ECG measurement

Summary

- 2- Op-Amp differential amplifier
- Summing amplifier

→ Instrumentation amplifier

- ECG: sources of interference and solutions

Common and differential mode

In many applications what we need is the difference between two signals.

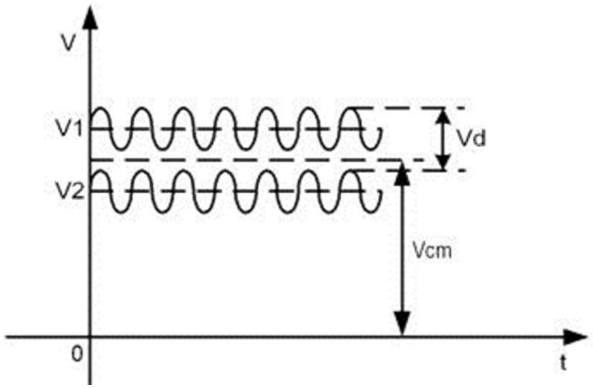
Every signal present in both v_1 and v_2 is noise.

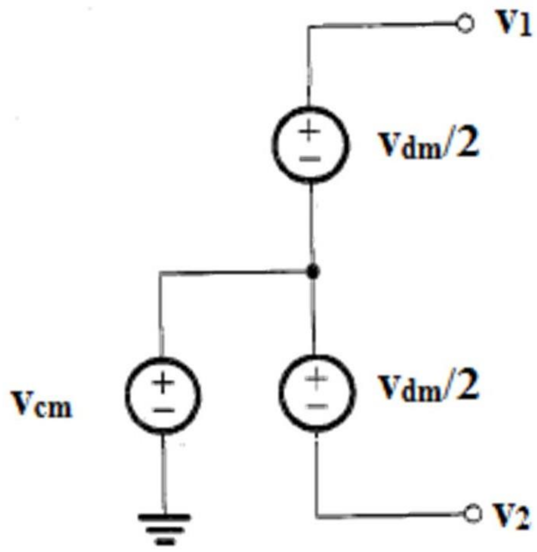
(e.g. EEG, EMG, other bio-potentials)

v_{cm} : unwanted common mode signal

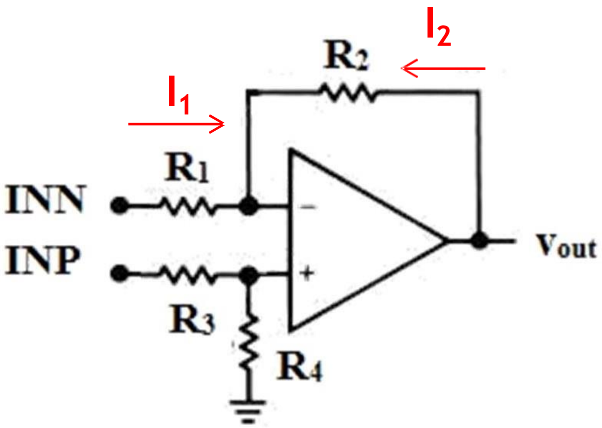
v_{dm} : desired differential mode signal

$$\begin{cases} v_{cm} = (v_1 + v_2)/2 \\ v_{dm} = v_1 - v_2 \end{cases} \Rightarrow \begin{cases} v_1 = v_{cm} + v_{dm}/2 \\ v_2 = v_{cm} - v_{dm}/2 \end{cases}$$





Summing amplifier



$$v_p = IN_P \frac{R_4}{R_4 + R_3} = v_n$$

$$I_1 = \frac{IN_N - v_n}{R_1} = \frac{1}{R_1}\left(IN_N - IN_P \frac{R_4}{R_3 + R_4}\right) = -I_2$$

$$V_{out} = R_2 I_2 + v_n$$

If $R_4 = R_2$ and $R_1 = R_3$:

$$V_{out} = (IN_P - IN_N)\frac{R_2}{R_1}$$

If $IN_P = IN_N$ => $V_{out} = 0$, $A_{cm} = 0$

If $IN_P \neq IN_N$ => $A_{dm} = R_2 / R_1$

CMMR

The extent to which common mode signal is suppressed, in respect to the amplification of the differential mode signal.

