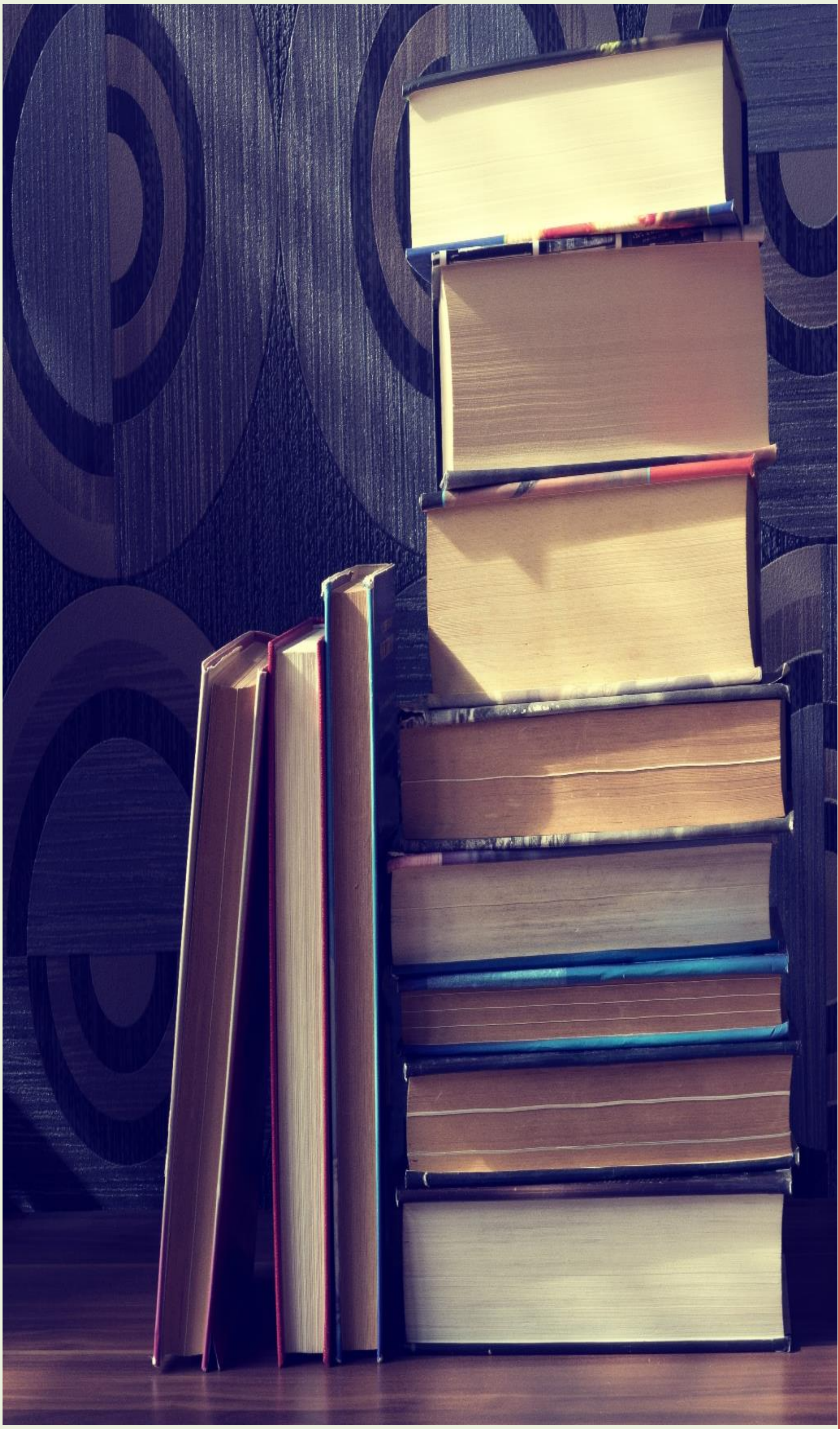

IMPLEMENTING NAND GATE USING TRANSISTOR

INTODUCTION TO ELECTRONICS

PROJECT BY:

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Abstract

This capstone presents a general framework involved in project planning which may be used by students, as well as objectives involved in implementing nand logic using transistor .

This project was developed with the purpose of familiarizing the concepts with the applications of transistors.

The Logic NAND Gate is considered as a “Universal” gate because it is one of the most commonly used logic gate types. NAND gates can also be used to produce any other type of logic gate function, and in practice the NAND gate forms the basis of most practical logic circuits.

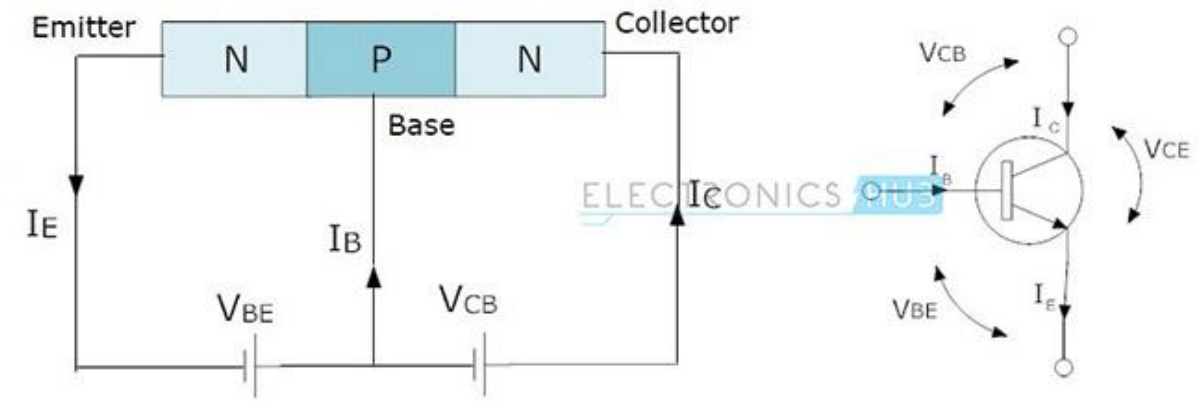
The purpose of the project is to implement a NAND gate circuit using transistors. Owing to the reason that NAND (and NOR) gates are made of the fewest transistors and therefore are cheaper to make, faster, and smaller than logic made from other gates.

