Exclusive Technology Feature

ISSUE: April 2025

Exploring Advanced Configurable Logic For Current, Voltage And Power Measurement

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The increasing complexity of electronic devices often demands precise and reliable monitoring of current, voltage, and power. Beyond capturing instantaneous readings, analyzing how these parameters change over time is crucial for optimizing performance and efficiency. A highly effective approach to this challenge is leveraging configurable logic, which enables the creation of flexible measurement systems tailored to specific applications.

The SLG47011V programmable logic chip provides an ideal solution by combining high-speed data processing with functional adaptability, making it a powerful tool for modern engineering applications. In this article, we will explore the advanced capabilities of the SLG47011V for measuring current, voltage, and power, highlighting the importance of leveraging its configurable logic and specialized features to meet the specific requirements of modern monitoring applications.

The discussion begins with a description of the functional blocks within SLG47011V and how they support the desired measurements. An internal design diagram and an application circuit are shown to illustrate how the chip is configured internally and externally to make these measurements. The equations used to obtain the desired voltage, current and power readings are presented.

This application circuit is then implemented on SLG47011V demo boards, which are then used to collect voltage and current data to assess measurement accuracy. Finally, some advanced features that may be implemented in these types of measurement applications are described.

Fig. 1. SLG47011 demo board for USB power measurement.

Current, Voltage, And Power Monitoring

As one of the latest members of the GreenPAK family, the SLG47011[1] stands out for its integration of several key functional blocks:

- A 14-bit SAR ADC capable of achieving speeds up to 2.35 Msamples/s in 8-bit mode
- A programmable gain amplifier (PGA) which supports six amplifier configurations, with gain settings ranging from 1x to 64x, providing flexibility in analog signal processing
- An integrated 12-bit DAC, operating at sampling rates of up to 333 ksps, which enables precise generation of analog output signals

- Another notable feature is the hardware math unit (MathCore) which supports multiplication, addition, subtraction, and division operations, facilitating efficient data processing without the need to rely on external processors.
- Built-in dynamic memory for 4096 words

With these integrated blocks, the SLG47011V offers a versatile approach to monitoring current, voltage, power, and temperature. The use of these internal blocks reduces the number of required external components. For example, the built-in PGA block eliminates the need for an external differential amplifier for current measurements. Moreover, it provides additional advantages since this configurable block allows for flexible adjustment of its settings during the measurement process, including gain adjustment, which in turn increases the measurement range.

This combination of highly integrated analog and digital blocks within the SLG47011V significantly simplifies system design while enhancing functionality. The ability to perform measurements and process data within a single chip not only reduces the overall system complexity but also improves reliability by minimizing potential points of failure associated with using other external components. This level of integration, coupled with the flexibility of its programmable features, makes it particularly well-suited for creating compact and efficient monitoring solutions.

The configurable nature of this device makes it possible to dynamically adapt to the changing measurement requirements without any hardware modifications. This adaptability is especially valuable in applications where measurement conditions may vary significantly, enabling the system to maintain optimal performance across different operating scenarios.

This design shown in Fig. 2 is intended to interface with an MCU via I²C and can be divided conceptually into the three blocks shown.

