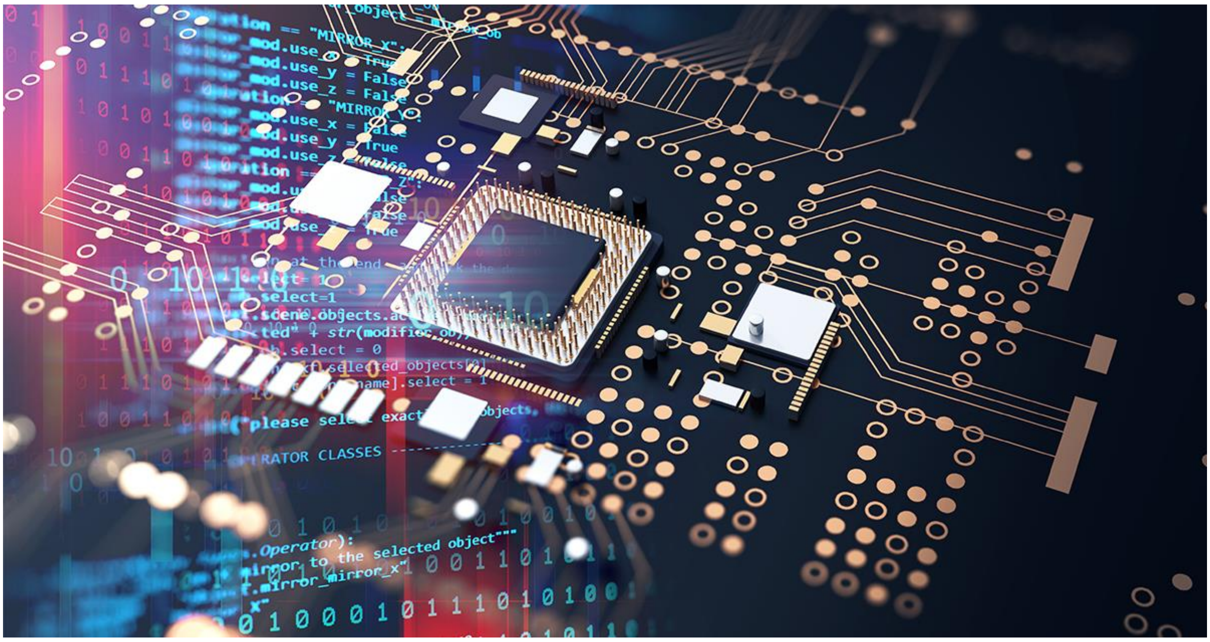

# INTRODUCTION TO ELECTRONICS PROJECT 19AIE113

## A Voltage Comparator Circuit Using A Differential Amplifier With Transistors


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# ABSTRACT

The following report details upon the construction of a Voltage Comparator circuit. Though voltage comparators are generally built using Operational Amplifiers, this project will involve a differential amplifier circuit built using two PNP transistors.

The circuit has been simulated on two platforms: MultiSim and Tinkercad. While MultiSim can fully represent the working of the circuit and provide an output, Tinkercad provides a platform in which the actual components can be used. To further verify the output, a hardware implementation using the ADALM kit has also been performed. The steps for this process have also been explained in detail.

We have also included the inferences obtained from this project and explained the limitations that it poses. Furthermore, the applications of differential amplifiers and voltage comparators have been discussed.

# TABLE OF CONTENTS

## AIM:

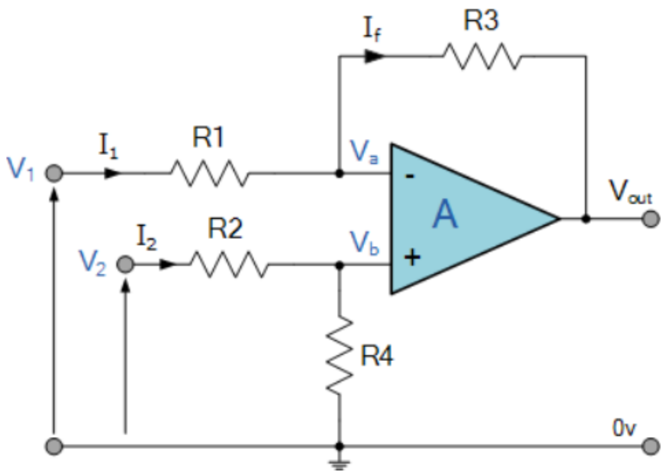
1. To design a differential amplifier using transistors and use the differential circuit to design a voltage comparator circuit.
2. Simulation platforms for obtained circuit:
    - MultiSim
    - TinkerCad
3. Hardware implementation using ADALM module and ALICE M1K desktop

