RL78 Family

RL78 Low Power MCU Application Note

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Introduction

The purpose of this application note is to show prospective users the advantages of the new Renesas RL78 low power 16bit MCU family over the major 8/16/32 low power MCU competitors, and how to utilize key RL78 low power features

Target Device

RL78/G12, G13 and G14 Series

Contents

1. Introduction

Recent developments in advanced low-power Microcontroller (MCU) technology, like the Renesas 16bit RL78 Family, enables designers to attain high MCU processing performance, and yet achieve low power consumption in standby mode to maximize battery life in those portable battery-operated and battery-backed applications.

Increasingly, consumers look to wireless and battery-operated instruments for freedom of mobility, and to achieve green power goals of lower energy consumption. Security and safety-oriented products can be made more secure and reliable by not being tied to the AC power line or if used in AC power applications with battery back-up or SuperCap back-up, they can provide longer coverage during an extended power outage, by using a smart, low-power MCU system. Security examples are fire, smoke, Carbon Monoxide, and intruder alarms, or Electronic entry locks or Electronic Lockboxes, the latter used by real estate sales Agents to retrieve a physical door key for the property if authorized to do so. The MCU can also provide data logging to record any user access events, and monitor unauthorized entry.

If a wireless/RF communication device is also part of a remote, battery-operated system, the current drain requirements of the RF receiver and transmitter increases the battery load, and therefore the MCU needs to draw even less average current, so as to keep the battery size/capacity as small as possible. As many RF systems may draw 10mA-20mA in Transmit and10mA in Receive mode, the duty cycle of both RX and TX modes need to be carefully managed, often by the MCU, which can provide both timing and communications control of the RF subsystem.

2. RL78 Low Power Operational Modes

In battery operated or SuperCap backup applications, two of the most important MCU features are (1) the ability to monitor MCU supply voltage and (2) the ability to tightly control system current drain by changing operating modes and moderating CPU performance. This section will summarize RL78 attributes to help designers both monitor the health state of the power supply voltage and optimize MCU power usage.

As any low power system designer knows, the key to achieving long battery life is to turn off any clocks and peripheral blocks that are not being used, and turn off or scale back the CPU clock speed whenever possible. So good Power Management functions are critical and the RL78 MCU includes special operation modes to stop portions of the chip and reduce power when only a portion of the device is required to operate. A flow diagram for these operational modes is shown here in **Figure 1**.

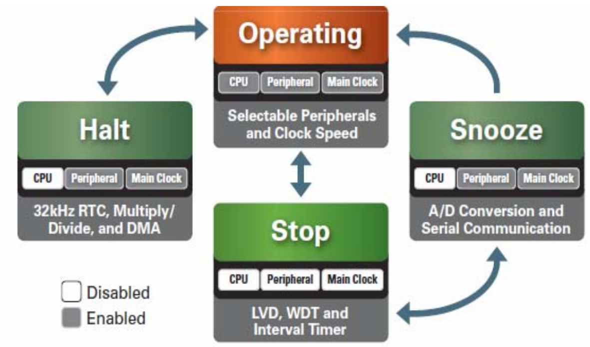

Figure 1: RL78/G13 Low Power Mode (State Diagram)

We will spend the remaining few pages of this app note to elaborate on these low power modes that have advantages in key applications, such as;

- Hand-held, battery operated units, such as Medical instruments like Blood Glucose Meters and Blood pressure meters, or Security Lockboxes and Electronic Key locks
- AC-powered units with SuperCap backup, such as small appliances, like a Timed coffee maker or light timer
- Wireless sensors, such as a Window-mounted Glass Break sensor
- Units that "steal" power from a low voltage system, as in an HVAC thermostat powered by a 24V AC transformer or in an Industrial sensor application that draws power from a 4mA-20 mA current loop
- Energy harvesting units where the application runs off very small, rechargeable Li-Ion batteries that are charged from incidental energy sources like photo-voltaic, wind, RF, vibration or thermal.

RL78 MCU low power mode Highlights:

3. RL78 STOP/Standby mode with all Clocks off

In this mode, the RL78 MCU is at the very lowest power consumption, 0.23uA typical at 25C, but with all RAM contents retained. Usually applications requiring STOP mode with-no-clocks rely on external wakeup, either by an external device that has its own power, or by using an external switch or sensor that triggers an MCU interrupt input, assuming that interrupt is unmasked. If an external device, like an 802.15.4 RF transceiver has its own wakeup timer, it may be advantageous to let it wake up the MCU. In the flow diagram **(Figure 1)** above, enabled peripherals in gray are optional, so they also can be turned off. Now we will examine several highlights of this lowest powered RL78 MCU operation mode:

RAM data is ALWAYS retained on the RL78 MCUs. There is no RL78 low power mode with RAM disabled, but the standby current, with no Clocks and with RAM data retained, is 0.23uA typical (0.50uA max) @ 25C on 64KB Flash parts with up to 4KB RAM, and 0.25uA typical (0.52uA max) @25C on 256KB Flash memory versions up to 20KB RAM size. Also, this standby current is stable over power supply voltages of +1.6V to +5.5V and doesn't increase at higher battery voltages.

