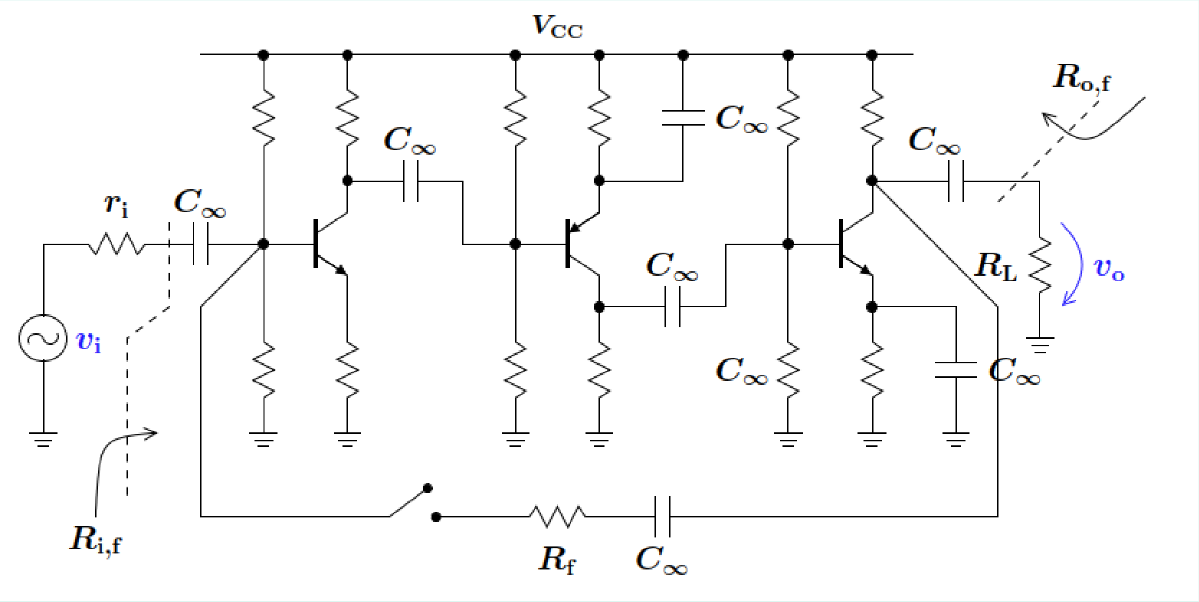
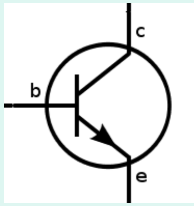
ELEC 301 - CB amplifier configuration

L14 - Oct 07

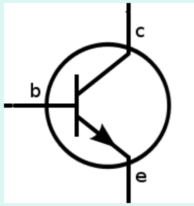
Instructor: Edmond Cretu





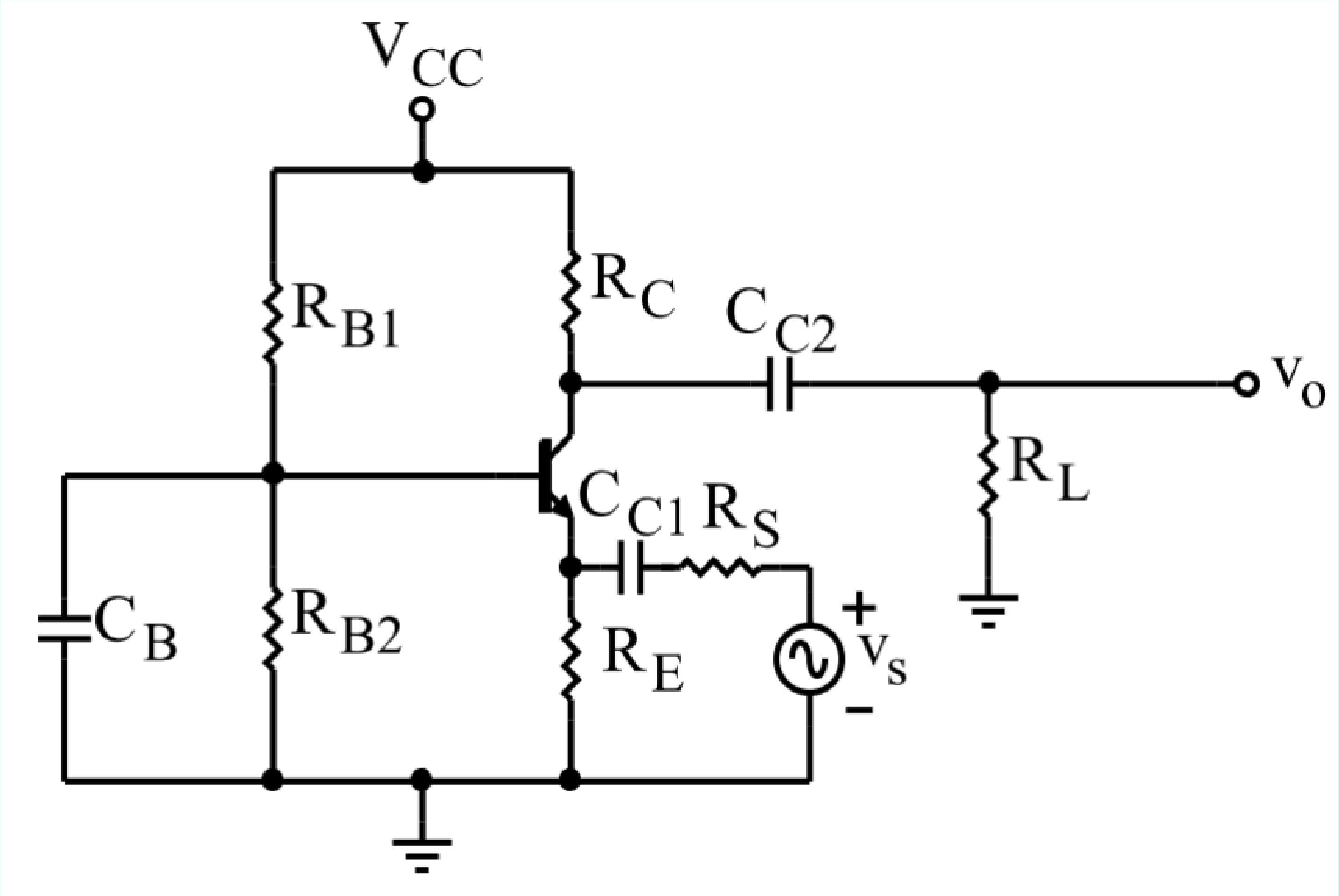
Last lecture

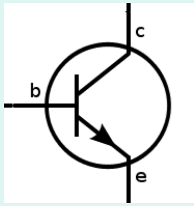
- Analysis of common-emitter configuration - from biasing to AC small signal analysis
- Complex transfer function - 5 poles, 3 zeros - difficult to analyze without fast and approximate analysis methods
- Lessons:
  - HF response limited by internal capacitors (C_μ magnified by the Miller effect)
  - Mid-band - voltage amplification
  - LF response limited by the coupling capacitors - because the “demagnification” of the resistance in the B when seen from E, C_E usually gives ω_{L3dB}



The common-Base amplifier

- Input port: E, Output port: C
- We assume proper biasing (1/3 rule); C_B to ground B in AC mode





L14 Q01 - ideal voltage amplifier

- What are the input and output impedances of an ideal voltage amplifier diport?

