Power Management IC with Pushbutton Control Generates Six Voltage Rails from USB or 2 AA Cells Via Low Loss PowerPath Topology

by John Canfield

Introduction

As the complexity of portable electronic devices continues to increase, the demands placed on power supplies, and their designers, expand dramatically. Not only must typical power systems accommodate multiple input sources, with voltages as low as 1.8V for two AA cells, but they must also provide an increasing number of independent output rails to support a wide range of requirements—for memory, microprocessors, backlights, audio and RF components. To further complicate matters, expanding feature sets add up to increased power dissipation, making it important to optimize overall power system efficiency. This is particularly challenging given that the constant drive to minimize the required board area and profile height of the power system is at direct odds with improving efficiency.

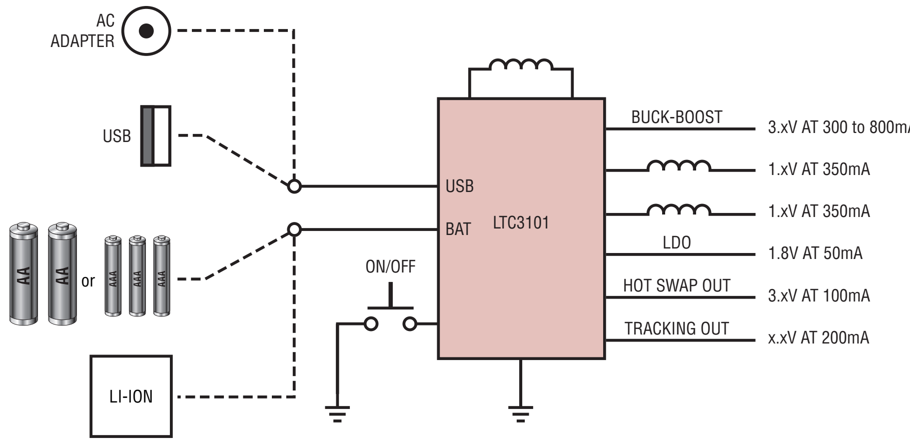

Figure 1. Six output rails, a low loss PowerPath and integrated pushbutton control

The LTC3101 addresses all of these challenges with a single-IC power management solution that allows a designer to easily maximize overall power system efficiency while minimizing space requirements. The LTC3101 can generate six power rails by integrating three synchronous switching converters, two protected switched power outputs, and an LDO. Its integrated low loss PowerPath™ topology allows each switching converter to run directly from either of two input power sources.

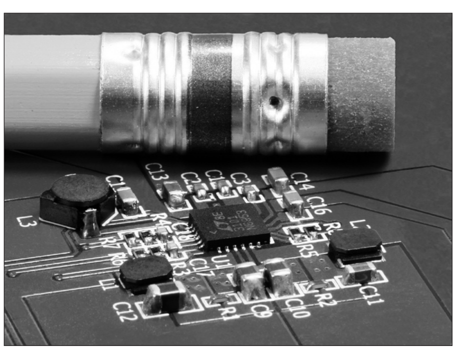

Figure 2. Complete portable power solution with a 16mm × 19mm footprint

Two 350mA, high efficiency low voltage rails, typically used to power processors and memory, are generated by synchronous buck converters. Each converter is able to operate down to an input voltage of 1.8V thereby enabling single stage conversion from any input power source.

A single inductor buck-boost converter generates a high efficiency intermediate output rail, typically at 3V or 3.3V, and is able to operate from either input power source and with input voltages that are above, below, or even equal to the output regulation voltage. The buck-boost converter can supply a 300mA load at 3.3V for battery voltages down to 1.8V and an 800mA load for input voltages of 3.0V and greater.

Two always-alive outputs—MAX, which tracks the higher voltage input power source and LDO, a fixed 1.8V output—provide power to critical functions that must remain powered under all conditions. An integrated pushbutton controller with programmable µP reset generator provides complete ON/OFF control using only a minimal number of external components while independent enables allow total power-up sequencing flexibility. This complete portable power solution is packaged in a single low profile 24-lead 4mm × 4mm QFN package and the entire power supply, including all external components, occupies a PCB area of less than 3cm^2 as shown in Figure 2.

Zero Loss PowerPath Topology Maximizes Efficiency

Although rechargeable Li-Ion and Li-Polymer batteries are the leading chemistries for powering portable devices due to their high energy density and long cycle life, many portable devices continue to be powered by alkaline and NiMH cells. This allows indefinite periods of use away from a charging socket—which is particularly important for devices intended for use in remote locales such as handheld personal navigation devices or portable medical devices. Voice recorders, digital still cameras and ultra-small video recorders are additional examples of devices that benefit from the ability to operate from a pair of commonly available batteries, rather than requiring the lengthy recharging cycle needed for an internal Li-Ion battery.

