AC AND NULL METHOD ANALOG MEASURING INSTRUMENTS

EE 306 – SS2016

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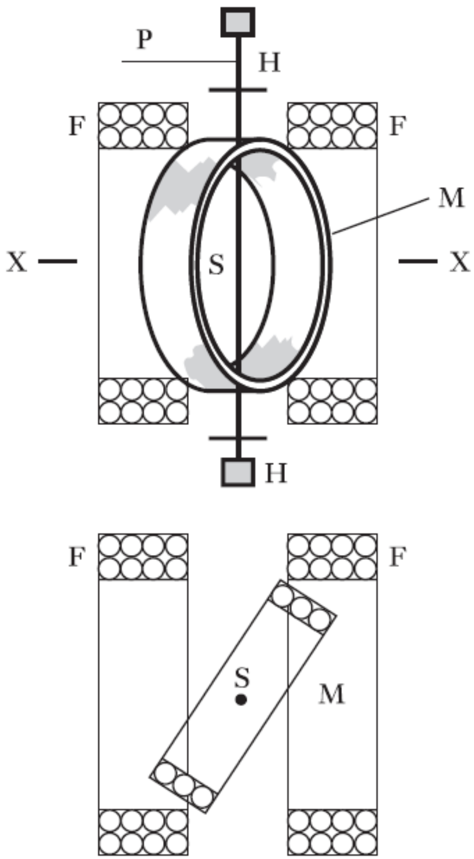
Electrodynamic (Dynamometer) Instrument

- Action of this type of instrument depends upon electromagnetic force exerted between fixed and moving coils carrying current

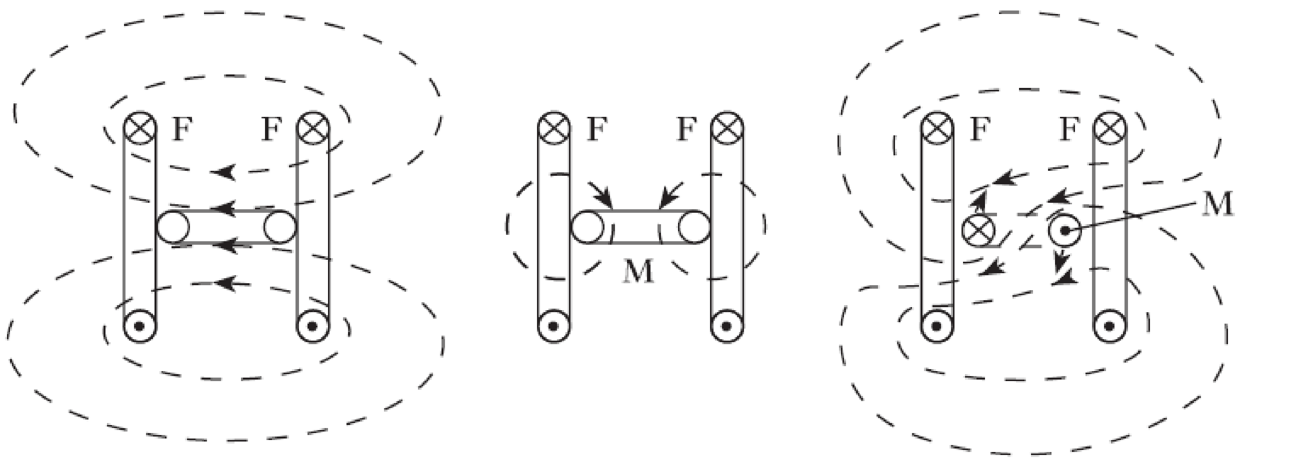


Deflecting force on each side of M

$\propto$ (current in M)

$\times$ (density of magnetic field due to current in F)

$\propto$ current in M $\times$ current in F



Electrodynamic (Dynamometer) Wattmeter

- Owing to the higher cost and low sensitivity of dynamometer ammeters and voltmeters, they are rarely used commercially
- *However, electrodynamic* or *dynamometer wattmeters* are important and commonly employed for measuring power in a.c. circuits
  - Fixed coils F are connected in series with the load, moving coil M is connected in series with non-reactive resistor *R* across the supply

