Shahjalal University of Science and Technology

Department of Electrical and Electronic Engineering

Electrical and Electronic Circuits Lab

List of Experiments

Experiment 1: To familiarize students with some basic components like resistor, capacitor, inductor, diode, transistor, some basic logic ICs, breadboard, etc.

Resistors

A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element. The current through a resistor is in direct proportion to the voltage across the resistor's terminals. This relationship is represented by Ohm's law. It is a device used in electrical circuits to maintain a constant relation between current flow and voltage.

Figure 1: Resistors of different values

Circuit Diagram

Fixed Resistor

Variable Resistor

Resistor Color Code

The resistance value and tolerance of resistors are usually indicated by color coding. Color bands are printed on the body. They consist of four color bands or 5 color bands & they are read from left to right. A typical resistor with color bands is shown in figure

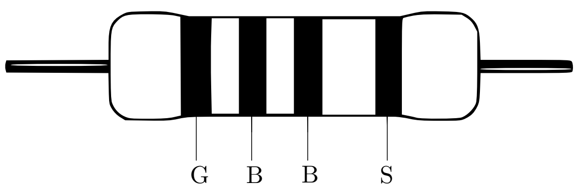


Figure 2: Values of resistors can be determined using their color code

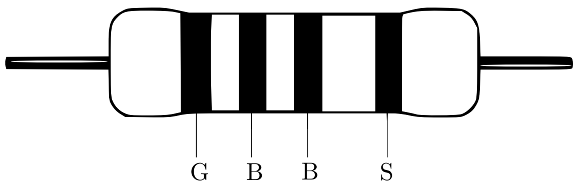
The above resistor has 4 color bands. The first band represents the first digit. The second band represent second digit The third band represent multiplier (this gives the no. of zeros after the 2 digits) The 4th band represents tolerance in %

The color codes are presented in below table

Color	First Digit for the 1st Band	Second Digit for the 2nd Band	Multiplier Digit for the 3rd Band	Resistance Tolerance
Black	0	0	10^0	-
Brown	1	1	10^1	$\pm 1\%$
Red	2	2	10^2	$\pm 2\%$
Orange	3	3	10^3	$\pm 3\%$
Yellow	4	4	10^4	-
Green	5	5	10^5	-
Blue	6	6	10^6	-
Violet	7	7	10^7	-
Gray	8	8	10^8	-
White	9	9	10^9	-
Gold	-	-	10^{-1}	$\pm 5\%$
Silver	-	-	10^{-2}	$\pm 10\%$
No Color	-	-	-	$\pm 20\%$

N.B. The resistance value can also be measured directly using a Multimeter

Example
The resistor has a color band sequence green, blue, brown and silver. Identify the resistance value.



1st Band	2nd Band	3rd Band	4th Band
1st Digit 5	2nd Digit 6	Multiplier 10^1	Tolerance $\pm 10\%$

The resistance value $= 56 \times 10^1 \pm 10\% = 560\Omega \ \pm 10\%$
Therefore the resistance should be within the range 555Ω to 565Ω

Capacitors

Capacitors can store energy in the electric field located between plates. They are commonly used in electronic circuits for storage. They can also be used in filter circuits to differentiate between high and low-frequency signals. Capacitors can be majorly classified into Ceramic Capacitors, Electrolytic Capacitors, Mylar capacitors etc.

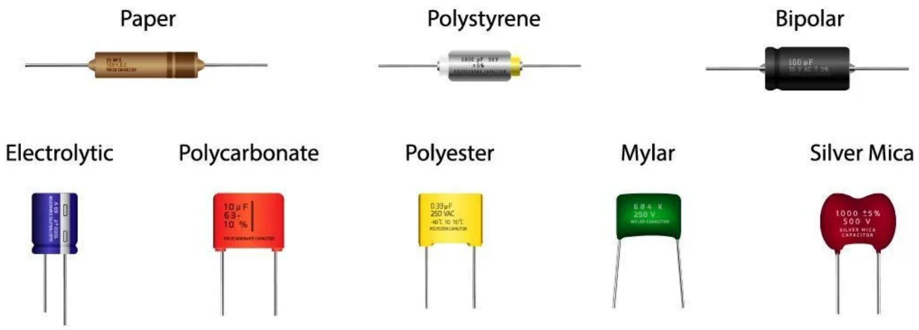


Figure 3: Different types of capacitors

Inductors

An inductor, also called a coil or reactor, is a passive two-terminal electrical component which resists changes in electric current passing through it. It consists of a conductor such as a wire, usually wound into a coil. When a current flows through it, energy is stored in a magnetic field in the coil. When the current flowing through an inductor changes, the time-varying magnetic field induces a voltage in the conductor, according to Faraday's law of electromagnetic induction, which by Lenz's law opposes the change in current that created it.

Inductors, also called coils, can be a bit harder to figure out their values. If they are color coded, the resources listed for resistors can help, otherwise a good meter that can measure inductance will be needed.

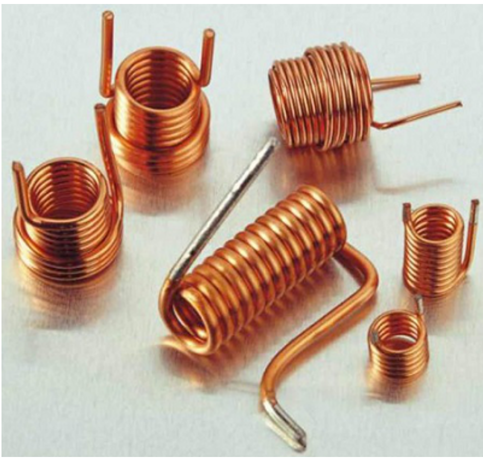


Figure 4: Inductors

Diode

In electronics, a diode is an active two-terminal electronic component with unidirectional conductance, it has low (ideally zero) resistance to current flow in one direction, and high (ideally infinite) resistance in the other.

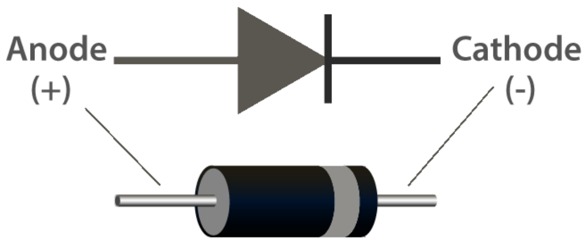


Figure 5: Diode and it's circuit symbol is shown at the top

Transistors

A transistor is a semiconductor device used to amplify and switch electronic signals and electrical power. It is composed of semiconductor material with at least three terminals for connection to an external circuit. A voltage or current applied to one pair of the transistor's terminals changes the current through another pair of terminals. Because the controlled (output) power can be higher than the controlling (input) power, a transistor can amplify a signal. The most popular and commonly used transistors are `BC547`, `2N2222`, and `BC557`.

