

# ECE 4043 Spring 2020

## Homework Problem Set No 6 for Experiment No. 6

**Due Week of February 22**

1. Shown below is a differential amplifier using BJTs as the amplifying elements. The N Channel JFET is being used as a current source. Design the circuit so that the dc quiescent current in each BJT is 1 mA and the differential gain has a magnitude of 10. The JFET has the parameters  $I_{DSS} = 4 \text{ mA}$ ,  $V_p = -4 \text{ V}$  and  $\lambda = 0.001 \text{ V}^{-1}$ . For the design assume that  $\beta = \infty$  for each BJT. For the simulation use the value below.

For the discrete BJT differential amplifier use National Instruments SPICE, Multisim, to determine:

- the dc operating point of the circuit, viz., the dc voltage at each terminal of each transistor and the current flowing into the collector and base leads and out of the emitter.
- the small signal ac differential voltage gain, viz., a plot of the gain,  $|A_d| = \left| (\bar{V}_{o1} - \bar{V}_{o2}) / (\bar{V}_{i1} - \bar{V}_{i2}) \right|$  versus frequency where the frequency range is from 10 Hz to 100 MHz. This is done by performing an ac analysis where the inputs are ac voltage each of which has an amplitude of 0.5 V and  $\bar{V}_{i1}$  has a phase of 0 degrees (the default value) and  $\bar{V}_{i2}$  has a phase of 180°. Alternatively, connect a 1 V ac source between the two bases with no ground terminal.
- the dc transfer characteristic. This is a plot of the voltage at the outputs versus the differential input voltage. Perform a dc sweep with  $v_{i1}$  a dc voltage with an amplitude  $A$  and  $v_{i2}$  a dc voltage with an amplitude  $-A$ . Plot both output voltages as the differential input sweeps from  $-1.5 \text{ V}$  to  $1.5 \text{ V}$ . Alternatively, connect a 1 V dc source between the two bases and sweep it from 0 to 3 V.
- the small signal ac common mode voltage gain, viz., a plot of the gain,  $|A_d| = \left| (\bar{V}_{o1} + \bar{V}_{o2}) / (2\bar{V}_{i1}) \right|$  versus frequency where the frequency range is from 10 Hz to 100 MHz. This is done by performing an ac analysis where the inputs are ac voltage sources each of which has an amplitude of 1 V and a phase of 0 degrees, i. e. the same or common source.
- the positive and negative clipping levels, viz., the maximum and minimum possible values of the output voltages,  $v_{o1}(t)$  and  $v_{o2}(t)$ . This is done by performing a transient analysis where  $v_{i1}(t) = A \sin(\omega t)$  and  $v_{i2}(t) = A \sin(\omega t + 180^\circ)$ . Simply make the amplitude  $A$  large enough so that the outputs clip. Alternatively, connect a voltage source with an amplitude of  $A$  between the two bases.
- the total harmonic distortion and plot of the output voltages for 3 cycles of the input for a differential input signal with a frequency of 1 kHz and a peak value 2 V. This is done by performing a transient analysis where  $v_{i1}(t) = A \sin(\omega t)$  and  $v_{i2}(t) = A \sin(\omega t + 180^\circ)$  and  $A$  is selected to be 2 V. Perform a spectral decomposition of either of the two outputs. Alternatively, connect the sinusoidal voltage source between the two bases with an amplitude of  $A$ .

Assume that the SPICE parameters for the NPN BJTs are: saturation current, 10 fA; forward beta, 200; Early voltage, 170 V, zero-bias base collector capacitance, 3.6 pF; forward transit time, 0.3 ns, and base spreading resistance, 10  $\Omega$ . The circuit parameters are:  $R_{C1} = R_{C2} = 7.5 \text{ k}\Omega$  and  $R_1 = R_2 = 20 \text{ k}\Omega$ . The dc power supply voltages are  $V^+ = 15 \text{ V}$  and  $V^- = -15 \text{ V}$ .

