Renesas Synergy™, RL78/G1D

Personal Medication Adherence (PMA) Kit User Guide

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1. Introduction

Personal Medication Adherence (PMA), or lack of PMA compliance, is a $337 billion problem annually in the U.S. that bogs down our healthcare system. Patients forget to take or may confuse their medication, which can result in being readmitted to the hospital, a skilled nursing home or assisted-living facility, or with another visit to the doctor's office. The advent of the Internet of Things (IoT) has brought various technologies to the forefront that, when applied to PMA devices, can help resolve some of the issues we currently face. The Renesas PMA Solution is one such reference design which enables development of products to solve the PMA compliance issue.

The solution showcases the following products from Renesas:

1. Synergy Platform consisting of the S3A7 microcontroller operating with the Synergy Software Package (SSP). This performs the application processing.
2. RL78/G1D Bluetooth Smart Microcontroller for communicating blister pack information to mobile platforms.
3. R2A20056BM Lithium-Ion Battery Charger IC with Auto Load Current Distribution for charging the built-in battery pack over USB.

Note: Please read section 8.1 before reproducing hardware using provided schematic and gerber files.

2. Target Device

RL78/G1D and R7FS3A77C3A01CFP

3. Contents

1. Binary file for Synergy S3A7 Microcontroller
2. Binary file for RL78/G1D Module (RY7011)
3. Source code for PMA Application processing
4. Source code for BLE Communication Interface
5. Mobile Application
    a. https://itunes.apple.com/us/app/renesas-pma/id1410856515?ls=1&mt=8
    b. https://play.google.com/store/apps/details?id=com.renesas.pma
6. Documentation
    a. Schematic files
    b. Layout files
    c. API Guide
    d. Bill of Materials
    e. Assembly Instructions
    f. Usage Guide
    g. Quick Start Guide

4. System Requirements

4.1 Hardware Requirements

The highlighted hardware in the PMA Solution is the Smart Connector and Smart Sleeve. The Connector model, Figure 1, showcases a trace breaking mechanism to detect the action of opening a blister slot. The Sleeve model, Figure 2, showcases optical sensing to detect the action of opening a blister slot. As the optical sensing mechanism requires no changes to the existing packaging form, the demonstration is fully supported on the Smart Sleeve model. The Smart Card

model is presently for showcase purposes only. The following equipment is needed to program and demonstrate operation of the PMA device.

- 1x PC running Microsoft Windows 7 or Windows 10
- 1x Android 7.0+ device
- 1x Renesas PMA Smart Sleeve hardware & 1x Renesas PMA Smart Card hardware
- 1x E1 Debugger (for RL78/G1D only)

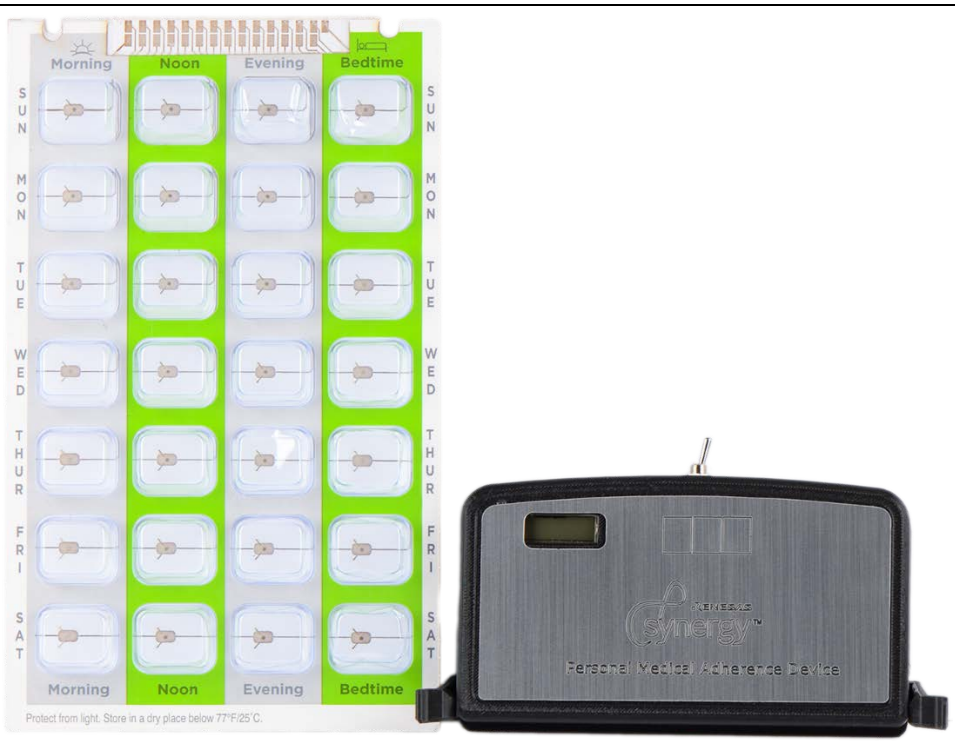


Figure 1: PMA Smart Connector Model

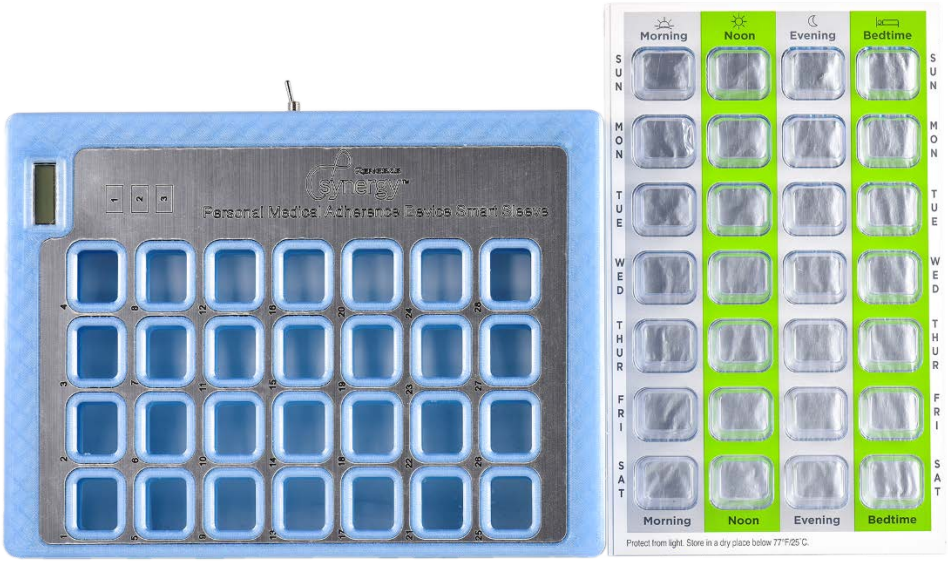


Figure 2: PMA Smart Sleeve Model

4.2 Software requirements

The following software should be installed on to personal and mobile computing platforms as instructed by the respective installation manuals:

