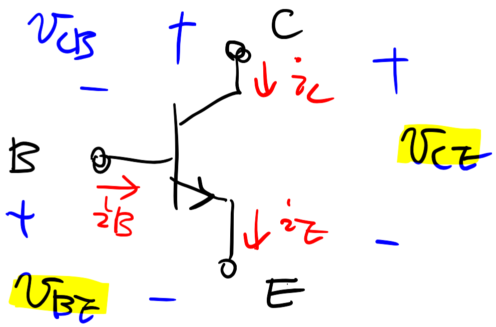
L22 – Power Electronics: Linear Amplifier

- BJT (npn)



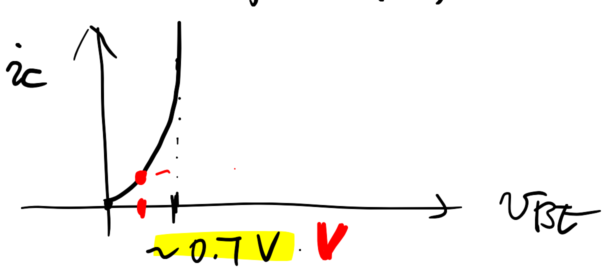
Terminal Variables

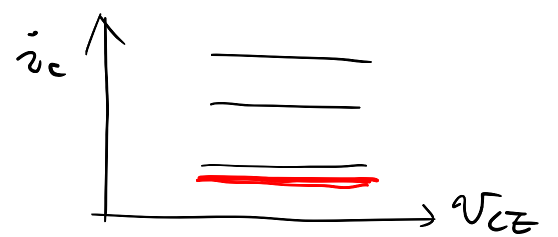
- Currents: i_B, i_C, i_E
- Voltages: v_{BE}, v_{CE}, v_{CB}

Terminal Relations ("Active": $v_{BE} > 0$. AND $v_{CE} > v_{BE}$

$v_{BC} > 0$

$$i_C \simeq I_s \exp\left(\frac{v_{BE}}{V_T}\right).$$





- $i_C = \beta i_B \iff i_B = \frac{1}{\beta} i_C$.

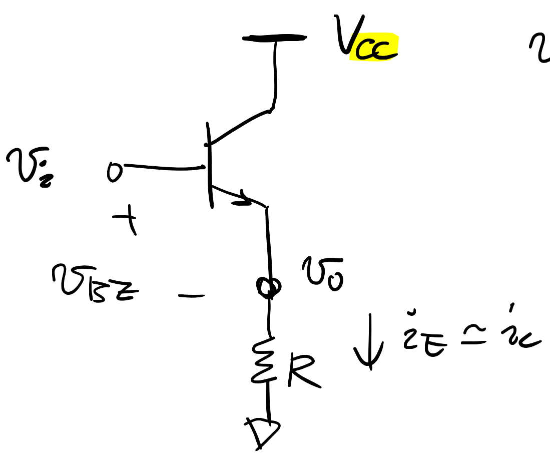
- $$i_E = i_C + i_B = i_C\left(1+\cancel{\frac{1}{\beta}}\right) \simeq i_C$$

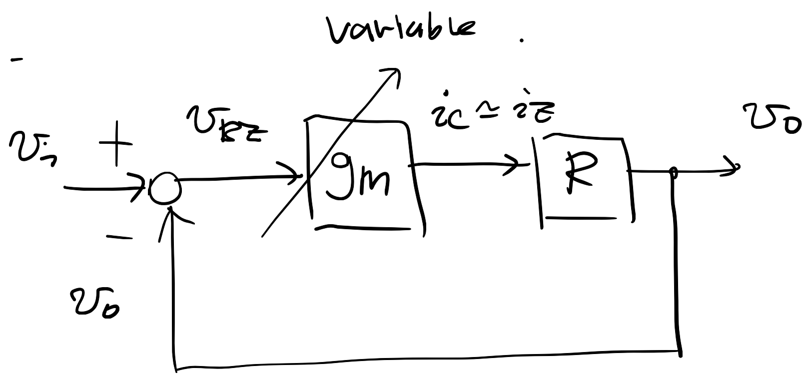
Transconductance.

