# Binary Phase Shift Keying Using Op-Amps and BJTs

**Mini Project Report**

**in Electrical Circuits and Systems (EC280)**

**SYED ABUBAKER BIN JUNAID**

**221EC257**

**VEDANT DARJI**

**221EC261**

**NATIONAL INSTITUTE OF TECHNOLOGY**
**SURATHKAL, KARNATAKA – 560050**

**III SEM (JULY - DEC)**

## Index

# INDEX

**Contents** **Page No.**

# Abstract

This project endeavors to transmit digital information through a phase-toggling approach using a carrier wave. Central to this effort are operational amplifiers (op-amps) and bipolar junction transistors (BJTs), key components facilitating the success of both modulation and demodulation processes in digital signal transmission. The primary aim is to create a circuit implementing the binary phase shift keying (BPSK) modulation scheme, alongside a complementary circuit proficient in demodulating BPSK-modulated signals. Through careful design and configuration, the project aims to showcase the effectiveness of op-amps and BJTs in achieving a seamless BPSK modulation and demodulation cycle.

# Introduction and Motivation

BPSK stands for Binary Phase Shift Keying, which is a digital modulation scheme used in telecommunications and signal processing. It is a type of phase shift keying in which the phase of the carrier signal is shifted to represent binary data. In BPSK, two different phases are used to represent the two binary values (0 and 1).

The basic idea behind BPSK is to modulate the carrier signal's phase based on the binary data being transmitted. If the binary data is 0, the carrier signal maintains its current phase. If the binary data is 1, the phase of the carrier signal is shifted by 180 degrees. This modulation allows for the transmission of digital data over a communication channel.

We were inspired to pursue a project centered on BPSK modulation and demodulation to actively engage in implementing and comprehending various modulation techniques. Our aim is to gain practical experience and a deeper understanding of how these methods function within communication systems.

# Literature Review

## 1. Operational Amplifiers

Op Amps have been used as an inverting and non inverting summing amplifier and as a comparator.