Instantaneous force on each side of M

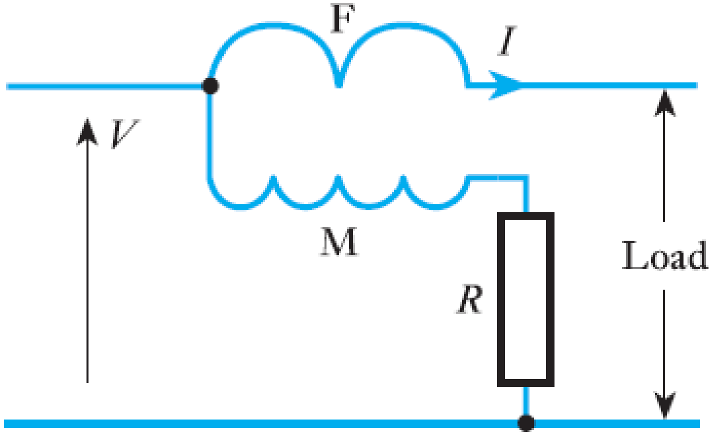
$\propto$ (instantaneous current through F)

$\times$ (instantaneous current through M)

$\propto$ (instantaneous current through load)

$\times$ (instantaneous p.d. across load)

$\propto$ instantaneous power taken by load

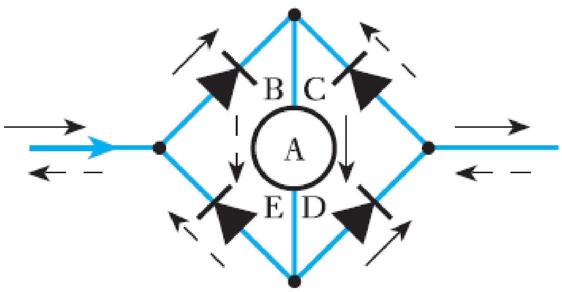


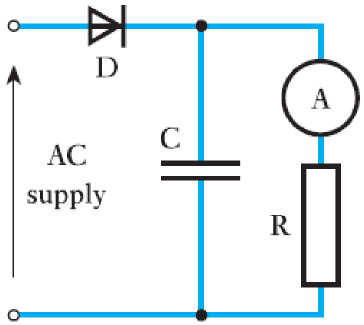
Average deflecting force on M

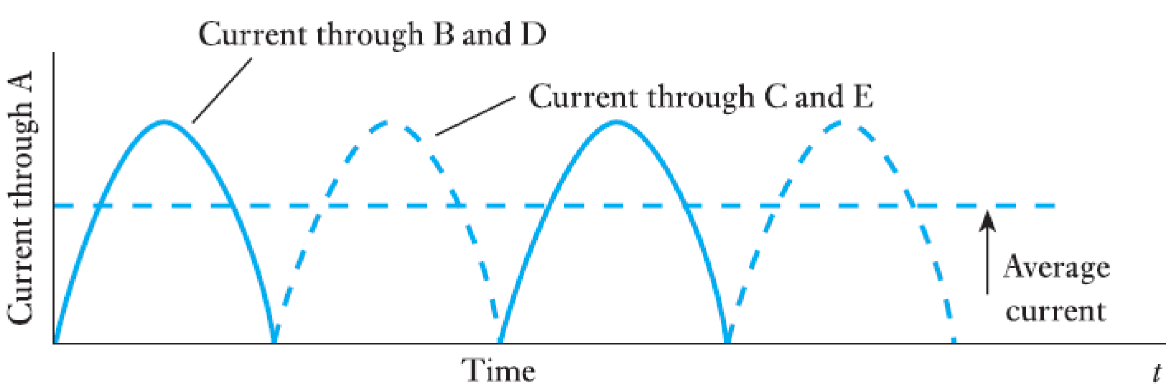
$\propto$ average value of the power over a complete number of cycles

Rectifier AC Ammeters and Voltmeters

- Rectifier is used to convert AC current into unidirectional current
  - Mean value is measured using MC type instrument
- Main advantage: far more sensitive than other types of AC voltmeter and can be incorporated in universal instruments (e.g., Avometer)
  - Enabling MC instrument to be used in combination with bridge rectifier and suitable resistors to measure various ranges of alternating current and voltage







