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# User Manual for CAN Extension Module

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## Components

- 6-643 iMOD X-Series™ CAN Extension Module Kit
  - 4-832 CAN Extension Module
  - 4-835 Balance PCBA to CAN PCBA Cable Assembly (Balance Board Rev ≤3)
  - 4-887 Balance PCBA to CAN PCBA Cable Assembly (Balance Board Rev ≥4)
  - 4-837 18 pin CAN Module to Balance Cable Assembly
- 4-615 5 pin CAN Cable Assembly 360 mm (14")
- 4-616 120 Ω CAN Terminator
- 4-630 5 pin CAN Cable Assembly 910 mm (36")
- 4-889 18 pin CANEM Programming Cable Assembly
- 4-890 90° 5 pin CAN Cable Assembly 165 mm (6.5")
- 4-891 90° 5 pin CAN Cable Assembly 360 mm (14")
- 4-892 90° 5 pin CAN Cable Assembly 5 m (16'8")



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## Table of Contents

<b>Components</b> .....	<b>1</b>
<b>Warning</b> .....	<b>3</b>
<b>Overview</b> .....	<b>4</b>
<b>Technical Data</b> .....	<b>5</b>
Connector Pinout .....	5
Input Power .....	6
<b>Handling</b> .....	<b>6</b>
<b>Installation</b> .....	<b>6</b>
CAN Extension Module Installation .....	7
CAN Module Connection.....	8
<b>CAN Communication</b> .....	<b>9</b>
Host to Module Communications .....	9
Module Data Messages .....	10
Configuration Command Messages .....	12
Data Scaling .....	14
Data Scaling Accuracy .....	15
Unlock Level.....	15
<b>Firmware Update</b> .....	<b>16</b>
Processor Flashing.....	16
<b>Safety</b> .....	<b>18</b>
Discharging .....	18
<b>Maintenance</b> .....	<b>19</b>
<b>Disposal</b> .....	<b>19</b>

## Warning



**Never touch the power terminals on ultracapacitor modules as any residual voltage can cause fatal electrical shocks. Always check with a calibrated meter that the ultracapacitor module is discharged prior to handling the module. Please see the step by step instructions in this manual for the discharge procedure.**

### Warranty Limitation

**ioxus modules are unserviceable property of the customer and if opened or otherwise modified, are no longer covered by any warranty written or implied.**

## Overview

The CAN Extension Module provides a way to monitor multiple Ioxus X-series™ ultracapacitor modules on a control area network, hereafter referred to as CAN.

The CAN Extension Module provides 5 kVAC galvanic isolation between ultracapacitor modules and CAN bus.

The CAN Extension Module is powered externally from the ultracapacitor modules and does not affect the ultracapacitor module performance whether powered or not.

The CAN Extension Module is typically configured for 125 kbit/s CAN bus bit rate.

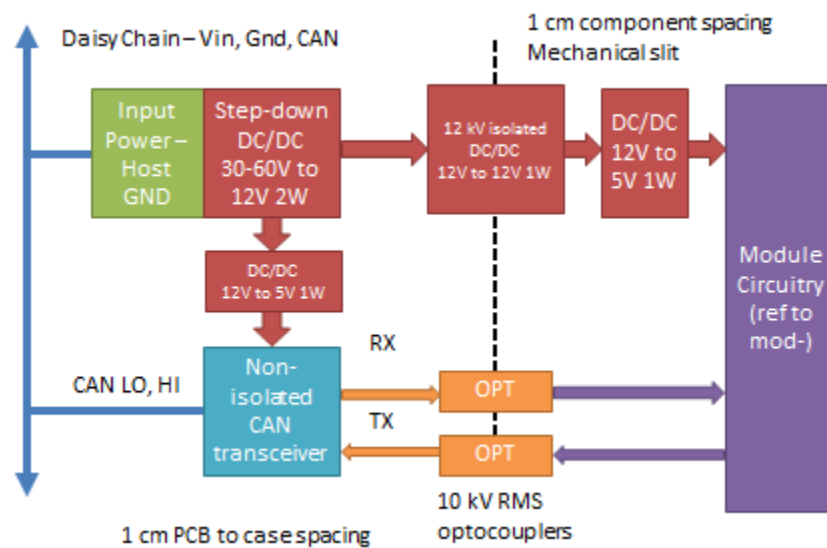


Figure 1 – Block Circuit Diagram

The CAN Extension Module contains a 2 W 24 – 60 V to 12 V step down converter to take input power supplied to the system and regulate it for smooth operation. The 12 V power is split between a 1 W 12 V to 5 V non isolated power supply for powering the CAN transceiver and a 1 W 12 V to 12 V power supply with 5 kVAC isolation to power the ultracapacitor module monitoring circuitry. Power consumption of each CAN Extension Module is typically around 1 W, although total power consumption will be higher as the number of connected modules grows, especially at the low end of the input power voltage range.

