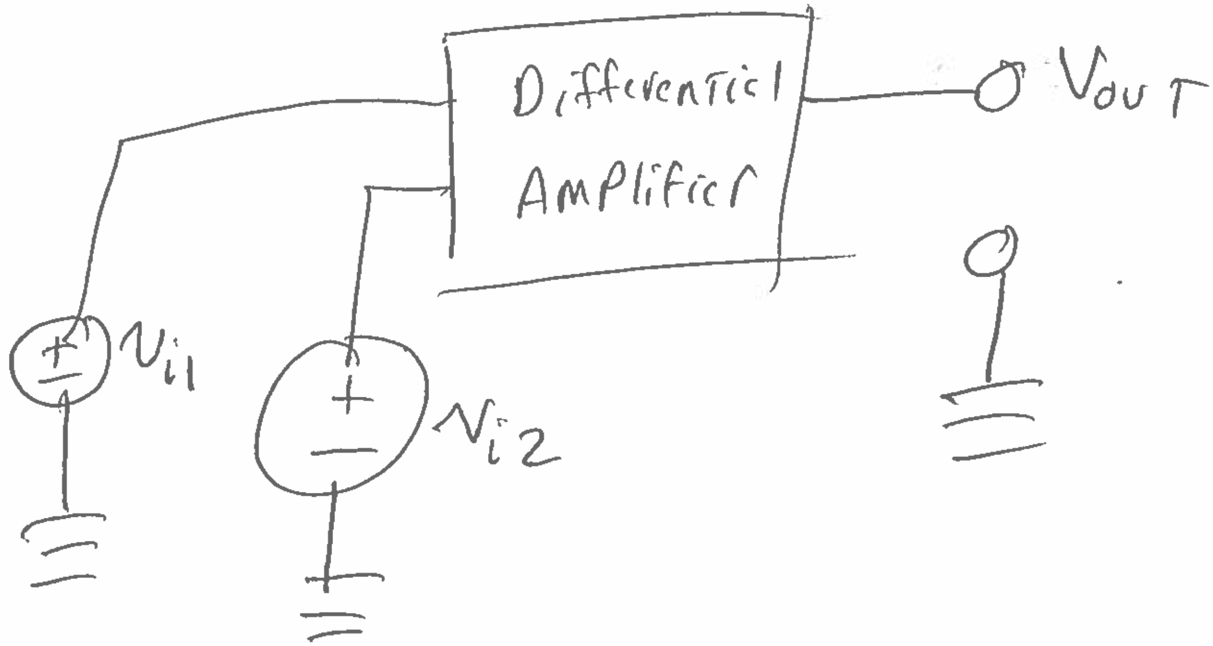


ideally $\Rightarrow$ $V_O = G_D\left(v_{i1} - v_{i2}\right)$

$v_{di} = v_{i1} - v_{i2}$ $\Rightarrow$ differential input signal

G_D is the differential Gain

$$G_D = \frac{V_O}{v_{di}}$$

However there also exists v_{cmi} known as common mode input voltage

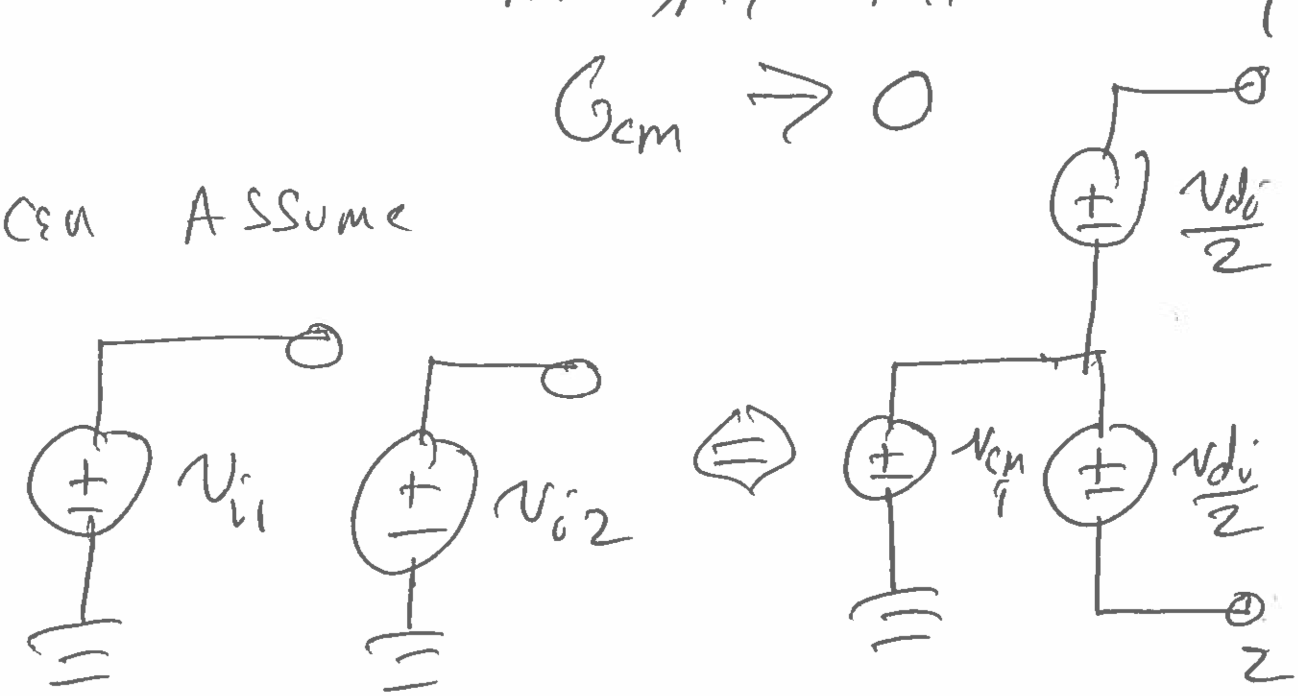
$$v_{cmi} = \frac{v_{i1} + v_{i2}}{2} = \text{average value of } v_{i1}, v_{i2}$$

$$G_{cm} = \frac{v_o}{v_{cmi}}$$

You would prefer Amplifier didnot Amplyfy this

$G_{cm} \Rightarrow 0$

We can Assume



Theoretically $v_o = G_D v_{Di} + G_{cm} v_{cmi}$

We like $G_{cm} \Rightarrow 0$

CMRR – common mode Rejection Ratio

$$CMRR = 20\log\left(\frac{|G_D|}{|G_{cm}|}\right) = f(\omega)$$

freq

At 60hz CMRR of ~120dB is considered Good.

