

# eTC Rejutor Voltage Divider

## 1 Introduction

The **eTC Rejutor**, from Microbridge, provides electrical adjustment of resistance and temperature-coefficient of resistance (TCR), to independent values in a single passive resistor. This technology provides flexibility and control for temperature related circuit problems in an all-passive, all-analog solution.

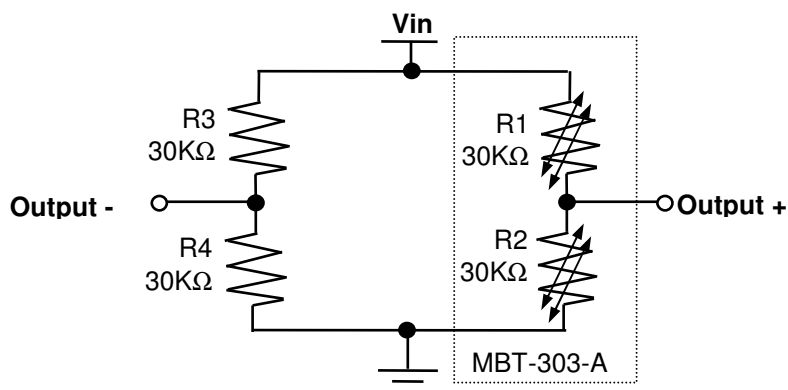
This application note presents the MBT-303-A in a voltage divider configuration to provide a temperature controlled reference voltage. The **eTC Rejutor** divider allows adjustment of the divider output voltage away from its initial ratio (“Offset” in mV per Volt applied to the top of the divider), and at the same time allows independent adjustment of the temperature coefficient of the output voltage (TC-Offset in  $\mu\text{V}$  per degree Kelvin per volt applied to the top of the divider). In this way, a temperature-conditioned voltage divider is obtained.

The adjustment of both resistance and TCR are controlled by **Rejust-it** calibration software from Microbridge. In this example, the adjustment is performed using the MBK-408A **Rejutor** Calibration tool. Microbridge also provides hardware and software for use with National Instruments NI\_DAQ hardware multiple parallel systems can be calibrated simultaneously for product environments. Connections to the calibration tool are only required during the calibration process. Once adjusted, **eTC Rejutors** maintain the resistance and TCR in the material properties of the device.

## 2 Overview

This application note describes the process of adjusting both output voltage and the temperature coefficient of the output voltage using coarse and fine adjustments based on data collected from below  $-55^{\circ}\text{C}$  and above  $+145^{\circ}\text{C}$ . Final accuracy of 0.1% was achieved.

The basic circuit is shown in Figure 1. The circuit is configured as a bridge, with “fixed” resistors R3 and R4, and **eTC Rejutors** to be adjusted R1 and R2. The bridge has been deliberately mismatched by using a previously adjusted MBT-303-A **Rejutor** divider on the left-side of the bridge. For the purpose of this experiment, the **eTC Rejutor** on the left will be treated as a fixed resistor. This pre-set mismatch is intended to demonstrate the process of correcting offset and TC-Offset, and mimics many real-world applications.



**Figure 1: eTC Rejutor Divider Configuration**

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The **MBT-303-A** is an **eTC Rejistor** divider with a 1-to-1 ratio, that is, both **Rejistor**s have nominally the same initial resistance and TCR. The resulting divider output voltage adjustment range is from +100mV/V to -100mV/V, with a temperature coefficient of output adjustment range from +150 $\mu$ V/V/K to -150 $\mu$ V/V/K. Applying a voltage across the adjusted divider generates a stable reference voltage (Offset) with a fixed temperature response (TC-offset).