## Technical Data

### Connector Pinout



Figure 2 – Connector Pinout

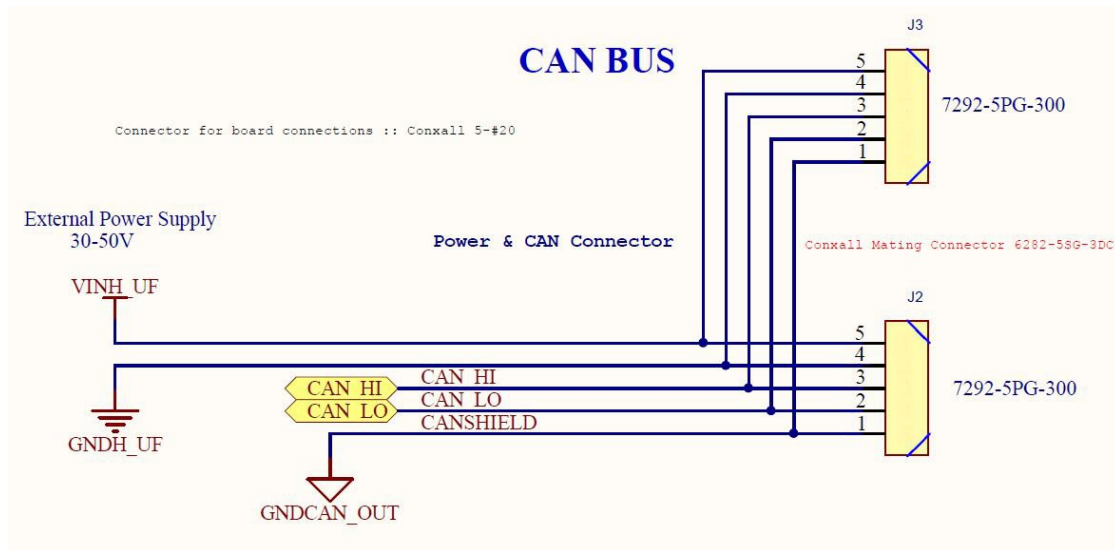


Figure 3 – Connector Pin Assignments

Pin #	Name	Note
1	CAN_SHIELD	Shielding for CAN cables, connected to host ground
2	CAN_LO	CAN - connection
3	CAN_HI	CAN + connection
4	GNDH_UF	External Power Negative Supply Voltage
5	VINH_UF	External Power Positive Supply Voltage

## Input Power

Absolute Maximum Ratings	
CAN Voltage (Pins 1, 2, 3)	20 V
Positive Voltage (Pins 4, 5)	70 V
Negative Voltage (Pins 4, 5)	70 V
Number of Series Devices	50
CAN Cable Length (20 AWG)	30 m
Supply Current (50 Devices, 24 V)	4 A

Recommended Conditions	Min	Typ	Max	
Input Voltage	24	48	60	V
Input Current (per Device)	20	30	80	mA

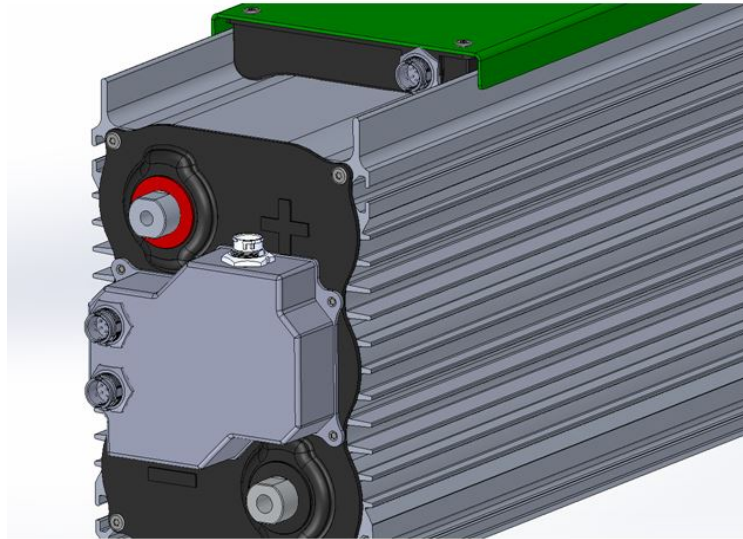
## Handling

The CAN Extension Module is an external accessory to Ioxus X-series™ ultracapacitor modules. All of the handling recommendations for Ioxus ultracapacitor modules apply to the CAN Extension Module as well. Due to the location of the CAN Extension Module, additional precautions must be taken to prevent damage to the CAN Extension Module and ultracapacitor module. The following precautions must be observed.

