J R KERR
AUTOMATION
ENGINEERING

____ *PIC-SERVO 3PH* Motor Control Board _________

For 3-Phase Brushless & Brush-type DC Motors

The ***PIC-SERVO 3PH*** Motor Control board is a full-function servo control system with the following features:

- ***PIC-SERVO CMC*** chipset providing servo control of DC motors with incremental encoders, including trapezoidal, velocity profiling and support for coordinated multi-axis motions. The ***PIC-SERVO*** board may also be used with the standard ***PIC-SERVO c***hipset.
- On-board amplifier for 3-Phase brushless motors (with 3 hall effect sensors) *or* conventional brush-type motors. Advanced commutation reduces 3-phase torque ripple.
- **10 amp** maximum current, 12 to 48vdc supply voltage (36 max. recommended). Complete overcurrent, undervoltage, and thermal protection.
- RS485 serial interface allows up to 32 controllers to be controlled from a single serial port. Connects to an RS232 port through commonly available full-duplex adapters or using the ***Z232-485*** converter board.
- Two general purpose I/O bits for limit switch inputs or control outputs. Encoder index input.
- Small size (3.1" x 3.1") allows it to be mounted near motors, reducing noise and simplifying wiring.
- Windows test software provided including Windows 95/98/NT DLL and C source code. DOS based C code and Basic code are also available.

1. Quick Start

What you will need:

PIC-SERVO 3PH Motor Control Board
Z232-485 Converter Board (or equivalent)
Brushess Motor, 3-phase with hall effect sensors and incremental encoder
-or-
Conventional DC brush motor with incremental encoder
Motor power supply (12v min. - 36vdc max. recommended)
Logic power supply (10 - 16vdc, 500 ma)
Note: a 9 to 12vdc unregulated supply may be used
Motor & encoder cables
10 pin flat ribbon cable with standard IDC socket connectors at both ends
Straight DB9 male / DB9 female cable to PC COM port
PC compatible computer running Windows
Test software - NMCTest for Windows95/98/2000/NT
(available for download from http://www.jrkerr.com)

CAUTION

The ***PIC-SERVO 3PH*** Motor Control Board does not incorporate safeguards for fail-safe operation. As such, this board should not be used in any device which could cause injury, loss of life, or property damage. J.R. Kerr makes no warranties whatsoever regarding the performance, operation, or fitness of this board for any particular purpose.

Most of the cables are available from computer or electronics stores. However, you will probably have to make your own motor/encoder cable to connect to your particular motor. Refer to *Section 2.1* for the connector pin definitions.

To start off, connect your encoder to connector P3 and your hall effect sensors to connector P5. If you are using a brush-type DC motor, do not connect anything to connector P5. Your motor leads will connect to the three-position screw terminals marked P2. If you are using a brush-type motor, you will connect the leads to just the first two positions on this screw terminal.

Because there is not standard for the exact order of phase commutation, you will most likely have to re-arrange your motor leads by trial and error once you start testing. Even with brush-type motors, there is a 50-50 chance you will have to reverse the motor leads to get the polarity right.

Interconnections and Jumpers:
Basic interconnections and jumpers are shown in *Figure 1* for both a single controller and for a multiple controller configuration. On the ***Z232-485*** converter, jumpers JP3 and JP4 are installed in the 1-2 position for use as a simple converter. (Please refer to the ***Z232-485*** documentation for use with the optional standalone processor cards.) Jumper JP5 is installed to distribute logic power to the controller boards over the communications cable. Logic power (10 - 16vdc) is supplied on connector JP6. (If you are using a different type of serial port adapter, you may supply power to connector JP8 on the ***PIC-SERVO 3PH*** board.)

On the ***PIC-SERVO 3PH*** controller board, jumpers JP6 and JP7 are installed to connect logic power supplied by the communications cable to the board's logic supply. In the *single* controller configuration, the three jumpers labeled JP3, JP4 and JP5 should be installed as shown. In the *multiple* controller configuration, these jumpers should only be installed on *last* controller, furthest from the PC host. On all intermediate controllers, jumpers at JP3, JP4 and JP5 should be left *uninstalled*. Jumper JP9 should be in the 1-2 position.

