Fundamentals of Electrical Engineering

Digital Communication

- Bit transmission schemes
- Transmission bandwidth

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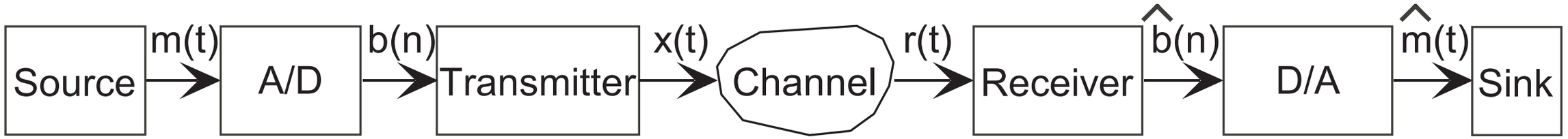
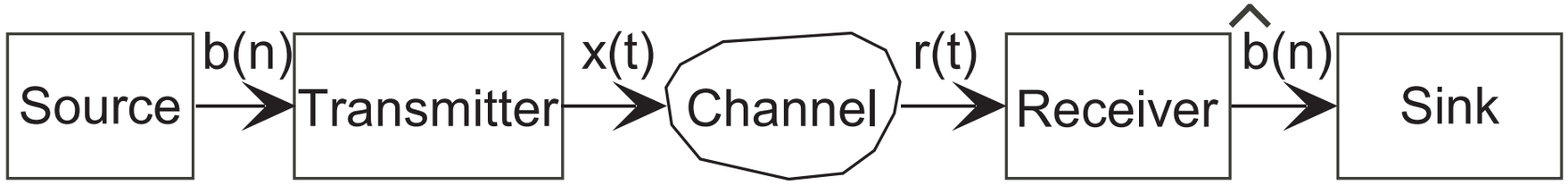
Digital Communication Model

Analog message



Digital message



(Almost) *all* channels for digital communication are analog

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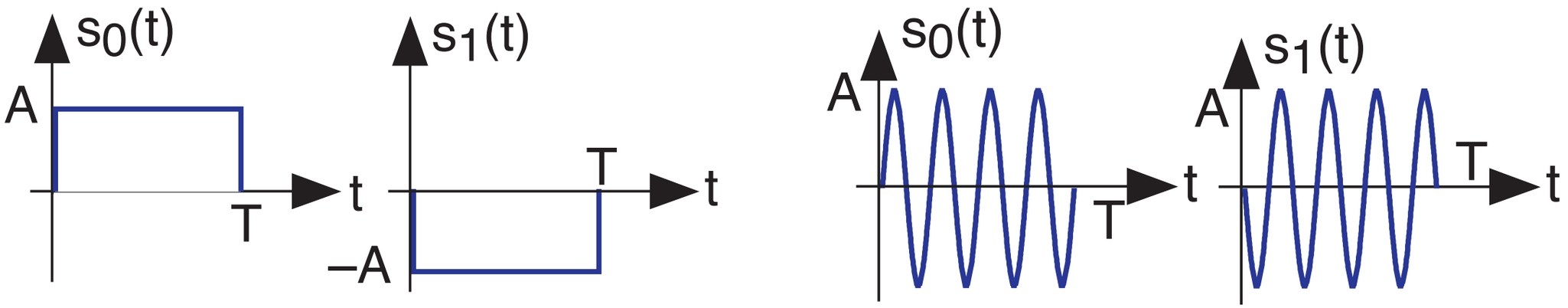
Signal Set Design

Assign a signal to each bit value, forming a *signal set*

Binary Phase Shift Keying (BPSK)



baseband modulated

$$s_1(t) = -s_0(t)$$

T - bit interval (time taken to transmit a bit)

