Spring 2019 Purdue University

ECE 255: L37

Review for Final Exam

Mark Lundstrom
School of ECE
Purdue University
West Lafayette, IN USA

PURDUE UNIVERSITY

Announcements

Final Exam: Thursday, May 2, 7:00 – 9:00 PM, CL50

HW11 Due 5:00 PM Friday, April 26 in EE-209 dropbox (note submission sheet)

Please complete the online course evaluation

No class on Friday, April 26!

About the final exam

The final exam is comprehensive, but will emphasize topics since Exam 3

1) Multi-stage amplifiers

2) Differential amplifiers:
   - BJT diff amp with R_C
   - MOS diff amp with R_D
   - MOS diff amp with active load

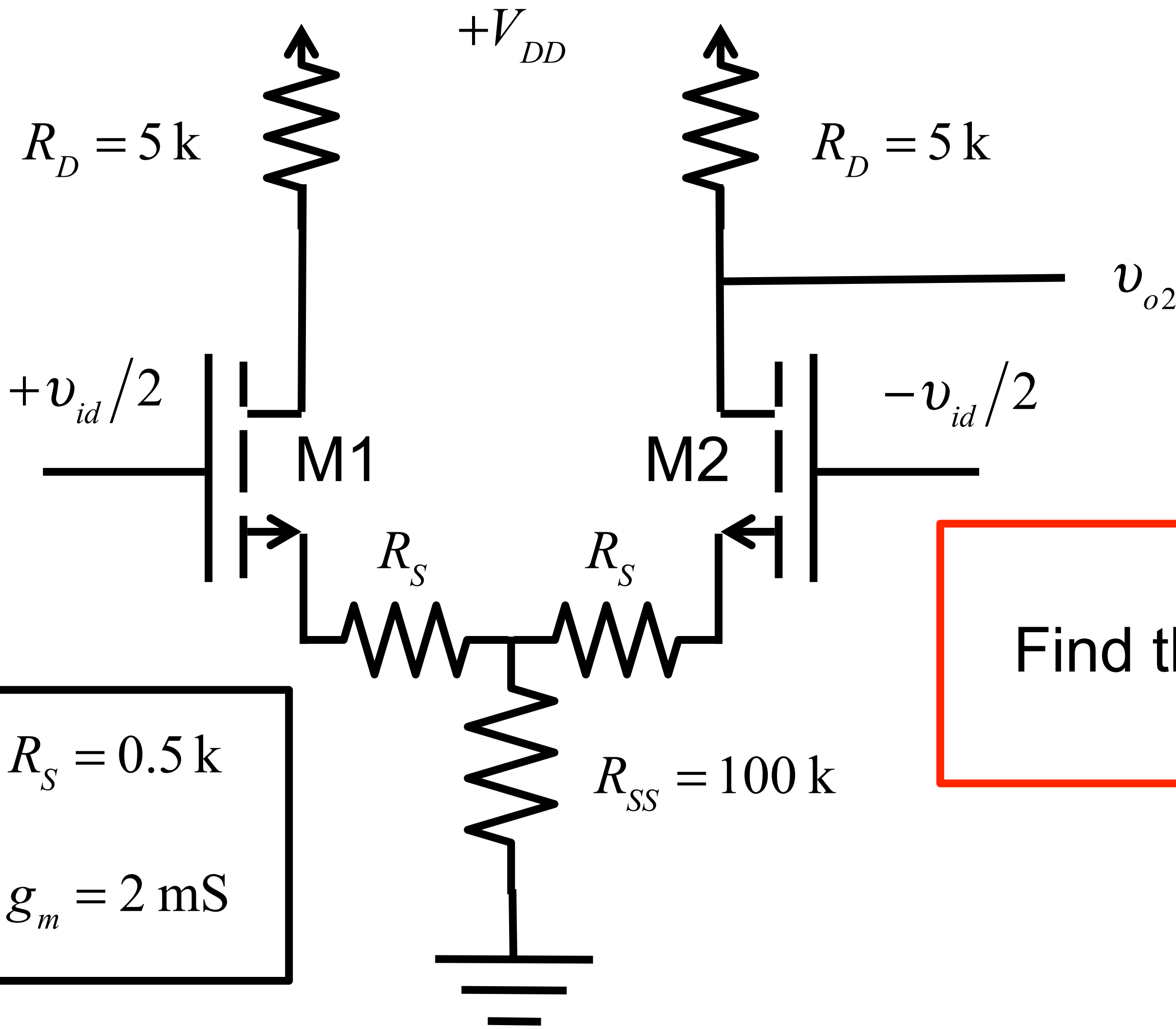
3) Op Amps
   - General definitions / characteristics
   - 2-stage MOS op amp

About the final exam

4) Low-frequency response
   - Short-circuit time constant method
   - Finding Rth for each C
   - Dominant pole
   - Overall f_L: combining poles (adding frequencies)

5) High-frequency response
   - Hybrid-pi transistor models
   - Open-circuit time constant method
   - Finding Rth for each C
   - Dominant pole
   - Overall f_H: combining poles (adding time constants)
   - **Miller effect**

Review problem 1a)



$R_S = 0.5\,\mathrm{k}$

$g_m = 2\,\mathrm{mS}$

Find the gain: $A_{dm} = \dfrac{v_{o2}}{v_{id}}$

Review problem 1a)