Motor power should be connected to the two position screw terminals, P1, with 12 - 36vdc connected to the terminal towards the upper edge of the board and GND connected to the terminal towards the center as shown in *Figure 1*. **Caution:** Please read Section 3.3, *Motor Power Supply* before proceeding to prevent damage to your board. Because the logic power supply, the motor power supply, and your host computer are all connected with a common ground, we recommend that your motor power supply and your logic power supply have floating outputs to avoid ground loops.

Loading and Running Software:
First unzip NMCTEST.ZIP into a single directory. Before starting up the test code, make sure all of your jumpers and interconnections are as shown in *Figure 1*. Also make sure you have logic power supplied to the ***Z232-485*** converter.

Run the program NMCTest.exe. Select the correct COM port when prompted (leaving the default baud rate at 19200 for now). If you are using a different COM port, you will get an error message saying no modules were found. If this is the case, click on the Reset Network button and set the COM port to the correct value. The program will attempt to locate controllers on the RS485 network and will respond with the number of controllers found. If the number of controllers reported does not match the number connected, re-check the interconnections, jumpers and power, and then try again.

The list box on the left side of the window will display the list of motors found. Module 1 will be the last controller which is furthest from the host PC. Clicking on different controllers will display the status and controls for that particular motor. Click on the ***PIC-SERVO*** module you are testing and spin the motor shaft by hand. See that the position changes accordingly in the status panel.

Before testing the servo, make sure that the motor is disconnected from any mechanism so that it is able to spin freely. To test the servo, first turn on the motor power. Next, click on the Enable Amplifier box in the Motion Command panel. You should see the Motor Power box checked in the status panel when *both* the motor power is on *and* the amplifier is enabled.

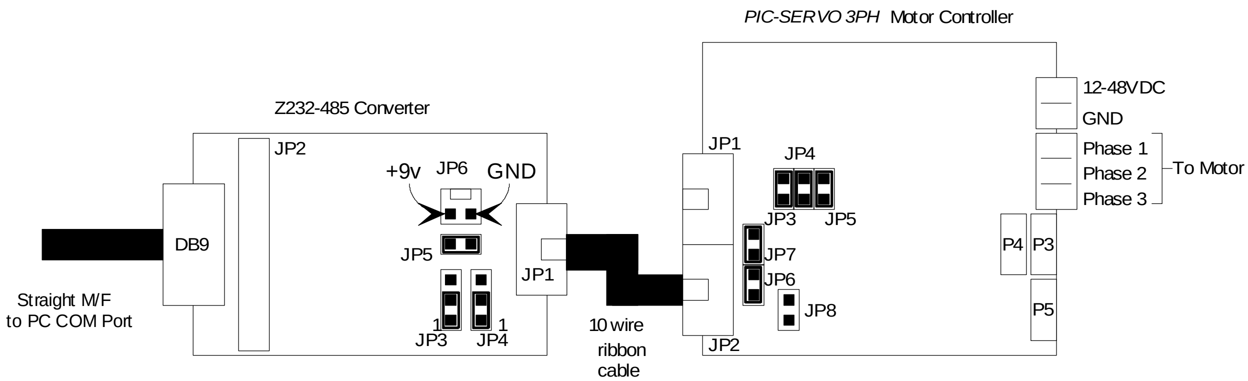
Next, you will need verify that your brushless motor leads are connected in the proper order, and rearrange them if they not. (Skip to the next paragraph if you are using a brush motor.) Select PWM mode, type in a value of 64 (about 25% of full voltage), and click on the GO button. If the motor does not spin, click the Motor Off button and try a different arrangement of the motor leads (there are a total of 6 possible arrangements). If the motor does spin, try entering a value of -64, and see if the motor spins at approximately the same speed in the opposite direction. If it does not, you still don't have it right - try a different lead arrangement. When the motor is connected correctly, it will spin smoothly with equal ease in both directions.

At this point, the commutation is correct, but the motor still may be rotating backwards in relation to the encoder. You can check this by looking at the motor velocity when you run in PWM mode with a PWM value of +64: the velocity reading should be *negative*. If the velocity value reads *positive*, the polarity is reversed and you have two choices for fixing it: 1) you can swap the encoder Channel A and Channel B wires, effectively making the encoder count in the other direction, or 2) rearrange both the hall effect sensor wires *and* the motor lead wires until the commutation is correct *and* the polarity with respect to the encoder is correct. (For brush motors, you can simply reverse the encoder wires or reverse the motor leads to correct any polarity mismatch.)

