SOLUTIONS CUBED

ICON H-Bridge Data Sheet

Revision 6

September 23rd, 2002

Table of Contents – Electrical / Mechanical Specifications

List of Figures

1. **Revision Log – Electrical / Mechanical Specifications**

Date	Rev	Description	By
11-06-01	1	Original Implementation	L. Glazner
11-28-01	2	Documented changes in CAL registers for Rev. 14 firmware	L. Glazner
02-07-02	3	Modified temp. table for NHQM thermistor, Rev. 16 firmware	L. Glazner
03-26-02	4	Removed retail pricing in body of datasheet	L. Glazner
05-06-02	5	Removed warnings regarding shoot-through to match product functionality	L. Glazner
09-23-02	6	Added phone number to footer of document	L. Glazner

2. Introduction

ICON H-Bridge
DC Motor Interface Module

FEATURES
- Logic level control of H-Bridge
- Up to 40Vdc motors
- Up to 12A continuous current
- Serial or Direct Drive interface
- Adjustable/non-volatile over current trip point
- Adjustable/non-volatile over temperature trip point
- System parameters accessed through serial interface
- Small size versatile footprint

2.1 DESCRIPTION
The ICON H-Bridge provides easy connectivity to a wide range of medium power DC motors. An on-board microcontroller monitors current and temperature to provide protection if either trip point is exceeded. Various configuration registers may be monitored and programmed via the serial interface. These registers contain information such as the system load current, board temperature, over current trip point, over temperature trip point, and status information.

In serial mode the H-bridge is enabled/disabled via a serial command set. In direct drive mode the serial input line becomes the H-bridge enable control pin, while the serial output can be used to monitor the H-bridge status. In both operating modes each MOSFET in the H-bridge is controlled individually by a control input (four MOSFET control lines in all).

The ICON H-bridge is designed to operate with motor voltages up to 40V, and can carry continuous currents up to 12A with the active cooling solution available from Solutions Cubed. This robust H-Bridge handles peak currents of 25A and can operate to 85°C.

Connectivity to the ICON H-Bridge is simplified to 2 – 1x8 0.156” receptacles capable of top or bottom insertion of 1x8 0.156” headers. With the small size (2.5”x1.9”x0.5”) and versatile interface capabilities of the ICON H-Bridge, it meets the requirements of many DC motor interface designs.

Pricing in single unit quantities is $100.

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
Supply Voltage (+12V)	-0.3V to 16.0V
Voltage on HI-A, HI-B, LO-A, LO-B	-0.3V to (voltage at +12V pin+0.3V)
Voltage on VMOTOR, LOAD+, LOAD-,	70V
Motor Current Load	25A peak / 12A continuous
Power Dissipation – No Cooling	1.7W

3.2 DC Electrical Characteristics

At T_A = 25°C, +12V = 12.0V, V_{MOTOR} = 24V, I_{LOAD} = 5A F_{PWM} = 19.2kHz

Characteristic	Symbol	Min	Typ	Max	Unit	Notes
Controller Voltage	+12V	9.5		15.0	V	
Motor Voltage	V_{MOTOR}	1		40	V	ICON H-bridge must be provided 12VDC regardless of motor voltage
+12V rise time to ensure good reset	S_{12V}	0.05			V/ ms	If this condition is not met then microcontroller may not power up correctly
Supply Current	I_{CC}	15	20	40	mA	Average current no cooling fan in system
Low Level Input HI-A, HI-B, LO-A, LO-B	V_{CIL}			0.8	V	
High Level Input HI-A, HI-B, LO-A, LO-B	V_{CIH}	2.7			V	
Low Level Input DIN pin	V_{DIL}			0.5	V	DIN pin pulled to +5V with 2.2kΩ resistor
High Level Input DIN pin	V_{DIH}	2.0			V	DIN pin pulled to +5V with 2.2kΩ resistor
Low Level Output DOUT pin	V_{DOL}			0.6	V	DOUT pin pulled to +5V with 2.2kΩ resistor
High Level Output DOUT pin	V_{DOH}	+5V – (I_{PULLUP} * 2.2kΩ)			V	Output high voltage is based on 2.2kΩ pullup resistor and DOUT load conditions
DOUT Output Pull Up current	I_{DOUTPU}	2.16	2.25	2.39	mA	DOUT is pseudo open collector and is tied to Vcc with a 5% 2.2kΩ resistor.
DIN Output Pull Down current	I_{DINPD}	2.16	2.25	2.39	mA	DIN is tied to Vcc with a 5% 2.2kΩ resistor.

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

3.3 H-Bridge Switching Characteristics

At T_A = 25°C, +12V = 12.0V, VMOTOR = 24V, ILOAD = 5A FPWM = 19.2kHz

Characteristic	Symbol	Min	Typ	Max	Unit	Notes
LO-B, LO-A gate drive rise time	TLOR		100		nS	19.2kHz switching frequency
LO-B, LO-A gate drive fall time	TLOF		200		nS	19.2kHz switching frequency
HI-B, HI-A gate drive rise time	THIR		100		nS	19.2kHz switching frequency, VMOTOR = 24VDC
HI-B, HI-A gate drive fall time	THIF		200		nS	19.2kHz switching frequency, VMOTOR = 24VDC
LO-B, LO-A "ON" input to gate drive propagation delay	TLOPON		50		nS	19.2kHz switching frequency, VMOTOR = 24VDC
LO-B, LO-A "OFF" input to gate drive propagation delay	TLOPOFF		50		nS	19.2kHz switching frequency, VMOTOR = 24VDC
HI-B, HI-A "ON" input to gate drive propagation delay	THIPON		100		nS	19.2kHz switching frequency, VMOTOR = 24VDC
HI-B, HI-A "OFF" input to gate drive propagation delay	THIPOFF		150		nS	19.2kHz switching frequency, VMOTOR = 24VDC
DIRECT DRIVE mode ENABLE "ON/OFF" propagation delay	TPDD	9	150	230	uS	ADC sample number set to 32 for this measurement

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

Figure 1: H-Bridge Propagation Delay Timing

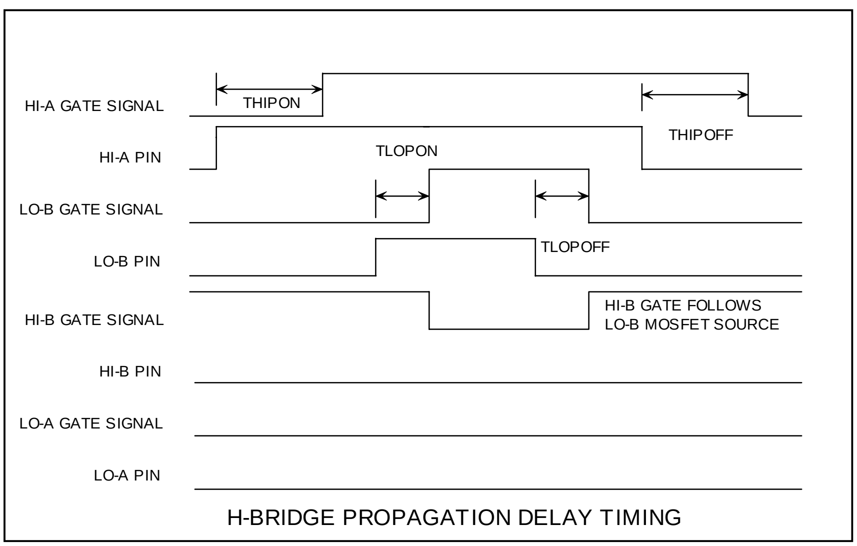


Figure 2 displays a typical turn-on propagation delay resulting from a 0V to 5V signal transition on the LO-B pin of the ICON H-Bridge. Roughly 50ns later the LO-B MOSFET has its gate driven to +12V. The rise time of the gate drive signal (roughly 100ns) can also be seen in this figure.

