K.D.K.COLLEGE OF ENGINEERING

DEPARTMENT OF ELECTRICAL ENGINEERING

THIRD SEMESTER ELECTRICAL ENGINEERING

SUBJECT:

EMI (ELECTRICAL MEASUREMENT AND INSTRUMENTATION)

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Loading Effect:

Loading Effect of Instruments:

- In Ideal Condition original signal should remain undistorted.
- When any signal is used for Signal Sensing, conditioning, transmission or detection into system it is expected that the signal should remain undistorted.
- In Practical condition it is not possible, generally the signal are distorted when it is used in any system.
- The energy is extracted from signal when it is introduced in any system.
- The extraction of energy from signal results in distortion of signal.
- The distortion may be in the form of attenuation (reduction in amplitude), phase shift and some time some undesirable feature are put together.
- This distortion in signal makes the ideal measurement impossible.
- The incapability of system to faithfully measure, record or control the input signal in undistorted form is called loading effect.

Generally measurement consists of three stages:

1. Detector: Transducer Stage
2. Signal Conditioning Stage which also includes transmission stage
3. Signal Presentation stage

The First Stage detector Transducer loads the input signal.

Second stage loads the first stage.

Third Stage loads the second stage.

Example of Loading Effect:

Input Impedance: Please see Figure No. 1

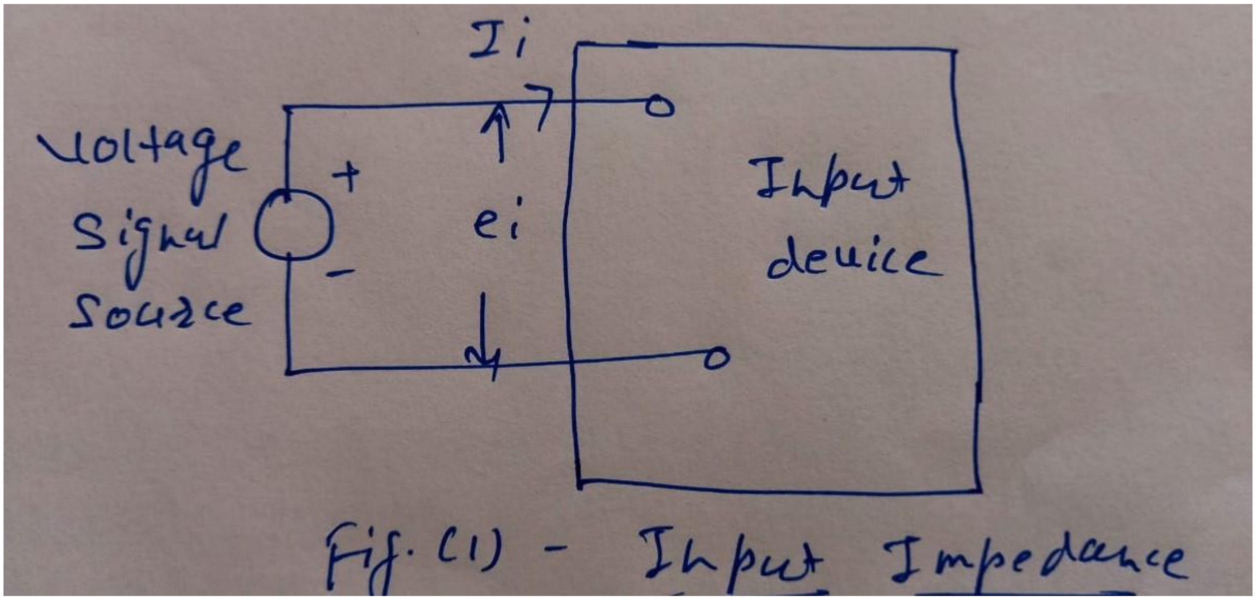


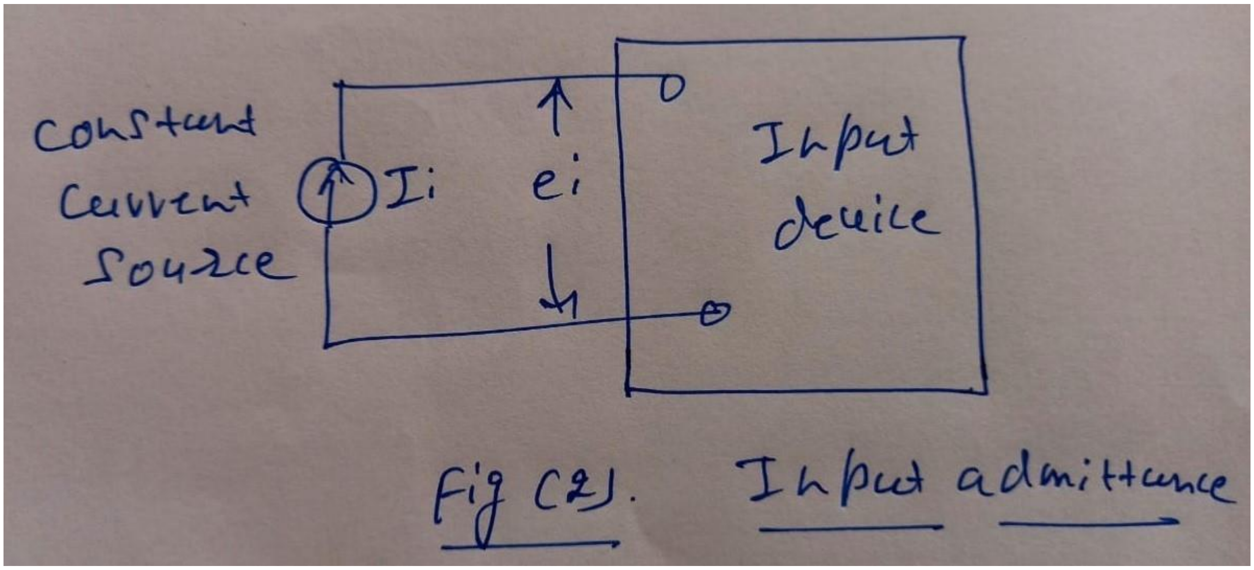
