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High Frequency Electronics

Optimizing Averaging for Better Power Measurements

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Pullquote:
Answering the question: What should I set my power sensor's averaging to?

One of the most often asked questions from power sensors users is *what should I set my power sensor's averaging to?* This question is asked by new power sensor users as well as advanced users, often from engineers creating test systems with programmatic remote control. This paper will explain the reasoning behind averaging, what is occurring in the sensor and how to best determine the requirements in your situation.

Figure 1 Set Averaging

Background

What is averaging? Modern power sensors use a detector circuit coupled to analog to digital converters to measure signal power. The sample conversion occurs at a very rapid pace, often over a million times per second on any input signal including CW signals. This rapid conversion of the signal makes possible the measurement of very short variations in power level including noise in high sensitivity sensors such as LadyBug's LB480A. Most modern power sensors whether they be thermal, diode or logger-based will have a fast analog to digital converter system.

To manage the measurements and create a stable result, individual digital converted values are averaged together as selected by the user. This is what we call averaging. In some instances averaging is referred to as integration or integration time, for the purposes of this paper we will use the term averaging. Averaging may be referred to in units of time or the number of samples. We generally refer to averages in terms of the number samples.

The samples may already have been pre-averaged by analog or digital methods. For example, in a diode detector circuit the diodes will drive a capacitor, this capacitor will establish the initial averaging. In many test system environments wherein measurement speed is very important, users may choose set averaging as low as possible, particularly if the signal is at a relatively high level. A power sensor user can set a LadyBug LB479A or LB480A to continuously collect over 2,000 pre-averaged measurements per second. Pre-averaging in these sensors is 124 samples for each of the 2,000 measurements. In this case, the downside can be measurement variation due to noise or other signal related factors on low level signals. Conversely, a power sensor user replacing a traditional thermal sensor and desiring a very stable measurement on a CW signal, may choose to set averaging to a very long period of time. Long averaging periods are often used to average out noise on low level.

<u>Noise</u>
Even though your settings may be different, whether you are looking at a CW signal or a Modulated signal, averaging works the same. A good example for the use of averaging is noise reduction.

Noise is always present in any electrical system, further all components generate electrical noise in some form or another. A simple internet search for "resistor noise" will net many, many results and may help put noise sources into perspective. Noise reduction in passive components is a science in itself. As a result of noise power, with no user signal present, there can be measurable power that may interfere with a low level signal when applied. Figure #2 depicts a power sensor input system with internal noise sources indicated.

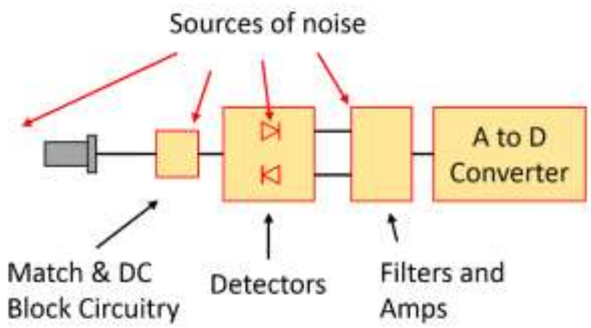

Figure 2 Power Sensor Front End

Quality power sensors generally have a very wide dynamic range and may be capable of measuring signal levels down to the sensors noise floor. To make low level measurements, all noise sources must be mitigated. Averaging is one tool used to do this. Because noise is random in its nature, averaging the noise samples and processing the information can eventually result in a stable, meaningful measurement on extremely low level signals.

Noise can be average to a single value; however changing conditions may cause this stable value to shift. For example if the temperature is changed, the level of noise generated by electronic components will also change. With LadyBug Sensors, this is largely managed for you by our patented No-Zero system. These patents allow for management of zero offset and eliminate the need to zero the sensor prior to use. Further, LadyBug sensors account for thermal change making it unnecessary to stop measuring to zero. This is a significant advantage; many sensors with built in zero circuitry must stop making measurements to perform zero function. This can often take 10-20 seconds.

Averaging power from modulated signals

Signal variation is an important consideration when setting averaging for a stable, accurate average power measurement. Signal power can vary for various intentional and un-intentional reasons. Today, there are many modulation schemes that must be tested in manufacturing, laboratory and in the field. With enough averaging, any modulated signal can be smoothed into a stable value. Known factors such as pulse repetition rate can be applied to the stable average power to achieve desired information.

In the example below, a pulse stream is depicted with a repetition rate of 10ms and a pulse width of 1ms. The signal, shown in Figure #3 with an averaging time of 5ms would result in an inaccurate average power measurement. The power meter will display erroneous data as the 5ms averaged measurements are reported.

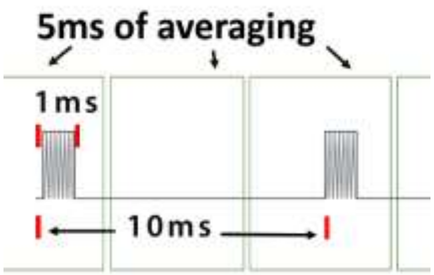

Figure 3 Signal with 5ms of averaging

In this case averaging of 100 times the 10ms repetition rate (1 second of averaging) would result in a fairly small error. If higher accuracy is desired, averaging should be increased further. Averaging of several seconds may be needed. LadyBug sensors can also be set to employ extended averaging to optimize power measurements. Extended averaging uses exponential averaging along with normal averaging and can be used to stabilize the measurement and provide fast averaged measurement times.

Time or number of averages

LadyBug sensors continuously collect data. Data is collected at over 2,000 measurements per second. Each measurement is considered one average. It is easy to convert from the number of averages to averaging time using the formula below.