- e2 studio (5.4.0.018 or higher)
- Renesas Flash Programmer (v 3.03 or higher)
- Synergy Software Package (v1.3.3) i.e. SSP
- GNU Tools for ARM Embedded Processors 4.9.3 20150529 (release)
- Segger J-Link Debugger Tools (Installed to default location C:\Program Files (x86)\SEGGER)
- PMA Solution (PMAS) Project Sources
- RL78/G1D BLE Stack (v 1.21)
- RL78/G1D Custom Profile Firmware Hex file for PMA device
- Bluetooth Developer Studio and RL78/G1D plugins
- Renesas PMA Mobile application APK installed on to a mobile platform

5. Out-of-Box Experience

The PMA reference design should be programmed upon receipt. However, you may follow the instructions below to re-program the devices.

5.1 Reprogramming the S3A7 microcontroller

1. Use Windows File explorer to navigate to the Segger J-Link Debugger Tools install location and identify the latest version of the tool found.
2. Edit the path contained in *pma_root\binaries\target_mcu_s3a7\pma_program_sleeve.bat* and *pma_root\binaries\target_mcu_s3a7\pma_program_card.bat* to match the version from previous step.
3. Execute pma_program_sleeve.bat or pma_program_card.bat with the respective hardware connected to the PC through a USB cable.

Sample output is as shown in Section 7.2.

5.2 Mobile Application Installation

Mobile Applications are available for installation on Android and iOS devices at the following locations:

- https://itunes.apple.com/us/app/renesas-pma/id1410856515?ls=1&mt=8
- https://play.google.com/store/apps/details?id=com.renesas.pma

Alternatively, the applications can be found by searching with the keywords "Renesas PMA" in the respective application stores.

5.3 Power-On Initialization Behavior

These steps are best carried out with the Blister card inserted in the sleeve and battery attached to the system.

1. Program the Synergy S3A7 Microcontroller with the instructions specified in the previous section.
2. Upon application of power, through the battery or USB, the S3A7 tests different components. The first component tested is the Audio Beeper. A single beep is output.
3. The application then tests the Display Segments and then shows the SSP version information.
4. Then the remaining systems such as the RFID hardware, Battery Management System, and Pill Popping Sensor interface are tested.
5. If all testing succeeds, a second beep is heard before the power-on initialization system enables the remaining systems.[1] At this point; Power-On Initialization is complete.

[1] **Note**: If your system is programmed for the first time, and the BLE MAC Address does not match parts of the Unique ID of the Synergy microcontroller, then the S3A7 will attempt to reprogram the address of the RL78/G1D. Upon

5.4 Demonstration Loop

1. If a blister pack is not inserted, then the system indicates using two beeps and **no Crd** indication on the screen.
2. When a blister pack with a programmed NFC tag is inserted into the assembly, the system indicates recognition with three quick beeps followed by a read out of the tag information (8 hexadecimal bytes). The insertion test occurs every three seconds.
3. Log in to the PMA Mobile Application, select the **RenesasPMAS** device currently advertising, and observe the Bluetooth icon turn white indicating a connection to the PMA Device.
    a. Use the **Settings** tab in the mobile application to Reset Slots.
    b. The Mobile Application will program the RTC of the S3A7 and the "expected time to take" for each pill slot. This is indicated by **rtc** and **L:XX** on the display.
    c. The mobile application will then read the pill slot information, and show the Blister Card Identifier, Temperature, Humidity, and the Battery level information.
4. When it's time to take a pill, the PMA device will indicate using three quick audio beeps and **P:XX** on the screen, where **XX** is the pill slot to pop.
    a. The mobile application will indicate the slot to pop using an exclamation mark in the corresponding slot.
5. When popped, the PMA device will indicate using two audio beeps and **n:XX** on the screen; where **XX** was the pill popped.
    a. When popped, the mobile application will update the pill slot information accordingly.
6. Pressing and releasing any active touch button will provide audio feedback.
    a. Button 1 quick touches will scroll through the data.
    b. Holding button for 10 seconds will change the temperature units from Celsius to Fahrenheit (**C-F**), and vice versa (**F-C**).
    c. Button 2 allows muting the audio beep alarm. When muted, the display will indicate using **Alr OFF**. When un-muted, the display will indicate **Alr On**
    d. Holding button for 10 seconds will clear the metadata associated with each pill slot (allowing a pill slot to be popped again).
    e. Button 3 is reserved for future use.
7. When a USB cable is inserted, or a Wireless charger is detected, the display shows message **CHr**. The presence of a charger, and battery level is updated every 15 seconds.

5.5 Verification of BLE Operation with third-party applications

This section illustrates how to verify the operation of the Bluetooth Smart Connectivity using the nRF Connect mobile application.

1. Complete Power-On Initialization with a smart blister pack inserted into the enclosure.
2. Use **nRFConnect** to connect to **RenesasPMAS** device.
3. Use **Read characteristics** to read blister time stamp information.
4. Enable Indications for characteristic with UUID E6CDCB81-18F5-446A-A46C-4013FC132EFD. Popping a blister cell will cause this indication to be updated. You can then read all characteristics to observe changed timestamps.

successful reprogramming, the system will reset. Turn Off the reset system after the first audio beep; to allow the RL78/G1D to receive a hardware reset and apply the new MAC address.

