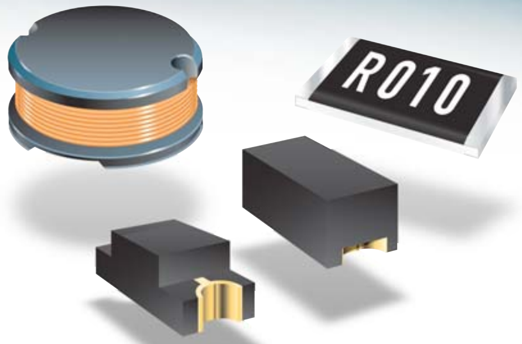
APPLICATION NOTE

Reliable Electronic Solutions



Networks Application Note

Designer's Guide to Chip Resistors, Chip Diodes, & Power Chokes For Power Supplies & DC-DC Converters

Industry:

Telecommunication, Computer, Industrial, Automotive

Application:

DC-DC Converters in Power Supplies

Statement of the Problem:

Designers of electronic systems are challenged to provide circuits with improved efficiency and the ability to handle greater currents and higher voltages while reducing current leakage and decreasing the board space required for these circuits. At the same time, purchasing groups strive to reduce the list of suppliers on the approved vendor list and to ally with strategic suppliers focused on meeting their global requirements.

Bourns offers a range of passive components for the designer of linear and switched mode power supplies. Chip resistors, chip diodes, and inductors are just three of these product lines. Further, Bourns is a global supplier of components working with companies throughout the world.

The Design Challenge:
The DC-DC converter is an integral element of power supplies. Low-value current-sense resistors, diodes and inductors are three associated components whose correct selection will optimize performance.

The principle of operation of a DC-DC converter is shown in *Figure 1*. In its most basic form, the circuit uses a capacitor and an inductor as energy storage elements to transfer energy from input to output in discrete packets. Feedback circuitry regulates the energy transfer to maintain a constant voltage within the load limits of the circuit.

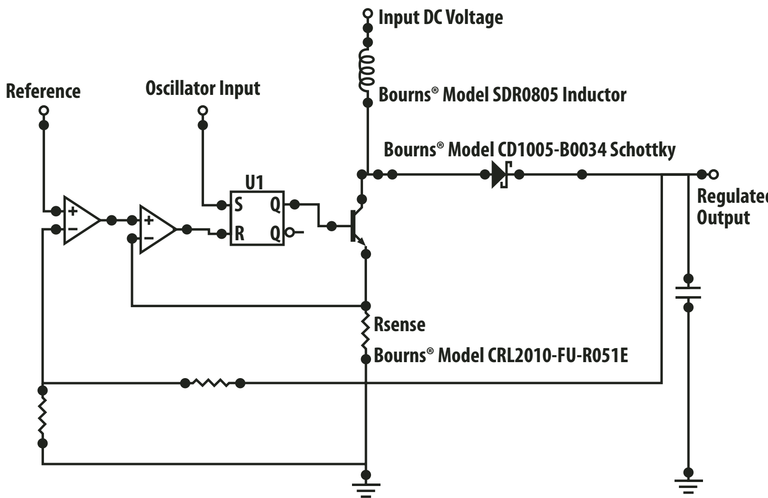


Figure 1: Schematic of a DC-DC Converter

In *Figure 1*, the control technique is a peak inductor current limit. As soon as the output voltage goes out of regulation, the switch (transistor) turns on until the current reaches the programmed current limit, set with a low ohmic resistor (Bourns type CRL) in the inductor (Bourns type SDR) current path. The Schottky diode (Bourns type CD) prevents the capacitor from discharging through the switch to ground. When the inductor current reaches the programmed limit, the switch turns off for a time constant. At the end of the feedback constant, the feedback circuit compares Vout to the regulation voltage and either turns the switch on again (if Vout remains out of regulation) or holds the switch off until Vout falls out of regulation.

Solution:

Low Ohmic Chip Resistors

The sensing voltage, (Vsense), is used to determine the inductor current, given by the following equation:

Vsense = Io x R-sense

Typically Vsense will be set to 100 mV to save power and at the same time keep the level high enough above the noise. To sense a 2A average output current, for example, R-sense must be
100 mV/2 A = 50 mW.

The amount of ripple voltage allowed at the output-regulated voltage will determine the allowable error of the resistance value required. Therefore, as the precision of the voltage increases, the allowable error of the resistance value decreases.

The two most significant contributors to error of a resistor's value are initial tolerance and temperature coefficient of resistance (TCR). Initial tolerance is the accuracy of the resistance value as supplied by the manufacturer. Commonly available values have an initial tolerance of 1 % or 5 %.

TCR causes the value of the resistance to vary with change in temperature. The change in temperature of the resistor can occur from two causes: 1) the change in ambient temperature and 2) self-heating due to power dissipation of the resistor. The ambient temperature can vary due to causes such as the heating of a PC board by components near the resistor or the increase or decrease of the temperature of the air around the resistor.

