Department of Communications Engineering

Communication Systems

Third Year Class

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Lecture 18

Pulse Modulation, Pulse Time Modulation (PTM) and Pulse Code Modulation (PCM)

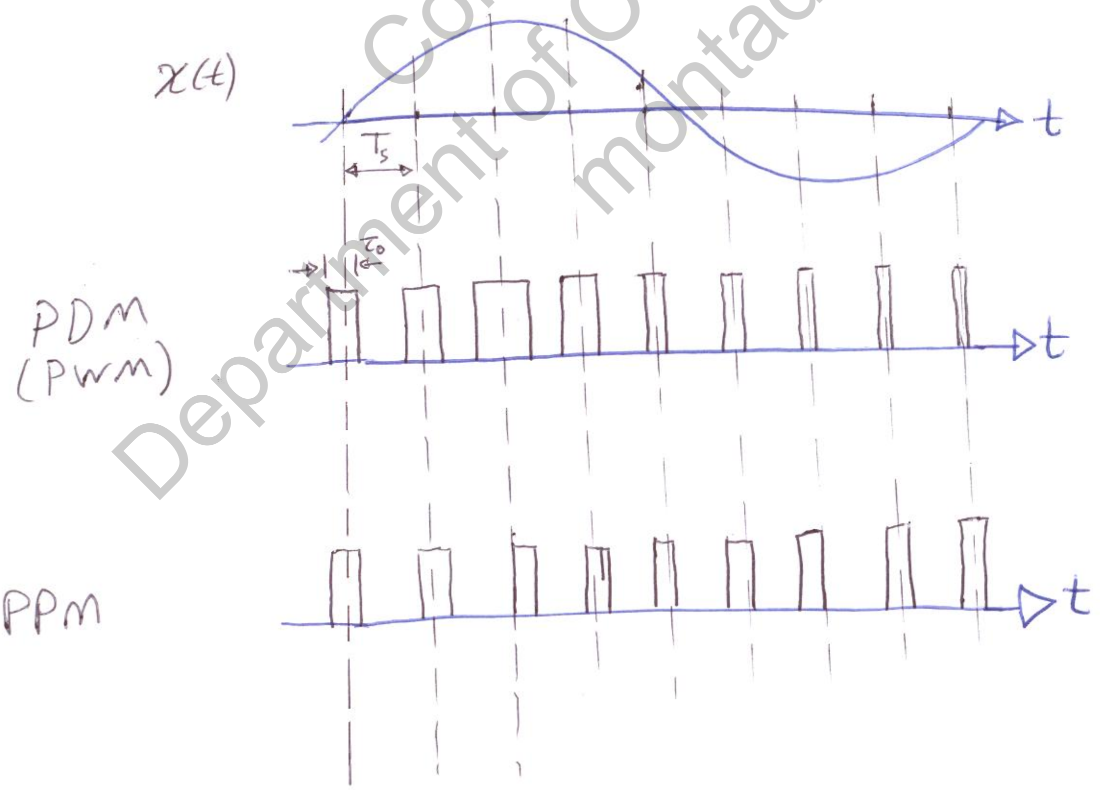
Pulse-Time Modulation

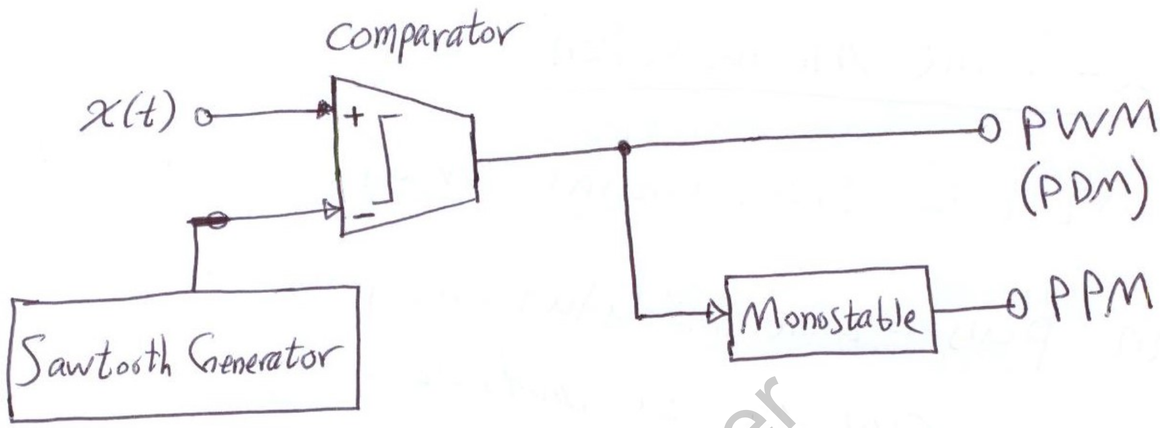
* Just like traditional modulation schemes; in pulse-time modulation, pulse width and pulse position can also be modulated.

