2.7V to 38V V_{IN} Range, Low Noise, 250mA Buck-Boost Charge Pump Converter

George H. Barbehenn

The LTC3245 is a buck-boost regulator that dispenses with the traditional inductor, and instead uses a capacitor charge pump. The LTC3245's input voltage range is 2.7V to 38V, and it can be used without a feedback divider to produce one of two fixed output voltages, 3.3V and 5V, or programmed via a feedback divider to any output voltage from 2.5V to 5.5V. Maximum output current is 250mA. As a result of its buck-boost topology, the LTC3245 is capable of regulating a voltage above or below the input voltage, allowing it to satisfy automobile cold crank requirements.

The LTC3245 achieves efficiency of 80% when delivering 5V, 100mA from a 12V source, significantly higher efficiency than an LDO, making it possible to avoid the space and cost requirements of an LDO with a heat sink. The LTC3245 is available in an exposed pad MSOP12 or 3mm × 4mm DFN12.

CHARGE PUMP OPERATION

Figure 3 shows a simplified block diagram of the LTC3245 converter. Charge pumps can operate as $N/M \times V_{IN}$ converter, where N and M are integers. ½, 1, and 2 are the simplest forms and only require one flying capacitor. Higher order N and M require more flying capacitors and switches.

Because N and M are integers, a straight charge pump cannot be used to produce an arbitrary output. Instead the controller modifies V_{IN} to produce V_{IN}', which is then fed to the charge pump. The charge pump can operate in one of three modes, buck, LDO or boost, resulting in $½V_{IN}'$, V_{IN}' or $2V_{IN}'$, respectively.

By properly controlling both V_{IN}' and the operating mode of the charge pump any arbitrary voltage can be achieved. When operating in buck mode, the input current is approximately half that of an equivalent LDO, offering a significant efficiency improvement.

INPUT RIPPLE AND EMI

The LTC3245 charges the flying capacitor each switching cycle, so V_{IN} must be sufficiently decoupled to minimize EMI.

To decouple the LTC3245, place a 3.3µF ~ 10µF MLCC capacitor as close to the V_{IN} pin as possible. One way to move it closer is to limit the voltage rating on the capacitor, which helps minimize the size of the cap, and the smaller it is, the nearer the V_{IN} pin it can be placed. For instance, although LTC3245 is rated to operate up to 38V input, for an automotive supply, an MLCC with 16V rating should be sufficient.

A decoupling capacitor with a short, low inductance supply connection, but a high inductance ground connection,

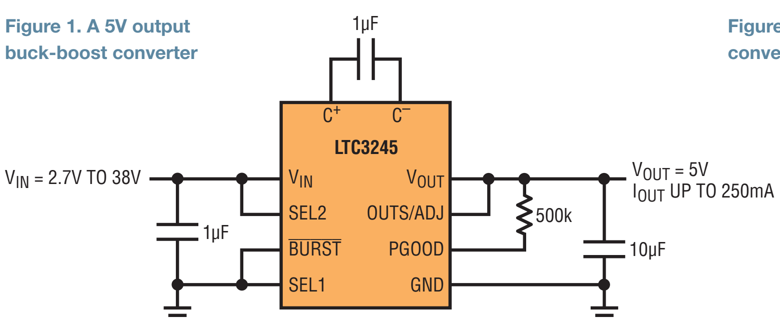


Figure 1. A 5V output buck-boost converter

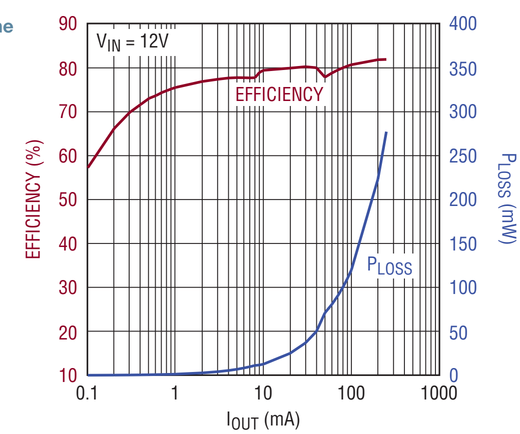
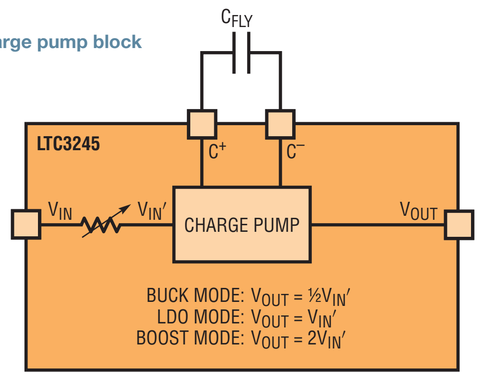