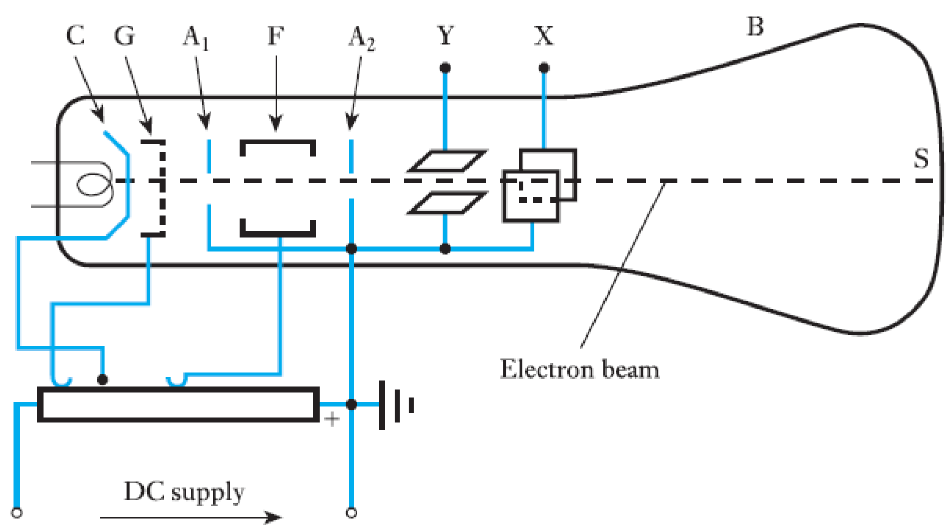
Oscilloscope

- Oscilloscope is the most important measuring device with graphical display
  - One of the most powerful diagnostic tools
  - Commonly used to measure exact wave shape of electrical signal, including the amplitude and frequency
  - Can also measure quantities such as pulse width, period and rise time, and can compare two signals and measure their relative timing
- Old technology relied on cathode-ray tube (CRT) display
  - Cathode Ray Oscilloscope (CRO)
- Modern technology uses LCD or LED screens

Cathode-Ray Tube

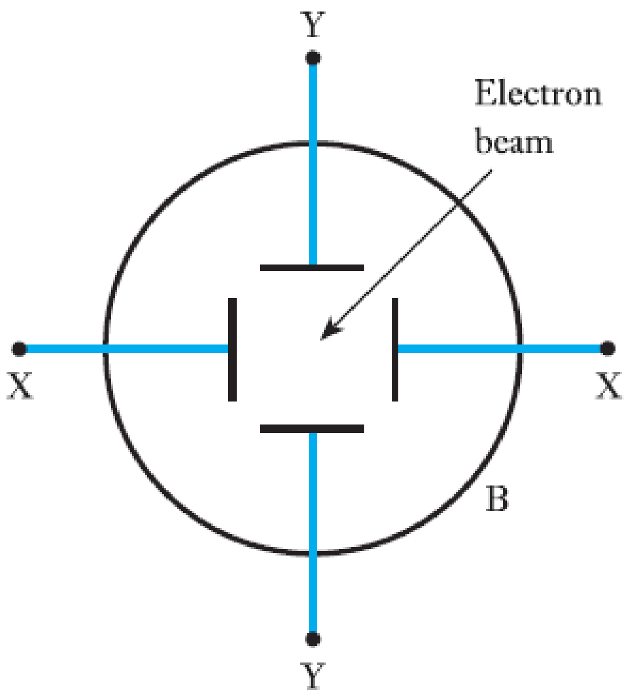
- Cathode-ray tube was an important component of both cathode-ray oscilloscope (CRO) and old TVs
  - CRO now known as analog oscilloscopes to distinguish them from the now almost universally used digital oscilloscope

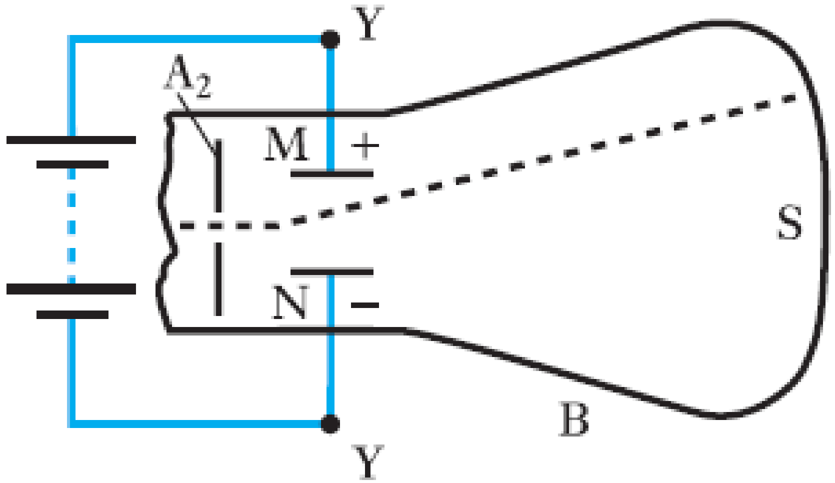
C	Indirectly heated cathode
G	Control grid with negative bias
A1/A2	Anode discs
F	Focusing electrode
X	Horizontal deflection plates
Y	Vertical deflection plates
S	Fluorescent screen
B	Glass bulb evacuated