From the half-circuit:

$$\upsilon_{o2} = -\frac{g_m R_D}{1+g_m R_S}\left(-\upsilon_{id}/2\right)$$

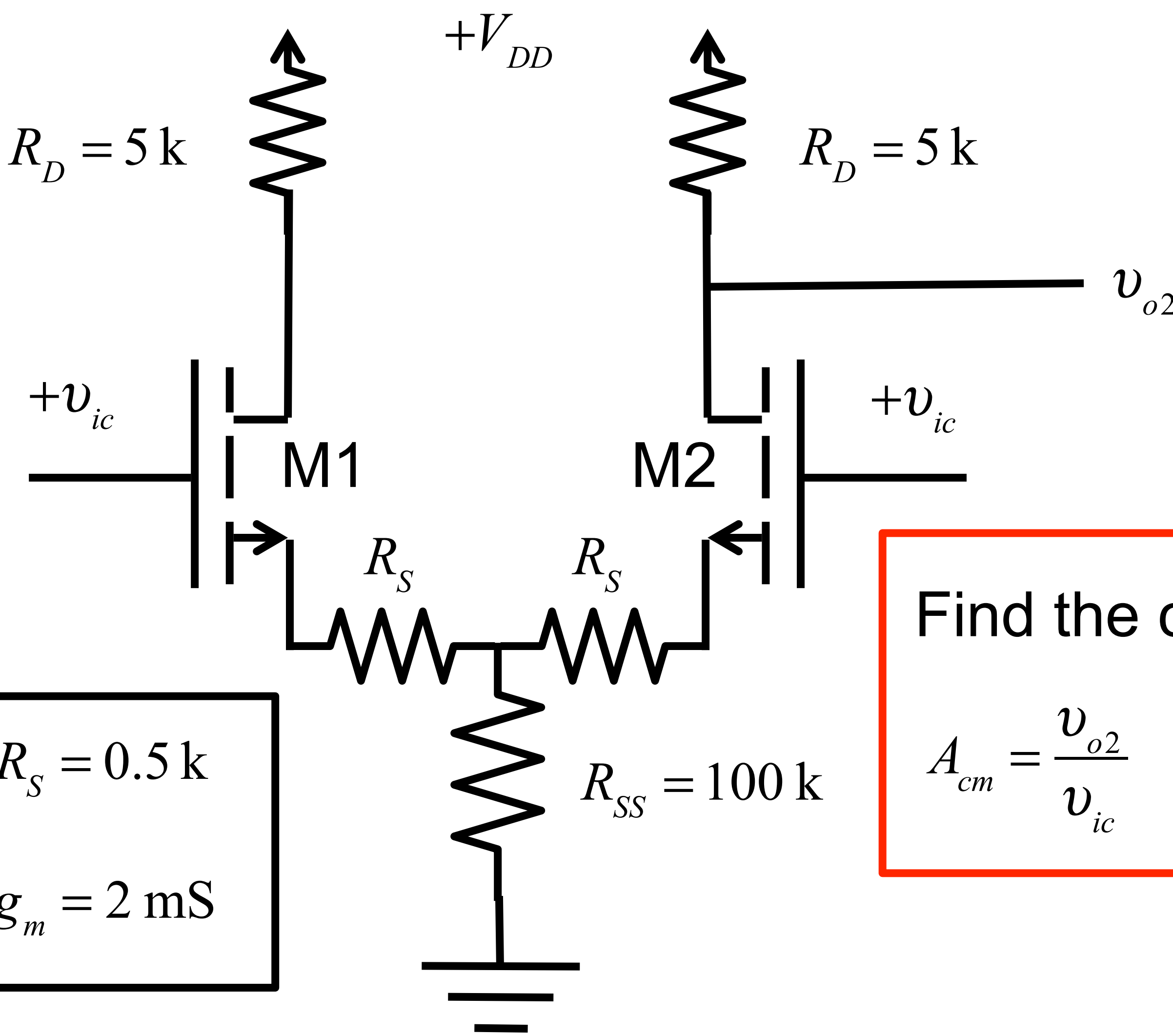
$$R_S = 0.5\,\text{k}$$

$$g_m = 2\,\text{mS}$$

$$\frac{\upsilon_{o2}}{\upsilon_{id}} = \frac{1}{2}\frac{g_m R_D}{1+g_m R_S}$$

$$A_{dm} = \frac{1}{2}\left(\frac{2\times 5}{1+2\times 0.5}\right) = \frac{10}{4}$$

Review problem 1b)



$R_S = 0.5\text{ k}$

$g_m = 2\text{ mS}$

Find the common mode gain:

$$A_{cm} = \frac{\upsilon_{o2}}{\upsilon_{ic}}$$

Review problem 1b)

From the half-circuit:

$$\upsilon_{o2} = -\frac{g_m R_D}{1 + g_m\left(R_S + 2R_{SS}\right)}\left(\upsilon_{ic}\right)$$

$$A_{cm} = \frac{\upsilon_{o2}}{\upsilon_{ic}} = -\frac{g_m R_D}{1 + g_m\left(R_S + 2R_{SS}\right)}$$

