

LadyBug LB5900 Programmatic Measurement Commands and Examples

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Section I – Programmatic Measurements Overview

General

LadyBug LB5900 Series True-RMS Power Sensors are state of the art sensors that employ SCPI (Standard Commands for Programmable Instruments) commands. These standard commands are defined for use in Power Sensors and are used by other leading Power Sensor manufacturers.

LadyBug Power Sensors are fully compliant to the SCPI standards. There are three commands that can be utilized to make power measurements. These commands are referred to as queries because they are requests and a response is expected. Each has its own unique features and is designed for a specific measurement purpose. This document details these three measurement methods to help the system programmer select the ideal commands for their purpose.

This document is broken into three sections, Section I describes the basic function of each command; Section II covers non-triggered measurements; and Section III covers measurements utilizing triggering.

Document Notice

This document provides several examples and explanations specific to measurements using LadyBug LB5900 Series Sensors. This document is considered a supplement to the LadyBug LB5900 Programming Guide; and is not a replacement for the guide. This document does not cover complete details of the commands.

Zeroing and Calibration

LadyBug's patented No-Zero No-Cal system eliminates the need to zero or calibrate its sensors. High accuracy is assured for measurements from the sensors noise floor to its highest level power measurement. In order to provide support for replacement of competitive sensors that require calibration prior to use, LadyBug LB5900 Series Sensors support SCPI CAL instructions, however SCPI CAL instructions (and CAL variations) will be returned with 0 (zero) indicating success.

Sensing Range

Competitive sensors may utilize auto-ranging or suggest measurement path specification using the RANGE instructions in their recommended programmatic control schemes. LadyBug's patented measurement system processes all measurement paths simultaneously and provides a single full dynamic range measurement with each sample; path selection is irrelevant. This significantly shortens measurement time, and is particularly beneficial in programmatic measurements requiring wide dynamic range. In order to maintain SCPI command compatibility, users that utilize RANGE to specify a path will receive range limited measurements.

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Section II - Non-Triggered Measurements

READ? (Non-Triggered)

READ? is ideal for making a single measurement that has a specific starting point. Each query using READ? causes the sensor to begin averaging data starting with the current sample (Unlike FETCH?, previous averaged data is discarded). Once the specified number of Averages are integrated into the measurement, the sensor returns the completed measurement and the sensor goes to its idle state.

To make a measurement using READ? the user must first set the measurement up. Example #1 defines a minimum measurement using READ?. The sensor is first set to its known default state then automatic averaging & step detection are disabled and INITiate:CONTinuous is set to OFF. Averaging and the measurement frequency are set, then READ? can be utilized as needed.

SCPI Command Sequence	Function
SYST:PRES DEF	Set to the default settings
AVER:COUN:AUTO OFF	Turn off automatic averaging
SENS:AVER:SDET OFF	Turn off Step Detection
INIT:CONT OFF	Turn off continuous triggering (Allows Read? To Initiate)
SENS:AVER:COUN 5	Set to 5 averages (use your own specification)
FREQ 2600 MHz	Set to 2.6 GHz (Use your own frequency)
READ?	Make the measurement
READ?	Repeat as desired

Example #1 Command sequence for a measurement using READ?

In this example, Step Detection is disabled. Step detection detects large changes in power level and resets averaging to enhance the measurement. Note: Step Detection does not change the number of Averages; it resets the starting point of the average count. It is disabled here so that a predictable amount of time, based on the number Averages can be employed to make the measurement.

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FETCh? (Non-Triggered)

FETCh? in free run mode (continuous trigger) is ideal for many typical power measurements and is similar to a manual measurement made with a traditional power meter. Like measurements made using READ?, the sensor must be set up to use FETCh?. FETCh? measurements can be triggered; however a common use of the method is to simply measure the power when requested without any triggering.

When the sensor is placed in free run mode using INIT:CONT ON, the sensor begins averaging measurements. Measurements can be collected prior to completion of the first Average; however, once the first set of Averages is complete, the sensor continues integrating Averages of the specified number in a circular buffer manner (See Image #1). This makes a “trailing” measurement available when each Average is completed. FETCh? returns this “trailing” Average, as opposed READ?, which discards the previous Averages and starts a new measurement.

