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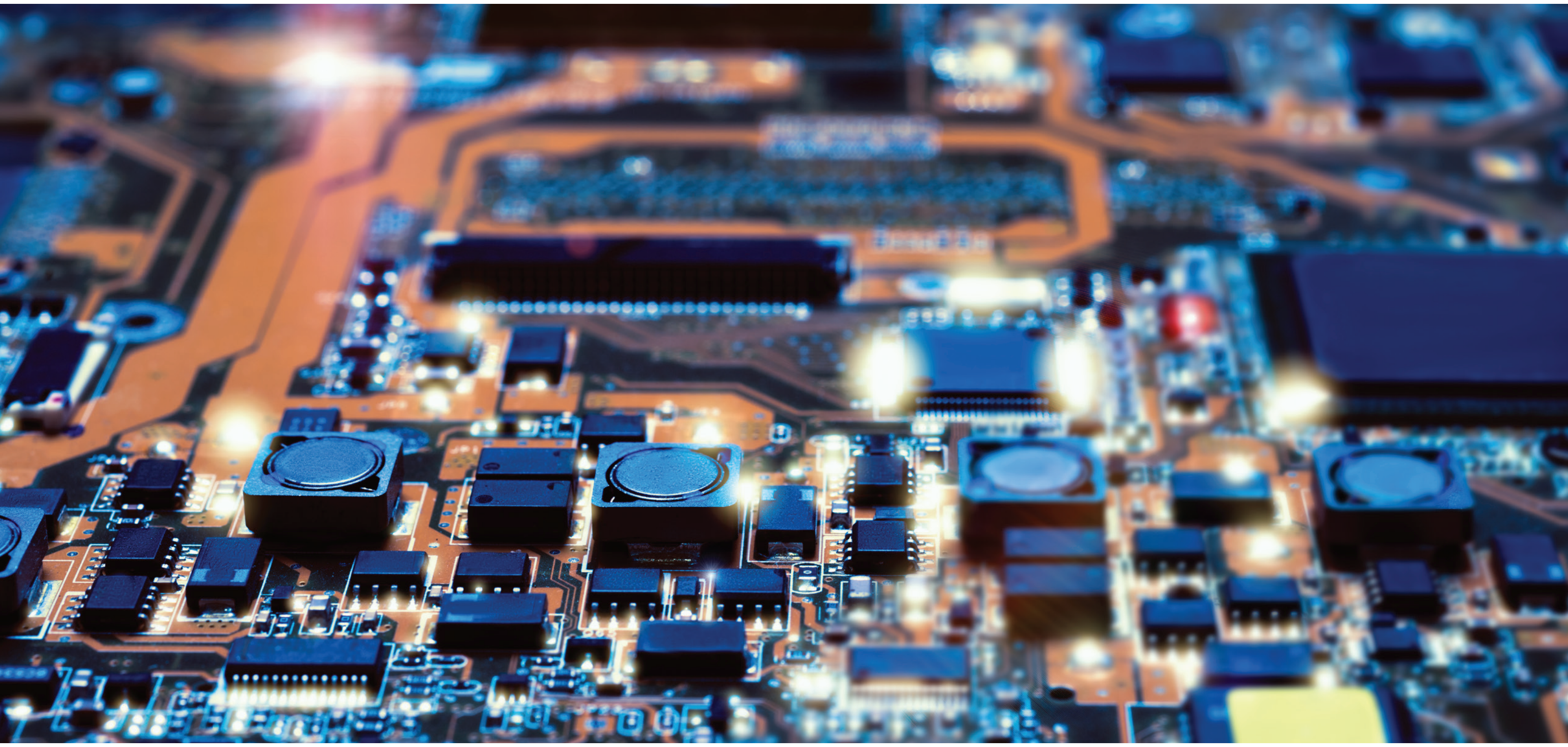

Understanding Source Measure Unit Specifications

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UNDERSTANDING SOURCE MEASURE UNIT SPECIFICATIONS

Before purchasing any type of test equipment, it is important to fully understand the specifications and its capabilities towards the application with which you intend to use it. In the case of a Source Measure Unit, also known as SMU, you may be familiar with some of the basic specifications such as channel-count, while you may be unfamiliar with other specifications.

In this article, I will present a series of explanations about some of the key specifications for an SMU and examine some key features with examples along the way.

