AS104-PDTURBOPOCZ USB PD with Turbo Boost

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1. Introduction

The AS104-PDTURBOPOCZ is reference solution board for Universal Serial Bus Power Delivery (USB PD). It has a USB PD 3.0 controller R9A02G011 and Bidirectional Buck-Boost Voltage Regulator (BB-VR) ISL81401 and battery charger controller ISL9238. This document describes the application on the use of voltage level beyond USB Type C application. The input voltage which is supported by a USB Power Delivery (USB PD) provider such as a USB PD AC adapter in the 5-20V range. The board is designed to support those beyond 20V application ie printer motor 24V and 32V so the buck boost converter which include in this design will work as turbo boost USB PD voltage to the desired higher voltage. Renesas USB Power Delivery Controller (R9A02G011) is based on the Universal Serial Bus (USB) Power Delivery Specification Revision 3.0 and USB Type-CTM Cable and Connecter Specification Revision 1.3. The PD controller performs negotiation for more current and/or higher voltages over the USB cable (VBUS) than are defined in the USB2.0, USB3.0 or BC1.2 specifications, and controls circuitry to select local power source or power sink. The R9A02G011 uses a 300kbps BMC modulated signal through the CC wire in the USB Type-CTM

The ISL81401 are 4-switch synchronous buck-boost controller with peak and average current sensing and monitoring at both ends provide the turbo boost function to boost the USB PD voltage to higher voltage. It is designed to achieve as high as 32V which can be delivered upto 45W output maximum power.

The ISL9238C is a buck-boost Narrow Output Voltage DC (NVDC) charger. The ISL9238C provides NVDC Charging into for 2-, 3-, or 4-cell Li-ion batteries and support kick start application where inrush current become very critical during power up and the supplementary from battery will avoid system collapse due to inadequate of power limited from US PD.

Their is an optional reference solution board that comes without the ISL9238C battery charger board attached (refer to Figure 2 and 3). RL78G14 MCU with HMI allows the user to define and regulate the output power of ISL81401 based on the USB type C voltage detection. This allows the user to implement a programmable power supply (PPS), which outputs an adjustable voltage outside USB-C voltage range but limit it to operate within the USB-C power limit range detected by R9A02G011. This allows user to power devices beyond the max 20V limit that USB-PD can support AND still need to operate within the power limit determine by type C source.

2. Target Device

USB PD : R9A02G011

Buck-Boost Controller : ISL81401

Battery Charger : ISL9238C

Microcontroller : RL78/G14

Op Amp : ISL28213

When applying the sample program covered in this document to another microcomputer, modify the program according to the specifications for the target microcomputer and conduct an extensive evaluation of the modified program. It should be fully evaluated if replace the analog or power supply devices in this system to other.

3. Features

The proof on concept board supports the following features.

- USB Power Delivery and USB Type-C™
  - Having one USB Type-C™ port
  - Power Role: Single Role (Supports Try.SRC mode)
  - Power Sink: 5 to 20V (Supports variable input)
  - Supports USB Type-C™ Authentication Responder feature (optional)
  - Supports USB Power Delivery Firmware Update feature (PDFU)
- Battery Charger
  - Battery type: Li-ion battery
  - Number of cells: 2, 3 or 4 series cells (Normal function: Default setting = 3 series cells)
  - Trickle Charging
  - USB Type-C™ port status indicator (1 LED)
- Protections
  - Over Temperature Protection (USB Type-C™ Receptacle)
  - Over Voltage Protection (VBUS voltage)
  - Over Current Protection (VBUS current)

