56F8300 3-Phase AC Induction Motor

Vector Control using Processor Expert

Targeting Document

MC56F8300
16-bit Digital Signal Controllers

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Document Revision History

Version History	Description of Change
Rev 0	Initial public release

3-Phase AC Induction Motor Vector Control on Processor Expert

This application exercises vector control of the 3-phase AC Induction Motor (ACIM) using Processor Expert (PE), a 56F8346, 56F8357, or 56F8367 EVM board, and 3-phase AC / BLDC High-Voltage (HV) power stage.

Applications developed for this demonstration board were not designed for the 56F8100 devices. The 56F8300 demonstration board does, however, fully support 56F8100 software development.

Note: The PC master software referenced in this document is also known as Free Master software.

1. Specifications

This application performs principal vector control of the 3-phase AC induction motor using a 56F8300 processor. The concept of the application is a speed closed-loop AC drive using a vector control technique. The control technique obtains d and q current components and rotor flux vector from regularly sampled 3-phase stator currents. The d and q current components and rotor flux are controlled separately. The q component corresponds to torque and the d component corresponds to flux. An incremental encoder is used to derive the actual rotor speed.

The Actual Speed, derived from a quadrature decoder, monitors the actual behavior of the system, and is compared with the reference signal (Required Speed).

Protection is provided against overcurrent, overvoltage, undervoltage, and overheating drive faults.

System Outline

The system is designed to drive a 3-phase ACIM. The application has the following specifications:

- Vector control technique used for AC induction motor control
- Speed control loop
- Targeted for a 56F8346, 56F8357, or 56F8367 EVM
- Runs on a 3-phase ACIM control development platform at variable line voltage 115V AC and 230V AC (range -15% to +10%)
- Motor mode
- Generator mode
- DCBus brake
- Minimum speed 50rpm
- Maximum speed 2500rpm at input power line 230V AC
- Maximum speed 1100rpm at input power line 115V AC
- Fault protection

- Interfaces:
  - Manual interface
    - RUN / STOP switch
    - UP / DOWN push buttons control
    - LED indication
  - PC master software remote control interface
    - START MOTOR / STOP MOTOR push buttons
    - Speed set-up
- PC master software remote monitor
  - Software monitor interface
    - Required speed
    - Actual motor speed
    - PC master software mode
    - START MOTOR / STOP MOTOR controls
    - Drive fault status
    - DCBus voltage level
    - Drive status
    - Mains detection
  - Software speed scope
    - Observes actual and desired speed
  - Software recorder for:
    - Phase currents
    - D, q currents

Application Description

The vector control algorithm is calculated on Freescale's 56F8346EVM, 56F8357EVM, or 56F8367EVM. The algorithm generates 3-phase PWM signals for the ACIM inverter according to the user-required inputs, measured and calculated signals.

The concept of the ACIM drive incorporates the following hardware components:

- ACIM motor-brake set
- 3-phase AC / BLDC high-voltage power stage
- 56F8346EVM, 56F8357EVM, or 56F8367EVM
- Legacy Motor Daughter Card (LMDC)
- In-line optoisolation box, ECOPTINL, which is connected between the host computer and the 56F83xxEVM

Note: The AC induction motor-brake set incorporates a 3-phase AC induction motor and attached BLDC motor brake. The AC induction motor has four poles. The incremental position sensor (encoder) is coupled on the motor shaft. See **Table 1-1** for detailed motor-brake specifications.

Table 1-1 Motor Brake Specifications

Set Manufactured	EM Brno, Czech Republic	
Motor	Motor Type	AM40V 3-Phase AC Induction Motor
	Pole Number	4
	Nominal Speed	1300rpm
	Nominal Voltage	3 x 200V
	Nominal Current	0.88A
Brake	Brake Type	SG40N 3-Phase BLDC Motor
	Pole Number	6
	Nominal Speed	1500rpm
	Nominal Voltage	3 x 27V
	Nominal Current	2.6A
Position Sensor (Encoder)	Type	Baumer Electric BHK 16.05A 1024-12.5
	Pulses per revolution	1024