$$g_m \triangleq \frac{d i_C}{d v_{BE}} = \frac{I_S}{V_T}\exp\left(\frac{v_{BE}}{V_T}\right) = \frac{i_C}{V_T}.$$

- BJT : VCCS. vs $i_B \to \boxed{\beta} \to i_C$. CCCS

- Emitter follower.





$$\frac{v_o}{v_i} = \frac{g_m R}{1+g_m R} = \frac{R}{\frac{1}{g_m}+R} \simeq 1 \quad \text{when } g_m R \gg 1$$

· "power Amplification"

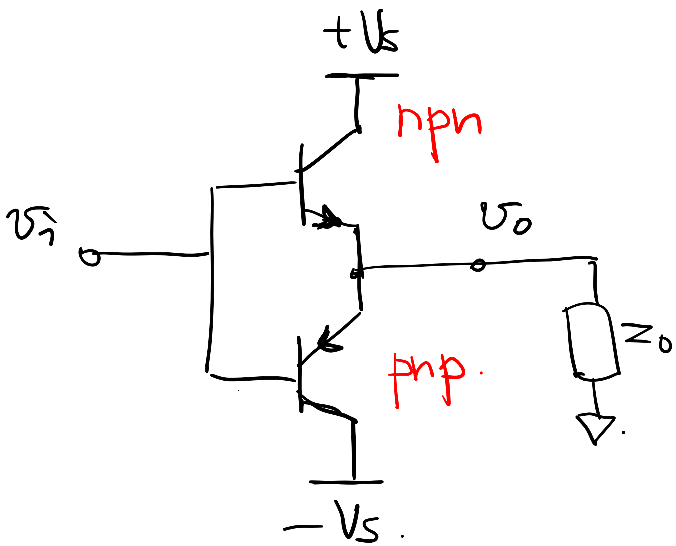
$P_{in} = v_i \, i_B$

$P_{out} = v_o \cdot i_o \simeq v_i \, i_B \cdot \beta$

$\Rightarrow \dfrac{P_{out}}{P_{in}} \simeq \beta$ "

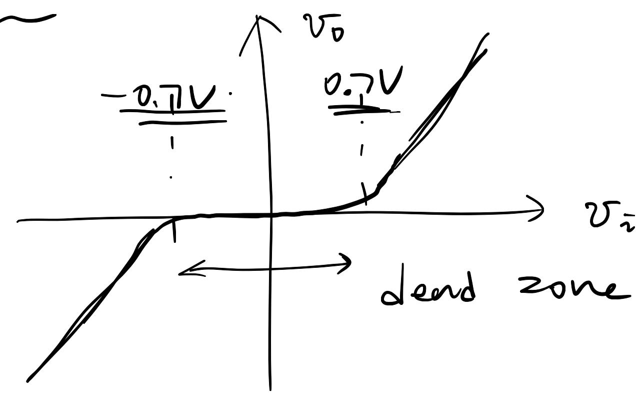
· Cannot "sink" current, $\underline{i_o > 0}$.

∘ Push-pull stage. (Class B).

