

DMM 8588A/Null

Null Meter vs. Nanovoltmeter:

A Comparative Analysis

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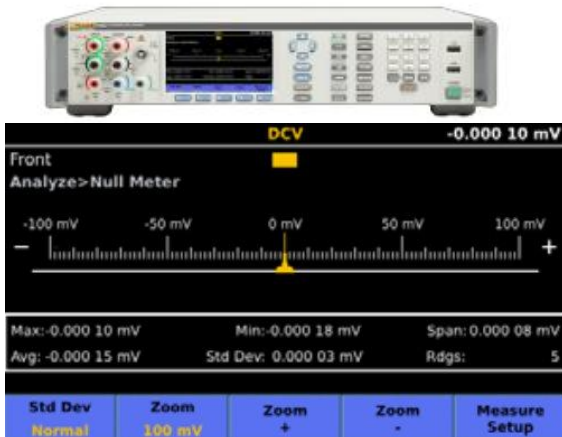
Calibration

 **FORTIVE**

Introduction - Measuring Tiny Voltages

Measuring Tiny Voltages: Null Meters and Nanovoltmeters

- When dealing with extremely small electrical potentials, standard voltmeters often fall short.
- Two specialized instruments are designed for precision measurements in the microvolt and nanovolt range: the **Null Meter** and the **Nanovoltmeter**.
- This presentation will explore their principles, applications, and key differences.



Fluke 8588A/Null Option

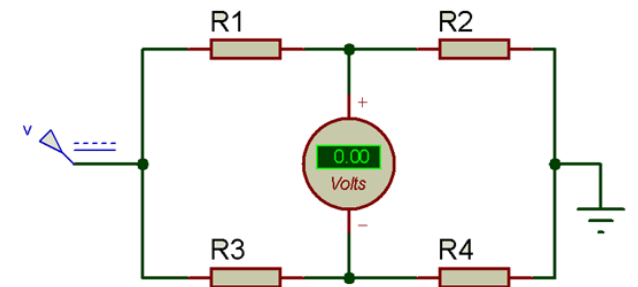


Keithley Nanovoltmeter
Model 2182A

What is a Null Meter?

The Null Meter: A Precision Comparator

- **Definition:** A null meter (or null detector, galvanometer) is a highly sensitive device used to detect the absence of a potential difference (i.e., a "null" point) in a circuit.
- **Principle of Operation:**
 - It doesn't directly measure voltage but indicates when the **voltage difference between two points is zero or extremely close to zero.**
 - Typically used in bridge circuits (e.g., Wheatstone bridge, potentiometer) where an unknown voltage is balanced against a known, adjustable voltage.
 - When the meter reads zero, it signifies that the two voltages are equal, allowing for precise determination of the unknown.
- **Key Characteristic:** High sensitivity, but primarily a comparative tool.



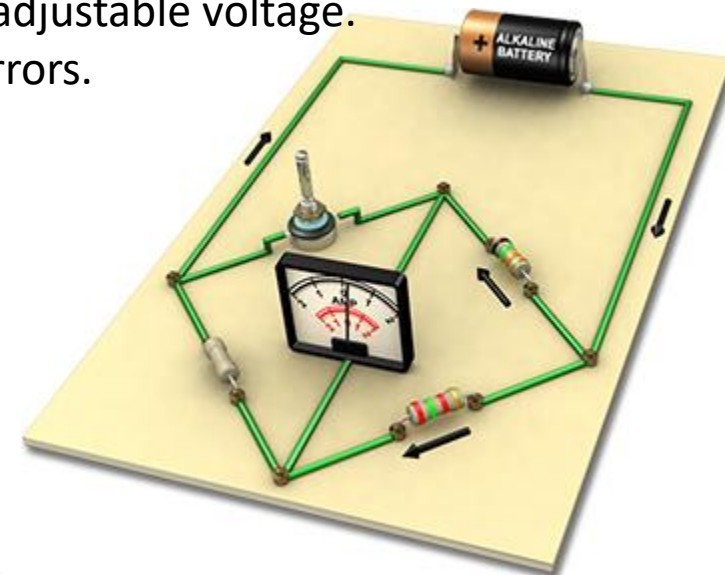
At Balance point of Wheatstone Bridge,

$$\frac{R1}{R2} = \frac{R3}{R4}$$

How a Null Meter Works (in a Potentiometer)

Null Meter in Action: The Potentiometer

- ❑ **Potentiometer Setup:** An unknown voltage source is connected in opposition to a known, adjustable voltage source (often derived from a precisely calibrated slide wire).
- ❑ **Detection:** The null meter is placed between the two sources.
- ❑ **Balancing:** The known voltage is adjusted until the null meter shows no deflection (**zero current**).
- ❑ **Measurement:** At the null point, the unknown voltage is precisely equal to the known, adjustable voltage. This method draws no current from the unknown source at balance, avoiding loading errors.



What is a Nanovoltmeter?