Fig. (1) - Input Impedance

- In Figure No. 1 Voltage Source is applied to input device.
- The magnitude of input impedance is given by $Z_i = e_i / I_i$.
- The Instantaneous power extracted by the input devices is given by

  Power $p = e_i \, I_i = e_i^2 \;/ Z_i$.
- Hence when an instruments is connected across any system for measurements power is drawn from the system.
- The system condition changes as power is drawn from the system.
- The amount of deviation from the original condition depends on input impedance.
- If the Input impedance is less Power extraction will be more and if Input impedance is more Power extraction will be less.

- In Ideal case Voltmeter when connected to the system should not draw any power from system, this is possible only when Voltmeter has impedance that has infinite value.

Input Admittance: Please see Fig. No. 2



- In Figure No. 2 Current Source is applied to the input device.
- The magnitude of Input Admittance is given by $Y_i = I_i / e_i$
- $Z_i = e_i / I_i = 1/ Y_i$ (Impedance = 1/ Admittance)
- Instantaneous Power = $p = I_i . e_i = I_i^2 / Y_i = I_i^2 Z_i$
- The power drawn from the source is small when the input admittance of the device is high. i.e. loading effect is less.
- The power drawn from the source is high when the input admittance of the device is low. i.e. loading effect will be high.

- An Ammeter is connected in series.
- Ammeter should be designed with low input impedance, so that the current is correctly measured.
- Ideally an Ammeter should have an infinite input Admittance.

