:

- Insulated gate bipolar transistors (IGBTs)

  Six 6SGS5N60RUFD insulated-gate bipolar transistors are used under PWM control to generate the required 3-phase AC motor drive current from a high-voltage DC supply. Although these IGBTs are rated for momentary short-circuit operation, the Z8 Encore! MC™ PWM deadband feature is used to reduce leakage when the IGBTs are switched.

  Three IR21064S high- and low-side gate drivers are used to convert the Z8 Encore! MC™ microcontroller's CMOS PWM outputs into signals with the voltage needed to drive the IGBT gate inputs.

- High-voltage (HV) gate drive module

  This module contains the three IR21064S high- and low-side gate drivers that convert the Z8 Encore! MC™ microcontroller PWM outputs into the voltage needed to drive the IGBT gate inputs.

  The module uses 600-V level-shifted drivers for the three high-side IGBTs.

- UART interface module

  This module interfaces to the tachogenerator and optoisolated UART. The tachogenerator produces a single sine wave with voltage and frequency proportional to motor speed. The optoisolators are used for UART communication.

- FMC16100 control module

  This module contains the Z8 Encore! MC™ microcontroller, a 20-MHz ceramic resonator, the ZiLOG 6-pin DBG interface, and the off-chip components of the high-voltage current sense and overcurrent detection circuits.

- High-voltage power module

  This module uses an LNK304G IC to convert rectified AC from the power stage to generate the application's 120-mA, 12-V supply. This 12-V supply is then regulated by a UA78M33 IC to provide the 3.3V supply.

  The HV power module contains an unisolated switcher. A Buck converter takes the 240-VDC (rectified AC) bus and generates 15 V for the gate drivers. A 3.3-V regulator converts 15 V to 3.3. V for the MCU, DAC, and any auxiliary circuitry.

- Digital-to-analog converter (DAC) module

  The Z8 Encore! MC™ microcontroller's I^2C interface is used with a DAC5574 digital-to-analog-converter to generate up to four analog test outputs based on internal program values. This allows the internal values to be directly compared to the motor controller's output waveform on an oscilloscope.

  The I^2C data is sent from the FMC16100 control module. The outputs are 8-bit data scaled to the 3.3-V supply. The real-time data is updated every 250 μs on the A channel.

- Rectifier

  A full-bridge rectifier passes the DC to the bus.

- Relay

  The relay is a disconnect for the DC bus voltage.

- Bus capacitors

    The bus capacitors provide storage for the DC bus voltage.

Figure 10 shows the Vector Control Unit.
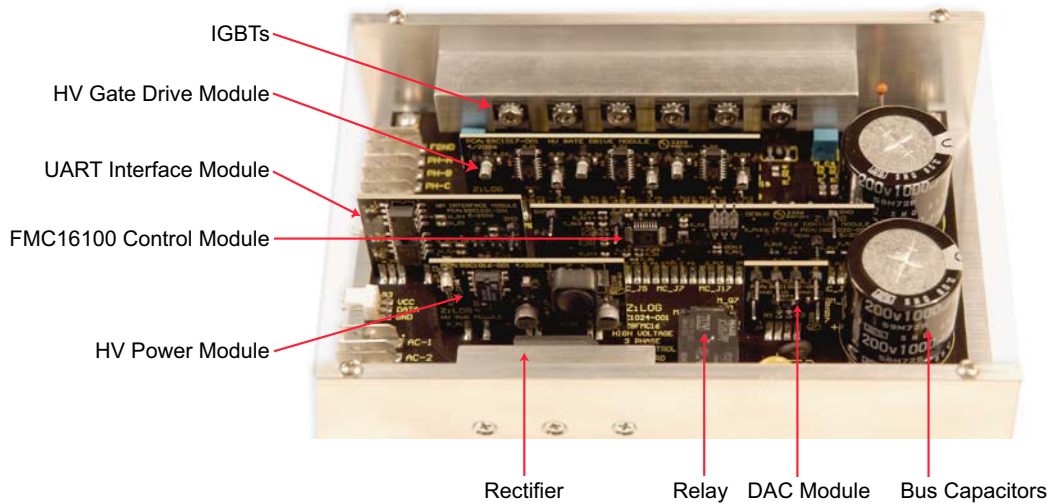
Figure 10. Vector Control Unit

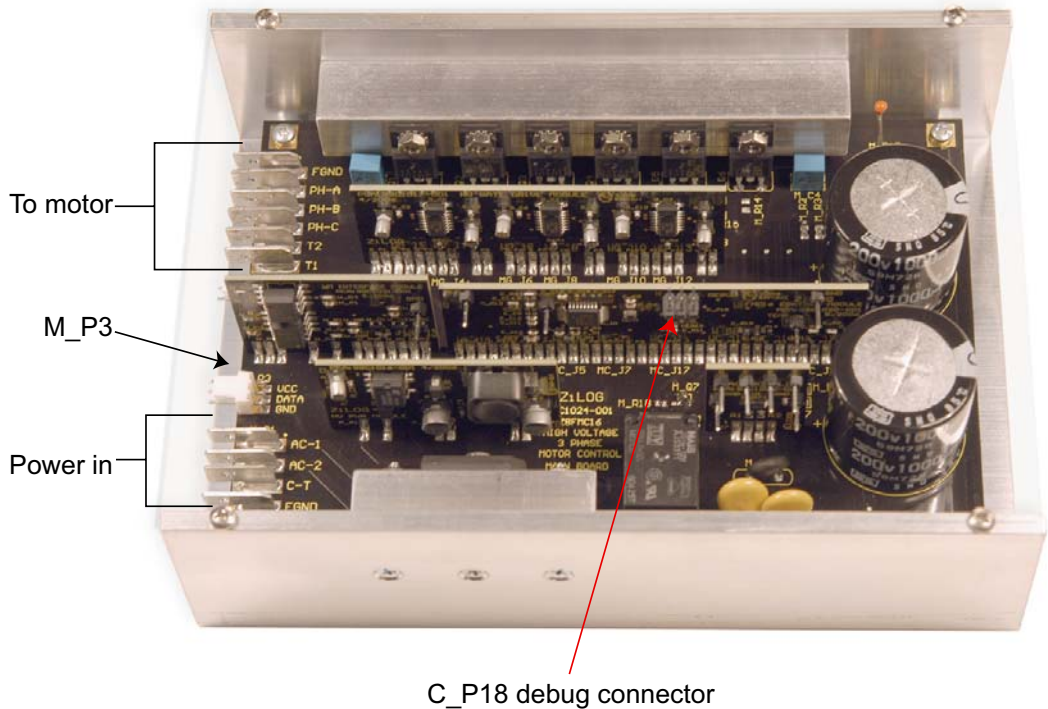Figure 11 shows the Vector Control Unit connection.