- The CAN Extension Module should be guarded against impacts or stresses that could damage the plastic housing
- Do not use the 4-837 18 pin CAN Module to Balance Cable as a handle or lift point as this could damage the plastic housings or connector seals and nullify the modules' ingress protection against water

## Installation

The CAN Extension Module is a field installable accessory to Ioxus X-series™ ultracapacitor modules. Customers may order 6-643 iMOD X-series™ CAN Extension Module Kits at any time to add to existing Ioxus X-series™ ultracapacitor modules. Installation should be performed by an Ioxus authorized installer to ensure continuation of ingress protection ratings.



### CAN Extension Module Installation

1. Discharge an Ioxus X-series™ ultracapacitor module following the discharge instructions in this manual.
2. Remove middle 4 screws on Ioxus X-series™ ultracapacitor module terminal plate with a T20 driver.
3. Install the provided gasket in the groove on the CAN Extension Module housing.
4. Place 4-832 CAN Extension Module on Ioxus a module terminal plate such that the 18 pin connector is oriented toward the balancing enclosure side of the module and line up the mounting holes with the 4 empty screw holes.
5. Screw down the CAN Extension Module housing with the screws removed in step 2 and torque them to 3 – 4 N·m.
6. Remove the screws from the balancing enclosure cover nearest to the CAN Extension Module with a T25 driver.
7. Remove the nylon screws retaining the balancing PCB with a PHI driver.
8. Disconnect the 2 pin thermistor connector and 5 pin OV signal connector. Use a knife blade or equivalent to pry open the locking tab on the 2 pin thermistor connector.
9. Remove the plastic retaining nut on the 4 pin I/O connector and remove the connector from balancing PCB housing.
10. Install 4-835 or 4-887 Balance PCBA to CAN PCBA Cable Assembly connector in the hole for the 4 pin I/O connector and tighten the plastic retaining nut.
11. Connect the 10 pin connector on the 4-835 or 7 and 3 pin connectors on 4-887 to the balancing PCB.
12. Cut the cable tie retaining the thermistor cable and connect the 2 pin thermistor connector to the balancing PCB.
13. Screw down the balancing PCB with the nylon screws with maximum torque < 0.5 N·m.
14. Install and screw down the balancing enclosure cover removed in step 6 and torque the screws to 3 – 4 N·m.
15. Install 4-837 18 pin CAN Module to Balance Cable Assembly between the balancing connector and CAN Extension Module connector.

### CAN Module Connection

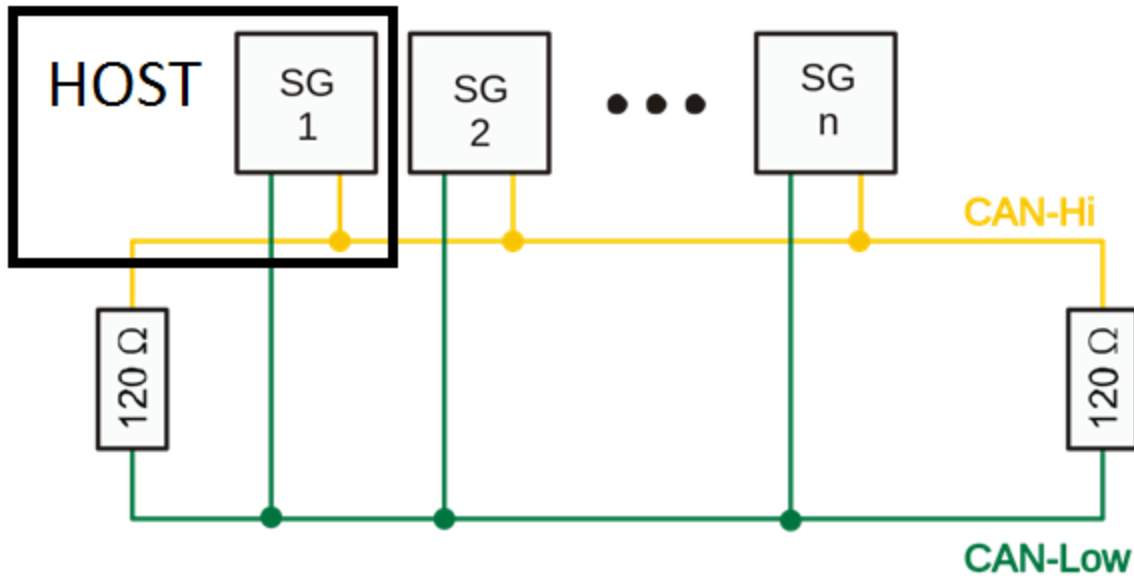


Figure 4 – CAN Bus Wiring Diagram

CAN Extension Modules can be daisy chained with 4-615 or 4-630 5 pin CAN Cable Assemblies. Two 5 pin CAN connectors are on every CAN Extension Module. The last CAN Extension Module in a daisy chain must be terminated with 4-616 120 Ω CAN Terminator and the host must also provide a 120 Ω termination at the other end of the CAN bus.