Output Impedance: Please see Fig. No. 3 and 4

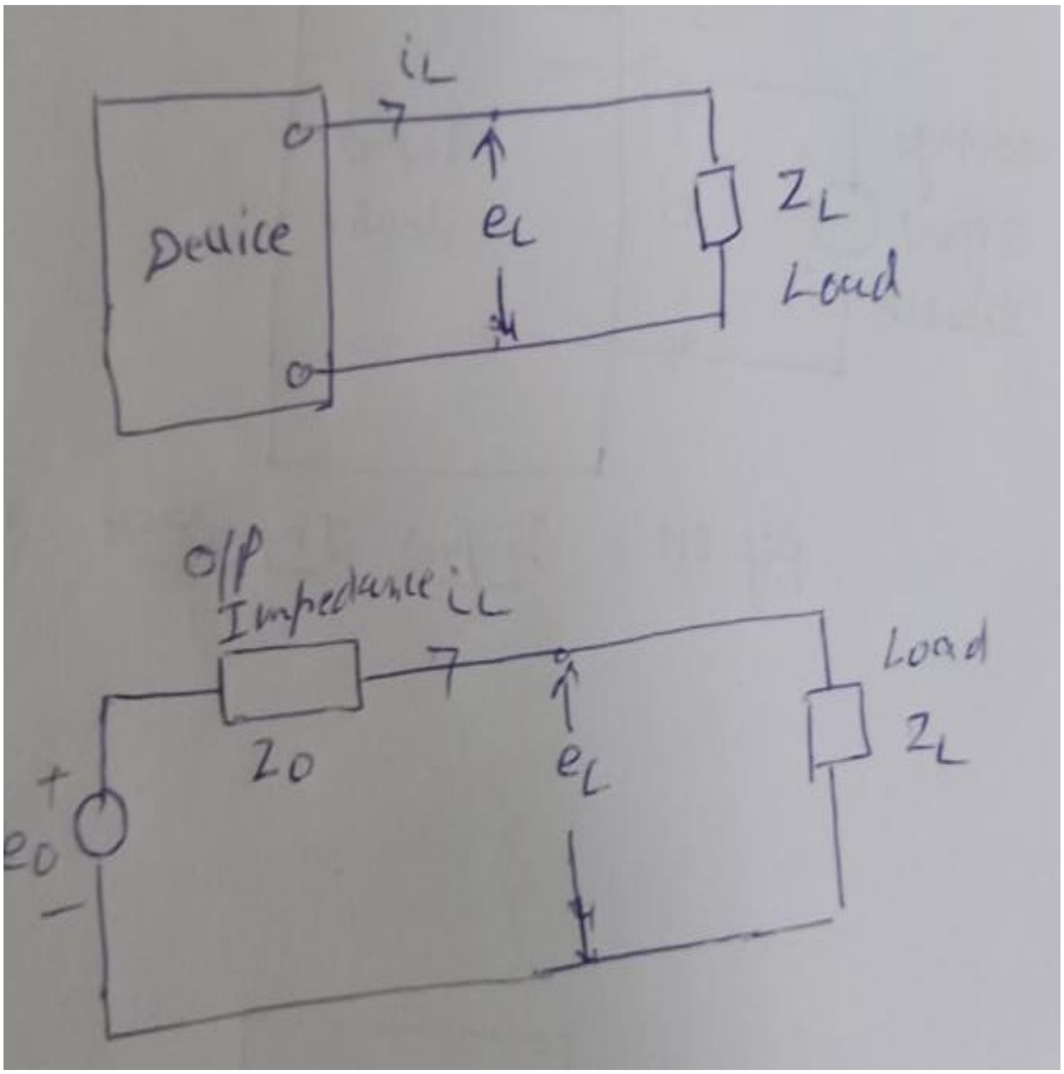


Fig. No.3 and 4 Voltage Source and Shunt Connected Instruments.

- The output impedance is defined as its equivalent impedance as seen by the load.

- The equivalent impedance term is implies that the device can be represented by Thevenin's equivalent circuit.

- Let e_o = Voltage across output terminals of the device when load is not connected.

  e_L = Volage across the output terminals of the device when load is connected.

- Output Impedance of active device is

  $Z_o = (e_o - e_L) / i_L$

  OR we can also write

  $e_o - e_L = i_L Z_o$

  Power loss in voltage source = $p = (e_o - e_L)\ i_L = i_L{}^2\ Z_o$

  For Voltage Source:

- The lower the output impedance the lower is the voltage drop and lower is power consumption lower will be loading effect.

- Ideally there should not be any loading effect, this requires that output impedance Z_o of the voltage source be equal to zero.

