ECEN326: Electronic Circuits
Fall 2022

Lab 4 Notes

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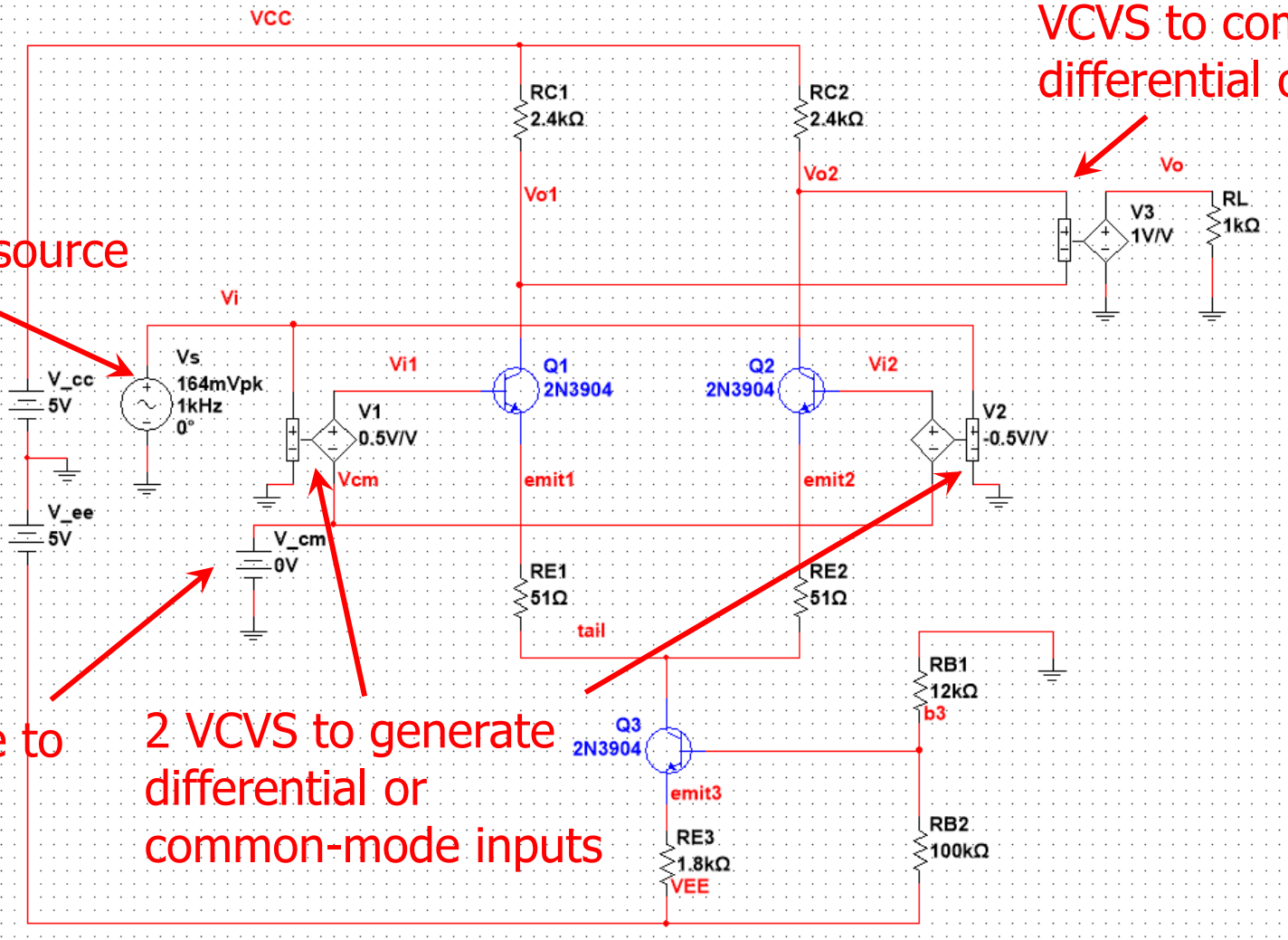
Simulating Differential Amplifiers

- To simulate differential amplifiers, I like to use voltage-controlled voltage sources (VCVS or "E" elements) to generate the differential input signal and combine the differential output into a single-ended signal