Content:

Introduction

A semiconductor device with three connections, capable of amplification in addition to rectification. There are two types; NPN and PNP.

NPN transistor is one of the Bipolar Junction Transistor (BJT) types. The NPN transistor consists of two n-type semiconductor materials and they are separated by a thin layer of p-type semiconductor. Here the majority charge carriers are the electrons. The flowing of these electrons from emitter to collector forms the current flow in the transistor. Generally the NPN transistor is the most used type of bipolar transistors because the mobility of electrons is higher than the mobility of holes. The NPN transistor has three terminals – emitter, base and collector. The NPN transistor is mostly used for amplifying and switching the signals.



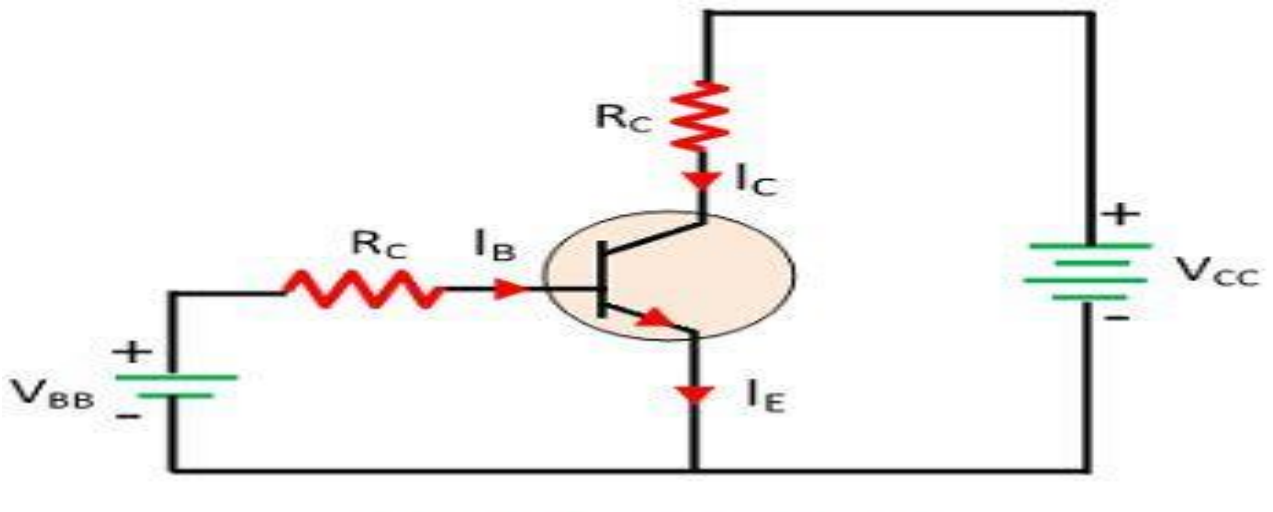
The above figure shows the symbol and structure of NPN transistor. In this structure we can observe the three terminals of transistor, circuit currents and voltage value representations. Now let us see the operation of the NPN transistor with explanation.

Definition:

The transistor in which one p-type material is placed between two n-type materials is known as **NPN transistor**. The NPN transistor **amplifies the weak signal** enter into the base and produces strong amplify signals at the collector end. In NPN transistor, the direction of **movement of an electron** is from the **emitter to collector** region due to which the current constitutes in the transistor. Such type of transistor is mostly used in the circuit because their majority charge carriers are electrons which have high mobility as compared to holes.

Circuit Diagram of NPN Transistor:

The circuit diagram of the NPN transistor is shown in the figure below. The collector and the base circuit is connected in reverse biased while the emitter and base circuit is connected in forward biased. The collector is always connected to the positive supply, and the base is in negative supply for controlling the ON/OFF states of the transistor.



NPN Transistor

Operating Modes of Transistors

It depends on the biasing conditions like forward or reverse, transistors have three major modes of operation namely cutoff, active and saturation regions.

Active Mode

In this mode transistor is generally used as a current amplifier. In active mode, two junctions are differently biased that means emitter-base junction is forward biased whereas collector-base junction is reverse biased. In this mode current flows between emitter and collector and amount of current flow is proportional to the base current.

Cutoff Mode

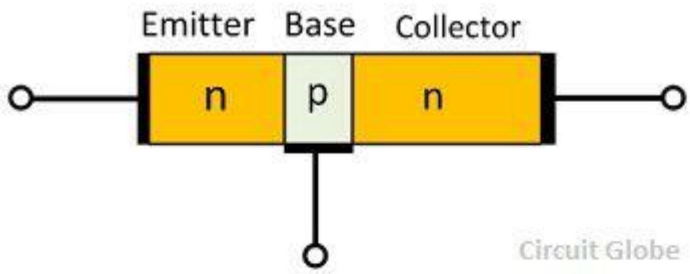
In this mode, both collector base junction and emitter base junction are reverse biased. This in turn not allows the current to flow from collector to emitter when the base-emitter voltage is low. In this mode device is completely switched off as the result the current flowing through the device is zero.