Loading effect of Series Connected Instruments:

Please Refer Fig. No. 5

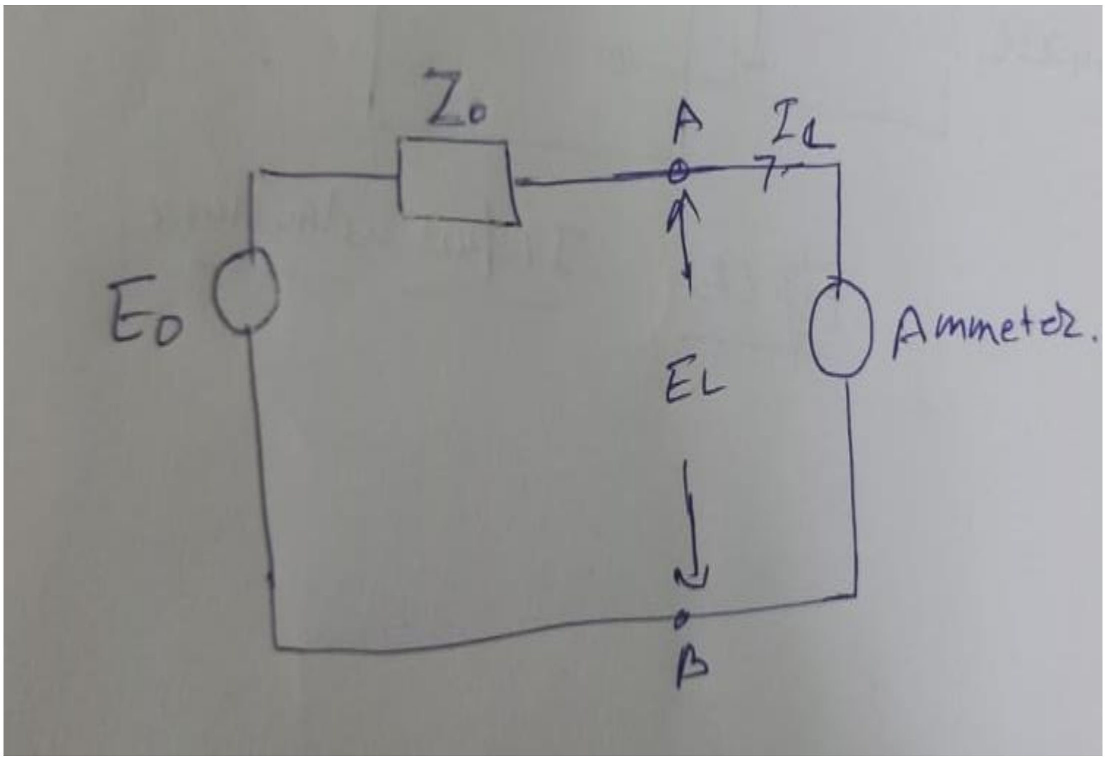


Fig.No. 5 Loading Effect of Series Connected Instruments.

- Under Ideal Condition when Ammeter is not connected and both point a And B are shorted the current flowing is I_o.
- $I_o = E_o / Z_o$

- When Current measuring device Ammeter is connected between terminal A and B it adds Impedance to the circuit.

- Let the impedance of the ammeter is Z_L

- From Figure the current $I_L = E_o / (Z_o + Z_L)$

  $I_L = I_o Z_o / (Z_o + Z_L)$

  $I_L = I_o / 1+ (Z_L / Z_o)$

- In order to have the measured value of current I_o the value of $\mathbf{Z_o >> Z_L}$

- This indicates that the input impedance of Ammeter Z_L should be very small as compared with the output impedance Z_o of the source.

- In terms of Admittance we can write $I_L = I_o / 1+ (Y_o / Y_L)$

- The admittance of series element should be as large as possible to reduce the loading effect.

- For Achieving 99% accuracy (1% error) in measurements the output resistance should be at least 100 times more than the resistance of input device.

