Energy Harvesting Gets a Boost

A wide range of low-power industrial sensors and controllers are turning to alternative sources of energy as the primary or supplemental means of supplying power. Ideally, such harvested energy will eliminate the need for wired power or batteries altogether. Although energy harvesting has been emerging since early 2000 (its embryonic phase), recent technology developments have pushed it to the point of commercial viability. In short, in 2010 we are poised for its "growth" phase. Building automation sensor applications utilising energy harvesting techniques have already been deployed in Europe, illustrating that the growth stage may have already begun. **Tony Armstrong, Director of Power Product Marketing, Linear Technology, USA**

Transducers that create electricity from readily available physical sources such as temperature differentials (thermoelectric generators or thermopiles), mechanical vibration (piezoelectric or electromechanical devices) and light (photovoltaic devices) are becoming viable sources of power for many applications. Numerous wireless sensors, remote monitors, and other low-power applications are on track to become near "zero" power devices using harvested energy only (commonly referred to as "nanoPower" by some).

Commercial acceptance

Even though the concept of energy harvesting has been around for a number of years, the implementation of a system in a real world environment has been cumbersome, complex and costly. Nevertheless, examples of markets where an energy harvesting approach has been used include transportation infrastructure, wireless medical devices, tire pressure sensing, and of course, building automation. In the case of building automation, systems such as occupancy sensors, thermostats and light switches can eliminate the power or control wiring normally required and use a mechanical or energy harvesting system instead.

Similarly, a wireless network utilising an energy harvesting technique can link any number of sensors together in a building to reduce heating, ventilation & air conditioning (HVAC) and lighting costs by turning off power to non-essential areas when the building has no occupants. Furthermore, the cost of energy harvesting electronics is often less than running sense wires, so there is clearly economic gain to be had by adopting a harvested power technique.

A typical energy scavenging configuration or system, (represented by the four main circuit system blocks shown in Figure 1/2), usually consists of a free energy source such as a thermoelectric generator (TEG) or thermopile attached to a heat generating source, such as an HVAC duct for instance. These small thermoelectric devices can convert small temperature differences into electrical energy. This electrical energy can then be converted by an energy harvesting circuit (the second block in Figure 2) and modified into a usable form to power downstream circuits. These downstream electronics will usually consist of some kind of sensor, analogue-to-digital converter and an ultra-low power microcontroller (the third block in Figure 2). These components can take this harvested energy, now in the form of an electric current, and wake up a sensor to take a reading or a measurement then make this data available for transmission via an ultra-low power wireless transceiver - represented by the fourth block in the circuit chain shown in Figure 2.

Each circuit system block in this chain, with the possible exception of the energy source itself has had its own unique set of constraints that have impaired its commercial viability until now. Low cost and low power sensors and microcontrollers have been available for quite sometime; however, it is only within the last couple of years that ultra-low power transceivers have become commercially available. Nevertheless, the laggard in this chain has been the energy harvester and power manager.

Existing implementations of the power manager block are a low performance discrete configuration, usually consisting of 35 components or more. Such designs have low conversion efficiency and high quiescent currents. Both of these deficiencies result in performance compromised in an end system. The low conversion efficiency will increase the amount of time required to power up a system, which in turn increases the time interval between taking a sensor reading and transmitting this data. A high quiescent current limits how low the energy-harvesting source can be since it must first overcome the current level needed for operation before it can use any excess to supply power to the outputs.

New boost converter and system manager

What has been missing until now has been a highly integrated DC/DC boost

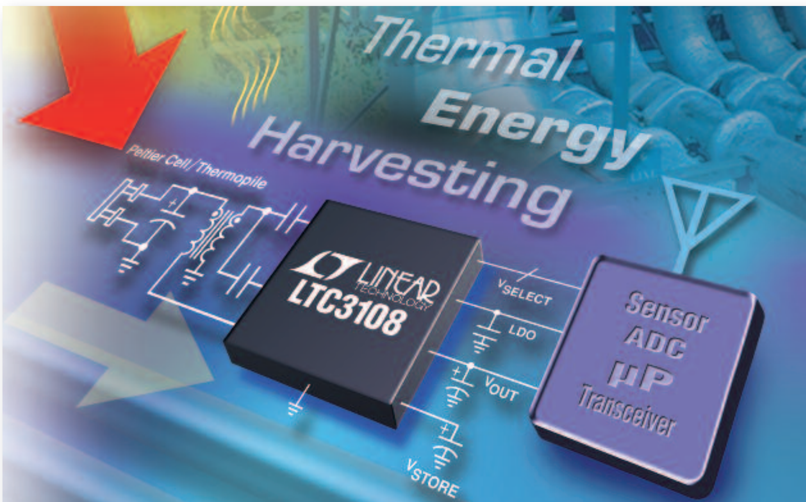

Figure 1: The LTC3108 serves as ultra-low voltage boost converter and power manager in energy-scavenging systems

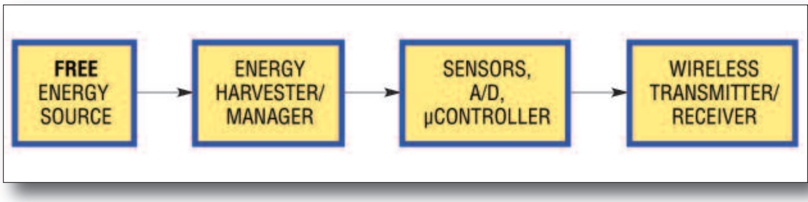

Figure 2: The four main blocks of a typical energy-scavenging system

converter that can harvest and manage surplus energy from extremely low input voltage sources. However, the LTC3108 (Figure 1), an ultra-low voltage boost converter and power manager, greatly simplifies the task of harvesting and managing surplus energy from extremely low input voltage sources such as thermopiles, thermoelectric generators (TEGs) and even small solar panels. Its step-up topology operates from input voltages as low as 20mV. This is significant since it allows the LTC3108 to harvest energy from a TEG with as little as 1K temperature change.

