Product Manual

PMA-12 PRECISION POWER METER APPLICATION

FOR USE WITH LB5900 SERIES POWER SENSORS

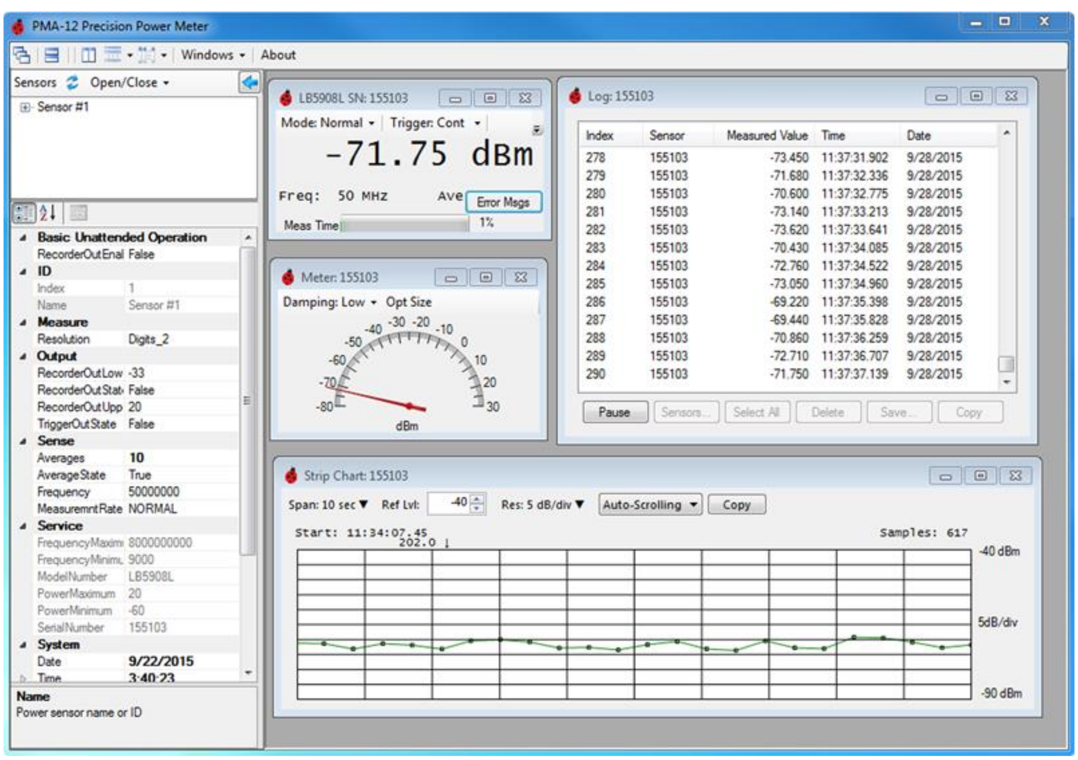


TABLE OF CONTENTS

INDEX OF FIGURES AND DIAGRAMS

NOTICES

SAFETY

A ***WARNING*** indicates a potential hazard that could completely damage the product. Do not continue until you fully understand the meaning.

A ***CAUTION*** indicates a potential hazard that could partially damage the product. Do not continue until you fully understand the meaning.

A ***NOTE*** provides additional pertinent information related to the operation of the product.

CONFORMITY

WEEE Compliant
RoHS Compliant
USB 2.0 Compliant

DISCLAIMER

The information contained in this document is subject to change without notice. There is no guarantee as to the accuracy of the material presented or its application. Any errors of commission or omission will be corrected in subsequent revisions or made available by errata.

WARRANTY

See the warranty section of this document for details.

DOCUMENT NUMBER

Not Assigned (Reference LB5900 Series Product Manual for the PMA-12 Precision Power Meter Application).

1. General Information

Introduction

This manual provides information about the installation and operation of the LB5900 series USB power sensors when using the ***PMA-12 Precision Power Meter Application*** software. The LB5900 series of sensors make True RMS Average - (CW or modulated) measurements. This manual also contains information regarding product features and support, specifications, compatibility, and some measurement examples. Refer to the specific product's Programming Manual for programmatic remote control information. The Errata and User Update section at the end of this document reflects recent changes in product development.

Compatible Sensors

All LB5900 Series sensors are compatible with PMA-12 software; however portions of the application are sensitive to the sensor's firmware version. In some cases, the sensor's firmware may require updating to use updated versions of PMA-12 software. If this is the case, PMA-12 will issue a warning and may close. In this case, it is recommended that the sensor be sent back to LadyBug for updating. Contact LadyBug sales for further information.

Description

The LB5900 Series USB Power Sensor features a highly compact power sensor body that connects directly to a desktop or laptop computer using a standard USB port and standard USB cable(s). A separate power meter is not required. The sensors convert RF and microwave power into fully calibrated and processed digital data at the point of measurement. The companion ***PMA-12 Precision Power Meter Application*** software provides a front panel display that allows the user to make typical average power measurements. This application is the primary subject of this document. A programmatic interface is also supplied with the product.

LB5900 sensors and PMA-12 Precision Power Meter software use standard SCPI commands. Consult LadyBug's programming manual for detail on the commands and structure.

Patented No-Zero No-Cal features eliminate sensor zeroing and meter reference calibration. The sensor features optional Trigger IN/OUT or Recorder OUT connectors in addition to optional RF input connectors. Please refer to the sensor specification sheet for a complete listing of product options.

PowerSensor+™ products address key aspects of general purpose scalar measurements as well as CW, pulse, and other modulated power measurements. PowerSensor+™ products offer benefits in overall cost, accuracy, measurement speed, flexibility and test development time.

USB Considerations

The Universal Serial Bus (USB) provides adequate power for the sensor under normal circumstances. However, when using a longer cable (greater than 3-5 meters), or when some laptop or portable computers are used, an active or self-powered hub may be required. These are available at most computer stores and often sell for under $20.00. The sensor is powered directly via the USB cable and typically draws less than 400 mA at a nominal 5 VDC. An active hub will compensate for the DC voltage drop beyond approximately 3-5 meters. An active hub is recommended when using a portable computer is to conserve the battery life of the computer. PowerSensor+™ products are USB 2.0 compliant. The following information is provided for reference when selecting a hub:

Bus-powered hub: Draws a maximum of 100 mA at power up and 500 mA during normal operation.
Self-powered hub: Draws a maximum of 100 mA and *must* supply 500 mA to each port.
Low power, bus-powered functions: Draws a maximum of 100 mA (often applies to portable computers).
High power, bus-powered functions: Self-powered hubs: Draws a maximum of 100 mA and *must* supply 500 mA to each port.
Suspended device: Draws a maximum of 0.5 mA

More information related to USB

1. Supplied voltage by a host or a powered hub port is between 4.75 V and 5.25 V.
2. Maximum voltage drop for bus-powered hubs is 0.35 V from its host or hub to the hub output port.
3. Normal operational voltage for functions is 4.75 V (minimum).
4. LB5900 Sensors can be enumerated as either USB HID or USBTMC.
5. By default, LadyBug's PMA-12 Precision Power Meter uses USB HID.

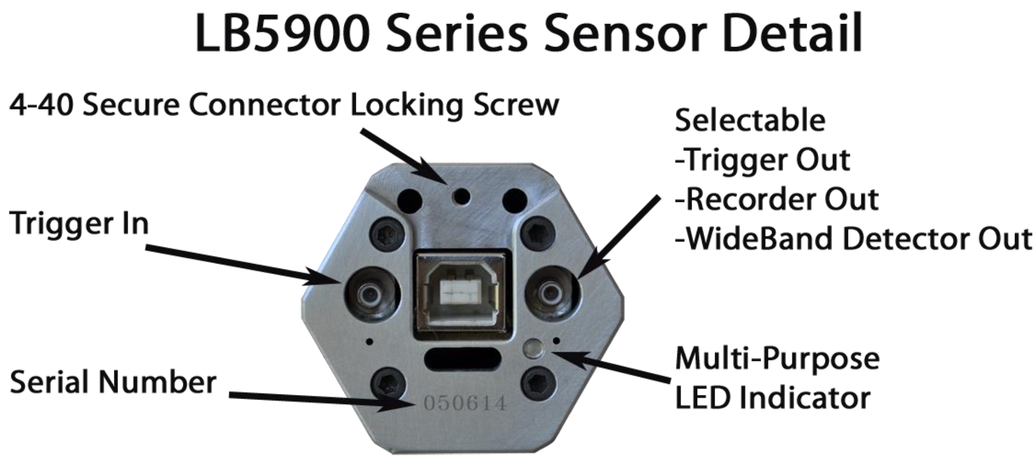


Figure 1 - Sensor Rear Bulkhead

LED Indicator

- Green: Normal & Ready to use
- Single Green blink: Normal activity-flashes with communication
- Alternating Green / Red: Interface state not known & Self-test
- Blinking Green at 1HZ: Operating in un-attended mode
- Blinking Red: Hardware Error
- Solid Red: Error, an error code can be read

Applications

The LB5900 PowerSensor+™ line of products is designed specifically for the following measurement applications:

- General Average Power Measurements
- Power Measurements Requiring High Accuracy:
  - CW & Pulsed Signals
  - Narrow and Wide Band Signals: CDMA, W-CDMA, QAM, OFDM, GSM, TDMA, QPSK, FSK, AM, FM
  - Recorders, Power Monitoring, and ALC Loops
- Research & Development and Manufacturing
- Maintenance, Repair, Installation and Service
- Communications
- Radar, Wireless, Satellite, Radio Links

Accessories Supplied

The product is shipped with the following items:

1. A sensor with selected hardware and software options.
2. Standard or optional return to factory warranty.
3. 2-meter high speed USB cable.
4. Software USB flash drive, includes the following:
   - This product manual.
   - A user application (GUI) – provides a means of making measurements.
   - Drivers – several interfaces are available.
   - Programming Guide with sample code.
5. Quick Start Guide and Quick Start Card.
6. NIST traceable calibration certification with data.
7. Packing list and invoice.

Options

Refer to the order guide by individual model number for all product options. Order guides are available on-line at the company website – see Contact Information.

Option MIL Notice

When Option MIL is installed, writing to internal non-volatile memory locations is disallowed. Additionally, with certain versions of Option MIL, no non-volatile memory is installed in the sensor. This manual is written without consideration of Option MIL. If the option is installed in the purchased sensor, consult the Option MIL specifications detail available from LadyBug.

Warranty

The warranty on the LadyBug PowerSensor+™ series of products is one year, return to factory. Extended warranty and calibration service options are available. Please see the Order Guide for details.

Service

There are no serviceable parts on the LadyBug PowerSensor+™ series of products. Recommended service is return to factory for repair. A high-quality connector saver (adapter) can be used on the RF input connector to extend the useful life of the factory installed connector.

Calibration Cycle

The recommended calibration cycle for the LadyBug PowerSensor+™ series of products is one year, return to factory. Extended warranty and calibration service options are available. Please see the Order Guide for details.

Contact Information

LadyBug Technologies LLC
3317 Chanate Rd. Suite 2F
Santa Rosa, CA 95404
Phone 707.546.1050
Fax 707.237.6724
www.ladybug-tech.com

2. Installation

Driver Note

LB5900 Series sensors are composite USB devices that enumerate as two USB classes. This gives the user a lot of flexibility when using the sensor programmatically or using VISA IO Libraries. LadyBug's PMA-12 software utilizes the system USB HID driver since it is available on all computers.

The Sensor will also attempt to enumerate a USBTMC driver. Since USBTMC drivers may not be installed on your computer, you may receive a warning. You should simply ignore and/or bypass this warning. If you have VISA IO libraries, the driver will automatically load without warning.

Initial Inspection

Check the shipment for any damage to the shipping container or the components inside.

Support Contact Information

LadyBug Technologies LLC
3317 Chanate Rd. Suite 2F
Santa Rosa, CA 95404
Phone 707.546.1050
Fax 707.237.6724
www.ladybug-tech.com

Operating System and Computer Requirements

The PowerSensor+™ line of products is compatible with Windows 2000 (SP2 or greater), Windows XP, and Windows 7, Windows 8 and Windows 10 operating systems. Support is available for various test development environments including MS C++, MS Visual Basic 6.0; MS Visual Basic .NET; MS C# .NET; NI LabVIEW; NI LabWindows; and Agilent VEE.

Recommended PC configuration:
Pentium D
1G RAM
1.0 GHz Processor
CD Drive
*USB 2.0 Port**

* The USB port or hub *must* supply 400 mA @ 5 V for each power sensor operation. *Refer to the USB Considerations section of this manual to determine if your computer has a USB 2.0 port(s).*

Installation Procedure

Refer to the Quick Start Card(s).

Operating Precautions

Observe the cautions and warnings about maximum input power in the specifications section. Insure that the RF input connector on the sensor is clean and undamaged as well as the mating connector. The following procedures assume the software and hardware have been installed according to the installation process outlined in the preceding section of this manual.

General Note

LB5900 sensors are fully self-contained. All measurement processing is done inside the sensor. Preset and default measurement settings are stored in the sensor itself, not the application, this includes factory default averaging and frequency settings, along with offset features. Window, view and certain other user settings are stored on the computer. Using the application's ***Preset Normal*** button located in the ***Mode*** dropdown menu for any sensor issues a command to the sensor causing it to reload its internally stored factory presets.

