

## Inverter Circuit using *npn* bipolar-transistor

Wilson Sahani, UG Student, Dept. of, ECE, GIET University, 23ece059.wilsonsahani@giet.edu  
Mukhi kausik, UG Student, Dept. of, ECE, GIET University, 23ece008.mukhikausik@giet.edu  
Tolada Apparao, Associate Professor, Dept. of, ECE, GIET University, tapparao@giet.edu

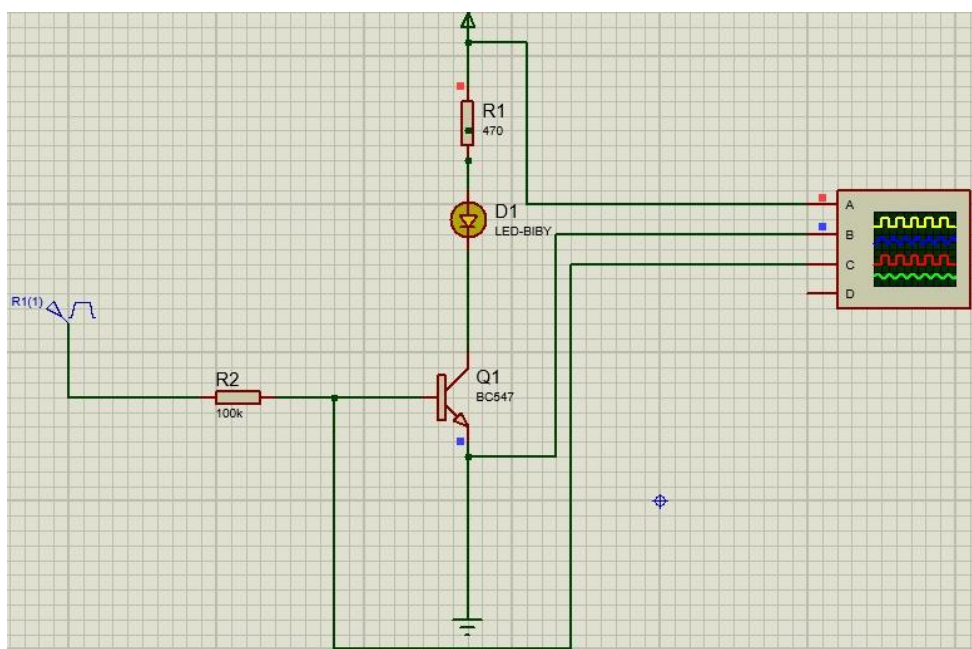
**Abstract:** In this paper we present the design and implementation of a blinking LED circuit using a simple Bipolar Junction Transistor (BJT) inverter. In this guide, we will attempt to create a simple and effective blinking effect by using a capacitor's charging and discharging properties. An NPN transistor is used in the circuit to operate as the switch, which drives the LED on or off depending upon a voltage from a timing capacitor. Initially, current is supplied to the collector of Q1 through Rb for charging the capacitor will raise Vbe and turn on T. This allows current to pass through the LED, lighting it up. The moment the capacitor starts discharging, the base-side voltage decreases, and the transistor shuts down halting LED\_service. This goes on in a cycle that creates an animation of continuous blinking. It is possible to alter the blink frequency of the current design by simply changing the resistor and capacitor values since it is made up of some adjustable elements. It brings out basic concepts of electronics such as working with transistors, RC timing circuits, and enabling LEDs at a basic level with a perspective on BJTs in digital and Analog devices. Normally, the switching LED circuitry makes it easy to visualize and practice using the transistor behavior in designing the circuits with either a novice approach or a more complicated one in electronic systems.

**Keyword:** BJT, Inverter, Resistor, LED

**INTRODUCTION:** The NPN transistor inverter circuit is used as one of the simplest building blocks of the digital systems in this and upcoming sections [1]. Semiconductors more specifically bipolar junction transistors (BJTs) have given new power to the electronics industry and given man a method for controlling signals [6]. The NPN transistor which consists of three layers of semiconductor – n, p, and n, works as current controlled technology, which can perfectly switch or amplify a signal [8]. Similarly, in digital circuits, the inverter also assumes an important part by presenting a basic but essential approach of signal negation.

