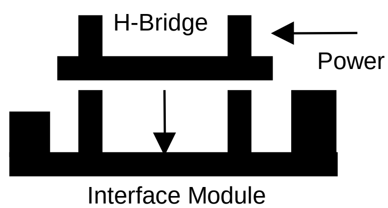
SOLUTIONS CUBED

Mounting Technique – MOSFETS face away from Interface Module, motor connections mount next to screw terminal



ICON Interface Module Data Sheet

Revision 6

October 13th, 2003

Table of Contents – Electrical / Mechanical Specifications

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1. Revision Log

Date	Rev	Description	By
11-06-01	1	Original Implementation	L. Glazner
02-28-02	2	Fixed typos in datasheet	L. Glazner
03-26-02	3	Removed retail pricing from body of datasheet	L. Glazner
07-04-02	4	Fixed typos in datasheet	L. Glazner
07-04-02	5	Added phone number to footer	L. Glazner
10-13-03	6	Changed info in figure 3 regarding _ERROR pin	L. Glazner

2. Introduction

ICON Interface Module
ICON H-Bridge Interface and Control Module

FEATURES
- Up to 12A continuous current
- Up to 40VDC brushed motors
- Adjustable PWM frequency, PWM-delta limits, and dead-band setting
- Five modes of operation
- Mode1: Direct serial control of 10-bit PWM
- Mode2: Uni-directional 10-bit ADC based PWM control
- Mode3: Bi-directional 10-bit ADC based PWM control
- Mode4: Frequency to voltage based set point speed control
- Mode5: User customizable look-up table PWM profile

2.1 DESCRIPTION
The ICON Interface Module has been designed to work seamlessly with the ICON H-Bridge module. The ICON Interface Module can act as a programming platform for the ICON H-Bridge, as a stand-alone controller, or as a serial interface between a master unit and the ICON H-Bridge.

This module provides all of the support circuitry to successfully implement set-point DC motor control when used in conjunction with the ICON H-Bridge. This circuitry includes a switching step-down regulator, 10-bit analog-to-digital conversion, indicator LEDs, frequency-to-voltage converter, and two channels of 10-bit PWM generation.

The five modes of operation include two forms of motor speed control with 0-4.096V analog control input. One mode of operation makes use of a frequency to voltage converter for speed control. A fourth mode of operation allows the user to configure a custom motor speed profile that uses the 0-4.096V analog input as the address for a look-up table containing motor speed and direction information. And finally, motor speed and direction can be controlled with a direct serial interface.

A multitude of configuration settings can be programmed via the serial interface. These settings include the PWM frequency and resolution (the default is 19.2kHz, 10-bit resolution), step limits for changes in the PWM duty-cycle, and an expandable dead-band setting. Various function setting registers and status registers can also be accessed with a serial link. In addition to the various non-volatile configuration registers, the master unit has free access to 16 EEPROM bytes stored in registers 19-34.

Ease of connectivity, a flash-based controller, and connections for in-circuit-debugging allow the ICON Interface Module to be quickly configured for custom applications. The unit measures 4.0” x 1.9” x 0.6”. Motor connections are made via a screw terminal.

3. Engineering Specifications

3.1 Absolute Maximum Ratings

These are stress ratings only. Stresses above those listed below may cause permanent damage and/or affect device reliability. The operational ratings should be used to determine applicable ranges of operation.

Storage Temperature	-55°C to +150°C
Operating Temperature	-20°C to +85°C
Motor Voltage (VM)	-0.3V to 40.0V
Voltage on logic control pins (J5)	-0.3V to +5.5V
Voltage on VM, M+, M-	65V
Motor Current Load	25A peak / 12A continuous

3.2 DC Electrical Characteristics

At T_A = 25°C, V_{MOTOR} = 24V, I_{LOAD} = 5A F_{PWM} = 19.2kHz

Characteristic	Symbol	Min	Typ	Max	Unit	Notes
Logic Supply Voltage	$+5V_{DC}$	4.5		5.5	V	
Logic Supply Current Source Capability	I_{5V}		25	50	mA	+5VDC pins can supply a modest amount of current to external circuitry
ICON H-Bridge Supply Voltage	$+12V_{DC}$	11.2		12	V	
ICON H-Bridge Supply Current Source Capability	I_{12V}		25	80	mA	Tapping into the +12V supply should be avoided if the ICON Active Cooling solution is being used on the ICON H-Bridge
Motor Voltage	V_M	1		40	V	See jumper settings for appropriate jumper location and external
ANALOG_IN voltage range	V_{ANAIN}	0		5	V	4.096V is the full-scale input for the 10-bit ADC
ADC resolution	ADC_{RES}	3.96	4	4.04	mV	Per ADC bit
TCH terminal voltage	TCH_{MAX}			16	V	
TCH crossing voltage	TCH_{CRS}		2.5		V	
Peak load current	I_{PK}			25	A	
Max continuous motor current	I_{CON}		12	15	A	
Low Level Input RX pin	V_{RXIL}			0.5	V	RX pin pulled to +5V with 10kΩ resistor
High Level Input RX pin	V_{RXIH}	2.0			V	RX pin pulled to +5V with 10kΩ resistor
Low Level Input _BRAKE pin	V_{BRKIL}			0.5	V	_BRAKE pin pulled to +5V with 10kΩ resistor
High Level Input _BRAKE pin	V_{BRKIH}	2.0			V	_BRAKE pin pulled to +5V with 10kΩ resistor

note: “Typ” values are for design guidance only and are not guaranteed

DC Electrical Characteristics (continued)

At T_A = 25°C, V_M = 24V, I_{LOAD} = 5A F_{PWM} = 19.2kHz

Characteristic	Symbol	Min	Typ	Max	Unit	Notes
Low Level Input _RESET pin	V_{RSTIL}			0.5	V	_RESET pin pulled to +5V with 10kΩ resistor
High Level Input _RESET pin	V_{RSTIH}	2.0			V	_RESET pin pulled to +5V with 10kΩ resistor
Low Level Output FLAG pins				0.6	V	FLAG pins pulled to +5V with 10kΩ resistor
High Level Output FLAG pins		5V – (I_{LOAD} * 10kΩ)				FLAG pins pulled to +5V with 10kΩ resistor, these pins are configured as inputs when not asserted
Low Level Output TX pin	V_{TXOL}			0.6	V	TX pin pulled to +5V with 10kΩ resistor
High Level Output TX pin	V_{TXOH}	3.8		4.8	V	TX pin pulled to +5V with 10kΩ resistor

note: "Typ" values are for design guidance only and are not guaranteed

3.3 AC Electrical Characteristics

At T_A = 25°C, V_M = 24V, I_{LOAD} = 5A F_{PWM} = 19.2kHz

Characteristic	Symbol	Min	Typ	Max	Unit	Notes
Communication bit period	T_{BIT}		26.04		uS	The bit period is determined by an on-board oscillator, and is temperature sensitive
Time for a command to be responded to	T_{TURN}	2		15	mS	Look-Up Restore can take as long as 1500ms
Time after power-up before device will communicate	T_{PWRUP}		530		mS	The onboard microcontroller allows 500ms for the ICON H-Bridge to power up before allowing outside communication
V_M rise time to ensure good reset	S_{VM}	0.05			V/ms	If this condition is not met then microcontroller may not power up correctly
PWM update rate	P_{PWM}		833		uS	UPDATE_PERIOD = 1, PWM frequency = 19.2kHz
PWM frequency	F_{PWM}	0	19.2	153.6	kHz	Set in PWM_RES
F to V resolution	FV_{RES}	10.11		20.22	Hz	Per ADC bit
F to V response time	FV_{RSP}		250		mS	Time to respond to 0Hz to 1kHz change in frequency

note: "Typ" values are for design guidance only and are not guaranteed

3.4 Mechanical Dimensions

The following diagram may be used to develop PCB carrying boards or enclosures used to fit the ICON Interface Module into custom designs.

Figure 1: Mechanical Dimensions

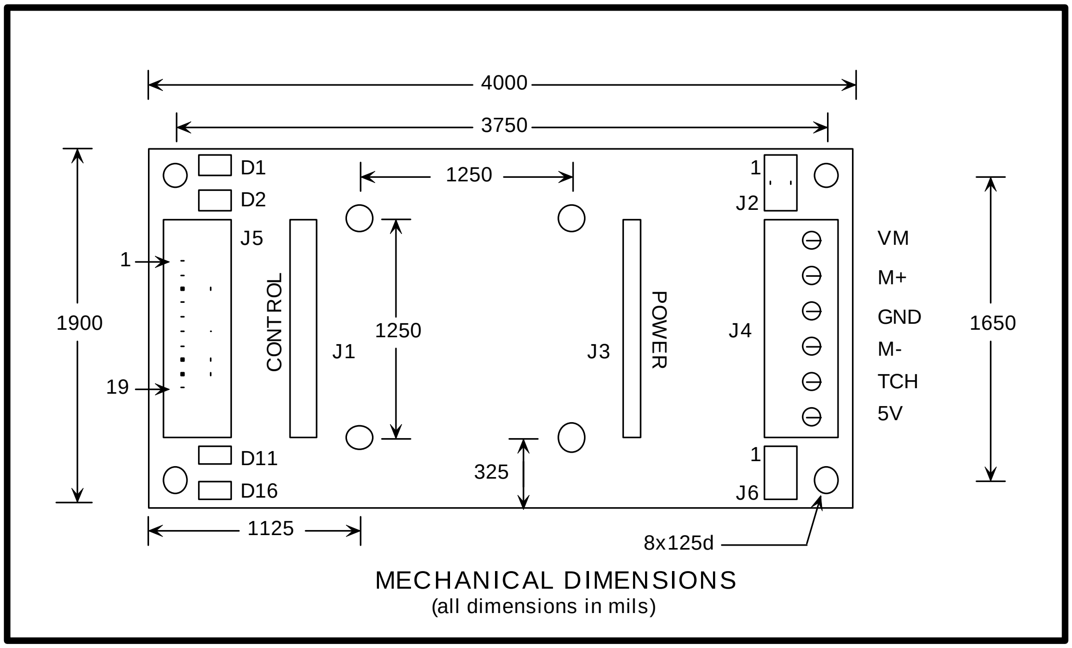


Figure 2: Mechanical Landmark Descriptions

Landmark	Type	Description
D1	LED – green	Visual indicator of +5VDC supply
D2	LED – green	Visual indicator of +12VDC supply used by ICON H-Bridge and ICON Interface Module
D11	LED – green	Communication LED, lit when valid communication is received by ICON Interface Module from a Master unit
D16	LED – red	Error indicator this LED is lit when the _ERROR pin is pulled low by the ICON Interface Module
J1	8x0.156" header	The receptacle marked "CONTROL" on the ICON H-Bridge plugs into this header
J2	2x3 header	Jumpers are used with this header to select the motor voltage setting for the ICON Interface Module
J3	8x0.156" header	The receptacle marked "POWER" on the ICON H-Bridge plugs into this header
J4	1x6 screw terminal	This screw terminal connects the brushed DC motor leads to the ICON Interface Module. This part is rated at 15A and accepts wires from 22-14AWG in size.
J5	20 pin 0.1" shrouded header	J5 is a Tyco-Amp part (PN: 103308-5) that can be used with CW Industries cable (PN: C3AAT-2006G). Both of these parts are available through Digi-Key (www.digi-key.com).
J6	2x3 jumper header	Jumpers are used with this header to connect the frequency to voltage conversion circuitry to the ANALOG_IN pin on J5, a jumper setting also exists to connect the TCH terminal to a 10kΩ +5V pull-up resistor

3.5 Connectivity Overview

The ICON Interface Module possesses two 8x0.156" headers for direct connection to the ICON H-Bridge. The ICON H-Bridge should be mounted so that the receptacle labeled "POWER" is above the header labeled "POWER" on the ICON Interface Module. The DC motor connections are made through J4 (a screw terminal). Control and programming interface lines are made through J5. The connections for J5 and J4 are listed below.

