ECE 255: L35

High Frequency Response III

(Sedra and Smith, 7th Ed., Sec. 10.2-10.5)

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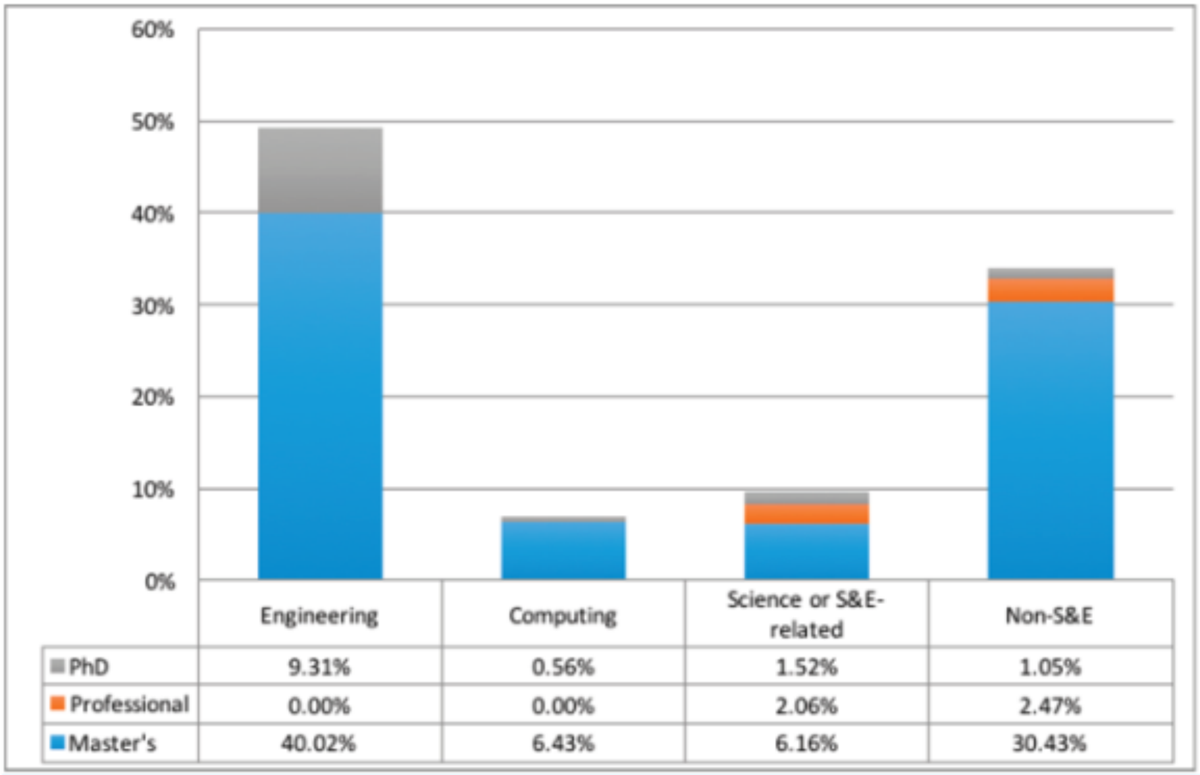
PURDUE UNIVERSITY

Announcements

HW11 Due 5:00 PM Friday, April 26 in EE-209 dropbox

Beyond a Bachelor’s Degree

Percentage of the >40% of engineering bachelor’s degree holders over the age of 25 who earned an additional degree beyond the bachelor’s, by degree level and area of degree.



Source: National Academies Press, *Understanding the Educational and Career Pathways of Engineers* (2018)

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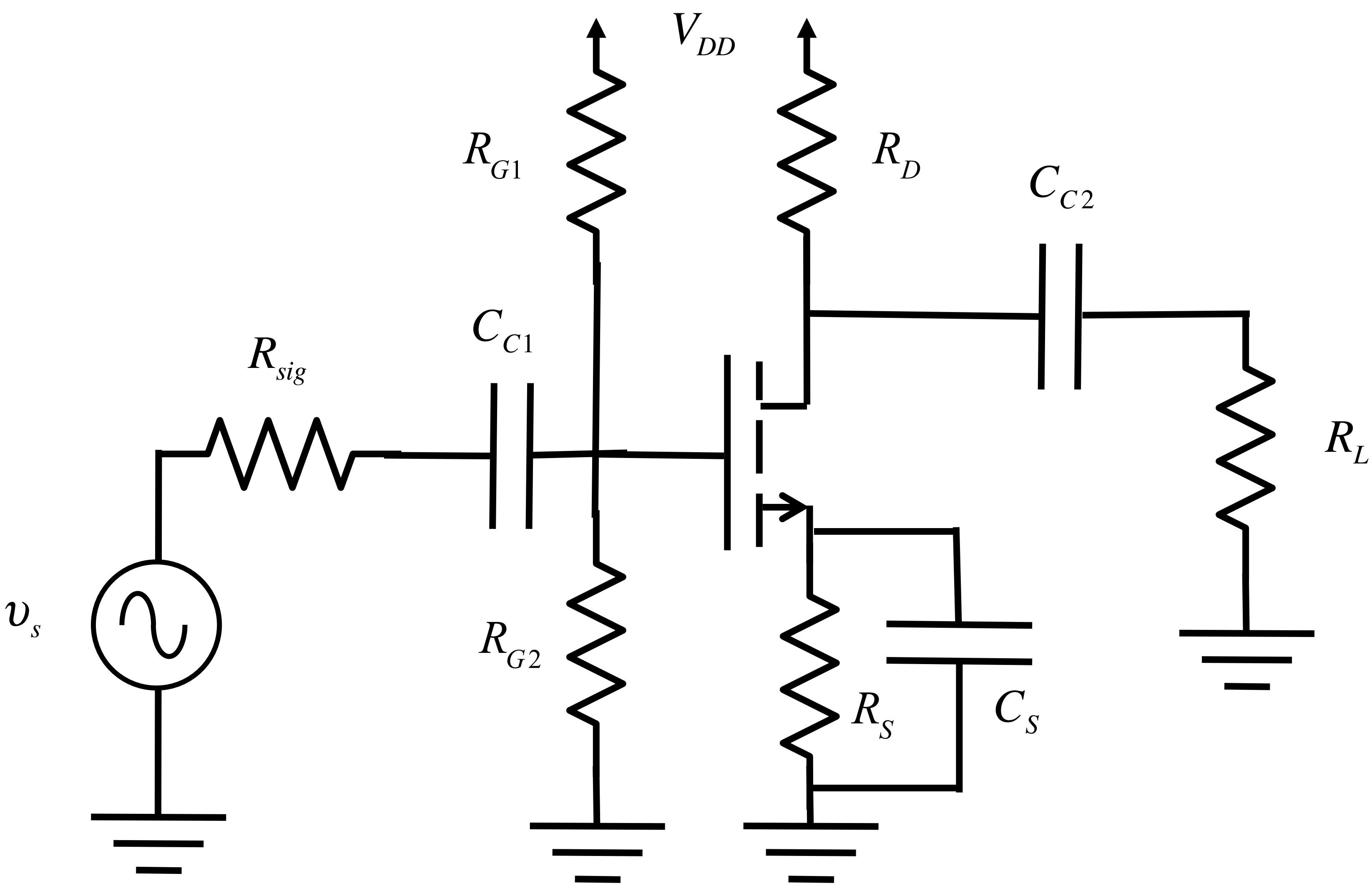
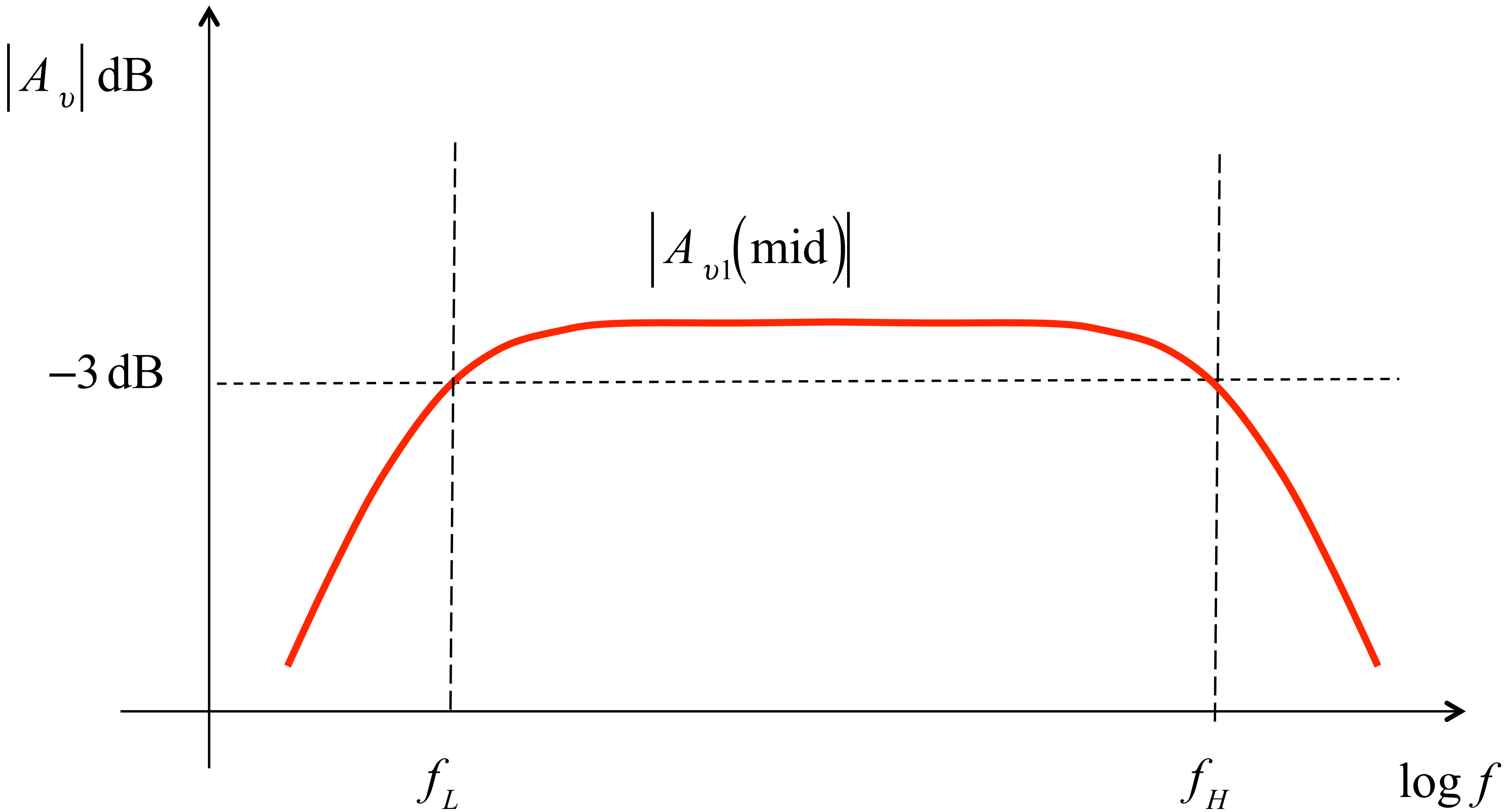
BREADTH AT THE EDGES | IDEAS TO INNOVATION | FREQUENTLY ASKED QUESTIONS

