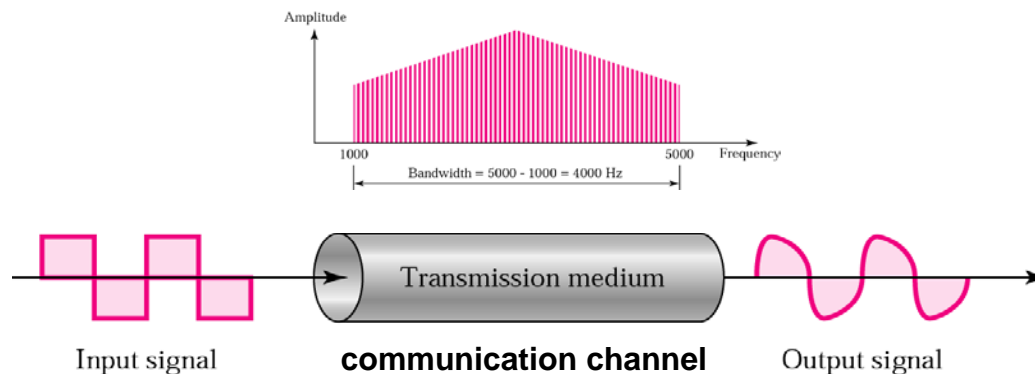


Composite Signals and Transmission Medium

– no transmission medium is perfect – each medium passes some frequencies and blocks or weakens others

- composite signal sent at one end of transmiss. medium (comm. channel), may not be received in the same form at the other end
- **passing a square wave through any medium will always deform the signal !!!**

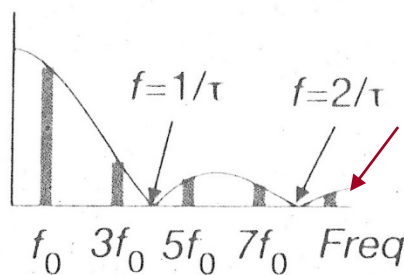
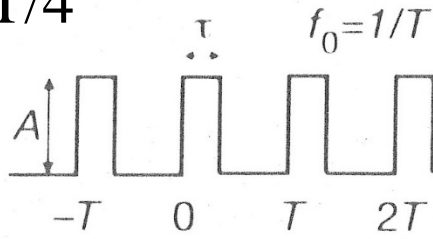


Channel Bandwidth

– range of frequencies passed by the channel – difference between highest and lowest frequency that channel can satisfactorily pass

Example [frequency spectrum of a data pulse]

$\tau = T/4$

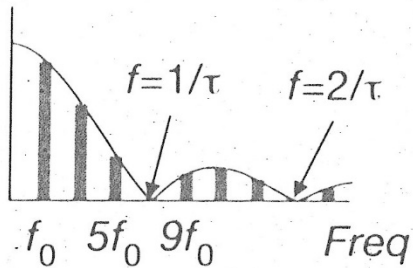
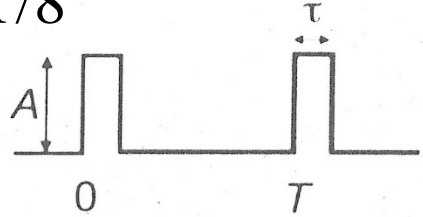


$$\left| \frac{2A\tau}{T} \cdot \frac{\sin(\pi\tau/T)}{\pi\tau/T} \right| \approx \boxed{\left| \frac{\sin(\pi \cdot f \cdot \tau)}{\pi \cdot f \cdot \tau} \right|} \text{ or } \left| \frac{\sin(x)}{x} \right|$$

zeros at $f = k/\tau$

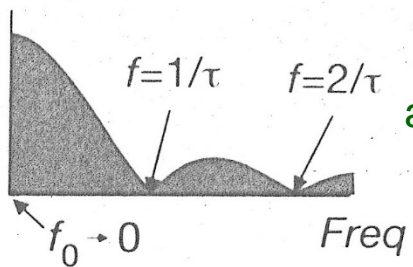
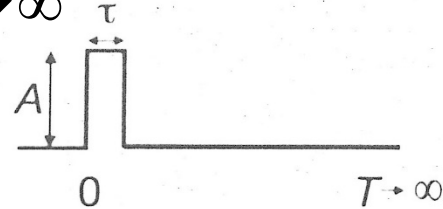
envelope of frequency spectrum

