



# CIRCUIT PROTECTION SOLUTIONS OPTIMIZED FOR Smart Meter Power, Measurement and Communications Port Protection WHITE PAPER

## BACKGROUND

The process of generating and distributing energy has been undergoing changes over the past several years and more changes are on the horizon. Generating energy from alternative sources, such as solar power, and spanning to the smart meter at the customer's location adds to the requirement and design challenge complexities facing engineers. One such challenge is selecting a Photovoltaic (PV) inverter and placing it within a system that delivers the desired quality and reliability. Additionally, the awareness of downtime is greater, so circuit protection solutions must be robust to ensure systems remain unharmed when exposed to overcurrent and overvoltage conditions from transients. The presence of communications ports in smart meters introduces another set of interfaces to protect. Overall, a design paradigm shift required for energy generation and distribution systems can be narrowed down to three main areas within a smart meter: power, measurement and communications.

This paper will introduce a variety of components available to help optimize the circuit protection design in smart meters that includes power circuits, current sensing for measurement and port protection for communications.



# CIRCUIT PROTECTION SOLUTIONS OPTIMIZED FOR Smart Meter Power, Measurement and Communications Port Protection

## SMART METERS ENABLE THE NEW GRID

Legislation such as the American Clean Energy Leadership Act of 2009 has formalized the need to manage aging grids and reduce greenhouse gases. This policy requires utility companies to obtain 15 % of their energy from renewable resources by 2020, and interim levels of renewable sourced energy have already been required since 2011. These same utility companies have had to implement new pricing models based on usage time calculated to manage the aging utility grid. Making the process more efficient, communications interfaces now supported by smart meters allow customers to communicate from outside the building or home with a smart meter connected over wired or wireless ports. This helps to reduce overall energy usage, thereby lowering CO<sub>2</sub> emissions.

Figure 1 shows the three main blocks in a smart meter. Transient protection is at the front end. The conditioned, filtered power line then interfaces with the measurement block that contains signal conversion circuitry, a microcontroller for calculations and a display that replaces the dials used in traditional meters. A battery back-up is in place to ensure that the system remains powered even when the main power line is disabled. Communications and other external interfaces also provide a method for interacting with the rest of the grid or the end user.

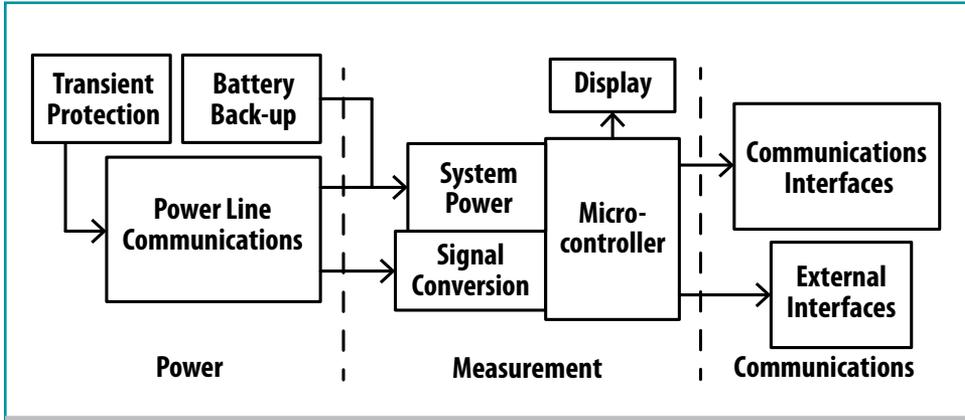


Figure 1. | A Smart Meter is Protected from Transient Events, Consumed Power is Analyzed, and Usage Data is Shared Through the Display and Communications Blocks



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### SMART METERS ENABLE THE NEW GRID *(Continued)*

Several things set the smart meter design apart from the previous infrastructure, traditional power meters and other communications applications. For instance, smart meters and communications-enabled equipment are entirely new to the grid in the last decade and require compact components running on lower voltages than were present in the old system. The amount of protection for the communications ports and any other equipment in the system must scale to fit within the new design constraints. An important consideration is that communications ports and PV inverters are connected to higher voltage equipment than in consumer applications. Additionally, the conditions in which the smart meter will be used are not uniform and all of the electronics it contains must be capable of operating reliably in harsh environments. These considerations are complicated further by the expected lifespan of approximately 25 years that must be maintained in these designs, rather than the 10 years or fewer that is common for electronics in other industries. It is essential that the optimal power, measurement and communications components are selected at the beginning of the design to ensure the smart meter design will meet these multi-decade product lifecycle requirements.



