EE-213L Analog & Digital Electronic Circuits

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Marks	

Experiment # 1

To Understand Working of Transistor as a Switch and Designing Inverter Circuit

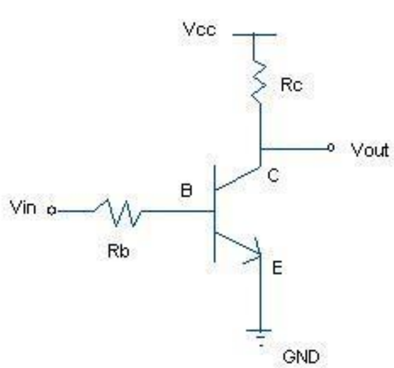
Objective:

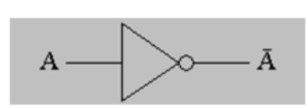
- *To understand modes of operation of transistor in digital circuits*
- *To understand the working of transistor as an inverter.*
- *To understand the designing of inverter.*

Apparatus:

Transistor, Resistors, Power Supplies, DMM, Jumpers, Connecting wires, bread board

Theory:





Symbolic Representation

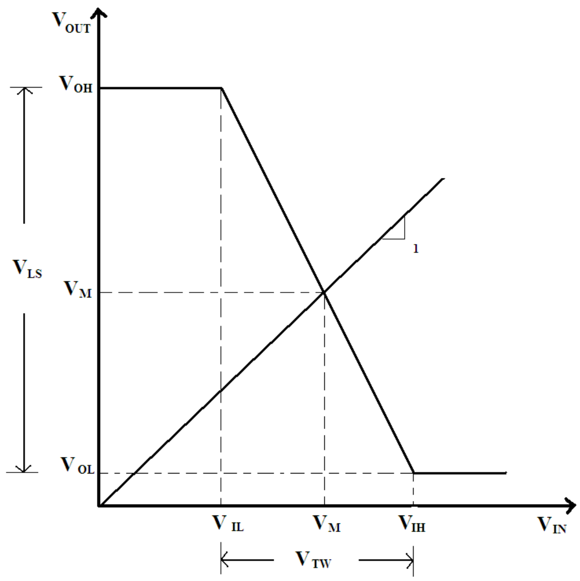
Transistor inverter is essentially an overdriven common emitter circuits. The input may be a square wave pulse waveform, or even a sine wave, provided that input amplitude is sufficient to drive the transistor into saturation and cutoff. When input is zero, there is no collector current and the output is approximately V_{CC} , which is taken as high or logic level ‘1’. When input becomes positive, transistor switches into saturation and the output becomes $V_{CE(sat)}$, taken as low or ‘0’ . Thus, a positive going output produces a negative going output, and vice versa. The output waveform is then inverse of input, hence the name inverter.

Inverter symbol is also shown above. It inverts the input from ‘0’ to ‘1’and ‘1’ to ‘0’. The small circle is referred as inverting bubble or inverting circle. This circle shows logic inversion

	BE Junction OFF	BE Junction ON
BC Junction OFF	Cut-off	Forward Active
BC Junction ON	Reverse Active	Saturation

MODES OF OPERATION OF BJT INVERTER

The logic ‘0’ is represented by the voltage range $0 < V_{IN} < V_{CC}/2$, since the input in this range will generate a logic ‘1’ output state. Similarly logic ‘1’ is represented by voltage range $V_{CC}/2 < V_{IN} \leq V_{CC}$. The input voltage $V_{IN} = V_{CC}/2$ has an undefined output and will cause unpredictable result.



Inverter Voltage Transfer Characteristics

The voltage transfer characteristic for logic inverter is shown. It shoes the linearized form of an idealized voltage transfer characteristic. Indicated on the output (vertical)axis are the voltages V_{OH} and V_{OL}, which correspond to the *output high* and *output low* levels, respectively. On the input (horizontal) axis, the *input low voltage* is V_{IL} and *input high voltage* is V_{IH}. Input voltage is increased from zero, V_{IL} is the maximum input voltage that provides a high output voltage(logic 1 output). Furthermore, V_{IH} has the definition of being the minimum input voltage that provides a low output voltage (logic 0 output). The Values V_{OH} , V_{OL} , V_{IL} and V_{IH} are referred to as the critical voltages of VTC. In order that the high and low voltage levels always be distinguishable, we must always have

$V_{OH} > V_{IH}$ and $V_{OL} < V_{IL}$

Manufacturers usually specify worst case values for these four voltages. One final critical point labled on VTC is the *midpoint voltage* V_M. It is defined as a point on the VTC where $V_{OUT} = V_{IN}$ and ideally appears at the center of transition region.

