MBSTC-02 A/B

Analog Amplifier/Sensor Conditioner with Integrated Temperature Correction

FEATURES

- Complete analog Piezo-resistive Bridge Sensor Conditioner
- Sensor error Compensation
  - Offset, Span and Temperature Correction
- Linear Voltage Output (ratiometric)
- Total error 0.5% or less(1)
- Passive offset and TC-Offset compensation
- Active Span (gain) and TC-Span compensation
- Stand-alone performance
  - No external temperature sensor required
- Bandwidth 40kHz
- Propagation time 50uSec.
- Ratiometric output
- -40°C to +125°C operation
- In-circuit adjustable at component-, board- or system-level
- RoHS and Pb-free and green compliant
- Easy to adjust with Rejust-it software

APPLICATION

- Piezo-resistive Wheatstone Bridge Type Sensors

GENERAL DESCRIPTION

The MBSTC-02A/B (Figure1) is an analog adjustable sensor conditioner with integrated temperature correction for use with Piezo-resistive bridge sensors. It is intended for differential (DIF) or absolute (ABS) sensors. Nominal adjustable gain values are 23 and 46 for DIF and ABS sensors, respectively. Nominal (adjustable) offset values are ±10mV/V referred to input. MBSTC-02A adjusts TC-span (Gain) for sensors with TC-sensitivity between -900ppm/K to -1900ppm/K. MBSTC-02B adjusts TC-span for sensors with TC-sensitivity between -1700ppm/K to 2700ppm/K(2).

STAGE 1: OFFSET/ TC_OFFSET ADJUSTMENT

Before any amplification, Offset and TC-Offset are adjusted by four passive eTC(3) (R- and TCR-adjustable) Rejustors, connected in parallel to each of four sensor-bridge resistors. The supply voltage V_{DD} (Nominal 5.0Volts) is common for stage 1 and all MBSTC-02 A/B stages.

STAGE 2: COARSE TC-SPAN LOW NOISE AMPLIFIER

The input buffer is a low noise amplification stage. It provides a fixed positive TC-span of approximately +1400ppm/K (MBSTC-02A) or +2200ppm/K (MBSTC-02B).

STAGE 3: FINE TC-SPAN ADJUSTMENT

Fine TC-span adjustment stage has a pair of Rejustors for fine adjustment of TC-span in a range ±500ppm/K (to fine-compensate residual TC-span remaining after Stage 2).

STAGE 4: GAIN ADJUSTMENT AND DIFFERENTIAL OUTPUT

Amplification Stage 4 has a pair of low-TCR Rejustors (<±100ppm/ºC) for adjustment of absolute Gain in a range approximately ±50% of the initial Gain value. This stage serves as DIF output stage. It provides an output voltage (V_{REL}) with full scale (V_{DD}/2)±2V.

STAGE 5: ABSOLUTE OUTPUT

This stage serves as ABS output stage. It provides an output voltage (V_{ABS}) with full scale (V_{DD}/10)+4V.

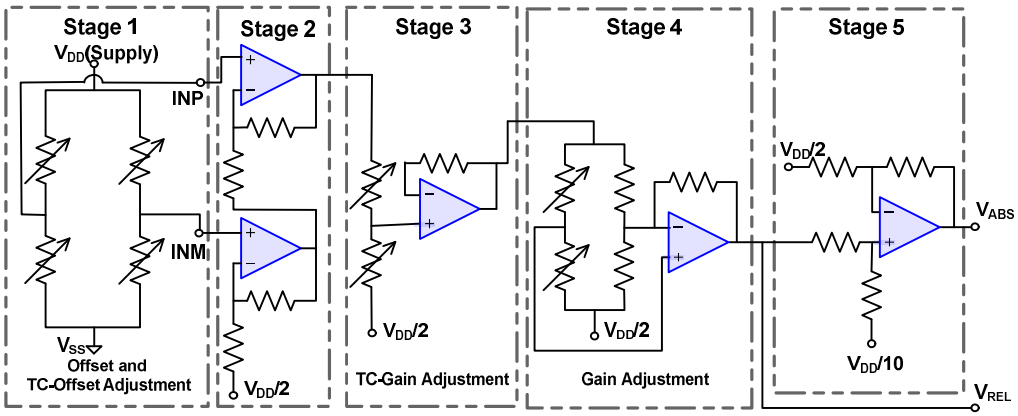

Figure 1: MBSTC-02A/B Functional Block Diagram

1. In temperature range -40-85°C. 2. Contact Microbridge for different TC ranges 3. Rejustor and eTC are registered trademarks of Microbridge Technologies, Inc.

