Part II Multiplexing

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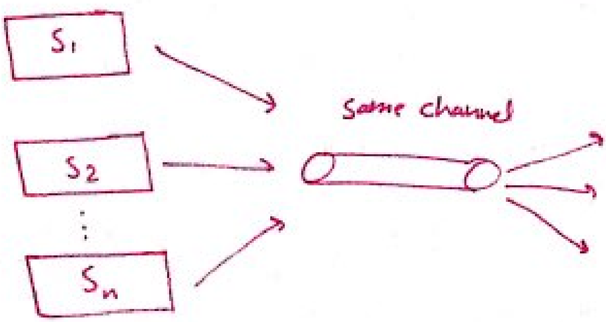
Introduction

Multiplexing

- Multiplexing:is the transmission of information (in any form) from more than one source to more that one destination over the same transmission medium (facility)
- The transmission medium may be:
  - Metallic wire pair
  - Coaxial cable
  - PCS mobile telephone
  - Microwave radio system
  - Satellite microwave system, ..
- The three most predominant methods of multiplexing signals are:
  - TDM: Time-division multiplexing → system has to be digital
  - FDM: Frequency-division multiplexing → it can be for analog and digital, but it's used for Analog
  - WDM: Wave-division multiplexing



Resources :-
1) Time
2) Frequency
3) Power

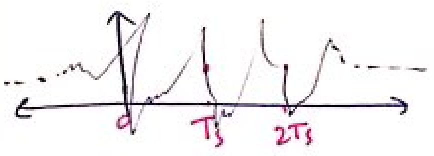
Time-Division Multiplexing (TDM)

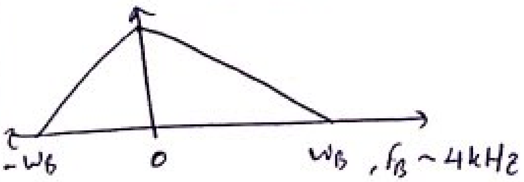
TDM definition

- With TDM, transmissions from multiple sources occur on the same facility but not at the same time.
- Transmissions from various sources are interleaved in the time domain.
- The most common type of modulation used with TDM systems is PCM (Pulse-code-modulation).
- With PCM-TDM systems, two or more voice-band channels are sampled, converted to PCM codes, and then time-division multiplexed onto a single metallic cable pair or an optical fiber cable.

DS-0 :- PCM

voice band ch



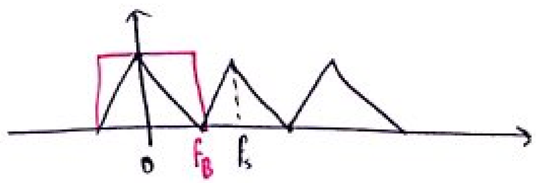


Sampling : $f_s \geq 2f_B$, $f_s = 8k$ sample/sec

$$T_s = \frac{1}{f_s} = \frac{1}{8000} = 125\ \mu sec$$

$$x(t) \longrightarrow x_s(t) = \sum_{n=0}^{\infty} x(nT_s)\,\delta(t - nT_s)$$

$X(w)$ $X_s(w)$



Time-Division Multiplexing (TDM)

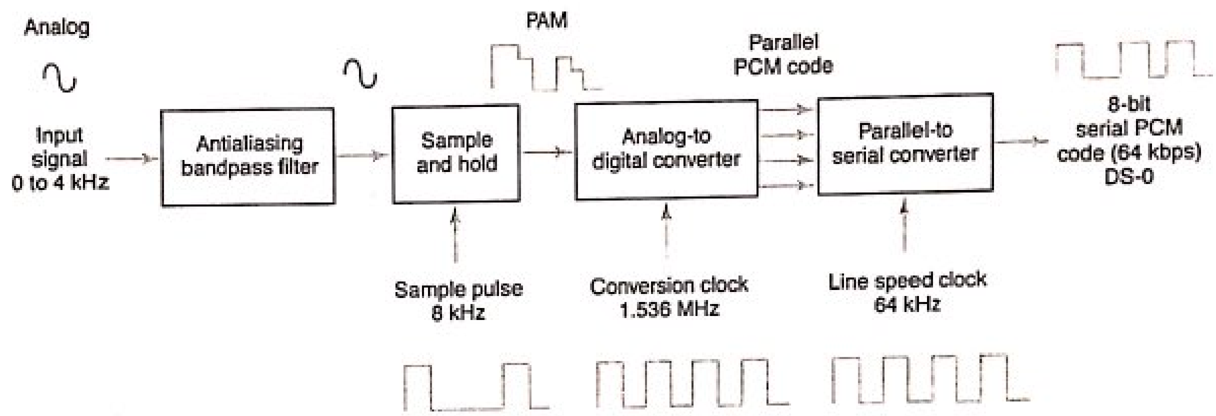
Digital-signal level 0 (DS-0)