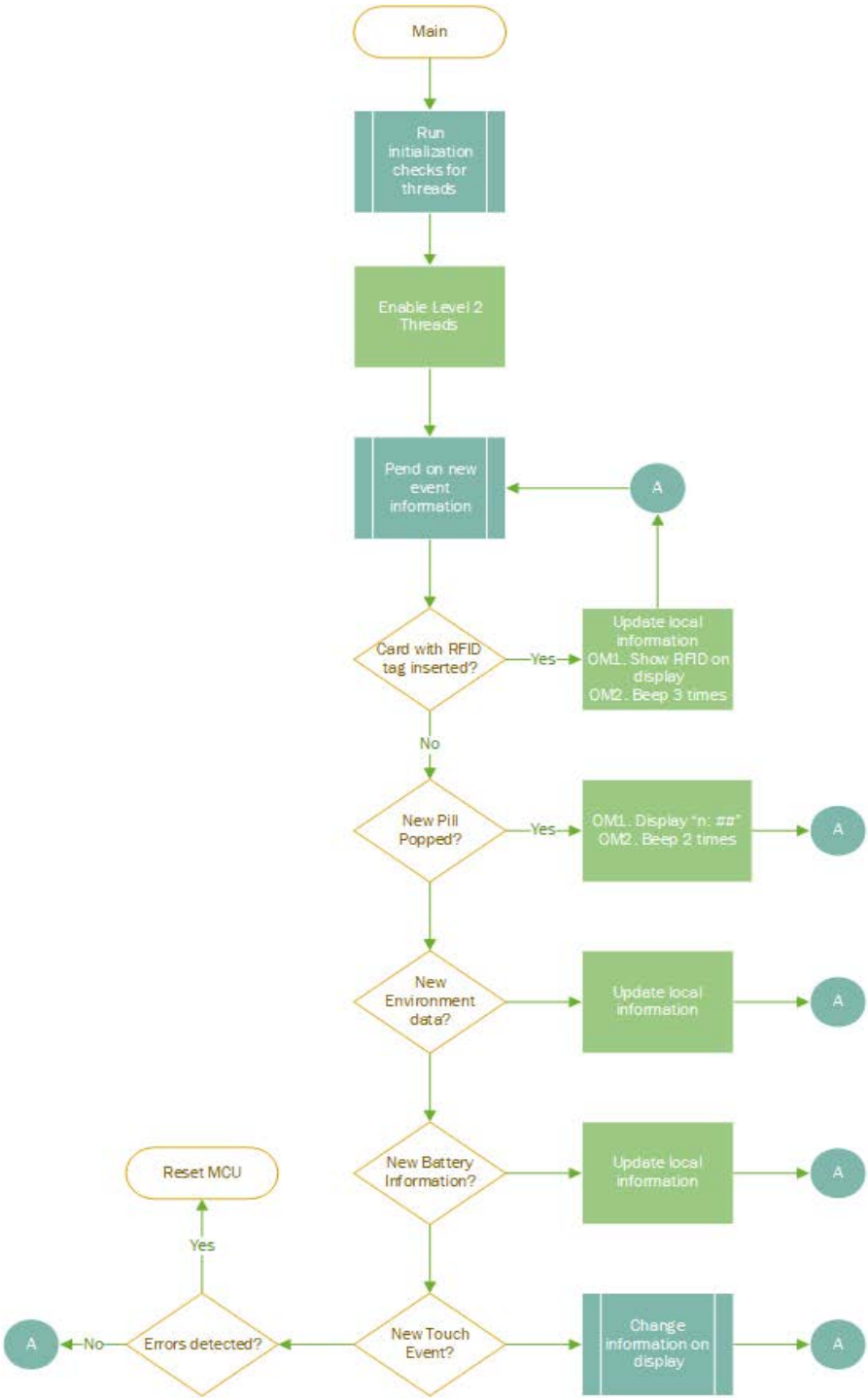
6. PMA Reference Application Flow

The PMA Reference Application consists of sub-systems (threads) described in the following sub-sections. The operation of each sub-system is approximated by the flowchart provided in each section.

It is important to note that flow of data within the application is managed by the Synergy Messaging Framework.

6.1 Main Thread

This is the only thread permitted by the SSP Configurator to run upon application of power. It runs the initialization routines for other sub-systems before enabling them.



