

Digital Isolation in Smart Energy Metering Applications

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IDEA IN BRIEF

DC tolerant current transformers have long been used to sense ac currents in smart energy meters, but they have drawbacks and can be expensive. For some applications, resistive shunts make better current sensors as they are inexpensive, highly linear, and immune to magnetic influences. Unfortunately, resistive shunts do not have the inherent electrical isolation of current transformers. In applications such as smart energy meters that require isolation, digital isolators with isolated power technology combined with shunt resistors offers a good solution to this problem.

Single-Phase Anti-Tamper Smart Meter

Consider the single-phase anti-tamper smart meter in Figure 1. The analog front end (AFE) IC calculates energy and monitors the quality of the load by measuring the phase current using a resistive shunt and the phase voltage using a simple voltage divider. In this application, the power line phase voltage serves as the ground reference for the AFE. The neutral line current measurement must be be isolated so as to protect the AFE from high voltages. The AFE transmits the computed electrical quantities to a microcontroller (MCU) using standard SPI or I²C communications. The MCU then sends the data to a communication module, usually using a UART interface where safety isolation must be ensured and ground loops avoided. Thus, the MCU must either be isolated from the AFE, sharing ground with the communication module (Isolation 1), or from the communication module, sharing ground with the AFE (Isolation 2).

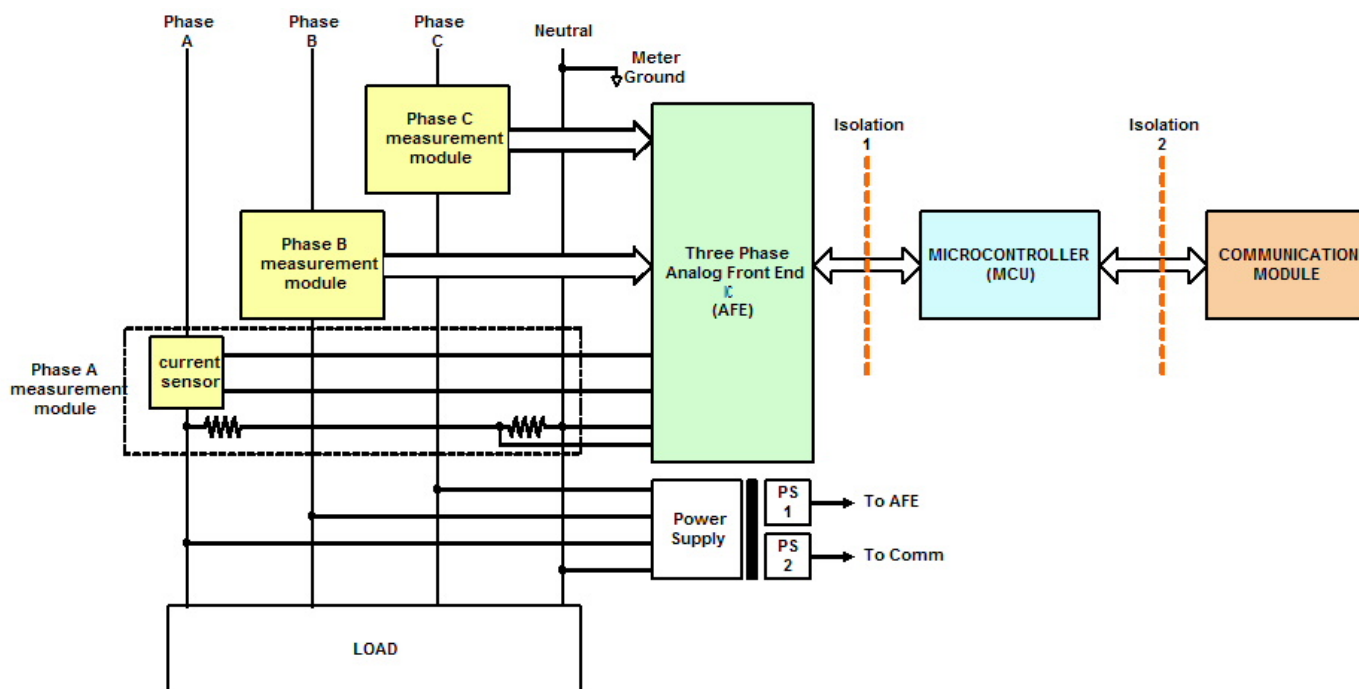


Figure 1. Single-Phase Anti-Tamper Smart Meter

The meter power supply is derived from the power lines, but two power domains are created by the safety isolation barrier. PS1 in Figure 1 is in the same domain as the phase and can be used without isolating the AFE. However, either safety isolation barrier 1 or 2 requires the use of an isolated power supply, PS2, to provide power to the MCU and communications module (Isolation 1) or only to the communications module (Isolation 2).

