ECE4902 Lecture 12

How to Increase Open Loop Gain?

Improving Performance: Cascode Op-amp *
- Tradeoff: + Higher node impedance
- \- Reduced signal swing

2-Stage Op-Amp
- CL, Phase Margin Issue

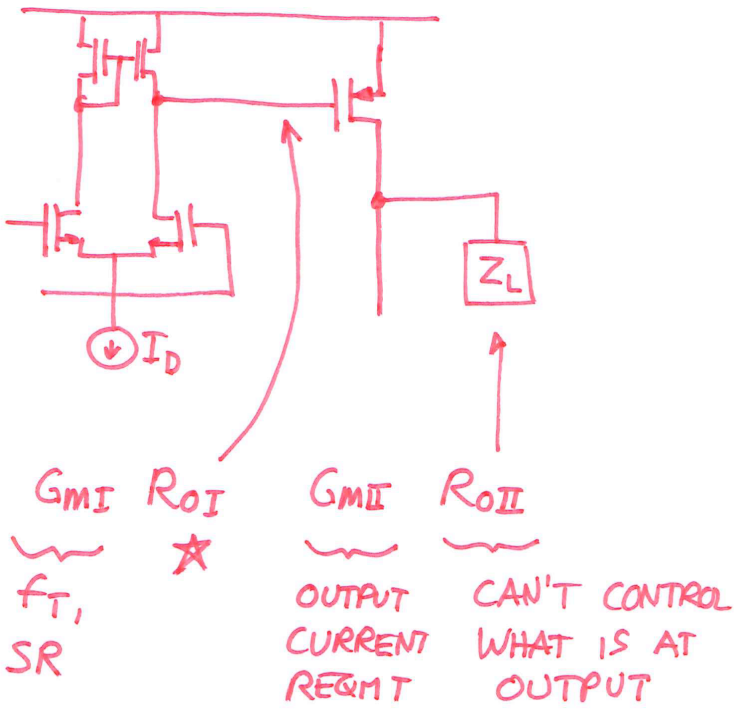
1-stage op-amp (Johns & Martin 6.2)
- Improving Performance: Cascode

* Bandgap Voltage Reference

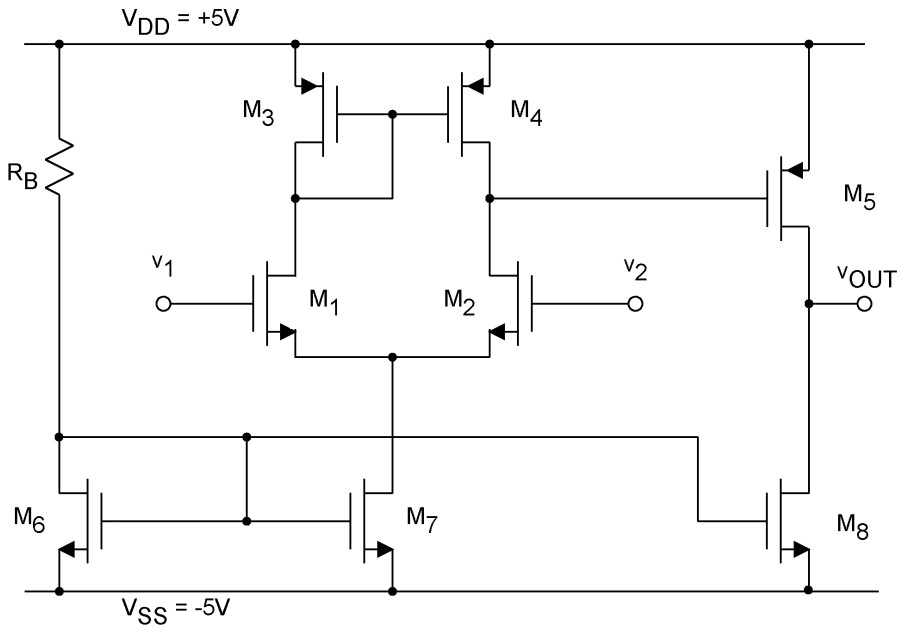
(* Optional Lab Circuit)

Hand In:
HW 5

Handout:
Op-Amp Slides
Cascode Op-Amp
Bandgap Voltage Reference
- Principle
- Circuit



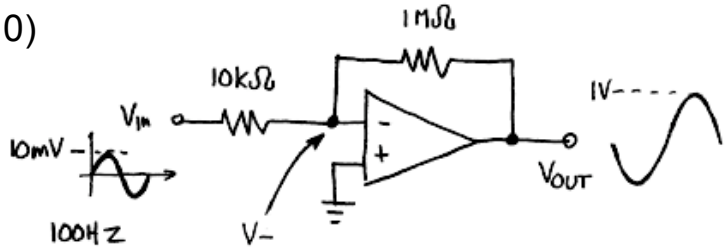
Review: Small signal (ac) model of 2-stage op-amp



Complete transfer function, stability plot

Increasing node impedance at 1st stage output does not affect phase margin! Separate gain, stability problems

Cascode Op-Amp (Optional Lab 10)



