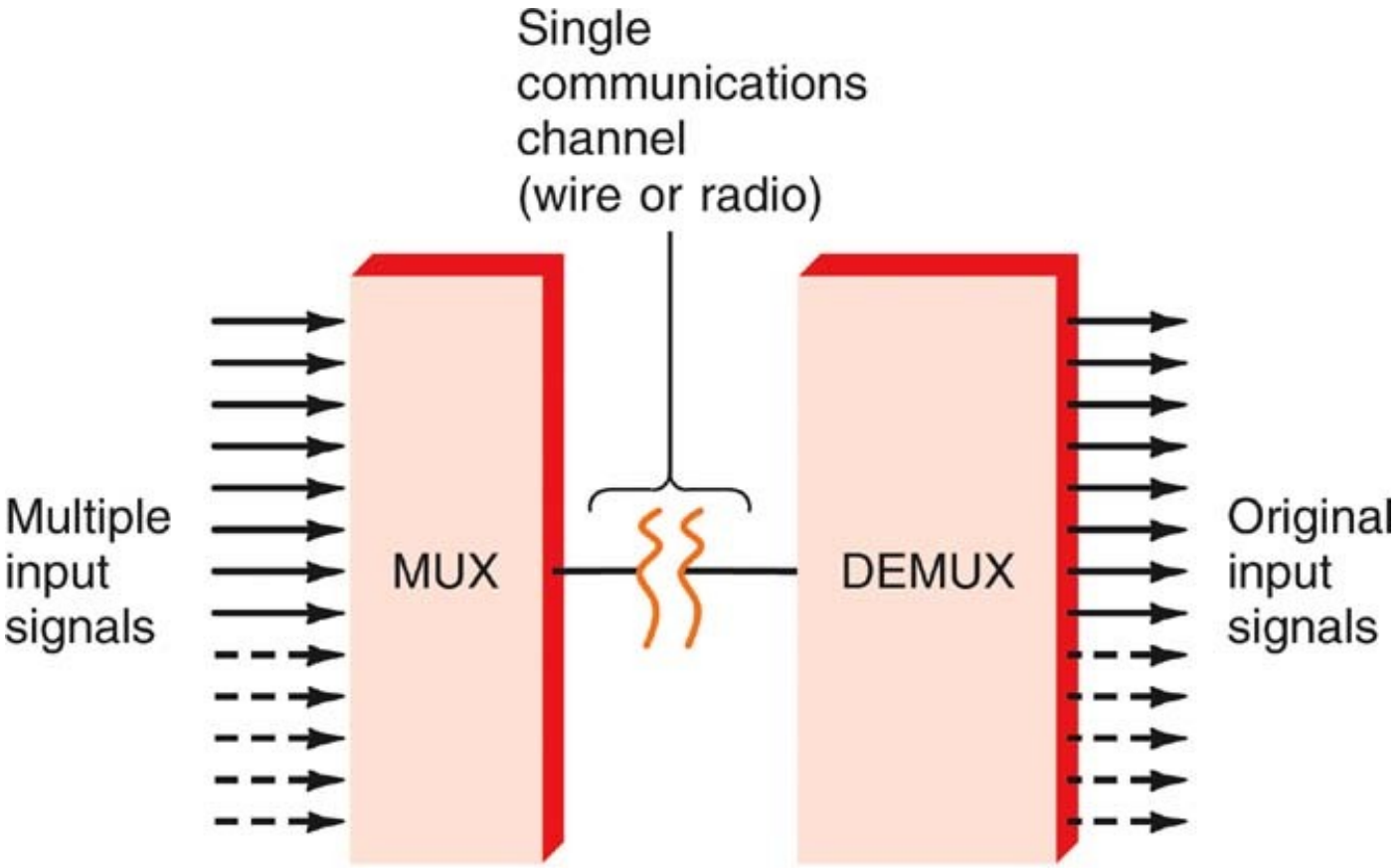
# Chapter 10
# Multiplexing and Demultiplexing

- Transmitting two or more signals simultaneously can be accomplished by setting up one transmitter-receiver pair for each channel, but this is an expensive approach.
- A single cable or radio link can handle multiple signals simultaneously using a technique known as **multiplexing**.
- Multiplexing permits hundreds or even thousands of signals to be combined and transmitted over a single medium.
- Cost savings can be gained by using a single channel to send multiple information signals.

# Fig. 10-1: Concept of multiplexing



# The two most common types of multiplexing

Frequency-division multiplexing (**FDM**)

- Generally used for analog information.
- Individual signals to be transmitted are assigned a different frequency within a common bandwidth.

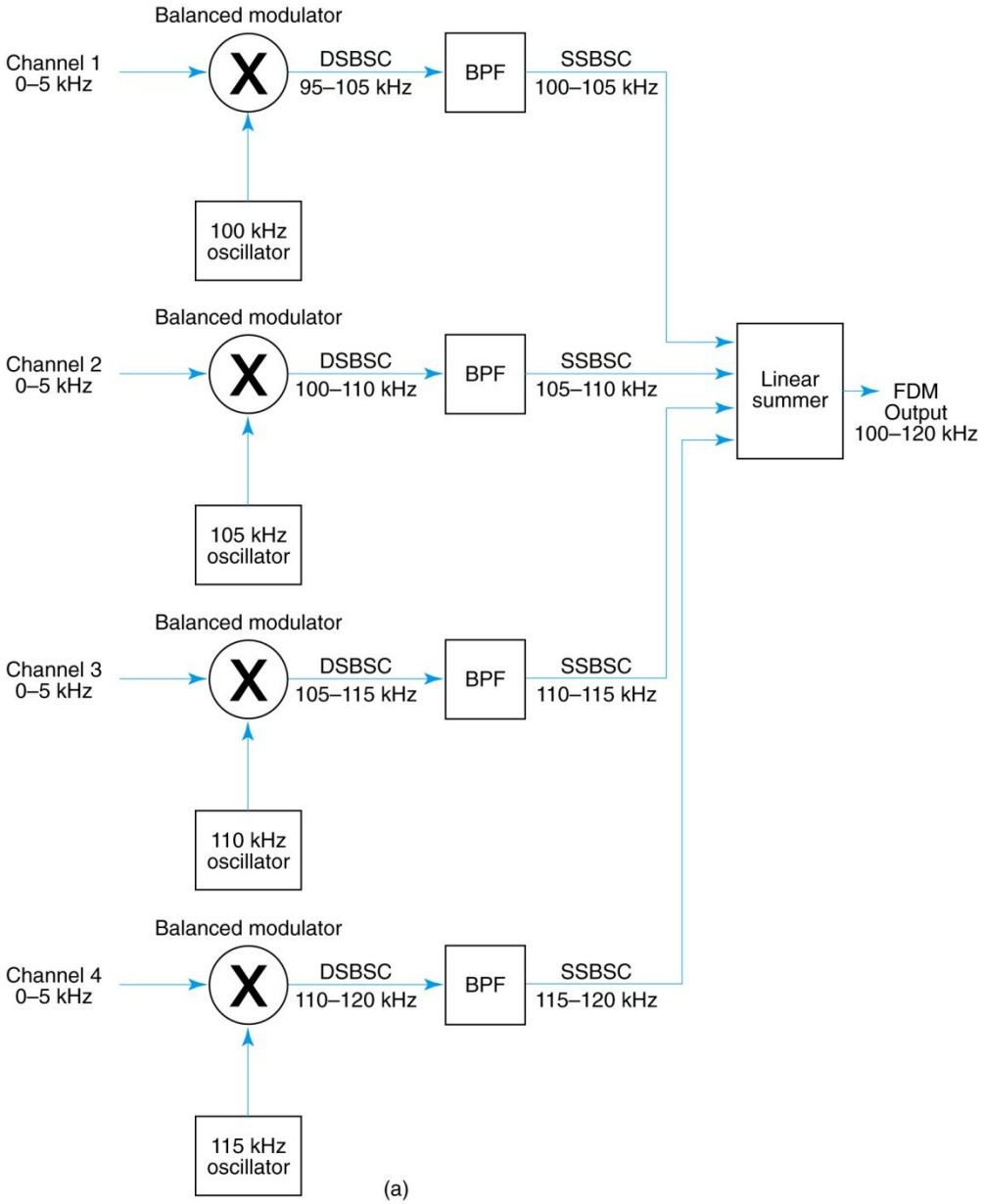
Time-division multiplexing (**TDM**)

