



ELECTRICAL & ELECTRONIC PRINCIPLES ASSIGNMENT

HNC Electrical and Electronic Engineering

Transistor Amplifiers

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Year 1

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Introduction

The aim of this assignment is to demonstrate the ability to design, simulate and build transistor amplifier circuits, and to justify the choice of components within the design. The assignment also requires the ability to assess the design in terms of efficiency and reliability.

Objectives

The objective of this assignment is to:

- Investigate different types of transistor amplifiers
- Produce a circuit design
- Demonstrate circuit calculations
- Build a circuit replica
- Take suitable measurements
- Discuss findings
- Simulate the circuit using Multisim
- Analyse results
- Produce a two stage amplifier in Multisim

Theory / Research

Types of Transistors

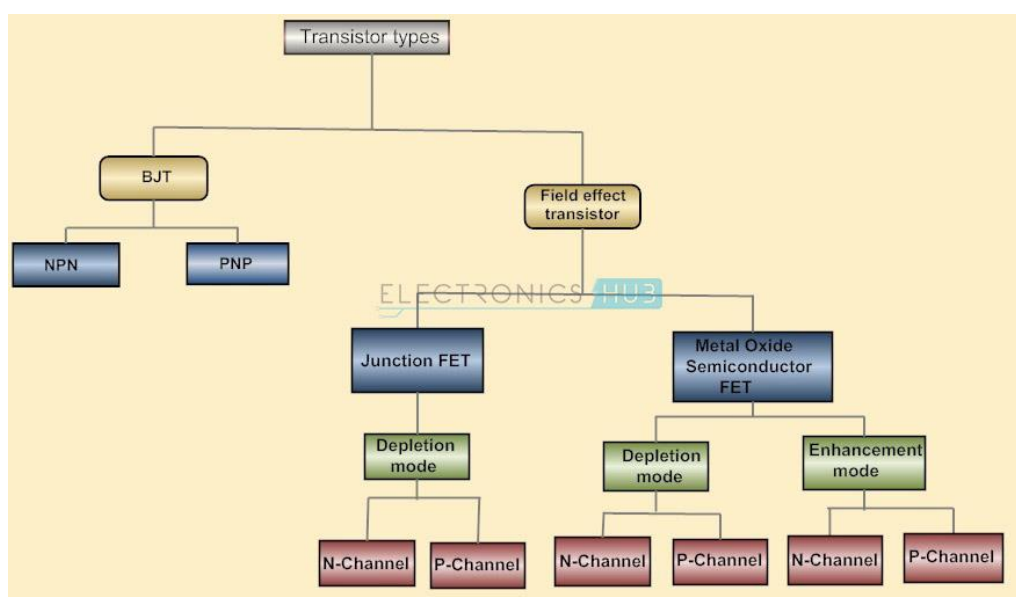
Transistors are effectively two diodes connected in series back to back sharing a common P or N terminal. The fusion of these two diodes produces a three-layer two junction three terminal device forming a transistor. They are made from semiconductor materials that can either act as either an insulator or conductor by the application of a small signal voltage. The transistors ability to change between these two states enables it to have two functions: Switching (digital electronics) or Amplification (analogue electronics). (Bipolar Transistor, 2020)

There are 2 main groups of transistors, namely:

- bipolar junction transistor (BJTs)
- field-effect transistors (FETs)

Within these groups there are different types:

- Bipolar Junction Transistors
 - NPN
 - PNP
- Field-Effect Transistors
 - Junction-Field-Effect Transistor (JFET)
 - N-Channel JFET
 - P-Channel JFET
 - Metal-Oxide-Semiconductor Field-Effect Transistors (MOSFET)
 - N-Channel MOSFET
 - P-Channel MOSFET



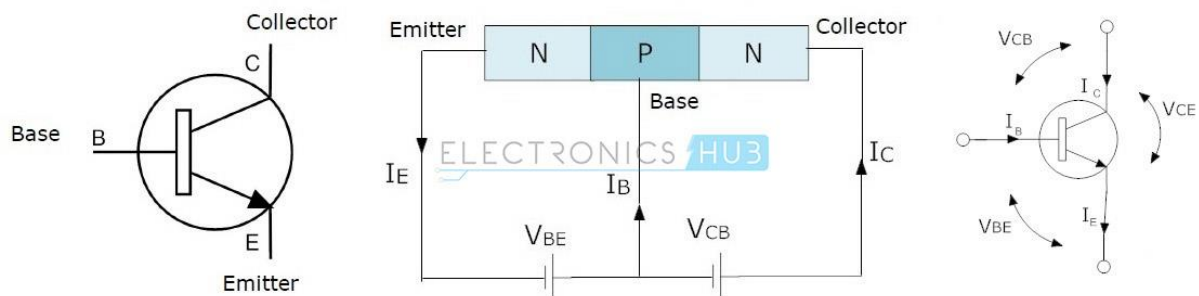
(Classification and Different types of Transistors BJT, FET, NPN, PNP, 2019)

Bipolar Junction Transistors

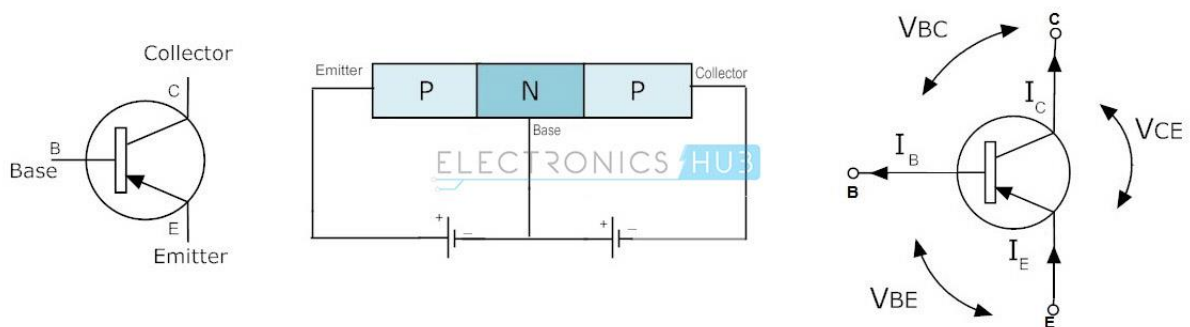
A Bipolar Junction Transistor is a semiconductor device which can be used for switching or amplification purposes. They are constructed from two different types of semiconductor materials, namely P-type and N-type. These transistors have three connecting terminals, namely the Emitter, Base and Collector. Bipolar Transistors are current regulating devices that control the amount of current flowing through them from the Emitter to the Collector terminals in proportion to the amount of biasing voltage applied to their base terminal, thus acting like a current-controlled switch. As a small current flowing into the base terminal controls a much larger collector current forming the basis of transistor action. The operation of PNP and NPN Transistors are very similar, the difference between them is their biasing and the polarity of the power supply for each type.

(Bipolar Transistor, 2020)

The symbols and structure for NPN transistors are given below:



The symbols and structure for PNP transistors are given below:



(Classification and Different types of Transistors BJT, FET, NPN, PNP, 2019)

Bipolar Transistor Configurations

As the Bipolar Transistor is a three-terminal device, there are basically three possible ways to connect it within an electronic circuit with one terminal being common to both the input and output. Each method of connection responding differently to its input signal within a circuit as the static characteristics of the transistor vary with each circuit arrangement.

- Common Base Configuration
- Common Emitter Configuration
- Common Collector Configuration

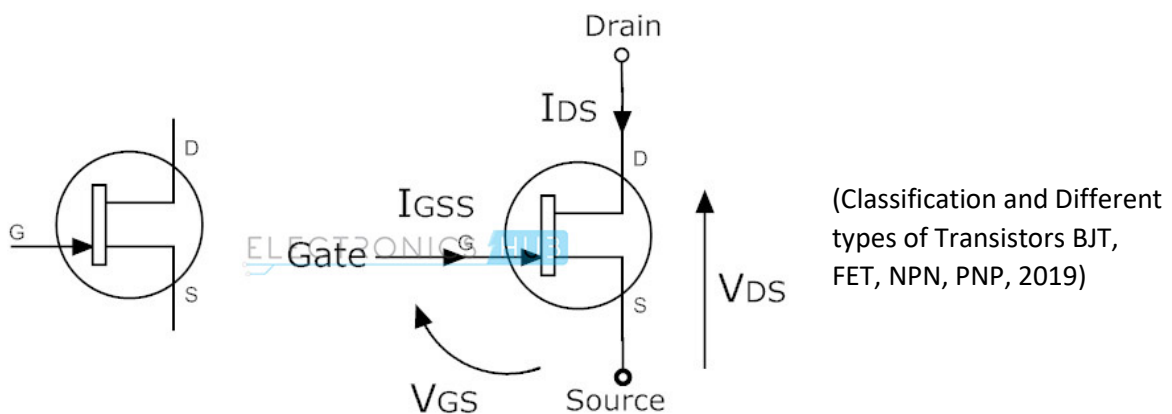
Field-Effect Transistors

The Field-Effect-Transistor (FET) is another transistors type. Basically, the FET transistors have three terminals they are gate (G), Drain (D) and Source (S). FET transistors are classified into Junction Field Effect transistors (JFET) and Insulated Gate FET (IG-FET) or MOSFET transistors. (Classification and Different types of Transistors BJT, FET, NPN, PNP, 2019)

