BOARD DATA SHEET

Brushed DC Motor Control Module

Ordering Information

Product No.	Description
MDL-BDC	Stellaris® Brushed DC Motor Control Module for Single-Unit Packaging
MDL-BDC-B	Stellaris® Brushed DC Motor Control Module for Volume Packaging
RDK-BDC	Stellaris® Brushed DC Motor Control Reference Design Kit (includes the MDL-BDC module)

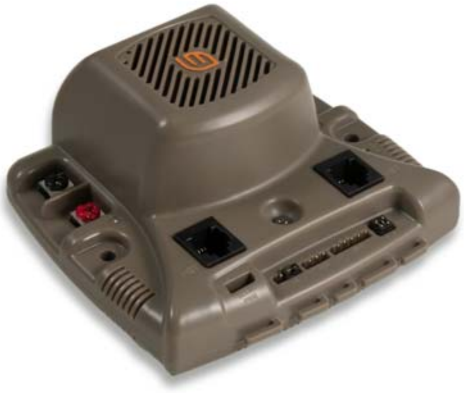


Figure 1. Brushed DC Motor Control Module

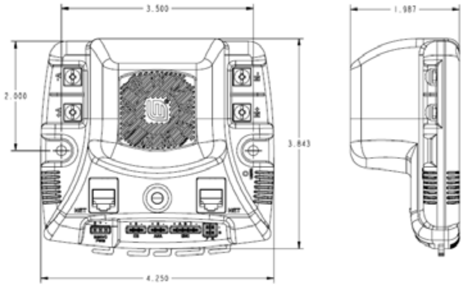


Figure 2. Mechanical Drawing

Contents

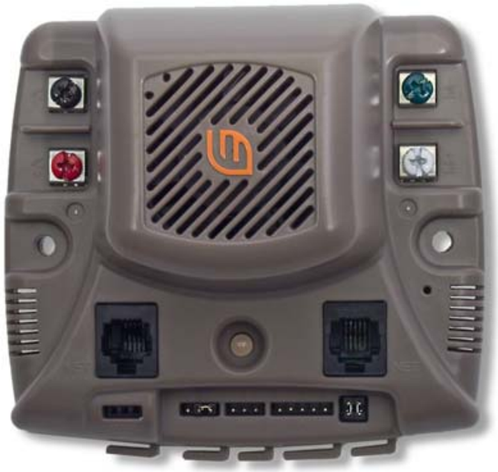
General Description

The MDL-BDC motor control module is a variable speed control for 12 V brushed DC motors at up to 40 A continuous current. The motor control module includes high performance CAN networking as well as a rich set of control options and sensor interfaces, including analog and quadrature encoder interfaces.

The high-frequency pulse width modulator (PWM) enables the DC motor to run smoothly and quietly over a wide speed range. The MDL-BDC uses highly optimized software and a powerful 32-bit Stellaris microcontroller to implement open-loop speed control as well as closed-loop control of speed, position, or motor current.

The MDL-BDC is a Stellaris reference design. The Brushed DC Motor Control Reference Design Kit (RDK) contains an MDL-BDC motor control module as well as additional hardware and software for evaluating CAN communication. After evaluating the RDK-BDC, users may choose to either customize the parts of the hardware and software design or use the MDL-BDC without modification. See the *Brushed DC Motor Control Reference Design Kit (RDK) User's Manual* (available for download from www.ti.com/stellaris) for complete technical details on using and customizing the motor control board.