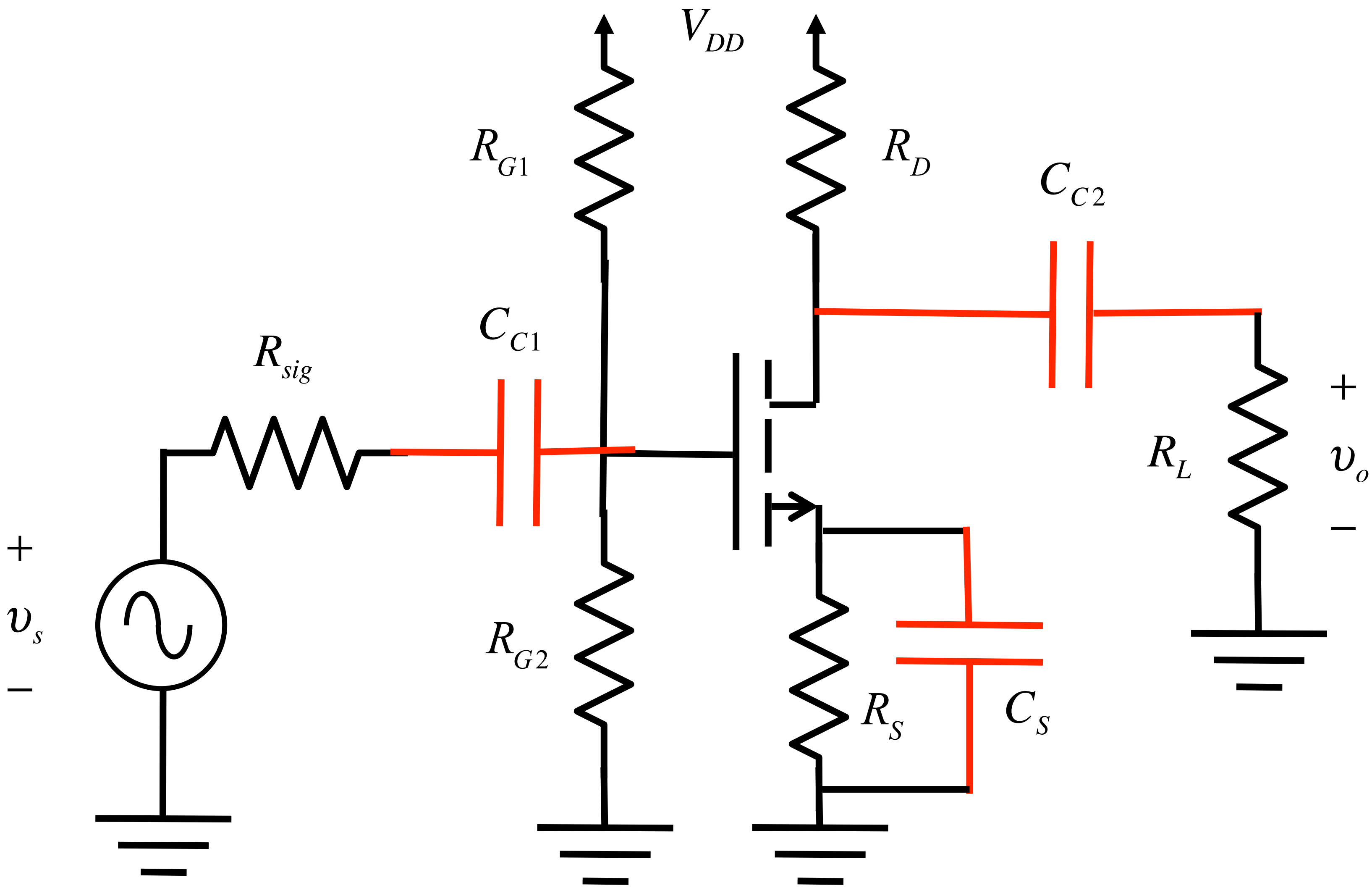
Discrete CS Amplifier



Frequency response



CS Amplifier: LF response



Short circuit time constant method

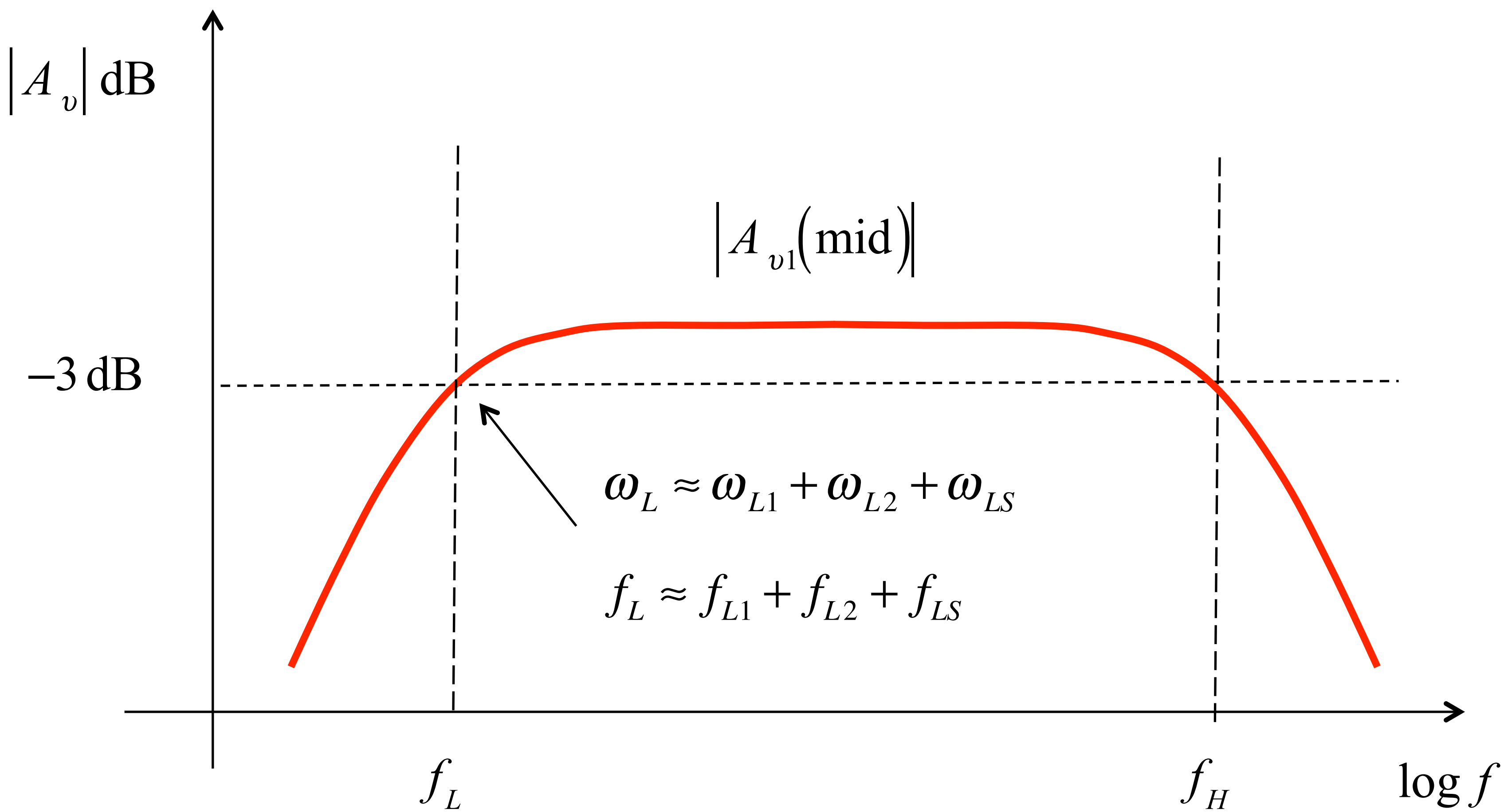
$$\omega_{L1} = \frac{1}{R_{th1}C_{C1}}$$

$$\omega_{L2} = \frac{1}{R_{th2}C_{C2}}$$

$$\omega_L \approx \omega_{L1} + \omega_{L2} + \omega_{LS}$$

$$\omega_{LS} = \frac{1}{R_{thS}C_S}$$

Low frequency response



Comments: S-C time constant method

$$\omega_{L1} = \frac{1}{R_{th1}C_{C1}}$$

$$\omega_{L2} = \frac{1}{R_{th2}C_{C2}}$$

$$\omega_{LS} = \frac{1}{R_{thS}C_{S}}$$

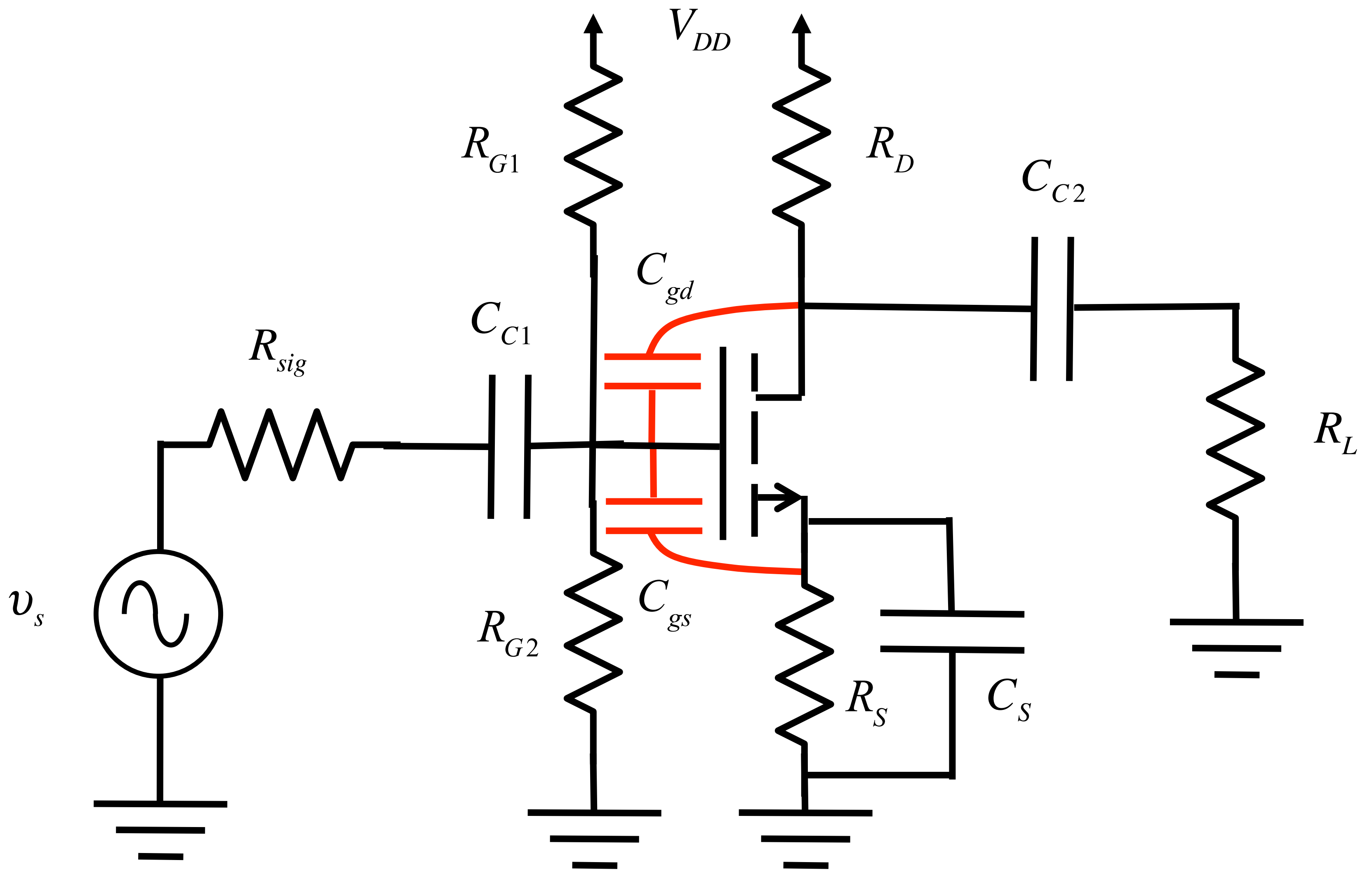
$$\omega_{L} \approx \omega_{L1} + \omega_{L2} + \omega_{LS}$$

Note that this is an approximate method that works well when there is a **dominant pole**.

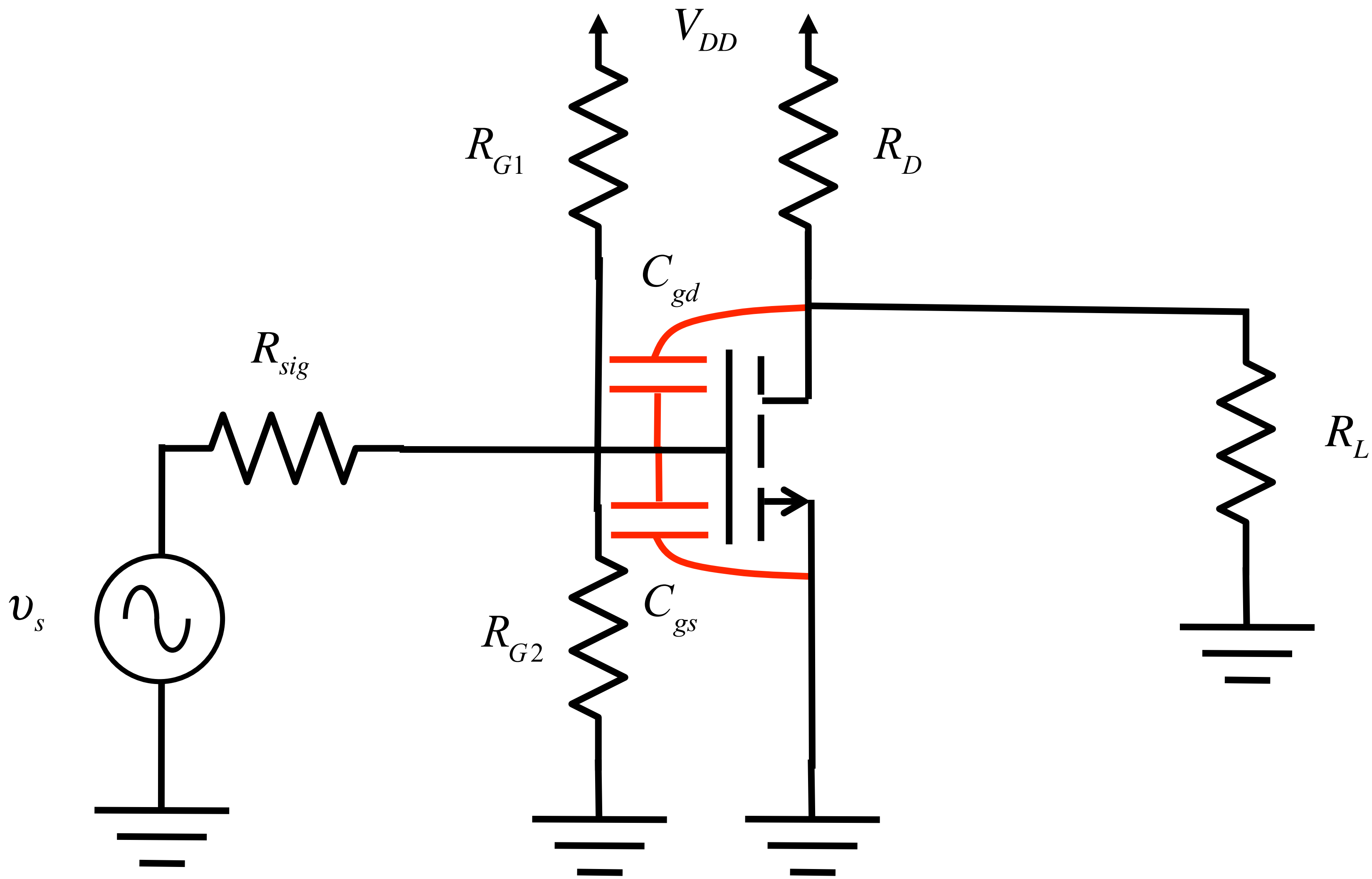
For exact solution, see Sec. 10.1 in Sedra and Smith (also appendix in L32).

An added benefit is that the short-circuit time constant method gives insight into which capacitor controls the LF response.

