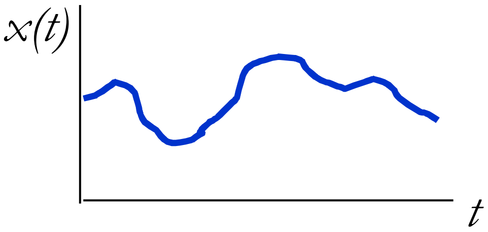
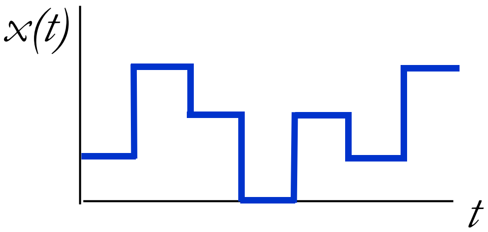
Digital Data Transmission

Analog vs. Digital

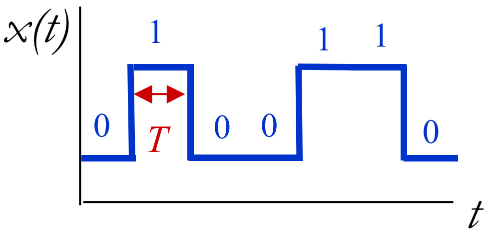
- **Analog signals**
  - **Value varies continuously**



- **Digital signals**
  - **Value limited to a finite set**



- **Binary signals**
  - **Has at most 2 values**
  - **Used to represent bit values**
  - **Bit time *T* needed to send 1 bit**
  - **Data rate *R=1/T* bits per second**



Information Representation

- Communication systems convert information into a form suitable for transmission
- Analog systems→Analog signals are modulated (AM, FM radio)
- Digital system generate bits and transmit digital signals (Computers)
- Analog signals can be converted to digital signals.

Digital Data System

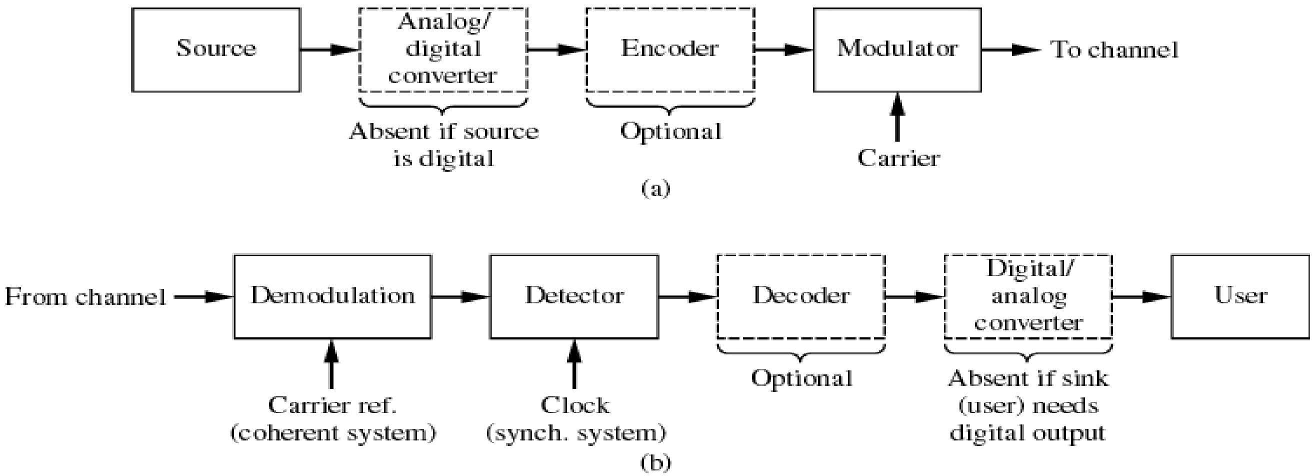


Figure 7-1 Block diagram of a digital data system. (a) Transmitter. (b) Receiver.

