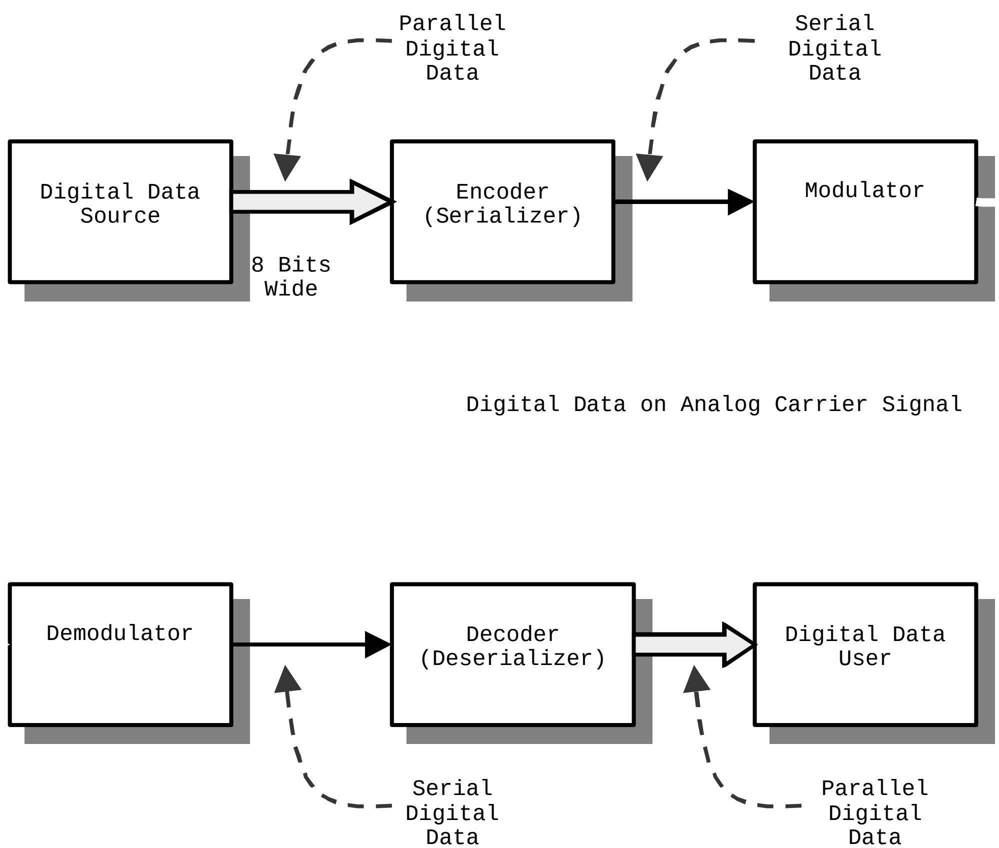
Data Communication System



Describe the signal at each point using the following terms:

- Analog or Digital
- Serial or Parallel
- Baseband or Broadband

Terminology

Define the following terms:

•Analog:

•Parallel Data:

•Serial Data:

•Baseband:

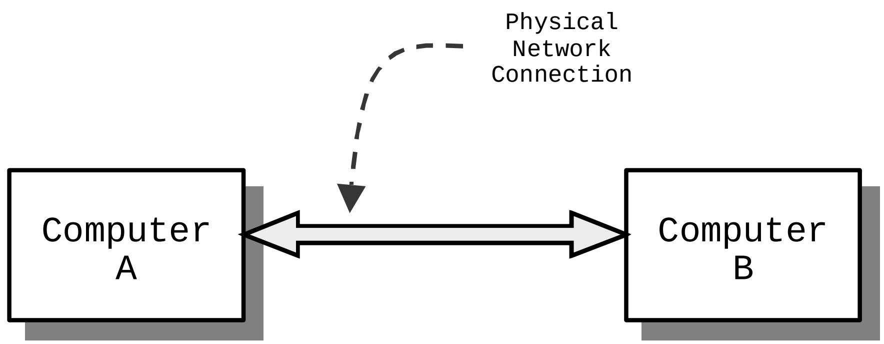
•Broadband:

•Simplex:

•Half Duplex

•Full Duplex

Network Topologies



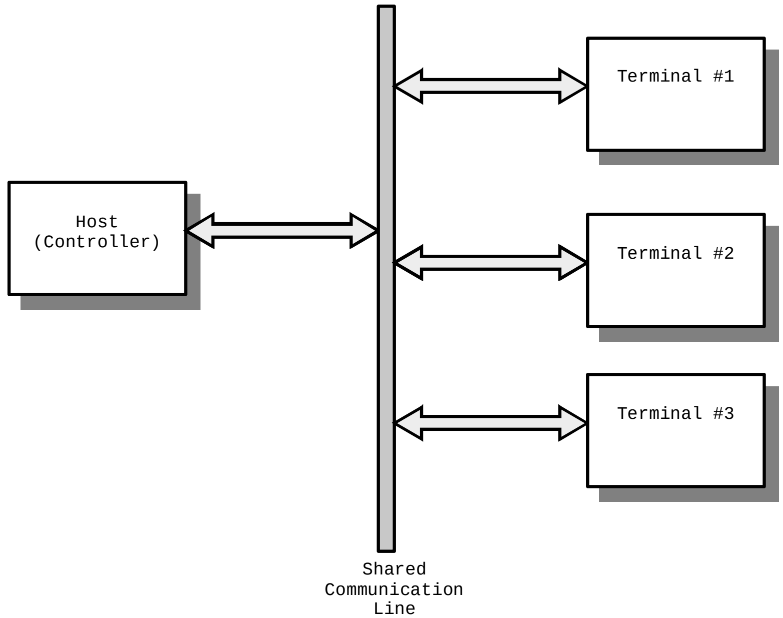
A Point-to-Point Network

What is meant by the term “topology?”

For the point-to-point network pictured above, give several advantages and disadvantages.

What is the difference between a “point-to-point” and “peer-to-peer” network?

Network Topologies

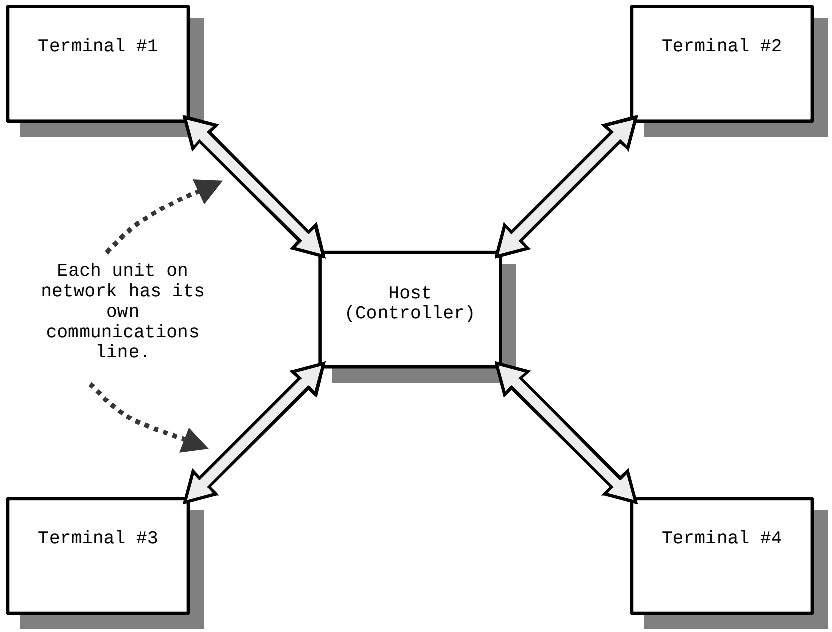


A Multipoint or Multidrop Network

For the multipoint network pictured above, give several advantages and disadvantages.

Why are there security concerns with this type of network?

Network Topologies



A Star Network

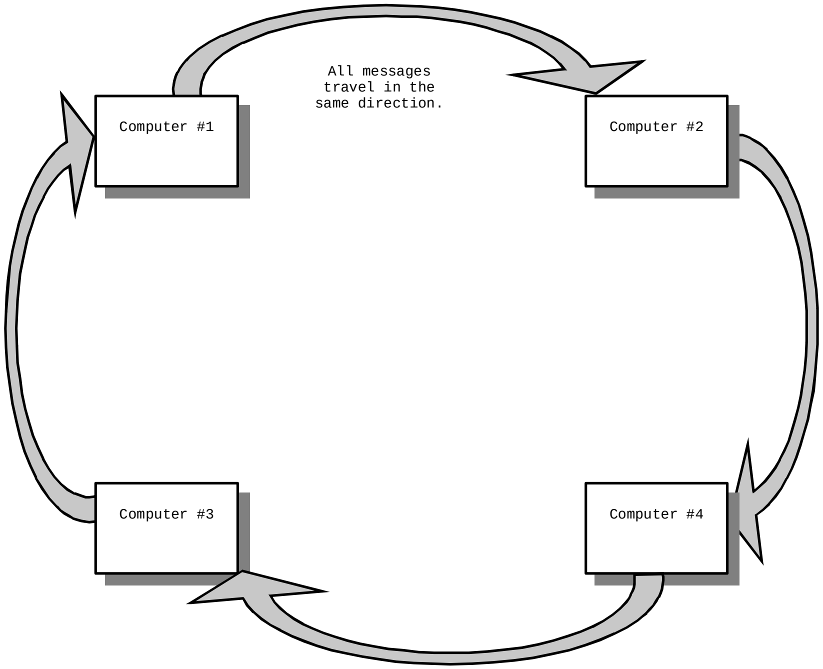
For the star network pictured above, give several advantages and disadvantages.

Why is a star network more secure than a multipoint network?

Network Topologies

List the steps in sending a message on a ring network:

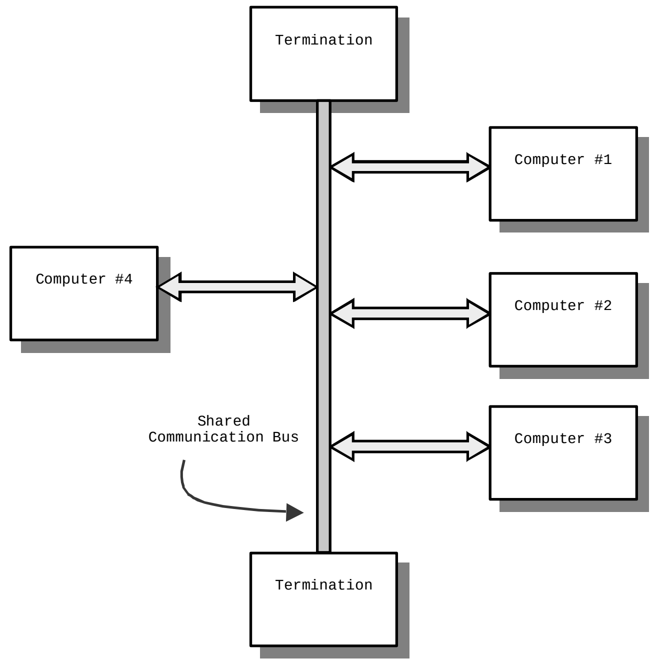
1.
2.
3.
4.
5.