$$120\,dB = 20\log\left(\frac{G_D}{G_{cm}}\right)$$

$$6 = \log\left(\frac{G_D}{G_{cm}}\right.$$

$$10^6 = \frac{G_D}{G_{cm}} \Rightarrow G_D = 10^6\,G_{cm}$$

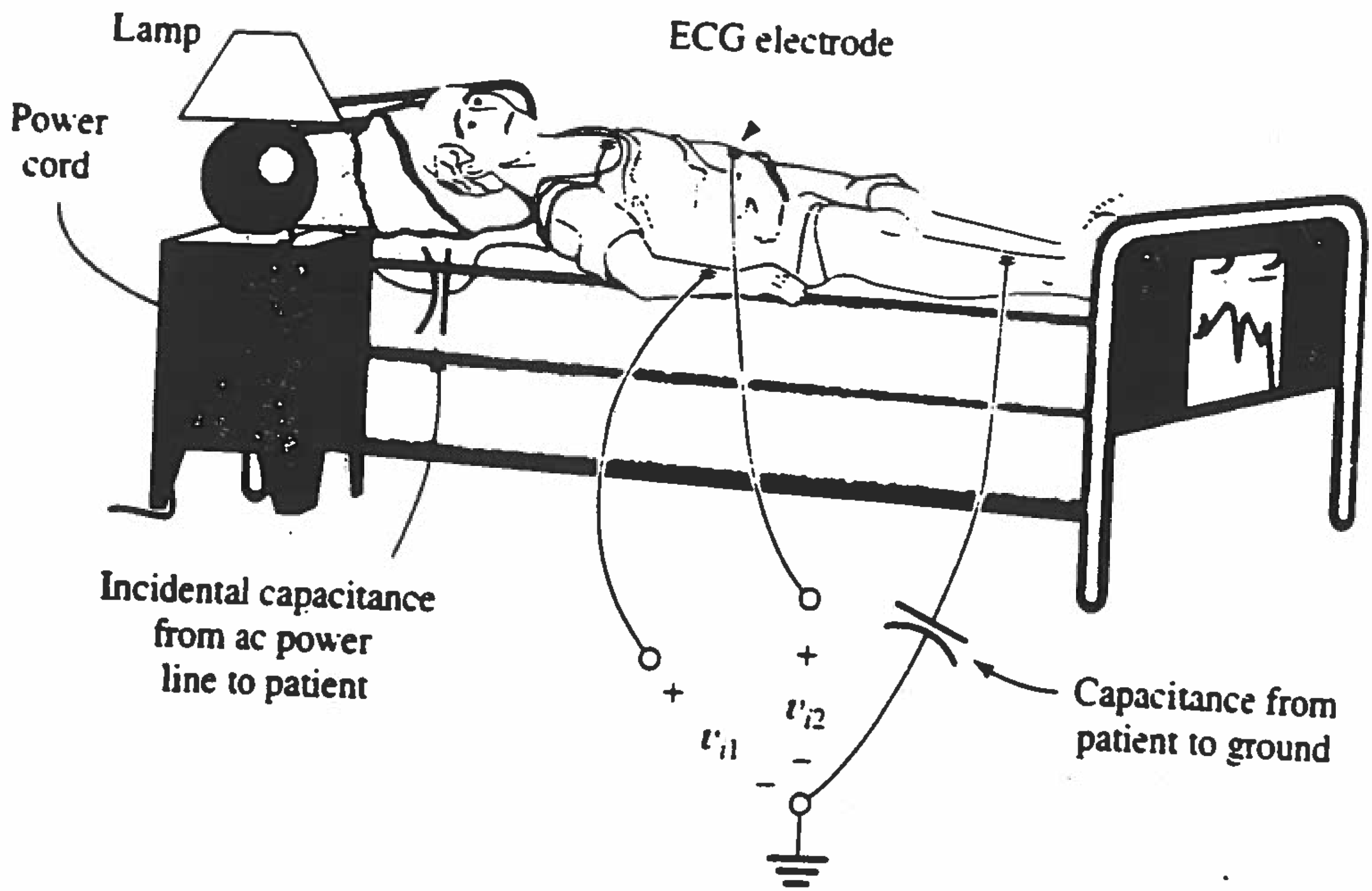
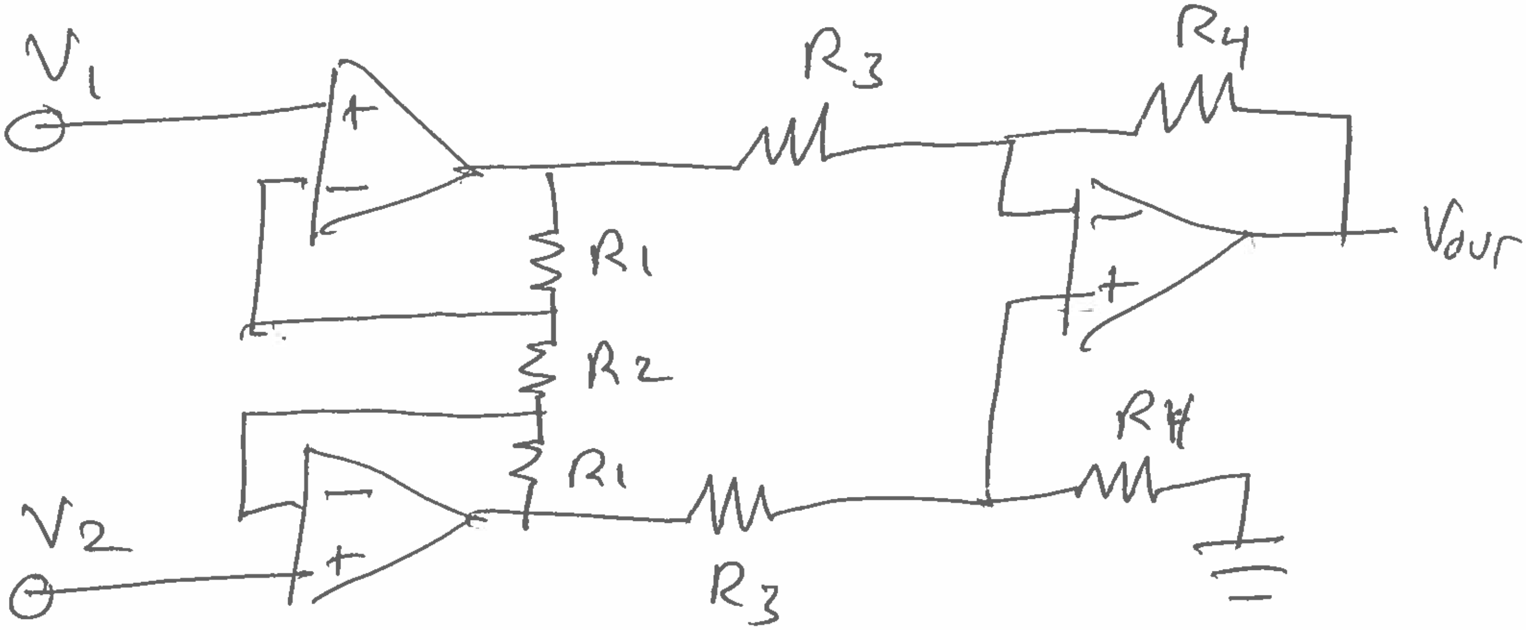


