Time Division Multiplexing

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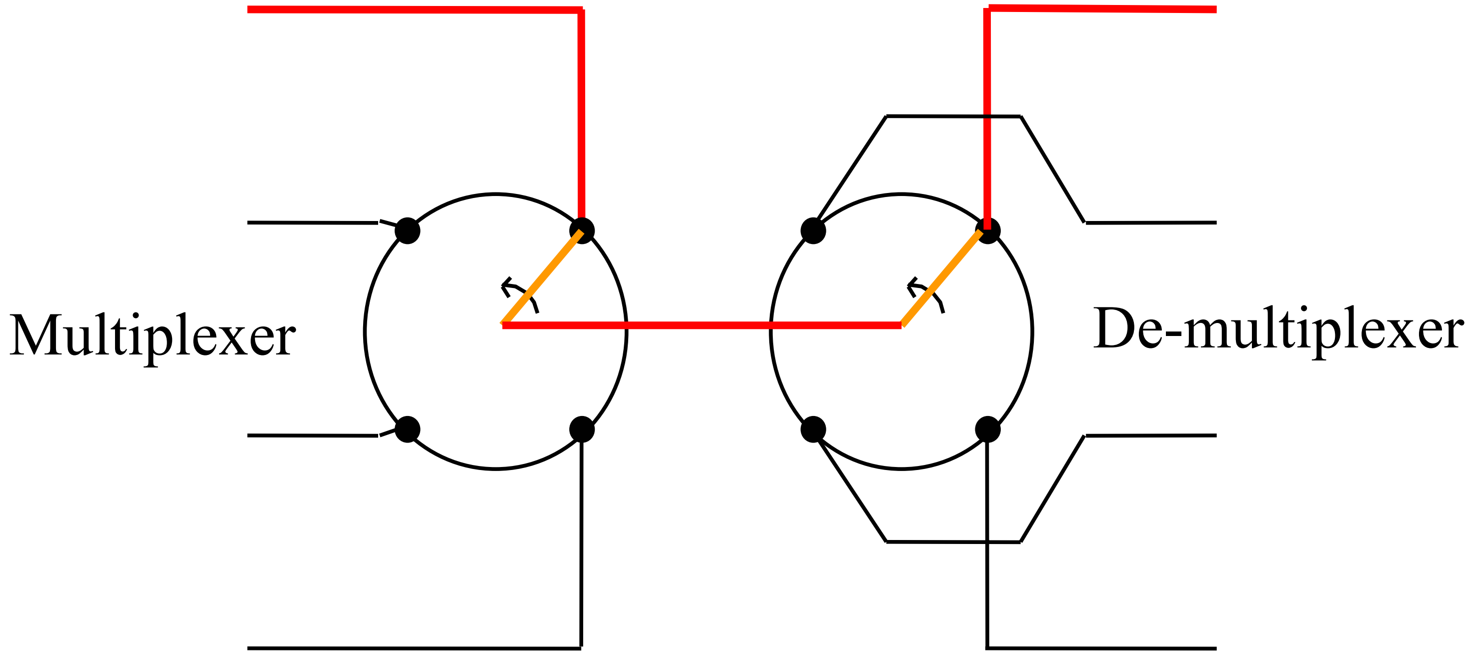
Time division multiplexing

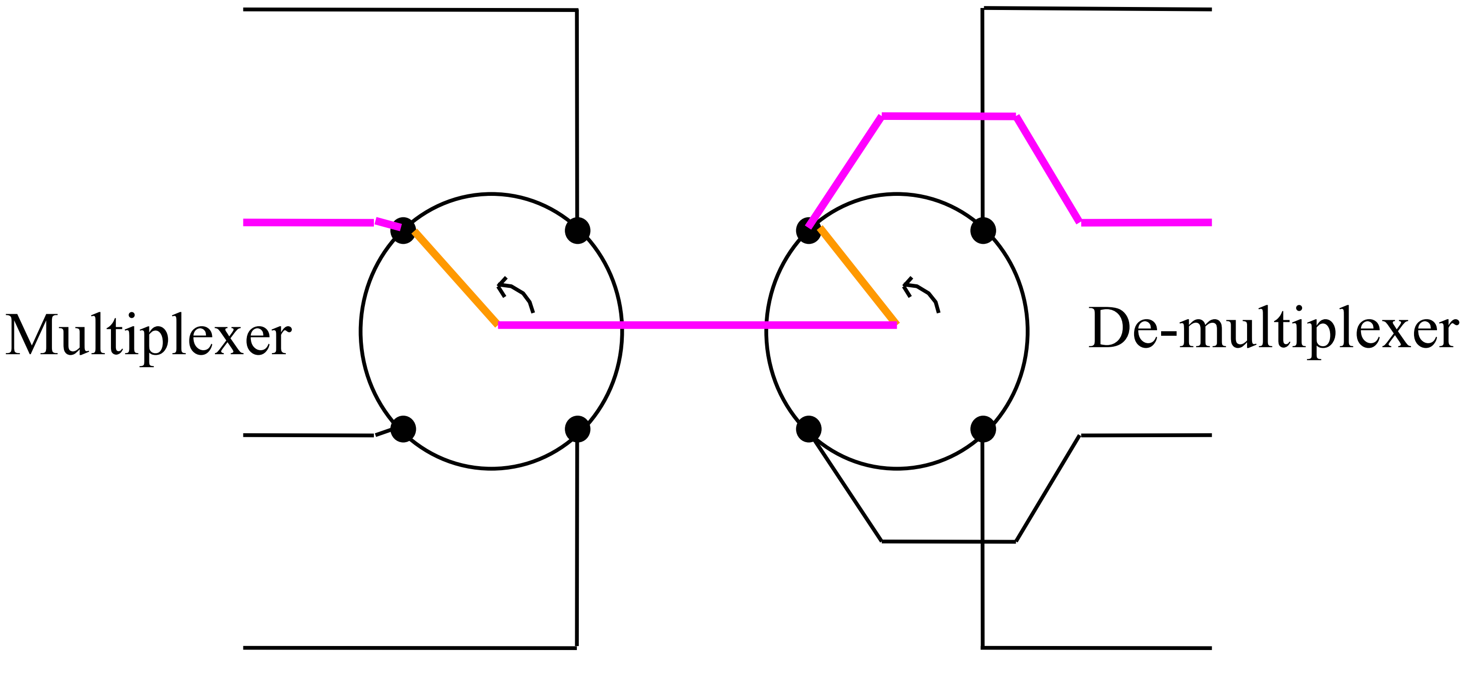
Time Division multiplexing (1)

- Time Slot 1



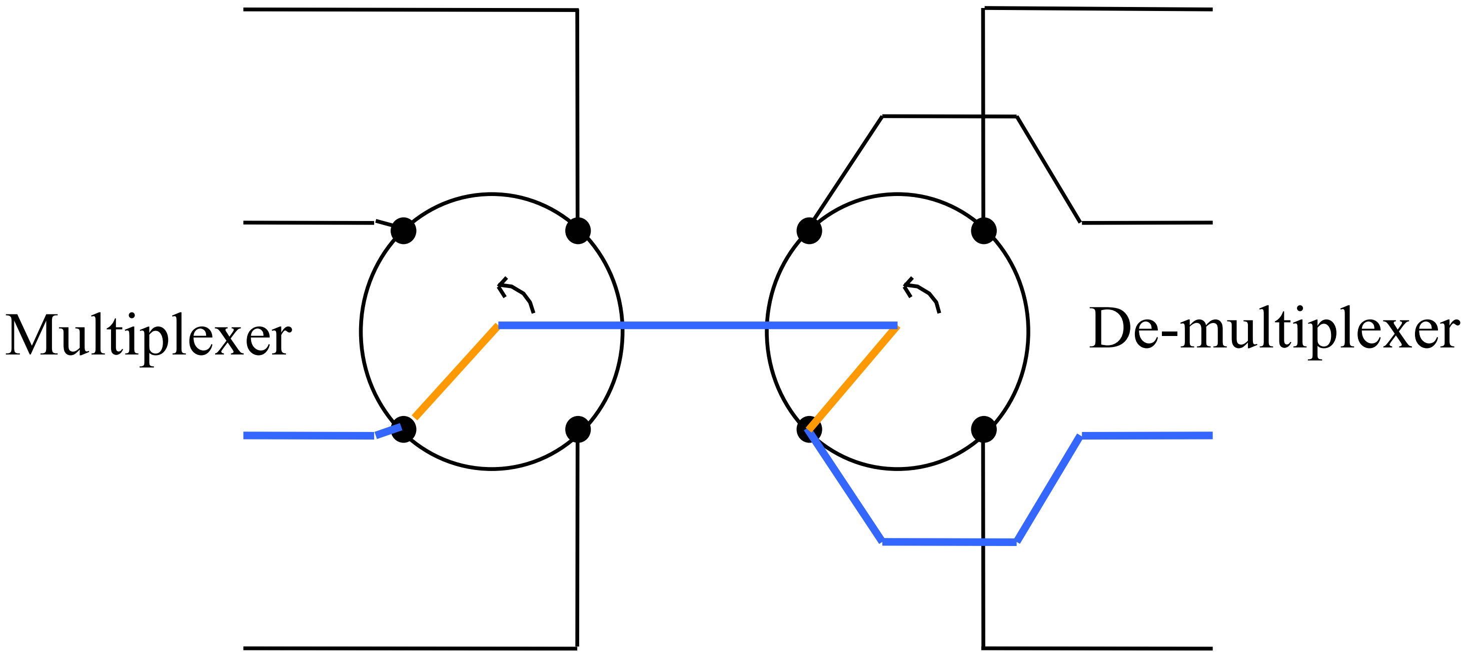
Time Division multiplexing (2)

- Time Slot 2



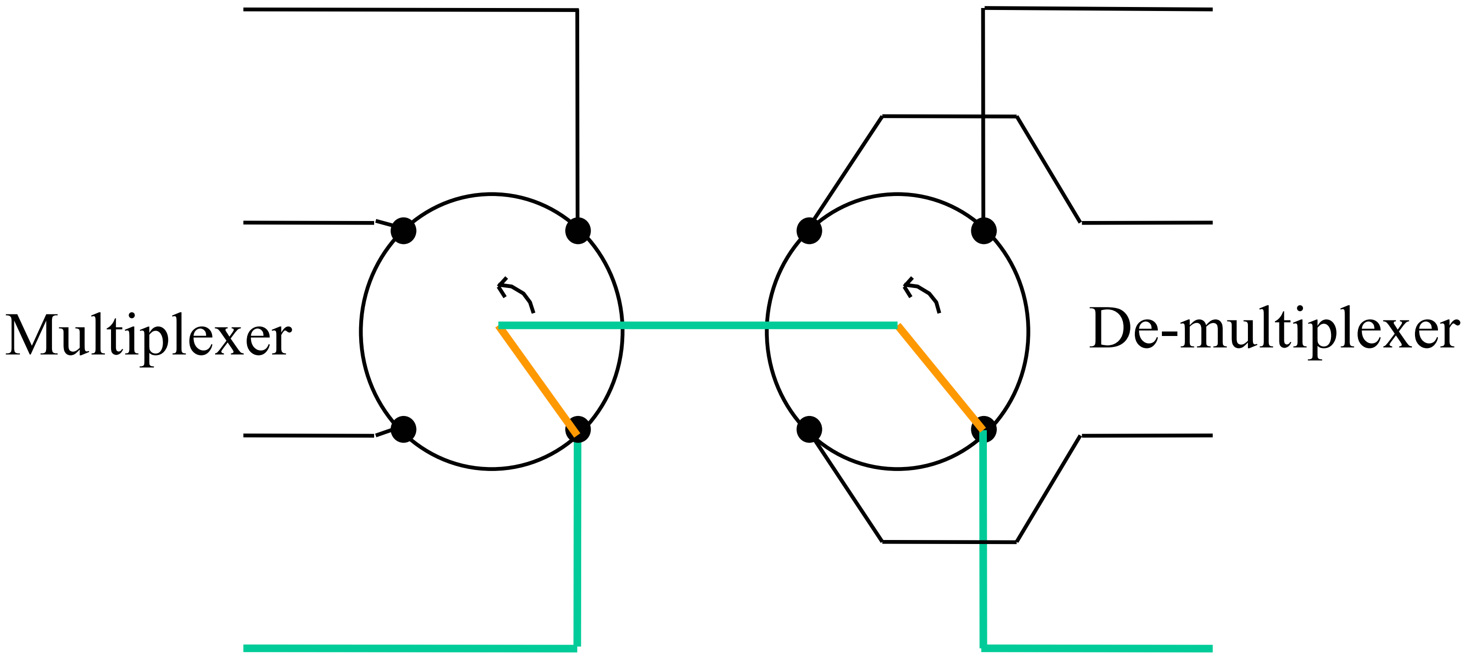
Time Division multiplexing (3)