Program Start Up

Start the software if it is not currently running by clicking on the desktop icon or launch it from its program location. *Start* > *All Programs* > *LB Technologies LLC*. Sensor(s) are selected by serial number if more than one sensor is connected to the computer. The serial number is stamped below the USB port on the sensor body.

When started, LadyBug Precision Power Meter accesses any connected LB5900 sensors. If none are present, the application will appear similarly to the image below at left. Once a sensor(s) is connected, click the circular two arrow *Sensors* icon circled in the left image, and any connected sensors will be listed. A small sensor window similar to the image below is opened inside of the application display for each connected and simulated sensor. Highlight and open any sensors desired as shown in the image below.

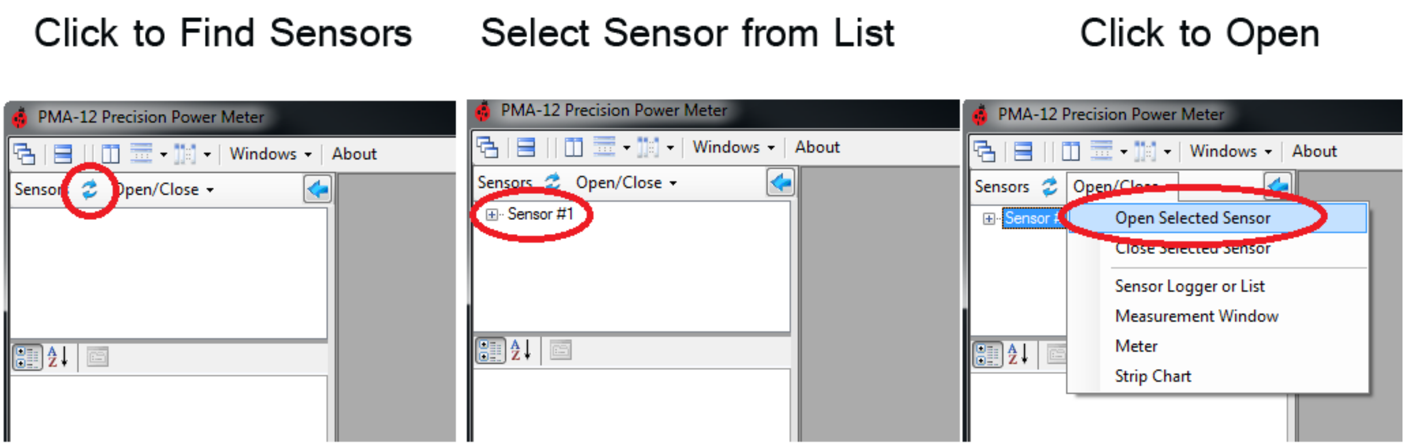


Figure 2 - Startup and Select Sensors

Configuration Settings & Sensor Window

Once a sensor is selected, a sensor window similar to the one in Figure 3 below will open. Settings such as the basic mode of operation, number of averages, measurement frequency, and update rate can be changed on the sensor window. Detailed sensor functions can be accessed in the *Details Pane* left. If multiple sensors are present, sensors can be identified by serial number. For more information, see the example measurement later in this document.

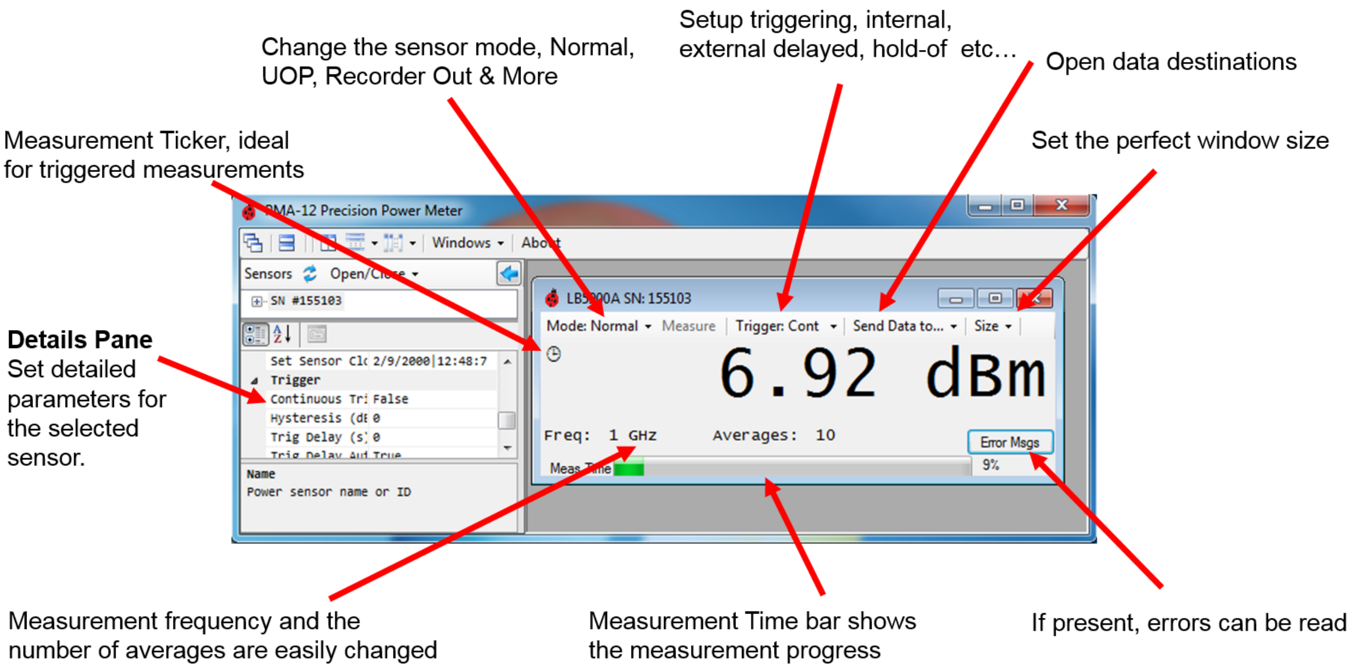


Figure 3 - Sensor Window

A Note on Zeroing and Reference Power Calibration

The patented design of the power sensor does not require zeroing or power calibration and there is no provision for zeroing or calibration.

NOTE: While zeroing is not required for any LadyBug sensor, LB5900 series sensors require time to thermally stabilize. Little if any warm-up time is required for measurements above -40.0 dBm. However, to make accurate measurements below -40 dBm the LB5900 series sensor should be allowed to thermally stabilize for one hour.

Setting the Center Frequency

LadyBug power sensors are carefully and accurately calibrated at multiple frequencies. LB5900 series sensors have very good frequency flatness, however as with all power sensors, the center frequency *must* be set whenever the incoming signal frequency changes to assure maximum accuracy. Measurement frequency can be set in either the sensor's *Details Pane* or using Freq on the sensor window.

Averaging

Averaging is the number of samples that are averaged together to create the measured value. A CW signal may require a very short period of averaging, while a pulsed signal with significant off time may require a long period to achieve an accurate average power measurement. Averaging can be set in either the sensor *Details Pane* or using Averages on the sensor window.

Display Preferences

Windows can be scaled to various sizes. Clicking the Opt Size button automatically optimizes the width / height. The data in the window will automatically scale with the window.

4. Operating Instructions and Examples

Quick Start Average Power Measurement

If a sensor is connected, PMA-12 will start making measurements as soon as it is started, however certain settings may not be correct for your particular signal. The following example is designed to guide the user in setting up the sensor to make an accurate basic typical CW measurement (all models):

1. Using a signal generator or other appropriate source, provide a signal source with the following parameters:

   CW Frequency: 1 GHz
   Power Level: 0 dBm (1 mW)
   Modulation: OFF
   RF Power: OFF

   WARNING: **VERIFY THE DAMAGE LEVEL IN THE SENSOR'S DATA SHEET. Many LadyBug sensors have a damage level specification of +23dBm, 200mW, or 3.15VRMS.**

2. Examine the Precision Power Meter shown below. Note: Default parameters can be utilized for everything except frequency, however we will set the number of averages since it is a common setting.

3. Select: *Freq:* (It is set to 50 MHz by default)
   Enter: 1GHz

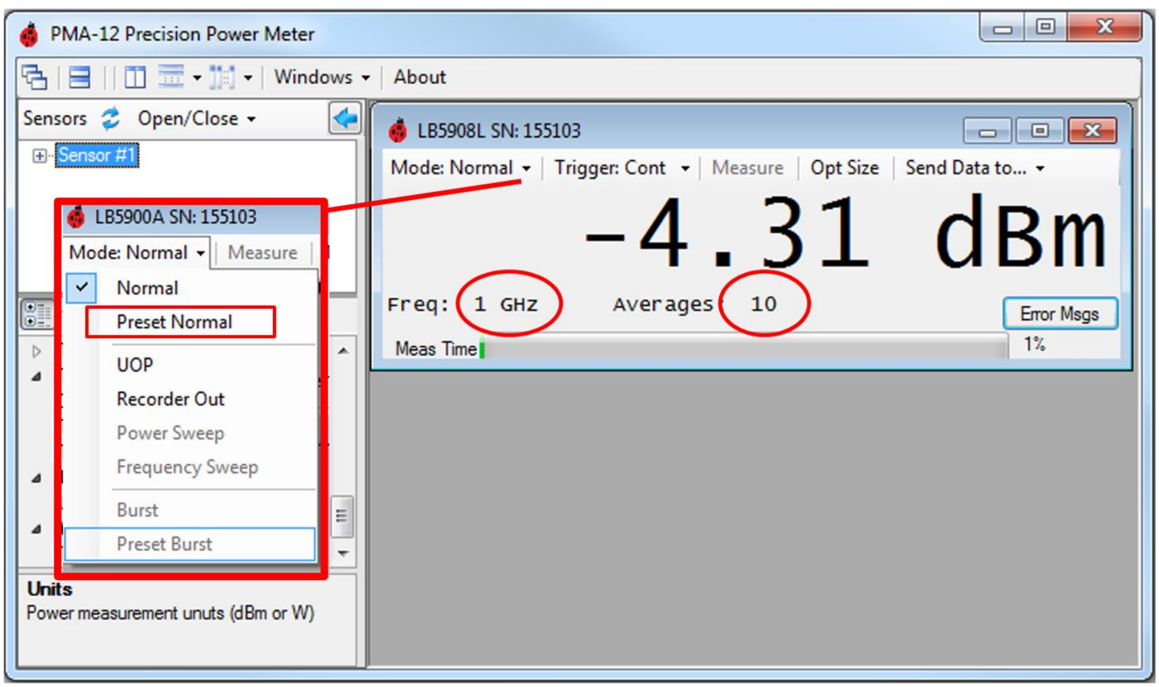


Figure 4 - Set Averages, Frequency & Preset

4. Select: *Averages*: (It is set to 4 by default)
   Enter: 10
5. Connect the sensor to the RF source and turn the RF power on.
6. The GUI display should now indicate approximately ~0 dBm at 1 GHz.
7. Vary the source power to see if the GUI display tracks the source power.

Settings and Measurements Detail

The LB5900 series of True RMS RF power sensors makes average measurements on any signal regardless of the signal's modulation.

Refer to the block diagram in the Measurement Accuracy section of this document for the following discussion: The incoming broadband RF/microwave energy is first conditioned and converted to digital format. The input power drives two measurement channels of differing sensitivity. The transition between these paths is typically between -30 and -20 dBm. LadyBug LB5900 power sensors continually digitize both paths simultaneously and use a weighted average approach over the transition range. This approach to the measurement means that a seamless measurement transition between paths is possible. It also means that the full dynamic range of the sensor is available to all measurements all of the time.

Default Settings

The user has control over many settings in the sensor and software application. It is very easy to change settings. To make it easy to get back to a settings reference point, PMA-12 software includes a selection in the Mode dropdown called *Preset Normal* as shown in Figure 4. Selecting this, returns the sensor and PMA-12 to their default configuration. Note: Stored presets in the sensor are not cleared or changed.

Units

By default, LadyBug sensors display power units in dBm. Users can change the units to Watts using the Units Property located in the sensor Detail Pane. Note that some functions such as offsets, corrections, recorder scaling and others must be set in dB.

Averaging

Averaging is the number of data samples that are averaged together to make a measurement. The default settings for the number of averages is stored in the sensor, not the application. Setting averaging in the application simply sets the sensor's internal measurement processing system to the requested settings. The number of averages is settable from the Sensor Detail Tab or the Sensor Window for each connected sensor as previously shown.

