Complete 2-Cell-AA/USB Power Manager in a 4mm × 4mm QFN

Introduction
One of the most popular battery solutions for consumer handheld devices is the venerable two-cell AA (alkaline or nickel-metal hydride) source, especially in GPS navigators, digital cameras and MP3 players. AA batteries are readily available, relatively low cost and offer high power density. Many of these same portable devices supplement battery power with plug-in wall adapter and offer a USB bus (for data transfer). The USB bus can also be used to provide power. The problem is how to seamlessly switch between these three disparate types of supplies: 2-cell AA, wall and USB. The solution is the LTC3456.

The LTC3456 is a complete system power IC that seamlessly manages power flow between an AC wall adapter, USB and 2-AA battery, while complying with USB power standards—all in a 4mm × 4mm QFN package (Figure 1). The device generates two separate power rails: a 3.3V (fixed) main supply and a 1.8V (adjustable) core supply. In addition, the LTC3456 contains a fully featured USB power manager, a Hot Swap output for powering memory cards and an uncommitted gain block suitable for use as a low-battery comparator or an LDO controller. The device also generates an always-alive \( V_{\text{MAX}} \) output, suitable for supplying power to critical blocks like the real time clock, which needs to stay alive even during shutdown.

About the LTC3456
The LTC3456 contains four high efficiency 1MHz fixed frequency switching regulators that operate with efficiencies up to 92%. Figure 2 shows a typical LTC3456 application. Most processors used in portable applications require dual power supply voltages. These voltages can be 3.3V for the I/O circuitry and 1.5V or 1.8V for the processor core. Additionally, the processor might require that the power supplies startup in a specific sequence to prevent processor latch-up.

The LTC3456 squeezes a USB power manager, four high efficiency DC-DC converters, a Hot Swap controller, a low-battery indicator and much more into a 4mm × 4mm QFN package.
The LTC3456 has in built power supply sequencing for the core and main outputs. At power-up, the V\textsubscript{INT} output, a fixed 3.3V supply, is the first one to power up. It supplies power to most of the internal circuitry. The amount of external loading at this output should be limited (Refer to the LTC3456 datasheet for more details). The core output, adjustable from 0.8V to 1.8V, comes up next followed by the V\textsubscript{MAIN} output. The V\textsubscript{MAIN} output, a fixed 3.3V supply, powers up with a delay of 0.8ms (typ) after the core output comes into regulation. The V\textsubscript{MAIN} output is generated from the V\textsubscript{INT} output through an internal 0.4Ω (typ) PMOS switch and can be used to power the I/O circuitry. The 0.8ms delay gives sufficient time to the processor to stabilize the system clock and load internal registers before the peripheral circuitry powers up.

The LTC3456 produces a Core output, adjustable from 0.8V to 1.8V suitable for powering new low voltage processors (ARM and others). The LTC3456 control scheme allows 100% duty cycle operation for the core output. It provides low dropout operation when the core output is powered from the battery, thereby extending battery life. Both Main and Core converters offer Burst Mode operation (MODE Pin selectable) when powered from the battery resulting in high efficiency at light loads as seen in Figure 3. The Core converter features greater than 92% efficiency when powered from the battery. Burst Mode operation is disabled when powered from USB/wall power. Figure 4 shows the system efficiency when powered from the USB. The Main converter achieves up to 90% efficiency when powered from the USB.

The LTC3456 has a built-in Hot Swap output suitable for powering flash memory cards. The Hot Swap output features short-circuit and reverse voltage blocking capability. It allows memory cards to be hot swapped into and out of the system. It has a built-in 120mA (typ) current limit suitable for powering flash memory cards.