A Ring Network

For the ring network pictured above, give several advantages and disadvantages.
What (once-popular) LAN uses this topology?

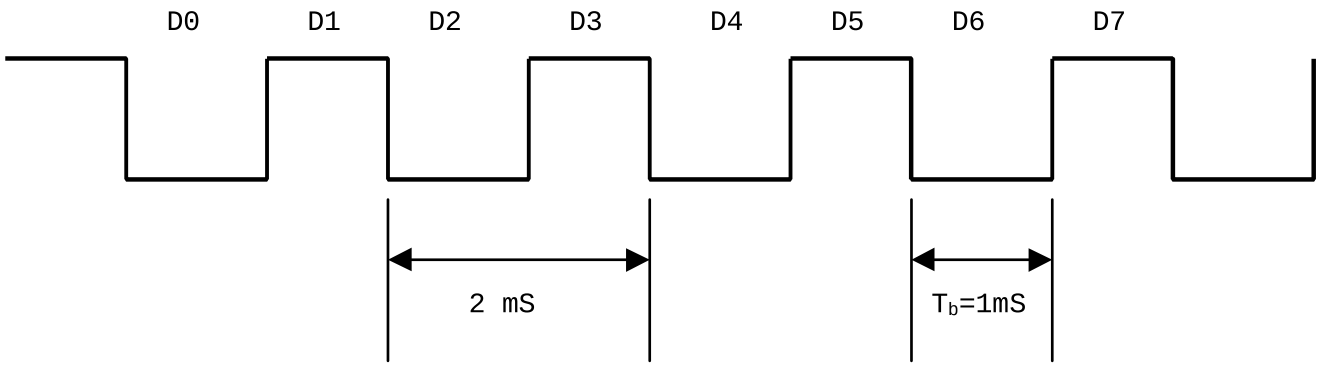
Network Topologies



A Bus Network

For the bus network pictured above, give several advantages and disadvantages.
What popular LAN uses this type of network?

Digital Information



What are the fundamental units of information?

What are the units of information flow (data rate)?

How is the data rate of a signal calculated?

What is the frequency of the square wave above?

What is the data rate of this wave (and how does it compare to the frequency)?

The signal above is a “1010 . . .” pattern. Why is this pattern commonly used for testing digital data systems?

Digital Modulation Techniques

“Tb” is the time needed to send one bit of digital data. The units of digital data flow are bits per second (bps):

$$bps = \frac{1}{T_b}$$

A transition is any *change* in a modulated wave that is used to convey information. We can change the amplitude (AM), frequency (FM), or phase (PM) of the carrier wave. Sometimes a transition is called a symbol.

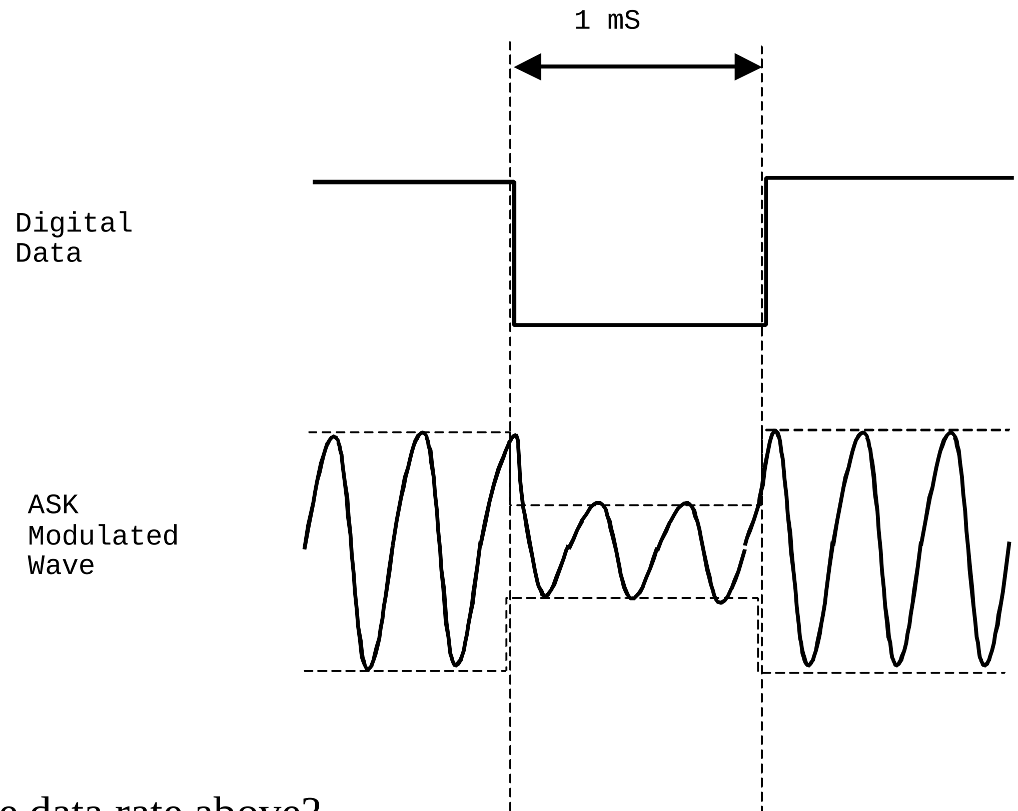
Signaling is the process of modulating a carrier in order to impress information upon it. The rate of signaling is measured in BAUD, which has units of transitions per second.

The signaling rate is calculated as: $BAUD = \frac{1}{T_s}$

A single-level modulation system represents one bit with one symbol (transition).

The bandwidth required is always directly proportional to the signaling rate.

Data Rate, Signaling Rate, and Bandwidth – ASK System

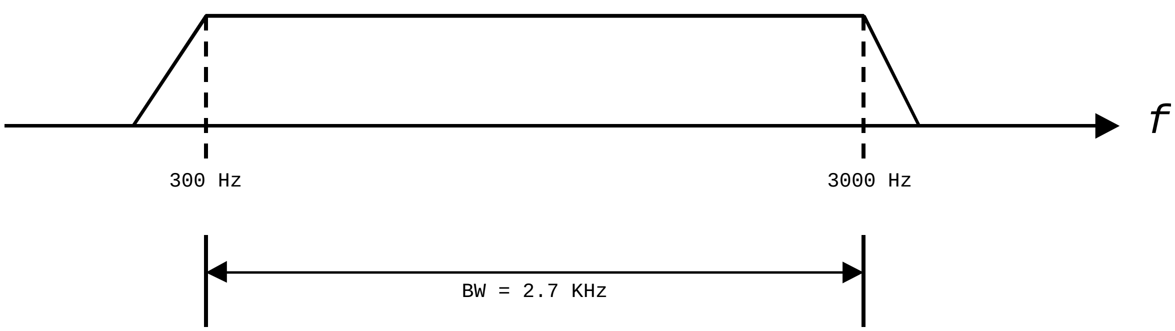


What is the data rate above?

What is the signaling rate above?

If the approximate bandwidth of an ASK signal is 11 times the BAUD, what bandwidth will be required to send the signal above?

PSTN Standard Characteristics

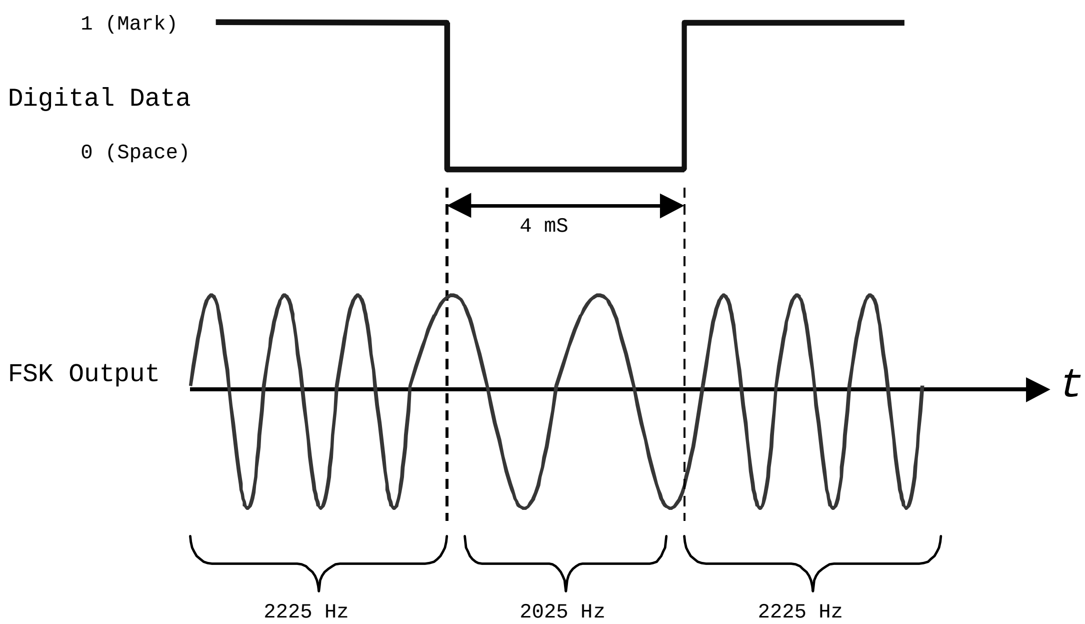


What is the frequency response of a standard telephone line?

What is the approximate bandwidth available on a telephone line?

Will the ASK signal from the previous page fit within the bandwidth of a phone line?
Why or why not?

Frequency Shift Keying (FSK)



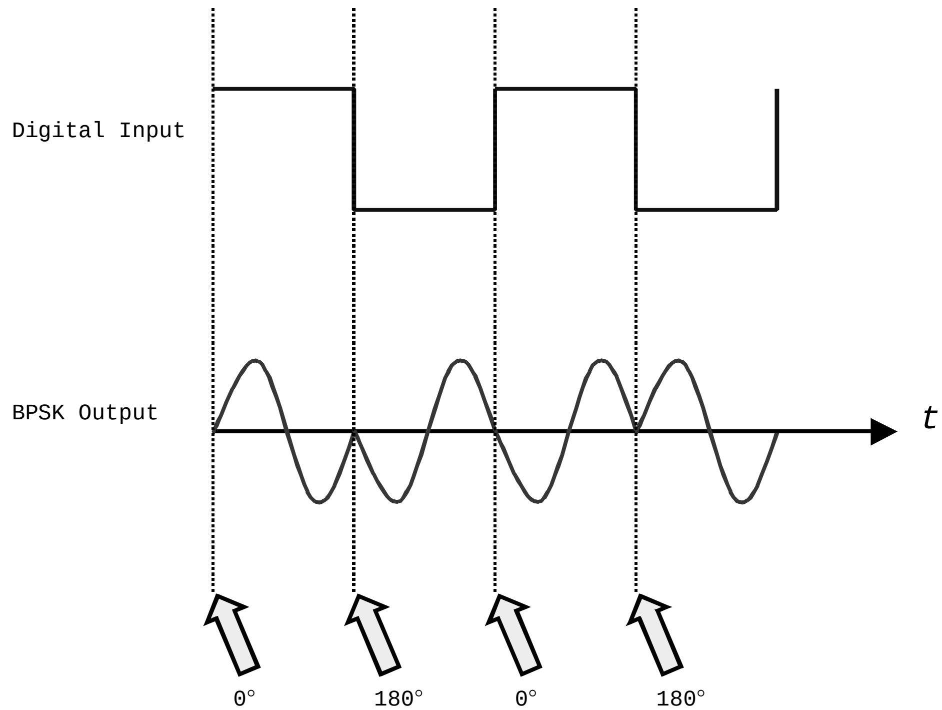
How does FSK represent 1s and 0s?