- Generally used for digital information.
- Multiple signals are transmitted in different time slots on a single channel.

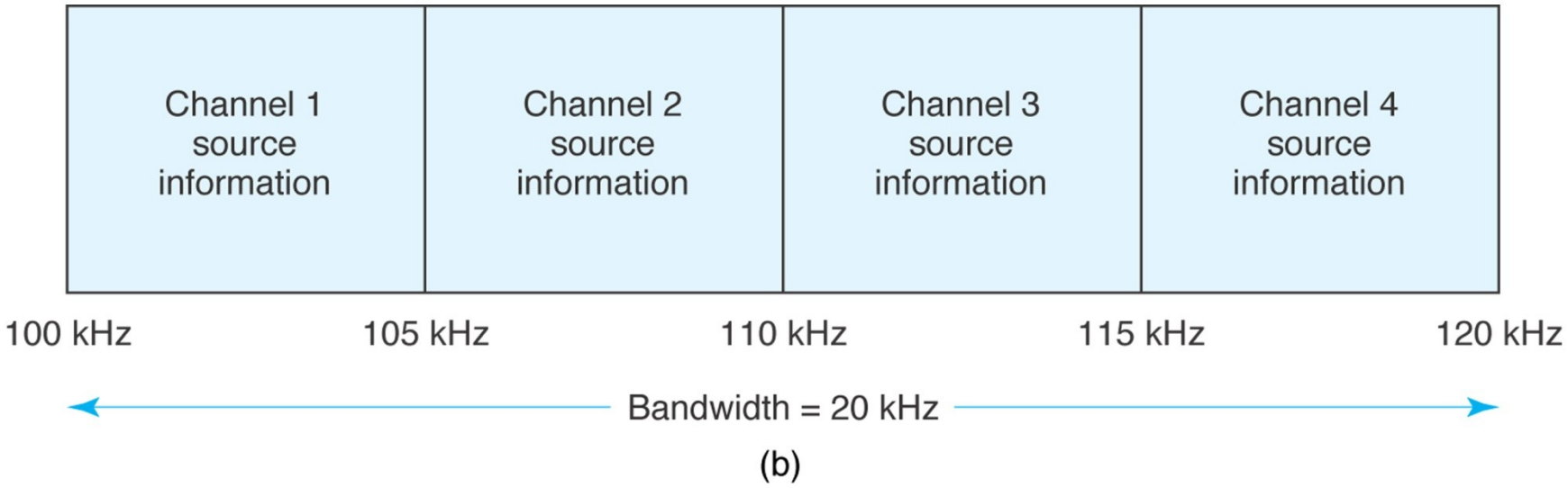
# Transmitter-Multiplexers

- In an FDM system, each signal to be transmitted feeds a modulator circuit.
- The carrier for each modulator ($f_c$) is on a different frequency.
- The carriers are equally spaced from one another.
- These carriers are referred to as **subcarriers**.
- Each input signal is given a portion of the bandwidth.

