# PULSE WIDTH AND PULSE POSITION MODULATION

**AIM**:

To design and study the working of

      i)        Pulse Width Modulation (PWM) and

      ii)       Pulse Position Modulation (PPM)

with the help of suitable circuits.

**COMPONENTS REQUIRED**:

| Components | (Specifications, Numbers) |
|------------|---------------------------|
| ICs        |                           |
| Diodes     |                           |
| Resistors  |                           |
| Capacitors |                           |

**THEORY:**

Pulse modulation systems represent a message-bearing signal by a train of pulses. The four basic pulse modulation techniques are Pulse Amplitude Modulation (PAM), Pulse Width Modulation (PWM), Pulse Position modulation (PPM) and Pulse Density Modulation (PDM). Figure below illustrates these four fundamental principles of analog pulse modulation.



Pulse Amplitude Modulation (PAM)           Pulse Position Modulation (PPM)

Pulse Width Modulation (PWM)           Pulse Density Modulation (PDM)
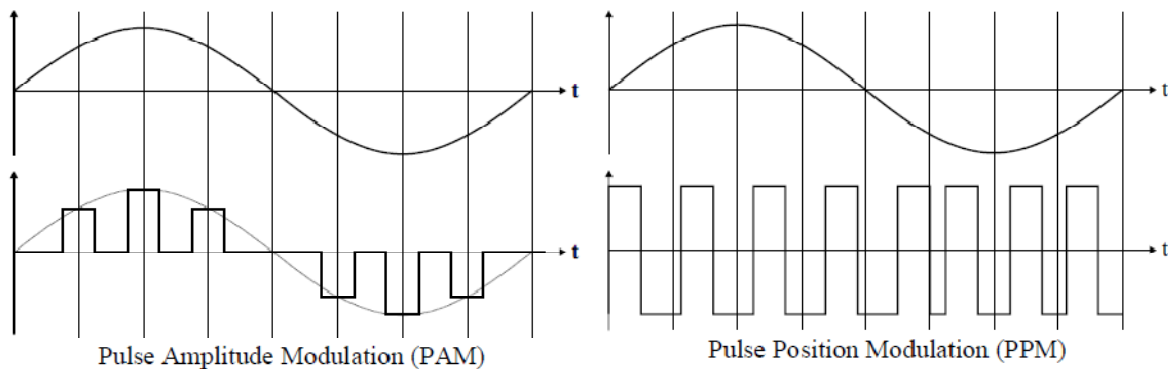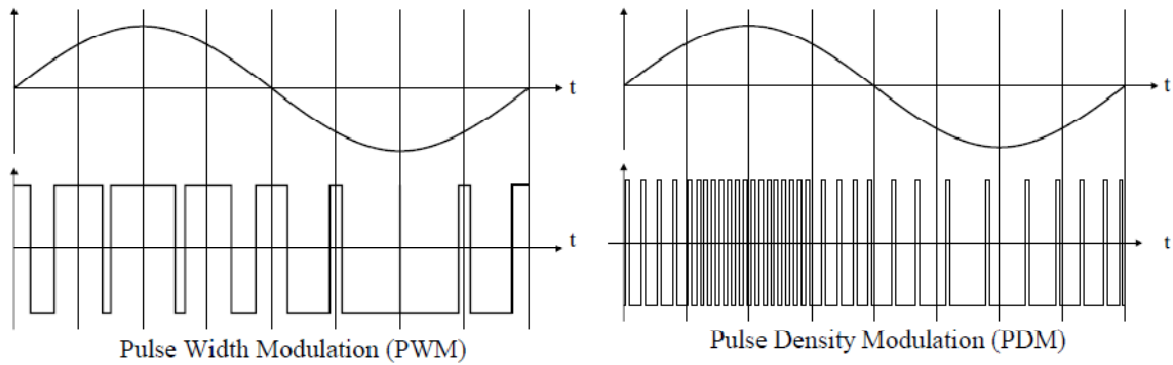
Pulse Amplitude Modulation (PAM) is based on a conversion the signal into a series of amplitude-modulated pulses. The bandwidth requirements are given by the Nyquist sampling theorem, so the modulated signal can be uniquely represented by uniformly spaced samples of the signal at a rate higher or equal to two times the signal bandwidth. An attractive feature of PAM is this low bandwidth requirement resulting in a minimal carrier frequency, which would minimize the power dissipation in a switching power amplification stage. Unfortunately, PAM is limited by the requirements for pulse amplitude accuracy. It turns out to be problematic to realize a high efficiency power output stage that can synthesize the pulses with accurately defined amplitude. If only a few discrete amplitude levels are required, as it is the case with the other three pulse modulation methods, the task of power amplification of the pulses is much simpler.

