RL78 Group

RL78/G11 Smart Moisture Sensor

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Introduction

This user's manual describes the Smart Moisture Sensor system. This system uses the RL78/G11 microcontroller as well as the Renesas Bluetooth Low Energy (BLE) RL78/G1D microcontroller. Please refer to the following documents for more information regarding the RL78/G11 and the RL78/G1D microcontrollers.

Document Type	Document Name	Document No.
User's Manual	RL78/G11 User's Manual: Hardware	RO1UH0637EJ0110
User's Manual	RL78/G1D User's Manual: Hardware	R01UH0515EJ0120
User's Manual	RL78/G1D Module (RY7011) User's Manual: Hardware	R02UH0004EJ0120
User's Manual	RL78/G1D Module Firmware User's Manual	R01UW0160EJ0101

Target Device

RL78/G11

RL78/G1D BLE (RY7011)

List of Abbreviations and Acronyms

Abbreviation	Full Form
ADC	Analogue to Digital Converter
BLE	Bluetooth Low Energy
BoM	Bill of Materials
DC	Direct Current
EEPROM	Electrically Erasable Programmable Read-Only Memory
I^2C	Inter-Integrated Circuit
IDE	Integrated Development Environment
LED	Light Emitting Diode
MCU	Microcontroller Unit
MOSFET	Metal-Oxide-Semiconductor Field-Effect Transistor
PCB	Printed Circuit Board
PGA	Programmable Gain Amplifier
QFN	Quad Flat No-leads package
RAM	Random Access Memory
ROM	Read Only Memory
SMS	Smart Moisture Sensor
UART	Universal Asynchronous Receiver Transmitter

Table 1-1 List of Abbreviations and Acronyms

Contents

1. Outline of System Function

This design provides an automatic system for monitoring and watering plants. The Smart Moisture Sensor (SMS) includes a Bluetooth module allowing a smart phone app to configure the conditions which trigger watering. It can automatically water the plant at regular time intervals, or when a particular a moisture level has been reached. Additionally, the app allows the user manual control to turn the watering valve on or off. The app also shows the battery level, and a moisture vs temperature graph. The system also includes a buzzer to warn the user if the soil becomes too dry.

The basic outline of the system can be seen in Figure 1-1.

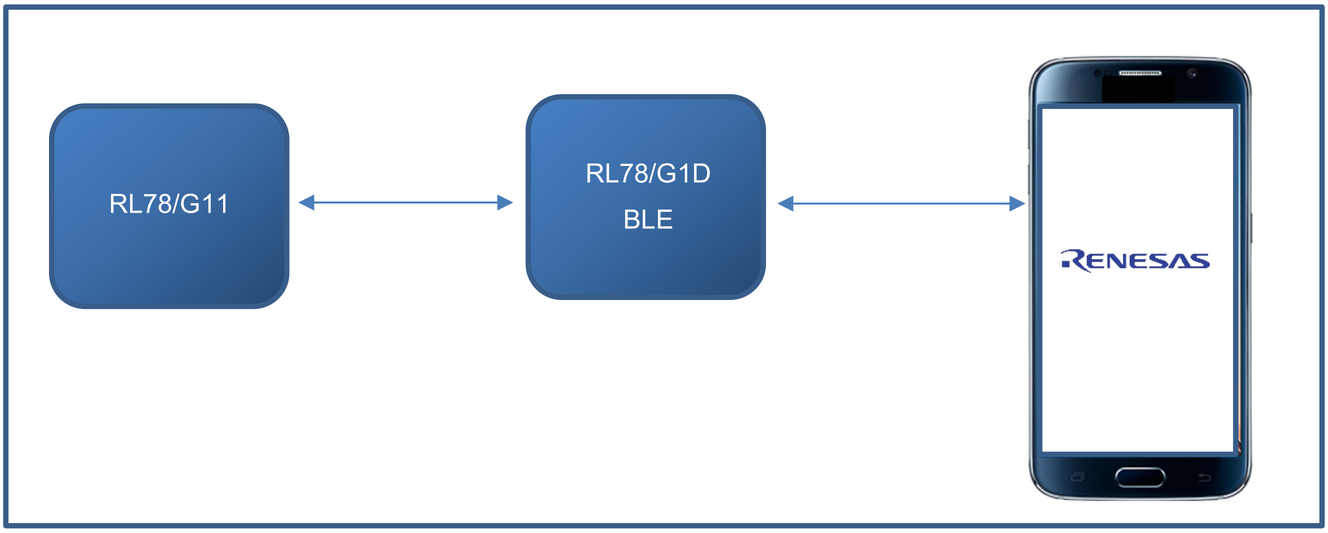


Figure 1-1 SMS System

1.1 Product Overview

The SMS product contains both the RL78/G11 and the RL78/G1D MCUs. The front and back of the product can be seen in Figure 1-2 Product PCB (Front) and Figure 1-3 Product PCB (Back) respectively.

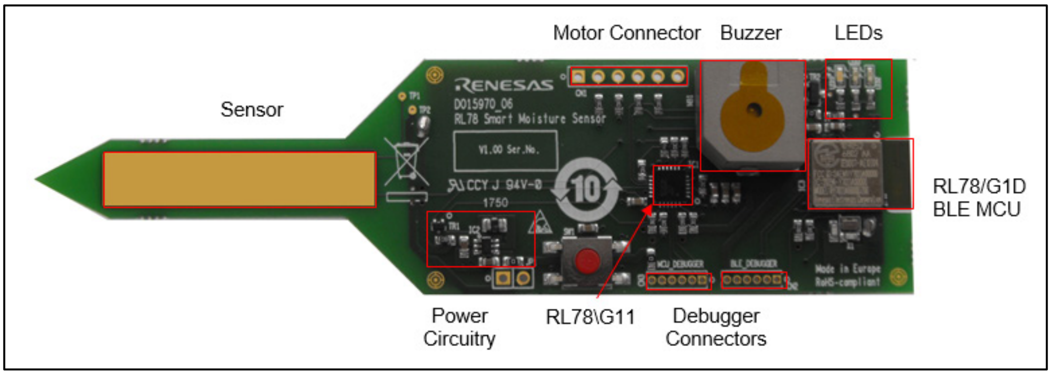


Figure 1-2 Product PCB (Front)

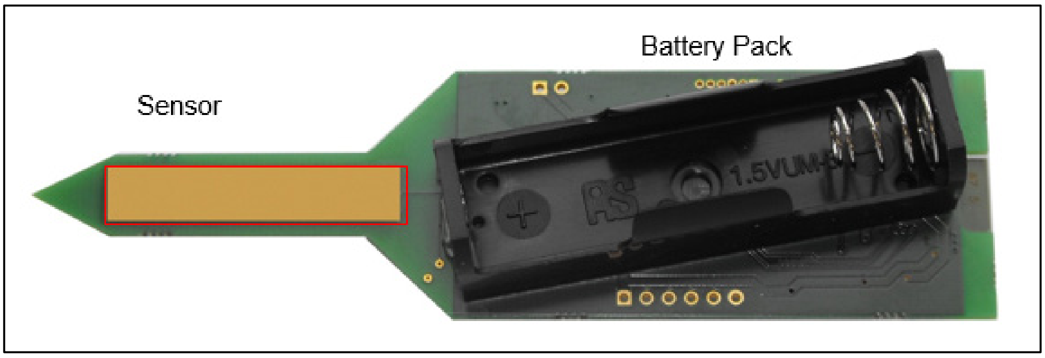


Figure 1-3 Product PCB (Back)

2. Description of Hardware

The following sections will describe the hardware for the SMS.

2.1 Hardware Overview

The SMS hardware is to be able to:

- Read soil moisture levels
- Warn the user of a low moisture level
- Control a motor (watering valve) connected to an on-board header.
- To be powered by a single AA battery
- To implement suitable BLE hardware in order to send measurement information to a BLE enabled device e.g. a smartphone or tablet.

An overall view of the hardware can be seen in Figure 2-1.

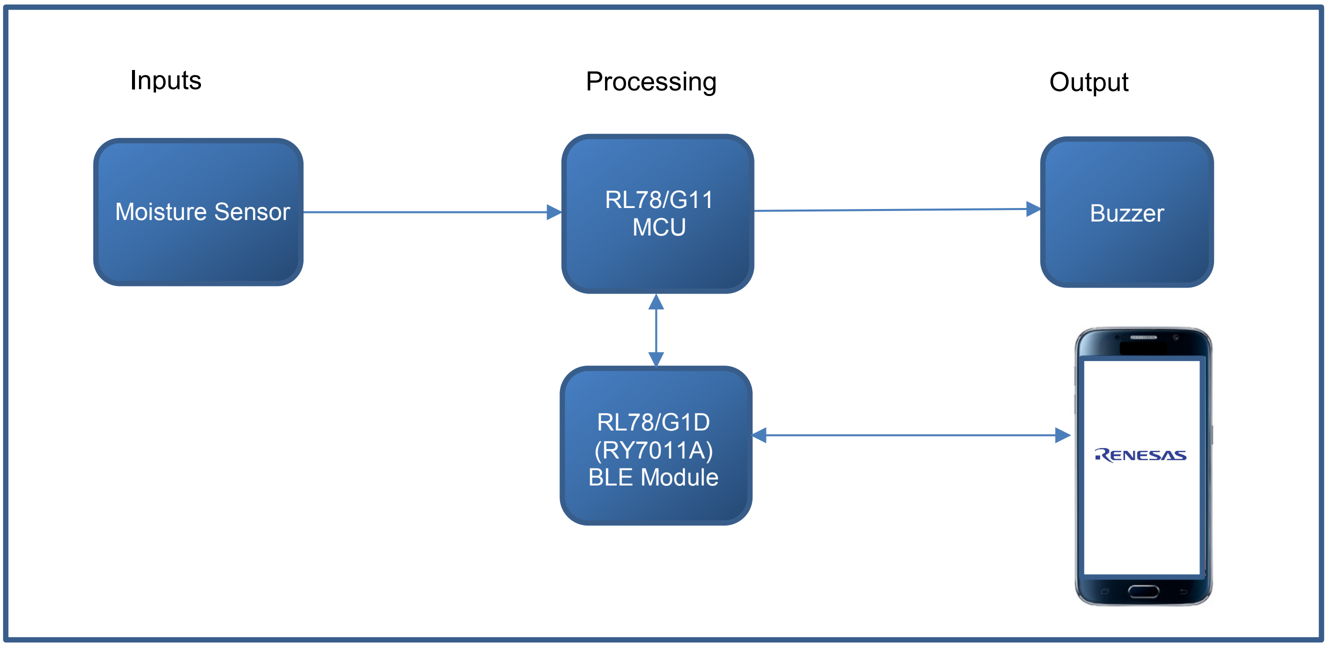


Figure 2-1 Required Hardware for the SMS System

The hardware for the SMS can be split into the following circuits:

