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Royal University of Phnom Penh

Data Communication I

Chapter 2.2 : Digital signals

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Outline

- Why Digital signal?
- Bit Interval vs Bit Rate?
- Data Rate Limit
- Transmission Impairment
- Filter

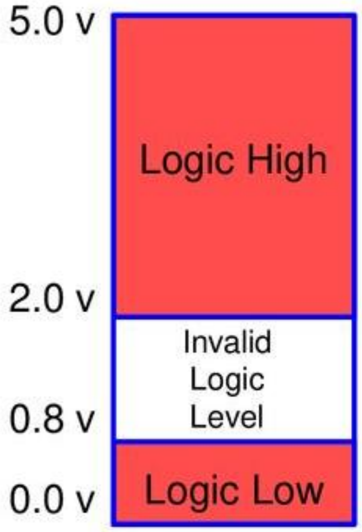
Why digital signal?

Why digital signal?

- All real life signals are analog
- Analog signal seems to be better then digital, but they are not
- Digital signals are used in communication process
- Digital signals are used to minimize the effect of noise
- Noise is unwanted signal
- Digital signals are because they can be programmed to multiple tasks using Digital signal processing (DSP).
- Easy to simulate and design

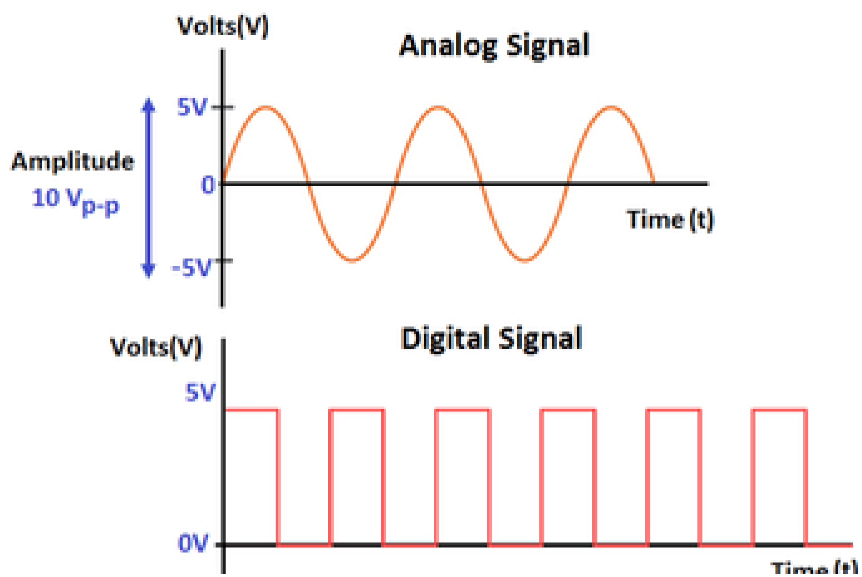
Why digital signal?

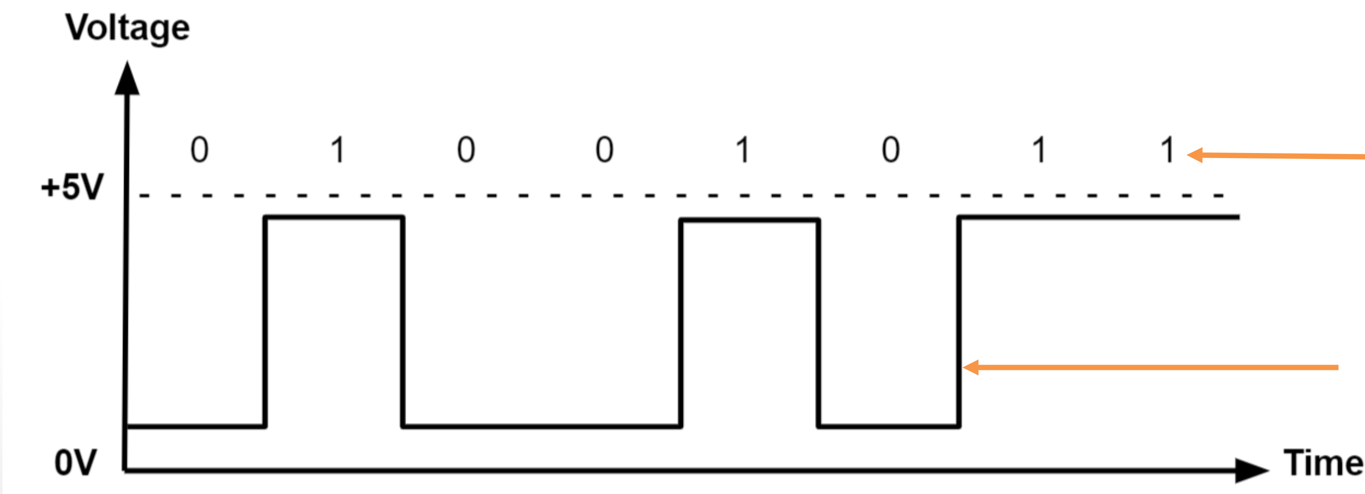
- Before examining digital signals, we must define logic levels.
- A **logic level** is a voltage level that represents a defined digital state.
- Logic HIGH: the higher of two voltages, typically 5 volts.
- Logic LOW: the lower of two voltages, typically 0 volts.



Logic Level	Voltage	True/False	On/Off	0/1
HIGH	5 volts	True	On	1
LOW	0 volts	False	Off	0

Why digital signal?



