Lab 7: Transistors II

Goal

The goal is to understand the most important bipolar transistor circuits.

Objectives

1. Construct a simple oscillator
2. Construct a common-emitter amplifier
3. Construct a transistor switch

Expectations

1. You are expected to take detailed notes during each step outlined in the procedure that can be used during the lab report write-up.
2. You are expected to provide a neat table of the data that you measured where you clearly label what each data set is and include units for all measured quantities.
3. You are expected to clearly record the measured values of any components that you use.
4. You are expected to clearly record the detail related to images captured by the oscilloscope.
5. You are expected to make your final plots in a program such as Excel. Make sure that your data points appear clearly on the plots, that all axes are clearly labeled and have units.
6. If it is possible to compare your measurements with an expectation or a prediction, you are expected to do so in your lab report
7. You are expected to answer the questions encountered in this manual as well as discuss exercises given during the lectures in your lab write up.

Introduction to Concepts

The Common-Emitter Amplifier

A common-emitter amplifier (Figure 1) has a voltage gain hence it's a voltage amplifier, with a voltage amplification (or "Gain") given by Gain $= \mathrm{V_{out}/V_{in}} = -\mathrm{R_C/R_E}$. The negative sign means that a positive wiggle at the input gets turned into a negative wiggle (with "Gain" times as large) at the output. This is called a common-emitter amplifier. A blocking capacitor must be attached to the input so that all frequencies of interest are passed by the high-pass filter formed in combination with the input impedance of the common-emitter amplifier. The collector current ($\mathrm{I_C}$) when no input signal is connected is called the quiescent collector current of the common-emitter amplifier.

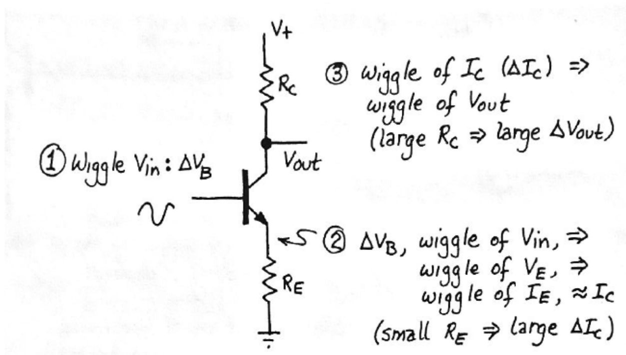

Figure 1: A common emitter amplifier.

The Transistor Switch

The transistor can be configured to act as a switch is when large I_B current is supplied to reach the maximum possible I_C current. At this limit the relation $T_C = \beta I_B$ does not hold on. At the saturation limit the V_{CE} has reached the minimum voltage drop possible, ~ 0.1 V.

Preliminary Lab Questions

You will find useful to complete the preliminary lab questions before starting the procedure.

1. Calculate the gain (amplification) of the common-emitter amplifier to be build in the lab.

2. Calculate the currents I_B and I_C for the transistor switch circuit to be build in the lab.

Equipment and Parts

1. Signal generator (Instek GFG-8216G)

2. Power supply (EXTEC 18 V DC power supply)

3. Oscilloscope (RIGOL DS11002E)

4. Two multimeters

5. RLC meter

6. proto-board with power supply

You will also need the following components in order to carry out this lab.

1. 0.01 μF (103), 2 of 0.001 μF (102), 100 pF, and 68 pF capacitors

2. 2N3904 transistor

3. Resistor box

4. 680 Ω, 1 kΩ, 5.0 kΩ, 5.6 kΩ, 6.8 kΩ, 56.0 kΩ, and 220 kΩ
5. 4.0 MHz and 4.098 MHz quartz crystals
6. Light Dependant Resistor (LDR)
7. Four pairs of crocodile cables
8. Connecting wires (4 - 6)
9. Three BNC to crocodile cables

Procedure

The Simple Transistor+Crystal Oscillator

As a demonstration of how to produce oscillating signal we will build a simple transistor+Crystal Oscillator known as Colpitts oscillator.

- Build the circuit shown in Figure 2.
- Use the Figure 3 as a guide to build a compact circuit on the proto-board.
- Use the 4 MHz quartz crystal first and reproduce a oscilloscope trace similar to Figure 4
- Capture the oscilloscope trace with frequency visible on the oscilloscope trace.
- Compare the value printed on the quartz crystal with the frequency observed.
- Calculate the percent error.
- Repeat the circuit with 4.098 MHz quartz crystal
- Capture the oscilloscope trace with frequency visible on the oscilloscope trace similar to Figure 5.
- Compare the value printed on the quartz crystal with the frequency observed.
- Calculate the percent error.
- Discuss applications of oscillator circuits and why quartz crystal is a good choice.