Figure 3: ICON Interface Module J5 Pin Definitions

Pin	Name	Type	Description
1	VCC_EXT	POWER	This pin is used to provide a +12VDC supply to the interface module and H-Bridge when the motor voltage is less than 10V, otherwise it can remain unconnected
2	_RESET	INPUT	Pulling _RESET low performs a hardware reset of the ICON Interface Module, this pin should be left unconnected if not used
3	ICSP1	ICSP	In circuit serial programming pin 1, used by Microchip DV164002
4	ICSP2	ICSP	In circuit serial programming pin 2, used by Microchip DV164002
5	ICSP3	ICSP	In circuit serial programming pin 3, used by Microchip DV164002
6	ICSP4	ICSP	In circuit serial programming pin 4, used by Microchip DV164002
7	GROUND	POWER	Ground return, , used by Microchip DV164002
8	ANALOG_IN	INPUT	Analog control input, this pin should be left unconnected if the ICON Interface Module is operating in Speed Control mode
9	+5VDC	POWER	+5VDC output, can supply up to 25mA, should be left unconnected if not needed
10	+5VDC	POWER	+5VDC output, can supply up to 25mA, should be left unconnected if not needed
11	GROUND	POWER	Ground return
12	_BRAKE	INPUT	Pulling _BRAKE low forces the ICON Interface Module to clear its PWM register
13	RX	INPUT	TTL level, 8N1, 38.4kBPS serial reception pin (data from the Master unit)
14	TX	OUTPUT	TTL level, 8N1, 38.4kBPS serial transmission pin (data to the Master unit)
15	COM_FLAG	OUTPUT	COM_FLAG is driven low if communication to the ICON H-Bridge fails, this pin is driven low when asserted but configured as an input when not asserted
16	TEMP_FLAG	OUTPUT	TEMP_FLAG is driven low if IH_STATUS register shows the OVER TEMP flag is set, this pin is driven low when asserted but configured as an input when not asserted
17	AMP_FLAG	OUTPUT	AMP_FLAG is driven low if IH_STATUS register shows the OVER AMPS flag is set, this pin is driven low when asserted but configured as an input when not asserted
18	NO_CONNECT	NC	This pin should be left unconnected
19	_ERROR	OUTPUT	The ERROR output is asserted (drive low) when the ADC_FAIL, HCOM_FAIL, AMPS_TRIP, TEMP_TRIP, or I2C_FAIL status bits are set, D16 will be lit when _ERROR is asserted
20	GROUND	POWER	Ground return

Figure 4: ICON Interface Module J4 Terminal Definitions

Terminal	Name	Type	Description
1	VM	POWER	The primary supply voltage connects to this terminal
2	M+	POWER	The positive lead of the brushed DC motor, or other load, connects to this terminal
3	GND	POWER	The supply voltage return connects to this terminal
4	M-	POWER	The negative lead of the brushed DC motor, or other load, connects to this terminal
5	TCH	INPUT	A tachometer or encoder can be connected to the TCH pin that connects to the frequency to voltage converter, frequencies up to 20kHz, and signal voltages up to 16V can be applied to this terminal
6	5V	POWER	This terminal can be used to power an encoder or tachometer circuit, the external circuitry should draw very little current (a maximum of 25mA)

3.6 Jumper Settings

Located above and below the screw terminal (J4) the ICON Interface Module maintains a pair of 2x3 dual headers used to select different operating configurations. Component J2 (located closest to terminal 1 of the screw terminal) must be set to match the motor voltage that is being used. The component J6 is also used for jumper settings. J6 jumpers are used to configure and connect the frequency to voltage conversion circuitry to the ANALOG_IN pin of the ADC.

3.6.1 Power Supply Jumper Settings (J2)

As a rule of thumb only one jumper should be connected to J2 at any time. The one exception is discussed below. J2 is used to select the circuitry being used to power the ICON Interface Module, as well as the ICON H-Bridge.

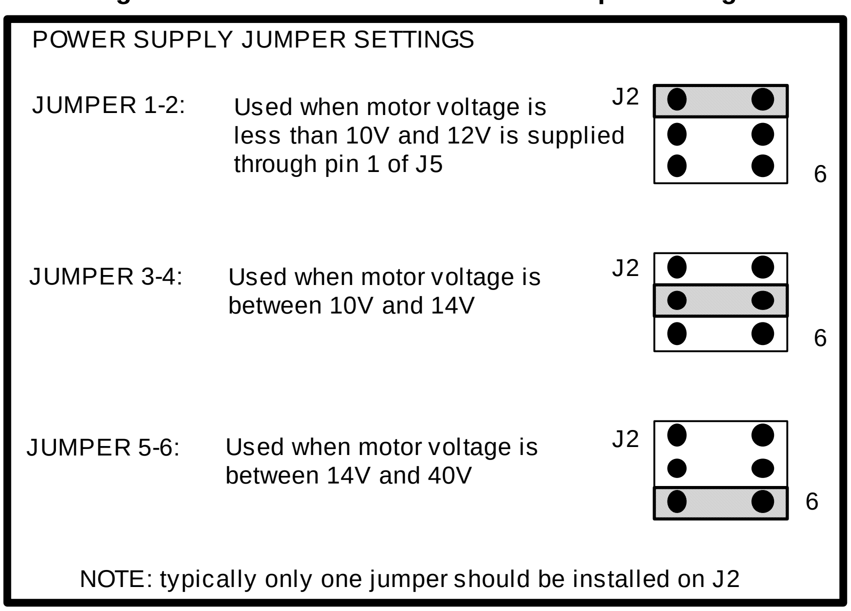
For motor voltages of 14VDC to 40VDC the jumper should be placed across pins 5 and 6 of J2 (jump J2(5:6)). This connects a step-down switching regulator that is used to provide roughly +12VDC to the ICON H-Bridge and powers the linear regulator used to generate +5VDC needed by the ICON Interface Module.

Jump J2(3:4) if your motor voltage falls within the range of 10VDC to 14VDC. This jumper bypasses the switching regulator mentioned previously, and allows the main supply voltage to power the ICON H-Bridge directly. In this case the linear regulator providing +5VDC for the ICON Interface Module is also powered directly from the motor voltage.

For motor voltages of less than 10VDC jump J2(1:2) and provide a separate +12VDC supply at pin 1 of J5 (labeled VCC_EXT). The voltage at VCC_EXT will directly power the ICON H-Bridge and the linear regulator used to power the ICON Interface Module. Supply voltages greater than 14V should not be connected to VCC_EXT.

Previously it was mentioned that only one jumper should be connected to J2 at any given time. If your system is running on 10VDC to 40VDC (you are not providing power at VCC_EXT) then you can tap into the +12VDC voltage by jumping J2(1:2). The +12VDC supply (which is typically closer to 11.5V due to a protection diode) can be accessed at J5 pin 1 (the VCC_EXT pin). This supply can source about 200mA of current. About 25mA could be spared for external circuitry other than the ICON modules.

Figure 5: ICON Interface Module J2 Jumper Settings



3.6.2 Frequency to Voltage Converter Jumper Settings (J6)

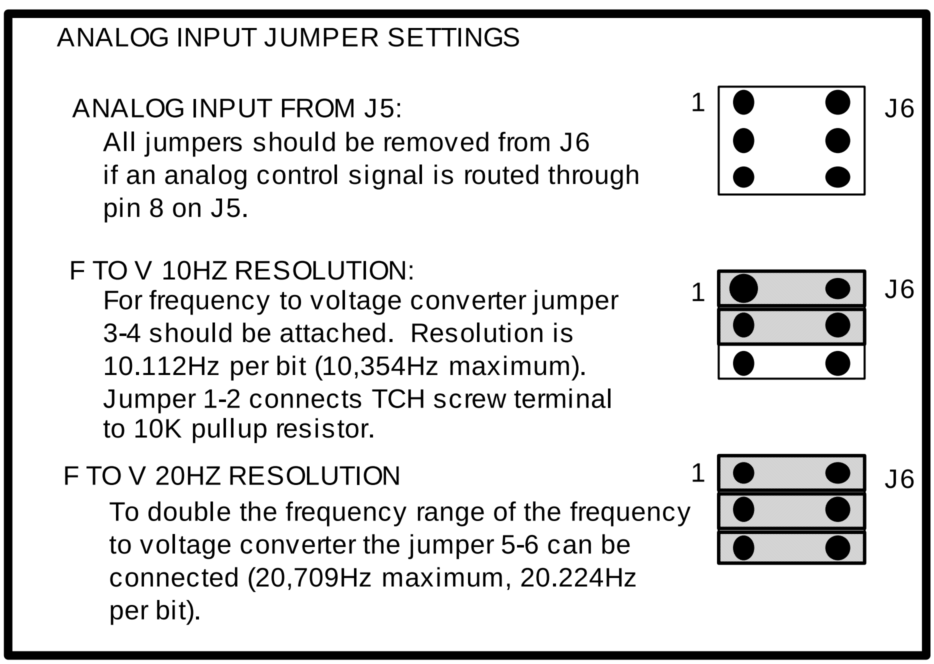
The ICON Interface Module can operate in Speed Control mode where the actual ADC input (stored in A_ANALOG_x registers) is compared to the desired ADC value (this is user defined and stored in D_ANALOG_x registers). Many applications require a motor to turn at a constant speed, and motors are often equipped with tachometers or encoders that can be used to measure the operating speed of a motor. For this reason the ICON Interface Module comes with an on-board frequency to voltage (F-to-V) converter.

When connecting a tachometer or encoder to the ICON Interface Module there are two pieces of information that must be known. First, does your output signal require a pull-up resistor? Many encoders and tachometers have open-collector outputs. For these devices you should jump J6(1:2) which connects a 10kΩ resistor between the TCH and 5V terminals. The second piece of information is the maximum frequency that you expect to see coming out of your tachometer or encoder. For signals less than 10kHz jump J6(3:4) and for signals less than 20kHz jump J6(3:4) and J6(5:6). If J6(3:4) is jumped then pin 8 of J5 (ANALOG_IN) must be left unconnected.

Some design tradeoffs were made in the implementation of the F-to-V circuitry that should be discussed. First the tolerance of the circuit is somewhat wide due to component selection. Additionally, since applications involving motors are typically noisy, components were selected to enhance response time, which has the effect of producing an output voltage that can be up to 20mVpp. It is also of note that the ICON Interface Module’s update rate will need to be slowed down to prevent the corrections in motor speed from overshooting their mark (this causes a “loping” sound in the motor). To do this the PWM_STEP value should be reduced to “1”, and the PWM_UPDATE register should be incremented until the motor responds smoothly to changes in speed.

