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# User Manual DA9070 / DA9231 Fuel Gauge Development Kit

# **UM-PM-039**

# Abstract

This document describes the hardware in the DA9070 / DA9231 Fuel Gauge Evaluation and Development Kit.



# DA9070 / DA9231 Fuel Gauge Development Kit

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## **Terms and Definitions**

- SOC State of Charge
- VBAT Voltage of Battery
- IBAT Current of Battery
- FG Fuel Gauge
- ADC Analog to Digital Converter
- MCU Micro-Controller Unit
- UART Universal Asynchronous Receiver-Transmitter
- USB Universal Serial Bus
- PMIC Power Management IC
- GUI Graphic User Interface
- EVK Evaluation Kit
- PCB Print Circuit Board

## References

- [1] DA9070 Datasheet
- [2] DA9231 Datasheet
- [3] Application Note: AN-SW-121\_DA9070 Power Profile Manager and SOCF
- [4] Schematic: DA9070\_FG\_EVAL\_v3\_schematic.pdf
- [5] PCB Layout: DA9070\_FG\_EVAL\_v3\_pcb.pdf
- [6] Bill of Materials: DA9070\_EVAL\_BOARD\_REV3\_BOM.pdf



## Introduction

DA9070 Fuel Gauge EVK is a fuel gauge development and evaluation platform to demonstrate a low power fuel gauge system using the DA9070, DA9231, and an MCU with Dialog's proprietary algorithm. The DA9070 is an ultra-low quiescent current PMIC with integrated charger, buck converter, boost converter, and 3 LDOs. The DA9231 is an ultra-low quiescent current buck converter that is efficient down to 10  $\mu$ A with a nano-ampere LDO.

The low-power consumption MCU (STM32L151RD) allows the user to program the battery charging profile, discharge load profile, and fuel gauge algorithm. The DA9070 Fuel Gauge EVK can also be used as an evaluation board for both the DA9070 and DA9231.

This document describes the system diagram, the various functional sections on the EVK board, and board set-up for chip evaluation and fuel gauge development.

Two GUIs are provided with the DA9070 Fuel Gauge EVK:

1) The DA9070 Fuel Gauge EVK, SmartCanvas GUI, communicates with both the DA9070 and the DA9231. It also has a fuel gauge display and can control the on-board loads. This GUI is used for evaluation purposes.

2) The Power Profile Manager (PPM). This GUI generates or loads battery profile data and runs the fuel gauge performance test. This GUI is used to develop a software fuel gauge based on the user's battery.

## **Default Settings**

The DA9070 settings are loaded from the on-board MCU at startup, including charge current and voltage settings:

#### Buck output: 2.0V, enabled

In the default configuration, the buck output voltage powers the MCU. If a different output voltage is required, change the J24 position to 3.3V. This allows the Buck voltage to be modified as needed. However, the GUI fuel gauge function will not be accurate in this configuration.

#### Boost output: 12V, disabled

#### Charge current: 40mA

#### Charge voltage: 4.2V

#### LDO outputs:

All LDO voltages are set to 0.8V initially, but the voltage may change if load settings are changed in the GUI load profile tool. If the load profile tool is not used, LDO output settings may be changed manually in the GUI.

#### **Battery Information:**

The battery profile for the included 80mAh battery is pre-loaded in the MCU. This includes capacity, charge current, state of charge (SOC) lookup table, and other data. The pre-set battery data can only be changed by first running the Power Profile Manager software.

A battery other than the one included can be used for evaluation without changing the profile. However, charging settings must be changed manually in the GUI.

Also, the GUI based fuel gauge will not be accurate unless a new profile is updated and saved to the MCU.

Refer to AN-SW-121 for details about the battery profiling procedure.

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## **Board overview**

The whole system is designed to demonstrate the charge and discharge of a single lithium-polymer battery, and the SOC (state-of-charge) prediction via fuel gauging. It also enables customer to do independent evaluation on both DA9070 and DA9231 ICs. Figure 1 shows the top view of DA9070 Fuel gauge EVK board and highlights the function of each section.