If the input signal is used at the base of the NPN transistor it defines the state of the output signal [4]. When the input is high (or logic 1), the transistor conducts thereby giving a low output or logic 0. On the other hand, when the input (VIN) is low (at logic 0), the transistor is turned off and hence giving a high output (called logic 1). This behavior is used in the realisation of different logic functions and is commonplace in simple logic gates all the way through to sophisticated digital systems [5]. This is so also because in addition to offering a simple and straightforward form [6], the NPN transistor inverter circuit is also a versatile circuit. It is also easy to incorporate with other circuits, and hence its evaluative rank is high among the designers and engineers. It is important to comprehend this inverter circuit and its behaviour in order for anyone aspiring to work on circuits and electronics to understand this as a backbone when designing Digital logic circuits [7].

In this paper, the operational principle, design factors, and application of the NPN transistor inverter circuit will be discussed together to bring out the relevance of this circuit into the present day electronic systems and its relevance in the development of electronic systems and technologies [8].



**Fig. 1 Circuit diagram of a Bipolar junction transistor-based LED driver**

#### **CIRCUIT OPERATION:**

1. **Input Signal:** The described circuit is provided with the signal of square wave form at the base of the transistor Q1. This signal can be produced via an outsider input, for instance a function generator, or a microcontroller.
2. **Transistor Switching:** If the input signal is high (logic 1) the transistor Q1 is on in other words, its collector to emitter path is in use. This makes it possible for current to pass from the positive supply ( $V_{cc}$  not shown in figure but assumed to have been included) through the collector of Q1, resistor R2 and then through the LED D1. The LED illuminates.
3. **LED Off State:** If the input signal is low (logic 0) then the transistor Q1 is off. The current flows through the LED with certain path, and the LED goes off.
4. **Current Limiting:** The resistor R1 determines the amount of current that flows into base of the transistor. This is important to ensure that the transistor does not over heat thereby being destroyed or becoming effective.
5. **Resistor R2:** This resistor acts as a current-limiting resistor for the LED. It prevents excessive current from flowing through the LED, which could damage it.

#### **COMPONENTS:**

- Q1 (BC547): An NPN bipolar junction transistor.
- D1 (LED-BIBY): A light-emitting diode (LED)
- R1 (470 ohms): A base resistor for the transistor.
- R2 (100k ohms): A current-limiting resistor for the LED.

As with the prior circuit, this circuit is used just as a simple switch between on and off for the LED. Through this way, the LED is able to turn on and off again because of the high and low voltages of the square wave signal. The frequency of the square wave signal identifies the flash rate of the LED and can be adjusted using pin 1 of the 4060.



**CALCULATION:**

1. Supply Voltage ( $V_{CC}$ ): 5V.
2. LED Forward Voltage ( $V_{LED}$ ): ~2V.
3. Transistor Saturation Voltage ( $V_{CE(sat)}$ ): ~0.2V.
4. Base-Emitter Voltage ( $V_{BE}$ ): ~0.7V for the BC547.
5. Transistor Gain ( $\beta$ ): Assume typical value of 200 (can vary for BC547).

Given,

- $R_1 = 100\text{ k}\Omega$
- $R_2 = 470\ \Omega$

Parameter	Symbol	Value	Calculation
Supply Voltage	$V_{cc}$	5V	Given
Base Resistor	$R_2$	100k $\Omega$	Given
Collector Resistor	$R_1$	470 $\Omega$	Given
Base Current	$I_B$	43 $\mu$ A	$I_B = \frac{V_{in} - V_{BE}}{R_2} = \frac{5V - 0.7V}{100k\ \Omega} = 4.3 \times 10^{-5}$
Collector Current	$I_C$	8.6mA	$I_C = \beta \times I_B = 200 \times 43\mu A = 8.6 \times 10^{-3}$
LED Current	$I_{LED}$	6mA	$I_{LED} = \frac{V_{CC} - V_{LED} - V_{CE(sat)}}{R_1} = \frac{5V - 2V - 0.2V}{470\ \Omega} = 6.340 \times 10^{-3}$

The oscilloscope shows four channels, each representing a different signal. The channels are labeled A, B, C, and D.

- Channel A is a square wave signal with a peak-to-peak voltage of 10 volts. The signal is centered at 0 volts.
- Channel B is a sine wave signal with a peak-to-peak voltage of 22.17 volts. The signal is centered at 0 volts.
- Channel C is a square wave signal with a peak-to-peak voltage of 50 volts. The signal is centered at -25 volts.
- Channel D is a square wave signal with a peak-to-peak voltage of 20 volts. The signal is centered at -125 volts.

