Monitoring and Protecting Smart Meter Circuitry and Communications

CIRCUIT PROTECTION WHITE PAPER

BACKGROUND

The smart grid is the next evolution of the utility framework that converges utility providers, telecommunications infrastructure and information technology. The ultimate goal is to allow seamless communication between utility companies and their end users for a true “end-to-end” smart grid. One of the key application elements of the smart grid is the smart meter located at the end-user’s location that is designed to allow two-way, real-time communication between the utility substation or headquarters and the user. Smart meters are hybrid devices combining measurement, processing, and recording with communication functions. Smart meters are available with numerous communication protocols to transmit resource consumption information via a network back to the local utility company for monitoring and billing purposes also known as telemetering.

There are several challenges to replacing traditional meters with smart meters that include the management of numerous communication protocols, deploying systems that must meet varying global standards, and protecting the communication and smart meter circuitry. In response to the latter, Bourns provides reliable and efficient circuit protection for communication interfaces. Designers must consider multiple circuit protection elements to accommodate specific requirements used throughout the meter system: shunt resistors for current measurement; transient voltage suppression (TVS) diodes, gas discharge tubes (GDTs), fuses, and positive temperature coefficient (PTC) devices to provide circuit protection for internal signals and communications interfaces. This paper will provide a brief overview of smart meter design, the components necessary to monitor and protect its circuitry, and optimal protection solutions for several communication interfaces that are typically used in these applications.

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INTRODUCTION TO SMART METERS

A smart meter appears to be very similar to a traditional electricity, gas, or water meter located in a residence or business. Both smart and traditional meters provide metrology by measuring quantities of voltage, current, pressure, velocity, temperature, or flow rate, and communicate this information to the utility. The first difference between the two types is that smart meters record consumption in intervals of an hour or less. Additionally, the Advanced Metering Infrastructure (AMI) of smart meters provides two-way communication between the utility and the user, and AMI supports remote reporting. The key factors involved in a smart meter installation are energy awareness (providing cost signals to the end user device), energy response (allowing the end user device to respond to the price signals) and energy emergency (ability to provide immediate response to power shortages).

Inside a Smart Meter

The three main internal areas of a smart meter design include the power system, microcontroller, and communications interface. The power system has a switched mode power supply and battery backup to ensure that the metering electronics remain powered even when the main line is disabled. A MicroController Unit (MCU) typically includes an Analog-to-Digital Converter (ADC) and Digital-to-Analog Converter (DAC) to provide intelligence. Finally, a wired or wireless communication interface allows the meter to interact with the rest of the grid, and in some cases the end user's network. The main and auxiliary sections of a smart meter design are shown below in figure 1.

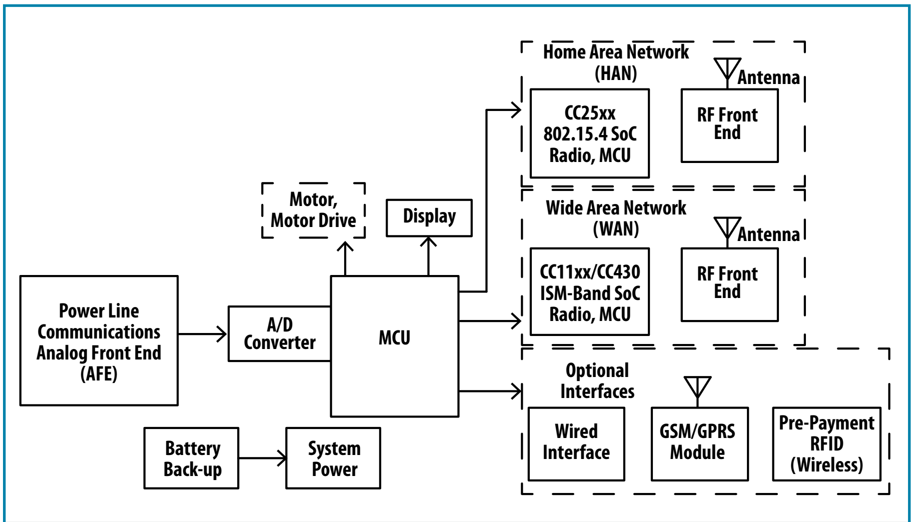


Figure 1. | *Smart Meter Block Diagram*

INTRODUCTION TO SMART METERS (*Continued*)

Power System

A switched-mode power supply provides power to the electronics in the meter, converting from the main line Alternating Current (AC) voltage to the Direct Current (DC) voltages required. A switch will turn on the battery backup AC/DC only when there is no power from the main line. The battery remains isolated from the power system during normal operation.

