Faculty of Engineering
Electrical Engineering Department
Communication Engineering I Lab (EELE 3170)

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EXPERIMENT #7

FM MODULATION

Theory ..

- Frequency modulation is a form of angle modulation in which the amplitude of the modulated carrier is kept constant while its frequency is varied accordance with the instantaneous value of the modulating signal voltage (Amplitude).
- The FM signal is expressed as

$$X_{FM}(t) = A_c \cos[\theta(t)] = A_c \cos[2\pi f_c t + 2\pi f_\Delta \int x(\lambda) d\lambda]$$

$$Where\ , \qquad x(\lambda) = A_m \cos[2\pi f_m \lambda]$$

$$X_{FM}(t) = A_c \cos[2\pi f_c t + \frac{f_\Delta A_m}{f_m} \sin[2\pi f_m t]]$$

Continued ..

$$X_{FM}(t) = A_c\, cos[2\pi f_c t + \beta\, sin[2\pi f_m t]]$$

Where :

- $\theta(t)$: Instantaneous modulated frequency
- A_c : amplitude of the carrier signal
- f_c : carrier frequency
- f_m : modulating signal frequency
- f_Δ : frequency deviation
- β : modulation index of the FM wave ($\beta = \frac{f_\Delta A_m}{f_m}$)

Continued ..

- The maximum frequency deviation

  The difference between the maximum or minimum frequency in frequency modulated carrier and unmodulated.

- The modulation index

  The ratio of the maximum frequency deviation to the modulating frequency.

- The bandwidth required for FM

  Unlike AM modulation the bandwidth of FM signals isn't determine by the message bandwidth only, but also by message (maximum) amplitude and frequency deviation. The bandwidth is approximated by Carson's rule.

$$BW \approx 2B(\beta + 1) = 2f_m\left(\frac{f_\Delta A_m}{f_m} + 1\right) = 2(f_\Delta A_m + f_m)$$

Notes ..

- The bandwidth required for an FM signal depends upon two factors:
  - **message signal amplitude.**
  - **message signal frequency.**
- The main advantage of FM modulation is that it can provide better discrimination against noise and distortion since it isn't sensitive to random amplitude variations.
- The main disadvantage of FM modulation is that it’s broadcast uses more bandwidth than AM
- In FM, the carrier signal frequency deviates only with the message signal amplitude.
- In FM, the message signal’s frequency does not deviate the carrier signal’s frequency but does affect the rate of deviation.

Generations of FM Signals ..

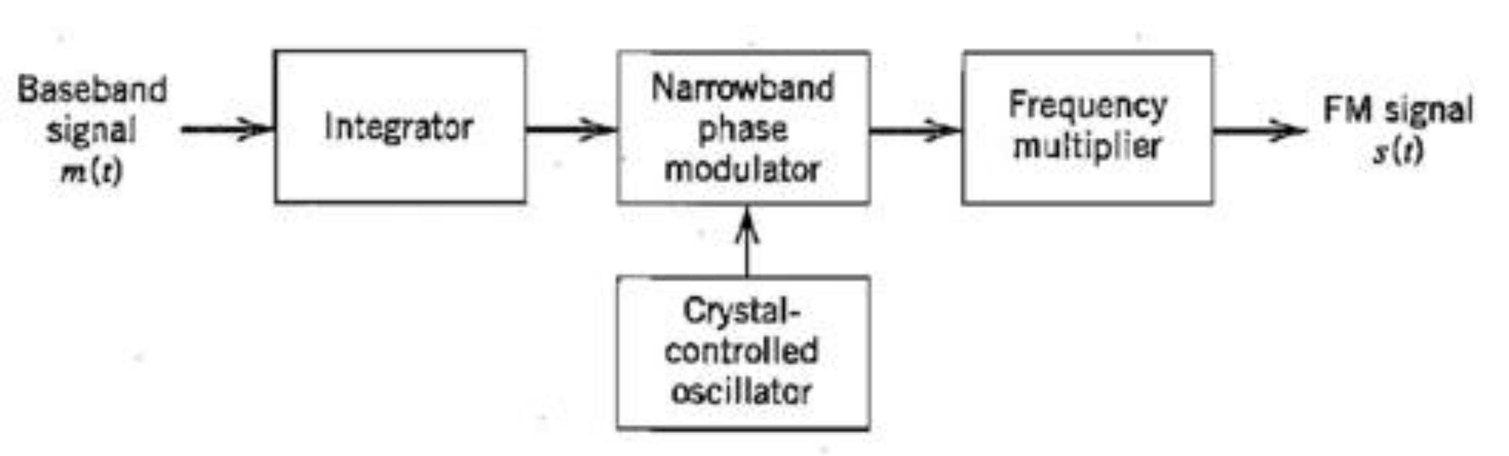
- The amplitude of input modulated signal controls the instantaneous output frequency by means of a device known as a voltage controlled oscillator. (VCO)
- Frequency modulated signal can be generated by using :
  - **Direct method**