Table 1: MAXIMUM RATINGS [4]

Parameter	Minimum	Maximum	Units	Notes
Supply Voltage (V_{DD})	4.5	5.5	V	
Input pin with respect to ground	2.0	3.0	V	For 5.0V Supply
Input pin differential	-0.1	0.1	V	
Output Current		1	mA	
Operating Temperature	-40	125	ºC	

4. Stresses above these ratings may cause permanent damage. Exposure for extended periods may degrade reliability.

Table 2: ELECTRICAL SPECIFICATIONS

DC operating conditions T=-40 to +125ºC, V_{DD} = 5.0V (Typical), unless otherwise specified

Parameter	Device	Minimum	Typical	Maximum	Units	Notes
Supply Current (for 5.0V Supply)		0.5	0.7	0.9	mA	1
OFFSET AND TC-OFFSET COMPENSATION						
Offset Adjustment Range (RTI)	MBSTC-02A/B	-50		50	mV	1, 2
Offset Adjustment Resolution (RTI)		-0.5		0.5	mV	1, 2
TC-Offset adjustment Range (RTI)		-150		150	µV/K	1, 2
TC-Offset Adjustment Resolution (RTI)		-5		5	µV/K	1, 2
SPAN AND TC-SPAN COMPENSATION						
TC-Span Adjustment Range	MBSTC-02A	-900	-1400	-1900	ppm/K	
TC-Span Adjustment Resolution	MBSTC-02B	-1700	-2200	-2700	ppm/K	
	MBSTC-02A/B		±30		ppm/K	
Sensor Sensitivity Adjustment Range		-35		35	%	
Sensitivity Adjustment Resolution			±0.2		%	
AMPLIFIER						
Gain (nominal), V_{REL}	MBSTC-02A/B	15	23	31	V/V	
Gain (nominal), V_{ABS}		30	46	62	V/V	
Gain adjustment resolution			±0.2		%	
INPUT FRONT-END						
Input Noise Voltage (without offset adjustment)	MBSTC-02A/B		10		µVp-p	3
OUTPUT						
Output Voltage V_{REL} (zero sensor stimulus)			(V_{DD}/2)		V	4
Output Voltage V_{REL} Full Scale (FSO)			±2000		mV	4
Output Voltage V_{ABS} (zero sensor stimulus)			(V_{DD}/10)		V	5
Output Voltage V_{ABS} Full Scale (FSO)			4500		mV	5

Notes:

1. Wheatstone Bridge Sensor output at 5V typical excitation voltage
2. Overall offset referred to input
3. Measured RTI at 100Hz bandwidth
4. With differential sensor after calibration
5. With absolute sensor after calibration

RTI – Referred to input

Table 3: RELIABILITY DATA[5]

Characteristics	Specification (Worst Case)	Test Method or Conditions
Thermal Shock/ Cycling	0.08% FSO	JESD22-A104, -65°C to 125°C, 1000 cycles,
High Temperature Exposure	0.1% FSO	JESD22-A108 150°C, 1000hrs
Humidity and Moisture Resistance	0.1% FSO	JESD22-A110, 110°C, 85%RH, 264hrs, by analysis
Operational Life Test	0.2% FSO	MIL-STD-202 method 108 (125°C, 250hrs, 1.5hrs on /0.5hrs off)
Shock	0.05% FSO	500G, 1ms duration, X,Y,Z axis each 5 shocks
Vibration, High Frequency	0.05% FSO	Max acceleration 20G, 20~2000~20Hz, 8 min, X,Y,Z each 4 sweeps