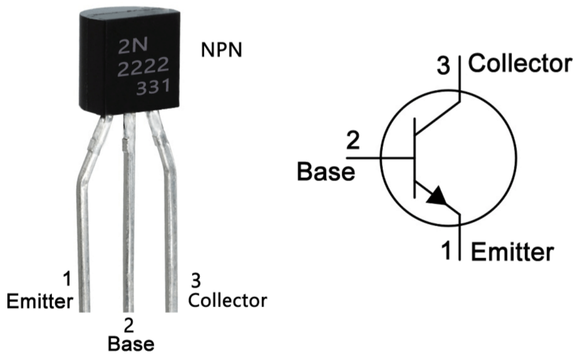


Figure 6: 2N222A pin configuration and symbol

Basic Logic Gates ICs

An integrated circuit or monolithic integrated circuit (also referred to as an IC, a chip, or a microchip) is a set of electronic circuits on one small plate ("chip") of semiconductor material, normally silicon.

Digital electronics rely on the actions of just seven types of logic gates, called AND, OR, NAND (Not AND), NOR (Not OR), XOR (Exclusive OR) XNOR (Exclusive NOR) and NOT. These can be implemented using the following IC pin diagrams.

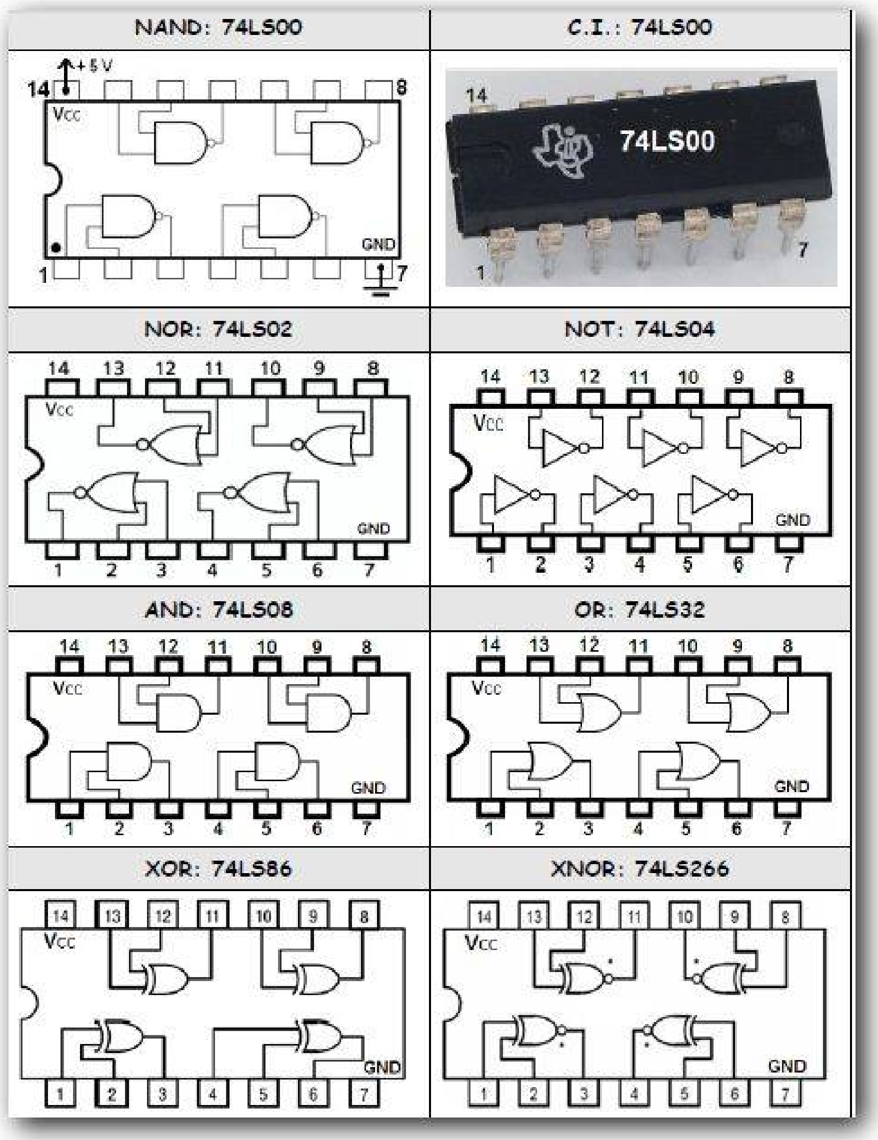


Figure 7: Different logic gates

Breadboard

The breadboard has two basic internal connections, the vertical and horizontal. The verticals are connected from top to bottom, if 5 volts is placed on the very first pin, 5 volts will be present at the very last pin and any pin in between; this is demonstrated in Figure 1.2 from red pin to red pin. The horizontal strips are connected by every 5 pins. Looking at Figure 1.3 pin A1 to E1 are connected internally.

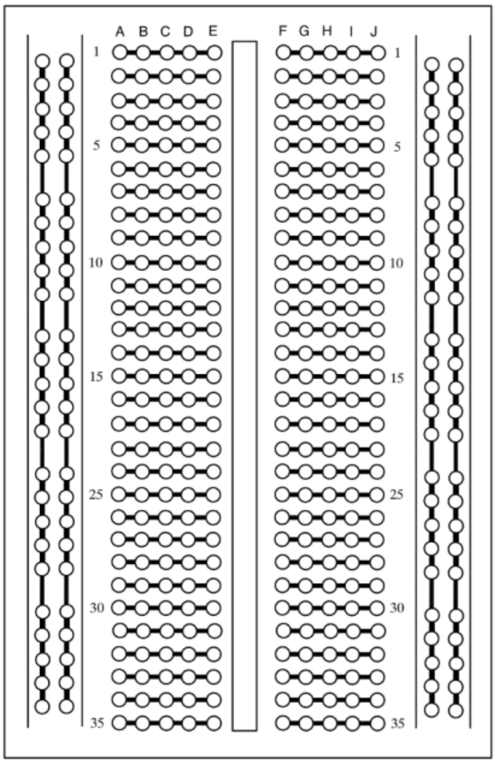


Figure 1.1

Figure 1.2

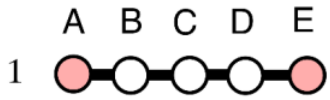


Figure 1.3

Experiment 2: To familiarize students with the operation of different electrical instruments including measuring equipments: Multi-meter, Frequency meter, Oscilloscope, Signal generator/Function generator

Summary

This lab experiment will familiarize you with the operation of basic electrical instruments commonly used in electrical engineering and electronics. These instruments are essential for measuring various electrical quantities and analyzing electrical signals.

Learning Objectives

1. Identify and describe the functions of a multimeter, frequency meter, oscilloscope, and signal generator/function generator.
2. Operate each instrument to measure voltage, current, resistance, frequency, and observe waveforms.
3. Interpret the readings and waveforms displayed by each instrument.

Equipment

- Multimeter (Digital or Analog)
- Frequency Meter
- Oscilloscope (Analog or Digital)
- Signal Generator/Function Generator
- Connecting leads (BNC cables for oscilloscope)
- Resistors (various values)
- Power supply (optional, depending on the experiment setup)

Procedures

Part 1: Multimeter

1. **Identify the controls:** Familiarize yourself with the control knobs and buttons of the multimeter. These typically include a selector switch for different measurement modes (voltage, current, resistance, etc.), range selectors for different measurement ranges, and test leads for connecting to the circuit.
2. **Measuring Voltage:**
   - Set the multimeter to the appropriate DC or AC voltage range based on the expected voltage you are measuring.