Figure 2. Efficiency of the converter in Figure 1

The LTC3245 achieves efficiency of 80% when delivering 5V, 100mA from a 12V source, significantly higher efficiency than an LDO, making it possible to avoid the space and cost requirements of an LDO with a heat sink.

Figure 3. Detail of the charge pump block



is not very effective. The ideal situation is when the supply connection is short and wide, and the ground connection is an area fill with a very wide connection to the exposed pad on the LTC3245.

The assumption is made that V_{IN} does not have a very long connection back to a low impedance supply. If the input supply is high impedance, or the connection to the input supply is longer than 5cm, it is recommended that the supply be decoupled with additional bulk capacitance, as needed. In many cases, 33µF is adequate.

The LTC3245 can be optimized for light load efficiency or low output ripple by choosing high efficiency Burst Mode® operation or low noise mode. Burst Mode operation features low quiescent current and hence higher efficiency at low load currents. Low noise mode trades off light load efficiency for lower output ripple at light loads.

Figure 4 shows measured radiated and conducted signatures of the LTC3245, tested in a microchamber in accordance with CISPR25. As can be seen here, when properly decoupled, the LTC3245 does not present any issue when striving to meet government regulations for radiated or conducted emissions.

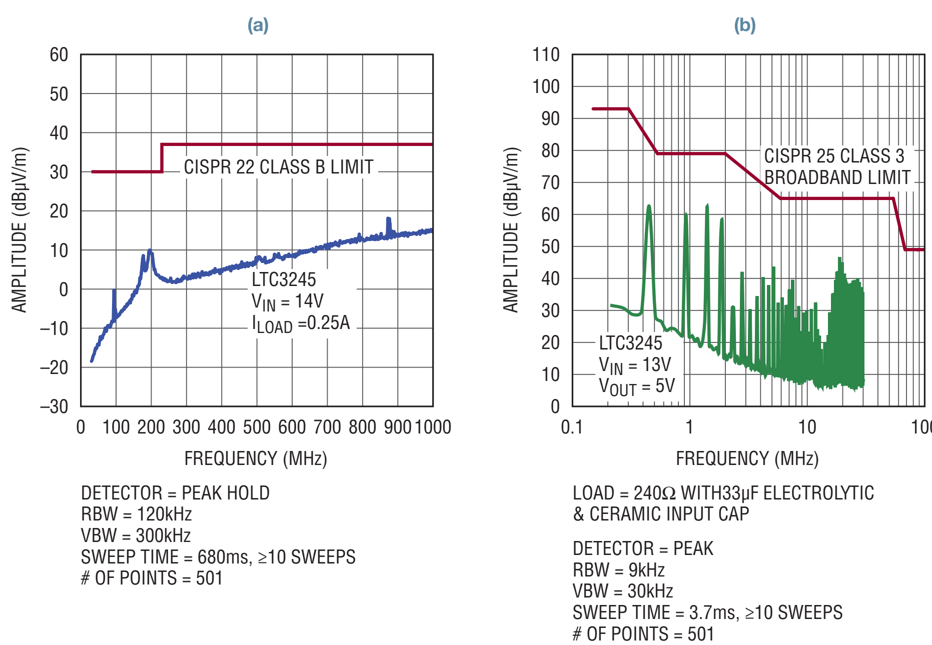
CHOOSING THE FLYING CAPACITOR

The detail of the charge pump block (Figure 3) suggests that the flying capacitor is only involved in the charge pump itself. However, the flying capacitor is also involved in the variable attenuator that generates V_{IN}'. Consequently, the capacitor should not be chosen based on straightforward calculation, but instead by observing a few constraints.

The flying capacitor cannot be polarized, such as an electrolytic or tantalum capacitor. The voltage rating of the flying capacitor should be about 1V more than the output voltage, such as using a 6.3V flying capacitor for a 5V output.

