Application Brief

Benefits of Switching to Rogowski Coil in E-metering

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Introduction

The first step in designing a reliable electricity meter is selecting the appropriate current sensor. Current transformers (CTs), shunt resistors, and Rogowski coils are the three most commonly used options in modern E-meters, but each comes with limitations—including temperature variation, insulation and isolation requirements, and susceptibility to tampering. If these drawbacks are not properly addressed, they can lead to serious consequences such as inaccurate energy measurement and financial losses for utility companies.

This application note is intended to give E-meter designers a clear comparison of these current-sensing technologies. This outlines the strengths and weaknesses of each sensor type, explains how these drawbacks impact system performance, and ultimately helps designers select the most preferred current-sensing solution for the meter architecture.

Limitations With Each Current Sensor

Current Transformers (CTs)

Current Transformers (CTs) offer high accuracy, excellent linearity, and reliable performance across a wide current and temperature ranges, making them preferred for precision metering applications. They provide galvanic isolation to protect electronic component, and have low power losses. However, despite accuracy, CTs present several design and operational limitations that make them less preferred in modern metering systems. These limitations include high cost, tampering, size and weight, and manufacturing constraints.

Tampering and Reliability Concerns:

One of the most significant challenges with CTs is tampering. This issue is a major concern for meter manufacturers, vendors, and especially utility companies, as any compromise in billing accuracy can result in financial losses far greater than the cost of the meter itself. Tampering typically is caused by the magnetic core's physical limitations. For example, CTs can be saturated by simply placing a magnet near the sensor, applying a high-voltage pulse to the input terminals, or connecting the neutral line to earth ground—each of which can distort measurement accuracy or disable the device entirely causing inaccurate billing.

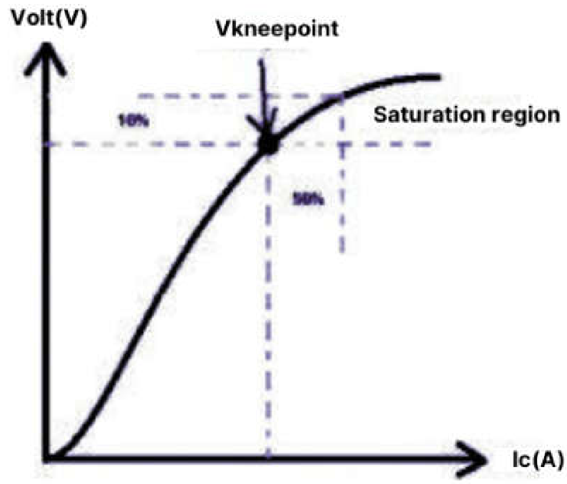

Figure 1. Saturation in Current Transformers Due to Over Current

Cost and Manufacturing Limitations:

The cost of CTs is another critical factor driving the search for alternative current-sensing technologies. Since residential and commercial energy meters are produced in high volumes and expected to last approximately ten years, cost efficiency is essential. CT manufacturers typically offer only standard sizes at lower costs, while custom CTs are significantly more expensive. This lack of flexibility can restrict meter designers, forcing design compromises that can prevent compliance with customer or utility specifications. Such limitations not only lead to potential product losses for manufacturers and vendors but also waste valuable engineering development time.

Size and Weight:

Although a full CT-based meter can seem cost-effective at first, the physical characteristics of the current transformer—specifically the size and weight

—can introduce significant logistical challenges. Bulky CTs increase both transportation complexity and shipping expenses, particularly when distributed in large volumes. In some cases, the combined costs of shipping, handling, and packaging can raise the overall price per unit enough to offset the initial cost advantage. This added expense can make CT-based meters less competitive in the market, potentially leading vendors or manufacturers to lose bids or customers to competitors who offer lighter, more compact, and easier-to-ship meters.

Shunt Resistors

Cost effective meters typically use shunt resistor for current sensing due to the straightforward working principle, low cost, and compact profile. Shunt resistors provide excellent linearity, fast response, and stable performance over a wide range of current levels. Shunt-based sensing enables accurate measurement without magnetic components, eliminating issues such as saturation and hysteresis commonly found in magnetic sensors. However, despite the simplicity and precision, shunt resistors present several challenges that limit the use in certain metering systems. These limitations include the lack of electrical isolation, increased power dissipation at high currents, temperature drift, and potential faults in high-voltage environments.

