UNB &
NB Power

2021

The Mobile Current Measurement Device (MCMD)

User Guide

Proudly brought to you by: **Capstone Design Group 6**

MCMD

List of Abbreviations

Table i. List of Abbreviations

Abbreviation	**Expanded Form**
MCMD	Mobile Current Measurement Device
AC	Alternating Current
DC	Direct Current
GND	Ground
NB	New Brunswick
2P3S	Two Parallel Three Series
RMS	Root Mean Squared
CT	Current Transformer
PPE	Proper Protective Equipment
PID	Proportional Integral - Derivative
LED	Light Emitting Diode
LTE	Long Term Evolution
IoT	Internet of Things
GB	Gigabyte
MPPT	Maximum Power Point Tracking
RTC	Real-time Clock
BMS	Battery Management System
DIP	Dual In-Line Package
USB	Universal Serial Bus
Micro-SD	Micro Secure Digital
Wh	Watt-hour
mAh	Milliamp-hour
SIM	Subscriber Identification Module
IFTTT	If This Than That
IDE	Integrated Development Environment
FAT32	File Allocation Table 32
CSV	Comma Separated Value

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1.0 Product Introduction

Thank you for choosing the Mobile Current Measurement Device (MCMD) as your current metering solution. The MCMD is a unique solution that will help NB Power monitor the power demand on distribution lines. The MCMD can monitor, record, and transmit the data to NB Power via a cellular connection, idealized to be implemented as the prototype in Figure 1.

1.1 What is the MCMD?

The MCMD is an easy-to-use device for remotely monitoring current levels between 2A and 1000A on the distribution line, safely and efficiently. This device is to be installed on an overhead line with a nominal voltage of $69kV_{L-L}$, $12.47kV_{L-L,}$ or $7.2kV_{L-N}$. Through cellular communication, the MCMD will monitor the electrical usage and automatically transmit the data to a secure cloud storage. This will provide the MCMD with the opportunity to notify its clientele when a low current event occurs, such as a power fault, or an insufficient level of current on the line. The MCMD has an internal battery source capable of being charged or maintained by a solar panel included in the prototype design as a sustainable power solution.

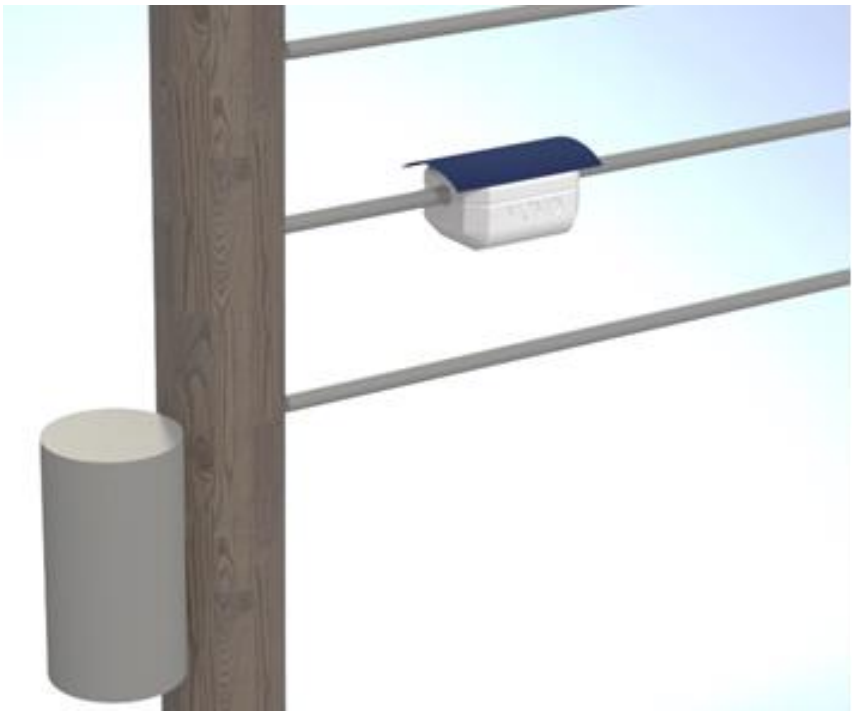


Figure 1. A prototype of the MCMD on a transmission line.

1.2 Why use the MCMD?

The MCMD is an excellent way of monitoring the current being drawn by appliances, either individually or in bulk through a node, such as your house's electrical panel. With a simple set-up procedure, the MCMD will make its data available to the user in a Google spreadsheet such that it can be easily accessed and processed for greater analysis. Unlike other electrical meters, the MCMD is a low-cost solution that can easily, and safely, be installed and removed from various electrical conductors. Rather than reading directly from the meter, data is permanently stored on a secure online storage to be accessed from the user's web portal of choice, be it a computer or other smart devices.

1.3 What are the benefits of the MCMD?

- **3 Functioning Modes:**
  The MCMD is capable of being self-powered using a solar panel and energy is stored using a battery bank. Based on the battery level, the MCMD will switch its operating mode accordingly: Functional Mode (100% Battery), Reduced Mode (50% Battery), and Shutdown Mode (10% Battery).
- **2 Ways to Operate:**
  The MCMD can be used in normal operation but can also easily be used in a testing mode, so the user can familiarize themselves with the device without the need for high currents. This also allows the user to test the device if there is any doubt about its performance.
- **Safety Features:**
  If there is a sudden spike in current from the secondary side, a Bi-Stable Relay is used to short the CT, preventing excessive heat from damaging the MCMD. Simultaneously, the MCMD will go into Safety Mode until the current is back to normal.
- **Secure Data Storage:**
  Data recorded is stored internally on the MCMD and the secured cloud server storage. It can only access by authorized personnel.
- **LTE data transmission:**
  The MCMD uses the SARA_R410M_02B LTE module for cellular communication to transmit its collected data to a cloud-based server.

1.4 How does it work?

The MCMD uses a split-core current transformer (CT) to induce an internal current proportional to that which is being measured on the primary line. The 1000A:5A current transformer steps down the current by a factor of 200 for the MCMD. The MCMD uses this internally induced current to generate informative reports on the current of concern. A report is generated every 5 minutes from samples collected every second. Each report will include the average and peak RMS current from the sampling period.

At intervals of either 12 or 24 hours, the MCMD will transmit its data to the online server to be accessed by the user in a Google Drive via Google Spreadsheets, following the process shown in Figure 2 below. Internal storage, through means of a micro-SD card, is also adequate for no less than two weeks of data and will clear itself every two weeks. For information about extending this period, please refer to the end of Section 10.08 Verifying the SIM Card Status.

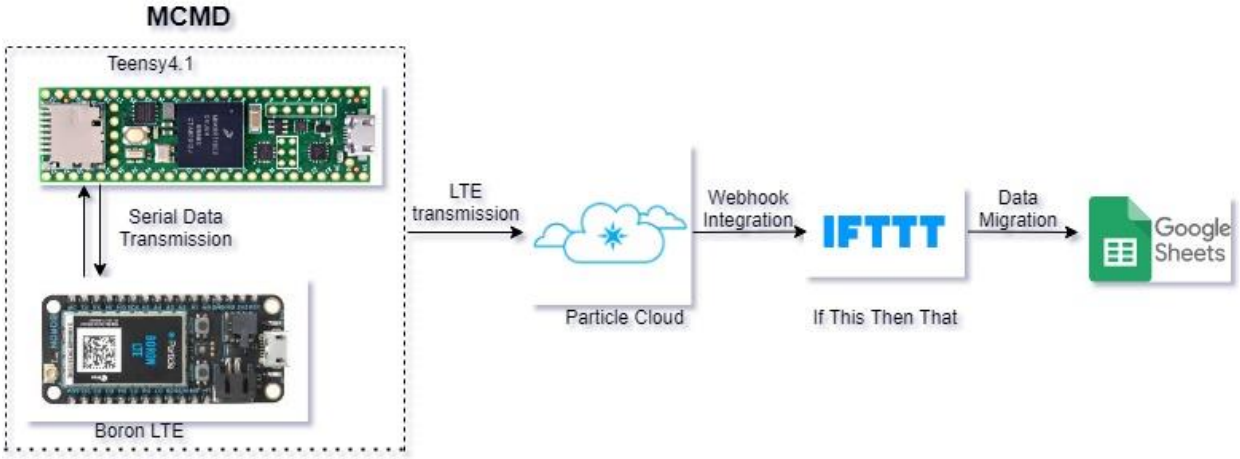


Figure 2. The flow of data from the MCMD to the Google Spreadsheets

1.5 Rated Operation of the MCMD

To ensure no damage occurs to the device during use, the MCMD is programmed to isolate itself from currents exceeding 1300A or internal temperatures exceeding 80 °C on the measurement board. **Do not deploy the MCMD on the current expected to be higher than this threshold.** As detailed in Section 2.4 Safety Mode, the MCMD will cease to function if either threshold is reached or exceeded. For high detected temperatures, the device will allow its internal temperature to decrease below the threshold before resuming activity.