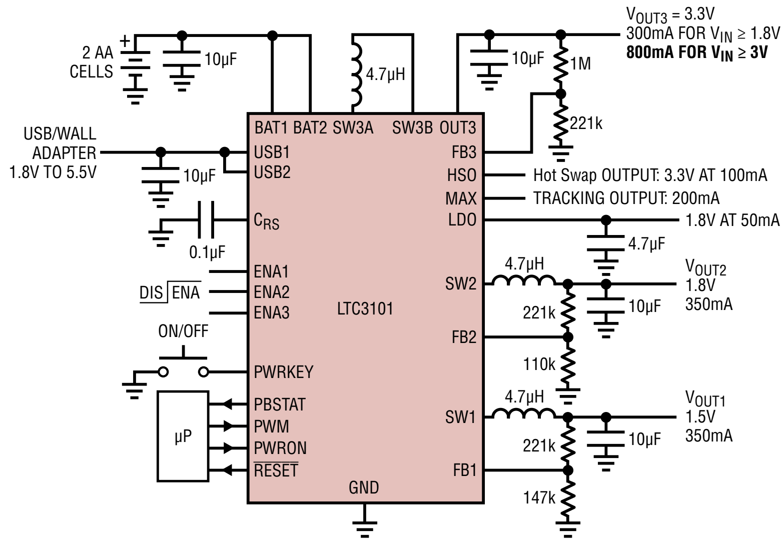

Figure 3. Typical application

Even in portable devices where the primary power source is restricted to AA or AAA form factor cells, there still exist a wide variety of compatible chemistries including alkaline, rechargeable alkaline, NiMH and single-use lithium. As a result, the AA/AAA powered device must accommodate a wide range of input voltages, from 1.8V for two series alkaline cells near end of life, to approximately 3.7V for a pair of fresh non-rechargeable lithium cells. With its wide 1.8V to 5.5V input voltage range, the LTC3101 can easily support all of these battery chemistries. In addition, the LTC3101 is able to operate from a single standard Li-Ion/Polymer cell in cases where recharging is performed independently.

Although rechargeable cells are usually charged outside these types of devices, the power supply must accommodate a secondary tethered power source such as USB or a regulated wall adapter. Consequently, the power supply must include a means to generate every power rail from either of two input sources, and the ubiquitous 3.3V rail must be generated from input power sources that can be higher or lower voltage.

In many devices, the capability to handle dual power sources is provided by using discrete power MOSFETs to switch regulator inputs between the two input power sources or by utilizing two regulators for generation of each rail (for example, a buck converter that generates a 3.3V rail from the USB input in conjunction with a boost converter that generates the 3.3V rail from the battery input).

Both of these approaches suffer from significant drawbacks. The parallel converter approach increases system cost and size given that only one converter is ever active at any given time and often suffers from glitches and disruptions to the output rails during the transition between the two input power sources. Similarly, the discrete power switch technique reduces efficiency due to the addition of extra series elements in the power path, increases component count, and can also lead to disruptions in the output rails unless the supply crossover is carefully controlled.

The LTC3101 avoids these problems by using a low loss PowerPath topology as shown in Figure 4, where each converter is able to operate directly from either input power source. In this architecture, each switching converter utilizes an additional power switch, which is connected to the alternate power input. As a result, each converter is able to run with maximum efficiency from either input power source so no efficiency penalty is incurred in supporting dual input power sources.

The total solution area is minimized by the fact that the same inductor is used in either case. In addition, the automatic transition between the two input power sources is seamless—there is no interruption to any of the output rails. Figure 5 shows the transient response of the buck-boost converter as the input power source transitions from battery power to USB power in response to a live cable plug into a USB port.

Integrated Buck-Boost Provides High Efficiency 3V/3.3V Rail from Any Power Source

In many portable devices an intermediate supply rail, typically regulated to 3.3V, is required to power an RF stage or audio amplifiers. Often this rail is generated from the two series AA cells using a boost converter. However, the higher cell voltage of single-use lithium

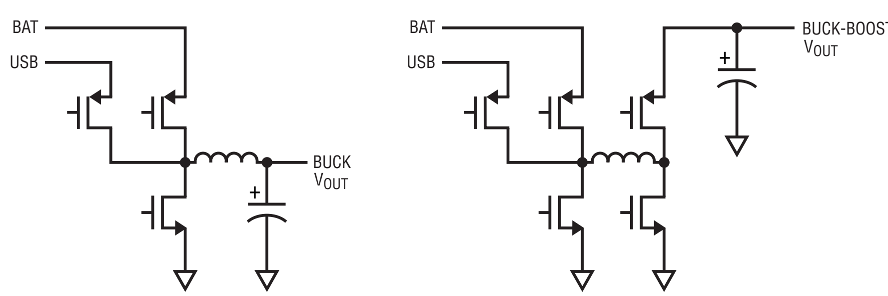

Figure 4. The low loss PowerPath architecture

batteries such as the Energizer e[2] brand can cause problems when the battery voltage is significantly higher than the output voltage. Depending on the boost converter utilized, this can result in low efficiency operation or even loss of regulation on the 3.3V rail.