The drive can be controlled in two operating modes:

- In the **Manual operating mode**, the required speed is set by UP / DOWN push buttons and the drive is started and stopped by the RUN / STOP switch on the EVM board
- In the **PC master software operating mode**, the Required Speed is set by the PC master software active bar graph and the drive is started and stopped by the START MOTOR and STOP MOTOR controls

Measured quantities:

- DCBus voltage
- Phase currents (Phase A, Phase B, Phase C)
- Power module temperature
- Rotor speed

The faults used for drive protection:

- Overvoltage (PC master software error message = *Overvoltage fault*)
- Undervoltage (PC master software error message = *Undervoltage fault*)
- Overcurrent (PC master software error message = *Overcurrent fault*)
- Overheating (PC master software error message = *Overheating fault*)

The following software tools are needed for to compile, debug, and load to the EVM, and to use remote control and monitoring, and the RUN / STOP Switch and UP / DOWN Buttons:

- Metrowerks CodeWarrior v. 6.1.2
- PC master software
- Processor Expert v. 2.94

Control Process

After reset, the drive enters the INIT state in manual operation mode.When the RUN / STOP switch is detected in the STOP position and there are no faults pending, the STOP application state is entered. Otherwise, the drive waits in the INIT state, or if faults are detected, the drive goes to the FAULT state. In the INIT and STOP states, the operation mode can be changed from PC master software. In the manual operational mode, the application is operated by the RUN / STOP switch and UP / DOWN buttons; in the PC master remote mode, the application is operated remotely by PC master software.

When the Start command is accepted (using the RUN / STOP Switch or PC master software command), the rotor position is aligned to a predefined position to obtain a known rotor position. The rotor alignment is done at the first start command only. Required speed is then calculated according to UP / DOWN push buttons or PC master software commands (if in PC master software remote mode). The required speed goes through an acceleration/deceleration ramp. The comparison between the actual speed command and the measured speed generates a speed error. Based on the error, the speed controller generates a stator current, *Is_qReq*, which corresponds to torque. A second part of the stator current, *Is_dReq*, which corresponds to flux, is given by the Field Weakening Controller. Simultaneously, the stator currents *Is_a*, *Is_b* and *Is_c* are measured and transformed from instantaneous values to the stationary reference frame α, β, and consecutively to the rotary reference frame d, q (Clarke-Park transformation). Based on the errors between required and actual currents in the rotary reference frame, the current controllers generate output voltages *Us_q* and *Us_d* (in the rotary reference frame d, q). The voltages *Us_q* and *Us_d* are transformed back to the stationary reference frame α, β and, after DCBus ripple elimination, are recalculated to the 3-phase voltage system, which is applied on the motor.

Drive Protection

The DCBus voltage, DCBus current and power stage temperature are measured during the control process. They protect the drive from overvoltage, undervoltage, overcurrent and overheating. Undervoltage and overheating protection is performed by software, while the overcurrent and over voltage fault signal utilizes a fault input of the hybrid controller. Line voltage is measured during application initialization and the application automatically adjusts itself to run at either 115V AC or 230V AC, depending on the measured value.

If any of the previously mentioned faults occur, the motor control PWM outputs are disabled to protect the drive, and the application enters the FAULT state. The FAULT state can be left only when the fault conditions disappear and the RUN / STOP switch is moved to the STOP position manual mode or by the PC master software in the PC master software remote mode.

The application can run on:

- External RAM or Flash
- 3-Phase AC / BLDC High-Voltage Power Stage powered by 115V AC or 230V AC
- Manual or PC master software operating mode

The voltage level is identified automatically and the appropriate constants are set.

