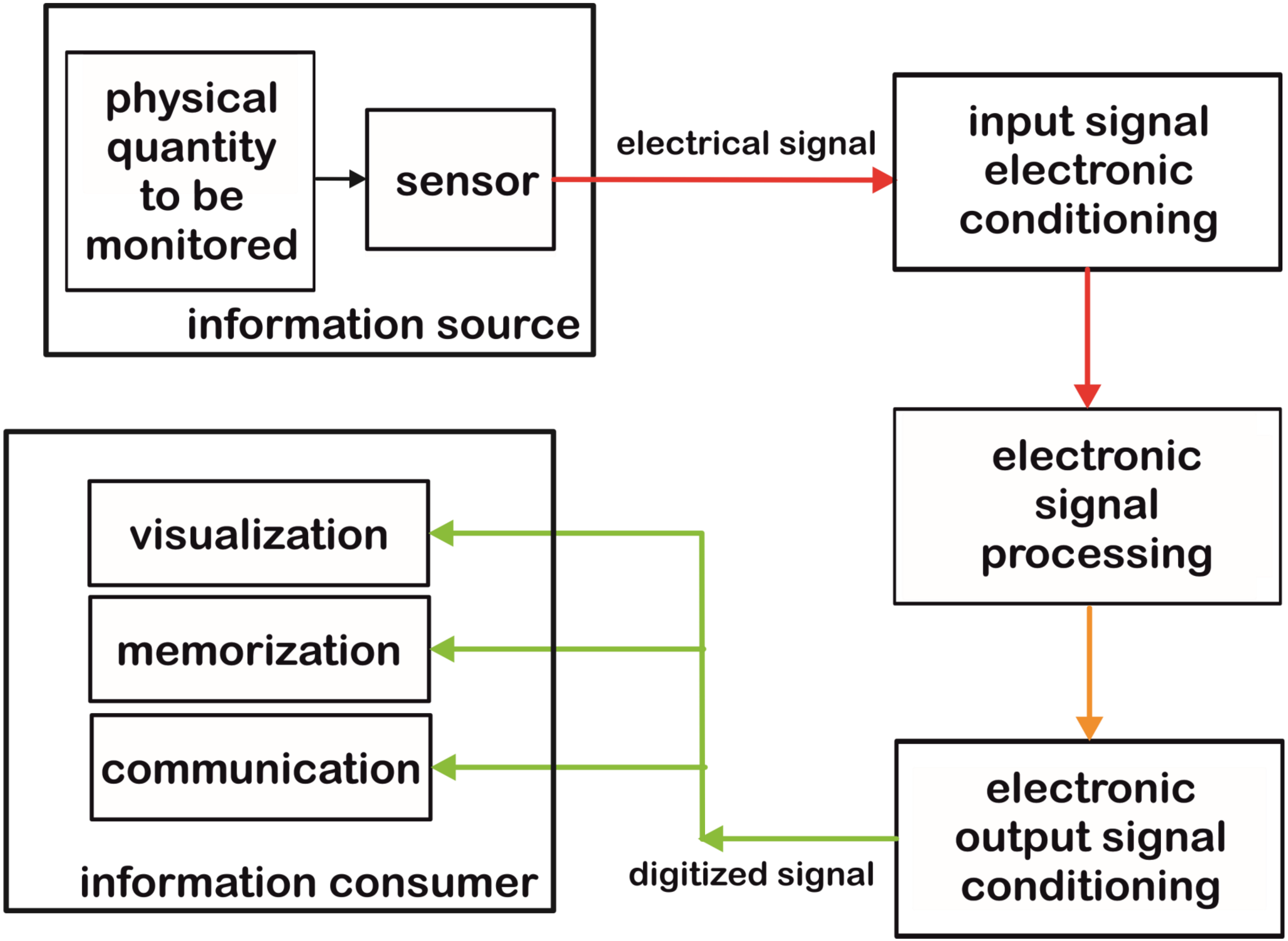
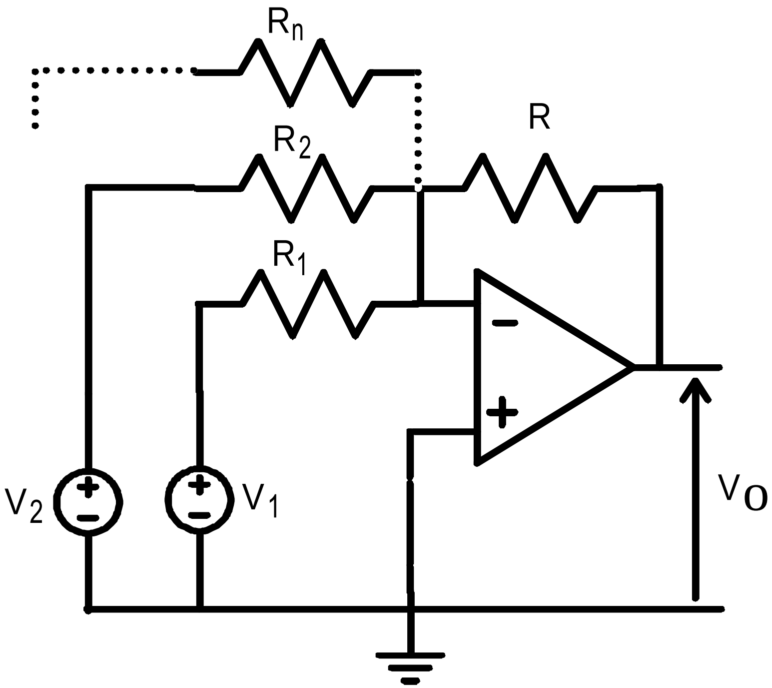
Measuring chain