Figure 3. Brushed DC Motor Control Module



Overview

The MDL-BDC motor control board provides the following features:

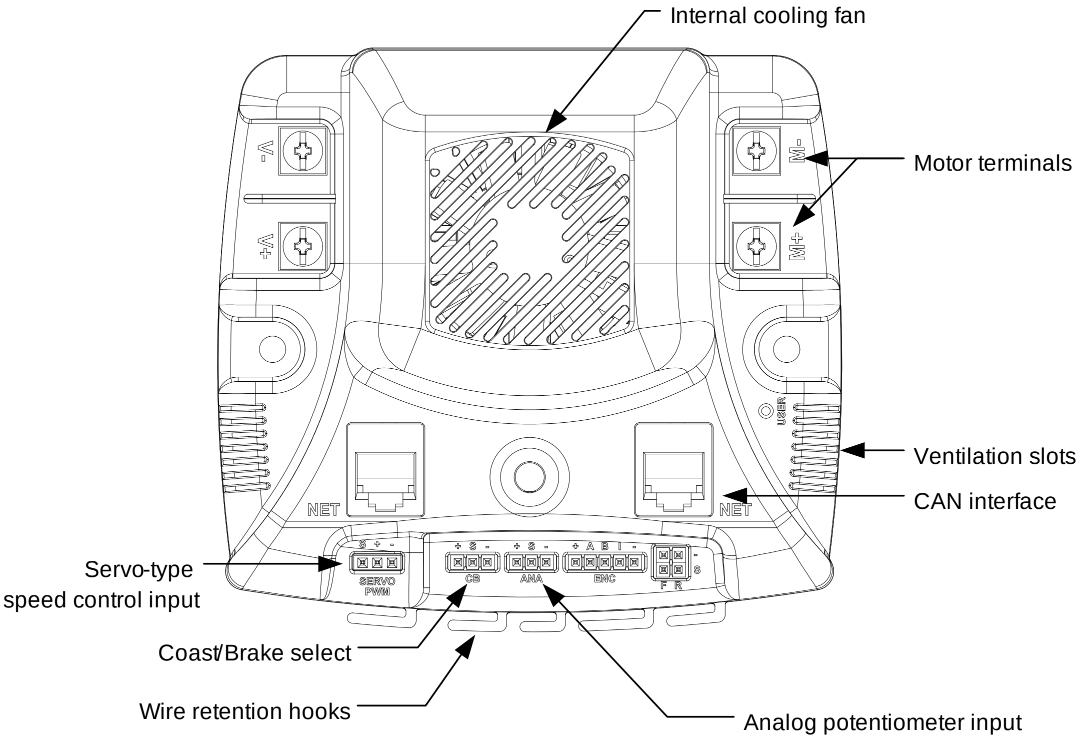
- Controls brushed 12 V DC motors up to 40 A continuous
- Controller Area Network (CAN) interface at 1 Mbit/s
- Industry-standard servo (PWM) speed input interface
- Limit switch, encoder, and analog inputs
- Fully enclosed module includes cooling fan
- Flexible configuration options with simple source file modification
- Easy to customize—full source code and design files available
- Factory source code compiles to less than 16 KB

Features

- Quiet control of brushed DC motors
  - 15 kHz PWM frequency
- Two options for Speed control
  - Industry-standard R-C servo type (PWM) interface
  - Controller Area Network (CAN) interface
- CAN communication
  - Multicast shared serial bus for connecting systems in electromagnetically noisy environments
  - 1M bits/s bit rate
  - CAN protocol version 2.0 A/B

  - Full configurability of module options
  - Real-time monitoring of current, voltage, speed, and other parameters
- Status LED indicates Run, Direction, and Fault conditions
- Motor brake/coast selector
- Limit switch inputs for forward and reverse directions
- Quadrature encoder input (QEI)
  - Index input
  - 5 V supply output to encoder
- Analog input
  - Accepts 10 kΩ potentiometer or 0-3 V input
- Screw terminals for all power wiring
- Headers (0.1 inch pitch) for all control signals

Figure 4. Detailed Drawing of the MDL-BDC Motor Control Module



Operational Specifications

The following tables provide the operation specifications for the MDL-BDC motor control board including power, motor output, environment, and so on.

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

Table 1. Power Supply

Parameter	Min	Typ	Max	Units
Supply voltage range	6	12	13	Vdc
Supply voltage absolute maximum	–	–	15[a]	Vdc
Supply current (motor off, fan off)	–	90	–	mA
Supply current (motor off, fan on)	–	156	–	mA
Under-voltage detect threshold	–	6	–	Vdc

a. Exceeding this limit, even momentarily, will cause permanent damage.

