White Paper

Auto-Zeroing
Automatic Dark Current Compensation in Optical Power Meters

Summary

Zeroing is a very powerful and well-known function for optical power meters to increase the measurement accuracy. It is done manually with disconnection of the signal.

This procedure is a source of error and slows down test speed.

Auto-zeroing is a built-in function in JDSU's new SMART range of power meters. It is done automatically between every measurement cycle. It takes only a few ms and will not be noticed by the user.

Power meters – the workhorses – of optical communications testing

Power meters are the most widely used instruments in the field of optical communications. Several different types have been developed which use different techniques depending on the area of application. Some of the more significant differentiating features are:

The type of signal coupling

Figure 1 shows the measurement of optical power level using a large area photo diode (∅ 2 mm) with free air coupling or with a coupled fiber. The coupled fiber plug connection is not 100% reproducible, resulting in an additional variation of about 0.2 dB in the measured level each time the connection is remade.

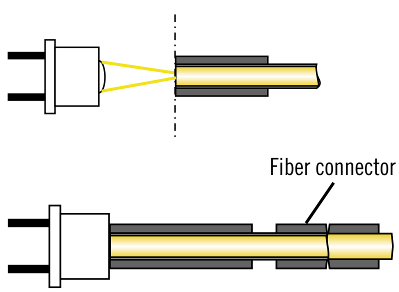


Figure 1

The wavelength measurement range: photo diode type

Semiconductors have different opto-electrical conversion properties: Silicon: blue, Germanium: green, InGaAs: red. InGaAs or Germanium photo diodes are used to detect the infrared wavelengths used in optical communications.

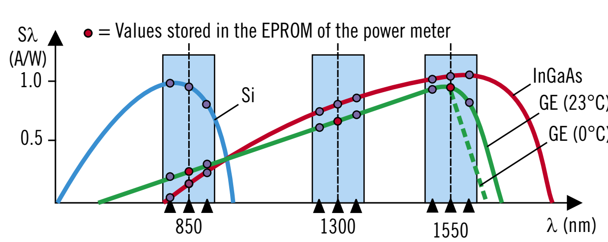


Figure 2

The power level range: dynamic range and max. power

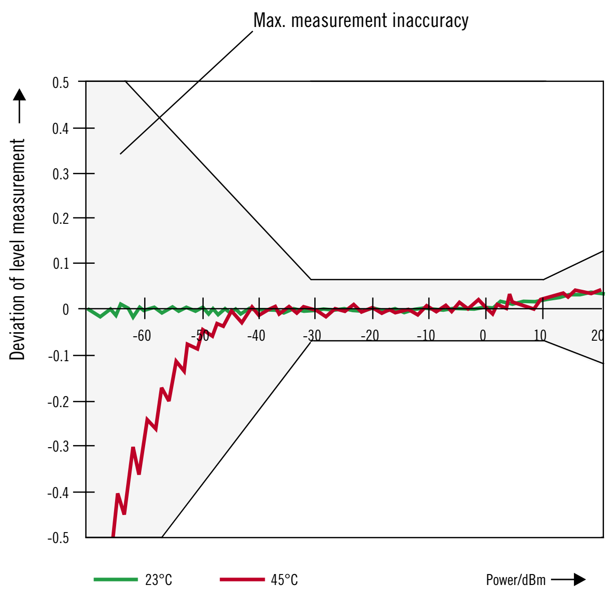


Figure 3

There is obviously a reduction in measurement accuracy for low power levels and high temperatures. The red curve is an example for T = 45° C without zeroing. The deviation of level measurement is a function of power level and temperature, because of the photo diode impedance drift and offset voltage drift in the photo receivers.

Power meters have finite accuracy

All these power meters have one thing in common: they use a photo diode as the optical receiver, which converts the power level of the optical radiation into an electric current more or less ideally, depending on the type of diode used. The shortcomings are caused by the finite impedance R_i of the photo diode and the offset voltage of the photo receiver. Even when completely dark, a small current still flows, simulating the presence of an optical radiation power level.

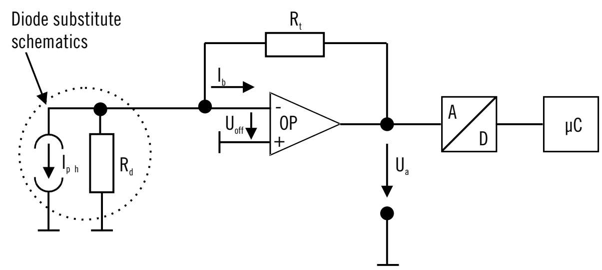
This small error in the displayed value of optical power level is a major measurement uncertainty and limits the power level range that can be measured at low power levels.