Figure 2: Low Side MOSFET Turn-on Propagation

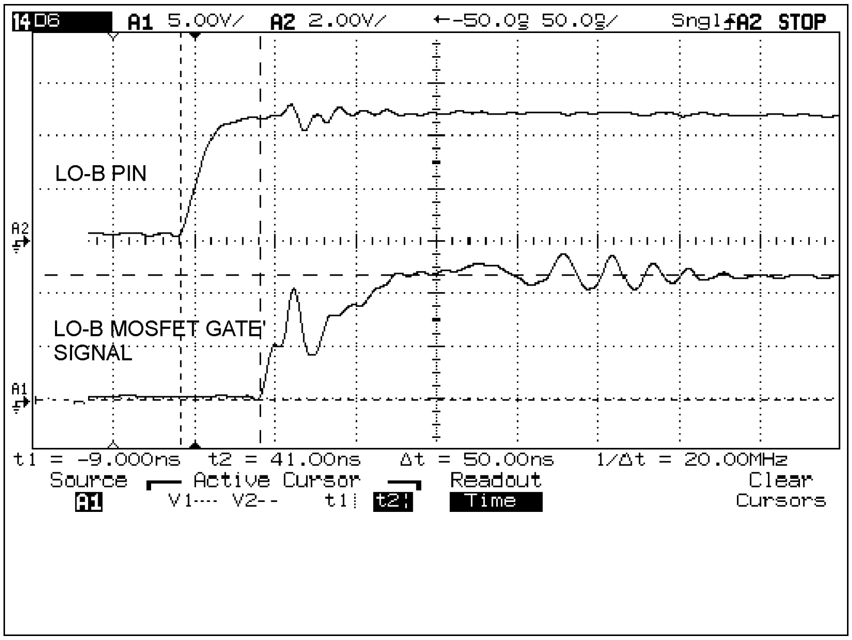
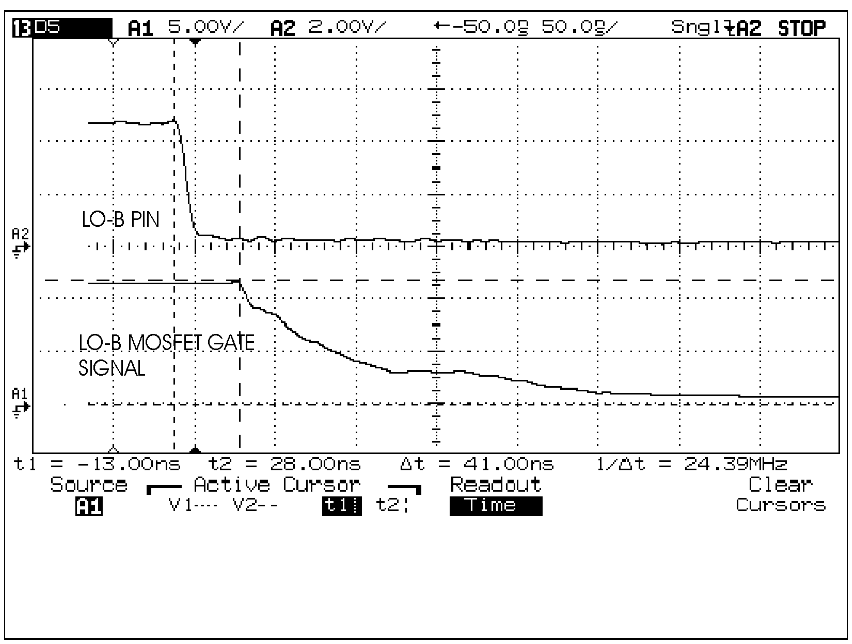


Figure 3 displays a typical turn-off propagation delay resulting from a 5V to 0V signal transition on the LO-B pin of the ICON H-Bridge. Roughly 50ns later the LO-B MOSFET has its gate driven to +0V. The fall time of the gate drive signal (roughly 200ns) can also be seen in this figure.

Figure 3: Low Side MOSFET Turn-off Propagation



3.4 AC Electrical Characteristics

At T_A = 25°C, +12V = 12.0V, V_{MOTOR} = 24V, I_{LOAD} = 5A F_{PWM} = 19.2kHz

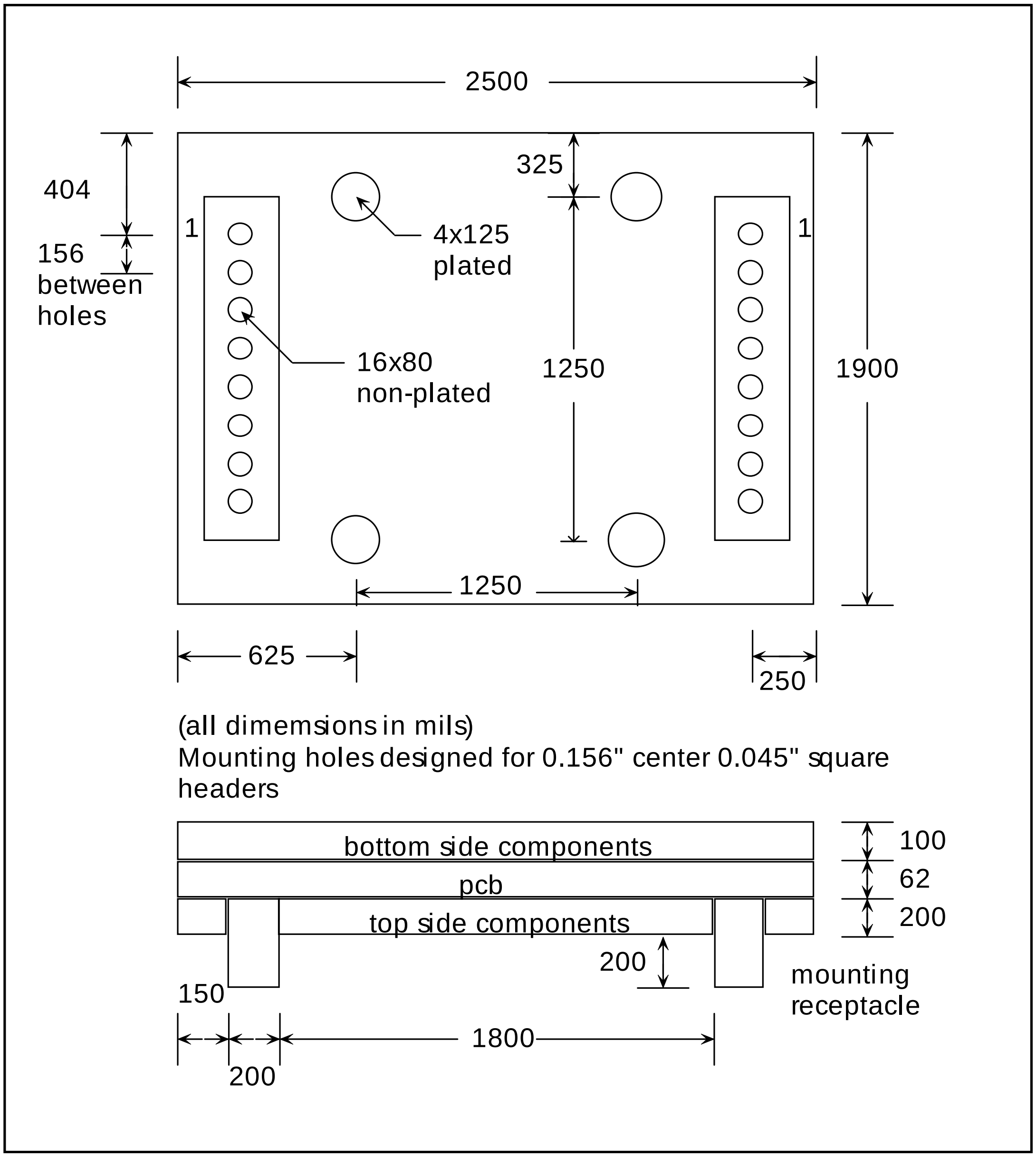
Characteristic	Symbol	Min	Typ	Max	Unit	Notes
Communication bit period 2400 baud 4800 baud 9600 baud	T_{BIT}	 413 206 103	 416 208 104	 419 211 105	uS	The bit period is determined by an on-board oscillator, and is temperature sensitive
Offset when a bit is read 2400 baud 4800 baud 9600 baud	T_{RD}	 180 90 45	 200 100 50	 220 110 60	uS	This is used to ensure a bit is valid when read. A bit must be valid for at least this long in order for the communication to not be erroneous
Time for a command from Master to be responded to	T_{TURN}	1200	1250	2000	uS	This time is used to allow for a Master to change from transmission mode to reception mode
Time after power-up before device will communicate	T_{PWRUP}	100		350	mS	The onboard microcontroller allows 350ms for the Master to power up in serial mode and 100ms in direct drive mode
Bit period temperature coefficient	BP_{TEMPCO}	-1.8	-1.6	-1.7	nS/°C	Therefore at higher temperatures, a slower baud rate may be necessary at the Master
PWM frequency	T_{PWM}	0	20	750	kHz	
Thermal shutdown temperature	T_J			85	°C	The over-temperature trip point should not be disabled or set to exceed 85°C
Max peak load current	I_{PK}			25	A	The over-current trip point should not be disabled, although it can be safely set to 25.5A with proper cooling
Max continuous motor current	I_{CON}		12	16	A	
Max continuous motor current no cooling	I_{NOCOOL}	5.0	6.0	7.5	A	Maximum current to load without external cooling devices (fans, etc.)
Max continuous motor current active cooling	I_{ACTIVE}	10.0	12.0	13.0	A	Maximum current to load with ICON Active Cooling solution
Max continuous motor current massive cooling	I_{BLOWER}			20.0	A	Maximum current to load with AC blower 3" from H-Bridge, 95% duty cycle, 24V

