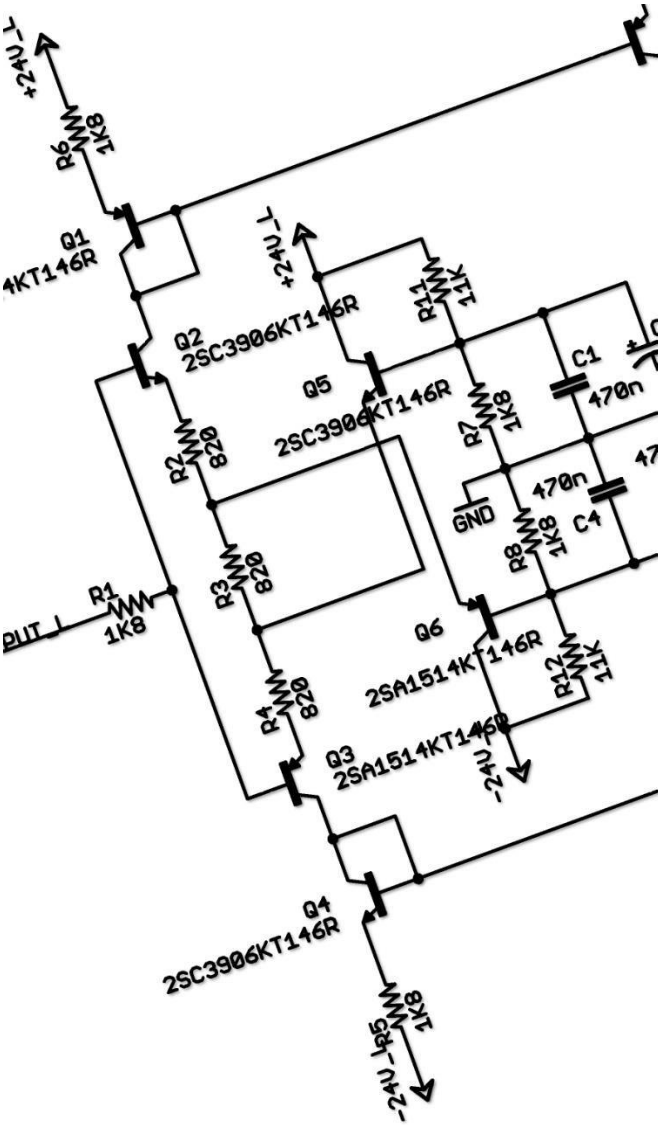
MONASH University
Engineering

ECE2131

Electrical Circuits

Laboratory Notes



2022 Edition

Name:	Student ID:	Email:

Electrical and Computer Systems Engineering, Monash University

2022

11 Bipolar Junction Transistors

11.1 Learning Objectives and Introduction

Transistors form the foundations of virtually all modern electronics, and as such it is something of an understatement to say that they are an important component to understand! The aim of this experiment is to explore, in depth, the operating regions and characteristics of Bipolar Junction Transistors (BJTs), operating as analogue devices.

At the conclusion of this lab, you should be comfortable with the different operating regions and characteristics of a BJT transistor. You will also get the opportunity to learn how to use the digital storage oscilloscope to easily capture more information about active devices.

By the end of this lab you should:

- Experimentally measure the basic characteristic of BJT transistors
- Observe the difference in modes of operation for BJT transistors, and how these can be achieved
- Trace a characteristic curve for a BJT transistor

11.2 Equipment and Components

- Breadboard.
- Transistor: BC 547.
- Resistors: 1 Ohm, 100 Ohm, 10 kOhm, 100 kOhm.

11.3 Important Notes

All circuit calculations will be done in the preliminary quiz for this lab. Ensure you have the formulas you developed for the quiz on hand!

Besides the specially mentioned components and instruments, you may assume that standard passive components will be available (resistors and capacitors). Note that the BJT transistors used have a nominal current gain β_N of ≈150, but the gain specified in the data sheet can vary between 110 and 800.

Some measurements to be made in this experiment involve measuring switching times in the order of 10's of nanoseconds. Second order effects can affect these measurements significantly, and must be accounted for in your simulations and workings. In particular, the rise and fall times of the signal generator can be significant, and the oscilloscope probe capacitance can also have a significant influence. Try and make some allowance for these effects when comparing measured, simulation and calculated results.

