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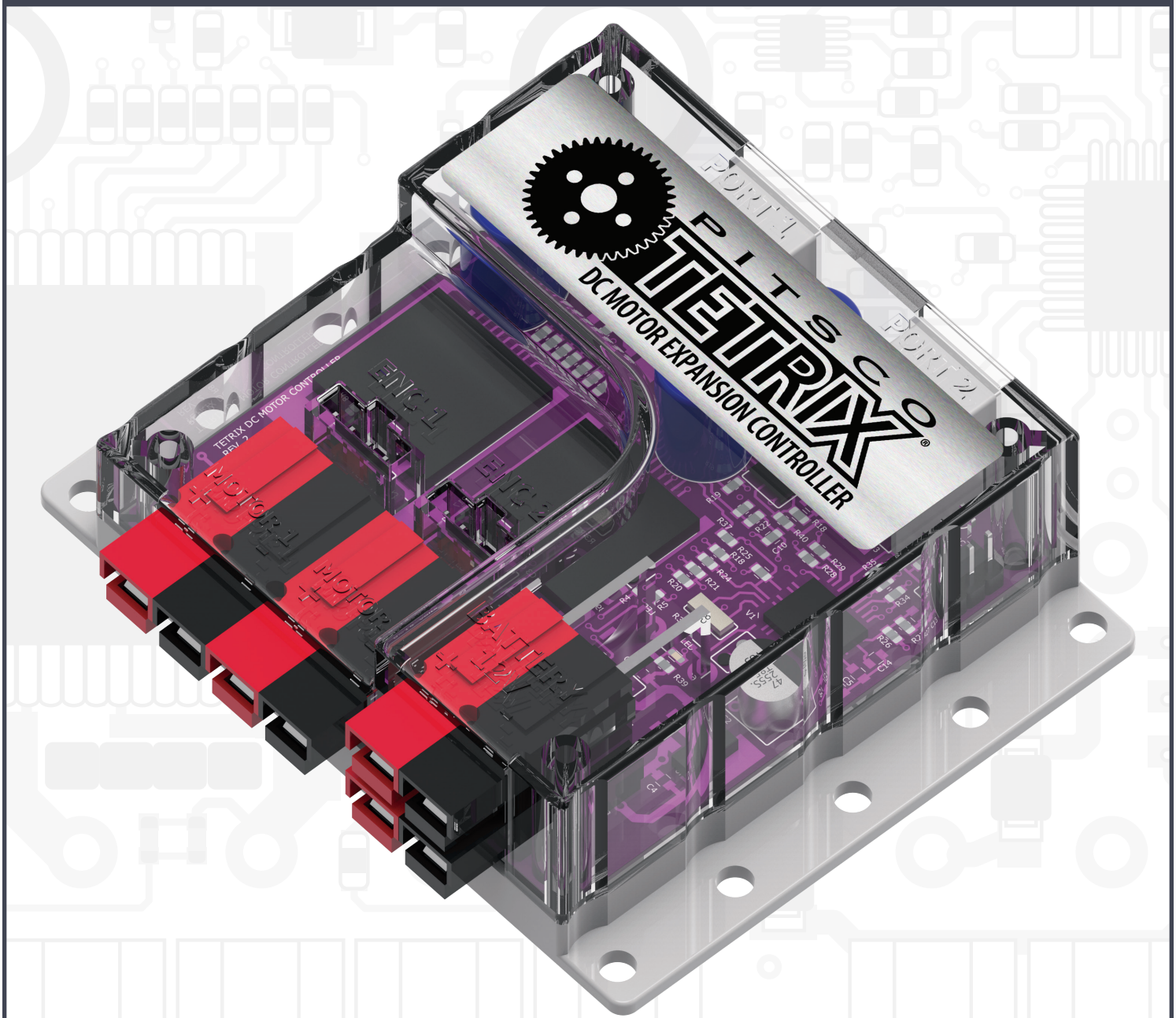
TETRIX® MAX



TETRIX® DC Motor Expansion Controller Technical Guide

PITSCO EDUCATION

44559

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A downloadable PDF of the most recent version of this guide can be found at
Pitsco.com/TETRIX-MAX-DC-Motor-Expansion-Controller#resources.

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TETRIX® DC Motor Expansion Controller Technical Guide

General Description

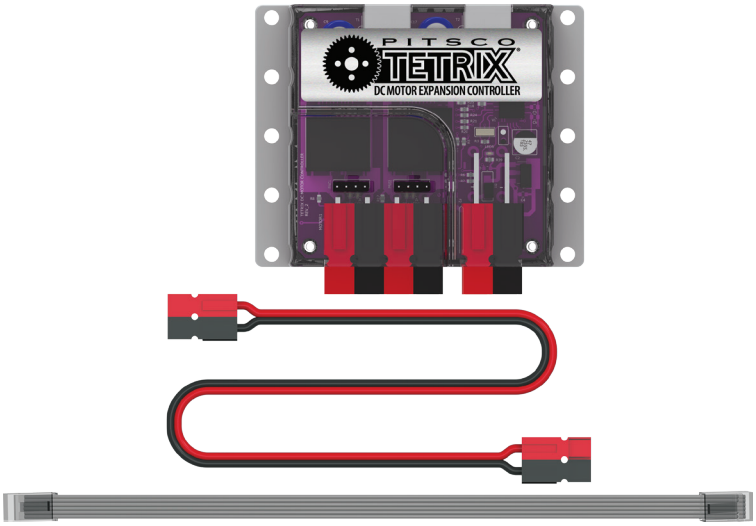
The TETRIX® MAX DC Motor Expansion Controller is a DC motor expansion peripheral designed to allow the addition of multiple DC motors to the PRIZM® Robotics Controller. The device provides an additional two DC motor output channels and two quadrature encoder inputs for increased motor control capacity. Additional expansion controllers can be daisy-chained for a total of four motor expansion controllers connected to the PRIZM at one time. The onboard firmware provides a comprehensive set of programmable motor control functions.

The TETRIX MAX DC Motor Expansion Controller features the following:

- Connects to the PRIZM expansion port, enabling users to control up to two additional 12-volt DC motors
- Up to four motor controllers can be connected to the PRIZM expansion port.
- Has two H-bridge outputs to control the speed and direction of two DC motors
- Includes two quadrature encoder input ports
- Additional power and expansion ports support daisy chain configurations.
- Can be connected to the LEGO® EV3 Brick and National Instruments' myRIO. Software blocks can be downloaded from the product page for this controller at **Pitsco.com**.

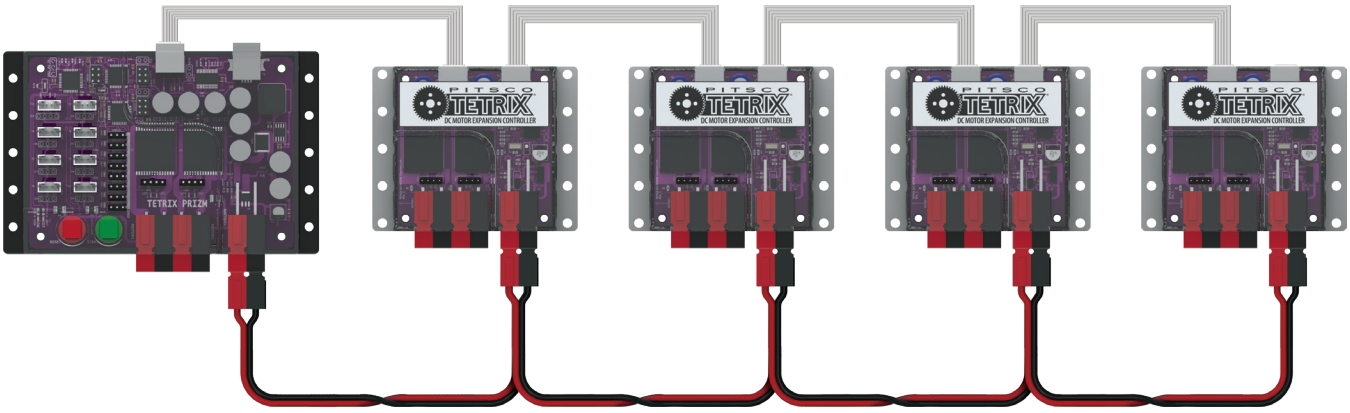
What's Included

- TETRIX MAX DC Motor Expansion Controller
- TETRIX MAX Powerpole Extension Cable
- Daisy chain data cable



Connections

The DC motor expansion controller connects to the PRIZM battery power expansion terminals using the included Powerpole extension cable. The motor controller's data port connects to the PRIZM expansion port using the included data cable. Additional motor controllers can be daisy-chained for increased motor channel capacity. Up to four motor controllers can be daisy-chained to a single i2C data bus.