Table 4: MANUFACTURABILITY DATA

Characteristics	Test Method or Conditions
ESD Discharge	JESD22-A114, human body model weakest pin pair, all lead combinations. Class 2
Solder ability	J-STD-020C, MSL1, 260ºC convection reflow for QFN packages

PACKAGING OPTIONS

Table 5: Nominal Package Dimensions

Type	Lead Count	Body Width	Body Length	Lead Pitch	Lead Width	Lead Length	Body Thickness	JEDEC/ EIAJ	Temperature Range
QFN	24	4mm	4mm	0.5mm	0.25mm	0.4mm	0.9mm	MO-220	-40°C to +125°C

ORDERING INFORMATION

Table 6: ORDERING INFORMATION

Part Number	Order Code	Package	Part Marking[6]	Delivery	Quantity
MBSTC-02A	7113	QFN-24	7113-zzzz	Tape and Reel	500[6,7]
MBSTC-02B	7115	QFN-24	7115-zzzz	Tape and Reel	500[6,7]

5. By analysis
6. Where zzzz represents the 4-digit date code
7. Sample quantities are available in tubes

PIN FUNCTIONAL DESCRIPTION

Table 7: PIN FUNCTION DESCRIPTIONS

Signal	Pin Number	Description	Function
V_{ABS}	7	Absolute Analog Output	Absolute Analog Output has a range between (V_{DD}/10) to (V_{DD} /10) + 4V.
V_{REL}	8	Relative Analog Output	Relative Analog Output has a range between (V_{DD}/2) ± 2V.
TCG	9	TC-Gain Adjust (Up and Down)	TCG controls the Rejustors in Stage 3 of Figure 1 for TC_Sensitivity compensation. Connection to TCG is only necessary during adjustment.
OSU	10	Offset Adjust (Up)	OSU controls half of the Rejustors in Stage 1 of Figure 1 for Offset, TC_Offset compensation. Connection to OSU is only necessary during adjustment.
V_{DD}	11	Supply Voltage	Supply Voltage
V_{SS}	12	Supply Ground	Analog ground
INM	19	Negative Input (from sensor)	Negative differential input from Bridge. Full scale signal must be in the range of 20 to 100mV.
INP	20	Positive Input (from sensor)	Positive differential input from Bridge. Full scale signal must be in the range of 20 to 100mV.
Hcom	21	Adjust Common	Common connection for ***Rejustor*** adjustment. Connection to HCom is only necessary during adjustment..
OSD	22	Offset Adjust (Down)	OSD controls half of the Rejustors in Stage 1 of Figure 1 for Offset, TC_Offset compensation. Connection to OSD is only necessary during adjustment.
GADJ	23	Gain Adjust (Up and Down)	GADJ controls the Rejustors in Stage 4 of Figure 1 for Gain compensation. Connection to GADJ is only necessary during adjustment.
	1, 2, 3, 4, 5, 6, 13, 14, 15, 16, 17, 18, 24	Not Connected	

PIN DIAGRAM

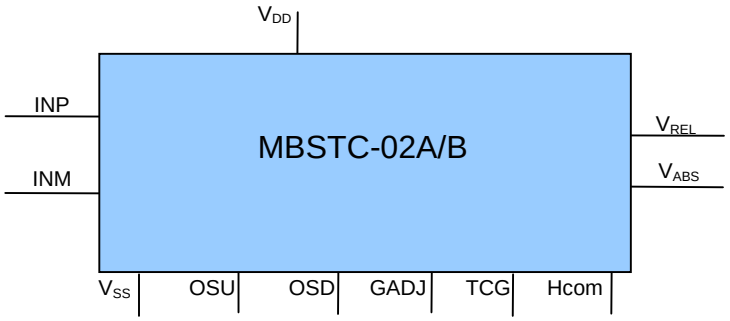

Figure 2: MBSTC-02A/B Pin Diagram

REJUSTOR OVERVIEW

Unlike other sensor compensation devices that use digital correction and look-up tables, the MBSTC-02 uses Rejustors. Rejustors are continuous valued adjustable resistors. There are no discrete steps, quantization errors or least-significant-bits (LSB) to constrain performance. Rejustors can be adjusted, typically, within 0.1% precision using a simple calibration process that physically changes the material properties of the resistors so that the adjusted device becomes a fixed-resistor with all the material properties associated with precision fixed resistors, such as, low noise, wide operating temperature range and wide bandwidth.