A. $Z_{in}=0$, $Z_{out}=\infty$

B. $Z_{in}=\infty$, $Z_{out}=0$

C. $Z_{in}=0$, $Z_{out}=0$

D. $Z_{in}=\infty$, $Z_{out}=\infty$

L14 Q02 - equivalent impedance

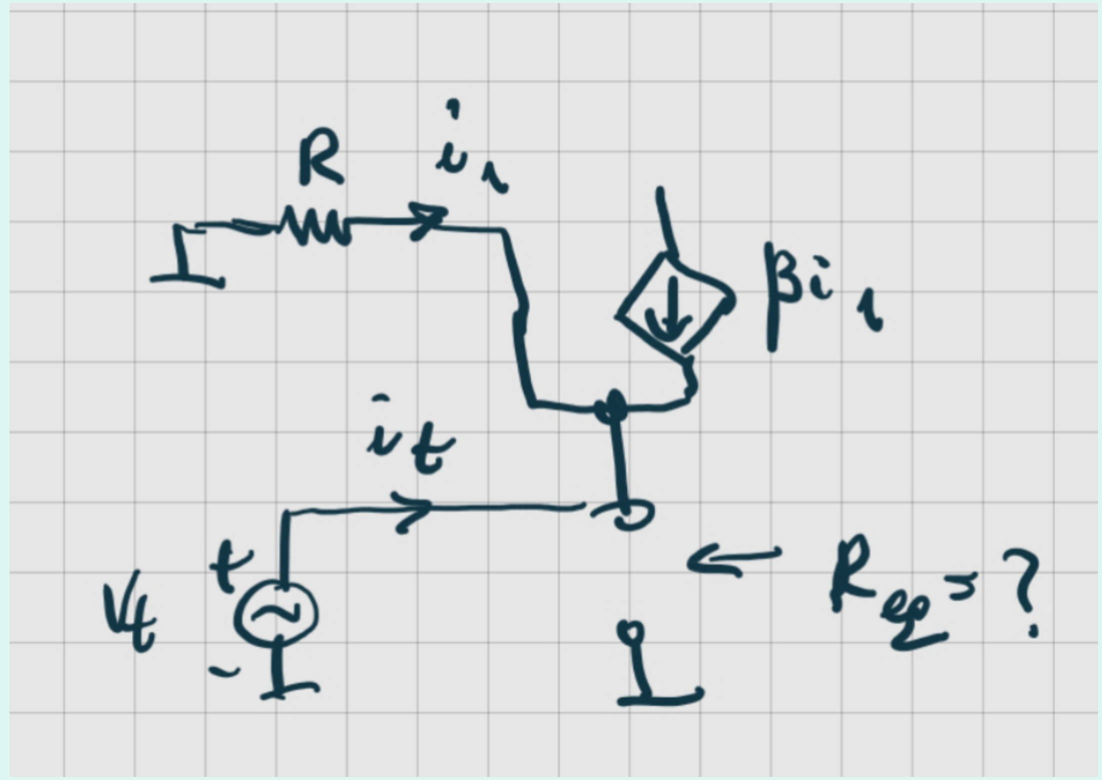
- What is the equivalent input resistance?

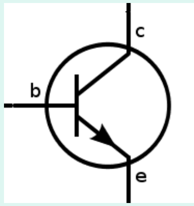
A. R(1+β)

B. R/(1+β)

C. R

D. R/(1-β)





L14 Q03 - equivalent impedance (2)

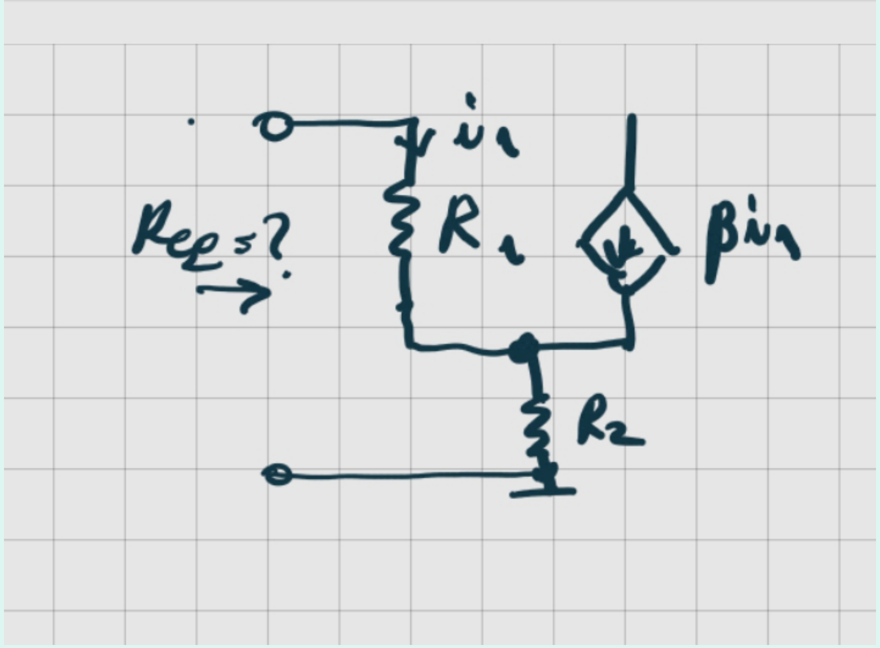
- What is the equivalent input resistance?