Although **RL78's 0.23uA typical (@25C) STOP/Standby current** isn't the lowest around, it is still very good and low enough for over 99% of battery applications. Consider that a 0.23uA continuous current draw for 1 year is about 2.01mA-hours battery load. That is slightly less than 1% per year of the rated capacity for a modest size lithium coin cell battery, the CR2032 at 220mA-hour total battery capacity. With alkaline batteries, such as 2x AA cells which have approximately a 2200mA current capacity rating, the 0.23uA continuous current drain of 2.01mA-hour per year is less than 0.1% of an AA Akaline battery capacity. Considering that the shelf-life of Akaline batteries is typically 5years, the total STOP/standby current is less that 0.5% typical of the total AA battery capacity. The **Figure 2 comparison** shows that although RL78 does not have the lowest standby current around, is still compares favorably amongst the low standby current leaders (vendors D & E).

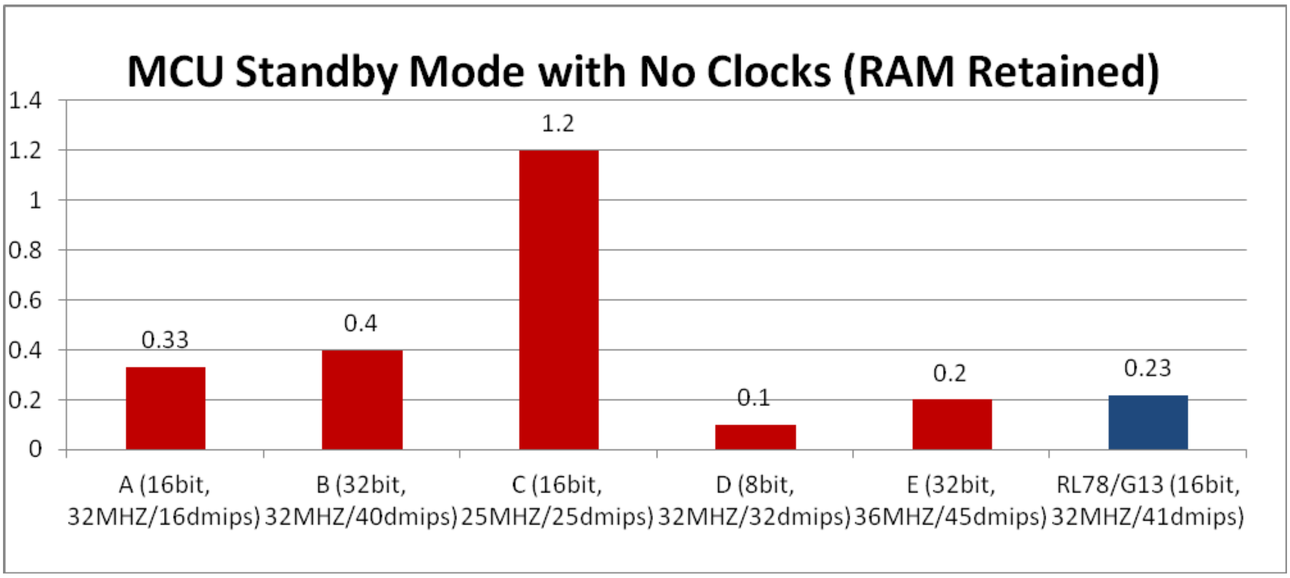

Figure 2: RL78/G13 Standby Mode, No Clocks Current Drain versus Competition

Using POR (Power-On-Reset). Since the POR circuit is always on, and included in the 0.23uA Standby current drain, a minimum MCU voltage threshold of 1.51V is always monitored at no extra battery drain load. This POR block provides a solid RESET function without requiring any external circuitry.

Using the LVD (Low-Voltage-Detect) circuit. If it is desired to have a higher minimum battery voltage than the 1.51V POR RESET voltage, the LVD circuit has both a RESET and Interrupt function (you can select Reset Mode, Interrupt, both, or disabled settings). For example, when using Lithium coin cell batteries, the minimum desired operation voltage is often around 2.3-2.4V, and the LVD RESET mode can be set for this. By the way, LVD only adds 0.09 uA typical load to the total current drain. In RESET mode, LVD has 14 different threshold settings from 1.69V to 4.07V. For higher performance applications it is often necessary to set the minimum operation higher than 2.7V, so the LVD can be used to detect these minimum levels, too.

High Speed On-chip oscillator (HOCO) Since the HOCO has a speedy start-up time of 18uSEC minimum, to 26uSEC maximum, stabilizing to full +/-1% frequency accuracy, the latency is very short to wake up from STOP mode, and resume program execution.

Figure 3 (Block Diagram) below is representative of many fundamental battery-operated, portable instruments, for example; the Blood Glucose meter, Blood pressure meter, or Electronic lockbox. For these basic applications, there is most likely a need for Time/date running in the background from a Real-Time-Counter with the ability to either wake up periodically on timed events or from un-timed, external key presses. Since many of these applications are targeted for consumer, low-cost units, they won't typically have large or expensive batteries. Therefore, inexpensive lithium coin cell battery or a pair of alkaline batteries will be adequate. However, an electronic lock box might possibly have a specialized, long-life battery to reduce maintenance intervals or minimize risk of an outage. In either case, the unit is mainly in Standby running at less than 1uA, waiting for the usually infrequent User activity. In many of these battery-operated applications, high CPU performance is not necessary, and modest performance at low current drain is adequate. For this Low speed mode, the RL78 MCU 8MHZ CPU performance is rated at 150uA/MHZ typical, over a wide power supply range of +1.8V minimum to +5.5V maximum. The internal low dropout Voltage regulator (2.1V nominal value) helps maintains a constant current over the full voltage range, with no increase when batteries are at full charge.