- Time Slot 3



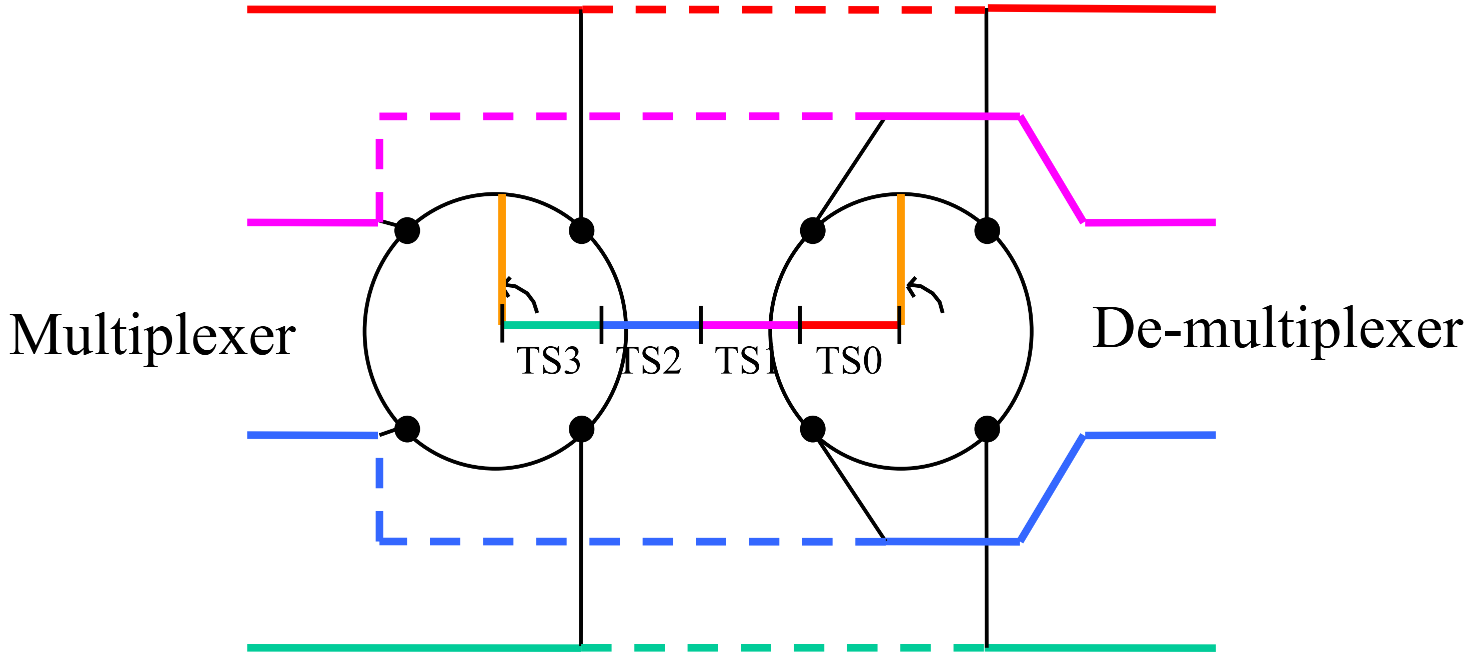
Time Division multiplexing (4)

- Time Slot 4



Frames

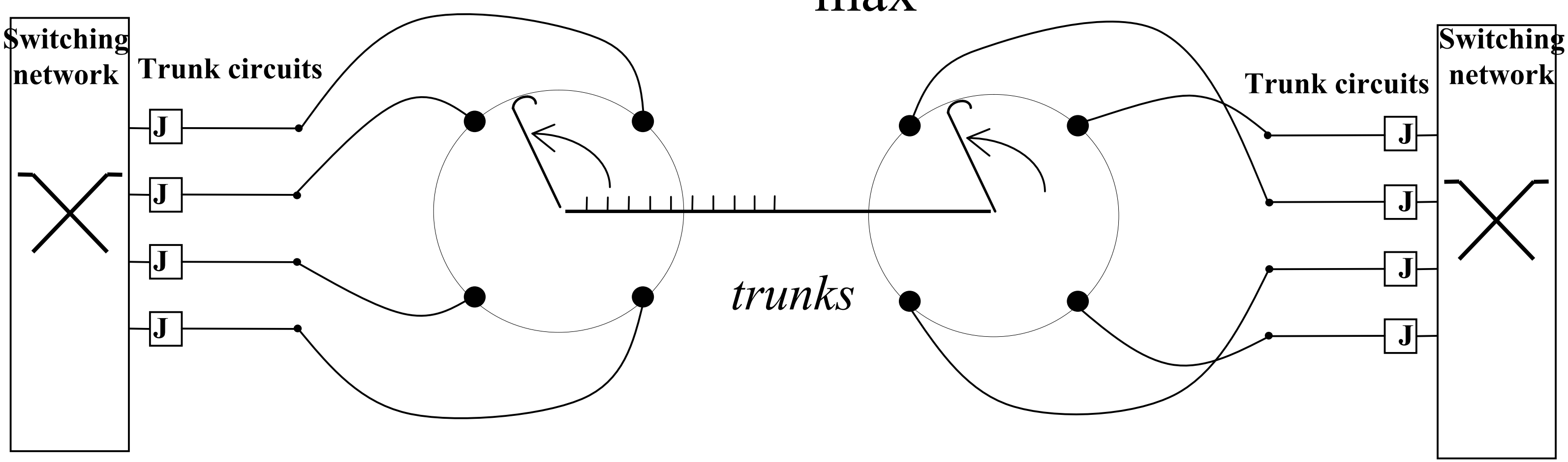
- Each rotation corresponds to a frame on the multiplex



Time Division multiplexing

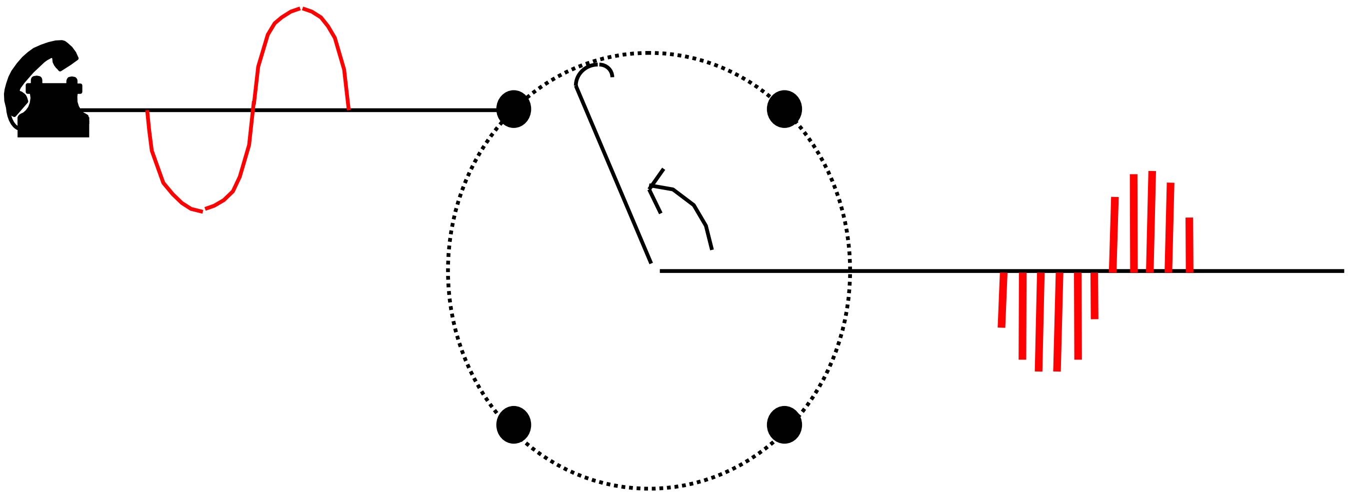
- Time division multiplexing is based on peak rate
- TDM is adapted to constant rate sources (like voice)

$$n_t = \frac{C}{d_{\max}}$$

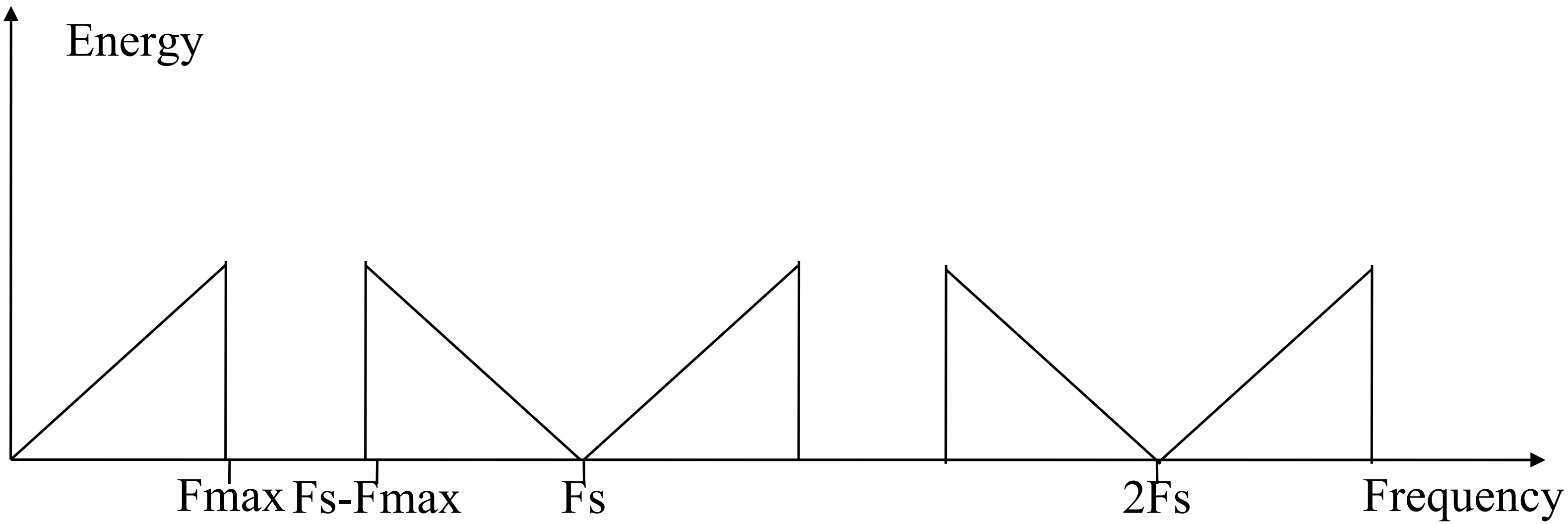


Sampling an analog signal

- Time division multiplexing requires that only samples of the signal are transmitted. If we have f_s rotations /second, the sampling frequency is f_s