    The instantaneous frequency is directly varied with the information signal.
  - **Indirect method**

    The signal is first integrated and then phase modulated to get the required FM output.

Indirect Method Of Generating WBFM

This type of modulation gives Narrow Band FM signal which is then converted to required range and bandwidth by using frequency multipliers and converters.



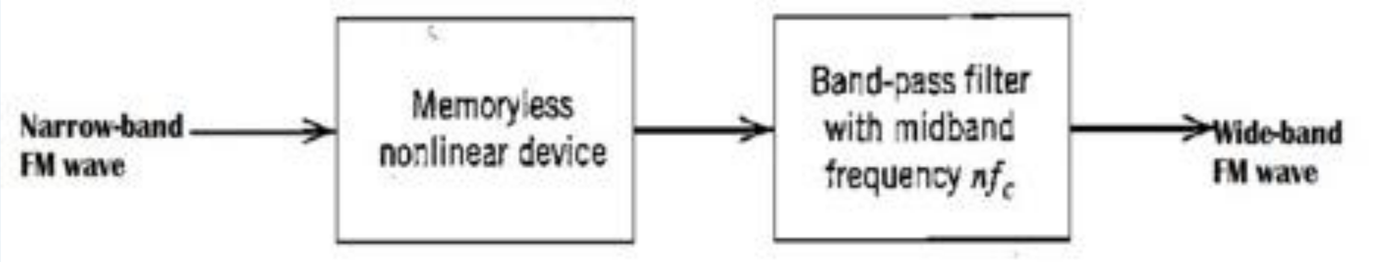
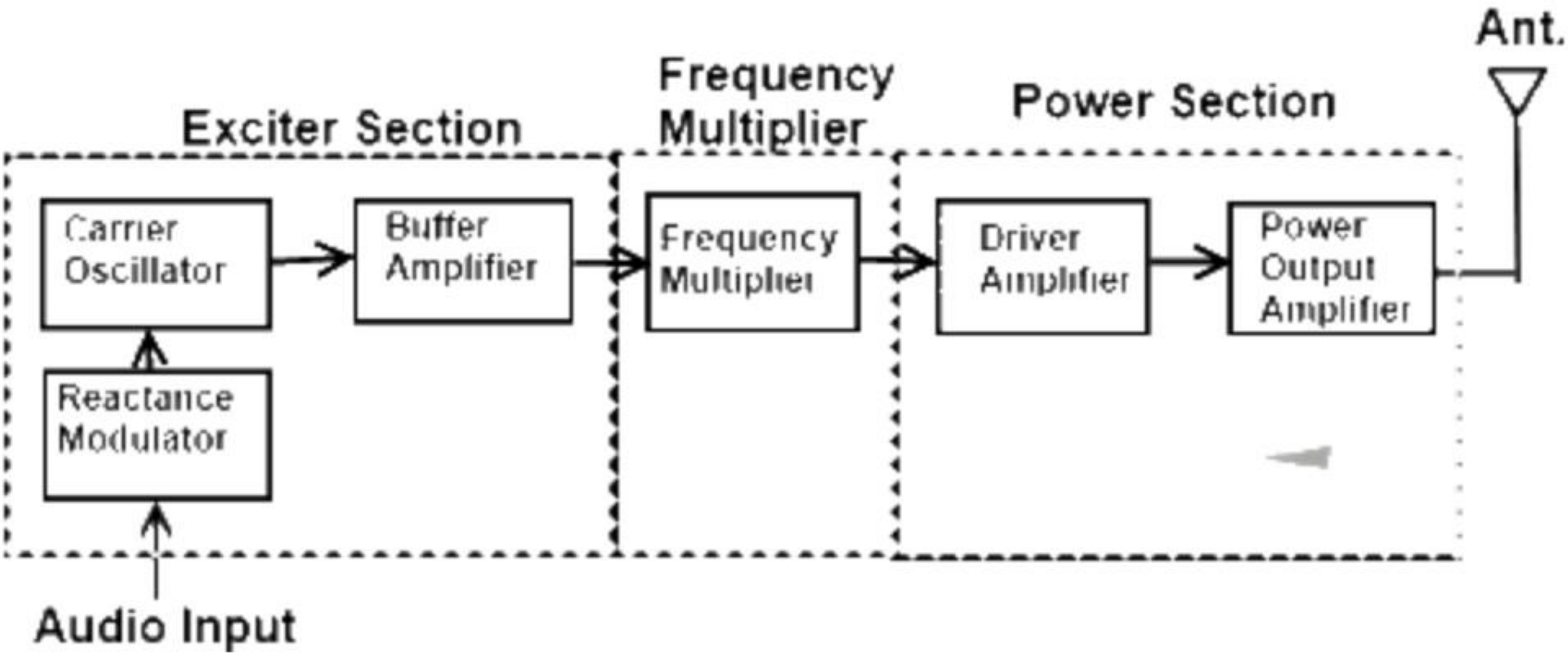


