Determining the practical limit for boost factor in DC-DC voltage conversion

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Today almost all portable devices are powered by low-voltage batteries. However, these same devices must power some circuits -- like LEDs -- that require higher supply voltages. There is therefore a clear need for boost voltage conversion. This article will discuss design issues and tradeoffs associated with typical DC/DC boost converters and the relevant limits to voltage boosting.

Where boost conversion is used
The batteries mostly used in portable devices are lithium-ion and produce voltages between 2.7 V and 4.2 V. Dual-cell alkaline batteries (NiCd or NiMH) with a 1.6 V - 3.4 V output range are also common. Next-generation batteries will have even lower output voltage ranges. However, many typical application circuits within the device require a stable voltage supply that is higher than the battery voltage. For example, 12 V or higher is required for OLED display power supplies, LCD bias generators, driving LEDs, as well as to power other ICs in mobile & cordless phones, tablets, PDAs and organizers, portable terminals and other battery-powered devices. Producing such a stable output from a low-voltage battery is possible with DC/DC boost converters but require a large boost factor.

What is the practical limit for boost conversion?
Figure 1 shows a commonly used DC/DC boost converter configuration, with an NMOS transistor implements used as switch S1 between the coil and ground. A PMOS transistor or a diode can implement the switching function S2 between the coil and the output. However, to produce a higher voltage, a diode is most frequently used instead of a PMOS transistor. If a PMOS transistor is used, there is a need for high side regulation, and that adds more cost and makes for a more complicated solution. So, a better and more flexible solution is to use an external diode.

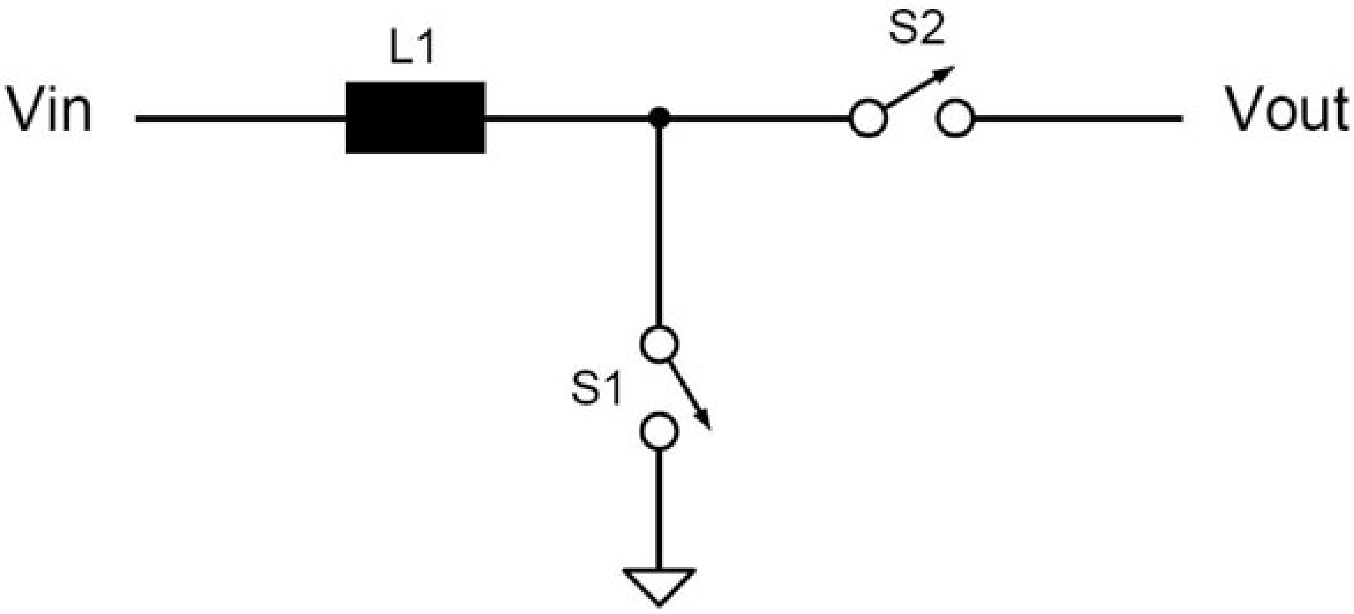

Figure 1. Simplified schematic of a boost converter.

The boost conversion process involves two states. During the first state, S1, the NMOS transistor is on, and the current flowing into the coil rises and the energy is stored in the coil. During the second state the NMOS transistor is off, but current still must flow through coil and the stored energy is transferred to the output through the diode, S2.

