Using Power Sensors in Test Sets

Power sensors such as LadyBug’s LB5918A USB sensor are often used in test systems to build complete solutions for specialized communication equipment, RF component testing, printed circuit board testing, manufacturing test, military equipment, aviation test, wearable personal devices, medical applications and countless other applications.

These important systems provide a complete test solution for the user and have become very important in applications wherein devices with new signal types, high power components, and other advanced technologies are constantly introduced. Usually called ATE (Automated Test Equipment) these test sets help designers and manufacturers of various devices and equipment get quick, complete analysis of their targets without performing individual tests. Using these test sets also frees up more of the user’s valuable time to develop, test and manufacture. A typical modern ATE system is shown in Figure 1.

Figure 1. Modern 802.11 Communications Test Set. Courtesy Larson Automation.

As years have passed and technology evolved, test sets have advanced from giant, cumbersome systems that required multiple power meters with special connections, to individual sensors along with other components. These systems were, for the most part, manually controlled. Systems like this were only cost-effective for large companies and militaries. Today’s fully automated test systems are often smaller racks or boxes with computers and test devices such as the LadyBug LB5926A sensor shown in Figure 2. The components are connected and controlled by USB cabling and represent a significant advance in testing.

Figure 2. LadyBug LB5926A Power Sensor with SPI & I2C.

The new systems both cost less and do more than their predecessors. These factors have resulted in an increase in the number of test sets that are in service. As an example, manufacturers of wearables and new medical devices will introduce hundreds of new products and spawn several new companies this year alone. This new industry must have reliable test systems that are capable of verifying their devices in development, and then scaling up for use in manufacturing to test the same products.

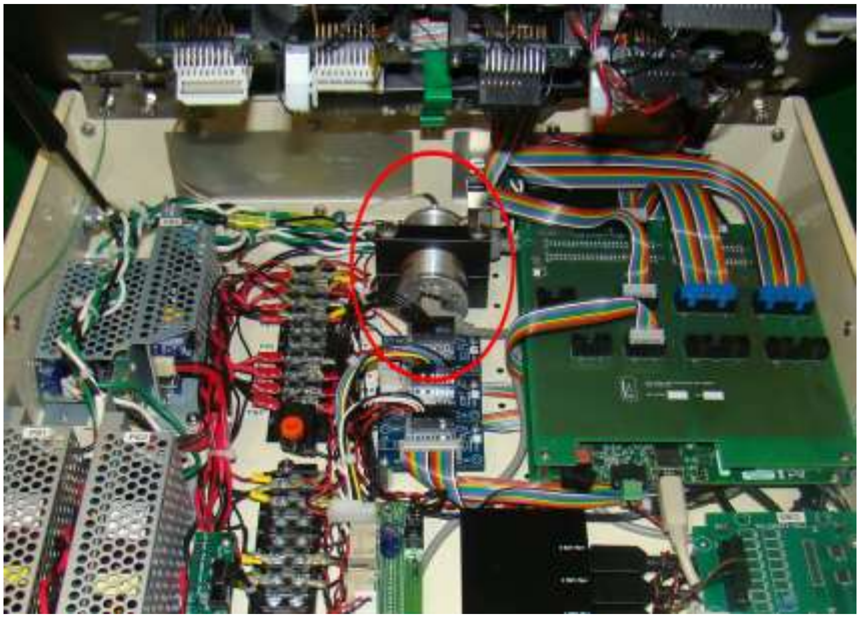

Figure 3. Test set for wearable devices. Courtesy Larson Automation.

Figure 3 shows a test set recently designed for wearables. The set is opened: note the circled USB power sensor that connects to the upper deck by an SMA-ended cable. Atop are mounting fixtures for the customer devices. Testing is critical: wearables are often used for medical applications. Further, many medical devices that utilize advanced communication techniques are employed inside the human body. These are just a few reasons that ATE test set development is a vibrant, fast-growing market in the RF and Microwave test industry.

What Will the Next Generation of Test Sets Be Like?

With hundreds of new single-board computers and microcontroller development board systems available, there is no doubt that many test set engineers will seek to reduce or eliminate traditional computers in their designs. While powerful and often necessary, these computers have layer upon layer of drivers, timing constraints, and hardware access limitations.

One of the most common complaints is the possibility the computer will lock-up, causing distressed communications between the customer and test set manufacturer. Using a single-board computer running custom firmware or a custom operating system places the software developer in full control of the system.

