Multiplexing

- FDM
- TDM

Introduction

- Definition

1. The transmission of information from one or more source to one or more destination over the same medium.

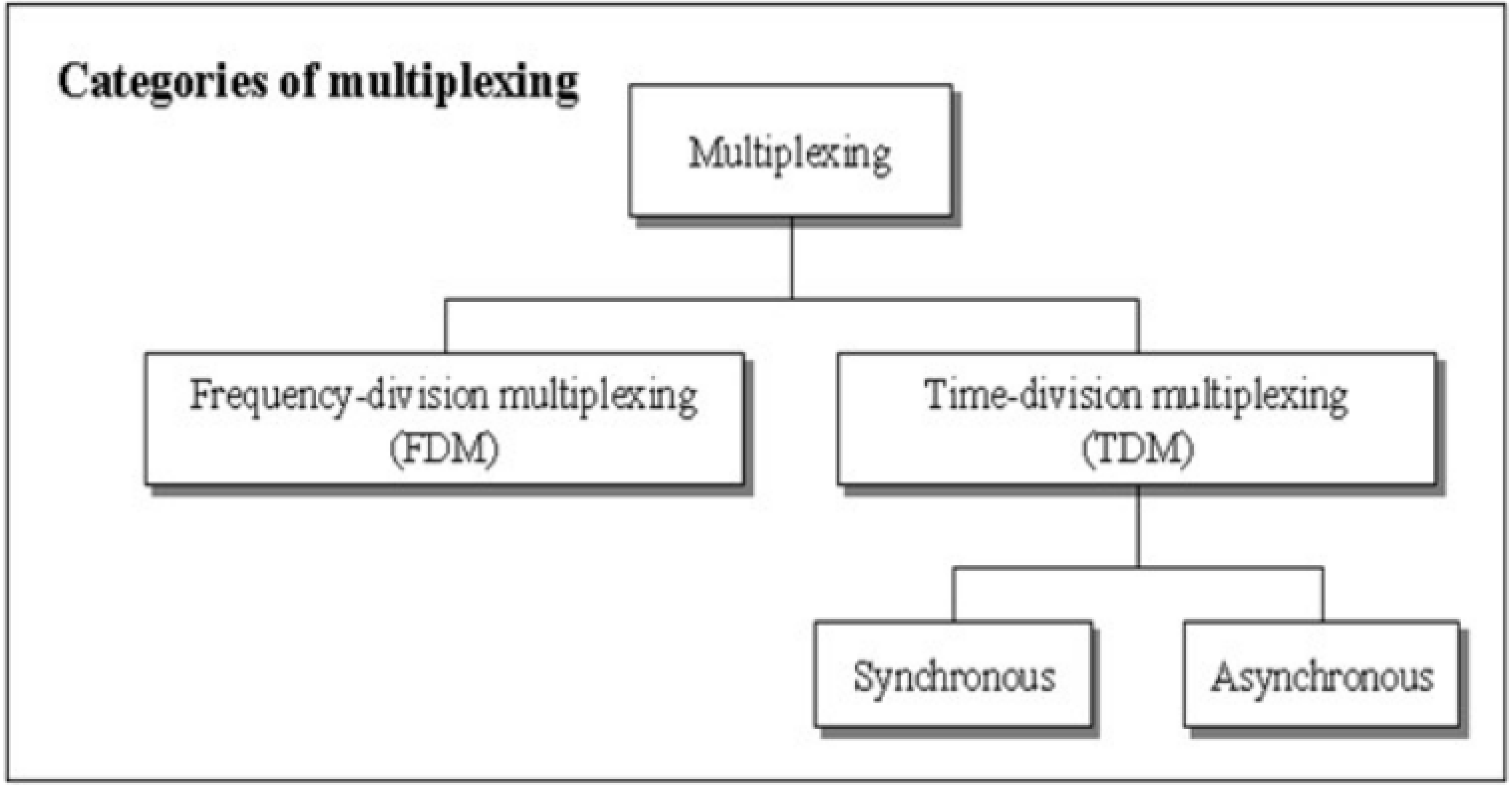
Or

2. The process which two or more signals are combined for transmission over a single communications path.

Or

3. A process where multiple analog message signals or digital data streams are combined into one signal with the aim is to share an expensive resource.
http://en.wikipedia.org/wiki/Multiplexing

Categories of multiplexing



Cont'd...

- Make the communications very economical by transmitting thousands of independent signals over a single transmission line.
- Three predominant ways to multiplex
    1. Frequency Division Multiplexing (FDM)
    2. Time Division Multiplexing (TDM)
    3. Wavelength Division Multiplexing (WDM)

Cont'd...

