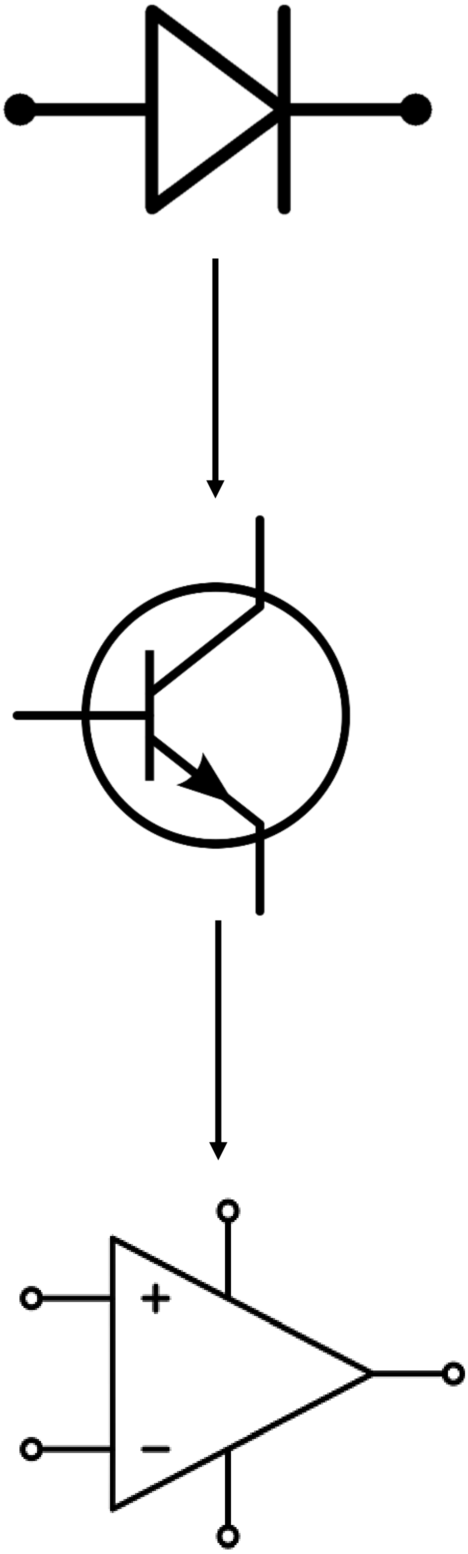
2021



BTEC

Analogue electronic devices and circuits

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Number:

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Class:

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Contents table

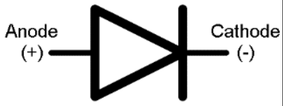
Task 1

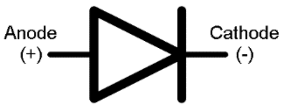
A) Diode Circuits

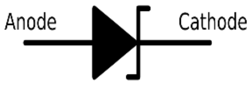
Task i
Identify different types of diodes and their uses

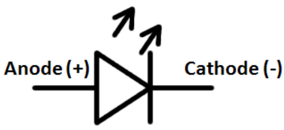
What are diodes: *Diodes are electrical components that have block electrical flow and have high resistance on one end and allow current to pass and have low resistance on the other. That is due to the conductive side using N-type extrinsic semi-conductors and the insulated side using P-type extrinsic semi-conductors.*

Different types of diodes:

Signal diodes		
	*Specifications*	*Uses*
	A signal diode requires 0.7 volts for electrical current to flow through it in forward bias/voltage, and it cannot operate in reverse bias.	*Signal diodes are used in application that work with low voltage and current (100mA), and are mostly used as rectifier switches and current limiters.*

Power diodes		
	*Specifications*	*Uses*
	Power diodes are similar to signal diodes in which they both have a forward voltage of 0.7V and don't work in reverse bias, except that power diodes can block larger voltages	*Power diodes are used in applications that require the use of high voltage and current. Said applications are battery charging, DC power supplies, and rectifiers.*

Zener diodes		
	*Specifications*	*Uses*
	These types of diodes work with a forward voltage of 0.7V, but they also work in reverse bias at a reverse voltage of -1.8V and higher.	*Zener diodes are used as voltage regulators due to them being able to make a reverse voltage constant. They're mostly seen in AC to DC power supplies.*

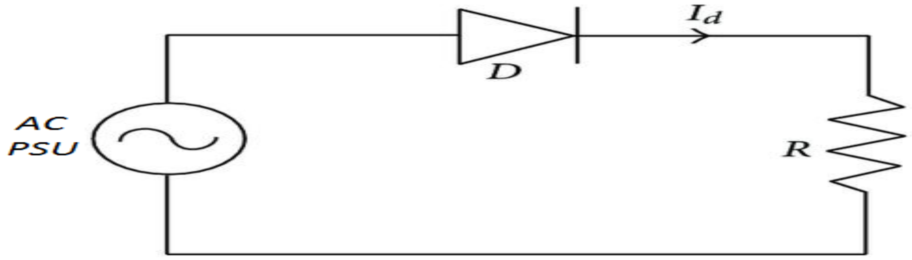
Light emitting diode		
	*Specifications*	*Uses*
	LEDs have a forward bias of 2V and emit light when electrical current flows through the component, LEDs also have a reverse voltage of -3V	*These diodes are mostly used for electrical current flow testing and prototyping, and for light works and illumination related applications.*

Task ii
Construct a schematic of a diagram of and simulate the operation of a diode as a half-wave rectifier

What are rectifiers?

A rectifier is a type of circuit used to convert alternating current to direct current.

Half-wave rectifier

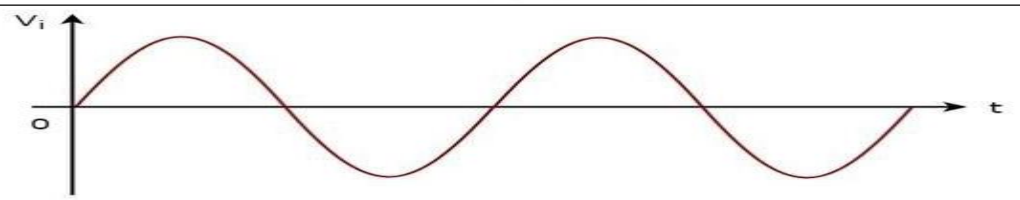


A half-wave rectifier makes use of one diode only, the way it works is that during the positive AC cycle, electrical current would simply flow through the conductive terminal of the diode, and because of that, the diode would just act as a closed switch for the current to pass through, however, during the negative AC cycle, the flow of current would be blocked as it would not be able to pass through the insulative terminal of the diode since said terminal would act as an open switch. Thus, AC gets turned into a form of DC known as pulsating direct current, and in which, the positive cycle fluctuates and is very unstable, not only that, but with the use of a half-wave rectifier, only one cycle of the alternating current would be utilized while the other going completely unused.

Due to the dissipation of the other half of the AC cycle (which is how half-wave rectifiers got named), half-wave rectifiers are rather inefficient, and due to that, they're rarely used practically nowadays and are only employed in special applications where one cycle would be required for the function of the circuits such as soldering iron circuits, low power battery chargers, and pulse generators.

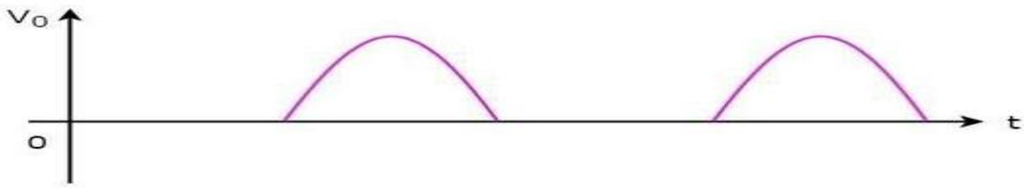
AC signal

The AC's signal before being before going through a half-wave rectifier



Signal after half wave rectifier

The signal within a half-wave rectifier; the flat sections are during the negative cycle of the AC

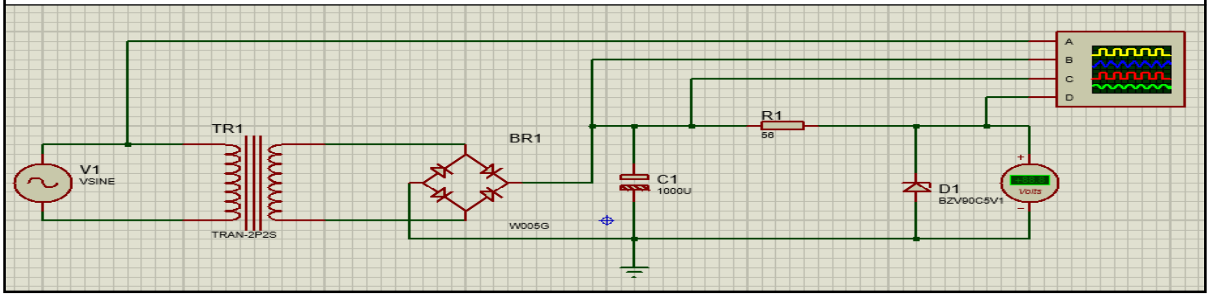


Task iii

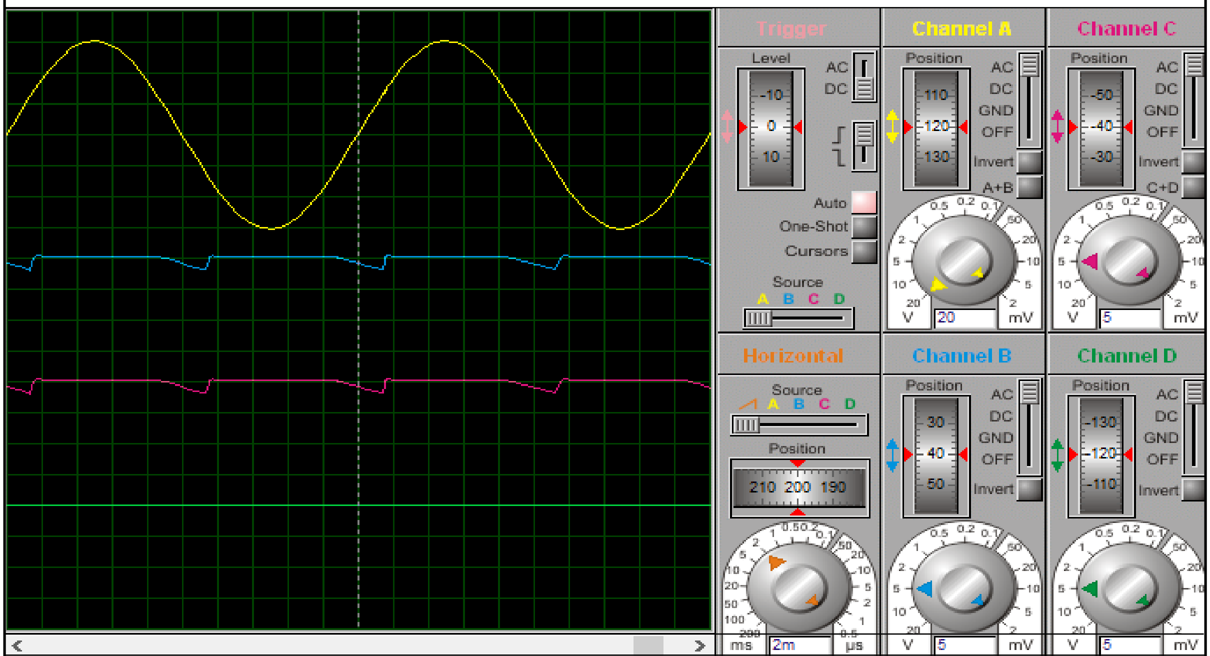
Develop the circuit schematic and simulation to a full-wave rectifier with capacitor smoothing and Zener diode voltage regulation.