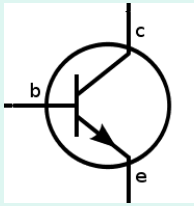
A. R_1+R_2

B. $R_1+R_2/(\beta+1)$

C. $(\beta+1)R_1+R_2$

D. $R_1+(\beta+1)R_2$

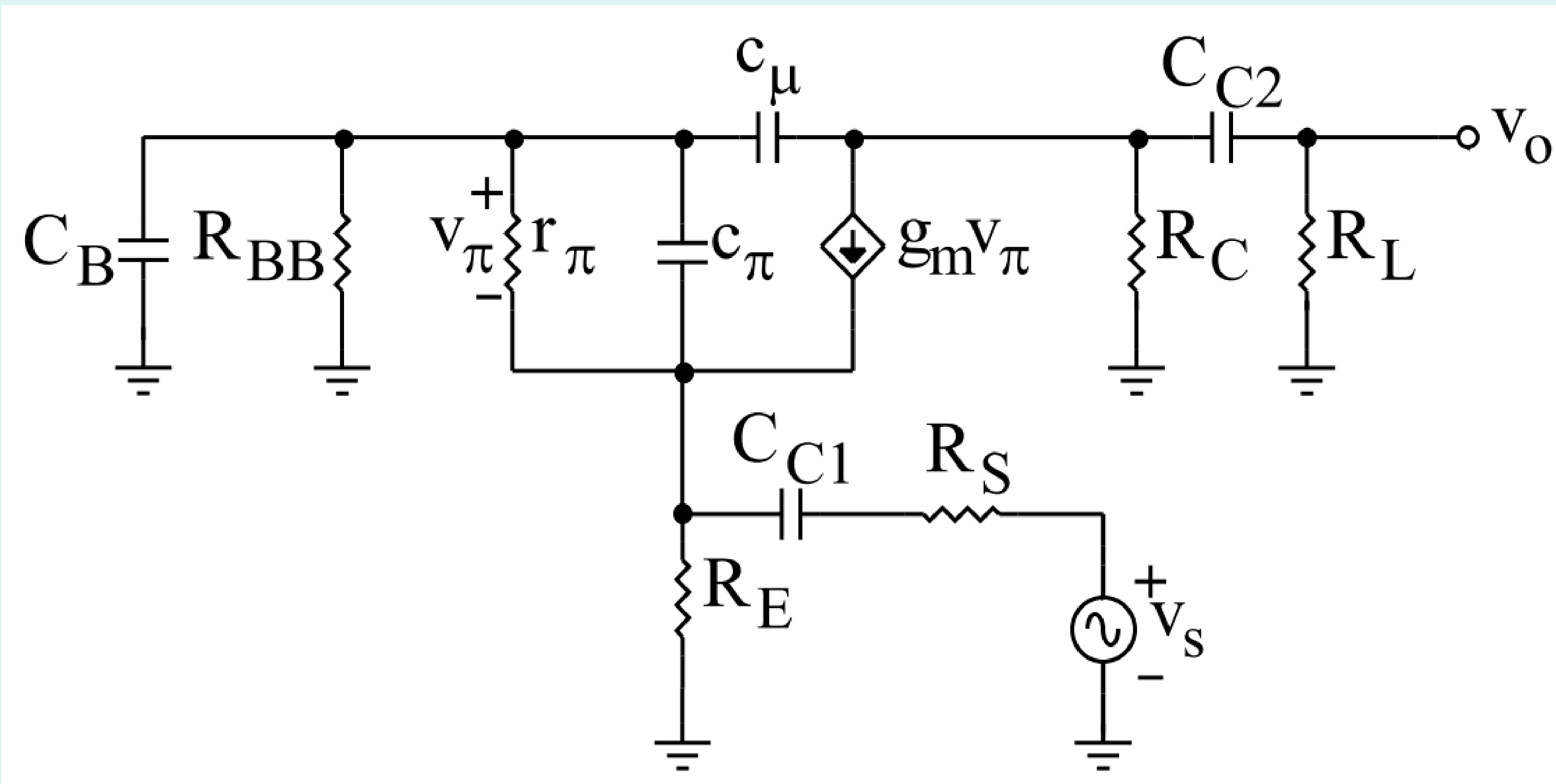




Small-signal model

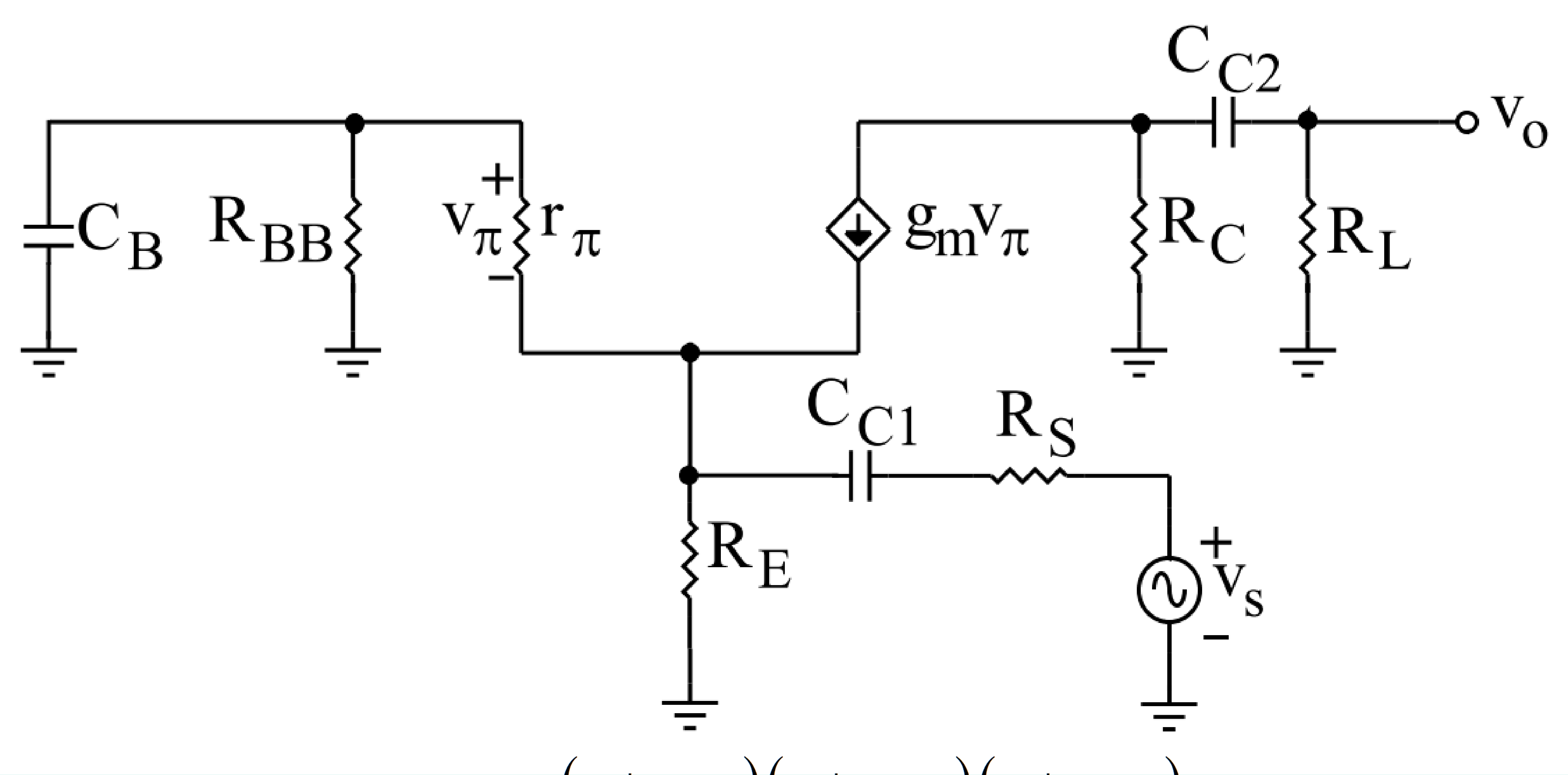
- Start with small signal circuit
- C_B, C_{C1}, C_{C2} - LF capacitors
- C_μ, C_π - HF capacitors

$$F(s) = \underbrace{F_L(s)}_{LF\ part}\ \underbrace{A_M}_{Midband}\ \underbrace{F_H(s)}_{HF\ part}$$

