

COMPONENT DATASHEETS

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3 COMPONENT DATASHEETS

This section of the FRC Control System Manual contains datasheets for all of the control system components manufactured specifically for the FIRST Robotics Competition.

3.1 DRIVER STATION

3.1.1 Functional Description

The Driver Station (DS) is the module that controls the robot remotely. The heart of the DS is an ARM9 based single board computer running Linux. This enables new features to be added and provides improved user interactions. The DS communicates with the robot through Ethernet packets, sending command packets and receiving status packets. The Field Management System (FMS) also communicates with the DS via Ethernet packets to control matches, monitor status, and provide the needed safety features for competitions.

3.1.2 Features

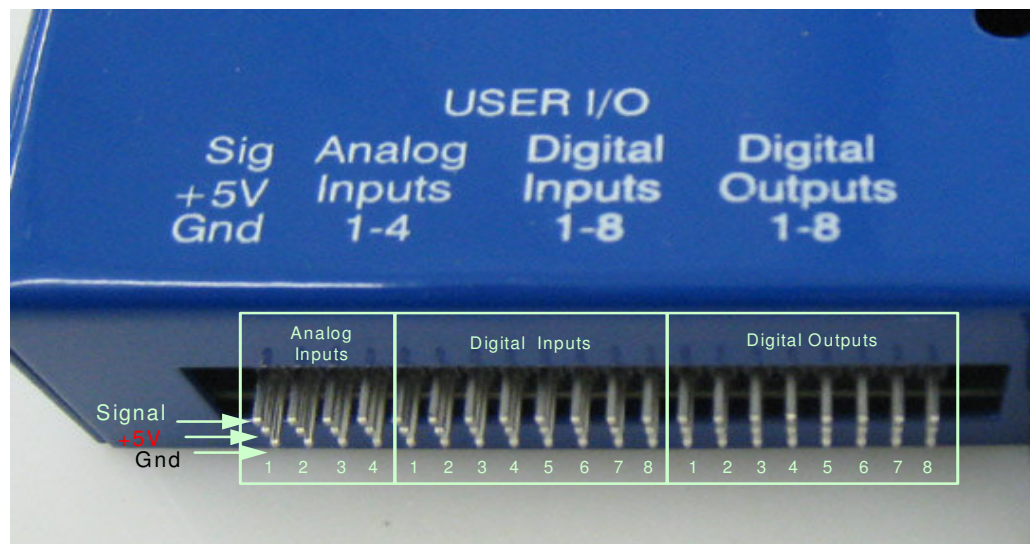
The Driver Station provides 2 Ethernet ports, a DE9 connector competition port, 4 USB ports, 8 digital input ports, 8 digital output ports, and 4 analog input ports. The DS is supplied power via either the barrel connector top left side from a 12V AC wall adaptor or via the competition port (used during competitions on the field). With a LCD graphic display the teams can monitor the status of the robot and the operating mode live. Switches are provided for controlling Autonomous/Tele-operation mode and for manipulating the LCD Display modes.



3.1.3 Port and Indicator Light Descriptions

The following describes the various ports on the Driver Station.

- Power LED - Indicates the Driver Station has power.
- Power Jack – Connects to the AC adapter to supply up to 13.8V DC to the Driver's Station.
- Competition Port – Connects to the Field Management System through a DE9 connector to provide power and enable/disable during competition. Pinouts for this connector are in section 3.1.7
- Ethernet Jacks (2) –Connects the Driver Station to the wireless device (either at home or to the field access point) and to the team laptop or PC.
- Ethernet LED – Indicates communication between the Driver Station and the connected device.
- Autonomous / Tele-operation Switch – Switches the Driver Station between Autonomous and Tele-operation modes. Used during team practice while not connected to the FMS in competition.
- LCD Display - Displays IP address, battery level, team name, Auto vs. Tele-operation mode, and enable vs disable. Associated with the LCD Display are 3 push button switches: Up, Down, and Select. These are used to select various modes of operation for the DS such as: Setting Team ID and Updating the DS software via USB.
- Digital Input pins 5V input level (8) – Used to monitor switches. See pin ordering below. Note that the Digital Inputs do not include “pulldown” resistors, so unconnected inputs will have unpredictable values.
- Digital Output pins 5V output level (8) – Provides 5V TTL for interfacing to digital devices and to drive LEDs (with current limiting resistors).
- Analog Input Pins (4) – Used to monitor analog voltages up to 5V from potentiometers, resistor dividers, etc.



- USB LED – Indicates communication between the Driver Station and the USB devices.
- USB Ports (4) – Connects to USB Joysticks

3.1.4 Typical Application

** Always refer to FIRST rules for using this module within competition robots. The following Figure shows an example setup and the connections.



Connect the Driver Station to the joysticks using the USB ports. Make sure you connect each joystick to the USB port programmed for its use. Note: The joysticks should be plugged in prior to powering up the Driver Station.

Connect a cat5 Ethernet cable to an Ethernet jack on the Driver Station, then to either a wireless device or to Ethernet port #1 on the cRIO. This shows the Linksys Wireless unit connected.

Connect the AC adapter (12V) to the Driver Station, then plug the AC adapter into the wall outlet.

There is no power switch for the Driver Station; it is powered on whenever it is plugged in. The Driver Station requires 15 seconds to boot, plus an additional 10 seconds per USB device, giving a required boot time range of from 15 to 55 seconds.

3.1.5 Setting Team ID and Updating the DS software.

3.1.5.1 Setting Team ID

The team number is stored on the driver station and is used to generate the IP addresses for the Driver Station and the Robot. In order to set or change the Team ID on the Driver Station the following sequence is used:

1. Hold the DOWN button (center button under the LCD Display) wait for over 5 seconds until the LCD Display changes. It should read "SET TEAM NUMBER" with the current number displayed.
2. Use the UP button (leftmost) to increment the current highlighted digit to desired number. Holding this button will continue to increment up to the number Nine and then it rolls over back to Zero. There is no going back only counting up.
3. To move to the next digit for setting, hold the Down button until the desired digit is highlighted. Note: It is not necessary to re-set every digit if they are currently correct. In the case of a single digit team, only the rightmost digit must be set.
4. To cause the new Team ID to be stored, push and hold the SELECT button (rightmost) until the LCD screen changes and indicates updating. Note: The Driver Station will reboot after this point.

3.1.5.2 The following sequence is used to update the DS Software

The Driver Station software is updated via the USB ports. The process is semi-automated and is started by a particular LCD button sequence with the USB memory stick inserted into any USB port on the DS. The image that is uploaded onto the Driver Station must be called DSUD_PKG.BIN on the memory stick and may not be a link but must be the named file. The updater software on the DS will check for the correctly named file and size.

To start the update process, follow these steps:

1. Insert the USB memory stick into a USB port on the Driver Station
2. Simultaneously hold the UP button (leftmost) and the DOWN button (center). Wait for the LCD Display to prompt for release of the buttons (approximately 8secs) before performing the next step in the update button sequence.
3. Hold the UP button (leftmost) down until the display prompts the user to release it.
4. When the display prompts the user to hold the DOWN button (center) do so until the display prompts the user to release it.
5. Wait for the display to prompt the user to hold the SELECT button (rightmost) down. Hold the button until the display gives the "DO NOT SHUT OFF! ..." prompt.
6. Do not shut off the DS. Leave the USB memory stick in place until after the system reboots. NOTE: It will be necessary to reset the Team ID after updating the software.
7. If the Driver Station does not display the warning message but instead drops out to the normal status display this is due to any number of issues. (Please see section 3.1.8)
8. REMEMBER to reset the Team ID afterwards!!

3.1.6 Specifications

Parameter	Min	Nom	Max	Units	Description
DS Supply Voltage	9V	12V	13.8V	Volts	DC Supply for Driver Station
DS Supply Current			900	MA	DC current at 12V
Digital Input	2.0		5.0	Volts	Standard TTL input High voltage

High					levels for digital inputs.
Digital Input Low	0.0		0.8	Volts	Standard TTL input Low voltage levels for digital inputs.
Analog INPUT	0.0		5.0	Volts	Permitted input voltage levels for analog inputs.
Digital Outputs	0.0		5.0	Volts	Low to High Digital Output (typical) expected levels.

3.1.6.1 General Guidelines for Driver Station Input and Outputs

To save debugging headaches, make sure the circuit ground is connected to the DS user pin ground(s).

Do not power external circuits with additional power supplies. Use the +5VDC supplied by the DS user pin(s). All user pins are 0V - 5V, max.

Watch out for potential shorts between power (+5VDC) and ground when connecting to the I/O pins; any shorts between power and ground will prevent the Driver Station from booting.

3.1.6.2 Driver Station Digital Outputs:

The DS digital output pins are driven directly by 5V transceiver (SN74LVC4245A device). Be sure to use caution as each pin can source/sink more than 40mA. It is possible to damage the device if too much current is driven on a single pin or the total current supplied by the device on all pins is excessive. Best practice should be to use a limiting resistor to prevent external loads from drawing excessive current, especially for LEDs, be sure to use a series resistor to limit the current.

3.1.6.3 Driver Station Digital Inputs:

The DS digital input pins are routed directly to an input transceiver. Be sure to use caution as the device can be damaged with excessive input voltages. This applies for large positive and negative voltages: above +5VDC and below the DS ground (0V).

The input pins are not terminated so as to not place unnecessary constraints on the input circuits. This means the pins are floating unless driven/terminated on the user circuit. Best practice should tie unused input pins to ground or +5VDC, preferably through a resistor.

3.1.6.4 Driver Station Analog Inputs:

The DS analog input pins are routed directly to a buffer op amp. The same precautions taken with the digital inputs should also be applied to the analog input signals.

The apparent input impedance is very large (orders of Megaohms). This reduces demands placed on external circuits. As a result of the high input impedance, the circuit behaves more like a true voltage input. Watch out for high-frequency input signals. While the sampling frequency may be sufficient for the input, the system may not report this data at a rate required to recreate the input signal. See Nyquist-Shannon sampling theorem for more information.