To motor

M_P3

Power in

C_P18 debug connector

Figure 11. Vector Control Unit Connection

Hardware Specifications and Power Requirements

Input

100–120 VAC at 60 Hz (voltage doubler connection), 200–240 VAC at 50/60 Hz, 50–350 VDC

United States

In the United States, use 110 VAC (voltage doubler). See Figure 12.

- AC-2 Line
- C-T Neutral
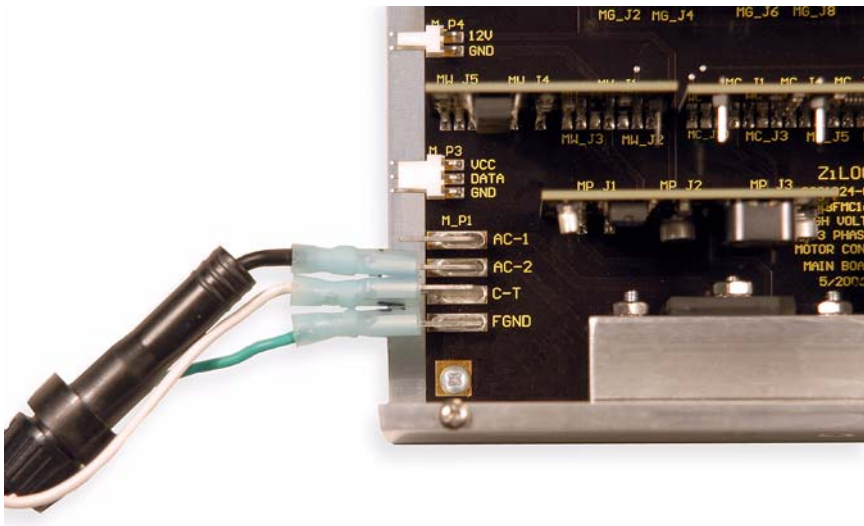
Figure 12. Power Connections (United States)

Outside of the United States

Outside of the United States, use 220-240 VAC. See Figure 13.

- AC-1 Line
- AC-2 Neutral
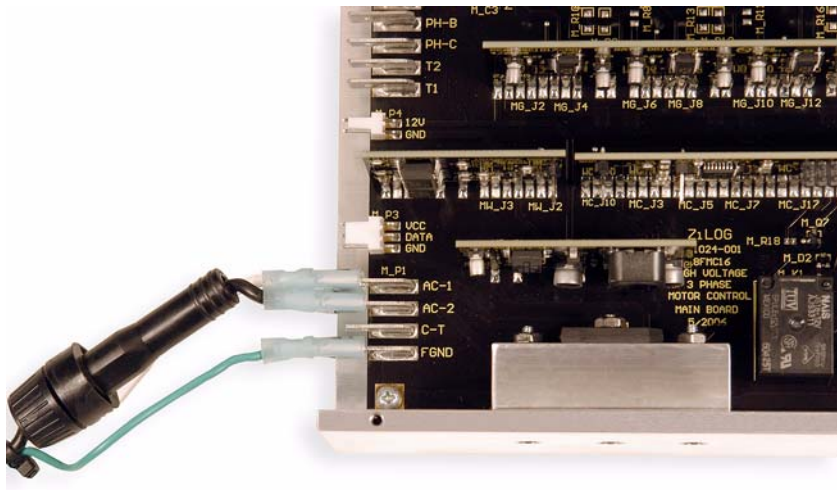
Figure 13. Power Connections (Outside of the United States)