Cathode-Ray Tube

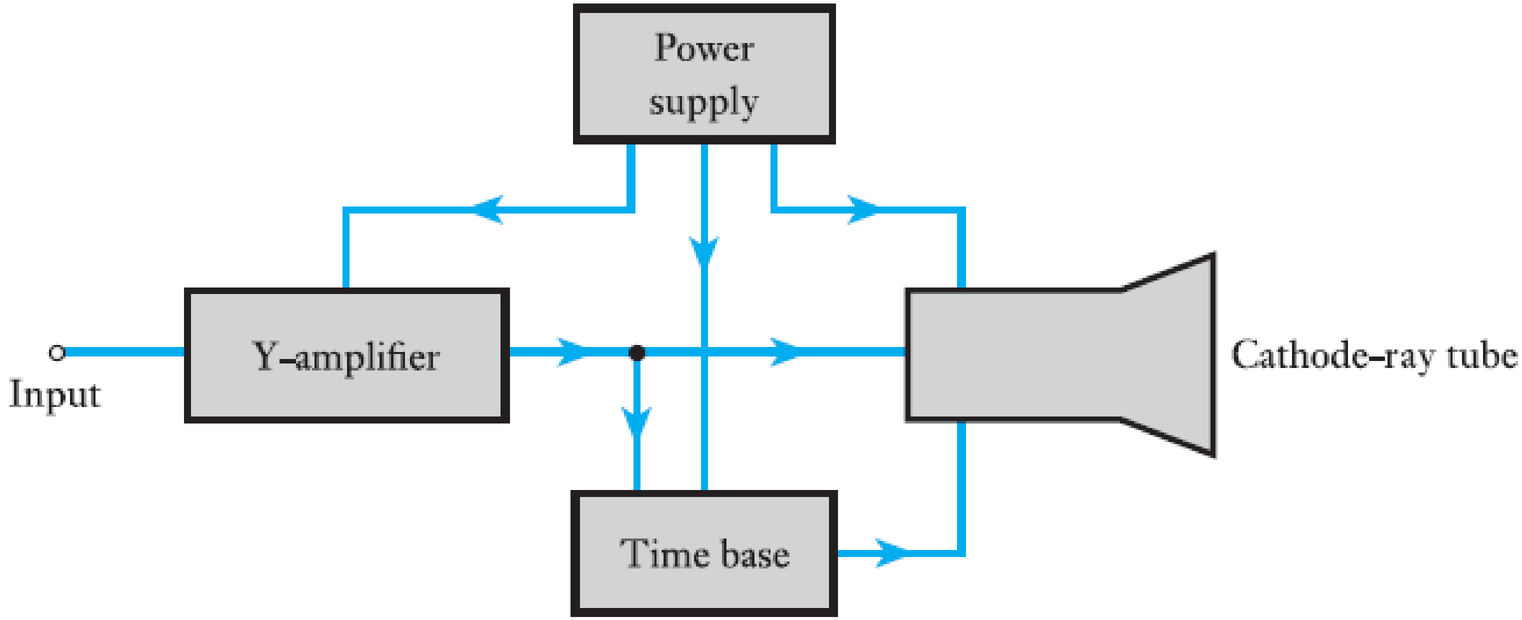
- Electron lens: combination of A1, A2 and F
- Electron gun: system of electrodes producing the electron beam
- Electrostatic deflection systems of cathode-ray tube: plates X and Y





