



LEVEL 4 ASSESSMENT SPECIFICATION

Student name:	Harry Owen	Student ID number:	
Programme:	HNC Electrical/Electronic Engineering		
Module:	Electronics 1		
Module code:	PSDE4004	Contribution to Overall Module Assessment (%):	25%
Lecturer:	Jason Pointer	Internal Verifier:	Steve Roberts
Assignment Title:	Diodes and Transistors	Word count (or equivalent):	1500
Submission deadline:	13/12/18	Return date of provisional marks & written feedback:	
Submission method:	All written assessments, where practical and possible, must be submitted via Turnitin unless otherwise instructed by the Lecturer. (Please DO NOT put this assessment specification into Turnitin or it will match many similarities with other students' submissions.) Alternative submission method (if applicable): Late submission of the assessment will result in a late penalty mark. Penalties for late submission: Up to one week late, maximum mark of 40%. Over one week late, 0%. Only the Extenuating Circumstances Panel may approve a change to submission dates.		
Academic honesty / referencing:	Academic honesty is required. In the main body of your submission you must give credit to authors on whose research and ideas your work is based. Append to your submission a reference list that indicates the books, articles, etc. that you have used, cited or quoted in order to complete this assessment.		

Module Learning Outcomes (from module syllabus)

1. Demonstrate an understanding of semi-conductor components and characteristics and their application in **analogue** and digital electronic circuits.
2. To design, simulate, build, test and evaluate **analogue** and digital electronic circuits using information gained from datasheets.

STUDENT FEEDBACK FORM

This section details the *extent* to which the assessment criteria are demonstrated by you, which in turn determines your mark. The marks available for each category of skill are shown. Lecturers will use the space provided to comment on the achievement of the task(s), including those areas in which you have performed well and areas that would benefit from development/improvement.

Generic Assessment Criteria	Marks available	Marks awarded
1. Engagement with Literature Skills	10	5
Engagement with a limited range of mostly relevant and credible sources but with some reliance on information gained through class contact. Have made no direct reference except for the datasheet. This is something to work on in your next assignment.		
2. Knowledge and Understanding Skills	20	12
Achieved for 55% for Part A. Achieved for 65% for Part B. Competent knowledge of the basic underlying concepts and principles. Exhibits very good understanding but have made some errors in some of the calculation work.		
3. Cognitive and Intellectual Skills	20	9.5
Achieved for 50% for Part A. Achieved for 45% for Part B. Limited attempt at evaluation of the underlying concepts and principles, tending towards description. Need to make more links to relative ideas and concepts.		
4. Practical Application Skills	40	29
Achieved for 70% for Part A. Achieved for 75% for Part B. An excellent application of practical work, very good use of the test equipment to obtain all of the required results.		
5. Transferable Skills for Life and Professional Practice	10	5.5
Mostly coherent, organised and accurate work, in a suitable structure and is for the most part clearly expressed.		

Assessment Mark (Assessment marks are subject to ratification at the Exam Board. These comments and marks are to give feedback on module work and are for guidance only until they are confirmed.)

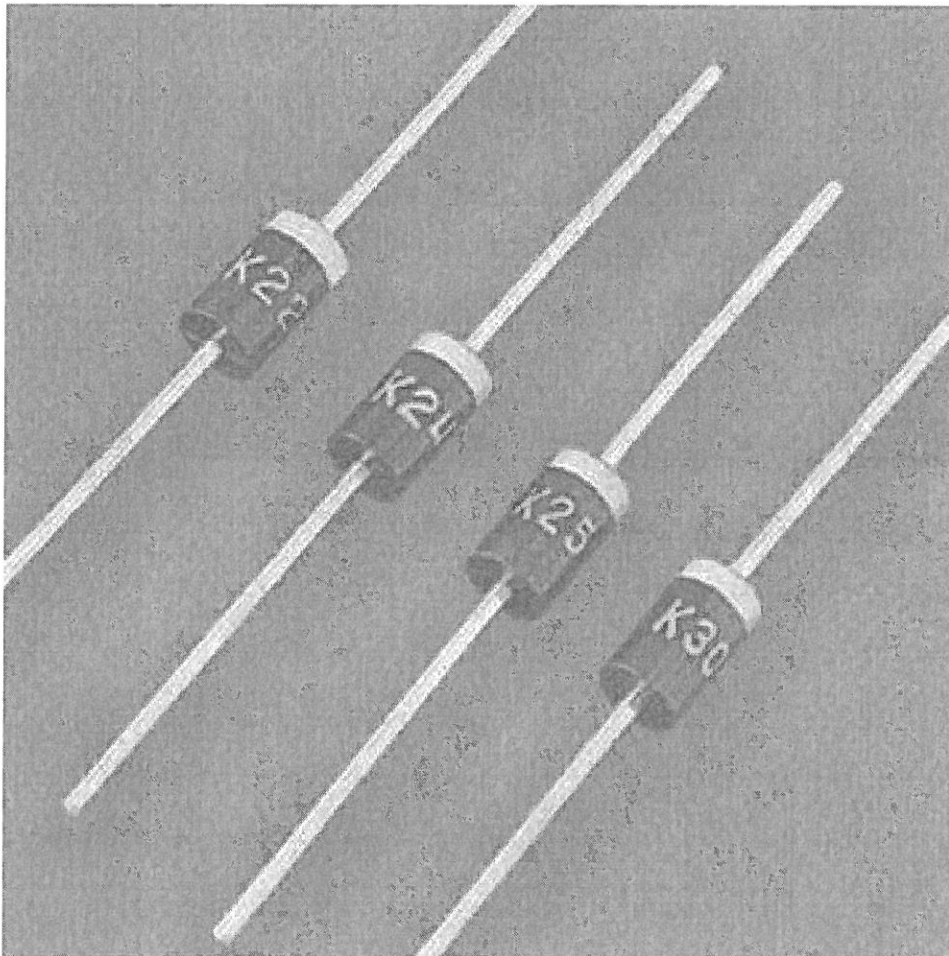
Late Submission Penalties (tick if appropriate)

Up to 1 week late (40% Max)

Over 1 week late (0%)

61%

Diodes and Transistors



By Harry Owen

REFERENCES

<http://alexeys4847-2012.blogspot.com/2012/03/diodes-and-transistors.html> this website was used to gather the picture used in the assignment title sheet.

<https://learn.sparkfun.com/tutorials/diodes/all> - Used to show the picture of a normal diode graph in forward and reverse conditions.

<https://www.robomart.com/bc-557> - used for the picture of a transistor.

PDF of the transistor used in the practical BC550 -

<https://www.mouser.com/ds/2/149/BC550-888526.pdf>

Should be attached at the end.

*Should have used known sources
for references.*

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Introduction

In this assignment I will be looking at what the characteristics of diodes are with specific investigation into silicon and germanium diodes. This will be performed through practical's and research theorem. Using this knowledge, a transmitter amplifier circuit will then be constructed through a range of components including diodes and resistors. This assignment will then be finished with a summary of the practical experiments and the results I achieved from them.

Task 1 - Characteristics of Diodes

In this task I will be looking to look at the characteristics of silicon and germanium. I will then plot the forward and reverse characteristics for the diodes, determine the static and dynamic resistance (in the forward bias mode) for each diode at about $V_D = 0.7$ volts and determine the static and dynamic resistance (in the reverse bias mode) at about -9 volts. I will then comment on your results discussing the characteristics of each diode and how they compare.