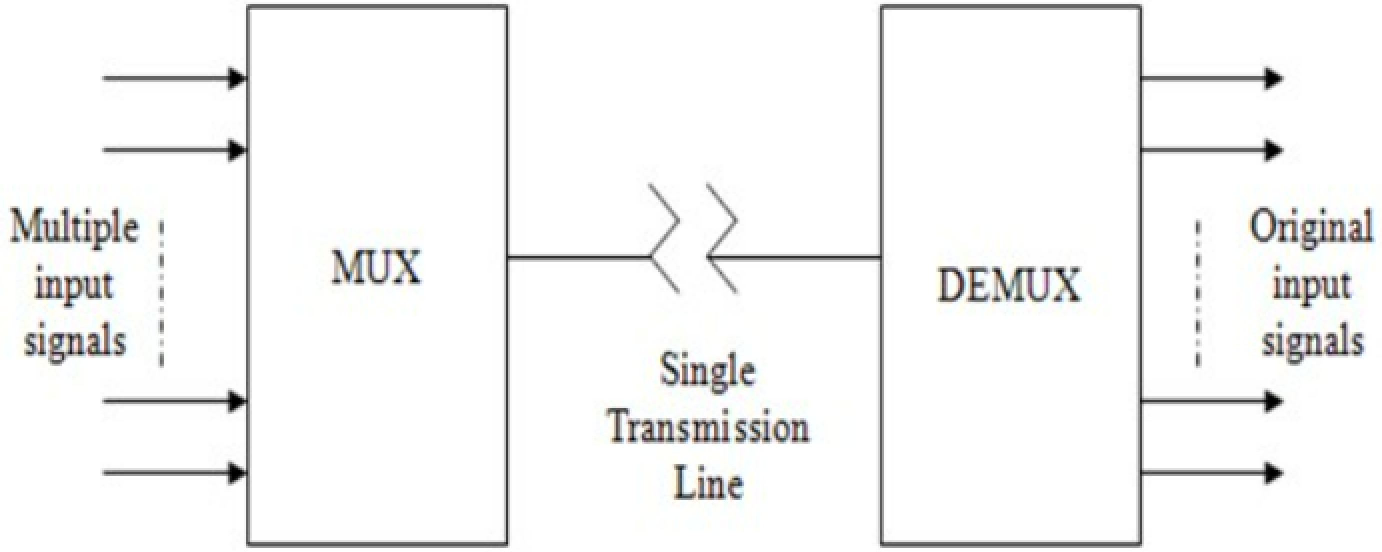
- Multiplexing allows several analog signals to be processed by one analog-to-digital converter (ADC)
  - E.g. Several phone calls may be transferred using one wire.
- The multiplexed signal is transmitted over a communication channel which may be a physical transmission medium.

Cont'd...

- The multiplexing divides the capacity of the low-level communication channel into several higher-level logical channels, one for each message signal or data stream to be transferred.
- A reverse process, known as demultiplexing, can extract the original channels on the receiver side.

Cont'd...

