basics of Design

Evaluate The Impact Of EMI On Smart Meters

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Smart meters are quickly growing as Smart Grid technology automates power grids, allowing power utility companies to monitor their customers' use of power. In the United States, the federal Smart Grid program is encouraging the replacement of traditional side-of-building-mounted power meters (that must be checked by utility personnel) with smart meters that can provide energy-use information using many different communications protocols, including power-line communications (PLC) and wireless networks.

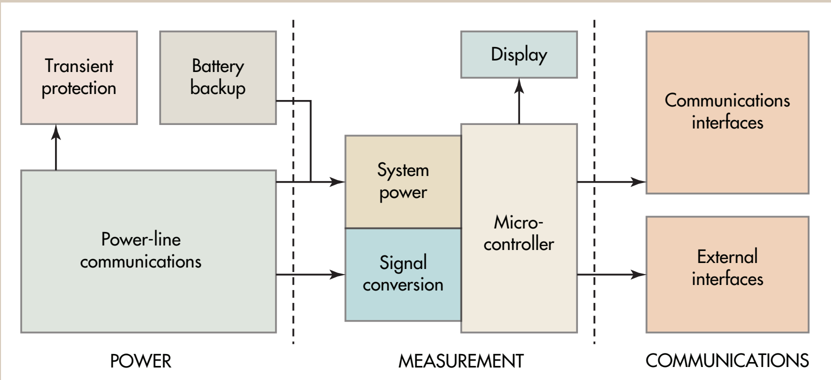
The advanced metering infrastructure (AMI) of a smart meter allows two-way communications between a customer and a power utility. Smart meters read signals transmitted from energy-consuming equipment, such as a washing machine or a refrigerator, provided that such equipment has been outfitted with a proper transmitter. But for all their widespread adoption by consumers, smart meters include sensitive sensing and communications circuits that must be designed for proper protection against overvoltage and overcurrent conditions to minimize the effects of electromagnetic interference (EMI).

EMI is generated from both smart meter circuitry and the adjacent electronic devices around it (surrounding energy sources, such as power lines and antennas). It is of increasing concern as more sensitive wired and wireless electronics units are used near each other and connected to mains power. Deleterious effects of EMI can prevent a smart meter from accurately reading and reporting energy consumption, or they could even provide users with misleading information about energy usage. Smart meters, then, are equipped with input filters to suppress unwanted radiated, reflected, and power-line energy emissions that can degrade their measurement accuracy or otherwise disrupt their proper operation.

As part of a Smart Grid, smart meters will be everywhere, and not always in the most ideal operating conditions. Smart meters work with separate transmitters mounted or built into energy-consuming devices, such as refrigerators and washing machines, which send information to the meters about the amount of energy being used. These transmissions from separate appliances take place during extremely short periods, often less than a second, throughout the day. The details are relayed to a power utility by means of a smart meter nearest the energy-consuming appliances.

Another type of meter, known as a collector meter, gathers information from energy-consuming devices in multiple dwellings, often more than a few thousand homes in one area, and sends the collected energy-use information back to the power utility. Smart meters typically incorporate two antennas, while collector meters have three antennas. All meter types incorporate sensitive circuitry for power sensing and communications, whether over power lines or wirelessly.

Together, these meters form an automated power grid or mesh network that operates as a distributed antenna system (DAS) for power utilities to know of their customers' power consumption and for those customers to have access to information about their own power



1. A smart meter comprises three main sections: the power system, a microcontroller, and a communications interface. Operation requires proper electromagnetic isolation.

2. Inductors are among the passive circuit elements essential for building EMI filters for smart meters.

consumption in hopes of making their own energy-use practices more efficient. The Smart Grid has also been called an advanced metering infrastructure (AMI), linking many customers to utilities as part of a real-time network.

Shielding A Meter

Although they provide fairly straightforward functions, including power measurement and communications, smart meters are not simple devices. They include numerous sections and components that can be affected by internal or external EMI. A smart meter has three main sections: the power system, a microcontroller section, and a communications interface (Fig. 1).

The power system typically is a switched-mode power supply with backup battery. The microcontroller unit (MCU) includes the smart meter's intelligence and measurement capabilities, with an analog-to-digital converter (ADC) and digital-to-analog converter (DAC) for signal processing. Communications may use wired or wireless technologies, across several different frequency bands. Designing a smart meter requires EMI to be properly shielded from potential internal sources. Also, EMI from external sources must not degrade the smart meter's performance.

Filtering at the input of a smart meter is an important step in minimizing EMI effects from external sources, which is critical considering some of the environments in which these meters must operate. EMI tends to increase in environments with higher electronic device density, and smart meters used in multiple dwelling units (MDUs) must operate in much more challenging environments than single meters tied to single dwellings. As a result, MDU meter implementations can have greater filter requirements to minimize the effects of conducted and spurious radiated EMI emissions compared to single-meter installations, requiring careful consideration of filter components for all three main sections of the meter.

Inductors are available in many forms for use within smart meters for EMI control and protection. Although shielded and non-shielded inductor versions can provide the isolation needed from EMI, shielded inductors are usually preferred for use in smart meters, especially considering the dense and often difficult electronic environments in which they must operate and provide consistent performance. In addition, the shielding helps to minimize internal emissions and noise coming from the inductor itself within the smart meter circuitry.