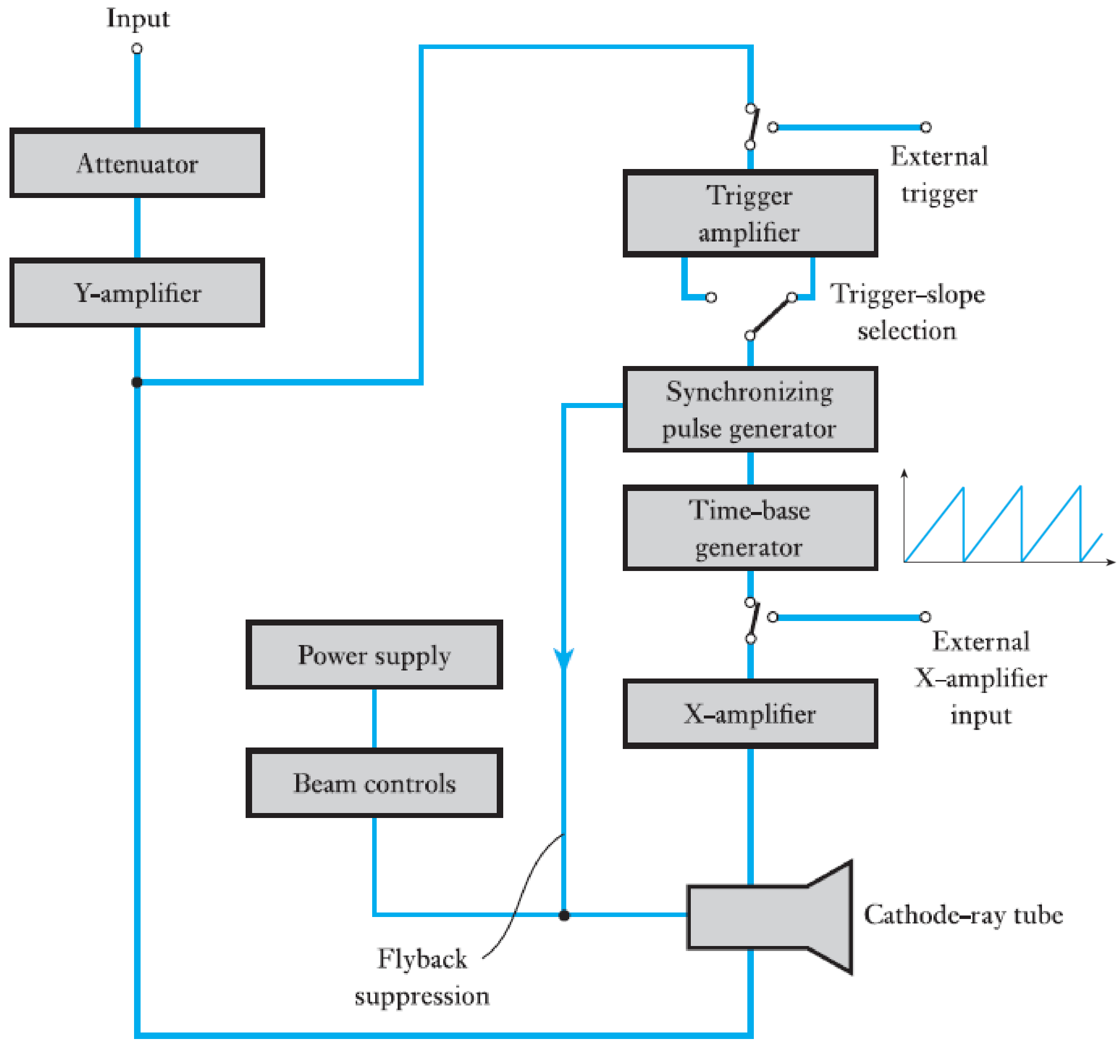
Cathode-Ray Oscilloscope (CRO)

- Input signal is amplified by Y-amplifier and causes beam to be driven up and down screen of CRT in Y direction
- Time base moves beam across the screen of the tube, in X-direction



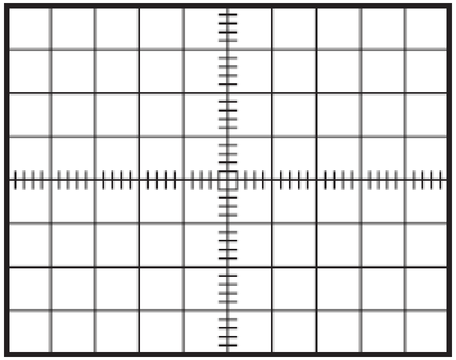
Cathode-Ray Oscilloscope (CRO)

