Electrical Measurements

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Lecture 1

- Measurement:
  an estimation of a physical (chemical or biological) variable by a measurement device.
- Metric System (SI)
  - Is a decimal system based on 10
    - Prefixes in units
      - [+] Tera T ==> 10^12
      - [+] Giga G ==> 10^9
      - [+] Mega M ==> [+] 10^6
      - [+] Kilo k ==> 10^3
      - [+] Hecto h ==> 10^2
      - [+] Deci d ==> 10^-1
      - [+] Centi c ==> 10^-2
      - [+] Milli m ==> 10^-3
      - [+] Micro μ ==> 10^-6
      - [+] Nano n ==> 10^-9
      - [+] Pico p ==> 10^-12
  - Dimensions
    - [+] Length L L
    - [+] Mass M M
    - [+] Time T T
    - [+] Force F ==> M*L/T^2
    - [+] Acceleration a ==> L/T^2
    - [+] Energy E ==> M*L^2/T^2
    - [+] Power P ==> M*L^2/T^3
    - [+] Moment of inertia I ==> M*L^2
    - [+] Torque τ ==> F*L
  - Units of The Metric System
    - length meter m
    - volume liter L
    - mass gram g
    - temperature Celsius °C
- System Types
  - 2- FPS (Foot, pound, second)
  - 3- CGS (centimeter, gram, second)
  - 1- MKS (meter, kilogram, second)
    - Units
      - Fundemental Units
        - Primary
          - meter (m)
          - Kilogram (kg)
          - Second (s)
        - Auxiliary
          - ampere (A)
          - Kelvin (K)
          - mole - mol
          - candela (cd)
      - Derived Units
        - [+] Area [A] ==> (m^2)
        - [+] Volume [V] ==> (m^3)
        - [+] Density [p] ==> (kg/m^3)
        - [+] Velocity [v] ==> (m/s)
        - [+] Acceleration [a] ==> (m/s^2)
          - [+] Force F ==>newton (N)
          - [+] Pressure P ==>pascal (Pa)
          - [+] Energy E ==>joule (J)
          - [+] Power P ==>watt (W)
          - [+] El0ectric charge Q ==>coulomb (C)
          - [+] Electric potential V==>volt (V)
          - [+] Electric resistance R ==> ohm (Ω)
          - [+] Electric conductance G ==>siemens (S)
          - [+] Magnetic flux Φ ==>weber (Wb)
          - [+] Magnetic flux density B ==>tesla (T)

Lecture 2

- Accuracy
  - refers to how close a measured value is to the true or accepted value for that quantity.
  - (Measured value - True value)
- Precision
  - The closeness of a series of measurements to each other
  - Range (Max value - Min value)
- Sensitivity:
  - is a response of instrument to change of input or measured value
  - Calibration
    - the process of applying known values of a measurement to determine the response of a measurement system
      - Static Calibration==> calibration using a constant measurand
      - Dynamic Calibration==> calibration using a time-dependent measurand
- Parallax Error
  - Parallax occurs in analog meter due to non perpendicular view of pointer
- Arthmetic mean
  - It is the sum of all of the list divided by the number of items in the list.

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i = \frac{1}{n}(x_1 + \cdots + x_n),$$

$$Average_range_of_error = \frac{(\bar{X} - X_{min}) + (X_{max} - \bar{X})}{2} = \frac{X_{max} - X_{min}}{2}$$

Lect :3_Measurement Errors

- Gross Errors
  - Improper use instrument
  - Miscalculations
  - Misreading
- Random Errors
  - is caused by any factors that randomly affect measurement of the variable across the sample
- Systematic Errors
  - Environmental error due to
  - Instrumental Error
  - **is caused by any factors that systematically affect measurement of the variable across the sample**
- Static Analysis of Measurement Errors
  - Gaussian Distribution
  - Probable Error
    - It is range which contains 50 % of the measured values .
    - r=+/- 0.6745 σ
  - Limiting Error
    - R = 30 (+/-) 10%
    - The values limit that the manufacture guarantee
  - When Using voltameter
    - Observe correct polarity.
    - Use highest range
    - Be ware of Loading effect
    - It should be connected in parallel in circuit