Saturation Mode

In this mode of operation, both the emitter base and collector base junctions are forward biased. Current flows freely from collector to emitter when the base-emitter voltage is high. In this mode device is fully switched ON.

Constructions:

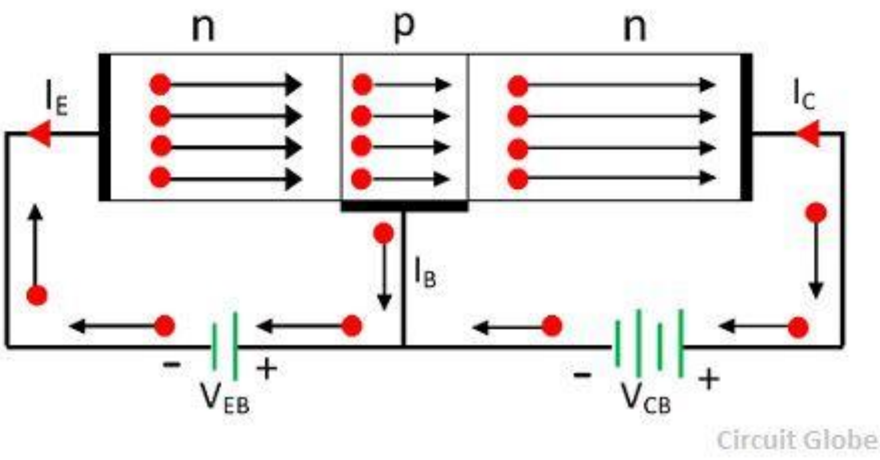
The NPN transistor has two diodes connected back to back. The diode on the left side is called an emitter-base diode, and the diodes on the right side are called collector-base diode. These names are given as per the name of the terminals.



The NPN transistor has three terminals, namely emitter, collector and base. The middle section of the NPN transistor is lightly doped, and it is the most important factor of the working of the transistor. The emitter is heavily doped, and the collector is moderately doped.

Working of NPN Transistor:

The circuit diagram of the NPN transistor is shown in the figure below. The forward biased is applied across the emitter-base junction, and the reversed biased is applied across the collector-base junction. The forward biased voltage V_{EB} is small as compared to the reverse bias voltage V_{CB}.



The emitter of the NPN transistor is **heavily doped**. When the forward bias is applied across the emitter, the majority charge carriers move towards the base. This causes the emitter current I_E. The electrons enter into the P-type material and combine with the holes.

The base of the NPN transistor is **lightly doped**. Due to which only a few electrons are combined and remaining constitutes the base current I_B. This base current enters into the collector region. The reversed bias potential of the collector region applies the high attractive force on the electrons reaching collector junction. Thus attract or collect the electrons at the collector.

The whole of the emitter current is entered into the base. Thus, we can say that the emitter current is the sum of the collector or the base current.

The equation for base current of a bipolar NPN transistor is given by, $\mathbf{I_B = (V_B - V_{BE})/R_B}$

Where,

I_B = Base current
V_B = Base bias voltage
V_{BE} = Input Base-emitter voltage = 0.7V
R_B = Base resistance

The output collector current in common emitter NPN transistor can be calculated by applying Kirchhoff's Voltage Law (KVL).

The equation for collector supply voltage is given as

$$V_{CC} = I_C R_L + V_{CE} \text{ .... } (1)$$

From the above equation the collector current for common emitter NPN transistor is given as

$$I_C = (V_{CC}-V_{CE})/R_L$$

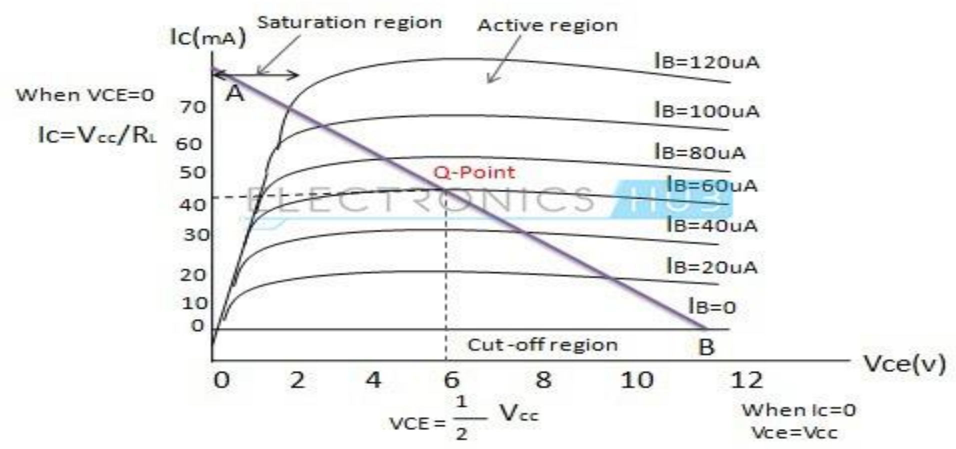
In a common emitter NPN transistor the relation between collector current and emitter current is given as

$$I_C = \beta\ I_B$$

In active region the NPN transistor acts as a good amplifier. In common emitter NPN transistor total current flow through the transistor is defined as the ratio of collector current to the base current IC/IB. This ratio is also called as "DC current gain" and it doesn't have any units. This ratio is generally represented with β and the maximum value of β is about 200. In common base NPN transistor the total current gain is expressed with the ratio of collector current to emitter current IC/IE. This ratio is represented with α and this value is generally equal to unity.

