MBH-273-AS1 Die
MBH-293-AS2A/B Die
High Temperature *HT-Rejustor™*

High Temperature ***HT-Rejustor*** dividers are precision-adjustable passive resistors designed for extended operating temperature range. Two types are presently available. Type 1 ***HT-Rejustors*** are designed to maintain a ±2.5% tolerance from -55°C to +230°C. Type 2 ***HT-Rejustors*** are designed to maintain a tighter tolerance, for example 0.7%, within a narrower 50°C focus temperature range. Refer to table 1.

The resistance of each ***HT-Rejustor*** in the divider can be adjusted up to 20% down from the nominal resistance (R_{nom}), in-circuit, at any temperature within the operating range. Each ***HT-Rejustor*** can be adjusted to 0.1% precision (instantaneous precision at the operating temperature during adjustment) using electrical signals. The adjustment software controls precision setting of the resistance of each resistor in the pair, for set-on-test applications.

HT-Rejustors offer excellent temperature-stability for high-temperature applications, embodied in the predictability of their normalized behavior vs. temperature ($\Delta R/R_{25C}$ vs. T curve). As ***HT-Rejustors*** are down-adjusted through their 20% adjustment range, they maintain the same $\Delta R/R_{25C}$ vs. T curve, within <1% throughout the operating temperature range.

HT-Rejustor dividers are temperature stable so that the ratio between the two resistors is predictable within +/-1% regardless of adjustment state of either ***HT-Rejustor***.

Precision resistance adjustment of each ***HT-Rejustor*** is accomplished by changing the physical properties of the resistor under control of ***Rejustor*** Calibration tools and Rejust-it software. The adjustment process is typically complete within 1-2 seconds[1]. After adjustment, the resistance and $\Delta R/R_{25C}$ vs. T behavior of the ***HT-Rejustor*** are stable.

HT-Rejustors are ideal for gain setting, offset and bias adjustment, voltage adjustment and a variety of high-precision analog applications intended for High Temperature operation. The ***HT-Rejustor*** features the lowest noise, widest bandwidth and widest operating temperature range of any adjustable resistor technology.

The ***HT-Rejustor*** is presently available in die form for evaluation.

BENEFITS

- Widest temperature operating range of any precision adjustable resistor technology
- Low relative temperature errors between a pair of ***HT-Rejustors*** on the same die
- Low absolute drift per Rejustor, very low relative drift between Rejustors on the same die
- Externally adjust or calibrate parameters on circuits or sensors at final assembly
- Adjustment process isolated from circuit allowing true in-circuit calibration
- Single chip solution to calibrate voltages, currents, offsets, gains, etc.
- No moving parts, ideal for vibration sensitive applications
- Improved reliability, dependability; dust and moisture resistance over mechanical parts
- Lowest noise and widest bandwidth of any adjustable resistor technology

ELECTRICALLY ADJUSTABLE 1:1 HIGH-TEMPERATURE RESISTOR DIVIDER

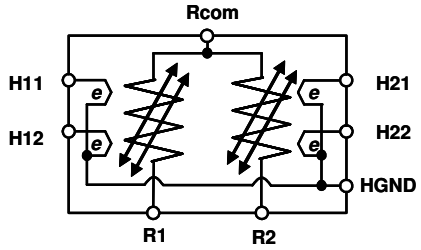

Figure 1: Functional Block Diagram

Table 1: Operating Specifications

PARAMETER	SPECIFICATION
Operating Temperature	-55 to +230°C
Adjustment Precision	0.1%
Rated power (per *HT-Rejustor*)	1mW (max)
Type 1 (MBH-273AS-1)	
Nominal resistance (R_{nom})	27KΩ
Minimum adjustable resistance	21KΩ
Resistance tolerance over -55 to +230°C range	±2.5%
Type 2 (MBH-293AS-2)	
Nominal resistance (R_{nom})	29KΩ
Minimum adjustable resistance	23KΩ
MBH-293AS- Type 2A	
Specified temperature Range	+150 to +200°C
Resistance tolerance over +150 to +200°C range	±0.7%
Resistance in specified temperature range	3% to 4.5% less than R_{25C}
MBH-293AS- Type 2B	
Specified temperature Range	+175 to +225°C
Resistance tolerance over +175 to +225°C range	±0.7%
Resistance in specified temperature range	3.5% to 5% less than R_{25C}