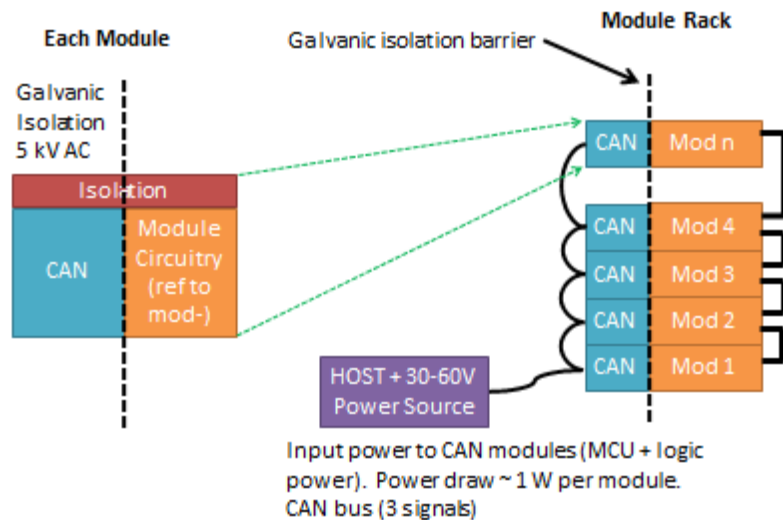


Figure 5 – Installation Block Diagram



## CAN Communication

### Host to Module Communications

The standard 11-bit CAN ID (SID) will define message flow. All CAN IDs have a 3-bit Data ID. All command messages have Data ID 0x0. The Group ID may be used to set up to 16 individual module clusters on the same CAN bus. The default Group ID is 0x1. The type of message is coded in a 4-bit Type ID.

11-bit Command Message ID:

10	9	8	7	6	5	4	3	2	1	0
Data ID			Group ID				Type ID			

Message Type IDs:

Type ID	Message Type
0x1	Module Data Response
0x2	Module Data Request
0xC	Module Configuration Command

Examples:

CAN ID – 0x012 = Requesting data from module in group 0x1

CAN ID – 0x121 = Module in group 0x2 responding with Data ID 0x1

CAN ID – 0x03C = Configuration command to module in group 0x3

The specific module to be addressed is found in the command message payload. All messages have 8 bytes.

Data request message payload (Master CAN Controller to Module Slave) CAN ID – 0x012

No.	7	6	5	4	3	2	1	0
0	Destination Module ID (0x01 to 0xFF)							
1	Command ID (0x00 to 0xFF)							
2	Reserved							
3								
4								
5								
6								
7								

Configuration message payload (Master CAN Controller to Module Slave) CAN ID – 0x01C

No.	7	6	5	4	3	2	1	0
0	Destination Module ID (0x01 to 0xFF)							
1	Command ID (0x00 to 0xFF)							
2	Command Data							
3								
4								
5								
6								
7								

## Module Data Messages

The module request Command IDs are in Byte 1 of a data request message payload.

Command ID	Data requested	Requested Data ID
0x01	Message 1	0x1
0x02	Message 2	0x2
0x03	Message 3	0x3
0x08	Voltage Taps	0x4, 0x5

### Command ID [0x01]: Get data message 1

Response payload

CAN ID – 0x111

No.	7	6	5	4	3	2	1	0
0	Module ID							
1	Command ID (LSN)				Group ID (0x0-0xF)			
2	Full Module Voltage (Voltage Tap 6)							
3								
4	Reserved						OV Alarm	OT Alarm
5	Module Temperature							
6	Tap with Highest Delta Voltage							
7	High Delta Voltage							

### Command ID [0x02]: Get data message 2

Response payload

CAN ID – 0x211

No.	7	6	5	4	3	2	1	0
0	Module ID							
1	Command ID (LSN)				Group ID (0x0-0xF)			
2	Reserved							
3	Reserved						Unlock Level	
4	Module Voltage Setting (0x10-0x80)							
5	Reserved							
6	Reserved							
7	Reserved							

### Command ID [0x03]: Get data message 3

Response payload

CAN ID – 0x311

No.	7	6	5	4	3	2	1	0
0	Module ID							
1	Command ID (LSN)				Group ID (0x0-0xF)			
2	Board Serial Number							
3	Major Firmware Revision (0x1-0xF)				Minor Firmware Revision (0x0-0xF)			
4	Reserved							
5	Reserved							
6	Reserved							
7	Reserved							