4. Block Diagrams

Figure 1 shows the system block diagram of AS104-PDTURBOPOCZ

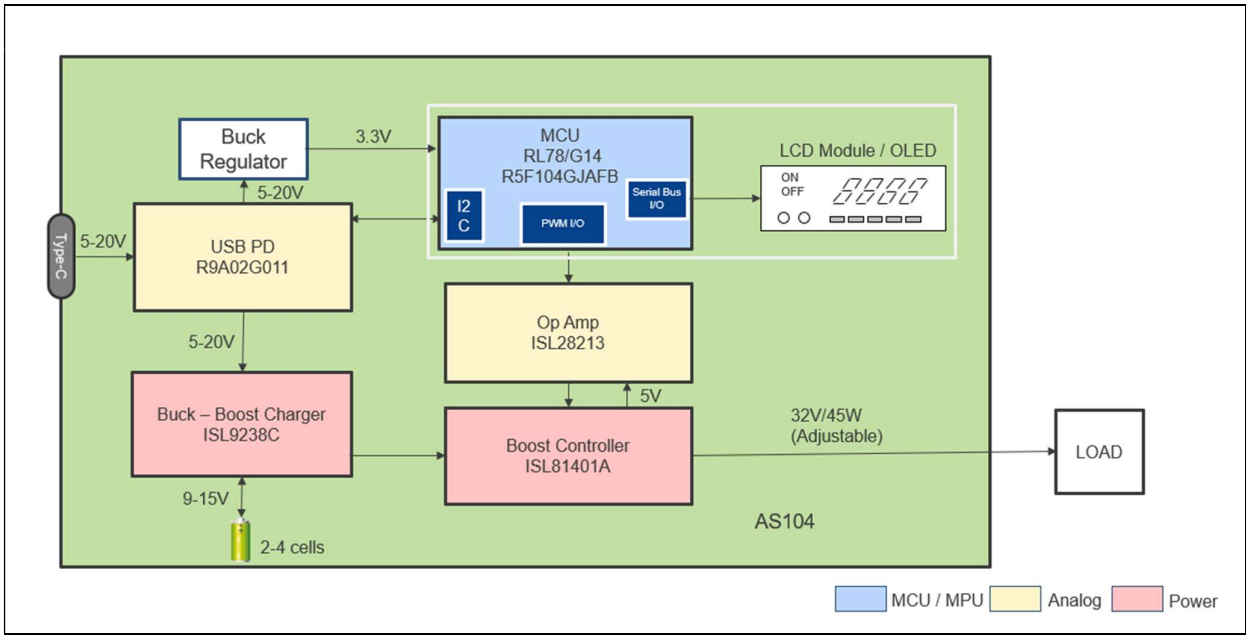


Figure 1 System Block Diagram of AS104-PDTURBOPOCZ

Figure 2 shows the optonal system block diagram of AS104-PDTURBOPOCZ

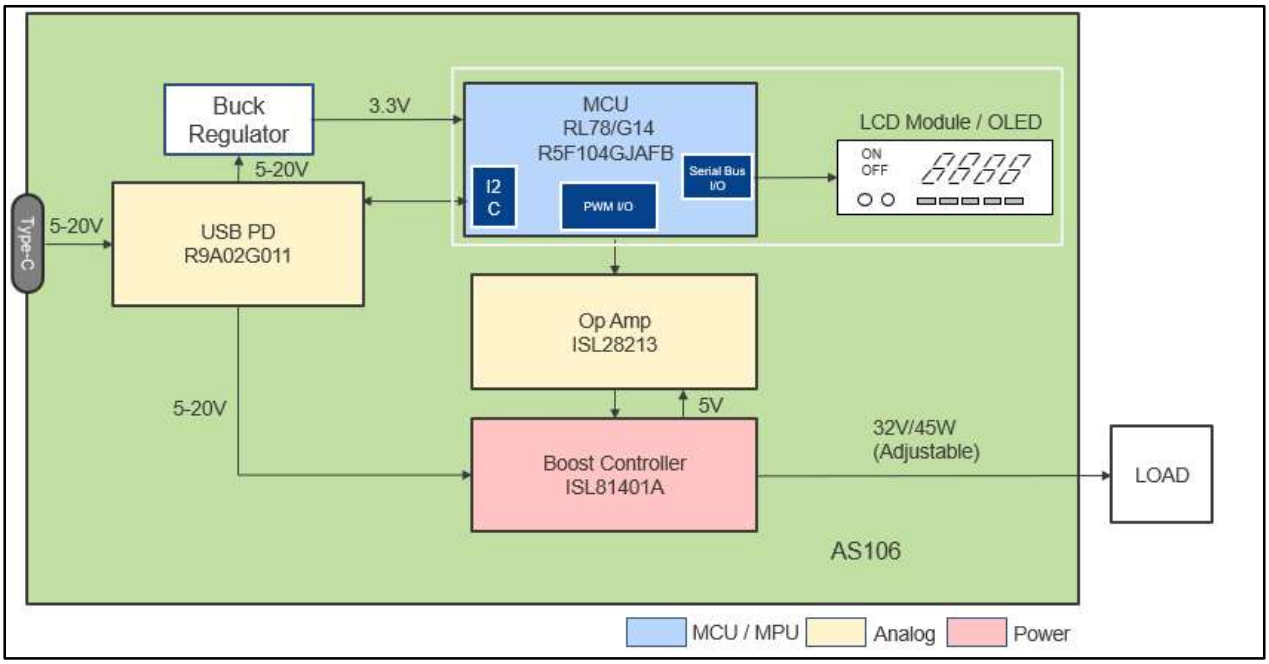


Figure 2 Optional System Block Diagram of AS104-PDTURBOPOCZ

5. Operation Procedure

This system is powered from the adapter. USB PD TYPE Adapter will be used for this application.

Initial preparation:

- Short all pins of CN9 with the jumper