Figure 1: DA9070 Fuel Gauge EVK Board Top View

# **Key Features**

- Single USB connector supports both charging power and communication with PC
- Support STM32L151 MCU firmware update through JTAG 20 pin connector

- Two configurable modes through jumper: Chip evaluation mode; Battery Profile Mode including Fuel Gauge Performance Test

- Supports register read/write in chip evaluation mode with Dialog's SmartCanvas GUI

- Supports battery characterization with real-time voltage and charge/discharge current measurement which can be monitored with Dialog's Power Profile Manager (PPM) on PC

- Supports on-board customized load-profile programming

- Supports a performance comparison between Dialog's low-power software fuel gauge solution and a reference Coulomb-counter based fuel gauge IC

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# System Diagram

Figure 2 shows the DA9070 fuel gauge EVK system diagram. The whole system includes the following major portions:

-DA9070: Dialog nano-power battery charge management PMIC with Fuel Gauge

-DA9231: Dialog nano-power PMIC

-STM32L151 MCU: For implementing fuel gauge SOC algorithm

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-FDTI: Communication interface-bridge between USB and UART, SPI ports

-JTAG: Communication port for STM32L151 MCU firmware update

-LTC2941: Reference Coulomb-count based fuel gauge IC

-Battery V&I Monitor: Circuitry to monitor battery voltage & current in real-time. For battery profiling

-System Load Model: A set of on-board resistors with ON/OFF control issued by MCU to mimic various load patterns in real applications

-PC GUI: Software on PC. For chip evaluation. Both registers of DA9070 and DA9231 can be read or written through GUI

-PC PPM: Software on PC. For battery profiling and fuel gauge performance test

-BAT: Single lithium-poly battery. Support up to 500mAh



Figure 2: DA9070 Fuel Gauge EVK System Diagram

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## **Chip Evaluation Mode**

DA9070 Fuel gauge EVK is able to be configured to perform chip evaluations with or without battery. For example, DA9070 or DA9231 can be evaluated for current consumption, efficiency, load/line regulation, load/line transient etc. without battery; DA9070 can also be evaluated for sequence, system load transient while the battery being plugged-in.

# **Evaluation Mode Basic Set-up**

It is recommended to follow the following steps while setting up the chip evaluation mode.

- Install jumpers as shown in Figure 3.



#### Figure 3: Basic Jumper Settings for Evaluation Mode

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- The boxed jumpers must be installed in designated positions in order to evaluate both DA9070 and DA9231. If only evaluate DA9070, change J22 jumper to IC\_EN=AGND so DA9231 is disabled; If only evaluate DA9231, remove J14 jumper so DA9070 is disabled.

- Connect the battery to J27. The positive terminal is labeled VBAT\_P, adjacent to the red test point TP26

- Plug in a USB cable into J8 connector. Connect the USB cable to either a traveler adapter or a PC. The Yellow LED light is ON which means the EVK board is powered. By default, both DA9070 and DA9231 are OTP programmed to start up automatically as soon as the EVK board is powered.

- If the USB cable is connected to a PC, open the "DA9070 Fuel Gauge EVK" GUI that was installed on the PC. Start to configure device registers as well as read device status using GUI, as shown in Figure 4.

