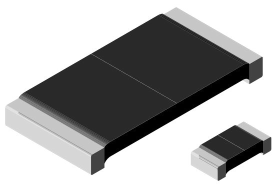
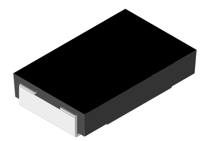
Intelligent Li-ion Rechargeable Batteries and Power Metal Strip® Resistors

By Masatake Nakazawa





INTELLIGENT LI-ION RECHARGEABLE BATTERIES

Utilize ultra-low-ohmic current sensing resistors with low TCR, tight tolerances, high withstanding surge current, and low thermal EMF.

In notebook PCs, tablet computers, mobile phones, and other portable electronics, the demand for intelligent Li-ion rechargeable batteries continues to grow because of their high energy density (approximately 1.5 times in volume and 2.0 times by weight compared to Ni-MH batteries), high output voltage (3 V to 4 V), long cycle life, and low self-discharge rate (5 % to 10 % per month).

However, to assure the performance of intelligent Li-ion rechargeable batteries, three inherent difficulties must be taken into account. First, heavy current discharge can cause degraded performance; i.e., available energy will drop down to 90 % and even 50 % of nominal energy. Second, high internal impedance causes a potential voltage drop, which makes it difficult to utilize the expected potential energy at high efficiency. Third, required constant-current and constant-voltage charging is difficult to control. To solve these difficulties, various intelligent electronic charger and monitoring circuits have been developed that utilize resistive components (see appendix).

SENSE RESISTOR: GENERAL APPLICATION

For the precise determination of charge and discharge activities of the battery, designers need very stable and accurate sense resistors with the following characteristics:

- **Very Low Ohmic Value**
  To minimize energy loss, the required ohmic values must be below 100 mΩ. Power Metal Strip® resistance values extend down to 0.2 mΩ.
- **Tight Tolerance**
  To maintain the total accuracy of the Intelligent Li-ion rechargeable batteries as close as +1 %, -0 % of the total available power capacity, the tolerance of the sense resistor must be ± 1 % or tighter.
- **Low TCR**
  Low TCR is necessary to minimize measurement error. This value is influenced by two different sources of heat: the ambient temperature and self-heating as a result of power dissipated due to current flow. As battery capacities increase, charging currents increase to achieve full capacity in the same or reduced amount of time. Low TCR becomes essential with increased charging currents.
  In general, the maximum ΔR due to self-heating must be as low as 100 ppm across the ambient temperature range of 0 °C to +40 °C. Thus, a low TCR resistor for current sensing is required. See chart 1 for TCR comparison.
- **Low Thermal EMF**
  During standby mode, a notebook PC or smartphone requires 50 mA to 100 mA to operate its DRAM, CPU, wireless, and cellular circuits. Therefore, in the standby mode, the thermal EMF of the sense resistor must be low compared to the terminal voltage generated by the current output because of the associated low signal levels.

Intelligent Li-ion Rechargeable Batteries and Power Metal Strip® Resistors

In Application - Resistance Values

To minimize the power loss and charging time, and maximize the efficiency of the potential energy of the intelligent Li-ion rechargeable batteries to the connected equipment, the ohmic value of the sense resistor must be as close to zero as possible. However, this ideal condition is unrealizable since the limited resolution of the microcomputer requires a certain level of voltage between the terminals of the sense resistor.

The key factors determining the resolution of the microcomputer are its semiconductor noise and offset voltage. Typical resistance values utilized in various microcomputers range down to 100 mΩ, 50 mΩ, 20 mΩ, 10 mΩ, and even lower. For example, the Vishay Dale Power Metal Strip WSLP (0603, 0805, 1206, 2010, 2512), WSLP3921/5931, WSR5, and WSHM offer high power ratings and extremely low values down to 0.2 mΩ in one resistor. This saves mounting costs and space, and improves the MTBF of intelligent Li-ion rechargeable batteries.

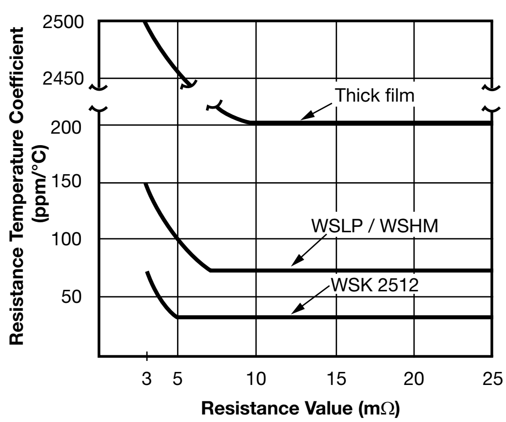
By comparison, four to six conventional cermet chips are needed to achieve very low ohmic values. And with conventional thin film chips, at least two chips are needed due to their low power capability. Additionally, the use of parallel resistors for current measurement is not as accurate as a single resistor because of the likelihood that a small resistance imbalance can exist between the branches, causing current flow in the measurement circuit.