In cold climates, the MCMD will make use of an ATtiny85 microcontroller with a PID controller program to turn on and manage a heating pad to warm up the device's internal batteries. The MCMD's hardware components were selected for their ability to operate 24/7 in harsh climates, such as Canadian cold winters and hot summers. To avoid damaging the MCMD due to temperature extremes, **do not deploy the MCMD in regions where the temperature will go below -30 °C (-22 °F) or above +50 °C (122 °F).**

2.0 MCMD Operational Modes

Before using the MCMD, it is best to understand more about its operating modes. The MCMD will be able to operate in four distinct modes depending on the current level of the conductor, operational temperature of the device, and its internal battery source level.

2.1 Functional Mode

The MCMD will operate in functional mode when the measured current from the line conductor belongs to the normal expected range of 2A to 1000A and that the MCMD's internal battery source level is above 50%, equivalent to 3500 mAh. In normal operation, the RGBW LED produces a 5-second pulse of Green indicating the device has entered Functional Mode and the device will transmit its stored data every 12 hours.

2.2 Reduced Power Mode

The MCMD will enter reduced power mode when its internal battery source level is equal to or below 50% (3500 mAh). The RGBW LED produces a 5-second pulse of Yellow indicating the MCMD has entered Reduce Power Mode and the device will transmit its stored data every 24 hours in normal operation.

2.3 Shutdown Mode

The MCMD will enter this mode when its internal battery level reaches 10% or lower, equivalent to 700 mAh or less. The device will only return to Reduced Power Mode once the internal battery level reaches 25%, equivalent to 1750 mAh. The MCMD is programmed to cease all data transmission and disable all its modules except for its internal charging module while operating in Shutdown Mode until it returns to Reduced Power Mode.

2.4 Safety Mode

The MCMD will enter Safety Mode when it detects currents higher than 1300A from the primary conductor or that its measurement board's internal temperature exceeds 80 °C (176 °F). When either of these events occurs, the MCMD will temporarily isolate the CT to protect the rest of the device's components. The MCMD is programmed to check the temperature condition of the device and the current from the line conductor once per second. The MCMD will only exit this mode when it detects lower current measurements and internal temperature.

3.0 Device Setup

The following section will highlight the process of setting up the MCMD for use. The first subsection will address the installation of the device for proper use. For more detailed information on the setting of the individual aspects of the MCMD, the following subsections will discuss the hardware and software in greater depth.

3.1 Prior to Installation

Before being employed on the conductor, the user must ensure that the MCMD is prepared for this task. The following tasks are critical for proper use.

1) Ensure the MCMD has a micro-SD card inserted within it, as shown in the lower right-hand corner of Figure 3 below. For more information on how to add a new micro-SD card to the MCMD please go to Section 10.01 Adding a New micro-SD Card to the MCMD.

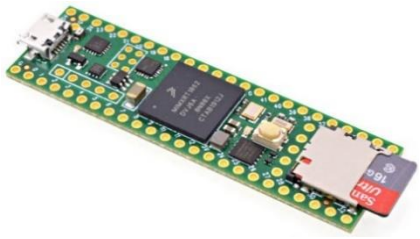


Figure 3. Teensy 4.1 with micro-SD card. [1]

2) Ensure the MCMD has six 18650 batteries that have been properly charged. Using batteries not intended for the MCMD will cause the device's behavior to be irregular. For information on replacing the batteries, please refer to Section 10.05 Changing the Batteries .
3) Ensure the solar panel is clean, with nothing obstructing the solar cells' capabilities of receiving direct sunlight. If the solar panel needs to be cleaned, see Section 10.02 Cleaning the Solar Panel.
4) Ensure the Current Transformer is not damaged.
5) Download the "Particle Application" on your mobile device and follow the instructions to claim and set up the Boron LTE. For more questions, visit https://docs.particle.io/quickstart/boron/.

3.2 Installation of a Conductor

Once ready for use, the MCMD can be installed on a conductor, much like the mockup in Figure 4 below, by following these subsequent steps. If the current transformer must be added to the MCMD, please refer to Section 10.11 Adding or Removing the Current Transformer from the MCMD.

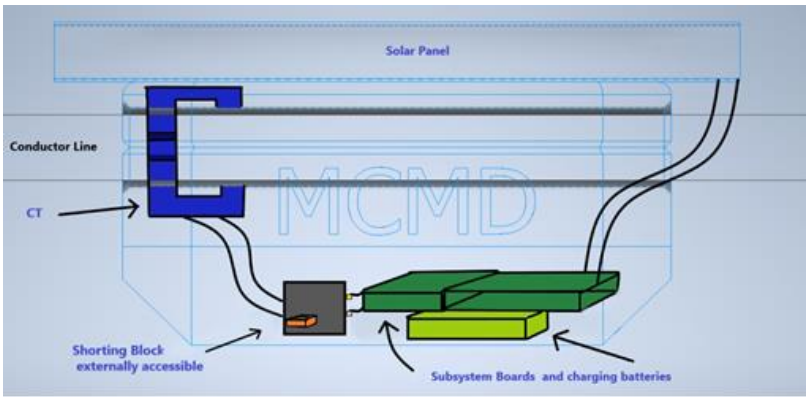


Figure 4. Internal mockup of the MCMD prototype with a theoretical encasing.

Note: Please note that only trained professionals with proper protective equipment (PPE) authorized to install and operate equipment on high-voltage lines conduct this process. The conductor in question will determine the exact equipment required, though we always recommend eye protection and gloves.

1) If possible, deactivate the conductor to be measured. This will help ensure no risk of damage to the device or the installer.
2) Open the shorting blocks on the MCMD, shown in Figure 5. This will ensure no current enters the MCMD until the user is ready.

Figure 5. The MCMD's shorting blocks. [2]

3) Using the side clips on the current transformer shown in Figure 6 below, open the CT and place the desired conductor inside the CT's sensing window. Ensure that the proper orientation is used, referring to the second picture in Figure 6 below before reattaching the CT's bottom. Ensure a clicking sound occurs to ensure the CT's bottom has been properly reattached.

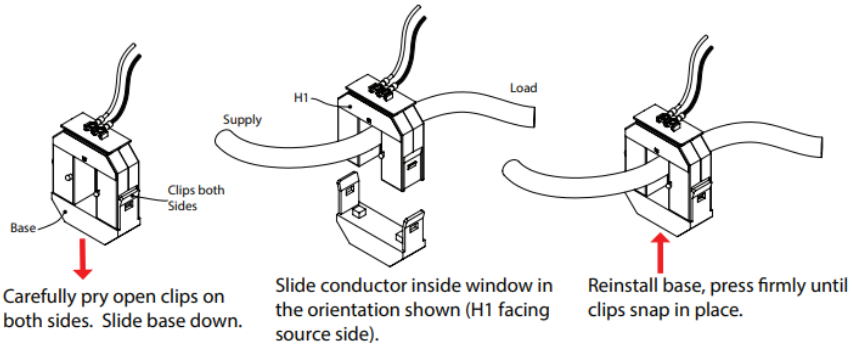


Figure 6. CTF 1000-5 SB Current Transformer [3]

- Note: The "load" refers to the item(s) using power, for which you wish to monitor the current usage. The "supply" is either an outlet or panel from which the current is being provided.

4) Hold down the POWER button, shown in Figure 7 below, to turn it on and initiate the device.
   - The MCMD will confirm that it has turned on with its LED by flashing green for 2 seconds.

Figure 7. The MCMD power button.

5) Before measuring the current, the MCMD will first initialize itself, performing a zeroing process to ensure the current measurements are accurate and ensuring it has cellular connectivity.
    - The MCMD will confirm that the initialization is complete with its LED by blinking green twice.
6) The MCMD's shorting blocks can now be closed.
    - The MCMD will then start sampling the measured current value from the conductor.

4.0 Managing the MCMD's Data

Once operation, the management of the MCMD is a simple procedure and will require the user to access the data transmitted by the MCMD either via Google Drive or the local CSV files saved to micro-SD card. The following sections will address these tasks.

4.1 Accessing the MCMD's Online Reports

Once in operation, the MCMD will upload its data every 12 or 24 hours (in normal operation), depending on the capacity of the internal power source. To access these reports, follow these steps:

1) Log into Google Drive with the following account information:
    a. Username: unbmcmd@gmail.com
    b. Password: MCMDNBPower2021

    Note: The user can choose to change the password for security reasons. In the case that the password has been forgotten, creating a new password can be done by following the steps in Section 10.04 Creating a New Password.

2) Select the "MCMD" folder, then the "Reports" folder.

Two folders should now be visible, "MCMD Status" and "MCMD Datapoints". The following subsections will explore the significance of both.

4.1.1 MCMD Status Folder

Within the MCMD Status folder, a report is generated and appended to the spreadsheet every time a significant event occurs. The MCMD Status spreadsheet will have the following columns shown in Table 1.

Table 1. Label definition of MCMD Status spreadsheet.

Label	**Meaning**
Date/Time of Report Generation	The time and date the report was sent to the internet.
Date/Time of Event	The time and date the individual event occurred within the MCMD.
Event Type	Describes what occurred within the MCMD to generate the report.
Reason for Event	Describes the reason the event occurred.