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### POWER CIRCUITS

An increased awareness of electrical transients that cause downtime is driving surge protection to be designed into incoming lines as well as onboard circuitry. The types of power circuits that are of particular interest because of the shift to renewable sources are the PV inverters used for energy generated by sunlight. PV inverters are used to convert the variable Direct Current (DC) output of the solar panel into Alternating Current (AC) to feed back into the commercial electrical grid or supply a local off-grid electrical network. The PV inverter can match the phase of utility-supplied power or can be used independently. Battery backup inverters draw energy from a battery or charger and then supply AC energy or export excess energy to the utility grid. Common reasons for PV inverter failure include exposure to transients from the grid or from the PV panel, usage beyond its designed limits, extreme temperature conditions and overvoltage and overcurrent conditions.

Circuit protection is important for inverter interfaces as well as for preventing damage to wiring and other system components of operation. Part of the challenge in protecting power circuits is identifying the tolerances and trip levels for the system, and then determining which components will meet these requirements. The calculations may be different than those used in commercial electronics because voltage levels are higher and signals are combined in numerous places between generation and consumption. Selecting proven components as the building blocks of the smart meter design helps to ensure its reliable operation over time. Smart meter power circuits are composed of three main functions: rectification, conditioning and filtering and protecting against overvoltage and overcurrent events. Each of these functions relies on a unique set of components.

### *Power Rectification*

An important part of conversion from AC to DC power is rectification. Power rectification may use bridge rectifiers, Schottky diodes and high voltage, fast response rectifier diodes. The choice of technology can be based on the voltage and current ratings of the bridges and diodes and what is required for the conversion. To meet these varying requirements, Bourns offers bridge rectifiers rated from 200 V - 800 V for currents in the narrow range of 800 mA - 1 A; Schottky diodes from 20 V - 100 V with a wider 1 A - 3 A current rating and rectifier diodes available in the wide range of 50 V to 1000 V with a current rating of 1 A - 3 A.



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## POWER CIRCUITS (Continued)

### Power Conditioning and Filtering

Ferrite beads and inductors are commonly used for power conditioning and filtering. Ferrite beads filter out high frequency signal components, thus preventing interference with the rest of the circuits on a board or at an interface. Unshielded or shielded surface mount power inductors in a variety of shapes and sizes also are used for power conditioning and filtering in smart meter power design, such as Bourns® Mocal SDR, SRR, and SRU Series. The inductor models in Bourns® Model SDR Series are non-shielded surface mount components in square, oval, and round shapes. The Model SRR and SRU shielded inductors are ideal for smart meter power circuits since they can handle high current and control Electromagnetic Interference (EMI). Inductors from any of these three series are ideal at input or output of DC-to-DC converters, and can also be used in power supplies for portable communications equipment or stand-alone electronics. These inductors are available in low profile packages and are suitable for designs that have height and space constraints.

Deciding between shielded and unshielded inductors for a particular design requires taking into account the environment of the circuit board and characteristics of the application. In many situations, the noise generated by a non-shielded inductor can interfere with the reliable behavior of the rest of the circuitry. This often is the case when microcontrollers or high frequency components are used in neighboring circuits or within the board assembly. For such situations, a shielded inductor is typically the better choice. Once a decision between shielded and unshielded technology is reached, size, shape, inductance, and current rating are the biggest differentiators within each family. For example, an oval SDR model is available with current rated up to 16 A, but a round SDR model combines a lower current rating with a higher inductance of 15,000  $\mu\text{H}$ . Table 1 contains the size (where Outer Diameter (OD) is given for length and width of the round shape), inductance range and current of the Bourns® Model SDR, SRR, and SRU series inductors.