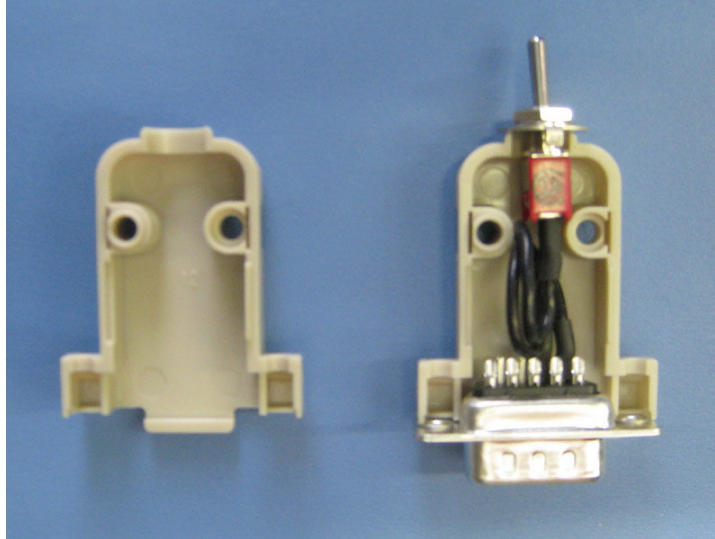
3.1.7 Competition Port Pinouts

The competition port is used to enable / disable the robot. A “dongle” is provided in the Kit of Parts for teams to use for this purpose when not in a competition. If teams need to make a replacement dongle or need additional spare dongles, a team-constructed dongle can be fashioned by connecting pins 8 and 9 of the competition port to a switch. NOTE: it is essential that the other pins

of the connector be left unconnected, as some of the other pins contain power and/or ground – accidentally shorting other pins of this connector can permanently damage the Driver Station.

An inexpensive dongle (shown in the photo below) can be fashioned out of components readily available locally:

- PC Board Toggle Switch SPST
- D-Sub Connector 9 pin male
- D-Sub Connector Hood sized to fit



3.1.8 Known Limitations

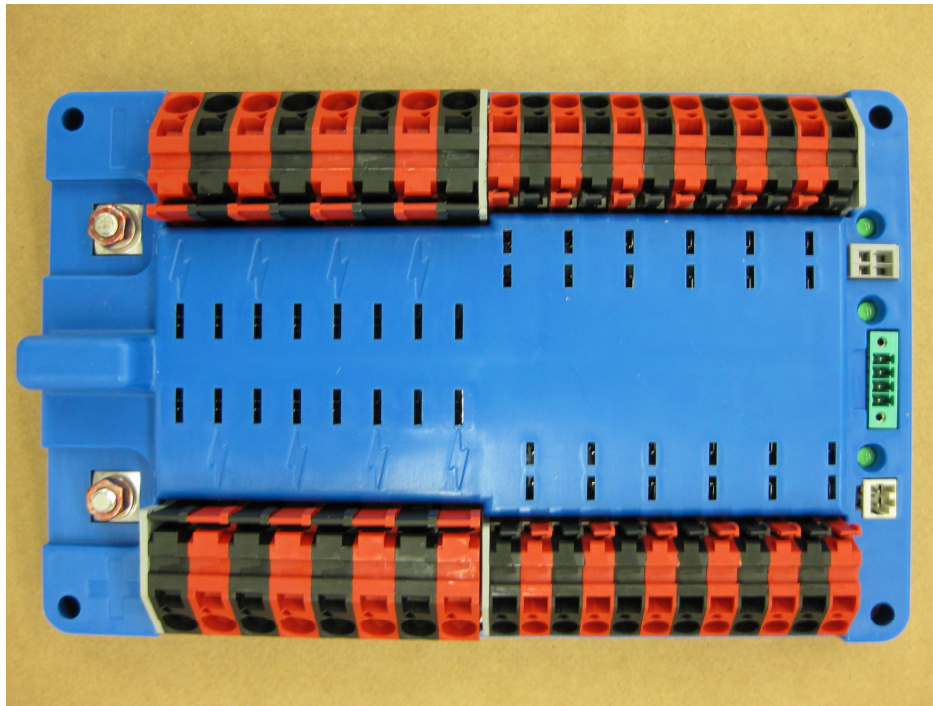
As of the time of the “early control system release” in November 2008, there are some known limitations of the Driver Station observed in beta testing. FIRST and its developers are working to resolve all safety-related features as soon as possible.

- Hot plugging joysticks is not supported. If you plug in a joystick after the DS has already booted, it will not be recognized. The workaround is to always have joysticks plugged in.
- The DS only supports joysticks that use the standard HID interface. This means that if a joystick requires special drivers on windows, it won't work with the DS. Unfortunately, this means the XBOX 360 controller won't work.
- There is no API for displaying data on the DS LCD (like the UserMode byte from previous years). This is planned, but not implemented yet.
- Occasionally the DS will send bad joystick data before the joystick has been moved the first time. The workaround is to always make sure the robot is disabled when first starting up, and move the joysticks before enabling for the first time. (This problem will be fixed soon!)
- When a joystick is unplugged, the DS continues sending the last valid joystick value. The workaround is to not unplug joysticks while running.
- Occasionally, communication will lag by about 2 seconds. The workaround is to unplug any Ethernet cable for a second, then plug it back in.
- Occasionally, communication will stop between the DS and the cRIO. One way to notice this the robot will stay disabled when you enable. The battery voltage on the DS display will also not update. The workaround is to unplug power to the DS and then let it reboot.

3.1.9 Troubleshooting and FAQ

- The power LED isn't on.
 1. Make sure you are using the correct AC adapter (12V 1A).
 2. Check to see if the AC adapter is plugged into a working wall outlet.
- The robot doesn't move when I move the joystick.
 1. Make sure the robot is on and the DS is powered up.
 2. Make sure the driver's station is set to the correct team number and the cRIO is configured for the correct IP address. THIS error is most likely after a re-imaging operation.
 3. Ensure that the DS is connected either directly to the cRIO Ethernet port #1 or if using wireless verify both the DS and the robot wireless setups are correct and cables are connected.
 4. Ensure that the robot program is using the correct joystick USB port and that the Joysticks were plugged in prior to power up of the DS.
 5. Check the LCD display to make sure the Driver's Station is Enabled (default is Disabled if nothing is connected to the competition port).
 6. Check the LCD display for proper mode of operation: Autonomous or Tele-operation.
 7. Ensure the correct software is loaded in the cRIO. THIS is a frequent cause of the problem.
- Firmware upgrade fails:
 1. The upgrade file is not on the USB stick.
 2. The upgrade file is not correctly named: DSUD_PKG.BIN (or dsud_pkg.bin).
 3. The upgrade file is not the correct size or type.
 4. The upgrade file is not the real file but a link to the real file. Do not use links.
 5. The USB stick has an auto boot program that launches on USB connect or there are multiple partitions on the stick. The upgrade boot loader uses a basic driver that expects a minimal memory stick setup.

3.2 POWER DISTRIBUTION BOARD

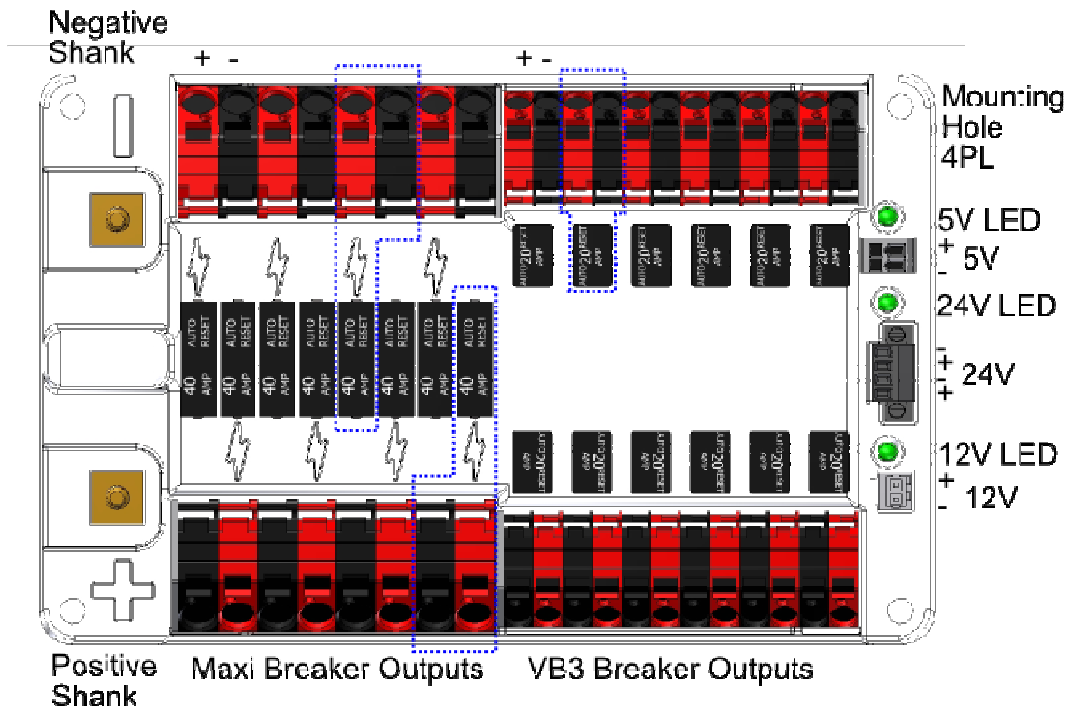


3.2.1 Functional Description

The PD Module is used to safely distribute battery power via thermal breakers and WAGO connectors. The PD also includes a set of power supplies for various devices.