- Detailed diagram

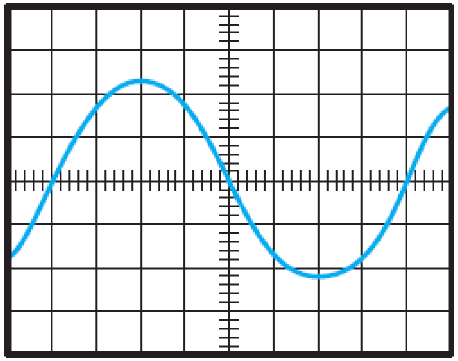


Waveform Measurement with CRO

- To aid observation of display on CRO, set of squares is marked on the transparent screen cover termed graticule
  - Graticules are marked out with a 1 cm grid and are generally 10 cm across by 8 cm high
  - To avoid parallax error, always observe trace directly through graticule and not from the side

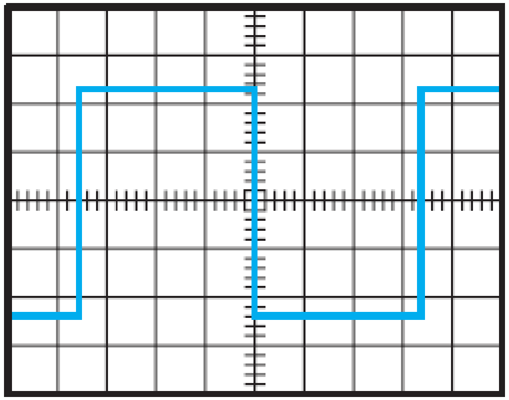


- Ex: Let vertical control be set to 2 V/cm and time-base control to 500 μs/cm:
  - Peak-to-peak height of display is 4.8 cm, hence the peak-to-peak voltage is $4.8 \times 2 = 9.6$ V
  - length of one cycle of display is 8.0 cm, hence the period of the waveform is $8 \times 500 \times 10^{-6} = 4$ ms and frequency of signal is 250 Hz



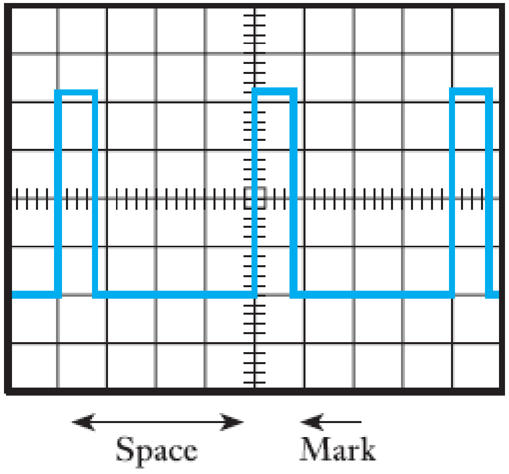
Examples

The trace displayed by a CRO is as shown in Fig. 45.20(a). The signal amplitude control is set to 0.5 V/cm and the time-base control to 100 s/cm. Determine the peak-to-peak voltage of the signal and its frequency.



(a)

An oscilloscope has the display shown in Fig. 45.20(b). The signal amplitude control is set to 0.2 V/cm and the time-base control to 10 s/cm. Determine the mark-to-space ratio of the pulse waveform and the pulse frequency. Also determine the magnitude of the pulse voltage.

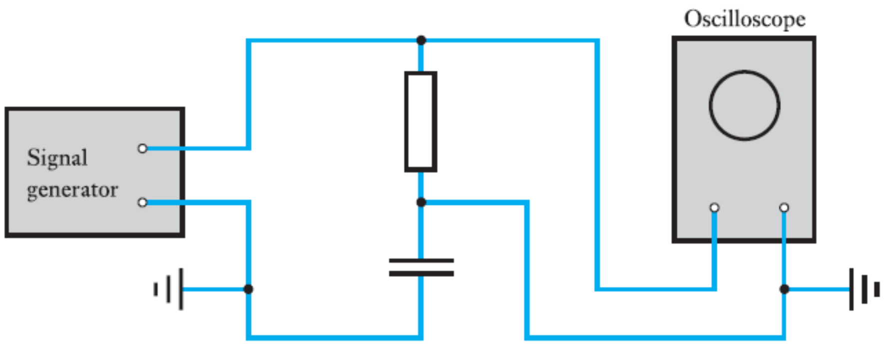


(b)