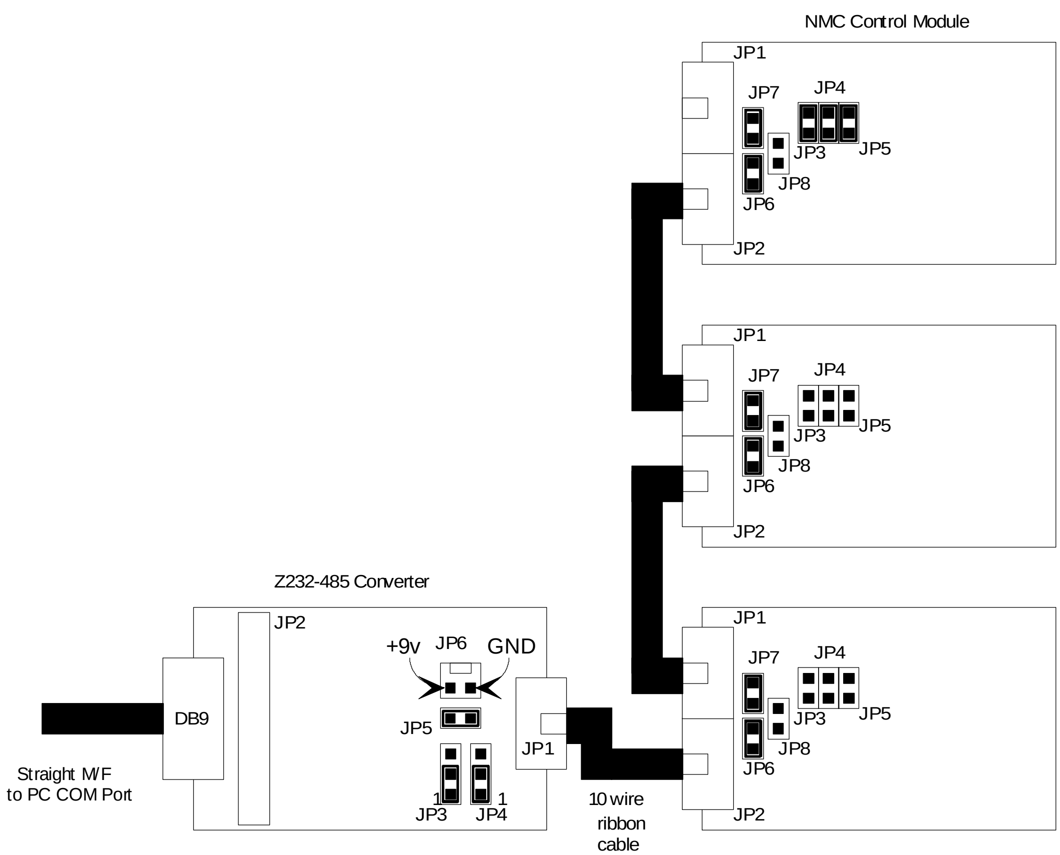
Finally, click on the STOP! button to enable the position servo. Try turning the motor shaft by hand. (If the motor jerks and stops, or spins out of control, you probably still have the motor and encoder polarities reversed.) The motor should attempt to hold a fixed position. If it does, click on Pos mode, type in a position value of 1000, and then click on GO. The motor should move to position 1000 (or close to it, depending on how the gains are set). Try moving to several different positions until you are satisfied that the motor is moving as it should. (Note that if your motor has a gearhead, the motion of 1000 counts may produce an imperceptibly small motion, and you should use a larger number instead.)

The control gains, and maximum velocities and accelerations are set to default values which are reasonable for most small motors. Please refer to the ***PIC-SERVO*** datasheet for details on the values for the gains, velocities and accelerations. The online help also has a great deal of information about the ***PIC-SERVO*** controller.

Single Controller Configuration



Multiple Controller Configuration



CAUTION: Connecting communications cables incorrectly, or installing jumpers JP3, JP4 and JP5 (on the *PIC-SERVO* board) in the wrong location may damage the *PIC-SERVO* or other NMC controller chip!

Figure 1 - Basic Interconnections.