4.1.1.1 MCMD Event Types

With regards to the events to be logged in the MCMD Status spreadsheet, the following events in Table 2 may be seen:

Table 2. MCMD Status Event Types

Report Type	Event Meaning	Remedy
Safety Mode – High Current	The MCMD recorded a current above 1300A and has isolated itself.	The MCMD will periodically sample the current and will return to normal operation once the current has gone below 1300A.
Safety Mode – High Temperature	The MCMD recorded a temperature above 80℃ and has isolated itself.	The MCMD will periodically sample the temperature of the measurement subsystem and will return to normal operation once the internal temperature has gone below 80℃.
Entered Reduced Power Mode (I)	The MCMD's battery charge level has decreased to 50% or less of its full charge.	None. Allow the MCMD to charge.
Entered Shutdown Mode	The MCMD's battery charge level has decreased 10% or less from its full charge.	None. Allow the MCMD to charge.
Entered Reduced Power Mode (II)	The MCMD's battery charge level has increased to 25% of its full charge and has returned to Reduced Power Mode from Shutdown Mode	None
Entered Functional Mode	The MCMD's battery charge level has increased above 50% of its full charge.	None
Low Current Detected	The MCMD has sensed a current below its threshold of 1A or 2A (mode dependent, see Section 8.1 Testing Modes) for 60 consecutive samples.	Ensure this was expected. If unexpected, contact an electrician or the power commission to report the incident if necessary.

4.1.2 MCMD Datapoints

Within the MCMD Datapoints folder, numerous spreadsheets can be found, all of which will be specific to your device. Datapoints, generated every 5 minutes, are appended to a spreadsheet. When the spreadsheet has 2000 rows of data, equivalent to approximately 14 days, it will automatically create a new spreadsheet to append the upcoming data. The columns of the Datapoints spreadsheet will use the naming scheme shown in Table 3 below.

Table 3. Label definition of Datapoints spreadsheet.

Label	**Meaning**
Date & Time of Report Generation	The date and time that the report was sent to the spreadsheet.
Date & Time of Data Collection	The date and time that the individual data point was created within the MCMD.
Average RMS Current	The average RMS current of all samples collected within the 5-minute interval.
Peak RMS Current	The peak RMS current of all samples collected within the 5-minute interval.

4.1.2.1 Downloading the Datapoints

Google Drive is suitable to hold many spreadsheets for the MCMD's usage. However, it is limited to 15GB of storage. With frequent usage, the user should consider backing up the MCMD's data to a local storage location to make room for more incoming data. To do this, the user can choose to download the files or simply delete them. To download the data and save it locally, follow these steps:

To save data as a standard Microsoft Excel File:

1) From Google Drive, right-click on the file or folder you wish to save locally.
2) Within the drop-down menu, select the "Download" option. The file or folder has now been saved locally.

To save data as a comma-separated value (CSV) file:

1) From Google Drive, open the spreadsheet you wish to save locally.
2) In the upper left-hand corner of the window, select the "File" tab.
3) Within the drop-down menu, hover over the "Download" option. This should open a new drop-down menu.
4) From the last drop-down menu, select "Comma-separated values (.csv, current sheet)". The file has now been saved locally.

To delete a file or folder from Google Drive:

1) From Google Drive, identify the file or folder you wish to remove.
2) Right-click on the file or folder of choice.
3) From the drop-down menu, select "Remove". The file is now no longer saved within Google Drive.

4.2 Accessing the MCMD's Local CSV Files

An alternative to the online transmissions of the MCMD's data is to refer to its micro-SD card within the Teensy 4.1 microcontroller. To access this information, adhere to the following steps. For safety, it is suggested that the MCMD not be operational during this process.

1) Remove the micro-SD card from the Teensy 4.1 and place it within a micro-SD card adapter such as those in Figure 8. If your personal computer has an SD card port, the smaller adapter on the bottom can be used, otherwise, a USB adapter is suggested.

Figure 8. Micro-SD card adapter and micro-SD card [4].

2) Within the micro-SD card, three files will be found, "datapointsOUT.csv", "event.csv" and "samples.csv". The first two files will contain the data you wish to recover. The third, "samples.csv", will contain the samples taken every second that was used to compute the latest datapoint within "datapointsOUT.csv".

Note: Once copied to your local hard drive, these files can be deleted from the micro-SD card. The MCMD will automatically recreate these documents without causing any further problems.

5.0 The MCMD's Operation

The following section will address the process with which the MCMD will perform during operation. Section 5.1 will demonstrate the system's internal flowchart, and Section 5.2 will demonstrate the visual feedback that the MCMD will engage.

5.1 MCMD System Flowchart

To better understand the process by which the MCMD will process its data, the following flowchart in Figure 9 demonstrates the logic steps conducted by the MCMD. Note that the MCMD has four DIP switches that can change the operation of the device. For more information on these parameters, please refer to Section 8.1 Testing Modes.

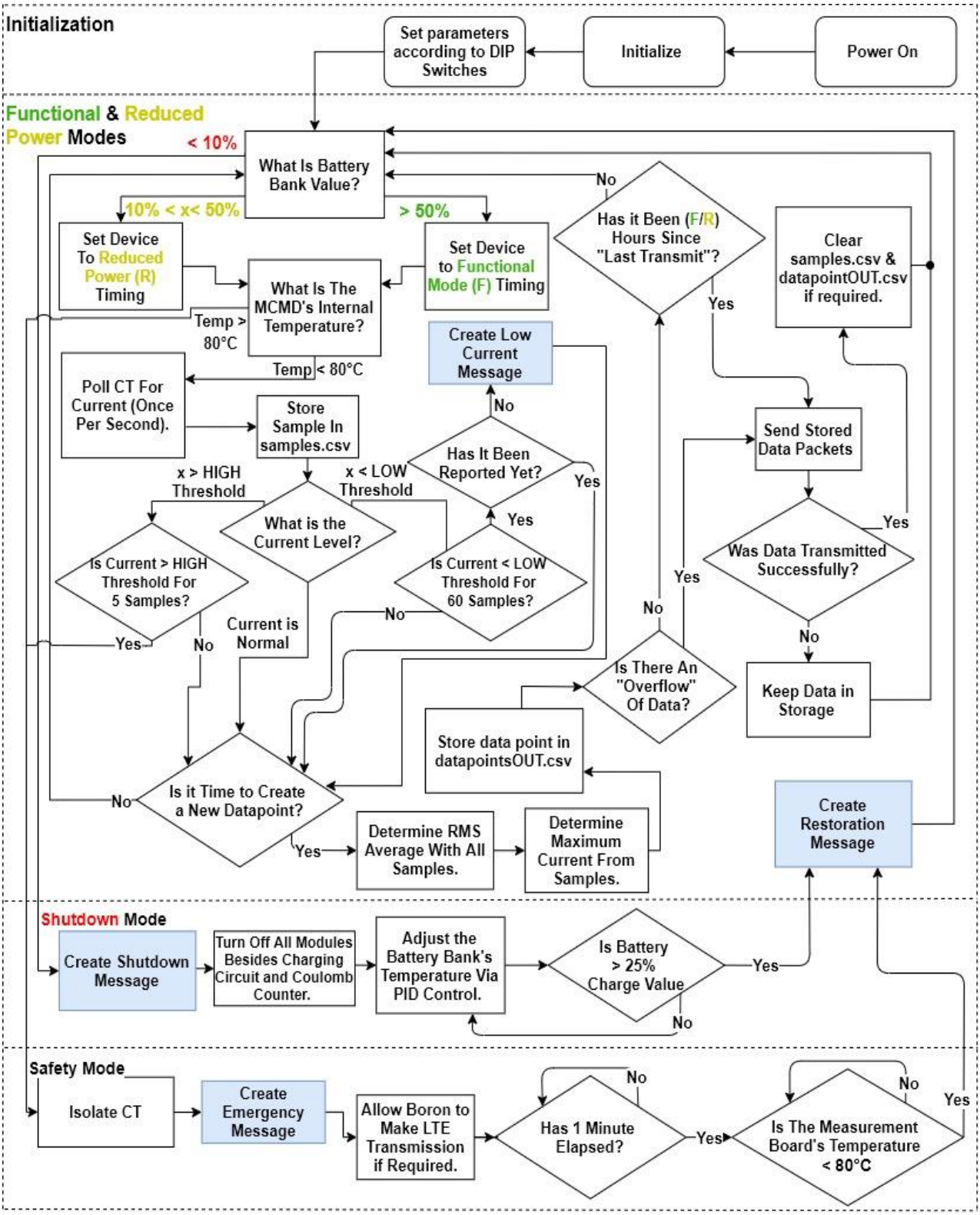
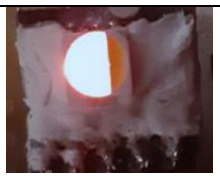


Figure 9. MCMD Operational Flowchart

5.2 The MCMD's Visual Feedback

During normal operation, the MCMD will indicate several important events about its operating mode using its RGBW LED and will also use a separate blue LED to demonstrate the use of the cellular module. Table 4 below will outline its patterns and will show the LED color with Figure 10 through 14. For information on the Testing Mode LEDs, please refer to Section 8.1 Testing Modes and visit our website at https://wordpress.com/page/mcmdca.wordpress.com/7 to see the videos demonstration for each test case.