# FDM: (a) block diagram



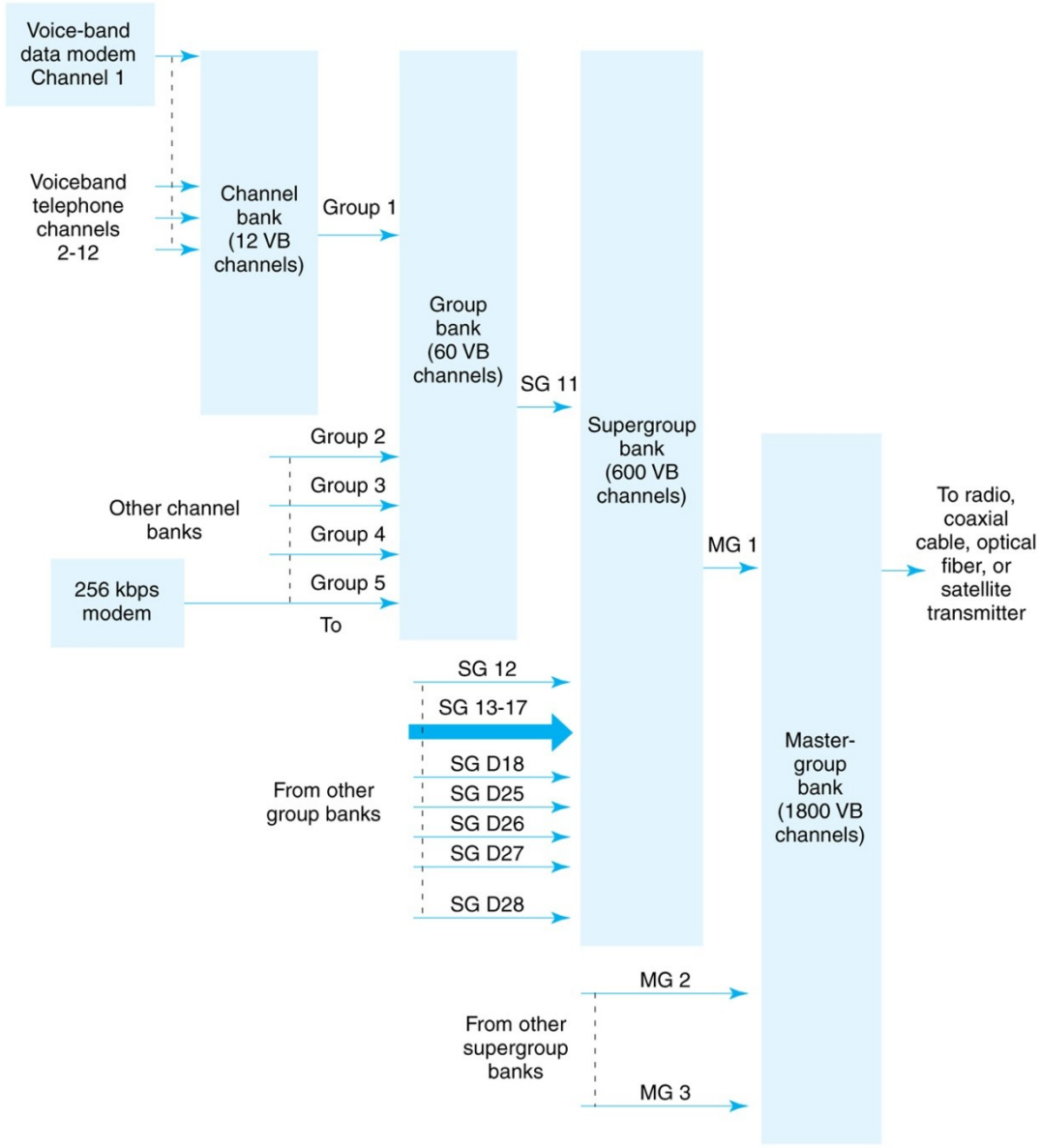
# FDM: (b) frequency spectrum



# Transmitter-Multiplexers

- The modulator outputs containing the sideband information are added algebraically in a linear mixer.
- The resulting output signal is a composite of all the modulated subcarriers.
- This signal can be used to modulate a radio transmitter, or can itself be transmitted over a single channel.
- The composite signal can also become one input to another multiplexed system.

# American Telephone & Telegraph Company's FDM hierarchy



# Example 10-1

A cable TV service uses a single coxial cable with a bandwidth of 860 MHz to transmit multiple TV signals to subscribers. Each TV signal is 6 MHz wide. How many channels can be carried?

Solution:
Total channels = *860/6 = 143.33 or 143*

# Time Division Multiplexing (TDM)

- In FDM, multiple signals are transmitted over a single channel, each signal being allocated a portion of the spectrum within that bandwidth.
- In **time-division multiplexing (TDM),** each signal occupies the entire bandwidth of the channel.
- Each signal is transmitted for only a brief period of time.