SCPI Command Sequence	Function
SYST:PRES DEF	Set to the default settings
AVER:COUN:AUTO OFF	Turn off automatic averaging
SENS:AVER:SDET OFF	Turn off Step Detection
INIT:CONT ON	Turn on continuous triggering (sets free run mode)
SENS:AVER:COUN 5	Set to 5 averages (use your own requirement)
FREQ 2600 MHz	Set to 2.6 GHz (Use your own frequency)
FETCh?	Make the measurement
FETCh?	Repeat as desired

Example #2 Command sequence for a measurement using FETCh?

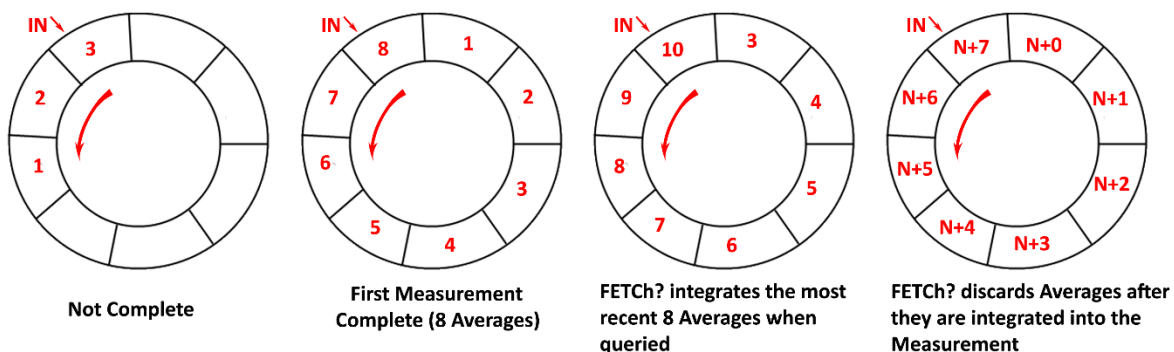


Image #1 FETCh? Examples with Averages Set to 8 (Measurement is the average of 8 Averages).
 Not complete measurement is not ready to return.
 First measurement returns with the 8 Averages.
 FETCh? Return if query sent when Averages #3-#10 are available, 1 and 2 have been discarded.

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MEAS?

MEAS? (MEASure?) is designed to make the measurements accurate and easy. MEAS? has no triggering capability.

MEAS? is an automatic measurement command. The sensor automatically determines the parameters for the measurement including Averaging. This can cause extremely long measurement times because the sensor may set the number of Averages very high in order to assure accuracy on a very low level signal. During programmatic testing and development, with no signal applied, this can cause 30 or more seconds of processing time. If the system programmer has knowledge of the signals that will be applied, FETCH? or READ? are recommended.

SCPI Command Sequence	Function
SYST:PRES DEF	Set to the default settings
FREQ 2600 MHz	Set to 2.6 GHz (Use your own frequency)
MEAS?	Make the measurement
MEAS?	Repeat as desired

Example #3 Command sequence for a measurement using MEAS?

MEAS? Functions by executing a CONFig, then a READ?. The CONFig determines the measurement settings and the READ? Initiates and returns the measurement.

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Section III - Triggered Measurements

Overview

LB5900 Power Sensors have advanced triggering features including external TTL triggering and internal triggering with full control of the trigger level, hysteresis, slope and more. A trigger output pulse is also available. The triggering section of the sensor can be utilized with both READ? and FETCh? commands. MEAS? does not support user controlled triggering.

Measurements are accomplished by reading power levels from the detector circuitry using an ADC. When the sensor is at an idle state, power is not being processed. When the sensor is set to free run as described in the non-triggered section (INIT:CONT ON), it is continuously processing power. To use triggering, continuous triggering is off (INIT:CONT OFF) and the sensor is idle. To make measurements, the sensor must be initiated, this starts the processor reading power. This is done using the measurement command (FETCh? or READ?). Issuing the measurement command starts the sensor processing the incoming power; however the measurement is not taken until a trigger occurs. The sensor does however, collect measurements and place them in memory, after the measurement command has been issued. This method allows the sensor to deliver pre-trigger data. As described later, measurements are processed differently by READ? and FETCh?.

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Triggered READ? Measurements

The READ? query is a straightforward method and is the most common method to make triggered measurements. The method can be described as a trigger and capture method, once triggered it collects the specified number of Averages then stops. Trigger delay, hold off and other functions can be added as required.