Output Characteristics of NPN Transistor:

The curves show the relationship between the collector current (IC) and the collector-emitter voltage (VCE) with the varying of base current (IB). We know that the transistor is 'ON' only when at least a small amount of current and small amount of voltage is applied at its base terminal relative to emitter otherwise the transistor is in 'OFF' state.



The collector current (IC) is mostly affected by the collector voltage (VCE) at 1.0V level but this IC value is not highly affected above this value. Already we know that the emitter current is the sum of base and collector currents. i.e. IE =IC+ IB. The current flowing through the resistive load (RL) is equal to the collector current of the transistor. The equation for the collector current is given by,

$$\mathbf{I_C = (V_{CC} - V_{CE}) / R_L}$$

The straight line indicates the 'Dynamic load line' which is connecting the points A (where V_{CE} = 0) and B (where I_C = 0). The region along this load line represents the 'active region' of the transistor.

The common emitter configuration characteristics curves are used to calculate the collector current when the collector voltage and base current is given.

NPN Transistor Applications

- NPN transistors are mainly used in switching applications.
- Used in amplifying circuit applications.
- Used in the Darlington pair circuits to amplify weak signals.
- NPN transistors are used in the applications where there is a need to sink a current.
- Used in some classic amplifier circuits, such as ‘push-pull’ amplifier circuits.
- In temperature sensors.
- Very High frequency applications.
- Used in logarithmic convertors.

NPN Transistor as a switch

A transistor is used for switching operation for opening or closing of a circuit. This type solid state switching offers significant reliability and lower cost as compared with conventional relays. Both NPN and PNP transistors can be used as switches. Some of the applications use a power transistor as switching device, at that time it may necessary to use another signal level transistor to drive the high-power transistor.

Based on the voltage applied at the base terminal of a transistor switching operation is performed. When a sufficient voltage ($V_{in} > 0.7$ V) is applied between the base and emitter, collector to emitter voltage is approximately equal to 0. Therefore, the transistor acts as a short circuit. The collector current V_{cc}/R_c flows through the transistor.

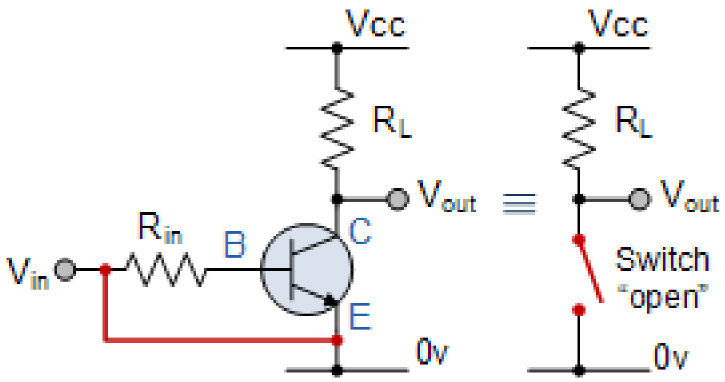
Similarly, when no voltage or zero voltage is applied at the input, transistor operates in cutoff region and acts as an open circuit. In this type of switching connection, load (here LED lamp) is connected to the switching output with a reference point. Thus, when the transistor is switched ON, current will flow from source to ground through the load

.

Cut-off Region

Here the operating conditions of the transistor are zero input base current (I_B), zero output collector current (I_C) and maximum collector voltage (V_{CE}) which results in a large depletion layer and no current flowing through the device. Therefore the transistor is switched “Fully-OFF”.

Cut-off Characteristics

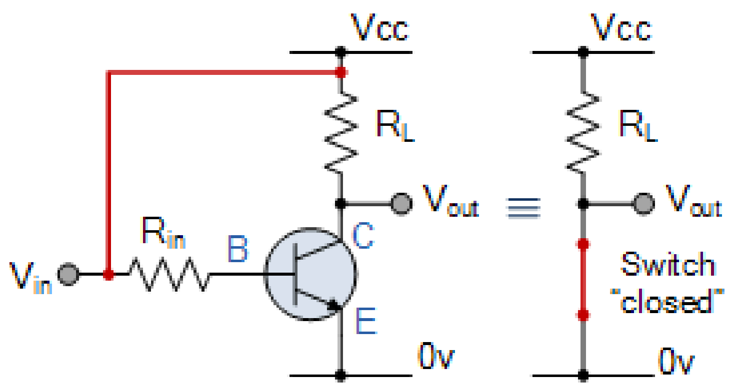
 	• The input and Base are grounded (0v) • Base-Emitter voltage V_{BE} < 0.7v • Base-Emitter junction is reverse biased • Base-Collector junction is reverse biased • Transistor is “fully-OFF” (Cut-off region) • No Collector current flows ($I_C = 0$) • $V_{OUT} = V_{CE} = V_{CC}$ = ”1 ” • Transistor operates as an “open switch”

Then we can define the “cut-off region” or “OFF mode” when using a bipolar transistor as a switch as being, both junctions reverse biased, V_B < 0.7v and $I_C = 0$. For a PNP transistor, the Emitter potential must be negative with respect to the Base.

Saturation Region

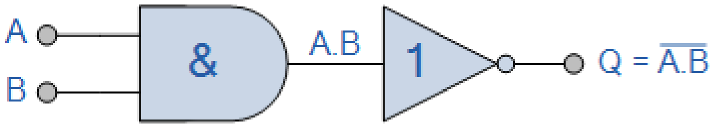
Here the transistor will be biased so that the maximum amount of base current is applied, resulting in maximum collector current resulting in the minimum collector emitter voltage drop which results in the depletion layer being as small as possible and maximum current flowing through the transistor. Therefore the transistor is switched “Fully-ON”.