Additionally, eTC Rejustors have an adjustable temperature response. After adjustment, the eTC resistor has a fixed TCR which can be set positive, negative or zero, to enable compensation for temperature coefficient in the sensor. After adjustment, the value of the devices is stable, requiring no external power to maintain the adjusted value. Rejustors can be adjusted at anytime with Rejustor Calibration tools.

GENERAL OVERVIEW

The MBSTC-02A/B is a fully CMOS integrated single-chip compensation amplifier for Wheatstone bridge sensor conditioning combining the adjustability advantages of ***Rejustors*** with high-gain amplifiers to produce analog outputs in the range (V_{DD}/10) to (V_{DD}/10)+4V, or (V_{DD}/2) ±2V full scale for absolute or differential sensors, respectively.

Rejustors are passive resistors with the ability to have their resistance adjusted using auxiliary pins (refer to adjustment procedure, below, for more information). ***eTC Rejustors*** are devices which allow independent adjustment of resistance and temperature coefficient of resistance (TCR). The result is a resistor that can be adjusted to meet the resistance and TCR requirements in a variety of applications.

Rejustors are used in conjunction with active amplification elements to create a unique analog sensor conditioner. The ***Rejustors*** and op amps together provide a completely analog signal path. Once adjusted, ***Rejustors*** maintain their resistance and TCR values indefinitely with high stability and precision. ***Rejustors*** can be re-adjusted any time, as required. As a pure analog solution, wide ranges of finite gain and offset can be achieved. In addition, resistance temperature coefficients are set, allowing true passive temperature compensation and eliminating the requirement to separately monitor temperature. Essentially the material properties of the ***Rejustor*** are adjusted to calibrate and compensate deviations in the material properties of the sensor.

GENERAL DESCRIPTION

The MBSTC-02A/B is an analog amplifier and signal conditioner for sensors with negative TC-Sensitivity. This high-precision differential instrumentation amplifier provides complete analog compensation and amplification for Wheatstone Bridge sensors. The device incorporates ***Rejustors*** and low-noise operational amplifiers to provide analog adjustment and temperature compensation.

This device is suited for applications that require sensor calibration over wide manufacturing variations in both offset and sensitivity along with temperature-induced offset and span drift. The combined sensor and amplifier are adjusted to have output voltage span with negligible offset and temperature coefficient (Tempco).

Rejustors are placed in parallel with each of the sensing elements in the bridge to compensate sensor OFFSET and TC-OFFSET. This maximizes the input gain of the amplifiers. Rejustors are also used to adjust the GAIN and TC_GAIN of the amplifier to match the electrical characteristics of the sensor (Span and TC-Span).

Rejustors are purely passive resistive elements that are adjustable over a continuous range with high precision. As such, there are no quantization errors typical of digital solutions. As a fully-integrated solution, there are no external potentiometers or other manual adjustments required to achieve target values and no external memory to store calibration coefficients. No external temperature sensor required. The Rejustor itself works as adjustable temperature sensor. The adjustment process is fully automated using Rejustor Calibration Tools from Microbridge with Rejust-it Calibration software.

Two versions of the MBSTC-02 are available. The MBSTC-02A is recommended for sensors with nominal TC-Sensitivity of -1400ppm/K. The MBSTC-02B for sensors with nominal TC-Sensitivity of -2200ppm/K, Both devices provide an output voltage at (V_{DD}/2)±2V (Out1) and from (V_{DD}/10) to (V_{DD}/10)+4V full-scale (Out2) for use with either differential or absolute sensors.

