

ECEN326: Electronic Circuits

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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

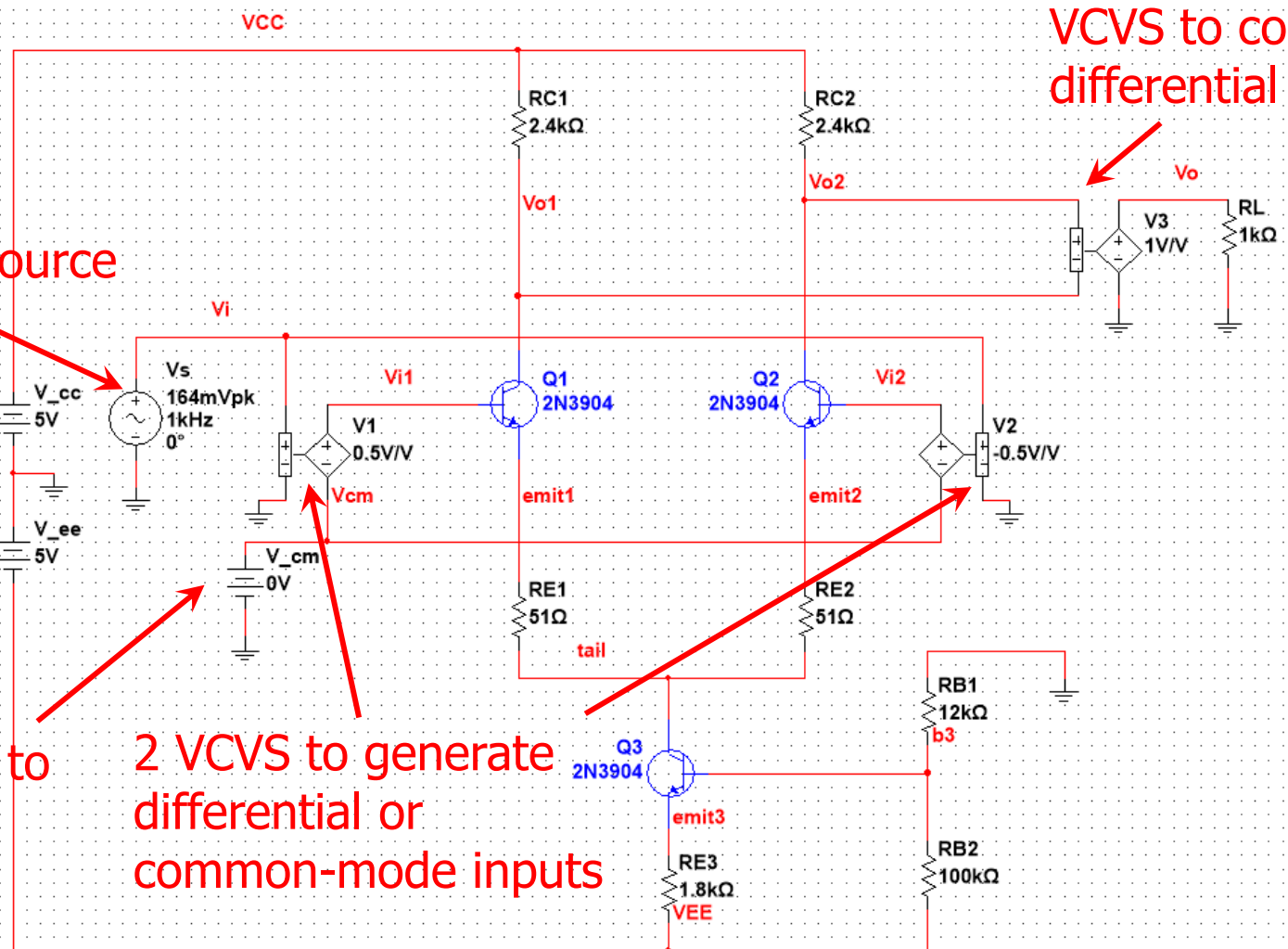
Note: This example doesn't meet the Lab 4 gain spec