The Nanovoltmeter: Direct Measurement of Ultra-Low Voltages

- ❑ **Definition:** A nanovoltmeter is a highly specialized digital voltmeter designed to directly measure voltages in the nanovolt (nV) range (10^{-9} V).
- ❑ **Principle of Operation:**
 - ❑ Employs sophisticated techniques to minimize noise (thermal noise, Johnson noise, $1/f$ noise) and drift, which can easily overwhelm tiny signals.
 - ❑ Often uses techniques like chopping (AC amplification) or integration to improve signal-to-noise ratio.
 - ❑ Features very high input impedance to minimize loading effects on the circuit being measured.
- ❑ **Key Characteristic:** Direct, quantitative measurement of extremely small voltages.

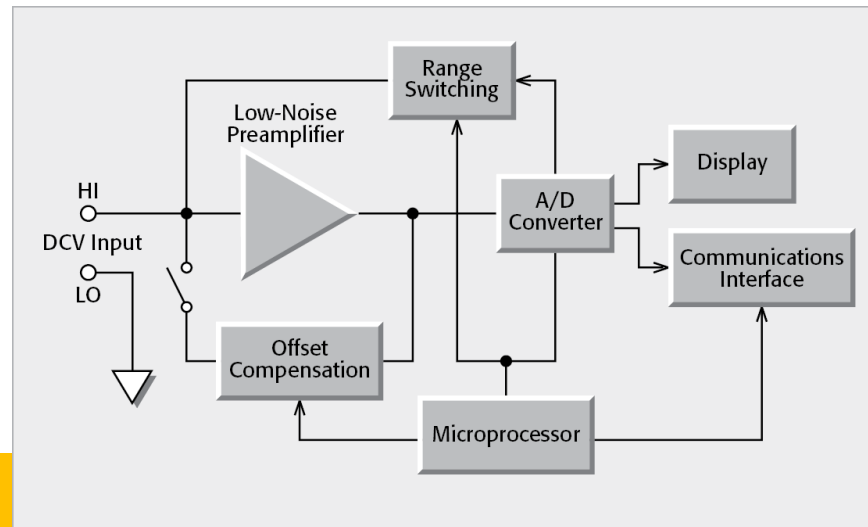


Keithley Nanovoltmeter Model 2182A

Key Features of a Nanovoltmeter

Nanovoltmeter Capabilities

- **Content:**
 - **High Sensitivity:** Can resolve voltages down to a few nanovolts.
 - **Low Noise:** Designed with meticulous shielding, low-noise components, and advanced signal processing to reduce internal and external noise.
 - **High Input Impedance:** Prevents the meter from drawing significant current from the source, ensuring accurate readings.
 - **Filtering:** Incorporates various filters to remove unwanted frequency components.
 - **Digital Readout:** Provides a direct numerical value of the measured voltage.



A basic block diagram showing the internal components of a nanovoltmeter

Null Meter vs. Nanovoltmeter: The Core Difference

The Fundamental Distinction

○ Null Meter:

- **Purpose:** Detects *zero* potential difference (a **null point**).
- **Method:** Comparative measurement (balancing).
- **Output:** Indication of balance/unbalance (e.g., needle deflection, LED).
- **Accuracy:** Limited by the precision of the known standard and the sensitivity of the detector.
- **Loading:** No current drawn at null.

○ Nanovoltmeter:

- **Purpose:** Directly *measures* the magnitude of very small voltages.
- **Method:** Direct amplification and digitization.
- **Output:** Quantitative numerical value (e.g., 5.23 nV).
- **Accuracy:** Limited by internal noise, calibration, and resolution.
- **Loading:** Very high input impedance minimizes loading.

Where Are They Used?

Null Meter:

- ❑ **Precision Resistance Measurement:** Wheatstone bridges.
- ❑ **Calibration of Voltmeters:** Potentiometers for highly accurate voltage calibration.
- ❑ **Temperature Measurement:** Thermocouple calibration (though nanovoltmeters are now more common for direct reading).
- ❑ **Bridge Balancing:** Any application requiring precise balancing of electrical parameters

Nanovoltmeter:

- ❑ **Low-Level Sensor Measurements:** Thermocouples, Hall effect sensors, strain gauges.
- ❑ **Material Science:** Characterizing semiconductor properties, superconductivity research.
- ❑ **Metrology:** High-precision voltage standards and calibration.
- ❑ **Noise Research:** Measuring intrinsic noise in electronic components.

The accuracy of the 8588A/Null Meter

- **Primary Function:** A nullmeter's primary purpose is to detect a null condition, meaning a point where the voltage difference between two points is exactly or very nearly zero. It's often a center-zero meter, indicating the presence and direction of a small imbalance.
- **Comparative Measurement:** Instead of giving an absolute voltage reading, it's used in null-balance circuits (like Wheatstone bridges for resistance, or potentiometers for voltage) to indicate when two potentials are equal.
- **Minimal Loading (Ideal):** The key advantage of a null measurement is that when the null condition is achieved (meter reads zero), no current flows through the null detector. This means the measuring device theoretically does not load the circuit under test, leading to extremely accurate measurements, especially with high-impedance sources.
- **Sensitivity around Zero:** Nullmeters are typically designed to be extremely sensitive around their zero point, even if their accuracy for large deflections is not as critical.
- **Historical Context:** Historically, galvanometers were used as simple null detectors. Modern nullmeters often use sophisticated amplifiers to achieve very high sensitivity.