- Short pins 1-2 of JP4(PULLUP to 3V3) and
- Short jumper for selection of 2,3 CELLS battery
- SW2 switch to High
- Short pins 1-2 of J11 (IIN to VCC5/disable input current monitoring)
- Short pin 1-2 of J13 (MODE to GND / for forcing to CCM operation)
- Short pin 1-2of J14(LG2 pin to low / for constant current overcurrent protection)
- Short pins 2-3 of J12 (FBi to GND/ disable input voltage feedback or no use reverse direction operation)

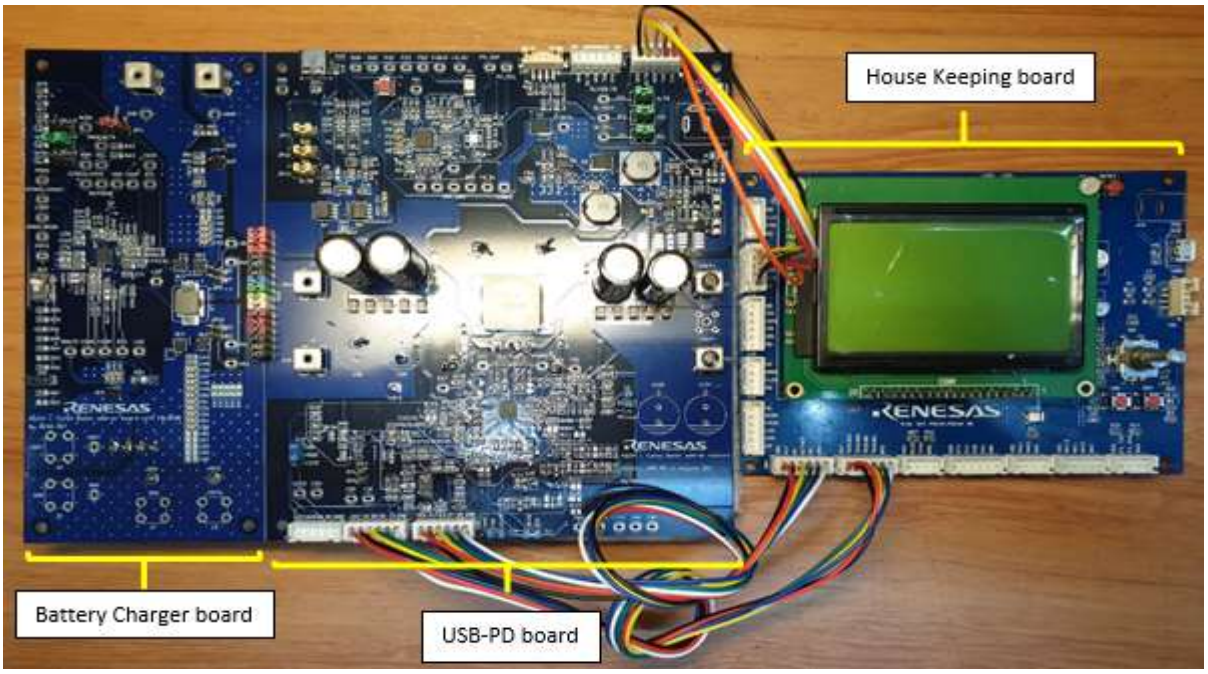


Figure 3 Board Setup Picture

Connection between Housekeeping Board and PD Board.