FEATURES

- Each Resistor is independently electrically adjustable to any value from nominal down 20%
- Bi-directional, continuous adjustment within active range
- Low relative drift over temperature
- Suitable for operation up to 230°C
- Low noise: Typ. -15dB
- Passive device requires no power during operation
- In-circuit adjustable at component, board or system level
- Available as Die

APPLICATIONS

Calibrating electronics for:

- Jet Engine monitoring instruments
- Down-hole drill sensors
- Military sensors
- Furnace and boiler sensors
- Strain gage sensors
- Vibration sensors
- Gas detectors

Table 2: RATINGS – *HT-Rejustors* -55℃ < T_A < +230℃ and rated power; unless otherwise noted.

Item	Conditions	Typical Specifications
As-manufactured resistance		30KΩ[1]
Type 1 Nominal Resistance (R_{nom})		27KΩ
Type 2 Nominal Resistance (R_{nom})		29KΩ
Adjustment range	Down from nominal	20%
Rated Power (per Rejustor)		1.0mW
Operating Temperature		-55 to +230℃
Isolation Voltage (between any pins)	Subject to power limits	80V
Tolerance of as-manufactured resistance		±10%
Tolerance of Nominal Resistance Value		±10%
Nominal Pair Matching	Unadjusted	±2%
Ratio Matching	Adjusted MBH-303-AS Type 1 MBH-293-AS Type 2A MBH-293-AS Type 2B	 ±1% ±1% ±1%
Drift Stability	High-temperature exposure for 1000hrs at 225℃	+1%

Table 3: RELIABILITY DATA

Characteristics	Test Method or Conditions	Limit
Thermal Shock/ Cycling	JESD22-A104, -65℃ to 125℃, 1000 cycles at 2 cycles/hour	+ 1.0%[2]
Overload	MIL-R-55342H Par 4.8.6 (Rated Voltage x2.5, 5sec.), Rated voltage based on rated power $V = \sqrt{PR}$	+ 0.5%[2]
High Temperature Exposure (long-term stability)	JESD22-A303 150℃, 1000hrs	+ 1.0%[2]
Humidity and Moisture Resistance	JESD22-A101, 85% RH, 85℃, 1000hrs	+ 0.8%[2]
Operational Life Test	JESD22-A108, 125℃, 1000 hrs., static operation at rated power MBH-273-AS Type 1 MBH-293-AS Type 2A MBH-293-AS Type 2B	 + 1.0%[2] + 1.0%[2] + 1.0%[2]
Shock	500G, 1ms duration, X,Y,Z axes each 5 shocks	± 0.1%
Vibration, High Frequency	Max acceleration 20G, 20~2000~20Hz, 8 min, X,Y,Z each 4 sweeps	± 0.1%

Table 4: MANUFACTURABILITY DATA

Characteristics	Test Method or Conditions
ESD Discharge	JESD22-A114, human body model weakest pin pair testing, all combinations. Class 1A, by analysis

[1] As-manufactured resistance is higher than nominal active adjustable range
[2] Where indicated, drift specifications refer to resistance drift in the positive direction. Best performance is achieved at adjustments larger than 10% down from the as-manufactured resistance.

OVERVIEW

Microbridge ***HT-Rejustors*** represent a technology revolution in resistive adjustment for precision electronic systems. Each ***HT-Rejustor*** on the divider die provides independent, precision adjustment of resistance in a continuous range for in-circuit, set-on-test adjustment of a wide variety of analog electronic circuits and systems.

Rejustors are MEMS-based passive chip-resistors, adjustable using electrical signals. After the resistance is adjusted to the appropriate value, no further action or control is required and the adjustment pins can be disconnected. Adjustment is done in-circuit using the output of the circuit-under-test for feedback. The resistance of ***HT-Rejustors*** is adjusted using Rejustor Calibration tools to null out cumulative variations and mismatches in the application circuit. Typical instantaneous adjustment precision is 0.1% or better depending on the accuracy of the measuring equipment and temperature stability during adjustment. The high-temperature performance of ***HT-Rejustors*** is such that long-term drift is under ~1% after 1000 hours at 225℃. Resistance vs. temperature curves are predictable, as shown in Figure 2 and Figure 3 with a parabolic shape.