FIGURE: Block diagram of frequency multiplier.

Direct Method Using Reactance Modulator

- A Varactor diode can be used whose reactance changes with the input signal and hence output frequency can be varied.



Varactor Diode

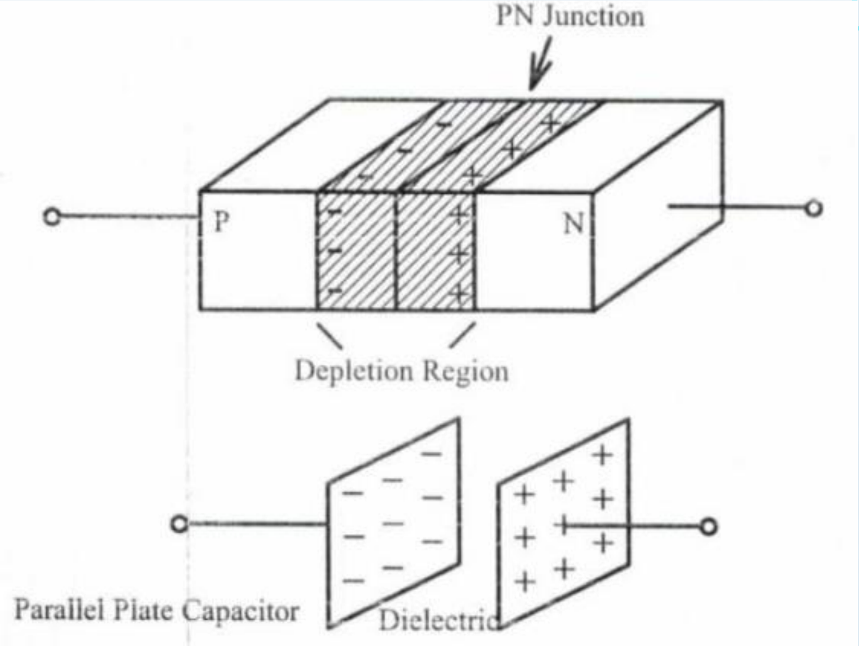
- Also known as a tuning diode, designed for FM tuning.
- A varactor diode is a P-N junction diode that changes its capacitance and the series resistance as the bias applied to the diode is varied.
- The property of capacitance change is utilized to achieve change in the frequency of an carrier signal.
- Accordance to reverse biased voltage when increased then the depletion region becomes wide so the capacitance value decreased and vice versa.
- AC signal (voltage) is added to varactor diode and then the variation of capacitance will follow the amplitude of modulating signal.