SCPI Command Sequence	Function
SYST:PRES DEF	Set to the default settings
FREQ 2600 MHz	Set to 2.6 GHz (Use your own frequency)
SENS:AVER:COUN 5	Set to 5 averages (use your own specification) The command also disables Auto Averaging and Step Detection
MRAT DOUBLE	Optional, see <i>Section IV Reducing Measurement Time</i>
INIT:CONT OFF	Turn off continuous triggering (Allows Read? To Initiate)
TRIG:DEL:AUTO ON	Already on here for example purposes. Could be turned off and set to a specific positive or negative delay time.
TRIG:SOUR INT	Select Internal Triggering
TRIG:LEV -20	Set the sensor to trigger when the power exceeds -20dBm
READ?	Make the measurement (Sensor will not re-trigger until the power level drops below -20dBm plus the set hysteresis)
READ?	Repeat as desired

Example #4 Command sequence for a triggered measurement using READ?

In this example, the commands disabling automatic averaging and step detection are left out. They are automatically disabled when average count is set, and have been listed in previous examples for explanatory purposes.

Figure 1, shows what occurs when the above measurement is run. The setup instructions are not detailed in the timing diagram. The diagram is marked with notations 1 through 7 for reference.

Referring to Figure 1, Note #1, *READ? issued*. Because INITCONT is set to OFF, when READ? is issued, the sensor begins collecting power levels but does not process the measurement. Instead, it begins storing the individual power levels at its maximum rate. The sensor has significant storage and can collect several seconds of data.

Since the sensor is set for internal triggering with default positive slope, and the trigger level has been set to -20dBm, no power measurements will be processed until this level is reached. This occurs at Note #2, *Internal trigger occurs* in the diagram. At that time, the sensor will apply any trigger delay that has been set (*Note #3 Trigger Delay Set*). If trigger delay is negative, the sensor will read data that was stored before the trigger occurred. In this case, Trigger Delay is set to AUTO and the sensor will apply an automatic delay to account for its rise time. For an example with negative-time triggering, see the TRIG:COUN example. TRIG:DEL AUTO may not

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be sufficient for some signals in which case a manual positive delay should be determined and added to the measurement routine.

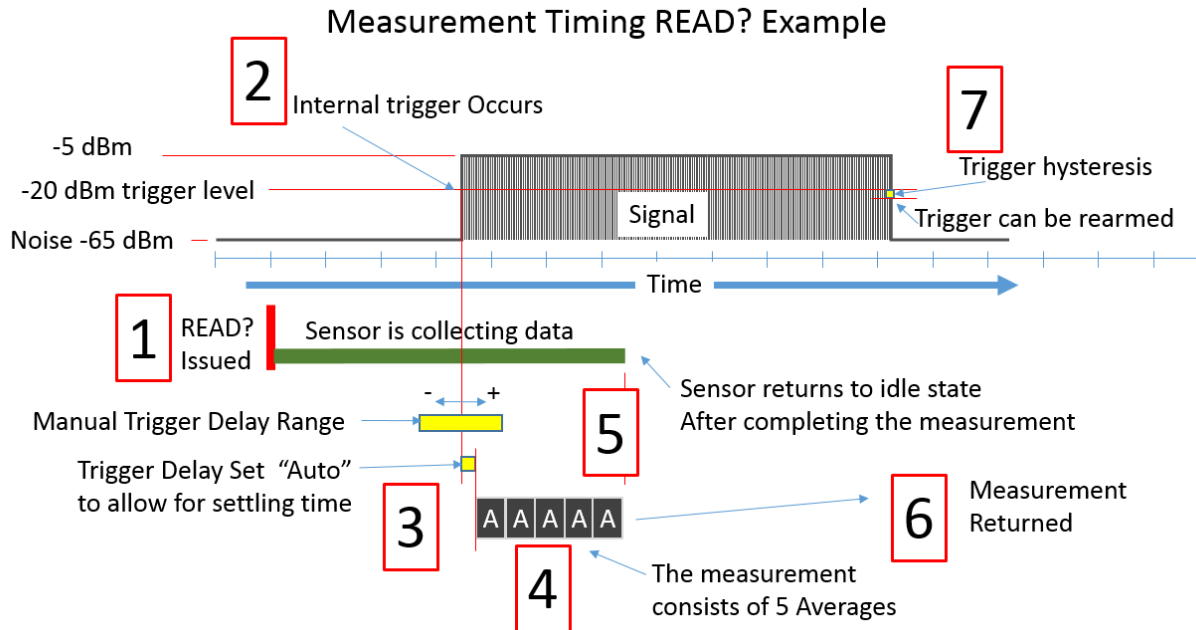


Figure 1 - Triggered READ? Measurement Timing

After the trigger delay shown by Note #3 has elapsed. The sensor begins with an empty averaging buffer and collects the specified number of Averages, which is 5 in this case (See Note #4, *The measurement consists of 5 Averages*). After collecting the Averages the measurement is complete and the sensor stops collecting data (Note #5, *Sensor returns to idle state...*) and returns the measurement (Note #6, *Measurement Returned*).