The TC-Offset vs. Offset characteristics of the **MBT-303-A eTC Rejistor** are shown in Figure 2, below. The Offset is the deviation of the divider output voltage,  $V_{out} = V_{in} \left( \frac{R1}{R1 + R2} \right)$  measured in mV per volt of divider input voltage  $V_{in}$ . The TC-Offset is the temperature coefficient of that divider output voltage, measured in  $\mu$ V per degree-C (or Kelvin) per volt of divider input voltage. Microbridge's eTC adjustment software allows the choice of target values for Offset and TC-Offset as any point within the roughly-parallelgram-shaped region shown in Figure 2. For example, if initially the divider input voltage is low by 5% (50mV/V) from the required value for a given application, and, additionally, it has an undesired +75 $\mu$ V/VK temperature variation, then the resistance and TCR of the divider can be adjusted using Rejust-it software and the **Rejistor** Calibration Tool to the point (+50mV/V, -75 $\mu$ V/VK).

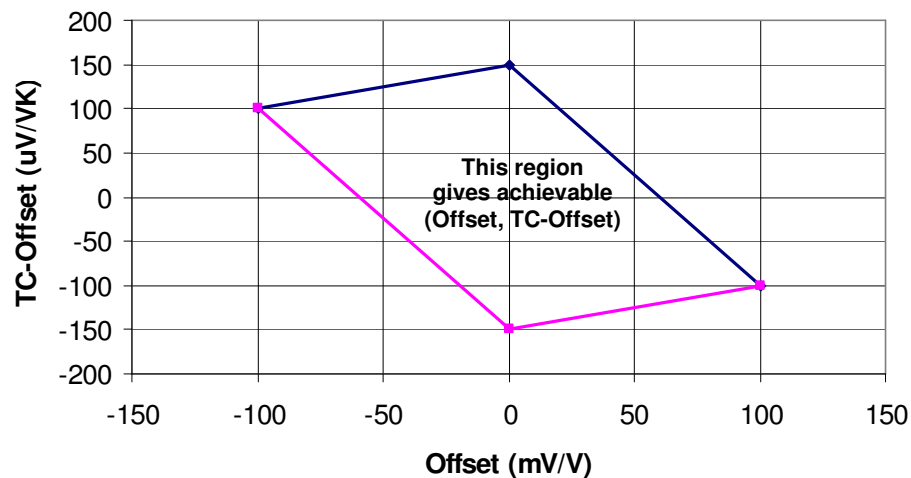


Figure 2: MBT-303-A Adjustment Range

### 3 Rejistor Adjustment – Hardware Connections

Electrical connections are required between the calibration pins of the two adjustable resistors and the MBK-408A calibration hardware to drive the analog adjustment signals into each **Rejistor** to perform the adjustment. An input to the calibration tool (the output of the circuit under test) is required to provide feedback to **Rejust-it** software. The adjustment process is performed as a closed-loop feedback system during which adjustments are made and the corresponding change in the output of the circuit is observed. Changes are performed in a controlled manner to iterate to the final resistance value. The software automatically manages the electrical signals, while monitoring the bridge output differential voltage.

The MBK-408A **Rejistor** Calibration Tool from Microbridge Technologies provides all the I/O requirements to adjust resistance and TCR of the MBT-303-A in this application. Adjustments are made to the target voltage using the Channel 4 input, performing single-ended measurements through the amplifier with an input gain of  $4^{V/V}$  to improve precision.

The Circuit configuration with the MBK-408A is depicted in Figure 3. In this application HGND and reference ground could optionally be connected, but are kept separate in this application, recognizing that many bridge applications may require a separate ground. In this example, R1 is adjusted using DAC1 and DAC2, while R2 is adjusted with DAC3 and DAC4.

