EECE356 – Electronic Circuits II

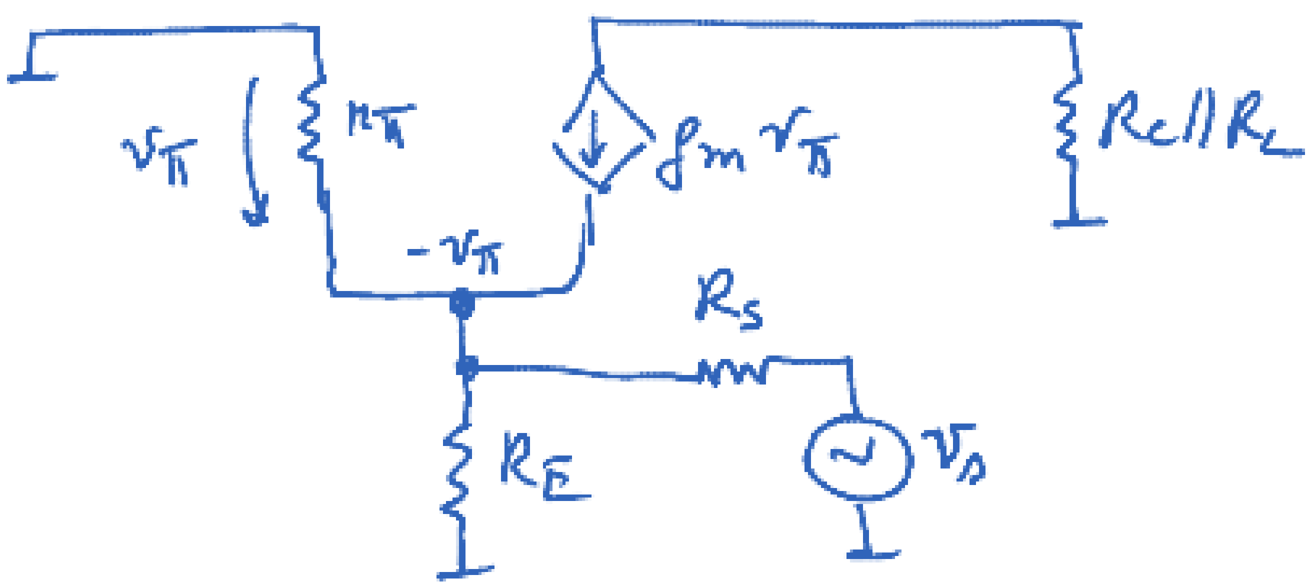
Edmond Cretu

Agenda

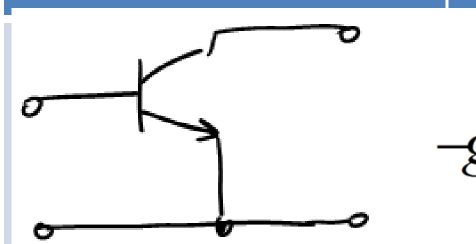
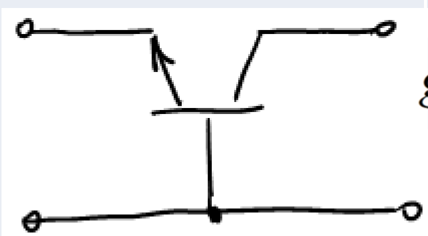
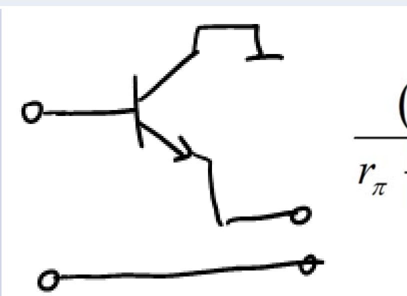
- Some comments on quiz 3
- Summary single-stage amplifiers
- Differential stage – why differential?
- Common and differential modes
- Differential stages – discrete circuits versus ICs
- Bias analysis

Remarks on quiz 3

- Engineering insight and the art of engineering approximation
- Superposition with dependent sources



