# Choose a Regulator with an Accurate Input Current Limit to Safely Extract Maximum Power from USB

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Most of us would not use a paintbrush to sign our names on our checks. It's simply the wrong tool for the job—wasting paint where a thin line of ink offers better results. Likewise, using a power supply IC with a broad-brush ±40% output current limit is wasteful, requiring a designer to leave 80% of the input current on the table, or worse, ignore the tolerance and risk collapse of the input supply. To design an input-current-limited supply that maximizes input power usage requires a detailed approach, ideally incorporating a regulator with tight tolerances.

The LTC3619 and LTC3619B are 400mA and 800mA dual monolithic synchronous buck regulators with tight ±5% programmable average input current limits. The LTC3619 uses Burst Mode operation to improve efficiency at light loads, while the LTC3619B uses pulse-skipping to improve efficiency and also reduce noise. The accurate input current limit allows utilization of 90% of the maximum input current for fast supercap charging, strong signal and lag-free operation without risk of collapsing the input supply.

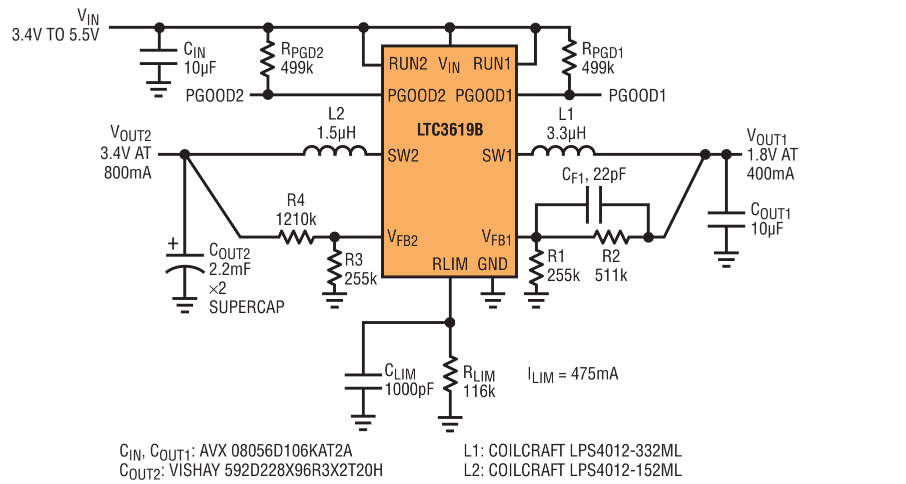


**Figure 1. GSM receiver power supply operates from the USB. Although GSM receivers require bursts of power beyond the USB current limit, this design complies with USB current limits by incorporating a supercap to provide short bursts of current at $V_{OUT2}$. Only $V_{OUT2}$ is actively input current limited. The current at $V_{OUT1}$ must operate within the power constraints of the USB input, but it is not actively input current limited, so the voltage at $V_{OUT1}$ remains stable for important circuits.**

An increasing number of portable electronics are powered from the USB, which is current limited to 500mA. Surges in current on the USB commonly occur from plugging a device into a port. If the surge current is high, non-current-limited load dumps at the USB port can glitch the source power supply, which can affect other systems that depend on the supply. Plugging in an improperly current-limited USB device into a laptop can glitch the laptop CPU, causing it to lock up or reboot. High peak current pulses during GSM wireless data transfers can also cause supply glitches. The accurate current limits of the LTC3619 and LTC3619B protect the supply while maximizing usage of available input current.

## GSM APPLICATION

Users expect a high level of mobile functionality in their electronic devices—they want their GSM modems to detect a strong signal at all corners of the city. As more current is required for better transmission and reception, the importance of an accurate input current limit cannot be ignored.

Programming the LTC3619B's accurate input current limit to maximize available current usage is simple with an external resistor $R_{LIM}$ and capacitor $C_{LIM}$, sized using the following expression:

$$R_{LIM} = \frac{55k\Omega \cdot A}{I_{DC}}$$

Determine $R_{LIM}$ for the average input current being limited ($I_{DC}$), and choose

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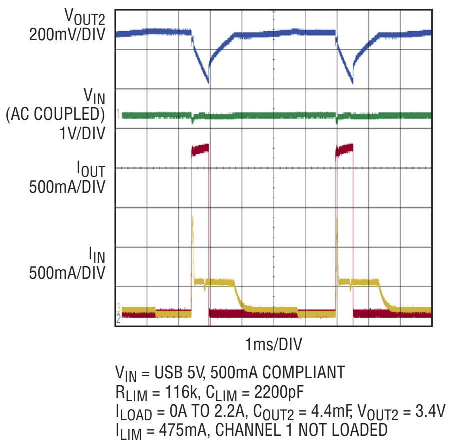


**Figure 2. Operation of the GSM modem power supply showing bursts of current beyond the input current limit and quick charging of the supercap on $V_{OUT2}$. Note the stability of $V_{IN}$.**

$C_{LIM}$ greater than 100pF for averaging $I_{LIM}$ current. When the sum of both channels' current exceeds the input current limit, only channel 2 is current limited while channel 1 remains regulated. Input current limit starts when $V_{RLIM}$ = 1V ±5%.