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

3.5 Mechanical Dimensions

The following diagram may be used to develop PCB carrying boards or to fit the ICON H-Bridge into custom cooling solutions. All dimensions are in mils (1 mil = 1/1000 of an inch). The side view displays areas with adequate keep-out spacing to prevent overlapping the ICON H-Bridge components with components in your design. In most cases the measurements are symmetrical. For example each of the 4 - 125mil mounting holes is 325mils from the 2500mil sides of the PCB. All of the 125mil mounting holes are also 625mils from the 1900mil sides of the PCB. Measurements are not shown for each mounting hole because of the board symmetry.

Figure 4: Mechanical Dimensions

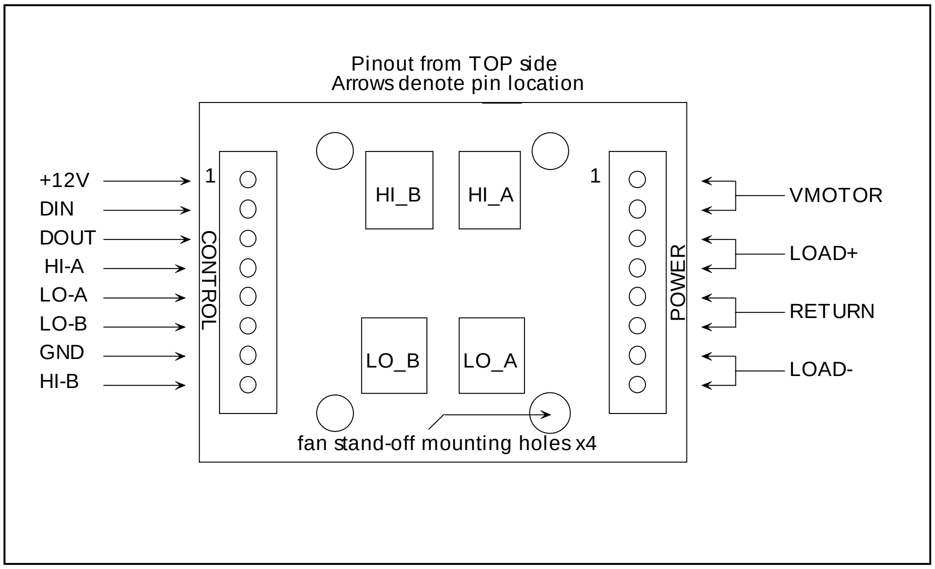


3.6 Connectivity Overview

The ICON H-Bridge has been designed to simplify the interface of a microprocessor, microcontroller, or other embedded control device to a DC motor via an H-bridge. Each MOSFET in the H-bridge can be controlled individually via logic level control signals. An on-board microcontroller enables or disables the H-bridge with either a serial communication interface, or by logic level control when in direct drive mode of operation (see section 4 for more on these operating modes).

Pin	Description	Notes
+12V	+12V input	Accepts 9.5V-15V should be protected from transients, PCB has 140mA resettable fuse
DIN	Serial data in or /Enable for direct drive mode	Pulled to 5V with 2.2kΩ resistor
DOUT	Serial data out or Status for direct drive mode	Pulled to 5V with 2.2kΩ resistor, this pin is pseudo open-collector, it is configured as an input when high, and an output when pulled low
HI-A	Controls high side MOSFET “A”	Pulled to ground with 2.2kΩ resistor, this pin can accept voltages up to the voltage on the +12V pin, a logic high turns on the MOSFET
LO-A	Controls low side MOSFET “A”	Pulled to ground with 2.2kΩ resistor, this pin can accept voltages up to the voltage on the +12V pin, a logic high turns on the MOSFET
LO-B	Controls low side MOSFET “B”	Pulled to ground with 2.2kΩ resistor, this pin can accept voltages up to the voltage on the +12V pin, a logic high turns on the MOSFET
GND	Logic circuit ground return	
HI-B	Controls high side MOSFET “B”	Pulled to ground with 2.2kΩ resistor, this pin can accept voltages up to the voltage on the +12V pin, a logic high turns on the MOSFET
VMOTOR	Motor voltage input 1-40VDC	2 pins rated 14A at 70°C, avoid peak voltages greater than 70V
LOAD+	Positive motor lead	2 pins rated 14A at 70°C, avoid peak voltages greater than 70V
RETURN	Motor current return	2 pins rated 14A at 70°C, avoid peak voltages greater than 70V
LOAD-	Negative motor lead	2 pins rated 14A at 70°C, avoid peak voltages greater than 70V

Figure 5: ICON H-Bridge Pins Locations



3.7 Mechanical Mounting Techniques

The ICON H-Bridge may be mounted from either the bottom or top side of the PCB. For higher current applications the MOSFETS should be faced away from the mounting PCB and a fan or other cooling system should be used to augment power dissipation capabilities. The Solutions Cubed ICON Active Cooling System is a prepackaged solution to many power dissipation problems. The bottom side mounting dimensions show the placement of the fan and standoffs used in the ICON Active Cooling System. Solder points are available on the ICON H-Bridge to connect a 12VDC fan to the H-Bridge PCB.

Figure 6: Bottom Mounting Dimensions

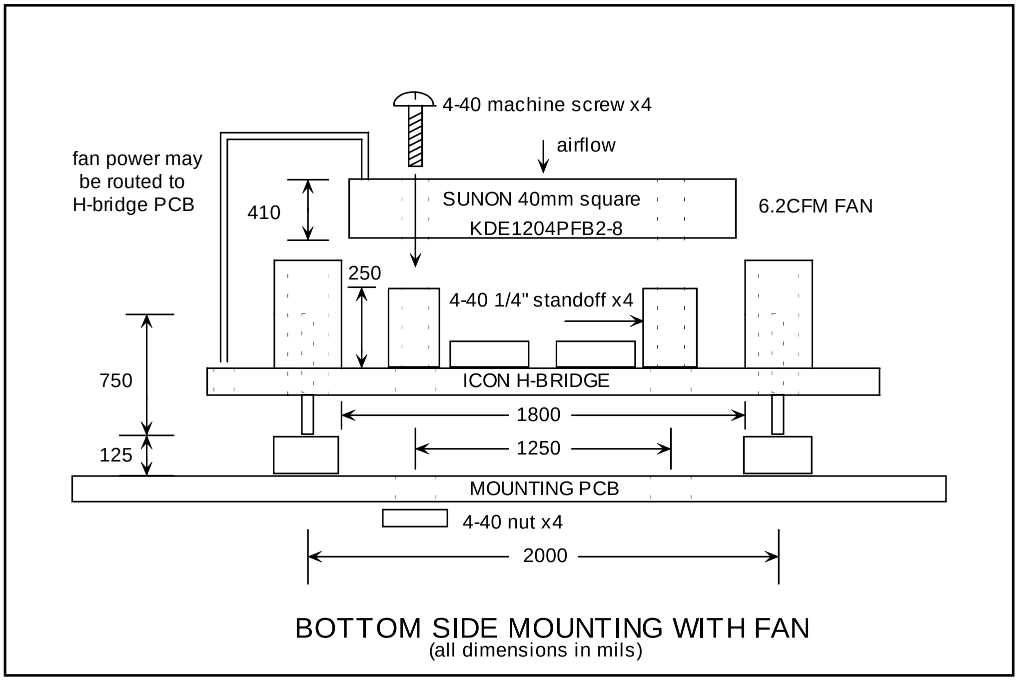
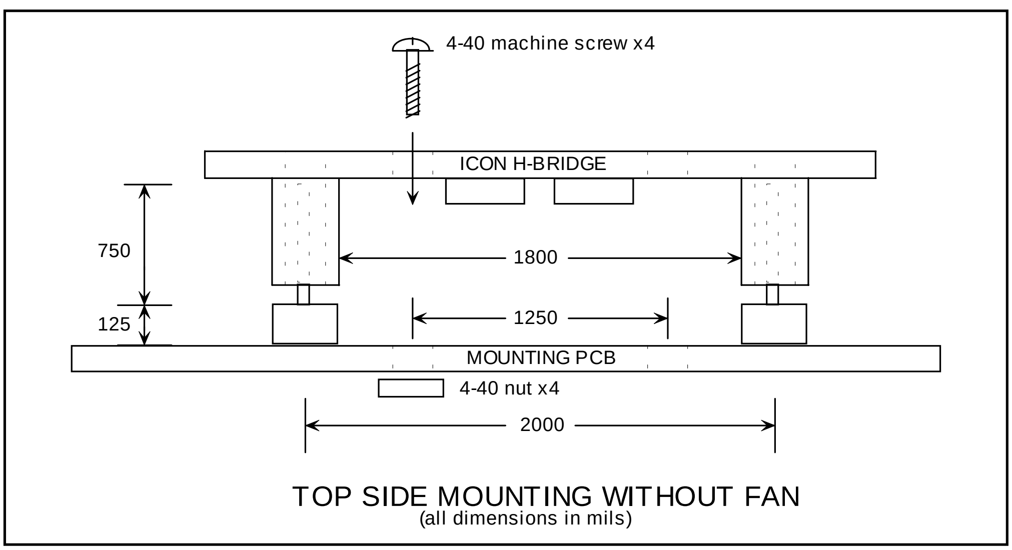