If a new READ? were to be issued at this time, the sensor would begin collecting data again; however no measurement would be made even though the level is above the trigger level. The trigger must re-arm itself, this occurs when the level falls below the trigger level plus the hysteresis (Note #7, *Trigger hysteresis*). The purpose of the hysteresis is to prevent multiple undesired triggers from occurring due to a noisy signal.

With this example, MRATE is set to DOUBLe. This means that each Average will take 19.6ms. Since there are 5 Averages, the capture time Figure 1, Note 4, will be 98 milliseconds ($5 \times 19.6 = 98$). Review the Reducing Measurement Time section for further information on MRATE.

External Triggering measurements are similar except that the sensor expects a digital TTL signal and therefore Trigger Level is irrelevant; it is either active or not. Slope, Delay and other trigger functions are usable with internal or external triggering.

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READ? with TRIG:COUN

TRIGger:COUNT can be used with the READ? query to take a specified number of back-to-back measurements. Prior to setting TRIGGER:COUN, the measurement rate (MRATe) must be set to FAST, or an error will be set. Readings are 3.2ms apart, made back-to-back. See the *Reducing Measurement Time* section for MRATe information.

In addition to explaining TRIG:COUN, in this example trigger delay will be set to a negative value so that it delivers measurements that occurred prior the trigger. Other triggering features can be added as required.

SCPI Command Sequence	Function
SYST:PRES DEF	Set to the default settings
FREQ 2600 MHz	Set to 2.6 GHz (Use your own frequency)
MRAT FAST	Set MRATe to FAST as required by TRIG:COUN
INIT:CONT OFF	Turn off continuous triggering (Allows Read? To Initiate)
TRIG:COUN 6	Deliver 6SYST measurements
TRIG:DEL:AUTO OFF	Turn off automatic trigger delay and set a negative trigger for example purposes.
TRIG:DEL -0.0125	Set Trigger delay to start 10ms before the trigger
TRIG:SOUR INT	Select Internal Triggering
TRIG:LEV -40	Set the sensor to trigger when the power exceeds -40dBm
READ?	Make the measurement (Sensor will not re-trigger until the power level drops below -40dBm plus the set hysteresis)

Example #5 Command sequence using READ? and TRIG:COUN

When MRATe is set to FAST, averaging is disabled and 1 Average is delivered for each measurement. With TRIG:COUN set to 6, six 1 average measurements will be made. TRIG:COUN and TRIG:DEL were set in such a way as to show a major portion of the change in signal level with the 6 samples. The easily duplicated measurement was triggered by enabling and disabling the power on an RF source manually.

Figure 2, shows what occurs when the above measurement is run. The timing diagram (Figure 2) does not detail the set up instructions. The diagram is marked with notations 1 through 7 for reference.

Referring to Figure 1, Note #1, *READ? issued*. Because INITCONT is set to OFF, when READ? is issued, the sensor begins collecting power levels but does not process the measurement. Instead, it begins storing the individual power levels at its maximum rate. The sensor has significant storage and can collect several seconds of data.

Since the sensor is set for internal triggering with default positive slope, and the trigger level has been set to -40dBm, no power measurements will be processed until this level is reached. This occurs at Note #2, *Internal trigger occurs* in the diagram. At that time, the sensor will apply

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the negative 12.5ms delay that has been set (*Note #3 Manual Trigger Delay*). Because the trigger delay is negative, the sensor will read data from memory that was stored starting 12.5ms before the trigger occurred.