Figure 1.45 Electrocardiographs encounter large 60-Hz common-mode signals.

To fix this situation we use an

Instrumentation Amplifier.



essentially voltage followers

Difference Amplifier

$$V_{out} = \frac{R_4}{R_3}\left(1 + \frac{2R_1}{R_2}\right)(V_2 - V_1)$$

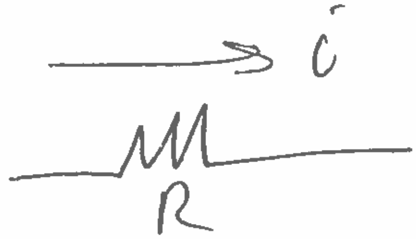
if $R_2 = 2R_1$

$$V_{out} = 2\left(\frac{R_4}{R_3}\right)(V_2 - V_1)$$

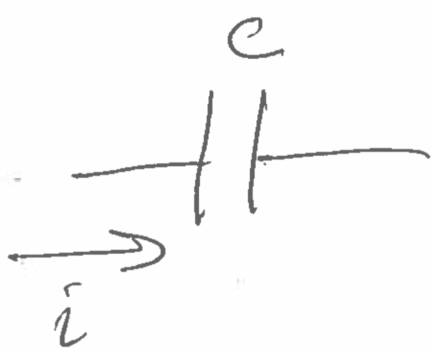
Difference Amp has relatively low impedance

Instrumentation Amp has high impedance

· Resistor matching much less critical in instrumentation amp than in difference amp.