Effect of sampling

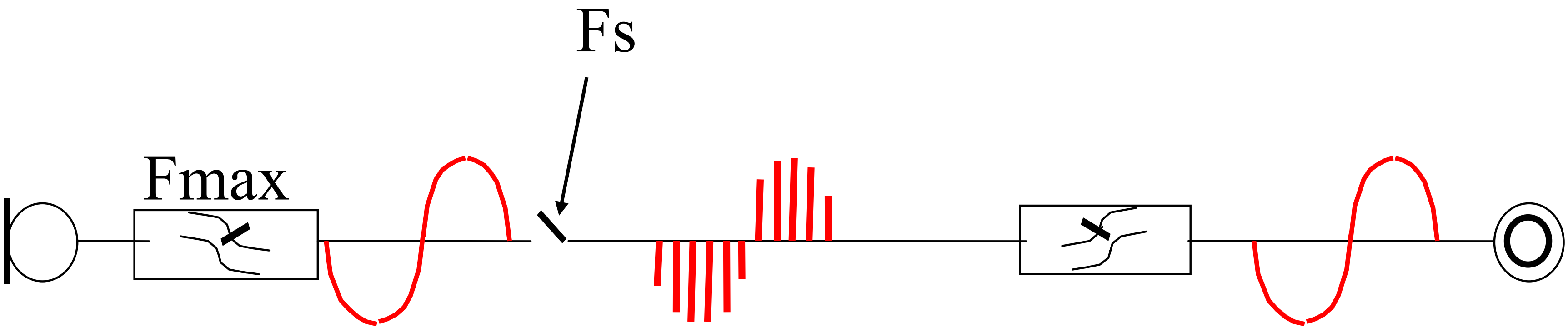


To recover the original signal, there should be no overlapping :

$$f_{s-}\ f_{max} > f_{max}$$

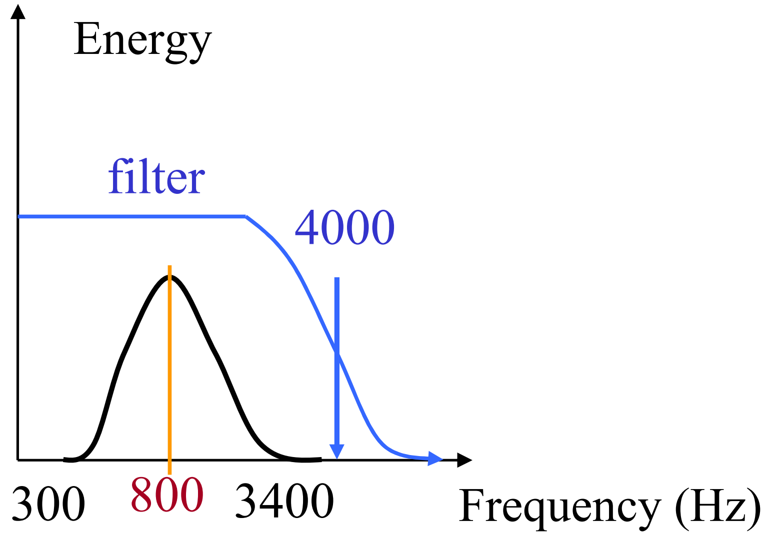
$$\text{or : } f_s > 2f_{max}$$

PAM modulation



Fs > 2 Fmax

Voice spectrum

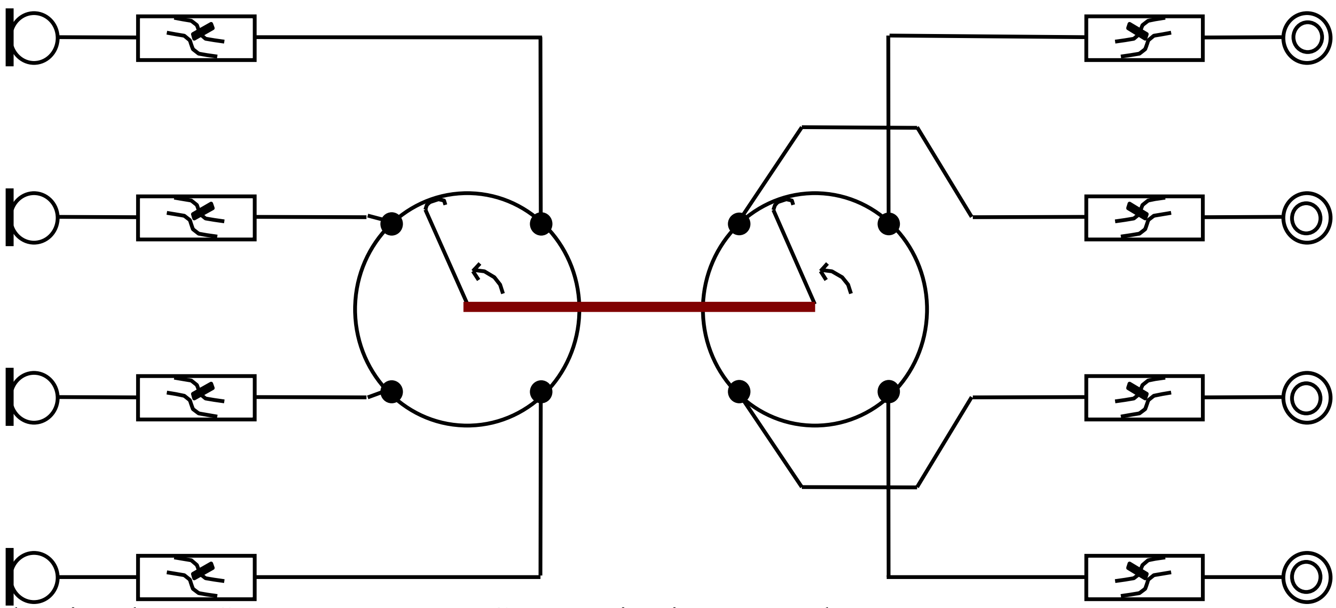


Cut off frequency of filter is at 4000 Hz

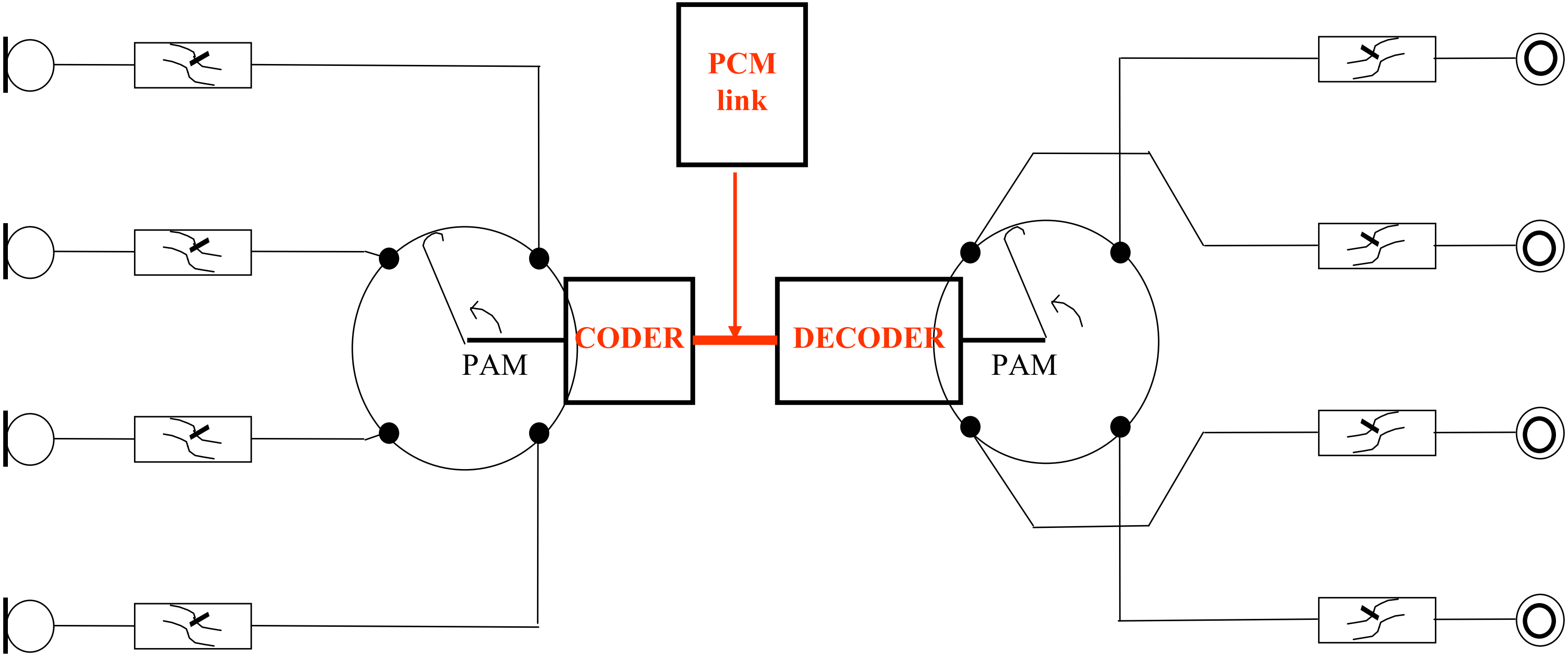
$\Rightarrow f_s = 8000$ Hz

PAM and Time division multiplexing

- 8000 rotations / second
- Advantage of TDM : the filter is the same everywhere
- Disadvantage of PAM : analog system ⇒ noise sensitivity

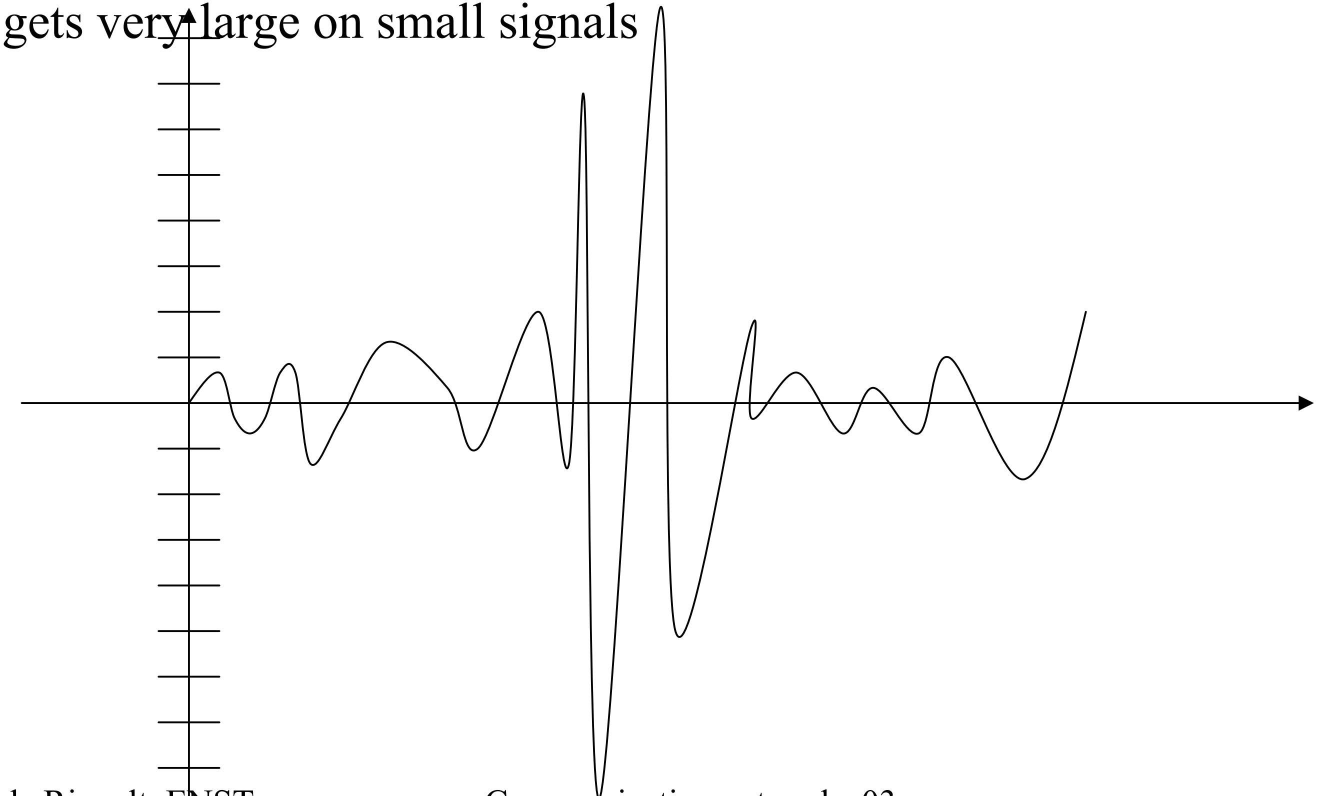


PCM and Time division multiplexing



Voice signal dynamics

- The dynamics of the voice signal is very large ⇒ quantization noise gets very large on small signals