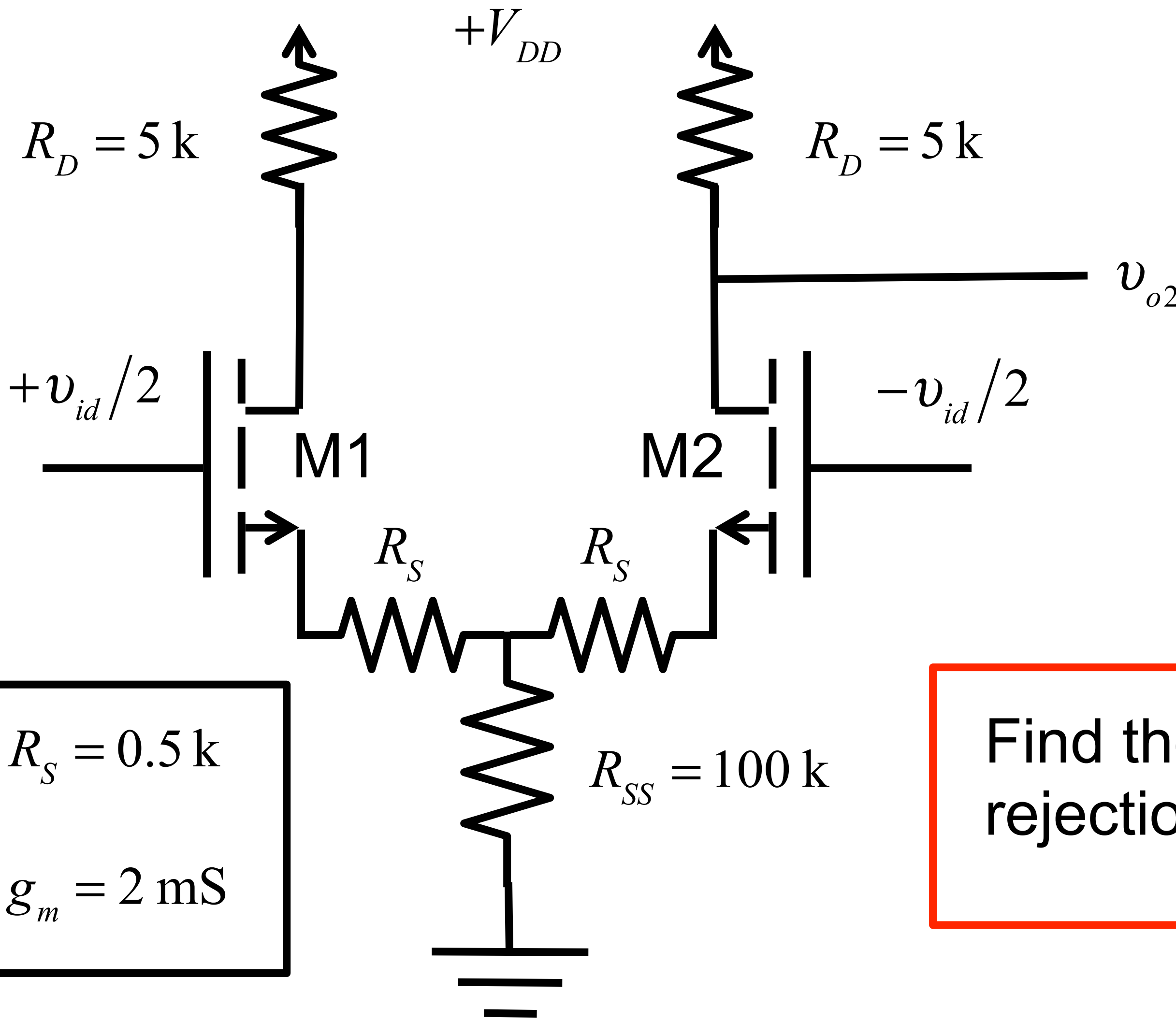
$$A_{cm} = -\frac{2 \times 5}{1 + 2\left(0.5 + 200\right)} = \frac{10}{402}$$

$$R_S = 0.5\,\mathrm{k}$$

$$R_{SS} = 100\,\mathrm{k}$$

$$g_m = 2\,\mathrm{mS}$$

Review problem 1c)



