Application Note

DA9070 Power Profile Manager and SOCF

AN-SW-121

Abstract

The application note describes the State of Charge Function (SOCF) with DA9070 and how its functionality is realized with DA9070 and the target system. It describes the list of features provided by the related code and how it is incorporated into the target system. It also introduces a tool which is used to calibrate the Fuel Gauge (FG) demo board and characterize a battery.

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1 Terms and Definitions

ADC	Analog to Digital Converter
CC	Constant Current
COM	Communication Port
CV	Constant Voltage
EOC	End Of Charge
FG	Fuel Gauge
FTDI	Future Technology Devices International
HW	Hard Ware
IBAT	Current to/from Battery
IMON	Battery discharge current Monitor
MCU	Micro Controller Unit
PPM	Power Profile Manager
SOC	State Of Charge
SOCF	State Of Charge Function
USB	Universal Serial Bus
VBAT	Voltage of Battery

2 References

[1] DA9070, Datasheet, Dialog Semiconductor.

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3 Introduction

The State of Charge (SOC) is an important parameter in modern day applications that will provide the energy level of a rechargeable battery. It is an abstract energy concept which is typically the ratio of the available capacity to the attainable capacity of a battery pack. This Application Note first introduces the SOC concept followed by the algorithm implemented in our system. Then it describes how to deploy the State Of Charge Function (SOCF) for DA9070 based applications and Power Profile Manager (PPM) is also introduced to characterize the battery. The SOCF consists of interface code and a library. The usage of the code and library is described within this document.

4 State of Charge Concept and Algorithms

As defined earlier, the SOC is the ratio of the available capacity to the total capacity of a battery pack. However, modelling a battery is a complex task. The battery specification only provides its capacity for a given discharge rate. If one draws a different current from a battery which in turn means a different discharge rate, then the capacity of the battery changes. In Figure 1, the battery voltage versus the capacity of the battery is plotted for different discharge rate.

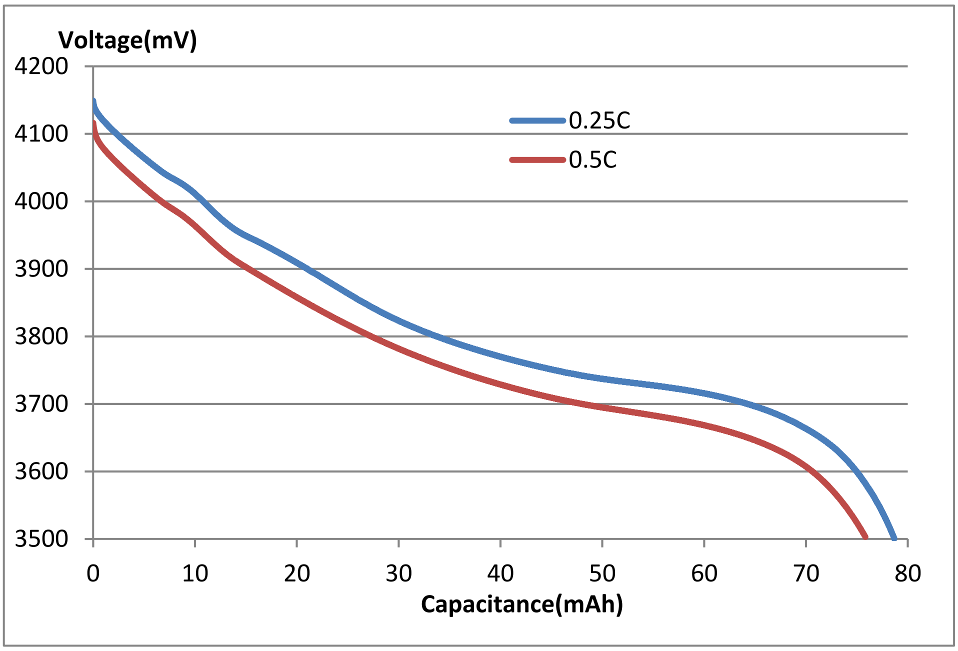

Figure 1: Battery Voltage versus Battery Capacity

A C-rate is a measure of the rate at which a battery is discharged relative to its maximum capacity. A 0.5C rate means that the discharge current will discharge the entire battery in two hours. In the graph, given that the cut off voltage of the battery is 3.5 V, it is evident that the battery has a lower capacity for a higher discharge rate. Hence, the current drawn from the battery is needed to estimate the SOC accurately.

4.1 Coulomb Count Based Algorithm

Generally, hardware (HW) coulomb counter integrates a voltage which is the result of a current flowing through a sensing resistor. The coulomb counting is maintained continually and SOC is calculated from the coulomb counting result directly. This algorithm has several weak points. This HW-based algorithm must always run on the target system. It is not a good solution for an application requiring very low power consumption like BLE or wearable devices. Additionally, an offset error due to some tolerance of a component or ADC itself can be accumulated for a long time. Therefore, some complex algorithms for cancelling this accumulated error are required.

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4.2 Only Voltage Based Algorithm

This solution is SOC estimation from a lookup table of voltage versus SOC. This table can be generated through the measurement of the voltage of a battery during a specific constant power consumption. Though this algorithm is very simple, it is not suitable for any application with dynamic power consumption like wearable devices.

4.3 SOCF Algorithm

The SOCF algorithm is based on the voltage and the current of the battery. The voltage is from ADC of the target system and current is from IMON of DA9070. The SOC is worked out with parameters and battery profile data, see Figure 2. There is no accumulation error in this algorithm and SOC can be estimated accurately at various ranges of power consumption. There is no apparent power consumption by the SOC estimation because a measurement is done very quickly with intervals over 10 seconds.

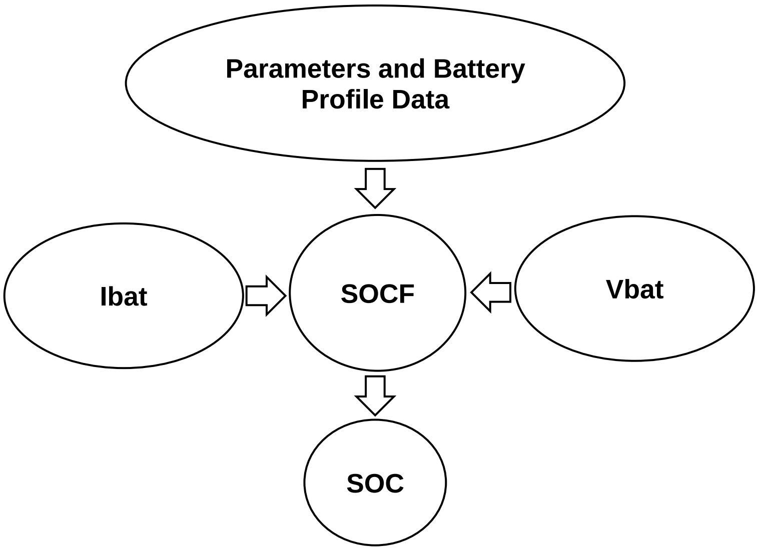

Figure 2: SOCF Algorithm

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5 Battery Profile Process

The SOCF algorithm is based on battery profile data which can be generated using DA9070 Fuel Gauge (FG) demo board and the PPM. The battery profile process with the PPM consists of three sub-processes, see Figure 3. It is recommended that all processes are performed at room temperature for accurate data, measurement, and comparison.

Figure 3: Battery Profile Process with the PPM

5.1 Calibration and Parameters

The voltage and current are measured during battery profile process. To achieve accurate measurement, power calibrations are required for reducing potential differences due to the tolerance of components and power levels on the board. Various parameters for correct PPM operation must be loaded from the DA9070 FG demo board. This process must always be performed before a battery profile or a performance test.