The theoretical resolution of the F-to-V circuit is 10.112Hz per ADC bit if J6(3:4) is jumped. This range of operation can be doubled by jumping J6(3:4) and J6(5:6). Jumping both of these points has the effect of doubling the minimum resolution to 20.224Hz per bit.

Figure 6: ICON Interface Module J6 Jumper Settings



4. Operating Information

4.1 Overview

The ICON Interface Module has five different modes of operation. The first of these modes is a simple serial interface for motor speed and direction control. Four of these modes require an analog control voltage. The last of the analog control modes, Speed Control, can make use of frequency to voltage conversion circuitry provided on the ICON Interface Module.

The modes of operation have been designed to allow a significant level of customization for the end user. While the ICON Interface Module does not employ a PID filter it does allow for a variety of feedback based set point controls. The ICON Interface module has been designed to operate as a programming platform for the ICON H-Bridge, a stand-alone motor speed controller, or to facilitate control and communication of the ICON H-Bridge for a Master unit.

The specific mode of operation is defined by the bit settings in the IM_FUNCTION register.

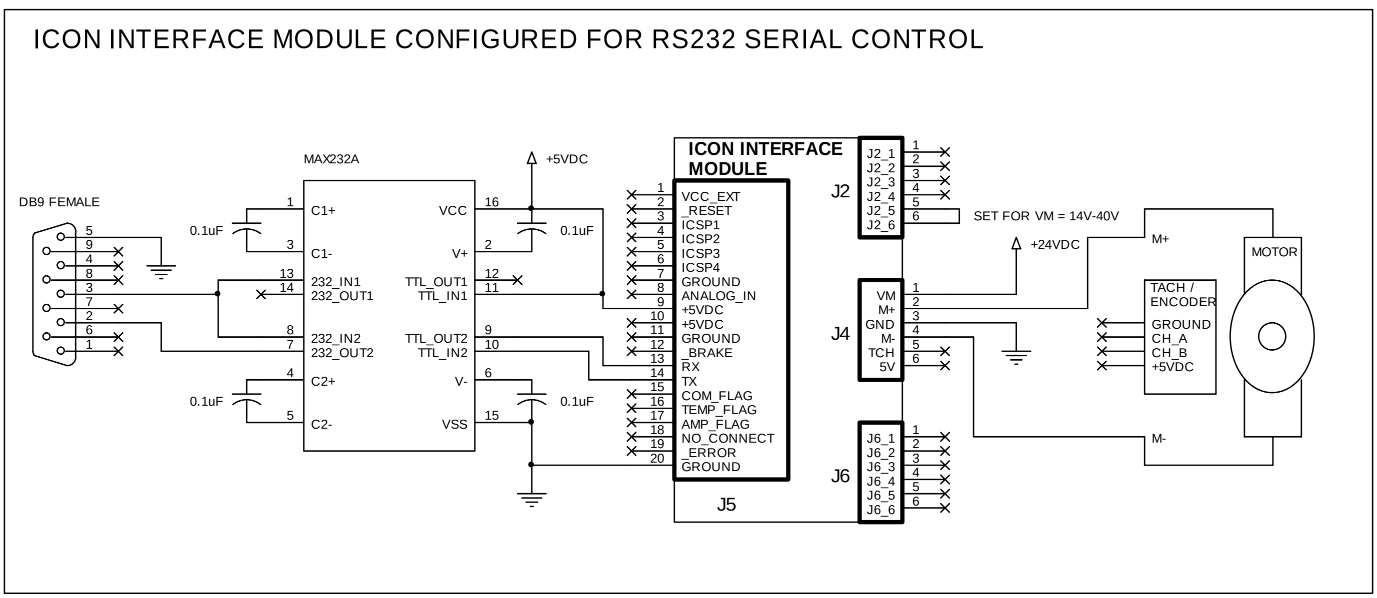
4.2 Serial Control Mode

The default mode of operation for the ICON Interface Module is the serial control mode of operation. When in this mode motor speed and direction are determined by the values sent to the ICON Interface module's PWM_x registers via the SetDC command (See the ICON Interface Communication Protocol in this data sheet for specific information on the command structure).

The serial control interface would also be used if the ICON Interface Module were to be used as a programming platform for ICON H-Bridges destined for use in a custom application. Using the ICON Interface Module as a programming platform is simplified with the ICON Adapter Board and the ICON Interface Software. Furthermore, custom firmware may be written for the ICON Interface microcontroller and downloaded to it via the ICON Adapter Board and Microchips DV164002 In-Circuit-Debugger (ICD) module.

There are several uses and methods of utilizing the ICON Interface Module's serial control mode of operation. Some of them are sampled here.

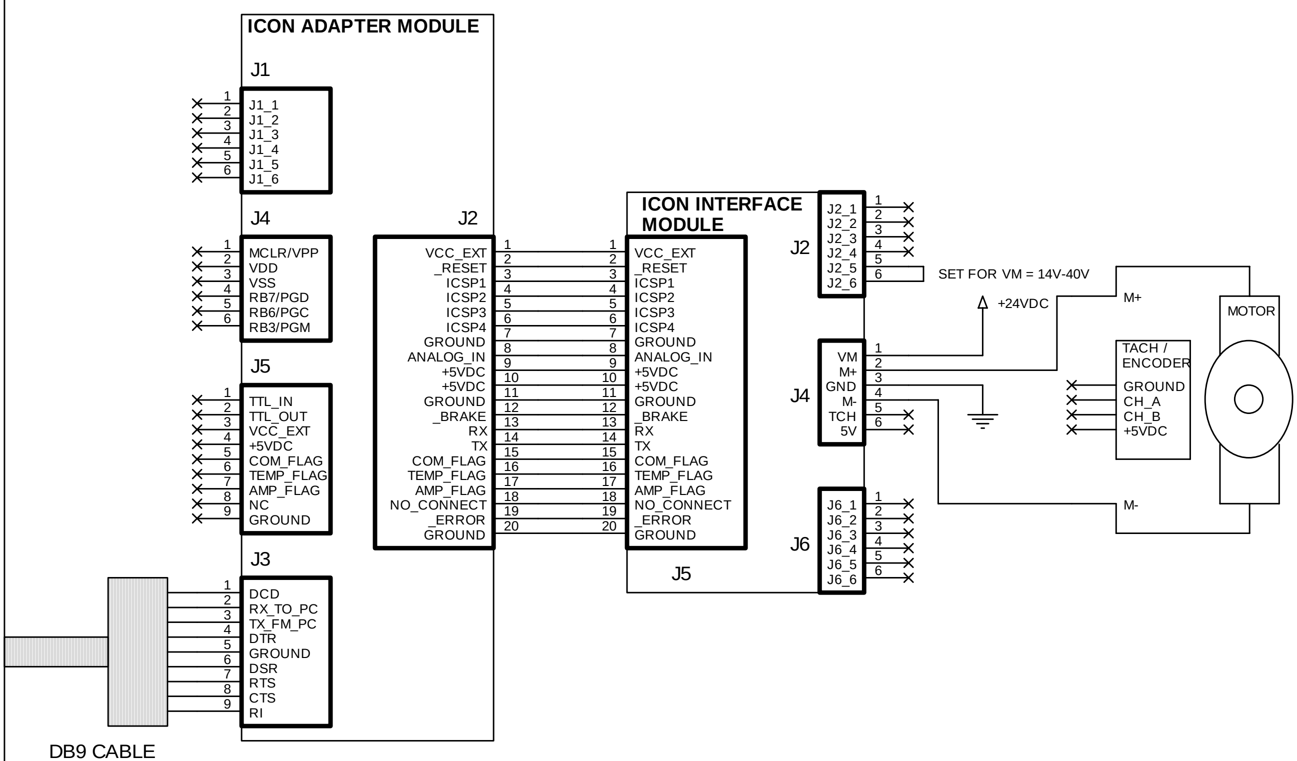
Figure 7: ICON Interface Module PC Serial Port Connection



Solutions Cubed provides a useful development tool for the ICON Interface Module. The ICON Adapter Board provides RS232 to TTL conversion circuitry, connectors, test headers, a potentiometer, reset switch, brake switch, and a programming/emulation port. The ICON Adapter Board was designed to ease testing and allow quick connectivity to the ICON Interface Module when used in conjunction with the ICON Interface Module Software.

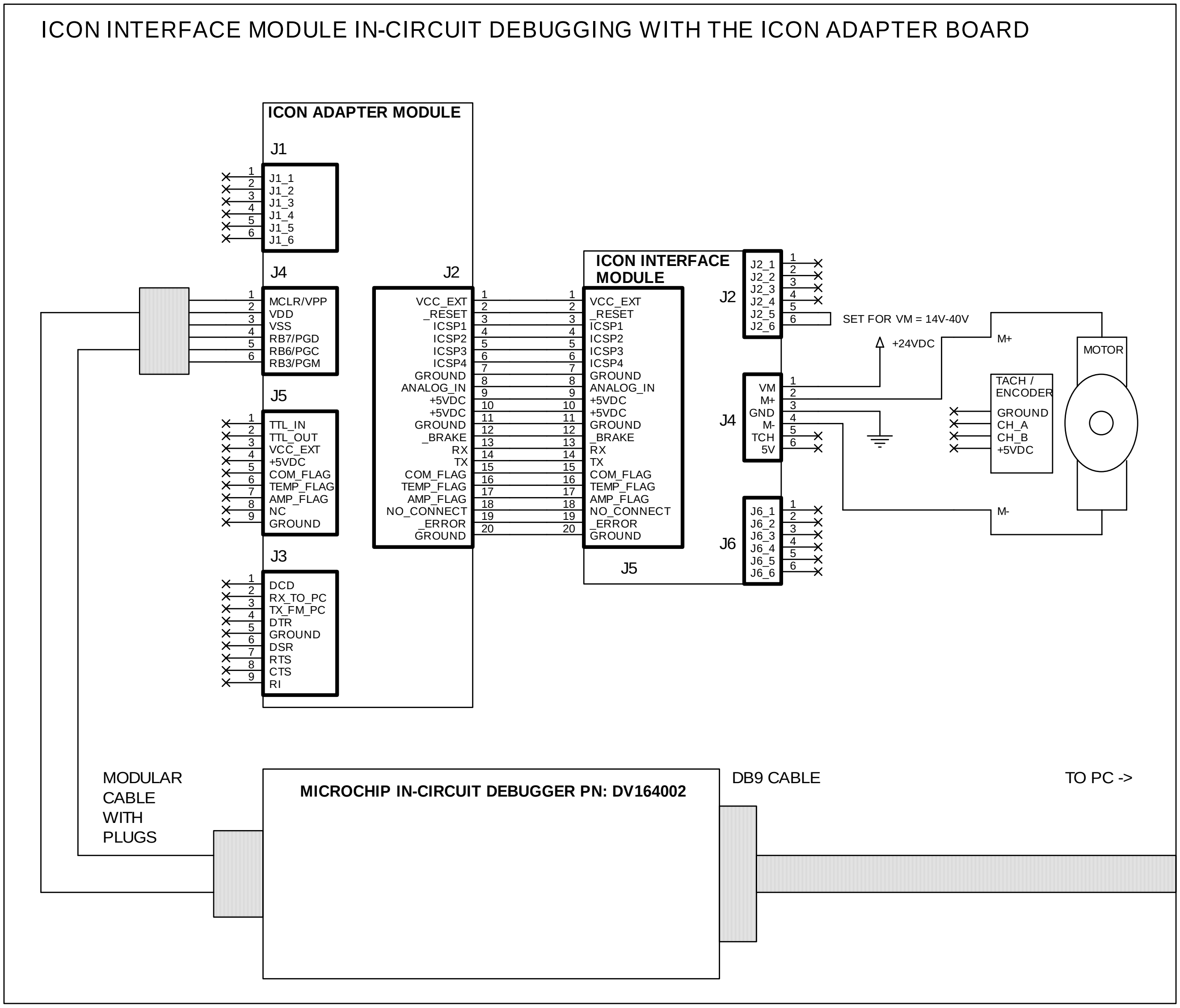
Figure 8: ICON Interface Module with ICON Adapter Board

ICON INTERFACE MODULE CONNECTIVITY TO A SERIAL PORT WITH THE ICON ADAPTER BOARD



In addition to simplifying serial connectivity the ICON Adapter Board can be used to download custom firmware into the PIC16F873 loaded onto the ICON Interface Module. Solutions Cubed provides a sample piece of firmware (available at **www.solutions-cubed.com)**. This firmware can be used as the framework for a custom solution that interfaces directly to the ICON H-Bridge. Custom firmware may be downloaded into the ICON Interface Module with Microchip's DV164002 in-circuit-debugger (ICD module) and the ICON Adapter Board. The ICD module can be used with Microchip's MPLAB programming environment and facilitates in-circuit-debugging with a single break point, as well as in-circuit-serial-programming.