Microcontroller

While a microcontroller is of central importance to the design, there are several possible levels of integration with the other functional blocks in the system. The figures below illustrate three possible architectures for a smart meter that all include Analog Front-End (AFE) metrology, ADC, Digital Signal Processor (DSP) or MCU, and communications. The first example is a two-chip solution that provides flexibility for system upgrades. Second is a single-chip solution with tight hardware and software integration, making it less flexible for upgrades or modification. The data transmission over the network, shown third, may be the best communication solution depending on the location.

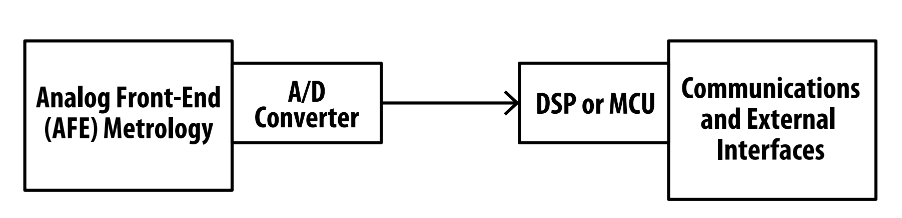


Figure 2A. | *Two-Chip Architecture*

INTRODUCTION TO SMART METERS (*Continued*)

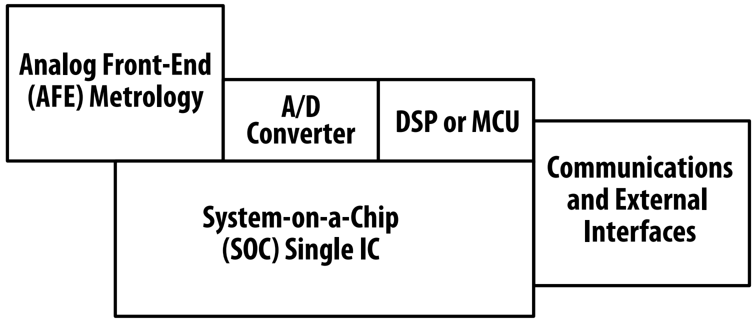


Figure 2B. Single-Chip Architecture

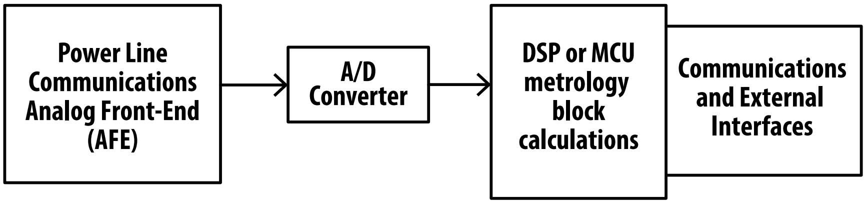


Figure 2C. Network Architecture

DESIGNING FOR VARIED COMMUNICATION INTERFACES

As with the microcontroller architecture, no single solution has been adopted for communication between the smart meter and the utility or end user. Communication protocols vary widely based on factors such as geographical regions, location of an individual meter, what is supported by the utility servicing the area, and the maturity and longevity of those supported technologies. Wireless protocols are quickly emerging as the preferred method of connecting the networks within the grid.

Radio Frequency (RF) based technology is changing the way that customers and the utility company interact with the use and sale of resources. In some cases, smart meters act as the gateways for home automation, using RF signaling such as Zigbee® to communicate the resource pricing and consumption to the end user. Devices operating with 6LoWPAN, Zigbee®, and RFID are examples of RF based technology connected with RF mesh networks. Cellular solutions make use of the existing cellular network to transmit metering information. Broadband over PowerLine (BPL) has been viewed as a potential replacement of POTS and cable networks for providing broadband, though it is not in service in all areas. It is desirable for a network to be capable of connecting a variety of device types, like WiMax, since it increases the interoperability of equipment from different manufacturers following numerous protocols.

With this variety of protocols, the equipment that supports communication in the grid will be quite diverse. The following table outlines a selection of the types of equipment that are found in these networks.

