



Bourns Technology Enables Efficient and Compact DC-DC Converter Design

WHITE PAPER

BACKGROUND

Power management has evolved as electronics continually are miniaturized and deployed in an increasing array of applications. Since there are so many types of specialized circuits with unique operating voltages, it has become commonplace to provide a single external voltage level to a device and to rely on conversion within the device to provide the appropriate power levels to each load. For example, a device may have nine loads and require five voltages, which can be provided by incorporating DC-DC converters. Bourns offers a variety of inductors, diodes, and resistors that accurately meet the requirements of the DC-DC converter design while addressing the need for smaller, higher power devices. This article will introduce these three technologies and their role in DC-DC converters.

DC-DC CONVERTER BASICS

DC-DC converters are used in applications including computers, electronic equipment, and a range of embedded computing platforms. An ideal DC-DC converter will be energy efficient for higher power conversion, offer design flexibility, utilize small components, and exhibit a low temperature rise. DC-DC converters employ a transistor that switches on and off to manipulate the flow of current in the circuit, thus changing the DC voltage level at the input to another at the output. A non-isolating converter, where the output and input have no electrical isolation, is used in applications when voltage is stepped up or stepped down by a ratio less than 4:1, such as for a 24 V to 12 V voltage reducer or a 1.5 V to 5 V voltage step. Converters inevitably experience loss due to resistance in the inductor windings, eddy current and hysteresis losses in the inductor, the resistance of the transistor in the on state, and forward voltage drop in the rectifier diodes.



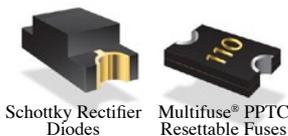
Shielded/Unshielded Inductors



Dual-Winding Shielded Inductors



Current Sense Chip Resistors



Schottky Rectifier Diodes Multifuse® PPTC Resettable Fuses



LED Shunt Protectors



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MARKET DRIVERS

Efficiency, operating frequency, and size are the major market drivers for DC-DC converters. An efficient DC-DC converter wastes only a minimal amount of incoming DC energy. Converters typically experience loss due to resistance in the inductor windings, core loss in the inductor, the resistance of the transistor in the on state, and forward voltage drop in the diodes. This varies based on the frequency of operation, which is high for most modern DC-DC converters compared with 50-60 Hz AC power mains. Higher frequency converters allow smaller inductors, transformers, and capacitors to be used for the same power level, thus reducing the size, cost and material in the converter. However, some inductor materials have frequency limitations. Beyond a few hundred kHz, iron cannot be used as an inductor because its high core loss is too great. Instead, a ferrite material is used to ensure efficient operation at hundreds of kHz. As DC-DC converters demand smaller and more efficient solutions, new inductor materials are being developed that allow operation up to the MHz range and may go even higher.

INDUCTORS IN ACTION

Inductors are found in nearly every DC-DC conversion circuit. An inductor is an energy storage component that stores energy in the form of magnetic flux. Within the DC-DC converter it limits the rate at which the current flows through the power switch or transistor. The main market drivers for inductors are performance, lead-free construction, and RoHS compliance*. In terms of performance, inductors should have low loss and operate with high efficiency at high frequencies. The two main styles of inductors are shielded and unshielded. The shielded option is suited for designs with high AC ripple current, where radiation is a concern, in high density board assembly with low noise interference requirements, and where lower DC resistance is required for low energy consumption, especially in battery powered devices. Unshielded inductors are used where noise interference is not a concern and where cost-effectiveness is a top priority.

The new cost-effective Bourns® Semi-shielded Power Inductor SRN Series has a semi-shielded package and offers shielding performance between the shielded and unshielded inductor styles. Bourns® SRN Series is the newest inductor technology offered by Bourns. It is ideal for use in DC-DC converters for computers, mobile electronics, data storage, and consumer electronics. The percent coupling and signal coupling of Bourns® SRN Series inductors are in between that for shielded and unshielded inductors with about half the magnetic flux coupling of the unshielded part. Bourns® SRN Series is a good middle ground for magnetic coupling and, at 15-20 % cost savings over shielded inductors, for cost-effectiveness as well.