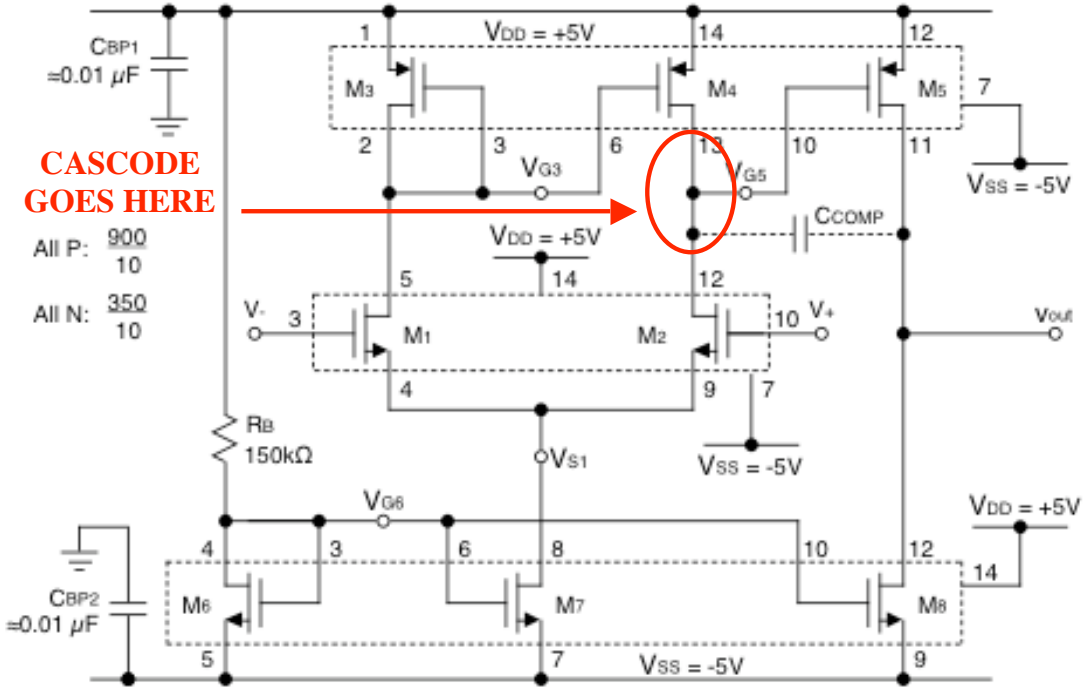
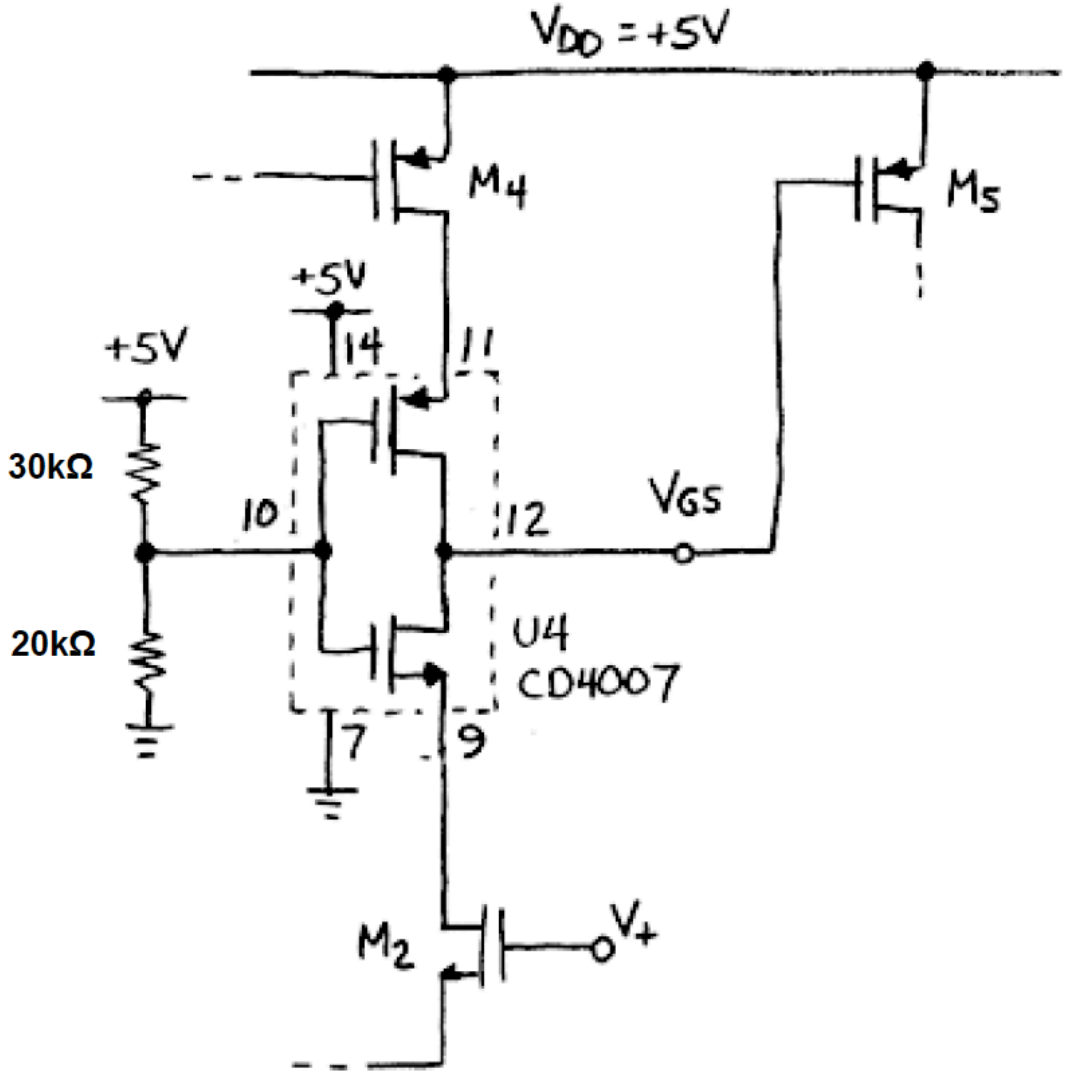
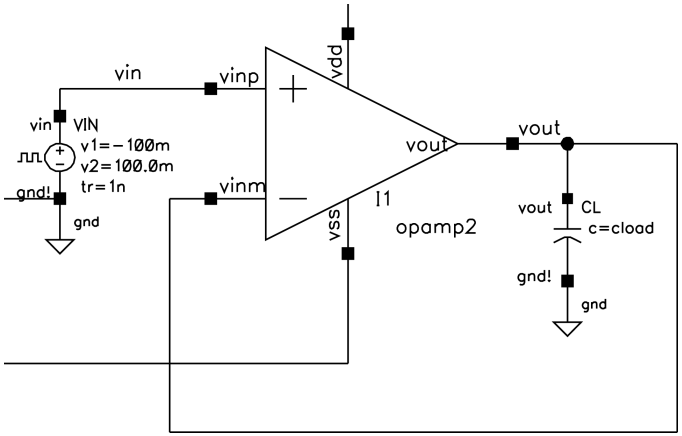