- battery input voltage range of 6-15V
- M6 shanks for battery connection
- Sufficient copper mass and low-resistance distribution for use with a 120A main breaker supplying the module
- 8 outputs that support up to 40A breakers
- 12 outputs that support up to 30A breakers
- 24V/1.5A boost supply with on-board 1.1A PTC for over-current protection (typically for powering a cRIO from National Instruments)
- 5V/3A buck supply with integral over-current protection (typically for powering an Ethernet camera)
- 12V/2A boost supply with on-board 2A PTC for over-current protection (typically for powering a WiFi adapter, the boost supply tracks battery voltage when the battery is fully charged and greater than 12V)
- Reverse battery protection for the cRIO, WiFi, and Camera power supplies
- LEDs for each power supply

3.2.2 Pinout

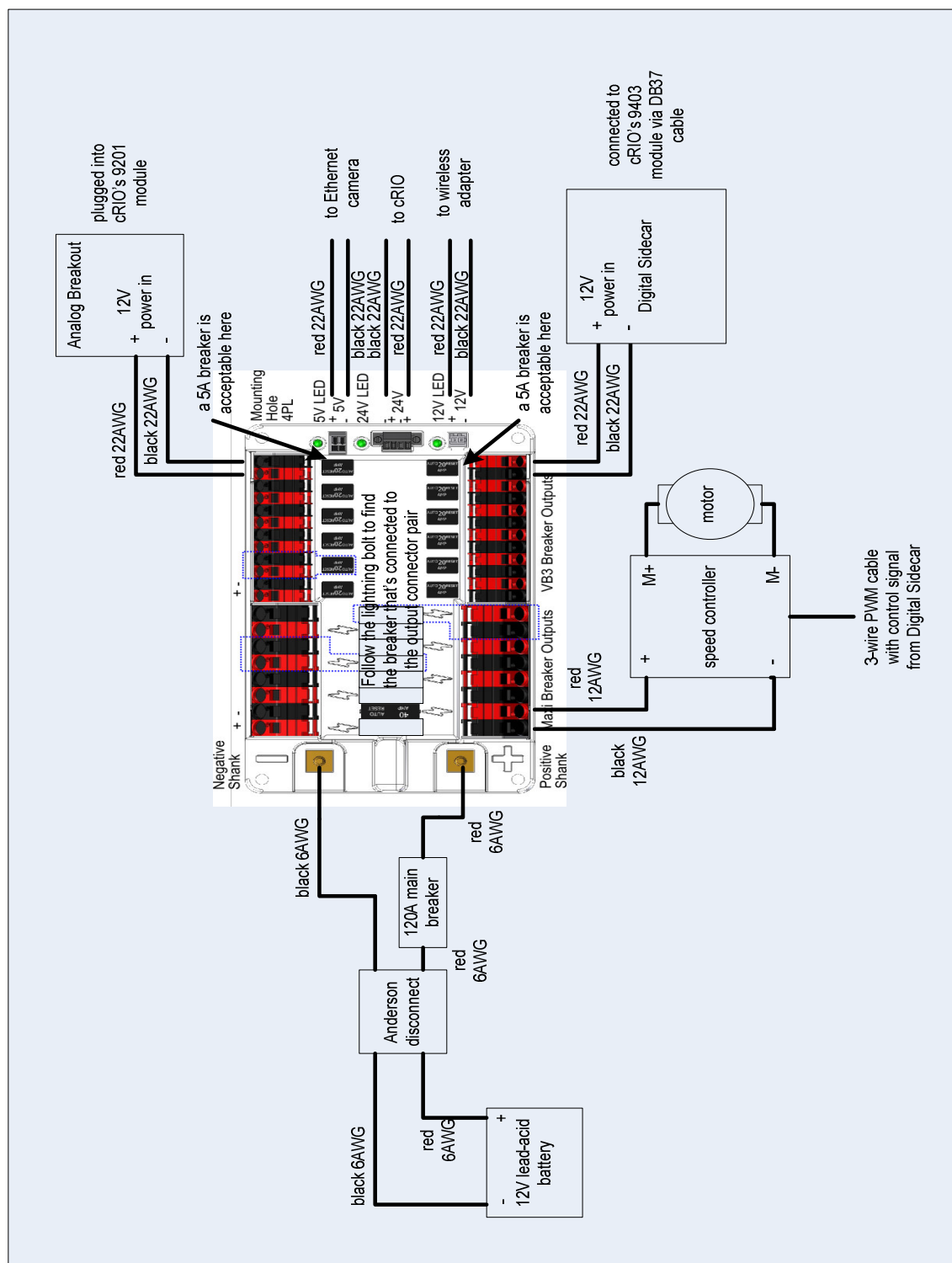


PCB Reference Designator	Name	Description
J27	Negative Shank	M6 post for connecting the negative terminal of a battery
J23	Positive Shank	M6 post for connecting the positive terminal of a battery (typically a 12V sealed lead acid battery through a 120A main breaker)
J1/J3, J4/J5, J6/J7, J8/J9, J29/J28, J31/J30, J33/J32, J35/J34	Maxi Breaker Outputs	WAGO 745-85X connector pairs that provide battery positive (red terminals, protected via thermal breaker) and battery negative/return (black terminals) Accepts stranded wire 6-12 AWG stripped 12-13mm
J11-J22, J37-J48	VB3 Breaker Outputs	WAGO 745-83X connector pairs that provide battery positive (red terminals, protected via thermal breaker) and battery negative/return (black terminals) Accepts stranded wire 10-24AWG stripped 11-12mm
CB7-CB14	Maxi Breaker Terminals	Press-in terminals that accept Snap Action Maxi-Style breakers with capacity up to 40A
CB1-CB6, CB19-CB24	VB3 Breaker Terminals	Press-in terminals that accept Snap Action VB3-Style breakers with capacity up to 30A

PCB Reference Designator	Name	Description
J26	5V Output	<p>FRC control system usage: Axis camera.</p> <p>Output from a 5V/3A buck supply via WAGO 739-302 terminal strip.</p> <p>Accepts stranded wire 14-22 AWG stripped 7mm</p>
J24	12V Output	<p>FRC control system usage: Linksys WiFi adapter</p> <p>Output from a 12V/2A boost supply via WAGO 734-132 header. WAGO 734-102 is the typical mating connector with wire size between 14 and 22 AWG.</p>
J25	24V Output	<p>FRC control system usage: National Instruments cRIO</p> <p>Output from a 24V/1.5A boost supply via Sauro CTM040V8 connector. The mating connector is Sauro CTF04BV8-CN. The positive and negative terminals are duplicated on the 4-position header to mimic the input structure on the National Instruments cRIO power entry connector. Use wire size between 14 and 22 AWG.</p>

3.2.3 Typical Application

** Always refer to FIRST rules for using this module in competition robots. The following diagram shows an example application that may not fully comply with FIRST rules.



3.2.4 Specifications

24V supply

Parameter	Min	Nom	Max	Units	Description
Input Voltage, Operational	4.5	12	15	V	
Input Voltage, Survive	-20		20	V	limited by TVS and reverse battery protection FET
Output Voltage, Unloaded	23	24	25	V	
Output Voltage Ripple (pk-pk), Unloaded			1	V	
Output Current Limit, PTC		1.1	2.2	A	hold characteristic, this PTC is in the ground return path to the power supply
Output Power Limit			20	W	boost channel protection
Input Current Limit		15		A	input fuse (at the input to the power supply from battery input terminal, the primary purpose of this fuse is to protect from shorts on the PD)

12V supply

Parameter	Min	Nom	Max	Units	Description
Input Voltage, Operational	4.5	12	15	V	
Input Voltage, Survive	-20		20	V	limited by TVS and reverse battery protection FET
Output Voltage, Unloaded	11	12	13	V	for Vbattery < 11 V, for Vin > 11V the power supply output tracks Vbattery
Output Voltage Ripple (pk-pk), Unloaded			1	V	
Output Current Limit, PTC		2	4	A	hold characteristic, this PTC is in the ground return path to the power supply
Output Power Limit			20	W	boost channel protection
Input Current Limit		15		A	input fuse (at the input to the power supply from battery input terminal, the primary purpose of this fuse is to protect from shorts on the PD)

5V supply

Parameter	Min	Nom	Max	Units	Description
Input Voltage, Operational	5.5	12	15	V	
Input Voltage, Survive	-20		20	V	limited by TVS and reverse battery protection FET
Under-voltage Lockout	5.3		5.5	V	
Output Voltage, Unloaded	4.8	5	5.2	V	
Ripple (pk-pk), Unloaded			1	V	
Per Cycle Current Limit	4	5	6	A	
Continuous Current Limit		3	4	A	

3.2.5 Warnings

The PD's power input/battery shanks are Metric 6. A ¼" nut and a bit of torque WILL strip these nuts. Use M6 nuts for the PD Shanks.

Don't panic if the 12V power supply output is a bit higher than 12V. The supply tracks battery voltage when the battery is fully charged and greater than 12V.

The reverse battery protection only protects the power supplies on the PD (and their attached loads). Applying batteries to the PD with reversed polarity may damage devices attached to the thermal breakers.

The large 40A-capable Maxi-style breakers are interleaved – follow the lightning bolt to the connector.

The smaller VB3 breakers must be correctly oriented or they will interfere.

When under light load, the 24V boost supply will emit an audible whining noise and have a larger voltage ripple. This is an artifact of its power saving mode, and should not cause concern.

When designing the layout of the electronic components, leave enough room to access the WAGO connectors with the WAGO tool.

3.2.6 Troubleshooting and FAQ

What are the part numbers for the mating connectors?

connector	manufacturer and P/N for mating connector
24V power output	Sauro CTF04BV8-CN
12V power output	WAGO 734-102

How do I build a cable for passing 24V power to the cRIO?

- Take a color coded pair of 22-14AWG wire and cut to length
- Optionally twist the pair now for better cable management.
- Strip 5-6mm off of both ends of both wires.
- Use a small flat head screwdriver to actuate the Sauro CTF04BV8-CN connectors
- Insert the positive wire in the port labeled “V”
- Insert the negative wire into the port labeled “C” next to the “V” port.
- Insert into the Sauro CTM040V8. Tighten screws to $\sim 1/4$ Nm.
- Give a smart tug to verify the connection is secure.

How do I build a cable for passing 12V power to the WiFi adapter?