The Common-Emitter Amplifier

- Measure the resistance and capacitance of all the elements of the amplifier circuit shown in Figure 6
- Construct the amplifier circuit shown in Figure 6
- Set the signal generator to sine-wave and set the frequency to 1 kHz

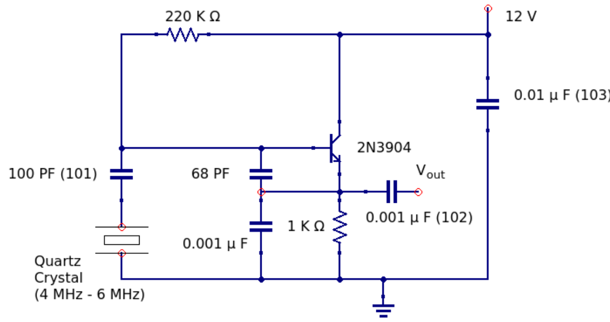

Figure 2

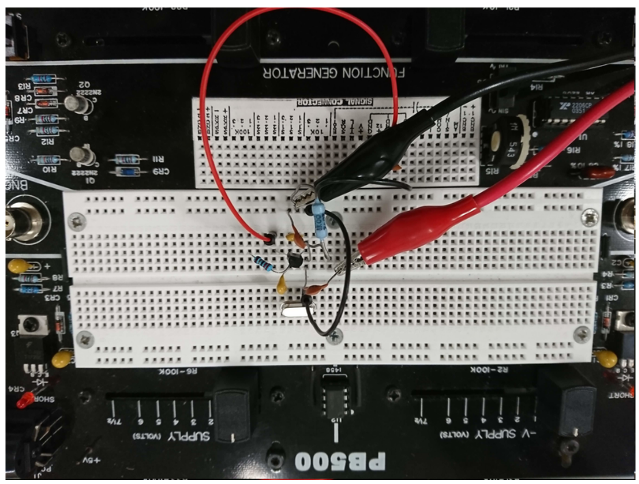

Figure 3

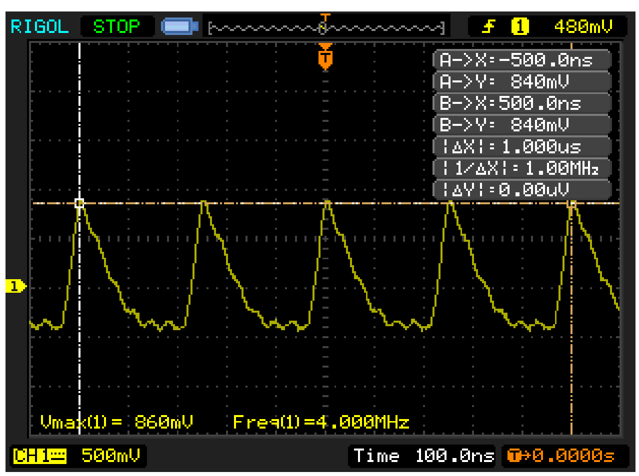

Figure 4

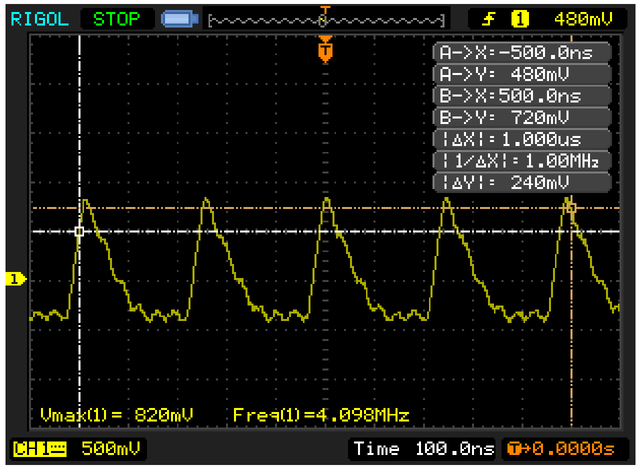

Figure 5

- Set the signal amplitude to minimum at the signal generator
- Attenuate the signal generator signal by using “-20 dB” switch in the signal generator
- Set the oscilloscope channels to “DC” mode
- Connect the input signal from the signal generator into Channel 1 of the oscilloscope
- Connect the output of the amplifier to the Channel 2 of the oscilloscope
- Measure the input and output amplitudes
- Measure the phase shift of the output with respect to the input
- Calculate the “Gain” of the amplifier
- Save the oscilloscope image of input and output signals
- Measure the input and output amplitudes for following input frequencies, 100 Hz, 1 kHz, 5 kHz, 10 kHz, 15 kHz, 50 kHz, and , 100 kHz
- Compare maximum gain of the amplifier to the theoretical estimate of the gain of the amplifier.