## THEORY:

### Differential Amplifiers:

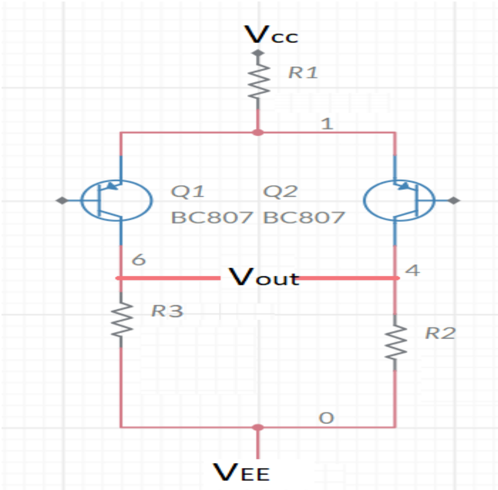
Differential Amplifiers are devices used to amplify the difference between the two inputs given. They are commonly implemented using Operational Amplifiers (Op-Amps).

All Op-Amps are “Differential Amplifiers” due to their input configuration. But, by connecting one voltage signal onto one input terminal and another voltage signal onto the other input terminal the resultant output voltage will be proportional to the “difference” between the two input voltage signals of V1 and V2.




In an ideal differential amplifier, the output voltage Vo is proportional to the difference between two input voltages. $V_{out} = A_d(V_1\text{-}V_2)$, where $A_d$ is the differential gain.

In the project a differential amplifier using two PNP BJTs has been implemented. The circuit diagram for the differential amplifier followed in this project is given below. $V_{CC}$ stands for the positive power supply and $V_{EE}$ stands for the negative power supply, since we know in a PNP diode, the emitter-base junction is forward biased and the collector-base junction is reverse biased.

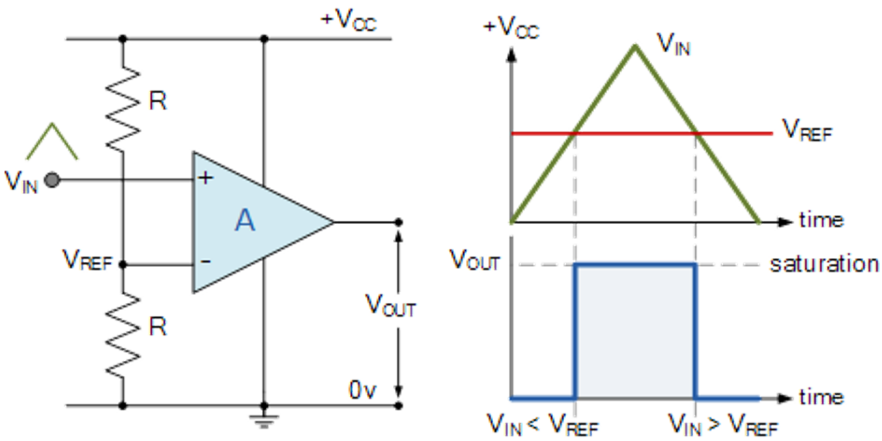



## Voltage Comparator:

A voltage comparator is a circuit that compares two inputs. In this project the voltage comparator compares an input voltage $V_{in}$ to the other input voltage $V_{REF}$. According to whether the voltage $V_{in}$ is higher or lower than the reference voltage $V_{REF}$ the output voltage of the circuit changes to high and low states. (i.e.) if $V_{in}<V_{REF}$ then $V_{OUT}$ will be low, and if $V_{in}>V_{REF}$ then $V_{OUT}$ will be high. A Voltage Comparator circuit can generally be implemented in two ways.

1. Voltage Comparator using OP-AMP
2. Voltage Comparator using BJT

In this project we demonstrate the second method. The circuit diagram of the first method, implementing a non-inverting comparator using Op-Amp is briefly explained below.



