# Drift Compensation in Data Acquisition Using the KPCI-3108 AutoZero Technique

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## Introduction

Measurement drift is one inherent attribute that all test and design engineers must address. Gradual zero drift, as well as reference and gain drifts, are essentially caused by the effect of ambient temperature on electronics. Other factors such as aging of electronic components, humidity, and pressure could also play a role in long term drift.

An intelligent analog design is very important for predicting and balancing potential drifts introduced by different components in the circuit. A typical example is thermocouple measurement, which requires microvolts of sensitivity and high gain amplification. Any small drift within the measurement device would lead to false temperature readings of the device under test.

Advanced autozero techniques are typically available on benchtop instruments that address higher resolution applications (more than 16-bit) and are usually equipped with autonomous processing power. On the other hand, most data acquisition (DAQ) plug-in boards do not address this issue and are therefore more vulnerable to measurement drift.

The Keithley KPCI-3108 is a multifunction plug-in DAQ board equipped with accurate and precise measurement techniques, including a programmable autozero capability that is designed to eliminate zero drift. This document discusses the KPCI-3108's calibration details and shows how to use its autozero feature with DriverLINX®.

## Calibration Background

To fully understand how autozero works, the user will need to know some background information about the calibration procedure and hardware. The KPCI-3108 has 24 different gains: 12 bipolar and 12 unipolar. Every one of these gains (ranges) is individually calibrated, and different calibration constants are stored for each range. This ensures maximum accuracy per range. The KPCI-3108 is fully programmable and digitally calibrated. There are no calibration potentiometers in the KPCI-3108. Instead, onboard trimming, digital-to-analog converters (trim digital-to-analog converters (DACs)) are adjusted digitally to introduce the proper gains and offsets in the calibration circuit. The analog input subsystem has three trim DACs: gain, coarse offset, and fine offset. These trim DACs are precise and accurate and have 8-bit resolution.

During calibration, three eight-bit trim-DAC values are searched for and then adjusted for each range. These values are: a gain value, a coarse-offset value, and a fine-offset value. Therefore, a complete analog input calibration involves 72 calibration constants: 2 polarities x 12 gains/polarity x 3 adjustments/gain. These 72 constants (0 to FF hex) are first stored in the CALRAM then moved to onboard nonvolatile RAM (NVRAM) for permanent storage. The CALRAM is the temporary storage of calibration constants available to the trim DACs. The key point is that constants in the CALRAM are fetched in real time into the trim DAC based on the programmed gain in the QRAM. The QRAM holds the channel gain queue information, such as the channel number, gain, polarity, and single ended or differential. *Figure 1* is a comprehensive block diagram of the calibration hardware.

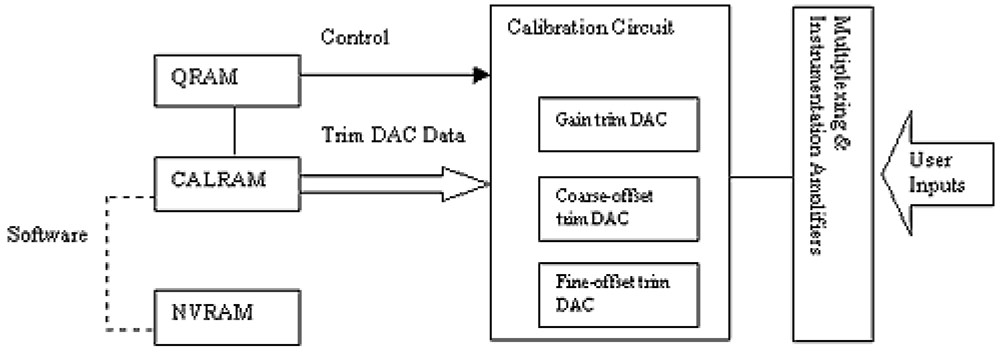


**Figure 1. KPCI-3108 Calibration Block Diagram**

Unlike the CALRAM, the NVRAM retains its data even when the board is unpowered. During calibration or bootup, DriverLINX acts as the liaison between the NVRAM and the CALRAM. DriverLINX is the advanced Windows® device driver that is required to communicate with the hardware under Windows. DriverLINX includes calibration utilities to help you re-calibrate your board if needed. The KPCI-3108 is calibrated at the factory using NIST traceable measurement systems.

## Autozero

Autozero is the process of shorting an internal reference (0V) and re-adjusting the coarse and fine-trim DACs until the measured value is as close as possible to 0V. This process eliminates the zero drift due to the measurement hardware itself. Therefore, after autozero has been performed on the measurment hardware, the hardware will be able to provide accurate and repeatable measurements of the device under test. This autozero feature is fully programmable and completely independent of the user's input signals and external circuitry. By applying the internal 0V reference, the user's input signals are disconnected, so they will not effect the internal zero adjustments. Therefore, this autozero process runs seamlessly in the hardware, independently of user inputs. However, since the short is applied internally, external offsets due to connector thermal voltages, drift in signal conditioning equipment, etc., cannot be removed using the autozero function. When a signal conditioner is known to have a drifting signal, the application programmer usually designs a method of applying a known reference to the sensor, and then uses a subtraction operation in software.