Example of a Motor Control Routine

The overall program flow is illustrated in Figure 14 on page 28. After `main()` initializes the application, it drops into an infinite loop. Meanwhile, the PWM timer generates an event every 50 μs. The PWM ISR is timed to execute on every fifth PWM event, once every 250 μs. The ISR calls one of ten low-priority subfunctions on every loop cycle, so each subfunction is called once every 2.5 ms. Figure 15 on page 29 illustrates the PWM ISR main loop.
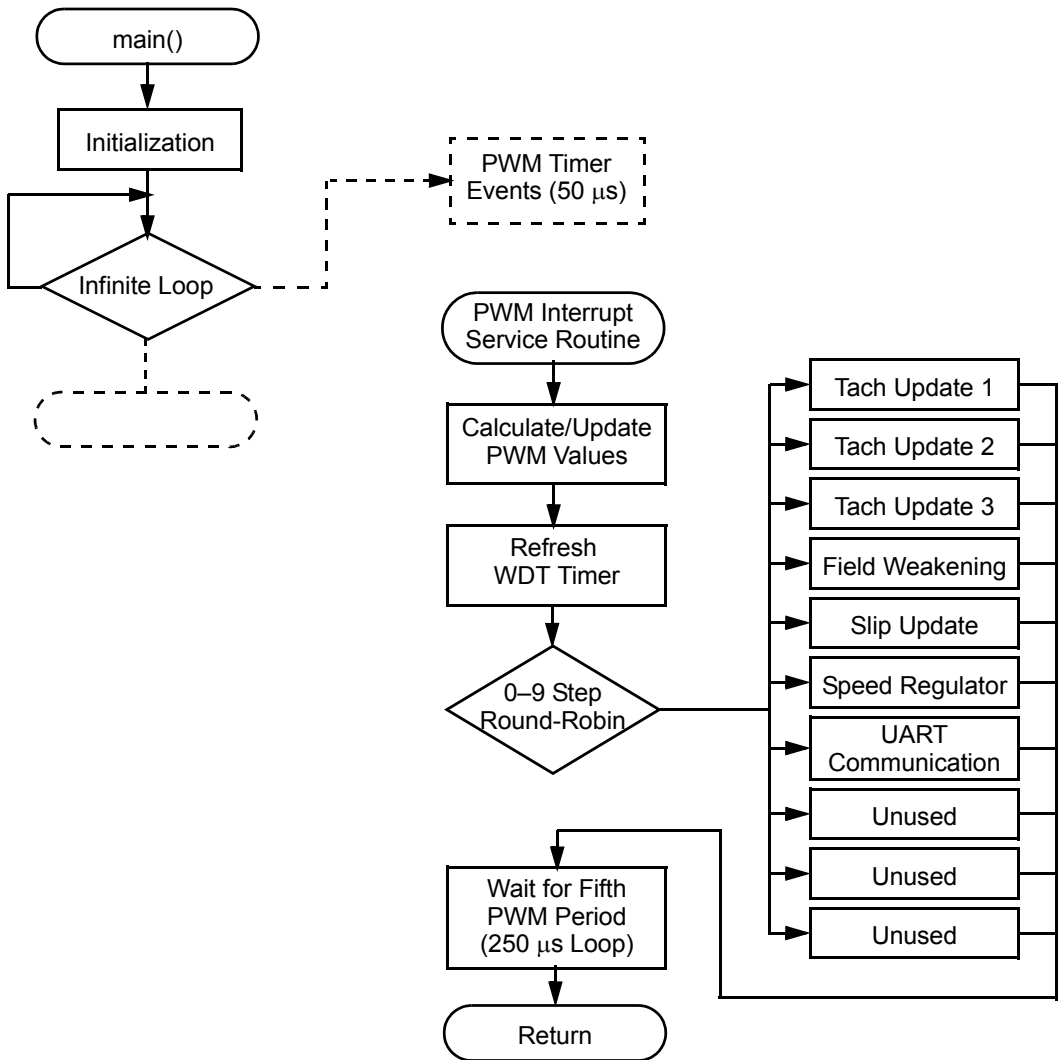
Figure 14. Flowchart for the Application
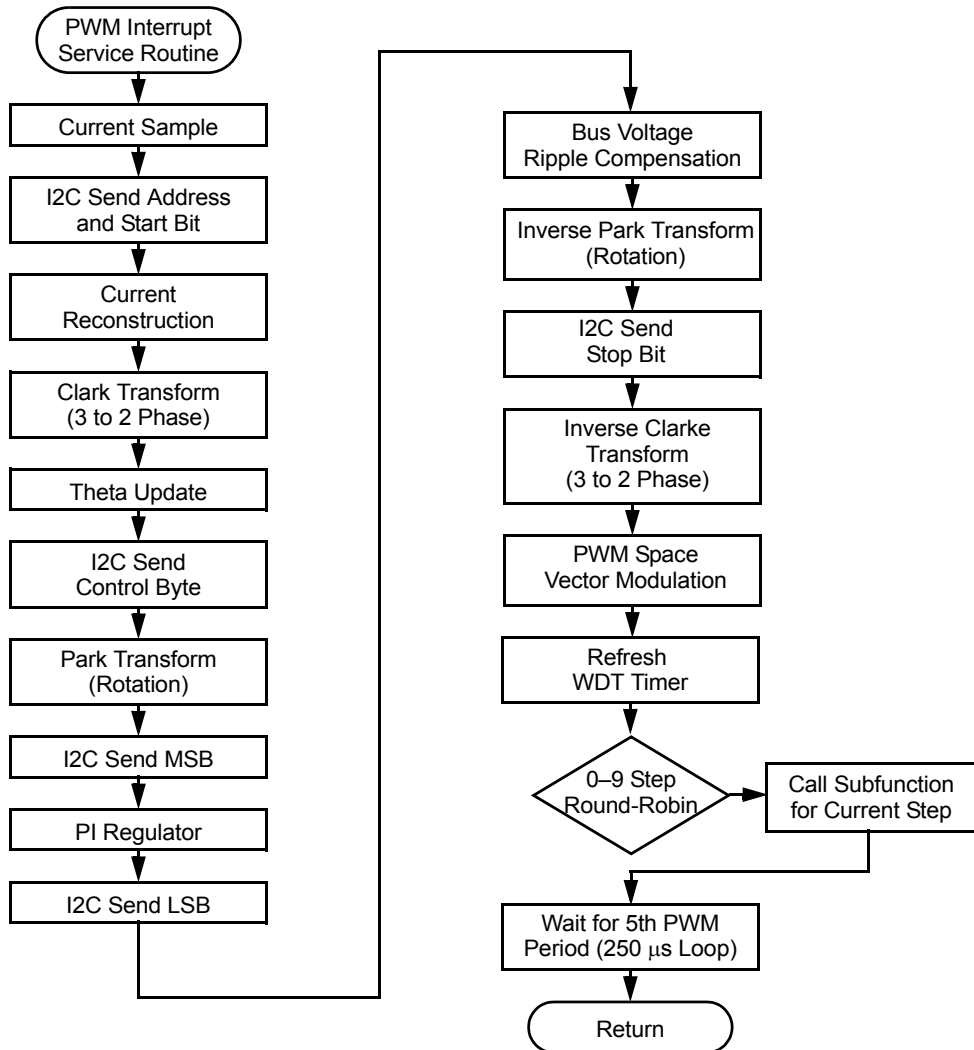
Figure 15. Flowchart for the PWM ISR

Example of a Motor Control Routine

Timing Descriptions

For details about timing, see the *Vector Control of a 3-Phase AC Induction Motor Using the FMC16100 MCU Application Note* (AN0247).