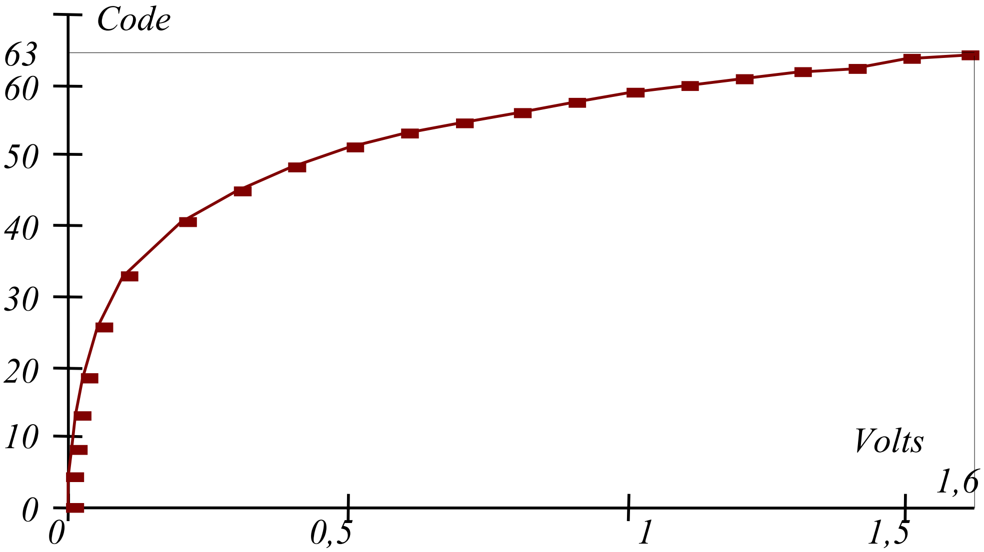


Quantization noise

- Quantization produces « Quantization noise »
- A linear measurement scale would result in a lower SNR for small signals than for big signals

- What we want is an **amplitude independent SNR**

‘μ’ Law coding

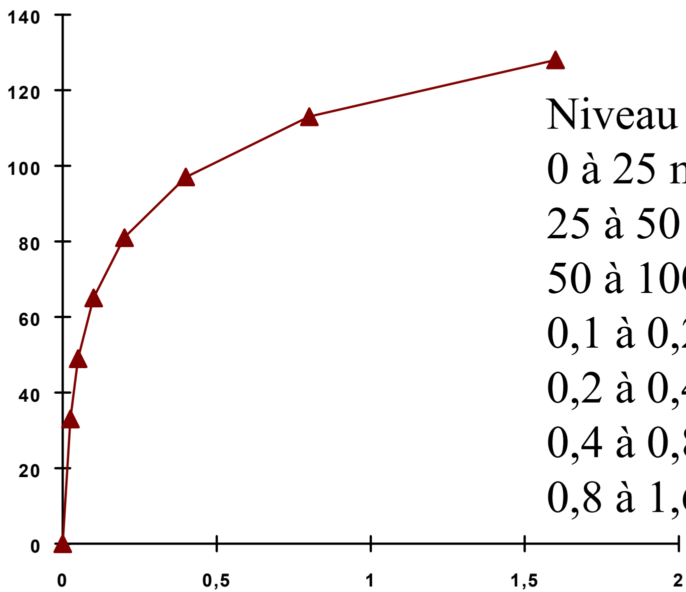


$$x = \frac{v}{v_{max}}, \quad y = \frac{c}{c_{max}}$$

$$y = \frac{\mathrm{Log}(1+\mu x)}{\mathrm{Log}(1+\mu)}$$

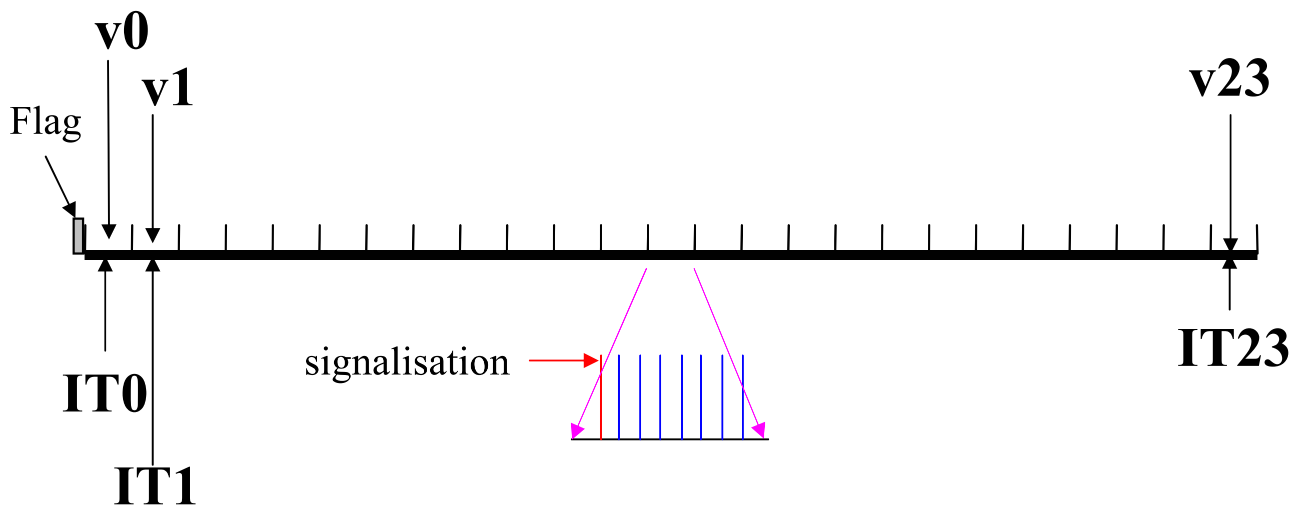
$$\mu = 255$$

‘A’ Law coding



Niveau du signal	Code sur 13 bits	Code sur 8 bits
0 à 25 mV	0 à 63	0 à 33
25 à 50 mV	64 à 127	34 à 49
50 à 100 mV	128 à 255	50 à 65
0,1 à 0,2 V	256 à 511	66 à 81
0,2 à 0,4 V	512 à 1023	82 à 97
0,4 à 0,8 V	1024 à 2047	98 à 113
0,8 à 1,6 V	2048 à 4095	114 à 128

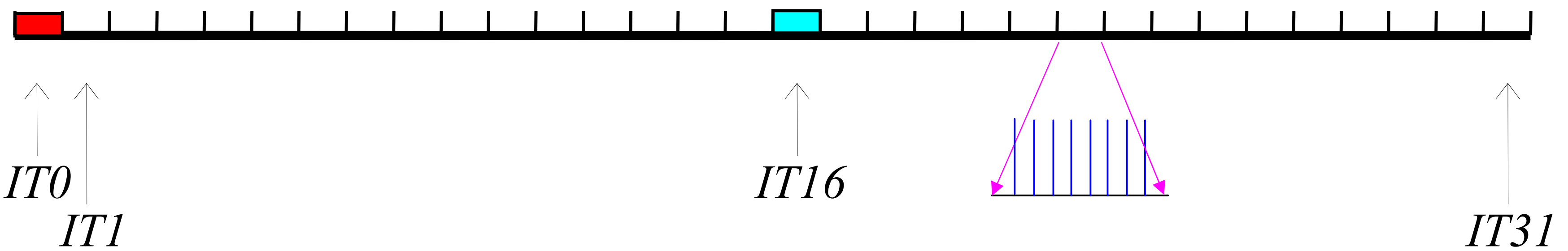
Primary multiplex T1 (T1 carrier)



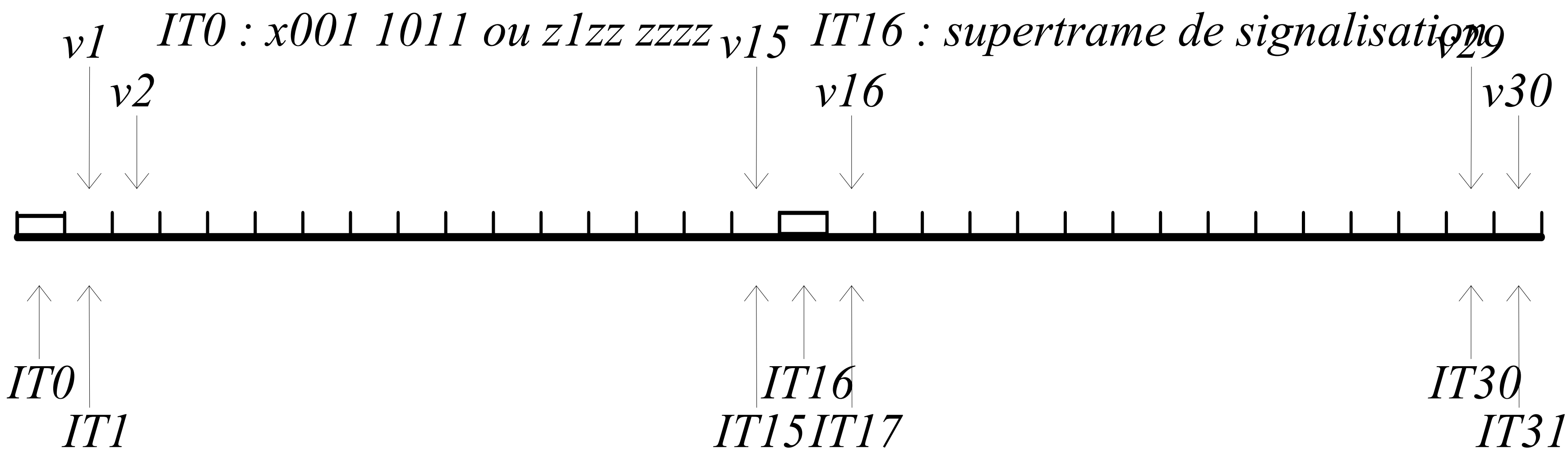
$$(24 \times 8) + 1 = 193 \text{ bits par trame}$$