VCVS to combine differential output

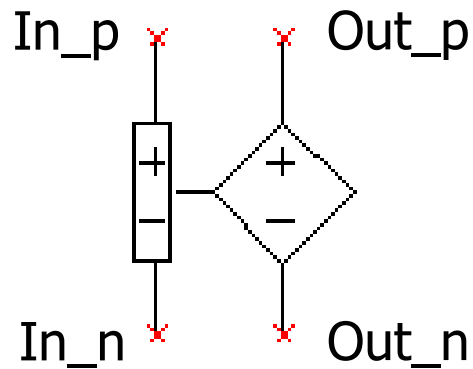
Single-ended input source

DC voltage source to set input DC level

2 VCVS to generate differential or common-mode inputs



VCVS Elements



$$Out_p - Out_n = Gain * (In_p - In_n)$$

Select a Component

Database: Master Database

Group: Sources

Family: <All families>

- POWER_SOURCES
- SIGNAL_VOLTAGE_SOURCES
- SIGNAL_CURRENT_SOURCES
- CONTROLLED_VOLTAGE_SOURCES
- CONTROLLED_CURRENT_SOURCES
- CONTROL_FUNCTION_BLOCKS
- DIGITAL_SOURCES

Component: AGE_CONTROLLED_VOLTAGE_SOURCE

ABM_VOLTAGE

CONTROLLED_ONE_SHOT

CURRENT_CONTROLLED_VOLTAGE_SOURCE

FSK_VOLTAGE

VOLTAGE_CONTROLLED_PIECEWISE_LINEAR_SOURCE

VOLTAGE_CONTROLLED_SINE_WAVE

VOLTAGE_CONTROLLED_SQUARE_WAVE

VOLTAGE_CONTROLLED_TRIANGLE_WAVE

VOLTAGE_CONTROLLED_VOLTAGE_SOURCE

VOLTAGE_TRIGGERED_PIECEWISE_LINEAR_SOURCE

Symbol (ANSI Y32.2)

Function:
Voltage controlled voltage source. The output voltage of this source depends on the voltage applied at the input terminals.

Model manufacturer/ID:
IIT / VCVS

Package manufacturer/type:

Hyperlink:

Components: 10 Searching: Filter: off

VOLTAGE_CONTROLLED_VOLTAGE_SOURCE

Label Display Value Fault Pins Variant

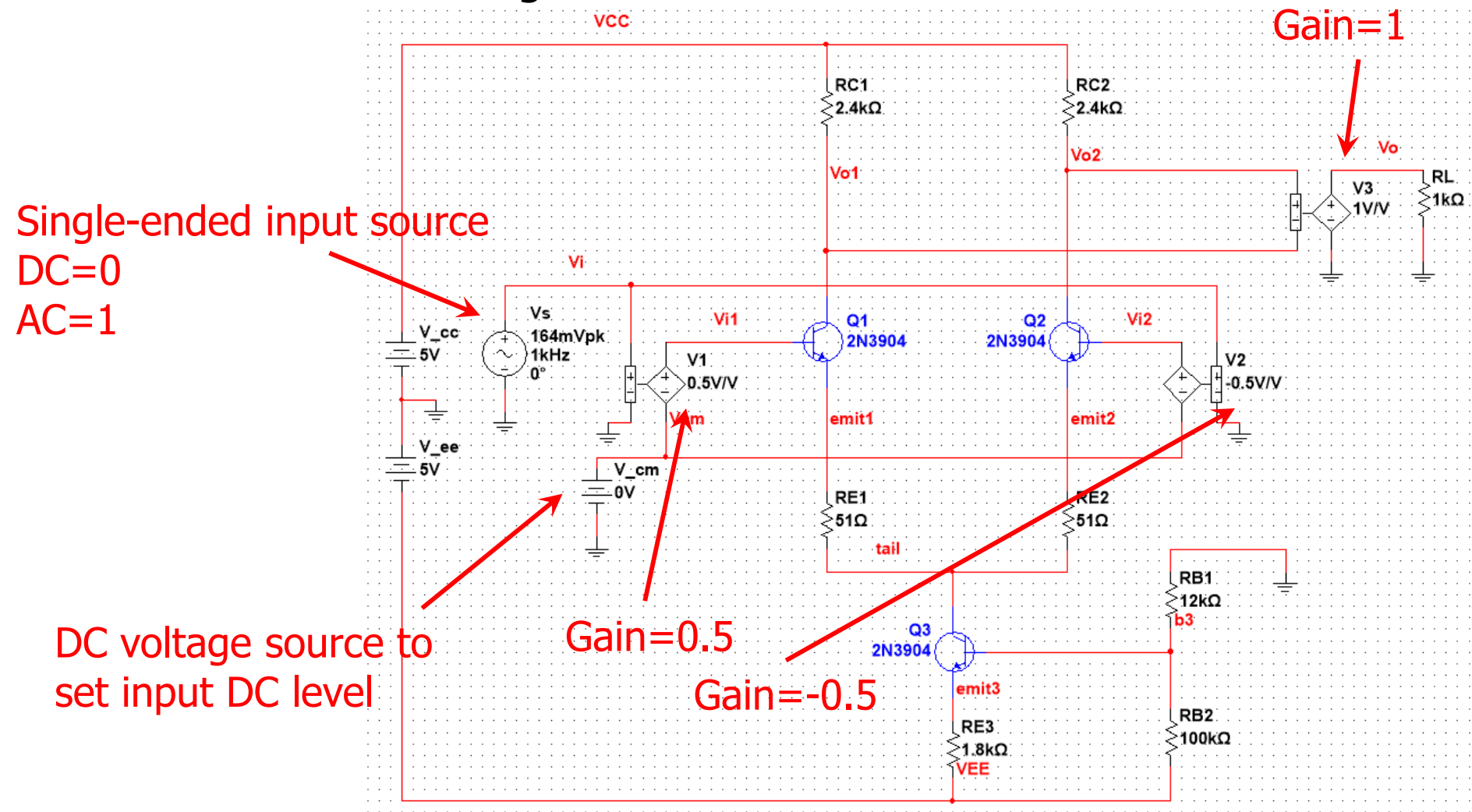
Voltage gain (E): v/v

OK Close Search... Detail report View model Help