Circuit Schematic

The following circuit is an AC to DC converted. The first section shows current flowing through a full-wave bridge rectifier, said rectifier negates negative side of the signal, which consequently generates pulsating DC signals. From then on, a capacitor known as a filter which charges and discharges the signal quickly, causing a ripple effect and somewhat smoothing out the signal. Finally, the signal goes through a voltage regulator made up of a Zener diode and a resistor, which smoothens out the ripple signal and creates a Direct Current.



Results



Output voltage: $\mathbf{5.36V}$

Verdict

The channel A signal is the one taken from the input, where no effect was done to the AC signal. After that, the second signal is the one after the full-bridge wave rectifier, the signal should have looked like pulsating DC signals that occur on the positive side, however certain technical issues occurred with the utilized software. After which is the ripple voltage signal, which is caused by the quick charging and discharging of the capacitor. Finally, the signal outputted by channel D is of the fully transformed DC signal.

Task iv, v, & vi

Build a prototype for your final circuit, record the output voltage, and estimate the voltage ripple for different loads.

The mentioned tasks were done in separate worksheets that should be attached on/included with the report.

Task vii

Compare the results from theory, simulation, and measurement

Comparison

When comparing the simulation to the practical done and the overall measurements that were deduced during both, there certainly are come discrepancies, with the main ones being in the rectified and filtered signal. That is the case since the rectified signal shown in the simulation should – as stated earlier – look like pulsating DC signal, probably due to certain technical issues, said signal looks more like the a filtered one. In terms of the filtered signal, the ripple voltage does look relatively odd due to the fact that there are huge spaces where the line is straight, whereas normally the signal would be constantly going upwards and downwards. However, with all that has been said, the final voltage found in the simulation was 5.36V, with the one in the practical being 5V exactly, which is a relatively small difference. As such it can be deduced that the final issue related to the signals is merely a visual one rather than one that effected the final outcome.

Task A References

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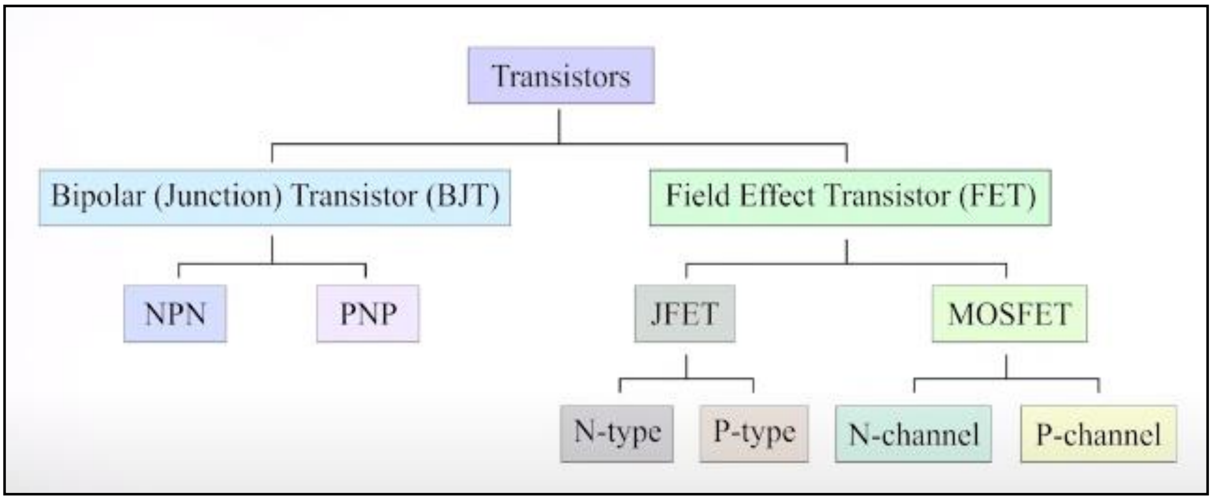
B) Transistor Circuits

Task i

Identify different types of transistors and their uses

What are transistors: *Transistors are a three terminal electrical component that utilizes N-Type and P-Type semiconductors to function and are used as either switches or amplifiers for an electrical circuit.*

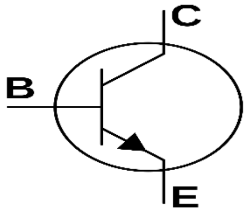
Different type of transistors:



BJT transistors

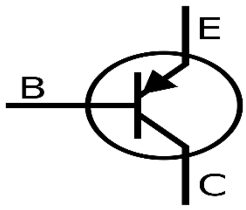
The middle terminal in a BJT transistor is known as the Base (B), while the ones in the side are known as the Collector (C) and the Emitter (E), there are two BJT transistors, NPN and PNP.

NPN transistor



An NPN transistor is a transistor in which current flows into the transistor through the base and collector, and goes out of it through the third terminal, which is the emitter ($I_E = I_C + I_B$). The Collector and Emitter are made with the use of N-Type semiconductors, while the Base is made out of a lightly doped P-Type semiconductors (hence the name NPN).

PNP transistor



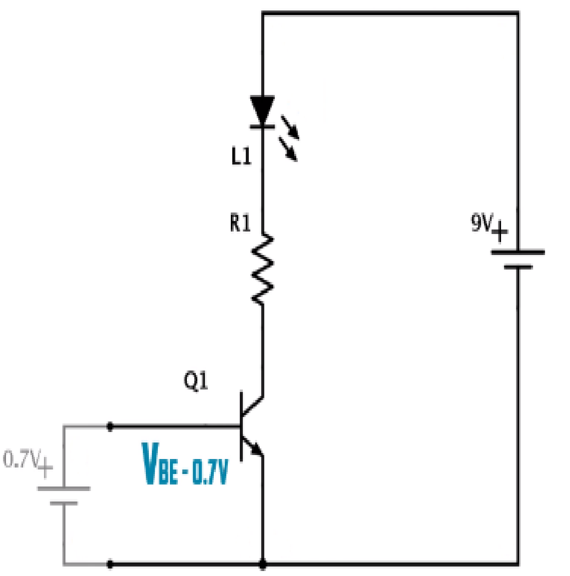
A PNP transistor is the opposite of an NPN one in that the Collector and Emitter terminals are made out of P-Type semiconductors while the base is made out of a lightly doped N-Type semiconductors (Which is why it's called PNP). And current flows into it the transistor through the emitter and out of it through both the base and collector.

Theory behind BJT transistors

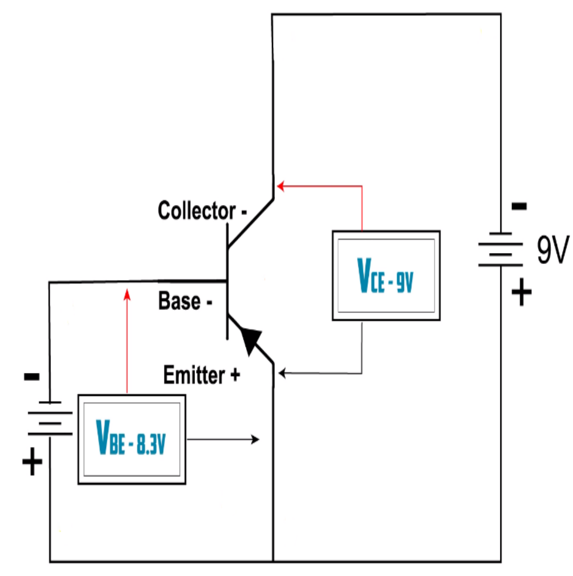
The way that the NPN transistor works is that when a positive voltage is applied to the collector in reverse bias, no electrical flow would occur since the electrons at the emitter won't be able to pass through the depletion region in the middle – which is the base – to get to collector side. However, if a minimum positive voltage of 0.7V known as the input voltage is applied to the Base, this would cause the VBE (base and emitter connection) to be forward biased, allowing for the flow of electrons from the emitter to pass the lightly depletion region of the base, causing it to push through and go the other side (the collector's side), which thus leads to the flow of electrons through the transistor. This can be used as a means of an automatic electronic switch.

The same concept could be applied to a PNP transistor with the difference between that with a PNP transistor the electrical signal is working with holes, rather than electrons, meaning the positive voltage would have to be applied to the emitter, and the Collector and Base would have to be connected to the negative side of the power source. Also, unlike an NPN transistor, for an NPN transistor, a difference of 0.7V between the VCE and VBE (VCE = 12V & VBE = 11.7V or less) would have to be applied, rather than only 0.7V through the VBE like in an NPN transistor.

