AN992

Sensorless BLDC Motor Control Using dsPIC30F2010

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INTRODUCTION

This application note describes how to provide sensorless BLDC motor control with the dsPIC30F2010 Digital Signal Controller. The technique used is based on another Microchip application note: *Using the dsPIC30F for Sensorless BLDC Control* (AN901).

This application note explains how to apply the dsPIC30F2010 device to the hardware and software described in AN901, which uses the dsPIC30F6010 device and dsPICDEM™ MC1 Motor Control Development Board. The 80-pin dsPIC30F6010 has 144 Kbytes of Flash Program Memory, 8 Kbytes of RAM available and abundant I/O. The 28-pin dsPIC30F2010, on the other hand, has limited I/O, only 12 Kbytes of Flash program memory and 512 bytes of RAM. As you can see, the resources are finite.

This application note prescribes changes to the hardware, software and user interface described in AN901 to facilitate the easy transfer of the code to the dsPIC30F2010 device. You will want to thoroughly review AN901 for details on BLDC sensorless design using the dsPIC30F. Functionally, the code does not change, so all BLDC control functions available and described in AN901 are still the same.

HARDWARE REQUIRED

You will need the following hardware to implement the described motor control application:

- PICDEM™ MCLV Development Board (Figure 1)
- Hurst DMB0224C10002 CL B 6403 24 V BLDC Motor
- 24 VDC Power Supply

You can purchase these items from Microchip as a complete kit or as individual components. Check the Development Tools section of the Microchip web site for ordering information.

HARDWARE MODIFICATIONS

Figure 2 is a simplified block diagram for a Sensorless BLDC motor control application. This diagram will help you develop your own hardware, if you so choose, to drive a sensorless BLDC motor. Schematics for the PICDEM MCLV board are included in Appendix A.

FIGURE 1: PICDEM™ MCLV DEVELOPMENT BOARD

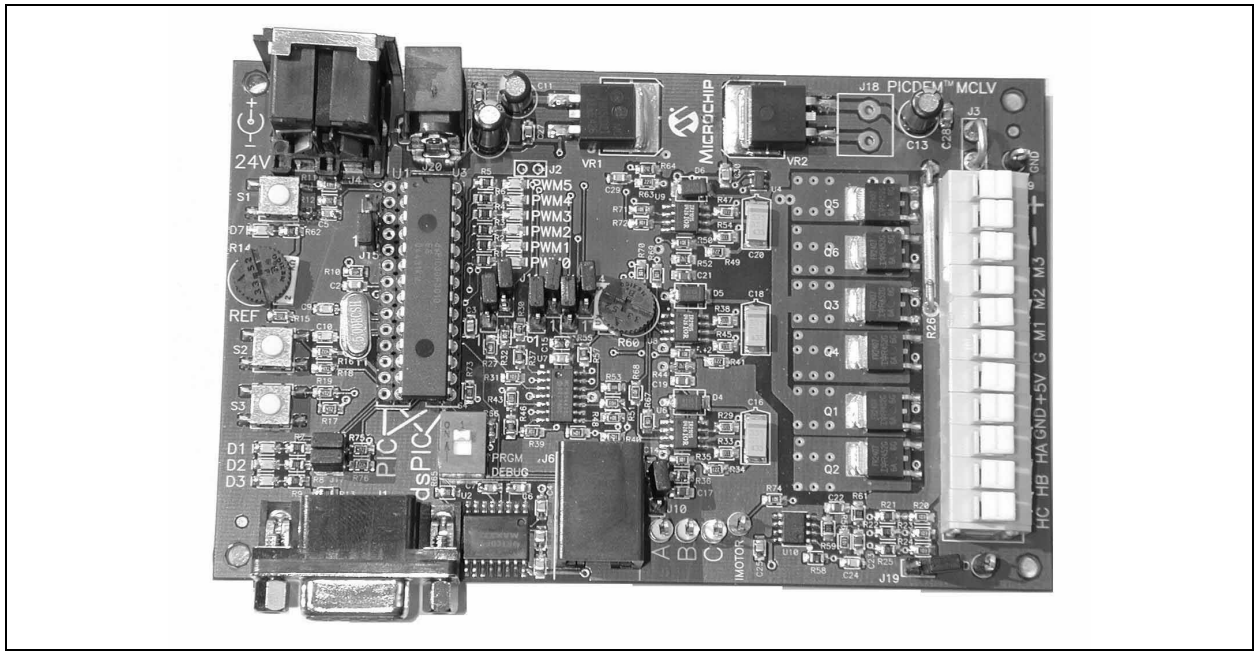
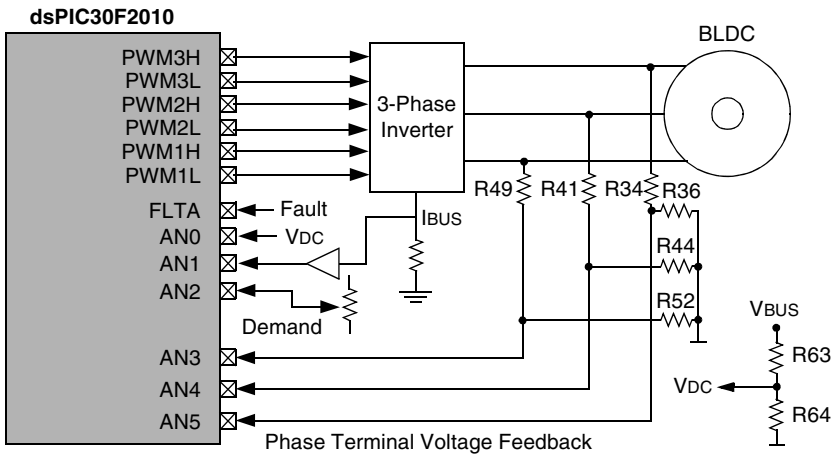


FIGURE 2: PICDEM™ MCLV BOARD FUNCTIONALITY



Except for the dsPIC30F2010 device, the basic block diagram is exactly the same as that used in AN901.

- A pot selects the demand for the speed.
- VBUS voltage is sensed as VDC using resistor pairs R63/R64. VDC/2 is used as the "zero-crossing" voltage for back EMF sensing.
- Feedback voltage is sensed using resistor pairs R34/R36, R41/R44 and R49/R52.
- Current feedback is provided through a simple operational amplifier circuit (U10A)
- Fault input is received through a comparator circuit (U7D) connected with the current feedback circuit. The current is sensed using a 0.1 ohm resistor (R26). The current gain is 11 and the threshold of the comparator can be adjusted using pot R60.

