Technology Edge

National's LM2623 Boost Converter - A Simple Technology Twist Produces The Industry's Most Versatile Supply

By John Fairbanks

- Efficient operation from single NiMH to three LiIon input voltages.
- Application circuit meets the emerging 1.8 to 4.5 volt industry standard.
- Iq allows up to 6 months shelf life for rechargeable applications.
- Can be used by most electrical engineers - a control system specialist is not required to design for stable operation.
- Usable in circuits requiring very low ripple voltage.
- Low cost per watt.

Many traditional analog problems are increasingly being solved with digital solutions. As a result, the majority of today's electronic product designers are digital engineers who find it difficult to design with switching power supply ICs. Analog engineers are specialists and control system engineers are even more specialized. Today's high speed, low voltage systems require tight tolerance power supplies with fast response times. This increases the opportunity for complex control system problems (stability problems). These represent stumbling blocks for product designers and they end up needing the IC manufacturers to design their solutions. The product designers would usually prefer to do it themselves and have a higher degree of control over their projects. Since the product designers are usually not control system engineers, their application of a switching power supply requires a supply that is inherently stable.

Gated Oscillators - Advantages and Limitations

Gated oscillator based switching power supplies use inherently stable, on-off control systems, rather than proportional controllers, such as the ones used in pulse width modulated (PWM) systems. The gated oscillator parts typically exhibit higher levels of ripple. However, because of their inherent stability, gated oscillators are usually safe for a digital hardware engineer to design into an application without encountering a control system problem.

Gated oscillators operate at a fixed duty cycle, which limits their range of output voltage and load capability. In order to maintain continuous current mode in a boost converter, a duty cycle greater than 1-Vin/Vout must be maintained. When this ratio is not maintained, the output capability drops dramatically. Fixing the duty cycle sets the maximum output to input voltage ratio for the power supply. This is an inherent architectural limitation of this type of system. For low output to input voltage ratios, the duty cycle of a gated oscillator will limit the output current of the supply. If the output transistor is conducting 90% of the time, the coil can only discharge into the load 10% of the time. When the output current exceeds 10% of the coil current, the system cannot supply the load. For these ratios, 400 milliamps load current requires an output transistor that can sink at least 4 amps to supply the load. If the duty cycle was 10%, the output transistor would only need to sink 1.1 amps. Running higher coil current than necessary results in excessive overshoot (ripple) when the supply reaches the voltage limit, stops the oscillator and discharges all the stored energy in the coil. Higher than necessary peak coil current also lowers the efficiency because the output is proportional to the current while the losses are proportional to the current squared. Making the duty cycle user adjustable would allow a gated oscillator to be an effective solution for a much broader range of applications.

The Ratio Adaptive Gated Oscillator - Adapts The Duty Cycle To Optimize Output, Efficiency And Ripple As The Battery Discharges

The LM2623 is a gated oscillator with a frequency proportional to the current into the oscillator pin (see figure 1A). The duty cycle is user adjustable with the addition of a small capacitor. This capacitor (C3 in figure 1A) also makes the duty cycle adjust itself as the battery runs down. It transfers a constant charge into the oscillator pin when the output device turns off and out of that pin when the output device turns on. This increases the on time and decreases the off time (increases the duty cycle). As the input current and frequency decrease due to the battery voltage running down, the fixed charge transfer becomes a larger percentage of the oscillator current and the duty cycle increases further. This increase in duty cycle as the battery runs down significantly expands the gated oscillator operating range.