The duty cycle D is the fraction of the commutation period T during which the NMOS switch (S1) is on. The boost or transformation factor, Vout/Vin, is mostly dependent on the duty cycle. In an ideal case (no energy loss) Vout = Vin/(1-D). If the NMOS transistor (S1) is on 50% of the period time, D = 0.5 and Vout = 2*Vin. Similarly, if we need Vout to be 10 times higher than Vin, we have to set D to = 0.9; in other words S1's on time is 90% of the period (see Table 1 and Fig. 2).

Duty cycle	0.5	0.75	0.8	0.9
Vout	2*Vin	4*Vin	5*Vin	10*Vin

Table 1: Maximum Vout dependent on duty cycle D

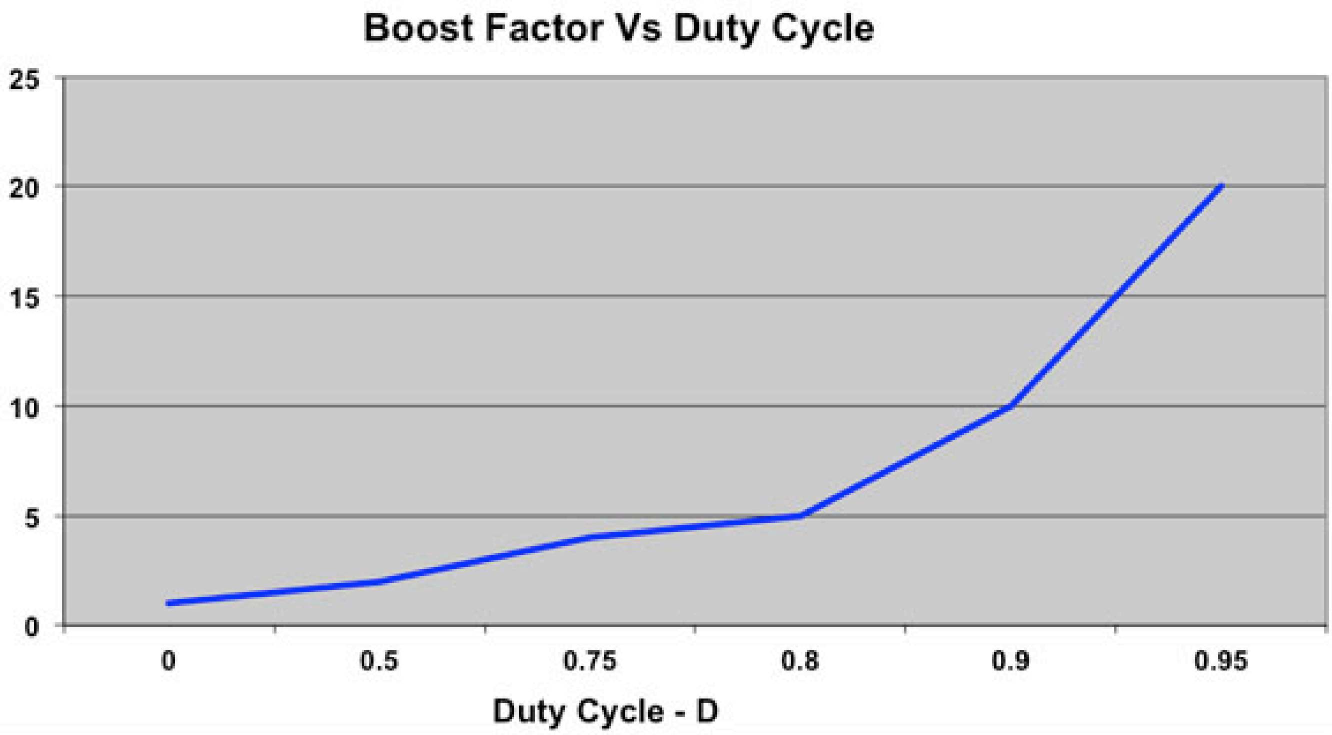

Figure 2. Maximum boost factor (Vout/Vin) dependent on duty cycle D

However, in a real application, you have to add other losses, such as resistive and switching losses, which mean that D should be larger to compensate. But this will eventually become a problem since the feedback loop is difficult to stabilize if D is > 0.9 (i.e. the duty cycle is greater than 90%). Also, changes in the transistor state (on state to off state and vice versa) require a finite amount of time. Usually a few percent of the period is spent on switching time.

Because of these reasons, many designers won't use boost factors higher than 6. This means that if a supply of 12 V is needed, a minimum battery voltage of 2 V is needed. But the minimum voltage of frequently used dual-cell alkaline batteries (NiCd or NiMH) is 1.6 V, and often a supply bus of 15 V or even higher is required. This means the designer could need 2 DC/DC boost converters to fulfill these applications. Such a solution is not only expensive, but also requires more space and will have poor efficiency because you double the losses with 2 converters.