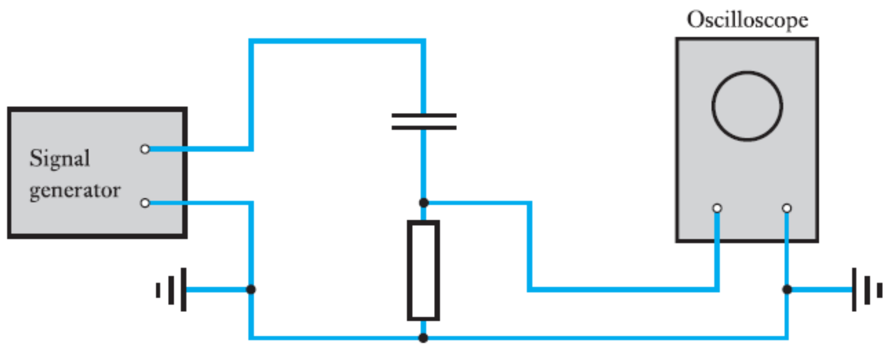
Oscilloscope Connection

- Most oscilloscopes operate with the body or chassis of the instrument at earth potential
- Also, most oscilloscopes are connected to the signal source by means of a coaxial cable, the outer conductor of which is connected to the body of the oscilloscope and is therefore at earth potential
- It follows that one of the connections from the oscilloscope will connect one terminal of the signal source to earth

