EMBS Hardware Circuits – Equation Sheet

📏 Symbols & Units

- **V** = Voltage (Volts, **V**, mV, µV)
- **I** = Current (Amperes, **A**, mA, µA)
- **R** = Resistance (Ohms, **Ω**, kΩ, MΩ)
- **Q** = Charge (Coulombs, **C**)
- **C** = Capacitance (Farads, **F**, µF, nF, pF)
- **f** = Frequency (Hertz, **Hz**)
- **f_c** = Cutoff frequency (Hz)
- **R_{in}, R_f** = Input and feedback resistors (Ω)

🔌 Ohm's Law

$$V = I \cdot R$$

- Voltage = Current × Resistance.
- Used to size resistors, check circuit behavior.

Kirchhoff's Laws

KCL (Current Law):

$$\sum I_{in} = \sum I_{out}$$

At a node, total current in = total current out.

KVL (Voltage Law):

$$\sum V_{loop} = 0$$

- Around a loop, voltage rises = voltage drops.

Voltage Divider

$$V_{out} = V_{in} \cdot (R_2 / R_1+R_2)$$

- Scales down a voltage (e.g., sensor output into ADC).

Capacitors

Charge:

$$Q = C \cdot V$$

Current–Voltage Relationship:

$$I(t) = C \cdot (dV(t) / dt)$$

- Capacitors block DC, pass AC (used for filtering biosignals).
- Current through capacitor = capacitance * change in voltage over time

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RC Low-Pass Filter

(Cuts out high-frequency noise, passes slow/biological signals)

$$f_c=1 / 2\pi RC$$

- f_c = cutoff frequency
- R = resistance in Ohms
- C = capacitance in Farads

RC High-Pass Filter

(Removes baseline drift, passes faster changes)

$$f_c = 1 / 2\pi RC$$

- f_c = cutoff frequency
- R = resistance in Ohms
- C = capacitance in Farads

Operational Amplifier (Op-Amp)

Gain:

$$\text{Gain} = V_{out} / V_{in}$$

- V_{out} = output voltage amplitude
- V_{in} = input voltage amplitude

Inverting Amplifier:

$$V_{out} = -(R_f / R_{in})V_{in}$$

Non-Inverting Amplifier:

$$V_{out} = (1 + R_f / R_{in})V_{in}$$

Buffer (Voltage Follower):

$$V_{out} = V_{in}$$