To summarize, multiple points in a single-phase anti-tamper meter require isolation:

- The neutral line current sensing
- Between AFE and MCU (Isolation 1) or between MCU and communication module (Isolation 2)

The signals that must pass isolation barriers 1 and 2 are digital. Many technologies have been developed to isolate digital signals. The traditional approach uses optocouplers with LEDs and photodiodes. However, newer technology exists in the form of digital isolators that use chip-scale transformers. *iCoupler*® digital isolators, for example, offer advantages over optocouplers, including improved reliability, smaller size, lower power consumption, higher communication speed, better timing accuracy, and ease of use. Chip-scale isolation technology can also be combined with other semiconductor circuits to achieve highly

integrated solutions in a small footprint. These advantages are strongest in applications with higher data rates. Smart energy metering is one such application as newer meters now require a much higher flow of real-time information.

Chip-scale transformers may also be used in an isolated dc-to-dc converter, allowing both data and power isolation to be integrated into a single package. *iCoupler* products offer this capability with *isoPower*® isolated dc-to-dc converters integrated into the same surface-mount, low profile package as the isolated data channels. Consider neutral line current sensing in the example above. A current transformer is traditionally used because it provides inherent isolation, but current transformers must be dc tolerant to avoid being saturated, and this increases their cost. They also introduce phase delay that differs by frequency components and is thus difficult to compensate across an entire frequency spectrum. Shunts offer appreciable advantages. They are less expensive, cannot be influenced by external ac or dc magnetic fields, and would have identical characteristics with the shunt used to sense the phase current. However, they are not inherently isolated. This can be overcome using digital isolators that incorporate an integrated dc-to-dc converter with isolated data channels. This allows for a new structure of the single-phase anti-tamper smart meter (Figure 2).

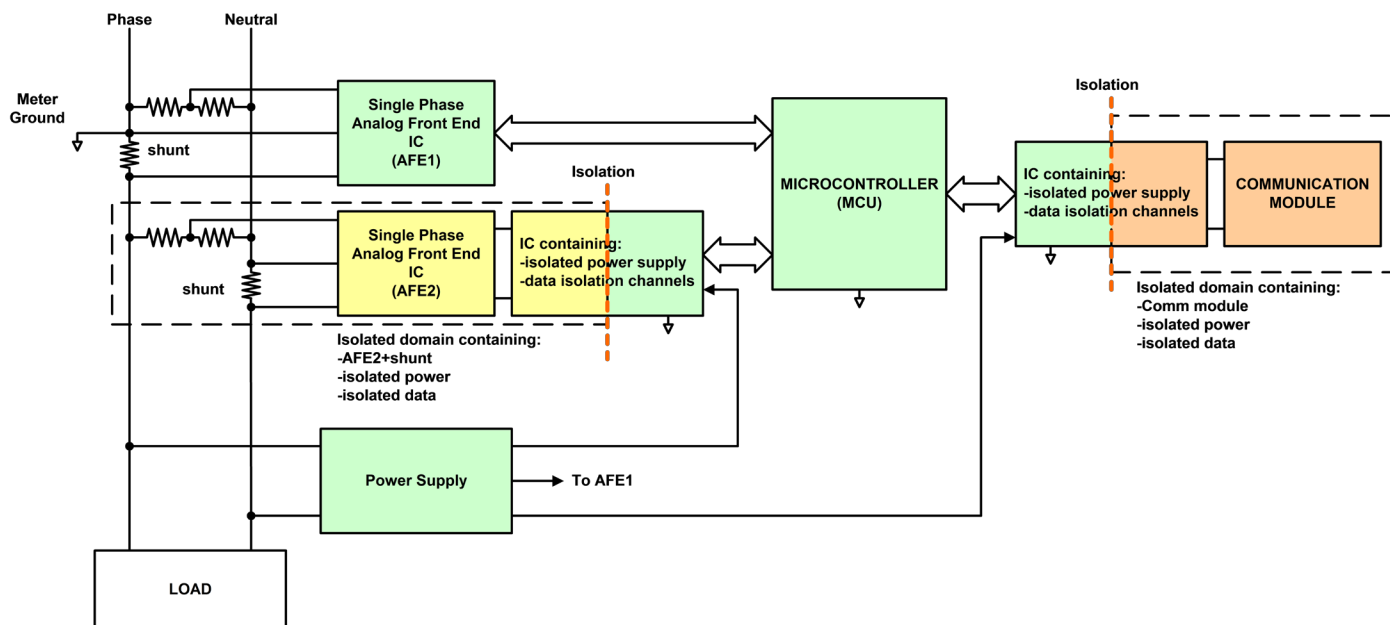


Figure 2. Single-Phase Anti-Tamper Smart Meter with ICs Containing Chip-Scale Transformers

This new structure uses AFE1 to measure electrical quantities derived from the line current and AFE2 to measure the electrical quantities derived from the neutral currents. Both currents are measured with shunts that are immune to external magnetic fields, thus eliminating tamper concerns. AFE2 receives power using an IC containing an isolated power supply based on digital isolators. It communicates with the MCU using isolated data channels that are embedded within the same IC and use the same technology.

