USB Compliance in Wireless Modem Design

With USB being a standard interface in PC peripherals, the number of applications that can be powered from a USB port is increasing at an exponential rate. The need for flexibility and continuous connectivity in our lives is becoming more important. In a growing wireless world, many applications are taking portable form allowing users the ease and flexibility of connecting to the web anywhere. With all the benefits this brings, there are a number of extra requirements that need to be taken into account when designing a device that is powered from a USB port. **John Constantopoulos, Systems Engineer, WW Low Power DC/DC, Texas Instruments, USA**

A growing variety of portable wireless modems for data communication applications use TDMA techniques which require peak current during the transmission of signals which can exceed the maximum current specified by the USB standard. Therefore the modem must be designed to limit the input power and draw on card-based storage for most of the energy requirement during a typical transmission cycle.

As shown in Figure 1, the GSM signal is transmitted over the carrier at a rate of 216Hz (4.616ms pulse repetition interval). The transmission period is divided into eight time slots and depending on the power class being used (8, 10 or 12) , the duty cycle of this high current pulse can range anywhere between one-eighth of the cycle (577μs) up to half of the transmission cycle (2.308ms).

Much of the work in GSM power supply design revolves around the transmission cycle due to the high current consumption in this mode. The main problem with the GSM or GPRS requirement is that in portable wireless modem applications, the average input current being drawn at the USB host is limited to 500mA, while most transmitters will need 1.5A to 2A peak bursts to transmit at full power.

For example, when transmitting in GPRS Class 10, a maximum of two of the eight 577_s slots are used, while the remaining six slots are used to recharge the capacitor, during which the supply current is reduced to less than 100mA. Therefore the power supply must be able to supply at least the average current over one transmission period, as well as be capable of handling the 2A transmission bursts.

There are numerous different topologies which can be used to support these power requirements, many of which exceed what is specified in the USB specification. But there are many PC manufacturers that strictly abide to the USB specification, and these solutions will either not be compatible with them causing the system to fail or worst case the PC to crash. As a result of this, many vendors are placing stricter requirements on USB applications to maintain USB compliancy.

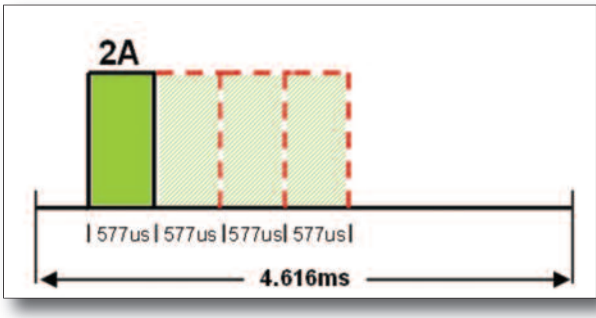

Figure 1: Transmission period of a typical GSM/GPRS pulse

It is therefore clearly not possible for a DC/DC converter used in a USB wireless modem to operate correctly without any special design measures and features which allow the system to be USB compliant.

Buck converter with integrated current limit switch

The TPS62750 is a 94% efficient step-down converter optimized for USB powered applications. It features a highly accurate adjustable average input current limit (± 5% at 500mA), and key protection features such as hot-plug and reverse current protection. Figure 2 shows how the TPS62750 is used to power a typical USB wireless modem.

As the USB port can only supply up to 500mA, it is especially important to maximize the amount of current drawn from the USB port. This can be achieved by using a highly accurate current limiting circuitry, allowing the amount of current drawn from the USB port to be as close to 500mA as possible.

TPS62750 incorporates two highly accurate adjustable average input current limits which can be digitally selected by the H/L pin. This allows the designer to set an input current limit of 100mA during Low Power Mode for enumeration (effectively charging up the output cap), and then by pulling the H/L pin high, shifting into High Power 500mA mode when requested.

