Lab 7: Transistors (version 1.3)

WARNING: Use electrical test equipment with care! Always double-check connections before applying power. Look for short circuits, which can quickly destroy expensive equipment.

Summary
Lab focuses on the use of transistors and applications to switches, amplifiers, and logic gates

Learning Outcomes

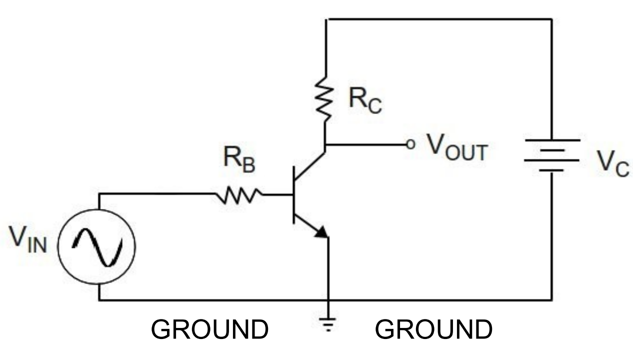
- Understand the basic function of an n-p-n transistor.
- Build an amplifier from an n-p-n transistor.
- Build a switch from n-p-n transistors.
- Build a logic gate from n-p-n transistors.

Lab Goals
Build and investigate/study/characterize, amplifiers, switches, and logic gates.

Equipment needed:
DC Power Supply
Digital oscilloscope
Function generator
Circuit breadboard and components/cables/probes: Transistors, Resistors, and Capacitors.

Experiment/Procedure
We will use the 2N2222A (PN2222A) bipolar junction transistor, which is commonly used in many circuit designs. Note: when using metal 2N2222A transistors, the entire case (metal can) is at the potential of the collector, and one must use caution to prevent shorts.

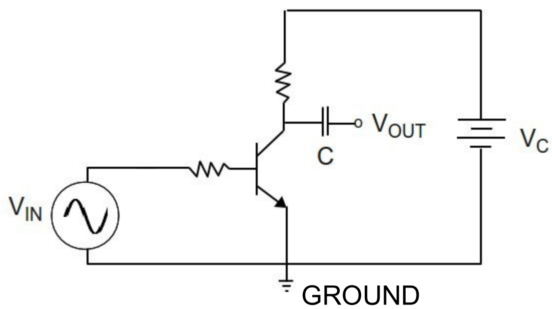
Transistor amplifier
Build the amplifier shown the circuit below. None of the resistor values, V_{IN}, or V_C are critical. One possible choice is R_B = 50 kΩ and R_C = 4.7 kΩ; V_C = +15V or +12V. Use an external function generator to generate V_{IN} sinusoidal wave with a possible offset to overcome the threshold voltage. Example: V_{IN} can be 1 kHz sine wave with 100 mV p-p amplitude and a 1 V DC offset.



Monitor V_{IN} and V_{OUT} together on the oscilloscope. Investigate the effect of the offset in V_{OUT}. Study the amplifier by observing the dependence of V_{OUT} for different inputs V_{IN}. Discuss your observations in the lab book.

Set the coupling of both channels on AC coupling. Measure the gain of the amplifier V_{OUT}/V_{IN}, and the relative phase between input and output. In your lab notebook, compare your results with the theoretical gain calculated with your experimental parameters. Do you observe any difference?

Add a capacitor C = 100 nF (not critical) in series as indicated below and investigate its effect in V_{OUT}. Next set the offset of V_{IN} to zero and investigate the effect in V_{OUT}. In your lab notebook, explain, discuss, and analyze your observations. Show the results (gain, phase, capacitive coupling, base bias) to the instructor.