$R_S = 0.5\,\text{k}$

$g_m = 2\,\text{mS}$

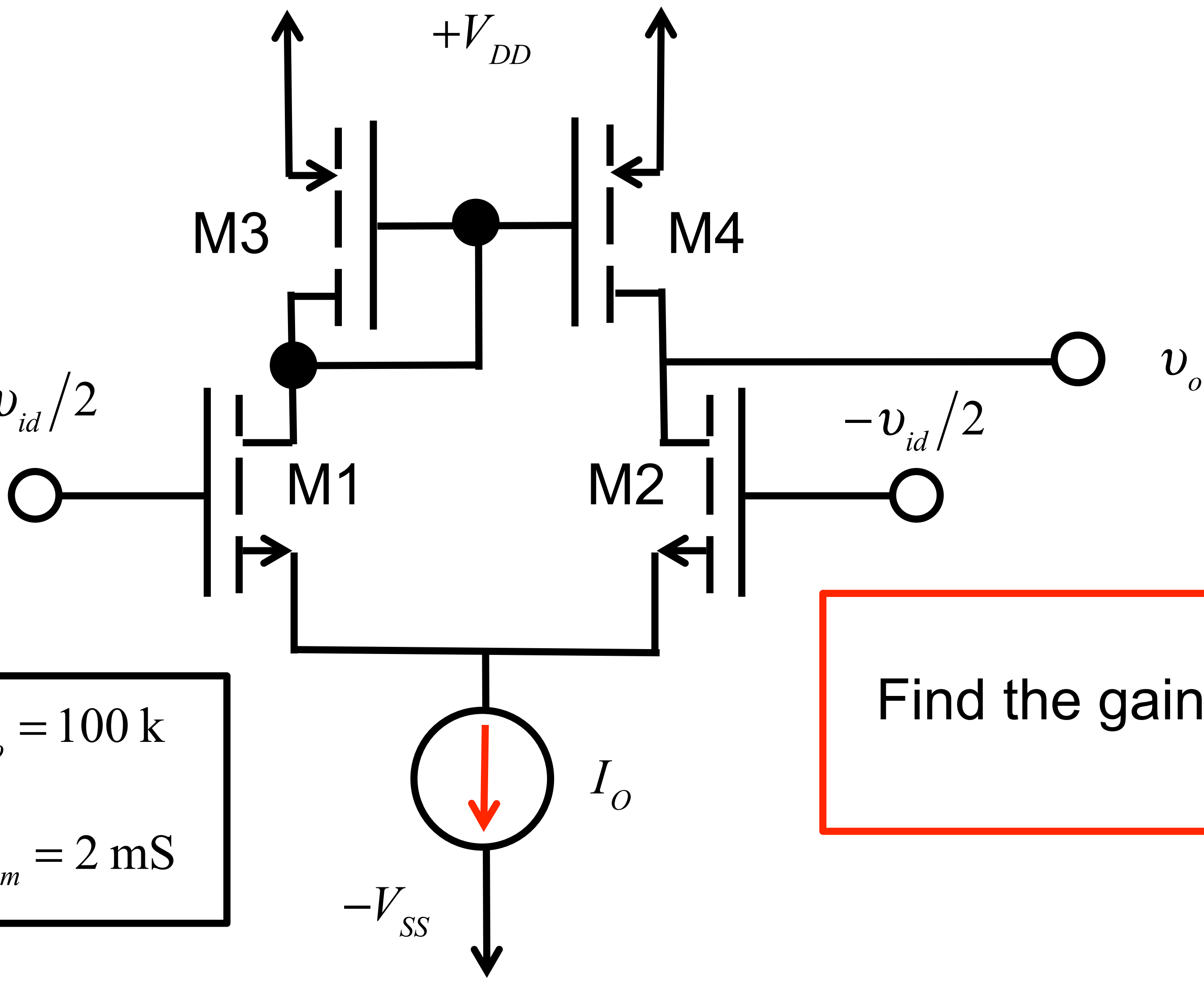
Find the common mode rejection ratio:

Review problem 1c)

$$CMRR = \frac{|A_{dm}|}{|A_{cm}|} = \frac{10/4}{10/402} = \frac{402}{4} \approx 100$$

$$CMRR = 40 \text{ dB}$$

Review problem 2)



$r_o = 100\ \text{k}$

$g_m = 2\ \text{mS}$

Find the gain: $A_{dm} = \dfrac{v_o}{v_{id}}$

Review problem 2)

$$A_{dm} = \frac{\upsilon_o}{\upsilon_{id}} = +g_m\left(r_{o4} \parallel r_{02}\right)$$