Appendix A—AC Power Cable Assembly

The power cable is not included in the kit and must be assembled by the user.

For the power cable, use a local power plug with in-line Fast Blow fuse of 10 AMP for 120 VAC or 5 AMP for 240 VAC. For the connection to the Control Unit, use insulated 0.25-inch female spade connectors. See Figure 16.

Figure 16. Power Cable

Appendix B—Control Panel
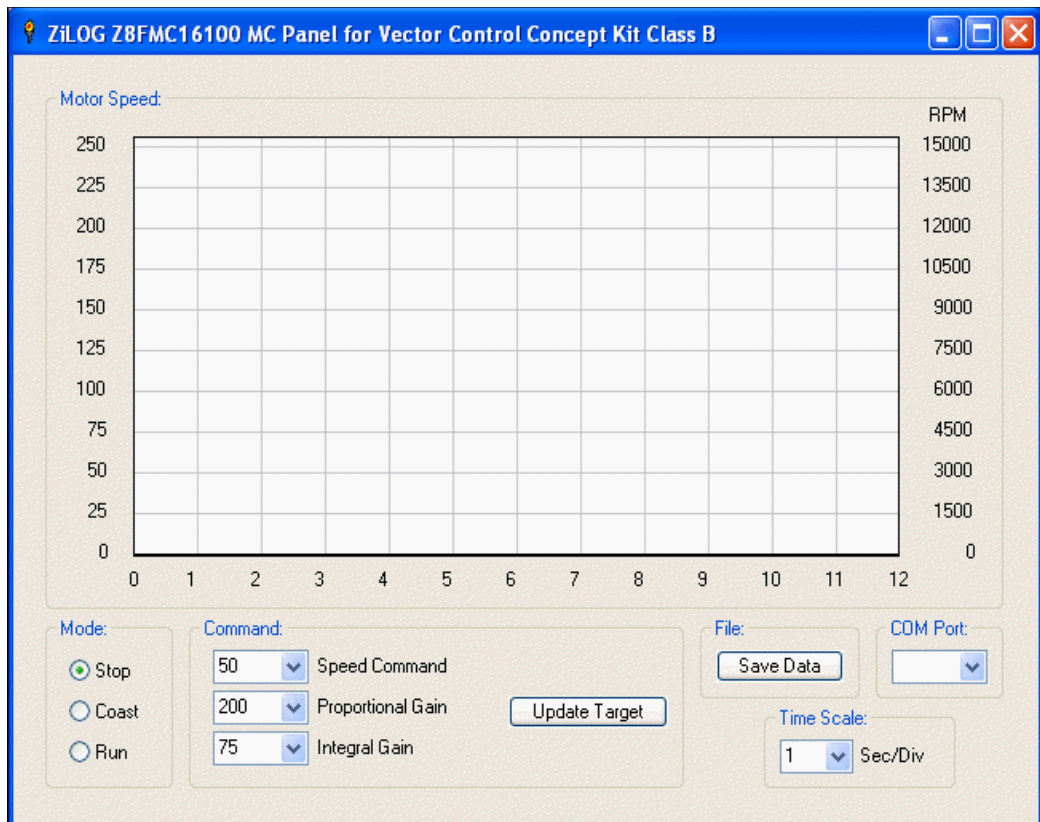
Figure 17. Control Panel

The following options are available in the Control Panel:

- Stop button

  The Stop button stops the motor.

- Coast button

  The Coast button allows the motor to continue running without additional power.

- Run button

  The Run button starts the motor.

- Speed Command drop-down list box

  The Speed Command drop-down list box allows you to set the speed of the motor. The default is 50.

- Proportional Gain drop-down list box

  The Proportional Gain drop-down list box allows you to set the proportional gain of the motor. The default is 200.

- Integral Gain drop-down list box

  The Integral Gain drop-down list box allows you to set the integral gain of the motor. The default is 75.

- Update Target button

  The Update Target button sends the instructions from the Control Panel to the motor.

- Save Data button

  The Save Data button saves the raw speed data that is displayed on the screen in the `data.csv` file located in the same directory as the Vector Control executable. The default location is

  ```
  C:\Program Files\ZiLOG\VectorControl_1.0\
  Control Panel
  ```

- COM Port drop-down list box

  The COM Port drop-down list box allows use to select the port that the USB-to-UART cable is mapped to in Windows.

- Time Scale drop-down list box

  The Time Scale drop-down list box changes the number of seconds per division of the motor speed graph. The default is 0.1 seconds per division.