Another approach is to use the microcontroller system for control of the measurement system and the PC for user I/O thereby isolating measurement controls that require critical timing from the PC. This also gives the engineer more control over problem mitigation. Further, many of these microcontroller systems are capable of driving multi-color graphic displays and managing keyboard input. These factors open the door to a new generation of compact test systems built from high-quality connectorized microwave devices.

Today, more and more connectorized system components are available with SPI (Serial Peripheral Interface), I2C (Inter-Integrated Circuit) or TTL communication of some other form. These are easily connected directly to microcontroller systems, or to PCs with appropriate interfaces. The list of connectorized microwave devices with these types of interfaces is likely to continue to grow rapidly.

Figure 4. LB5918A with SPI Connection in Action.

Newly released, highly accurate RF and microwave power sensors are available with SPI and I2C in addition to their USB interfaces. These new sensors are fully characterized and calibrated, plus they are first tier NIST traceable. A LadyBug Technologies LB5918A Power Sensors and its SPI/I2C interface cable and connector is shown secured in its ATE mounting bracket in Figure 4.

A Simple Return Loss Example System

Figure 5 depicts a simple single board system to measure return loss or S11. The example is presented to show one way SPI & I2C can be utilized with power sensors as building blocks in compact test sets.

The system consists of a microprocessor board, a display panel with a few buttons, two LB5926A 26.5GHz power sensors each with a directional coupler, plus a simple source controlled by the microprocessor. These sensors have a dynamic range of over 90 dB, making the system capable of measuring very low power levels. It is important to note that as power levels become very low, coupler directivity can result in uncertainty becoming a factor and may dominate the measurement. Also, to assure the greatest accuracy, the coupler measuring return power is paced electrically nearest the DUT because it is measuring the return and lowest power level. The entire system could be built into a package smaller than many of today's thin, flat oscilloscopes and could be expanded to perform additional functions, as well.

Almost any modern microprocessor will have a C compiler available that will make fast, easy work of the required calculations. The flexible power sensors can be configured to output power in IEEE 754 binary format or textual strings. Further, the sensors will output power levels in linear or log (dB), making the calculations easy.

Note: For details on the calculations and further discussion on the subject of scalar analysis and return loss using power sensors, including match, voltage and impedance, refer to our article ***Scalar Analyzer using Power Sensors,*** available in the downloads area of www.ladybug-tech.com.

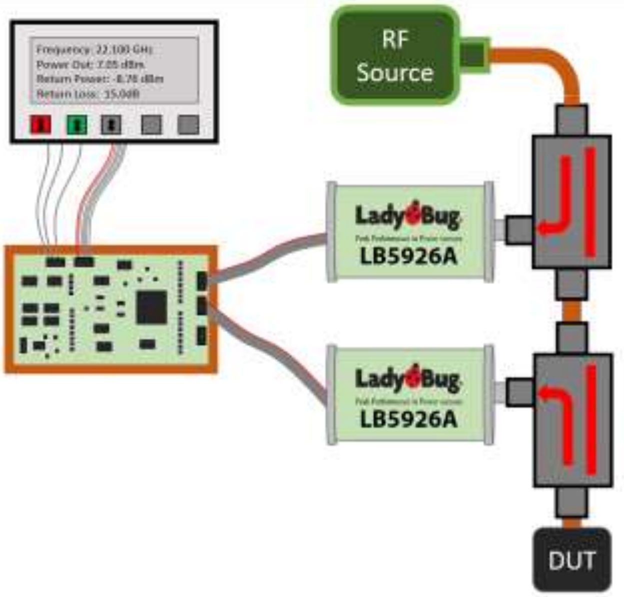

Figure 5. Example SPI Return Loss Test Set.

In the example, some of the power sent into the DUT (Device Under Test) is reflected back into the system. This relationship between reflected power and incident power is called Return Loss (RL). Return loss is expressed in dB, due to the potentially high dynamic range of the result. The basic calculation for return loss is:

$RL(dB)=-10\log_{10}(Pr/Pi)$

Where RL is the Returned Loss ratio in dB, Pi is the incident power entering the DUT, and Pr is the reflected power coming back from the DUT. In this equation, the power levels are linear, and the result is converted to dB.

To use the measurements from the power sensors in the equation, we need to apply corrections that account for coupling factors, coupler losses and other system losses. To accomplish these corrections easily, we set the power sensors to report power in linear units such as mW and use linear math for the corrections; then convert the result to dB as already described.