Table 1. Characteristics of Bourns® Inductors Used for Power Conditioning and Filtering

Family	Shape	Models	Length (mm)	Width (mm)	Height (mm)	Inductance ( $\mu\text{H}$ )	Current (A)
SDR shielded	Rectangle	7	5.8 - 12.7	4.5 - 12.7	2.2 - 4.8	1 - 10,000	0.08 - 7
SDR shielded	Oval	4	6.6 - 22	4.5 - 15	4.5 - 7	0.68 - 10,000	0.07 - 16
SDR shielded	Round	8	3 - 13 (OD)	3 - 13 (OD)	2.5 - 7	1 - 15,000	0.06 - 9.5
SRR	Square	21	3.8 - 12.7	3.8 - 12.7	1.2 - 8.5	0.47 - 15,000	0.07 - 20
SRR	Oval	4	10.5 - 18.3	8 - 14	3 - 6.8	1 - 3,300	0.1 - 4.5
SRU	Octagon	23	2.8 - 10	2.8 - 10	0.9 - 4.8	0.8 - 1,000	0.15 - 8



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### POWER CIRCUITS (*Continued*)

#### *Transient Protection*

Transients from lightning and other surge events introduce overvoltage and overcurrent conditions that may cause damage to the smart meter, wiring or system. To protect from power overcurrent conditions, a Polymer Positive Temperature Coefficient (PPTC) resettable fuse from the Bourns® Multifuse® series can be used. This resettable overcurrent protection device is available for currents of 50 mA up to approximately 14 A. This device has negligible resistance during normal operation and quickly transitions to a very high resistance to form an effective open circuit when the current or ambient temperature is above the rated level. The microcontroller power supply line is an example of an interface that can take advantage of the speed and resettable nature of a Bourns® Multifuse® device.

For more sensitive or higher performance systems, Bourns® TBU® High-Speed Protectors (HSPs) provide resettable overcurrent and overvoltage protection. The TBU® HSP reacts within nanoseconds, effectively blocking dangerous levels of transients almost immediately. When a fuse is needed, Bourns® SinglFuse™ thin film chip fuses provide single-use protection between 500 mA and about 7 A with a fast acting or slow blow option. When an interface does not require reset capability, such as in the display, a Bourns® SinglFuse™ chip fuse can be used.

Protecting power busses from 3 kA to 10 kA can be achieved with a Power TVS (PTVS) diode. Similarly, a pair of TVS diodes can be used to protect the input and output lines of the microcontroller. Metal Oxide Varistors (MOVs) between 7 mm and 20 mm are good solutions to provide overvoltage protection in a compact package. Gas Discharge Tubes (GDTs) help provide high-current surge protection for common signal transients. Bourns® Model 2097 GDT is a high voltage part rated at 20 kA for operating voltages less than or equal to 2.2 kV. For circuits that must withstand higher currents, Bourns® Model 2061 or 2063 GDTs can handle 40 - 60 kA. Selection of the optimal GDT must be based on the expected current and voltage levels in the circuit.



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## CONTINUOUS MONITORING OF POWER LINES

Shunt resistors are commonly used for measuring current in the smart meter. Current sensor measurements must be rugged enough to operate reliably and accurately even in the harshest conditions. Low value resistors can provide current sensing and current feedback inside the smart meter, which is ideal for residential smart meters. In the smart meter, the resistor is placed in series with the high-current electric bus bar at the meter terminal interface. The current flowing through the resistor is calculated based on the proportional relationship of voltage and current in a resistor of known value. Multiplying current and voltage yields the instantaneous power consumed at that time. Current sense measurements feed directly to the smart meter's processing circuit. A microcontroller performs continuous monitoring and precision is of paramount importance. Bourns® precision resistors enable accurate scaling and current sense, while their low parts per million per degree centigrade (PPM/°C) results in stability over temperature variations.