# Figure 10-14: Simple rotary-switch multiplexer

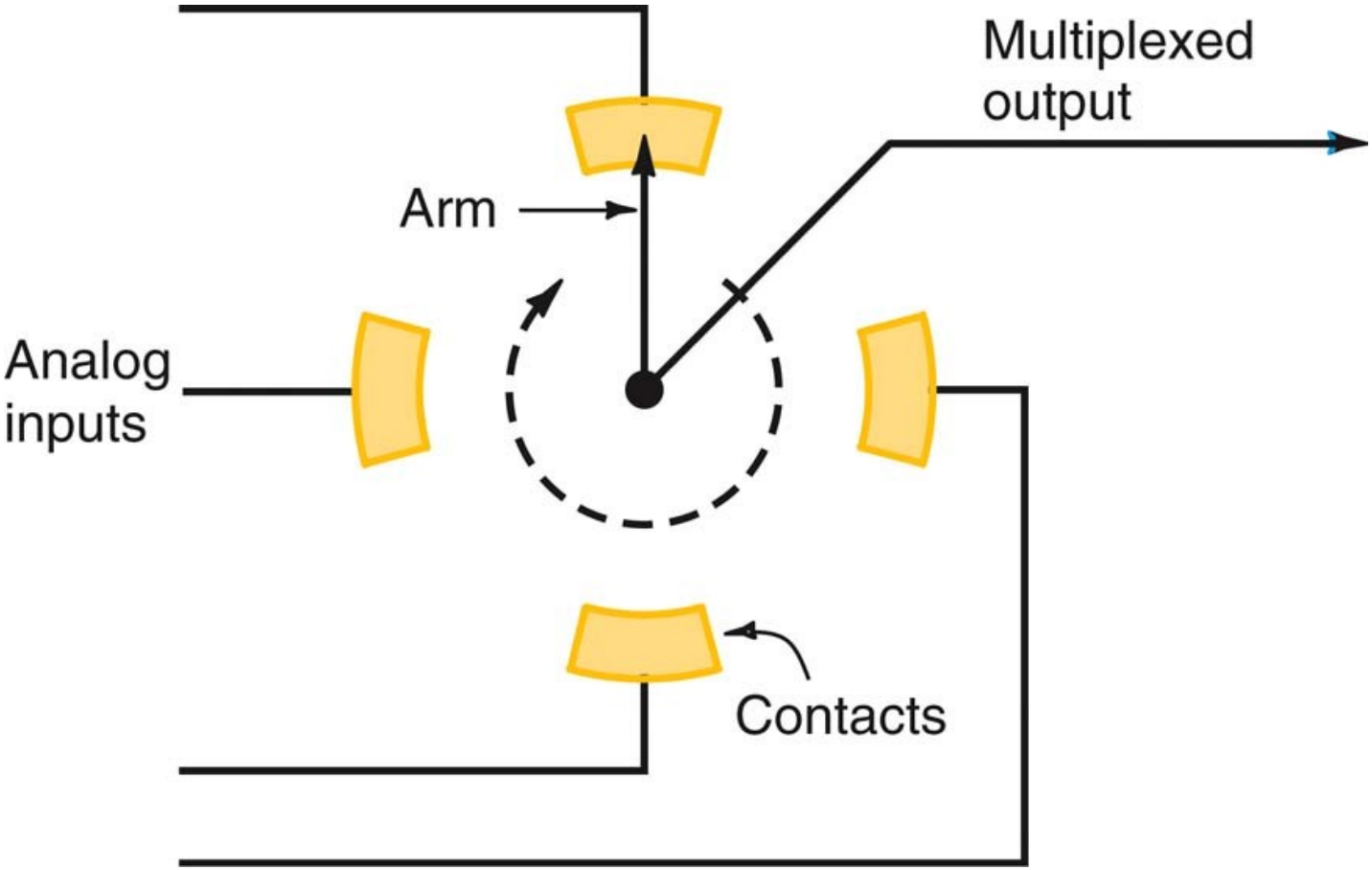


**FIGURE 11-1** Single-channel (DS-0-level) PCM transmission system

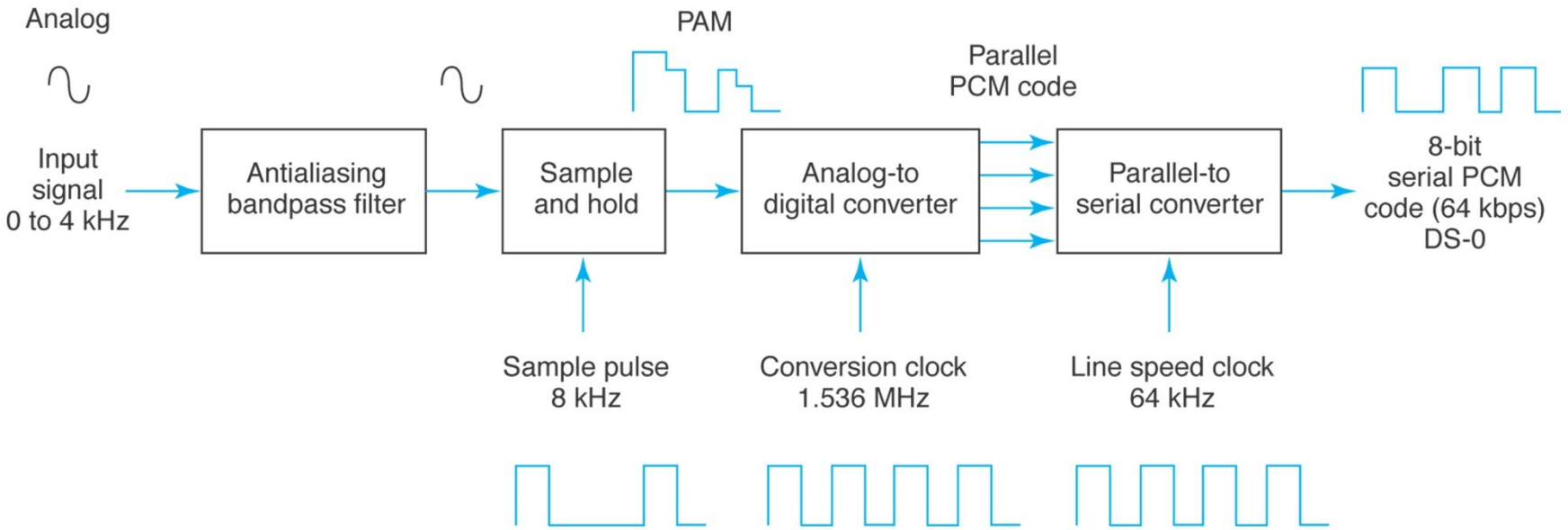
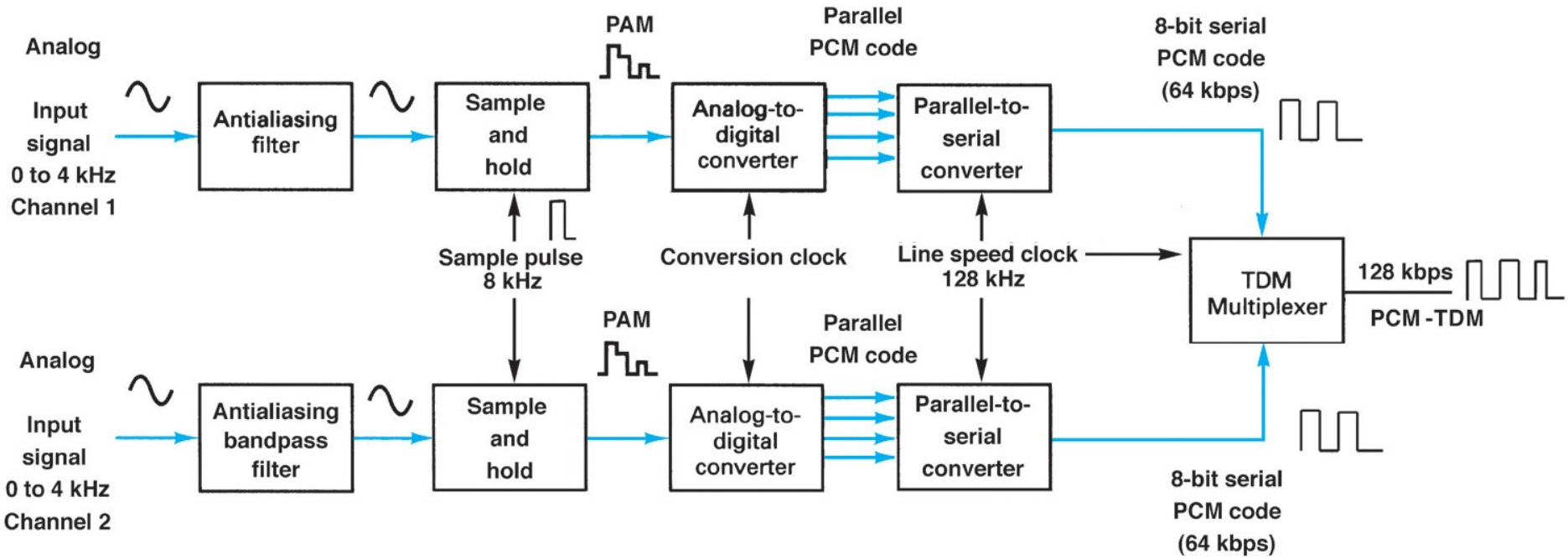
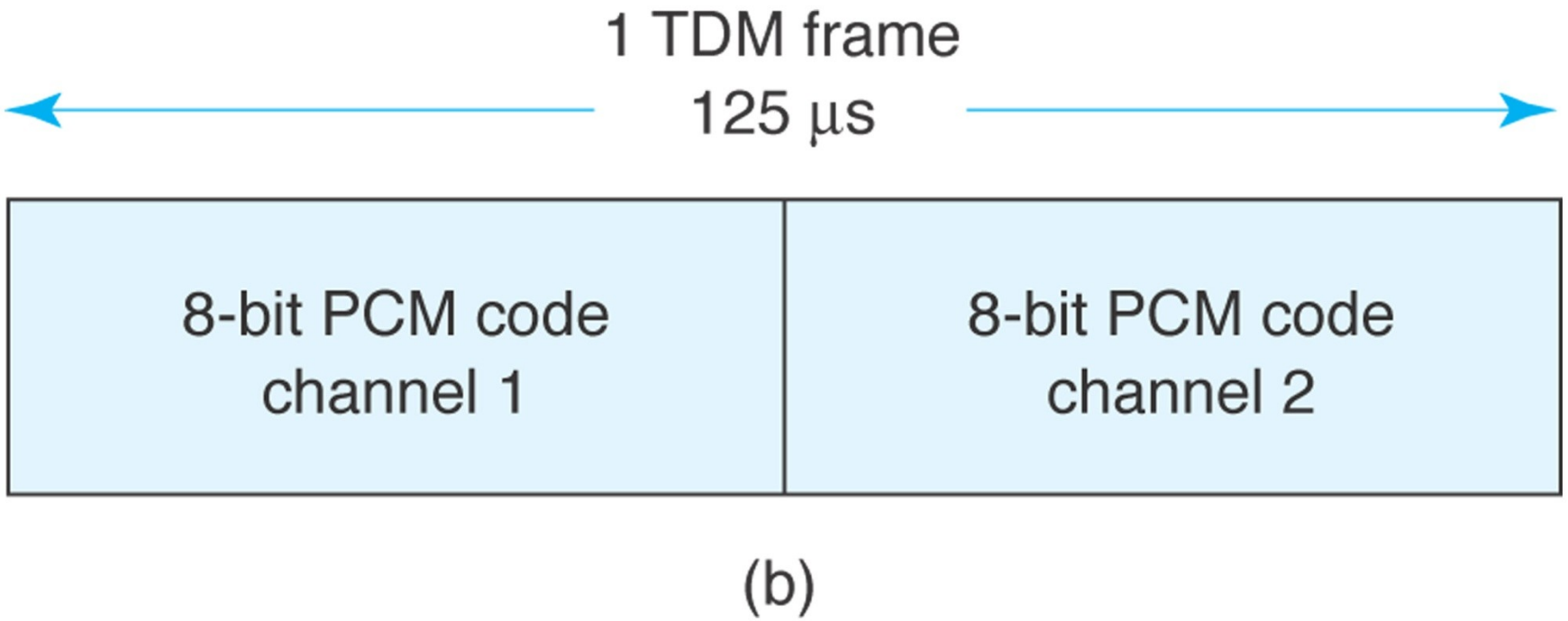