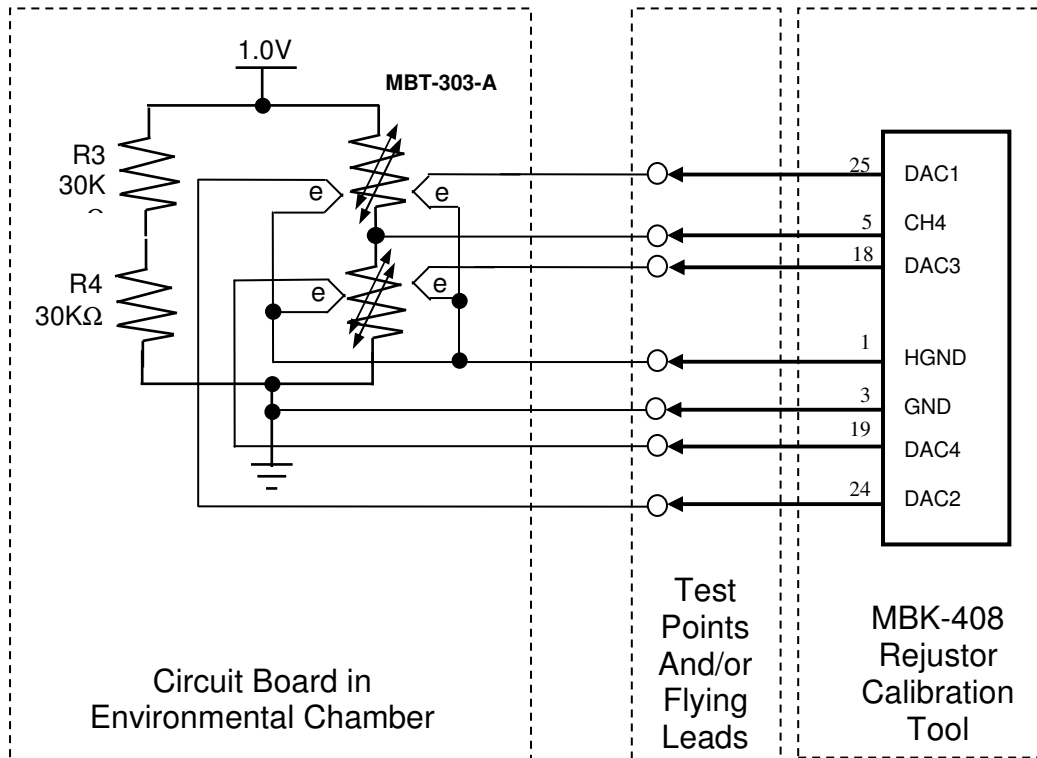


Figure 3: Rejistor Hardware Connection

There are several methods available to connect the calibration tool to the circuit including using flying probes or installing a custom connector. This example uses hard-wired connections between the **Rejistor** and the MBK-408A. The **Rejistor** network is placed within the environmental chamber with leads running out to the MBK-408A.

## 4 Develop *Rejust-it* Configuration File

*Rejust-it* software from Microbridge Technologies Inc. is based on executable, LabVIEW<sup>1</sup> based software. The **Rejust-it** user interface provides the connection between the MBK-408A **Rejistor** Calibration Tool and the **Rejistor** compensation algorithms.

The relationship between the output from the unit-under-test (or input to the MB-408A Calibration Tool) and the **Rejistors** (or output from the calibration tool) must be defined in *Rejust-it*. This relationship maps the percentage change in output voltage and TC of output voltage to a percentage change in the resistance of the **Rejistors**.

The Transfer Function Editor, a software tool from Microbridge, was used to develop the relationships between resistance and TCR for each **eTC Rejistor** in the circuit. The details of the Transfer Function Editor are omitted for clarity.

The Circuit Configuration file defines the connections between the circuit-under-test and the MBK-408A Calibration Tool. It imports the output of the Transfer Function Editor to define the relationships between the adjustment signals and the corresponding change in each **Rejistor**. The process is similar to developing Spice files for simulation. A snap-shot of the Circuit Configuration GUI is shown in Figure 4.

<sup>1</sup> LabVIEW is a registered trademark of National Instruments  
MB-APP23-V00