Figure 2 illustrates various resistors employed inside the smart meter for measurement. The resistor divider provides a voltage measurement to the microcontroller, and shunt resistors provide current sense measurements from each main to the microcontroller. Additional resistors may be included on signal and voltage lines to limit the supply current, thus preventing damage to other components.

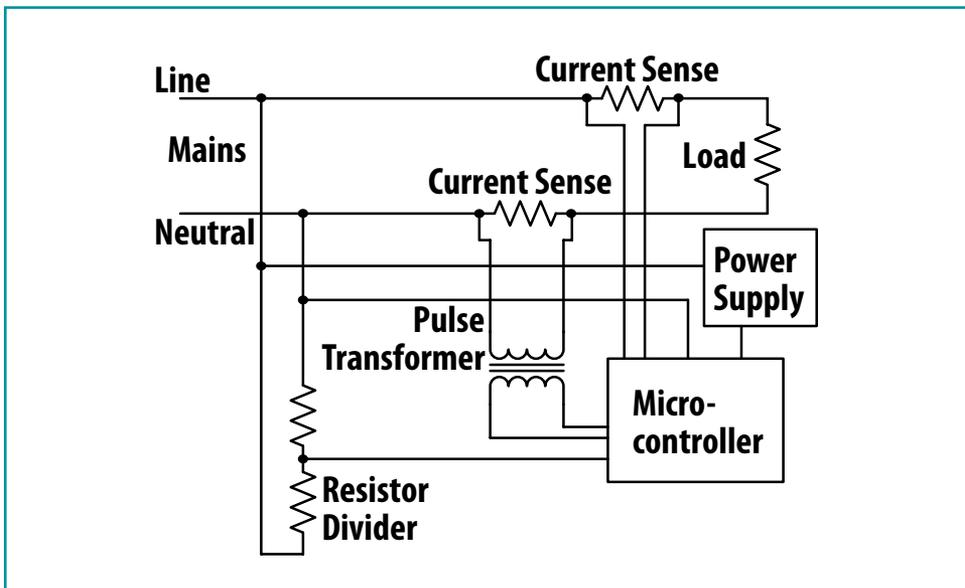


Figure 2. | Current Sense Resistors and Resistor Dividers Provide Current and Voltage Measurements to the Microcontroller Inside a Smart Meter



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### GOING BEYOND A DISPLAY USING COMMUNICATIONS PORTS

Numerous communications protocols dominate smart meters, though none have been selected as an international standard. Until a universal communications protocol is identified for electric metering, the equipment must have the flexibility to operate over one of several interfaces including RS-485, Ethernet or T1/E1. Each is unique in its operating voltage level and data rates and each must be compliant with specific standards.

#### **RS-485**

RS-485 is a balanced data transmission scheme that uses voltage levels from -7 V to +12 V at data rates up to 10 Mbps. Use of TBU® High-Speed Protectors, Metal Oxide Varistors, and TVS Diodes provide protection against Electrostatic Discharge (ESD), Electrical Fast Transients (EFT) and power and surge faults. RS-485 typically must comply with IEC 61000-4-2 level 4 (ESD), IEC 61000-4-4 (EFT), and IEC 61000-4-5 current surge standards.

#### **Ethernet**

Ethernet interfaces employ 2 V digital signals operating on a 125 MHz clock. TVS Diode Arrays provide ESD protection commonly required in indoor, short-cable applications where ESD is the primary threat. An Ethernet interface will typically meet a minimum compliance with IEC 61000-4-2 level 4 requirements.

#### **T1/E1**

To communicate over long cable distances, T1/E1 ports are used. The solution for this data communications interface contains TBU® High-Speed Protectors, TISP® Thyristor Surge Protectors, and Gas Discharge Tubes. A T1/E1 solution should comply with GR-1089-CORE, section 4, port types 1, 3 and 5 standards, protecting against surge and power contact threats.