You can very easily adjust the values of the resistors to accommodate the current capabilities of the motor being used for the application. The motor drive circuit, on the other hand, is designed to drive a 24V BLDC motor. You can change the drive requirement of the motor (refer to the *PICDEM™ MCLV Development Board User's Guide* for details on how to change the hardware for use with motors greater or less than 24V).

On the low side, the voltage limit is 10V. On the high side, the voltage limit is 40V. It is important to note that the heat sink on the IGBTs have very limited heat dissipation, so high power requirements may not be easily met with the PICDEM MCLV board.

To use the PICDEM MCLV board for this application, use the jumper settings shown in Table 1 and the motor connections shown in Table 2.

TABLE 1: JUMPER SETTINGS FOR PICDEM™ MCLV BOARD

Jumper	Sensorless Control
J7, J11, J13	Short between 2-3
J15	Open
J8,J12,J14	Open
J10, J16, J17, J19	Open

TABLE 2: MOTOR CONNECTIONS

Connector J9 Label	Sensorless Control
M1	Phase C (Red)
M2	Phase A (White)
M3	Phase B (Black)
G	Ground (Green) If available

The colors referenced in Table 2 are as per the Hurst 24V motor available from Microchip. The ground wire is sometimes not available on some motors.

Once the code is developed and downloaded to the system, you will need to press switch S2 to start and stop the motor. The pot marked REF (R14) sets the demand for the speed. It is rotated clockwise to increase the speed of the motor.

Due to the limited I/O on the dsPIC30F2010, the LEDs on the board are not used to signal fault conditions. Instead, fault conditions are displayed on Windows® HyperTerminal® on your PC using the serial port.

PROGRAMMING THE dsPIC30F2010

The dsPIC30F2010 can be programmed using the PICDEM MCLV board. Due to the limited I/O resources on the dsPIC30F2010, the serial port is shared with the programming pins. When you are ready to program the part, DIP switch S4 should have its TAB in the PRGM direction. When programming is completed, the DIP switches must be moved to the DEBUG position to execute the code. If the IDC2 is connected to the PICDEM MCLV board as a debugger, then the connector at J6 should be attached. If, however the ICD2 is being used as a programmer, then the connector at J6 should be unplugged from the ICD2 for normal execution.

The following configuration settings are required for the applications to work on a PICDEM MCLV board:

Oscillator Source:	Primary Oscillator
Primary Oscillator Mode:	XT w/PLL 8x
Comm Channel Select:	EMUC2 and EMUD2

Other settings can be enabled or disabled as needed, or modified in the application.

SOFTWARE MODIFICATIONS:

The software has not been modified significantly from that described in AN901. However, the user interface to the LCD and the debug routines have been removed. The LCD interface has been replaced by the Serial User Interface mentioned in the next section. The User Interface does add to the code space and will require a dsPIC30F3010 device during the development stage of the application.

During the development mode you must set:

```
#define DEVELOPMODE TRUE
```

This setting in the `def.s` file allows for all the conditional statements in the code to automatically enable the UART and run the user interface mode. Once the code has been fully developed, you can then select:

```
#define DEVELOPMODE FALSE
```

This setting in the `defs.s` file disables the serial user interface and hard codes the parameters to Flash memory.

To ensure that the code fits into the dsPIC30F2010, you must use the space optimization option in the C30 compiler options. From the MPLAB *Main* menu, select *Project>Build Options>Project*. When the Build Options dialog displays, select the MPLAB® C30 tab and set *Categories>Optimization>Optimization level>s* (for space optimized).

Note:	The source code for this application is available on the Microchip web site (www.Microchip.com), appended to the electronic (pdf) version of this application note.

USER INTERFACE

The user interface is necessary to tune the different parameters used in the sensorless BLDC motor control applications. There are 45 user parameters that can be modified in the applications. For more details on these parameters, their functions/uses and how to tune them, refer to the *Using the dsPIC30F for Sensorless BLDC Control* (AN901) application note.

In AN901, the user parameters are modified using an LCD display and key switches. Since an LCD display is not available on the PICDEM MCLV board, the user interface has been modified to a 2 wire serial interface.

The new user interface for this application uses the RS-232 port on the dsPIC30F2010 connected to a communication terminal (e.g., Windows HyperTerminal) running at 19200 Baud.

The communication terminal is then used to change parameters in the user interface. All the parameters in AN901 that were set on the PICDEM MC1 Motor Control Development Board using the LCD screen can now be set through the serial interface.

Table 3 lists the parameter names, abbreviations and descriptions. A total of 45 control parameters are available for the user interface.

The parameters are categorized by:

- **Motor Parameters** - parameters that relate to the motor
- **Starting Parameters** - parameters that relate to the starting ramp
- **Control Parameters** - parameters that relate to the different PI or PID control parameters used in the software
- **Limit Parameters** - parameters that relate to the various limit settings in the software
- **Board Parameters** - parameters that relate to the components on the board and how they interact with the software

TABLE 3: MOTOR CONTROL PARAMETERS

For This Parameter	Type This Abbreviation	Comment
Motor Parameters		
DIRECTION	DD 0 or DD 1	0 = Forward 1 = Backward
No. Motor Poles	MP <Value>	Number of Motor Poles
Blanking Count	BC <Value>	
Windmilling Dem	WD <Value>	
Starting Parameters		
Lock Pos.1 Time	LP1T <Value>	In 10-msec intervals
Lock Pos.2 Time	LP2T <Value>	In 10-msec intervals
Lock Pos.1 Dem	LP1D <Value>	In PWM duty cycle percentage
Lock Pos.2 Dem	LP2D <Value>	In PWM duty cycle percentage
Ramp Start Speed	RSS <Value>	Ramp Start Speed in RPM
Ramp End Speed	RES <Value>	Ramp End Speed in RPM
Ramp Start Dem	RSD <Value>	In PWM duty cycle percentage
Ramp End Dem	RED <Value>	In PWM duty cycle percentage
Ramp Duration	RD <Value>	In 10 msec intervals
Tolerance Check	TC <Value>	
Auto Re-acquire	ARA 0 or ARA 1	0 = disable 1 = enable
Starting Control	SC 0 and SC 1	0 = Voltage Control 1 = Current Control
Acquire Method	AM 0 or AM 1	0 = Method 1 1 = Method 2
ZeroX Enable Spd	ZXES <Value>	Speed at which zero crossing is enabled

TABLE 3: MOTOR CONTROL PARAMETERS (CONTINUED)