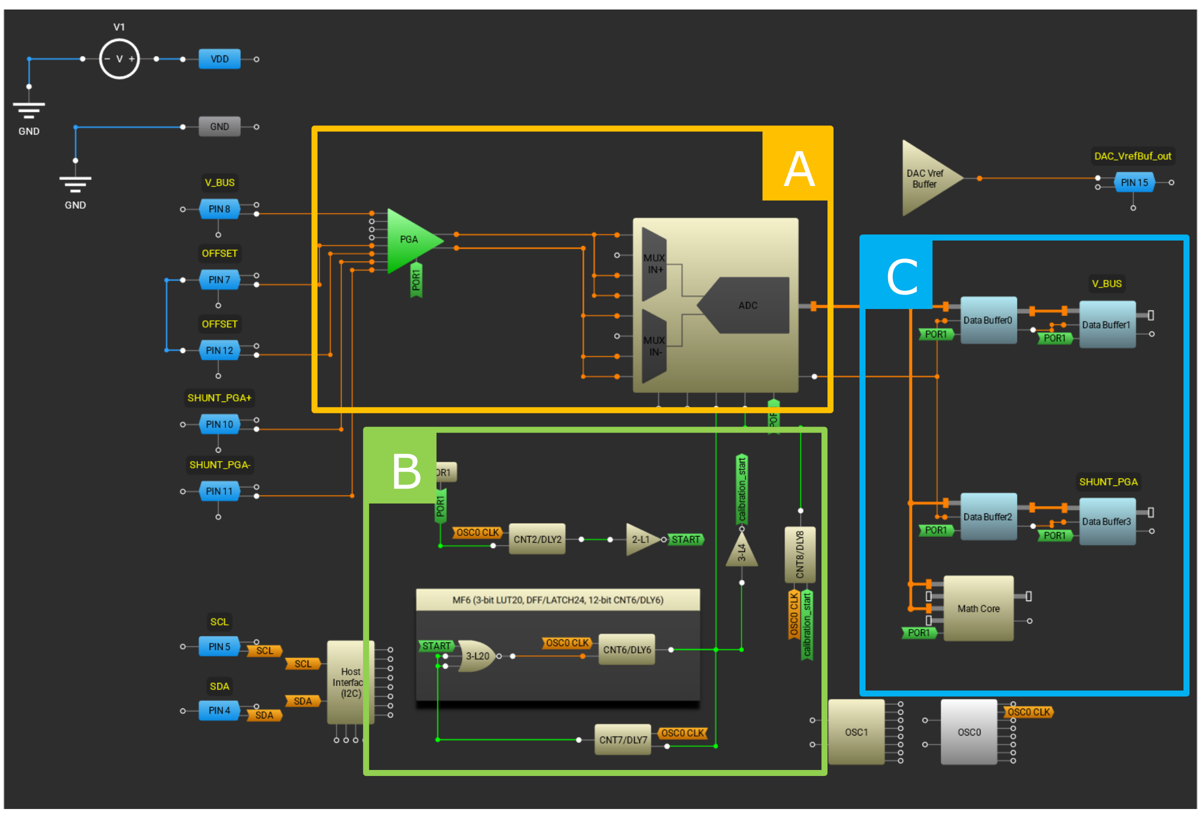

Fig. 2. A typical design for voltage, current, power measurement.

Those blocks are:

- Block A: Responsible for digitizing incoming analog signals. Notably, the programmable gain amplifier (PGA) can be reconfigured through I²C, allowing individual gain adjustment for each measurement channel based on the specific characteristics of the signals being measured.
- Block B: Manages the ADC control logic, ensuring proper initiation of the ADC. The SLG47011V also offers offset compensation capabilities for differential measurements. This block oversees timing and the correct operation of offset compensation during current measurement.
- Block C: Handles the storage and the processing of digitized data. Buffers 0 to 3 store digitized data (from the ADC) and function as filters by updating data based on a moving average principle. The MathCore performs power calculations by multiplying the digital outputs of the voltage and current.

The results from each buffer can be read via I²C and subsequently displayed through the MCU, or connected to a computer to establish a monitoring system.

The solution shown in Fig. 3 makes it possible to measure voltages up to 20 V and currents up to 4 A, provided that the PGA gain is switched via I²C depending on the current, namely: x32 for currents up to 1 A, x8 for currents from 1 A to 3 A, and x4 for 4 A.

Otherwise, this circuit can measure currents up to 1 A with a gain of x32. It is possible to reduce the gain to x16, thereby increasing the maximum measured current to 2 A. However, since the initial design is based on overwriting the gain via I²C, it is important that the gain needs to be overwritten for both channel 3 (which is responsible for measuring the current) and channel 2, as it is responsible for calibrating the offset for channel 3.

The input voltage is applied to the +V_BUS pin and is designed for a 4-V to 20-V voltage range.

Pins 7 and 12 must be connected together as they are responsible for the offset calibration.

Pin 16 (Sync) serves as a signal pin that controls when the MCU can access the SLG47011. Communication with the chip via I²C is only possible when pin 16 is low.

R3 is a shunt resistor from which the current is measured.