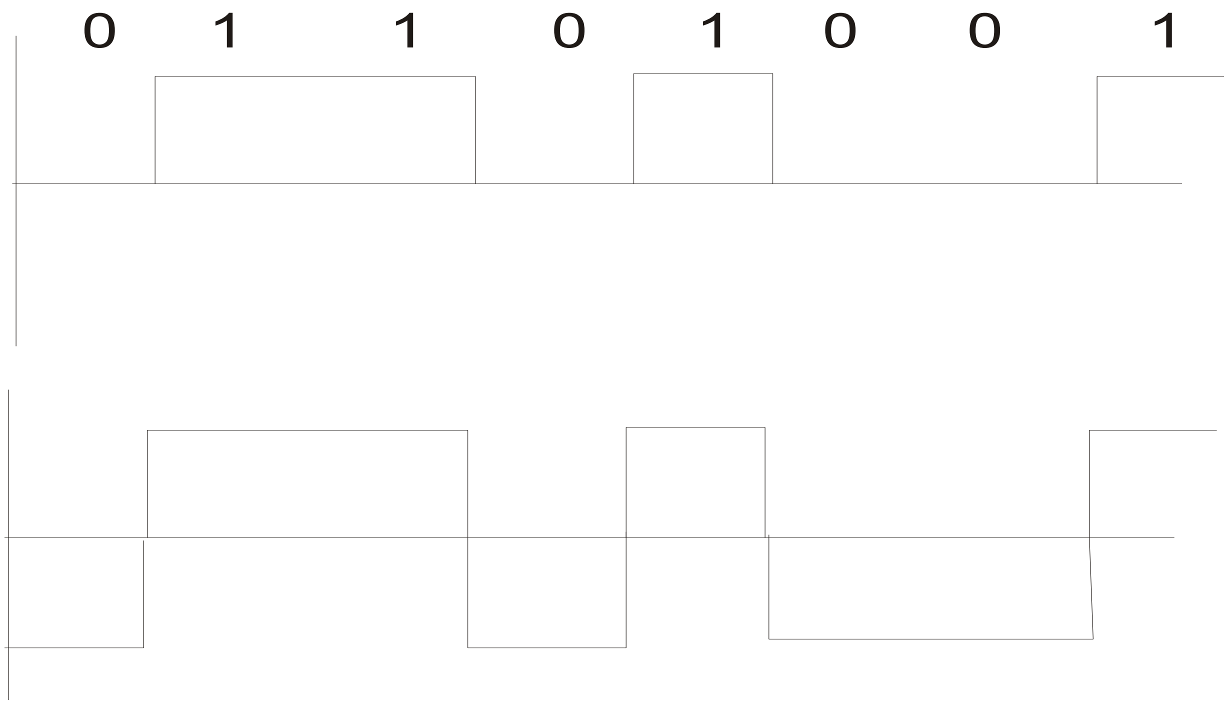
Components of Digital Communication

- Sampling: If the message is analog, it's converted to discrete time by sampling.

  (What should the sampling rate be ?)
- Quantization: Quantized in amplitude.

  Discrete in time and amplitude
- Encoder:
  - Convert message or signals in accordance with a set of rules
  - Translate the discrete set of sample values to a signal.
- Decoder: Decodes received signals back into original message

Different Codes



Performance Metrics

- In analog communications we want, $\hat{m}(t) \cong m(t)$
- Digital communication systems:
  - Data rate (R bps) (Limited) Channel Capacity
  - Probability of error P_e
  - Without noise, we don't make bit errors
  - Bit Error Rate (BER): Number of bit errors that occur for a given number of bits transmitted.
- What's BER if $P_e=10^{-6}$ and 10^7 bits are transmitted?

