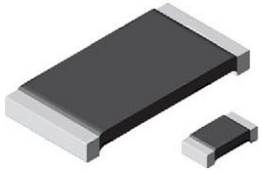
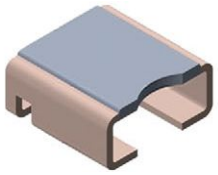
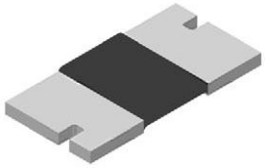
Power Metal Strip® Resistors in DC/DC Converters

By Masatake Nakazawa



DC/DC CONVERTER

DC/DC converter utilizes current sensing resistors with ultra low ohm, low TCR, tight tolerance, high current capability, and low thermal EMF.

Due to the increase in the sales of notebook PC, the demand for the DC/DC converter has been showing rapid growth because of its high energy conversion efficiency (95 % vs. 50 % to 70 % for the conventional IC regulator), and its precise current-limiting capability.

However, to assure the performance of the multiple output DC/DC converter, the current limiting voltage must be detected precisely to protect the expensive notebook PC from an overload, which in general, is due to shorts within the capacitors used in these devices.

For high energy conversion efficiency, various control ICs have been developed that utilize resistive components. (see page 2 for a typical design).

To achieve the perfect cut-off mode of the DC load current at the programmed current-limiting voltage of the control IC [(1)], a very stable and accurate sense resistor with the following characteristics is required for precise voltage comparison:

- **Very Low Ohmic Value**
  For maximizing energy conversion efficiency of the DC/DC converter the ohmic value, for minimizing power consumption at the current sense resistor, should be below 25 mΩ.
- **Tight Tolerance**
  For maximizing the current supply within the limit of acceptable current, the tolerance of the sense resistor must be ± 1 % or tighter (down to 0.1 %).
- **Low TCR**
  Since the maximum normal DC load current is in excess of 3 A, in general, the maximum ΔR due to self-heating must be as low as 1000 ppm across the ambient temperature range of 0 °C to +60 °C. Thus, a low TCR is required for current sensing.
- **Low Thermal EMF**
  For an accurate comparison between the programmed current-limiting voltage (typically, ≤ 100 mV) of the control IC and the detected voltage by the sense resistor, the error due to thermal EMF of the sense resistor must be minimized.
- **Resistance Value**
  For maximizing energy conversion efficiency of the DC/DC converter, the value of the current sense resistor is calculated according to the worst-case-low current-limiting threshold voltage of the control IC and the peak inductor current by the following equation:

$$R_S = \frac{V_L}{I_{peak}}$$

Where: R_S = sense resistor (Ω)
I_{peak} = peak inductor current [(2)] = maximum DC load current x 1.15
V_L = worst-case-low current-limiting threshold voltage

The key factor in determining the resolution (current-limiting threshold voltage) of the control IC is its semiconductor noise. Typical resistance values utilized in various control ICs are 20 mΩ to 25 mΩ.

The Vishay Dale® WSLP, WSLF, WSK2512, WSLP2726, WSK1216, WSLP3921, WSHM, and WSHP can provide extremely low values down to 1 mΩ with one resistor. This saves mounting costs and space, and improves the MTBF of the DC/DC converter. In comparison, with conventional cermet chips, 4 to 6 chips are needed to achieve very low ohmic values; and with conventional thin film chips, at least 2 chips are needed due to their low power capability.

Notes

(1) Current level is programmed by the user by choosing ohmic value of the current sense resistor
(2) For smoothing circuit

You can view the full range of Power Metal Strip® resistors, by following the link: www.vishay.com/doc?49581

APPLICATION NOTE

For technical questions, contact: ww2bresistors@vishay.com

Power Metal Strip® Resistors in DC/DC Converters

- **Terminal Construction**
  Down to 0.1 mΩ, two-terminal construction is accepted for the DC/DC converter. However, when better accuracy is required the four-terminal WSK-2512 is available. Four-terminal construction will reduce as mounted resistance tolerance variations:
  - reduce lead resistance
  - reduce TCR of copper terminal
  - reduce TCR of solder joint
- **High Current Capability**
  The maximum DC load current of an up-to-date notebook PC with high-speed CPU, large memory (D-RAM) and the CD-ROM is in excess of 3 A. In this case, the sense resistor must be able to withstand a high continuous current of at least 1.15 times the DC load current (peak inductor current) due to the effect of the inductor connected in series for smoothing the circuit. Otherwise, the DC/DC converter will fail to function due to a failed sense resistor.
- **High Temperature Capability**
  Utilization of DC/DC converters in industrial and automotive applications may expose components to higher temperature environments. The sense resistor must be capable of operating in high temperature conditions with minimal reduction (derating) of rated power.

The Vishay Dale® WSLP, WSLF, WSK2512, WSLP2726, WSK1216, WSLP3921, WSHM, and WSHP will withstand high temperatures. In comparison cermet chips have poor high temperature capability. See chart 1 for high temperature comparison.