Gain, offset and temperature correction adjustments are performed by adjusting Rejustors to match the span and offset of each sensor on a unit-by-unit basis. Once adjusted, the resistance of the Rejustors is stable over time across the -40°C to +125°C temperature range.

The MBSTC-02A/B provides signal conditioning and amplification for Wheatstone bridge sensors with bridge resistance in the range of 3.0KΩ to 6.0KΩ and a full-scale bridge output of 20-100mV.

DETAILED FUNCTIONAL DESCRIPTION

The MBSTC-02A/B is a factory-adjustable analog signal conditioner for resistance-based Wheatstone Bridge sensors. Passive eTC Rejustors on the front-end balance OFFSET and TC-OFFSET of the sensor to maximize the input signal to the amplification stages. The Span Adjustment Gain and TC-GAIN stages provide span amplitude and temperature correction.

OFFSET/ TC_OFFSET ADJUSTMENT

Before any amplification (Stage1,Figure1), Offset and TC-Offset are adjusted by four passive eTC (R- and TCR-adjustable) Rejustors, connected in parallel to each of four sensor-bridge resistors. The Rejustors are each 30KΩ, designed to provide suitable adjustment ranges and precision when connected with typical 3-6KΩ sensor bridges. Typical minimum adjustment ranges (Referred to input) for 3 - 6 KΩ sensors are +/-10mV/V (Offset) and +/-30µV/V/K (TC-Offset). See Figure 3 below, showing the achievable Offset and TC-Offset adjustment ranges, with and without sensor attached.

Typically the Offset is reduced by at least an order of magnitude (often more than an order of magnitude) for a given set of output measurements at two temperatures, pending measurement accuracy (and curve-fitting accuracy, in the case of an absolute pressure sensor). Even finer precision of offset adjustment can usually be obtained by making another set of output vs. temperature measurements, to establish fine-adjustment targets. TC-Offsets can be typically reduced well below 1µV/V/K referred to input (RTI).

The OSD and OSU pins are used to adjust the resistance and TCR of the input offset ***Rejustors*** to calibrate the offset and compensate TC-Offset inherent in the sensor. Adjustments are done in-circuit, using the output of MBSTC-02 for feedback to the adjustment software. In this way, any offsets and TC-offsets in the CMOS amplification stages are simultaneously adjusted out. Refer to Adjustment Procedure for more information.

Rejustors along with the input amplifier provide a precision, low-drift front end with low 1/f noise. Any inherent offset in the input stage of the MBSTC-02A/B is cancelled along with offset from the sensor during calibration.

