Whitepaper 1: Lemon Powered Design

Abstract

For those who did not attended Embedded World 2012 or have not seen any of the articles and videos, the title refers to a Renesas RL78 microcontroller LCD demonstration which was powered from a single lemon for the duration of the show (three days!!), truly demonstrating that the RL78 was and remains one of the lowest power microcontroller families.

While this may seem a bit of a gimmick and while not suggesting using fruit as an alternative to batteries, the point to the demonstration is that battery powered applications such as gas and water meters, HVAC controllers, portable test tools and portable medical equipment and many others can significantly increase their battery life and in some cases the battery can last for the life of the product.

For those who have not seen this before, many videos and articles exist, so visit the Renesas website or search for "Renesas lemon demonstration" on the web.

A picture of the system demonstrated at Embedded World is shown in figure 1 below.

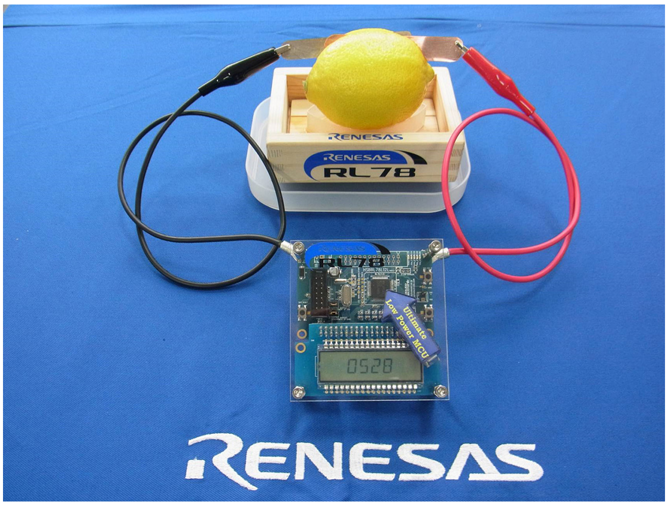

Figure 1 – Renesas RL78/L12 LCD demonstration

The need for low power operation is being driven by market demands for a greener environment and better use of resources, making batteries last longer as the total costs of battery based equipment is higher (product plus disposal costs) than an equivalent line powered system.

Government regulation worldwide is driving reductions in operating and standby power making strong demands on the total power consumption of electronic equipment. An increasing number of products today are or will become battery operated or include a battery backup placing more demands on the design and especially the microcontroller. Reducing power consumption is vital in equipment meeting power targets and required regulations.

Introduction

This is the first in a series of four whitepapers examining many of the techniques that allow designers to combine both performance and low power consumption into their applications. For the purposes of reference two low power Renesas Electronics MCU families are used, the RL78, a high performance low power (63 µW/MHz) 16-bit family already mentioned above and the RX100, a high performance low power (100 µW/MHz) 32-bit family offering more performance but retaining good low power qualities.

While these specific products (RL78/L12 and RX111) are used for reference and comparison, the principles and techniques apply equally to all of the other Renesas RL78 and RX product families.

While this paper focuses mainly on the LCD "lemon" demonstration and its configuration, it also provides an introduction to the series of papers defining many of the common principles necessary for low power design.

The remaining three whitepapers (listed below) analyse in more detail many of the specifics of low power operation and design.

Whitepaper 2: The Rules of Low Power MCU Design
Analysis of many techniques to provide the lowest power consumption possible

Whitepaper 3: De-Clocking vs MCU Standby for Low Power Design
Reducing MCU clock speeds during operating and idle times and effects of combining with standby

Whitepaper 4: Maximise Your Battery Life
Analysis of systems that are designed to spend long periods in standby operation

All papers, including this one should ideally be read together making a complete review of low power MCU usage.

Low Power Operation

With many products operating for their entire lifetime from battery power alone without any recharges or battery changes, it is critical to have the ability to wait in a very low power state and then wake up using as little current as possible. It is therefore important that modern MCU's not only have a low operating current with a choice of operating frequencies, but are supported with flexible low power standby operation allowing the designer to optimise the selection of clock speed against run time power consumption and the use of the standby modes to meet the requirements of the system and battery life. However the MCU while a significant factor is not the only area of the design that may need to be considered when minimising power consumption.

While applications will differ in requirements there is a common set of topics that we will examine as part of this series of whitepapers. These are:

1. MCU Standby modes
2. MCU Operating clock speed
3. MCU Clock Source Selection
4. MCU Peripheral Operation
5. MCU I/O Pin use
6. System Integration
7. Power Supply options

These topics are covered in detail in the other whitepapers.

For our reference products, the RL78 includes two standby modes, HALT where fundamentally only the clock to the CPU is stopped and STOP where almost all of the MCU is stopped. Both can be used to dramatically reduce current consumption as shown in figure 2 on the right. However the RL78 includes an additional advanced low power mode linked to STOP, called SNOOZE. When this mode is used in conjunction with the ADC, UART or CSI peripherals (in any combination) it allows the main system clock and the peripheral to be woken from STOP, an event checked (ADC range, valid UART/CSI reception) and either the CPU woken to process the valid event, or the MCU returned to STOP mode. This can dramatically decrease the number of times that the CPU needs to be active until a valid system wake up is required. This combined with some of the special on chip peripheral functions provided on many RL78 products, such as an "Event Link Controller" (ELC), which can be used to trigger a sequence of events using other peripherals without any operation required from the CPU. This allows efficient processing such as ADC results or moving UART/SPI received data to memory to be made without using the CPU allowing the CPU to process application tasks in parallel to these "linked" events, saving execution time.