CS Amplifier: HF response



CS Amplifier: mid to high frequencies



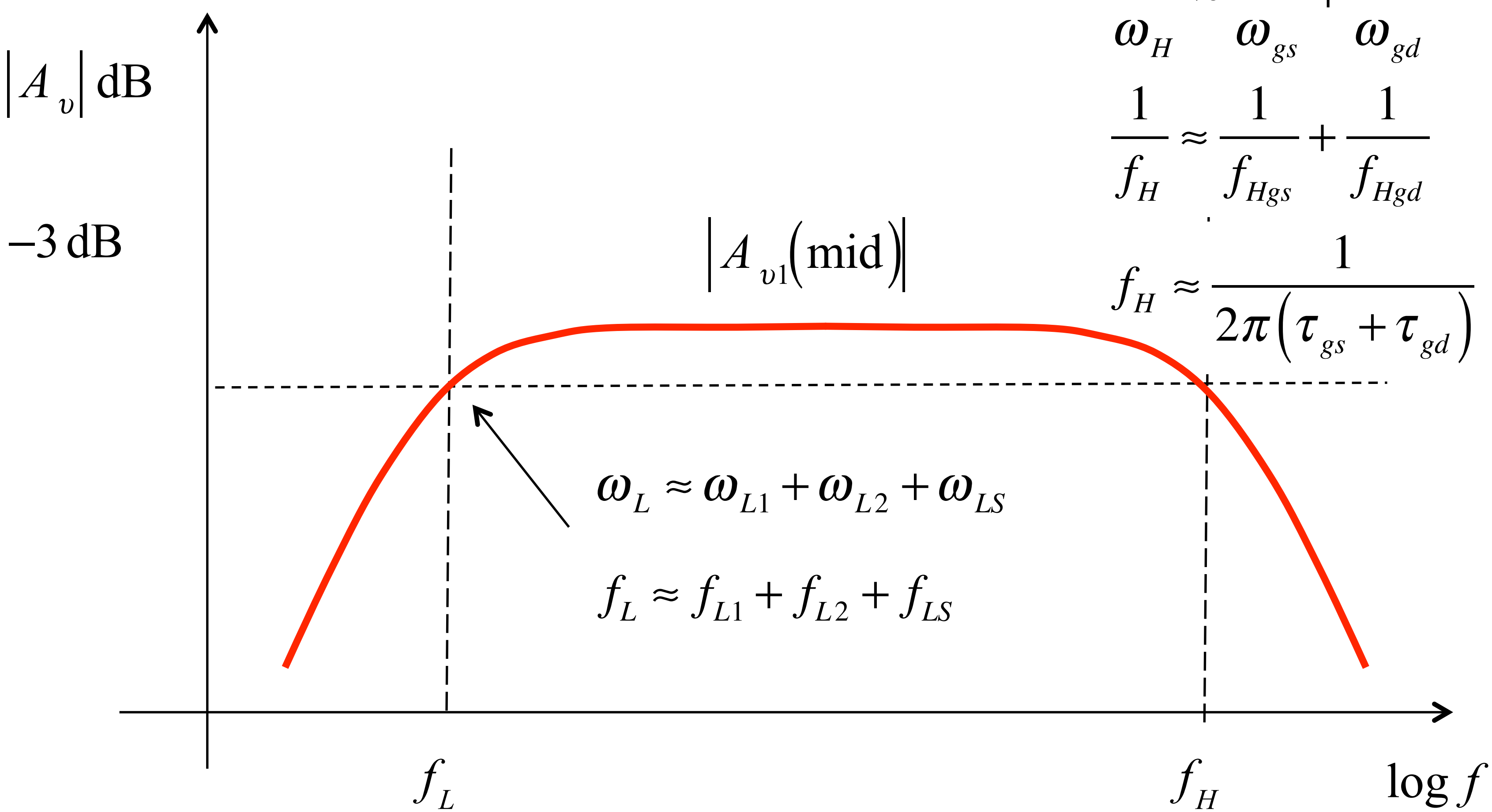
Open circuit time constant method

$$\tau_{gs} = R_{thgs} C_{gs} = \frac{1}{\omega_{gs}}$$

$$\tau_{gd} = R_{thgd} C_{gd} = \frac{1}{\omega_{gd}}$$

$$\omega_H \approx \frac{1}{\tau_{gs} + \tau_{gd}} \qquad \frac{1}{\omega_H} \approx \frac{1}{\omega_{gs}} + \frac{1}{\omega_{gd}}$$

Frequency response



$$\frac{1}{\omega_H} \approx \frac{1}{\omega_{gs}} + \frac{1}{\omega_{gd}}$$

$$\frac{1}{f_H} \approx \frac{1}{f_{Hgs}} + \frac{1}{f_{Hgd}}$$

$$f_H \approx \frac{1}{2\pi\left(\tau_{gs} + \tau_{gd}\right)}$$

$$\omega_L \approx \omega_{L1} + \omega_{L2} + \omega_{LS}$$

$$f_L \approx f_{L1} + f_{L2} + f_{LS}$$

Comments: O-C time constant method

$$\tau_{gs} = R_{thgs} C_{gs}$$

$$\tau_{gd} = R_{thgd} C_{gd}$$

$$\omega_H \approx \frac{1}{\tau_{gs} + \tau_{gd}}$$

Note that this is an approximate method that assumes there is a **dominant pole**.

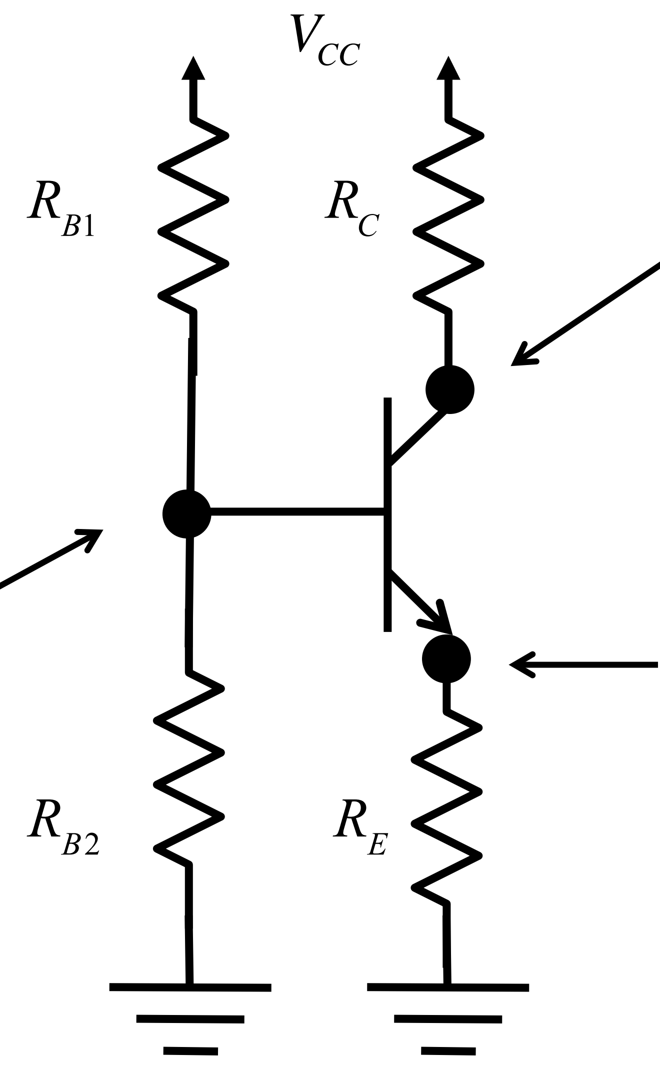
As discussed Sec. 10.4.3 in Sedra and Smith the OC time constant method generally works well even when there is no dominant pole.

An added benefit is that this OC time constant method gives insight into which capacitor controls the HF response of the amplifier.

Outline

1) Review
2) **HF response of CG/CB**
3) HF response of cascode
4) HF response of CD/CC

