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DIGITAL COMMUNICATION LAB (EC39001)

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Title Of Experiment: Generating and Demodulating FSK Signal
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Introduction

This experiment involves Frequency Modulating a digital signal(PN Sequence) and Demodulating the Frequency Shift Key'ed(FSK) signal to recover the original PN Sequence. Modulation requires IC XR2206 and Demodulation involves a Differentiator, Envelope Detector and Comparator Circuit.

Key Objectives

For this experiment, out key objectives are:

- Generating the Modulated Signal.
- Demodulated Signal.
- Threshold the demodulated signal in order to recover the original Digital Signal.

Theory

Frequency Shift Keying(FSK) involves changing the frequency of Carrier Signal based on whether the Message Signal is **HIGH** or **LOW**. Since this is Frequency Modulation, we need to use IC XR 2206 to perform the task. Basic idea of Frequency Modulation is to have an Oscillator that generates the Signal. And the components of the Oscillator(Resistance and Capacitance for a simple RC Oscillator) are changed based on the Message Signal. For FSK generation, XR 2206 supports a mechanism where we provide 2 Resistors and a single Capacitor. Based on **whether the message is greater** than a Threshold or not, the IC selectively uses either $\mathbf{R}_1$ or $\mathbf{R}_2$ with **C** to generate the Modulated Signal.

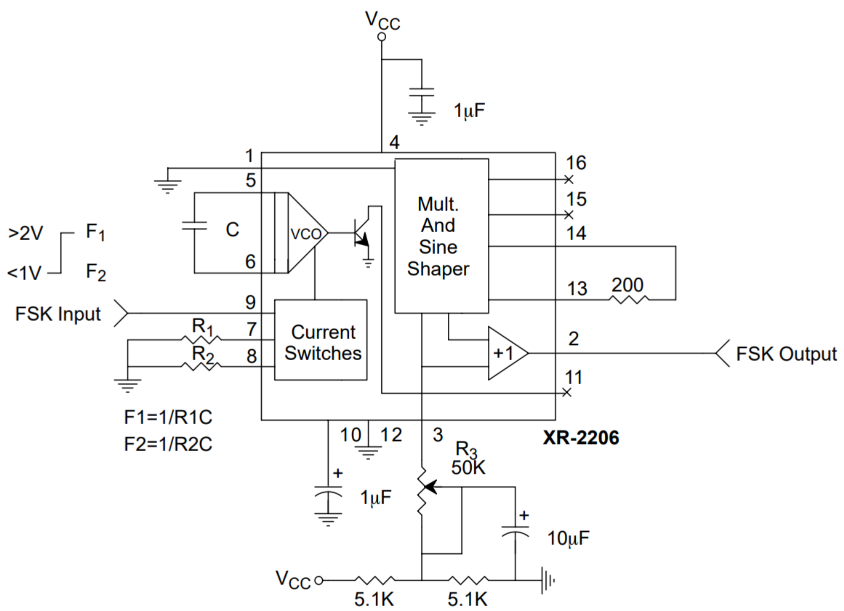


Figure 1: Circuit Diagram

Here the FSK input is the Message Signal(PN Sequence). F_1 and F_2 are design parameters and they need to be chosen in order to find the values of R_1 and R_2 and C and design the circuit. Here we chose $\mathbf{F}_1 = 20$ KHz and $\mathbf{F}_2 = 10$ KHz, with C = 4.7 nF and find Resistances accordingly.

$$R_1 = \frac{1}{F_1.C} \qquad R_2 = \frac{1}{F_2.C}$$

$$R_1 = \frac{1}{20e3.4.7e-9} \qquad R_2 = \frac{2}{10e3.4.7e-9}$$

$$R_1 = 10.638\ K\Omega \qquad R_2 = 21.276\ K\Omega$$

We use the $R_1 = 10\ K\Omega$ and $R_2 = 20\ K\Omega$.