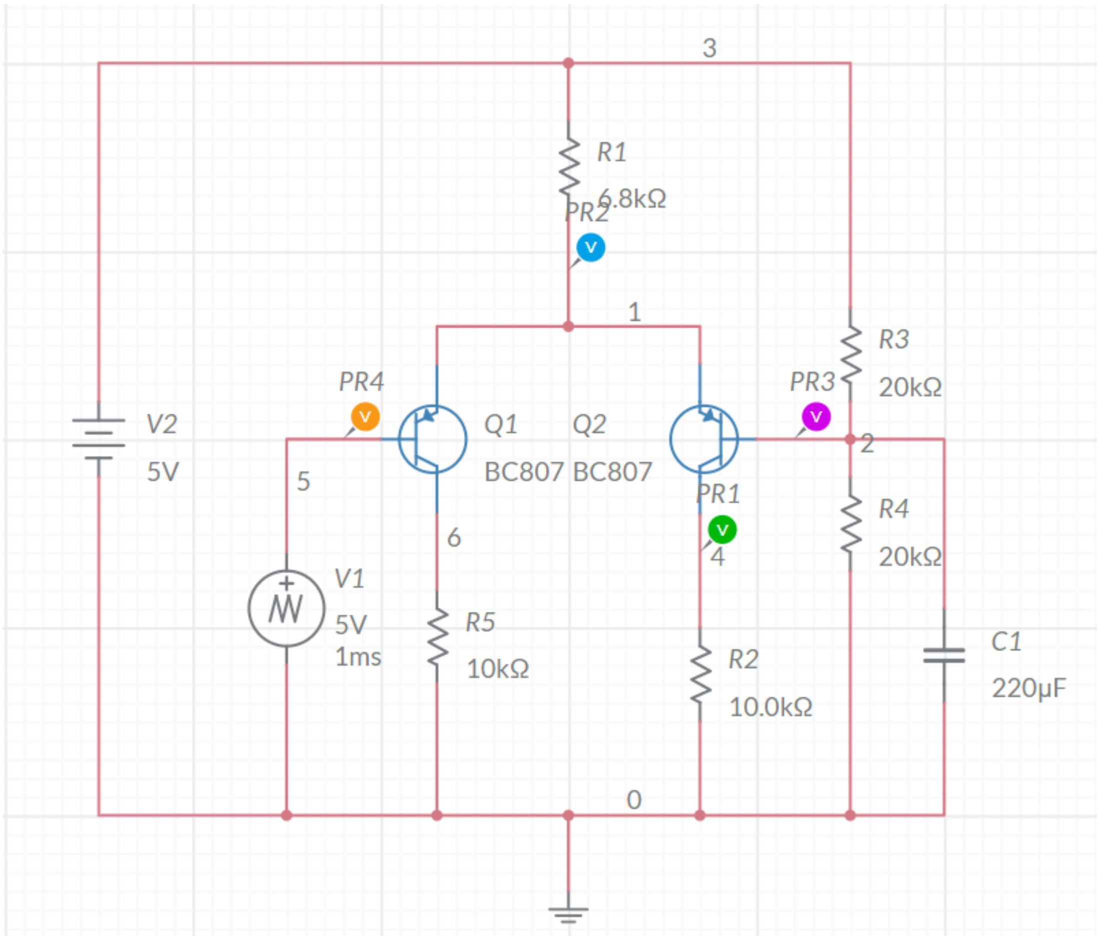
The reference voltage ($V_{REF}$) is applied to the inverting input and the voltage to be compared is applied to the non-inverting input (Vin). Thus, whenever $V_{in}<V_{REF}$, $V_{out}$ swings to the negative saturation, which is 0 since it is grounded. Likewise, when $V_{in}>V_{REF}$, $V_{out}$ will swing to the positive saturation which is equal to $V_{CC}$.

# VOLTAGE COMPARATOR USING BJT:

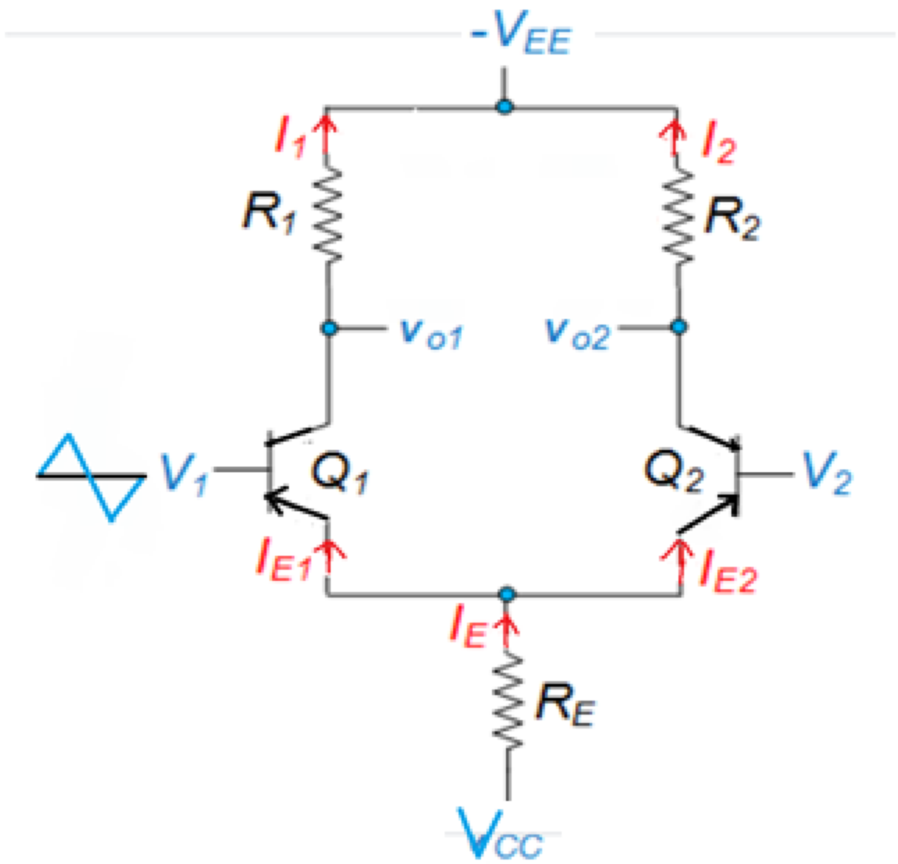
## Components required:

- Two PNP BJTs
- One 5V DC power supply
- AC power supply (Triangular 5V)
- One 220µF capacitor
- Connecting wires
- Resistors Required:
  - Two 20kΩ
  - Two 10kΩ
  - One 6.8kΩ

## Circuit Diagram:



## Theory behind the circuit:




In this case, the voltage $V_1$ at $Q_1$ is triangular. As $V_1$ continues to increase, the transistor $Q_2$ starts to conduct and this results in a heavy collector current $I_{C2}$ (collector current of $Q_2$) increasing voltage drop across the resistor $R_2$, causing an increase in $V_{O2}$.Due to the same effect, $I_{E2}$(emitter current of $Q_2$) increases which increases the common emitter current, $I_E$ resulting in an decrease of voltage drop across $R_E$.

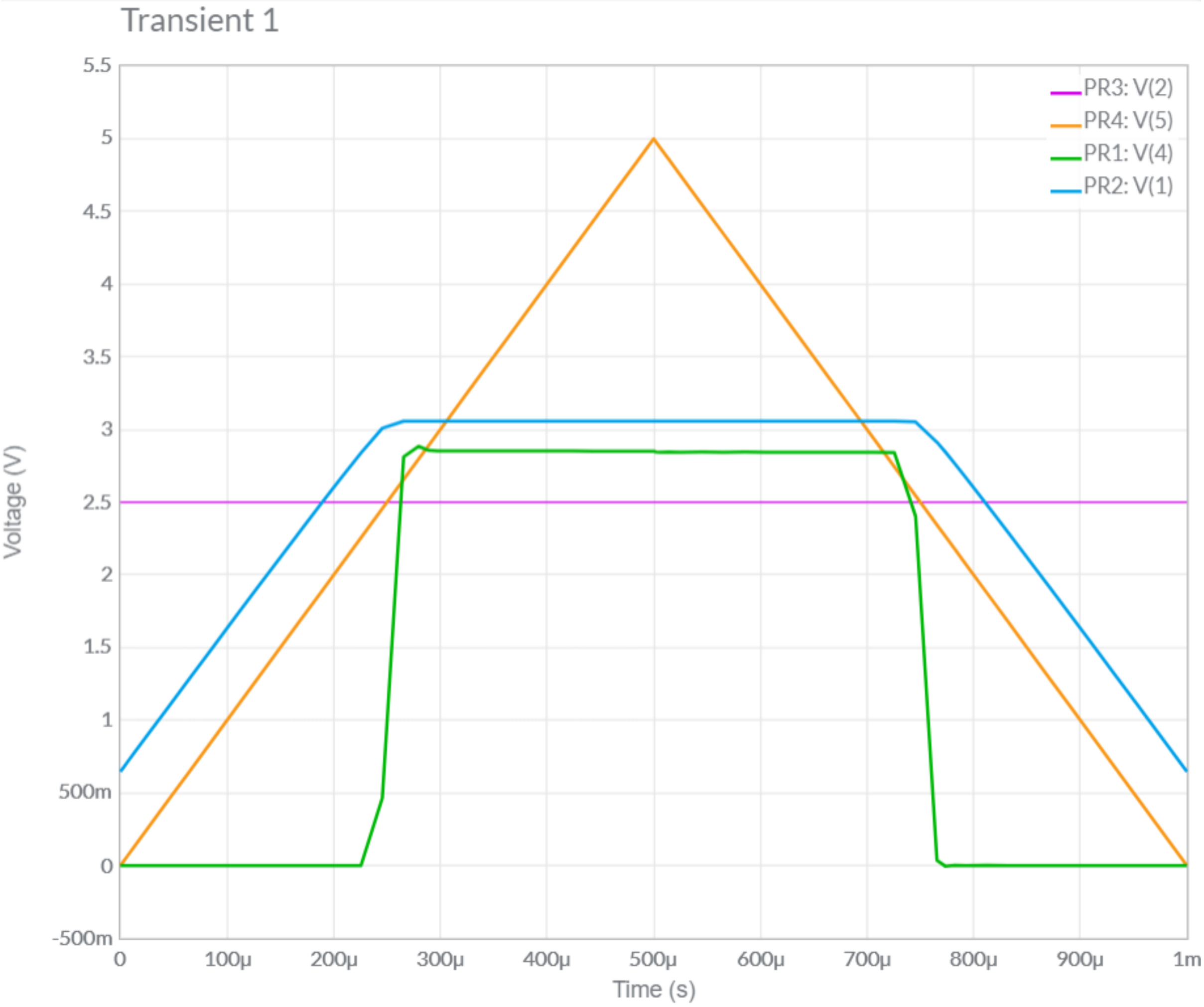
This results in a decrease of collector current, $I_{C1}$ which in turn decreases the voltage drop across the collector resistor $R_1$, resulting in a decrease in the output voltage $V_{O1}$. For a comparator circuit the output can be measured from the collector terminal of the opposite transistor to which the $V_{in}$ is given. Therefore, in this case the output voltage has been measured at the collector of the $Q_2$ transistor.

