

## White Paper

# Renesas RL78 Quick Solutions for the IoT Edge

January 2019

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## Abstract

Renesas RL78 family of microcontroller units (MCUs) is optimal for implementing a wide variety of IoT (Internet of Things) sensors and edge devices due to their support for wireless device-to-device and device-to-system connectivity coupled with low power consumption and highly efficient CPU performance. This makes RL78 MCUs ideal platforms for near sensor processing, which places data and signal processing closer to the edge sensor to decrease latency and enable real-time reporting. Combined with a highly integrated architecture, robust development support, superior design tools, and built-in security and safety features, RL78 MCUs simplify the development of compact and energy-efficient IoT systems at a lower cost.

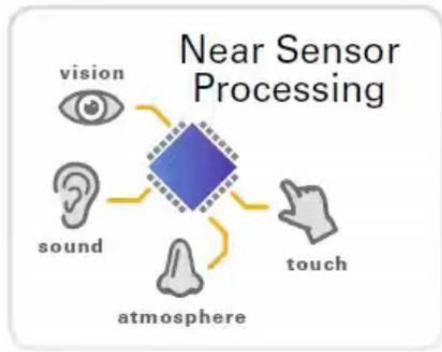
Some IoT use cases are featured as RL78 Quick Solutions, which are fully developed reference designs with a downloadable library of documentation and software including: user's manuals, source code, sample code, circuit diagrams, bills of material, printed circuit board (PCB) layouts and Gerber files. RL78 Quick Solutions can help speed prototype and product development for IoT applications, and help design engineers reduce time to market.

## Enabling Near Sensor Processing in Connected IoT Systems

Large IoT systems contain thousands of networked sensors, each monitoring, collecting and transmitting growing volumes of data and analog phenomena, with the increasing requirement to transmit and process this data more rapidly, and deliver intelligence more swiftly, than ever before. Traditional IoT network designs centralize IoT data processing: The sensor nodes at the network edge detect events and send all raw data sent back to a central monitoring point – often distant from the network's edge – for processing. This centralized design has the unintended consequence of introducing data latency and the potential for data corruption when signals are transmitted over a noisy link. These become disadvantages, and even hazards, as IoT systems play increasingly strategic roles in manufacturing, public safety, transportation and medical treatment.

A newer IoT network design called: Near Sensor Processing addresses these issues by moving the IoT system's data and signal processing closer to the sensor itself. Filtering and processing the sensor output before transmission results in increased signal integrity and greater system reliability; however, digital signal processing is very math intensive and power hungry, requirements that were traditionally challenging to deliver at the network edge.

Near sensor processing relies on a new generation of highly miniaturized, sensor-based subsystems with reduced size, weight and power (SWaP) while also lowering cost, latencies, bandwidth requirements, and system complexity. Therefore, a critical element of effective near sensor processing is an ultra low-power, low cost MCU with the ability to deliver efficient signal processing, high speed wake-up times, and power management to optimize energy consumption and battery life for remote and portable applications. Near sensor processing also requires low-cost, easy-to-design wireless connectivity to ensure that IoT data can be reliably communicated across the system to gain the benefits of real-time analytics based on this data.



**Figure 1.** Near sensor processing allows for the rapid processing of increasing volumes and types of analog phenomena

The Renesas RL78 family of MCUs offers multiple features to support near sensor processing for faster, mission-critical IoT systems. Wireless connectivity is key to transmitting IoT data and select RL78 MCUs have radio frequency (RF) peripheral components built in. RL78 MCUs offer other already integrated analog peripherals, including on-chip analog-to-digital (A/D) and digital-to-analog (D/A) converters, programmable gain amplifiers, comparators, operational amplifiers, and analog multiplexers. Because RL78 MCUs deliver greatly improved power efficiency and enable substantially longer battery life than comparable microcontrollers, they provide an ideal platform for IoT sensor systems that place data and signal processing closer “to the source” to decrease latency and enable real-time reporting.

### Wireless Connectivity for Near Sensor Processing

Two wireless technologies are most effective for device-to-device and device-to-system connectivity for near sensor processing scenarios: Bluetooth Low Energy and Sub-GHz wireless communications.

### Bluetooth Low Energy

Bluetooth Low Energy is an intelligent, low power mode of Bluetooth wireless technology. The power-efficiency of Bluetooth Low Energy makes it perfect for portable, battery-powered, and very low-energy-consumption applications.