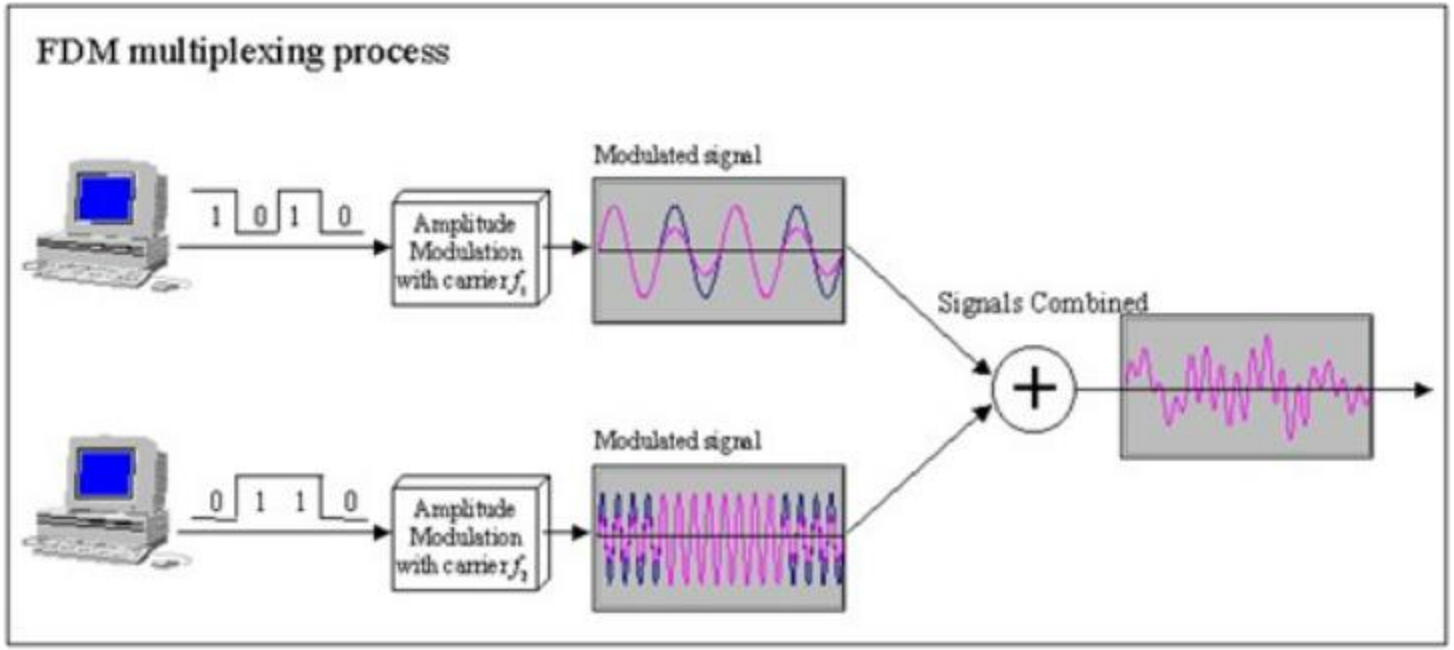
- Concept of multiplexing



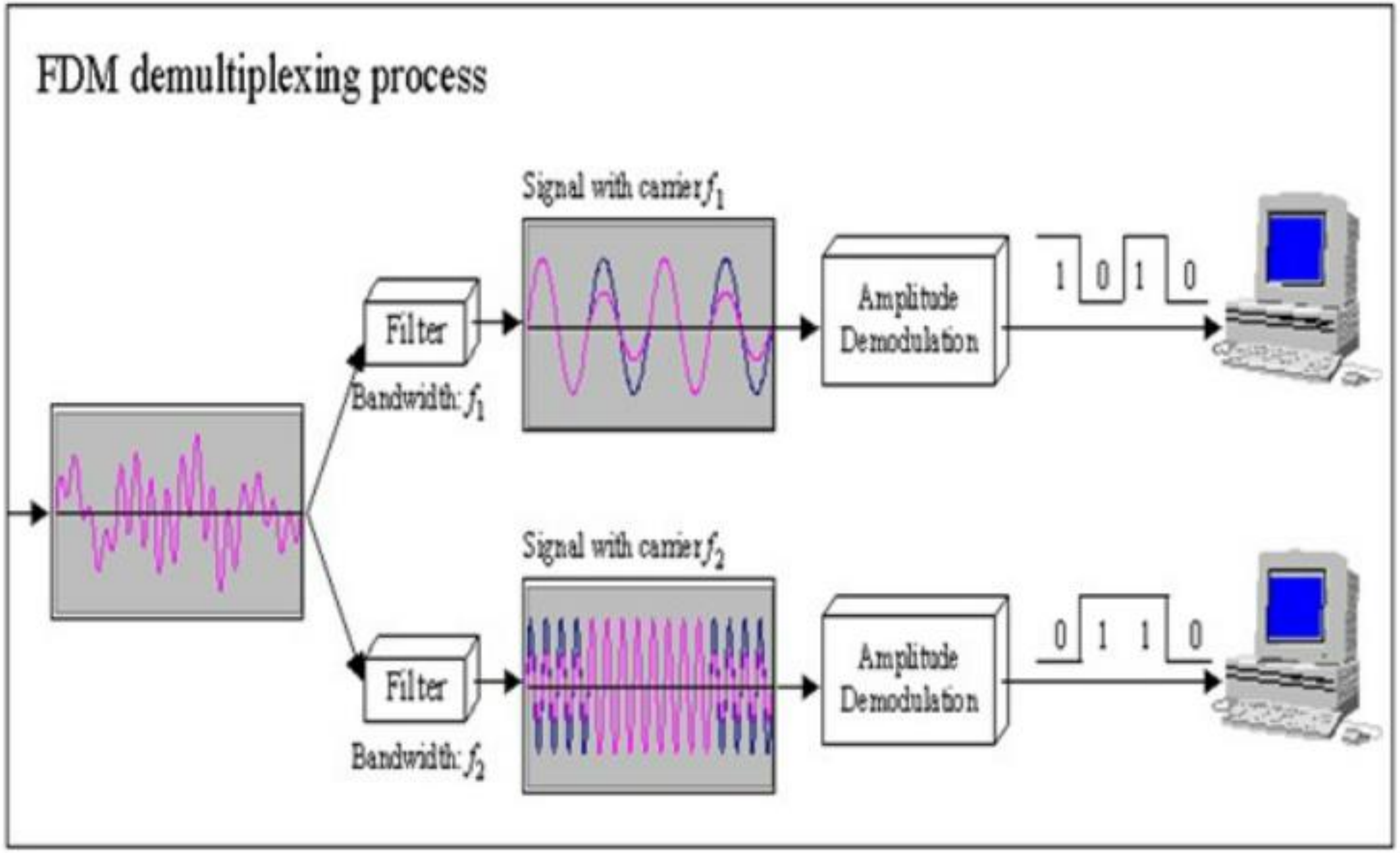
Frequency Division Multiplexing (FDM)

- Predominantly used in analog communications.
- Widely used in FM stereo broadcast.
- Compatibility with mono-receivers.
- Requires only a slight increase in BW.
- Great advantage in increasing system capacity.