The 3-phase AC Induction Motor Control Application can operate in two modes:

1. **Manual Operating Mode**
   The drive is controlled by the RUN / STOP switch (S3) on the Legacy Motor Daughter Card (LMDC). The motor speed is set by the UP (S1) and DOWN (S2) push buttons on the LMDC; see **Figure 1-1**. In this application, the PWMA module output LEDs are used as USER LEDS. If the application runs and motor spinning is disabled (i.e., the system is ready), the GREEN USER LED (LED2, shown in **Figure 1-2**) will blink. When motor spinning is enabled, the USER LED is *On*. Refer to **Table 1-2** for application states; the actual state of the PWM outputs are indicated by PWMB output LEDs. If overcurrent, overvoltage or overheating occur, the GREEN USER LED (LED2) starts to flash quickly and the PC master software signals the type of fault identified. This state can be exited only by an application reset. It is strongly recommended that you inspect the entire application to locate the source of the fault before starting it again. Refer to for application states.

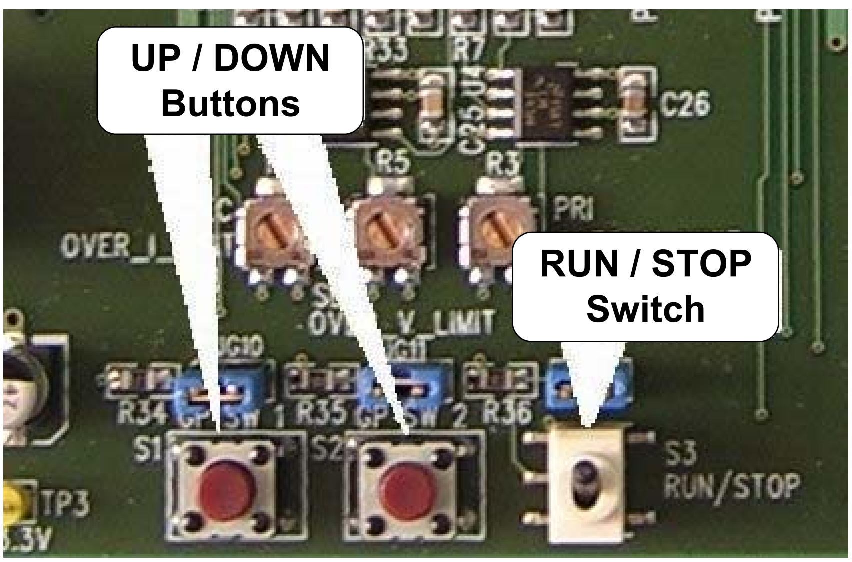

Figure 1-1 RUN / STOP Switch and UP / DOWN Buttons on the Legacy Motor Daughter Card (LMDC)