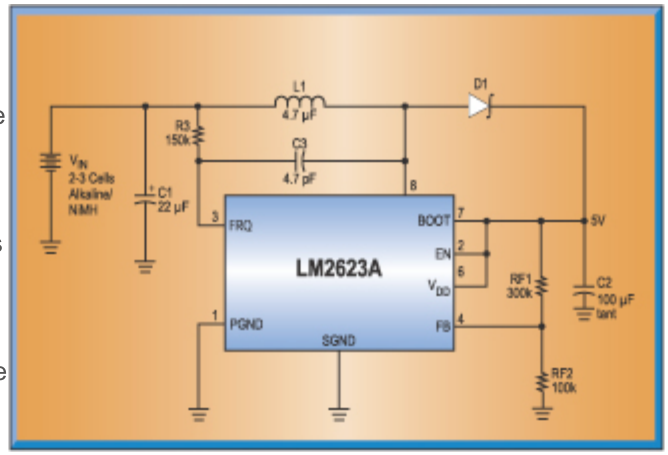

Figure 1A - Circuit

The circuit in figure 1A is a very practical LM2623A ratio adaptive circuit to drive a digital camera motor. It produces 5 volts from input voltages ranging between 1.8 and 4.5 volts. The graph below (Figure 1B) shows the efficiency at different input voltages and output loads. The duty cycle is not shown, but it varies from about 86% at 1.8 volts in to 71% at 4.5 volts in. Maintaining the 86% duty cycle at 4.5 volts would reduce the efficiency and increase the ripple. Maintaining the 70% duty cycle at 1.8 volts would significantly reduce the output capability. Several camera manufacturers are already requiring 1.8 to 4.5 volt operation from all the power supplies. The 1.8 to 4.5 voltage standard allows a manufacturer to build his product and let the user select disposable Alkalines, NiMH or LiIon at the point of purchase.

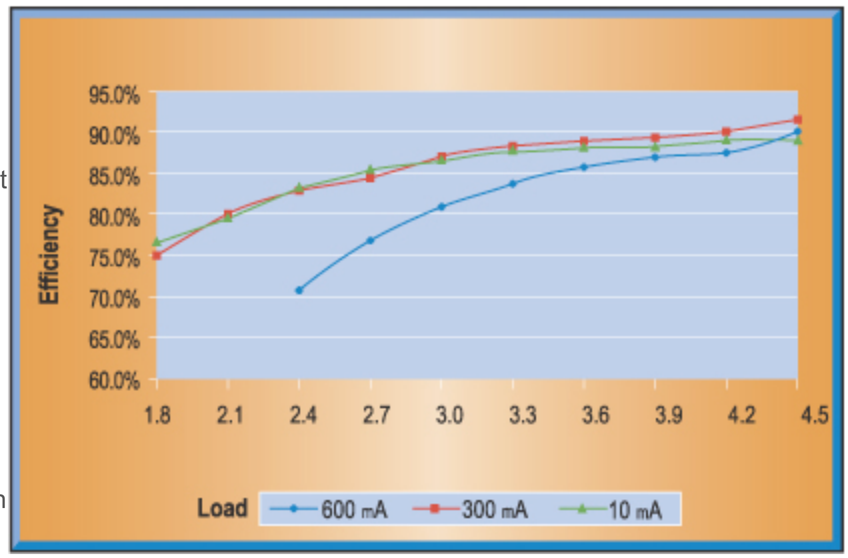

Figure 1B - Graph

The industry's most flexible power supply needs to solve more problems than just wide range efficiency. Low ripple is important for many applications, particularly digital cameras. This requires matching the duty cycle to the voltage ratio to limit the overshoot due to excessive stored energy in the coil. The change in duty cycle with battery voltage can be increased significantly by adding resistance in series with C3 (see Fig 2 below). The ripple can also be decreased significantly by adding a small capacitor (30 to 100pf) in parallel with RF1 and adding a ceramic capacitor (4.7 to 10uf) in parallel with C2. The circuit in Figure 2 was developed to supply the analog and digital circuits in a digital camera. It runs between 80% and 90% efficient with ripple below 30 millivolts at 300 ma. Ripple is below 10 millivolts from 50 ma to no load. The typical duty cycle ranges from 69% at 1.8 volts to 38% at 3 volts. These ripple and efficiency figures compare favorably with PWM parts in the same application. The quiescent current of this circuit will also support up to 6 months of shelf life in a rechargeable application using two AA NiMH cells.