Figure 9: ICON Interface Module with DV164002 ICD Module



4.3 Uni-Directional Analog Control Mode

Uni-Directional Analog Control mode reads the voltage at pin 8 of J5 (ANALOG_IN) and uses it as a setting for the PWM_x registers. For instance, if the ICON Interface Module reads a voltage of 2.048V at ANALOG_IN, the A_ANALOG_x registers should read 512 (0x200 or half of full-scale). This translates into a PWM output of 50% positive duty cycle. The PWM_RES, UPDATE_PERIOD, PWM_STEP, and DEAD_BAND registers can effect the result that finally gets loaded into the PWM_x registers. For instance, if the PWM_STEP value is set to 2 and the control voltage were to go from 0V to 2.048V instantaneously, the PWM output would not reach half scale for 256 update periods (213ms for 19.2kHz PWM frequency and UPDATE_PERIOD register value of 1).

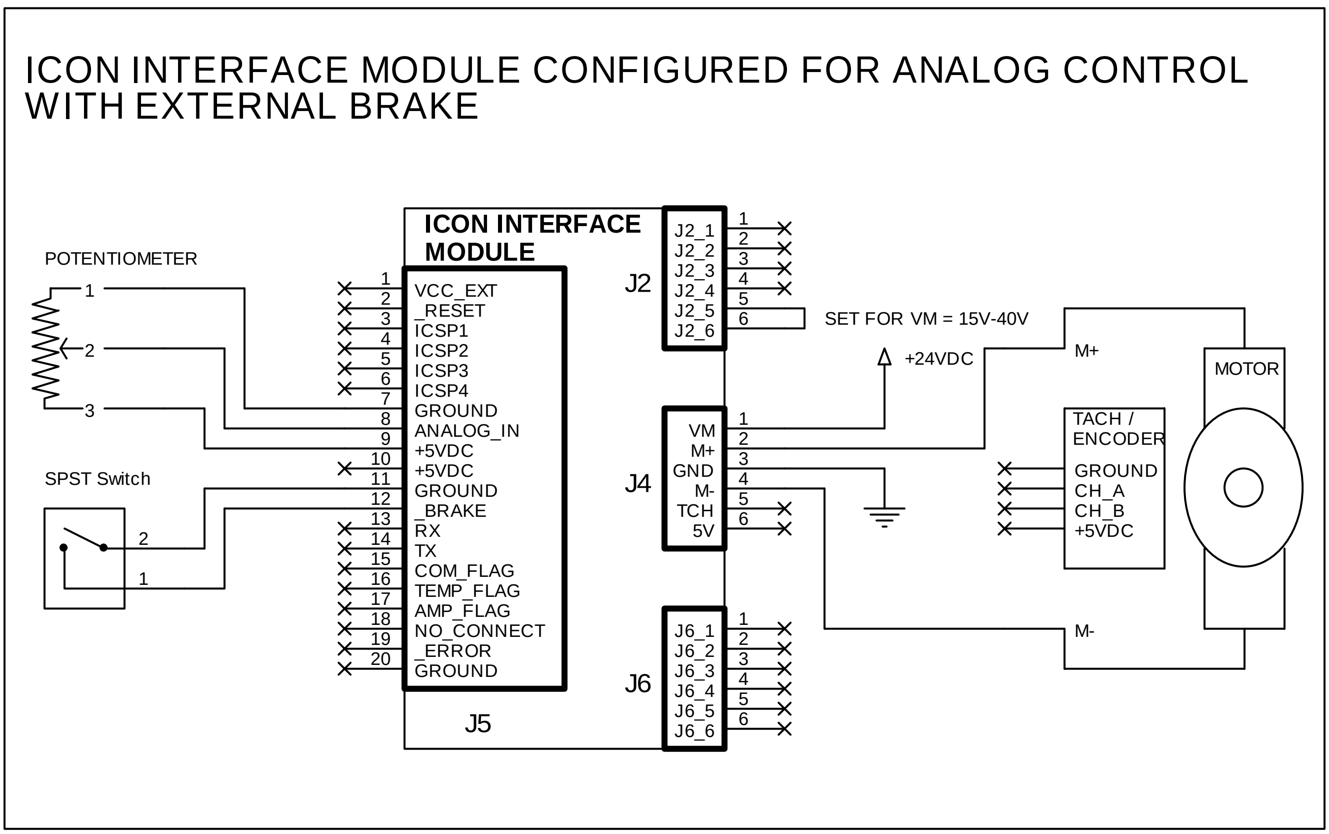
The PWM update is once every 16 PWM periods for the default settings. This translates to one update every 833us. The value in the UPDATE_PERIOD can be used to extend the PWM update time. Slow update periods may be necessary for some applications.

The PWM_RES register is used to define the frequency of PWM operation for the ICON Interface Module. As the frequency goes up, the PWM resolution goes down.

PWM_STEP is used to limit the change in the PWM ouput from one update to the next. This value can be used to smooth the PWM output after abrupt transitions in the analog control voltage. The largest step value allowed is 255 or 0xFF.

Any analog connection to the ANALOG_IN pin should be limited to values between 0V and 5V, and should have a-source impedance of less than 10kΩ. The full scale reading for the ADC occurs at 4.096V.

Figure 10: ICON Interface Module with Analog Control (VM = 24V)



4.4 Bi-Directional Analog Control Mode

Bi-Directional Analog Control mode reads the voltage at pin 8 of J5 (ANALOG_IN) and converts it into a setting for the PWM_x registers. The conversion takes place by subtracting 512 (0x200) from the A_ANALOG_x registers, and multiplying the result by 2. This has the effect of placing the "PWM off" point at 2.048V. A voltage of 0V then becomes (0–512) x 2 = -1024 (limited to –1023 internally) which forces the PWM_x registers to run at full-scale reverse. Likewise a voltage of 4.096V at ANALOG_IN creates a condition where the motor is running full forward. Because of the multiplication that occurs when the ADC value is converted to a PWM value the PWM output is only 9 bits for this mode of operation (9 bits forward and 9 bits reversed).

The DEAD_BAND in centered at 2.048V when operating in Bi-Directional Analog Control mode.

The PWM update is once every 16 PWM periods for the default settings. This translates to one update every 833us. The value in the UPDATE_PERIOD can be used to extend the PWM update time. Slow update periods may be necessary for some applications.

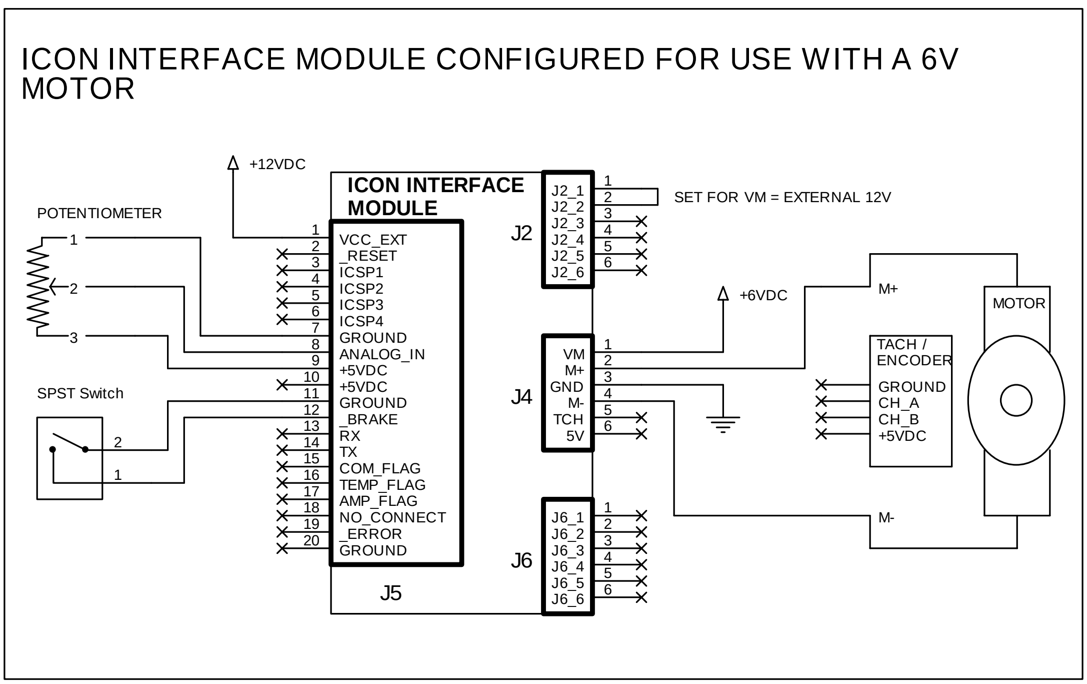
The PWM_RES register is used to define the frequency of PWM operation for the ICON Interface Module. As the frequency goes up, the PWM resolution goes down.

PWM_STEP is used to limit the change in PWM registers from one update to the next. This value can be used to smooth the PWM output after abrupt transitions in the analog control voltage. The largest step value allowed is 255 or 0xFF.

Any analog connection to the ANALOG_IN pin should be limited to values between 0V and 5V, and should have a source-impedance of less than 10kΩ. The full scale reading for the ADC occurs at 4.096V.

The connection diagram below is also an example of how to operate the ICON Interface Module and ICON H-Bridge with motors requiring less than 10V.

Figure 11: ICON Interface Module with Analog Control (VM = 6V)



4.5 Look-Up Table Control Mode

When operating in look-up table control mode the ICON Interface Module uses the voltage at the ANALOG_IN pin as an address for a look-up table stored in memory. The address values range from 0 to 1023. From the factory each address is loaded with its own value (addresses 0-1023 contain PWM values of 0-1023 respectively). This look-up table is stored in "Flash" memory and is therefore non-volatile.

