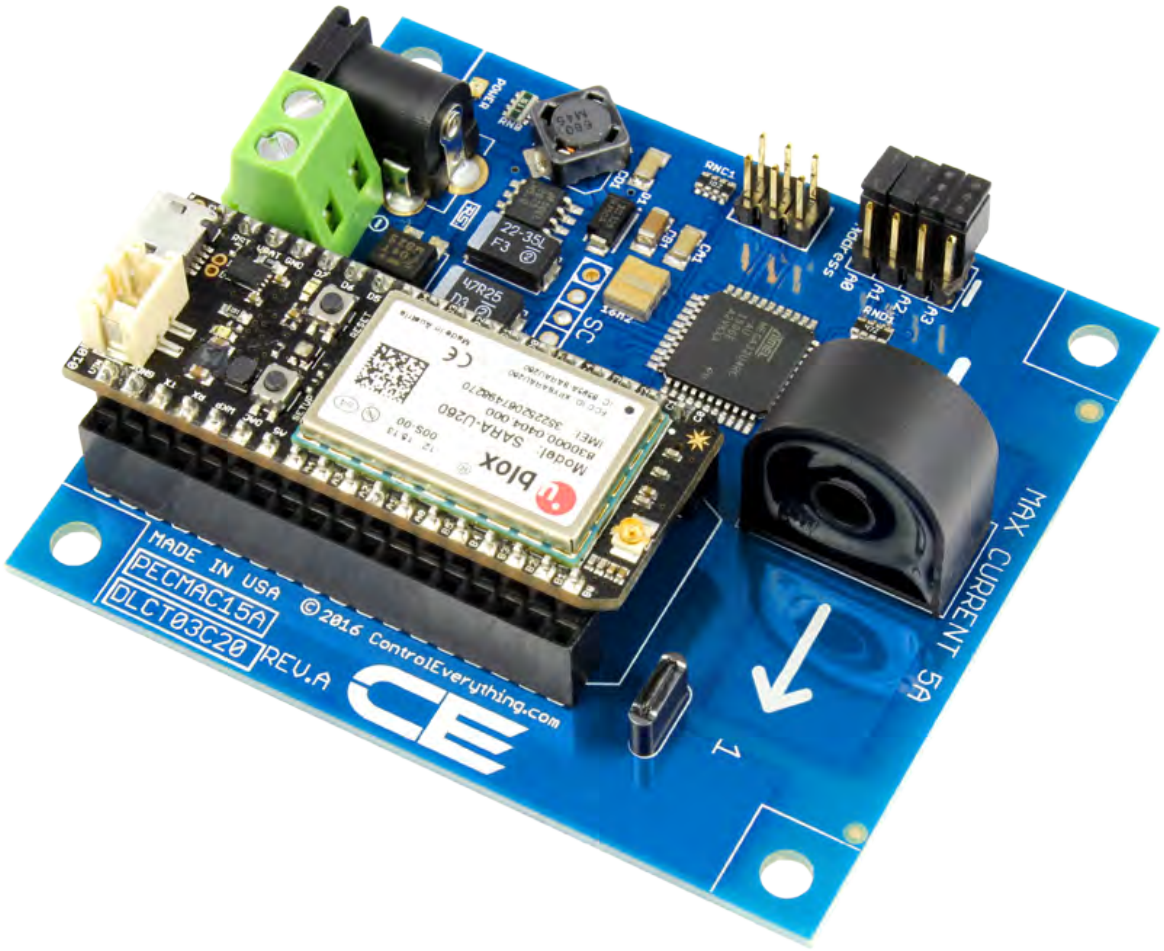
Current Monitoring Controllers

Command Reference Guide



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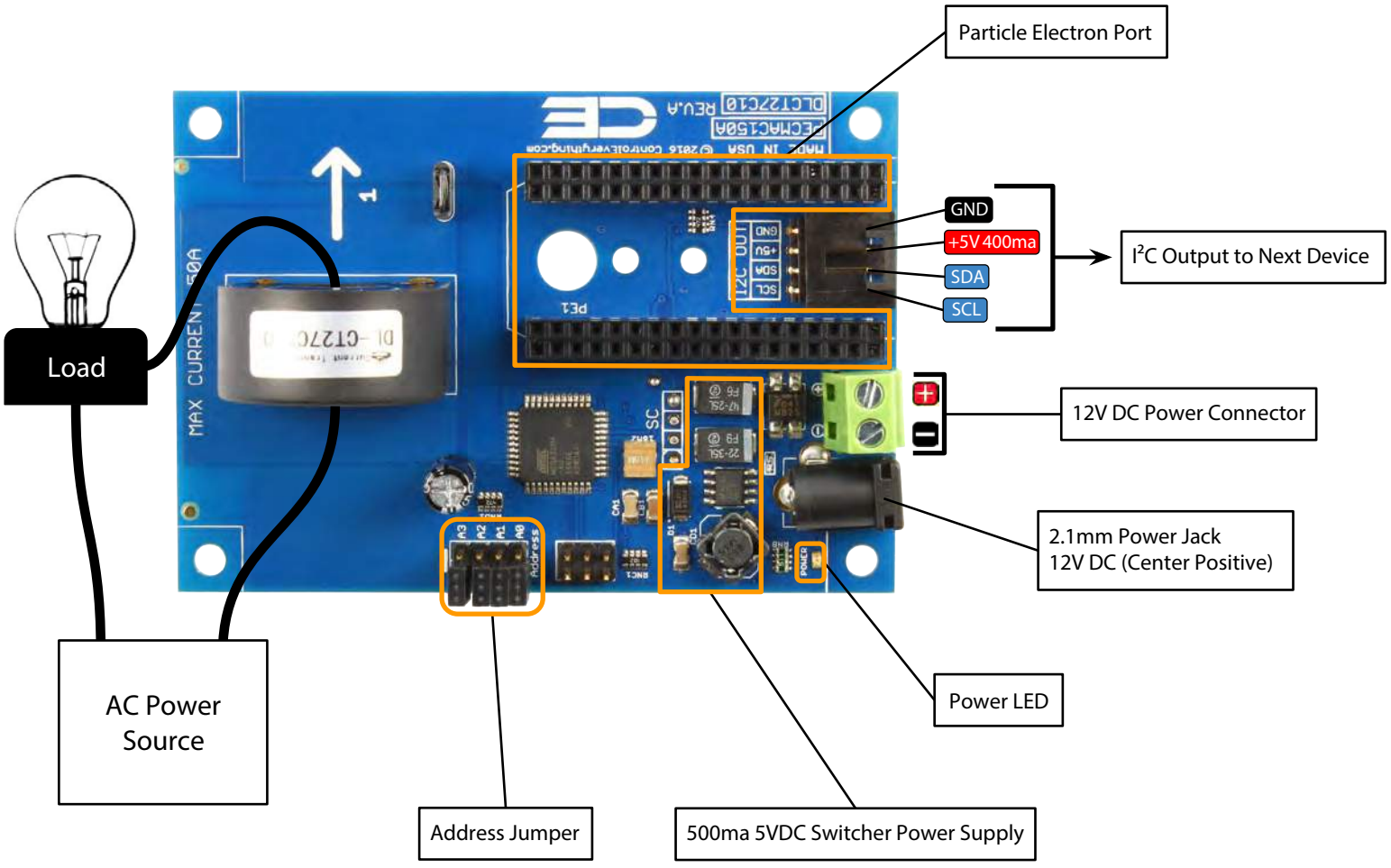
ControlEverything.com current monitoring controllers provide an easy cross-platform solution for communicating current monitoring data for a wide variety of energy management solutions. We developed a custom CPU that handles the difficult task of current measurement, all you have to do is communicate a simple set of I^2C commands to ask the controller the amperage draw across each channel. This guide was developed to help you understand the I^2C commands implemented by our extensive line of current monitoring devices.

Getting Started:

Before getting started, we wanted to share a few important points about this series of controllers.

1) We post our Sample Code on the ControlEverythingCom GitHub repository page. Sample code should be referenced when reading this manual. We have developed code for Arduino, Particle Photon, Particle Electron, and the PC. Sample code shows specific information for I^2C implementation.
2) Current monitoring controllers require a minimum of 100ma to operate properly.
3) A 12VDC power supply is required to power the current monitoring controller.
4) Only a single wire may passed through the core sensor. Passing more than a single wire will invalidate the data for the associated channel.
5) Current Monitoring controllers spend 1/2 second evaluating each channel. Data returned to the user may be up to 6 seconds old when monitoring current on 12-Channel controllers.
6) We think you will be very pleased with the accuracy of our sensors. We have been very conservative in our advertised values. We think you will find our controllers to be significantly more accurate than most commercially available clamp meters. However, our test equipment is limited to 20 Amps, therefore, higher current controllers have only been tested and calibrated up to 20 Amps. User calibration beyond 20 Amps may be necessary.