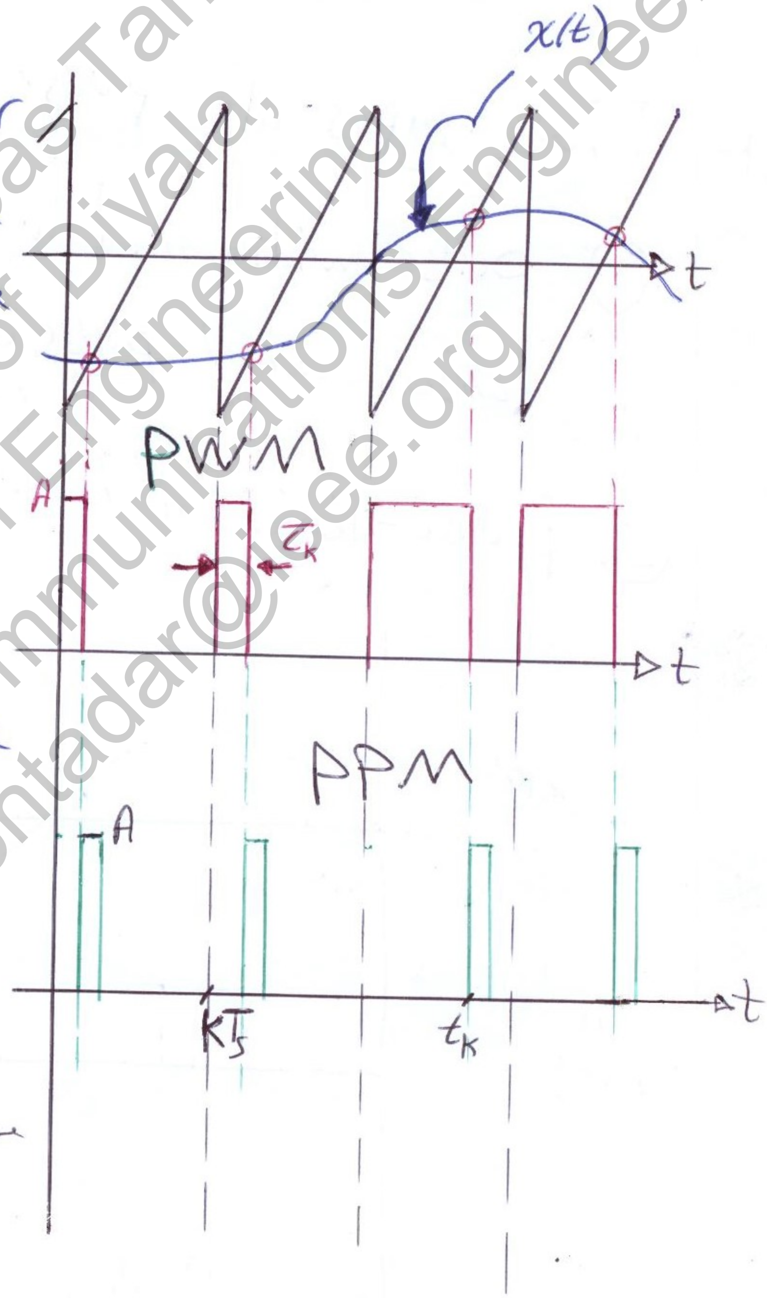
* Two types of pulse-time modulation:

① pulse width modulation (PWM)
also called pulse duration modulation (PDM)

② Pulse-Position modulation (PPM)







* The output of the comparator is zero except when the message waveform $x(t) >$ the sawtooth waveform.