Measurement value = True value + Gross error + Random error + Systematic error

Lect.7 Digital Voltmeter

- Digital Voltmeter Classification
  - 1- Ramp type
  - 2-Integrating
  - 3-Continous balance
  - 4-Successive Approximation
- comparator
  - As Vr < Vin, comparator o/p is high, so pulses From clock gen.pass Through AND then To register. At Vr = Vin, comparator o/p is low
- Ramp-type Digital Voltmeter

$$t_1 \alpha V_{input}$$

Accuracy of DMM

Indicate as ± (% of reading + No. of digits)

- Successive Approximation DVM

Number of trial	Number	Compare with 499	Error in reading
1st guess	256	< our #	1st trial < 256
2nd guess	$256+\frac{256}{2}=256+128=384$	< our #	2nd trial < 128
3rd guess	$384+\frac{128}{2}=384+64=448$	< our #	3rd trial < 64
4th guess	$448+\frac{64}{2}=448+32=480$	< our #	4th trial < 32
5th guess	$480+\frac{32}{2}=480+16=496$	< our #	

Number of trial = number of digits = 9

It uses D/A converter
The technique is called Binary regression

$$V_{in} = k \times \text{Digital output}$$

Where k is step size or resolution

Quantization error or Conversion error of a A/D

$$\text{Quantization error} = \frac{\text{step size}}{\text{full scale}} \cdot 100 = \frac{1}{2^N - 1} \cdot 100\%$$

Where N is the number of bit

Lect.6 Analog Electronic Equipment

- Transistor Voltmeter circuits
  - R1 = Rs = Multiplier resistance
    $I_{collector} \approx I_{Emitter} = I_{meter}$
    β=h_{fe} : Transistor current Gain
    $I_{collector} = \beta I_{base}$
  - It offers high input resistance and low output resistance
  - Loading effect is reduced
- OP AMP Voltmeter Circuit
  - Volt to Current Converter
    - I3>> Ibase
    - VR3 = input volt =E
- Voltmeter Types
  - Digital Voltmeters:
  - Analog Voltmeters:
  - Oscilloscope:
  - Vacuum Tube Voltmeters:
  - Solenoid Voltmeters:

Comparison of Digital and Analog Meter

Digital meter	Analog meter
Leaves no doubt about the measured quantity.	Wrong scale might be used or might be read incorrectly.
Superior resolution and accuracy. (±0.5% or better)	Inferior resolution and accuracy. (±3% in common)
Indicates a negative quantity when the terminal polarity is reversed	Pointer attempts to deflect to the left when the polarity is reversed
No usually damaged by rough treatment	Can be damaged when dropped from bench level

Lect. 5 DC and AC Bridges

- WHEATSTONE Bridge

$$I_1 R_1 = I_2 R_2$$

$$I_3 R_3 = I_4 R_4$$

- Since I1 = I3 and I2 = I4
  , divide equation 2-12 by equation 2-13:

$$R_X = R_4 \frac{R_2 R_3}{R_1}$$

$$E_s = E \times \left(\frac{R_3}{R_1 + R_3} - \frac{R_V}{R_2 + R_V} \right)$$

Bridge Controlled Circuit

$$\frac{R_X}{R_2} = \frac{R_3}{R_1} = \frac{R_{f1}}{R_{f2}}$$

KELVIN Bridge

- Wein Bridge Oscillator
  - [+] When output voltage is positive, D1 turns on and R3 is switched in parallel causing A to drop
    [+] When output voltage is negative, D2 turns on and R3 is switched in parallel causing A to drop
    - Zin = R1
    - Zfn = R2//R3
    - Zip = R/c
    - Zfp= R+1/jwc

+ve feed back block (Freq. of osc.) |
Negative feed back block (gain)

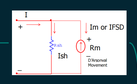
Lect4: Direct instruments using Permanent-Magnet Moving Coil (PMMC)