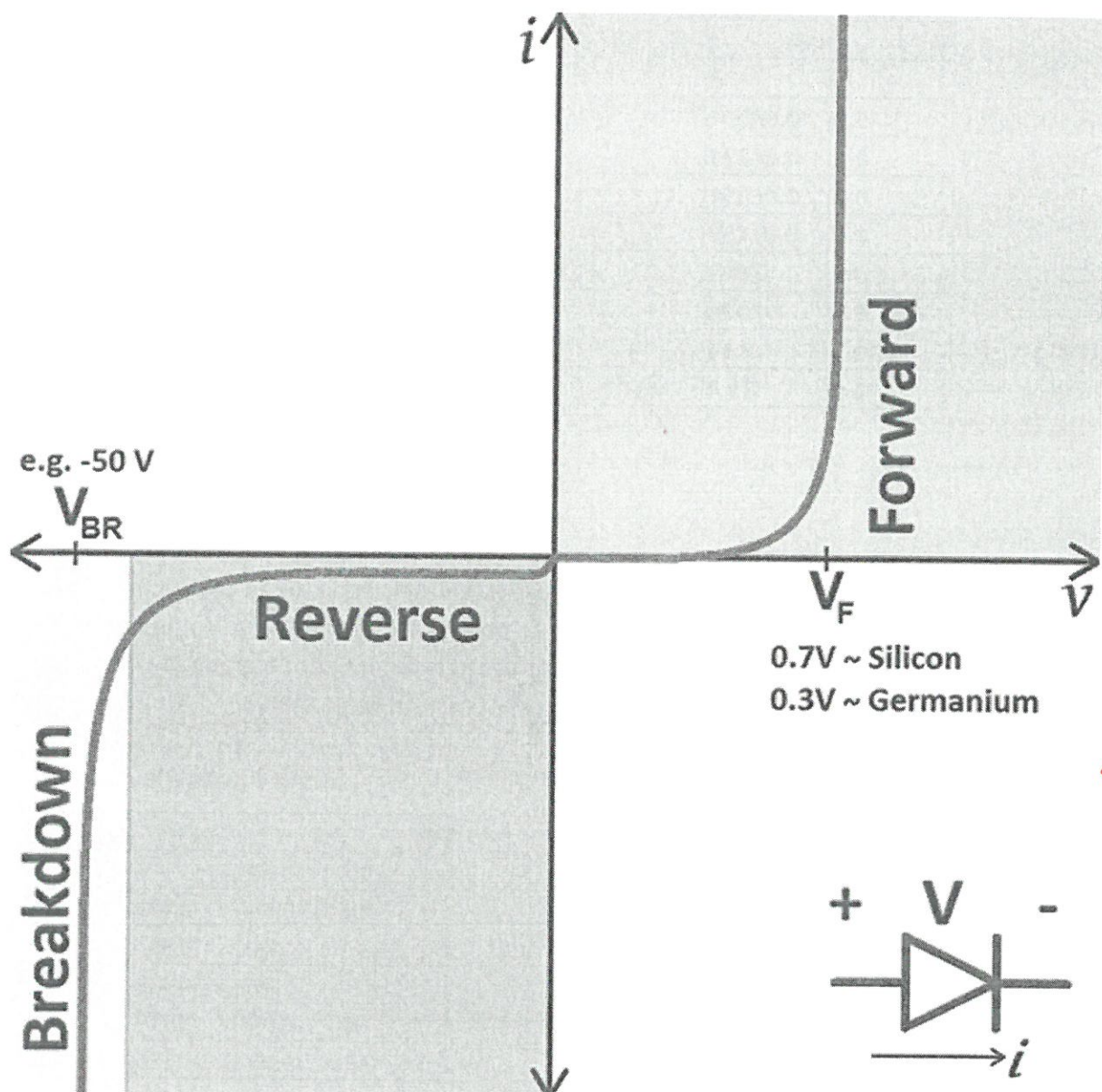
Firstly it would be best to first describe what diodes are and what some of the key terms associated with diodes are. A diode is a semiconductor device that basically works as a one-way switch for current. It allows current to flow easily in one direction, but its internal resistance is very high in the other direction restricting the current coming through.

Diodes have polarity, determined by an anode and cathode. This is mostly determined by the solid black band positioned on a diode, that band signifies the cathode or negative side of the diode.

The relationship between voltage and current is not a linear relationship like you would find in a resistor, the voltage and current relationship in a diode is non-linear as it only starts to allow current to flow once it has reached its designed minimum amount of starting voltage. This voltage is different in each diode depending on what material they are made from. With our diodes silicon starts to carry current at $0.7V$ and germanium starts to conduct current at $0.3V$.

Do not refer to yourself within a report.

A diode can be in three states, Forward, Reverse or in breakdown. Forward is where the positive voltage is applied to the diode and when the diode has met its minimum conducting voltage will start passing the current in a very steep curve when plotted on a graph. Reverse state is when negative voltage is applied to the diode. When this happens current is mostly blocked from passing through the diode until it reaches its breakdown state. This is where the negative voltage applied to the diode is so great that it 'breakdown' and allows the current to flow backwards through the diode.



Practical

When starting this practical I firstly carried out a quick resistance test to see if the diodes are working correctly. As we already know diodes are designed to block current in the reverse direction so there internal resistance should be higher in the reverse direction (cathode-anode). This test had shown the diodes to be working probably with the 1N4148 silicon diode reading 0.627Ω so I assembled the circuit and carried out the practical experiment.

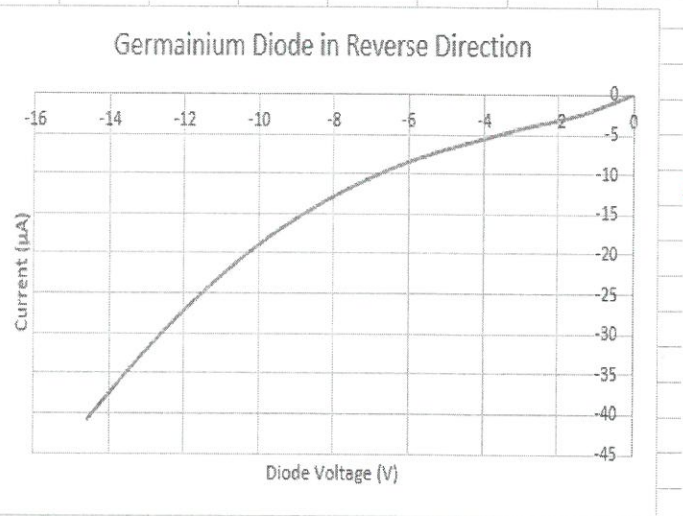
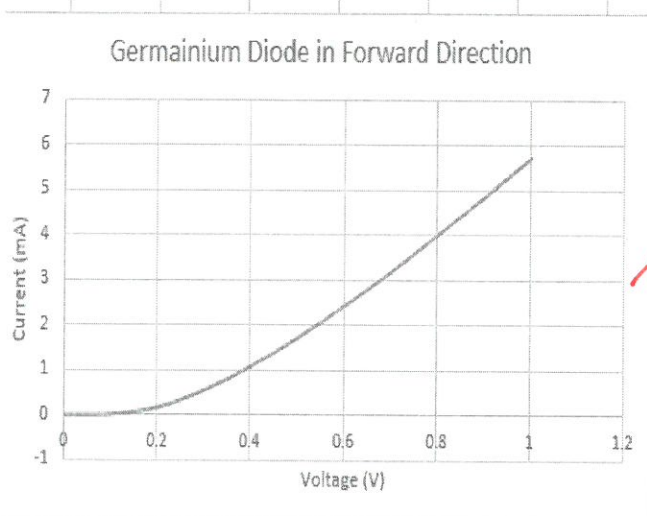
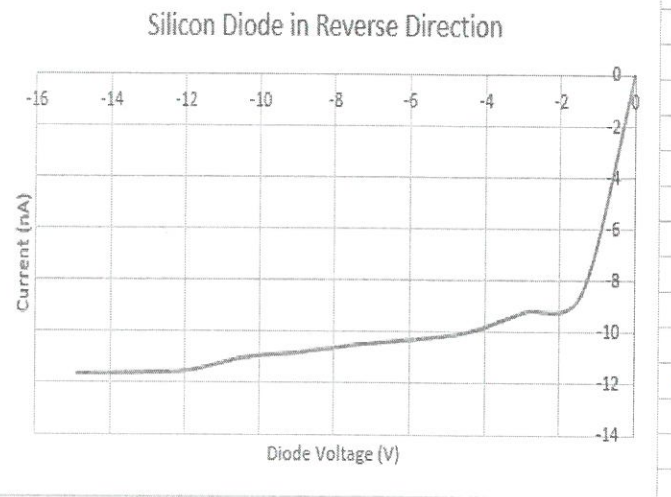
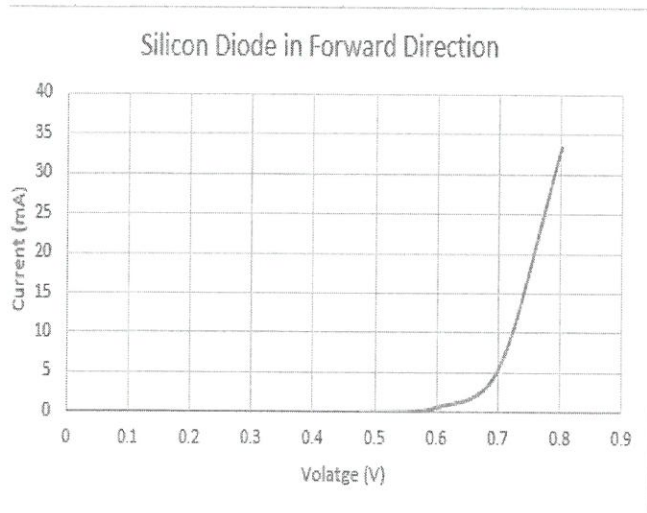
My results come out as followed -