5.2 Battery Profile

Battery profile can start after all values and parameters are set. No manual control is needed during battery profile and the profile data is automatically sent to a PC when completed.

5.3 Performance Test

Performance test starts automatically after a battery profile is done. The SOC from Reference HW FG on the board and SOCF algorithm in the MCU are compared during full discharging and charging cycle. The result should be stored in the specified path of the PC.

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6 Power Profile Manager

This section describes the PPM which is designed for calibration, managing profile data, battery profile, and performance test. The PPM runs on a PC connected to a DA9070 FG demo board, see Figure 4. The major functions of the PPM are:

- Configuration of FTDI device for serial communication
- Power calibration
- Set parameters
- Battery profile
- Performance test
- Manage/import/export battery profile data

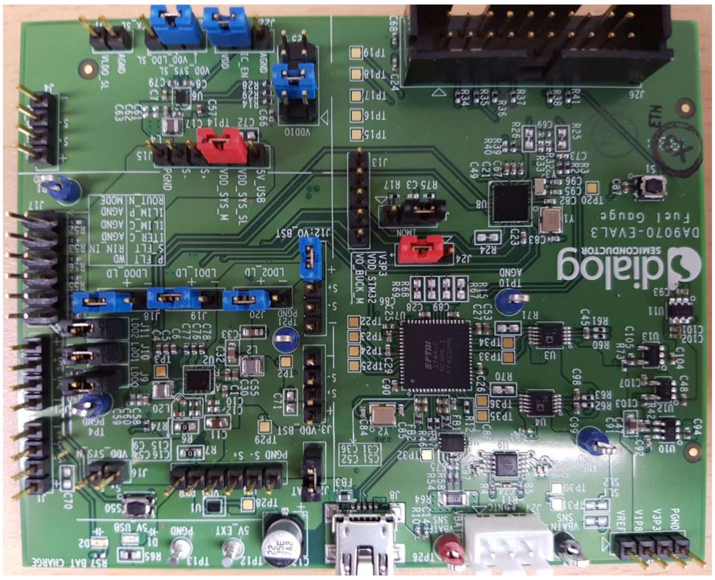

Figure 4: DA9070 FG Demo Board

NOTE
Confirm the jumper configurations shown in Table 1 before performing any test.

Table 1: Jumper Configurations

Jumper	Pin Connection	Jumper	Pin Connection
J23	2-3	J18	1-2
J22	1-2	J19	1-2
J25	3-4	J20	1-2
J15	2-3	J11	1-2
J6	2-3	J10	1-2
J12	1-2	J9	1-2
J24	2-3	J2	1-2

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6.1 PPM Main Window

Figure 5 shows the main screen of the PPM, which has six options:

- **FTDI port selection**: Select a port of the FTDI device on the board for serial communication between the PPM and DA9070 FG demo board.
- **Calibration and Parameters**: Power calibration and set parameters for battery profile or performance test.
- **Profile Data**: Manage/import/export battery profile data.
- **Battery Profile**: Generates the battery profile data which characterizes the battery under consideration.
- **Performance Test**: Compares the SOC from Reference FG and SOCF algorithm.
- **File Path**: Setting a default directory for importing/exporting profile data and the result of battery profile.

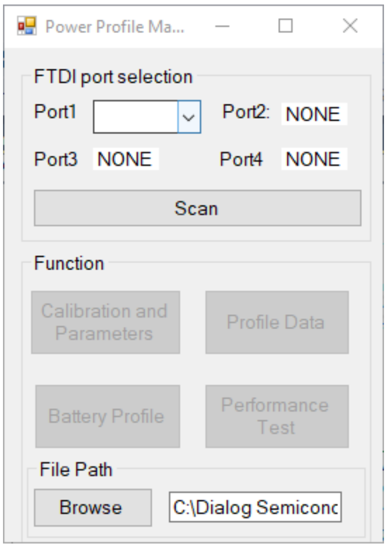

Figure 5: Main Menu of the PPM

6.2 FTDI Port Selection

The FTDI device on DA9070 FG demo board creates four USB serial ports in Windows OS. The control of the battery profile, performance test, export/import profile data, and communication to the target system are done through these ports.

- **Scan**: Scan possible FTDI UART port

6.3 Calibration and Parameters

Before battery profile or performance test, power calibration and setting the parameters are required for accurate measurement and data. If the **Calibration and Parameters** button is clicked, all these values should be imported from the MCU on the board. Figure 6 shows the initial window of **Calibration and Parameters** when the values and parameters are imported from DA9070 FG demo board. There are four menu groups.

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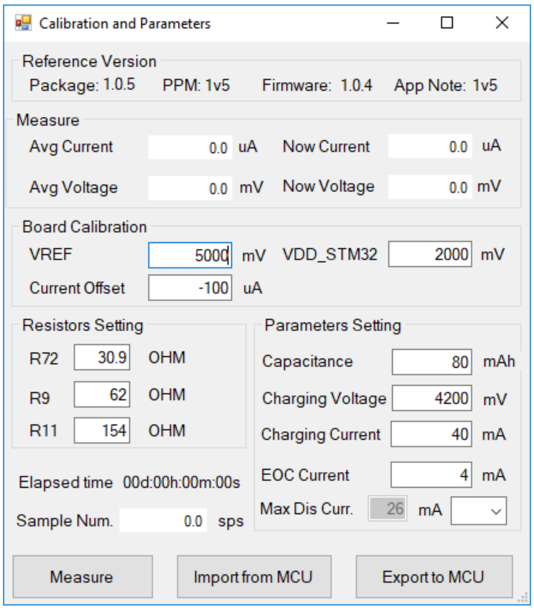

Figure 6: Initial Screen of the Calibration and Parameters

6.3.1 Measure

The measured instant current, average current, instant voltage, and average voltage of battery are shown in this group. These are used during calibration.

6.3.2 Board Calibration

In this group, the VREF, VDD_STM32, and current should be calibrated. These are used for accurate measurement of voltage and current on the board during battery profile or performance test. The allowed ranges for board calibration are shown in Table 2.

Table 2: Allowed Range for Board Calibration

Calibration Item	Allowed Range
VREF	4800 ~ 5200 mV
VDD_STM32	1950 ~ 2050 mV
Current Offset	-1000 ~ 1000 µA

6.3.3 Resistors Setting

R72, R9, and R11 on the board are used as a load during discharging. The resistance of each resistor decides possible **Max Dis Curr** values. The default values in the board are 30.9, 62, and 154 Ohms. The possible load values with the combination of 3 resistors are shown in Table 3.

NOTE
If larger **Max Dis Curr** than the default values are required for the battery profiling, the resistors on the board must be replaced with the same value of this settings. The possible minimum resistance of each resistor is 9.4 Ohms. The tolerance of resistors must be as low as possible for exact load and allowable power must be over 0.5 W considering maximum power. Do not battery profile or performance test with different setting values from the resistance of the resistors on the board.

Table 3: Possible Load Values with 3 Resistors

Index	Equation for Possible Load (mA)	Default (mA)	With all 9.4 Ohms (mA)
1	800 / R11 + 3	8	88

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Index	Equation for Possible Load (mA)	Default (mA)	With all 9.4 Ohms (mA)
2	800 / R9 + 3	16	88
3	800 / R11 +800 / R9 + 3	21	173
4	800 / R72 + 3	29	88
5	800 / R72 + 800 / R11 +3	34	173
6	800 / R72 + 800 / R9 + 3	42	173
7	800 / R72 + 800 / R11 + 800 / R9 + 3	47	258
8	1400 / R11 + 3	12	152
9	1400 / R9 + 3	26	152
10	1400 / R11 +1400 / R9 + 3	35	301
11	1400 / R72 + 3	48	152
12	1400 / R72 + 1400 / R11 +3	57	301
13	1400 / R72 + 1400 / R9 + 3	71	301
14	1400 / R72 + 1400 / R11 + 1400 / R9 + 3	80	450

6.3.4 Parameters Setting

The parameters must be loaded from or updated to the board before the battery profile or performance test. The recommended values of each parameter are shown in Table 4.