IMPORTANT USAGE WARNINGS:

This Current Monitoring Device is for use in AC Circuits Only.
The Maximum Current Rating Printed on the Circuit Board
Must be Followed or Damage to the CPU May Occur.

Up to 16 current monitoring devices can share a single I²C data bus. You can easily mix our entire range of 5A to 100A current monitoring controllers in any combination across a single I²C bus. A set of 4 jumpers, labeled A0, A1, A2, and A3 define the I²C Start Address of Each Device. Please See the Table Below to determine the I²C Start Address of your Current Monitoring Controller:

Start Address	A0 Jumper	A1 Jumper	A2 Jumper	A3 Jumper
0x2A	Removed	Removed	Removed	Removed
0x2B	Installed	Removed	Removed	Removed
0x2C	Removed	Installed	Removed	Removed
0x2D	Installed	Installed	Removed	Removed
0x2E	Removed	Removed	Installed	Removed
0x2F	Installed	Removed	Installed	Removed
0x30	Removed	Installed	Installed	Removed
0x31	Installed	Installed	Installed	Removed
0x32	Removed	Removed	Removed	Installed
0x33	Installed	Removed	Removed	Installed
0x33	Removed	Installed	Removed	Installed
0x34	Installed	Installed	Removed	Installed
0x35	Removed	Removed	Installed	Installed
0x36	Installed	Removed	Installed	Installed
0x37	Removed	Installed	Installed	Installed
0x38	Installed	Installed	Installed	Installed

NOTE: We will use the I²C Start Address of 0x2A in all examples shown in this manual.

Communications:

ControlEverything.com current monitoring devices support 4 commands. We have provided samples demonstrating communications in multiple languages, greatly simplifying development. All of our software samples begin with an I^2C Start Address, and end with a valid checksum. All 4 commands are 8 bytes in length. All current monitoring controllers will ignore commands with an invalid checksum. Similarly, data is returned to the I^2C Master with a valid checksum.

Our sample software will compute a checksum and compare it to the received checksum. Current monitoring is considered a high-noise application, it is our company policy to provide complete checksum based communications in all custom firmware to help reduce the chances of errant data communications. Our software samples should be consulted as the primary programming resource, as they provide complete working samples for 2-way communications with checksum validation. This guide should be used to help supplement the program examples we have provided.

Current data is represented using 24-bits (3 bytes) at 1ma resolution (the least significant bit = 1ma). Computing the current data is very easy: (MSB x 65536) + (MSB2 x 256) + LSB = Milliamps. So if the result value is 32,338, the total current draw is 32 amps and 338 ma. Despite this seemingly high resolution, the actual value is usually within 5% or 3% (depending on controller model), which is more accurate than most commercial clamp meters we have tested. Further calibration can yield more accurate results (some of our testing has yielded an accuracy within 10ma of actual), we have pre-calibrated all controllers to match our master designs, we do not calibrate each controller individually.

Crosstalk (or channel bleed) does occur at higher amperages (20A and higher). Typically, the higher the current, the more crosstalk between signals. Crosstalk can account for a significant portion of the total error per channel. However, the crosstalk errors introduced

are typically insignificant when compared to the errors displayed by most commercial clamp meters we have tested. We typically test our controllers up to 20A unless otherwise noted. Any controllers rated for higher currents have not been validated for accuracy, and may require further calibration. Duration testing of several weeks has been performed on our controllers. There tends to be very little drift over time, making our current monitoring series controllers ideal for long-term energy management applications.

Matching Controllers to Current

Every current sensing controller we manufacture is pre-calibrated to measure current over a specified range. For instance, a 20A controller is designed to measure a current over a range of 0 to 20A, but it can measure slightly higher currents to account for over-current conditions. Exceeding the Max current by more than 25% can cause damage to the CPU. For instance, exceeding 20A + 25% (25A) can cause permanent damage to the CPU. This is true of all current monitoring controllers we offer. Please note that we have a 25% safety margin designed into all of our controllers.

Because each controller is pre-tuned for a particular amperage range, we highly recommend using a controller that meets, but does not exceed your amperage range. For instance, if you need to measure current on a 20A circuit, using a 30A controller is not advised. The correct match would be a 20A controller. Never over-rate your controller, doing so will cause an unnecessary loss of resolution across the intended tuning range.