2. Connectors and Jumpers

2.1 Pinouts

Motor Power Connector **P1**

Pin	*Definition*
1	Motor Power Supply 12 - 36vdc (48v absolute max.) - *near top edge of board*
2	Motor Power Supply Ground (connected internally to logic ground)

Logic Power Connector **JP8** (1x2 pin header - 0.100” spacing)
(Use only if logic power is **not** supplied via the network communications cable.)

Pin	*Definition*
1	10 - 16vdc (towards the lower edge of the board) Note: a 9 to 12vdc unregulated supply may be used
2	Ground

Motor Connector **P2** (3 position screw terminals)

Pin	*Definition*
1	Phase 1 for 3-phase motors, M+ for brush-type motors
2	Phase 2 for 3-phase motors, M- for brush-type motors
3	Phase 3 for 3-phase motors

Hall Effect Sensor Connector **P5** (1x5 pin header - 0.100” spacing)

Pin	*Definition*
1	+5v output
2	Hall sensor 1
3	Hall sensor 2
4	Hall sensor 3
5	Ground

Encoder Connector **P3** (1x5 pin header - 0.100” spacing)

Pin	*Definition*
1	+5v output
2	Channel A
3	Channel B
4	Index
5	Ground

Limit Switch Connector **P4** (1x5 pin header - 0.100” spacing)

Pin	*Definition*
1	+5v output
2	Limit switch 1
3	Limit 1 return (Ground)
4	Limit switch 2
5	Limit 1 return (Ground)

Network Connectors JP1, JP2 (2x5 pin header - 0.100” spacing)

Pin	*Definition*
1	RCV+
2	RCV-
3	XMT+
4	XMT-
5	ADDR_IN on JP1, ADDR_OUT on JP2
6	Ground
7	Logic power (10 - 16vdc)
8	Ground
9	Logic power (10 - 16vdc)
10	Ground

2.2 Jumpers

Jumper	*Description*
JP3	Connects ADDR_IN to GND. Insert jumper for the last controller board on the network (or if only 1 controller is used)
JP4, JP5	Enables termination resistors on RX and TX. Insert these jumpers for the last controller on the network (or if only 1 controller is used).
JP6,JP7	Logic power interconnection. Inserting JP6 connects logic power to network connector JP2. Inserting JP7 connects logic power to JP1. These are used to control the distribution of logic power over the network cables. Normally both these jumpers are installed.
JP9	Install this jumper in the 1-2 position (jumper towards bottom edge of board) to enable 12 step commutation (default). Install in the 2-3 position to use 6 step commutation only.

2.3 Ordering Information

Part Number	***Description***
KAE-T0V5-BD3PHV1	***PIC-SERVO 3PH*** Motor Controller Board with ***PIC-SERVO CMC***
KAE-T0V4-BD3PHV1	***PIC-SERVO 3PH*** Motor Controller Board with standard ***PIC-SERVO***

3. *PIC-SERVO* Motor Control Board Description

The ***PIC-SERVO 3PH*** Motor Control board is a complete motor servo control system including a servo controller, amplifier, serial communications interface, optical encoder interface, limit switch inputs, and an auxiliary analog input with pre-amplifier. The board is designed so that up to 32 controllers can be connected directly to a single standard serial port (using an RS232-RS485 converter if necessary).

3.1 *PIC-SERVO CMC* Chipset

The ***PIC-SERVO CMC*** chip set forms the core of the controller. The ***PIC-ENC*** performs the time critical encoder counting task, while the ***PIC-SERVO*** executes the servo control, the communications interface, and outputs a 20 KHz PWM and Direction signal to the amplifier. Please refer to the ***PIC-SERVO*** and ***PIC-SERVO CMC*** chipset data sheets for complete details on the theory of operation of the servo control and motion profiling algorithms. You should also refer to the ***PIC-SERVO*** Programmer's Application Note for details on sending commands and receiving data from the ***PIC-SERVO***.

The ***PIC-SERVO CMC*** provides support for coordinated motion control. For simpler applications not requiring coordinated motion, the ***PIC-SERVO 3PH*** board may also be used with the standard ***PIC-SERVO*** chipset.

3.2 Communications Interface

The ***PIC-SERVO 3PH*** uses an RS485 multi-drop interface for allowing multiple control modules to communicate over the same RS485 communication port. The host computer sends commands out over a dedicated pair of transmit wires, and all data comes back over a shared pair of receive wires. Because the host has a dedicated transmit line, a standard RS232 serial port can be used with simple RS242-RS485 converter.

