Voltage-Controlled Oscillator (VCO)

A ***Voltage-Controlled Oscillator*** (**VCO**) is a circuit that provides a varying output signal (typically of square-wave or triangular-wave form) whose frequency can be adjusted over a range controlled by a dc voltage. An example of a VCO is the **566** IC unit, which contains circuitry to generate both square- wave and triangular-wave signals whose frequency is set by an external resistor and capacitor and then varied by an applied dc voltage. Figure (1) shows that the 566 contains current sources to charge and discharge an external capacitor C_1 at a rate set by external resistor R_1 and the control dc input voltage. A Schmitt-trigger circuit is used to switch the current sources between charging and discharging the capacitor, and the triangular voltage developed across the capacitor and square wave from the Schmitt trigger are provided as outputs through buffer amplifiers.

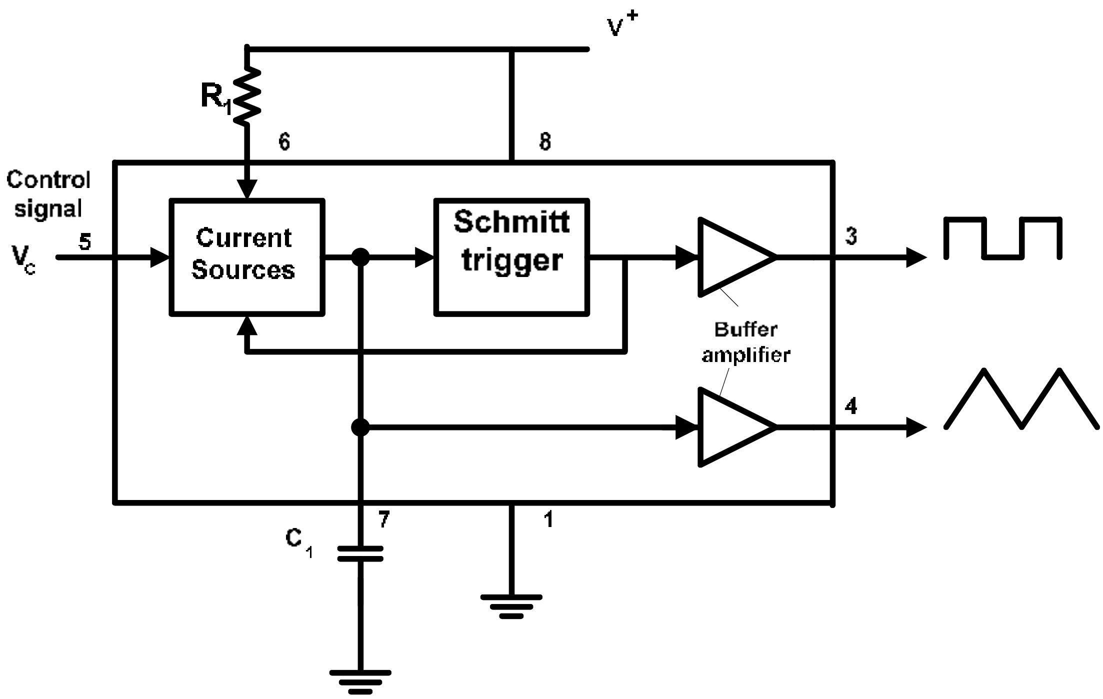

Fig.(1) A block diagram of 566 IC.

A free-running or center-operating frequency, f_o, can be calculated from Eq.(1).

$$f_o = \frac{2}{R_1 \times C_1} \times \left(\frac{V^+ - V_C}{V^+}\right) \quad \text{.................(1)}$$

With the following practical circuit value restrictions:

1. R_1 should be within the range ($2K\Omega \le R_1 \le 20K\Omega$).
2. V_C should be within range ($\frac{3}{4}V^+ \le V_C \le V^+$).
3. f_o should be below 1MHz.
4. V^+ should range between 10 V and 24 V.