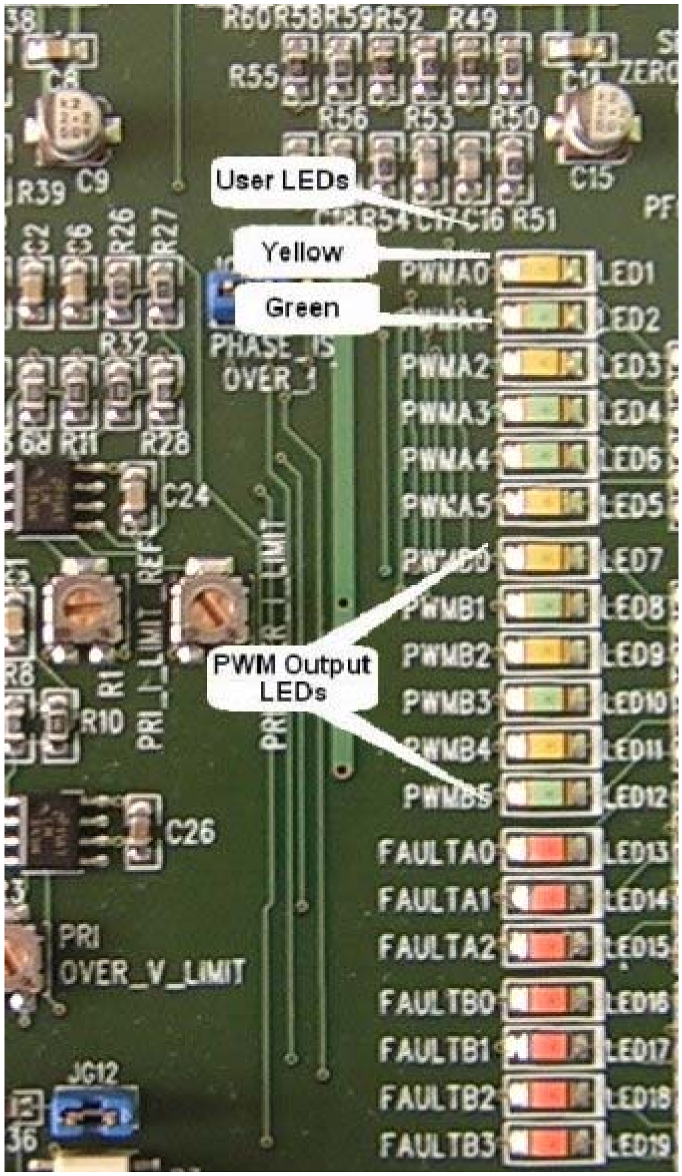

Figure 1-2 USER and PWM LEDS on the Legacy Motor Daughter Card (LMDC)

Table 1-2 Motor Application States

Application State	Motor State	Green LED State
Stopped	Stopped	Blinking at a frequency of 2Hz
Running	Spinning	On
Fault	Stopped	Blinking at a frequency of 8Hz

2. **PC Master Software (Remote) Operating Mode**
   The drive is controlled remotely from a PC through the SCI communication channel of the hybrid controller via an RS-232 physical interface. The drive is enabled by the RUN / STOP switch, which can be used to safely stop the application at any time. PC master software enables the user to set the motor's Required Speed.

The following PC master software control actions are supported:

- Set the motor control system's PC master software mode
- Set the motor control system's manual mode
- Start the motor
- Stop the motor
- Set the motor's Required Speed

PC master software displays the following information:

- The motor's Required Speed
- The motor's Actual Speed
- Application status:
  - Init
  - Stop
  - Run
  - Fault
- DCBus voltage level
- Identified line voltage
- Fault Status:
  - No_Fault
  - Overvoltage
  - Overcurrent
  - Undervoltage
  - Overheatin

Start the PC master softwre window's application, *3ph_acim_vector_control.pmp*. **Figure 1-3** illustrates the PC master software control window after this project has been launched.

Note: If the PC master software project (*.pmp* file) is unable to control the application, it is possible that the wrong load map (*.elf* file) has been selected. PC master software uses the load map to determine addresses for global variables being monitored. Once the PC master software project has been launched, this option may be selected in the PC master software window under *Project / Select Other Map File Reload*.