An additional problem is caused by the fact that the offset voltage and photo diode impedance are both temperature dependent.

If both these parameters could be known when the measurement is being made, the intrinsic error of the power meter could be compensated for, thus making the measurement more accurate and extending the measurement range down to lower power levels. In particular, power meters using inexpensive photo diodes would benefit from this, as such diodes are generally characterized by high dark current, low impedance, and greater temperature dependency. The compensation should be kept simple and should not result in additional costs.

How accuracy can be effectively increased

The basic setup for a power meter designed to measure optical power levels is:



I_b: Bias current operational amplifier

U_{off}: Offset voltage operational amplifier

Figure 4 Circuit diagram of an optical power meter

If I_b and U_{off} are ignored, then: $U_a = I_{ph} \times R_t$ where $I_{ph} = r \times P_{opt}$

I_b and U_{off} must be taken into account at low photo currents of less than about 100 pA (corresponding to low optical power levels).

For $P_{opt} = I_{ph} = 0$ (no light) it follows that:

$U_{a0} = I_b \times R_t + U_{off} \times (1 + R_t/R_d)$ (1)

U_{a0} is measured for each power meter individually during production. The value is stored in a calibration EPROM and deducted from the measurement result during operation. The temperature dependence of I_b, U_{off} and R_d means that compensation can only be fully achieved at test bench room temperature (23 °C).

For this reason, the measurement error has usually been estimated by disconnecting the optical input form the measurement signal and blacking it out using a cover or an optical switch. Such solutions are either troublesome or too complicated (expensive).

Hence the following suggestion (pat. pend. EU 04011136.1):

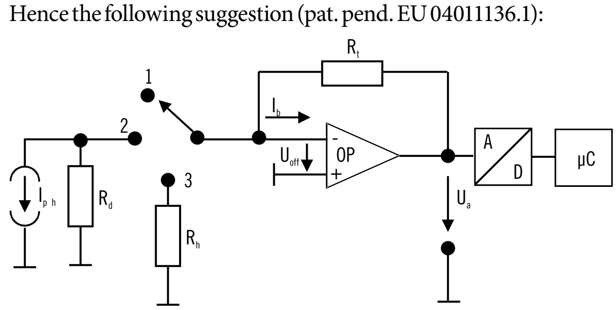


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Figure 5 Extended circuit diagram of a power meter with auto-zeroing function

A switch is used to connect a known resistance R_h instead of the photo diode.

For normal measurements, the switch is in position 2. Positions 1 and 3 are used for zeroing.

Auto-zeroing: Simple, effective, and unnoticed

Knowing the temperature (temperature sensor on board), this zeroing procedure will compensate all errors for all operating temperatures. In this way, a considerable increase in accuracy can be achieved for every power meter and every type of photo diode.

Since this entire auto-zeroing process takes very little time, it passes unnoticed by the user and is always performed between recordings of consecutive measurement values.

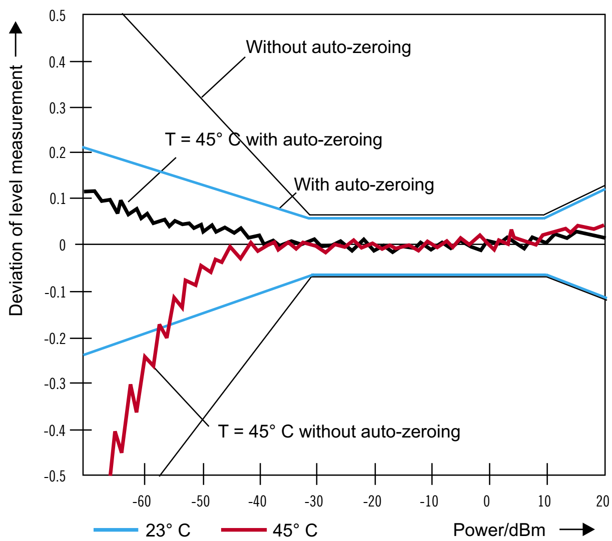

Figure 6

The auto-zeroing function enables constant measurement accuracy over the entire level range and for the full temperature range.