Switching Converters (DC-DC) – Quick Reference Guide

Quick reference guide

DC-DC switching regulators are by far the most efficient way to convert one DC voltage to another. Even if more complex and expensive than linear regulators, the added flexibility and superior efficiency have contributed to the popularity of switching regulators. This guide provides developers with an overview of our most commonly used switching regulators and will help identify the most appropriate solution for each type of application.

Why switching regulators?

Efficiency

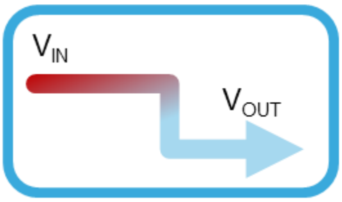
While linear regulators remain popular thanks to their low noise factor, simplicity, and small size, the primary reason for implementing a switching regulator is to increase the application's efficiency. While the power lost in a linear regulation is lost directly to excess power being dissipated as heat, the power losses in switching regulators are only caused by small biasing currents and losses in non-ideal components. In a well-made design, the efficiency can be more than 95% over a wide range of working conditions.

Flexibility

The primary application for DC-DC regulators is to step-down a higher input voltage to a lower output voltage, but owing to their mode of operation many regulators can also be configured to work with outputs that can be higher than their input, or even convert input voltages that are both higher and lower than the output voltage.
These three main topologies are referred to as *Buck*, *Boost*, and *Buck-Boost*

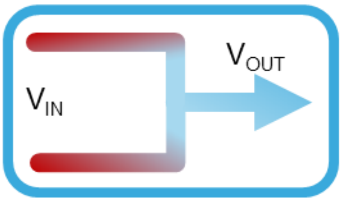
Buck

- The most common topology
- Used when the input is higher than the output
- As most existing regulators are made for this purpose, solutions are plenty, easy and well-developed



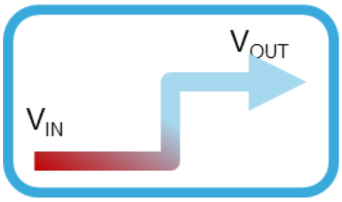
Buck-boost

- Buck-boost topology is applied when the input voltage is expected to be both higher and lower than the output voltage during operation
- This, for example, occurs in battery-operated circuits, where the voltage of a fully charged battery may be higher than needed, while the voltage gradually becomes too low as the battery discharges



Boost

- Boost (step-up) topology converts a low input voltage to a higher output voltage
- This is often seen in handheld and wearable devices where the output voltage is consistently expected to be higher than the input voltage, and using multiple batteries in series is considered too bulky



– How do I pick the right DC-DC for an application?

While some applications may require more attention to specific characteristics, a generalized approach to selecting a DC-DC switching regulator is to match criteria in the following order:

- Input voltage range and output voltage (fixed or adjustable)
- Current requirement of the load
- Efficiency and quiescence
- Rectification architecture
- Switching frequency
- Compensation
- Output accuracy
- Extra features (Enable, Soft-start, Power Good, etc.)

Input/output voltage range and relation

It is important that the regulator can work with the desired input and output voltages, some devices have fixed output voltages, while many are adjustable. Depending on the input/output voltage relation, different topologies will be used, such as the Buck/Boost/Buck-Boost topologies.

Maximum output current

The regulator needs to be able to supply the load appropriately. Some overhead margin is recommended in order to achieve optimal product performance.

Efficiency and quiescence

The main selling point of the switching regulator is its efficiency. While an ideal regulator can convert power without losses, a real regulator will have some losses caused by factors such as internal references, operation of the switches, and dissipation caused by resistive parasitics in traces and components. The quiescent current is that which is consumed to operate the regulator.

Rectification architecture

Switching regulators are either a*synchronous* or *synchronous*, meaning that they, respectively, have an external catch diode or an internal second pass element. Typically the synchronous option improves efficiency while also reducing the area needed on the PCB. On the contrary, the asynchronous architecture is cheaper, and the external diode allows for dissipation of heat over a larger area.