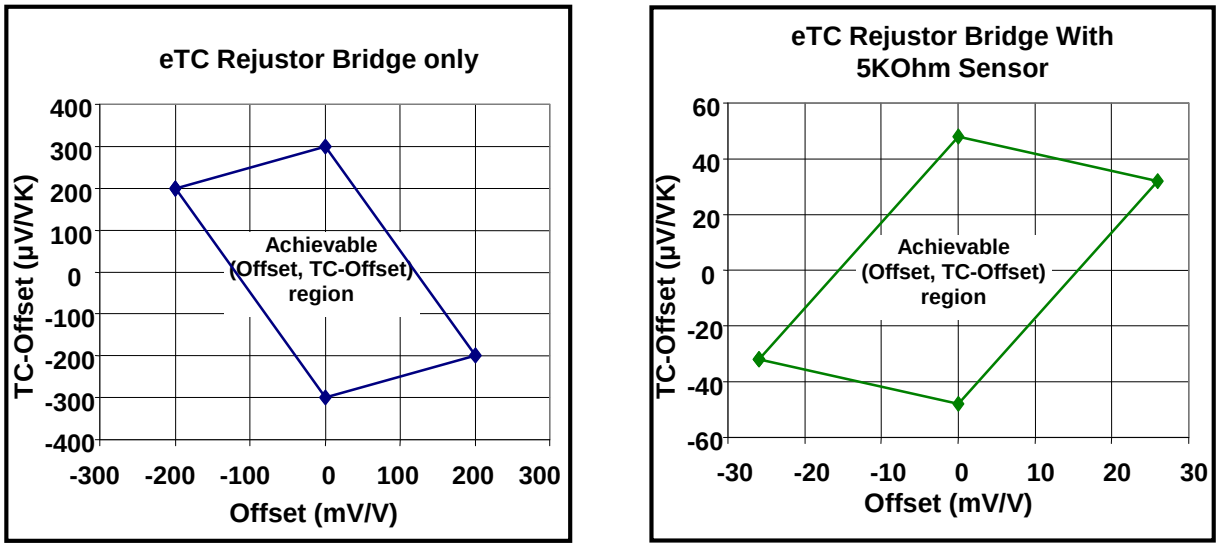

Figure 3: Achievable Offset and TC-Offset regions, for the passive eTC stage without sensor (left), and for the passive eTC stage with 5k Ohm sensor connected.

COARSE TC-SPAN AMPLIFIER

The input buffer (Stage2, Figure1), has low-noise amplification and provides a fixed positive TC-Gain of approximately +1400ppm/K (MBSTC-02A) or +2200ppm/K (MBSTC-02B), for coarse compensation of the large negative TC-Sensitivity which is commonly found in piezo-resistive bridge sensors. Just connecting the MBSTC-02A/B chip to the sensor immediately compensates much of the typical TC-Sensitivity, leaving the fine-tuning to the next Stage (Stage 3).

TC-SENSITIVITY ADJUSTMENT

Amplification Stage 3 (Figure1) has a pair of Rejustors for fine adjustment of TC-Gain in a range +/-500ppm/K (to fine-compensate residual TC-Sensitivity remaining after Stage 2 above). Typical TCS after fine-adjustment is +/-50ppm/K or better, assuming sufficient measurement accuracy in the measurements of output vs. temperature.

The TG pins are used to adjust the TCR of the input ***Rejustors*** feeding the amplifier to compensate TC-Sensitivity for each sensor. Refer to the Adjustment Procedure, below, for more information.

GAIN ADJUSTMENT

Amplification Stage 4 (Figure1) has a pair of low-TCR Rejustors for adjustment of absolute Gain in a range approximately +/-50% of the initial Gain value. The overall nominal Gain of the MBSTC-02A/B (including all stages) is ~46x. Gain adjustments do not appreciably degrade previously adjusted Offset, TC-Offset and TCS. This allows convenient sequencing of independent calibration steps. Since the TC's are already adjusted out before this Stage, the final Gain adjustment doesn't need a fresh set of temperature-measurements – just single-temperature output-voltage measurements versus external stimulus (for example pressure).

OUTPUT DRIVERS

Stage 4 (Figure1) is optional, for level-shifting to center at (V_{DD}/2), as would be needed for a relative pressure sensor where the output can swing in both directions. Without Stage 5, the output voltage is unidirectional, such as would be appropriate for absolute pressure sensors.

V_{REL} provides a zero output at (V_{DD}/2) with ±2V full-scale span. V_{REL} is used for differential sensors. V_{ABS} provides an output voltage from (V_{DD}/10) to (V_{DD}/10)+4V full-scale for absolute sensors.

POWER UP AND NORMAL OPERATION

Rejustors are poly-silicon resistors, with the exception that they are adjustable. There is no power-up or boot-up sequence. Rejustors always maintain their adjusted state even after years of storage. As soon as power is stable, the MBSTC-02A/B is in normal operating mode as adjusted to meet the compensation requirements of the sensor.