**FIGURE 11-2A** Two-channel PCM-TDM system: (a) block diagram; (b) TDM frame




(a)

**FIGURE 11-2B** Two-channel PCM-TDM system: (a) block diagram; (b) TDM frame



# Figure 10-12: The basic TDM concept

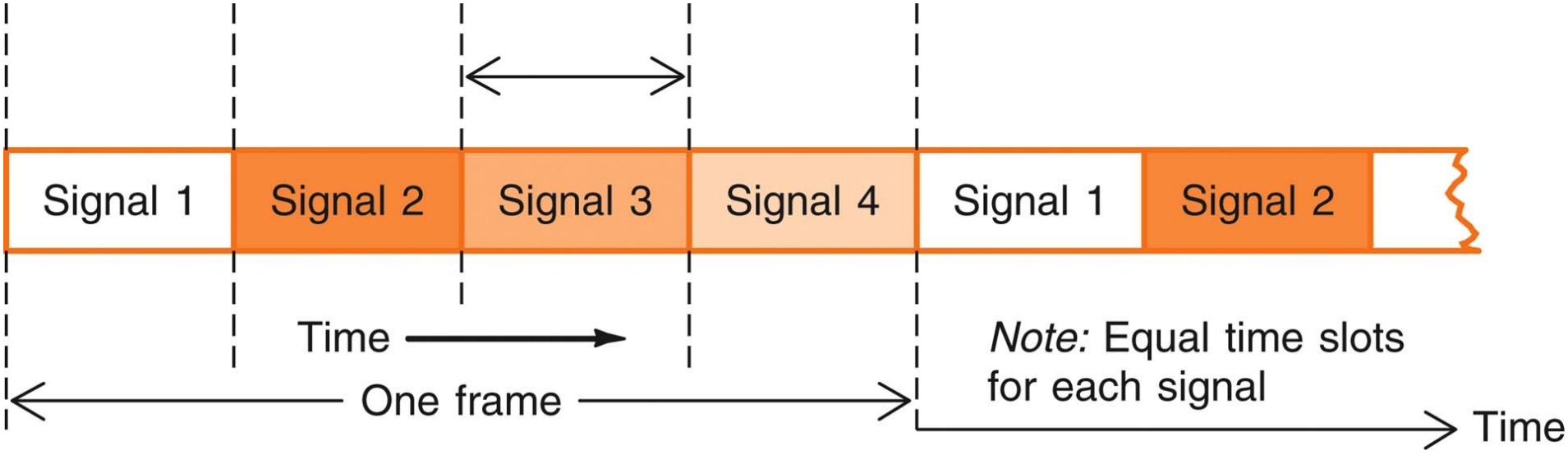
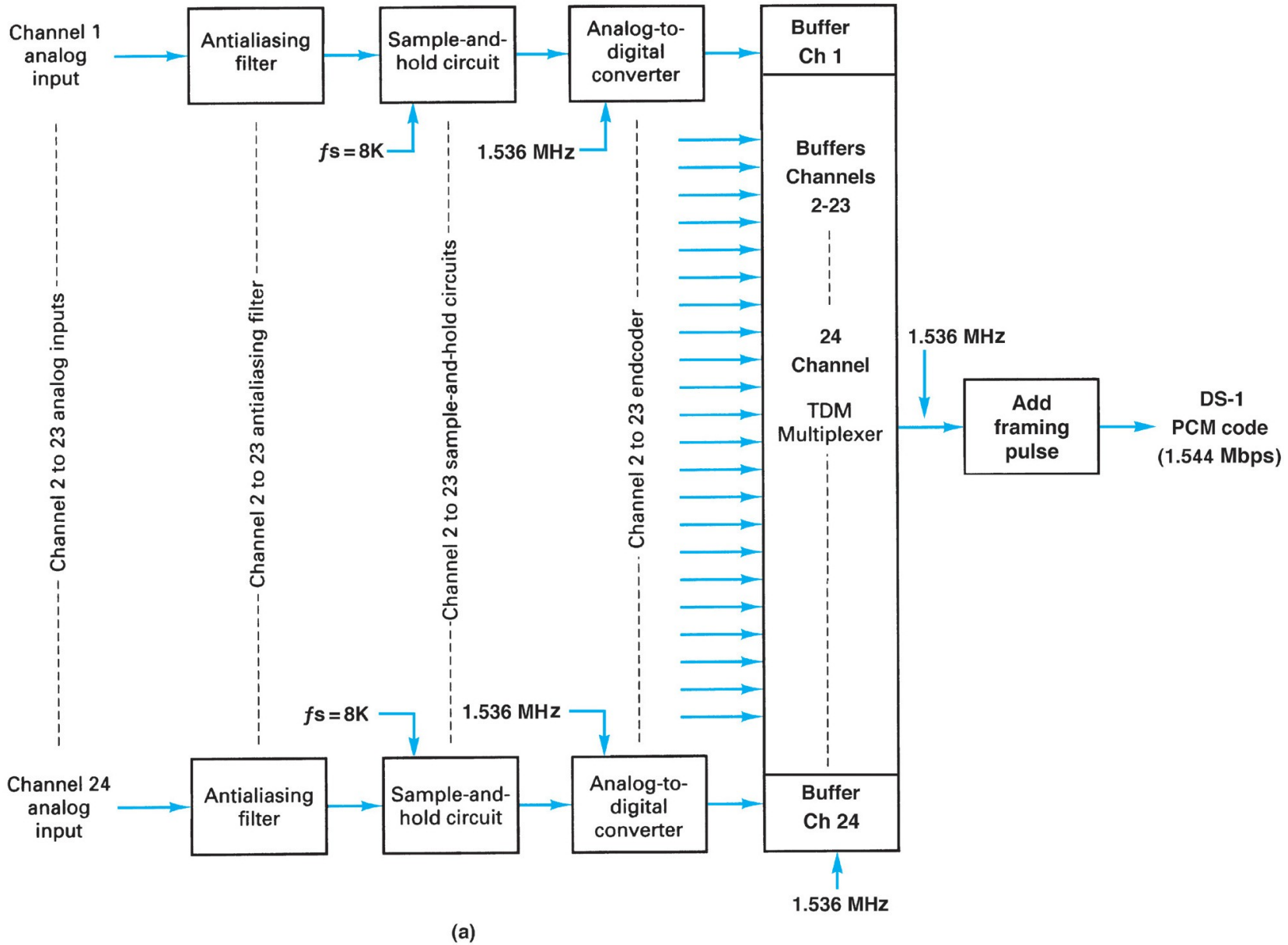
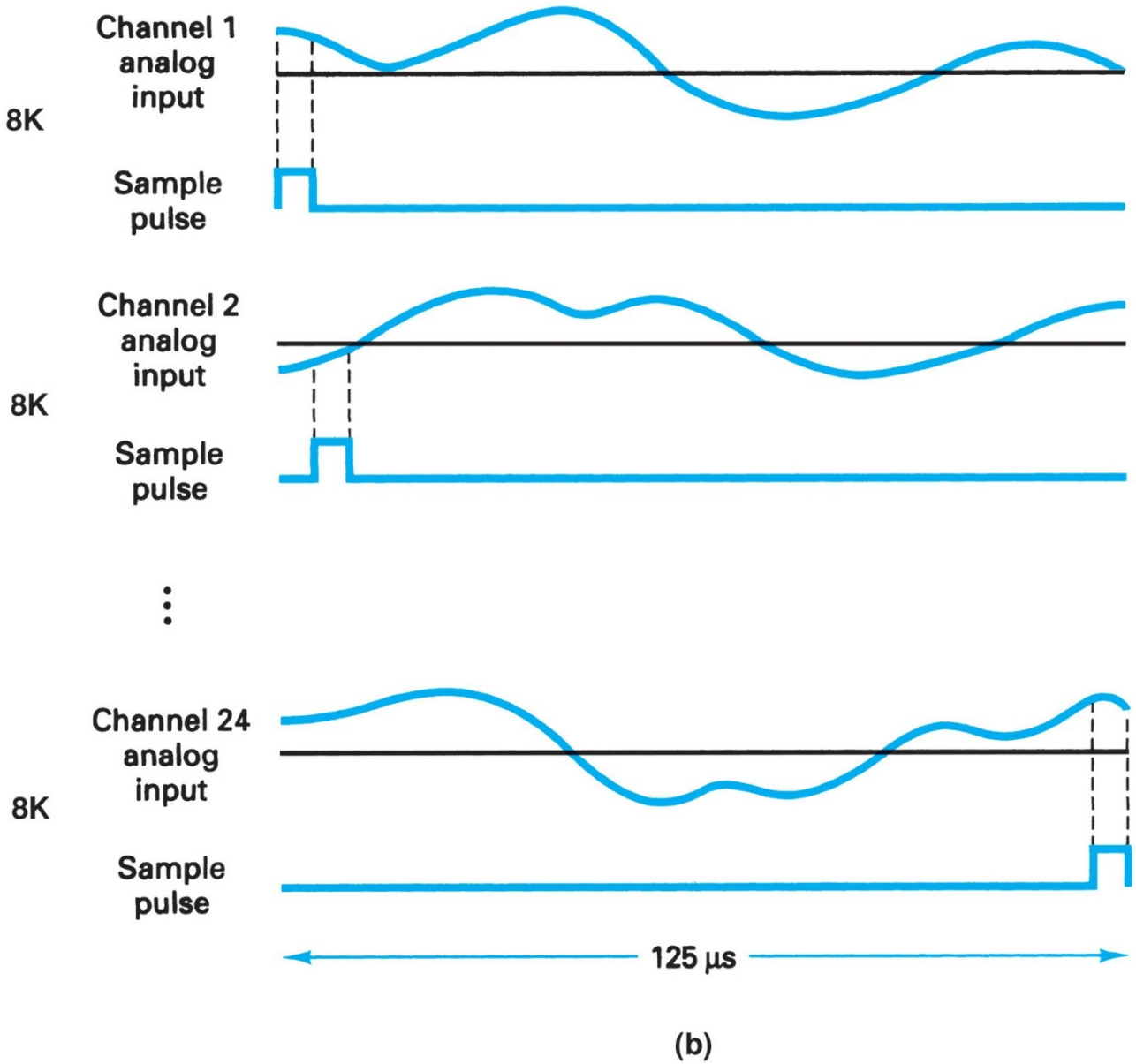