Note: This example doesn't meet the Lab 4 gain spec

VCVS to combine differential output

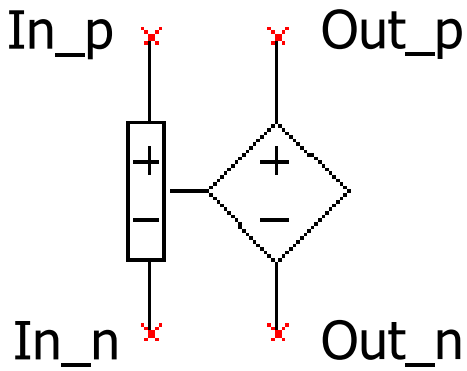
Single-ended input source



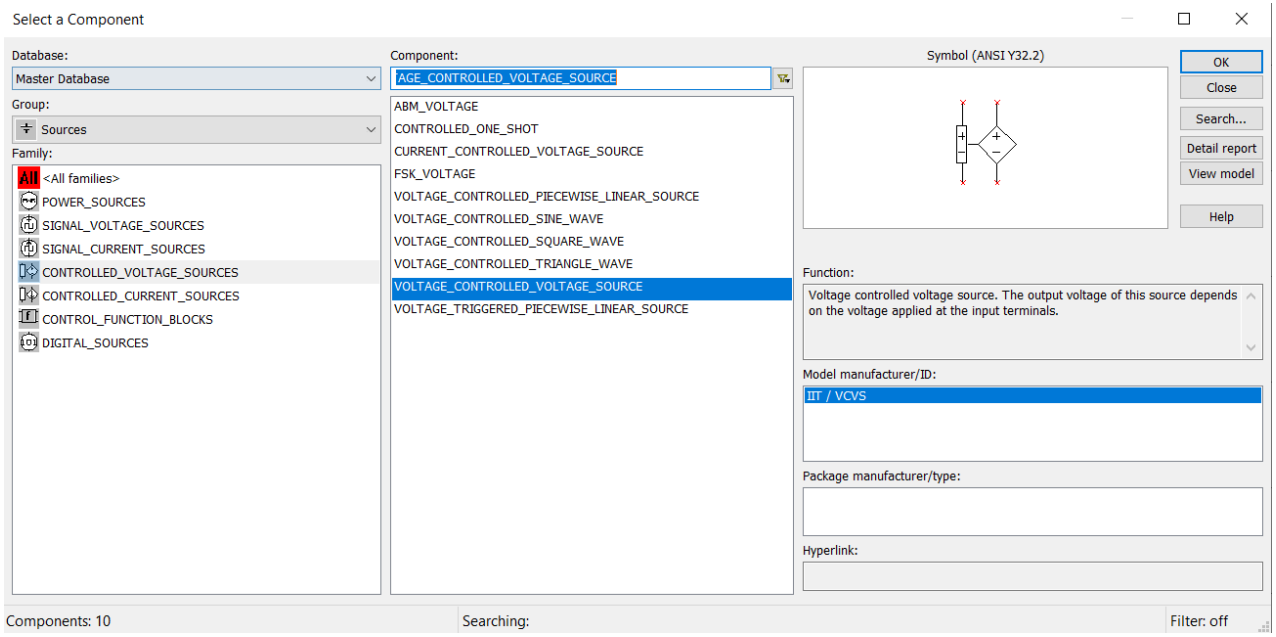
DC voltage source to set input DC level