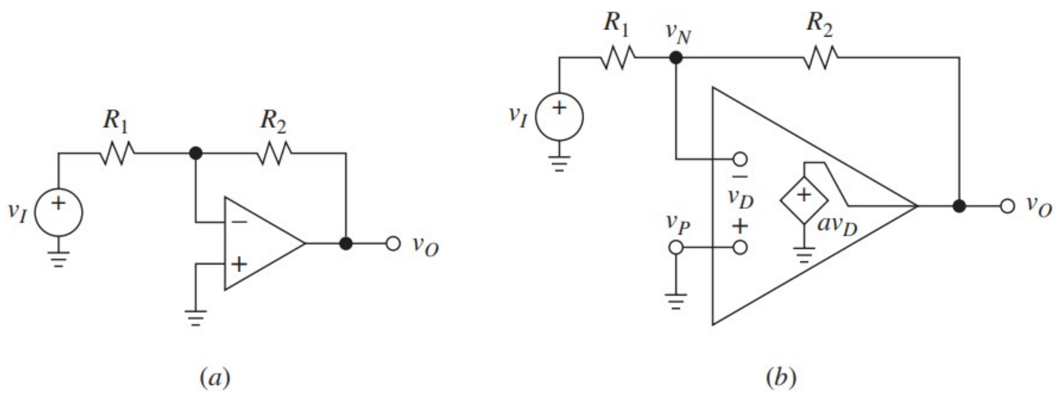



**FIGURE 1.10**
Inverting amplifier and circuit model for its analysis.

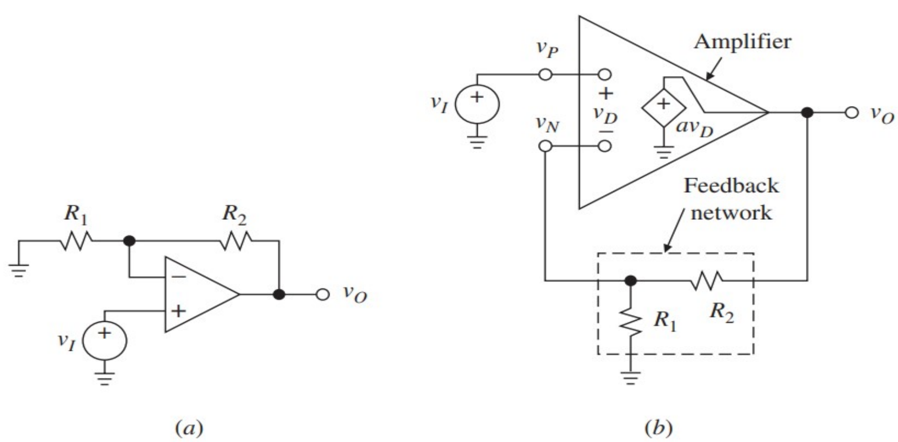



**FIGURE 1.6**
Noninverting amplifier and circuit model for its analysis.

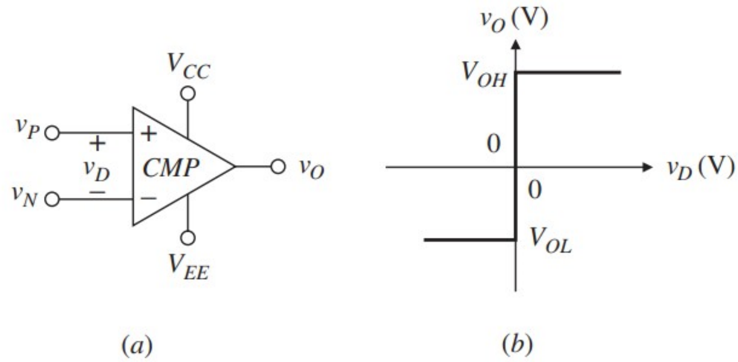



**FIGURE 9.1**
Voltage-comparator symbolism and ideal VTC. (All node voltages are referenced to ground.)

## 2. BJT as a Switch

Transistors can be used as amplifiers of AC signals when their biasing voltage is applied in a way that it operates in the active region. By changing the biasing voltages accordingly, the transistor can also be made to function as an ”on/off” type solid state switch. This can be achieved by driving the transistor back and forth between its cut-off and saturation region without having to study the Q-point biasing and voltage divider circuits required for amplification. In this case, a Common Emitter Configuration is used to demonstrate the function of a transistor as a switch.

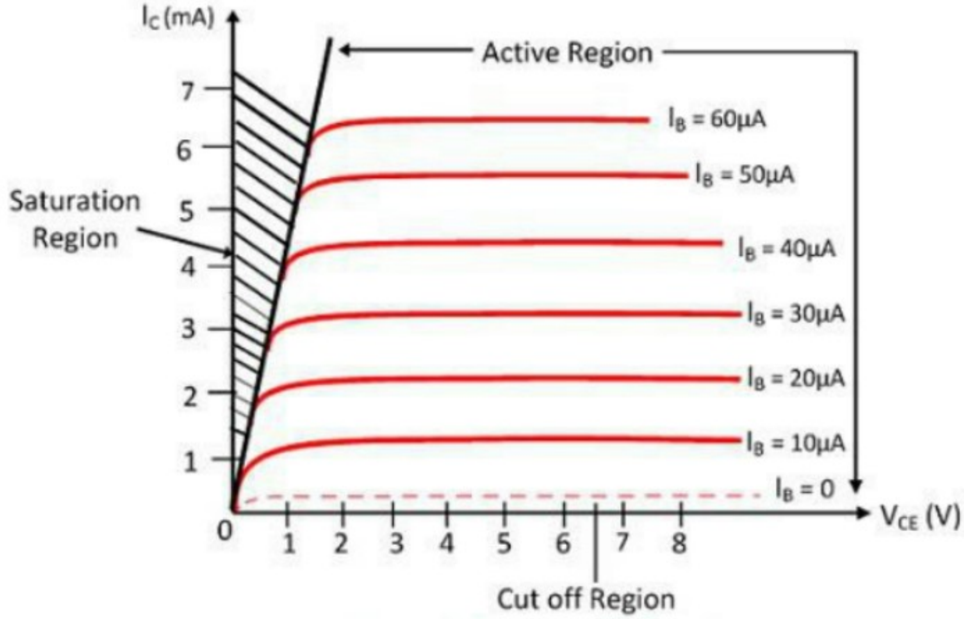



Figure 1.5: Operating regions of a Bipolar Junction Transistor

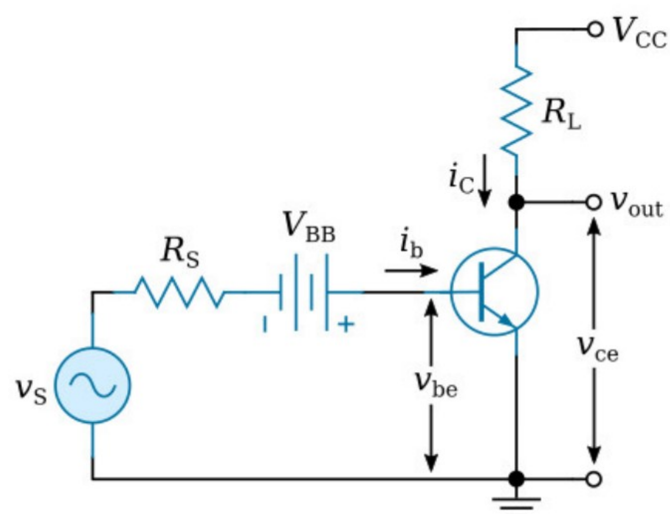



Figure 1.6: Common Emitter Configuration of a Bipolar Junction Transistor

In the cutoff region, both the Base-Emitter and Collector-Emitter junctions are reverse biased by changing the operating conditions to zero input base current (ib) and zero output collector current (ic). This results in a large depletion layer and prevents current from flowing through the device. The transistor in this state is considered to be off. In the saturation region, the transistor will be biased so that the maximum amount of base current is applied, resulting in maximum collector current. This in turn results in a minimum collector emitter voltage drop which causes the depletion layer to be as small as possible and enables maximum current flowing through the transistor. The transistor in this state is considered to be on.