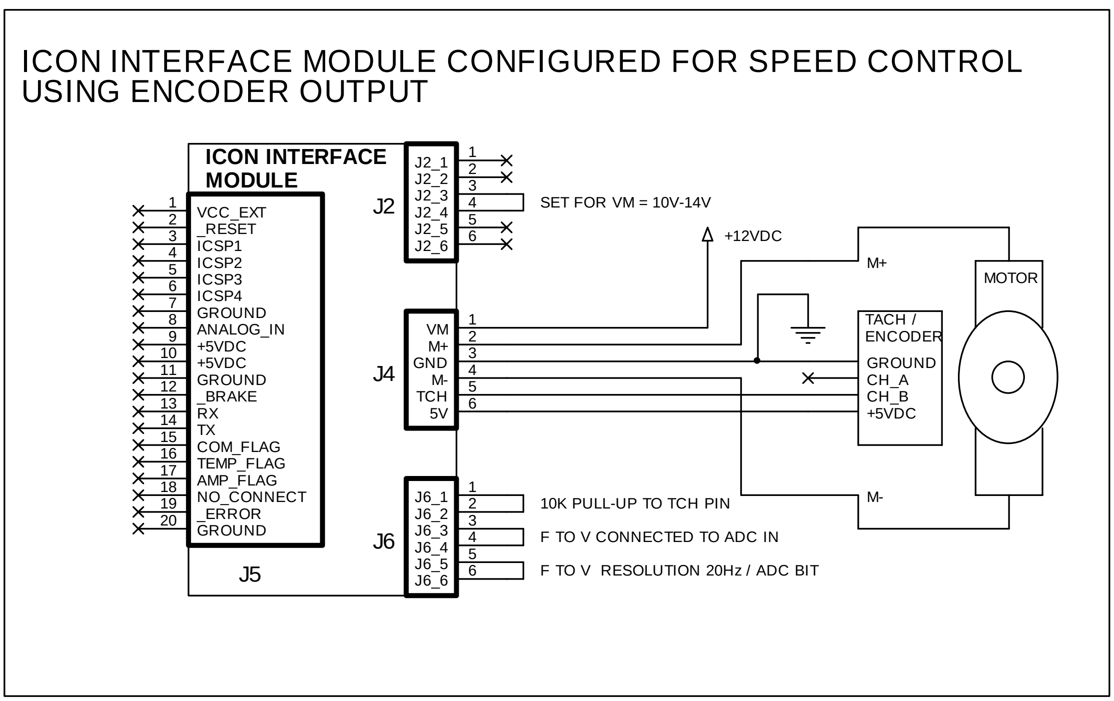
The true value of the look-up table control mode is in the ability to configure custom motor control profiles based on the control voltage available in the system. Simulated gears and a minimized reverse could be used on robotic units that don't need full-scale reverse. The look-up table could be configured to run at full reverse with an input of 4.096V and full forward at 0V. Systems that only provide output voltages of 1V to 2V could be used without signal conditioning circuitry between the ICON Interface Module and the voltage source.

When the look-up table is accessed with the Look-Up Write or Look-Up Restore commands normal program operation is suspended and the motor control lines between the ICON Interface Module and the ICON H-Bridge are disabled. Furthermore, serial communication is disabled while the "Flash" memory is accessed. For these reasons the Look-Up Write and Look-Up Restore commands should only be used in a programming environment.

4.6 Speed Control Mode

The speed control mode of operation can be used to maintain a motor's speed under changing load conditions. When placed in speed control mode the ICON interface Module will modify the PWM_x registers in an attempt to force the A_ANALOG_x registers to match the D_ANALOG_x registers. The A_ANALOG_x registers contain the actual 10-bit ADC measurement. The D_ANALOG_x registers are supplied by the Master unit and represent the desired analog input. The speed control mode was designed to work with the on-board frequency-to-voltage converter, but it could be used with an analog input fed through the ANALOG_IN pin of J5.

Figure 12: ICON Interface Module using Speed Control Mode



Speed control mode is a simple set-point method of controlling a motor's speed. Since the ICON Interface Module does not employ a PID filter for making speed adjustment it tends to overshoot the desired motor speed if its registers are left in their default state. This will cause the motor to have a "loping" or revving sound. Reducing the value in the PWM_STEP register to a 1, and increasing the value in the UPDATE_PERIOD register to 2,4, or 8 can usually minimize this effect. The actual setting will have to be experimentally determined for each specific application. The desire is to have the ICON Interface Module's response to changes in the ANALOG_IN voltage follow the tachometers ability to change frequency.

The frequency to voltage converter on-board the ICON Interface Module can have a rather loose tolerance. This is due in part to the discrete components, but the primarily culprit is the IC used in converting the frequency to a usable voltage. For some systems the relationship between the frequency input and voltage output may have to be determined experimentally. The output voltage of the converter will vary roughly 20mVpp from its average, and the ideal frequency correlation to the output voltage is 10.112Hz per ADC bit. The maximum frequency measured may be expanded by placing a jumper on J6(5:6), the jumper will cause the frequency resolution to expand to 20.224Hz per ADC bit.

Figure 13 displays the voltage output of the frequency to voltage conversion circuitry responding to a 1.0kHz sweep. The frequency sweep occurs over a 250ms period. This time period is about as fast as the circuit can respond to changes in frequency.

Figure 13: Frequency to Voltage Circuit Response to 1kHz Sweep

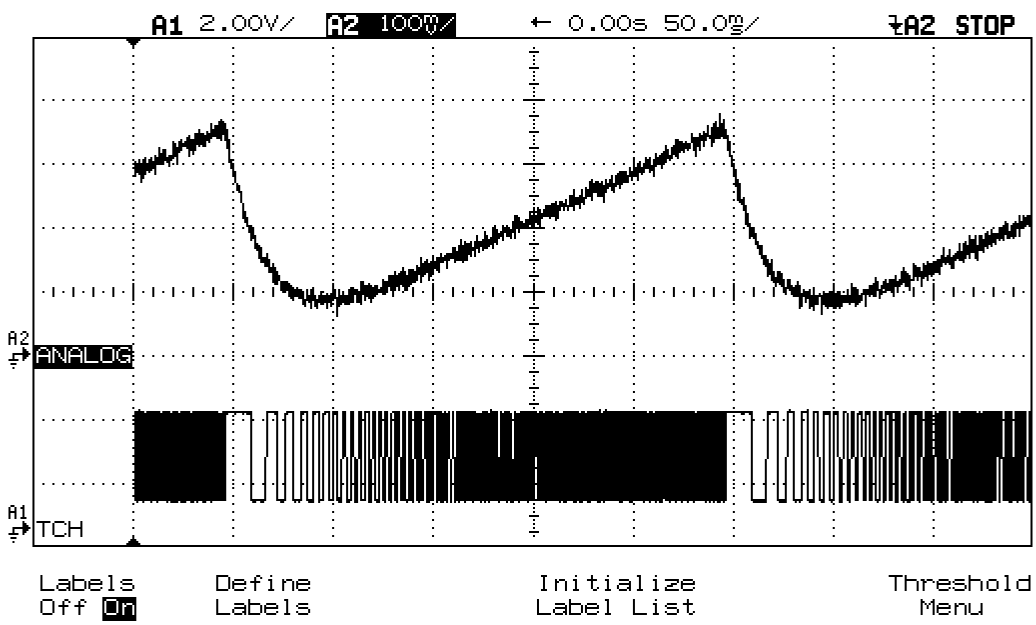


Table of Contents – Communication Protocol

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1. Connectivity

1.1 Connectivity Description

The ICON Interface Module is used to control and/or program the ICON H-Bridge. Serial data sent to the ICON Interface Module should be TTL level (0V = logic 0, and 5V = logic 1). Solutions Cubed provides free interface software that allows our customers to access all aspects of the ICON Interface Module through an IBM style PC serial port. Communication from a PC serial port is at RS232 electrical levels (+10V = logic 0, and –10V = logic 1). Therefore to facilitate communication between a PC and the ICON Interface Module the RS232 levels must be converted to TTL levels. This can be done with the ICON Adapter Board (available at www.solutions-cubed.com), or with an RS232 converter IC such as the HIN232 from Intersil.

2. Introduction

This document defines the command protocol used in conjunction with the ICON Interface Module. The ICON Interface Module provides programming and control functions for use with the ICON H-Bridge. The ICON Interface Module Communication Protocol (IIMCP) must be followed in order to implement commands, or to modify functionality in the ICON Interface Module.

2.1 Scope

This document provides the necessary information for implementation of IIMCP in both Master and Slave units. The Master is assumed to be a terminal controlling the ICON Interface Module. The Slave device is the fore-mentioned ICON Interface Module device, which has been developed by Solutions Cubed. The command structures and register / data formats are defined herein.

2.2 Definitions, Acronyms, and Abbreviations

Baud / BPS:	Transmitted or received data bits per second
Byte:	Eight bits of Data
Half Duplex	Transmission and Reception do not take place simultaneously
Master:	The computer or terminal responsible for controlling communications on the bus. The Master will initiate all communication.
Slave:	Device being controlled by Master. A Device will respond only when requested to do so by the Master. In this protocol the ICON Interface Module is the Slave.
TBD:	To Be Determined

3. Functional Description

3.1 Overview

The IIMCP is a Master / Slave protocol implemented on a half-duplex TTL serial bus. A Slave device will *NEVER* implement communication without first being prompted by the Master.

Typically, the Master will send a command packet to a Slave to request data or perform a task. The Slave will either respond back with the requested data, respond with an acknowledge (ACK) that the task has been performed, or not respond at all, indicating that an error has taken place.

Monitoring the order of how a packet is sent performs error detection, the device address, time between received bytes, and a checksum are also used for detecting erroneous commands. The Master will be responsible for detecting errors and taking action to recover. If the Slave detects an error, no response will be sent to the Master.

3.2 Data Representation

All numeric data used by devices implementing the IIMCP will be represented by eight bit values (bytes). The relationship between these byte values and actual values such as pulse-width-modulation (PWM) duty cycle, or baud rate will be discussed later in this document.

3.3 Hardware Usage

Asynchronous communication takes place with a 38,400 BPS rate, using eight data bits, no parity, and one stop bit (38,400, n, 8, 1). A single pair of TTL 8N1 lines from the Master will be distributed to each Slave device.

4. Detailed Description

4.1 Binary Mode

This mode uses three types of packets. They are Command Packets, ACK Packets, and Reply Packets. No response can be thought of as a NAK Packet.

4.1.1 Command Packets

The Master always sends command Packets to the Slave. Each Command Packet will begin with the command byte requested by that string. A Command Packet in IIMCP has *four* dependent components. The first component is an eight-bit address used to pick the Slave to receive communication. An ICON Interface Module has addresses ranging from 0x01-0xFF. The second component is a byte containing the length of the message. The length of the message is defined as the number of bytes of data following the Length byte and preceding the Checksum byte. The third component is the actual message, which is generally data destined for use by the Slave. The final component is a modulo 256 sum of all characters in the Command Packet.

Figure 1: Command Packet Construction

Command	Address of Destination	Length	Msg1	Msg2	…	MsgN	Checksum

4.1.2 ACK Packets

The Slave sends ACK packets to the Master when a command arrives that requires no data to be returned. This is the case only when the Universal Address of 0x00 is not used. The Slave will return a hex value of 0x06 if the Command Packet was received correctly and all went as planned. In the case of a Command Packet implementing the Universal Address of 0x00, the Slave will return no response of any kind.

