Improved Energy Harvesting Efficiency in MCU Design

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Abstract
This paper explores energy harvesting applications and methods for using continually improving microcontroller specifications to maximize system efficiencies. It will also explore the usage of a new modular Energy Harvesting Platform tool which allows designers to build, test, and modify their designs before spinning their own completed board.

Introduction
Effective usage of environmentally harvested and renewable energy will continue to expand into more markets and applications. While “green” initiatives have been popular reason for this technology push, matters of user convenience and system autonomy are becoming larger reasons for engineers to incorporate energy harvesting into their designs.

With advances in low power microcontrollers, the door is open for more products and applications where harvesting of light, kinetic energy, or thermal energy can be used to power an intelligent product without the need for external power or battery replacement. The market for autonomously powered energy harvesting application is expanding as renewable energy solutions improve and microcontrollers such as the Renesas RL78 achieve lower sleep mode currents, run currents, and higher MIPS ratings allowing faster code execution for a smaller clock cycle cost.

Design engineers trying to utilize energy harvesting technology can often struggle with unexpected system behavior while achieving their desired energy outputs. In addition, it can be difficult for a company to justify the costs to explore redesigning existing successful products to make use of renewable energy technology. The ability to fully characterize their system in a cost effective manner before building initial prototypes would greatly reduce time to market and development costs to speed the growth of this market, new methods and tools must be created to lower the barrier of entry as well as simplify methods of integrating energy harvesting techniques into existing products.

Energy Harvesting Overview
All energy harvesting systems require five general parts which are outlined in Figure 1. The first selected is generally the method of capturing ambient energy for the system, which will come from the Energy Source. Technologies for generating electricity through solar, RF, vibration, and thermal means can be utilized to harvest energy into the system.

Once this energy has been harvested and converted to electricity, it generally needs to be regulated in a voltage conversion stage in order to be stored into a battery, super capacitor, or other energy storage medium for prolonged use. This is often considered to be the charge circuit for the energy harvesting application and can be something as simple as a voltage regulator, or may use more complicated methods such as Maximum Power Point Tracking to improve the efficiency of energy harvested from the source and reduce the impact of change in source impedance caused by various environmental variables. Partial shading on solar panel or ambient temperature change can be taken as an example of such variation.

This charge circuit plays a key role in overall unit performance. Insufficient or inappropriate charging may impact the storage medium capacity and eventually the product life. For example, when a lead acid battery is used as the storage medium, it might develop sulphate layers over the active electrode plates when repeatedly submitted to insufficient charging cycles. The sulphate layer reduces the exposed electrode area and hence reduces the battery capacity. Also, if overcharged, the lead oxide plate starts buckling and then crumbles down. Excessive charging of battery might also cause overheating and explosion. Some battery chemistries like Lithium based batteries are very sensitive to charge termination. Hence, proper charging control, with an appropriate charging profile, is essential to keep the battery in good health. The role of the charge controller is very critical in this respect.

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Maximum Power Point Tracking (MPPT)
In any energy harvesting application the typical focus for maximizing system autonomy is on reducing all possible power consumption in the application circuit. This is absolutely critical, but great efficiency gains can also be achieved by reducing quiescent currents in the regulation circuitry, and maximizing the usage of the energy being collected by the energy source.

This is perhaps most easily demonstrated in a solar energy harvesting design. Solar panels act as constant current sources and their output voltage will match the voltage of the load being charged. If the load is a severely depleted battery or super capacitor, the voltage will remain low until the storage device begins to charge. This prevents the solar panel from generating the full amount of power it is truly capable of. The dotted line in Figure 2 below shows how a solar panel will operate in these conditions.

To maximize the harvesting energy from light, the charging circuit can utilize MPPT in the power...
conversion stage. The effects of incorporating an MPPT are shown by the solid line in Figure 2 above. By lowering the impedance of the load, the solar panel will output the maximum possible power into the energy storage device, only reducing the power output as the device becomes fully charged.

The MPPT circuit itself is a boost (also it can be buck) regulator, with a microcontroller controlling the duty cycle of the switching FET. In one of the simplest MPPT configurations called an Enhanced Perturb and Observe (EPT&O) the microcontroller monitors the voltage and current outputs of the solar panel and simply utilizes Watt’s law to determine the power output. It then will adjust the duty cycle of the FET to see if power improves. This process repeats until improvement ceases and the duty cycle is held steady. The circuit and pseudocode used for an EPT&O MPPT is found in Figure 3 below.

Figure 3

Because an MPPT circuit requires the microcontroller to be in constant operation analyzing and adjusting system performance, design engineers must select a microcontroller with the lowest possible operating currents and the ability to go quickly into sleep modes while peripherals remain active. Every amount of current that the microcontroller is taking to perform the MPPT algorithms is efficiency lost in the system. With microcontroller technology constantly advancing, devices such as the Renesas RL78 low power microcontroller minimize these losses and expand the number of applications where an MPPT can improve system efficiency.

Energy Harvesting Platform (EHP)

With all of the design considerations and possible component combinations available for engineers designing an energy harvesting product, Future Electronics has worked to create a platform that will allow designers to test and analyze an array of options before laying out their own board. Future Electronics’ EHP is a modular development tool that allows designers to evaluate the use of energy harvesting in their systems. The flexible nature of the platform makes it possible for fast prototyping of a designer’s energy harvesting system and full real-time characterization of the performance of that system.

The EHP, shown below in Figure 4, is available today with a variety of standard modules that can be used for testing and analysis. Future Electronics’ System Design Centers also works with customers to develop modules specific to their own end applications allowing the EHP to fully model their desired energy harvesting system. With these custom modules developed, design engineers can start to model their system, examine performance of energy creation, and see in real time the performance of different circuit configurations.

The platform’s hardware is controlled, monitored, and characterized by an application running on a PC. The main screen for this application is shown below in Figure 5. This application collects and displays real time information on the power throughout the system so that efficiencies and energy generation can be fully characterized. Design engineers can use this system to understand every aspect of their system and collect the data for analysis, using it to improve their performance and product viability.

The EHP is upgradable to operate autonomously with battery power and continue to collect system operation data allowing the designer’s system to be installed in the field so that performance data can be collected for later analysis. The backbone of the platform is the Renesas RL78, a low power MCU featuring a 16-bit CISC core running at 32MHz. With support for a wide range of operating modes that support low power consumption (ranging from as low as 220nA to 144μA), the RL78 MCU is the perfect processing solution for energy harvesting systems.

Conclusion

The Future Electronics EHP reduces the barrier to entry, the time for system characterization, and costs associated with validating integration of renewable energy solutions into an application. With this tool, engineers will be able to make the appropriate part selection and architectural decisions for their designs before spending considerable time and money spinning their own boards.

For more information on how to receive one of these platforms or to begin working with Future to start to fully characterize a system, please visit www.FutureEnergySolutions.com or email Todd Baker at Todd.Baker@FutureElectronics.com.

Figure 5

A charge circuit module option for the platform also utilizes the Renesas RL78 to allow customers to test the Enhanced Perturb and Observe MPPT circuit in their systems and see the power improvements it offers over a simple regulation circuit. Because the RL78 operates at such a low run current (down to 66μA/MHz), it can provide significant benefit in many applications. While the simple EPT&O MPPT algorithm is used, the board can be reprogrammed and reconfigured to utilize more complex methods of maximum power point tracking if necessary.