Appendix C—Schematics

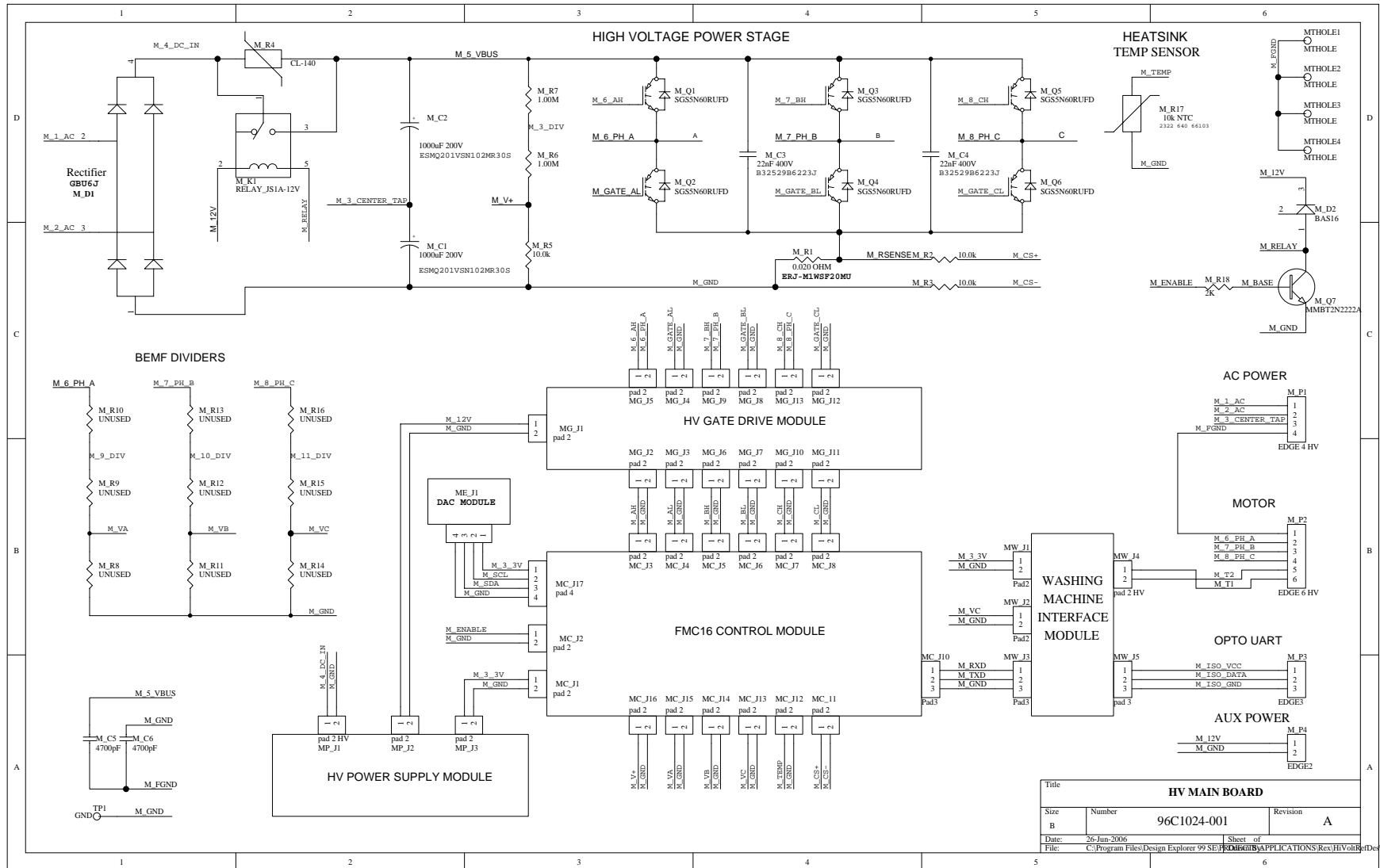Figure 18 through Figure 23 are the schematic diagrams for the Vector Control application modules.
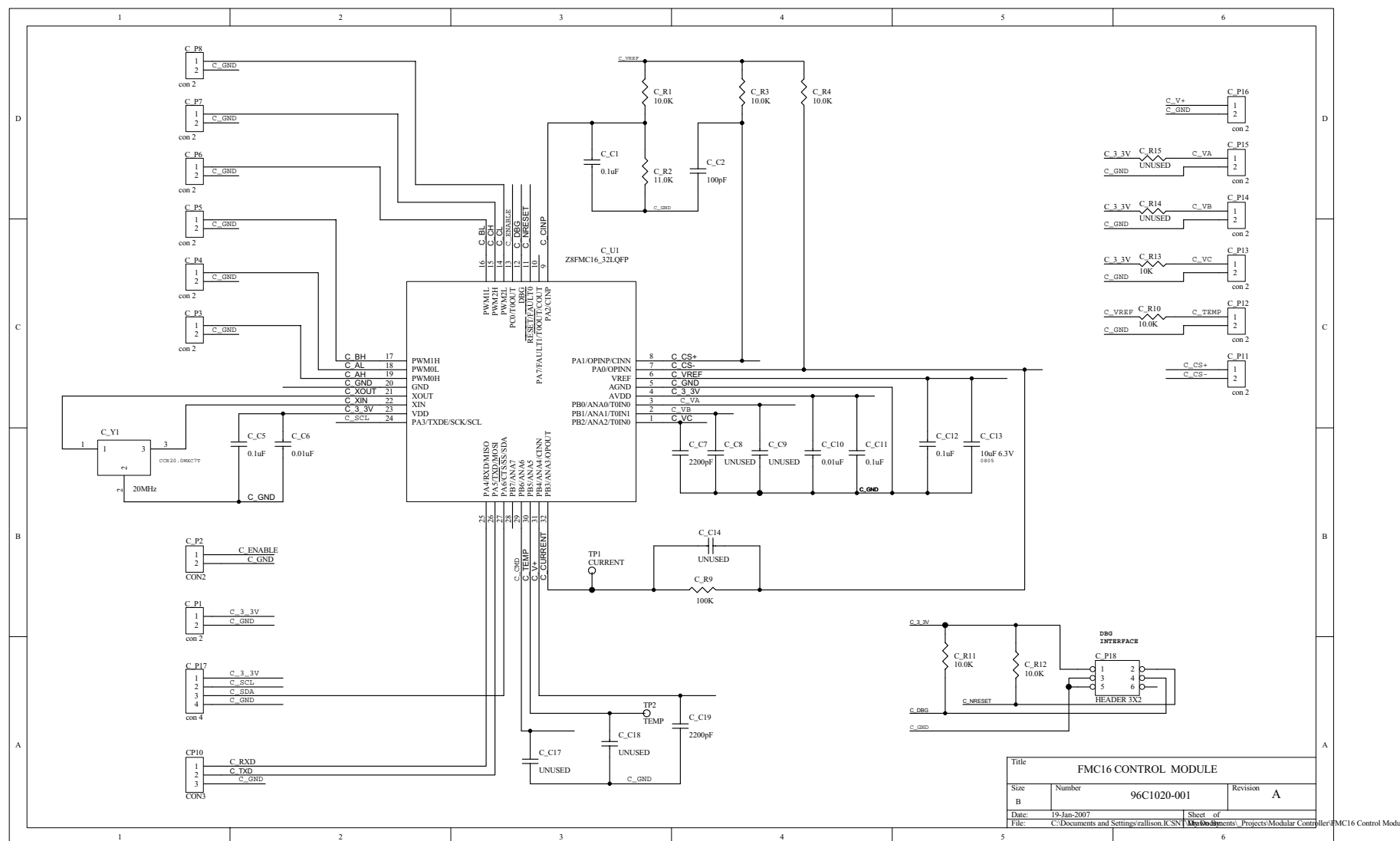