Common Mode Rejection Ratio :

$$CMRR = A_{dm} / A_{cm}$$

Usually expressed in dB:

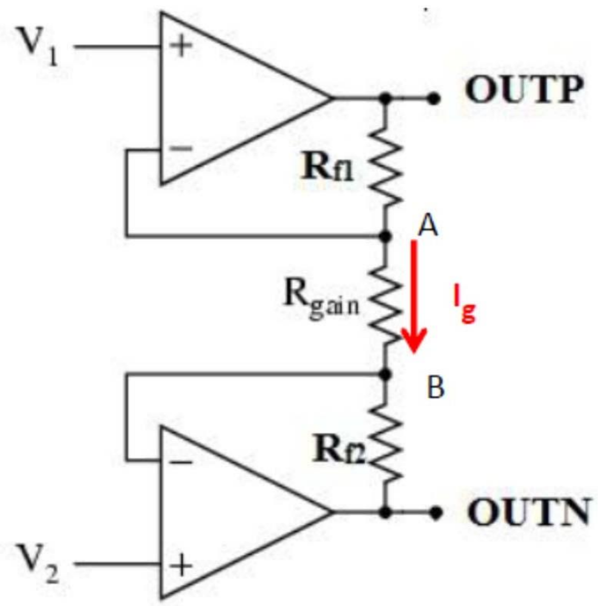
$$CMRR_{dB} = 20 \log_{10}(A_{dm}/A_{cm})$$

2 Op-Amp differential amplifier

$v_1 = v_{cm} + v_{dm}/2$
$v_2 = v_{cm} - v_{dm}/2$

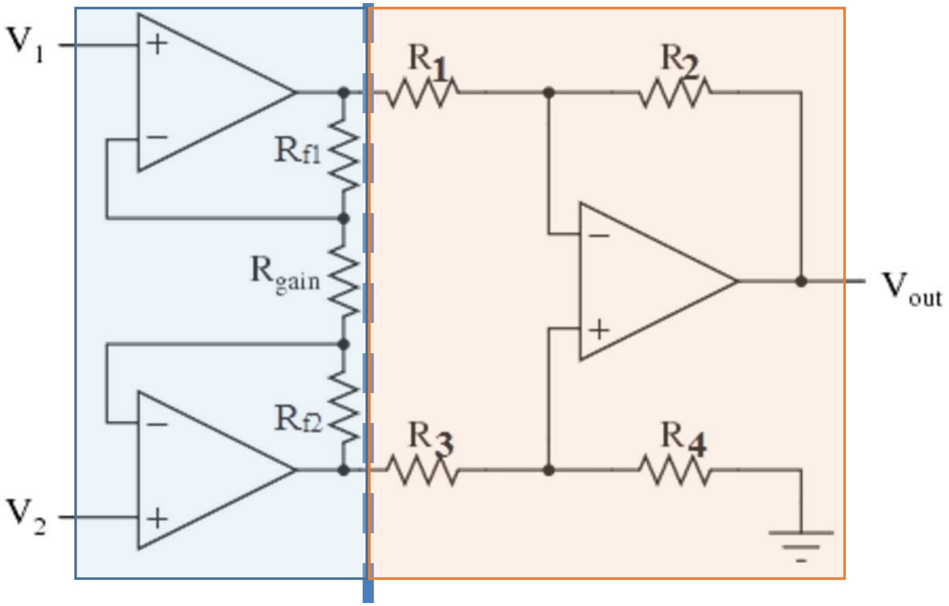
$I_g = (v_1 - v_2) / R_{gain} = v_{dm} / R_{gain}$

$V_{out} = (R_{f1} + R_{f2} + R_{gain}) * I_g$
$= (2 R_f + R_{gain}) * v_{dm} / R_{gain}$



Instrumentation amplifier

2 Op-Amp differential amplifier + summing amplifier



$V_{in} = V_1 - V_2$

$R_{f1} = R_{f2}$

$R_1 = R_3$

$R_2 = R_4$

$$V_{out} = \left(1 + \frac{2R_f}{R_{gain}}\right)\left(\frac{R_2}{R_1}\right) V_{in}$$