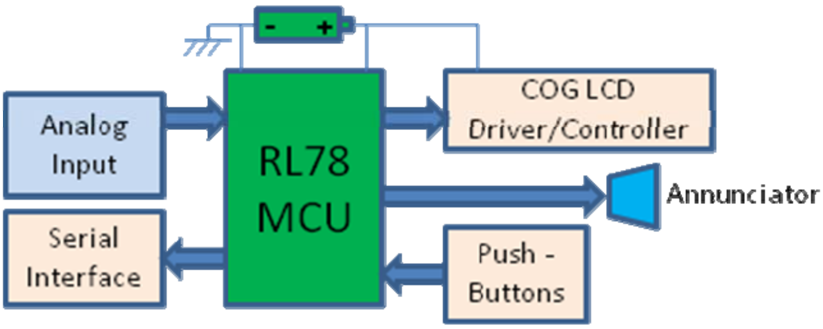

Figure 3: Block Diagram, Battery-Operated/Portable Application Example

(e.g.: Blood Glucose Meter, Blood Pressure Meter, or Electronic Lockbox)

4. RL78 STOP/Standby mode with Timer clock(s) enabled

In this mode, the MCU can wake itself up by use of periodic timer interrupts or a one-time future alarm, but can still accept external pin interrupt inputs and of course, still retains RAM data. The Timer can be either the basic 12bit interval timer or the RTC, and the clock source can either be the internal low speed oscillator at 15Khz or the external, high accuracy 32,768HZ clock.

A majority of applications do require keeping track of the time and date. Handheld instruments (like Blood Glucose Meters) often need to display the time for user convenience, and time-stamp data with the current time/date when a reading is captured. For small and large appliances powered by the AC line, there is no problem counting line cycles to keep time. However, as soon as there is a power outage, the time/date is lost and cleared unless there is a backup system. A modest size SuperCap can keep the RL78 MCU RTC function running for hours, to keep the appliance clock timing on track. There is generally no need to run the appliance during the power outage, but just keep the time function. Thus, the cook start time, or coffee brew start time can occur on time after resuming from many power outages.

The **Figure 4 comparison** on page 5 shows that RL78 MCU family does indeed beat out all the competition for lowest STOP/standby current when both retaining RAM data and running the RTC (Real-Time-Counter) clock/calendar function.

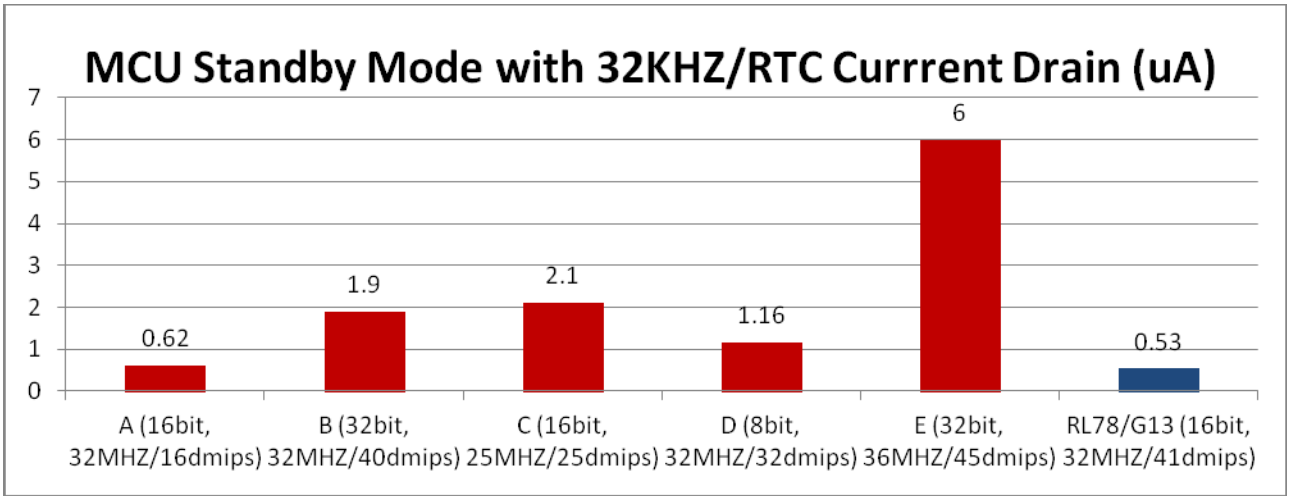

Figure 4: RL78/G13 Standby Mode w/32KHZ/RTC Current drain versus Competition

When running the 32KHZ sub-clock with RTC (Real Timer Counter) with clock/calendar function enabled, the RL78 MCU standby current drain is only 0.53uA typical. When using the RTC as a constant wakeup interrupt, the wakeup interval can be every 0.5sec, or 1.0 sec, or once every minute, hour, day or month. With no wakeup interval set, the RTC is also useful for accurate time-stamping of random external events since RTC quietly accumulates the date/time value in the background. In the example of a window glass-break sensor, the remote sensor may be needed to send its status back to a central unit at a 1hour interval (Sensor is normal, Battery Good/Low, minor vibrational activity is detected, etc.). Conversely, in the event of confirmed glass breakage sensed, the remote sensor may be needed to store a time stamp of the event into its Flash Memory or external EEPROM for later retrieval.

12bit Interval timer. Additionally, the 12bit Interval counter can create interrupts at a faster rate than the RTC, from 31.125uSEC (1 count) minimum to 0.125second (4096 counts of 32KHZ) maximum. This 12bit timer has a low current drain in the 0.1-0.2 ua range. If there is a requirement to trigger the ADC at periodic rates faster than 0.5sec, the 12bit interval timer is the best way to conserve power, by mainly staying in STOP mode.