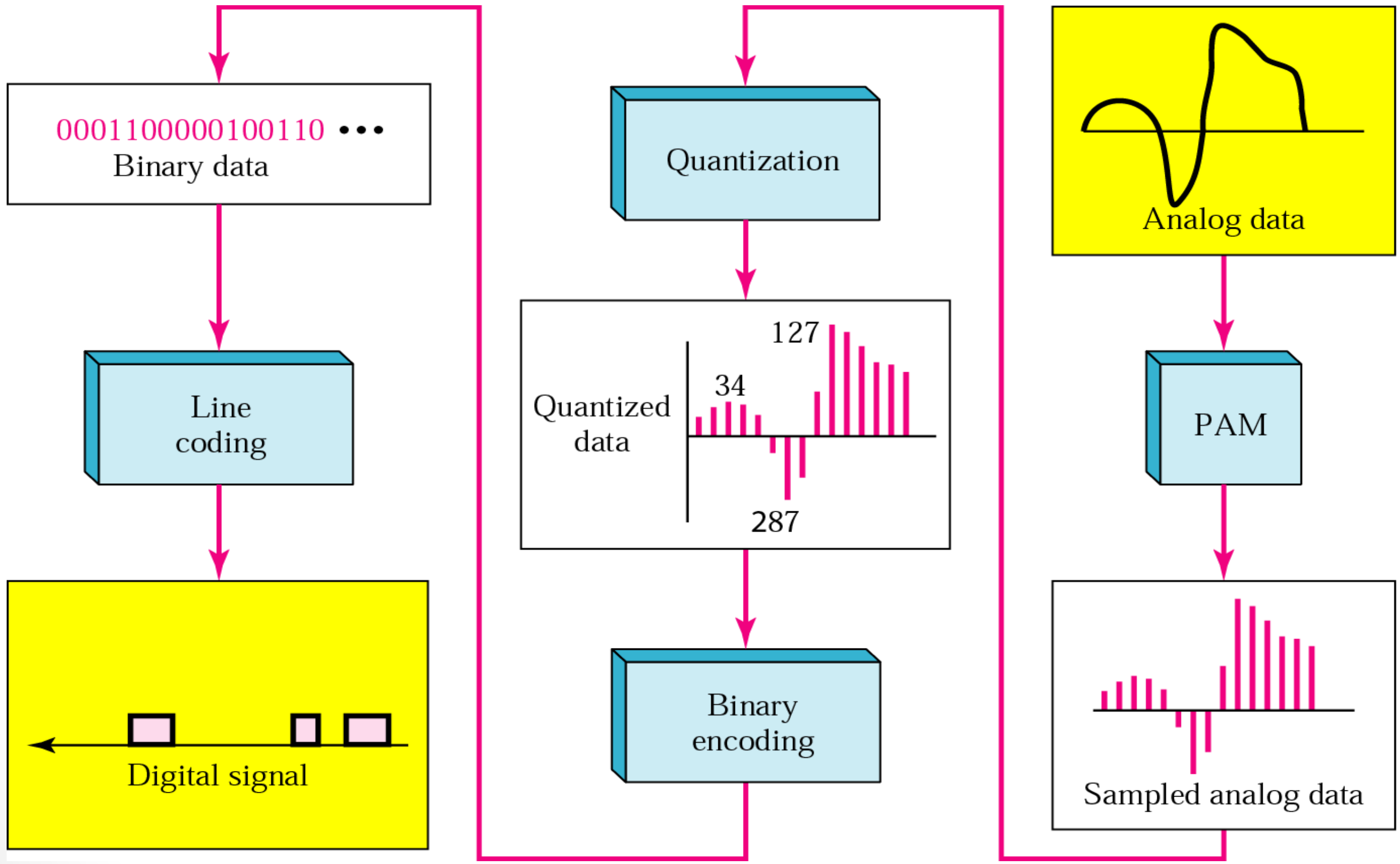


Digital Binary Or Digital Data

Digital Signal

Why digital signal?

Analog to Digital Conversion



Summary scheme of Analog to Digital Conversion

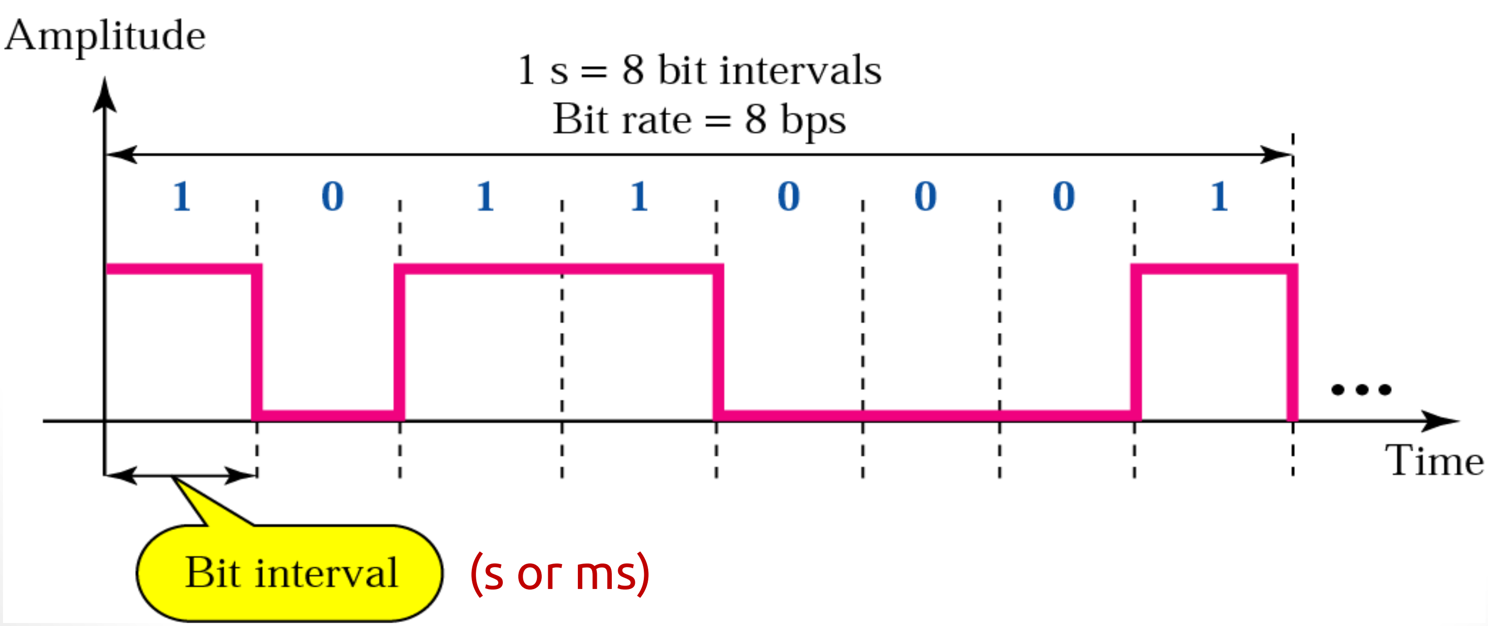
Bit Interval vs Bit Rate

Storage Units

UNIT	ABBREVIATION	STORAGE	Example
Bit	b	0 or 1	
Byte	B	8 bits	*Character*
Kilobyte	KB	1024 bytes	*Half page of text*
Megabyte	MB	1024 KB	*2mins of MP3*
Gigabyte	GB	1024 MB	*1hour movie*
Terabyte	TB	1024 GB	*128 DVD movie*
Petabyte	PB	1024 TB	*7 billion Facebook photos*

Bit Interval vs Bit Rate

- Data can be represent by a digital signal. For example a 1 can be encoded as a positive voltage and a 0 can be encode as a zero voltage.
- Bit Interval is the time required to sent one signal bit.
- Bit rate is the number of bits transmitted per second.