Silicon Forward		Germanium Forward	
V	mA	V	mA
0	0	0	0
0.1	0.00004	0.1	0.015
0.2	0.00024	0.2	0.16
0.3	0.00154	0.3	0.537
0.4	0.01158	0.4	1.072
0.5	0.092	0.5	1.709
0.6	0.724	0.6	2.42
0.7	5.56	0.7	3.18
0.8	33.4	0.8	4.01
		0.9	4.85
		1	5.73

It can be seen that in the forward direction as suspected the silicon diode conducts current at around 0.7V mark while germanium allows it to pass at around the 0.3/4V mark. While the silicon diode allowed quick passing of current the germanium diode gradually increased the current with increase in voltage.

Silicon Reverse				Germanium Reverse			
V1	mV2	Diode V	nA	V1	V2	Diode V	μ A
0	0	0	0	0	0	0	0
-1.5	-85	-1.415	-8.5	-1.5	-0.027	-1.473	-2.7
-3	-92	-2.908	-9.2	-3	-0.043	-2.957	-4.3
-4.5	-99.8	-4.4002	-9.98	-4.5	-0.062	-4.438	-6.2
-6	-103	-5.897	-10.3	-6	-0.084	-5.916	-8.4
-7.5	-105	-7.395	-10.5	-7.5	-0.114	-7.386	-11.4
-9	-108	-8.892	-10.8	-9	-0.152	-8.848	-15.2
-10.5	-110	-10.39	-11	-10.5	-0.2	-10.3	-20
-12	-115	-11.885	-11.5	-12	-0.259	-11.741	-25.9
-13.5	-116	-13.384	-11.6	-13.5	-0.328	-13.172	-32.8
-15	-116.4	-14.8836	-11.64	-15	-0.407	-14.593	-40.7

It can be seen in the reverse direction that the silicon diode is better at blocking the negative current. Both have not yet broken down but the germanium diode allows more current to pass than the silicon diode in the same circumstances. These plotted graphs give a good visual representation of how the diodes performed in a forward and reverse state.



It is easier to see from these graphs that the germanium diode not only has a gentle curve when in the forward direction but also tries in the reverse direction where at -4V the curve starts to slowly drop. In the silicon diode even though the steep fall at the start of the reverse graph may look like the diode has failed, it is only allowing -12nA to pass at -15V where the germanium diode allows -40μA to pass at -15V.

We can also compare the two diodes from their static and dynamic resistance value. A static resistance is the resistance of the p-n junction of the diode in a direct current circuit. In the forward direction this is known as static forward resistance and is abbreviated to R_f . This is calculated by dividing the voltage over current at a certain point in the graph. The point that is chosen for both diodes is 0.7V forward, for the silicon diode it was

$V/I = \text{Static forward resistance}$

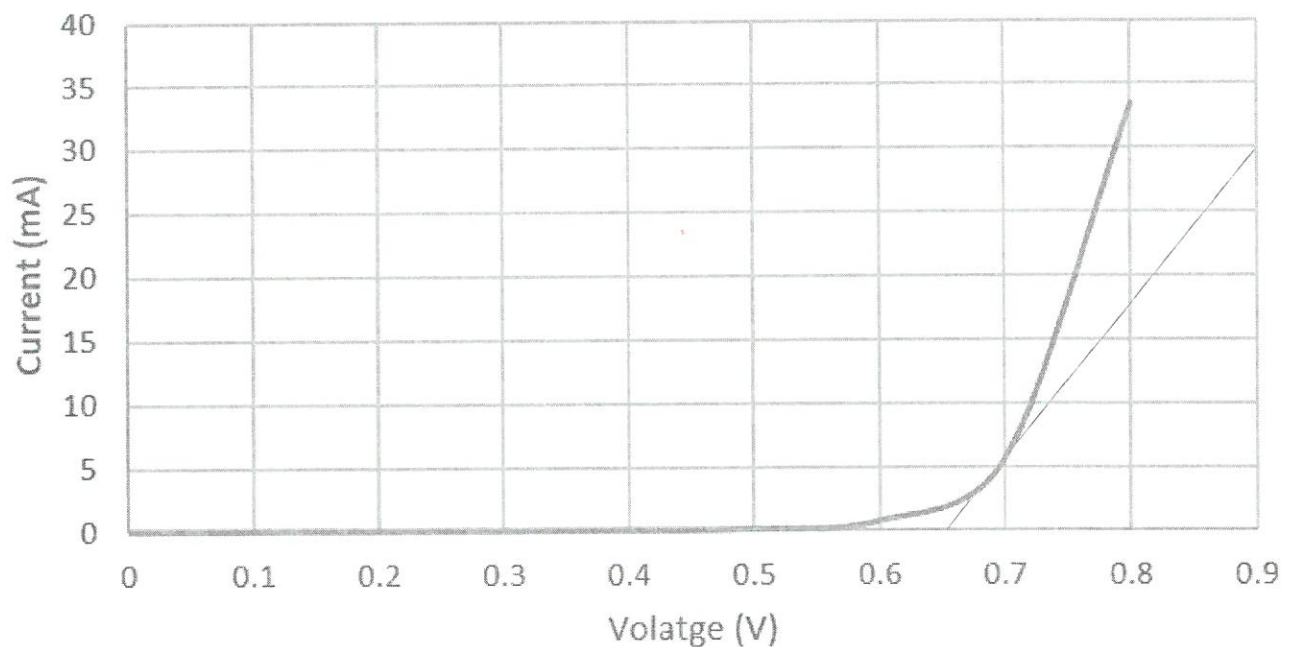
$$0.7 / 5.56 \times 10^{-3} = 125.89\Omega$$

And for the germanium diode it was the same point –

$$0.7 / 3.18 \times 10^{-3} = 220.12\Omega$$

To work out the dynamic resistance it is easier to show it on the graphs. For this, a tangent line is placed on the forward graphs for each diode at the 0.7V mark and extended out to the graph border. I then calculate the Difference in voltage / Difference in current and that will produce my dynamic resistance in the forward direction.