Advantages

- Stability of components: Analog hardware change due to component aging, heat, etc.
- Flexibility:
  - Perform encryption
  - Compression
  - Error correction/detection
- Reliable reproduction

Applications

- Digital Audio Transmission
- Telephone channels
- Lowpass filter,sample,quantize
- 32kbps-64kbps (depending on the encoder)

- Digital Audio Recording
- LP vs. CD
- Improve fidelity (How?)
- More durable and don't deteriorate with time

Baseband Data Transmission

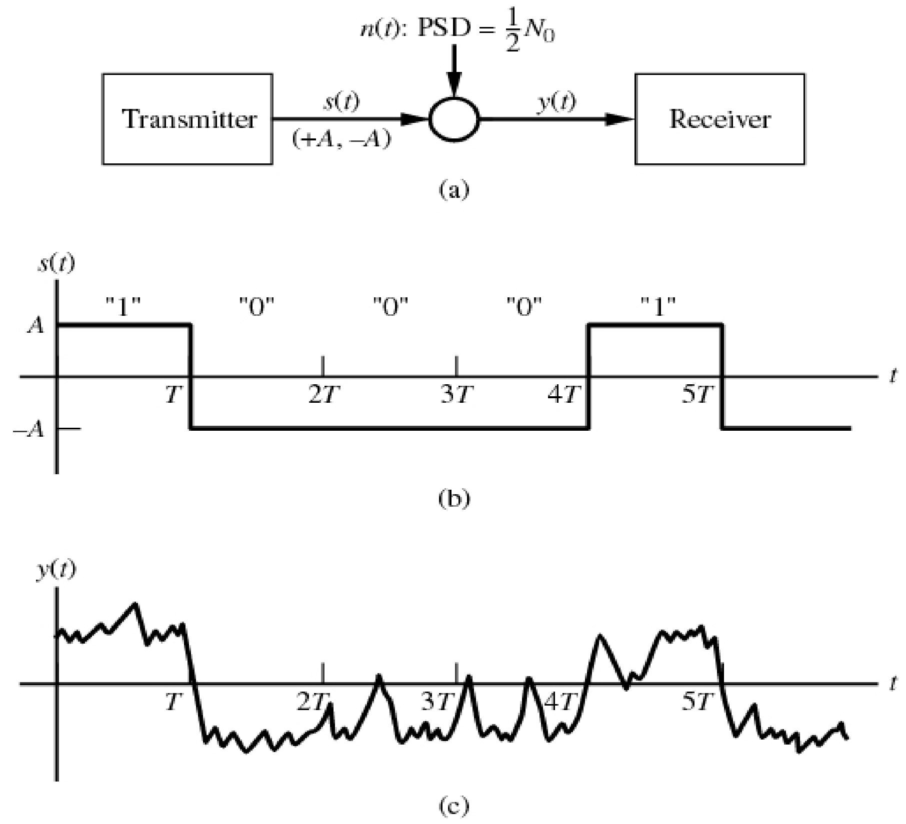


Figure 7-2
System model and waveforms for synchronous baseband digital data transmission. (a) Baseband digital data communication system. (b) Typical transmitted sequence. (c) Received sequence plus noise.

- Each T-second pulse is a bit.
- Receiver has to decide whether it's a 1 or 0

(A or –A)
- Integrate-and-dump detector
- Possible different signaling schemes?