Table 1. | Network Equipment in Smart Meter Systems

Network Type	Equipment
RF Mesh Networks	Bridges, relays, routers, access points, wireless gateways
Cellular	Cell relays, access points
Broadband over Power Line (BPL)	Gateways, bypass equipment
WiMax	Routers, access points

COMPONENTS FOR SENSING AND PROTECTING

A smart meter is comprised of sensitive circuitry and may support numerous communications protocols. In addition, there are sensing and circuit protection circuits included in the design of the smart meter in which resistors are naturally a fundamental part of the electronic design. The metrology AFE revenue-grade measurements rely on the accuracy of series resistors for current sampling, scaling resistors with low PPM and low tolerance for voltage sampling, and current sense resistors for velocity, pressure, temperature, and flow rate measurements. To safeguard this information, smart meters must be capable of handling line and ground voltage and transients with protection to IEC 61000-4-5 requirements. On the power lines, it is common to find protection in the form of metal oxide varistors such as Bourns® Model MOV20D device. In order to ensure robust transmission of data, the communications interfaces must be protected as well.

Passives

Low value resistors can provide current sensing and current feedback inside a smart meter. This solution is ideal for residential smart meters as these precise low value resistors are very cost-effective and straight-forward to use. In an electricity meter, a resistor is simply placed in series with the high current electric bus bar, and the current flowing through it is calculated. The calculation can be performed based on the proportional relationship of voltage and current in a resistor of known value. This current value and the instantaneous voltage are multiplied to get the power consumed at any instant, and is continually monitored by the microcontroller. Resistors can be placed between the voltage and signal lines where the supply current may need to be limited to prevent damage to other components. Adding flexibility to deployment, it is also possible for power resistors to be used in a heating function to stabilize the internal meter temperature in frigid environments. Popular resistors include the Bourns® Model PWR221T, CRT and PWR4522 series.

Smart meter designs utilize magnetic elements for EMI filtering/noise suppression, isolation, and power converter energy storage. Specifically, pulse transformers are used to isolate current sense metrology from mains power and a combination of differential and common-mode inductors are used for power convertor energy storage, filtering of EMI/noise and output ripple. The Bourns® Model SRR series power inductor and Model 7400/7500/2300 series CMC inductors are among a few that are used to provide differential/CMC and RF filtering for these high frequency designs. For transient protection, the MOV is a cost-effective voltage clamping device designed to handle transients. Since the MOV is known to allow higher voltage overshoot than other suppressors, a current trend is to employ high voltage (transient tolerant) power inductors. These inductors are designed to handle transients on mains connected systems providing typical operating voltages from 400 V to 500 V with transient immunity performance to 1 kV, delivering long-life asset performance by meeting increased expectations on reliability.

COMPONENTS FOR SENSING AND PROTECTING (*Continued*)

Passives (*Continued*)

The circuit in figure 3 illustrates the typical MCU-based smart electricity meter application utilizing transient protection, AFE filtering, isolation, and a power supply output inductor.

Transient protection: MOV, high voltage input inductor
Magnetics: High voltage input inductor as differential filter, EMI filter, pulse
Transformer for isolated current measurement, power convertor energy storage output inductor
Resistors: Current sense resistors, resistor pair as a divider to allow voltage measurement