Silicon Diode in Forward Direction

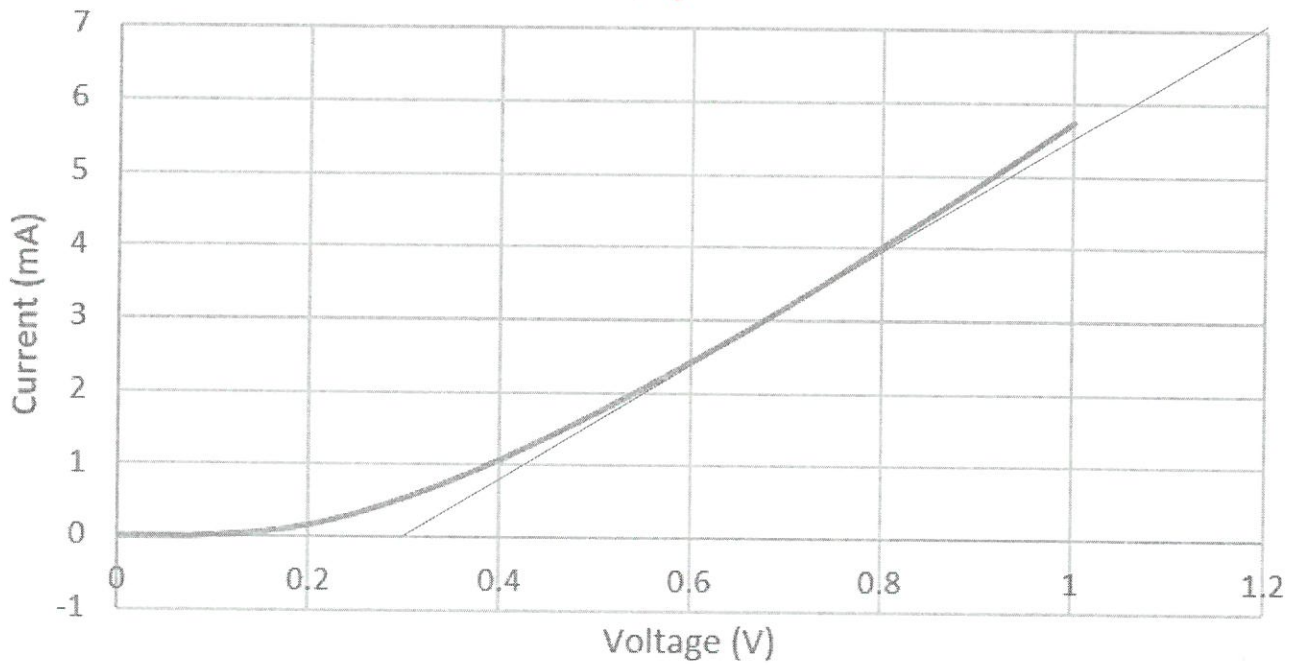


Dynamic forward resistance = Change in Voltage / Change in Current

$$0.9V - 0.65V = 0.25V / 0.0030 - 0 = 0.0030A = 83.3\Omega$$

Germanium forward dynamic resistance –

Germanium Diode in Forward Direction



Dynamic Germanium resistance = Change in voltage / Change in current

$$1.2\text{V} - 0.3\text{V} = 0.9\text{V} / 7 - 0\text{mA} = 7\text{mA} = 128.57\Omega$$

For the reverse resistance it will be the same equation just in the negative values and at -9V.

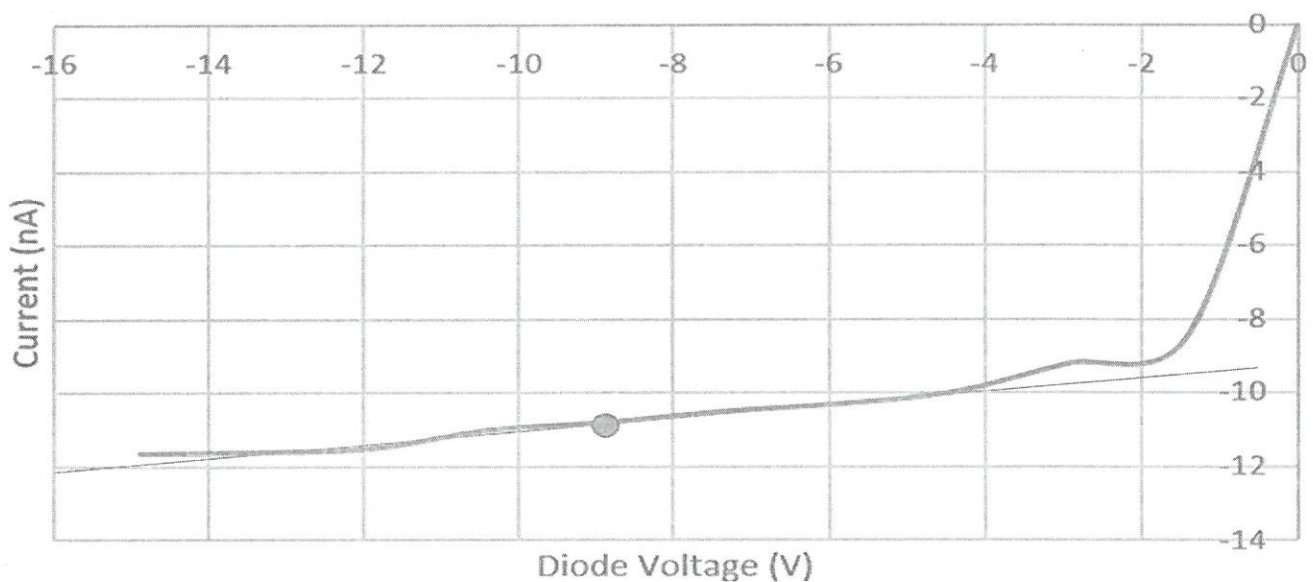
Reverse static resistance –

$$\text{Silicon} = -9 / -10.8 \times 10^{-9} = 833333333.3\Omega \text{ or } 8.3\text{nA}$$

$$\text{Germanium} = -9 / -15.2 \times 10^{-6} = 592105.26\Omega$$

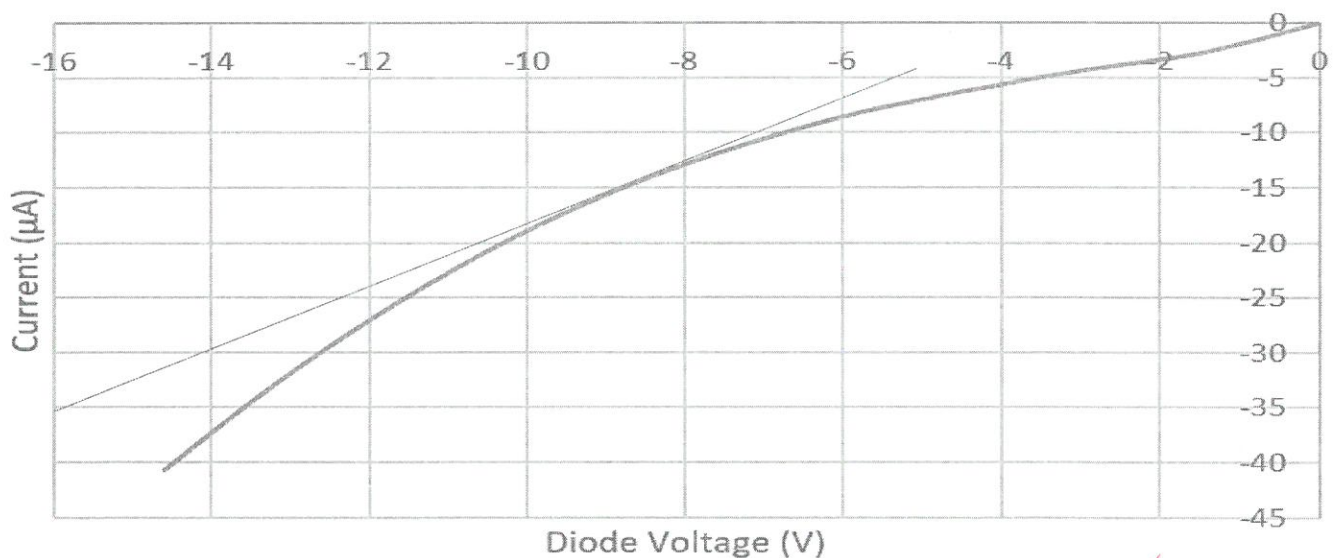
Reverse Dynamic resistance –

Silicon Diode in Reverse Direction



$$\text{Silicon Reverse dynamic resistance} = -16 - 0 = -16\text{V} / -11.5 - -9.5 = -2\text{nA} = 80000000\Omega$$