Summing amplifier



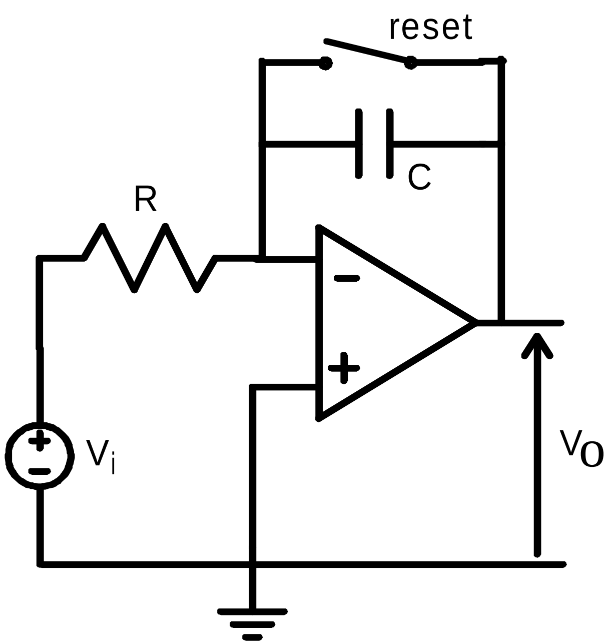
- $V_o = -R \cdot \left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \ldots \frac{V_n}{R_n} \right)$

setting $R_1 = R_2 = R_3 = R_n$

- $V_o = -\frac{R}{R_1} \cdot (V_1 + V_2 + \ldots V_n)$

- input impedance relatively small
- the gain can be different for each input
- the get an accurate sum it is necessary to use resistors with small tolerances

Integrator



- the reset switch is opened at the instant t=0:

- $$V_o(s) = -V_i(s) \cdot \frac{1/sC}{R} = -\frac{1}{s} \cdot \frac{V_i(s)}{RC}$$

$\Rightarrow$ $$V_o(s) = -V_i(s) \cdot \frac{1/sC}{R} = -\frac{1}{s} \cdot \frac{V_i(s)}{RC}$$

- **if there is a continuous component of the input signal then the circuit will saturate**
  - **the solution is the approximate integrator**
- **performances depend on the quality of the capacitor:**
  - **polypropylene and polystyrene capacitors**