$$r_o = 100\ \text{k}$$

$$g_m = 2\ \text{mS}$$

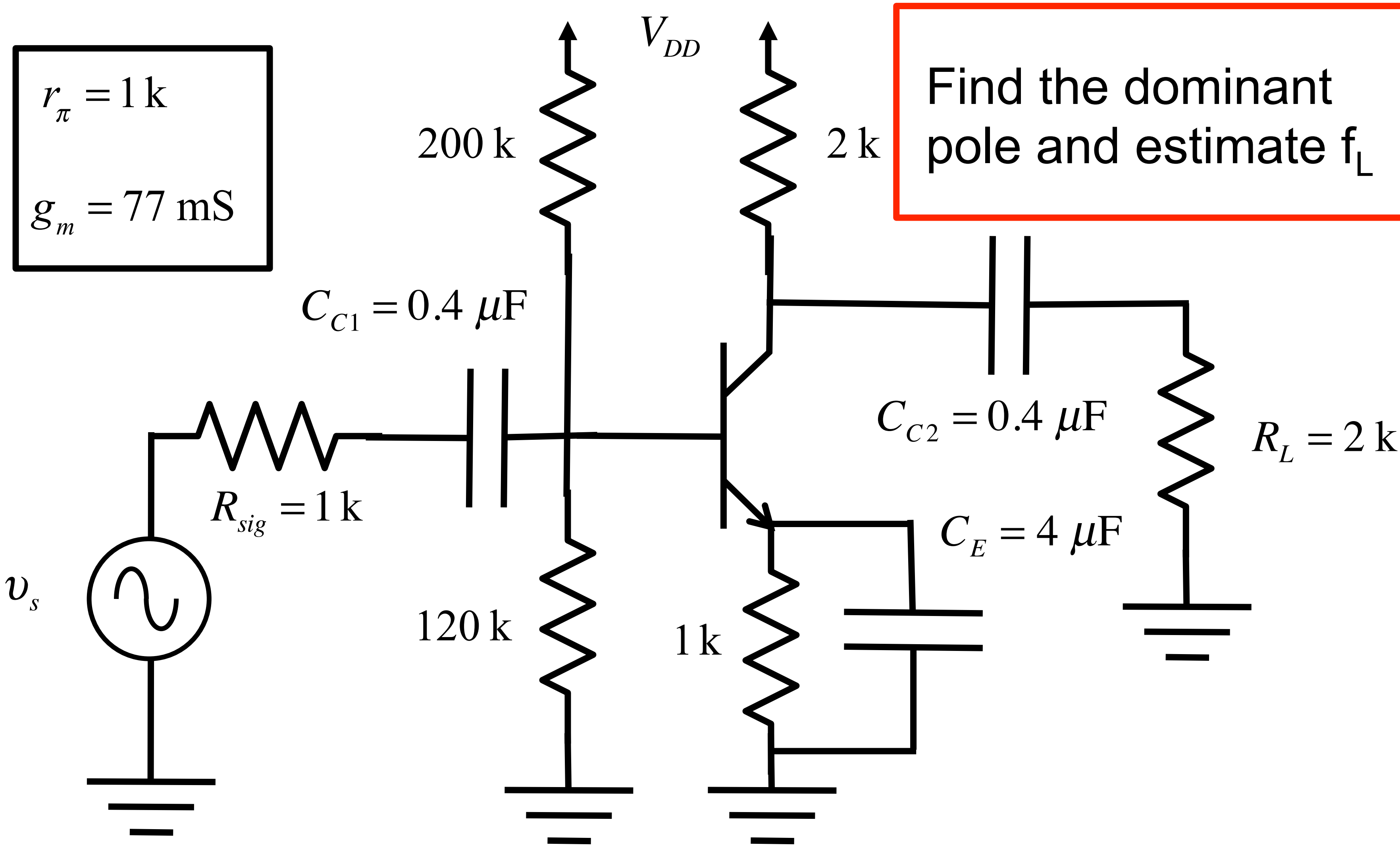
$$A_{dm} = +2\left(50\right) = +100$$

Review problem 3)

$r_\pi = 1\ \text{k}$

$g_m = 77\ \text{mS}$

Find the dominant pole and estimate f_L



Review problem 3)

$$\omega_L = \frac{1}{R_{th}C}$$

$$\omega_L = \frac{1}{R_{th}C_E} = \frac{1}{\left(1k \parallel \left[\frac{r_\pi + 200 \parallel 120 \parallel 1}{\beta + 1}\right]\right)C_E}$$

$$\omega_L \approx \frac{1}{\left(1k \parallel \left[\frac{1+1}{78}\right]\right)C_E}$$

$$\omega_L \approx \frac{1}{\left(1\,\mathrm{k} \parallel 0.026\,\mathrm{k}\right)C_E}$$

$$\omega_L \approx \frac{1}{(26) \times 4 \times 10^{-6}} \approx 10^4$$

$$f_L \approx \frac{10^4}{2\pi} = 1600\ \mathrm{Hz}$$

$$r_\pi = 1\,\mathrm{k}$$

$$g_m = 77\ \mathrm{mS}$$

Review problem 3)

$$\omega_{C_E} \approx 10^4$$

$$r_\pi = 1\,\text{k}$$

$$g_m = 77\ \text{mS}$$

Let’s check the other two poles:

$$\omega_{C_1} = \frac{1}{\left[1\,\text{k} + \left(200\,\text{k} \,\|\, 120\,\text{k} \,\|\, 1\,\text{k}\right)\right] \times 10^{-6}}$$

$$\omega_{C_1} \approx \frac{1}{\left[2\,\text{k}\right] \times 10^{-6}} = 500$$

$$\omega_{C_2} = \frac{1}{\left[2\,\text{k} + 2\,\text{k}\right] \times 10^{-6}} = 250$$