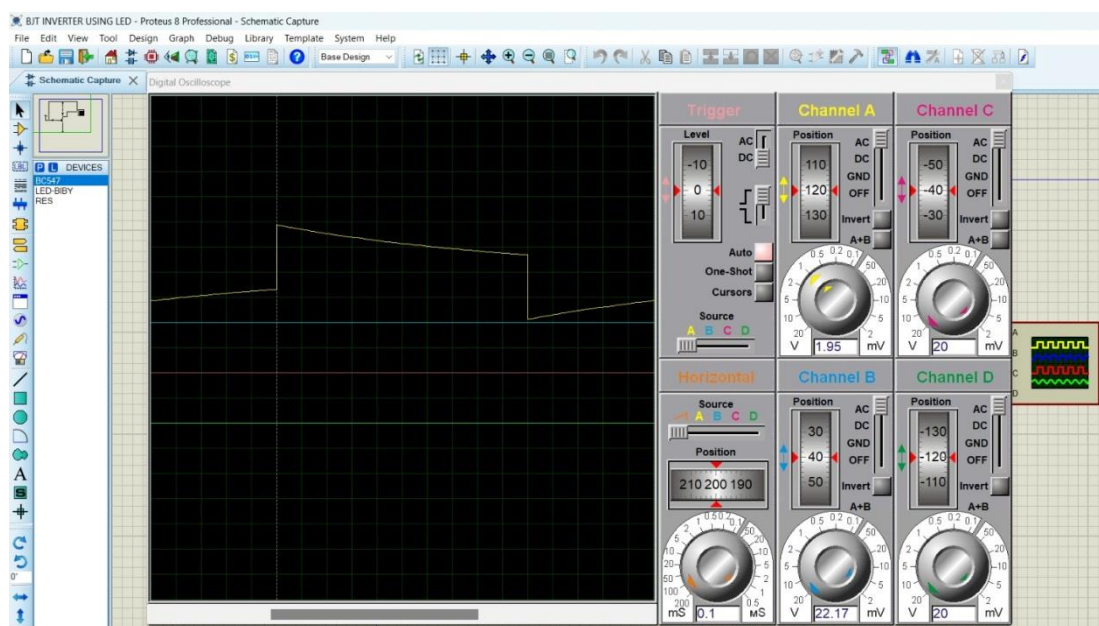


Fig. 2: The figure shows a digital oscilloscope capture of a BJT inverter circuit

The horizontal time scale of the oscilloscope is divided into equal to 0.1 millisecond intervals. What this means is that each of the horizontal divisions shown on the figure represents 0.1 milliseconds. The voltage sensitivity of the oscilloscope is divided into 2 vertical divisions for channel A, B and C. And this means that each single vertical division on the two axes forms 2 volts. There is Channel D oscilloscope set to voltage horizontal division of the oscilloscope which is 5 volts per division. This is within 5 V, thus each of the vertical divides represents a particular voltage level. Its waveform similar to that of a square wave with a frequency of 5kHz and a 50 % duty cycle is being displayed by the oscilloscope. From the waveform it can be seen that the positive half amplitude is 5V and the negative half amplitude is -5V. There is no noise in the waveform which shows that the waveform is clean and has no disturbances. The oscilloscope is also providing sale that looks like the signal is at 0 volts and has a 50% duty cycle. The square wave seems to originate from an output of a logic gate, because the waveform seems to be balanced at the middle. The display on the oscilloscope is now presenting a waveform that looks very much like a sine wave which has a frequency of one kHz and whose amplitude seems to have a maximum value of 11.085 volts. The waveform is also equally horizontally shifted 0 volts. The waveform does not seem to have any peaks and troughs and has a solid and no noise can be seen at all. The oscilloscope is also displaying what seems to be a square wave wave form of 1kHz and a 50% duty cycle. A waveform has a positive amplitude of 10 volts and a negative amplitude of -10 volts. The waveform does not show any kind of noise or artifacts on it and seems to be very calm.