Replace... OK Cancel Help

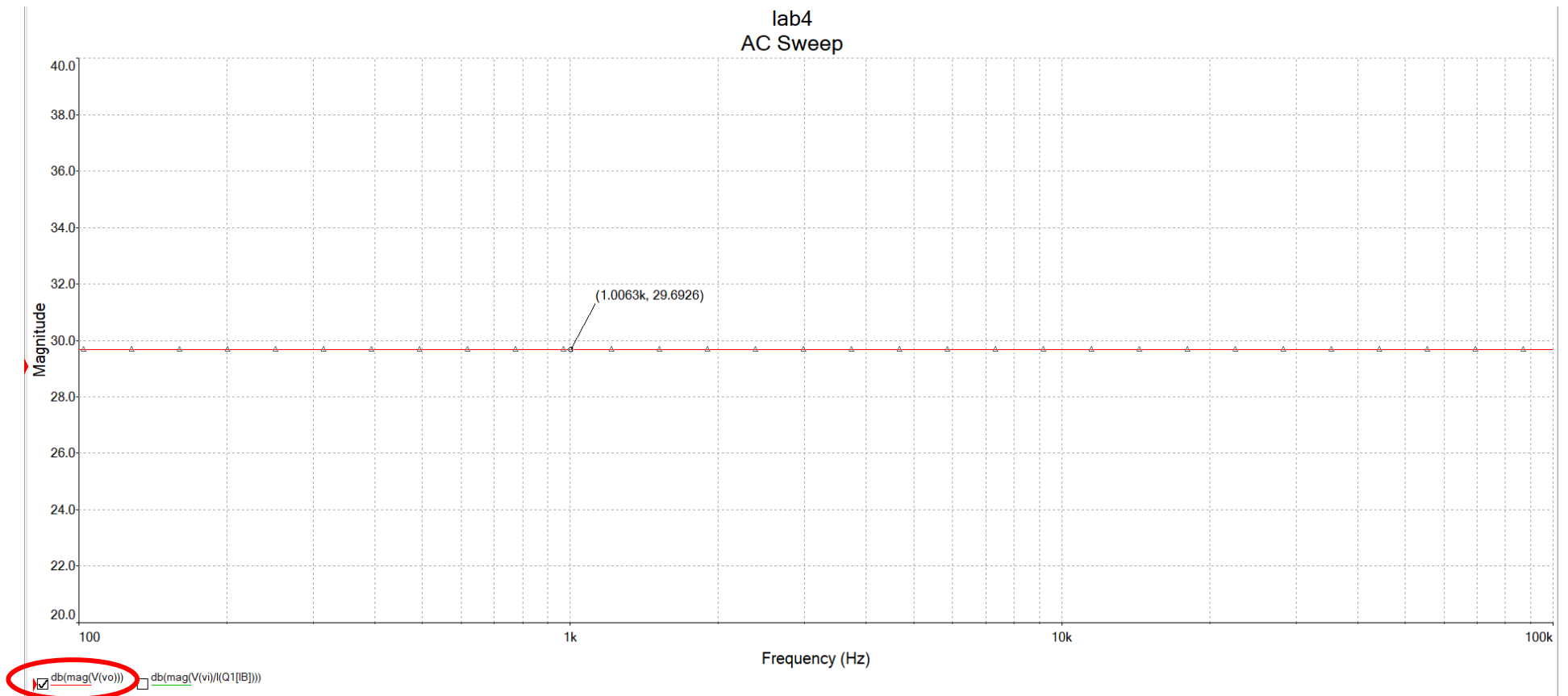
Simulating Differential Gain

- 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 (V_o) to get the differential AC gain