<u>Example 1</u>:-

For the circuit shown in Fig.(2), R_1= 10 KΩ and C_1=820 pF, Find:

1. The control voltage V_C.
2. The free running-frequency f_o.

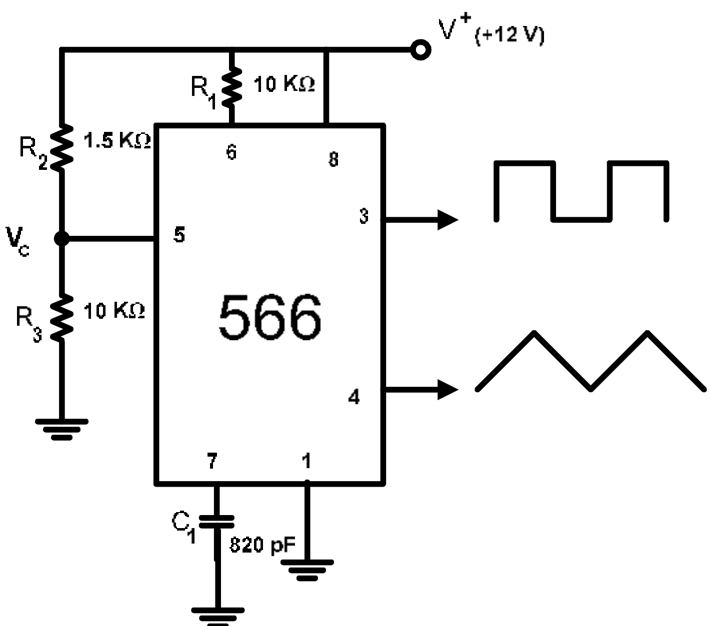

Fig.(2) Connection of 566 VCO unit.

<u>Solution:</u>

1. $V_C = \dfrac{R_3}{R_2 + R_3} \times V^+ = \dfrac{10K\Omega}{1.5K\Omega + 10K\Omega} \times (12V) = 10.4V$

2. Using equation (1) yields:

$$f_o = \frac{2}{(10\times 10^3)(820\times 10^{-12})} \times (\frac{12-10.4}{12}) \approx 32.5KHz$$

<u>Exercise (1):</u>

The circuit of Fig.(3) shows 566 as a VCO unit. Potentiometer R_3 allows varying V_C from about 9 V to near 12 V. Find the control voltage V_C and free-running frequency f_o for the following condition:

1. With the potentiometer wiper set at the top of R_3.
2. With the potentiometer wiper set at the bottom of R_3.

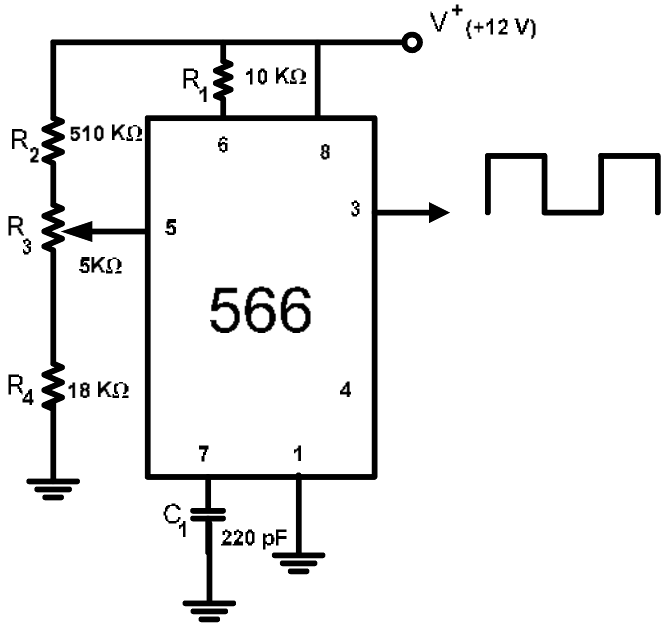

Fig.(3) Connection of 566 as a VCO unit.

Example 2:-
Rather than varying a potentiometer setting to change the value of V_C, as shown in previous exercise, an input signal V_{IN} can be applied as shown in Fig.(4). The voltage divider sets V_C=10.4V, V_{IN}= 1.4V peak can drive V_C around the bias point between voltage of 9 and 11.8 v, causing the output frequency to vary over about a 10-to-1 range. The free-running frequency = 121.2 KHz. Find the control voltage V_C?.