Measurement Accuracy in the Application

Battery capacities continue to increase, but maintaining or reducing charging time requires an increased charging current. The higher charging currents can increase the stress on the Li-ion battery, and this can lead to a catastrophic failure or reduced cycle life. This makes it more important to ensure that the charging circuit is accurate and stable across temperature, because measurement errors caused by tolerance, TCR, and thermal EMF can lead to a higher than expected charging rate that increases the risk of battery failure. Some designers recommend that the total error budget should be kept to < 1 %.

The Power Metal Strip series combines high power ratings for fast charge capability, tight tolerances down to 0.1 %, low TCR down to 35 ppm, and a < 3 μV/°C thermal EMF. These characteristics enable stable and accurate current measurements through the entire temperature and power range.

CHART 1
POWER METAL STRIP - TCR PERFORMANCE



ADDITIONAL RESOURCES

- Technical Note: Components and Methods for Current Sense: www.vishay.com/doc?30304
- Power Metal Strip® Product Overview: www.vishay.com/doc?49581
- Technical Questions: ww2bresistors@vishay.com

APPLICATION NOTE

Intelligent Li-ion Rechargeable Batteries and Power Metal Strip® Resistors

APPENDIX I

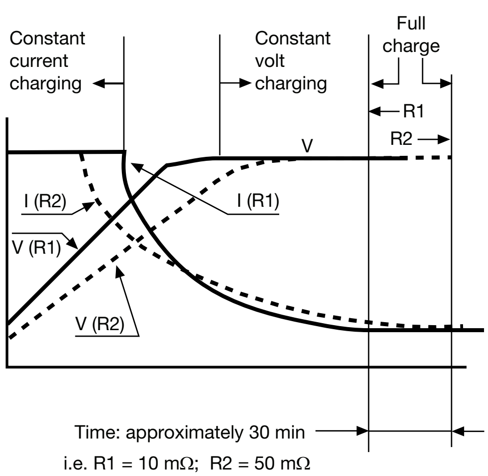
Microcomputers for intelligent Li-ion Rechargeable Batteries

Microcomputers have various functions for maintaining an accurate record of the available capacity for intelligent Li-ion rechargeable batteries:

- Monitoring a voltage drop across a sense resistor, connected in a series between the negative battery terminal and ground, to determine the charge and discharge activity of the battery.
- Applying accurate compensation for battery temperature and rate of charge or discharge and self-discharge calculations to provide available capacity information across a wide range of operating conditions.
- To automatically recalibrate the battery capacity or to learn the capacity in the course of a discharge cycle from full to empty.

In the sequence of battery charging, there is first constant current charging until the terminal voltage reaches 4.1 V or 4.2 V. Next, the battery is switched to constant voltage charging mode until a full charge is achieved, immediately after which the sequence must be stopped.

High Ohmic Values Increase the Time for Charging and Cause Large Power Losses



APPENDIX II

Intelligent Charger Circuits

There are two basic intelligent charger circuits:

- **Active Potential – Conventional Type**

  When the intelligent Li-ion rechargeable batteries are removed from the equipment, the potential between the terminals is still active (Fig. 1). In the case of a short circuit by misuse, they can be seriously damaged due to an abnormally high discharge current. Therefore, intelligent Li-ion rechargeable batteries require protective resistors or fuse resistors to cut off the abnormally high current. This inactivates the circuit.

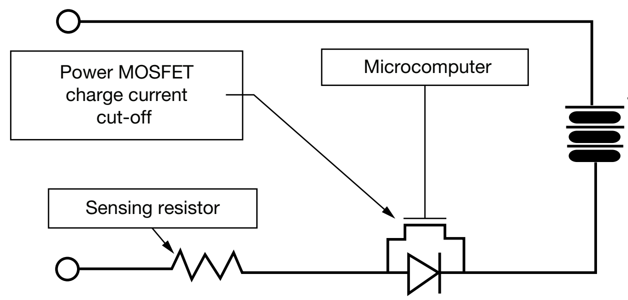


Fig. 1 - Active Potential Type (conventional)

When removed from the equipment, the potential between the terminals is still active. Thus, to protect the charging circuit, fuse resistors that burn out at high currents are used.

- **Non-Active Potential – Advanced Type**

  When the intelligent Li-ion rechargeable batteries are removed from the equipment, the potential between the terminals is zero (Fig. 2). Thus, they do not have a chance of electrical short circuit.

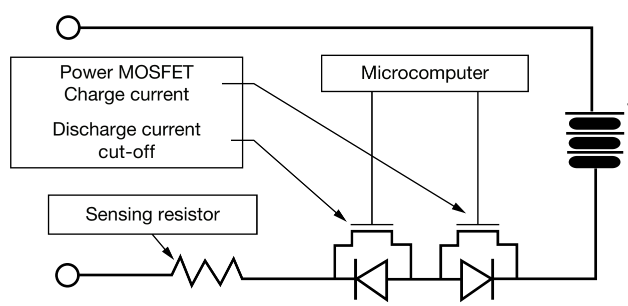


Fig. 2 - Non-Active Potential Type (advanced)

When removed from the equipment, the potential between the terminals is still zero. Thus, the Vishay Dale Power Metal Strip resistor is used.