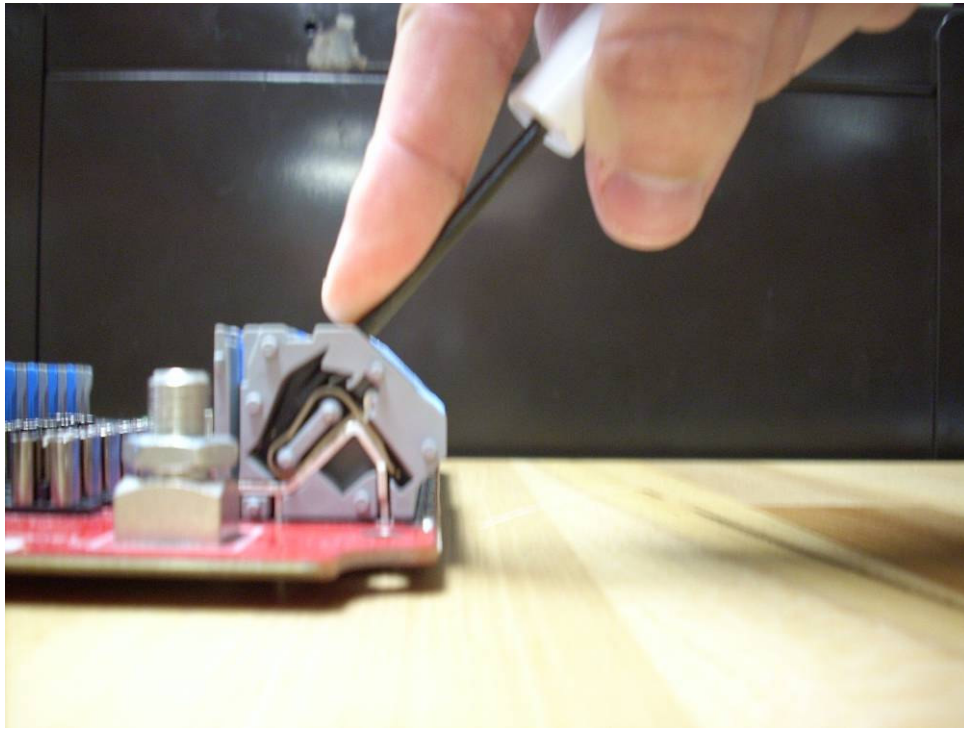
- Take the module’s power adapter and cut the wire off close to the Wall-Wart.
- Separate the wires and strip 7mm off the ends.
- To insert wire into a WAGO 734-102 connector, push down on the actuation port in back. Alternatively, use the plastic actuation lever.
- Insert the positive (striped) wire in the right port of the WAGO 734-102 connector. Note: the correct orientation can be verified by looking at the silk screen on the PD Module.
- Insert the negative wire in the left port of the WAGO 734-102 connector.
- Give a smart tug to verify the connection is secure.
- Insert the WAGO 734-102 into the mating connector on the PD.
- Power the PD, and verify that the barrel connector’s center conductor is positive.

How do I build a cable for passing 5V power to the Ethernet camera?

- Take the camera’s power adapter (PN SA106A-0512-6) and cut the wire off close to the Wall-Wart.
 - Note: There are two power adapters for the camera included in the Kit, one in the camera box and one separate. Use the separate one (PN SA106A-0512-6) to make this adapter.
- Separate the wires and strip 5-6mm off the ends.
- Use a small flat head screwdriver to open the WAGO 739-302.
- Insert the positive (striped) wire in the right port. Note: the correct orientation can be verified by looking at the silk screen on the PD Module.
- Insert the negative wire in the left port.
- Give a smart tug to verify the connection is secure.
- Power the PD, and verify that the barrel connector’s center conductor is positive.

How do I operate the large WAGO connectors?

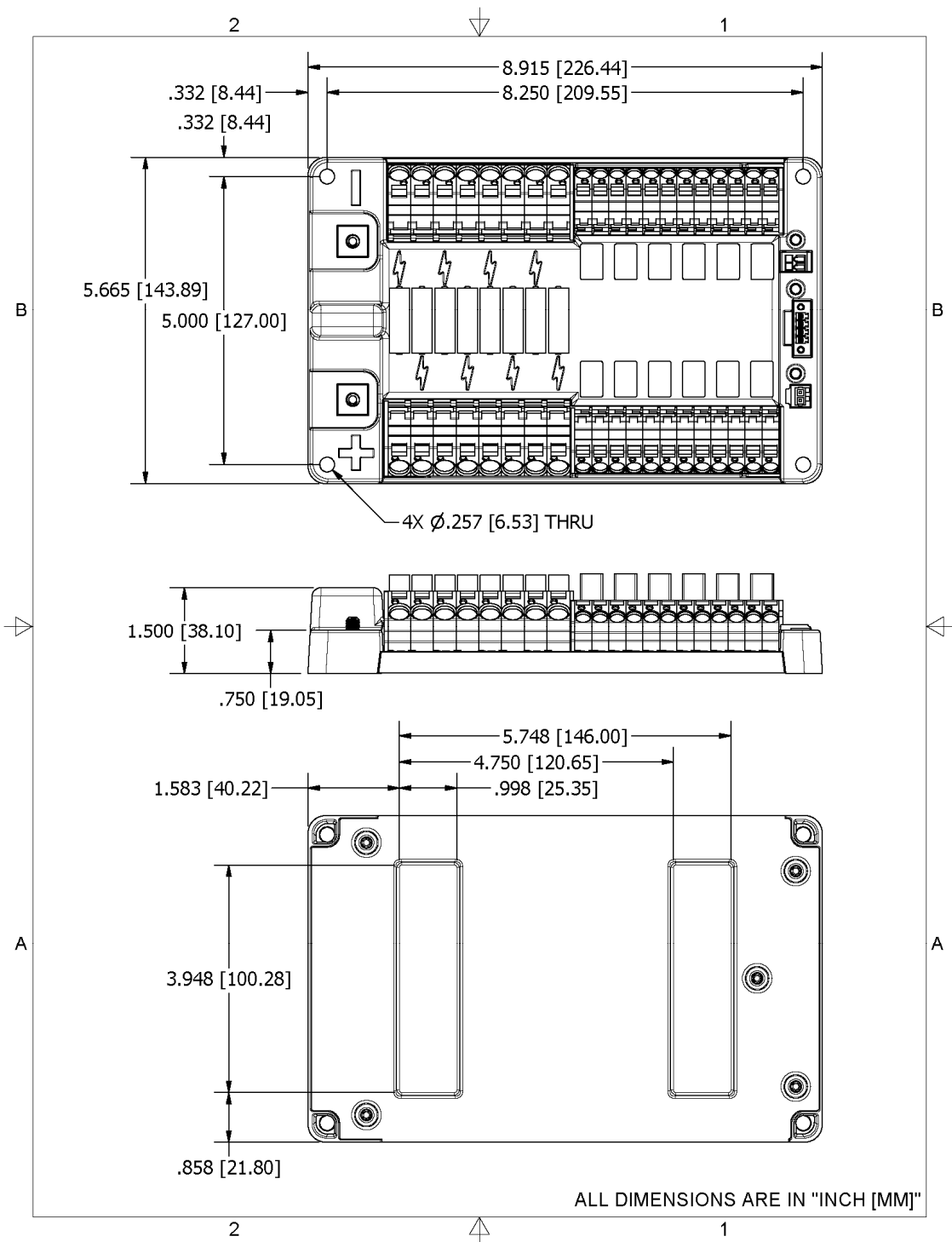
To actuate a 745-85X or 745-83X series connector, gently shove your WAGO tool into the actuation port until it hits a hard stop. Beginning with the tool parallel to the circuit board, push inward and up with the palm of your hand, while pushing down with your finger.



DO NOT attempt to pry the connector open. This will result in frustration. If you are applying force to the WAGO tool when you are inserting the wire, you are doing it wrong.

Note: It is possible to “stab” the 745-8XX connector by inserting the tool at too great an attack angle. This may break the plastic tab. This is only aesthetic. Try again with a flatter angle.

