EEE109 Lab 2 – BJT and Amplifiers

Lab Report 2

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Abstract:

With the objective of verifying basic behaviors of BJT as a switch and amplifier, this lab is mainly divided into 4 sections. The first section covers the exploration of BJT output characteristic curves. Students make use of NI ELVIS III along with Measurement Live to examine and plot their waveforms. Our group has a measured error in part 1 of section 3, and we made a speculation about the possible reasons and provide solutions as well. Our results generally confirm the CCCS characteristic of BJT, and its utilization as an amplifier.

1. Introduction

1.1 Background

A BJT is an electronic element with 3 terminals capable of amplifying signals when biased in forward-active region. The gain of BJT has diverse applications in production, such as weak signal amplification, modification of the waveforms of signal, and improvement of anti-interference ability of circuits. These functions make BJT widely used in production and life.

1.2 Experiment

Clarifying the targets of the experiment is indispensable for students at first. Students have to discuss the characteristics, operation, and application of BJT. After that, experimenter have to understand the working region and corresponding mechanisms in different conditions. Ultimately, students need to understand BJT circuit as a switch by controlling its input.

Secondly, the experiment's scope needs to be clearly illuminated. Students must be equipped with all points in Chapter 4—Bipolar Junction Transistor and Chapter 6—Basic BJT Amplifiers, which is also the range of experiment.

Finally, it is highly recommended that students should predict the possible outcomes of the experiment before operating the simulation software. They will gain a deeper understanding of what they are weak with when there exists a gap between their prediction by knowledge and measurement by instruments.

1.3 Organization

There will be 5 sections in this lab report. Initially, the introduction of the experiment is elaborated. Then, it comes the lab aim. Subsequently, the detailed procedure of this lab will be explained. Afterwards, the results and discussion will be shown. Last, the conclusion of this lab will be given.

2. Aim

1. Bipolar Junction Transistors
2. Bipolar Junction Transistor as a Switch
3. Transistor Amplifiers
4. Emitter Follower Amplifiers

3. Experiment procedure

- There are 4 sections in this lab, and we complete all the experiments by following the algebraic order of section numbers.
- Section 1
    a) In part 1.1, we fetched 2N3904 NPN Transistor, and placed the corresponding terminals correctly on NI ELVIS III. After that, we connected our circuit to the computer and start simulation with initial value setting of IV Analyzer.

    Notice that we did not derive the correct image until screwing down three terminals of BJT.

    b) In part 1.2, we build the circuit by linking BJT to a potentiometer and voltage source with variable power supply mode.

Table 1-2 Variable Power Supply settings

Power supply "+"	Static
Voltage (V_B)	2.38 V
Power supply "-"	Inactive

Then, we applied DMM and VPS 1-15V DC in Measurement Live. After that, each time, we rotated the potentiometer to make V_{CE} a fixed value, and we measured the current I_C by converting from voltage to current under that condition. For example, if we wanted to measure I_C at V_{CE}=6V, we needed to adjust the potentiometer to some degree when V_{CE}=6V, and then we changed the mode from voltage to current and got the current by using probes. Repeat these steps when V_{CE} and V_B changes.

✧ Section 2

a) In part 2.1, we redrew this circuit and applied Thevenin Equivalent Method, basic circuit analysis, and the knowledge we learnt in our lectures to solve all these parameters.

✧ Section 3

a) In part 3.1, we linked the anode of CH1 and CH2 to capacitor C1 and positive electrode of V_C. After that, we grounded the cathodes of CH1 and CH2, and finished the construction of the rest circuits. Before we started simulation, we checked whether our polarities of capacitors are correct which requires the longer pin input and the shorter one output. Next, we open DMM, FGen-Arb, Oscilloscope in Measurement Live, and initialize the values.

Subsequently, we utilize DMM and probes to measure I_B and I_E, then calculate β and V_{BE} based on the measured value. Finally, we compare those measured statistics with the given value, and gave some conclusions.

b) In part 3.2, we clicked stop button and opened Bode Analyzer to find the gain with initial values setting as below.

Table 3-3 Bode Analyzer Settings

Stimulus Channel	
Start Frequency	10 Hz
Stop Frequency	5 kHz
Cursors	On

✧ Section 4

a) In part 4.1, we clicked the linked and examined the emitter follower circuit. The two probes PR1 and PR2 which corresponded to input load and output load were given in the circuit, and we just need to run the simulation and calculate the current gain.