- House Keeping board CN3 to USB PD Turbo Boost board CN2
- House Keeping board CN7 to USB PD Turbo Boost board CN8
- House Keeping board CN8 to USB PD Turbo Boost board CN6
- House Keeping board CN12 to USB PD Turbo Boost board CN7

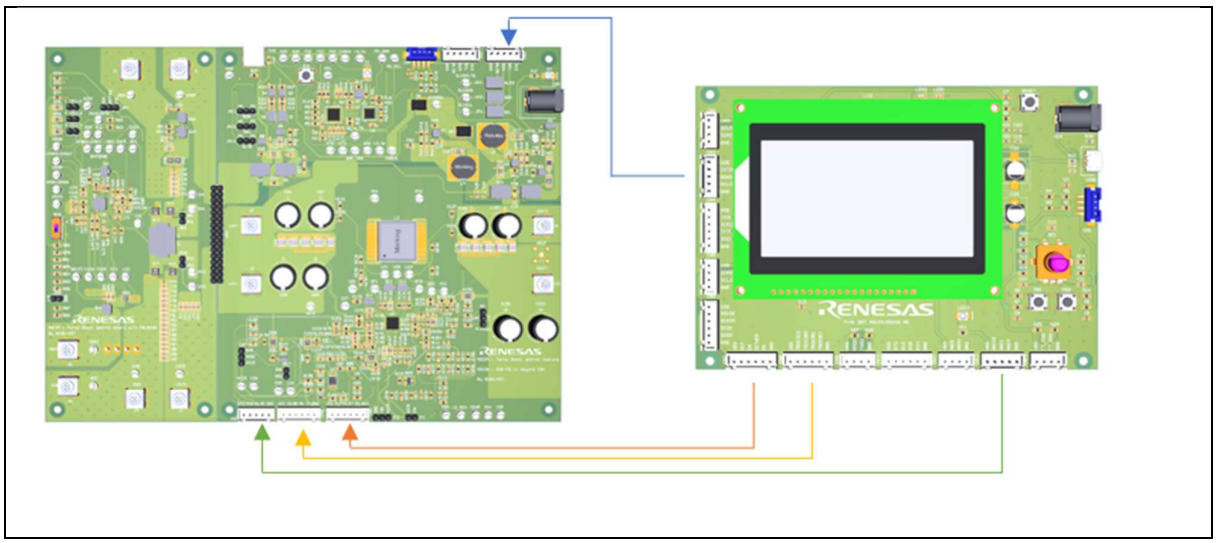


Figure 4 Connection

6. Start up operation

Plug USB PD Adapter 45W (ie Lenovo Adapter model SA10e75841 or ZMI HA832) to USB Type C connector. Press reset for system to start up with firmware, which it will show – Renesas PD GUI.

Press PB2 on house keeping board, it will show power input status. Perform the reading at output connector J9 and J10. It should read 32V properly

For operation on battery charger board, please make reference to ISL9238C datasheet and EVK document.