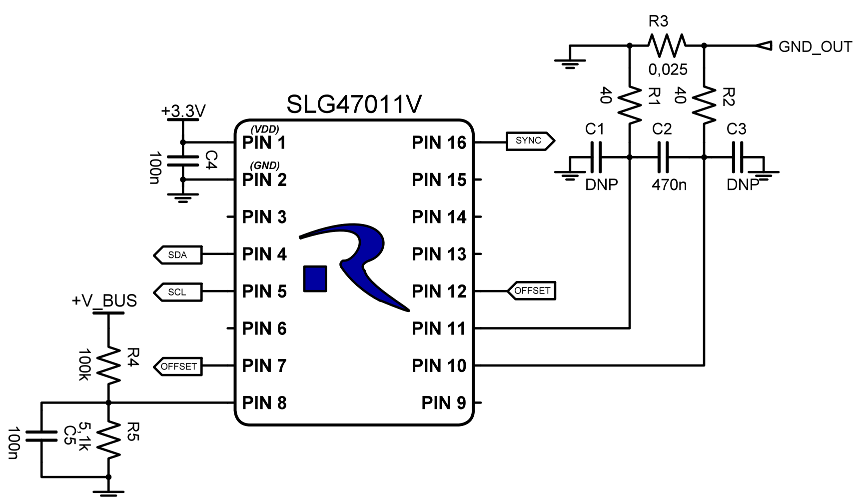

Fig. 3. Typical application circuit.

The MathCore read data is converted using the following formula:

$$P = \frac{(2298537 \cdot M \cdot 2048)}{285212672000 \cdot G_e}$$

where M is the data read from MathCore and G_e is the gain of channel 3.

It is also possible to read voltage and current values from buffers 0 and 3, and they will be averaged in the same manner as the buffer following the MathCore. However, since two buffers are connected in series for the current, 16 bytes are averaged over 14 bits.

The read voltage is converted using the following formula:

$$V_{bus} = \frac{(ADC_{Vbus}/2^N \cdot Vref)}{(R5/(R4 + R5))}$$

where ADC_{Vbus} is data read from buffer 1 and N is ADC resolution.

The read current is converted using the following formula:

$$I = \frac{(ADC_{SHUNT}/2^N) \cdot Vref/2}{(R3/G_e)}$$

where ADC_{SHUNT} is the data read from buffer 3.

Demo Board Functional Description

A practical demonstration of the SLG47011V's voltage, current, and power measurement capabilities can be seen in the SLG47011V demo board #1,[2] which features an MCU to read and display data from the chip, along with the necessary components for accurate measurements (Fig. 4). Three boards were tested for voltage and current measurement accuracy, the results of which are described in section 3.1.

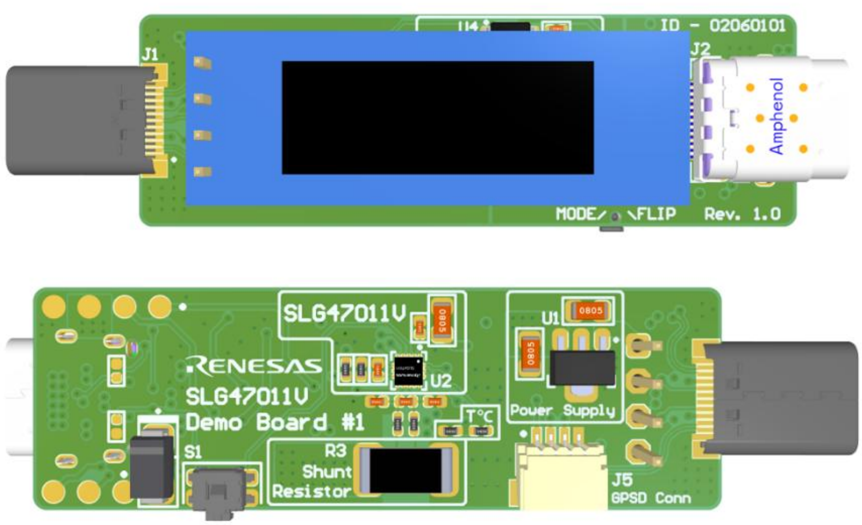

Fig. 4. SLG47011V demo board #1.

The demo board is USB-PD type C power delivery compatible (up to 28 V, 5 A); performs voltage, current, power and temperature measurements including measurements in both directions (via plug and receptable connection) and contains a 128 x 32 OLED monochrome display.

A simplified functional diagram is shown in Fig. 5.