Please note that the notes for this experiment are not intended to provide a complete recipe of the procedure to be followed, and you are encouraged to make whatever measurements you consider necessary to get better results. Electronics is about THINKING about what you are trying to achieve, UNDERSTANDING the basic theory, and APPLYING this knowledge to achieve a result.

You will use the BC547A transistor in this experiment. You will need to use the datasheet you found as part of your preliminary quiz, ensure you have a copy of it available.

11.4 EXPERIMENTAL SECTION

11.4.1 PART A – MEASURE BJT β_F

The principle proposed to measure the BJT β_F is to energise the transistor using the circuit shown in Figure 1 below, where the excitation source is a relatively slow triangular waveform with peak limits adjusted to just cycle the transistor between cutoff and saturation. This will cause a fairly slow turn on and turn off process, allowing the point at which the transistor becomes saturated to be easily determined. The base and collector currents are determined by measuring the voltages across R1 and R2, and the current gain (β_F) can then be measured by dividing the collector current by the base current, for various parts of the excitation waveform.

NOTE: you cannot directly use the voltages across the 10k and 100k resistors. For V_{100k}, you must measure the input triangular voltage and subtract v_{be}, the base-emitter voltage. For V_{10k} you must measure V_{ce} and subtract this voltage from the 15V supply to find the voltage across the 10k ohm resistor.

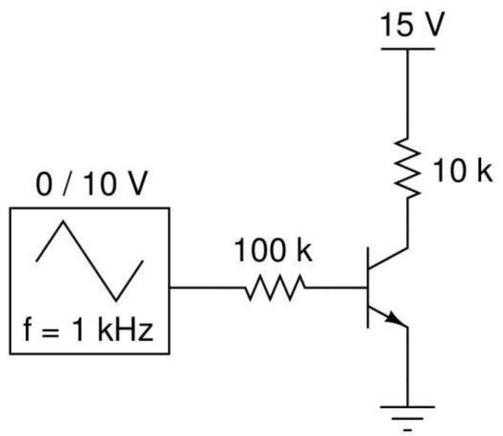


Fig. 1: Test Circuit to measure transistor βF

11.4.1.1 Setup the circuit shown in figure 1, and then adjust the **upper** and **lower** triangle waveform limits using amplitude and DC offset settings in Scopy. Adjust the triangle waveform so that the BJT just goes into saturation and cut-off at the upper and lower limits of the waveform respectively. To help you with this, connect one oscilloscope channel at V_{BE} and another oscilloscope channel at V_{CE}. Record the values of your triangle waveform.

HINT: We want the operation of the transistor to be in the forward-active region for most of the time. Saturation occurs when $V_{BE} \geq 0V$ and $V_{CE} \leq V_{BE}$, while cut-off occurs when $V_{BE} \leq 0V$; and $V_{BC} \leq 0V$ or $V_{CE} \leq V_{BE}$

11.4.1.2 Measure the triangular source upper peak voltage (V_{peak}) and the BJT collector voltages (V_C) at the **same time**. Use these measured values to calculate the base current (I_B) and the collector current (I_C), and then use these values to find β_F.

11.4.1.3 Repeat the measurement process of 11.4.1.2 when your triangular source is at half of V_{peak}. Compare the two values of β_F. Explain the differences between the two values of β_F.

11.4.1.4 Which value of β_F is more appropriate for operation of the transistor in the forward active region?

11.4.1.5 Measure the BJT base-emitter voltage and collector-voltage as the BJT goes into saturation. How do these values compare with the data sheet for the BC547?

11.4.1.6 Reverse the BJT connection by swapping the emitter and collector pins, and repeat the test to measure β_R (using similar steps that you have done in 11.4.1.2). How does this value compare with β_F?

11.4.2 PART B – MEASURE BJT ACTIVE REGION CHARACTERISTICS (I_C–V_{CE} plot)

The aim of this part of the experiment is to plot the transistor active region static characteristics using the digital oscilloscope. The principle proposed is to use an adjustable voltage feeding through a 100k resistor to create an adjustable base current, and then to apply a triangular voltage to the BJT collector. In theory, for any particular base current, the collector current should be independent of the collector-emitter voltage when this voltage is greater than about 0.7V.

NOTE: in this part of the experiment we are using the oscilloscope in a mode you are not familiar with, please read the instructions carefully to avoid frustration!