Saturation Characteristics

	• The input and Base are connected to V_{CC} • Base-Emitter voltage $V_{BE} > 0.7v$ • Base-Emitter junction is forward biased • Base-Collector junction is forward biased • Transistor is “fully-ON” (saturation region) • Max Collector current flows ($I_C = Vcc/R_L$) • $V_{CE} = 0$ (ideal saturation) • $V_{OUT} = V_{CE} = ”0”$ • Transistor operates as a “closed switch”

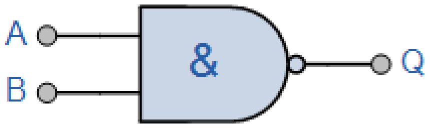
Then we can define the “saturation region” or “ON mode” when using a bipolar transistor as a switch as being, both junctions forward biased, $V_B > 0.7v$ and I_C = Maximum.

NAND Gate



2-input "AND" gate plus a "NOT" gate

"If both A and B are true, then Q is NOT true"

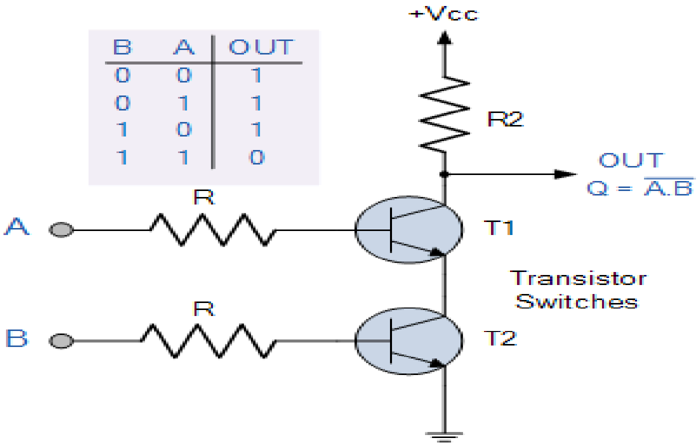
Symbol	Truth Table		
	B	A	Q
 2-input NAND Gate	0	0	1
	0	1	1
	1	0	1
	1	1	0
Boolean Expression **Q = A.B**	Read as A **AND** B gives **NOT** Q		

The **Logic NAND Gate** is generally classed as a "Universal" gate because it is one of the most commonly used logic gate types. NAND gates can also be used to produce any other type of logic gate function, and in practice the NAND gate forms the basis of most practical logic circuits.

How to Create a Transistor NAND Gate Circuit

This electronics project shows how to assemble a simple transistor NAND gate on a solderless breadboard. Normally open pushbuttons are used for the two inputs. The LED will be on until you press both of the pushbuttons. This action causes both inputs to go HIGH, which causes the output to go LOW and the LED to go dark.

A two-input NAND gate produces a LOW output if both of its inputs are HIGH. It's easy enough to create a NAND gate by using just two transistors.



A NAND gate circuit is almost identical to an AND gate circuit. The only difference is that instead of connecting the output to the emitter of the second transistor, the output is obtained before the collector of the first transistor.

If both of the inputs are HIGH, both of the transistors will conduct through their collector-emitter paths, which creates a short circuit to ground. This causes the current to bypass the output altogether, which in turn causes the output to go LOW.

If either transistor turns off, however, the supply current can't flow through the transistors to ground, so it flows through the output circuit instead. Thus, the output is HIGH if either one of the inputs is LOW. If both inputs are HIGH, the output is LOW.