Main Processing System

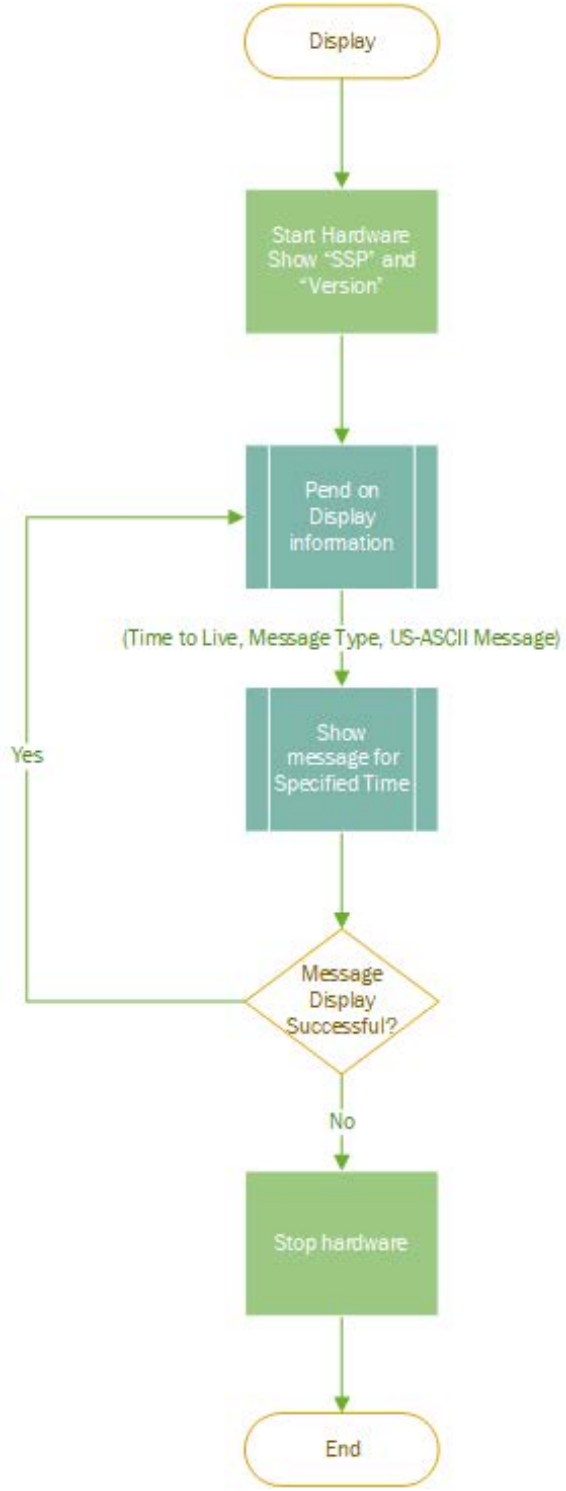
6.2 Audio Thread

This thread controls the output of a waveform. When initialized, this thread waits for events of class SF_MESSAGE_EVENT_CLASS_AUDIO_BEEP, and then generates an audio beep waveform depending upon the duty cycle, and repetitions requested.

Audio Beep Control System

6.3 Display Thread

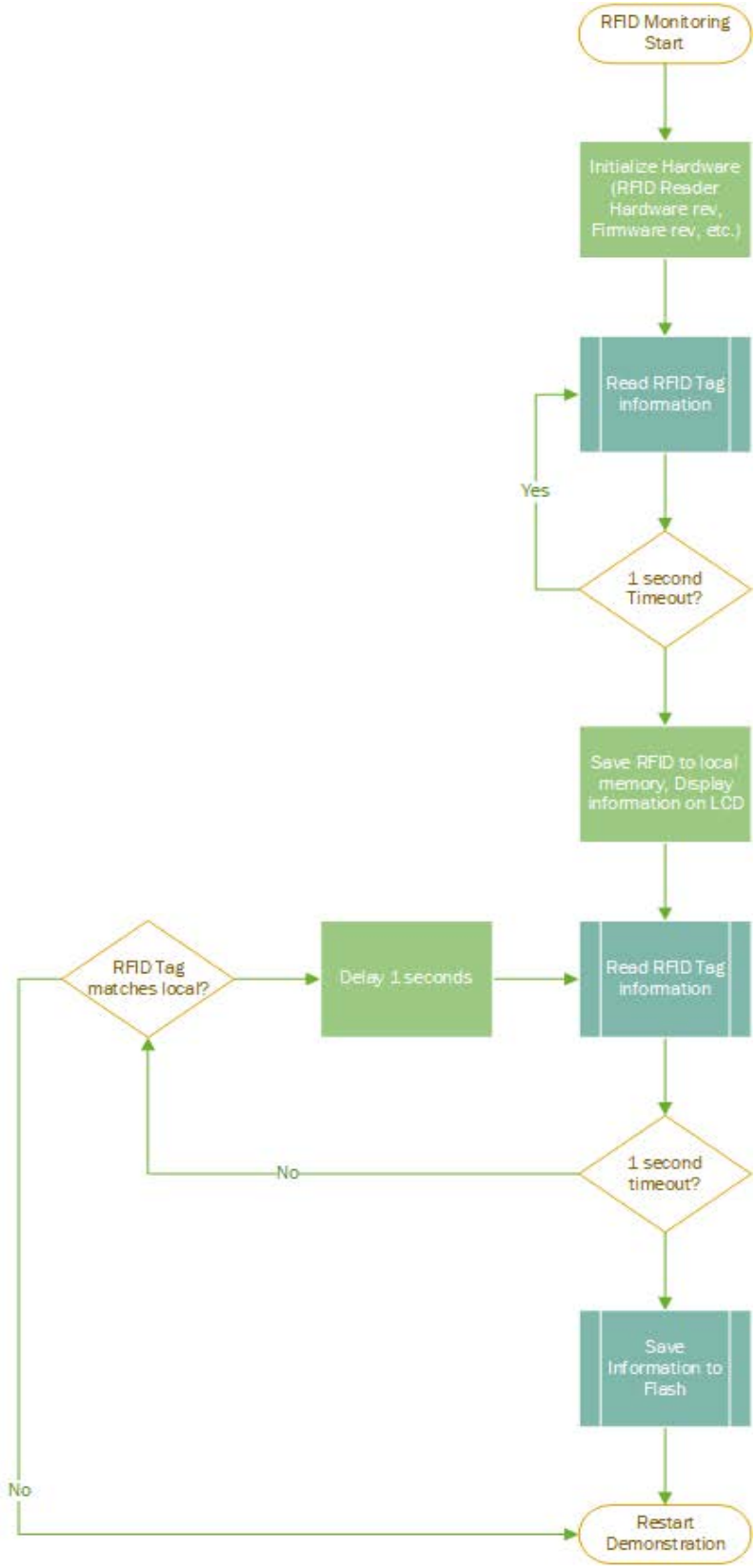
This thread controls the display of information on the Segment LCD. It waits for events of class SF_MESSAGE_EVENT_CLASS_DISPLAY and then shows the provided information for the user-specified time period on the LCD.