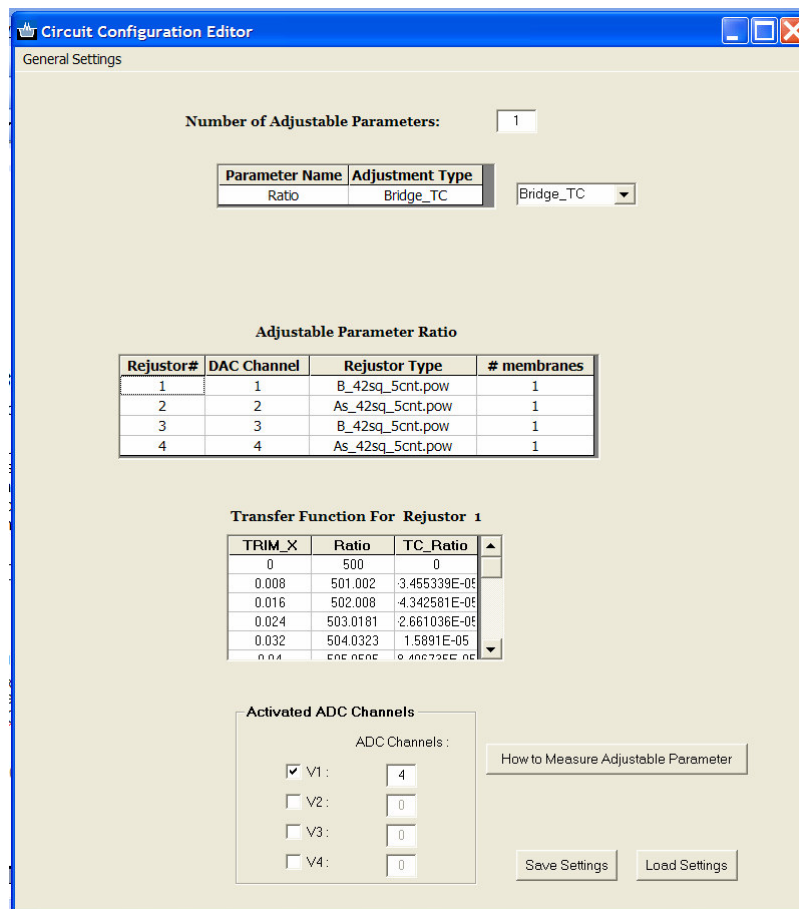


Figure 4: Circuit Configuration Editor

## 5 Adjustment Process

The adjustment process consists of both coarse and fine adjustment. Each adjustment is completed after a temperature cycle, as shown in Figure 5. In all cases, measurement data was collected as the temperature of the assembly was cycled from above +145 °C to below -55 °C.

In this experiment the measurement process took the assembly below freezing which increased the risk of moisture build-up due to condensation from freezing. To avoid condensation problems, the assembly was always ramped from hot to cold. In most applications the assembly would be taken from one extreme to the other and then returned to the first temperature point. **Rejistor** adjustment would be performed at each stabilized temperature.

In applications where high-precision is required, it is recommended that both coarse and fine adjustments be made on each assembly. As mentioned previously, they can be combined within the same cold-to-hot-to-cold temperature cycle<sup>2</sup>.

Alternatively, if the target TC is known (e.g. batch characterization determines that they all have temperature non-ideality roughly 75µV/VK), then it may not be necessary to temp-cycle the devices – the software can roughly hit the TC target needing only output voltage feedback, as long as the transfer function between **Rejisters** and circuit output is well-enough known. The precision of adjustment (for both offset and TC-offset) using this method will depend on how well-known is this transfer function.

<sup>2</sup> In most cases it would be possible to combine the measurement steps. Ideally, the data for coarse adjustment would be collected as the assembly was taken from low temperature to high temperature, then fine adjustment would be made after returning from high-temperature to low temperature.