Table 2. Motor Output

Parameter	Min	Typ	Max	Units
Motor voltage[a]	0	–	12	V
Motor current - continuous	–	–	40	A
Motor current – for 2 seconds	–	–	60	A
Motor current – peak at starting	–	–	100	A
PWM frequency	–	15.625	–	kHz
PWM resolution	–	0.1	–	%
Output current for resistive loads[b]	–	–	30	A

a. The motor voltage is controlled by using a pulse-width modulated waveform.
b. The output current for resistive loads is continuous and the value shown is the maximum value.

Table 3. Environment

Parameter	Min	Typ	Max	Units
Operating temperature range	0	–	50	°C
Storage temperature range	-25	–	85	°C
Fan on temperature	–	42	–	°C
Fan off temperature	–	38	–	°C

Table 4. Servo-Style Speed Input

Parameter	Min	Typ	Max	Units
Minimum pulse width[a,b]	–	0.67		ms
Neutral pulse width[b]	–	1.5	–	ms
Maximum pulse width[b,c]	–	2.33	–	ms
Servo signal period	5.0125	–	29.985	ms
Valid pulse width range	0.5	–	2.50625	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)[d]	–	–	40	V

a. Sets full-speed in reverse.
b. These are the default values. Pulse-width range can be calibrated for different values. See the servo PWM calibration procedure, “Servo-Style PWM Input” on page 7.
c. Sets full-speed in forward direction.
d. The servo input is optically isolated.

Table 5. Analog Input

Parameter	Min	Typ	Max	Units
Analog input voltage	0	–	3	V
Potentiometer value	–	10	–	kΩ
Potentiometer reference voltage (+ pin)[a]	2.9	3.0	3.1	V
Measurement resolution	–	10-bit	–	bits
Measurement rate	–	15.625	–	kHz

a. With 10 kΩ potentiometer connected.

Table 6. Voltage, Current, and Temperature Measurement

Parameter	Min	Typ	Max	Units
Temperature measurement accuracy	–	+/-6	–	°C
Supply voltage measurement accuracy	–	+/- 0.3	–	V
Motor current measurement accuracy	–	+/- 1	–	A
Measurement resolution	–	10-bit	–	bits
Measurement rate	–	15.625	–	kHz

Table 7. Brake/Coast Input

Parameter	Min	Typ	Max	Units
Digital low-level input voltage[a]	-0.3	–	1.3	V
Digital high-level input voltage[b]	2.0	3.3	5.0	V
Digital input pull-down resistor	–	200	–	kΩ
Response time	–	64	–	us

a. Selects Brake mode.
b. Selects Coast mode.

Table 8. Quadrature Encoder Input (QEI)

Parameter	Min	Typ	Max	Units
Digital low-level input voltage[a]	-0.3	–	1.3	V
Digital high-level input voltage[a]	2.0	3.3	5.0	V
Digital input pull-up resistor	–	10	–	kΩ
Encoder rate[b]	DC	–	1	M
Encoder supply voltage	4.90	5.0	5.10	V
Encoder supply current	–	–	20	mA

a. Applies to A, B, and Index inputs.
b. Measured in transitions per second.

Table 9. CAN Interface

Parameter	Min	Typ	Max	Units
Bit rate	0.0133[a]	1	1	Mbps
Recommended bus termination[b]	–	120	–	Ω
Absolute maximum CANH, CANL voltage	-27	–	40	V
Watchdog time-out	–	100	–	ms
Number of modules per network[c]	1	–	63	#

a. Limited by fail-safe CAN transceiver SN65HVD1050.
b. Two terminations per network.
c. Must be a valid ID range.

Power Supply

The MDL-BDC is designed primarily for use with 12 V sealed lead-acid batteries, although other power sources can be used as long as the voltage range is not exceeded. See the *Brushed DC Motor Control Reference Design Kit (RDK) User's Manual* for more detail.