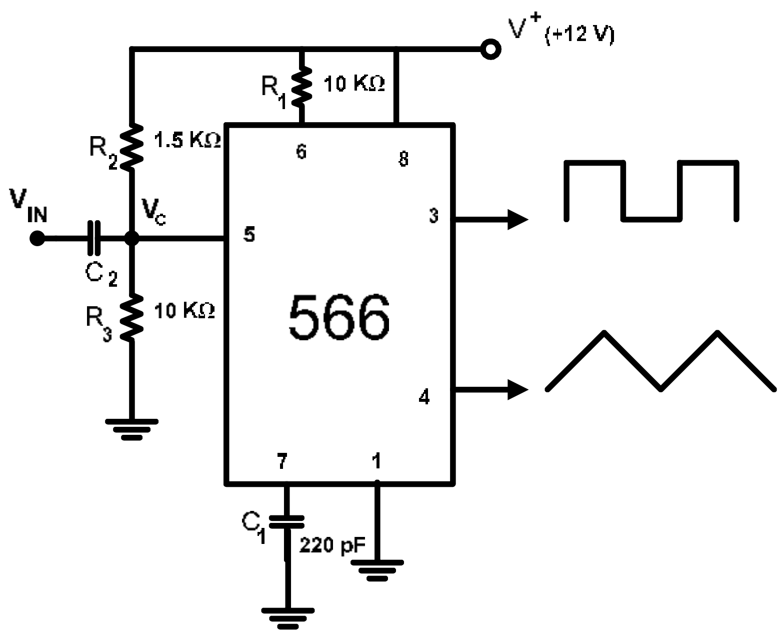

Fig.(4) Operation of VCO with frequency-modulated input.

Phase-locked Loop (PLL)

A phase-locked loop (PLL) is an electronic circuit that consist of a phase detector, a low-pass filter, and a voltage-controlled oscillator (VCO), as shown in Fig.(5)

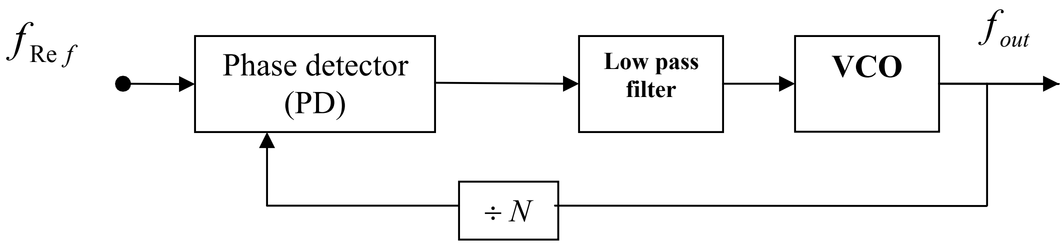

Fig.(5) The block diagram of phase-locked loop.

Operation of PLL

An output signal of frequency f_{out} is generated, and f_{out} is divided by N. The output of the divider is a signal with a low frequency (f_{out}/N), which is sent to the phase-detector (PD). At the PD, the phase of the signal are compared with an external signal of frequency (f_{Ref}), which is generated using a crystal oscillator. The output signal of the PD is then low pass filtered, and the filtered signal is sent to the VCO input to control the frequency of the output signal.

Applications

The PLL can be used in a wide variety of applications:

1. Frequency synthesis.
2. Frequency demodulation (detection).

Frequency Demodulation

FM demodulation or detection can be achieved using the PLL circuit. If the PLL centre frequency is selected at the FM carrier frequency, the output signal is desired demodulated signal. One popular PLL unit is the **565**, as shown in Fig.(6).

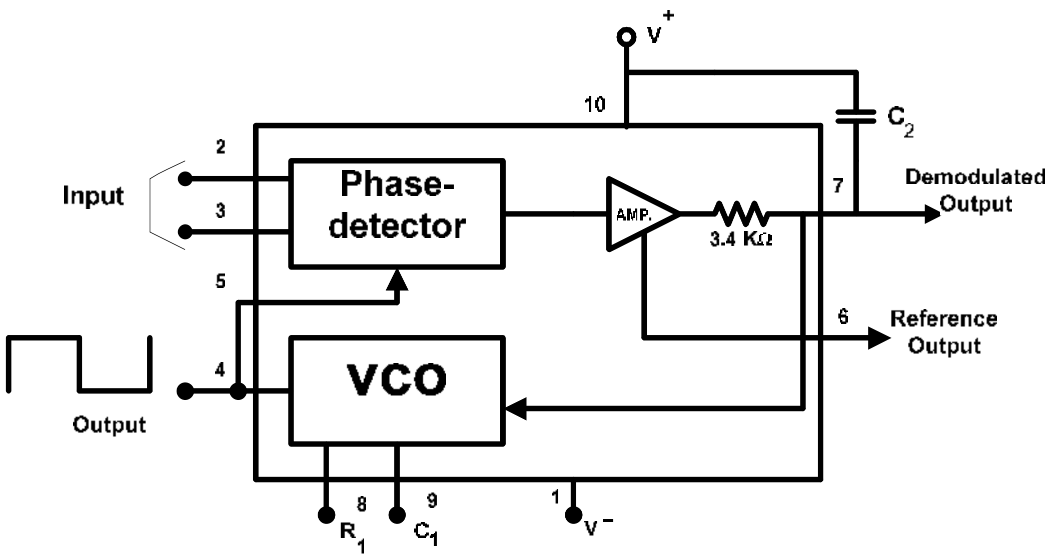

Fig.(6) A block diagram of 565 IC.