## 3. Digital Information Transmission Using Carrier Modulation

Digital carrier modulation is the process by which a user bit stream is converted into bandpass (BP) waveforms that are compatible with transmission characteristics of many important communication channels such as radio, satellite, and cellular. Information bit stream is embedded into the carrier waveform by varying, or modulating, some attribute of the carrier, such as its amplitude, frequency, phase, or a combination thereof. The resultant BP signal contains the user information and occupies a frequency slot centered about a carrier frequency fc in the available spectrum of a radio, satellite, or cable channel. At the destination, the carrier demodulation process recovers the underlying baseband waveform from the received signal in the presence of noise.

Digital transmission by a carrier is a key enabling technology that makes cellular/wireless, satellite, telco dial-up, and cable modem communications possible. We present the fundamental concepts and techniques of digital carrier modulation and demodulation. As in the case of baseband signals, the geometric representation of carrier modulated digital signals is used in assessing their performance in the presence of additive Gaussian noise.

*<u>Common binary carrier modulation schemes:</u>*

- *Binary amplitude-shift keying (BASK)*

The digitally modulated baseband signal modulates the amplitude of the carrier. If the digital signal is a positive pulse (e.g., corresponding to a binary 1), the carrier is turned on for the duration of a bit interval. No carrier burst is transmitted during a bit interval for a binary 0 (corresponding to absence of a pulse).

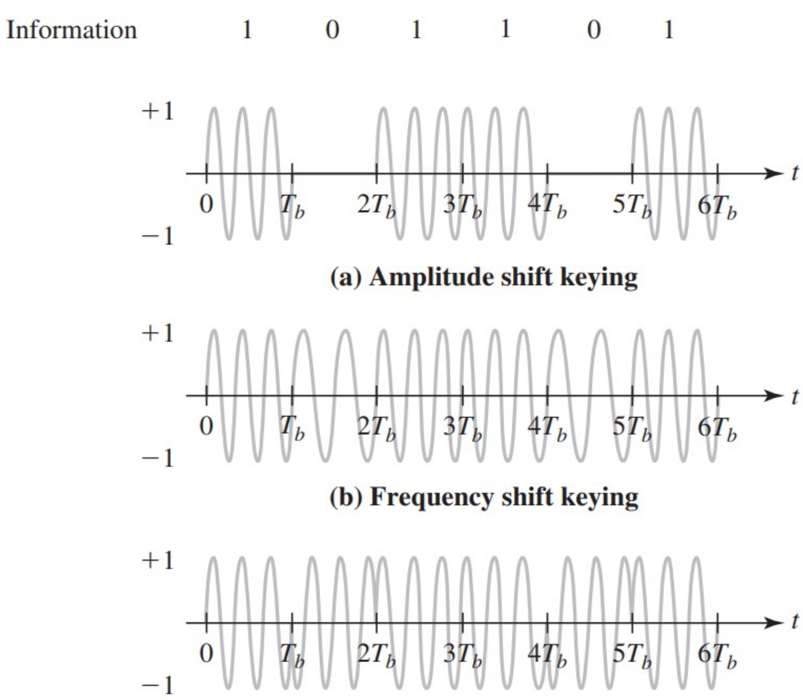
- *Binary phase-shift keying (BPSK)*

The digitally modulated baseband signal modulates the phase of the carrier. In the case of BPSK, the carrier phase is toggled to represent a binary digital signal. If the digital signal is a positive pulse (e.g., corresponding to a binary 1), cos(2 πfct ) is transmitted, and if it is a negative pulse (corresponding to a binary 0), the carrier burst cos(2 πfct 1 p ) 5 2 cos(2 πfct ) is transmitted.

• *Binary frequency-shift keying (BFSK)*

The digitally modulated baseband signal modulates the frequency of the carrier. In the case of BFSK, the carrier frequency is toggled to represent a binary digital signal. If the digital signal is a positive pulse (e.g., corresponding to a binary 1), the carrier has the frequency $f_1 = f_c + (\Delta f/2)$, and if it is a negative pulse (corresponding to a binary 0), the

$$x(t) = A(t)\cos\left[2\pi f_c t + \psi(t)\right] \tag{11.1}$$




**(a) Amplitude shift keying**

**(b) Frequency shift keying**

**(c) Phase shift keying**

carrier has the frequency $f_2 = f_c - (\Delta f/2)$, where $\Delta f$ is called the frequency deviation.

## BINARY PHASE-SHIFT KEYING

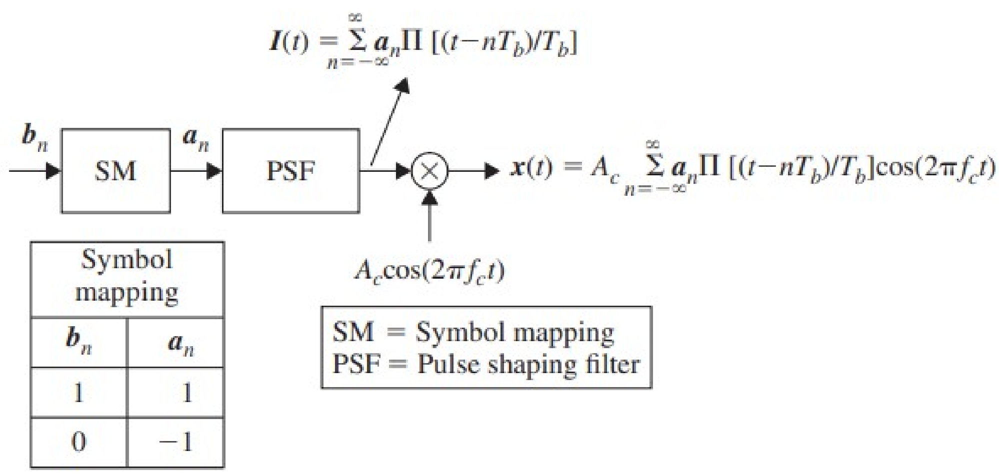
In BPSK, the symbol mapping table encodes information bits ( bn ) 1 and 0 to transmission symbols ( an ) 1 and 2 1, respectively. The resultant output of the pulse shaping filter is a polar NRZ pulse train which then modulates the carrier. Every Tb seconds the modulator transmits one of the two carrier bursts that corresponds to the binary information bit being a 1 or 0.