Segmented LCD Display Control System

6.4 RFID Thread

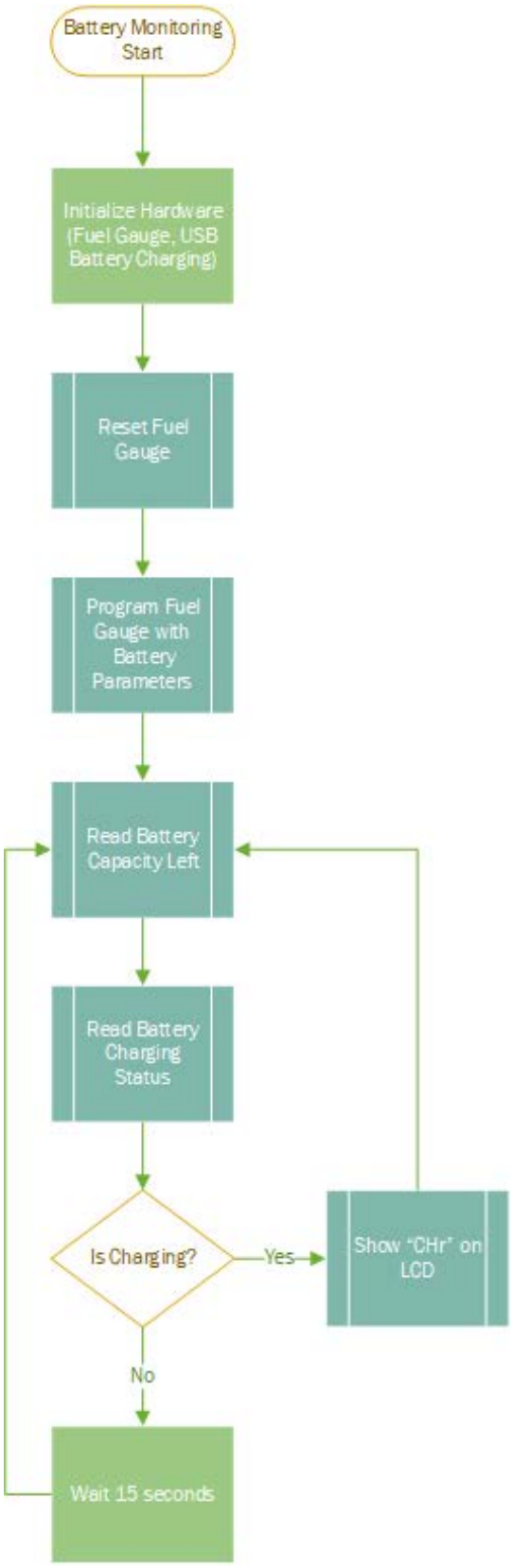
This thread monitors the presence of a RFID Tag available with a smart blister package.



RFID Monitoring System

6.5 Battery Thread

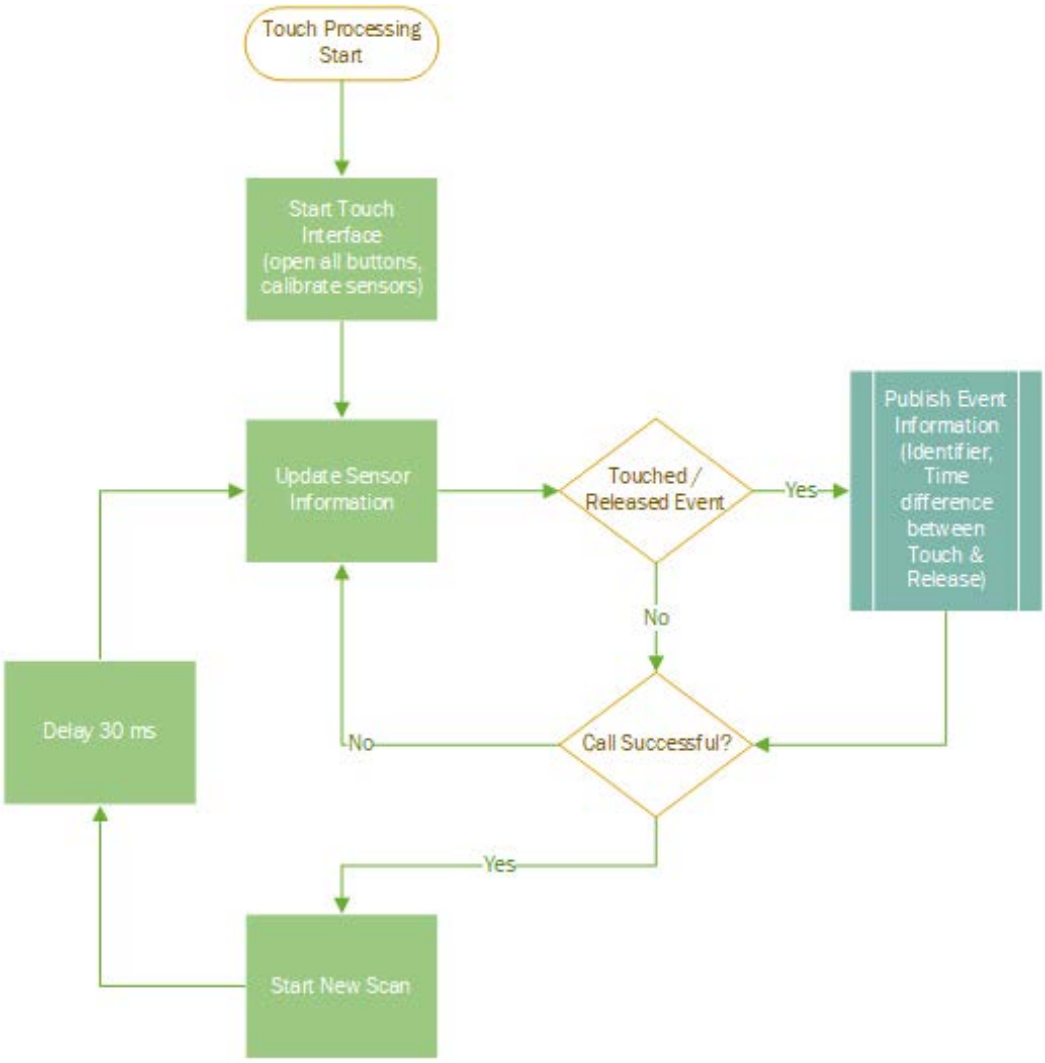
This thread monitors the amount of battery energy available.