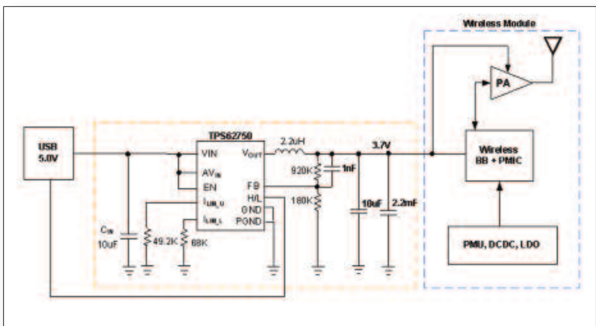

Figure 2: Overview of Buck converter only solution

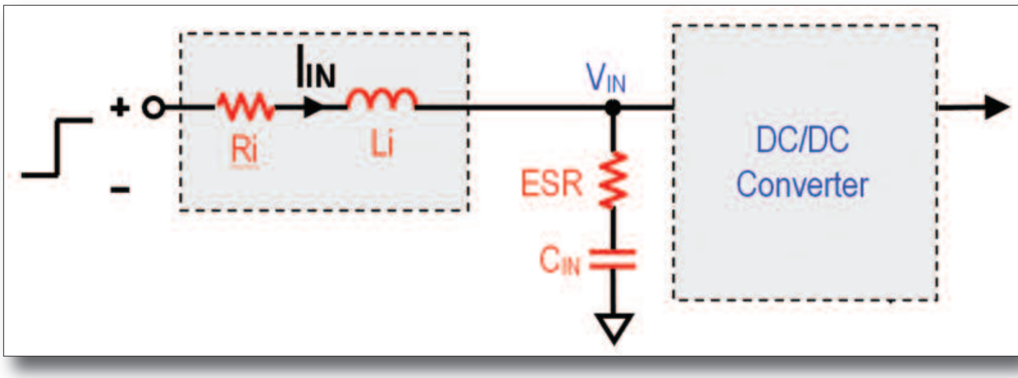

Figure 3: **Basic overview of hot-plug system**

The high accuracy of ±5%, is achieved by sensing the current ripple over the high-side transistor. This is then amplified by a high-speed amplifier which allows the fast detection of the current pulses, allowing for the high level of current accuracy. This signal is then averaged by an integrator circuit, creating the required average input current which is set by the external resistor.

Most DC/DC converters used in portable applications use ceramic capacitors to filter DC/DC converter inputs. Ceramic capacitors are often chosen because of their small size, low equivalent series resistance (ESR) and high RMS current capability (see Figure 3).

When power is supplied via the USB bus or a USB dongle is plugged into the USB port, the cable inductance along with the self resonant and high Q characteristics of ceramic capacitors can cause substantial ringing which could exceed the maximum voltage ratings and damage the DC/DC converter without any dedicated protection. As shown in Figure 4, these voltage spikes can easily be twice the amplitude of the input voltage step.

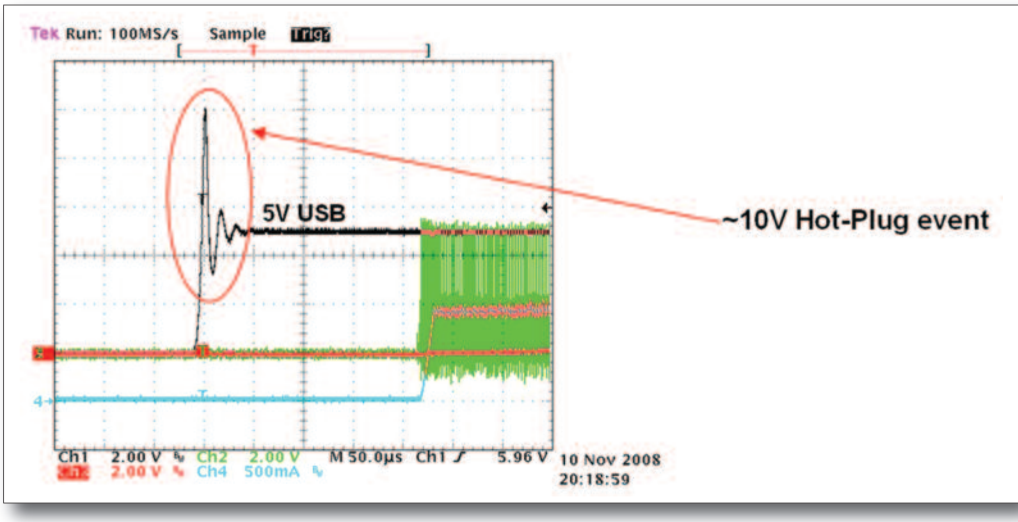

Figure 4: **Voltage spikes at USB hot-plugging**

One possible protection option is to use a TVS (transient voltage suppression) Zener diode to clamp such high-pulse transient voltages. But these devices are generally expensive and in space limited portable applications this may not be an option at all.

A key feature of the TPS62750 is that it incorporates internal hot-plug protection circuitry which limits the transient voltage during a hot-plug event to a level below the absolute maximum rating of the DC/DC converter.

Figure 5 shows how the internal clamp circuitry reacts to a hot-plug event, limiting the voltage on the input of the DCDC converter to a level below where the device may potentially be damaged. This allows the design engineer to develop his circuitry without any extra protection circuitry.