So, what is an SMU? First, let me explain what an SMU is not - an SMU is not simply a programmable power supply with a meter on it. It offers much better accuracy, resolution, and stability than a power supply in each as a source unit and as a measure unit. An SMU is, in-fact, a precision “source” and a precision “measure” in one “unit” or chassis; the “source” can be set up as either a voltage source, or a current source, and the “measure” can be a measurement of voltage, current, or resistance. Generally speaking, the measure side of the SMU cannot be used as standalone, but it can be disconnected from the source side in order to guarantee absolute minimum noise performance. You can expect a source measure unit to be well characterized in the bulletin or specifications literature provided with the instrument. Let’s discuss the most important SMU specifications as well as some features which will be important during the selection process.

ACCURACY

Accuracy is one of the first specifications to consider when selecting an SMU. Without accuracy, the SMU would not be able to reliably produce a given output (or measurement) on a repeatable basis. Consider the source side of the SMU - for each voltage or current range, the specification of accuracy will be listed as a plus/minus percentage of the setting and will often include an additional fixed amount of uncertainty as well.

For example, when the Yokogawa GS200 voltage source is set to the 1V range, it will exhibit a one-year accuracy of ±0.016%, plus an additional fixed uncertainty of 120uV. Ninety-day accuracy, in many cases, may be listed as well, stating a better accuracy for the first ninety-days of a one-year calibration period. So, for this example, if the SMU is adjusted for 1.000 volts, we can expect it to always fall between 0.99972 VDC and 1.00028 VDC for the entire one-year calibration period of the instrument.

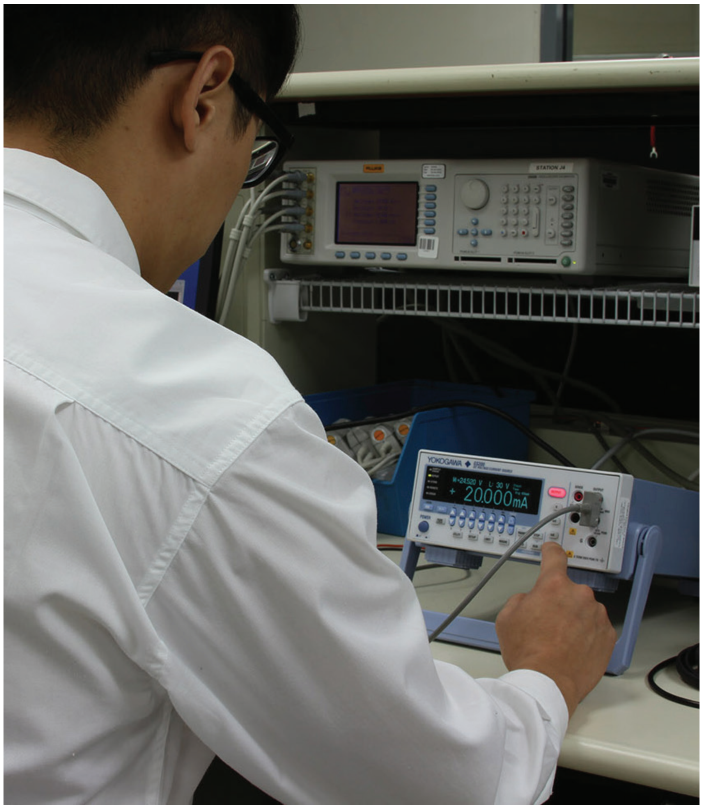
STABILITY

Stability is another specification to consider. In the voltage source example, stability will describe any short-term or long-term deviation of the voltage source from its set point over a stated period and at a stated temperature range. For the GS200, 24-hour stability is listed as ±0.001% of setting + 10uV at 23°C ± 1°C. While accuracy for a 1VDC setting for one year is 0.99972 VDC and 1.00028 VDC, the stability specification predicts that the 1VDC source setting will remain between 0.99998 VDC and 1.00002 VDC over any 24-hour period; again, assuming a 23°C ± 1°C environment.

But what if the environment is not strictly controlled to 23°C ± 1°C as listed in the specification? What can be expected of the above example, a 1VDC source, in different environments? In this case, there is additional information in the specification. Most SMU specifications will list a stability spec for a wide temperature range, such as 23°C ± 5°C, so the example above can be recalculated using this specification. In addition, most SMU specifications will also list an additional error, a temperature coefficient that can be added to the accuracy specification. In the case of the GS200 set to 1VDC example - add ±0.0009% of setting + 7uV per each 1°C change in temperature. This additional accuracy uncertainty is added to both the 90-day accuracy specification and the 1-year accuracy specification for the following two ranges: 5°C to 18°C and 28°C to 40°C. Again, you should expect an SMU to be well-characterized in the bulletin or specification literature provided with the instrument.