- Connect the red test lead to the positive terminal and the black test lead to the negative terminal of the voltage source (or across the desired points in the circuit).
- Read the displayed value on the multimeter.

Figure 8: A multimeter

3. **Measuring Current:**
   - Set the multimeter to the appropriate DC or AC current range based on the expected current you are measuring.
   - Open the circuit at a convenient point and connect the multimeter in series with the break. The red lead typically goes to the positive side of the break.
   - Read the displayed value on the multimeter. Caution: When measuring current, ensure the selected range is greater than the expected current to avoid damaging the meter.
4. **Measuring Resistance:**
   - Set the multimeter to the resistance (Ω) mode.
   - Ensure the component being measured (resistor) is disconnected from any circuit.
   - Touch the test leads to the terminals of the resistor.
   - Read the displayed value on the multimeter. Note that some multimeter require holding the test leads for a stable reading.

Part 2: Frequency Meter

1. Identify the input terminals on the frequency meter.
2. Connect the frequency meter to the output of a signal generator using appropriate leads.

Figure 9: Frequency Meter

3. Set the signal generator to a specific frequency (e.g., 1 kHz, 10 kHz).
4. Observe and record the reading displayed by the frequency meter. It should match the set frequency on the signal generator.

Part 3: Oscilloscope

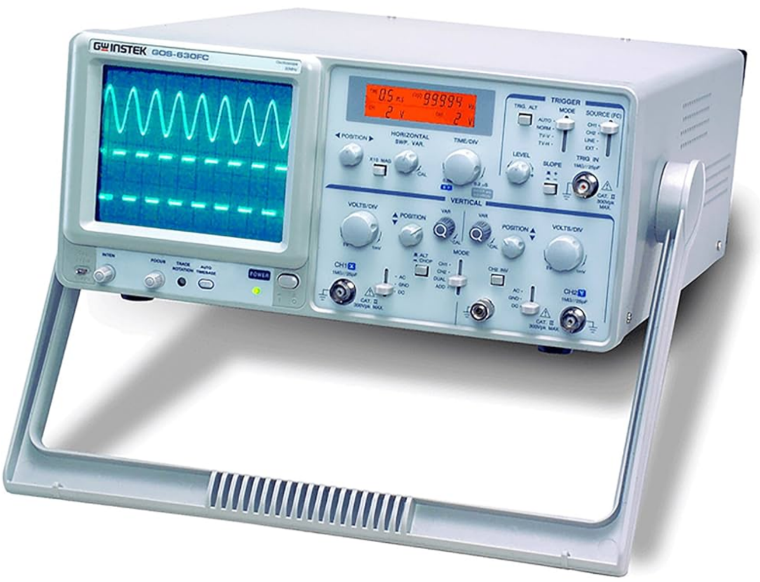


Figure 10: Oscilloscope

1. **Grounding:** Connect the ground clip of the oscilloscope probe to a common ground point in the circuit.

2. Connect the oscilloscope probe tip to the point in the circuit where you want to observe the waveform.

3. **Adjusting the Display:**

   - Adjust the vertical scale (Volts/Div) to obtain a clear view of the waveform on the screen.
   - Adjust the horizontal scale (Time/Div) to observe an appropriate number of cycles of the waveform.
   - Use the trigger controls to achieve a stable display of the waveform.

4. **Signal Observation:**

   - Set the signal generator to generate a sinusoidal waveform of a known frequency (e.g., 1 kHz).
   - Observe the waveform displayed on the oscilloscope screen and measure the peak-to-peak voltage and frequency using the oscilloscope's graticule or cursors.
   - Repeat the observation for different waveforms (e.g., square wave, triangular wave) generated by the signal generator.

   A useful video on Oscilloscope: Oscilloscope tutorial in Bangla by Rajib Sir BUET - YouTube

Part 4: Signal Generator/Function Generator

1. Familiarize yourself with the controls of the signal generator. These typically include knobs for setting frequency, amplitude, waveform (sine, square, triangle), and output impedance.

2. Set the desired frequency, amplitude, and waveform on the signal generator.

3. Connect the output of the signal generator to the oscilloscope using appropriate leads.

4. Observe the generated waveform on the oscilloscope screen and verify that it matches the settings on the signal generator.

Figure 11: Signal Generator

Data and Calculations

- In a table, record the measurements obtained for voltage, current, resistance, and frequency using the multimeter and frequency meter.
- For the oscilloscope observations, sketch the waveforms observed for different settings on the signal generator and note down the measured peak-to-peak voltage and frequency.

Conclusion

This lab experiment provided an introduction to the operation of basic electrical instruments. You should now be able to:

- Identify and describe the functions of a multimeter, frequency meter, oscilloscope, and signal generator/function generator.

Experiment 3: Verification of Thevenin's theorem

Learning Objectives

To verify Thevenin's theorem

Equipment:

- Voltmeter
- Ammeter
- Rheostats
- Connecting wires
- DC Power Supply

Statement:

Thevenin's theorem states that any linear two-terminal circuit can be replaced by an equivalent circuit consisting of a voltage source V_{Th} in series with a resistor R_{Th}.

Thevenin's theorem states that "Any linear circuit containing several voltages and resistances can be replaced by just one single voltage in series with a single resistance connected across the load." In other words, it is possible to simplify any electrical circuit, no matter how complex, to an equivalent two-terminal circuit with just a single constant voltage source in series with a resistance (or impedance) connected to a load.

Thevenin's equivalent circuit

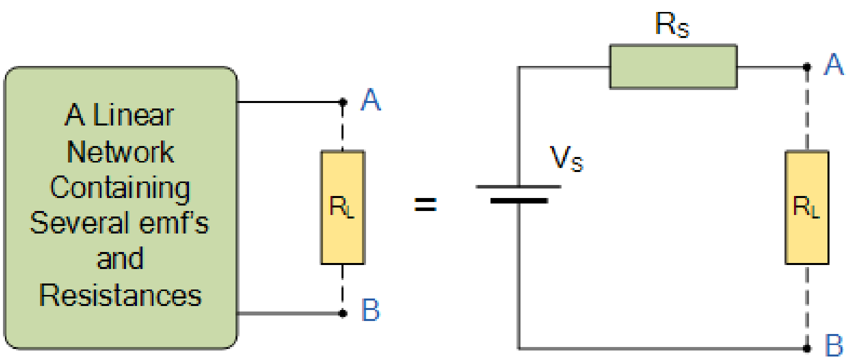
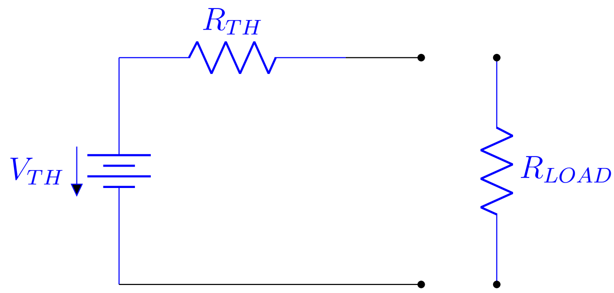


Figure 12: Thevenin's equivalent circuit

Procedure:

The voltage source is denoted by V_{TH} (thevenin equivalentt voltage), and the resistor by R_{TH}(Thevenin resistor). The objective is to evaluate V_{TH} and R_{TH}. The procedure of obtaining V_{TH} and R_{TH} is stated below for the circuits containing independent sources only.