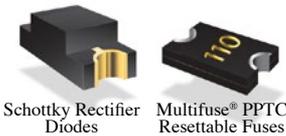
Shielded/Unshielded Inductors



Dual-Winding Shielded Inductors



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Table 1. Characteristics of Inductor Styles

Inductor Style	Size	Radiation	Number of Turns	Cost
Shielded	Largest	Low	Low	Highest
Unshielded	Smallest	High	High	Lowest
Semi-shielded	Middle	Middle	Middle	Middle



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STYLES OF DC-DC CONVERTERS

There are several styles of DC-DC converters including buck, boost, buck-boost, and Sepic. Each uses five main components including a diode (D), inductor (L), resistor (R), transistor (Q), and output filter capacitor (C) as shown in figures 1-4. The transistor is switched on and off at a fixed rate, also called the converter operating frequency. A control circuit is used to monitor the output voltage and maintains the desired voltage level by varying the percentage of time that the switch is on and off during each cycle. The configuration for each of the four converter styles shown is altered slightly in order to produce the desired voltage at the output.

Buck converters typically reduce the input voltage to lower output levels for use in the device. When the transistor is on, current begins flowing from the input source through Q and L, and then into C and the load. The magnetic field in L builds up and the voltage drop across L opposes or 'bucks' part of the input voltage. When the transistor is off, the inductor opposes any drop in current and supplies current to the load itself through the diode.

Boost converters instead provide an output voltage that is greater than the input voltage. When the transistor is on, energy is stored in the inductor's magnetic field. There is no current through the diode, so the load current is supplied by the charge in C in this state. When the transistor is off, the inductor opposes any drop in current and its voltage adds to the source voltage.

Buck-Boost converters allow the voltage to be stepped either up or down based on the duty cycle as shown in figure 3. When the transistor is on, current flows through L, storing energy in its magnetic field. Since the diode is connected in reverse bias, no current can flow through D to the load. Instead the capacitor must supply the load current. When the transistor is off, L is disconnected from the source and opposes any tendency for the current to drop. This generates a voltage that puts the diode in forward bias, allowing current to flow into the load and recharge C. Inductors commonly found in buck, boost, and buck-boost converters are Bourns® Models RLB, SRR, SRU, SDR, and SRN Series inductors.

The fourth type is a Sepic converter, which uses a coupled inductor to increase or maintain the input voltage at the output as shown in figure 4. When the transistor is on, current flows in L1 and negatively in L2. When the transistor is off, current from L1 and L2 both flow into the load and charge C2. The coupled inductor L1/L2 is often Bourns® Models SRF0703, SRF1260, or SRF1280.



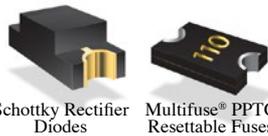
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STYLES OF DC-DC CONVERTERS *(Continued)*



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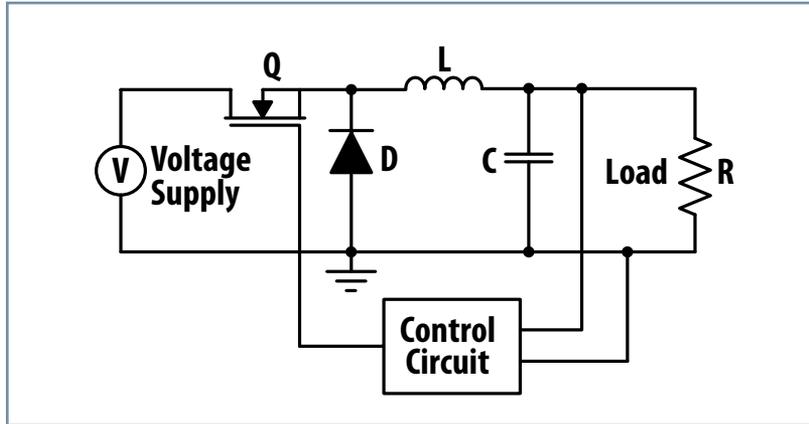