**FIGURE 11-3A** Bell system T1 digital carrier system: (a) block diagram; (b) sampling sequence



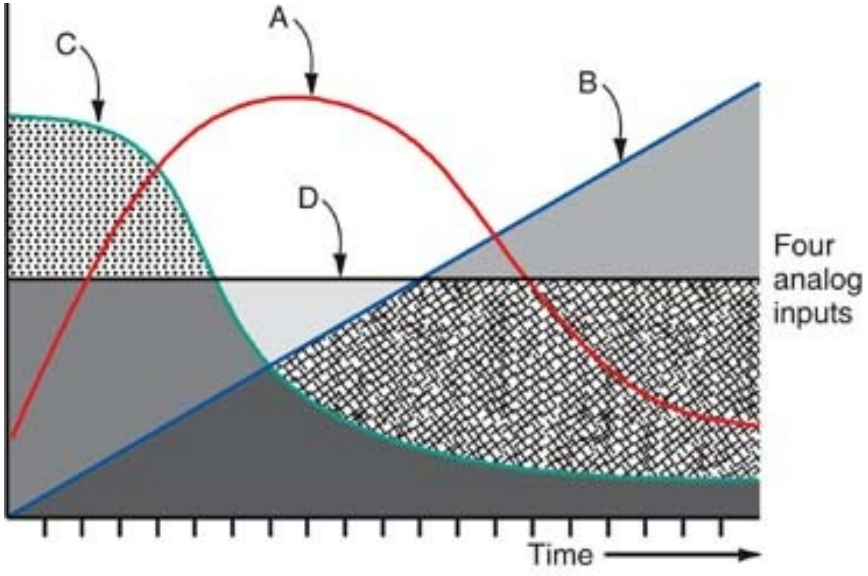

(a)

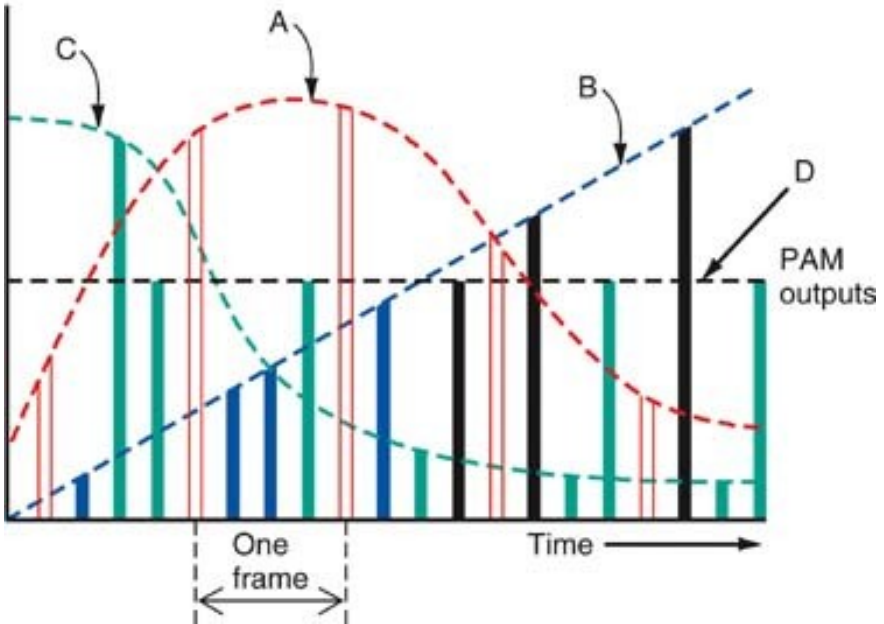
**FIGURE 11-3B** Bell system T1 digital carrier system: (a) block diagram; (b) sampling sequence