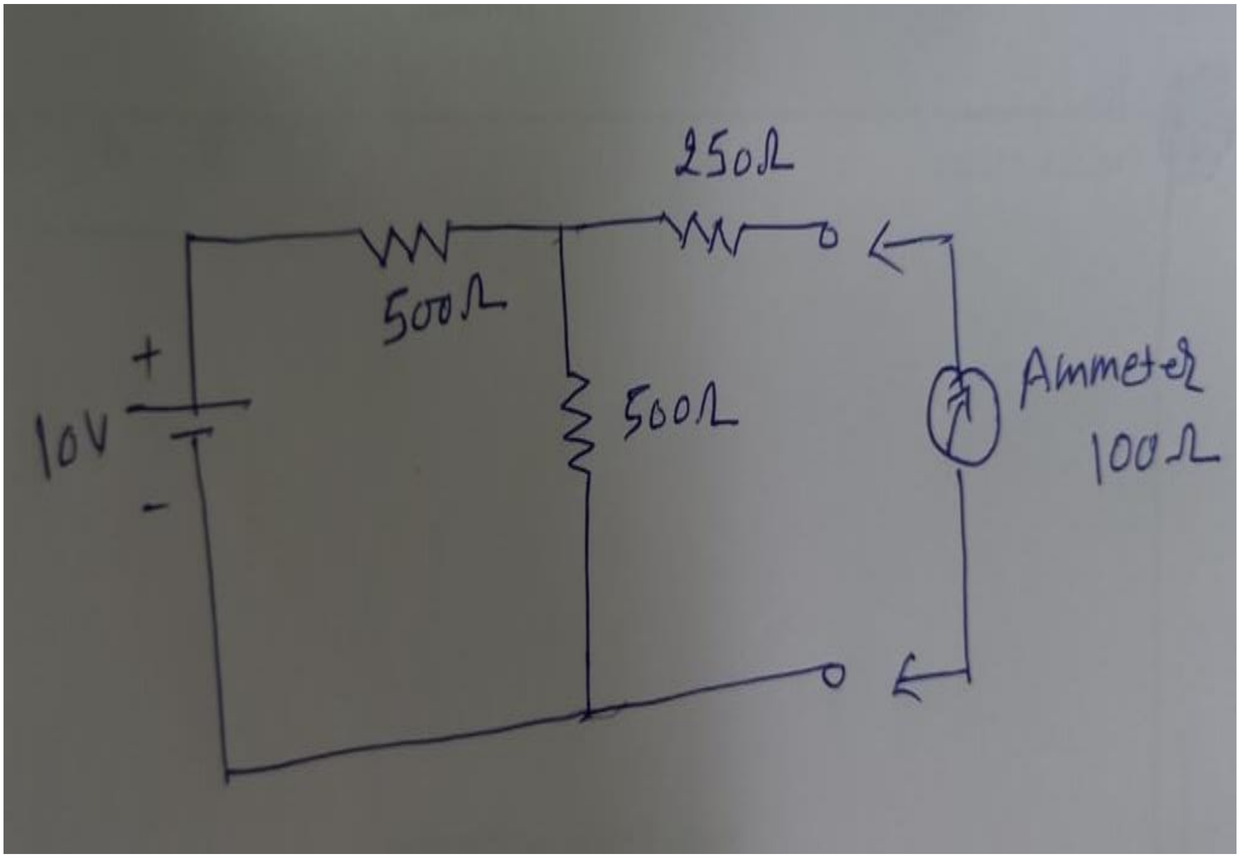
- For Achieving 95% accuracy (5% error) in measurements the output resistance should be at least 20 times more than the resistance of input device.

Example: It is desired to measure the value of current in the 250 Ω resistor by connecting a 100 Ω ammeter as shown in the figure.

Calculate: 1) The actual value of current.

2) Measured value of current.

3) Percentage Error in measurement and accuracy.