To avoid this problem, the LTC3101 generates the 3.3V rail utilizing a buck-boost converter, which accepts any input voltage in the range 1.8V to 5.5V without sacrificing efficiency. In fact, when operating with a fresh pair of single-use lithium batteries at 3.7V, the LTC3101 buck-boost efficiency is greater than 94% at 150mA load current. In addition, the same buck-boost converter is able to operate directly from the USB input, so generation of the 3.3V rail requires only a single inductor.

Reverse Blocking LDO Enables Data Retention During Battery Swaps

Many portable electronic devices contain critical circuitry such as real time clocks, which must remain powered under all conditions. The MAX and LDO outputs of the LTC3101 are alive as long as either input power source is present, regardless of the state of the pushbutton interface or enable inputs. It is also possible to connect a large capacitor directly to the LDO output to serve as a charge reservoir for powering critical functions during times, such as battery swaps, when both input power sources are temporarily removed. In its reverse blocking state, the maximum reverse current through the LDO is limited to under 1µA in order to preserve charge in the reservoir capacitor.

MAX and Hot Swap Outputs Power Additional Regulators and Flash Memory Cards

Portable electronic devices often require additional miscellaneous power supplies, such as current regulated drivers for LED backlighting and LDOs for low power rails. Typically these secondary supplies must be functional whenever either input power source is present, so they also require power path control to switch between the two input power sources.

External supplies can take advantage of the LTC3101's PowerPath control circuit via the MAX output, which continuously tracks the higher voltage input power source. Additional regulators can be directly connected to this output, thus freeing the designer from the need to implement an additional switched power path. The MAX output is able to support a 200mA load and is current limited to protect against overload conditions and short circuits.

Many portable electronic devices provide flash memory card interfaces for use as bulk storage memory. Typical flash memory cards such as Compact Flash (CF) and Secure Digital (SD) formats require a regulated 3.3V supply that is typically capable of providing tens of milliamps. However, many flash memory cards have a significant amount of supply bypass capacitance installed on the card and when hot plugged into a live 3.3V rail, the inrush current required to charge these supply bypass capacitors on the memory card can momentarily drag down the host's supply, causing disruption to other ICs powered by that rail.

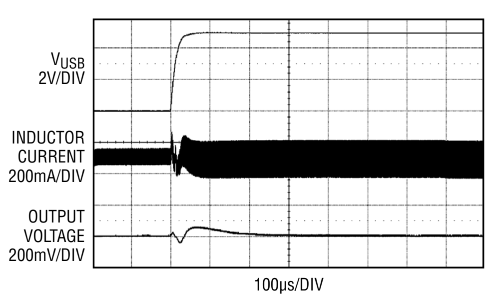

Figure 5. Buck-boost output voltage transient on USB hot plug

The LTC3101's dedicated 100mA hot swap output (powered from the buck-boost converter rail) does not have this problem. The independent current limit of the hot swap switch allows flash memory cards to be hot plugged without disruption to the primary 3.3V rail. In addition, the hot swap output is fully short circuit protected to safeguard against accidental shorts at the memory card interface port.

Low Quiescent Current Minimizes Battery Drain

Most portable electronic devices spend significant, if not the majority, of their time in sleep or standby modes. In fact, even when an appliance is off, there is often circuitry that must remain powered, including real time clocks and volatile memory storing configuration settings. The always-alive 1.8V LDO and tracking MAX outputs remain powered whenever either input power source is present allowing them to be utilized for supplying such critical functions. In order to minimize battery discharge during this time, the total quiescent current draw of the LTC3101 with both the MAX and LDO outputs active is reduced to 15µA.

Many portable electronic devices also support a standby mode in which several of the system's voltage rails must be kept in regulation. Typically, in standby the microprocessor and memory remain powered and the processor is placed in a low current sleep mode enabling the device to return to an active operating state with minimal delay.