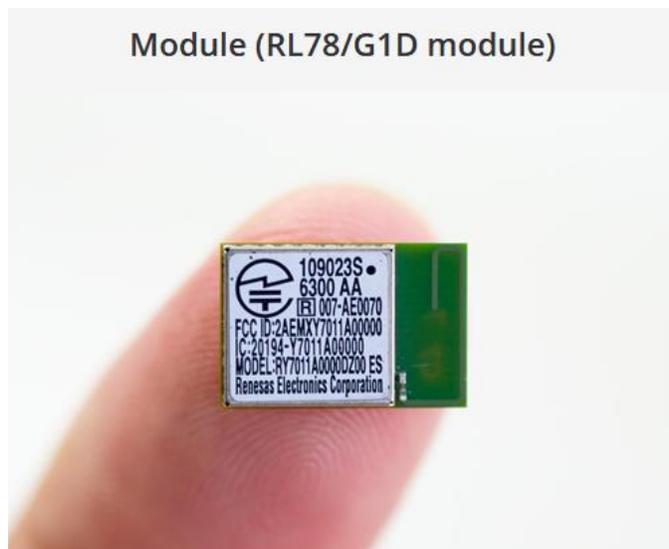
What makes Bluetooth Low Energy attractive is its ability to provide communication between IoT networks and smartphones or tablets. Bluetooth low energy is specially suited for beacon functions (for pushing information to smart phones), applications targeting health and fitness, home appliances, home automation, retail, location-based services and many other emerging IoT applications.

**Renesas RL78/G1D microcontrollers are equipped with low-power Bluetooth Low Energy transceivers** and rich peripheral functions, such as serial interfaces and A/D converters. The RL78/G1D delivers the lowest level of current consumption in the industry at 4.3 mA RF transmission current (0 dBm output) and 3.5 mA RF receiving current. Renesas has also developed a software stack for the RL78/G1D that supports wireless updating, helping increase the efficiency of software maintenance.

Since circuit elements necessary for connecting an antenna are built-in to the MCU, not only does this simplify circuit design for the antenna connection, but it also helps reduce the cost of the end product because many external parts are not needed. The RL78/G1D is also available as a module that integrates the MCU, an antenna and a 32 MHz crystal resonator for the RF chip, all in a compact 8.95 x 13.35 x 1.7 mm package.

Moreover, the module inherits the functional pins of the RL78/G1D, so not only can developers use it for modem configuration, they can also leverage the strengths of the MCU for embedded configuration.

In addition, the RL78/G1D has a function that automatically optimizes radio frequency characteristics and current according to radio wave conditions. This enables ultra low power operation at short distances, up to 65 feet (20 meters).



**Figure 2.** The RL78/G1D module incorporates an antenna and a RF circuit

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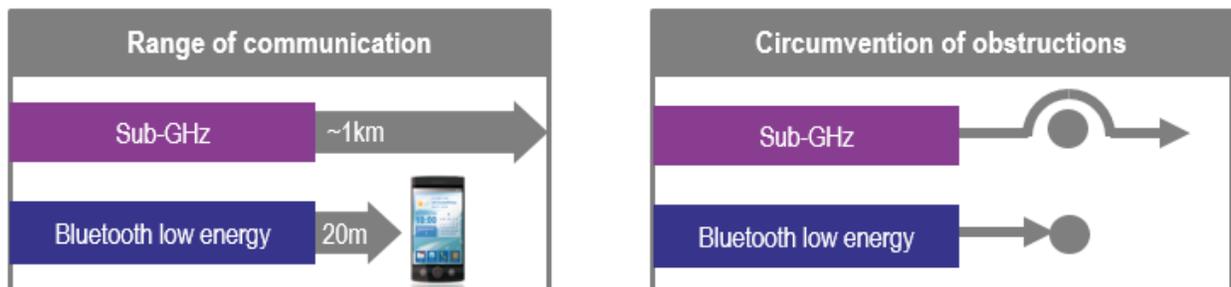
## Sub-GHz (Wi-SUN)

Compared to Bluetooth Low Energy, which uses the 2.4 GHz band, Sub-GHz wireless communications technology uses waves around the 920 MHz band. Sub-GHz devices are capable of transmitting data over half a mile (one kilometer) and unlike either Wi-Fi or Bluetooth Low Energy, Sub-GHz waves are able to circumvent physical obstructions.

Sub-GHz wireless technologies are ideal for IoT applications in such areas as smart agriculture, building management, lighting, disaster response, crime prevention, security, factory automation, detection, remote control, and so on.