BJT bias circuit

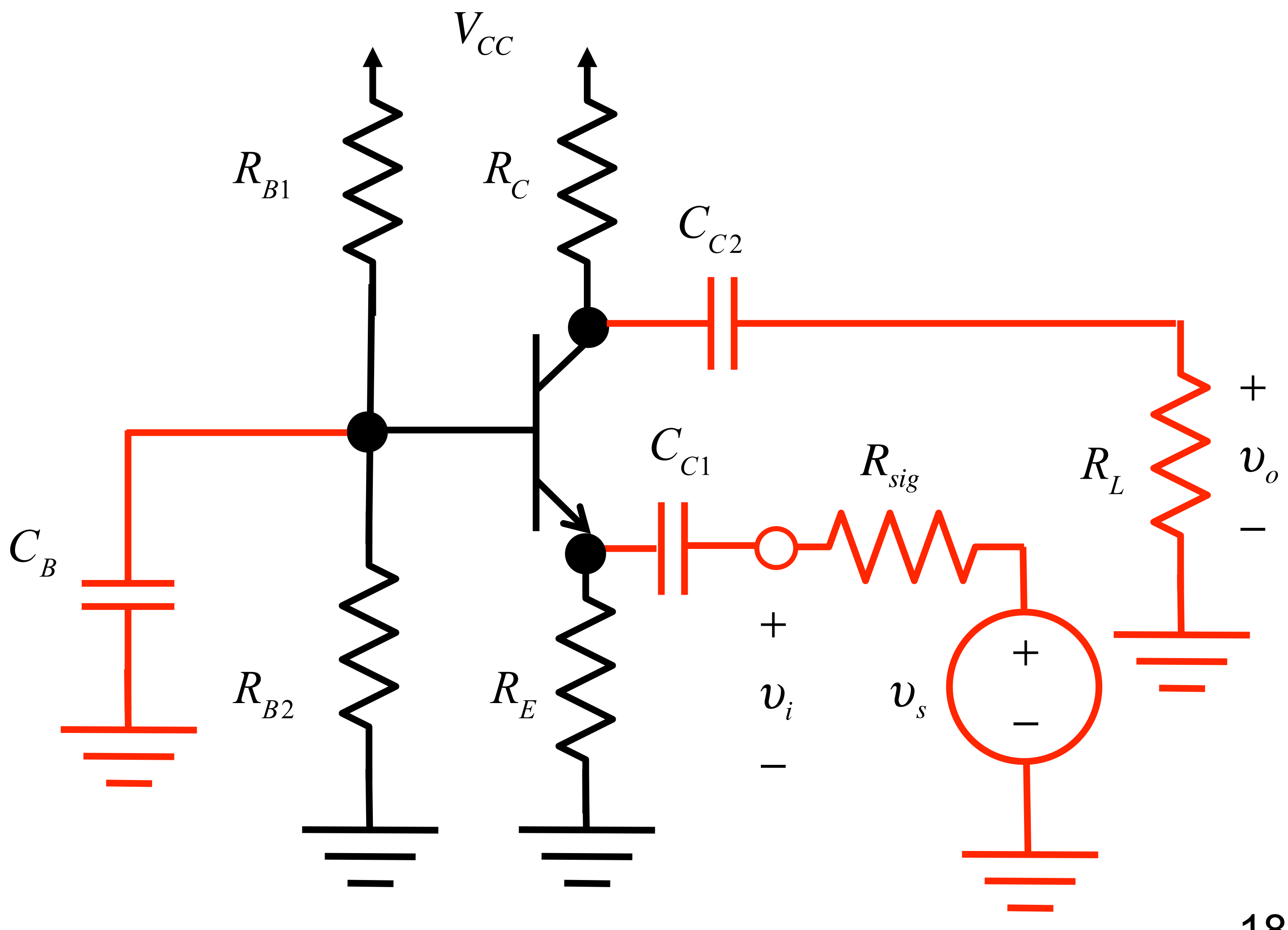


Take output from the collector

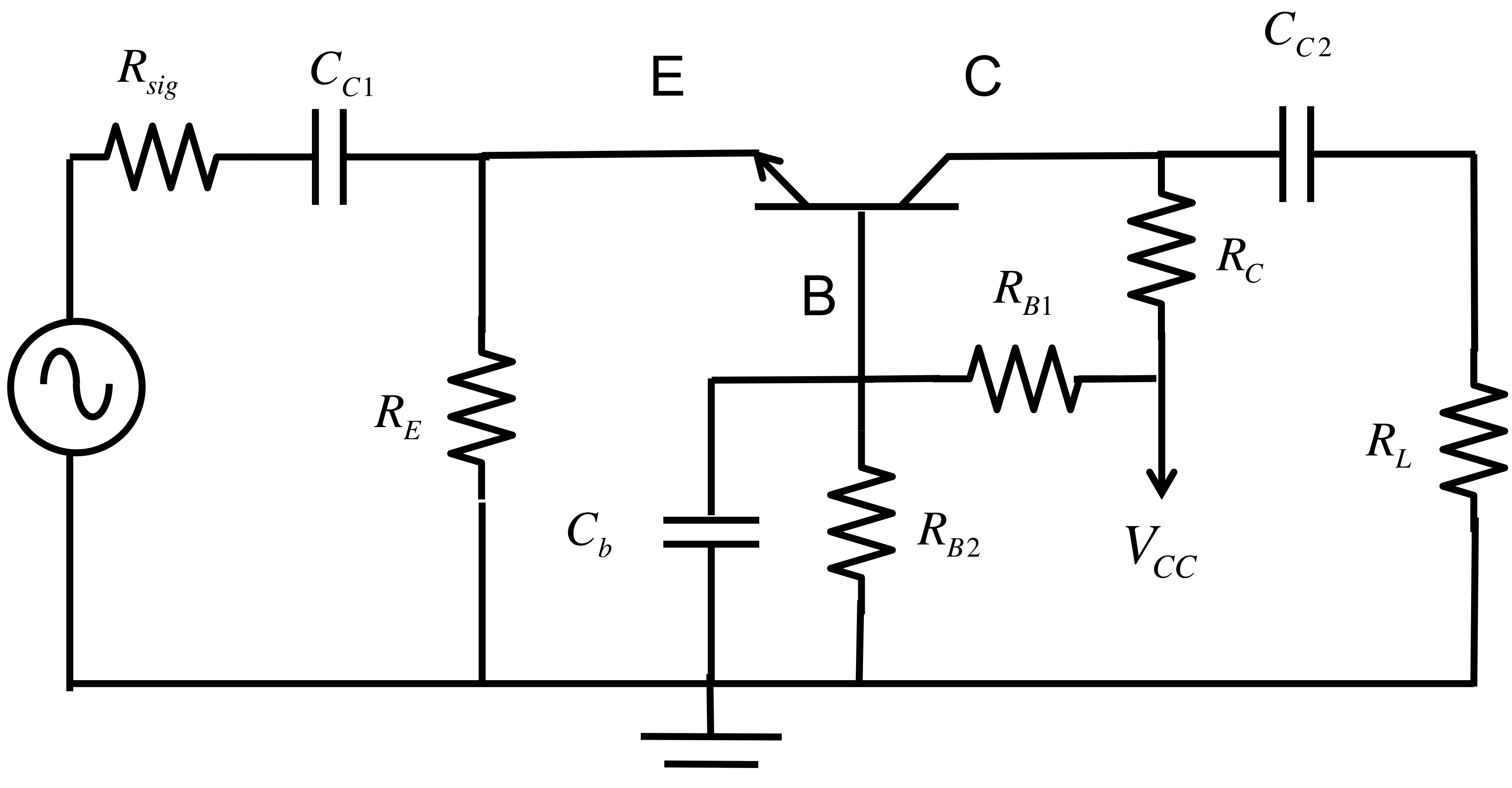
Input applied to the emitter

Base must be grounded

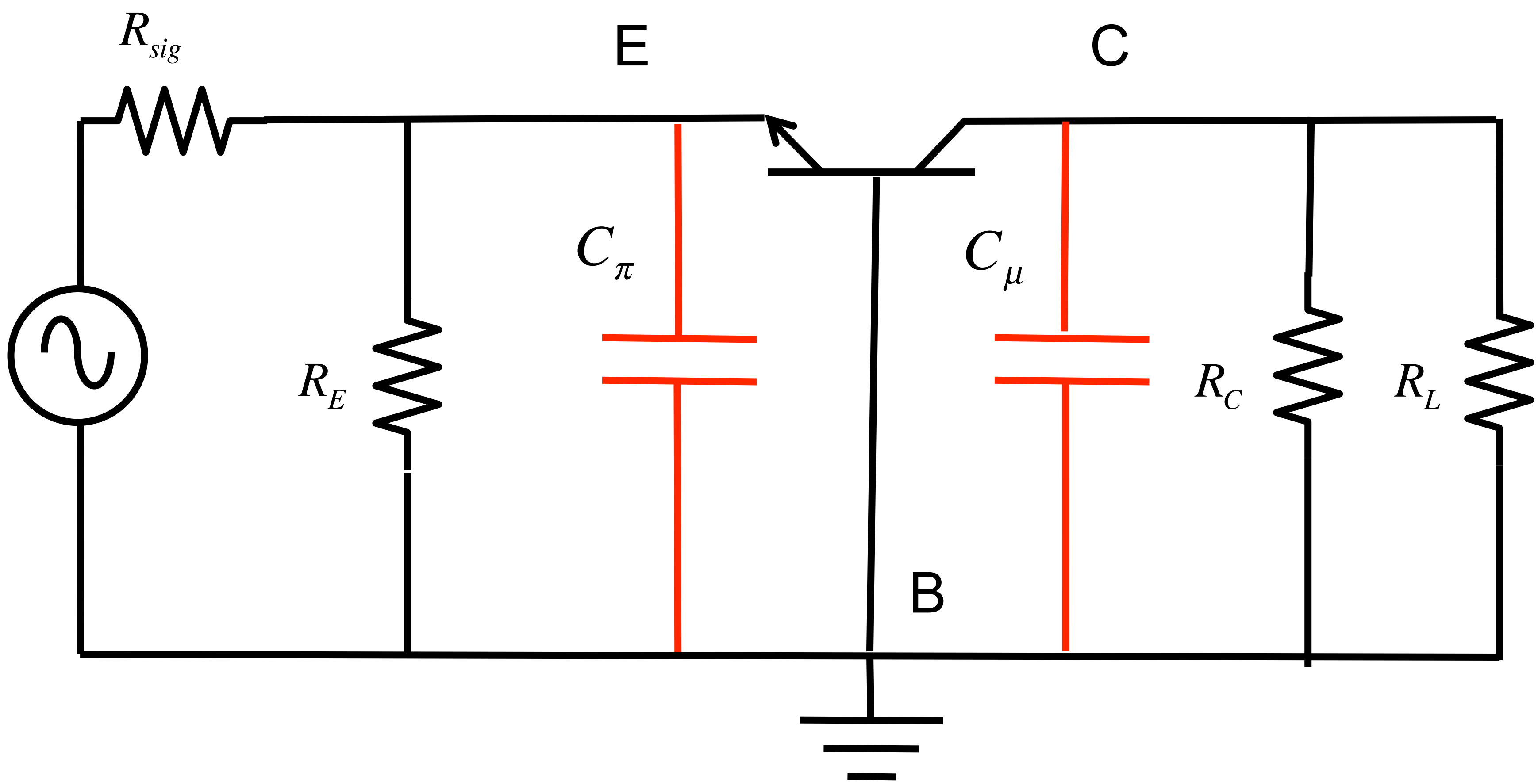
CB amplifier



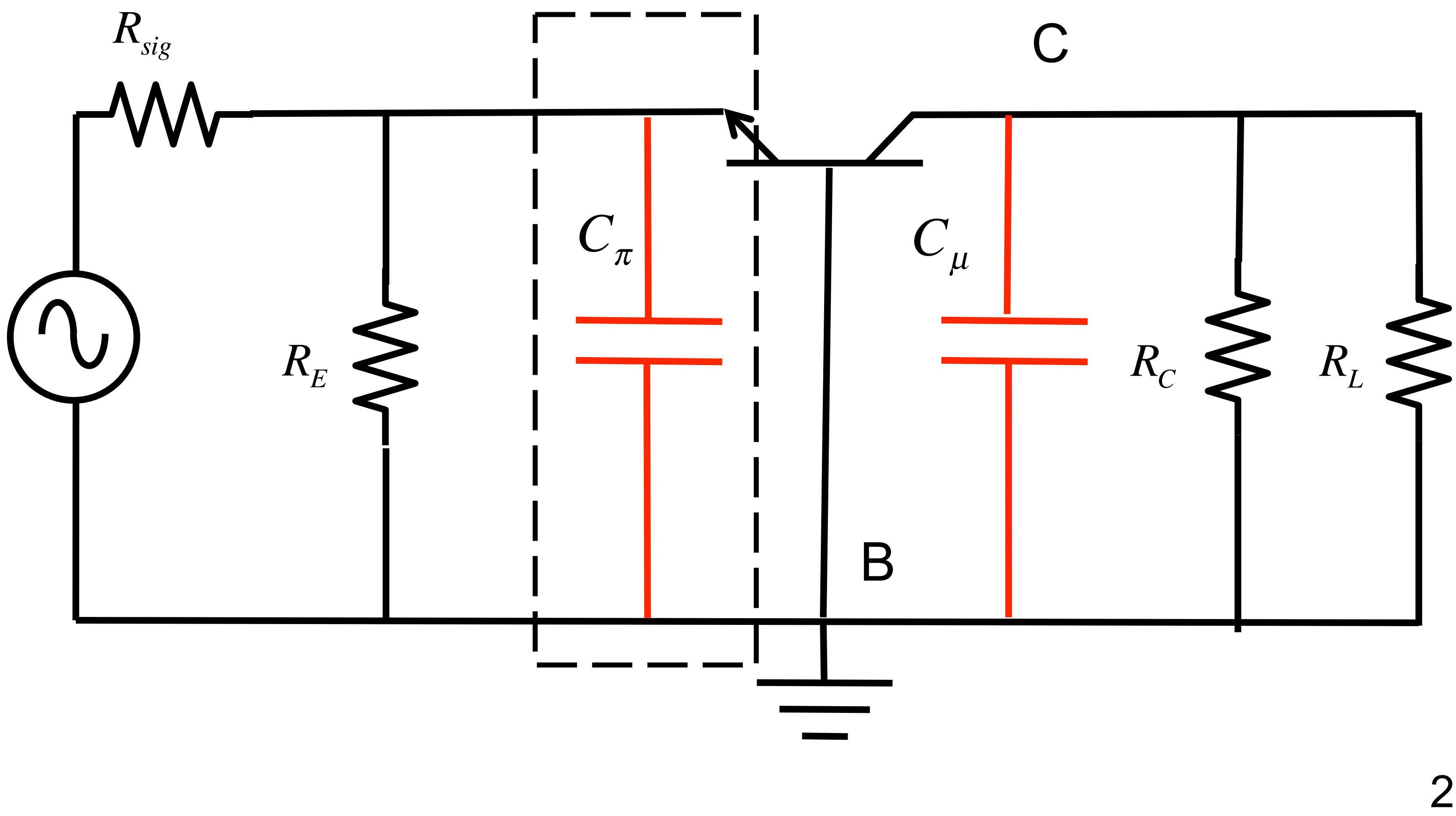
CB



CB at mid and high frequencies

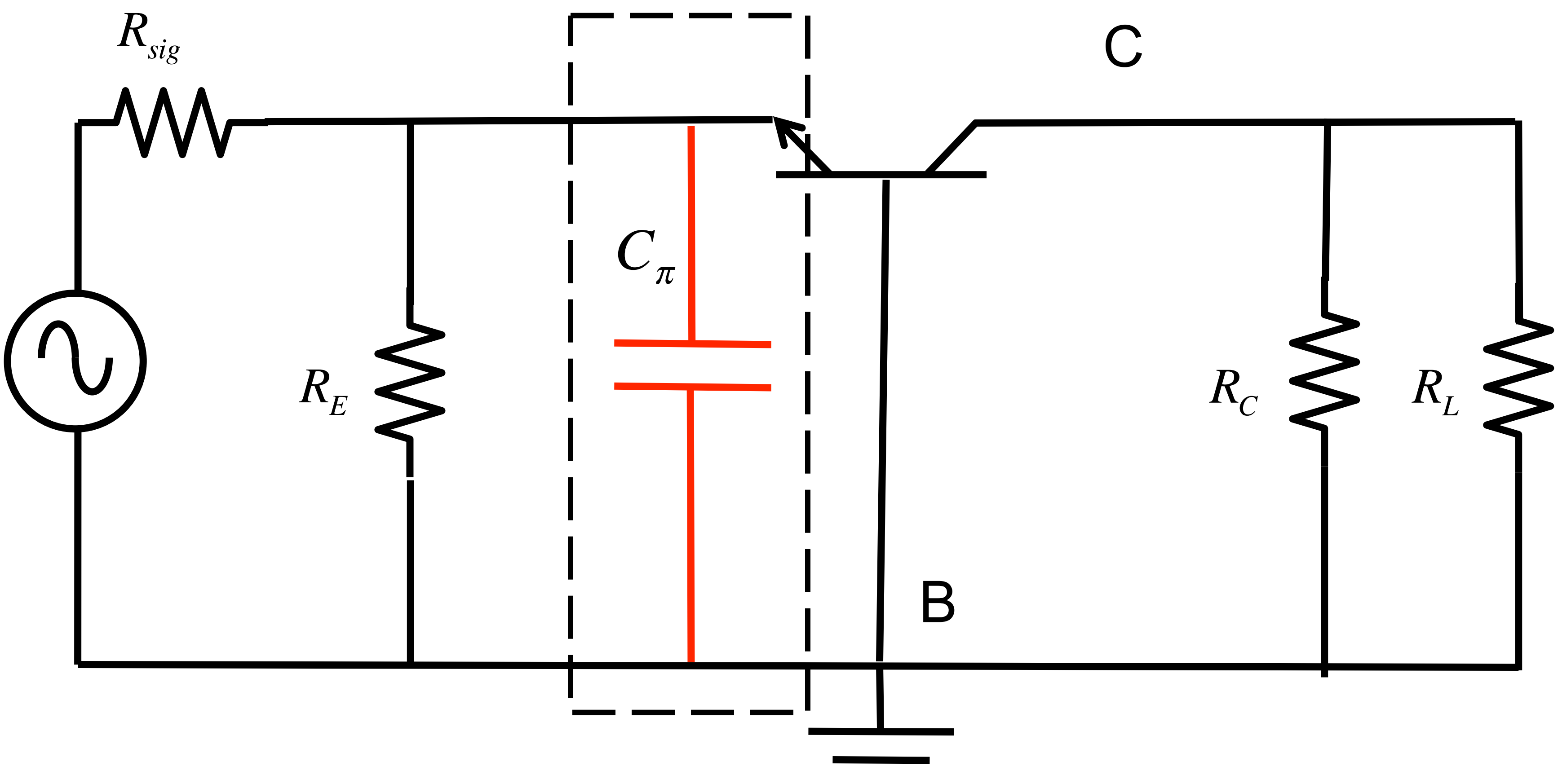


CB at mid and high frequencies



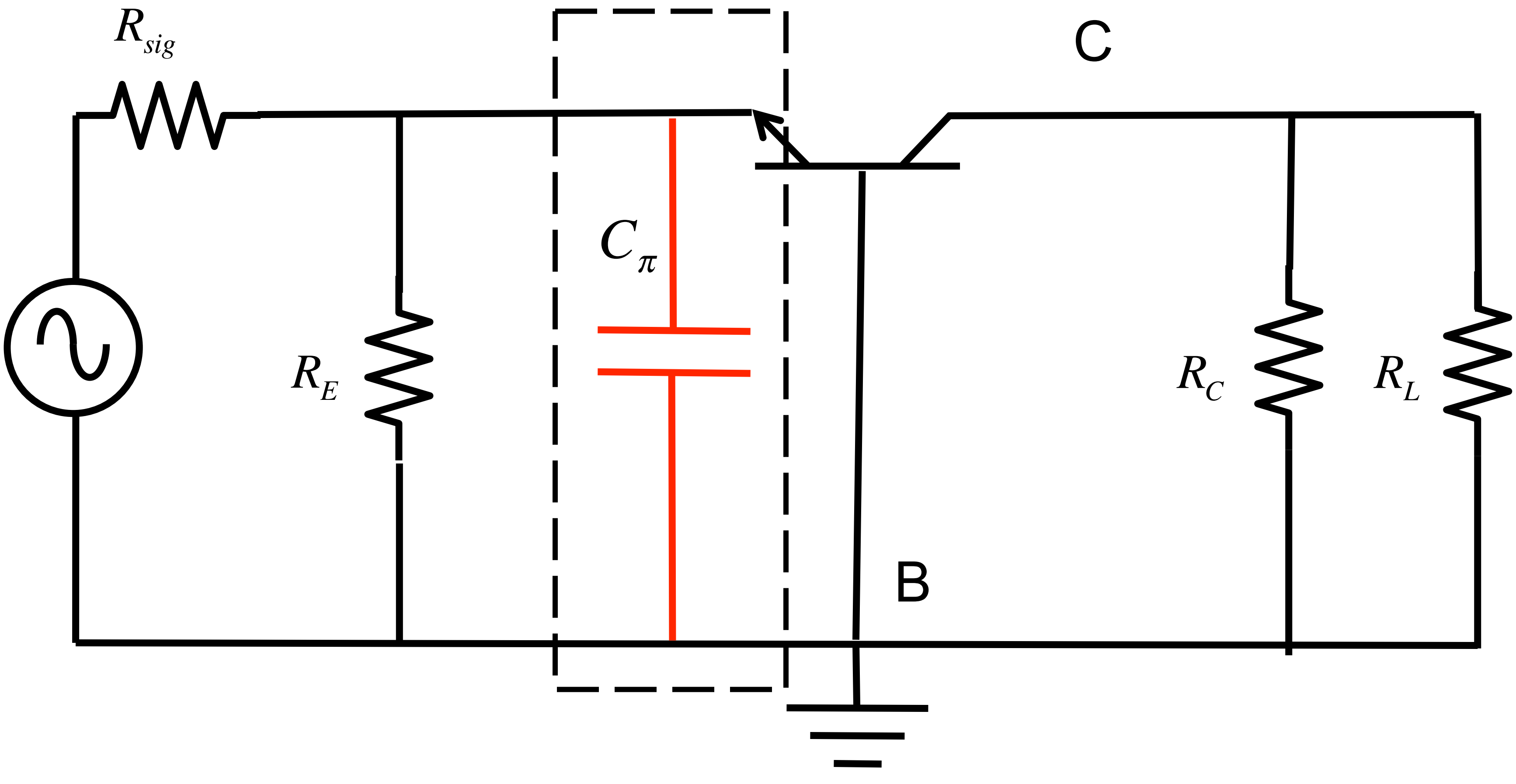
CB at mid and high frequencies

$$\tau_{\pi} = ?$$

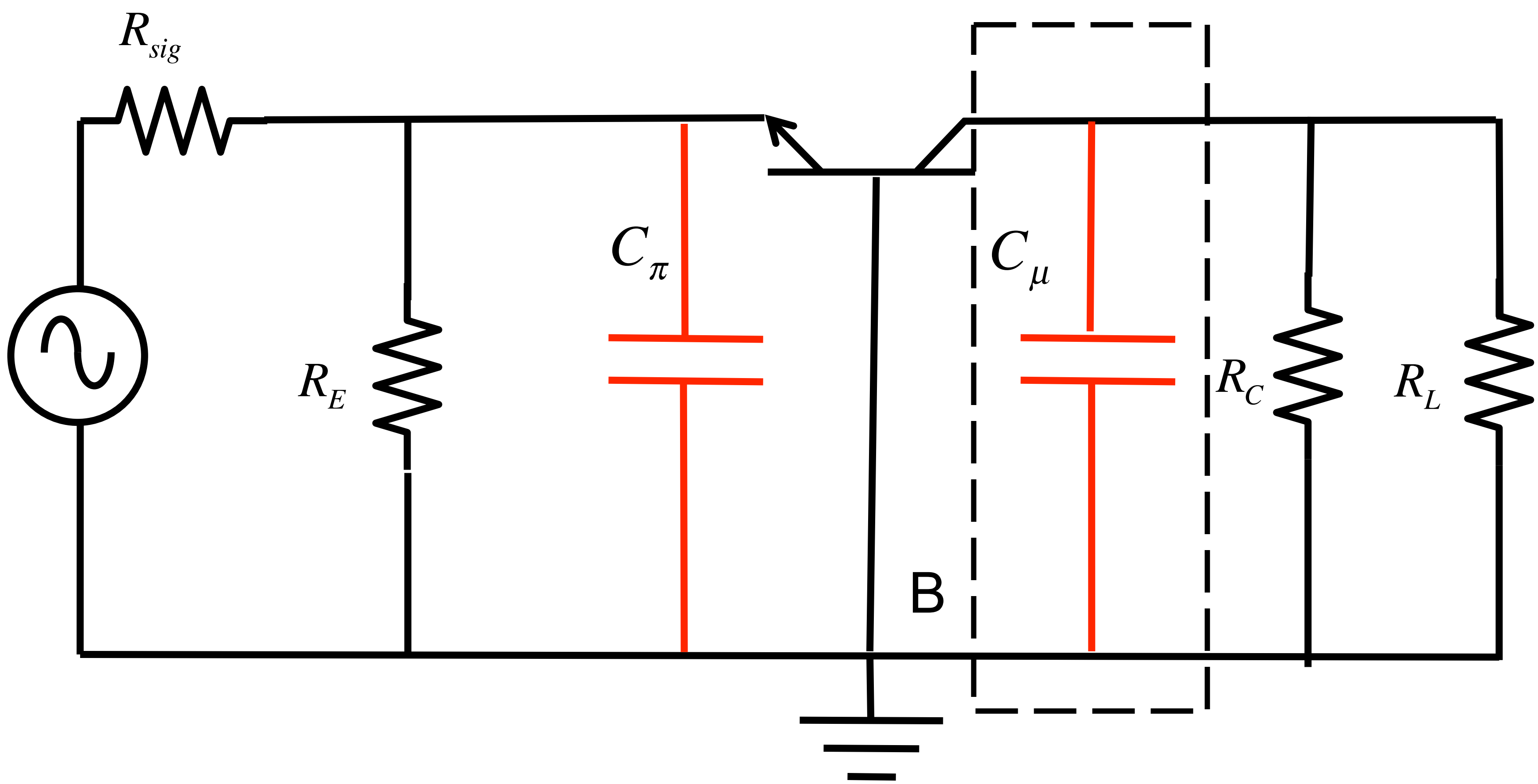


CB at mid and high frequencies