FDM Multiplexing

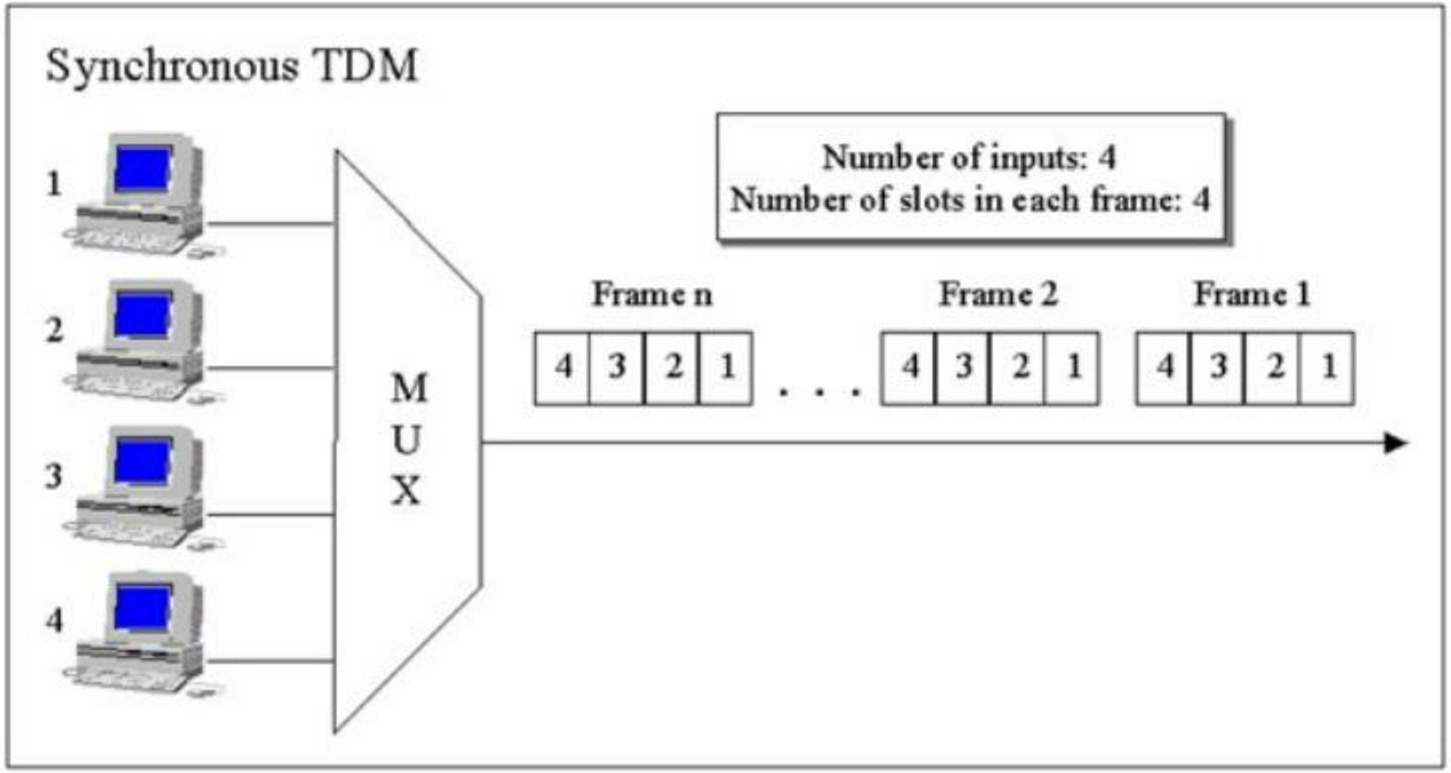


FDM Demultiplexing

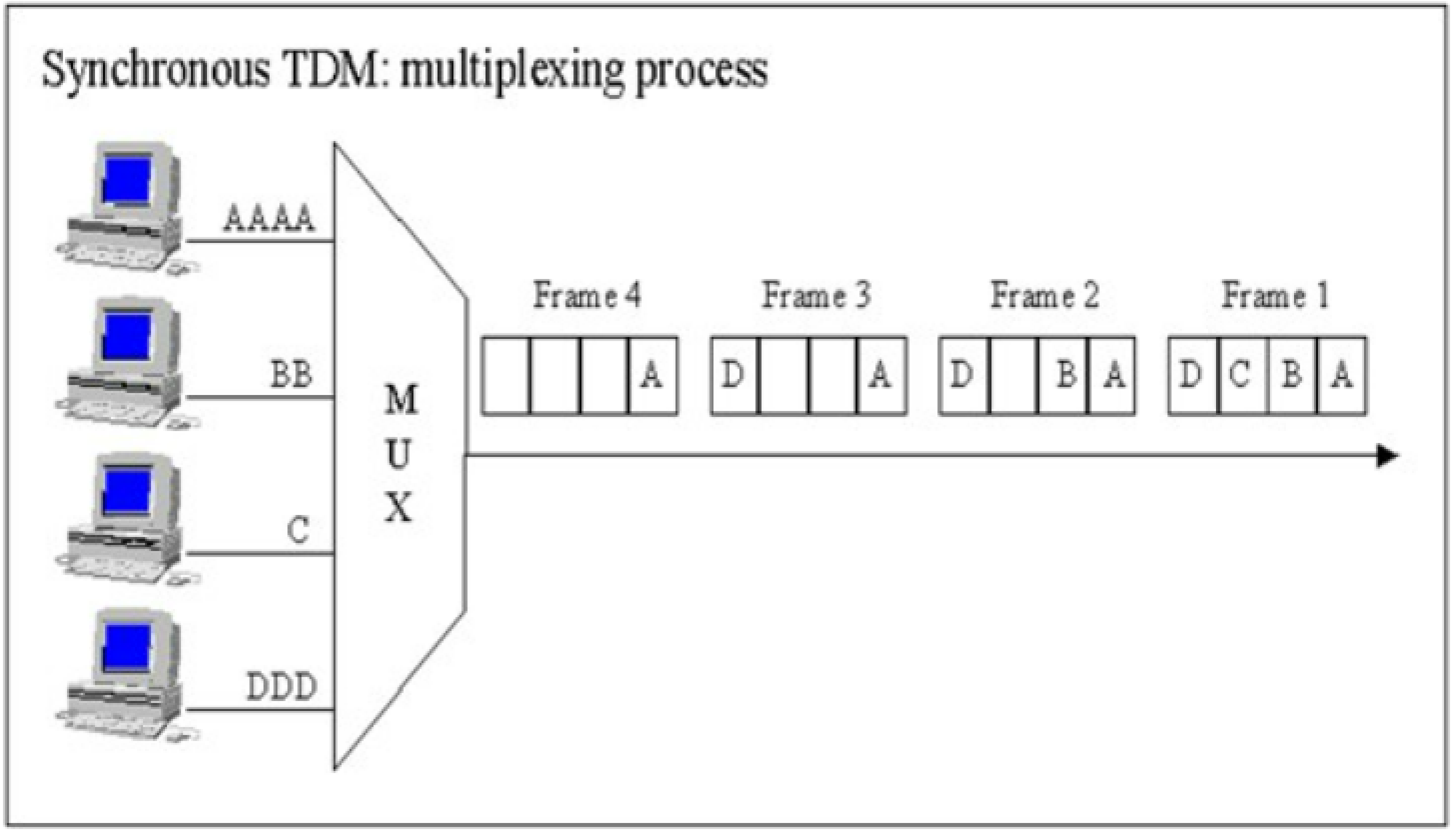


Time-Division Multiplexing

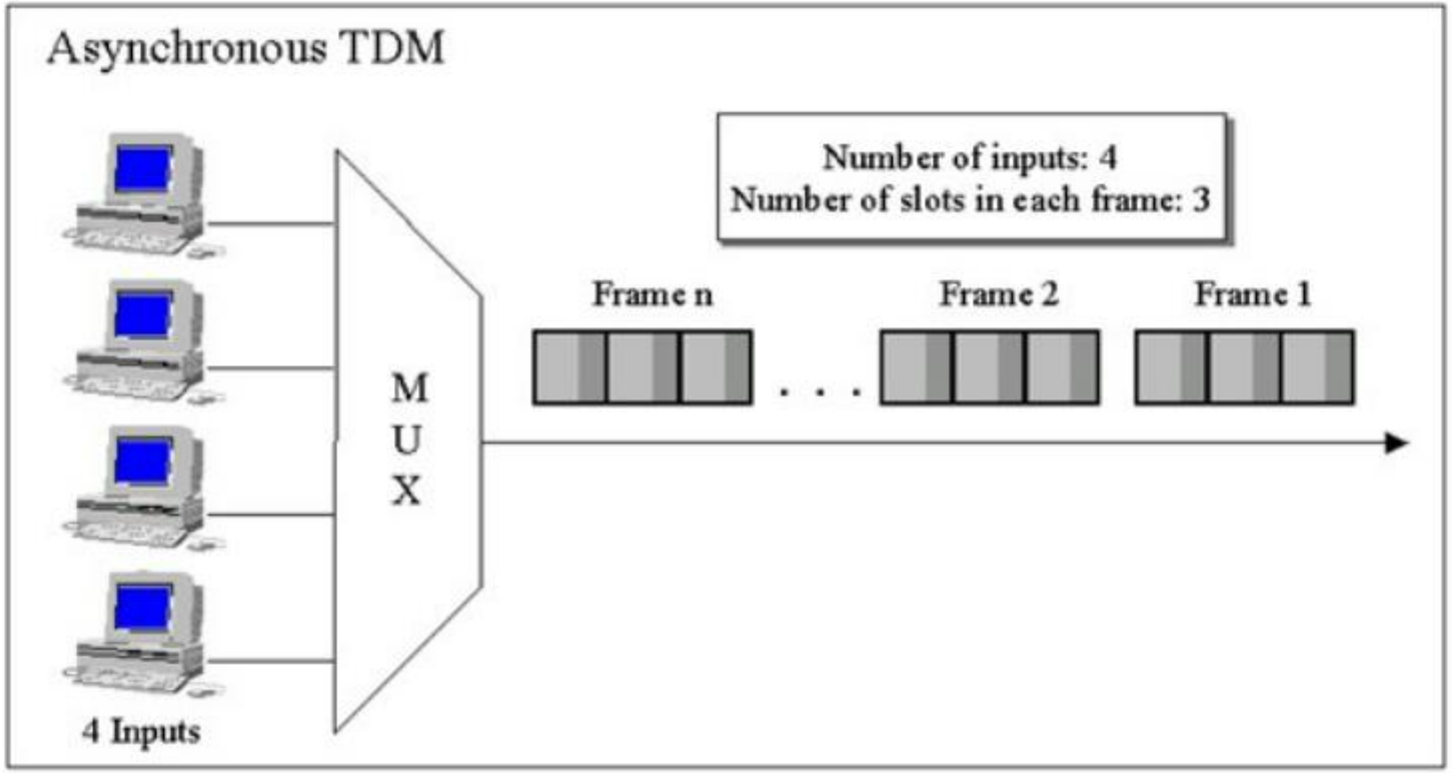
- This technique combines time-domain samples from different message signals (sampled at the same rate) and transmits them together across the same channel.
- The multiplexing is performed using a commutator (switch). At the receiver a decommutator (switch) is used in synchronism with the commutator to demultiplex the data.


Synchronous TDM
Number of inputs: 4
Number of slots in each frame: 4
1
2
3
4
M
U
X
Frame n
Frame 2
Frame 1
4 3 2 1
. . .
4 3 2 1
4 3 2 1