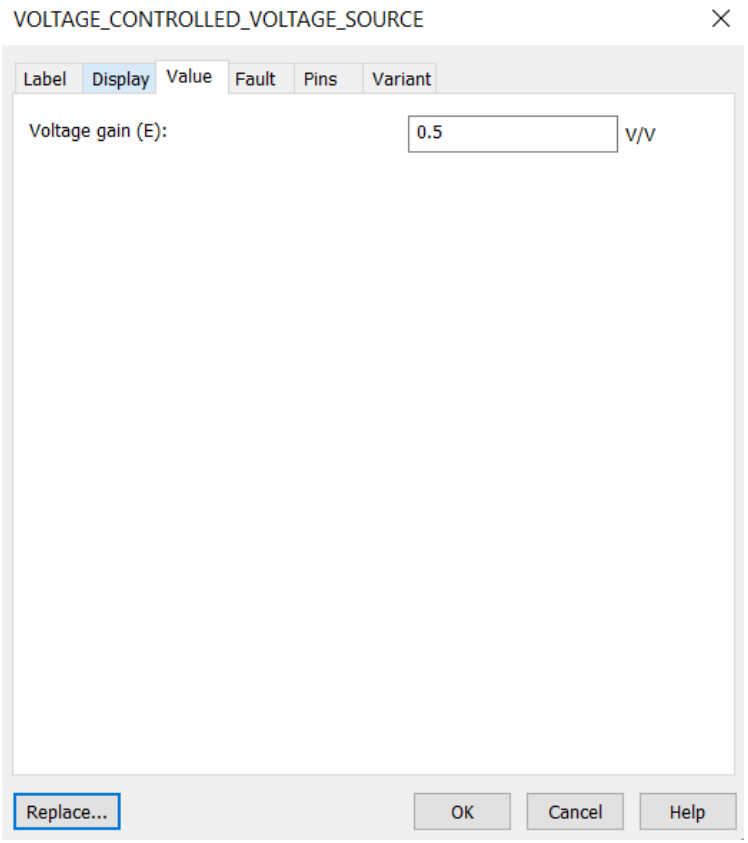
2 VCVS to generate differential or common-mode inputs

VCVS Elements



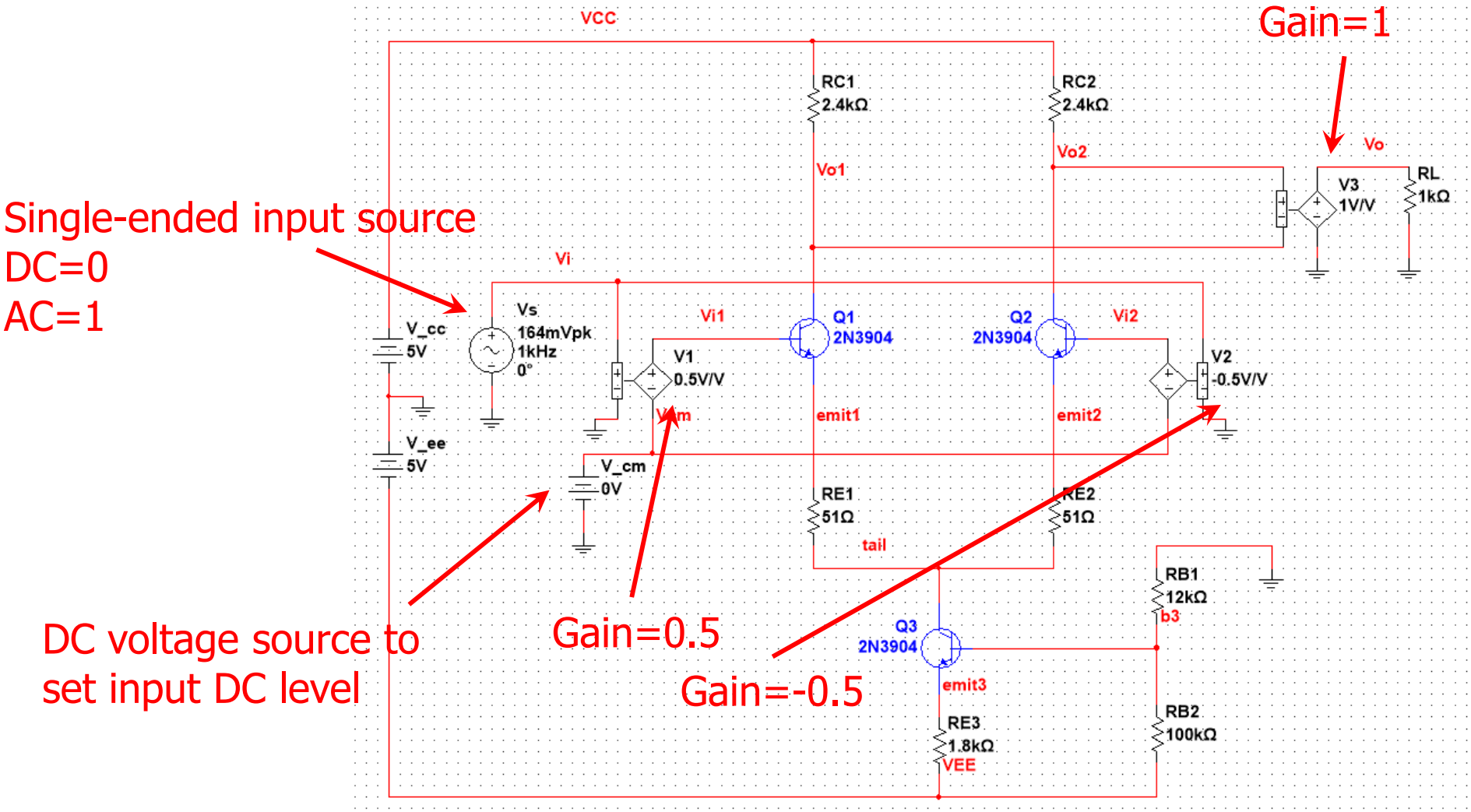
$$Out\_p - Out\_n = Gain*(In\_p - In\_n)$$