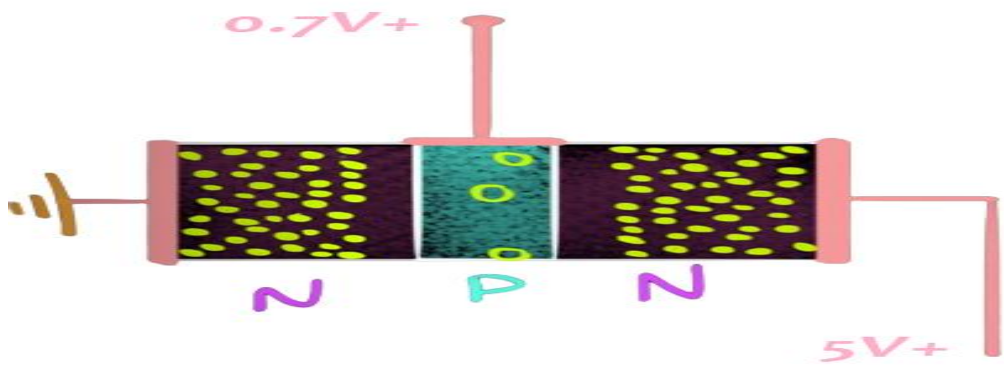
NPN schematic diagram



PNP schematic diagram



NPN SEMI diagram



FET transistors

FET transistors consists of the middle terminal known as the Gate, which is equivalent to the Base in a BJT transistor, and the side pins which are known as the Source and Drain, which are equivalent to the Collector and Emitter. There are two different types of FET transistors, with them being called JFETs and MOSFETs, each with their separate subtypes as well, with P-JFETs and N-JFETs for JFET transistors and D-MOSFETs and E-MOSFETs for MOSFET transistors.

JFET transistors

Theory & Function

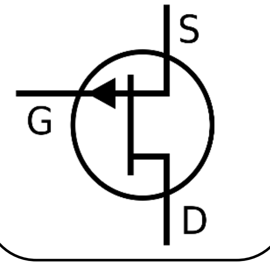
A JFET transistor is able to act as a way of restricting or cutting off the flow of current with the use of a depletion region.

In an N-JFET, the space in the middle – also known as the channel – between the Source and collector is made with the use of an N-Type semiconductor, which consists of the majority of the transistor, however the Gate and the region opposite to it is made out of a P-Type semiconductor, which the exact opposite being true for P-Type semiconductors.

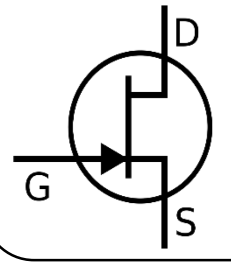
If an N-JFET transistor were to be used, and a positive voltage were to be applied to the Source, current would pass through normally as if in an open switch, however, if the Gate were to be connected to the negative terminal of the power source at the same time, this would cause the holes at the Gate to be pushes away, as such pushing through the of the transistor, which causes a depletion region to form in the middle, thus restricting the flow of current. The magnitude at which this occurs is dependent on the voltage difference between the voltage going through the Source and the voltage going through the Gate, with the higher the difference being leading to a bigger depletion region and less current flowing through.

Same idea could be applied for P-JFETs with the only difference being that positive voltage would be applied to the Gate and negative to the Source.

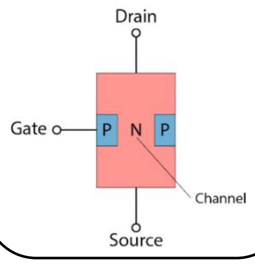
N-JFET: Symbol



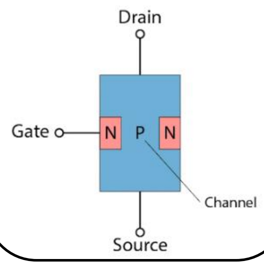
P-JFET: Symbol



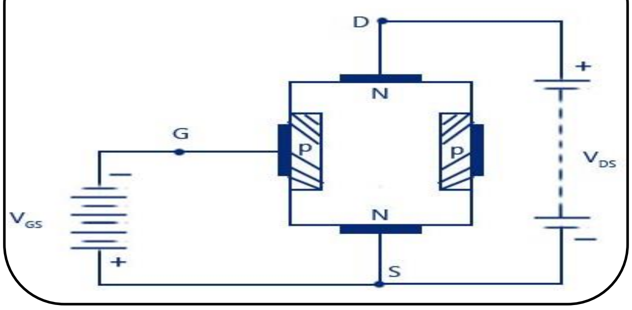
N-JFET SEMI diagram



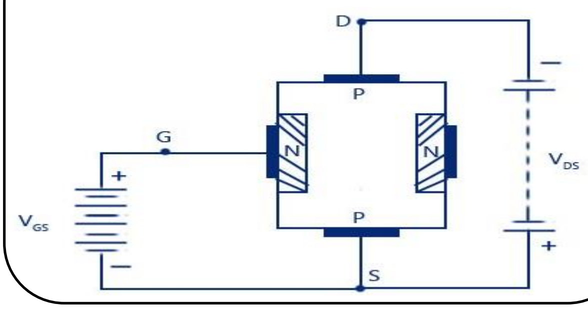
P-JFET SEMI diagram



N-JFET diagram schematic



P-JFET diagram schematic



MOSFET transistors

MOSFET transistors have 2 different subtypes, as mentioned earlier, they are D-MOSFETs and E-MOSFETs, however, both of them also have their own subtypes, with P-channel and N-Channel D-MOSFETs and P-channel and N-Channel E-MOSFETs

D-MOSFETs Theory & Function

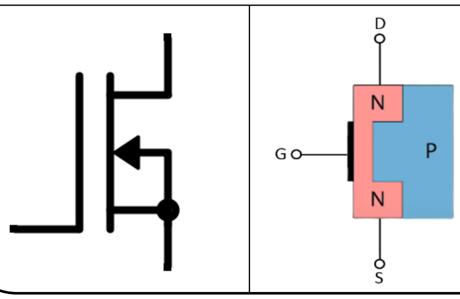
D-MOSFETs have two operational modes, one being known as depletion mode with the other being known as enhancement mode.

In depletion mode, D-MOSFETs act the same way as JFET transistors. N-Type D-MOSFETs have a bridge made out of an N-Type semiconductor also known as the channel which is connecting both the Drain and the Source together. As such, if voltage was applied through the Drain, electrical current would flow through it. However, if gate were to be operated in reverse bias, a depletion region would form due to the biasing pushing the hole of the P-Type semiconductor towards the channel, which thus decreases the size its size and causes the flow of current to either completely break off or is restricted with the bigger the voltage being applied, the higher the restriction.

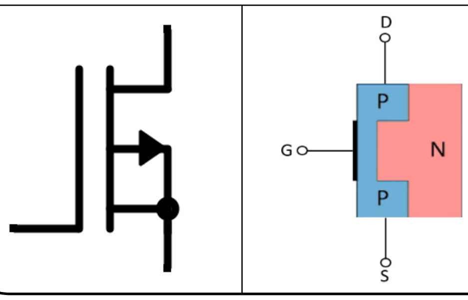
In enhancement mode, the difference lies within the biasing of the gate, as in the gate is forward biased rather than reverse biased. This has the opposite effect, in that it causes the electrons in the free electrons N-Type material to push away from the gate, causing them to move towards the right side of the transistor (As seen in the enhancement mode diagram), which thus leads to the widening of the channel and causes more current to flow.

The aforementioned transistor that was used to explain the theory was an N-Channel D-MOSFET, however the same concept could be applied with a P-Channel D-MOSFET with the only difference being the utilization of the opposite biases than that of N-Channel D-MOSFETs.

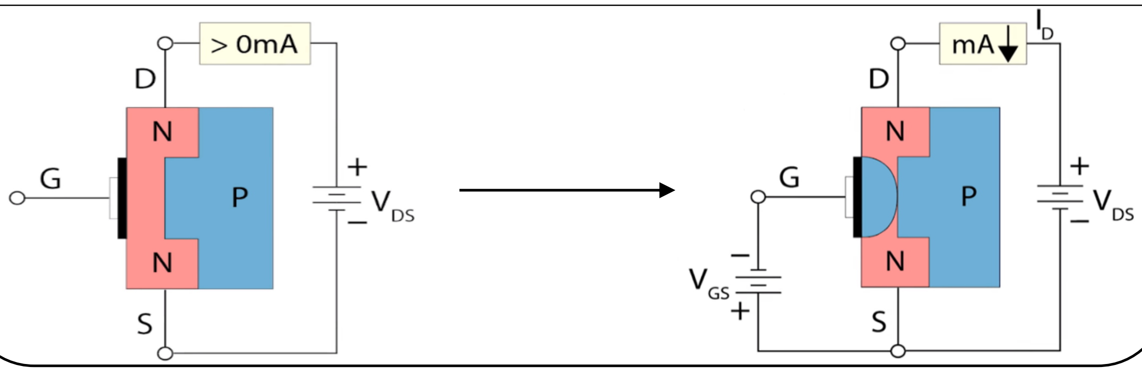
N-Channel D-MOSFETs



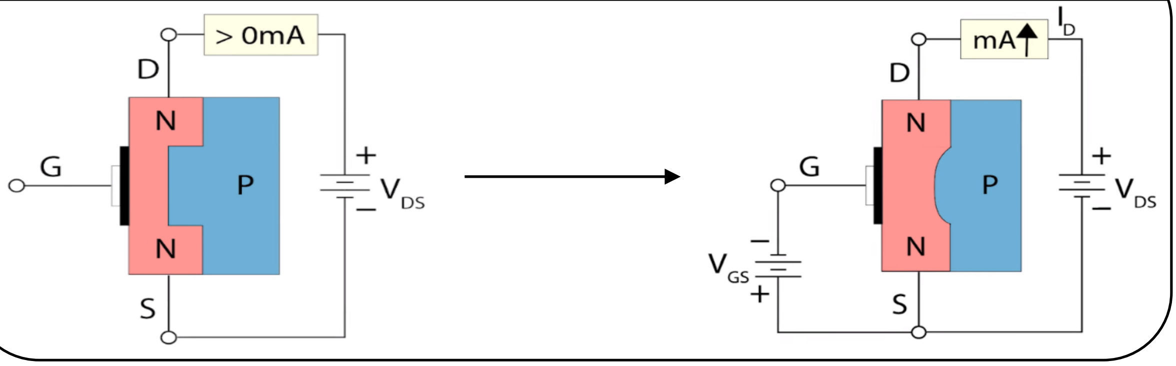
P-Channel D-MOSFETs



Depletion mode



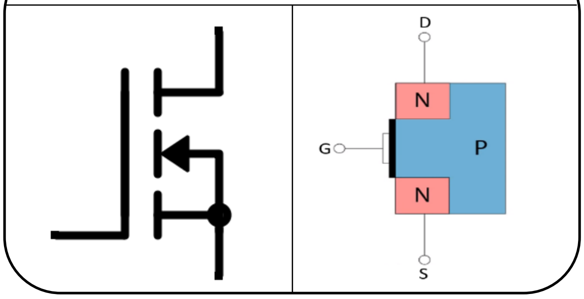
Enhancement mode



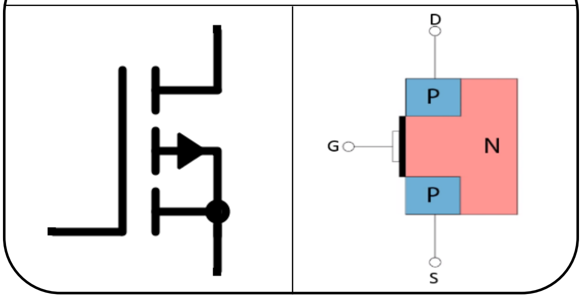
E-MOSFETs Theory & Function

In contrast to D-MOSFETs, E-MOSFETs do not possess a channel connecting the Drain with the Source (As shown in the diagram below), meaning that if voltage were to be applied to the Drain, thus during E-MOSFETs default state, current does not flow through the component. For current to flow, a voltage would have to be applied to gate to activate enhancement mode which – unlike D-MOSFETs – is the only mode that E-MOSFETs operate on, said enhance mode functions in the same manner as the enhancement mode of D-MOSFETs, as such, for the sake of avoiding repetition, enhancement mode would not be explained again in this section.