Thus the output is constant positive A

* Assuming uniform sampling: The pulse duration in PWM is

$$\boxed{\tau_k = \tau_0 \left[1 + \mu\, x(kT_s)\right]}$$

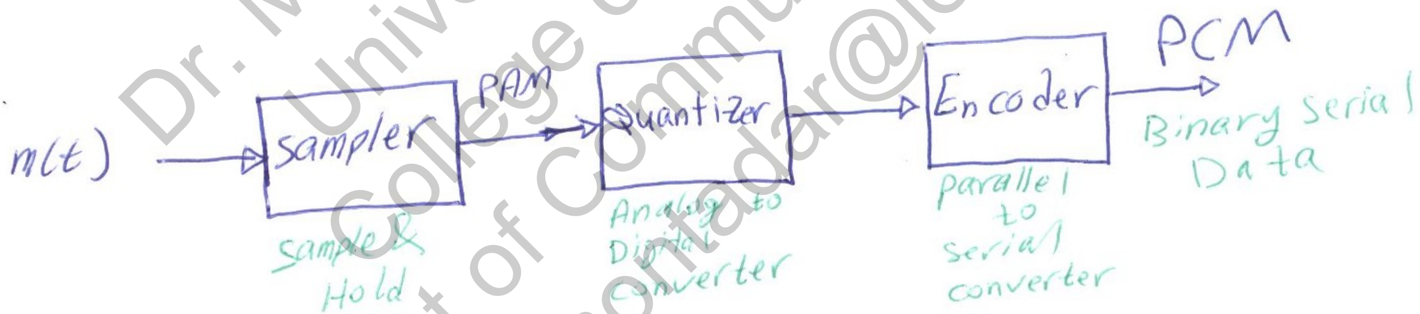
* In PPM, pulse width and amplitude are constants.

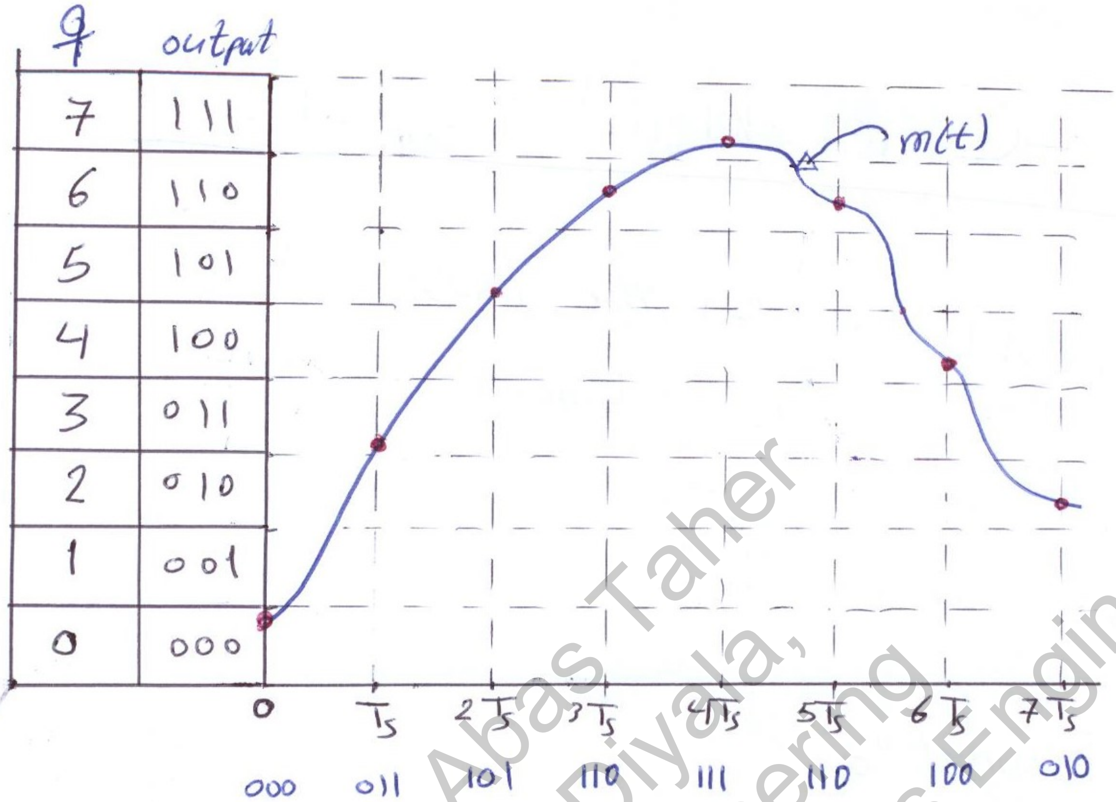
pulse-Code Modulation PCM

* The PCM samples the message $m(t)$, quantizes it, and encodes it to a binary sequence.