What are the data and signaling rates in the signal set above?

If an FSK signal requires a bandwidth approximately 5 times the BAUD, what bandwidth will be required for the above FSK signal?

Will the FSK output above “fit” into a standard PSTN line? Why or why not?

Phase Shift Keying (PSK)



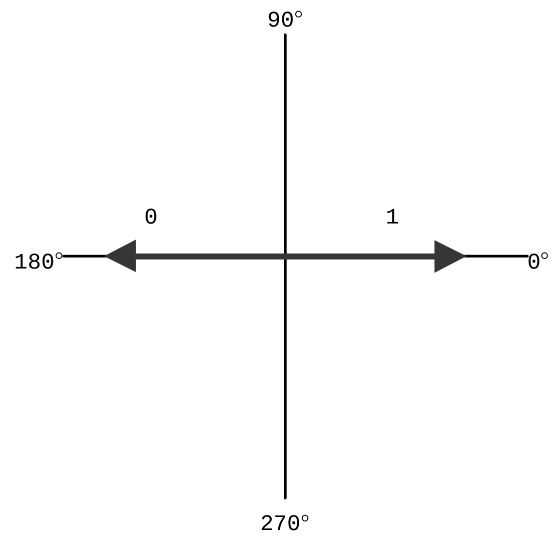
How does PSK represent 1s and 0s?

What are the data and signaling rates in the signal set above, if Tb = 1 mS?

If a PSK signal requires a bandwidth approximately equal to the BAUD, what bandwidth will be required for the above PSK signal?

Will the PSK output above “fit” into a standard PSTN line? Why or why not?

Phase Shift Keying (PSK) Constellation



What are modulation states?

What two pieces of information are given for each state in the diagram above?

How many states are in the PSK constellation above?

How many modulation states does a single-level system have?

Single Level Limitations, and Multilevel (m-ary) Systems

What is the biggest limitation of a single-level modulation system?

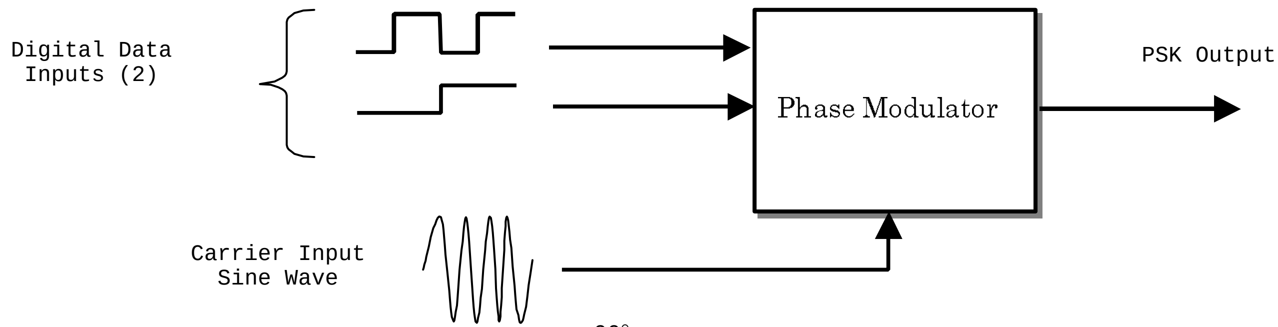
What is a multilevel modulation system?

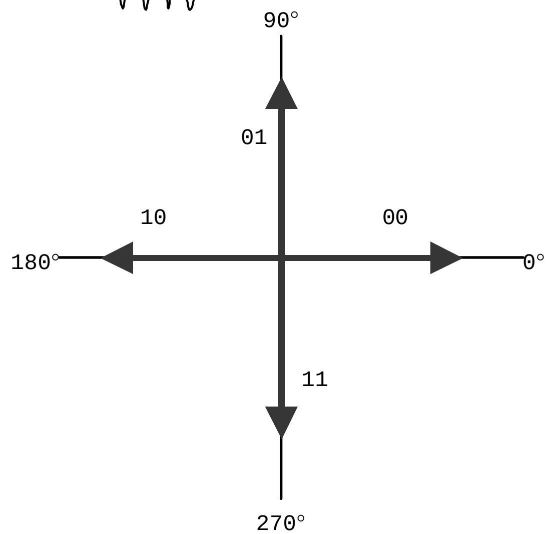
How is the number of states calculated in a multilevel system?

How is the signaling rate (BAUD) calculated in a multilevel system?

What is a good analogy for understanding single and multilevel systems?

Multilevel PSK



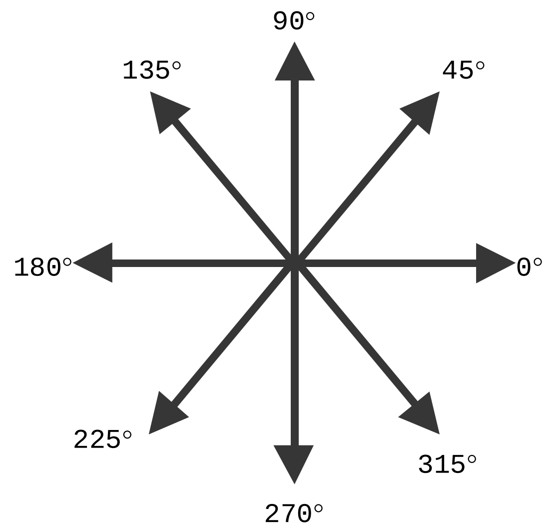


How many bits per symbol (transition) are encoded above?

If the input data rate is 1200 bps, what is the signaling rate?

What is the main advantage of a multi-level system?

Multilevel PSK



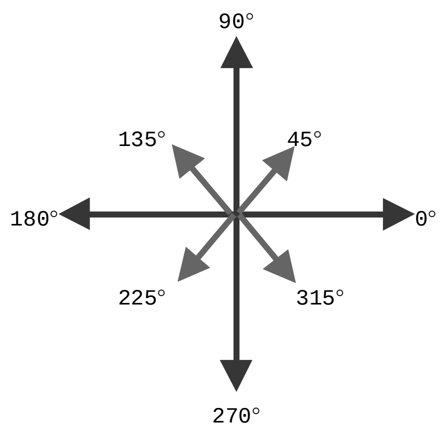
How many modulation states are there in the figure above?

How many bits per symbol (transition) are encoded above?

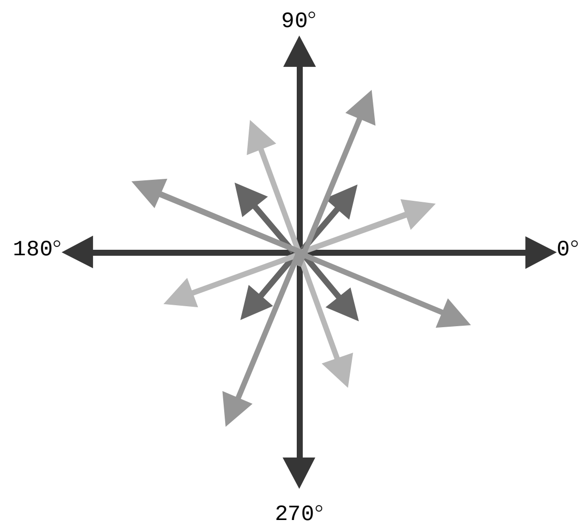
If the input data rate is 1200 bps, what is the signaling rate?

Given the same data input rate, which system uses the least bandwidth, this one (level 3) or the level 2 system on the previous page?

QAM (Quadrature Amplitude Modulation)



a) Level 3
8-QAM



b) Level 4
16-QAM

What are the two types of modulation used in QAM?

How does this help?

List the two factors that limit the amount of information that can be sent through a communications channel.

QAM (Quadrature Amplitude Modulation)

The Hybrid cable modem system uses “64-QAM” (64 states) to send downstream data to Internet users. If the data rate is 2 Mbps (2 million bits per second), what is the signaling rate?

Fiber Optics

Fiber Optic Advantages

- Security: It is very difficult to “tap” a fiber optic connection without causing a detectable disturbance on the line.
- Immunity to EMI: Good for harsh environments (industrial, avionics, nuclear, etc.)
- Low Loss: Single-mode fibers can carry signals for miles with little attenuation.
- Very wide bandwidth (GHz) available.

Fiber Optic Disadvantages

- Fiber requires special tools for connections and splicing. Splicing is not always possible on broken lines.
- Expensive test equipment may be needed to verify operation.

Light and Wavelength

- The speed of light (or radio waves) is approximately $\underline{3 \text{ x } 10^8 \text{ m/s}}$
- The wavelength of a light or radio wave is calculated as follows: $\lambda = \frac{v}{f}$

- As frequency increases, wavelength decreases.
- Each type of fiber optic works best at certain wavelengths.

