REPORT

AUTOMATIC GAIN CONTROL

PROJECT IN ANALOG ELECTRONICS WITH SPECIALIZATION IN TRANSISTORS AND OPERATIONAL AMPLIFIERS

NAME & ID:
V SAI CHARAN GUPTA (B221065)
PRUTHIRAJ JENAMANI (B221044)

COURSE:
ANALOG ELECTRONICS CIRCUITS
DATE:
09/12/2022

ABSTRACT:

The aim of this project is to design and implement an automatic gain control (AGC) system using JFET, operational amplifier (Op-Amp), and bipolar junction transistor (BJT) devices.

The AGC system is designed to automatically adjust the gain of an amplifier to maintain a constant output level, regardless of changes in the input signal level. This is achieved by using a JFET as the variable gain element, an Op-Amp as the control amplifier, and a BJT as the output amplifier.

The JFET is biased in the common-source configuration, with the drain voltage controlled by the Op-Amp. The Op-Amp compares the output voltage of the AGC system to a reference voltage and adjusts the drain voltage accordingly to maintain a constant output. The BJT amplifier is used to provide the necessary gain and drive the load.

Simulations are performed using **LT Spice** to verify the performance of the AGC system. The results show that the AGC system can maintain a constant output level over a wide range of input signal levels.

A physical prototype of the AGC system is also built and tested, with results showing good agreement with the simulated results. The prototype is found to be stable and reliable.

CONTENTS:

1. AIM OF THE EXPERIMENT:

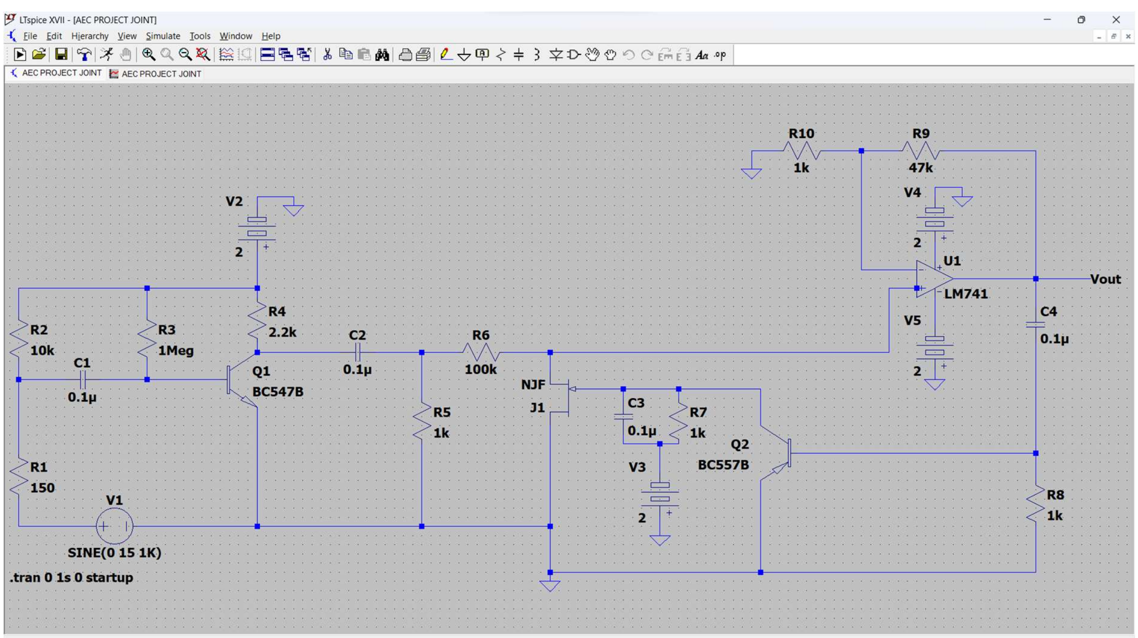
Implement an amplifier circuit with a gain which is continuously, automatically adjusted so that it's gain value is constant for any input signal.

2. MOTIVATION AND OBJECTIVE:

Automatic gain control (AGC) is a closed-loop feedback regulating circuit in an amplifier or chain of amplifiers, the purpose of which is to maintain a suitable signal amplitude at its output, despite variation of the signal amplitude at the input. The average or peak output signal level is used to dynamically adjust the gain of the amplifiers, enabling the circuit to work satisfactorily with a greater range of input signal levels. It is used in most radio receivers to equalize the average volume (loudness) of different radio stations due to differences in received signal strength, as well as variations in a single station's radio signal due to fading. Without AGC the sound emitted from an AM radio receiver would vary to an extreme extent from a weak to a strong signal; the AGC effectively reduces the volume if the signal is strong and raises it when it is weaker. In a typical receiver the AGC feedback control signal is usually taken from the detector stage and applied to control the gain of the IF or RF amplifier stages.

3. CIRCUIT DIAGRAM

Here is the circuit diagram of our project done in LTSpice software



4. COMPONENTS AND SYSTEM REQUIRED

S NO	COMPONENTS	QUANTITY
1	FUNCTION GENERATOR	1
2	OSCILLOSCOPE	1
3	VOLTAGE SOURCE	1
4	JFET (BFW 10)	1
5	BJT NPN TRANSISTOR(B547)	1
6	BJT NPN TRANSISTORS (B557)	1
7	CAPACITORS (0.1uF)	4
8	RESISTORS (150 Ohm)	1
9	RESISTORS (10 KOhm)	1
10	RESISTORS (1KOhm)	4
11	RESISTORS (2.2 KOhm)	1
12	RESISTORS (47 KOhm)	1
13	RESISTORS (1 MOhm)	1
14	BREADBOARD	2
15	WIRES	As per required

5. THEORY

Automatic Gain Control (AGC) was implemented in first radios for the reason of fading propagation (defined as slow variations in the amplitude of the received signals) which required continuing adjustments in the receiver's gain in order to maintain a relative constant output signal. Such situation led to the design of circuits, which primary ideal function was to maintain a constant signal level at the output, regardless of the signal's variations at the input of the system. Now AGC circuits can be found in any device or system where wide amplitude variations in the output signal could lead to lose of information or to an unacceptable performance of the system.

The main feature of a control system is that there should be a clear mathematical relationship between input and output of the system.

• When the relation between input and output of the system can be represented by a linear proportionality, the system is called a linear control system.

• When the relationship between input and output cannot be represented by single linear proportionality, rather the input and output are related by some non-linear relation, the system is referred to as a non-linear control system.

CLOSED-LOOP CONTROL SYSTEM

• Any system that can respond to the changes and make corrections by itself is known as a closed-loop control system.

• Automatic Gain Control (AGC) system is a closed-loop control system.

• The main difference between open-loop and closed-loop systems is the feedback action. An open-loop control system does not use a feedback action network, when a close-loop control system uses feedback action.

• AGC using closed-loop control are accurate, can use wide bandwidths, but may become unstable under certain conditions.

• An AGC control system it adjusts itself to the changes in the system, providing a reduced effect of non-linearity in these systems.

• An AGC system is deterministic if the response is predictable and repeatable. If not, the control system is a stochastic control system that involves random variable parameters.

• An AGC system is called dynamic or time-dependent if its present output depends on past input, whereas, a static system is the one whose current output depends only on the current input.

REQUIREMENTS OF AN AUTOMATIC GAIN CONTROL (AGC) SYSTEM

• Accuracy is the measurement tolerance of the instrument and defines the limits of the errors made when the instrument is used in normal operating conditions. Accuracy can be improved by using feedback elements. To increase the accuracy of any AGC system, an error detector should be present in the control system.