For This Parameter	Type This Abbreviation	Comment
Control Parameters		
CONTROL MODE	CM 0, CM 1, CM 2 or CM 3	0 = Closed Volts 1 = Closed Current 2 = Open Volts 3 = Open Current
Phase Adv. Enable Spd	PAES <Value>	
Phase Adv. Slope	PAS <Value>	
Current P Gain	CKP <Value>	
Current I Gain	CKI <Value>	
Current D Gain	CKD <Value>	
Speed P Gain	SKP <Value>	
Speed I Gain	SKI <Value>	
Voltage Demand	VD <Value>	
Volts P Gain	VKP <Value>	
Volts I Gain	VKI <Value>	
Limit Parameters		
Stall Time Limit	STL <Value>	
Over Speed Limit	OSL <Value>	Over Speed Limit in RPM
Over Volts Limit	OVL <Value>	
Over Current Lim	OCL <Value>	
Board Parameters		
Current Scale X	CSX <Value>	
Current Scale /	CSD <Value>	
Volts Scale X	VSX <Value>	
Volts Scale /	VSD <Value>	
Zero X Level Thd	ZXL <Value>	
Acquire Threshld	AT <Value>	
Acquire Level Td	AL <Value>	
Rotation Timeout	RT <Value>	
Pot / for Duty	PDD <Value>	
Pot / for Currnt	PDC <Value>	
Pot X for Speed	PXS <Value>	
Braking Ramp T	BRT <Value>	

USING THE SERIAL USER INTERFACE

The user parameters can only be modified during the standby or reset state of the system. When the motor is running, the communications terminal displays the speed and the percentage duty cycle of the PWM.

The terminal must be connected to the PICDEM MCLV board at the RS232 connector (J1) and set to operate with these parameters:

Bits per second	19200
Data bits	8
Parity	None
Stop bits	1
Flow control	None

The command set is case sensitive. If you type a command incorrectly, the message shown in Figure 3 displays.

To get more information about the command set, type

?? <Return>

In response, the message shown in Figure 4 prompts for a more specific request.

To get information about a specific category of commands, type a question mark followed by the letter that corresponds to the command set category.

FIGURE 3: INCORRECT COMMAND MESSAGE

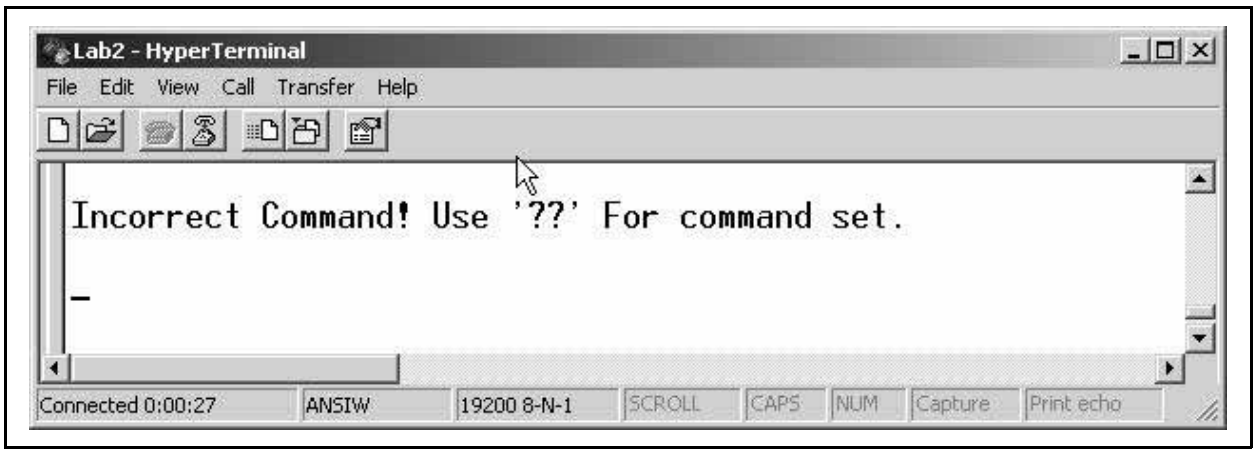
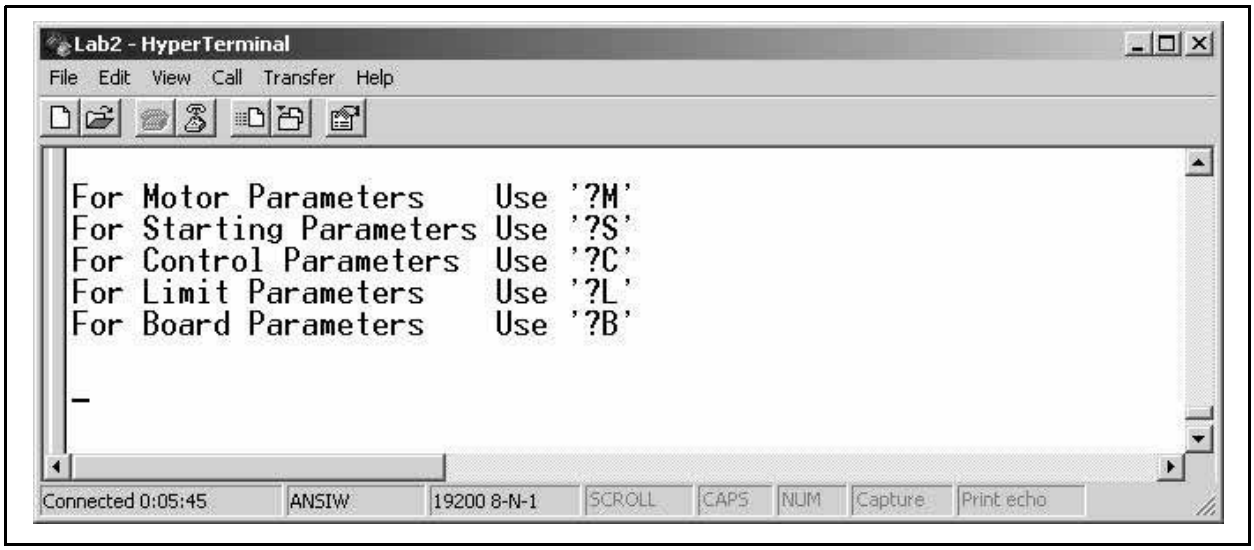


FIGURE 4: COMMAND SET HELP MENU



Motor Parameters

Motor Parameters are displayed by typing:

?M<Return>

The response message lists the motor parameters and displays their current value, as shown in Figure 5. To change any of the parameters, you type the parameter abbreviation followed by the new value (separated by a space).