Light and Wavelength

- What is the wavelength of a 441 THz light wave?

$$\lambda = \frac{v}{f} = \frac{3\times10^{8}\,m/s}{441\times10^{12}\,Hz} = \underline{\underline{680.27nm}}$$

- What is the frequency of a blue-green light ray (500 nm wavelength)?

$$f = \frac{v}{\lambda} = \frac{3\times10^{8}\,m/s}{500\times10^{-9}\,m} = \underline{\underline{600THz}}$$

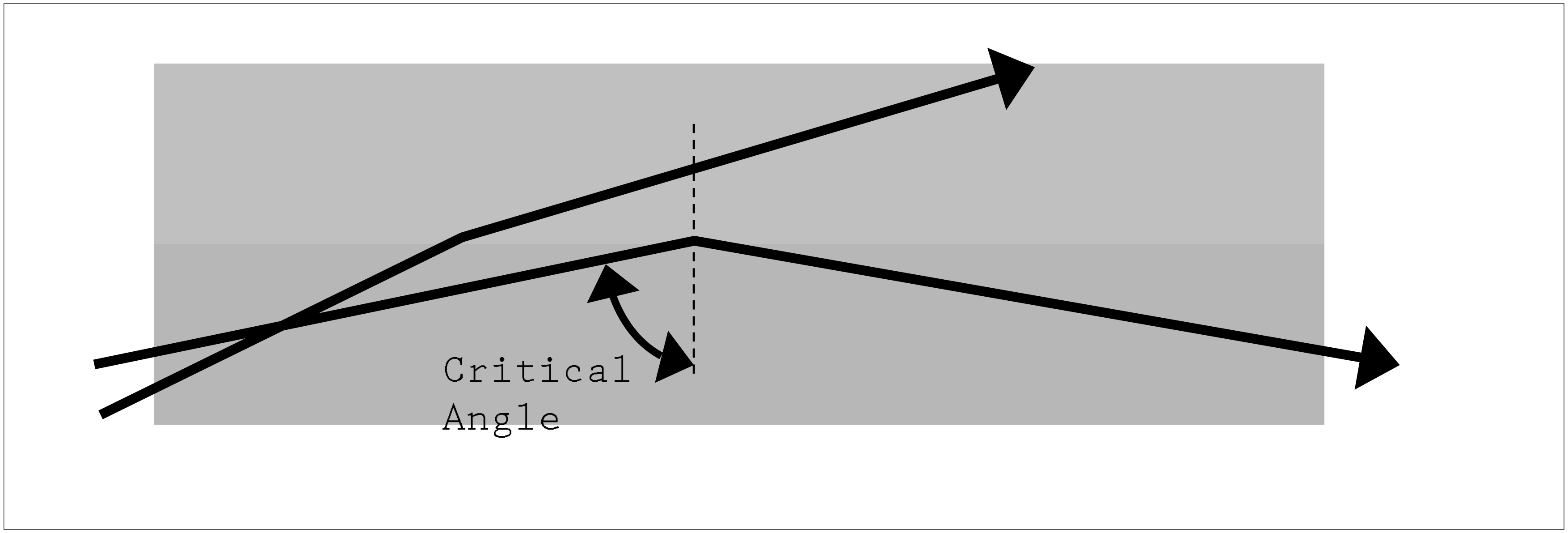
Index of Refraction

- The refractive index of a material is the ratio of light speed in free space to light speed in the material:

$$n = \frac{v_{free-space}}{v_{material}}$$

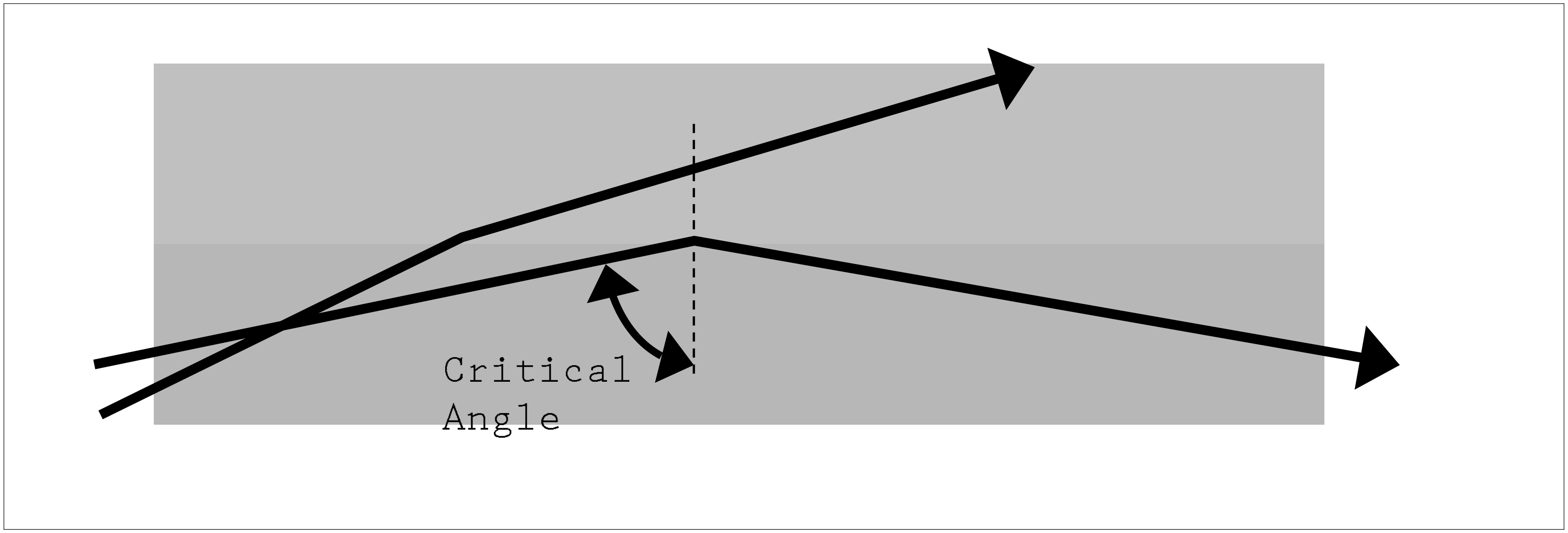
- Higher refractive indices mean slower light wave propagation.
- Fiber optics have a core and cladding. The relative refractive indices of these materials controls how light can pass through the fiber.

Refraction



- Refraction is the bending of light. When a light wave approaches a boundary at more than the critical angle, total internal reflection occurs and the light wave stays in the original medium.

Refraction



- The internal critical angle is calculated by:

$$\theta_{crit} = \sin^{-1}\left(\frac{n_2}{n_1}\right)$$

n_1 is the starting medium, n_2 is the refracting medium. $n_2 <= n_1$.

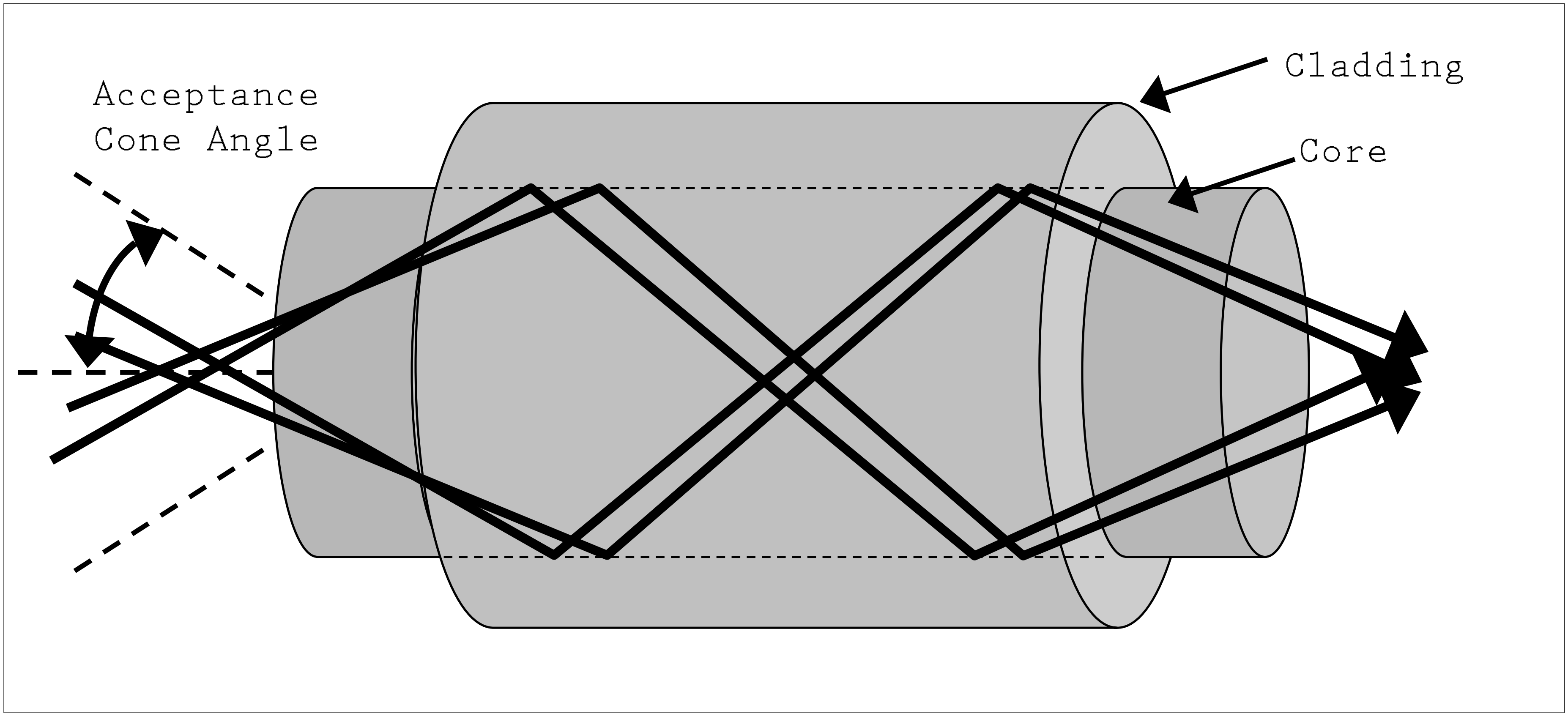
Numerical Aperture

- NA is a measure of how easily light can be coupled into a fiber optic cable. The higher NA is, the easier it is to get the light in. The maximum value possible is 1.

$$NA = \sqrt{n_1^2 - n_2^2}$$

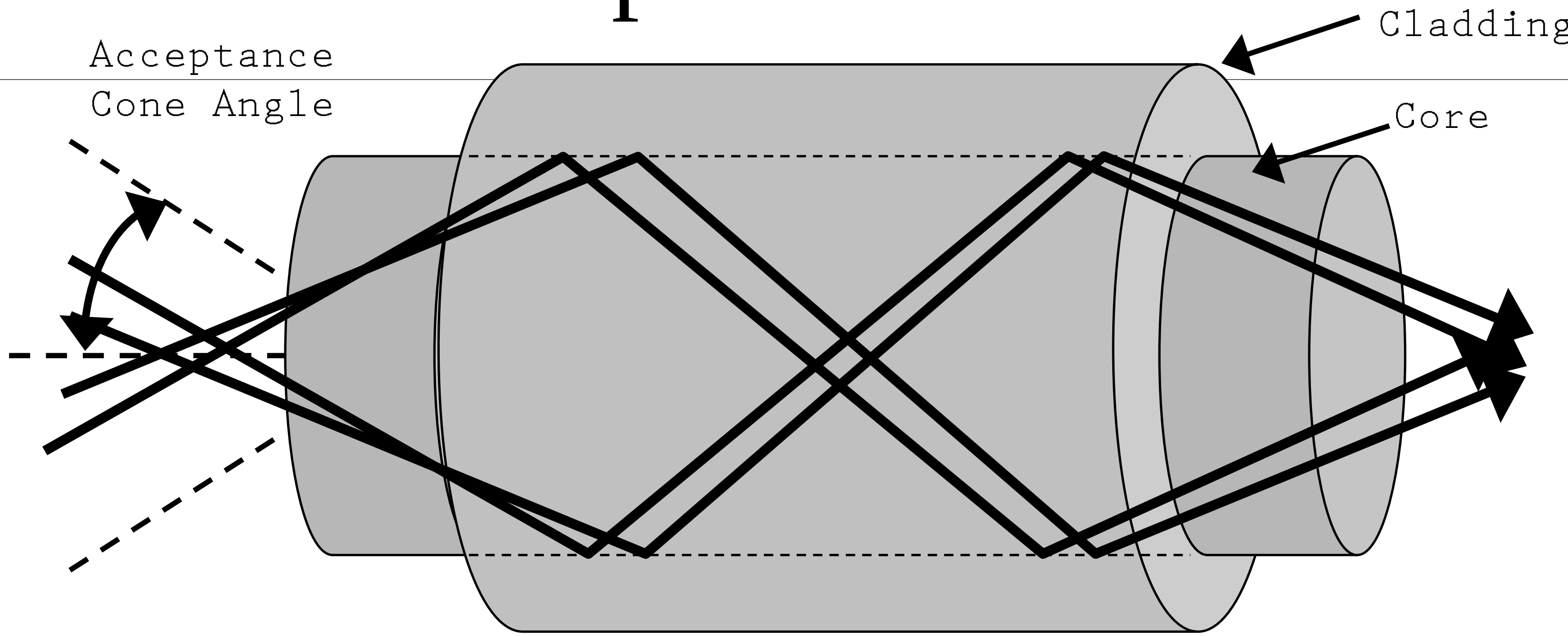
- N1 is the core, N2 is the cladding refractive index.