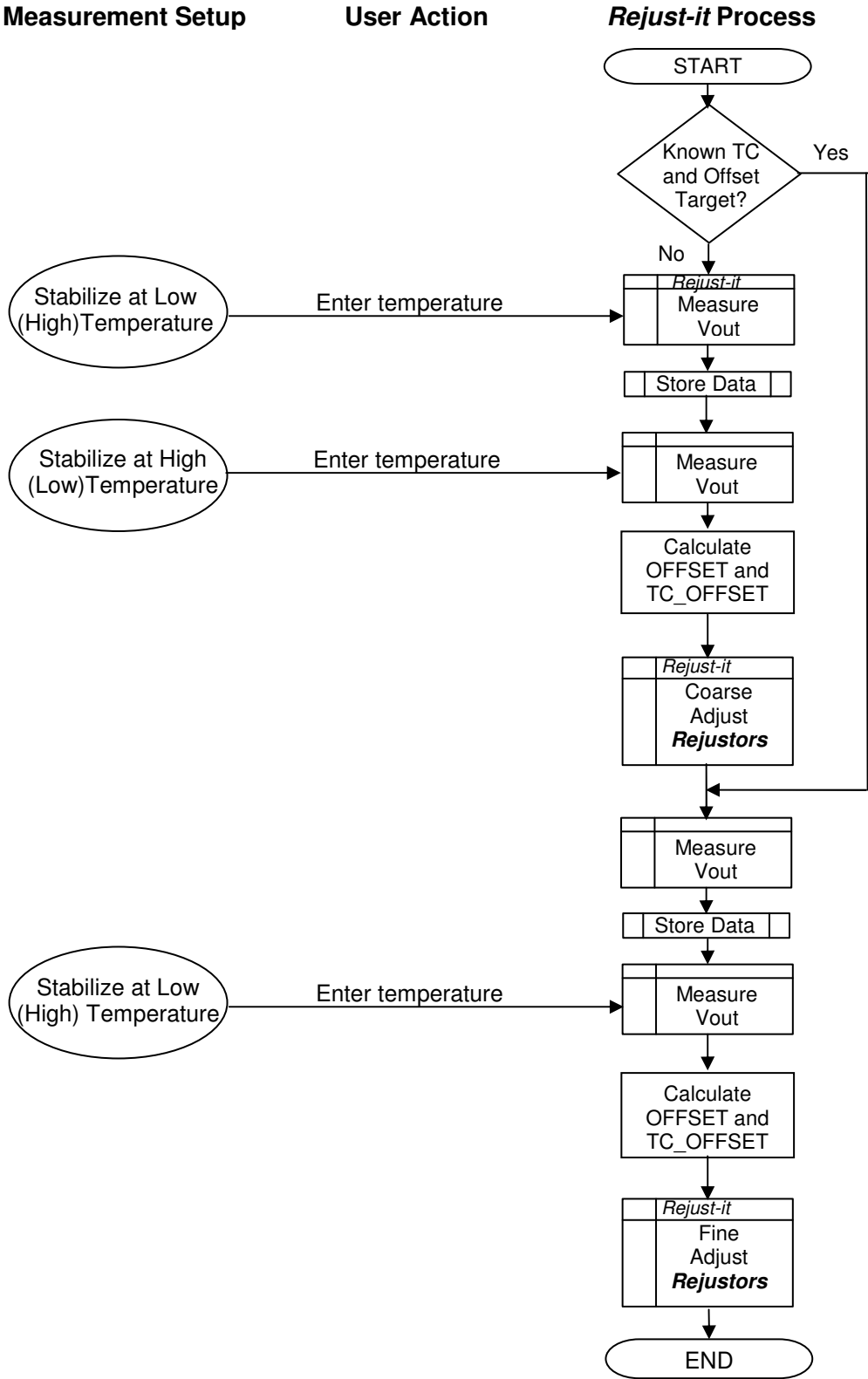


Figure 5: Adjustment Process Flow Diagram

Ten measurement points were collected across the temperature range of interest for each sample. Rejust-it software requires measurements for offset and TC of the circuit. Offset is measured directly. TC was provided to **Rejust-it** using straight-line approximation from the slope of the temperature response.

**Rejutor** adjustment is performed with Rejust-it executable software. A sample screen-shot from Rejust-it is shown in Figure 6. Rejust-it measures the offset directly from the MBK-408A. The initial TC-Offset (gathered from measurements performed during temperature cycling) must be entered along with target values for Offset and TC-Offset. Normally the targets for Offset and TC-Offset are both zero, although this is not always the case. Remember that the MBK-408A with Rejust-it software is used to control the overall system of which the MBT-303-A is a portion. Normally the MBK-408A monitors the output of the system, whether it's an opto-detector, a sensor or an amplifier and sets the overall system offset and temperature response of the system.

