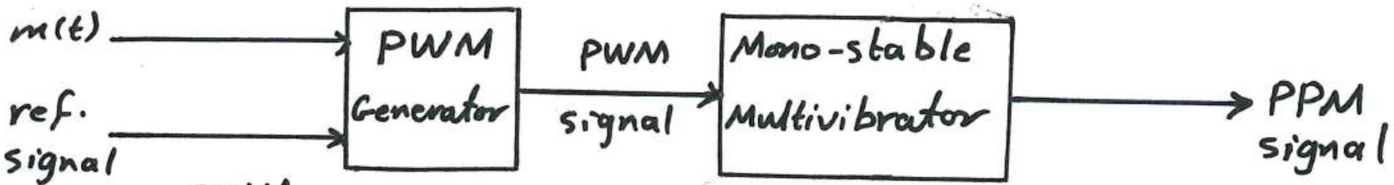
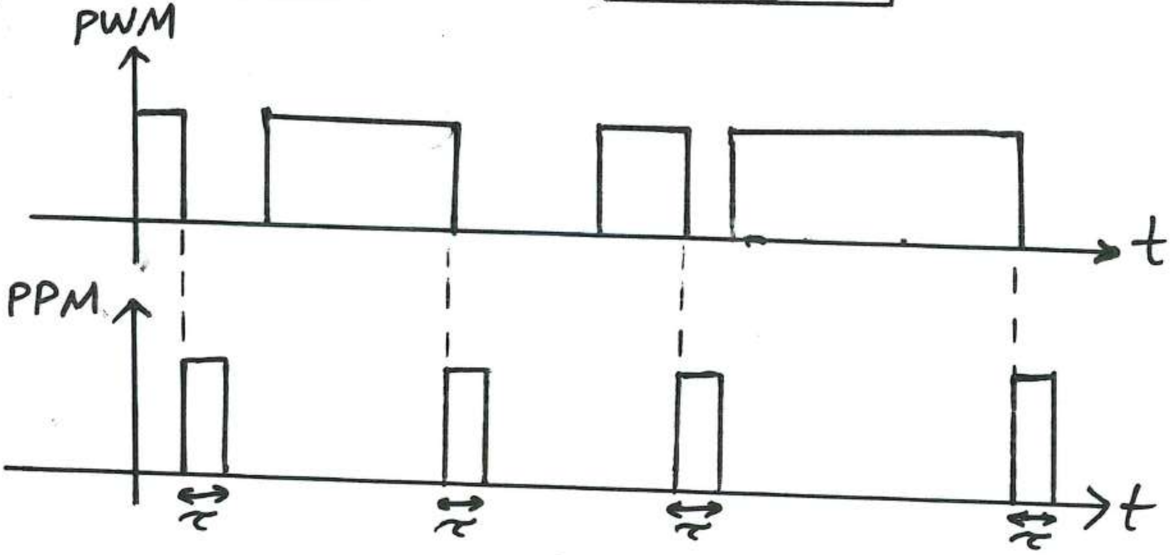
4.3 Pulse Position Modulation (PPM):

In (PPM), the amplitude and the width of the pulse are kept constant, whereas the position of each pulse is changed according to the amplitude of the message m(t).

[A] Generation of PPM:

In fact, PPM can be generated by adding a mono-stable multivibrator at the output of PWM generator.

