

LTC6806 isoSPI Fuel Cell Monitor

DESCRIPTION

Demonstration circuit 2192B is a fuel cell monitor featuring the [LTC®6806](#), a 36-channel fuel cell monitor. Multiple boards can be linked through a 2-wire isolated serial interface (isoSPI™) to monitor a long series of cells in a stack. The DC2192B demo circuit also features reversible isoSPI enabling a redundant communication path. The PCB, components and DuraClik connectors are optimized for low EMI susceptibility and emissions.

The DC2192B can communicate to a PC by connecting a [DC2792B](#) dual master isoSPI together with

[DC2026](#) Linduino® One. The DC2026 must be loaded with the appropriate program (called a **sketch**) to control the battery stack monitor IC and receive data through a USB serial port. The DC2026C provides a standard SPI interface which can be translated to isoSPI and then connected to a DC2192B isoSPI port (J3/J4 connector). The DC2792B provides two SPI-isoSPI channels for reversible operation.

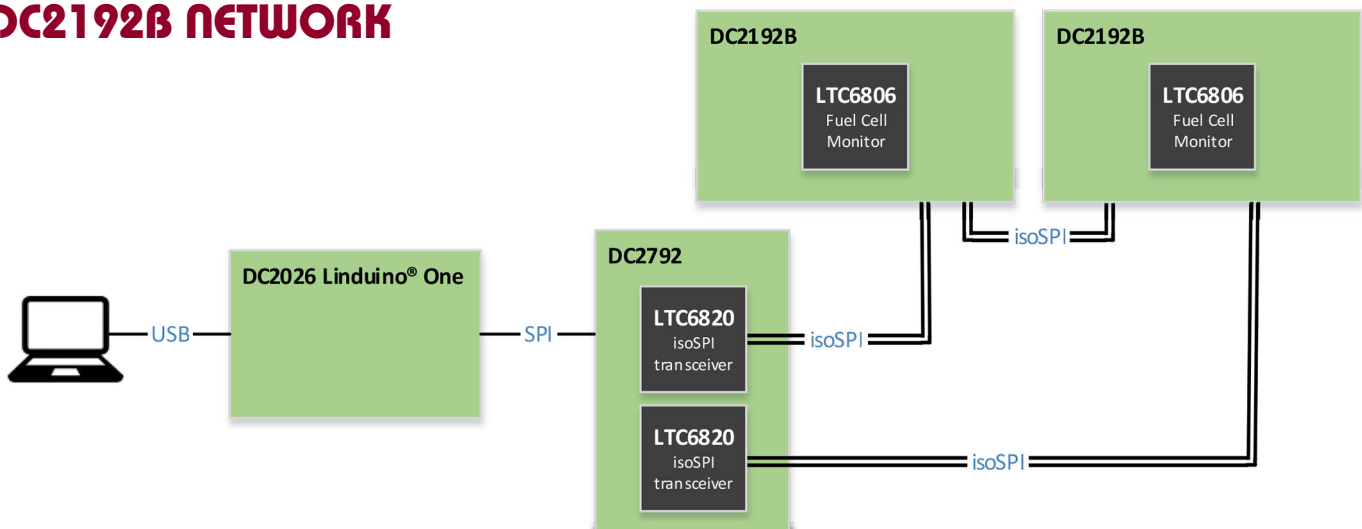
Design files for this circuit board are available.

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PERFORMANCE SUMMARY Specifications are at $T_A = 25^\circ\text{C}$

PARAMETER	MIN	TYP	MAX	UNITS
V ⁺ Supply Voltage (Relative to V ⁻) where TME Specifications are Met	4.75	5.0	5.5	V
Input Voltage Range, C25 – C36 to V ⁻	–5.0		140	V
Input Voltage Range, C14 – C24 to V ⁻	–5.0		95	V
Input Voltage Range, C0 – C13 to V ⁻	–5.0		60	V
V _{REF1} 1st Reference Voltage, No Load	2.700	3.058	3.300	V
V _{REF2} 2nd Reference Voltage, 1mA Load to V ⁻	2.200	2.500	2.700	V
V _{BIAS} I _{BIAS} Voltage, READY/ACTIVE State	1.9	2.0	2.1	V
CPIN Input Measurement Range with HIRNG = 0	–2.5		2.5	V
CPIN Input Measurement Range with HIRNG = 1	–5.0		5.0	V
Cell Count			36	

DC2192B NETWORK



HARDWARE SETUP

Table 1. J1 Pinout

J1 PIN	CPIN INPUT	J1 PIN	CPIN INPUT
19	C0/GND	10	C18
37	C1	28	C19
18	C2	9	C20
36	C3	27	C21
17	C4	8	C22
35	C5	26	C23
16	C6	7	C24
34	C7	25	C25
15	C8	6	C26
33	C9	24	C27
14	C10	5	C28
32	C11	23	C29
13	C12	4	C30
31	C13	22	C31
12	C14	3	C32
30	C15	21	C33
11	C16	2	C34
29	C17	20	C35
		1	C36

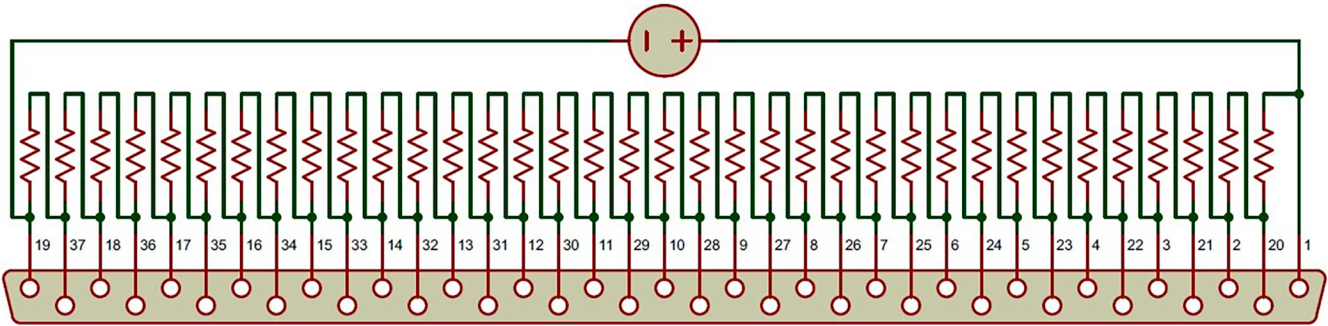


Figure 3. Resistor Divider String Connection D-SUB37 (DB-37) Female Receptacles Schematic of Figure 2. Includes the Power Supply Connection

DC2192B SERIAL INTERFACE OPTIONS

isoSPI is the only communication option to DC2192B. Due to the custom EMI optimized isoSPI cable with DuraClik connectors, it is highly recommended to use DC2792B Dual Master isoSPI demo board or equivalent for easy plug-and-play operation. The DC2792B Dual Master isoSPI demo board can be connected as a typical single-ended isoSPI bus master or to both ends of a reversible configuration with two isoSPI bus masters. Refer to DC2792B demo manual for usage details.

DC2792B to DC2192B Typical isoSPI Connection

A typical isoSPI connection begins with the isoSPI master connected to the first (or **bottom**) DC2192B. Additional DC2192B boards can be daisy-chained onto the isoSPI bus. Communication begins from the first (or **bottom**) DC2192B then to the next **upper** DC2192B and, finally, to the last (or **top**) DC2192B.