- RL78/G11 MCU
- RL78/G1D BLE MCU
- Programming / Debug interfaces for MCUs
- Power
- Header for motor control
- Buzzer
- Moisture sensor

2.1.1 RL78/G11 MCU

The RL78/G11 was chosen for this design due to its low power capabilities. The 24-pin QFN provides a small footprint to keep the physical size of the board to a minimum. The RL78/G11 controls the entire system, and its connections to other circuitry is shown in Table 2-1.

Pin No.	Port Name.	Function
1	P137	Motor Input 2
2	P122	Motor Input 1
3	P121	Switch Input (INTP2)
4	REGC	REGC
5	VSS	V_{SS}
6	VDD	V_{DD}
7	P51	Pull down resistor (_Probe_Drive3)
8	P52	Pull down resistor (_Probe_Drive2)
9	P53	Pull down resistor (_Probe_Drive1)
10	P54	G11 TxD0 to Bluetooth Receive Signal (BLE_RXD0)
11	P55	G11 RxD0 to Bluetooth Transmit Signal (BLE_TXD0)
12	P56	Bluetooth Clock Signal (BLE_CLK)
13	P30	Buzzer output (PCLBUZ0)
14	P31	Motor GPIO 1
15	P32	Motor GPIO 2
16	P33	Read Battery Voltage (BAT_SENSE)
17	P23	V_{SS}
18	P22	Read moisture level (ANI12/PGAI)
19	P21	Control Power to the Bluetooth Module (BLE_POWER)
20	P20	To enable the battery reading (BAT_CONTROL)
21	P01	G11 TxD1 to Debugger (serial to USB)
22	P00	G11 RxD1 to Debugger (serial to USB)
23	P40	Debugger TOOL0 signal
24	P125	Debugger Reset Signal

Table 2-1 RL78/G11 MCU Connections

2.1.2 RL78/G1D BLE MCU

The RL78/G1D BLE MCU provides a wireless connection from the RL78/G11 to a smart phone app. The BLE Module is connected as described in Table 2-2.

Pin No.	Port Name.	Function
1,11,20,30,32-38	GND[1-11]	Ground
2	P30	INTP3
3	P16	Not Connected
4	P15	Not Connected
5	P14	Not Connected
6	P13	Not Connected
7	P12	BLE_TXD0
8	P11	BLE_RXD0
9	P10	BLE_CLK
10	VDD	Power (3.3V)
12	P147	Not Connected
13	P23	Not Connected
14	P22	Not Connected
15	P21	Not Connected
16	P20	Not Connected
17	P03	RXD1
18	P02	TXD1
19	P01	Not Connected
21	P00	Not Connected
22	P120	LED
23	P40	BLE_TOOL0
24	RESET#	BLE_RESET
25	P137	Not Connected
26	P124	XT2
27	P123	XT1
28	P60	Not Connected
29	P61	Not Connected
31	IC	Not Connected
39-42	EXP_PAD[1-4]	Ground

Table 2-2 BLE Connections

To summarise, this hardware includes:

- An oscillator (X1) facilitates the low power capabilities of the Bluetooth module
- A blue LED provides an indication of BLE operation
- UART and I^{2}C connections allow alternative communication methods with the RL78/G11 MCU
- Debugger connections to program the device
- Power to the device is controlled by the RL78/G11

2.1.3 Debuggers

The MCUs are designed to be programmed with an E2 Lite debugger. To keep the area of the PCB low an external debugger is used. The debugger connector allows for the debugger on the RL78/G11 RPB to program the both the RL78/G11 and the RL78/G1D BLE MCU. The RPB RL78/G11 can be seen in Figure 2-2.

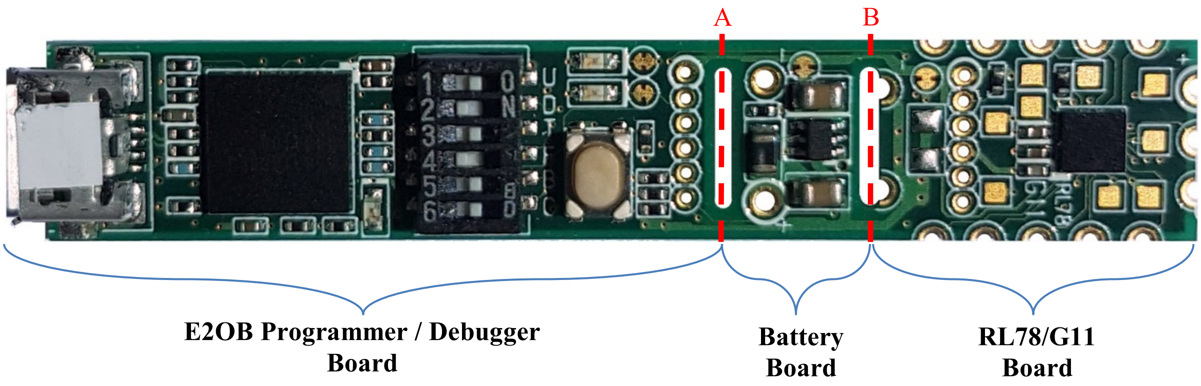


Figure 2-2 RPB RL78/G11

To use the debugger, a cut in the board is required. A cut in part 'B' allows for the battery circuit to be used. Whereas, a cut in part 'A' results in just the debugger.

If the boards are separated, then the connections between the E2OB programmer / debugger and RL78/G11 board can be remade by using the row of six pads on both boards. These are on a 1.27mm (0.05") pitch, and so suitable header plugs and sockets can be soldered in. Connection details are shown in Figure 2-3.

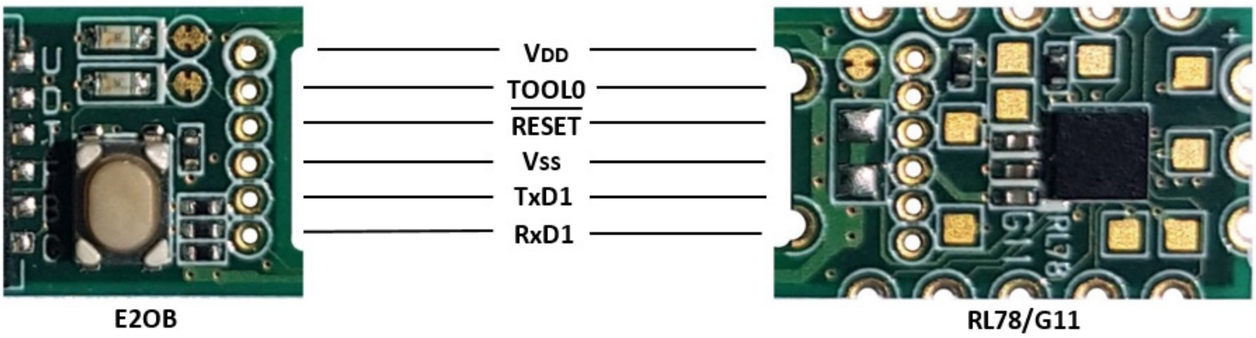


Figure 2-3 Connections for E20B and RL78/G11

This can then be used for both the RL78/G11 MCU and the RL78/G1D BLE MCU.

2.1.4 Power

The SMS hardware is powered by a single AA battery. The battery supplies 1.5V, however as the MCUs require a 3.3V supply, a boost switched-mode power supply is used to step up the voltage.

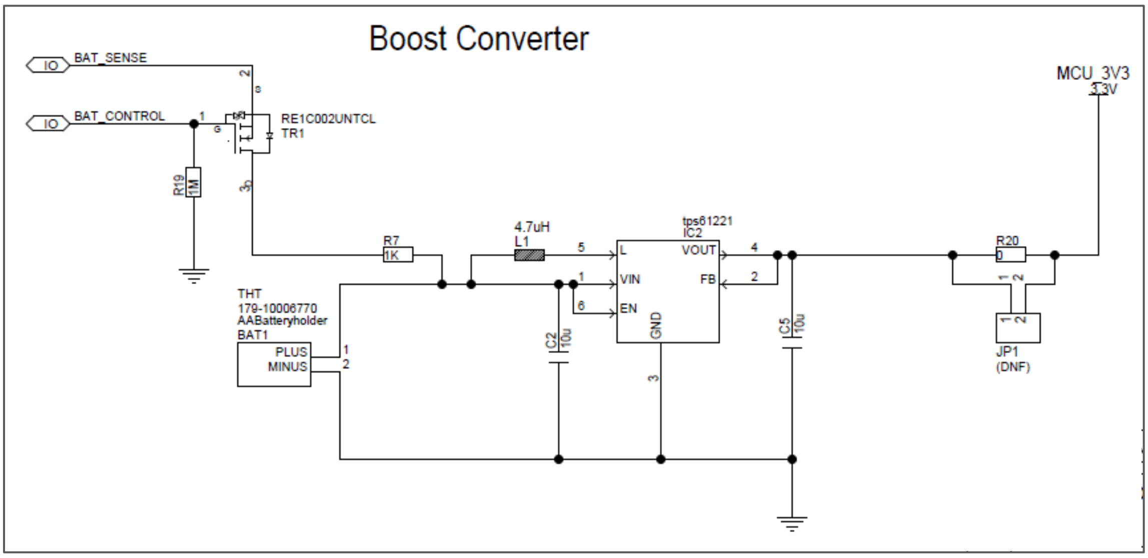


Figure 2-4 Boost Converter

In order to read the battery voltage, the battery is connected to the RL78/G11 ADC Channel (BAT_SENSE) via an n-channel MOSFET. The MOSFET is used to prevent battery discharge when measurement is not underway. This MOSFET is controlled by the BAT_CONTROL output. A jumper (JP1) allows the MCU current to be measured (as long as R20 is not fitted).