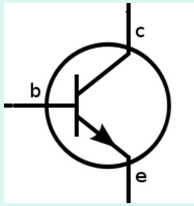


Low-frequency small-signal model

- The HF capacitors are open-circuited

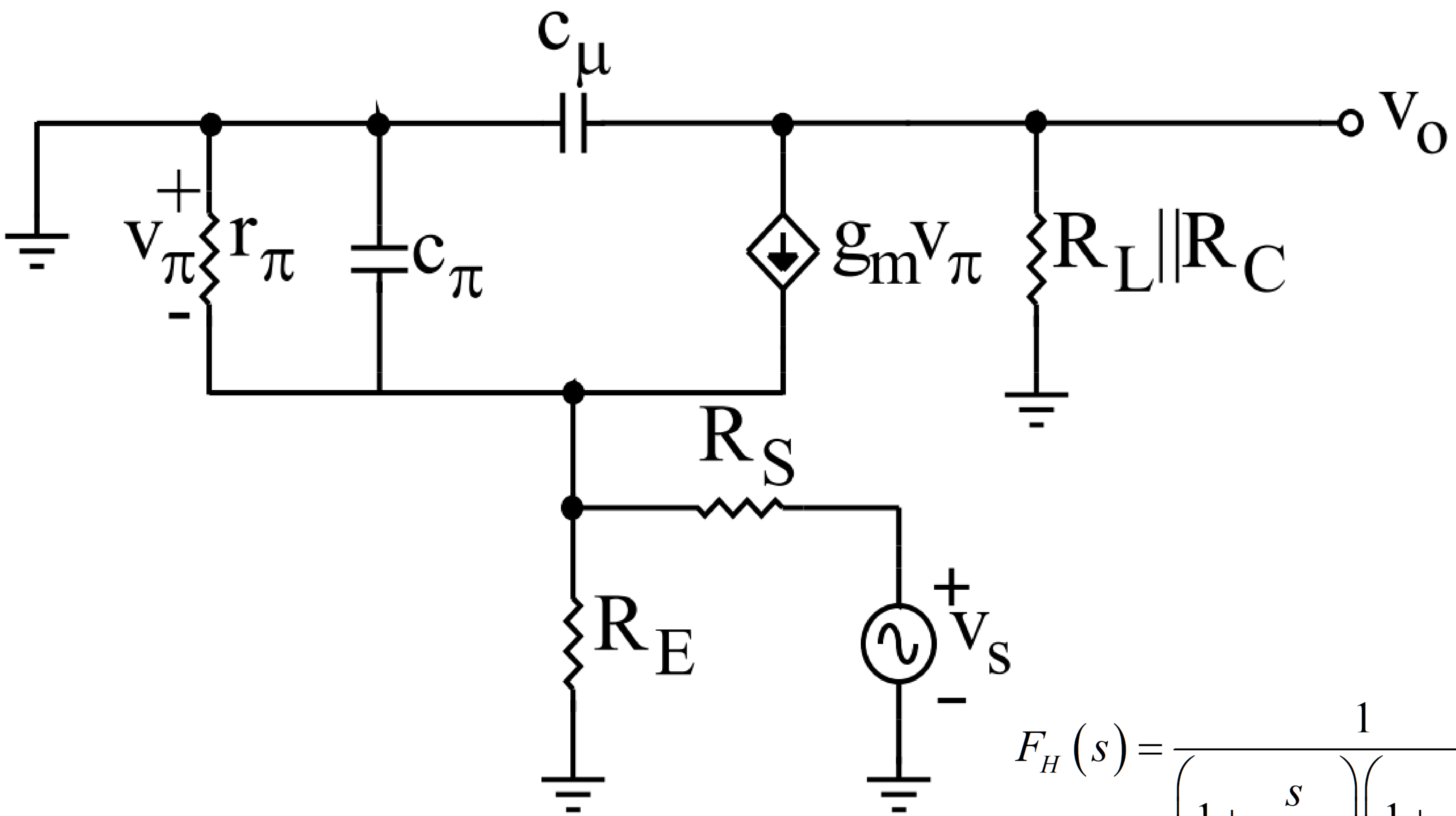


$$F_L(s) = \frac{(s+\omega_{Lz1})(s+\omega_{Lz2})(s+\omega_{Lz3})}{(s+\omega_{Lp1})(s+\omega_{Lp2})(s+\omega_{Lp3})}$$



High-frequency small signal model

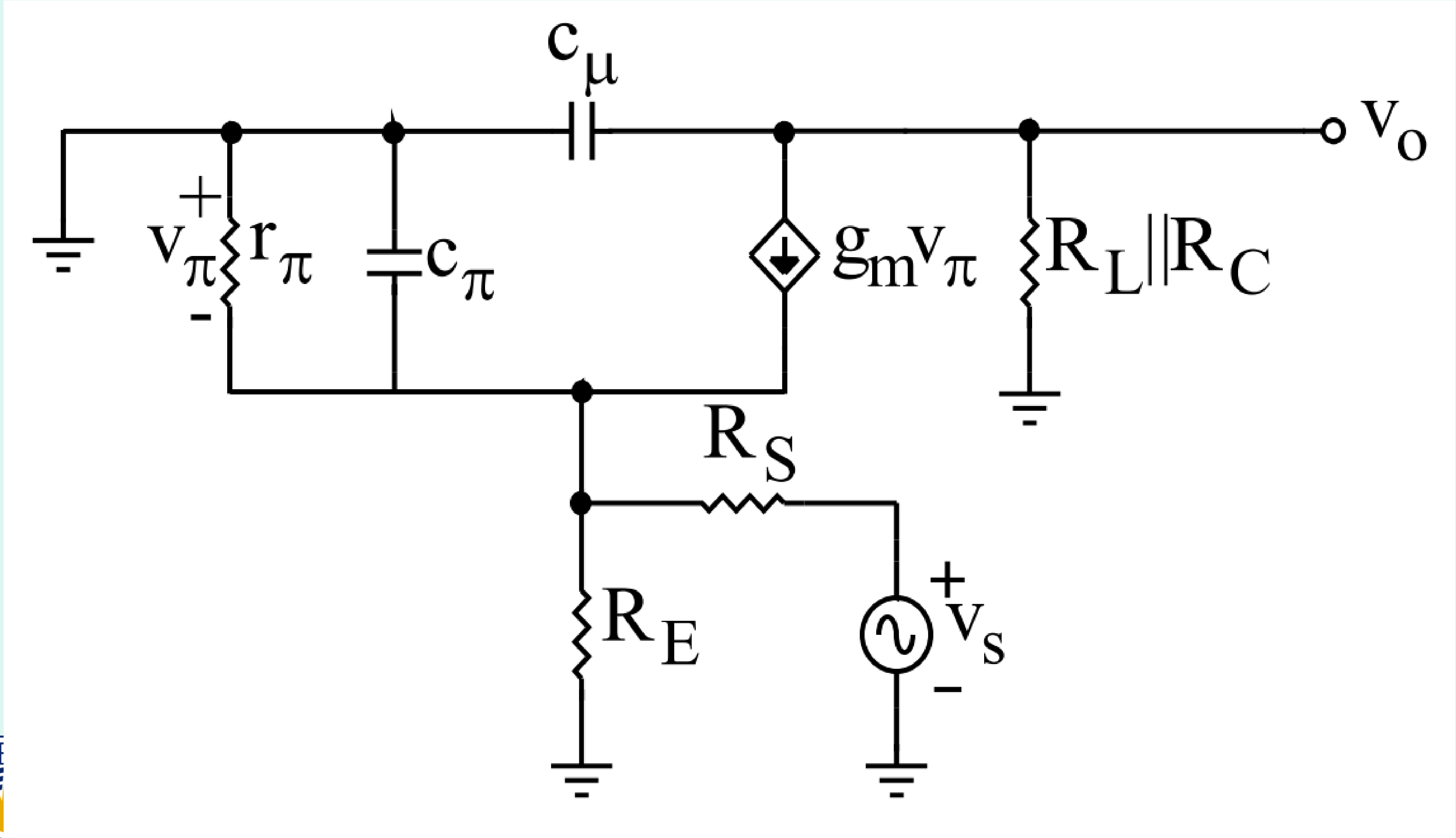
- The LF capacitors are short-circuited

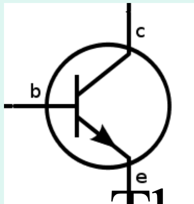


$$F_H(s) = \frac{1}{\left(1+\frac{s}{\omega_{Hp1}}\right)\left(1+\frac{s}{\omega_{Hp2}}\right)}$$