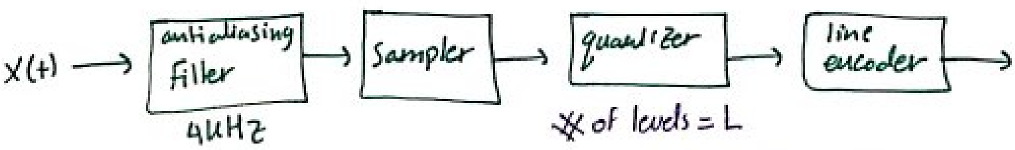
- The fundamental building block for any TDM system begins with a digital-signal level 0 (DS-0).
- Fig.1 shows the simplified block diagram for a DS-0 single-channel PCM system.
- As shown in Fig.1, DS-0 channels use an 8 KHz sample rate and an 8-bit PCM code which produces a 64-Kbps PCM signal at its output:

$$\frac{8000 \text{ samples}}{\text{second}} \times \frac{8\text{bits}}{\text{sample}} = 64 \text{ kbps}$$

Time-Division Multiplexing (TDM)

Fig.1: Digital-signal level 0 (DS-0) PCM transmission system



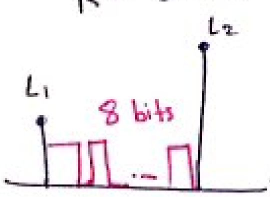


\# of levels = L

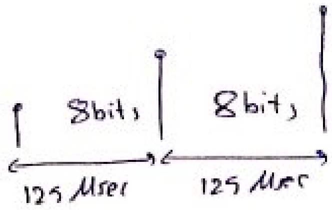
\# of bits/level = $R = \log_2(L)$

DS-0 : $L = 256$

$R = 8$ bits



Data rate : $\frac{\#\text{ of bits}}{\text{Time}} = \frac{8 \text{ bits}}{125\ \mu\text{sec}} = 64$ kbps



OR

$R_b = 8000 \frac{\text{sample}}{\text{sec}} * 8000 \frac{\text{bits}}{\text{sample}}$

$= 64$ kbits/sec

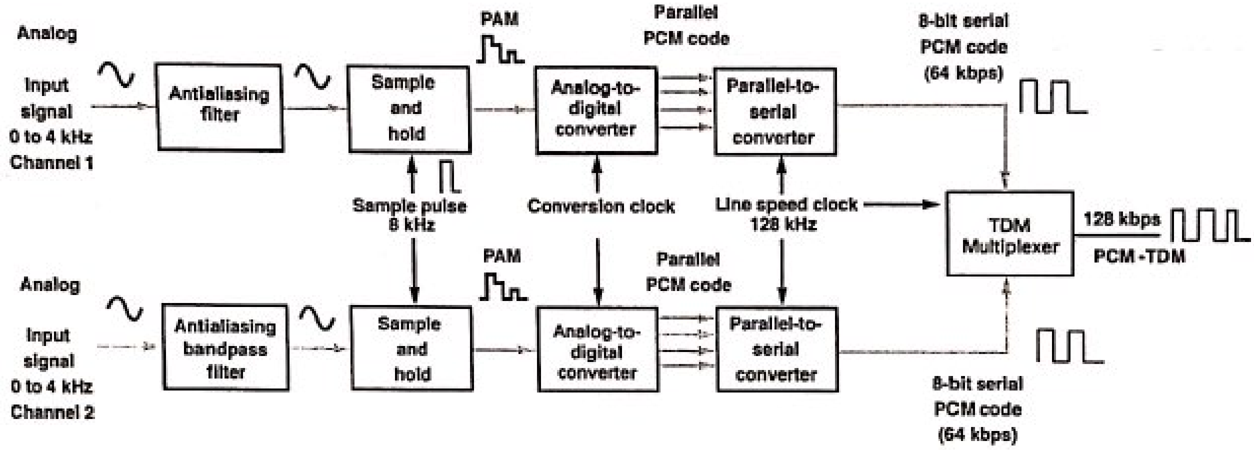
Time-Division Multiplexing (TDM)

Two multiplexed DS-0 channels

- Fig.2 shows the simplified block diagram for a multiplexed PCM-TDM carrier system made of two DS-0 channels.
- Each input channel is alternately sampled at an 8-KHz rate and converted to PCM code.
- While the PCM code for Ch1 is being transmitted, Ch2 is sampled and converted to PCM code.
- While the PCM code from Ch2 is being transmitted, the next sample is taked from Ch1 and converted to PCM code.
- This process continues and samples are taken alternately from each channel, converted to PCM code, and transmitted.
- The multiplexer is simply an electronically controlled digital switch with two inputs and one output. Ch1 and Ch2 are alternately selected and connected to the multiplexer output.