• The parameters of an AGC system are always changing with the change in surrounding conditions, internal disturbance or any other parameters. This change can be expressed in terms of Sensitivity. Any AGC system should be insensitive to such parameters, but sensitive to input signals only.

• An undesired input signal is known as Noise. A good AGC system should be able to reduce the noise effect for better performance.

• Stability it is an important characteristic of the AGC system. For the bounded input signal, the output must be bounded and if the input is zero then the output must be zero then such an AGC system is said to be a stable system.

• The time response and the operating frequency range decides the Bandwidth of the AGC system. Bandwidth should be as large as possible for the frequency response of a good AGC system. However, in a receiver could exist more AGC control-loops, each having different bandwidths, so different frequency responses.

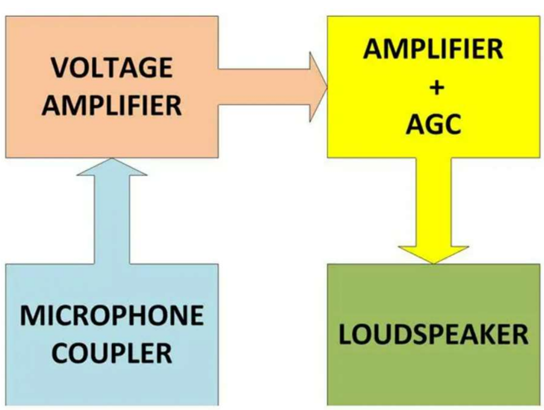
• Speed it is the time taken by the AGC system to achieve its stable output. A good AGC system possesses high speed, but sometime low speed is required. The transient period for high speed AGC system is very small, when for a low speed AGC the transient period is high.

• A small number of Oscillation or constant oscillation of output tends to indicate the system to be stable.

Automatic Gain Control (AGC) circuits are employed in many systems where the amplitude of an incoming signal can vary over a wide dynamic range. The role of the AGC circuit is to provide a relatively constant output amplitude so that circuits following the AGC circuit require less dynamic range. If the signal level changes are much slower than the information rate contained in the signal, then an AGC circuit can be used to provide a signal with a well-defined average level to downstream circuits. In most system applications, the time to adjust the gain in response to an input amplitude change should remain constant, independent of the input amplitude level and hence gain setting of the amplifier.

DESCRIPTION:

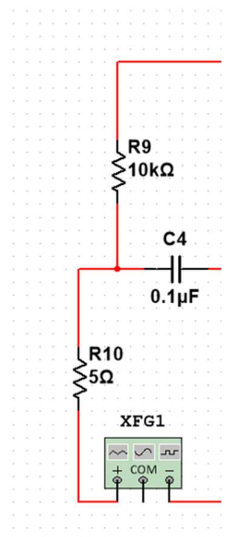
This circuit is using a two-stage amplification of the signals, first with a simple transistor amplifier and then with an op-amp based AGC amplifier. A condenser microphone is used at the input and a normal headset with volume controller feature is used at the output. The entire system can be represented using the following block diagram:



Now in the circuit performed by us is just a simple automatic gain controller which does not include variable gain amplifier.

MICROPHONE COUPLER

The microphone coupler is a circuit which helps to couple out the weak audio signals generated at the microphone. There are different kinds of microphones which have different working principle, but all of them have a diaphragm which vibrates according to the sound signals. As the diaphragm vibrates the current flowing through the microphone varies according to the sound signals amplitude which made the diaphragm to vibrate. Here in this circuit a condenser microphone is used which and the varying current is made to flow through a resistor across which the equivalent voltage get generated due to the current flow. This voltage across the resistor will be having a DC voltage on to which the varying voltage gets added up. This varying voltage is separated out from the DC voltage with the help of a coupling capacitor and fed to the following amplifier circuits.
With a condenser microphone a 10K resistor and a 0.1uF coupling capacitor is used in most of the circuits.



VOLTAGE AMPLIFIER

This is an amplifier with a fixed gain and it is used to pre-amplify the audio signals from the microphone to the required level for the AGC amplifier circuit. The signals produced on the microphone especially from the distant sound sources will be very feeble and needs to be amplified several times before they can be applied to any other circuits.

Here a single transistor-based amplifier circuit is used to amplify the audio signals coupled out from the microphone. This circuit is designed to have extremely high gain so that the audio signals are get amplified enough. The transistor is connected in a common emitter configuration and fixed bias technique is used for biasing the transistor.

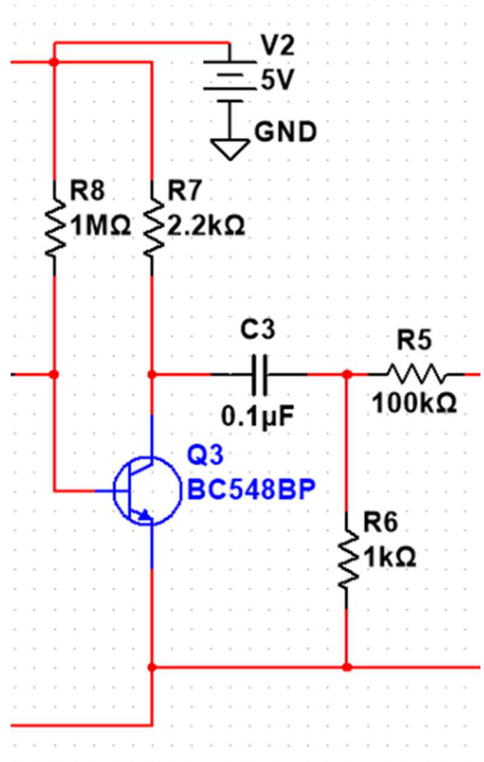
As the value of the Rc increases the gain of the circuit increases and it should be taken care of that when there is no input signals present the amplifier must be in its quiescent state, means in case of a transistor based circuit the output voltage without any input signal should be exactly the half of the total supply voltage.

Here a 2.2K ohm resistor is selected, which will allow to flow more than one milli-ampere current through the transistor and the resistor itself in series with it, creating around 2.8 volts across Vce.

Vce = 5 – (2200 * 1mA) = 2.8 V; (almost quiescent voltage)

Since the expected output current Ic is fixed at 1mA, the input current at quiescent state that will produce that output current can be calculated with the help of the relation of the hfe of a transistor with the input and the output currents. The hfe is generally called the current gain and is given by the equation
hfe = Ic / Ib; where Ic is the output collector current and the Ib is the input base current.

The hfe of the transistor BC548 has a maximum value of 300, and applying the values of Ic and hfe on to the above equation the Ib can be calculated around 4uA.