**Command ID [0x08]:** Get voltage tap data

Response payload

CAN ID – 0x411

No.	7	6	5	4	3	2	1	0
0	Module ID							
1	Command ID (LSN)				Group ID (0x0-0xF)			
2	Voltage Tap 1							
3								
4	Voltage Tap 2							
5								
6	Voltage Tap 3							
7								

Response payload

CAN ID – 0x511

No.	7	6	5	4	3	2	1	0
0	Module ID							
1	Command ID (LSN)				Group ID (0x0-0xF)			
2	Voltage Tap 4							
3								
4	Voltage Tap 5							
5								
6	Voltage Tap 6							
7								

## Configuration Command Messages

The module configuration Command IDs are in byte 1 of a configuration command message payload.

Command ID	Configures	Unlock Level
0x40	Polled/Broadcast Mode	0x0
0x41	Module ID	0x1, 0x2
0x42	Group ID	0x1, 0x2
0xC0	Measurement sample rate	0x0
0xC1	CAN baud rate	0x0
0xD0	Voltage tap scaling	0x2
0xDF	Unlock level	Any

**Command ID [0x40]:** Change periodic broadcast interval of data message 1

Command Data: New periodic interval in Byte 2

Unlock Level: 0x0

Example: CAN ID: 0x01C Data: 0xFF 40 0A 00 00 00 00 00 = Set periodic broadcast of data message 1 at 1 second intervals on all connected modules in Group ID 0x1.

Note: Sending any Command Message with Module ID 0xFF will be executed by all modules on the bus.

By default, the periodic interval is set to 0, or polled mode, with periodic data updates disabled. Sending command [0x40] with the new interval multiplier in Byte 2 will set periodic transmissions over CAN in 100 ms steps. Changes to this setting are retained if the CAN power is cycled off. Sending command [0x40] with 0x00 in byte 2 disables broadcast and returns to polled mode.

Response: CAN ID 0x1G1 messages are broadcast at the periodic interval where G is Group ID.

**Command ID [0x41]:** Change Module ID

Command Data: New module ID in Byte 2

Unlock Level: 0x1, 0x2

Example: CAN ID: 0x01C Data: 0x01 41 32 00 00 00 00 00 = Change Module ID from 0x01 to 0x32 for Module with ID 0x01 in Group ID 0x1

By default, Module ID is set to 0x01. Sending command [0x41] with the new Module ID in Byte 2 will change the module's Module ID. In order to change Module ID, the configuration unlock level has to be set to 0x1 by sending message CAN ID: 0x0GC Data: 0xMM DF D9 4B 00 00 00 00, where G is Group ID and MM is Module ID.

All CAN Extension Modules have Module ID 0x01 by default, so care has to be taken when configuring Module IDs to prevent multiple modules from receiving the same Module ID. Best practices are to set Module IDs with one module connected at a time to a CAN bus if multiple CAN Extension Modules have default software configurations. The global response Module ID 0xFF feature is disabled for setting Module IDs, so it is only possible to change a Module ID if its existing Module ID matches the value in Byte 0 of the configuration command message.

Response: New Module ID appears in Byte 0 of data messages and can be addressed in Byte 0 of command messages.

**Command ID [0x42]:** Change Group ID  
Command Data: New Group ID in Byte 2  
Unlock Level: 0x1, 0x2

Example: CAN ID: 0x01C Data: 0xFF 42 02 00 00 00 00 00 = Change all modules in Group ID 0x1 to Group ID 0x2

By default, Group ID is set to 0x1. Sending command [0x42] with the new Group ID in Byte 2 will change a module's Group ID. In order to change Group ID, the configuration unlock level has to be set to 0x1 by sending message CAN ID: 0x0GC Data: 0xMM DF D9 4B 00 00 00 00, where G is Group ID and MM is Module ID.

Response: New Group ID appears in second nibble of CAN ID for data messages and all command messages must use the new Group ID in the CAN IDs for communication.

**Command ID [0xC0]:** Change measurement sample rate  
Command Data: New periodic sample interval in Byte 2  
Unlock Level: 0x0

Example: CAN ID: 0x01C Data: 0xFF C0 02 00 00 00 00 00 = All modules in Group ID 0x1 set measurement sample interval at 100 ms.

By default, the sample rate is equal to 0 (polled) to minimize parasitic load on ultracapacitors during measurement. Samples will be taken whenever a data request messages received, however this may not be often enough to get accurate voltage tap readings. Sending command [0xC0] with the new measurement sample interval multiplier, in 50 ms steps, in Byte 2 will change the measurement sample rate.