Command Summary:

Command 1: Reading Current
Command 2: Reading Device Information
Command 3: Reading Calibration Values
Command 4: Writing Calibration Values

Command 1: Reading Current

ControlEverything.com current monitoring controllers are constantly monitoring current. Our custom current monitoring CPU examines each channel and computes a current reading and stores this reading in a buffer. When current data is requested, the CPU instantly pulls the latest reading from the buffer and returns it to the I^2C Master device. Current Monitoring controllers require 1/2 second to evaluate each channel. One-channel controllers refresh current readings every half second. Twelve-channel controllers refresh current readings every 6 seconds. These delays do not affect communication in any way; however, current readings could be up to 6 seconds old by the time they are communicated to the Master I^2C controller.

The following section explains each byte of Command 1, followed by a sample implementation.

Byte 1: 0x2A I^2C Start Address

The I^2C Start Address is determined by jumpers A0-A3 on the circuit board. Please see the "Addressing" table earlier in this guide.

Byte 2 and 3: Header Bytes

The header bytes are used to identify current monitoring controllers, these bytes are fixed and cannot be changed. These bytes are specific to the current monitoring series of controllers, but have no other purpose.

Byte 4: Command 1: Read Current

This byte 0x01 calls command 1 for reading the current from the controllers.

Bytes 5 & 6: Channel Range
Bytes 5 and 6 of this command indicate the range of channel numbers you would like to read. Valid decimal values are 1 to 12 (0x0 to 0xC) for these parameters. Here are a few examples to show the proper use of bytes 5 and 6:

Read Channel 1 Only:
Byte 5: 1
Byte 6: 1
3 Bytes + Checksum will be Returned

Read Channels 1 through 12:
Byte 5: 1
Byte 6: 12
36 Bytes + Checksum will be Returned

Read Channels 11 and 12 Only:
Byte 5: 11
Byte 12: 12
6 Bytes + Checksum will be Returned

Byte 7: Reserved, Always Use 0

Byte 8: Reserved, Always Use 0

Byte 9: Checksum Calculation (See Below)

Checksum Calculation:

Checksum calculation is very easy. If you are working with a Micro-controller, Checksum should be defined as a Byte, (avoid word or integer definitions). By defining the Checksum value as a Byte, data is automatically rolled over and truncated to the 8 least significant bits. Checksum is a very easy calculation: It is the 8-Bit sum of Bytes 2-8, Byte 1 is omitted from the Checksum Calculation.

Example:

Byte 1: 0x2A = 42 Decimal I^2C Start Address
Byte 2: 0x92 = 146 Decimal Header Byte 1
Byte 3: 0x6A = 106 Decimal Header Byte 2
Byte 4: 0x1 = 1 Decimal Command Number 1: Read Current
Byte 5: 0x1 = 1 Decimal Start Channel Number
Byte 6: 0xC = 12 Decimal Stop Channel Number
Byte 7: 0x0 = 0 Decimal Reserved Byte
Byte 8: 0x0 = 0 Decimal Reserved Byte
Byte 9: 0xA Checksum (Least Sig. Byte, Sum of Bytes 2 to 8)

Note: Byte 1 is NOT Included in the Checksum Calculation
146+106+1+1+12+0+0 = 266 Decimal
The 16-Bit Value of 266 in Binary Looks Like this:
MSB:00000001:00001010:LSB
The Least Significant Byte of 266 = 00001010 = 10 (Decimal)
10 Converted to Hexadecimal = 0xA
Byte 9: 0xA (or 10 if you prefer decimal values)

Note: This page represents our standard method of calculating checksums for data transmission and reception. When receiving data, the number of bytes received will change, but the checksum calculations remain the same for all communications. The first byte of a received packet will always be included in the checksum calculation.

Receiving Data from Command 1:
Command 1 always returns 3 Bytes per Channel in consecutive ascending order, one additional byte is also included indicating the 8-bit checksum of all bytes sent. In the sample above, 36 Bytes (+ 1 Checksum) would be returned. The return data will look like this:

0x01,0x00,0x05,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,
0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,
0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,
0x00,0x00,0x00,0x06