RESOLUTION

Resolution is the smallest step that the source can be adjusted to. Using the GS200 as an example, on the 1V range one can select steps of 10uV. For instance,the source could be set to 0.999990VDC. At the same time, the GS200 would be able to measure the voltage source current to the nearest 10µA.



RANGE

Range is important, too. The overall maximum and minimum range for the SMU output is usually best specified by using a graph. The graph in Figure 1 provides information on simultaneous voltage and current output (or input) for the GS200. The operation range for the GS200 is the same during sink operation as the range during source operation. In other words, the SMU can be used not only as a high-accuracy voltage or current source, but also as a high-accuracy programmable electronic load. The instrument will further divide that total range into a number of sub-ranges. While the GS200 can go to 30 VDC and 200mA, the voltage range is further divided into 10mV, 100mV, 1V, 10V, and 30V ranges. Each range has a unique resolution associated with it. For example, the 10mV range can be adjusted in 100nV steps, and the 30V range can be adjusted in 1mV steps (resolution).

Source range can be further described in terms of polarity and over-under allowances. By example, the GS200 can go from -32VDC to +32VDC. In fact, the GS200 can perform four-quadrant operation by operating as a current source or a current sink in the range of ±30 V and ±200 mA. It is not hard to imagine that this could be very important to the end-user in terms of fine-tuning the SMU output to suit the application.

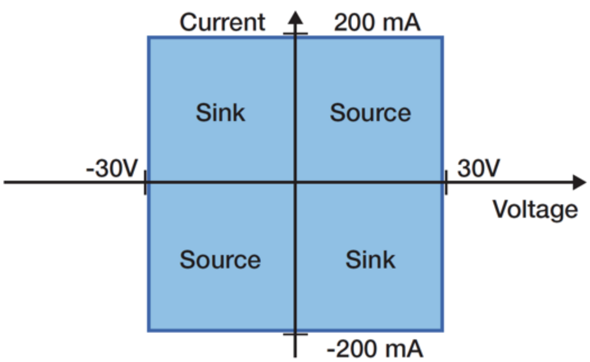


Figure 1 - GS200 Four-Quadrant Range

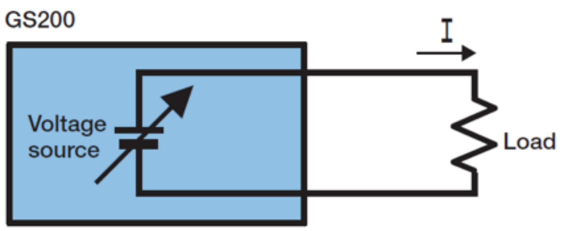


Figure 2 - Source Operation

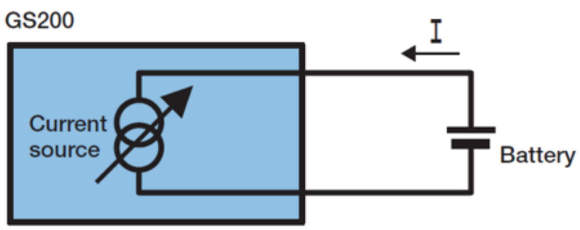


Figure 3 - Sink Operation

OUTPUT RESISTANCE

Output resistance is usually specified for each of the sub-ranges, which is simply the internal resistance of the source, a series resistor for a voltage source, and a parallel resistor for a current source. The GS200 provides ≤2mΩ for a voltage source on the 1V range, and a ≥10MΩ output resistance for a current source on the 200mA range.

OUTPUT NOISE

Output noise is the noise sourced by the source unit in the SMU and is characterized and specified for the SMU for each range of both the voltage and the current sources. The output noise will be specified across one or more frequency bands. Following the 1VDC voltage source example on the GS200, the noise is specified as 10μVpp total noise within a DC to 10Hz band, and 60μVpp total noise within a DC to 10 kHz band. Naturally, an SMU will provide the very best (minimum) output noise performance when the measure unit is off, which disconnects from the source, internally. The current source noise is very similar, but will typically be specified in units of current, such as μApp.