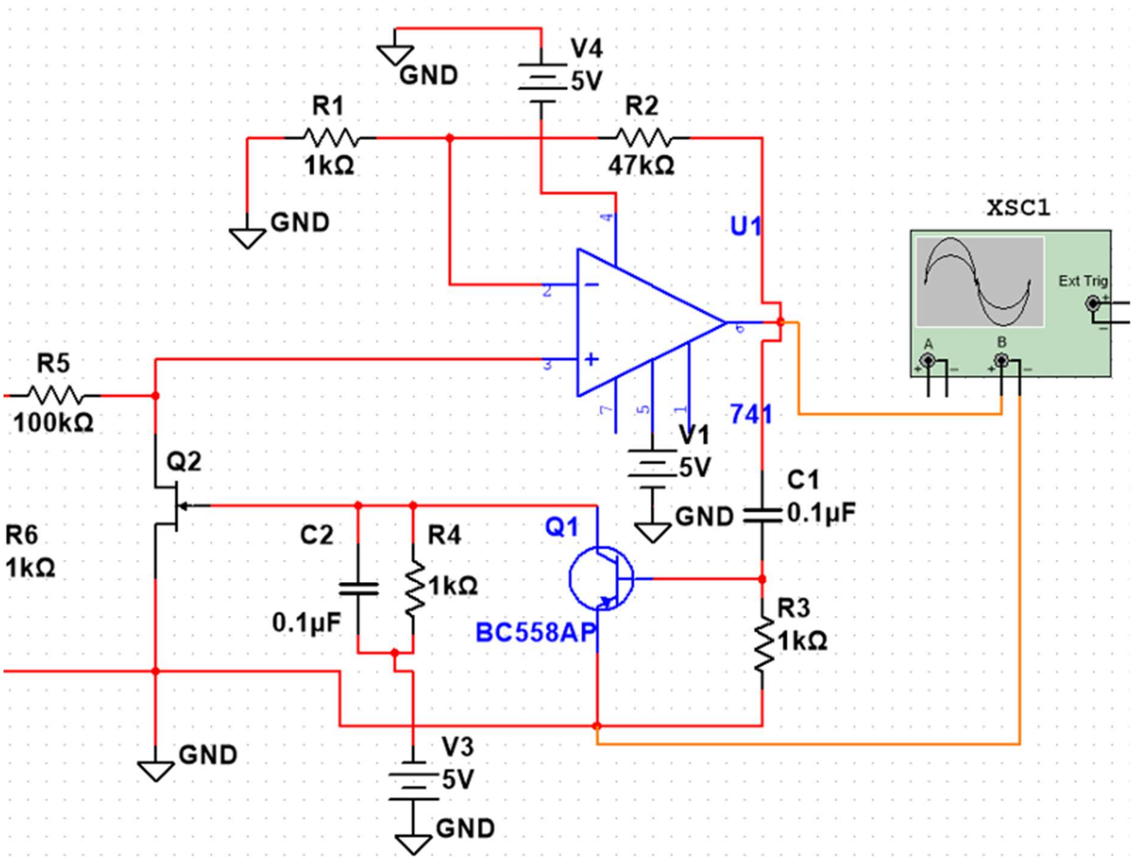
The voltage Vb across base resistor Rb will be the supply voltage minus 0.7 volts for a silicon transistor at quiescent state. Here since the supply voltage is 5V, the Vb can be calculated as 4.3 V. Now since the voltage Vb across the resistor and the current Ib flowing through the resistor is known, the required value of the resistor can be calculated using the ohms law;
Rb = 4.3 V / 4.3 uA = 1M

A 0.1uF capacitor is commonly used to couple the audio signals in between the amplifier stages.

AMPLIFIER + AGC

This circuit uses a normal op-amp based negative feedback amplifier with an extra feedback network on its positive input pin. Normally the gain of a negative feedback amplifier is fixed by the feedback resistance on its negative input pin, but since this circuit has a feedback network connected to the positive input pin, the gain depends on that circuit also. The feedback network on the positive pin includes mainly a FET which acts like a voltage varying resistor, a transistor to drive that FET and a RC filter circuit that generates the varying gate voltage for the FET according to the varying signal strength at the output of the op-amp.

The capacitor C1 couples the audio signals from the output of the op-amp to the base of the PNP transistor. The converts the AC signal coupled from the op-amp output to a DC equivalent voltage with the help of the C2 and R4. The operation of the Q1 and the C2 and R4 are very much like a single diode rectifier where the Q1 acts as a rectifier and the C2 and R4 acts like a RC filter smoothing out the ripples at the output of the rectifier diode and creating a DC voltage. Here the value of this DC voltage depends on the amplitude of the signal at the output of the op-amp. If the op-amp output is low, the DC voltage will be low and if the op-amp output is high then the DC voltage will also be high.



This voltage applied to the gate of the FET to control the trans-conductance it, which acts as a voltage varying resistor in this circuit. If the voltage at the gate of the FET decreases it conducts less from ground to the positive input pin of the op-amp which increases the gain of the op-amp. When the voltage at the gate of the FET increases it conducts more and hence reduces the gain. Hence this mechanism controls the gain of the op-amp according to the amplitude of the signal at the output of the op-amp, which happens according to the amplitude of the input signal to the op-amp.

At very small amplitude signals the gate voltage of the FET will be very small and it will not conduct from ground to the positive pin of the op-amp. In such a case the feedback network on the positive pin can be completely ignored and the entire circuit behaves as a simple negative feedback op-amp amplifier. The gain will be at the maximum at that time and can be found out using the following equation:

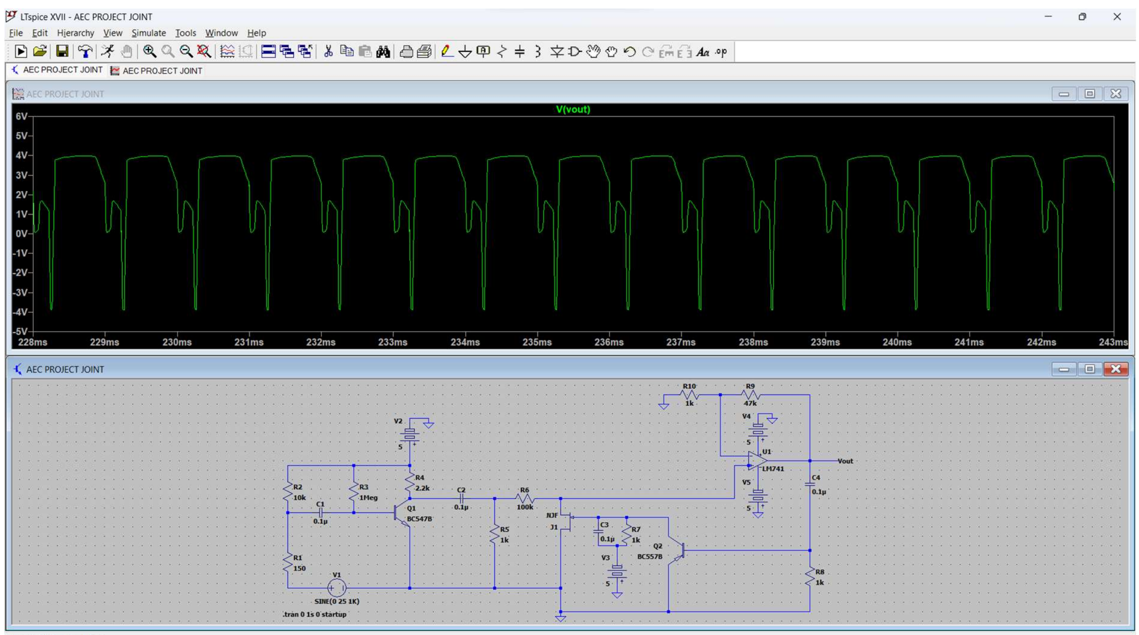
G = – (R2 / R1) dB

This circuit provides a maximum gain of around 50 dB and holds the amplitude of the output signal constant at 2.5 V p-p from input signal amplitude of 50mV p-p.

The above values are based on the circuit diagram shown individually.