So C_E does produce the dominant pole

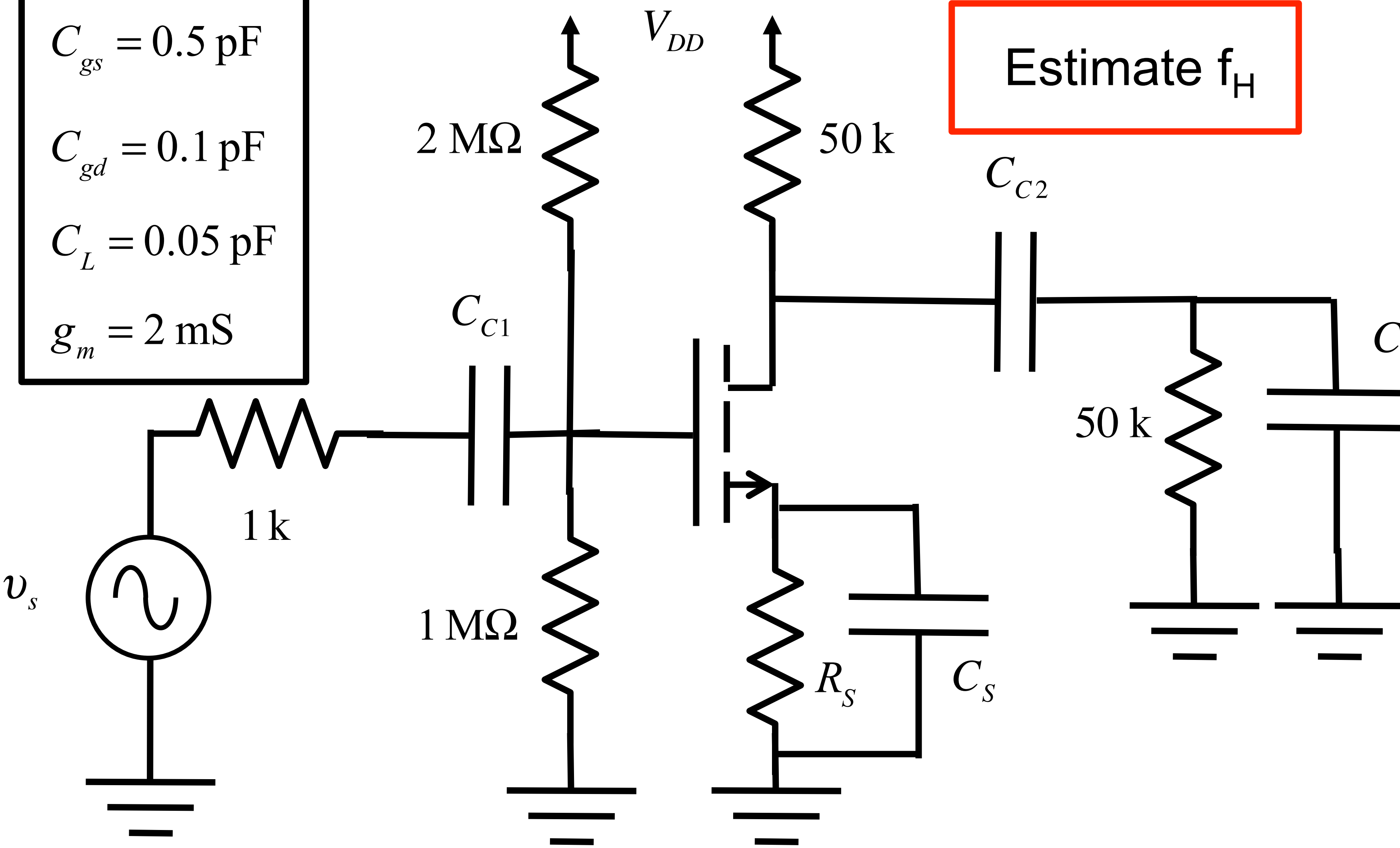
Review problem 4)

$C_{gs} = 0.5\ \text{pF}$

$C_{gd} = 0.1\ \text{pF}$

$C_L = 0.05\ \text{pF}$

$g_m = 2\ \text{mS}$



Estimate f_H

Review problem 4)