Acceptance Cone



- Because of the limit of critical angle for refraction, not all rays can be coupled into the fiber.

Acceptance Cone



- Acceptance cone angle is calculated by: $\theta_{accept} = \sin^{-1} NA$

- If n1=1.57 (core) and n2=1.42 (cladding):

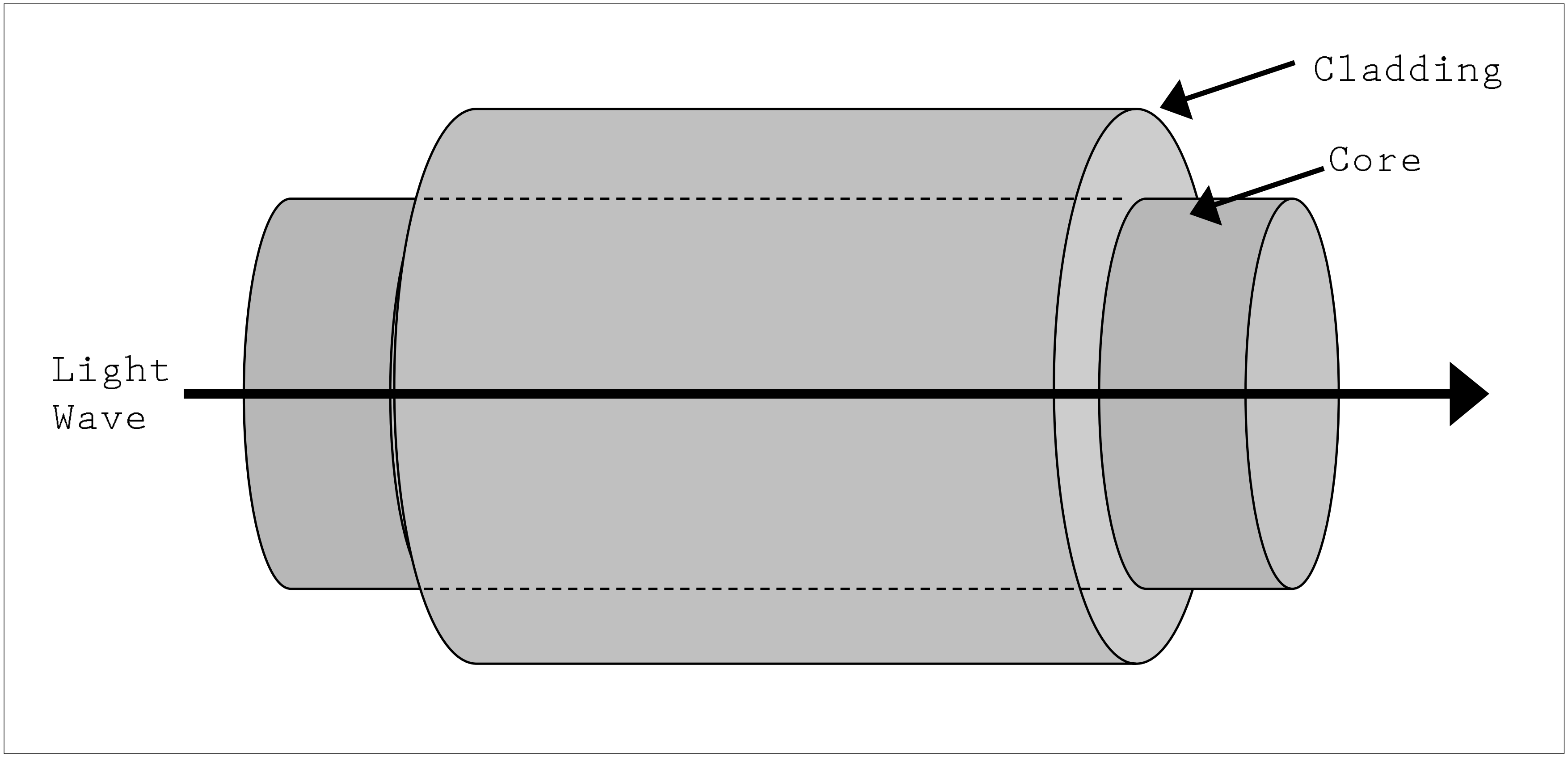
$$NA = \sqrt{n_1^2 - n_2^2} = \sqrt{1.57^2 - 1.42^2} = 0.6697$$

$$\theta_{accept} = \sin^{-1} NA = \sin^{-1} 0.6697 = \underline{\underline{42^o}}$$

Propagation of Light in Fiber

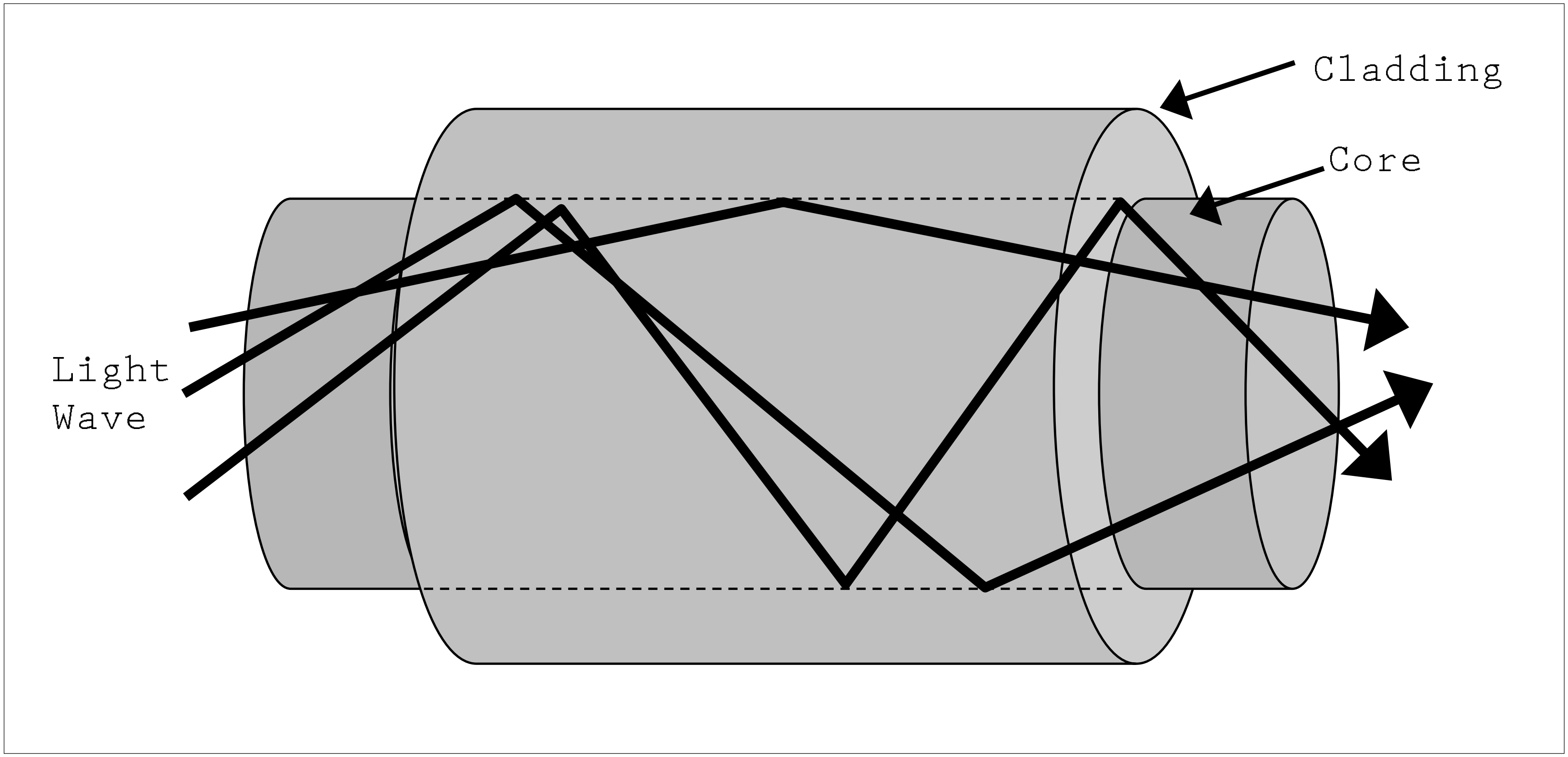
- Light can move in a fiber in either a straight line, or a zig-zag pattern.
- Fibers that are very narrow encourage straight-line propagation and are called single-mode fibers. Single-mode operation gives the greatest bandwidth.
- In a multi-mode fiber, light can take several paths to the destination, resulting in dispersion distortion.