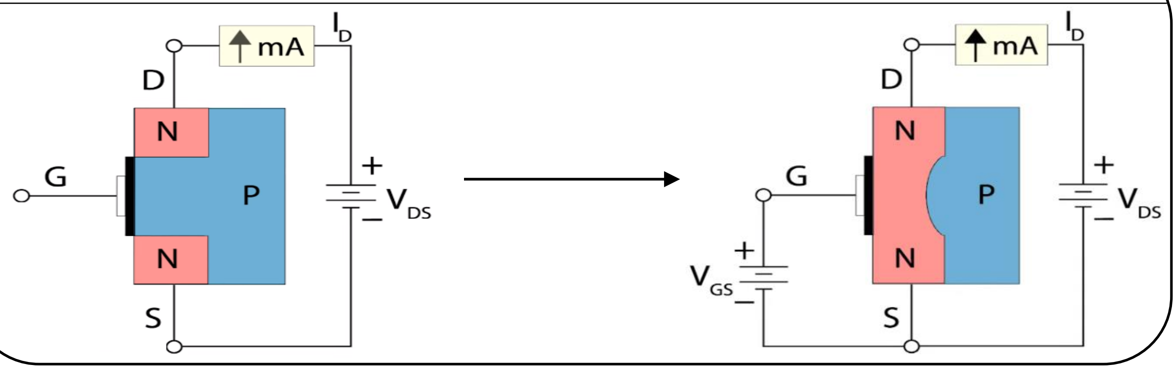
N-Channel E-MOSFETs



P-Channel E-MOSFETs



E-MOSFETs enhancement mode

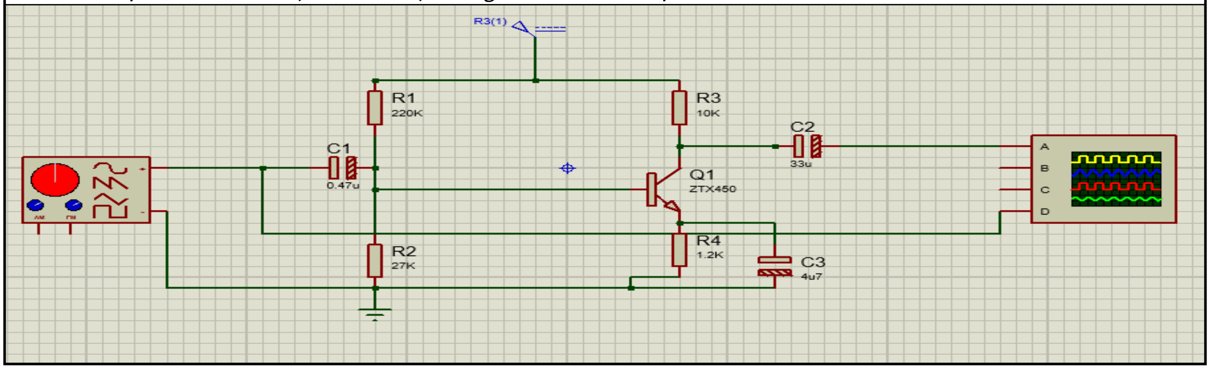


Task ii

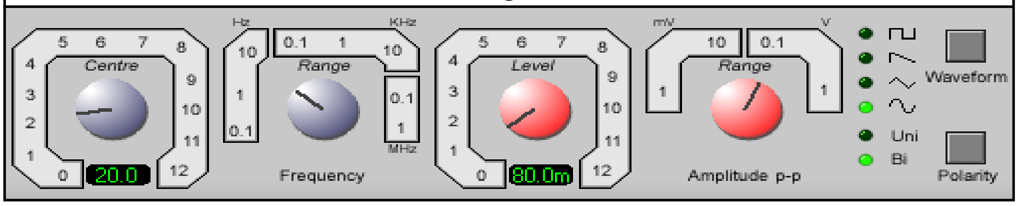
Construct the schematic circuit of a common emitter amplifier in your ECAD package

Circuit schematic

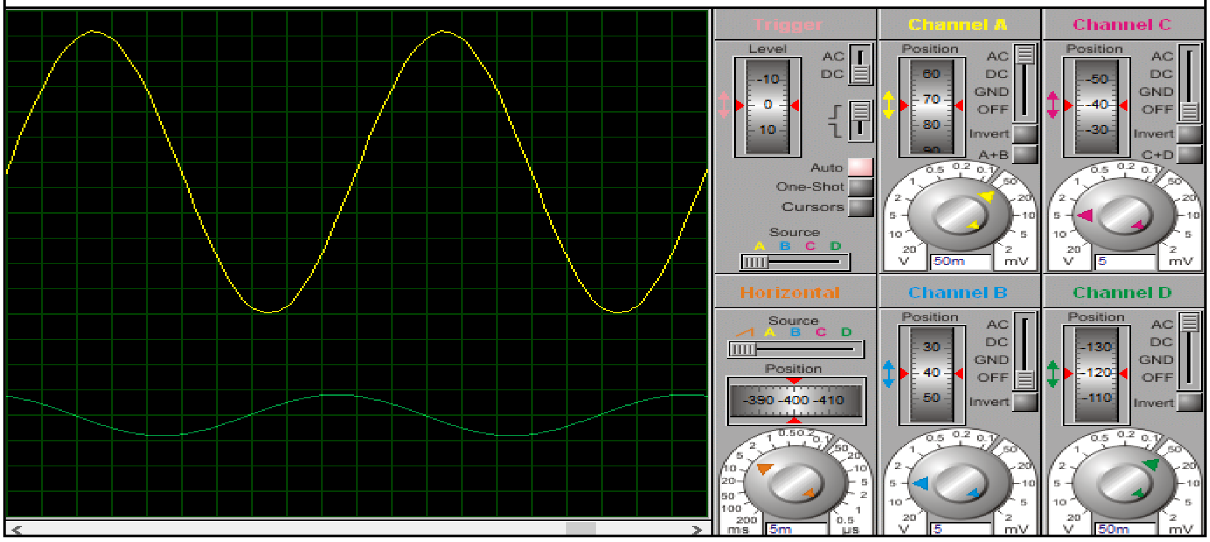
The following circuit represents an NPN common emitter amplifier transistor circuit, meaning that emitter sends signals back towards the input as well as going towards the output. Said circuit also utilizes 3 resistors and two capacitor for the input, two of said resistors and one of the capacitors are connected immediately the base with the other being connected to the collector. In terms of the output, a single resistor and capacitor are connected to the output, with both of them also feeding back into the input.



Function generator



Results



Verdict

Due to the fact that the utilized circuit is built with a common emitter configuration, this results in the function of the circuit being an amplifier, which can be noticed from the given results in that the output's voltage is at 9 volts (1.8 x 5), while the input is at 0.56 volts (11.2 x 0.05), with the gain ratio being around 16.07 (9/0.56).

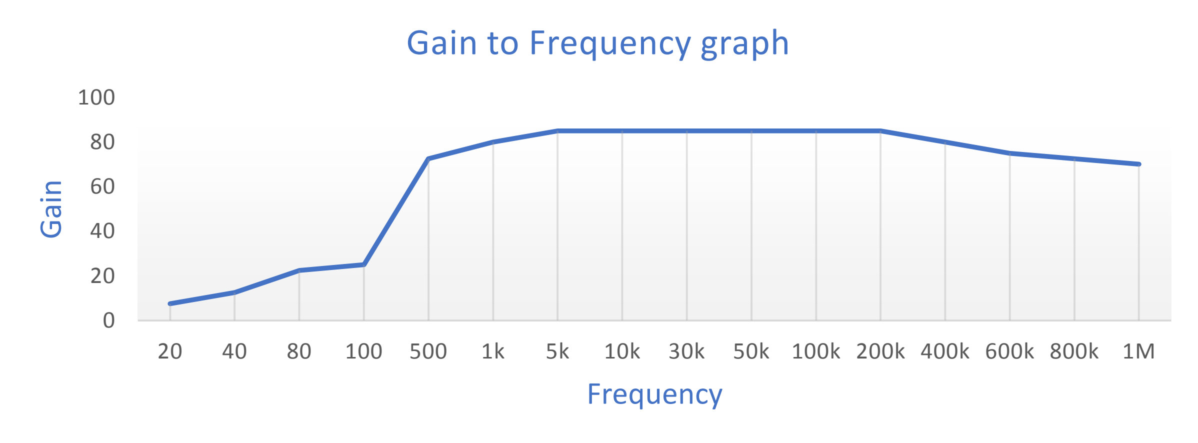
Task iii

Use the schematic to simulate the behaviour of the circuit with a low voltage sine wave input signal of frequency 1 kHz. Adjust the amplitude of the input voltage to give the largest undistorted output voltage.

Frequency (Hz)	$V_{in}(v)$	$V_{out}(v)$	Gain
20	0.04	0.3	7.5
40	0.04	0.5	12.5
80	0.04	0.9	22.5
100	0.04	1	25
500	0.04	2.9	72.5
1k	0.04	3.2	80
5k	0.04	3.4	85
10k	0.04	3.4	85
30k	0.04	3.4	85
50k	0.04	3.4	85
100k	0.04	3.4	85
200k	0.04	3.4	85
400k	0.04	3.2	80
600k	0.04	3	75
800k	0.04	2.9	72.5
1M	0.04	2.8	70

Task iv

Investigate how the voltage gain changes with frequency between 1 kHz and 1 MHz



Theory

As can be observed from the gain to frequency graph, the gain's value initially increases rapidly, after which – at 5kHz – the gain ceases to increase and becomes constant up until 200k Hz, in which the gain actually starts to decrease. The reason for said decrease is that the increase in frequency causes the capacitive reactance to decrease due to it being inversely proportional to the frequency, which thus leads to a decrease in voltage, and consequently, a decrease in the gain.