Let's break these data into pieces and identify each segment:
0x01,0x00,0x05, Channel 1: MSB,MSB2,LSB
0x00,0x00,0x00, Channel 2: MSB,MSB2,LSB
0x00,0x00,0x00, Channel 3: MSB,MSB2,LSB
0x00,0x00,0x00, Channel 4: MSB,MSB2,LSB
0x00,0x00,0x00, Channel 5: MSB,MSB2,LSB
0x00,0x00,0x00, Channel 6: MSB,MSB2,LSB
0x00,0x00,0x00, Channel 7: MSB,MSB2,LSB
0x00,0x00,0x00, Channel 8: MSB,MSB2,LSB
0x00,0x00,0x00, Channel 9: MSB,MSB2,LSB
0x00,0x00,0x00, Channel 10: MSB,MSB2,LSB
0x00,0x00,0x00, Channel 11: MSB,MSB2,LSB
0x00,0x00,0x00, Channel 12: MSB,MSB2,LSB
0x06 Checksum

Calculating Current:
Calculating current values for each channel is very easy:
Current = (MSB * 65536) + (MSB2 * 256) + LSB
Current = (1*65536) + (0*256) + 5
Current = 65,541mA = 65 Amps 541ma for Channel 1

Current calculations should be discarded if the received checksum value does not equal the 8-bit sum of bytes for the first 12 channels.

Command 1 Sample 2:
In this sample, we will demonstrate a 1 channel request using all decimal values:

Send Bytes: 42, 146, 106, 1, 1, 1,0,0, 255

42	I^2C Start Address
146	Header Byte 1
106	Header Byte 2
1	Command Number
1	Start Channel
1	End Channel
0	Reserved Byte
0	Reserved Byte
255	Checksum (146+106+1+1+1+0+0 = 255)

Receive Bytes: 0,5,112,117

0	MSB
5	MSB2
112	LSB
117	Checksum

0+5+112=117

Checksum Validation:

117 Calculated = 117 Data Received so Data Packet is Valid
If these values are not equal, data packet should be rejected

Converting to a Current Reading:

0	Current MSB
5	Current MSB2
112	Current LSB

Current = (MSB x 65536) + (MSB2 x 256) + LSB
Current = (0 x 65536) + (5 x 256) + 112
Current = 1392mA
Current = 1 Amp, 392ma

Command 1 Sample 3:
In this sample, we will read channels 1,2, and 3 using decimal values.

Send Bytes: 42, 146, 106, 1, 1, 3,0,0,2

42	I^2C Start Address
146	Header Byte 1
106	Header Byte 2
1	Command Number
1	Start Channel Number
3	End Channel Number
0	Reserved Byte
0	Reserved Byte
1	LSB of 257 = Checksum ((146+106+1+1+3+0+0=257) AND 255)

257 converted to a 8-Bit using the "And" Math function
Checksum = 257 AND 255 (Extracts Lower 8 Bits) = 1

Receive Bytes: 0,5,112,0,10,137,0,15,45,68

0	Current MSB Channel 1
5	Current MSB2 Channel 1
112	Current LSB Channel 1
0	Current MSB Channel 2
10	Current MSB2 Channel 2
137	Current LSB Channel 2
0	Current MSB Channel 3
15	Current MSB2 Channel 3
45	Current LSB Channel 3
68	Checksum

Current Channel 1 = (0 x 65536) + (5 x 256) + 112 = 1,392ma
Current Channel 2 = (0 x 65536) + (10 x 256) + 137 = 2,697ma
Current Channel 3 = (0 x 65536) + (15 x 256) + 45 = 3,885ma

Command 2: Read Device Identification Data
This command is used to identify various features of your current monitoring controller. This is a fixed command, there are no parameters for this function:

Send Bytes: 42, 146,106,2,0,0,0,0,254

42	is the I^2C start address
146	is the header byte 1
106	is the header byte 2
2	Command 2: Read Device Data
0	Reserved byte
0	Reserved byte
0	Reserved byte
0	Reserved byte
254	is the CheckSum (146+106+2+0+0+0+0=254)

Receive Bytes Sample: 1,5,1,1,0,0,8
The controller will respond with 7 bytes indicating various parameters of the controller:

1	Indicates sensor type, see last page of this guide for a complete list of supported sensors
5	Indicates the max current supported by this device, in this case the max current supported by this controller is 5A.
1	Indicates the max no of channels supported by this device, in this case the number of channels is 1; however, valid return values include 1, 2, 4, 6, 8, and 12.
1	Indicate the firmware revision, in this case the firmware revision is 1.
0	Reserved Byte
0	Reserved Byte
8	Checksum (1+5+1+1+0+0=8)

Command 3: Read Calibration Value

This command is used to retrieve the calibration values from the controller. Altering the calibration values may improve accuracy. The default values recorded into each controller are based on our master designs, as we do not calibrate each controller individually. All controllers are calibrated up to 20 Amps Max, controllers with ratings above 20 Amps may require manual calibration.