HT-REJUSTOR TYPES OVERVIEW:

Two different types of high-temperature performance are being targeted:

Type-1 *HT-Rejustors*

Type-1 *HT-Rejustors* feature an overall resistance tolerance (including long-term drift) of better than ±2.5% over an extended temperature range of -55℃ to +230℃. They feature precision adjustment within approximately 20% resistance adjustment range down from the as-manufactured value.

These Type-1 ***HT-Rejustors*** are designed such that, at a specific elevated temperature (e.g. 200C), the resistance returns to its room-temperature value, within +/-1.0%. Pairs of these ***HT-Rejustors*** (unadjusted and adjusted) will maintain their ratio-matching within better than 1% over the entire temperature and adjustment ranges, as long as the two ***HT-Rejustors*** are at the same temperature.

Special-purpose Type-2 *HT-Rejustors*

Special-purpose Type-2 ***HT-Rejustors*** feature a tighter resistance tolerance of better than 0.7% over narrower temperature ranges (e.g. 150℃ to 200℃, 175℃ to 225℃). They are intended for high temperature applications where fine tolerance is desired *within a specific "focus-range" of temperatures*.

These Type-2 HT-Rejustors are designed such that their high-temperature resistance values are a specific percentage (e.g. 4% ±0.7%) below their room-temperature value. Pairs of these ***HT-Rejustors*** (unadjusted and adjusted) will maintain their ratio-matching within better than 1% over the entire -55℃ to +200℃ temperature range, throughout the 20% adjustment range, and within better than 0.7% within the specific focus-range.

Other ***HT-Rejustors*** with different temperature characteristics and/or focus-ranges are also achievable. For example higher precision with a narrower adjustment range or different focus temperature ranges may be produced to meet specific operating requirements. Contact Microbridge with your requirements.

Note: Performance specifications achieved with production devices may vary from the numbers cited herein for prototypes.

Table 5: ORDERING INFORMATION

Part Number	Operating Range	Order Code	Package
MBH-273-AS Type 1	-55 to 230	115P	Die
MBH-293AS- Type 2A	+150 to +200℃	115R	Die
MBH-293AS- Type 2B	+175 to +225℃	115S	Die

INCOMING WAFER TESTING (DIE LEVEL INSPECTION)

Inspect to MIL-STD-883G Method 2010.11 condition B (waiving bondpad discoloration) at five PCM spots on each wafer. Criteria for bondpad discoloration is waived due to proprietary die capping procedure which causes surface roughness on aluminum. Wirebond pull tests show no adverse affects on pad performance.

HT-REJUSTOR PERFORMANCE EXAMPLES:

The following examples are for illustrative purposes. They demonstrate resistance deviation from the initial value (adjusted and un-adjusted) as a function of temperature and adjustment. For example the 27KΩ ***HT-Rejustor*** adjusted 14% down would be observed across temperature with respect to its 23,220Ω set point. Devices were packaged in ceramic dip packages during testing to facilitate measurement.

Type 1 Device:

- Nominal 27KΩ divider
- Measurement temperature range: -55℃ to 200℃
- Curve-fitted and extrapolated to 250℃
- Resistance tolerance +/- 2% across -55℃ to 200℃