Task v
Build a prototype of the final circuit and measure the voltage gain for the same frequency range.

The mentioned task was done in separate worksheets that should be attached on/included with the report.

Task vi
Compare the results from theory, simulation, and measurements

End result comparison of experiment to simulation

When comparing both the gain and overall voltage values received in the experiment and the values received from the simulation that was ran, it can evidently noticed that there is a significant difference, with the simulation gain values being 1kHz and 1MHz being 80 and 70 and the practical experiments being 50 and 10.71. No reasonable explanation to why said difference has occurred was found, as such it can be concluded that there had to have been some technical occur that occurred with the circuit development software that was being utilized, which is Proteus. That is the case since multiple verification checks were done to the plethora of circuits that were made, with all of them having been connected properly, and even with the ones that were slightly off, fixing them only caused little difference in the end result. As well as that, the gain's value is generally much lower than what was shown in the simulation. It should be noted however that the utilized resistors for the experiment were a bit different than the one used in the simulation due to none of said resistors being available at the time. Nevertheless, the difference in the resistor's was very small, and would not have caused a very noticeable impact on the final outcome either way.

Task B References

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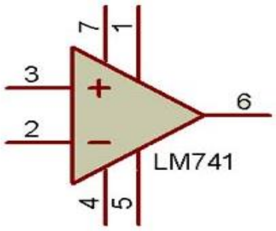
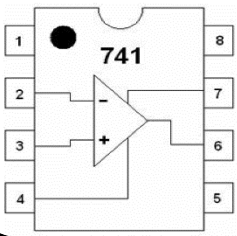
C) Operational amplifiers

Task i
Identify the pin-out of an operational amplifier and relate it to the schematic diagram

What are operational amplifiers: *Operational amplifiers, commonly called op-amps, are integrated circuits used to amplify a circuit used – as the name indicates – amplify voltage that flows through the component. Op-amps are known for having extremely high voltage gain, to put it into perspective, some common op-amps can create voltage gains of over 100,000. The operational amplifier that is specifically going to be discussed and used in the following report is the LM741 IC op-amp.*

Op-amp pins (LM741)

Symbol 	**1**	***Offset null:*** *Allows for the balance of the output voltage by removing any fluctuation in the signal*
	2	***Inverting input:*** *Used to apply the input voltage that would determine if the signal is going to be inverted.*
	3	***Non-inverting input:*** *Used to apply the input voltage which leads to the output signal's cycle being the same as the input's one.*
	4	***Negative VCC:*** *This terminal is connected to ground; used to turn on the op-amp with relevance to the positive VCC.*
Diagram 	**5**	***Offset null:*** *Has the same function as pin 1 of controlling any fluctuation in the output.*
	6	***Output:*** *The terminal in which the amplified voltage is going to be outputted.*
	7	***Positive VCC:*** *Connected to the positive terminal of the power supply and is used to turn on the op-amp.*
	8	***No connection:*** *The pin is not shown in the symbol as it does not affect the internal circuit and has no use but symmetrize the component*

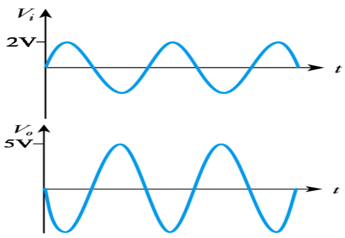
The circuit of inverting and non-inverting op-amp modes

An op-amps is initially turned on by connecting the positive end of a power supply unit to pin 7, while the negative end is connected to pin 4. After which, a separate voltage source is connected through either the inverting (pin 2) or non-inverting (pin 3) terminals , this connection which allows for the user to determine whether the output's signal is going to be the same or opposite to that of the input signal's phase. Said operation is determined via which terminal is grounded, in that if the non-inverting terminal were to be grounded, and a voltage source was connected through the inverting terminal, the output would have a 180° phase difference to the input signal (Input = positive side ∴ output = negative side). With the opposite being true if the inverting terminal were to be grounded, meaning that the output would be in the same phase as the input. In addition, in the inverting mode two resistors are connected with one being before the inverting terminal and the other after it and is connected to the output. And in the non-inverting mode, the two resistors are connected after the inverting terminal and after the output, with resistor after the terminal being the connection of the terminal to ground, the non-inverting circuit is also known for being a feedback loop.

Inverted signal

Input:

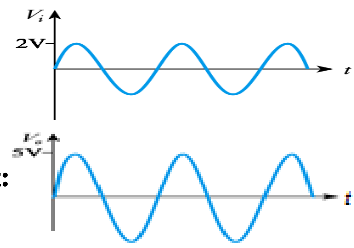
Output:



Non-inverted signal

Input:

Output:

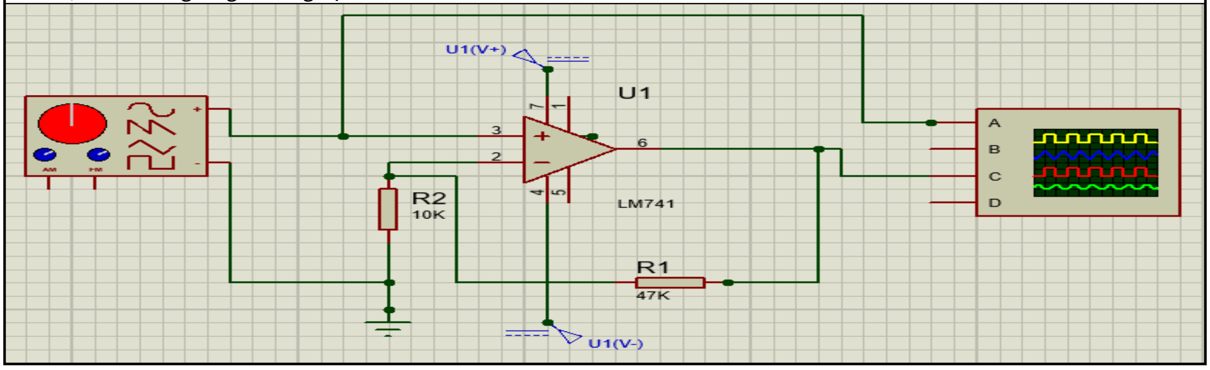


Task ii

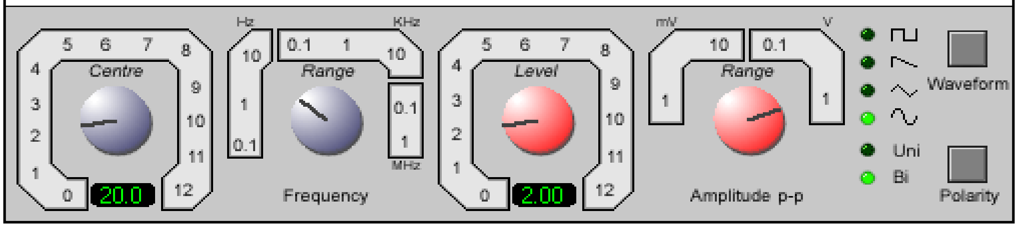
Simulate inverting and non-inverting amplifier applications of an operational amplifier, noting the effect of the resistor values on the voltage gain.

Non-inversing Schematic diagram 1

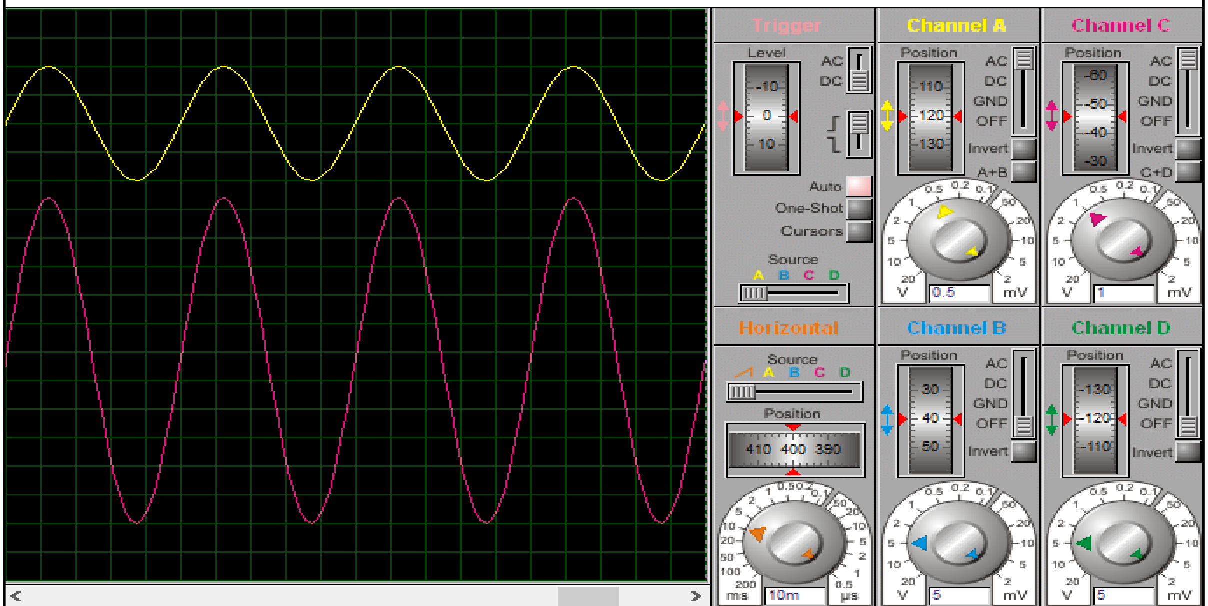
The following shows a non-inversing op-amp circuit, which can be deduced with the fact that the inversing terminal is grounded. It also should be noted that the utilized resistors for the circuit are 47k for Rf and 10k for Rin, and 9 and -9 volts are going through pins 7 and 4.