The DIRECTION parameter (DD) uses only two parameter values: '0' or '1'.To change the direction of the motor rotation, you type:

DD<Space>1<Return>

Note that DD is upper case and there is a space between the parameter abbreviation and the value 1.

The command and its response are shown in Figure 6. The value has changed from '00000' to '00001' (the opposite direction).

Suppose you want to change the number of motor poles from 10 to 8. You would type:

MP<Space>8<Return>

This command and its response are shown in Figure 7. The value has changed from '00010' to '00008'.

FIGURE 5: MOTOR PARAMETERS

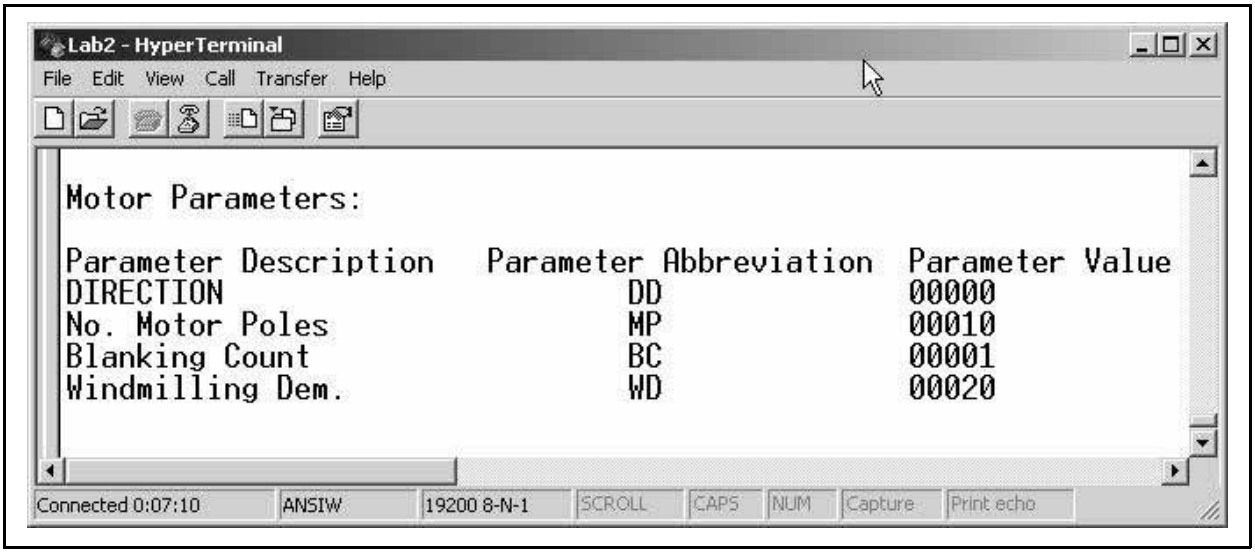


FIGURE 6: MOTOR DIRECTION COMMAND AND RESPONSE

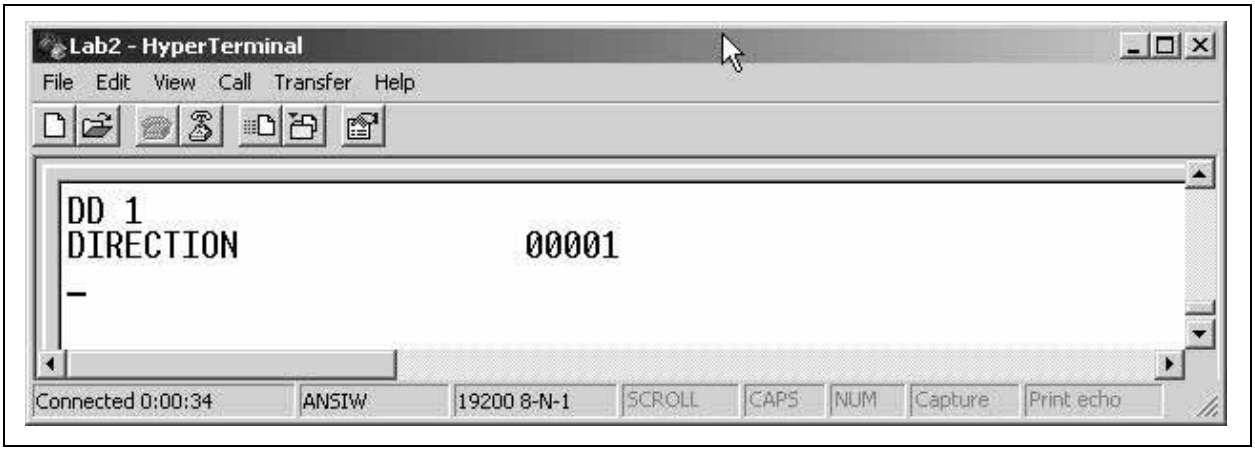
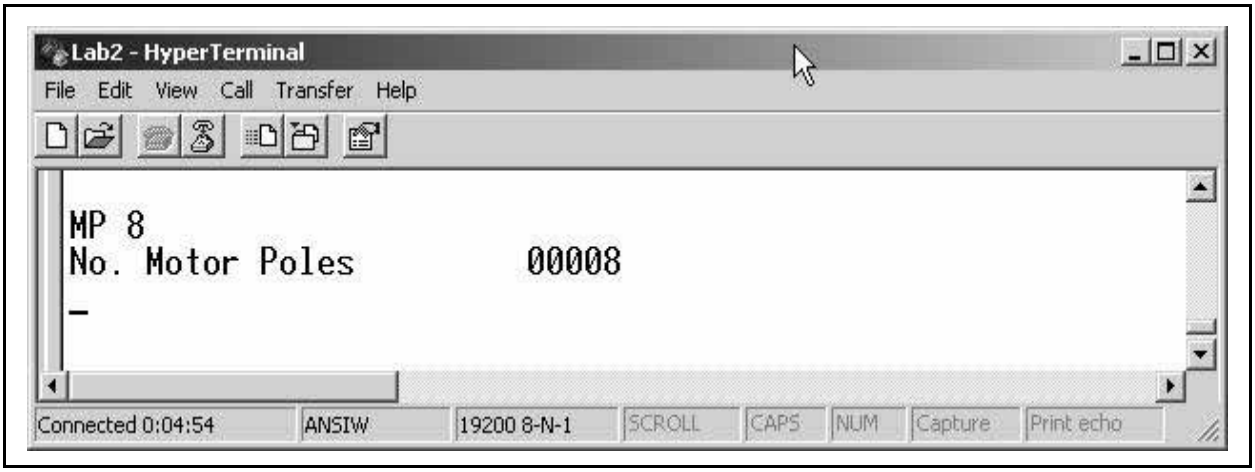