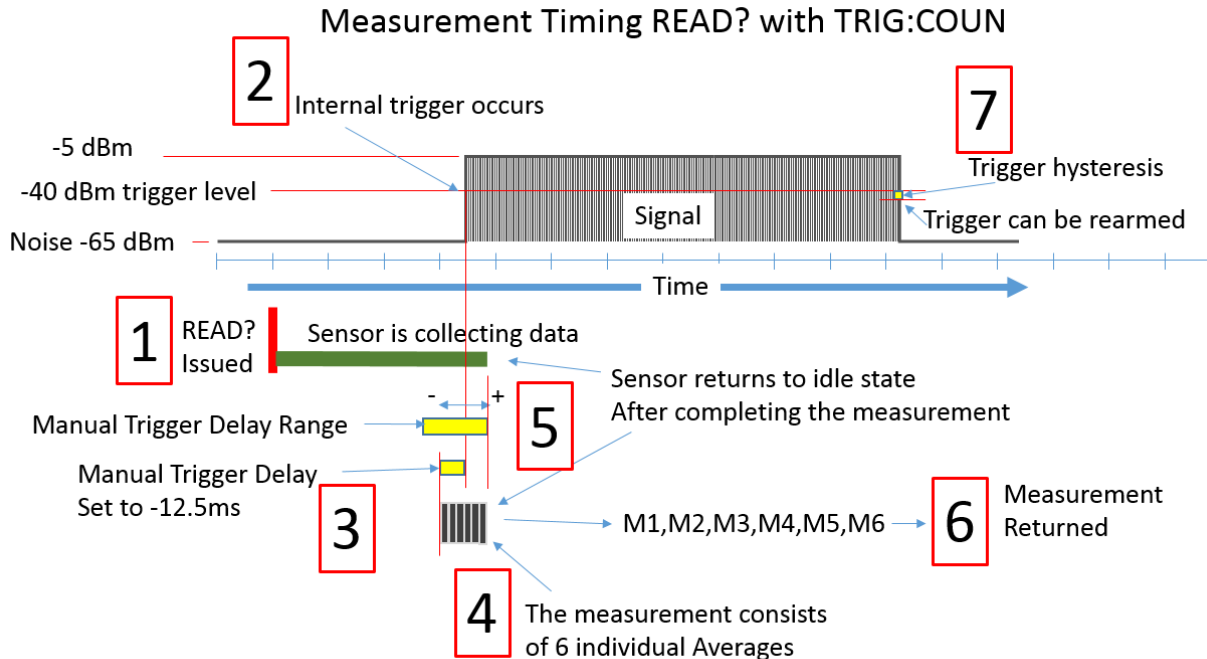


Figure 2 - READ? Measurement with Trigger Count & Negative Delay

Measurements with TRIG:COUN are forced to one Average. TRIG:COUN was set to 6, so the sensor will begin collecting the six back-to-back measurements. (See Note #4, *The measurement consists of 6 individual Averages*). After collecting all six individual Averages and placing them in the outgoing buffer, the measurement is complete and the sensor stops collecting data (Note #5, *Sensor returns to idle state...*) and returns the measurement (Note #6, *Measurement Returned*). The measurement is returned as 6 comma separated values according to SCPI specifications. Refer to the programming guide for further information.

If a new READ? were to be issued at this time, the sensor would begin collecting data again; however no measurement would be made even though the level is above the trigger level. The trigger must re-arm itself, this occurs when the level falls below the trigger level plus the hysteresis (Note #7, *Trigger hysteresis*). The purpose of the hysteresis is to prevent multiple undesired triggers from occurring due to a noisy signal.

This example can easily be set up using a sensor, a basic source and LadyBug's Interactive IO application. The Interactive IO is included with free and can be downloaded from the LB Website. Figure 3, shows the measurement commands and results from this example. As can be seen in Figure 3, the first two of the 6 single Average measurements are at the noise floor, after that the measurement begins to increase in value. Control of the measurement length and starting time is possible using TRIG:COUN and TRIG:DEL.

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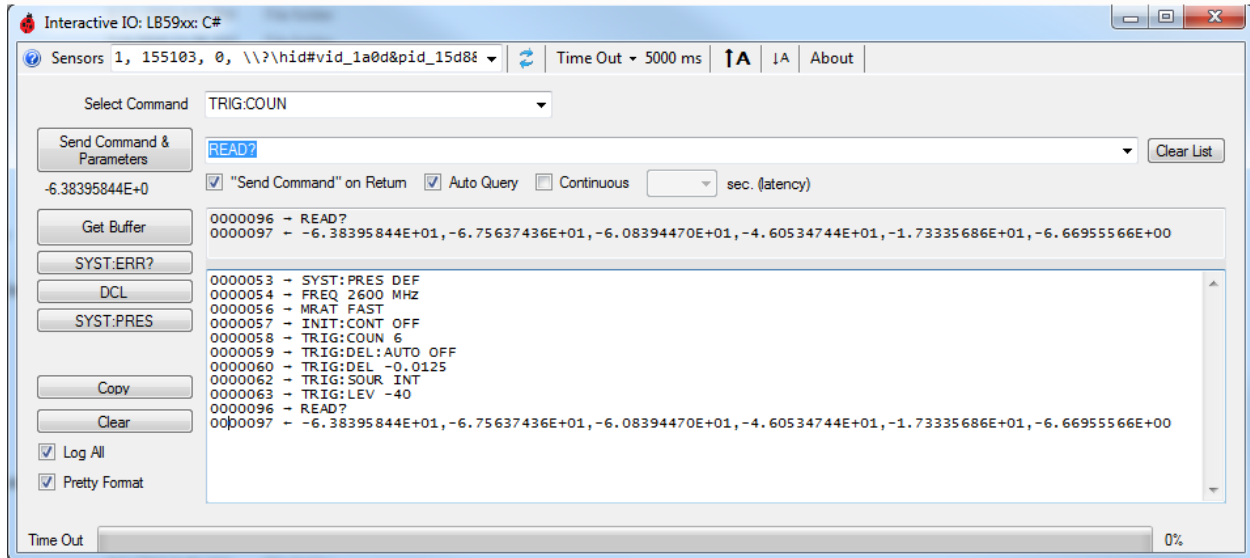