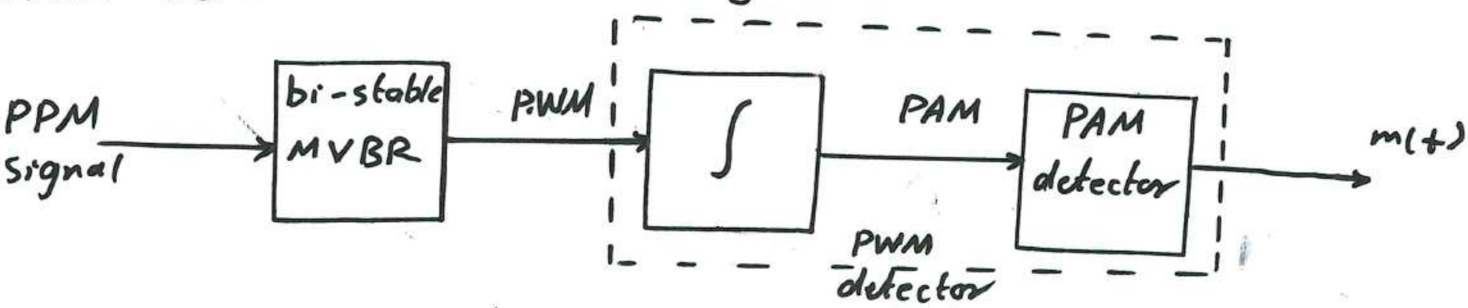




The transmission bandwidth of PPM is ($B_T \propto \frac{1}{\tau}$).

[B] Demodulation of PPM:

There is no direct method to demodulate PPM, so it is converted to PWM with the aid of bi-stable multivibrator, then detected as a PWM signal.



5. Time-Division Multiplexing (TDM):

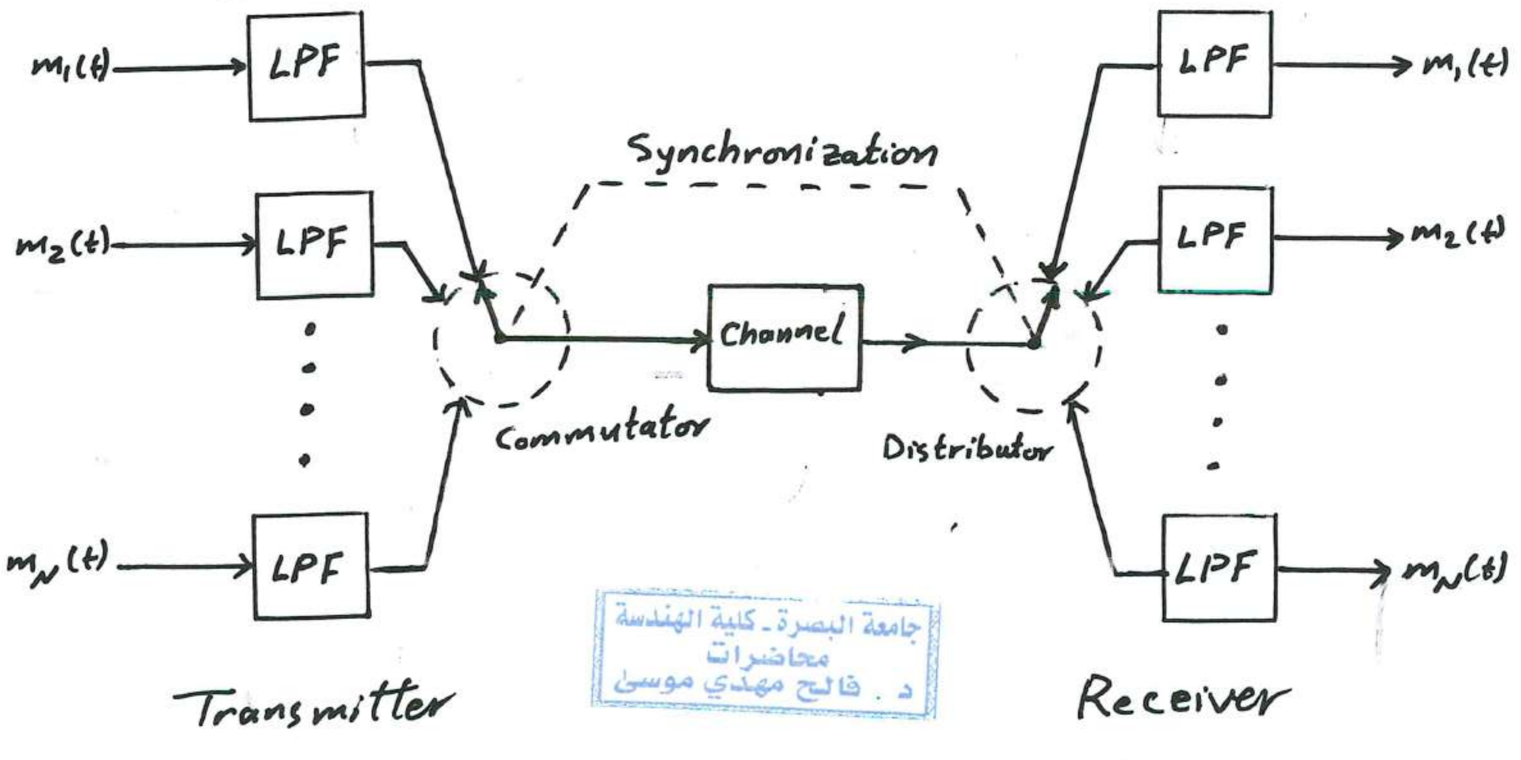
It is a technique used to transmit several different signals over a single channel by dividing the time domain into slots, one slot for each message. Unlike FDM systems which divides the frequency domain of the channel to provide simultaneous transmission for the messages, TDM and FDM are working togather in some systems to serve large number of subscribers, such as: The 2nd generation of the cellular communications (2G):