Bit Interval vs Bit Rate

Example1: A digital signal has a bit rate of 2000bps. What is the duration of each bit (bit interval)?

Example2: A device is sending out data at the rate 1000 bps. How long does it take to send a file of 100,000 characters?

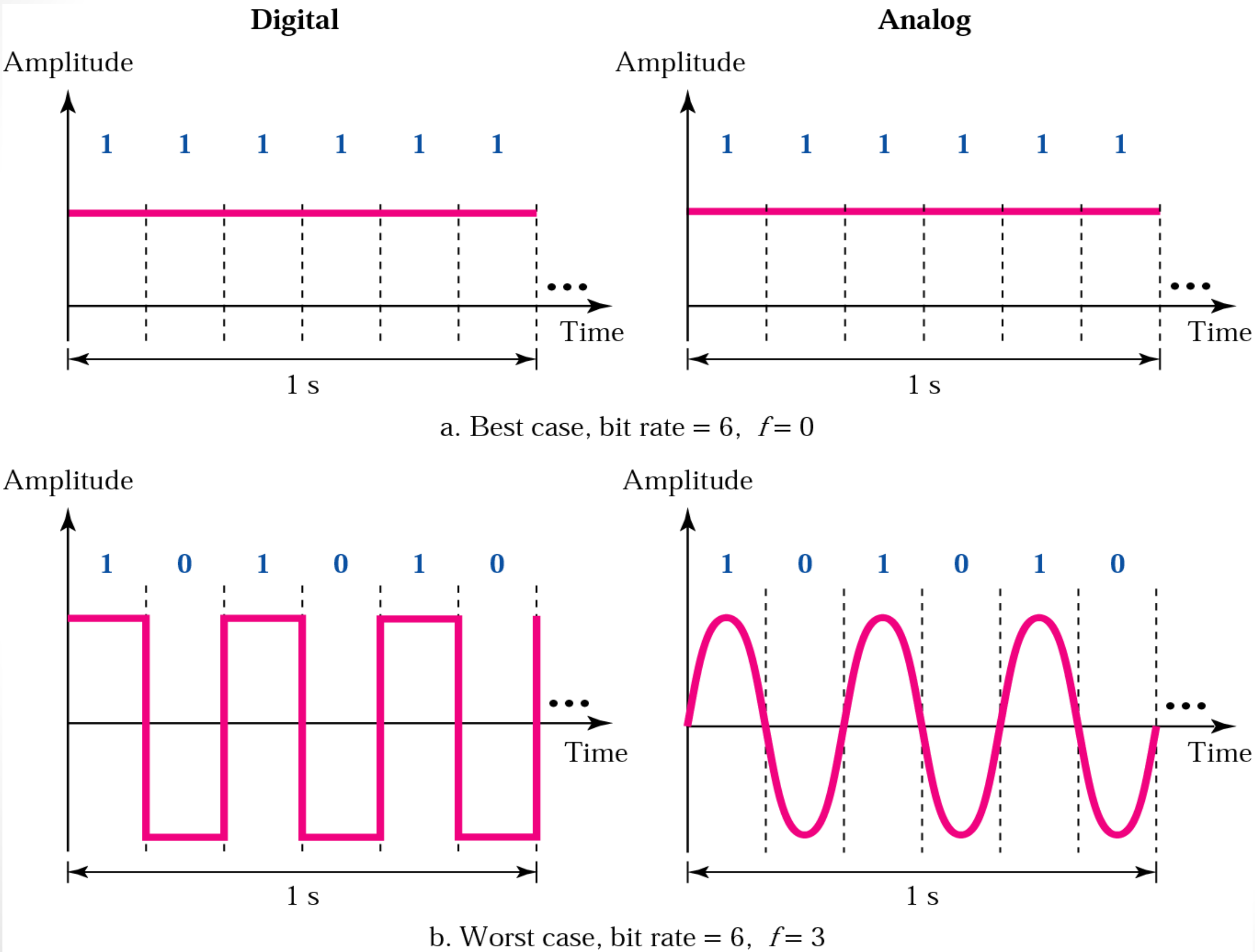
Bit Interval vs Bit Rate

Example3: An image has a size of 1920x1080pixels (Full HD) with true color, which mean that 3Byptes per pixel are used for the color information.

How long does it take to transmit the uncompressed image via a:

1. 56kbps Modem connection?
2. 64kbps ISDN connection?
3. 1 Mbps DSL connection?
4. 100 Mbps Ethernet connection?
5. 1 Gbps Ethernet connection?

