Application Note: A *PIC-SERVO SC* Based High-Power Servo Controller Using the IRAMS10UP60B 3-Phase Driver

- Integrated servo controller/amplifier for 3-Phase brushless or conventional DC motors
- Uses the ***PIC-SERVO SC*** motion control chip
- 7.5 amp continuous, 15 amp peak current
- Motor supply voltage from 24 to 90v
- Compatible with other ***PIC-SERVO*** controller modules
- CAD files included

1.0 Overview

This application note describes the construction of a high-power integrated servo controller using the ***PIC-SERVO SC*** motion control chip and the IRAMS10UP60B driver module from International Rectifier. This application note includes schematic and PCB layout files for fabricating circuit boards using ExpressPCB software (available from *expresspcb.com* at no charge). The following additional files are included:

PSSC_IRAMS.SCH	Schematic file
PSSC_IRAMS.PCB	PCB layout file
PSSC_IRAMS.TXT	Part list for the circuit

2.0 The *PIC-SERVO SC* Controller

The ***PIC-SERVO SC*** is a single chip motion control system which interfaces to standard serial ports and to amplifiers with little additional circuitry. It provides servo control and motion profiling functions as well as many other features which are needed for a complete motion control system. Please download the data sheet PICSRVSC.PDF from *jrkerr.com/docs.html* for complete details on the functionality and use of the ***PIC-SERVO SC*** controller chip.

3.0 The IRAMS10UP60B Driver

The IRAMS10UP60B driver is hybrid module consisting of three high-voltage IGBT half-bridge drivers as well as interface circuitry for safely switching the IGBT transistors. It has a built-in current sense shunt resistor which provides a current sensing output, as well as being used for internal over-current shutdown. It also has a built-in thermistor for temperature sensing. (External circuitry must be provided for over-temperature shutdown.) The IRAMS10UP60B interfaces directly to logic level signals.

The IRAMS10UP60B requires two supply voltages: a 12v to 20v logic supply (which is also used for turning on the lower IGBT transistors) and a high-voltage motor supply. Although the IRAMS module can use a motor supply voltage as high as 450v, this application circuit is designed for a maximum supply voltage of 90v. A circuit design for higher voltage would require additional isolation safety features and a significantly different circuit layout.

The peak current per phase is 15 amps, limited by the IRAMS10UP60B's internal over-current shutdown. The continuous current rating can be as high as 10 amps, but it depends on the amount of heatsinking, the PWM switching frequency, and the commutation switching frequency. Please see the IRAMS10UP60B data sheet from International Rectifier for complete details.

An internal thermistor is used to protect the IRAMS10UP60B from thermal failure. External circuitry must be provided to make sure the drivers are shut off when the thermistor temperature reaches 100 degrees C (about 6K ohms).

The IRAMS10UP60B is designed for driving AC motors or 3-Phase brushless motors. However, the ***PIC-SERVO SC*** also allows it to be used to drive conventional brush-commutated DC motors.

4.0 The Application Circuit

The application circuit is shown in Figure 1. This is the same schematic as found in the file PSSC_IRAMS.SCH.

4.1 Communications

Like the other motion controllers sold by **JEFFERY KERR, LLC**, the controller in this application note uses 4-wire RS485 communications, with connectors JP1 and JP2 used for RS485 network interconnections. An LTC491 is used to convert differential RS485 signals to standard logic levels.

Also like other controllers, it has ADDR_IN and ADDR_OUT signals which are daisy-chained from one controller to the next to enable jumperless dynamic addressing. Please refer to the ***PIC-SERVO SC*** chip data sheet for a complete explanation of the communications protocol.

4.2 Driver Interface

The ***PIC-SERVO SC*** has six output signals for interfacing with driver chips: three PWM signals and Enable signals. The Enable signals indicate which of three half-bridges drivers should be enabled, and the PWM signals set the percentage “on” time for each half-bridge driver.

The IRAMS10UP60B, however, and six inputs for independently controlling each IGBT transistor. Each pair of inputs, HINx and LINx, turns on the high side or low side transistor of a given half-bridge. For example, a LOW input on HIN1 will turn on the high-side transistor of the first half-bridge, or a LOW input on LIN2 will turn on the low-side transistor of the second half-bridge. Internal logic prevents both the low and high sides of a single half-bridge from being turned on at the same time. A set of three 3-input NAND gates and three inverters are used to translate the PWM and Enable signals into the proper HINx and LINx signals.