Table 4. The MCMD's RGBW LED Patterns

Reason	LED Pattern	Color
Powering ON	The LED will turn on GREEN for 2s.	 *Figure 10. The MCMD's Green LED*
Initialization Complete	The LED will flash GREEN twice within 2 seconds.	
Entering Functional Mode	The LED will turn on GREEN for 5s.	
Entering Reduced Power Mode	The LED will turn on YELLOW for 5s.	 *Figure 11. The MCMD's Yellow LED*
Entering Shutdown Mode	The LED will turn on RED for 5s.	 *Figure 12. The MCMD's Red LED*
Entering Safety Mode	The LED will turn on WHITE for 5s.	 *Figure 13. The MCMD's White LED*
Cell Module Initializing	The LED will blink rapidly until the initialization is complete.	 *Figure 14. The MCMD's Blue LED*
Cell Module Transmitting	The LED will be on BLUE during the entire transmission.	
Cell Transfer Complete	The LED will blink slowly twice to confirm the transmission is complete.	

6.0 The MCMD's Subsystems

This section will examine the various subsystems which make up the MCMD, to facilitate the identification of issues if required. For a full schematic of the MCMD, please refer to Section 9.0.

6.1 The Measurement Board

The data processing board is shown in Figure 15 below. The items and their functions are defined in Table 5 below.

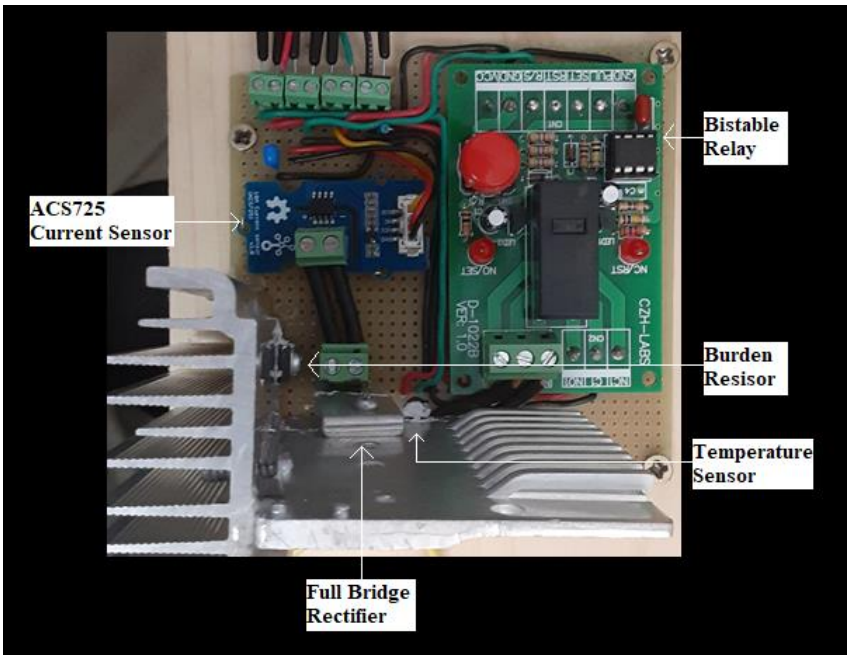


Figure 15. The MCMD's Measurement Board

Table 5. The MCMD's measurement board item list.

Component	Purpose
ACS725 Current Sensor	Measures the current entering the MCMD.
Bistable Relay	Isolates the MCMD in Safety Mode. For more information, see Section 2.4 Safety Mode.
Burden Resistor	Prevents inrush currents and regulates the power of the measurement board.
Temperature Sensor	Measures the temperature of the measurement board, allowing the MCMD to enter Safety Mode when required. For more information on Safety Mode, see Section 2.4 Safety Mode and Section 5.1 MCMD System Flowchart.
Full Bridge Rectifier	Rectifies the input AC to a pulsating single polarity current.

6.2 The Data Processing Board

The data processing board is shown in Figure 16 below. The items and their functions are defined in Table 6 below.

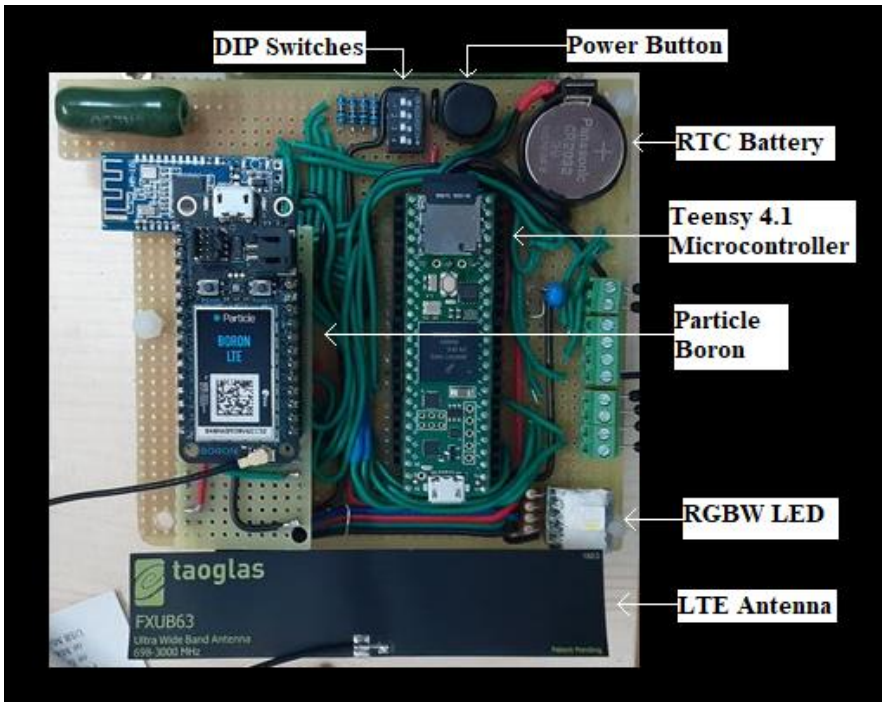


Figure 16. The MCMD's Data Processing Board

Table 6. The MCMD's data processing board item list.

Component	Purpose
Power Button	Turns the MCMD on or off.
Teensy 4.1	Primary microcontroller (Data & Battery).
Particle Boron	Secondary microcontroller (LTE).
RTC Battery	Keeps track of time when the MCMD is not powered.
DIP Switches	Used for various tests. See Section 8.1 Testing Modesfor more information.
RGBW LED	Used for the MCMD's visual feedback. See Section 5.2 The MCMD's Visual Feedback for more information.
LTE Antenna	Used to communicate data from the MCMD to the online server.

6.3 Power Board

The power board is shown in two parts, in Figure 17 and Figure 18 below. Their items and their functions are defined in Table 7 and Table 8 below.

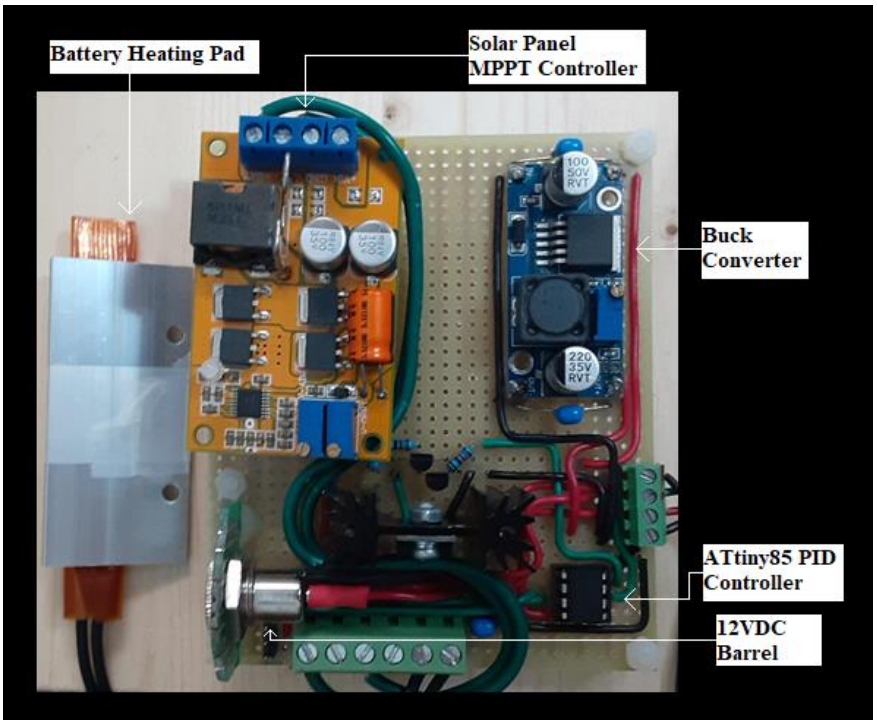


Figure 17. The MCMD's First Power Board

Table 7. The MCMD's power board item list.

Component	Purpose
Solar Panel MPPT Controller	The MPPT module is responsible for matching a steady voltage between the solar array and the battery bank for charging. It will ensure no over-charging occurs.
Buck Converter	To step down the voltage of the solar panel (8.4-12.6V) to the voltage supply to the MCMD (3.3V).
ATtiny85 Microcontroller	To manage and disable the heating pad with a PID controller.
Battery Heater Pad	Heats the battery array based on the requirements set by the ATtiny85 microcontroller.
12VDC Barrel Plug	Used for charging the 18650 batteries when in storage or removed from storage. For more information, please refer to Section 10.12 Placing the MCMD in Storage

Figure 18. The MCMD's Second Power Board

Table 8. The MCMD's second power board item list.