The same approach, having an IC containing an isolated power supply together with isolated data channels, can be applied to the communication module, as it also needs an isolated power supply and data communication through the isolation barrier.

The advantages of this approach are clear when compared to large, expensive isolated power supplies that are difficult to certify. Digital isolation technology creates the industry's smallest UL certified dc-to-dc converter. The ICs have high thermal and mechanical stability, excellent chemical resistance, and good ESD performance. Designers can now

focus on improving the system design, not worrying about isolation.

Three-Phase Smart Meter

The same approach can be taken when dealing with three-phase smart meters (Figure 3). In classic four-wire systems, the neutral line is selected as the ground reference for the meter AFE. The phase currents are measured using current transformers. The power supply uses all three phases to create two domains: one that supplies the AFE and one that supplies the communication module, which must be isolated for safety reasons. The MCU can be placed in either domain, so one isolation barrier exists between AFE and MCU (Isolation 1) or between MCU and the communication module (Isolation 2).

Similar to the approach in the single-phase anti-tamper meter, using digital isolation technology, the current sensors can be replaced with isolated modules that use shunts, and the communication module can be supplied and communicate with the MCU using an IC containing the isolated power and data channels that communicate through the isolation barrier (Figure 4).

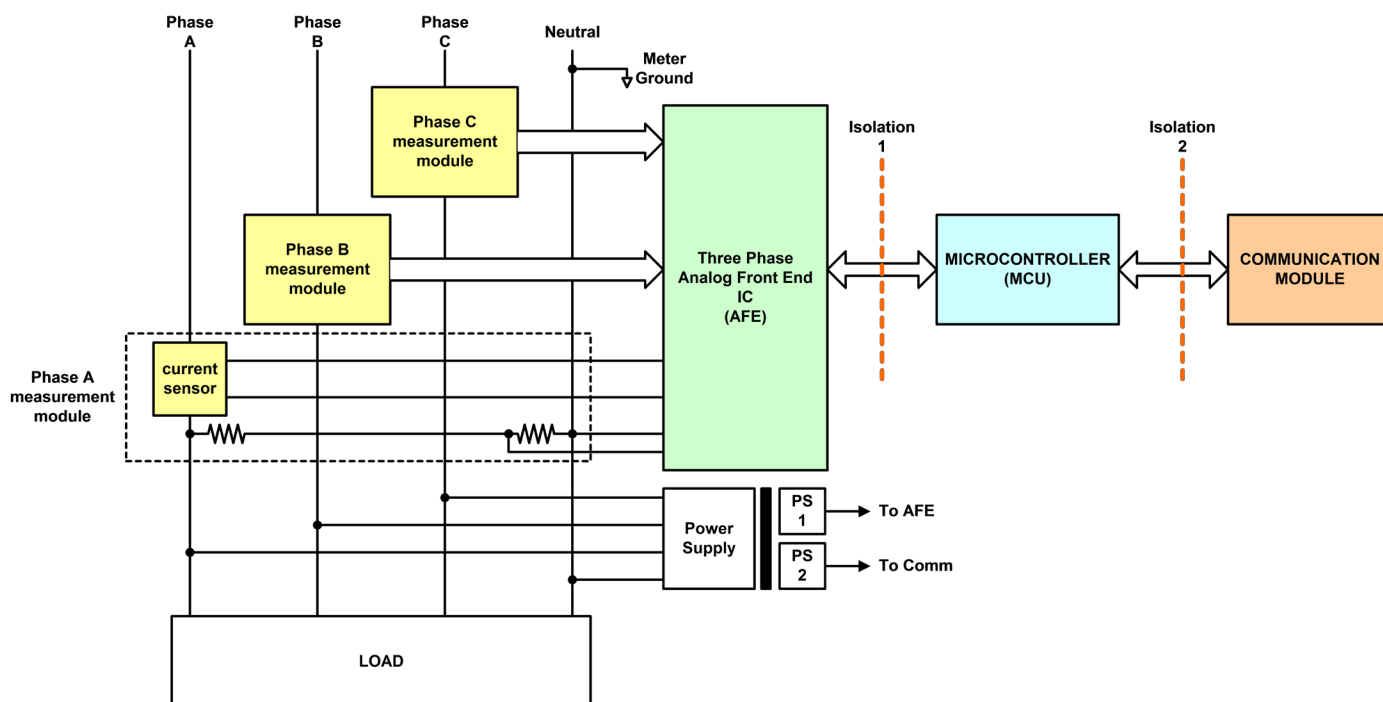


Figure 3. Three-Phase Smart Meter

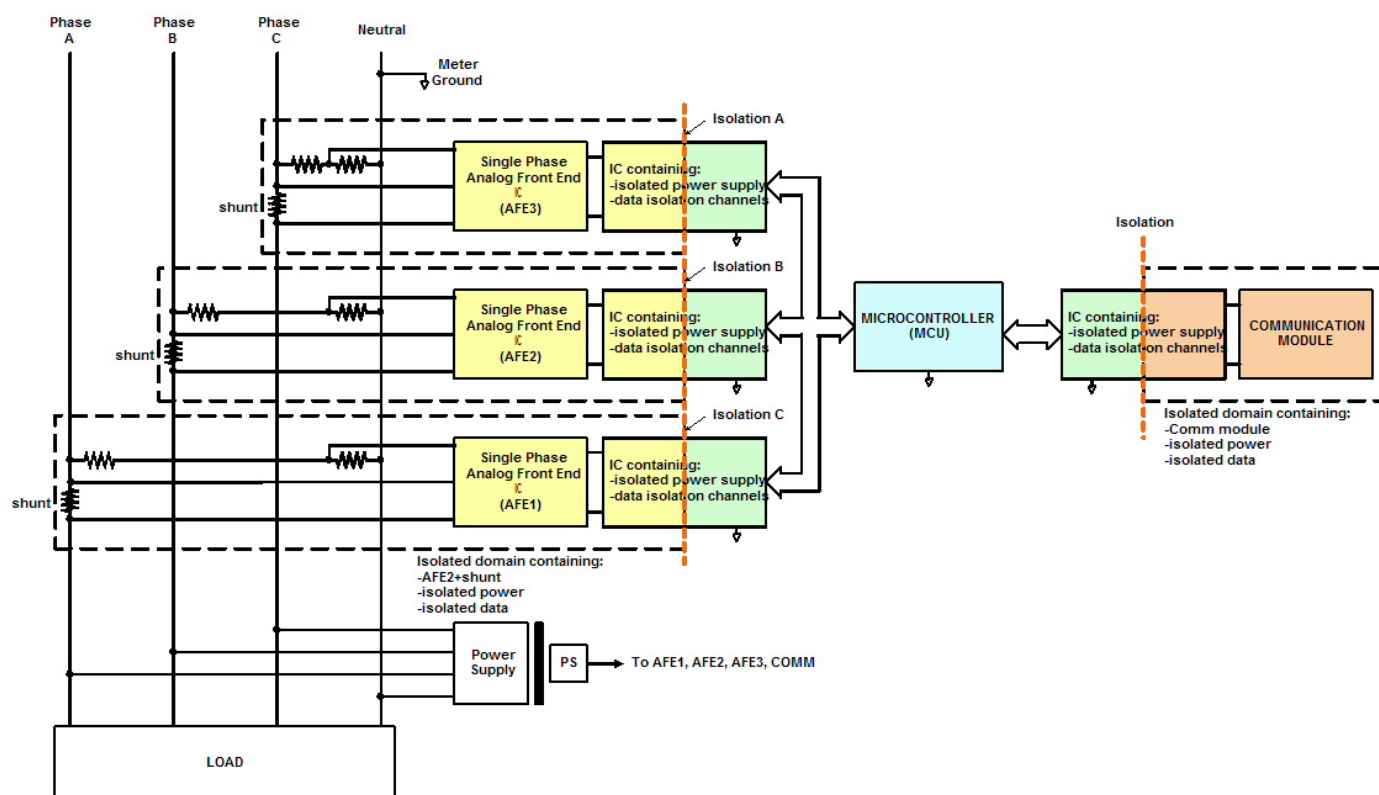


Figure 4. Three-Phase Smart Meter with ICs Containing Chip-Scale Transformers

Conclusion

DC tolerant current transformers can be successfully replaced with shunts and digital isolators that use chip-scale technology to integrate both data and power isolation. These digital isolators provide benefits over traditional optocouplers, and various serial communications can be supported: SPI, I²C, or UART. They are indeed an alternative to optocouplers because they offer more performance, are easier to use, and are more reliable.

This changes the system perspective of architecting smart meters:

- Phase and neutral currents can be sensed with resistive shunts, eliminating the threat of magnetic tampering and the difficulties in dealing with current transformer phase delay.

- Both single- and three-phase meters can use a single main power supply, using UL-certified ICs. Particularly in three-phase meters, this can dramatically reduce the power-supply footprint, allowing for smaller meter case dimensions.

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