6. SIMULATION AND IT'S RESULTS

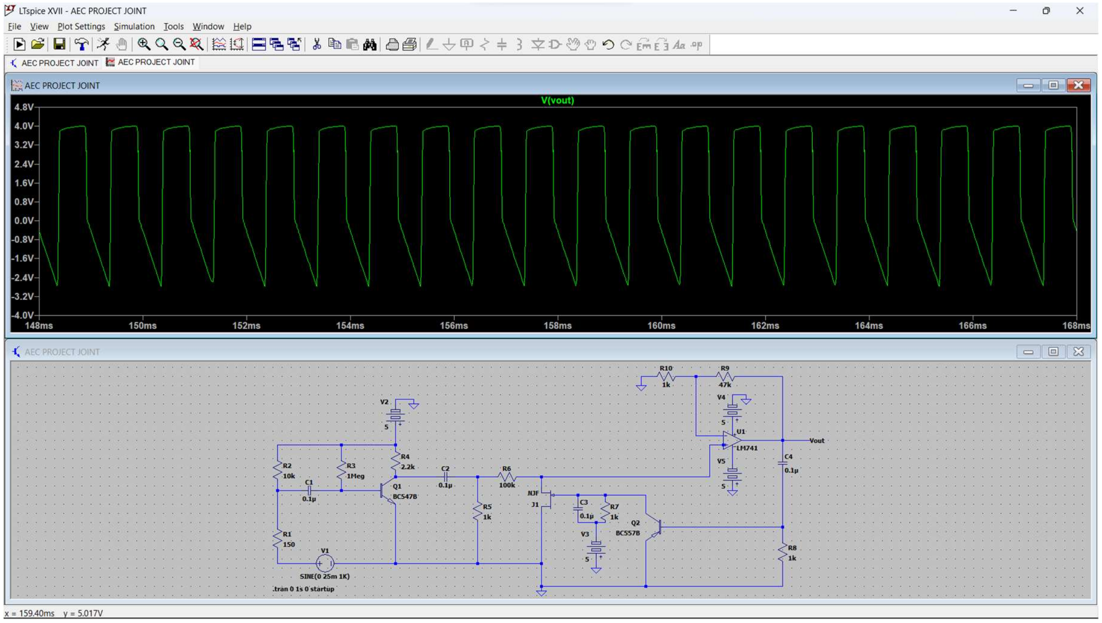
FINAL OUTPUT GRAPH FOR SIMULATION:



It is observed that when the supply voltage is **25 V p-p** we got **8 V p-p** as output.

As per the working of automatic gain control, now we need to check that the output voltage needs to be maintained the same for any value of the input. So, for this thing to be satisfied and to be proved we have taken another input of **25 mV p-p** and we got the same output voltage and with this we can conclude that we are getting a constant gain for any input value whether it is very less value or a very large value.

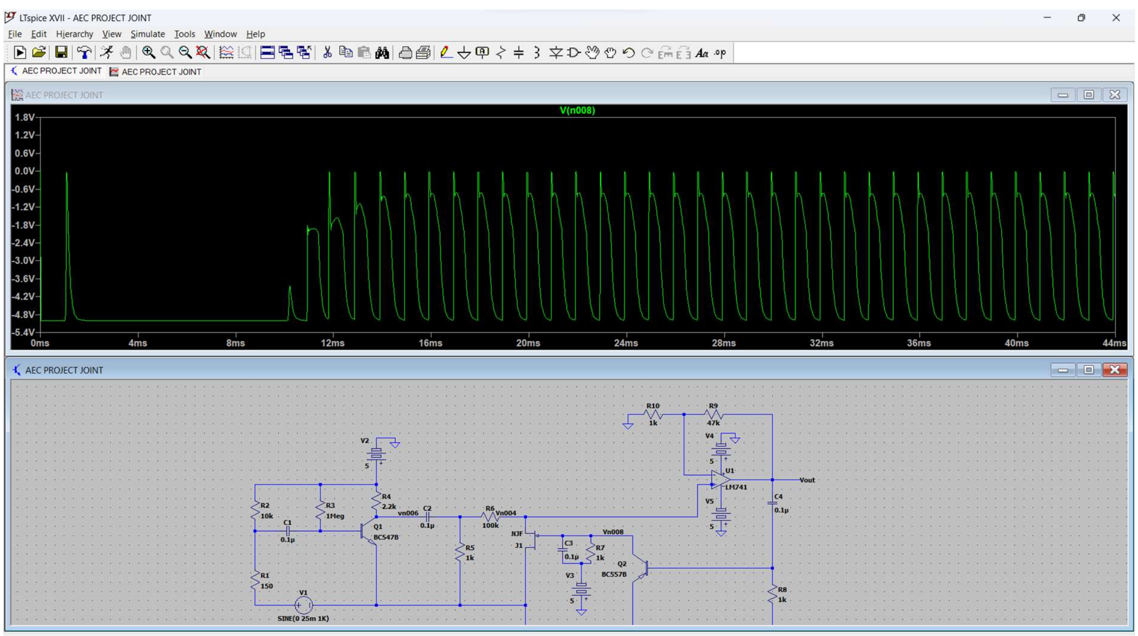
It is seen that the output is not dependent on the input voltage and this depends on the FET we are using in the circuit as its acts like a variable resistance and control's the gain of the circuit by making our output voltage constant for all values of input.



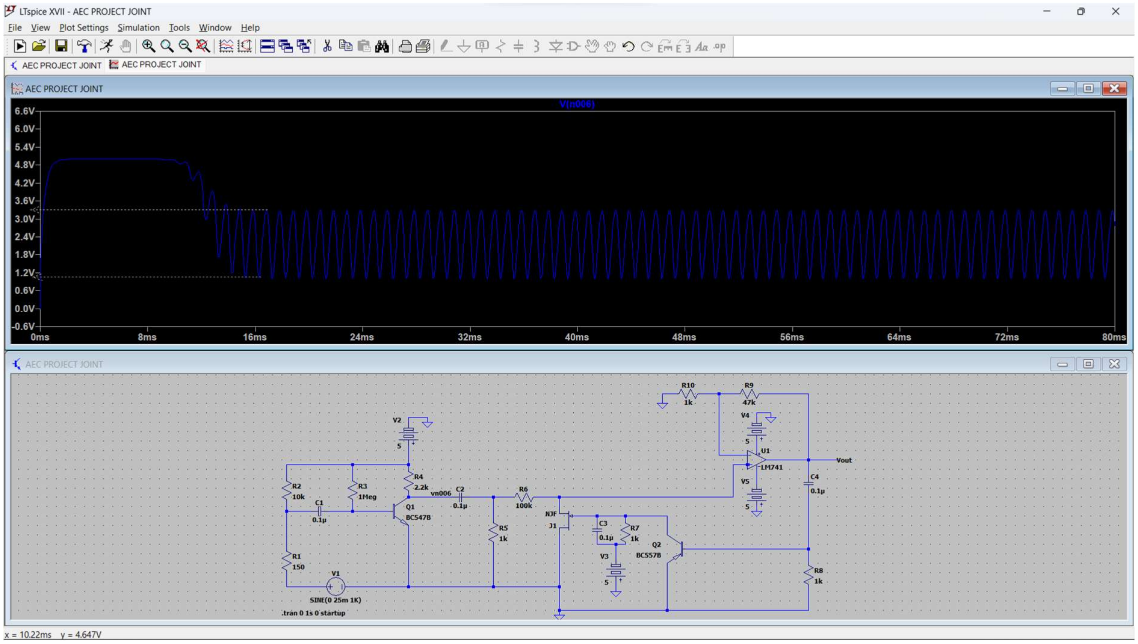
It is observed that when the supply voltage is **25 mV p-p** we got **8 V p-p** as output.

Now here are the output simulations for various reference points in the circuit.