LM2623 Boost Converter Circuit
Typical Applications
Digital Cameras

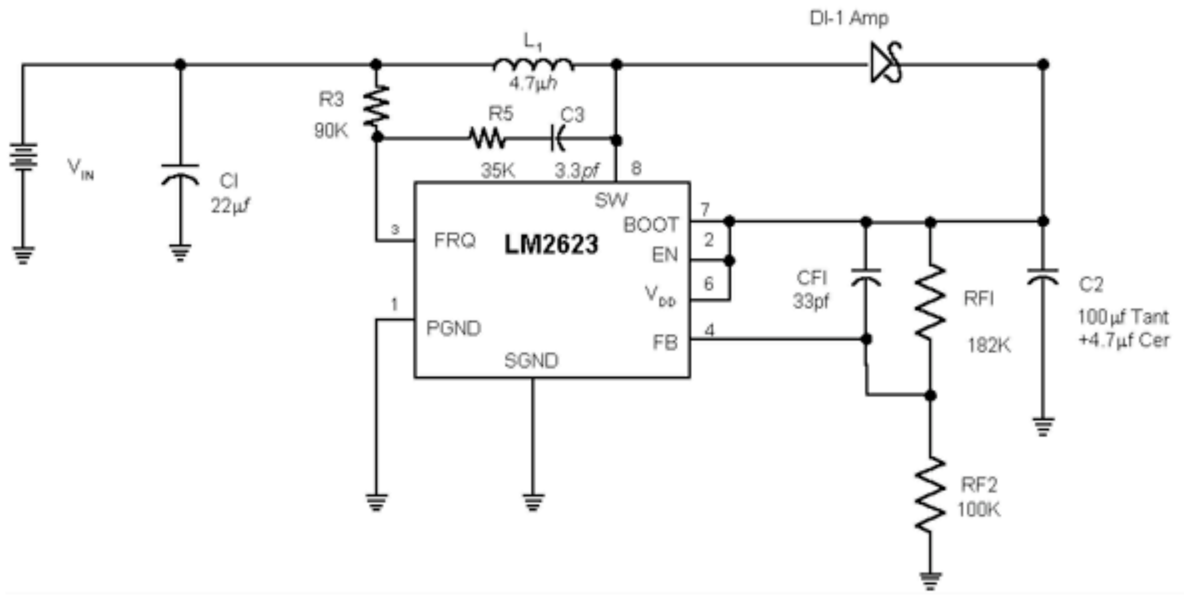

Figure 2

The LM2623 also has the capability to handle both buck and buck/boost applications cost effectively and efficiently. This can be done with a transformer coupled circuit like the one shown in Figure 3 below. This circuit requires a duty cycle adjustment from the 17% open loop value but does not require a significant duty cycle change with voltage. For loads of 200 ma, this circuit runs 75% to 80% efficient, generating 3.3 volts over the LiIon voltage range of 2.7 to 4.5 volts. This alternative compares favorably with both the cost and efficiency of dedicated buck/boost converter products. The inherent stability of the LM2623 also comes in very handy when multiple output windings are used. Since the LM2623 operates from input voltages up to 14 volts, it can handle a significant variety of transformer coupled applications.