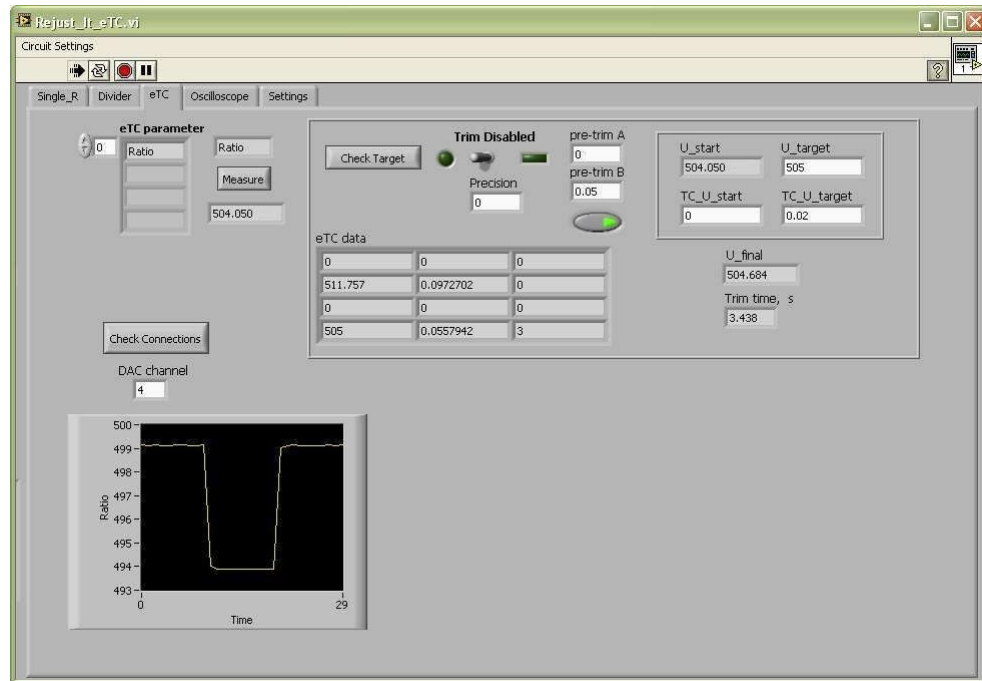


Figure 6: Rejust-it Graphical User Interface

## 6 Measurements

### 6.1 Example 1 - Coarse Adjustment

Ten measurements were collected across the temperature range with a 6-1/2 digit Keithley 2400 Source Meter and an Agilent 34970A DAQ as the assembly was ramped-down from above 145°C to below -55°C. In practice, only the end-points are required to calculate the slope of the temperature response curve. In this measurement, we were interested in demonstrating linearity in addition to adjustment accuracy.

Adjustments were made to the MBT-303-A independently after it had been removed from the temperature chamber. Offset at room temperature was measured directly by input channel 4 of the MBK-408A.

$$\text{Offset} = -38.00 \text{ mV}$$

Using these two measurements and temperature, Rejust-it calculated TC-Offset

$$\text{TC\_Vout} = \frac{\Delta V}{\Delta T}$$

$$TC\_Vout = \frac{-29.44mV - (-43.43mV)}{147.13C - (-50.0C)}$$

$$= 70.97 \times 10^{-3} \text{ mV/VC}$$

Rejust-it adjusted resistance and TCR of each **Rejutor** in the divider to targets of 0mV/V offset and 0µV/VK TC-offset. Data collecting before and after compensation is shown in Figure 7. Notice that following the first calibration cycle, the results are close to the desired behavior. The physical adjustment was performed in less than 5 seconds.