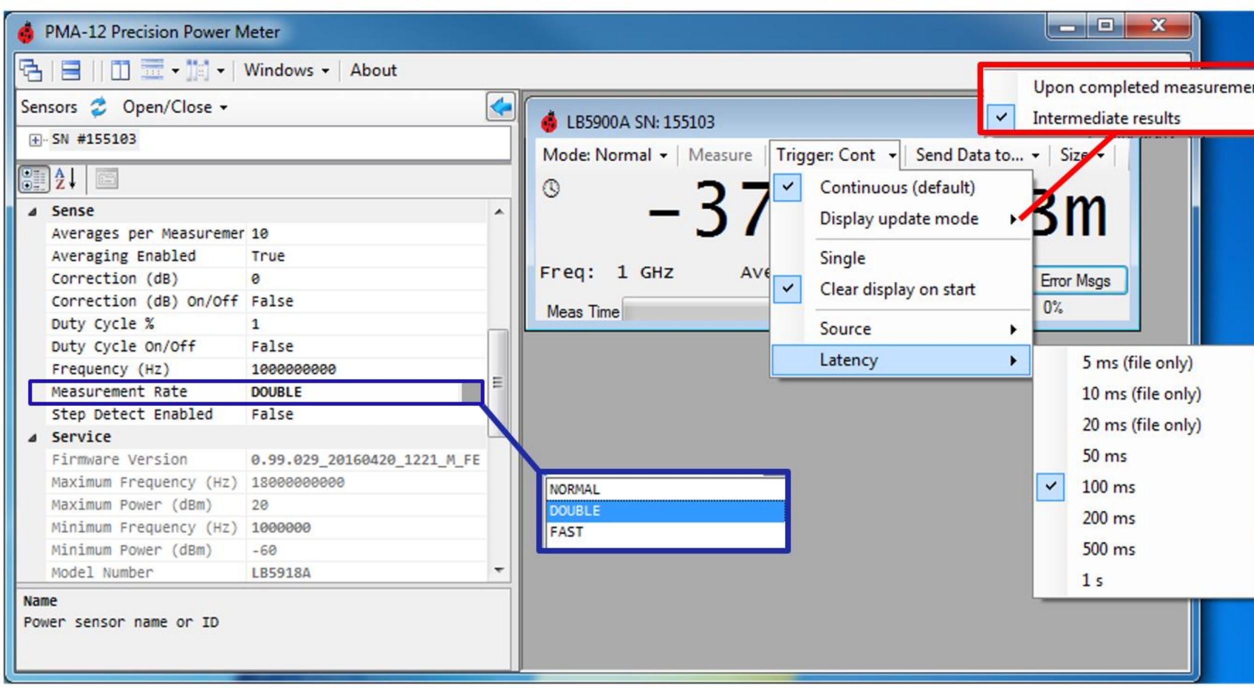


Figure 5 – Timing, Display & Update Mode

Step Detect
Step detection may be useful for some measurements requiring a long measurement period. If a large signal change occurs, step detection resets the average buffer so that a clean average measurement can be returned. By Default, PMA-12 disables Step Detection.

Measurement Timing & Latency
The primary factors affecting measurement timing are Latency, Measurement Rate and the number of Averages. LB5900 Measurement timing functions are controlled in both the Sensor's Window and Detail Pane. The image in Figure 5 shows some of the timing features. In the shown *Preset* configuration, PMA-12 requests measurements from the sensor continuously. Once the sensor receives the measurement request, it will process the measurement. This can take from a millisecond to many seconds depending on the Measurement Rate and number of averages requested by the user. The measurement will then be returned to PMA-12 which will display the reading. PMA-12 will then start a "latency" timer, when the timer times out, PMA-12 will request a new measurement from the sensor, repeating the process. Note that Latency is not a sensor function. Latency is the delay after a measurement is received back from the Sensor before PMA-12 software requests a new measurement from the Sensor. This process occurs continuously when the mode is set to *Normal*. (Mode: Normal; Trigger: Continuous), and allows the user to establish measurement timing. Each time the application requests a measurement, it starts a timer. The timer is represented by the green *Meas Time* bar at the bottom of the display. *Time Out (ms)* can be changed at the top of the *Details Pane* under *Application*. Due to Windows screen processing, Latency time is limited to 50ms and greater for screen usage. Latency can be set to faster times for storage directly into a file, see the *Logging to a File* section for more information. When Latency is set to less than 50ms, the screen update rate will at a rate lower than set, however data sent to the file will be rapid. See Figure 5 for the Latency control. To set the system for fast measurements, consider the sections *Averaging*, *Measurement Rate and Accuracy, Step Detect* and *Trigger Delay Auto.,*

Warning

When latency is set below 50ms, measurement communication activity is very rapid and may take precedents over user requests for measurement control changes. Where low latency times are to be utilized, it is recommended that all other settings be made prior to setting latency (set the latency last).

Note: With low latency times such as 5ms to 20ms, the screen may not be able to update as rapidly as measurements are returned and some measurements will not be displayed, these measurements will be captured when measurements are sent to a file as explained in the Logging to a File section.

Measurement Rate
Measurement Rate is a sensor function (MRATe) and is set in the Detail Pane of PMA-12, see Figure 5. Measurement Rate determines how sampled power levels are handled prior to averaging. If fast measurements are required, it may be desirable to change the Measurement Rate. For example, if the Measurement Rate is set to *Fast*, averaging is disabled and un-averaged samples are delivered very rapidly. At up to 1,000 per second, samples are taken much faster than can be visualized. MRATe fast is normally used programmatically. Better choices for use visually are *Double* or *Normal*. A setting of *Double*, allows for good measurements speed and accuracy, and is set when *Preset Normal* is clicked (Figure 4). If a very low power level is to be measured, *Normal* and a high number of averages may be required to achieve the desired accuracy. This will result in a long measurement time, regardless of PMA-12's Latency setting. For additional data regarding Measurement Rate (MRATe) refer to the LB5900 Programming Guide.

Measurement Query (Display Update Mode)
To achieve the best results for your particular measurement, PMA-12 issues one of two different sensor measurement commands. These are set in the *Trigger* dropdown, *Display update mode* section.

The default mode is *Intermediate Results* which uses the sensors FETCh? query. In this case, the sensor is essentially free running. When PMA-12 requests the measurement, the sensor delivers the most recent average of the specified number of samples. This "circular buffer" method provides a good responsive measurement in most cases. If averaging is set such that a long period of time is required, such as 1000 averages intermediate results are provided (after initiation) until the first 1000 samples have been taken. For example, if averaging is set to 1000, and latency is set at a rate that is a more rapid pace, such as required for 10 averages, PMA-12 will deliver the intermediate results prior to completion of 1000 averages. First 10 averages then 20 and so forth. Once 1000 samples have been taken, and thereafter, the measurements will be the last 1000 at the time the request was made even if there is only a difference if 1 sample.

If *Upon Completed Measurement* is selected in the *Trigger* dropdown, *Display update mode* section, the sensors READ? query is utilized. In this case the sensor is not free-running and measurements are initiated when the request is made (after the latency time as elapsed). No intermediate results are delivered. When the specified number of samples are averaged the measurement is returned.

Single Measurements

Individual triggered measurements can be made using either of the above queries. This would normally be done with the *Measurement Update Mode* set to *Upon Completed Measurement* (READ?) as detailed above. To make individual measurements upon manual request, referring to Figure 6, in the *Trigger* dropdown, move the check from *Continuous (default)* to *Single.* PMA-12 will stop making measurement requests (the display will not clear) and the *Measure* button will appear in PMA-12. Each time the Measure button is clicked, a measurement will be initiated and displayed upon completion. Refer to the section on Triggering for additional options.

Measurement Ticker
The Measurement Ticker in the sensor window (Figure 3, Figure 6 blue) can be used for several purposes. The Ticker is measurement based and not time based. The primary usage is to indicate measurement activity. Each time a measurement is returned, the ticker advances. The ticker is especially useful when making continuous triggered measurements, and can provide an indication that a trigger has occurred in cases where the power level remains unchanged.

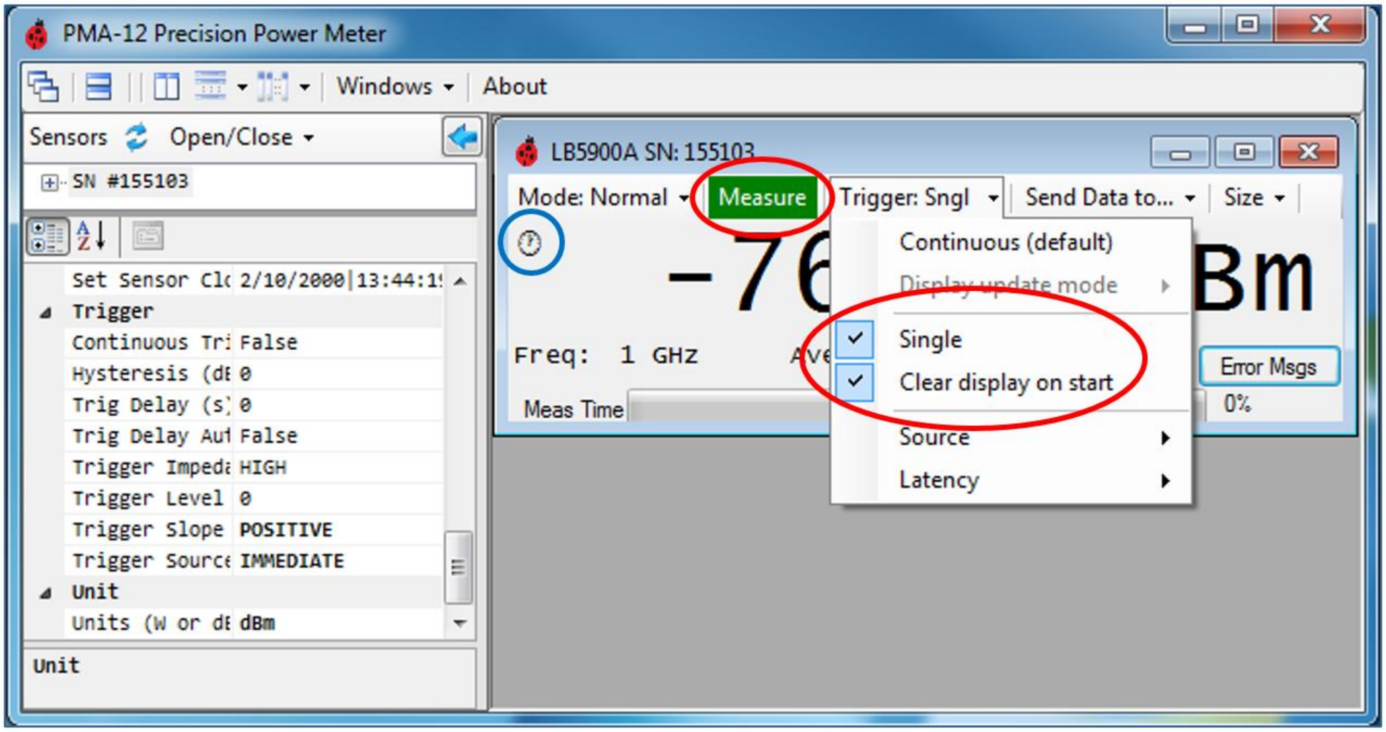


Figure 6 - Single Measurements

Triggering

LB5900 Sensors have a full set of internal and external triggering functions. Triggering can be used to synchronize the LB5900 series sensor with the measured signal. Management of the triggering system is handled by PMA-12 and the commands may be transparent to the user, however it is important to have an understanding of how the triggering system function in order to make good measurements. There three primary sensor functions used to make triggered measurements:

Abort.
Once a triggered measurement is initiated, the sensor may not respond to other commands because it is busy waiting for a trigger to occur. Abort (ABORt) places the sensor in the idle state.

Initiate.
The set of commands that begin a measurement. IE: cause the sensor wait for a trigger.

Trigger.
The set of commands that control how the triggering system behaves. Trigger functions are explained below and include several examples.

Trigger Delay Auto
When active, Trigger Delay Auto inserts delay after the trigger occurs to allow the measurement to settle prior to sampling. The feature is set in the triggering section of the Detail Pane. If set to false, sampling will begin immediately after the trigger occurs. If large power level changes occur, Trigger Delay Auto may not insert sufficient delay for

settling to occur. In such cases, it is recommended that the manually set Trigger Delay value be set according to the measurement requirement and Trigger Delay Auto be set to False. The default is state is True (ON).

Set Trigger Delay Manually
Trigger Delay is a delay after the trigger occurs to allow the measurement to settle prior to sampling. In some cases, particularly where a high number of averages is utilized with Measurement Rate set to Normal in order to measure a low level signal, it may be desirable to set Trigger Delay manually. To do this, first determine the amount of delay required, the sensor will accept delays up to 150ms. Referring to Figure 7, in the *Trigger* section of the Detail Pane, set *Trig Delay Auto* to *False*, and place the required delay (in seconds) in *Trig Delay (s)*.

Hysteresis
Hysteresis sets the level that the signal must fall below the trigger level before a rising trigger edge will be detected (positive slope); or sets the level that the signal must rise above the trigger level before a falling trigger edge will be detected (negative slope). This can be adjusted to accommodate movement in the trigger level whether it is internal or external.