Pulse Width Modulation (PWM) is dramatically different form PAM in that it performs sampling in time whereas PAM provides sampling in amplitude. Consequently, the information is coded into the pulse time position within each switching interval. PWM only requires synthesis of a few discrete output levels, which is easily realized by topologically simple high efficiency switching power stages. On the other hand, the bandwidth requirements for PWM are typically close to an order of magnitude higher than PAM. This penalty is well paid given the simplifications in the switching power stage / power supply.

Pulse Position Modulation (PPM) differs from PWM in that the value of each instantaneous sample of a modulating wave is caused to vary the position in time of a pulse, relative to its non-modulated time of occurrence. Each pulse has identical shape independent of the modulation depth. This is an attractive feature, since a uniform pulse is simple to reproduce with a simple switching power stage. On the other hand, a limitation of PPM is the requirements for pulse amplitude level if reasonable powers are required. The power supply

level of the switching power stage will have to be much higher than the required load voltage. This leads to sub-optimal performance on several parameters as efficiency, complexity and audio performance.

Pulse Density Modulation is based on a unity pulse width, height and a constant time of occurrence for the pulses within the switching period. The modulated parameter is the presence of the pulse. For each sample interval it is determined if the pulse should be present or not, hence the designation density modulation. It is appealing to have a unity pulse since this is easier to realize by a switching power stage. Another advantage is the simplicity of modulator implementation. However, PDM requires excess bandwidth generally beyond what is required by e.g. PWM.

A qualitative comparison of the four fundamental methods is shown in Table below. Only PDM and PWM are considered relevant, i.e. potential candidates to reach the target objectives.

| Type | Bandwidth Requirements | Modulation depth | Efficiency | Complexity |
|------|------------------------|------------------|------------|------------|
| PAM  | +                      | +                | -          | -          |
| PPM  | -                      | -                | -          | -          |
| PWM  | -                      | +                | +          | +          |
| PDM  | -                      | +                | +          | +          |

**CIRCUIT:**

i)    Pulse Width Modulation (PWM)

a)    Op-amp based PWM system:

Fig. 1 has two parts, first being a saw tooth wave generator and the second part being a comparator. The saw tooth wave generator consists of a square wave generator i.e. a Schmitt Trigger and integrator. The saw tooth output has a frequency $f = R_3/4R_1R_2C$. The saw tooth output is given at the inverting terminal of the comparator to whose non-inverting terminal is given the modulating signal. The output of the comparator is a pulse width modulated signal.

**Design:**

For an output voltage of the triangular wave, $V_{out} = 7V_{pp}$ and $V_{sat} = 13V_{pp}$
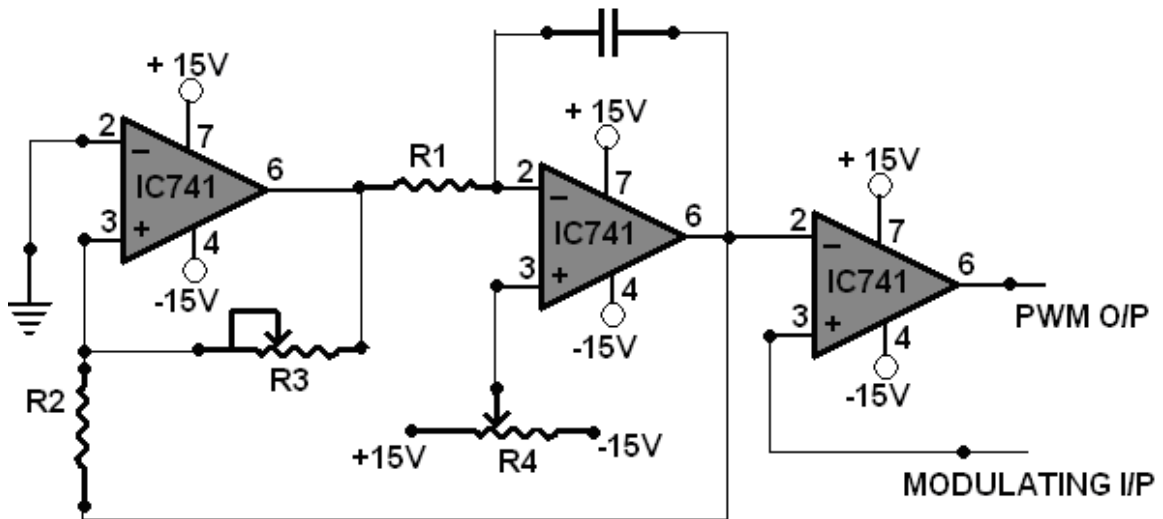
$$V_{out} = 2R_2\ V_{sat}/R_3$$

