

DC-DC Converters For Battery-Operated Systems: Charge Pump or Switcher?

Take a Hard Look at Charge Pumps Before Designing with that Switcher!

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INTRODUCTION

Small, battery-operated systems often require multiple DC voltages. For example, the 1.5V cell in a pager must be transformed to other voltages required by the receiver, logic, and display. The industry's latest round of charge pump products offer several enticing advantages over switchers in low current (<100mA) applications. Designers who instinctively choose a switching regulator for such applications might want to take a close look at charge pumps.

FACTORS INFLUENCING CONVERTER SELECTION

Figure 1 shows simple block diagrams for an inductor-based switching regulator, an unregulated capacitive charge pump converter, and a regulated charge pump converter. All three operate by first storing energy, then releasing this energy in a controlled manner to achieve a desired output voltage. Switching regulators use inductors to store energy while charge pumps use capacitors.

The best DC-to-DC converter for the job is the one that satisfies the overall needs of the system at the lowest installed cost. These needs translate into a set of specific attributes the converter must have, which typically include:

- 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

The power conversion efficiency of most low cost, battery-operated switching regulators is typically 80% to 85%. Losses result mainly from power dissipated in the external diode and modulator switch.

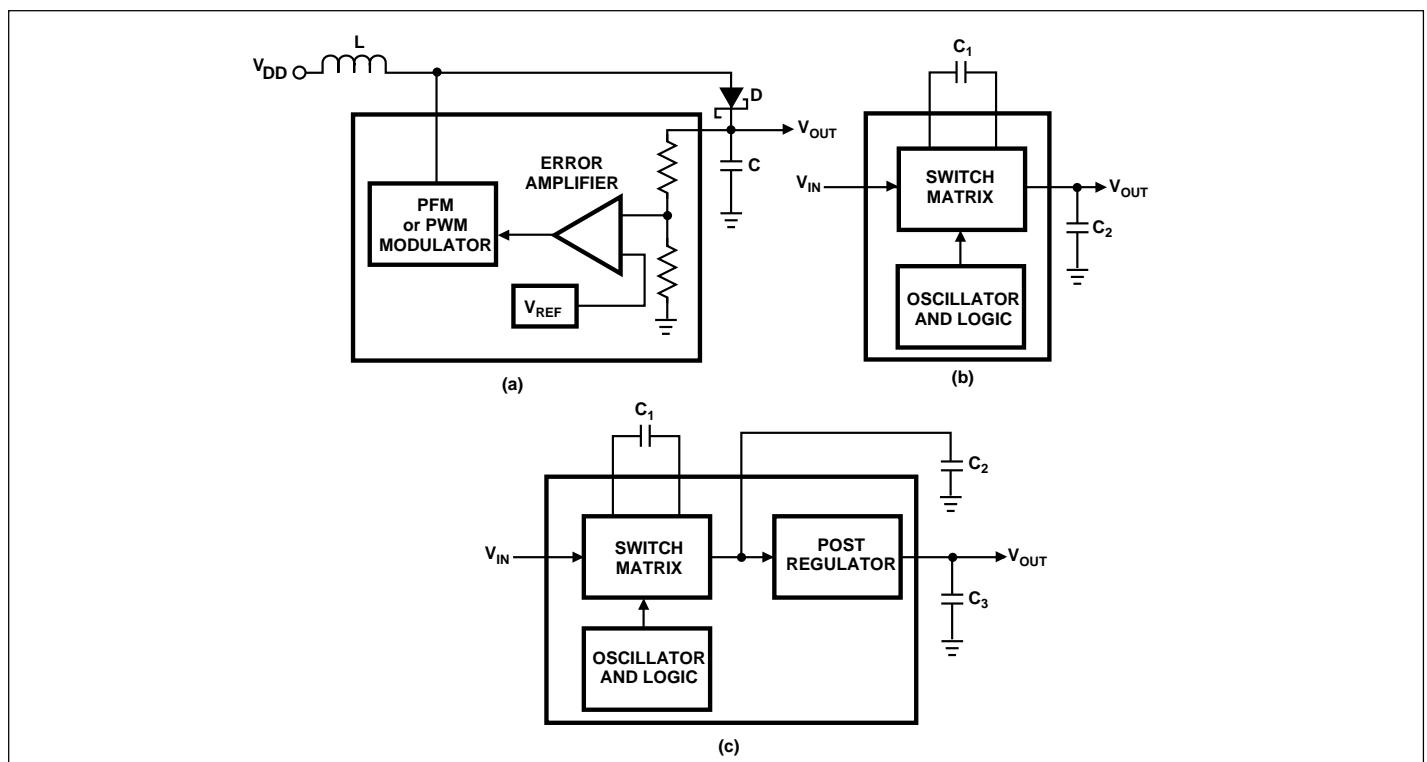


Figure 1: Switcher, Charge Pump, Regulated Charge Pump Block Diagrams

Unregulated Charge Pump

Basic charge pumps (like the TC7660H) have very high power conversion efficiency (usually in excess of 90%). This is because losses come mainly from capacitor ESR and internal switching transistor RDSON, both of which can be made small.

Regulated Charge Pump

The regulated charge pump (Figure 1) adds a low drop linear post regulator to the output of the basic charge pump. While this certainly provides regulation, it reduces efficiency in direct proportion to the power dissipated in the post regulator. For highest efficiency, the output of the charge pump should be operated as close to the dropout voltage of the post regulator as possible.

Best Choice

Unregulated charge pump (in applications where tight output regulation is not required), or regulated charge pump (if the differential voltage across the post regulator is kept small).