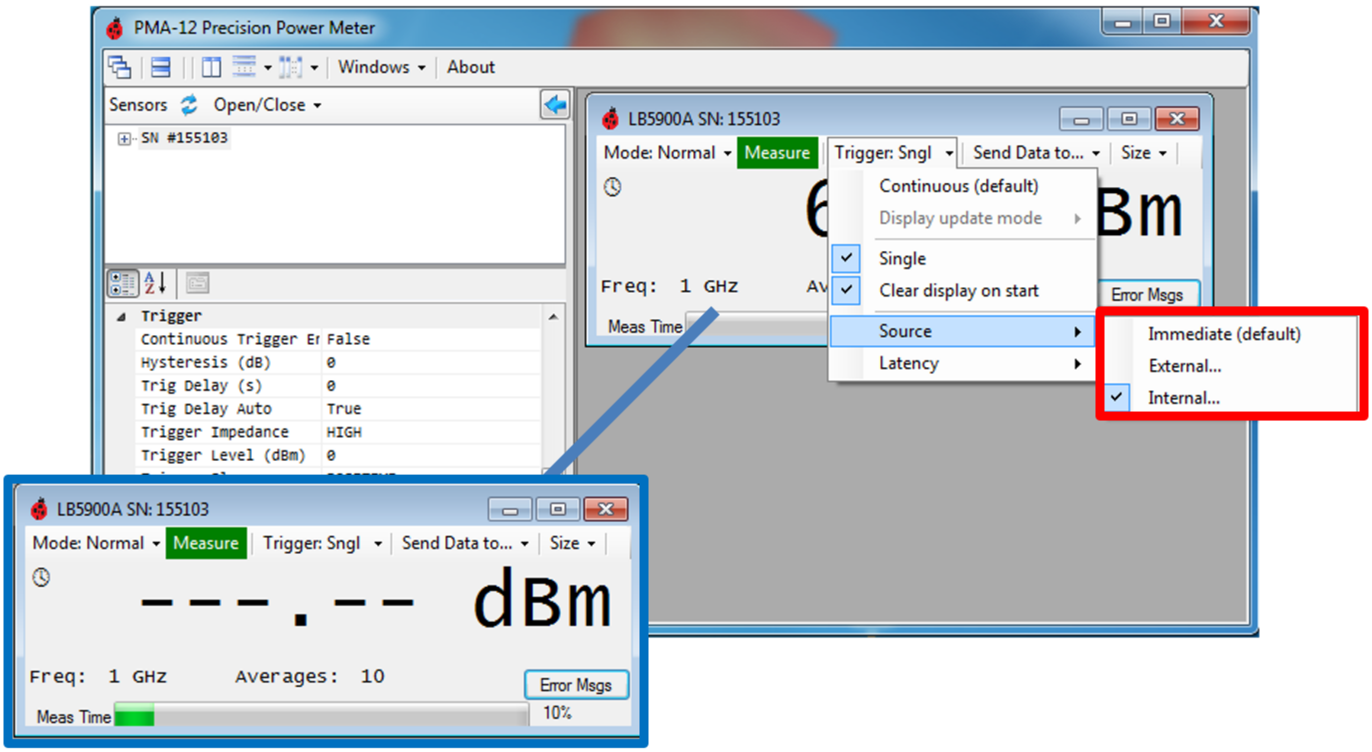


Figure 7 - Triggering Functions

Single Internally Triggered Measurement

In the following basic triggered measurement using an RF Source, the sensor will be set to wait for a level change; once the level change occurs, a single measurement consisting of 100 averages will be triggered and returned.

1. Set the RF Source Instrument to 0 dBm, then disable the output.
2. Set averages to 100
3. Set the trigger level to -30dBm
4. In the Sensor Window, set the trigger to Single (The green *Measure* Icon will show - Figure 7)
5. Set the trigger source to Internal (Figure 7 red inset or Detail Pane)
6. Set *Clear display on start* in the *Trigger* dropdown of the sensor window (Figure 7)
7. Click *Measure* the green *Meas Time* bar begins to move (Figure 7, blue inset)
8. Enable the RF Source output
9. Note the measurement on PMA-12
10. Disable the RF Source output to reset the trigger
11. Repeat the measurement by clicking *Measure*

Clear display on start is set so that any previous value in the display is cleared when the *Measure* button is clicked; if not set the previous value will be replaced when the new measurement is returned.

Continuous Internally Triggered Measurement

In the following basic triggered measurement using an RF Source, the sensor will be set to wait for a level change; once the level change occurs, a single measurement consisting of 10 averages will be triggered and returned.

1. Set the RF Source Instrument to 0 dBm, then disable the output.
2. Set averages to 10
3. Set the trigger level to -30dBm
4. In the Sensor Window, set Trigger to Continuous (Figure 7 top)
5. In the Sensor Window, set the trigger source to Internal (Figure 7 red inset or Detail Pane)
6. In the Sensor Window, set the latency to 50us so that repeated requests are made
7. Enable the RF Source output
8. Note the measurement on PMA-12
9. Disable the RF Source output to reset and rearm the trigger
10. Repeat the measurement by enabling and disabling the source

In the above example, the signal level was changed manually. A much faster continuously pulsed signal within the sensors capabilities could be measured.

Using External Triggering

When Trigger Source is set to External, the trigger section is controlled by the signal applied to the TI SMB connector on the rear bulkhead of the sensor. The triggering functions themselves act the same whether it is and internal or external trigger that is applied.

Impedance

The external triggering input impedance is in the High state (100k Ohms) by default. The impedance can be set to 50 ohms by setting *Trigger Impedance* to *LOW* in the *Trigger* menu of the Detail Pane.

Single Externally Triggered Measurement

In the following externally triggered measurement using an RF Source, the sensor will be set to wait for an external trigger; once the trigger occurs, a single measurement consisting of 100 averages will be made and returned.

1. Set the RF Source Instrument to 0 dBm, and enable the output.
2. Set averages to 100
3. In the Sensor Window, set the trigger to Single (The green *Measure* Icon will show Figure 7)
4. Set the trigger source to External (Figure 7 red inset or Detail Pane)
5. Set *Clear display on start* in the *Trigger* dropdown of the sensor window
6. Click *Measure* the green *Meas Time* bar begins to move (Figure 7, blue inset)

7. Apply 0 to ≈4 volts edge or pulse to the trigger input.
8. Note the measurement on PMA-12

Clear display on start is set so that any previous value in the display is cleared when the *Measure* button is clicked; if not set the previous value will be replaced when the new measurement is returned.

Using Triggering Output

Trigger output is available on all LB5900 sensors. The output is a single pulse that occurs each time a measurement is triggered and can be used for various purpose. To prevent retriggering in time sensitive applications the pulse width is fixed at 500ns. The trigger out pulse is issued when any trigger occurs, including internal triggers, external triggers and continuous triggers. The images in Figure 8 were made with a sensor running in continuous (default) mode.

Trigger out is a TTL level (Nominal 5 Volts) signal that can be set to generate a positive or negative pulse. The TO Port (Figure 1) is shared with Recorder Output and Wideband Detector Out; simultaneous use of these features is not possible. The sensor sets the output drivers depending upon user settings. This design makes it possible to order sensors with both features and use each one when needed.

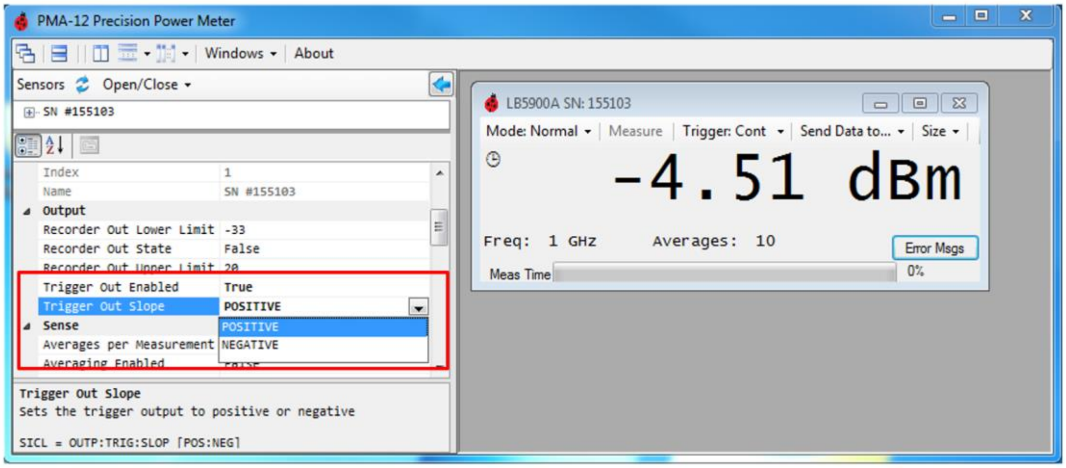


Figure 8 - Trigger Out Settings

Trigger Out Example

1. Set up a measurement. Note: It may be helpful to set averages to a low value and set *Measurement Rate* to *Fast* so that a high repetition rate is issued. Once the setup is tested, set the values as required.

2. If a low to high pulse is desired, set the *Trigger Out Slope* to *POSATIVE*, otherwise for a high to low pulse set the *Trigger Out Slope* to *NEGATIVE.* Refer to Figure 9.

3. Set *Trigger Out Enabled* to *True,* refer to Figure 9, this will enable the output and disable Recorder Out and Wide Band Video Out.

4. Trigger out pulses will appear on the output.

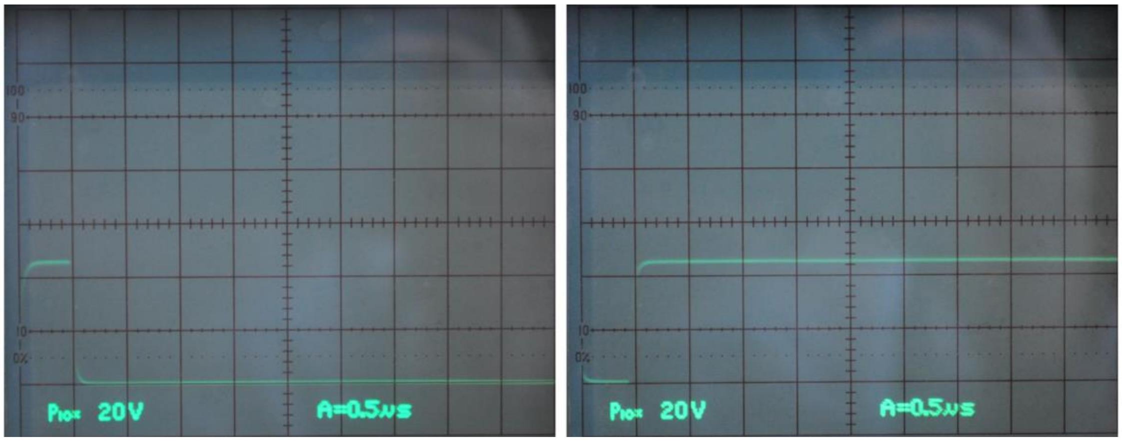


Figure 9 - Trigger Out Signals

Offsets and Corrections

Offsets and corrections are calculations made on the measurement to provide a result in a different or scaled form. Simple offsets can be enabled to offset an attenuator or coupler or to compensate for a cables loss or for other purposes. The MLP (minimum loss pad) function is included for 75 ohm users. This function is intended for use with standard 75 to 50 ohm resistive pads that exhibit a 5.719 dB loss. Duty Cycle correction is provided so that the user can input the known duty cycle of an averaged pulse measurement, and display the pulse power.

Simple Offsets

A simple offset is a value that is applied to the measured value then displayed. All offsets are set in dB, even if the units are Watts. A negative value will decrease the measurement and a positive value will increase the measurement. To use the offset once it is setup, it must be enabled. See Figure 10. The offset can be disabled and enabled as required and its value will remain in place until the sensor is reset or powered off.

Minimum Loss Pad

The standard Minimum Loss Pad matches 75 ohm devises to 50 Ohm instruments and consists of two resistors. The standard design exhibits a loss of 5.719 dB. Selecting PMA-12's MLP Offset corrects the measurement by +5.719dB so that measurements are reported correctly when the MLP is installed. To use the offset once it is setup, it must be enabled. See Figure 10, *Correction (dB) On/Off* in the Detail Pane, circled in red. The offset can be disabled and enabled as required and its value will remain in place until the sensor is reset or powered off. Note that if additional corrections are required for attenuators or for other purposes in the users system, corrections should be summed into a single simple offset rather than using the MLP correction.

Duty Cycle Correction

Duty cycle correction is expressed as a percentage. Take for example, a wideband pulsed signal with a known duty cycle of 2%, and an average power measurement from the LB5900 series sensor of -20dBm (10µw). The user can set the Duty Cycle Correction value of PMA-12 to 2%, and the software will calculate the pulse power. In this case, Pulse Power is -3 dBm.

.00001W/.02 = .0005W = - 3 dBm

The LB59XX True-RMS diode sensor will very accurately measure this signal even if the pulse width is extremely narrow such a 1ns or less.

See Figure 10 to set the Duty Cycle Correction. The correction can be disabled and enabled as required and its value will remain in place until the sensor is reset or powered off. In the Detail Pane, to the right of *Correction (dB)* click the dotted box to open the *Set Offset* detail. To use the offset once it is setup, it must be enabled. See Figure 10, *Correction (dB) On/Off* in the Detail Pane, circled in red.