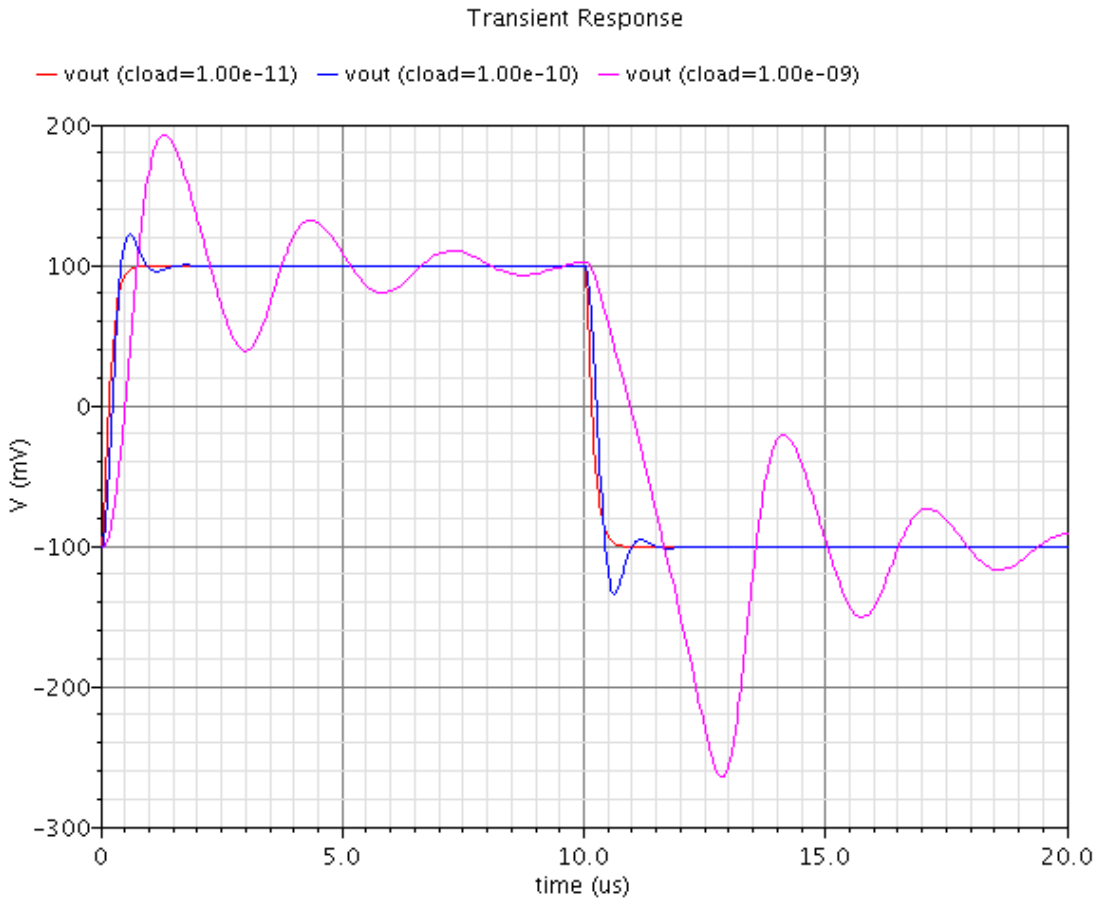
Figure 9-1

To cascode the internal node, you'll need a fourth CD4007 chip. Connect it as shown here:



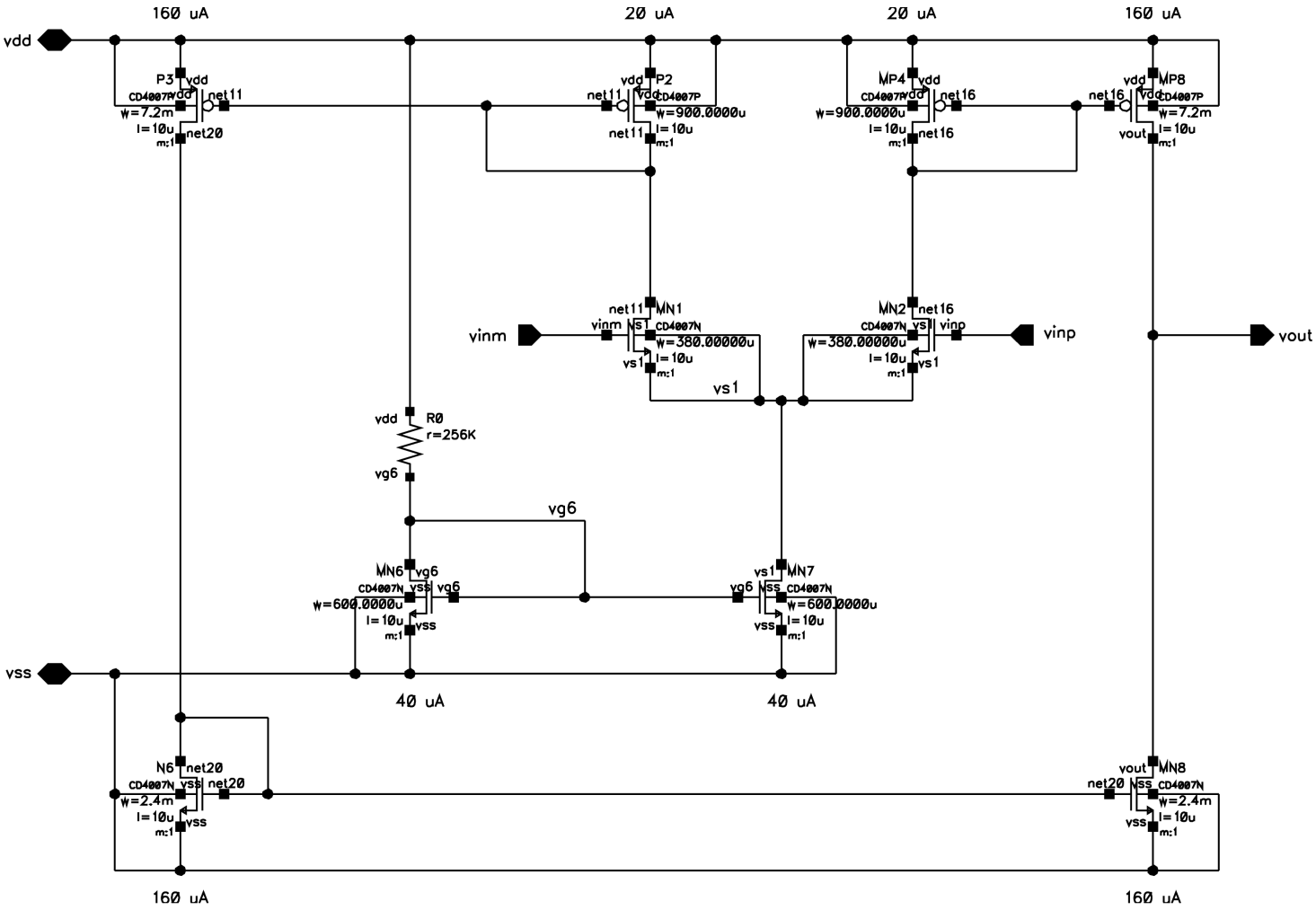
2-Stage Op-Amp Phase Margin vs. C_{LOAD}





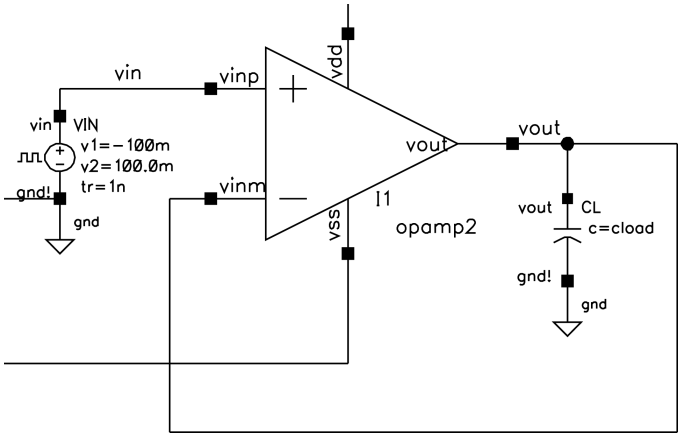
- C_{LOAD} = 10pF, 100pF, 1000pF
- Phase margin ϕ_M degrades as C_{LOAD} increases

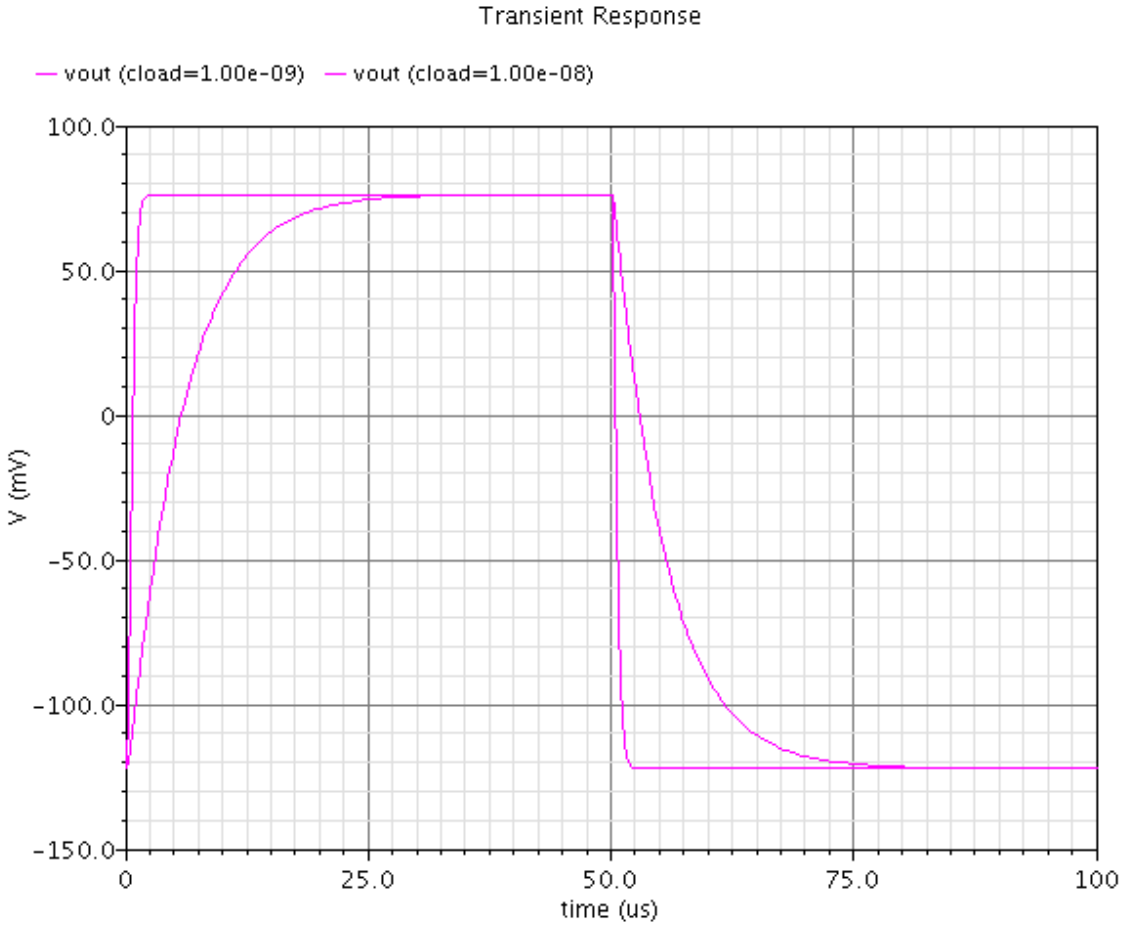
1-Stage ("gm-C" "transconductor") Op-Amp