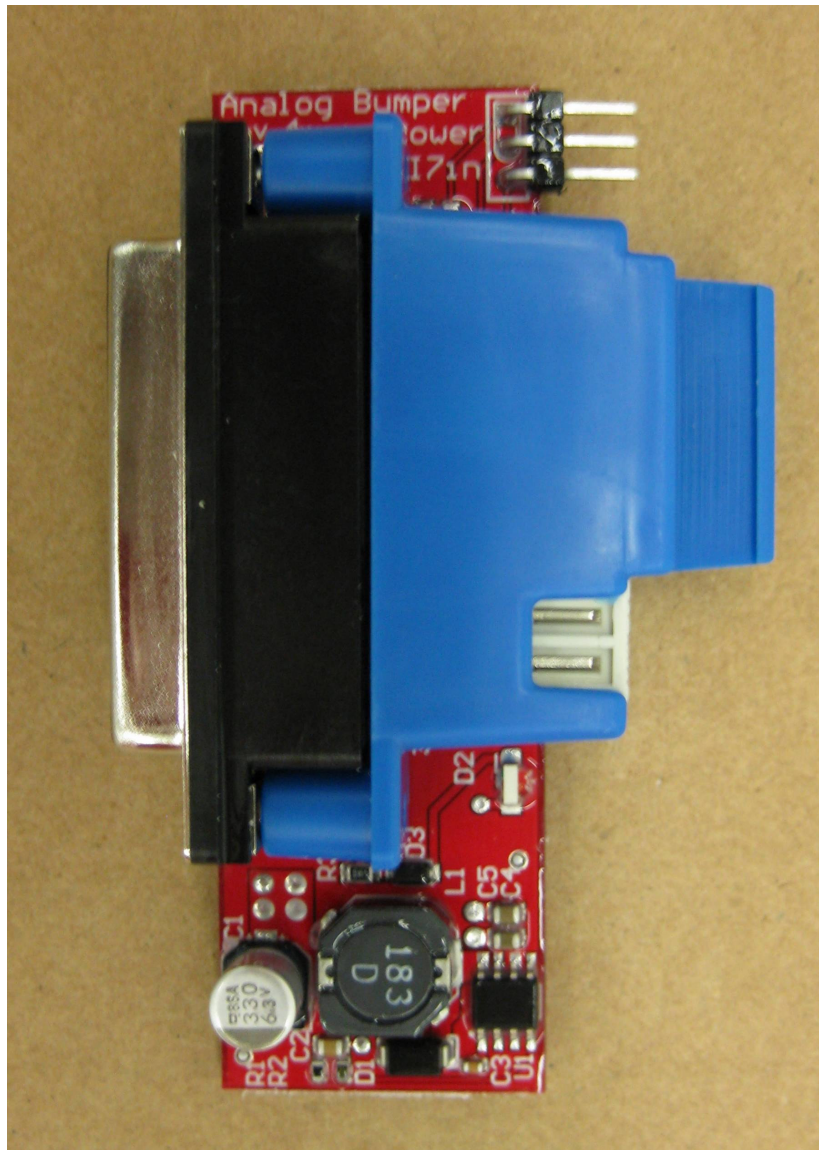
3.2.7 Mechanicals

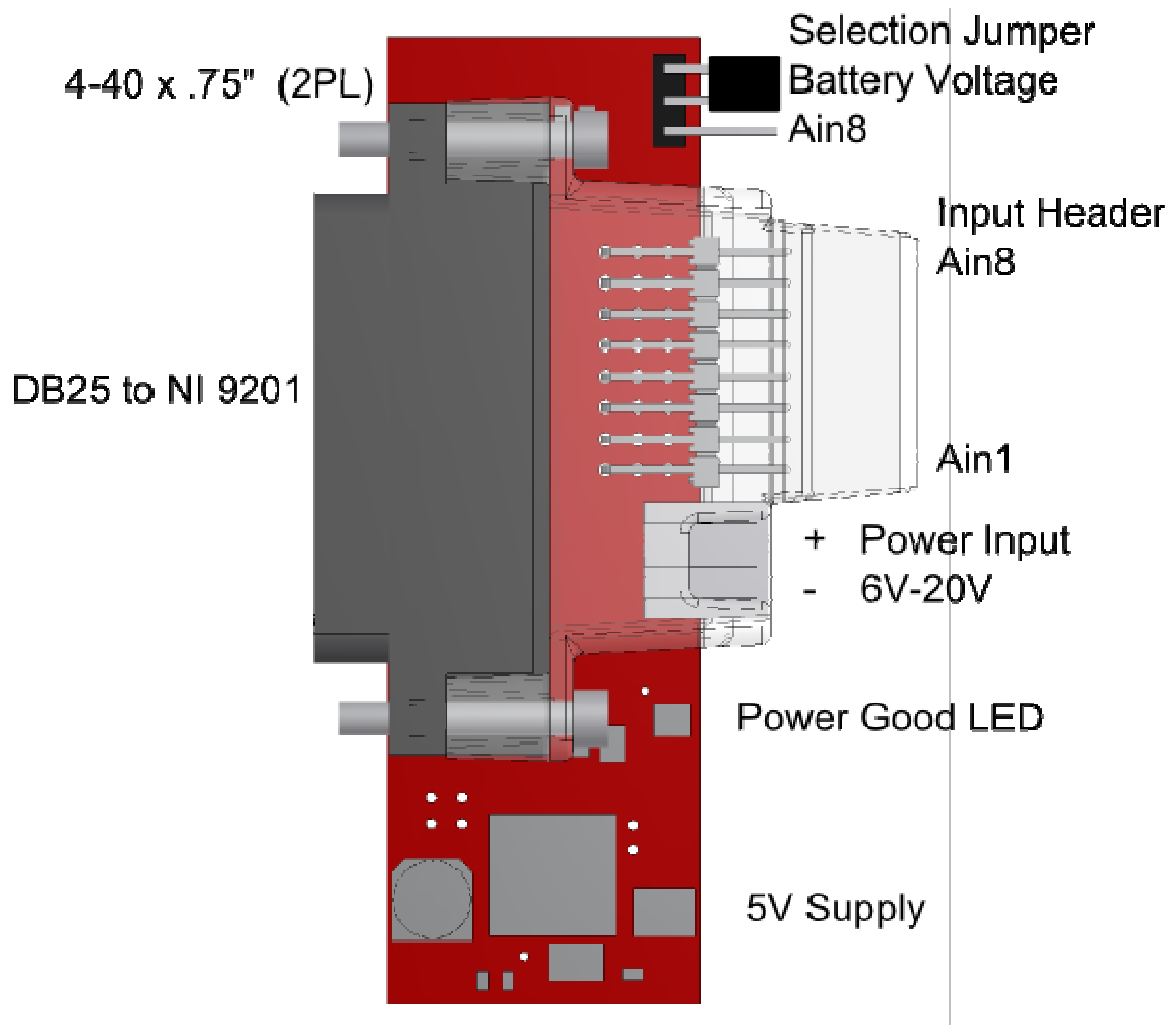


3.3 COMPACT RIO

For the full data sheet please refer to the NI website: <http://decibel.ni.com/content/docs/DOC-2632>

3.4 ANALOG BREAKOUT





3.4.1 Functional Description

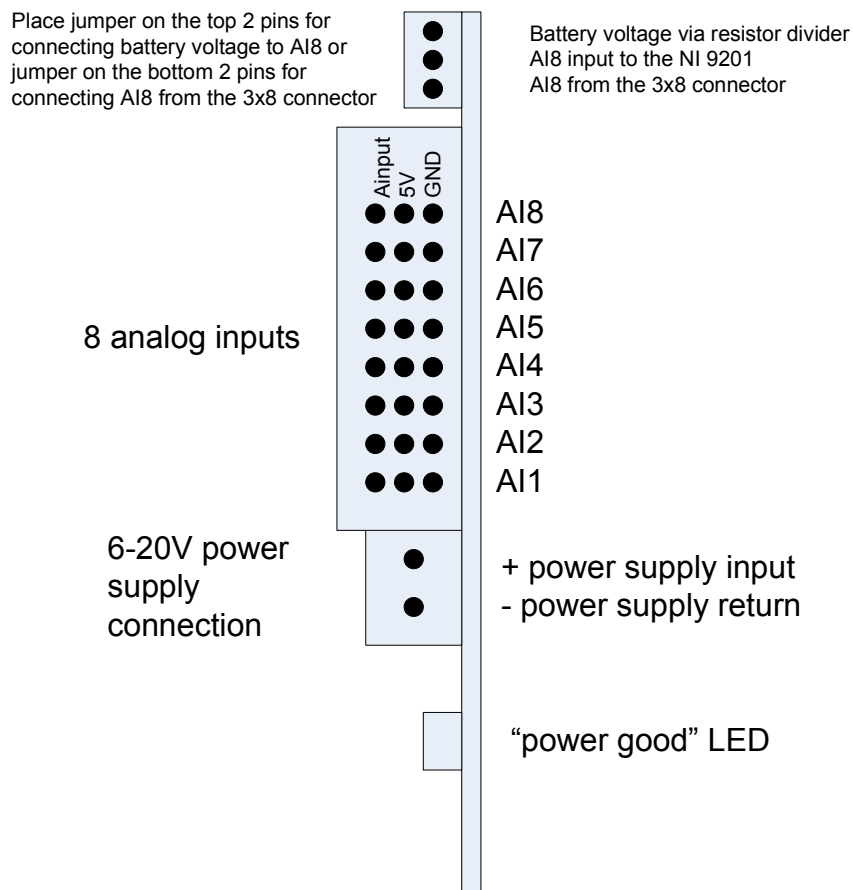
The Analog Breakout is designed to make interfacing with the NI 9201 analog input module easier for FIRST teams. It adapts the DB25 interface to the familiar three row 0.1" pin field and provides a 5V rail to power sensors. The included plastic shroud provides an easy way to lock the connectors.

3.4.1.1 Features

- 5V/3A power supply for providing power to analog sensors
- Wide-range power input for tolerating battery voltage variations
- Jumper to optionally connect battery voltage to AI8 for sensing battery/power input status
- Standard 3-pin PWM cable interface (5V, ground and analog input) for sensors with locking feature built into the plastic shroud
- DB25 connector with screw holes for securely mounting to an NI 9201 analog input module

3.4.1.2 Pinout

Analog Breakout – side view of connectors



PCB Reference Designator	Name	Description
J1	DB25	Mates to NI 9201 (with optional cable)
J2	Analog Input	Mates to 8 3-conductor cables
J3	Power Input	734-162 mates to 734-102 Supplies power to the module
J4	AI8 Select	Accepts 2 conductor Shunt Selects what AI8 is connected to.
D2	Power LED	Lit when power is applied

3.4.2 Typical Application

** Always refer to FIRST rules for using this module within competition robots. The following sequence describes an example application that may not fully comply with FIRST rules.

- 1) Plug the Analog Breakout module into an NI 9201 analog input module and secure with screws
- 2) apply power to J3 from the PD via 5A breaker and smaller WAGOs
- 3) select whether AI8 is to be connected to the 3x8 header or input power for battery sensing and apply jumper accordingly
- 4) attach sensors via 3-pin PWM to the 3x8 header with careful consideration of polarity

3.4.3 Specifications

Parameter	Min	Nom	Max	Units	Description
Vin Survive	-0.3		25	Volts	Survivable voltage on J3
Vin Operational	6	12	25	Volts	Acceptable voltage on J3 for normal operation
Vout	4.9	5	5.26	Volts	Output Voltage of buck supply.
Vout Ripple		21	100	mV	Output ripple with a 2A load
Iout Total			3	Amps	Output Current of buck supply
Iout / Channel			.75	Amps	Output Current per pin
AI Voltage	-10		10	Volts	Input on any AI pin on J2 (from 9201)
AI8 Divider	0.590	0.595	0.6		

3.4.4 Warnings

There is no reverse voltage protection for this module. ALWAYS CONFIRM POWER SUPPLY POLARITY BEFORE ENERGIZING THIS MODULE!

3.4.5 Troubleshooting and FAQ

How do I build a cable for passing 12V power to the Analog Breakout?

- Take a color coded pair of 22AWG or better wire and cut to length
- Optionally twist the pair now for better cable management.
- Strip 7mm off the ends.
- To insert wire into a WAGO 734-102 connector, push down on the actuation port in back with a screw driver, or use an actuation lever.
- Insert the positive wire in the right port of the WAGO 734-102 connector. Note: the correct orientation can be verified by looking at the silk screen on the Analog Breakout
- Insert the negative wire in the left port of the WAGO 734-102 connector.
- Give a smart tug to verify the connection is secure.
- Insert the WAGO 734-102 into the mating connector on the Breakout.

How can I verify that my power cable is correct?

- Use a Solenoid Breakout: Plug the cable into it. If the green LED lights, your cable is correct.

How do I measure the battery voltage using the Analog Breakout?

- Use a shunt (jumper) to connect the outer two pins of the “AI8 Select” connector
- Battery voltage is reduced to ~40% of its actual value by a 680/1k voltage divider and filtered by a 0.1uF capacitor.

Why isn't AI8 working?

- Use a shunt (jumper) to connect the inner two pins of the “AI8 Select” connector

D2 isn't lit, and all my sensors don't work. Why?

- Check with a multi-meter to see if you are getting power onto J3. Is a breaker missing?
- The Analog Breakout is not protected from reversed polarity on J3. Did you wire it backwards? You may need to replace the module.

How do I connect a potentiometer?

- Connect the wiper to the input pin – Top row.
- Connect the other two pins to +5 and ground – Middle and bottom rows.