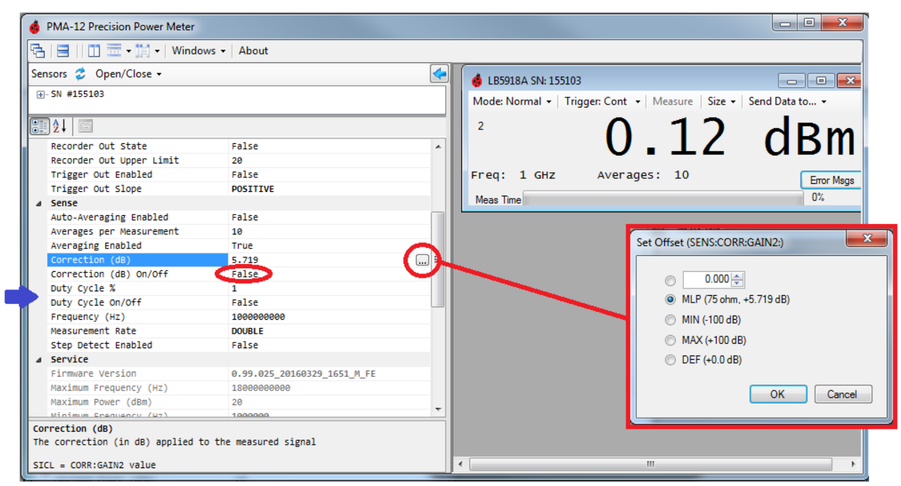


Figure 10 - Offsets & Corrections

Error Messages

LadyBug LB5900 Series power sensors have built in error management. If an error occurs such as a communication error or out of range specification, such as attempting to set a frequency out of range, the sensor will store this error. To let the user know that there is an error, the sensor's red LED indicator will lite solid red. The *Error Msgs* button shown in Figure 11 *can* be clicked to read the error message(s) that are stored in the sensor queue. For example, the error *-222 Data out of range* shown in Figure 11 is a result of the error that was stored when the frequency was set to 99 GHz on the connected 8 GHz sensor.

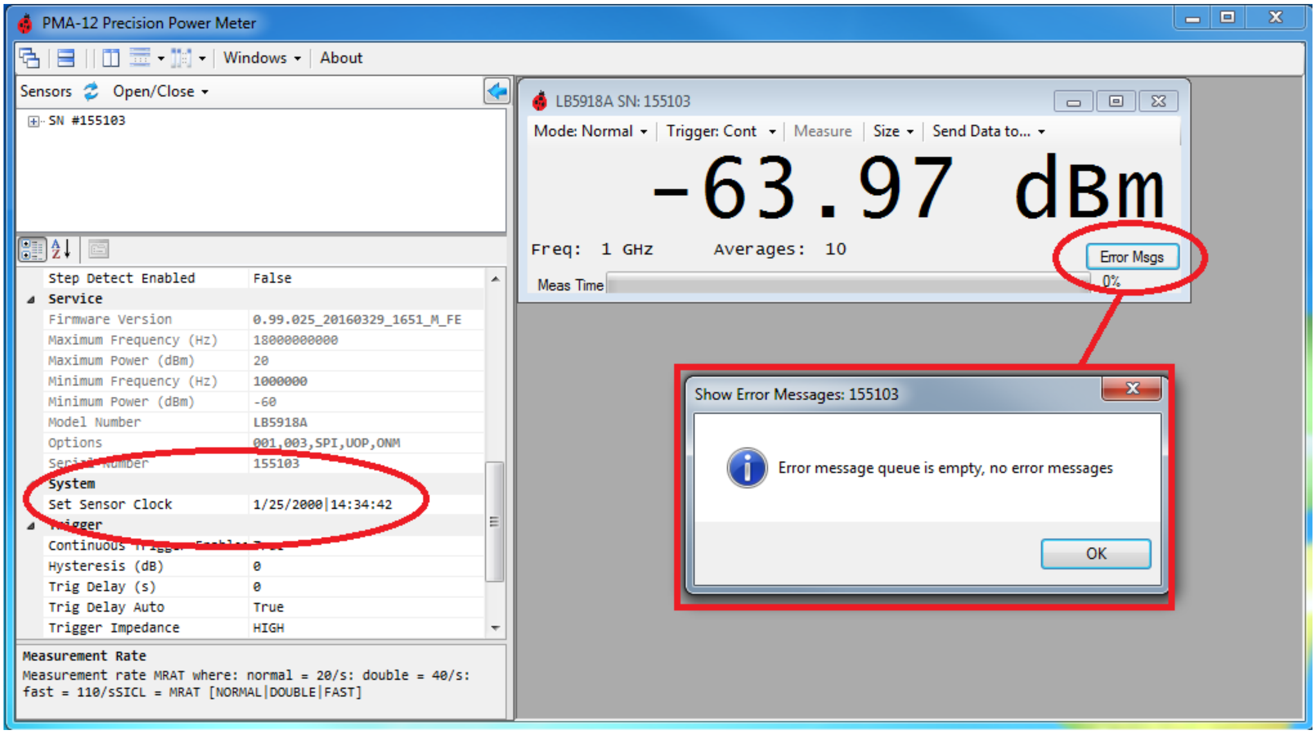


Figure 11 - Error Messages & RTC

Sensor Real Time Clock

LadyBug LB5900 Series power sensors contain a backed up real time clock. The real time clock is used by unattended operation, and is not necessary for most sensor functions. The standard back up system functions for a few days (review sensor specification sheet) and may have to be set from time to time if the sensor has not been used for several days and Unattended operation is to be utilized. To set the time and date, locate the *System* section in the Detail Pane and click either *Date* or *Time* and make the change. The new data will be stored in the sensor.

Logging to Screen

LadyBug's PMA-12 Precision Power Meter includes a tabular log. Prior to starting the Log, set up the measurement's averaging and frequency as described earlier. Measurements will be logged at the measurement rate determined by the measurement settings. Review the *Measurement Timing* section above for additional information. Once the measurement is setup, click the *Send Data to..* drop down or the *Open/Close* button from the main tool bar as shown below.

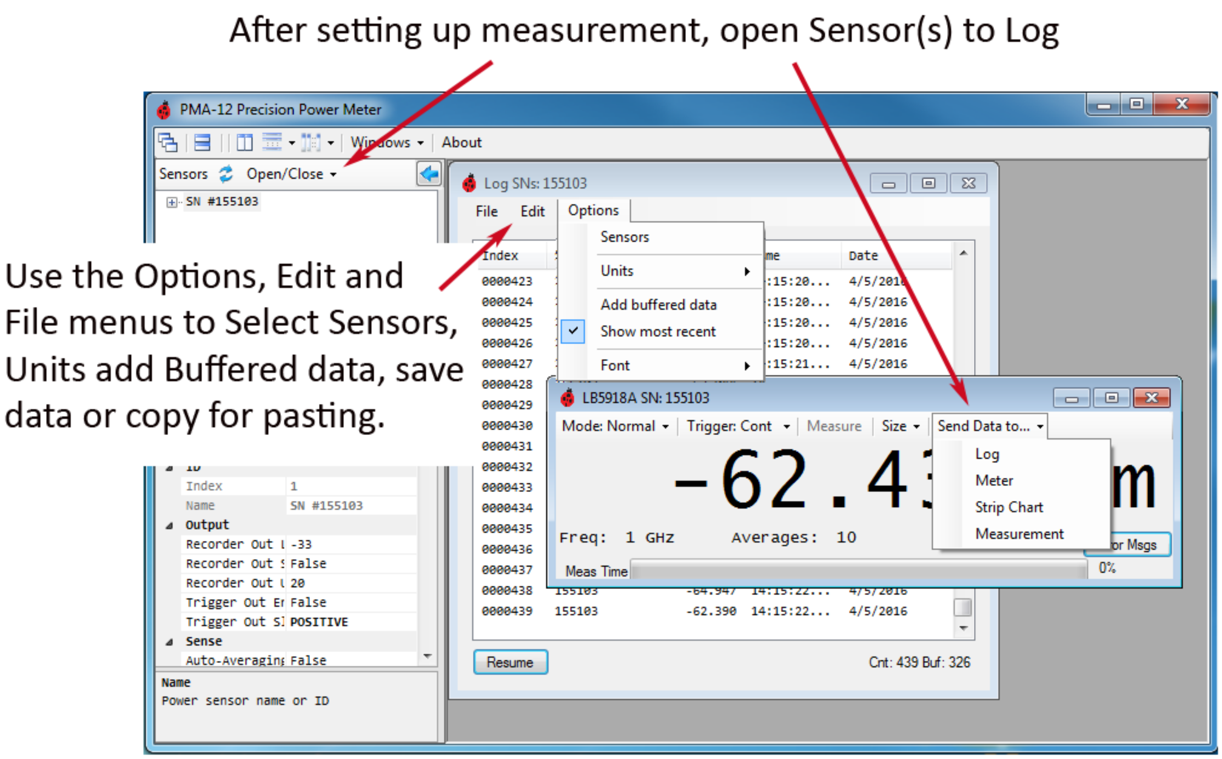


Figure 12 - Tabular Log View

The log must be paused by clicking the *Pause* button prior to using the data management features; the button will then change to resume which can be clicked to restart measurements.

After Pausing the log, data can be saving using the File dropdown save button or data can be selected and copied into the clipboard. If *Select All* is clicked, everything that has been logged will be selected, otherwise selection can be made from the log. Once selection is complete, data can be pasted into compatible software such as EXCEL or Notepad.

Additional sensors can be added to the log by clicking the *Options* drop down then *Sensors*, once clicked, a list of all connected sensors will appear. One or more sensors may be added.

Logging to a File

When fast measurements are requested by setting latency to a low value and configuring averaging & other sensor settings configured for speed; computer screen updates limit the rate that measurement can be processed. File IO can be utilized to make faster measurements. Over 60 measurements per second can be stored using PMA-12's log to a file feature.

Files are saved as tab separated text files using the measurement setup that is currently in process. Triggering and other measurement features can be utilized. Referring to Figure 13, first a file is selected using the *File…* selection. A standard windows file dialog will open for file naming and selection, once the file is selected, the file menu will close. The file name is stored and will be utilized during the entire session unless changed. To view the name of the selected file later, click *Current Log Fil…*

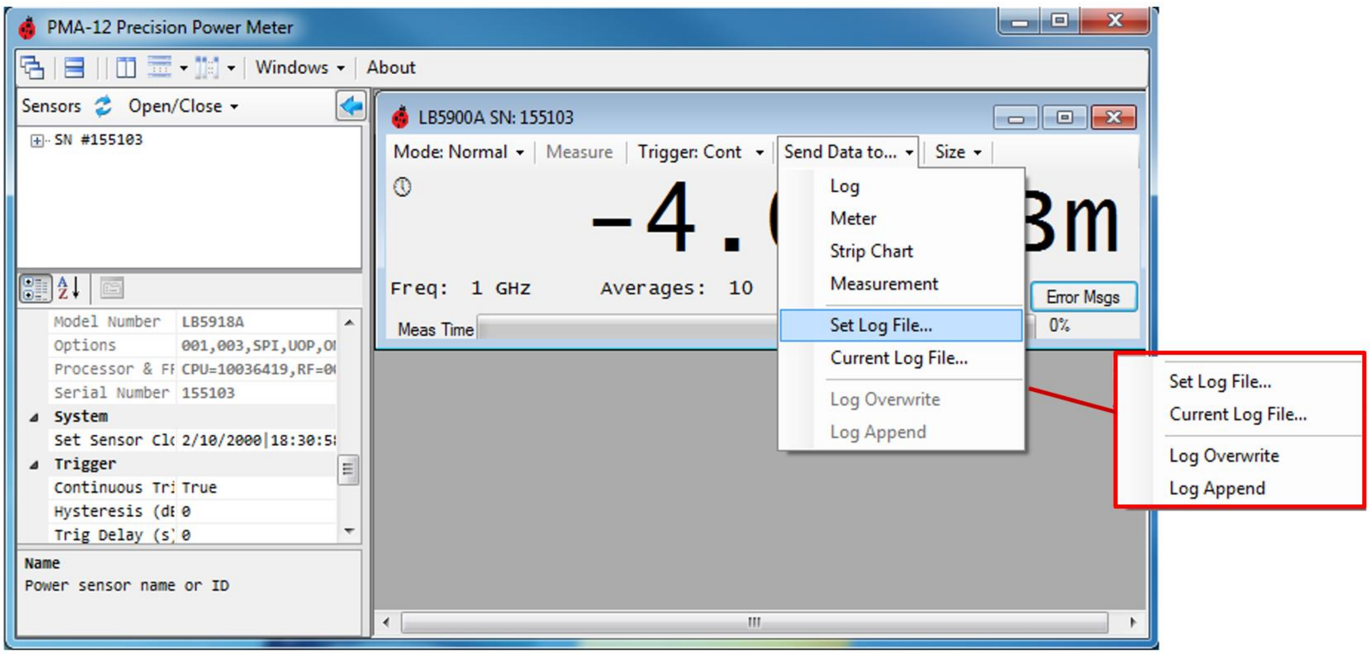


Figure 13 - Log to File

Now that a file has been stored, the selections *Log Overwrite* and *Log Append* are available for selection in the *Send Data to...* dropdown as shown in the red inset of Figure 13.

If *Log Overwrite* is selected (checked) when the named file exists, the file will be opened and any data in the file will be deleted. New data will be placed starting at the beginning of the file. If the file is not in existence it will be created and data will be placed in the file.

If *Log Append* is selected (checked) when the named file exists, the file will be opened and new data will be placed starting immediately after any previous data or text in the file. If the file is not in existence it will be created and data will be placed in the file.

When the selection is Unchecked the file storage will stop and the file will be closed, measurements will continue to be made to the screen. Re-checking *Log Append* or *Log Overwrite* will re-initiate each of the functions as detailed above. If PMA-12 is closed while log to file is active, the file will automatically close.

A feature of the append method is that the files can be opened in notepad or other text editor and notes placed in the file. Additional data can be place in the file after the notes by selecting the append method.