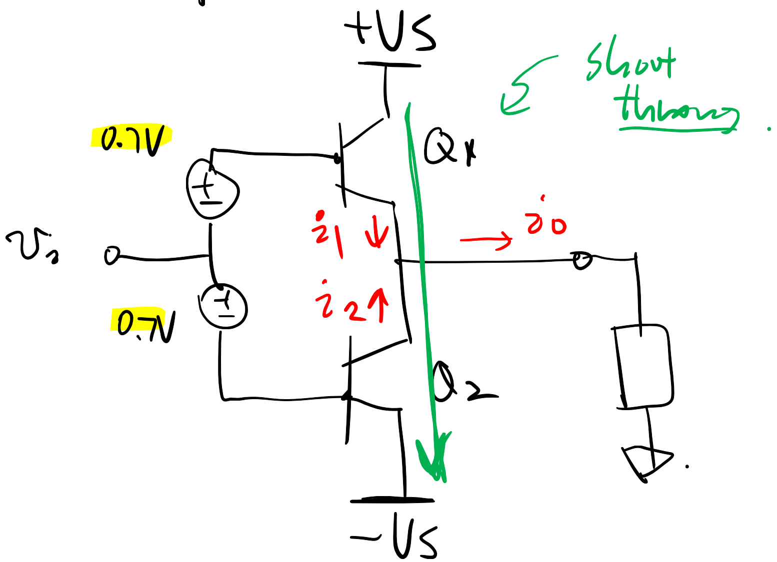


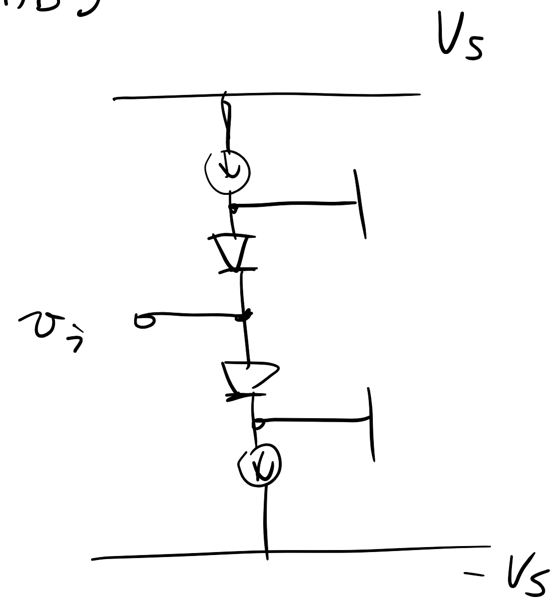
· Now. Both source & sink i_o.

· $\dfrac{v_o}{v_i} = \dfrac{g_m Z_o}{1 + g_m Z_o} \simeq 1$.



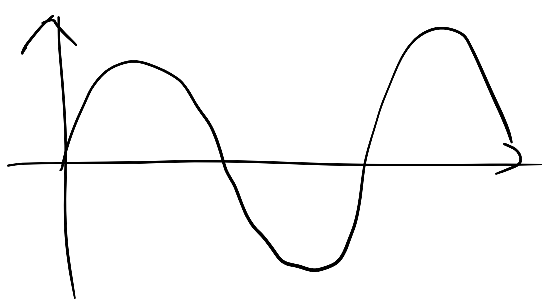
- Improved push-pull (Class AB)

