Objective:

The objective of this laboratory experiment is to become familiar with applications of MOS and Bipolar transistors as small-signal amplifiers. Both BJTs and MOSFETs are semiconductor devices that can be used in both analog and digital applications. In this lab, MOS transistors will come from the MC4007 MOSFET array. The BJT that will be used is the 2N4400.

In this experiment, you will be measuring waveforms, operating points, and gains. All of these measurements should be made with the oscilloscope. The multimeter that is on the laboratory bench should not be used for any measurements in this experiment.

Discussion:

Although the major emphasis in this course has been on integrated devices, discrete transistors will be used in this experiment.

Components Needed:

2N4400 BJT, MC 14007 transistor array, operational amplifier, 24V other standard electronic components. Data sheets for these components are posted on the EE 330 class WEB site.

Part 1. Voltage Controlled Amplifier

The circuit shown serves as a voltage controlled amplifier when the transistor M₁ is biased to operate in the triode region. As the dc voltage V_{CONT} changes, the gain of the amplifier changes as well.

From information obtained in the datasheet, determine R so that the voltage gain is 30 with V_{CONT} = 5V. Use the n-channel transistor with W/L = 152/6 on your MOS array. What does V_{CONT} need to be changed to for a gain of 10? Experimentally verify the operation of this circuit. Use ± 6V biasing for the op amp. Show the output to your TA.

Fig. 1. Voltage Controlled Amplifier.
Part 2. Common Source Amplifier

Two common-source amplifiers are shown below. The one on the left uses the resistors $R_{B1}$, $R_{B2}$, the capacitor $C_X$, and the voltage source $V_{DD}$ for biasing. The one on the right uses the two voltage sources $V_{DD}$ and $V_{SS}$ for biasing.

![Common Source Amplifiers](image)

Derive an expression for and compare the voltage gains of these two amplifiers if the transistor is operating in the saturation region. Then build and test one of the two. When building the amplifier, use $V_{DD}=5V$, $R_L=10K$ and design for a voltage gain of -5. Select the remaining components to achieve the required gain. Test the circuits with a sinusoidal input voltage of 100mV 0-P and frequency of 1KHz. Compare the measured voltage gain with the calculated gain. Show the output to your TA.

Part 3. Common-Emitter Amplifier

A Common-Emitter amplifier is shown. The value of $\beta$ for the 2N4400 varies considerably from one device to another. In the data sheet that is linked on the class WEB page, the parameter $\beta$ is designated as $h_{FE}$. The large variations in the values of this parameter should be apparent from the data sheet. You will need to measure the value of $\beta$ for your transistor. The coupling capacitor should be large; in the 1uF range or larger. Note the polarity of the electrolytic coupling capacitor is critical.

.a) After this value for $\beta$ is measured, determine the value of $R_B$ necessary to establish a quiescent collector current of 1mA when $V_{DD}=12V$, $V_{SS}=0V$, and $R_L=5K\Omega$. 
b) Compare the theoretical small-signal voltage gain with what is measured for this circuit. In this measurement, use a 1KHz sinusoidal input signal with the input amplitude adjusted so that the output signal swing is 2Vpp. Show the output to your TA.

c) Gradually increase the amplitude of the input until clipping distortion is observed on the output. How big can the output signal be without clipping.

d) Listen to the output signal with a speaker as the output amplitude is increased to barely clipping and if the input amplitude is then increased further to cause severe clipping. Describe how the sound changes when clipping occurs and identify why the sound changes.

Part 4 Amplifier Design

Build and test a small-signal voltage amplifier using the BJT as the active device with a small signal gain of -10 that can drive a 5K load resistor. If you use the circuit of Part 3, the resistor $R_L$ can be considered as the load. Demonstrate design to your TA.

Part 5 A Nonlinear Application

Two circuits are shown. Analytically predict the relationship between $V_{OUT}$ and $V_{IN}$ for $-4V<V_{IN}<4V$ and verify experimentally. Also predict the output if the input is a 1KHz sinusoidal waveform of 4V 0-p value and experimentally verify. Use an n-channel MOSFET from the 4007 array for $M_1$ and use a 1N4148 diode for $D_1$. Comment on what useful functions these circuits provide. Use ±6V biasing for the op amp. (Hint: The connection of Gate to Drain of a MOSFET is often termed a “diode-connected” transistor) Show the output to your TA.