High CMMR

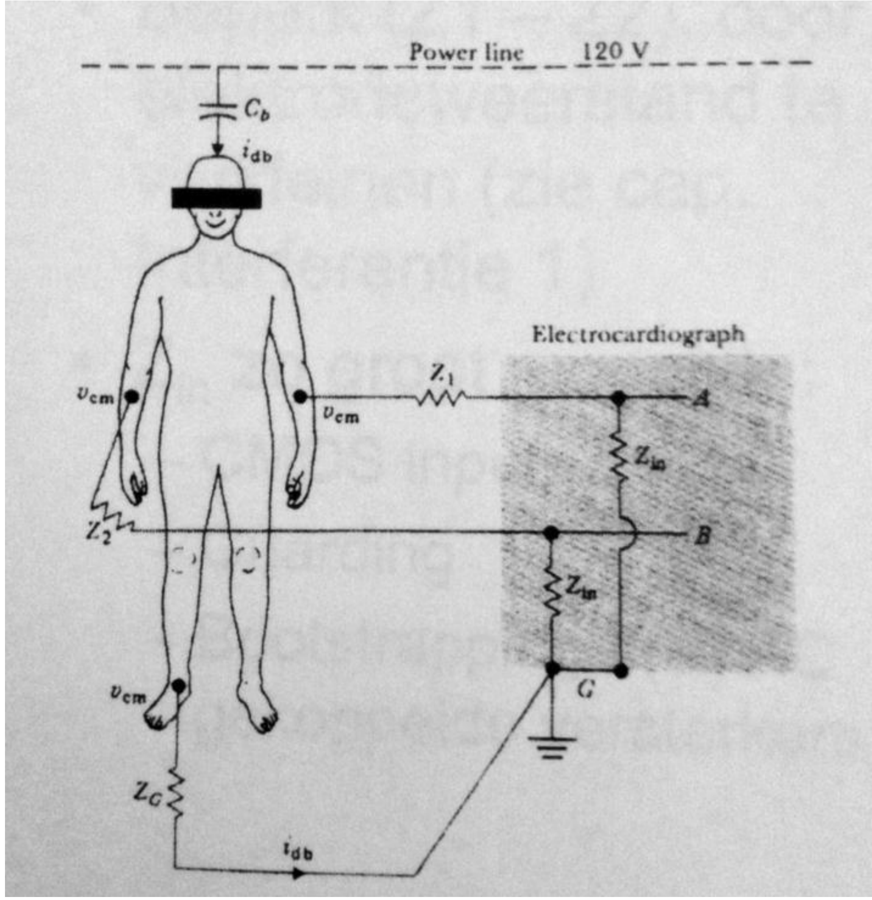
High Input impedance

→ Ideal as bio-potential amplifier

Sold as 1 IC component

ECG interferences

- Capacitive coupling of power lines (50 Hz) and radiation fluorescent lamps (100 Hz) on the lead wires of the electrodes
- Capacitive coupling of power lines on human body
- Inductive coupling on the lead wires
- Motion artifacts



The solutions

- Shielding: conductive layer around the conductor connected to lowimpedance pathways (*ground or power supply*)

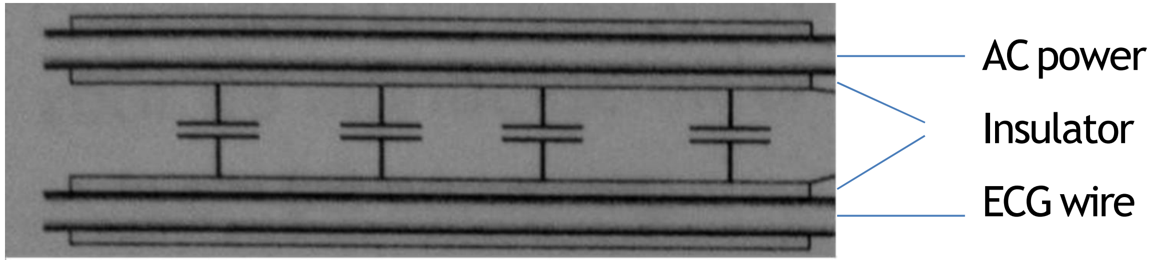
- Active control (Guarding) on:
  - Buffered input signal
  - Common mode signal

- Limiting electrode-skin resistance (e.g. *slightly abrade the epidermis*)