Unsuitable Connection

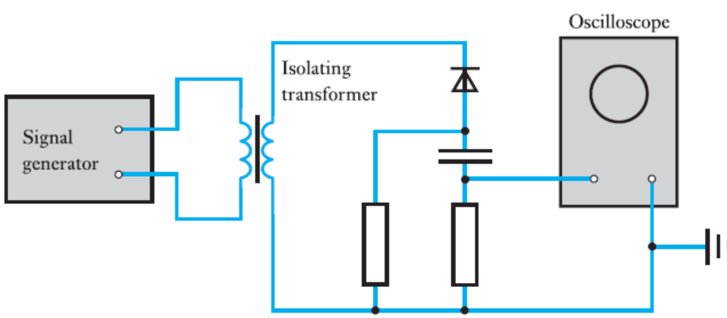


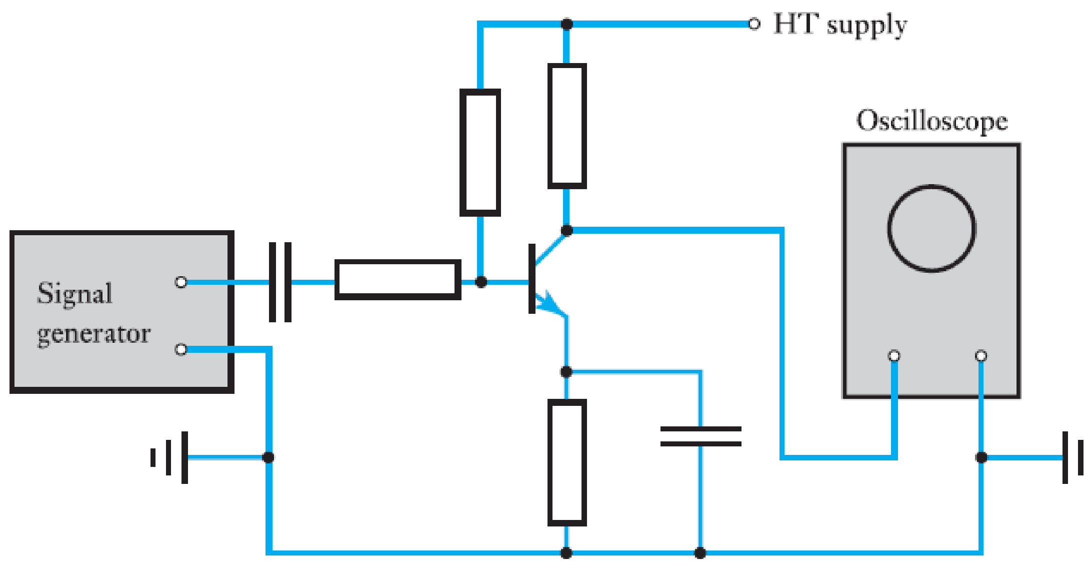
Suitable Reconnection



Oscilloscope Connection Challenges

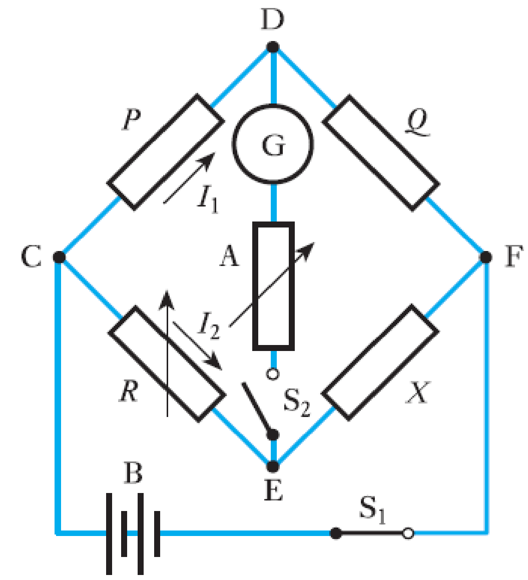
- Amplifier transistor circuit shown could not be reconnected in order to observe the voltage across the base–collector junction
- Method 1: Isolation of the source from earth
- Method 2: Isolation of the load from the source
- Method 3: Dual-trace measurements
- Method 4: Isolation of the oscilloscope from earth





Null method: Measurement of Resistance by Wheatstone Bridge

- Bridge has two known resistances P and Q, known variable resistance R and the unknown resistance X
- Battery B is connected through switch S1 to C and F
- Galvanometer G, variable protection resistor A and switch S2 are in series across D and E
- With S1 and S2 closed, R is adjusted until there is no deflection on G
  - Very accurate because no loading effect is involved



$$PI_1 = RI_2$$

$$QI_1 = XI_2$$

$$\frac{Q}{P} = \frac{X}{R}$$

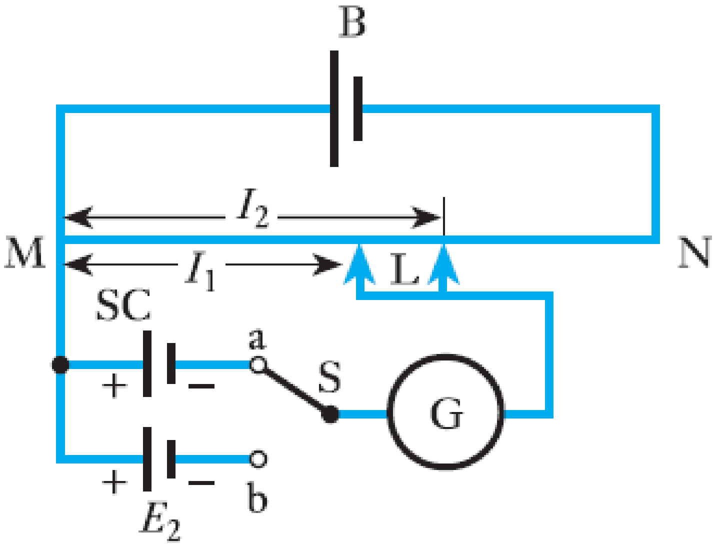
$$X = R \times \frac{Q}{P}$$

Null Method: Measurement of Voltage by Potentiometer

- One of the most accurate instruments for measuring voltage
- Slider L position is adjusted until the galvanometer deflection is zero
  - First time: for E1 (SC) and find length between M and L (l_1)
  - Second time: for E2 (Unknown) and find length between M and L (l_2)
- Main advantage: no current flows at balance
  - Very accurate because no loading effect is involved

$$\frac{E_1}{E_2} = \frac{l_1}{l_2}$$

$$E_2 = E_1 \times l_2 / l_1$$



Suggested Readings and Exercises

- Hughes textbook – Chapter 45.8, 45.9, 45.10, 45.11, 45.12, 45.13 and Chapter 46.7, 46.9, 46.10, 46.11
- Exercise 45 (Hughes)
  - Problems 6, 8
- Exercise 46 (Hughes)
  - Problems 11, 15, 16, 17, 18, 23