- Remove the portion of the circuit external to which the Thevenin's equivalent circuit is to be found.
- Compute the voltage across the open-loop terminals. This voltage is V_{OC}.
- Eliminate all the sources and compute the resistance across the open-loop terminal. This resistance is R_{TH}. A voltage source is eliminated by replacing it with a short circuit and a current source is eliminated by replacing it with an open circuit.
- Draw the Thevenin equivalent circuit by placing the load resistor across the open-loop terminal



Tabulation:

S.No	Supply voltage (V)	MEASURED VALUES			THEORETICAL VALUES		
		V_{TH} (V)	R_{TH} (Ω)	I_L (mA)	V_{TH} (V)	R_{TH} (Ω)	I_L (mA)

Calculation:

Now the value of load current can be calculated as I_{LC} = calculated value of $I_L = V_{TH}/(R_L + R_{TH})$

The value of R_L can be calculated using the voltmeter and ammeter readings taken in step 2 of the procedure of $R_L = V/I$ of the procedure

Conclusion:

By comparing the measured and theoretical values, verify the validity of Thevenin's Theorem for DC circuits.

Experiment 4: Verification of Kirchhoff's Current Law (KCL) and Kirchhoff's Voltage Law (KVL)

Learning Objectives:

- Understand Kirchhoff's Current Law (KCL) and Kirchhoff's Voltage Law (KVL).
- Verify KCL and KVL through experimentation in a DC circuit.

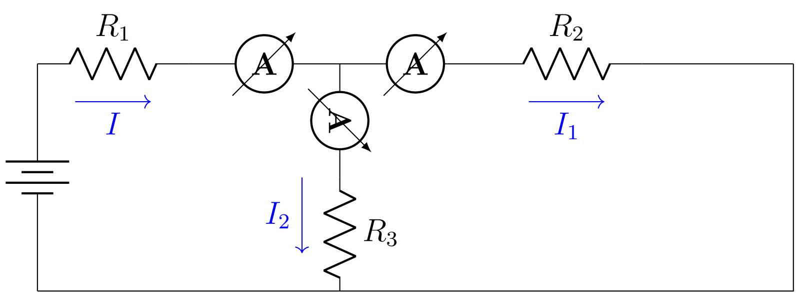
Equipment:

- DC Power Supply
- Resistors (various values - 100Ω, 220Ω, 330Ω)
- Multimeter
- Jumper Wires

Procedure:

Part A: Verification of KCL

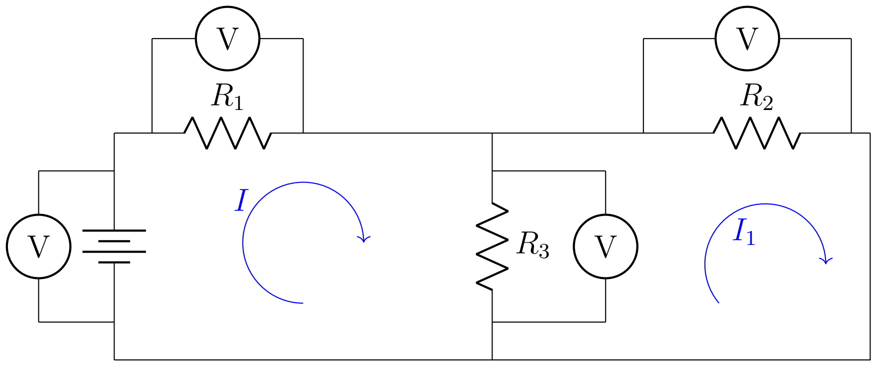
1. **Circuit Construction:** Build the following circuit on the breadboard:
    - The circuit consists of a DC power supply connected to a point (node) where three resistors (R1, R2, R3) are connected together.
2. **Current Measurement:** Set the multimeter to measure current (DC Amps).



3. **Measuring Branch Currents:** Measure the current flowing through each branch (individual resistors) leading away from the junction (I_1 and I_2). Record these values in a table.
4. **Measuring Current at the Junction:** Measure the total current entering the junction (I_{total}) by connecting the multimeter in series with the power supply feeding the circuit. Record this value.
5. **KCL Verification:** Compare the sum of the branch currents ($I_1 + I_2$) with the total current entering the junction (I_{total}). According to KCL, these values should be equal.
6. Compare the value with the theoretical results.

Part B: Verification of KVL

1. **Circuit Modification:** Modify the circuit from Part A like the figure.
2. **Voltage Measurement:** Set the multimeter to measure voltage (DC Volts).



3. **Measuring Individual Voltages:** Measure the voltage drop across each resistor in the closed loop of the circuit (V_{R1}, V_{R2}, V_{R3}). Record these values in a table.
4. **KVL Verification:** Add the voltage drops across all the resistors in the closed loop ($V_{R1} + V_{R3} - V$) and ($V_{R2} - V_{R3}$). According to KVL, the algebraic sum of these voltages should be equal to zero.
5. Compare the value with the theoretical results.

Observation Table:

KCL

Input Voltage, V	I_1	I_2	Total Current, I_{total} [measured value]	Total Current, I_{total} [theoretical value]

KVL

Loop no.	Input Voltage, V	V_{R1}	V_{R2}	V_{R3}	Algebraic Sum of Voltages [measured value]	Algebraic Sum of Voltages [theoretical value]

Data and Calculations:

- In a table, record the measured values of branch currents, total current, and individual voltage drops.
- Calculate the expected total current based on KCL (sum of branch currents).
- Calculate the expected sum of voltage drops around the closed loop based on KVL (sum of individual voltage drops).

Conclusion:

By comparing the measured and theoretical values, verify the validity of Kirchhoff's Current Law and Kirchhoff's Voltage Law for DC circuits.

Experiment 5: Verification of Superposition Theorem

Learning Objectives:

- To verify Superposition Theorem

Equipment:

- Resistors
- Ammeter
- Connecting wires
- DC Power Supply

Statement:

Superposition theorem states that in a linear bilateral network containing more than one source, the current flowing through the branch is the algebraic sum of the current flowing through that branch when sources are considered one at a time and replacing other sources by their respective internal resistances.

Procedure:

1. Give the connections as per the diagram.
2. Set a particular voltage value using RPS1 and RPS2 & note down the ammeter reading
3. Set the same voltage in circuit using RPS1 alone and short circuiting the RPS2 terminals and note the ammeter reading.
4. Set the same voltage in RPS2 alone as in circuit and short circuit the RPS1 and note down the ammeter reading.
5. Verify the superposition theorem.