The minimum capacitance of the flying capacitor must be 0.4µF. Since polarized capacitors are not allowed, the most appropriate capacitor is MLCC. MLCC capacitors with enough capacitance to meet the 0.4µF are likely Class II dielectric capacitors, with strong voltage

Figure 4. Radiated (a) and conducted (b) emissions



The OUTS/ADJ pin is used either for sensing V_{OUT} for fixed 3.3V and 5V outputs or as the feedback pin for an adjustable output voltage. It is connected directly to the output when using the fixed values. An adjustable output can be set anywhere between 2.5V and 5V through the choice of suitable feedback resistors.

coefficients on their capacitance. The voltage coefficient of the capacitance is a function of the maximum voltage, so a capacitor of maximum voltage of 16V operating at 5V will have much more in-circuit capacitance than a 6.3V capacitor of the same nominal capacitance and size, operating at 5V.

So, a 0.47µF, 6.3V, Class II dielectric capacitor operating at 5V will likely not meet the minimum capacitance, while a 0.47µ, 50V, Class II dielectric capacitor likely will. A capacitor such as the TDK C1005X5R1C105K 1µF, 16V, 0402 is suitable for most applications.

OUTPUT CAPACITOR

The choice of output capacitor value is a trade-off between ripple and step response. As the output capacitance is increased, the ripple decreases but the step response is also increasingly overdamped.

The required voltage rating of the output capacitor is the output voltage of the regulator, so a 6.3V capacitor would suffice for a 5V output. Nevertheless, as discussed above, Class II dielectric capacitors lose more than half their nominal capacitance at their rated voltage. Consequently, it may be necessary to choose a larger capacitor when operating close to the rated voltage of the capacitor, to minimize ripple.

A good compromise between ripple and response is a capacitor with a capacitance, at bias, of 10× ~ 20× the flying capacitor. This means 10µF to 20µF for the recommended flying capacitor value of 1µF. Since Class II capacitors lose a little more than half their capacitance at rated voltage, this indicates a 47µF nominal capacitance capacitor.

ADJUSTABLE OUTPUT

Besides the two fixed output voltage values of 3.3V and 5V, it is possible to program the output voltage of the LTC3245 using feedback resistor as shown in Figure 5.

Adjustable output mode is achieved by setting SEL2 low and SEL1 high. The OUTS/ADJ pin is used either for sensing the output for fixed output voltages or as the feedback pin for an adjustable output voltage. It is connected directly to the output when using the fixed values. For adjustable output, the feedback reference voltage is 1.200V ±2%. The output can be set anywhere between 2.5 and 5V, through the choice of suitable feedback resistors.

SHUTDOWN

The LTC3245 can also be placed in shutdown to reduce the quiescent current to just 4µA. Pull both SEL1 and SEL2 low to shutdown the LTC3245.

PGOOD

PGOOD is an active high, open drain signal that indicates the output of the LTC3245 is in regulation. The threshold for the PGOOD indication is 90% of the desired feedback or sense voltage.

CONCLUSION

The LTC3245 is a switched capacitor buck-boost DC/DC converter that produces a regulated output (3.3V, 5V or adjustable) from a 2.7V to 38V input. No inductors are required. Low operating current (20µA with no load, 4µA in shutdown) and low external parts count (three small ceramic capacitors) make the LTC3245 ideal for low power, space-constrained automotive and industrial applications. ■

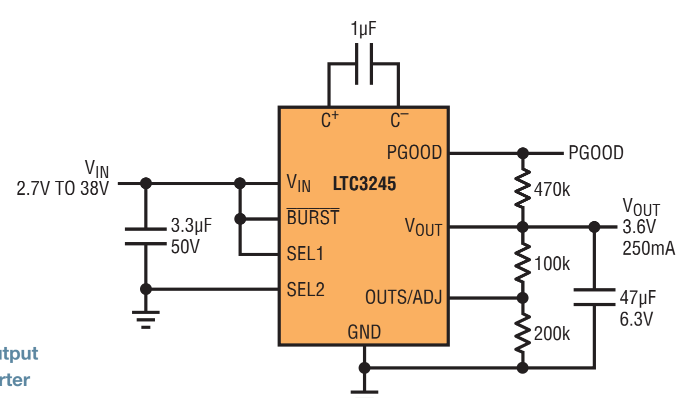


Figure 5. A 3.6V output buck-boost converter