Figure 3- Example run using Interactive IO

External Triggering measurements are similar except that the sensor expects a digital TTL signal and therefore Trigger Level is irrelevant; it is either active or not. Slope, Delay and other trigger functions are usable with internal or external triggering.

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MRATe SUPER & READ? with TRIG:COUN

The above example is compatible with competitive sensors utilizing SCPI commands. The LB5900 Series Sensors have additional MRATe specifications including SUPER Mode which allows full control over averaging and a 1.6ms read rate, as opposed to the 3.2ms read rate and no averaging supported by MRAT FAST. See the *Reducing Measurement Time* section for more on MRATe.

Figure 4, details functionality with MRATe SUPER mode if averaging is set to 4 and TRIGGER:COUN is set to 6. In this case, the sensor is sampling rapidly and readings are delivered every 1.6ms. In this example an Average is 4 readings, and will take 6.4ms (4*1.6). Unlike MRATe FAST, which will only deliver un-averaged readings, once the trigger conditions and delay have been satisfied, the sensor delivers averaged measurements back-to-back. Since TRIG:COUN is set to 6, six measurements are returned, each consisting of 4 averages and no lost samples. If averaging were set to 1, six single readings at twice the rate of MRAT FAST would be returned.

Using MRATe SUPER with TRIGGER:COUN 6 and 4 Averages

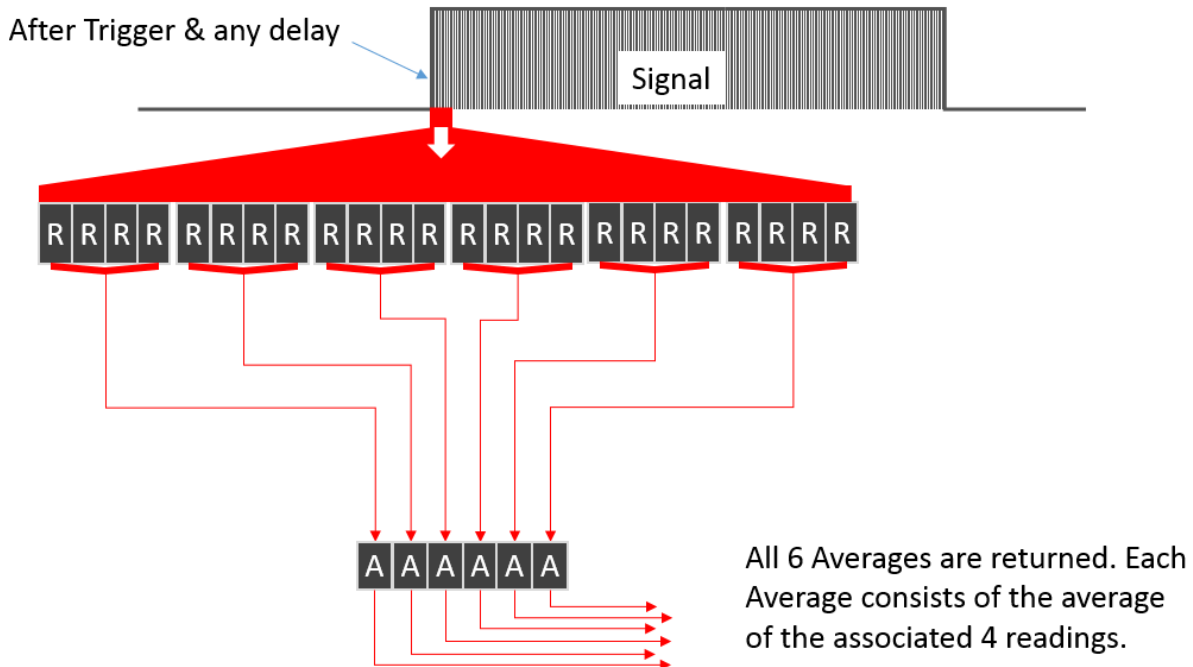


Figure 4 - MRATe SUPER with TRIGGER:COUN & averaging

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Triggered FETCh? Measurements