Switching frequency

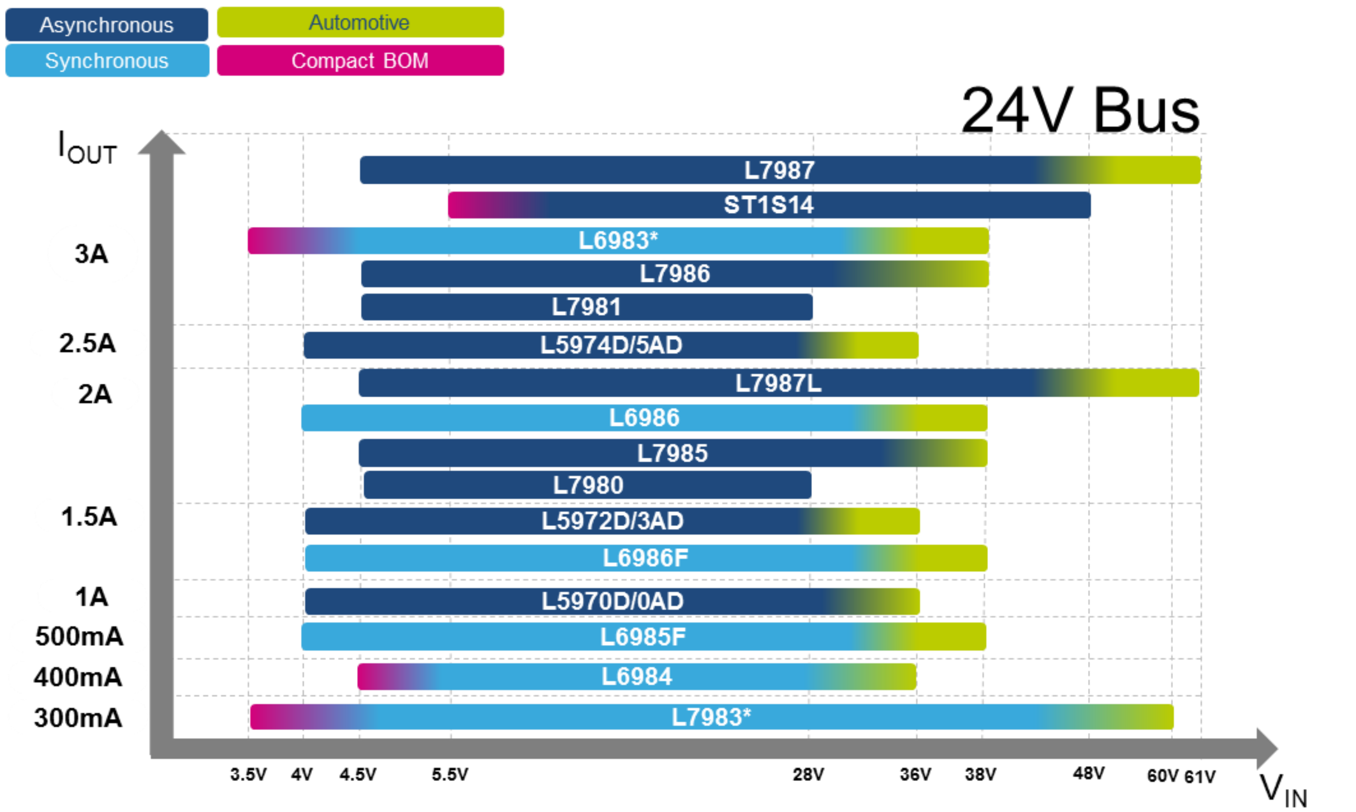
The switching frequency and efficiency are directly related, and also affect the noise, size and cost of the regulator. A higher switching frequency means that smaller inductors and other passives can be used, but it will also incur higher power consumption and increase EM radiation. While some regulators have fixed frequencies, many also allow for adjustment, allowing the designer to tailor the regulator to the application.