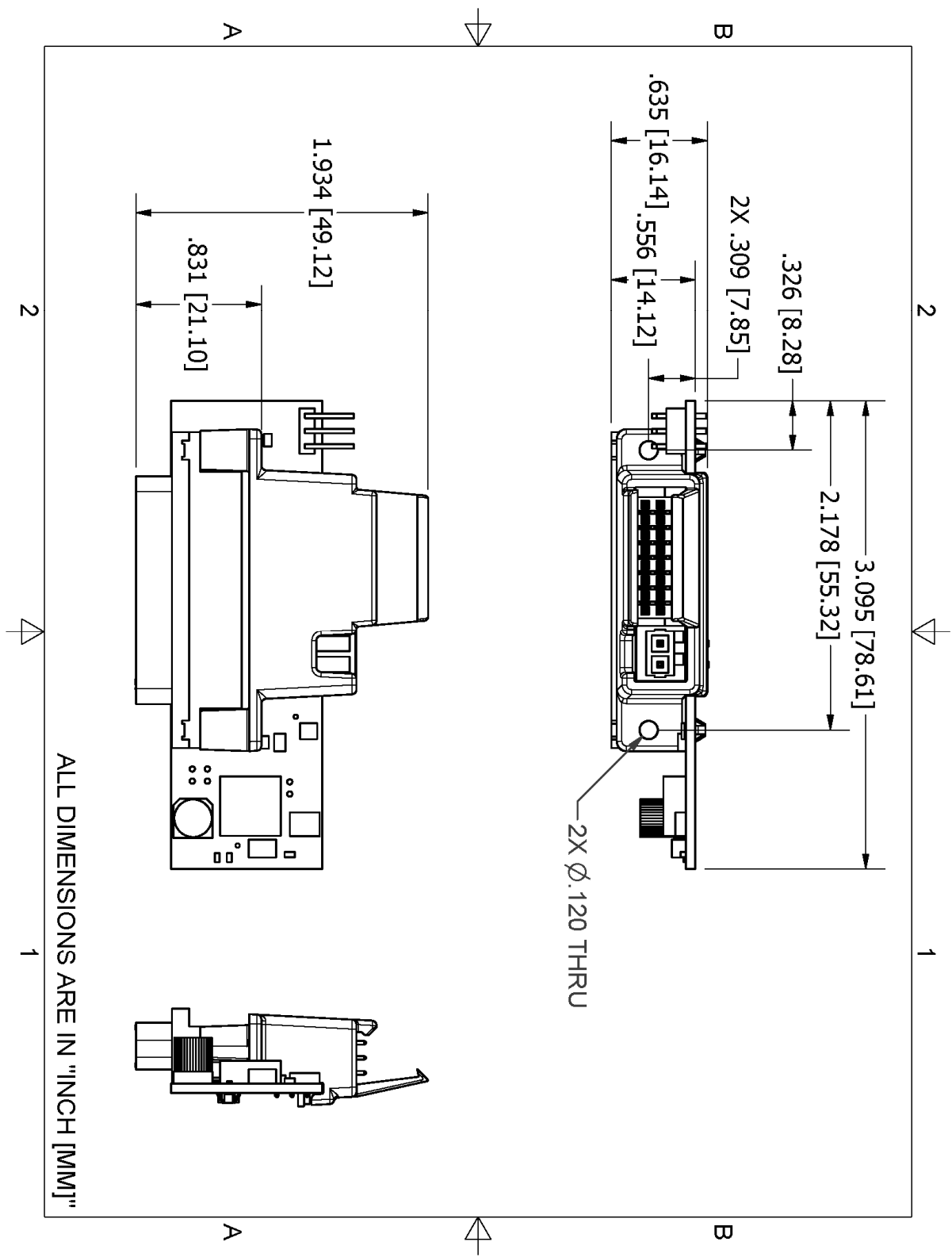
My sensor draws more than 0.75A. Can I use it??

- First, check the FRC robot rules and verify it is competition legal. None of the sensors that ship in the Kit of parts draw this much current.
- Each pin can handle 0.75A. Use several ground pins and several power pins together to share the load.

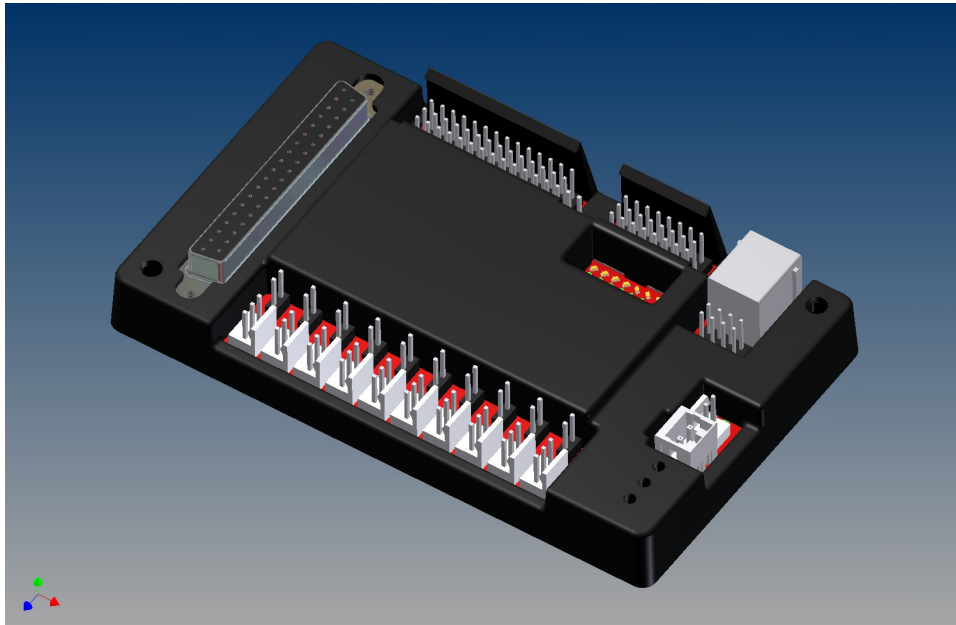
Why does the Breakout's PCB say "Analog Bumper"?

- This module was called the Analog Bumper during development. During the beta test it was decided that "Analog Breakout" better captured the functionality of the module.

3.4.6 Mechanicals



3.5 DIGITAL SIDECAR



3.5.1 Functional Description

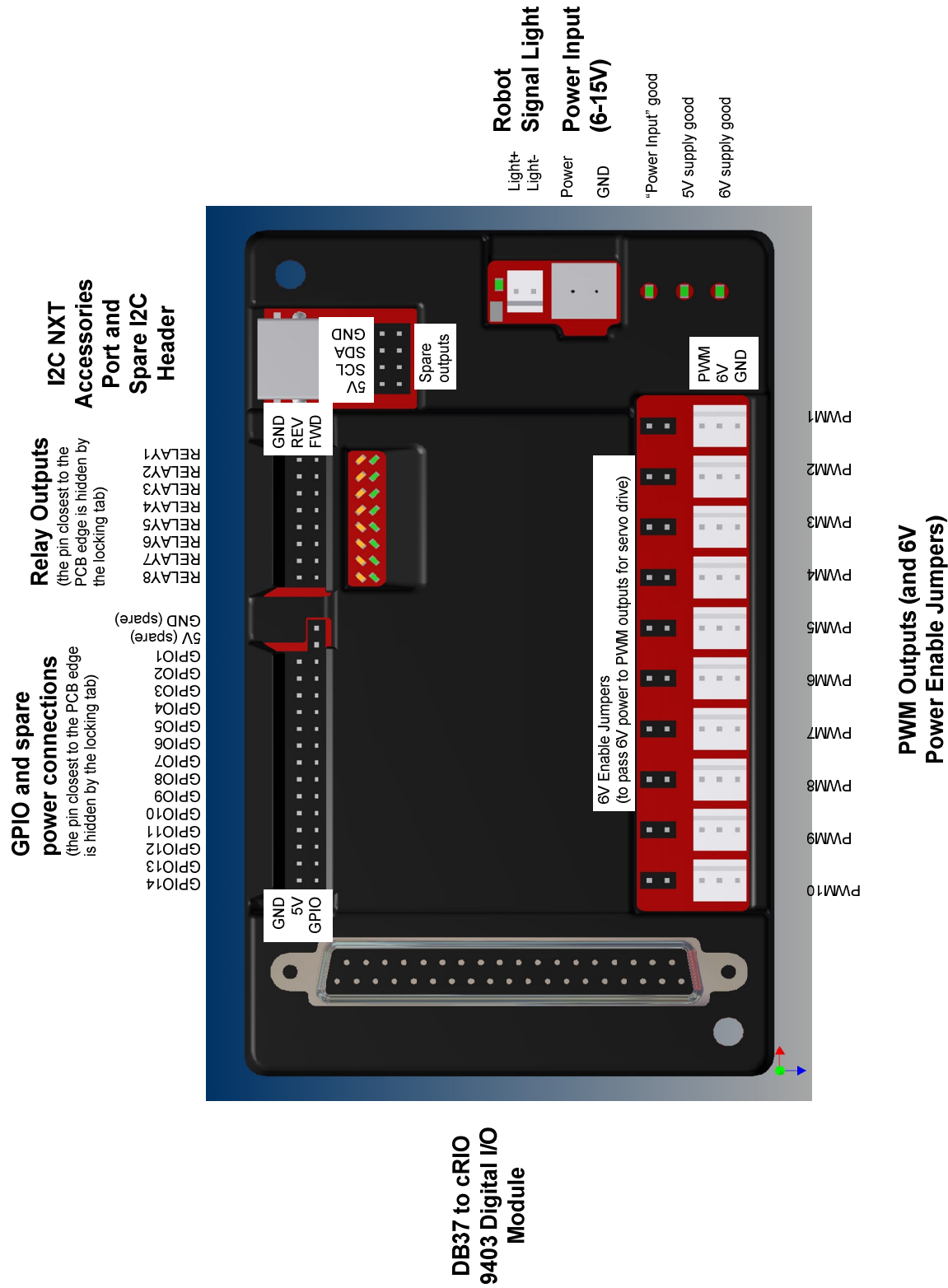
The Digital Sidecar is a breakout module that is designed to adapt a single cRIO 9403 32-channel digital I/O module into a set of I/O that is familiar to robotics hobbyists.