The 15KHZ internal Low Speed On-chip-oscillator (LOCO) is available to run the Watchdog timer, but also can clock the 12bit Interval timer or the RTC. For the 12bit interval timer running with 15KHZ clock, the constant interrupt interval can be set from 66.7uSEC to 267.7mSEC. In cases where the 32KHZ sub-clock is either not available (pin counts of 40-128 have the 32KHZ external resonator pins, whereas pin counts of 20-36 do not) or where the system cost needs to be minimized, the 15KHZ LOCO clock can also be used to clock the RTC in constant interrupt mode. The RTC intervals are now lengthened to 1.09 sec, or 2.18 second for the constant interrupt mode using the 15KHZ clock source.

The total RL78 MCU current drain with 32KHZ sub-clock and RTC running, with LVD enabled and watchdog timer running is 0.7uA typical. With this low a standby current, it is possible to keep a capacitor charged by “stealing” current from a 4mA/20mA communications loop (ex: industrial sensors) or a 24VAC HVAC transformer (ex: battery-less thermostat application). When the MCU is in standby mode it can draw much less then the charging current for the storage cap. Then, when the MCU is woken up, it can draw extra current from the capacitor for short periods as long as its duty cycle is low enough to allow the capacitor charging to recover. Additionally, since the RL78 can run at 4MHZ down to 1.6V minimum (or 8MHZ down to +1.8V minimum) and up to 5.5V maximum supply voltage, the capacitor can keep the MCU alive at a wider voltage range than many other conventional low power MCUs that have a +3.6V maximum operating voltage, since a larger percentage of the capacitor charge can be utilized with a wider MCU voltage range.

For battery-operated RF sensors (example in **Figure 5, Block diagram** on the next page), such as glass break alarm, there is probably a need to for the remote unit to report into the central control unit periodically, to notify the base unit of a low battery situation, or just to announce it is still alive. Of course any random event, whether a valid glass break detection, or a false alarm, is an asynchronous trigger that needs to be analyzed by the CPU. Then, a fast CPU wake-up time will help the system determine if the event is serious, needing to be reported or ignored so returns to standby mode. In the case of the travel temp sensor, temp data may be continuously sampled every few minutes for hours, days or weeks and stored in data Flash memory for later retrieval, when the trip is complete. Then, when polled, the unit dumps out it data store over the wireless transceiver.

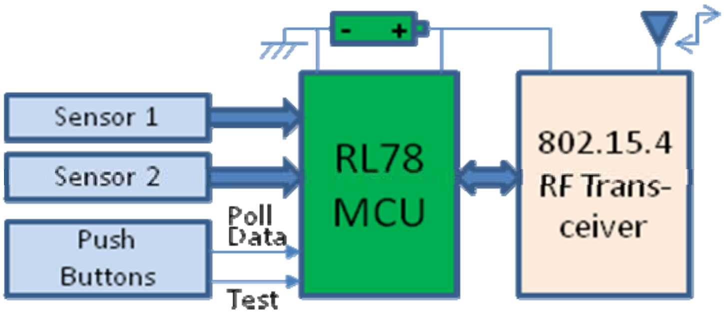

Figure 5: Block Diagram, Wireless RF Sensor Application Example

(e.g.: Glass Break/Intrusion Sensor, or Travel Temp Monitor)

5. RL78 Snooze Mode

In this mode, the MCU can be set up to accept a periodic ADC conversion or a Serial Port reception, while keeping the CPU in standby mode, thus lowering the overall battery current drain.
Snooze mode allows power to be reduced by as much as 60% during simple analog conversions and serial data reception operations where previously CPU intervention was required.

Looking back at **1** again, you'll notice that there is no path between Halt and STOP modes. **Figure 6** below shows how the Snooze mode would work in a Thermostat application example, where Snooze mode is used to reduce overall MCU current drain. In Snooze Mode, when a data reception event is triggered by specific peripherals the applicable peripheral clock (via HOCO) is enabled and data is received without CPU operation. Data reception from the synchronous or UART serial port, or a data conversion by the A/D converter can operate in the Snooze mode by waking-up the appropriate block and not the CPU. The A/D converter can 'wake-up' when the RTC timer or Interval timer interrupt signals the start of a conversion. The synchronous serial port can 'wake-up' when the Serial Clock input pin (SCKp) edge is detected or the UART can 'wake-up' when an edge on the RxD input line is detected. However, in those cases, the CPU operation is dormant during the entire data capture process.

After any data reception operation in the Snooze Mode is complete, selected interrupt conditions can be checked. If the serial data is received without error, the Snooze mode is exited and the CPU Run mode is entered to operate on, or store the data. If a serial data error occurs, operation returns to the Stop Mode. This allows the CPU to only be enabled when CPU intervention is required. For example, an A/D conversion can operate in the Snooze Mode without the CPU running. The result of the A/D conversion can be checked to see if it is within pre-defined range that is 'safe'. When the analog value is in this 'safe range' the CPU need not be enabled and the MCU transitions from the Snooze Mode back to the Stop Mode.