With multiple controllers on a single network, each controller must have a unique address for sending commands. Rather than using dip switches or jumpers to assign addresses, the ***PIC-SERVO 3PH*** uses a method of daisy-chaining an ADDR_IN signal and an ADDR_OUT signal for dynamically assigning addresses. With the controllers interconnected as shown in *Figure 1*, the ADDR_OUT signal of one board is connected to ADDR_IN of the next board. The very last board has ADDR_IN jumpered to GND. On power-up, all boards with ADDR_IN held high will have their communications disabled. Therefore, only the last board will be able to communicate with a default address of 0.

To initialize the network, a command is sent to the last controller (with address 0) to change its address to a value of 1. This has the side effect of causing its ADDR_OUT to lower, enabling communications with the next controller. The next command sent to address 0 will now be sent to the second-to-last controller. This process of assigning addresses is repeated until all controllers have been given a unique address.

3.3 Amplifier

The amplifier on the ***PIC-SERVO 3PH*** board is capable of driving 3-phase brushless motors or conventional brush-type DC motors. The commutation circuitry will check to see if hall effect sensors are connected at connector P5. If they are, it commutates the motor as a 3-phase brushless motor. If nothing is connected to P5, the commutator will only drive pins 1 and 2 of the motor connector P2 to work with a regular 2-wire brush-type DC motor.

The transistors of the amplifier are connected to an aluminum heat-sink bar. If you are driving more than 3 amps continuously, this bar should be attached to an additional heat-sinking surface.

Overcurrent & Thermal Protection

The amplifier is capable of driving up to 7 amps continuously and 10 amps maximum,[*] with a supply current of 12 to 48vdc (36v recommended). It uses self-protecting transistors which will

[*] The 7 amp continuous current limit is imposed by the current sense resistor, which only draws current while the PWM signal is HIGH. This resistor can handle 10 amps for about a minute. Therefore, only applications which run at full current and at high speeds for long periods need adhere to the 7 amp limit, and the ***PIC-SERVO's*** current limit parameter should be set accordingly.

limit the current to 10 amps and with automatic thermal shutdown. If you attempt to drive more than 10 amps, the transistors will go into “linear” mode, effectively increasing their resistance to keep the current at a maximum of 10 amps. The transistors will heat up very quickly in this mode, and automatic thermal shutdown will take place after a few seconds. Thermal shutdown will also take place if the heat sinking is insufficient, even at currents less than 10 amps. Once the transistors cool, they will resume normal operation automatically. The amplifier also has undervoltage protection.

Motor Power Supply

The ***PIC-SERVO 3PH*** amplifier does not have over-voltage protection, so you must take care that your power supply does not exceed the rated voltage. The recommended supply voltage of 36v max. will allow you to mostly ignore the finer points of power supply regulation.

The absolute maximum supply voltage rating is 48v. If you do need to use a supply voltage in the 36 to 48v range, the use of a linear power supply with a *regulated* output is recommended. If you are using an unregulated power supply, you must ensure that the peak voltage does not rise above 48v. If the output does rise above 48v, the amplifier’s drive transistors may be damaged.

You should also note that whenever your motor decelerates, it acts as a generator pumping current *into* your power supply. Many switching power supplies are not designed for sinking current, and will not regulate the output adequately. Linear power supplies with insufficient output capacitance will also have difficulty regulating the voltage while decelerating.

If you are unsure of your power supply’s ability to sink current, you should attach transient voltage suppressors between each of your motor’s leads and to the power supply ground. (The cathode of each suppressor should go to the motor lead, with the anodes connected to ground.) The voltage rating for the transient voltage suppressor should be just above your maximum power supply voltage.

Lastly, because the logic power supply, the motor power supply, and your host computer are all connected with a common ground, we recommend that your motor power supply and your logic power supply have floating outputs to avoid ground loops.

Current Sensing

Current sensed by the amplifier is read through the ***PIC-SERVO*** chip’s A/D input. The current sense value is somewhat non-linear, depending on your motor winding constants and your supply voltage. It is provided mostly for use with the ***PIC-SERVO***’s software current limiting feature for protecting the motor. (The amplifier is self-protected against overcurrent and is self-limiting to 10 amps). The following is a rough guide for setting the ***PIC-SERVO***’s current limit parameter:

Current	*Current limit setting*
3 amps	3
4	5
5	9
6	13
7	17
8	21
9	25
10	0 (no software limiting)

For more accurate current limiting values for your particular motor and supply voltage, measure the peak current across the 0.10 ohm current sense resistor, R7, with an oscilloscope. Look at the corresponding A/D value as various loads are placed on the motor. Note the current limit value should always be odd (1,3, 5, etc.) or set to 0 to disable current limiting altogether.