FIGURE 7: MOTOR POLES COMMAND AND RESPONSE

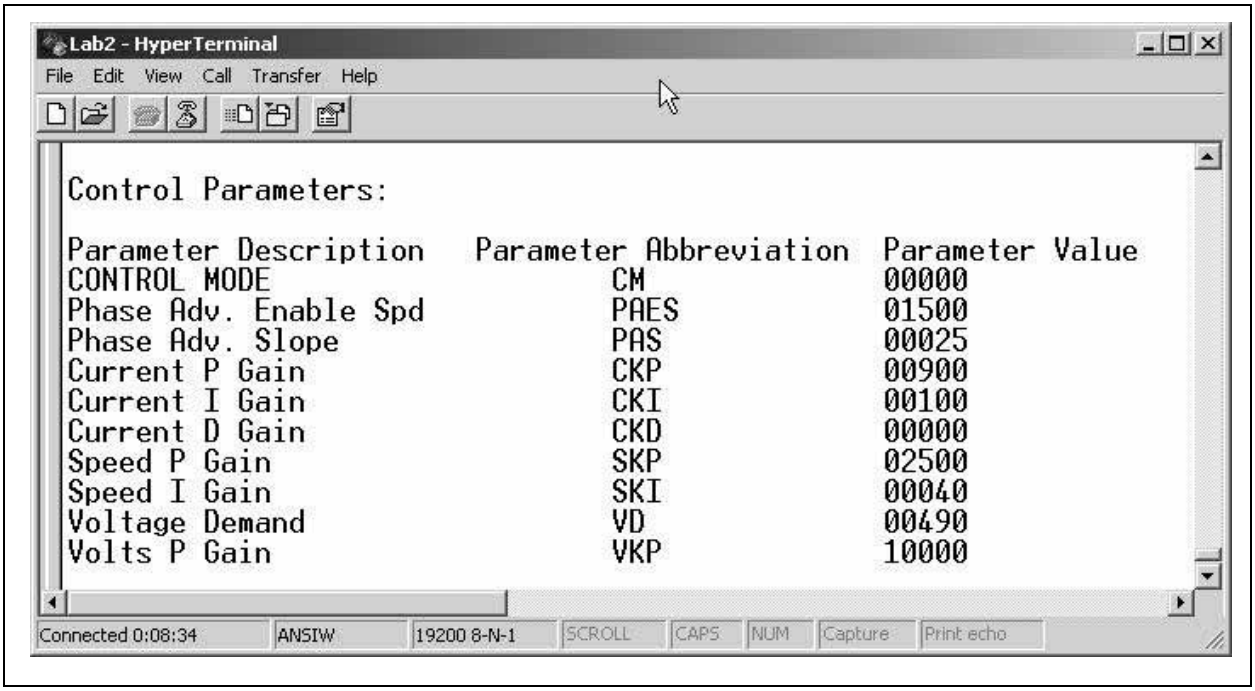


Control Parameters:

The Control Parameters and their current values are displayed in response to the '?C' command, as shown in Figure 8.

To change a control parameter, type the parameter abbreviation followed by the desired value. For example, if the Speed Integral Gain needs to go from 40 to 200, you would type 'SKI 200'.

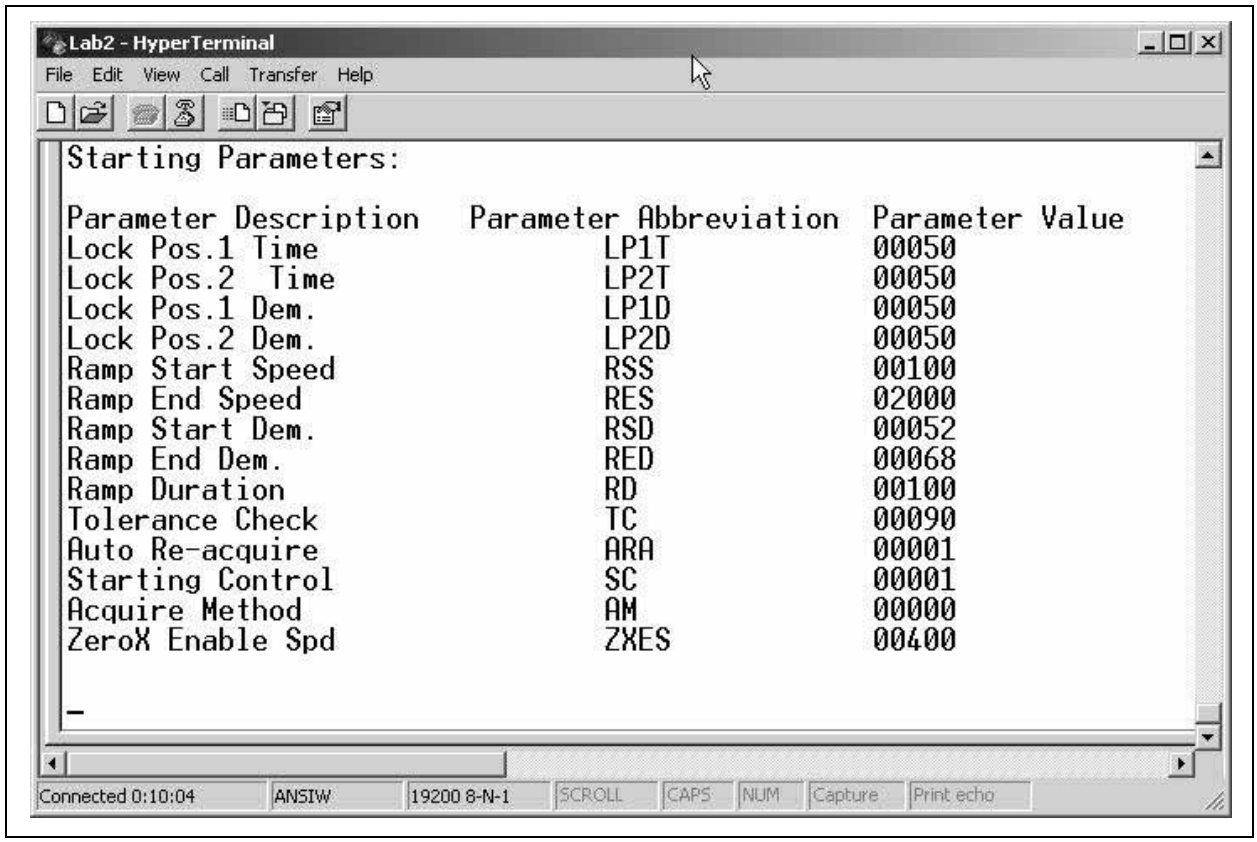
FIGURE 8: CONTROL PARAMETERS



Starting Parameters

The Starting Parameters fine tune the sensorless starting algorithm and are probably the most often modified parameters. Because some of the parameters are varied by tens of milliseconds, please note the comments in Table 3 and carefully review AN901.

