

# *Rejutor Operating Guidelines for -55 to +125 °C Operation*

## **1 Introduction**

The **Rejutor™**, an adjustable analog micro-resistor from Microbridge Technologies, represents a major technological improvement for analog compensation. **Rejutors** are specified for operation from 0 to 70 °C, but are suitable for operation in select applications from -55 to +125 °C, or higher. Similar performance can be expected at extended temperatures but operation above 70 °C or the combination of high power and temperature may affect the TCR and drift stability. Below zero Celsius, only the TCR is affected.

Beyond the 0 °C to 70 °C temperature range two effects must be considered: Temperature coefficient of resistance (TCR) – the amount the resistance drifts as a function of temperature, and drift stability.

- 1) Over a wider temperature range, the second-order coefficient of TCR inherent in the material properties of the **Rejutor** becomes important
- 2) At temperatures greater than 70 °C, resistance drift may increase due to the elevated temperature and care should be taken to account for self-heating induced resistance drift.

Internal temperature is a function of ambient (or case) temperature, and the heat generated within the device (due to self-heating). Heat generated within the device, of course, is a function of power dissipated in the **Rejutor** during operation. Consequently the device can be used at lower power and higher ambient temperature or higher power with lower ambient temperature and maintain the same 0 to 70 °C operating parameters. This application note provides more insight on the relationship between power and internal temperature and describes the effects of exceeding these specified parameters.

As a thermally adjusted device, operation is sensitive to heat. The temperatures required to make permanent changes to the resistance of the **Rejutor** are typically greater than 400 °C. At nominal temperatures less than 70 °C, the device is very stable.

This application note provides guidelines for **Rejutor** operation, both within the power and temperature limits specified in the datasheet and beyond. Because of the inter-dependence between power and temperature, this application note should be viewed with MB-APP07, **Rejutor Power Guidelines**.

## **2 Overview**

Temperature contributes to two observable behaviors in the **Rejutor**:

- 1) Temporary resistance changes due to the **Rejutor's** TCR (Temperature Coefficient of Resistance)
- 2) Drift, or permanent changes to the resistance of the **Rejutor** after adjustment

Temperature coefficient of resistance (TCR) relates changes in resistance as a function of temperature. Low-TCR **Rejutors** are designed for zero TCR, with a tolerance of  $\pm 100$ ppm/K across the adjustment range for operation from 0 to 70 °C. The second order coefficient of TCR (TC2) becomes more important when considering operation over a wider temperature range, for example a temperature range that extends below 0 °C to above 70 °C. If the **Rejutor** was used in an application where the temperature varied from 90 °C to 110 °C, a simple first-order TCR would provide a sufficient representation of the performance of the resistance across this narrow temperature range.

Information furnished by Microbridge Technologies is believed to be accurate and reliable. However, no responsibility is assumed by Microbridge Technologies for its use, nor for any infringements of patents or other rights of third parties that may result from its use. Specifications subject to change without notice. No license is granted by implication or otherwise under any patent or patent rights of Microbridge Technologies. Trademarks and registered trademarks are the property of their respective companies.

© 2008 Microbridge Technologies, Inc. 1980 Sherbrooke St. West, Montreal, Quebec, H3H 1E8 Tel: 514-938-8089 Fax: 514-938-9089

Excursions of power and temperature beyond recommended limits may result in permanent change to the resistance of the **Rejistor** (drift), depending on the length of time and severity of the excursions. Drift specified in the datasheet is a result of accelerated life testing un-powered at 150°C. After 1000hours testing, drift plateaus at +0.5%.

### 3 Power Handling

**Rejistors** are capable of sustained operation at 5x rated power without damage. Operating within rated power and temperature maintains drift as specified in the individual datasheets.

All resistors generate heat as they dissipate power. The internal temperature of the resistive element in the **Rejistor** is a function of both power dissipation and environmental ambient (case) temperature. **Rejistor** performance is specified at rated power for operation at ambient temperatures from 0 to 70°C. Rated power varies by product family and device. **Rejistors** in the Standard (S) family are nominally 1mW per **Rejistor** but are specified with different power handling capabilities for non 1:1 ratio parts. Individual **Rejistors** within the 'L' family have different power consumption ratings, ranging from  $\frac{5}{8}$  mW to  $\frac{1}{8}$  mW.

At rated power, **Rejistors** increase the internal temperature by approximately 5C. At 5x rated power (the maximum power specification), they increase the internal temperature by 25°C

Power dissipation during normal operation (as specified in the datasheet) can result in temporary changes to the resistance of the **Rejistor**. The increase in internal temperature of the **Rejistor** due to self-heating during normal operation is insufficient to cause a permanent change to the resistance of the **Rejistor**. In cases where the **Rejistor** is adjusted in-circuit under normal (relatively constant) load, self-heating is compensated as part of the adjustment process.