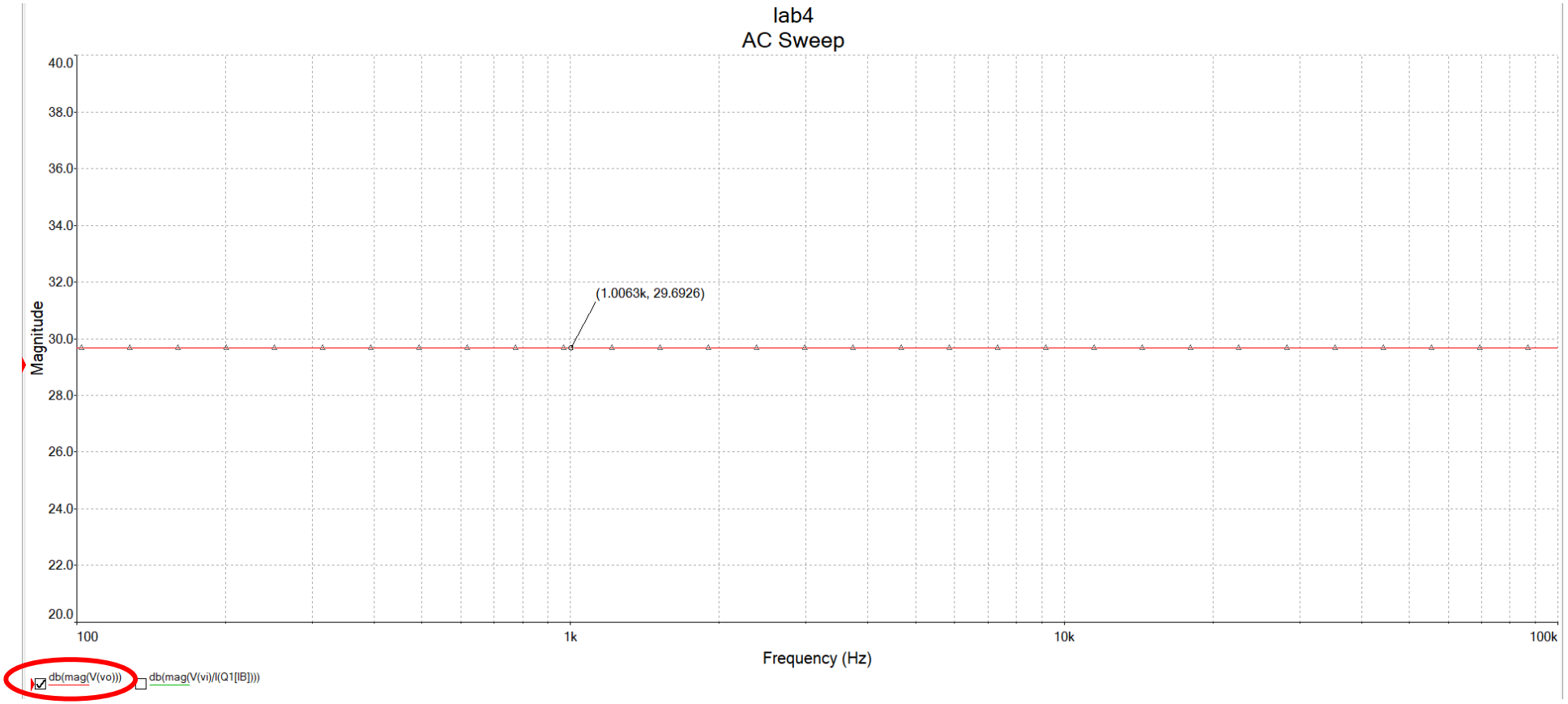
Simulating Differential Gain

- Set Inputs E1 Gain=0.5 and E2 Gain=-0.5, Output E3 Gain=1
- With input source AC=1, simply plot the output of E3 (Vo) to get the differential AC gain