Figure 4 shows the following connections for two boards on a stack interfaced to a PC.

1. Connect a USB cable from the PC USB port to the DC2026 J5 connector.
2. Connect DC2026 to DC2792B Dual Master isoSPI demo board.
- a. Connect a 14-pin ribbon cable from the DC2026 J1 header to the DC2792B J1 header.
3. Connect DC2792B to DC2192B in isoSPI mode. This DC2192B is the first (or **bottom**) board of the stack.
 - a. Connect a 2-wire twisted-pair patch cable from the DC2792B J2 MAIN DuraClik connector to the **bottom** DC2192B J3 isoSPI A DuraClik connector.
- b. Connect an external 3.3V – 15V power supply to the **bottom** DC2192B VEXT+ E2 and VEXT- E1 turrets.

CAUTION! The 2-wire twisted-pair patch cable with the DuraClik end plugs have 1mm thick center locking tabs on the wiring side that must be pressed down to release from the DuraClik receptacles. Failure to do so may damage the cable and prevent board-to-board isoSPI communication.

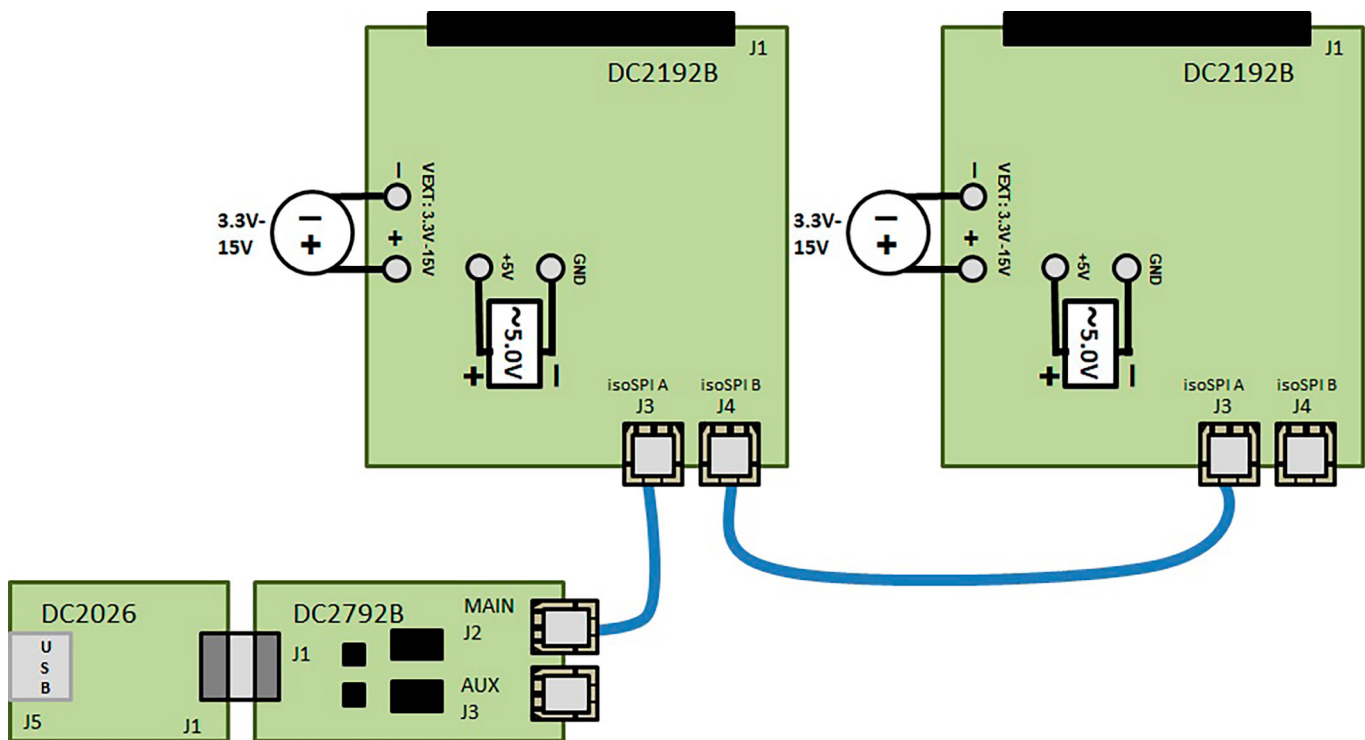


Figure 4. DC2792B Typical isoSPI Connection to the *Bottom* DC2192B in a Two-Board DC2192B Stack

DC2192B SERIAL INTERFACE OPTIONS

4. Connect or daisy-chain the DC2192B to another DC2192B in isoSPI mode. This DC2192B is the last (or **top**) board of a two-board stack. More DC2192B **upper** boards can be daisy-chained together in the same manner.

- Connect a 2-wire twisted-pair patch cable from the **bottom** DC2192B J4 isoSPI B DuraClik connector to the next **upper** or **top** DC2192B J3 isoSPI A DuraClik connector.

CAUTION! The 2-wire twisted-pair patch cable with the DuraClik end plugs have 1mm thick center locking tabs on the wiring side that must be pressed down to release from the DuraClik receptacles. Failure to do so may damage the cable and prevent board-to-board isoSPI communication.

- Connect an external 3.3V – 15V power supply to the next **upper** or **top** DC2192B VEXT+ E2 and VEXT- E1 turrets.

5. **CAUTION!** The fuel cell voltage must be connected correctly to prevent damage to the DC2192B. Refer to Table 1 and Figure 2 then confirm that the fuel cell voltage connections to the DB-37 female matches the DC2192B J1 pinout.

- Plug the DB-37 female receptacle connector onto the J1 fuel cell voltage DB-37 male plug connector.

6. Refer to Software Setup section of this demo manual to properly setup the PC with the Arduino IDE software to allow communication to the DC2192B boards.

DC2792B to DC2192B Reverse isoSPI Connection

A reverse isoSPI connection begins with the isoSPI Master connected to the last (or **top**) DC2192B. Additional DC2192B boards can be daisy-chained onto the isoSPI bus. Communication begins from the last (or **top**) DC2192B then to the next **lower** DC2192B and, finally, to the first (or **bottom**) DC2192B.

Figure 5 shows the following connections for two boards on a stack interfaced to a PC.

- Connect a USB cable from the PC USB port to the DC2026 J5 connector.