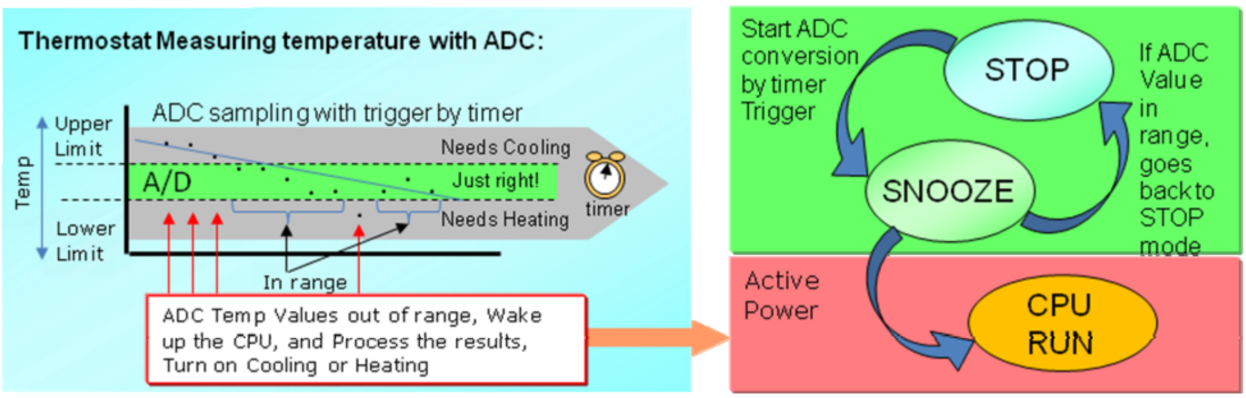

Figure 6: Snooze Mode Operation Example

Only if the A/D conversion returns a result outside of the pre-defined range will the CPU be enabled. Thus the use of the Snooze Mode could avoid the costly power dissipation associated with turning on the CPU during a majority of the measurements. Since the A/D conversion uses only a fraction of the power needed to run the CPU there can be a dramatic savings, prolonging battery life.

The **Figure 7 comparison** shows a real life example of current drain savings between the RL78 MCU and a representative 16bit MCU competitor, both running the ADC data conversion with an 8MHZ clock setting.

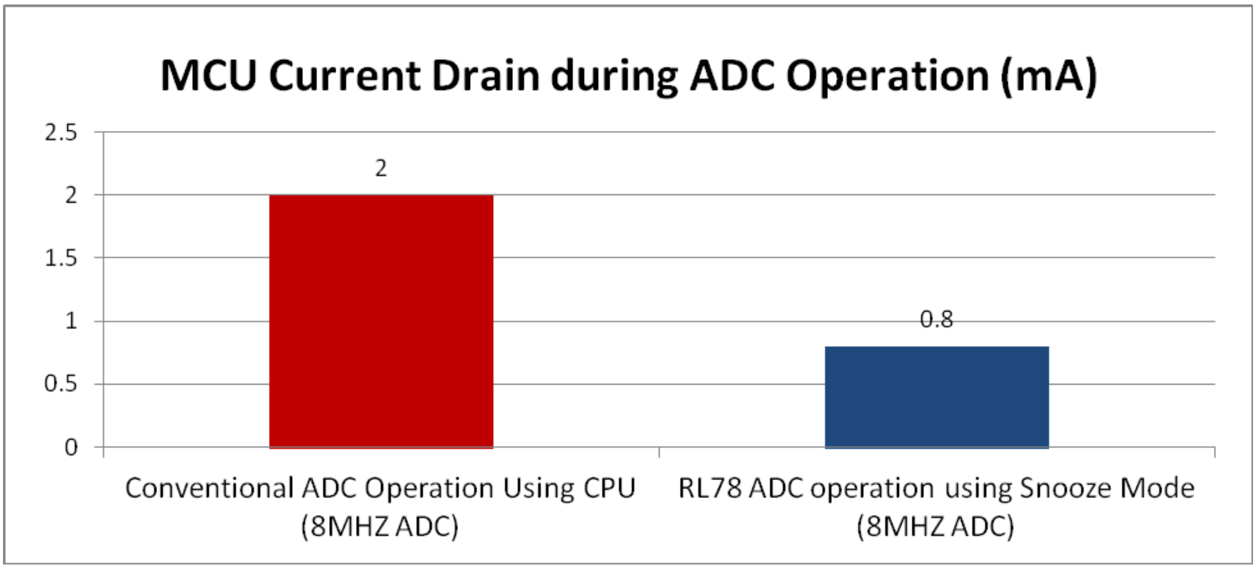

Figure 7: ADC Using RL78 Snooze mode versus conventional MCU ADC operation

Figure 8, Block Diagram shows a possible system configuration for a Energy harvesting system using a solar cell. New rechargeable battery technologies incorporate small and thin battery profiles, often no thicker than PCB they are mounted on. Some of these specialized batteries range from tenths of mA-Hr to several mA-Hr capacities in a very slim profile. If a sensor is transmitting status or analog readings on an 802.15.4 or WiFi transceiver, the higher current duty cycle can be made very low, maybe a few milliseconds out of minutes. For example, a duty cycle of 0.1% at 25mA per RF transaction (RF + MCU current) averages to 25uA average. Then with the MCU in RTC standby mode at 0.7uA, the total average current drain is 25.7uA per hour. In a 24 hour period, this equates to a about a 0.617mA-Hour load, so a 1mA-hour capacity thin battery can carry the sensor overnight, provided around 7-8hours at 100uA or larger charge is available on a daily basis.