Figure 2: ACK Packet Construction

0x06

4.1.3 NAK Packets

NAK Packets are not currently used in IIMCP.

4.1.4 Reply Packets

Reply Packets are used to send data from the Slave to the Master after the Master requests data. A Reply Packet is identical to a Command Packet except that it will begin with the address of the sending unit, and not a command byte.

Figure 3: Reply Packet Construction

Address Sender	Length	Msg1	Msg2	…	MsgN	Checksum

4.2 Communications Sequence

There are only two possible communication sequences in IIMCP. They are shown in figure 4.

Figure 4: Communication Sequence

		Master	**Slave**
Normal Message:		Command →	
			← Ack or Reply
Error in Message:		Command →	
			No Response

4.3 Error Detection / Communication Requirements

Error detection is accomplished by inspection of the received data and making sure that the data was received in a timely fashion.

Inspection of the data packets will be performed by…
1) verifying that all elements of the packet are present
2) making sure that the message is the correct length
3) verifying the checksum
4) verifying that the message is supported by the Slave
5) testing all values with limited range

Two time periods are monitored for error detection. They are…
1) inter-character time
2) response time

The inter-character time is the time between successive characters in the same packet. The maximum time allowed is 2 milliseconds for the IIMCP.

The response time is the time from when the Master sends the last character of the Command Packet, to when the Master receives a response from the Slave. The maximum allowable response time is 2 milliseconds. This timing should be extended to 15ms when using commands that access EEPROM such as the STORE and RESTORE commands. For the commands that access the look-up table internal to the ICON Interface Module the response time can be as long as 1500ms.

The firmware in the ICON Interface Module will not accept messages greater than 48 bytes in length.

Universal Address

The ICON Interface Module will accept communication if addressed as H '00' regardless of the contents of the ADDRESS register. No communication is returned by the ICON Interface Module when the universal address is implemented, therefore a READ operation is effectively ignored when issued with a universal address of H'00'. The universal address can be used to recover devices that have been inadvertently programmed with an unknown address value. Or it may be used to issue commands to multiple ICON Interface Module devices on the same serial data bus.

4.4 Commands and Registers

4.4.1 ICON H-Bridge Commands (0xCx)

Since the ICON Interface Module is designed specifically for interfacing to the ICON H-Bridge module, any commands with a command byte whose higher nibble is 0xCx will be passed to the ICON H-Bridge. Responses from the ICON H-Bridge will likewise be returned through the ICON Interface Module to the Master unit. The example below displays a message string implementing the Energize function for an H-Bridge at address 0x01. See the ICON H-Bridge data sheet for a full list of commands.

C5, 01, 00 C6 (all in hexadecimal)

4.4.2 SetDC Command (0xD0)

The SetDC command is used to set the duty cycle of the H-Bridge. The message string should consist of the Command packet byte (0xD0), the Address byte, the Length byte, and the value to be loaded into the PWM_HI and PWM_LO registers. All of these bytes are followed by the checksum. For example, to send a –50% duty cycle value (half-speed reversed) the data string would appear as,

D0, 01, 02, FE, 00, D1 (all in hexadecimal)

The SetDC command is the only command that allows direct access to the PWM registers.

4.4.3 Read Command (0xD1)

The Read command message string should consist of the Command packet byte (0xD1), the Address byte, the Length byte, and the register numbers that are to be read from. All of these bytes are followed by the checksum. For example, to read the IM_STATUS register (register 0x00) from an ICON Interface Module at address 0x01 the data string would appear as,

D1, 01, 01, 00, D3 (all in hexadecimal)

4.4.4 Write Command (0xD2)

The Write command message string should consist of the Command packet byte (0xD2), the Address byte, the Length byte, the register number which is to be written to, and the hexadecimal value which is to be written. All of these bytes are followed by the checksum. The Write command is used to set values within the ICON Interface Module. An example of setting the ICON Interface Module, with an address of 0x01, for bi-directional analog control mode is shown below.

D2, 01, 02, 0F, 02, E6 (all in hexadecimal)

4.4.5 Store Command (0xD3)

The Store command message string should consist of the Command packet byte (0xD3), the Address byte, and the length the Length byte (0x00 in this case). All of these bytes are followed by the checksum. The Store command is used to store values in registers 0x09 through 0x22 (9-34) in nonvolatile EEPROM memory. These values then become the power-on default values of the ICON Interface Module device. After this command is executed the Master should refrain from issuing another command for 15ms (or until an ACK is received). An example of executing a Store Command in an ICON Interface Module residing at address 0x01 is shown below.

D3, 01, 00, D4 (all in hexadecimal)

4.4.6 Restore Command (0xD4)

The Restore command message string should consist of the Command packet byte (0xD4), the Address byte, and the Length byte (0x00 in this case). All of these bytes are followed by the checksum. The restore command is used to reset the ICON Interface Module’s internal registers 0x09 – 0x12 (9-18) to their default factory settings. After this command is executed the Master should refrain from issuing another command for 15ms (or until an ACK is received). The example below assumes an ICON Interface Module address of 0x06

D4, 06, 00, DA (all in hexadecimal)

4.4.7 Reset Command (0xD5)

The Reset command first turns off the ICON H-Bridge. It then forces the ICON Interface Module into its hardware reset condition.

D5, 01, 00, D6 (all in hexadecimal)

4.4.8 Look-up Write Command (0xD6)

The Look-Up Write command is used to write values to the PIC microcontrollers memory. The value can then be accessed via the LOOK_UP operating mode. LOOK_UP mode uses the analog input value (0 to 1023) as an address for a look-up table. The Look-up Write command allows the user to modify the look-up table and store custom drive characteristics in the table. The command meets the standard requirements established by this protocol. However the data sent must represent a single location in the lookup table. The command starts with the command byte (0xD6), the address of the unit (0x01 in this example), and the number of bytes to be sent (0x04). The body of the command consists of the address in the table to be modified, followed by the value to write to that location. All of these bytes are followed by the checksum. For example, to write the value 533 (0x215) to address location 277 (0x115) the command would take the form…

D6, 01, 04, 01, 15, 02, 15, 08 (all in hexadecimal)

The Look-Up Write command will disable serial communication and turn off all outputs to the ICON H-Bridge MOSFET control lines until the command is fully implemented. The Master unit should receive an ACK within 15ms of sending a Look-Up Write command.

4.4.9 Look-up Read Command (0xD7)

The Look-Up Read command is used to read values to the PIC microcontrollers memory. LOOK_UP mode uses the analog input value (0 to 1023) as an address for a look-up table. The Look-up Read command allows the user to read the look-up table and determine which PWM registers are associated with specific analog-to-digital measurements. The command meets the standard requirements established by this protocol. However the data sent must represent a single location in the lookup table. The command starts with the command byte (0xD7), the address of the unit (0x01 in this example), and the number of bytes to be sent (0x02). The body of the command consists of the address in the table to be read. All of these bytes are followed by the checksum. For example, to read the value address location 277 (0x115) the command would take the form…

D7, 01, 02, 01, 15, F0 (all in hexadecimal)

4.4.10 Look-up Restore Command (0xD8)

The Look-Up Restore command is used to restore the default values to the PIC microcontrollers look-up table memory. LOOK_UP mode uses the analog input value (0 to 1023) as an address for a look-up table. The Look-up Restore command allows the user to load values 0-1023 into look-up table memory locations 0-1023. The command meets the standard requirements established by this protocol. The command starts with the command byte (0xD8), the address of the unit (0x01 in this example), and the number of bytes to be sent (0x00). All of these bytes are followed by the checksum. After receiving this command the ICON Interface Module will enter into a mode of operation that does not allow normal program flow. The ICON H-Bridge control lines will be disabled and serial communication will not be possible until an ACK is received from the ICON Interface Module. This may take as long as 1500ms.

D8, 01, 00, D9 (all in hexadecimal)

4.5 ICON Interface Module Commands

Figure 5 shows the commands supported by the ICON Interface Module.

Figure 5: ICON Interface Module Commands

Command	Syntax (hex)	Reply	Description
H-Bridge Data	CX XX XX … XX	Reply or Ack	Passes data through ICON Interface Module to ICON H-Bridge
SetDC	D0 XX 02 XX XX XX	Ack	Write to PWM_HI and PWM_LO registers
Read	D1 XX XX XX XX … XX	Reply	Read from one or more ICON Interface Module registers
Write	D2 XX XX XX XX … XX	Ack	Write to one or more ICON Interface Module registers
Store	D3 XX 00 XX	Ack	Set ICON Interface Module registers as default values
Restore	D4 XX 00 XX	Ack	Restores ICON Interface Module factory default values
Reset	D5 XX 00 XX	Ack	Shuts down H-Bridge and forces ICON Interface Module into hardware reset condition
Look-Up Write	D6 XX 04 XX XX XX XX XX	Ack	Writes a single value to a location in the look-up table
Look-Up Read	D7 XX 02 XX XX XX	Reply	Reads a single value from the look-up table
Look-Up Restore	D8 XX 00 XX	Ack	Restores factory default values to the look-up table

4.6 ICON Interface Module Registers

Figure 6 shows the registers of the ICON Interface Module. The current values of all Read / Write registers can be copied into EEPROM with the Store command.

Figure 6: ICON Interface Module Registers

Index	Name	Size (Bytes)	Read / Write	Description
0	IM_STATUS	1	R	Maintains flags pertinent to ICON Interface Module
1	IH_STATUS	1	R	Maintains flags pertinent to H-Bridge
2	A_ANALOG_H	1	R	Actual analog measurement high byte
3	A_ANALOG_L	1	R	Actual analog measurement low byte
4	PWM_H	1	R	Pulse-width-modulation register, high byte
5	PWM_L	1	R	Pulse-width-modulation register, low byte
6	IH_AMPS	1	R	Stores current measurement from H-bridge
7	IH_TEMP	1	R	Stores temperature measurement from H-bridge
8	FIRMWARE	1	R	Current firmware revision running on ICON Interface Module
9	DEAD_BAND	1	R/W	Sets band around desired analog measurement that equates to zero (or stopped)
10	PWM_RES	1	R/W	Sets PWM frequency and resolution
11	UPDATE_PERIOD	1	R/W	PWM update occurs every PWM_FREQ x 16 x UPDATE_PERIOD
12	PWM_STEP	1	R/W	Maximum change in PWM allowed with each update
13	IH_BAUD	1	R/W	H-Bridge Baud rate limited to 2400bps (0x00), 4800bps (0x80), and 9600bps (0xC0)
14	ADDRESS	1	R/W	Address of ICON Interface Module
15	IM_FUNCTION	1	R/W	Sets mode of operation for ICON Interface Module
16	IH_FUNCTION	1	R/W	Sets mode of operation for ICON H-Bridge
17	D_ANALOG_H	1	R/W	Desired analog high byte, used in speed control mode
18	D_ANALOG_L	1	R/W	Desired analog low byte, used in speed control mode
19-34	EEPROM	1	R/W	Each register 19-34 can be used by the Master units as non-volatile storage space

4.7 ICON Interface Module and ICON H-Bridge Status Registers

Figure 7: ICON Interface Module Status Register (IM_STATUS)