Receiver Structure

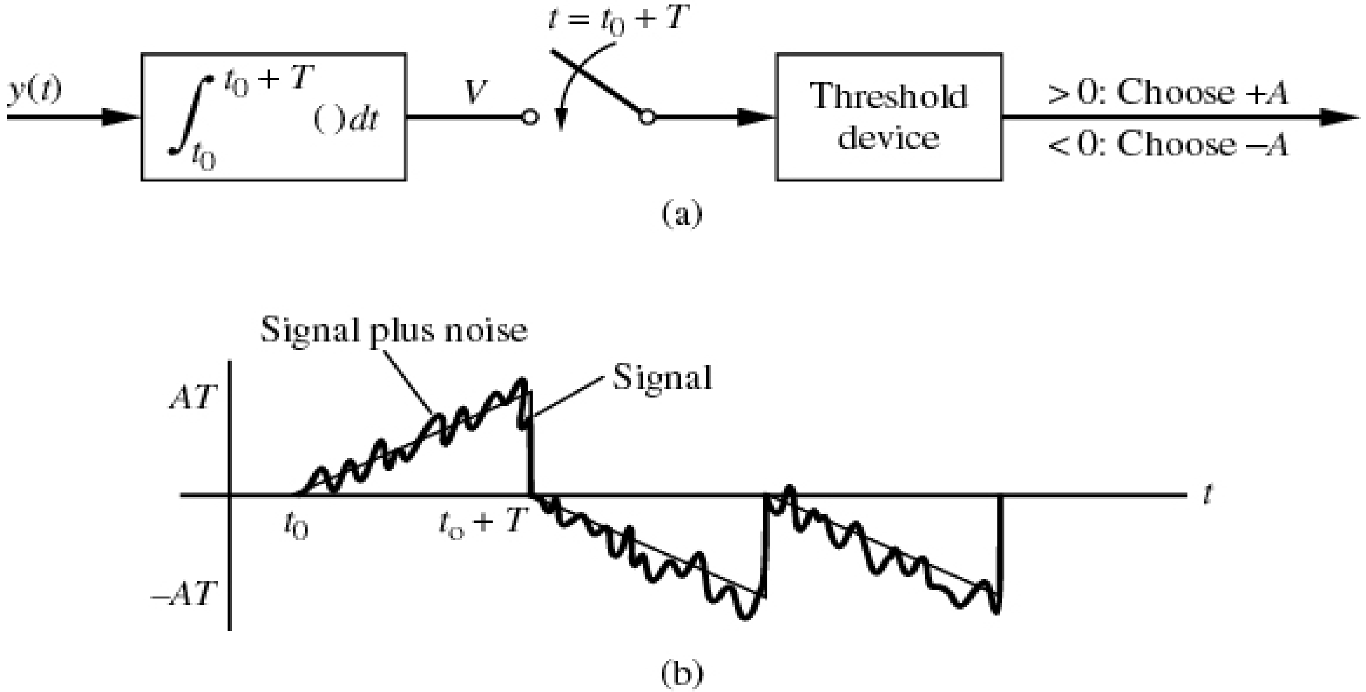


Figure 7-3 Receiver structure and integrator output. (a) Integrate-and-dump receiver. (b) Output from the integrator.

Receiver Preformance

- The output of the integrator:

$$V = \int_{t_0}^{t_0+T} [s(t) + n(t)]dt$$

$$= \begin{cases} AT + N & A \quad is \quad sent \\ -AT + N & -A \quad is \quad sent \end{cases}$$

- $N = \int_{t_0}^{t_0+T} n(t)dt$ is a random variable.
- N is Gaussian. Why?

Analysis

$$E[N] = E[\int_{t_0}^{t_0+T} n(t)dt] = \int_{t_0}^{t_0+T} E[n(t)]dt = 0$$

$$\begin{aligned}
Var[N] &= E[N^2] - E^2[N] \\
&= E[N^2] \qquad Why? \\
&= E\left\{\left[\int_{t_0}^{t_0+T} n(t)dt\right]^2\right\} \\
&= \int_{t_0}^{t_0+T}\int_{t_0}^{t_0+T} E[n(t)n(s)]dtds \\
&= \int_{t_0}^{t_0+T}\int_{t_0}^{t_0+T} \frac{N_0}{2}\delta(t-s)dtds \qquad Why?(White \quad noise \quad is \quad uncorrelated!) \\
&= \frac{N_0 T}{2}
\end{aligned}$$

- Key Point
  - White noise is uncorrelated

Error Analysis

- Therefore, the pdf of N is:

$$f_N(n) = \frac{e^{-n^2/(N_0 T)}}{\sqrt{\pi N_0 T}}$$

- In how many different ways, can an error occur?

Applications

- Modems: FSK
- RF based security and access control systems
- Cellular phones