4.3 Current Sensing

The IRAMS10UP60B has an internal current sensing shunt resistor which is connected to the Itrip pin. When any of the PWM signals is HI, current flows through the shunt resistor, and the voltage on the Itrip pin is proportional to the motor current. When the PWM signals are all LOW, however, the current recirculates rather than flowing through the shunt resistor. The current sense circuit, therefore, uses an analog switch (TC4S66F) to only connect the Itrip voltage to a hold capacitor C15 when *any one* of the PWM signals is HIGH. The PWM signals are OR'ed together using diodes and then buffered using a couple of spare inverters. Lastly, there is a 100K resistor R15 to slowly bleed the hold capacitor for when the PWM is turned off altogether. The output at the hold capacitor is finally fed into the current sense input of the ***PIC-SERVO SC***.

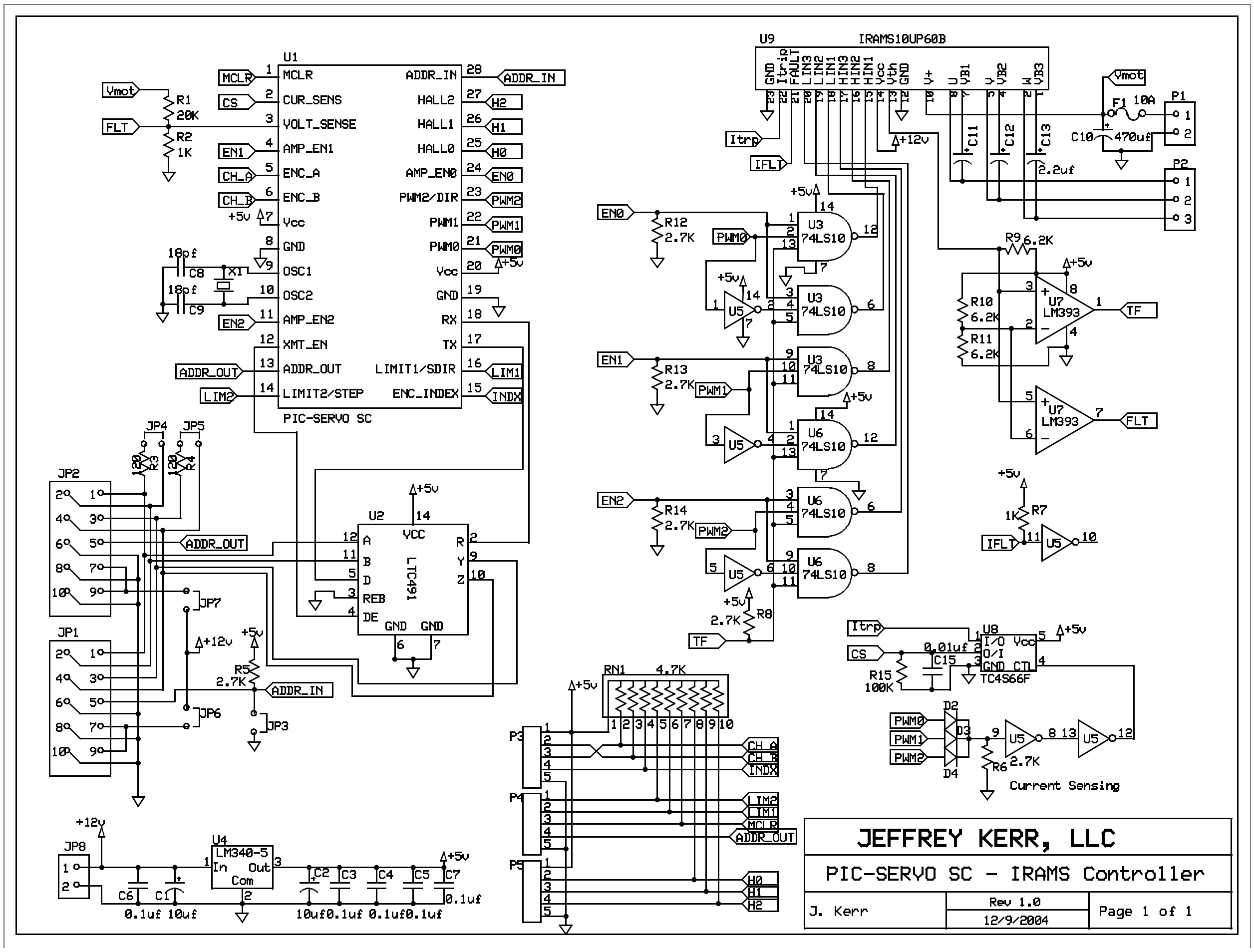

Figure 1 – ***PIC-SERVO SC*** IRAMS Schematic.