Function generator



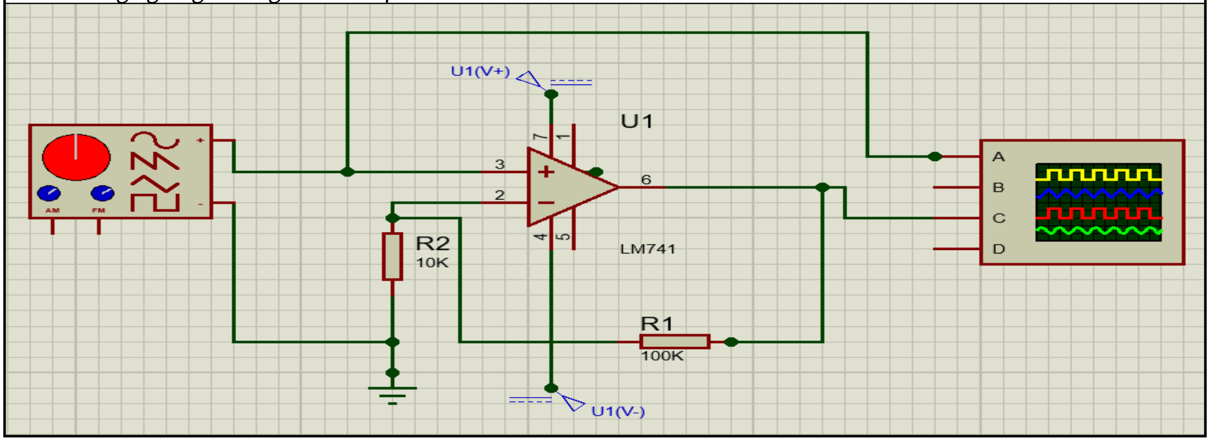
Results



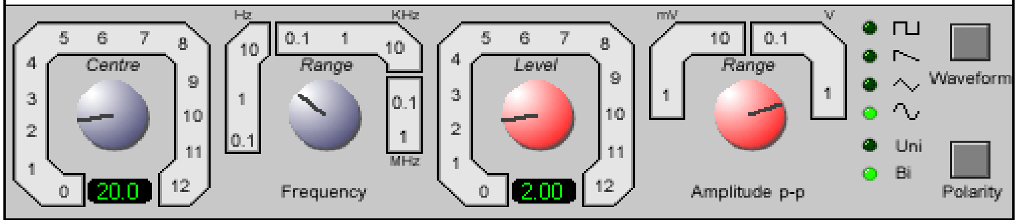
Resistance	*Vin*	*Vout*	*Gain*
$\mathrm{Rf} = 47\mathrm{k}\Omega$ $\mathrm{Rin} = 10\mathrm{k}\Omega$	$\frac{4 \times 0.5}{2} = 1\mathrm{V}$	$\frac{11.4 \times 1}{2} = 5.6\mathrm{V}$	$\frac{5.6}{1} + 1 = 6.6$

Non-inversing Schematic diagram 2

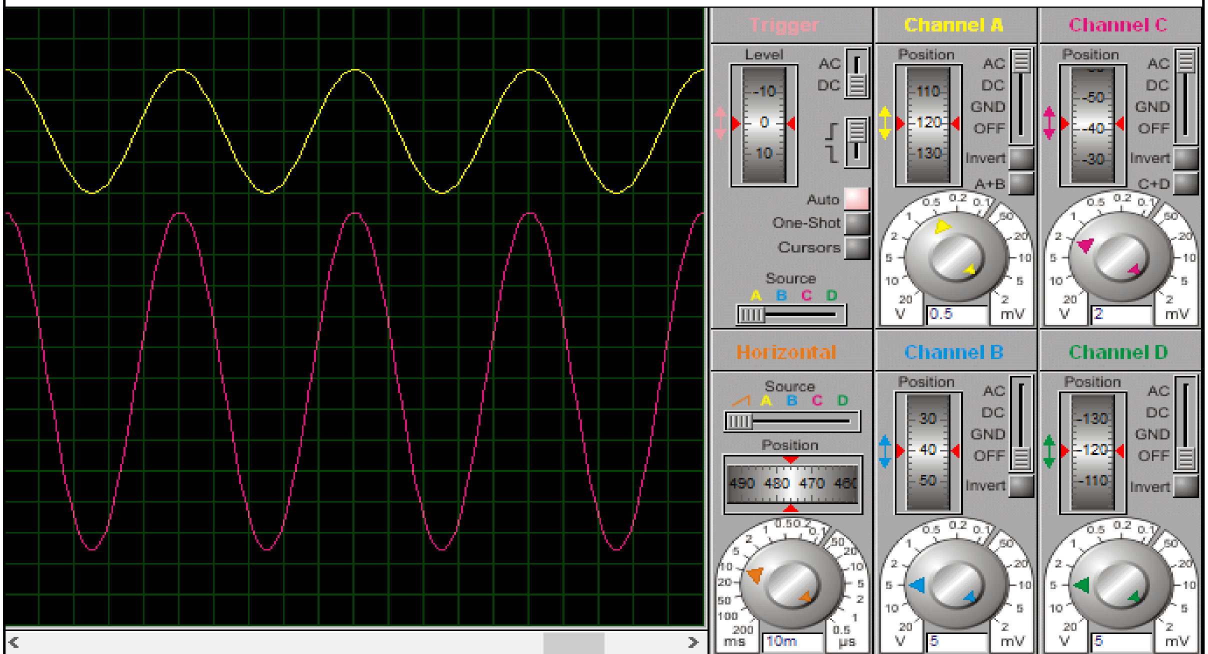
The circuit – just like the previous one – represents a non-inverting op-amp circuit, however, this one contains a higher resistance ratio, with Rf being at 100kΩ, and Rin being at 10kΩ. Due to said increase the resistance ratio, the voltage going through the VCC pins has also been increased to 12 and -12V.



Function generator



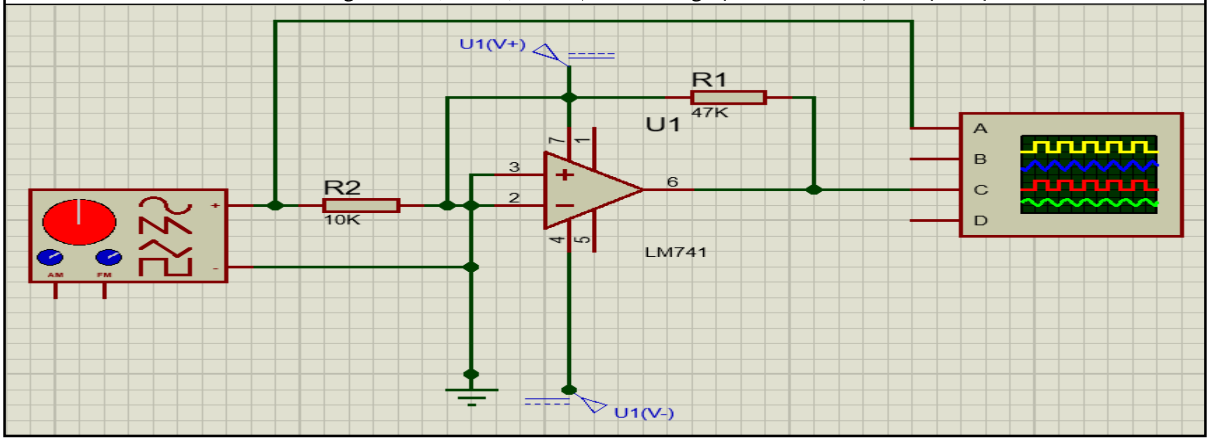
Results



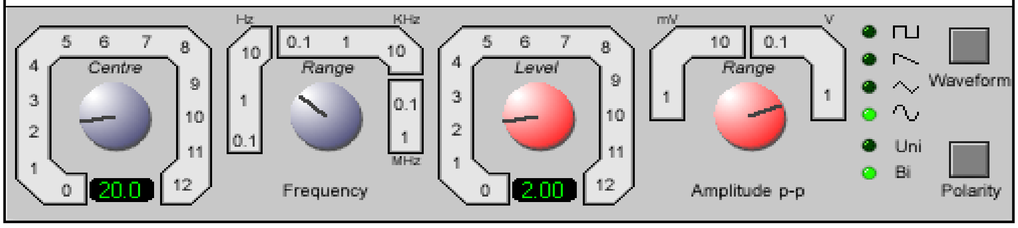
Resistance	*Vin*	*Vout*	*Gain*
$\mathrm{Rf} = 100\mathrm{k}\Omega$ $\mathrm{Rin} = 10\mathrm{k}\Omega$	$\frac{4 \times 0.5}{2} = 1\mathrm{V}$	$\frac{11.9 \times 2}{2} = 11.9\mathrm{V}$	$\frac{11.9}{1} + 1 = 12.9$

Inversing Schematic diagram 1

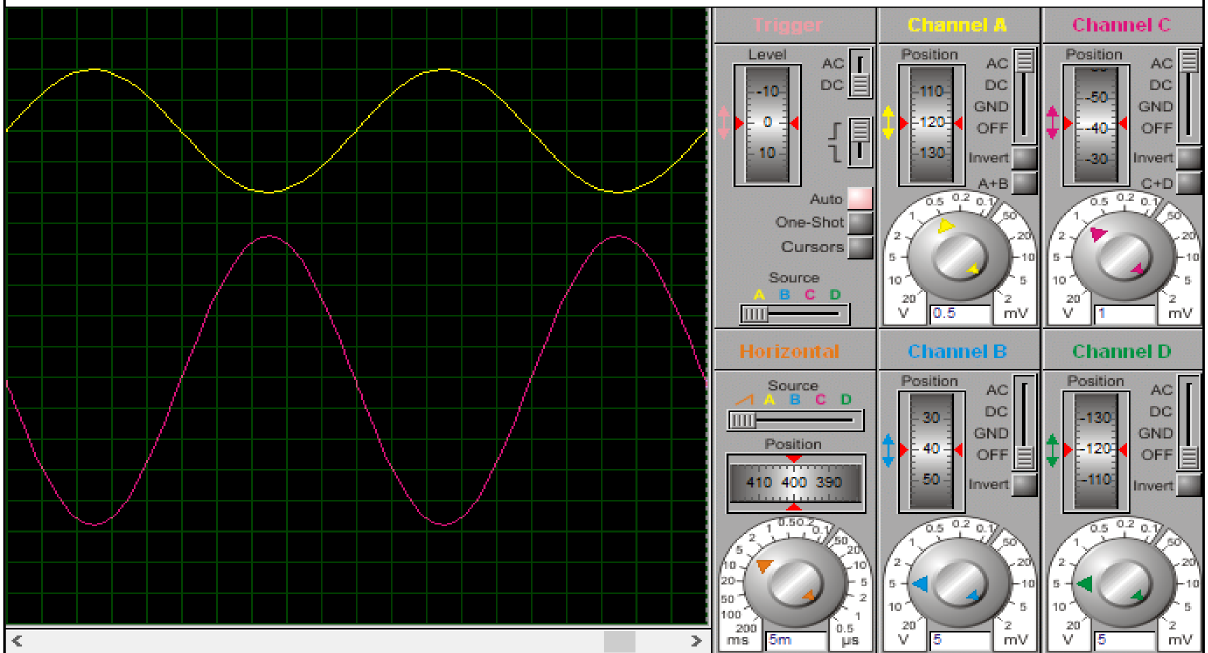
The circuit displays an inversing op-amp circuit, the reason to which the circuit is inversing is due to the non-inversing terminal being connected to ground. Rf in the circuit has a value of 47kΩ and Rin has a value of 10kΩ. Just like the initial non-inversing circuit, 9 and -9 volts flow through pins 7 and 4 of the op-amp.