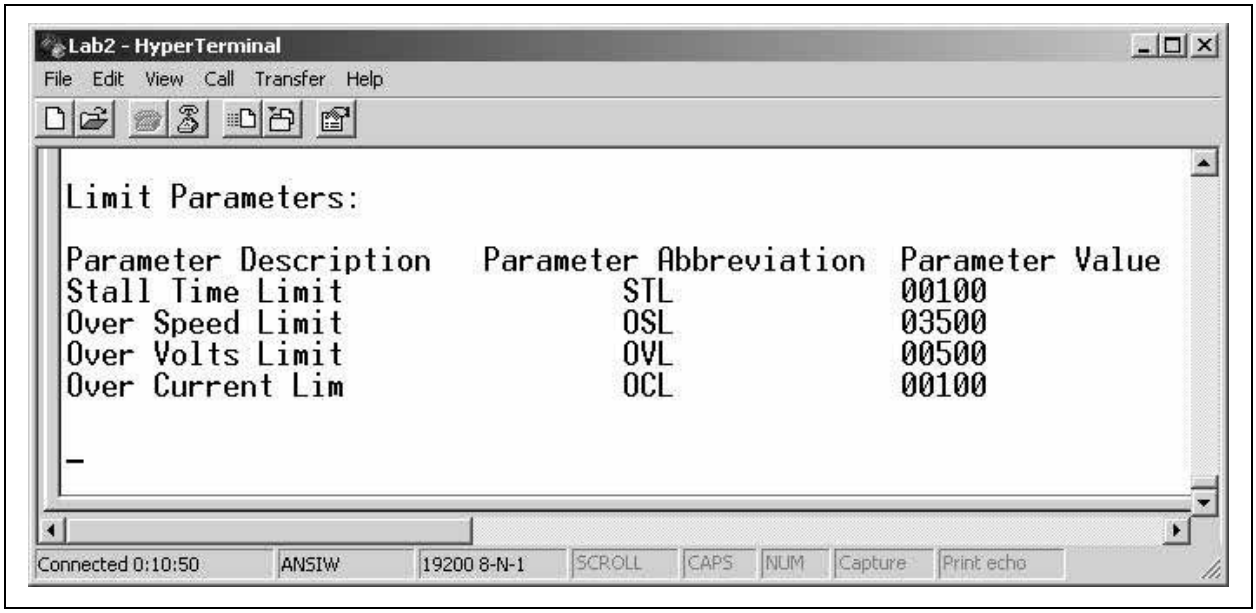
FIGURE 9: STARTING PARAMETERS



Limit Parameters

The limit parameters are shown in Figure 10.

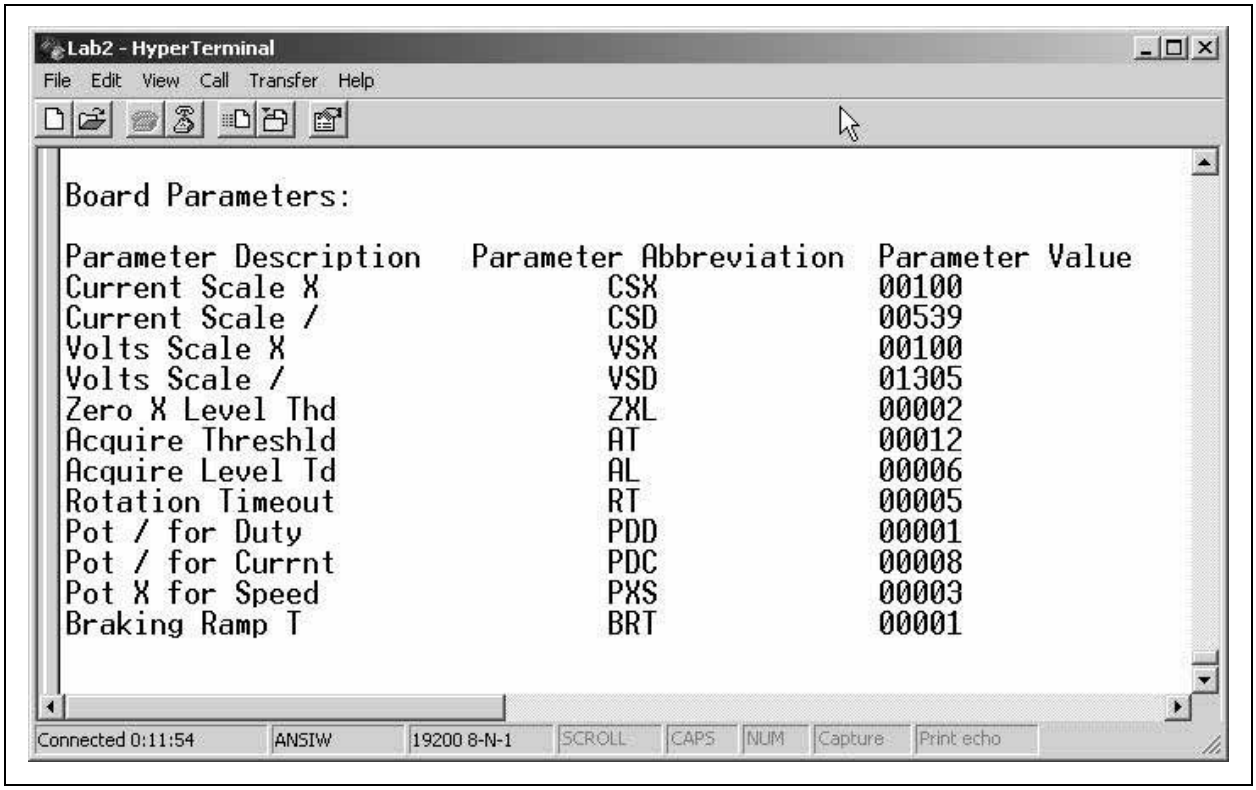
FIGURE 10: LIMIT PARAMETERS



Board Parameters

The board parameters are shown in Figure 11. Refer to AN901 for details on these parameters.