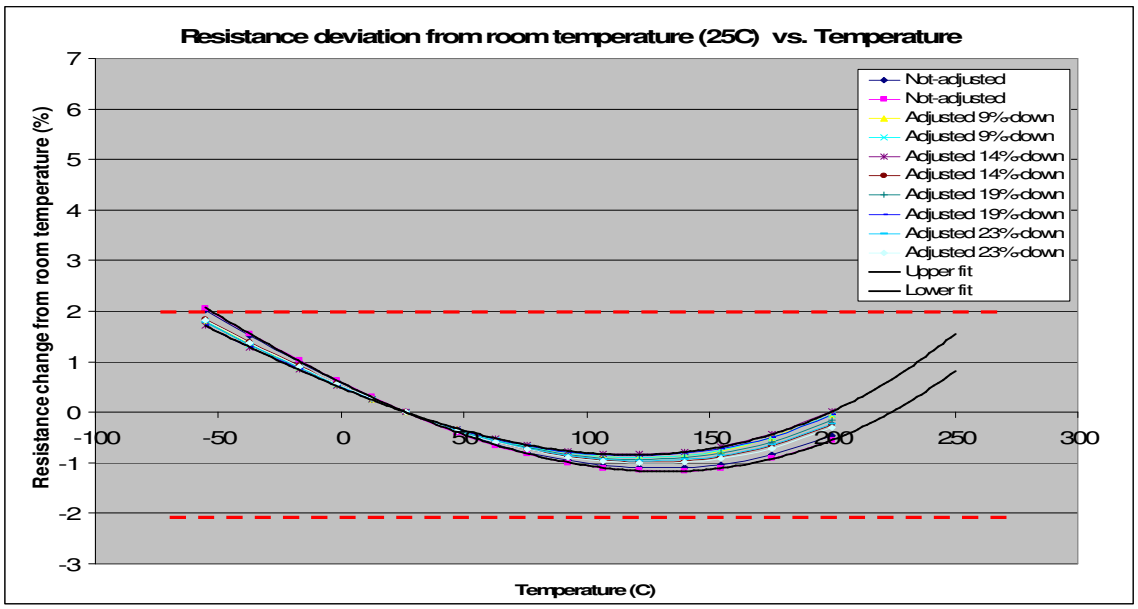

Figure 2: Type 1 Resistance Deviation as a function of Temperature ($\Delta R/R_{25C}$ vs. T)

Type 2 Device:

- Nominal 29KΩ divider
- Measurement temperature range: -55℃ to 200℃
- Tight Resistance tolerance ΔR < 0.5% within a 50℃ range (175℃-225℃)

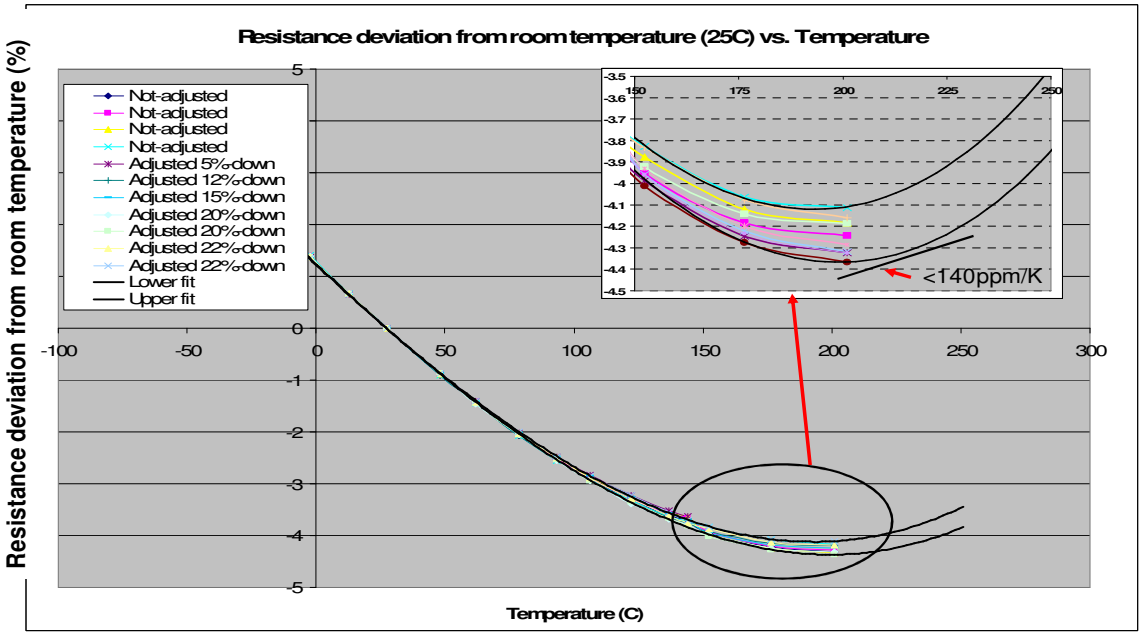

Figure 3: Type 2 Resistance Deviation as a function of Temperature ($\Delta R/R_{25C}$ vs. T)