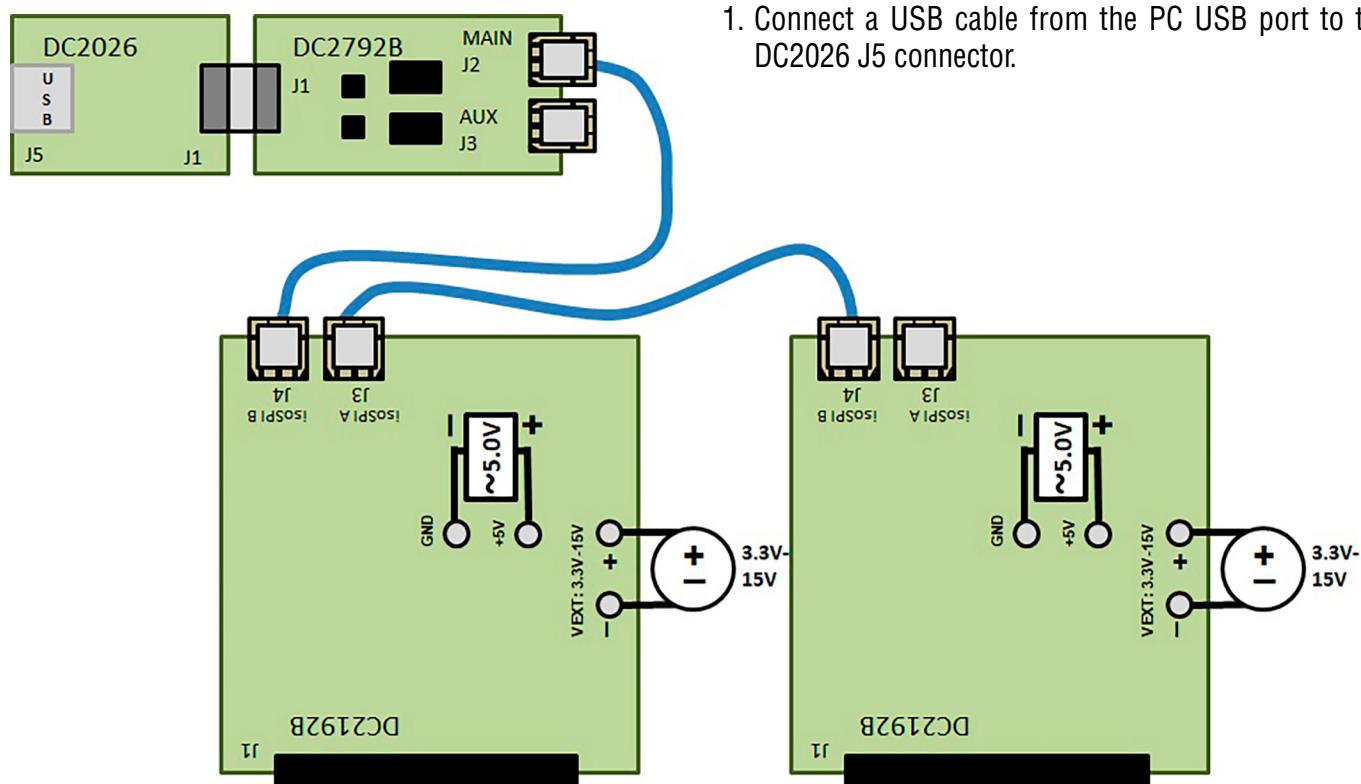


Figure 5. DC2792B Reverse isoSPI Connection to the *Top* DC2192B in a Two-Board DC2192B Stack

DC2192B SERIAL INTERFACE OPTIONS

2. Connect DC2026 to DC2792B Dual Master isoSPI demo board.

- a. Connect a 14-pin ribbon cable from the DC2026 J1 header to the DC2792B J1 header.

3. Connect DC2792B to DC2192B in isoSPI mode. This DC2192B is the last (or **top**) board of a two-board stack.

- a. Connect a 2-wire twisted-pair patch cable from the DC2792B J2 MAIN DuraClik connector to the **top** DC2192B J4 isoSPI B DuraClik connector.

CAUTION! The 2-wire twisted-pair patch cable with the DuraClik end plugs have 1mm thick center locking tabs on the wiring side that must be pressed down to release from the DuraClik receptacles. Failure to do so may damage the cable and prevent board-to-board isoSPI communication.

- b. Connect an external 3.3V – 15V power supply to the **top** DC2192B VEXT⁺ E2 and VEXT⁻ E1 turrets.

4. Connect or daisy-chain the DC2192B to another DC2192B in isoSPI mode. This DC2192B is the first (or **bottom**) board of a two-board stack. More DC2192B **lower** boards can be daisy-chained together in the same manner.

- a. Connect a 2-wire twisted-pair patch cable from the **top** DC2192B J3 isoSPI A DuraClik connector to the next **lower** or **bottom** DC2192B J4 isoSPI B DuraClik connector.

CAUTION! The 2-wire twisted-pair patch cable with the DuraClik end plugs have 1mm thick center locking tabs on the wiring side that must be pressed down to release from the DuraClik receptacles. Failure to do so may damage the cable and prevent board-to-board isoSPI communication.

- b. Connect an external 3.3V – 15V power supply to the next **lower** or **bottom** DC2192B VEXT⁺ E2 and VEXT⁻ E1 turrets.

5. **CAUTION!** The fuel cell voltage must be connected correctly to prevent damage to the DC2192B. Refer to Table 1 and Figure 2 then confirm that the fuel cell voltage connections to the DB-37 female matches the DC2192B J1 pinout.

- a. Plug the DB-37 female receptacle connector onto the J1 fuel cell voltage DB-37 male plug connector.

6. Refer to the Software Setup section of this demo manual to properly setup the PC with the Arduino IDE software to allow communication to the DC2192B boards.

DC2792B TO DC2192B Redundant isoSPI Connection

A redundant isoSPI connection begins with the primary (or **main**) isoSPI Master connected to the first (or **bottom**) DC2192B and has a backup auxiliary (or **aux**) isoSPI Master connected to the last (or **top**) DC2192B. Additional DC2192B boards can be daisy-chained between the two isoSPI masters on the isoSPI bus. Primary (or **main**) communication begins from the first (or **bottom**) DC2192B then to the next **upper** DC2192B and, finally, to the last (or **top**) DC2192B. The backup auxiliary (or **aux**) communication begins in the reverse direction to provide coverage when a possible isoSPI daisy-chain break occurs.

Figure 6 shows the following connections for two boards on a stack interfaced to a PC.

1. Connect a USB cable from the PC USB port to the DC2026 J5 connector.

2. Connect DC2026 to DC2792B Dual Master isoSPI demo board.

- a. Connect a 14-pin ribbon cable from the DC2026 J1 header to the DC2792B J1 header.

3. Connect DC2792B primary (or **main**) isoSPI master to the first (or **bottom**) DC2192B board of the stack.

- a. Connect a 2-wire twisted-pair patch cable from the DC2792B J2 MAIN DuraClik connector to the **bottom** DC2192B J3 isoSPI A DuraClik connector.

CAUTION! The 2-wire twisted-pair patch cable with the DuraClik end plugs have 1mm thick center locking tabs on the wiring side that must be pressed down to release from the DuraClik receptacles. Failure to do so may damage the cable and prevent board-to-board isoSPI communication.

- b. Connect an external 3.3V – 15V power supply to the **bottom** DC2192B VEXT⁺ E2 and VEXT⁻ E1 turrets.