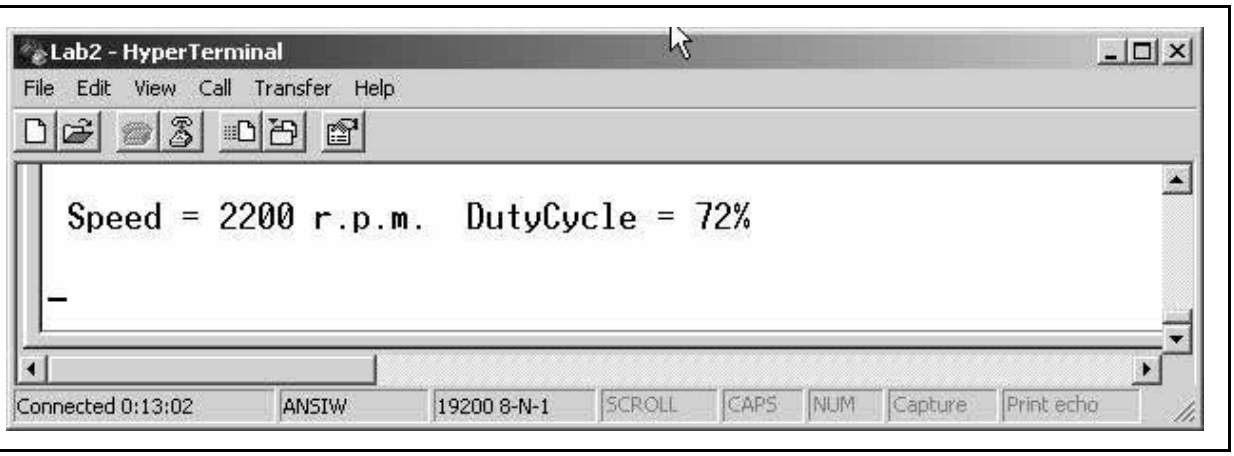
FIGURE 11: BOARD PARAMETERS



Run Time Mode

As noted before, the parameters can be viewed in Standby mode only. During the actual operation of the motor, the speed of the motor and the percentage Duty Cycle being used by the motor PWM are constantly updated, as shown in Figure 12.

FIGURE 12: RUN TIME DISPLAY OF SPEED AND PWM DUTY CYCLE



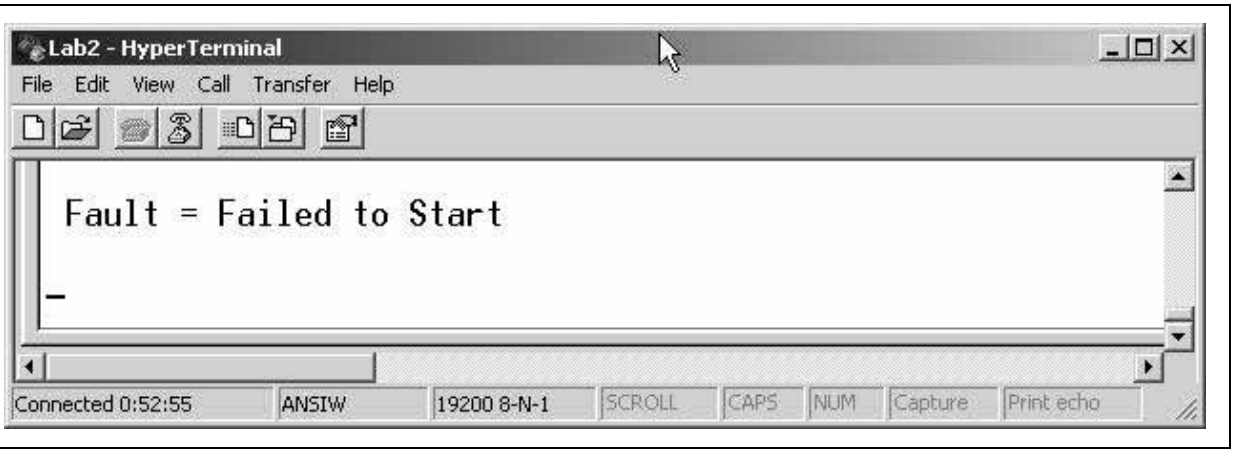
Fault Condition

If a fault condition occurs during the starting or operation of the motor, it is reported as shown in Figure 13. The faults reported include:

- FAILED TO START
- OVER CURRENT
- OVER VOLTAGE
- HARDWARE TRIP
- OVER SPEED
- SENSORLESS LOST
- STALLED

To reset the fault or stop the motor, you must press S2 on the board. When the system resets, you can edit the necessary parameters.

FIGURE 13: FAULT MESSAGE



CONCLUSION

The 28-pin dsPIC30F2010 is an ideal low-cost solution to control a sensorless BLDC motor. Using the flexible serial user interface described in this application note, you can fine tune the application parameters required to start and run a sensorless BLDC motor application as described in detail in AN901.

APPENDIX A: SCHEMATICS

FIGURE A-1: BLDC MOTOR CONTROL BOARD (SHEET 1 OF 2)