Binary 1: $s_1(t) = A_c\cos(2\pi f_c t),\ 0 \le t \le T_b$

Binary 0: $s_2(t) = A_c\cos(2\pi f_c t + \pi) = -A_c\cos(2\pi f_c t)$

The resultant BPSK signal can be expressed as

$$\boldsymbol{x}(t) = A_c \sum_{n=-\infty}^{\infty} \boldsymbol{a}_n \Pi\left[(t - nT_b)/T_b\right]\cos(2\pi f_c t),\quad \boldsymbol{a}_n \in \mathscr{A}_2 = \{1\ -1\}$$




**BPSK MODULATOR**

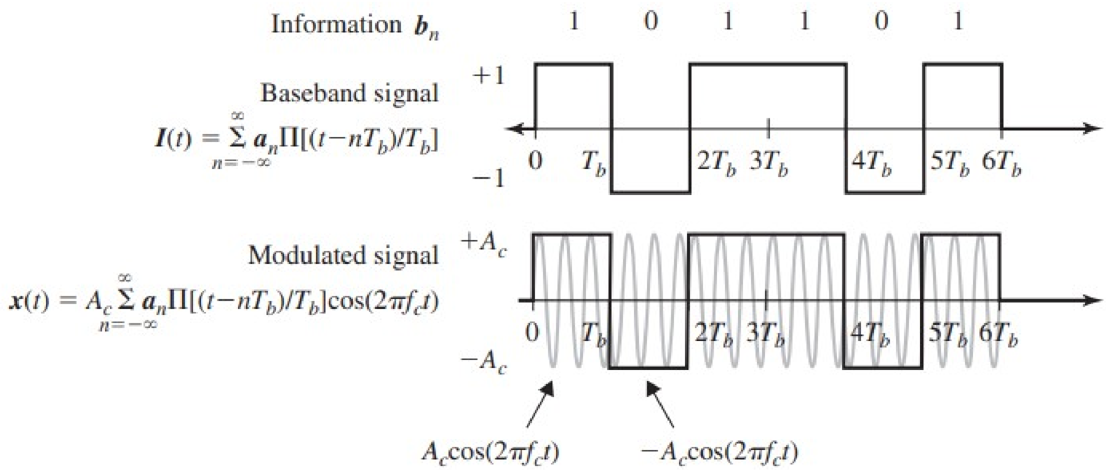



Figure 11.11 BPSK modulator waveforms.

