Vol 55, No 4—December 2021

Software-Configurable Analog I/O Heralds More Compact and Convenient Calibrators

Konrad Scheuer, Senior Principal MTS, and
Sean Long, Executive Director

Introduction

Industrial analog I/O modules are used to transmit and receive precise, low level voltage and current signals to and from sensors and actuators situated on the factory floor. Like all electronic devices, repeated use and changing environmental conditions over extended time periods cause their performance to deteriorate, meaning periodic calibration is necessary to ensure that they continue operating to a predetermined standard.

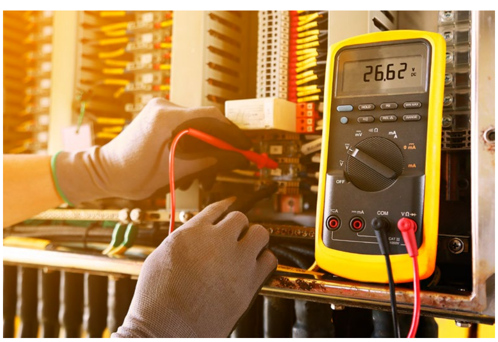

Figure 1. A technician performing calibration at a wiring cabinet.

Indeed, in many industries (for example, pharmaceuticals), periodic calibration is a regulatory requirement, necessitating a trained technician to visit the wiring cabinet housing the I/O module to perform the calibration routine and document the results. This needs a variety of instruments (sources and meters) that are sometimes heavy and cumbersome to transport and operate simultaneously. In this design solution, we review the features and specifications of typical examples of such calibration equipment. We then consider the features of a new reference design based on a software configurable analog (SWIO) IC that potentially sets the benchmark for a new generation of ultra-portable, lightweight calibrators that still provide the functionality and performance of incumbent offerings.

Calibration Equipment

Calibrating all channel types within an I/O module requires a voltage source and meter (typically ±10 V range), a current source and meter (typically ±20 mA range), and a source that can simulate the voltage outputs from different types of thermocouples and RTDs (PT100/PT1000) used by I/O channels measuring temperature. Depending on the functionality of available instruments, this can sometimes require a technician to transport several pieces of equipment to the wiring cabinet. Precision instruments that incorporate all features are available, but they are expensive, have large dimensions, and their weight limits their portability.

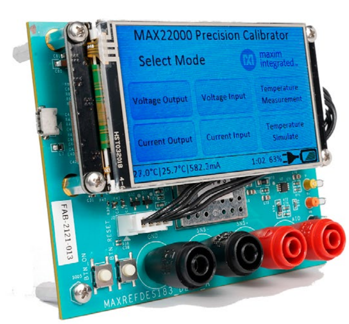

Figure 2. The MAXREFDES183# precision calibrator.

More Compact Calibrator

The MAXREFDES183# reference design (see Figure 2) is a software-configurable battery-powered precision calibrator that is compatible with common industrial analog input and output, and voltage and current ranges. It also provides the following functions:

- Precision analog voltage output, ±10 V (+25% over range)
- Precision analog current output, ±20 mA (+25% over range)
- Precision analog voltage input, ±10 V (+25% over range)
- Precision analog current input, ±20 mA (+25% over range)
- Precision temperature measurement (external PT100/PT1000/thermocouple type K)
- Precision temperature simulator

Compared with bulky desktop calibrators, this reference design calibrator measures only 108 mm × 83 mm × 36 mm and weighs just 283 g.

The functional diagram for the MAXREFDES183# is shown in Figure 3.

Features

The MAXREFDES183# is based on the MAX22000, a software-configurable, industrial-grade analog I/O that can be used to measure voltage and current with additional inputs for measuring temperature (TC and RTD). This IC has a fast-settling 18-bit DAC and a 24-bit sigma-delta ADC, each of which use a stable 5 ppm/°C internal voltage reference, accurate to within 0.01% at 25°C. Linear range is set at 105%, while full-scale range is set at 125% of the nominal range (for example, ±10.5 V and ±12.5 V respectively for a nominal range of ±10 V), while a low noise on-board PGA has high voltage and low voltage input ranges to support RTD and TC measurements by the ADC. The IC is configured using a high speed SPI bus that also transports conversion results. Operating from 2.7 V to 3.6 V analog and digital supplies, and up to ±24 V high voltage supplies, it is available in a 64-pin LGA package and operates over the –40°C to +125°C industrial temperature range. The reference design also features the MAX32625, an ultra low power Arm® Cortex®-M4 microcontroller with 512 kB flash and 160 kB SRAM, which interfaces to the MAX22000 via an SPI. It has a UART interface that connects to the on-board USB bridge (FT234XD) and a receiver/transmitter pair for the touchscreen display. A Nextion NX4024K032 3.2" 400 × 240 pixels touchscreen color display enables user control and feedback.