Design tolerance should be sufficient so that maximum power is not exceeded over the entire anticipated adjustment range (typically the minimum adjustable resistance for the **Rejistor**)

### 4 Drift-Stability

Drift stability is a function of external temperature, applied power and time. Drift is defined as a permanent change in resistance. That is, after the **Rejistor** is subject to high power or temperature, or both, when the power is reduced and temperature returns to ambient (or room) temperature, the resistance change is still present. In this way it is different from self-heating coefficient of resistance and TCR, where the resistance change is temporary.

**Rejistor** drift is specified under normal operating conditions at less than +0.5% based on un-powered accelerated life testing at 150°C for 1000hours.

High-temperature operation increases the magnitude of and rate of resistance drift. High-temperature can be a function of increased power (which increases internal temperature) or ambient temperature or both.

The same 0.5% resistance change has been observed for standard parts operating carrying 5mW (five-times rated power) at 125°C for 1000hours. This is consistent with the local temperature at the **Rejistor** element being elevated to approximately 150°C.

Aside from temporary resistance changes due to self-heating, at these elevated ambient temperatures, and/or above rated power, the **Rejistor's** local temperature is approaching the temperatures used for long-term ageing tests (e.g. 150C, 175C). For example, if our standard-power **Rejistors** are operated at 125C with 5mW (5x rated power), then the internal temperature will be about  $125+25=150^{\circ}\text{C}$  instead of about  $125+5=130^{\circ}\text{C}$ .

It should be noted that accelerated life testing shows approximately 60% of the drift occurs within the first 100 hours. That is, after 100 hours the resistance of the **Rejistor** has drifted 60% of the way to the value observed after 1000hrs when operating within rated power and temperature.

Drift is always positive. This determinism provides several options for overall resistance management. For example, knowing drift will be positive allows users to intentionally adjust the resistance of the **Rejistor** slightly low knowing it will drift to closer to target with time, or to introduce a burn-in cycle following final adjustment.

## 4.1 Power Derating

The **Rejistor** can operate at higher temperature and maintain drift specifications if the power is derated. A sample power derating curve is shown in **Error! Reference source not found.**, below. The **Rejistor** can be operated at rated power to a case temperature of 125°C, after which power must be decreased, reaching 0mW at 130°C. Maintaining power and temperature within these bounds will maintain drift stability as specified in the datasheet.

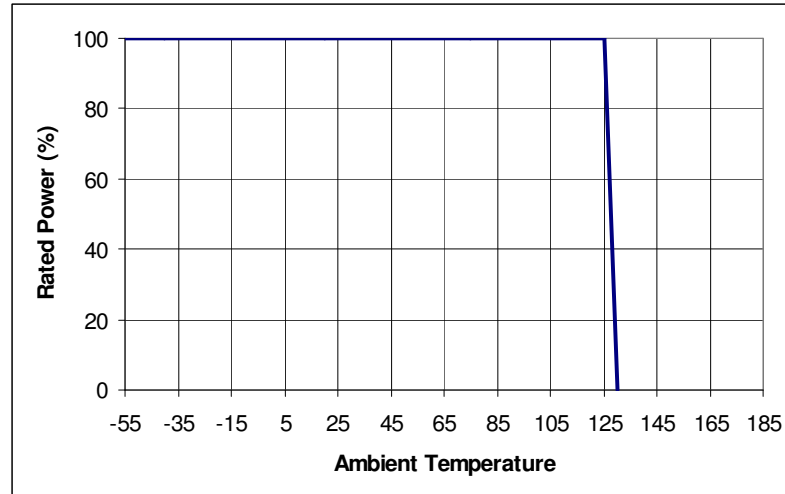


Figure 1: Power Derating to Maintain Drift Specification in datasheet

## 5 TCR Stability

Low-TCR **Rejistors** maintain absolute TCR at  $0 \pm 100 \text{ ppm/K}$  across the normal operating and adjustment ranges. Pairs of **Rejistors** (adjusted and unadjusted) within the same package maintain a relative TCR in the range of  $\pm 50 \text{ ppm/K}$ . These TCR specifications are based on linear (first-order) temperature coefficients (commonly referred to as TC1). Within the 0 to 70°C operating range, TC1 is a sufficient approximation of the temperature behavior, (the 2<sup>nd</sup>-order coefficient is  $+1 \text{ ppm/K}^2$  or less). Over the -55°C to +125°C range, the full second-order behavior of resistance vs. temperature (R vs. T) should be considered.