**The Renesas RL78/G1H integrates on-chip sub-GHz wireless functionality** with the ultra-low-power RL78 core. This MCU has industry-leading low power consumption, drawing a minimum 5.8 mA (3.3V) in waiting for RF receipt, which greatly extends battery life. Battery life can be increased by using the RL78/G1H MCU in combination with a sub-GHz RF transceiver.

Renesas offers sub-GHz wireless communication solutions with a high-performance IEEE 802.15.4g-compliant system already on chip, plus evaluation boards, convenient starter kits, and software stacks certified by the Wi-SUN Alliance to help developers to easily start designing sub-GHz IoT applications. As with other RL78 MCUs, the G1H has multiple built-in peripheral functions, including a pre-integrated balun circuit and filter circuit to simplify the antenna circuit design. More than 20 external components can be eliminated from the IC package, reducing the costs of components, mounting, management and PCB re-design.



**Figure 3.** Bluetooth Low Energy and sub-GHz address different wireless connectivity requirements for IoT systems

These solutions enable system manufacturers to ensure interconnectivity with all third-party devices and simplify certification of home energy management systems (HEMS) products with the Wi-SUN standard.

## True Low Power Components to Reduce Energy Consumption

In addition to wireless connectivity technologies optimized for IoT applications at the network edge, an effective MCU for near sensor processing requires highly efficient CPU performance to enable the maximum amount of data and signal processing to occur at the source node.

The RL78 family delivers true low-power consumption in two major ways: by lowering power consumption of the MCU itself, and by helping to enable more efficient energy management of the end application.

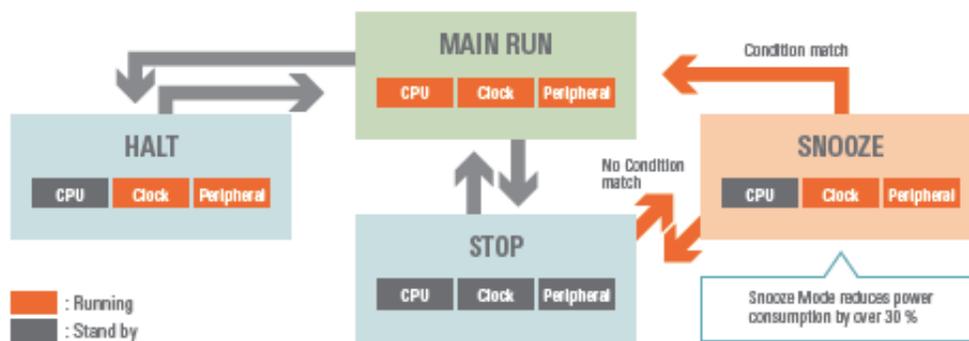
Renesas RL78 MCUs offer ultra-low-power consumption of .23 $\mu$ A in Standby-Stop mode (Stop mode with no clock operating and RAM contents retained) while still attaining as low as 66 $\mu$ A/MHz while running NOP instructions and 144 $\mu$ A/MHz operating current in CPU Run mode. This results in highly efficient power consumption at up to 51.2 DMIPS performance at 32MHz operation. The RL78 family offers much higher performance compared to other 8- and 16-bit microcontrollers in the marketplace.

RL78 MCUs have a power management system that further facilitates efficient use of the power supply critical for optimizing battery life of portable applications. Since the RL78 MCU itself doesn't draw much power – less than 20

milliwatts typical at 32 megahertz operation with +3V supply with all peripherals enabled – it will easily meet the appliance industry standby power target of less than 100 milliwatts drawn from the AC line. The RL78 MCU power can be reduced further when devices are in one of three low power operating modes (Snooze, Halt and Stop) that maximize battery life by disabling the CPU and peripherals that are not being used.

One of the keys to maximizing battery life is ensuring that the CPU is idle as much as possible and, when active, has the flexibility to operate as efficiently as possible. In CPU **Run mode**, the RL78's on-chip oscillator can be scaled down to even lower frequencies to save MCU current when maximum CPU performance is not required. **Halt mode** suspends CPU processing but allows all peripherals to run. This mode maintains the system clock that was running before entering Halt mode, allowing for CPU operation to be quickly re-established without having to wait for the system clock to start up. Halt mode can save as much as 80 percent of the total MCU current compared to when the CPU is running. For **Stop mode**, the watchdog timer and the voltage detector, such as a power-on-reset (PoR) circuit, are both operational with all RAM data retained, but the system draws a mere 0.53µA typical. In addition, the 15kHz low-speed clock and 32kHz sub clock can still run, enabling the operation of the real-time counter for date/time and the LCD controller driver boost circuit, as well as 8-bit or 12-bit interval timers for timed events. All these stop mode peripherals are low-power and draw less than one microamp total.