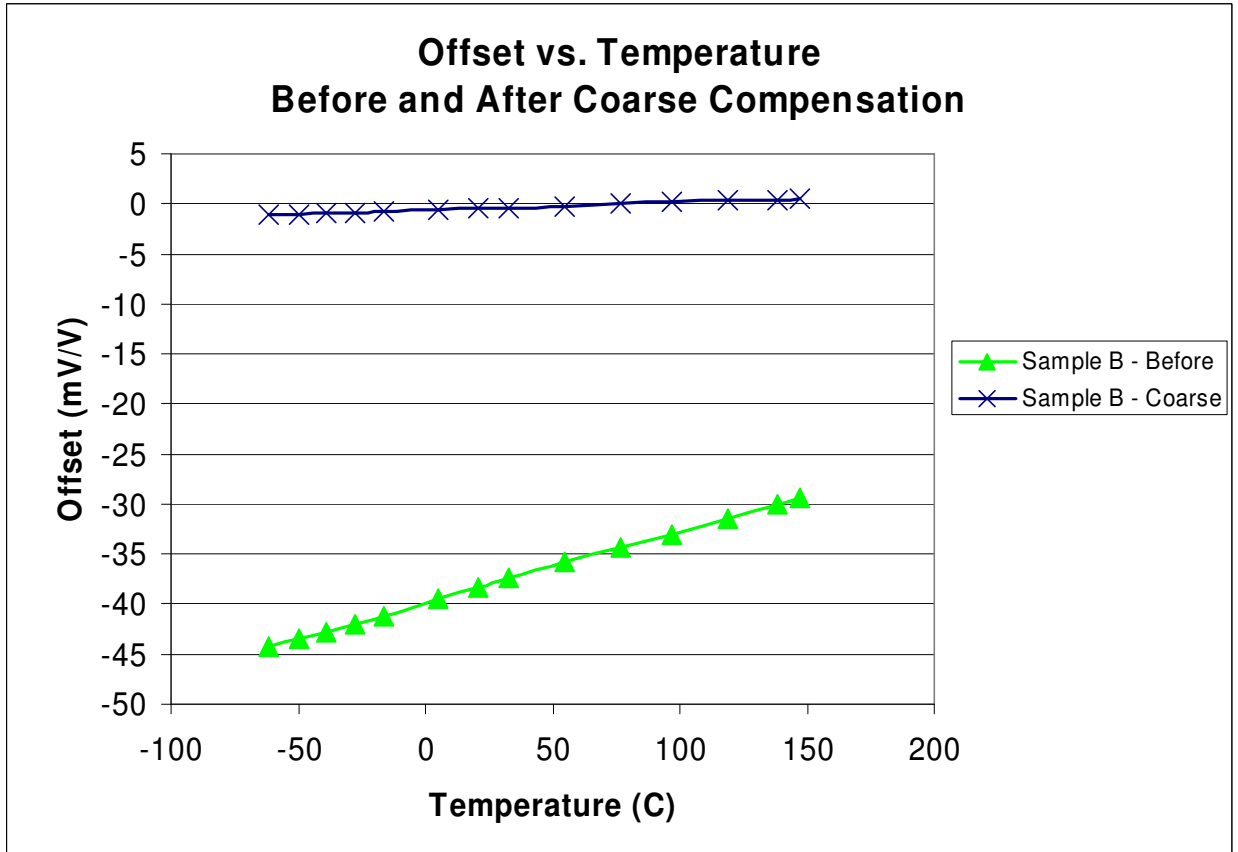


Figure 7: Observed Offset and TC-Offset before and after Course Adjustment

### 6.2 Example 2 - Fine Adjustment

The same assembly was then re-adjusted to demonstrate fine-adjustment. The same experimental setup and configuration files were used for this demonstration.

Measurements were collected at hot and cold:

$$\text{Offset}(147.13^\circ\text{C}) = 0.501\text{mV} \qquad \text{Offset}(-49.97^\circ\text{C}) = -1.015\text{mV}$$

TC-offset was calculated at  $7.69 \times 10^{-3} \text{ mV/VK}$ .

Fine adjustment was performed in approximately 5 seconds using Rejust-it software and the MBK-408A **Rejutor** Calibration Tool. The results are shown in Figure 8.