The LTC3619B's input current limit is trimmed to less than 2% at room temperature and deviates no more than a few percent over temperature. (See the LTC3619B data sheet for detailed explanation in selecting $R_{LIM}$ and $C_{LIM}$.) Figure 1 shows the LTC3619B in a solution that converts USB input ($V_{IN}$ = 5V) to $V_{OUT2}$ = 3.4V to deliver GSM pulsed current load. Figure 2 shows the GSM output waveforms.

GSM modems demand high bursts of current, up to 2A, to the RF power amplifier, which well exceeds the maximum 500mA input current available via USB. In Figure 1, LTC3619B quickly charges a reservoir cap or supercap, which in turn can adequately provide bursts of current.

Because channel 1 is not input current limited, its output voltage does not collapse even as the GSM modem draws high current bursts. Thus, it is safe to use this channel to power up baseband chips, power management ICs or keep-alive circuitry while maximizing the available current for channel 2.

## $V_{OUT}$ POWER GOOD

The PGOOD indicator pins are useful for monitoring the regulation status of the two outputs. The PGOOD pins are open-drain outputs—pulled high with an external pull-up resistor when in regulation. In Figure 1, if the supercap is not fully charged or the output is not in regulation, the PGOOD2 pin is pulled low by the internal NFET. A red LED indicator can be used instead of a pull-up resistor. Of course, PGOOD can be used to handshake with other circuitry, providing a ready signal for the next load dump.

## OVERCURRENT INDICATOR

In applications that require additional system control, the LTC3619B provides accurate current sense information for both channels. This information can be used for protection schemes, feedback control and other features. Figure 3 shows a scheme for an LED overcurrent indicator.

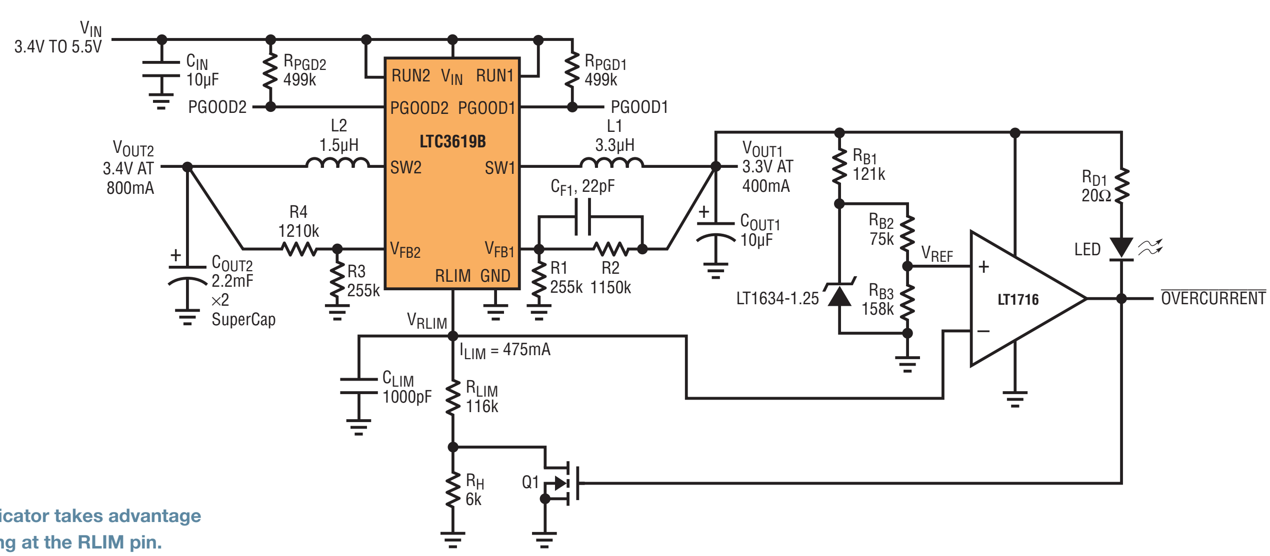


**Figure 3. Overcurrent indicator takes advantage of input current monitoring at the RLIM pin.**

Figure 4 shows the relationship between the $V_{RLIM}$ voltage and the input current. Set $V_{REF}$ equal to $V_{RLIM}$ voltage at the overcurrent limit of interest. For example, if the overcurrent limit were to be set at 85% of max current or 400mA, then set

$V_{REF}$ = (400mA/55kΩ-A) × 116kΩ = 0.85V.