COMMON MODE REJECTION RATIO

Common Mode Rejection Ratio, or CMRR, characterizes the ability of the source to reduce any signal present on the Device Under Test, or DUT, to a smaller signal (minimalize it). For example, if my DUT had noise on it or was drawing current at a rate of 50Hz, can the SMU reduce that noise by very much? The answer is yes, and the CMRR is specified in decibels as referenced to the test waveform, or the noise or other waveform present on the DUT. Furthermore, it will be specified at a frequency or a frequency range - typically at 50Hz/60Hz. In the case of the GS200, the voltage source has ≥120dB on the 1VDC source, which means the SMU can reduce a noise source equal-to-or-less-than -120dB. Similarly, the current source CMRR will also be specified, not in dB, but rather amps per volt.

Both the current source and the voltage source will often have these specifications provided in easy-to-use formats, such as using a table to correlate range, resolution, stability, accuracy, temperature coefficient, output resistance, output noise, common mode rejection ratio, and more.

OTHER SPECIFICATIONS

LIMITER FUNCTIONS

To protect the device under test, an SMU almost always has a built-in limiter function. When the SMU is sourcing voltage, a user-defined current-limiter adjustment will permit the engineer to set an absolute value beyond which a limiter circuit will activate. So if the limiter is set to 10mA, the SMU will not permit current to exceed 10mA under any condition. Similarly, when the SMU is sourcing current, a user-defined voltage-limiter adjustment is also available. Note that the limiter is not an alarm condition and that the SMU will quietly limit the output and will otherwise resume normal operation. The GS200 limiter, for example, ranges from 1mA to 200mA in 1mA steps, and 1VDC to 30VDC in 1V steps.

RESPONSE TIME

Response time is typically specified in units of time, typically as milli-seconds, and under very specific conditions. Response time is the amount of time that the SMU takes to change from any current output setting to within 0.1% of the final value at maximum output, maximum resistive load, and with no limiter operation. For the GS200, that time is 10milliseonds, or less, for all voltage source and current source ranges. See Figure 4 for a response time example.

Because an SMU provides a response time, which is typically much faster than that of a power supply, it can be prone to overshoot or oscillation under the right conditions. An SMU must strike a balance between response to a transient load and stability under all conditions. Therefore, most SMUs will have a maximum capacitive and inductive load specification. For the Yokogawa GS200, the largest capacitive load permitted is 10μF, while the largest inductive load is 1mH. Stability is guaranteed if the reactive portion of the load lies between these two values.

An SMU will typically have a four-terminal connection. When an SMU is measuring voltage in current source mode and the current becomes large, the voltage drop in the lead wire can be significant. In such a case, the SMU can measure the voltage while eliminating the voltage-drop due to the lead wire resistance by using a four-terminal connection (4W) and the SENSE terminals near the DUT. The effects of the lead wires also appear in voltage source mode. In this case, using the four-terminal connection enables the GS200 to apply the specified voltage to the DUT, thus reducing the effect of the lead wire resistance. The GS200 features the four-terminal connection set on the front panel.

INPUT VOLTAGE

The input voltage specification is an important consideration, too, for an SMU. While one tends to think of the SMU being used as a source, it can also sink current and therefore be considered as an electronic load. As such, it has limitations. This is called input voltage specification. For the GS200, that is 32VPEAK between the Hi and the Lo terminals, and 42VPEAK between Lo terminal and ground. Furthermore, a maximum of 250VPEAK is permitted between the ground terminal and the case.