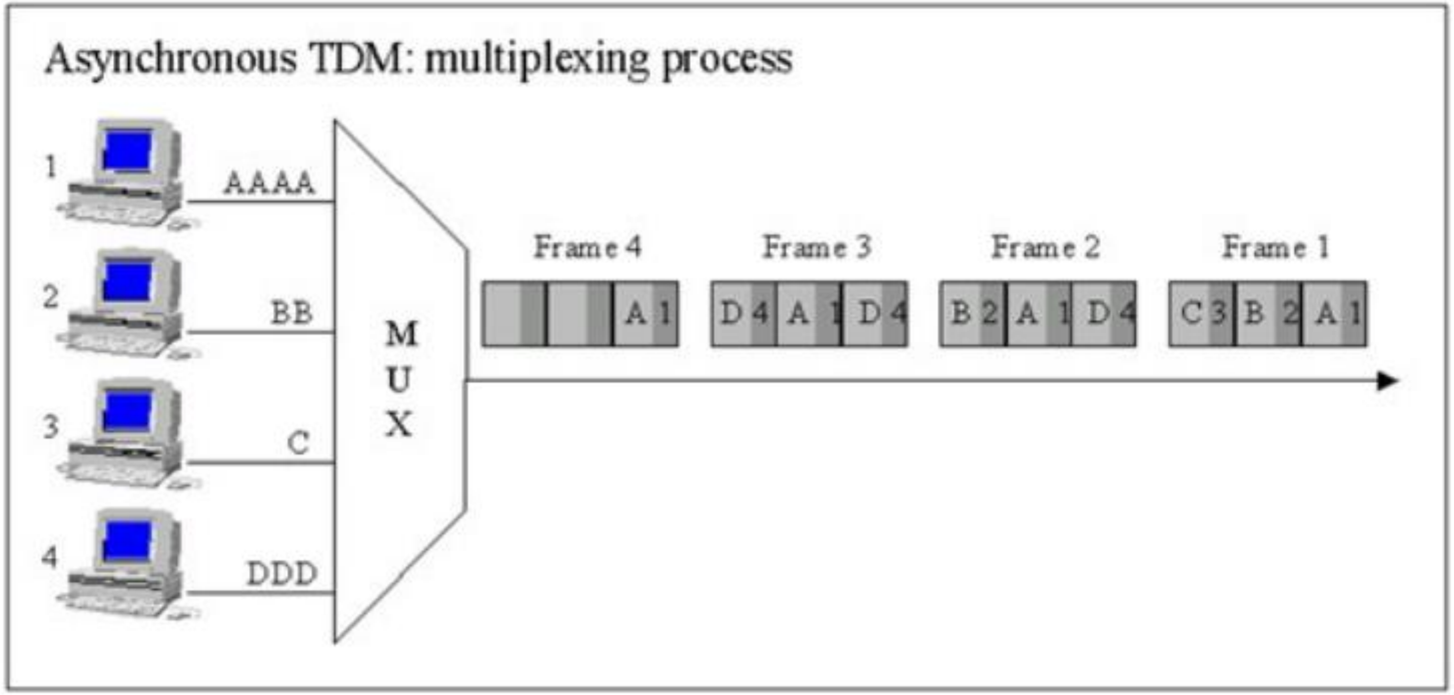
- **Frames :** In synchronous TDM, a frame consists of one complete cycle of time slots. Thus the number of slots in frame is equal to the number of inputs.
- Two figures below are an example of how the synchronous TDM works.


Synchronous TDM: multiplexing process
AAAA
BB
C
DDD
M
U
X
Frame 4
Frame 3
Frame 2
Frame 1
A
D
A
D
B
A
D
C
B
A

- **Asynchronous TDM (or statistical time-division multiplexing)**
- In asynchronous TDM, each slot in a frame is not dedicated to the fix device. Each slot contains an index of the device to be sent to and a message. Thus, the number of slots in a frame is not necessary to be equal to the number of input devices. More than one slots in a frame can be allocated for an input device. Asynchronous TDM allows maximization the link. It allows a number of lower speed input lines to be multiplexed to a single higher speed line.


Asynchronous TDM
Number of inputs: 4
Number of slots in each frame: 3
Frame n
Frame 2
Frame 1
M
U
X
. . .
4 Inputs

- **Frames :** In asynchronous TDM, a frame contains a fix number of time slots. Each slot has an index of which device to receive.
- The two figures below is an example of how asynchronous TDM works.


Asynchronous TDM: multiplexing process
1
AAAA
2
BB
3
C
4
DDD
M
U
X
Frame 4
Frame 3
Frame 2
Frame 1
A 1
D 4
A 1
D 4
B 2
A 1
D 4
C 3
B 2
A 1

Time Division Multiplexing (TDM)

- Offers greater system improvement.
- Capable of combining various protocols & different types of signals onto a single high speed transmission link.
  - E.g. voice and data
- More efficient than FDM

Comparison between TDM and FDM

TDM	FDM
1. The individual channels are assigned to different time slots but jumbled together in the frequency domain.	1. The individual channels are assigned to different frequency slots but jumbled together in the time domain.
2. Offers simpler instrumentation	2. Requires an analog subcarrier modulator,bandpass filter and demodulator for every message .
3. No crosstalk or inteference between adjacent channels.	

Comparison between TDM and FDM

TDM

4. Greater transmission BW required .
5. Transmission medium is subjected to fading.

FDM

3. The inteference in FDM is normally due to imperfect bandpass filtering and non-linear cross modulation .
4. The bandwidth is used effectively.

Amplitude Shift Keying (ASK)

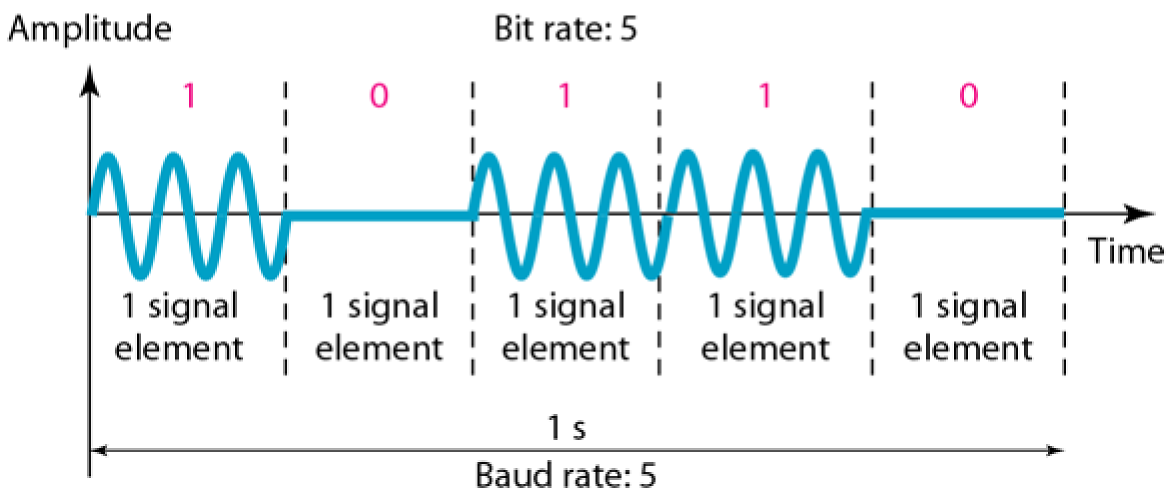
- ASK is implemented by changing the amplitude of a carrier signal to reflect amplitude levels in the digital signal.
- For example: a digital “1” could not affect the signal, whereas a digital “0” would, by making it zero.
- The line encoding will determine the values of the analog waveform to reflect the digital data being carried.