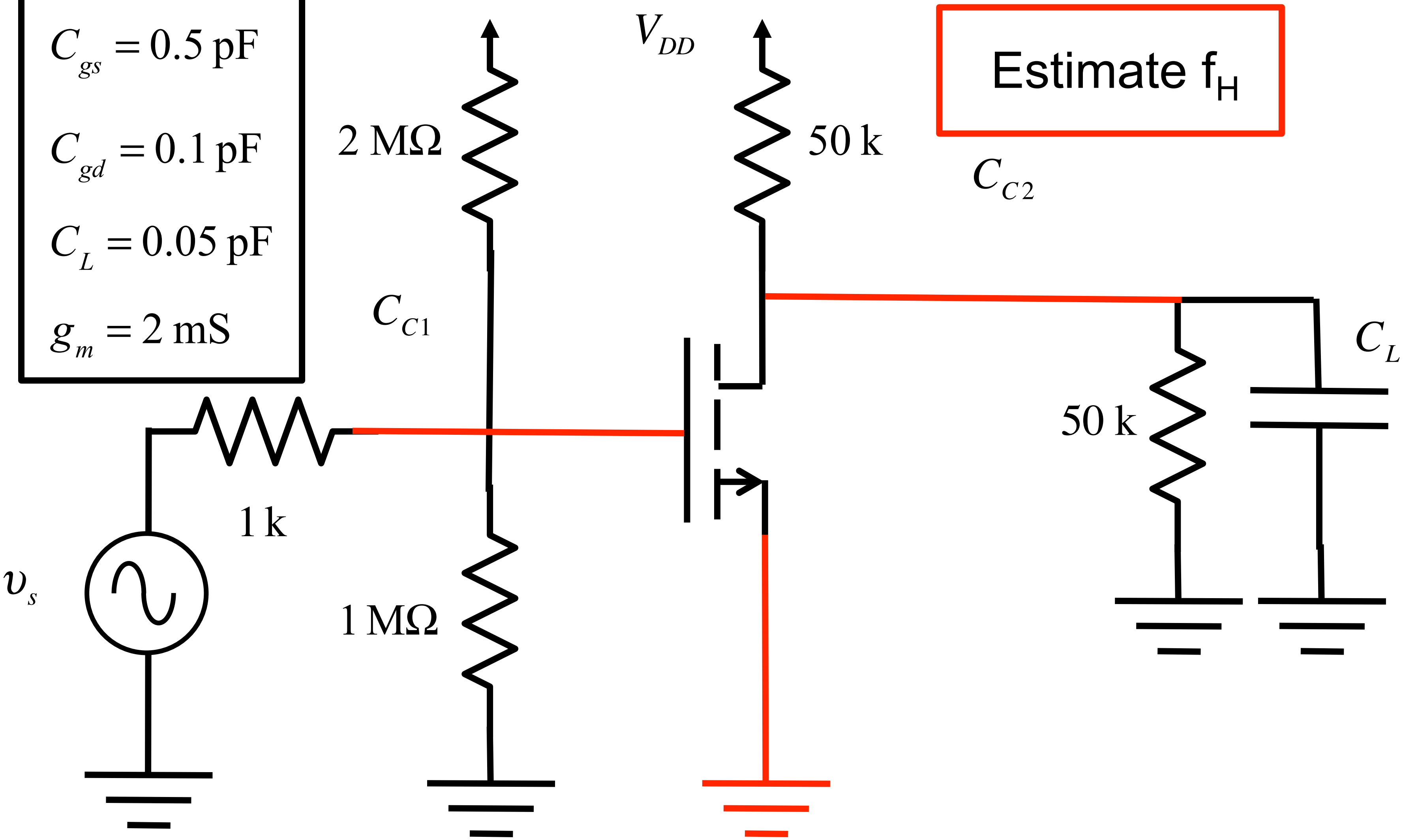
$C_{gs} = 0.5\text{ pF}$

$C_{gd} = 0.1\text{ pF}$

$C_L = 0.05\text{ pF}$

$g_m = 2\text{ mS}$

Estimate f_H



Review problem 4)

$C_{gs} = 0.5\ \text{pF}$

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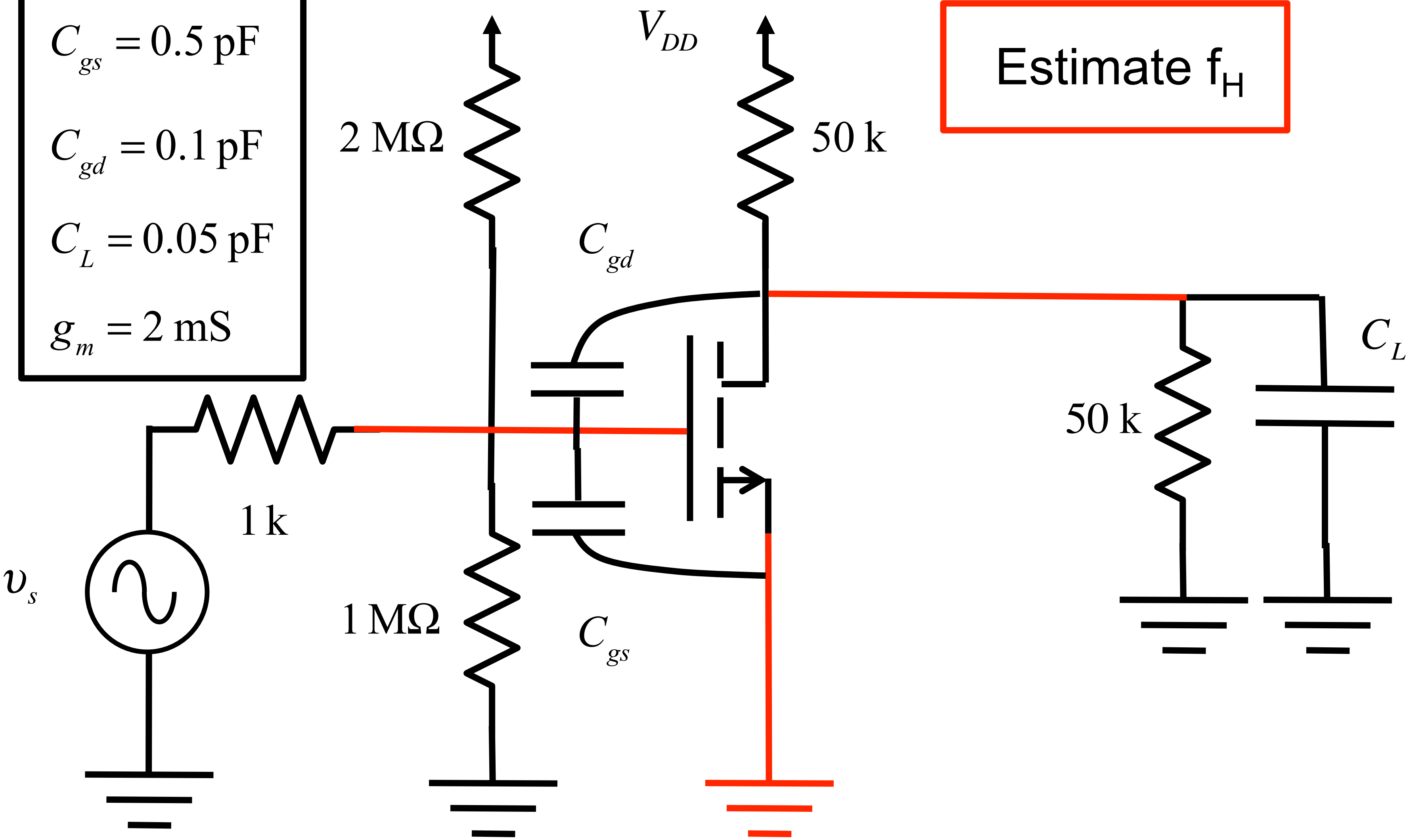
Estimate f_H



Review problem 4)