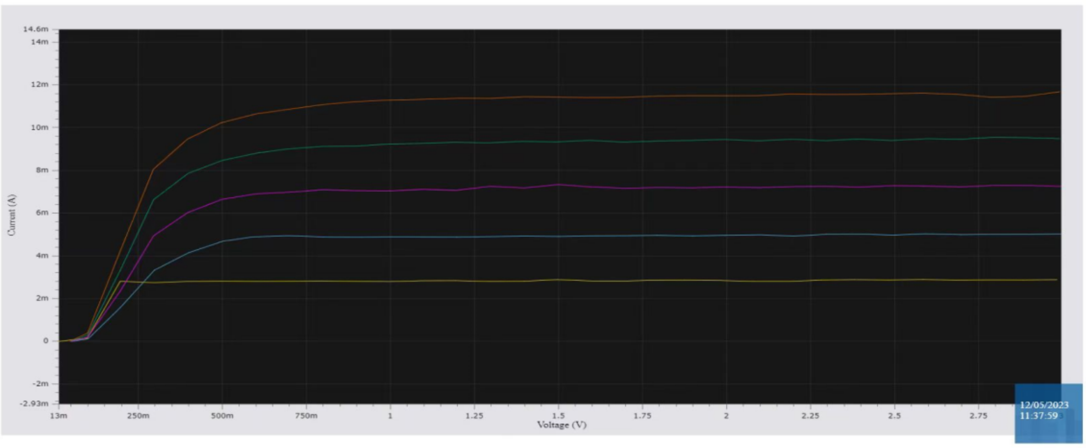
b) In part 4.2, we clicked the link and adjusted the value of resistor RE, and calculated the current gain by measured value.

4. Results and Discussion

- Section 1

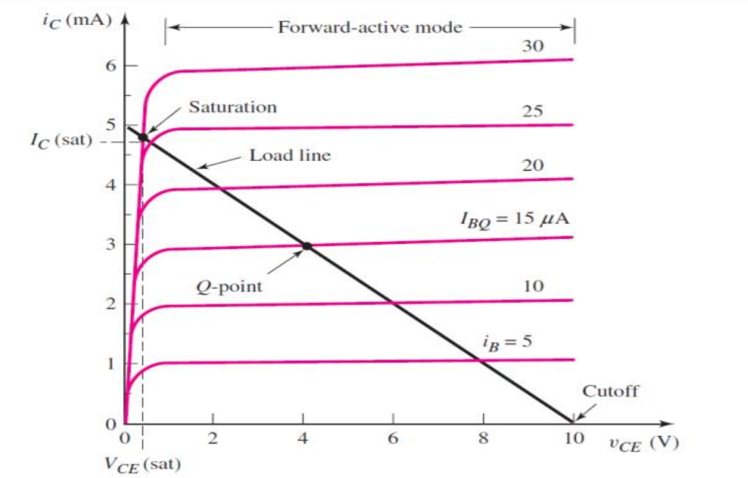
a) 1.1 BJT Behavior

We set the parameters as Table 1-1 shows, and obtained the graph as below.



Settings	
Mode	transistor
Transistor Type	NPN
Collector Resistance	100Ω
Vc Start	0 V
Vc Stop	3 V
Vc Step	100 mV
Ic Limit	30 mA
Ib Start	15 µA
Ib Step	11 µA
Curve Count	5

From the graph, it is clear that each curve has its saturation point, and when V_{CE} is larger than it, I_C remains constant.The graph here is similar to what we learnt in Chapter 4, but has slight difference. We would like to post the diagram in lecture to make a contrast.



In this plot, we can discover that all of the curves share a fixed line segment with a large tangent. However, the graph we measured manifests that the shared line segment has a low tangent and nearly horizontal.

We guess that the discrepancy may contribute to temperature If the temperature of BJT increases, the ratio of I_C and I_B changes, leading to the decrement of slope.

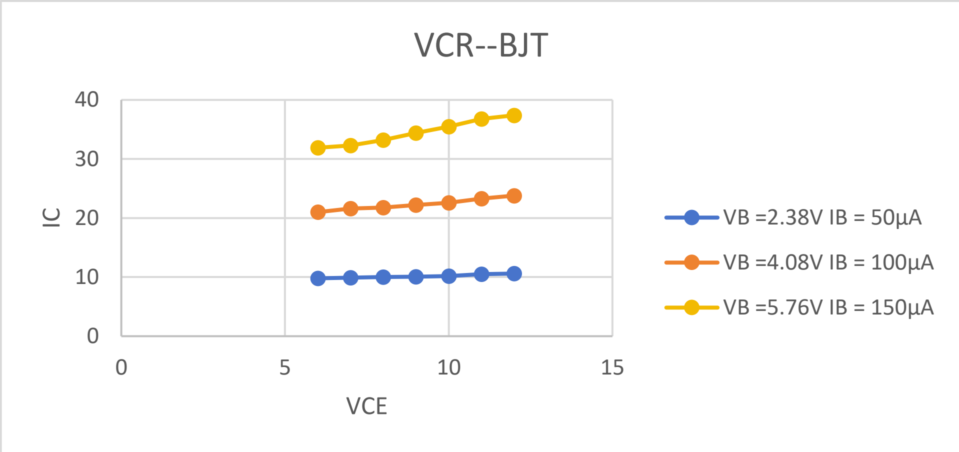
b) 1.2 BJT Measurements in the Active Region

The results we measured are shown as below.