Equivalent Circuit Diagram of Varactor Diode

Tuning ratio TR:

The ratio of capacitance value under two different biases for varactor diode.

$$TR = \frac{c_{v1}}{c_{v2}}$$

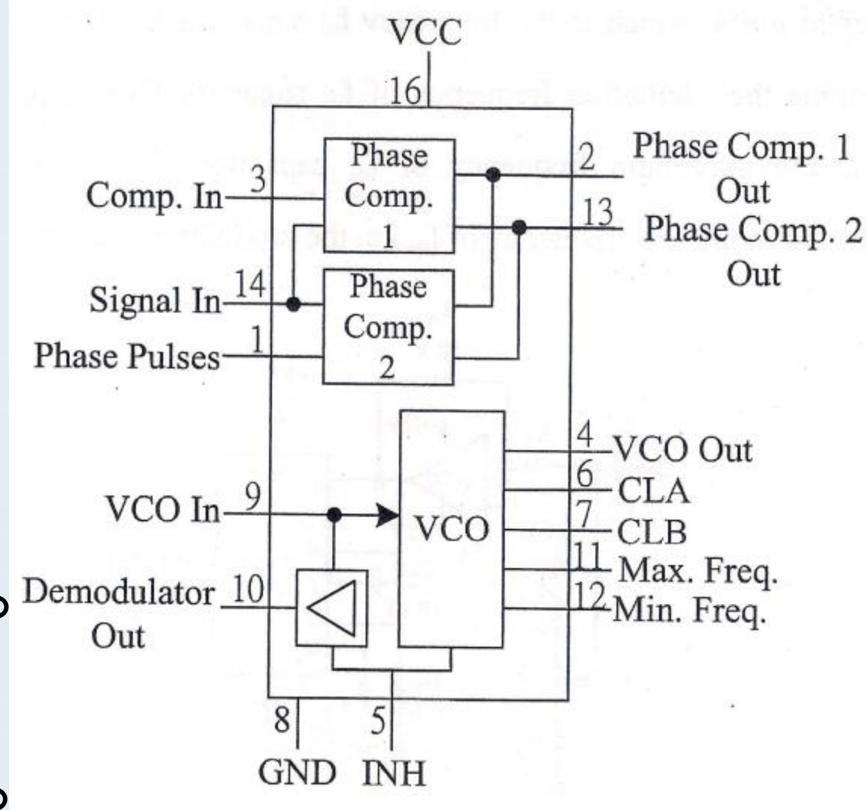


(a) Circuit symbol

(b) Equivalent circuit

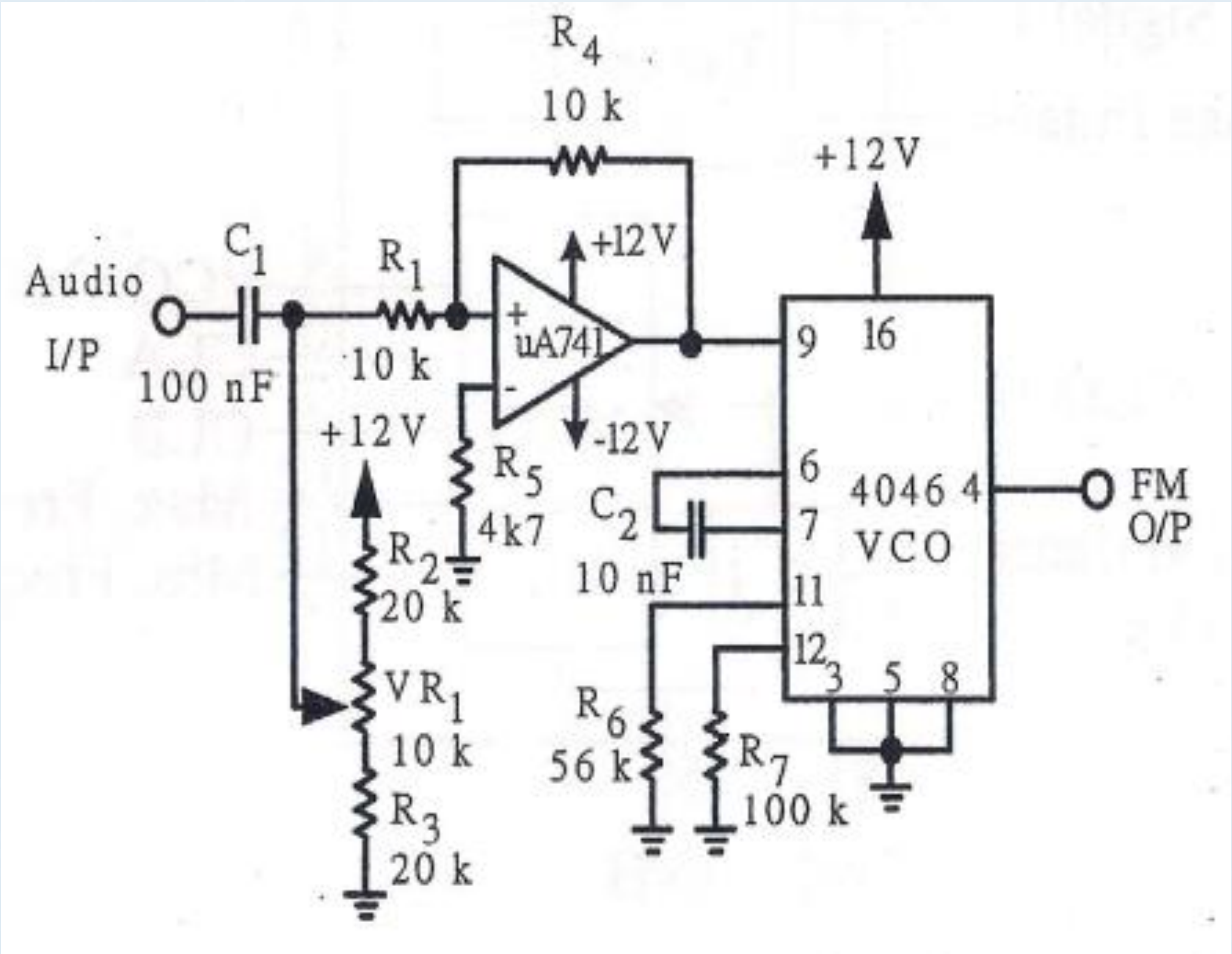
Implementation of FM modulator using PLL MC4046 IC