- **Battery Capacity** (mAh): The capacity of the battery to be used by the target system. Normally the specification of the battery provides a total capacitance figure, but it has a tolerance (usually 5 ~ 10 %) and the usable capacity is related to the maximum discharging current of the target system as described in Section 4. The minimum voltage the target requires to operate must be sustained at the maximum current draw. So, it is necessary to select the capacity of the fully charged battery which can be used without a risk of reaching the minimum voltage requirement, even under full load. If such information for capacitance is unavailable, then the minimum capacitance from the specification can be used.
- **Charging Voltage** (mV): The voltage value of the battery during Constant Voltage (CV) charging period as detailed in the battery specification. The charging voltage of most lithium type battery is 4200 ~ 4400 mV.
- **Charging Current** (mA): The current value during Constant Current (CC) charging period as detailed in the battery specification or set for target application. 0.5C charging current is recommended considering the specification and lifecycle of battery.
- **EOC Current** (mA): The End Of Charge (EOC) current which should be set in the DA9070 charger. 10% of **Charging Current** is recommended.
- **Max Dis Curr** (mA): The maximum average discharging current whilst the target works in the active state. The average measurement should be taken over dozens of milliseconds. This then excludes some peak discharging current from consideration. The maximum current supplied by an LDO of DA9070 is around 150 mA. So, the maximum possible **Max Dis Curr** is around 450 mA with 3 LDOs. A **value** within 450 mA must be defined with the combination of 3 resistors. According to the battery specification, the capacitance of a battery is measured with 0.2C or 0.25C. If full capacitance of the battery is required at target application, it is recommended that 0.2C or 0.25C is set as **Max Dis Curr**.

Table 4: Recommended Value of Each Parameter

Parameter	Recommended Value	Example
Battery Capacity	The minimum capacitance from the specification	200 mAh
Charging Voltage	A specified value in the specification	4200 mV

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Parameter	Recommended Value	Example
Charging Current	0.5C	100 mA
EOC	10 % of Charging Current	10 mA
Max Dis Curr	0.2 ~ 0.25C	40 ~ 50 mA

6.3.5 Control Buttons

- **Measure**: Start measuring the current and voltage of the battery.
- **Import from MCU**: Import all values from the MCU.
- **Export to MCU**: Export all values to the MCU.

6.4 Battery Profile

After all values are set in the **Calibration and Parameters**, the battery profile can start, and all processes are completed automatically. The **Status** field displays the elapsed time, which depends on the capacitance, load, and charging current. An estimated time remaining is also shown in the **Status** field during the battery profiling. The process number and sampling speed are shown for debug purpose. The output files are written to the **File Path**, as defined in Section 6.1.

- **Status**: Elapsed time, remained time, progress bar, process number, and ADC sampling speed.
- **Setting**
  - The parameter values which are defined in the **Calibration and Parameters.**
  - **Min Battery Voltage**: Minimum battery voltage during discharging state. It is defined as discharging cut-off voltage**,** minimum discharging voltage or end voltage in the specification.
- **Start**: Start a battery profile

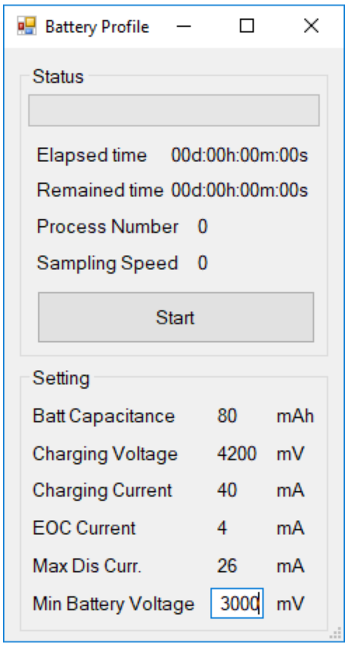

Figure 7: Initial Screen of the Battery Profile

6.5 Performance Test

The performance test for the comparison of SOC from Reference FG and SOCF algorithm starts automatically after battery profile, or it can be done manually later. Everything processed during full discharge and charging cycles are performed automatically. The **Done** dialog appears when the **Performance Test** is complete. The initial screen of the performance test is shown in Figure 8.

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- **Start**: Start a performance test.
- **Load Profile**: Select load during performance.
- **Elapsed Time**: Elapsed time after starting.
- **State**: The state of performance test.
- **SOCF**: SOC from SOCF.
- **REF**: SOC from Reference FG.
- **Now Voltage**: The voltage of battery.
- **Now Current**: The current to/from battery.
- **Avg Current**: The averaged current during test.
- **Max Diff**: The maximum difference between SOC from SOCF and Reference FG.

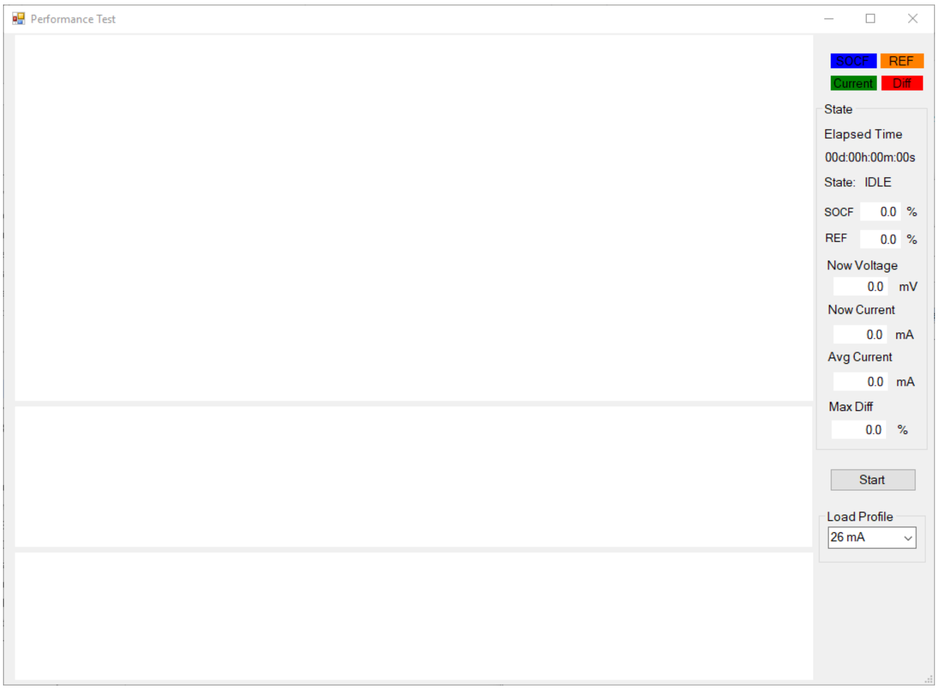

Figure 8: Initial Screen of the Performance Test

6.6 Profile Data

The profile data can be imported from PC or the MCU. Also, the data can be manipulated and exported to PC or the MCU. The exported data to the MCU should be applied to SOCF algorithm immediately. The initial screen of the Profile Data is shown in Figure 9.

- **Data1, Data2, Data3**: Imported or selected 3 battery profile data.
- **Change**: Add or update selected value of lookup tables.
- **Parameters**: The parameters related with SOCF algorithm.
- **Import**: Import to the MCU or PC.
- **Export**: Export from the MCU or PC.
- **Average**: Average 3 profile data and set the values to Data1.
- **Clear**: Clear all values of selected Data.