V_B =2.38V I_B = $50\mu A$		V_B =4.08V I_B = $100\mu A$		V_B =5.76V I_B = $150\mu A$	
V_{CE} (V)	I_C (mA)	V_{CE} (V)	I_C (mA)	V_{CE} (V)	I_C (mA)
6	9.8	6	21.0	6	31.9
7	9.9	7	21.6	7	32.3
8	10.0	8	21.8	8	33.2
9	10.1	9	22.2	9	34.4
10	10.2	10	22.6	10	35.5
11	10.5	11	23.3	11	36.8
12	10.6	12	23.8	12	37.4

Based on the results, it is clear that when we increase V_{CE}, the growth rate of I_C is slowing down, which corresponds the curve we derived in part 1.1.

Moreover, this table reflects the CCCS-trait of BJT, we can find that I_C differs if I_B changes by observing vertically. Because β is positive, so I_C in direct proportion with I_B. Notice that the scatter diagram is shown as below according to our data.



- Section 2: Bipolar Junction Transistor as a Switch

a) BJT as a Switch

Analyzing this circuit by Thevenin Equivalent Method and basic knowledge, we calculated the value of parameters and presented it as below.

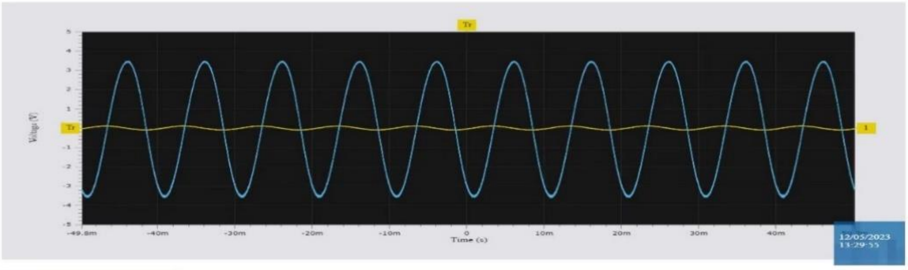
Data	Calculated Values
VCE (cut-off)	13.2 V
VCE (saturation)	0.1 V
VRC (saturation)	13.1 V
IC (saturation)	13.1 mA

The order of magnitudes of our results seems reliable. Also, we gain a deeper understanding of electronic circuit analysis.

- Section 3: Transistor Amplifiers

a) Transistor Amplifiers

We follow the steps and make a table based on measured and calculated statistics as below.



General Settings	
Trigger Type	Analog edge
Trigger Source	Channel 1
Trigger Slope	Rising
Trigger Level	0 V
Time Per Division	10 ms
Sampling Mode	Decimate
Repetitive Sampling Mode	Off

Advanced Trigger Settings	
Acquisition Delay	Disabled
Trigger Position	190.7 µs

Channels						
Name	State	Coupling	Probe Attenuation	Vertical Offset	Vertical Position	Volt Per Division
Channel 1	Enabled	DC	1x	0 V	0 V	1 V
Channel 2	Enabled	DC	1x	0 V	0 V	1 V
Channel 3	Disabled					
Channel 4	Disabled					

Reference Channels						
Name	State	Reference Mode	Source File Name	Source File Channel	Vertical Position	Volt Per Division
Reference 1	Disabled					
Reference 2	Disabled					
Reference 3	Disabled					
Reference 4	Disabled					

Reference Channels							
Name	State	Reference Mode	Source Circuit	Source Probe	Trigger Source Checked	Vertical Position	Volt Per Division

Additional Channels - FFT	
Name	FFT
State	Disabled

Additional Channels - Math	
Name	Math
State	Disabled

Channel Measurements Data				
Channel Name	VPP	RMS	Frequency	Period
Ch 1	261 mV	71.53 mV	99.07 Hz	10.09 ms
Ch 2	7.132 V	2.494 V	99.99 Hz	10 ms

Taking the ratio of VPP (CH2) and VPP (CH1), we calculated Oscilloscope Gain (dB) = 27.326

Data	Calculated value	Measured value
IB	65 μA	0.1 mA
IE	65 mA	6.7 mA

Data	Given value	Calculated value
β	100	67
VBE	0.7	0.63

It is clear that our calculation of β has a low coincidence with the given value. We guess that it may be due to temperature, and our low measured value of β means low temperature which can be explained by winter season.

