Jaguar (MDL-BDC) Speed Controller for *FIRST®* Robotics Competition 2009
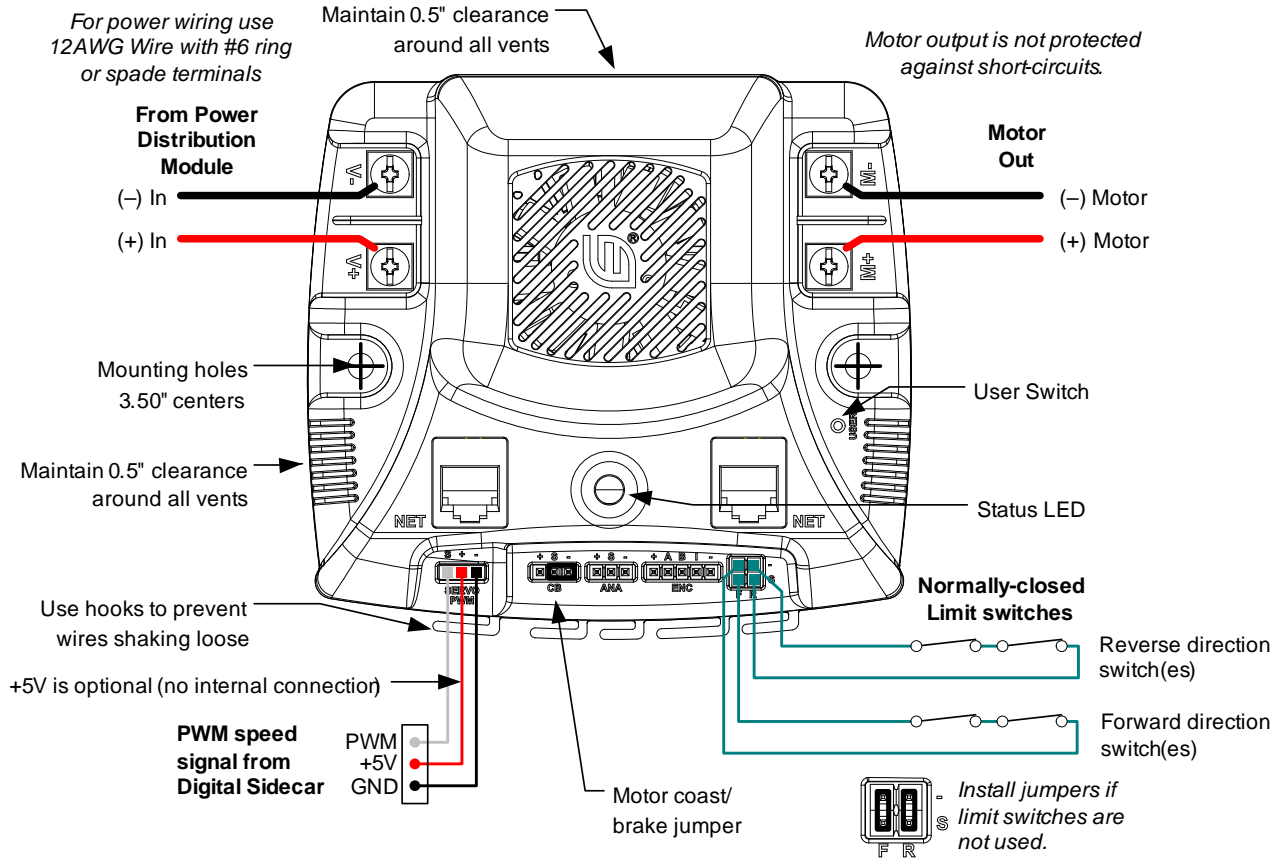

What's Inside

Luminary Micro presents the new official *FIRST®* Robotics Competition (FRC) motor controller: the Brushed DC Motor Control module known as Jaguar. Luminary Micro's Jaguar module will be included in the 2009 FRC Kit of Parts. Designed specifically for the FRC competition, the Jaguar module facilitates the design of complex robots within the short six-week FRC build period.

WARNING – Be aware of the following warnings. Failure to heed warnings may result in damage to the module or invalidation of the module warranty.

- ■ Mount the Jaguar module so that the vents in the top and sides of the unit are not restricted in any way. Maintain a clearance of at least ½ inch between modules.

- ■ Reverse wiring is unprotected; doing so will void the Jaguar module's warranty.

- ■ Do not exceed the absolute maximum supply voltage of 15 Vdc. Doing so will cause permanent damage to the module.