The LTC3456 features short-circuit protection for both the main and core outputs. It also provides output disconnect for all the outputs with the exception of the V\textsubscript{MAX} output. The Core, Main and Hot swap outputs are all discharged to ground in shutdown. The V\textsubscript{MAX} output is the highest of the V\textsubscript{BATT}, V\textsubscript{INT}, V\textsubscript{EXT} and USB voltages. This output can be used to supply a maximum of 1mA output current. The V\textsubscript{MAX} output stays alive even when the IC is in shutdown and is suitable for supplying power to critical system blocks like a real time clock.

**PowerPath Control**

The LTC3456 contains a proprietary PowerPath control scheme that seamlessly switches over the system power from a 2-AA battery to USB/wall Power and vice versa. Figure 5 shows a simplified block diagram of the internal power-path. The AC adapter and the USB bus supply power to the switching regulators via the V\textsubscript{EXT} pin. The LTC3456 contains a full featured USB power manager to control the flow of power from the USB pin via the state of the USBHP and SUSPEND pins. The current through the USB pin is accurately limited to 100mA or, 500mA depending on the state of the USBHP and SUSPEND pins. All USB functionality can be disabled by pulling the SUSPEND pin high.

DC-DC conversion is a particularly challenging task when the 2 AA battery voltage (1.8V to 3.2V) must be boosted to generate 3.3V output, and the USB/wall power (4V to 5.5V) must be stepped down to generate the same voltage. The LTC3456 accomplishes this task via the BOOST and BUCK2 converters. This is the most efficient
The LTC3456 achieves efficiency greater than 90% when generating 3.3V output from the battery or USB/wall adapter. The core output (1.8V) is generated via BUCK1 (USB/wall Powered) and BUCK3 (Battery Powered) converters. The unique topology of LTC3456 generates the 1.8V rail via a single inductor resulting in a cost and space saving. It achieves efficiency greater than 92% when generating the 1.8V output from the battery. The various operational modes of LTC3456 are summarized in Table 1.

Portable devices are required to seamlessly switch-over from the battery power to USB or wall power and vice versa to ensure smooth system operation. As an example, a user is playing music on a portable MP3 player with the USB cable connected. If the USB cable is suddenly yanked off the device, the user should be able to continue listening to the music without any interruption. The LTC3456 makes it possible through seamless switch-over of system power. Figure 6 shows USB and 2-AA battery power supply switch-over waveforms for Figure 2’s circuit. The USB power is disconnected when the Suspend pin is taken high. Main and core outputs both exhibit less than ±2% total deviation at the time of switchover. It makes it possible to continue listening to the music without any interruption. The LTC3456 makes it possible through seamless switch-over of system power.

Figure 6. USB and 2AA Battery power supply switchover waveforms for Figure 2’s circuit. The USB power is disconnected when the Suspend pin is taken high. Main and core outputs both exhibit less than ±2% total deviation at the time of switchover.
when battery or externally powered. The RESET pin is held low for a delay of 262ms after \( V_{\text{CORE}} \) comes into regulation. When the IC is shut-down, both \( V_{\text{MAIN}} \) and \( V_{\text{CORE}} \) outputs are disconnected from the input power and discharged to ground. This prevents the outputs from being stuck in an indeterminate logic-level state and adversely affecting the operation of the microprocessor. It also ensures that the outputs rise in a predictable fashion during power-up.

**Voltage Monitoring**

The LTC3456 has an on-chip gain block that can be used for low-battery detection, with the low battery trip point set by two resistors (Figure 2) at the AIN pin. The nominal voltage at AIN is 0.8V. The AO pin is an open-drain logic output that sinks current whenever the voltage at the pin AIN falls below 0.8V. The gain block can also be configured to drive an external PNP or PMOS transistor to generate an auxiliary voltage.

In addition, the LTC3456 has on-board voltage comparator circuitry to detect the presence of USB or wall power, with a status output at the EXT_PWR pin. The open-drain logic output of EXT_PWR is capable of sinking up to 5mA, suitable for driving an external LED. The on-board voltage detectors continuously monitor the status of the USB voltage and AC adapter voltage (via the WALLFB Pin). Whenever the USB or, wall power is available and in regulation, the EXT_PWR pin is pulled low.