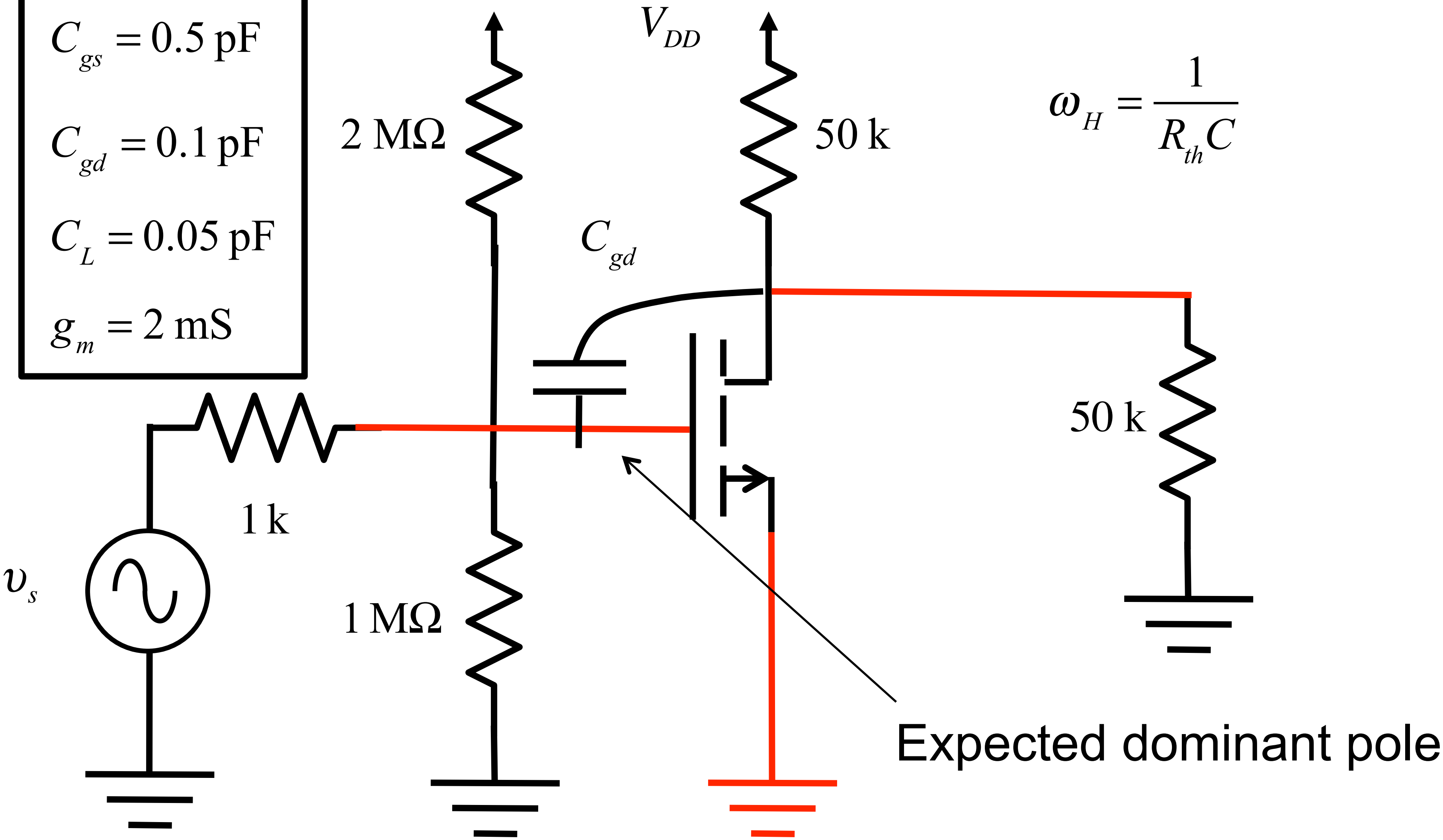
$C_{gs} = 0.5\text{ pF}$

$C_{gd} = 0.1\text{ pF}$

$C_L = 0.05\text{ pF}$

$g_m = 2\text{ mS}$

$$\omega_H = \frac{1}{R_{th}C}$$



Review problem 4)

Miller capacitance will probably dominate

$$C_{gs} = 0.5\ \text{pF}$$

$$C_{gd} = 0.1\ \text{pF}$$

$$C_L = 0.1\ \text{pF}$$

$$g_m = 2\ \text{mS}$$

$$\tau_{gd} = \left[1\text{k} \parallel \left(2\text{M} \parallel 1\text{M}\right)\right] C_M + \left[50\,\text{k} \parallel 50\,\text{k}\right] C_{gd}$$

$$C_M = \left[1 + \left|A_\upsilon\right|\right] C_{gd} = \left[1 + g_m\left(50\,\text{k} \parallel 50\,\text{k}\right)\right] C_{gd}$$

$$C_M = \left[51\right] 0.1 \times 10^{-12} = 5.1 \times 10^{-12}$$

$$\tau_{gd} = \left[1000\right] 5.1 \times 10^{-12} + 25000 \times 0.1 \times 10^{-12} = 7.6 \times 10^{-9}$$

$$\omega_H = \frac{1}{\tau_{gd}} = 1.3 \times 10^{8} \qquad f_H = \frac{1}{\tau_{gd}} = 21 \times 10^{6}\ \text{Hz}$$