High-frequency small signal model

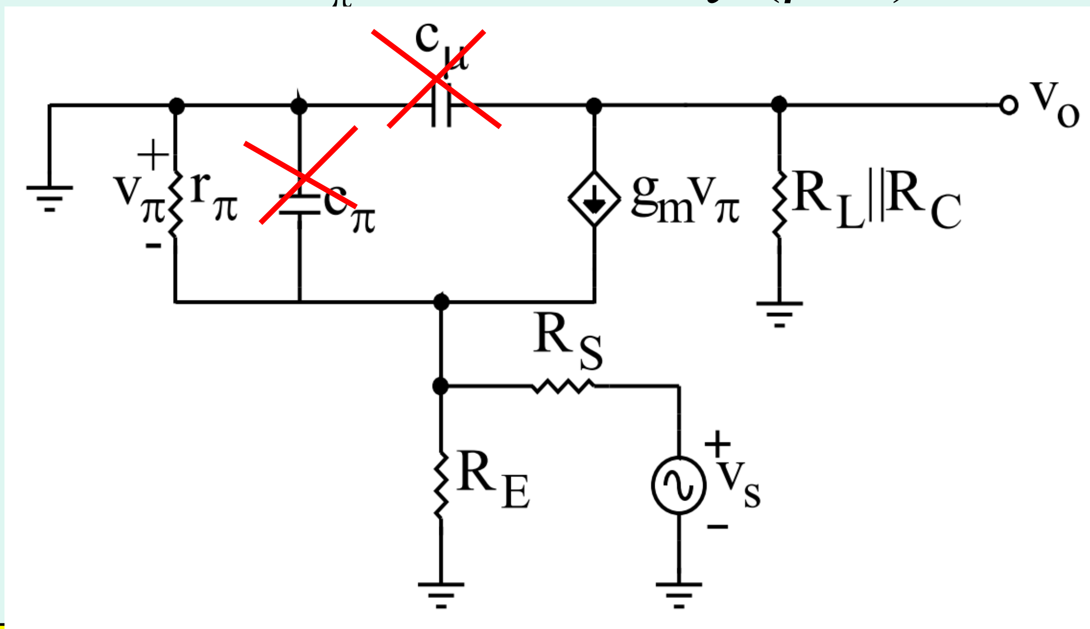
- The LF capacitors are short-circuited





Mid-band gain

- The junction capacitances C_μ, C_π treated as OC
- REM: r_π is reduced by $(\beta+1)$ times when looking from E



$$v_\pi = -\frac{\frac{r_\pi}{1+\beta} \| R_E}{R_S + \frac{r_\pi}{1+\beta} \| R_E} v_s \approx -\frac{\frac{r_\pi}{1+\beta}}{R_S + \frac{r_\pi}{1+\beta}} v_s$$

$$R_{E,eq}\Big|_{CB} = R_E \,\|\, \frac{r_\pi}{\beta+1}$$

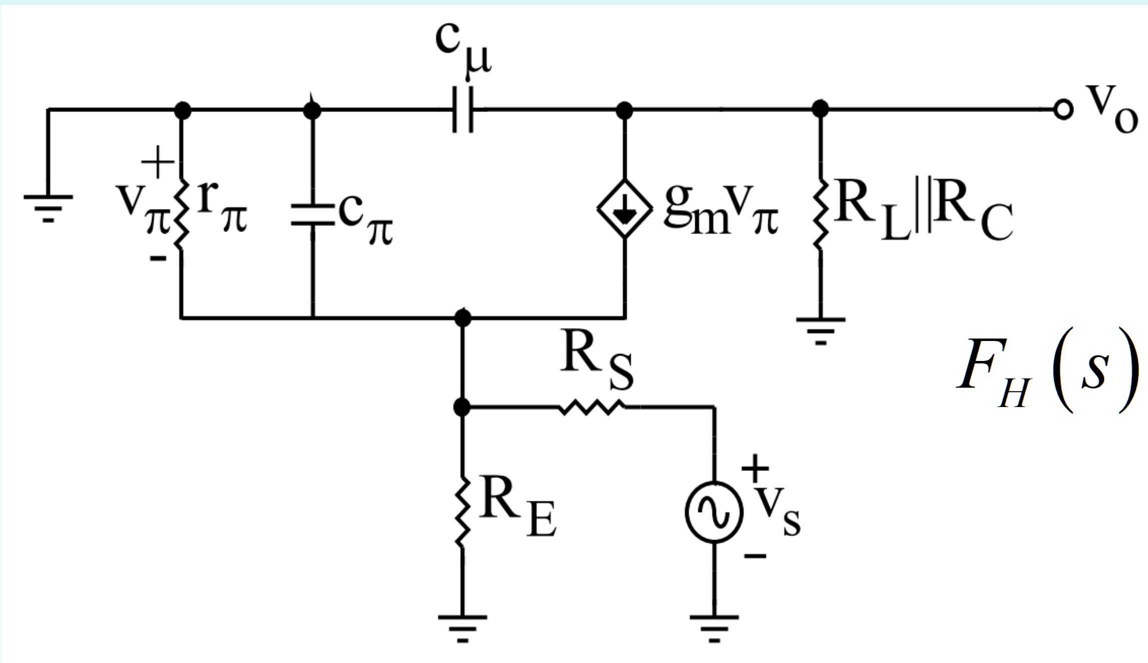
$$A_M\Big|_{CE} = -g_m R_C \,\|\, R_L \frac{R_{BB} \,\|\, r_\pi}{R_{BB} \,\|\, r_\pi + R_S}$$

$$R_{B,eq}\Big|_{CE} = R_{BB} \,\|\, \left(r_\pi + (\beta+1) R_E\right)$$

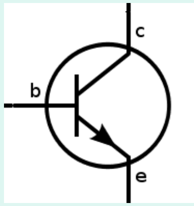
$$A_M\Big|_{CB} = g_m R_C \,\|\, R_L \frac{\frac{r_\pi}{\beta+1} \,\|\, R_E}{R_S + \frac{r_\pi}{\beta+1} \,\|\, R_E}$$

