

Introduction to Electrical Measurements

Introduction to Electrical Measurements

Fundamentals, instruments, techniques, and best practices

1. Why Electrical Measurements Matter

- **Design & Development** – Verify that circuits meet specifications.
- **Troubleshooting** – Locate faults, diagnose performance issues.
- **Safety & Compliance** – Ensure equipment adheres to standards (e.g., IEC, UL).
- **Quality Control** – Maintain consistency in production and testing.

2. Basic Electrical Quantities

Quantity	Symbol	Unit	Typical Range
Voltage (potential difference)	V or U	volt (V)	μV – kV
Current (electric flow)	I	ampere (A)	μA – kA
Resistance	R	ohm (Ω)	$\mu\Omega$ – M Ω
Power	P	watt (W)	μW – MW
Energy	E	joule (J) or watt-hour (Wh)	μJ – kWh
Frequency	f	hertz (Hz)	Hz – GHz
Capacitance	C	farad (F)	pF – μF
Inductance	L	henry (H)	nH – mH

3. Measurement Principles

Principle	Description	Typical Use
Direct Measurement	Connect instrument directly across or in series with the quantity.	DC voltage, DC current, resistance (using a multimeter).
Indirect Measurement	Derive the quantity from another measured value (e.g., power = $V \times I$).	Power meters, impedance analyzers.
Differential Measurement	Measure the difference between two points, rejecting common-mode noise.	Differential probes, bridge circuits.

Introduction to Electrical Measurements

Principle	Description	Typical Use
Averaging / RMS	Convert a varying signal to an equivalent DC value (root-mean-square).	AC voltage/current, audio signals.
Four-Wire (Kelvin) Method	Separate current-carrying and voltage-sensing leads to eliminate lead resistance.	Low-ohm resistance measurements.

4. Core Instruments

Instrument	Primary Function	Key Features	Typical Accuracy
Digital Multimeter (DMM)	Voltage, current, resistance, continuity, diode test	Auto-range, true-RMS, data logging	$\pm(0.5\% + 2 \text{ counts})$
Oscilloscope	Time-domain waveform capture	Bandwidth, sampling rate, trigger modes	Vertical: $\pm(3\% + 2 \text{ div})$
Power Analyzer	Real, reactive, apparent power; harmonic analysis	Three-phase measurement, PQ metrics	$\pm(0.5\% + 0.5\% \text{ FS})$
LCR Meter	Inductance, capacitance, resistance at various frequencies	Auto-frequency, Q factor, ESR	$\pm(0.2\% + 1 \text{ digit})$
Clamp Meter	Current without breaking the circuit	AC/DC, inrush, true-RMS	$\pm(1\% + 0.5\% \text{ A})$
Data Acquisition (DAQ) System	Multi-channel analog/digital conversion, logging	Sampling rate, channel count, isolation	$\pm(0.1\% + 1 \text{ LSB})$

**Network Analyzer