To calculate Return Loss from the measurements, we need to account for these item:

-Coupling factor each coupler
-Loss through each coupler
-Cable and Connector losses

Since all of the losses through the couplers and coupling factors are linear, they can be treated mathematically as constants. These constants can be worked out to a single correction factor normally referred to as Tracking Correction, T. Tracking correction is applied to the coupled power measurements to properly scale the power measurements from the couplers, incident (Pi') and reflected (Pr') power as shown in the equation below:

$RL(dB)=-10\log_{10}((Pr'/Pi')*T)$

Tracking correction, could be calculated and the calculation could include Cable, Connector and other losses. Another good way identify accurate tracking correction is to measure it directly by placing a short on the port and measuring both sensors. Using the same formula solved for T, and since 100% of the power is reflected back, RL equals 0, resulting in this simplified equation solved for T:

$T=Pi'/Pr'$

This method will more closely take into account the losses and coupling factors and will include some items that would not easily be calculable such as the Cable and Connector losses. To further increase accuracy, the short can be removed, and an open placed on the port. The reader might expect the result to be the same as the result with a short. However, that is not the case. System source match reflections will be 180 degrees out of phase between the short and open measurements. Averaging these two calibration measurements effectively removes source match errors. Using the new averaged value, Tave, reduces system uncertainty significantly. Functions can be built into the system to calibrate and store Tave.

Once Tave is available, the final equation is as follows:

$RL(dB)=-10\log_{10}((Pr'/Pi')*Tave)$

The power sensors used in this example have excellent dynamic range and are capable of accurately measuring very low returned power levels. At these low levels, coupler uncertainty will be significant. A warning system could be employed to indicate that the user should set power to a higher level so that return power will be sufficient to overcome coupler uncertainty.

Figure 6 details the digital connectivity required for use of SPI on an LB5900 series power sensor. Additional sensors can be connected, and each sensor will use the SCLK, MOSI and MISO connections and will also require an individual slave select connection (SS).

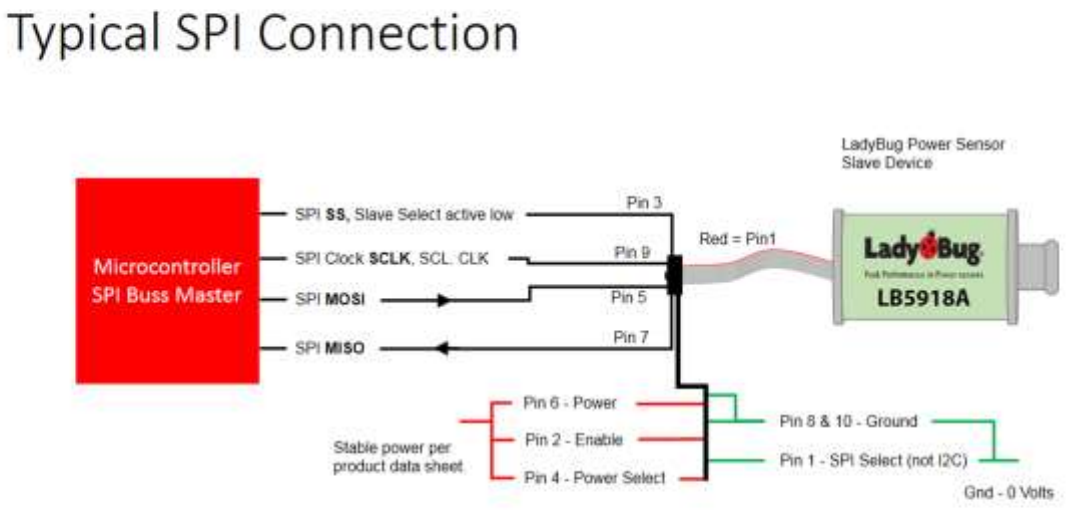

Figure 6. SPI Connection.

The LB5900 sensors use SCPI (Standard Commands for Programmable Instruments) commands. The SCPI command set is a time tested standard used for various test instruments, a set of commands is included for power meters and sensors. These straightforward commands are recognized by the LB5900 sensors whether the user is accessing the sensor using SPI, I2C or with one of its two USB interfaces. The reader is encouraged to learn more about the command set online.

Today, high-quality microwave measurement devices and components, including high-accuracy, high-frequency power sensors, are available with SPI and I2C connectivity. These newly available devices can be utilized to build test sets with multiple sensors, displays and advanced features. Engineers can utilize these capabilities to build smaller test sets with more features and better reliability.