Bit Interval vs Bit Rate



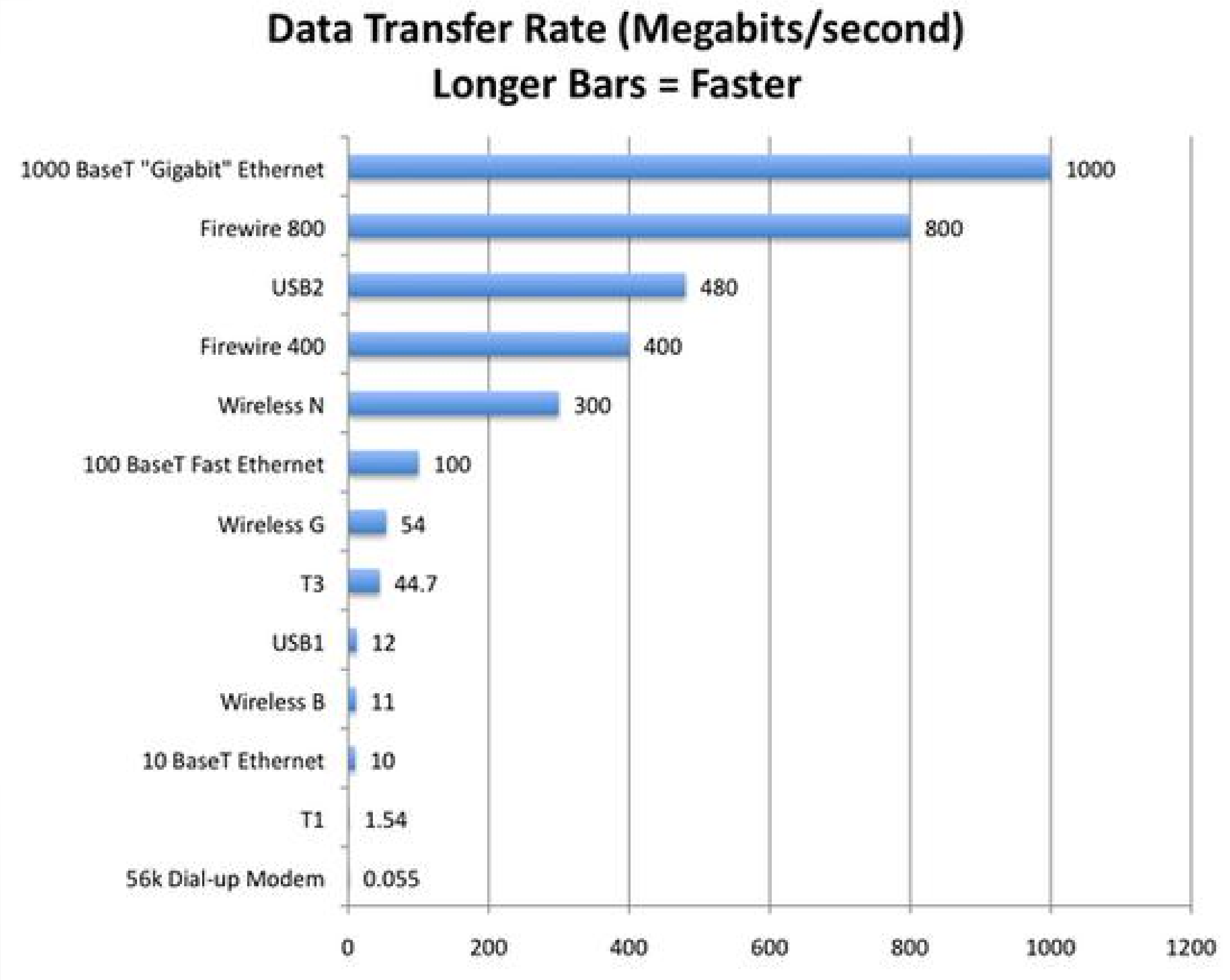
Data Rate Limit

- A very important consideration in data communications is how fast we sent data in a bits per second over a channel.

- Data rate depends on 3 factors:
  1. The bandwidth available
  2. The level of the signals we use
  3. The quality of the channel (the level of noise)

- We have two formulas to calculate data rate:
  1. Noiseless Channel: Nyquist Bit Rate
  2. Noisy Channel: Shannon Capacity

Data Rate Limit



Data Rate Limit

Audio and image processing data rate

Bitrate	Sound Quality
8kbps	AM
16kbps	AM
24kbps	AM
32kbps	FM
56kbps	FM
64kbps	CD
96kbps	CD
128kbps	CD
256kbps	CD

In audio processing

Bitrate (kbps)	Resolution
235	320x240
375	384x288
560	512x384
750	512x384
1050	640x480
1750	720x480
2350	1280x720
3000	1280x720
4300	1920x1080
5800	1920x1080

In image processing

Data Rate Limit

1. Noiseless Channel: Nyquist Bit Rate

For a noiseless channel, the Nyquist bit rate formula defines the theoretical maximum bit rate:

$$Bit\ Rate = 2\ x\ B\ x\ log_2 L$$

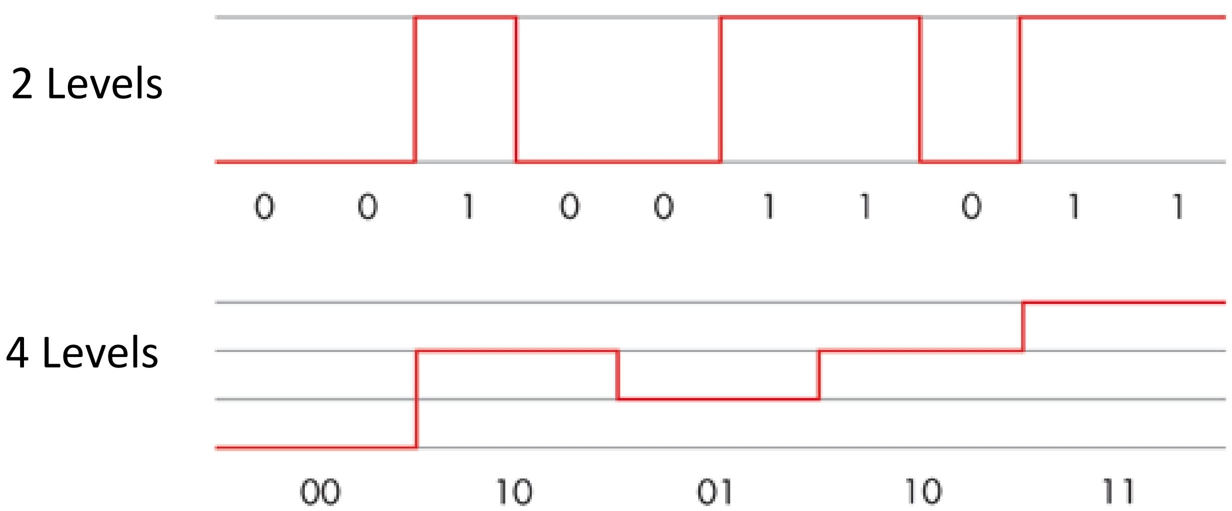
(bps)

- B is the bandwidth of the channel
- L is the number of signal levels used to represent data

- Note: *Increase the levels of a signal may reduce the reliability of the system*

Data Rate Limit

1. Noiseless Channel: Nyquist Bit Rate



Signal Level Example

Data Rate Limit

1. Noiseless Channel: Nyquist Bit Rate

Example 1: Consider a noiseless channel with a bandwidth of 3000 Hz transmitting a signal with two signal level. The maximum bit rate can be calculated as

Example 2: Consider the same noiseless channel transmitting a signal with four signal level. The maximum bit rate can be calculated as

Data Rate Limit

1. Noiseless Channel: Nyquist Bit Rate

Example 3: We need to send 265 kbps over a noiseless channel with a bandwidth of 20 kHz. How many signal levels do we need?