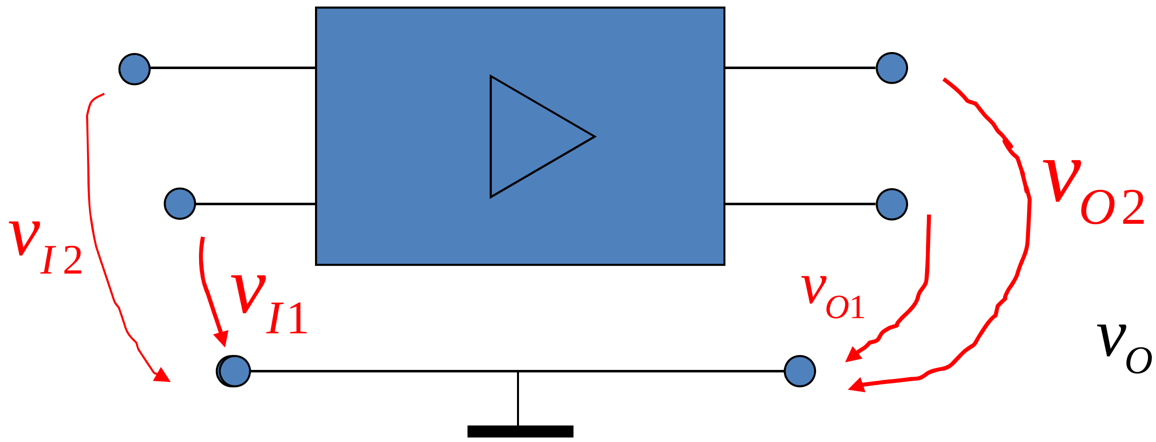
Single stage amplifiers - summary

Configuration	Av	Ai	Rin	Rout	Comments
	$-g_m(R_c \| \| R_L)$	$-\beta$	$R_{BB} \| \| r_\pi$	$R_C \| \| r_o$	medium BW high power gain C coupling
	$g_m(R_c \| \| R_L)$	$\simeq 1$	$R_E \| \| \frac{r_\pi}{\beta+1}$	$R_C \| \| r_o$	large BW low Rin C coupling
	$\frac{(\beta+1)R_E}{r_\pi+(\beta+1)R_E} \approx 1$	$\frac{R_B}{R_E}$	$r_\pi+(\beta+1)R_E$	$\frac{r_\pi+R_B}{\beta+1}$	Large Rin Low Av Low Rout DC in coupling

Differential versus single-ended

- Differential inputs - the voltages of the input terminals are floating w.r.t. the analog ground
- Single-ended inputs - there is a common analog ground (analog LOW wire) shared by all inputs => possibility of undesired cross-couplings when several inputs (exm: ADC), save connector space + cost
- Differential inputs - provide a better solution for amplifying weak signals in the presence of noise - electromagnetic interference (EMI), radio frequency interference (RFI)
- Exm: high speed communication lines, measuring thermocouples, strain gauges, bridge type pressure sensor inputs, small signals in a sea of large common-mode signals