Lack of Electrical Isolation:

One of the main drawbacks of shunt resistors is the absence of electrical isolation between the measurement circuit and the high-voltage line. Unlike current transformers (CTs), which inherently provide galvanic isolation, shunts directly connect to the current path, exposing the measurement system to line voltage. This lack of isolation poses a risk of damaging equipment, especially in high-voltage or three-phase systems. It also requires additional isolation circuitry such as isolated ADCs, which adds design complexity, cost, and space, offsetting the simplicity that makes shunts an attraction.

Power Dissipation at High Currents and Temperature Drift:

As current flows through a shunt resistor, power is dissipated in the form of heat following P = (I^2) R. At high current levels, even a small resistance value can result in significant heat generation. This heat not only reduces efficiency but can also cause the temperature of the resistor to rise, affecting both performance and long-term reliability. As the temperature of the resistor changes, the resistance value slightly varies, introducing measurement errors. In outdoor or industrial environments with wide thermal fluctuations. If the application does not allow for adequate heat dissipation, then the shunt resistor is not able to operate beyond as low as one-fourth rated current. Temperature drift can cause cumulative energy measurement errors over time, making shunt resistors less preferred for precision metering applications that must comply with Class 0.1 or higher accuracy standards.

Higher-rated resistors or heat management designs (heat sinks and fans), making the design bulkier and less efficient for compact, energy-sensitive metering systems.

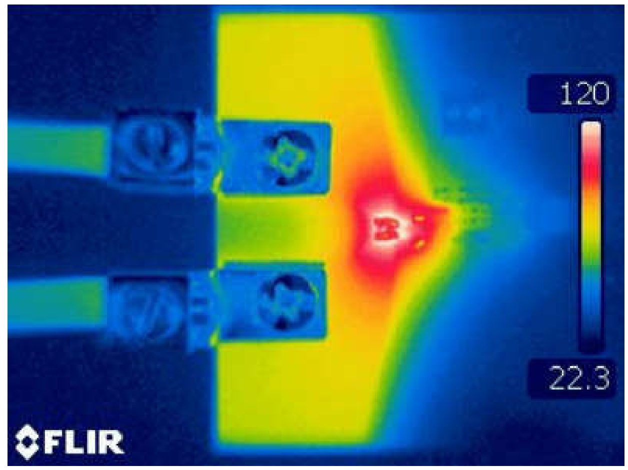

Figure 2. Shunt Resistor Thermal Behavior at 50A

Faults in High-Voltage Systems:

In high-voltage metering applications, shunt resistors pose protection risks because they must handle both high current and high potential differences. A fault, such as a short or surge, can lead to catastrophic failure, damaging nearby circuitry or endangering users. Ensuring adequate creepage, clearance, and insulation increases PCB complexity and cost. As a result, while shunt resistors are excellent for low-voltage or DC metering, they become less practical and less safe for high-voltage AC systems where isolation and fault protection are critical.

Rogowski Coils

Rogowski coils are used in modern metering systems where size, flexibility, customizability, and performance under extreme conditions such as high voltage, high current, and wide frequency ranges are critical. The absence of a magnetic core makes the Rogowski coil preferred for applications where tampering can lead to financial losses for utility companies. Without a ferromagnetic core, Rogowski coils are inherently immune to magnetic saturation and hysteresis, verifying consistent performance even under large current transients, distorted waveforms, or superimposed signals.

One of the key advantages of Rogowski coils is the versatility in design and form factor. They can be manufactured in various sizes and geometries to fit around conductors or busbars, and most notably, they can be fabricated using Printed Circuit Board (PCB). A PCB Rogowski coil offers several benefits: it is lightweight, cost-effective, and highly customizable for compact metering designs. Unlike traditional CTs, shunts and Hall effect sensors.

Rogowski coil is a di/dt sensor, meaning this measures the rate of change of current over time and outputs a voltage proportional to that change. Therefore, the output of the coil is 90 degrees out of phase with the actual current waveform. To obtain an accurate current representation, the signal is passed through an integrator circuit, which reconstructs the original current waveform for measurement and analysis, this can be done via an external application amplifier (op amp) or by using software integration algorithm.