The 565 contains a phase-detector, amplifier, VCO, which are only partially connected internally. An external resistor and capacitor (R_1 and C_1) are used to set the free-running frequency of the VCO. Another external capacitor, C_2, is used to set the low-pass filter, and the VCO output must be connected back as input to the phase-detector to close the PLL loop. The 565 typically uses two power supplies, V^+ and V^-.

A free-running or center-operating frequency, f_o, can be calculated from Eq.(2).

$$f_o = \frac{0.3}{R_1 C_1} \quad \text{.............................(2)}$$

With limitation $2K\Omega \le R_1 \le 20K\Omega$. The lock range is:

$$f_L = \pm \frac{8 f_o}{V} \quad \text{..............................(3)}$$

And the capture range is:

$$f_C = \pm \frac{1}{2\pi}\sqrt{\frac{2\pi f_L}{R_2 C_2}} \quad \text{.......................(4)}$$

The ***capture range*** of a PLL is the frequency range centered about the VCO free-running frequency, f_o, over which the loop can acquire lock with the input signal. Once the PLL has achieved capture, it can maintain lock with the input signal over a somewhat wider frequency range called the ***lock range***.

Exercise (3):

For the circuit shown in Fig.(7), R_1= 10 KΩ and C_1=220 pF, Find:

1. The free running-frequency f_o.
2. The lock range f_L.
3. The capture range f_C.

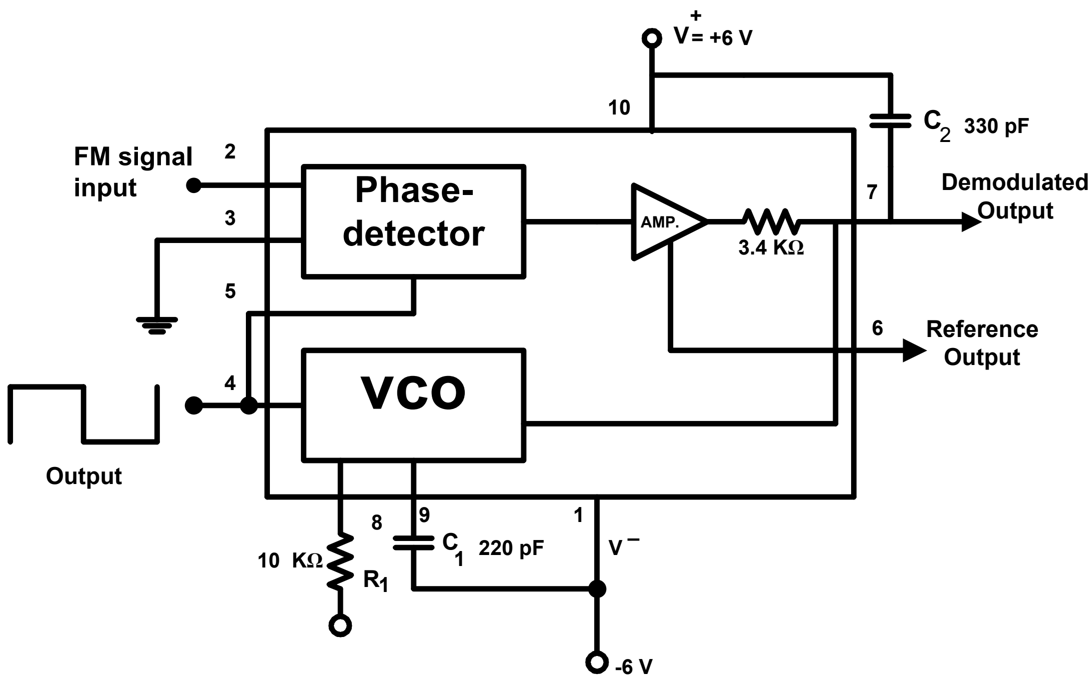

Fig.(7) Connection of 565 as a FM demodulator.

Exercise (4):

What value of capacitor, C_1, is required in the circuit of Fig.(7) to obtain a center frequency of 100 KHz.