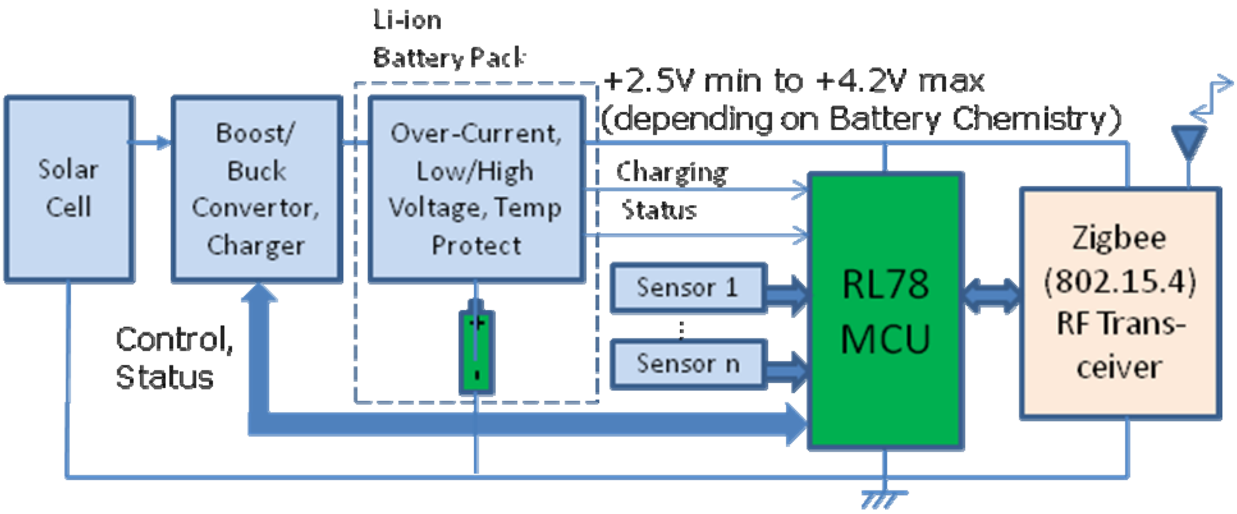

Figure 8: Block Diagram, Energy Harvesting w/ Solar power, for recharging a Li-ion Battery

(e.g.: Remote Sensor for Temp, Pressure or Intrusion Alarm)

6. RL78 Halt Mode

In Halt mode, all the RL78 MCU peripherals can be available and enabled, since the Main system (HOCO) clock is enabled, but CPU instruction execution is suspended. At first glance, the Halt Mode appears to be a simple way to just suspend CPU operation, while keeping the system clock running. In fact, CPU instruction execution can be resumed more quickly from Halt Mode than in STOP Mode. However, you can still be operating key system processes in Halt Mode. The main benefit is that up to 85% active current drain of the MCU can be reduced in Halt Mode, since the CPU activity is suspended. Almost any application can take advantage of intermittent usage in the Halt state, since many applications can be waiting for a peripheral action to complete. There could be one or more possible events pending that the CPU is just sitting idle waiting for completion, and the corresponding interrupt to occur:

- ADC conversion
- Timer compare/capture
- Serial port data receive/transmit completion

The application may be continually capturing data, or outputting data to the timers or serial ports. Often when running the ADC conversions, timer operations or serial port operations, a series of bytes or words must be saved or sent out before the process is complete. The CPU could be sitting in a “While (forever)” loop waiting for the peripheral to complete its operation, but is burning up battery current needlessly. By putting the MCU in Halt mode, up to 80% of the MCU current drain can be saved relative to that in CPU run mode.

HALT Mode is released by any Interrupt request that is also Unmasked (MK bit = 0), with the following possibilities:

- If the interrupt acknowledgment is enabled (IE = 1), a vectored interrupt servicing is carried out;
  (13 cycles minimum to 15 cycles maximum, CPU latency)
- If an interrupt acknowledgment is disabled (IE = 0), the next address instruction (inline after the Halt Instruction) is executed, thus ignoring the original interrupt;.
  (8 cycles minimum to 9 cycles maximum, CPU latency)

There are either 2 or 4 channels of DMA available on the RL78/G13 MCU family, depending on the pin count. (2 DMA channels for 20-64pins and 4 DMA channels for 80-128pin RL78 MCUs). DMA transfers can be used to either store data or re-load peripherals needing data, triggered by an interrupt request. Up to 1024 bytes or words can be transferred before the DMA channel must be re-initialized. Since the DMA can operate in Halt Mode indefinitely without CPU intervention, this is a key method for conserving battery power. In the **Figure 9 comparison** shown here, The RL78/G13 Halt mode current is reduced by over 85% from 4.6mA typical for CPU running all instructions to 0.54mA when idled (HALT mode.)