* PCM consists of:

1. Sampling
2. Quantizing
3. Encoding





q : is the number of quantization levels.

output : consists of ν binary bits, thus

$$\boxed{q = 2^{\nu}}$$

EX. For the Figure above, $\nu = 3$ Hence,

$q = 2^3 = 8$ levels.

* Each sample is converted to ν binary bits.

* Number of samples per second are f_s

Number of bits/s = Number of bits/sample × Number of samples/s

$= \nu \times f_s$

Definition: Number of bits per second is called Signaling Rate (r)

* $r = \nu f_s$ ——— (1)

where $f_s \geq 2 f_m$ ——— (2)

* Bandwidth needed for PCM is $\frac{r}{2}$, hence the PCM transmission bandwidth is

$$B_{PCM} \geq \frac{1}{2} r$$

since $r = \nu f_s$

$$\therefore B_{PCM} \geq \frac{1}{2} \nu f_s \qquad \text{since } f_s \geq 2 f_m$$

$$\therefore \boxed{B_{PCM} \geq \nu f_m}$$

* In the quantizer,

total amplitude range $= x_{max} - (-x_{max}) = 2x_{max}$

* Dividing the total range by q levels, we get the step size Δ

$$\boxed{\Delta = \frac{2x_{max}}{q}}$$

the range of quantization error is

$$-\frac{\Delta}{2} \leq \mathcal{E}_{max} \leq \frac{\Delta}{2} \quad \text{OR} \quad \boxed{\mathcal{E}_{max} = \left|\frac{\Delta}{2}\right|}$$

Now :- signal power - to - quantization noise ratio can be defined as

$$\boxed{\frac{S}{N} \triangleq \frac{\text{signal power (normalized)}}{\text{Noise power (normalized)}} = \frac{3P}{x_{max}^2}\, 2^{2v}}$$

$$\boxed{\frac{S}{N} = 3 \times 2^{2v}} \qquad \boxed{\left(\frac{S}{N}\right)_{dB} = 4.8 + 6v}$$

Q1 A PCM system uses a uniform quantizer followed by a ν bits encoder. Show that the rms signal to quantization noise ratio is approximately given as $(1.8 + 6\nu)$ dB.

Solution Let us assume that the modulating signal is a sinusoidal voltage, having a peak amplitude equal to A_m. Also, let this signal cover the complete excursion of representation levels.

Then the power of this signal is $P = \frac{V^2}{R}$

where $V = \frac{A_m^2}{2}$

Therefore, we have $P = \frac{A_m^2}{2} \frac{1}{R}$ let $R = 1$ (normalized power)

$$P = \frac{A_m^2}{2}$$

since $\frac{S}{N} = \frac{3P}{x_{max}^2} \times 2^{2\nu}$ $\left(P = \frac{A_m^2}{2} \; \& \; x_{max} = A_m\right)$

$$\therefore \frac{S}{N} = \frac{3 \times \frac{A_m^2}{2} \times 2^{2\nu}}{A_m^2} = \frac{3}{2} \times 2^{2\nu} = 1.5 \times 2^{2\nu}$$

$$\left(\frac{S}{N}\right)_{dB} = 10 \log_{10}\left(\frac{S}{N}\right) = 10 \log_{10}\left(1.5 \times 2^{2\nu}\right)$$

$$\boxed{\left(\frac{S}{N}\right)_{dB} = 1.8 + 6\nu}$$

Q2 A Television signal having a bandwidth of 10.2 MHz is transmitted using binary PCM system. Given that the number of quantization levels is 512. Determine:

① code word length ② Transmission bandwidth ③ Final bit rate
④ output signal to quantization noise ratio.

Solution $f_m = 4.2\ MHz$, $q = 512$

① $q = 2^{\nu} \rightarrow 512 = 2^{\nu} \rightarrow \log_{10}(512) = \nu \log_{10}(2) \rightarrow \nu = \frac{\log_{10} 512}{\log_{10} 2}$

$\therefore \nu = 9$ bits is the code word length.

② Transmission bandwidth $BW \geq \nu f_m = 9 \times 4.2 \times 10^6 = 37.8\ MHz$.

③ Signaling rate $r = \nu f_s$

$f_s \geq 2 f_m = 2 \times 4.2\ MHz = 8.4\ MHz$

$\therefore r = 9 \times 8.4 \times 10^6 = 75.6\ M$ bits/sec.

④ $\left(\frac{S}{N}\right)_{dB} = 4.8 + 6\nu = 4.8 + 6 \times 9$

$\therefore \left(\frac{S}{N}\right)_{dB} = 58.8\ dB$