$$193 \times 8000 \text{ trames/s} = 1544 \text{ Kbit/s}$$

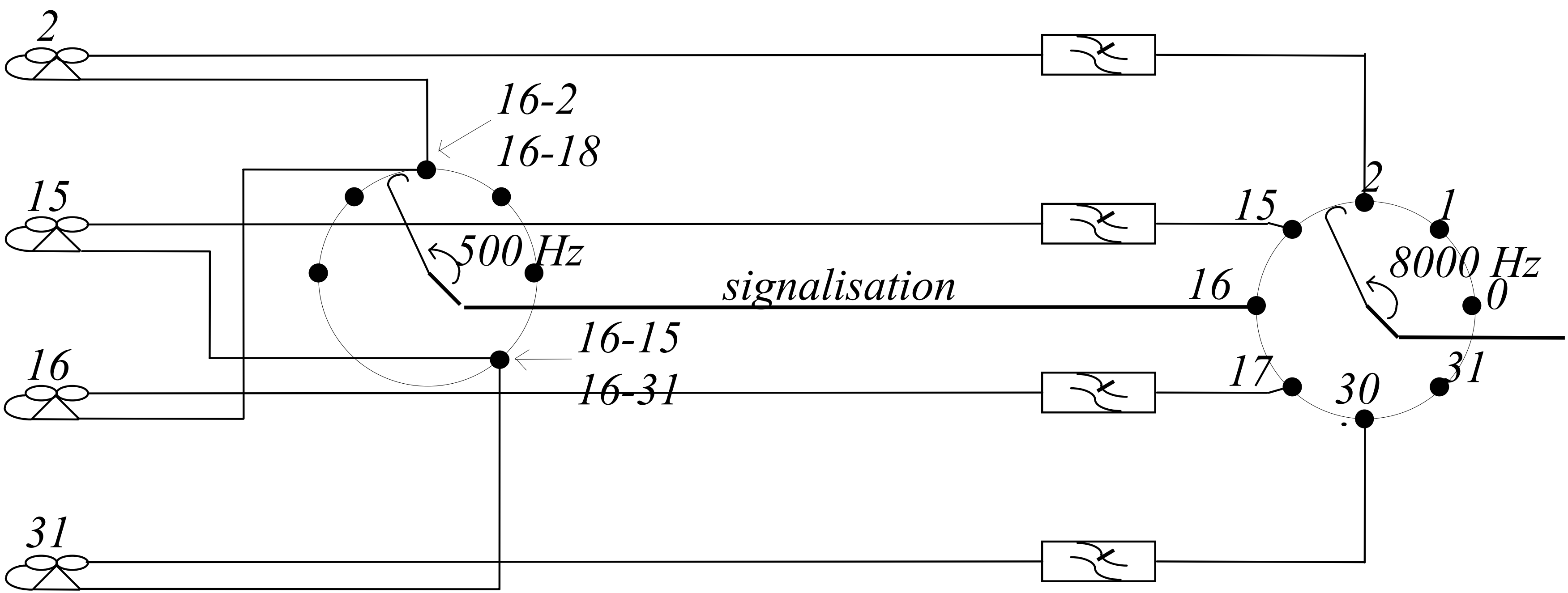
Primary multiplex E1



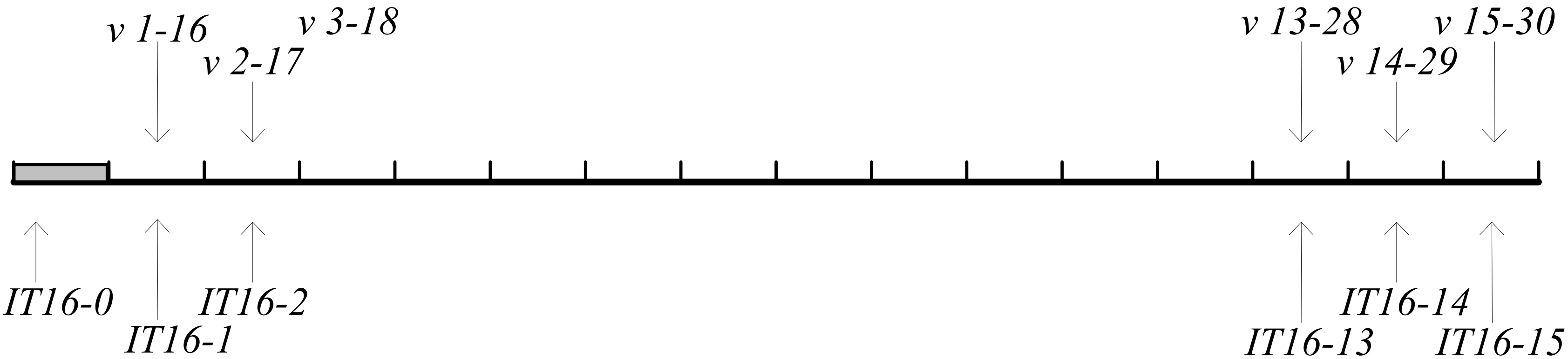
E1 frame organization



In-band

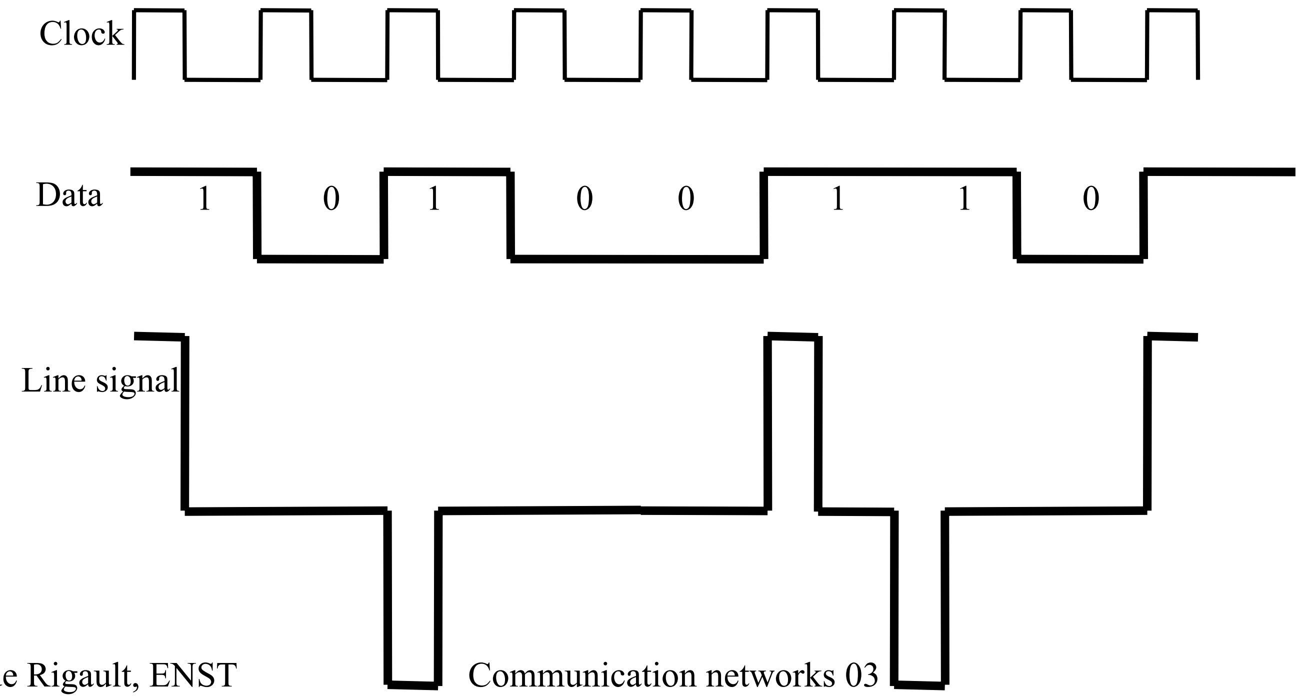

2
15
16
31
16-2
16-18
500 Hz
16-15
16-31
signalisation
2
1
15
8000 Hz
16
0
17
30
31