Germanium Diode in Reverse Direction



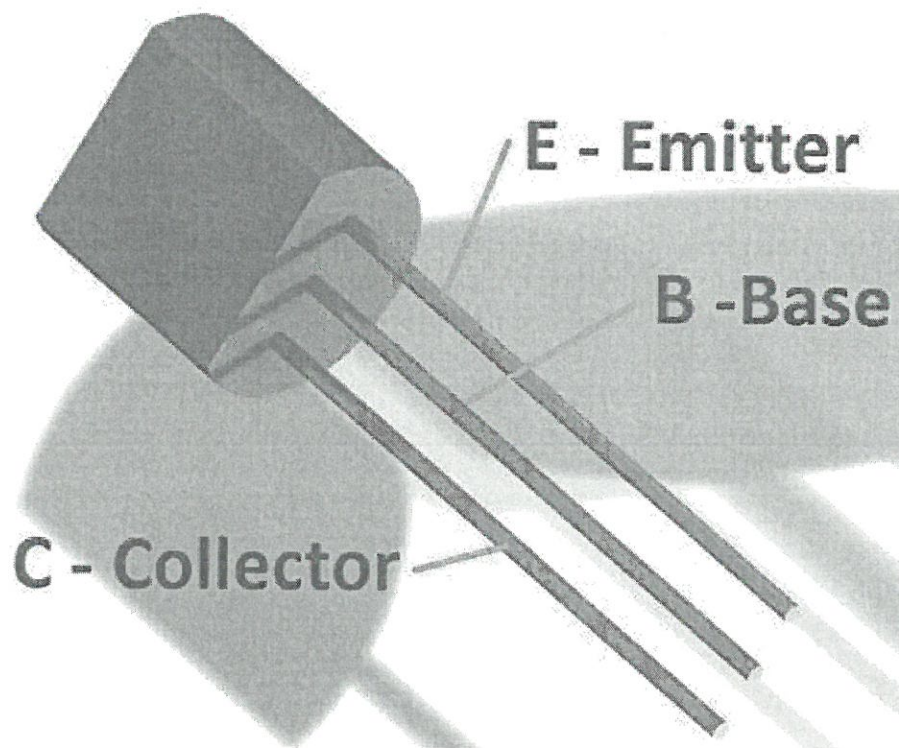
$$\text{Germanium Reverse dynamic resistance} = -16 - 5 = -11\text{V} / -35 - -0 = -35\mu\text{A} = 457142.85\Omega$$

From these resistances we can see that reverse direction silicon is better at blocking the current from coming through. Even though the graph makes it to look like it has failed at the start, it is only allowing -11nA in at -15V , compared to the germanium diode in reverse the silicon one proves better. In the forward state the germanium diode allows current to flow at an earlier voltage mark than the silicon diode does but gradually allows more to flow through with the increase in voltage while the silicon diode doesn't pick up until around the 0.7V mark which then spikes and allows a lot of current to flow through. If comparing the diodes at 0.8V in forward state, the silicon diode allows 35mA while the germanium diodes only allows 4mA .

TASK 2

Designing a common emitter amplifier –

For this task, one of the main components used in the circuit is a transistor. A transistor is basically an electronic component that can either work as a switch or an amplifier. As a switch, a transistor can allow big currents to pass by using a smaller current as the switching signal, these are found in computer chips and in small lighting circuits. When it works as an amplifier it converts a small current into a big current for different applications. This process is mostly used in items such as a hearing aids and mobile phones.



- A) Design a common emitter amplifier using a suitable transistor that has a h_{fe} value between 100 to 500 (value to be checked using datasheets and multimeter). The circuit will have a 10V supply, the decoupling capacitor will be 100 μ F and coupling capacitors will be 10 μ F.

The transistor type I have chosen is a BC550 transistor. The datasheet I used to make sure the calculations were correct and for help in the design of the circuit can be found as an attachment at the end of this assignment. Its measured Hfe is -

Measured Hfe = 482

When creating the circuit I used these steps -

- 1) Select supply voltage $V_{cc} = 10V$
- 2) Select a suitable NPN transistor, Make sure it has the correct HFE – BC 550 , Hfe 482
- 3) Find the quiescent current (Supply current), from the Data sheet this is seen to be $I_{Cmax} = 100mA$. For practical requirements, let $I_c = 1mA$
- 4) Determine $R_c = V_{cc}/2 \times I_c = 10 / 2 \times 1 \times 10^{-3} = 5k\Omega$ - Nearest value is 4.7K
- 5) Determine R_e , assume $I_e = I_c$ and V_e is 10%-15% of V_{cc} . Let $V_e = 0.1 \times 10 = 1V$
Then $R_e = V_e/I_e = 1 / 1 \times 10^{-3} = 1k\Omega$
- 6) Find I_b , $I_b = I_c/h_{fe} = 1 \times 10^{-3} / 482 = 2.07\mu A$
- 7) Find the base voltage V_b . $V_b = V_e + V_{be}$ (V_{be} obtained from datasheet = 0.66V)
 $V_b = 1 + 0.66 = 1.66V$
- 8) Determine R_2 , Assume I_2 is 10x greater than I_b .
 $R_2 = V_b / 10 \times I_b$ $R_2 = 1.66 / 10 \times 2.07 \times 10^{-6} = 80.19k\Omega$ - Nearest resistor value is 82k Ω
- 9) Determine R_1 , $V_1 = V_{cc} - V_b = 10V - 1.66 = 8.44V$
- 10) $I_1 = I_2 + I_b = 10 \times I_b + I_b = 11 \times I_b = 11 \times 2.07 = 22.77\mu A$
- 11) $R_1 = V_1/I_1 = 8.44/22.77 = 370.66k\Omega$ nearest value is 390k Ω

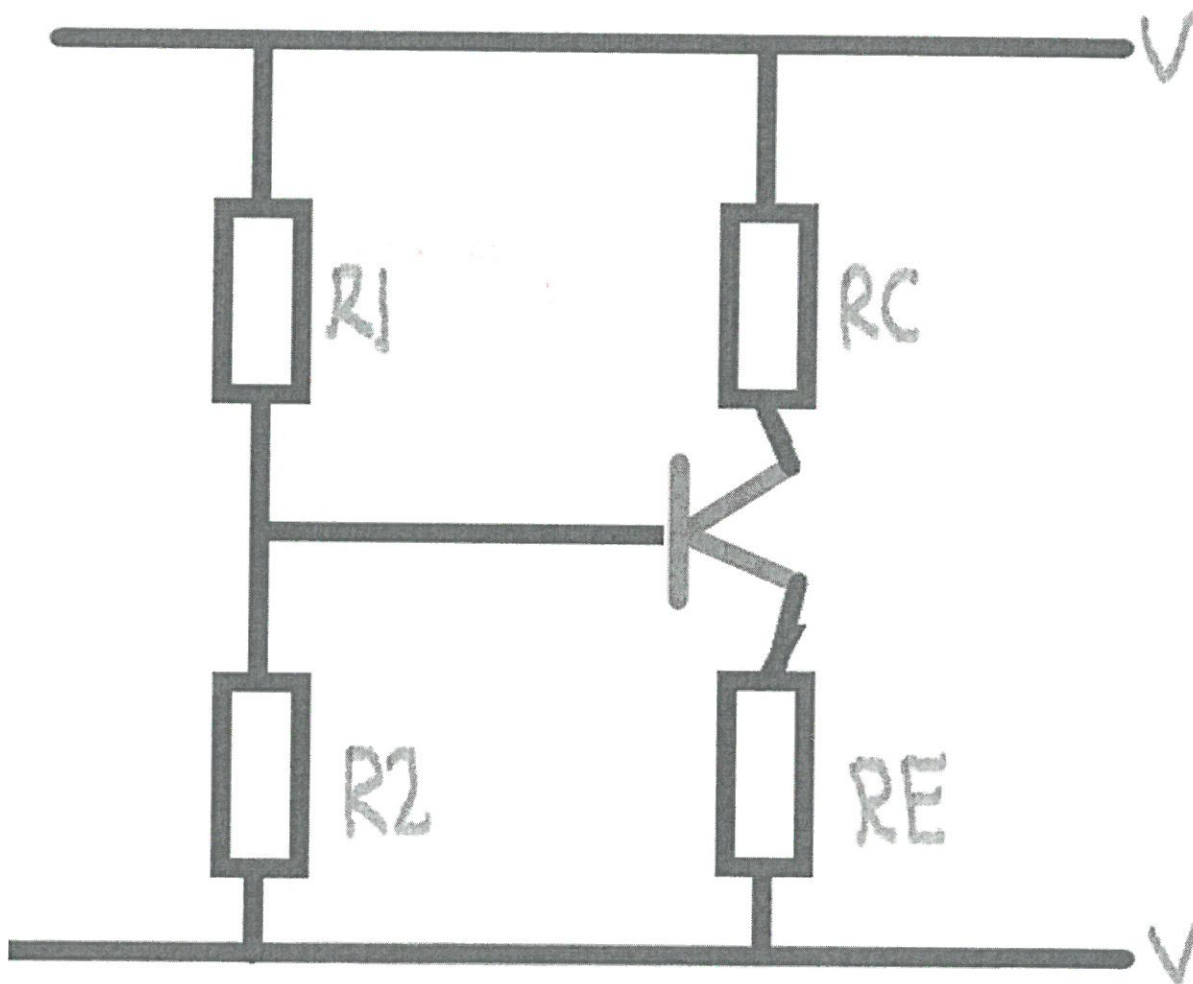
b)