$$V_{O2} = V_{EE} + I_2 R_2$$

Instead of giving a constant DC 2.5V (Vref) as the input to Q2, we have instead included a voltage divider circuit. It must be noted that a direct supply could also be given in its place, and this change will not affect the output in any manner. To output a 2.5V output, we have the following formula (notations as in circuit diagram):

$$V_{ref} = \frac{V_{CC} * R_4}{(R_3 + R_4)}$$

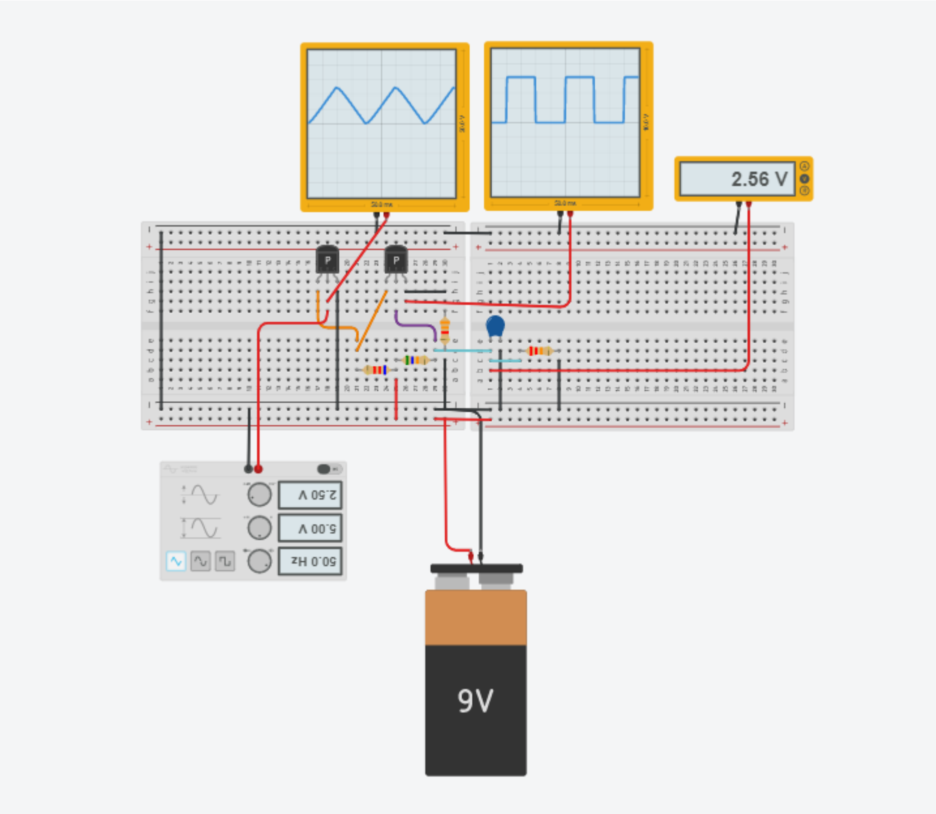
## Output of Multisim Simulation:




NOTE:

- Triangular wave(orange): input
- Square wave(green): output
- Blue line is emitter voltage
- Purple line is $V_{REF}$.