Figure 1. | Buck Converter

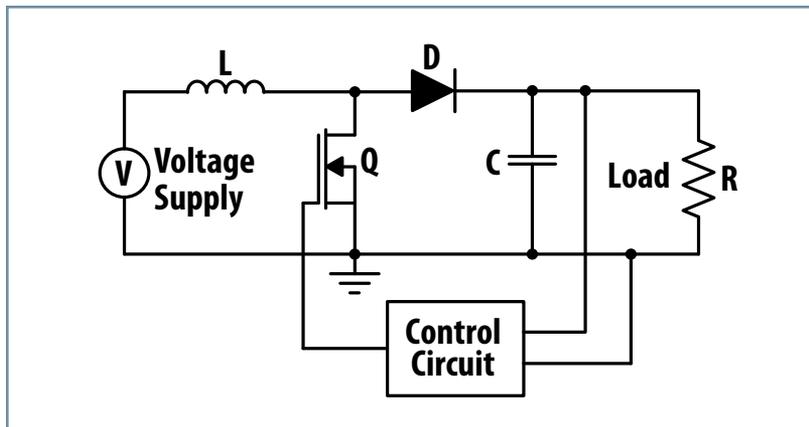


Figure 2. | Boost Converter



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STYLES OF DC-DC CONVERTERS (Continued)



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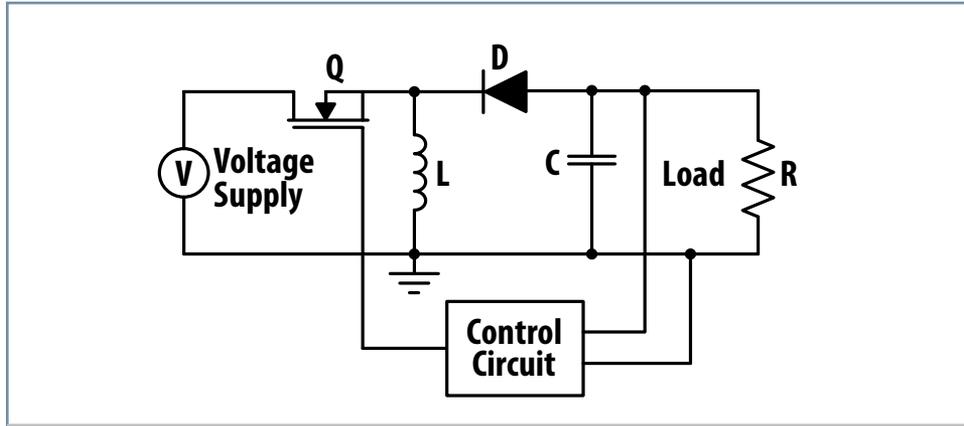


Figure 3. | Buck-Boost Converter

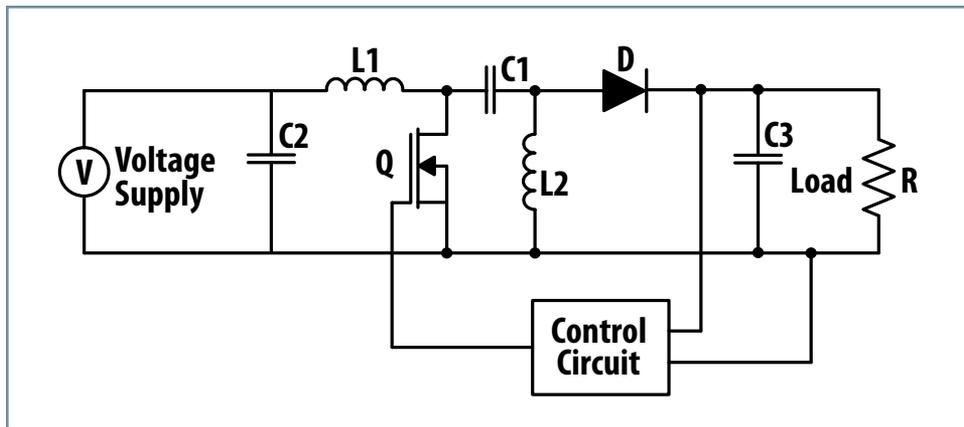


Figure 4. | Sepic Converter



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SELECTING THE RIGHT COMPONENTS