How Transistor NAND gate works

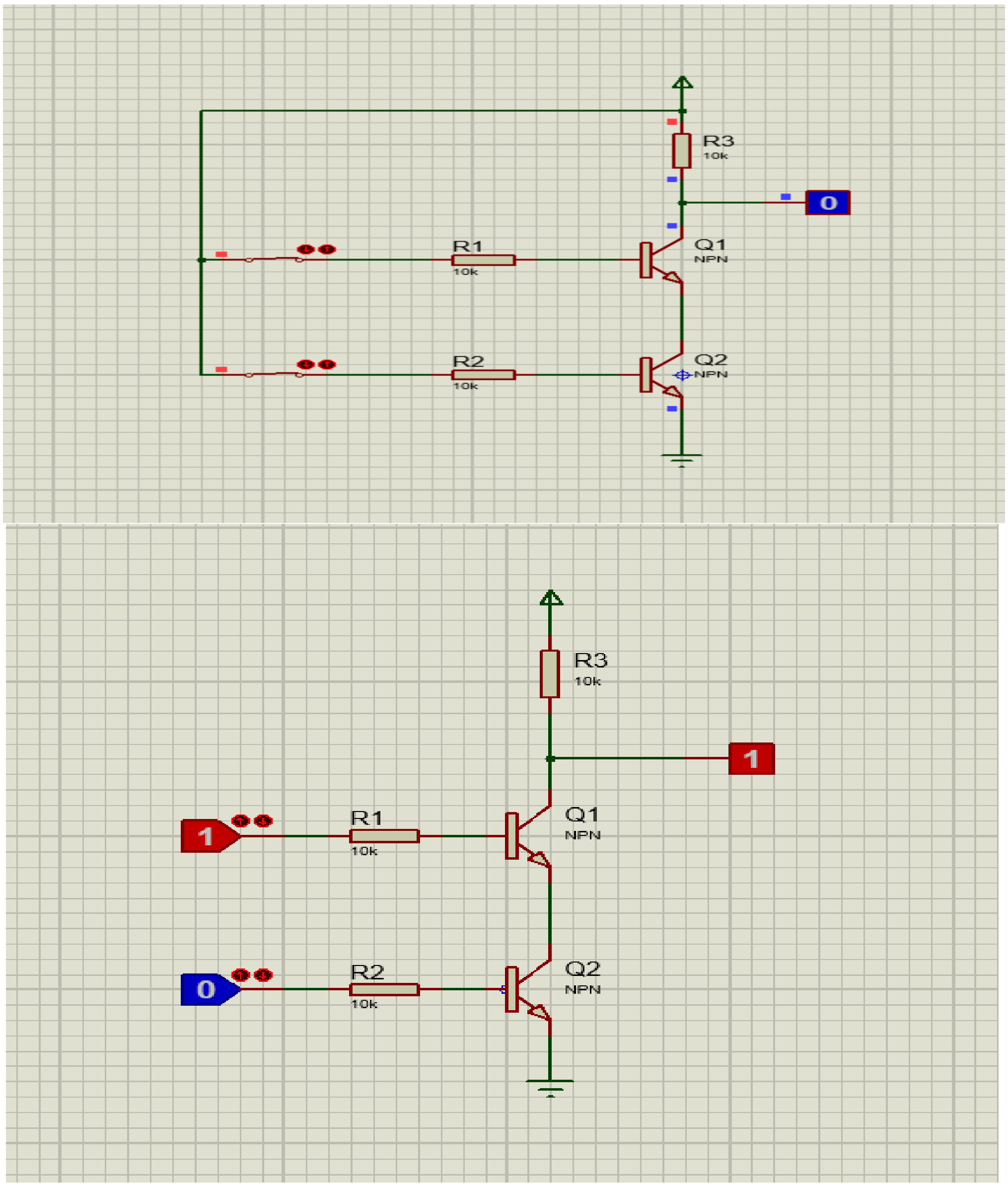
Logical 0 denotes LOW/negligible current and logical 1 denotes HIGH current. Transistors T1, T2 are being used as switches. When the input to the transistor is LOW, the transistor operates at cutoff mode, so there is no current flow from the collector to the emitter. The transistor acts like an open circuit during the cutoff mode. Therefore, only when both A and B is High, the circuit is closed.
For the first three cases in the truth table, it results in an open circuit. The current flows from the voltage source denoting logical 1 (HIGH). In the last case when both A and B is HIGH, the circuit is closed. Since the circuit is grounded, no current flows at the output Q denoting LOW.

Applications of transistor as nand gates.

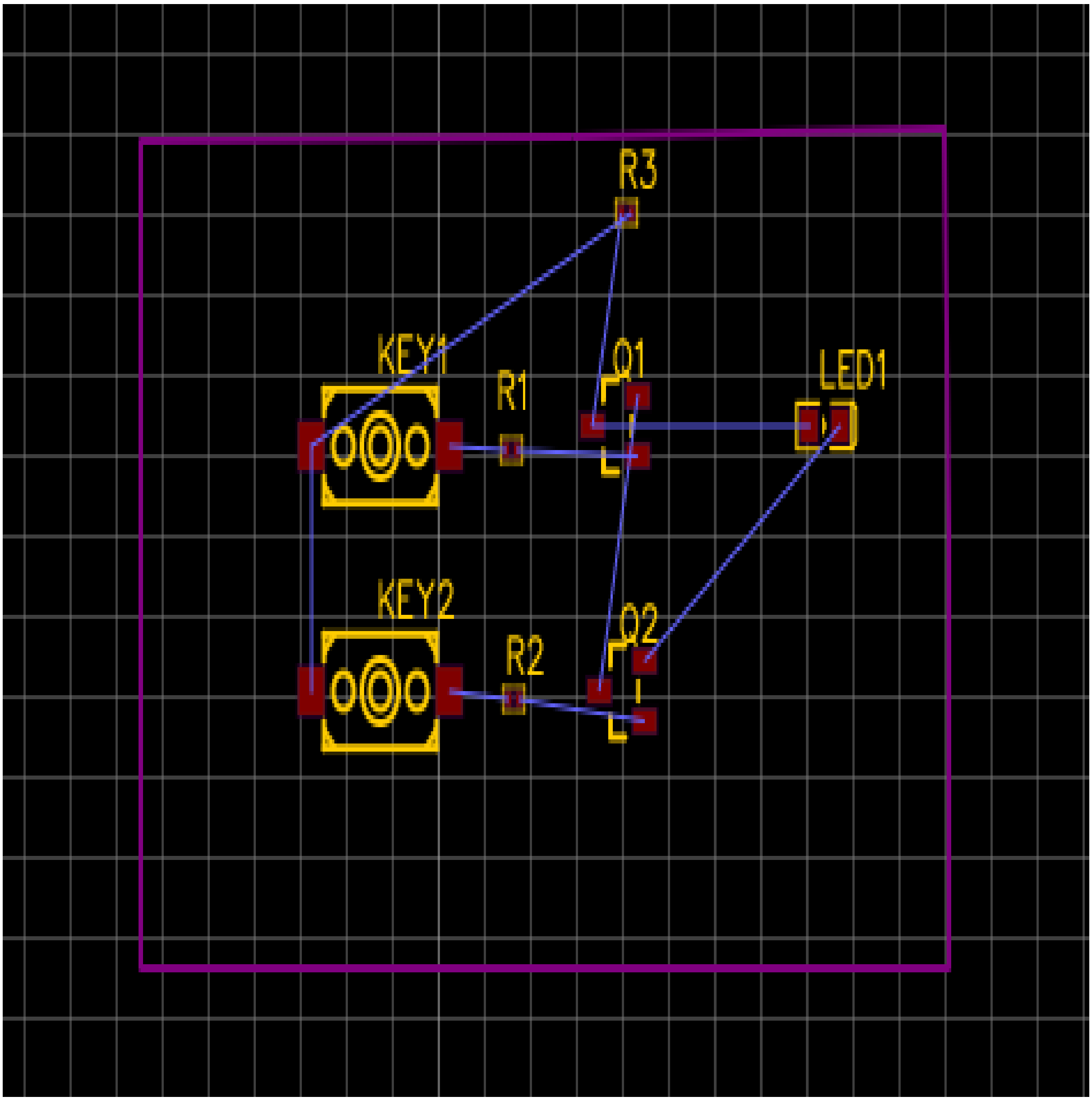
The use of transistors for the construction of logic gates depends upon their utility as fast switches. When the base-emitter diode is turned on enough to be driven into saturation, the collector voltage with respect to the emitter may be near zero and can be used to construct gates for the TTL logic family. For the NAND logic, the transistors are in series, but the output is above them. The output is high unless both A and B inputs are high, in which case the output is taken down close to ground potential.