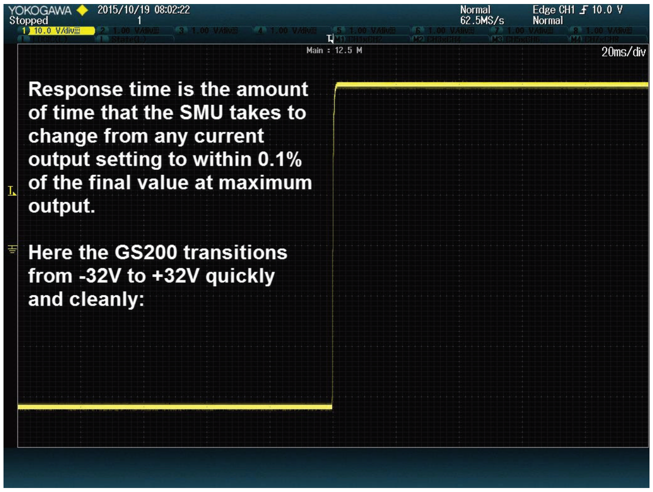
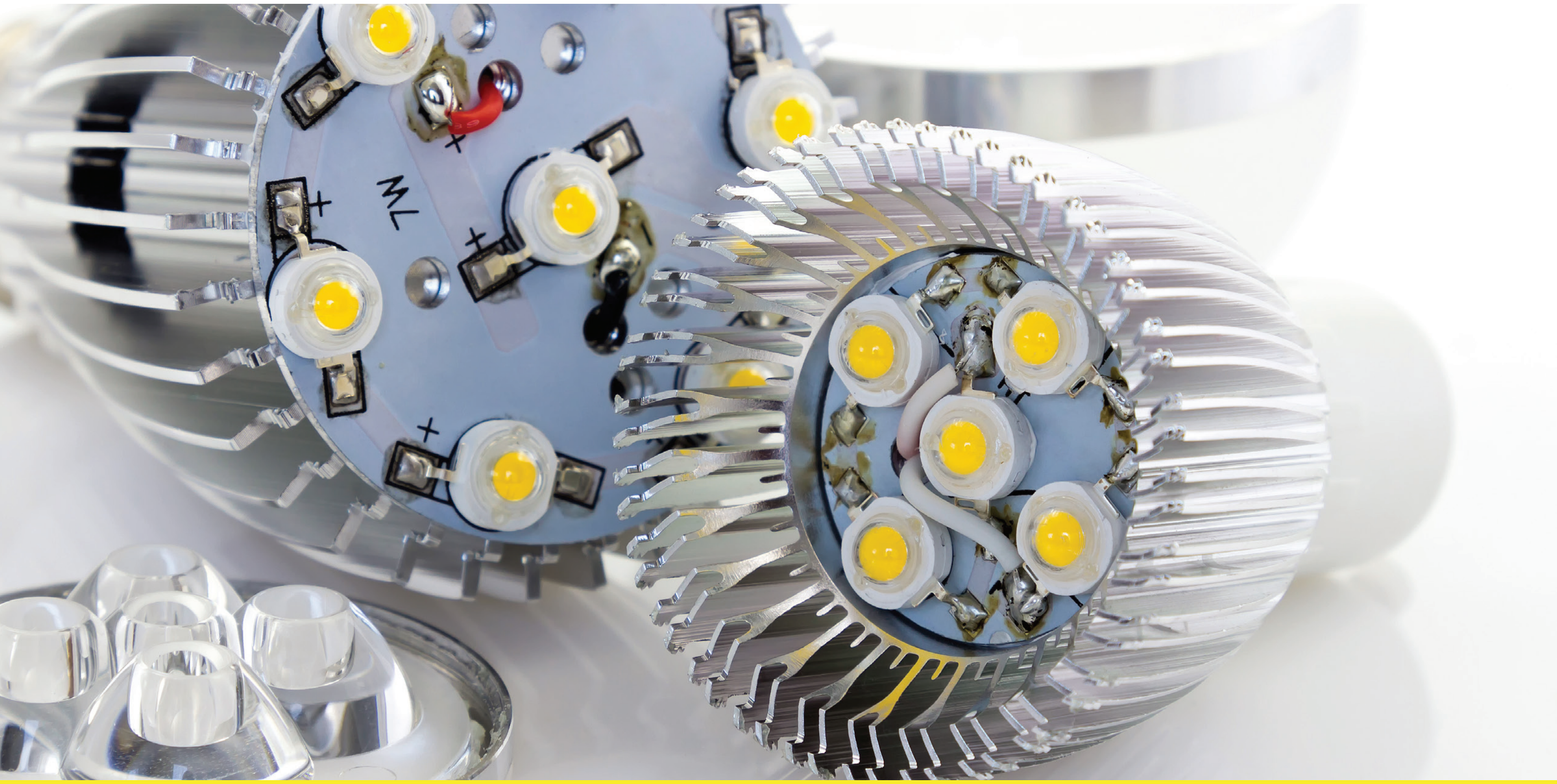