Figure 7: Top Mounting Dimensions



4. Operating Information

4.1 Overview

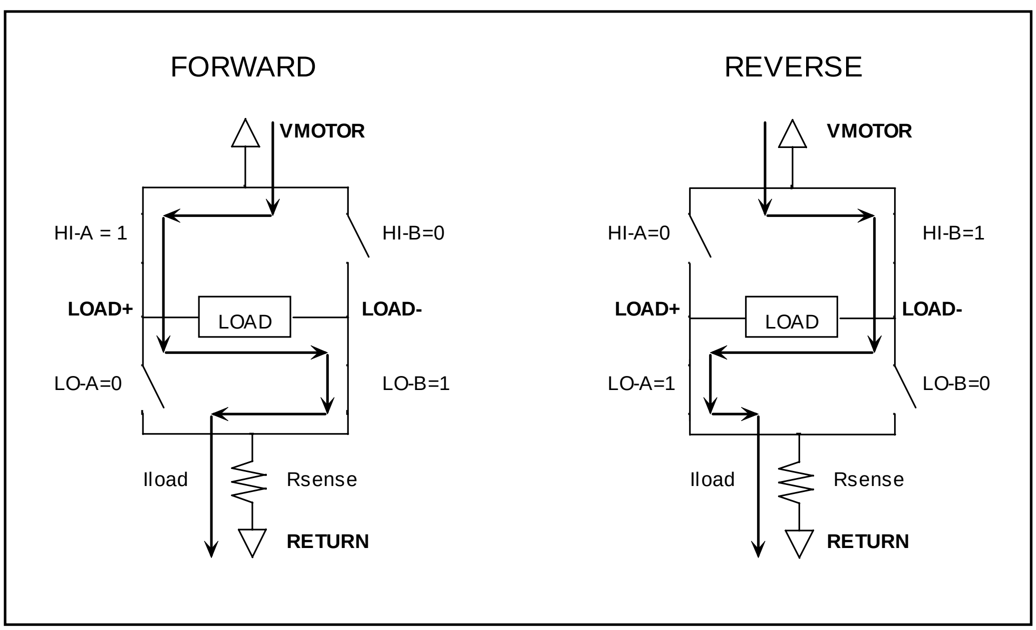
The ICON H-Bridge allows for a simplified interface to a DC motor. Speed and direction of a DC motor can be defined by the signals on pins LO-A, LO-B, HI-A, and HI-B. Each of these control lines is used to drive the gate of one of the 4 MOSFETs that make up the H-Bridge. Shoot-through conditions are not possible. See the truth table and figure 8 below for clarification of drive signals that may be used.

LO-B	HI-A	LO-A	HI-B	Mode of Operation
1	1	0	0	Forward
0	0	1	1	Reverse
1	0	1	0	Braking – motor leads tied to ground return
1	0	0	1	HI-B is disabled whenever LO-B is enabled
0	1	1	0	HI-A is disabled whenever LO-A is enabled
1	1	0	1	Forward – HI-B state will be opposite of LO-B
0	1	1	1	Reverse – HI-A state will be opposite of LO-A
1	1	1	1	Braking – motor leads tied to ground return

A “1” designated above represents a logic high, that enables the MOSFET associated with the control line. A “0” represents a logic low which disables the MOSFET associated with the control line. The mode designated as forward occurs when current flows through the load from the LOAD+ connection to the LOAD- connection on the ICON H-Bridge. Speed control can be accomplished by pulse-width-modulating (PWM) either LO-A or LO-B pins depending on the direction the motor is turning. The high side control lines may be pulse-width-modulated but doing this will result in increased power loss in the high side MOSFETs during PWM.

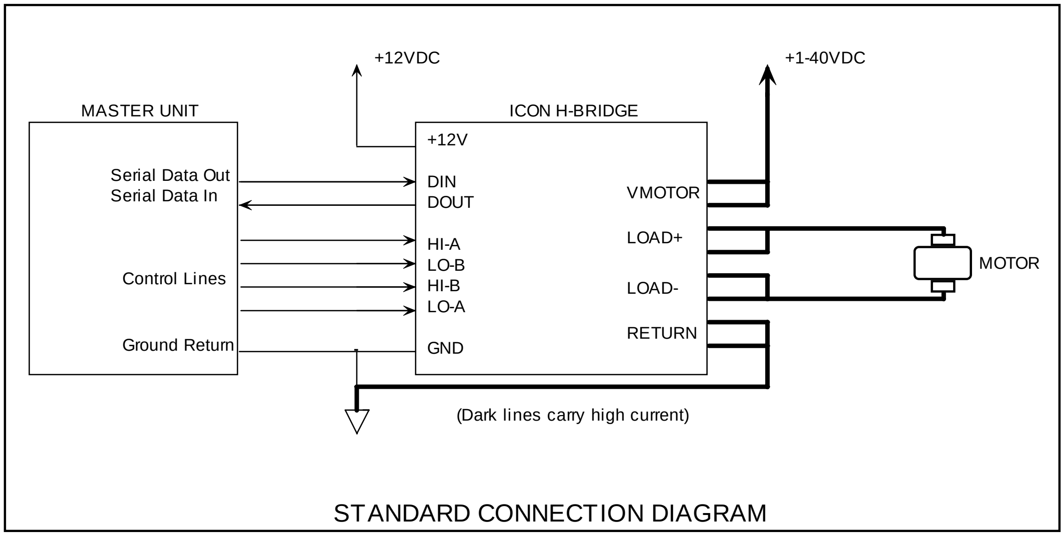
Figure 8 displays the state of each MOSFET (schematically described by a switch) in the two valid modes of operation. The load is typically a DC motor, but could be a halogen lamp, or a heating coil, and is attached between the LOAD+ and LOAD- pins. Changes in operating mode should be made in a break-before-make fashion.

Figure 8: Control Line Modes



Connectivity between the ICON H-Bridge module, a Master unit and a DC Motor is detailed below in figure 9. This example shows the Master with serial data line connections. If the ICON H-Bridge were configured in direct drive mode the "Serial Data Out" line would be used as the "/Enable" line, which is asserted low. Additionally, the "Serial Data In" line would be the "Status" output, and would mirror the status of the H-bridge (low for on, high for off).

