Chapter 3.2
DC ammeters

- A generic D’Arsonval movement is limited to measuring whatever current produces a FSD.
- How can we increase the range of current that can be measured?
- Consider the following circuit:

![Circuit Diagram]

- We have modelled the ammeter as having the PMMC movement in series with a resistance $R_m$ which represents the coil resistance of the particular ammeter. If we add a resistor $R_s$ in parallel with the meter we can now develop the following:

$$I = I_s + I_{FSD}$$

$$V_m = I_{FSD}R_m$$

$$\therefore I_s = \frac{V_m}{R_s}; \quad R_s = \frac{V_m}{I_s} = \frac{I_{FSD}R_m}{I_s};$$

$$\therefore R_s = \frac{I_{FSD}R_m}{I - I_{FSD}}$$

- Therefore a value for $R_s$ exists that can be calculated based on the total current $I$, that we wish to measure. We call $R_s$ a shunt resistor.
- Its purpose is to bypass or shunt excess current greater than $I_{FSD}$ around the meter movement.

Example:
- Design an ammeter to measure 100mA using a 50μA PMMC meter movement with internal resistance 3kΩ.

Solution
- Using the same circuit arrangement as before:
\[ I_{FSD} = 50 \times 10^{-6} \text{ A} \]
\[ R_m = 3 \text{k}\Omega \]
\[ I = 100 \times 10^{-3} \text{ A} \]

\[ \therefore R_s = \frac{I_{FSD}R_m}{I - I_{FSD}} = \frac{50 \times 10^{-6} \times 3 \times 10^3}{100 \times 10^{-3} - 50 \times 10^{-6}} = 1.5 \Omega \]

**Note:** Since the total meter current is so much higher than the capability of the PMMC movement, we must bypass a significant amount of it. We would expect that the shunt should therefore be of small resistance in comparison to the PMMC.

### Multi-range Ammeter

- In practical terms, ammeters with a single range are not very useful;
- Some exceptions
  - *Marine meters-voltage, fuel*
  - *Power station meters - voltage, frequency*
  - *Automotive meters - ammeter, tachometer*
  All of which have one useful range
- How can we now make an ammeter to measure several ranges at once? One approach is to have a **separate shunt** resistor for each range and we can calculate each resistor value of the shunt as we just did. Consider the following circuit:

- By the **position** of the switch, one of R1 to R4 would be connected as a shunt across the meter.
- Can you identify a problem with the above arrangement?
- What happens if as the switch is moved from position 1 to position 2 say, it momentarily loses contact with both 1 and 2 while still carrying current?
• At that point, the PMMC movement will be forced to pass a current that may be \( I_{FSD} \). This will most likely destroy the meter, or at best blow a fuse.

• This can be solved in 2 ways
  – A make-before-break switch
  – A Universal or Ayrton Shunt

![Diagram of a make-before-break switch](image)

• The make-before-switch establishes contact with the next contact position **before losing contact** with the existing connection. In this manner, the shunt resistors are **never** removed from the circuit and the PMMC movement is **always** protected.

**The Universal or Ayrton shunt.**

• Consider the following circuit arrangement:

![Diagram of a universal or Ayrton shunt](image)

• Here, the shunt resistors, R1, R2 and R3, are all in **series** and **collectively in parallel** to the meter movement.

• Thus:

\[
R_S = R1 + R2 + R3
\]

• Let us connect input 1:
We can then say that:

\[ I_{S1} = \frac{I_{FSD} R_m}{(R_1 + R_2 + R_3)} \]

where \( I_{S1} \) is the shunt current for this switch position

- Note that this is identical to our previous calculations.
- Let us now analyse the ammeter in switch position 2

• Note that for this situation, \( R1 \) is now in series with the meter and \( R2 \) and \( R3 \) form the shunt.
• Therefore:

\[ I_{S2} = \frac{V_{AB}}{(R_2 + R_3)} = \frac{I_{FSD}(R_1 + R_m)}{(R_2 + R_3)} \]

where \( I_{S2} \) is the shunt current for this switch position

• In switch position 3 we have:
• Therefore,

\[ I_{S3} = \frac{I_{FSD}(R_1 + R_2 + R_m)}{R_3} \]

where \( I_{S3} \) is the **shunt current** for this switch position

**Disadvantages**

• The main **disadvantage** of the Universal shunt concerns the shunt resistors. What happens if \( R_1, R_2 \) or \( R_3 \) changes value or fails? The overall accuracy of this type of arrangement is **entirely dependent** on all of the shunt resistors.

• **Precautions using an ammeter**
  • *Never* connect an ammeter across a source of emf. Why?
    – **Think of the value of** \( R_m \) **and** \( I_{FSD} \)
  • **Observe polarity** when connecting the ammeter in circuit
  • When using a multi-range ammeter, start with the **highest range**, then **decrease** to get the highest reading for a particular current.
    – **The nearer** the FSD, **the better** the accuracy.