Data Rate Limit

2. Noisy Channel: Shannon Capacity

- In reality, we cannot have a noiseless channel; the channel is always noisy.
- In 1944, Claude Shannon introduced a formula, called the Shannon capacity, to determine the theoretical highest data rate for a noise channel:

$$\underset{(bps)}{\mathrm{C}} = B\ x\ log_2(1 + SNR)$$

- B is the bandwidth of the channel
- SNR is the signal to noise ratio
- C is the capacity of the channel in bits per second

Data Rate Limit

2. Noisy Channel: Shannon Capacity

Example1: Consider an extremely noisy channel in which the value of the signal to noise ratio is almost zero. In the other words, the noise is so strong that the signal is faint. For this channel, the capacity C is calculated:

Data Rate Limit

2. Noisy Channel: Shannon Capacity

Example2: We can calculate the theoretical highest bit rate of a regular telephone line. A telephone line normally has a bandwidth of 3000 Hz (300 Hz to 3300Hz). The signal to noise ratio is usually 3162. For this channel the capacity is calculate as:

Data Rate Limit

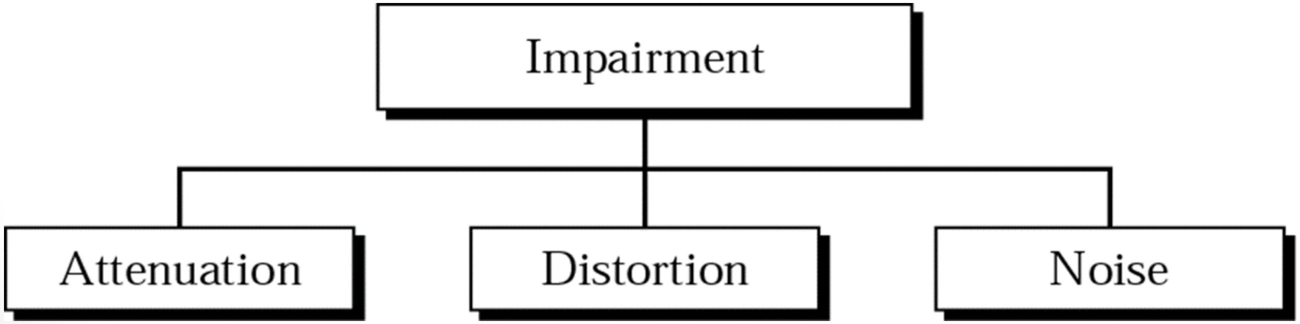
Example3: The digital signal is to be designed to permit **160 kbps** for a bandwidth of **20kHz**.

a. Find the number of signal level?

b. Find Signal to Noise Ratio (SNR)?

Transmission Impairment

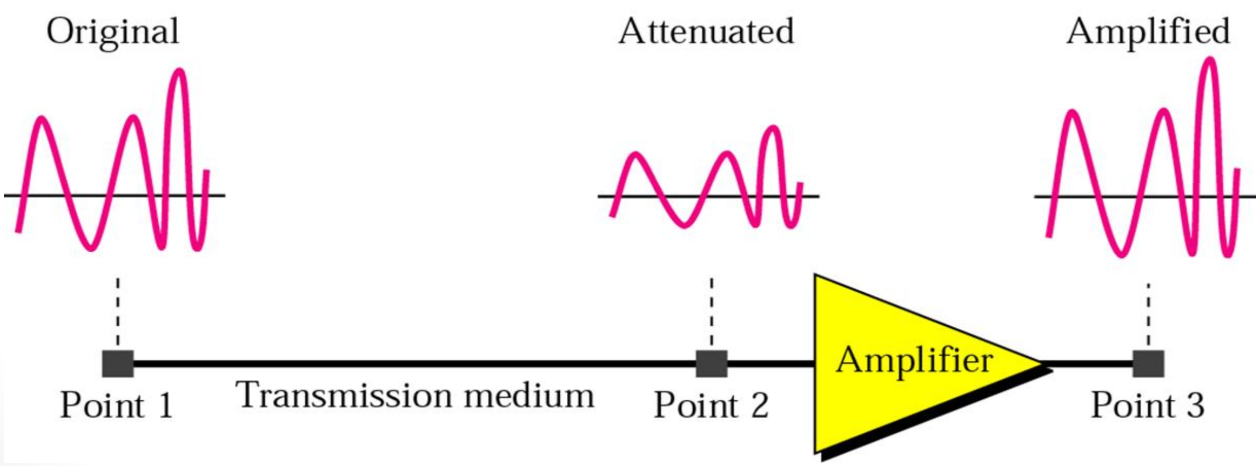
- Signals travel through transmission media, which are not perfect. The imperfection causes signal impairment.
- This mean the signal at the beginning of the medium is not the same as the signal at the end of medium. What is sent is not what is received.
- Three causes of impairment are attenuation, distortion and noise.



Transmission Impairment

1. Attenuation

- It's mean loss of energy → Weaker signal
- When a signal travels through a medium it loses energy overcoming the resistance of the medium.
- Amplifiers are used to compensate for this loss of energy by amplifying the signal.