High-frequency behavior - $F_H(s)$

- No Miller multiplication of C_μ in the input circuit
- poles given by C_μ, C_π

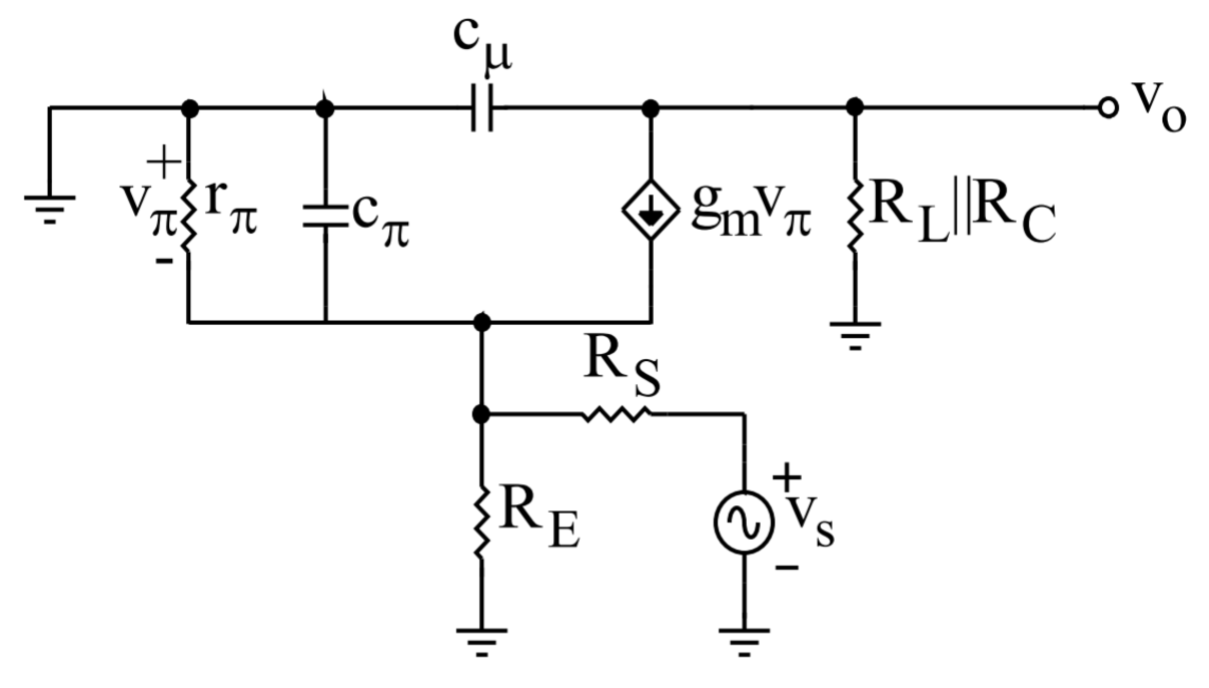


$$F_H(s) = \frac{1}{\left(1+\frac{s}{\omega_{Hp1}}\right)\left(1+\frac{s}{\omega_{Hp2}}\right)}$$



C_μ - component

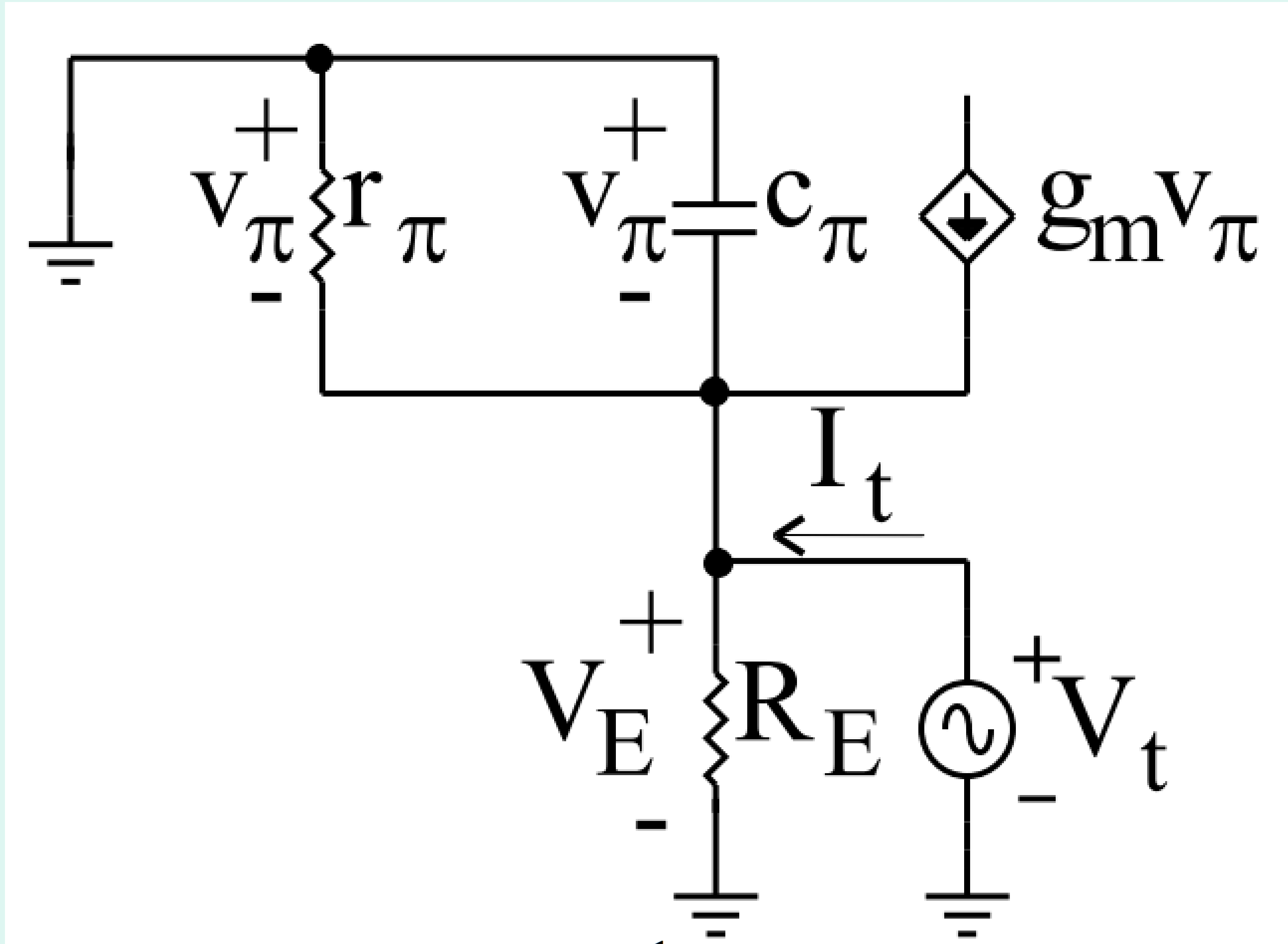
- C_π is OC



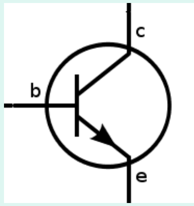
$$R_{C_\mu}^{OC} = R_L \parallel R_C \Rightarrow \omega_{Hp1}^{OC} = \frac{1}{\left(R_L \parallel R_C\right) C_\mu}$$

C_π component

- C_μ is OC



$$R_{C_\pi}^{OC} = R_S \parallel R_E \parallel \frac{r_\pi}{\beta+1} \Rightarrow \omega_{Hp2}^{OC} = \frac{1}{\left(R_S \parallel R_E \parallel \frac{r_\pi}{\beta+1}\right) C_\pi}$$



