An Introduction to MPS's Boost, Buck, and Buck-Boost Converters

Introduction

Converters are one of the most simplistic and necessary devices in modern electronics. As their name implies, converters are meant to convert a given value to a target value. This functionality is vital for any system where connected devices may not have specifications that perfectly match one another, and they can be implemented in smartphones, smart trackers that can quickly communicate location, and power banks that can charge devices on the go.

This article will focus on DC/DC converters that convert a device's input voltage (V_{IN}) to a target output voltage (V_{OUT}). However, there are also converters of increasing complexity, such as those that convert analog and digital values. This article will describe the key factors of three basic converters — boost, buck, and buck-boost — while introducing innovative MPS converters that can be implemented in a wide array of applications.

Basic Converter Components

Before describing the differences between these three converter types, it is important to recognize that boost converters, buck converters, and buck-boost converters are similar in many ways. As mentioned before, these three converters regulate V_{IN} to a particular V_{OUT}, but they also utilize common components to complete the solution. A few of these components are described below:

- Inductors: Inductors are passive electronic components that store energy when current flows through them. Inductors are typically used to both store and release energy, which can stabilize V_{OUT} as V_{IN} fluctuates.
- Switching transistors: Switching transistors (also called switches) control current flow by turning on and off; when they are off, current does not flow, while current flows when they are on. This current regulation enables V_{OUT} control. Switches are recommended for applications that require precise current flow.
- Diodes: Diode are protective devices that force current to move in a single direction, which prevents reverse-voltage conditions and ensures that current flows through the circuit from the input to the output.
- Capacitors: Capacitors store and release electrical energy in an electric field. Unlike inductors, capacitors do not store current, and they only store then discharge electrical energy. Both input capacitors and output capacitors can be used within a circuit to stabilize V_{IN} and V_{OUT}. They also minimize voltage ripples, which are instances during which V_{OUT} or V_{IN} suddenly rises or falls.

Figure 1 shows a simplified DC/DC converter circuit. This example includes a power source (E), inductor (L), switch (S), diode (D), and capacitor (C), but many converter diagrams are more complex and have additional components.

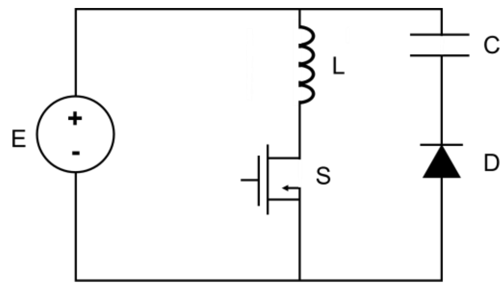

Figure 1: Simplified Circuit

All three basic converter types can operate synchronously or asynchronously. For synchronous rectification, a metal–oxide–semiconductor field-effect transistor (MOSFET) is typically used to control current flow, while asynchronous rectification uses at least one passive diode. Asynchronous converters are less efficient due to power loss across the external diode, but they are more cost-effective. Choose a synchronous converter or asynchronous converter based on the end application requirements.

Boost Converters

Boost converters, which are also known as step-up converters, are DC/DC converters that increase V_{IN} to a higher V_{OUT}. To raise the voltage, boost converters draw power from a source to supply power to the succeeding device; otherwise, the system would fail. Boost converters can be utilized in a varity of applications, including:

- Battery-powered devices: Devices that use batteries (e.g. smartphones and LED flashlights) can benefit from boost converters, since the converter maintains a consistent voltage while the battery voltage drops.
- Telecommunications: Similar to battery-powered devices, telecommunication applications use boost converters to provide stable output voltage from lower input voltages. Boost converters can be utilized in base stations and help radio frequency (RF) transmitters operate reliably, with these transmitters including RF remote controls.

Figure 2 shows a standard boost converter topology. In this figure, the magnetic energy from the inductor (L) transfers energy from the lower voltage source (V_{IN}) to a higher voltage source for V_{OUT}. A switch (S) is turned on to connect the inductor to the power supply (E). E forces the inductor current (I_L) to rise so that it can charge V_{IN}.

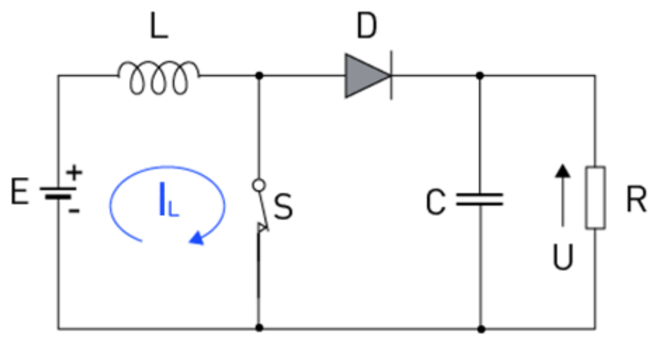

Figure 2: Boost Converter Topology

MPS Boost Converter Example

The MP28600 is synchronous boost converter with an ultra-low quiescent current (I_Q), which makes it well-suited for smoke and heat detectors, fitness machines, and IR contactless thermometers by increasing the time between charging. This device can start at an incredibly low 0.7V V_{IN} then work down to a 0.1V V_{IN} after start-up, which allows for continuous operation in the event of voltage sags.

In addition, the MP28600 features a unique down mode, which regulates V_{OUT} to its target value, even when V_{IN} exceeds V_{OUT}. This feature, typically reserved for buck or buck-boost converters, lends flexibility to the design and enables the device to work in conditions that would typically be suboptimal for boost converters.