- Based on your measurements estimate the f_{-3dB} points of the amplifier. The f_{-3dB} is the frequency where gain falls to 0.707 of the maximum gain. This is known as the bandwidth of the amplifier.
- See Figure 7 for sample bandwidth graph for an amplifier.
- Note that you may have to take few extra frequency data points to accurately estimate the f_{-3dB} points
- Plot the gain vs frequency using your data.

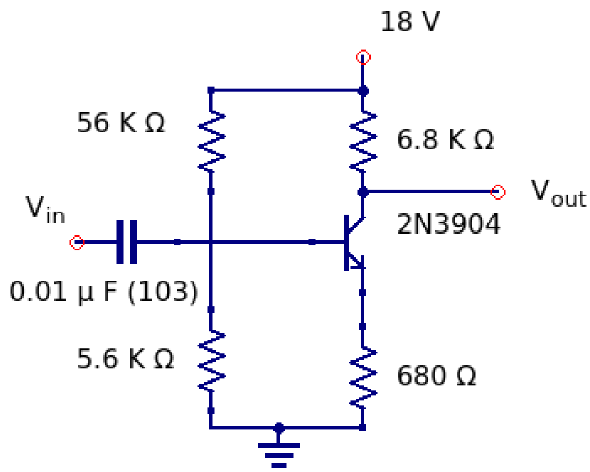

Figure 6: Common emitter amplifier.

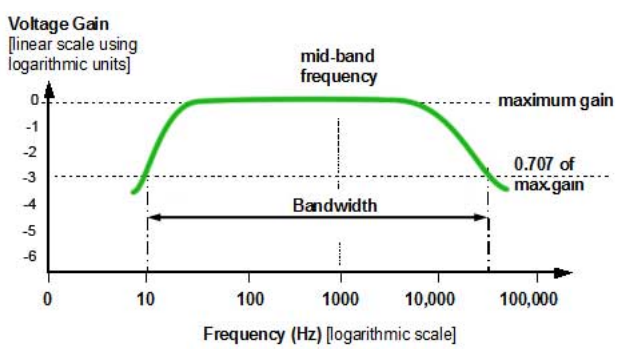

Figure 7: Bandwidth of an amplifier.

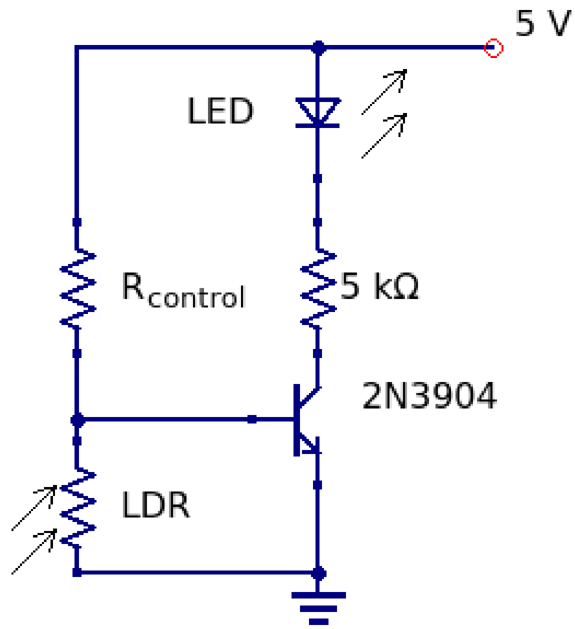

Figure 8: Light sensitive transistor Switch.

Light Sensitive Transistor Switch

- Measure the resistance values for all the resistors in the circuit shown in Figure 8
- Measure the resistance of the light dependant resistor (LDR) under light and under dark (cover by hand)
- The switch needs to be turned off when light is incident on the LDR, therefore the $R_{control}$ must be chosen such that $V_{BE} < 0.6$ V for the circuit shown in Figure 8
- For the circuit shown in Figure 8, Calculate the value of $R_{control}$ that will result in $V_{BE} \sim 0.2$ V to prevent biasing the transistor when light is incident on the LDR
- Construct the simple light sensing circuit shown in Figure 8
- Use the resistor box for $R_{control}$
- Observe and report the function of the light sensitive transistor switch

References