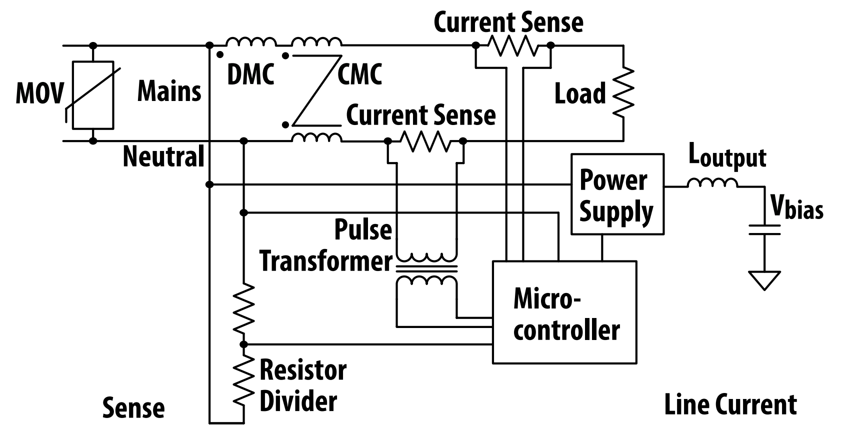


Figure 3. Resistors and Magnetics in the AFE and Power Interfaces

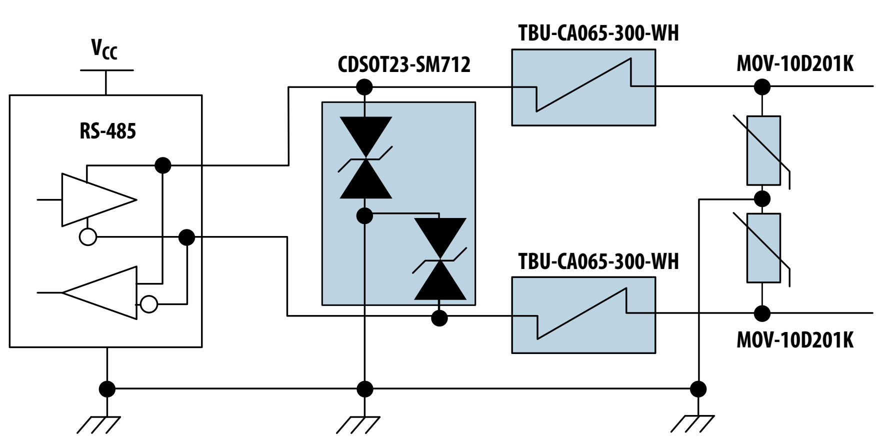
Protecting Intelligence

Smart meters contain more sensitive electronics than traditional meters and require circuit protection components such as TVS diodes, fuses, and PTCs to protect against overcurrent and overvoltage conditions. For example, the microcontroller will require resettable protection with a fast reaction time as a defense against surges. A fast-acting resettable fuse or PTC can handle this task. In other situations that do not require reset capability, a thin film chip fuse may be employed. Diodes can provide suppression of transient voltage on the input and output signals of the microcontroller.

COMPONENTS FOR SENSING AND PROTECTING (*Continued*)

Communications Protection

Reliability becomes more important as utilities depend on Automatic Metering Infrastructure (AMI) data to accomplish high-level tasks. To meet Quality of Service (QOS) requirements, high reliability electric, water, or gas smart meter systems must include robust circuit protection. Whether using broadband or RF communication interfaces, a combination of overvoltage and overcurrent circuit protection devices (TVS diodes, MOVs, TBU® High-Speed Protectors, PTCs, fast-acting fuses, GDTs, magnetics, etc.) will potentially be needed to protect a variety of transport used to carry the information (i.e., RS-485, T1/E1, Zigbee®, optical). Figure 4 illustrates an RS-485 solution which provides environment-specific ESD, EFT, and current surge transient protection. It includes TVS diodes, Bourns® TBU High-Speed Protector and MOV devices. Bourns has developed a broad selection of helpful documents called PortNote® Solutions. Bourns created these documents as a guideline to assist designers in selecting the appropriate circuit protection solution for a specific port interface.



The schematic above illustrates the application protection and does not constitute the complete circuit design. Customers should verify actual device performance in their specific applications.

Figure 4. | Communications Protection for RS-485 Transport

CONCLUSION

As the smart meter market gains momentum, it is important for design engineers to consider reliable circuit protection early in the development cycle. Selecting proven components that ensure the reliable operation and communication of smart meters are essential application building blocks. Current sensing feeds directly to the processing portion of the design, and precision in this portion of the design is of paramount importance. The optimal circuit protection solution will depend on the types of processors and communication protocols for a given installation. The good news is that Bourns offers a broad range of solutions that are available for integration with numerous communication standards. A smart meter generally will contain several connectivity options for maximum versatility in installation. Wireless smart meters interface with a variety of equipment, so care must be taken to ensure the level of circuit protection from the end user to the utility company meets or exceeds the involved standards to provide the desired “end-to-end” solution.

THE BENEFITS OF WORKING WITH BOURNS

Bourns has been a leader in passive components and circuit protection for several decades and is committed to continued innovation. There are many benefits to using Bourns® components in smart meters. Bourns® resistors have low PPM and low tolerance for scaling and current sense. Power resistors are available with a high pulse rating, such as the Bourns® Model PWR221T-50, or with an integrated fuse such as Bourns® Model PWR4522. Bourns offers a wealth of options for overcurrent and overvoltage protection in communications ports. Bourns® ChipGuard® devices are designed to protect against ESD, EFT, and current surge, and are capable of supporting bandwidths up to 3 GHz. Bourns® magnetics devices feature sealed chips for filtering, and RF conversion inductors and EMI solutions that meet standards for conducted and radiated regulatory compliance. Bourns helps take the guesswork out of circuit protection design by providing high quality components, superior customer service, and design resources such as PortNote® Solutions to illustrate sample interface solutions.

ADDITIONAL RESOURCES

For more information about Bourns’ complete line of circuit protection solutions for telecommunications applications, please visit:

www.bourns.com

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