Transmission Impairment

1. Attenuation

- Attenuation decides the signal to noise ratio hence the quality of received signal. Attenuation is given in decibels as:

$$\text{Attenuation}(db) = 10\ x\ log_{10}\left(\frac{P_{out}}{P_{in}}\right)$$

- P_{out} = Power at the receiving end
- P_{in} = Power at the sending end

Transmission Impairment

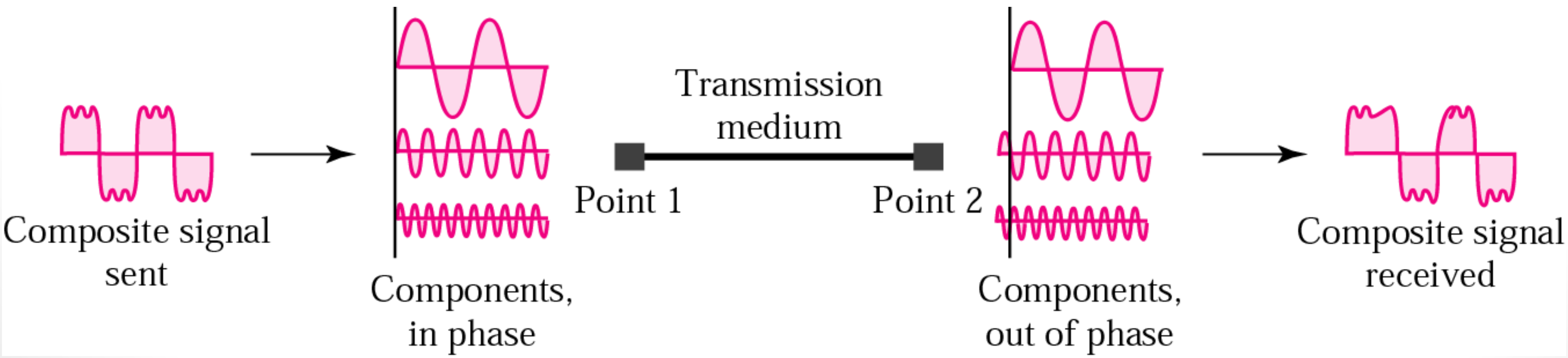
1. Attenuation

Example: Imagine a signal travels through a transmission medium and its power is reduced to half. This mean that Pout=1/2 Pin. In this case, the attenuation can be calculated:

Transmission Impairment

2. Distortion

- Distortion means signal changes its form or shape
- Distortion occurs in a composite signals made of different frequency.
- Each signal component have its own propagation speed through a medium and therefore its own delay in arriving at the final signal.



Transmission Impairment

2. Distortion

Attenuation	Distortion
-Loss in signal strength because of resistance in the medium	- Any alteration of the original signal induced by any types of interference
-Does not change the waveform	- Changes waveform
-Relatively easy to overcome the effects	-Difficult to remove the effectes
-Amplitude reduces over the specific amount in the signal	-Attenuation happening at different places in the signal

Transmission Impairment

3. Noise

- When data travels over a transmission medium, noise gets added to it. Noise is a major limiting factor in communication system performance.
- Noise can be categorized into **four** types:
  1. Thermal noise: thermal agitation of electrons in a conductor
  2. Intermodulation noise: multiple signals share the same transmission medium.
  3. Crosstalk noise: crossing between one transmission medium to the other one.
  4. Impulse noise: irregular pulses or noise happening in a short duration generated by phenomena like lightning,…

Transmission Impairment

3. Noise

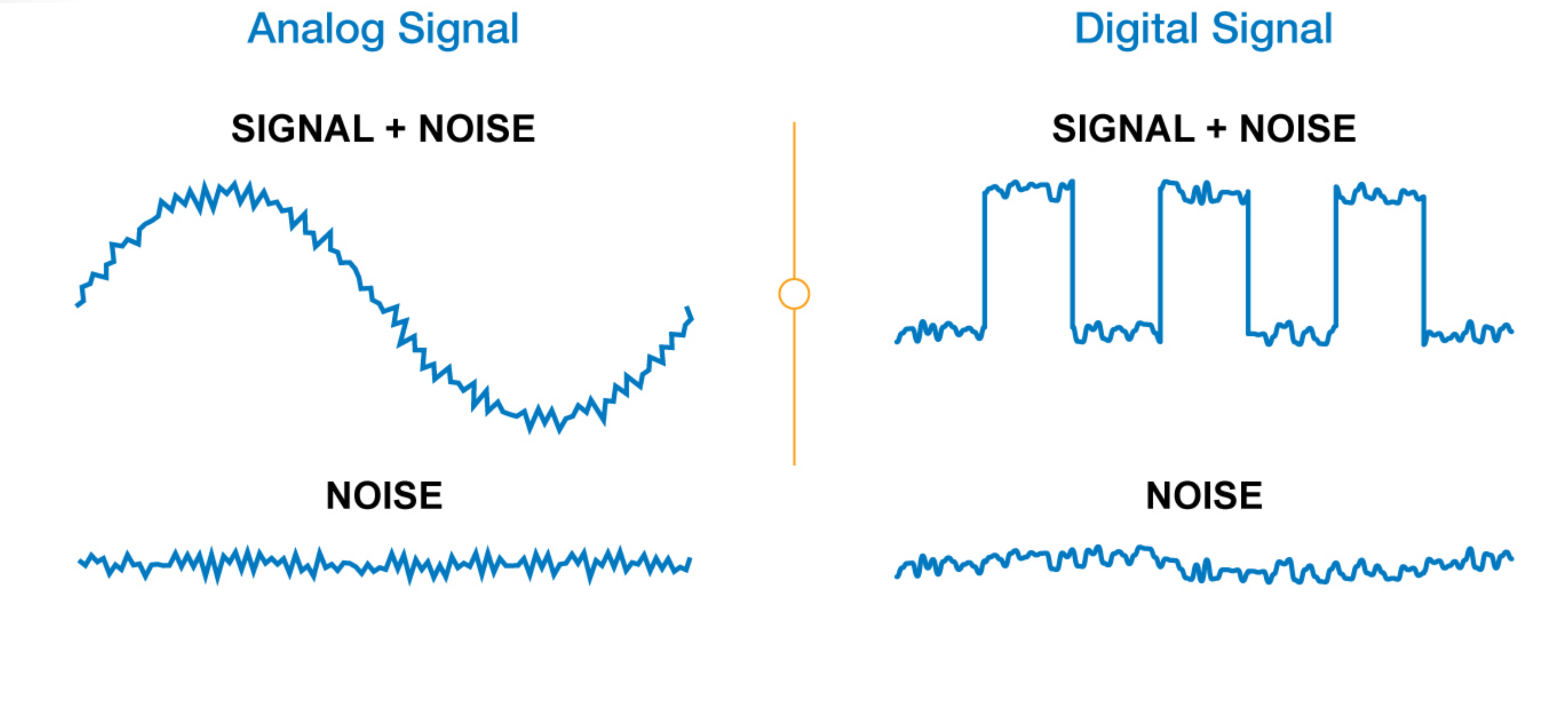


FIGURE 1. Noise in Analog and Digital Signals

Transmission Impairment

3. Noise (SNR)

- Signal to Noise Ratio is use to measure the quality of a system.
- It's indicates the strength of the signal with respect to the noise power in the system.
- It's the ratio between two power and usually given in db and referred to as SNRdB.