Figure 2, below, depicts typical 2<sup>nd</sup>-order curves of R vs. T for **Rejistors** across the -55°C to +125°C temperature range. The two curves represent the two extremes, (a) TC1 =  $+100 \text{ ppm/K}$ ; (b) TC1 =  $-100 \text{ ppm/K}$ , where TC1 is the slope of the R vs. T curve at 20°C.

If the operating temperature is relatively stable, the option exists to calibrate the **Rejistor** at the average operating temperature thereby improving precision and reducing the relative changes in the temperature range of interest. For example, if the **Rejistor** is intended to operate between -55°C and 0°C, looking at the curves in Figure 2, it can be seen that calibrating at -20°C (the average) would give a TCR-based error less than  $\pm 0.5\%$ .

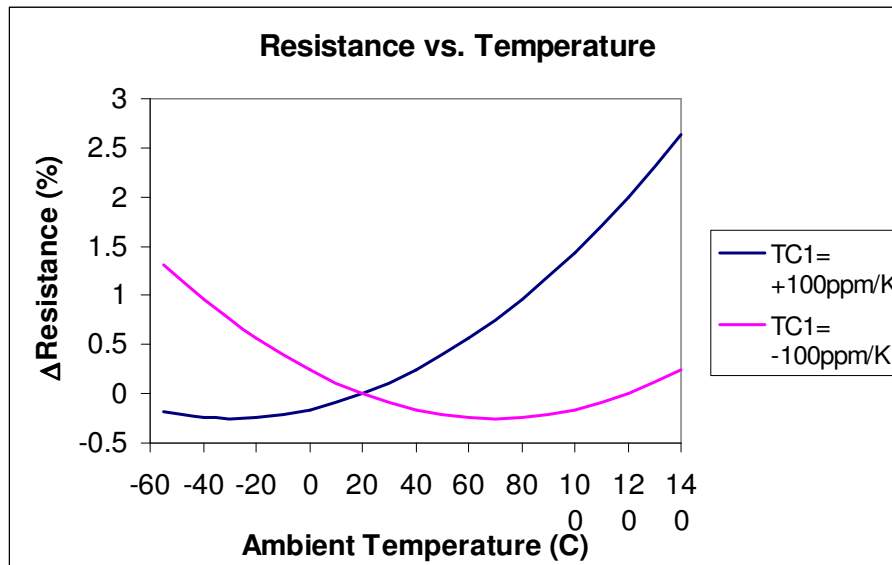


Figure 2: Resistance vs. Ambient Temperature

## 6 High Temperature Operation

**Rejutor** devices will operate up to an internal temperature beyond 175°C. The ambient temperature of packaged **Rejutors** is limited by the glass transition temperature at 160°C. If the **Rejutor** continually operates at the elevated temperature, it should also be calibrated at this temperature, which will reduce the impact of TC2.

At high temperature, the magnitude of and rate of resistance drift will increase beyond specifications in the datasheet. Please consult Microbridge for more information regarding extended high-temperature operation.

## 7 Low Temperature Operation

**Rejutors** will operate down an ambient temperature of -55°C. If the **Rejutor** continually operates at low temperature, it should also be calibrated at this temperature, which will reduce the impact of TC2.

## 8 Summary

As a thermally adjusted device, the **Rejutor** has some sensitivity to heat. Heat comes from two sources – external or ambient temperature and internal heat generated through power dissipation within the resistor. **Rejutor** drift is stable, as specified in the datasheet, in a range of -55°C to 125°C, or up to an internal temperature of 150°C (unpowered). Above an internal temperature of 150°C, magnitude of and rate of resistance drift may increase slightly beyond that specified in the datasheet.

Internal power dissipation and ambient or case temperature are directly related. Power can be increased if external temperature is decreased to maintain performance as specified in the datasheet. **Rejutors** can be operated for sustained periods when the power is five times the rated power.

When operating in a wide temperature range, such as beyond 0 to 70°C, it is important to consider 2<sup>nd</sup>-order variation of resistance with temperature (R vs. T). The second order coefficient is +1ppm/K<sup>2</sup> or less, and is insensitive to resistance adjustment. In a narrow range the simple first-order TCR would provide a sufficient representation of the performance of the **Rejutor**.

The **Rejutor** is uniquely positioned within the adjustable resistor market because it allows for operation in the -55 to +125°C range and beyond, providing the application can tolerate relatively small increases in the overall resistance of the **Rejutor** away from the value to which it was adjusted in the 0 to 70°C range. Extended temperature operation facilitates **Rejutor** use in automotive markets and other harsh environments.