- MC4046 used for FM modulation and demodulation
- For modulation:
  - Pin 1, 10, 15 are not connected
  - Pin 5 is Inhibit Input (INH)
    set to zero to enable the VCO
  - Pin 9 is to determine VCO oscillations
  - Pin 4 is the output frequency
  - Pin 6 and 7 are connected to a capacitor
  - Pin 11 and 12 are connected to a two resistors
  - Pin 6, 7, 11 and 12 are to determine max and min frequencies according to capacitor and resistors value



Block diagram of MC4046.

Circuit Diagram of FM modulator (MC4046)

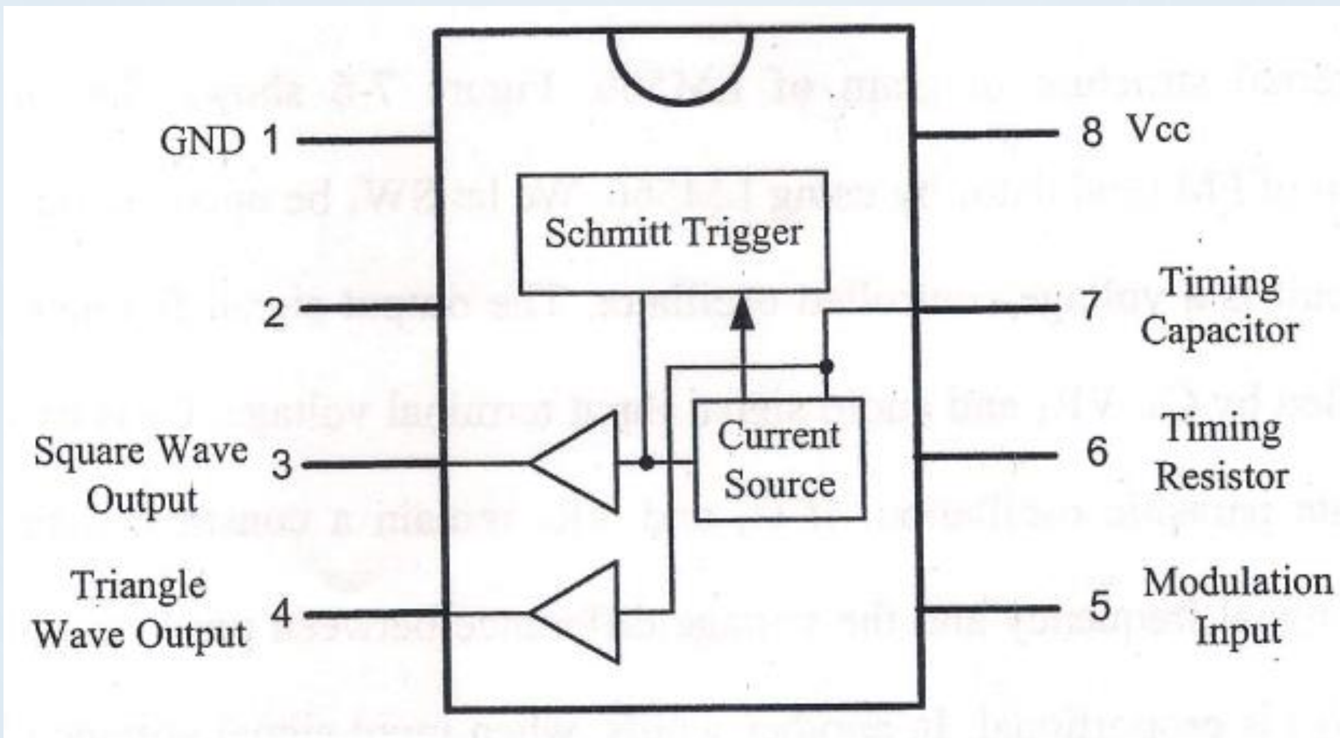


By adjusting variable resistor VR_1 we can control the output frequency