NOTE: MDL-BDC does not have reverse polarity input protection.

Motor Selection

The MDL-BDC operates 12 V brushed DC motors. Typical motors include the BI802-001A model from CIM and the RS-555PH-S255 model from Mabuchi. Some very small DC motors or motors in lightly loaded applications may have a limited useful speed range. See the *Brushed DC Motor Control Reference Design Kit (RDK) User's Manual* for additional information on motor selection.

The MDL-BDC can also drive resistive loads with some de-rating to allow for increased ripple current inside the module.

Operating Modes

The MDL-BDC can be controlled using either the servo-style PWM input or the CAN interface. Table 10 compares the capabilities of the two control methods.

Table 10. Comparison of Control Methods

	Control Method	
	Servo-Style PWM Input	**CAN Interface**
Speed Control	Yes	Yes
Analog Position Control	No	Yes
Encoder Position Control	No	Yes
Configurable Parameters	No	Yes
Voltage, Current Measurement	No	Yes
Limit Switches	Yes	Yes
Coast/Brake Feature	Yes	Yes
Firmware Update	No	Yes

The MDL-BDC does support the simultaneous use of CAN for monitoring and the servo-style input for speed.

Servo-Style PWM Input

The MDL-BDC incorporates support for speed and direction control using the standard servo-style interface found on many radio-control receivers and robot controllers. See the electrical specifications for default timing of this signal.

To accommodate variation in the timing of the supplied signal, the MDL-BDC has a calibrate feature that sets new values for full-forward, full-reverse, and points in between. Follow these steps to initiate calibration:

1. Hold down the user switch for five seconds (see Figure 4 on page 3).
2. Set the controller to send a full-forward signal.
3. Set the controller to send a full-reverse signal.
4. Set the controller to send a neutral signal.
5. Release the user switch.

The MDL-BDC samples these signals and centers the speed range and neutral position between these limits.

NOTE: See the *Brushed DC Motor Control Reference Design Kit (RDK) User's Manual* for additional calibration information.

CAN Communication

The Controller Area Network (CAN) provides a powerful interface for controlling one or more MDL-BDC modules. The MDL-BDC has two RJ11/RJ14 6P-4C sockets (more specifically, RJ16 sockets) for daisy-chaining modules using standard cables. Each end of the CAN network must be terminated properly.

Each MDL-BDC module on the CAN bus is accessed using an assigned ID number. The ID number defaults to 1, but can be changed by sending a CAN `assign ID` command to the bus. The LED flashes green when the `assign ID` command is received and then flashes yellow when the button is pressed (with the number of yellow flashes corresponding to the ID number). Pressing the user switch on the MDL-BDC informs that particular module to accept the previously specified code. See the *RDK-BDC User's Manual* on the RDK CD for instructions on how to set an ID using an EK-LM3S2965 evaluation board.

The CAN protocol used by the MDL-BDC includes the following capabilities:

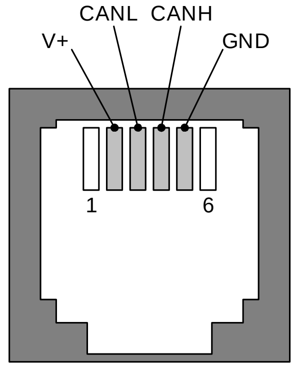
- Firmware update over CAN
- Read supply voltage, motor voltage, temperature, and current
- Set motor voltage or target position
- Set control mode to speed or position

See the *MDL-BDC CAN Communication API Specification* for complete details. The RDK includes a CAN board with an example application that demonstrates CAN control.

CAN Connector Pin Assignments

The pin assignments for the RJ11 6P-4C connectors are defined in CAN in Automation (CiA DS102). Figure 5 on page 9 shows the network connector pin assignments.

Figure 5. Network Connector Pin Assignments



CAN Socket Viewed from Top
(Tab down)

Default Parameters

The MDL-BDC parameters are shown in Table 11 which lists the default configuration of the MDL-BDC. Parameters can be modified using CAN commands or by modifying the software source code. Parameters changed using CAN commands are volatile and must be reloaded if power is cycled.