Inductors are available in many different shapes, with low-profile packages that can meet the size requirements of the smallest smart meter designs (Fig. 2). For example, chip inductors are often specified for extremely tight smart meter packaging requirements.

Filtering EMI

Filtering EMI in smart meters involves selection of the traditional components required for fabricating filters: resistors, inductors, and capacitors (RLC), with values and package styles that will be best determined by the configuration of the smart meter and the needs of an application. In most cases, these are low-power (less than 1 W) components that must fit within low-profile circuitry and smart meter housings.

Filter components will be selected according to the performance requirements of the target circuit: rejection of unwanted signals, self-resonant frequency (SRF) of each element, how it coincides with the sampling rates of the smart meter's different circuit sections, and the amount of insertion loss that is suitable within the frequency passband. The smart meter environment is demanding. Consequently, it requires high-quality components with industrial temperature specifications and low tolerance so any filters fabricated with those components also remain stable over time and temperature.

EMI conditions can vary a great deal across an electric service area, especially for smart meters that may need to rely on PLC to transfer details about power consumption to a utility. Because electric power lines and grids were designed to deliver power, they are not always optimal for transferring high-speed digital signals, such as those required between a smart meter and a utility. High-speed digital signals are often coupled along the power lines by means of narrowband orthogonal frequency-division multiplexing (NB-OFDM), which can achieve data rates of a few hundred kilobits per second across a communications distance of several kilometers.

For smart meters to function in these applications, the PLC network must transfer data in spite of

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noise from a wide range of sources, including switching loaded, dc-dc converters, ac motors and controllers, even synchronous noise from light dimmers. These many different noise sources are coupled to the power-line network via electrical connections or by means of EMI radiation. Combined with an analog front end (AFE), modulation techniques such as OFDM are quite capable of overcoming the effects of impulse noise while effectively transferring data at reasonably high rates.

In addition to the PLC networks, more and more smart meters rely on wireless communications to transfer energy-use data to a utility. EMI problems for the smart meter are more likely to come from other electronic devices nearby, such as an air conditioner or a television.

Smart meters for wireless use are designed to operate within specific available frequency bands, sending information in short bursts. Depending on the location, electric utilities may use the frequency range from 800 to 1000 MHz, while gas meters may communicate from 400 to 500 MHz and home appliance networks (HANs) run from 2400 to 2500 MHz.

In California, smart meters from Pacific Gas & Electric (www.pge.com) use 902 to 928 MHz to report electricity usage and frequencies from 450 to 470 MHz to communicate gas usage, typically at peak transmit power levels of much less than 1 W and in short bursts. These wireless smart meters must operate according to the Part 15 Federal Communications Commission (FCC) rules, but they are still subject to the effects of EMI.

Regardless of frequency, EMI can be a concern for a smart meter. In many cases, a smart meter will be mounted in a location that is electromagnetically noisy, with many other sources of electromagnetic energy near it. The meter's sensitive measurement circuits must be protected from distortion because of external EMI sources, while its communications circuits, which may operate for very short periods but at relatively high data rates, must also be guarded against distortion and degradation from internal and external EMI sources. Again, through proper filtering and the selection of passive RLC circuit elements for those filters, the effects of EMI on smart meters can be minimized within a small size and at low cost.

The compact size and relative high level of integration employed in most smart meters increase the importance of sufficient circuit-level isolation within these devices. Inductors and magnetic devices for EMI noise suppression can provide the electromagnetic isolation required between the smart meter's current-sensing measurement circuitry (often precision resistors in series) and its power supply/conversion circuitry.

Additional passive circuit elements such as resistors and capacitors can help form the filtering circuitry needed to suppress the effects of EMI within a smart meter as well as the effects of outside EMI sources on proper smart meter operation. A wide range of commercial chip and packaged circuit elements can help produce low-cost EMI filtering within small smart meter housings, such as the Bourns® (www.bourns.com) common-mode-filter Model 7400, 7500, and CM series high-frequency chip inductors for RF isolation and noise suppression.

New Applications

Designing circuitry intended to perform reliably for 25 years or longer is never an easy task since, for one thing, it is difficult to know which electronic applications will gain in importance and influence in the years to come. One example is the rapid growth of wireless portable devices and how such devices have now become the central communications hub for many users.

One recent report pointed out how smart meters can help prevent the spread of a relatively new phenomenon, energy theft (see "Smart Meter Advances Stop Electricity Theft" at http://electronicdesign.com/power/smart-meter-advances-stop-electricity-theft), and ensure the proper delivery of energy and services from energy utilities to their customers. Furthermore, eliminating energy theft helps reinforce the investment value in smart meters on the part of the energy utilities.

Smart meters offer an efficient and effective means of monitoring the use of power and other utilities, such as water and gas. They often may be mounted in hostile EMI environments. Yet through proper design of filtering circuitry and circuit elements, smart meters can provide dependable results for relatively long operating lifetimes.

Different organizations offer relatively unbiased background information on smart meters and the Smart Grid, including the Smart Grid Consumer Collaborative (www.smartgridcc.org), and how smart meters are expected to benefit both consumers and power utilities in the years to come.

Establishing and maintaining reliable smart meter performance requires careful consideration and selection of critical components, such as inductors, when designing the different filtering and resonant circuits to provide protection from both external and internally generated sources of EMI. ■