Component	Purpose
Coulomb Counter	This module will monitor the battery level and will be used as a reference for the prompts to change the device's operating state.
Battery Monitoring System	The BMS will include the fusing, Polyamide Heater, and three series (2P3S) Li-ion batteries. It will make sure that the Li-ion batteries stay at a temperature suitable for charging.
18650 Batteries	A series of reliable batteries capable of powering the MCMD for long periods, arranged in a 2P3S formation.

7.0 MCMD Software

The following section will describe the process of accessing the inner workings of the MCMD via its software.

Warning: Changes to the settings of this section should not be done unless necessary and it is recommended to first contact the MCMD administrative team for any concerns about modifying the MCMD's operating system.

To avoid any irreparable changes, please visit "https://github.com/UNBMCMD" and download all content to access the software used for the MCMD's operation with the following login credentials.

a. Username: unbmcmd@gmail.com
b. Password: MCMDNBPower2021

7.1 Arduino IDE

Most of the software written for the MCMD was done in the Arduino IDE for the MCMD's primary microcontroller, the Teensy 4.1. To make changes to the software of the MCMD, the following steps must be followed.

1) Go to "https://www.arduino.cc/en/software" and download Arduino IDE version 1.8.11. It is important for this version to be selected, as it must be compatible with the software in step 2 below.
2) Go to "https://www.pjrc.com/teensy/td_download.html" and download Teensyduino, Version 1.53. This software library will make the MCMD compatible with the Arduino IDE.
3) Once the Teensyduino software packages have been download, unzip its content into the library folder for the Arduino IDE. This will ensure all packages are properly accessible to the Arduino IDE.
4) Access the "MCMD Master Code" software from the GitHub link and open the file from the Arduino IDE.
5) Before making any changes to the software, save it as a new revision by "File" and "Save As".
6) You may now make the appropriate changes to the device.

7.2 Particle IDE

The software responsible for the transmission of data from the MCMD to the Google Spreadsheets is compiled within the Particle IDE for the MCMD's secondary microcontroller, the Particle Boron. To make changes to this software, the following steps must be followed.

1) Go to "https://www.particle.io/" and select the "Login" option in the upper right-hand corner.
2) Similar to the Google Docs login process, log into Particle IoT with the following account information:
    c. Username: unbmcmd@gmail.com
    d. Password: MCMDNBPower2021
3) On the left-hand of the screen, select the "Particle IDE" option. A new window/tab will open and direct you to the Particle IDE.
4) To make changes to the software, select the program called "MCMD Master Code".
5) To complete the update, ensure the MCMD's Particle Boron is connected to a computer via its micro-USB port and select the "Flash" option on the right-hand side of the screen. If there are any issues regarding flashing a new revision to the Particle Boron, please refer to Section https://docs.particle.io/tutorials/device-os/led/boron/#standard-modes

6) 10.07 Trouble Flashing to the Boron.

7.3 Webhooks

The process of sending data from the MCMD to the Google Spreadsheets is done in two distinct steps, the first of which is the use of Webhooks. To make changes to the Webhooks process, follow these next steps. Again, please do not make any changes to these parameters unless necessary, and contact the MCMD's admin team if you have any concerns.

1) Go to "https://www.particle.io/" and select the "Login" option in the upper right-hand corner.
2) Similar to the Google Docs login process, log into Particle IoT with the following account information:
    a. Username: unbmcmd@gmail.com
    b. Password: MCMDNBPower2021
3) On the left-hand of the screen, select the "Integrations" option. You will now see all integrations used to send data from the MCMD to the Google Spreadsheets.
4) To make changes to any of these integrations, click on the one of concern.
5) In the upper right-hand corner, select the "EDIT" option. The following information in Figure 19 will be seen.

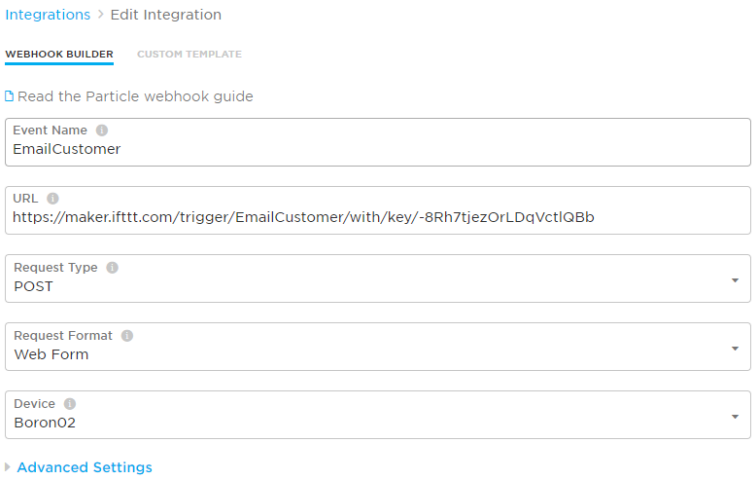


Figure 19. Particle IoT Webhook Integration Window

6) Clicking on "Advanced Settings" will show the parameters in Figure 20 below, which are those to be sent to the Google Docs server for your reports.

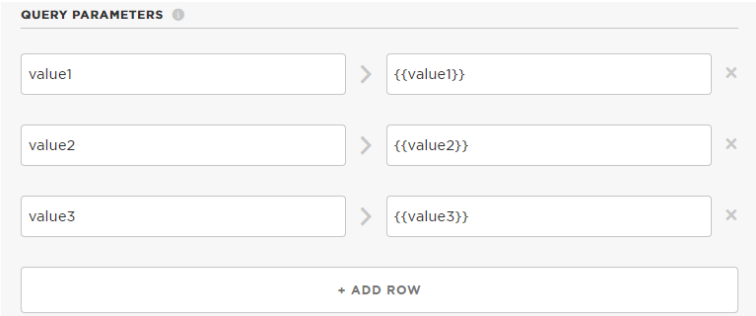


Figure 20. Particle IoT Webhook Customer Parameters

7.4 If This Than That (IFTTT)

The fourth component to the MCMD's inner working is the use of IFTTT to direct the data from the Particle IoT to the Google Docs' spreadsheet. To make any required changes, follow these steps.

Warning: Changing this field could have a great effect on the MCMD's ability to convey its data to the user. Do so carefully and only if necessary.

1) Go to "https://ifttt.com/" and select the "Login" option.
2) Enter the MCMD's login information as follows:
    a. Username: unbmcmd@gmail.com
    b. Password: MCMDNBPower2021
3) You should see all the "Applets" used by the MCMD, as shown below in Figure 21.

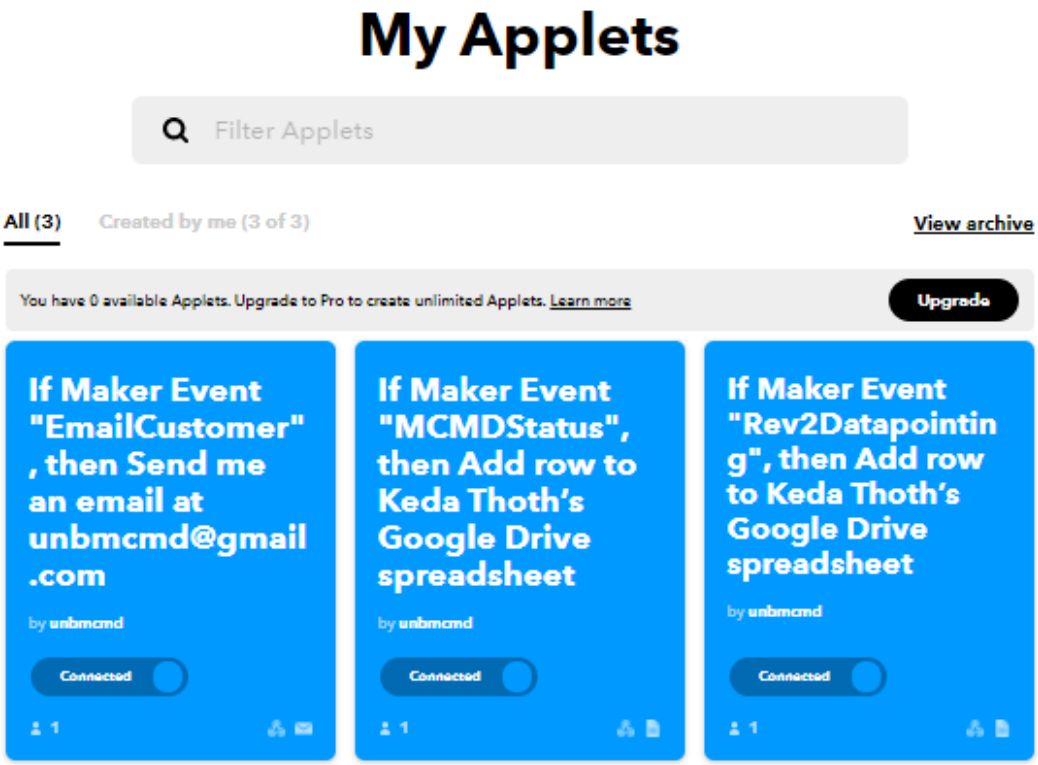


Figure 21. IFTTT Applets

4) To make changes to any of the applets, click on the one of concern.
5) In the upper right-hand corner click the "Settings" button.
6) You will now see the following visualization of the IFTTT flow, shown in Figure 22 below.