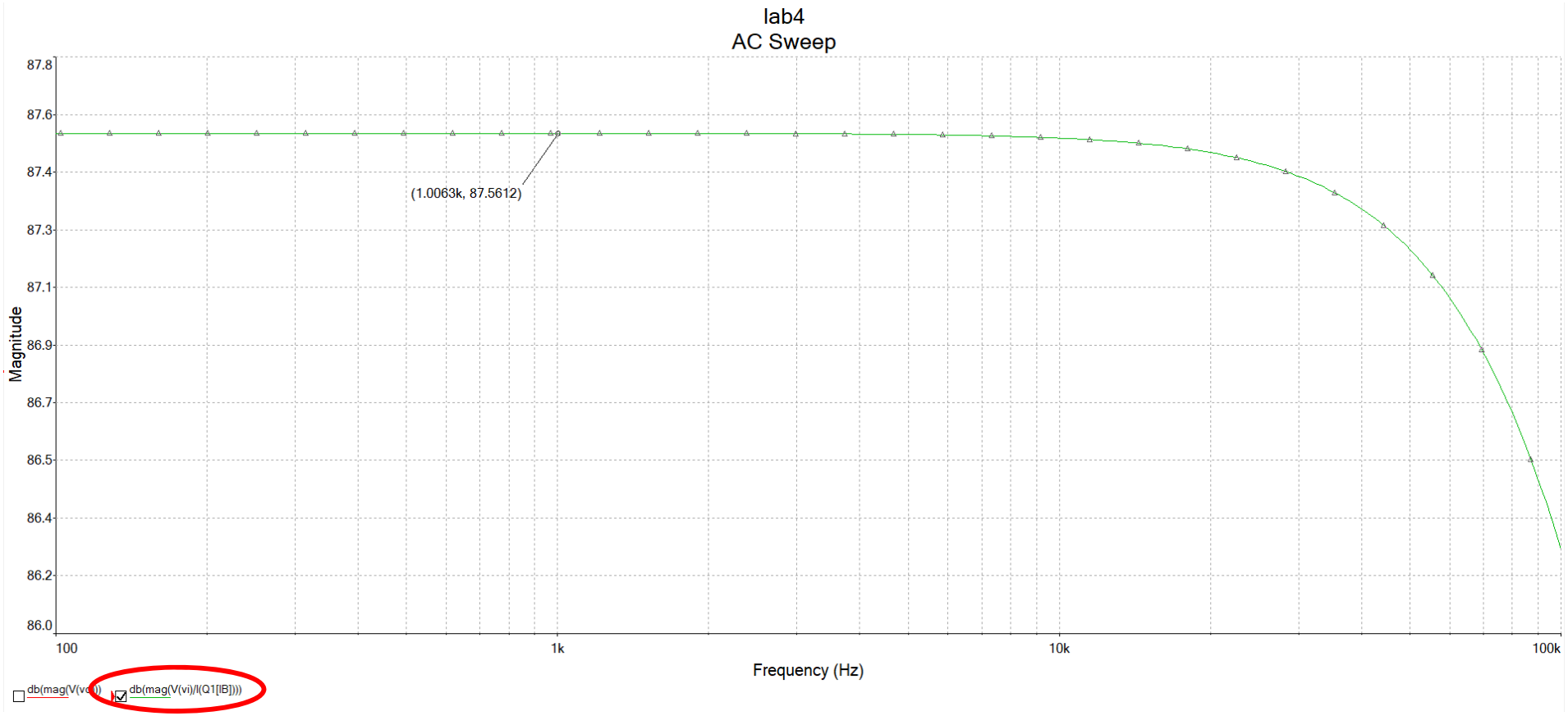
Simulating Differential Gain

- A_{dm} = 30.5 V/V = 29.7dB



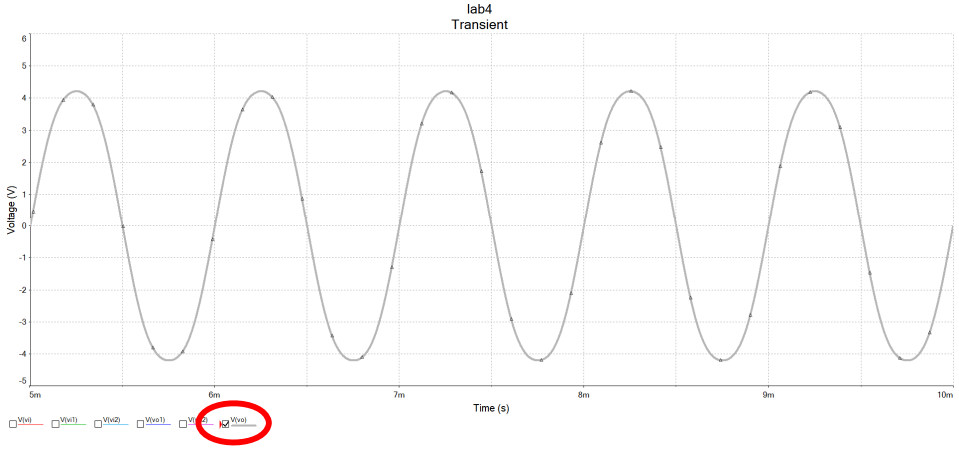
Simulating Differential R_{ind}

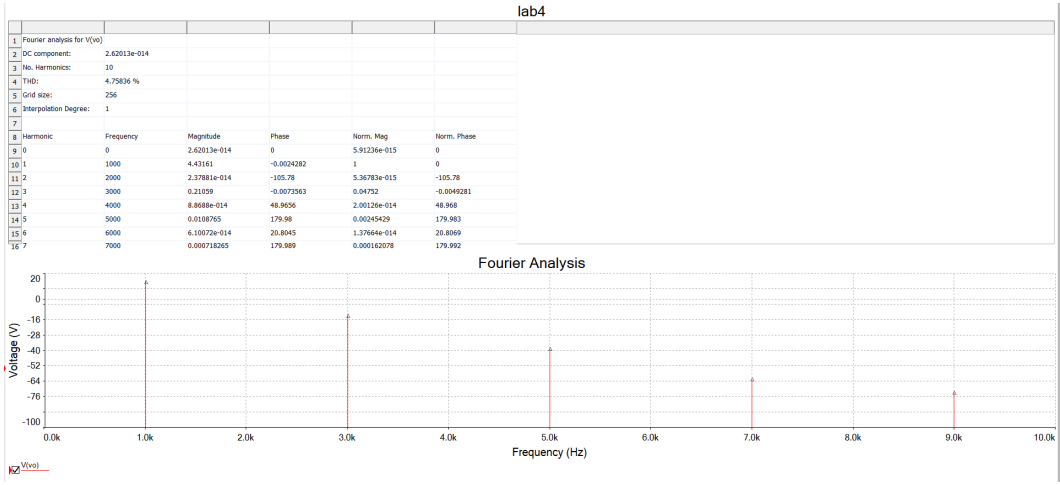
- The differential input resistance is equivalent to the differential input (Vi) divided by the input current, where I use the base current of Q1 or IB(Q1)
- R_{ind} = 24.0kΩ = 87.6dBΩ



Simulating THD

- Set input source to Differential Output Amplitude/A_{dm}
  - For Lab 4, that is 5V/A_{dm}
  - In this example I set the differential input VAMPL = 5V/30.5 = 164mV