4.4 Fault Detection

There are several fault conditions which need to be detected by the ***PIC-SERVO SC***: overvoltage, undervoltage, overcurrent and thermal overload. The ***PIC-SERVO SC***, however, has only the VOLT_SENSE pin for detecting overvoltage or undervoltage conditions. The behavior of the ***PIC-SERVO SC*** is such that when the voltage on the VOLT_SENSE pin drops below 0.9v, it automatically disables the servo and sets the PWM output values to zero. Hence, with clever use of open-collector outputs, we can actually connect multiple fault signals to the VOLT_SENSE pin.

Overcurrent Faults The FAULT output of the IRAMS10UP60B is an open-collector output which goes LOW when its internal overcurrent condition is triggered. The IRAMS10UP60B will disable the drivers for about 8 milliseconds. The driver will automatically attempt to restart after this timeout period. If the excess load on the motor is removed, normal operation of the servo will resume. If the excessive load persists, a servo position error will eventually occur.

This FAULT pin is also connected inside the IRAMS module to an internal Enable input*. Therefore this pin requires a 1K pull-up resistor for operation.

Thermal Faults The thermistor in the IRAMS10UP60B is internally connected to GND. A pull-up resistor R9 on the Vth pin, and an LM393 comparator are used to detect when the resistance of the thermistor drops below about 5Kohm. You will notice that there are actually two comparators fed the same signals for detecting thermal faults:

The first comparator has an output labeled TF (thermal fault) which has a pull-up resistor and is connected to all six of the driver NAND gates. This will automatically disable all the drivers on a thermal fault.

The second comparator is left as an open-collector output and is connected to the FAULT signal at the ***PIC-SERVO SC***'s VOLT_SENSE pin. This will cause the ***PIC-SERVO SC*** to also disable the servo and set the PWM outputs to zero on a thermal fault.

Voltage Faults A voltage divider (R1 and R2) is used to scale the motor supply voltage to the input range of the ***PIC-SERVO SC***'s voltage sense pin. The voltage on this pin should be between 0.9v and 4.5v for normal operation. The values for R1 and R2 are selected to accommodate supply voltages in the nominal range of 24 to 90v. Note that the thermal and overcurrent fault inputs (both open-collector) also connected to this pin will not affect the analog VOLT_SENSE input unless a fault condition occurs.

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*At some point, International Rectifier *changed* the IRAMS10UP60B to make an internal connection to the Enable input. An earlier version of this application note had the Fault output directly connected to the VOLT_SENSE input of the ***PIC-SERVO SC*** to directly detect overcurrent faults. In the current version of the application circuit, the FAULT output simply has a pull-up resistor and is buffered through an inverter for future use.

4.5 Connector Pin Definitions

Motor Power Connector **P1** (2 position screw terminal)

Pin	*Definition*
1	Motor Power Supply 24 - 90vdc - *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	12 - 16vdc (towards the lower edge of the board)
2	Ground

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

Pin	*Definition*
1	Phase 0 for 3-phase motors, M+ for brush-type motors
2	Phase 1 for 3-phase motors, M- for brush-type motors
3	Phase 2 for 3-phase motors

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

Pin	*Definition*
1	+5v output
2	Hall sensor 0 (This signal has an internal pull-up resistor to +5v)
3	Hall sensor 1 (This signal has an internal pull-up resistor to +5v)
4	Hall sensor 2 (This signal has an internal pull-up resistor to +5v)
5	Ground

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

Pin	*Definition*
1	+5v output
2	Channel A (This signal has an internal pull-up resistor to +5v)
3	Channel B (This signal has an internal pull-up resistor to +5v)
4	Index (optional) (This signal has an internal pull-up resistor to +5v)
5	Ground

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

Pin	*Definition*
1	Limit Switch 2 (reverse limit) *or* Step Input if Step & Direction is mode enabled (This signal has an internal pull-up resistor to +5v)
2	Limit Switch 1 (forward limit) *or* Dir Input if Step & Direction mode is enabled (This signal has an internal pull-up resistor to +5v)
3	Enable input used if in Step & Direction mode (connects to MCLR) (This signal has an internal pull-up resistor to +5v)
4	Servo Fault output if in Step & Direction mode (connects to ADDR_OUT)
5	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 (7.5 - 12vdc)
8	Ground
9	Logic power (7.5-12vdc)
10	Ground

Jumpers **JP3**, **JP4**, **JP5**, **JP6** and **JP7**

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 JP1. Inserting JP7 connects logic power to JP2. These are used to control the distribution of logic power over the network cables. Normally both these jumpers are installed.