Datarate $R = 1/T$ bits/s

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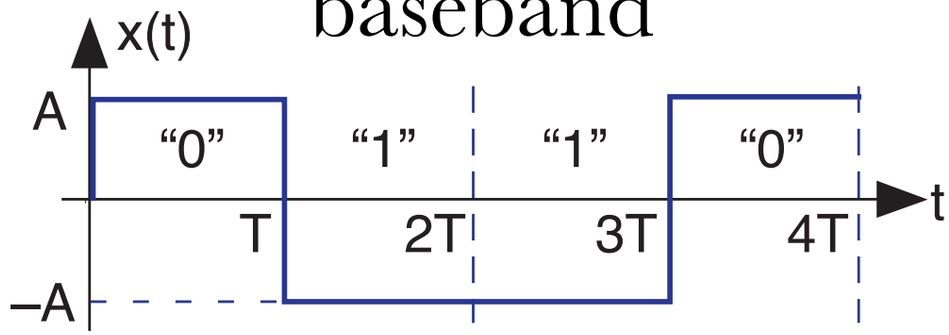
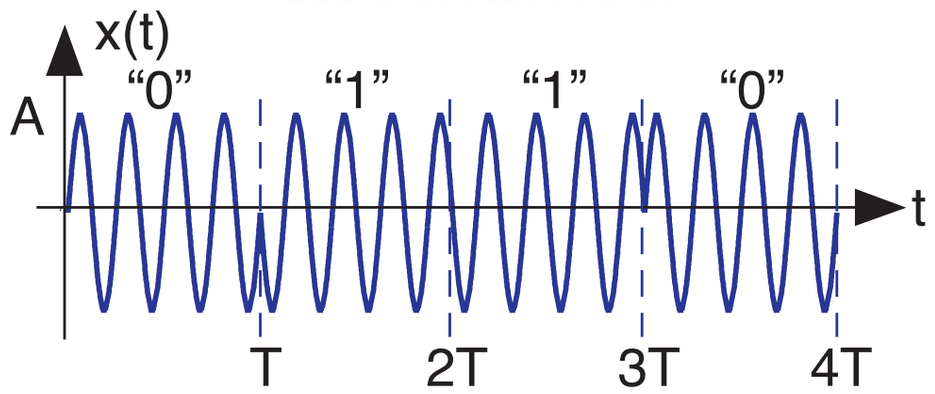
Digital Transmission (BPSK)