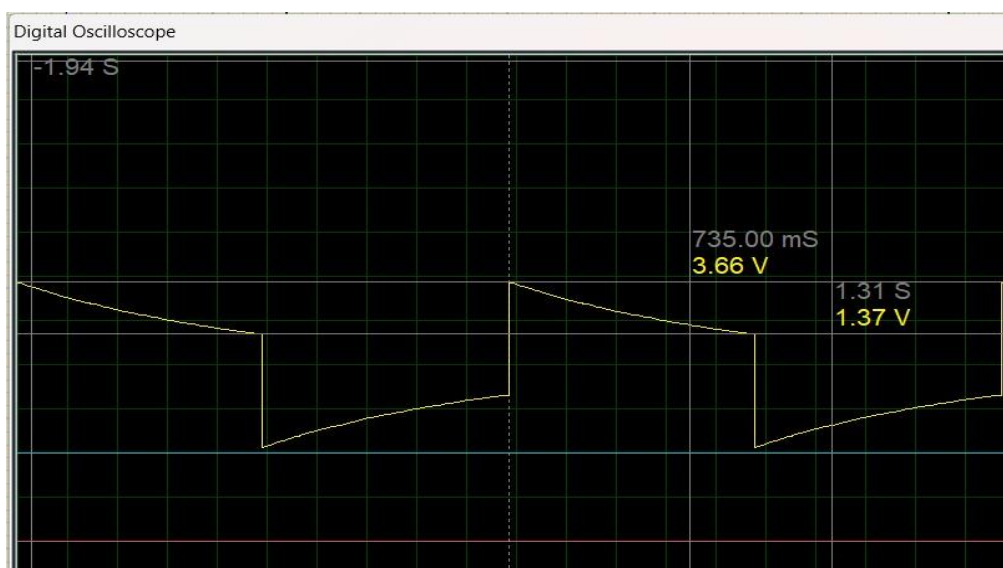


Fig. 3: This oscilloscope shows a square wave with a period of 735 milliseconds and an amplitude of 1.37 volts

As well we can see the wave form is show in the oscilloscope is a square wave and its frequency is about 1 Hz. The amplitude of the wave is approximately measured to be equal to 3.66 V. The signal is somewhat modified for smoothness of corners. At the bottom of the oscilloscope we can see, it divides time equally to 0.5 s and voltage equally to 1 V. The waveform is that of a periodic signal and there is a steady state. But the signal is shifted toward about 0.3 V up. There is also a little ringing on the signal and that is probably because of the inductance in the circuit. The signal is presented in two channels and the waveform is characterized by less rise time and high fall time.

**Conclusion:** The NPN bipolar transistor inverter circuit is another simple but essential circuit that you find in any digital electronics devices; it shows signal inversion by the help of a semiconductor device. This circuit has sought to employ the properties of the NPN transistor in order to toggle the state of the output depending on the state of the input signal. If positive voltage is impressed at the base of the transistor then the transistor is in the active region and the collector conducts current to the emitter giving the low output (0 state). On the other hand, when there is no base voltage or small base current the switch is off and thus for high output HIGH or logic 1 is obtained.

## REFERENCE

1. Wieslaw Kuzmicz  
[https://www.researchgate.net/publication/357245663\\_A\\_Thermally\\_Stable\\_Quasi-CMOS\\_Bipolar\\_Logic](https://www.researchgate.net/publication/357245663_A_Thermally_Stable_Quasi-CMOS_Bipolar_Logic)
2. Sedra, A. S., & Smith, K. C. Microelectronic Circuits. Oxford University Press.
3. Horowitz, P., & Hill, W. (2015). The Art of Electronics. Cambridge University Press.
4. Millman, J., & Halkias, C. (1991). Integrated Electronics: Analog and Digital Circuits and Systems. McGraw-Hill.
5. Rashid, M. H. (2014). Power Electronics: Circuits, Devices, and Applications Coughlin,
6. R. F., & Driscoll, F. F. (2001). Operational Amplifiers and Linear Integrated Circuits



7. Miller, A. (2005). Design of a High-Speed NPN Inverter. IEEE Transactions on Circuits and Systems I: Regular Papers, 52(5), 1025-1032.
8. Baker, R. J. (2010).  
<https://www.wiley.com/enus/Chinese+Character+Writing+For+Dummies-p-9781119475552>
9. CMOS: Circuit Design, Layout, and Simulation.
10. Sze, S. M. (1985). Semiconductor Devices: Physics and Technology. A fundamental of semiconductor devices, including bipolar junction transistors (BJTs).