Thermal Stability

As expected for a high performance measurement instrument, the MAXREFDES183# incorporates multiple design techniques to maximize thermal performance and improve the overall accuracy and stability of the calibrator. Temperature monitoring is provided by two instances of a low power I²C temperature sensor, the MAX31875, which has a high accuracy of ±1°C between 0°C and 70°C. One of these ICs is placed adjacent to the MAX22000, while the other is placed in close proximity to the source terminals. This enables temperature compensation of the voltage gradient between the terminals. A 50 Ω resistor (used to set I/O current) is selected to have high accuracy (0.1% tolerance), and temperature stability (0.2 ppm/°C). Also, four FET-driven heating resistors are located close to the MAX22000, allowing the ambient temperature to be set and stabilized before measurements are made. For added thermal stability, a small metal enclosure (approximately 1 square inch in area) is used to cover the MAX22000 along with its local temperature sensor IC and the heating resistors.

Power Management

The calibrator is powered by two 3.6 V, 3500 mAh capacity Li-Ion batteries. A MAX17320 fuel gauge monitors and manages battery states including voltage, current, and temperature, and uses external high-side FETs to guard against over/undervoltage, overcurrent, short-circuit, temperature extremes, overcharging, and internal self-discharge. Charging prescription ensures that the batteries operate under safe conditions, prolonging life between recharging. The IC automatically compensates for cell aging, temperature, and discharge rate, and provides accurate state of charge in milliampere-hours (mAh) or percentage (%) over a wide range of operating conditions. A thermistor is used to measure

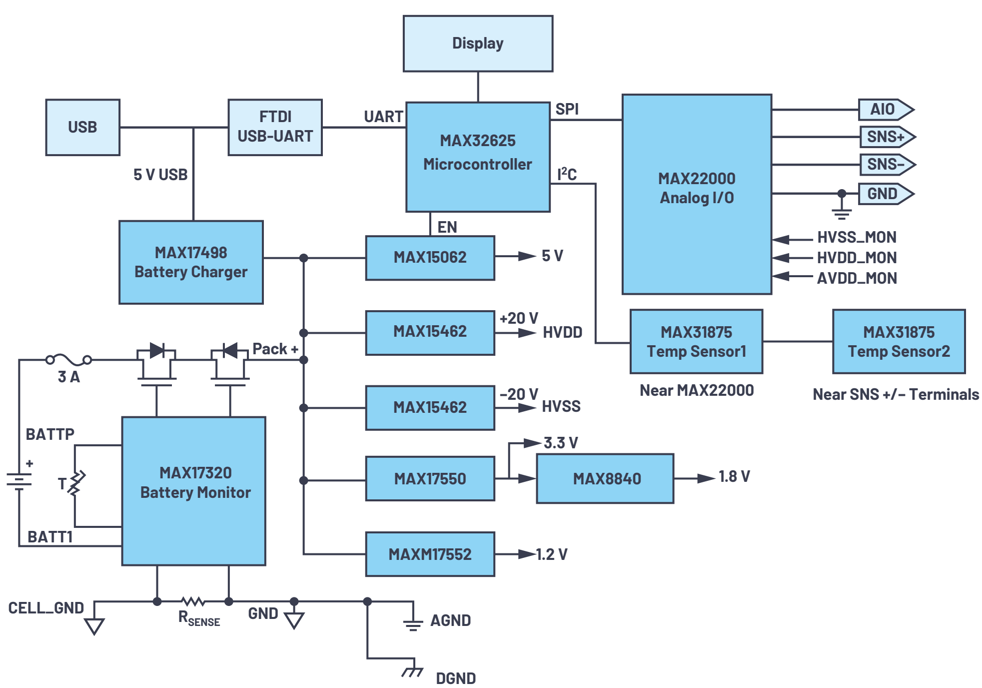

Figure 3. Functional diagram of the MAXREFDES183# precision calibrator.

battery temperature. A MAX17498 flyback converter boosts the USB voltage (5 V nominal) to the battery pack voltage (nominally 7.2 V), providing voltage input to the multiple DC-to-DC converters that generate the voltage rails required to power other components. The MAXREFDES183# consumes 110 mA (typical), providing up to 31 hours of normal usage between battery charging cycles.