DC2192B SERIAL INTERFACE OPTIONS

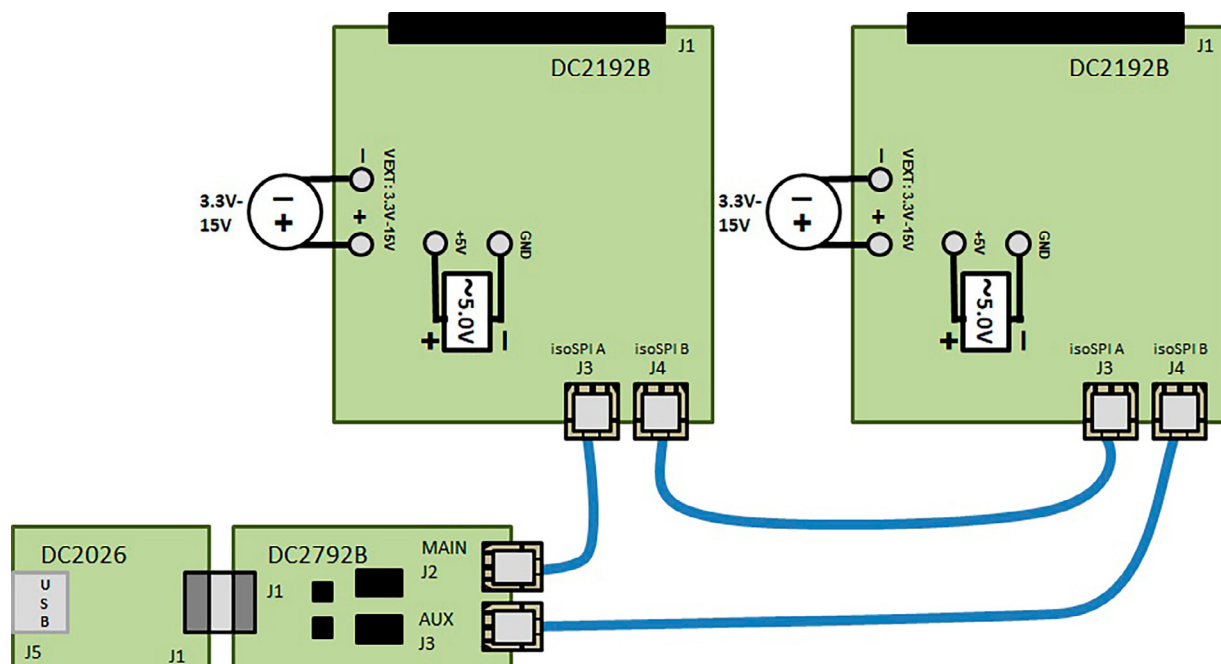


Figure 6. DC2792B Redundant isoSPI Connections to the *Bottom* and *Top* DC2192B in a Two-Board DC2192B Stack

4. Connect or daisy-chain the DC2192B to another DC2192B in isoSPI mode. This DC2192B is the last (or **top**) board of a two-board stack. More DC2192B **upper** boards can be daisy-chained together in the same manner.
 - a. Connect a 2-wire twisted-pair patch cable from the **bottom** DC2192B J4 isoSPI B DuraClik connector to the next **upper** or **top** DC2192B J3 isoSPI A DuraClik connector.
CAUTION! The 2-wire twisted-pair patch cable with the DuraClik end plugs have 1mm thick center locking tabs on the wiring side that must be pressed down to release from the DuraClik receptacles. Failure to do so may damage the cable and prevent board-to-board isoSPI communication.
 - c. Connect an external 3.3V – 15V power supply to the **upper** or **top** DC2192B VEXT+ E2 and VEXT- E1 turrets.
5. Connect the DC2792B auxiliary (or **aux**) isoSPI Master to the last (or **top**) DC2192B board of the stack.
 - a. Connect a 2-wire twisted-pair patch cable from the DC2792B J3 AUX DuraClik connector to the **top** DC2192B J4 isoSPI B DuraClik connector.
CAUTION! The 2-wire twisted-pair patch cable with the DuraClik end plugs have 1mm thick center locking tabs on the wiring side that must be pressed down to release from the DuraClik receptacles. Failure to do so may damage the cable and prevent board-to-board isoSPI communication.
6. **CAUTION!** The fuel cell voltage must be connected correctly to not damage the DC2192B. Refer to Table 1 and Figure 2, then confirm that the fuel cell voltage connections to the DB-37 female matches the DC2192B J1 pinout.
 - a. Plug the DB-37 female receptacle connector onto the J1 fuel cell voltage DB-37 male plug connector.
7. Refer to the Software Setup section of this demo manual to properly setup the PC with the Arduino IDE software to allow communication to the DC2192B boards.

SOFTWARE SETUP

The DC2192B can be controlled by the DC2026 Linduino One board together with DC2792B Dual isoSPI Master or equivalent isoSPI transceiver. The DC2026 is part of the Arduino compatible Linduino platform that provides example code that will demonstrate how to control the multicell battery stack monitor ICs. Compared to most Arduino compatible microcontroller boards, the DC2026 offers conveniences such as an isolated USB connection to the PC, built-in SPI MISO line pull-up to properly interface with the battery stack monitor IC open-drain SDO, and an easy ribbon cable connection for SPI communication through the DC2792B 14-pin QuikEval™ J1 connector.

Arduino IDE Setup

1. Download then install the [Arduino IDE](#) onto the PC. Detailed instructions can be found under the quick start tab.
2. Set the Arduino IDE to open BMS Sketchbooks. From within the Arduino IDE, click on **File** menu select **Preferences**. Then under **Sketchbook location**: select Browse and locate the path to the extracted **LTSketchbook.zip** file that was downloaded (see Figure 7).
3. Close then re-open the Arduino IDE to enable the use of the Sketchbook Location that was previously set.