MDL-BDC OVERVIEW

For power wiring use 12AWG Wire with #6 ring or spade terminals

Maintain 0.5" clearance around all vents

Motor output is not protected against short-circuits.

From Power Distribution Module

(–) In

(+) In

V–

V+

Motor Out

M–

M+

(–) Motor

(+) Motor

Mounting holes 3.50" centers

User Switch

Maintain 0.5" clearance around all vents

NET

NET

Status LED

Use hooks to prevent wires shaking loose

+5V is optional (no internal connection)

CB

ANA

ENC

Normally-closed Limit switches

Reverse direction switch(es)

Forward direction switch(es)

PWM speed signal from Digital Sidecar

PWM
+5V
GND

Motor coast/ brake jumper

Install jumpers if limit switches are not used.

F R

STATUS LED

LED State	Module Status
Normal Operating Conditions	
Solid Yellow	Neutral (speed set to 0)
Fast Flashing Green	Forward
Fast Flashing Red	Reverse
Solid Green	Full-speed forward
Solid Red	Full-speed reverse
Fault Conditions	
Slow Flashing Yellow	Loss of servo link
Slow Flashing Red	Fault condition
Calibration Conditions	
Fast Flashing Red and Green	Calibration mode active
Fast Flashing Red and Yellow	Calibration mode failure
Fast Flashing Green and Yellow	Calibration mode success
Slow Flashing Red and Green	Calibration mode reset to factory default settings success

CALIBRATION PROCEDURE

To calibrate the servo-style PWM input for a specific range, connect a PWM source, then:

1. Hold down the USER switch with a straightened paperclip.
2. After 5 seconds, the LED flashes Red and Green quickly to indicate Calibration mode.
3. Instruct the controller to send a full-forward signal.
4. Instruct the controller to send a full-reverse signal.
5. Instruct the controller to return to a neutral signal.
6. The LED flashes Green and Yellow quickly to indicate a successful calibration.
7. Release the USER switch.

The MDL-BDC samples these signals and centers the speed range and neutral position between these limits. A calibration failure will be signaled if an out-of-range signal is detected.

To reset the servo-style PWM input to the default factory range:

1. Disconnect the power to the MDL-BDC.
2. Hold down the USER switch with a straightened paperclip.
3. Reconnect power to the MDL-BDC
4. After 5 seconds, the LED flashes Red and Green slowly to indicate a successful calibration reset to factory settings.
5. Release the USER switch.

Fault Conditions

A slow flashing Red LED indicates that the MDL-BDC detected one of the following fault conditions:

- Power supply under-voltage
- Over temperature
- Over current
- Limit switch activated in the current direction of motion

When a fault condition occurs, the motor shuts down and the LED indicates a fault state during the fault condition and for 3 seconds after the fault cause is cleared (except for the limit switch fault, which is cleared instantly). A slow flashing Yellow LED indicates that the MDL-BDC is not receiving a valid control signal.

Coast/Brake Jumper

The coast/brake signal controls the dynamics of the drive signal to the motor. When set to brake, the MDL-BDC is able to achieve greater deceleration and holding torque because it decays regenerative current from the motor.

The coast/brake signal can be set with a jumper or controlled by a signal from a digital source. A single wire connected to the center (S) pin, is recommended. Do not connect to the + pin (+3.3 V) of this connector as any mis-wiring could damage the MDL-BDC.

Power and Motor Wiring

The Overview diagram shows motor and power connections to the MDL-BDC. For power wiring, use 12 AWG wire terminated with #6 ring or spade terminals. The control is not protected against reverse polarity or short-circuits.

Servo-style PWM Speed Control Input

The servo PWM input controls motor speed and direction. The digital signal must meet the timing and voltage requirements listed in the MDL-BDC specifications. The center pin (+) has no internal connection. Because the signal is optically isolated, both the signal (S) and GND (-) pins must be connected to the signal source.

Limit Switches

The normally closed limit switch inputs provide a simple method for limiting range of motion. When a limit switch input is open, motor operation in that direction is disabled. Install jumpers if limit switch functionality is not required.

Isolation

The servo-style PWM input is optically isolated. All other control inputs are non-isolated and are referenced to the power supply (-).

Future Features

The MDL-BDC has several interfaces that are for future use. Do not connect wiring to the NET, ANA, or ENC connectors.