2.1.5 Motor Control and Buzzer

To control the watering valve, a 6-pin header allows for different types of motor to be controlled. The 3.3V supply line and ground connections are included for reference purposes. P32 and P33 provide two motor control lines for opening and closing the valve. MOTOR_INPUT1 and MOTOR_INPUT2 provide a way to receive feedback, for example detecting when the motor has driven the valve to a particular position. Two LEDs (LED2 and LED3) are connected to these pins on the PCB, for indication purposes. They will be illuminated when the relevant control port is pulled low.

The buzzer uses the MCU buzzer controller output, and is connected to P30 (PCLBUZ0).

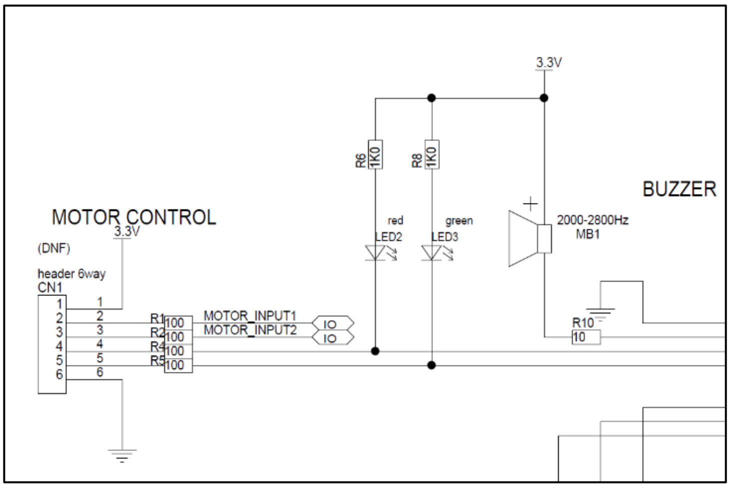


Figure 2-5 Motor Control Connector and Buzzer

2.1.6 Moisture Sensor

The measured resistance of soil is typically between 50Ω and 10MΩ. Physically, the moisture sensor consists of two contacts (one on each side of the prong) which measure the resistance of the surrounding soil. This resistance is related to the moisture content of the soil, with wet soil having a low resistance and dry soil being virtually open-circuit. The soil resistance is also related to the chemical content of the soil (the resistance of water depends on the chemicals dissolved in it), so the probe will need calibrating for different soil types.

In order to minimise power consumption, the moisture sensor is only turned 'ON' when a measurement is to be taken. The sensor is activated by pulling one of the probe drive lines low.

For maximum flexibility each of these three probe drive lines connects to the sensor via a different value pull-down resistor. The soil and the selected resistor creates a potential divider between +3.3V and ground, and the centre point of this divider is input to the RL78/G11's Programmable Gain Amplifier (PGA) or directly to its analogue to digital converter. The three resistors together with the PGA give the flexibility to measure the full range of potential soil resistance values.

The circuit for this can be seen in Figure 2-6.

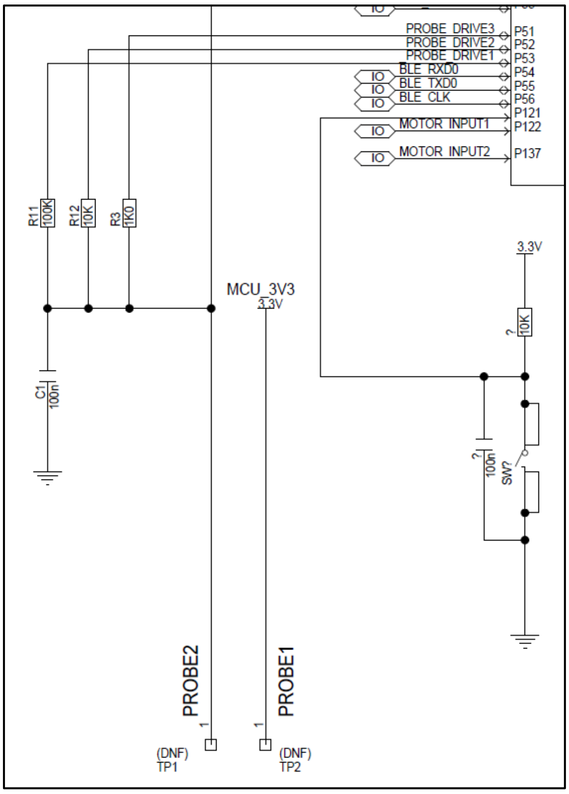


Figure 2-6 Sensor Circuit

3. Schematic, PCB and BoM

3.1 Schematic

The circuitry in the schematic is shown in Figure 3-1, Figure 3-2, and Figure 3-3.