Battery Monitoring System

6.6 Capacitive Touch Thread

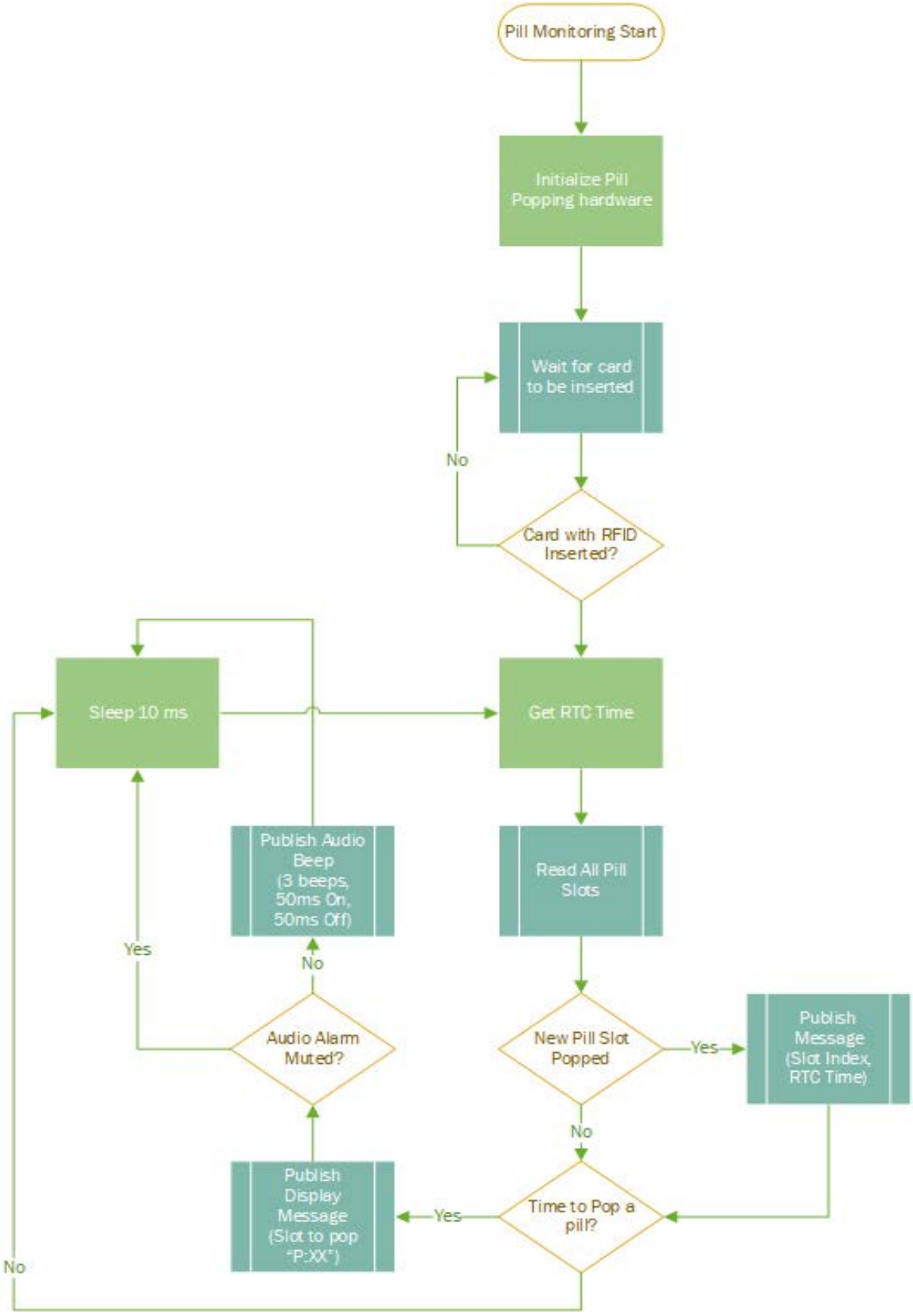
This thread monitors user interactions through capacitive touch interfaces (buttons).



Capacitive Touch Interface System

6.7 Pill Dispensing Monitor Thread

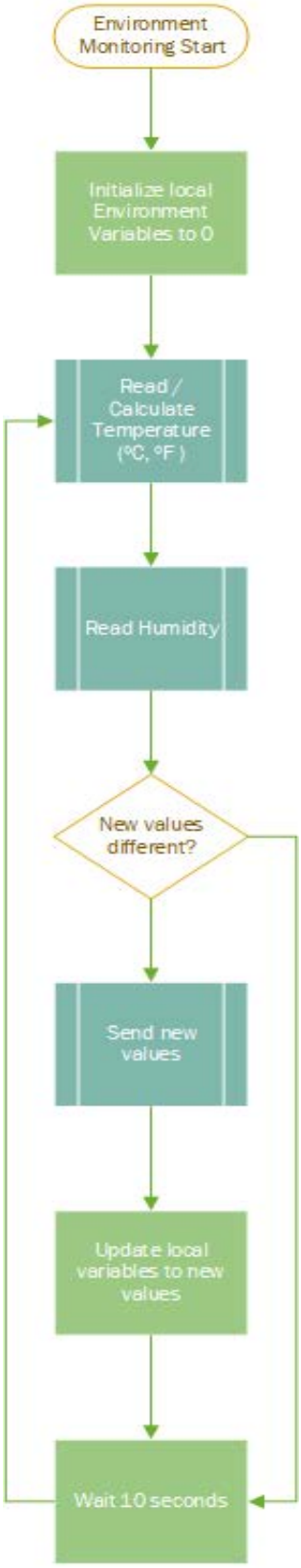
This thread monitors the operation of the pill dispense sensing mechanism.