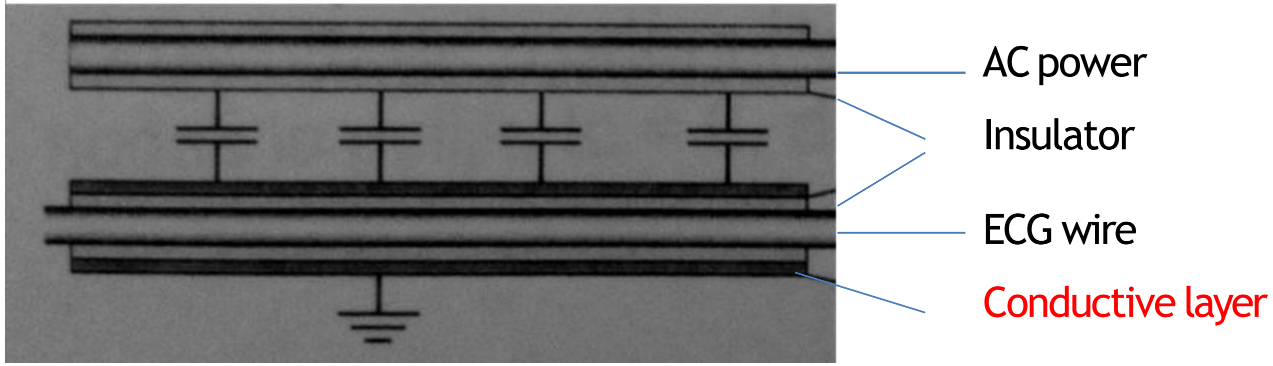
Shielding

With both shielding and guarding the capacitive coupling to the signal wires is efficiently reduced

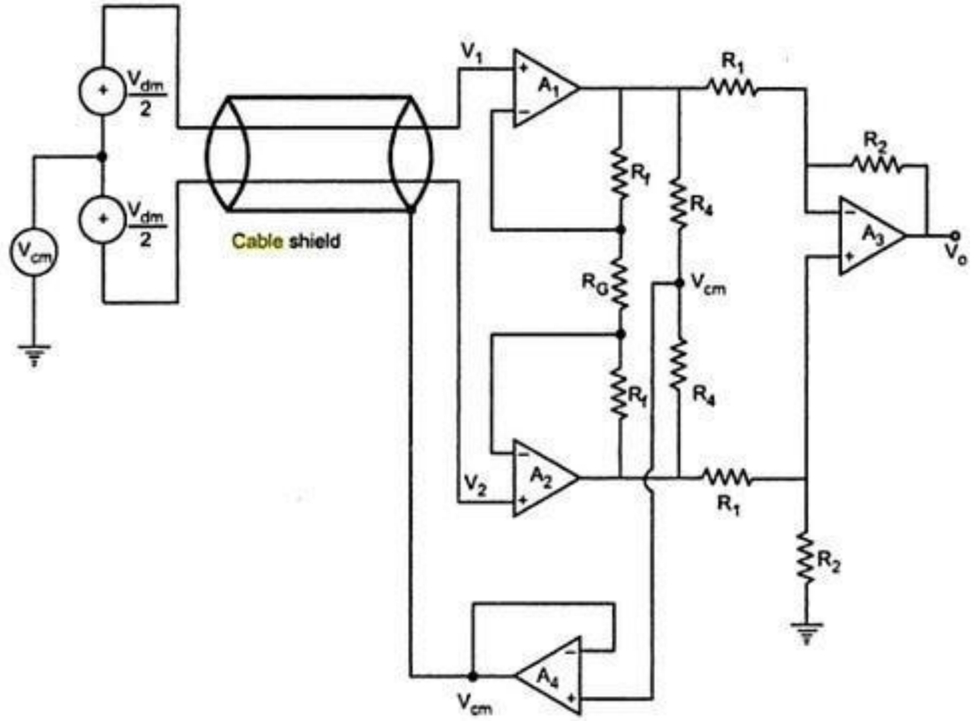
Without shield:



With shield and ground:

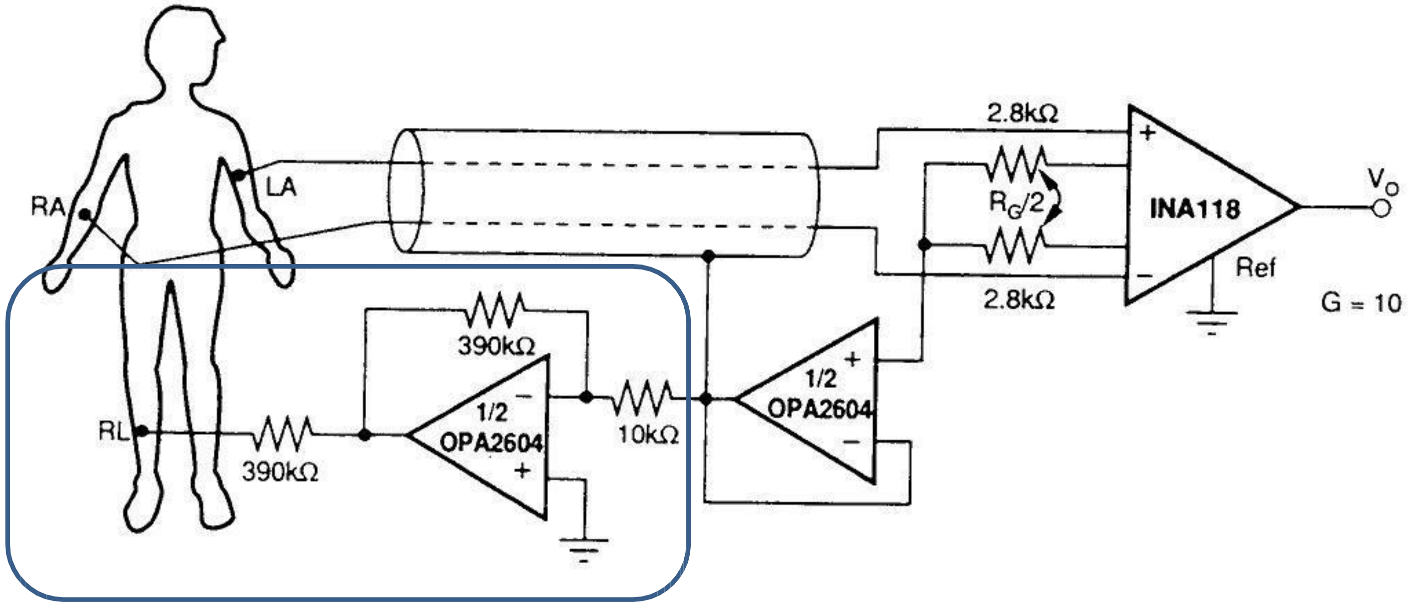


Input guarding



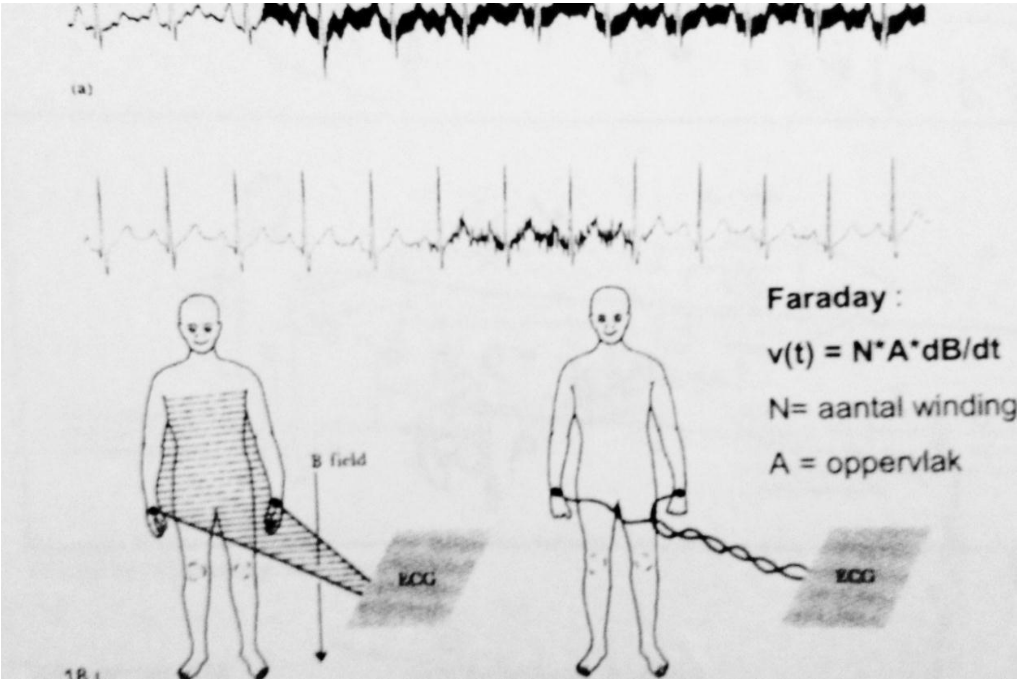
The common mode signal is obtained by two averaging resistors connected between outputs of the input Op-Amp of the instrumentation amplifier

Right leg drive



As for the input guarding of the shielding, we can measure the common mode and drive it actively in the right leg. This actively cancels common mode noise before it gets into the high gain stage where it could be amplified as a dm signal.

Inductive interference



The body together with the cables generates a coil. The magnetic field originated by all the electronic components in the environment induce currents in the coil, proportional to the surface of the coil.

Reducing the area of the coil reduces the inductive interference.