PCM E1 : superframe



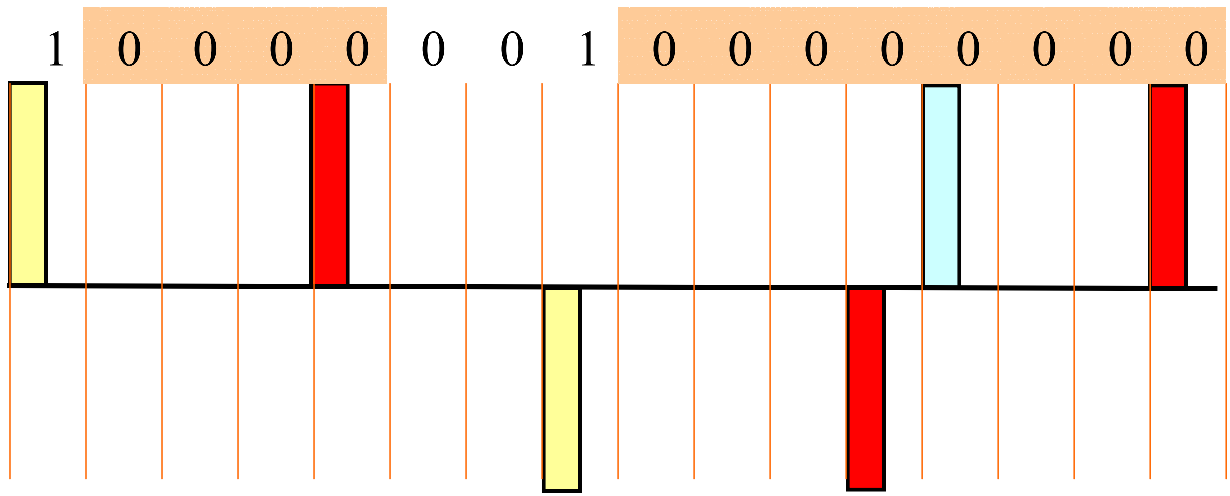
The HDB 3 line code

- 1 ⇒ Mark, 0 ⇒ Space
- Alternate Mark Inversion

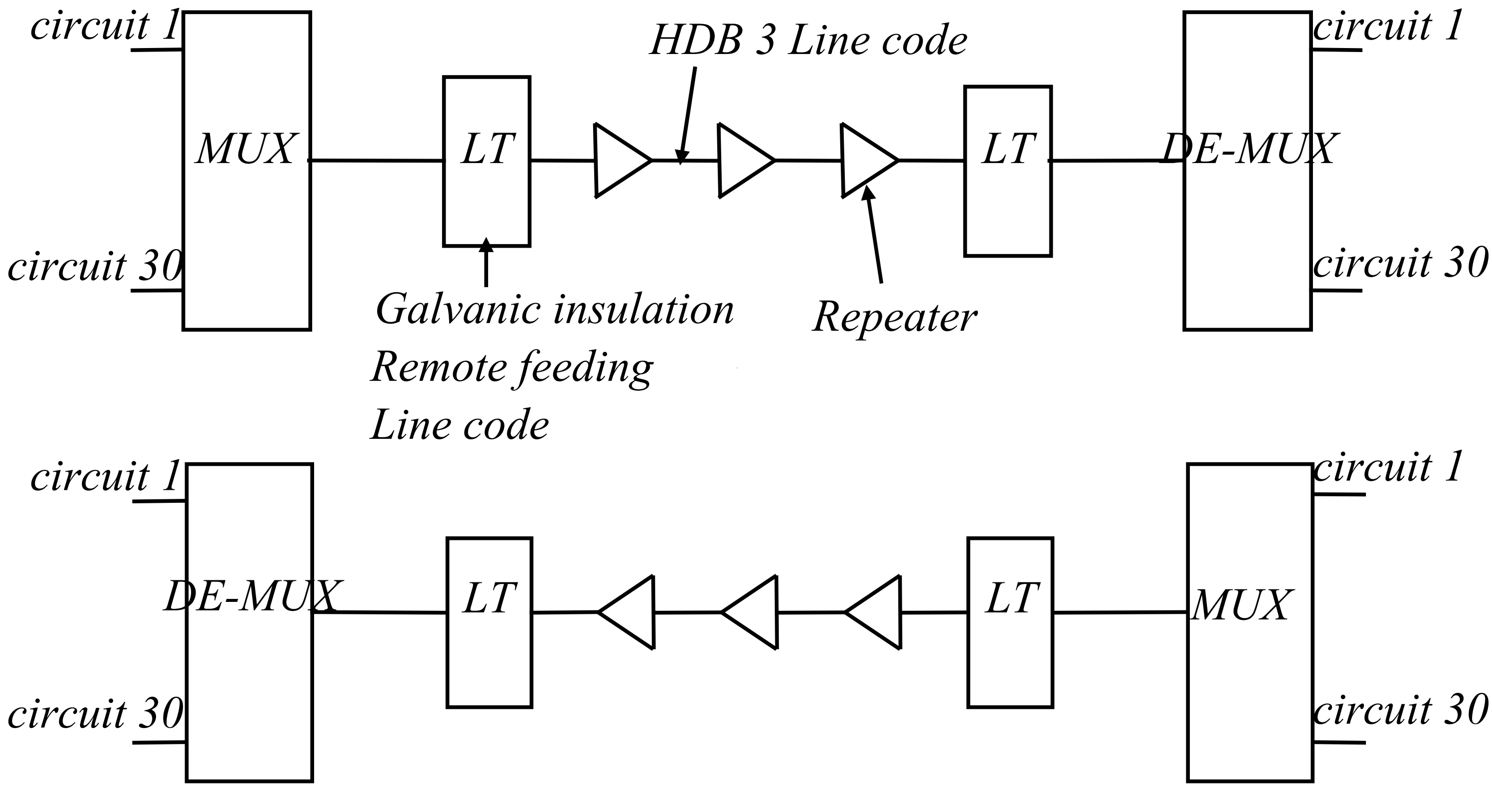


The HDB 3 line code

- Coding of sequences of 4 zeros : alternate violations inversion

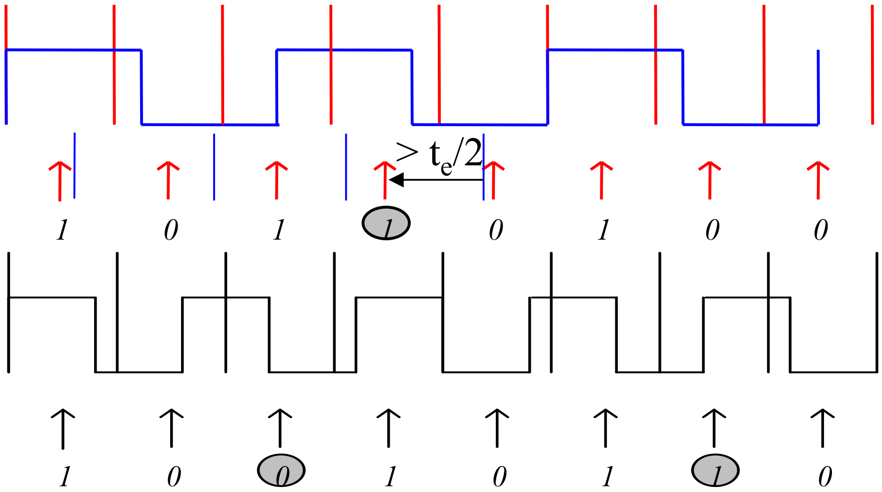


Line Termination



Asynchronous Transmission

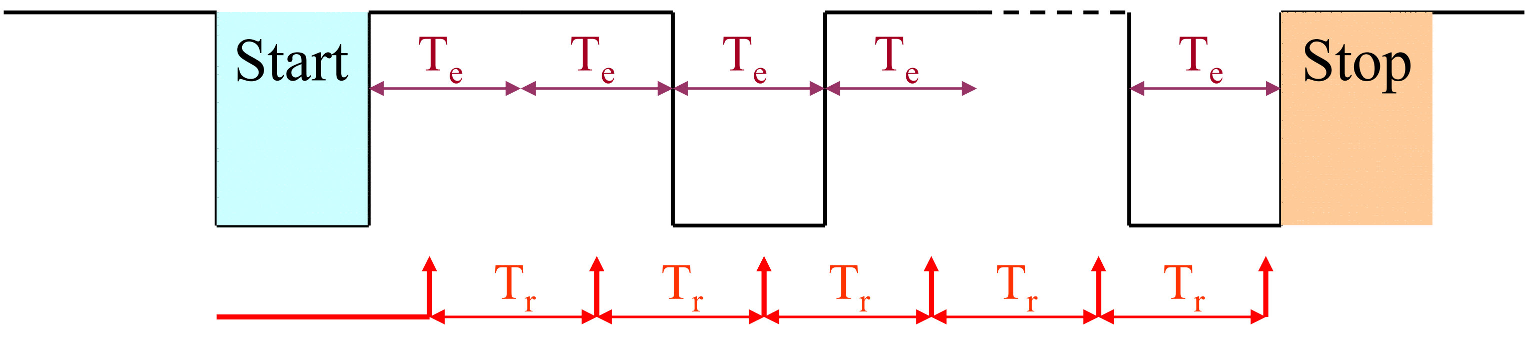
- Slips occur after n bits



$$n = \frac{t_e}{2(t_e - t_r)} = \frac{\frac{1}{f_e}}{2\left(\frac{1}{f_r} - \frac{1}{f_e}\right)} = \frac{f_r}{2(f_e - f_r)}$$

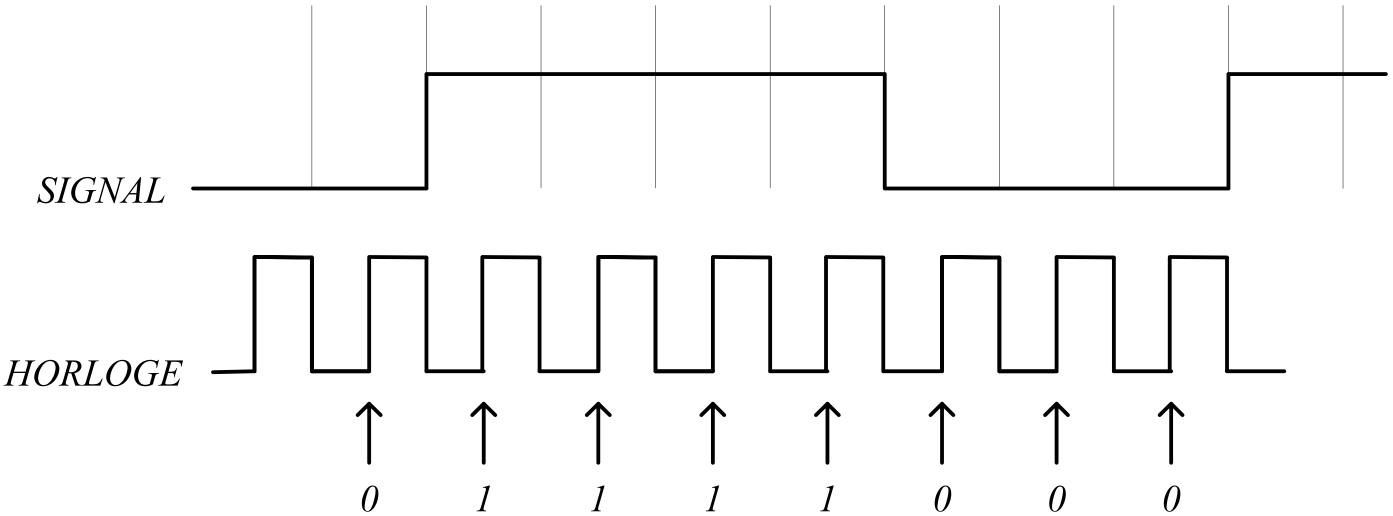
Asynchronous Transmission

- Start and Stop signals required
- Caracter Oriented Procedure (COP)



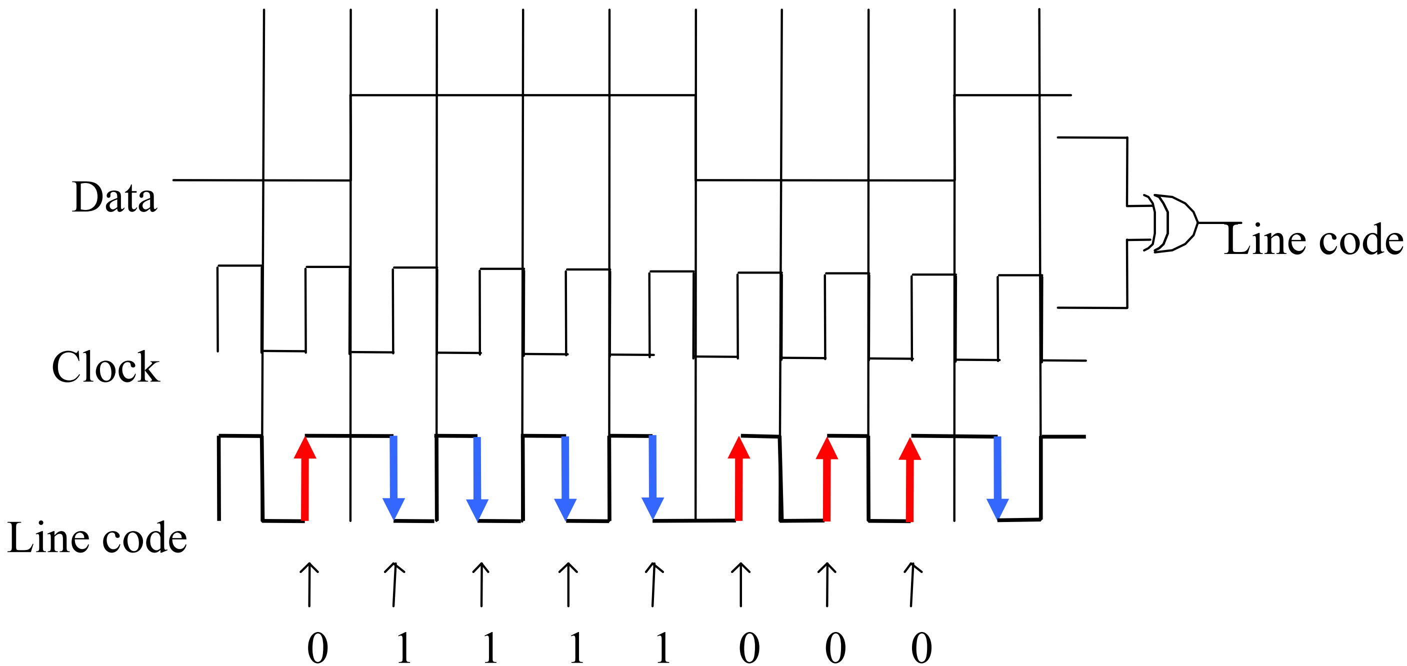
Synchronous Transmission

- 2 channels required : one for data, one for clock
- Bit Oriented Procedure (BOP)