TYPICAL APPLICATION

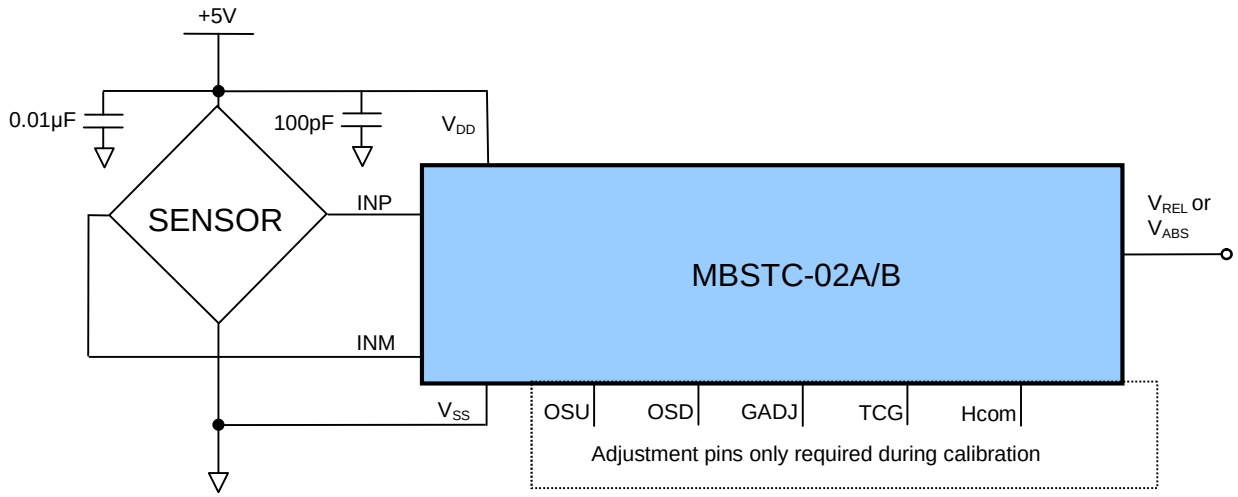

Figure 4: MBSTC-02A/B Typical Sensor Compensation Application

ADJUSTMENT PROCEDURE

Precision adjustment of the resistance of each ***Rejustor*** **during** calibration by means of a proprietary process which adjusts the resistive poly-silicon element in a closed-loop system under control of ***Rejustor*** Calibration tools and Rejust-it software. After adjustment, the calibrated ***Rejustor*** is stable from -40°C to +125°C.

The adjustment pins OSU, OSD, GADJ, TCG and Hcom are only required only during the short period during which the ***Rejustors*** are being adjusted. The resistance of each ***Rejustor*** is adjusted by applying a controlled current between the corresponding pin and Hcom. ***Rejustor*** TCR is adjusted by with a compound ***eTC Rejustor***.

Rejustors are adjusted using LabVIEW-based ***Rejust-it*** software from Microbridge Technologies. ***Rejust-it*** software operates with adjustment hardware in a closed loop to adjust the ***Rejustors*** to achieve the desired output condition while monitoring both the output and the input. ***Rejust-it*** works with off-the-shelf hardware such as ADC (analog to digital converters) to monitor the system. DAC (digital to analog converters) are used to generate electrical pulses to adjust the ***Rejustor***. Off-the-shelf hardware is available from equipment providers such as National Instruments. The low-cost MBK-408B adjustment kit from Microbridge Technologies Inc can also be used to adjust the MBSTC-02A/B (Figure 5).

Recognizing that these pins are only required during calibration and compensation affects design of the calibration fixture. In normal operation these pins can be left open, or grounded (Connected to V_{SS}) with no impact. The calibration fixture can be designed to allow connection to the adjustment pins with pogo-pins, probes or similar temporary connections. Optionally, a header can be designed on the PCB to allow connection between these pins and the calibration hardware.

In order to perform sensor compensation, the performance of the sensor must be monitored across the four corner conditions. The input conditions are no-load and full-load. In order to perform temperature compensation, the two input conditions must be collected at two temperatures – low and high temperature.

The output voltage (V_{ABS} or V_{REL}) is monitored for each of the four conditions and collected by ***Rejust-it***. In addition, the desired results are entered into ***Rejust-it***. For example, the full-scale-output target maybe 4500mV at full-load across the entire operating temperature. This implies a finite gain (between the sensor and V_{ABS} or V_{ABS}) and zero TC_Sensitivity. The ***Rejustors*** are automatically adjusted under ***Rejust-it*** control to create the required resistance and TCR profiles to achieve the desired results.