Installed Size

Switcher

While many of the newer switchers are available in SOT packages they still require an external inductor, which is often physically large. The circuit layout of the switcher itself sometimes consumes additional board space (additional decoupling, special grounding, shielding, etc.).

Charge Pump:

Charge pumps are “inductorless”, but require external capacitors. Newer charge pumps come in SOP packages and operate at high frequencies, allowing the use of small (1 μ F) capacitors for minimum space consumption. Basic charge pump converters can invert, double, or split the input voltage. In some cases, the space consumed by the charge pump I.C. and capacitors is less than the area required by the switcher’s inductor alone! It is also easier to get combination positive and negative output voltages from charge pumps. A device like the TCM680 supplies output voltages of +2V_{IN} using only external capacitors. The same output voltages from a switching regulator would require either 2

separate switchers, or a single switcher operated in a complex topology using a transformer.

Regulated Charge Pump

Adding a discrete post regulator consumes more space, however many such regulators are available in SOT packages, minimizing this problem. Newer, regulated charge pumps like the TCM850 combine the charge pump, adjustable post regulator, and shutdown controls in a single 8-pin SOIC.

Best Choice

Unregulated or regulated charge pump.

Quiescent Current

Switcher

Frequency modulated (PFM) switchers are among the lowest quiescent current switching topologies available. Voltage regulation via frequency modulation minimizes supply current at low load currents.

Unregulated Charge Pump

Charge pump quiescent current is directly proportional to the frequency at which it operates. Most of the newer charge pumps run at frequencies beyond 150Khz, allowing the use of 1 μ F (or smaller) capacitors. To overcome the resulting high quiescent current, some charge pumps have a shutdown input to turn the charge pump off during long standby periods, reducing supply current to near zero.

Regulated Charge Pump

The post regulator adds quiescent current, so the regulated charge pump has a disadvantage over even the basic charge pump.

Best Choice

Switcher (especially a frequency modulated (PFM) switcher).

Minimum Oating Voltage

Switcher

Dedicated battery-operated switching regulators (like the TC16) operate down to 1V or less making them suitable for applications powered by a single cell.