$$\mathrm{SNR(db)} = 10\ x\ log_{10}\left(\frac{Signal\ Power}{Noise\ Power}\right) = 10log_{10}\frac{P_s}{P_n}$$

$$= 10\ x\ log_{10}(SNR)$$

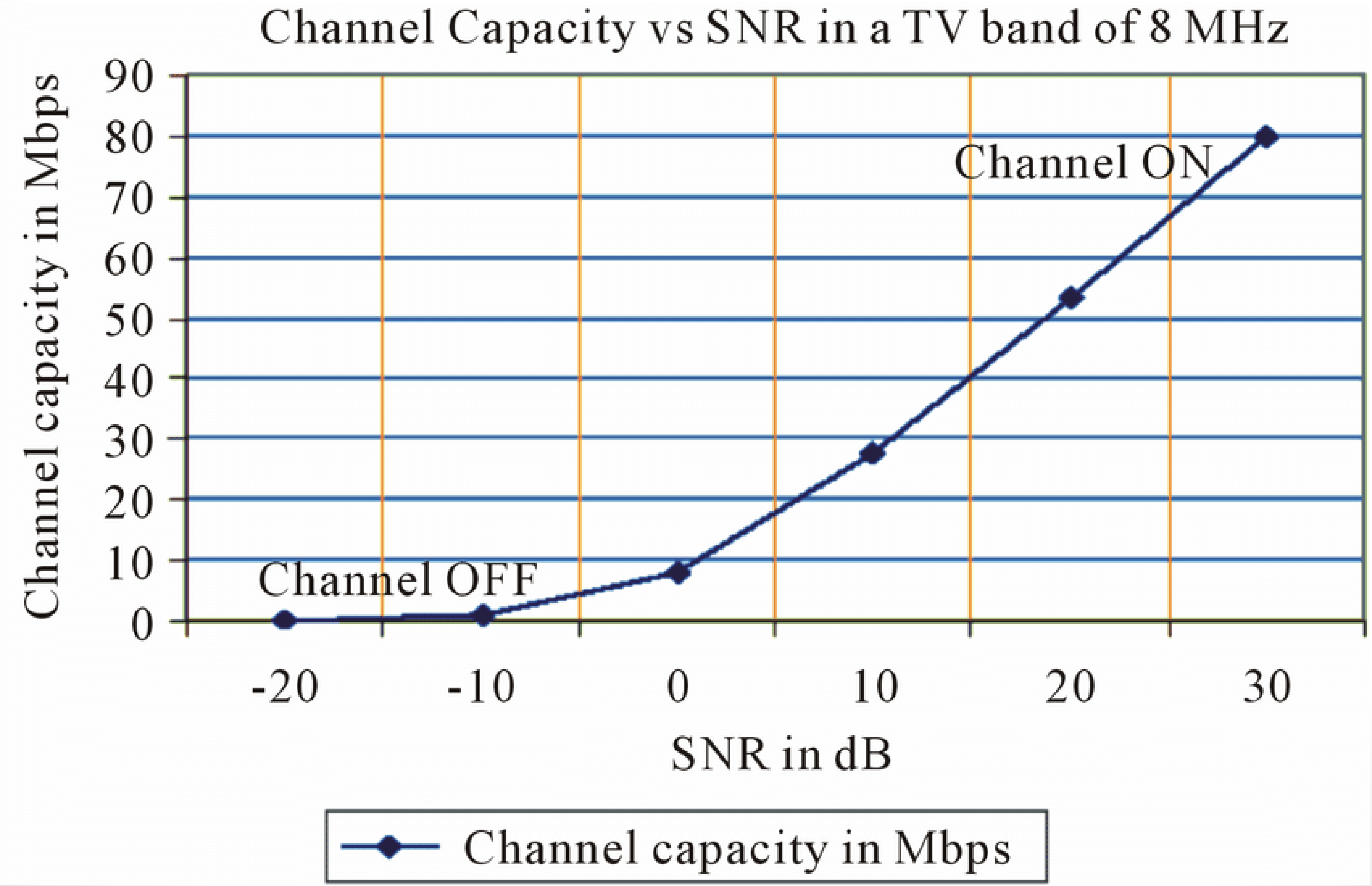
Transmission Impairment

3. Noise (SNR)

Example: The power of a signal is 10 mW and the power of the noise is 1 μW; what are the values of SNR(db)?