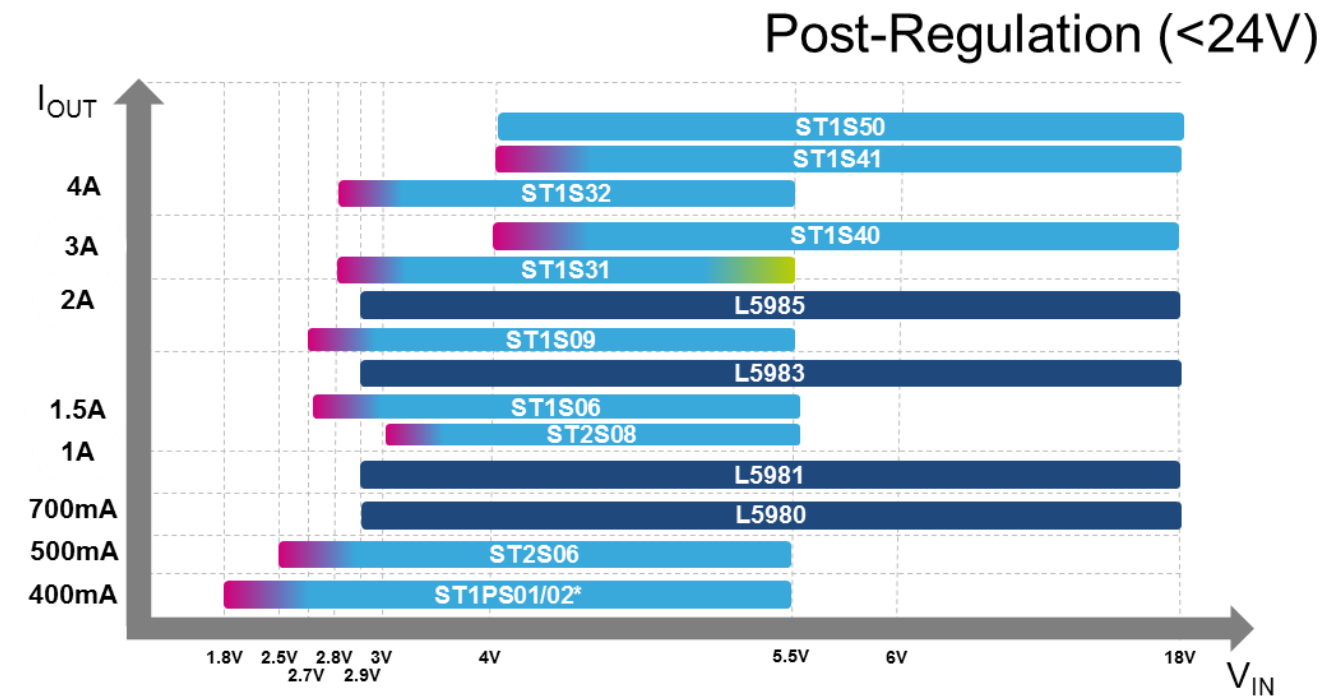
Compensation

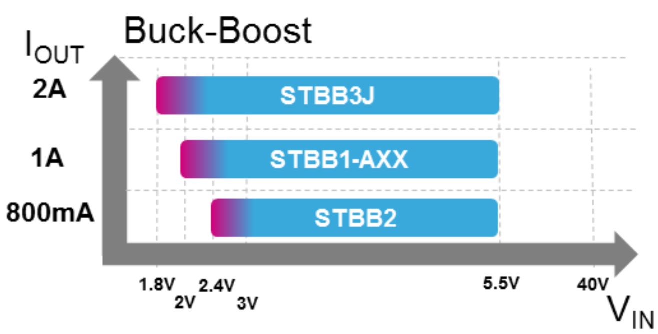
Compensation refers to the feedback and compensation networks that keep the regulator stable. For some regulators these are external and allow for customization and flexible designs, while other regulators have embedded compensation networks that contribute to easier and more compact designs.