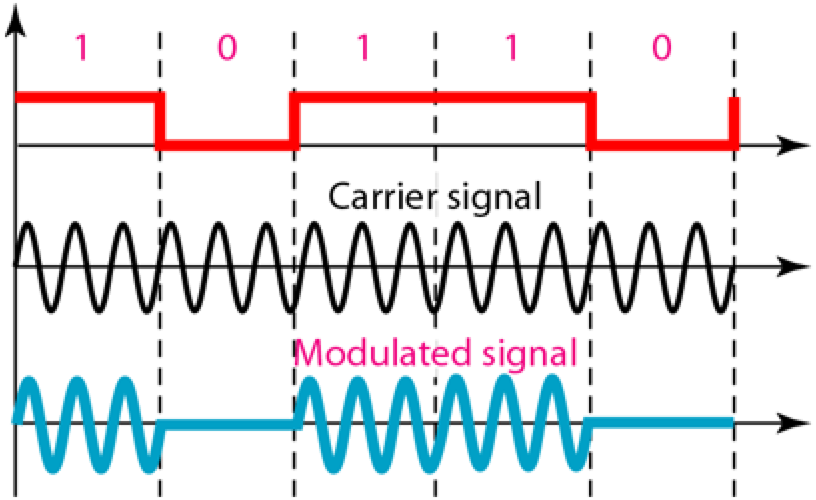
Bandwidth of ASK

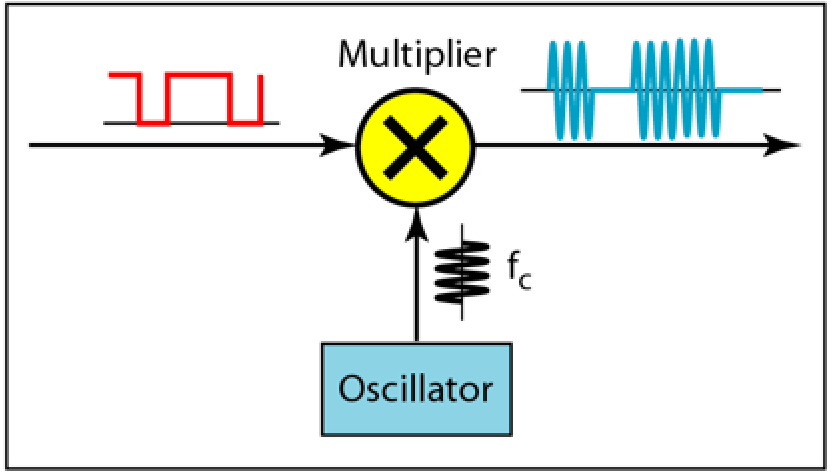
- The bandwidth B of ASK is proportional to the signal rate S.

$$B = (1+d)S$$

- “d” is due to modulation and filtering, lies between 0 and 1.

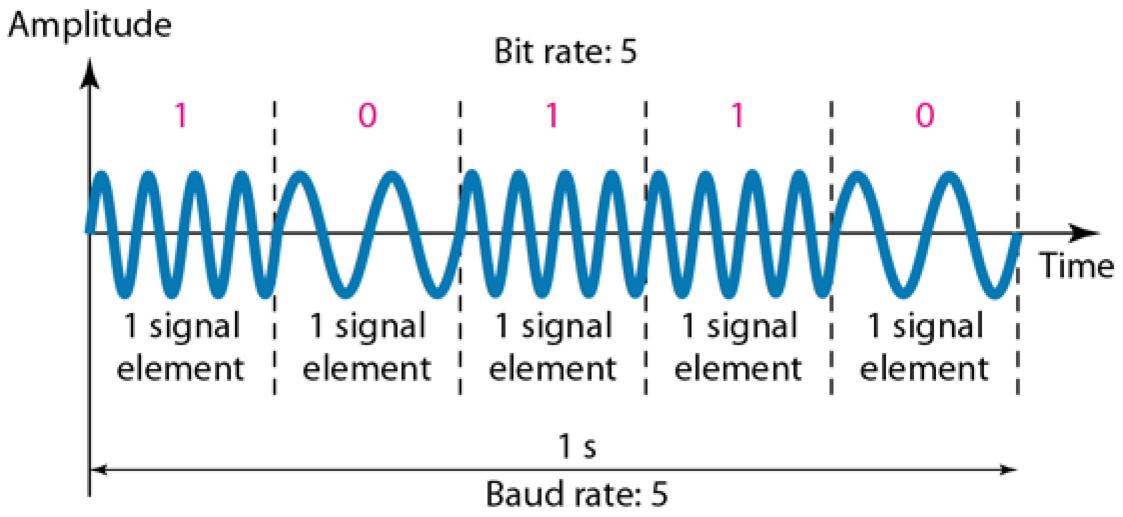

Amplitude
Bit rate: 5
1
0
1
1
0
Time
1 signal element
1 signal element
1 signal element
1 signal element
1 signal element
1 s
Baud rate: 5


1
0
1
1
0
Carrier signal
Modulated signal


Multiplier
f_c
Oscillator

Frequency Shift Keying

- The digital data stream changes the frequency of the carrier signal, f_c.
- For example, a "1" could be represented by $f_1=f_c+\Delta f$, and a "0" could be represented by $f_2=f_c-\Delta f$.