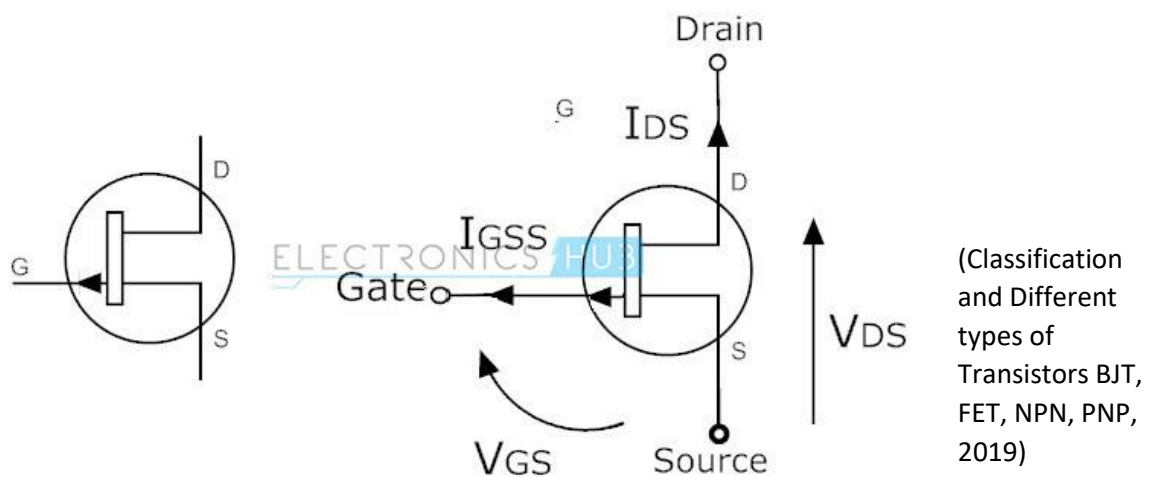
Junction-Field-Effect Transistors

The Junction-Field-Effect transistor (JFET) is an earliest and simple type of FET transistors. These JFETs are used as switches, amplifiers and resistors. This transistor is a voltage-controlled device. It doesn't need any biasing current. The voltage applied between gate and source controls the flow of electric current between source and drain of a transistor. The JFET transistors are available in both N-channel and P-channel types. (Classification and Different types of Transistors BJT, FET, NPN, PNP, 2019)

Junction-Field-Effect Transistors: N-Channel



Junction-Field-Effect Transistors: P-Channel

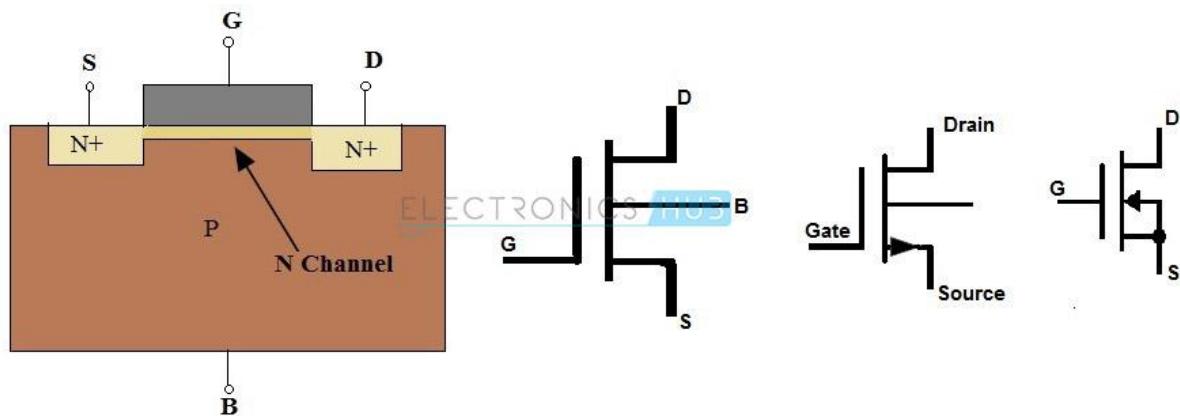


Metal-Oxide-Semiconductor Field-Effect Transistors

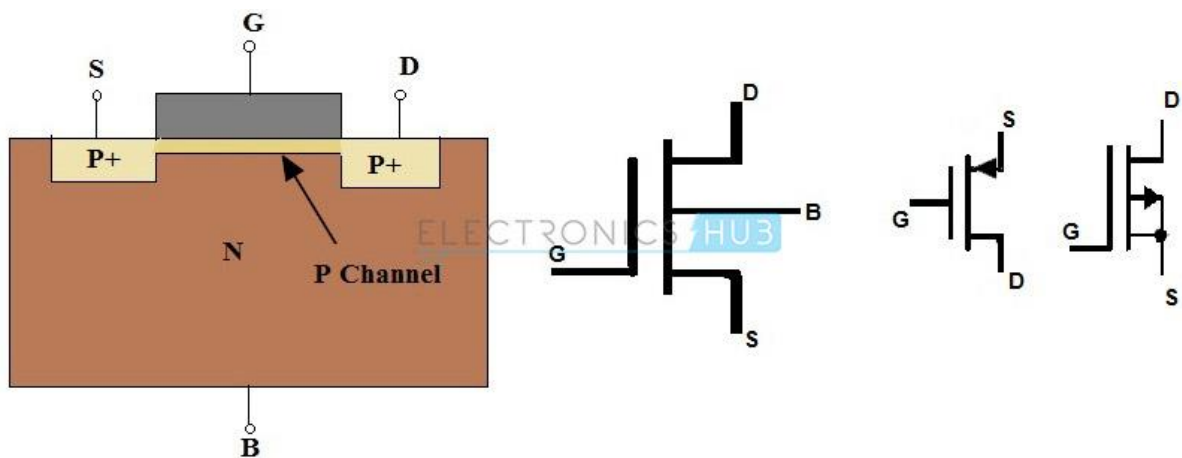
Metal-Oxide-Semiconductor Field Effect Transistor (MOSFET) is most useful type of among all transistors. The name itself indicates that it contains metal gate terminal. The MOSFET has four terminals drain, source, gate and body or substrate (B). MOSFET has many advantages over BJT and JFET, mainly it offers high input impedance and low output impedance. It is used in low power circuits mainly in chip designing technologies.

The MOSFET transistors are available in depletion and enhancement types. Further the depletion and enhancement types are classified into N-channel and P-channel types.

Metal-Oxide-Semiconductor Field-Effect Transistors: N-Channel

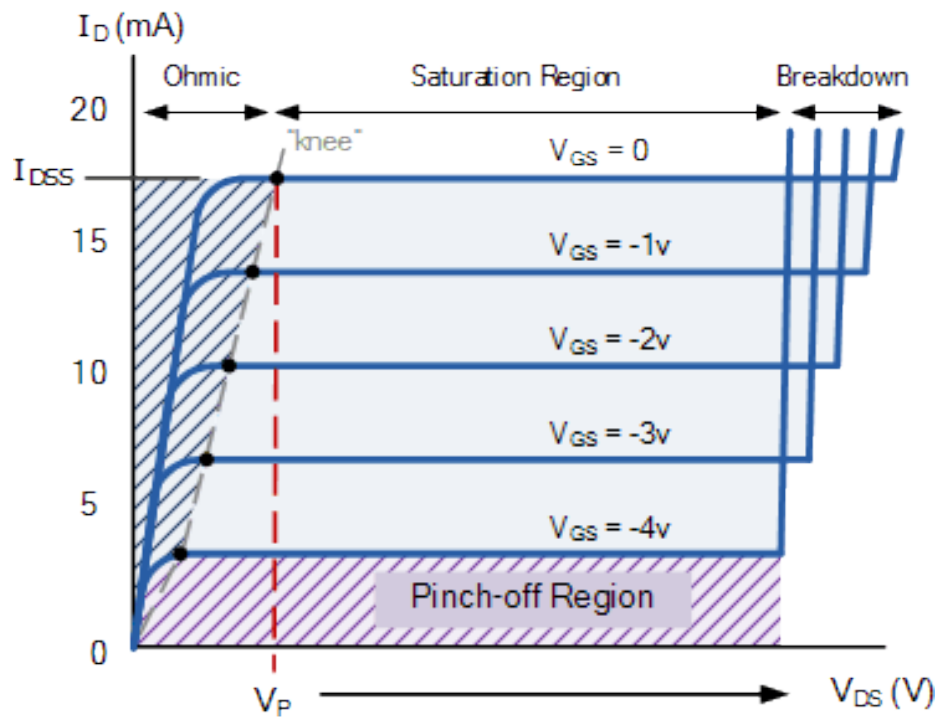


Metal-Oxide-Semiconductor Field-Effect Transistors: P-Channel

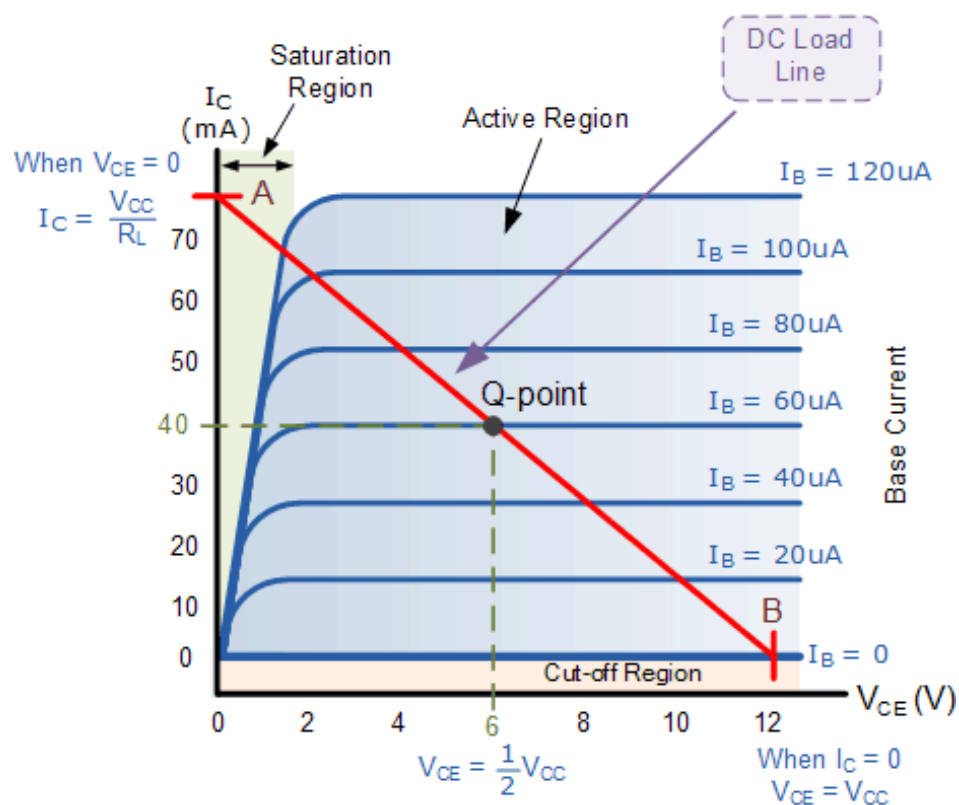


(Classification and Different types of Transistors BJT, FET, NPN, PNP, 2019)

Output characteristic V-I curves of a typical junction FET



Output Characteristics Curves of a Typical Bipolar Transistor



(Bipolar Transistor, 2020)