FUNCTIONAL DESCRIPTION

High-temperature operation is a problem for electronic circuits for many reasons. Digital systems typically are limited to +125°C gate breakdown temperatures. Analog circuits are subject to variations in electrical properties and even accelerated failure. For most components, temperature related drift creates inaccuracies which require relaxation of specifications, calibration over a broad range, or controlled operation within a narrower operating temperature range. Typically such adjustment is done by trimming or matching resistors to meet the requirements of the circuit. However, resistors, whether trimmable or not, may have the same types of problems at high temperatures. HT-Rejustors were developed to address the need for precise resistive calibration at high-temperature. Two types are available with experimental $\Delta R/R_{25C}$ vs. T curves as shown in Figure 2 and Figure 3.

HT-Rejustors are adjusted in-circuit to meet the precision requirements of the application. For example, the ***HT-Rejustor*** can be adjusted to provide a desired output voltage or to adjust a gain setting. In all cases, the exact resistance value of the ***HT-Rejustor*** is less important than desired output parameters of the circuit being adjusted. The ***HT-Rejustor*** is the only pure-passive resistive element that can be adjusted at final assembly, using only electrical signals. Furthermore, unlike laser-trimmed resistors, ***HT-Rejustors*** can be adjusted bi-directionally.

HT-Rejustors are adjusted using ***HT-Rejustor*** Calibration Tools, such as the MBK-408A – Low cost, high-precision ***HT-Rejustor*** Calibration tool. ***HT-Rejustors*** can also be adjusted with a high-volume, high-precision Calibration tool based on the National Instruments NI-DAQ chassis.

Each ***HT-Rejustor*** has two adjustment pins (one for each heater), and a common Heater GND pin. During the calibration process, the ***HT-Rejustor*** is connected to the ***HT-Rejustor*** Calibration Tool, or equivalent hardware[3]. The Calibration tool provides the electrical connections to monitor the circuit output behavior and drive power into the Adjustment pins of the ***HT-Rejustor***. Power applied to the Adjustment pins controls the heating and cooling process which in-turn changes the resistance. Refer to Figure 4 for a sample connection between the MBK-408A ***HT-Rejustor*** Calibration tool and the ***Rejustor***. This connection to the calibration tool is only required during the adjustment step.

Rejust-it software, provided as part of the ***Rejustor*** Calibration Tool is a LabVIEW-based executable and controls the adjustment process using the ***Rejustor*** Calibration Tool in a closed-loop feedback system. ***HT-Rejustors*** are automatically adjusted to the target values, as specified in the graphical user interface. A sequence of electrical heating pulses, governed by Microbridge's proprietary algorithms, is enough to fine-tune the material properties within approximately 1 second for most applications.

After adjustment, the circuit is disconnected from the ***Rejustor*** Calibration tool. The ***HT-Rejustor*** does not require active power to maintain its adjusted resistance. The material properties of the ***HT-Rejustor*** are permanently altered to affect the current flow, which means the resistance is changed. ***HT-Rejustors*** are intended for set-and-forget applications that involve factory calibration. The Calibration tool can be reconnected as required and devices can be adjusted dozens-of-times, as may be required for periodic maintenance or calibration.

The resistive element of the ***HT-Rejustor*** is electrically isolated from both substrate and Adjust (heater) pins and can therefore float, electrically.

Adjusted ***HT-Rejustors*** are highly stable and retain their electrical and temperature performance characteristics indefinitely. ***HT-Rejustors*** can be adjusted many times, bi-directionally without compromising stability or performance. ***HT-Rejustors*** also feature the lowest noise and the widest bandwidth of any adjustable resistor technology.

Microbridge ***HT-Rejustors*** are an electrical replacement for mechanical compensation techniques. They replace manual trim pots, digital pots and laser trimming. The Microbridge Technologies Low-TCR ***HT-Rejustor*** family of electrically adjustable micro-resistors can be matched to values for precision control of sensors, voltage regulators, amplifiers and other applications.

[3] Using Microbridge's scalable production-calibration hardware (based on the NI-DAQ platform from National Instruments) and Rejust-it software, multiple units can be calibrated simultaneously during roughly the same amount of time for high-volume applications.