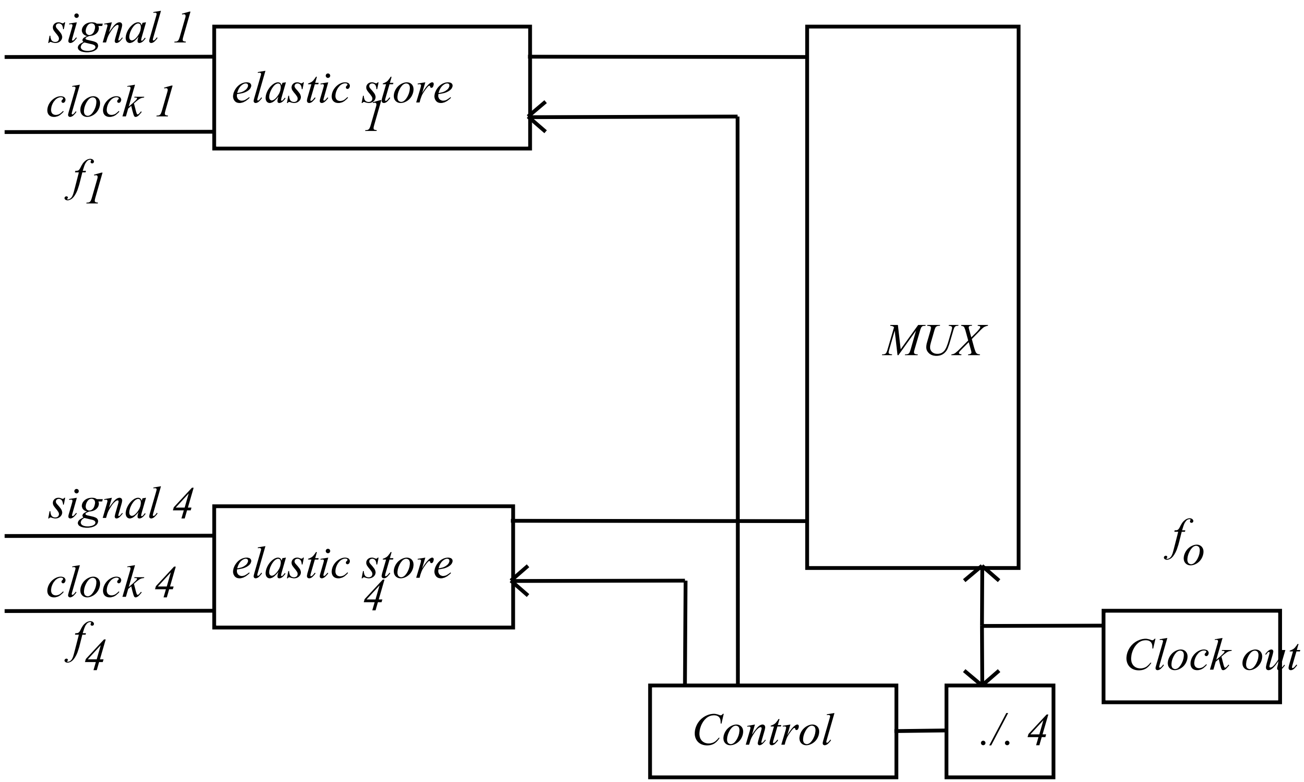


Mixing clock and data

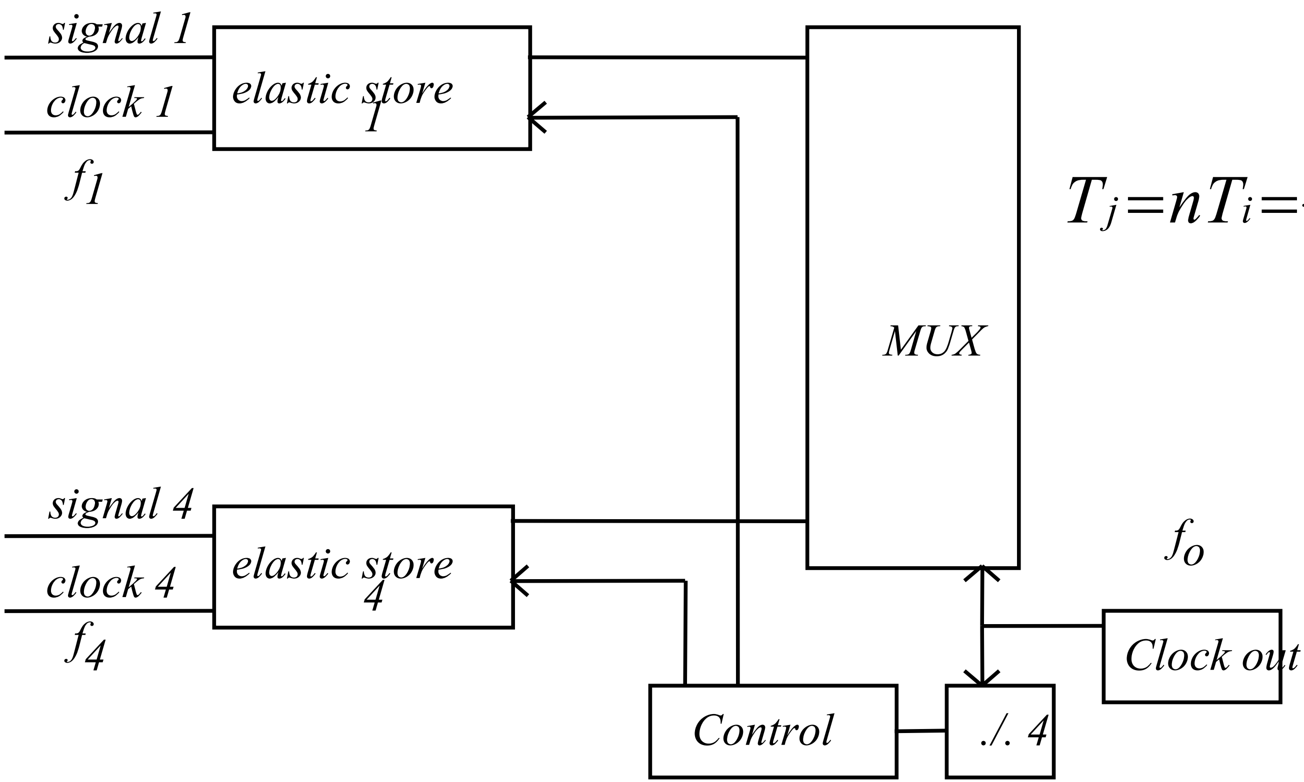
- Line codes such as the Manchester code give a mean to recover the clock, at the expanse of bandwidth



Asynchronous multiplexing

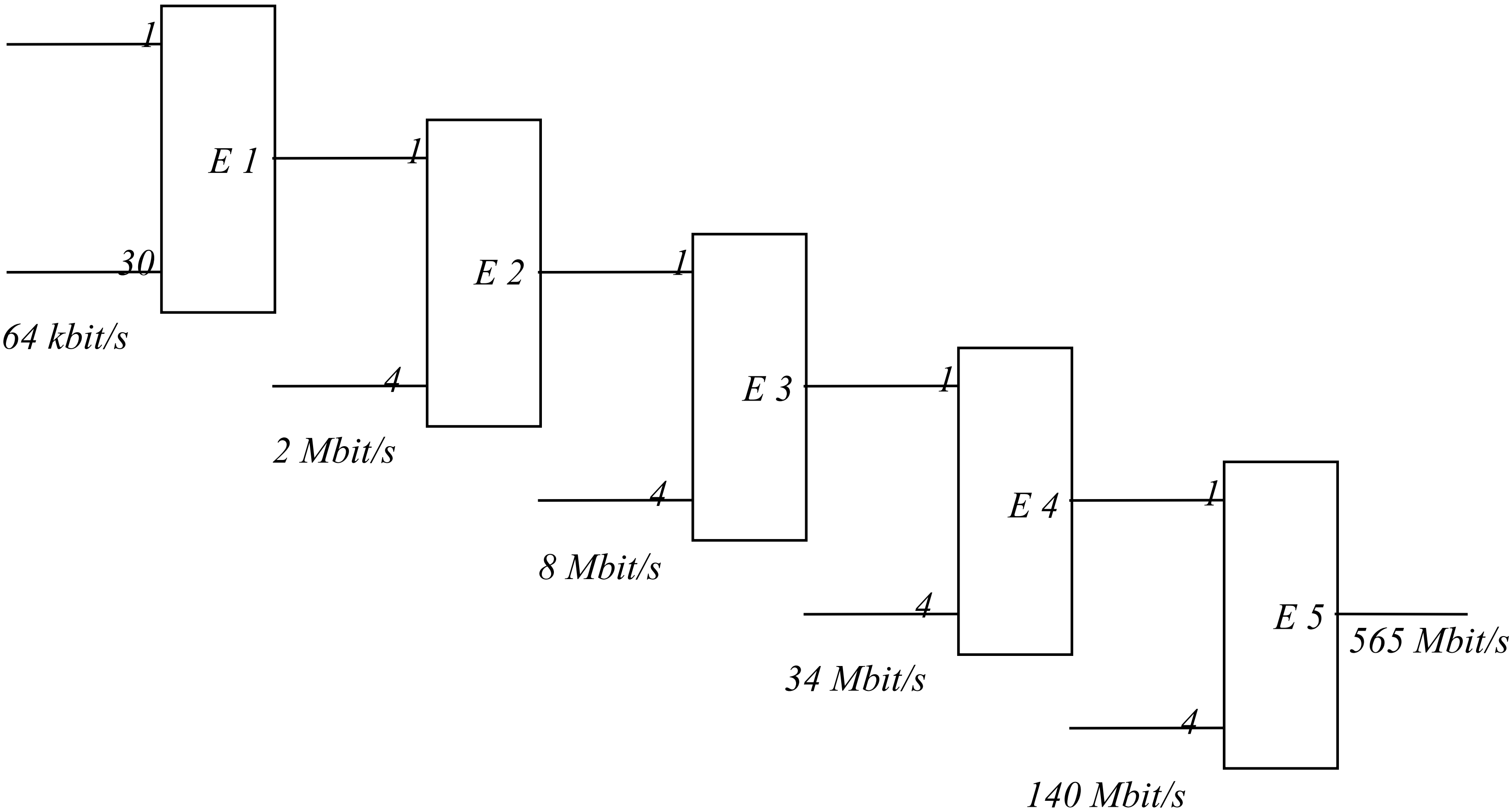


Justification



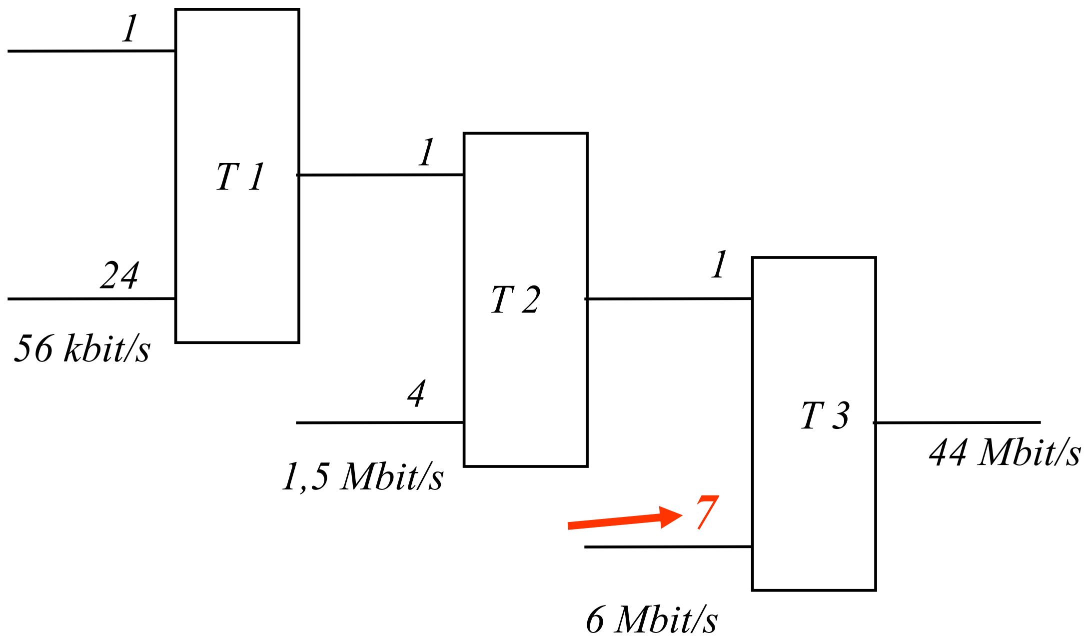
$$T_j = nT_i = \frac{1}{\frac{f_o}{4} - f_i}$$

