**FM GENERATION**

**INFORMATION:**

Frequency modulation (FM) is a form of angle modulation in which the carrier frequency is made to vary in proportion to the instantaneous amplitude of the modulating signal. It is one of the most prevalent forms of modulation techniques used in the telecommunications industry.

In this experiment, the LM566 voltage controlled oscillator (VCO) will be used as an FM modulator to produce a frequency modulated square wave and triangular wave output signal. The circuit is illustrated in Figure 1. Various modulation input frequencies and voltages will be used to demonstrate that the FM signal's maximum frequency deviation, $\delta$, is independent of modulation frequency and dependent upon modulation voltage.

**OBJECTIVE:**

Our objective in this experiment is to construct the FM modulator circuit shown in Figure 1(a) and measure and observe the "FMing" affect for various modulation input frequencies and amplitudes. We will note that the maximum frequency deviation, $\delta$, is independent of modulation frequency and dependent upon modulation voltage.

**EQUIPMENT AND MATERIALS:**

1. Oscilloscope and 2 probes  
2. Sine wave generator  
3. 10 V DC Power supply  
4. LM566 VCO  
5. 1-100 $\mu$F capacitor  
6. 1-10 $\mu$F capacitor  
7. 1-0.1 $\mu$F capacitor  
8. 2-0.001 $\mu$F capacitors  
9. 1-10 k$\Omega$ 1/4 W resistor  
10. 1-2.7 k$\Omega$ 1/4 W resistor  
11. 1-1.5 k$\Omega$ 1/4 W resistor

**NOTE:** DO NOT DISASSEMBLE YOUR CIRCUIT. WE WILL USE THIS SETUP AS AN FM GENERATOR SOURCE IN OUR NEXT EXPERIMENT
Output frequency equation:

\[
f_o = \frac{2 \left( V_{cc} - V_c \right)}{R1 \cdot C1 \cdot V_{cc}} \quad V_c = \frac{V_{cc} \cdot R3}{R2 + R3}
\]

where \( V_{cc} \) = Supply voltage
\( V_c \) = Control voltage at pin 5 (8.70 V here)
\( f_o \) = Carrier frequency
\( R1 \) should be between 2 kΩ and 20 kΩ.

\[
\frac{3}{4} V_{cc} \leq V_c \leq V_{cc}
\]
DIRECTIONS:

1. Connect the FM generator circuit shown in Figure 1(a).

2. The equation for computing the carrier frequency for the FM generator circuit is shown in Figure 1(a). Calculate the carrier frequency, $f_o$, for the values of R1 and C1 shown.

   \[ f_{o\text{ calc.}} = \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ ]

3. Power up your circuit. With your oscilloscope AC coupled, monitor the square wave and triangle wave output of the FM generator circuit with no modulation input signal. Draw the output waveforms below. For each output signal, measure and record on your drawing the peak-to-peak voltage, $V_{p-p}$, and the period, T.

Square wave output (AC coupled):

\[ V \]
\[ t \]

Triangle wave output (AC coupled):

\[ V \]
\[ t \]
4. Compute the frequency of the waveforms above based on the period you measured.

\[ f_{\text{meas.}} = \quad \]

5. Compute the percent error between the measured carrier frequency, \( f_{\text{meas.}} \), in step 4 and the computed frequency, \( f_{\text{calc.}} \), in step 2 above.

Percent Error = \( \frac{\text{(measured} - \text{calculated)}}{\text{calculated}} \times 100\% \)

\[ = \quad \]

6. Connect your sine wave generator to the modulation input of the FM generator circuit. With your oscilloscope, set the amplitude of the sine wave to 1 V_{p-p} at a frequency of approximately 1/2 Hz. This very low frequency will allow you to see the "FMing" effect at the FM output. Verify that FMing is occurring at the triangle (or square) wave output.

VERIFIED: \( \quad \)

7. Set the frequency of the sine wave, \( f_m \), to the values listed in the table below and measure the maximum frequency deviation, \( \delta \), at the triangle wave output. Compute the corresponding modulation index, \( m_r = \delta / f_m \), and include this in the table. Note that \( \delta \) remains constant and is independent of \( f_m \).

**TIP:** In measuring maximum frequency deviation, \( \delta \), trigger your scope in the NORMAL MODE off of the rising edge of the frequency modulated triangle wave. You will see the triangle wave's period deviating from its minimum to maximum value. Measure the minimum period of the wave since this is the maximum frequency, \( \delta \).
8. Change the modulation input voltage, $V_i$, from $1 \ V_{pp}$ to $0.5 \ V_{pp}$ and record the same information in the following table. Note that $\delta$ has changed and is therefore dependent upon $V_i$ and independent of $f_m$.

<table>
<thead>
<tr>
<th>$f_m$</th>
<th>$\delta$</th>
<th>$m_r = \delta/f_m$</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 Hz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 Hz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 kHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 KHz</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[
V_i = 1 \ V_{pp}
\]

\[
V_i = 0.5 \ V_{pp}
\]
QUESTIONS:

1. Define FM:

2. What effect does changing the modulation frequency of an FM signal have on its maximum carrier frequency deviation?

3. What effect does changing the amplitude of a modulation signal have on an FM signal's maximum carrier frequency deviation?

4. Referring to Figure 1, how would you change the carrier frequency to 50 kHz?

5. Explain what you would add to this circuit to generate an FM sine wave instead of a triangle or square wave.