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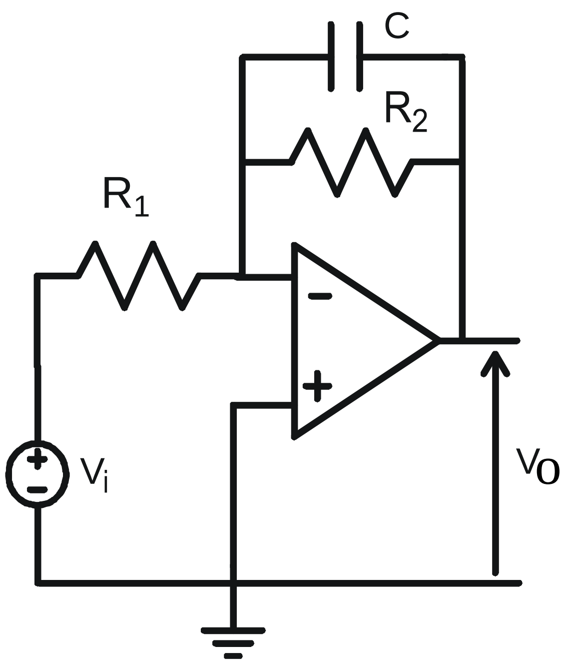
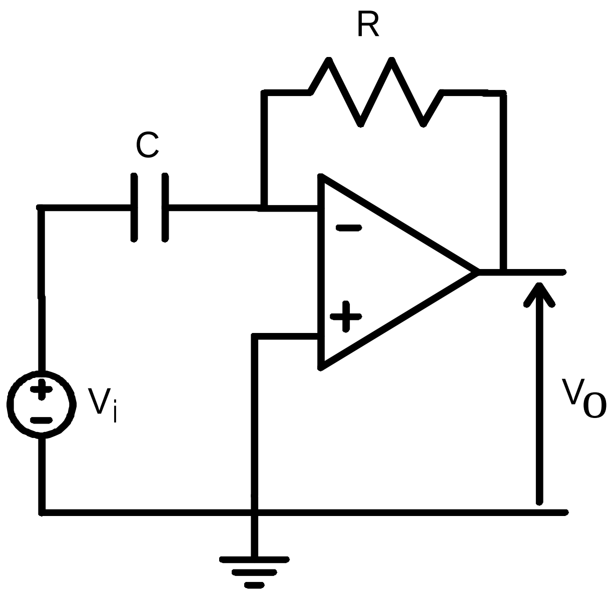
Approximate integrator



$$V_o(s) = -V_i(s) \cdot \frac{1}{R_1} \frac{R_2 \cdot 1/sC}{R_2 + 1/sC} = -\frac{R_2}{R_1\left(1 + sR_2C\right)} V_i(s)$$