Time-Division Multiplexing (TDM)

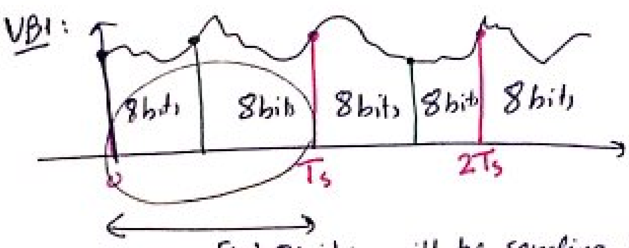
Fig.2: Two DS-0 channels PCM-TDM system: block diagram



$f_s = 8000 \frac{\text{sample}}{\text{sec}}$, $T_s = 125\ \mu sec$

← sample Period (frame time)

VB1:



$R_b = \frac{16\ bit}{125\ \mu sec} = 128\ kbps$

First 8bits will be sending info to cH1 , second 8 bits will stop and info will be sent from cH2 to the channel

VB2:

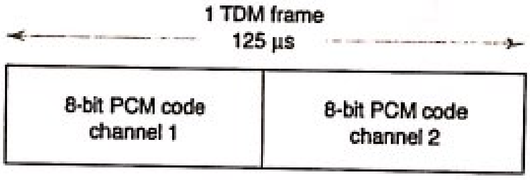
Time-Division Multiplexing (TDM)

Fig.3: Two DS-0 channels PCM-TDM system: TDM Frame

- Frame time: is the time taken to transmit one sample from each channel:

$$\text{frame time} = \frac{1}{f_s} = \frac{1}{8000} = 125\ \mu s$$

- Fig.3 shows the TDM frame allocated for two-channel PCM system with an 8-kHz sample rate. The PCM code for each channel occupies a fixed time slot (epoch) within the total TDM frame



Time-Division Multiplexing (TDM)

Two DS-0 channels PCM-TDM system: transmission speed

- Eight bits from each channel must be transmitted during each frame (a totla of 16 bits). Thus, the line speed at the output of the multiplexer is:

$$\frac{2\text{ channels}}{\text{frame}} \times \frac{8000\text{ frames}}{\text{second}} \times \frac{8\text{bits}}{\text{channel}} = 128\text{ kbps}$$

- Although each channel is producing and transmitting only 64-kbps, the bits must be clocked out onto the line at 128-kHz rate to allow eight bits from each channel to be transmitted in each 125 μs time slot.

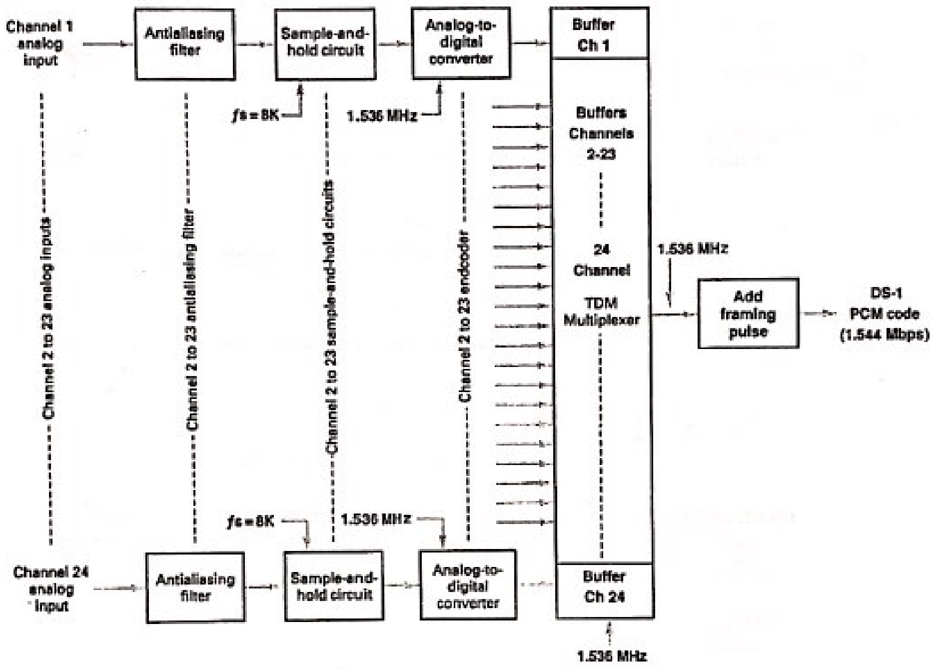
Time-Division Multiplexing (TDM)