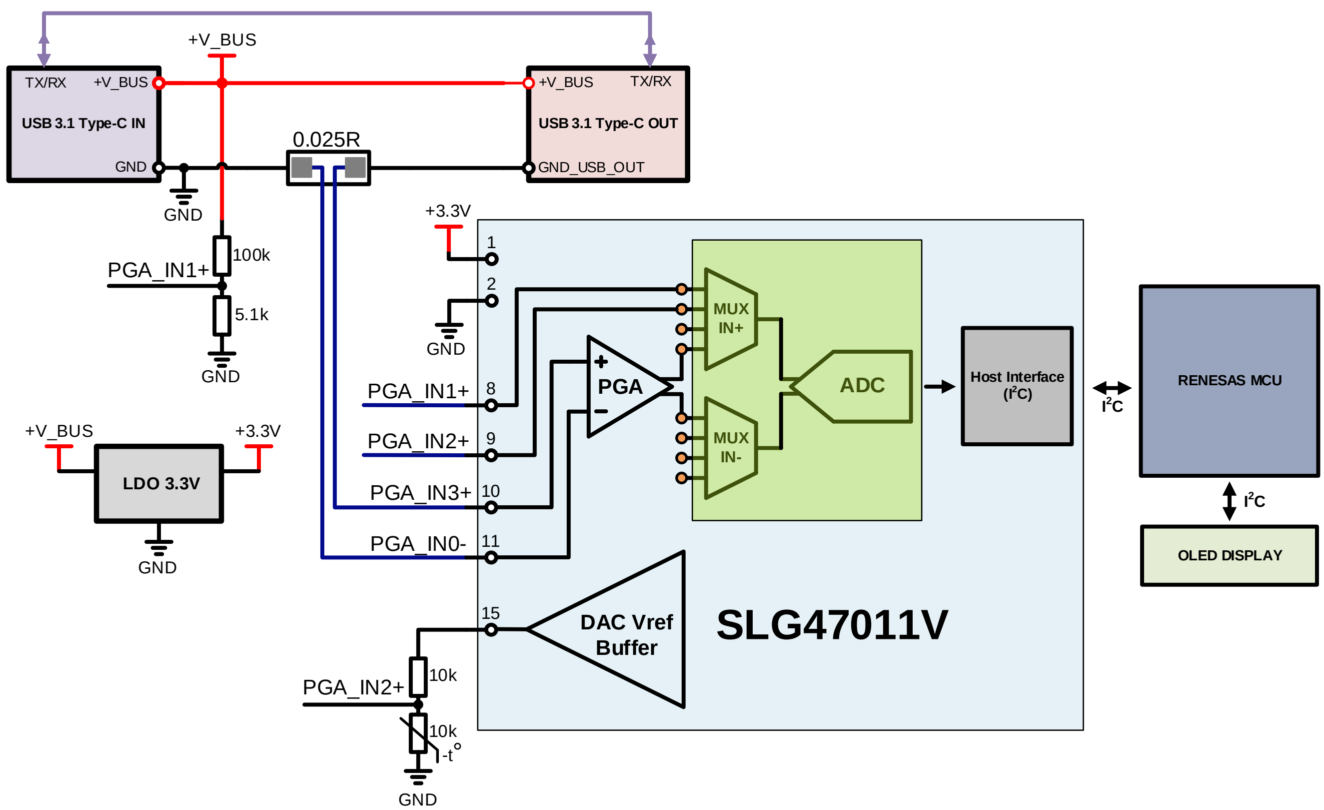

Fig. 5. Functional block diagram of the SLG47011V demo board #1 R1.0

Measurement Accuracy

Voltage and current measurements were performed on three different boards to gather statistics on accuracy (see Tables 1 and 2).

Table 1. Voltage measurement data.

Demo board #1		Demo board #2		Demo board #3	
Applied voltage (V)	Measured voltage (V)	Applied voltage (V)	Measured voltage (V)	Applied voltage (V)	Measured voltage (V)
4.989	4.99	4.985	4.99	4.988	4.98
8.986	9.00	8.985	9.00	8.987	8.99
11.987	12.02	11.986	12.01	11.987	12.00
19.990	20.06	19.987	20.05	19.990	20.03

Table 2. Current measurement data.