Differentiator

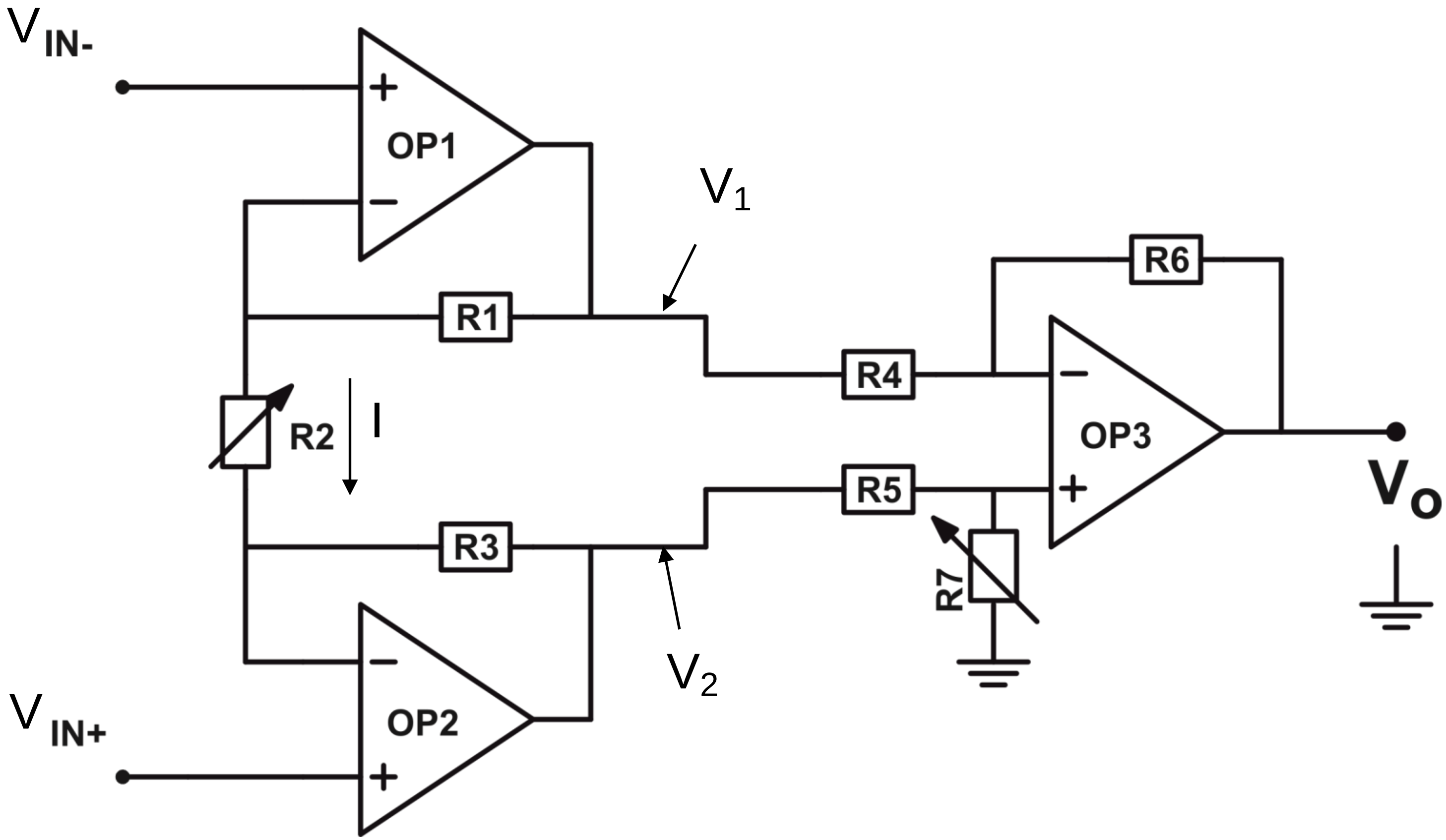


$$V_o(s) = -V_i(s) \cdot \frac{R}{1/sC} = -s \cdot RC \cdot V_i(s)$$

$$\Rightarrow \quad V_o(t) = -RC \cdot \frac{dV_i(t)}{dt}$$

- bias currents and offset voltages are not critical
- due to the non-idealities of the amplifier, the circuit may become unstable and may oscillate. A small resistor in series with C and a small capacitor in parallel with R can solve the problem.
- eventual noise at high frequency is amplified at the output

Instrumentation amplifier

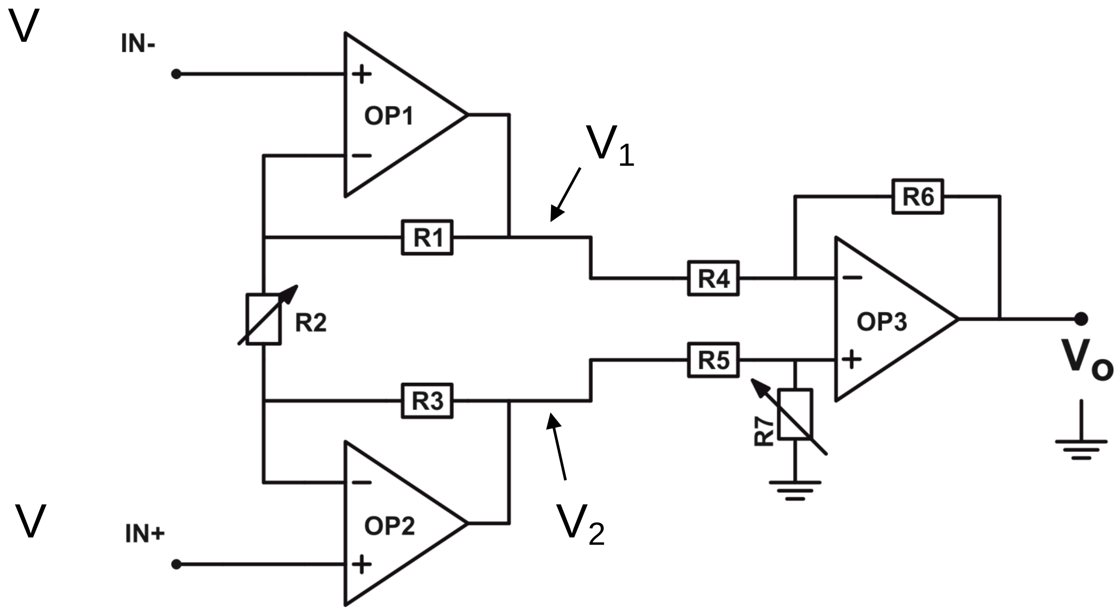


$$I = \left(\frac{V_{IN-} - V_{IN+}}{R_2} \right) \Rightarrow$$

$$V_1 = V_{IN-} + R_1 \cdot I = V_{IN-} + \frac{R_1}{R_2}\left(V_{IN-} - V_{IN+}\right)$$

$$V_2 = V_{IN+} - R_3 \cdot I = V_{IN+} - \frac{R_3}{R_2}\left(V_{IN-} - V_{IN+}\right)$$