- Only one high impedance node: C_{LOAD} compensates

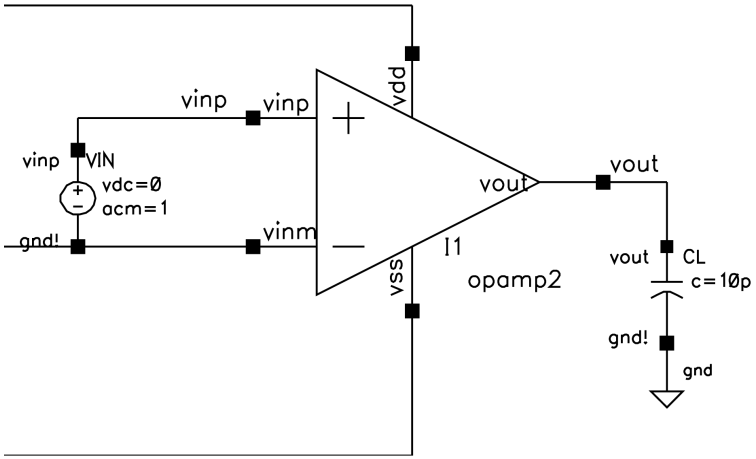
1-Stage ("gm-C" "transconductor") Op-Amp

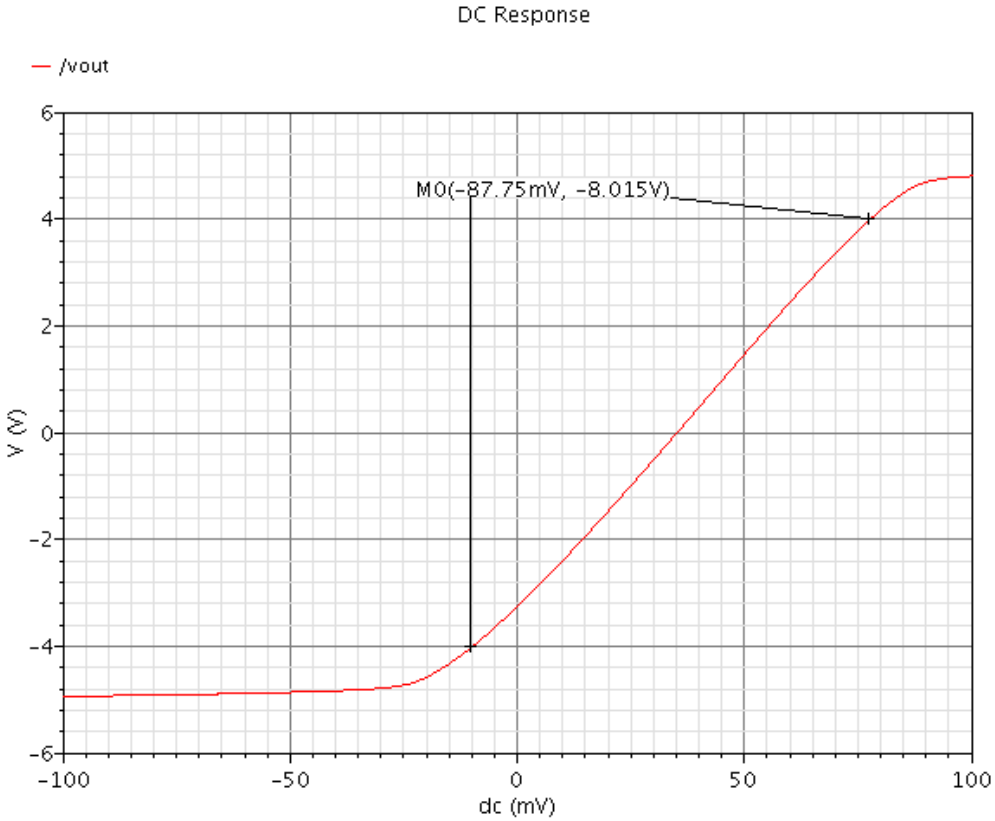




- C_{LOAD} = 1000pF, 10000pF: ϕ_M same as C_{LOAD} ⇧
- Unity gain frequency f_T worse, but always stable

