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## Introduction To Circuit Protection

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## Chapter 1: Circuit Measurement

### Learning Objectives

By the end of this section, you will be able to:

- Identify the primary uses and advantages of in-circuit and out-of-circuit meters in electrical systems.
- Explain the operational principles of basic meter movements, including the d'Arsonval movement, magnetic fields in DC and AC, and the function of damping and rectification.
- Define the concepts of sensitivity and ranging for ammeters and voltmeters, and apply associated safety precautions for accurate measurement.

### Circuit Measurement Fundamentals

Circuit measurement is a foundational necessity in electrical engineering practice. Since electricity is invisible, physical devices, collectively known as test equipment, are essential to ascertain the forces and values within a circuit.

Measurement techniques allow engineers to:

- Monitor System Operation: Track live parameters of electrical or electronic equipment.
- Troubleshoot Malfunctions: Accurately diagnose why a device is not operating to specification, which is critical for repair (e.g., determining why a component is failing or an oven is not working).

**Executive Summary:** Electrical measurement moves beyond theoretical knowledge to practical application by verifying live parameters (Voltage, Current, Resistance, Power) and is the core of effective troubleshooting and diagnosis in any electrical or electronic system.

### Types of Measuring Devices

Test equipment typically employs some form of metering device. These can be broadly categorized based on their installation and portability:

- In-Circuit Meters
  - Description: Meters permanently built into the device or system being monitored.
  - Primary Use: Monitor continuous operation (e.g., an alternator gauge on a vehicle, frequency meters on power plant control panels, or power consumption meters on a building).
  - Value: Provides immediate visual indication of proper operation simply by scanning the control panel.

- Out-of-Circuit Meters
  - Description: Portable, self-contained meters that are connected to a circuit only for testing.
  - Primary Use: Used in troubleshooting at various test points.
  - Advantage: They are highly versatile and can be used on multiple devices (moved from one piece of equipment to another), making them valuable for locating the root cause of a malfunction.

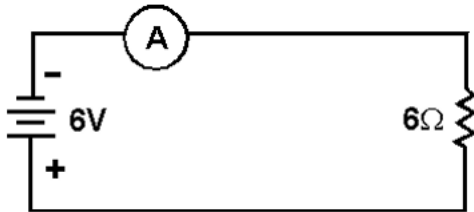


Figure 1-1. —A simple representative circuit.

### Basic Meter Movements

A meter movement serves as an energy converter, transforming electrical energy (current) into mechanical energy (pointer movement). The underlying principle for many meters is the interaction of magnetic fields.

#### Early Concept: Compass and Conductor

An early understanding of this principle involved observing a compass near a current-carrying conductor.

- A conductor with current generates a magnetic field around it.
- A nearby compass needle aligns itself with this magnetic field, displacing it from magnetic north.
- The strength of the conductor's magnetic field is directly proportional to the amount of current flowing. An increased current yields a stronger field and greater needle deflection.
- Reversing the current's direction reverses the magnetic field's polarity, causing the compass needle to move in the opposite direction.

This principle led to the creation of the galvanometer, an instrument initially designed to measure small currents using the electromagnetic principle.

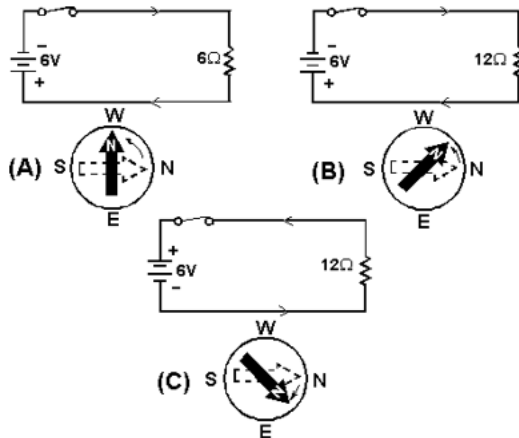


Figure 1-2.—Compass and conductor with direct current.

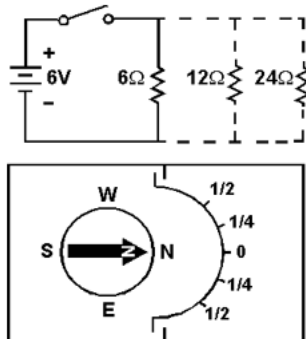


Figure 1-3. —A simple meter from a compass.