Practical test

DC conditions –

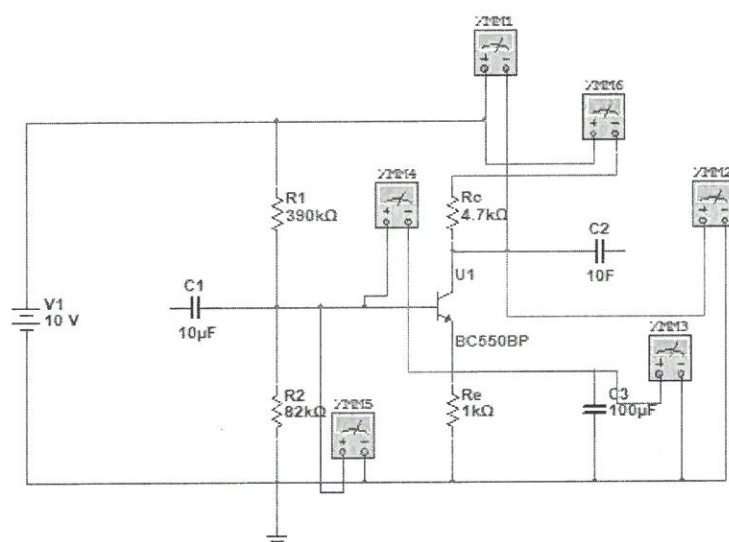
 $V_C - 5.35V$ $V_E - .98V$ $V_{RC} - 4.62V$ $V_{BE} - .6V$ $V_B - 1.58V$ $I_C - 1mA$

AC conditions -

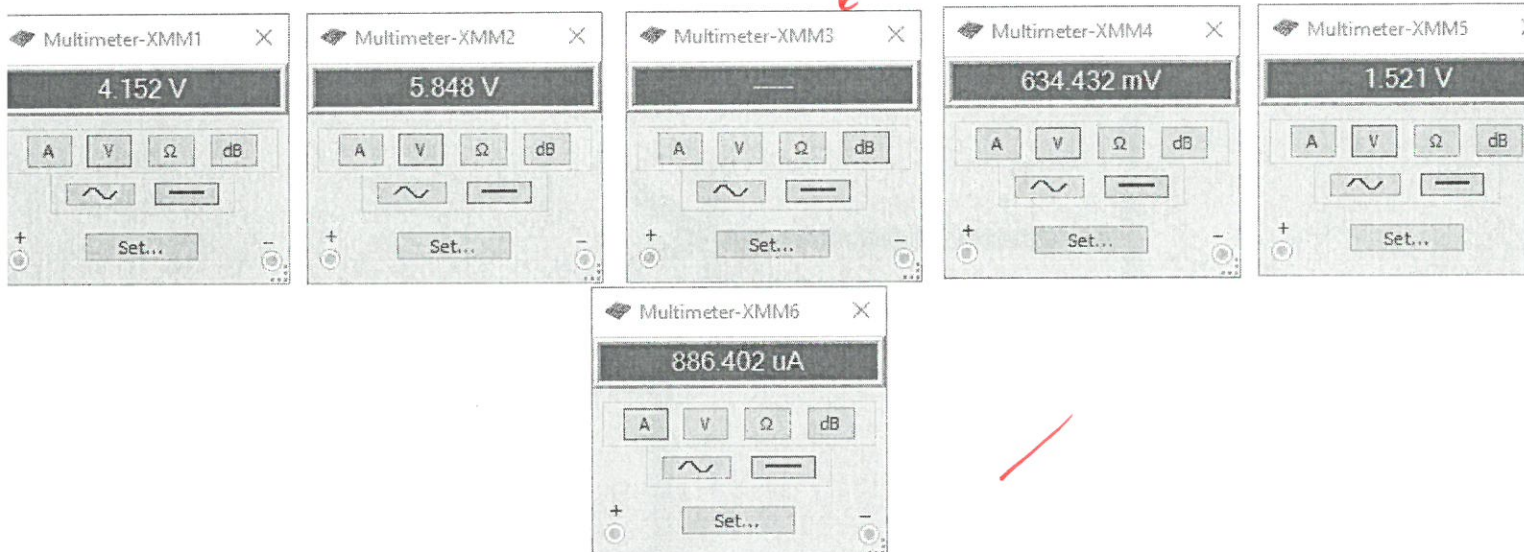
 $V_{in} - 40mV$ P-P $V_{out} - 5.7V$ $V_{gain} - V_{out}/V_{in} = 5.7/(40 \times 10^{-3}) = 142.5$ 

This is how a constructed my circuit, Four resistors and one transistor.

C)



No value

**DC stimulation results**

VRC = 4.152V

VC = 5.848V

VE = 886.533mV

VBE = 634.432mV

VB = 1.521V

IC = 886.402μA

AC stimulation results(Screenshot provided below)

Vin = 40mV

Vout = 8.5V

Gain = Out/in = 8.5/40 = 213.5

FI = 50Hz

Fh= 17MHz

From these results we can compare from my practical DC circuit results.