Name	Register	Bit	R/W	Description
MOTOR_DIR	IM_STATUS	0	R	Direction motor is turning, set for forward
ADC_FAIL	IM_STATUS	1	R	Set if failure occurs in ADC module
BRAKE_FLAG	IM_STATUS	2	R	Set when _BRAKE pin is asserted
HCOM_FAIL	IM_STATUS	3	R	Set if H-Bridge Communication has failed
DEAD_FLAG	IM_STATUS	4	R	Set when inside DEAD_BAND setting
Unused	IM_STATUS	5	R	This bit location unused at this time
Unused	IM_STATUS	6	R	This bit location unused at this time
Unused	IM_STATUS	7	R	This bit location unused at this time

Figure 8: ICON H-Bridge Status Register (IH_STATUS)

Name	Register	Bit	R/W	Description
AMPS_TRIP	IH_STATUS	0	R	Set if current trip point exceeded on H-Bridge
TEMP_TRIP	IH_STATUS	1	R	Set if temperature trip point exceeded on H-Bridge
H_OFF	IH_STATUS	2	R	Set if H-Bridge is disabled
I2C FAIL	IH_STATUS	3	R	Set if I2C Communication has failed on H-bridge
Unused	IH_STATUS	4	R	This bit location unused at this time
Unused	IH_STATUS	5	R	This bit location unused at this time
Unused	IH_STATUS	6	R	This bit location unused at this time
Unused	IH_STATUS	7	R	This bit location unused at this time

4.8 ICON Interface Module and ICON H-Bridge Function Registers

Figure 9: ICON Interface Module Function Register

Name	Register	Bit	R/W	Description
AD_UNIDIR	IM_FUNCTION	0	R/W	Analog voltage of 0-4.096V controls motor, forward direction only (0V = stop)
AD_BIDIR	IM_FUNCTION	1	R/W	Analog voltage of 0-4.096V controls motor, forward and reverse direction (2.048V = stop)
AD_SPDCON	IM_FUNCTION	2	R/W	D_ANALOG_x registers used to establish desired analog input value. Motor ramped up/down to match desired value. Forward direction only.
AD_LOOKUP	IM_FUNCTION	3	R/W	Analog voltage of 0-4.096 is used as address in look-up table. Value at look-up table address determines motor speed and direction.
ALL_RETRY	IM_FUNCTION	4	R/W	ICON Interface Module attempts to energize H-bridge if it shuts off for any reason
AMPS_RETRY	IM_FUNCTION	5	R/W	ICON Interface Module attempts to energize H-bridge if it shuts off due to current trip point
TEMP_RETRY	IM_FUNCTION	6	R/W	ICON Interface Module attempts to energize H-bridge if it shuts off for due to temperature trip point
DYN_BRAKE	IM_FUNCTION	7	R/W	Set to enable braking function that turns on both low side MOSFETs on H-bridge when duty cycle is zero

Figure 10: ICON H-Bridge Function Register

Name	Register	Bit	R/W	Description
AMPS_FUSE	FUNCTION	0	R/W	Set to enable over current protection
TEMP_FUSE	FUNCTION	1	R/W	Set to enable over temperature protection
PWR_ON	FUNCTION	2	R/W	Set if power-on state of ICON Interface Module is ON. Cleared if ICON Interface Module powers-up off
Unused	FUNCTION	3	R/W	This bit location unused at this time
Unused	FUNCTION	4	R/W	This bit location unused at this time
Unused	FUNCTION	5	R/W	This bit location unused at this time
Unused	FUNCTION	6	R/W	This bit location unused at this time
DIRECT_DRIVE	FUNCTION	7	R/W	Set to enable direct drive of H-Bridge.

4.9 Detailed Register Descriptions

Accessing the ICON Interface Module registers described herein can modify various configuration settings. The registers are described by their location or "Index" value and whether they are Read only or Read / Write registers. The registers designated as Read / Write may be modified and stored in EEPROM as default values. See figure 6 for a summary of these registers.

4.9.1 INDEX0: IM_STATUS register

The ICON Interface Module status byte maintains various status flag registers useful in determining the current operating state of the module. There are four bits stored in the ICON Interface Module status register. These bits designate the current direction the motor is turning, the state of the on-board analog-to-digital converter, the state of the BRAKE input pin, whether or not communication to the ICON H-Bridge is being performed successfully, and whether or not the PWM value is within the dead band setting. See figure 7 for the bit definitions and locations for this register.

4.9.2 INDEX1: IH_STATUS register

The ICON H-Bridge status byte maintains various status flag registers useful in determining the current operating state of the H-bridge module. There are five bits stored in the ICON H-Bridge status register. These bits designate the state of the over-current and over-temperature protection features (tripped or not tripped), the state of the H-bridge driver chip (off or on), and whether or not the on-board EEPROM is functional. See figure 8 for the bit definitions and locations for this register.

4.9.3 INDEX2: A_ANALOG_H register

The ICON Interface Module maintains a single 10-bit analog-to-digital converter (ADC) with a 4.096V 150ppm 1% voltage reference. The ADC returns a value from 0 to 1023, with each bit representing 4mV. This measurement is stored in the actual-analog-high and actual-analog-low registers. A_ANALOG_H maintains high byte (upper two bits) of this measurement. The A_ANALOG_L stores the lower 8 bits from the ADC. This measurement is used to control motor speed in the Uni-Directional, Bi-Directional, Speed Control, and Look-up Table modes of operation. While resolution is 10-bits, the accuracy of the ADC is based in external filtering (if present) and system noise). For quieter systems accuracy may be in the +/-5 bit range (+/- 20mV).

4.9.4 INDEX3: A_ANALOG_L register

The lower eight bits of the on-board 10-bit ADC are stored in the register. See A_ANALOG_H register for more details.

4.9.5 INDEX4: PWM_H register

The ICON Interface Module provides 2 channels capable of generating 10-bit pulse-width-modulation (PWM). These channels connect to the LO-A and LO-B pins of the ICON H-Bridge (pins 5 and 6 of J1 respectively). The PWM_H register maintains the upper two bits of the PWM duty cycle, while the PWM_L register maintains the lower eight bits of the duty cycle. The PWM frequency and resolution can also be effected by the value stored in the PWM_RES register. The Master unit can only write to the PWM registers with a SetDC Command. If the ICON Interface Module is operating in Uni-Directional, Bi-Directional, Speed Control, or Look-up Table mode then the PWM registers will be generated internally based on the value in the A_ANALOG_x registers. Therefore, for the Master unit to directly control PWM the IM_FUNCTION register should have bits 0,1,2, and 3 cleared.

The PWM value is based on a 2's compliment value. Negative numbers force the ICON Interface Module to reverse the motor direction.

4.9.6 INDEX5: PWM_L register

The PWM_L register maintains the lower eight bits of the PWM value.

Figure 11: PWM Register Value Examples

Description	Dec	Hex	LO-A	HI-B	LO-B	HI-A
Forward 100%	1023	0x03FF	PWM	ON	OFF	OFF
Forward 50%	512	0x0200	PWM	ON	OFF	OFF
Forward 10%	102	0x066	PWM	ON	OFF	OFF
Stopped	0	0x0000	OFF	OFF	OFF	OFF
Reverse 10%	-102	0xFF9A	OFF	OFF	PWM	ON
Reverse 50%	-512	0xFE00	OFF	OFF	PWM	ON
Reverse 100%	-1023	0xFC01	OFF	OFF	PWM	ON

4.9.7 INDEX6: IH_AMPS register

The IH_AMPS register stores the ICON H-Bridge current measurement. This measurement is in 100mA increments. High currents at low duty cycles can cause significant error in this measurement. This measurement is designed to be used for over-current protection and may not be feasible for torque control applications due to accuracy and response time constraints.

4.9.8 INDEX7: IH_TEMP register

The IH_TEMP register stores the ICON H-Bridge temperature measurement. The IH_TEMP register contains the temperature measurement derived from a thermistor on-board the ICON H-Bridge. Due to switching noise, high temperature, and component tolerances this value can vary especially at temperatures greater than 60C. The following table can be used to determine the range of values you might expect to see for various temperatures.

Figure 12: ICON H-Bridge TEMP Register Values

Temperature Celsius	Temperature Fahrenheit	TEMP Register Range
0	32	7-8
5	41	9-10
10	50	11-13
15	59	14-16
20	68	17-21
25	77	22-26
30	86	27-31
35	95	32-38
40	104	39-46
45	113	47-55
50	122	56-65
55	131	66-76
60	140	77-89
65	149	90-102
70	158	103-117
75	167	118-132
80	176	133-148
85	185	149-165

4.9.9 INDEX8: FIRMWARE register

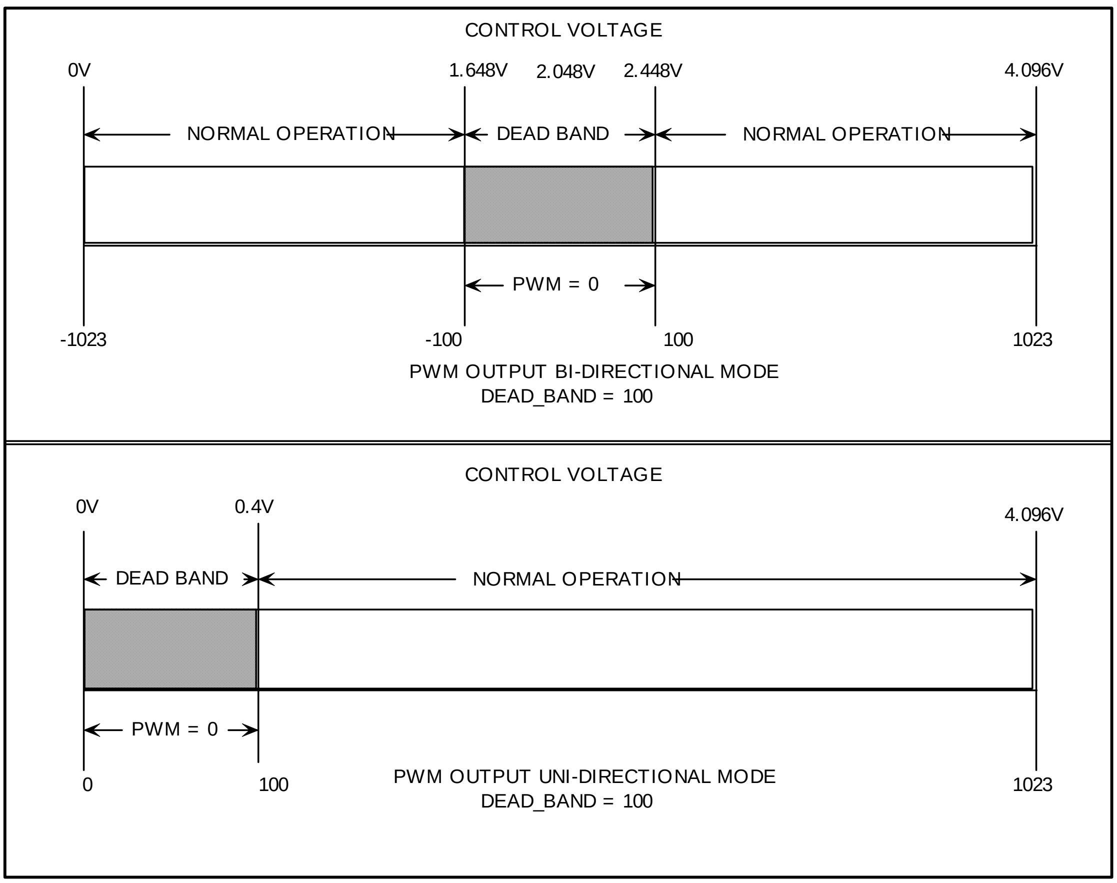
The loaded firmware revision may be found in this register. The firmware revision may be useful when determining if errata data pertains to your module.