When choosing an inductor, the first consideration is whether to use an unshielded or shielded package. As a compromise, the semi-shielded Bourns® SRN Series is available with an expanding offering. A variety of winding technologies provides for flexibility in design. Flat wire inductors make efficient use of space, offer lower DC resistance, and are capable of withstanding high current. An example of an application that would be suited for flat wire inductors is a laptop computer. This battery-operated computer must be capable of handling surges such as those created when the hard drive begins spinning. Set-top boxes, on the other hand, have relatively stable operating current and are ideal for Bourns® SRN Series. Further flexibility is provided for board designers with Bourns® SRU Series since a single footprint can accommodate a range of inductance values. In this series, the height rather than the footprint of the component varies with inductance value. Therefore, a change in the required inductor would not necessitate redesigning the board. This flexibility saves time and money by protecting against setbacks from redesign. Additional considerations in selecting an inductor include performance and cost.

The most important factors in diode selection are its recovery time, current rating, forward voltage drop, and packaging. Especially in higher frequency converters, it is essential for the diode to act instantly. A diode with a low forward voltage drop will contribute to low power drop and help maintain efficiency in the converter. The Schottky diode is the most popular choice of diode in DC-DC converters since its forward voltage drop is significantly lower than a silicon diode, thus wasting less power. Bourns offers a range of Schottky diodes that switch fast and that have low voltage drop. Bourns offers chips like Model CD1206 rather than MELF or mini-MELF. The construction of Bourns® Schottky Rectifier Diodes helps them switch quickly and react in harmony with the switching in the DC-DC converter circuit.

Finally, current sense resistors are an integral part of the DC-DC conversion circuit. Current sense resistors are used for precise control of current. A resistor is chosen for its tolerance, Temperature Coefficient of Resistance (TCR), power rating, and size. Bourns® Current Sense Resistors commonly have 1% tolerance, and components with a tighter tolerance are available. TCR is an important factor in resistor selection since the resistance of the component will vary with shifts in temperature. Any change in resistance will affect the voltage output and the current. For instance, in LED applications the current is related to the intensity of the emitted light. Compact components are highly sought out for most designs. Common types of current sense resistors used in these designs are surface mount metal strip chip resistors (Bourns® CRA and CRF Series), and thick film resistors (Bourns® CRM Series). Two products that stand out in the Bourns portfolio are the 3 W Model CRA2512 and the 1 W Model CRF1206 since they have a small form factor and high-power ratings.



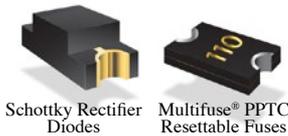
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Table 2. Current Sense Resistors

Series	Package	TCR	Resistance	Power
CRA/CRF	2010-2512	±75 to ±200 ppm	0.001-0.1 Ohms	1-3 W
CRM	0805-2512	±90 ppm	0.047-1 MOhm	0.5-2 W



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DC-DC CONVERTERS IN LED LIGHTING APPLICATIONS

An application with growing popularity that uses DC-DC conversion is LED lighting. The solution shown in figure 5 features a constant current supply and current sense resistor.

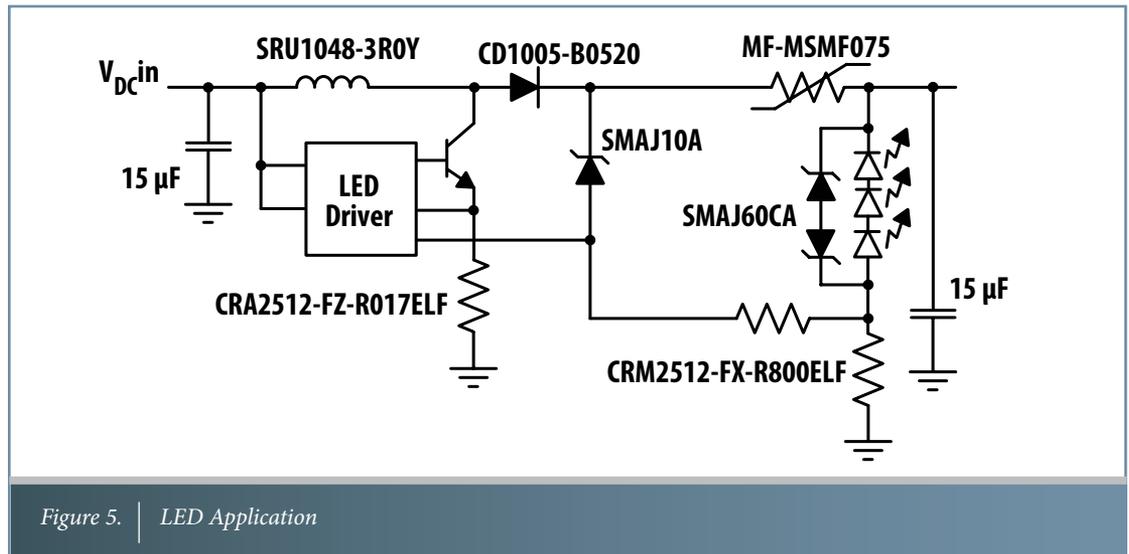
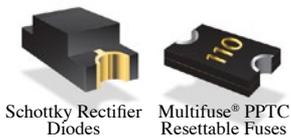