Choosing the Right Tool

- ❑ Both null meters and nanovoltmeters are indispensable for precision low-voltage measurements.
- ❑ The **null meter excels in comparative, high-accuracy balancing applications** where a zero-current condition is critical.
- ❑ The **nanovoltmeter provides direct, quantitative measurements** of extremely small voltages, offering speed and automation.
- ❑ The choice depends on the specific measurement task, required accuracy, and the nature of the signal.

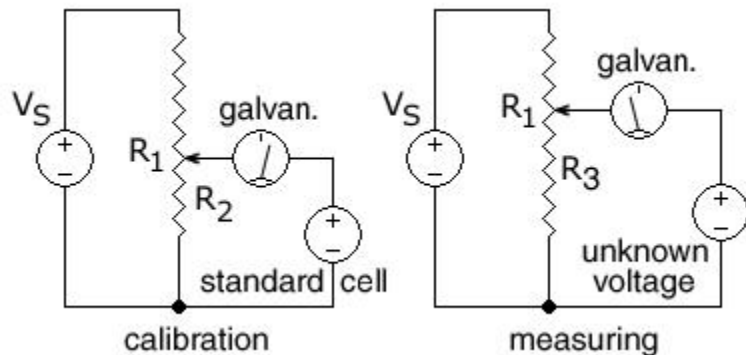
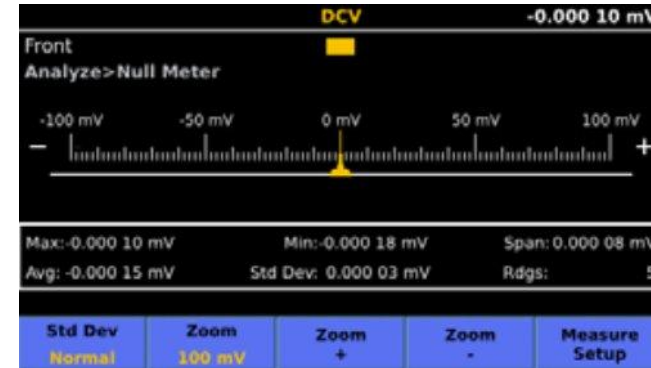
Questions & Discussion



Thank you for your attention



Fluke 845AB null-meter



A potentiometer being calibrated and then measuring an unknown voltage.
 R_1 is the resistance of the entire resistance wire. The arrow head represents the moving *wiper*.

Nullmeter (or Null Detector)

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Nanovoltmeter

- **Primary Function:** A nanovoltmeter is a specialized digital voltmeter (DVM) designed to directly measure very small voltages, typically in the nanovolt (nV, 10^{-9} V) range.
- **Direct Measurement:** It provides a direct reading of the voltage present across its input terminals.
- **High Sensitivity & Low Noise:** Its design focuses on achieving extremely high sensitivity and minimizing internal noise sources (like thermal noise, offset voltage drift, and bias currents) to accurately resolve these tiny voltages. This often involves sophisticated input amplifiers, careful shielding, and sometimes techniques like chopping or auto-zeroing.
- **Input Impedance:** While ideally high, nanovoltmeters still have a finite input impedance. When connected to a circuit, they draw a tiny amount of current, which can slightly "load" the source, potentially affecting the measurement if the source impedance is very high.

What is 1×10^9 or (10^9) ?

1×10^9 is equal to 1,000,000,000 (one billion).

This is a number expressed in scientific notation, where:

- The number before the multiplication sign (1 in this case) is the coefficient.
- 10 is the base.
- The exponent (9 in this case) indicates how many times 10 is multiplied by itself.

Therefore, 10^9 is 10 multiplied by itself 9 times, which results in 1,000,000,000. In the notation 1×10^9 , you multiply 1 by 10^9 , which gives you 1 billion.

The exponent 9 indicates that the decimal point in the number 1.0 should be moved 9 places to the right

What is 1×10^{-9} or (10^{-9}) ?

1×10^{-9} is a way of expressing a very small number using scientific notation.

In standard (decimal) notation, it is equal to 0.000000001.

Explanation:

- 10^{-9} means 1 divided by 10 raised to the power of 9.
- 10 to the power of 9 (10^9) is 1,000,000,000 (one billion).
- Therefore, 10^{-9} is the reciprocal of 10^9 , which is 1 divided by 1,000,000,000.
- This results in 0.000000001.

In terms of metric prefixes, 10^{-9} is equivalent to "nano" (n). For example, a nanometer (nm) is 10^{-9} meters.