Pill Dispensing Monitor System

6.8 Environment Monitoring Thread

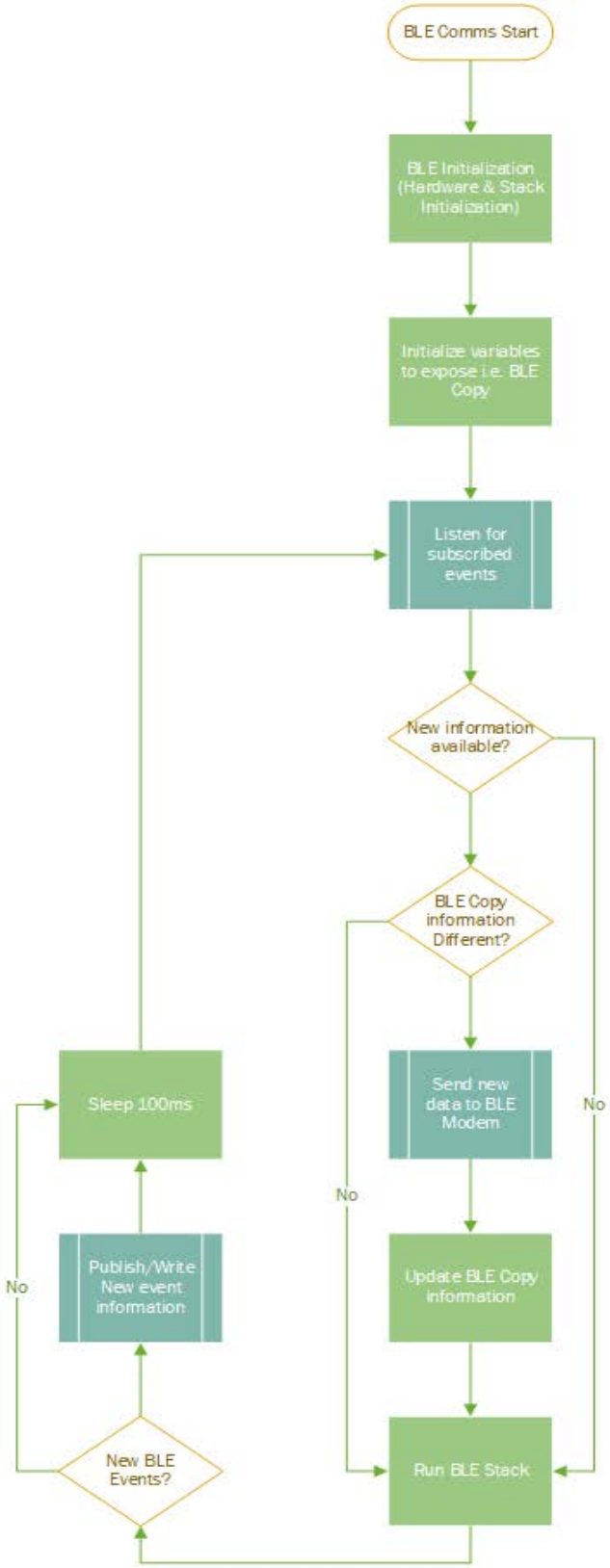
This thread monitors environment variables such as Temperature and Humidity.



Environment Monitoring System

6.9 Bluetooth Low Energy Communication Thread

This thread manages information exchanged with the BLE modem.



Bluetooth Low Energy Communications

7. Next Steps

With an understanding of the Reference Application flow, it is possible to import, build, and modify the application to match actual product needs.

7.1 Importing the Synergy Project

Import the PMAS project using the procedure specified in the document R11AN0023 available via the Renesas website.

7.2 Building the Synergy Project

There are two build configurations included in the project.

1. *DebugSleeve*: A build configuration to debug the Smart Sleeve hardware.
2. *DebugCard*: A build configuration to debug the Smart Card hardware. Note: The Pill sensing mechanism is disabled due to mechanical issues listed in section 7.1.3.

Any PMAS build configuration should build with the following output:

```
../src/rBLE/src/rscip/rscip_cntl.c: In function 'RSCIP_Config_Res_Rx_Done':
../src/rBLE/src/rscip/rscip_cntl.c:1232:111: warning: logical 'and' of mutually exclusive tests is always false [-Wlogical-op]
   if ((RSCIP_INTEGRITY_TYPE    != ((rscip.config & RSCIP_INTEGRITY_TYPE_MASK) >> RSCIP_INTEGRITY_TYPE_SIFT)) &&
                                                                                                           ^
../src/rBLE/src/rscip/rscip_cntl.c:1261:111: warning: logical 'and' of mutually exclusive tests is always false [-Wlogical-op]
   if ((RSCIP_INTEGRITY_TYPE    != ((rscip.config & RSCIP_INTEGRITY_TYPE_MASK) >> RSCIP_INTEGRITY_TYPE_SIFT)) &&

'Finished building target: PMAS.elf'
' '
'Invoking: Cross ARM GNU Create Flash Image'
arm-none-eabi-objcopy -O ihex "PMAS.elf"  "PMAS.hex"
'Invoking: Cross ARM GNU Print Size'
arm-none-eabi-size --format=berkeley "PMAS.elf"
  text    data     bss     dec     hex filename
 241560    1123   72044  314727   4cd67 PMAS.elf
'Finished building: PMAS.siz'
'Finished building: PMAS.hex'
' '
' '

14:04:39 Build Finished. 0 errors, 2 warnings.
```

8. Appendix

8.1 Identified Hardware Issues

8.1.1 Common issues

1. [Optional] A jumper J6 is used to enable power supply from battery. It is recommended to use a toggle switch for ease of use. Assembling the switch in the enclosure is left to user discretion.
2. [Optional] A battery may not be connected to J3. Recommended and tested battery pack for wired and wireless charging is https://www.sparkfun.com/products/13813.
3. [Change-Request] Connect coin cell battery to RTC/VBAT pin for maintaining time.
4. [Change-Request] Improve capacitive touch sensor design.
5. [Charging Issue] If the battery connected to J3 is completely discharged, then use wireless charging to initially charge the battery, then use USB charging to fully charge the battery.

8.1.2 Smart Sleeve Interface

The following issues have been identified with the blister popping interface using optical sensing:

1. The RFID antenna assembly is glued to the enclosure incorrectly. Antenna should be placed to face the cavity of the enclosure to minimize distance to the tag.
2. The RFID tag orientation needs to be changed to allow the reader to read the tag information. See orientation shown in Figure 3:

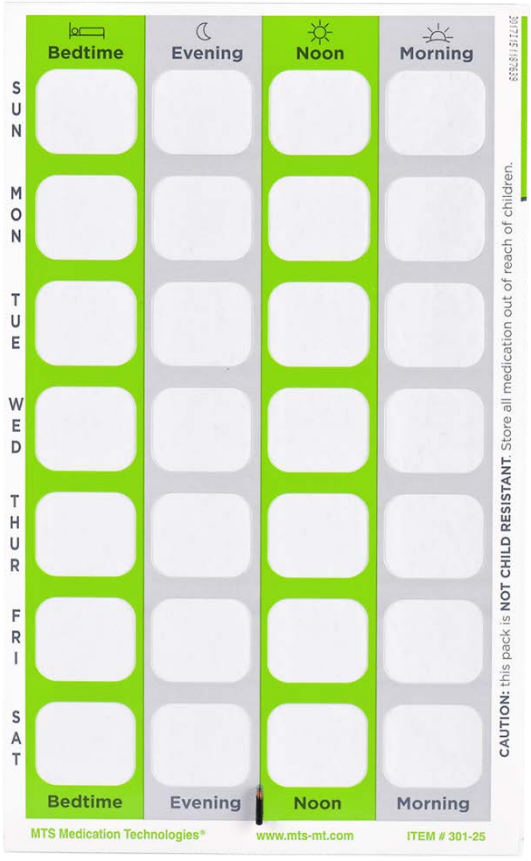


Figure 3: RFID tag orientation

8.1.3 Smart Card Interface

The following issues have been identified with the non-optical sensing blister popping interface.