baseband



modulated

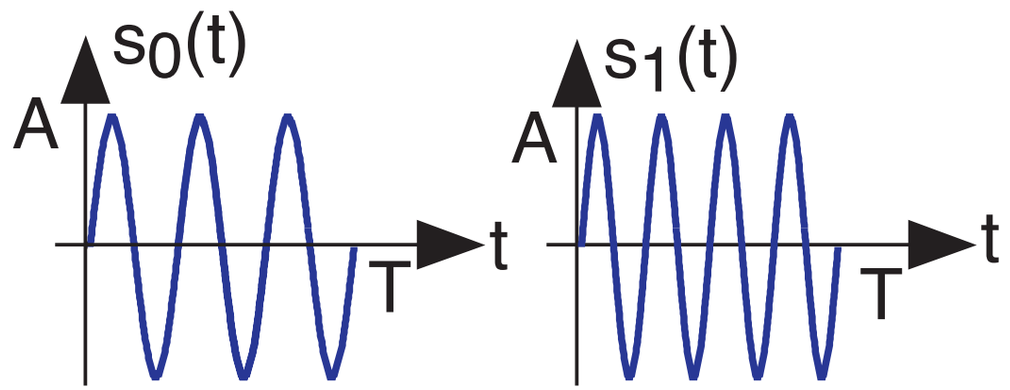


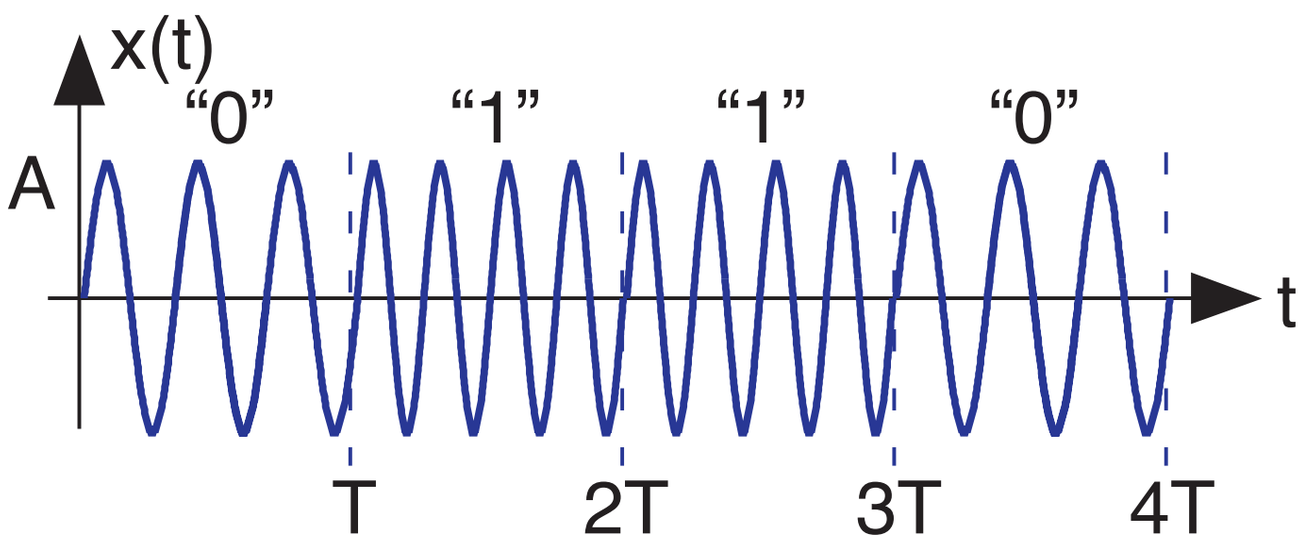
Another Signal Set

Frequency-Shift Keying (FSK)

$$s_0(t) = A p_T(t) \sin 2\pi f_0 t$$

$$s_1(t) = A p_T(t) \sin 2\pi f_1 t$$





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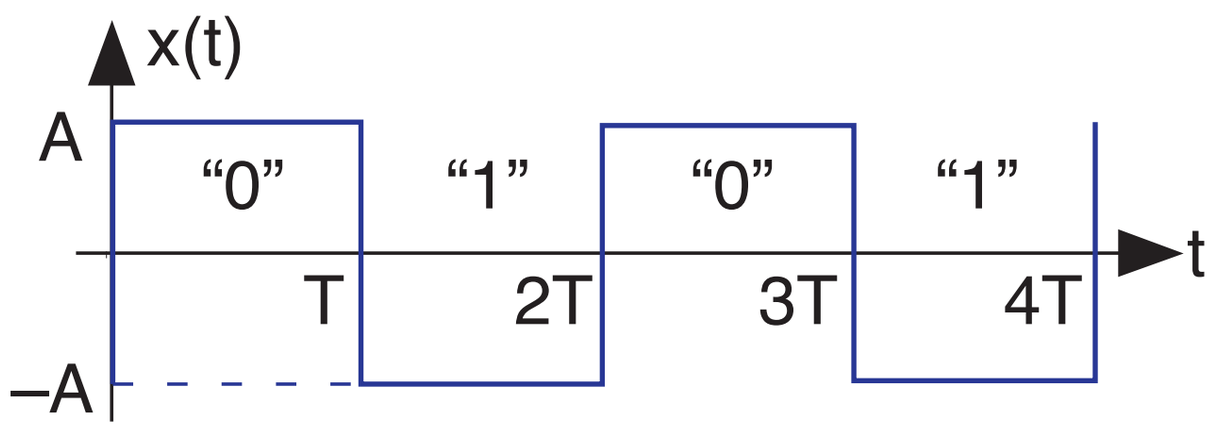
Transmission Bandwidth

- Bandwidth depends on the bit sequence
- What's the worst case bit sequence?



- Spectrum given by Fourier series

$$c_k = \begin{cases} \frac{2}{j\pi k} & k \text{ odd} \\ 0 & k \text{ even} \end{cases} \qquad f_k = \frac{k}{2T}$$