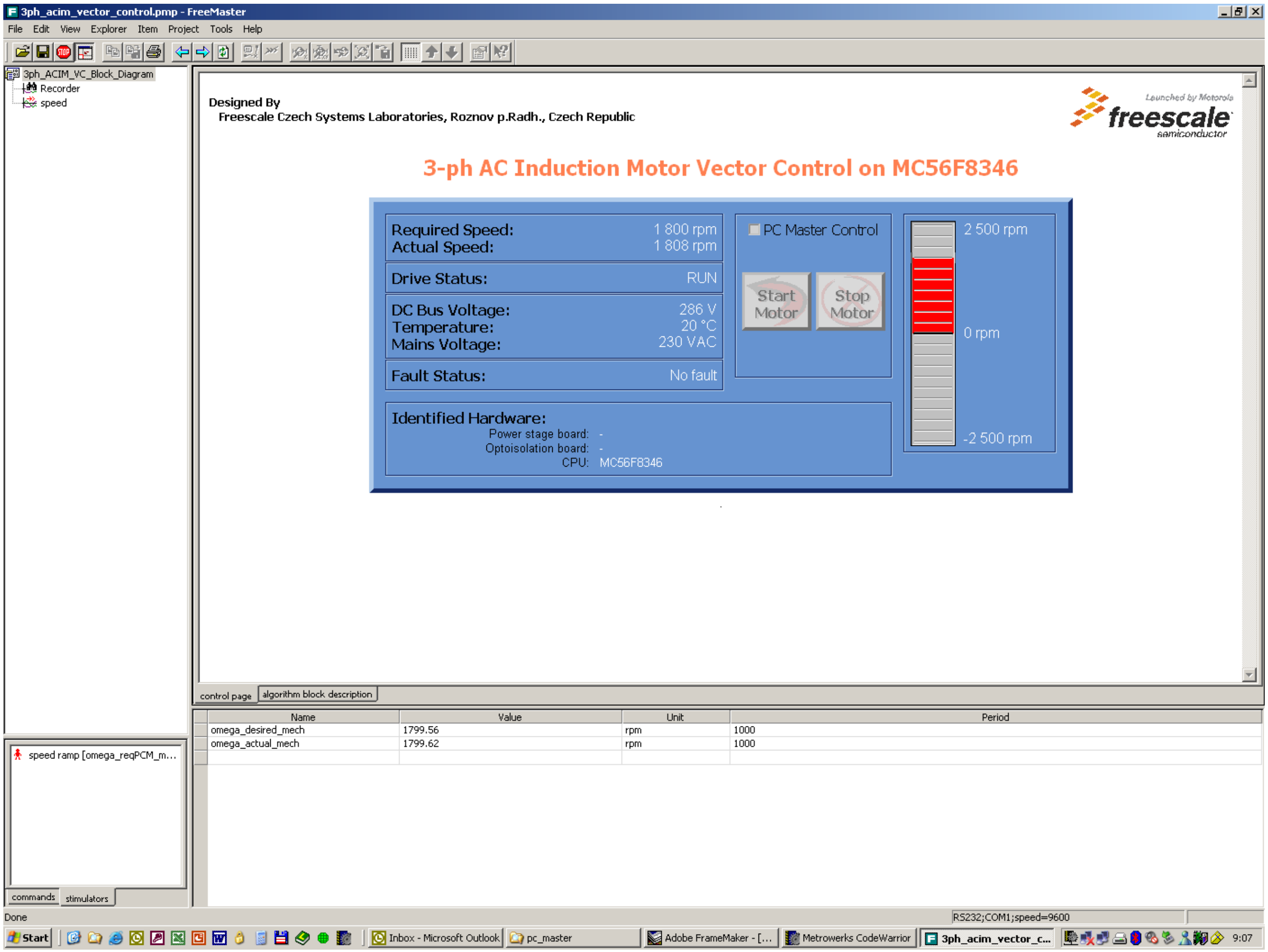

Figure 1-3 PC Master Software Control Window

2. Hardware Set-Up

Figure 2-1 illustrates the hardware set-up for the 3-phase AC Induction Motor Vector Control Application.

WARNING:

Danger, high voltage—risk of electric shock!

The application's PCB modules and serial interface (connector, cable) are not electrically isolated from the mains voltage—they are live.

Use the In-line Optoisolation Box (ECOPTINL) between the PC and 56F83xxEVM as protection from dangerous voltage on the PC-user side, and to prevent damage to the PC and other hardware.

Do not touch any part of the EVM or the serial cable between the EVM and the In-line Optoisolation Box unless you are using an insulation transformer. The application is designed to be fully controllable only from PC master software.

To avoid inadvertently touching live parts, use plastic covers.

In the rest of this application, the description supposes use of the insulation transformer.