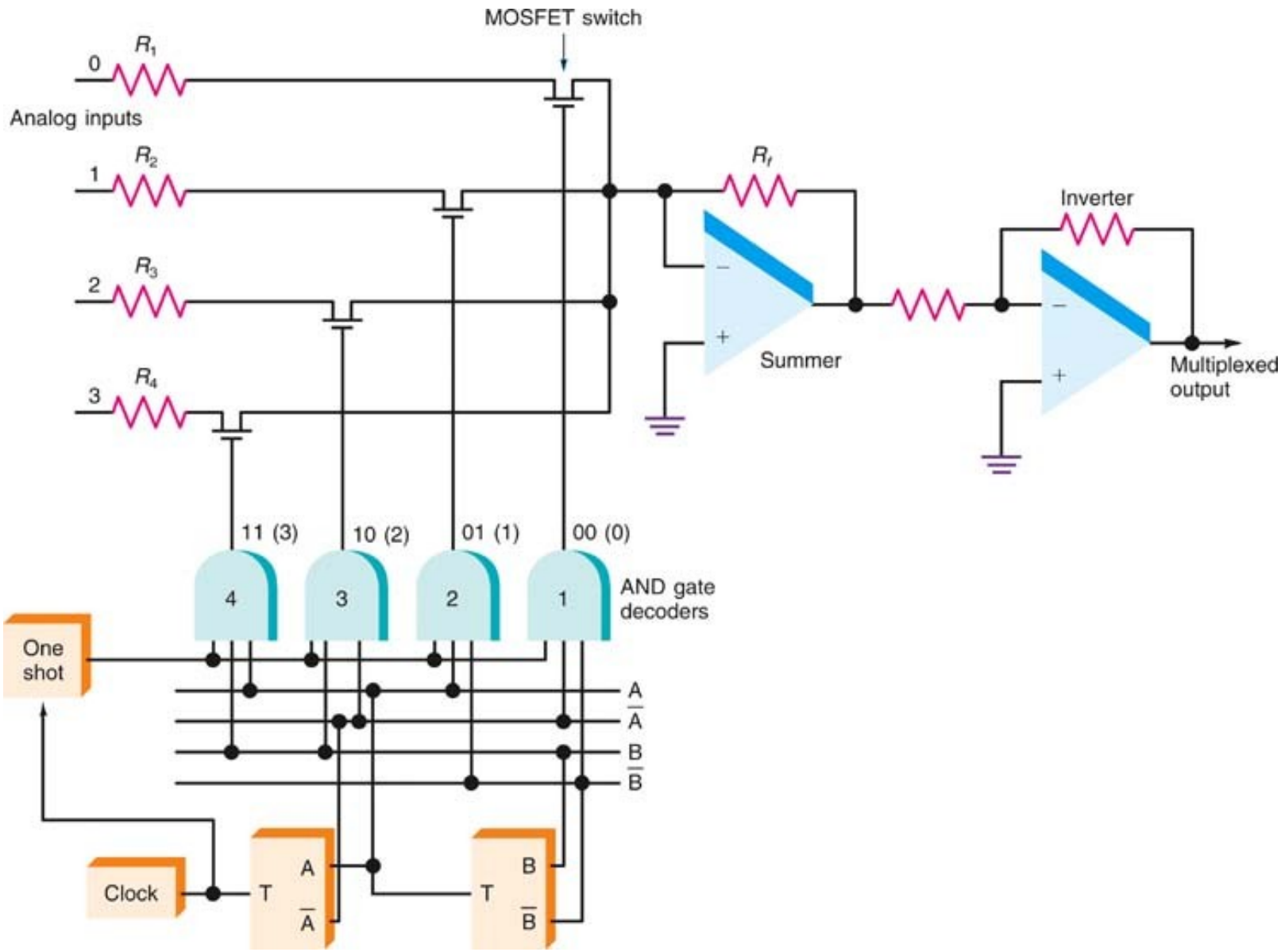
# Figure 10-15: Four-channel PAM time-division multiplexer

- Four different analog signals can be sampled by a PAM multiplexer.
  - Signals A and C are continuously varying analog signals.
  - Signal B is a positive-going linear ramp.
  - Signal D is a constant DC voltage.