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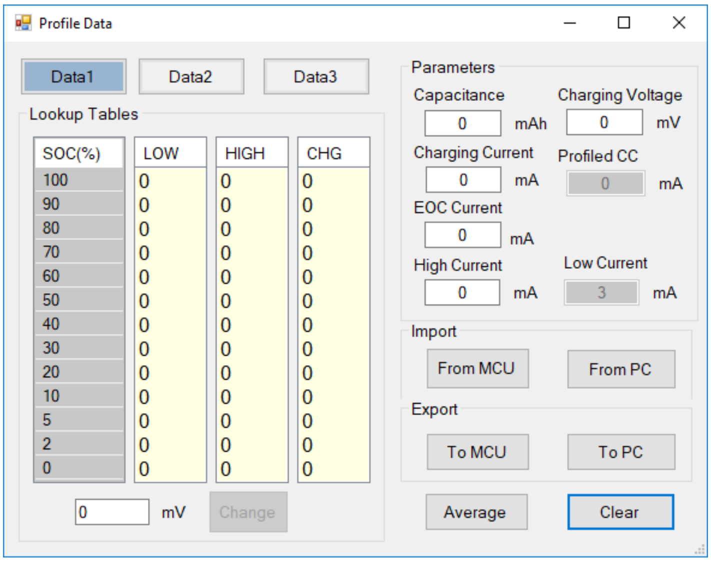

Figure 9: Initial Screen of the Profile Data

7 Profiling a Battery

7.1 Prepare the Board and Battery

A DA9070 FG demo board and a rechargeable battery should be prepared for battery profiling. The jumper configurations on the DA9070 FG demo board must be as shown in Figure 4 and Table 1.

NOTE
Confirm the jumper configurations shown in Table 1.

7.2 Connect the Battery and USB Cable

The prepared battery must be connected to **J27** and then connect the USB cable to the PC. Figure 10 shows the board with battery and USB cable connected.

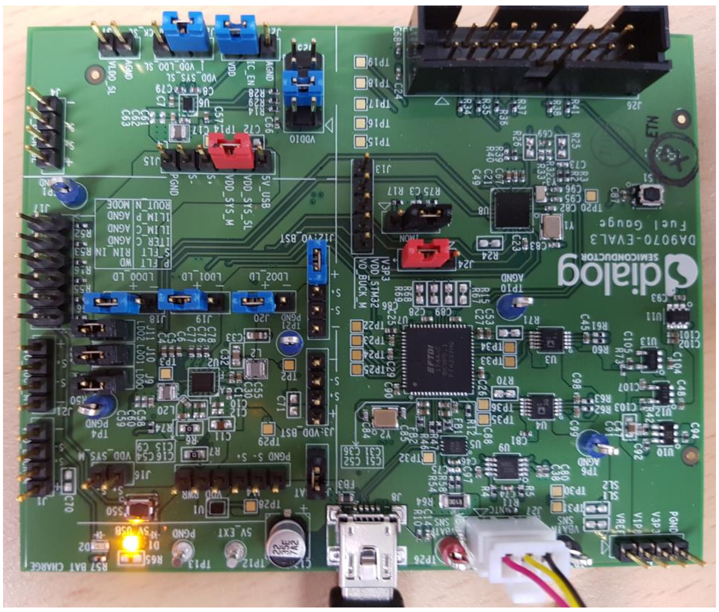

Figure 10: FG Board with Battery and USB Cable Connected

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7.3 Finding FTDI Ports

When PPM is started in a Windows system, the main menu is shown, see Figure 5.

When a USB cable is connected between the PC and the USB port of DA9070 FG demo board, the four sequential ports of FTDI are generated, see Figure 11. If the ports in the device manager are observed when the cable is connected, it is easy to find which ports are for DA9070 FG demo board. If the **Scan** button is clicked, the ports will be shown in the drop-down list, see Figure 12. Choosing the first of the four sequential ports automatically populates the others, see Figure 13.

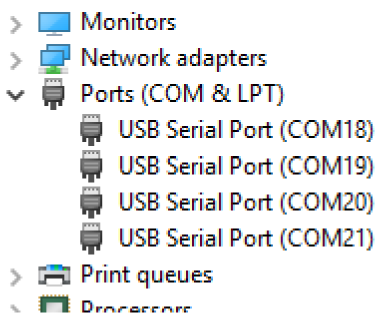

Figure 11: USB Serial Ports in Device Manager of Windows 10

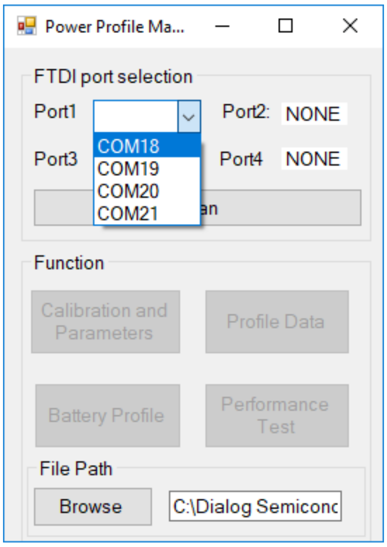

Figure 12: USB Serial Ports in the PPM

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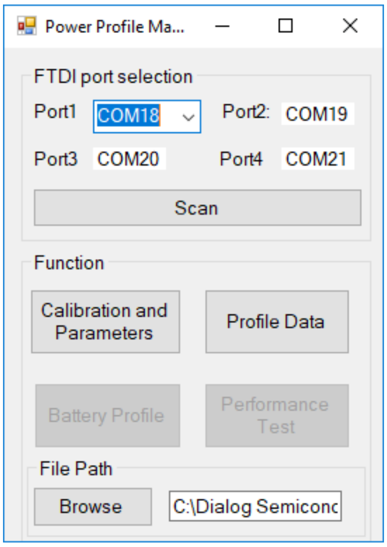

Figure 13: USB Serial Ports in the PPM Selected

7.4 Calibrating and Setting Parameters

When the **Calibration and Parameters** menu is selected, all default values for calibration and parameters from the previous battery are imported from the MCU automatically, see Figure 14.

NOTE
The board has been pre-calibrated. The Section 7.4.1 – 7.4.3 can be skipped unless you want to re-calibrate.

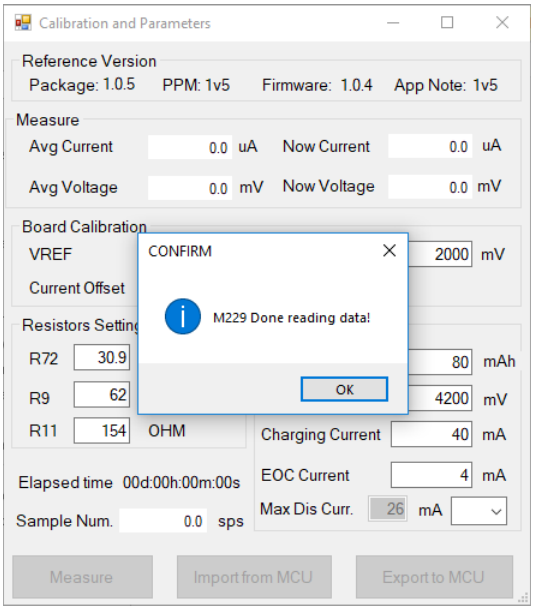

Figure 14: Imported Data from the MCU Automatically

7.4.1 Find Current Offset

The procedure for finding current offset is:

1. Remove the jumpers of **J2**, see Figure 15.
2. Enter 0 in the **Current Offset** field.
3. Click the **Measure** button and then after one minute, click **Stop**.
4. Enter the value (-100 - the value of the **Avg Current**) in the **Current Offset** field.

