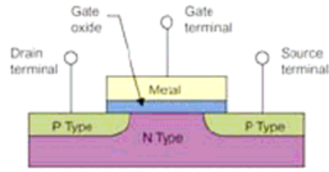
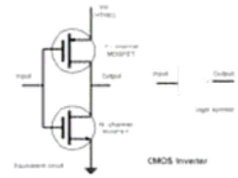
The Transistor Inverter



BACKGROUND

In this lab, we investigate several forms of the transistor *inverter*, a basic building block found in digital logic circuits as well as in circuits capable of linear amplification. Our primary focus in this assignment is inverters used for linear amplification.

The *voltage transfer function* or *voltage transfer characteristic* of an and inverter describes the relationship between its input and output voltages. The transfer function may be expressed in either mathematical form or as a graphical plot in which v_{IN} is plotted on the horizontal axis and v_{OUT} on the vertical axis.

One key property of an inverter operating in the analog regime is that a change in its input voltage causes a proportional, but larger, change in its output voltage. When the input voltage to an inverter goes up, its output voltage goes down, and vice versa; hence the name "inverter". The *incremental gain* (sometimes called the *small-signal*, or *ac gain*) of the inverter is defined as as dv_{OUT}/dv_{IN} . This derivative is to be evaluated at a fixed (bias) value of v_{IN}.. When we wish to amplify a signal in analog mode, we intentionally operate the inverter in its high gain region, i.e. where dv_{OUT}/dv_{IN} is large.

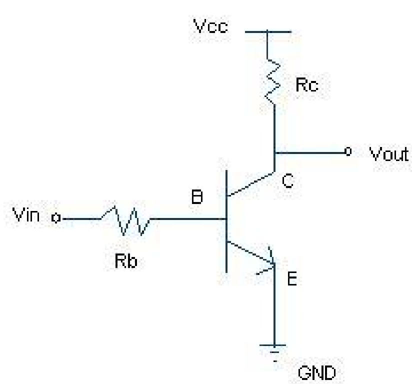
LEVEL 1: BJT INVERTER WITH RESISTIVE LOAD

In this level, we examine the voltage transfer function for the simple BJT inverter shown below. The transfer function is derived under the assumption that the transistor operates in the constant-current region, where $i_C = \beta_F i_B$. Obtaining i_C and i_B from analysis of the circuit, we can derive the following equations:

$$i_C = \frac{V_{CC} - v_{OUT}}{R_C} = \beta_F \frac{v_{IN} - V_f}{R_B}$$

or

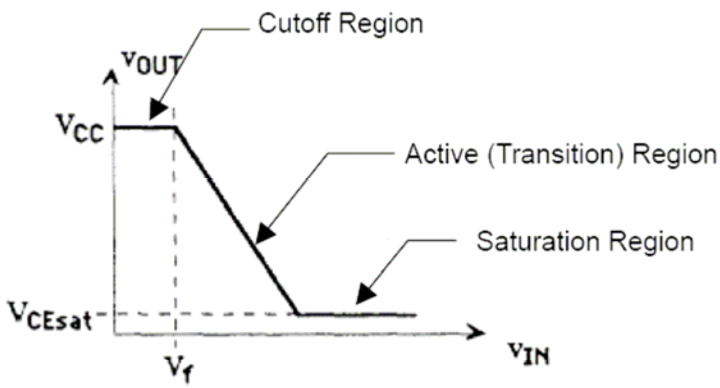
$$v_{OUT} = V_{CC} - \beta_F \frac{R_C}{R_B}\left(v_{IN} - V_f\right),$$



Here V_f is the "turn-on" voltage of the transistor' s base-emitter junction (V_f = 0.5 to 0.7 V). For smaller values of v_{IN} , the transistor will be in cutoff, and i_C will be zero. Under these conditions, the output voltage v_{OUT} will equal V_{CC}, the open-circuit voltage seen via R_{C}. .

If v_{IN} becomes too large, the transistor will reach saturation, where $v_{OUT} = v_{CE}$ drops to just a few tenths of a volt, with the transistor out of the constant-current region, and i_C no longer equal to $\beta_F i_B$.

Plotting the above equation plus the cutoff and saturation regions yields the following voltage transfer function:



BJT Inverter Voltage Transfer Characteristic

The slope in the linear region is given by

$$\frac{dv_{OUT}}{dv_{IN}} = -\beta_F \frac{R_C}{R_B}$$

This slope, or *gain*, can be considerably greater than unity in magnitude if the resistor values are properly chosen.

Construct a simple BJT inverter using the 2N2222 or PN2222 transistor in your lab kit. Aim for a gain of about −10. You'll need to add some form of DC offset, or bias, to the input signal, so that the inverter operates in the middle of the linear portion of its transfer characteristic when the signal component of its input signal is zero. Show that your inverter can accept a ±0.1-V sinusoidal signal and convert it into a ±1-V signal.

<u>Level 2:</u>
Substitute a single NMOS transistor from your parts kit for the BJT in the resistive-load inverter that you built in Level 1. Derive a mathematical expression for the voltage-transfer characteristic, then choose component values so that the amplifier can accept a ±0.1-V input signal while always operating in the constant-current region.

Show via a simultaneous display of the input and output signals on an oscilloscope that the output signal is *not* a faithful reproduction of the input signal due to the square-law-device nature of the MOSFET.

<u>Level 3:</u>
Find the integrated circuit in your parts kit that contains matched NMOS/PMOS pairs. Connect one such pair as a simple CMOS inverter operating from a 5-V supply voltage. Devise an experiment to measure the small-signal gain of the inverter in the region were both transistors operate in their respective constant-current regions.