Figure 1

For $R_2 = 10K\Omega$; $R_3 = 47.14K\Omega$

For an output frequency of triangular wave = 2KHz

$f = R_1/(4R_2R_3C)$

for $C = 0.05\mu F$; $R_1 = 10K\Omega$
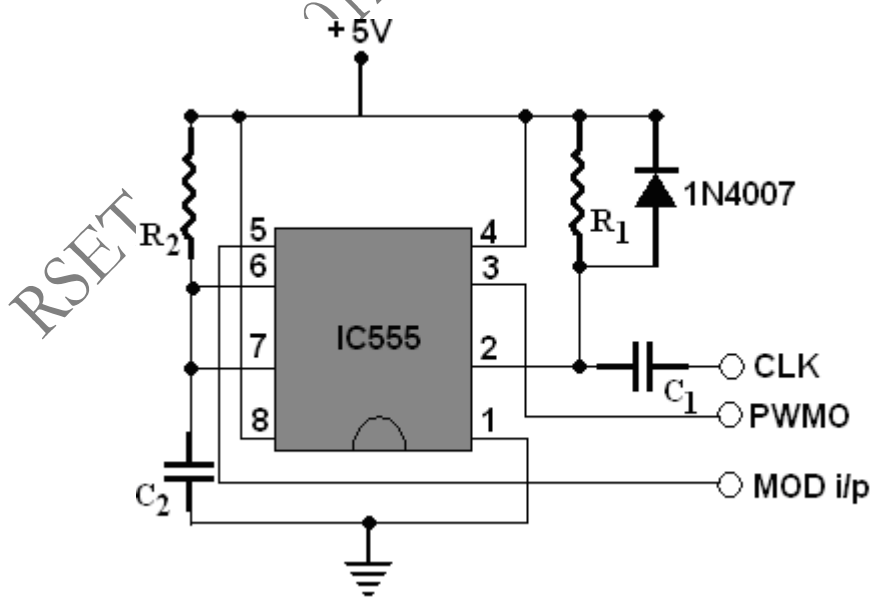
b)      555 timer based PWM system:



Figure 2

Fig. 2 shows the circuit with a 555 timer working in a monostable mode. The $R_1C_1$ network acts as a differentiator to provide the triggering pulse for the monostable multivibrator. The clock pulse is differentiated by $R_1C_1$ network, positive half is bypassed by the diode and negative spikes is introduced at pin 2 of the 555. When no modulating input is given output is a periodic train of pulses of width $1.1R_2C_2$ and frequency same as the clock input. When the modulating signal is applied, the charging time of the capacitor varies as it charges to $(2/3V_{CC} + V_{mod})$, where $V_{mod}$ is the modulating voltage magnitude, which can be either positive or negative; which results in variation of pulse width of output signal.