- Each cell has its own frequency (FDM).
- Every cell has number of time slots (TDM).

TDM is also used in data processing and telemetry.

[A] Transmitter:

The figure shown below shows a schematic diagram of the switching operation in TDM.



The LPF is used to limit the BW of the message by removing the non-essential frequency components to an adequate signal representation and anti-aliasing.

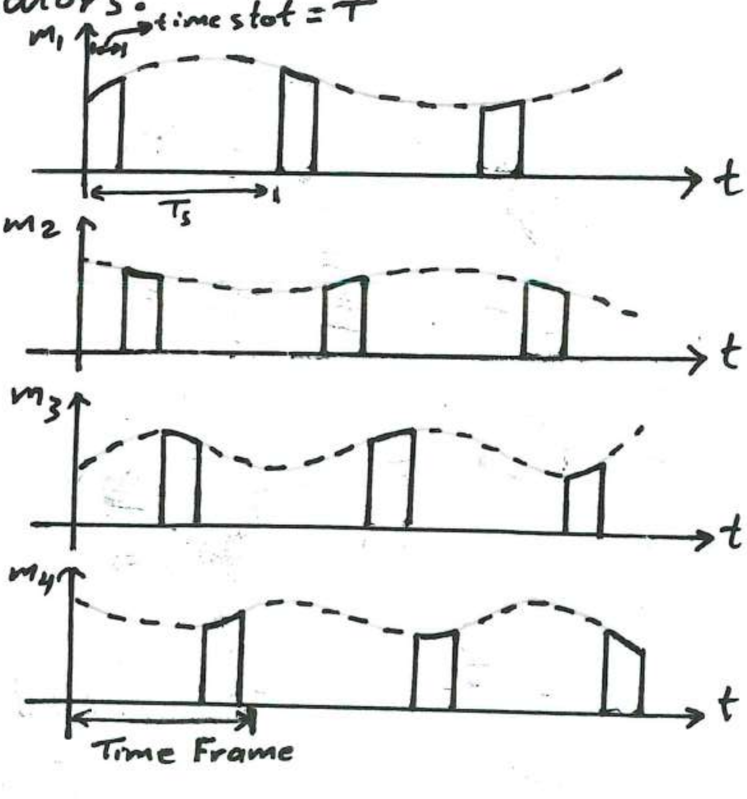
- An electronic switch is usually used as a commutator.
- Each message signal is sampled at the (Nyquist rate) or higher (usually 1.1 times the Nyquist rate) to avoid aliasing.
- The samples (of all input signals) are interleaved, and a single sample is transmitted over the channel at each time slot.