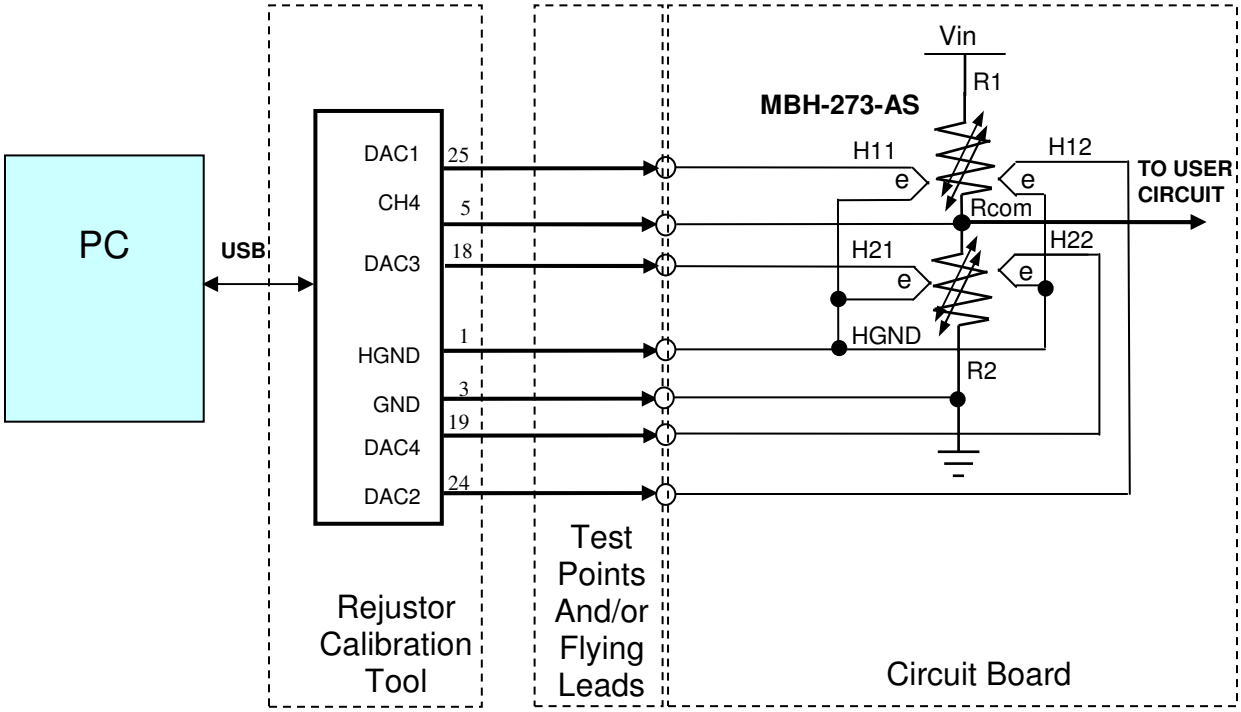

Figure 4: *HT-Rejustor* Hardware Connection during Calibration

ADJUSTMENT STRATEGIES AND PROCEDURES

HT-Rejustors can be adjusted in-circuit at room-temperature or at elevated temperatures more suited to the application. After adjustment, these devices are stable purely-passive resistors and do not require power to hold their resistance set point. This family of solutions for high-temperature electric circuit applications enables several adjustment strategies for high-temperature circuit operation.

The R vs. T behavior for ***HT-Rejustors*** is predictable as shown in Figure 2 and Figure 3. This predictability can be exploited to adapt the adjustment process to the needs of the application. Several general examples are outlined below.

Adjustment Strategy 1: Calibrate at Room Temperature:

If it is necessary to execute the adjustment at room temperature, one can use the known $\Delta R/R_{25C}$ vs. T curve to predict how the ***HT-Rejustor***'s resistance will behave at an elevated temperature. For example, a Type-1 ***HT-Rejustor***, with a resistance trimmed at room temperature to 25000Ω +/-0.1%, will be approximately 24750 Ω +/-1% at +125C, but will increase back up to 25000 Ω +/-1% at 200°C. Overall, it should vary by less than 2% from its room-temperature value, at any temperature from 25°C to 200°C. Alternatively, a Type-2 ***HT-Rejustor*** resistance trimmed at room temperature to 25000Ω +/-0.1%, will decrease to approximately 24000 Ω +/-1% by +150°C. If it is intended to operate at a specific elevated temperature, a deliberate offset can be introduced into the calibration targets at room temperature to achieve target resistance within the target temperature range.