Figure 22. IFTTT Applet Editing

You may now choose to change either the prompt or the result of the prompt by following the next options:

7.4.1 Changing Webhooks from IFTTT

To make changes to how the applet is triggered by the MCMD, you will need to change the webhook that initiates the process in question. For this, click on the "If" tab, shown in Figure 22 above.

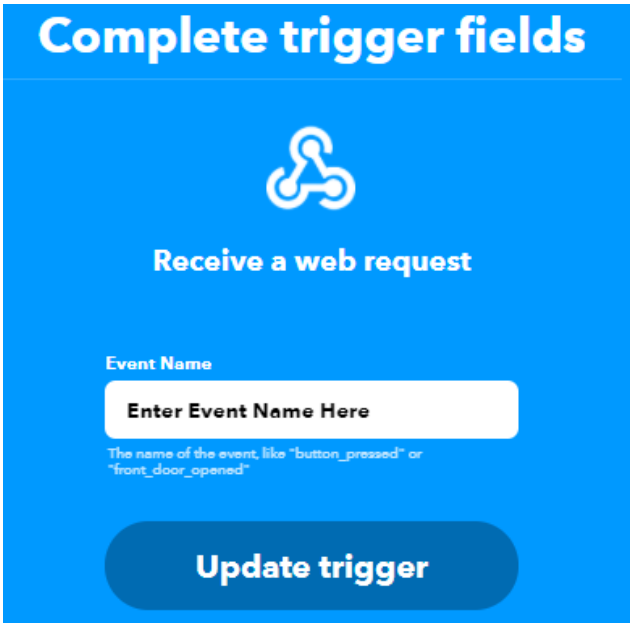


Figure 23. IFTTT Webhook Editing

You will now see what is shown in Figure 23 above. Changing this field will change the prompt which the MCMD uses to publish its data to the desired spreadsheet. Select "Update trigger" when you have completed the required action.

f72jtkIrkH4iVIvpkjGXh7EpiuVTa9UuWUsxxiIIiUN

7.4.2 Changing the IFTTT Spreadsheet Parameters

The second tab of Figure 22 above, termed "Then", which determined what the MCMD does with the data it is publishing, can be selected to modify the process. Figure 24 below shows the options given to the user, and Table 9 described their function.

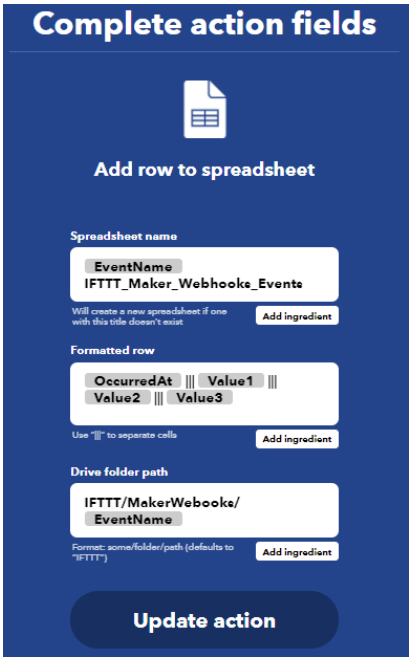


Figure 24. IFTTT Spreadsheet Editing

Warning: Please note that all applets used by the MCMD are created purposefully and should not be changed unless necessary. Changing anything in these fields may result in the MCMD no longer being capable of creating the reports as designed.

Table 9. IFTTT Spreadsheet creator options.

Label	**Meaning**
Spreadsheet name	The name of the spreadsheet, as it shows in Google Docs
Formatted row	These are the columns, in order, that will populate the Google Spreadsheets.
Drive folder path	This is the folder hierarchy within your Google Docs.

Note that in each case, there is a "Add Ingredient" button. This allows the user to select and add variables that IFTTT refers to as ingredients. Table 10 below will outline their significance.

Table 10. IFTTT Ingredients Definition.

Label	**Meaning**
Event Name	Identical to the text entered in the field of Figure 23 above.
Occurred At	The time at which the event was published online. This is the parameter used in the first column of all spreadsheets generated by the MCMD.
Value 1-3	IFTTT allows for up to 3 dynamic variables to be sent to the spreadsheets. This field should only be changed if less than three values are required. Changing the variables themselves is done within the Particle IoT software, seen in Section 7.2 Particle IDE, and the integrations discussed in Section 7.3 Webhooks.

When the required changes have been made, click on the “Update Action” button. This will return you to the menu in Figure 22, and you may now select “Update” to finish and apply the changes made to the IFTTT applet.

8.0 Device Testing

The following section is to be used for testing to ensure the MCMD is operating properly and for general familiarization of the MCMD. Note that these tests are best conducted without the CT, making use of a 5A variable constant current supply to mimic the secondary side of the CT. For information on adding or removing the CT or current supply, please refer to Section 10.11 Adding or Removing the Current Transformer from the MCMD.

8.1 Testing Modes

The MCMD is outfitted with 4 DIP switches, each responsible for a different parameter, all focused on increasing the rate at which the MCMD operates, such that the user can confirm various functionalities much quicker than with normal operation. With all switches, the down position indicates testing mode, as shown in Figure 25, while up corresponds to normal operation.

Figure 25. MCMD DIP Switches in Testing Mode.

Table 11. DIP switch identification and description.

DIP Switch #	DIP Switch Function	Description
1	Datapoint Intervals	Normal: 5 Minutes
		Testing: 1 Minute
2	Current Thresholds	Normal: 2A – 1300A
		Testing: 1A – 5A
3	LED Functionality	Normal: As indicated in Table 4.
		Testing: Always ON, displaying the current state.
4	LTE Transmission Intervals	Normal: 12/24 Hours, depending on the state.
		Testing: 5/10 Minutes, depending on the state.

8.2 Performing Testing on the MCMD

Several software packages will be provided with the MCMD prototype, available at the GitHub account “https://github.com/UNBMCMD”, which will allow the user to validate the MCMD functionality. For each case, the MCMD should be connected to a personal computer via USB to power the device, thus eliminating the need for batteries. Download the appropriate file and upload it to the Teensy via the Arduino IDE. For more information on this, please refer to Section 7.1 Arduino IDE.

Note: Ensure the DIP switches are all within the testing mode position, exactly as indicated in Figure 25 above. For a quick demonstration, the following revisions of the testing code may not follow the timings in Table 11.

8.2.1 Functional Sampling

This revision of the MCMD software will allow the MCMD to remain in functional mode to focus solely on its ability to measure a healthy current. Samples will be collected every second and computed into data points every 15 seconds. Then, the Particle Boron will initiate a transmission once every minute to the Google Spreadsheets.

To ensure the MCMD is working properly, allow this software module to run for several minutes, verifying that all recorded data points, each spaced by 15 seconds, are uploaded to the MCMD Datapoints spreadsheet. For information on accessing this data, please refer to Section 4.1 Accessing the MCMD's Online Reports.

8.2.2 MCMD OpModes

This revision of the MCMD software will allow the MCMD to cycle through its operating state (Functional, Reduced Power, and Shutdown), without the need for the battery or a current to sample. Uploading the software to the Teensy 4.1 microcontroller will start the MCMD in Functional mode, then to Reduced Power mode after 15 seconds, then to Shutdown Mode 15 seconds later. The device will then come out of Shutdown Mode and return to Reduced Power Mode, before finally returning to Functional Mode.

Once complete, an event will be logged for each of the changes and will be published to the MCMD Status spreadsheet on Google Drive. For information on accessing this data, please refer to Section 4.1 Accessing the MCMD's Online Reports.

8.2.3 Low-High Current

This revision of the MCMD software will test low and high currents to validate its ability to detect currents below the rated limit and above the safe thresholds. Since the DIP switches are set to testing mode, this will correspond to currents below 1A and above 5A. For information on installing a constant current source to the MCMD, see Section 10.11 Adding or Removing the Current Transformer from the MCMD.

Once uploaded to the Teensy 4.1 microcontroller, start the constant current source at a value below 1A. After 60 samples of low current, corresponding to approximately 60 seconds, an event will be logged indicated the current is below the threshold set by the DIP switches. Once this has been successfully logged, increase the current above the 5A threshold. After 5 samples, equivalent to approximately 5 seconds, the MCMD will respond by entering Safety Mode and logging the event. At this point, lower the current to within the 1-5A range. It will then wait for 1 minute before verifying the temperature of the measurement board and return to Functional or Reduced Power mode where it will then log this event as well. To conclude the simulation, the events logged will be uploaded to the MCMD Status spreadsheet on Google Drive. For information on accessing this data, please refer to Section 4.1 Accessing the MCMD's Online Reports.

9.0 Full Design Schematic

A full schematic of the MCMD is shown below in Figure 26 to demonstrate the connections between each module covered earlier in this document.