**Portable GPS Navigator Power Supply**

Today’s portable GPS navigators run off two AA batteries or an AC adapter and come equipped with a USB bus (for data transfer). Long battery life and small system size are the key requirements for the power supply. The microprocessor used in GPS navigators usually require at least two different voltage supplies: typically 3.3V for the I/O circuitry and 1.5V or 1.8V for the processor core. The navigator might also require an auxiliary 2.8V supply voltage to bias the LCD display controller IC.

Figure 8 shows a complete, compact and efficient power supply for a portable GPS navigator. The \( V_{\text{MAIN}} \) (fixed 3.3V) provides power to the I/O circuitry. The power supply for the processor core, \( V_{\text{CORE}} \), is set at 1.8V and can be adjusted by changing the feedback resistor ratio. The 3.3V Hot Swap output powers flash memory cards. The LTC3456 contains an uncommitted gain block (Pins AIN and AO) that can be used as a low-battery indicator or an LDO controller. The circuit in Figure 8 shows the gain block being used as an LDO with an external PNP to generate an auxiliary 2.8V output voltage from the Main output. The auxiliary 2.8V supply is being used to power an LCD controller IC. The \( V_{\text{MAX}} \) output of the LTC3456 stays alive even in shutdown and is used to supply power to a real-time clock.

continued on page 19
Drift calculations assume that the part is in continuous operation during the entire time period of the calculation. The movements of ions which results in drift is usually aided by electric fields in the operating parts, and drift is substantially lower if the parts are not powered up during the entire period of drift. Conservative calculations would use a tenth of the drift specification for time when power is not applied to the part.

**Switching the DIV Pin**

The DIV input pin on the LTC6906, similar in many ways to the DIV pin on other LTC silicon oscillators, is a three state input, capable of resolving three different states: high, open and low. Three state input pins allow greater functionality in low pin-count packages, and are compatible with the tri-state outputs of many microcontrollers. Static configuration is easily accomplished by tying the pin to either the positive supply or ground, or leaving it floating.

In the OPEN state, the DIV pin of the LTC6906 is reasonably immune to noise commonly found on PC boards, but care should be taken to avoid routing a long floating trace off the pin, or routing the pin driving that trace next to a line with strong AC signals. The noise immunity of the DIV pin can be easily improved by adding a capacitor to ground, or a series resistor of up to 100kΩ placed near the DIV pin.

In normal operation, the DIV pin uses a small current of about 1µA to pull the DIV pin voltage close to half of the power supply voltage. Therefore, if the pin is left open, any extra capacitance on the pin slows its settling to the OPEN state.

Applications that use the DIV pin to switch frequency in real time need to take into account that, because it is designed for low power operation, the DIV pin buffer circuit is slow, with delays up to around 12µs between activation of the DIV pin and changes in the output of the LTC6906. This switching delay must be accounted for in the application, or an external frequency divider can be substituted for the internal frequency divider in order to decrease the frequency change response time.

**Manipulating the SET Pin**

The LTC6906 can be configured in applications where the SET resistor needs to be changed for operation at different frequencies. When changing the SET resistor, performance and accuracy is obtained by placing the switching mechanism between the set resistor and GND, not between the set resistor and the SET pin (see Figure 7).

By modulating the SET pin current through the SET pin in real time need to take into account that, it is designed for low power operation, the DIV pin buffer circuit is slow, with delays up to around 12µs between activation of the DIV pin and changes in the output of the LTC6906. This switching delay must be accounted for in the application, or an external frequency divider can be substituted for the internal frequency divider in order to decrease the frequency change response time.

**Conclusion**

The LTC6906 is a micropower oscillator with 0.65% accuracy and very low jitter. Its small size, simple configuration and extremely low power consumption make it ideal for low power applications driving microcontrollers, FPGAs and providing a clock reference for battery powered devices.