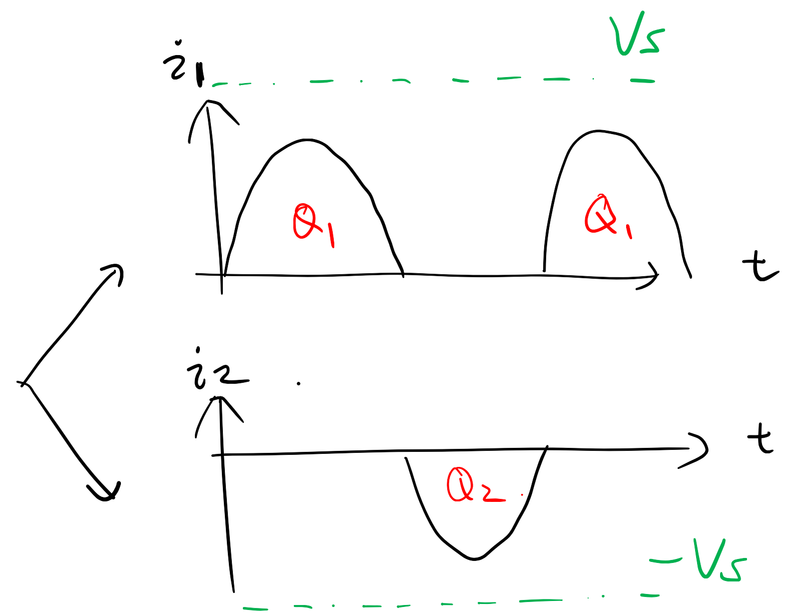


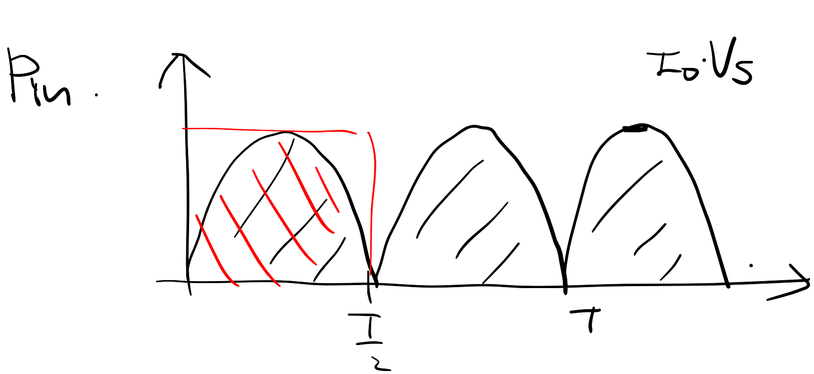


- Power Dissipation:

Suppose $\begin{cases} Z \simeq L_s \\ i_o = I_o \sin \omega t \end{cases}$



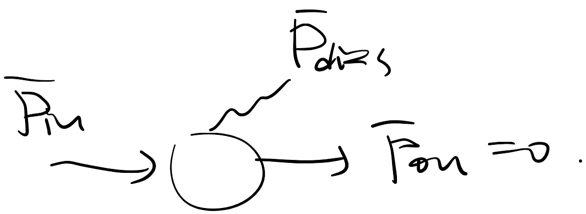




$$\overline{P_{in}} = \frac{2}{T}\int_0^{\frac{T}{2}} I_o V_s \cdot \sin\omega t \cdot dt$$

$$= \frac{2}{\pi} I_o V_s$$

$\overline{P_{out}} = 0$ for pure inductor.



$$\overline{P_{diss}} = \frac{2}{\pi} I_o V_s \quad !$$

- For efficiency, we want $V_s \downarrow$.
- For control, we want $V_s \uparrow$

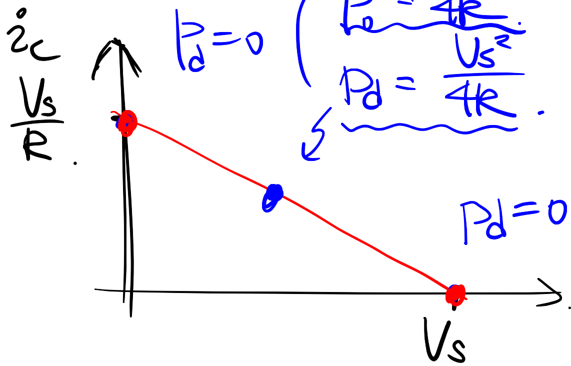
$$\max\left(\frac{di}{dt}\right) = \frac{V_s}{L}$$

- Large P_{diss} limits device downsizing.
  - $\uparrow$ size of power semiconductors
  - Requires add. comps (Heat sinks, fans).

- Switched-mode

$P_d = 0$

$\left(\begin{array}{l} P_o = \dfrac{V_s^2}{4R} \\ P_d = \dfrac{V_s^2}{4R} \end{array} \right.$

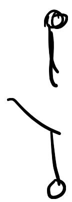


$P_d = 0$

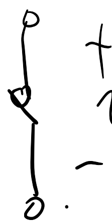
v_{CE}. $\downarrow$ $i_c \simeq i_E$.

$v_{CE} = V_s - R \cdot i_c$.

$\underline{P = i_c \cdot v_{CE}} = 0 \quad \left\{ \begin{array}{l} i_c = 0. \\ v_{CE} = 0. \end{array} \right.$



$\downarrow i_q = 0$



$+$

$v_q = 0$. $\quad P_d = i_q v_q$

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$\underline{\simeq 0}$ "