Single Mode Propagation



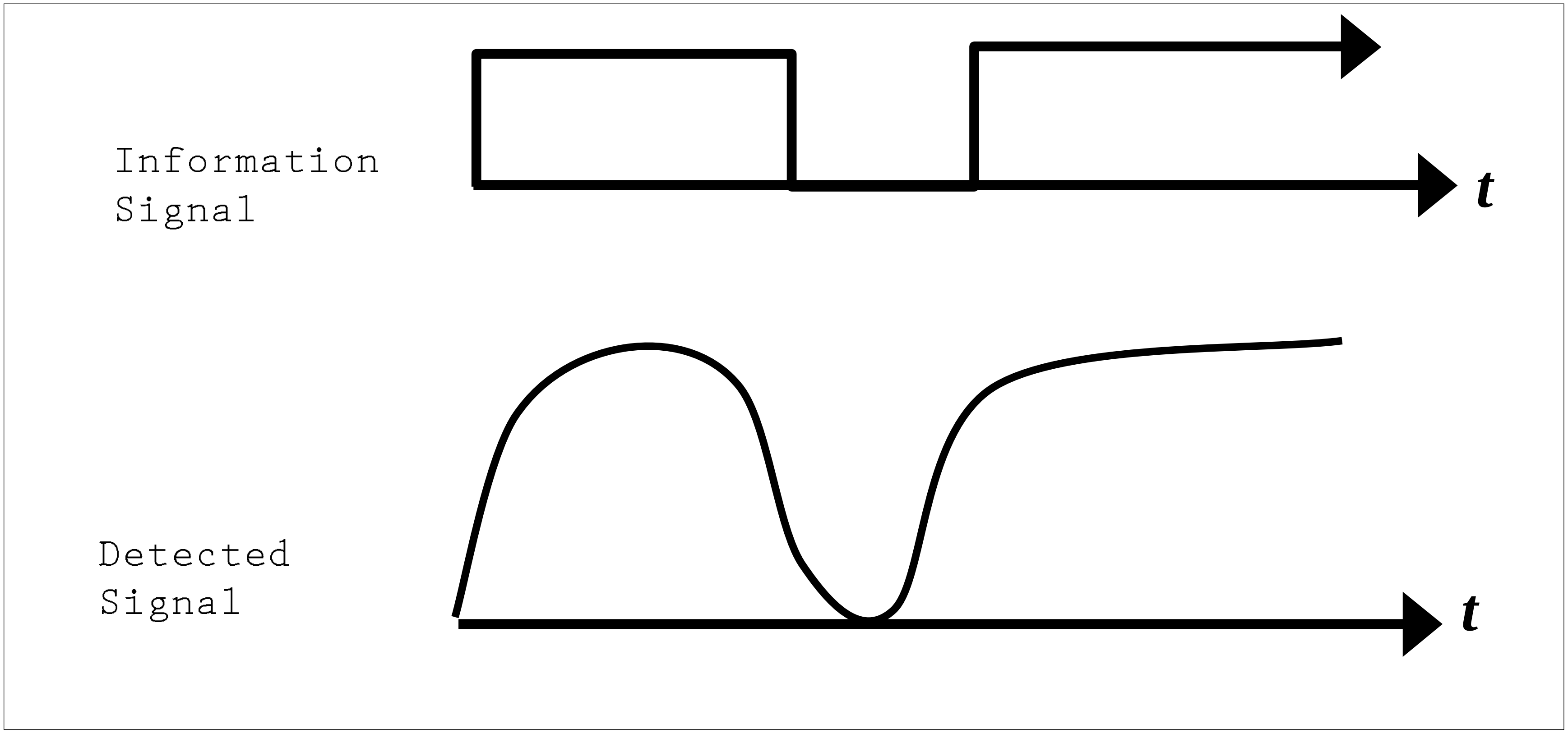
- Light travels in a straight line. The core must be less than a wavelength thick to encourage this mode.

Multi-Mode Propagation



- A light ray can take many paths. All paths are of different lengths, causing dispersion and pulse-spreading.

Effect of Dispersion



- Dispersion rounds off and widens digital pulses. The effect is similar to passing the information through a low-pass filter.

Fiber Optic Light Sources

- 1. LASER - Cleanest spectral output, output powers in excess of 1 mW possible. Gives maximum range and bandwidth from a fiber. Much more expensive and less reliable than LEDs.

- 2: LED - Inexpensive, spectrally “dirty”, power levels limited to less than 1 mW. Very reliable.

Fiber Optic Light Detectors

- 1. Phototransistor: Provides DC gain which simplifies receiver circuitry. Very slow - data rates limited to less than 100 Kb/second.
- 2: Photodiode: Requires more complex receiver circuitry (provides no gain), but much faster response. Data rates in excess of 100 Mb/S are possible. “PIN” diodes are popular.

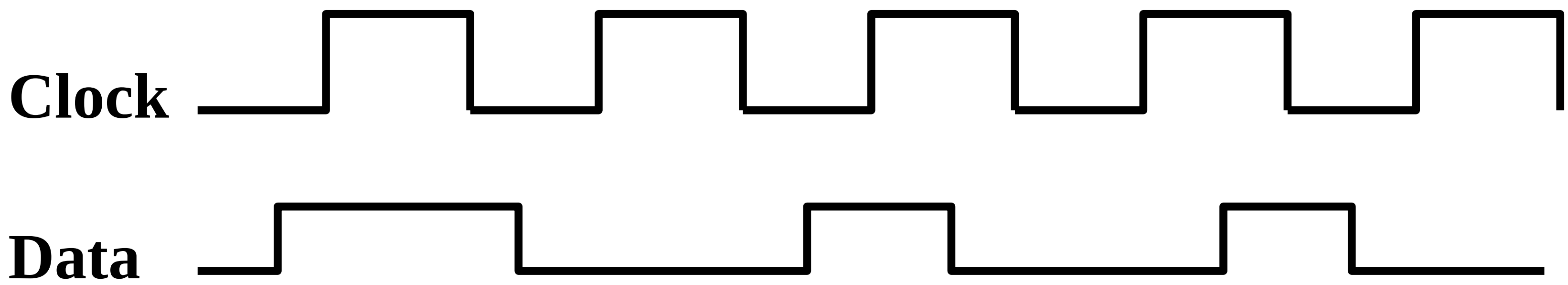
Serial Data Formatting

Types of Serial Data

- Synchronous: A clock signal is sent with the data; there is one clock pulse for each digital bit. The clock may be interleaved with the data in various ways.

- Asynchronous: No clock signal is sent. The receiver must regenerate the clock. Transmitter and receiver must agree on the data rate for this to work!

Synchronous Data Example



- The clock signal is required and is generally supplied by the DCE (modem, router, or other equipment.) The transmitting computer synchronizes to this clock.

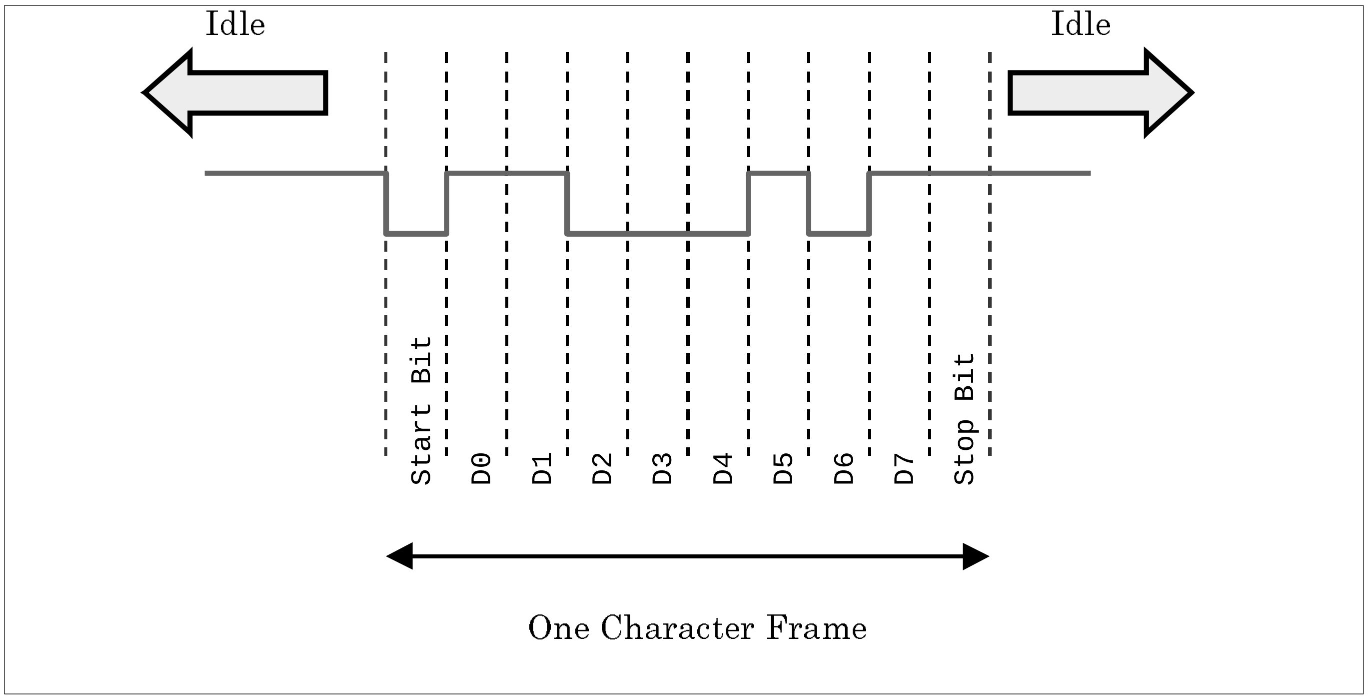
Asynchronous Transmission

- Idle - When no data is being sent, the data line is held “marking” or “high.”
- Start Bit - To mark the beginning of a frame, a start bit is sent. It is one bit-time long.
- Data - Five to eight data bits are sent, starting with the D0, the LSb.
- Parity - Optional bit for error checking.
- Stop Bit(s) - 1 to 2 stop bits mark end of chararacter, and are logic 1 in value.

Parameter Shorthand

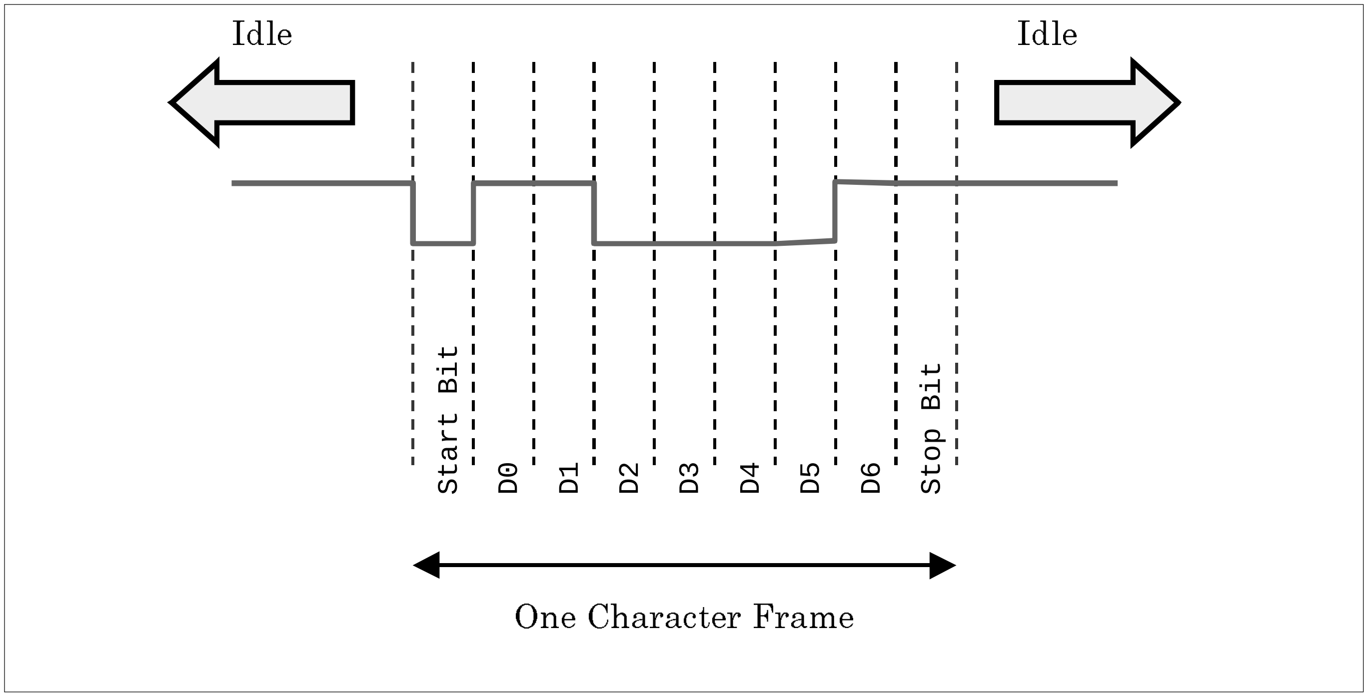
- 8,N,1 means 8 data, No Parity, 1 stop.
- 7,N,2 means 7 data, No Parity, 2 stop.
- 8,E,1 means 8 data, Even Parity, 1 stop.
- 5,O,1 means 5 data, Odd Parity, 1 stop.