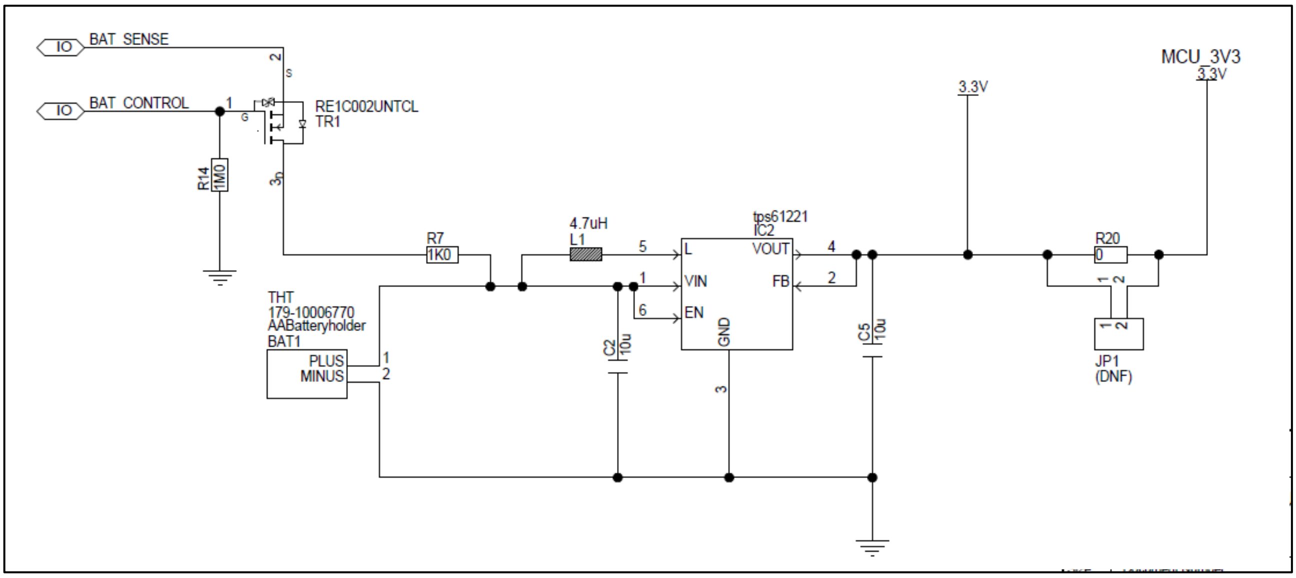


Figure 3-1 Power Supply Schematic

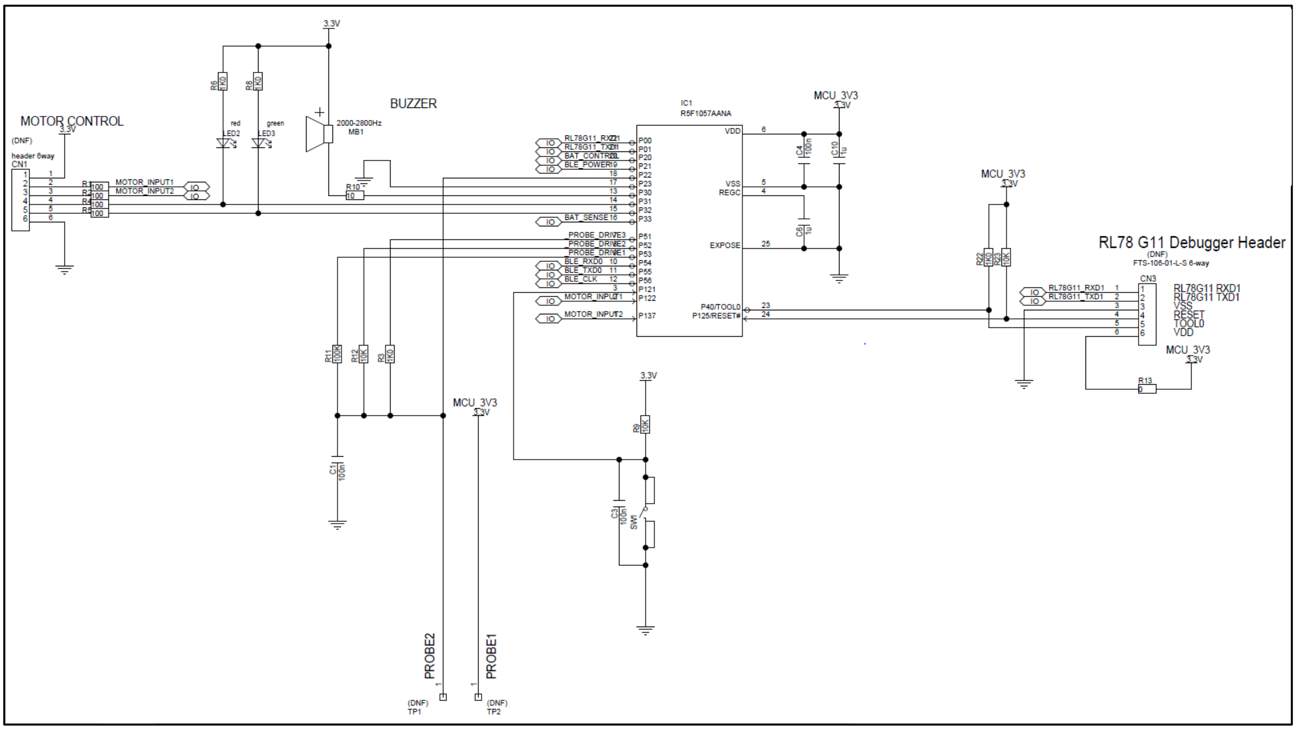


Figure 3-2 RL78/G11 Schematic

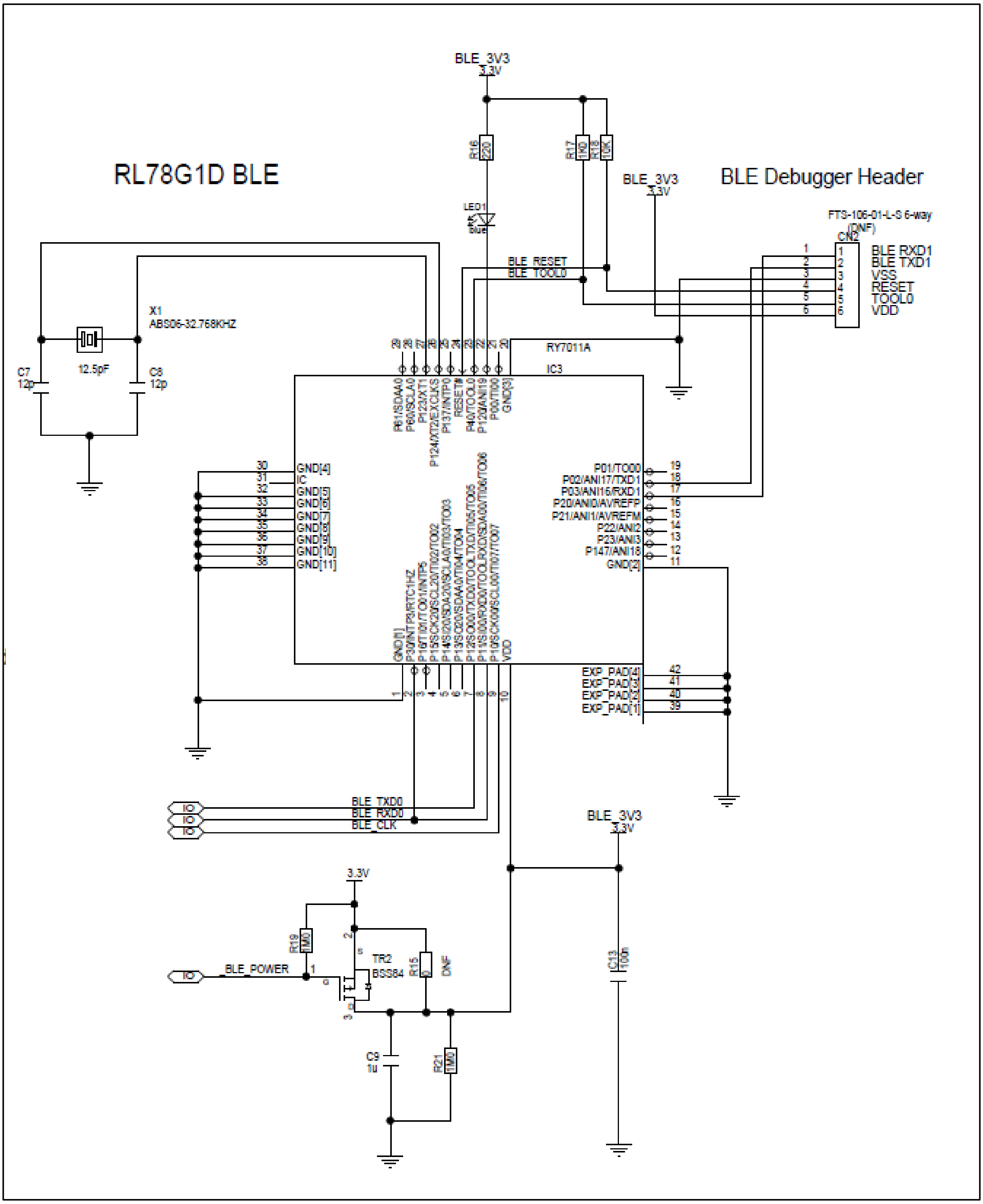


Figure 3-3 RL78/G1D BLE Schematic

3.2 PCB

The PCB for the SMS can be seen in Figure 3-4. The measurements indicated on the diagram are in mm.

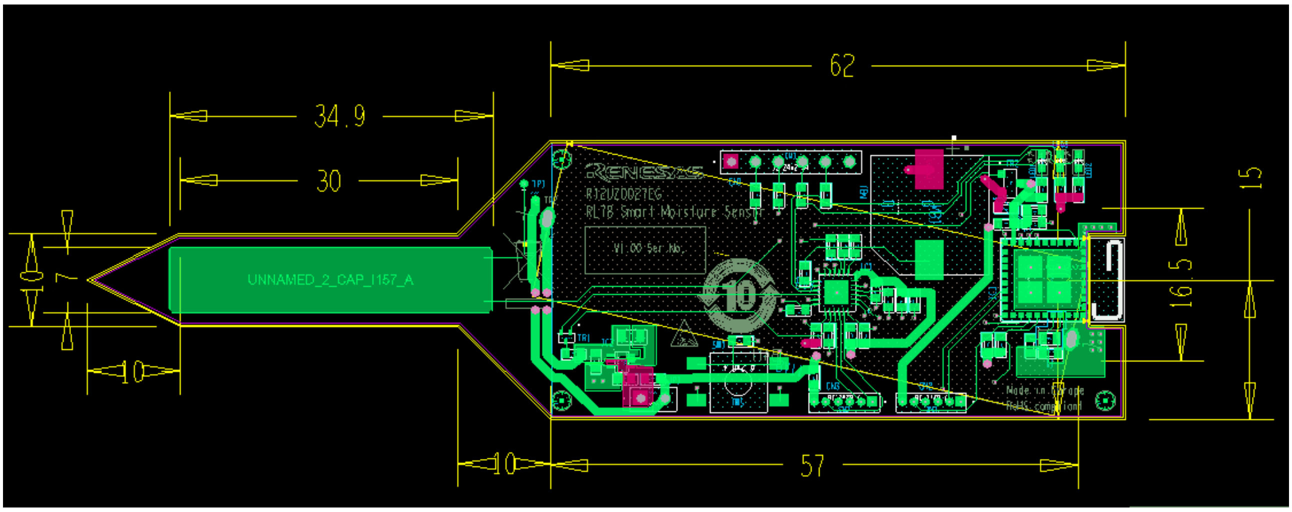


Figure 3-4 PCB Layout

3.3 BoM

The BoM for the Smart Moisture Sensor is shown in Table 3-1.

Qty	Value	Description	Ref Des
1	AA Battery holder	AA Battery holder	BAT1
4	100nF	Capacitor, X7R, 0603	C1, C4, C6, C13
3	1uF	Capacitor, X7R, 0603	C3, C9, C10
2	10uF	Capacitor, X5R, 0603	C2, C5
2	12pF	Capacitor, NP0, 0603	C7, C8
1	Header 6-way	Header, 6-way, 1-row, vertical	CN1
2	FTS-106-01-L-S 6-way	THT MICRO Header	CN2, CN3
1	R5F1057AANA	RL78/G11, 24-pin QFN, 16K ROM, 1.5K RAM	IC1
1	TPS61221	Voltage Regulator DC-DC Booster	IC2
1	RY7011A	Bluetooth Module (BLE)	IC3
1	Header 2-way 2.54mm	Header, 2-way, 1-row	JP1
1	Jumper 2.54mm black	Jumper, 2.54mm, black, open top	JP1
1	4.7uH	Fixed Ferrite Inductor	L1
1	Blue	Blue LED	LED1
1	Red	Red LED	LED2
1	Green	Green LED	LED3
1	2000-2800Hz	Piezo Buzzer	MB1
4	100R	Resistor, 0603, 1/10 Watt	R1, R2, R4, R5
1	10R	Resistor, 0603, 1/10 Watt	R10
1	100K	Resistor, 0603, 1/10 Watt	R11
4	10K	Resistor, 0603, 1/10 Watt	R9, R12, R18, R23
3	0R	Resistor, 0603, 1/10 Watt	R13, R15, R20
3	1M0	Resistor, 0603, 1/10 Watt	R14, R19, R21
1	220R	Resistor, 0603, 1/10 Watt	R16
6	1K0	Resistor, 0603, 1/10 Watt	R3, R6, R7, R8, R17, R22
1	Push button 4-pin SMD	Push button, Tactile Switch, 4-pin, SMD	SW1
2	Plated Hole 0.3mm Cu C1mm	Plated Hole, THT, 0.3mm	TP1, TP2
3	Fiducial_1mm	Fiducial, 1mm, PCB Marker	TP3, TP4, TP5
1	RE1C002UNTCL	MOSFET	TR1
1	BSS84	MOSFET	TR2
1	ABS06-32.768KHZ	32.768KHz Crystal	X1

Table 3-1 BoM

4. Description of Software

4.1 Integrated Development Environment

The IDE required for the software requires the items seen in Table 4-1.