$$\tau_\pi = \left(R_{sig} \parallel R_E \parallel \frac{r_\pi}{\beta+1} \right) C_\pi$$

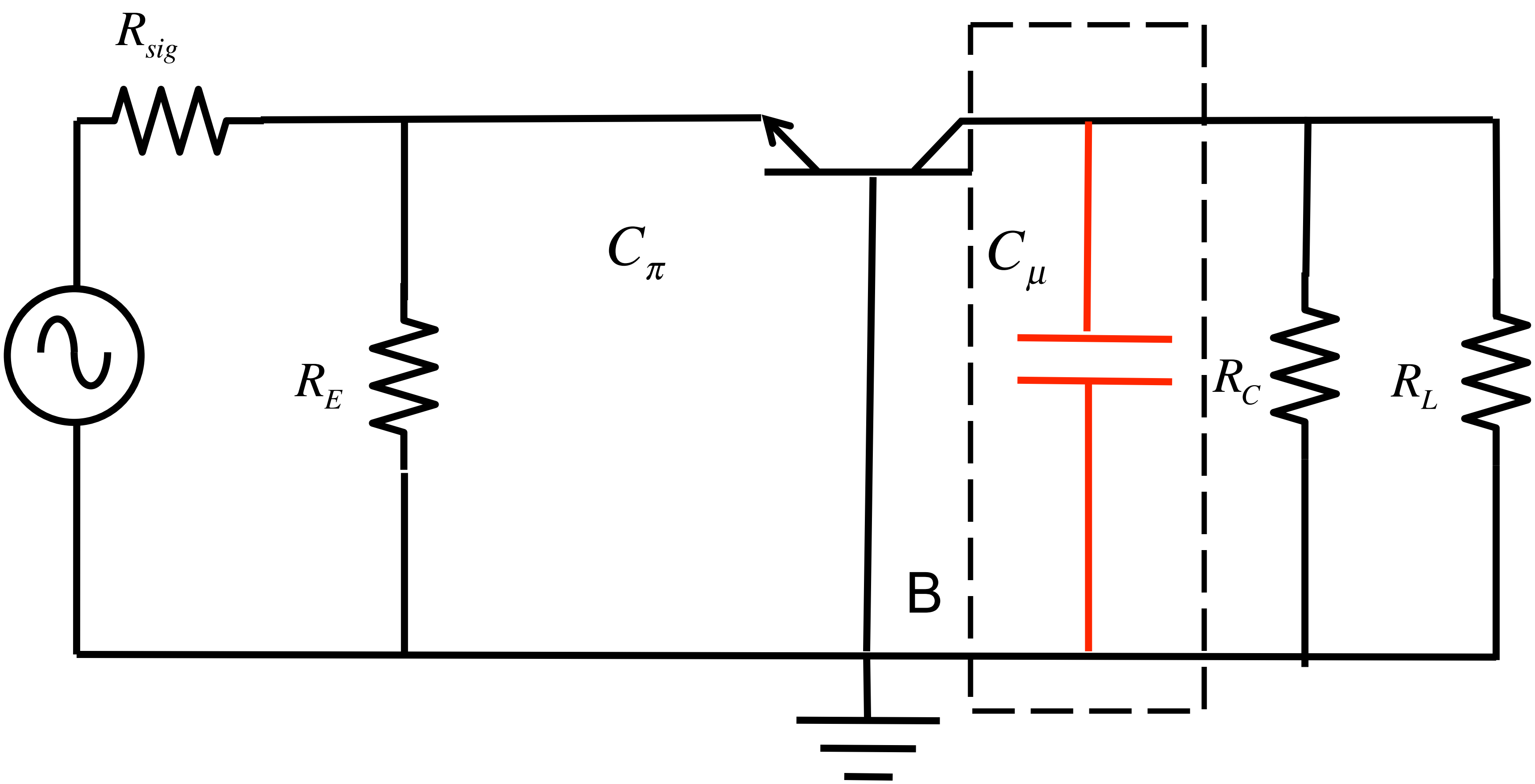


CB at mid and high frequencies



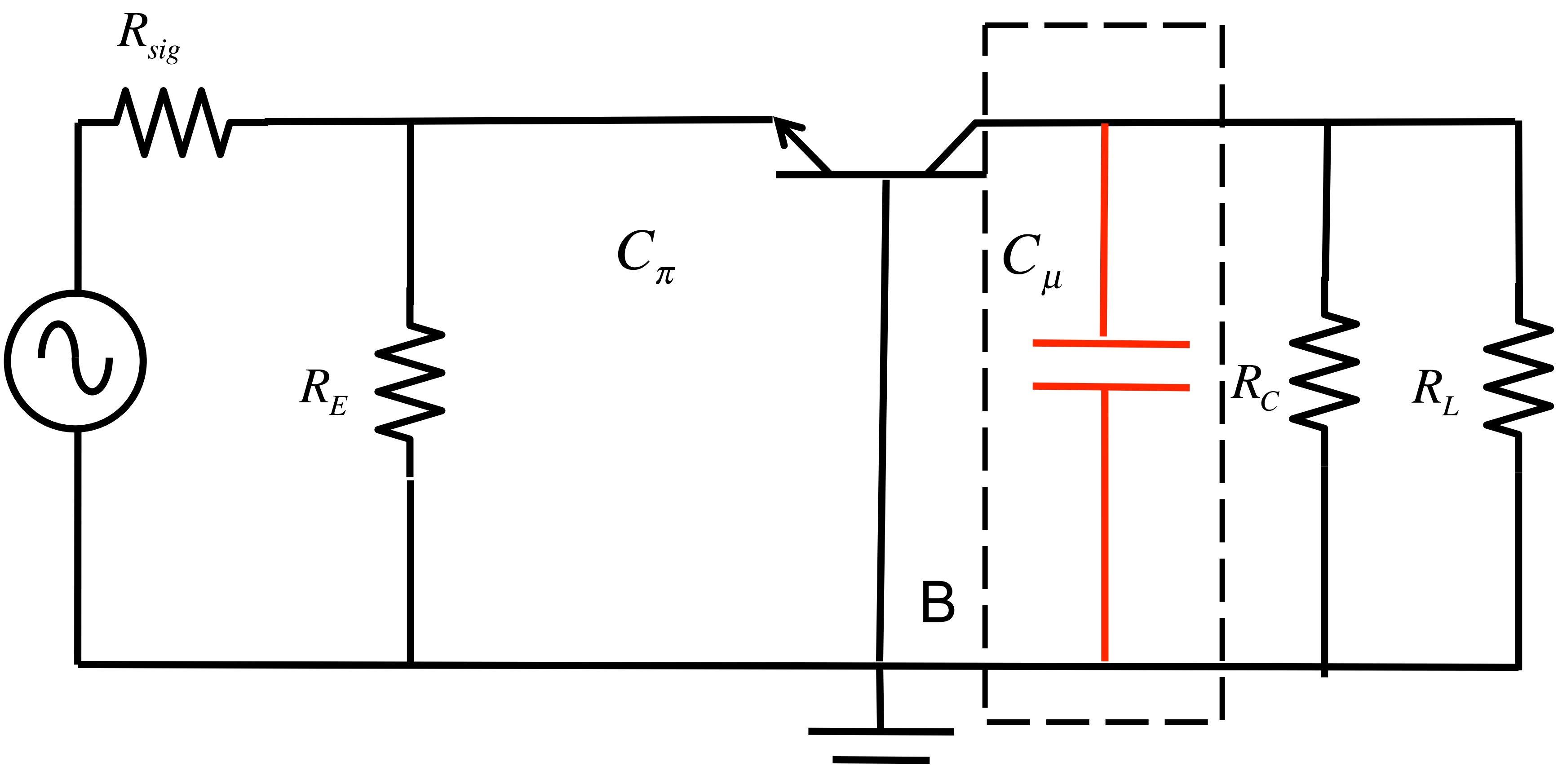
CB at mid and high frequencies

$$\tau_{\mu} = ?$$



CB at mid and high frequencies

$$\tau_\mu = \left(R_C \parallel R_L\right) C_\mu$$



CB

$$\tau_\mu = (R_C \parallel R_L) C_\mu$$

$$\tau_\pi = \left(R_{sig} \parallel R_E \parallel \frac{r_\pi}{\beta + 1} \right) C_\pi$$

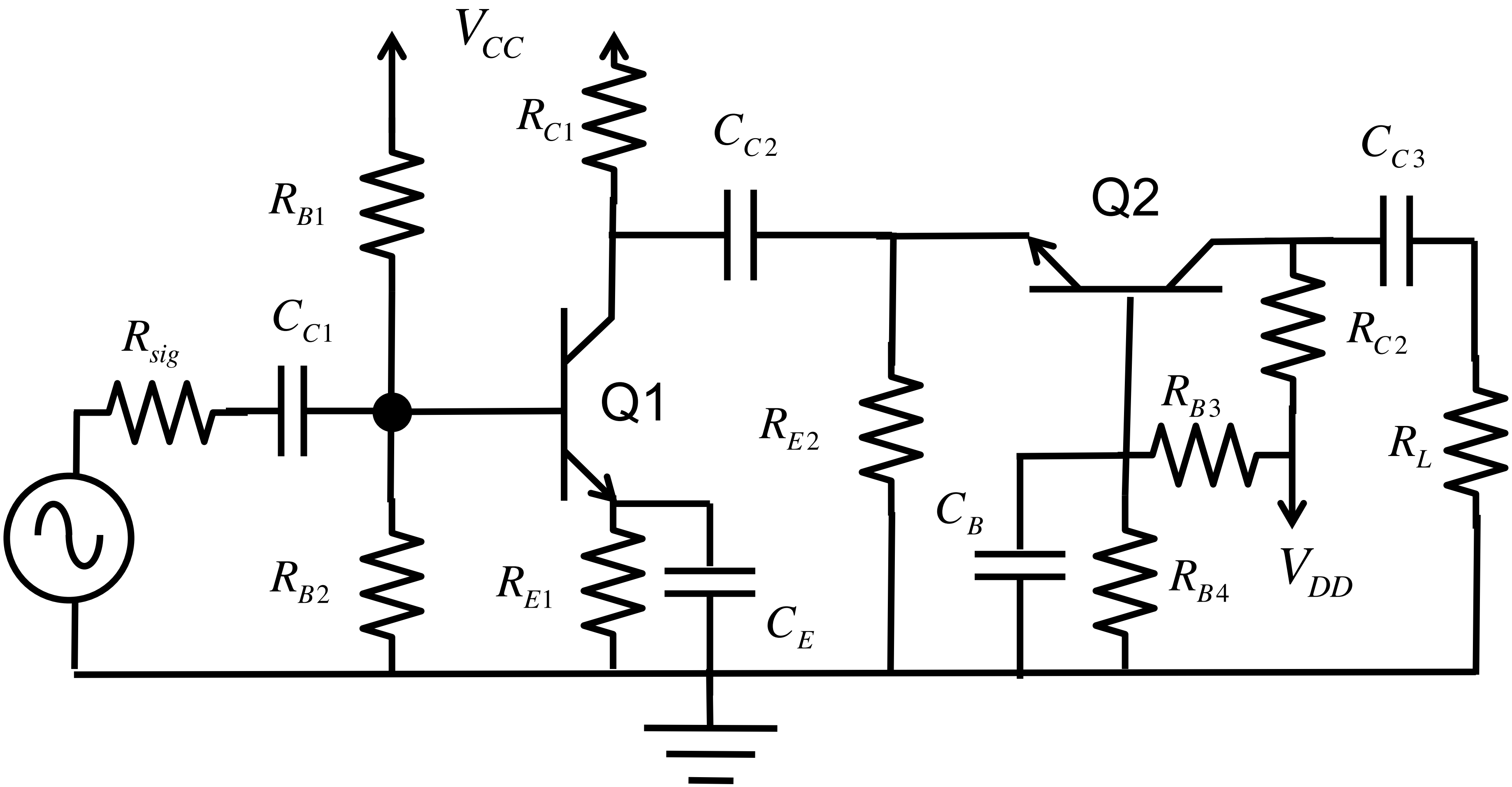
$$\omega_H \approx \frac{1}{\tau_\pi + \tau_\mu}$$