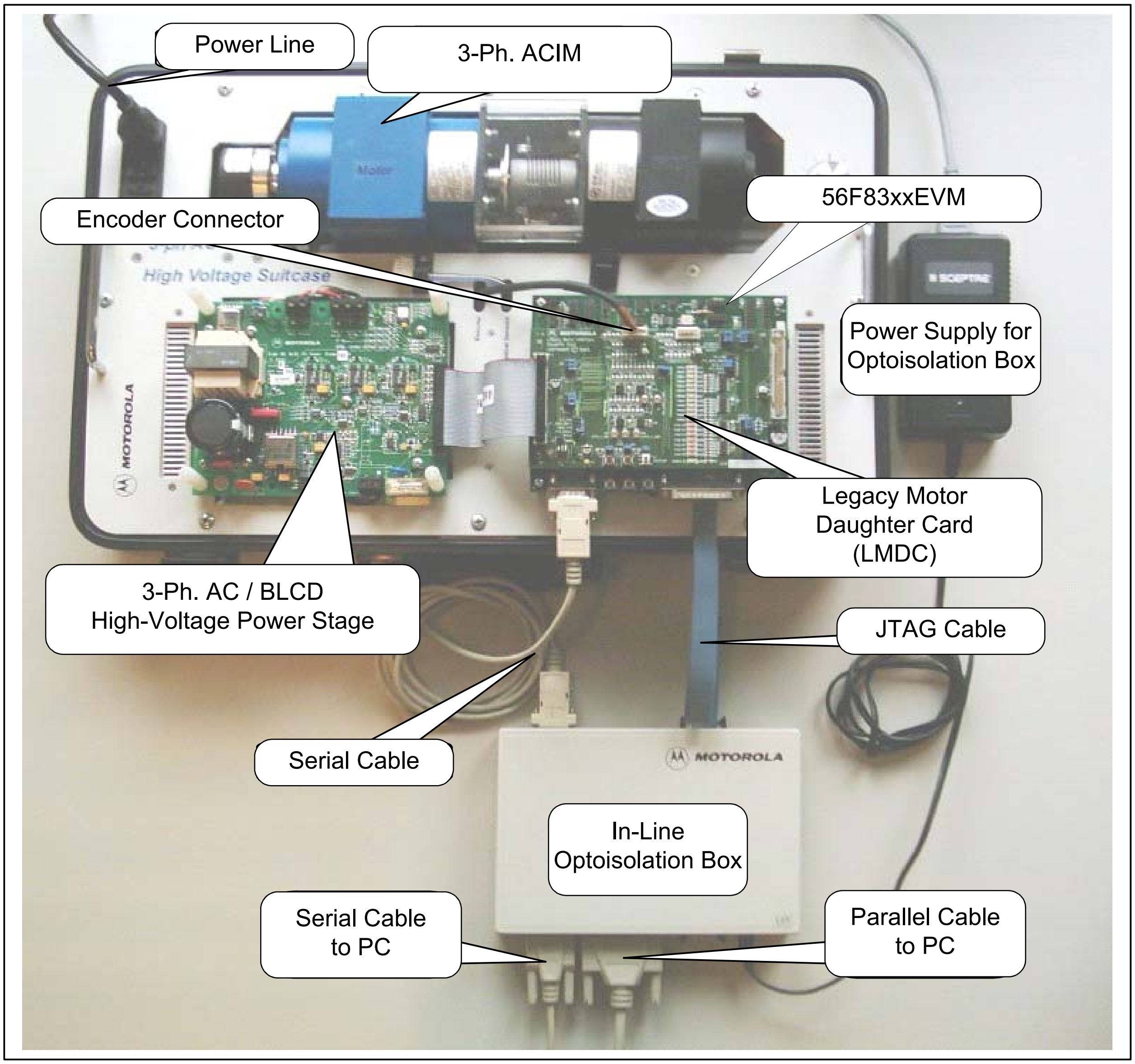

Figure 2-1 Application Set-Up

The correct order of phases for the AC induction motor shown in **Figure 2-1** is:

- Phase A = red wire
- Phase B = white wire
- Phase C = black wire

When facing a motor shaft, the phase order is: Phase A, Phase B, Phase C; the motor shaft should rotate clockwise (i.e., positive direction, positive speed).

For detailed information, see the appropriate **56F83xx Evaluation Module Hardware User Manual** for the device being implemented. The serial cable is needed only for the PC master software debugging tool.

2.1 Jumper Settings

2.1.1 EVM Jumper Settings

For jumper settings, see the **56F8346 Evaluation Module Hardware User's Manual, 56F8357 Evaluation Module Hardware User's Manual** or **56F8367 Evaluation Module Hardware User's Manual**.

Note: When running the EVM target system in a stand-alone mode from Flash, in the **56F8346EVM**, the **JG9** jumper must be set in the 1-2 configuration to disable the command converter parallel port interface. In the **56F8357EVM** or the **56F8367EVM**, the **JG3** jumper must be set in the 1-2 configuration to disable the command converter parallel port interface.