- **TCR**
  At steady state conditions, notebook PCs generally require input currents in excess of 3 A. For accurate current limiting control by the control IC, the ΔR of the sense resistor, due to self-heating, must be low enough to ensure that the accuracy of comparison between the worst-case-low current-limiting threshold voltage of the control IC and the sense resistor voltage is ± 5 %.

To meet this standard current limit, the dynamic tolerance (no load, static resistance tolerance +% ΔR caused by self-heating + apparent % ΔR caused by thermal EMF) allocated to the sense resistor is 2 %; and, to assure 2 % tolerance of the sense resistor across the temperature range of 0 °C to +100 °C (ambient temperature + self-heating), the resistor must have a low TCR.

The Vishay Dale® WSLP, WSLF, WSK2512, WSLP2726, WSK1216, WSLP3921, WSHM, and WSHP have the lowest TCR in the industry. See chart 2 for TCR comparison.

- Vishay Dale® sense resistors provide characteristics required and demanded by DC/DC converter operations that cannot be met with other conventional cermet and thin film resistive chip components.

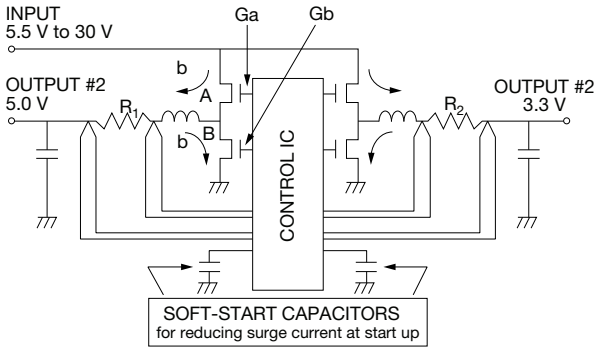
TYPICAL CONTROL IC FOR DUAL OUTPUT STEP-DOWN DC/DC CONVERTER

The two key functions of a control IC are to supply dual step-down DC potential energy and to perform accurate current limiting which is programmed by the user.

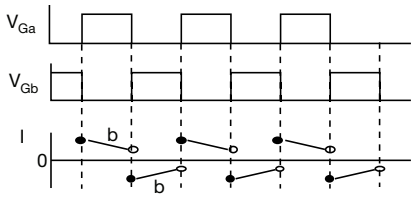
A. A voltage drop across a sense resistor connected in series between the n-channel power MOSFET and the output terminal is monitored in order to compare the worst-case low current-limiting threshold voltage of the control IC with the current level programmed by the user via sense resistor.

B. The sense resistor also functions as a part of the smoothing circuit to supply high linear DC current.

The sequence of the dual output step-down converter's steady state operations is first the gate (Ga) turns on the n-channel power MOSFET (A) and sinks the DC current into the load until the terminal voltage reaches the programmed positive voltage of the control IC, then, second, (Ga) cuts off (A), and (Gb) turns on (B), and leaks the DC current to the load until the terminal voltage reaches the programmed negative voltage, then, third (Gb) cuts off (B) • • •.



R_1 and R_2: current surge resistors
A and B: n-channel power MOSFETs



APPLICATION NOTE

Power Metal Strip® Resistors in DC/DC Converters

CHART 1
POWER METAL STRIP - HIGH TEMPERATURE CAPABILITY

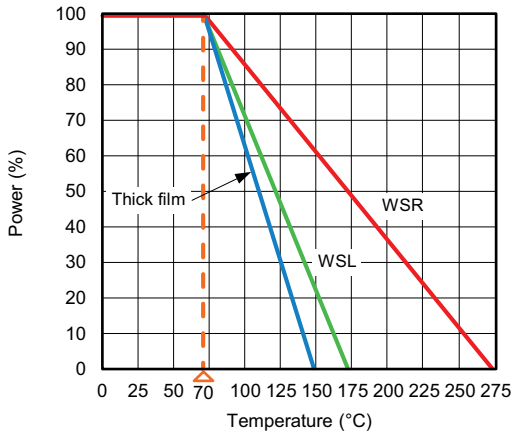
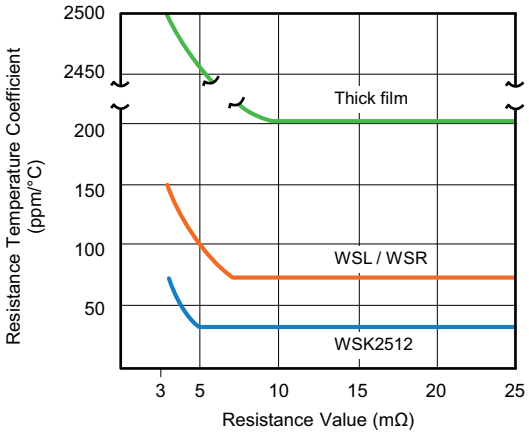


CHART 2
POWER METAL STRIP - TPC PERFORMANCE



ADDITIONAL RESOURCES

- Thermal Management for Surface-Mount Devices
  www.vishay.com/doc?30380
- Temperature Coefficient of Resistance for Current Sensing
  www.vishay.com/doc?30405
- Power Metal Strip Pulse Capability
  www.vishay.com/resistors/power-metal-strip-calculator/

APPLICATION NOTE