Item	Contents
IDE	e² studio V6.1. (Renesas Electronics Corporation)
C complier	CC-RL V1.05.00 (Renesas Electronics Corporation)
Debugger	E20B (RPB RL78/G11 Pinout)

Table 4-1 IDE Configuration

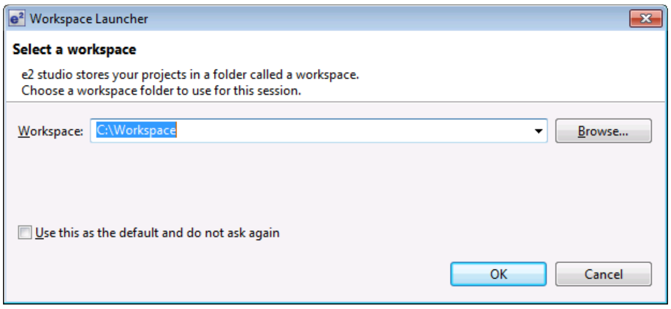
4.2 Getting Started…

To get the system up and running the following will be required:

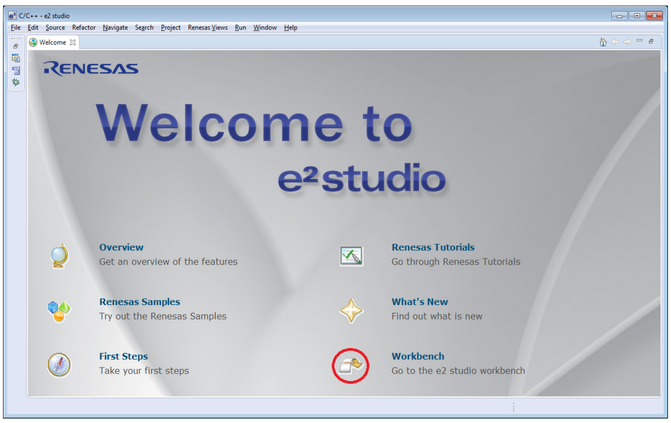
- e² studio V6.1
- CCRL Compiler V1.05.00
- RL78 Smart Moisture Sensor Board
- RPB RL78/G11
- AA battery, 1.5v.

4.2.1 Starting e² studio and Importing Sample Code

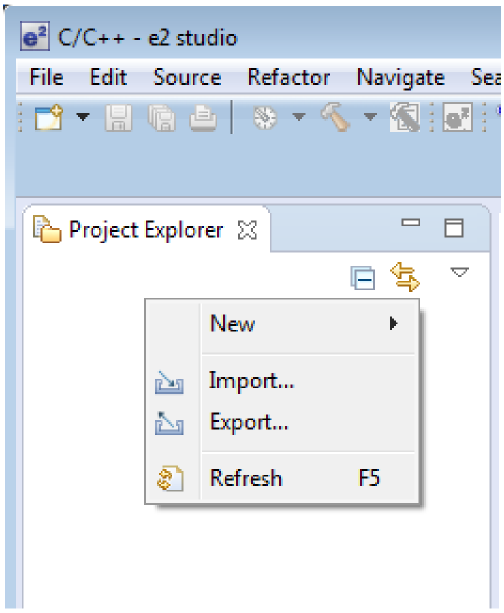
- Start e² studio by selecting it from the Windows™ Start Menu. The first dialog box to appear will be the Workspace Launcher.
- Click 'Browse' and select a suitable location to store your workspace, using the 'Create New Folder' option as necessary. Click 'OK'.



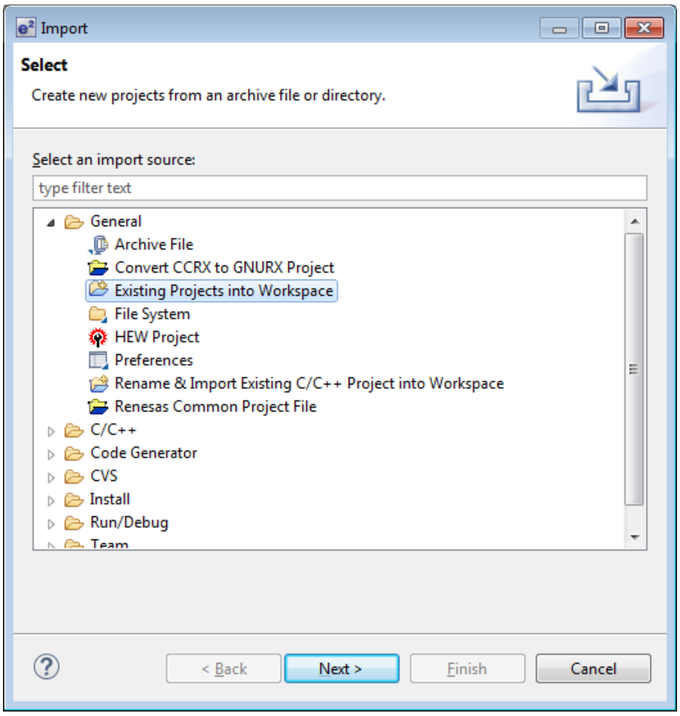
- The e² studio welcome splash screen will appear. Click the 'Go to the e2 studio workbench' arrow button on the far right (circled in the screenshot opposite).



- Once the environment has initialized, right click in the 'Project Explorer' window and select 'Import…'

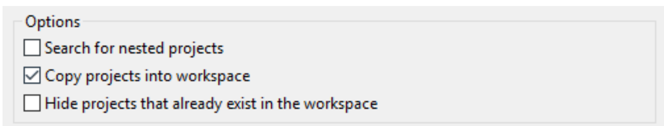


- The Import dialog box will be shown. Expand the 'General' folder icon, and select 'Existing Projects into Workspace', then click 'Next'.



- The Import dialog box will allow you to specify a project to import. Click the 'Browse' button and locate the downloaded software.

- Ensure that the 'Copy projects into workspace' option is ticked, and then click 'Finish'.



4.2.2 Build Configurations and Debug Sessions

The e² studio workspace will be created with two build configurations: 'HardwareDebug' and 'Release'.

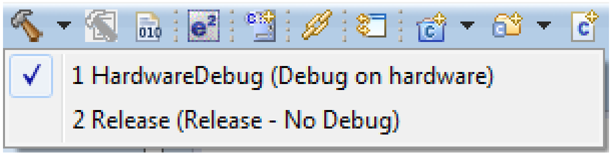
Release

This build mode has optimisation turned ON, and provides little debug information. The C code execution may appear to be out of order, due to the way compiler optimises the code. This build configuration is intended for final ROM-programmable code.

HardwareDebug

This build mode has all optimisation turned OFF, and provides full debug information. This is the best configuration to use whilst developing code, as C code execution will be linear.

- Click the top level project folder again, and then the arrow next to the build button (hammer icon), and select the 'HardwareDebug' or 'Release' option depending on the user requirements.



- e² studio will now build the code.

4.2.3 Modifying the Debugger Connections

As previously mentioned in section 2.1.3, the RPB RL78/G11 debugger is required to program the RL78/G11 and the RL78/G1D BLE devices on the SMS.

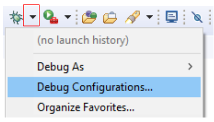
- On RPB RL78 ensure that microcontroller is disconnecting by cutting the board at point B denoted in Figure 3-2.
- Solder a 6-way 0.05" pitch male header to the debugger connections on the RPB RL78 to connect to CN3 and CN2.
- To configure the RPB to program the RL78/G11 and RL78/G1D, ensure the switch is configured as shown in Table 4-2.

SW1.1	OFF
SW1.2	ON
SW1.3	OFF
SW1.4	OFF
SW1.5	ON
SW1.6	OFF

Table 4-2: RPB Configuration

4.2.4 Programming the RL78/G11

To program the RL78/G11:



- Connect the RPB to the SMS via the CN3 connector.
- Insert the AA battery into the battery holder on the SMS.
- Select the arrow next to the debug icon and select 'Debug Configurations'.
- Under 'Renesas GDB Hardware Debugging' select either 'Smart_Moisture_Sensor_G11 HardwareDebug' or 'Smart_Moisture_Sensor_G11 Release' depending on the user requirements.
- Once Selected click 'Debug'.
- The red LED on the RPB will now flash indicating that the debugger is programming the device.

4.2.5 Programming the RL78/G1D BLE

To programme the RL78/G1D BLE device:

- Connect the RPB to the SMS via the CN2 connector.
- Select the arrow next to the debug icon and select 'Debug Configurations'.
- Under 'Renesas GDB Hardware Debugging' select either 'Smart_Moisture_Sensor_BLE HardwareDebug' or 'Smart_Moisture_Sensor_BLE Release' depending on the user requirements.
- Once Selected click 'Debug'.
- The red LED on the RPB will now flash indicating that the debugger is programming the device.
- On the SMS the blue LED will now flash. Once connected to the Android phone the LED will blink twice as fast.