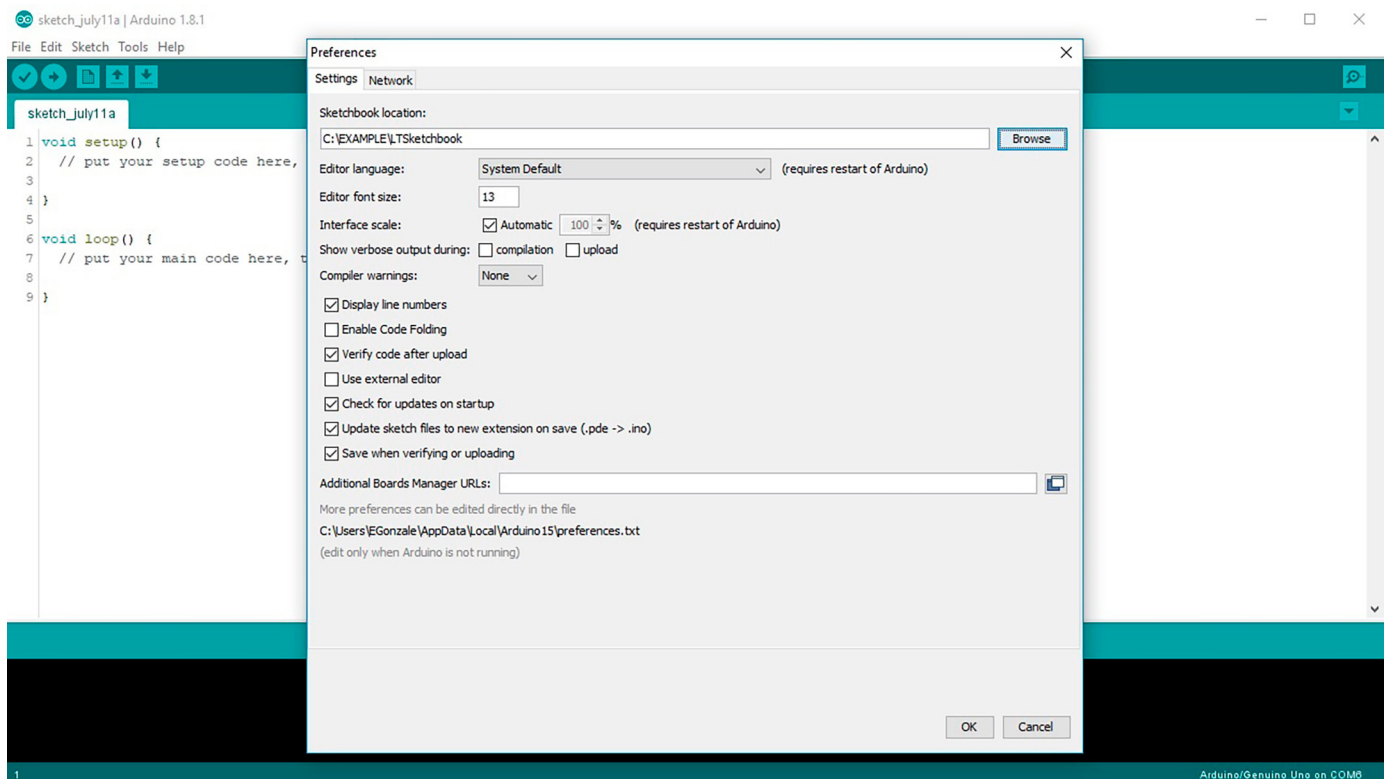


Figure 7. Sketchbook Location Path

SOFTWARE SETUP

4. Select the correct COM port to allow communication to DC2026 through USB. Under the **Tools** menu, select **Port** → Select the highest number **COMxx**. There may be more than one option—DC2026 is usually the highest COM port number. The PC screenshot (Figure 8) used in this example shows the DC2026 connected to COM6.
5. Select the correct Arduino compatible microcontroller board. Under the **Tools** menu, select **Board** → **Arduino/Genuino Uno** with the “•” black dot symbol (see Figure 9).

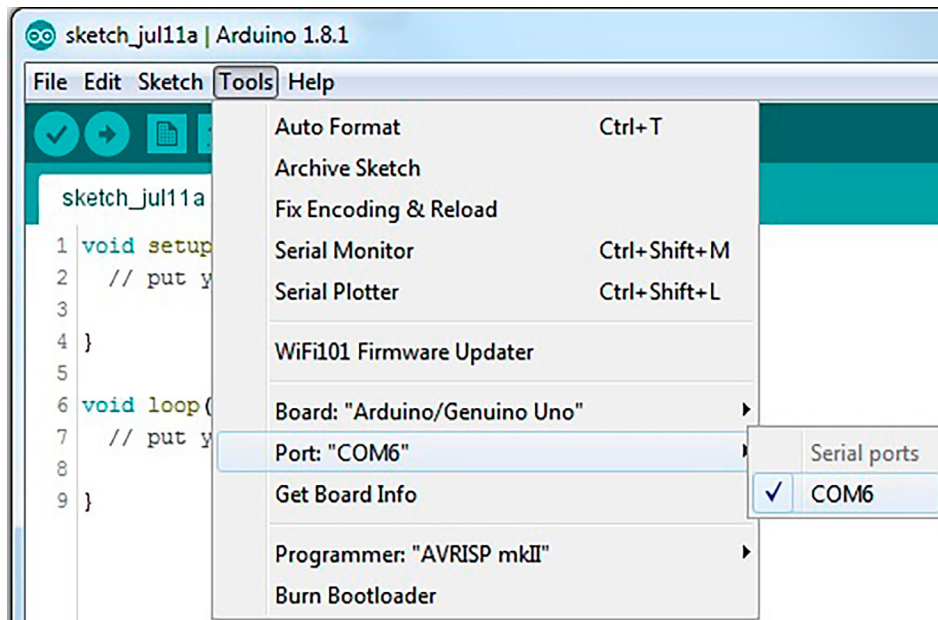


Figure 8. Selecting the Correct COM

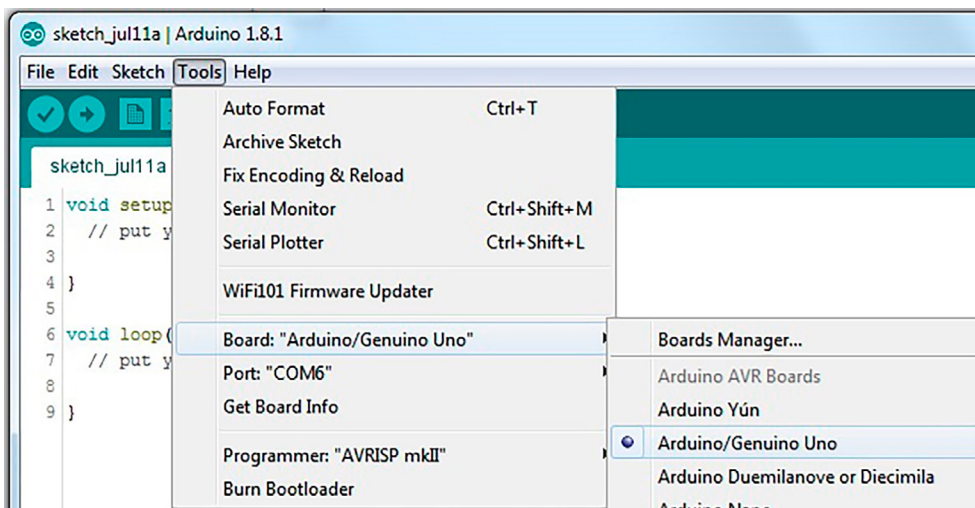


Figure 9. Selecting the Compatible Microcontroller Board

SOFTWARE SETUP

6. Open one of the programs or **sketches** associated with the DC2192. In this example LTC6806 sketch will be opened. Under the **File** menu, select **Sketchbook** → **Part Number** → **6000** → **6806** → **DC2192** (see Figure 10).
7. Upload the **DC2192** sketch onto the DC2026 by clicking on the **Upload** button on the top left corner. When this process is completed there will be a **Done uploading** message on the bottom left corner (see Figure 11).