Transistor Amplifier Configurations

As the object of this assignment is to design, build and simulate a transistor amplifier circuit, let us now look at different types of Transistor Amplifier Configurations and their Voltage, Current and Power Gains. As discussed previously, we learned that there are three different circuit arrangements/configurations:

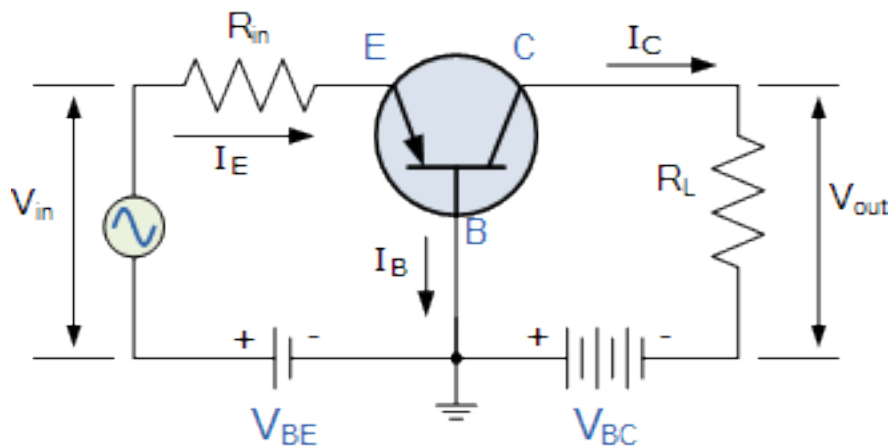
- Common Base Configuration.
- Common Emitter Configuration.
- Common Collector Configuration.

The Common Base (CB) Configuration

As its name suggests, in the Common Base or grounded base configuration, the BASE connection is common to both the input signal AND the output signal. The input signal is applied between the transistors base and the emitter terminals, while the corresponding output signal is taken from between the base and the collector terminals as shown. The base terminal is grounded or can be connected to some fixed reference voltage point.

The input current flowing into the emitter is quite large as its the sum of both the base current and collector current respectively therefore, the collector current output is less than the emitter current input resulting in a current gain for this type of circuit of “1” (unity) or less, in other words the common base configuration “attenuates” the input signal.

The Common Base Transistor Circuit



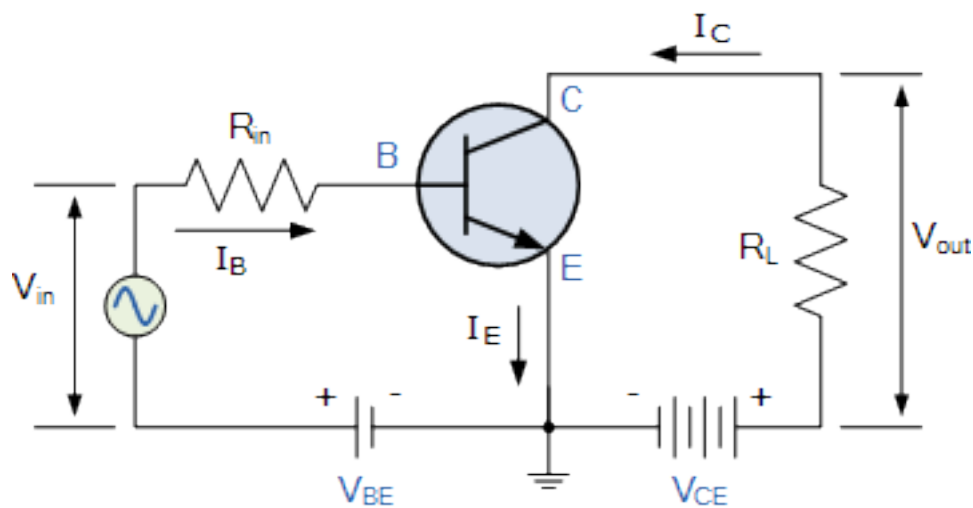
This type of amplifier configuration is a non-inverting voltage amplifier circuit, in that the signal voltages V_{in} and V_{out} are “in-phase”. This type of transistor arrangement is not very common due to its unusually high voltage gain characteristics. Its input characteristics represent that of a forward biased diode while the output characteristics represent that of an illuminated photo-diode. (Bipolar Transistor, 2020)

The Common Emitter (CE) Configuration

In the Common Emitter or grounded emitter configuration, the input signal is applied between the base and the emitter, while the output is taken from between the collector and the emitter as shown. This type of configuration is the most commonly used circuit for transistor-based amplifiers and which represents the “normal” method of bipolar transistor connection.

The common emitter amplifier configuration produces the highest current and power gain of all the three bipolar transistor configurations. This is mainly because the input impedance is LOW as it is connected to a forward biased PN-junction, while the output impedance is HIGH as it is taken from a reverse biased PN-junction.

The Common Emitter Amplifier Circuit



In this type of configuration, the current flowing out of the transistor must be equal to the currents flowing into the transistor as the emitter current is given as $I_E = I_C + I_B$.

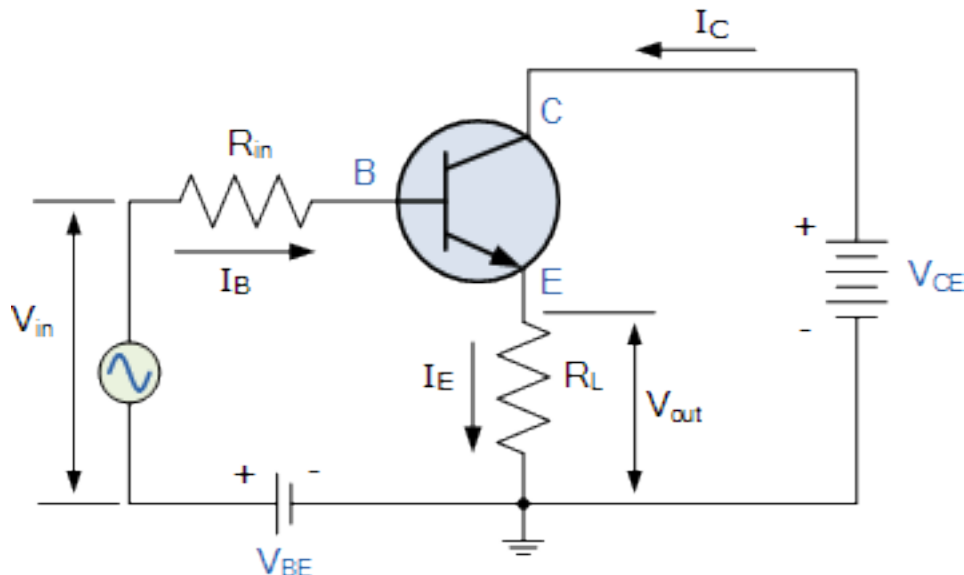
Then to summarise a little. This type of bipolar transistor configuration has a greater input impedance, current and power gain than that of the common base configuration but its voltage gain is much lower. The common emitter configuration is an inverting amplifier circuit. This means that the resulting output signal has a 180° phase-shift with regards to the input voltage signal. (Bipolar Transistor, 2020)

The Common Collector (CC) Configuration

In the Common Collector or grounded collector configuration, the collector is now common through the supply so the collector is common to both the input and the output. The input signal is connected directly to the base terminal, while the output signal is taken from across the emitter load as shown. This type of configuration is commonly known as a Voltage Follower or Emitter Follower circuit.

The common collector, or emitter follower configuration is very useful for impedance matching applications because of its very high input impedance, in the region of hundreds of thousands of Ohms while having a relatively low output impedance.

The Common Collector Transistor Circuit



The common emitter configuration has a current gain approximately equal to the β value of the transistor itself. However, in the common collector configuration, the load resistance is connected in series with the emitter terminal so its current is equal to that of the emitter current.

As the emitter current is the combination of the collector AND the base current combined, the load resistance in this type of transistor configuration also has both the collector current and the input current of the base flowing through it.

The Common Collector Current Gain

This type of bipolar transistor configuration is a non-inverting circuit in that the signal voltages of V_{in} and V_{out} are “in-phase”. The common collector configuration has a voltage gain of about “1” (unity gain). Thus it can be considered as a voltage-buffer since the voltage gain is unity.

The load resistance of the common collector transistor receives both the base and collector currents giving a large current gain (as with the common emitter configuration) therefore, providing good current amplification with very little voltage gain.

(Bipolar Transistor, 2020)

The characteristics are summarised below:

Transistor Configuration Summary Table			
Transistor Configuration	Common Base	Common Collector (Emitter Follower)	Common Emitter
Voltage Gain	High	Low	Medium
Current Gain	Low	High	Medium
Power Gain	Low	Medium	High
Input / Output Phase Relationship	0°	0°	180°
Input Resistance	Low	High	Medium
Output Resistance	High	Low	Medium

Base Voltage (V_{BE})

There is a voltage drop between the Base and the Emitter terminal of about 0.7V (one diode volt drop) for silicon devices as the input characteristics of an NPN Transistor are of a forward biased diode.

The base voltage, (V_{be}) of a NPN transistor must be greater than this 0.7V.

Choosing A Transistor

For the purpose of this assignment we have been given the type of transistor to use:

∴ Transistor to use = BC109

Codes beginning with B (or A), e.g. BC109

The first letter B is for silicon, A is for germanium (rarely used now). The second letter indicates the type; for example C means low power audio frequency; D means high power audio frequency; F means low power high frequency. The rest of the code identifies the particular transistor.