Tab separated files can be opened in many programs including notepad and Excel. To use Excel, set the file open filter to *.txt or *.* then select the file and then open it. Selecting the default settings in Excel's text import wizard will open the file as intended. Excel's default time settings can be edited by selecting the cells in the time column and then format cells. The default settings do not include hours and only tenths of second resolution. Refer to Figure 14 for guidance for changing the data format in Excel (may vary by Excel version).

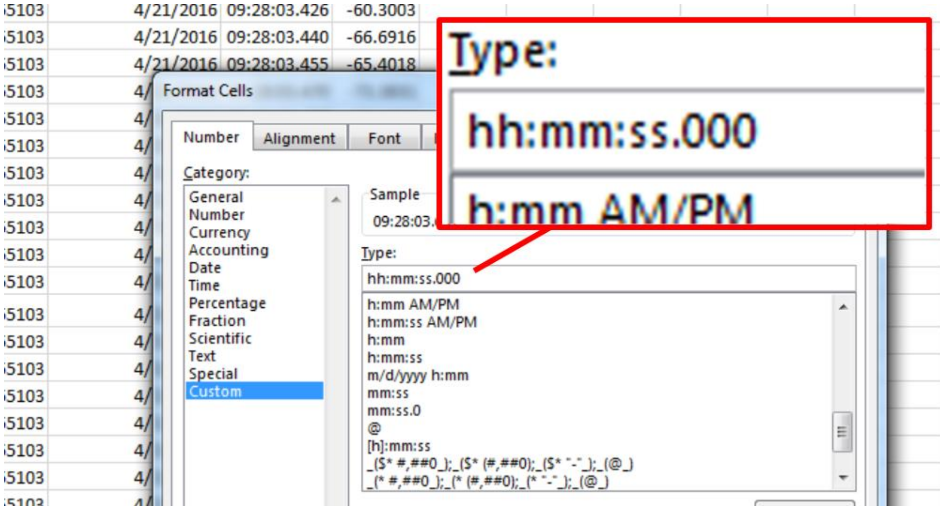


Figure 14 - Set Excel Time Resolution

Each row of data in the log file contains the sensor serial number allowing multiple sensor logging, followed by the date then time (computer system clock) then the power measurement.

Strip Chart

LadyBug's PMA-12 Precision Power Meter includes a flexible strip chart. The chart is used to plot power over various time periods. Prior to starting the Log, set up the measurement averages and frequency using the sensor window; the chart utilizes the measurement that is already setup for the selected sensor. It is important to note that measurements can not be logged faster than they are collected. Please refer to the *Measurement Timing* section of this document to determine the total time required to make a measurement. Measurement parameters can be changed after the chart is opened if desired. Once the measurement is setup, click the *Send Data to…* dropdown or the *Open/Close* dropdown, and select *Strip Chart*. A chart will open similar to that of Figure 15. Multiple Sensors can be logged.

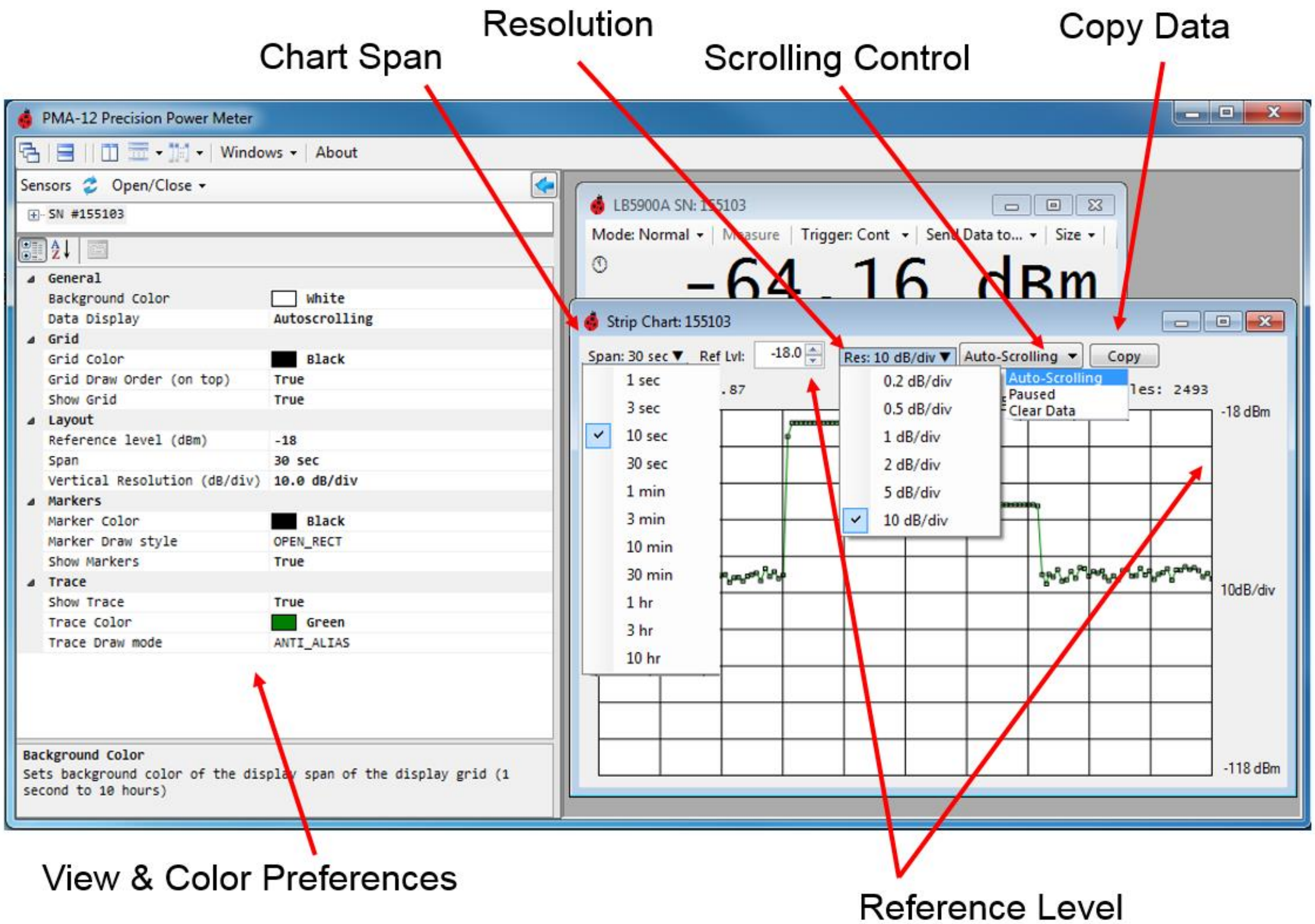


Figure 15 - Strip Chart Settings

The scale can be changed to accommodate signals of various power levels. To do this, click the *Resolution* button and a list of values similar to those listed in the image at right will display. Select the desired units per division. This may cause the measured value to move out of the ranges listed. To bring the measurement value into range, adjust the *Reference Level*, this is the highest value chartable, see Figure 15, with the Reference Level set to -18 dBm.

The amount of data shown on the screen can be set from 1 second to 10 hours by selecting the *Span* button. The Span may be adjusted after data has been collected without losing measurements. For example, after collecting days of data with the span set at 1 hour, the span can be changed to 1 minute or less to view the detail.

To rapidly navigate through the data, hold the left mouse button on the data area and move the chart until the desired area is located. Using the *Auto-Scrolling* control, scrolling may be paused to make it easier to navigate through and examine the information. Data collection continues while scrolling is paused, when Auto-Scrolling is re-enabled the measurements that occurred while the pause was in effect will be present in the chart.

Data can be copied into the computer's clipboard by clicking the copy button. The copied data can easily be pasted into any program utilizing windows copy and paste features. For example, pasting the data into EXCEL results in pasting the start time plus three columns of data. The first column is the measurement number; second is the time offset and lastly the power value. The listed offset time can be added to the start time to identify the time the measurement was taken. Once the data is in EXCEL, the user is free to create any number of graphs or charts.

If faster charting rates are required, consider the *Logging to a File* section, this allows logging directly to a file and eliminates the overhead associated with screen updates. Once the data has been logged to a file, it can be opened in EXCEL, which has a rich set of chart features.

Analog Meter

To set up an Analog Meter, first set up the measurement within the sensor window, then click the *Send Data to…* dropdown from the sensor window and select *Meter*. Alternatively, select the *Open/Close* button and a list of all connected sensors will appear. Select the desired sensor and click open.

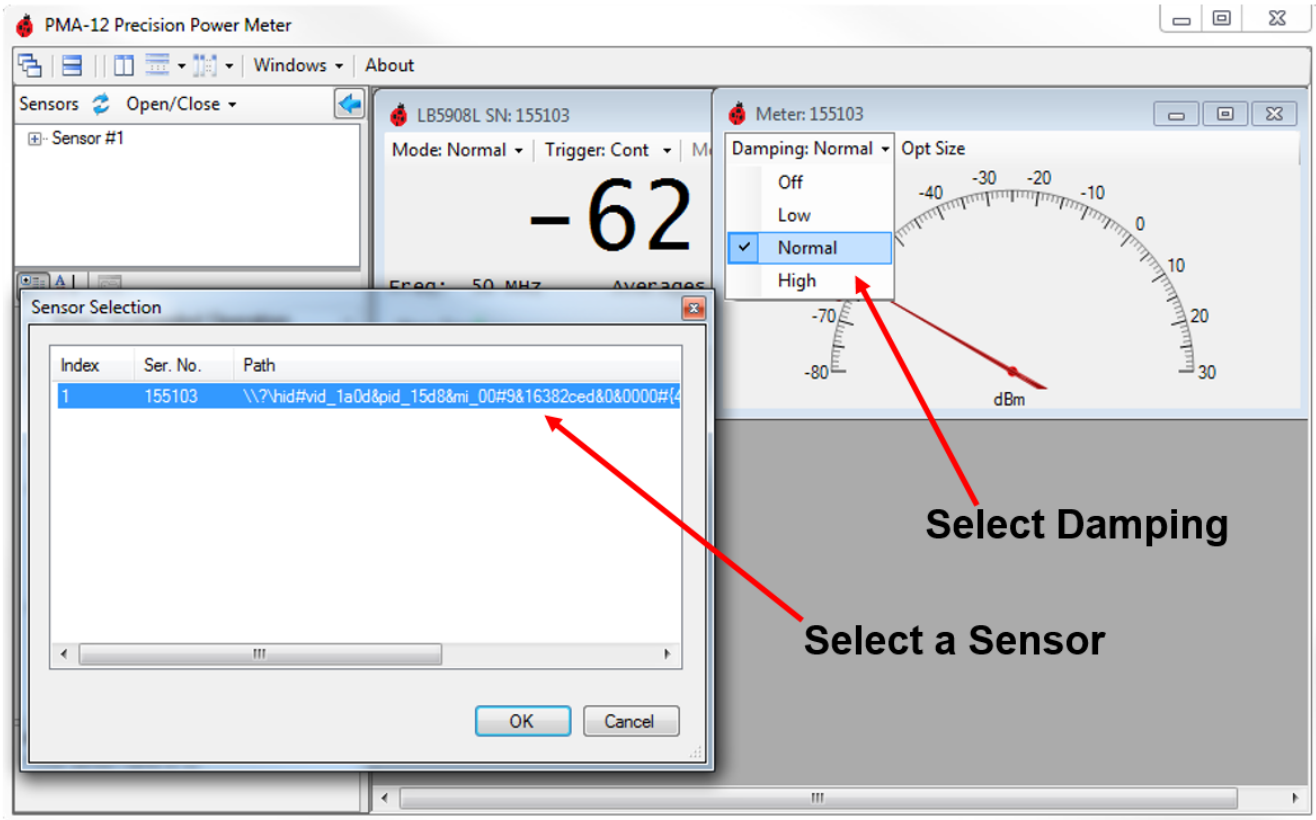


Figure 16 - Analog Meter Setup

Once the meter is open, damping can be set so that a smooth reading can be made. Damping is similar in effect to adding additional averaging. Click the *Damping* dropdown as shown in Figure 16 to set damping.

Unattended Operation

Option UOP (Unattended Operation) allows the sensor to function with no computer connected to the sensor. LB5900 series sensors are fully self-contained and do not require a computer. When utilizing UOP, the sensors current measurement setup will be utilized and measurements are stored in the sensors non-volatile memory. Unattended operation can also be utilized while the sensor is connected to the sensor. In this case, the user can be assured that measurements will not be interrupted while the computer is used for other purposes, even those with high USB activity that could interrupt fast measurements.