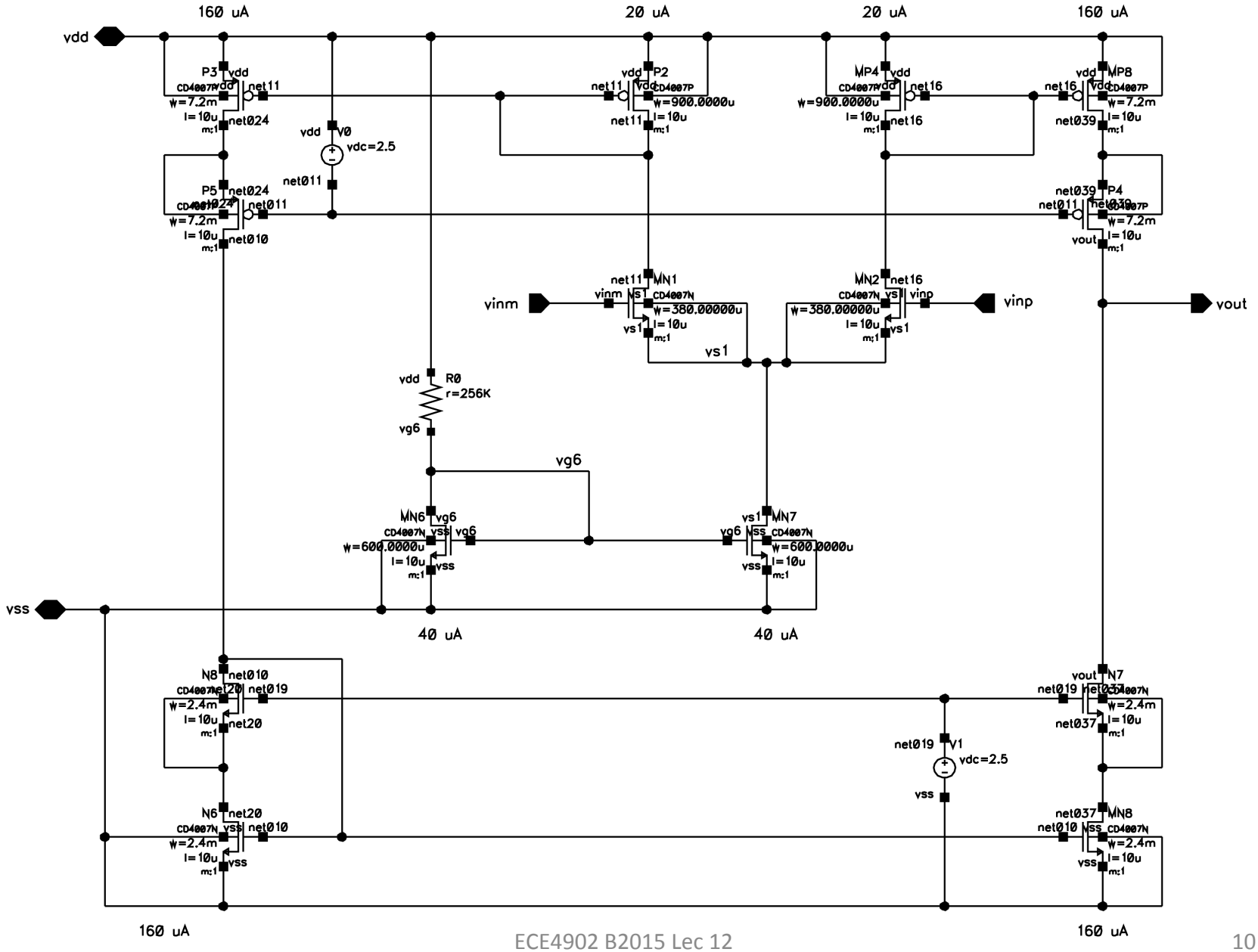
1-Stage Problem



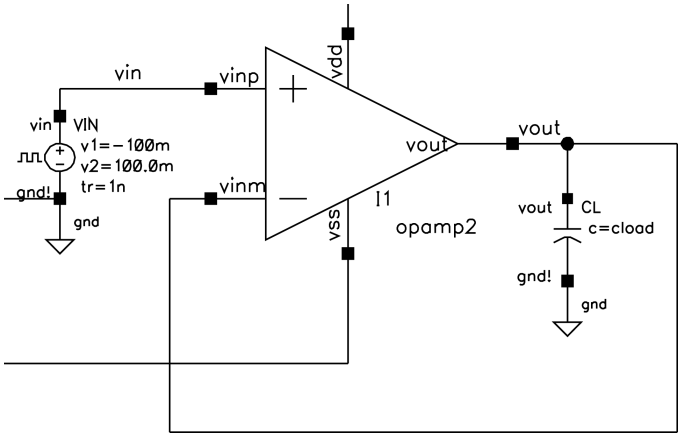


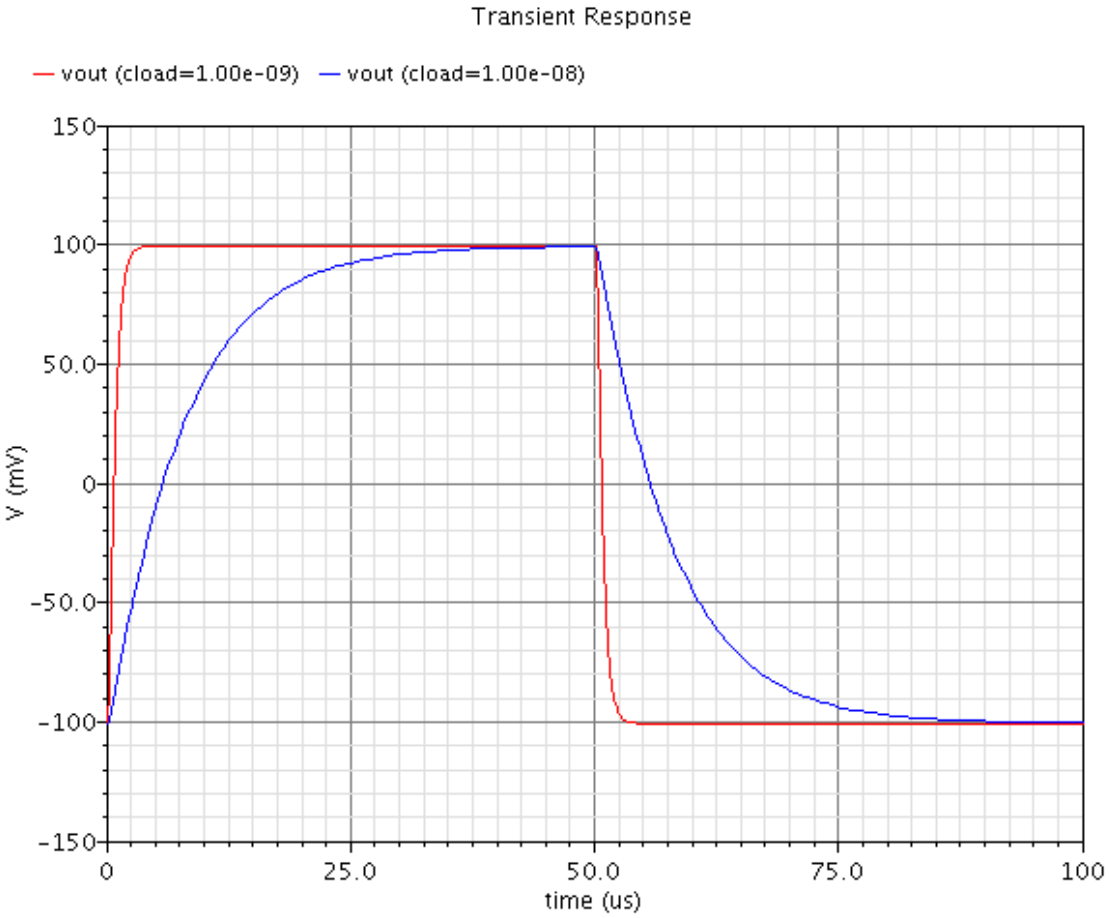
- Lousy DC gain ≈ 90 (39 dB)
- Solution: Add cascode to high impedance node