Solution:

By Thevenins theorem

The open circuit voltage applying between terminal A and B is

$$E_o = 10 - (10 \times 500) / (500 + 500)$$

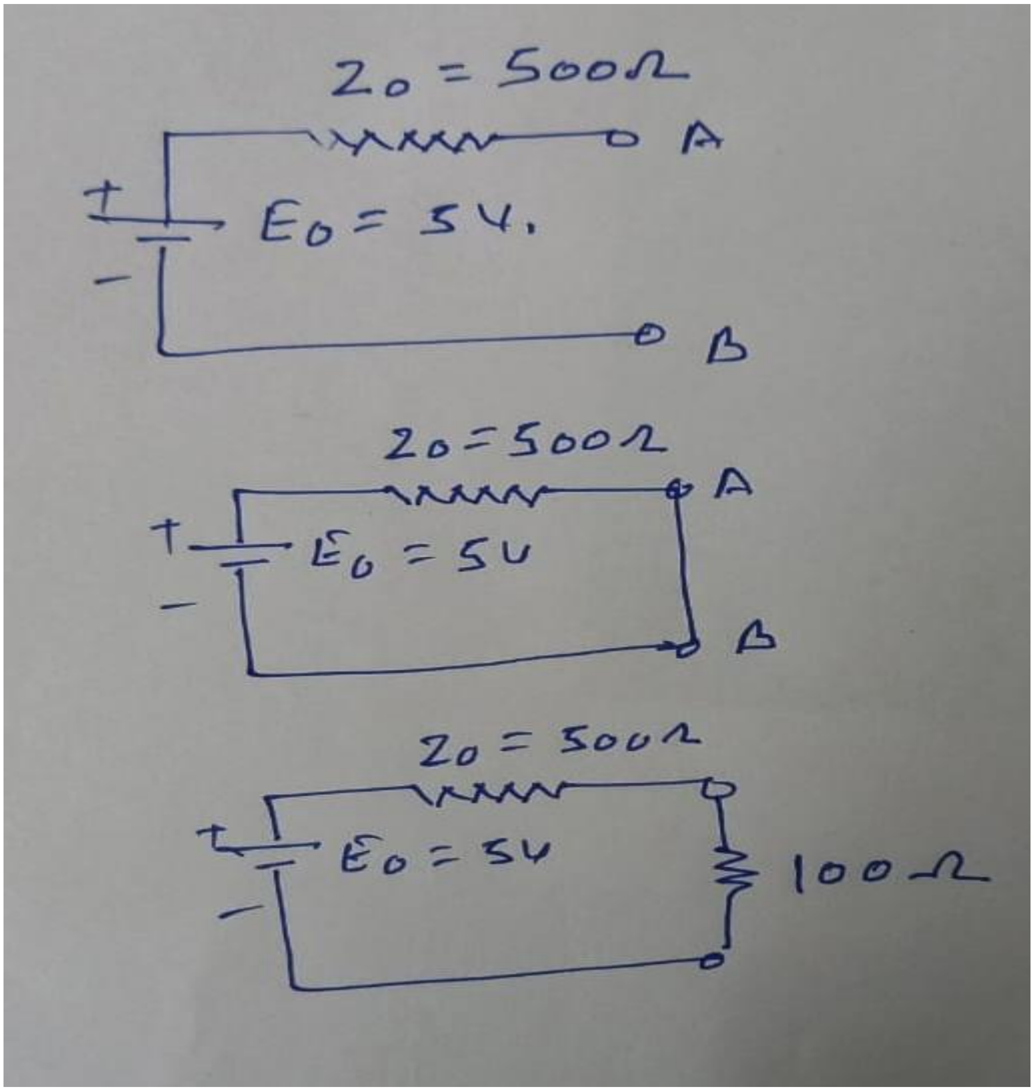
$$E_o = 5 \text{ V.}$$

The output impedance of source looking between terminal A and B is

$$Z_o = [(500 \times 500) / (500 + 500)] + (250)$$

$$Z_o = 500\ \Omega$$

By drawing equivalent thevenins equivalent circuit we get:



Actual value of Current :

$I_o = E_o / Z_o = 5 / 500 =$ 10 mA……Answer…

When the Ammeter is Introduced in the circuit the value of current will be

The measured value of current = $I_L = E_o / (Z_O + Z_L)$

$I_L = 5 / (500 + 100) = 8.33$ mA…..Answer…

Percentage Error in measurement = [(8.33 – 10)/ (10)] x 100% = -16.7 %

Accuracy in measurement = 100-16.7 = 83.3 % … Answer ….