S DA9070 Fuel Gauge EVK - 🗆 🗙				
File Options Tools Search View Help			Control	
DA9070 DA9231			Control ×	
SYSTEM CHARGER BBL CONTROL Table View			<b>S</b> smartcanvas	
Wout				
	CCFG VOUT LS LDOO	VOUT LS LDO1 VOUT LS LDO2	Raw I/O	
BUCK_VOUT 2.00 V V SEL_ILIM_DLT		US_LDO_1 2.475 V US_LDO_2 2.475 V	Advanced 0xD0 + Dev Addr	
VOUT_RANGE_HI High BUCK_PD_CFC	FG2 Enable EN_LS_LDO_0 High	EN_LS_LDO_1 High EN_LS_LDO_2 High	Batch Mode 0x00 TReg Addr	
BUCK_EN High 0x30 0xDC + 0x31	0x00 • 0x32 0x82 •	0x33 0xA1 0x34 0xA1	Send 0x00 🖶 Send Data	
	,		Read 0x00 Read Data	
VOUT_L5_LD0_CFG VOUT_B0051 SEL_LDSW_0 LD0 B00ST_VOUT		VOUT_BOOST_CFG1         VOUT_BOOST_CFG2           BST_CFG_OC         1.45 A         BST_CFG_PCHGLMT         x14         V	Communication	
SEL_LDSW_1 LDO BOOST_EN	Low TPCHG_SEL 2 ms V	BST_CFG_OCS 380 mA BST_CFG_ANTI High	Bus communication	
SEL_LDSW_2	TSS_SEL 6 ms 🗸			
SEL_FULLON_0 Enable			USB connection	
SEL_FULLON_2 Enable			USB device	
0x35 0x00 🕂 0x36	0x27 0x37 0x40 +	0x38 0x86 + 0x39 0x70 +	Reconnect to device	
			_1/0	
			Read all registers (excluding event) Read Event/Status/Fault regs	
			Save Register Dump	
		T Info	Load Register Dump	
	Status	x Info	USB Interface Info	
Console Log		Bitfield: BST_CFG_FREQ_[0]	Interface: Dialog UART Interface USB Device Port: Not connected	
Clear Mark Save to file Filter (reg	eg expr): Log level: Info		STM Firmware Version: ??? Uart Interface Version: 0.6.0	
2018-10-03, 16:44:01 [INFO] Reading Event/Status/Fault registers 2018-10-03, 16:44:01 [INFO] 9 registers took 0.03 seconds		Access: Read/Write Default: 1 MHz (0x0)		
2018-10-03, 16:44:01 [INPO] 9 registers took 0.03 seconds		Current Value: 1 MHz = 0 (0x0 or 0b0)		
		Description:		
		Switching frequency select, cant be written when boost is enabled. 0: 1 MHz		
		1: 2 MHz		

Figure 4: GUI for DA9070 Fuel Gauge EVK

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## **DA9070 Evaluation**

The typical application diagram of DA9070 is shown in Figure 5.

DA9070 includes a Buck regulator, a Boost Regulator, 3x LDO/LDSW, and a linear battery charger.

On DA9070 Fuel gauge EVK, each regulator can be evaluated individually. It is recommended to follow the operation conditions as shown in Table 1 to avoid any damage to the EVK board. For test and measurement set-up, please refer to Table 2 for descriptions of connectors on the EVK board.





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# **Recommended Operating Conditions**

#### **Table 1: Recommended Operation Conditions**

			1	-		
Parameter	Description	Conditions	Min	Тур	Max	Unit
VDD_PWR	VDD_PWR voltage	Including OVP range	3.6	5	20	V
	VDD_PWR		3.6	5	5.5	V
	operating voltage					
VBAT	Battery voltage	VDD_PWR supplied	0	3.7	4.7	V
	Battery voltage	VDD_PWR not supplied	2.8	3.7	4.7	V
VDD_LDO	VDD_LDO voltage	Load switch mode	0.8		5.5	V
		LDO mode	1.8		5.5	V
VDDIO	IO voltage	VDDIO < VDD_PWR or	1.4	1.8	3.3	V
		VBAT, whichever is				
		greater				
I_PWR	VDD_PWR current				500	mA
I_BAT	Battery discharge				800	mA
I_SYS	VDD_SYS current				800	mA
I_LDO	LDO output current				150	mA
I_BUCK	Buck output current				300	mA
I_BOOST	Boost output current	12Vout, 2.7VBAT			100	mA