Another major strength of Rogowski coils is the inherent electrical isolation. Because they do not make physical contact with the conductor, they isolate the metering electronics from high-voltage lines, protecting against voltage spikes, surges, and transient bursts. Additionally, PCB Rogowski coils can be routed differentially, which provides excellent common-mode noise rejection and makes the sensor immune to electromagnetic interference (EMI). The lack of magnetic materials also means there is no core temperature drift, verifying stable accuracy over a wide temperature range.

While Rogowski coils offer many advantages, they also present some design challenges that must be managed to make them an optimal choice for current sensing in E-meters. In particular, the need for external signal conditioning varies depending on the application's current range, frequency, and accuracy requirements.

For low-current or high-accuracy metering applications, an external signal conditioning circuit consisting of amplification and integration stages is required to accurately reconstruct the current waveform. However, in high-frequency or high-amplitude environments, such as power quality monitoring or industrial metering, the inherent frequency-dependent sensitivity of the coil increases with frequency (a linear relationship), producing an output voltage large enough to be measured directly, often in the millivolt range, without the need for additional circuitry.

When a signal conditioning circuit is required, the inclusion of precision instrumentational amplifiers such as INA828, INA333, INA826, and INA823, active integrators such as TLV9001, power supplies, and passive components inevitably increases the bill of materials (BOM) and overall system cost. However, this added complexity is justified in applications where high accuracy, stability, and billing precision are critical performance requirements. In such cases, a well-designed Rogowski-based sensing system can still offer design flexibility, isolation, and long-term reliability compared to conventional current sensors and shunt resistors.

Since Rogowski coils are electromagnetic sensors, their orientation around the current-carrying conductor plays a crucial role in maintaining signal integrity and overall system stability. When the meter is calibrated with the coils positioned in a specific orientation, any subsequent movement or displacement of the coils can alter the magnetic coupling. As a result, the meter must be recalibrated to verify accurate measurements. Although, this can pose a concern to meter manufacturers and vendors. However, most meter designers aim for a compact design, making PCB Rogowski coil closely wrapped around the wire where any orientation changes are negligible, contributing to the overall compactness of the full solution while maintaining reliability and signal integrity of the signal.

Some can express concern that the high component count of the signal conditioning circuit of the Rogowski coil could affect the ability to maintain accuracy over the typical 10-year lifetime of an energy meter. This is precisely where the importance of calibration comes into play. Every meter must undergo factory calibration before shipment, and in some cases—such as those governed by ANSI C12.1 (2024)—meters are also field-calibrated upon installation to verify compliance with accuracy standards. Once a Rogowski-based meter is properly calibrated, any variations in voltage, current, or power measurements are effectively compensated for. As a result, the system maintains long-term measurement stability and precision, verifying reliable billing accuracy throughout the service life of the meter.