Function generator

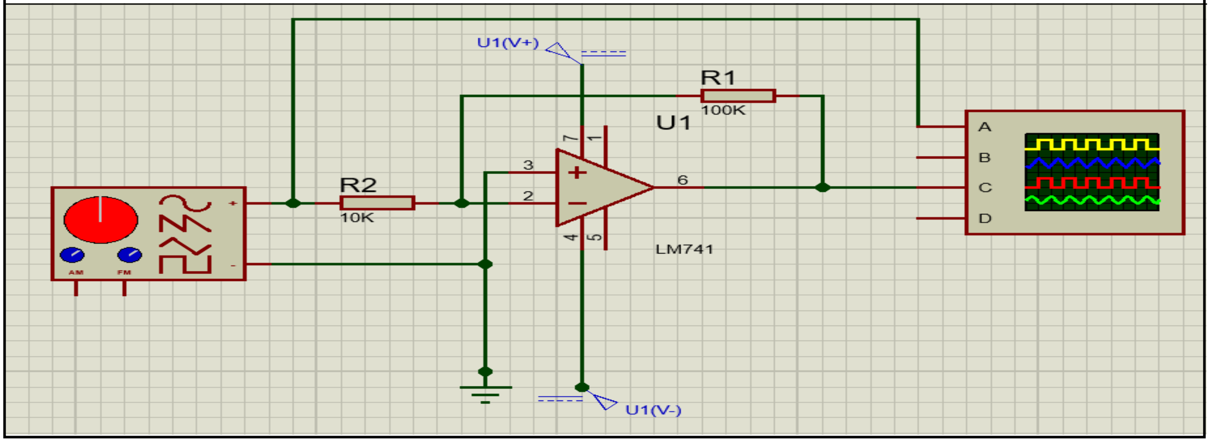


Results

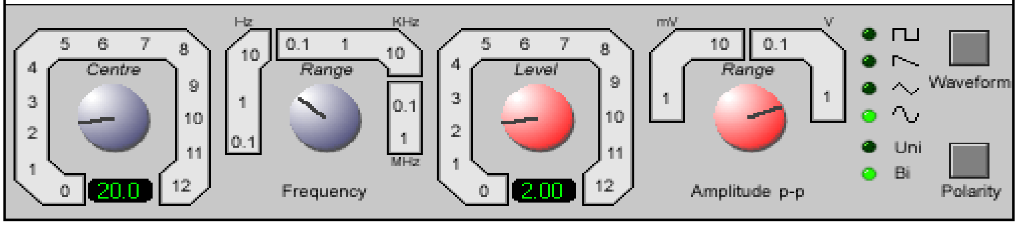


Resistance	***Vin***	***Vout***	***Gain***
$\mathrm{Rf} = 47\mathrm{k}\Omega$ $\mathrm{Rin} = 10\mathrm{k}\Omega$	$\frac{4 \times 0.5}{2} = 1\mathrm{V}$	$\frac{9.4 \times 1}{2} = 4.7\mathrm{V}$	$-\frac{4.7}{1} = -4.7$

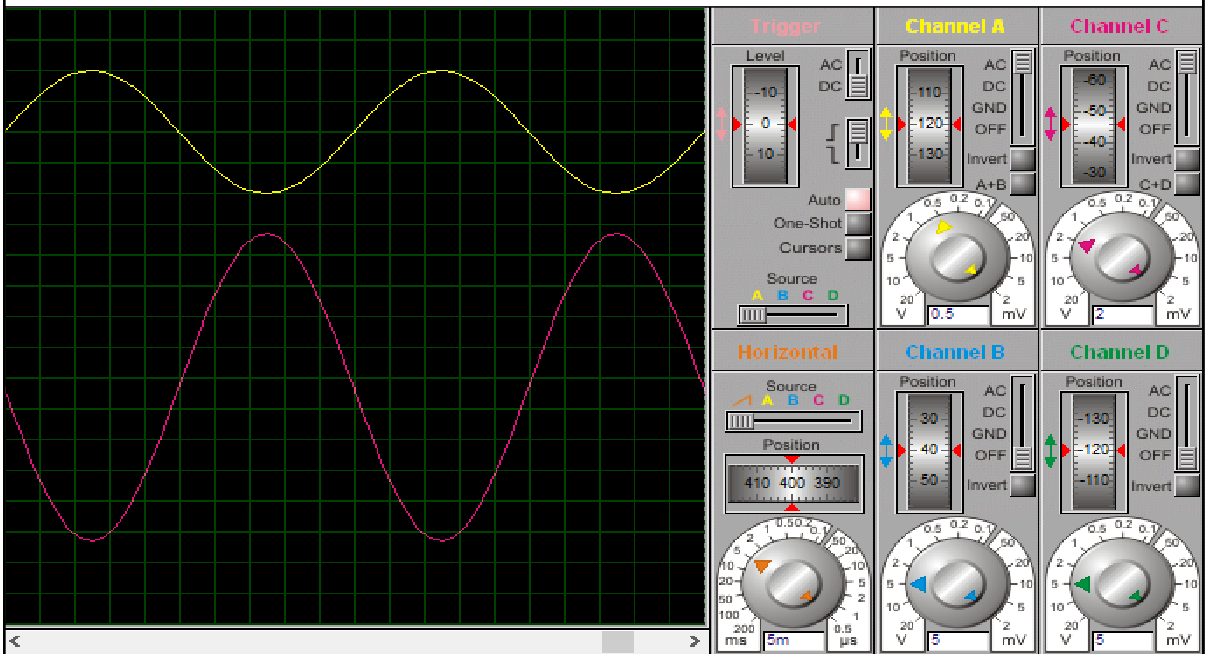
Inversing Schematic diagram 2
This schematic represents the same circuit as the previous one shown, with the exception of the utilized circuits being 100kΩ for Rf and 10kΩ for Rin, and to match with said utilized resistors, the VCC voltages have been increased to 12 and -12 volts.



Function generator



Results



Resistance	***Vin***	***Vout***	***Gain***
$\mathrm{Rf} = 100\mathrm{k}\Omega$ $\mathrm{Rin} = 10\mathrm{k}\Omega$	$\frac{4 \times 0.5}{2} = 1\mathrm{V}$	$\frac{10 \times 2}{2} = 10\mathrm{V}$	$-\frac{10}{1} = -10$

Verdict

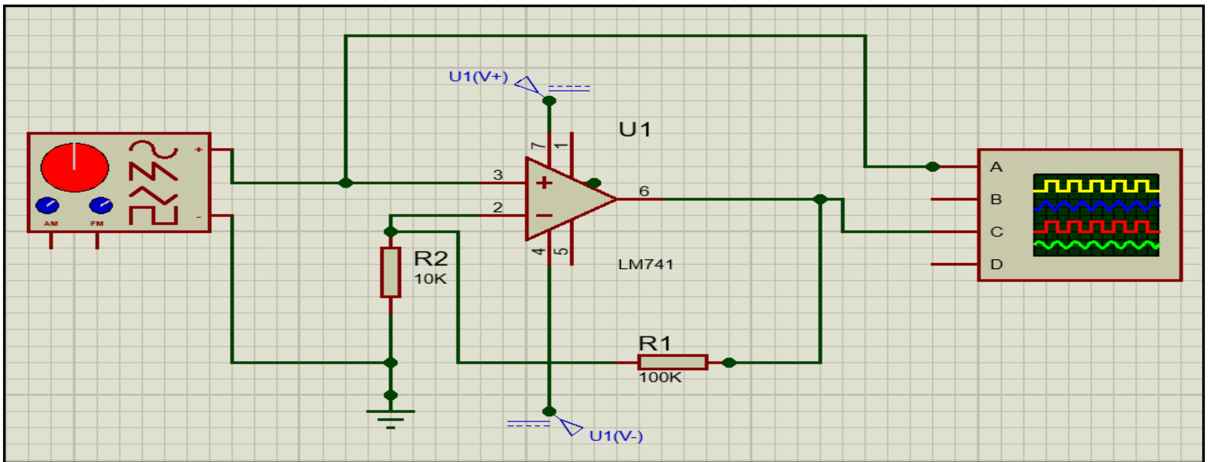
The first two circuits designed were non-inverting operational amplifier circuits, which can be confirmed with the given signal results, since as can be noticed, in outputted signal for the first two were on the same phase of the input, which is contrasted in the last two circuits, with which the outputted signal was on the opposite phase, in that when the input signal was in the positive cycle, the output was in the negative.

Another matter that can be deduced is that the gain's value of the non-inverting circuits was added by one, said addition has been done due to the fact that since no phase change has occurred to the signal, the input voltage is equal the output voltage (Vin = Vout) meaning it can only increase but not decrease. Which – again – is contrasted by inverting circuits, which evident due to the lack of the aforementioned addition their gain's equation.

Lastly, it can also be realized that the increase in the resistance ratio consequently increased the gain in both inverting and non-inverting circuits, which can be seen if the first and second circuits were compared as well as the third and fourth one. This is one of the main features that op-amps possess, which is that increase the Rs to Rin ratio also induces an increase in the overall gain.

Task iii

Construct the schematic diagram of a non-inverting amplifier with gain



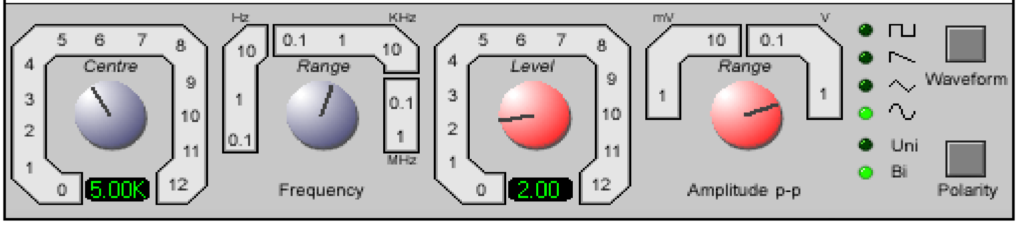
The shown circuit is an example of a non-inverting op-amp mode. This can be deduced from the fact that the non-inverting terminal is grounded. As stated earlier, regarding the resistor connection, one of them is connected from the output with the other being connected to the inverting terminal and is the connection of said terminal to the ground. In terms of the non-inverting terminal, it is connected to the function generator, which in this case is the separate power source. Finally, pins seven and 4 are connected to the positive and negative ends of separate power supply. The oscilloscope is connected to the initial input area and the output, thus it would show the initial unamplified signal as well as the amplified one, with the amplified signal staying in the same phase as the input, which can be noticed in the graph given in pages 14 and 16, which is the case due to the grounded inversing terminal making the overall circuit a non-inversing one. It has also been stated earlier than the non-inversing circuit is known for being a feedback loop, what is meant by such is that the outputted signal is fed back to the input, in that the output the sixth terminal is connected and goes back to the second/inversing terminal.