Figure 18. High-Voltage Main Board Schematic

Figure 19. FMC16 Control Module Schematic
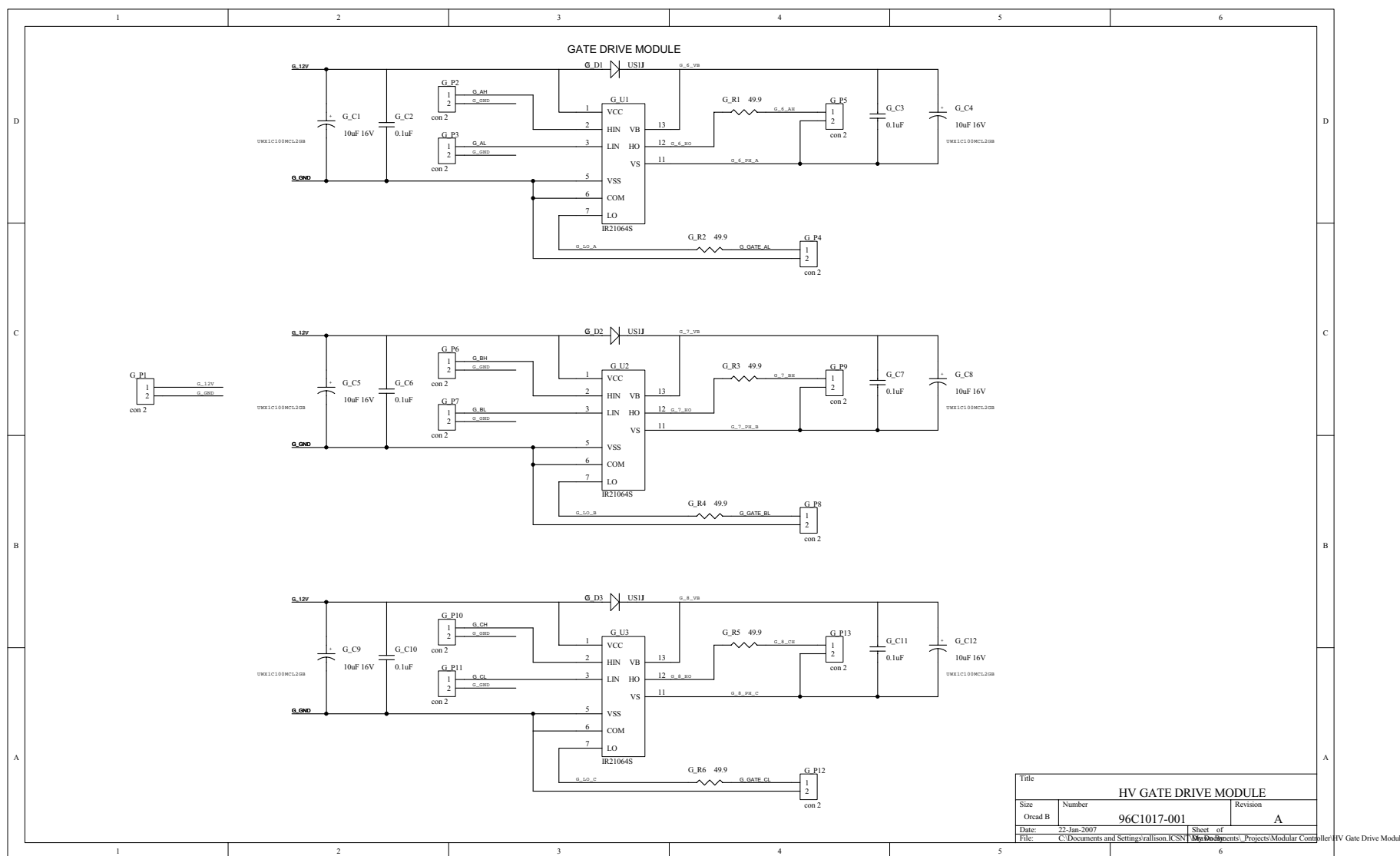
Figure 20. HV Gate Drive Module Schematic
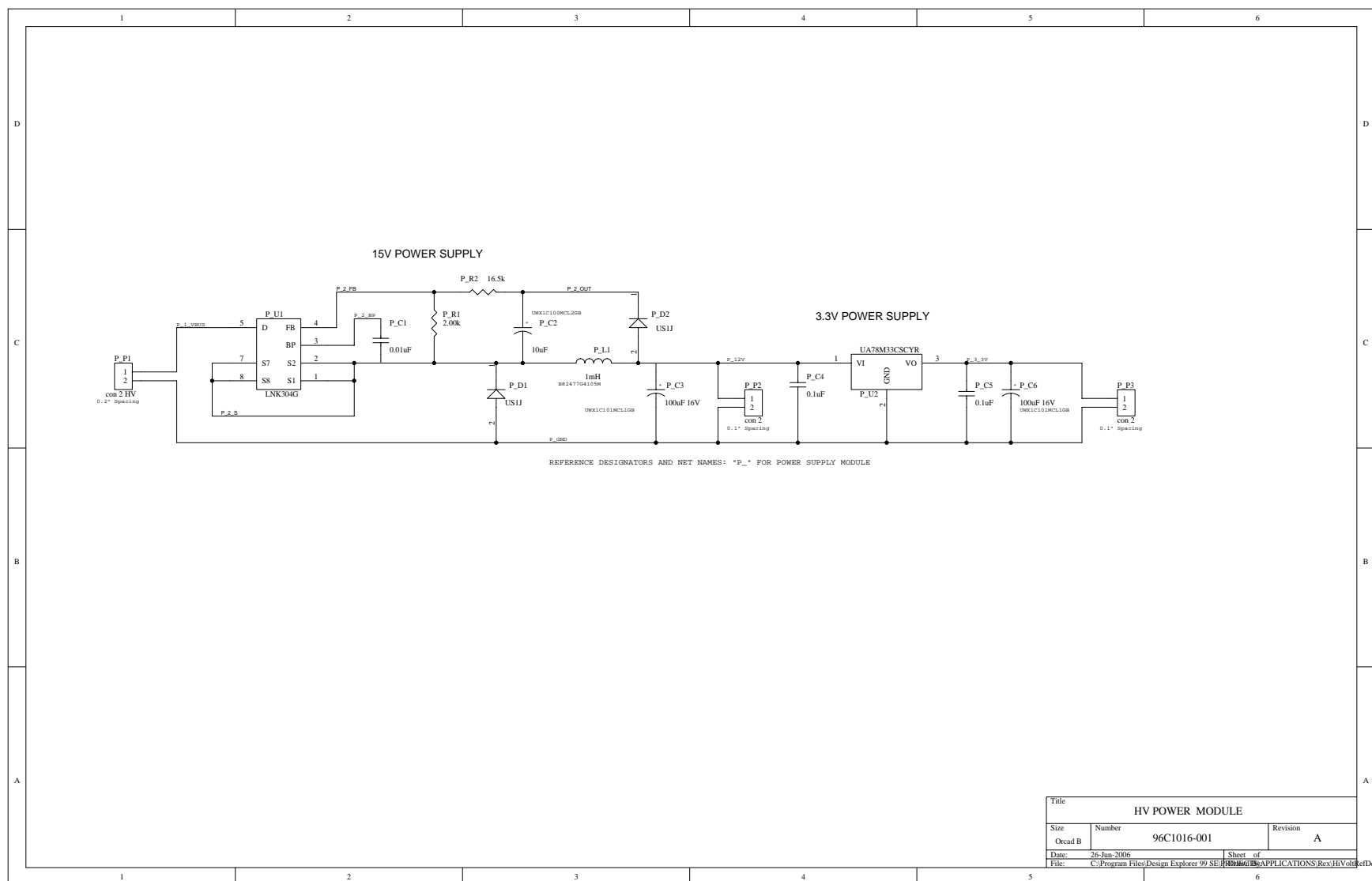
Figure 21. HV Power Module Schematic
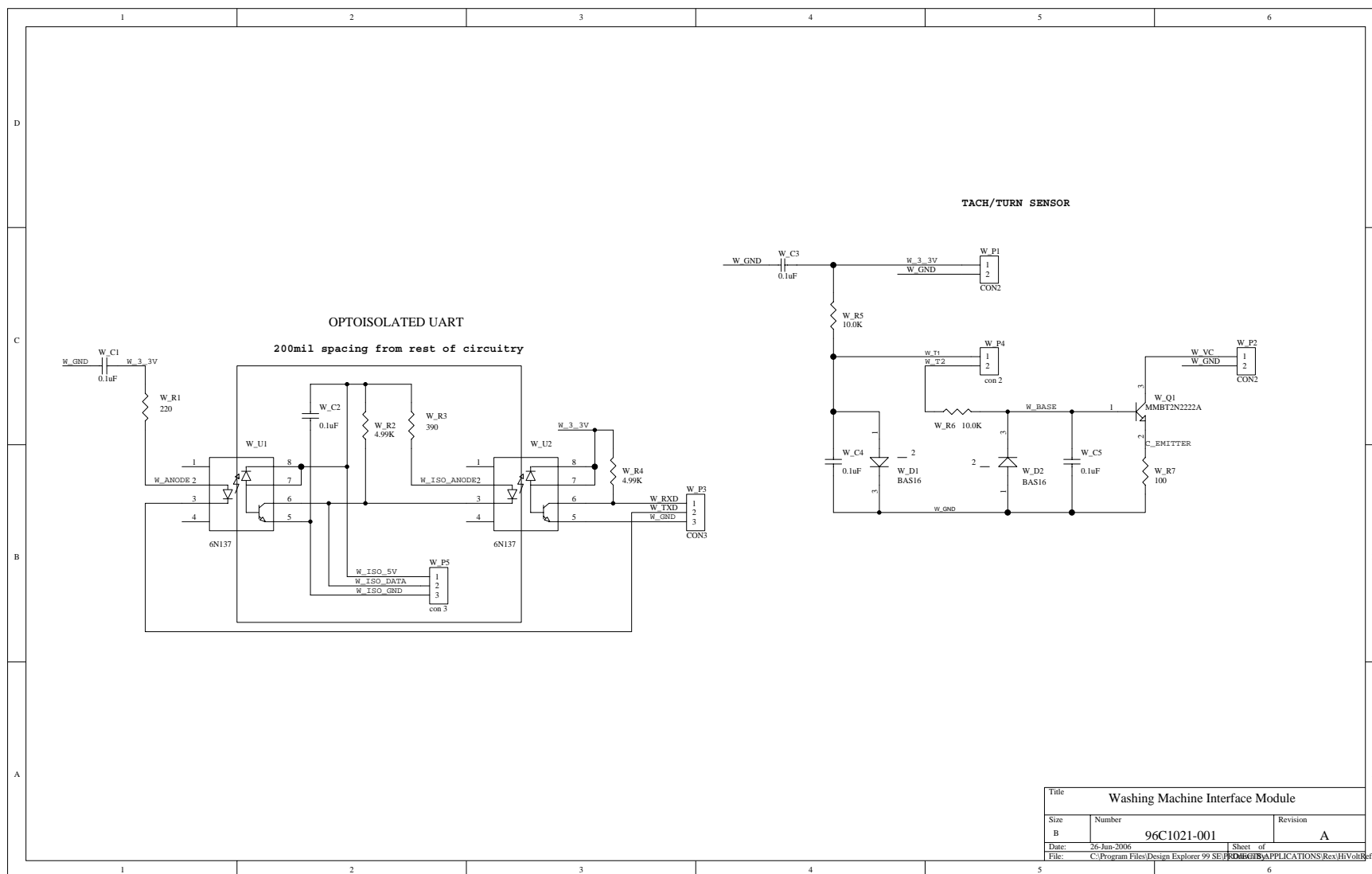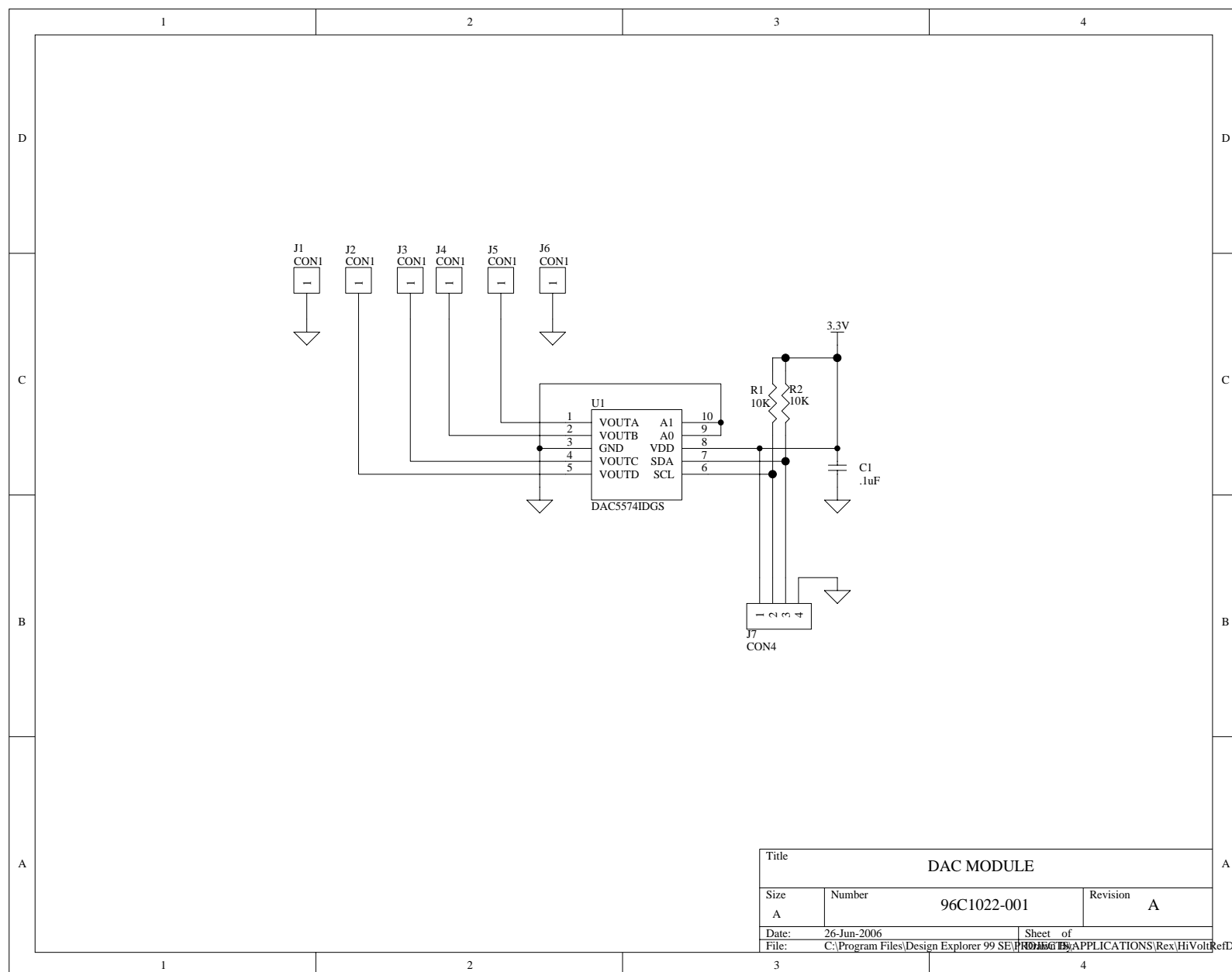
Figure 22. Washing Machine Interface Module Schematic

Figure 23. DAC Module Schematic

Customer Support

For answers to technical questions about the product, documentation, or any other issues with ZiLOG's offerings, please visit ZiLOG's Knowledge Base at http://www.zilog.com/kb.

For any comments, detail technical questions, or reporting problems, please visit ZiLOG's Technical Support at http://support.zilog.com.

⚠️ **Warning:** DO NOT USE IN LIFE SUPPORT

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As used herein

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