The RX100 includes three standby levels, **SLEEP, DEEP SLEEP** which are hardware triggered modes similar to the RL78 ***HALT*** operation and **SOFTWARE STANDBY** which is the basically equivalent to the ***STOP*** mode of the RL78. These offer the same power saving benefits to that of the RL78 as can be seen from figure 3 on the right and combined with fast wake up times make the RX100 one of the lowest power 32-bit MCU's available. The RX100 also includes peripherals such as the Event Link Controller again allowing the CPU to process application tasks in parallel to these "linked" events, saving execution time and power.

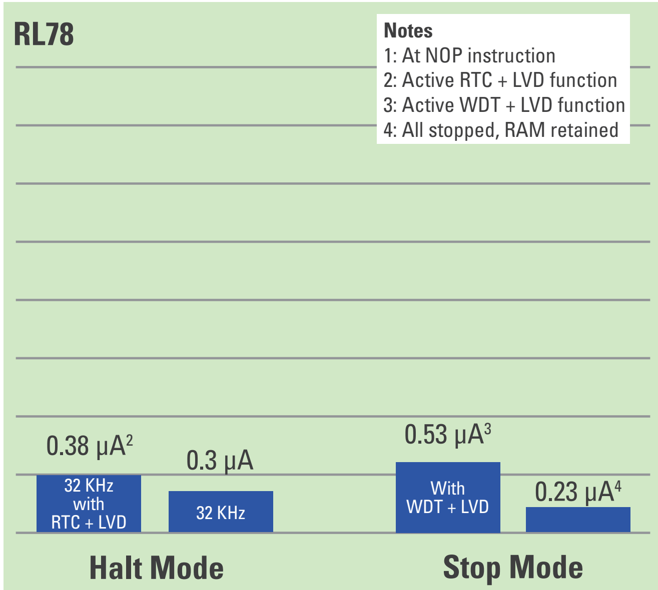

Figure 2 – RL78 Standby Current Consumption

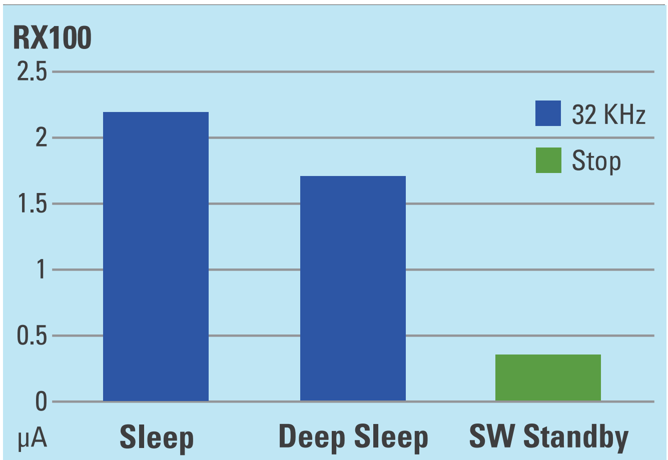

Figure 3 – RX100 Standby Current Consumption

Lemon Demonstration

Having set the scene for low power design and operation above, we return to the main theme of this paper and the lemon demonstration example. The big question is *"How did the RL78 demonstration last for three days?"* There are a number of factors that were taken into consideration when setting up the demonstration.

1. Utilising standby for as long as possible, waking the device to process events as little as possible.
2. Reducing the system clock speed to the minimum possible
3. Configuring the system to operating from the widest supply voltage possible

Using these criteria the RL78/L12 was configured to operate from an external resonator at 32 KHz using the RL78 ultra low power (ULP) oscillator option which after initialisation operated the CPU, RTC and LCD controller.
The demonstration was started using the internal 1 MHz oscillator which once the system was initialised the main clock was changed to 32 KHz and the internal oscillator turned off. The system spent over 90% of the time in HALT mode, with the CPU only woken by RTC every 1/2 second to update the LCD display data.
All other unused peripheral functions were turned off.
The lemon "battery" was made from a single lemon with a magnesium plate for the -Ve terminal and a copper plate for the +Ve terminal. The two plates were spaced carefully apart to maximise the dielectric effect and the voltage and current generated. The whole system took around 2.4 µA at a nominal 1.8 V.
While the lemon was able to supply a nominal 1.8 V and the RL78/L12 able to operate down to 1.6 V, the LCD display required a higher operating voltage, so the LCD controller was configured in "boost" mode in order to maintain a working LCD voltage for as long as possible.

Conclusion

This paper set out many of the key factors that apply to low power design and operation and using the "lemon" example show that it is possible to increase the operating life of your battery (or lemon!).
While every application has its own specifications and targets, by careful power management design and operation can make any battery powered application last longer, achieving the goal of increasing battery life.
While our "lemon" example is relatively simple it is not too different from a sensor, heating controller or meter application where an event is processed periodically and much of the remaining time is spent asleep, showing that with careful design and operation battery life can be extended when applied to real applications.

On a final note for our lemon demonstration, it was in fact the LCD that stopped working due to the supply voltage finally being too low to operate properly, the CPU, Timers etc. were still actually running, although after three days the lemon was showing severe signs of deterioration, not something that usually occurs with batteries.
For further information please read the other three whitepapers and visit the Renesas design resources centre.

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Document No. R01PF0078ED0200