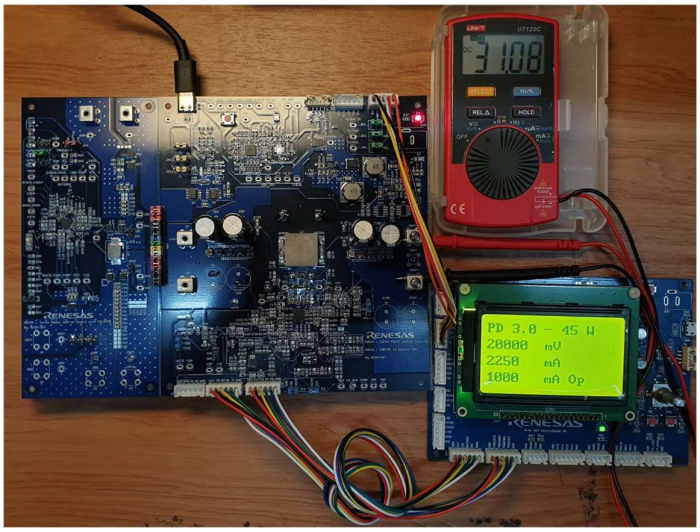
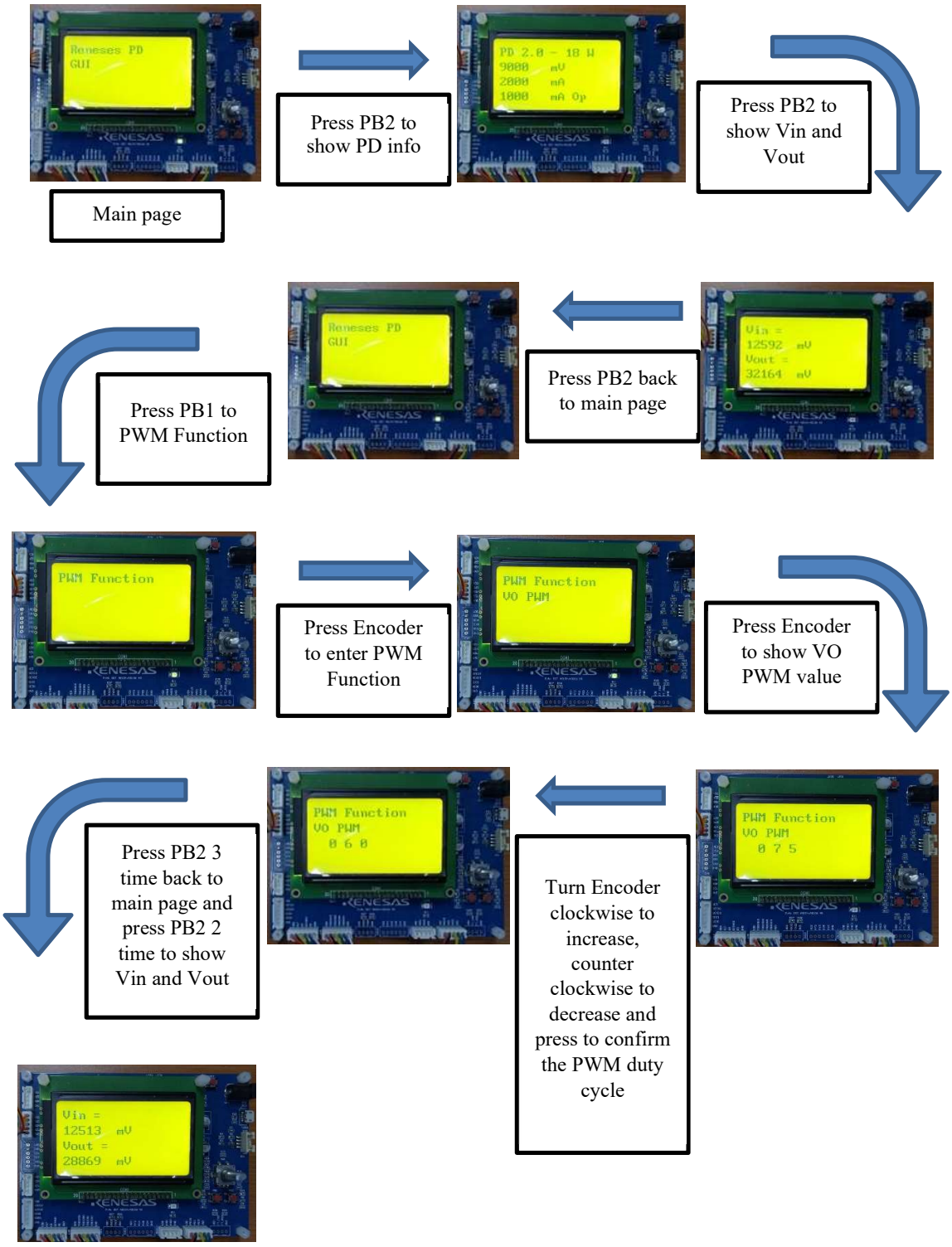


Figure 5 Power up and Measure

7. Housekeeping Board Operation

Below shows the sequence of operation to display USB PD info, V-in values, V-out values, and to adjust the V-out PWM duty cycle.



8 Theory of Operation

USB Power Delivery perform the Universal Serial Bus (USB) Power Delivery according to Specification Revision 3.0 and USB Type-CTM Cable and Connecter Specification Revision 1.3. The technology provide negotiation for more current and/or higher voltages over the USB cable (VBUS) than are defined in the USB2.0, USB3.0 or BC1.2 specifications, and controls circuitry to select local power source or power sink. Renesas R9A02G011 PD controller uses a 300kbps BMC modulated signal through the CC wire in the USB Type-CTM cable. It comes in a small 32-pin QFN package and integrates several commonly required external components, making it ideally suited for applications with limited PCB space. low-power technology.