It is used to reduce space used in building small computers.

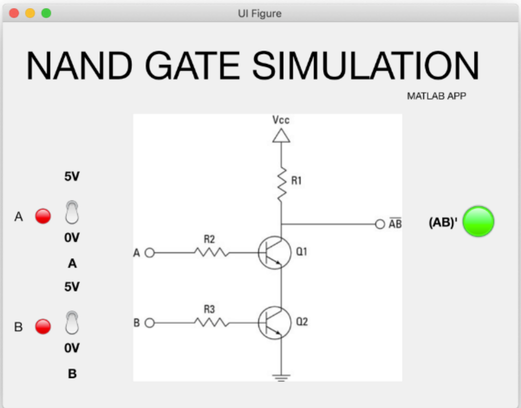
Implementation using proteus.

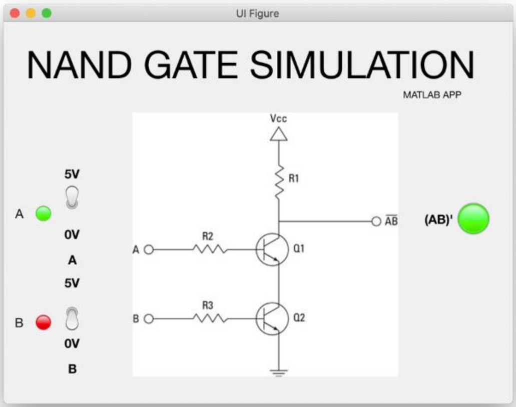


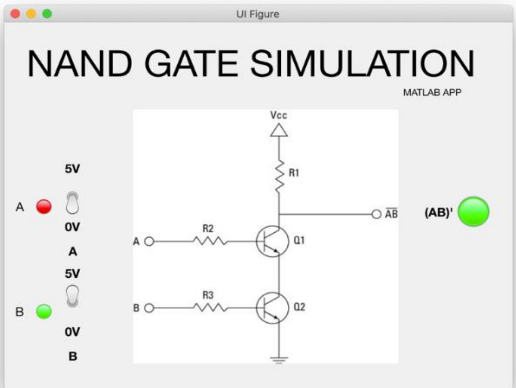
PCB design using EasyEDA

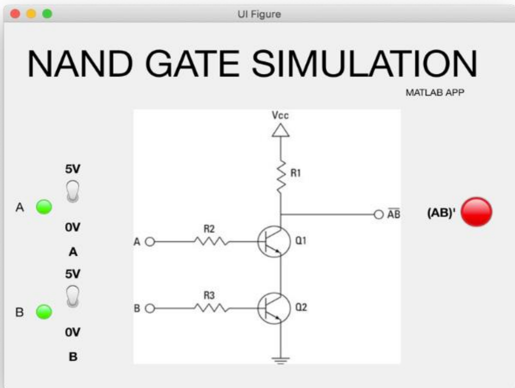


Nand gate simulation using matlab









Matlab code

```
classdef test < matlab.apps.AppBase

    % Properties that correspond to app components
    properties (Access = public)
        UIFigure                  matlab.ui.Figure
        ALampLabel                matlab.ui.control.Label
        ALamp                     matlab.ui.control.Lamp
        ASwitchLabel              matlab.ui.control.Label
        ASwitch                   matlab.ui.control.ToggleSwitch
        BLampLabel                matlab.ui.control.Label
        BLamp                     matlab.ui.control.Lamp
        BSwitchLabel              matlab.ui.control.Label
        BSwitch                   matlab.ui.control.ToggleSwitch
        ABLabel                   matlab.ui.control.Label
        Lamp3                     matlab.ui.control.Lamp
        Image                     matlab.ui.control.Image
        NANDGATESIMULATIONLabel  matlab.ui.control.Label
        MATLABAPPLabel            matlab.ui.control.Label
    end


    properties (Access = private)
        switch_1 = '0V';
        switch_2 = '0V';
        flag = 0;
    end


    % Callbacks that handle component events
    methods (Access = private)

        % Value changed function: ASwitch
        function ASwitchValueChanged(app, event)
            value = app.ASwitch.Value;
            %flag = 0;
            switch app.ASwitch.Value
                case '5V'
                    app.ALamp.Color = 'green';
                    app.switch_1 = 1;
                    switch app.BSwitch.Value
                        case '5V'
                            app.Lamp3.Color = 'red';
```

```
                case '0V'
                    app.Lamp3.Color = 'green';

            end

        case '0V'
            app.ALamp.Color = 'red';
            app.switch_1 = 0;
            app.Lamp3.Color = 'green';
            % switch_2 = 0;
    end

end


% Value changed function: BSwitch
function BSwitchValueChanged(app, event)
    value = app.BSwitch.Value;
    %flag = 0
    switch app.BSwitch.Value
        case '5V'
            app.BLamp.Color = 'green';
            app.switch_2 = value;
            switch app.ASwitch.Value
                case '5V'
                    app.Lamp3.Color = 'red';
                case '0V'
                    app.Lamp3.Color = 'green';

            end
        case '0V'
            app.BLamp.Color = 'red';
            app.switch_2 = value;
            app.Lamp3.Color = 'green';
    end


end
end


% Component initialization
methods (Access = private)


% Create UIFigure and components
function createComponents(app)


    % Create UIFigure and hide until all components are created
```

```
app.UIFigure = uifigure('Visible', 'off');
app.UIFigure.Position = [100 100 640 480];
app.UIFigure.Name = 'UI Figure';

% Create ALampLabel
app.ALampLabel = uilabel(app.UIFigure);
app.ALampLabel.HorizontalAlignment = 'right';
app.ALampLabel.FontSize = 16;
app.ALampLabel.Position = [1 230 25 22];
app.ALampLabel.Text = 'A';

% Create ALamp
app.ALamp = uilamp(app.UIFigure);