Implementation of FM modulator using VCO LM566

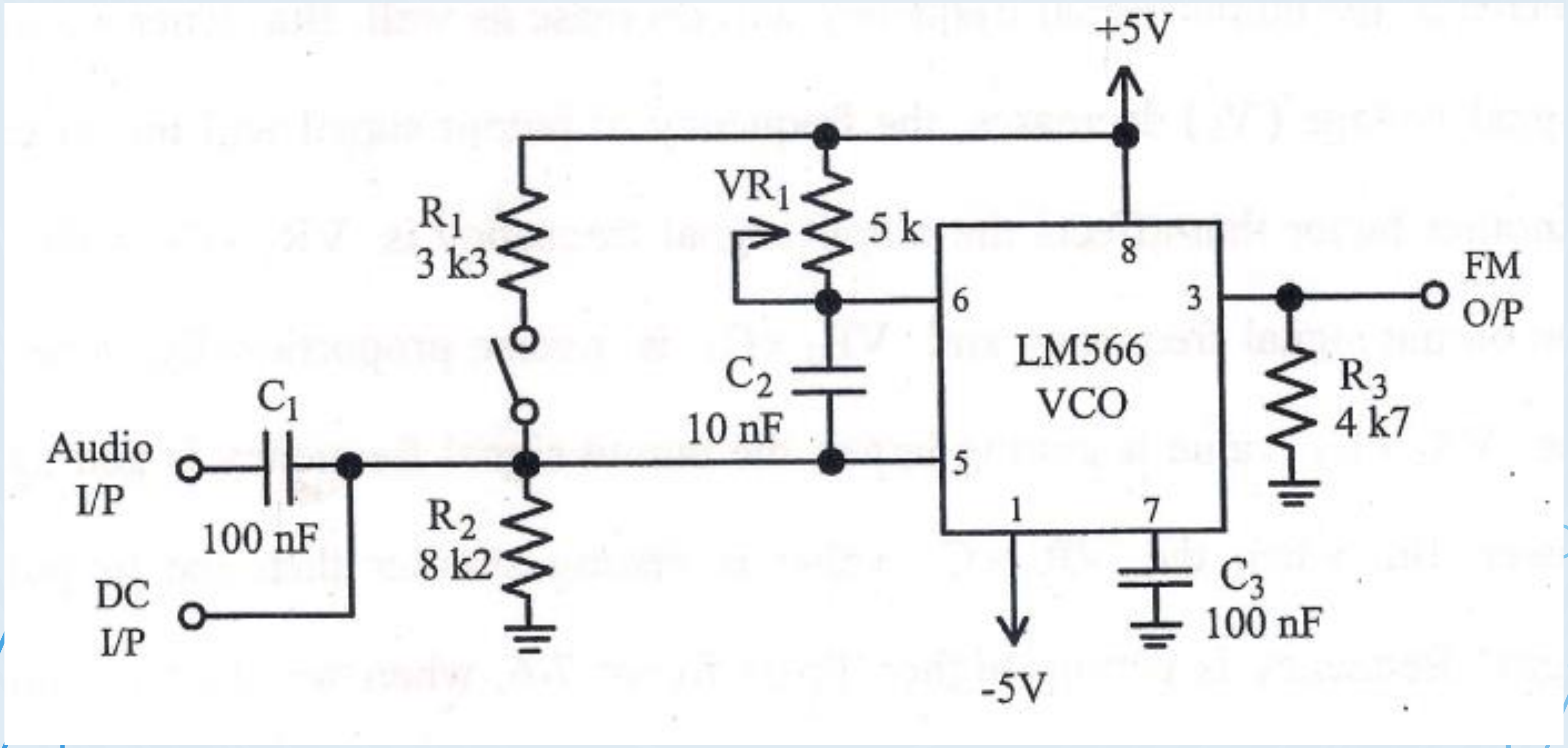
- LM566 is for purpose of voltage controlled oscillator which may be used to generate square and triangular waves.
- **voltage controlled oscillator** (**VCO**) is a device that accepts an analog voltage as its input and produces a periodic waveform whose fundamental frequency depends on that voltage.
- Another common name for VCO is "voltage to frequency converter".
- LM566 contains a current source to charge and discharge an external capacitor at pin 6 with rate set by an external resistor at pin 7.
- The frequency is a function of an external resistor and capacitor.