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5. Connect the jumpers of **J2** again, see Figure 10.
6. Reset MCU by pressing and releasing **S1**.
7. Follow Section 7.4.2 or Export the value to the MCU by clicking **Export to MCU** button, see Figure 17.

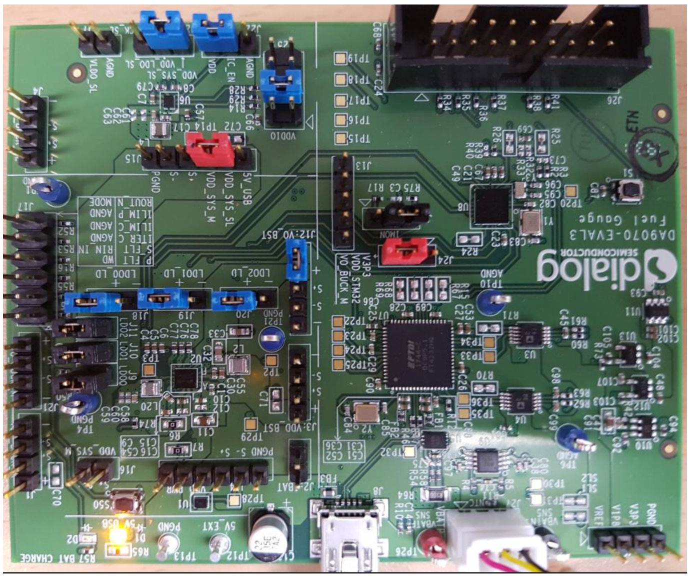

Figure 15: The Jumper Configurations for Finding Current Offset

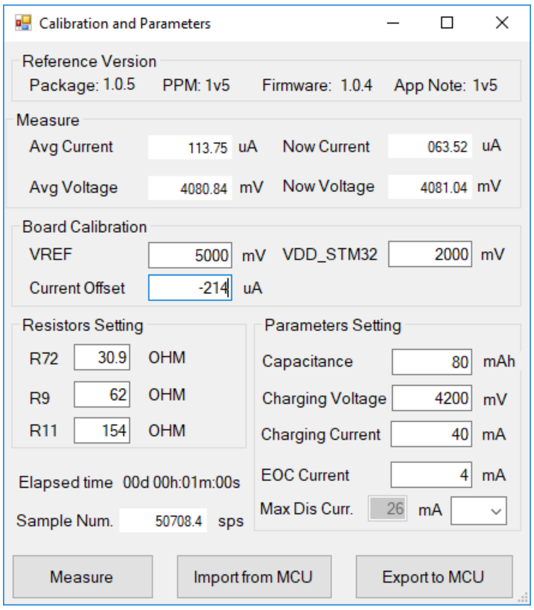

Figure 16: Measure Current Offset and Enter Values

7.4.2 Find VREF Voltage

The procedure for finding VREF voltage is:

1. Confirm the jumper configurations of the board, see Figure 10.
2. Click **Measure**.
3. Measure the voltage between **VREF** and **PGND** at **J5** using a multimeter.
4. Enter the value in the **VREF Voltage** field, see Figure 16.
5. Follow Section 7.4.3 or Export the value to the MCU by clicking **Export to MCU** button, see Figure 17.

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7.4.3 Find VDD_STM32 Voltage

The procedure for finding VDD_STM32 voltage is:

1. Confirm the jumper configurations of the board, see Figure 10.
2. Measure the voltage between **VDD_STM32** and **PGND** at **J24** using a multimeter.
3. Enter the value in the **VDD_STM32 Voltage** field, see Figure 16.
4. Export the value to the MCU by clicking **Export to MCU** button, see Figure 17.

7.4.4 Set Resistor Values

Once **Max Dis Curr** value is decided, proper resistor values must be selected and replaced in accordance with Table 3.

7.4.5 Set Parameters Values

Battery capacitance, charging voltage, charging current, EOC current, and max discharging current must be updated according to the battery and target system, see Section 6.3.4.

7.4.6 Export all Values

After all settings are complete, the values must be exported to the MCU by clicking **Export to MCU** button. A **Done** popup message is shown once the export is complete, see Figure 17.

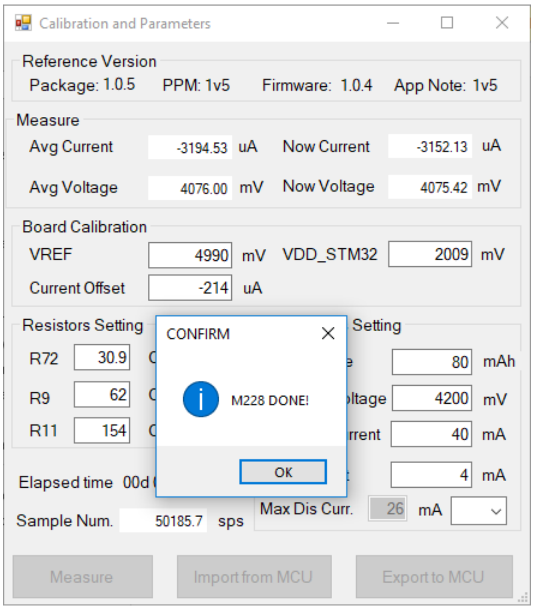

Figure 17: Exported Values to the MCU

7.5 Starting a Battery Profile

Figure 18 shows the jumper configurations required for battery profile on DA9070 FG demo board. A difference from Figure 10 is the connection of (2) and (3) of **J14**.

The battery profile is launched by clicking the **battery profile** button of the PPM main menu, as shown in Figure 13. The battery profiling starts by clicking the **Start** button, see Figure 19.

When the battery profile is complete, the 3 files (BP_CHG_TB_xxx.txt, BP_DISCHG_TB_ xxx.txt and BP_ProfileData_xxx.txt) are written to the **File Path**, as defined in Section 6.1. Figure 20 shows example files, and Figure 21 and Figure 22 show example file contents. The profile data and parameters within the files are used for SOCF application. BP_ProfileData_xxx.txt can be used for importing and exporting profile data at the **Profile Data** menu.

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NOTE
Confirm the jumper configurations shown in Table 1 and J14. The time for a battery profile depends on the capacitance, discharging, and charging current. The typical time for 80 mAh capacitance, 20mA discharging current and 40mA charging current is around 12 ~ 15 hours. Please confirm the PC should not go to sleep during this process.