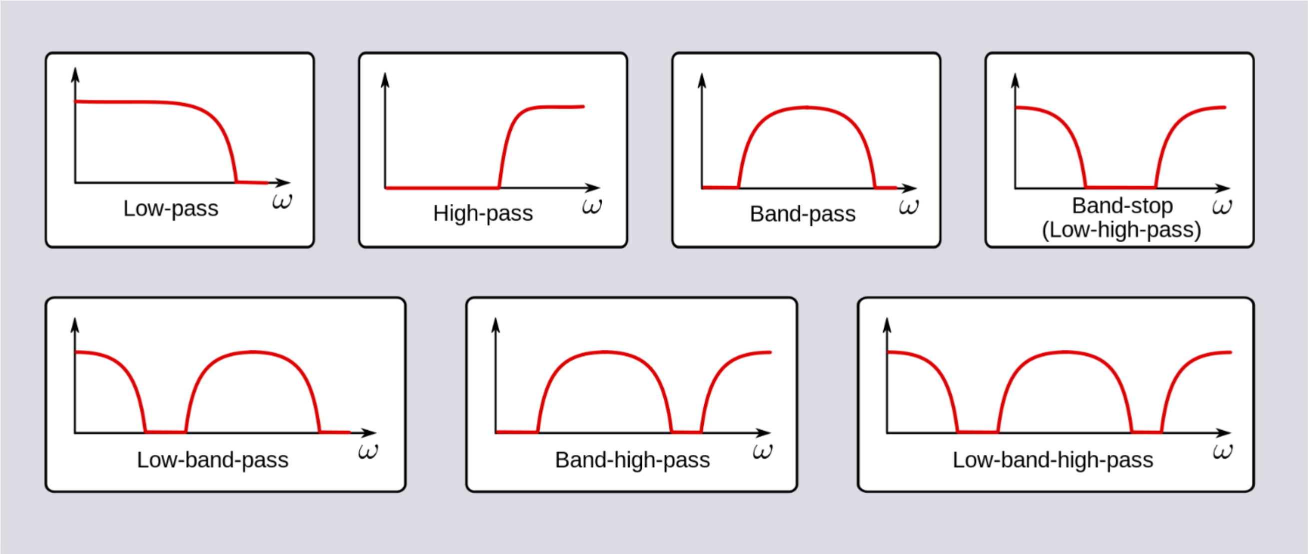
Transmission Impairment

3. Noise (SNR)



Filter

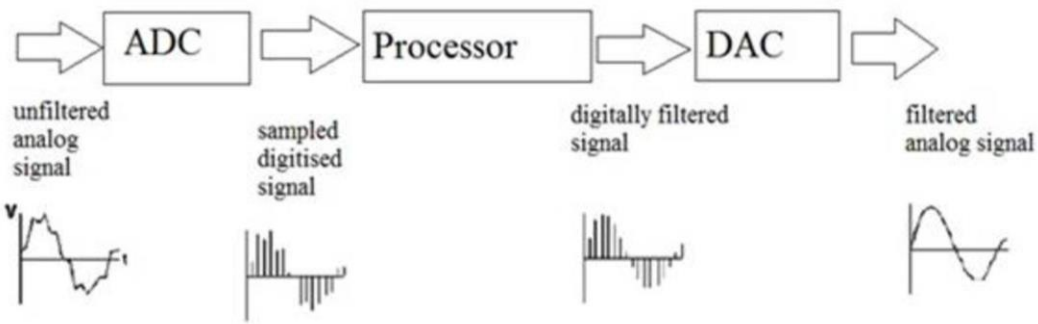
- Digital and Analog filters both take out unwanted noise or signal components, but filters work differently in the analog and digital domains.
- Analog filters will remove everything above or below a chosen cutoff frequency, while digital filters can be more precisely programmed.



Type of analog filters

Filter

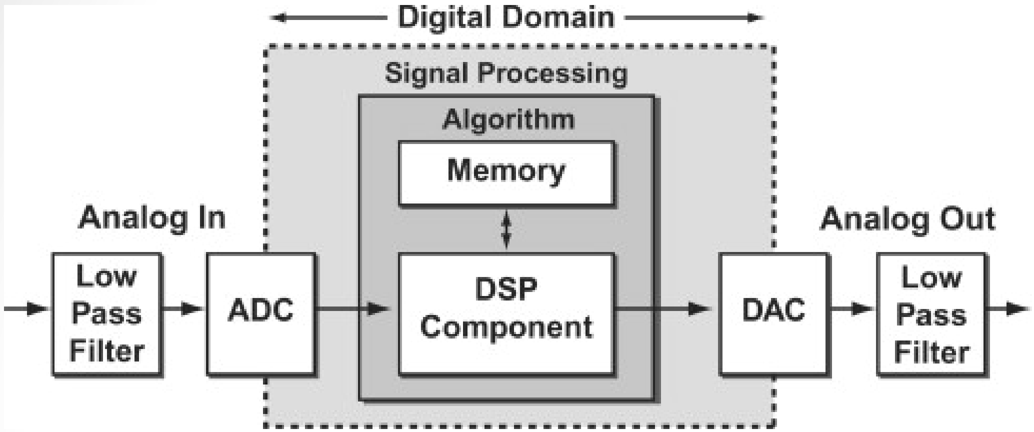
- Digital filters uses a digital processor to perform numerical calculations on sampled values of the signal.
- The processor may be a general-purpose computer such as a PC or a specialized DSP chip.

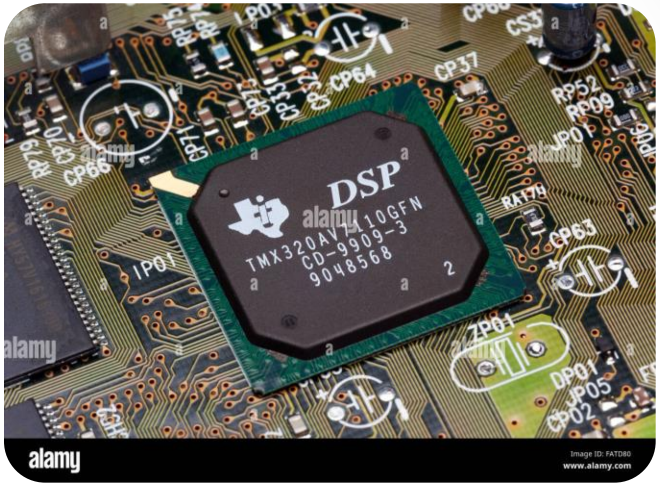


Block diagram of digital filter.

DEMO

Filter


Digital Domain
Signal Processing
Algorithm
Memory
Analog In
Low Pass Filter
ADC
DSP Component
DAC
Analog Out
Low Pass Filter


DSP
TMX320AV7110GFN
CD-9909-3
9048568
alamy


4-WAY
DSP 2.4X
DIGITAL SIGNAL PROCESSOR
PRV audio
FEATURES
2 CHANNEL INPUTS
10 DIGITAL CROSSOVER FILTERS
HI-VOLT PRE AMP
4-WAY INDEPENDENT OUTPUT PARAMETRIC EQ
LIMITER, PHASE & DELAY CONTROLS
RC Remote Control (Sequencer)
TG Tone Generator
FS Frequency Sweep
EP 12 Equalizer Presets
DL Display LCD
REMOTE OUT SEQUENCER
REM IN
GND
+BAT
DSP 2.4X
Digital Signal Processor
MAIN CONTROL
OUTPUT SELECT
LIMITER

Filter

- The analog bandwidth of a medium is expressed in Hz. while the digital bandwidth expressed in Bits per second (bps).
- Analog transmission
  - Continues difference tones sent
  - Any value between two different point
  - Can use a band pass channel

- Digital transmission
  - Character converted to ASCII
  - Sent as zeroes (0) and ones (1)
  - Can use a low pass channel.

Q&A