Transmission Bandwidth

Use 90% bandwidth

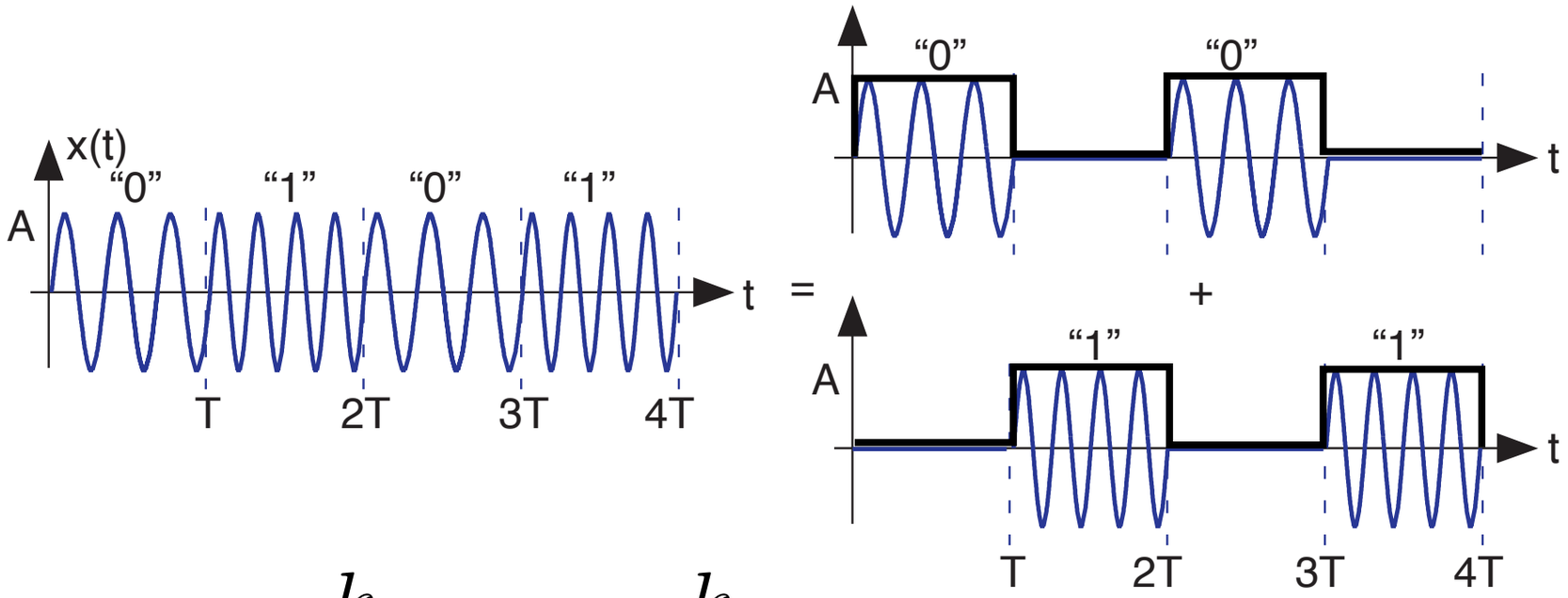
$$\max_K \frac{|c_0|^2 + 2\sum_{k=1}^{K} |c_k|^2}{|c_0|^2 + 2\sum_{k=1}^{\infty} |c_k|^2} \leq 0.90$$

For BPSK, $K = 3$

Baseband BPSK, bandwidth $= \frac{3}{2T} = \frac{3}{2}R$

Modulated BPSK, bandwidth $= \frac{3}{T} = 3R$

Transmission Bandwidth (FSK)



Assume $f_0 = \dfrac{k_0}{T},\ f_1 = \dfrac{k_1}{T}$

Because $c_0 \neq 0,\ 90\%$ bandwidth occurs for $K = 1$

$$\text{lowest frequency } = f_0 - \frac{1}{2T} = \frac{k_0 - \frac{1}{2}}{T}$$

$$\text{highest frequency } = f_1 + \frac{1}{2T} = \frac{k_1 + \frac{1}{2}}{T}$$

$$\implies \text{bandwidth } = f_1 - f_0 + \frac{1}{T} = \frac{k_1 - k_0 + 1}{T} = (k_1 - k_0 + 1)R$$

Transmission Bandwidth

- BPSK: bandwidth (modulated) = $3R$
- FSK: if $k_1 = k_0+1$, bandwidth = $2R$

Digital Communication

- Assign a signal set

$$\begin{aligned} \text{“0”} &\longleftrightarrow s_0(t) \\ \text{“1”} &\longleftrightarrow s_1(t) \end{aligned} \qquad 0 \le t < T$$

- Datarate determined by source *and* channel

- Signal set choice affects…
  - ✴ bandwidth
  - ✴ reception performance

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