The four expansion controllers can be a mix of DC and servo motor expansion controllers. The TETRIX Servo Motor Expansion Controllers (44355) can be added to increase the number of servo motor channels for programming and control. Each motor controller in the daisy chain must have a unique i2C address, or ID, in order to communicate. By default, the DC motor expansion controller uses ID Number 1, and the servo expansion controller uses ID Number 2. The unique ID of any additional controllers in the daisy chain can be set or changed by using software commands. ID numbers supported by the PRIZM Arduino Library are 1, 2, 3, and 4. There are programming examples in the TETRIX PRIZM Arduino Library that demonstrate how to read a motor controller ID and how to set and change the ID.

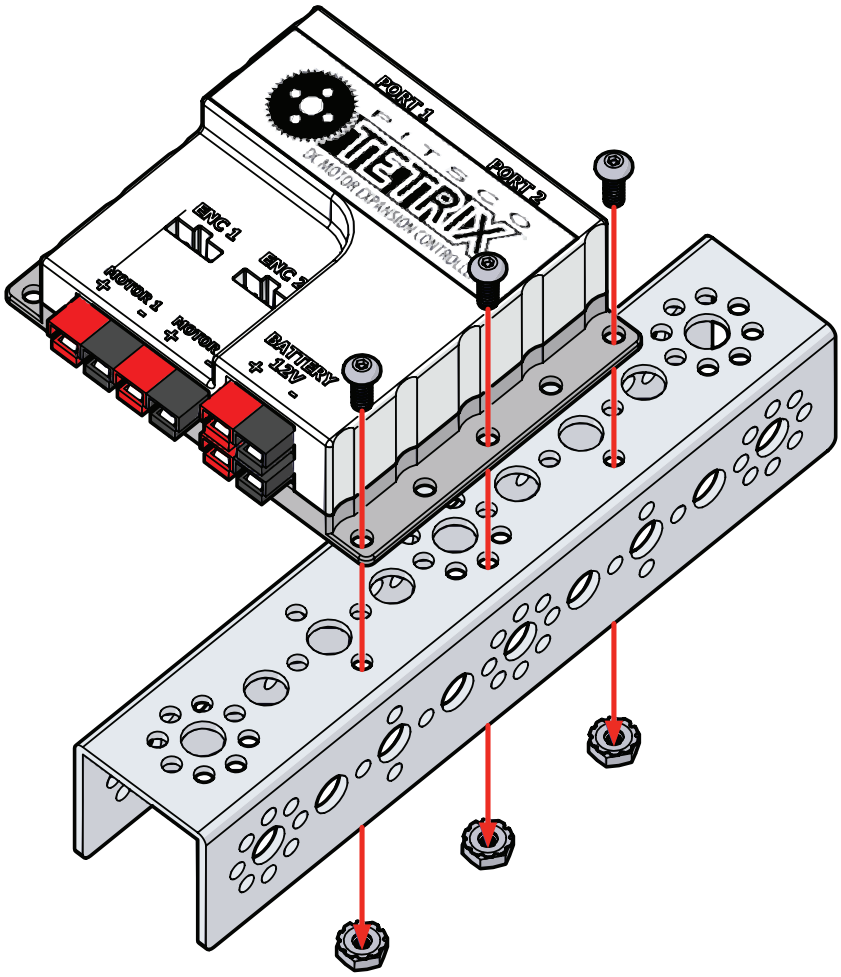
The operation of the motor controller is very similar to the PRIZM controller because they use comparable command formats. The TETRIX PRIZM Arduino Library has been updated to support the DC motor expansion controller. The TETRIX PRIZM Arduino Library contains several sketches in the examples folder that demonstrate how to program using the DC motor expansion controller and PRIZM. A thorough understanding of how to program using PRIZM and completion of the activities within the *TETRIX PRIZM Robotics Controller Programming Guide* are highly recommended to better understand the programming application of the DC motor expansion controller. The appendix provides a detailed description of each function used by the TETRIX PRIZM Arduino Library for interfacing with the DC motor expansion controller. Please be sure to download and install the latest TETRIX PRIZM Arduino Library from the TETRIX website at **Pitsco.com/TETRIX-PRIZM-Robotics-Controller#downloads**.

Important Safety Information

Caution: Use only a TETRIX battery pack that is equipped with an in-line safety fuse. Failure to do so could result in damage or injury. Connect the TETRIX battery pack to either the top or bottom red/black power inlet row at the battery connection port. Do **not** connect two battery packs to the PRIZM controller.

Attaching the DC Motor Expansion Controller

The DC motor expansion controller mounting holes are spaced to align with the TETRIX hole pattern. The expansion controller can be attached to the TETRIX building elements using the screw and nut hardware included in the TETRIX robotics sets.



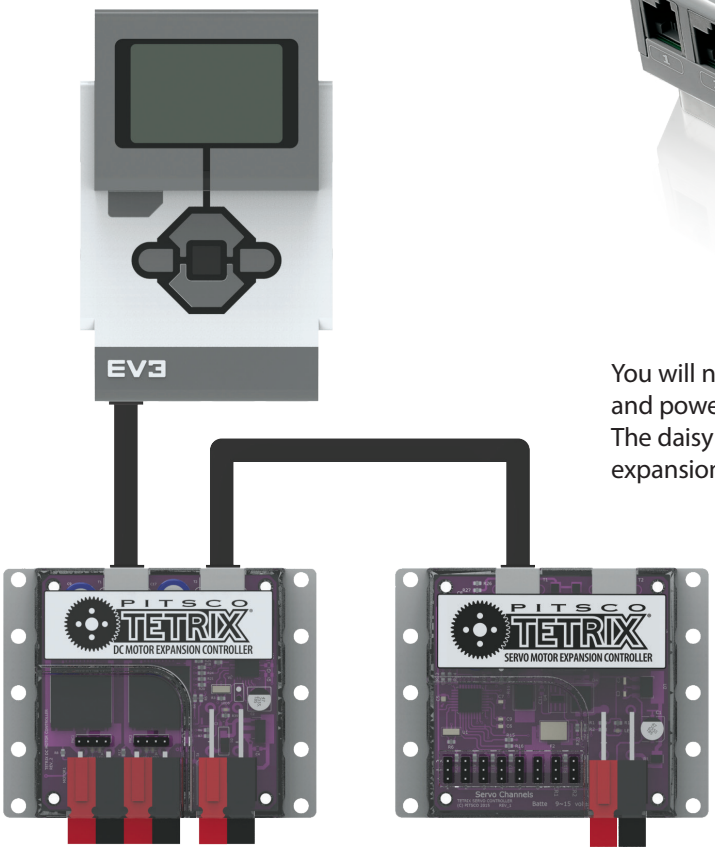
Supported Software and Additional Resources

The DC motor expansion controller is designed with flexibility in mind and can interface with any master controller with an i2C communications bus. Pitsco Education provides software support materials and other resources that enable the DC motor controller to interface with the PRIZM controller, the LEGO MINDSTORMS® EV3 Brick, and the National Instruments myRIO.

The DC motor controller can interface with other devices such as Raspberry Pi or Arduino, but software support is not provided.