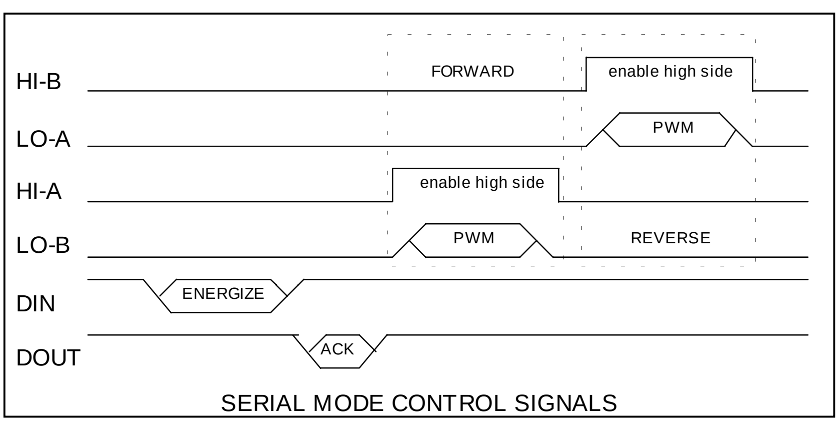
Figure 9: Standard Connection Diagram



4.2 Serial Mode

The default mode of operation for the ICON H-Bridge is the serial mode of operation. When in this mode the FAULT LED on the bottom of the ICON H-Bridge PCB will flash twice on power up. In serial mode the ICON H-Bridge accepts commands at 2400 bits-per-second (BPS), 4800BPS, or 9600BPS. The speed of communication is selected by the user via the ICON H-Bridge Communication Protocol (see the document under that title for complete information on the protocol and command set). In serial mode the Master unit sends serial commands to enable or "Energize" the H-Bridge. After the H-bridge is energized individual MOSFET control is based on the state of each of the control lines (LO-A, LO-B, HI-A, and HI-B). In serial mode the ICON H-Bridge can have its status checked, the current and temperature readings can be monitored, and various operating functions can be modified. The "De-energize" command is used to turn off the H-Bridge.

Figure 10: Serial Mode Control Signals



A multitude of commands and registers reside on-board the ICON H-Bridge. All of these aspects of the product are fully defined in the ICON H-Bridge Communication Protocol, and that document should be referenced when interfacing to the ICON H-Bridge. For quick reference, the command set, and register definition table for the ICON H-Bridge is listed below.

Figure 11: ICON H-Bridge Commands

Command	Syntax (hex)	Reply	Description
Read	C1 XX XX XX … XX	Reply	Read from one or more controller registers
Write	C2 XX XX XX … XX	Ack	Write to one or more controller registers
Store	C3 XX 00 XX	Ack	Set current registers as default values
Restore	C4 XX 00 XX	Ack	Restores factory default values
Energize	C5 XX 00 XX	Ack	Enables H-Bridge, clears fuses
De-energize	C6 XX 00 XX	Ack	Disables H-Bridge, clears fuses

Figure 12: ICON H-Bridge Registers

Index	Name	Size (Bytes)	Read / Write	Description
0	STATE	1	R	State of H-Bridge bits
1	AMPS	1	R	Current measurement value
2	TEMP	1	R	Temperature measurement value
3	FIRMWARE	1	R	Firmware revision
4	FUNCTION	1	R/W	Function settings register
5	AMPS-TRIP	1	R/W	Over current trip point
6	TEMP-TRIP	1	R/W	Over temperature trip point
7	NUMBER SAMPLES	1	R/W	Number of samples to average temperature and current measurements
8	BAUD	1	R/W	Baud rate setting for IHCP
9	ADDRESS	1	R/W	Address for ICON H-Bridge
10	CALIBRATE AMPS	1	R/W	Constant for calibration of current measurement
11	CALIBRATE TEMP	1	R/W	Constant for calibration of temperature measurement

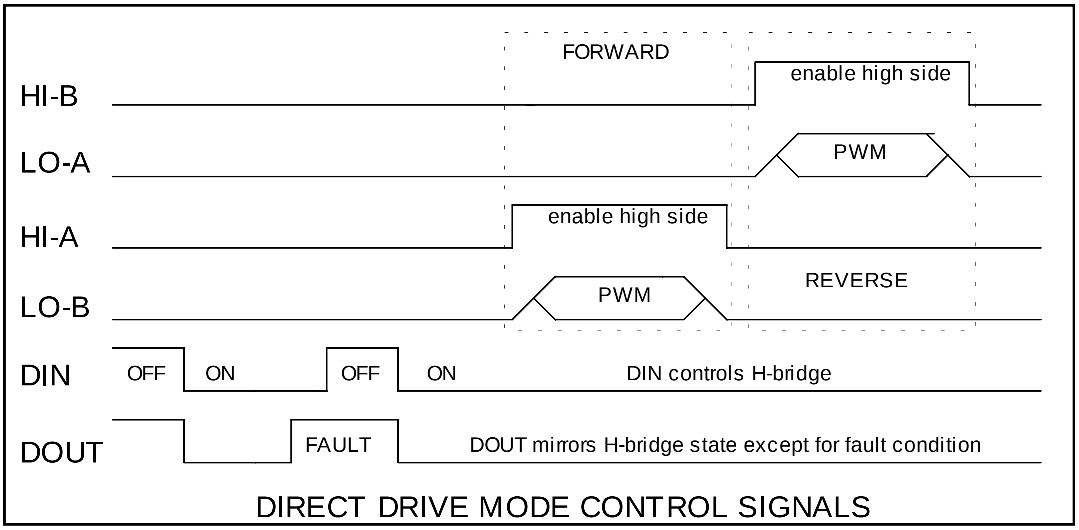
4.3 Direct Drive Mode

The ICON H-Bridge may be placed in direct drive mode by setting the highest bit of the FUNCTION register, and storing that new value in EEPROM (this is done while in serial mode with the “Write” and “Store” commands). The next time that the ICON H-Bridge is powered up it will enter into direct drive mode (serial communication will no longer be possible). The FAULT LED located on the bottom of the ICON H-Bridge PCB will flash once on power-up when the device is in direct drive mode.

In direct drive mode the DIN pin is used as the H-bridge enable pin. A logic low on the DIN pin enables the H-bridge. The DOUT pin mirrors the state of the actual H-bridge enable pin (internal to the ICON H-Bridge). Therefore, under normal operating conditions DOUT will mirror DIN. If a fault condition occurs (over-current or over-temperature trip point is exceeded) then the DOUT pin will be released high, to mirror the state of the internal H-bridge enable pin. In order to re-enable the H-bridge the DIN pin must be taken high and then pulled low again. Figure 13 shows an example of the signals one could see on the ICON H-Bridge control lines while in direct drive mode.

As mentioned above, while in direct drive mode serial communication is not possible. The only way to exit direct drive mode is to short the connection on the top side of the ICON H-Bridge marked “DDE” for direct-drive-escape” and power up the device. This can be done by placing a small conductor (such as a screw driver tip) across the two pads, and applying power to the ICON H-Bridge. Once powered the conductor should be removed. Shorting the “DDE” pads enables the H-bridge and this process of escaping direct drive mode should be done with the load (motor) disconnected, and all control line pulled low or disconnected.

Figure 13: Direct Drive Mode Control Signals



While in direct drive mode the ICON H-Bridge continues to monitor current and temperature, and adheres to the “number of samples” setting as defined by its internal registers. For this reason the direct drive mode propagation delay is effected by the state of these registers. For fastest response time the NUMBER SAMPLES register should be loaded with a 0x01 (hexadecimal 1) and stored in EEPROM with a STORE command prior enabling direct drive mode.

4.4 Current Handling – Power Dissipation

In both serial mode and direct drive mode the over-current and over-temperature trip points are used to protect the ICON H-Bridge and the attached Master unit from destruction. These protective features should not be disabled. If a fault condition occurs it will set a flag in the STATUS register. Additionally, if a fault condition occurs the FAULT LED on the bottom of the ICON H-Bridge will light until the fault flag is cleared. In serial mode, clearing a fault flag can be accomplished by sending the “Energize” or “De-energize” command. In direct drive mode toggling the DIN line (high-to-low) will reset the fault flags.

The current handling capability of the ICON H-Bridge is based on both the motor voltage and the power dissipation considerations of your system. The over-temperature trip point defaults to 80°C. The MOSFETs that make up the power-handling portion of the ICON H-Bridge can operate to 175°C. However most other components on the ICON H-Bridge are limited to 85°C. Therefore the over-temperature trip point should be maintained below 85°C to insure proper operation of the device.