$\tau = T/8$



periodic signal \Rightarrow discrete freq. spectrum

$T \rightarrow \infty$



aperiodic signal \Rightarrow continuous freq. spectrum

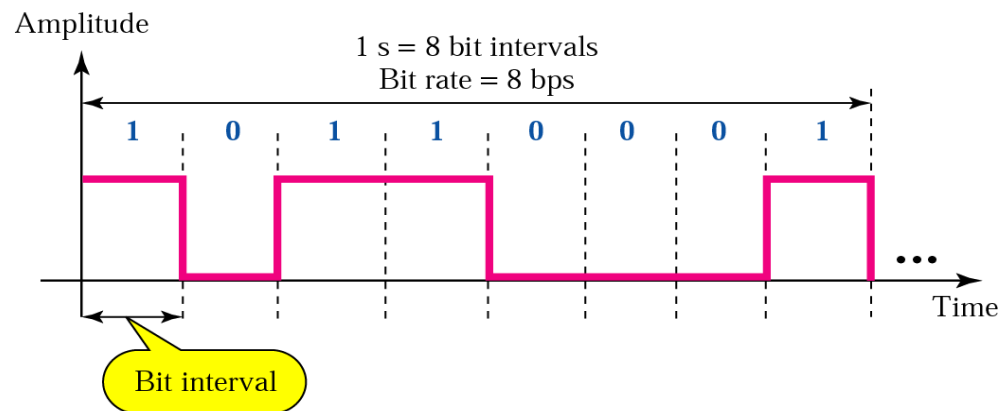
What happens if $\tau \rightarrow 0$???

- **Data vs. Signal**
- **Analog vs. Digital**
- **Analog Signals**
 - Simple Analog Signals
 - Composite Analog Signals
- **Digital Signals**

Digital Signals

Digital Signals – sequence of voltage pulses (DC levels) – each pulse represents a *signal element*

- binary data are transmitted using only 2 types of signal elements (1 = positive voltage, 0 = negative voltage)
- key digital-signals terms:
 - **bit interval** – time required to send a single bit, unit: [sec]
 - **bit rate** – number of bit intervals per second – unit: [bps]

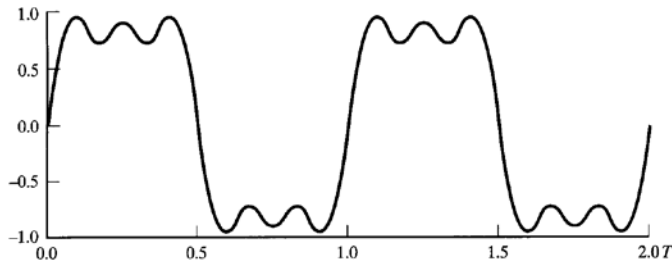


**Most digital signals are aperiodic,
so it is not appropriate / correct to talk about their period.**

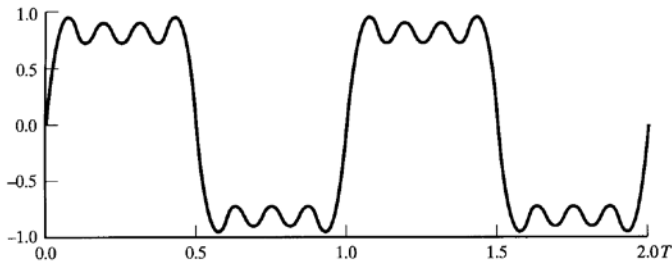
Digital Signal as a Composite Analog Signal

– digital signal, with all its sudden changes, is actually a composite signal having an infinite number of frequencies

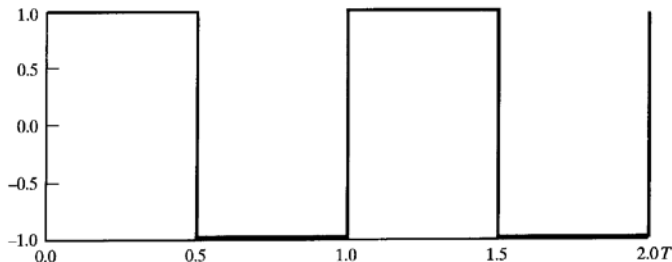
- a digital signal is a composite signal with an infinite bandwidth
- if a medium has a wide bandwidth, a digital signal can be sent through it
 - some frequencies will be weakened or blocked; still, enough frequencies will be passed to preserve a decent signal shape
- what is the minimum required bandwidth B [Hz] of a band-limited medium if we want to send n [bps]?