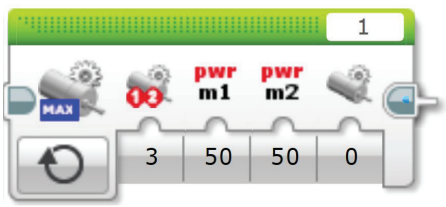
Support for LEGO MINDSTORMS EV3

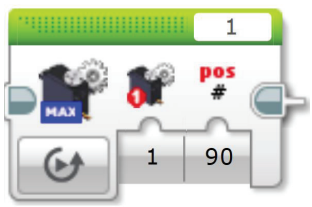
While the DC motor expansion controller has been designed to work primarily with the TETRIX PRIZM Robotics Controller, it can also be connected directly to the LEGO EV3 Brick for programming and control of TETRIX DC gearhead motors.



You will need a TETRIX MAX 12-volt rechargeable battery and power switch kit to supply power to the controller. The daisy chain data cable that comes with the DC motor expansion controller will connect to the EV3 sensor ports.

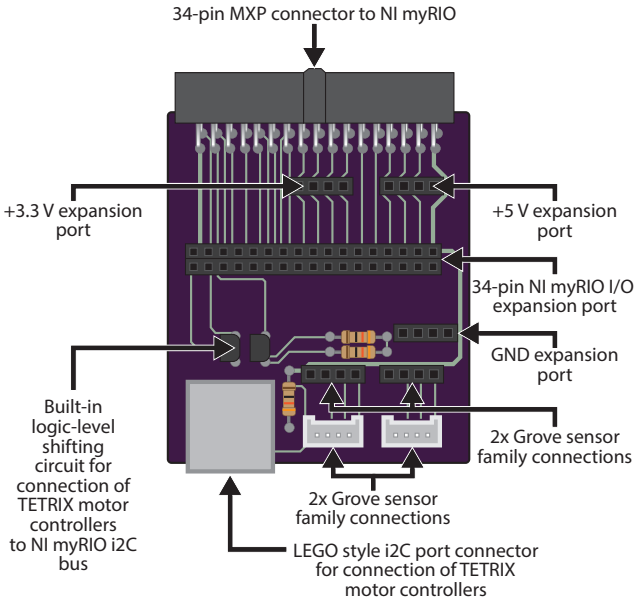
EV3 programming blocks for the DC motor expansion controller are available for free download at **Pitsco.com/TETRIX-MAX-DC-Motor-Expansion-Controller#downloads**.





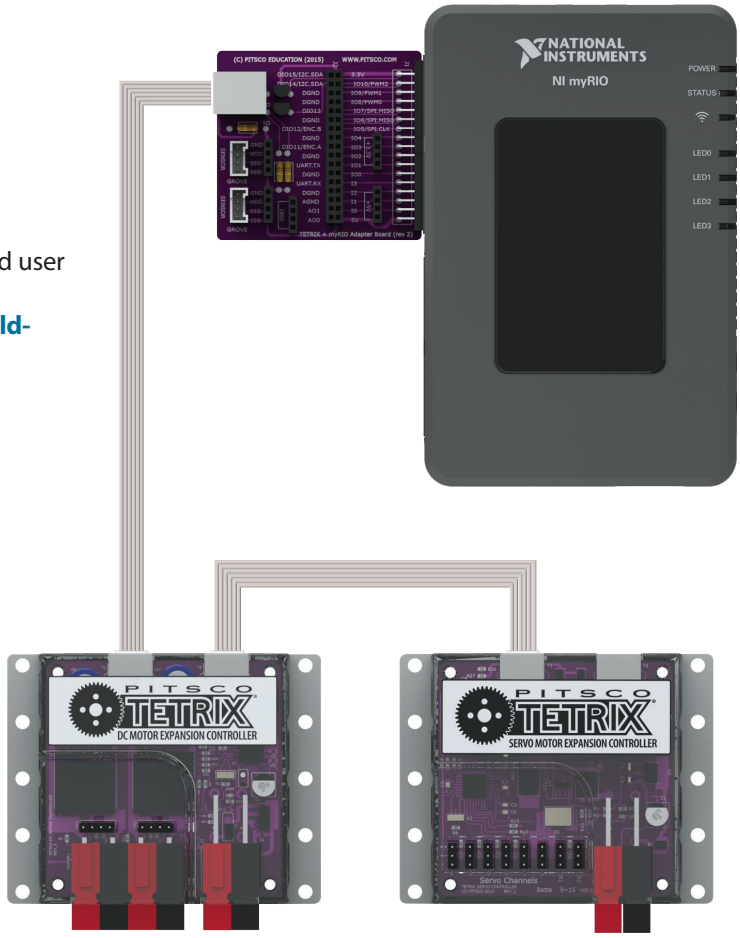
Support for National Instruments myRIO

In addition, there is support for the National Instruments myRIO platform to enable TETRIX DC motor control using the *LabVIEW*™ programming language.



A hardware adapter (41306) enables easy connection of expansion controllers to the myRIO MXP ports.

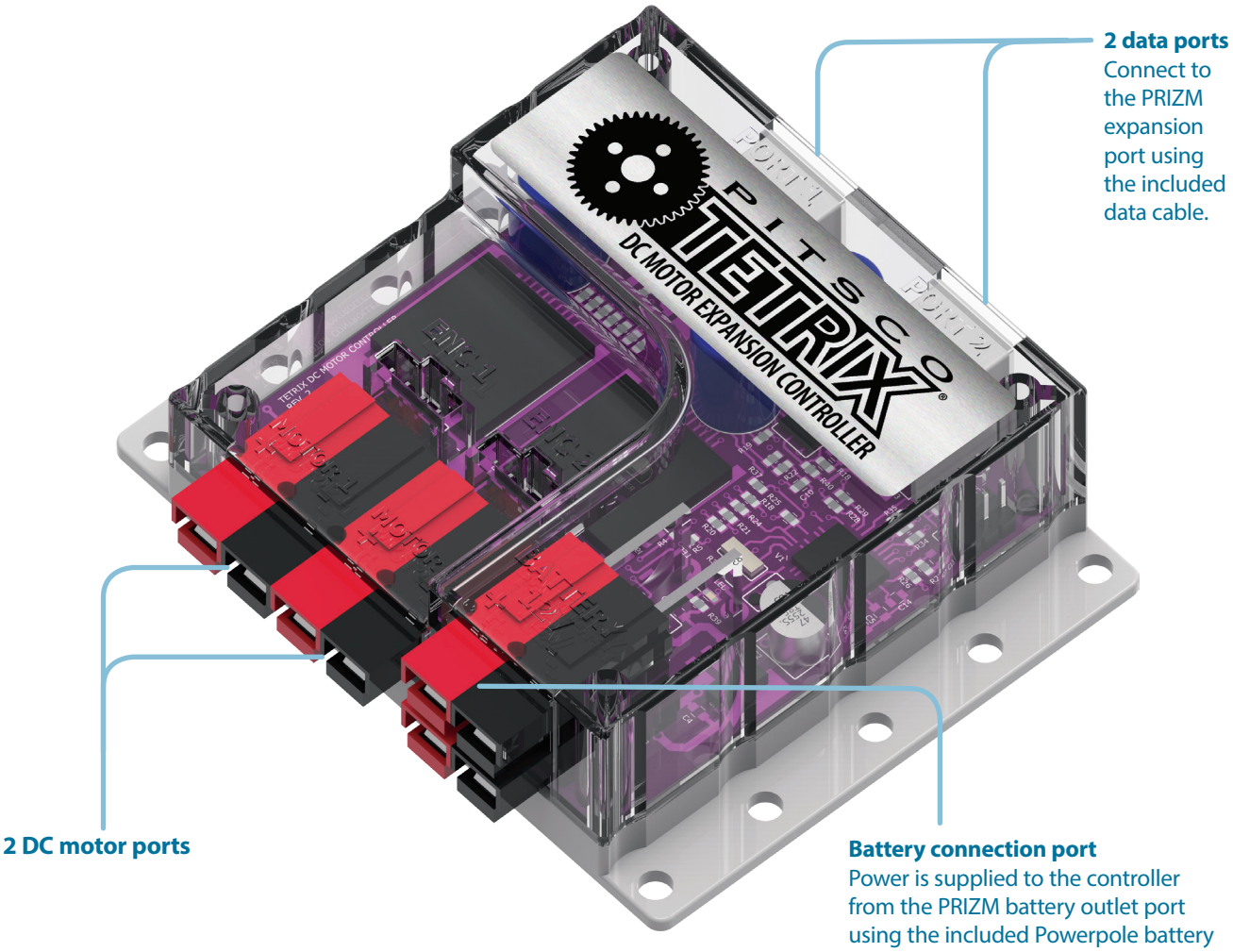
A free downloadable TETRIX *LabVIEW* control palette and user documentation are available for download at **Pitsco.com/Competitions,-Clubs,-and-Programs/World-Robot-Olympiad**.