Ohm's Law $\Rightarrow i = \frac{1}{R} V$



in D.C. current flows until capacitor is fully charged.

in A.C. current flows during periods when capacitor is not fully charged

$$i = \frac{1}{X_C} V$$

Ohm's Law now

X_C is called capacitive reactance.

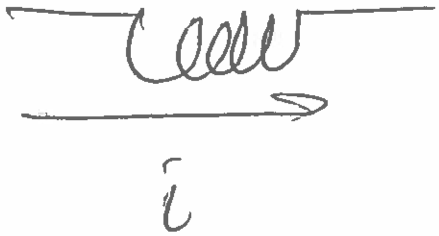
$\sqrt{-1}$

$$X_C = \frac{i}{wC}$$

so as $w \uparrow$ $X_C \downarrow$

as $w \to 0$ $X_C \to \infty$

open circuit



when i starts i induced opposes i

$$i = \frac{1}{X_L} V$$

At DC i is constant

coil appears to be wire (short circuit)

$$X_L = i\omega L$$

as $\omega \to \infty$ $X_L \to \infty$

open circuit

as $\omega \to 0$ $X_L \to 0$

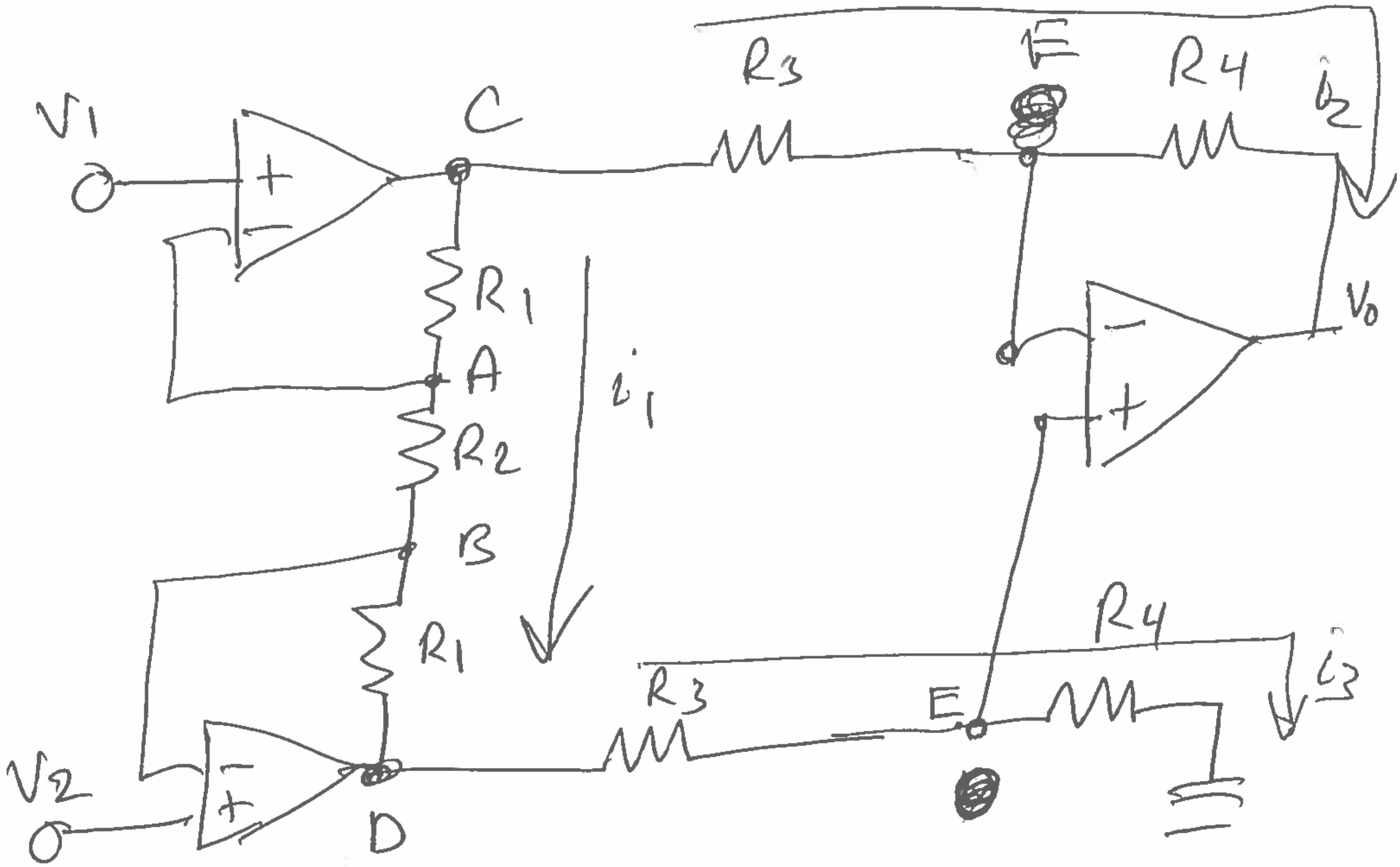
short circuit

Impedence Z

$$Z = \sqrt{(X_L - X_c)^2 + R^2}$$

ohms Law in AC $\Rightarrow$ $i = \frac{1}{Z} V$

ELI The ICE Man



$$i_1 = \frac{V_1 - V_2}{R_2} \qquad V_C = V_1 + i_1 R_1$$

$$V_D = V_2 - i_1 R_1$$

$$V_C = V_1 + \frac{V_1 - V_2}{R_2} R_1 = V_1\left(1 + \frac{R_1}{R_2}\right) - V_2\left(\frac{R_1}{R_2}\right)$$

$$\boxed{V_C = V_1\left(1 + \frac{R_1}{R_2}\right) - V_2\left(\frac{R_1}{R_2}\right)}$$

