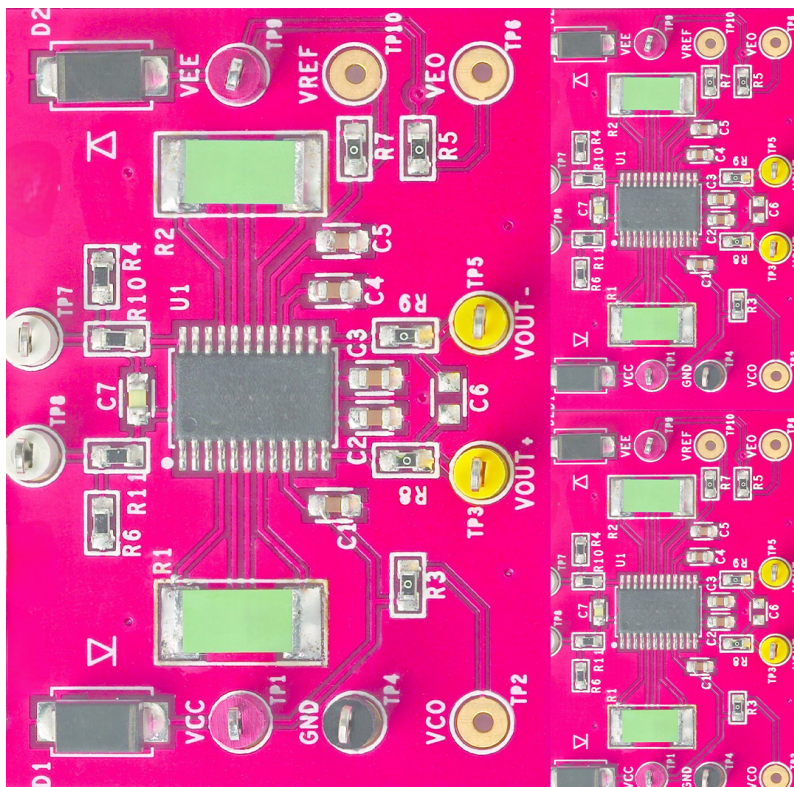


Source: https://www.linkedin.com/posts/vishay-precision-group_eval-board-tip-precision-resistors-are-worth-activity-7450161087431446528-Uv20?utm_source=share&utm_medium=member_desktop&rcm=ACoAAD49EfoBJLW2pXoNMhEA9nRP-w5NZu7IAH0

Precision Beyond the IC: How Resistor Stability, Thermal Control, and PCB Layout Improved Measurement Integrity on an Evaluation Board

In precision electronics, engineers often focus heavily on processors, ADCs, amplifiers, and firmware algorithms when troubleshooting measurement instability. Yet in many real-world systems, the root cause of gain error, drift, and inconsistent validation results lies elsewhere, within the passive component network and PCB implementation itself.



This case study draws inspiration from a recent technical discussion within the precision resistor engineering community, highlighting how a seemingly minor -bill of materials (BOM) upgrade, combined with improved layout discipline and thermal management, transformed the performance of a high-accuracy evaluation board. By replacing standard resistors in critical analog paths with ultra-stable Bulk Metal Foil resistors and optimizing implementation practices, the engineering team eliminated persistent measurement drift and

significantly improved system confidence without altering the silicon design.

The project reinforces a critical lesson for modern electronics development:

Measurement accuracy does not begin at the IC. It begins with the entire signal chain.

Background

Evaluation boards are often used as the first validation platform for precision analog systems. They help engineers characterize sensor interfaces, verify amplifier performance, assess ADC accuracy, and evaluate overall system behavior before product integration.

However, evaluation boards also expose a common misconception in electronics development: that component tolerance specifications alone guarantee system-level accuracy.

In practice, even highly accurate resistors can produce unstable results if the surrounding thermal, mechanical, and layout conditions are poorly controlled.

The engineering team encountered this challenge during the overnight development of a precision measurement demo board intended for high-resolution signal validation. Despite using quality active components and a robust analog architecture, the board exhibited:

- Gain inconsistencies
- Measurement drift over time
- Unstable low-level readings
- Temperature-related offset shifts
- Reduced repeatability during validation

At first glance, the issues appeared to originate from the analog front end or IC performance. However, deeper analysis revealed that the primary contributors were thermal effects, resistor instability under stress, and PCB implementation limitations.