For a detailed description for jumper settings, see the appropriate **56F83xx Evaluation Module Hardware User's Manual** for the device being implemented.

2.1.2 Legacy Motor Daughter Card (LMDC) Jumper Settings

To execute the 3-Phase AC Induction Motor Vector Control Application, the 56F8300 Legacy Motor Daughter Card (LMDC) requires the strap settings shown in **Figure 2-2** and **Table 2-1**.

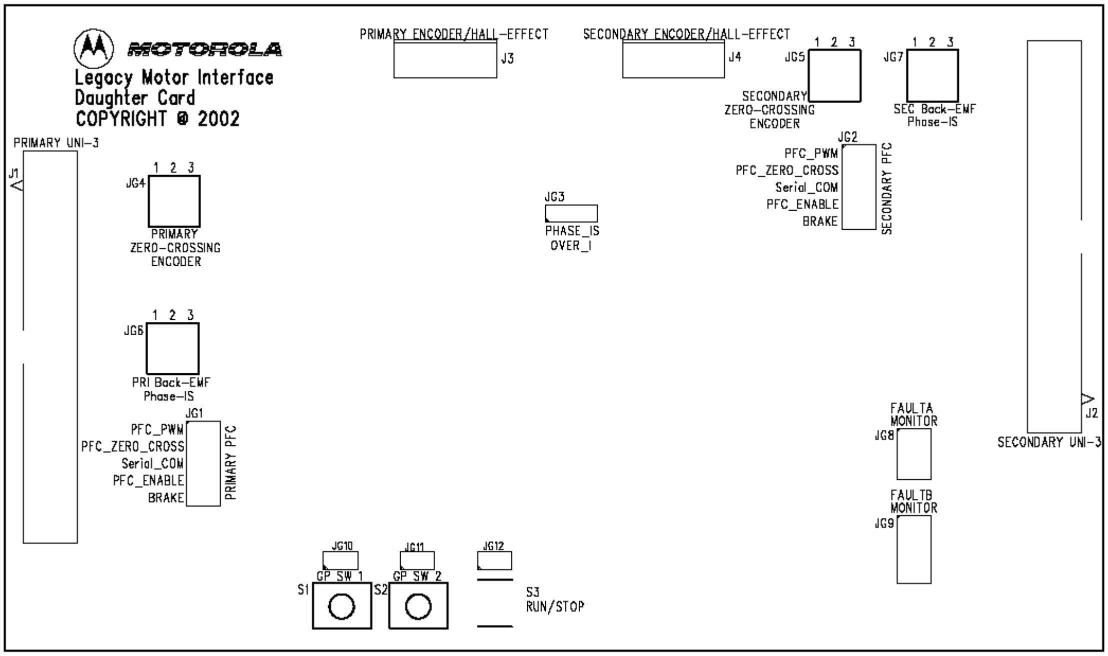

Figure 2-2 56F8300EVM Legacy Motor Daughter Card (LMDC) Jumper Reference

Table 2-1 56F8300EVM Legacy Motor Daughter Card (LMDC) Jumper Settings

Jumper Group	Comment	Connections
JG1	Primary PFC	1-2 & 3-4 & 5-6 & 7-8 & 9-10
JG2	Secondary PFC	NC
JG3	Phase_IS / Over_I	2-3
JG4	Primary Zero-Crossing / Encoder	2-3 & 5-6 & 8-9
JG5	Secondary Zero-Crossing / Encoder	2-3 & 5-6 & 8-9
JG6	Primary Back-EMF / Phase-IS	1-2 & 4-5 & 7-8
JG7	Secondary Back-EMF / Phase-IS	1-2 & 4-5 & 7-8
JG8	Fault A Monitor	1-2 & 3-4 & 5-6
JG9	Fault B Monitor	1-2 & 3-4 & 5-6
JG10	Switch 1 (Up)	1-2
JG11	Switch 2 (Down)	1-2
JG12	Switch 3 (Run / Stop)	1-2

3. Build

To build this application, open the *3ph_acim_vc_56F83xx_onPE.mcp* project file and execute the *Make* command, as shown in **Figure 3-1**. This will build and link the 3-phase AC Induction Motor Vector Control Application and all needed Metrowerks and Processor Expert libraries.