Demo board #1		Demo board #2		Demo board #3	
Applied current (A)	Measured current (A)	Applied current (A)	Measured current (A)	Applied current (A)	Measured current (A)
0.1	0.098	0.100	0.098	0.100	0.099
0.3	0.302	0.300	0.302	0.300	0.302
0.5	0.503	0.500	0.504	0.500	0.499
1	1.010	1.000	1.002	1.000	1.006
3	3.039	3.000	3.018	3.000	3.030

All of the above data was taken from the demo board shown in Fig. 1.

Customization Features

As mentioned previously, the SLG47011V is a configurable logic IC, which allows for the implementation of advanced features such as watchdog functionality, overvoltage/overtemperature protection, among others, unlike other chips typically used in electrical parameter monitoring systems.

This enhanced design is utilized for the application note (AN-CM-375 Voltage, Current, Power, and Temperature Monitor).[3] See Fig. 6.

This configuration not only allows for making simple measurements but also includes fault detection for the measured signals and outputs a fault signal externally as needed.

Another feature is the ability to measure the current on a copper pad (refer to AN-CM-394 Current Sensing with Cu Trace).[4]

In addition to the standard offset compensation available through the Memory Table and MathCore, it is also possible to measure current with the ability to compensate for temperature drift as well (Fig. 7).

Conclusion

The SLG47011V offers a flexible and efficient solution for current, voltage, and power measurement applications. Its configurable logic, along with features like offset compensation, temperature drift correction, and fault detection, makes it a reliable choice for monitoring systems.

The option to integrate additional functions, such as watchdog timers and overvoltage/overtemperature protection, adds to the chip’s adaptability. With its programmability and high integration, the SLG47011V provides a practical platform for creating accurate, real-time monitoring solutions across various applications.

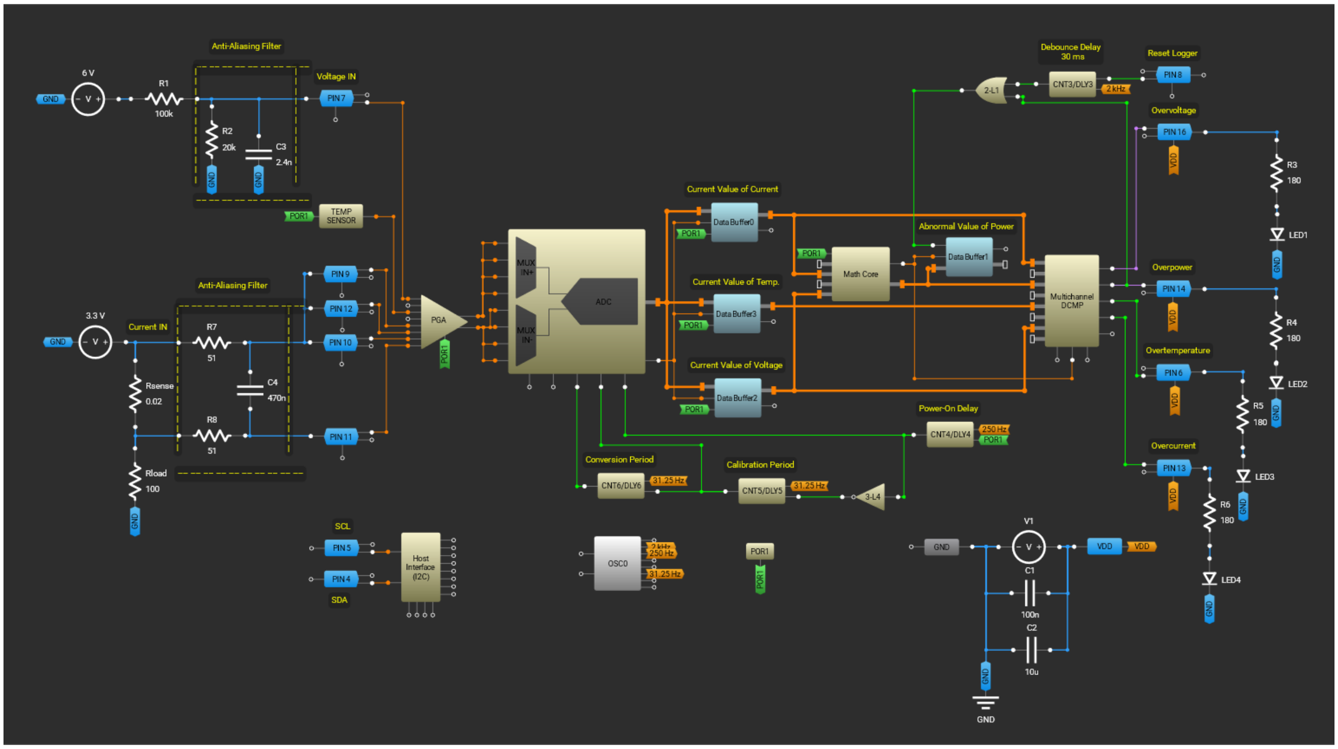

Fig. 6. Design with OVP, OCP, and OTP features.