In order to minimize battery drain in such modes of operation, all three switching converters in the LTC3101 feature Burst Mode operation, which can be enabled via a dedicated pin. With Burst Mode operation enabled, the buck converters automatically transition from PWM to Burst Mode operation at sufficiently light load (typically 10mA) while the buck-boost converter uses Burst Mode operation at all load currents. In Burst Mode operation with all six output rails maintained in regulation the total quiescent current draw of the LTC3101 is reduced to only 38µA. In addition, to ensure low supply rail noise, the Burst Mode operation output voltage ripple is typically less than 1% of the regulation voltage of each output rail. All three switching converters can be forced into fixed frequency PWM mode operation to ensure low noise operation while critical system functions are underway.

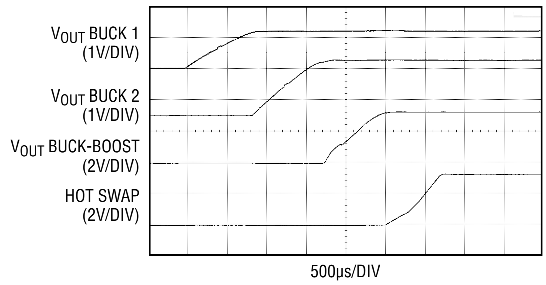

Figure 6. Default power-up sequencing

Flexible Power-Up Sequencing Options

The LTC3101 provides a variety of sequencing options. Most systems that incorporate multiple power supply rails require that they come into regulation in a certain sequence with specific timing. This is because individual ICs and modules that are powered from multiple rails need particular sequencing to minimize start-up current and ensure predictable power-up behavior.

Common examples include microprocessors and FPGAs, which often require that the peripheral supply powering the I/O buffers is made available only after the lower voltage core is in regulation. In addition, at the board level, many systems bring up the supplies for peripheral devices only after the processor is powered up to avoid erratic behavior from peripherals lacking processor oversight.

Each switching converter in the LTC3101 has an internal power-good comparator, which is used internally to sense when that rail is in regulation. The default power-up sequence enables the individual outputs in the following order: buck converter 1, buck converter 2, buck-boost converter, and finally the hot swap output. Each converter is enabled once the preceding converter in the sequence reaches regulation (typically 94% of the target output voltage). The default power-up sequence using all converter channels is shown in Figure 6.

If the dedicated enable pin for any switching converter is held low during the pushbutton triggered initiation, that converter is simply skipped in the default power-up sequence, but that channel can still be enabled at a later time. This functionality allows the LTC3101 to implement any arbitrary power-up sequence using few if any external components.

For example, in some systems the 3.3V buck-boost rail must come up first, followed by both buck rails in unison. This can be accomplished by driving the buck enables from the hot swap output, HSO, as shown in Figure 7. The bucks do not power up in the normal sequence since their enables are low to start. Once the buck-boost reaches regulation, the hot swap output is enabled, which in turn enables the two buck converters. Since the hot swap output is not powered until the buck-boost is in regulation, this configuration ensures that the buck converters do not become active until after the buck-boost is in regulation, as shown by the waveforms in Figure 8.

If an additional delay is required before the bucks are enabled, this can be accomplished by adding a simple RC filter with the desired time constant between the hot swap output and the buck enables. Notice however, that if the hot swap output is forced to ground, the buck converters will be disabled. If there is a potential for the hot swap output to fall below the enable threshold (typically 0.7V) during normal operation, then the buck enables can instead be driven through an RC delay from the buck-boost voltage directly rather than from the hot swap output.

Conclusion

The LTC3101 is perfectly suited for the needs of the next generation of extended functionality compact portable electronic devices.

The job of the power system designer is simplified by its compact solution footprint and ability to generate six commonly required output voltage rails automatically from two independent wide input voltage range power sources. The LTC3101's low quiescent current and a high efficiency, low loss PowerPath architecture maximize battery life. A wide range of output voltages, programmable duration µP reset generator, and independent enables offer flexibility and easy customization.

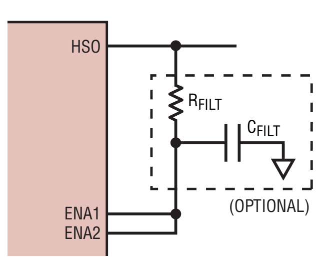

Figure 7. Sequencing the buck enables using the hot swap output rail

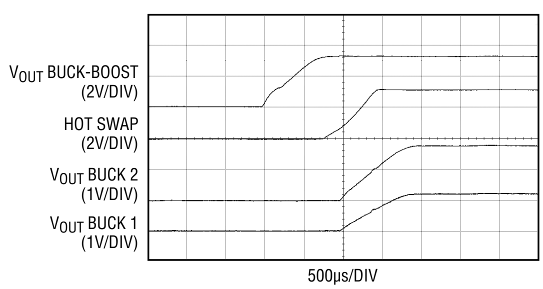

Figure 8. Power-up sequencing, buck-boost followed by the buck outputs