Pin diagram of LM566



Internal structure diagram of LM566.

Circuit Diagram of FM modulator (LM566)



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- Output signal frequency affected by two factors:
  1) **Modulating signal amplitude (directly proportional)**
  2) **VR1×C3(inversely proportional)**
- If the SW1 is open, output frequency is determined by the values of C3, VR1 and the audio input voltage.
- When the values of C3 and VR1 are fixed, then output frequency is directly proportional to the voltage difference between pins 8 and 5, (V8-V5).
  - Increase in audio input voltage (V5) causes a decrease in the value of (V8-V5) and a decrease in the output frequency
  - Decreasing the audio input voltage (V5) will cause the output frequency to increase.

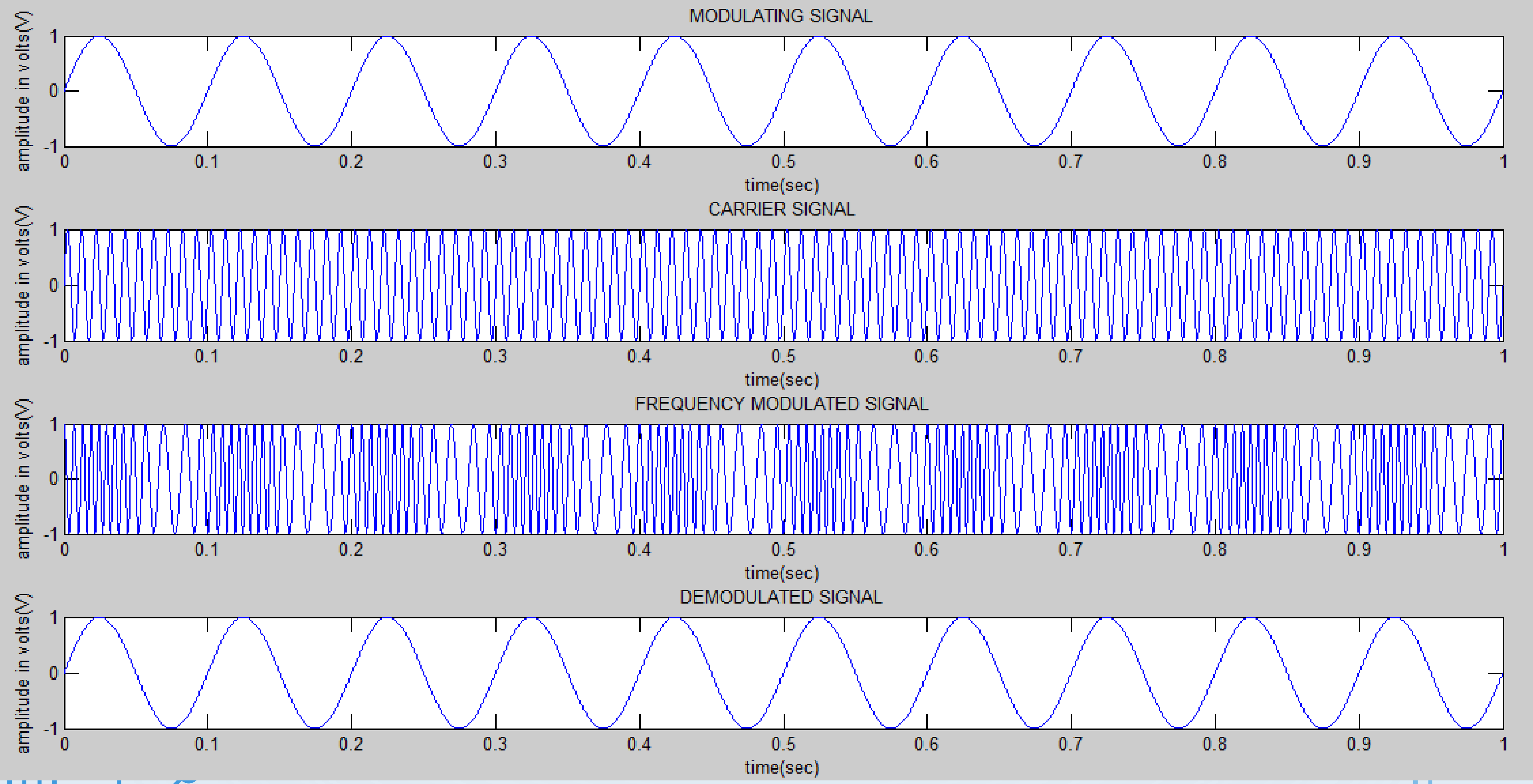
Continued ..