$$(a) \sin(2\pi f_1 t) + \frac{1}{3} \sin[2\pi(3f_1)t] + \frac{1}{5} \sin[2\pi(5f_1)t]$$



$$(b) \sin(2\pi f_1 t) + \frac{1}{3} \sin[2\pi(3f_1)t] + \frac{1}{5} \sin[2\pi(5f_1)t] + \frac{1}{7} \sin[2\pi(7f_1)t]$$



$$(c) \sum(1/k) \sin[2\pi(kf_1)t]$$

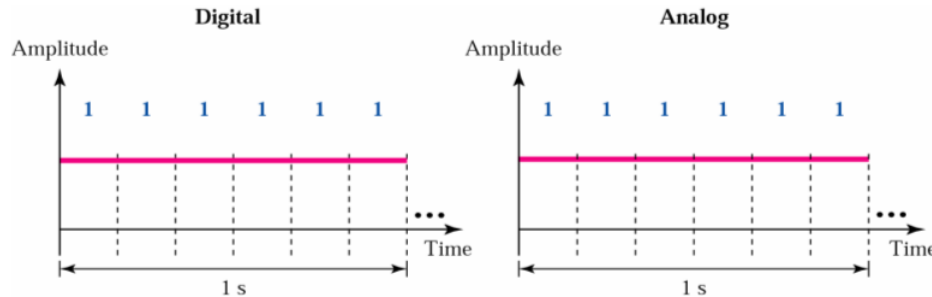
FIGURE 4.6 Frequency Components of a Square Wave ($T = 1/f_1$).

Example [approximation of digital signal's spectrum using 1st harmonic]

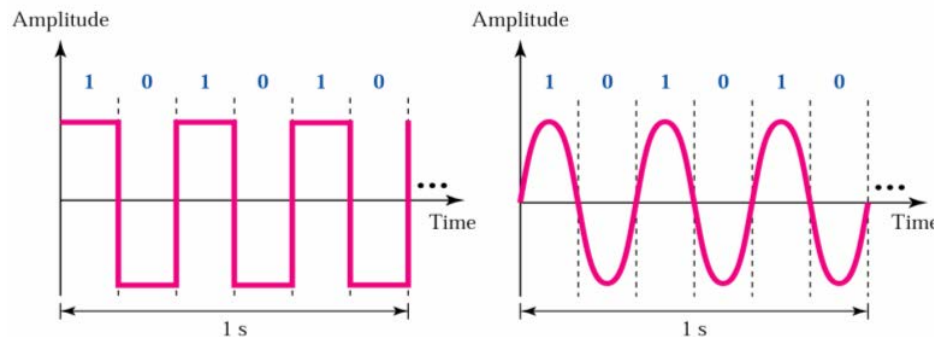
Assume our computer generates 6 bps.

Possibilities (periodic combinations) : 000000, 111111, 110011, 101010 etc.

1. Best case: min # of changes \Rightarrow min freq. of substitute analog signal



2. Worst case – max # of changes \Rightarrow max freq. of substitute analog signal



bit rate: $n = 6$ [bps]
 frequency: $B = 3$ [Hz]

$$B \approx \frac{n}{2}$$

Exercise

1. Before data can be transmitted, they must be transformed to _____.
 - (a) periodic signals
 - (b) electromagnetic signals
 - (c) aperiodic signals
 - (d) low-frequency sinewaves

2. In a frequency-domain plot, the vertical axis measures the _____.
 - (a) peak amplitude
 - (b) frequency
 - (c) phase
 - (d) slope

3. In a time-domain plot, the vertical axis measures the _____.
 - (a) peak amplitude
 - (b) amplitude
 - (c) frequency
 - (d) time

4. If the bandwidth of a signal is 5 KHz and the lowest frequency is 52 KHz, what is the highest frequency _____.
 - (a) 5 KHz
 - (b) 10 KHz
 - (c) 47 KHz
 - (d) 57 KHz

Exercise

5. If one of the components of a signal has a frequency of zero, the average amplitude of the signal _____.
- (a) is greater than zero
 - (b) is less than zero
 - (c) is zero
 - (d) (a) or (b)
6. Give two sinewaves A and B, if the frequency of A is twice that of B, then the period of B is _____ that of A.
- (a) one-half
 - (b) twice
 - (c) the same as
 - (d) indeterminate from
7. A device is sending out data at the rate of 1000 bps.
- (a) How long does it take to send out 10 bits?
 - (b) How long does it take to send out a single character (8 bits)?
 - (c) How long does it take to send a file of 100,000 characters?