5. Android App

5.1 Main Activity

An Android app is available which communicates with the Smart Moisture Sensor via its built-in Bluetooth module. Once the app is installed and run, it will start scanning for a Smart Moisture Sensor, as seen in Figure 5-1 below:

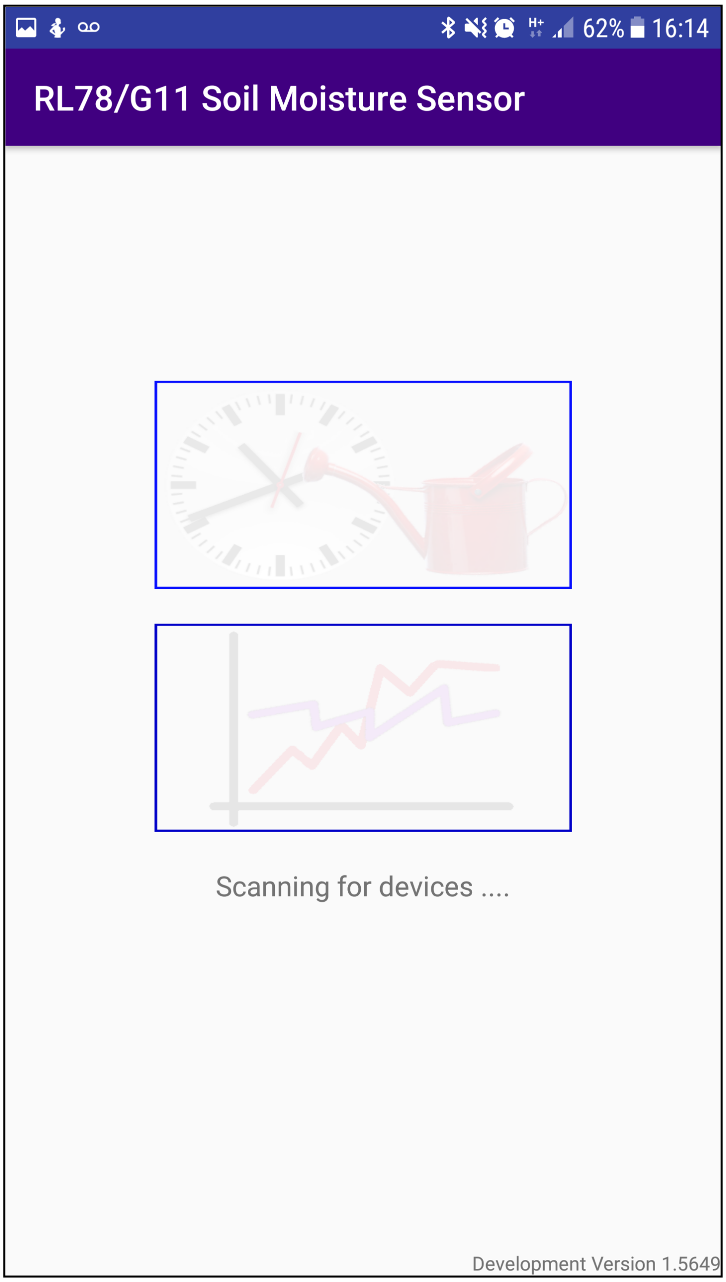


Figure 5-1 Android App Scanning for a Smart Moisture Sensor

The app briefly makes a list of responding devices, and will then connect to the one with the strongest signal. After the connection has been established, the app will retrieve the current values of moisture level, temperature and battery voltage from the sensor. These are displayed at the top of the screen as shown in Figure 5-2. While the app is running, these values will be updated approximately once per minute.

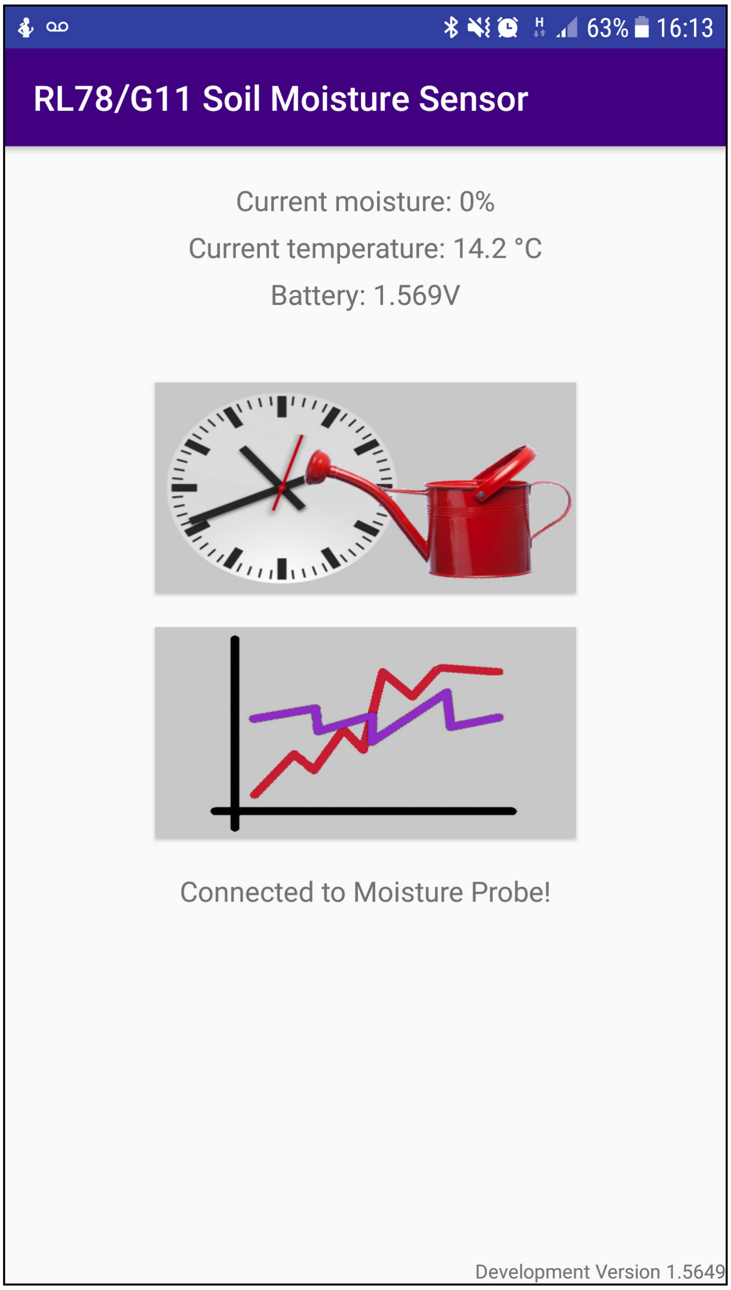


Figure 5-2 Android app Connected to a Smart Moisture Sensor

The two previously disabled controls are now available. The top one navigates to the watering control activity where the watering settings can be viewed and updated. The bottom one navigates to the graph activity, which shows the most recent moisture and temperature readings.

5.2 Watering Control Activity

The watering control activity allows the automatic watering mode to be specified and configured. It also allows manual override of the watering at any time. Figure 5-3 below shows the sensor configured to automatically water the plant when the detected moisture level drops below 30%. It is also configured to sound the on-board alarm should the moisture level drop below 20%.

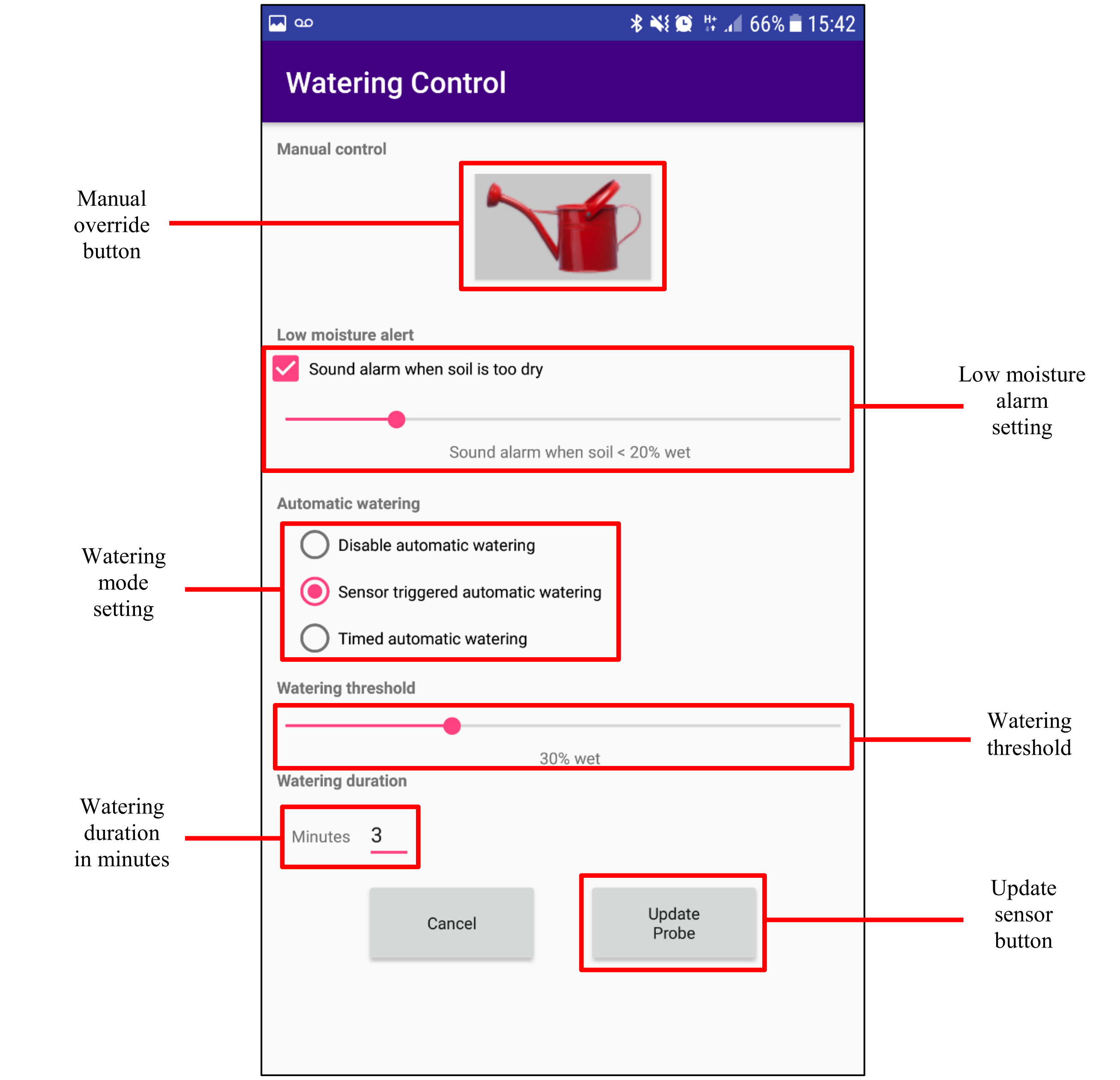


Figure 5-3 Android app Watering Control Activity - Sensor Triggered

Figure 5-4 below shows the watering control activity when the mode has been set to automatically water the plant at intervals of 12 hours. When selected the 'Disable automatic watering' will only permit manual control via the 'watering can' button.