[B] Receiver:

As shown in the schematic diagram of the TDM system,

- The output of the second commutator is distributed to the appropriate LPF for demodulation.
- Proper synchronization is usually used between the two commutators.

Four messages transmitted via TDM channel



Notes:

- Time slot : The time required to transmit each sample.
- Time frame: The time required to transmit one cycle of samples for the all signals.
- If all the messages have equal bandwidths, then the samples are transmitted sequentially.
- If the messages have unequal bandwidths, then more samples (per time frame) should be transmitted from the wide-band message.

C BW Requirements for TDM:

If all the messages have the same bandwidth (f_m), they are equally sampled at (T_s), which is equal to the time fram in this case.

$$\therefore \quad T = \frac{T_s}{n}$$

T : time required for each sample (time slot).

n : number of input messages

$$T_s = \frac{1}{f_s} \Rightarrow f_s \geq 2f_m \quad \therefore \quad T_s \leq \frac{1}{2f_m}$$

$$\text{time slot} = \frac{\text{time frame}}{n}$$

* The entire TDM signal is a base band signal with signal bandwidth of (f_{TDM}):

$$f_{TDM} = n\, f_m$$

Therefore, the total sampling frequency of TDM is:

$$f_{s\,tot.} = 2f_{TDM} = 2nf_m$$ For equal BW messages.

* For non-equal BW messages:

$$f_{TDM} = f_{m1} + f_{m2} + \cdots + f_{mN}$$
$$f_{s\,tot.} = f_{s1} + f_{s2} + \cdots + f_{sN}$$

Comparison between TDM and FDM

S.N	TDM	FDM
1	Transmits several messages via one channel by dividing the time domain into time slots.	Transmits several messages via one channel by dividing the frequency domain spectrum
2	Requires commutator and distributer in addition to the modulator and demodulator.	Requires modulator and demodulator only.
3	Requires perfect synchronization between the Tx and Rx.	synchronization is not required.
4	Preferred for digital signal transmission.	Preferred for analog signal transmission.
5	Crosstalk is not sever.	Suffers from crosstalk due to imperfect BPF response

Example: An analog signal is expressed by:

$$m(t) = 5\cos(100\pi t) + 20\sin(400\pi t) - \cos(200\pi t)$$

Calculate the Nyquist rate for this signal.

Sol.

There are three frequencies in this signal:

$$f_1 = \frac{100\pi}{2\pi} = 50\,Hz, \quad f_2 = \frac{400\pi}{2\pi} = 200\,Hz$$

$$f_3 = \frac{200\pi}{2\pi} = 100\,Hz.$$

Sampling theorem is applied on the max. available freq.:

$$f_s \geq 2 f_m$$

$$f_N = 2 f_m \Rightarrow f_N = 2 \times f_2$$

$$\therefore \boxed{f_N = 400\,Hz}$$

<u>Example:</u> For the following message signal:

$$m(t) = 5 \cos(1000\pi t) \cos(4000\pi t)$$

a) Find the Nyquist rate and the Nyquis period.

b) Find the bandpass sampling rate.

<u>Sol.</u>

a) $m(t) = \frac{5}{2}\left[\cos(3000\pi t) + \cos(5000\pi t)\right]$

$$f_1 = \frac{3000\pi}{2\pi} = 1500\,Hz$$

$$f_2 = \frac{5000\pi}{2\pi} = 2500\,Hz$$

$$f_s \geq 2 f_m \Rightarrow f_N = 2 f_m$$

$$f_N = 2 \times 2500 \Rightarrow \boxed{f_N = 5000\,Hz}$$

$$T_N = \frac{1}{f_N} = \frac{1}{5000} \Rightarrow \boxed{T_N = 0.2\,msec.}$$

b) $m(t) = \frac{5}{2}\left[\cos(2\pi(1500)t) + \cos(2\pi(2500)t)\right]$

$$f_u = f_m = 2500\,Hz$$

$$f_B = 2500 - 1500 = 1000\,Hz$$

$$f_u / f_B = \frac{2500}{1000} = 2.5$$

$$\therefore K = \boxed{2}$$

$$\therefore f_s = 2 f_u / K = \frac{2 \times 2500}{2}$$

$$\therefore \boxed{f_s = 2500\,Hz}$$

Example: Four signals with frequencies given below in the table. TDM is used to transmit these four signals:

a) Suggest a scheme to acomplish the TDM requirements with each signal sampled at its Nyquist rate (f_N).

b) Calculate the commutator speed in (sample/sec.).

c) Calculate the transmission BW of the TDM system.