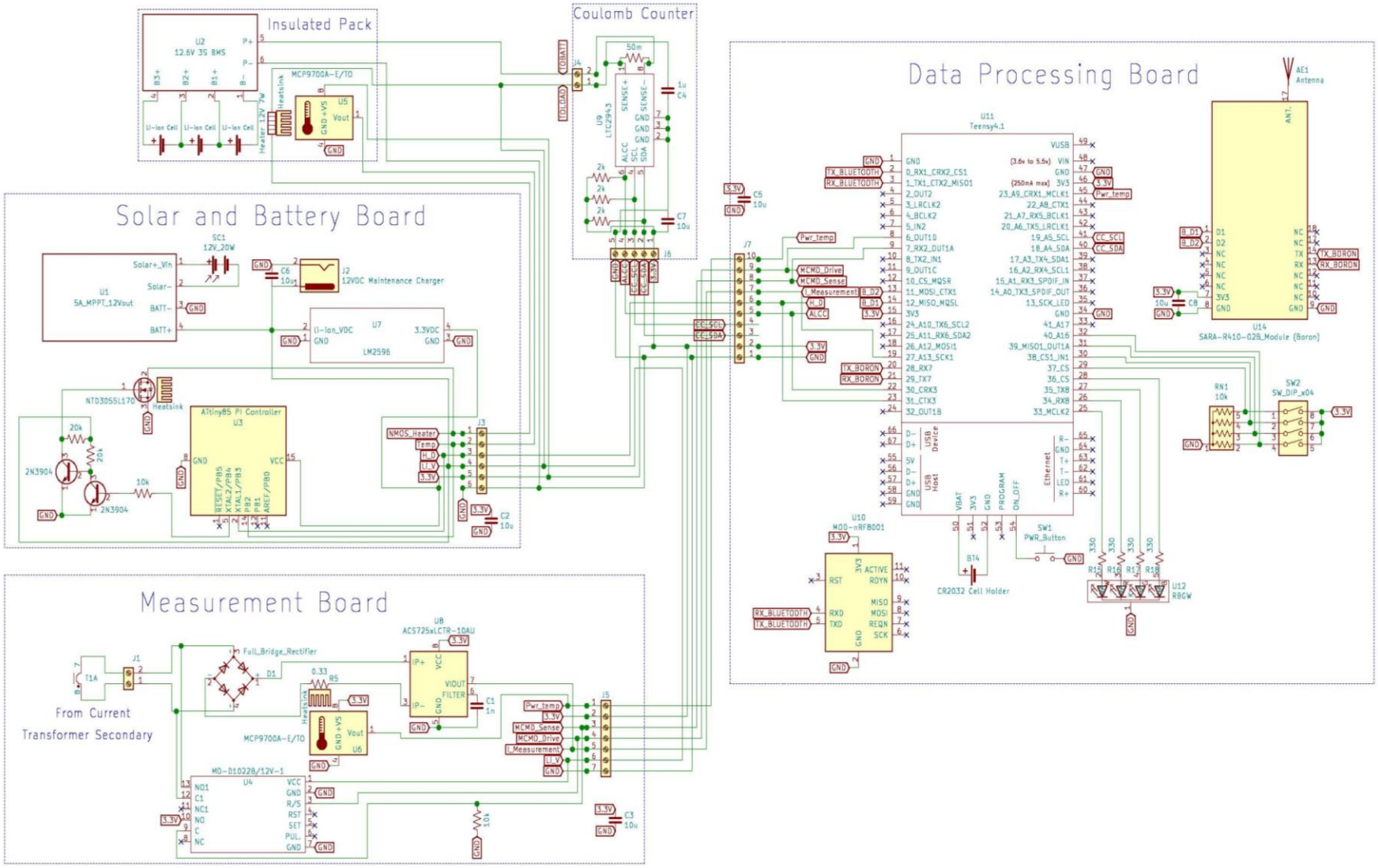


Figure 26. A full schematic of the MCMD.

10.0 Troubleshooting

The following section will address the troubleshooting of errors and concerns you may encounter while using or preparing the MCMD for use.

10.01 Adding a New micro-SD Card to the MCMD

If the micro-SD provided with the MCMD is either lost or damaged, it can easily be replaced. To ensure proper management of its data, it is strongly recommended to get a micro-SD with no less than 1GB of storage space.

For the micro-SD card to function properly in the MCMD, it must be formatted as FAT-32. To do this, the user will require a micro-SD card adapter for a computer. Follow these steps to complete the process.

Note: Formatting a storage device will clear any data currently within it. Due to this, ensure you have moved anything you wish to keep from this drive to a more permanent location.

Warning: Removing the micro-SD card while in use will result in corrupted data. Ensure that the MCMD is not on when removing the micro-SD card.

1) Place the micro-SD card within the adapter and connect it to a computer.
2) On the computer, access “This PC” (Windows) or “Finder” (Mac).
3) Right-click on the micro-SD storage device.
4) In the drop-down menu, select “Format”. The following window in Figure 27 appears:

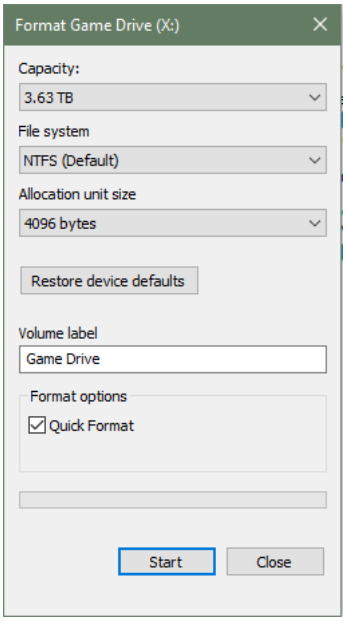


Figure 27. Storage Device Formatting Window

5) Select the “File System” drop-down and select FAT-32.
6) Click “Start” and allow the process to complete.
7) Once the system reports the process as complete, you may remove the micro-SD and place it within the MCMD.

10.02 Cleaning the Solar Panel

The solar panel is made of durable plexiglass and is quite easy to clean. Using a rag with warm water, wipe away any debris on the solar panel's surface will be satisfactory. A mild cleaning agent such as vinegar or Windex can be used, but be sure to rinse away the vinegar properly if used.

10.03 Setting the Recovery Email Account

To ensure the user can recover the unbmcmd@gmail.com account if the password is lost, it is recommended that you set your account as the recover account. To do this, follow these steps.

1) From a Google website, select "Manage you Google Account",
2) Go to the "Contact Info" section,
3) First, select "EMAIL", then set the "Recovery Email" as that of your choosing.
4) Next, select the "PHONE" option and enter your preferred contact number for security.

Note: You may choose to add more than one recovery account if desire.

10.04 Creating a New Password

In case the password has been changed and cannot be recalled, the password reset must go through MCMD admin.

1) On the Google login page, after entering the username as unbmcmd@gmail.com, select "Forgot Password".
2) Assuming the previous password cannot be found, select "Try another way".
3) An email will be sent to the MCMD administrative group if you have not yet set your alternative email account. For information on how to do so, please refer to Section 10.03 Setting the Recovery Email Account.
4) After validation, a link will be provided to the unbmcmd@gmail.com account to select a new password. Record this for safekeeping.

10.05 Changing the Batteries

Due to usage and deterioration, the MCMD's battery pack may need to be replaced. In this case, the following steps are to be followed:

1) Acquire a replacement battery pack from the MCMD supplier.
2) Remove the MCMD from its field operation.
3) Ensure it is powered down before continuing.
4) Open the MCMD casing by removing the case bolts using an Allen key.
5) Separate the MCMD casing along its center seam, taking care not to damage the water-tight seal.
6) By unscrewing the screw terminal on the MCMD power board, disconnect the battery pack's 12 VDC bare copper wire.
7) Cover the 12 VDC bare copper wire with electrical tape to ensure no shorting occurs.
8) Disconnect the battery pack GND wire from the MCMD power board screw terminal.
9) Unplug the MCMD battery pack data cable from the MCMD power board.
10) Remove the battery pack mounting bolts with an Allen key and remove the battery pack.
11) Insert the new battery pack and affix it with the mounting bolts.
12) Plug-in the data cable and affix the GND wire to the MCMD power board connectors.
13) Remove the protective cover from the 12 VDC wire and connect it to the 12 VDC MCMD power board terminal.
14) Close the case ensuring the water-tight seal is in place and tighten the case bolts.

15) Turn on MCMD to verify its functionality.

10.06 Particle Status LED

While using the particle boron, the status LED will indicate the state of the Boron at any given time. For a greater understanding of its various LED functions, please refer to Particle Boron's Tutorial website, indicated below.

https://docs.particle.io/tutorials/device-os/led/boron/#standard-modes

10.07 Trouble Flashing to the Boron

Due to the nature of the Particle Boron's LTE communication, it may be found that flashing code to the Boron is not a simple task. To facilitate this process, the design team recommends placing the Boron in Safe Mode before flashing a new revision to it. To do this, follow the instruction outlined below and refer to Figure 28 for reference.