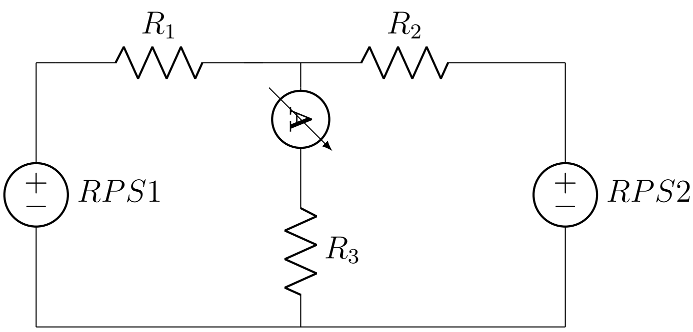


Figure 13: Superposition theorem should be applied in this circuit

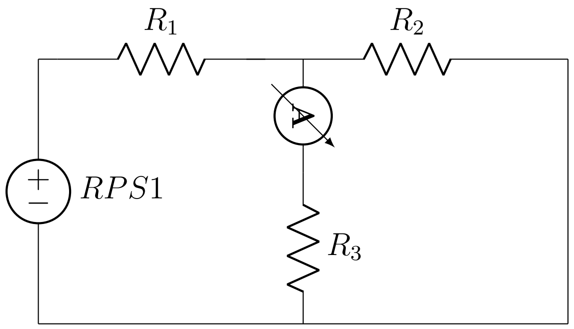


Figure 14: When RPS 2 is short circuited

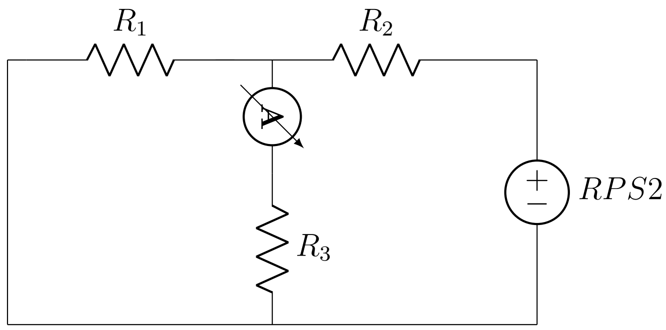


Figure 15: When RPS 1 is short circuited

Observation Table:

Theoretical Table

	RPS		Ammeter Reading (I) (mA)
	1	2	
Figure 1	10V	10V	
Figure 2	10V	0V	
Figure 3	0V	10V	

Practical Table

	RPS		Ammeter Reading (I) (mA)
	1	2	
Figure 1	10V	10V	
Figure 2	10V	0V	
Figure 3	0V	10V	

Calculation

Measure the current values through the desired node for the three cases and compare it with the obtained practical results

Conclusion:

Superposition theorem is verified both theoretically and practically.

Experiment 6: Verification of Maximum Power Transfer Theorem

Learning Objectives:

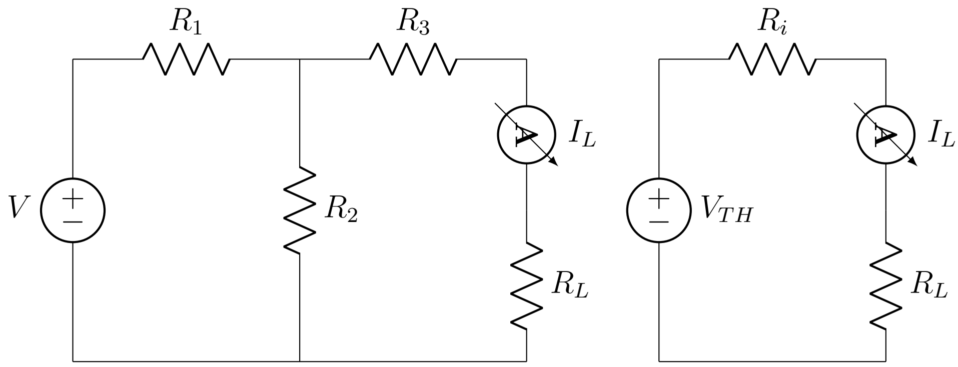
- Understand the concept of maximum power transfer theorem.
- Verify the theorem through experimentation with a DC circuit.

Equipment:

- DC Power Supply (adjustable voltage)
- Breadboard
- Resistors (various values - 100Ω, 220Ω, 330Ω, 1$k\Omega$)
- Multimeter

Procedure:

1. **Circuit Construction:** Build the following circuit on the breadboard:



   - The circuit consists of a DC power supply connected as shown in the figure above. The variable load resistor (R_L) and fixed resistors (R_1, R_2 and R_3). The internal resistance (R_i) and V_th represent Thevenin's equivalent resistance and voltage supply respectively.

2. **Voltage and Current Measurement:** Set the multimeter to measure voltage (DC Volts) and current (DC Amps).

3. **Variable Load:**

   - Adjust the voltage of the DC power supply to a fixed value (e.g., $5V$).
   - Measure the voltage across the load resistor (V_L) and the current flowing through the load resistor (I_L) for various values of the load resistance (R_L) by adjusting the variable resistor. Record these values in a table.

Data and Calculations:

- For each set of readings, calculate the power delivered to the load resistor (P_L) using the formula $P_L = V_L \times I_L$.
- Plot a graph of the calculated load power (P_L) versus the load resistance (R_L).

Serial no	Load resistance, R_L	Load Current, I_L [observed]	Load Current, I_L [calculated]	Power, P [observed]	Power, P [calculated]

Analysis:

- Observe the shape of the power curve.
- Identify the point on the graph where the load power reaches its maximum value.
- At this point, calculate the value of the load resistance (RL_{max}).

Theoretical Verification:

If the internal resistance of the DC power supply (R_i) is known, calculate the value of the load resistance for maximum power transfer using the formula: $RL_{max} = R_i$. The formula of maximum power transfer, $P_{max} = (V_{th})^2/(4RL_{max})$

Conclusion:

By observing the graph and comparing the measured maximum power transfer resistance (RL_{max}) with the calculated value (if R_i is known), verify the principle of the maximum power transfer theorem.

Experiment 7: Analysis of the Waveform of the Half Wave Rectifier Circuit

Learning Objectives:

- Understand the operation of a half wave rectifier circuit.
- Analyze the output waveform of a half wave rectifier using an oscilloscope.

Equipment:

- Signal Generator (adjustable frequency and amplitude)
- Breadboard
- Diode
- Resistor
- Wires
- Oscilloscope

Theory

A Half Wave Rectifier is a single PN junction diode connected in series to the load resistor. As you know a diode is to electric current like a one-way valve is to water, it allows electric current to flow in only one direction. This simply means the diode is operational when the diode is forward biased while it blocks the current when it is reversed biased. This property of the diode is very useful in creating simple rectifiers which are used to convert AC to DC. In Half wave rectification only the positive half cycle is obtained in output while the negative cycle is discarded.