continue …



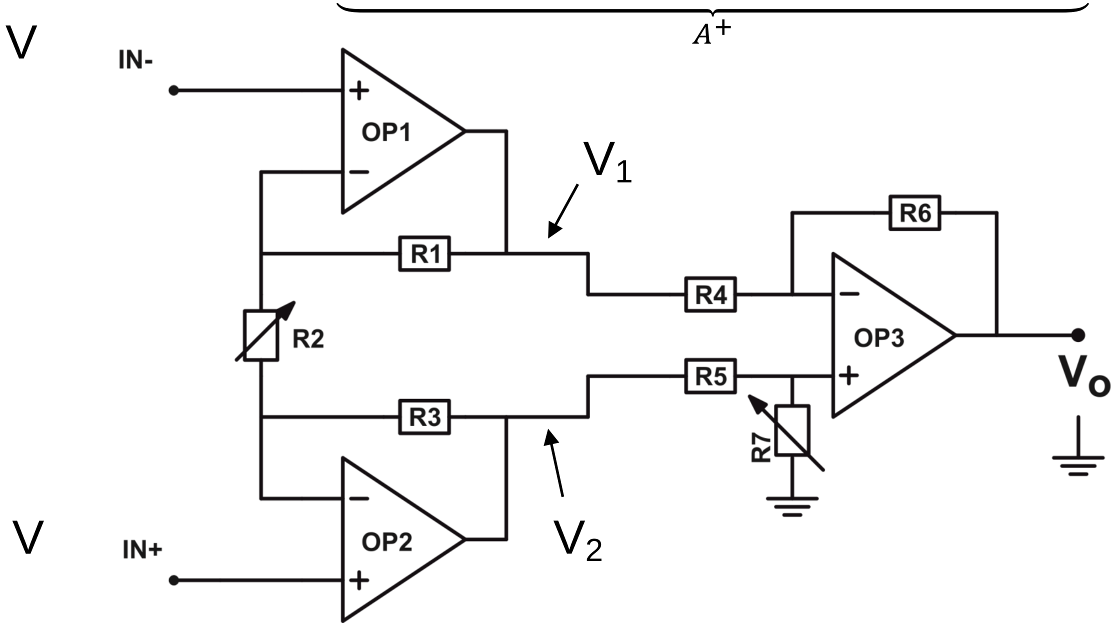
$$V_o = V_2 \cdot \frac{R_7}{R_5 + R_7} \cdot \left(1 + \frac{R_6}{R_4}\right) - V_1 \cdot \frac{R_6}{R_4}$$

$$V_o = \left(V_{IN+} - \frac{R_3}{R_2}(V_{IN-} - V_{IN+})\right) \cdot \frac{R_7}{R_5 + R_7} \cdot \left(1 + \frac{R_6}{R_4}\right) - \left(V_{IN-} + \frac{R_1}{R_2}(V_{IN-} - V_{IN+})\right) \cdot \frac{R_6}{R_4}$$

$$V_o = V_{IN+} \cdot \underbrace{\left[\frac{R_7}{R_5 + R_7} \cdot \left(1 + \frac{R_6}{R_4}\right) \cdot \left(1 + \frac{R_3}{R_2}\right) + \frac{R_1}{R_2} \cdot \frac{R_6}{R_4}\right]}_{G^+} - V_{IN-} \underbrace{\left[\frac{R_7}{R_5 + R_7} \cdot \left(1 + \frac{R_6}{R_4}\right) \cdot \frac{R_3}{R_2} + \frac{R_6}{R_4} \cdot \left(1 + \frac{R_1}{R_2}\right)\right]}_{G^-}$$

continue …

- **we want** $\underbrace{\left[\frac{R_7}{R_5+R_7}\cdot\left(1+\frac{R_6}{R_4}\right)\cdot\left(1+\frac{R_3}{R_2}\right)+\frac{R_1}{R_2}\cdot\frac{R_6}{R_4}\right]}_{A^+} = \underbrace{\left[\frac{R_7}{R_5+R_7}\cdot\left(1+\frac{R_6}{R_4}\right)\cdot\frac{R_3}{R_2}+\frac{R_6}{R_4}\cdot\left(1+\frac{R_1}{R_2}\right)\right]}_{A^-}$



- **by setting** $R_1 = R_3$, $R_5 = R_4$ **and** $R_6 = R_7$

- **we obtain:** $A^+ = A^- = \frac{R_6}{R_4}\left(1+\frac{2R_1}{R_2}\right)$