The RL78 adds a special low-power mode, called the **Snooze mode**, that didn't exist on previous low-power MCU generations. The Snooze mode enables serial communication and the ADC converter to start up with a high-speed, on-chip oscillator clock operation from Stop mode but without clocking the CPU. Therefore, Snooze mode is similar to Halt mode in that no CPU intervention is needed until after the data is captured, thus saving the current drain. This mode is excellent for battery-powered systems as it greatly increases battery life.



**Figure 4.** The RL78 has three low-power operating modes to maximize battery life

### Superior Performance to Enable More Data Processing at the Edge

RL78 MCUs deliver an unparalleled power consumption-to-performance ratio. The RL78 uses an optimized 16-bit CPU with Harvard architecture with a full 16-bit data bus for RAM, control registers and peripherals, with three-stage pipelining to enable implementation of instruction-level parallelism within a single processor. Eighty-six percent of instructions are executed in one or two clock cycles at the maximum 32MHz clock speed. This high performance yields a Dhrystone benchmark of 1.6 DMIPS/MHz or about 51.2 DMIPS at 32MHz operation. The RL78 family also offers the widest operating voltage in its class, from 1.6V to 5.5V.

Additionally, RL78 MCUs offer hardware assist for multiply, multiply-accumulate, and divide functions. The multiply and MAC are executed in one and two cycles respectively. Up to four independent DMA channels allow peripheral data transfer to/from RAM memory in two clock cycles; however, some RL78 MCU groups have DTC (data transfer control) to offer more flexibility and more channels for peripheral data transfer functions.

### More RL78 Benefits for IoT System Development

The RL78 MCU family offers other key features to support and simplify the design and development of IoT applications.

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- **Broad scalability**, with over 1000 devices available in packages ranging from 10 to 128 pins and from 1 KB to 512 KB of flash memory. Designers can easily expand from the smallest to largest code flash size within the same series, enabling them to easily add additional I/O and functionality by migrating to a larger pin count without having to rewrite the previous code drivers already written and debugged. Software code can be reused across the full RL78 family.
  - **High quality, reliability, security and safety**, with certification for the UL/IEC 60730 standard. RL78 MCUs have a number of safety functions that allow for critical confirmation of normal operations and enhance system reliability. RL78 MCUs provide “always on” protection for critical software code and data stored in flash memory. RL78 flash memory uses a proven flash cell structure at 130 nanometer geometry for lowest power error correction coding (ECC) with 38 bits of coding on every 32-bit flash. If flash memory is altered beyond the ability of ECC repair, the RL78 CRC (cyclic redundancy check) function block can identify gross errors so the software can immediately act to shut down the MCU safely. Additionally, RL78 flash memory supports an On-Chip Debug (OCD) function which provides password protections to thwart would-be hackers from reverse engineering customer application code.
  - **A comprehensive ecosystem of design resources**, including development tools, solution kits, online resources and partner networks, to minimize design and development costs and speed time to market.

## Introducing RL78 Quick Solutions for Popular IoT Applications

Quick Solutions are easy-to-build reference kits that assist designers with RL78-based IoT product development. Twenty Quick Solutions are currently available, addressing the development challenges and opportunities in such target IoT segments as household appliances, portable medical and personal healthcare solutions, building and industrial automation and consumer electronics.

RL78 Quick Solutions address the most challenging design issues that face developers as they prototype new IoT applications. These can include configuring wireless functionality for an IoT sensor node, or optimizing low-power capabilities to extend battery life for remote devices on the IoT network edge.

RL78 Quick Solutions are available as [a download from the Renesas website](#), and include user’s manuals, schematics, bills of materials, source code and project files – everything that designers need to quickly and easily prototype new products.

Following are two examples of how RL78 Smart Solutions facilitate the development process for two IoT sample designs.