Self-heating occurs as power is dissipated by the resistor in response to current flowing through the resistor. Resistors have Derating Curves from which their self-heating may be determined. For example, Bourns® CRL 2010 device has a power rating of 0.5 watt at 70°C, derating to zero watts at +125 °C. The self-heating may be determined by the equation:

$$\textit{Rate of self-heating} = \frac{(125\ °C - 70\ °C)}{(\text{Power rating at } +70\ °C) - (\text{Power rating at } +125\ °C)}$$

For the CRL2010, the self-heating rate is (55 °C / 0.50 watt) = 110 °C per watt.

Two amps flowing through a 51 mW resistance creates 0.2 watts. In the case of a CRL2010, the application of 0.2 watts will create a self-heating of 22 °C (0.2 watts x 110 °C/watt).

If a CRL2010-FW-R051E (51 mW, 1 %, TCR = ±200 PPM/°C) is used in an application in which the maximum error can be ±5 %, and the operating temperature is 0 °C to +70 °C, will the CRL2010-FW-R051E remain within the allowable error? Again, the three sources of error are: Initial tolerance, TCR error due to change in ambient temperature and TCR error due to self-heating.

A. Initial tolerance = 1.0 %

B. TCR Error due to ambient temperature: (70 °C –25 °C) x 200 PPM/°C = 11000 PPM = 1.1 %

C. TCR Error due to self-heating: 110 °C/watt x 0.2 watt x 200 PPM/°C = 4400 PPM = 0.44 %

Maximum error = 1.0 % + 1.1 % + 0.44 % = 2.54 %

Therefore, the CRL2010-FW-R051E would produce a worst-case error of almost half of the desired amount.

As you can see, it is straightforward to calculate the error budget of a resistor when TCR is given and self-heating has been calculated.

The CRL series from Bourns are thick-film chip resistors ranging from 0603 (0.06 x 0.03 inch) to 2512 (0.25 x 0.12 inch) in size, and from 0.01 W to 9.10 W at 1 % and 5 % tolerances. The maximum power rating is 1 watt at 70 °C in the 2512 size package.

The table below shows a cross reference of competitors' models:

Supplier	Part Number(s)	Bourns® Compatible
Vishay	CRCW2010	CRL2010
KOA	SR732H	CRL2010
Yageo	RL2010	CRL2010

The Solution:

Chip Diode

During the “off time” of the transistor, the diode is forward biased and charges the capacitor C1. The inductor supplies the current. To improve the efficiency of the DC-DC converter, the power loss through the diode should be reduced by using a device with a minimum forward voltage (Vf). The power loss will be If x Vf. Schottky Barrier diodes, such as Bourns® CD1005 series, have lower forward voltages than PN junction diodes.

For example, CD1005-B00340 has a Vf of only 0.37 V. During the “on time” of the transistor, the diode is reverse biased and prevents the charged capacitor from discharging to ground through the transistor. The output voltage of the DC-DC converter is provided by the capacitor.

Bourns supplies a wide range of switching, Schottky, Schottky rectifier and TVS diodes for telecom, industrial, computing and automotive applications. Among the distinguishing features of Schottky barrier diodes for power supply applications are low forward voltages, flat leadless packages and lead free terminations. Furthermore, the 1005 size (1.0 mm x 0.5 mm) package can be a drop-in replacement for industry standard SOD-323 and Micro-melf packages.

The following table provides cross reference information between the Bourns® Schottky barrier diode CD1005-B00340 and other models on the market.

Supplier	Part Number(s)	Bourns® Compatible
Rohm	RB751V-40	CD1005-B00340
Panasonic	MA2J728/MA728	CD1005-B00340
Panasonic	MA2J732/MA732	CD1005-B00340
Philips	1PS76SB40	CD1005-B00340
ON-Semi	RB751V40	CD1005-B00340
GS/Vishay	SD104XWS	CD1005-B00340

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The Solution:

Inductors

When the switch closes, the input voltage is impressed across the inductor. Because the input voltage is DC, current through the inductor rises linearly with time at a rate that is linearly proportional to the input voltage divided by the inductance. Assuming a fixed inductor peak current, the inductor selection is straightforward; size the inductor core to meet the fixed limit.

Assuming an output average current of 2 A, there are several versions of the SDR0805 SMT power chokes which offer saturation currents of 6-7 A. The saturation current begins the area of non-linear performance. The power choke that is chosen should have a saturation current rating much greater than the current limit of the regulation circuit.

The inductor and capacitor also act as a low pass filter removing any harmonics introduced by high frequency switching and attenuating of the voltage ripple at the output. Generally, switching frequencies are in the kilohertz range depending on the capability of the power transistor to turn on and off at high speeds. Furthermore, high frequencies enable the use of a smaller inductor and capacitor.

The following table shows a cross reference for the SDR0805 power choke.

Supplier	Part Number(s)	Bourns® Compatible
JW Miller	PM75	SDR0805
Sumida	CD75	SDR0805
Central Tech	CTGS75	SDR0805
Dale & Vishay	IDCP-3020	SDR0805
API Delevan	PD75	SDR0805

Bourns supplies a wide range of precision low ohmic resistors, magnetic and chip diodes for power supply applications. Bourns® products include surface mount chip inductors, power chokes, chip beads, chip bead arrays, as well as radial-leaded and axial-leaded inductors. These components are used in computer, communication, instrumentation, industrial and medical applications.

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