A3H Sent 8,N,1



- Note: A3H = 0xA3 = $A3_{16}$ = $1010\ 0011_2$

43H Sent 7,N,1



- Note: 43H = 0x43 = 43_{16} = $100\ 0011_2$

Parity

- Parity is a count of the number of logic 1s in the data. The stop bit is not counted. It is a very crude error detection mechanism.

- Even Parity means that the total number of 1s sent (including the parity bit) is an even number.

- Odd Parity means that the total number of 1s sent is odd.

Parity

- Suppose a we want Odd parity for the following data:

  0010 0101 0

✔ There are already three logic 1s here. Therefore, the parity bit will be zero, since we want a an odd total number of logic 1s.

Parity

- Suppose a we want Odd parity for the following data:

  0111 0111   1

✔ There is an even number of logic 1s. To get a total number that is odd, the parity bit must be a one (that way, we get seven total 1s, an odd number.)

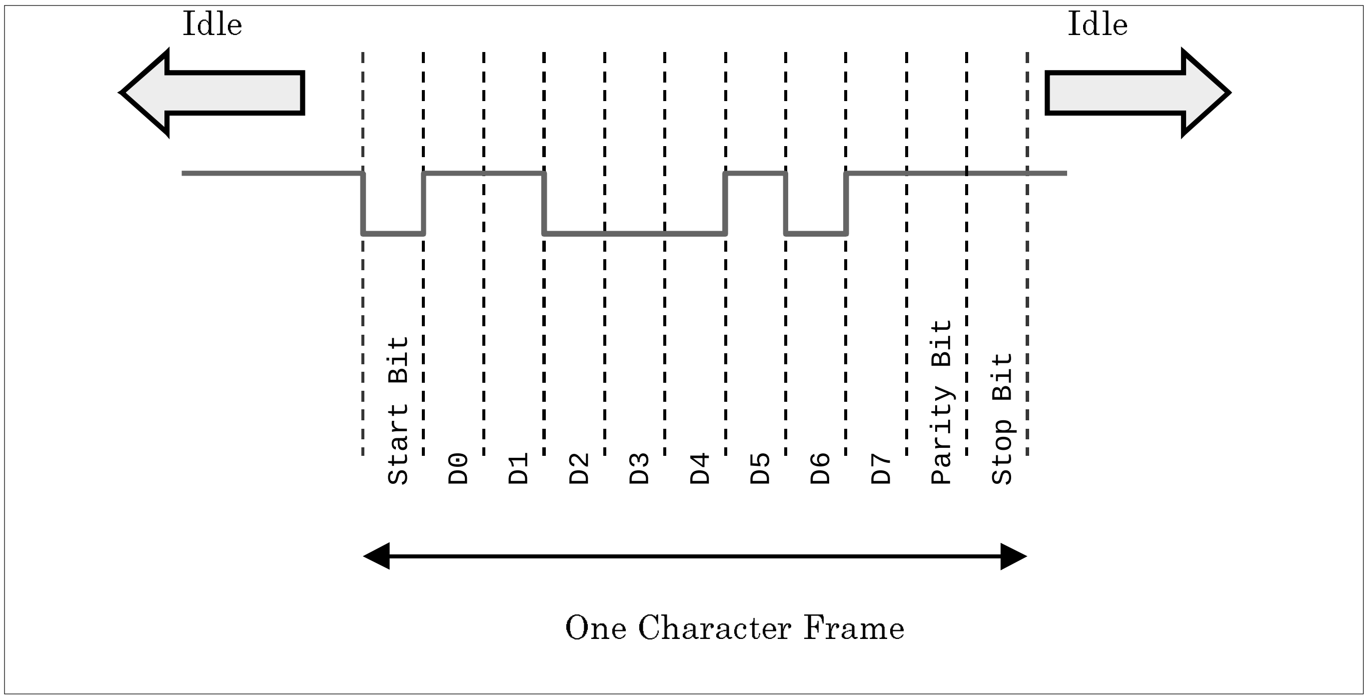
Parity

- Suppose a we want Even parity for the following data:

  0111 0011   1

✔ To get even parity, the total number of 1s must be an even number. Therefore, a logic 1 is added.

A3H Sent 8,O,1



- Note: A3H = 0xA3 = $A3_{16}$ = $1010\ 0011_2$

Data and Character Rates

- The data rate is measured in bps and is simply the reciprocal of the bit time.
- The character rate is measured in CPS and is the reciprocal of the character time.
- To find the character time, multiply the bit time by the number of bits in the character.

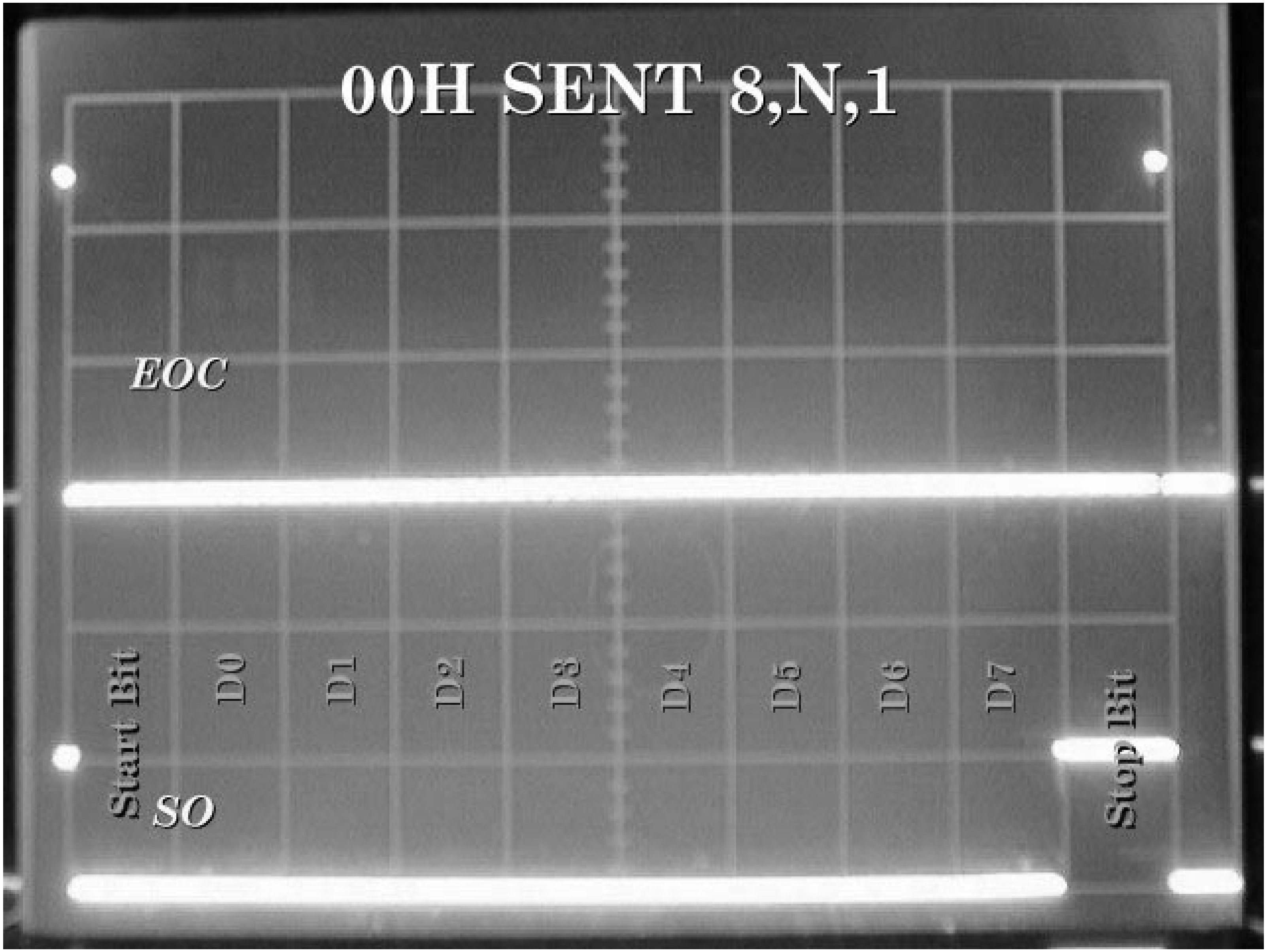
Character Rate Calculation

- The parameters are 1200 bps; 8,N,1
- The bit time is 1/1200 bps or 833 uS.
- Each character has 10 total bits:

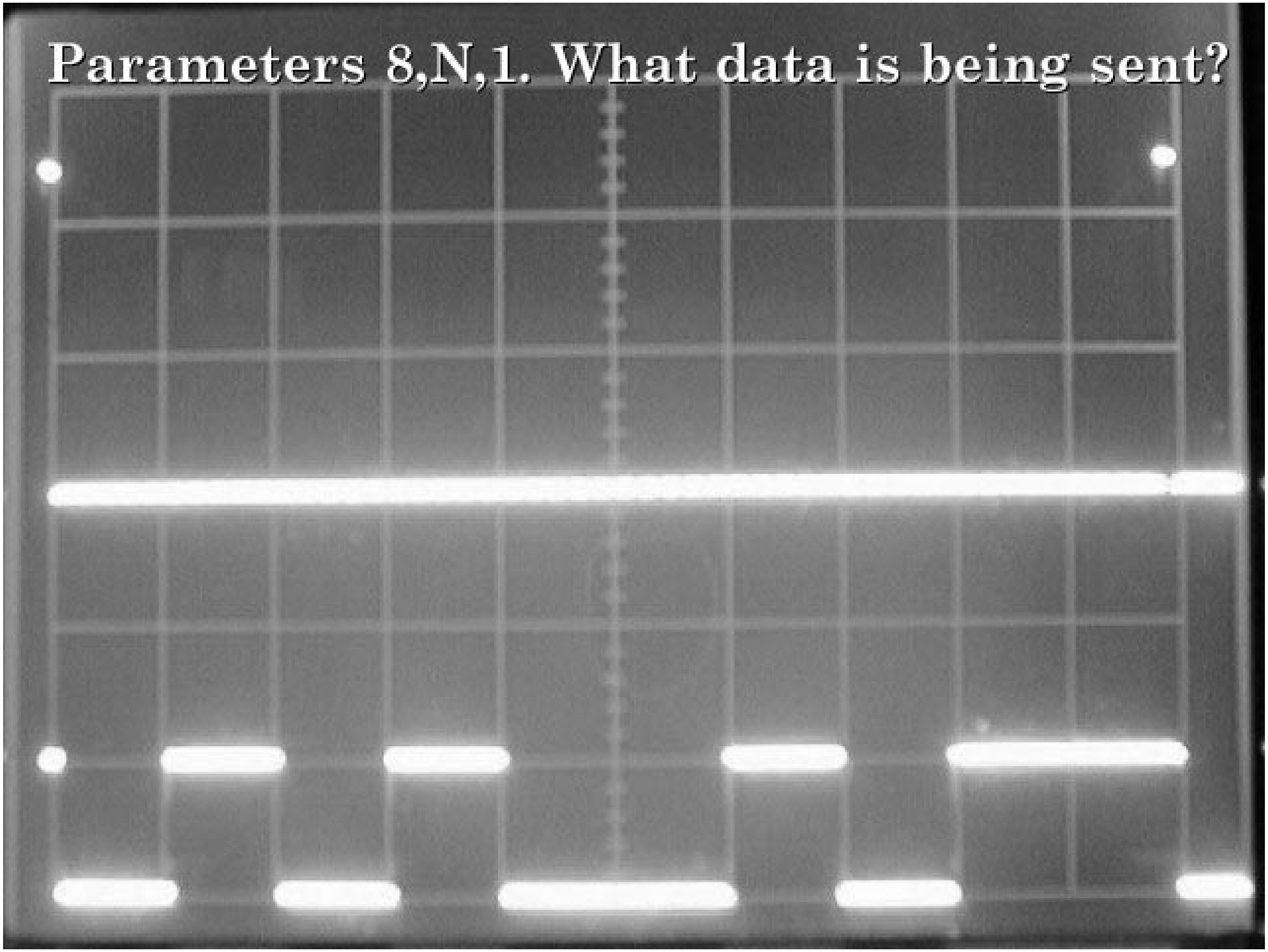
```
 1  Start
 8  Data
 1  Stop
 ---------
10 Total
```

- The character time is (10)(833 uS) = 8.3 mS
- The character rate = 1/Tc = 1/8.3 mS
  or 120 CPS.

Oscilloscope Data



Oscilloscope Data



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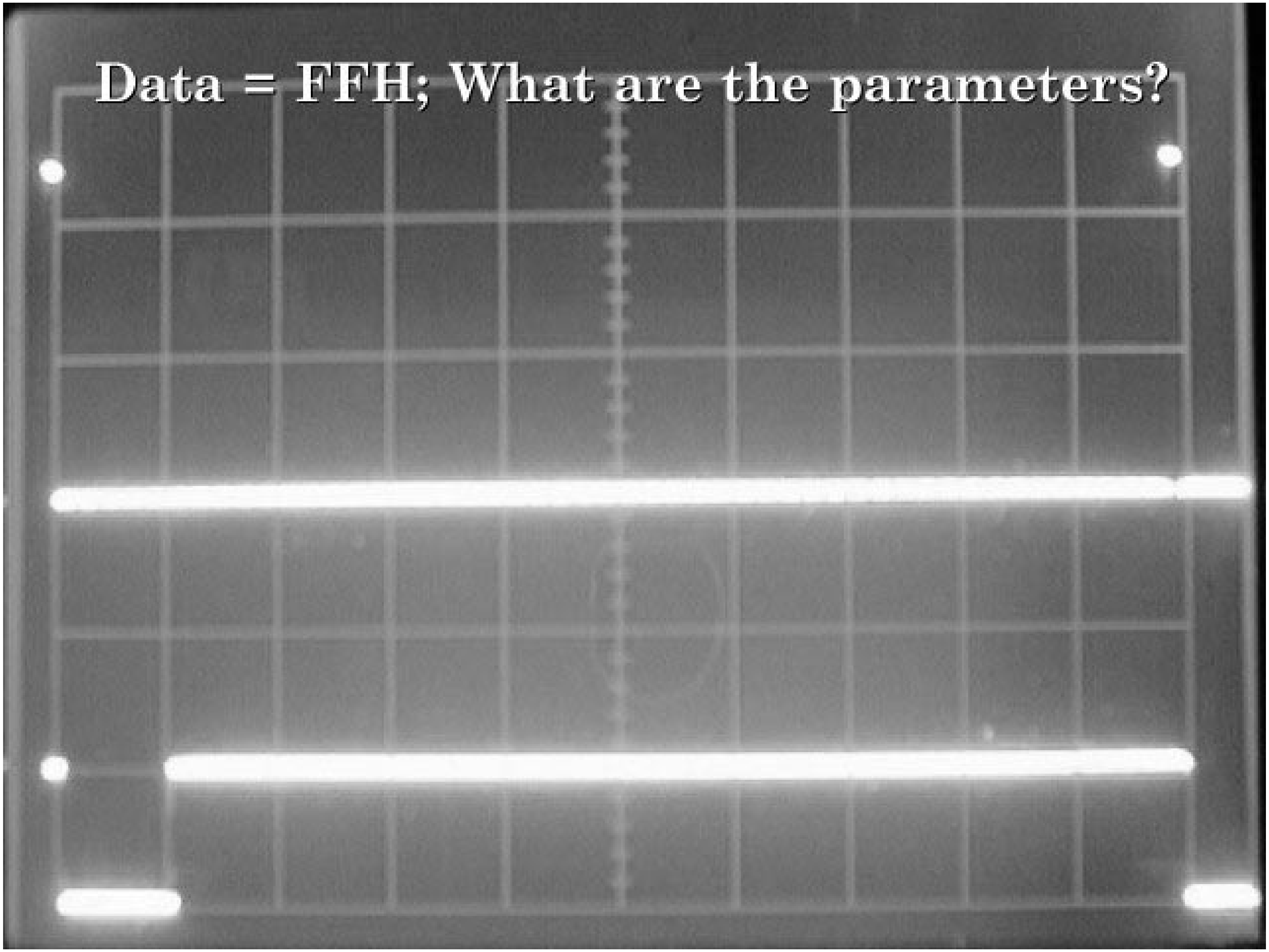
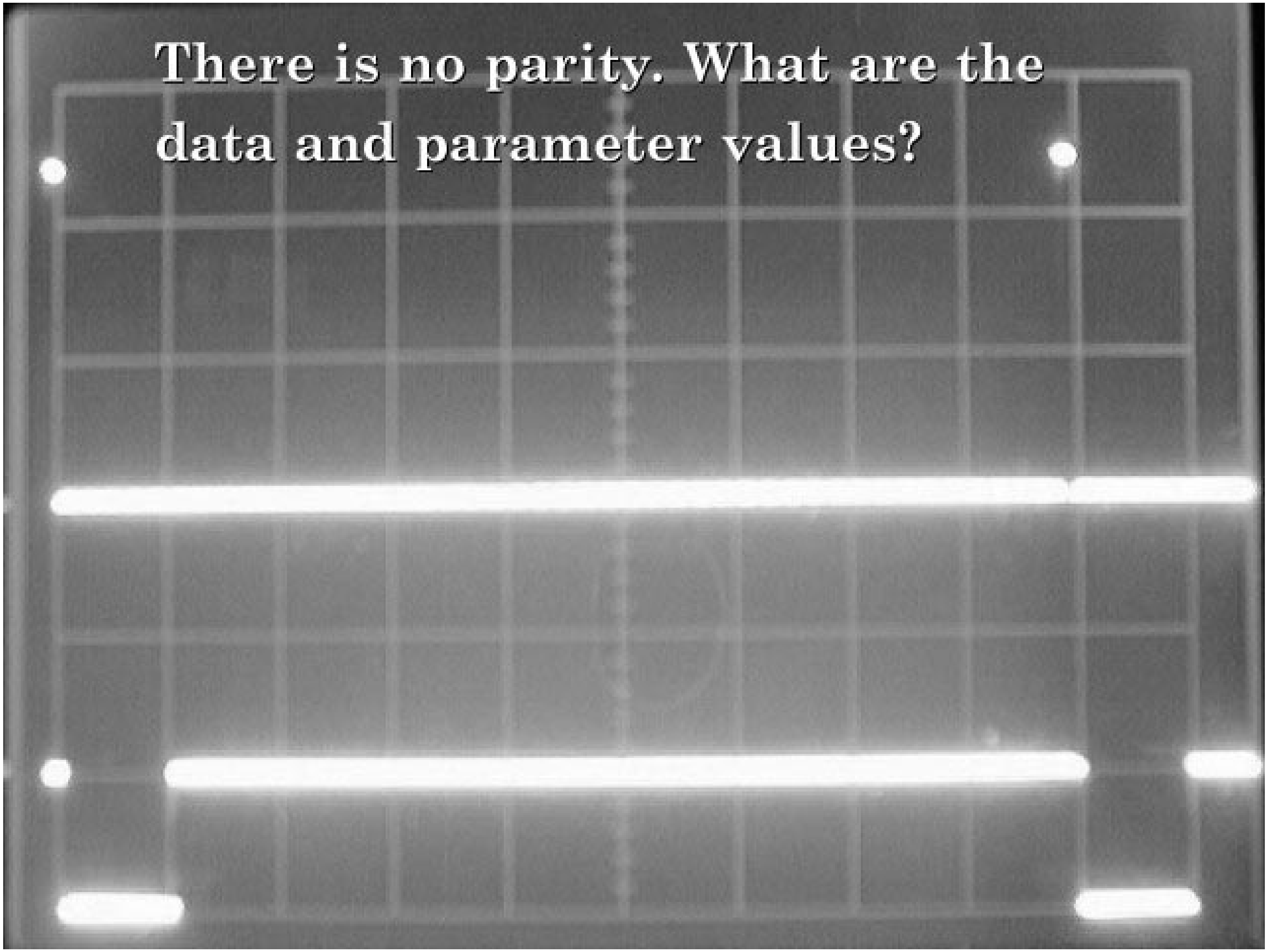


Oscilloscope Data



Oscilloscope Data