Figure 5. LED Application

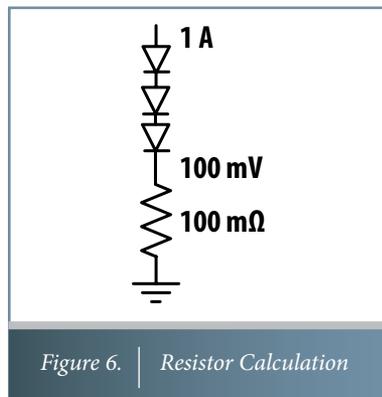


Figure 6. Resistor Calculation

Calculating the appropriate current sense resistor can be done with Ohm's Law. For example, to determine the requirements for the resistor in figure 6, the resistance is first calculated as:

$$R = V / I = 0.1 / 1 = 0.1 \Omega = 100 \text{ m}\Omega$$

Then the power requirement is calculated as:

$$P = V * I = 0.1 * 1 = 100 \text{ mW}$$

With these parameters, a part can be chosen from Bourns product data sheets. One suitable part in this case is the Bourns® Model CRM0805-Fx-R100ELF, which offers a power rating of 0.25 W, tolerance of 1 %, and TCR of ± 100 ppm.

In addition to the inductor, diode, and resistor technologies discussed, there are optional components to enhance the performance of the application. For example, Bourns® Model MF-MSMF075 Polymer Positive Temperature Coefficient (PPTC) devices can be used to sense overtemperature conditions in an LED circuit, as shown in figure 5. If the PTC senses a temperature above the safe operating range, this PTC would go into its high resistance protective state, essentially turning off the LEDs in order to preserve their life. Separately, a Bourns® Open LED Shunt Protector (LSP) can be placed in parallel with each LED. An open LED will cause a complete LED series string to go dark. The LSP device is designed to make the open LED failure mode tolerable, thus helping to ensure the integrity of the LED application.



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WHY BOURNS?

With decades of experience as a top-rated supplier, there are numerous advantages to working with Bourns for power management solutions, specifically with DC-DC converters. Bourns meets the needs of its customers with its large portfolio of power inductors, resistors, and Schottky diodes. Bourns® products are available for sampling and purchase through its broad distribution sales channels. If design and manufacturing are done in different locations, the identical product is available globally for installation in the design. In order to become familiar with a specific component or series, Bourns has design kits available. When minor modification to parts is necessary to meet the requirements of a given application, Bourns can work with its customers to customize even low component volumes.

With an exceptional portfolio of components, Bourns is a one-stop source for DC-DC converter and power management solutions. The flexibility offered by its components, such as the Models SRU and SRN Series Inductors, address customers' needs for cost-effectiveness, compact size, and efficiency. As a leader in the industry, Bourns offers some of the best components for power management designs. In addition to components for DC-DC converters, Bourns has an array of products such as Multifuse® PPTC and LSP products that can change the way LED designs are implemented and protected. Bourns is committed to working closely with and making the design process as easy as possible for its customers.

REFERENCES

Additional information about Bourns® products and applications can be found online at:

www.bourns.com

*RoHS Directive 2002/95/EC Jan. 27, 2003 including annex and RoHS Recast 2011/65/EU June 8, 2011.

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