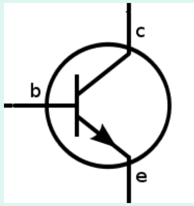
$F_H(s)$

- Apply the OC method

$$\frac{1}{\omega_{H3dB}} = \frac{1}{\omega_{Hp1}^{OC}} + \frac{1}{\omega_{Hp2}^{OC}} = \left(R_L \parallel R_C\right)C_\mu + \left(R_S \parallel R_E \parallel \frac{r_\pi}{\beta+1}\right)C_\pi \approx \left(R_L \parallel R_C\right)C_\mu$$

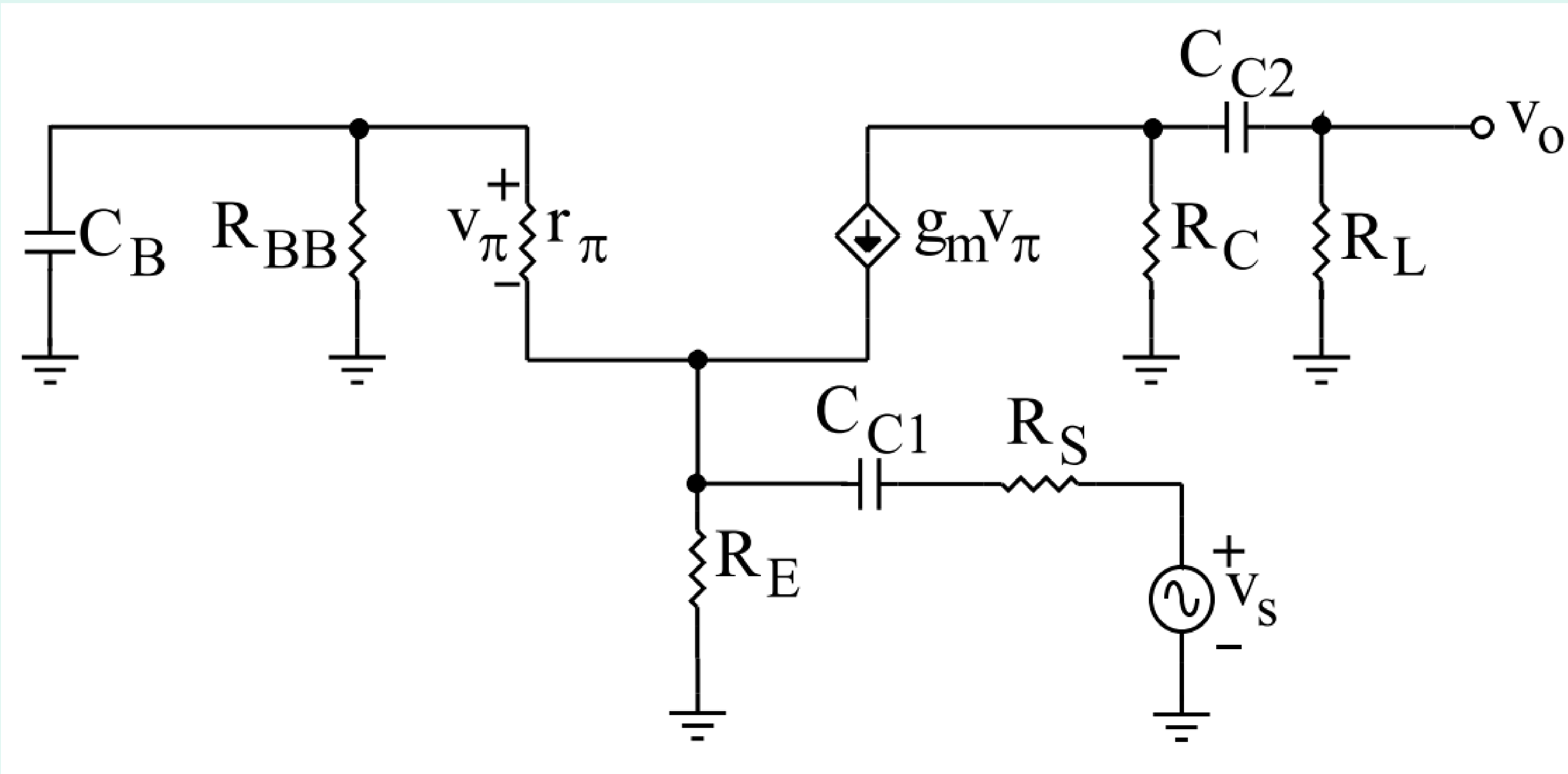
For the second pole (sub-dominant): if the lowest pole corresponds to C_μ, then we estimate the second pole with C_μ short-circuited → it does not change the second pole position

$$F_H(s) = \frac{1}{\left(1+s\left(R_L \parallel R_C\right)C_\mu\right)\left(1+s\left(R_S \parallel R_E \parallel \frac{r_\pi}{\beta+1}\right)C_\pi\right)}$$