The Core Problem

The evaluation board used standard precision resistors in several critical signal-conditioning paths, including:

- Gain-setting networks
- Current-sense paths
- Low-level measurement circuits
- Reference-divider sections

Although the resistors met nominal tolerance specifications on paper, real-world operating conditions introduced performance degradation that was not captured by basic tolerance values alone.

The following issues became significant contributors to measurement instability.

1. Thermal Drift and TCR Sensitivity

Temperature Coefficient of Resistance (TCR) became one of the most influential error sources on the board.

As current flowed through critical paths, localized heating caused resistance values to shift slightly. For example, a standard thin film resistor with 10 to 25 ppm/°C TCR exposed to a 10°C local rise can shift by 100 to 250 ppm (0.01 percent to 0.025 percent). In a gain stage, this directly translates into gain error at the same level. In contrast, Bulk Metal Foil resistors can achieve TCR values as low as 0.2 ppm per °C, reducing the same error to approximately 2 ppm.

While these changes were extremely small, the system's high sensitivity amplified their impact into measurable gain and offset errors.

This effect became more pronounced during:

- Continuous operation
- Load transitions
- Ambient temperature fluctuations
- Extended validation cycles

The engineering team observed that thermal drift created inconsistencies that mimicked analog noise or ADC instability.

Industry discussions surrounding the project emphasized an important principle:

Thermal drift and mechanical stress are often more detrimental than initial tolerance.

This observation proved accurate during testing.

2. PCB Mechanical Stress

Mechanical stress is frequently underestimated in precision electronics.

In conventional chip resistors, board-induced stress can introduce resistance shifts on the order of 50 to 200 ppm, depending on package size, soldering conditions, and board flex. Bulk Metal Foil resistors are designed to a few ppm or near zero through stress-compensation design.

Board flex, soldering stress, mounting pressure, and thermal expansion can subtly alter resistor characteristics — especially in high-precision analog circuits.

The original board layout placed several critical resistors in locations susceptible to:

- Uneven thermal gradients
- PCB bending stress
- Nearby heat sources
- Copper imbalance

Under operating conditions, these physical influences shifted resistance values enough to affect measurement repeatability.

The issue was not visible in schematics or simulation models, highlighting an important industry reality:

Schematics alone do not guarantee measurement integrity.

As one engineering comment summarized:

“Trust the data, not the schematic.”

3. Layout and Current-Sense Limitations

The board also suffered from layout-related inaccuracies in low-resistance measurement sections.

Traditional routing methods introduced parasitic resistance into current-sense paths, reducing the accuracy of low-value resistor measurements.

This created:

- Voltage measurement errors
- Inconsistent current calculations
- Additional thermal loading effects

The team identified that conventional two-wire sensing methods were insufficient for the application's precision requirements.

Engineering Solution

To address these challenges, the design team implemented a combination of component upgrades and board-level optimization techniques.

The changes focused on three major areas:

A. Upgrading Critical Paths to Bulk Metal Foil Resistors

Standard resistors in key analog locations were replaced with VPG Bulk Metal Foil resistors, including FRSM-series devices in gain-critical sections.

Bulk Metal Foil technology was selected because of its:

- Extremely low TCR
- Exceptional long-term stability (Typical load life drift can be as low as 0.005% (50 ppm) over 2000 hours at rated conditions.)
- Low thermal EMF. Thermal EMF in standard resistor terminations can reach 1 to 3 microvolts per °C. In low level measurements, this can be comparable to the signal. Bulk Metal Foil resistors are designed to minimize this effect, often below 0.05 microvolts per °C
- Strong resistance to mechanical stress effects

Compared to standard thin film technologies, Bulk Metal Foil resistors provide superior stability across temperature, time, and mechanical stress, particularly in demanding precision applications.

The upgrade targeted:

- Gain-setting networks
- Reference dividers

- Precision feedback loops
- Current-sense amplification paths

Importantly, the active silicon remained unchanged.

Only the passive implementation improved.

Yet the resulting data quality improved substantially.

B. Implementing Four-Wire Kelvin Connections

For low-value and current-sense resistors, the engineering team adopted four-wire Kelvin connections.