The devices generating most heat (dissipating most power) on the ICON H-Bridge are the MOSFETs and the sense resistor. Through experimentation and calculating approximate power dissipation of the ICON H-Bridge as a system it was determined that 1.7W of power dissipation would raise the ICON H-Bridge PCB by about 60°C. With ambient temperature at 25°C this places the ICON H-Bridge close to its upper operating parameter.

The current handling specification for the ICON H-Bridge is based on a positive duty-cycle of 95%. The equation used to calculate power dissipation and current handling is based on the equation below. This equation does not account for heating of the PCB due to the currents being handled by the ICON H-Bridge, but does provide a good approximation of results found in the lab.

$$P_{TOTAL} = P_{LOFET} + P_{HIFET} + P_{RSENSE}$$

Where P_{TOTAL} is the total system power dissipation as heat
P_{LOFET} is the power dissipated by the low side switching MOSFET
P_{HIFET} is the power dissipated by the low side non-switching MOSFET
P_{RSENSE} is the power dissipated by the current sense resistor

$$P_{LOFET} = (V_{MOTOR} \times (I_{AVG} / PWM_{DC}) \times (t_r + t_f) / 6 \times T_{PWM}) + I_{AVG}^2 \times R_{DSON}$$

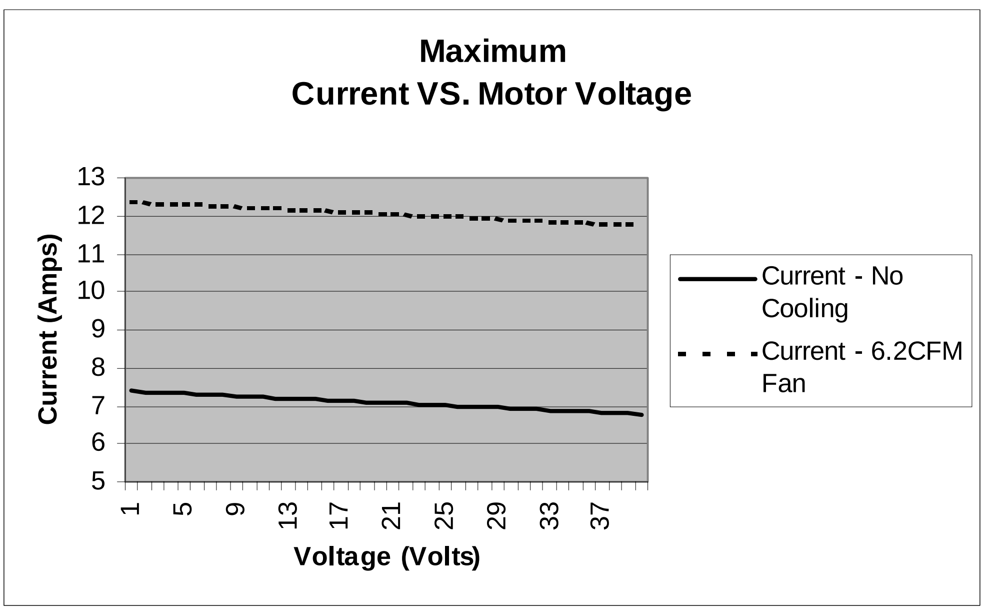
$$P_{HIFET} = I_{AVG}^2 \times R_{DSON}$$

$$P_{RSENSE} = I_{AVG}^2 \times R_{SENSE}$$

Where V_{MOTOR} is the motor voltage
I_{AVG} is the average load current
PWM_{DC} is the duty cycle (0.95 for 95%)
t_r is the rise time of the gate drive signal (100nS)
t_f is the fall time of the gate drive signal (200nS)
T_{PWM} is the period of the PWM frequency (52uS for our test)
R_{DSON} is the drain-source resistance of the MOSFET (13mΩ)
R_{SENSE} is the current sense resistance (5mΩ)

Using the 1.7W figure for the ICON H-Bridge in open air with no cooling, and 4.75W for the ICON H-Bridge in open air with the ICON Active Cooling System, the following current handling capabilities were determined and verified through experimentation.

Figure 14: Maximum Current vs. Motor Voltage



4.5 H-Bridge - Master Unit Transient Protection

DC motors driven via PWM signals can generate transient voltage and current spikes that can damage or destroy electronic circuits. Several techniques may be used with the ICON H-Bridge to minimize the effect of transient signals on your circuitry. First and foremost, all connections should be as short as possible. This includes the wiring connections for the motor voltage, motor leads, and motor ground returns, but it is especially important to minimize the length of control lines and +12V supply. Ideally, connections to the ICON H-Bridge should be via PCB and 0.156" headers.

Even with short leads or direct PCB connections the control signals can be provided with simple low cost circuitry to protect the ICON H-Bridge and its Master unit from other transients.

Figure 16: Transient Protection Circuits

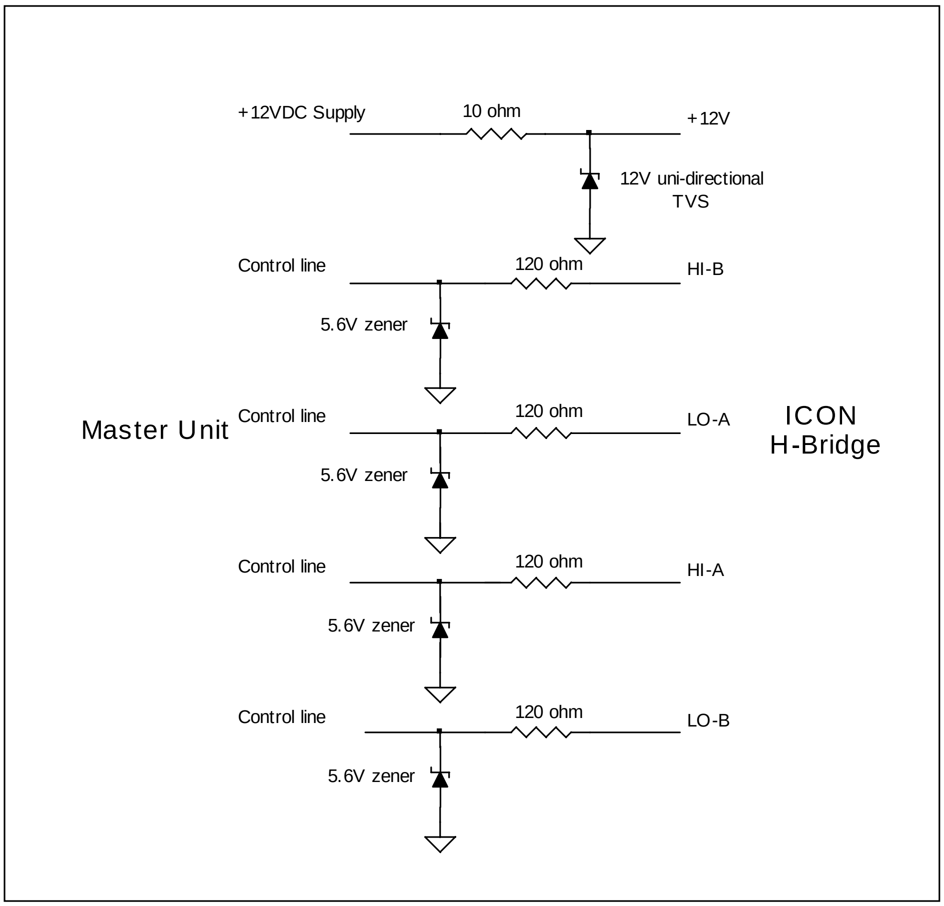


Table of Contents – Communication Protocol

List of Figures

1. Revision Log – Communication Protocol

Date	Rev	Description	By
03-02-01	1	Original Implementation	L. Glazner
10-25-01	2	Modified protocol to reflect changes in Direct Drive mode of operation	L. Glazner
11-03-01	3	Modified protocol to reflect changes in ICON H-Bridge default values and added thermistor ADC table	L. Glazner
11-03-01	4	Updated list of figures and index to match actual document	L. Glazner

2. Introduction

This document defines the command protocol used in conjunction with the ICON H-Bridge serial interface. The ICON H-Bridge has an analog monitor circuit embedded on its PCB for use in monitoring current and temperature. The monitor circuit may be accessed via a TTL serial interface. The ICON H-Bridge Communication Protocol (IHCP) must be followed in order to implement commands, or to modify functionality in the ICON H-Bridge.