High Accuracy

Figure 4 shows the results for voltage and current I/O measurements recorded for temperatures between –20°C and +70°C, which demonstrate that the accuracy of the reference design to be within 0.01% FSR at 25°C (room temperature).

Stability

While accuracy over temperature is important, calibration equipment is usually used (and stored) in environments that have a relatively stable temperature. Therefore, it is also important that they exhibit a high degree of repeatability over longer time intervals at a fixed temperature. Figure 5 shows the ±4 ppm accuracy (drift) of the MAXREFDES183# when configured for a 5 V analog output in voltage mode, recorded at 15-minute intervals over a 7-day (168 hours) period, using a National Instruments PXIe 1073 DMM (7.5 digits), at an ambient temperature of 25°C.

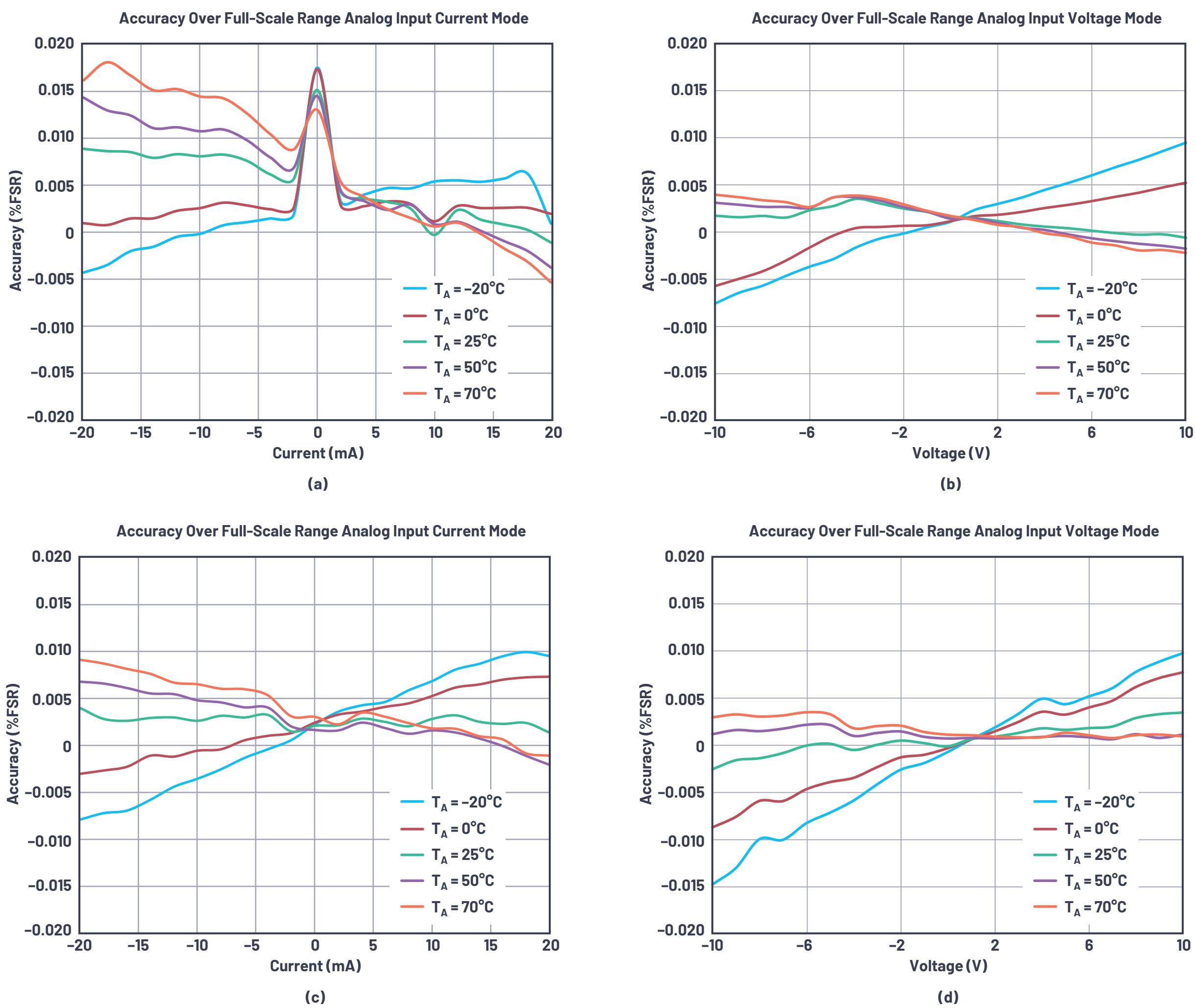

Figure 4. Voltage and current accuracy of the MAXREFDES183# from –20°C to +70°C.

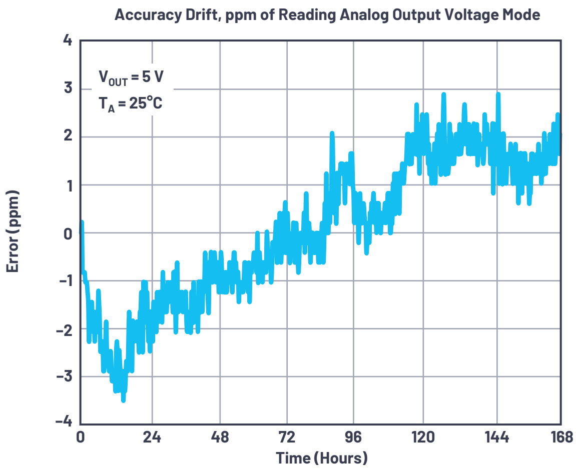

Figure 5. Analog output voltage stability (drift) of the MAXREFDES183#.

Calibrating the Calibrator

Even precision calibrators require periodic calibration. The MAXREFDES183# includes a preprogrammed calibration routine (see Figure 6) that clearly explains to the user how external meters and sources should be connected and provides feedback to the user, interpreting results to determine if they are within acceptable boundaries.