1-Stage with Cascodes



1-Stage with Cascodes

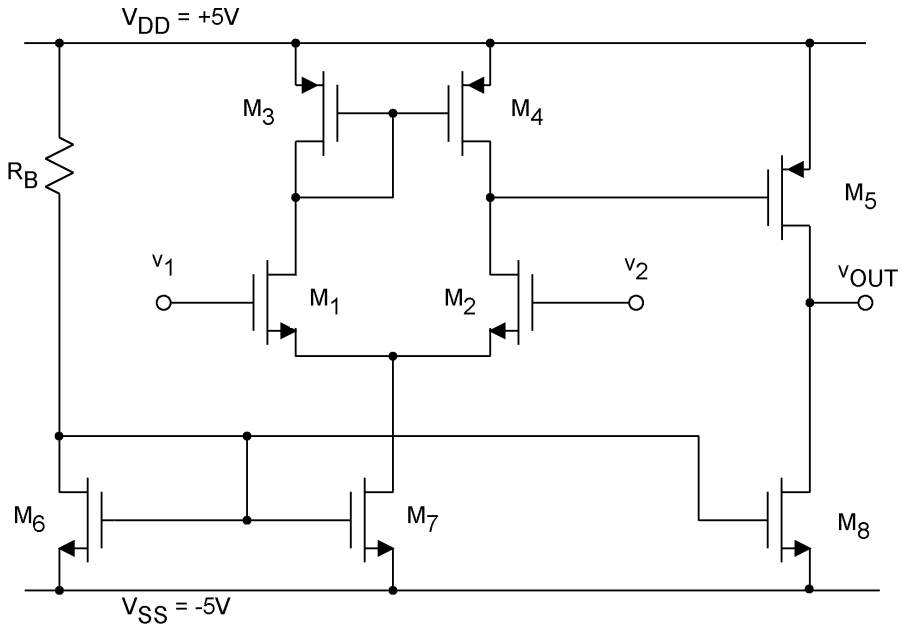




- C_{LOAD} = 1000pF, 10000pF: ϕ_M same as C_{LOAD} ⇧
- Unity gain frequency f_T worse, but always stable

Bandgap Voltage Reference (Optional Lab 11)