It is important to differentiate between the calibration process and the autozero process. At the factory, the calibration process is performed in very stable environmental conditions, typically 23°C and 50% humidity. The calibration constants in NVRAM are determined under these stable environmental characteristics. When the product is used in the field, these same environmental conditions, under which the product was calibrated, are rarely repeatable. Therefore, the measurement will not be as accurate as it should be. Autozero allows the measurement hardware to perform accurately under its operating environmental conditions. *Figure 2* shows a typical example before and after autozero. It represents measurements taken at one-hour intervals while a short circuit (0V) is applied to the input. To minimize noise and quantization errors, each reading on the chart is an average of 10000 samples taken at 100KHz.

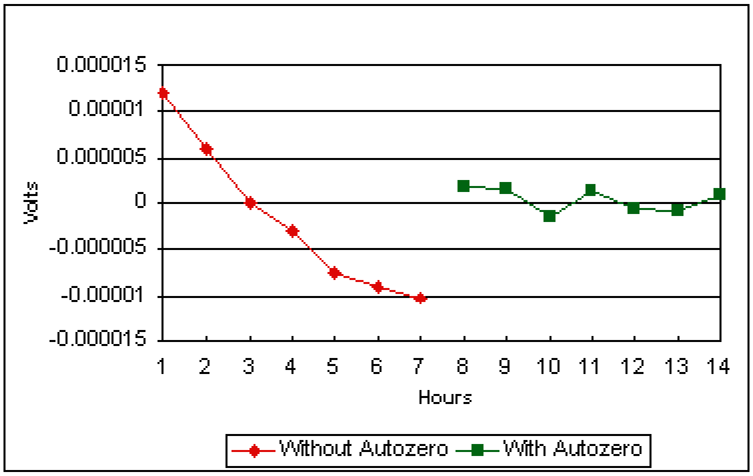


**Figure 2. Measurement of 0V with Autozero Off and On**

Note the slow drift in the measurement taken without autozero. This drift is due to the ambient temperature drift, and its effects on the measurement hardware. When autozero is enabled with each reading, the measurement is more accurate and closer to the actual value of 0V.

Gain drift is another valid concern when making accurate measurements. Gain drift is typically caused by resistive components in the circuit. The KPCI-3108 is designed to have low gain and reference drift by using low temperature coefficient components and implementing special design techniques. The KPCI-3108 autozero adjusts only the offset-trim DACs. This is because most drift is caused by temperature effects on the input current of certain amplifiers used in the input circuit. Gain or reference compensation is typically implemented on benchtop instruments that have higher resolution, better accuracy, and more demanding measurement requirements.

### Software

It is the programmer's responsibility to enable an autozero operation when accuracy and drift matter. Since drift is a long-term process, it is not necessary to leave autozero on all the time. Furthermore, autozero adds more time to the final measurement. It is typically enabled once at the start of the data collection and at different intervals (for example, every hour) that could be programmed in the application. Repetitive data acquisition tasks should usually be performed without autozero.

DriverLINX makes the autozero process seamless to the user. It is performed automatically by software and hardware when the programmer wishes to eliminate zero drift. For example, to enable autozero in your program using DriverLINX:

```
ServiceRequest.Sel_chan_0_ref = DL_HARDWARE_ZEROREF
```

To disable it

```
ServiceRequest.Sel_chan_0_ref = DL_DISABLE_ZEROREF
```

"ServiceRequest" is the data structure submitted to DriverLINX to execute a DAQ task. This data structure is represented by the DriverLINX ActiveX control. When DriverLINX detects that the "Sel_chan_0_ref" property of the service request is not equal to 0, it then executes the autozero algorithm on the gain(s) specified in the service request. This algorithm consists of shorting the internal reference, acquiring 5000 samples at 100KHz, and tweaking the coarse and fine offsets to obtain the best 0V possible. This search algorithm runs repetitively and could take seconds (1 to 5) to finish, depending on the number of gains to be adjusted. Higher gains take more time to adjust than lower gains. The newly found coarse and fine constants are stored in CALRAM and never copied to NVRAM. Refer to the downloadable program associated with this application note.

## Conclusion

When testing and monitoring a device under test, measurement errors can mislead your results. Autozero helps eliminate the zero drift errors by providing a repeatable and accurate measurement that represents the true state of your device under test. The KPCI-3108 is one of the unique plug-in data acquisition boards that have this autozero compensation technique.