12 Step Commutation

The 3-phase commutation circuit has an internal velocity estimator which can be used to introduce 6 intermediate commutation steps into the standard 6 step commutation to produce a 12 step commutation sequence. This 12 step sequence can reduce the theoretical torque ripple from 13.4% to less than 4%, smoothing the motion and reducing the excitation of mechanical resonances.

The 12 step commutation will only be performed over a limited velocity range, and only if the velocity varies by less than 25% between changes in the hall sensor states. Normal 6 step commutation is used otherwise. 12 step commutation is enabled by placing jumper JP9 in the 1-2 position, or disabled by placing it in the 2-3 position.

12 Step Commutation Velocity Range:

Minimum hall sensor transition frequency: 2.4 Hz (0.2 rev/sec for a 4 pole motor)
Maximum hall sensor transition frequency: 153 Hz (12.75 rev/sec for a 4 pole motor)

3.4 Limit Switch Inputs

Inputs for 2 limit switches appear on connector P4. They connect directly to the ***PIC-SERVO*** chip's limit switch inputs and have 4.7K pull-up resistors. The limit switch inputs can be connected to mechanical switches, or to electronic sensors which have TTL or open collector - type outputs.

3.5 Physical Dimensions

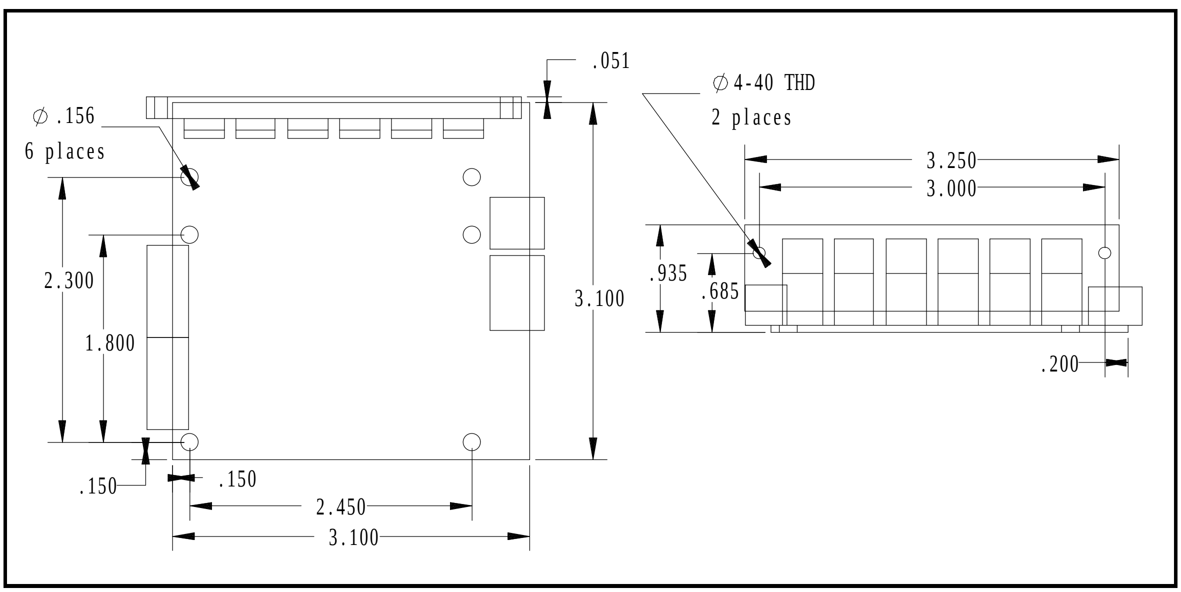


Figure 2 - ***PIC-SERVO 3PH*** Motor Control Board Dimensions

4. Contact Information

Additional information may be found from these sources:

J R Kerr Automation Engineering **www.jrkerr.com**

Data sheets, application notes and test code may be downloaded from: "http://www.jrkerr.com/docs.html". Technical support is provided via e-mail. Send your questions to "techsupport@jrkerr.com".