In order to maintain compatibility with existing and competitive sensors that utilize standard SCPI measurement commands, LadyBug LB5900 Series sensors' FETCh? command has two modes of triggered operation; COMPLIant and DEFault mode.

DEFault Mode with Triggering:

FETCh?'s default triggering mode is straightforward triggering. The measurement is setup then Triggered, and the result read back.

SCPI Command Sequence	Function
SYST:PRES DEF	Set to the default settings
AVER:COUN:AUTO OFF	Turn off automatic averaging
SENS:AVER:SDET OFF	Turn off Step Detection
INIT:CONT OFF	Turn off continuous triggering
SENS:AVER:COUN 5	Set to 5 averages (use your own requirement)
FREQ 2600 MHz	Set to 2.6 GHz (Use your own frequency)
FETCh?	Initiate the measurement (Wait for a trigger)

Example #3 Command sequence for a Triggered FETCh? measurement using Standard Mode

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Section IV Reducing Measurement time

Low power levels require a high number of Averages to average out noise that is inherent to power measurements. If fast measurements are required, and the power level is high and/or accuracy requirements are satisfied, a reduction in the number of Averages can be used to achieve faster measurements.

Average Detector Mode

Measurement rate can also be increased by adjusting MRATe (Measurement rate). Bear in mind that the settling time for the measurement is the primary factor and regardless of the rate that the measurement is collected, it will still take time to settle based on the sensor video bandwidth (40Hz Average Detector Mode). For stable higher power measurements, MRATe can be set to achieve very fast measurements.

MRATe	Time Per Average	Range of Averages
NORMal mode	38.4ms	1 to 1024
DOUBle mode	19.6ms	1 to 1024
FAST Mode	3.2ms	Forced to 1
SUPer Mode	1.6ms	1 to 1024

Table 1 Time per Average per MRATe setting

To determine the approximate time to make a measurement using Table 1, multiply the number of Averages by the Time Per Average in the given mode. For example, in Double Mode with 10 averages, the actual measurement will take $19.6\text{ms} * 10$, or 196ms. The total measurement time will vary depending on the setup time, communication method and other factors.

FETCh will return the fastest measurement because the sensor is free running and continually places completed measurements in the buffer. Unlike MEAS? and READ? measurements are not initiated with each request, instead they are “fetched” from the buffer.

For further information, consult LadyBug’s LB5900 Programming guide.

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Section V - Description of the Commands Used

This section details the commands used in this document for reference purposes. Shortened commands with minimal description are listed here. For full details of the commands and optional usage, refer to the sensor programming guide.

READ?

The READ? query is ideal for most measurements. When the query is sent to the sensor, the sensor begins a new measurement and discards any previous averaged data. This scenario is ideal for most triggered measurements because the trigger typically indicates the beginning of the measurement and in most cases requiring triggering, previous data should be ignored.

FETC? (FETCh?)

The FETCh? query in free run mode is useful for typical measurements where the user needs a quick measurement. When using FETCH? in free run, the sensor places Averages into a circular buffer continuously with the buffer size equal to the number of Averages requested. For example if the sensor is set to x Averages, once the first complete set of Averages is taken and the buffer is full, each FETCH? measurement represents the last x averages of the signal. Triggering can also be used with FETCh?; within FETCh?.

MEAS? (MEASure?)

Often this is the measurement command first chosen because of its name, however it has limitations and is usually not the best choice. MEAS? does not require or allow any setup and determines measurement parameters based on signal level and stability. If no signal, or a very low signal is present, MEAS? will set the number of averages to its maximum in order to achieve a good low level measurement. This can take about 30 seconds; during this time, the sensor is un-accessible, other than to reset it.

INIT:CONT (INITiate:CONTinuous)

Sets the power sensor for either a single trigger cycle or continuous trigger cycles. A trigger cycle means that the power sensor exits the wait for trigger state and starts a measurement.