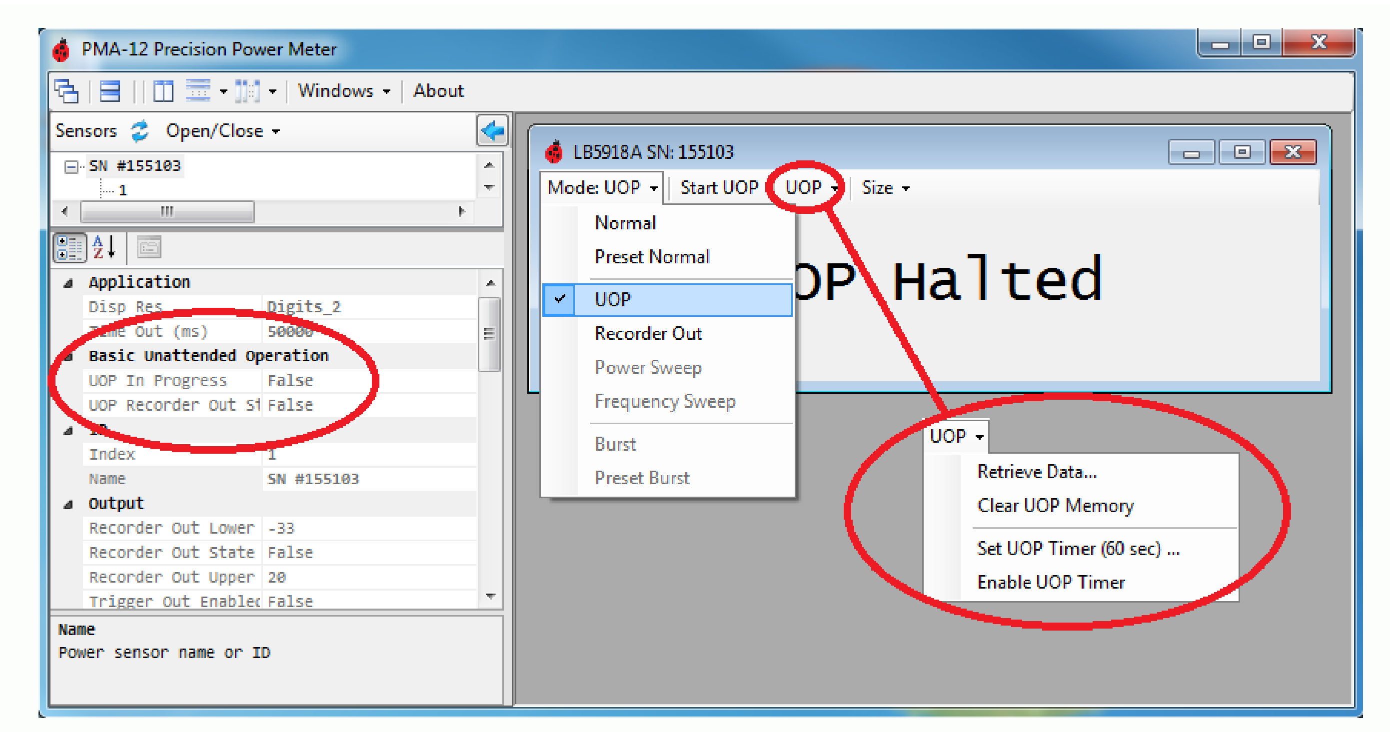


Figure 17 - UOP Setup

Figure 17 shows PMA-12's setup screen for UOP. A quick way to try UOP is to set the sensor up to its preset configuration by selecting *Preset Normal* then clicking UOP and then in the top menu, select *Start UOP.* Even though the computer is connected, the sensor is storing measurements into its internal memory. The sensor can now be unplugged and reconnected to power only or to a computer for its power supply. Either way, the sensor will begin appending measurements to its storage. If a UOP timer is setup (Circled in Figure 17), UOP will operate for the time period established then stop.

Clicking *Halt UOP* (not shown) will cause the sensor to stop storing measurements. Using the selections circled in Figure 17, the memory can be retrieved or cleared. Clicking *Retrieve Data* results in the sensor delivering a list of stored measurements as shown in Figure 18. Data can be saved to a file or copied to the clipboard for use in Spreadsheets or other programs.

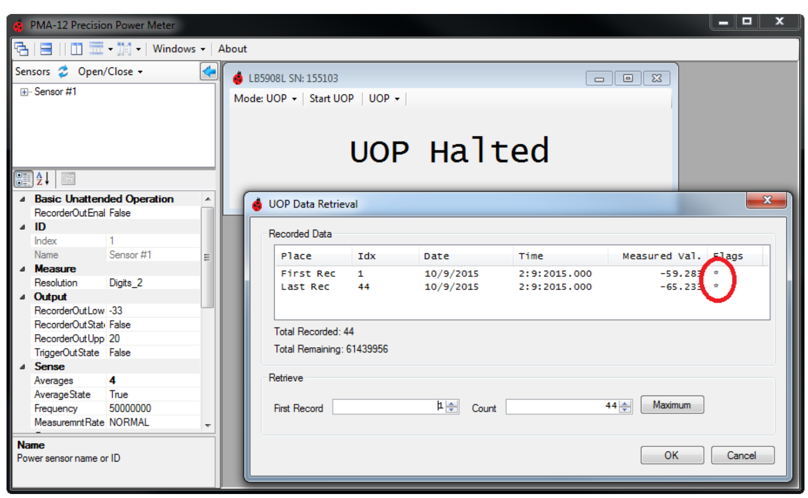


Figure 18 - UOP Retrieve Data

Operating conditions
Option UOP utilizes the sensor's real-time-clock. The backed up clock is disciplined by the primary processors high accuracy time base while the sensor is powered and utilizes its own crystal time base when the sensor is not powered. This system assures very high time accuracy. The backup system is designed to operate the clock for several days if fully charged. It is recommended that the sensor be powered on for several hours to allow the backup system to store power prior to relying on the backup for long periods of time. Note: The backup system only powers the real-time-clock the sensor will not make measurements without power. Setting the clock is described in *Operating Instructions and Examples*.

In order to make measurements of the highest accuracy, the sensor must be fully stable. It can take up to several minutes for the sensor to become stable. Measurements made prior to assured stability are marked with an * in the Flags column of the retrieved measurement data shown in Figure 18, circled in red.

Using Recorder Out in Unattended Mode
If both Option UOP (Unattended Operation) and Option 001 (Recorder Output) have been installed, a calibrated 0 to1 volt analog output can be obtained from the sensor while operating in Unattended Mode. Care must be utilized if the output is used to control other equipment.

During the power up cycle when UOP is active, Recorder Output will exhibit voltage transitions from 0 volts to 5 volts until the sensor's processor is running. After stability; and prior to measurement, the output will be at 1 volt (into its specified 1000 ohm load); after the sensor begins normal operation, the output will be stable and is updated 1000 times per second. Depending on the sensor model, firmware version and the number stored measurements, time to stability can be up to 20 seconds.

To protect equipment that may be controlled by Recorder Out, the default condition for Recorder Out when returning from power up is always OFF unless specifically set otherwise, this includes power up in Unattended Operation. To enable Recorder Out for use while the sensor is operating in Unattended Operation mode, a special function must be set. This parameter, *UOP Recorder Out State*, is circled at left in Figure 18. When set to True, Recorder Out will function while the sensor is running in Unattended Mode. The parameter can only be changed when the sensor is operating in Normal Mode (Figure 18 middle, Mode). While the sensor is in UOP Active (In progress) the function will remain set and the sensor can be repeatedly power cycled without losing the Recorder Out during UOP state. If the sensor is powered up while UOP is not active, *UOP Recorder Out State* will be cleared to FALSE and Recorder Out will not operate in Unattended Operation unless the parameter is set again.

Unattended Recorder Out Example
To enable Recorder Out while in Unattended Operation, perform the following.

1. Select *Preset Normal* to set the sensor to *Normal* and then set your Frequency
2. Set Recorder Out Upper and Lower Limits (See Recorder Out section for info)
3. In the Sensor Window, Under the Mode Dropdown, Set the mode to *Recorder Out* (Figure 17 middle)
4. Verify Recorder Out functionality
5. Under the Mode Dropdown, Set the mode back to *Normal* (Figure 17 middle)
6. Under *Basic Unattended Operation*, set *UOP Recorder Out State* to True (Figure 17 left)
7. In the Sensor Window, Under the Mode Dropdown, Set the mode to *UOP* (Figure 17 middle)
8. In the Sensor Window, Click Start UOP
9. Recorder Out becomes active
10. Remove and Reconnect power several times to verify
11. Connect to the computer, select *Halt UOP*, set Mode to *Normal* set *UOP Recorder Out State* to *False*

Download our Option UOP document from www.ladybug-tech.com for additional details.

Recorder Output

The ***Recorder Output*** function (Option 001) is a 0 to 1 VDC scalable output that is proportional to the measured RF input power. Note that on LB5900 series sensors Wideband Detector Out and Trigger Out share the connector with Recorder Out. Only one can be used at any one time. PMA-12 sets the output to Recorder Out automatically when *Recorder Out* is selected using the Mode dropdown menu. Once this is done, the Start RO button can be used to enable and disable Recorder Out. The recorder output signal passes through a 40 Hz hardware filter and the output is updated 1000 times per second.

An important unique feature of LadyBug's Recorder Output Option is that it is capable of running when no computer is connected if Option UOP (Unattended Operation) is also installed. For example, after the options are set up, and Recorder Out is active, the sensor can be powered through the USB cable or through the SPI cable if Option SPI has been purchased; and recorder output will deliver a calibrated analog output if set accordingly. Review the Unattended Operation section for additional information.

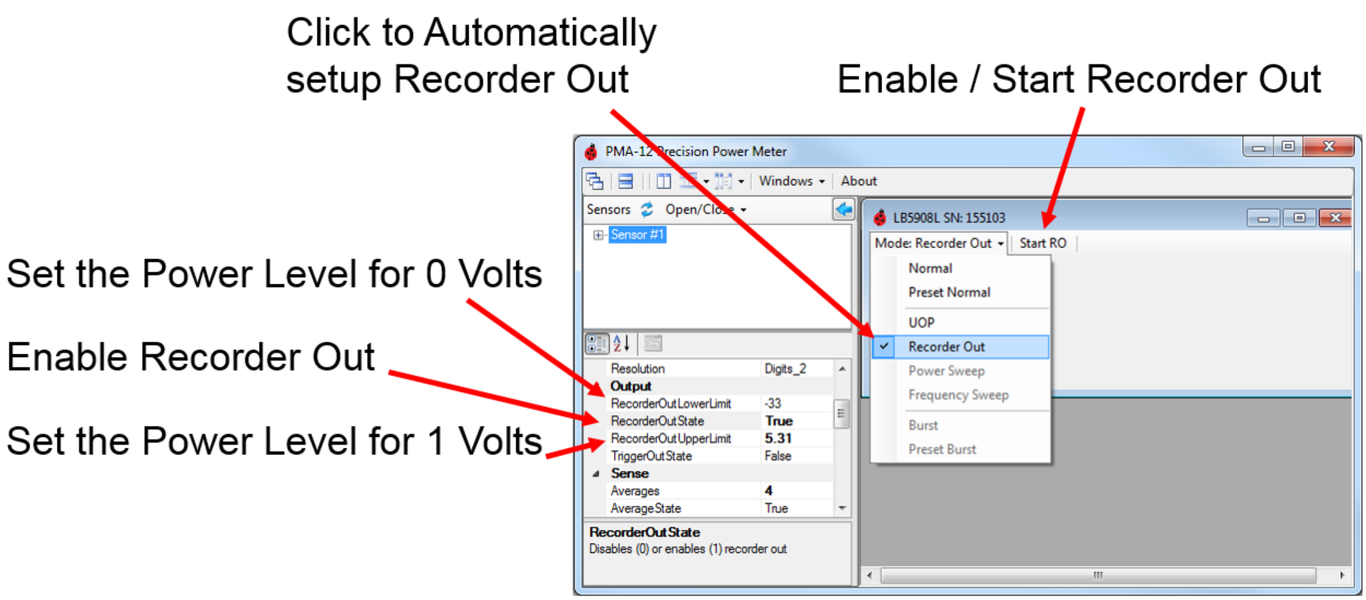
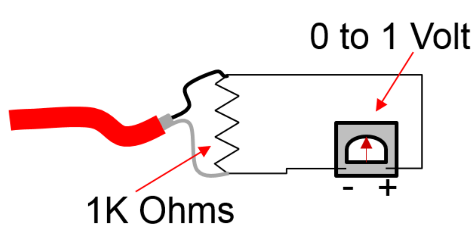


Figure 19 - Recorder Out Setup

The level setup for the ***Recorder Out*** is located in the Detail Pane for the selected sensor. Set up is accomplished by establishing a desired power level for 0-Volts (lower power level) on the Recorder Output and a power level that is to result in a 1-Volt Output (the higher power level). Power applied below the lower level will result in a 0-Volt output; and power over the higher power will result in a 1-Volt output. It is important to remember that the sensor's output MUST be driven into a 1,000 ohm load (see image at right). The output voltage will not be correct without the load. Once the settings are established, the output will be <u>a linear</u> representation of the power between the two levels. The output voltage inside these ranges is a calibrated DC measurement value.



To set up Recorder Out, identify the minimum and maximum power levels (in dBm) that you require. Place these values in the *RecorderOutLowerLimit* and *RecorderOutUpperLimit* in the Detail Pane as shown in Figure 19. Once the values are established, the formula below can be used to determine the output voltage (Vout) for any given dBm power level.

Vout= (10^(PMEAS/10)-10^(ZeroVoltSet/10))/(10^(OneVoltSet/10)-10^(ZeroVoltSet/10))

The same formula (shown below) can be copied and pasted into excel at cell B4. When pasted into cell B4, the cells listed below will establish the inputs values. All power units are in dBm. Out of range data is not accounted for.
B1 is the dBm power setting to deliver for 1 Volt
B2 is the dBm power setting to deliver 0 Volts
B3 is the actual input power.