# **Connectors for DA9070 Evaluation**

#### Table 2: DA9070 Input and Output Connectors

Connectors	Pin Names	Descriptions
J1 (VDD_BUCK_M)	+/ S+/ S-/ -	+ and - are terminals for connecting an external load to the DA9070 VDD_SYS; S+ and S- are kelvin sense points for DA9070 Buck input. For input voltage measurement during efficiency test, S+ and S- should connect to multi-meter for better accuracy.
J2 (IBAT)		Install J2 jumper will connect the VBAT pin of DA9070 to battery positive terminal VBAT_P through current sense shunt resistor. It also enables battery current monitoring using external current probe.
J3 (VDD_BST)	+/ S+/ S-/ -	+ and - are terminals for connecting external power supply to the Boost input; S+ and S- are kelvin sense points for the Boost input. For input voltage measurement during efficiency test, S+ and S- should connect to multi-meter for better accuracy.
J6 (IMON)		Install J6 jumper will connect the IMON pin of DA9070 to STM32L151(U8) ADC input. It also enables IMON current measurement using external multi-meter. Position 2-3 should be used.
J9 (LDO_0)	VDD_LDO0/ VDD_SYS_M	Install J9 jumper will connect LDO_0 input (VDD_LDO0) to VDD_SYS_M of DA9070.
J10	VDD_LDO1/	Install J10 jumper will connect LDO_1 input
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(LDO_1)	VDD_SYS_M	(VDD_LDO1) to VDD_SYS_M of DA9070.
J11 (LDO_2)	VDD_LDO2/ VDD_SYS_M	Install J11 jumper will connect LDO_2 input (VDD_LDO2) to VDD_SYS_M of DA9070.
J12 (VO_BST)	BST_LD/ +/ S+/ S-/ -	+ and - are terminals for connecting external load to the Boost output; When BST_LD (pin 1) is short to + pin on J12, the on-board load resistor will be used as the Boost output load. S+ and S- are kelvin sense points for the Boost output. For output voltage measurement during efficiency test, S+ and S- should connect to multi-meter for better accuracy.
J13	VBAT_DIV/ GND_DIV/ I_MON/ TMP_SNS/ AGND	Sense points. For probe only.
J14	SW_BYPASS/ VDD_PWR/ SW_USE/ S+/ S-/ PGND	DA9070 power input (VDD_PWR) supply selection and voltage sense. VDD_PWR can directly connect to the 5V_USB rail by shorting J14 pin-1 to pin-2; VDD_PWR can also connect to the 5V_USB rail though load switch U1 by shorting J14 pin-2 to pin-3. The load switch is controlled by the MCU during battery profiling. For evaluation use jumper positions 1 and 2. J14-S+ and J14-S- pins are kelvin sense points of DA9070 input VDD_PWR.
J16 (VDD_SYS_M)	S+/ S-	S+ and S- are kelvin sense points for DA9070 VDD_SYS.
J17	P_FLT, WD, S_FLT, RIN_N, ITER_C, AGND, ILIM_C, AGND, ILIM_P, AGND, ROUT_N, MODE	Sense points. For probe only.
J18 (LDO0_LD)	LDO0_LD/ +/ -	+ and - are terminals for connecting an external load to DA9070 LDO0 output; When pin-1 is shorted to the + pin on J18, the on-board load resistor will be used as the LDO0 output load.
J19 (LDO1_LD)	LDO1_LD/ +/ -	+ and - are terminals for connecting external load to DA9070 LDO1 output; When pin-1 is shorted to + pin on J19, the on-board load resistor will be used as the LDO1 output load.
J20 (LDO2_LD)	LDO2_LD/ +/ -	+ and - are terminals for connecting external load to DA9070 LDO2 output; When pin-1 is shorted to + pin on J20, the on-board load resistor will be used as the LDO2 output load.
J21 (VO_BUCK_M)	+/ S+/ S-/ -	+ and - are terminals for connecting an external load to DA9070 Buck output; S+ and S- are kelvin sense points for DA9070 Buck output. For output voltage measurement during efficiency test, S+ and S- should connect to multi-meter for better accuracy.

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## **GUI Features**

All DA9070 and DA9231 registers are accessible via the DA9070 Fuel Gauge EVK GUI.

The GUI also includes a fuel gauge function and on-board load control. These are shown in Figure 6.



Figure 6: Fuel Gauge and Load Profile Window

Note that the load values in the pull-down menu are based on the default resistor values in Table 3. The minimum value of 3mA is the MCU's typical standby current.

The fuel gauge displays the real time battery voltage, discharge current, and State-of-Charge based on the battery profile stored in the MCU. Be sure to update this profile if a different battery is used. The fuel gauge will display the correct state of charge regardless of whether the on-board or external loads are used. Charge current is not displayed and can be assumed to be the set charge current; either set by the MCU at the pre-loaded value or by I2C command through the GUI.

The DA9070 fuel gauge outputs (IMON and VBAT\_DIV) are directly controlled by the MCU. These registers should not be controlled by the user.

