Negative Bias Output
DC-to-DC Converters For Battery Operated Systems: Inductorless Boost/Buck Regulator or Switcher?

An inductorless regulator may be a better solution in certain applications

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INTRODUCTION

The 3.6V Li-Ion battery in a cellular phone is a good example of a small, battery-operated system that often requires multiple DC voltages. The battery must be changed into other voltage levels as required by the radio, logic, and display. In particular, the display and certain low-noise sections of the radio often require a negative DC voltage bias. Designers have a tendency to choose a switching regulator for such applications. With the recent introduction of regulated charge pumps, designers may want to rethink their strategy. Outlined below are several advantages regulated charge pumps offer over switchers in low-current (< 20 mA) applications.

CONVERTER SELECTION FACTORS

Figure 1 shows simple block diagrams for an inductor-based switching regulator (a), and an inductorless regulating boost/buck converter such as TelCom Semiconductor's TC1142 (b). To achieve a desired output voltage, both devices first store energy, then release this energy in a controlled manner. Switching regulators use inductors to store energy while regulating charge pumps use capacitors.

The designer should choose the best DC-to-DC converter for the job: one which satisfies the overall needs of the system and has the lowest installed cost. These needs translate into a typical set of specific characteristics the converter must possess:

- High Efficiency
- Small Installed Size
- Low Quiescent Current
- Low Minimum Operating Voltage
- Low Generated Noise
- High Functional Integration
- Sufficient Output Regulation
- Low Installed Cost

Efficiency

Switcher

Most low-cost, battery operated switching regulators have a power conversion efficiency of 80% to 85% (typical). Dissipated power in the modulator switch (and/or external diode) accounts for most of the loss in efficiency.

Inductorless Boost/Buck Regulator

An inductorless boost/buck regulator, such as TelCom's TC1142, utilizes pulse-frequency modulation (PFM) control to produce a regulated negative output voltage from –3V to –5V (per output voltage option) at 20 mA maximum load. PFM operation is obtained by enabling the oscillator (as needed) to maintain output voltage regulation.

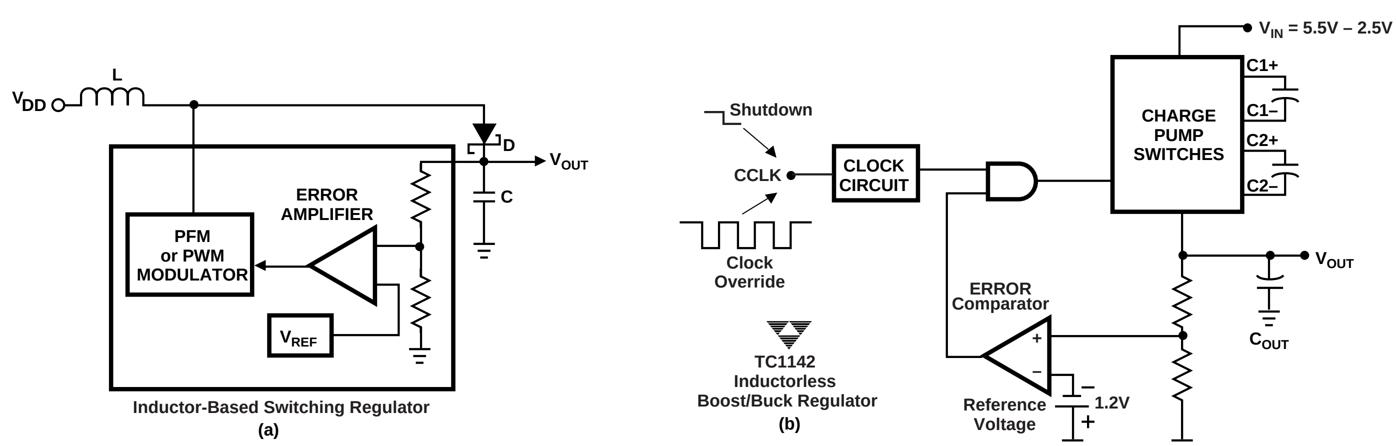

Figure 1: Switching Regulator Circuit (a) and an Inductorless Boost/Buck Regulator (TC1142) (b)

Assuming the output is loaded to at least 20% of the maximum available current, the power efficiency of the inductorless boost/buck regulator can be estimated as the absolute value of the regulated output voltage, divided by twice the input voltage. Thus, for a 3.6V battery input generating a –5V output, the efficiency of the inductorless boost/buck regulator will be approximately 70%.

Best Choice

Switcher, except in cases where the required output of the inductorless regulating converter is close to 2x the input voltage.

Installed Size

Switcher

Even with the availability of switchers in SOT packages, the required external inductor can be rather large in size. In addition, the circuit layout of the switcher itself can require a large amount of board space (additional decoupling, special grounding, shielding, etc.).

Inductorless Boost/Buck Regulator

Although the TC1142 is inductorless, it requires three external capacitors. Two of the capacitors (C1 and C2) are ‘flying’ capacitors — typically one-tenth the size of the output capacitor (C_{OUT}). The output current, output ripple voltage, and charge pump oscillator requirements of the TC1142 greatly influence the size of the capacitors for this inductorless solution. The TC1142 is packaged in a space saving 8-pin micro small outline package (MSOP). Occupying only half the board area of an 8-pin SOIC package, the 8-pin MSOP is often smaller in size than the inductors required for the switcher solution.