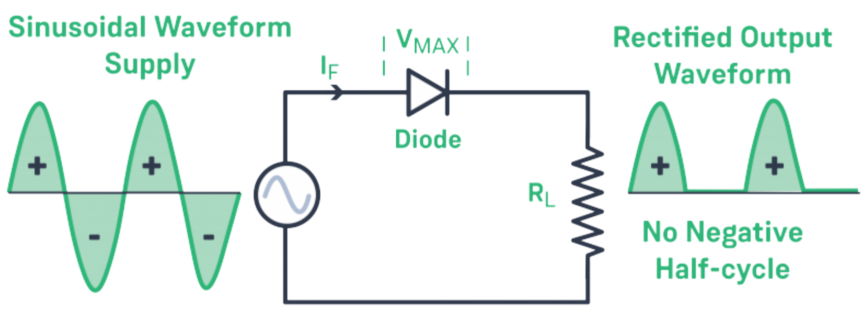


Figure 16: Half wave rectifier circuit

Procedure:

1. **Circuit Construction:** Build the above given circuit on the breadboard:
    - The half-wave bridge rectifier circuit is composed of a diode connected in series with a load resistor, R_L

- The input voltage and load resistor (R_L) are connected to the two channels of the oscilloscope to observe the waveforms.

2. **Setting Up the Signal Generator:**
   - Set the signal generator to output a sinusoidal waveform (AC).
   - Adjust the amplitude of the output signal to a suitable level (e.g., $5V$ peak-to-peak).
   - Start with a low frequency (e.g., 50 Hz).

3. **Observing the Waveform:**
   - Connect the oscilloscope probes to the input and output (across the load resistor) of the circuit.
   - Adjust the oscilloscope settings (vertical scale, horizontal scale, and trigger) to obtain a clear view of the waveforms.

4. **Analysis:**
   - Sketch the input and output waveforms observed on the oscilloscope.
   - Measure the peak-to-peak voltage of the output waveform.
   - Verify that the output waveform is rectified (converted to a pulsating DC waveform).

Data and Calculations:

- Record the measured peak-to-peak voltage of the input and output waveforms.
- Calculate the average DC voltage at the output using a multimeter. The DC voltage at the output is given by

$$V_{dc} = \frac{V_P - V_b}{\pi}$$

  Where, V_P = Peak input voltage and V_b = built-in voltage ($0.7V$ for silicon diode)

- When a voltmeter measures the input voltage, the root-mean-square voltage must satisfy

$$V_{rms} = \frac{V_P}{\sqrt{2}}$$

Observation Table:

Resistance, R_L	V_{dc}	V_{rms}	$I_{dc} = V_{dc}/R_L$	$I_{rms} = V_{rms}/R_L$

Conclusion:

By analyzing the waveforms and DC voltage measurement, verify the operation of the half wave rectifier circuit in converting AC voltage to pulsating DC voltage.

Experiment 8: Analysis of the Waveform of the Full Wave Rectifier Circuit

Learning Objectives:

- Understand the operation of a full wave rectifier circuit.
- Analyze the output waveform of a full wave rectifier using an oscilloscope.

Equipment:

- Signal Generator (adjustable frequency and amplitude)
- Breadboard
- Diodes (`1N4001` or similar - 4 required)
- Resistor, R_L $(100\Omega, 220\Omega, 470\Omega, 1k\Omega)$
- Capacitor, C $(10\mu F)$
- Multimeter (DC voltage measurement)
- Oscilloscope

Procedure:

1. **Circuit Construction:** Build the following circuit on the breadboard:
    - The full-wave bridge rectifier circuit is composed of four diodes connected in a bridge with no need for a center-tap transformer.
    - The output of the bridge rectifier is connected to a load resistor (RL) and then to the oscilloscope.
2. **Setting Up the Signal Generator:**
    - Set the signal generator to output a sinusoidal waveform (AC).

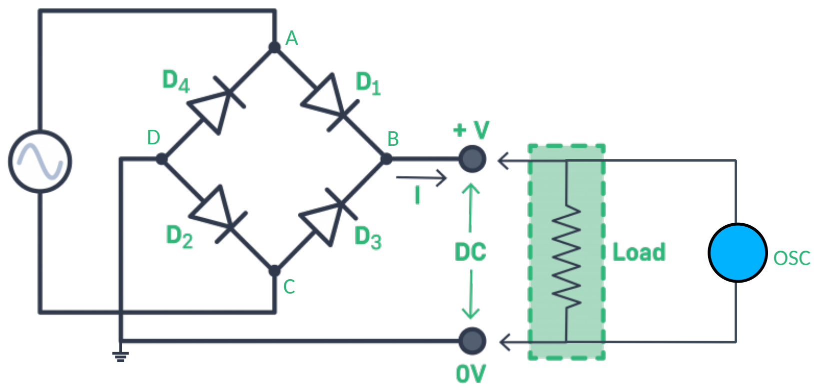


Figure 17: Full wave bridge rectifier circuit.

- Adjust the amplitude of the output signal to a suitable level (e.g., $5V$ peak-to-peak).
- Start with a low frequency (e.g., 50 Hz).

3. **Observing the Waveform:**

   - Connect the oscilloscope probes to the input (across point A and C) and output (across the load resistor) of the circuit.
   - Adjust the oscilloscope settings (vertical scale, horizontal scale, and trigger) to obtain a clear view of the waveforms.

4. **Analysis:**

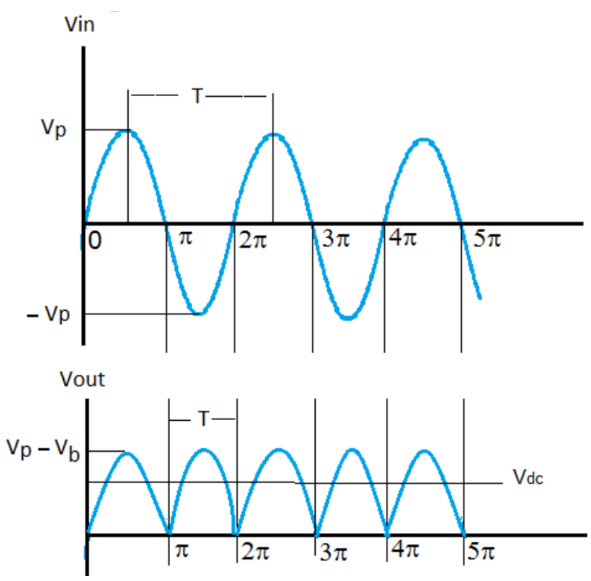
   - Sketch the input and output waveforms observed on the oscilloscope.
   - Measure the peak-to-peak voltage of the output waveform.
   - Verify that the output waveform is rectified (converted to a pulsating DC waveform).

5. Filtering (if using a capacitor):

   - Modify the circuit by adding a capacitor in parallel with the resistor at the output.
   - Observe the change in the output waveform on the oscilloscope.
   - Explain how the capacitor affects the rectified waveform.

Data and Calculations:

- Record the measured peak-to-peak voltage of the input and output waveforms.



- Calculate the average DC voltage at the output using a multimeter. The DC voltage at the output is given by

$$V_{dc} = 2 \times \frac{V_P - 2V_b}{\pi}$$

  Where, V_P = Peak input voltage and V_b = built-in voltage ($0.7V$ for silicon diode)

- When a voltmeter measures the input voltage, the root-mean-square voltage must satisfy

$$V_{rms} = \frac{V_P}{\sqrt{2}}$$

Observation Table:

Without capacitor:

Resistance, R_L	V_{dc}	V_{rms}	$I_{dc} = V_{dc}/R_L$	$I_{rms} = V_{rms}/R_L$

With capacitor:

Resistance, R_L	V_{dc}	V_{rms}	$I_{dc} = V_{dc}/R_L$	$I_{rms} = V_{rms}/R_L$

Conclusion:

By analyzing the waveforms and DC voltage measurement, verify the operation of the full wave rectifier circuit in converting AC voltage to pulsating DC voltage. Observe how the optional capacitor can help smooth out the rectified waveform.