Low Power Bipolar Transistors

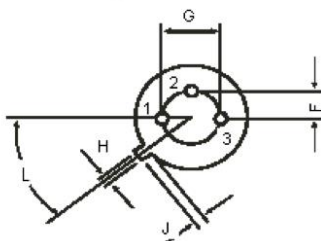
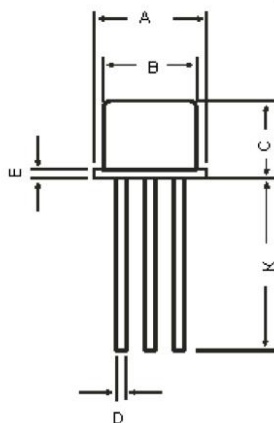
BC109 Series



Feature:

- NPN Silicon Planar Epitaxial Transistors

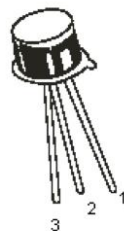
TO-18 Metal Can Package



Specification Table

Dimensions	Minimum	Maximum
A	5.24	5.84
B	4.52	4.97
C	4.31	5.33
D	0.4	0.53
E	-	0.76
F	-	1.27
G	-	2.97
H	0.91	1.17
J	0.71	1.21
K	12.7	-
L	45°	

Dimensions : Millimetres



Pin Configuration:

- Emitter
- Base
- Collector

Absolute Maximum Ratings

Description	Symbol	BC109	Unit
Collector - Emitter Voltage	V_{CEO}	25	V
Collector - Base Voltage	V_{CBO}	30	
Emitter-Base Voltage	V_{EBO}	5	
Collector Current Continuous	I_C	0.2	A

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Low Power Bipolar Transistors

BC109 Series



Absolute Maximum Ratings

Description	Symbol	BC109	Unit
Power Dissipation at $T_a = 25^\circ\text{C}$ Derate above 25°C	P_D	0.6 2.28	W mW / $^\circ\text{C}$
Power Dissipation at $T_C = 25^\circ\text{C}$ Derate above 25°C		1 6.67	
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	$^\circ\text{C}$
Thermal Resistance			
Junction to Case	$R_{th(j-c)}$	175	$^\circ\text{C} / \text{W}$

Electrical Characteristics ($T_a = 25^\circ\text{C}$ unless otherwise specified)

Description	Symbol	Test Condition	Minimum	Maximum	Unit
Collector - Emitter Voltage	V_{CEO}	$I_C = 2 \text{ mA}, I_B = 0$	25	-	V
Emitter Base Voltage	V_{EBO}	$I_E = 10 \mu\text{A}, I_C = 0$	5	-	
Collector Cut off Current	I_{CBO}	$V_{CB} = 25 \text{ V}, I_E = 0$ $T_{amb} = 125^\circ\text{C}$	-	15	nA
		$V_{CB} = 25 \text{ V}, I_E = 0$	-	4	μA
DC Current	h_{FE}	$I_C = 10 \mu\text{A}, V_{CE} = 5 \text{ V}$ B Group C Group	40 100	-	-
		$I_C = 2 \text{ mA}, V_{CE} = 5 \text{ V}$ B Group C Group	200 200 420	800 450 800	
Base Emitter Saturation Voltage	$V_{BE (Sat)}$	$I_C = 10 \text{ mA}, I_B = 0.5 \text{ mA}$	-	0.83 1.05	V
Collector Emitter Saturation Voltage	$V_{CE (Sat)}$	$I_C = 100 \text{ mA}, I_B = 5 \text{ mA}$	-	0.25 0.6	
Base Emitter On Voltage	$V_{BE (on)}$	$I_C = 2 \text{ mA}, V_{CE} = 5 \text{ V}$ $I_C = 10 \text{ mA}, V_{CE} = 5 \text{ V}$	0.55 -	0.7 0.77	
Collector Knee Voltage	$V_{CE (K)}$	$I_C = 10 \text{ mA}, I_B = \text{The value for which } I_C = 11 \text{ mA at } V_{CE} = 1 \text{ V}$	-	0.6	
Transition Frequency	f_t	$V_{CE} = 5 \text{ V}, I_C = 10 \text{ mA}, f = 100 \text{ MHz}$	150	-	MHz
Noise Figure	NF	$V_{CE} = 5 \text{ V}, I_C = 0.2 \text{ mA}$ $R_g = 2 \text{ k}\Omega$	-	4	dB
		$F = 30 \text{ Hz to } 15 \text{ KHz}$ $F = 1 \text{ kHz}, B = 200 \text{ Hz}$		4	dB
Output Capacitance	C_{obo}	$V_{CB} = 10 \text{ V}, f = 1 \text{ MHz}$	-	4.5	pF
Small Signal Current Gain	h_{fe}	ALL $f = 1 \text{ kHz}$ $I_C = 2 \text{ mA}, V_{CE} = 5 \text{ V}$	240	900	-
		B Group	240	500	
		C Group	450	900	

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Low Power Bipolar Transistors

BC109 Series



Electrical Characteristics ($T_a = 25^\circ\text{C}$ unless otherwise specified)

Description	Symbol	Test Condition	Minimum	Maximum	Unit
Input Impedance	h_{ie}	$I_C = 2 \text{ mA}, V_{CE} = 5 \text{ V}$			
		B Group	3.2	8.5	$\text{K}\Omega$
		C Group	6	15	$\text{K}\Omega$
Output Admittance	h_{oe}	$I_C = 2 \text{ mA}, V_{CE} = 5 \text{ V}$			
		B Group	-	60	$\mu\Omega$
		C Group		110	

Part Number Table

Package	Part Number
Transistor, NPN, TO-18	BC109
Transistor, NPN, TO-18	BC109B
Transistor, NPN, TO-18	BC109C

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Calculations

Assumed, Given and Researched values:

Before we can start calculating values for the given Single Stage Transistor Amplifier Circuit within this assignment, we first must find and list some assumed and researched values:

	Value	From?
Student Number:	2	Given
Vcc:	12 Volts	Given
Gain:	6	Given
β :	200	Data Sheet & Research
Vbe:	0.7 Volts	Research
Ic:	2mA	Assumed
Internal resistance of BC109	25 mV	Research

Voltage at Resistor C (V_C)
Research shows us that V_C = Half the value of V_{CC}
$\therefore V_{CC} / 2 = V_C$
$\therefore 12 / 2 = 6$
$\therefore V_C = 6$ Volts

Current at Resistor C (I_C)
This is an assumed value
$\therefore I_C = 2\text{mA}$

Resistance of Resistor C (R_C)
As we know the values of V_C & I_C we can now apply Ohms Law to determine the value of R_C
$V / I = R$ (Ohms Law)
$\therefore V_C / I_C = R_C$
$\therefore 6 / 2\text{mA} = 3000$
$\therefore R_C = 3000\Omega$

Resistance of Resistor E (R_E)
We know that our circuit gain is 6. Therefore, the resistance at the Collector must be 6 times higher than at the Emitter. As we know that R_C is $3\text{k}\Omega$, R_E must be 6 times
$\therefore R_E = R_C / \text{Gain}$
$\therefore R_E = 3000\Omega / 6$
$\therefore R_E = 500\Omega$

Current at Base of Transistor (I_B)
Research shows us that the current at the base of the transistor (I_B) is equal to I_C / the given transistor current gain (as per data sheet)
$\therefore I_B = I_C / \beta$
$2\text{mA} / 200 = 0.00001$
$\therefore I_B = 0.01\text{mA}$

Current at Resistor E (I_E)
Through research we know that $I_E = I_C + I_B$.
$\therefore I_E = 2\text{mA} + 0.01\text{mA}$
$\therefore I_E = 2.01\text{mA}$

Voltage at Resistor E (V_E)
As we know the values of R_E & I_E we can now apply Ohms Law to determine the value of V_E
$R \times I = V$ (Ohms Law)
$\therefore R_E \times I_E = V_E$
$\therefore 500\Omega \times 2\text{mA} = 1$
$\therefore V_E = 1$ Volt

Current at Resistor 2 (I_2)
For I_2 we use the rule of thumb which is that I_2 is ten times larger than the value of I_B
$I_2 = I_B \times 10$
$0.01\text{mA} \times 10 = 0.10$
$\therefore I_2 = 0.10\text{mA}$

Current at Resistor 1 (I_1)
For I_1 we use the rule of thumb which is that I_1 is eleven times larger than the value of I_B
$I_1 = I_B \times 11$
$0.01\text{mA} \times 11 = 0.11$
$\therefore I_1 = 0.11\text{mA}$

Voltage at Resistor 2 (V_2)
Through reasearch, we learn that the voltage at Resistor 2 is equal to V_E + Voltage at the Base of the transistor (V_{BE}). And also through reasearch we know that the transistor operates at 0.7 Volts at the Base.
$V_2 = V_E + V_{BE}$
$1 + 0.7 = 1.7$
$\therefore V_2 = 1.7 \text{ Volts}$

Resistance of Resistor 2 (R_2)
As we know the values of V_2 & I_2 we can now apply Ohms Law to determine the value of R_2
$V / I = R$ (Ohms Law)
$\therefore V_2 / I_2 = R_2$
$\therefore 1.7 / 0.10\text{mA} = 17000$
$\therefore R_2 = 17\text{k}\Omega$

Voltage at Resistor 1 (V_1)
Through reasearch, we learn that the voltage at Resistor 1 is equal to $V_{CC} - V_2$
$V_1 = V_{CC} - V_2$
$12 - 1.7 = 10.3$
$\therefore V_1 = 10.3 \text{ Volts}$