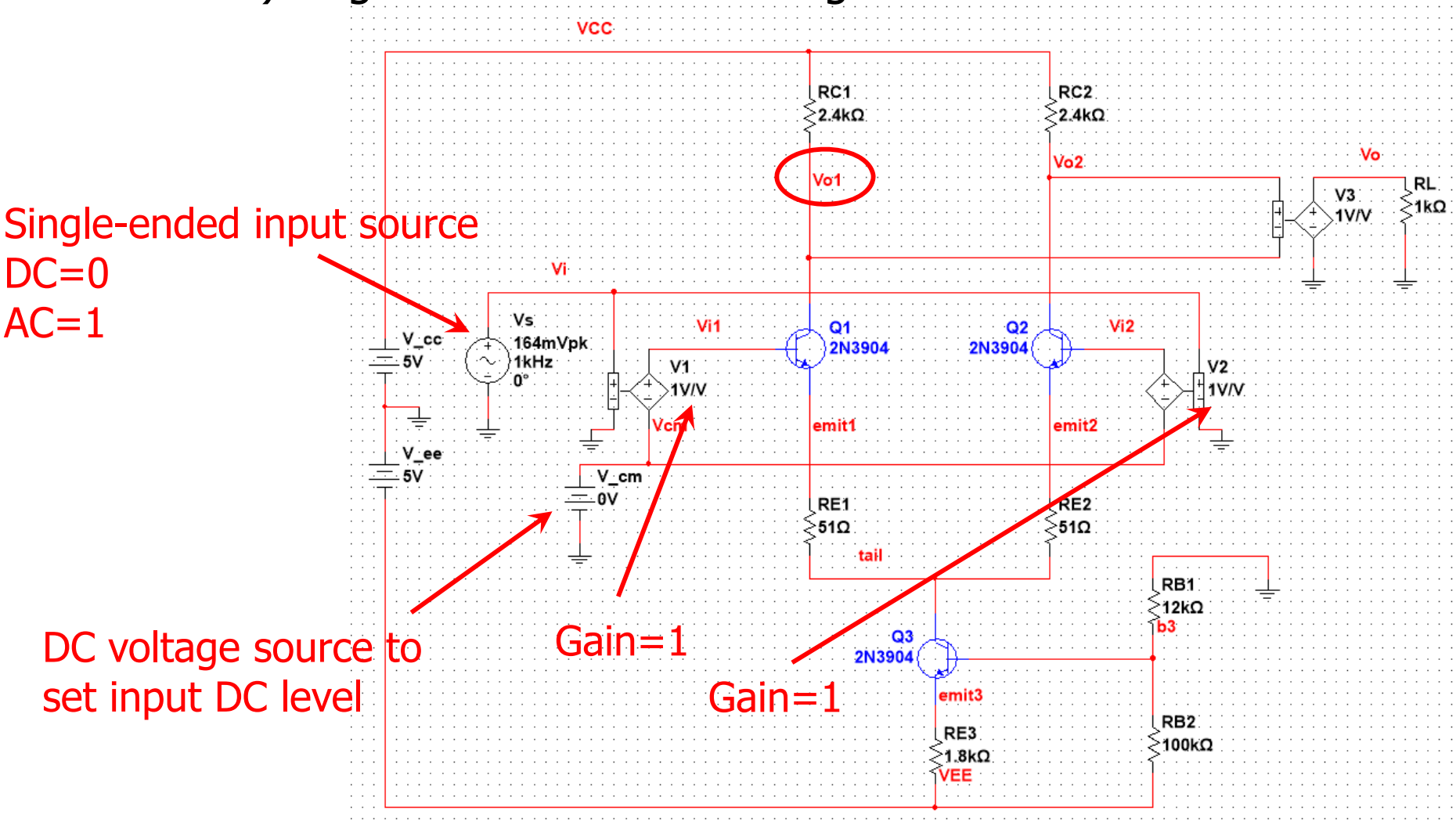




- Note that the even-order harmonics (HD2, HD4, …) are very small (ideally zero)
- A nice property of ideal differential amplifiers is that they reject even-order harmonics