When 'Timed automatic watering' is selected, the watering interval indicates the time between waterings. The range of this field is up to 9 days and 23 hours.

Watering duration sets the length of time the 'watering valve' is ON, the field's range is between 0 and 99 minutes.

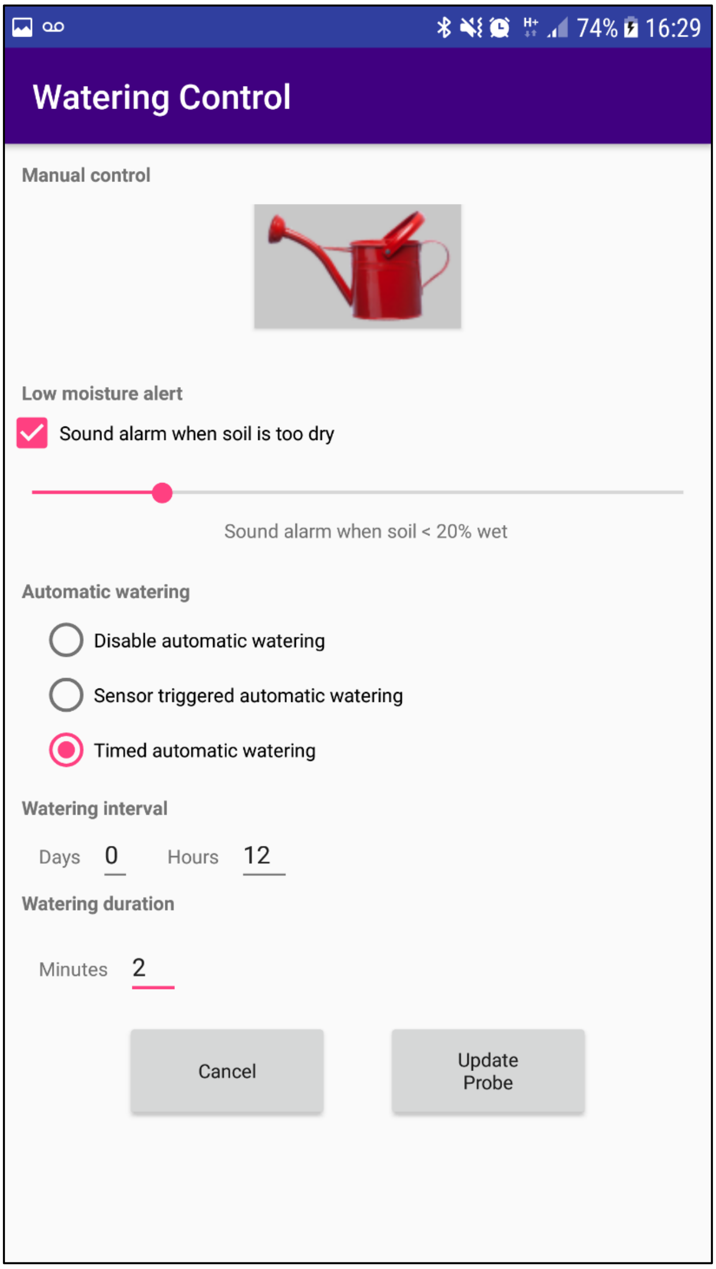


Figure 5-4 Android app Watering Control Activity - Timed Watering

5.3 Moisture Graph Activity

The Moisture Graph activity shows the last 24 readings taken of moisture and temperature. See Figure 5-5 below.

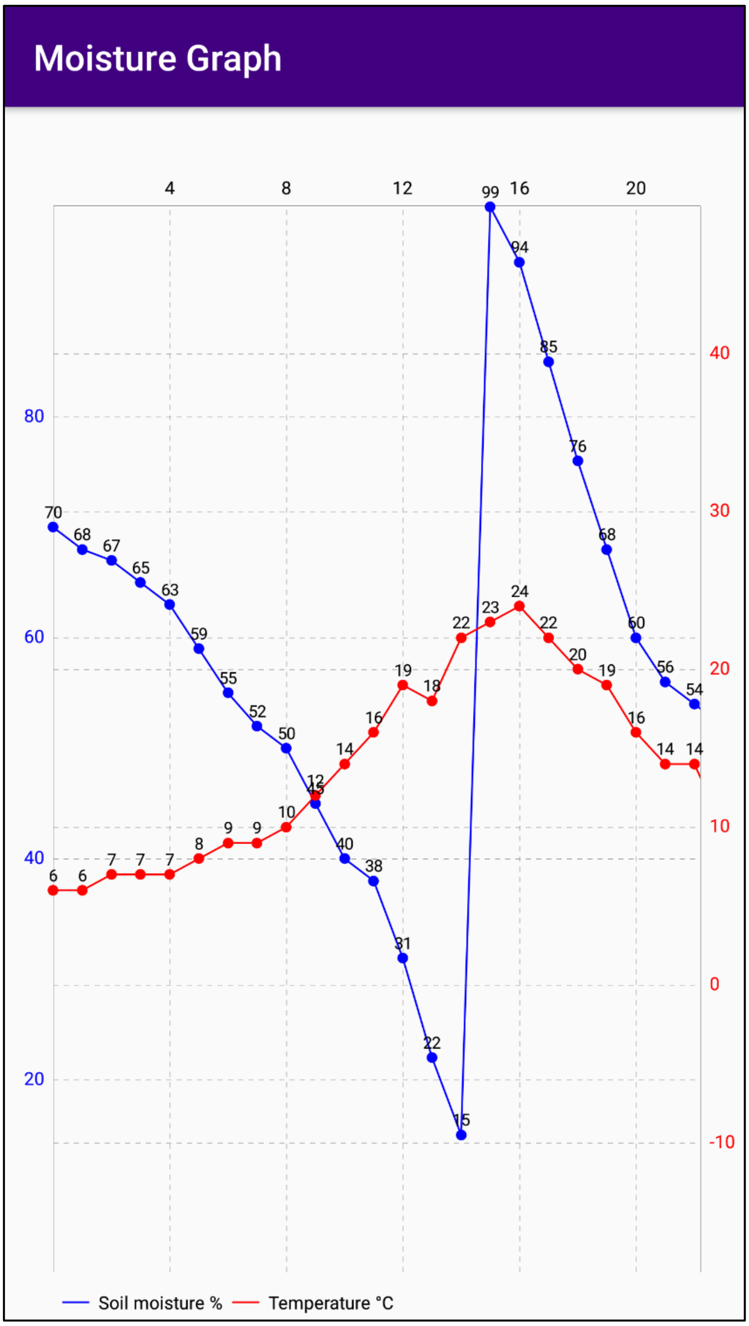


Figure 5-5 Android app Moisture Graph Activity

6. Block Diagrams

The block diagram for the RL78/G11, RL78/G1D firmware and for the smart phone app are included in the following sections.

6.1.1 Block Diagram of the RL78/G11 Firmware

The block diagram for the RL78/G11 firmware can be seen in Figure 6-1. Note that the moisture sensor probe is connected via the ADC or the PGA peripheral.