DC stimulation results

$$V_{RC} = 4.152V$$

$$V_C = 5.848V$$

$$V_E = 886.533mV$$

$$V_{BE} = 634.432mV$$

$$V_B = 1.521V$$

$$I_C = 886.402\mu A$$

Practical test

DC conditions –

$$V_C = 5.35V$$

$$V_E = .98V$$

$$V_{RC} = 4.62V$$

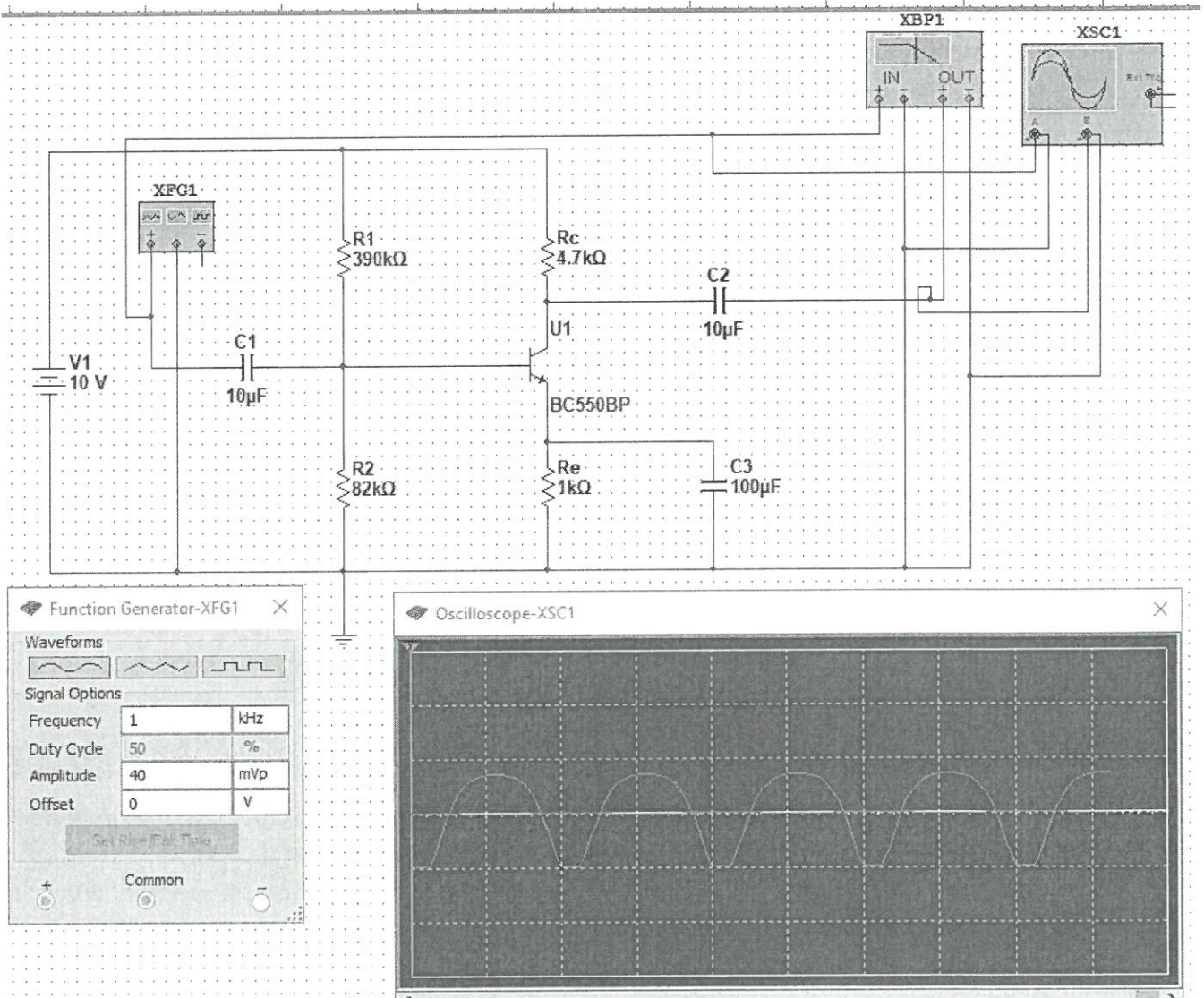
$$V_{BE} = .6V$$

$$V_B = 1.58V$$

$$I_C = 1mA$$

As you can see from these results there are discrepancies but where there are they could be mistakes made through myself rounding up and rounding down units, as well as uncalibrated equipment or used components that could be not to the best accuracy they could be. I am happy that these results are similar enough to understand that the circuit is working under DC conditions.

Very similar comments.



For the AC conditions we firstly added an function generator to produce a signal and used the oscilloscope to show the waveform visually. The results come out as followed –

Practical results

AC conditions -

$V_{in} = 40\text{mV P-P}$

$V_{out} = 5.7\text{V}$

$V_{gain} = V_{out}/V_{in} = 5.7/(40 \times 10^{-3}) = 142.5$

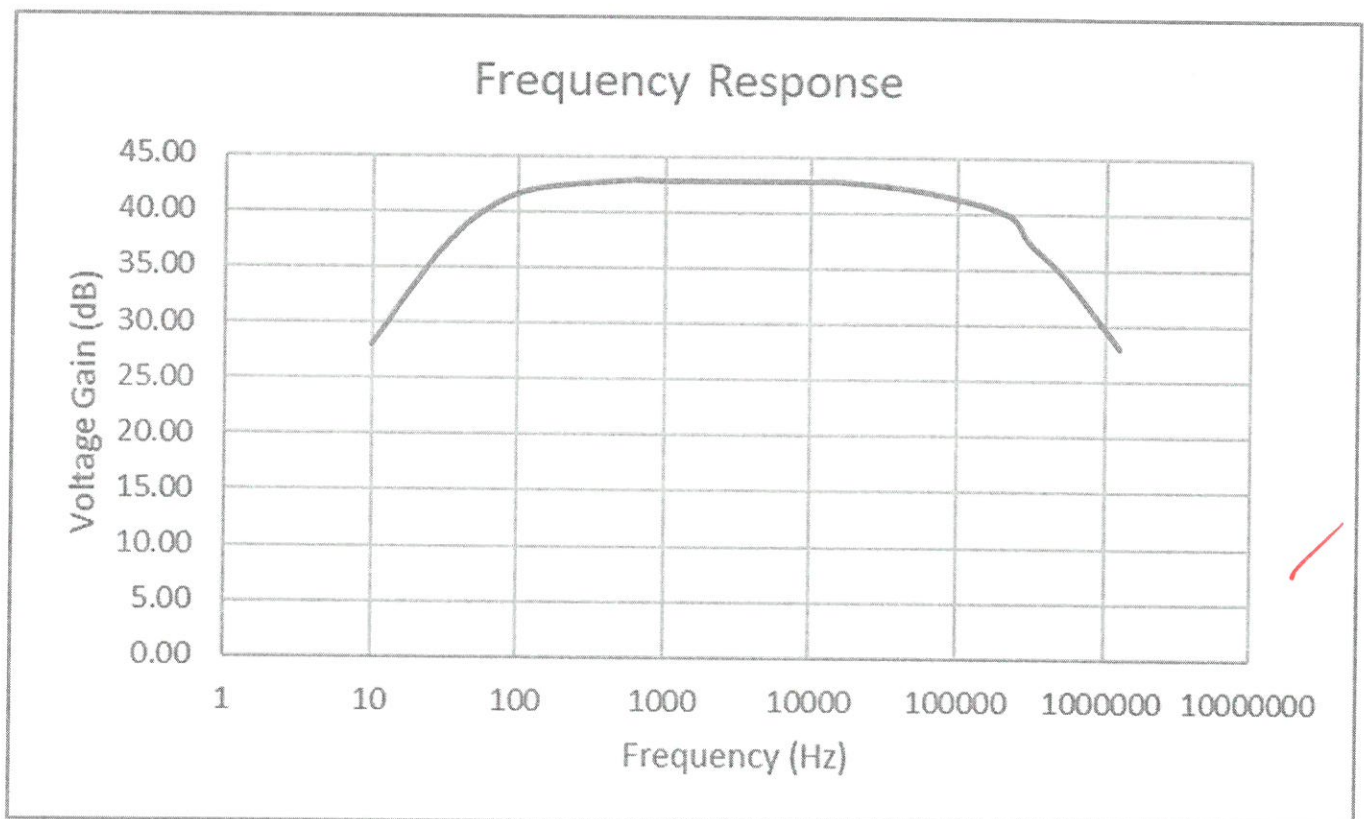
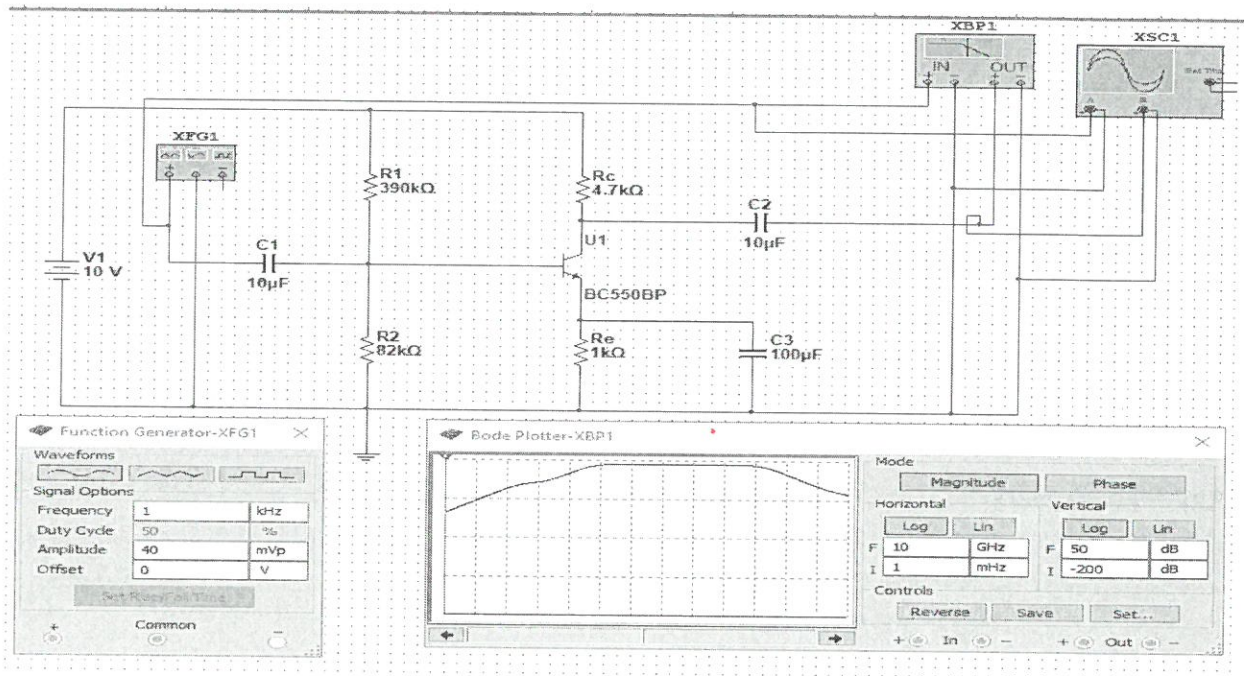
Stimulation results