app.ALamp.Position = [41 230 20 20];
app.ALamp.Color = [1 0 0];

% Create ASwitchLabel
app.ASwitchLabel = uilabel(app.UIFigure);
app.ASwitchLabel.HorizontalAlignment = 'center';
app.ASwitchLabel.FontSize = 16;
app.ASwitchLabel.FontWeight = 'bold';
app.ASwitchLabel.Position = [75 172 25 22];
app.ASwitchLabel.Text = 'A';

% Create ASwitch
app.ASwitch = uiswitch(app.UIFigure, 'toggle');
app.ASwitch.Items = {'0V', '5V'};
app.ASwitch.ValueChangedFcn = createCallbackFcn(app, @ASwitchValueChanged,
true);
app.ASwitch.FontSize = 16;
app.ASwitch.FontWeight = 'bold';
app.ASwitch.Position = [77 230 20 45];
app.ASwitch.Value = '0V';

% Create BLampLabel
app.BLampLabel = uilabel(app.UIFigure);
app.BLampLabel.HorizontalAlignment = 'right';
app.BLampLabel.FontSize = 16;
app.BLampLabel.Position = [1 93 25 22];
app.BLampLabel.Text = 'B';

% Create BLamp
app.BLamp = uilamp(app.UIFigure);
app.BLamp.Position = [41 93 20 20];
```

```
        app.BLamp.Color = [1 0 0];

        % Create BSwitchLabel
        app.BSwitchLabel = uilabel(app.UIFigure);
        app.BSwitchLabel.HorizontalAlignment = 'center';
        app.BSwitchLabel.FontSize = 16;
        app.BSwitchLabel.FontWeight = 'bold';
        app.BSwitchLabel.Position = [75 35 25 22];
        app.BSwitchLabel.Text = 'B';

        % Create BSwitch
        app.BSwitch = uiswitch(app.UIFigure, 'toggle');
        app.BSwitch.Items = {'0V', '5V'};
        app.BSwitch.ValueChangedFcn = createCallbackFcn(app, @BSwitchValueChanged,
true);
        app.BSwitch.FontSize = 16;
        app.BSwitch.FontWeight = 'bold';
        app.BSwitch.Position = [77 93 20 45];
        app.BSwitch.Value = '0V';

        % Create ABLabel
        app.ABLabel = uilabel(app.UIFigure);
        app.ABLabel.HorizontalAlignment = 'right';
        app.ABLabel.FontSize = 16;
        app.ABLabel.FontWeight = 'bold';
        app.ABLabel.Position = [525 223 41 22];
        app.ABLabel.Text = '(AB)''';

        % Create Lamp3
        app.Lamp3 = uilamp(app.UIFigure);
        app.Lamp3.Position = [571 213 41 41];

        % Create Image
        app.Image = uiimage(app.UIFigure);
        app.Image.Position = [136 35 388 332];
        app.Image.ImageSource = '311283.image0.jpg';

        % Create NANDGATESIMULATIONLabel
        app.NANDGATESIMULATIONLabel = uilabel(app.UIFigure);
        app.NANDGATESIMULATIONLabel.FontSize = 48;
        app.NANDGATESIMULATIONLabel.Position = [29 399 583 62];
        app.NANDGATESIMULATIONLabel.Text = 'NAND GATE SIMULATION';
```

```
        % Create MATLABAPPLabel
        app.MATLABAPPLabel = uilabel(app.UIFigure);
        app.MATLABAPPLabel.Position = [503 378 79 22];
        app.MATLABAPPLabel.Text = 'MATLAB APP';

        % Show the figure after all components are created
        app.UIFigure.Visible = 'on';
      end
    end

    % App creation and deletion
    methods (Access = public)

      % Construct app
      function app = test

        % Create UIFigure and components
        createComponents(app)

        % Register the app with App Designer
        registerApp(app, app.UIFigure)

        if nargout == 0
          clear app
        end
      end

      % Code that executes before app deletion
      function delete(app)
        % Delete UIFigure when app is deleted
        delete(app.UIFigure)
      end
    end
end
```

Tinkercad Design