Send Bytes: 42,146,106,3,1,1,0,0,1

42	I^2C Start Address
146	Header Byte 1
106	Header Byte 2
3	Command Number 3 Reads Calibration Values
1	Start Channel Number (1-12)
1	End Channel Number (1-12)
0	Reserved Byte
0	Reserved Byte
1	Checksum (146+106+3+1+0+0=0)

Receive Bytes: 00, 155,155

Example Above Reads 3 Bytes for Channel 1. Data is returned as a 16-Bit value + Checksum

0	Current Calibration MSB Channel 1
155	Current Calibration LSB Channel 1
155	Checksum

Calibration Value = (MSB x 256) + LSB
Calibration Value = (0 x 256) + 155
Calibration Value = 155

Command 3 Example 2:
Reading the calibration value from multiple channels at one time is also very easy, this sample demonstrates how to read calibration data from channels 1, 2, and 3.

Send Bytes: 42,146,106,3,1,3,0,0,3

42	I^2C Start Address
146	Header Byte 1
106	Header Byte 2
3	Command Number 3 Reads Calibration Values
1	Start Channel Number (1-12 Valid Range)
3	End Channel Number (1-12 Valid Range)
0	Reserved Byte
0	Reserved Byte
3	CheckSum ((146+106+3+1+3+0+0) AND 255) = 3

Receive Bytes: 0, 155, 00,155,00,157,211

0	Current Calibration Value MSB Channel 1
155	Current Calibration Value LSB Channel 1
0	Current Calibration Value MSB Channel 2
155	Current Calibration Value LSB Channel 2
0	Current Calibration Value MSB Channel 3
157	Current Calibration Value LSB Channel 3
211	Checksum ((0+155+0+155+0+157) AND 255)=211

Calibration Value Channel 1 = ((0 x 256) + 155) = 155
Calibration Value Channel 2 = ((0 x 256) + 155) = 155
Calibration Value Channel 3 = ((0 x 256) + 157) = 157

Command 4: Write Calibration Data
This command is used to store current sensor calibration data. Before using this command, we strongly suggest users make only small changes to the current settings, as the settings within the controller should be very close to a usable calibration value. We do not calibrate each controller individually, the values stored in your controller are the values we use in our reference designs. In some cases, calibration at the software level should be considered, as our controllers only allow for linear calibration. Our current monitoring test equipment is limited to 20 Amps, controllers above 20 Amps may benefit from a non-linear calibration scheme, though we have been unable to validate this theory.

Note: This command is able to pass only ONE calibration value. This calibration value may be applied to one channel or a range of channels; however, this command cannot be used to store a different calibration value into each channel as a single command. If your controller requires a different calibration value for each channel, this command should be called multiple times using the same Start and End channels. No data is returned with this command.

Choosing a New Calibration Value:
As we mentioned before, the internal calibration value should be close to the actual reading. Raising the default calibration value will increase the amperage readings from the controller. Similarly, lowering the default calibration value will decrease the amperage readings from the controller.

Send Bytes: 42,146,106,4,1,1,0,150,152
This sample demonstrates the storage of calibration value of 150 into Channel Number 1:

42	I^2C Start Address
146	Header Byte 1
106	Header Byte 2
4	Command Number 4 Stores Calibration Data
1	Start Channel Number (1-12)
1	End channel number (1-12)
0	Calibration MSB Value
150	Calibration LSB Value
152	CheckSum ((146+106+4+1+1+0+150) AND 255) = 152

Send Bytes: 42,146,106,4,1,3,0,150,154
This sample demonstrates the storage of calibration value of 150 into Channel Numbers 1 through 3:

42	I^2C Start Address
146	Header Byte 1
106	Header Byte 2
4	Command Number 4 Stores Calibration Data
1	Start Channel Number (1-12)
3	End channel number (1-12)
0	Calibration MSB Value
150	Calibration LSB Value
152	CheckSum ((146+106+4+1+3+0+150) AND 255) = 154

Sensor Types:
Current monitoring controllers know exactly what sensor they are working with. When querying device information data (found earlier in this guide), the controller will return a “Type” value shown below so your software can identify the type of sensor if necessary.

Supported Sensors:	Type:
DLCT03C20	1
DLCT27C10	2
DLCT03CL20	3
OPCT16AL	4