# **Charging and Discharging**

Battery charging is enabled by default. To stop battery charging, simply remove the jumper at J14. This will remove VDD\_PWR from the DA9070 and is the only method recognized by the MCU and fuel gauge. Charging can also be enabled and disabled using I2C command or with the MODE pin. When the battery is fully charged, the DA9070 will stop charging and restart only when the battery voltage has dropped to the re-charge threshold.

# Applying external loads to LDO and Boost outputs

For the three LDO rails as well as the Boost rail in DA9070, the DA9070 Fuel gauge EVK has the flexibility to use either on-board load resistors or connect to external loads.

If on-board load resistors are used, jumpers need to be installed on LDO0/1/2\_LD and VO\_BST connectors, as shown in Figure 3. The default load resistor values are shown in Table 3. The load current for each rail will be determined by the programmed output voltage divided by the fixed load resistor values. The total load can be controlled from the GUI Fuel Gauge window.

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Table 3:	Default L	oad Resistor	Values
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Designator	Description	Value
R72	Load resistor for LDO0 rail	30.9Ω, 1/2W
R9	Load resistor for LDO1 rail	62Ω, 1/4W
R11	Load resistor for LDO2 rail	154Ω, 1/8W
R8	Load resistor for Boost rail	3.3kΩ, 1/8W

If an external load needs to be applied to any rail, first remove the jumper previously installed on LDO0/1/2\_LD or VO\_BST connector. Then apply the external load between '+' and '-' terminals of LDO0/1/2\_LD or VO\_BST connector, as shown in Figure 7.

Make sure the load current always flows out of '+' terminal and flows into '-' terminal on the connectors.





Figure 7: Applying External Loads

LDO1 output

**Boost output** 

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## **DA9231 Evaluation**

The typical application diagram of DA9231 is shown in Figure 8.

DA9231 includes a Buck regulator and an LDO. On the DA9070 Fuel gauge EVK, both the Buck and LDO regulators can be evaluated individually. It is recommended to follow the operation conditions as shown in Table 4 to avoid any damage to the EVK board. For test and measurement set-up, please refer to Table 5 for descriptions of connectors on the EVK board.



Figure 8: DA9231 Typical Application Diagram

# **Recommended Operating Conditions**

#### **Table 4: Recommended Operation Conditions**

Parameter	Description	Conditions	Min	Тур	Max	Unit
VDD	Analog Input	VDD= VDD_SYS	2.5		5.5	V
VDD_SYS	Power Input	VDD= VDD_SYS	2.5		5.5	V
VDD LDO	LDO mode		1.8		5.5	V
	Load Switch mode		0.8		5.5	V
I_BUCK	Buck Output Current				300	mA
I_LDO	LDO Output Current				100	mA

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## **Connectors for DA9231 Evaluation**

#### Table 5: DA9231 Input and Output Connectors

Connectors	Pin Names	Descriptions	
J4 (VO_BUCK_SL)	+/ S+/ S-/ -	+ and - are terminals for connecting external load to DA9231 Buck output; S+ and S- are kelvin sense points for DA9231 Buck output.	
J7	VLDO_SL/ AGND	Terminals for connecting external load to DA9231 LDO output.	
J15	5V_USB/ VDD_SYS_SL/ VDD_SYS_M/ S+/ S-/ PGND	DA9231 Input supply selection and voltage sense. DA9231 input terminal (VDD_SYS_SL) can be selected from 5V_USB or VDD_SYS_M of DA9070. S+ and S- are kelvin sense points for DA9231 Buck input.	
J22	VDD/ IC_EN/ AGND	Set IC_EN to VDD to automatically start the DA9231 when VDD is applied. Set IC_EN to AGND to completely disables the DA9231, including I2C communication.	
J23	VDD_SYS_SL/ VDD_LDO_SL/ VO_BUCK_SL	LDO input supply selection. LDO input terminal VDD_LDO_SL can be selected from either DA9231 input VDD_SYS_SL or DA9231 Buck output VO_BUCK_SL.	
J25	VO_BUCK_SL/ VDDIO V2P5/ VDDIO VLDO_SL/ VDDIO VO_BUCK_M/ VDDIO	<ul> <li>VDDIO voltage selection.</li> <li>VDDIO can be connected from 4 options by installing a jumper between VDDIO pin and the pin next to its left: DA9070 Buck, DA9231 Buck, DA9231 LDO, or independent 2.5V supply.</li> <li>For evaluation purposes, the 2.5V supply position is recommended to provide communications regardless of which IC is enabled.</li> </ul>	