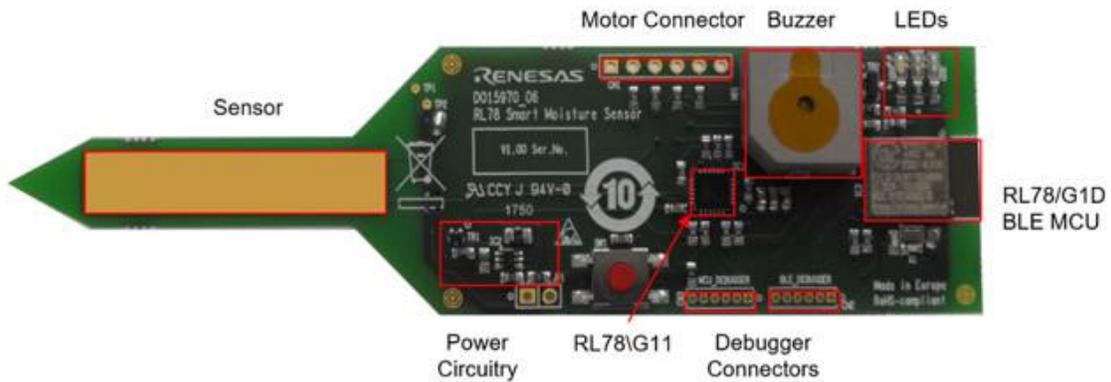
### RL78 Quick Solution for an Agricultural Moisture Sensor

This Quick Solution provides the documentation and source code for a smart agriculture moisture sensor with Bluetooth Low Energy connectivity that can monitor the temperature and humidity of plants and soil, and even supply water automatically.

This moisture sensor uses the 24-pin RL78/G11 MCU to measure the conditions of soil and transfer the data to a smartphone app via the RL78/G1D BLE module. Additionally, the solution can control the water valve by outputting motor signals.

In this design, three different selectable resistors are switched on one at a time dynamically to measure a wide range of soil conditions. This is done in conjunction with the programmable gain amplifier providing amplification to the ADC analog input. The RL78/G11 even handles all the sensor edge processing and manages four different activities:

- A buzzer output to the alarm if the soil gets too dry.
- Solenoid motor control to turn a water valve on and off and to drive the motor bi-directionally through a DC motor H bridge driver.
- Communications to the RL78/G1D BLE RF transceiver when the moisture level goes out of high or low range, which can be transmitted to an iOS or Android smartphone.
- Wake-up timing for sampling moisture levels and other periodic events.



**Figure 5.** The moisture sensor implementing the RL78/G11 and RL78/G1D BLE transceiver

To keep the sensor size small, a 4 X 4 mm QFN surface mount package and a single 1.5 AA alkaline battery are implemented. Therefore, a DC-to-DC boost converter is used to provide a constant 3.3V supply to the MCU. When the MCU is in stop standby mode, it only draws 0.35  $\mu$ A typical.

### RL78 Quick Solutions Smart Lock

This Renesas Quick Solution design reference provides all the documentation and source code required to build a smart lock that allows users to lock and unlock a door remotely via a smartphone application.

Key features of the Renesas Quick Solution smart lock design include:

- Remote key locking/unlocking, and confirmation of lock status
- Low current and low power consumption
- Key control via a smartphone
- Alarm function and password change function when the key is disconnected

This smart lock is built using the RL78/G1D MCU with built-in BLE (though the smart lock design can be adapted for other wireless technologies besides BLE). The BLE protocol stack library and application program are written to the RL78/G1D. Then, the appropriate app is written to a smartphone to achieve the smart lock control through BLE wireless functionality.



**Figure 6.** The smart lock system

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To ensure security, the correct password must be entered to unlock smart lock. The user can also remotely view the status of smart lock on a smartphone app. With the built-in alarm mode (which activates when the lock chain is cut off while in lock status) and a password management function in the smartphone application, the smart lock helps boost safety and security.

The control principle of the smart lock derives from a DC motor that drives the latch to enable the lock on/off operation. The motor current detection circuit detects of the latch position (when the motor reaches the preset position, it will be locked and the current will increase). When smart lock is in locking state, if the lock core is cut off, the buzzer will sound. The user can connect via the smartphone app to lock, unlock or disarm the alarm. The user password is stored in the RL78/G1D internal data flash. The smart lock uses three AAA batteries as its power supply.

## Conclusion

High performance, low power consumption Renesas RL78 MCUs are optimal for implementing near sensor processing at the IoT network edge. These MCUs can support IoT sensors and other edge devices by performing signal processing and offering power management modes that optimize battery life for remote and portable applications. Low power wireless connectivity is another requirement for near sensor processing, and select RL78 MCUs are available with built-in Bluetooth low energy and sub-GHz radio capabilities to make adding wireless functionality to IoT systems simple and cost-effective. Downloadable Quick Solution documentation from Renesas includes user's manuals, schematics, bills of materials, source code and project files – everything that designers need to quickly and easily prototype new products and address the fast-growing opportunities in the IoT market.

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