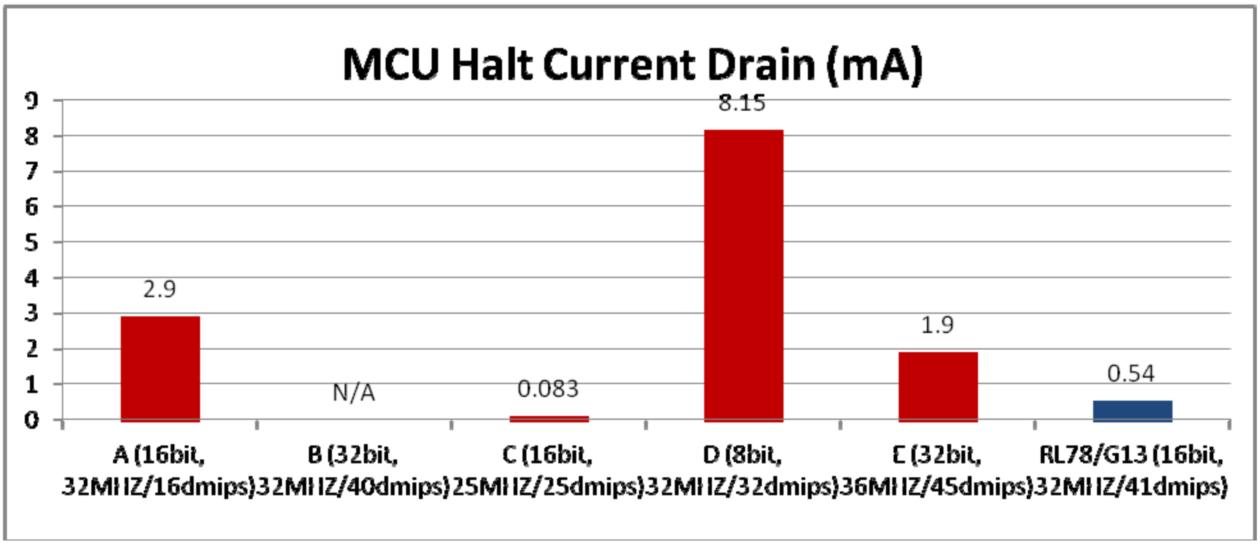

Figure 9: RL78/G13 CPU Halt Mode Current Drain versus Competition

The Figure 10 Block Diagram below (page 9) shows an AC line-power application utilizing a SuperCap for standby power. Often when AC power goes away, the machine may only need to keep the Real-Time-Clock (date/time) activity maintained. Even a modest sized SuperCap of 0.022F can keep the RTC running for over a day at 0.53uA typical current drain @25C. If CPU activity is desired at some low duty cycles, the designer can consider using larger SuperCap capacitances, or lowering the RTC backup time. The wide voltage operating range of the RL78 allows a larger percentage of the SuperCap charge to be used when power the RL78 MCU, especially in 5V supply applications where the RAM and RTC operation can be maintained over the +5.5V down to either +1.8V (low speed mode) or +1.6V (low voltage mode).

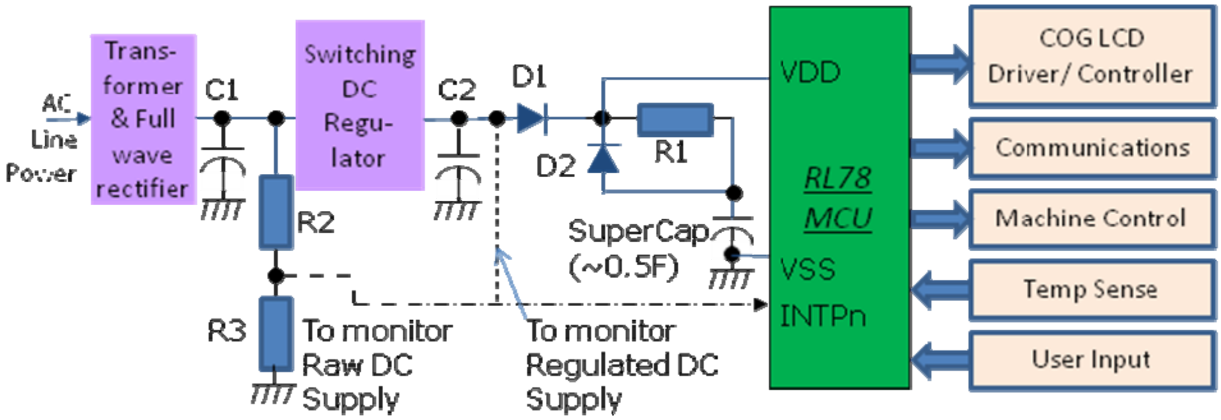

Figure 10: Block Diagram, AC Power Line supply with SuperCap backup

(e.g.: Small/Large Appliance, Smart Power Meter)

7. RL78 CPU operation mode at low system clock speed.

Since the CPU is capable of running at very low clock frequencies, very efficient instruction execution can result. At 32,768HZ CPU speed using the 32KHZ sub-clock oscillator, the MCU current drain is 4.1uA typical at 25C, resulting in a efficiency rating around 125uA/MHZ equivalent, allowing the RL78 MCU to achieve the lowest current drain while still executing the whole instruction mix.

One caveat is that ADC cannot operate at 32KHZ and the High Speed 16bit timers are limited to 32KHZ maximum speed operation. Otherwise Inputs can be checked and Output pins toggled, as well as having the RTC, and 12bit Interval Timer, LVD, CSI/SPI serial ports, and Interrupts operational.

An application example for using continuous 32KHZ CPU operation might be a remote Water sprinkler system that times the sprinkling function, but also has a daylight sensor and a moisture sensor. Possibly such a system could also have an 802.15.4 RF transceiver for centralized control. On the RL78 it is possible to run at 32KHZ CPU speed with the HOCO (high speed on-chip-oscillator) disabled, but then turn on the HOCO to allow the CPU to run at 1MHZ or higher speeds. Many such systems have pulsed-On/pulsed-Off solenoid to control the water valve. This configuration saves battery compared to water valve solenoid valves that require continuous current to turn on.

Running the CPU at a 32KHZ system clock, drawing 4.1uA continuously would result in a battery drain of 35.9mA-hours in a 12 month period, which is less than 1.7% of a 2200mA-hour capacity set of AA, alkaline batteries. At a 1.7% continuous battery drain, this is lower than Akaline battery self-leakage current, and the alkaline batteries will exceed their shelf life well before the 4.1uA current drain would deplete the batteries down to a 0.8V-0.9V level per cell. Since the RL78 MCU can operate down to a 1.6-1.8V power supply level for 2 cells, it can easily handle the low battery condition for Akaline batteries at their end of life.