Table 11. Default Factory Configuration

Parameter	Default Value
Acceleration rate	Instantaneous change
Deceleration rate	Instantaneous change
Motor Control mode	Open-loop speed control using voltage

For additional information on parameters, see the *Brushed DC Motor Control Reference Design Kit (RDK) User’s Manual*.

Wiring

The MDL-BDC is controlled using either a servo-type PWM source or CAN commands.

Figure 6 shows a typical, simple wiring arrangement with power, motor, PWM control, and optional limit-switch connections. Control wires must be looped through the wire retention hooks to prevent the connectors from shaking loose during operation. Basic servo-style PWM control is enabled by default and does not require CAN configuration.

Figure 7 on page 10 shows an advanced wiring configuration using the CAN interface. Wiring for position sensing using both a position potentiometer and a quadrature encoder is detailed. Although two sensor types are shown, the MDL-BDC software supports control and monitoring of only one sensor at a time.

Figure 6. Basic Wiring with a Servo-Style Speed Command for Open-loop Motor Control

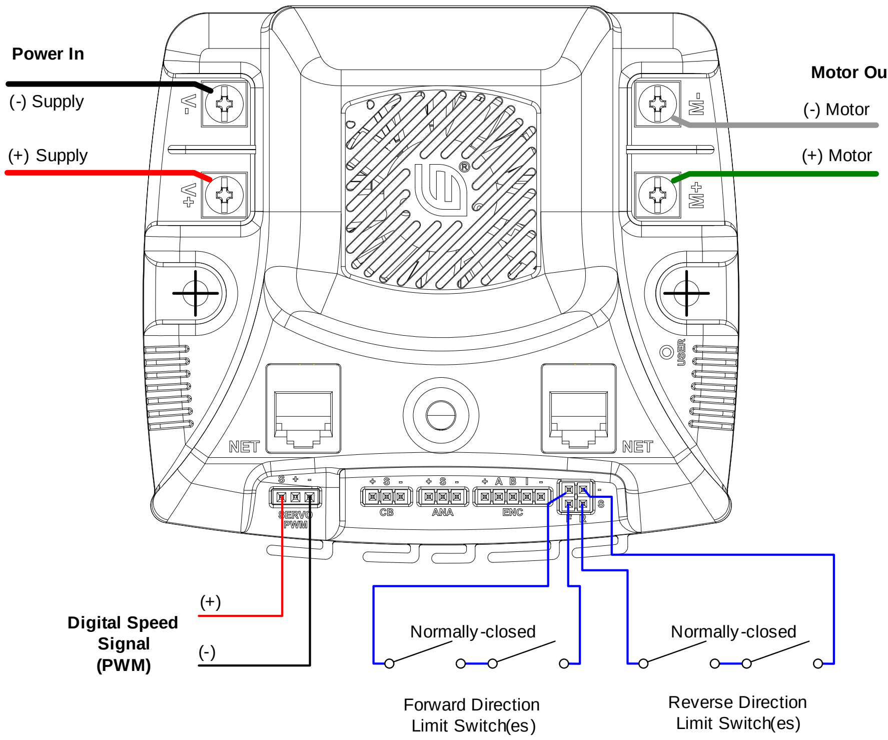


Figure 7. CAN-Based Control for Closed-loop Motor Control Wiring Diagram

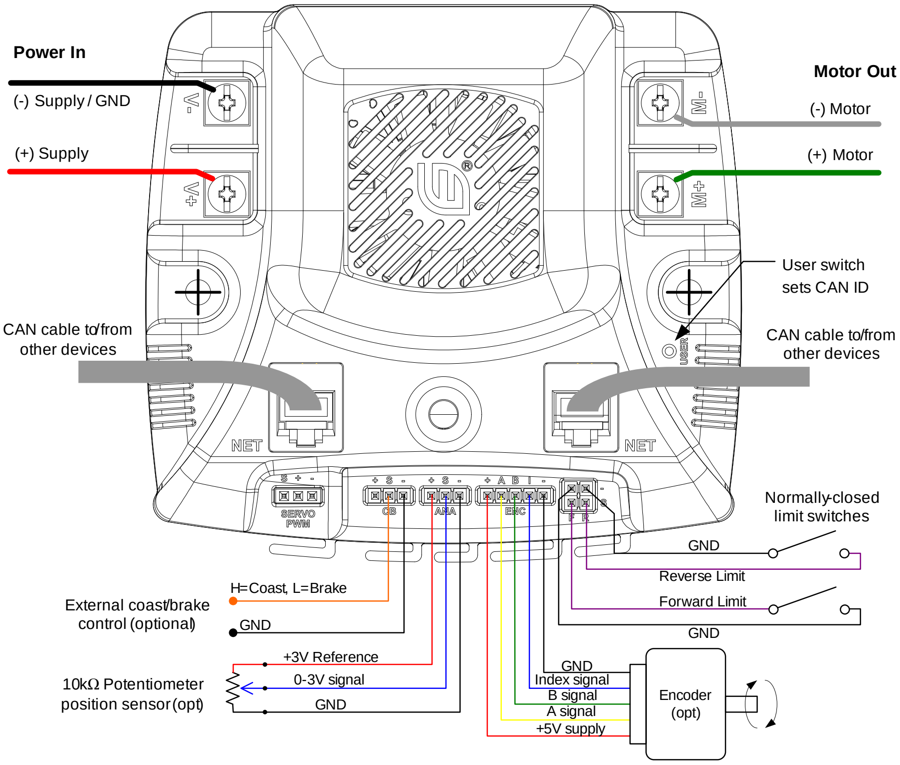
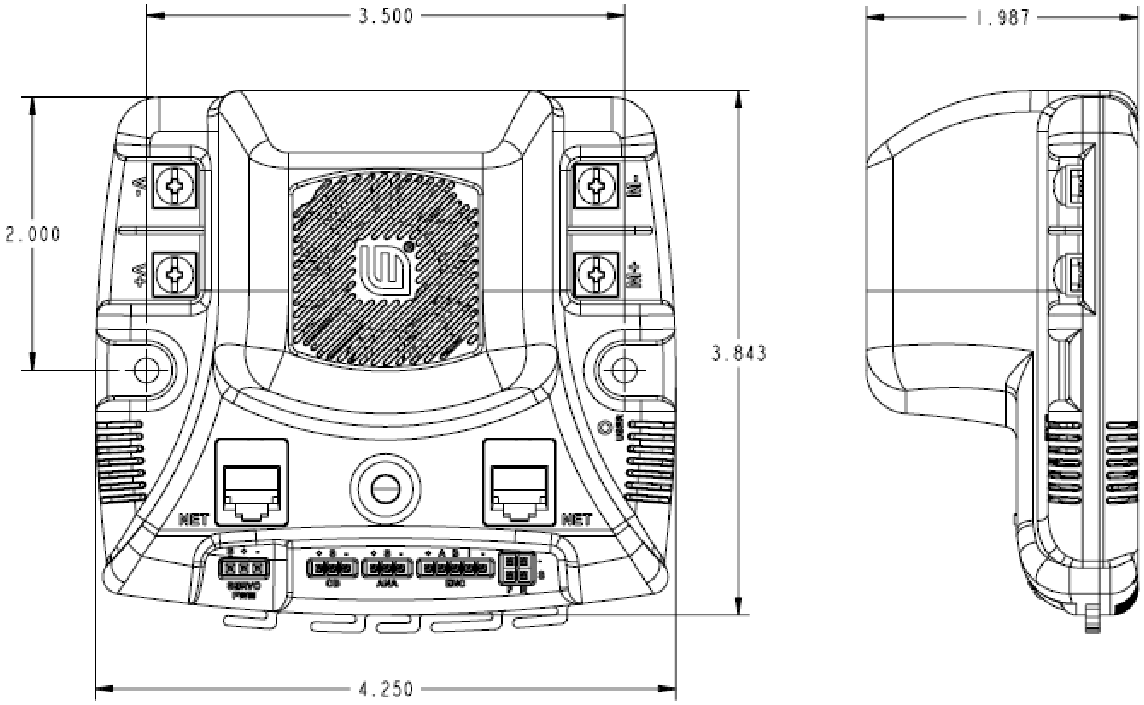


Figure 8 shows the MDL-BDC physical dimensions. The module has two 0.175” (4.5 mm) diameter mounting holes as indicated.