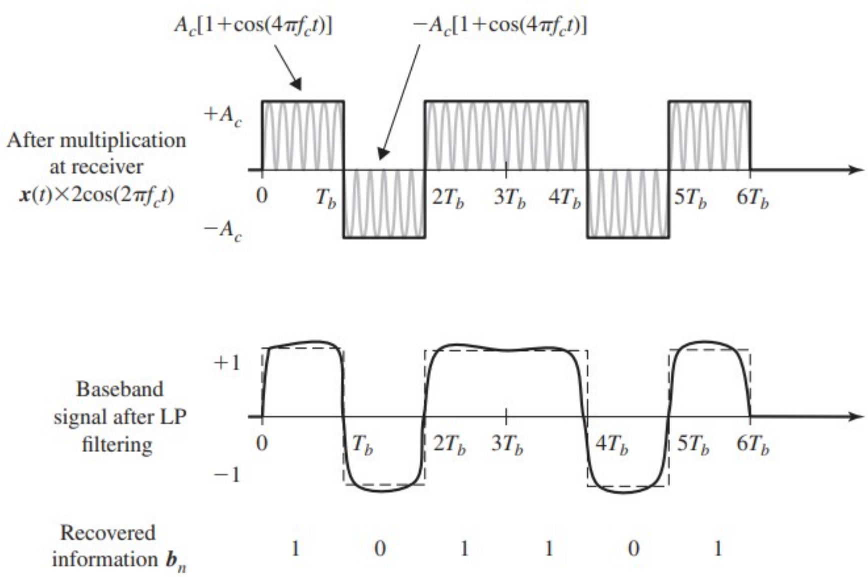
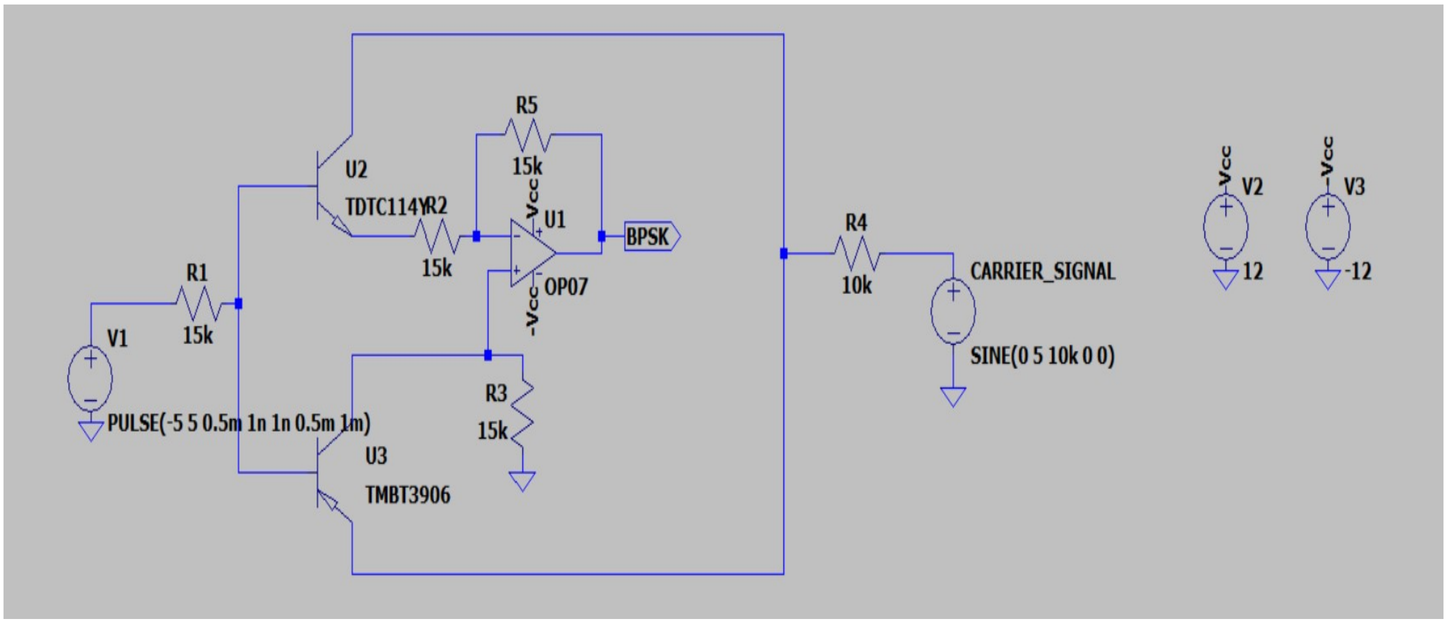


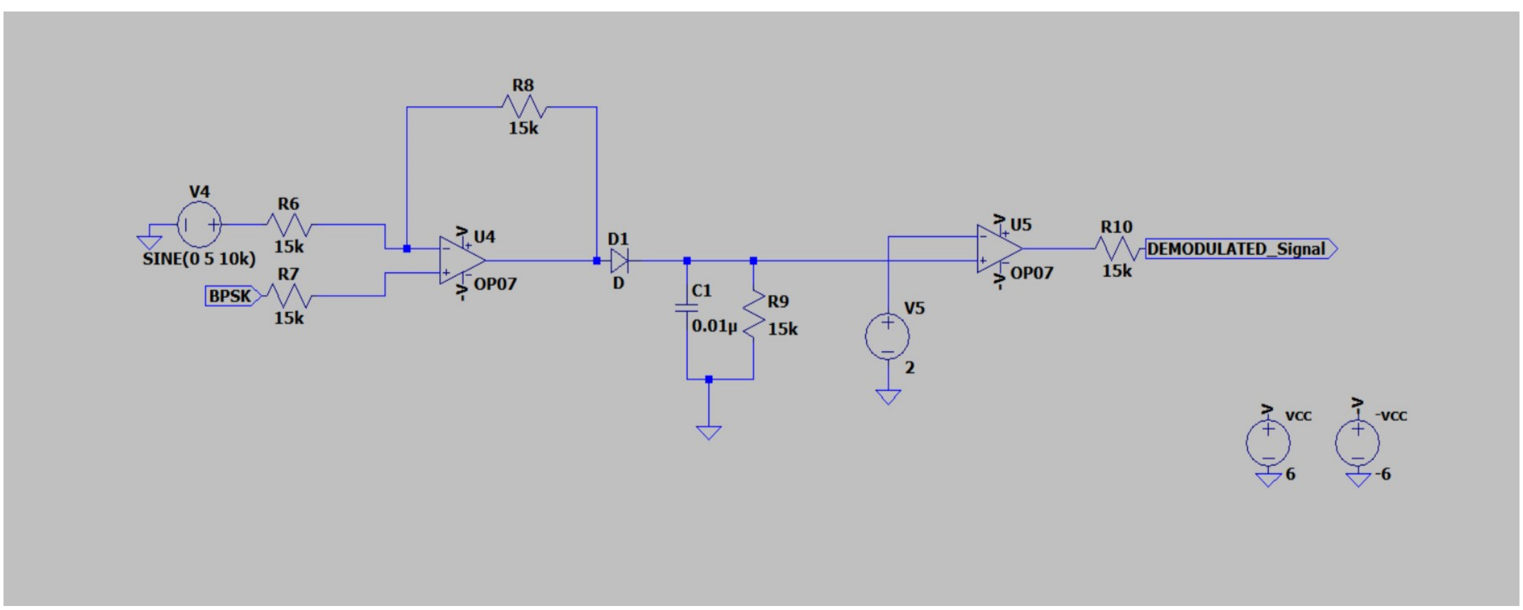

Figure 11.13 BPSK demodulator waveforms.