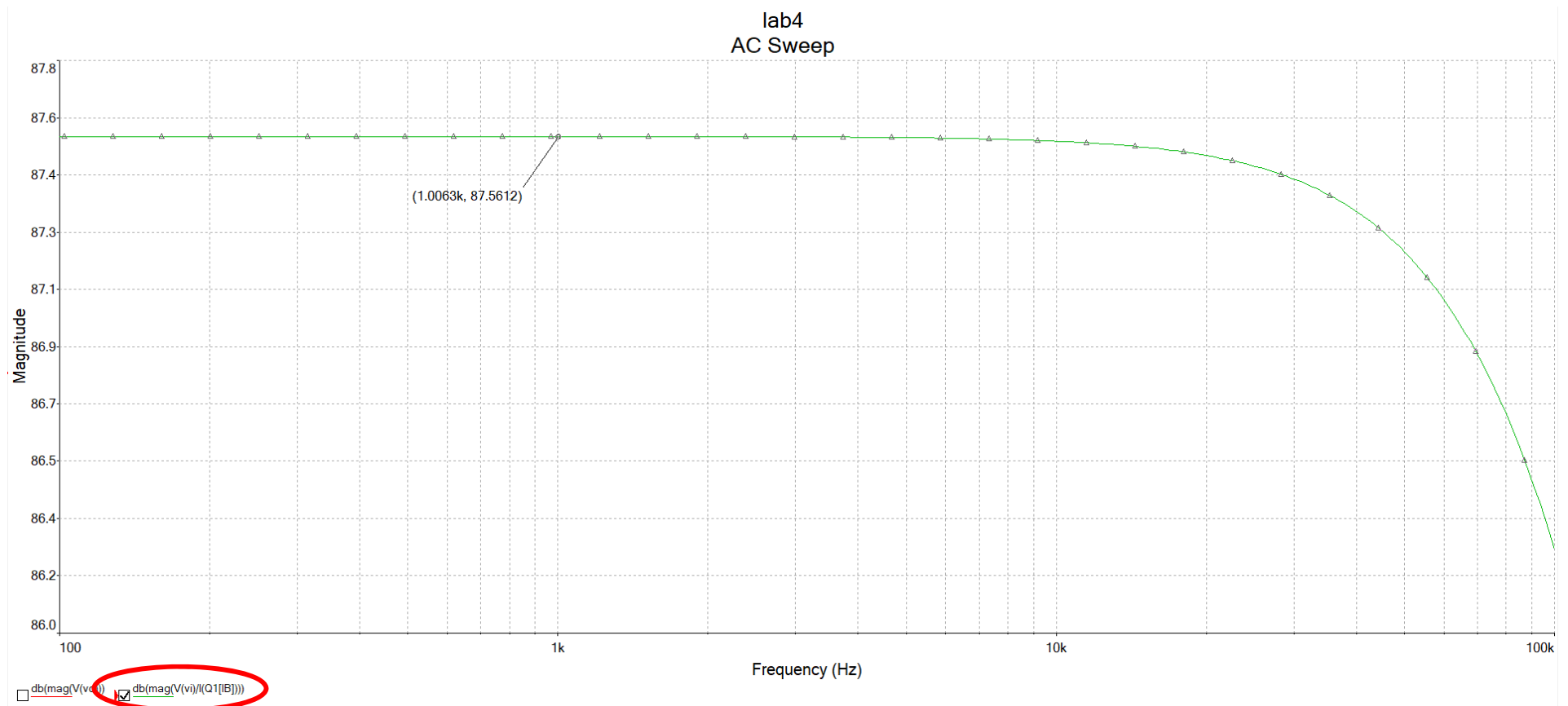
Simulating Differential Gain

- $A_{dm} = 30.5 \text{ V/V} = 29.7\text{dB}$



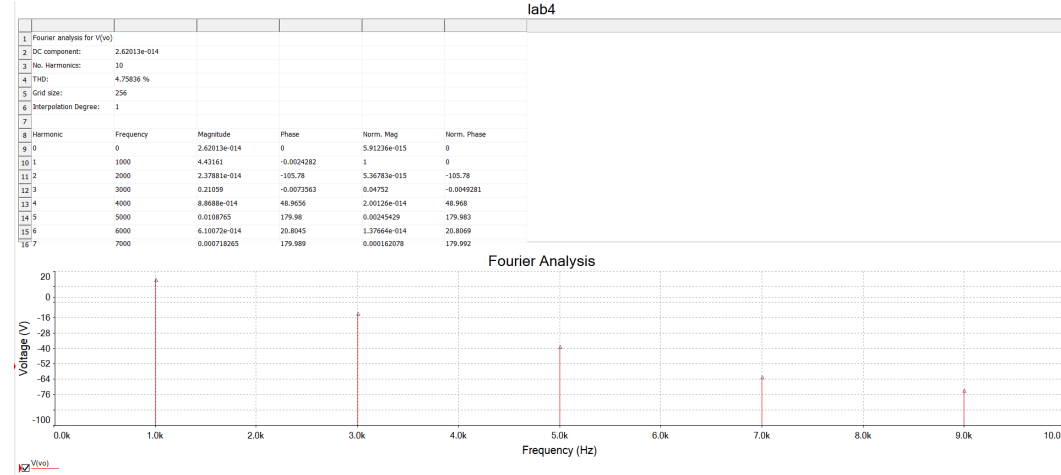
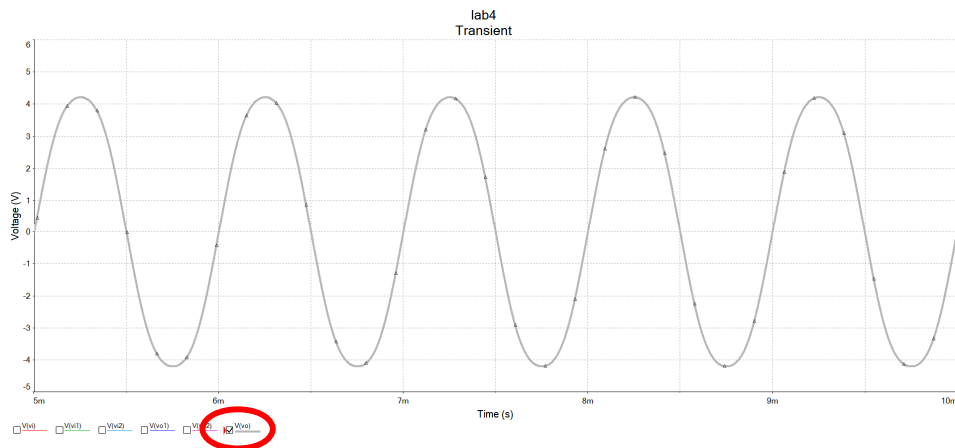
Simulating Differential R_{ind}