European PDH hierarchy

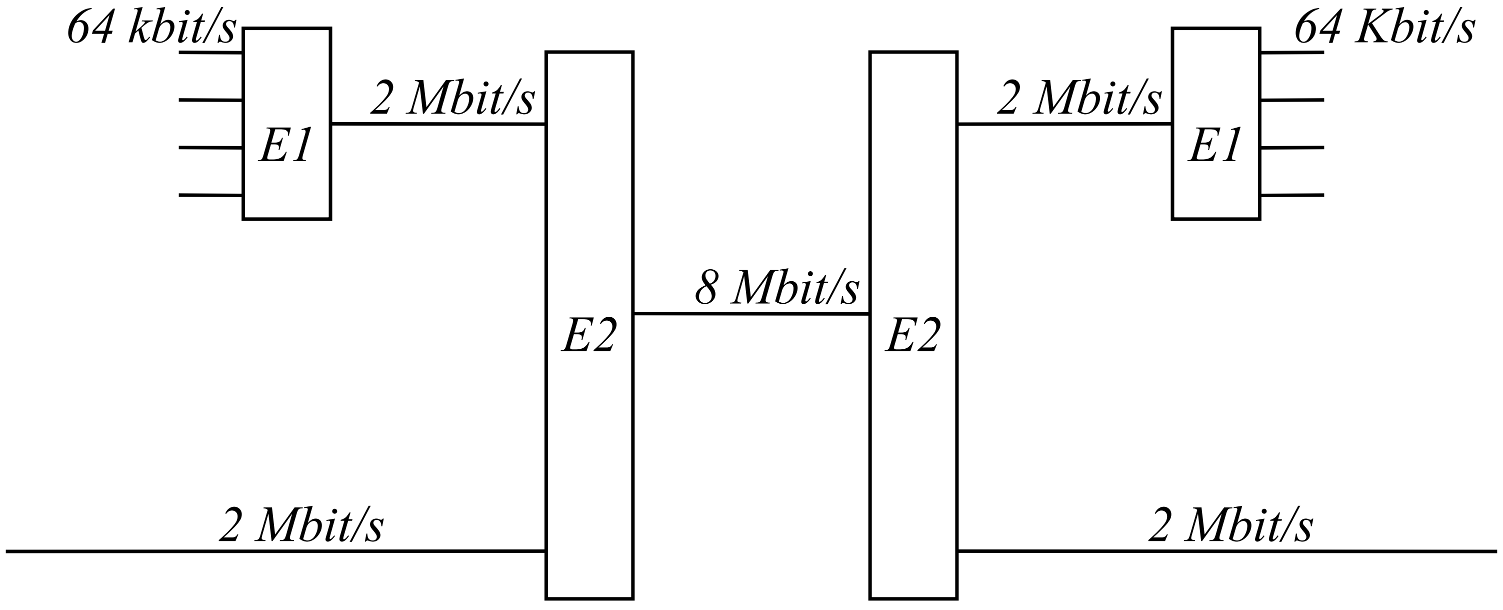


American PDH hierarchy

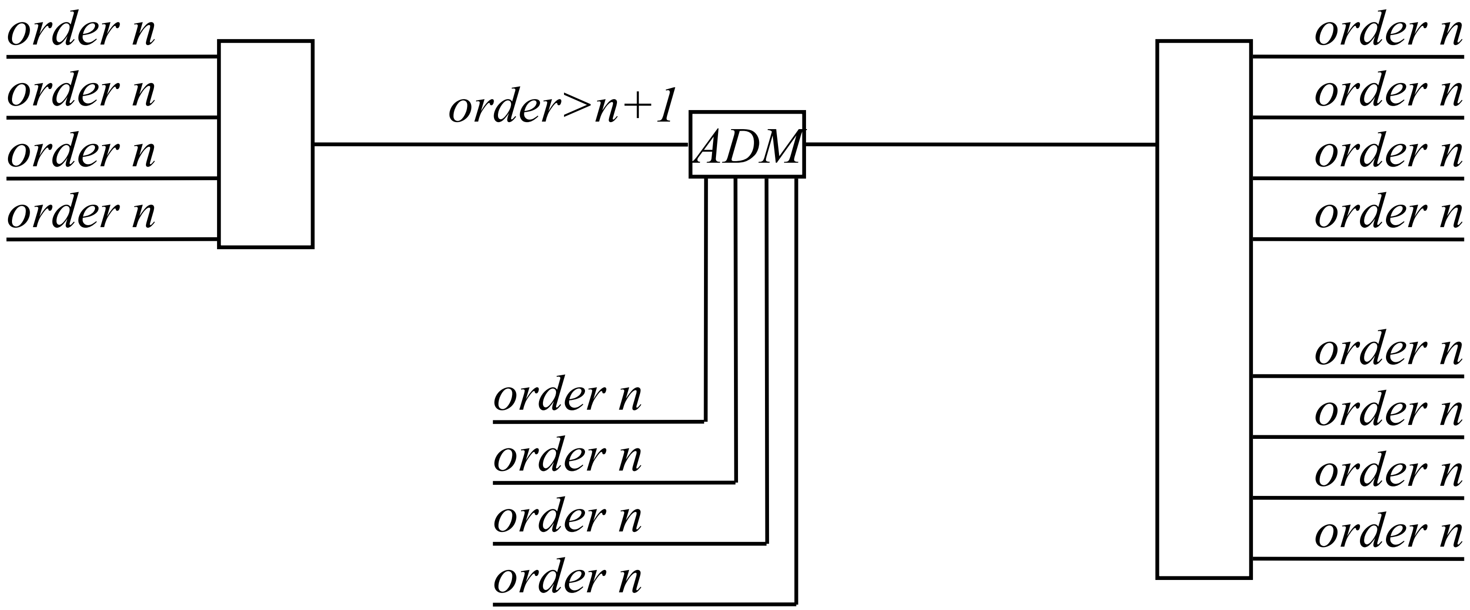
- Caution ! One T3 multiplexes **7** T2 !



Point to point structure of PDH networks

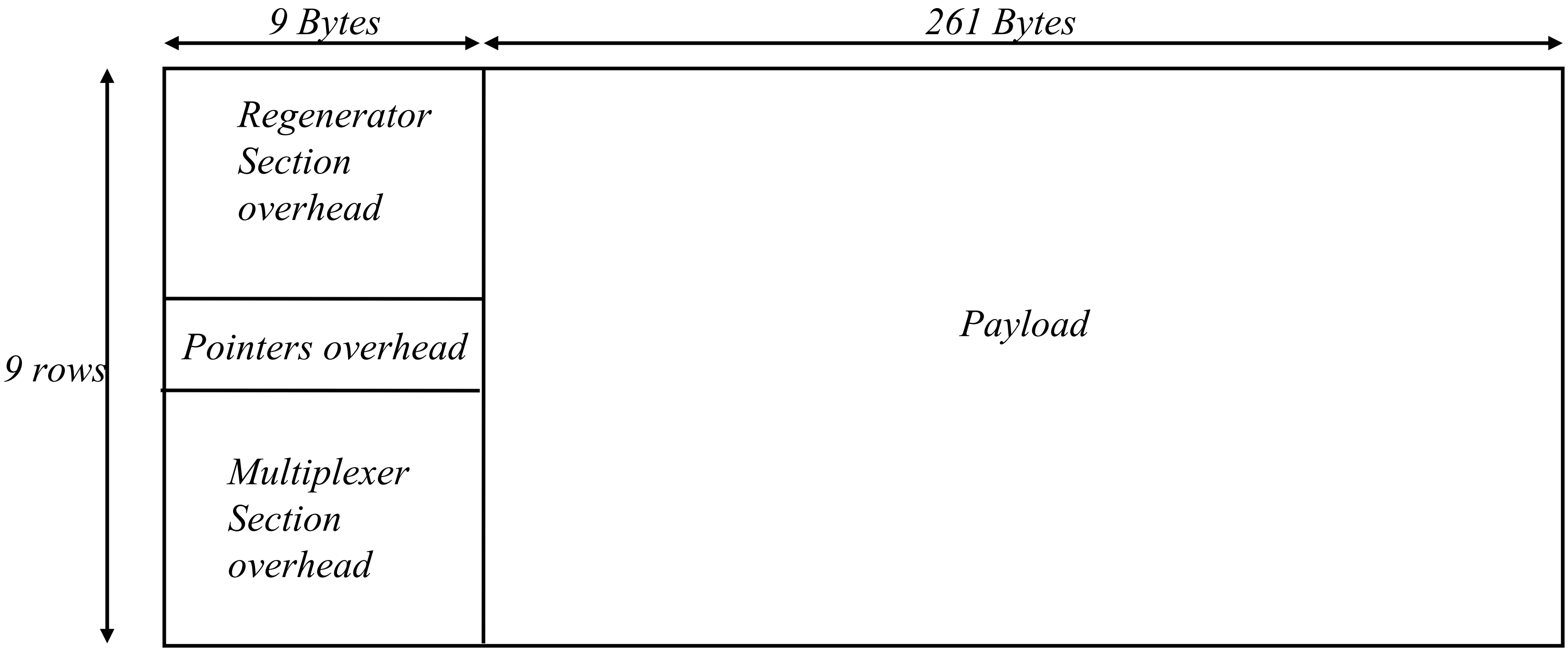


SDH : Adding and Dropping



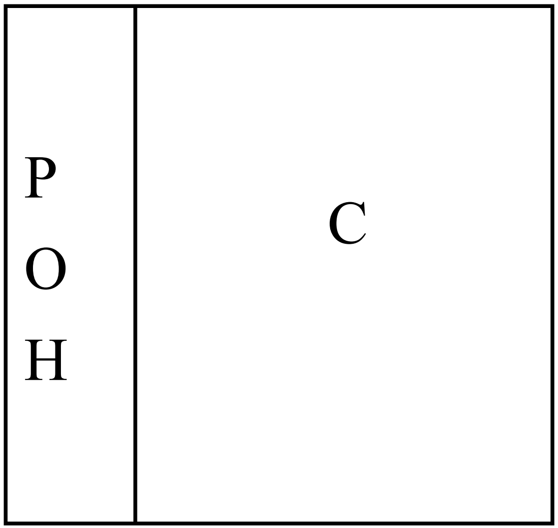
The condition : synchronous multiplexing

SDH : the STM-1 frame



STM-1 : Synchronous transfer module

Container and Virtual Container

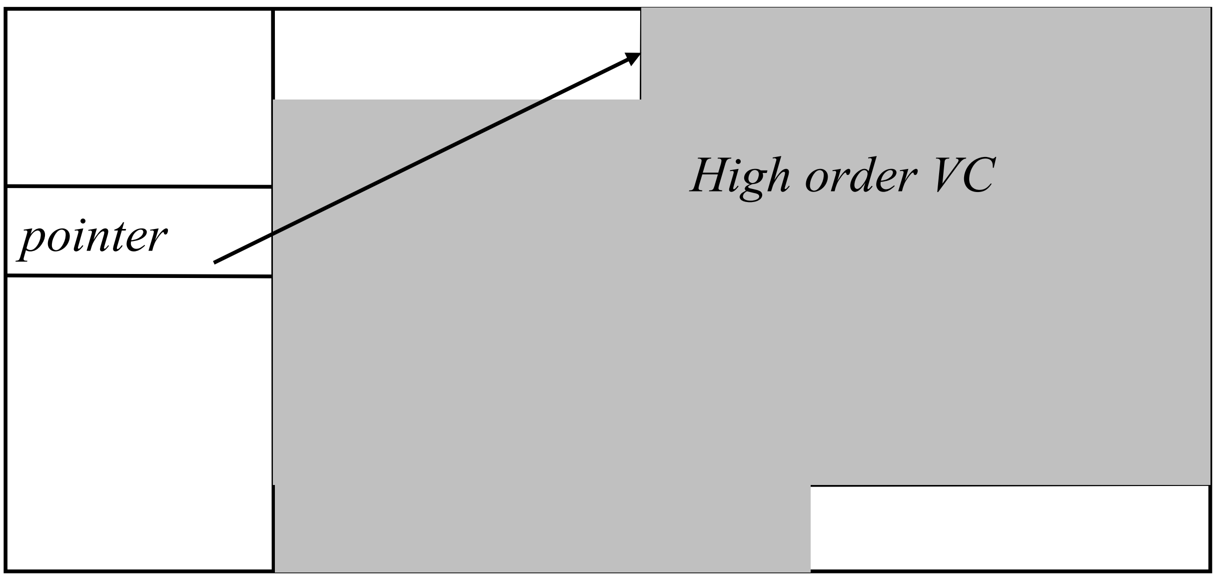


VC

C + POH → VC

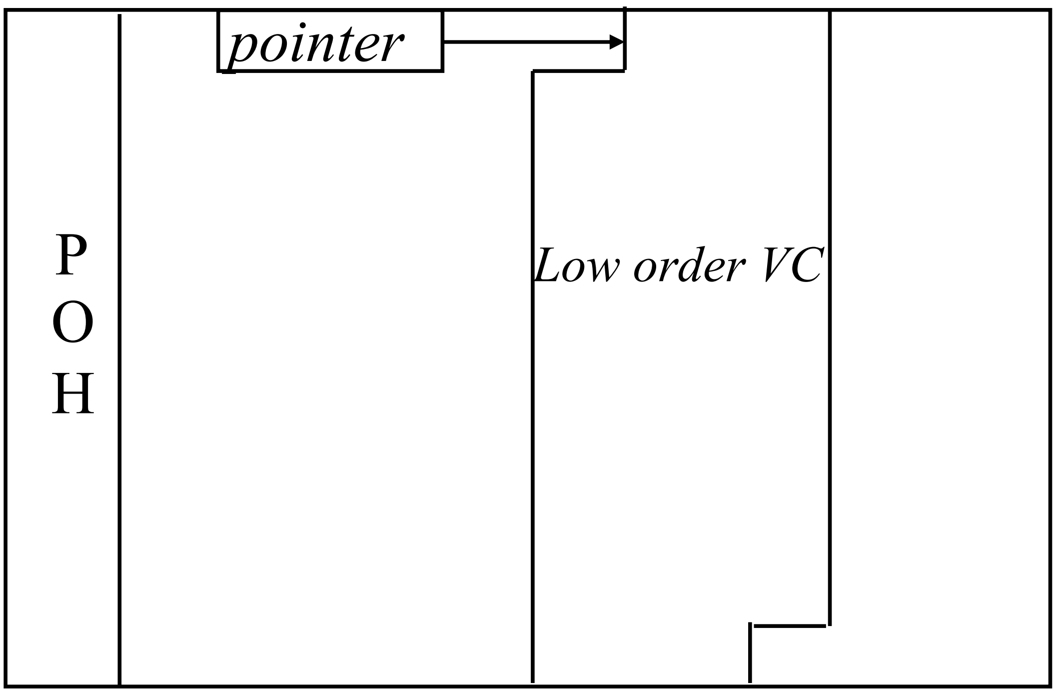
Synchronous multiplexing (high order)

- High Order Path (high order multiplex)



Synchronous multiplexing (low order)

- Low Order Path (low order multiplex)



SDH mechanisms

- C + POH → VC
- Low order VC + pointer → TU
- High order VC + pointer → AU

SDH tributaries

Container	Europe	US
C11		T1 1,5 Mbit/s
C12	E1 2Mbit/s	↓ 4
C2		T2 6 Mbit/s
	E3 34Mbit/s	↓ 7
C3		T3 44 Mbit/s
C4	E4 140Mbit/s	

Multiplexing paths