OFF or 0, the trigger system remains in the idle state until it is set to ON, or INITiate:IMMEDIATE is received. Once this trigger cycle is complete the trigger system returns to the idle state.

ON or 1, the trigger system is initiated and exits the idle state. On completion of each trigger cycle, the trigger system immediately commences another trigger cycle without entering the idle state. This state is often referred to as *free run mode*.

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TRIG:SOUR (TRIGger:SOURce)

TRIG:SOUR<xxxx> configures the sensor's trigger system as follows:

	Functionality
IMMEDIATE	The trigger system is always true, refer to INITiate:CONTinuous
INTernal	Set to accept a trigger from the internal trigger system.
EXTernal	Set to accept a trigger from the external TTL input
HOLD	Triggering is suspended (on hold)
BUS	Not normally used with USB sensors, just make the call (READ?)

Table 5 Trigger Source Functions

Refer to the programming guide for further details.

TRIG:COUN (TRIGger:COUnT)

TRIG:COUN causes the measurement to repeat, 1 or more times, back-back, for each trigger. For example, if a measurement is triggered and TRIG:COUN is set to 3, three measurements will be returned, each made immediately following the previous measurement. This allows for rapid un-interrupted measurements. There are several restrictions on averaging, measurement rate etc. The default setting for TRIGger:COUnT is 1. Refer to the programming guide for additional information.

TRIG:DEL (TRIGger:DELay)

Trigger delay is a time that is inserted after the trigger event occurs; after which the measurement process begins. A common use of trigger delay is to allow for measurement settling prior to taking readings, by default a delay is inserted (see TRIG:DEL AUTO). Trigger delay can also be negative. Negative trigger time (measurement in advance of the trigger) is possible using the LB5900 series sensor's memory that can collect and store readings so that they are available when the trigger occurs.

TRIG:DEL:AUTO (TRIGger:DELay:AUTO)

TRIG:DEL:AUTO is a small delay added to account for rise time it is set to ON by default. To use manual trigger delay, TRIG:DEL:AUTO must be set to off. Refer to TRIG:DEL for additional information.

TRIG:LEV (TRIGger:LEVel)

TRIG:LEV is used with internal triggering. The trigger event occurs when the signal level passes the TRIG:LEV set point. For re-triggering to occur, the level must fall back to a level that includes hysteresis. Trigger slope is also settable.

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AVER:COUN:AUTO (AVERAge:COUNt:AUTO)

Used to enable or disable automatic Averaging.

ON or 1, The sensor determines the number of Averages automatically.

OFF or 0, Automatic averaging is off and the user sets the number of Averages

Note: Setting the number of averages using AVER:COUN disables automatic averaging.

AVER:COUN (AVERAge:COUNt)

This command sets the number of Averages (1-1024) that the sensor will integrate into the measurement. An Average is a single value that is comprised of a number of readings. MRATe determines the number of readings and thereby determines the time required for each complete Average.

AVER:SDET (AVERAge:SDETECT)

Step detection detects large changes in power level and resets averaging to enhance the measurement. Note: Step Detection does not change the number of Averages; it resets the starting point of the average count. It is disabled here so that a predictable amount of time, based on the number Averages can be employed to make the measurement.

FREQ (FREQuency)

This command is used to set the measurement frequency to achieve the greatest possible accuracy. The sensor will also apply any user set frequency dependent offset corrections that have been stored in the sensor. Acceptable units (Hz; kHz; MHz; GHz) should be included.

SYST:PRES (SYSTem:PRESet)

Sets the Sensor to a predefined condition (SYST:PRES <XXXX>). DEFault (SYST:PRE DEF) is used if no other specification is made See the programming guide for additional information.

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CONF (CONFigure)

CONFigure is often used in conjunction with measurements. With certain competitive sensors, CONFigure determines measurement path automatically by examining the signal level. LadyBug sensors provide seamless full range measurements with no path selection and do not utilize this part of CONFigure. For this reason, CONFig has limited value. However CONFigure also sets the items listed in Table 1. CONFigure can be run; and then the settings changed prior to making the measurement to save a few programming steps.

SCPI Command Sequence	Function
INIT:CONT OFF	Turn off continuous triggering
TRIGger:SOURce IMMEDIATE	Sets the trigger source to trigger immediately
TRIGger:DELay:AUTO ON	Turn on automatic trigger delay
AVER:COUN:AUTO ON	Turn on automatic averaging
AVER:STATE ON	Turn on averaging

Table #1 CONFigure functions

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PRELIMINARY