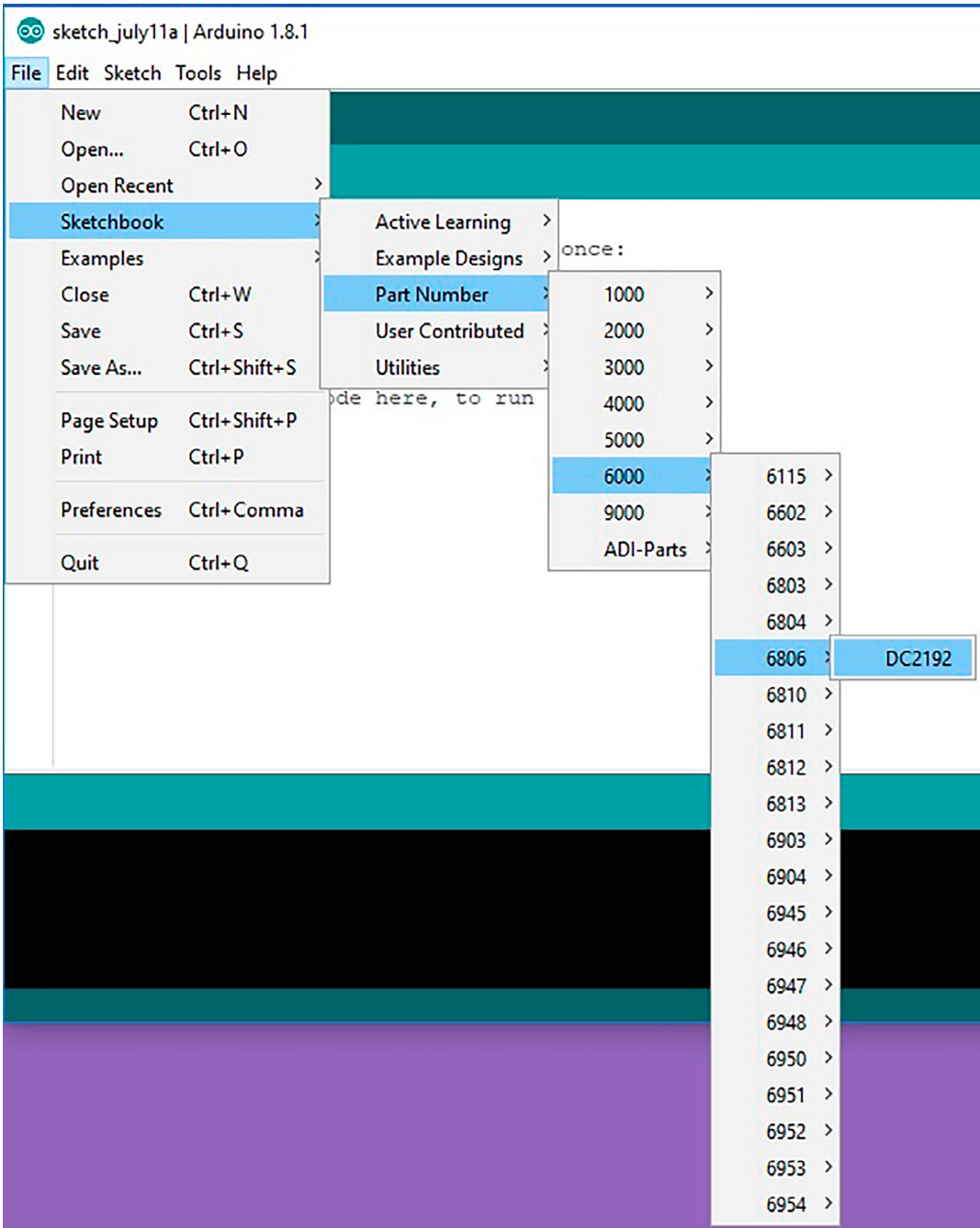


Figure 10. Selecting the LTC6806 Sketch

SOFTWARE SETUP

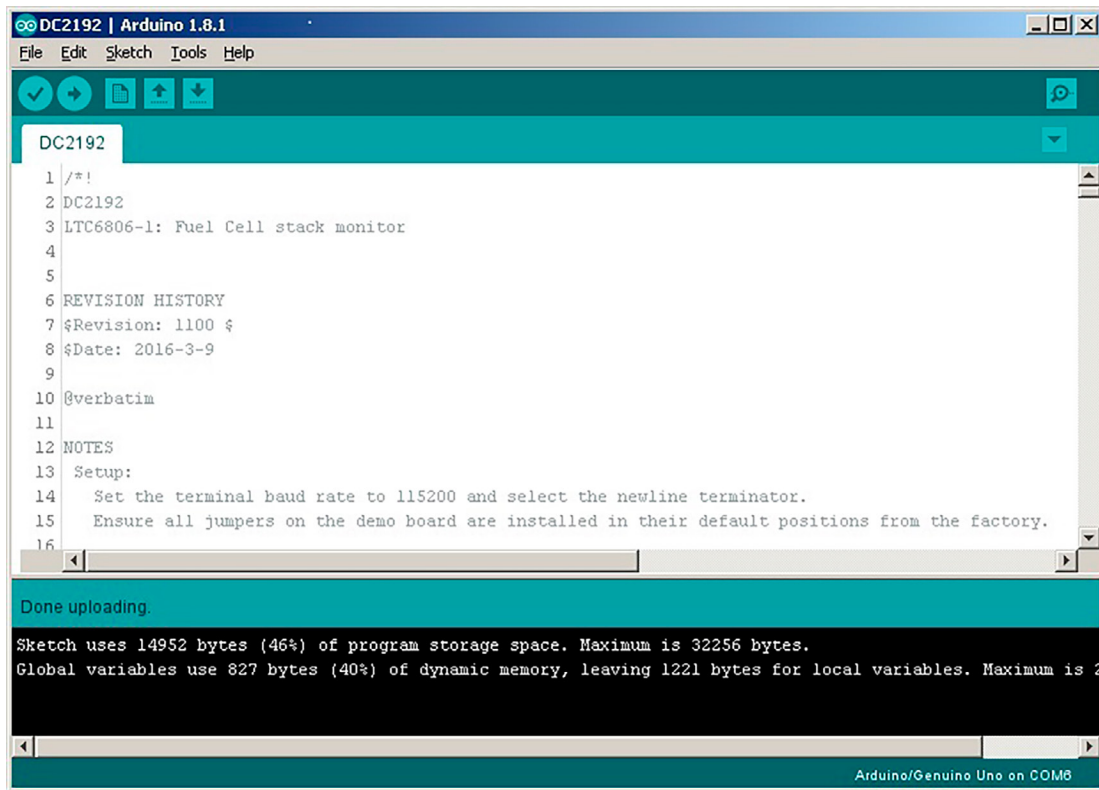


Figure 11. Uploading DC2192 Sketch

8. Open the Arduino **Serial Monitor** tool (Figure 12). Click on the Serial Monitor button on the top right corner then the Serial Monitor window will open and show on the top left corner the **COMxx** used.
9. Configure the **Serial Monitor** to allow communication to the DC2026 through USB. On the bottom of the Serial Monitor window, set the following starting from bottom left to bottom right:
 - a. Click on the **Autoscroll** checkbox to select it.
 - b. Select Both **NL & CR** on the left dropdown menu.
 - c. Select **115200** baud on the right dropdown menu.
 - d. As shown in Figure 13, when configured correctly the DC2192 sketch menu will appear.