Figure 4 - SMU response time



SOURCE GUARD

Since the output noise specification is one of the most important characteristics of a high-performance SMU, caution must be taken when connecting the SMU to the DUT so as not to degrade noise performance. The internal source guard is for just that purpose. While the SMU features excellent (minimum) noise performance, common-mode noise can still be an issue. This common-mode noise can affect the source circuitry internal to the SMU and worsen the noise delivered to the DUT (Figure 5). The guard feature is simply a switch between the front panel 'G' terminal and the internal guard, a floating internal shield or guard around the source circuit. This is a noise abatement technique that simply keeps the common-mode noise source current out of the Lo lead and, therefore, out of the source itself and can be used in two manners: guard set to ON diverts any ground-referenced Lo-side noise current through the guard and back to the common-mode noise source (Figure 6). Guard set to OFF permits a common third-wire added as a preferred path for common-mode noise to follow (Figure 7). When used properly, the guard feature assures the best noise performance that the SMU is capable of in the presence of common-mode noise sources.

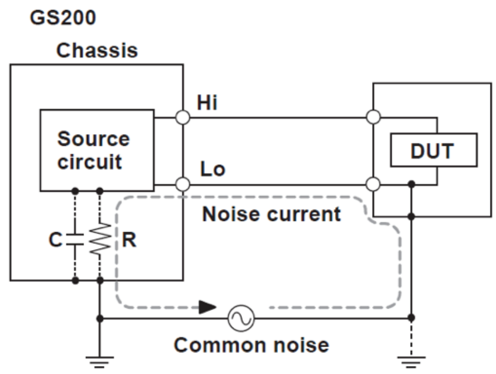


Figure 5 - Common-mode noise conducting into SMU source circuit

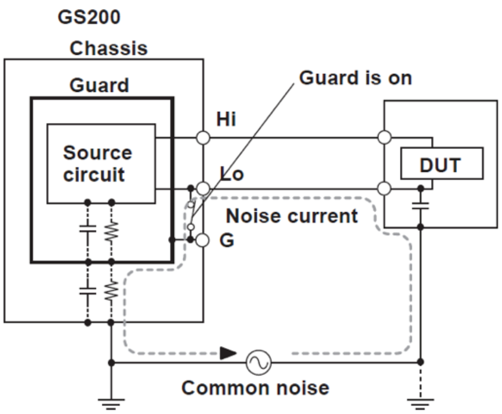


Figure 6 - Common-mode noise conducting through Lo and *guard*

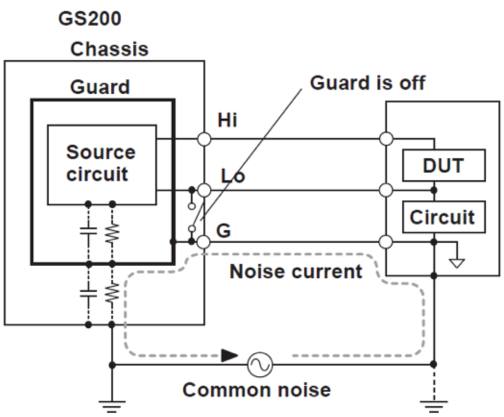


Figure 7 - Common-mode noise conducting through *ground* and *guard*

CONCLUSION

Referring back to our question of 'what is a source measure unit?'- the differences between a source measure unit, and, say, a power supply with a meter on it will become apparent while studying the specifications. That can be a number of things: accuracy, stability, resolution, noise, common-mode-rejection, and others. In one word, it is performance. In addition, the more-capable SMUs will, frankly, often have longer bulletins or spec sheets and a lot more can be expected of them.

SMU specification bulletins will also discuss the instrument in terms of functionality and features. Functions provided by an SMU should include programmability, sweep functionality, synchronization and trigger capabilities, and software and drivers. On the feature side of things, expect to see specifications on connectivity (Ethernet, USB, and GPIB), on board servers such as a web server and an FTP server, and on board media for storage measurements, programs and setup files.

ABOUT US

Since its foundation in 1915, Yokogawa has been recognized as a technology leader. Annually, Yokogawa reinvests nearly a quarter billion dollars in research and development, much of it aimed at core technologies like test and measurement. As a result, Yokogawa's annual corporate revenues have grown to nearly $4 Billion while amassing more than 6,000 patents and registrations. All of us within the Test and Measurement Division recognize it as our mission to continuously develop and supply the best possible solutions with optimum quality and value to customers and society, thereby contributing to our customer's growth.

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