Response: Ultracapacitor module measurements are briefly enabled at sample interval rate.

**Command ID [0xC1]:** Change CAN baud rate  
Command Data: CAN baud rate set in Byte 2  
Unlock Level: 0x0

Example: CAN ID: 0x01C Data: 0xFF C1 02 00 00 00 00 00 = All modules in Group ID 0x1 will have CAN baud rate set to 500 kbps on next power cycle.

By default, CAN bus speed is set at 125 kbps. CAN baud rate can be set at 125 kbps, 250 kbps, or 500 kbps by setting Byte 2 in command [0xC1] to 0x00, 0x01, or 0x02 respectively.

Response: CAN Extension Modules set to CAN baud rate configured in Byte 2 of Command [0xC1] the next time input power is cycled off and on.

### Data Scaling

**Command ID [0xD0]:** Configure voltage taps for module voltage

Command Data: New module voltage in Byte 2

Unlock Level: 0x2

There are six voltage taps available for monitoring on every Ioxus X-series™ ultracapacitor module. However, the X-series™ are available in a number of different voltage configurations. In order for the voltage taps to report correctly, the module voltage has to be set. By default, the voltage taps are set for 128 V modules. Follow the steps below to set the module voltage.

1. Send CAN ID 0x0GC Data: 0xMM DF EC 8A 00 00 00 00 to set unlock level 0x2
2. Send CAN ID 0x0G2 Data: 0xMM 02 00 00 00 00 00 00 to check unlocked status.
3. Send CAN ID 0x0GC Data: 0xMM D0 XX 00 00 00 00 00 where XX is the scaling code in hex.

Module Voltage	XX Code
<b>16 V</b>	0x20
<b>32 V</b>	0x30
<b>48 V</b>	0x40
<b>64 V</b>	0x60
<b>80 V</b>	0x70
<b>96 V</b>	0x80
<b>112 V</b>	0x80
<b>128 V</b>	0x80

4. Send CAN ID 0x0G2 Data: 0xMM 02 00 00 00 00 00 00 to confirm module voltage setting is correct.
5. Cycle power off to save settings.

The raw voltage tap data returned is a proportion of the full scale measurement. To convert the raw voltage tap data into useful units, scale factors will have to be applied. The scale factors are different for each module rated voltage. The chart below provides scale factors for the tap voltages in units of millivolts per count.

Module Voltage	Tap 1	Tap 2	Tap 3	Tap 4	Tap 5	Tap 6
<b>128V</b>	36.70	36.70	36.70	36.70	36.70	36.70
<b>112V</b>	36.70	36.70	36.70	36.70	36.70	36.70
<b>96V</b>	36.70	36.70	36.70	36.70	36.70	36.70
<b>80V</b>	32.70	32.70	32.70	32.70	32.70	32.70
<b>64V</b>	28.08	28.08	28.08	28.08	28.08	28.08
<b>48V</b>	24.08	24.08	24.08	24.08	24.08	24.08
<b>32V</b>	13.62	13.62	13.62	13.62	13.62	13.62
<b>16V</b>	9.62	9.62	9.62	9.62	9.62	9.62

### Data Scaling Accuracy

The voltage tap data is accurate to  $\pm 2\%$  of reading  $\pm 10$  counts. However, for measurements exceeding  $>2800$  counts the measurements become less accurate as the input voltage rises due to influence of a voltage clamp on the measurement line. This phenomenon only impacts 96V, 112V, and 128V modules for tap voltages  $>102$  V. It does not impact any other modules with the correct voltage scale settings.

### Unlock Level

**Command ID [0xDF]:** Change Unlock Level

Command Data: Password set in Bytes 2 & 3

Unlock Level: Any

Example: CAN ID: 0x01C Data: 0x01 DF D9 4B 00 00 00 00 = Module ID 0x01 with Group ID 0x1 is unlocked to level 0x1 and the variables Module ID and Group ID can be changed.

By default, unlock level is set at 0x0 and will revert to 0x0 two (2) minutes after it has been changed to a higher level. Password 0x4BD9 (0xD9 in Byte 2 and 0x4B in Byte 3) is used to unlock level 0x1 and Password 0x8AEC (0xEC in Byte 2 and 0x8A in Byte 3) is used to unlock level 0x2. Level 0x1 allows the changing of Module ID and Group ID variables. Level 0x2 allows the changing of the Module Voltage variable. If any value other than the correct passwords are entered in Bytes 2 & 3, the unlock level will revert to level 0x0. The unlock level can be found in Byte 3 of data message 2.

Response: Unlock level changes in Byte 3 of data message 2 of the affected module. Depending on password, variables Module ID, Group ID, and Module Voltage can become accessible for change via their respective configuration command messages.