HdB Electronics **www.hdbelectronics.com**

Distributor of ***PIC-SERVO*** products. Phone: 1-800-287-9432, Fax: 1-650-368-1347, Phone from outside US: 1-650-368-1388.

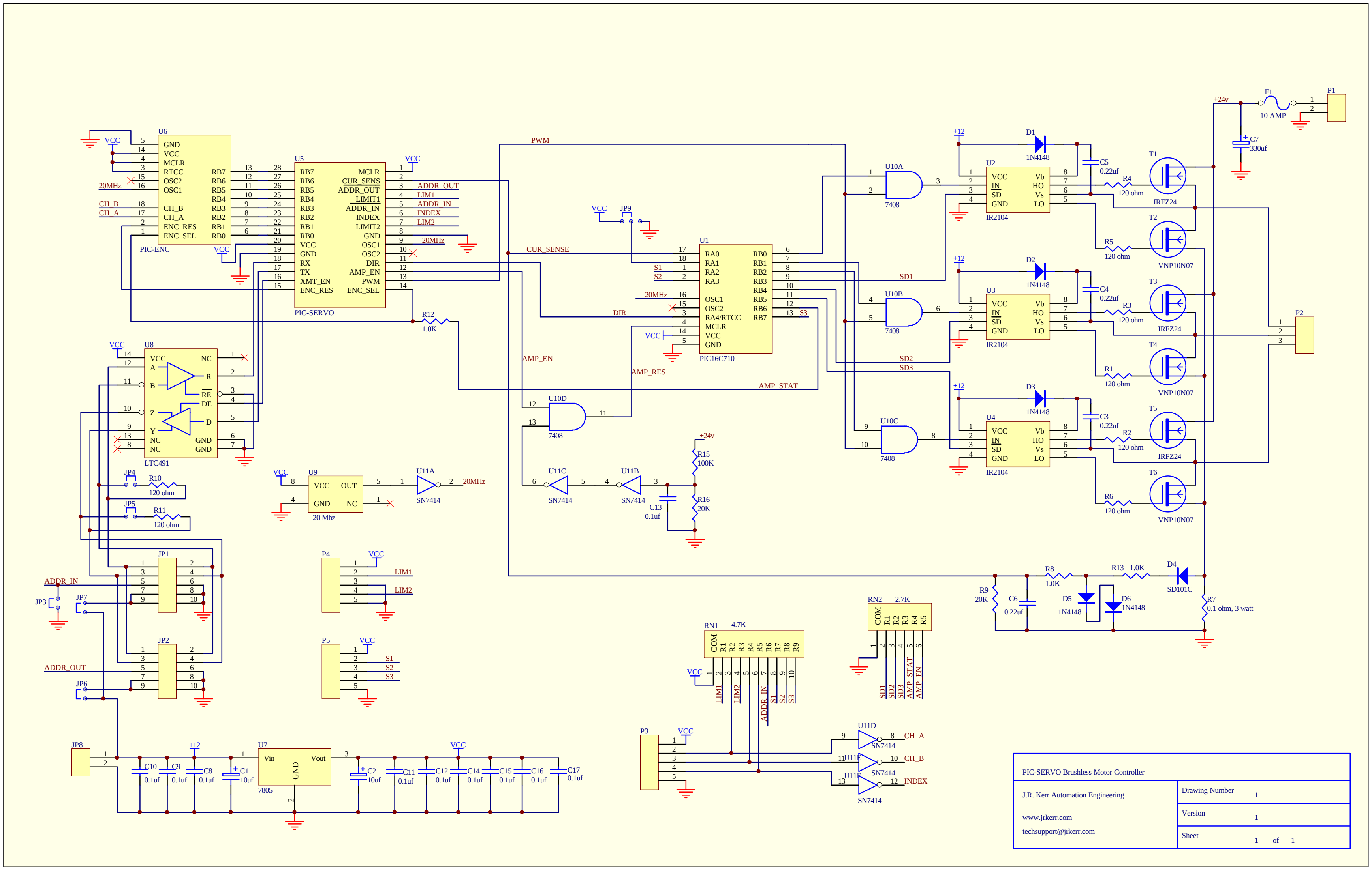


Figure 3 - ***PIC-SERVO 3PH*** Motor Control Board Schematic