That is all about FSK Modulation. Next up, let us look at how to demodulate the FSK Signal.

$$x(t) = A_C\cos(\omega t + \int m(t)\ dx)$$

In order to extract m(t), we need to differentiate x(t). On differentiating x(t), we get the Carrier Harmonic multiplied with m(t).

$$x'(t) = A_C(\omega + m(t)).\sin(\omega t + \int m(t)\ dx + \pi\$)$$

The Differentiator can be implemented using a Capacitor. However, one can't directly connect the Capacitor to a Voltage Source. A Differentiator has a linear graph in the Frequency Domain. Thus we will use a High Pass Filter such that the frequencies F_1 and F_2 fall in the Linear(Transition/Stop) region of the High Pass Filter. A Low Pass Filter would also do the job but we are going to go with the High Pass. After multiple hit and trials, we finally chose the High Pass Filter Cut Off is **570 KHz**. This value gave us a factor of 2 difference between responses of F_1 and F_2, i.e, $H(F_1) = 2\ .\ H(F_2)$.

Put an Envelope Detector in order to get the Message Signal m(t). The Envelope detector must have a Rise/Fall Time of Envelope(T_{ED}) Detector must be such that

$$F_m < 1\ /\ T_{ED} < F_c$$

So that the Envelope Detector is fast enough to follow the message signal but not fast enough to follow the Carrier Signal. The derivative is passed through an Envelope Detector circuit.

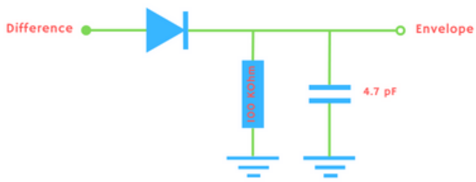


Figure 2: Envelope Detector Circuit

After Envelope detector, we pass it through a Comparator Circuit, that performs a thresholding operation on the output of Envelope Detector to give us the final Digital Signal.

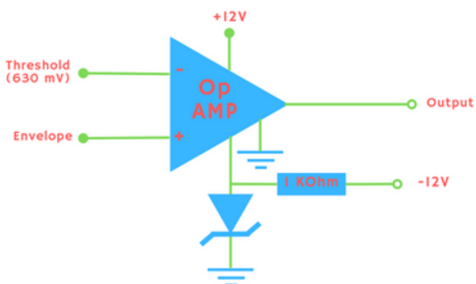
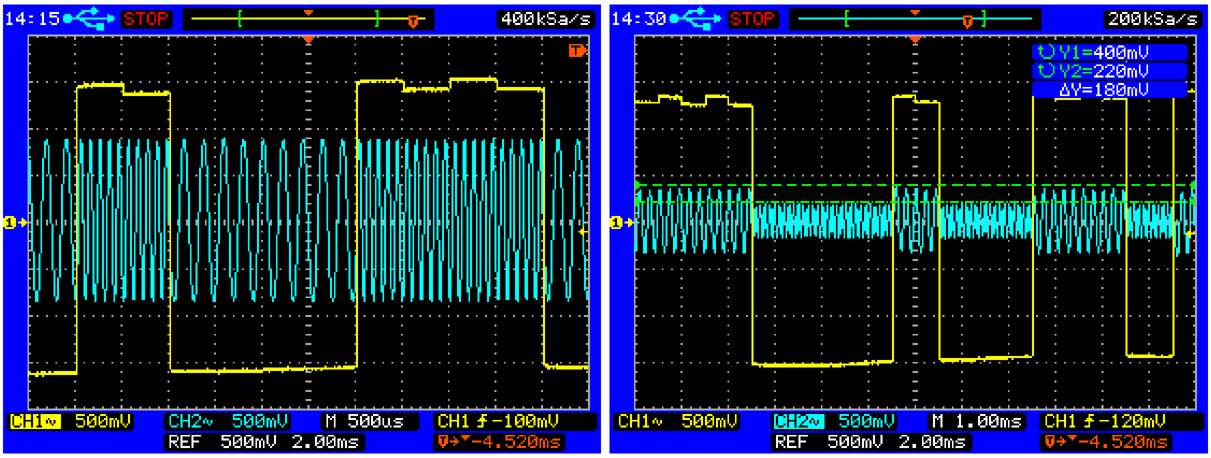