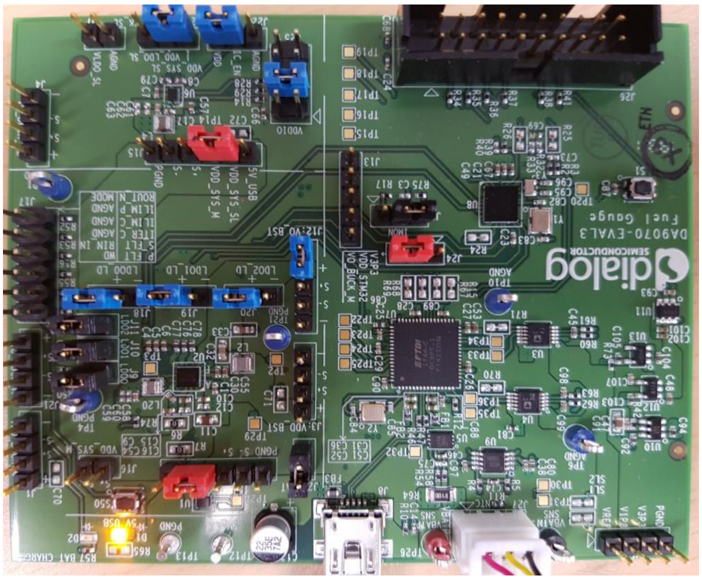

Figure 18: Jumper Configurations for Battery Profile and Performance Test

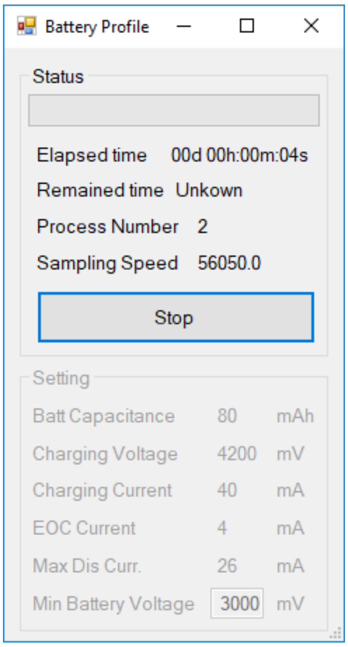

Figure 19: Start of Battery Profile

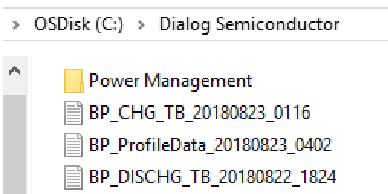

Figure 20: Output File of Battery Profile

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```
SOCF_MIN_DIS = 3
SOCF_MAX_DIS = 27
socf_lvolt[VOL2SOC_LUT_SIZE] = {3631 ,3652 ,3669 ,3695 ,3741 ,3764 ,3780 ,3807 ,3849 ,3921 ,3980 ,4068 ,4162 ,}
socf_hvolt[VOL2SOC_LUT_SIZE] = {3477 ,3511 ,3558 ,3612 ,3674 ,3703 ,3724 ,3756 ,3799 ,3859 ,3927 ,4021 ,4115 ,}
```

Figure 21: Profile Data of BP_DISCHG_TB_xxx.txt