2.1 Scope

This document provides the necessary information for implementation of IHCP in Master units. The Master is assumed to be a computer, microprocessor, or microcontroller that assumes control of the ICON H-Bridge. The Slave device is the fore-mentioned ICON H-Bridge device, which has been developed by Solutions Cubed. The command structures and register / data formats are defined herein.

2.2 Definitions, Acronyms, and Abbreviations

ASCII: American Standard Code for Information Interchange

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, terminal, or device 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. The Slave in this system is the ICON H-Bridge.

0xXX Format used to describe data in hexadecimal format.

TBD: To Be Determined

3. Functional Description

3.1 Overview

The IHCP 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. Since multiple Slave devices can share the same transmission lines, it is not feasible to have a device respond with a Negative Acknowledge (NAK) when an error occurs.

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 IHCP will be represented by eight bit values (bytes). The relationship between these byte values and actual values such as current and temperature will be discussed later in this document.

3.3 Hardware Usage

Asynchronous communication takes place with a 2,400 BPS, 4,800 BPS, or 9,600 BPS rate, using eight data bits, no parity, and one stop bit (default is 2,400, n, 8, 1). A single pair of TTL 8N1 lines from the Master will be distributed to the Slave device.

4. Detailed Description

4.1 Binary Mode

Binary mode is the only mode implemented in IHCP. This mode uses three types of packets. They are Command Packets, ACK Packets, and Reply Packets. A lack of 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 IHCP has *five* dependent components. The first component is the command byte. The second component is an eight-bit address used to pick the Slave to receive communication. The ICON H-Bridge has an address ranging from 0x01-0xFF. The third 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 fourth component is the actual message (Read, Write, etc). The final component is the 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 ICON-H-Bridge sends ACK packets to the Master when a command arrives that requires no data to be returned. The ICON H-Bridge will return a hex value of 0x06 if the Command Packet was received correctly and all went as planned.

Figure 2: ACK Packet Construction

0x06

4.1.3 NAK Packets

NAK Packets are not currently used in IHCP.

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 of Sender	Length	Msg1	Msg2	…	MsgN	Checksum

4.2 Communications Sequence

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

Figure 4: Communication Sequences

		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 1 millisecond for the IHCP.

The response time is the time from when the Master sends the last bit of the Command Packet, to when the Master receives the first bit or the response from the Slave. The maximum allowable response time is 2 milliseconds.

The firmware in the ICON H-Bridge will not accept messages greater than 16 bytes in length.

4.3.1 Universal Address

The ICON H-Bridge will accept communication if addressed as H '00' regardless of the contents of the its internal ADDRESS register. No communication is returned by the ICON H-Bridge 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 H-Bridge devices on the same serial data bus.

4.4 Commands and Registers

4.4.1 Read Command (0xC1)

The Read command message string should consist of the Command packet byte (0xC1), 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 STATE register (register 0x00) from an ICON H-Bridge at address 0x04 the data string would appear as,

C1, 04, 01, 00, C6 (all in hexadecimal)

4.4.2 Write Command (0xC2)

The Write command message string should consist of the Command packet byte (0xC2), 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 various thresholds within the switches themselves. An example of setting the AMP Fuse trip point to 0x80 in the ICON H-Bridge device, in a unit at address 0x04 is shown below.

C2, 04, 02, 02, 80, 48 (all in hexadecimal)

4.4.3 Store Command (0xC3)

The Store command message string should consist of the Command packet byte (0xC3), the Address byte, and 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 0x04 through 0x0B (registers 4 through 11) in nonvolatile EEPROM memory. These values then become the power-on default values of the ICON H-Bridge device. After this command is executed the Master should refrain from issuing another Restore or Store command for 15ms. An example of executing a Store Command in an ICON H-Bridge residing at address 0x04 is shown below.

C3, 04, 00, C7 (all in hexadecimal)

4.4.4 Restore Command (0xC4)

The Restore command message string should consist of the Command packet byte (0xC4), 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 internal registers 0x04 – 0x0B to their default factory settings. These values are stored in EEPROM with this command. After this command is executed the Master should refrain from issuing another Restore or Store command for 15ms. The example below assumes an ICON H-Bridge address of 0x06

C4, 06, 00, CA (all in hexadecimal)

4.4.5 Energize Command (0xC5)
An Energize command is used to turn on the ICON H-Bridge. This command also clears any tripped fuse bits. The Energize command message string should consist of the Command packet byte (0xC5), the Address byte, and the Length byte (in this case 0x00). All of these bytes are followed by the checksum. The example below assumes an ICON H-Bridge address of 0x08.

C5, 08, 00, CD (all in hexadecimal)

4.4.6 De-energize Command (0xC6)
A De-energize command is used to turn off the ICON H-Bridge. This command also clears any tripped fuse bits. A De-energize command message string should consist of the Command packet byte (0xC6), the Address byte, and the Length byte (in this case 0x00). All of these bytes are followed by the checksum. The example below assumes an ICON H-Bridge address of 0x08.

C6, 08, 00, CE (all in hexadecimal)

4.4.7 ICON H-Bridge Commands
Figure 5 shows the commands supported by the ICON H-Bridge.

Figure 5: ICON H-Bridge Commands

Command	Syntax (hex)	Reply	Description
Read	C1 XX XX XX XX … XX	Reply	Read from one or more controller registers
Write	C2 XX XX XX XX … XX	Ack	Write to one or more controller registers
Store	C3 XX 00 XX	Ack	Set current registers as default values
Restore	C4 XX 00 XX	Ack	Restores factory default values
Energize	C5 XX 00 XX	Ack	Enables H-Bridge, clears fuses
De-energize	C6 XX 00 XX	Ack	Disables H-Bridge, clears fuses

4.4.8 ICON H-Bridge Registers
Figure 6 shows the registers for the ICON H-Bridge. The current values of all Read / Write registers can be copied into EEPROM with the Store command.

Figure 6: ICON H-Bridge Registers

Index	Name	Size (Bytes)	Read / Write	Description
0	STATE	1	R	State of H-Bridge bits
1	AMPS	1	R	Current measurement value
2	TEMP	1	R	Temperature measurement value
3	FIRMWARE	1	R	Firmware revision
4	FUNCTION	1	R/W	Function settings register
5	AMPS-TRIP	1	R/W	Over current trip point
6	TEMP-TRIP	1	R/W	Over temperature trip point
7	NUMBER SAMPLES	1	R/W	Number of samples to average temperature and current measurements
8	BAUD	1	R/W	Baud rate setting for IHCP
9	ADDRESS	1	R/W	Address for ICON H-Bridge
10	CALIBRATE AMPS	1	R/W	Constant for calibration of current measurement
11	CALIBRATE TEMP	1	R/W	Constant for calibration of temperature measurement

4.5 Detailed Register Descriptions

Accessing the H-Bridge registers described herein can modify various H-Bridge 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. The STATE, FUNCTION, and NUMBER SAMPLES registers contain bit-size flags that describe the operating modes and current states of the ICON H-Bridge.

4.5.1 INDEX0: STATE Register

The STATE register maintains a set of flags that describe the current state of the ICON H-Bridge. The OVER AMPS flag is set as a binary "1" when the value in the AMPS register exceeds the value in the AMPS-TRIP register. This same relationship is true of the OVER TEMP flag, the TEMP, and TEMP TRIP registers. If the current or temperature protection is disabled via the FUNCTION register then the OVER AMP and OVER TEMP flags will be set if the trip points are exceeded, but the H-Bridge will not be disabled. The OVER AMP and OVER TEMP flags will only be cleared if the Energize or De-Energize commands are sent to the ICON H-Bridge. The DISABLED flag is set as a binary "1" when the ICON H-Bridge has been disabled by the over current or over temperature protection, or turned off by the De-Energize command. It will also be set or cleared based on the POWER-ON STATE flag in the FUNCTION register. The I2C FAIL flag is set when the EEPROM fails to respond to acknowledge polling. If this occurs on power-up the ICON H-Bridge is forced to load its registers with their default values.