Motivation: DC Bias



Bandgap Principle

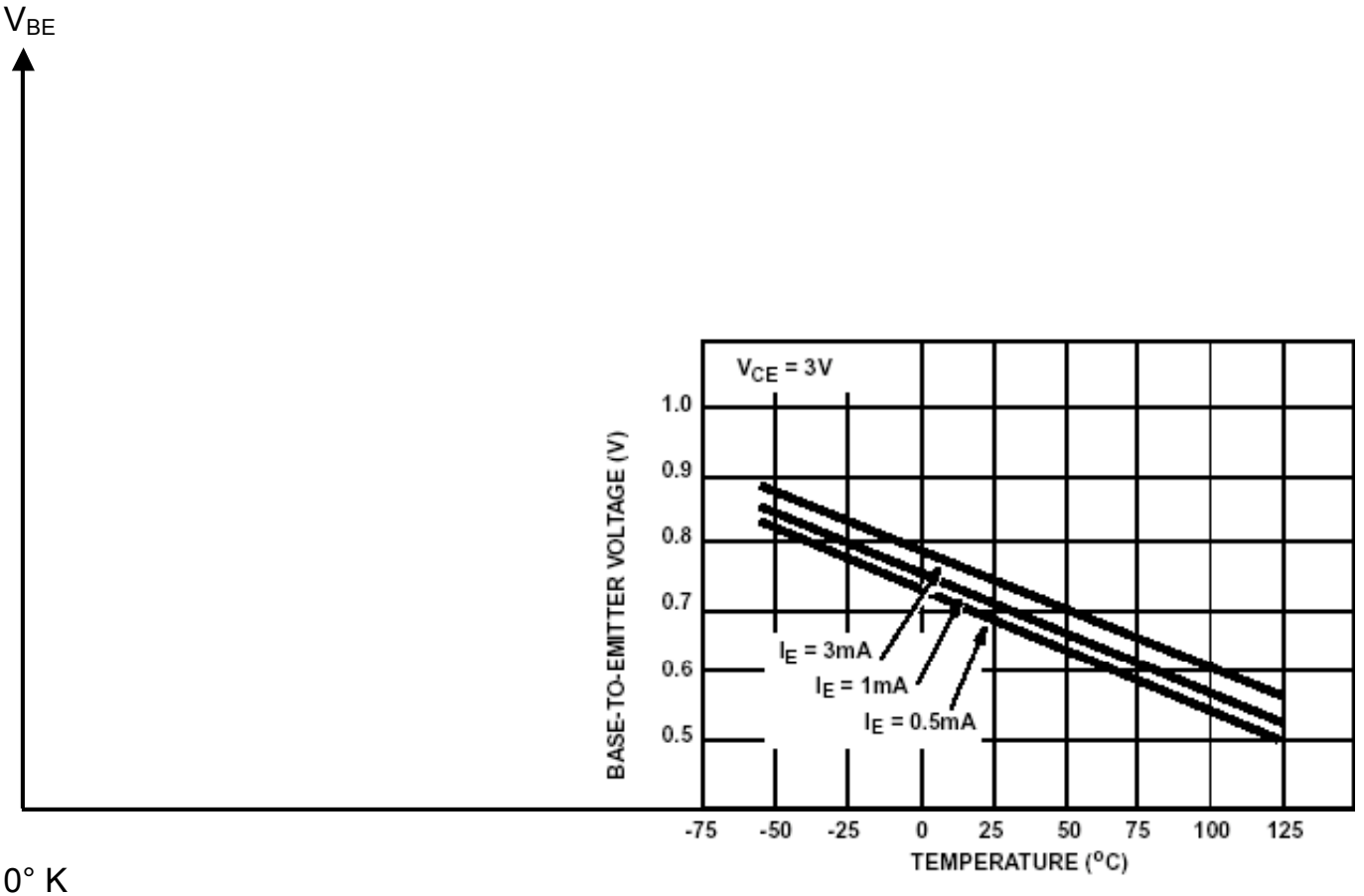
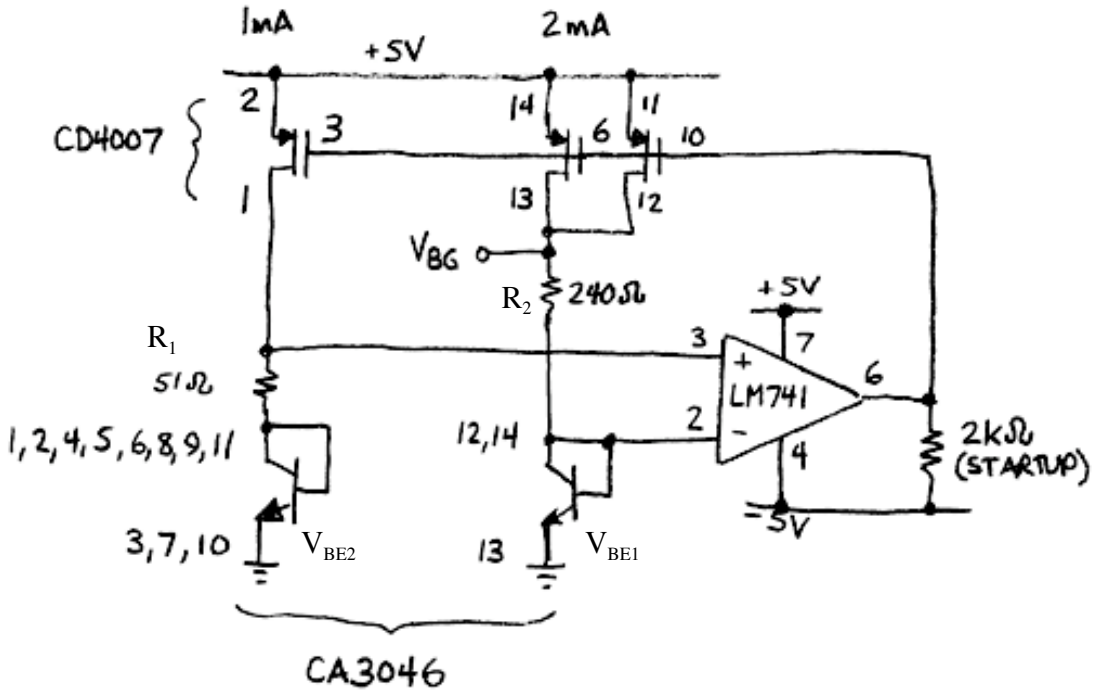


FIGURE 6. TYPICAL BASE-TO-EMITTER VOLTAGE CHARACTERISTIC vs TEMPERATURE FOR EACH TRANSISTOR

BANDGAP VOLTAGE REFERENCE

Here's the bandgap circuit covered in lecture:



The CA3046 is a 5 NPN transistor array. Its data sheet is available on the course website.