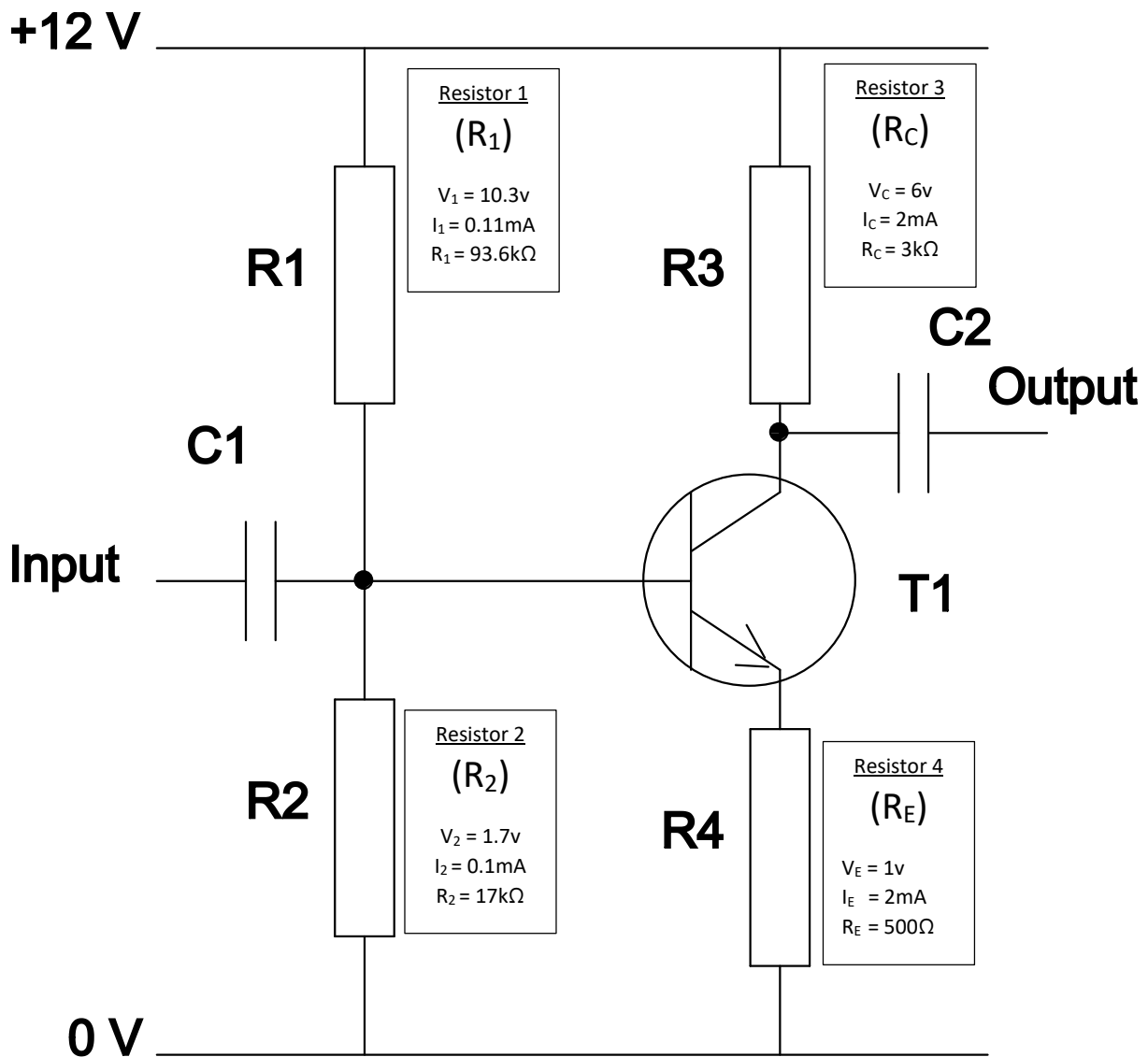
Resistance of Resistor 1 (R_1)
As we know the values of V_1 & I_1 we can now apply Ohms Law to determine the value of R_1
$V / I = R$ (Ohms Law)
$\therefore V_1 / I_1 = R_1$
$\therefore 10.3 / 0.11\text{mA} = 93636$
$\therefore R_1 = 93.6\text{k}\Omega$

True Gain
The equasion to find the True Gain of the circuit is = $(R_C) / (R_E + R_o)$
Before applying this equasion we must first get the values for R_E and R_o
$R_o = \text{Internal resistance value for the transistor} / I_C$
$25\text{mV} / 2\text{mA} = 12.5$
$\therefore R_o = 12.5\Omega$
$R_E = (R_C - (R_E \times \text{Gain})) / \text{Gain}$
$(3000 - (12.5 \times 6)) / 6 = 487.5$
$\therefore R_E = 487.5$
True Gain = $(R_C) / (R_E + R_o)$
$(3000) / (487.5 + 12.5) = 5.85$
$\therefore \text{True Gain} = 5.85\Omega$

Calculations Key

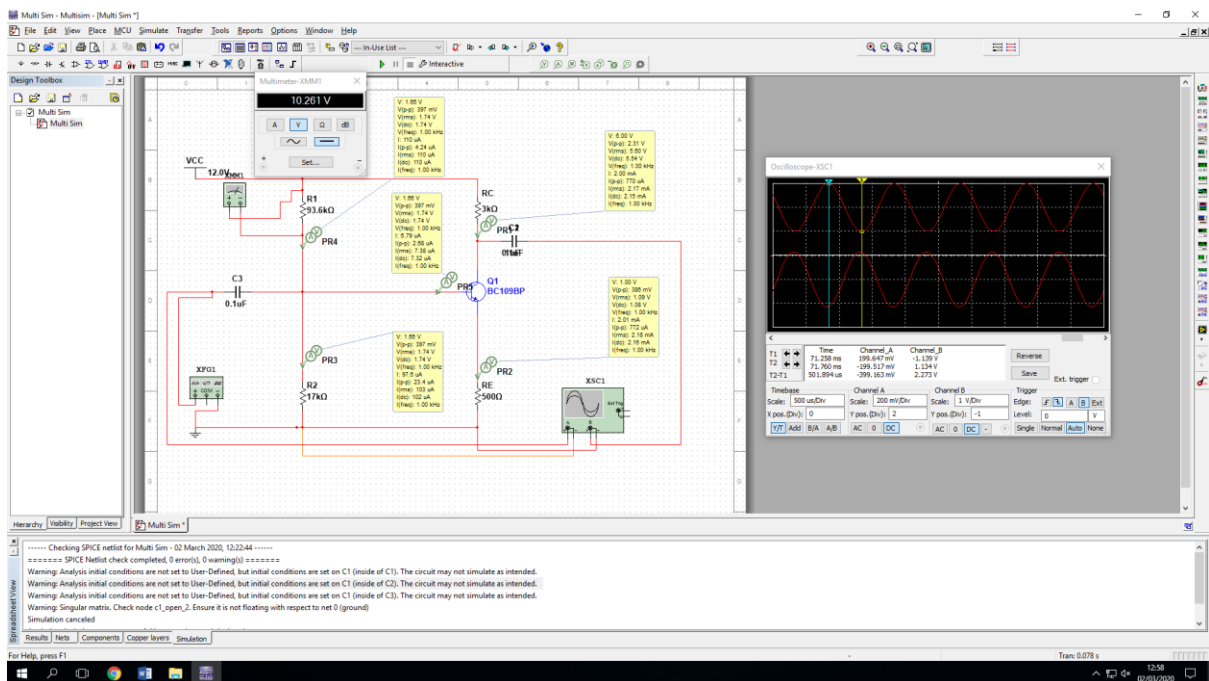
Calculation Title
Explanenation
Formula
Answer

To summarise the results from our calculations:

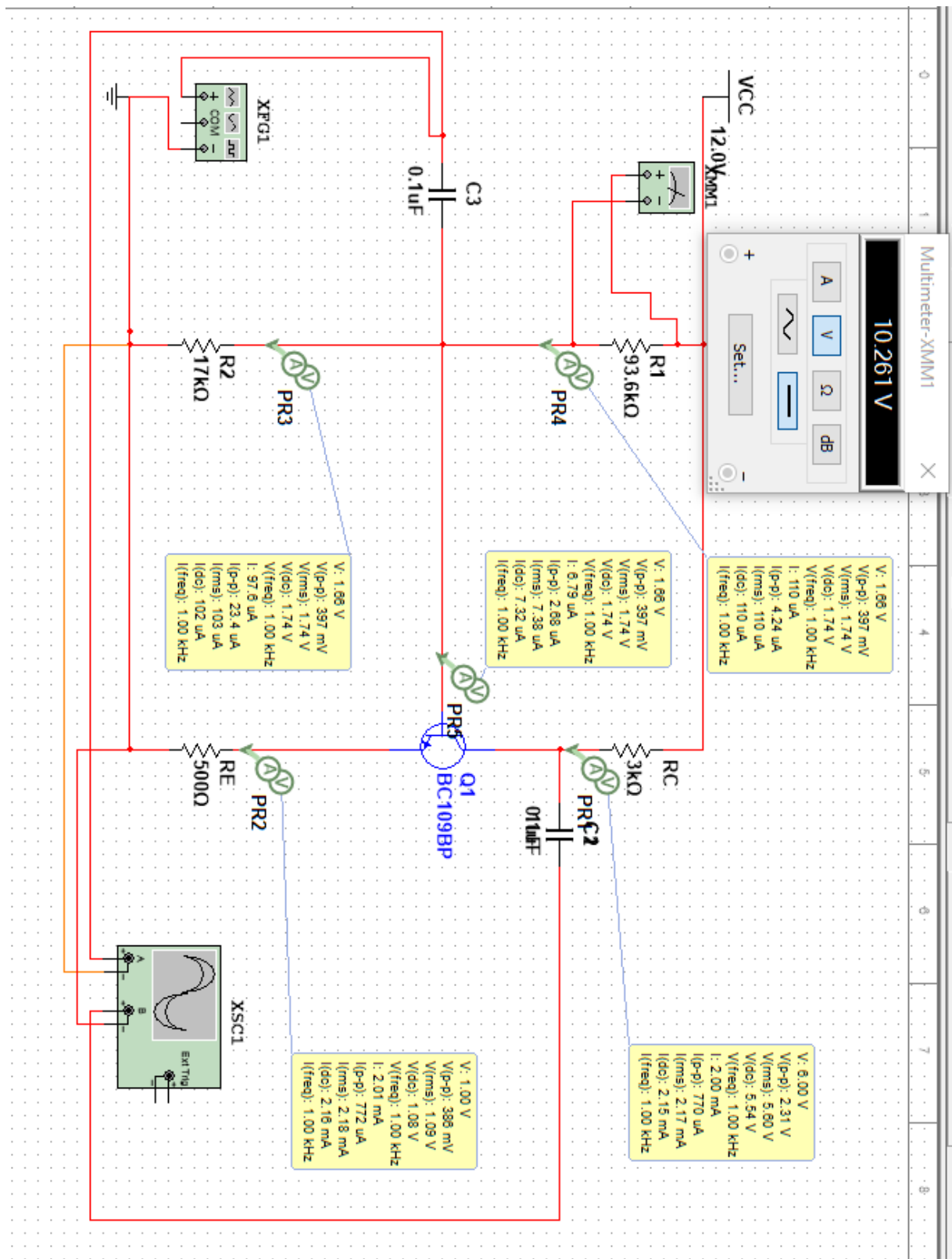


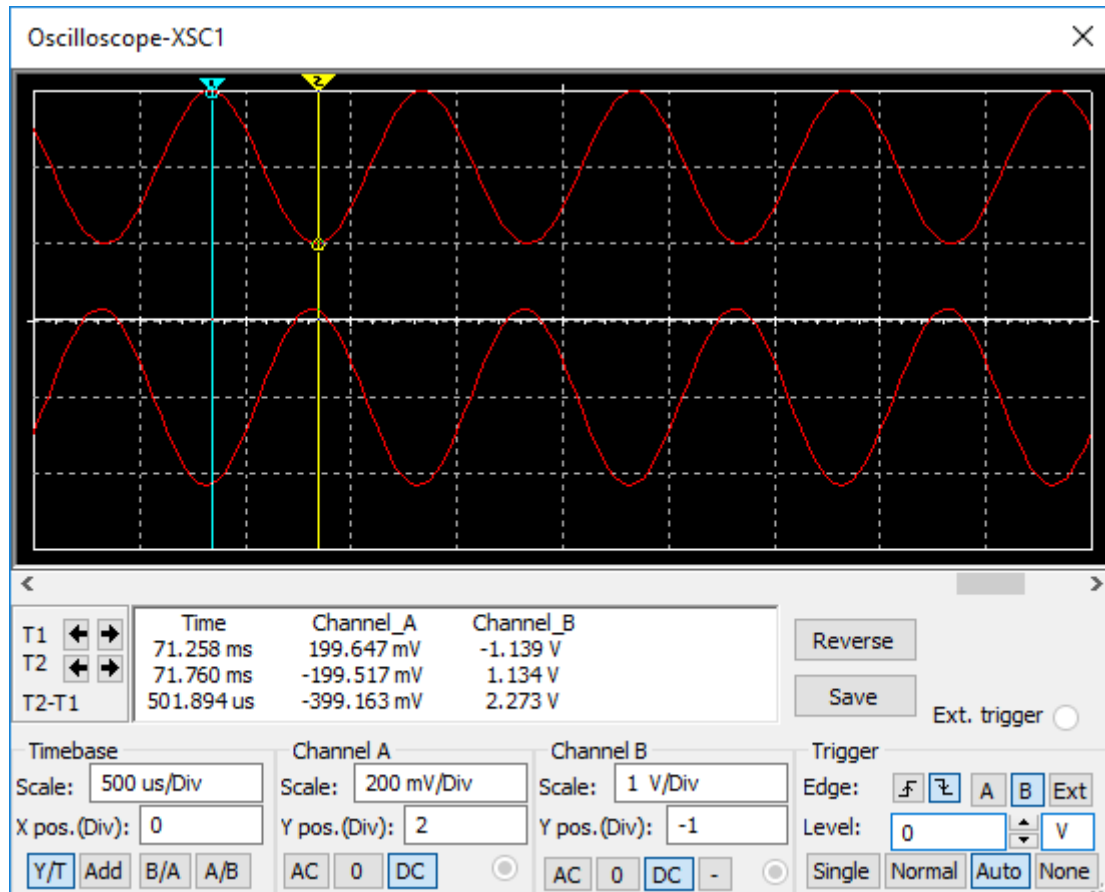
Multisim Simulation

Below is the Screen Shot of my Multisim simulation of the designed circuit:



The following two screenshots magnify the results above:





Multisim Analysis and Results

Oscilloscope

From looking at the Oscilloscope above, we need to analyse what the relationship between Channel A and Channel B shows us. If we know that Channel A is the input Voltage and that Channel B is the Output Voltage then we are able to ascertain what the Gain of the circuit is by using the formula:

$$\frac{\text{Output Voltage (Channel B)}}{\text{Input Voltage (Channel A)}}$$

∴ If we divide 1.139 V by 199.647mV we should end up with our Circuit Gain.

$$\frac{1.139 \text{ Volts}}{199.647\text{mV}} = 5.71$$

This figure of 5.71 is very close to my calculated True Gain of 5.85. The simulated circuit gives confidence to the calculated circuit being correct.

As we know from our previous research, the common emitter configuration is an inverting amplifier circuit. Hence, why the Oscilloscope screenshot above shows the Output signal 180° out of phase with the Input signal.

Voltage and Current:

When I analyse the results from the Multisim simulation, using the Multisim built in Ammeter and Voltmeter tools we can see that the measured results are very close indeed to the calculated results. A summary of which is below:

Parameter	Calculated Results	Multisim Results
Resistor 1 Voltage	10.3 V	10.26 V
Resistor 1 Current	0.11 mA	110 μA
Resistor 1 Resistance	93.6 kΩ	93.6 kΩ
Resistor 2 Voltage	1.7 V	1.66 V
Resistor 2 Current	0.1 mA	103 μA
Resistor 2 Resistance	17 kΩ	17 kΩ
Resistor C Voltage	6 V	6 V
Resistor C Current	2 mA	2.17 mA
Resistor C Resistance	3 kΩ	3 kΩ
Resistor E Voltage	1 V	1 V
Resistor E Current	2.01 mA	2.16 mA
Resistor E Resistance	500 Ω	500 Ω

Input and Output Impedance

Input and Output Impedance of the Amplifier Z_{IN} and Z_{OUT}

From research we know that the equation for Input Impedance (Z_{IN}) is:

$$Z_{IN} = R_1 \parallel R_2 \parallel \beta (r_e)$$

First we must determine r_e , which is the AC resistance value of the Emitter diode i.e. the Emitter Leg Signal Resistance:

$$r_e = \frac{\text{Internal resistance of Transistor}}{I_E} = \frac{25\text{mV}}{2.01\text{mA}} = 12.4\Omega$$

Now we are able to calculate Z_{IN} :

$$Z_{IN} = R_1 \parallel R_2 \parallel \beta (r_e)$$

$$\frac{1}{Z_{IN}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{\beta (r_e)}$$

$$\frac{1}{Z_{IN}} = \frac{1}{93.6\text{k}} + \frac{1}{17\text{k}} + \frac{1}{200 \times 12.4}$$

$$\mathbf{Z_{IN} = 2115\Omega}$$

The equation for Output Impedance (Z_{OUT}) is:

$$Z_{OUT} = R_C \parallel R_L$$

$$\frac{1}{Z_{OUT}} = \frac{1}{R_C} + \frac{1}{R_L}$$

$$R_L = \text{Voltage Out} / \text{Current Out (Ohms Law)} = 2.273\text{mV} / 2.17 \text{ mA} = 1.05 \times 1000 = 1050\Omega$$

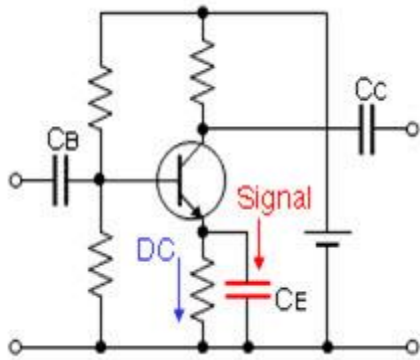
****I am treating the Output Coupling Capacitor (C_2) as a short circuit to AC signals and won't affect the calculation****

$$\frac{1}{Z_{OUT}} = \frac{1}{3000} + \frac{1}{1050}$$

$$\mathbf{Z_{OUT} = 778\Omega}$$

BYPASS CAPACITORS

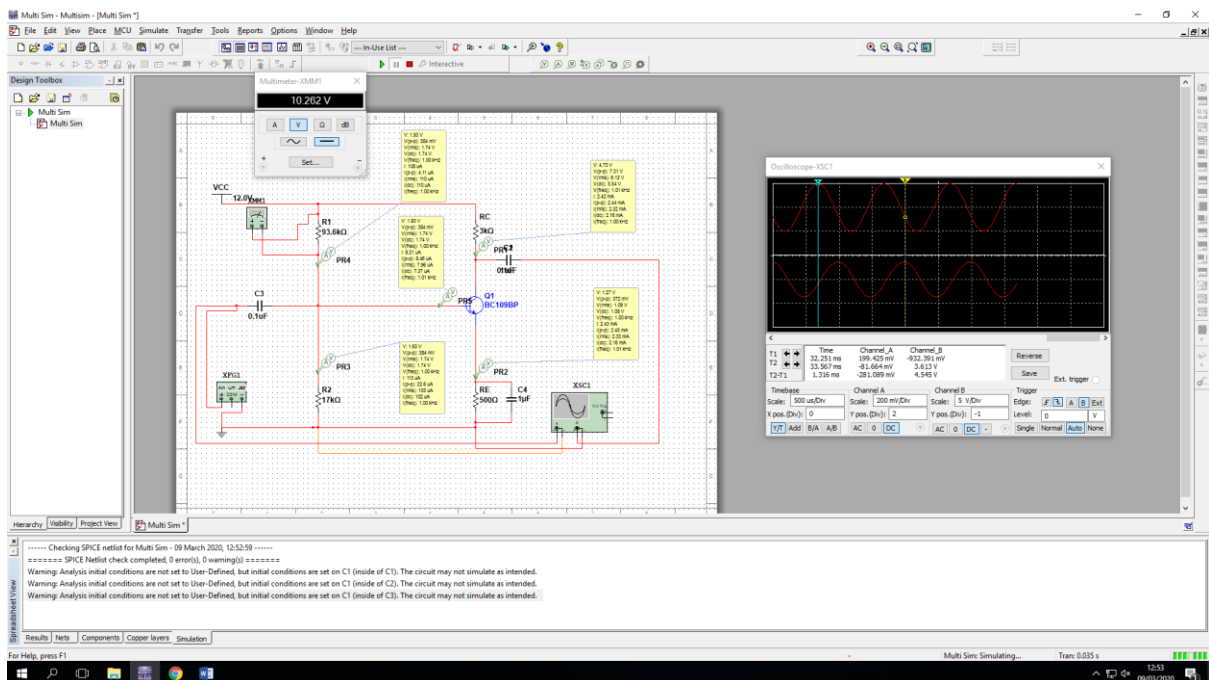
The bypass capacitor is a capacitor that shorts AC signals to the ground in a way that any AC noise that presents on a DC signal is removed producing a much cleaner and pure DC signal. A bypass capacitor basically bypasses AC noise that may be on a DC signal, filtering out of AC so that a clean, pure DC signal goes through without several AC ripples.