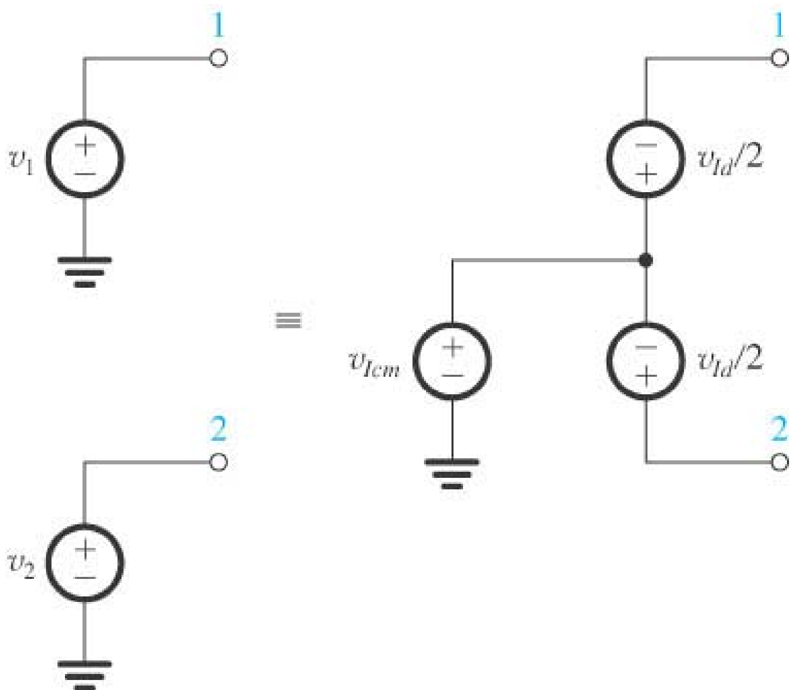
Common-mode and Differential-mode



$$v_{O2} - v_{O1} = A_{dd} v_{Id} + A_{dc} v_C$$

$$\begin{cases} v_{Id} = v_{I2} - v_{I1} \\ v_C = \dfrac{v_{I1} + v_{I2}}{2} \end{cases} \Leftrightarrow \begin{cases} v_{I1} = v_C - \dfrac{v_{Id}}{2} \\ v_{I2} = v_C + \dfrac{v_{Id}}{2} \end{cases}$$

Differential and Common-mode signals (opamps)

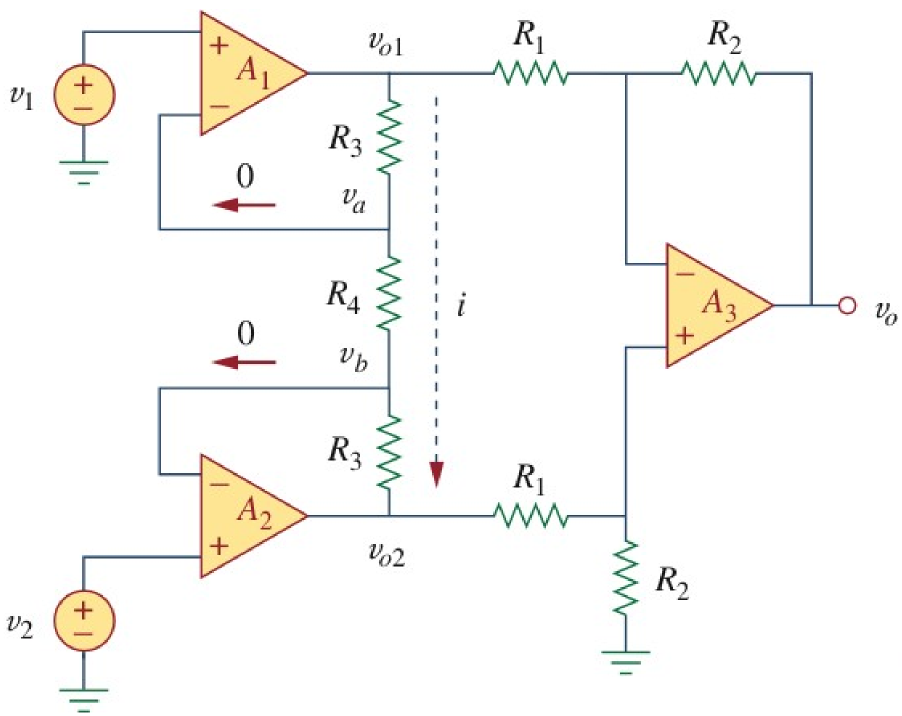


Decomposition of input voltages into a symmetric (common-mode, CM) and differential-mode (antisymmetric) components

$$\begin{cases} v_{Id} = v_2 - v_1 \\ v_{Icm} = \dfrac{v_1 + v_2}{2} \end{cases} \Rightarrow \begin{cases} v_1 = v_{Icm} - \dfrac{v_{Id}}{2} \\ v_2 = v_{Icm} + \dfrac{v_{Id}}{2} \end{cases}$$

$$v_o = A(v_2 - v_1) + \cancel{A_{cm}} v_{Icm} = A v_{Id}$$

Instrumentation amplifier



$$i = \frac{v_1 - v_2}{R_4}$$

$$v_{O1} - v_{O2} = \frac{2R_3 + R_4}{R_4}(v_1 - v_2)$$

$$v_O = \frac{R_2}{R_1}(v_{O2} - v_{O1}) = \frac{R_2}{R_1}\left(1 + \frac{2R_3}{R_4}\right)(v_1 - v_2)$$

$v_{O1} - v_{O2}$ does not depend on matching R_3 res.

v_{Icm} not amplified any more by the first stage

gain can be varied by changing only R_4