MAXREFDES183# 3D printer files can be downloaded to create an enclosure for the calibrator. The 3D print case is pictured in Figure 7.

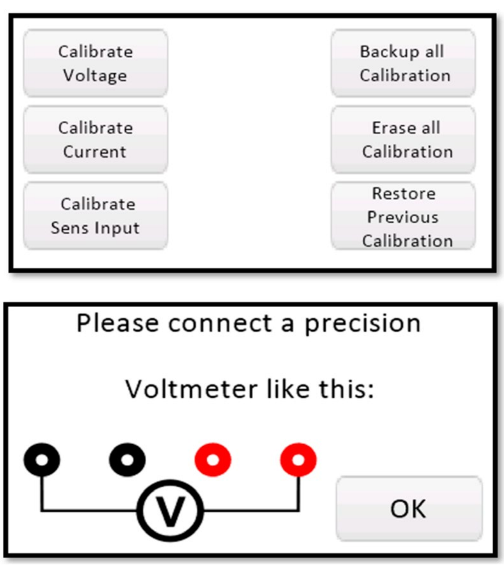

Figure 6. The MAXREFDES183# calibration menu.

Figure 7. The MAX220000 precision calibrator in a 3D print case.

Conclusion

The MAXREFDES183# precision calibrator reference design demonstrates a lightweight, ultra-portable, battery-powered calibrator with the functionality, performance, and accuracy of much larger, heavier, and more expensive solutions. Potential applications for products based on this design include laboratory equipment calibration, adjustment of industrial control equipment, and field calibration of smart sensors and actuators.

About the Author

Konrad Scheuer is a senior principal member of the technical staff at Maxim Integrated (now part of Analog Devices) and is responsible for industrial interfaces, covering Europe. He graduated from Fachhochschule Aalen in 2003 with a Dipl. Ing. (FH) degree in electrical engineering with a concentration in computer science. Konrad joined Maxim Integrated as an applications engineer in 2004. He can be reached at konrad.scheuer@analog.com.

About the Author

Sean Long is executive director of applications for the Industrial and Healthcare Business Unit at Maxim Integrated (now part of Analog Devices). Sean joined Maxim in May 2012. He has a B.Sc. (Hons) in electrical and electronic engineering from Aston University, Birmingham, U.K. He can be reached at sean.long@analog.com.