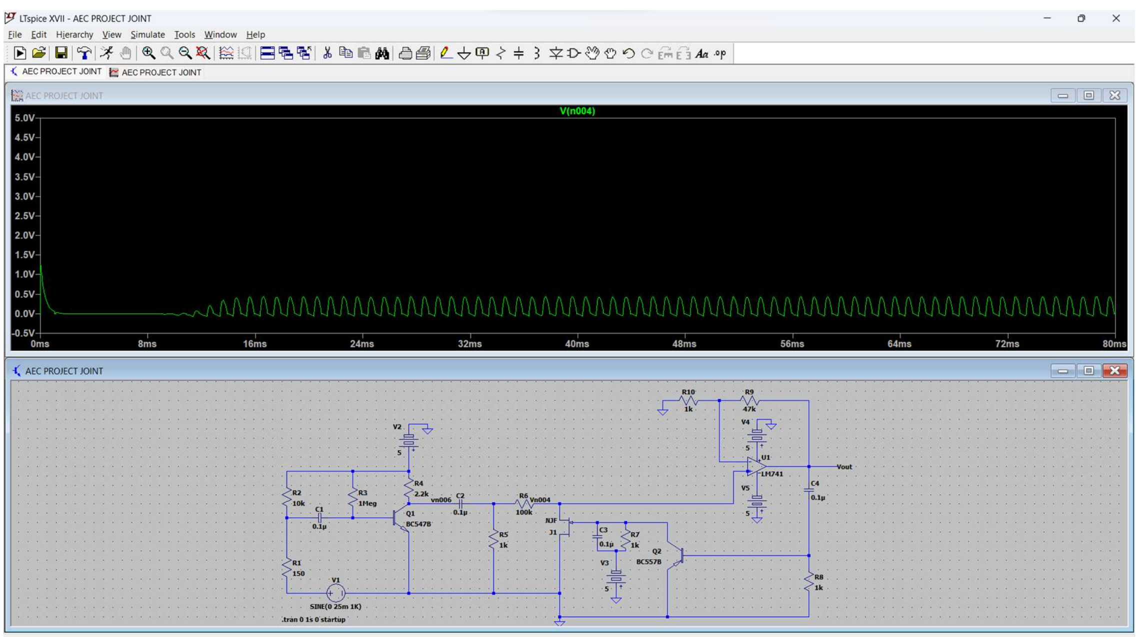
REFERENCE POINT 1: Vn008



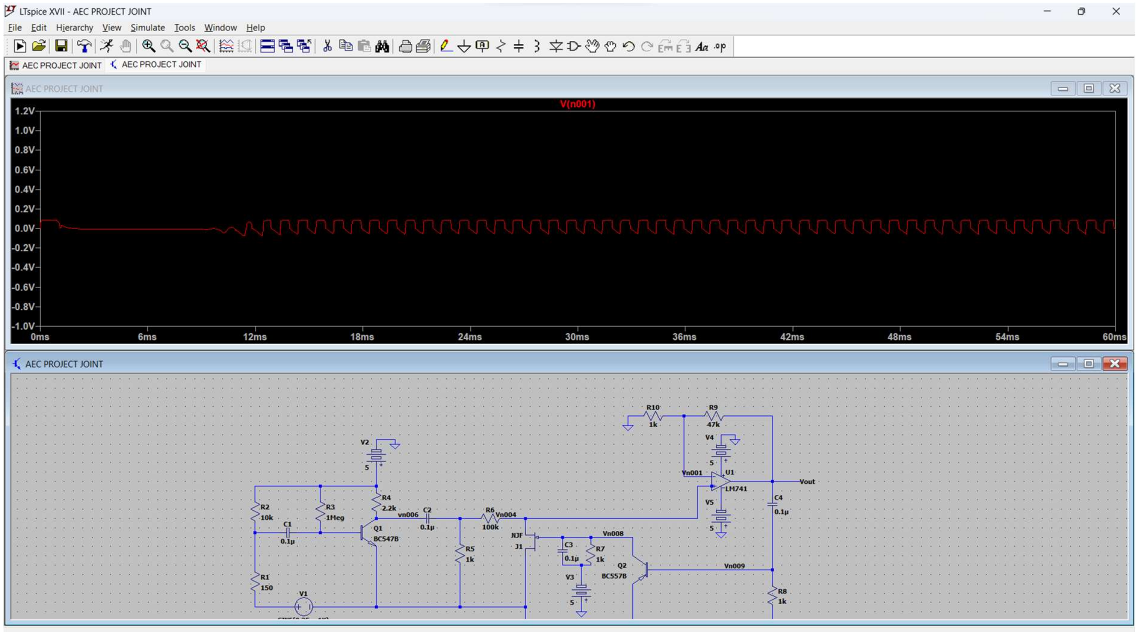
REFERENCE POINT 2: Vn006



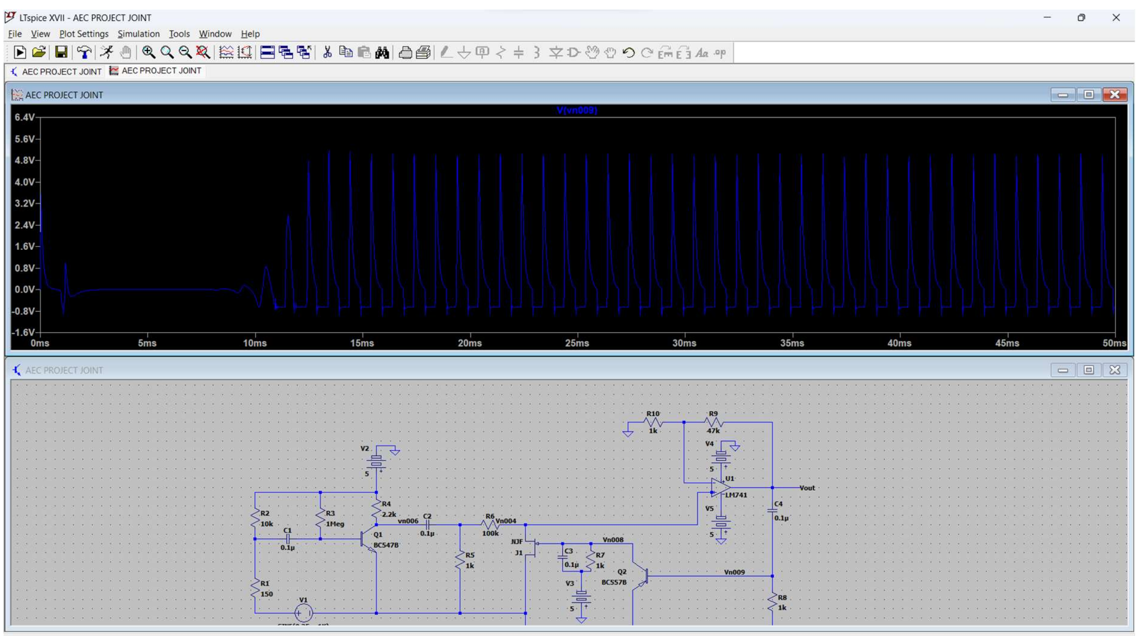
REFERENCE POINT 3: Vn004



REFERENCE POINT 4: Vn001

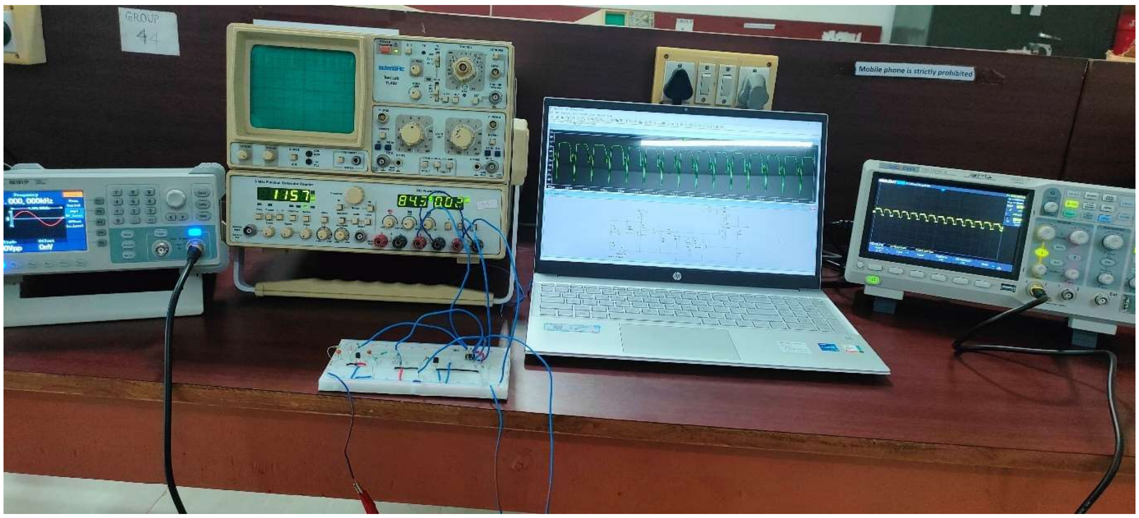