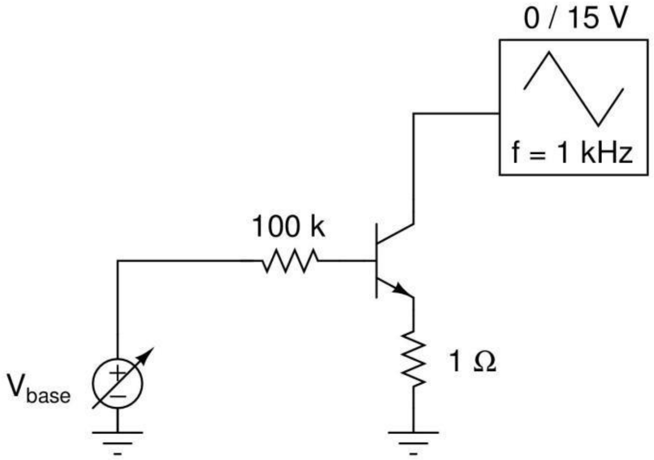


Fig.2: Test Circuit to measure I_C – V_{CE}.

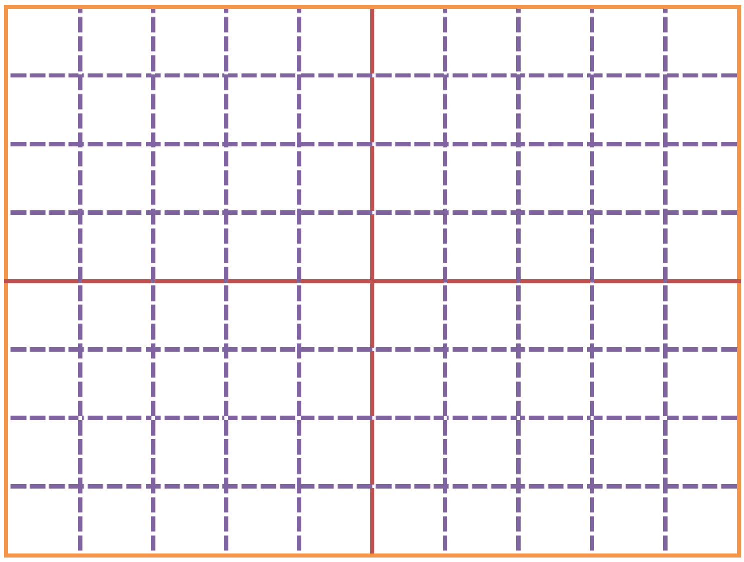
11.4.2.1 Setup the circuit shown in Figure 2 and place the probe for channel #1 on the BJT collector (with the ground on the ground as shown in figure 2). Attach channel #2 to emitter terminal next to the 1 Ohm resistor. **Since the voltage across channel #2 is very small, you should set the oscilloscope probe to X1 mode (and change the attenuation setting in the channel mode options) to get a better measurement.**

11.4.2.2 Adjust the oscilloscope timebase to display 2-3 cycles of triangular waveform.

11.4.2.3 Switch the oscilloscope to X-Y mode. You should now see one trace of the "Static characteristics" shown in the BC547 data sheet (I_C – V_{CE} characteristic). This characteristic should move vertically (increasing/decreasing collector current) as iBase is varied by adjusting the voltage feeding the 100k base resistor. *NOTE: you will probably have to swap between TIMEBASE and X-Y modes several times to get this trace effectively. You will need to adjust channel gains and offsets, and the time base, and some of these controls do not work effectively in X-Y mode.*

11.4.2.4 When you are confident you have captured a sensible result, sketch out the oscilloscope display on the axes below (you may also want to take picture of the DSO display with your phone, to record additional details).

Attempt to match several performance curves to those shown in the BJT data sheet by adjusting I_{Base}. Remember to allow for the base-emitter voltage when calculating the base current using the voltage drop across R2 (it may be easier to measure this voltage using a multimeter). Add the matching characteristics to the graph above.



☐ CHECKPOINT: Get a demonstrator to check your answers, and initial here

ASSESSMENT

Student Statement:

I have read the university's statement on cheating and plagiarism, as described in the *Student Resource Guide*. This work is original and has not previously been submitted as part of another unit/subject/course. I have taken proper care safeguarding this work and made all reasonable effort to make sure it could not be copied. I understand the consequences for engaging in plagiarism as described in *Statue 4.1 Part III – Academic Misconduct*. **I certify that I have not plagiarized the work of others or engaged in collusion when preparing this submission.**

Student signature:________________________________Date:____/____/____

TOTAL: ________(/7)

ASSESSOR: ________