This strategy is advantageous in a circuit where the high-temperature behavior of the circuit is well-enough characterized, and its performance could be predicted based on one or more resistance values, such that the circuit need not be characterized again at elevated temperature. If such a circuit demanded that the known resistance remained within the tolerance over a narrower temperature range, such as 175°C +/-25°C, then a Type-2 ***HT-Rejustor*** could be used. The adjustment could be done at room temperature, provided that the circuit was calibrated to the appropriate value ~4% above the resistance value which it is intended to have at its operating temperature between 150°C and 200°C.

Adjustment Strategy 2: Calibrate at an Alternate Temperature:

Consider the simplified graph in Figure 5 for a Type 1 ***HT-Rejustor***. In this example, the ***HT-Rejustor*** was calibrated at 25C (room temperature). The error across -55°C to +230°C is +1.8% at -55°C and -1% at 125°C. This displays an asymmetric error. To make the error more symmetric, the user could try calibrating the ***HT-Rejustor***, in-circuit, at 5°C. Likewise, if the circuit operates from 40°C to 200°C, the resistance variation would be symmetric if the Rejustor was calibrated at 80°C. Or, if it is important that the resistance be never more-negative than the calibrated value, an error range of -3% can be obtained, by adjusting the circuit at +125°C.

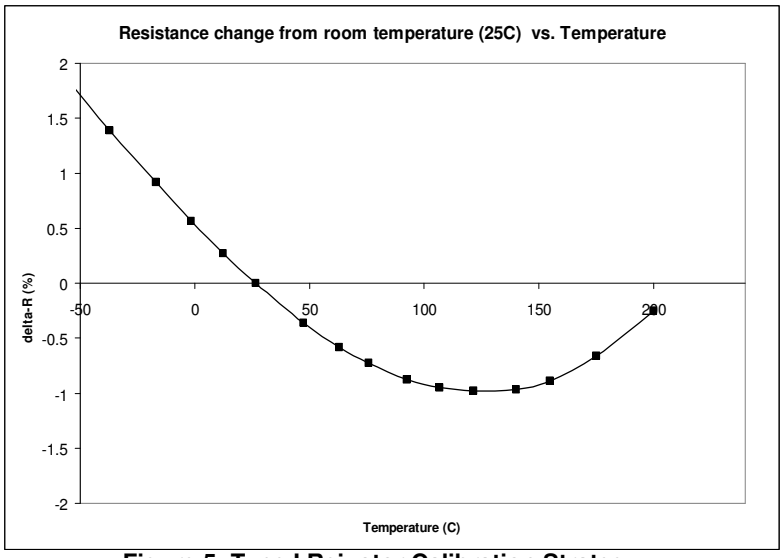

Figure 5: Type I Rejustor Calibration Strategy

Type-2 ***HT-Rejustors*** were designed to be suitable for adjustment at an elevated operating temperature, within a narrow temperature range within which the resistance must remain stable within 0.7%. See Figure 3 above.

This situation requires less knowledge of the component tolerances, temperature-coefficients, and circuit performance vs. temperature, since it is being adjusted at the desired operating temperature and conditions. In this case, it is important to remember that performance at room temperature may vary from the expected value (due to the change in the ***HT-Rejustor*** and other circuit components). In any case, the R vs. T of the ***HT-Rejustor***(s) is predictable vs. temperature.