## Tinker-Cad implementation:




Owing to the absence of a 5V source in Tinkercad, we have used a 9V battery as a replacement. Due to the change in the source voltage, the resistors have been changed accordingly.

## Components used:

- 2 PNP transistors (BJT)
- 2 5ms Oscilloscopes
- 9V battery
- 1 6.15kΩ resistor
- 1 55.5kΩ resistor
- 1 3.3kΩ resistor
- 1 1μF capacitor
- 1 21.5kΩ resistor
- 1 Triangle Function Generator
- 1 Voltage Multimeter

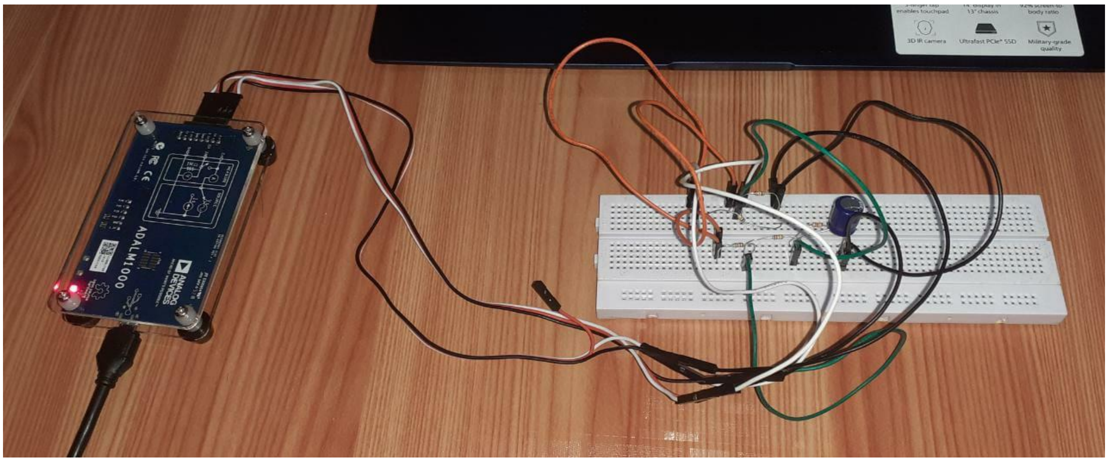
A function generator has been used to simulate the triangular input wave. The input and output waveforms have been displayed using two different oscilloscopes.

A multimeter has also been used to read the reference voltage which is visible in the figure above as 2.56V.

However, the magnitudes of the output wave could not be obtained due to the limitations of the Tinkercad features. But the output along with the magnitudes of the respective voltages have been obtained using the ADALM hardware module and ALICE M1K Desktop software which will be explained later in the report.

## ADALM Implementation:

The ADALM hardware module has been used to verify the output obtained in the MultiSim simulation. The following pictures depict the connections.




## Procedure:

1. Make the connections as shown in the MultiSim circuit
2. In the place of the triangular source, connect Channel A
3. Connect Channel B to the collector of Q2 to obtain the output wave

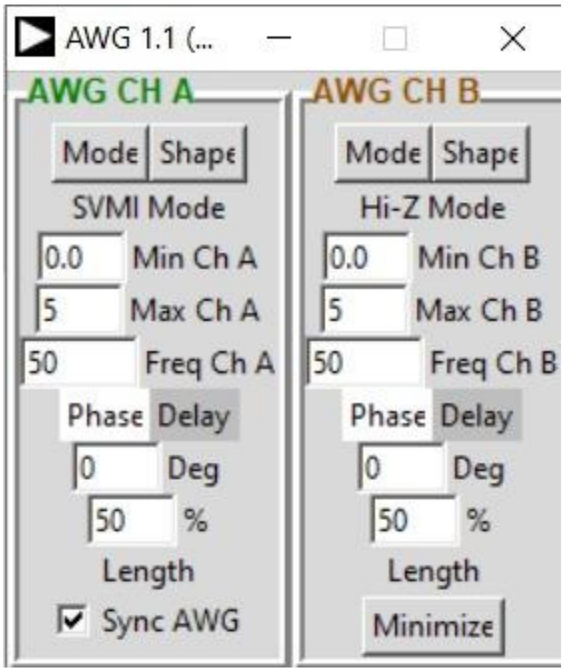
## AWG Window Settings:

## Channel A:

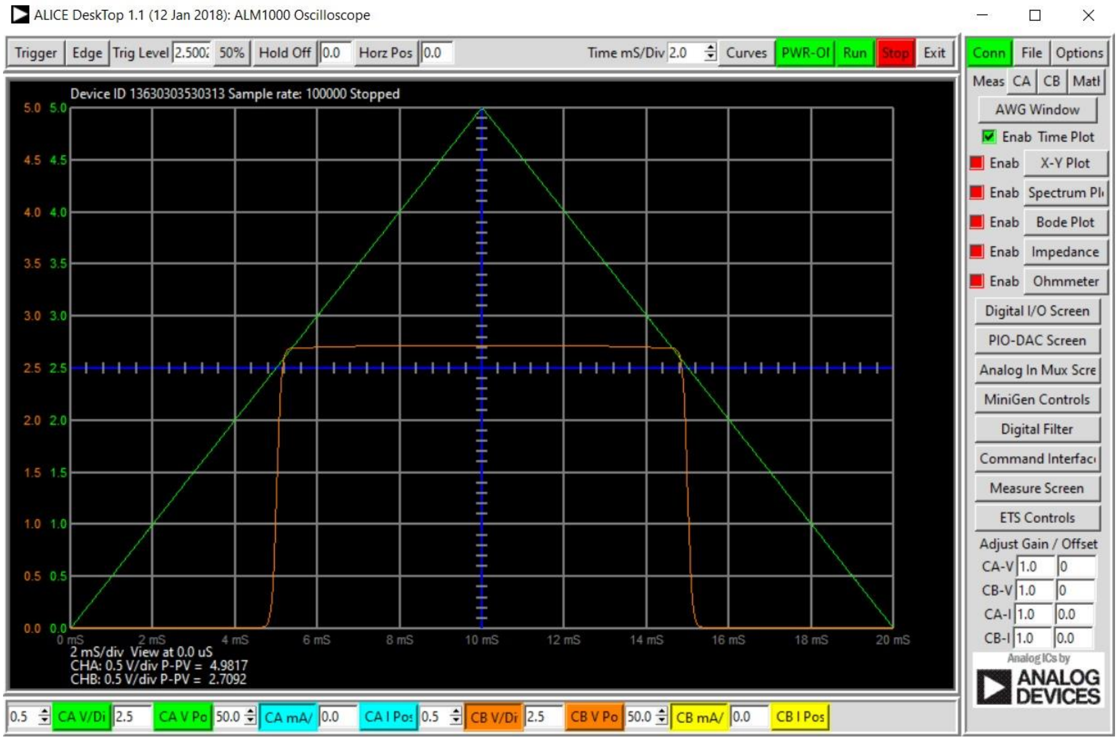
Mode: SVMI
Shape: Triangular
Max Voltage: 5V
Frequency: 50

## Channel B:

Mode: Hi-Z
Shape: NA
Max Voltage: NA
Frequency: NA




## Output of ADALM1000 Simulation *(Using ALICE M1K Desktop)*:



For a clearer understanding, we have supplied various DC voltages as the input voltage to the circuit (Channel A voltage) and recorded the corresponding output voltage (Channel B voltage) in the following table.

## Readings:

| CH A VOLTAGE | CH B VOLTAGE | REFERENCE VOLTAGE |
|---|---|---|
| 3.0 V | 2.6861 V | 2.5 V |
| 2.7 V | 2.6842 V | 2.5 V |
| 2.3 V | 0.0078 V | 2.5 V |
| 1.0 V | 0.0061 V | 2.5 V |