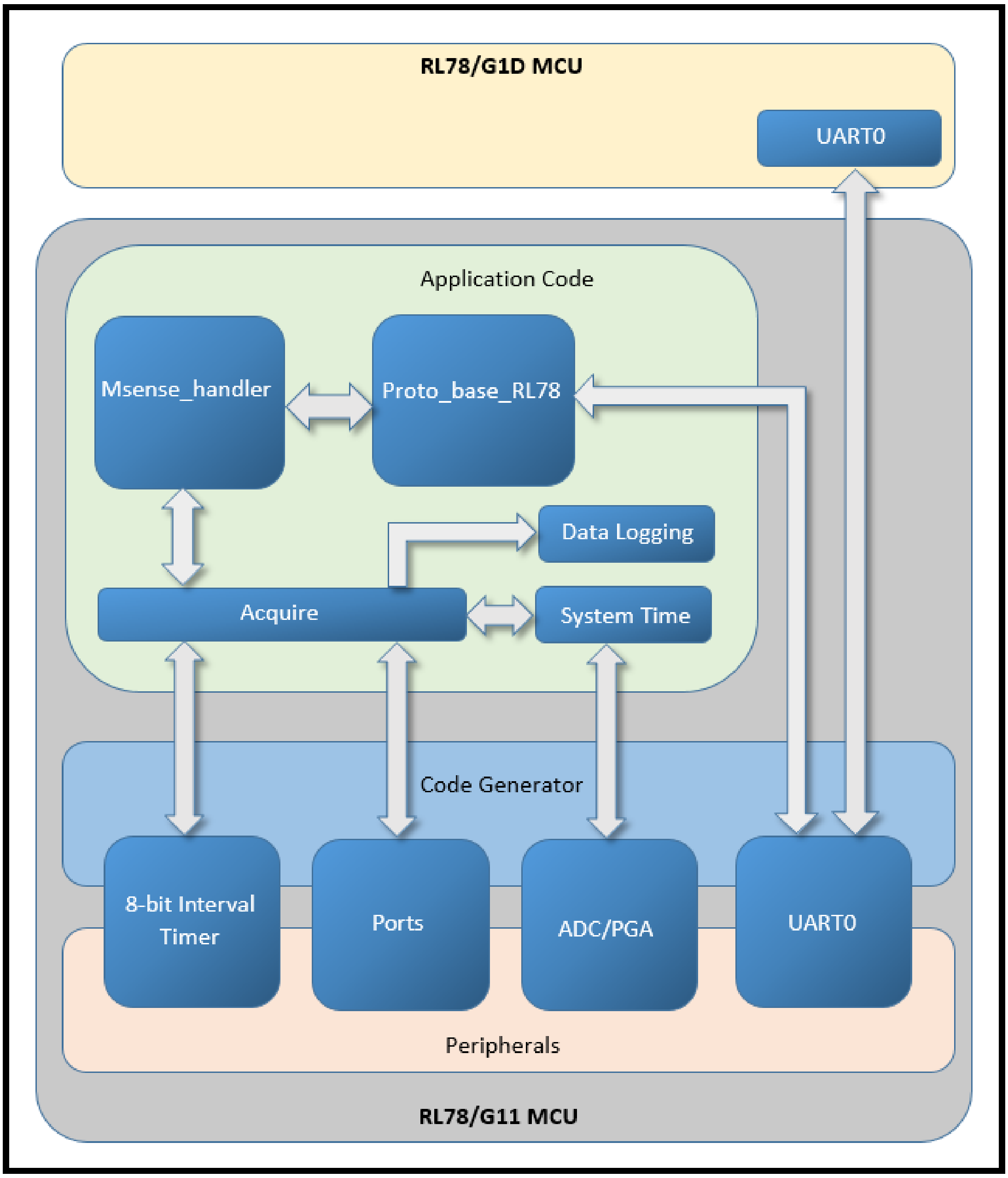


Figure 6-1 Block Diagram for the RL78/G11 Firmware

6.1.2 Block Diagram of RL78/G1D BLE Firmware

The block diagram for the RL78/G1D firmware can be seen in Figure 6-2.

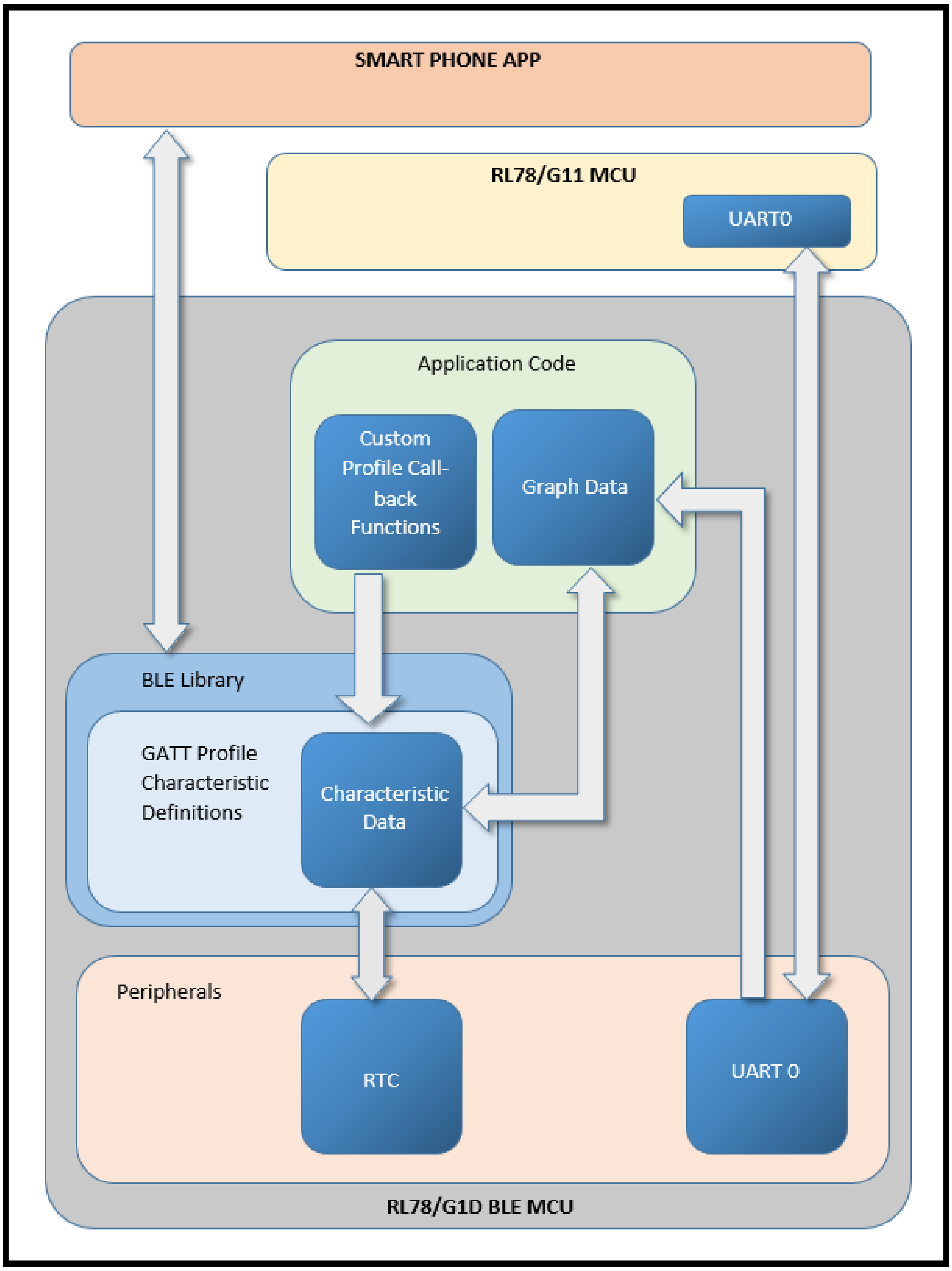


Figure 6-2 Block Diagram for the RL78/G1D Firmware

6.1.3 Block Diagram of Smart Phone App

The block diagram for the Smart Phone App can be seen in Figure 6-3.

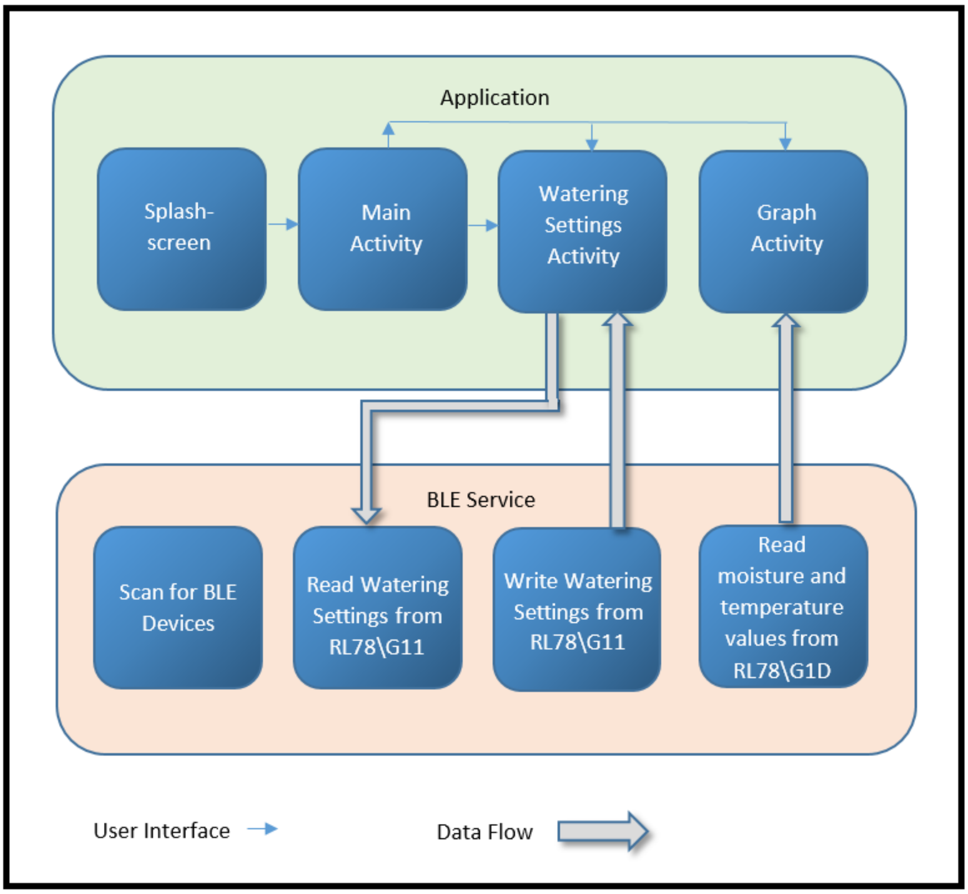


Figure 6-3 Block Diagram for the Smart Phone APP

6.1.4 LED Operation

Table 6-1 shows what the LEDs indicate:

LED	Operation
Green	Indicates opening the watering valve.
Green flashing	Indicates that watering is in progress.
Red	Indicates closing the watering valve.
Blue flashing	Indicates Bluetooth activity. Blinks faster when connected to the app.

Table 6-1 LED Operation

7. Sample Code

The sample code is available on the Renesas Electronics Website

Website and Support

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

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

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	24/01/2018	All	Created document.

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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Refer to "http://www.renesas.com/" for the latest and detailed information.

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