General Hardware Specifications

This section provides details on the communications of the DC motor expansion controller. This information can be used to interface with any master controller with an i2C communications bus.

Power:	12 volts DC using TETRIX MAX NiMH fuse-protected battery pack; blue LED power indicator
DC motor ports:	2 Powerpole connections; H-bridge controlled; 10 A continuous each channel; 20 A peak
Recommended motor:	TETRIX TorqueNADO™ (44260)
Motor indication:	Motor power and direction LED indicators; red and green; one set for each channel
DC motor control modes:	Constant power (-100% to 100%) PID constant speed (degrees per second) PID constant speed to encoder count and hold position PID constant speed to encoder degrees and hold position Brake or coast stop mode DC motor current monitoring (all modes)
Battery voltage monitoring:	0-18 volt range
Battery connection port:	Powerpole type; additional port for daisy-chaining battery power to additional motor controllers
i2C data port:	2 ports total sharing the same bus; one port used for input, the second for output to additional daisy-chained motor controllers
Motor encoder port:	2 quadrature ports; ENC1 and ENC2; 5 volts DC, 50 mA max; Spec: 360 CPR, 1,440 PPR; Type: Hall effect



2 data ports
Connect to the PRIZM expansion port using the included data cable.

2 DC motor ports

Battery connection port
Power is supplied to the controller from the PRIZM battery outlet port using the included Powerpole battery conversion cable.

TETRIX MAX DC Motor Expansion Controller Library

Following is a quick reference for each expansion controller function supported by the TETRIX PRIZM Arduino Library.

Note: Unless changed, the default ID# for the DC motor expansion controller is 1.

readDCFirmware(ID#);

setExpID(ID#);

readExpID();

WDT_STOP(ID#);

ControllerEnable(ID#);

ControllerReset(ID#);

setMotorPower(ID#, motor#, power);

setMotorPowers(ID#, power1, power2);

setMotorSpeed(ID#, motor#, speed);

setMotorSpeeds(ID#, speed1, speed2);

setMotorTarget(ID#, motor#, speed, target);

setMotorTargets(ID#, speed1, target1, speed2, target2);

setMotorDegree(ID#, motor#, speed, degrees);

setMotorDegrees(ID#, speed1, degrees1, speed2, degrees2);

setMotorInvert(ID#, motor#, invert);

readMotorCurrent(ID#, motor#);

readMotorBusy(ID#, motor#);

readEncoderCount(ID#, enc#);

readEncoderDegrees(ID#, enc#);

resetEncoder(ID#, enc#);

resetEncoders(ID#);

readBatteryVoltage(ID#);

setMotorSpeedPID(ID#, P, I, D);

setMotorTargetPID(ID#, P, I, D);

TETRIX MAX DC Motor Expansion Controller Arduino Library Functions Chart

Please be sure to download and install the latest version of the TETRIX PRIZM Arduino Library for the most up-to-date programming features and functionality.

All the DC motor control functions that implement PID control require encoder input data. For these functions to execute accurately, the motor encoder must be a TETRIX type or one that matches the TETRIX motor encoder specification. Please refer to the TETRIX TorqueNADO motor specifications table at **Pitsco.com/TETRIX-MAX-TorqueNADO-Motor-with-Encoder#resources** for the motor and encoder technical parameters. The examples in the Coding Example column are shown for the controller ID# set to 1. The ID# must match the controller or controllers' ID# for proper communication. **Unless changed, the DC motor expansion controller's default ID# is 1.** The first parameter in the function is always the controller ID#.

Description	Function	Coding Example (for controller ID = 1)
Read DC Controller Firmware Version Reads the version number of firmware.	**readDCFirmware**(ID#); Data Type: *ID#* = integer Data Type Returned: Unsigned integer	**readDCFirmware**(1); *Return the DC motor controller's firmware version.*
Set/Change Expansion Controller ID Number Sets/changes the unique i2C ID address of the expansion controller.	**setExpID**(ID#); Data Type: *ID#* = integer	**setExpID**(3); *Set the ID of the connected expansion controller to "3."* ***Important:*** *Only the controller that is being changed can be connected to the i2C bus when calling this function.*
Read the Expansion Controller ID Number Reads the i2C address/ID of the expansion controller.	**readExpID**(); Data Type: None Data Type Returned: *value* = integer	**readExpID**(); *Return the i2C address/ID of the connected expansion controller.* ***Important:*** *Only the controller that is being read can be connected to the i2C bus when calling this function.*
Watchdog Timer Time-Out Forces a watchdog timer reset of the expansion controller's processor.	**WDT_STOP**(ID#); Data Type: *ID#* = integer	**WDT_STOP**(1); *Command the expansion controller to do a processor reset.*
Send Controller Enable Sends an enable byte to the expansion controller to begin receiving motor commands.	**ControllerEnable**(ID#); Data Type: *ID#* = integer	**ControllerEnable**(1); *Send an enable command byte.*
Send Controller Reset Sends a reset command byte causing the controller's firmware to a full reset. All conditions are set to power-up defaults after a reset occurs.	**ControllerReset**(ID#); Data Type: *ID#* = integer	**ControllerReset**(1); *Send a firmware reset command byte.*

Description	Function	Coding Example (for controller ID = 1)
Set DC Motor Power Sets the power level and direction of a TETRIX DC Motor connected to the motor ports. Power level range is 0 to 100. Direction is set by the sign (+/-) of the power level. Power level 0 = stop in coast mode. Power level 125 = stop in brake mode.	**setMotorPower**(ID#, motor#, power); Data Type: *ID#* = integer *motor#* = integer *power* = integer Data Range: *motor#* = 1 or 2 *power* = -100 to 100 or *power* = 125 (brake mode)	**setMotorPower**(1, 1, 50); *Spin Motor 1 clockwise at 50% power.* **setMotorPower**(1, 2, -50); *Spin Motor 2 counterclockwise at 50% power.* **setMotorPower**(1, 1, 0); *Turn off Motor 1 in coast mode.* **setMotorPower**(1, 2, 125); *Turn off Motor 2 in brake mode.*
Set DC Motor Powers Simultaneously sets the power level and direction of **both** TETRIX DC Motors connected to the motor ports. Both Motor 1 and Motor 2 channel parameters are set with a single statement. The power level range is 0 to 100. Direction is set by the sign (+/-) of the power level. Power level 0 = stop in coast mode. Power level 125 = stop in brake mode.	**setMotorPowers**(ID#, power1, power2); Data Type: *ID#* = integer *power1* = integer *power2* = integer Data Range: *power1* = -100 to 100 *power2* = -100 to 100 or *power1* = 125 (brake mode) *power2* = 125 (brake mode)	**setMotorPowers**(1, 50, 50); *Spin Motor 1 and Motor 2 clockwise at 50% power.* **setMotorPowers**(1, -50, 50); *Spin Motor 1 counterclockwise and Motor 2 clockwise at 50% power.* **setMotorPowers**(1, 0, 0); *Turn off Motor 1 and Motor 2 in coast mode.* **setMotorPowers**(1, 125, 125); *Turn off Motor 1 and Motor 2 in brake mode.*