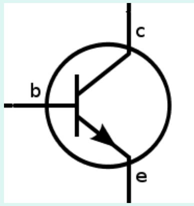


CB - LF behavior $F_L(s)$

- We get back to the LF circuit - 3poles + 3 zeros

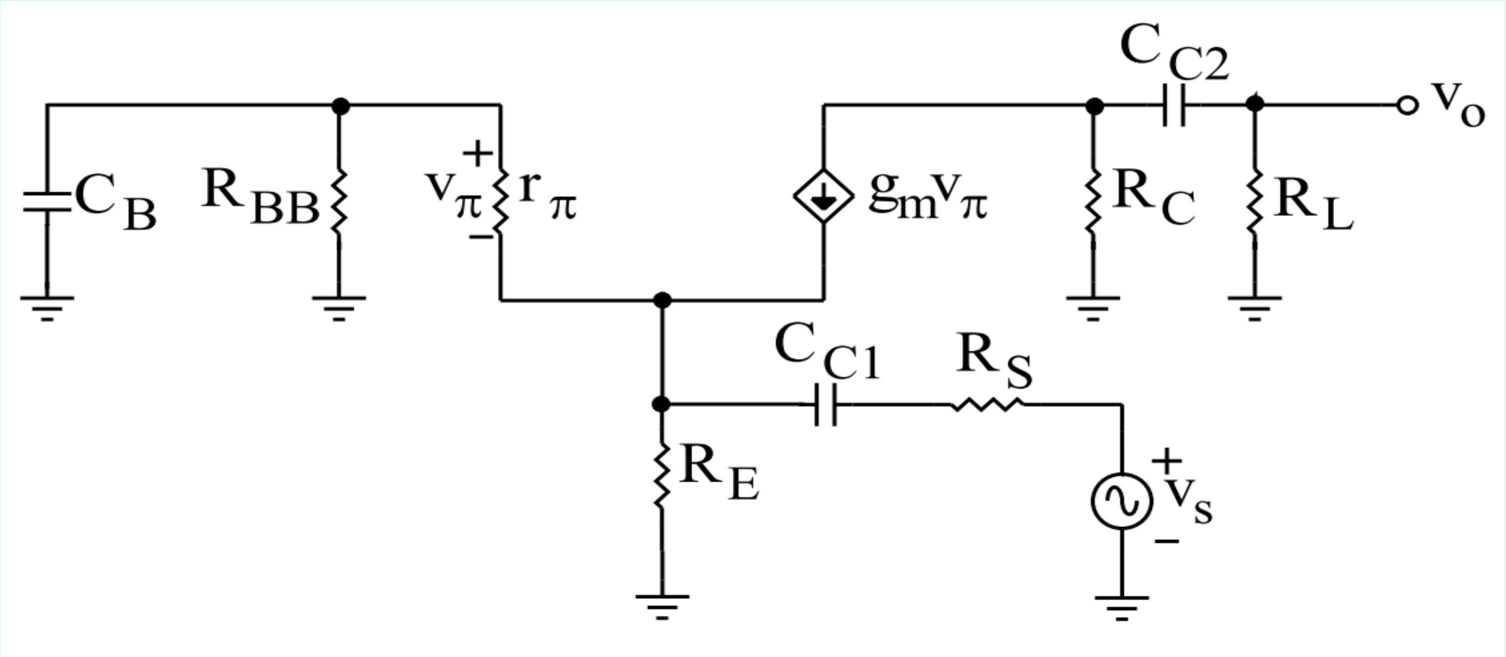


$$F_L(s) = \frac{(s+\omega_{Lz1})(s+\omega_{Lz2})(s+\omega_{Lz3})}{(s+\omega_{Lp1})(s+\omega_{Lp2})(s+\omega_{Lp3})}$$



FL(s) - zeros

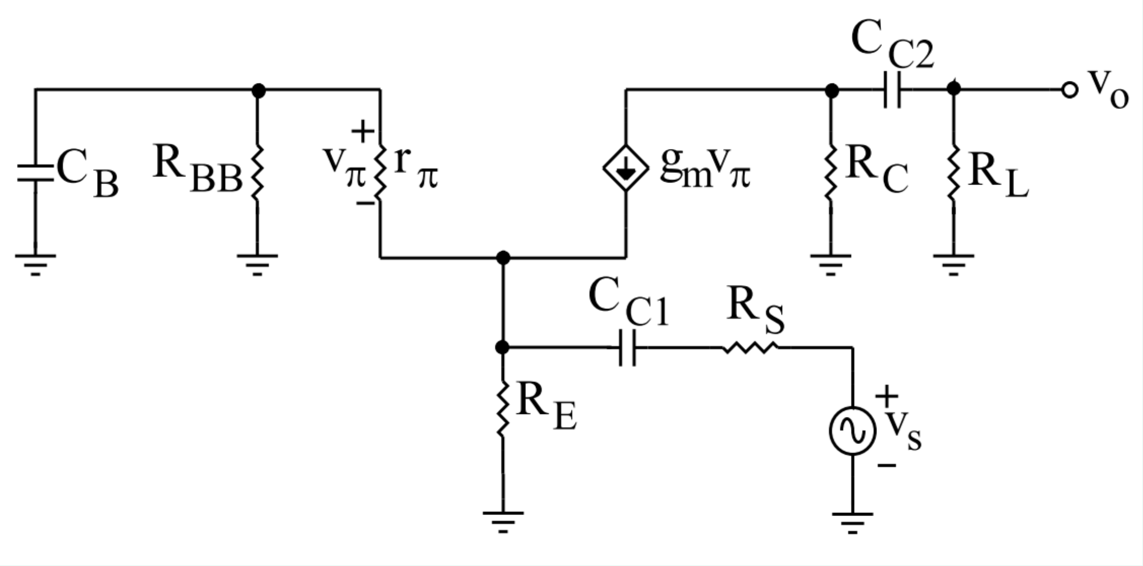
- Zeros: C_{C1}, C_{C2} introduce zeros at ω=0
- For CB - zero located when v_π=0 (or i_b=0)



$$Y_B = s_z C_B + \frac{1}{R_{BB}} = 0 \Rightarrow s_z = -\frac{1}{R_{BB} C_B} \Rightarrow \omega_{Lz3} = \frac{1}{R_{BB} C_B}$$

$F_L(s)$ - poles

- The pole associated with the output stage (decoupled from input) is straight forward

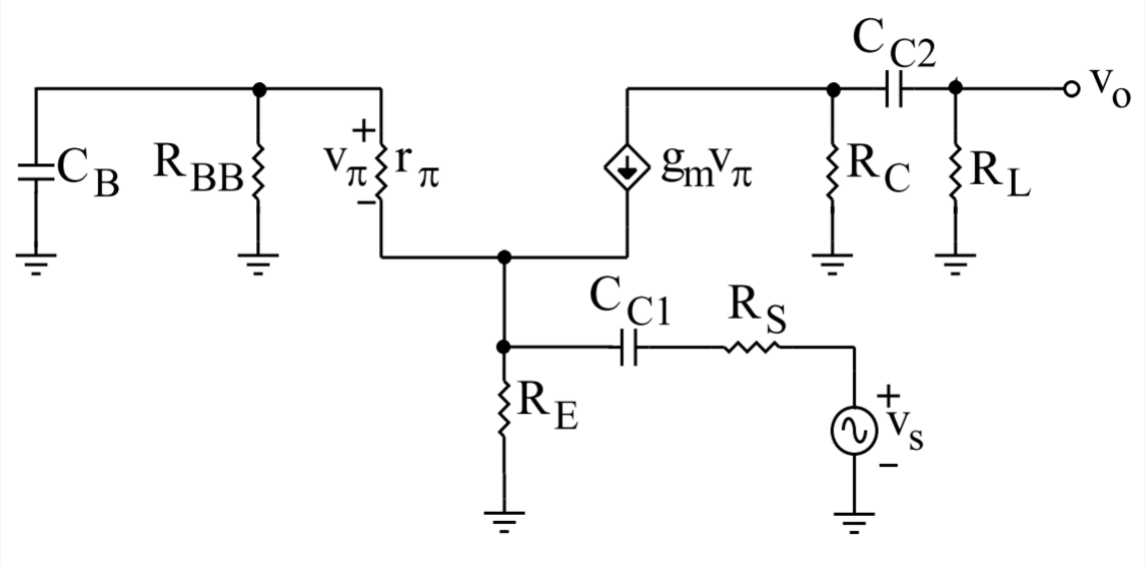


$$R_{C_{C2}} = R_C + R_L \Rightarrow \tau_{C_{C2}} = \left(R_C + R_L\right) C_{C2}$$

$$\omega_{Lp1} = \frac{1}{\left(R_C + R_L\right) C_{C2}}$$

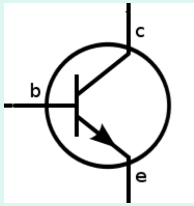
$F_L(s)$ - remaining 2 poles

- We use the SC time constant method (assuming the poles are well distanced)



When C_{C1} is SC => $R_E||R_S$ reflected into the B

$$R_{C_B}^{SC} = R_{BB} \,||\, \left(r_\pi + (\beta+1) R_E \,||\, R_S\right) \Rightarrow \tau_{C_B}^{SC} = \left(R_{BB} \,||\, \left(r_\pi + (\beta+1) R_E \,||\, R_S\right)\right) C_B$$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