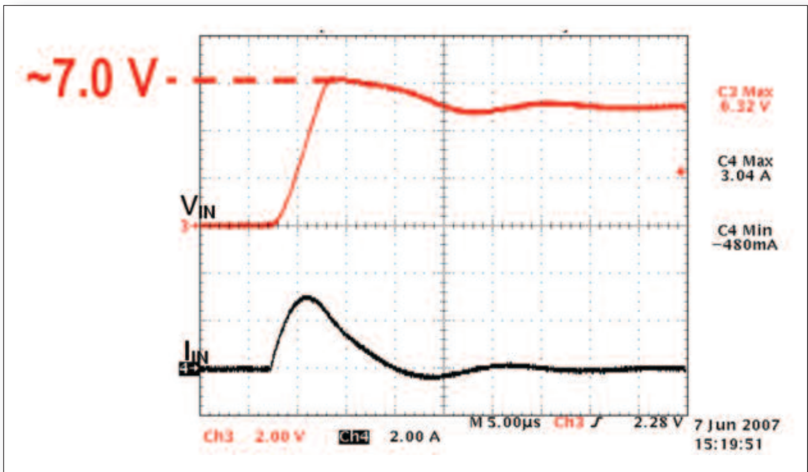

Figure 5: **TPS62750 internal clamp of hot-plug event**

Design example

Assuming that the DC/DC converter has a set input current of 500mA, with the supply voltage directly from the USB port (5V) and an output supply for the RFPA of 3.7V, allows for effectively supply around 675mA directly from the DC/DC converter (no switching losses taken into account).

Assuming 90% efficiency, the total amount of current delivered by the DC/DC converter is 610mA. The rest of the energy for a GSM/GPRS transmission slot needs to come from a bulk capacitor according to $I_{CAP} = I_{GSM} - I_{DC/DC}$ and $I_{CAP} = 2.0A - 610mA = 1.39A$.

The voltage drop in the circuit comprises two components, the I x R drop associated with the capacitor's internal resistance (as approximated by ESR) and the drop in capacitor voltage at the end of the pulse. Therefore the effective capacitance required to buffer each pulse, assuming class 8 transmission (0.577ms slot), is equal to:

$$C_{OUT} = \frac{\left(I_{PULSE} \bullet t_{PULSE}\right)}{V_{DROOP} - I_{PULSE} \bullet R_{ESR}}$$

$$C_{OUT} = \frac{\left(1.39A \bullet 0.577ms\right)}{400mV - 1.39A \bullet 50m\Omega}$$

$$C_{OUT} =\sim 2.4mF$$

where V_{DROOP} is the change in output voltage, I_{PULSE} and t_{PULSE} are the peak pulse current and duration respectively, R_{ESR} is the capacitor ESR and C_{OUT} is the output capacitance.

Figure 6 shows the screen plot of the TPS62750 configuration as calculated above. Using a 2.2mF bulk capacitor, while being loaded with typical 2A pulses at power class 8 (577µs). During the period where no transmission occurs, little or no current is being drawn from the device and the output voltage remains stable at 3.7V.

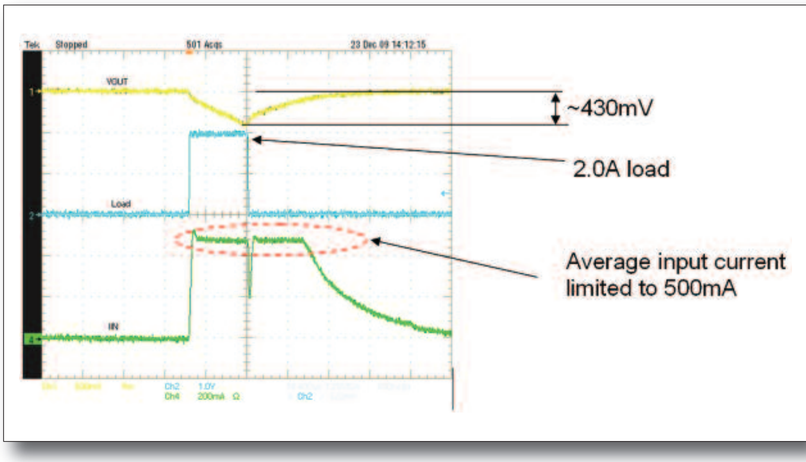

Figure 6: Screen plot of Class 8 transmission

As soon as transmission occurs, the output voltage of the DC/DC converter starts to droop while the required power level is supplied to the load.

Conclusions

Until recently, designers of portable systems have rarely used large capacitors for applications other than back-up or standby functions where currents are low and charge times are fairly long. But a growing range of new applications, led by a new generation of high performance Wireless Modems, demand high peak currents that are forcing designers to consider different approaches to reduce solution size and total cost, while still being able to deliver the high required peak currents. The compact solution TPS62750 step-down converter is a power supply solution for USB powered peripherals. Its small solution footprint, combined with today's low profile polymer and tantalum capacitors elegantly solves the pulsed load problem, providing a cost-effective, compact solution.