```
SOCF_CHG_CV = 4200
SOCF_N_CHG_CC = 40
SOCF_M_CHG_CC = 38
SOCF_CHG_EOC = 4
socf_cvolt[VOL2SOC_LUT_SIZE] = {3767 ,3788 ,3810 ,3839 ,3866 ,3883 ,3909 ,3950 ,3997 ,4049 ,4120 ,4195 ,4200 ,}
```

Figure 22: Profile Data of BP_CHG_TB_xxx.txt

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8 Testing Performance

Once the battery profile is complete, all battery profile data is exported to the MCU and a performance test starts automatically. Additional performance tests can be performed later. The preparation for a performance test is the same as for the battery profiling, see Sections 7.1 to 7.4. If the **Start** button is clicked or it starts automatically after a battery profile, PPM manages the state of the battery through the MCU for starting performance test. After some preparation process, shown in in Figure 23, the performance test continues for full discharging and charging cycle. The load profile can be changed manually during preparation or test.

During the performance test, SOC from Reference FG and SOCF, average current for 1 second, and the difference between two SOCs are shown graphically. When the performance test is completed, the results image is saved to the PC automatically in the **File Path** and a **Done** message appears, see Figure 24 and Figure 25.

NOTE
The jumper configurations are the same as for the battery profile, see Figure 18. Please confirm the default jumper configuration shown in table 1 and that J14 has (2)-(3) pin connection. The time for a performance test depends on the capacitance, discharging, and charging current. The typical time for 80 mAh capacitance, 20mA discharging current and 40mA charging current is around 7 ~ 10 hours. Please confirm the PC should not go to sleep during this process.

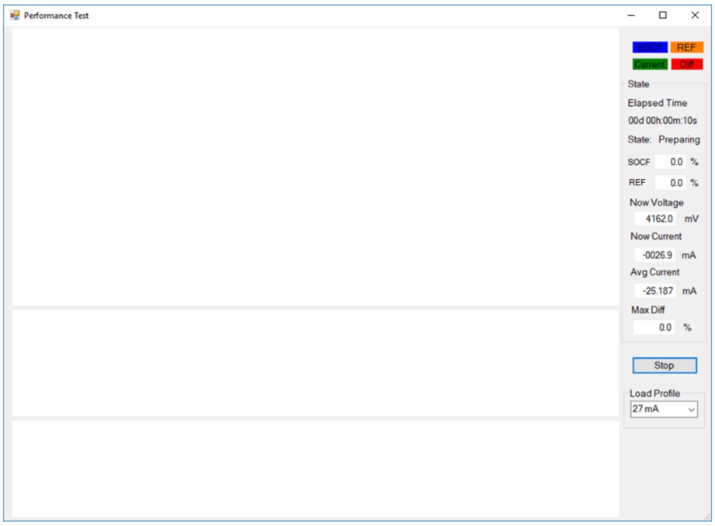

Figure 23: Preparation Process of Performance Test

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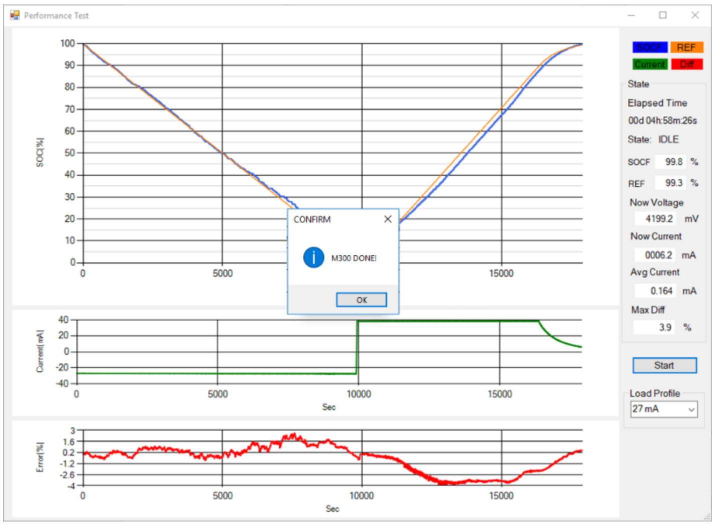

Figure 24: Finished Screen of Performance Test

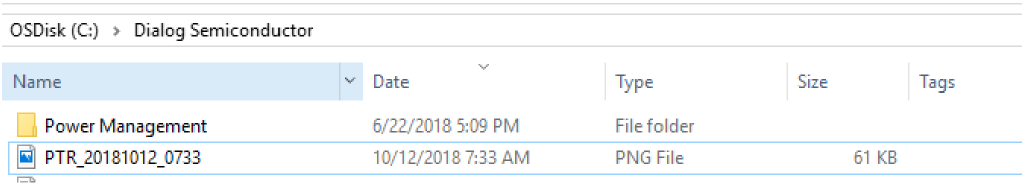

Figure 25: Output File of Performance Test

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9 Managing Profile Data

9.1 Profile Data from Battery Manufacturer

A battery manufacturer could provide the profile data for a customer and most of parameters are defined in the specification document of the battery. Additionally, the manufacturer might provide the voltage lookup tables for specified currents. If all profile data are available, these can be exported to the MCU using this menu without additional battery profile, see Figure 26. In this case, the **Profiled CC** should be the same as the **Charging Current**.

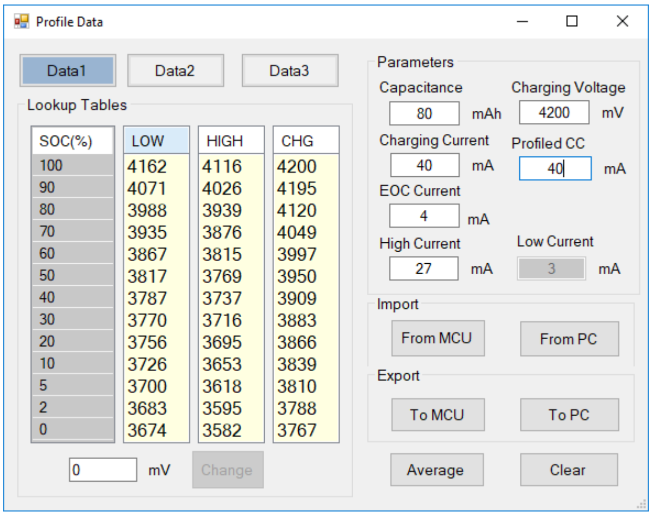

Figure 26: Added or Imported Profile Data1

9.2 Average Profile Data (from Three Batteries)

Even though batteries are produced at the same factory, the batteries have some tolerance for characteristics like capacitance. So, the profile data at each battery might be different due to the tolerance. Therefore, the average of different profile data from several batteries would be helpful for reducing the tolerances. This averaging process is to:

1. Select 3 batteries randomly.
2. Run battery profile with battery 1 and generate profile data1.
3. Run battery profile with battery 2 and generate profile data2.
4. Run battery profile with battery 3 and generate profile data3.
5. Import the profile data 1, data 2, and data 3 from the PC.
6. Average data 1, data 2, and data 3.
7. The averaged value is filled in data1.
8. Export the averaged data1 to the MCU and PC.
9. Run performance test.
10. Update socf_profile_data.h with the averaged profile data, see Table 5.

Figure 26, Figure 27, and Figure 28 show imported Data1, Data2, and Data3. These 3-profile data can be averaged by clicking the **Average** button and the data can be exported to the MCU, see Figure 29.

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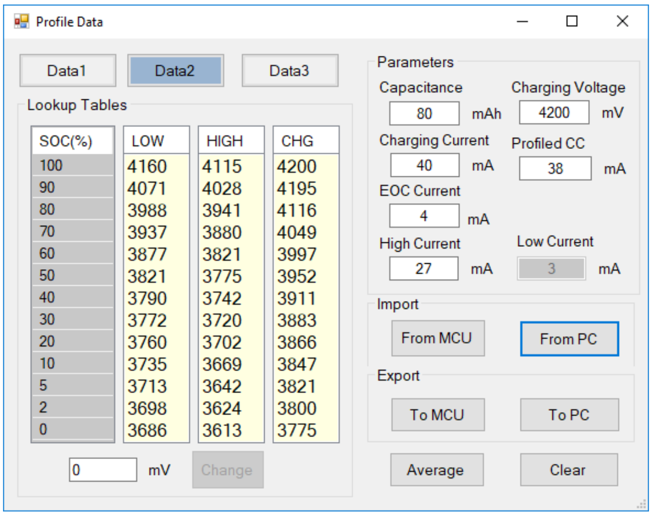

Figure 27: Added or Imported Profile Data2

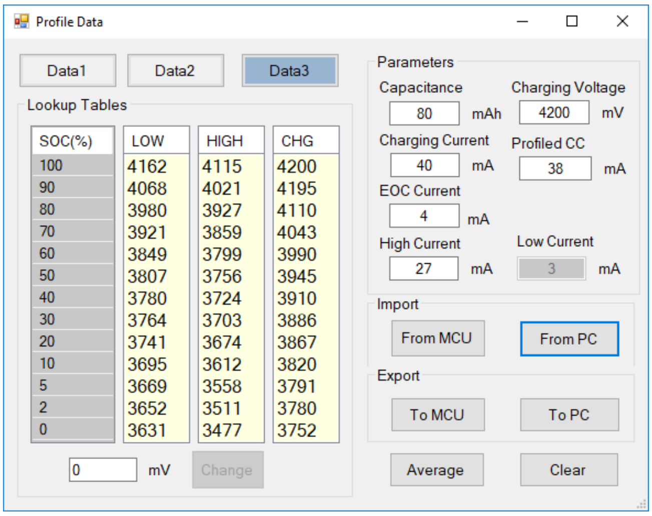

Figure 28: Added or Imported Profile Data3

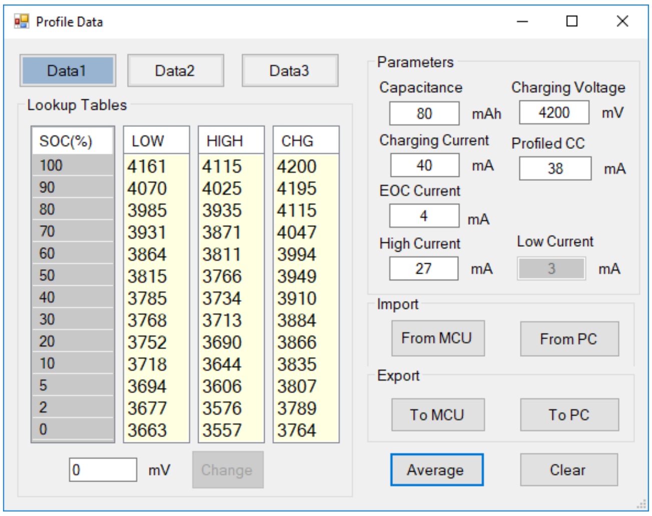

Figure 29: Averaged Profile Data

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10 Fuel Gauge Application

The Fuel Gauge application is composed of two source files, four header files, and one library.

- libsocf_da9070.a: SOCF library
- socf_client.c/h: system independent function
- socf_hal.c/h: system dependent function
- socf_profile_data.h: the output tables from battery profile
- socfi.h: internal function

10.1 Required Information in socf_profile_data.h

The profile data from **Battery Profile** or **Profile Data** must be copied for the target system. The contents are shown in Table 5.

Table 5: Information Required in socf_profile_data.h

Name	Description	Value
SOCF_CAP	Battery Capacitance	Example value 80 (80 mAh)
SOCF_N_CHG_CC	Charging Current set in DA9070	Figure 22 Example value 40 (40 mA charging current)
SOCF_M_CHG_CC	Charging Current during actual battery profile	Figure 22 Example value 39 (39 mA charging current)
SOCF_CHG_EOC	End Of Charge current	Figure 22 Example value 4 (4 mA)
SOCF_CHG_CV	Charging Voltage	Figure 22 Example value 4200 (4200 mV)
SOCF_MAX_DIS	Max discharging current during battery profile	Figure 21 Example value -26 (27 mA discharging current)
SOCF_MIN_DIS	Low discharging current during battery profile	Figure 21 A fixed value -3 (3 mA discharging current)
SOCF_SHUNT	The resistance value of shunt resistor A shunt resistor for Reference FG is used in demo board. But **normally there is no shunt resistor in a target system. In case of this, the value must be 0.**	Example value 0 (0 mOhm)
socf_lvolt/socf_hvolt/socf_cvolt	Copied from the output file of Battery Profile or Profile Data	Figure 21 and Figure 22

10.2 Functions in socf_client.c

The functions in socf_client.c are independent of the target system, so no modification is required.

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Table 6: Functions in socf_client.c

Name	Description
socf_set_pre_time	Set previous sample time used in client
socf_set_client_voltage	Set voltage value used in client
socf_set_client_current	Set current value used in client
socf_get_pre_time	Get previous sample time used in client
socf_get_client_voltage	Get voltage value used in client
socf_get_client_current	Get current value used in client
socf_get_soc	Get SOC as 100 percent standard
socf_calculation	Calculate soc with Vbat and Ibat
socf_init	The function called for SOCF initialization

10.3 Functions in socf_hal.c

The functions in socf_hal.c depend on the target system, so each function must be implemented according to the target system.

Table 7: Functions in socf_hal.c