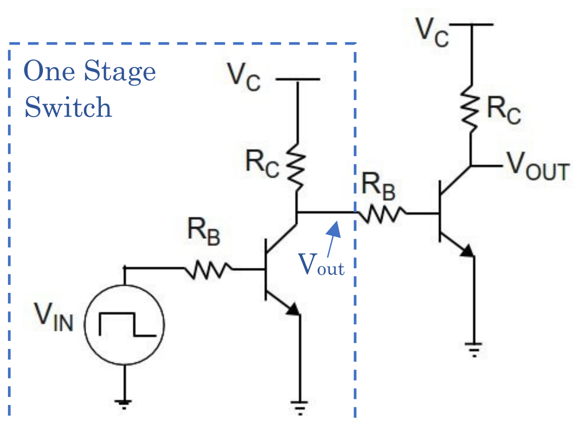


Transistor switches

<u>One-stage switch</u>

Build the circuit "One State Switch" below contained within the dashed square for a one-stage transistor switch. Use V_C of 5V DC, and the function generator to produce an alternating sequence of digital states Logic 0 ($0 < V_{low} < 200$ mV) and Logic 1 ($2\text{ V} < V_{high} < \sim 4$V) at a frequency of 1 kHz. Monitor V_{IN} and V_{OUT} together on the oscilloscope. This transistor switch should function as a logical gate that inverts the input, what is that gate? Show working circuit to instructor.

Measure the rise-time of the transistor switch. Note: Rise- and fall-times of a signal transient are typically defined as the temporal separation of points at 0.1 and 0.9 of the signal maximum.



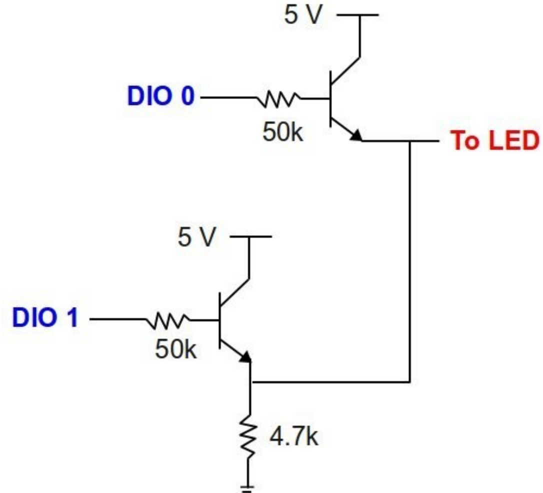
Two-stage switch

Add an identical transistor stage to the output of the first transistor as shown in the complete diagram above. Use the same parameters as part before. The second stage should undo the operation of the first, i.e. V_{OUT} should be the same waveform as V_{IN}. Two inverting gates in series will restore the input logic. Show the results to the instructor.

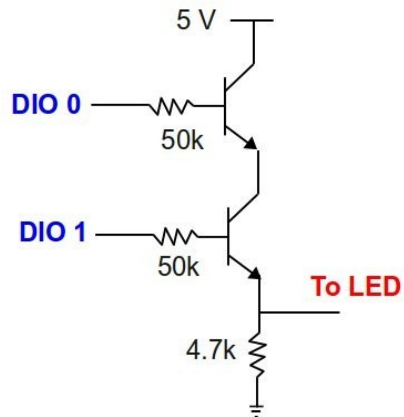
Boolean logic

Build the logical circuits below (one by one), using an LED for the output. Note that LEDs are diodes that light up when current passes through them, so need a return path to ground. If using stand-alone LEDs you need to use a resistor (R~200 Ω) in series with the LED to limit the current (see Lab 6).

Build and test the Gate as shown in the circuit diagram below. Using the HI and LO states of **DIO 0** and **DIO 1**, produce a Boolean logic table for all four possible combinations of input states and determine what gate it is. Demonstrate circuit operation to the instructor.



Construct the second gate shown below and generate the Boolean logic table for all four input combinations.



Analysis

The required elements of the analysis for the different circuits are already discussed in each part. Below are some pointers to the analysis to be realized.

Transistor-based voltage amplifier

Discuss and analyze the performance of the amplifier in terms of gain, phase, capacitive coupling, base bias. Use diagrams/figures. In your lab notebook, derive the expected gain from theoretical model. Compare your measurement results with the theoretical gain considering your experimental parameters.

Transistor switch

Build the circuit. Show diagrams. Explain and discuss how the circuit works and its response to binary inputs. Based on your observations, determine the gates being performed. Measure and report your risetime for the input and output of the gate. Compare it with the expected values for the components.

Boolean Logic

Build gates and demonstrate their functionality. Show diagrams. Explain and discuss how the circuit works and its response to binary inputs. Based on your observations, determine the gates being performed. Demonstrate to the instructor.