Description	Function	Coding Example (for controller ID = 1)
Set DC Motor Speed Uses velocity PID control to set the constant speed of a TETRIX DC Motor with a TETRIX motor encoder installed. The *speed* parameter range is 0 to 720 degrees per second (DPS). The sign (+/-) of the *speed* parameter controls direction of rotation.	**setMotorSpeed**(ID#, motor#, speed); Data Type: *ID#* = integer *motor#* = integer *speed* = integer Data Range: *motor#* = 1 or 2 *speed* = -720 to 720	**setMotorSpeed**(1, 1, 360); *Spin Motor 1 clockwise at a constant speed of 360 DPS.* **setMotorSpeed**(1, 1, -360); *Spin Motor 1 counterclockwise at a constant speed of 360 DPS.*
Set DC Motor Speeds Uses velocity PID control to simultaneously set the constant speeds of **both** TETRIX DC Motor channels with TETRIX motor encoders installed. Both Motor 1 and Motor 2 channel parameters are set with a single statement. The speed parameter range is 0 to 720 degrees per second (DPS). The sign (+/-) of the speed parameter controls direction of rotation.	**setMotorSpeeds**(ID#, speed1, speed2); Data Type: *ID#* = integer *speed1* = integer *speed2* = integer Data Range: *speed1* = -720 to 720 *speed2* = -720 to 720	**setMotorSpeeds**(1, 360, 360); *Spin Motor 1 and Motor 2 clockwise at a constant speed of 360 DPS.* **setMotorSpeeds**(1, 360, -360); *Spin Motor 1 clockwise and Motor 2 counterclockwise at a constant speed of 360 DPS.* **setMotorSpeeds**(1, 180, -180); *Spin Motor 1 clockwise and Motor 2 counterclockwise at a constant speed of 180 DPS.*
Set DC Motor Target Implements velocity and positional PID control to set the constant speed and the encoder count target holding position of a TETRIX DC Motor with a TETRIX encoder installed. The *speed* parameter range is 0 to 720 degrees per second (DPS). The encoder count target position is a signed long integer from -2,147,483,648 to 2,147,483,647. Each encoder count = 1/4-degree resolution.	**setMotorTarget**(ID#, motor#, speed, target); Data Type: *ID#* = integer *motor#* = integer *speed* = integer *target* = long Data Range: *motor#* = 1 or 2 *speed* = 0 to 720 *target* = -2147483648 to 2147483647	**setMotorTarget**(1, 1, 360, 1440); *Spin Motor 1 at a constant speed of 360 DPS until encoder 1 count equals 1,440. When at encoder target count, hold position in a servo-like mode.* **setMotorTarget**(1, 2, 180, -1440); *Spin Motor 2 at a constant speed of 180 DPS until encoder 2 count equals -1,440 (1 revolution). When at encoder target count, hold position in a servo-like mode.*

Description	Function	Coding Example (for controller ID = 1)
Set DC Motor Targets Implements velocity and positional PID control to simultaneously set the constant speeds and the encoder count target holding positions of **both** TETRIX DC Motor channels each with TETRIX encoders installed. Both Motor 1 and Motor 2 channel parameters are set with a single statement. The speed parameter range is 0 to 720 degrees per second (DPS). The encoder count target position is a signed long integer from -2,147,483,648 to 2,147,483,647. Each encoder count = 1/4-degree resolution.	**setMotorTargets**(ID#, speed1, target1, speed2, target2); Data Type: *ID#* = integer *speed1* = integer *target1* = long *speed2* = integer *target2* = long Data Range: *speed1* = 0 to 720 *target1* = -2147483648 to 2147483647 *speed2* = 0 to 720 *target2* = -2147483648 to 2147483647	**setMotorTargets**(1, 360, 1440, 360, 1440); *Spin Motor 1 and Motor 2 at a constant speed of 360 DPS until each motor encoder count equals 1,440. When a motor reaches its encoder target count, hold position in a servo-like mode.* **setMotorTargets**(1, 360, 1440, 180, 2880); *Spin Motor 1 at a constant speed of 360 DPS until encoder 1 count equals 1,440. Spin Motor 2 at a constant speed of 180 DPS until encoder 2 equals 2,880. Each motor will hold its position in a servo-like mode when it reaches the encoder target.* ***Note:** One encoder count equals 1/4-degree resolution. For example, 1 motor revolution equals 1,440 encoder counts (1,440 / 4 = 360).*
Set Motor Degree Implements velocity and positional PID control to set the constant speed and the degree target holding position of a TETRIX DC Motor with a TETRIX encoder installed. The *speed* parameter range is 0 to 720 degrees per second (DPS). The encoder degrees target position is a signed long integer from -536,870,912 to 536,870,911 with a 1-degree resolution.	**setMotorDegree**(ID#, motor#, speed, degrees); Data Type: *ID#* = integer *motor#* = integer *speed* = integer *degrees* = long Data Range: *motor#* = 1 or 2 *speed* = 0 to 720 *degrees* = -536870912 to 536870911	**setMotorDegree**(1, 1, 180, 360); *Spin Motor 1 at a constant speed of 180 DPS until encoder 1 degree count equals 360. When at encoder target degree count, hold position in a servo-like mode.* **setMotorDegree**(1, 2, 90, 180); *Spin Motor 2 at a constant speed of 90 DPS until encoder 2 degree count equals 180. When at encoder target degree count, hold position in a servo-like mode.*

Description	Function	Coding Example (for controller ID = 1)
Set Motor Degrees Implements velocity and positional PID control to set the constant speeds and the degree target holding positions of both TETRIX DC Motor channels with TETRIX encoders installed. Both Motor 1 and Motor 2 channel parameters are set with a single statement. The speed parameter range is 0 to 720 degrees per second (DPS). The encoder degree target position is a signed long integer from -536,870,912 to 536,870,911 with a 1-degree resolution.	**setMotorDegrees**(ID#, speed1, degrees1, speed2, degrees2); Data Type: *ID#* = integer *speed1* = integer *degrees1* = long *speed2* = integer *degrees2* = long Data Range: *speed1* = 0 to 720 *degrees1* = -536870912 to 536870911 *speed2* = 0 to 720 *degrees2* = -536870912 to 536870911	**setMotorDegrees**(1, 180, 360, 180, 360); *Spin Motor 1 and Motor 2 at a constant speed of 180 DPS until each motor encoder degree count equals 360. When a motor reaches its degree target count, hold position in a servo-like mode.* **setMotorDegrees**(1, 360, 720, 90, 360); *Spin Motor 1 at a constant speed of 360 DPS until encoder 1 degree count equals 720. Spin Motor 2 at a constant speed of 90 DPS until encoder 2 degree equals 360. Each motor will hold its position in a servo-like mode when it reaches the encoder target.*
Set Motor Direction Invert Inverts the forward/reverse direction mapping of a DC motor channel. This function is intended to harmonize the forward and reverse directions for motors on opposite sides of a skid-steer robot chassis. Inverting one motor channel can make coding opposite-facing DC motors working in tandem more intuitive. An *invert* parameter of 1 = invert. An *invert* parameter of 0 = no invert. The default is no invert.	**setMotorInvert**(ID#, motor#, invert); Data Type: *ID#* = integer *motor#* = integer *invert* = integer Data Range: *motor#* = 1 or 2 *invert* = 0 or 1	**setMotorInvert**(1, 1, 1); *Invert the spin direction mapping of Motor 1.* **setMotorInvert**(1, 2, 1); *Invert the spin direction mapping of Motor 2.* **setMotorInvert**(1, 1, 0); *Do not invert the spin direction mapping of Motor 1.* **setMotorInvert**(1, 2, 0); *Do not invert the spin direction mapping of Motor 2.* ***Note:*** *Non-inverting is the default on power-up or reset.*