The year 2015 opened up a new era of power management as high-profile devices began to adopt USB-C ports. A true all-in-one port, it is capable of delivering bidirectional data and power at the same time. USB-C charging requires a fundamental change to the existing power delivery architecture and presents a new challenge to system designers. With a default 5V voltage, the USB-C port is capable of negotiating with the plugged-in device to raise the port voltage to 12V, 20V, or another mutually agreed on voltage, at a mutually agreed current level. The maximum power a USB-C port can deliver is 20V at 5A current, which is 100W of power.

On emerging application where require to operate the power voltage level beyond 20V standard USB-C maximum voltage. Renesas present a complete buck-boost switching controller with a PWM modulation, internal drivers, references, protection circuitry, current and voltage control inputs, and monitor outputs. The ISL81401 and ISL81401A are current-mode controllers. They use a proprietary control algorithm to application beyond 20V to switch it in Boost modes as necessary to maintain a steady output voltage with changing input voltages and dynamic external loads. The controllers integrate four control loops to regulate not only V_{OUT}, but also average I_{OUT} and I_{IN} for constant current control. The driver and protection circuits are also integrated to simplify the end design. The part has an independent enable/disable control line, which provides a flexible power-up sequencing and a simple V_{IN} UVP implementation. The soft-start time is programmable by adjusting the soft-start capacitor
connected from SS/TRK.

The ISL9238 provide power to USB-C buck-boost charger functional to given two-way power delivery while using a single-chip technology that reduces BOM costs and improves efficiency. It can operate in buck, buck-boost, and boost mode to maintain an accurate output voltage and support USB On-The-Go with full range 5V to 20V OTG. The ISL9238 has an input voltage range of 3.2V to 23.4V with an output of 2.4V to 18.304V for 2 to 4-cell batteries. Automatic sensing allows the device to enter trickle charging mode when the battery is depleted; it has an option available setting for 2-level adapter current limit; and battery learn mode calibrates the battery fuel gauge. Programmable features using the SMBus or I^2C interface provide the user with flexibility in their design.

Furthermore, both devices achieve acoustic noise-free operation, superior light load efficiency and fast dynamic response, thanks to Intersil's patented R3 modulation.

The RL78/G14 MCU serves as a housekeeping controller to allow the developer or user to monitor the status of USB Input Power Source. It also allows the trimming of Voltage Output using the Potentiometer and provides the corresponding PWM duty cycle signals to the ISL81401 Boost Converter. Subsequently, the resulted Output Voltage is displayed on the LCD together with the Input Voltage. The RL78/G14 MCU has the capacity & rich peripherals to expand into more features for the system.

9. Main Components

Table 1 show lists the main component use in this design

Table 9.1 Main Components

Components	Type	Remark
USB PD Controller	R9A02G011GNP#AC0	Renesas
Buck-Boost Controller	ISL81401FRZ-T	Renesas
Battery	ISL9238CHRTZ-T	Renesas
Precision Op Amp	ISL28213FUZ-T	Renesas
MCU	RL78/G14(R5F104GJAFB)	Renesas

MCU Peripherals Used

Table 9.1 lists the peripherals used by the sample code and their functions.

Table 9.2 Peripherals Used

No.	Peripheral	Connection	Function Description	Function Module
1	Input Port	P121	Push Button PB1	Display & function switching
2	Input Port	P122	Push Button PB2	Display & function switching
3	Input Port	P41, P120, P140	Potentiometer trimmer & button	Duty cycle trimming & register
4	Output Port	CS01,SO01,SCK01, LCD_RESET	LCD Driver	LCD driver communication
5	Timer Output	TRDIOC0, TRDIOB0, TRDIOB1, TRDIOC1	PWM signal output	PWM Signal output to ISL81401
6	I^2C	SDA0, SCL0	I^2C communication	USB PD SMBus communication
7	ADC	ANI0, ANI1	ADC Voltage Input	Voltage level input of Vin & Vout

10. Software

a. Integrated Development Environment

The Housekeeping RL78/G14 MCU sample code described in this chapter has been developed under the conditions listed in the table below.