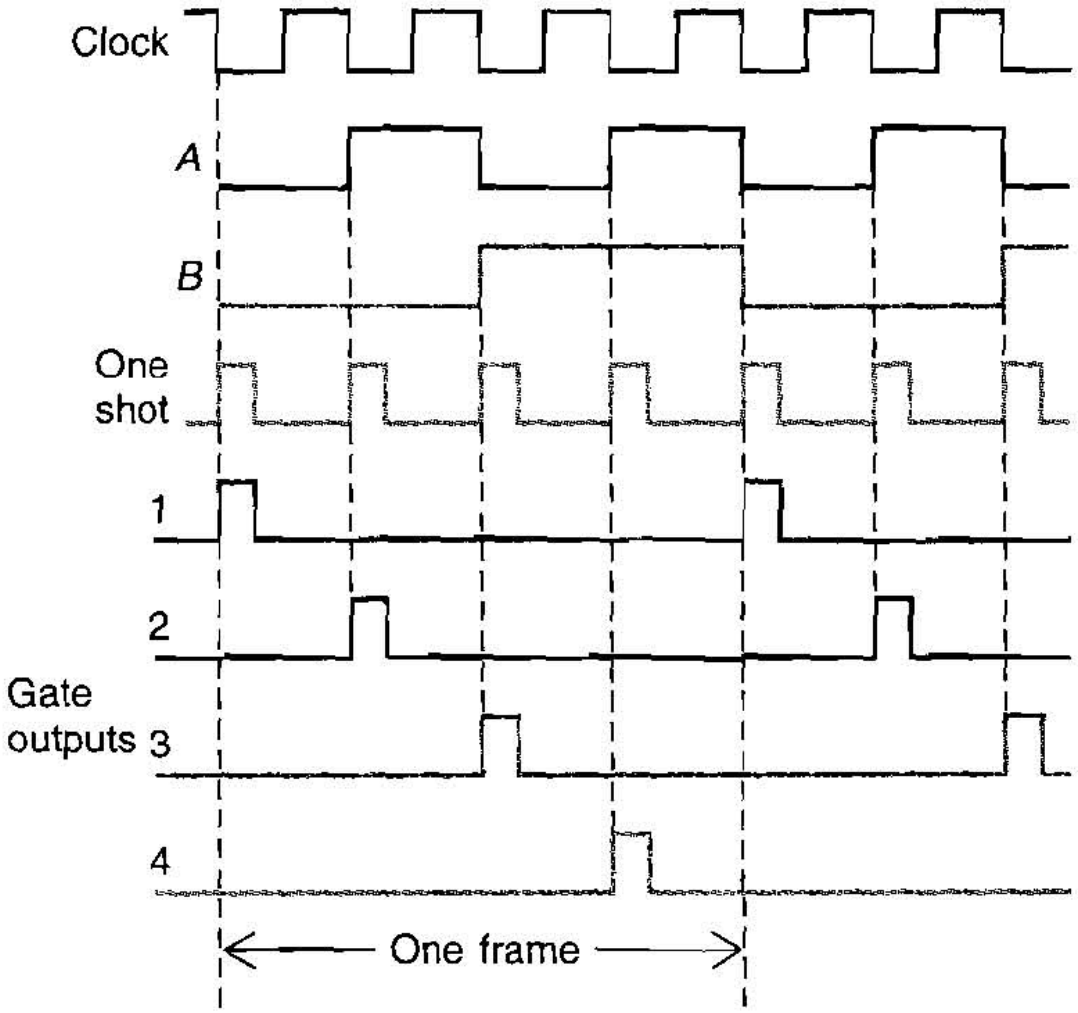


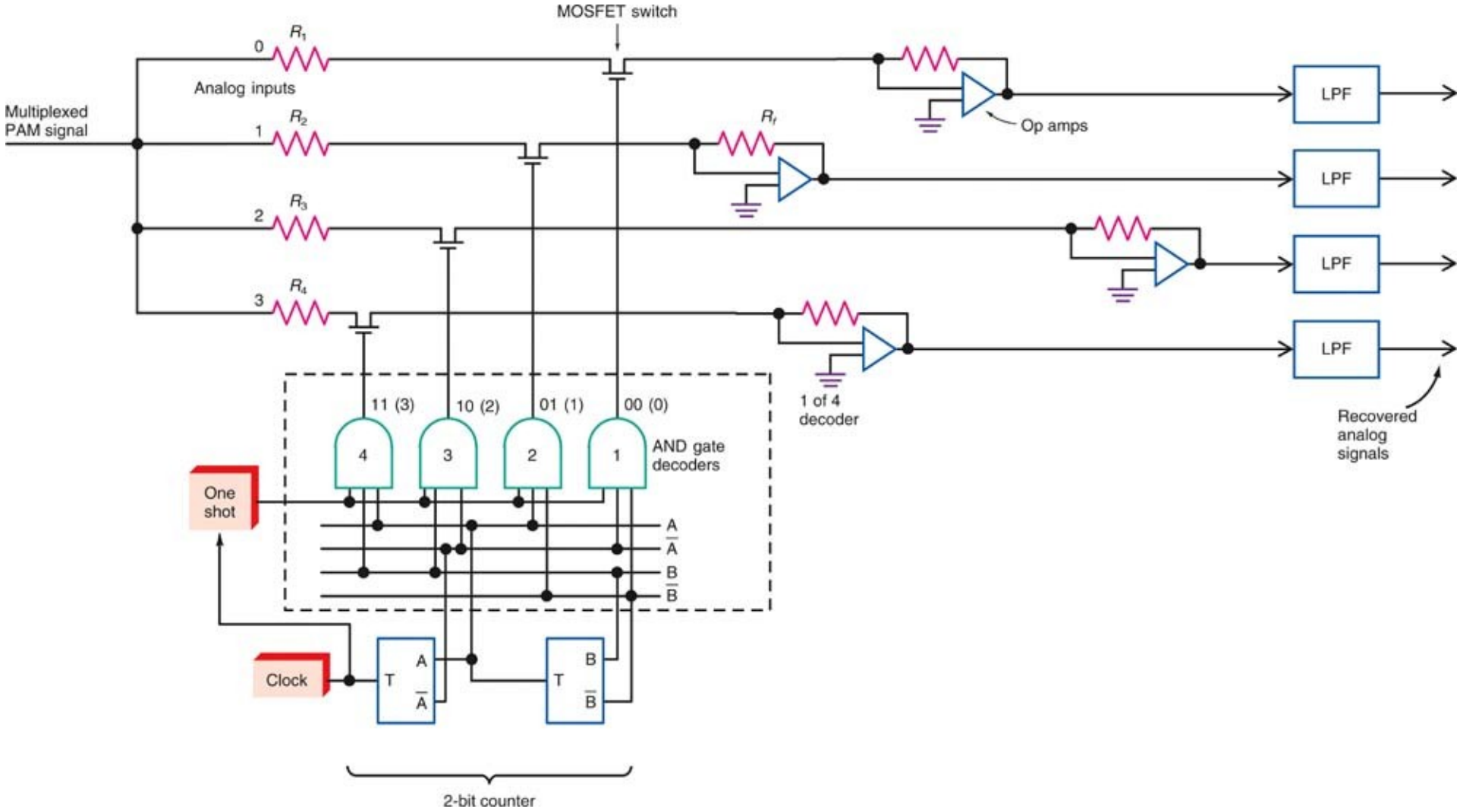
# Figure 10-16: A time-division multiplexer used to produce pulse-amplitude modulation



# Figure 10-17: Waveforms for a PAM multiplexer



# Figure 10-18: A PAM demultiplexer



**Example 10-2**

A special PCM system uses 16 channels of data, one whose purpose is identification (ID) and synchronization. The sampling rate is 3.5 kHz. The word length is 6 bits. Find *(a) the number of available data channels, (b) the number of bits per frame, and (c) the serial data rate.*

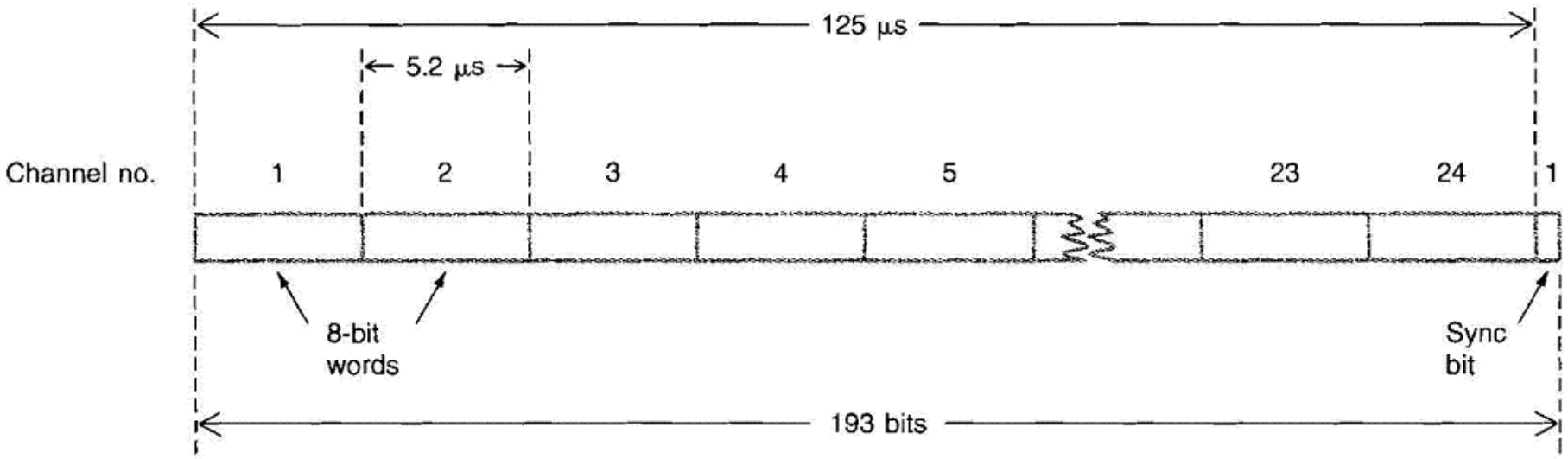
a. 16 (total no. of channels) -1 (channel used for ID) = 15 (for data)

b. Bits/frame = 6 X 16 = 96

c. Serial data rate = channels/frame x frames/s x bits/channel = 16 x 3.5kHz X 6 = 336 kHz

# Digital Carrier System

Figure 10-25 The T-1 frame format, serial data



# Figure 10-26 The T-carrier system