Description	Function	Coding Example (for controller ID = 1)
Read DC Motor Current Reads the DC motor current of each TETRIX DC Motor attached to the Motor 1 and Motor 2 ports. The integer value that is returned is motor load current in milliamps.	**readMotorCurrent**(ID#, motor#); Data Type: *ID#* = integer *motor#* = integer Data Range: *motor#* = 1 or 2 Data Type Returned: *value* = integer	**readMotorCurrent**(1, 1); *Read the motor load current of Motor 1 channel.* **readMotorCurrent**(1, 2); *Read the motor load current of Motor 2 channel.* *Example: 1500 = 1.5 amps*
Read Motor Busy Status Reads the busy flag read to check on the status of a DC motor that is operating in positional PID mode. The motor busy status will return "1" if it is moving toward a positional target (degrees or encoder count). When it has reached its target and is in hold mode, the busy status will return "0."	**readMotorBusy**(ID#, motor#); Data Type: *ID#* = integer *motor#* = integer Data Range: *motor#* = 1 or 2 Data Type Returned: *value* = integer	**readMotorBusy**(1, 1); *Return the busy status of Motor 1.* **readMotorBusy**(1, 2); *Return the busy status of Motor 2.*
Read Encoder Count Reads the encoder count value. The DC controller uses encoder pulse data to implement PID control of a TETRIX DC Motor connected to the motor ports. The controller counts the number of pulses produced over a set time period to accurately control velocity and position. Each 1/4 degree equals 1 pulse, or count, or 1 degree of rotation equals 4 encoder counts. The current count can be read to determine a motor's shaft position. The total count accumulation can range from -2,147,483,648 to 2,147,483,647. A clockwise rotation adds to the count value, while a counterclockwise rotation subtracts from the count value. The encoder values are set to 0 at power-up and reset.	**readEncoderCount**(ID#, enc#); Data Type: *ID#* = integer *enc#* = integer Data Range: *enc#* = 1 or 2 Data Type Returned: *value* = long	**readEncoderCount**(1, 1); *Read the current count value of encoder 1 (ENC1 port).* **readEncoderCount**(1, 2); *Read the current count value of encoder 2 (ENC2 port).*

Description	Function	Coding Example (for controller ID = 1)
Read Encoder Degrees Reads the encoder degree value. The DC controller uses encoder pulse data to implement PID control of a TETRIX DC Motor connected to the motor ports. The controller counts the number of pulses produced over a set time period to accurately control velocity and position. This function is similar to the encoder count function, but instead of returning the raw encoder count value, it returns the motor shaft position in degrees. The total degree count accumulation can range from -536,870,912 to 536,870,911. A clockwise rotation adds to the count value, while a counterclockwise rotation subtracts from the count value. The encoder values are set to 0 at power-up and reset.	**readEncoderDegrees**(ID#, enc#); Data Type: *ID#* = integer *enc#* = integer Data Range: *enc#* = 1 or 2 Data Type Returned: *value* = long	**readEncoderDegrees**(1, 1); *Read the current degree count value of encoder 1 (ENC1 port).* **readEncoderDegrees**(1, 2); *Read the current degree count value of encoder 2 (ENC2 port).*
Reset Each Encoder Resets the encoder count accumulator to 0.	**resetEncoder**(ID#, enc#); Data Type: *ID#* = integer *enc#* = integer Data Range: *enc#* = 1 or 2	**resetEncoder**(1, 1); *Reset the encoder 1 count to 0.* **resetEncoder**(1, 2); *Reset the encoder 2 count to 0.*
Reset Both Encoders (1 and 2) Resets encoder 1 and encoder 2 count accumulators to 0.	**resetEncoders**(ID#); Data Type: *ID#* = integer	**resetEncoders**(1); *Reset the encoder 1 count to 0 and encoder 2 count to 0.*

Description	Function	Coding Example (for controller ID = 1)
Read Battery Pack Voltage Reads the voltage of the TETRIX battery pack powering the controller. The value read is an integer.	**readBatteryVoltage**(ID#); Data Type: *ID#* = integer Data Type Returned: *value* = integer	**readBatteryVoltage**(1); *Read the voltage of the TETRIX battery pack powering the controller.* *Example: A value of 918 equals 9.18 volts.*
Set Speed PID Algorithm Coefficients Sets the P, I, and D coefficients for constant speed control.	**setMotorSpeedPID**(ID#, P, I, D); Data Type: *ID#, P, I, D* = integer	**setMotorSpeedPID**(1, 1500, 2500, 8); *Set the PID coefficients of the constant speed algorithm.* *P = 1.5, I = 2.5, D = .008* ***Note:** Controller firmware divides each coefficient by 1,000.*
Set Target Position PID Algorithm Coefficients Sets the P, I, and D coefficients for target hold position control.	**setMotorTargetPID**(ID#, P, I, D); Data Type: *ID#, P, I, D* = integer	**setMotorTargetPID**(1, 1500, 0, 5); *Set the PID coefficients of the constant speed algorithm.* *P = 1.5, I = 0, D = .005* ***Note:** Controller firmware divides each coefficient by 1,000.*

In-Depth Technical Specifications

TETRIX MAX DC Motor Expansion Controller Command Register Map

Register Name	HEX Byte Command	Write Bytes	Read Bytes	R/W Assembled Data Type	Description
DC_Firmware	0x26	0	1	unsigned	Returns the firmware version.
Set_EXP_ID	0x24	1	0	unsigned	Sets/changes the i2C address/ID of the motor controller.
Battery_Voltage	0x53	0	2	unsigned	Returns the battery voltage.
WDT_STOP	0x23	0	0	none	Forces a watchdog timer reset/restart of the motor controller processor.
Controller_Enable	0x25	0	0	none	Enables the motor controller.
Controller_Reset	0x27	0	0	none	Signals an internal firmware reset.
Motor1_Power	0x40	1	0	signed	Sets the power level for Motor 1.
Motor2_Power	0x41	1	0	signed	Sets the power level for Motor 2.
Motor_Powers	0x42	2	0	signed	Sets the power levels for Motor 1 and Motor 2.
Motor1_Speed	0x43	2	0	signed	Sets the speed parameter for Motor 1 in degrees per second.
Motor2_Speed	0x44	2	0	signed	Sets the speed parameter for Motor 2 in degrees per second.
Motor_Speeds	0x45	4	0	signed	Sets the speed parameters for Motor 1 and Motor 2 in degrees per second.
Motor1_Target	0x46	6	0	signed	Sets the encoder count target parameter for Motor 1.
Motor2_Target	0x47	6	0	signed	Sets the encoder count target parameter for Motor 2.
Motor_Targets	0x48	12	0	signed	Sets the encoder count target parameters for Motor 1 and Motor 2.
Motor1_Degree	0x58	6	0	signed	Sets the encoder degree target parameter for Motor 1.
Motor2_Degree	0x59	6	0	signed	Sets the encoder degree target parameter for Motor 2.
Motor_Degrees	0x5A	12	0	signed	Sets the encoder degree target parameters for Motor 1 and Motor 2.
Motor1_Invert	0x51	1	0	unsigned	Sets the invert direction condition for Motor 1.
Motor2_Invert	0x52	1	0	unsigned	Sets the invert direction condition for Motor 2.
Motor1_Busy	0x4F	0	1	unsigned	Returns the busy status of Motor 1.
Motor2_Busy	0x50	0	1	unsigned	Returns the busy status of Motor 2.
Motor1_Current	0x54	0	2	unsigned	Returns the Motor 1 load current in milliamps.
Motor2_Current	0x55	0	2	unsigned	Returns the Motor 2 load current in milliamps.
Encoder1_Count	0x49	0	4	signed	Returns the Motor 1 encoder count.
Encoder2_Count	0x4A	0	4	signed	Returns the Motor 2 encoder count.
Encoder1_ Degrees	0x5B	0	4	signed	Returns the Motor 1 encoder position in degrees.
Encoder2_ Degrees	0x5C	0	4	signed	Returns the Motor 2 encoder position in degrees.
Reset_Encoder1	0x4C	0	0	none	Resets encoder 1 count to 0.
Reset_Encoder2	0x4D	0	0	none	Resets encoder 2 count to 0.
Reset_Encoders	0x4E	0	0	none	Resets encoder 1 and encoder 2 to 0.
Speed_PID	0x56	6	0	unsigned	Sets the P, I, and D coefficients of the constant speed algorithm.
Target_PID	0x57	6	0	unsigned	Sets the P, I, and D coefficients of the target hold position algorithm.