Charge Pump/ Regulated Charge Pump

Most charge pumps have minimum operating voltages of 1.5V or higher, making them suitable for two cell applications at best. But...watch out! Lower input voltage charge pumps are on the way!

Best Choice

Switcher (for the time being).

Generated Noise

Switcher

Switchers are notorious sources of power supply noise and radiated switching noise (EMI). This is especially true of wide band PFM switchers, which generate noise over a wide range of frequencies. Many suppliers offer high frequency switchers whose generated noise falls well outside the frequency bands of interest within the system.

Charge Pump/ Regulated Charge Pump

Charge pumps do not use inductors, and therefore have negligible radiated EMI. Objectionable noise on the pump input is usually be eliminated with a small capacitor.

Best Choice

Regulated or unregulated charge pump.

Integration

Switcher

ICs that combine switching regulators with other functions (such as voltage detectors and linear regulators) are now available from several vendors. The TC16 for example, incorporates a PFM boost regulator, LDO and voltage detector in a single SO-8 package. These devices offer superior electrical characteristics compared with discrete implementations, and occupy less space.

Charge Pump

Basic charge pumps like the TC7660 offer no additional functional integration.

Regulated Charge Pump

Increased functional integration in the latest round of regulated charge pumps points to a trend. Clearly, next generation regulated pumps will have functional inte-

gration on a par with that of the latest switchers.

Best Choice

Switcher (for now).

Output Regulation

Switcher

Low cost, battery operated switchers offer more-than-adequate regulation for most portable applications. Some switchers also have external compensation pins which allows the user to “fine-tune” the output transient response characteristics to the application at hand.

Charge Pump

These devices do not regulate. They simply transform the input voltage (that is, $n \times V_{IN}$, where n is an integer). As a result, output voltage droops as load current increases. While this is not a problem in some applications (such as LCD bias), most other applications require a regulated output voltage.

Regulated Charge Pump

Regulation is supplied by the linear post regulator (either on-chip or externally). In some cases, it may be necessary to add switching stages to the pump to provide enough headroom for the linear post regulator. This adds additional external capacitors and adversely impacts size, cost and efficiency. In spite of this, the

linear post regulator makes the output regulation of the regulated charge pump as good as (or sometimes better than) that of a switcher.

Best Choice

Regulated charge pump.

Installed Cost

Switchers

Switchers are more affordable and require fewer external components than ever before. However, they usually require an external inductor, capacitor, and shottkey diode as a minimum. The costs of diode, inductor, and relatively higher price of the switcher itself usually result in a higher installed cost versus the charge pump. This is especially true if shielding is required.

Charge Pump

Unregulated charge pumps are less expensive than switchers because they are multiple sourced (assuring competitive pricing) and require only external capacitors (no inductor). This saves board area, the cost of the inductor, and in some cases, the added cost of shielding.

Regulated Charge Pump

Depending on the specific devices in question, the cost of a regulated charge pump could be roughly equal to that of the switcher. It may be possible, in certain

cases, to add the post regulator externally to save cost, but at the expense of size and possibly efficiency.

Best Choice

Charge pump (where tight voltage regulation is unimportant.) Otherwise, the costs of the regulated charge pump and switcher are roughly equal.

Comparison Summary

The following table summarizes the above comparisons. Quick inspection shows the relative strengths of switchers, charge pumps, and regulated charge pumps in applications needing 100mA or less of output current. Regulated and unregulated charge pumps stack up very well against switchers and are a better solution in some cases, all things considered. So in your next portable application, give charge pumps a hard look before designing with that switching regulator!

CRITERIA	SWITCHER	CHARGE PUMP	REGULATED CHARGE PUMP
EFFICIENCY	++	+++	++
INSTALLED SIZE	+	++	++
QUIESCENT CURRENT	+++	+	
MINIMUM INPUT VOLTAGE	++	+	+
LOW NOISE		++	+++
INTEGRATION	++		+
OUTPUT REGULATION	++		++
INSTALLED COST	++	+++	++

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