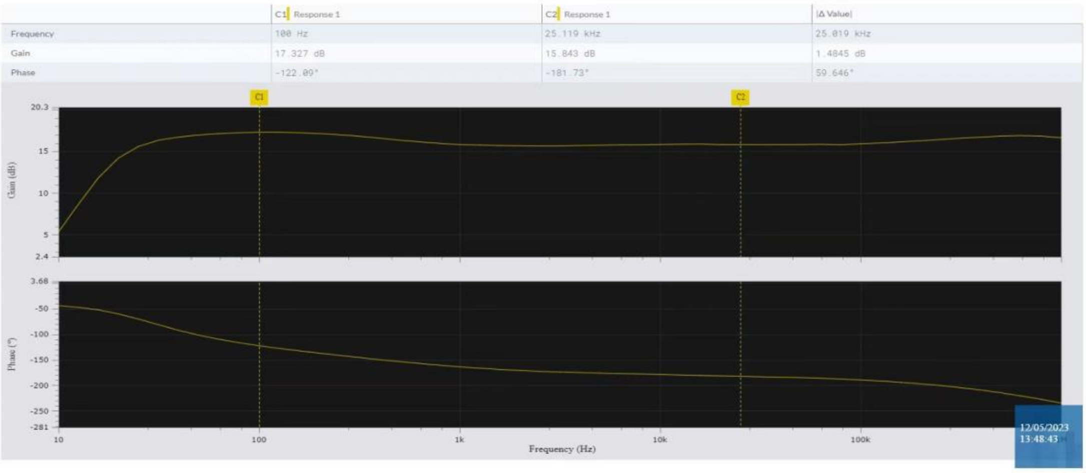
$$\frac{i_C}{i_B} = \beta$$

- Some factors may affect this ratio, such as the temperature.

To solve that problem, we may introduce temperature-related feedback signals and thermistors to correct the low temperature effect of the transistor which is also known as temperature compensation technology.

b) Frequency Response of the Amplifier

The bode diagram we obtained is shown as below.



Stimulus Channel	
Start Frequency	10 Hz
Stop Frequency	1 MHz
Steps Per Decade	10
Peak Amplitude	1 V

Response Channels		
Response Name	State	Channel Label
Response 1	Enabled	Oscilloscope CH2
Response 2	Disabled	
Response 3	Disabled	

Reference Channels				
Reference Name	State	Mode	Source File Name	Channel
Reference 1	Disabled			
Reference 2	Disabled			

The Bode Gain (dB) we derived is 17.327, which is lower than Oscilloscope Gain. The reason behind it may be testing errors, it is possible that we do not guarantee the precise connect of elements to board. Also, probably we changed the frequency unconsciously which made two measurements in different frequency ranges.

- Section 4

a) Simulate: Emitter Follower Amplifiers - Voltage Response

We opened the link and measured the parameters and recorded as below.

Probe	Peak-to-Peak Current (μA)
Probe 1 – Input Current	39
Probe 2 – Output Current	1000

The current gain here is 28.86.

b) Simulate: Identify the Relationship between Resistors and Current Gain

We modified the value of RE and finished the table as below.

Resistance of RE	Probe 1 – Input Current	Probe 2 – Output Current	Gain
1K	58 μA	1000 μA	17.24
2K	39 μA	1000 μA	28.86
3K	27 μA	1000 μA	37.04
5K	20 μA	1000 μA	50.00

If we try to draw a scatter plot of RE and Gain, we can find that their relation is non-linear. The combination of resistors in a transistor amplifier is often tailored for a specific application for the load varies depending on the application.

5. Conclusion

In summary, this lab covers 4 sections. First, we try to analyze BJT by plotting its output characteristic curve with scatter points measured by ourselves, and we conclude that BJT has 3 biased regions which are cut-off, saturation, and forward-active in section1. Secondly, we serve BJT as a switch between cut-off and saturation and dig into such switch circuit in section 2. Thirdly, we consider BJT working as an amplifier, and analyze gain and factors which can influence gain in section 3 and section 4.

In our experiment, the calculated value of β shows great errors, and we contribute it to low temperature and give adding temperature feedback as a solution to attenuate BJT from surrounding temperature.

Although we have a good command of BJT, there are many future developments we can expect. On the one hand, we can research into the impact of different materials on BJT. On the other hand, we can also apply BJT to other fields, such as optoelectronics, sensors, biomedicine.