- Operation of PMMC
  - · When current flows through the coil, the core will rotate.
  - · Amount of rotation is proportional to the amount of current flows through the coil.
  - · The meter requires low current (~50uA) for a full scale deflection, thus consumes very low power (25-200 Uw).
  - · Its accuracy is about 2% -5% of full scale deflection
  - · T = kθ where
    - · θ is the angle of rotation (degrees)
    - · k is spring constant (N-m/degree).
    - · At equilibrium
  - · T = BIAN
    - · N= number of turns, A=coil Area,
    - B=magnetic flux density Tesla (Wb/m2).
    - · torque [N-m]
- DC Ammeter
  - Rm = internal resistance of the movement
    Rsh = shunt resistance
    Ish =shunt current
    Im = Full scale deflection current of the movement
    I = total current

$$I_{sh} R_{sh} = I_m R_m$$

$$I_{sh} = I - I_m$$

$$R_{sh} = \frac{I_m R_m}{I - I_m}$$



- Ammeter insertion effects

$$I_e = \frac{E}{R_1}$$

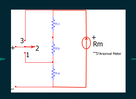
$$I_m = \frac{E}{R_1 + R_m}$$

$$\frac{I_m}{I_e} = \frac{R_1}{R_1 + R_m}$$

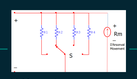
$$= \left(1 - \frac{I_m}{I_e}\right) X100$$

Insertion Error

- 1) Minimum Thermo Dielectric Voltage Drop
  - Soldering of joint should not cause a voltage drop.
- 2) Solderability
  - - never connect an ammeter across a source of e.m.f
  - - observe the correct polarity
  - - when using the multirange meter, first use the highest current range.



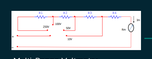
Aryton shunt or Universal shunt



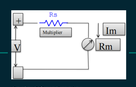
Multirange Ammeter

- DC Voltmeter
  - Basic Meter as a DC Voltmeter

$$S = \frac{1}{I_{fsd}}$$



Multi-Range Voltmeter



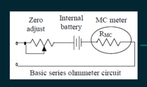
Basic DC voltmeter

$$V = I_m (R_s + R_m)$$

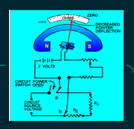
$$R_s = \frac{V - I_m R_m}{I_m} = \frac{V}{I_m} - R_m$$

$$R_s = \frac{V}{I_m} - R_m$$

- Im =full scale deflection current of the movement (Ifsd)
  Rm=internal resistance of the movement
  Rs =multiplier resistance
  V =full range voltage of the instrument
- Voltmeter loading effects
  - Total resistance will decrease, so the voltage across component will also decrease. This is called voltmeter loading.
    - The resulting error is called a loading error
  - The voltmeter loading can be reduced by using a high sensitivity voltmeter
- Ohmmeter



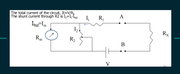
Basic series ohmmeter circuit



$$R_x = R_1 + (R_2 // R_m) = R_1 + \frac{R_2 R_m}{R_2 + R_m}$$

$$R_1 = R_h - \frac{I_{fsd} R_m R_h}{V}$$

The voltage across the shunt, Vsh= Vm



- AC Voltmeter using half wave rectifier
  - Peak voltage,
    $E_p = 10V_{rms} \times 1.414 = 14.14V$
    Average voltage,
    $E_{av} = E_{dc} = 0.636 \times E_p = 8.99V$
    - , the average voltage is given by:
      Eave / 2=4.5V
    - · In case of a half wave rectifier, if given input voltage, Ein = 10 Vrms, then:
  - The DC voltmeter sensitivity is given by:
    $S_{dc} = \frac{1}{I_{fsd}} = \frac{1}{1mA} = 1k\Omega/V$
    - $S_{ac} = 0.45 S_{dc} = 0.45 k\Omega / V$
      AC voltmeter sensitivity
  - $E_{dc} = 0.45 \times E_{rms}$
    $R_s = \frac{E_{dc}}{I_{dc}} - R_m = \frac{0.45 \times E_{rms}}{I_{dc}} - R_m$
    - · To get the multiplier resistor, Rs value:
    - $R_s = S_{dc} \times range - R_m$
      AC Voltmeter using full-wave rectifier

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