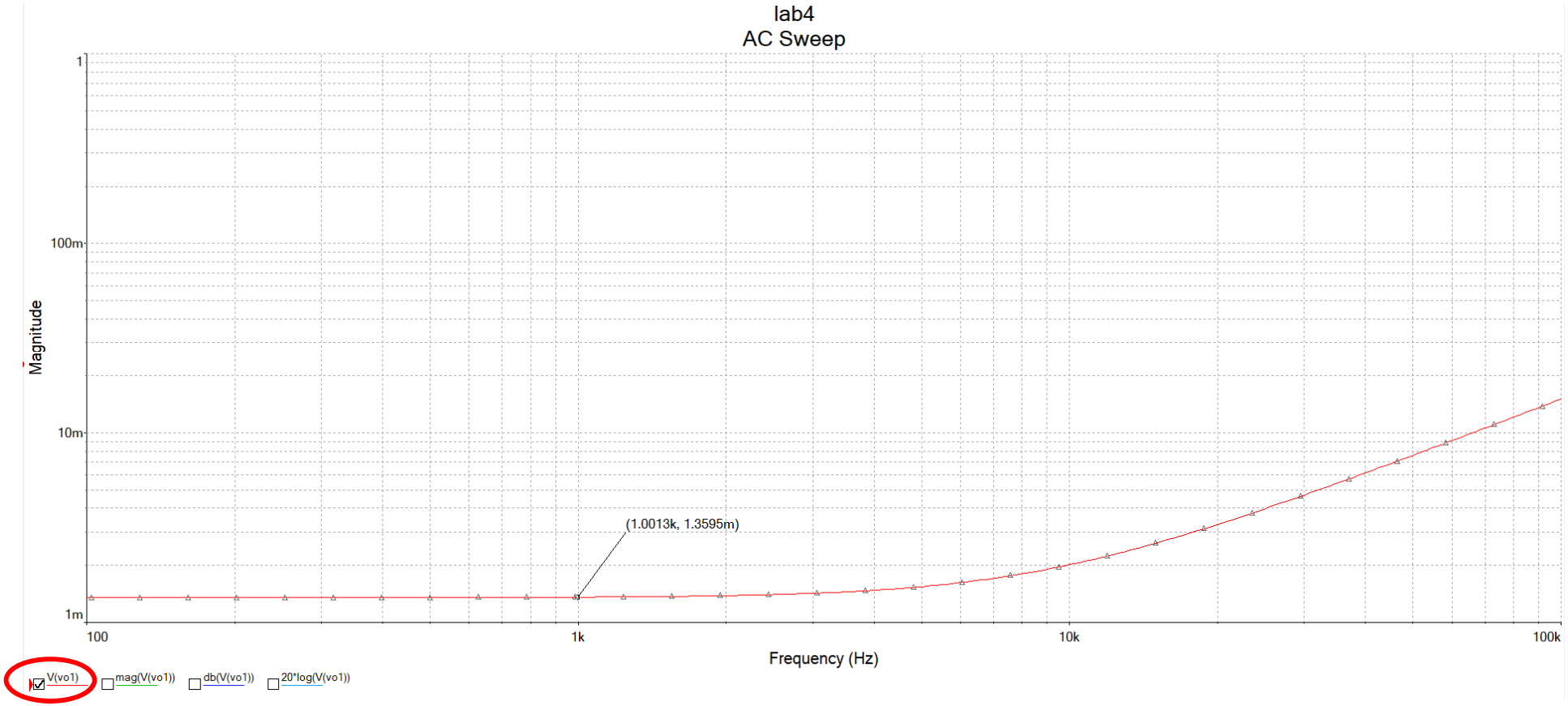
Simulating Common-Mode Gain

- Set Inputs E1 Gain=1 and E2 Gain=1, Output E3 Gain=1
- With input source AC=1, plot one of the single-ended outputs (Vo1 or Vo2) to get the common-mode gain



Simulating Common-Mode Gain

- A_{cm} = 1.36e-3 = -57.3dB at 1kHz



CMRR Definitions

- CMRR is the ratio of the differential-mode gain (A_{DM}) over the common-mode to differential conversion gain (A_{CM-DM})

$$CMRR = \frac{A_{DM}}{A_{CM-DM}}$$

- However, this can be hard to simulate without introducing variations in the circuit, as A_{CM-DM} will be zero without variations
- Thus, the lab uses an alternative CMRR definition which is the ratio of the differential-mode gain (A_{DM}) over the common-mode gain (A_{CM}), which is also a useful figure of merit

$$CMRR_{lab} = \frac{A_{DM}}{A_{CM}}$$

- Using the previous simulation data, the $CMRR_{lab}$ would be 29.7dB – (-57.3db) = 87.0dB