The 32KHZ CPU operation can also be suspended to Halt mode (sometimes referred to Sub-Halt, since it was previously running in Sub-clock System mode), to get down to a standby current below 1uA typical. Additionally, any CPU/SYSTEM clock speed setting from 1MHZ-4MHZ, divided down from the internal High-speed On-Chip-Oscillator (HOCO) can be used to conserve battery current drain, and program execution in the 1MHZ-4MHZ clock range is guaranteed down to 1.6V minimum supply voltage.

In the **Figure 11 Block Diagram** below, a Remote Sensor in a 4mA/22mA current loop configuration might use either run the CPU at 32KHZ or at a low frequency high speed clock (1MHZ-8MHZ) to stay well below the 4mA current drain level, but still have the ability to monitor the remote analog levels and provide proportional current signaling to the Base RCVR unit.

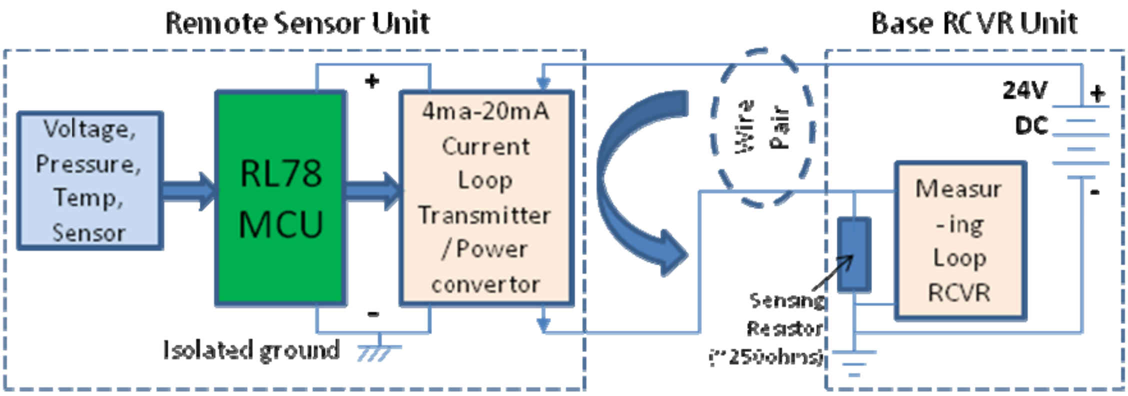

Figure 11; Block Diagram, 4ma-20mA Current Loop Remote Sensor

8. RL78 CPU operation mode at high system clock speed

In the **Figure 12 comparison** here, the RL78 Active Mode demonstrates very efficient use of battery drain at full 32MHZ performance (up to 41dMIPs rating), with by far the lowest current drain, in both microamps per MHZ and in microamps per dmip ratings compared to the competition.

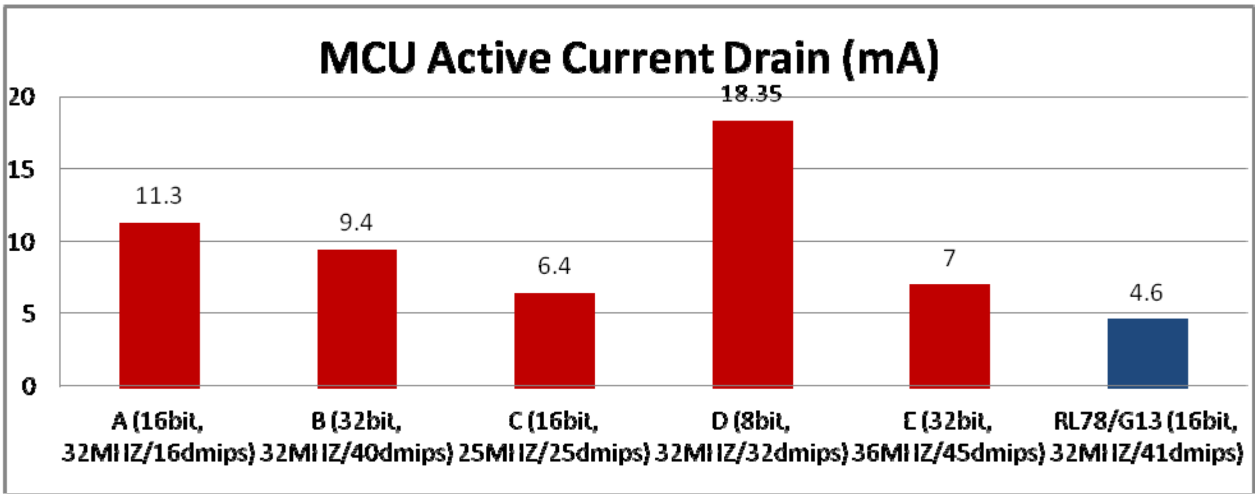

Figure 12: RL78 CPU Active Mode current versus Competition

Website and Support

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

Inquiries
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Revision Record

Rev.	Date	Description Page	Summary
1.00	Oct 27.11	—	First edition issued

General Precautions in the Handling of MPU/MCU Products

The following usage notes are applicable to all MPU/MCU products from Renesas. For detailed usage notes on the products covered by this manual, refer to the relevant sections of the manual. If the descriptions under General Precautions in the Handling of MPU/MCU Products and in the body of the manual differ from each other, the description in the body of the manual takes precedence.

1. Handling of Unused Pins

   Handle unused pins in accord 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 one with a different type number, confirm that the change will not lead to problems.

   — The characteristics of MPU/MCU in the same group but having different type numbers may differ because of the differences in internal memory capacity and layout pattern. When changing to products of different type numbers, implement a system-evaluation test for each of the products.

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