PACKAGE INFORMATION

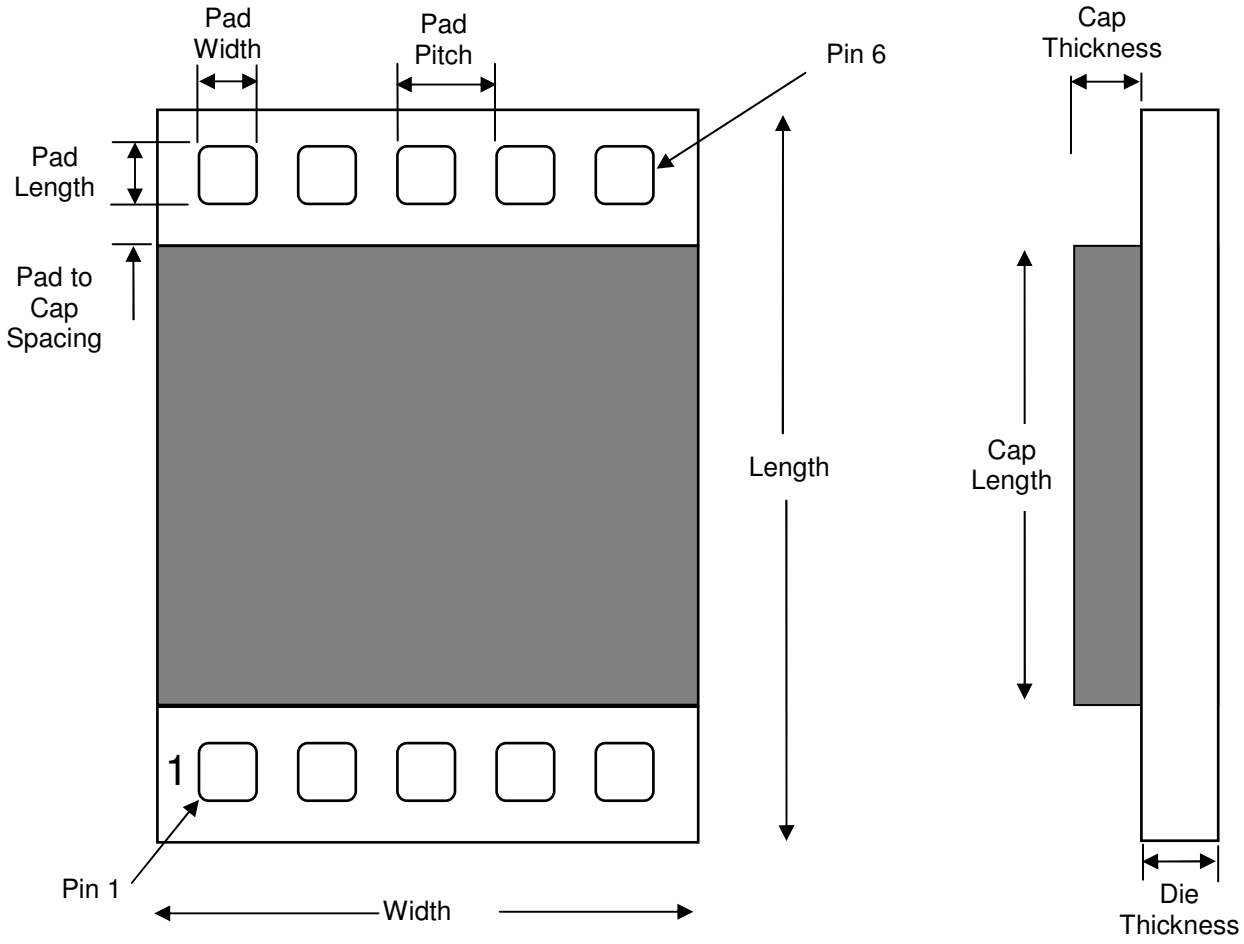

Figure 6: Mechanical Drawing, MBH-273-AS or MBH-293-AS

Table 6: Mechanical Dimensions

Description	Dimension (mm)
Length	1.50
Cap Length	0.80
Width	1.00
Cap Thickness	0.100 ± 0.015
Die Thickness	0.320 ± 0.025
Pad-to-Cap spacing	0.185
Pad length	0.10
Pad width	0.10
Pad pitch	0.19

Table 7: Pin Function Descriptions

Pin Name	Description	Pin No.
R1	*HT-Rejustor* 1 Terminal	1
Rcom	*Rcom*	2
R2	*HT-Rejustor* 2 Terminal	3
HGND	Heater Ground[5]	4
NC	*No connect*	5
NC	*No connect*	6
H21	*HT-Rejustor* 2 Adjust Input A[4]	7
H22	*HT-Rejustor* 2 Adjust Input B[5]	8
H11	*HT-Rejustor* 1 Adjust Input A[5]	9
H12	*HT-Rejustor* 1 Adjust Input B[5]	10

[4] Only required during adjustment