Figure 7: ICON H-Bridge STATE Register

Name	Register	Bit	R/W	Description
OVER AMPS	STATE	0	R	Set if current trip point exceeded
OVER TEMP	STATE	1	R	Set if temperature trip point exceeded
DISABLED	STATE	2	R	Set if H-Bridge is disabled
I2C FAIL	STATE	3	R	Set if I2C Communication has failed
Unused	STATE	4	R	This bit location unused at this time
Unused	STATE	5	R	This bit location unused at this time
Unused	STATE	6	R	This bit location unused at this time
Unused	STATE	7	R	This bit location unused at this time

4.5.2 INDEX1: AMPS Register

The AMPS register contains the current measurement in 100mA increments. For constant current measurements this value is typically +/- 200mA from the actual average current. When switching high currents through the ICON H-Bridge the current measurement error can become quite large (+/- 1000mA). The error is greatest at high average currents (8+ amps) occurring during low duty cycles. For your system using the CAL_AMPS register to offset errors can alleviate some of this error. The error in this measurement typically results in a higher value than might be measured with an averaging multimeter. If using over current protection you may also increase your trip point level to account for this error.

4.5.3 INDEX2: TEMP Register

The TEMP register contains the temperature measurement derived from an on-board thermistor. 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 8: 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	17-20
25	77	21-24
30	86	25-29
35	95	30-35
40	104	36-42
45	113	43-50
50	122	51-59
55	131	60-69
60	140	70-80
65	149	81-92
70	158	93-105
75	167	106-119
80	176	120-134
85	185	135-149

4.5.4 INDEX3: FIRMWARE Register

The FIRMWARE register contains the current firmware revision used as the operating system by the ICON H-Bridge. The firmware revision may be useful when viewing errata documents.

4.5.5 INDEX4: FUNCTION Register

ICON H-Bridge functionality can be selected by the user through the FUNCTION register flags. The AMPS FUSE and TEMP FUSE flags are set to enable the over current and over temperature protection features in the ICON H-Bridge. The POWER-ON STATE flag is set if the ICON H-Bridge is supposed to enable the power switch controller (similar to sending an energize command on power up) prior to serial communication with the ICON H-Bridge. In Direct Drive Mode the POWER-ON STATE flag is over-ridden by the state of the DIN pin.

The DIRECT DRIVE MODE flag is set to enable Direct Drive Mode. Direct Drive Mode allows the user to enable and disable the ICON H-Bridge without using the serial communication link. In Direct Drive Mode the DIN pin is used to turn on/off the ICON H-Bridge, while the DOUT pin reflects the actual state of the ICON H-Bridge. In Direct Drive Mode the over current and over temperature protection will be enabled based on the values stored in the FUNCTION register. To enter Direct Drive Mode the DIRECT DRIVE MODE flag must be set, and the FUNCTION register must be stored in EEPROM. The next time the ICON H-Bridge is powered up the serial communication process will no longer be available. For more information on Direct Drive Mode or escaping from Direct Drive Mode see the document “ICON H-Bridge Data Sheet”.

Figure 9: 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
POWER-ON STATE	FUNCTION	2	R/W	Set if power-on state of H-Bridge is ON. Cleared if H-Bridge powers-up off
TBD	FUNCTION	3	R/W	TBD
TBD	FUNCTION	4	R/W	TBD
TBD	FUNCTION	5	R/W	TBD
TBD	FUNCTION	6	R/W	TBD
DIRECT DRIVE MODE	FUNCTION	7	R/W	Set for H-Bridge to enter Direct Drive Mode on next power up (must be stored in EEPROM)

4.5.6 INDEX5: AMPS-TRIP Register

The value stored in the AMPS-TRIP register is used to set over current protection levels in the ICON H-Bridge. The value stored in this register is in 100mA increments. Trip points may therefore be set at levels from 0-25.5 amps.

4.5.7 INDEX6: TEMP-TRIP Register

The value stored in the TEMP-TRIP register is used to set over temperature protection levels in the ICON H-Bridge. The values displayed in figure 8 under the TEMP register should be used to establish trip points. Trip points can be set at levels from 0C-85C. The over temperature protection should not be set above 85C.

4.5.8 INDEX7: NUMBER SAMPLES Register

The NUMBER SAMPLES register allows the user to select the number of samples that the ICON H-Bridge takes before updating the AMPS and TEMP registers. This value is limited to 128, 64, 32, 16, 4, 2, or 1. The NUMBER SAMPLES register should not be changed on the fly. The value of samples desired should be loaded into the register, followed by a STORE command, and then the power should be cycled. The number of samples selected directly effects the maximum time that the ICON H-Bridge requires in identifying an over current or over temperature condition. As a rule of thumb the response time to a fault condition is 100uS x NUMBER SAMPLES. The NUMBER SAMPLES register is internally limited to 128, 64, 32, 16, 8, 4, 2, or 1 on power up.

4.5.9 INDEX8: BAUD Register

The ICON H-Bridge may operate at 3 different user selected baud rates. Once the BAUD register is written to it should be stored in EEPROM with a Store command. The baud rate change does not take effect until the power to the device is cycled. The different baud rates and the values associated with the BAUD register are listed below.

Figure 10: ICON H-Bridge BAUD Register Values

Baud Rate	BAUD Register in Hexadecimal	BAUD Register in Decimal
2400 BPS	0x65	101
4800 BPS	0x31	49
9600 BPS	0x17	23

This value is internally limited so that if any values other than those listed above are stored in EEPROM the BAUD register will default to 0x65. Some users may have communication when operating at 9600BPS. If this is the case try implementing a “retry” capability in your system or change to a lower baud rate. For noisy or high current systems implementing a “retry” capability is a must.

4.5.10 INDEX9: ADDRESS Register

The ICON H-Bridge has a programmable address register. Any change to the ADDRESS register should be followed by a Store command to force the device to maintain this new address after the next power-up. Changes in the address register value do not take place until the ICON H-Bridge has had its power cycled off and then on.

4.5.11 INDEX10: CALIBRATE AMPS Register

The CALIBRATE AMPS register value is used to modify the AMPS register. If the highest bit of the CALIBRATE AMPS register is set then the lower seven bits are subtracted from the AMPS register. The result is limited to 0x00 and will not roll under. If the highest bit of the CALIBRATE AMPS register is clear then the lower seven bits are added to the AMPS register. The result is limited to 0xFF and will not roll over. For example, to subtract 2 from the AMPS register the user would set the CALIBRATE AMPS register to 0x82, to add 2 to the AMPS register the user would set the CALIBRATE AMPS register to 0x02. This function can allow the user to account for inaccuracies in current measurements. If the AMPS register is 0x00 then the calibration value is ignored.

4.5.12 INDEX11: CALIBRATE TEMP Register

The CALIBRATE TEMP register value is used to modify the TEMP register. If the highest bit of the CALIBRATE TEMP register is set then the lower seven bits are subtracted from the TEMP register. The result is limited to 0x00 and will not roll under. If the highest bit of the CALIBRATE TEMP register is clear then the lower seven bits are added to the TEMP register. The result is limited to 0xFF and will not roll over. For example, to subtract 2 from the TEMP register the user would set the CALIBRATE TEMP register to 0x82, to add 2 to the TEMP register the user would set the CALIBRATE TEMP register to 0x02. This function can allow the user to account for inaccuracies in temperature measurements.

4.6 Default Values on Factory Power Up

Each ICON H-Bridge 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 H-Bridge device will test its write accessible RAM registers on power up for a 0xFF. If all registers equal 0xFF then the ICON H-Bridge 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 11: ICON H-Bridge Default Values

Index	Name	Size (Bytes)	Value 0x??	Description
4	FUNCTION	1	0x03	Current and temperature fuses enabled
5	AMPS TRIP	1	0x96	Over current trip point of 15.0A
6	TEMP TRIP	1	0x8C	Over temperature trip point of 80C
7	NUMBER OF SAMPLES	1	0x20	32 samples of temperature and current averaged
8	BAUD	1	0x65	Default is 2400bps
9	ADDRESS	1	0x01	Default address of 1
10	CALIBRATE AMPS	1	0x00	No AMPS register calibration
11	CALIBRATE TEMP	1	0x00	No TEMP register calibration

Disclaimer of Liability and Accuracy: Information provided by Solutions Cubed is believed to be accurate and reliable. However, Solutions Cubed assumes no responsibility for inaccuracies or omissions. Solutions Cubed assumes no responsibility for the use of this information and all use of such information shall be entirely at the user's own risk.

Life Support Policy: Solutions Cubed does not authorize any Solutions Cubed product for use in life support devices and/or systems without express written approval from Solutions Cubed.

Warrantee: Solutions Cubed warrants all ICON DC Motor Control Modules against defects in materials and workmanship for a period of 90 days. If you discover a defect, we will, at our option, repair or replace your product or refund your purchase price. This warrantee does not cover products that have been physically abused or misused in any way.