$V_{in} = 40\text{mV}$

$V_{out} = 8.5\text{V}$

$\text{Gain} = \text{Out/in} = 8.5/40 = 213.5$

We can now compare the AC results and find that there are some differences. I believe this to be from an error in the power supply in the practical as they are used frequently and not 100% accurate all the time. The last test to prove is the bandwidth frequency for the circuit, I created this on the stimulation by using a bode plotter.



The results come out as followed –

Stimulation results

FI = 50Hz

Fh = 17MHz

Practical Results

FI = 58Hz

Fh = 209000Hz

d)

These results are similar enough to say the circuit is working the way it was planned, these discrepancies again could be down to the equipment used or human error when rounding the numbers up or down.

On the whole I am happy that the circuit works the way it was designed. It amplifies a signal in DC and AC conditions and is not far off the stimulated circuit I produced as well. There are results that are not perfect but I wouldn't have thought the practical results would be exactly the same as the stimulated results as there are too many variables that could make the readings vary.



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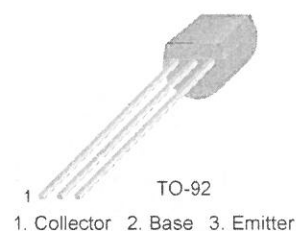


November 2014

BC546 / BC547 / BC548 / BC549 / BC550 NPN Epitaxial Silicon Transistor

Features

- Switching and Amplifier
- High-Voltage: BC546, $V_{CE0} = 65\text{ V}$
- Low-Noise: BC549, BC550
- Complement to BC556, BC557, BC558, BC559, and BC560



Ordering Information

Part Number	Marking	Package	Packing Method
BC546ABU	BC546A	TO-92 3L	Bulk
BC546ATA	BC546A	TO-92 3L	Ammo
BC546BTA	BC546B	TO-92 3L	Ammo
BC546BTF	BC546B	TO-92 3L	Tape and Reel
BC546CTA	BC546C	TO-92 3L	Ammo
BC547ATA	BC547A	TO-92 3L	Ammo
BC547B	BC547B	TO-92 3L	Bulk
BC547BBU	BC547B	TO-92 3L	Bulk
BC547BTA	BC547B	TO-92 3L	Ammo
BC547BTF	BC547B	TO-92 3L	Tape and Reel
BC547CBU	BC547C	TO-92 3L	Bulk
BC547CTA	BC547C	TO-92 3L	Ammo
BC547CTFR	BC547C	TO-92 3L	Tape and Reel
BC548BU	BC548	TO-92 3L	Bulk
BC548BTA	BC548B	TO-92 3L	Ammo
BC548CTA	BC548C	TO-92 3L	Ammo
BC549BTA	BC549B	TO-92 3L	Ammo
BC549BTF	BC549B	TO-92 3L	Tape and Reel
BC549CTA	BC549C	TO-92 3L	Ammo
BC550CBU	BC550C	TO-92 3L	Bulk
BC550CTA	BC550C	TO-92 3L	Ammo

BC546 / BC547 / BC548 / BC549 / BC550 — NPN Epitaxial Silicon Transistor

Absolute Maximum Ratings

Stresses exceeding the absolute maximum ratings may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only. Values are at $T_A = 25^\circ\text{C}$ unless otherwise noted.

Symbol	Parameter	Value	Unit
V_{CBO}	Collector-Base Voltage	BC546	80
		BC547 / BC550	50
		BC548 / BC549	30
V_{CEO}	Collector-Emitter Voltage	BC546	65
		BC547 / BC550	45
		BC548 / BC549	30
V_{EBO}	Emitter-Base Voltage	BC546 / BC547	6
		BC548 / BC549 / BC550	5
I_C	Collector Current (DC)	100	mA
P_C	Collector Power Dissipation	500	mW
T_J	Junction Temperature	150	$^\circ\text{C}$
T_{STG}	Storage Temperature Range	-65 to +150	$^\circ\text{C}$

Electrical Characteristics

Values are at $T_A = 25^\circ\text{C}$ unless otherwise noted.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
I_{CBO}	Collector Cut-Off Current	$V_{CB} = 30\text{ V}, I_E = 0$			15	nA
h_{FE}	DC Current Gain	$V_{CE} = 5\text{ V}, I_C = 2\text{ mA}$	110		800	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_C = 10\text{ mA}, I_B = 0.5\text{ mA}$		90	250	mV
		$I_C = 100\text{ mA}, I_B = 5\text{ mA}$		250	600	
$V_{BE(sat)}$	Base-Emitter Saturation Voltage	$I_C = 10\text{ mA}, I_B = 0.5\text{ mA}$		700		mV
		$I_C = 100\text{ mA}, I_B = 5\text{ mA}$		900		
$V_{BE(on)}$	Base-Emitter On Voltage	$V_{CE} = 5\text{ V}, I_C = 2\text{ mA}$	580	660	700	mV
		$V_{CE} = 5\text{ V}, I_C = 10\text{ mA}$			720	
f_T	Current Gain Bandwidth Product	$V_{CE} = 5\text{ V}, I_C = 10\text{ mA}, f = 100\text{ MHz}$		300		MHz
C_{ob}	Output Capacitance	$V_{CB} = 10\text{ V}, I_E = 0, f = 1\text{ MHz}$		3.5	6.0	pF
C_{ib}	Input Capacitance	$V_{EB} = 0.5\text{ V}, I_C = 0, f = 1\text{ MHz}$		9		pF
NF	Noise Figure	BC546 / BC547 / BC548		2.0	10.0	dB
		BC549 / BC550		1.2	4.0	
		BC549		1.4	4.0	
		BC550		1.4	3.0	

h_{FE} Classification

Classification	A	B	C
h_{FE}	110 ~ 220	200 ~ 450	420 ~ 800