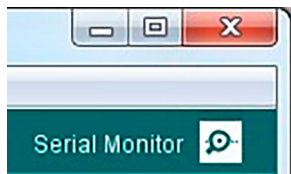


Figure 12. Arduino Serial Monitor Tool

SOFTWARE SETUP

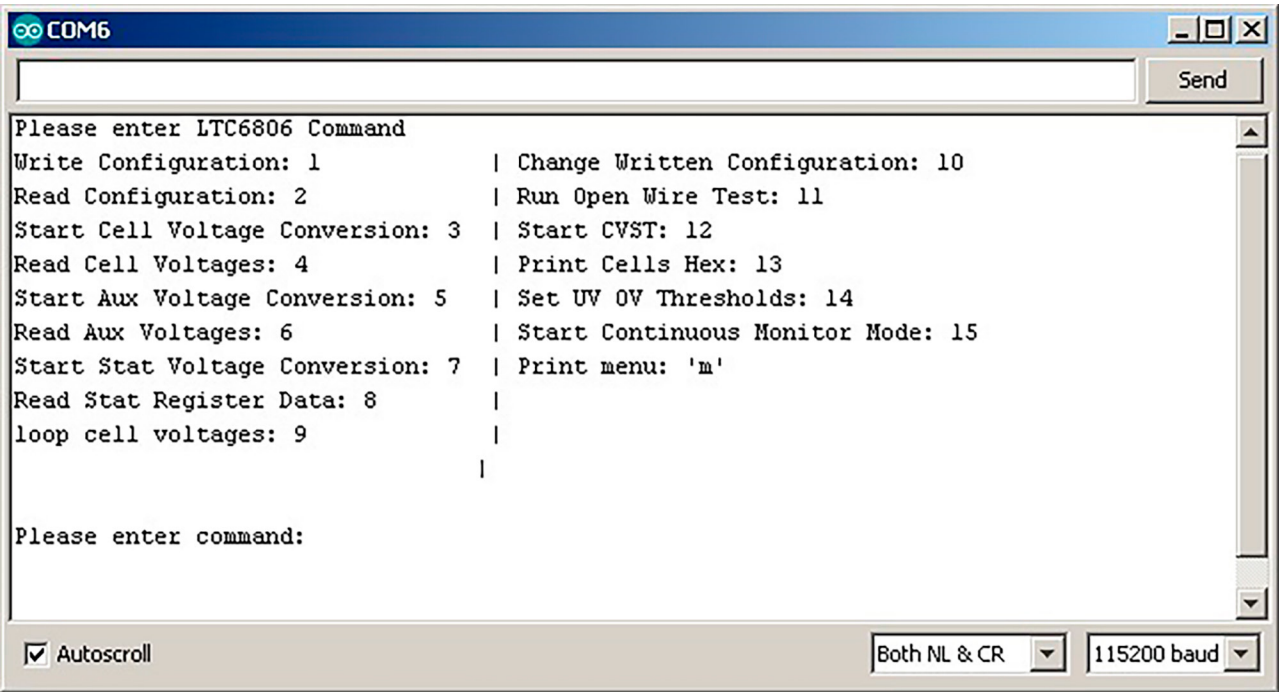


Figure 13. DC2192 Sketch Menu

APPENDIX A: THE SKETCHBOOK CONTENTS

The LTSketchbook will generally contain the following folders: Libraries, Part Number, Utilities and Documentation.

Libraries Directory contains a subdirectory for each IC in the sketchbook. Each subdirectory contains a *.cpp* and *.h* files. These files contain all the constant definitions and low-level IC command implementations. Porting to a different microcontroller requires changes to some library files.

Part Number Directory contains example control programs for each IC. Inside the Part Number folder, each BMS IC has a sketch(*.ino*) file that implements a control program to evaluate the functionality of the IC. This sketch allows the user to control the IC through a serial terminal and make all primary measurements. This sketch also allows for evaluation of self-test and discharge features of the IC. Generally, the name of a sketch relates to the IC's demo board. For example, the sketch for LTC6804 is *DC1942.ino*, for LTC6811 it is *DC2259.ino*, and for LTC6806 it is *DC2192.ino*.

Utilities Directory contains support programs, including a program that emulates the standard Analog Devices [DC590](#) isolated USB to serial controller.

Documentation Directory: contains *html* documentation for the provided code base. Documentation for all of the BMS ICs can be accessed by opening the *Linduino.html* file, as found in the main sketchbook directory (see Figure 14) and in the documentation directory.

What is A Sketch

A **sketch** is simply another word for a microcontroller/Linduino program. The term is generally only used when referring to Arduino-based programs, as sketches have several abstractions that remove some of the complexity of a standard microcontroller (MCU) program. All sketches contains two primary functions, the *setup()* and the *loop()* function. These are in fact the only functions that are mandatory in a sketch and are almost always implemented in some form in a typical MCU program. The *setup()* function is run once at power on or after the MCU is reset. The *setup()* function generally is used to initialize the MCU peripheral circuits and to initialize all of the control variables. The *loop()* function is similar to a *main()* function that has implemented an infinite loop inside a standard C program. The code within the *loop()* function is typically where the primary program code is placed. The code within the *loop()* function will repeat infinitely.

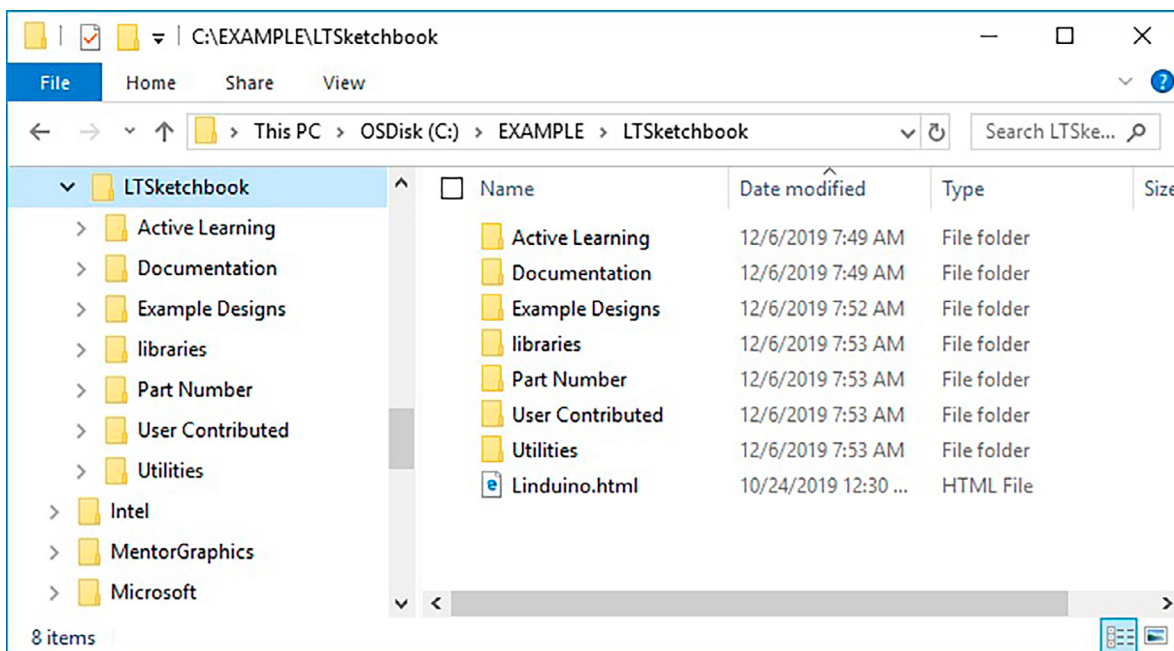


Figure 14. Documentation Directory

APPENDIX A: THE SKETCHBOOK CONTENTS

Sketch Modifications

Sketches can be modified to a set of applications specific requirements. All sketches are written such that the most common modifications can be made by changing the variables listed in the */*Setup Variables */* table at the top of the sketch. For reference, example modifications to a DC2259 (LTC6811) sketch are shown below. These modifications are applicable to most of the available BMS ICs in the sketchbook.

Common modifications can be made by changing the *Setup Variables*. The most common application changes are listed below. After the variables are changed, the sketch will need to be recompiled and uploaded to the Linduino.