Command Register Functions Descriptions

DC_Firmware: Sending the command byte 0x26 returns the motor controller firmware version. The value returned is an unsigned byte.

Set_EXP_ID: Sending the command byte 0x24 followed by an ID byte causes the DC motor expansion controller to change its i2C address/ID to the value of the ID byte sent. The PRIZM Arduino Library supports up to four controllers in a daisy chain arrangement with IDs ranging from 1 to 4. By default, the DC motor controller ships with the ID set to 1. Additional daisy-chained DC motor controllers must be set to a different ID. See the example sketches in the TETRIX PRIZM Arduino Library examples folder for setting controller IDs. Any change to the i2C address/ID will be effective upon next power-up of the controller. IDs 0, 5, and 6 may not be used. **Important:** When calling this function, only the expansion controller that is being changed can be connected to the PRIZM controller. No other i2C devices may be connected to PRIZM's expansion port.

Battery_Voltage: Sending the command byte 0x53 will return two bytes that when assembled into a 16-bit integer value represent the battery voltage. Actual voltage is the returned value divided by 100. The first byte is the High byte and the second byte is the Low byte.

WDT_STOP: Sending the command byte 0x23 forces a watchdog timer reset condition of the DC motor controller's internal processor. When the command is received, the controller will reset after a 15 ms time-out period. When triggered, all motor and encoder parameters will be set to their default power-up values.

Controller_Enable: Sending the command byte 0x25 enables the operation of the DC motor controller. The motor controller must receive an enable command after power-up or a reset in order to receive and execute motor commands. The enable command is automatically sent by the PrizmBegin function in the PRIZM Arduino Library.

Controller_Reset: Sending the command byte 0x27 signals a firmware reset. All motor channels will be set to 0% power level and all encoder values reset to 0. A Controller_Enable command will re-enable all channels.

Motor1_Power: Sending the command byte 0x40 puts motor channel 1 in power only mode. The power level data byte sets the power level percentage of motor channel 1. The motor power level parameter is a signed byte ranging from -100 to 100. Any negative values will run the motor in the reverse direction. A value of 0 will stop the motor in coast mode. A value of 125 will stop the motor in brake mode.

Motor2_Power: Sending the command byte 0x41 puts motor channel 2 in power only mode. The power level data byte sets the power level percentage of motor channel 2. The motor power level parameter is a signed byte ranging from -100 to 100. Any negative values will run the motor in the reverse direction. A value of 0 will stop the motor in coast mode. A value of 125 will stop the motor in brake mode.

Motor_Powers: Sending the command byte 0x42 puts both motor channels in power only mode. Two power level data bytes set the power level percentage of Motor 1 and Motor 2. Byte 1 sets the power level parameter for Motor 1. Byte 2 sets the power level parameter for Motor 2. The motor power level parameter is a signed byte ranging from -100 to 100. Any negative values will run the motor in the reverse direction. A value of 0 will stop the motor in coast mode. A value of 125 will stop the motor in brake mode.

Motor1_Speed: Sending the command byte 0x43 puts the motor channel 1 in constant speed mode. Two data bytes set the speed parameter in units of degrees per second (DPS) for motor channel 1. The first byte is the High byte and the second is the Low byte. The motor controller firmware will assemble the two bytes into a 16-bit signed integer with a range of -32,768 to 32,767. Motor 1 will run at the set speed value in constant speed mode. The speed is governed by a PID algorithm using encoder input data. Any negative speed values will run the motor in the reverse direction.

Motor2_Speed: Sending the command byte 0x44 puts motor channel 2 in constant speed mode. Two data bytes set the speed parameter in units of degrees per second (DPS) for motor channel 2. The first byte is the High byte and the second is the Low byte. The motor controller firmware will assemble the two bytes into a 16-bit signed integer with a range of -32,768 to 32,767. Motor 2 will run at the set speed value in constant speed mode. The speed is governed by a PID algorithm using encoder input data. Any negative speed values will run the motor in the reverse direction.

Motor_Speeds: Sending the command byte 0x45 puts both motor channels in constant speed mode. Four data bytes set the speed parameter in units of degrees per second (DPS) for Motor 1 and Motor 2 simultaneously. The first and second bytes are the High and Low bytes for the Motor 1 speed parameter. The third and fourth bytes are the High and Low bytes for the Motor 2 speed parameter. The motor controller firmware will assemble the first and second bytes into a 16-bit signed integer representing the Motor 1 speed parameter. The third and fourth bytes will be assembled into a 16-bit signed integer representing the Motor 2 speed parameter. Each speed parameter range is -32,768 to 32,767. Both Motors 1 and 2 will run at the set speed values in constant speed mode. The speed is governed by a PID algorithm using encoder input data. Any negative speed values will run the motor in the reverse direction.

Motor1_Target: Sending the command byte 0x46 puts motor channel 1 in encoder count targeting mode. Six data bytes set the speed and encoder target value for motor channel 1. The first two data bytes represent the speed parameter in degrees per second. The last four data bytes represent the encoder 1 target count value. The motor controller firmware will assemble the first and second bytes into a 16-bit signed integer representing the Motor 1 speed parameter with the first byte being the High byte. Each speed parameter range is -32,768 to 32,767. The last four bytes represent the encoder 1 target value, which gets assembled into a 64-bit signed long integer with the High byte transmitted first. Each encoder target value range is -2,147,483,648 to 2,147,483,647. Negative speed values will be ignored. Motor 1 will run at the set values governed by a PID algorithm at a constant speed until the encoder target is reached and then hold position in a servo-like mode.

Motor2_Target: Sending the command byte 0x47 puts motor channel 2 in encoder count targeting mode. Six data bytes set the speed and encoder target value for motor channel 2. The first two data bytes represent the speed parameter in degrees per second. The last four data bytes represent the encoder 2 target count value. The motor controller firmware will assemble the first and second bytes into a 16-bit signed integer representing the Motor 2 speed parameter with the first byte being the High byte. Each speed parameter range is -32,768 to 32,767. The last four bytes represent the encoder 2 target value, which gets assembled into a 64-bit signed long integer with the High byte transmitted first. Each encoder target value range is -2,147,483,648 to 2,147,483,647. Negative speed values will be ignored. Motor 2 will run at the set values governed by a PID algorithm at a constant speed until the encoder target is reached and then hold position in a servo-like mode.

Motor_Targets: Sending the command byte 0x48 puts both motor channels in encoder count targeting mode. Twelve data bytes set the speed and encoder target values for Motor 1 and Motor 2 simultaneously. Bytes 1 and 2 represent the speed parameter in degrees per second for Motor 1. Bytes 3, 4, 5, and 6 represent the encoder 1 target count value. Bytes 7 and 8 represent the speed parameter in degrees per second for Motor 2. The remaining four data bytes represent the encoder 2 target count value. All value parameters are transmitted with the High byte first. The motor controller firmware will assemble the speed value parameters for Motor 1 and 2 into two 16-bit signed integers. Each speed parameter range is -32,768 to 32,767. The target value parameters are each four bytes long, which the firmware will assemble into two 64-bit signed long integers each with the High byte transmitted first. Each encoder target value range is -2,147,483,648 to 2,147,483,647. Negative speed values will be ignored. Motors 1 and 2 will run at the set values governed by a PID algorithm at a constant speed until the encoder target is reached and then hold position in a servo-like mode.

