R8C/35C Group

Low Power Modes of Operation

REU05B0128-0100
Rev.1.00
Nov 15, 2010

Introduction

This document discusses options for Low Power Operation in the R8C/35C family of Microcontrollers for various applications.

Target Device

R8C/3x Series: R8C/35C Group

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1. Introduction

The R8C/35C Family of microcontrollers is designed to operate under a wide range of voltage, and is well suited to battery-powered applications with minimal power consumption. Special new modes of operation have been designed into this family, including: capability for low voltage operation, wide clocking options, and standby modes.

By using these modes, it is possible to apply this family of MCU's to many low-power applications to maximize battery life and maximize performance.

2. R8C/35C Low Power Features

The R8C/3x Microcontroller family is designed to operate under low voltage, battery powered applications with minimal power consumption. Special new modes of operation have been designed into this family, these are:

- Active operation down to 1.8VDC
- Low power clock modes
- Low Power Flash mode
- Wait Mode
- Stop Mode
- Power-Off Mode

The ability to operate the MCU with many clock options adds to the flexibility of the chip to fit specific needs while minimizing the current consumption. The clock generation options include:

- Low Speed On-Chip Oscillator at 125kHz
- High Speed On-Chip Oscillator at 40MHz, used by the core at up to 20MHz, but available for timers at 40MHz
- External XIN crystal oscillator, up to 20MHz
- External XCIN crystal oscillator, up to 50kHz, nominal at 32.768kHz, used for RTC timer, LCD and available for MCU core
- For the CPU, each of the clock generators can be divided by 1, /2, /4, /8, and /16. Other dividers are available for the peripherals and can be individually controlled.

Then, there are also the options of how to transition between modes to minimize the transition time. These include:

- Selectable clock generator on wake-up from sleep modes
- Selectable clock divider on wake-up from sleep modes
- Selectable peripheral control bits to automatically stop and restart peripherals not needed in sleep modes
- Selectable interrupt wake modes, with or without an ISR.
- The ability to move and execute code out of RAM as well as from Flash memory.

3. Typical Low Power Applications

With the variety of low-power options, it can be confusing to choose the best configuration for a particular application. Here, we offer some rules of thumb to help narrow the choices.

The choices will depend most on the application requirements. Applications where power is of prime concern usually fall into one of these categories:

3.1 Active

An Active application must stay awake or sleep very little. Despite requiring high activity, it may still be possible to reduce power consumption. This can be done by changing clock divider settings, disabling all unused peripherals and clocks, and using Low-Power flash options to minimize active current consumption for a *limited* active mode. The difference in power consumption may be very significant, perhaps using only a 10^{th} of the full active current. If burst of higher performance are occasionally needed, then the clocks chosen with a higher frequency for the high-demand times can be throttled back using a significant divider during less demanding times. It is quick to restore the higher clock in code as needed without a clock startup delay. This can really help reduce average power consumption.

3.2 Real-Time Clock

In this type of application, the MCU must keep track of time; it can sleep most of the time, but must wake itself up periodically. In this kind of application, look at Wait mode with real time clock using TimerRE. Once awake, use the fastest clock practical to minimize awake time and average power consumption, such as the High-Speed On-Chip-Oscillator. It is accurate in the full voltage and temperature range to be used even for UART communications. Wait mode operation can really save current; consuming around 3uA, so this can keep the average current very low.

3.3 Standby

This is the kind of application does not need to keep real time, it can sleep most of the time, but it must awaken from an external signal as needed. In this case, Stop mode with external wake-up pin is a good option to save. Just like Real-Time Clock mode, it is desirable to then get the job done while awake as fast as possible before returning to Stop mode, so use as fast a clock as is practical. By not running any clocks during Stop mode, the MCU current can be kept below a 1uA.

In some applications, it may be necessary to use a combination of Low Power modes to make the most effective use of the power available.

4. Choosing the best Low Power Options

In order to choose the best Low Power mode options, the basic operating parameters need to be set, as some particular modes may be eliminated. Here are some questions and answers about some applications that can help guide the designer.

Q: Does the MCU need to wake-up more often than once a second?

A: If so, consider using a TimerRE in timer mode rather than Real-Time clock mode to wake up from Wait mode in time units less than one second.