=(10^(B3/10)-10^(B2/10))/(10^(B1/10)-10^(B2/10))

Some Examples:

Power	Recorder Out Low Setting	Recorder Out High Setting	DC Voltage
+10 dBm (10mW)	-10 dBm (0.1mW)	+10 dBm (10mW)	1
-10 dBm (0.1mW)	-10 dBm (0.1mW)	+10 dBm (10mW)	0
0 dBm (1mW)	-10 dBm (0.1mW)	+10 dBm (10mW)	0.10 Volts
-24.4 dBm (3.6uW)	-40 dBm (0.1mW)	-20 dBm (10mW)	0.37 Volts

Grounding
LB5900 Sensors have solid grounding between the USB shield, USB Common and SMB (Recorder Out) Common connections. It is important to take ground current into consideration between all connected equipment. LadyBug Recorder Out resolution specifications are generally (see specification sheet for exact specification and sensor accuracy data) in the range of 25 micro volts. Small ground currents caused by power across shielded cables can swamp the measured output voltage if care is not utilized. For example, many USB cables exhibit shield and common resistance of greater than an ohm. In this case, with 200 ma current draw from the sensor, there will be 200mv across the sensor USB cable. If the computer and the device monitoring the Recorder signal share common grounding, this current will be driven in a loop and may result in a ground offset voltage on the monitoring device as depicted by the "I loop" shown in Figure 20. This offset voltage may dynamically change as the sensor's current draw changes and along with other changes in the ground system.

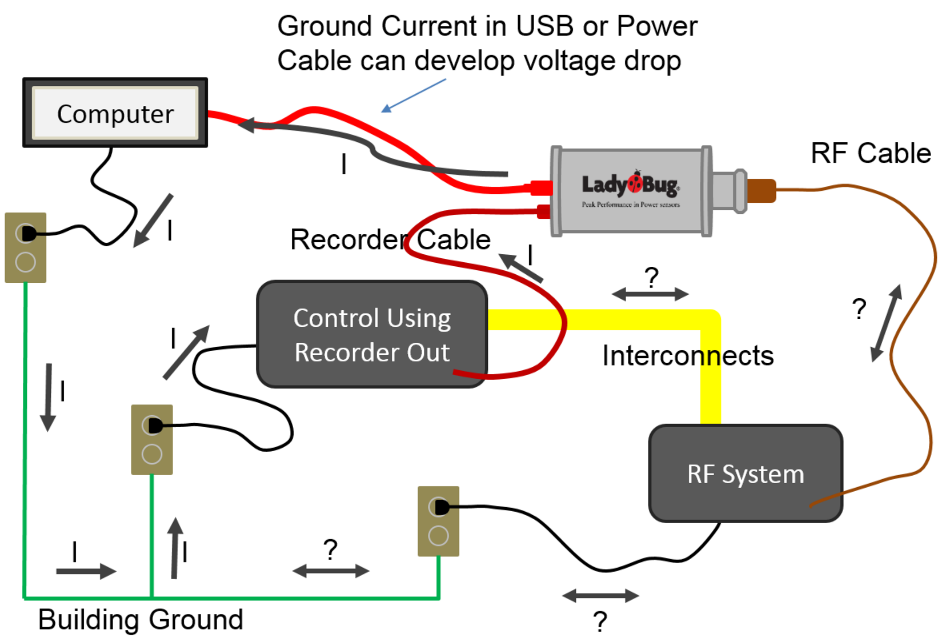


Figure 20 - Ground Management

5. Uncertainty Calculation Work Sheet

Use this sheet to calculate uncertainty for a specific set of conditions using the root sum of squares method. Following the work sheet is a completed example.

Conditions

Operating Frequency (GHz)	
Power Level (dBm)	
DUT Match (VSWR)	
Temperature (°C)	

Sensor characteristics at conditions

Cal Factor (% & Actual)		
Linearity (% & Actual)		
Noise (% & Actual)		
Uncertainty Due To Temperature (% & Actual)		
Match (VSWR)		
Zero Offset		

1. Calculate Sensor reflection coefficient, ρ from Sensor VSWR: ρ_{sens} = (VSWR-1)/(VSWR+1)

   ρ_{sens} =

2. Calculate DUT reflection coefficient, ρ from DUT VSWR: ρ_{DUT} = (VSWR-1)/(VSWR+1)

   ρ_{DUT} =

3. Calculate total match uncertainty: $Mm = (1+(\rho_{sens} * \rho_{DUT}))^2-1$

   Mm =

4. Calculate Zero Offset uncertainty (See Specification and notations)
   a. Convert power from dBm to Linear
      Linear Power = $10^{(PowdBm/10)}$

      Linear Power =

   b. Calculate Zero Offset
      Zero Offset = (Zero Offset Specification/Linear Power)

      Zero Offset =

5. Calculate Total RSS uncertainty
   Uncertainty (%) = $\sqrt{(Mm^{2+}CF^2+L^2+N^2+T^2+Z^2)}*100$

6. Uncertainty (%) =

Uncertainty Calculation Work Sheet Example

This sheet was completed using typical sensor data.

Conditions

Operating Frequency (GHz)	10
Power Level (dBm)	-20
DUT Match (VSWR)	1.19
Temperature (°C)	25

Sensor characteristics at conditions

Cal Factor (% & Actual)	1.35%	0.0135
Linearity (% & Actual)	0.22%	0.0022
Noise (% & Actual)	0.10%	0.0010
Uncertainty Due To Temperature (% & Actual)	0%	0.0
Match (VSWR)		1.2:1
Zero Offset		3.5E-10

1. Calculate Sensor reflection coefficient, ρ from Sensor VSWR
   ρ_{sens} = (VSWR-1)/(VSWR+1)

   ρ_{sens} = (1.2-1)/(1.2+1) = .091

2. Calculate DUT reflection coefficient, ρ from DUT VSWR
   ρ_{DUT} = (VSWR-1)/(VSWR+1)

   ρ_{DUT} = (1.19-1)/(1.19+1) = 0.087

Note: Reflection coefficient can be calculated from return loss using the formula $\rho=10^{(-RL/20)}$

3. Calculate total match uncertainty
   $Mm = (1+(\rho_{sens} * \rho_{DUT}))^2-1$

   $Mm = (1+(.091*.087))^2-1 = 0.0159$

4. Calculate Zero Offset uncertainty (See Specification and notations)
   a. Convert power from dBm to Linear
      Linear Power = $10^{(PowdBm/10)}$

      Linear Power = $10^{(-20/10)}$ = .01mw
   b. Calculate Zero Offset
      Zero Offset = (Zero Offset Specification/Linear Power)

      Zero Offset = (0.35nw / .01mw) = .000035

5. Calculate Total RSS uncertainty

6. Uncertainty (%) = $\sqrt{(Mm^{2+}CF^2+L^2+N^2+T^2+Z^2)}*100$

   Uncertainty (%) = $\sqrt{(.0159^{2+}0.0135^2+.0022^2+.0010^2+0.0^2+.0000352^2)}$ = .021 = 2.1%

6. Sensor Technology

Thermal Stability

The patented design of the PowerSensor+™ allows for internal error correction and eliminates the need to zero the sensor. Additionally, no separate power reference calibration is required which reduces system errors and increases overall accuracy. A high degree of temperature stability is achieved for a given input power level as shown in Figure 21.

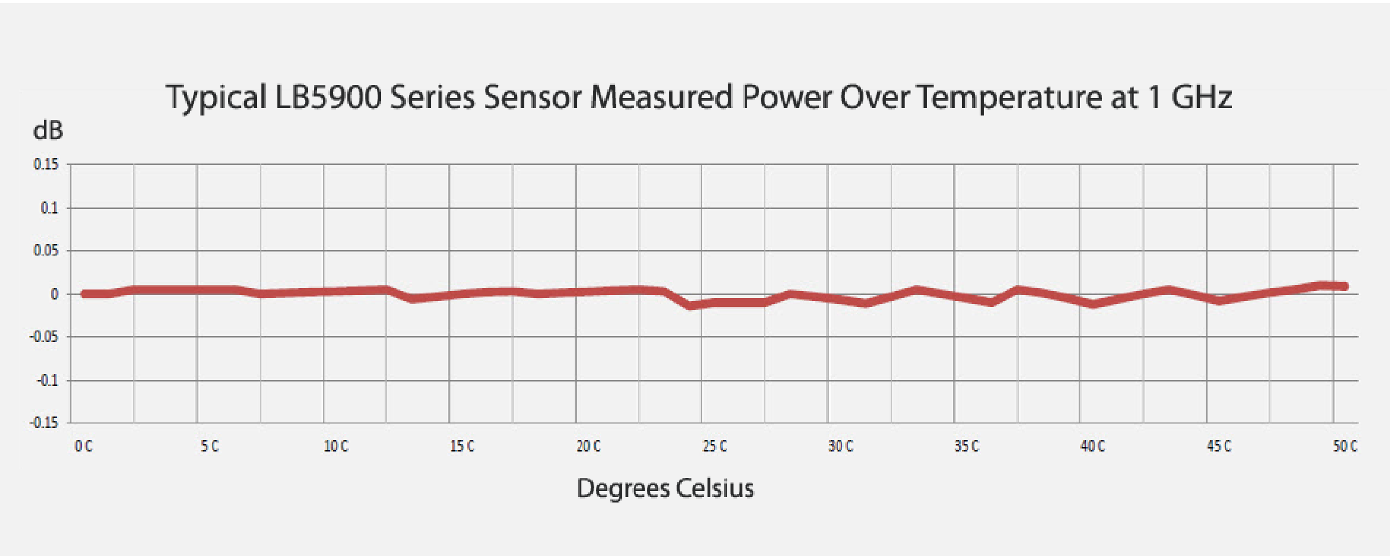


Figure 21 - Thermal Stability

Functional Block Diagram

A block diagram is shown below and is representative of the LB5900 series PowerSensor+™ products. Notice that the Trigger Output, Recorder Output and Wideband Detector options share a single a connector. These can be selected by software. Refer to the product Order Guide for a complete listing of available options.

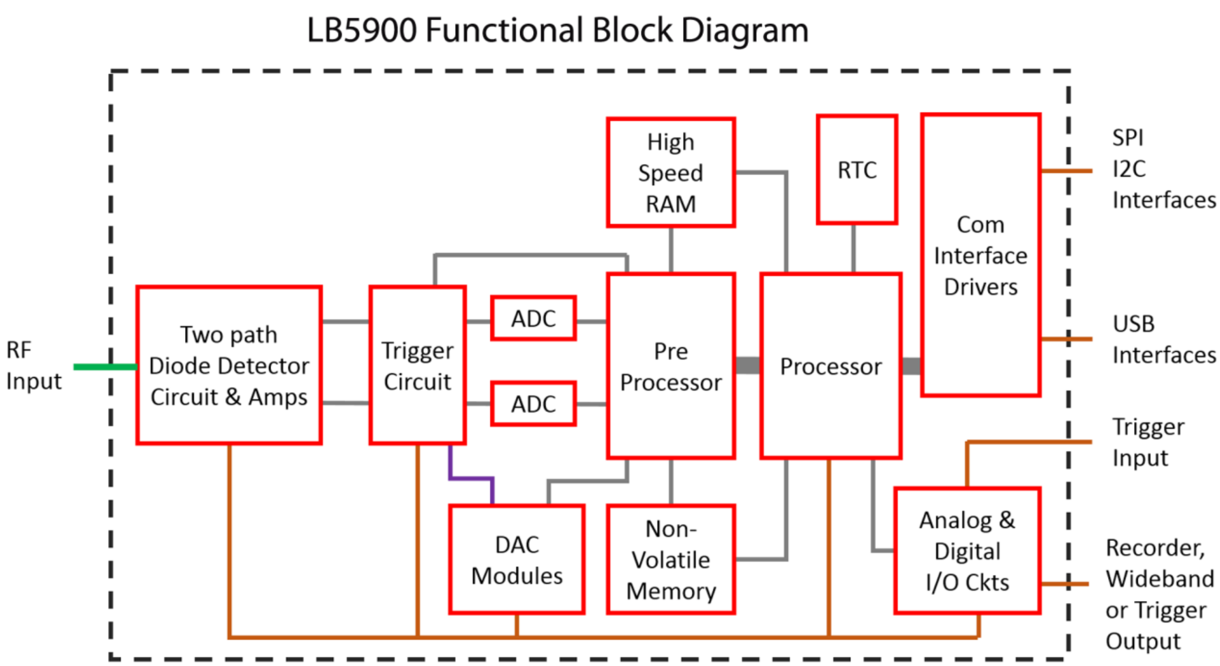


Figure 22 - Functional Block Diagram

Errata and User Updates – by date

Subsequent revisions to the user interface and other product changes are listed in this section by date. Periodically these changes will be incorporated into the body of the manual by revision date (MM/DD/YY). Meanwhile, you can check for any interim updates by downloading the product manual from the website. The latest software and documentation is available for download from the company website - see the Contact Information section of this manual.

Revisions

1. Initial release 8/29/2015
2. 10/15/15 Updated to Rev 3.0 - For Software Versions 0.0.0.0 to 1.1.0.0 & Firmware to 0.96.003_2015015
3. 4/16/16 Updated to Rev 4.0 - For Software Version 1.3.1.8 & Firmware to 0.99.029_20160401 & UP