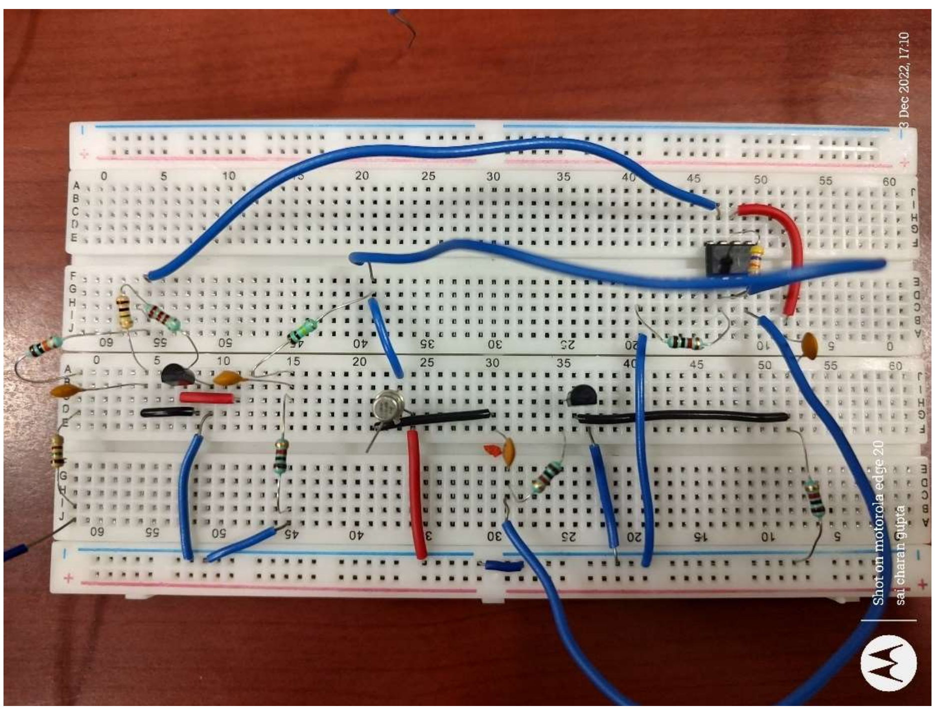
REFERENCE POINT 5: Vn009



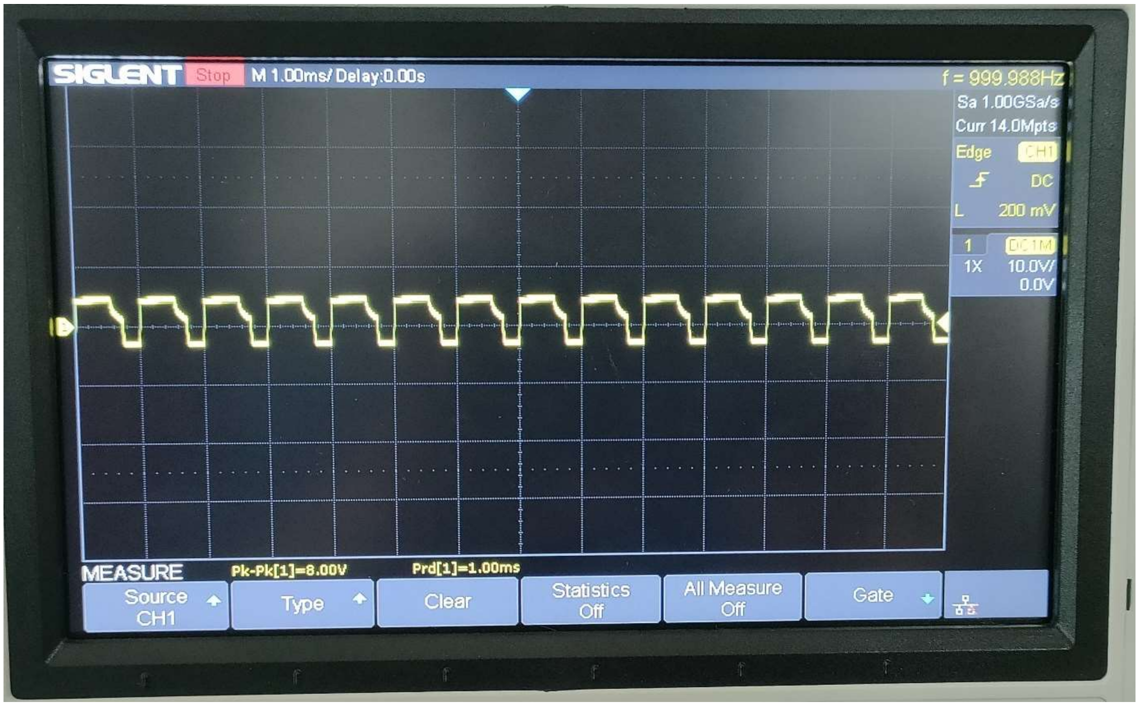
7. EXPERIMENT AND IT'S RESULTS

Final circuit after the connections has been made and the output been shown in the oscilloscope