Real-world implementation and performance
A boost converter example circuit using austriamicrosystems' AS1343 is shown in figure 3. This device is capable of producing an output of up to 42 V with the voltage adjustable via2 external resistors. The empirical data for this solution demonstrates the practical limits of boost converters.

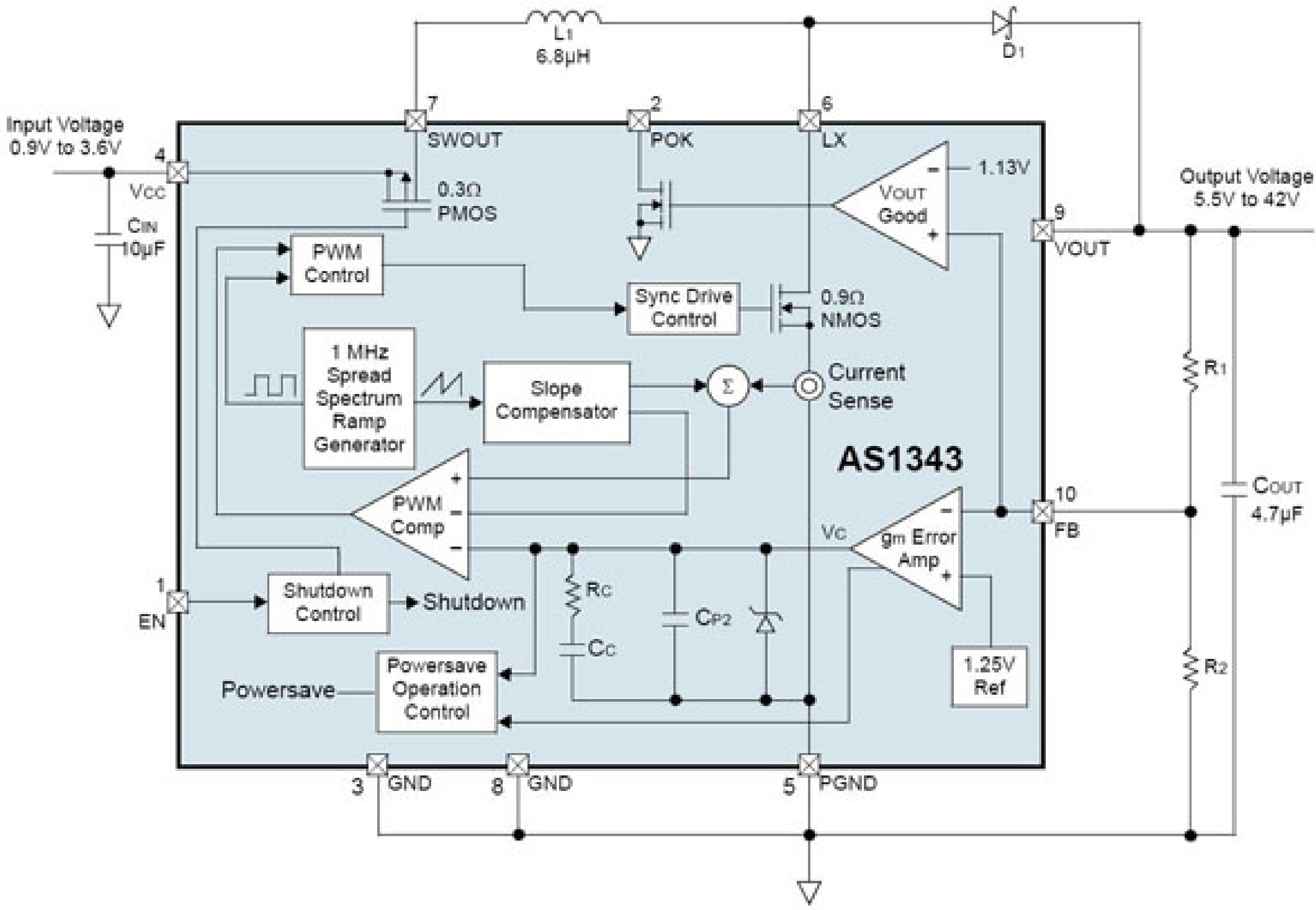

Figure 3. AS1343 – Typical boost converter application and block diagram

DC/DC conversion with boost factors to 10 or more times the input voltage is possible, but the designer must consider such inefficient operation with light loading. A solution would be to use two batteries so that even 15 volt buses can be powered with good efficiency, but that takes more space and also adds cost.

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