# Coherent Demodulation of BPSK Signals

# Circuit Design (in LTSpice)




## BPSK MODULATOR




## BPSK DEMODULATOR

The circuit shown above is the one that was simulated for the project. It utilizes all the components discussed previously including Op Amps and BJTs The simulation was done in LTSpice.

A pulse is sent into the modulator along with a carrier signal. At the BPSK modulator’s output, the modulated signal can be obtained. This signal is given as an input to the demodulator circuit.

The waveforms have been included in the upcoming pages.

# Understanding Circuit Behaviour

The BPSK modulator utilizes a carrier signal of the form $\cos(2\pi f_c t + \phi)$ . The circuit design uses a sinusoidal carrier of frequency 10k Hz. A square wave is used to modulate the carrier signal.

The BPSK modulator circuit exhibits a dynamic behavior achieved through the collaborative roles of an operational amplifier (OP07) and a transistor (TMBT3906). The circuit is designed to achieve Binary Phase Shift Keying (BPSK) modulation, where the phase of the carrier signal is altered to represent binary data. Let's delve into the distinct behaviors of each component:

- Phase Shifting (OP07):
- Acting as a differential amplifier, the OP07 dynamically compares the data and carrier signals.
- The non-inverting input receives the data signal, while the inverting input receives the carrier signal.
- The output reflects the disparity between these signals, generating a positive pulse for binary 1 and a negative pulse for binary 0.
- Power Boosting (TMBT3906):
- The TMBT3906 transistor serves a dual purpose as a buffer amplifier and a power amplifier.
- As a buffer, it ensures minimal loading on the OP07, allowing for accurate transmission of positive and negative pulses.
- In its role as a power amplifier, the TMBT3906 significantly enhances the power of the modulated signal. This amplification is crucial for efficient signal transmission, compensating for any inadequacy in the OP07's output strength.
- Switching Action (OP07 and TMBT3906):

- Both the OP07 and the TMBT3906 effectively operate as switches, facilitating the binary modulation process.
- The OP07, functioning as a voltage-controlled switch, adjusts the voltage applied to the TMBT3906 base based on the incoming data bit.
- The TMBT3906, acting as a current-controlled switch, responds to the OP07's control, producing a positive pulse for binary 1 and a zero voltage output for binary 0.

In summary, the BPSK modulator circuit dynamically adjusts the phase of the carrier signal to encode binary information. The OP07 and TMBT3906 collaborate to compare, shift, and amplify signals, collectively contributing to the circuit's effective behavior in achieving BPSK modulation