1. Blister pack connectors are weak. As a result, one needs to be careful not to damage them when inserting or removing the appropriate blister pack.

2. Handle used to press blister pack against the connectors may not provide sufficient pressure or an angle to make a robust contact with the metal connectors.
3. Port 2 Pin 0 on MCU does not have pull-up capability. Pill dispensing design in **Pill-popper Metal Contact Rev 3 Schematic.pdf** should be modified to adjust for this change.
4. Optional: Redesign hardware to connect J35-1 to MCU port pin and drive a waveform through it rather than a fixed value to GND; or Connect to VCC rather than to GND.

8.2 Sample Programming output

```
SEGGER J-Link Commander V6.16e (Compiled Jun 27 2017 18:47:39)
DLL version V6.16e, compiled Jun 27 2017 18:47:05


Script file read successfully.
Processing script file...

J-Link connection not established yet but required for command.
Connecting to J-Link via USB...O.K.
Firmware: J-Link OB RX621-ARM-SWD V1 compiled Mar  8 2017 13:46:30
Hardware version: V2.10
S/N: 700000881
VTref = 3.300V

Selecting SWD as current target interface.

Selecting 3000 kHz as target interface speed


Target connection not established yet but required for command.
Device "R7FS3A77C" selected.


Connecting to target via SWD
Found SW-DP with ID 0x5BA02477
Found SW-DP with ID 0x5BA02477
Scanning APs, stopping at first AHB-AP found.
AP[0] IDR: 0x24770011 (AHB-AP)
AHB-AP ROM: 0xE00FF000 (Base addr. of first ROM table)
CPUID reg: 0x410FC241. Implementer code: 0x41 (ARM)
Found Cortex-M4 r0p1, Little endian.
FPUnit: 6 code (BP) slots and 2 literal slots
CoreSight components:
ROMTbl[0] @ E00FF000
ROMTbl[0][0]: E000E000, CID: B105E00D, PID: 000BB00C SCS
ROMTbl[0][1]: E0001000, CID: B105E00D, PID: 003BB002 DWT
ROMTbl[0][2]: E0002000, CID: B105E00D, PID: 002BB003 FPB
ROMTbl[0][3]: E0000000, CID: B105E00D, PID: 003BB001 ITM
ROMTbl[0][4]: E0040000, CID: B105900D, PID: 000BB9A1 TPIU
ROMTbl[0][5]: E0041000, CID: B105900D, PID: 000BB925 ETM
ROMTbl[0][6]: E0042000, CID: B105900D, PID: 002BB908 CSTF
ROMTbl[0][7]: E0043000, CID: B105900D, PID: 001BB961 TMC
ROMTbl[0][8]: E0044000, CID: B105F00D, PID: 001BB101 TSG
Cortex-M4 identified.
Reset delay: 200 ms
Reset type NORMAL: Resets core & peripherals via SYSRESETREQ & VECTRESET bit.
Setting AIRCR.SYSRESETREQ

PC = 00011C58, CycleCnt = 00000000
R0 = 2000BBF8, R1 = 4001E000, R2 = 2000A110, R3 = 00000000
R4 = 2000BBFC, R5 = 2000A10C, R6 = 0000A502, R7 = 2000BB5C
R8 = 00000000, R9 = 00000000, R10= 2000E9F8, R11= 00000000
R12= 00000000
```

```
SP(R13)= 2000E1F8, MSP= 2000E1F8, PSP= 2000F910, R14(LR) = FFFFFFFF
XPSR = 01000000: APSR = nzcvq, EPSR = 01000000, IPSR = 000 (NoException)
CFBP = 00000000, CONTROL = 00, FAULTMASK = 00, BASEPRI = 00, PRIMASK = 00
FPU regs: FPU not enabled / not implemented on connected CPU.

Downloading file [PMAS-Sleeve-1508a223c245.hex]...

**************************
WARNING: CPU is running at low speed (8000 kHz).
**************************

J-Link: Flash download: Bank 0 @ 0x00000000: 1 range affected (2048 bytes)
```

8.3 Acknowledgements

We acknowledge the use of **nRFConnect** Mobile application which has been instrumental in the design and development of the non-commercial Renesas Personal Medical Adherence reference design.

Website and Support

Renesas Electronics Website
http://www.renesas.com/

Renesas Electronics Personal Medical Adherence Website
https://www.renesas.com/us/en/solutions/healthcare/personal-medical-device/pmasolutions.html

Renesas Electronics Healthcare Applications Website
https://www.renesas.com/us/en/solutions/healthcare.html

Inquiries
http://www.renesas.com/contact/

Revision History

		Description	
Rev.	**Date**	**Page**	**Summary**
1.00	August 30,2018		Release

General Precautions in the Handling of Microprocessing Unit and Microcontroller Unit Products

The following usage notes are applicable to all Microprocessing 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. 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 in the vicinity of 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. Unused pins should be handled as described under Handling of Unused Pins in the manual.

2. Processing at Power-on

   The state of the product is undefined at the moment 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 moment 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 moment 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 moment when power is supplied until the power reaches the level at which resetting has been specified.

3. Prohibition of Access to Reserved Addresses

   Access to reserved addresses is prohibited.

   — The reserved addresses are provided for the possible future expansion of functions. Do not access these addresses; the correct operation of LSI is not guaranteed if they are accessed.

4. Clock Signals

   After applying a reset, only release the reset line after the operating clock signal has become stable. When switching the clock signal during program execution, wait until the target clock signal has 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. Moreover, 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.

5. Differences between Products

   Before changing from one product to another, i.e. to a product with a different part number, confirm that the change will not lead to problems.

   — The characteristics of Microprocessing unit or Microcontroller unit products in the same group but having a different part number may differ in terms of the 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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