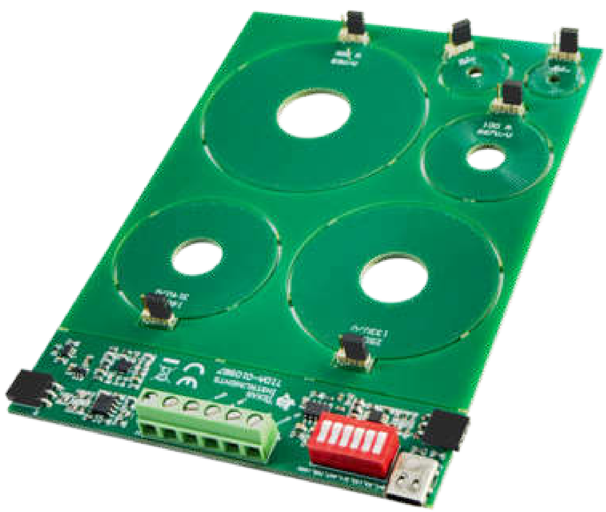

Figure 3. TIDA-010987 PCB Rogowski Current Sensor

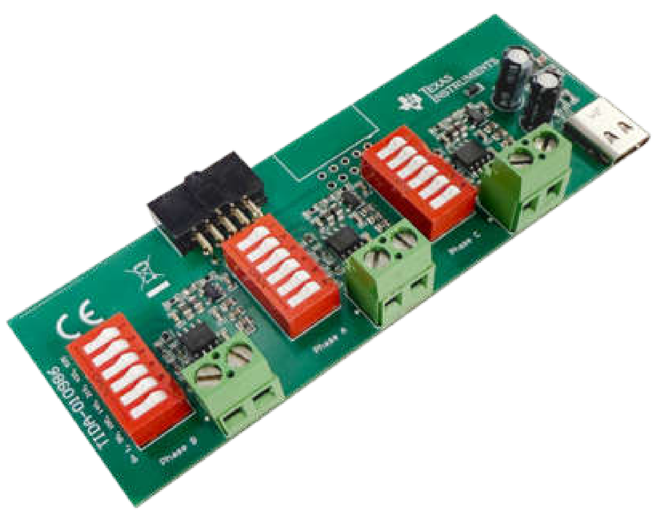

Figure 4. TIDA-010986 E-metering Rogowski Signal Conditioning Circuit

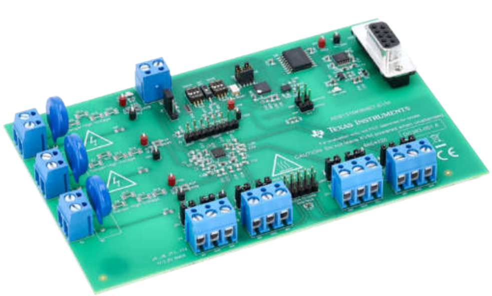

Figure 5. ADS131M08MET-EVM

Conclusion

The evolution of current-sensing technologies in energy metering has made it clear that PCB Rogowski coils are the next major trend for modern E-meter designs. Compared to traditional sensors such as current transformers (CTs), shunt resistors, and Hall effect sensors, PCB Rogowski coils deliver a superior balance of accuracy, isolation, flexibility, and manufacturability.

By leveraging a coreless, differential air-wound structure, Rogowski coils eliminate issues such as magnetic saturation, hysteresis, and tampering susceptibility, ensuring stable and linear performance across a wide range of currents. The PCB implementation further enhances these advantages by providing a lightweight, low-cost, and highly repeatable manufacturing and calibration process, enabling integration into compact, high-density meter designs.

Although Rogowski coils can require signal conditioning and calibration, particularly for low-current and high-accuracy applications, these considerations are outweighed by the benefits of the technology. Proper calibration, as required under standards such as ANSI C12.1 (2024), ensures that any measurement drift or component variation is effectively compensated, maintaining billing-grade precision over the meter's lifetime.

Ultimately, the transition to PCB Rogowski coils offers metering manufacturers and utility providers a path toward smarter, smaller, unlimited to manufacturers, and more resilient meters. Their scalability, immunity to tampering, design flexibility, and long-term stability make them not just an alternative—but a strategic improvement—for the next generation of energy measurement systems and so many other applications.

ADS131M08MET-REF, TIDA-010986, and TIDA-010987 are TI's most recent reference designs focusing on enabling the use of PCB Rogowski coils in revenue grade meters, tested against ANSI and IEC standards, able to achieve class 0.1 accuracy, and designed to address all the limitations that come with PCB Rogowski coils in E-metering.

Table 1. Current Sensor Comparison

Spec	Current Transformer	Shunt Resistor	PCB Rogowski Coil
DC Sensitive	Saturates with DC	Measures DC	Does not measure DC
Tamper Immune	Simple to tamper	Simple to tamper	Tamper resistant
Temperature Drift	Slightly effected (core dependency)	Affected	Not Affected
Isolation	Galvanic isolation	Needs isolation (digital or analog)	Electromagnetic isolation
External Circuit	Burden resistors	External circuit not needed	Precision amplifier and integrator needed for some applications
Current Range	A – kA	mA – A	mA - kA
Frequency Bandwidth	Limited (50/60Hz – few kHz)	Up to kHz	Up to MHz
Size	Bulky	Medium	Customizable

Table 2. TI Reference Designs Selection

Number of Phases	CT Based	Rogowski Based	Shunt Based
1 (single phase)	ADS131M08MET-REF / TIDA-010243	TIDA-010986 / TIDA-010987	TIDA-010940 / AMC-ADC-1PH-EVM
Split	x	x	TIDA-010944
3 (Poly-phase)	ADS131M08MET-REF/ TIDA-010243	TIDA-010986	TIDA-010244