3.5.1.1 Features

The Digital Sidecar includes the following features:

- 10 PWM outputs for driving speed controllers such as IFI Victors and Luminary Jaguars and servos such as the Hitec HS322HD
- 14 general purpose I/O (aka GPIO) lines with available 5V power for each
- 16 relay outputs (8 FORWARD and 8 REVERSE outputs) for driving relay controllers such as an IFI Spike
- I2C headers – one 2x4 pin header and one connector that is compatible with I2C-based Lego NXT accessories
- Robot Signal Light header for a robot status indicator
- 6V/3A buck power supply to power servos attached to the PWM outputs (with individual jumpers for each PWM output to select application of power)
- 5V/3A buck power supply for DSC circuitry with excess power available at the GPIO and I2C headers
- Extra 5V and ground connections adjacent to GPIO1 for using a single row-header to create a SPI interface (typically using GPIO1-4 for MOSI, MISO, SCLK and CS in addition to the supporting 5V and ground connections)
- Reverse-battery protection to prevent damage due to accidental reversal of applied power
- Power is derived from a nominal 12V supply
- DB37 connector for attachment to a cRIO 9403 32-channel digital I/O module

3.5.1.2 Pinout



PCB Reference Designator	Name	Description
J1	cRIO connector	A 37-line DB37 female connector for attaching the module to a cRIO 9403 32-channel digital I/O module (typically via ribbon or shielded cable)
J2-J11	PWM10..PWM1	PWM outputs for controlling speed controllers and servos. The header is a Molex P/N 22-23-2031 (or similar) with a friction locking feature which accepts any standard PWM cable in addition to many 0.1" spacing headers. The center pin is selectable for providing 6V power via adjacent jumper. The pin closest to the PCB's edge is ground. The pin furthest from the PCB's edge is the PWM output signal.
J12-J21	PWMx 6V Enable	Install an 0.1" jumper on these headers to provide 6V power on the adjacent PWM output. ONLY INSTALL A JUMPER WHEN ATTEMPTING TO POWER SERVOS SUCH AS A HITEC HS322HD. SPEED CONTROLLERS ATTACHED TO THE PWM OUTPUTS MAY BE DAMAGED IF THE DSC ATTEMPTS TO PROVIDE 6V POWER ON THE CENTER PIN.
J22	Power Input	Nominal 12V power input via WAGO 734-132. WAGO 734-102 is the typical mating connector with wire size between 14 and 20 AWG.
J23	Robot Signal Light	A 2-pin Molex P/N 22-23-2021 header for providing power to an indicator light.
J24	I2C and spare I/O	A 2x4 set of 0.1" pins with I2C, 5V, ground and 4 spare outputs.
J25	NXT I2C Header	A Lego NXT-compatible I2C header for use with NXT-compatible I2C accessories.
J26	GPIO	A 3x14 0.1" pin field for general purpose digital I/O with 5V available on the center pin, ground on the pin closest to the PCB's edge and I/O signal on the pin furthest from the PCB's edge.
J27	Extra 5V Header	An extra pair of 0.1" pins for providing power and ground adjacent to GPIO1 (typically for creating a SPI-compatible interface using GPIO1-4 for MOSI, MISO, SCLK and CS)
J28	Relay Outputs	A 3x8 0.1" pin field for driving relay modules. The pin closest to the PCB edge is ground, the center pin is REVERSE and the furthest pin is FORWARD.

3.5.2 Typical Application

** Always refer to FIRST rules for using this module in competition robots. The following sequence describes an example application that may not fully comply with FIRST rules.

- 1) apply power to the DSC via J22 from a 5A (or larger) breaker on the PD
- 2) connect to a cRIO 9403 via 37-channel ribbon cable
- 3) attach servos (eg Hitec HS322HD) to the PWM Outputs and place a corresponding jumper on the 6V Enable header for the PWM Outputs
- 4) attach speed controllers to the PWM Outputs (NO JUMPER FOR 6V ENABLE!)
- 5) attach relay modules to the Relay Outputs
- 6) attach a Robot Signal Light to the header
- 7) attach I2C-compatible NXT accessories to the NXT port
- 8) attach devices to the GPIO headers

3.5.3 Specifications

General

Parameter	Min	Nom	Max	Units	Description
PWM Output - Current			15	mA (source and sink)	There are 330 Ohm series resistors in each output's path. The outputs are buffered using a 74AC244 and a 74LVC2G125 with a 5V supply.
Relay Output - Current			7.5	mA (source and sink)	There are 680 Ohm series resistors in each output's path. The outputs are buffered using a pair of 74LV595s with a 5V supply.
GPIO – Pull-Ups		10		kOhms	these signals are passed directly to the NI 9403 module without any series resistance but include pull-ups to 5V
I2C Pull-Ups		3.16		kOhms	Pull-ups to 5V supply (included on the DSC) for I2C signals
Robot Signal Light - Voltage		Vin			The Robot Signal Light is powered by the same voltage as passed to the DSC via power input connection
Robot Signal Light – Current		1.1	2.2	Amps	Determined by a PTC for current-limiting, There is a snubber diode in parallel with the output header for protection from any load inductance.

6V supply

Parameter	Min	Nom	Max	Units	Description
Input Voltage, Operational	6.7	12	15	V	
Input Voltage, Survive	-25		25	V	limited by reverse battery protection FET
Undervoltage Lockout	6.3		6.5	V	
Output Voltage, Unloaded	5.8	6	6.2	V	
Ripple (pk-pk), 2A load		22	100	mV	
Per Cycle Current Limit	4	5	6	A	
Continuous Current Limit		3	4	A	

5V supply

Parameter	Min	Nom	Max	Units	Description
Input Voltage, Operational	5.5	12	15	V	
Input Voltage, Survive	-25		25	V	limited by reverse battery protection FET
Undervoltage Lockout	5.3		5.5	V	
Output Voltage, Unloaded	4.8	5	5.2	V	
Ripple (pk-pk), 2A load		21	100	mV	
Per Cycle Current Limit	4	5	6	A	
Continuous Current Limit		3	4	A	

3.5.4 Warnings

Only install the jumpers for applying 6V power to the PWM Output headers for connecting to servos such as a Hitec HS322HD. If the jumper is installed and the PWM Output is used to drive a speed controller, the application of 6V power could damage the speed controller and/or DSC.

3.5.5 Troubleshooting and FAQ

Either or both of the power supply LEDs are out, but the power-in LED is on. Why?

- Both of these supplies are internally protected against short circuits. It is possible to short one without affecting the other, which may explain why one is not working.
- Power off your robot – the offending element may be hot.
- Examine your wiring and your module carefully for the short.

Why isn't my servo motor moving?

- Check to make sure that the PWM channel's 6V selection jumper is inserted.
- Check the 6V supply LED.

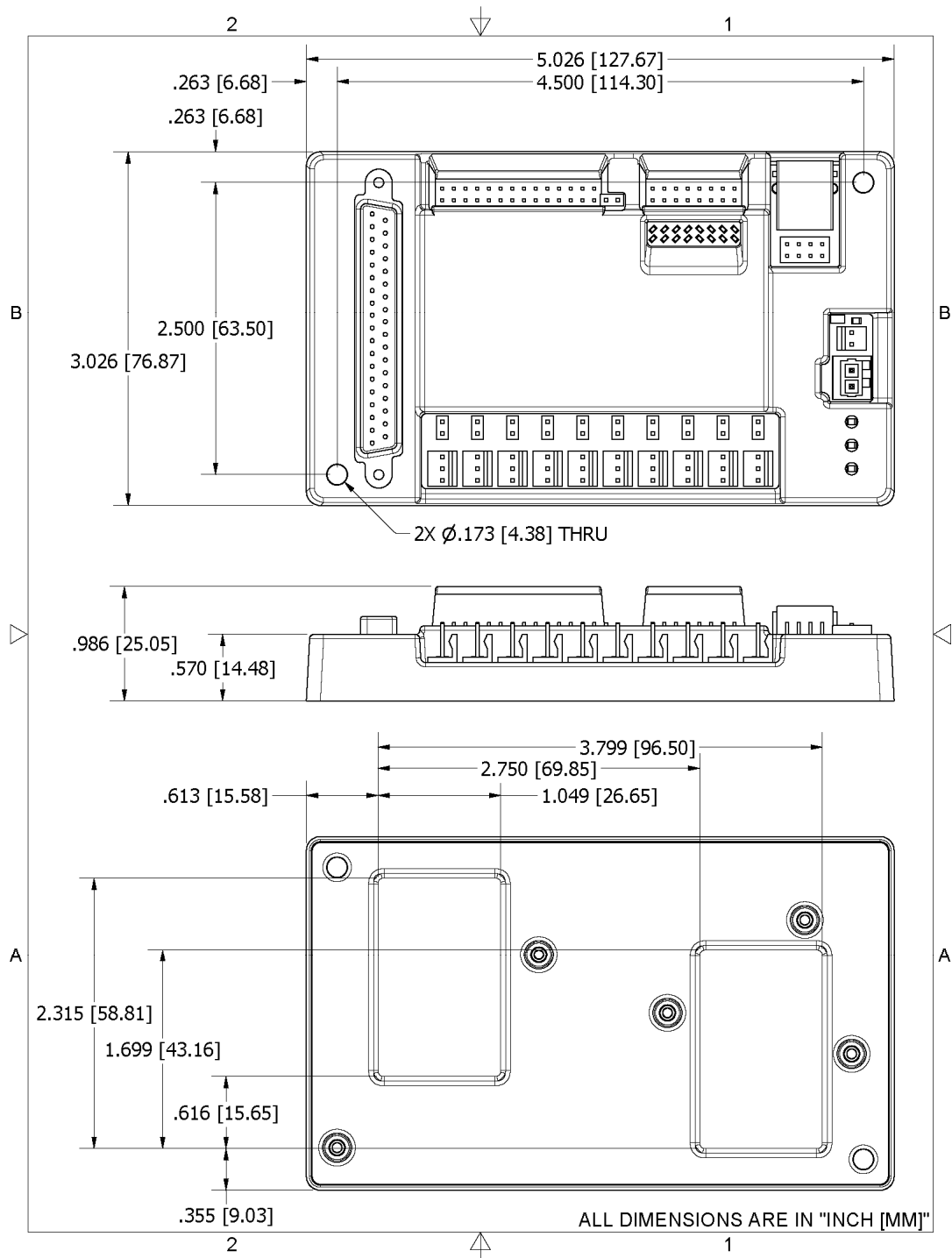
The PWM connectors have a locking tab. How do I use them?