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## GOING BEYOND A DISPLAY USING COMMUNICATIONS PORTS (Continued)

### Bourns® PortNote® Solutions

Regardless of which of the three popular communications protocols are used in a smart meter design, a port protection solution can be created with a collection of Bourns® components. Bourns has developed a helpful library of single-page PortNote® Solutions to guide designers through proven solutions for a specific port type and additional design options with applicable standards. It is an advantage to a designer to know that Bourns® PortNote® Solutions have been tested thoroughly with well-defined components. Table 2 indicates the circuit protection components and the protocol covered in each Bourns® PortNote® Solution.

Table 2. | Circuit Protection Components Used in Communications Ports

Part	RS-485	Ethernet	T1/E1
TBU® High-Speed Protectors	PortNote® Solution	Optional	PortNote® Solution
TVS Diodes/Arrays	PortNote® Solution	PortNote® Solution	
TISP® Thyristor Surge Protectors	Optional		PortNote® Solution
Metal Oxide Varistors	PortNote® Solution		
Gas Discharge Tubes	Optional		PortNote® Solution
ChipGuard® ESD Suppressors		Optional	
Transformers		Optional	
TCS™ High-Speed Protectors		Optional	
SinglFuse™ Thin Film Chip Fuses			Optional



# CIRCUIT PROTECTION SOLUTIONS OPTIMIZED FOR Smart Meter Power, Measurement and Communications Port Protection

## ADVANCING SMART METER DESIGNS

By remaining engaged with industry leaders and standards committees, Bourns is able to provide components that meet or exceed the needs of designers facing the challenges of updating legacy meter designs. Circuit protection components are complementary and when combined properly in a design they can provide thorough protection for power and communications ports alike. Single-phase, low-cost, tamper resistance and the availability of custom configurations are just some of the benefits of using resistive shunts for measurement current sensing. A summary of the components used in the power, measurement and communications port blocks of the smart meter is provided in table 3 along with the features and benefits that make these components ideal for the design.

*Table 3. Circuit Protection Components Used in Power, Measurement and Communications Port Blocks*

Block	Purpose	Component	Feature	Benefit
Power	Power Conditioning/ Filtering	Shielded Inductors	Small Footprint, Wide Range of Inductance	Low EMI
Power	Power Conditioning/ Filtering	Non-shielded Inductors	Small Footprint, Wide Range of Inductance, High Current	Lower Emissions
Power	Rectification	Bridge Rectifiers	Low Power Loss, High Efficiency	Integrated Package
Power	Rectification	Diodes	Small Footprint, Low Profile	High Peak Inverse Voltage (PIV)
Power	Overcurrent Protection	Multifuse <sup>®</sup> PPTC Resettable Fuses, TBU <sup>®</sup> HSPs	Resettable, High Speed	Low Let-through Energy, Extremely Fast-acting
Power	Overcurrent Protection	SinglFuse <sup>™</sup> Thin Film Chip Fuses	Fast-acting, Slow Blow	Small Package, High Reliability
Power	Overcurrent Protection	TVS Diodes, GDTs, TISP <sup>®</sup> Thyristor Surge Protectors	Standards Compliance	High Reliability
Measurement	Current Sensing	Shunts	Custom Configuration, Low PPM/°C	Ability to Match System, Accurate Revenue-grade Measurements
Communications	Port Protection	TBU <sup>®</sup> HSPs, MOVs, SinglFuse <sup>™</sup> Thin Film Chip Fuses, TISP <sup>®</sup> Thyristor Surge Protectors, TVS Diodes	Standards Compliance, Reference Design	High Reliability, Tested Solutions, Matched to Chipset



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### ADVANCING SMART METER DESIGNS *(Continued)*

A variety of components is required to ensure a smart meter is reliable and rugged to serve the grid for multiple decades. Size, ratings, construction, response time and tolerance are just a few of the criteria for selecting components for the power, measurement, and communications portions of the smart meter. Releasing a successful smart meter design amid changes to the energy generation and distribution system starts with components that have a proven track record of robustness and reliability. Investing attention at the onset to select the correct components helps ensure that the power circuits and communications ports remain protected and that measurements are accurate over the lifetime of the smart meter.

### ADDITIONAL RESOURCES

For more information about Bourns' complete line of circuit protection solutions, please visit:

[www.bourns.com](http://www.bourns.com)

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