Best Choice

Inductorless regulating charge pump.

Quiescent Current

Switcher

Among the lowest quiescent current switching topologies available are the frequency modulated switchers. Supply current (at low load currents) is minimized by voltage regulation via frequency modulation.

Inductorless Boost/Buck Regulator

Charge pump quiescent current is directly proportional to the frequency at which it operates. The TC1142, however, features a clock control input (CCLK) that can be used to disable the charge pump during long standby periods. When the CCLK pin is low, the supply current of the TC1142 reduces to approximately 1 µA.

The internal voltage comparator inhibits charge pump operation by means of pulse-skipping whenever the output voltage becomes more negative than the desired regulated value. When fully active, the TC1142 typically consumes 200 µA (switching at a 200 KHz rate). This pulse-skipping method allows the TC1142 to produce a regulated output voltage with a much higher efficiency than with charge pumps that use a post low dropout (LDO) regulator.

This pulse-skipping scheme also reduces the quiescent current in the inductorless boost/buck regulator architecture, allowing it to be competitive with the quiescent current of inductive switchers.

Best Choice

Because of their efficiency benefits, the inductive switcher is still marginally the best choice. However, the pulse-skipping operation of the inductorless boost/buck regulator minimizes the inductive switcher’s advantage.

Minimum Operating Voltage

Switcher

Suitable for applications powered by a single-cell alkaline battery, dedicated battery operated switching regulators operate down to 1V or less.

Inductorless Boost/Buck Regulator

Inductorless regulators require a minimum supply voltage of 2.5V, therefore, requiring a multi-cell alkaline battery or single-cell Li–Ion battery.

Best Choice

Switcher (for now).

Generated Noise

Switcher

Switchers are well known for generating power supply noise and radiated switching noise (EMI). Wideband PFM switchers, as a good example, generate noise over a wide range of frequencies. High frequency switchers, whose generated noise falls well outside the frequency bands of interest within the system, are being offered by many suppliers.

Inductorless Boost/Buck Regulator

Inductorless boost/buck regulators do not require inductors and, therefore, have negligible radiated EMI. Objectionable noise on the pump input can usually be eliminated with a small capacitor.

Best Choice

Inductorless regulating charge pump.

Integration

Switcher

ICs that combine switching regulators with other functions (LDOs and voltage detectors) are now available from many manufacturers. These devices occupy less space and offer superior electrical characteristics, as compared to discrete implementations.

Inductorless Boost/Buck Regulator

Inductorless boost/buck regulators provide no additional integration features at this time. However, future generations may incorporate additional features such as voltage detection and output ripple reduction circuitry.

Best Choice

Switcher (for now).

Output Regulation

Switcher

For most portable applications, low-cost, battery operated switchers provide more-than-adequate regulation. External compensation pins, provided on some switchers, allow the user to “fine-tune” the output transient response characteristics to their specific application.

Inductorless Boost/Buck Regulator

Depending on the load current required and the size of the capacitors, the inductorless regulating charge pump also provides more-than-adequate regulation for most portable applications. The following table below (Table 1) shows the relationship between output voltage ripple versus the two flying capacitors and the output capacitor (C_{OUT}). In each case, a 3.2V input is being converted to a –5V output.

Best Choice

The inductive switcher and the inductorless boost/buck regulator are roughly equal.

It is worth noting that neither the inductive switcher, nor the inductorless boost/buck regulator provide as tight a regulation as an unregulated charge pump followed by a post low dropout (LDO) regulator such as TelCom's 850 series.

Installed Cost

Switchers

Switchers are becoming more affordable and are requiring fewer external components. However, they usually require, as a minimum, an external inductor, capacitor, and Shottky diode. With the added cost of these components and the relatively higher price of the switcher, the switcher results in a greater installed cost versus the regulating charge pump. If shielding is required, the cost is that much higher.

Inductorless Boost/Buck Regulator

Inductorless regulating charge pumps, such as the TC1142, are less expensive because no external inductors or Shottky diodes are required. Only external capacitors are needed for the TC1142, which saves the user component cost, board area, and in some applications EMI shielding.

Best Choice

Inductorless regulating charge pumps.

Comparison Summary

While both systems have their strengths and weaknesses, the regulating charge pump offers several advantages over switchers in low-current (< 20 mA) applications. In the areas of installed size, generated noise, installed cost, output regulation, and efficiency (when the required output of the inductorless regulating converter is close to –2x the input voltage), the regulating charge pump will prove to be a better design solution for your next battery operated system.

Table 1. Voltage Ripple vs. C1/C2 Flying Capacitors and Output Capacitor C_{OUT} ESR = 0.1Ω

C1, C2 (µF)	C_{OUT} (µF)		V_{IN} (V)	V_{OUT} (V)	V_{RIPPLE} (mV)
0.01	4.7		3.2	–5	14.6
0.22	4.7		3.2	–5	31.4
0.33	4.7		3.2	–5	46.1
0.47	4.7		3.2	–5	63.9
0.68	4.7		3.2	–5	88.7
1.0	4.7		3.2	–5	123.2
0.1	10		3.2	–5	7.0
0.22	10		3.2	–5	15.1
0.33	10		3.2	–5	22.4
0.47	10		3.2	–5	31.5
0.68	10		3.2	–5	44.7
1.0	10		3.2	–5	63.8

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