Name	Description
socf_measure_vbat_ibat	Read the voltage of battery from ADC and the current through IMON
socf_is_charging	Return whether it is charging state
socf_hal_get_time	Get now time
socf_hal_get_duration	Get the duration between two times as milli second
socf_hal_timer_cb	SOCF HAL timer callback function Signal SOCF_FROM_ACTIVE_CAL_BIT must be sent to socf thread
socf_hal_stop_timer	Stop SOCF HAL timer
socf_hal_start_timer	Start SOCF HAL timer
socf_hal_create_timer	Create SOCF HAL timer
socf_calcaulation_after_wakeup	SOC calculation function at very early time after wakeup from sleep state. (**This function must be called in PostSleepProcessing in case of FreeRTOS**.) Signal SOCF_FROM_WAKEUP_CAL_BIT must be sent to socf thread.
socf_hal_calcaulation_before_sleep	SOC calculation function just before sleep state. (**This function must be called in PreSleepProcessing in case of FreeRTOS**.)
socf_cal_thread	Thread function for SOC calculation
socf_hal_create_thread	Create a SOCF thread

10.4 Development Environment

The development environment of SOCF in the DA9070 FG demo board is:

- OS: Window 7/10

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- SDK: STM32Cube_FW_L1_V1.7.0
- IDE: system workbench for STM32 (Eclipse Neo 3)
- Target OS: FreeRTOS

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11 Performance Test Result with SOCF Algorithm

To evaluate the performance of SOCF,

1. Select 4 x 80 mAh batteries (A, B, C, D) randomly.
2. Generate a battery profile data with each battery A, B, and C, see Figure 26, Figure 27, and Figure 28.
3. Average 3 batteries profile data as shown in Figure 29.
4. Export the averaged battery profile data to the MCU.
5. Complete a performance test with the averaged battery profile data and battery D.

The Reference FG in the FG demo board has 1~2 % accuracy in measuring coulomb with a fixed capacitance. However, Reference FG requires exact capacitance of the battery to generate very accurate reference SOC. Each battery normally has a tolerance of capacitance. The actual capacitance of a battery can be known with a full discharging cycle. So, after performance test, the SOC from Reference FG must be adjusted and updated based on the measured capacitance. The result of a performance test with battery D is shown in Figure 30. As shown, the maximum difference of SOCs is around 3.9 %.

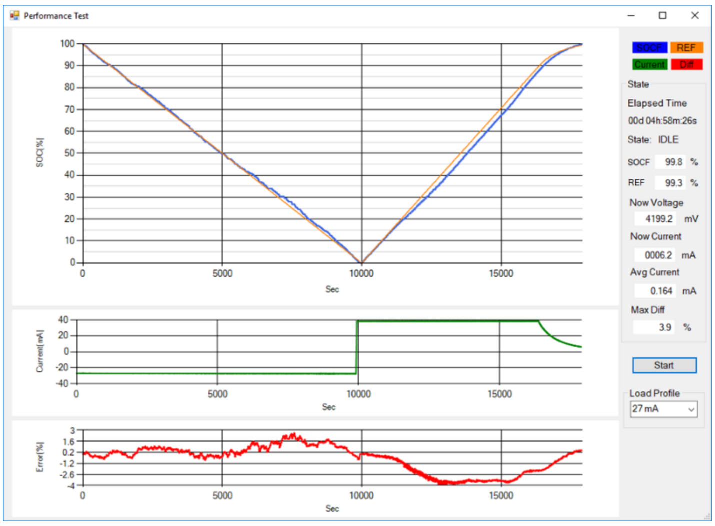

Figure 30: Result of Performance Test with Battery D

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12 Known Limitations

12.1 Temperature Compensation

There is no temperature compensation in this FG application, but the voltage-based FG algorithm has temperature compensation itself. At low temperature, though the energy of the coulomb in the battery is the same, the internal resistance is very large, and it causes a huge voltage drop. The SOC of SOCF simply follows the change of the voltage, so SOC will go to 0 % when the voltage drops to the equivalent value of 0 % SOC at room temperature. In the HW coulomb counter case, it requires a special algorithm for temperature compensation because the coulomb is available, but the voltage drop is huge at low temperature. At present there is no compensation algorithm in this FG demo board. So, the comparison of SOC between SOCF and Reference FG at low temperature is not valid.

NOTE
The JTAG for download consumes approximately 4 to 6 mA, so it must be disconnected during any test.

Appendix A The Update of a Firmware to DA9070 FG Demo Board

The firmware of DA9070 FG demo board can be updated using ST-LINK utility and JTAG JIG (ST-LINK/V2 ISOL). The utility can be download from https://www.st.com/en/development-tools/stsw-link004.html. The utility includes a user manual which describes how to download a firmware. If there is any difficulty in updating a firmware, please contact Dialog.

Appendix B Troubleshooting Guides with Message

Any error message during the PPM process consists of a number and message, See Figure 31. The troubleshooting guide for each message is shown in Table 8.

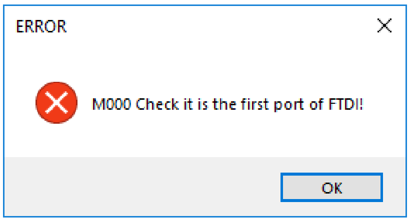

Figure 31: Error Message

Table 8: Troubleshooting Guides

Error Message Number	Message	Action
M000	"Check it is the first port of FTDI!"	1. Refer to Section 7.3.
M100	"The voltage is under the minimum battery voltage. Please check the value or the capacitance!"	1. Refer to Section 6.3.4 and Section 6.4. 2. Check the battery is a new one. 3. The capacitance is too small. Reduce the capacitance by 10 % steps and retry the battery profiling.

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Error Message Number	Message	Action
M101, M103, M104, M200, M201, M224, M225, M227, M234, M235, M236, M238, M239, M301, M302, M303, M304, M305, M306, M400, M401, M402, M403, M404	"Error in communicating with target!" "Error in FTDI or ADC!" "Error in staring the battery profiling!" "Error in starting Performance Test!" "Failed in opening the Port!"	1. Check the USB connection. 2. Check if the port is used by another device. 3. Check the jumper configurations on the board, especially J2 and J14. 4. Check if the PC went to sleep during the PPM process. 5. Do not use the PC during the PPM process, other applications may interfere with the process.
M237	"Incorrect firmware version: xxx"	1. Check that the correct firmware is being used.
M102, M202, M203, M204, M205, M206, M207, M208, M209, M210, M211, M212, M213, M214, M215, M216, M217, M218, M219, M220, M221, M222, M223, M226, M230, M231, M232, M233, M409, M410, M411, M412, M413, M414, M415, M416, M417	"Check empty values!"	1. Check that the values are within the allowed range.
M240	"Parameters has been changed but not exported. It must be exported or imported for battery profile and performance test."	1. Export the changed values to MCU, or import the values from MCU again.

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Revision History

Revision	Date	Description
1.7	22-Feb-2022	Document rebranded to Renesas.
1.6	06-Nov-2018	Update typos and incorrect description about jumper.
1.5	31-Oct-2018	Updated descriptions and snapshots of GUI for exceptional cases.
1.4	10-Oct-2018	Added troubleshooting guides with messages.
1.3	21-Sep-2018	Added more notes and cautions about jumper configurations.
1.2	13-Sep-2018	Updated for EVAL3.
1.1	31-Aug-2018	Fixed typos.
1.0	24-Aug-2018	Fully updated for BA device.

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Status Definitions

Status	Definition
DRAFT	The content of this document is under review and subject to formal approval, which may result in modifications or additions.
APPROVED or unmarked	The content of this document has been approved for publication.

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