LM2623 Sepic Circuit
Typical Applications - Digital Cameras

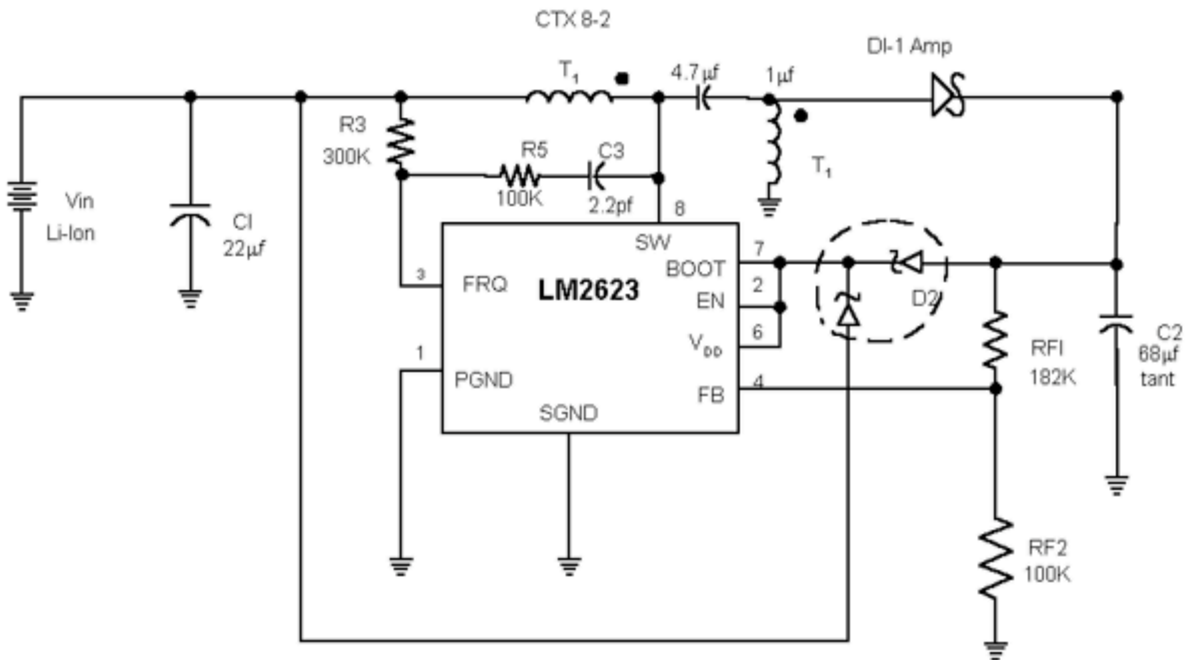

Figure 3

The industry's most flexible power supply also needs to handle single cell applications. The circuit below will put out 3.3 volts at efficiencies from 75% to over 80% in the 15 ma to 150 ma load range from a single NiMH battery. It requires the adaptive duty cycle feature as well as bootstrapping of the Vdd and the oscillator from the output voltage. Use of a large junction Schottky diode is recommended both for efficiency and to minimize the voltage drop from the input supply to the Vdd pin for start-up. The 3-amp diode used in this circuit has a forward drop of about 20 millivolts under start-up conditions. The maximum start-up voltage required at Vdd is 1.1 volts at 25 C. After start-up, the circuit will run down to below the minimum disposable battery voltage of .8 volts. It also runs efficiently up to 1.6 volts.

LM2623 1 Cell Converter Circuit
Typical Applications
Pager or Digital Cameras

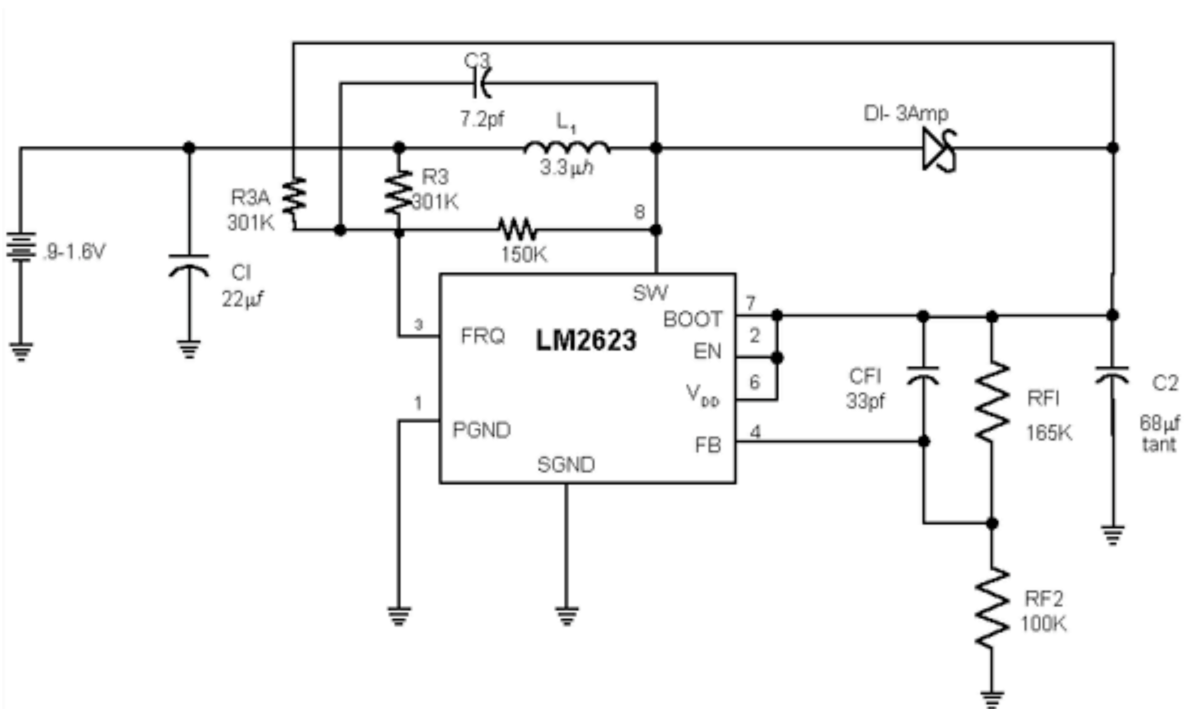

Figure 4

The LM2623 is not the optimum solution for all portable power applications. However, the simplicity of the gated oscillator architecture makes it a very cost effective solution. Its inherent stability eliminates most of the application problems and the adjustable duty cycle makes it versatile enough for almost any portable power application. If you only want to stock one IC switching supply and minimize your expense for training and obsolescence, the LM2623 is a very good choice.

Link to LM2623 Product Folder