Averaging time=Number of averages/2,000 or

Number of averages=Averaging time * 2,000

Therefore setting averages to 2,000 will result in about 1 second of averaging on a LadyBug sensor. In reality, each of the 2,000 measurements per second is pre-averaged by the sensors analog front end, digital processing plus any digital filters that the user may engage.

An example with visual results

In the case of a pulse profiling sensor with trace measurement capability such as the LB480A or LB680A, the entire repetitive signal can be averaged. This is a great way to visualize the application and results of averaging for noise reduction. The following example was done with an LB680A, 20 GHz Pulse Profiling Power Sensor. A 1.9 GHz signal modulated with a 1us pulse repeated every 11us, and 50db of attenuation, was applied to the sensor and various averaging scenarios implemented.

With this low level pulsed signal, the results of averaging can easily be seen as the noise floor becomes cleaner and cleaner as the number of averaged measurements is increased. Examine the following three images.

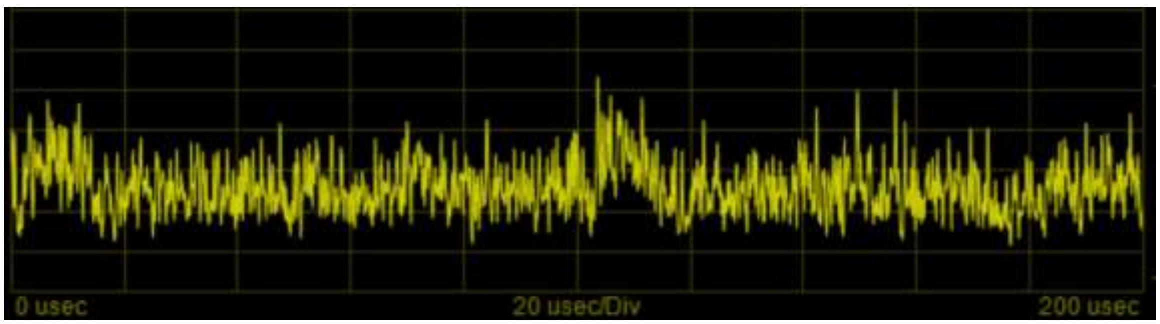

Figure 4 Low Level Pulsed Signal

In Figure #4, the attenuated pulsed signal with no averaging applied is buried in the noise and the pulses are nearly indiscriminable.

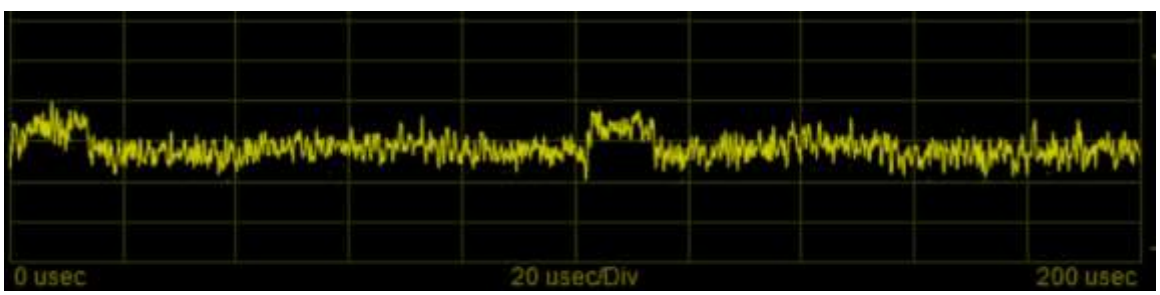

Figure 5 Low Level Pulsed Signal with 20 Averages Applied

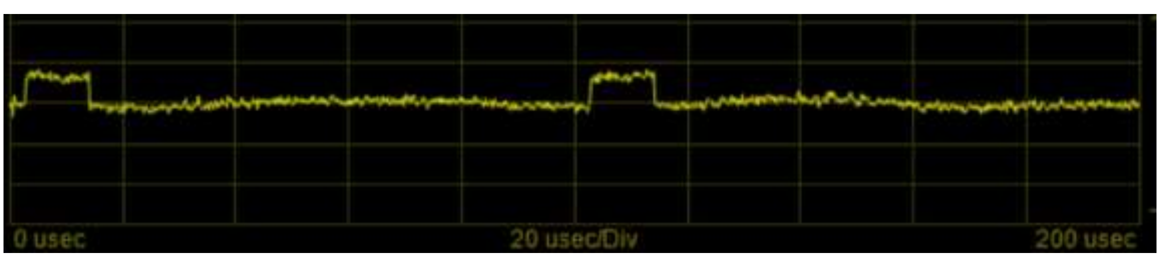

Figure 6 Low Level Pulsed Signal with 100 Averages Applied

In Figure #5; the same signal, the sensor is set to apply 20 averages and the signal begins to appear. Finally in Figure #6, the sensor is set to average the low level repetitive signal 100 times. As can be seen, the signal can now be examined with enough detail to gain important information. LadyBug's LB480A can automatically provide statistical and triggered pulse information on the signal. The LB479A sensor can measure statistical peak & pulse power and duty cycle on low level signal such as this one without triggering.

Summary

There are several primary considerations needed to determine the amount of averaging required for making RF power measurements. Some of these are noise and power level, signal type and stability, required accuracy and required measurement speed. These can be quantified fairly easily, however the interaction between some or all of them often requires user judgment.

LadyBug offers a broad selection of sensors that include very flexible methods to average CW and modulated signals. LadyBug's new LB5900 product line also includes selectable analog filters along with the already present digital filters that may be employed to pre-average incoming signals.

Using these methods and a LadyBug sensor, fast, reliable, accurate power measurements can be made on any signal between 9 kHz and 40 GHz.

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About the Author:

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