5.0 Fabrication

This application note includes files for fabricating the circuit board shown in Figure 2. These files were generated by software available from ExpressPCB.com. ExpressPCB is a low-cost service for fabricating quick-turn prototype circuit boards. To use these files, download the Schematic and Layout programs from ExpressPCB.com. Follow the instructions included with the software for opening the files and for ordering circuit boards.

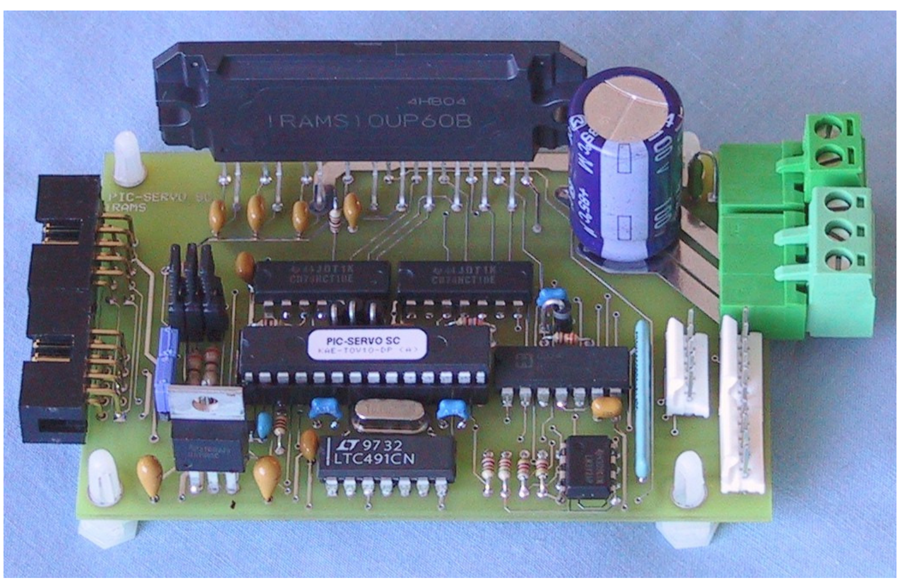

Figure 2 – ***PIC-SERVO SC*** IRAMS Board
(Note: there may be minor differences from current version of the board layout)

This application board was designed using ExpressPCB's "mini-board" service. With this service you can order three circuit boards of a specific size (2.5" x 3.8") for $51.00. The boards come without a solder mask or silkscreen legend, so you will need to print out the silkscreen layer to assist you in populating the board with components. With the same CAD files, you also can order boards using the ExpressPCB "ProtoPro" service which will include the solder mask and silk screen legend. (Note that when you order these boards, you are not ordering prefabricated boards – they will be fabricated according to the data in your .PCB file.)

All of the components on this board are thru-hole components except for the analog switch, which you will probably want to solder in place first. Note that without the solder mask, you must take care in soldering the components with metal parts that might come in contact with underlying traces. In particular, the crystal, with its metal case, and the IRAMS module itself, with its horizontal lead sections, should be elevated from the board slightly before soldering in place.

All the parts required for this board are listed in the file PSSC_IRAMS.TXT. This file also includes Digikey part numbers (see digikey.com) for convenience. The ***PIC-SERVO SC*** chip can be ordered from jrkerr.com/orders.html.

6.0 Using the Controller

The ***PIC-SERVO SC*** IRAMS controller board is very similar to the ***PIC-SERVO SC 3PH*** board sold by **JEFFREY KERR, LLC**. For the most part, you should be able to follow the documentation for that board (PSSC3PH.PDF available at *jrkerr.com/docs.html*) for using the board described here. However, there are a couple of differences worth noting:

1. The ***PIC-SERVO SC*** IRAMS board described here provided as an example and is not untended for commercial use. In particular, there is no isolation or other safety measures taken which you might need for a high-voltage application. When testing the board, first try out the board using a 24v supply. If then you need to use a higher voltage, you should use extreme caution.

2. The IGBT's of the IRAMS module will generate a lot of heat. You will have to provide a heatsink for the module if you are driving any more than a few hundred milliamps.

3. The IRAMS module needs a minimum PWM value before it will turn on the drive transistors. This means that for very low PWM values, the module will never actually drive any current. To compensate for this, you should use a Deadband Compensation value (DC) of about 10. This will eliminate the dead zone around the zero PWM output.

4. The current sense resistor in the IRAMS module is nominally 33 milliohms. This means that it will produce a A/D value of 1.7 per amp of current. Because the ***PIC-SERVO SC***'s current limit value should be set to only odd values (1, 3, 5, etc.), the motor current limit can only be set in increments of 1.2A with the lowest possible limit value of 0.6A.