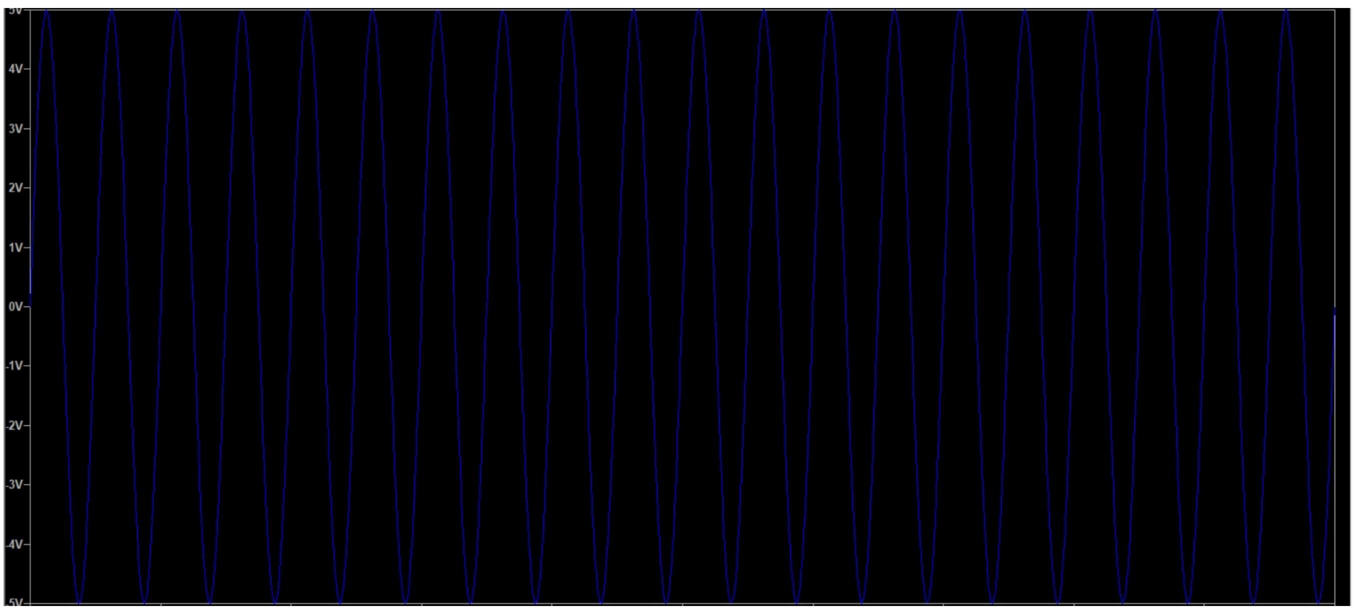
# Results

## Waveforms

### *BPSK MODULATOR*

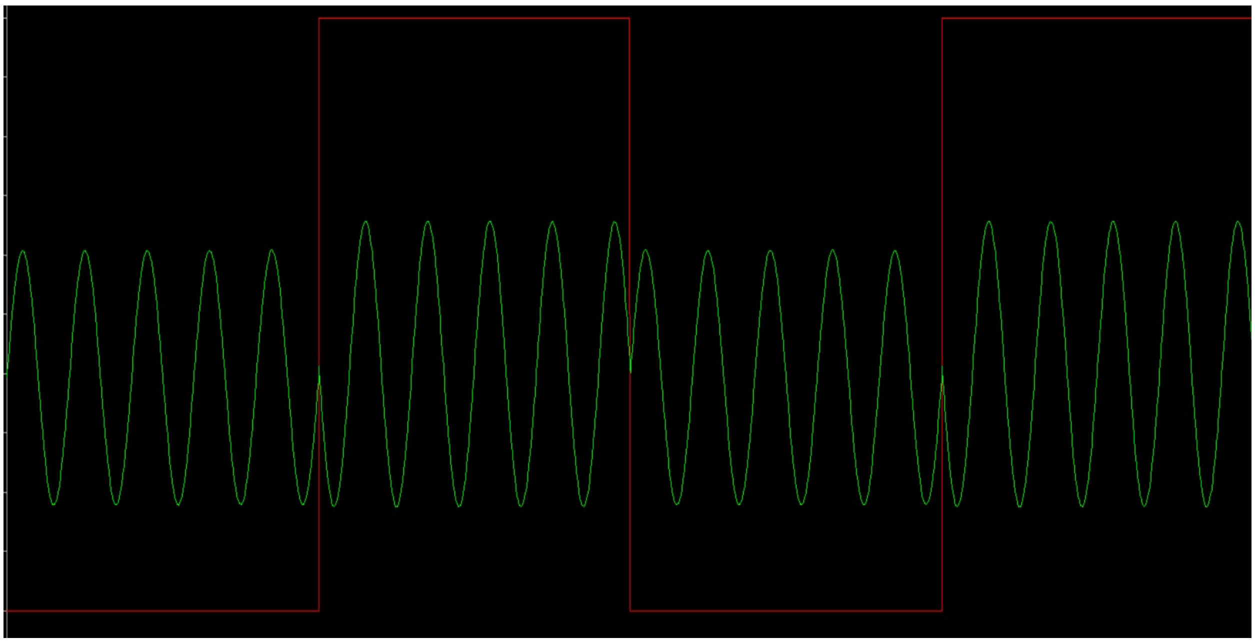
**Input Signals**

*Carrier Signal 10sin(2π($10^3$ )t)*

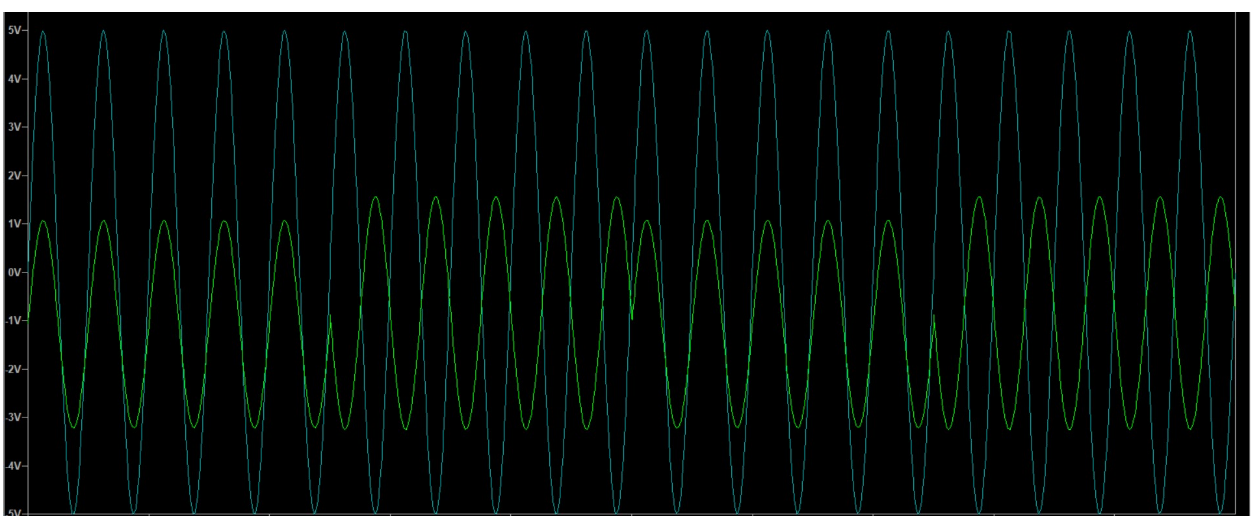


# Output Signals

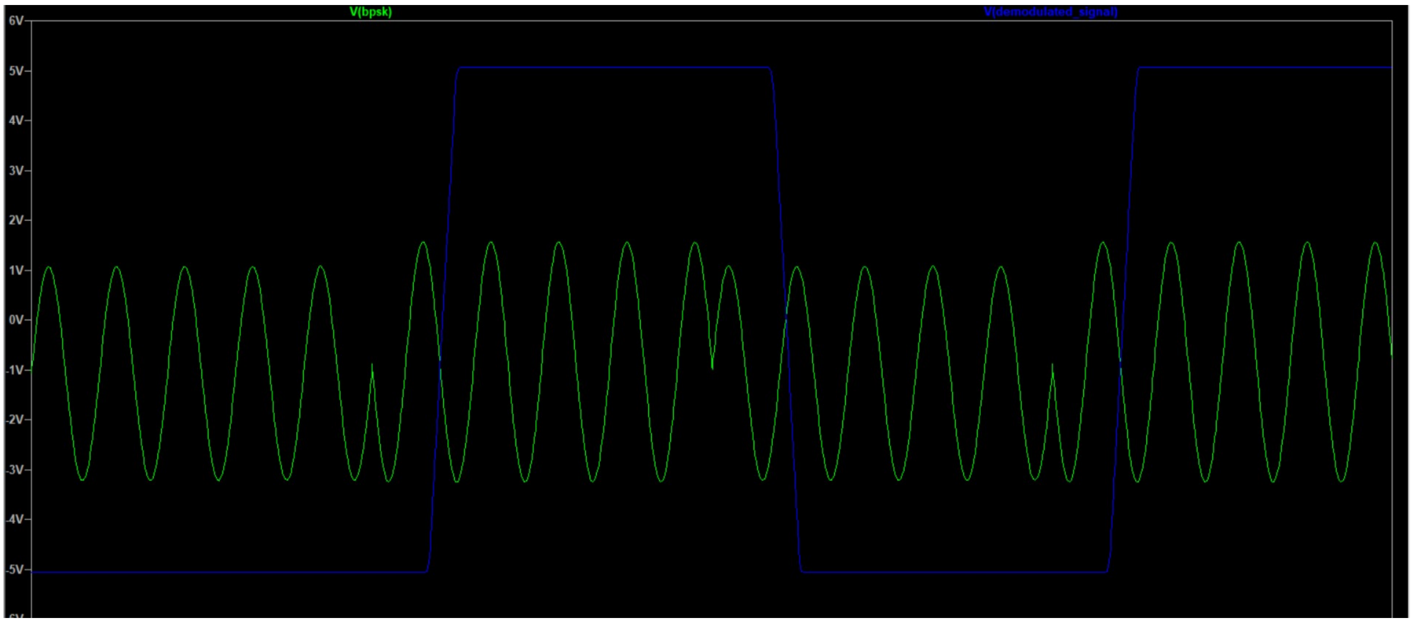
## *Modulated Signal*



*The modulated signal compared with the carrier signal.*



# *BPSK DEMODULATOR (OUTPUT WAVEFORM)*



# Conclusion

A Binary Phase Shift Keying modulation scheme was successfully implemented using basic components such as Op Amps and BJTs . A demodulator circuit ,for the signal generated, was also successfully designed and implemented.

BPSK is robust and can be used in wireless data transmission, including applications such as Bluetooth, Wi-Fi, and mobile communication systems. In conclusion, Binary Phase Shift Keying is a modulation technique that plays a pivotal role in digital communication systems.

Digital transmission by a carrier is a key enabling technology that makes cellular/wireless, satellite, telco dial-up, and cable modem communications possible.

# Future Developments

In the realm of Binary Phase Shift Keying (BPSK) modulation and demodulation, ongoing research and future works often revolve around enhancing performance, efficiency, and adaptability. Some potential areas of focus for future developments include:

1. *Advanced Modulation Techniques:*
Exploring higher-order modulation schemes beyond BPSK (QPSK, 8PSK, etc.) for increased spectral efficiency and data rates while maintaining robustness against noise and interference.
2. *Energy Efficiency:*
Designing low-power BPSK modulation/demodulation techniques suitable for battery-powered devices or IoT applications, focusing on energy-efficient transmission and reception.
3. *Channel Coding and Error Correction:*
Investigating advanced error correction coding techniques (like turbo codes, LDPC) to enhance the robustness of communication systems in noisy channels.
4. *Security and Encryption:*
Developing robust security mechanisms and encryption techniques to ensure data privacy and integrity in BPSK communication systems, especially in wireless networks.
5. *Software-Defined Radio (SDR):*
Integrating BPSK modulators/demodulators into flexible SDR platforms to facilitate dynamic reconfiguration, allowing for easy adaptation to different communication standards and protocols.

# References

1.Sergio Franco, “Design with OPAMPS and Linear Integrated circuits”, Tata McGraw Hill, 2002 or later edition

2.M.F.Mesiya, “Contemporary Communication Systems”, First Edition, McGraw-Hill India, 2014.