Message	Frequency BW
$m_1(t)$	3.6 KHz
$m_2(t)$	1.2 KHz
$m_3(t)$	1.2 kHz
$m_4(t)$	1.2 kHz

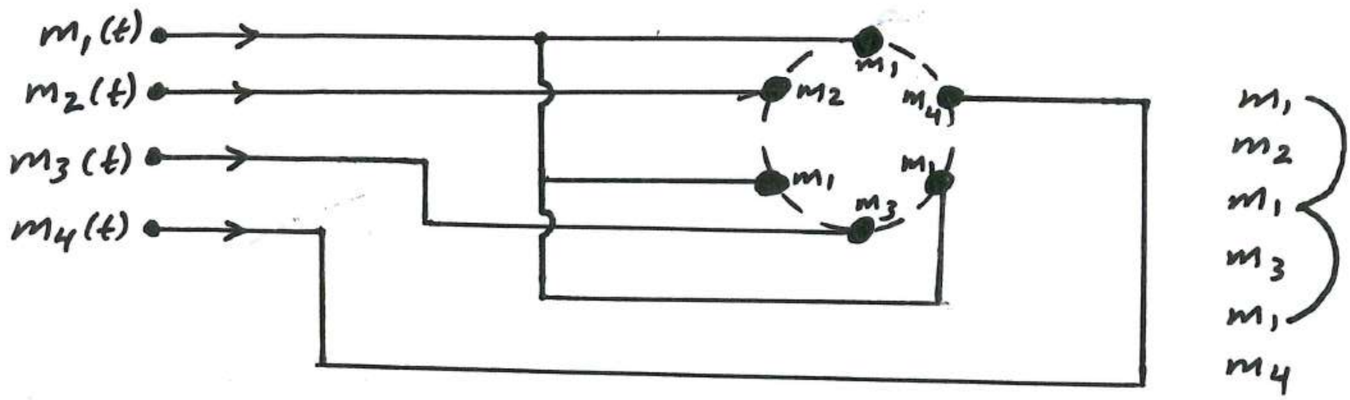
Sol.

a) The signals have unequal bandwidths

Message	BW	Nyquist Rate
$m_1(t)$	3.6KHz	$f_{s1} = 3.6\times2 = 7.2$ KHz
$m_2(t)$	1.2kHz	$f_{s2} = 1.2\times2 = 2.4$ kHz
$m_3(t)$	1.2kHz	$f_{s3} = 1.2\times2 = 2.4$ kHz
$m_4(t)$	1.2kHz	$f_{s3} = 1.2\times2 = 2.4$ KHz

It is clear that $m_1(t)$ has BW three times larger than the other signals, so every time frame should include:
- one sample from each signal (m_2, m_3, m_4)
- three samples from m_1.

The commutor should have at least six poles connected to these signals as shown in the next diagram.



b) The commutator speed in (sample/ sec.) represents the total sampling frequency of the TDM system.

$$f_{s\,tot} = f_{s1} + f_{s2} + f_{s3} + f_{s3}$$

$$f_{s.tot} = 7.2 + 2.4 + 2.4 + 2.4$$

$$\therefore \quad \boxed{f_{s\,tot} = 14.4\,kHz}$$

c) B_T of TDM is f_{TDM}:

$$f_{TDM} = f_{m1} + f_{m2} + f_{m3} + f_{m4} = \frac{f_{s\,tot.}}{2}$$

$$\boxed{f_{TDM} = 7.2\,kHz}$$