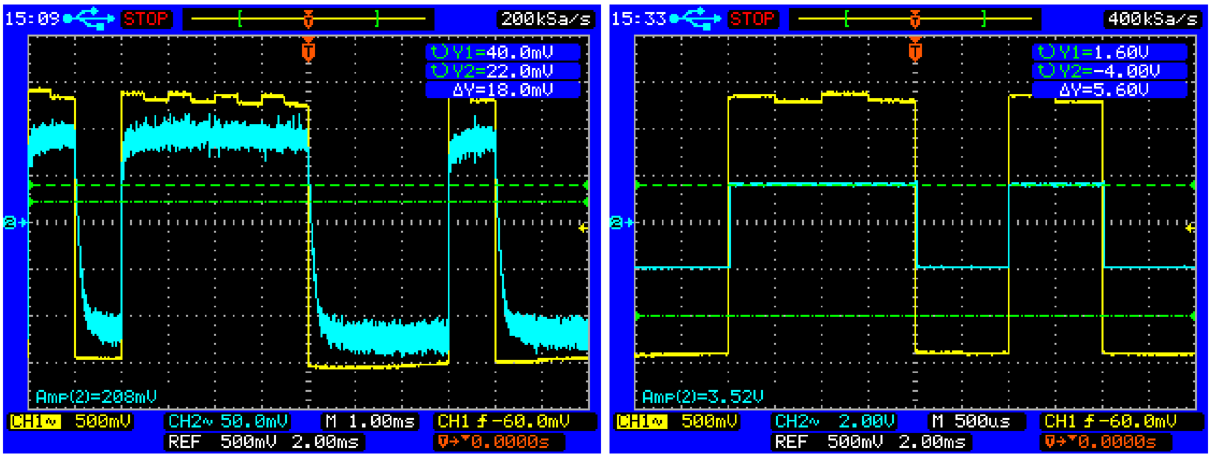
Figure 3: Comparator Circuit

Results



(a) Modulator Output (b) Differentiator

Figure 4



(a) Envelope Detector (b) Final Output(Comparator)

Figure 5

Discussion

From this experiment, our key takeaways were:

- **Comparator Circuit**

  It can be noticed that **unequal voltages** are being provided at the 2 Power Supply inputs of the Op-Amp. This has been done in order to **clamp the output values** of the Comaprator Circuit **between +5 V and 0 V**. The Zener Diode provides a volatage of -6.2 V to the Negative Supply of the Op Amp. Also note that the Op-Amp used for this purpose is IC 710. It is not the regular Op-Amp(IC 741) that we use.

- **Tuning Threshold**

  Comparator Circuit performs a **Thresholding Operation** on the Envelope of the Difference between BPSK and Carrier Signal. As we can see in the Envelope (Figure 5a), there are oscillations at both **HIGH** and **LOW** states of the PN Sequence. A threshold must be carefully chosen that maintains **maximum separation** with both Minima of Upper Oscillations and Peaks of Lower Oscillations. Threshold Voltage can be pre-calculated or manually adjusted using a Potentiometer. It may happen that the gap isn't enough for one to be able to manually find the threshold. In those cases, the gap can be increased by changing the following:

  - **Increasing Carrier Frequency**
  - **Decreasing Message Frequency**
  - **Increasing Carrier Amplitude**

We performed all of these changes and finally found a better output(Figure 5a Final Iteration).

Conclusion

In this experiment, we learnt about Frequency Shift Keying, circuit required to generate it, its properties and importance. BPSK is Phase Modulation and FSK is Freuquency Modulation

References

- Digital Communication Theory Class Notes
- Wikipedia
- ChatGPT
- Lab Manual