Amplitude
Bit rate: 5
1
0
1
1
0
Time
1 signal element
1 signal element
1 signal element
1 signal element
1 signal element
1 s
Baud rate: 5

Bandwidth of FSK

- If the difference between the two frequencies (f_1 and f_2) is $2\Delta f$, then the required BW B will be:

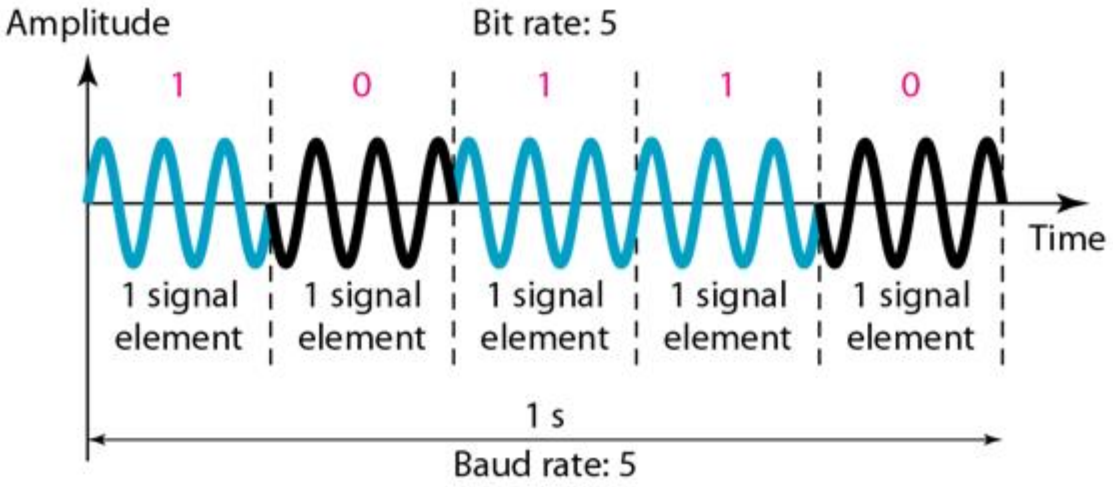
$$B = (1+d)xS + 2\Delta f$$

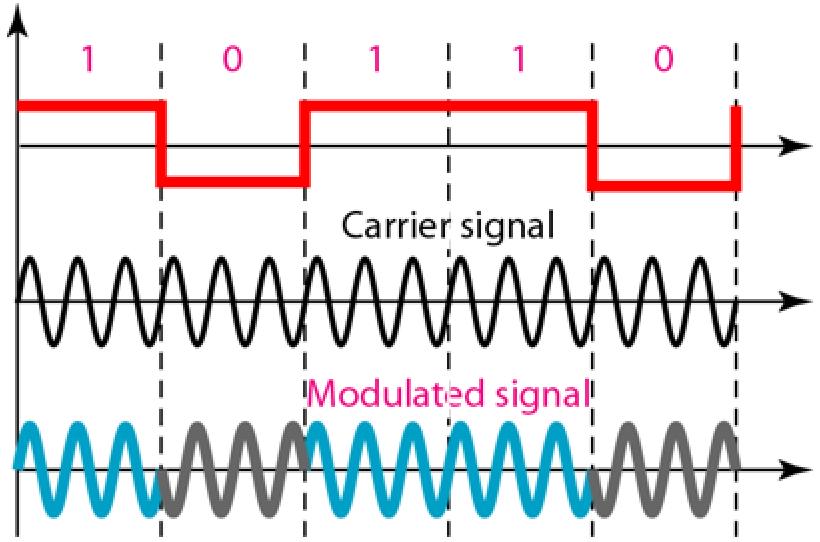
Phase Shift Keyeing

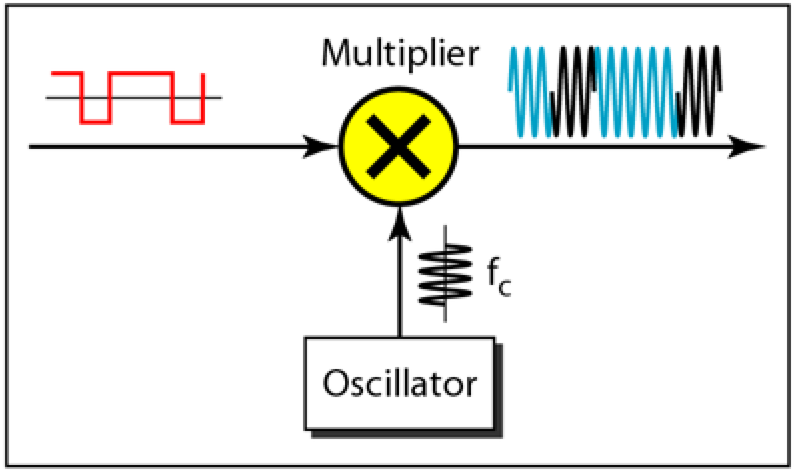
- We vary the phase shift of the carrier signal to represent digital data.
- The bandwidth requirement, B is:

$$B = (1+d)xS$$

- PSK is much more robust than ASK as it is not that vulnerable to noise, which changes amplitude of the signal.


Amplitude
Bit rate: 5
1
0
1
1
0
Time
1 signal element
1 signal element
1 signal element
1 signal element
1 signal element
1 s
Baud rate: 5


1
0
1
1
0
Carrier signal
Modulated signal


Multiplier
f_c
Oscillator