## Firmware Update

The CAN Extension Module contains a microprocessor which digitizes measurements taken from an Ioxus X-series™ ultracapacitor module and interfaces with CAN. The firmware for the microprocessor can be updated to provide new features and bug fixes for undesired behaviors. A programming cable (4-889 18 pin CAN Module to RJ-11 Cable Assembly) is available from Ioxus to perform firmware updates at installation sites. Firmware updates will be made available in the form of downloadable files which can be flashed to the CAN Extension Modules with a programming tool. Ioxus recommends the use of LOAD-n-GO, a low cost hand-held mobile programmer available from Custom Computer Services, Inc: [www.ccsinfo.com/load-n-go](http://www.ccsinfo.com/load-n-go).

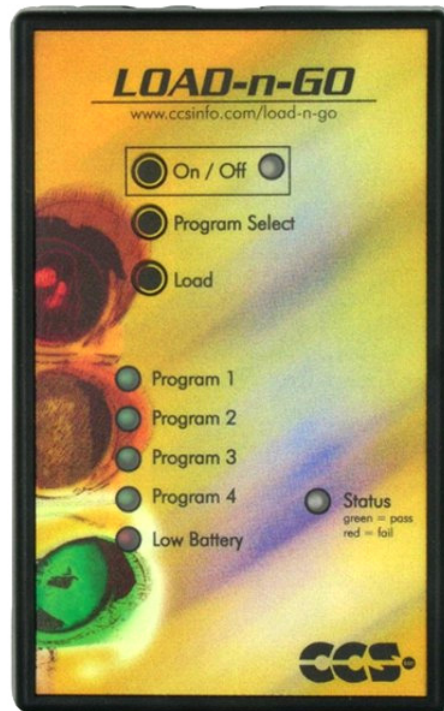


Figure 6 – LOAD-n-GO Programmer

## Processor Flashing

1. Obtain latest version of CAN Extension Module processor .hex file from Ioxus.
2. Load the .hex file into the programming tool. (In the ccsload application select load file in the Device panel, browse for the file path, and click open.)
3. Set the Target Chip as DSPIC30F4013 for the programming tool.
4. Set programming options to overwrite Program Memory and Configuration Bits, but not Data EEPROM. This will preserve settings such as Module ID and Module Voltage during a firmware upgrade. (In the ccsload application make sure the Program Memory and Config bits options are checked, but not Data EE on the Device panel.)
5. Write the program to a memory location on the programming tool if it is a hand-held mobile programmer. (In the ccsload application select a memory location and click Write to Memory on the Device panel.)



6. Disconnect 4-837 18 pin CAN Module to Balance Cable Assembly from the CAN Extension Module.
7. Connect 4-889 18 pin CAN Module to RJ-12 Cable Assembly to CAN Extension Module and programming tool.
8. With input power supplied to the CAN Extension Module, load the new firmware through the programming tool. (For LOAD-n-GO turn the programming tool on, select the program memory location, and press the Load button.)
9. Disconnect 4-889 18 pin CAN Module to RJ-12 Cable Assembly from the CAN Extension Module.
10. Connect 4-837 18 pin CAN Module to Balance Cable Assembly to CAN Extension Module.
11. Send a CAN message data request for Message 3 to the Group ID & Module ID of the module which was just programmed (e.g. CAN ID: 0x012 Data: 0x01 03 00 00 00 00 00) to check that the firmware revision in Byte 3 of the received data message matches the intended firmware version.