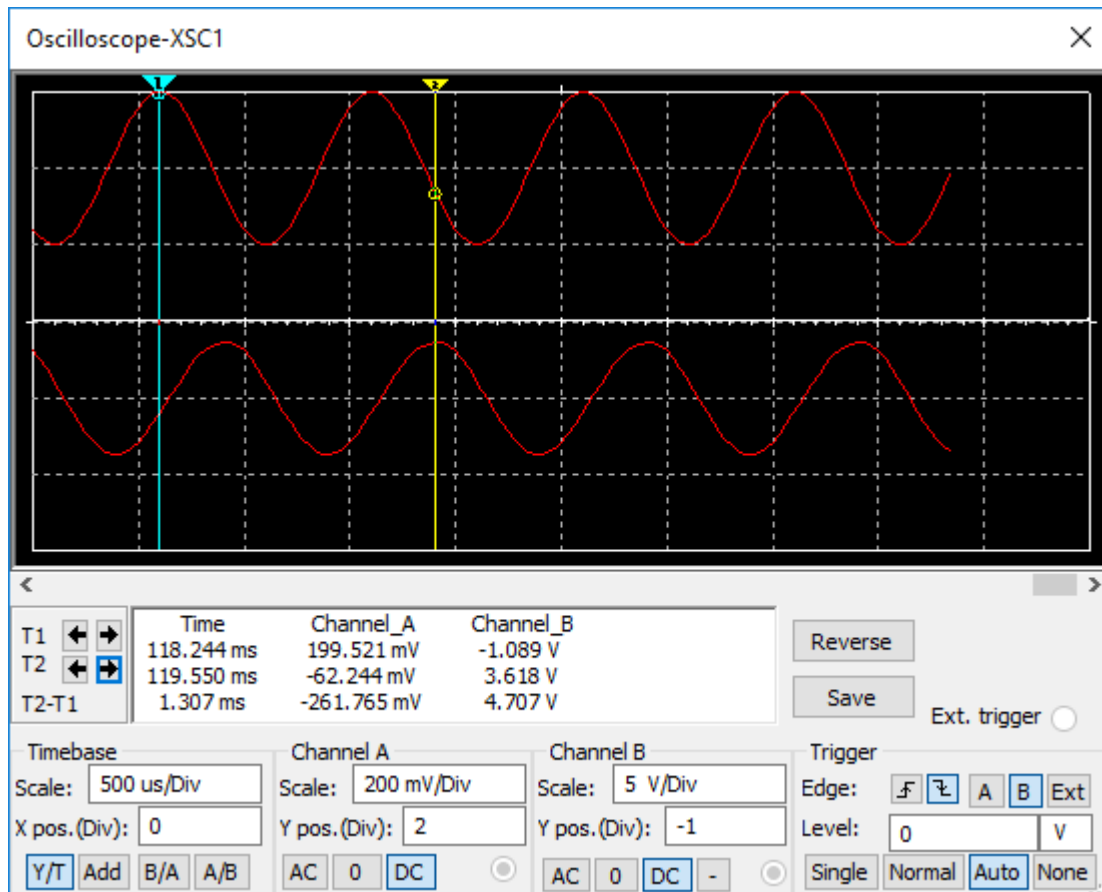
When an emitter resistance is added in a CE (Common Emitter) amplifier, its voltage gain is reduced, but the input impedance increases. Whenever bypass capacitor is connected in parallel with an emitter resistance, the voltage gain of CE amplifier increases.

(Basics of Bypass Capacitor, Its Functions and Applications, 2020)

Bypass Capacitor Installed Into Our Amplifier



Bypass Capacitor Analysis and Results



Before we installed the bypass capacitor in the emitter circuit we had an actual gain of 5.71.

From the above Oscilloscope readings we see that we have an Input Voltage of 199.647mV, and an Output Voltage of 3.618 Volts:

$$\frac{3.618 \text{ Volts}}{199.647\text{mV}} = 18.1$$

This figure of 18.1 is the new gain with a capacitor installed.

Two Stage Amplifier

To produce a multisim simulation of a two stage amplifier with an overall gain of 50 we have to work out how much gain we need from our second amplifier.

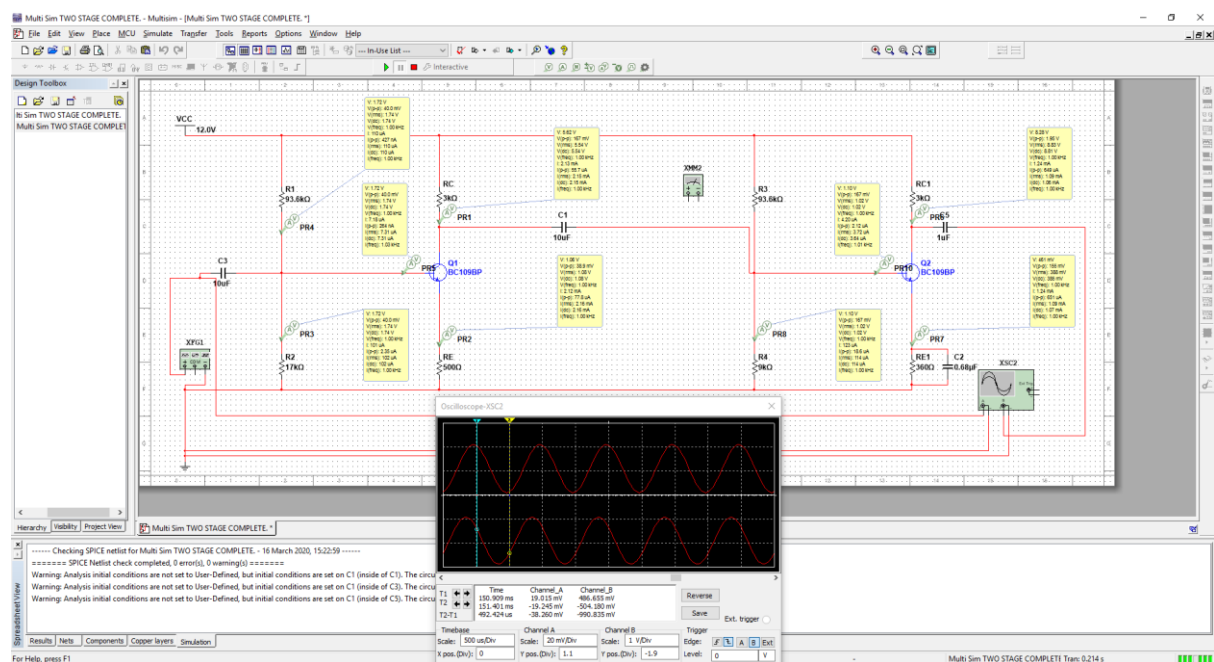
$$\text{Amplifier 1 Gain} \times \text{Amplifier 2 Gain} = \text{Overall Amplifier Gain}$$

We can transpose this to:

$$\text{Overall Amplifier Gain} / \text{Amplifier 1 Gain} = \text{Amplifier 2 Gain}$$

$$50 / 6 = 8.33$$

The gain we need from our second stage amplifier is 8.33.



Analysis

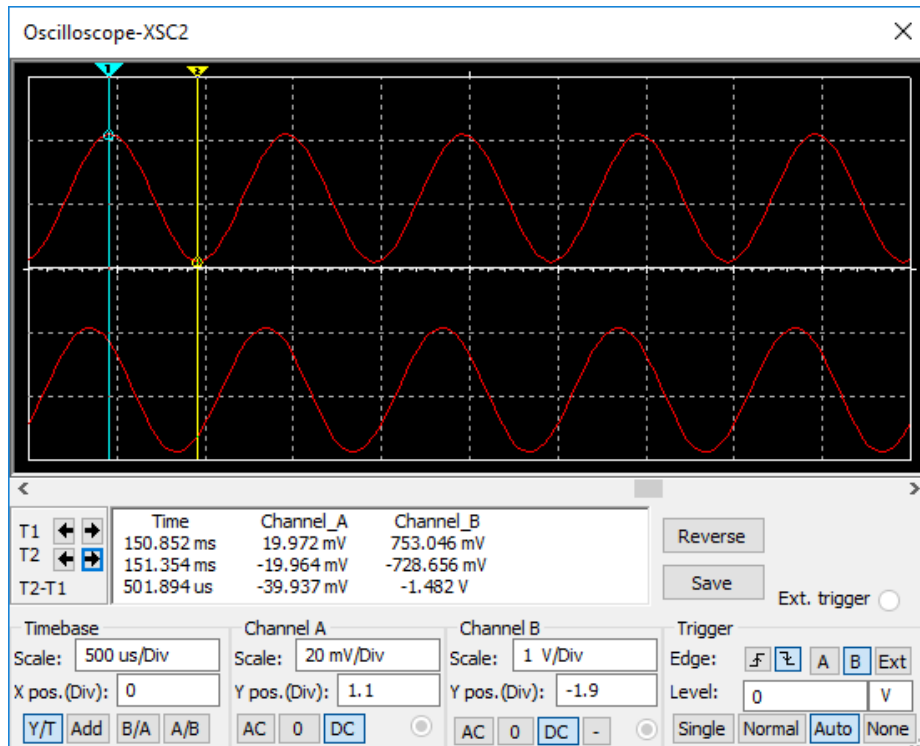
Channel A = 40mV Peak 2 Peak

Channel B = 1.940v Peak to Peak

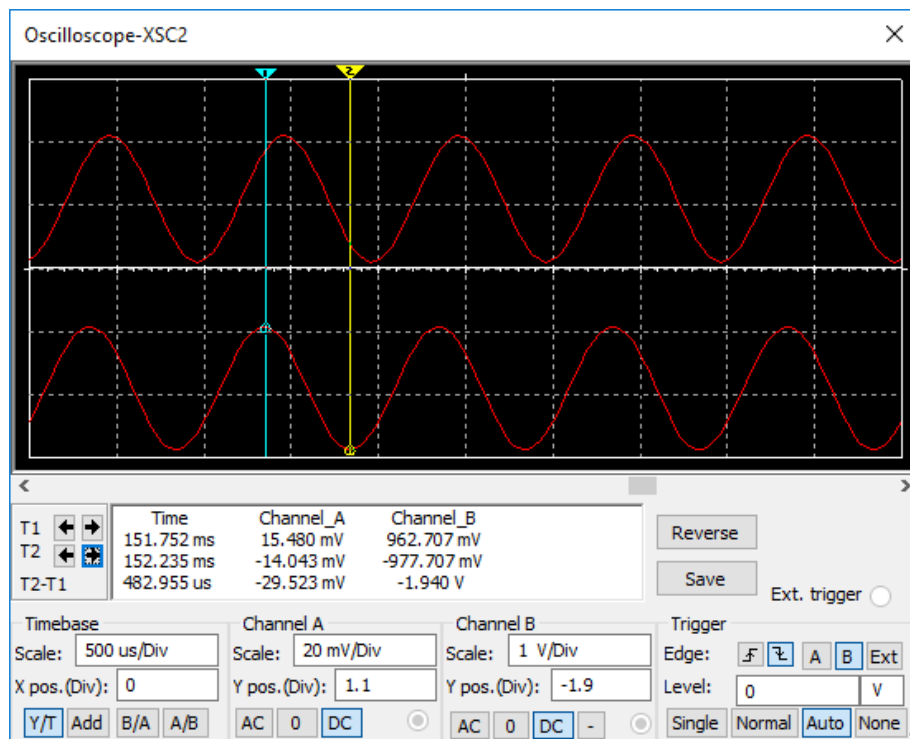
$$1.940 \text{ Volts} / 0.4 \text{ Volts} = 50$$