Also note the following terms:

Noise Margin: After determining the transfer function, DC noise margin is given by (Refer to figure)

$V_{NMH} = V_{OH} – V_{IH}$ and $V_{NML} = V_{IL} – V_{OL}$

Logic swing: $LS = V_{OH} - V_{OL}$

I_{CCH}: Amount of current drawn from the supply V_{CC} when output of the gate is at HIGH state.
I_{CCL}: Amount of current drawn from the supply V_{CC} when the output of the gate is at LOW state.

Designing:

Design RTL inverter using 3904 transistor. The value of V_{CC} is 10V, input is ±3v square wave 1KHz. Use I_C = 2mA and find speedup capacitor, also find the critical voltages and draw VTC.

Calculations:

- First of all, we will calculate the resistances values in our transistor.

=>For Rc:

$$Vcc=IcRc$$

$$Rc=Vcc/Ic$$

- Using the given values of Vcc and Collector Current.

$$Rc=10V/2mA$$

$$Rc=5k\Omega$$

=>For Rb:

$$Rb=Vrb/Ib$$

- Now , have two unknowns Vrb and Ib for Rb:
  - For Vrb:

$$Vrb=Vin-Vbe$$

$$Vrb=3-0.7$$

$$Vrb=2.3V$$

- For Ib(Consider B=100):

$$Ib = Ic/B$$

$$Ib = 2mA/100$$

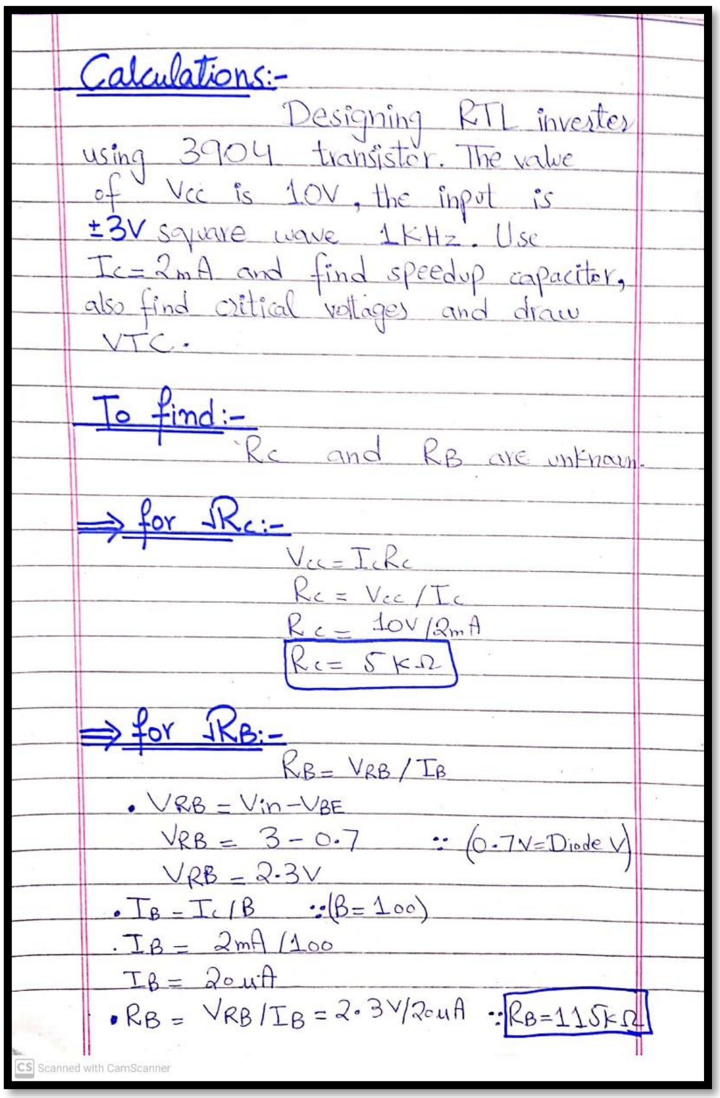
$$Ib = 20\mu A$$

- Now Put these values to get Rb:

$$Rb = Vrb/Ib$$

$$Rb == 2.3V/20\mu A$$

$$Rb = 115k\Omega$$



Calculations:-

Designing RTL inverter using 3904 transistor. The value of Vcc is 10V, the input is ±3V square wave 1KHz. Use $I_C = 2mA$ and find speedup capacitor, also find critical voltages and draw VTC.

To find:-

R_C and R_B are unknown.

⇒ for R_C:-

$V_{cc} = I_C R_C$

$R_C = V_{cc}/I_C$

$R_C = 10V/2mA$

$\boxed{R_C = 5k\Omega}$

⇒ for R_B:-

$R_B = V_{RB}/I_B$

- $V_{RB} = V_{in} - V_{BE}$

$V_{RB} = 3 - 0.7$ ∵ (0.7V = Diode V)

$V_{RB} = 2.3V$

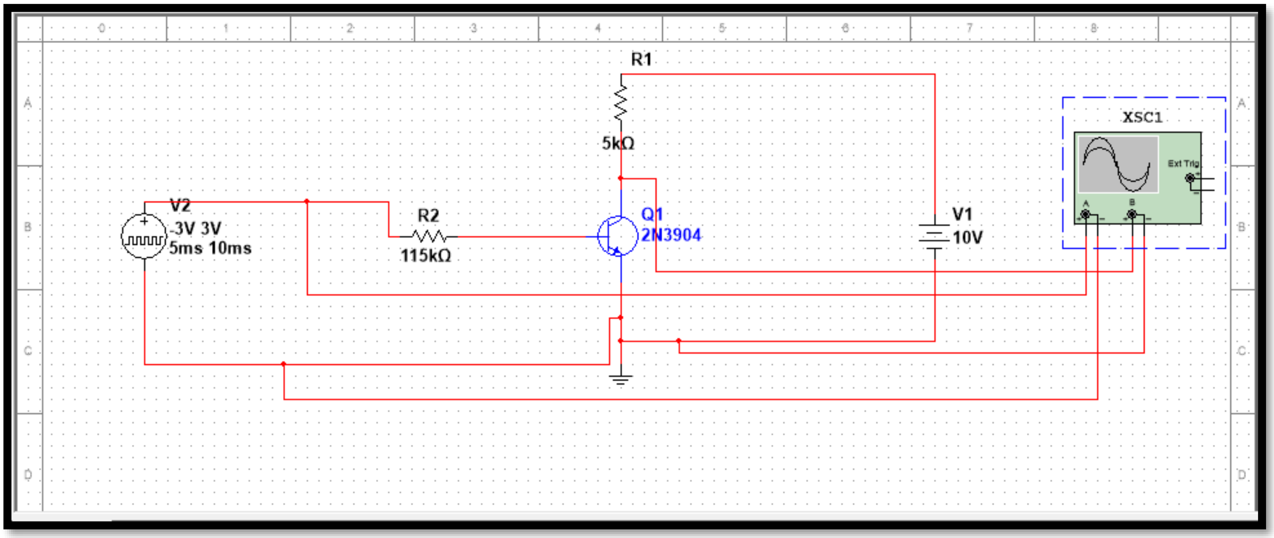
- $I_B = I_C/B$ ∵ $(B = 100)$

$I_B = 2mA/100$

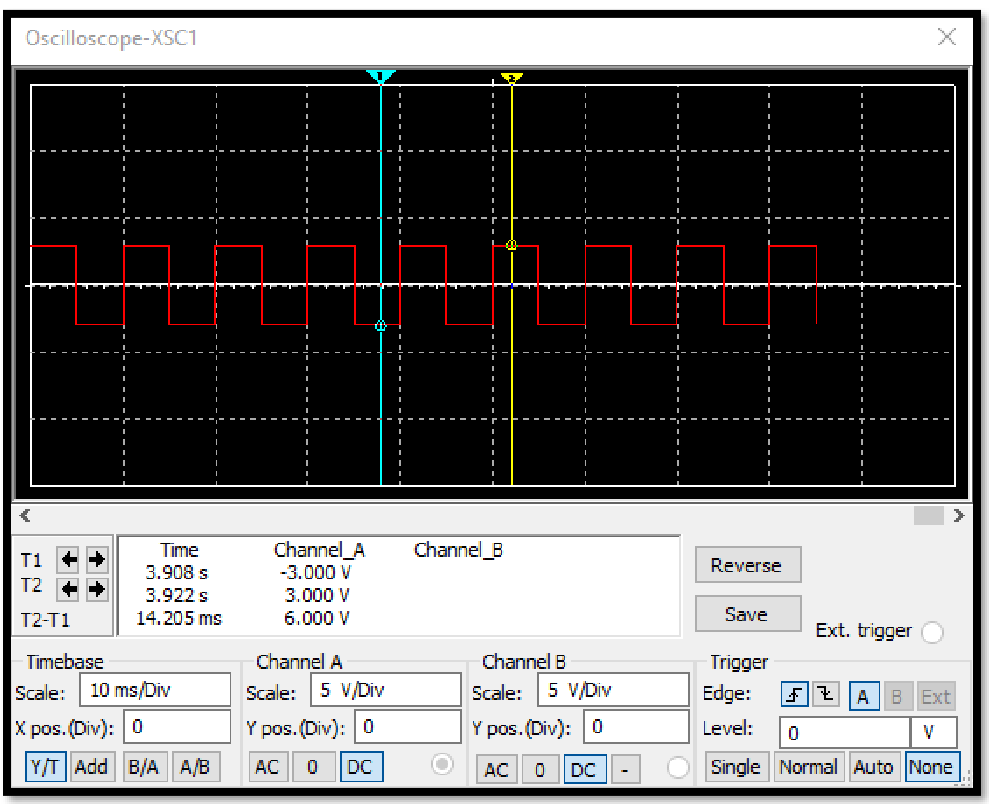
$I_B = 20uA$

- $R_B = V_{RB}/I_B = 2.3V/20uA$ ∵ $\boxed{R_B = 115k\Omega}$

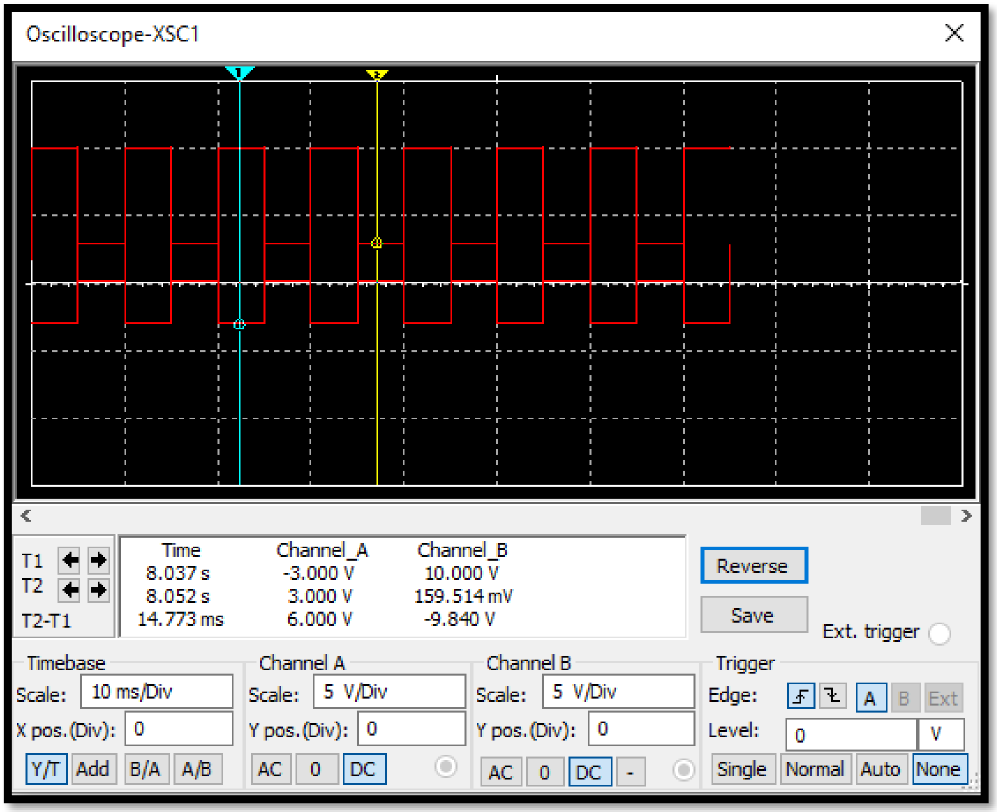
Circuit Diagram:



Input Waveform:



Output Waveform:



Questions:

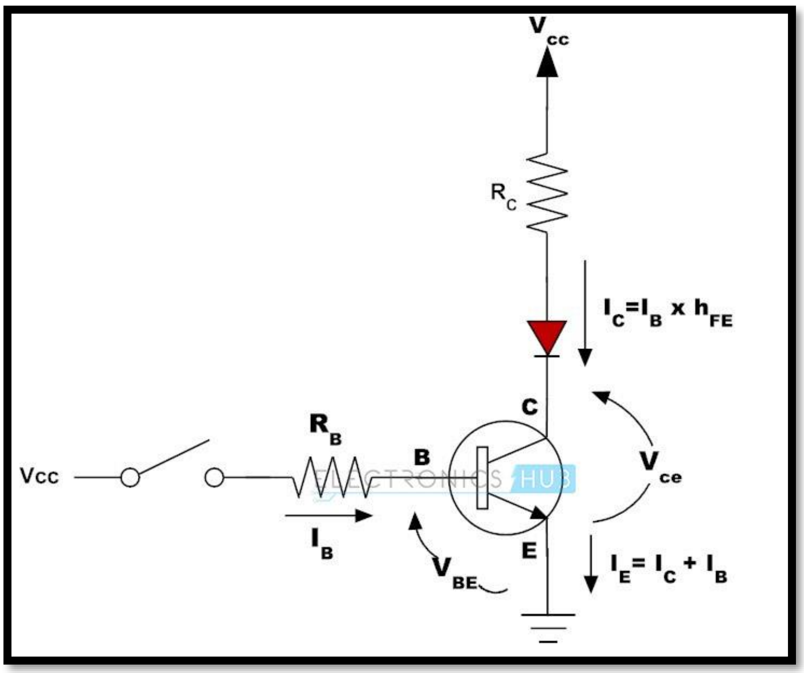
- **How can we protect Base-Emitter junction from excessive reverse bias voltage?**

The base-emitter junction can be driven into reverse bias to rapidly pull the excess charge carriers out of the base region to speed up the turn-off (minimize saturation delay). BJTs optimized for switching are specially doped to rapidly kill the excess carrier charge to minimize this delay.

- **Explain the performance of the transistor as an electronic switch?**

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 an LED is used as a load) 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.



- **For what purpose transistor used as a switch?**

When you use a transistor as a switch, it is either fully conducting or fully off that’s the benefit of witching in a transistor. Following are the purposes for which we use the transistor as an amplifier

- The most frequently used practical application that is used for the transistor as a switch is functioning of LED.
- The relay operation can be controlled by making the necessary changes in the circuit so that any external device is connected with respect to the relay and gets controlled.
- The dc motors can be controlled and monitored by using this concept of transistors. In order to turn ON the motor and OFF it this application is used. By varying the values of the frequencies of transistor the speed of the motor can be varied.
- One of the examples of these switches is light-bulb. It facilitates to switch on the light provided a bright environment and switches off based on the dark environment. It is done by using a light-dependent resistor (LDR).
- A component called thermistor that senses the surrounding temperature can be monitored by using this switching technique. The thermistor is referred to as a resistor. This resistance tends to increase when the sensed temperature is low and a decrease in the resistance is observed when the sensed temperature is high.