- The differential input resistance is equivalent to the differential input (V_i) divided by the input current, where I use the base current of Q1 or $I_B(Q1)$
- $R_{ind} = 24.0k\Omega = 87.6dB\Omega$



Simulating THD

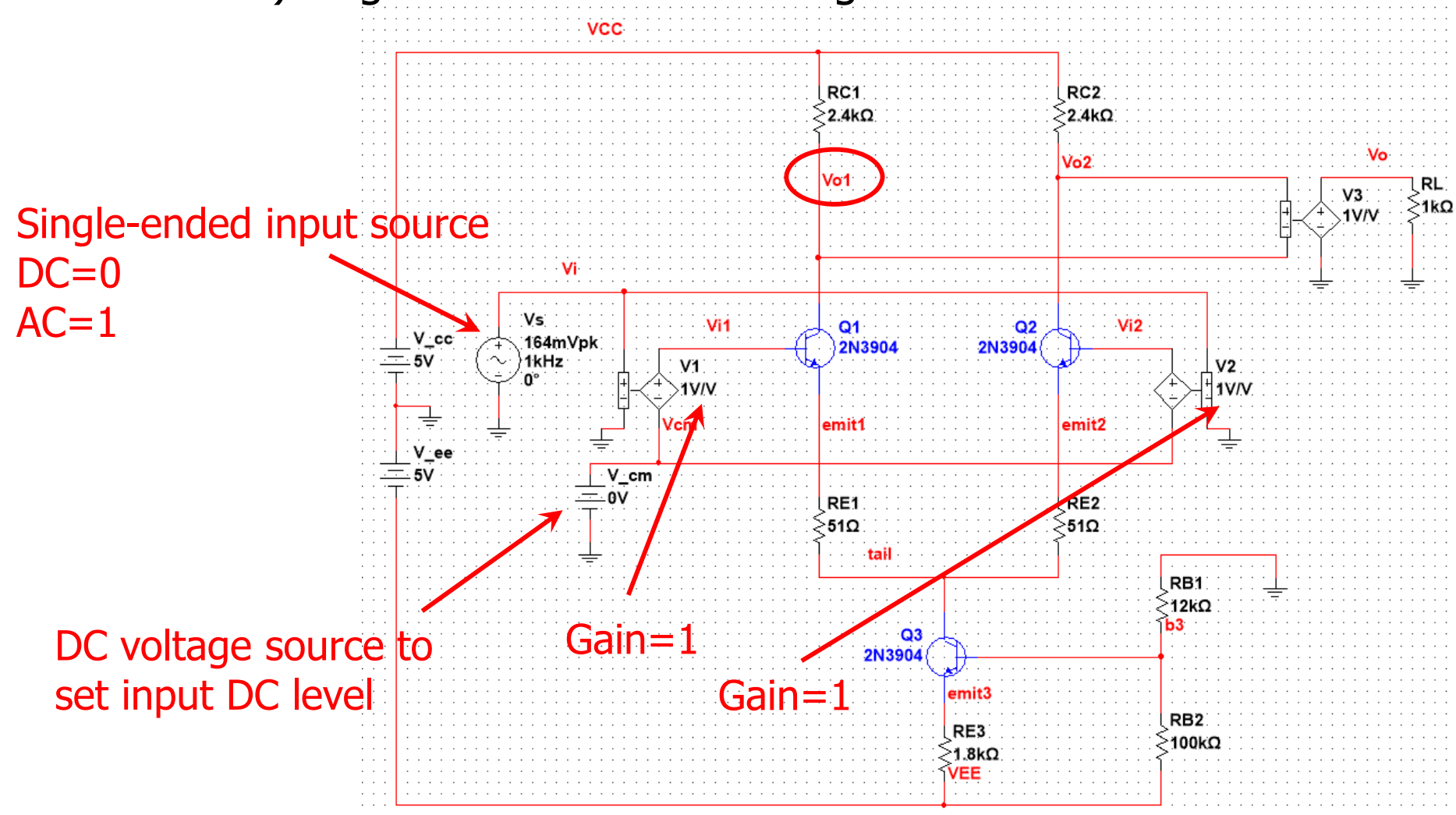
- Set input source to Differential Output Amplitude/ A_{dm}
 - For Lab 4, that is $5V/A_{dm}$
 - In this example I set the differential input $VAMPL = 5V/30.5 = 164mV$