The circuit shown in Figure 3 uses a small step-up transformer to boost the input voltage source to a LTC3108 which then provides a complete power management solution for wireless sensing and data acquisition. It can harvest small temperature differences and generate system power instead of using traditional battery power.

The LTC3108 utilises a depletion mode N-channel MOSFET switch to form a resonant step-up oscillator using an external step-up transformer and a small coupling capacitor. This allows it to boost input voltages as low as 20mV high enough to provide multiple regulated output voltages for powering other circuits. The frequency of oscillation is determined by the inductance of the transformer's secondary winding and is typically in the range of 20kHz to 200kHz.

For input voltages as low as 20mV, a primary-secondary turns ratio of about 1:100 is recommended. For higher input voltages, a lower turns ratio can be used. These transformers are standard, off-the-shelf components, and are readily available from magnetic suppliers. Our compound depletion mode N-channel MOSFET is what makes 20mV operation possible.

The LTC3108 takes a "systems level" approach to solving a complex problem. It can convert the low voltage source and manage the energy between multiple outputs. The AC voltage produced on the secondary winding of the transformer is boosted and rectified using an external charge pump capacitor and the rectifiers internal to the LTC3108. This rectifier circuit feeds current into the VAUX pin, providing charge to the external VAUX capacitor and then the other outputs.

The internal 2.2V LDO can support a low-power processor or other low power ICs. The LDO is powered by the higher value of either V_{AUX} or V_{OUT}. This enables it to become active as soon as V_{AUX} has charged to 2.3V, while the V_{OUT} storage capacitor is still charging. In the event of a step load on the LDO output, current can come from the main VOUT capacitor if V_{AUX} drops below V_{OUT}. The LDO output can supply up to 3mA.

The main output voltage on V_{OUT} is charged from the V_{AUX} supply and is user programmable to one of four regulated voltages using the voltage select pins VS1 and VS2. The four fixed output voltage are: 2.35V for supercapacitors, 3.3V for standard capacitors, 4.1V for Lithium-Ion

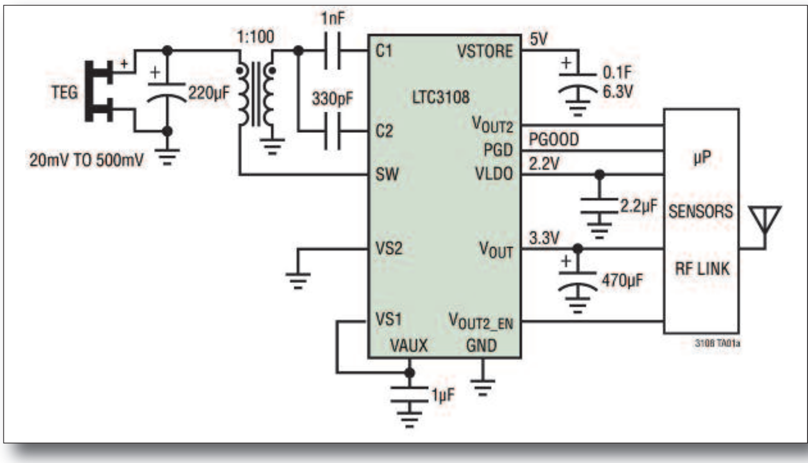

Figure 3: The LTC3108 used in a wireless remote sensor application powered from a TEG (Peltier cell)

battery termination or 5V for higher energy storage and a main system rail to power a wireless transmitter or sensors thereby eliminating the need for multi-MΩ external resistors. As a result, the LTC3108 does not require special board coatings to minimise leakage, such as discrete designs where very large value resistors are required.

A second output, V_{OUT2}, can be turned on and off by the host microprocessor using the V_{OUT2_EN} pin. When enabled, V_{OUT2} is connected to Vout through a P-channel MOSFET switch. This output can be used to power external circuits such as sensors or amplifiers that do not have low power sleep or shutdown capability. An example of this would be to power on and off a MOSFET as part of a sensing circuit within a building thermostat.

The V_{STORE} capacitor may be a very large value (even multiple Farads), to provide hold-up at times when the input power may be lost. Once power-up has been completed, the main, backup and switched outputs are all available. If the input power fails, operation can still continue, operating off the V_{STORE} capacitor. The V_{STORE} output can be used to charge a large storage capacitor or rechargeable battery after V_{OUT} has reached regulation. Once V_{OUT} has reached regulation, the V_{STORE} output will be allowed to charge up to the V_{AUX} voltage, which is clamped at 5.3V. Not only can the storage element on V_{STORE} be used to power the system if the input source is lost but it can also be used to supplement the current demanded by V_{OUT}, V_{OUT2} and the LDO outputs if the input source has insufficient energy.

Conclusion

With analogue switchmode power supply design expertise in short supply around the globe, it has been difficult to design an effective energy harvesting system as illustrated in Figure 1. However, with the introduction of the LTC3108 thermal energy harvesting, DC/DC boost converter and system manager that's all about to change. This device can extracts energy from solar cells, thermo-electric generators or other similar thermal sources. Furthermore, with is comprehensive feature set and ease of design, it greatly simplifies the hard-to-do power conversion design aspects of an energy harvesting chain.