1. To change the number of ICs in the isoSPI network, change the TOTAL_IC variable. A number between 1 and 4 should be entered. In an application that has 2 devices in the network the modified line will look like:

```
const uint8_t TOTAL_IC = 2;
```

2. Often an application may need to sample data at a rate faster than the default 500ms (2Hz). To modify the loop/sample rate the MEASUREMENT_LOOP_TIME variable should be changed. The loop time must be entered in milliseconds and should be a number larger than 20mS. To change the loop rate to roughly 10 measurements a second the loop rate should be changed to 100mS. The modified line will look like:

```
const uint16_t MEASUREMENT_LOOP_TIME = 100;
```

3. It is possible to modify which measurements fall within the loop during the Loop Measurements command. The following list are the measurements that can be looped:

```
const uint8_t MEASURE_CELL = ENABLED;
// This is ENABLED or DISABLED

const uint8_t MEASURE_AUX = DISABLED;
// This is ENABLED or DISABLED

const uint8_t MEASURE_STAT = DISABLED;
//This is ENABLED or DISABLED
```

By default, only a cell measurement is done, as noted by MEASURE_CELL = ENABLED. What measurements are made can be changed by setting what the measure field is equal to. To measure cells and the status register but not the AUX register, the variables would be setup as shown below.

```
const uint8_t MEASURE_CELL = ENABLED;
// This is ENABLED or DISABLED

const uint8_t MEASURE_AUX = DISABLED;
// This is ENABLED or DISABLED

const uint8_t MEASURE_STAT = ENABLED;
//This is ENABLED or DISABLED
```

4. ADC conversion settings can also be modified in the *Setup Variables* section. The default setup is to run the ADC in **Normal** mode, which has a 7kHz filter code; in this mode the ADC_OPT bit is disabled. Typical choice for which cell to convert is ALL. Full ADC conversion programming requires setting ADC_OPT, ADC_CONVERSION_MODE, CELL_CH_TO_CONVERT, AUX_CH_TO_CONVERT, and STAT_CH_TO_CONVERT. These variables are programmed with constants listed in the LTC68xy_daisy.h file. For simplicity they are also listed below.

```
MD_422HZ_1KHZ
MD_27KHZ_14KHZ
MD_7KHZ_3KHZ
MD_26HZ_2KHZ
ADC_OPT_ENABLED
ADC_OPT_DISABLED
CELL_CH_ALL
CELL_CH_1and7
CELL_CH_2and8
CELL_CH_3and9
CELL_CH_4and10
CELL_CH_5and11
CELL_CH_6and12
```


APPENDIX A: THE SKETCHBOOK CONTENTS

To set the ADC to have a 1kHz filter corner the ADC_OPT and ADC_CONVERSION_MODE variables would be changed to:

```
ADC_OPT = ADC_OPT_ENABLED;  
ADC_CONVERSION_MODE = MD_422HZ_1KHZ;
```

To convert only cells 2 and 8,

```
CELL_CH_TO_CONVERT = CELL_CH_2and8;
```

5. In another example, the user may wish to change the undervoltage and overvoltage thresholds. Each number is based on an LSB of 100 μ V.

```
//Under Voltage and Over Voltage Thresholds  
const uint16_t OV_THRESHOLD = 41000;  
  
// Over voltage threshold ADC Code.  
// LSB = 0.0001  
  
const uint16_t UV_THRESHOLD = 30000;  
  
// Under voltage threshold ADC Code.  
// LSB = 0.0001
```

**ESD Caution**

ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

Legal Terms and Conditions

By using the evaluation board discussed herein (together with any tools, components documentation or support materials, the "Evaluation Board"), you are agreeing to be bound by the terms and conditions set forth below ("Agreement") unless you have purchased the Evaluation Board, in which case the Analog Devices Standard Terms and Conditions of Sale shall govern. Do not use the Evaluation Board until you have read and agreed to the Agreement. Your use of the Evaluation Board shall signify your acceptance of the Agreement. This Agreement is made by and between you ("Customer") and Analog Devices, Inc. ("ADI"), with its principal place of business at One Technology Way, Norwood, MA 02062, USA. Subject to the terms and conditions of the Agreement, ADI hereby grants to Customer a free, limited, personal, temporary, non-exclusive, non-sublicensable, non-transferable license to use the Evaluation Board FOR EVALUATION PURPOSES ONLY. Customer understands and agrees that the Evaluation Board is provided for the sole and exclusive purpose referenced above, and agrees not to use the Evaluation Board for any other purpose. Furthermore, the license granted is expressly made subject to the following additional limitations: Customer shall not (i) rent, lease, display, sell, transfer, assign, sublicense, or distribute the Evaluation Board; and (ii) permit any Third Party to access the Evaluation Board. As used herein, the term "Third Party" includes any entity other than ADI, Customer, their employees, affiliates and in-house consultants. The Evaluation Board is NOT sold to Customer; all rights not expressly granted herein, including ownership of the Evaluation Board, are reserved by ADI. **CONFIDENTIALITY.** This Agreement and the Evaluation Board shall all be considered the confidential and proprietary information of ADI. Customer may not disclose or transfer any portion of the Evaluation Board to any other party for any reason. Upon discontinuation of use of the Evaluation Board or termination of this Agreement, Customer agrees to promptly return the Evaluation Board to ADI. **ADDITIONAL RESTRICTIONS.** Customer may not disassemble, decompile or reverse engineer chips on the Evaluation Board. Customer shall inform ADI of any occurred damages or any modifications or alterations it makes to the Evaluation Board, including but not limited to soldering or any other activity that affects the material content of the Evaluation Board. Modifications to the Evaluation Board must comply with applicable law, including but not limited to the RoHS Directive. **TERMINATION.** ADI may terminate this Agreement at any time upon giving written notice to Customer. Customer agrees to return to ADI the Evaluation Board at that time. **LIMITATION OF LIABILITY.** THE EVALUATION BOARD PROVIDED HEREUNDER IS PROVIDED "AS IS" AND ADI MAKES NO WARRANTIES OR REPRESENTATIONS OF ANY KIND WITH RESPECT TO IT. ADI SPECIFICALLY DISCLAIMS ANY REPRESENTATIONS, ENDORSEMENTS, GUARANTEES, OR WARRANTIES, EXPRESS OR IMPLIED, RELATED TO THE EVALUATION BOARD INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTY OF MERCHANTABILITY, TITLE, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF INTELLECTUAL PROPERTY RIGHTS. IN NO EVENT WILL ADI AND ITS LICENSORS BE LIABLE FOR ANY INCIDENTAL, SPECIAL, INDIRECT, OR CONSEQUENTIAL DAMAGES RESULTING FROM CUSTOMER'S POSSESSION OR USE OF THE EVALUATION BOARD, INCLUDING BUT NOT LIMITED TO LOST PROFITS, DELAY COSTS, LABOR COSTS OR LOSS OF GOODWILL. ADI'S TOTAL LIABILITY FROM ANY AND ALL CAUSES SHALL BE LIMITED TO THE AMOUNT OF ONE HUNDRED US DOLLARS (\$100.00). **EXPORT.** Customer agrees that it will not directly or indirectly export the Evaluation Board to another country, and that it will comply with all applicable United States federal laws and regulations relating to exports. **GOVERNING LAW.** This Agreement shall be governed by and construed in accordance with the substantive laws of the Commonwealth of Massachusetts (excluding conflict of law rules). Any legal action regarding this Agreement will be heard in the state or federal courts having jurisdiction in Suffolk County, Massachusetts, and Customer hereby submits to the personal jurisdiction and venue of such courts. The United Nations Convention on Contracts for the International Sale of Goods shall not apply to this Agreement and is expressly disclaimed.