It could save time in each waking period to run ISR code out of RAM rather than Flash. If waking into an ISR, chose the /B option on the ISR function to lessen the latency in calling the function.

Finally, you can use a peripheral flag to wake up and continue running code from just after the Wait was initiated, rather than calling an ISR. The CM30 bit is a new feature to initiate a wait, but which can be woken up by a flag or external pin, without actually needing to call an ISR.

Q: Is the Vcc voltage is from a battery, does the voltage need to be monitored?

A: If so, consider when to use the Low Voltage Detect for best benefit. Using it full time will use current full time, but when used briefly, it can still detect low battery conditions without as much average current.

Q: Does the code need to operate very quickly upon wake-up?

A: Use one the High-Speed On-Chip Oscillator to minimize clock stabilization time, and run code out of RAM instead of Flash to minimize Flash stabilization time.

Q: Using active operation down to 1.8VDC?

A: Given a particular processing requirement, CMOS will use power in proportion to the voltage of the logic and to frequency. This is due to the capacitance of the CMOS circuit elements having to be charged and discharged to High and Low levels. As such, it can allow the circuit to reduce its power consumption for a given clock frequency if it can be run at a lower voltage. Some static currents that are not clock related may also be reduced with lower voltage. Having an MCU that can operate at lower voltage provides more options to reducing the power consumption of the MCU and possibly the whole system. Beside basic power consumption, if the system is powered from a battery, battery life may be stretched when operated to a point further along its discharge curve. The R8C/3x family allows for 1.8V operation, and still runs at up to 5MHz CPU clock.

5. General System Considerations

5.1 Peripherals

Analog peripherals like the ADC, DAC and Voltage Detectors/Comparators require a bias current when enabled, whether they are performing a conversion or not. Also, the ADC requires a minimum clock rate of 2MHz, and a minimum voltage of 2.2VDC. For a system that needs to convert ADC data only once in a while, it is possible to start up a clock at 2MHz or more, enable the ADC circuit, take a measurement, then restore a lower quiescent current by turning the clock and ADC off. Note that the ADC result is undefined if the CPU is in wait mode, stop mode or in low-power consumption mode, so do not use the ADC to wake up the chip. When enabled, the current consumption of the ADC internal reference is roughly 45uA.

Other peripherals, like timers and UART's, are purely digital, and so their consumption is small and more linearly proportional with frequency. If not needed, they should also be disabled. If one of these has to run all the time, it may be more economical to use the lowest frequency clock into it as practical and still maintain desired operation.

5.2 Processing time

It should be obvious that the time it takes to process instructions is inversely proportional to the clock frequency running at the time. What is not so obvious is that the total energy to perform the operations may be less if the processor is running at higher speeds but only for brief periods. This is due to static loads that exist while the CPU is active. So, just like it was with the ADC, it is often best to run the CPU fast for a brief time, then to sleep, rather than to run constantly at a lower speed.

5.3 Sleep modes and system awareness

The best sleep mode to use (Wait or Stop mode) depends on what peripherals still have to run, what is needed to wake up, and how long it takes to wake up.

Stop mode is a very low-power mode, which can wake up with external interrupts like switches, external timers, inputs that do not themselves need a clock to detect, but will not allow for real-time clock.

Wait mode stops the CPU clock, but allows some peripherals to keep operating. This is best for UART reception, timer counting, voltage detection, and real-time clock counting.

The trade-offs for low-power operation begin when the operating parameters are established, then the modes of operation are fit into it. The power consumption can then be calculated or measured directly. Once the numbers are found, one can see if there is room to adapt the operating parameters to see if the power can be reduced even more.

On another point, when clock or Flash power modes are changed often, the power consumed while making the transition can become a significant portion of the total power consumption. A power transition chart can be created to show the power consumption in all the modes required, as well as the time and power consumption used in the transition areas between the modes. Once this information is compiled, it is easer to calculate peak and average power consumption and CPU clock cycles available to do various tasks.

More details on Low Power modes of operation as they apply to different chips are found in their respective Hardware Manuals. Look for the "Clock Generation" and "Power Control" sections.

Website and Support

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Revision Record

Rev.	Date	Description	
		Page	Summary
1.00	Nov.15.10	—	Initial Release

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

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