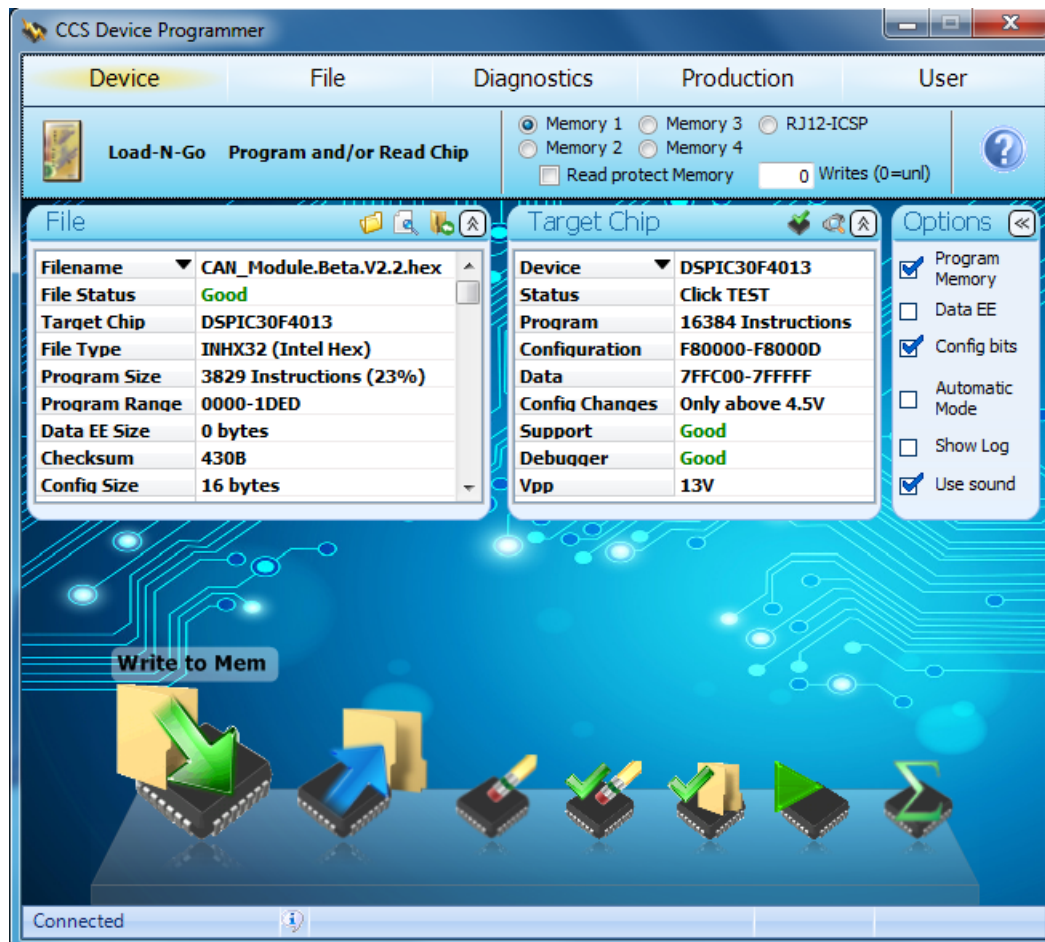


Figure 7 – CCSLOAD Application

## Safety



**Never touch the power terminals as any residual voltage can cause fatal electrical shocks, Always check with a calibrated meter that the module is discharged prior to handling the module, please see the step by step instructions in this manual for the discharge procedure.**

- Prior to installation or removal the ultracapacitor module and or system of modules must be discharged fully and shorting wires installed (procedure below)
- Provide sufficient electrical isolation for operation above 50 VDC
- Protect surrounding electrical and conductive components from incidental contact
- Do not operate above specified voltage or temperature range
- Do not touch terminals while charged, serious burns, shock or material fusing may occur

## Discharging



**A fully discharged ultracapacitor module may “bounce back” if it is stored without a shorting wire connected to the + and – terminals. This bounce back can be as much as 20% of the module’s nominal operating voltage, and is enough to cause dangerous electrical shocks and other undesirable consequences.**

Prior to any maintenance or replacement each ultracapacitor module should be individually discharged and shorted with a resistor or wire. Even a fully discharged module can rebound naturally to an unsafe condition. Be sure to discharge with an appropriately sized load or resistor bank (not provided) and either keep that load attached or replace it with a shorting wire or bus bar when the module voltage is depleted. Be sure to check the voltage with a calibrated meter prior to attaching the shorting device. The module voltage should be  $0.5\pm 0.5V$  when attaching a shorting device.

1. Using a voltmeter, measure the voltage between the 2 terminals.
2. If the voltage is above 1 V, a resistor pack (not supplied with the module) will need to be connected between the terminals. Proper care needs to be taken in the design and construction of such a dissipative pack. e.g. At 96V, for a 4 Ohm pack, the module will be initially discharged with a current of 24 A and will take about 25 minutes to fully discharge. However, in this case, the peak power dissipated in the resistor pack will be 2.3 kW. The resistor pack will need to be sized and provided with suitable cooling to handle this power dissipation. Additionally, proper enclosure or other packaging is necessary to ensure safety. In all cases, proper design of the dissipative resistor pack is necessary.
3. If the voltage is under 1 V, connect the shorting wire provided by Ioxus to the + and – connectors.
4. The module is now safe for handling. Leave the shorting wire connected at all times

## Maintenance

The modules should be kept free of dust and debris and cleaned at a regular interval. In inside locations, that should be no more than annually however this may vary with your particular circumstances. Outside location will be as needed. Once the modules are discharged, proceed with cleaning with a cloth and a simple water/soap solution. Avoid the use of hoses or pressurized sprays. Once the assembly is clean check for properly torqued fasteners and note any damage to any of the housings or signs of internal damage and replace as necessary.

## Disposal

Please recycle according to local codes and regulations for flammable materials