Once the ***Rejustors*** have been adjusted no further action is required. ***Rejustors*** retain their resistance and TCR values in their material properties and no further changes are required. No boot-up or warm period is required for the ***Rejustors***. ***Rejustors*** may subsequently be readjusted as required (for example if the MBSTC-02A/B were to be reconfigured for a different sensor).

ADJUSTMENT CONFIGURATION

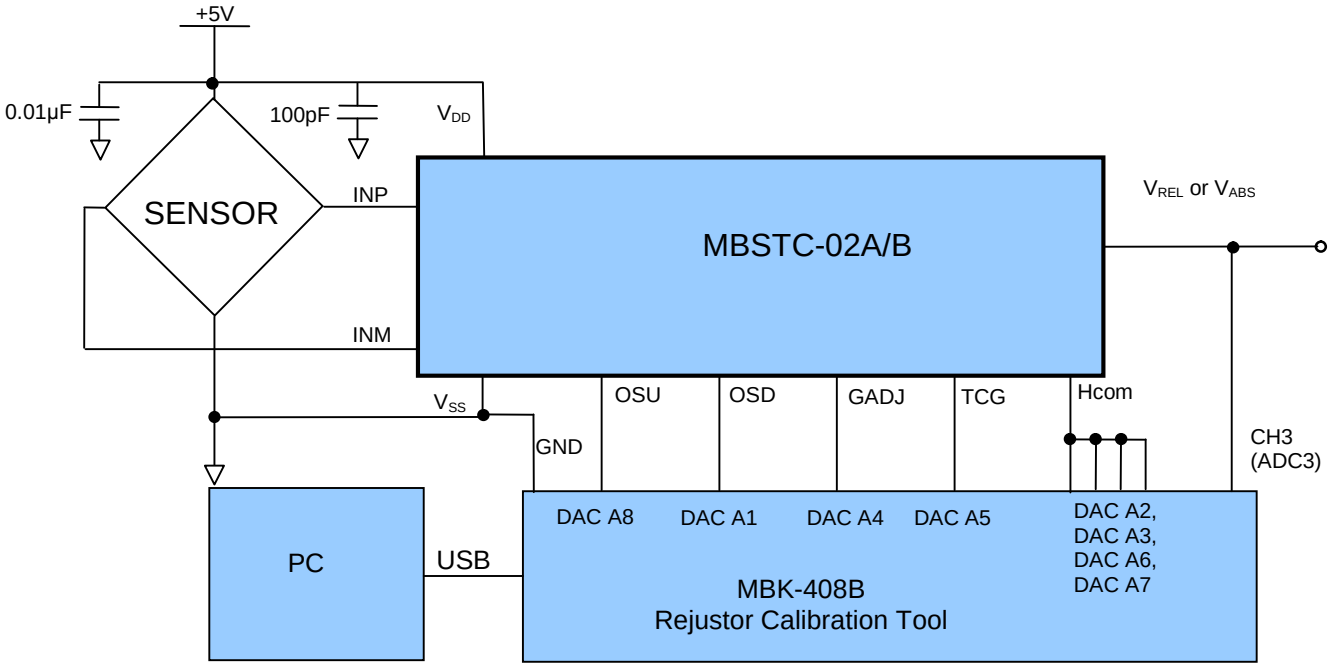

Figure 5: MBSTC-02A/B Adjustment diagram with MBK-408B, Low-cost Rejustor Calibration Tool

APPLICATION ADVANTAGES

- Offset, Span and temperature correction with the MBSTC-02A/B turns an inexpensive but repeatable sensor into a precision device
- Low cost and high precision analog adjustment replaces the requirement for digital signal conditioning
- No external temperature sensors or memory required
- Low power dissipation (also no power for external memory, since there isn't one)
- Easy adjustment with Rejustor calibration tools
- Small size for easy integration directly into sensor housing