T1 Digital Carrier System

- A digital carrier system is a communication system that uses digital pulses (rather than analog pulses) to encode information.
- Fig.4 shows the block diagram for the Bell System T1 digital carrier system
- This system is the North American telephone standard and recognized by the CCITT.
- The T1 carrier system multiplexes PCM-encoded samples from 24 voice-band channels (300 to 3000 Hz) for transmission over a single metallic wire pair or optical fiber transmission line.
- Again, the multiplexer is is simply a digital switch, except now it has 24 inputs and a single output.
- The PCM outputs from the 24 voice-band channels are sequentially selected and connected through the multiplexer to the transmission line.

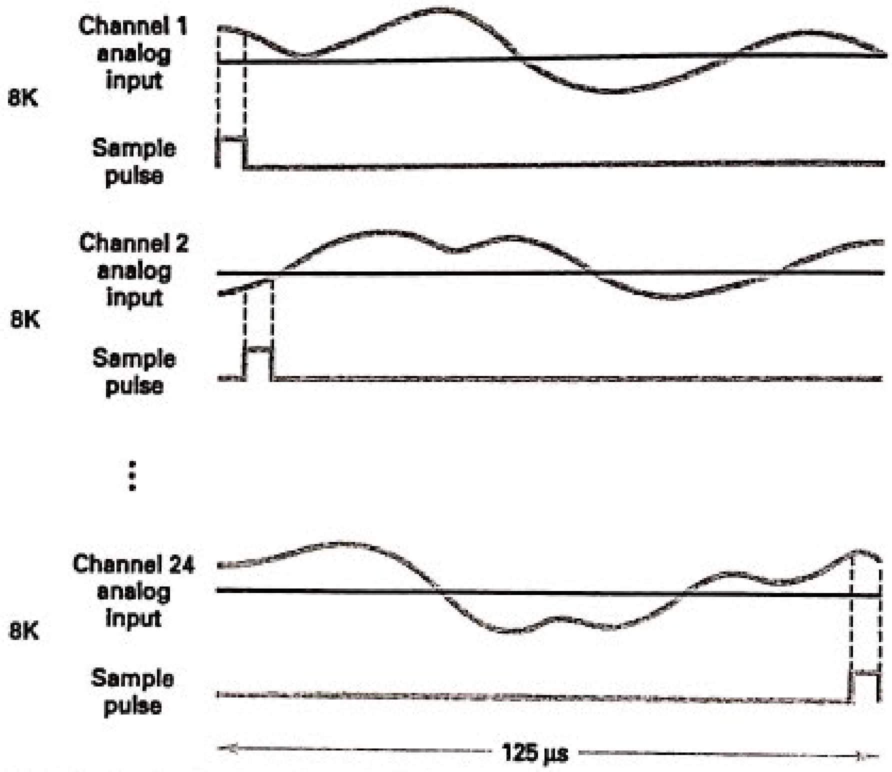
Time-Division Multiplexing (TDM)

Fig.4: Bell system T1 digital carrier system: block diagram



Time-Division Multiplexing (TDM)

Fig.5: Bell system T1 digital carrier system: sampling sequence



Time-Division Multiplexing (TDM)

Bell system T1 digital carrier system: transmission speed

- The transmit line speed of the T1 carrier system is calculated as follows:

$$\frac{24 \text{ channels}}{\text{frame}} \times \frac{8\text{bits}}{\text{channel}} = 192 \text{ bits per frame}$$

thus,

$$\frac{192 \text{ bits}}{\text{frame}} \times \frac{8000 \text{ frames}}{\text{second}} = 1.536\text{Mbps}$$

8 bits x 24

$T_s = 125\ \mu sec$

$$\frac{192}{125\ \mu sec} = 1.536\ Mbps$$

$$\frac{193}{125\ \mu sec} = 1.544\ Mbps$$