1) To either side of the status LED are the MODE and RESET buttons. To enter Safe Mode, hold down both the MODE and RESET buttons momentarily and release the RESET button while still holding the MODE button. When the LED turns magenta, release the MODE button.
2) The Boron will then cycle through various stages, allowing it to connect to the LTE network while not executing any software, allowing it to be ready for any new upload.

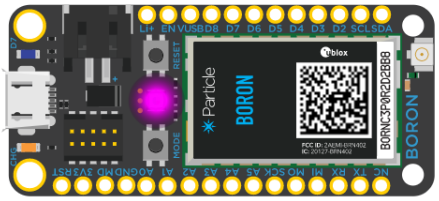


Figure 28. Particle Boron indicating Safe Mode with its status LED [5].

10.08 Verifying the SIM Card Status

The Particle Boron comes with a **Free Plan** including a development space limited to under 100,000 data operations per month. The user can choose to upgrade to the **Growth Plan** (720,000 data operations) or **Enterprise Plan** which offers pricing based on customer requirements [6].

However, if no data is being transmitted by the Boron, it may have exceeded its basic data limit. To verify this, go to "https://console.particle.io/sims", where you should see information similar to that in Figure 29 below.

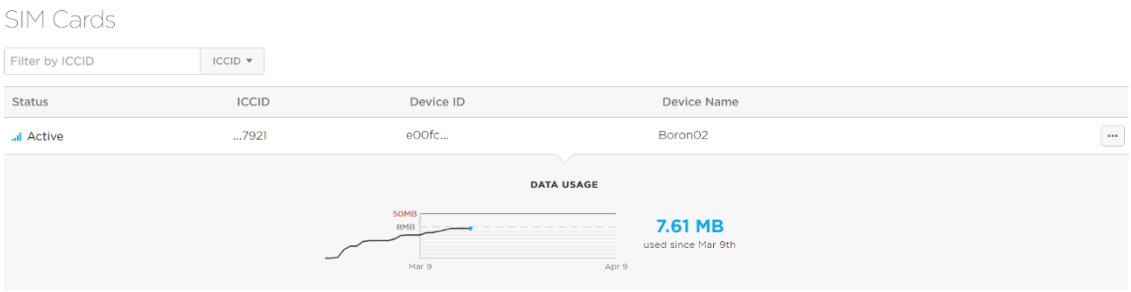


Figure 29. Particle IoT SIM Management

If the SIM card has exceeded its basic limit, it will show as inactive. An email will be sent from the Particle Team to inform the user of over-data usage. In place of a chart showing the consumption, a button to resume activity will be available. Click on this option and select the next threshold at which you wish the Boron to stop its transmissions.

Note that there is still an option to wait until the next billing cycle to resume regular usage according to the basic limit. The MCMD will continue to log its data points and events to the micro-SD within the Teensy 4.1 microcontroller and can be recovered manually, for more information on this, please refer to Section 4.2 Accessing the MCMD's Local CSV Files.

Recall that the MCMD will save up to two weeks of data on the micro-SD card, to increase this amount, refer to Section 7.2 Particle IDE to make changes to the software via the Arduino IDE and change the variable *CSVDaysSaved* from 14 (days) to a value of your choosing. Larger micro-SD cards will allow you to save much more data locally on the MCMD.

10.09 Missing One or More Datapoints on the Google Spreadsheets

It may occur that one or several data points are missing from the data transmitted to the online server locations. This is due to the less than perfect reliability of the Particle Boron's SARA_R410M_02B cellular module. If this occurs, the missing data can be collected from the MCMD internal micro-SD card storage. For more information on this, please refer to Section 4.2 Accessing the MCMD's Local CSV Files.

10.10 Time Saved on Datapoints is Not Correct

In the event where the timestamps on the MCMD data points are no longer accurate, one of two things may have occurred.

1) The RTC is no longer in sync.
2) The RTC's coin cell battery is depleted.

To resolve this issue, first, try reuploading the teensy software via a personal computer, this will resynchronize the time with the computer. Running the testing code, "Functional Sampling" in Section 8.2.1 Functional Sampling should indicate that timestamps are now accurate. Once complete, do not forget to re-upload the original code to the MCMD for proper operation.

If the problem persists, the coin cell battery may be depleted. To resolve this, a replacement for the MCMD's RTC coin cell battery, shown in Figure 30 below, will need to be inserted. Note that the battery is a very common type, the CR 2032, and can be purchased online or at most hardware stores.

Figure 30. The MCMD RTC Coin Cell Battery.

After replacing the battery, re-upload the MCMD primary software to re-synchronize the RTC module. The MCMD will now be able to accurately track time, events during power interruptions, such as transportation to the deployment site or during storage periods.

10.11 Adding or Removing the Current Transformer from the MCMD

In certain cases, mainly for testing purposes, the CT may be removed to input a small current directly into the MCMD without using the CT to step down the current by a factor of 200. Likewise, the CT may have already been removed and requires to be reinstalled on the MCMD.

To add a current source to the MCMD, either via the CT or directly from a current source:

1) Loosen the screw terminals with a Phillips screwdriver. The screws do not need to be loosened all the way, only enough to place the leads inside the gap, as shown in Figure 31.

Figure 31. Loosened Screw Terminal

2) Add the leads of the CT or the current source inside the screw terminals labeled Input #1 and Input #2 within Figure 32 below.

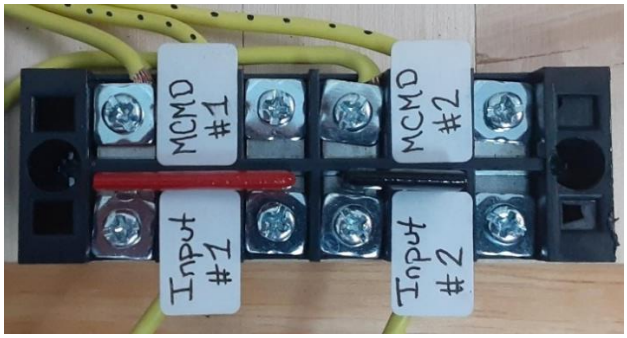


Figure 32. MCMD Screw Terminal Identification

3) Tighten the screw terminals. Do not tighten excessively, only enough to ensure the leads cannot be pulled out with any ease.

To remove the CT or the current supply, do the opposite of the steps above.

1) Loosen the screw terminals to the CT or current supply.
2) Remove the leads from the terminals marked Input #1 and Input #2 in Figure 32 above.

Note: Tighten the screw terminals before storing the MCMD. Do not leave the screw terminals loosened when not in use.

10.12 Placing the MCMD in Storage

If the MCMD is to be placed in storage, it can be connected to a 12 VDC source using a positive tip barrel plug to trickle charge the device or to prepare the device with an 80% charge before installing the MCMD on the line.

Contact Us

Don't hesitate to reach out to our technical support team with the contact information provided.

Email: IFT

Or, visit our website for more information, videos, and frequently asked questions about the MCMD.

Join the community!

Website:
https://wordpress.com/page/mcmdca.wordpress.com/33

Documentation:
https://wordpress.com/post/mcmdca.wordpress.com/134

FAQs:
https://wordpress.com/post/mcmdca.wordpress.com/188

Service Availability: (Atlantic Time (GMT-4))

Monday	9:00 am – 5:00 pm
Tuesday	9:00 am – 5:00 pm
Wednesday	9:00 am – 5:00 pm
Thursday	9:00 am – 5:00 pm
Friday	9:00 am – 5:00 pm
Saturday	Closed
Sunday	Closed

Thank you for your support! Tell us about your experience on our website.

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[1] PJRC, "Teensy 4.1 Released," [Online]. Available: https://www.pjrc.com/teensy-4-1-released/. [Accessed 28 February 2021].

[2] AutomationDirect, "KN-KBD10," [Online]. Available: https://www.automationdirect.com/adc/shopping/catalog/terminal_blocks/konnect-it_din-rail_terminal_blocks/disconnect_terminal_blocks_-a-_accessories/kn-kbd10. [Accessed 28 February 2021].

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[4] Walmart, "Gohope SD Card Reader Portable USB 3.0 Dual Slot Flash Memory Card Adapter Hub for SD, SDHC, SDXC, MicroSD, MicroSDHC, MicroSDXC WHITE," [Online]. Available: https://www.walmart.ca/en/ip/Gohope-SD-Card-Reader-Portable-USB-3-0-Dual-Slot-Flash-Memory-Card-Adapter-Hub-for-SD-SDHC-SDXC-MicroSD-MicroSDHC-MicroSDXC-WHITE/7HZ686ULUDC0. [Accessed 15 03 2021].

[5] Particle , "STATUS LED - BORON," [Online]. Available: https://docs.particle.io/tutorials/device-os/led/boron/#:~:text=To%20factory%20reset%2C%20hold%20down,the%20same%20time%2C%20safe%20mode). [Accessed 15 March 2021].

[6] Particle IoT, "Pricing FAQ," [Online]. Available: https://support.particle.io/hc/en-us/articles/360039741073-Pricing-FAQ/?mkt_tok=MDc5LU5VWi0zOTEAAAF74FIyi0rr9v_hf_Qjh09HN77n5HuIKWqEDs0fs_vg_LkKoBpnfW-WCR1m1qkRDiNaFEbM44iUkLAM6DF4SJhEs6EJBSWho8MyQABx7KYR. [Accessed 18 March 2021].