This method separates:

- Current-carrying paths
- Voltage measurement paths

By eliminating the influence of trace resistance and connector losses, Kelvin sensing dramatically improved low-level measurement accuracy.

For example, in resistors below 10 mΩ, a trace resistance of 1 mΩ can introduce up to 10 percent error in a two-wire configuration. Kelvin sensing effectively eliminates this error.

The benefits included:

- Reduced parasitic error
- Improved repeatability
- Better current-sense precision
- More accurate gain calculations

This practice is considered an industry best practice for precision current measurement systems and proved essential in stabilizing the evaluation board.

C. Thermal and Layout Optimization

The board layout was redesigned to improve thermal behavior and reduce stress-induced instability.

Key improvements included:

- Better spacing around precision components
- Reduced thermal coupling near heat-generating devices
- Improved copper balancing
- Minimized mechanical strain on resistor networks
- Enhanced airflow and heat distribution

The team also carefully managed resistor power dissipation to avoid self-heating effects.

Even 100 mW in a small SMD resistor can result in a temperature rise of approximately 20°C to 60 °C depending on PCB layout, copper area, and airflow.

This step alone significantly reduced drift during long-duration operation.

As industry feedback correctly highlighted:

“Specs are useless if layout and thermals aren’t right.”

Results

Following implementation, the engineering team observed immediate improvements across the evaluation platform.

Key Outcomes Included:

Reduced Gain Error

The upgraded resistor network stabilized gain performance and eliminated previously observed shifts during extended operation. Gain variation reduced from tens of ppm drift to near measurement noise levels.

Improved Thermal Stability

Temperature-induced drift dropped significantly, even during prolonged testing cycles. Observed reduction on the order of 5× to 10× in critical nodes.

Cleaner Measurement Data

Noise-like instability previously attributed to the analog front end disappeared after passive network optimization.

Faster Validation Cycles

Engineers spent less time troubleshooting inconsistent results and more time validating actual IC performance.

Higher Confidence in Test Data

Most importantly, the measurement results became trustworthy.

The board now reflected true silicon behavior rather than artifacts introduced by the passive network and PCB implementation.

Lessons Learned

This case study highlights several broader engineering principles relevant across precision electronics, instrumentation, industrial systems, medical devices, aerospace electronics, and automotive sensing applications.

1. Passive Components Influence System Accuracy

Precision systems cannot outperform unstable passive networks.

Resistor technology selection matters significantly in:

- Sensor conditioning
- Data acquisition
- Calibration systems
- Current sensing
- Analog gain stages

2. Thermal Design Is an Accuracy Parameter

Thermal management is not only a reliability concern.

It is also a measurement integrity requirement.

Even small thermal gradients can introduce measurable drift in high-precision systems.

For example, a 5 °C gradient across a 10 ppm/°C network can introduce ~50 ppm mismatch error.

3. PCB Layout Is Part of the Analog Design

Layout decisions directly influence:

- Noise
- Drift
- Gain stability
- Thermal behavior
- Mechanical stress sensitivity

Precision analog performance must be evaluated at the board level, not just at the schematic level.

4. Counterfeit Components Create Serious Risk

The engineering team sourced components exclusively through authorized distributors such as DigiKey, Mouser Electronics, RS, and Newark Electronics.

This decision helped avoid counterfeit components that often fail to meet claimed TCR and stability specifications.

In critical systems, counterfeit resistors can contribute to:

- Premature failure
- Calibration instability
- Safety risks

- Product recalls

For high-reliability applications, trusted sourcing is as important as component selection itself.

Distribution and Industry Accessibility

Another interesting insight from industry discussions is the growing accessibility of precision foil resistor technology through major electronic distribution channels.

This availability simplifies integration into both prototyping and large-scale production environments.

For many organizations, easy access to reliable precision components accelerates development cycles while supporting faster validation and deployment.

Conclusion

The project demonstrated that improving measurement integrity doesn't always require changing processors, converters, or amplifier architectures.

Sometimes the most impactful improvements come from:

- Better resistor technology
- Smarter layout practices
- Improved thermal management
- Reduced mechanical stress
- Proper sensing techniques

A small BOM upgrade fundamentally changed system confidence.

The silicon stayed the same.

The error sources changed.

The data improved.

And in precision engineering, trustworthy data is ultimately what matters most.