- They are [Molex 22-23-2031 KK vertical friction locks](#).
- You may use the same cables you have always used – The locking tab won't get in your way, and does add a small bit of friction to the connection.
- For added security, use a Molex 2695, 6471, 7880, 4455 or 7720 series connector. Our favorite is the [0022013037](#)

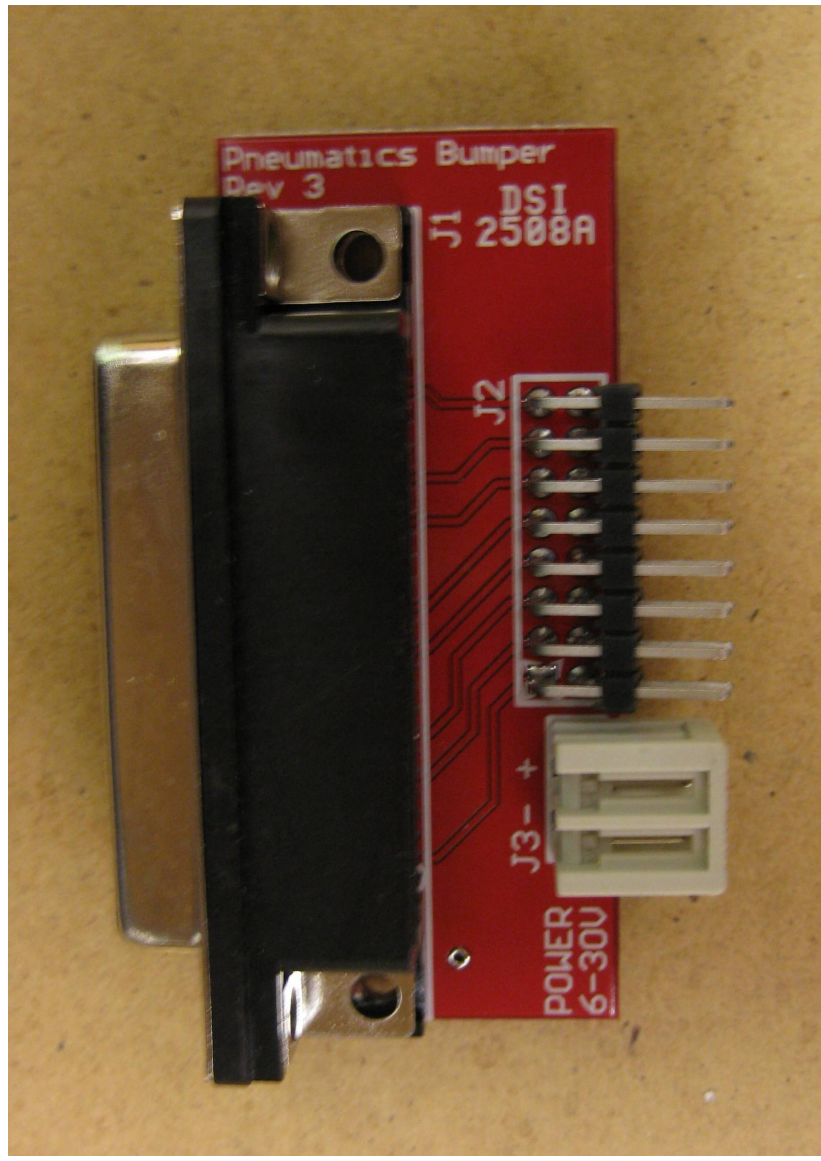
How do I build a cable for passing 12V power to the Digital Sidecar?

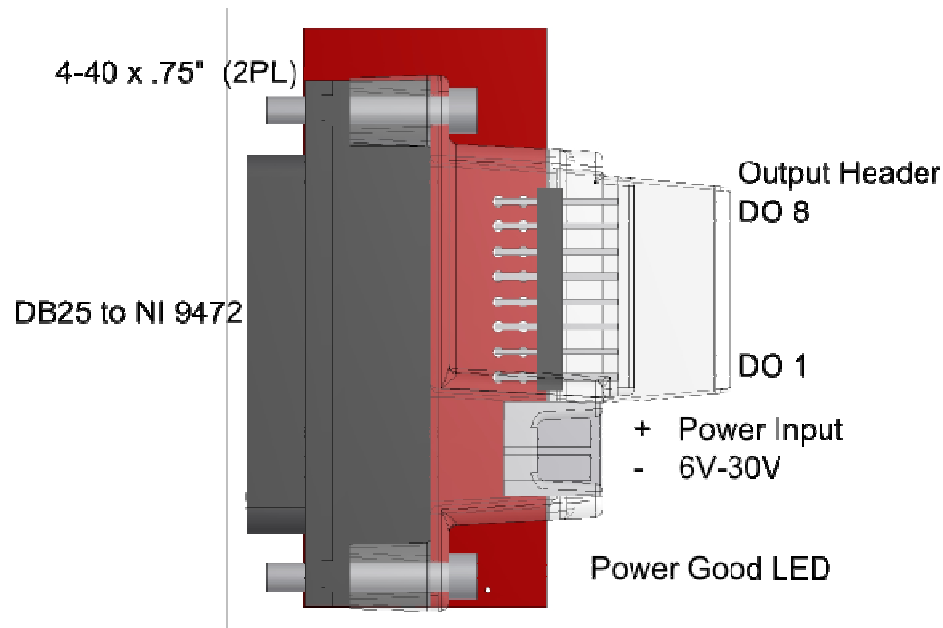
- Take a color coded pair of 22AWG or better wire and cut to length
- Optionally twist the pair now for better cable management.
- Strip 7mm off the ends.
- To insert wire into a WAGO 734-102 connector, push down on the actuation port in back with a screw driver, or use an actuation lever.
- Insert the positive wire in the right port of the WAGO 734-102 connector. Note: the correct orientation can be verified by looking at the silk screen on the Digital Sidecar.
- Insert the negative wire in the left port of the WAGO 734-102 connector.
- Give a smart tug to verify the connection is secure.
- Insert the WAGO 734-102 into the mating connector on the Digital Sidecar.

3.5.6 Mechanicals



3.6 SOLENOID BREAKOUT





3.6.1 Functional Description

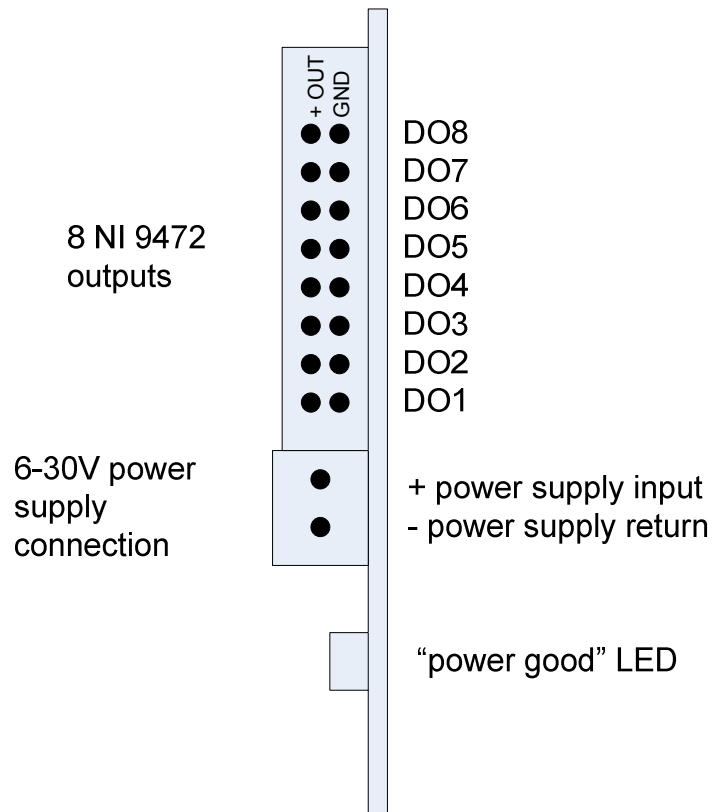
The Solenoid Breakout is designed to make interfacing with the NI 9472 Digital Sourcing Module easier for FIRST teams. It adapts the DB25 interface to the familiar two row 0.1" pin field. The included plastic shroud provides an easy way to lock the connectors.

3.6.1.1 Features

- Wide-range power input provided by the NI 9472
- 2-pin cable interface (switched power output and ground) for attaching loads with locking feature built into the plastic shroud
- DB25 connector with screw holes for securely mounting to an NI 9472 output module
- Reverse-voltage protection to avoid damage due to accidental reversal of applied power

3.6.1.2 Pinout

Solenoid Breakout – side view of connectors



PCB Reference Designator	Name	Description
J1	DB25	Mates to NI9472 (with optional cable)
J2	Digital Outputs	Mates to 2 conductor cables
J3	Power In	734-162 mates with 734-102
D1	Power LED	Lights when power is properly applied

3.6.2 Typical Application

** Always refer to FIRST rules for using this module in competition robots. The following sequence describes an example application that may not fully comply with FIRST rules.

- 1) secure the Solenoid Breakout to an NI 9472 using screws
- 2) apply power to J3 from the PD via 5A breaker and smaller WAGOs
- 3) attach loads via 2-pin connectors to the 2x8 header with careful consideration of polarity

3.6.3 Specifications

Parameter	Min	Nom	Max	Units	Description
Vin Survive	-30		30	Volts	Survivable voltage on J3
Vin Operational	6	12	30	Volts	Voltage on J3 for normal operation
Iout / Channel			0.75	Amps	Output Current per Channel

3.6.4 Warnings

3.6.5 Troubleshooting and FAQ

How do I build a cable for passing 12V power to the Solenoid Breakout?

- Take a color coded pair of 18AWG or better wire and cut to length
- Optionally twist the pair now for better cable management.
- Strip 7mm off the ends.
- To insert wire into a WAGO 734-102 connector, push down on the actuation port in back with a screw driver, or use an actuation lever.
- Insert the positive wire in the right port of the WAGO 734-102 connector. Note: the correct orientation can be verified by looking at the silk screen on the Solenoid Breakout.
- Insert the negative wire in the left port of the WAGO 734-102 connector.
- Give a smart tug to verify the connection is secure.
- Insert the WAGO 734-102 into the mating connector on the Breakout.

I have a load that takes more than 0.75A. May I use it?

- Check the FRC robot rules to ensure that your device is game legal.
- You can use several outputs together, such that each one sources up to 0.75A. Be sure to common them in the wiring (positive and negative) AND in the software.

Why does the Breakout's PCB say "Pneumatic Bumper"?

- This module was called the Pneumatic Bumper during development. During the beta test it was decided that "Solenoid Breakout" better captured the functionality of the module.

3.6.6 Mechanical