# Inferences

## From ADALM Implementation:

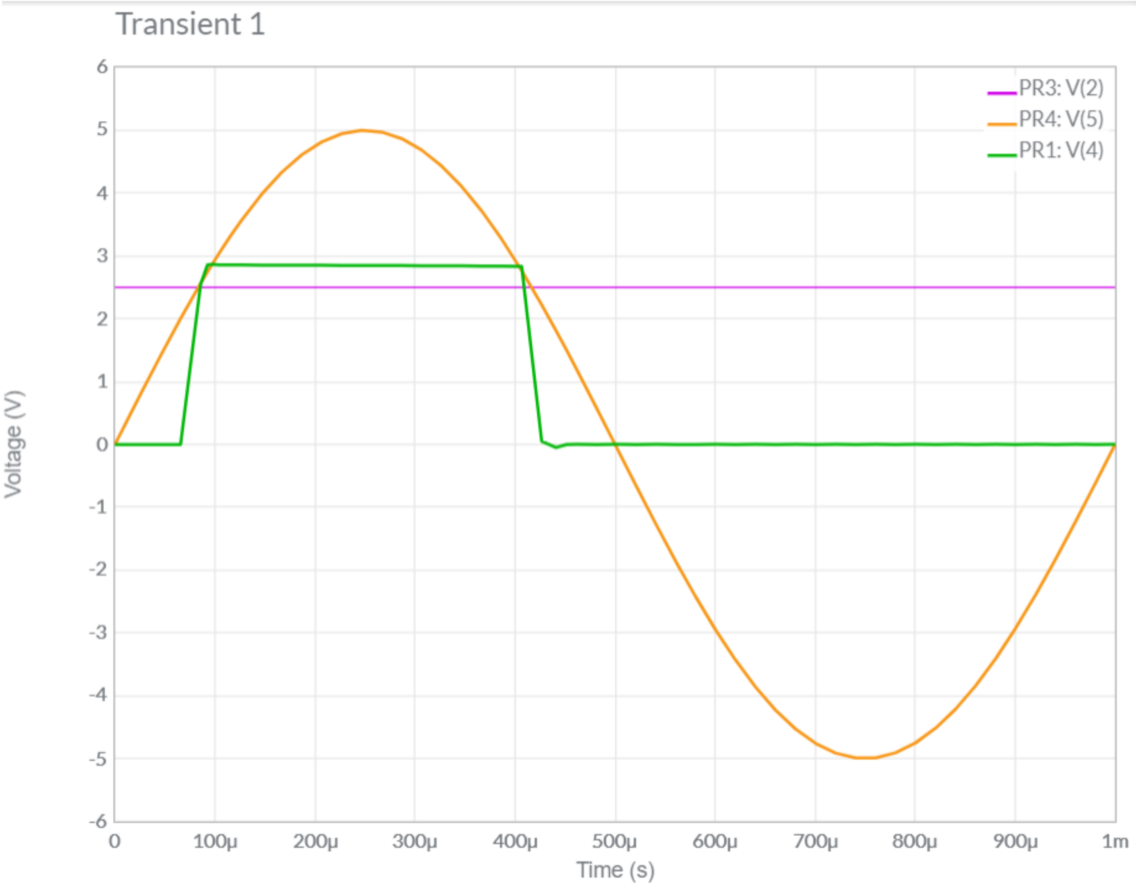
As observed from the readings table, when Channel A's voltage is greater than the reference voltage (2.5V), Channel B's voltage is almost equal to 2.69V.

On the contrary, when Channel A's voltage is lesser than the reference voltage, Channel B's voltage is almost equal to 0.

## General:

## For any input AC waveform:

- **Case 1:**
  Whenever the AC input voltage Vin exceeds 2.5V (Vref) at any point, the output waveform will always take the shape of a square. This is due to the fact that when Vin is greater than Vref, the output voltage will be high. In the figure below, this is represented by the positive half cycle of the sine wave.
- **Case 2:**
  Whenever the AC input voltage Vin does not exceed 2.5V (Vref), the output waveform will always be a straight line of 0V. This is due to the fact that when Vin is lesser than Vref, the output voltage will be low. In the figure below, this is represented by the negative half cycle of the sine wave.




## Limitations:

Theoretically, the peak amplitude of the output square wave should be equal to Vcc (V2). However, due to the voltage drop across the transistors and resistors, the output voltage obtained is less than the expected output voltage. This can be combatted by using MOS transistors.

MOSFETs (metal–oxide–semiconductor field-effect transistors) are usually more efficient switches for power supplies as the outputs are controlled by input voltage instead of input current. Furthermore, their switching ability between different resistors aids in decrease attenuation ratio, or changing the gain of operational amplifiers.

BJTs consume more power because leakage of current occurs when it is switched on. Furthermore, the BJT generally has a 0.3 voltage drop in the input pin, and it uses a considerable amount of base current for that.

# Applications:

## Differential Amplifiers:

- Amplifying audio signal (speakers, ship horn system)
- In voltage and current regulators
- In analog to digital converters (ADC) & vice versa
- As a servo amplifier in motors
- In Gyrocompass
- In various Sensors

## Voltage comparators:

- As null detectors to monitor when the given value becomes zero
- To detect whenever an AC pulse changes polarity
- In Analog-to-Digital converters

# References:


- https://www.electrical4u.com/differential-amplifier/
- https://www.electronics-tutorials.ws/opamp/opamp_1.html?utm_referrer=https%3A%2F%2Fwww.google.com%2F
- https://youtu.be/ehekdOHOIZ0
- http://www.circuitstoday.com/op-amps-operational-amplifiers
- http://www.bristolwatch.com/ele/vc.htm
- https://www.elprocus.com/differential-amplifier-circuit-working/
- https://sciencing.com/input-common-emitter-npn-transistors-6771607.html