4.9.10 INDEX9: DEAD_BAND register

The dead band setting programs the ICON Interface Module to shut down PWM generation whenever the analog measurement falls within the dead band value. This setting can be useful in systems where the analog input does not go all of the way to ground when at its lowest point. It could also be used with heavily geared motors that will rotate at very low duty cycles. With these systems it may be difficult to ensure the analog control voltage remains at a value that stops the motor from turning. The dead band setting can create a wider range of analog input values that result in the PWM signals being forced to zero (or off). Figure 13 displays the results in PWM generation for both uni-directional and bi-directional modes with a dead band setting of 100 (decimal). If the DEAD_BAND register is greater than the ADC measurement then the PWM output is forced to zero. The dead band setting functions in all modes of operation and should be set to zero for Speed Control mode.

If the PWM_x registers are within the dead band setting the IM_STATUS, DEAD_FLAG will be set.

Figure 13: Dead Band Diagram



4.9.11 INDEX10: PWM_RES register

The PWM resolution register can be used to increase the PWM frequency (and therefore decrease PWM resolution). The ICON H-Bridge is designed to operate at 19.2kHz with a PWM resolution of 10-bits. Changes to the PWM_RES may effect power dissipation in the ICON H-Bridge or have an effect on power distributed to the load. It is left to the user to determine whether or not changes to the PWM_RES register are beneficial or harmful to any particular design. Figure 14 shows the values that can be used in the PWM_RES register and the effective PWM frequency and resolution associated with a particular value. To take effect, changes in the PWM_RES register should be stored in EEPROM (with a Store command) and power should be cycled to the ICON Interface Module.

Figure 14: PWM_RES Values

PWM Frequency	19.2kHz	38.4kHz	76.8kHz	153.6kHz
PWM_RES value (hexadecimal)	0xFF	0x7F	0x3F	0x1F
Resolution – bits	10	9	8	7

4.9.12 INDEX11: UPDATE_PERIOD register

The update period sets the rate that the PWM registers are updated. The default setting is once per PWM period x 16. This results in a PWM update rate of 833us. The value in the UPDATE_PERIOD is multiplied by the default update period (833us) to get the actual update period (833us to 213ms). Extending the update period is useful when operating in Speed Control mode. Since Speed Control is accomplished by set point if the update rate of the ICON Interface Module is too fast the motor will "lope" due to overcompensation. Reducing the PWM_STEP register and increasing the UPDATE_PERIOD register can allow the Speed Control mode follow changes in motor speed and not overshoot them.

4.9.13 INDEX12: PWM_STEP register

The maximum change in PWM values from update to update is defined by the PWM_STEP value. If a step function were applied to the control voltage input pin the resulting change in PWM could cause significant current or voltage spikes to be seen in the system. The PWM_STEP register defines the maximum change allowed in the PWM registers from one PWM update to the next. Uni-Directional, Bi-Directional, and Speed Control modes of operation use the limitation on PWM changes imposed by the PWM_STEP register. Modifications to the PWM register via the SetDC command ignore the PWM_STEP register. Look-up Table mode also ignores the PWM_STEP register.

4.9.14 INDEX13: IH_BAUD register

The IH_BAUD register sets the baud rate used to communicate with the ICON H-Bridge module. This value can be changed on the fly, but is limited on power-up to one of three values (see figure 16). If none of the three values is present in the IH_BAUD register on power up then the baud rate is forced to 2400BPS. To modify the baud rate from the default, first modify and store the ICON H-Bridge baud rate register (INDEX8: BAUD, see the ICON H-Bridge data sheet for more information). Then modify and store the IH_BAUD register. After power is cycled both the H-bridge and the ICON Interface Module should be operating at the new baud rates.

Some users may experience difficulty when operating at 9600BPS. If this is the case either build a "retry" capability into your system, or switch to a lower baud rate. In noisy, high current systems, a "retry" capability should be used for any baud rate.

Figure 15: ICON H-Bridge Baud Rate Settings

Baud Rate	Decimal Value	Hexadecimal Value
2400BPS	0	0x00
4800BPS	128	0x80
9600BPS	192	0xC0

4.9.15 INDEX14: ADDRESS register

The ADDRESS register will change on the fly. As soon as a new address value is written to the ADDRESS register the new address value will take effect. The user must still store the data in EEPROM, for the new address value to become the default address value for the ICON Interface Module.

4.9.16 INDEX15: IM_FUNCTION register

Program functionality can be enabled or disabled by the bits stored in this register. Setting a bit enables the functionality. The first four bits are used to select the operating mode. Only one of bits 0 through 3 should be set at a time. On power up the ICON Interface Module will insure that only one bit is set, and therefore only one mode of operation is enabled. Figure 9 displays the bit locations for the IM_FUNCTION register. Each bit is described in detail below. Clearing bits 0 through 3 allows the Master unit to control motor speed and direction with the SetDC command.

4.9.16.1 BIT0: AD_UNIDIR

Setting the AD_UNIDIR bit places the ICON Interface Module into Uni-directional mode of operation. In this mode of operation the ICON Interface Module takes 10-bit ADC measurements and translates them directly to 10-bit PWM signals. The relationship between the ADC value and the PWM output therefore is every 4mV = 1 PWM bit. The acceptable analog input range is 0V to 4.096V. Registers such as DEAD_BAND, PWM_STEP, and PWM_RES can effect the PWM output.

4.9.16.2 BIT1: AD_BIDIR

Setting the AD_BIDIR bit places the ICON Interface Module into Bi-directional mode of operation. In this mode of operation the ICON Interface Module takes 10-bit ADC measurements, subtracts 512 and multiplies the result by 2. This translates into a result that is limited internally to –1023 to +1023. This results in a zero, or stopped motor, at 2.048V ((512-512)*2). 0V is equivalent to full reverse and 4.096V drives the motor full forward. The acceptable analog input range is 0V to 4.096V. Registers such as DEAD_BAND, PWM_STEP, and PWM_RES can effect the PWM output.

4.9.16.3 BIT2: AD_SPDCON

Setting the AD_SPDCON bit places the ICON Interface Module into Speed Control mode of operation. In this mode of operation the ICON Interface Module takes 10-bit ADC measurements and compares them to the value stored in the D_ANALOG_x register (desired analog register). The PWM signal is then adjusted up or down in an attempt to force the A_ANALOG_x (actual analog) value to match the D_ANALOG_x value. This mode is designed to be used with the frequency-to-voltage conversion circuitry on-board the ICON Interface Module. This mode only controls the motor in forward direction, can often overshoot the desired voltage. To reduce overshoot the PWM_STEP register should be set to 0x01, and the UPDATE_PERIOD register can be increased to the point that the ICON Interface Module response time is slower than the motors mechanical response time.

4.9.16.4 BIT3: AD_LOOKUP

Setting the AD_LOOKUP bit enable Look-Up Table mode of operation. Using the Look-Up Write command the Master unit can write PWM values to a look-up table consisting of 1024 locations (0x0000 to 0x03FF). In Look-Up Table mode the ADC measurements are used as the address of the look-up table. Stored at these addresses are 10-bit PWM values. This allows the user to program custom PWM profiles based on expected analog inputs. The PWM values stored can take the form of negative numbers, so profiles encompassing both forward and reverse directions may be used. PWM values stored are non-volatile so once written they will remain intact after cycling power. The command Look-Up Restore will reload the look-up table with its default values. Limitations imposed by the PWM_STEP register value is ignored by this operating mode.

4.9.16.5 BIT4: ALL_RETRY

Setting the ALL_RETRY bit forces the ICON Interface Module to send the Energize command to the ICON H-Bridge if it shuts off for any reason.

4.9.16.6 BIT5: AMPS_RETRY

Setting the AMPS_RETRY bit forces the ICON Interface Module to send the Energize command to the ICON H-Bridge if the AMPS_TRIP bit is set in the IH_STATUS register.

4.9.16.7 BIT6: TEMP_RETRY

Setting the TEMP_RETRY bit forces the ICON Interface Module to send the Energize command to the ICON H-Bridge if the TEMP_TRIP bit is set in the IH_STATUS register.

4.9.16.8 BIT7: DYN_BRAKE

Setting the DYN_BRAKE bit causes the ICON Interface Module to turn on both low-side MOSFETs (LO-A and LO-B are set high) when the PWM output goes to zero. This effectively shorts both leads of the motor to ground. When this bit is not set both low-side MOSFETs are turned off (LO-A and LO-B are pulled to ground) when the PWM output goes to zero, which leaves the motor connections floating.

4.9.17 INDEX16: IH_FUNCTION register

Program functionality can be enabled or disabled by the bits stored in this register. Setting a bit enables the function. Figure 10 describes the bit locations and functions associated with each bit in this register. More information on this register can be found in the ICON H-Bridge data sheet.

4.9.18 INDEX17: D_ANALOG_H register

This register is used with D_ANALOG_L to store the desired analog voltage when operating in Speed Control mode. The value stored in the two D_ANALOG_x registers should range from 0-1023 (0x0000-0x03FF).

4.9.19 INDEX18: D_ANALOG_L register

This register is used to store the lower 8-bits of the desired analog voltage when operating in Speed Control mode.

4.9.20 INDEX19-34: User EEPROM registers

Registers 19 through 34 are set aside for use as user accessible EEPROM. These register values are stored in EEPROM with the Store command, and can be used to hold program variables that the Master unit may need to store.

4.10 Default Values on Factory Power Up

Each ICON Interface Module loads variable data from EEPROM on power up. When power is first applied to these devices in a factory setting all loaded values from EEPROM would normally be 0xFF.

For this reason each ICON Interface Module device will test its write accessible RAM registers on power up for a 0xFF. If all registers equal 0xFF then the ICON Interface Module device assumes that this is its first time power up, and loads a set of default values into its important user configurable registers. The registers and their default values are detailed below.

Figure 16: ICON Interface Module Default Settings

Index	Name	Size (Bytes)	Value (hex)	Description
9	DEAD_BAND	1	0x04	Sets band around desired analog measurement that equates to zero (or stopped)
10	PWM_RES	1	0xFF	Sets PWM frequency to 19.2KHz and resolution to 10 bits
11	UPDATE_PERIOD	1	0x01	PWM update occurs every 16 PWM periods
12	PWM_STEP	1	0x04	Maximum change in PWM allowed with each update is 4
13	IH_BAUD	1	0x00	H-Bridge Baud rate defaults to 2400bps (0x00),
14	ADDRESS	1	0x01	Address of ICON Interface Module defaults to address 0x01
15	IM_FUNCTION	1	0x00	No analog control mode or retry setting is enabled
16	IH_FUNCTION	1	0x03	H-Bridge power up “off” in serial mode with current and temperature protection enabled
17	D_ANALOG_H	1	0x00	Desired analog high byte, used in speed control mode
18	D_ANALOG_L	1	0x00	Desired analog low byte, used in speed control mode
19-34	EEPROM	1	N/A	These registers are not effected by the RESTORE command

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