- When the values of C3 and VR1 are varied, then output frequency is inversely proportional to the product of VR1 and C3
  - Greater the VR1×C3 value the lower the output frequency.
  - Lower the VR1×C3 value the greater the output frequency.
- If the SW1 is closed, the voltage divider constructed by R1 and R2 provides a dc level to the audio input (pin 5).
- By adjusting the VR1, we can easily tune the VCO center frequency *fo*. When an audio signal is applied to the audio input, the output frequency will generate frequency deviations around *fo* in the variations of audio amplitude.

DSB-SC Demodulation Using MATLAB Without Function

```
Fs = 8000;                          % Sampling rate of signal
Fc = 100;                           % Carrier frequency
t = linspace(0,1,10000);            % Sampling times
x = sin(2*pi*10*t)                  % Channel 1
dev = 50;                           % Frequency deviation in modulated signal
y = fmmod(x,Fc,Fs,dev);             % Modulate both channels.
z = fmdemod(y,Fc,Fs,dev);           % Demodulate both channels.
subplot(411),plot(t,x)
xlabel('time(sec)'); ylabel('amplitude in volts(V)'); title('MODULATING SIGNAL');
subplot(412),plot(t,sin(2*pi*Fc*t))
xlabel('time(sec)'); ylabel('amplitude in volts(V)'); title('CARRIER SIGNAL');
subplot(413),plot(t,y)
xlabel('time(sec)'); ylabel('amplitude in volts(V)'); title('FREQUENCY MODULATED SIGNAL');
subplot(414),plot(t,z)
xlabel('time(sec)'); ylabel('amplitude in volts(V)'); title('DEMODULATED SIGNAL');
```

Results


MODULATING SIGNAL
amplitude in volts(V)
time(sec)
CARRIER SIGNAL
amplitude in volts(V)
time(sec)
FREQUENCY MODULATED SIGNAL
amplitude in volts(V)
time(sec)
DEMODULATED SIGNAL
amplitude in volts(V)
time(sec)

Answer these questions

- Effect of the modulation index on FM signal ?
- Why frequency modulation is better than amplitude modulation?
- What is frequency deviation ?
- Define modulation index for FM ?
- FM is more robust to noise compared to AM, why ?
- State advantages and disadvantages of FM
- Explain the methods for generation of FM
- What can you note in the modulated signal about frequency deviation if
  - Increase the amplitude of the modulating signal ?
  - Increase the frequency of the modulating signal ?