$$\boxed{V_D = V_2\left(1 + \frac{R_1}{R_2}\right) - V_1\left(\frac{R_1}{R_2}\right)}$$

$$i_3 = \frac{V_D - V_E}{R_3} = \frac{V_E}{R_4}$$

$$V_D = V_E\left(\frac{R_3}{R_4} + 1\right)$$

$$\boxed{V_E = V_b\left(\frac{R_4}{R_4 + R_3}\right)}$$

$$i_2 = \frac{V_C - V_E}{R_3} = \frac{V_E - V_0}{R_4}$$

$$\frac{R_4}{R_3} V_c - \frac{R_4}{R_3} V_E = V_E - V_o$$

$$V_o = V_E\left(1 + \frac{R_4}{R_3}\right) - V_c \frac{R_4}{R_3}$$

$$V_0 = V_D\left(\frac{R_4}{R_4+R_3}\right)\left(\frac{R_3+R_4}{R_3}\right) - V_C\frac{R_4}{R_3}$$

$$V_0 = \frac{R_4}{R_3}\left(V_D - V_C\right)$$

$$V_0 = \frac{R_4}{R_3}\left[\left(V_2\left(1+\frac{R_1}{R_2}\right) - V_1\left(\frac{R_1}{R_2}\right)\right) - \left(V_1\left(1+\frac{R_1}{R_2}\right) - V_2\left(\frac{R_1}{R_2}\right)\right)\right]$$

$$= \frac{R_4}{R_3}\left[V_2\left(1+\frac{R_1}{R_2}+\frac{R_1}{R_2}\right) - V_1\left(\left(1+\frac{R_1}{R_2}\right)+\frac{R_1}{R_2}\right)\right]$$

$$\boxed{V_0 = \frac{R_4}{R_3}\left(1+\frac{2R_1}{R_2}\right)\left(V_2 - V_1\right)}$$

Advantages of Instrumentation Amp

1) $G_D = 1 + \frac{R_1}{R_2}$

$G_{cm} = 1$ if $\frac{R_1}{R_2} >> 1$

$G_D >> G_{cm}$