Experiment 9: Design and analysis of AND gate, OR gate and NOT gate using BJT

Learning Objectives:

- Understand the working principle of Bipolar Junction Transistors (BJT)
- Implement Logic gates (AND, OR, NOT) using Bipolar Junction Transistors

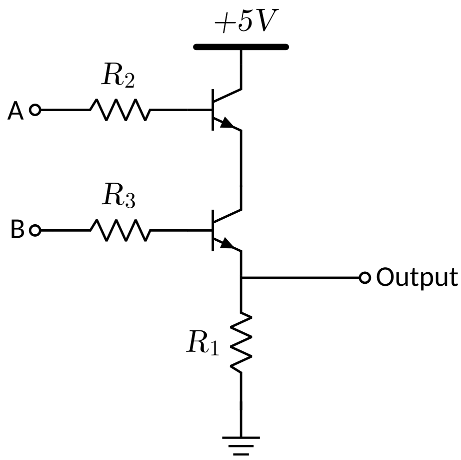
Equipment:

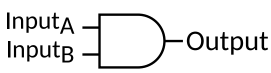
- Breadboard
- NPN transistors (e.g `2N2222`)
- LEDs (different colors for easier identification)
- Resistors
- Push Buttons
- Power Supply
- Jumper Wires

Theory

The use of transistors for the construction of logic gates depends upon their utility as fast switches. When enough voltage is applied to the base-emitter junction , the transistor is turned on i.e. collector voltage with respect to the emitter may be near zero and can be used to construct gates.

AND gate
For the AND logic, the two npn transistors are in series and both transistors must be in the conducting state or turned on to drive the output high.

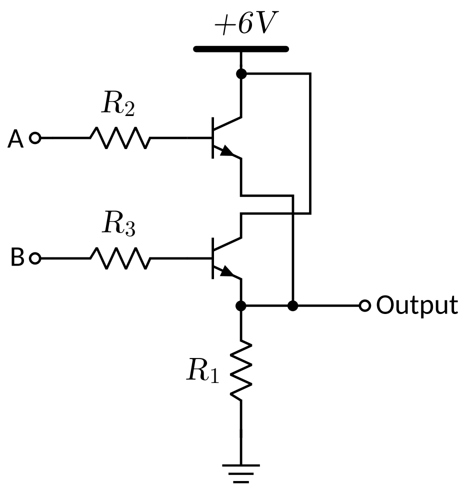


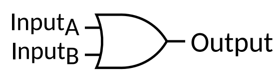


A	B	Output
0	0	0
0	1	0
1	0	0
1	1	1

Figure 18: AND gate implementation using BJT

OR gate
For the OR logic, the two npn transistors are parallel connected. The output is driven high if either of the transistors is conducting.

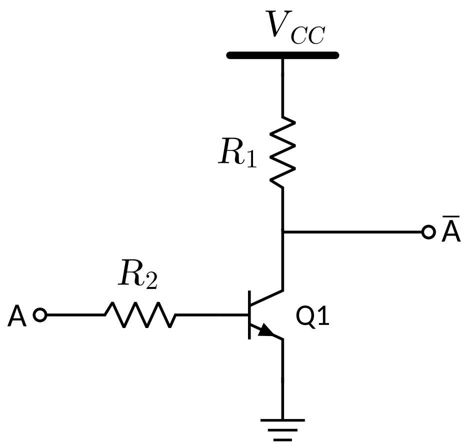


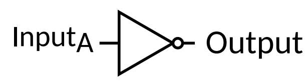


A	B	Output
0	0	0
0	1	1
1	0	1
1	1	1

Figure 19: OR gate implementation using BJT

NOT gate
A transistor with a collector resistor can serve as an inverter





A	Output
0	0
0	1

Figure 20: NOT gate implementation using BJT

Procedure

- Built circuits according to fig-18, fig-19, fig-20
- Give 5V DC power supplies (two power supplies for AND and OR; one for NOR) across the base- emitter terminal of the BJT
- Turn on/off the power supplied according to the truth tables. Consider 5V as binary 1 and 0V as binary 0.
- Measure the output

Tabulation

AND Gate

A	B	Output
0	0	
0	1	
1	0	
1	1	

OR Gate

A	B	Output
0	0	
0	1	
1	0	
1	1	

NOT Gate

A	Output
0	
1	

Conclusion

This experiment demonstrated the practical application of transistors in designing basic TTL logic gates. By constructing and testing AND, OR, and NOT gates, students gained hands-on experience in understanding transistor-based digital logic circuits.

Experiment 10: Verification of DeMorgan's Theorem using Logic Gate ICs

Learning Objectives:

- Understand DeMorgan's Theorem for logic gates.
- Verify DeMorgan's Theorem for NOT, AND, and OR gates using digital logic ICs.

Equipment:

- Breadboard
- Logic Gate ICs (e.g., `7404` for NOT gates, `7408` for AND gates, `7432` for OR gates)
- Inverter IC (e.g., `7404` for NOT gates)
- LEDs (different colors for easier identification)
- Resistors (220Ω or 330Ω)
- Push Buttons (2 or more)
- Power Supply (5V)
- Jumper Wires

Procedure:

Part A: Review of Inverter Operation (NOT Gate)

1. **Circuit Construction:** Build the inverter circuit again on the breadboard:
   - Connect a push button to the input of an inverter IC (e.g., `7404`).

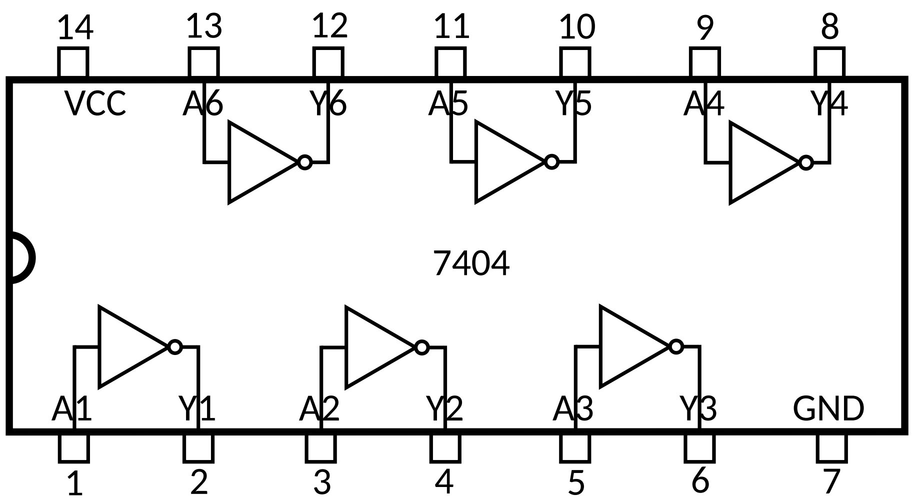


Figure 21: NOT Gate IC 7404

- Connect an LED with a current limiting resistor (e.g., 220Ω) to the output of the inverter.
- Connect the power supply (V_{cc} and GND) to the IC.