Motor1_Degree: Sending the command byte 0x58 puts motor channel 1 in encoder degrees targeting mode. Six data bytes set the speed and encoder target in degrees of rotation for motor channel 1. The first two data bytes represent the speed parameter in degrees per second. The last four data bytes represent the encoder 1 target degree value. The motor controller firmware will assemble the first and second bytes into a 16-bit signed integer representing the Motor 1 speed parameter with the first byte being the High byte. Each speed parameter range is -32,768 to 32,767. The last four bytes represent the encoder 1 target degree value, which gets assembled into a 64-bit signed long integer with the High byte transmitted first. Each encoder target degree value range is -536,870,912 to 536,870,911. Negative speed values will be ignored. Motor 1 will run at the set values governed by a PID algorithm at a constant speed until the encoder degree target is reached and then hold position in a servo-like mode.

Motor2_Degree: Sending the command byte 0x59 puts motor channel 2 in encoder degrees targeting mode. Six data bytes set the speed and encoder target in degrees of rotation for motor channel 2. The first two data bytes represent the speed parameter in degrees per second. The last four data bytes represent the encoder 2 target degree value. The motor controller firmware will assemble the first and second bytes into a 16-bit signed integer representing the Motor 2 speed parameter with the first byte being the High byte. Each speed parameter range is -32,768 to 32,767. The last four bytes represent the encoder 2 target degree value, which gets assembled into a 64-bit signed long integer with the High byte transmitted first. Each encoder target degree value range is -536,870,912 to 536,870,911. Negative speed values will be ignored. Motor 2 will run at the set values governed by a PID algorithm at a constant speed until the encoder degree target is reached and then hold position in a servo-like mode.

Motor_Degrees: Sending the command byte 0x5A puts both motor channels in encoder degrees targeting mode. Twelve data bytes set the speed and encoder degree target values for Motor 1 and Motor 2 simultaneously. Bytes 1 and 2 represent the speed parameter in degrees per second for Motor 1. Bytes 3, 4, 5, and 6 represent the encoder 1 target degree value. Bytes 7 and 8 represent the speed parameter in degrees per second for Motor 2. The remaining four data bytes represent the encoder 2 target degree value. All value parameters are transmitted with the High byte first. The motor controller firmware will assemble the speed value parameters for Motors 1 and 2 into two 16-bit signed integers. Each speed parameter range is -32,768 to 32,767. The target degree value parameters are each four bytes long, which the firmware will assemble into two 64-bit signed long integers each with the High byte transmitted first. Each encoder target degree value range is -536,870,912 to 536,870,911. Negative speed values will be ignored. Motors 1 and 2 will run at the set values governed by a PID algorithm at a constant speed until the encoder degree target is reached and then hold position in a servo-like mode.

Motor1_Invert: Sending the command byte 0x51 followed by one data byte will set the invert forward/reverse mode for Motor 1. Setting the data byte to 1 will set motor channel 1 to invert mode. Setting the data byte to 0 will set motor channel 1 to non-invert mode. By default, all motor channels are set to non-invert mode on power-up.

Motor2_Invert: Sending the command byte 0x52 followed by one data byte will set the invert forward/reverse mode for Motor 2. Setting the data byte to 1 will set motor channel 2 to invert mode. Setting the data byte to 0 will set motor channel 2 to non-invert mode. By default, all motor channels are set to non-invert mode on power-up.

Motor1_Busy: Sending the command byte 0x4F will return the busy status of motor channel 1. A value of 1 will be returned when the motor is in the process of moving to a command encoder value target under PID control. When the motor has reached its target, the busy status value will be set to 0.

Motor2_Busy: Sending the command byte 0x50 will return the busy status of motor channel 2. A value of 1 will be returned when the motor is in the process of moving to a command encoder value target under PID control. When the motor has reached its target, the busy status value will be set to 0.

Motor1_Current: Sending the command byte 0x54 will return two data bytes that represent the load current of motor channel 1. The first data byte is the High byte and the second byte is the Low byte. The motor controller firmware will assemble the two data bytes into a 16-bit unsigned integer that represents the motor load current in milliamps.

Motor2_Current: Sending the command byte 0x55 will return two data bytes that represent the load current of motor channel 2. The first data byte is the High byte and the second byte is the Low byte. The motor controller firmware will assemble the two data bytes into a 16-bit unsigned integer that represents the motor load current in milliamps.

Encoder1_Count: Sending the command byte 0x49 will return four data bytes that represent the current encoder count with the first being the High byte. The motor controller firmware will assemble the four data bytes into a signed 64-bit long integer representing the encoder count. The value range is -2,147,483,648 to 2,147,483,647.

Encoder2_Count: Sending the command byte 0x4A will return four data bytes that represent the current encoder count with the first being the High byte. The motor controller firmware will assemble the four data bytes into a signed 64-bit long integer representing the encoder count. The value range is -2,147,483,648 to 2,147,483,647.

Encoder1_Degrees: Sending the command byte 0x5B will return four data bytes that represent the current encoder degree position value with the first being the High byte. The motor controller firmware will assemble the four data bytes into a signed 64-bit long integer representing the encoder count. The value range is -536,870,912 to 536,870,911.

Encoder2_Degrees: Sending the command byte 0x5C will return four data bytes that represent the current encoder degree position value with the first being the High byte. The motor controller firmware will assemble the four data bytes into a signed 64-bit long integer representing the encoder count. The value range is -536,870,912 to 536,870,911.

Reset_Encoder1: Sending the command byte 0x4C resets the encoder 1 value to 0.

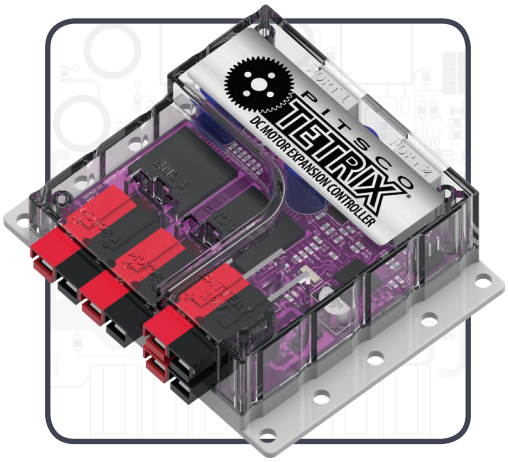
Reset_Encoder2: Sending the command byte 0x4D resets the encoder 2 value to 0.

Reset_Encoders: Sending the command byte 0x4E resets the encoder 1 and encoder 2 values to 0.

Speed_PID: Sending the command byte 0x56 followed by six data bytes will set the P, I, and D coefficients used by the constant speed control algorithm. The controller's internal firmware uses PID algorithm to accurately control the speed and position of a DC motor equipped with an encoder. The first two data bytes represent the P coefficient, the next two are the I coefficient, and the last two are the D coefficient. The firmware divides each coefficient by 1,000. For example, to set the P coefficient to 1.5, you would write 1500. By default, the PID coefficients are tuned for the TETRIX TorqueNADO motors, and it is recommended they not be changed. The default firmware settings are P = 1.5, I = 2.5, and D = .008. Any changes made will be lost when the controller is powered down. **Caution:** Changes to the PID coefficients might cause damage to motors and/or mechanisms.

Target_PID: Sending the command byte 0x57 followed by six data bytes will set the P, I, and D coefficients used by the targeting position control algorithm. The controller's internal firmware uses PID algorithm to accurately control the speed and position of a DC motor equipped with an encoder. The first two data bytes represent the P coefficient, the next two are the I coefficient, and the last two are the D coefficient. The firmware divides each coefficient by 1,000. For example, to set the P coefficient to 1.5, you would write 1500. By default, the PID coefficients are tuned for the TETRIX TorqueNADO motors, and it is recommended they not be changed. The default firmware settings are P = 1.5, I = 0, and D = .005. Any changes made will be lost when the controller is powered down. **Caution:** Changes to the PID coefficients might cause damage to motors and/or mechanisms.

TETRIX® DC Motor Expansion Controller Technical Guide



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