The following two screenshots magnify the results above:





Channel A = 40mV

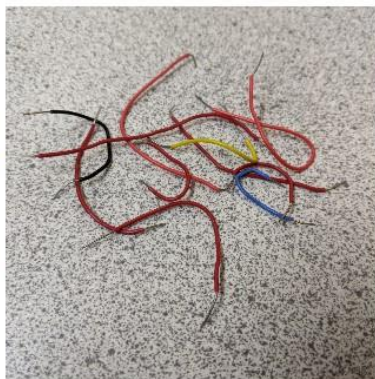
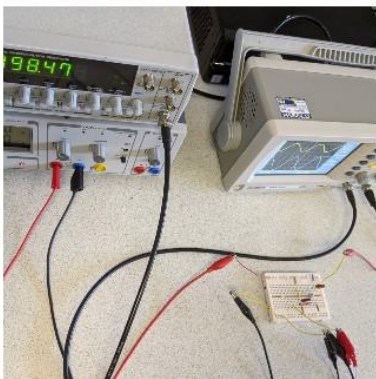
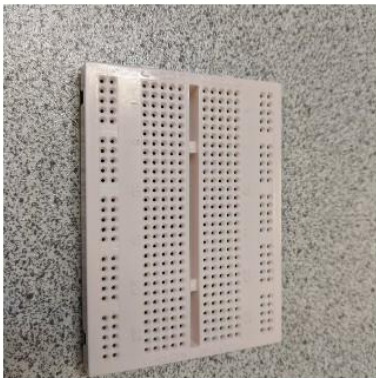


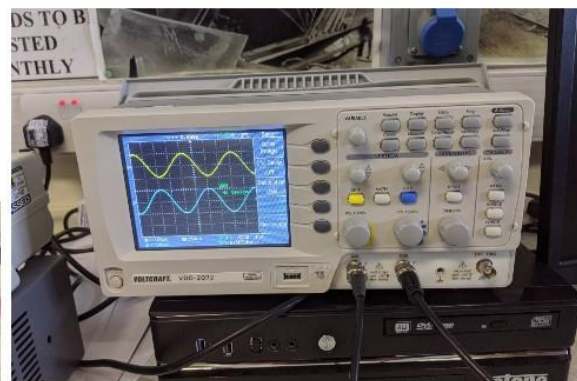
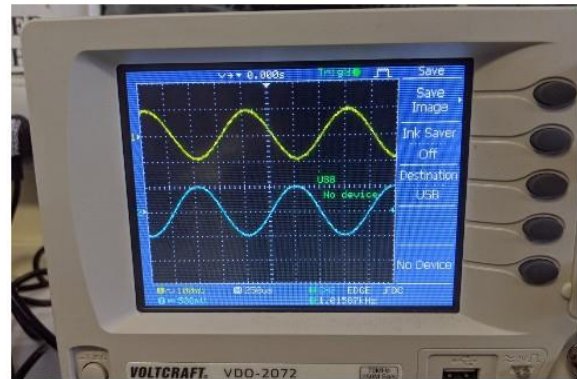
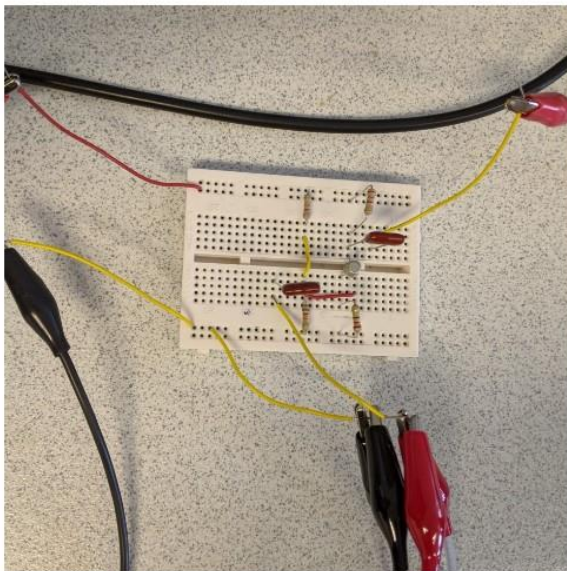
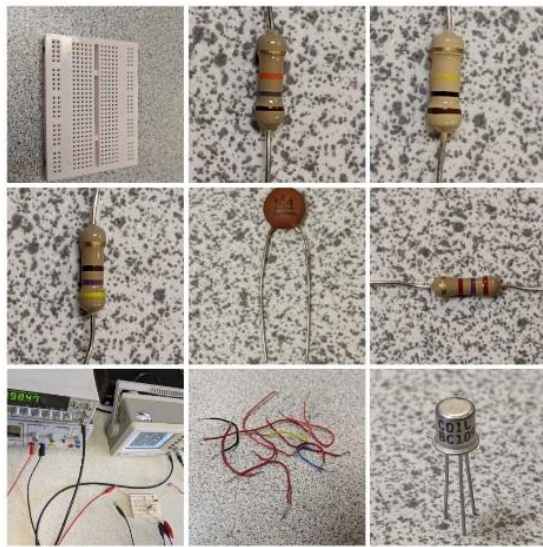
Channel B = 1.940 V

Building the Circuit: Equipment and Apparatus

To build my test circuit board, I used the following components and apparatus:

- Bread Board
- Capacitor
- Transistor
- Various Resistors
- Cable
- Oscilloscope
- Power Generator

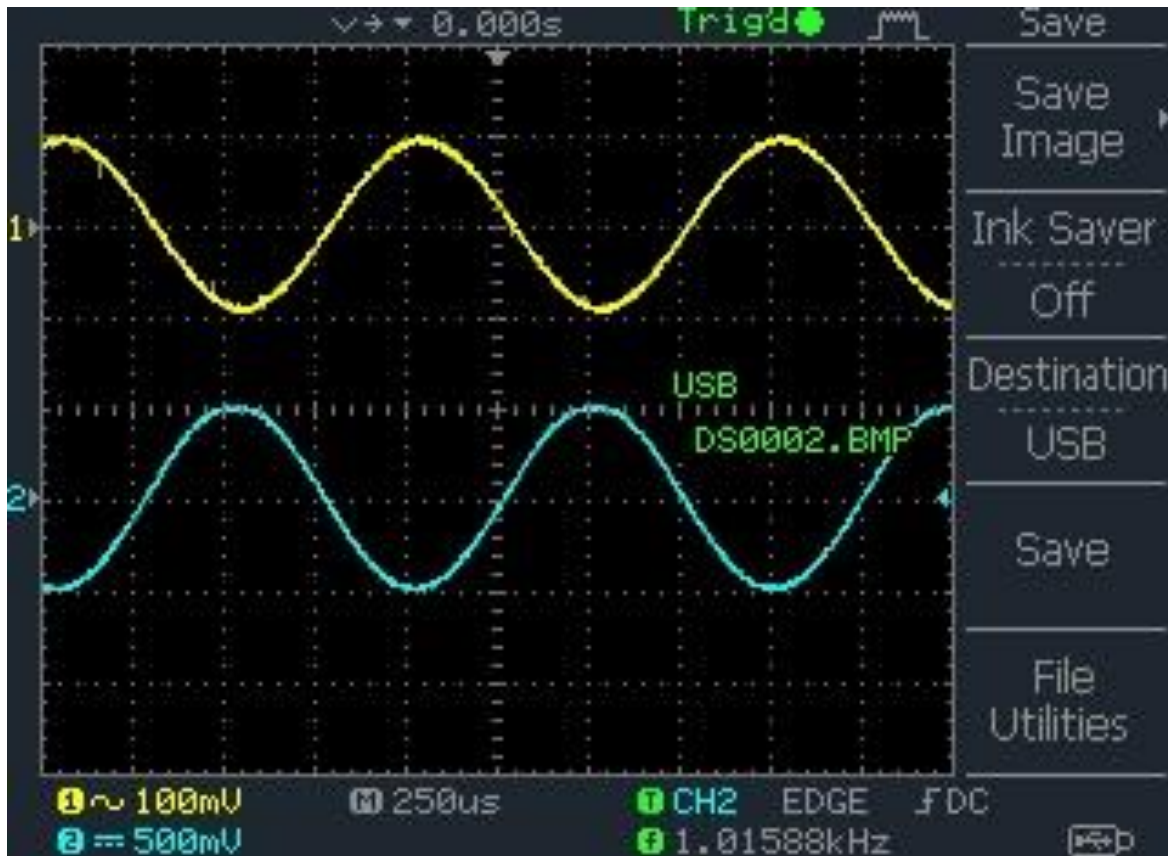




Building the Circuit: Experimental Procedure / Methodology

Fit the transistor, the four resistors and the capacitor in place on the breadboard together with the necessary wire links. Then after thoroughly checking all of the connections are correctly fitted connect the power generator, switch on and use the Oscilloscope to measure the voltage at Input and Collector

Building the Circuit: Analysis and Results



If we apply the gain formula to the above Oscilloscope readings:

$$\frac{\text{Output Voltage (Channel B)}}{\text{Input Voltage (Channel A)}}$$

∴ If we divide 500mV by 100mV we will find our circuit gain for our built circuit.

$$\frac{500 \text{ mV}}{100 \text{ mV}} = 5$$

The gain of 5 is less than the required gain of 6 due to having to use the nearest corresponding Resistor in the circuit. Once we calculated the appropriate size needed of Resistor, we were able to simulate the circuit within multisim with the calculated values for the Resistors, but when we built our circuits, we had to use the nearest possible size of resistor available off the shelf. This is the reason for the lower than expected gain.

- 2.7kΩ Resistor closest to 3kΩ Resistor
- 470Ω Resistor closest to 500Ω Resistor
- 100kΩ Resistor closest to 93.6kΩ Resistor
- 18kΩ Resistor closest to 17kΩ Resistor

Conclusions

In conclusion, the relationship between the Collector Resistance and the Emitter Resistance governs the gain of the amplifier. The resistances of R1 and R2 govern the Bias point of the Transistor.

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