The 0.85V reference is created via a resistor divider off of the LT1634 precision shunt voltage reference and is compared to $V_{RLIM}$ using the LT1716 precision comparator to create the overcurrent signal.

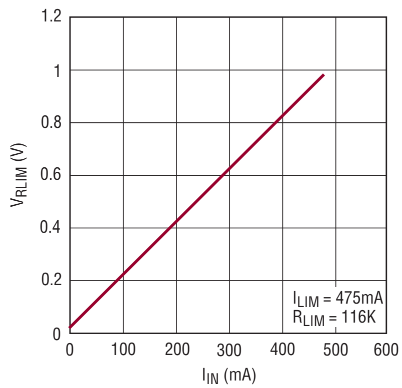


Figure 4. $V_{RLIM}$ vs $I_{IN}$ for circuit in Figure 3

In this example, when $V_{RLIM}$ rises above $V_{REF}$, the LT1716 pulls $\overline{\text{OVERCURRENT}}$ low and turns on LED1 while turning off Q1, allowing $R_H$ to provide about 5% of hysteresis for $V_{RLIM}$. $V_{RLIM}$ would have to be reduced by 5% in order to clear the $\overline{\text{OVERCURRENT}}$ condition.

## POWERING AN LED LIGHT AT INPUT CURRENT LIMIT

If an application requires independent monitoring of only one channel, the LTC3606B pulse-skipping, single channel monolithic buck with input current limit is a good choice. The LTC3606B can be used to power an LED driver chip or to directly drive a large LED light, such as LED1 in Figure 5.

LED1 has a nominal on-voltage of 3.2V and its current is limited by the input current limit of 400mA set by $R_{LIM}$. In this case, the current through LED1 is limited to 625mA, as calculated from

$(V_{IN}/V_{OUT}) \times I_{LIM}$ = (5V/3.2V) × 400mA,

assuming $V_{IN}$ = 5V. The circuit is configured so that the $\overline{\text{LAMPGOOD}}$ indicator goes high when LED1 turns off or burns out. When turned on, the current through LED1 is at the input current limit and the voltage at $V_{OUT}$ is 3.2V instead of the regulated 4V. Because the operating LED forces $V_{OUT}$ more than 11% out of regulation, PGOOD (a.k.a. $\overline{\text{LAMPGOOD}}$) falls low, indicating the lamp is on. If LED1 turns off or burns out (no current through it), $V_{OUT}$ returns to the regulated 4V and $\overline{\text{LAMPGOOD}}$ is pulled high via $R_{PGD}$, indicating that the lamp is not operating.

If the LTC3619B were used in the previous example, the available input current to channel 2 would be dependent on the input current of channel 1. Using the expression below, the current out of $R_{LIM}$ pin can be calculated. This is the summed representation of the inductor currents from both channels and illustrates how the currents are distributed.

$I_{R(LIM)} = I_{OUT1} \times D1 \times K1 + I_{OUT2} \times D2 \times K2,$

where $D1 = V_{OUT1}/V_{IN}$ and $D2 = V_{OUT2}/V_{IN}$ are the duty cycles of channels 1 and 2, respectively.

K1 and K2 are the ratio

$$\frac{R_{DS(ON)}(\text{POWER PFET})}{R_{DS(ON)}(\text{SENSE PFET})}$$

of channels 1 and 2, respectively and are internally trimmed to better than 2% accuracy at 1/55kΩ-A. Assuming K = K1 = K2, and dividing both sides by K, the input current is derived. Setting input current to the input current limit, we get the following expression.

$I_{LIM} = I_{OUT1} \times D1 + I_{OUT2} \times D2,$

Channel 2 is configured to power LED1 at $V_{OUT2}$ = 3.2V. If channel 1 is loaded at 400mA with $V_{OUT1}$ = 1.8V, which translates to 144mA of input current ($I_{OUT1} \times D1$), this subsequently leaves 400mA through LED2 instead of the original 625mA, which translates to 256mA of input current ($I_{OUT2} \times D2$) available for channel 2.

According to the above $I_{LIM}$ expression, a higher LED1 turn-on voltage, for instance due to looser manufacturing tolerance, would result in reduced current through LED1 and vice versa. This is an appealing, self-adjusting feature in this application to keep the intensity constant over manufacturing differences. Using an LED driver IC to power multiple LEDs on channel 2 is preferred although the LTC3606B may be used to drive an LED light bulb efficiently.

## CONCLUSION

The LTC3619 and the LTC3606B are buck regulators that combine average input current limit and current sense information in a 10-lead MSOP and DD package. The LTC3619's accurate input current limit is ideal for USB powered applications, where the USB port's output current is limited. At the same time, the current sense information simplifies designs in applications that require detection and monitoring of current in a single-chip solution requiring no additional board area. ■

Figure 5. LED driver with lamp status indicator ($\overline{\text{LAMPGOOD}}$)