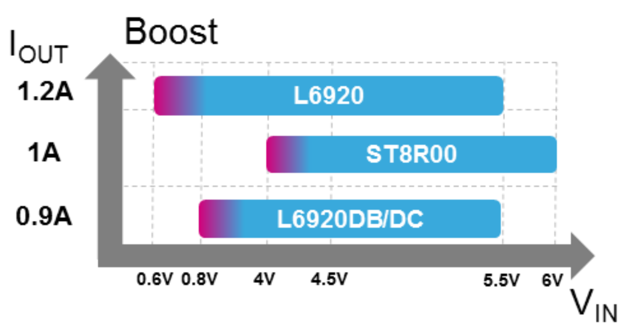
Accuracy

Accuracy describes is the variance in output voltage with respect to the desired target voltage. The overall output accuracy also includes variance caused by line and load changes.









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– Glossary

Accuracy – The maximum deviation from the specified output. Nominal accuracy can be affected by factors such as low tolerance resistors used in the feedback network. Commonly cited across temperature ranges, sometimes specified as Tolerance.

AEC-Q100 – Any integrated circuit needs to be tested for compliance with AEC-Q100 before it can be marketed as an automotive-grade device.

Buck-boost – A Buck-boost regulator is like a Buck and Boost combined; it can both step down and step up an input voltage to reach the specified output voltage.

Continuous current mode (CCM) – During CCM, the current in the output inductor is always above zero. This mode of operation simplifies stability analysis and improves noise characteristics.

Discontinuous current mode (DCM) – During DCM, the current is allowed to drop to zero. This typically occurs when the output power is low, or the output inductor has low inductance.

Enable/Inhibit (EN/INH) – Externally enabling (or disabling) the internal circuitry when the regulator is not required lowers the quiescent current and can prolong battery life.

Feedback network – Resistors are used to set the desired output voltage. Often the feedback networks also include capacitors to attenuate and amplify signals at specific frequencies (compensation).

Line Regulation – Line Regulation describes how well the regulator can maintain its intended output voltage given a change in the input voltage.

Load Regulation – Load regulation describes the regulator’s ability to maintain the specified output when the load condition changes.

Noise – Good noise figures are critical in circuits for wireless communication or that rely on high-speed clock signals.

Package – While the most obvious effect of the package sizing is the board area required, it also has a direct influence on the thermal properties.

Pass Element – The voltage regulation is performed by quickly switching a MOSFET fully on and off. This transistor is commonly referred to as the Pass Element.

Power Dissipation – When a voltage is regulated, excess power is dissipated as heat. As heat can affect the regulator and surrounding components negatively, and eventually cause a thermal shutdown or functional failure, thermal management is important.

Power Good (PG) – This signal indicates that the output is within regulation. It is useful for power-sequencing, reset triggering, and more.

PSRR – Power Supply Rejection Ratio, or a measure of the regulator’s ability to filter out noisy ripples in the input voltage. It is always specified in dB, and always over a range of frequencies.

Quiescent current – The current consumed by the regulator to operate. Lowering the quiescent current is especially important for battery-powered solutions.

Soft Start (SS) – Soft Start is a controlled gradual increase of the throughput power, which prevents large inrush currents that can overload the power supply.

Step-down – A step-down regulator converts a higher input voltage to a lower output voltage, and is commonly referred to as a Buck regulator.

Step-up – A step-up regulator converts a lower input voltage to a higher output voltage, and is commonly referred to as a Boost regulator

Switching frequency – A measure of how quickly the Pass Element is turned on and off. A higher switching frequency allows for smaller passive components, but also increases consumption and emissions.

Thermal shutdown – A protective function that shuts down the device to prevent damage from overheating.

Transient response – A description of the regulator’s ability to resist changes in the input and output voltages. See Line Regulation and Load Regulation.

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