The MP28600 can be used in wearable applications because of its extremely low power consumption when in standby mode. The MP28600 can work with the MPL-AT2512-3R3, a 3.3μH inductor, to complete the overall solution. It also provides thermal shutdown to prevent the device from overheating and damaging itself and nearby components.

Buck Converters

Buck converters, which are also called step-down converters, have the opposite function of boost converters, in that they take a higher V_{IN} and reduce it to a lower V_{OUT}. This is crucial in systems where one device might output a voltage that is too high for a receiving device. A buck converter prevents over-voltage conditions that could result in power failures. Applications that use buck converters include:

- Automotive (electric vehicles): When charging electric vehicles (EVs), buck converters step down the grid voltage to the vehicle's specified voltage to ensure safe and reliable charging.
- Computers: CPUs and GPUs use buck converters to protect from overheating and damage by delivering precise power.

Figure 3 shows a typical buck converter topology. This circuit has a power supply (E), a switch (S, typically a MOSFET), a diode (D), an LC filter and a load (R). The arrow marks the direction of current flow.

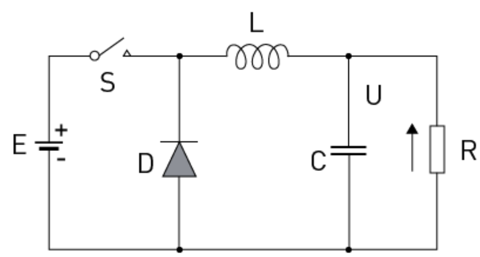

Figure 3: Buck Converter Topology

MPS Buck Converter Examples

MPS offers more than 450 buck converters to meet design needs, with V_{IN} as low as 2V and as high as 100V.

One example is the MP4581, which can accept a V_{IN} down to 8V or up to 100V. Like the MP28600, the MP4581 is optimized for use with MPS inductors, such as the MPL-AY3020-8R2 and MPL-SE6040-8R2. The devices provides constant-on-time (COT) control to provide fast transient response and stabilize the loop. An external resistor can be used to set the switching frequency (f_{SW}).

The MP4581 has a V_{OUT} range of 1V to 30V. Paired with its wide V_{IN} range, this buck converter can be used in a myriad of applications. For example, the MP4581 can complete an e-bike solution along with a digital isolator like the MP27631 and a power module like the MIE1W0505BGLVH. Its high-efficiency operation also makes it ideal for low-voltage energy storage that can be used to provide power in the event of a power outage, and power tools that can be used to both personal and industrial projects.

The MP4581 provides over-current protection (OCP) and short-circuit protection (SCP) to prevent current runaway.

Buck-Boost Converters

Buck-boost converters can act as both boost converters and buck converters by regulating V_{IN} to be above, below, or even equal to V_{OUT} as needed. These are highly versatile converters that are especially crucial in systems with an unpredictable V_{IN}, such as:

- Uninterruptable power supplies (UPS): A UPS requires a constant voltage to provide backup in the event the main power fails. They can lower V_{IN} during a voltage spike, and they can also raise V_{IN} when there is a voltage sag so that V_{OUT} does not change.
- Portable electronics: Many handheld devices like GPS trackers have voltage fluctuations that could result in a power failure if V_{IN} cannot be quickly regulated to the target V_{OUT}.

Figure 4 shows a buck-boost topology, which looks similar to both a boost converter and a buck converter's topology. Like a boost converter, the power source (E) charges the inductor (L), and current flow is controlled by the switch (S), which is placed similarly to a buck converter.

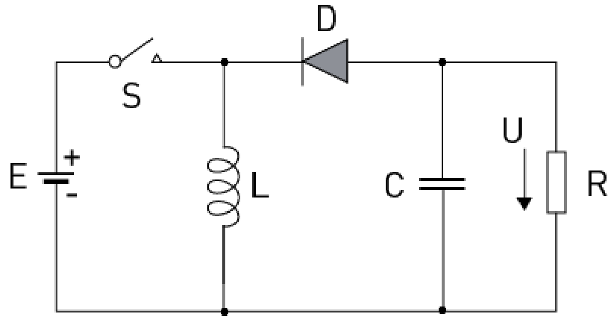

Figure 4: Buck-Boost Topology

MPS Buck-Boost Converter Example

The MP4248 is a configurable buck-boost converter with two integrated low-side MOSFETs (LS-FETs) and integrated high-side MOSFET (HS-FET) in a tiny QFN-20 (3mmx5mm) package. The V_{IN} range is between 3.6V and 36V, while its V_{OUT} range is between 1V and 36V with 1% accuracy. The MP4248 can be used in USB power delivery (PD) applications and meets USB-PD 3.1 EPR AVS and PPS specifications.

Because it can deliver output power (P_{OUT}) up to 100W, the MP4248 is recommended for applications including electrocardiograms and power banks.

The MP4248 can be configured via the I^2C interface for additional parameter flexibility, such as the reference voltage (V_{REF}) and f_{SW}. Protections include over-voltage protection (OVP), thermal shutdown, and constant-current (CC) limiting.

Conclusion

Boost converters, buck converters, and buck-boost converters are relatively similar devices that have completely different functions. While boost converters (such as the MP28600) raise V_{IN} to a higher V_{OUT}, buck converters (such as MP4581) reduce V_{IN} to a lower V_{OUT}, while buck-boost converters (such as MP4248) are able to flexibly adjust V_{IN} as needed to meet the target V_{OUT}.

This article introduced the basic differences and applications for these three converters while also introducing some of their similarities, such as general topology, necessary external components, and even applications in which they can be used.

MPS offers more than 500 converters for an even wider range of applications. Check out our robust catalog of boost converters, buck converters, and buck-boost converters that can be used in fitness machines, low-voltage energy storage, and electrocardiograms, among other applications.