- 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

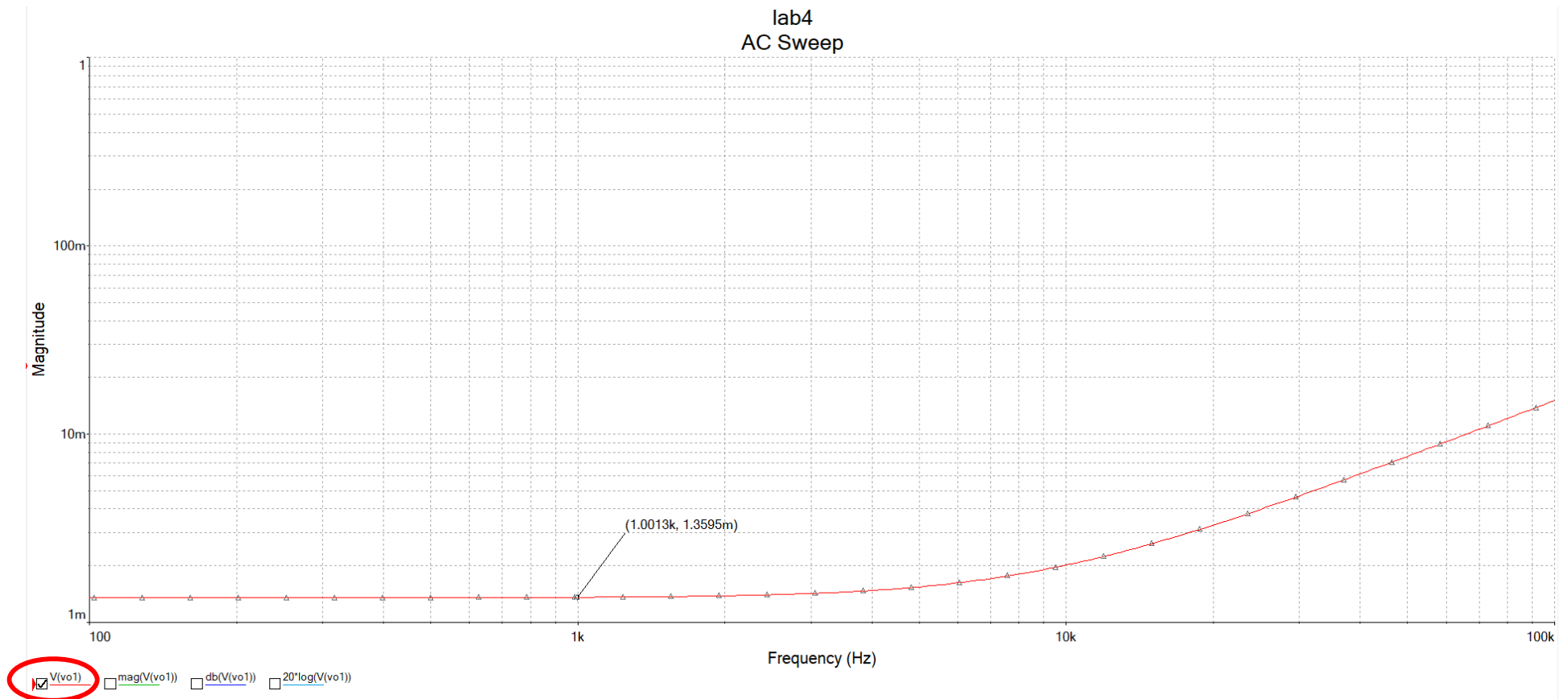
Simulating Common-Mode Gain

- 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 (V_{o1} or V_{o2}) 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 $29.7\text{dB} - (-57.3\text{dB}) = 87.0\text{dB}$