After calibration, the room-temperature offset is 0.401mV/V  
 TC-Offset is 1.43 µV/VK

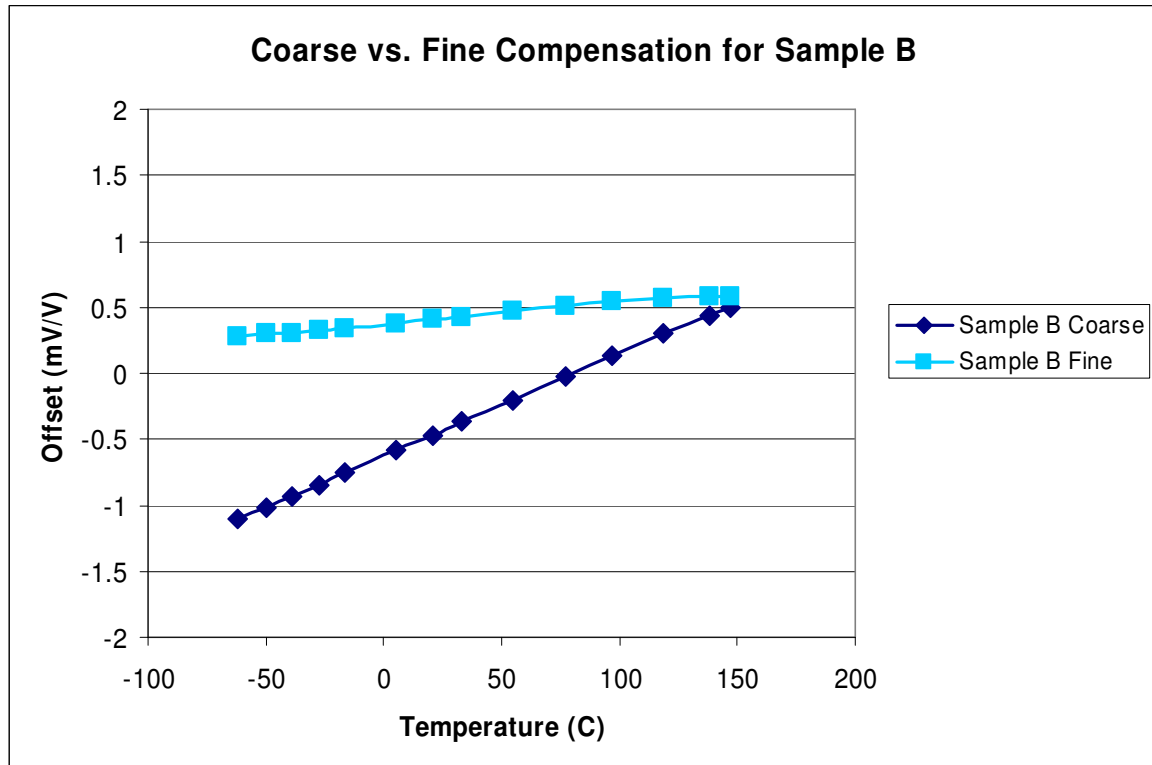


Figure 8: Observed Offset and TC-Offset before and after Fine Adjustment

## 7 Summary

This application note provided an overview of the adjustment procedure using an MBT-303-A to correct component mismatches and temperature drift. The process requires the Transfer Function Editor which develops the relationship between changes to the resistance of each **Rejistor** and the corresponding changes in TCR and output voltage for the circuit. The Circuit Configuration Editor imported the results of the Transfer Function Editor and provided information relating to the physical connection between the circuit under test and the MBK-408A **Rejistor** Calibration Tool.

Data was collected for the circuit under test. Specifically, the linear approximation of drift and the offset voltage at room temperature. Adjustments were made to the MBT-303-A at room temperature using Rejust-it Software and the MBK-408A **Rejistor** Calibration Tool. Adjusting the circuit took less than 5 seconds.

Offset and TC-Offset correction was achieved to within 0.1% of the target value. The **eTC Rejistors** also demonstrated accurate, linear response from below -55°C to above +145°C.

The MBT-303-A with **eTC Rejistor** technology offers analog designers a solution for all-passive, all-analog, electrically-controlled temperature compensation and offset adjustment, for post-package temperature conditioning. Resistance and TCR of each **Rejistor** in the pair can be adjusted to independent targets, allowing unprecedented flexibility for control of temperature-related circuit problems. For example, amplifier offset and TC-offset can be compensated, still in the analog domain, with continuous-valued adjustment. The adjustment is done electronically after board assembly and thus the design engineer can wait for all other parameter variances and temperature-sensitivities to "have their say", and then simply null out the cumulative effects during final test