No Miller effect

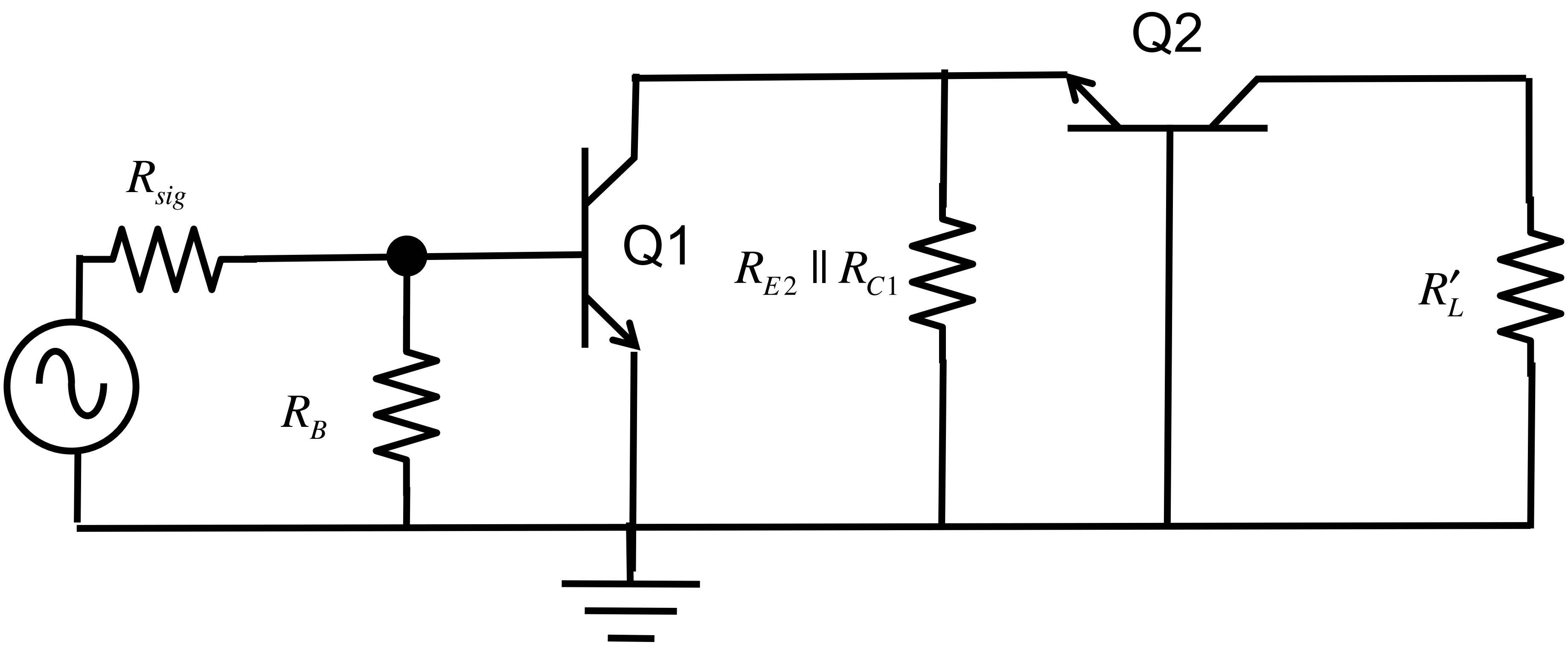
Outline

1) Review
2) HF response of CG/CB
3) **HF response of cascode**
4) HF response of CD/CC

Discrete cascode



Cascode – mid to high frequencies



Hybrid-pi model

$\tau_{\pi 1} = ?$

$\tau_{\mu 1} = ?$

$\tau_{\pi 2} = ?$

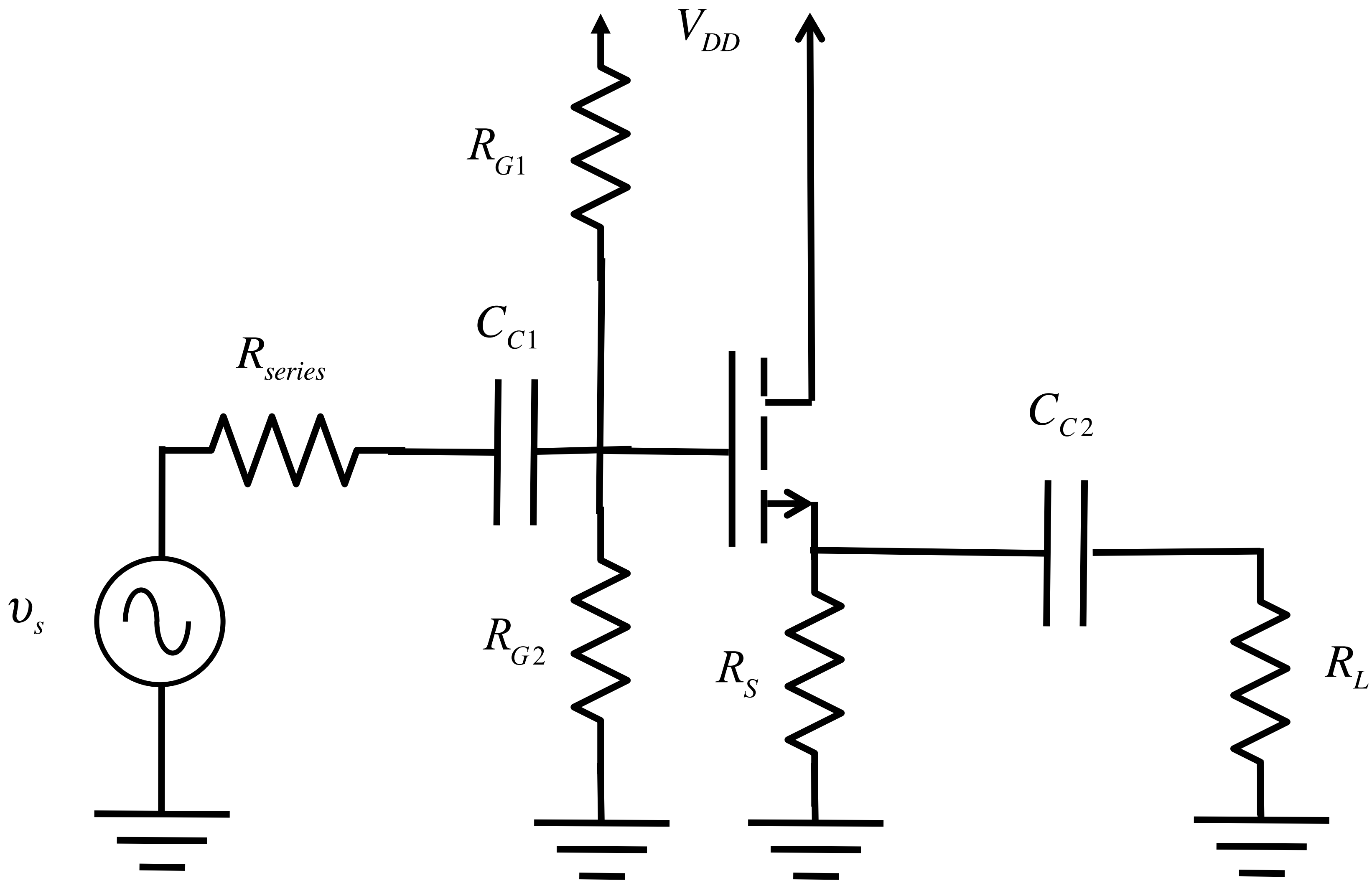
$\tau_{\mu 2} = ?$

Does this amplifier suffer from the Miller effect?

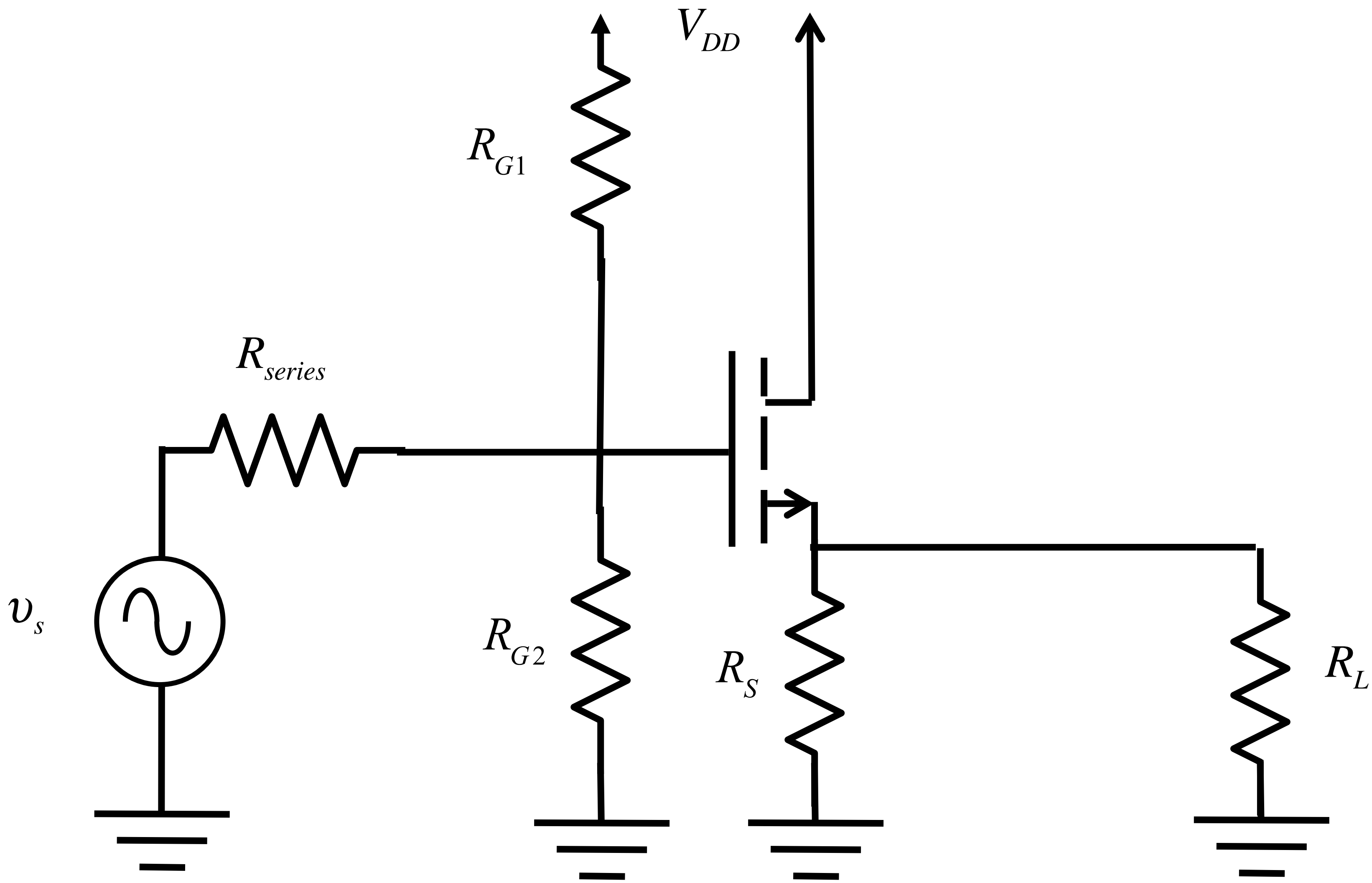
Outline

1) Review
2) HF response of CG/CB
3) HF response of cascode
4) **HF response of CD/CC**