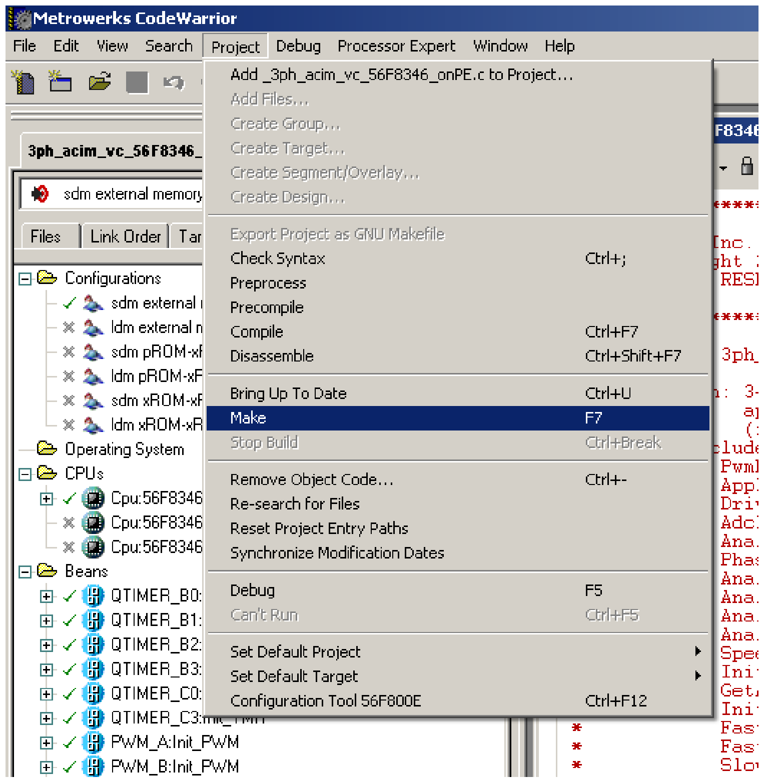

Figure 3-1 Execute *Make* Command

4. Execute

To execute the 3-Phase AC Induction Motor Vector Control Application, select *Project / Debug* in the CodeWarrior IDE, followed by the *Run* command.

If the *Flash* target is selected, CodeWarrior will automatically program the internal Flash of the hybrid controller with the executable generated during *Build*. If the *External RAM* target is selected, the executable will be loaded to off-chip RAM.

To execute the 3-phase AC Induction Motor Vector Control Application's internal Flash version, choose the *Program / Debug* command in the CodeWarrior IDE and when loading is finished, in the **56F8346EVM**, set jumper **JG9** to disable the JTAG port and **JG3** to enable boot from internal Flash, then push the RESET button. In the **56F8357EVM** or the **56F8367EVM**, set jumper **JG3** to disable the JTAG port and **JG4** to enable boot from internal Flash, then push the RESET button.

For more help with these commands, refer to the CodeWarrior tutorial documentation in the following file, located in the CodeWarrior installation directory:

<...>\CodeWarrior Manuals \ PDF \ Targeting_56800E.pdf

For jumper settings, see the appropriate **56F83xx Evaluation Module Hardware User's Manual** for the device being implemented.

Once the application is running, move the RUN / STOP switch to the RUN position and set the required speed with the UP / DOWN push buttons. Pressing the UP / DOWN buttons should incrementally increase the motor speed until it reaches maximum speed. If successful, the 3-phase AC induction motor will be spinning.

Note: If the RUN / STOP switch is set to the RUN position when the application starts, toggle the RUN / STOP switch between the STOP and RUN positions to enable motor spinning. This is a protection feature that prevents the motor from starting when the application is executed from CodeWarrior. You should also see a lighted green LED, which indicates that the application is running. If the application is stopped, the green LED will blink at a 2Hz frequency. If an undervoltage, overvoltage, overcurrent, or overheating fault occurs, the green LED will blink at a frequency of 8Hz.

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