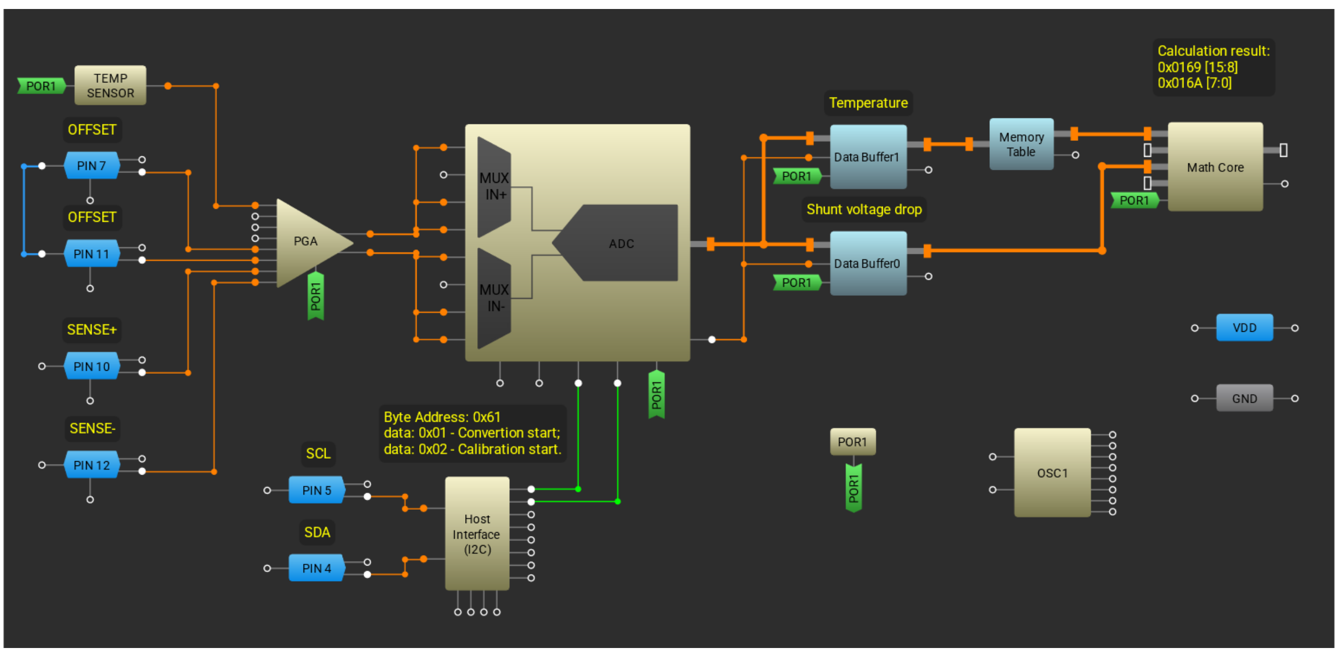

Fig. 7. Design with compensation for temperature drift.

References

1. SLG47011 product page.
2. SLG47011 AnalogPAK Power Meter Demo Board Lab Demonstration.
3. AN-CM-375 Voltage, Current, Power, and Temperature Monitor, application note.

4. AN-CM-394 Current Sensing with Cu Trace, application note.

About The Author

Ruslan Tykhovetskyi is an application engineer at Renesas, specializing in GreenPAK devices—configurable mixed-signal ICs. With deep expertise in analog circuit design, Ruslan combines engineering precision with hands-on experience to develop effective solutions in the field of microelectronics. His passion for accurate analog systems and dedication to continuous technical improvement drive the creation of innovative products and contribute to the advancement of modern technology.

For more on voltage and current measurement in power electronics, see the How2Power Design Guide, locate the Design Area category and select "Test and Measurement".