2. **Truth Table Verification:**

Input 1	Output LED 1
0	1
1	0

- Create a table with columns for Input (push button state) and Output (LED state).
- Press and hold the push button (Input = LOW). Observe the LED state (Output). Record the values in the table.
- Release the push button (Input = HIGH). Observe the LED state and record it in the table.
- Verify that the output of the inverter is the logical inverse of the input (Output = NOT(Input)).

Part B: Verification of DeMorgan's Theorem for AND Gate

1. **Circuit Construction:** Build the following circuit on the breadboard:

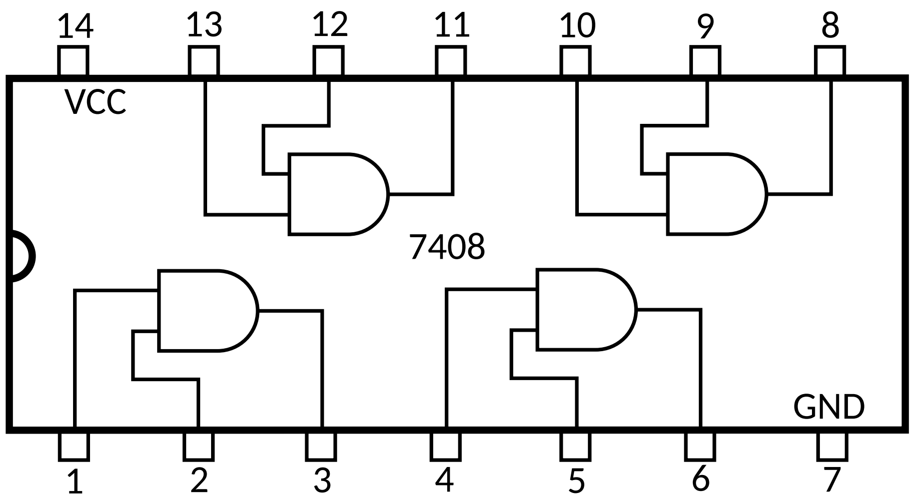


Figure 22: AND Gate IC 7408

- Connect two push buttons (SW1 and SW2) to the inputs of separate AND gate ICs (e.g., 7408).
- Connect two push buttons (SW1 and SW2) to the inputs of separate AND gate ICs (e.g., 7408).
- Connect the inverters (e.g., 7404) to the outputs of the push buttons.
- The inverted outputs of the push buttons are then connected to the inputs of another AND gate.

- Connect the final AND gate's output to another LED with a current limiting resistor.
- Connect the power supply (Vcc and GND) to all the ICs.

2. **Truth Table Verification:**

Input 1, A	**Input 2,** B	**Inverted Input 1,** $\overline{A}$	**Inverted Input 2,** $\overline{B}$	**Output LED 1,** $A * B$	**Output LED 2,** $\overline{A} * \overline{B}$
0	0	1	1	0	1
0	1	1	0	0	0
1	0	0	1	0	1
1	1	0	0	1	0

- Create a truth table with columns for Input 1 (SW1 state), Input 2 (SW2 state), Output of AND gate (LED1), Inverted Input 1, Inverted Input 2, and Output of final AND gate (LED2).
- Operate the push buttons (SW1 and SW2) independently (pressing one at a time, both pressed, and both released) to explore all possible input combinations.
- Observe the state of each LED (LED1 and LED2) and record the corresponding outputs in the truth table.
- In the table, also record the inverted values of Input 1 and Input 2 based on the push button states.

3. **DeMorgan's Theorem Verification:**

- Analyze the truth table. You should observe that the output of the final AND gate (LED2) is only HIGH (logical 1) when both Input 1 and Input 2 are LOW (logical 0).
- This verifies DeMorgan's Theorem for AND gates: **(NOT A) AND (NOT B) = NOT(A OR B)**

Part C: Verification of DeMorgan's Theorem for OR Gate

1. **Circuit Modification:** Modify the previous circuit on the breadboard:

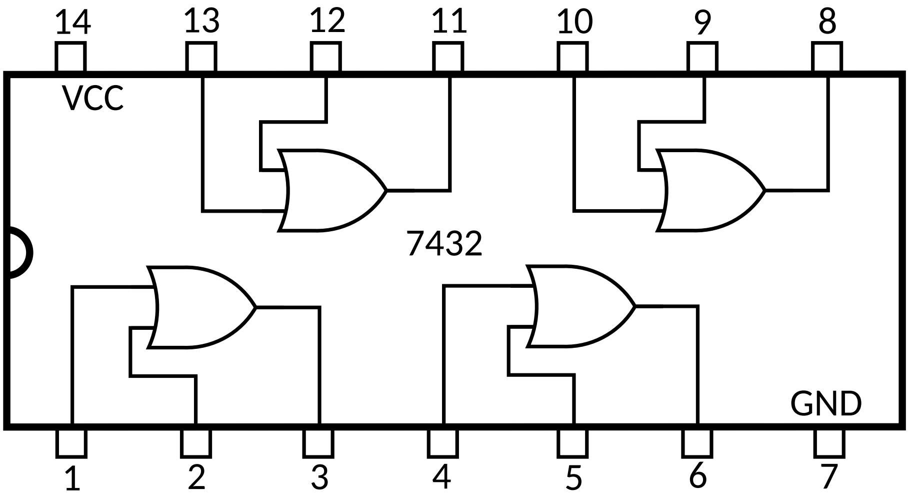


Figure 23: OR Gate IC 7432

- Replace the final AND gate with an OR gate (e.g., 7432).
- Update the circuit connections accordingly

2. **Truth Table Verification:**

Input 1, A	**Input 2,** B	**Inverted Input 1,** $\overline{A}$	**Inverted Input 2,** $\overline{B}$	**Output LED 1,** $A+B$	**Output LED 2,** $\overline{A}+\overline{B}$
0	0	1	1	0	1
0	1	1	0	0	0
1	0	0	1	0	1
1	1	0	0	1	0

- Create a new truth table similar to Part B, but for the OR gate configuration.
- Operate the push buttons (SW1 and SW2) and record the output states of LED1, LED2, Inverted Input 1, and Inverted Input 2 in the table.

3. **DeMorgan's Theorem Verification:**

- Analyze the new truth table. You should observe that the output of the OR gate (LED2) is HIGH (logical 1) whenever either Input 1 or Input 2 (or both) are LOW (logical 0).
- This verifies DeMorgan's Theorem for OR gates: **(NOT A) OR (NOT B) = NOT(A AND B)**

Conclusion:

By analyzing the truth tables for both AND and OR gate configurations, you have experimentally verified DeMorgan's Theorem. This theorem allows you to simplify logic expressions by replacing negated combinations (e.g., NOT(A AND B)) with equivalent expressions using only inverters and non-negated inputs (e.g., (NOT A) OR (NOT B)).