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# **Battery Profile Mode**

The DA9070 Fuel gauge EVK board can also be configured to perform battery characterization (battery profile) and run a fuel gauge performance test. This is done using the Power Profile Manager (PPM) software instead of the DA9070 Fuel Gauge GUI. The profile data for a specific battery is generated by the PPM and loaded to the MCU. This profile is then used by the pre-loaded Dialog algorithm for the SOC fuel gauge.

If the included 80mAh battery is used, battery profiling is not necessary; the MCU is pre-loaded with both the fuel gauge algorithm and 80mAh battery profile.

Also pre-loaded to the MCU is the eval board calibration data. The calibration steps are described in AN-SW-121 but do not need to be performed in most cases.

Figure 9 shows the jumper set-up of the DA9070 Fuel gauge board while battery profiling is running. Note the jumper position of J14 in battery profile mode.



Figure 9: Jumper Settings for Battery Profile Mode

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The entire battery profile process includes battery profiling, lookup table generation, and fuel gauge performance test. Board calibration can also be performed using the PPM software.

The main PPM windows are shown in Figure 10.

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Power Profile Ma	. – c	X C						
FTDI port selectio			🐖 Calibr	ration and F	arameters		- 0	×
Port1 COM4	Port2:	COM5	Cal Control	onorr arra r	oroniciens		-	
			Measur	e				
Port3 COM6	Port4	COM7	Avg Cu	rrent	0.0	uA Now Current	0.0	uA
			Avg Vo	ltago	0.0	mV Now Voltage	0.0	mV
	Scan		Avgvo	nage	0.0	niv Now Vollage	0.0	mv
	Joan		Board (	Calibration				
			VREF	Voltage	5006	mV VDD Voltage	2007	mV
Function			Curren	t Offset	80	uA		-
		_	P. de	0				
Calibration and	Profile	Data	Resisto	ors Setting		Parameters Sel	ung	
Parameters	FIOme	Jala	R72	30.9	OHM	Capacitance	80	mAh
			R9	62	OHM	Charging Voltag	ae 4200	) mV
	· · · · ·							
	Perform	ance	R11	154	OHM	Charging Curren	nt 40	mA
Battery Profile	Tes		-			EOC Current	10	mA
	Tes	, t	Elapsed	d time 000	1:00h:00m:00	5		1
File Path			Sample	Num.	0.0 sp	Max Dis Curr.	16 mA	~
Browse	:\Dialog Ser	niconc	Me	asure	Impor	t from MCU	Export to MC	CU
	Profile Data					- 🗆 ×		
	Data1	Data2	Data3	Param	neters			
	Lookup Tables		Datab	. i i i i i i i i i i i i i i i i i i i	citance 80 mAh	Charging Voltage 4200 mV		
	SOC(%) LO	N HIGH	CHG	Charg	ing Current	Profiled CC		
	100 462	457	466		70 mA	4 mA		
	90 452		466	EOC	Current			
	80 442		457		10 mA			
	70 436		449		Current	Low Current		
	60 429		443	-	16 mA	3 mA		
	50 423		438		io mA	5 mA		
	40 420		434	Import				
	30 418		431	E.	om MCU	From PC		
	20 416		429	FIG	Milliou	FIOMPC		
	10 413		426	Export				
	5 410		423					
	2 408	397	421	Т	o MCU	To PC		

Figure 10: PPM windows

418

395

To MCU

Average

To PC

Clear

Please refer to Application Note AN-SW-121 DA9070 Power Profile Manager and SOCF for step-bystep instructions on how to perform these tests.

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# **Revision History**

Revision	Date	Description
1.0	12-12-2017	Initial version
2.0	28-10-2018	Updated for EVAL 3
2.1	25-02-2022	Document rebranded to Renesas



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TOYOSU FORESIA, 3-2-24 Toyosu

Koto-ku, Tokyo 135-0061, Japan www.renesas.com

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