### D'Arsonval (Permanent-Magnet Moving-Coil) Movement

The modern basis for most measuring instruments is the d'Arsonval movement (or Permanent-Magnet Moving-Coil).

The mechanism consists of a:

- Fixed Permanent Magnet: Provides a constant magnetic field.
- Movable Coil: A coil of wire wound on an aluminum frame (bobbin) suspended by jeweled bearings.
- Pointer and Scale: A pointer attached to the coil to indicate the extent of movement on a calibrated scale.

### Operational Principle:

1. When DC current flows through the coil, the coil acts as an electromagnet with a magnetic field.
2. The interaction of the coil's field with the fixed permanent magnet's field generates a turning force (torque).
3. The greater the current, the stronger the magnetic field, and the farther the coil moves.

### Key Components for Accuracy:

- Hairsprings: Serve three essential functions:
  - Return: Returns the coil/pointer to the original (zero) position when no current is present.
  - Opposition: Provides a resisting force against the coil's movement when current is present.
  - Connection: Makes electrical connections to the moving coil.
- Iron Core: Placed inside the coil to concentrate the magnetic fields, increasing efficiency.
- Curved Pole Pieces: Shaped to ensure the turning force increases steadily as the current increases, promoting linearity.

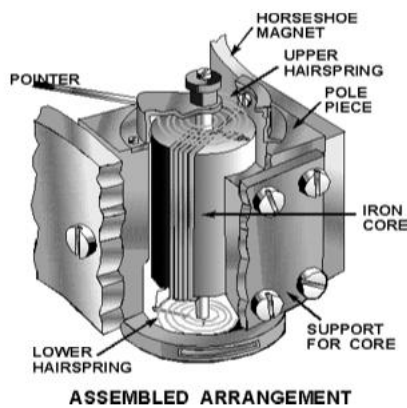


Figure 1-9. —Assembled meter movement.

### AC Measurement Challenge: The Rectifier

The d'Arsonval movement is fundamentally a DC device because current reversal would reverse the torque, damaging the movement.

1. Low-Frequency AC Reaction: If a compass or meter is exposed to low-frequency AC, the needle attempts to follow the rapid reversals of current (and magnetic field), swinging back and forth.
2. High-Frequency AC Reaction: At high AC frequencies, the meter cannot mechanically keep up with the reversals and simply vibrates near the zero point. This position represents the average value of the AC sine wave, which is zero, rendering the reading useless.
3. The Solution-Rectification: To measure AC with a d'Arsonval movement, a rectifier is used. A rectifier converts the alternating current into pulsating direct current.
4. Rectified Reading: The d'Arsonval movement then reacts to the average value of this pulsating DC (which corresponds to the average value of one-half of the AC sine wave).



Figure 1-12. —Rectifier action.

## Damping for Stability

Meter pointers must be stabilized for reliable reading, which is achieved through a process called damping. Damping also prevents the pointer from overshooting the correct reading when the current changes.

Damping Method	Principle	Description
<b>Electromagnetic Damping</b>	<b>Induced Counter-EMF</b>	The coil's movement through the magnetic field induces a current (and thus a field) in the coil that <i>opposes</i> its motion, acting as a natural brake.
<b>Mechanical Damping</b>	<b>Air Resistance</b>	A vane attached to the moving coil moves within an enclosed airtight chamber. The air's resistance acts against the coil's motion, damping oscillations.

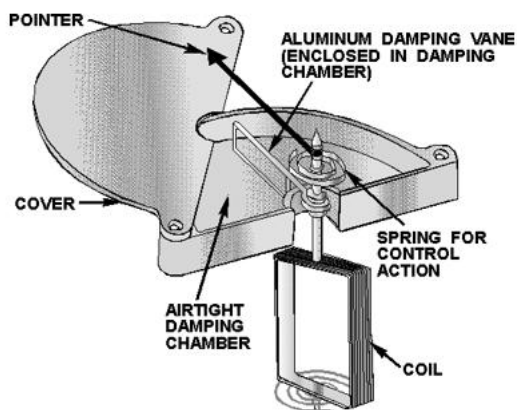


Figure 1- 14. —A typical meter damping system.



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