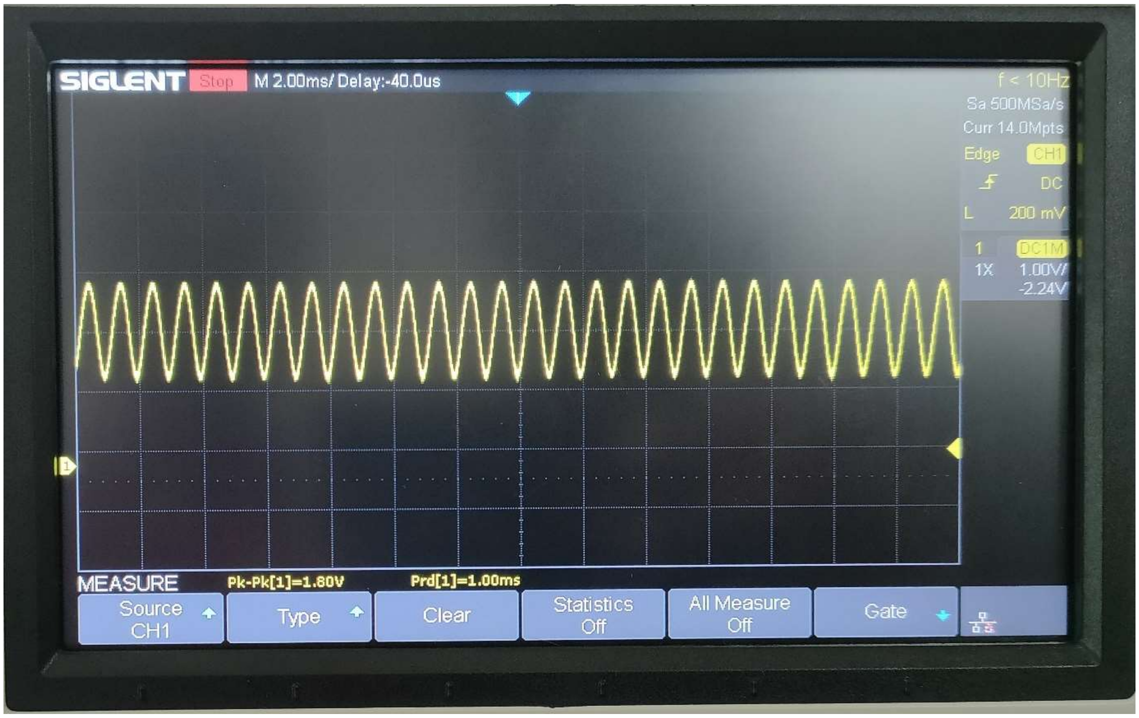
FINAL OUTPUT GRAPH



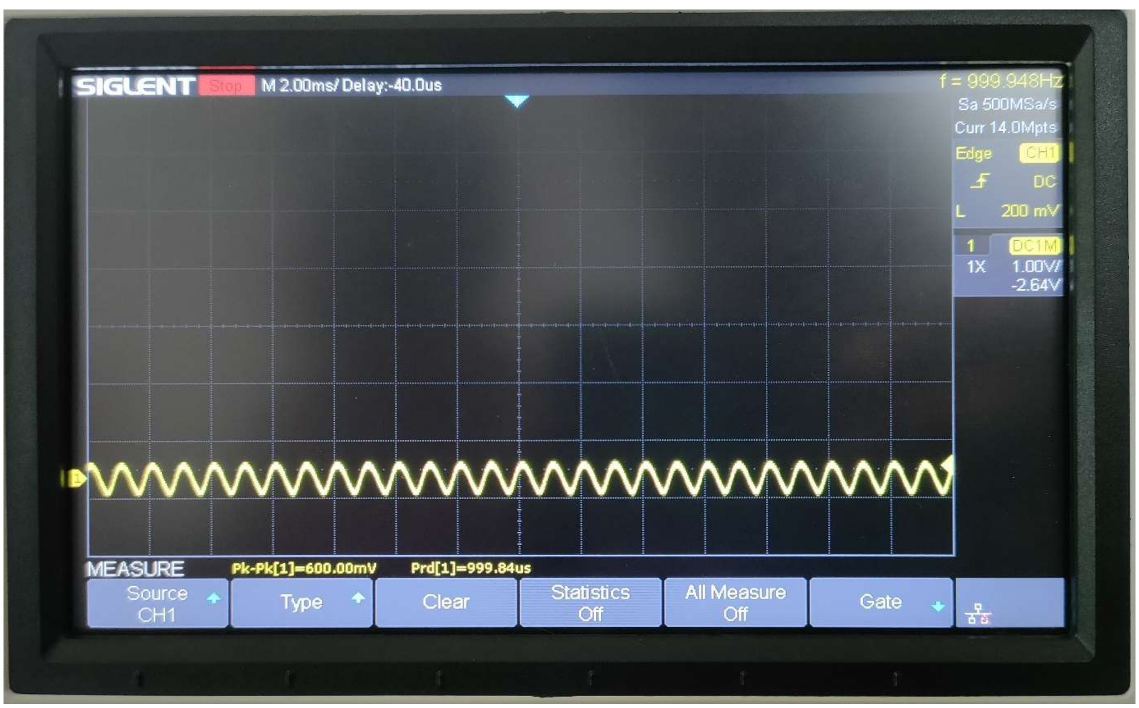
Now here are the output waveforms for various reference points in the circuit.

REFERENCE POINT: Vn008

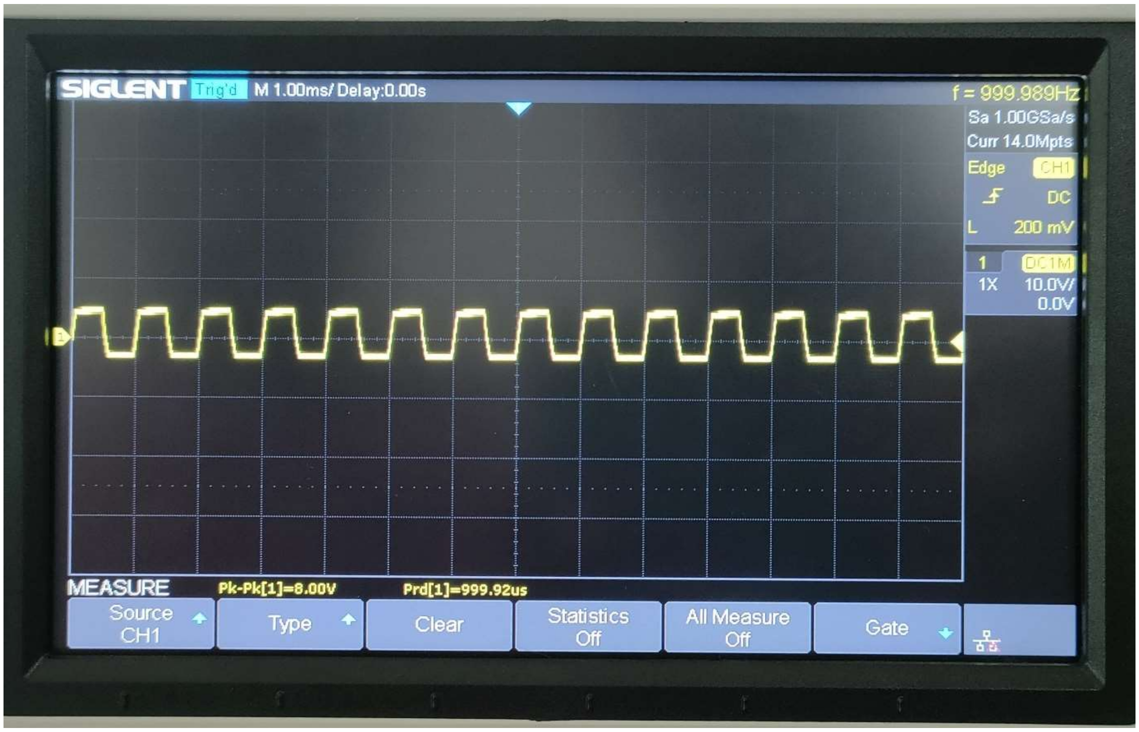
REFERENCE POINT: Vn006



REFERENCE POINT: Vn004



REFERENCE POINT: Vn001



REFERENCE POINT 5: Vn009

8. CALCULATIONS & PERCENTAGE OF ERROR

1ST READING

INPUT:

Vin = 25Vp-p F = 1KHz

OUTPUT:

OUTPUT AS PER EXPERIMENT:

Vout = 8Vp-p F = 1KHz

OUTPUT AS PER SIMULATION:

Vout = 7.9Vp-p F = 1KHz

PERCENTAGE OF ERROR:

[(8 - 7.9) / 8] * 100 = 1.25%

2ND READING

INPUT:

Vin = 25mVp-p F = 1KHz

OUTPUT:

OUTPUT AS PER EXPERIMENT:

Vout = 8Vp-p F = 1KHz

OUTPUT AS PER SIMULATION:

Vout = 7.9Vp-p F = 1KHz

PERCENTAGE OF ERROR:

[(8 - 7.9) / 8] * 100 = 1.25%

VALUES OF ALL REFERENCE POINTS RESPECTIVELY AS PER SIMULATION AND EXPERIMENTAL:

Vn006 OUTPUT:

OUTPUT AS PER EXPERIMENT:

Vout = 1.80Vp-p F < 10KHz

OUTPUT AS PER SIMULATION:

Vout = 2.2Vp-p F < 10KHz

PERCENTAGE OF ERROR:

[(2.2 – 2.0) / 2.2] * 100 = 9.09%

Vn004 OUTPUT:

OUTPUT AS PER EXPERIMENT:

Vout = 600mVp-p F = 999.99Hz

OUTPUT AS PER SIMULATION:

Vout = 560mVp-p F = 1KHz

PERCENTAGE OF ERROR:

[(600 - 560) / 600] * 100 = 6.67%

Vn008 OUTPUT:

OUTPUT AS PER EXPERIMENT:

Vout = 4.92Vp-p F < 10Hz

OUTPUT AS PER SIMULATION:

Vout = 4.90Vp-p F < 10Hz

PERCENTAGE OF ERROR:

[(4.92 - 4.90) / 4.92] * 100 = 0.40%

Vn001 OUTPUT:

OUTPUT AS PER EXPERIMENT:

Vout = 220mVp-p F < 10Hz

OUTPUT AS PER SIMULATION:

Vout = 200mVp-p F < 10Hz

PERCENTAGE OF ERROR:

[(220 - 200) / 220] * 100 = 1%

Vn009 OUTPUT:

OUTPUT AS PER EXPERIMENT:

Vout = 4.92Vp-p F = 1KHz

OUTPUT AS PER SIMULATION:

Vout = 5.20Vp-p F = 1KHz

PERCENTAGE OF ERROR:

[(5.20 - 4.92) / 5.20] * 100 = 5.38%

9. OBSERVATION FOR IMPROVEMENT

OBSERVATION:

After performing the project it has been noticed that the values of the simulation and the experimental are verified with a nominal error of 1.25%.

IMPROVEMENT:

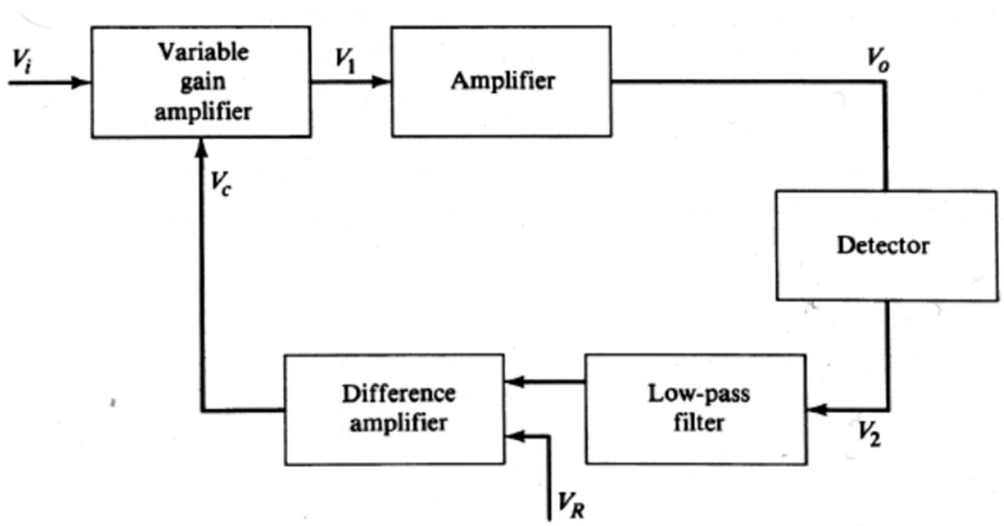
The large dynamic range of signals that must be handled by most receivers requires gain adjustment to prevent overload or IM of the stages and to adjust the demodulator input level for optimum operation.

• A simple method of gain control would involve the use of a variable attenuator between the input and the first active stage. Such an attenuator, however, would decrease the signal level, but it would also reduce the S/N of any but the weakest acceptable signal.

• A typical AGC loop circuit is shown in the picture below. This is a feedback system comprising a forward controlled gain stage, feedback gain and a signal comparison stage that generates a differential error signal. The AGC loop is analysed in terms of its closed-loop gain (forward transfer function) and open-loop gain. There is temperature compensation at the detector diode stage to compensate for diode detector forward voltage variation with temperature.

• Gain control is generally distributed over a few stages, so that the gain in later stages (the IF amplifiers) is reduced first, and the gain in earlier stages (RF and first IF) is reduced only for signal levels sufficiently high to assure a large S/N.

• If the RF gain is small is enough switching in/out an attenuator at RF only for sufficiently high signal levels. Variable gain control for the later stages can operate from low signal levels. Variable-gain amplifiers are controlled electrically, and when attenuators are used in receivers, they are often operated electrically either by variable voltages for continuous attenuators or by electric switches (relays or diodes) for fixed or stepped attenuators.

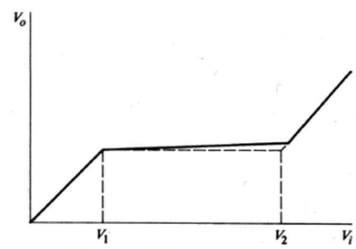


AGC Block Diagram

The input signal is amplified by a Variable Gain Amplifier (VGA), whose gain is controlled by an external signal VC. The output from the VGA can be further amplified by a second stage to generate and adequate level of Vo. Some the output signal's parameters, such as amplitude, carrier frequency, index of modulation or frequency, are sensed by the detector; any undesired component is filtered out and the remaining signal is compared with a reference signal. The result of the comparison is used to generate the control voltage (Vc) and adjust the gain of the VGA.

• If the control time constants are determined primarily by the detector circuit and the additional amplifier has a wider bandwidth than the detector, then the attack and decay times will be shortened by the amount of the post-amplification

• An AGC circuit in the receiver provides a substantially constant signal level to the demodulator independent of the input signal level.



AGC Ideal Transfer Function

For low input signals the AGC is disabled and the output is a linear function of the input, when the output reaches a threshold value (V1) the AGC becomes operative and maintains a constant output level until it reaches a second threshold value (V2). At this point, the AGC becomes inoperative again; this is usually done in order to prevent stability problems at high levels of gain.

10. SUMMARY AND FUTURE SCOPE

SUMMARY:

Automatic gain control (AGC) is a useful technique for maintaining a constant output signal level, regardless of variations in the input signal level. This can be useful in a wide range of applications, including audio processing, radio communication, and imaging systems.

FUTURE SCOPE:

The use of JFETs, op-amps, and BJTs in AGC circuits is well-established and can offer excellent performance. In the future, these devices may continue to be used in AGC circuits, but they may also be replaced by more advanced technologies, such as **microelectromechanical systems (MEMS) or integrated circuits (ICs)** based on newer materials, such as graphene or silicon carbide.

One potential application for AGC using JFETs, op-amps, and BJTs is in the design of **adaptive feedback systems for audio processing**. In such a system, the AGC circuit could be used to maintain a constant output level, even when the input signal level is changing. This could help to improve the overall performance of the system and make it more robust to variations in the input signal.

Another potential application for AGC using these devices is in the design of **radio communication systems**. In such systems, AGC can be used to maintain a constant output signal level, regardless of variations in the input signal level. This can help to improve the performance of the system and reduce the likelihood of signal distortion or interference.

Overall, the future scope for the use of JFETs, op-amps, and BJTs in AGC circuits is likely to remain strong, particularly in applications where maintaining a constant output signal level is important. As new technologies and materials become available, these devices may be replaced by more advanced alternatives, but they are likely to continue to play a crucial role in the design of AGC circuits for many years to come.