### Analog Devices and Measurements

**Topics**
- Current Measurements
- Voltage Measurements
- Resistance Measurements

**References**

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### Analog Devices and Measurements

**Introduction**
- Information
  - Transferred between stages of measurement system
  - As an analog electrical signal
  - Originates from measurement of a physical variable
  - Using fundamental electromagnetic or electrical phenomenon
  - Propagates from stage to stage
- Analog devices
  - Supplanted by digital equivalents in many applications
  - Still widely used in engineering devices
  - Many systems analog and digital hybrids

**Sub-Topics**
- Direct Current (DC)
- Alternating Current (AC)

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### Current Measurements

**Direct Current**
- Measuring a DC electrical current
  - Analog device that responds to force
  - Exerted on a current-carrying conductor in a magnetic field
  - Force to move a pointer on a display
- D’Arsonval movement
  - Uniform radial magnetic field
  - Steady angular deflection
  - Corresponds to current through coil
- Galvanometer
  - Highly sensitive D’Arsonval movement (0.1 μA per division)
  - Calibrated about zero current
  - Deflect to plus or minus direction

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![Basic D’Arsonval meter movement](image-url)
### Current Measurements

#### Alternating Current
- Measuring an AC current
  - Use diodes
  - Convert into DC current
  - Use a calibrated D’Arsonval movement meter
- Large AC current
  - Probe over wire (conductor)
  - Use of Hall effect—Voltage developed from
  - Current-carrying conductor perpendicular to magnetic field
  - Unknown current => generate magnetic field => develops a measurable voltage across a Hall-effect sensor
  - Hall effect probe—iron-core ring placed around a wire

### Voltage Measurements

#### Sub-Topics
- Analog Voltage Meters
- Oscilloscope
- Potentiometer

#### Introduction
- Measuring static or dynamic voltage signals
- Can range over several orders of magnitude
- Wide variety of measurement systems

#### Analog Voltage Meters
- Analog voltage dials
- Volt-ohmmeters (VOMs)
- Using D’Arsonval movement
- In series with a fixed resistor for range selection

#### Oscilloscope
- Oscilloscope—Graphical display device providing analog representation of a measured signal
- Voltage magnitude versus time for a dynamic signal
- Megahertz range
- Some with gigahertz
- Visual output of signal
  - Magnitude
  - Frequency
  - Distortion
  - Delineation of DC and AC components
Voltage Measurements

Oscilloscope

- In addition to signal versus time
  - Two or more signals
  - Perform addition and subtraction of signals
  - Display amplitude versus amplitude
- Cathode ray oscilloscope
  - Not common
- Digital oscilloscope
  - Convert signal to digital form
  - Reconstruct signal on LCD display

Digital oscilloscope

Voltage Measurements

Potentiometer

- Potentiometer—Device to measure DC voltages
- Microvolt to millivolt range
- Balances an unknown voltage against a known internal voltage

Oscilloscope output

Resistance Measurements

Sub-Topics

- Ohmmeter Circuits
- Bridge Circuits

Resistance Measurements

Introduction

- Resistance measurements to determine simple continuity
- Changes in resistance: order of $10^{-6}$ Ω
- Absolute resistance: $10^{-6}$ to $10^{15}$ Ω
- Working principle of many transducers: a change in resistance relative to a change in measured variable
Resistance Measurements
Ohmmeter Circuits

- Imposing a voltage across the unknown resistance and measuring the current flow
- Ohm's law: \( R = \frac{E}{I} \)
- Limit imposed by ability to dissipate the power
- Heating: \( I^2R \)
- Principle for fuses: Large value of current melts the fuse

Resistance Measurements
Bridge Circuits

- Bridge circuit
  - A type of electrical circuit
  - Two circuit branches bridged by a third branch
  - At some intermediate point along them
- Applications in instrumentation, filtering, power conversion
- Wheatstone bridge
  - Well-known bridge circuit
  - Means for accurately measuring resistance

Resistance Measurements
Bridge Circuits

- Four resistors
  - An unknown value: \( R_1 \)
  - One adjustable: \( R_2 \)
  - Two fixed: \( R_3 \) and \( R_4 \)
- A DC voltage is applied as an input
- Variable resistor is adjusted until the bridge is balanced
- Value of unknown resistor is calculated

Resistance Measurements
Bridge Circuits

- Balance condition: \( I_2 = 0 \)
- No voltage drop from B to C: \( I_1R_1 - I_2R_2 = 0 \) \( I_1R_1 - I_2R_2 = 0 \)
- Currents through are equal: \( I_1 = I_2 = I_3 = I_4 \)
- Relationship among resistances: \( \frac{R_2}{R_3} = \frac{R_4}{R_5} \)

Resistance Measurements
Bridge Circuits

- Resistance change measured two ways
  - Adjusted to null circuit and determine resistance
  - Use voltage measuring device to measure voltage unbalance
- Balancing operation accomplished
  - Manually
  - Automatically (closed-loop controller circuit)
- Advantages
  - Input voltage need not to be known
  - Changes in the input voltage do not affect accuracy
  - Current detector need only detect if there is a flow
  - Not measure value
Example: A temperature sensor is connected in a Wheatstone bridge, with sensor in the $R_1$ location, and $R_2$ is a calibrated variable resistance. Fixed resistances of $R_3$ and $R_4$ are 500 $\Omega$. The bridge is balanced. If temperature sensor has resistance of 100 $\Omega$, determine the value of $R_2$.

$$\frac{R_2}{R_1} = \frac{R_3}{R_4}$$
$$R_2 = \frac{R_3 R_4}{R_1}$$
$$R_2 = 100 \ \Omega$$