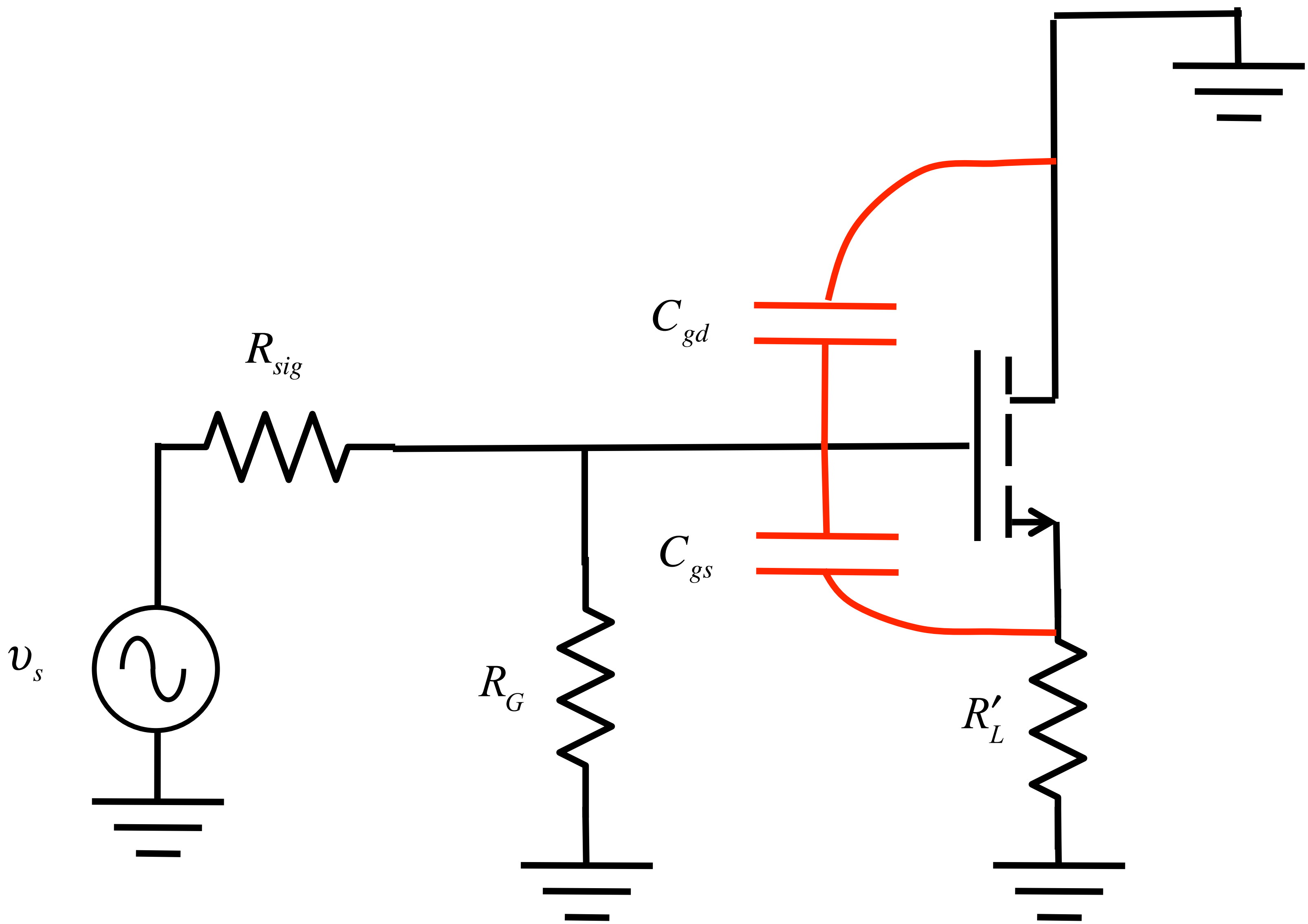
CD



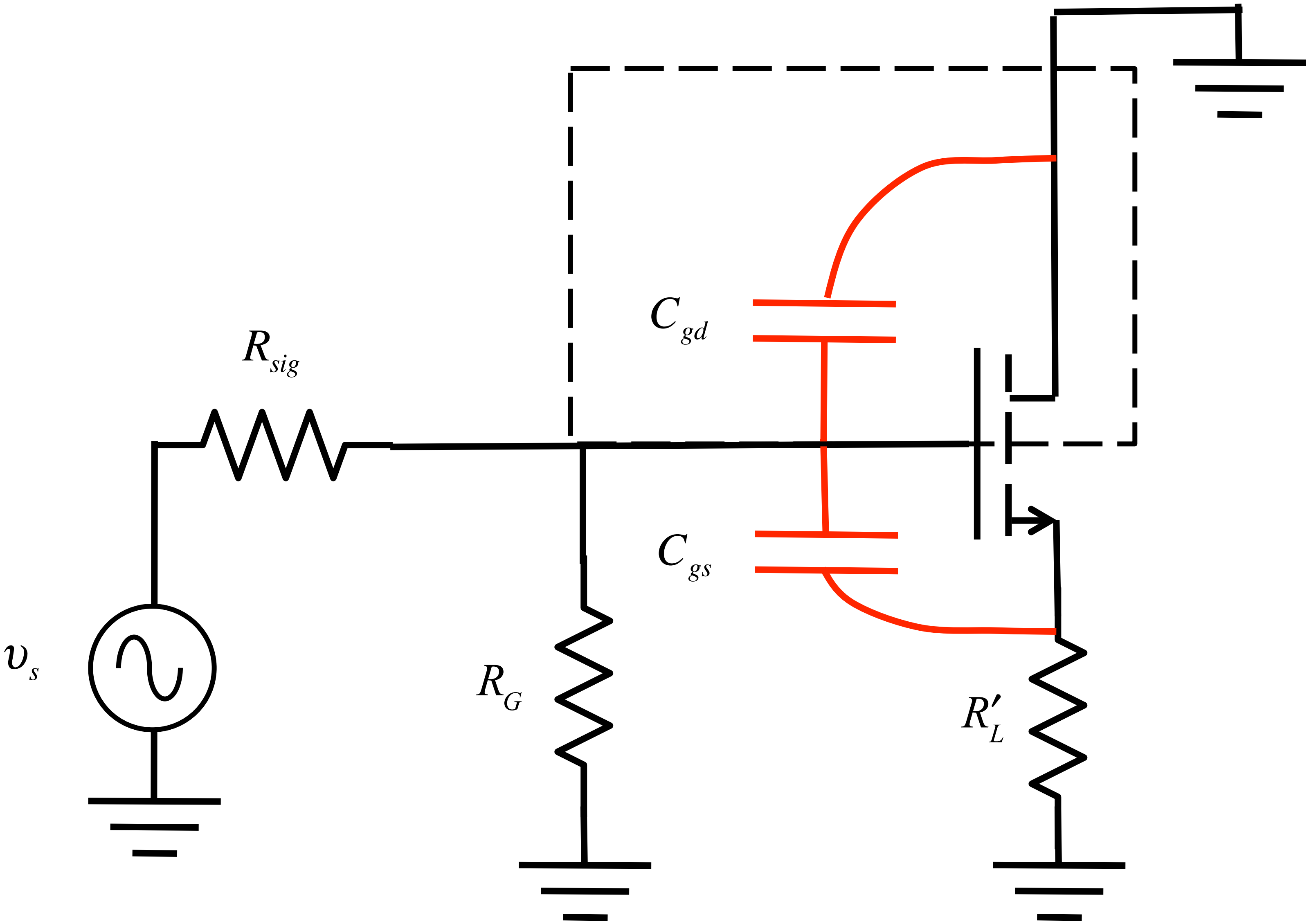
CD at mid-frequencies



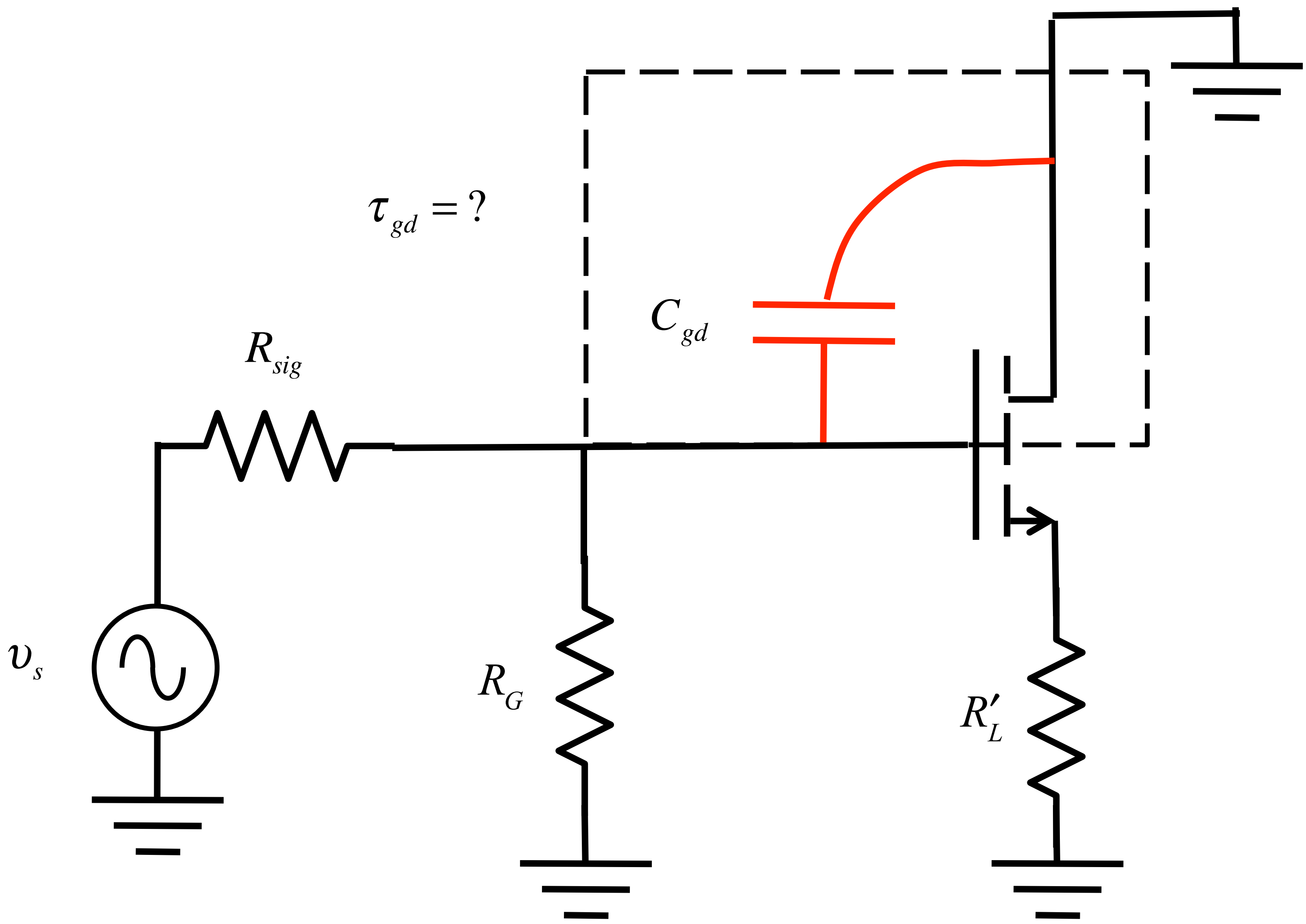
CD at high frequencies



CD at high frequencies

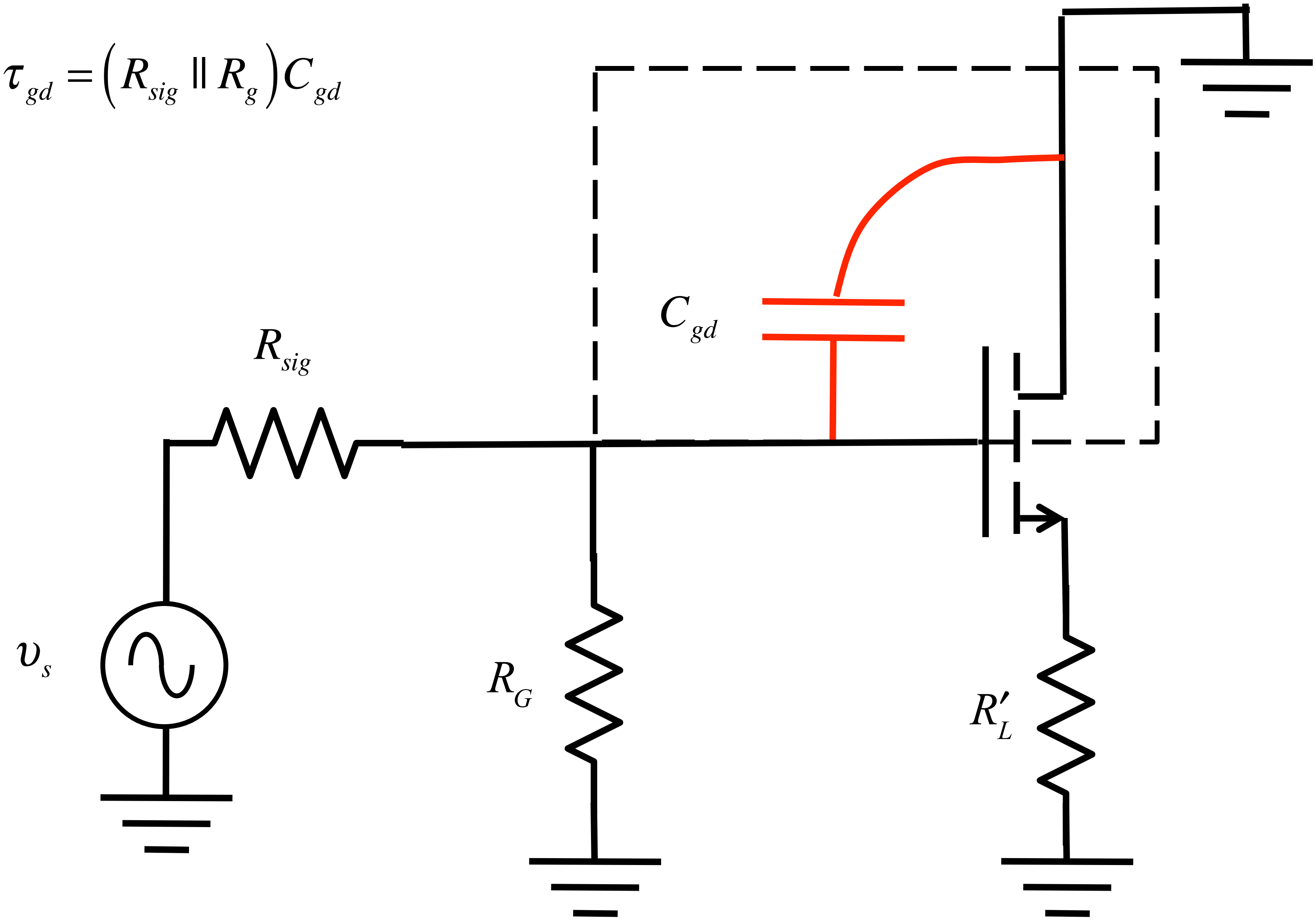


CD at high frequencies

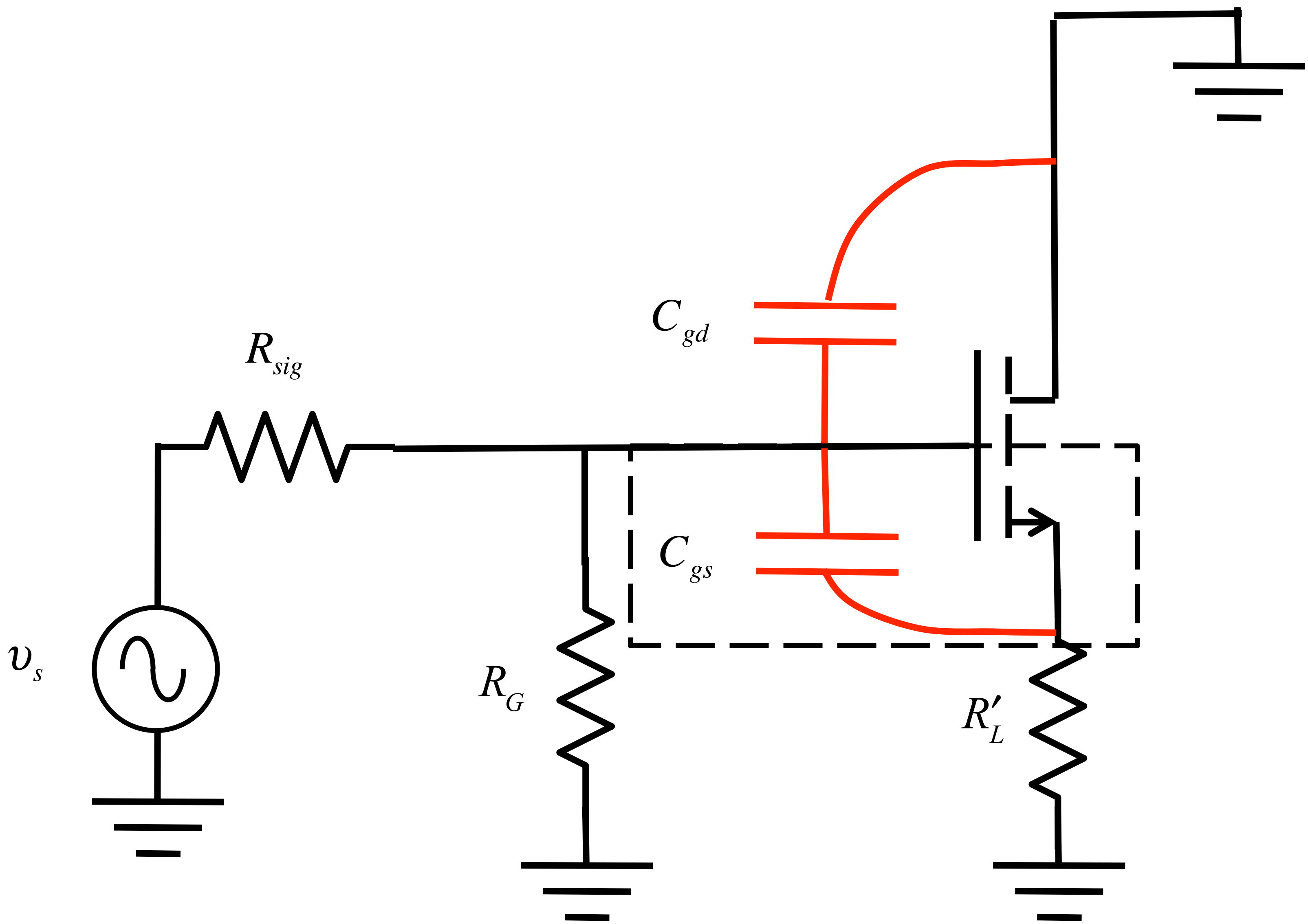


CD at high frequencies

$$\tau_{gd} = \left(R_{sig} \parallel R_g\right) C_{gd}$$

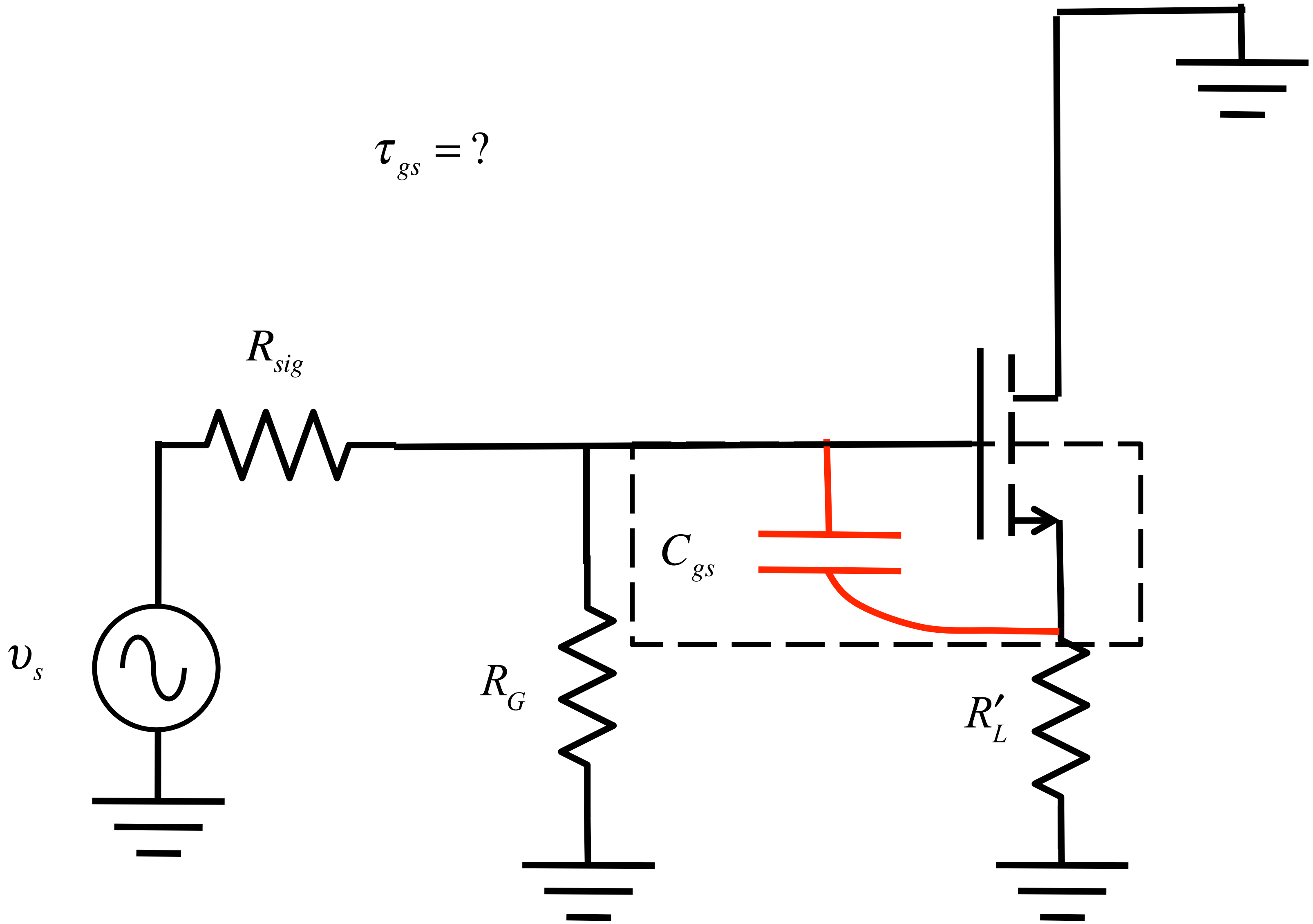


CD at high frequencies



CD at high frequencies

$$\tau_{gs} = ?$$



CD at high frequencies

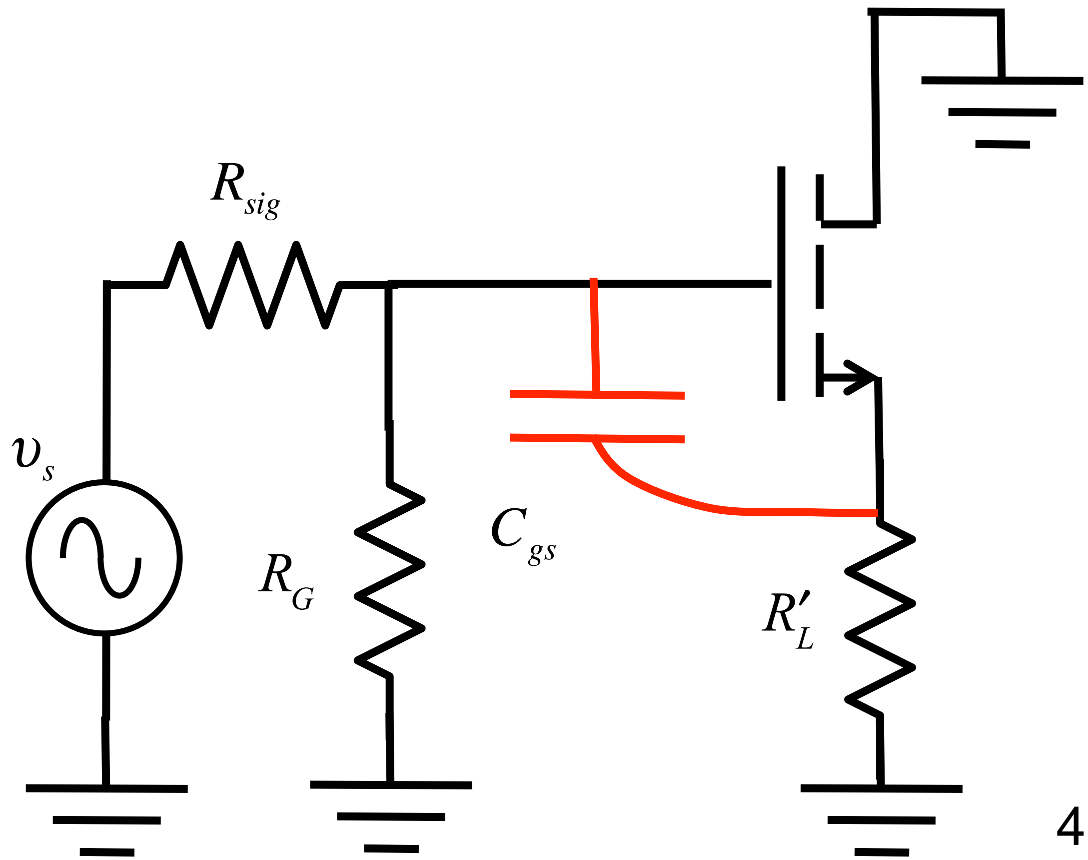
$$\tau_{gs} = R_{sig} \parallel R_G C_{in} + R_L' C_{out}$$