Figure 8. Mechanical Drawing



The MDL-BDC should be mounted so that the vents in the top and sides of the module are not restricted in any way. A clearance of ½ inch should be maintained around the module.

Status LED

Table 12 lists all of the LED status and fault codes for Normal Operating, Fault, and Calibration or CAN conditions. Fault information is prioritized, so only the highest priority fault will be indicated.

Table 12. Normal Operating Conditions

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	

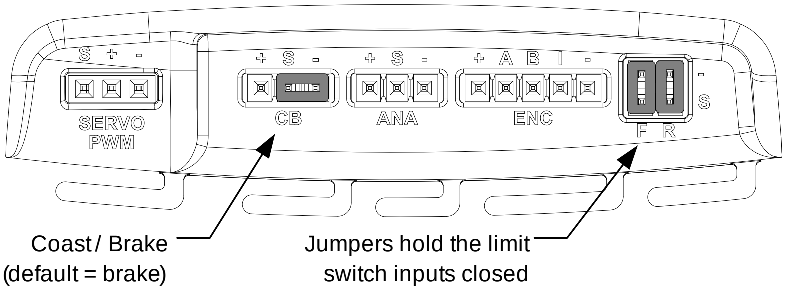
Table 12. Normal Operating Conditions (Continued)

LED State	Module Status
Normal Operating Conditions	
Slow Flashing Yellow	Loss of CAN or servo link
Slow Flashing Red	Fault
Calibration or CAN Conditions	
Flashing Red and Green	Calibration mode active
Flashing Red and Yellow	Calibration mode failure
Flashing Green and Yellow	Calibration mode success
Slow Flashing Green	CAN ID assignment mode
Fast Flashing Yellow	Current CAN ID (count flashes to determine ID)
Flashing Yellow	CAN ID invalid (that is, Set to 0) awaiting valid ID assignment

Jumper Settings

Figure 9 shows the factory-default jumper settings.

Figure 9. Default Factory Jumper Settings



Fault Detection

The MDL-BDC detects and shuts down the motor if any of the following conditions are detected:

- Power supply under-voltage
- Over temperature
- Over current
- Loss of CAN or servo-style speed link
- Limit switch activated in the current direction of motion

The LED indicates a fault state during the fault condition and for three seconds after the fault is cleared (except for the limit switch and link faults, which are instantaneous).

Firmware Update

The MDL-BDC firmware can be updated over CAN. The capability to update the MDL-BDC firmware can be added to most Host controllers by implementing the necessary CAN protocol. For users who are not developing a CAN host controller, an application that runs on the Stellaris® LM3S2965 Evaluation Board (EK-LM3S2965) is provided. This board is included in the RDK. The example application can be downloaded from www.ti.com/stellaris.

See the *Brushed DC Motor Control Reference Design Kit (RDK) User's Manual* for additional information on the firmware update procedure.

Additional Information

The following documents are available for download at www.ti.com/stellaris:

- *Brushed DC Motor Control Reference Design Kit (RDK) User's Manual*, Publication number RDK-BDC-UM
  - Schematics and Bill-of-Materials (BOM)
  - Detailed functional description
  - Firmware update, configuration, and operation using the RDK-BDC test application
- *Brushed DC Motor Control (RDK) Quickstart Guide*
  - A step-by-step guide to using the reference design kit (RDK-BDC)
- *RDK-BDC Firmware Development Package User's Guide*, Publication number SW-RDK-BDC-UG
  - Part of the StellarisWare® source code library