**Design:**

for a width of monostable pulse when no modulating signal is applied=0.2 mS

$T = 1.1R_2C_2$

For $C_2 = 0.01\mu F$; $R_2 = 18.2K\Omega$

For the differentiator circuit

$R_1C_1 \leq 0.0016/f_{clk}$

for $f_{clk} = 2KHz$ and $C_1 = 0.001\mu F$;

$R_1 = 820\Omega$
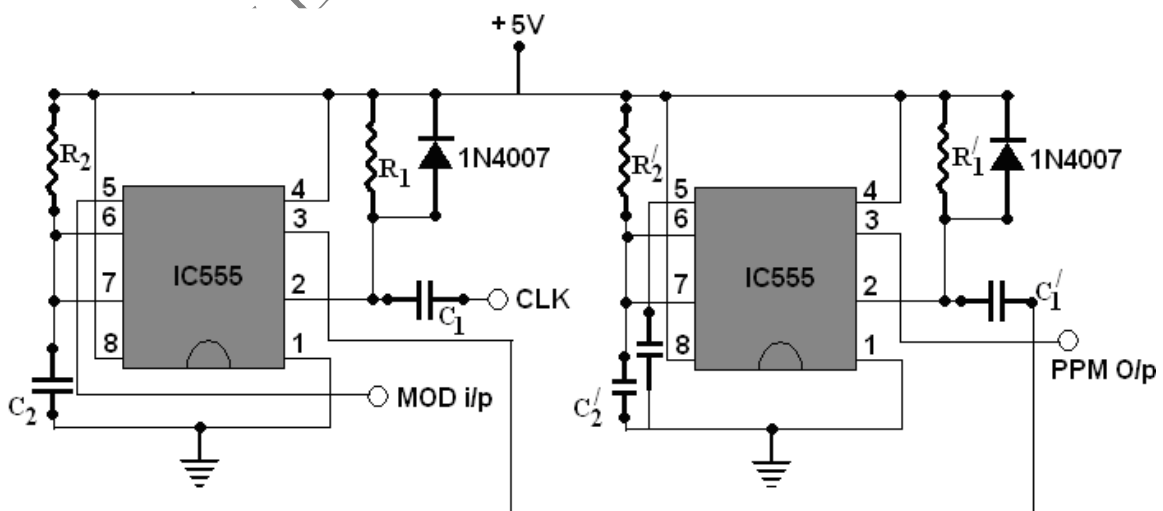
ii)     Pulse Position Modulation (PPM)

Figure 3

The circuit (Fig. 3) is designed in such a way that the PWM waveform generated by the first 555 is used as an input to the second 555 to obtain the PPM wave form, which is again working as a monostable multivibrator, but this time, with a fixed pulse width. Here too, the negative spikes are separated and given to pin 2 of 555 timer and the positive spikes are bypassed by the diode. The pulse width of second 555 timer is taken as a small value of $1.1R_2'C_2'$. As the negative spikes of the differentiated PWM signal is position modulated, capacitor $C_2'$ charges at a constant rate, but as the instance of charging changes in accordance with the instant of triggering, the output is pulse position modulated.

**Design:**

Second stage monostable multivibrator

Differentiator : $R_1'=R_1$ and $C_1'=C_1$

For a pulse width of 0.05mS

$T_1=1.1 R_2'C_2'$

For $C_2'=0.001\mu F$; $R_2'=45.4K\Omega$

**PROCEDURE**

- Set up the circuit as shown in the circuit diagram

- Apply the modulating signal and the clock pulse to the circuit

- Observe the modulated wave at the output and other waveforms at various nodes of the circuit on the CRO

- Observe the changes in the modulated wave by varying the amplitude, frequency of the modulating signal and the frequency of the sampling clock

- Plot the waveforms on a graph sheet

**OBSERVATIONS AND RESULTS:**

The circuits were setup and modulated wave was observed.

1.     Pulse Width Modulation (PWM)

a)     <u>Op-amp based PWM system:</u>

Modulating signal: frequency = _____and peak to peak amplitude = _____. A pulse train of amplitude _____ and frequency - _____was used.

b)      555 timer based PWM system:

Modulating signal: frequency = _____and peak to peak amplitude = _____. A pulse train of amplitude _____ and frequency _____was used.

2.      Pulse Position Modulation (PPM)

Modulating signal: frequency = _____and peak to peak amplitude = _____. A pulse train of amplitude _____ and frequency _____was used.

**Home Exercise :** Identify the demodulation circuits for PWM and PPM signals