MDL-BDC SPECIFICATIONS (FRC 2009)

	Parameter	Min	Typ	Max	Units	Notes
Power Supply	Supply voltage range	6	12	13	Vdc	
	Supply voltage absolute maximum	–	–	15	Vdc	Exceeding this value, even momentarily, will cause permanent damage.
	Supply current (motor off, fan off)	–	90	–	mA	
	Supply current (motor off, fan on)	–	156	–	mA	
	Under-voltage detect threshold	–	6	–	Vdc	
Motor Output	Motor voltage	0	–	12	V	PWM-controlled
	Motor current—continuous	–	–	40	A	
	Motor current—for 2 seconds	–	–	60	A	
	Motor current—peak at starting	–	–	100	A	
	Motor PWM frequency	–	15.625	–	kHz	
	Motor PWM resolution	–	0.1	–	%	
	Motor output current for resistive loads	–	–	30	A	Continuous
Environment	Operating temperature range	0	–	50	°C	
	Storage temperature range	-25	–	85	°C	
	Fan on temperature	–	42	–	°C	
	Fan off temperature	–	38	–	°C	
Servo-Style Speed Input	Default pulse width range	0.67	–	2.33	ms	
	Default neutral pulse width	–	1.5	–	ms	
	Pulse width calibration range	0.5125	–	2.4875	ms	
	Servo signal period	5.0125	–	29.985	ms	
	Duty cycle range	–	–	50%	%	
	Digital high-level input current	2	5	25	mA	
	Digital low-level input current	–	–	0.3	mA	
	Watchdog time-out	–	100	–	ms	
	Voltage isolation (servo+/- to other signals)	–	–	40	V	The servo input is optically isolated.
Brake/Coast Input	Digital low-level input voltage	-0.3	–	1.3	V	Selects Brake mode.
	Digital high-level input voltage	2.0	3.3	5.5	V	Selects Coast mode.
	Digital input pull-down resistor	–	200	–	kΩ	
	Response time	–	64	–	us	

FREQUENTLY ASKED QUESTIONS

General Questions

Q	Some of your documentation describes a device that looks like Jaguar, but is called MDL-BDC. How is this different than Jaguar?
A	"Jaguar" is the nickname of the MDL-BDC, which stands for **M**ODU**L**E-**B**RUSHED **DC** motor controller. Important: Use the actual "MDL-BDC" part number when searching the web or ordering additional Jaguars, you will have much more success.

Q	As an FRC team member or mentor, I thought we would be able to buy extra Jaguar (MDL-BDC) modules for a discount from the standard resale price. How do I do this?
A	Individual Jaguar (MDL-BDC) modules are available to FRC teams and mentors for a discount exclusively through Luminary Micro's distribution partner, Digi-Key. Here is your FRC exclusive order link to place an order for a discounted Jaguar (MDL-BDC):

Jaguar (MDL-BDC) Configuration

Q	I don't plan to use limit switches. Can I remove the jumpers?
A	No. The jumpers are there to act as a limit switch in lieu of the switch being used. If you do not plan on using limit switches, LEAVE THE JUMPERS IN PLACE. If you remove the jumpers and cannot remember how to reinstall the jumpers, please see page 2 of this *Getting Started Guide* to reinstall the jumpers. If you use a limit switch, you must remove the appropriate jumper and replace it with the limit switch circuit.

Q	Do I need to calibrate my Jaguar (MDL-BDC)?
A	Depends, but probably not. The Jaguar (MDL-BDC) module does have a calibration mode; however, the need to use the calibration mode is unnecessary if you are using a cRIO system and a new Jaguar (MDL-BDC)—because the default parameters of the Jaguar (MDL-BDC) are tuned for use with a cRIO. The calibration mode is provided if you want to use a Jaguar (MDL-BDC) with another source of Servo (PWM) signal that does not have the same range of pulse widths (for example, an older robot controller). If you have calibrated your Jaguar (MDL-BDC) from a different source and move it back to a cRIO system, you will need to recalibrate.

Jaguar (MDL-BDC) Layout and Connectors

Q	Jaguar (MDL-BDC) seems to have a lot more connectors and headers than I am allowed to use for FRC 2009. What are these for, and why can't we use them for FRC 2009?
A	*FIRST®* has specified the Jaguar (MDL-BDC) module for FRC 2009 and beyond. Therefore, Jaguar (MDL-BDC) contains some unused (and not permitted for use) features for FRC 2009, such as Controller Area Network, Analog Input, and Quadrature Encoder Input. How and when these additional features might be used in FRC 2010 and beyond will be disclosed at the sole discretion of *FIRST®*.