Table 4.1 Operation Conditions

Item	Description
Microcontroller used	RL78/G14 (R5F104GJAFB,256KB ROM,24KB RAM)
Operating frequency	High-speed on-chip oscillator (HOCO) clock: 64 MHz CPU/peripheral hardware clock: 32 MHz Internal low-speed oscillator clock (fIL): 15 kHz
Operating voltage	3.3 V
Integrated development environment	CS+ for CA from Renesas Electronics
RL78/G14 Hex Filename	RL78G14_48P_256KB_SMBUS_V1-20200812-show_info-18w-ANI.hex
Corresponding R9A02G011 Hex Filename	DRPEVB_with_SMBS.hex

b. Main Function

The Housekeeping RL78/G14 MCU sample code manages the following functions.

i. Reading of Status from USB PD Controller R9A02G011 via the SMBus (I^2C)

Please refer to USB Power Delivery Controller R9A02G011 Hardware User's Manual, Section 6.2.5 Command Code Index.

The USB PD Status Data that were used for display purposes are listed in the table below:

Table 4.2 SMBus Commands used

Code	SMBus Command	Description
03h	Status 1	Bit map of PD port/controller status
04h	Status 2	Bit map of PD port/controller status
71h	Object Data Mode	Object Data Select settings
91h	Object Data	Object Data

ii. Displaying of USB PD Controller Status on LCD

USB PD Controller status data that were shown on the LCD are listed as below:

- USB PD Version
- USB PD Input Power
- USB PD Input Voltage
- USB PD Input Current
- USB PD Operating Current

iii. Trimming of Voltage Output Duty Cycle with the Potentiometer

Please refer to the duty cycle operating procedure in Chapter 1.5 Housekeeping Board Operation of this User's Manual.

iv. Output PWM Signals to the Boost Converter ISL81401

PWM Signals output will be based on the duty cycle trimmed values set by the Potentiometer. Default duty cycle values are defined in the sample code.

v. Displaying of Voltage Input & Voltage Output on LCD

On the Main Display Page, Voltage Input & Voltage Output are shown on the LCD. These values are read using the MCU ADC.

11. Reference Documents

RL78/G14 Microcontroller User's Manual: Hardware

USB Power Delivery Controller R9A02G011 User's Manual: Hardware

ISL81401 datasheet and EVK document

ISL9238C datasheet and EVK document

(The latest versions of the documents are available on the Renesas Electronics Website and IDT website.)

Website and Support

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Inquiries
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Revision History

		Description	
Rev.	**Date**	**Page**	**Summary**
1.00	Aug. 27, 2020	—	First edition issued

General Precautions in the Handling of Micro processing Unit and Microcontroller Unit Products

The following usage notes are applicable to all Micro processing unit and Microcontroller unit products from Renesas. For detailed usage notes on the products covered by this document, refer to the relevant sections of the document as well as any technical updates that have been issued for the products.

1. Precaution against Electrostatic Discharge (ESD)

   A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can easily build up static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.
2. Processing at power-on

   The state of the product is undefined at the time when power is supplied. The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the time when power is supplied. In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the time when power is supplied until the reset process is completed. In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the time when power is supplied until the power reaches the level at which resetting is specified.
3. Input of signal during power-off state

   Do not input signals or an I/O pull-up power supply while the device is powered off. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Follow the guideline for input signal during power-off state as described in your product documentation.
4. Handling of unused pins

   Handle unused pins in accordance with the directions given under handling of unused pins in the manual. The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced near the LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible.
5. Clock signals

   After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is stabilized. When the clock signal is generated with an external resonator or from an external oscillator during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Additionally, when switching to a clock signal produced with an external resonator or by an external oscillator while program execution is in progress, wait until the target clock signal is stable.
6. Voltage application waveform at input pin

   Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between V_{IL} (Max.) and V_{IH} (Min.) due to noise, for example, the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between V_{IL} (Max.) and V_{IH} (Min.).
7. Prohibition of access to reserved addresses

   Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.
8. Differences between products

   Before changing from one product to another, for example to a product with a different part number, confirm that the change will not lead to problems. The characteristics of a micro processing unit or microcontroller unit products in the same group but having a different part number might differ in terms of internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.

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