Task iv

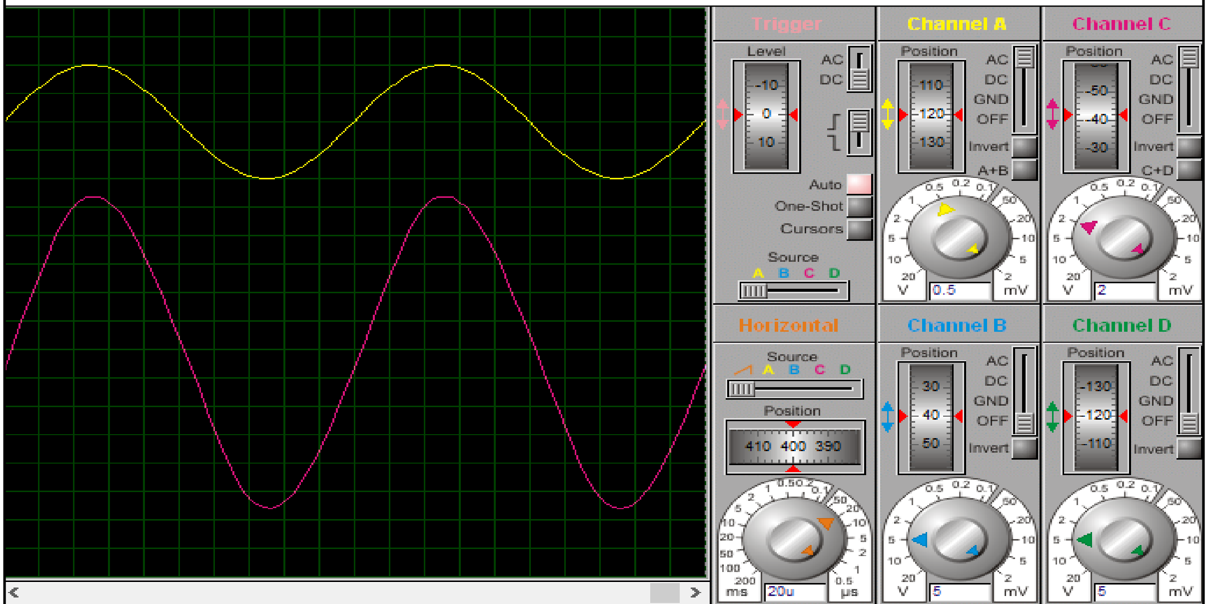
Simulate the gain frequencies between 1 kHz and 1 MHz

5 kHz

Function generator



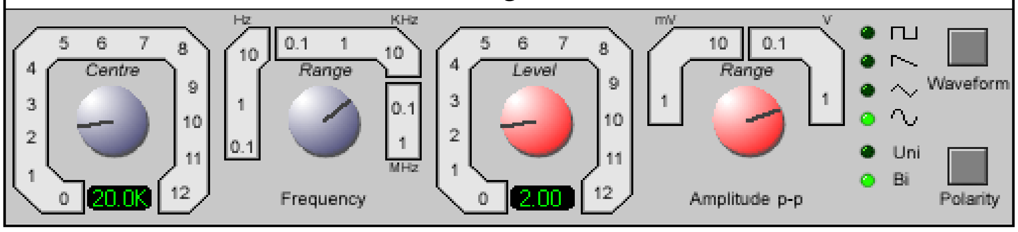
Results



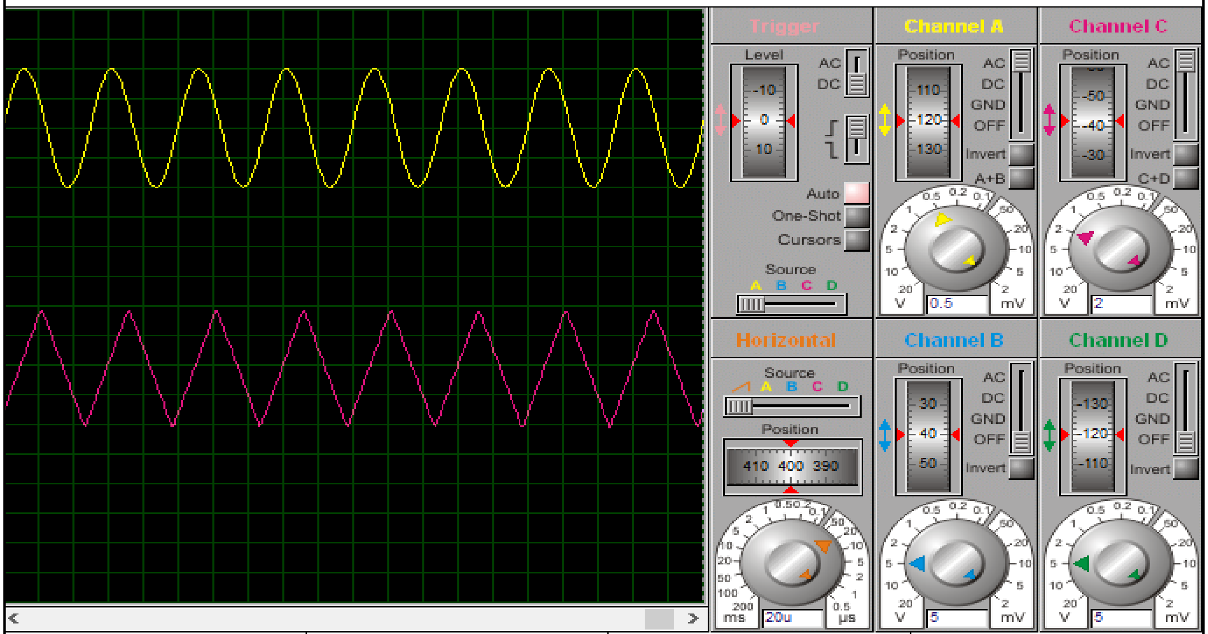
Resistance	*Vain*	*Vout*	*Gain*
$Rf = 100\text{k}\Omega$ $Rin = 10\text{k}\Omega$	$\dfrac{4 \times 0.5}{2} = 1\text{V}$	$\dfrac{10.9 \times 2}{2} = 10.4\text{V}$	$\dfrac{10.9}{1} + 1 = 11.9$

20 kHz

Function generator



Results



Resistance	Vin	Vout	Gain
$Rf = 100k\Omega$ $Rin = 10k\Omega$	$\frac{4 \times 0.5}{2} = 1V$	$\frac{3.9 \times 2}{2} = 3.9V$	$\frac{3.9}{1} = 3.9$

Verdict

It can be deduced that the gain and overall voltage increase in the circuit which contains a higher frequency is less. Explanation for said decrease is the same as the one touched upon in the transistors section. Which was that due to the increase in frequency, as a consequence, the capacitive reactance decreased, meaning that the general flow of current has also been slowed, thus causing the voltage to decrease. And since gain is a ratio measure of the net-positive voltage differential, the gain consequently decreased.

Task v

Build a prototype circuit and measure the voltage gain over the same range of frequencies

The mentioned task was done in separate worksheets that should be attached on/included with the report.

Task vi

Compare the results from theory, simulation, and measurements.

Note

Before comparing the following values, it should initially be stated that slight inaccuracies are to be expected. The reason to which is that the utilized Rin resistor across all circuits built in the experiment had a value of 12kΩ, while the one used in the simulation had a resistance of 10kΩ. Although some difference is going to be evident, it shouldn't be of any great significance to the final outcome of the circuit.

Non-inversing circuit comparison

The final gain outcome of the non-inverting op-amp circuit while using the 47kΩ Rf resistor was 6.6 for the simulation and 6 for the experiment, meaning if the utilized Rin resistor was the same across both the final result would be almost exactly the same. However in the 100kΩ Rin resistor, the outcome was 12.9 for the simulation and 11 for experiment, which is relatively much, the reason for which could be the fact that due to the higher overall gain value, the effect of the difference in the Rin resistor was probably increased, thus causing a bigger difference, however if the Rin resistor was the same, the results on both sides were most likely to be equal. Both simulation and experiment also maintained the phase of the input in the outputted signal.

↓

Inversing circuit comparison

The simulation results of the inverting circuit's were relatively similar to that of the results found in the experiment, in that they both were able to increase the input signal's phase by 180°. In terms of the gain results, the 47kΩ and 100kΩ Rf resistor circuits for the simulations were able to produce a gain of -4.7 and -10, while the experiment ones were at -3.43 and -8.31, and if not for the Rin resistor difference, the results would have been on point or much closer, as such, no further points are to be noted for either the simulation or experiment inverting circuits.

↓

5k & 20k Hz non-inversing circuits comparison

The gain value observed for the 5kHz circuit was 11.9 for the simulation and 10.2 for the experiment, with the 20kHz circuit being 3.9 for the simulation and 6 for the experiment. Said values are more different than what they should normally be even when considering the Rin resistor difference, and said issue is most likely caused by either certain technical issues with the simulation software or the inaccurate done with the experiment, however the circuit built for the experiment was verified to be correct, as such the issue is most likely due to the simulator's fault. Nevertheless, both circuits did experience a noticeable decrease in gain during the increase in frequency, which was an expected result due to the reasons that have been mentioned in the verdict stated in section iv.

Task C Reference

El-PRO-CUS. (2021, December 18). *Op-Amp IC's – Pin Configuration, Features & Working*. Retrieved from elprocus: https://www.elprocus.com/op-amp-ics-pin-configuration-features-working/

element14. (Director). (2020). *How OpAmps Work - The Learning Circuit* [Motion Picture]. Retrieved from https://www.youtube.com/watch?v=kbVqTMy8HMg&t=180s

“If you want to find the secrets of the universe, think in terms of energy, frequency, and vibration.”

-Nikola Tesla

Inventor of the Alternating current motor