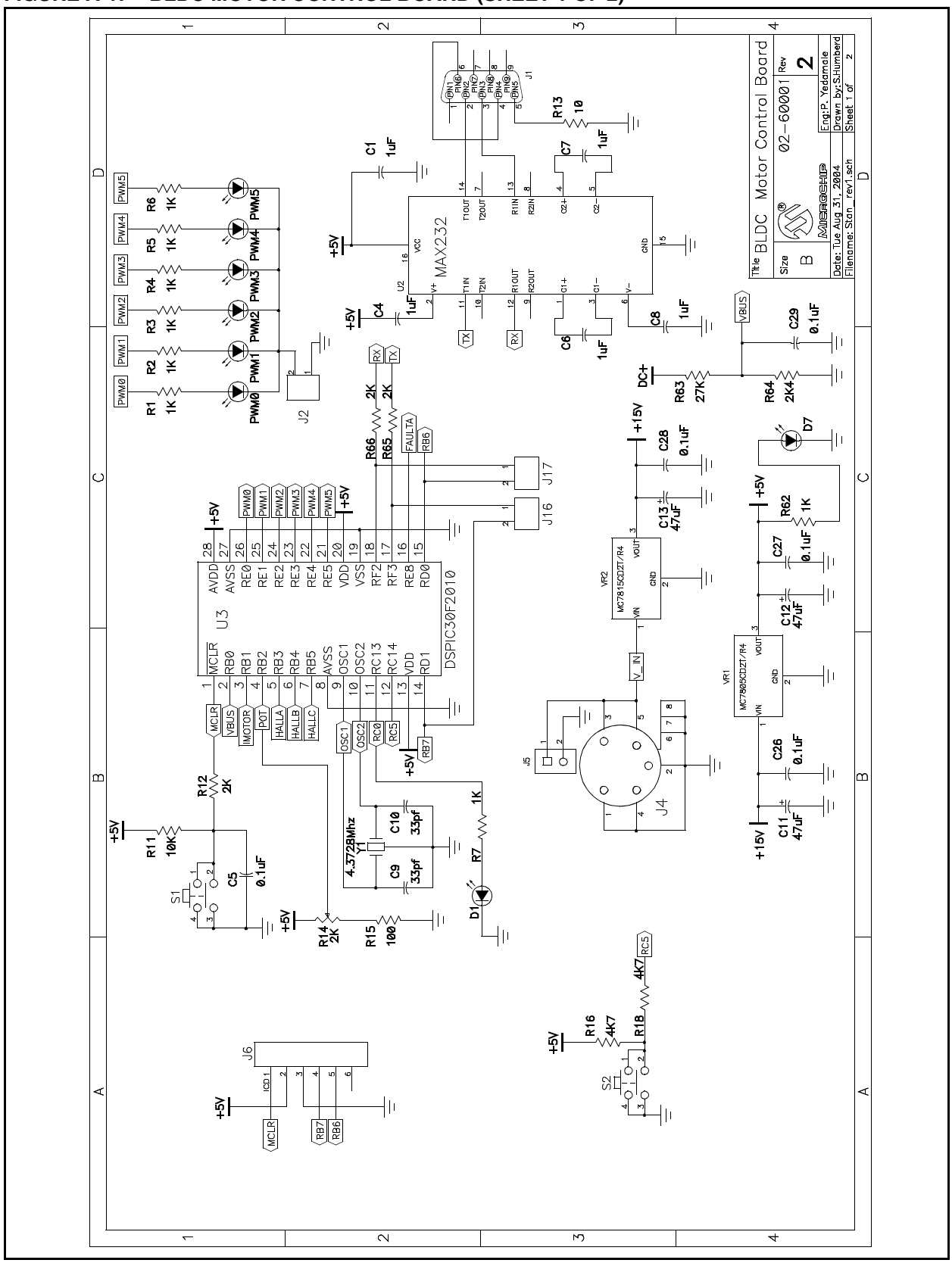
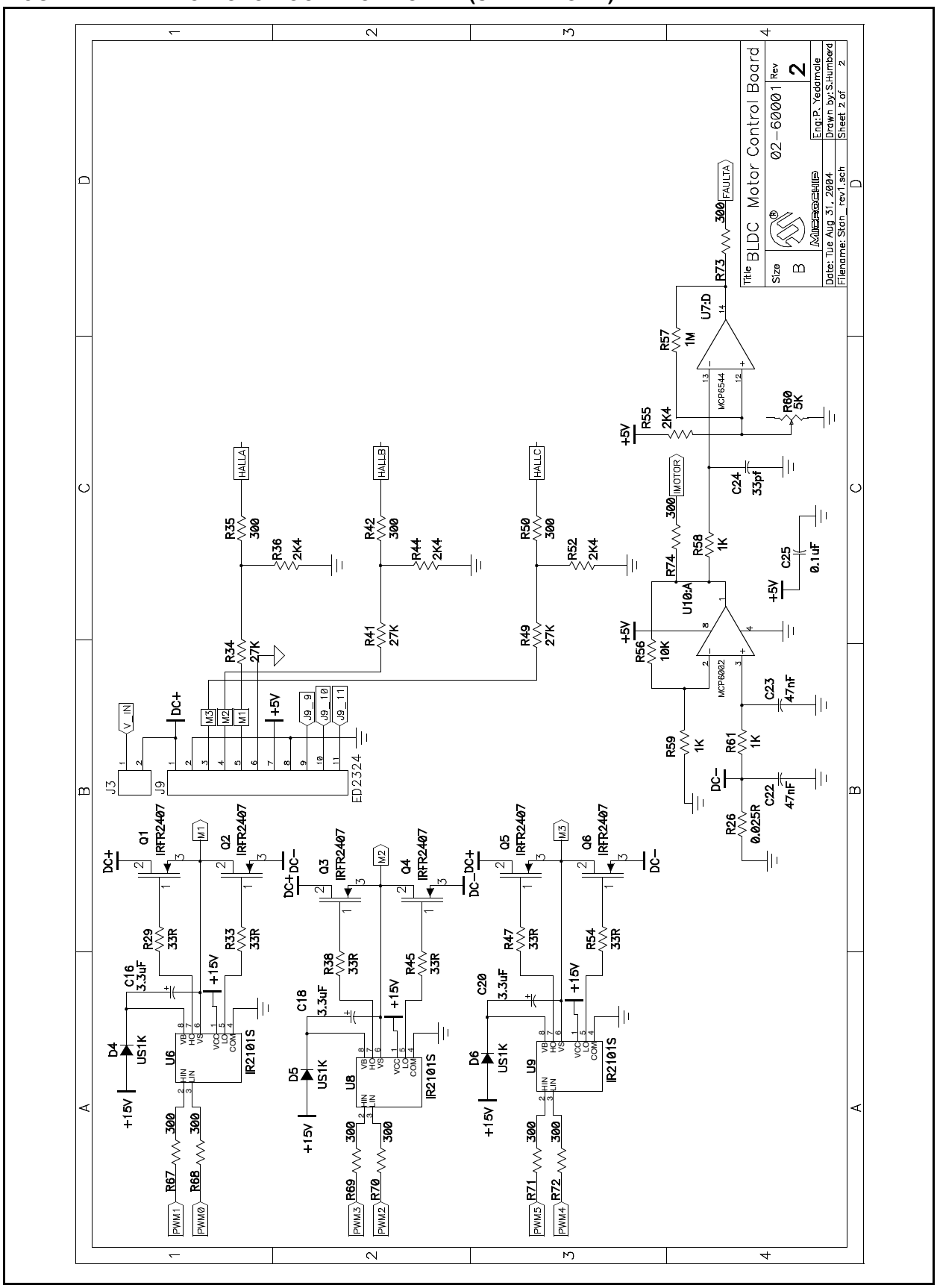


FIGURE A-2: BLDC MOTOR CONTROL BOARD (SHEET 1 OF 2)



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