Q	Since we are not permitted to use the CAN connectors for the 2009 competition season, what should we do with them?
A	We recommend putting electrical tape over the top of the connectors to prevent debris from getting into the connector. Be careful not to cover the vent slots on the side of the Jaguar plastics when putting the tape in place. Two short 1" segments should be enough to cover the connectors while not obstructing the air flow venting, the status LED, or the PWM connector.

Q	Do you have any recommendations regarding the air vents?
A	Yes, do not cover them! Jaguar draws air through the top vent and expels it out the side vents. If any of these vents are blocked, it reduces the airflow through the unit and will affect the cooling of the power transistors (MOSFETs). Similarly, we also recommend against placing Jaguar (MDL-BDC) modules directly next to each other (touching) so as to reduce any conflicting airflow.

Q	We want to use the limit switches. What part/supplier provides 1x2 headers that fit side-by side for use with the limit switches?
A	FCI offers part numbers 65039-035LF (housing) and 48248-000LF (receptacle), available from Digi-Key.

Q	Instead of putting two connectors side-by-side, we would rather use just one connector for the limit switches. What part/supplier provides 2x2 headers for use with the limit switches?
A	FCI offers part numbers 65043-035LF (housing) and 48248-000LF (receptacle), available from Digi-Key.

Q	We want to connect the Brake/Coast input to the cRIO and implement a dynamic Brake/Coast mechanism. What part/supplier provides a 1x3 header for use with the Brake/Coast input?
A	FCI offers part numbers 65039-034LF (housing) and 48248-000LF (receptacle), available from Digi-Key.

Jaguar (MDL-BDC) Operation

Q	My Jaguar (MDL-BDC) is receiving a good Servo (PWM) signal, but it is not generating any voltage on the output (that is, my motor is not turning). Is my Jaguar broken?
A	Probably not. The most likely reason for this occurrence is that the limit switch for Direction is open, or the jumper has been removed. A clue to this is the LED. If you are sending a Servo (PWM) signal and the LED is flashing slowly red, this usually means that the Jaguar is experiencing a fault condition; the most common fault condition being the limit switch.

Q	My robot has three arms that are driven by one motor, and I want to stop the motor when any one of the arms reaches a stop point. How do I do this with only one limit switch input?
A	The limit switch inputs, one for forward rotation and one for reverse rotation, use normally closed switches. Inside Jaguar (MDL-BDC), the sense pin is pulled up to a positive voltage. When the sense pin is connected by a normally closed switch to the other pin (ground), the switch connects the sense pin to ground. When the switch is pressed, the switch opens and the sense pin is pulled up by the internal pull up, causing the Jaguar (MDL-BDC) module to disable the generation of voltage for that given direction. Normally, closed switches can be used in series so that if ANY of the switches are pressed (opened) the Jaguar (MDL-BDC) will sense that condition.

Q	We notice that when our robot runs into a wall or obstacle and the robot is pushing really hard, the robot seems to shut down for a couple of seconds. Why does it do this?
A	The Jaguar (MDL-BDC) modules have a self-protection feature that does not allow excessive current to be drawn. This protects both the motor and the motor controller from damage. The Jaguar (MDL-BDC) module normally provides up to 40 A of continuous current to a heavily loaded motor. However, it is also capable of providing much higher currents, but for shorter periods of time. Jaguar provides 60 A for up to two seconds, and will provide 100 A for approximately 0.2 seconds.

Q	When we apply power to our Jaguar (MDL-BDC) module, the fan does not turn on. Is it broken?
A	Not necessarily. Unlike previous FRC speed controller solutions, the fan in Jaguar (MDL-BDC) is controlled to turn on only when necessary. Jaguar (MDL-BDC) turns the fan on when it is running a motor. By default, Jaguar (MDL-BDC) does not turn the fan on until you start to drive. Jaguar (MDL-BDC) will turn the fan off when the module is not driving a motor and the internal temperature is safe. This is done to save battery power which helps with power conservation!

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Company Information

Luminary Micro, Inc. designs, markets, and sells ARM Cortex-M3-based microcontrollers (MCUs). Austin, Texas-based Luminary Micro is the lead partner for the Cortex-M3 processor, delivering the world's first silicon implementation of the Cortex-M3 processor. Luminary Micro's introduction of the Stellaris® family of products provides 32-bit performance for the same price as current 8- and 16-bit microcontroller designs. With entry-level pricing at $1.00 for an ARM technology-based MCU, Luminary Micro's Stellaris product line allows for standardization that eliminates future architectural upgrades or software tool changes.