$$\tau_{gs} = \left(R_{sig} \parallel R_G\right) C_{in} + \left[R_L' \parallel \left(1/g_m\right)\right] C_{gs}$$

$$C_{in} = C_{gs}\left(1 - A\right)$$

$$C_{in} = C_{gs}\left(1 - \frac{g_m R_L'}{1 + g_m R_L'}\right)$$

$$C_{in} = \frac{C_{gs}}{1 + g_m R_L'}$$

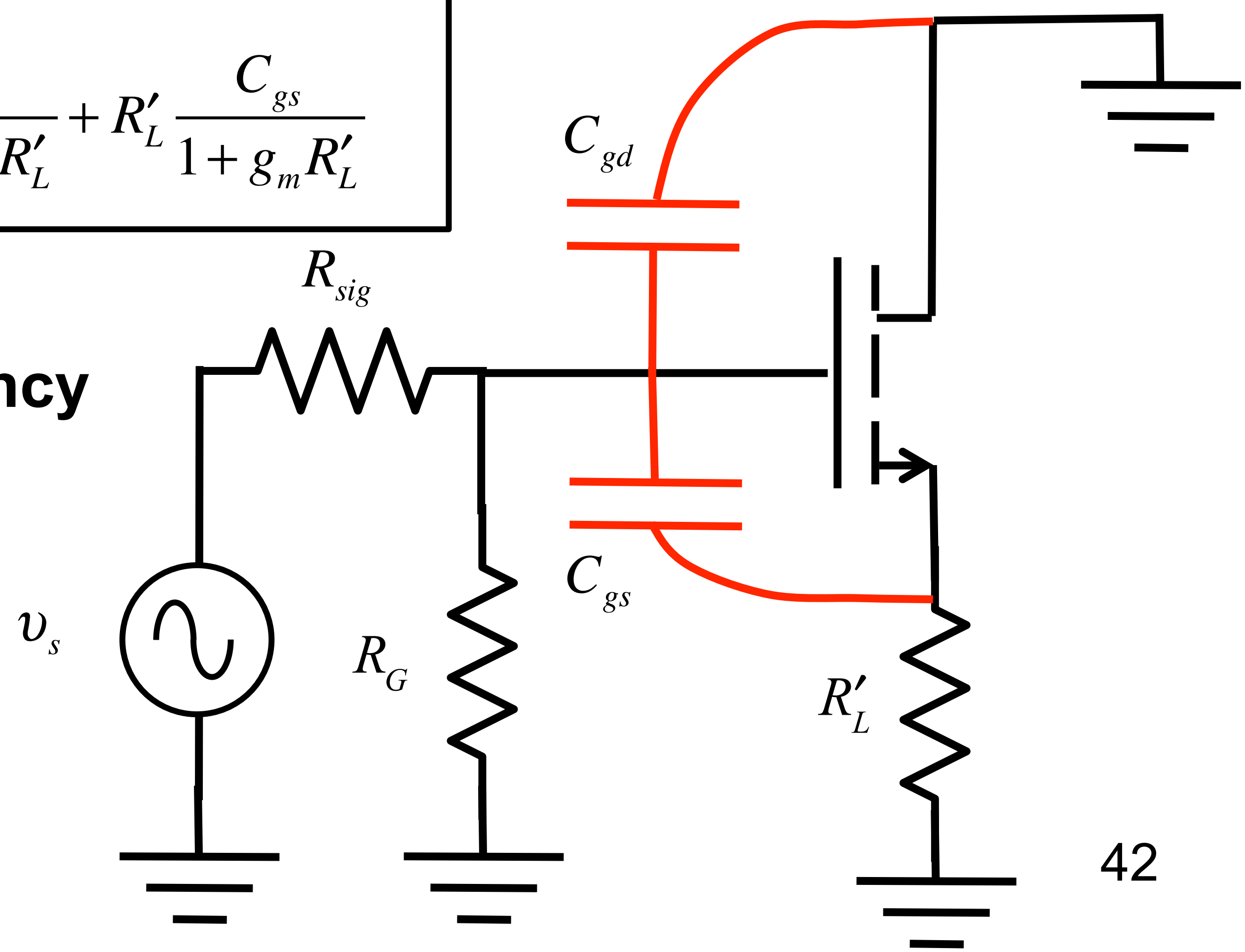


CD at high frequencies

$$\tau_{gd} = C_{gd} R'_S$$

$$\tau_{gs} = \left(R_{sig} \parallel R_G\right) \frac{C_{gs}}{1 + g_m R'_L} + R'_L \frac{C_{gs}}{1 + g_m R'_L}$$

Good high-frequency response



Comments: CD at high frequencies

We have derived eqns. (10.124) and (10.120) in Sedra and Smith, but S&S point out that often there is no dominant pole, and the analysis is much more complex.

See Sec. 10.6 in Sedra and Smith