# FORMATTING AND BASEBAND MODULATION

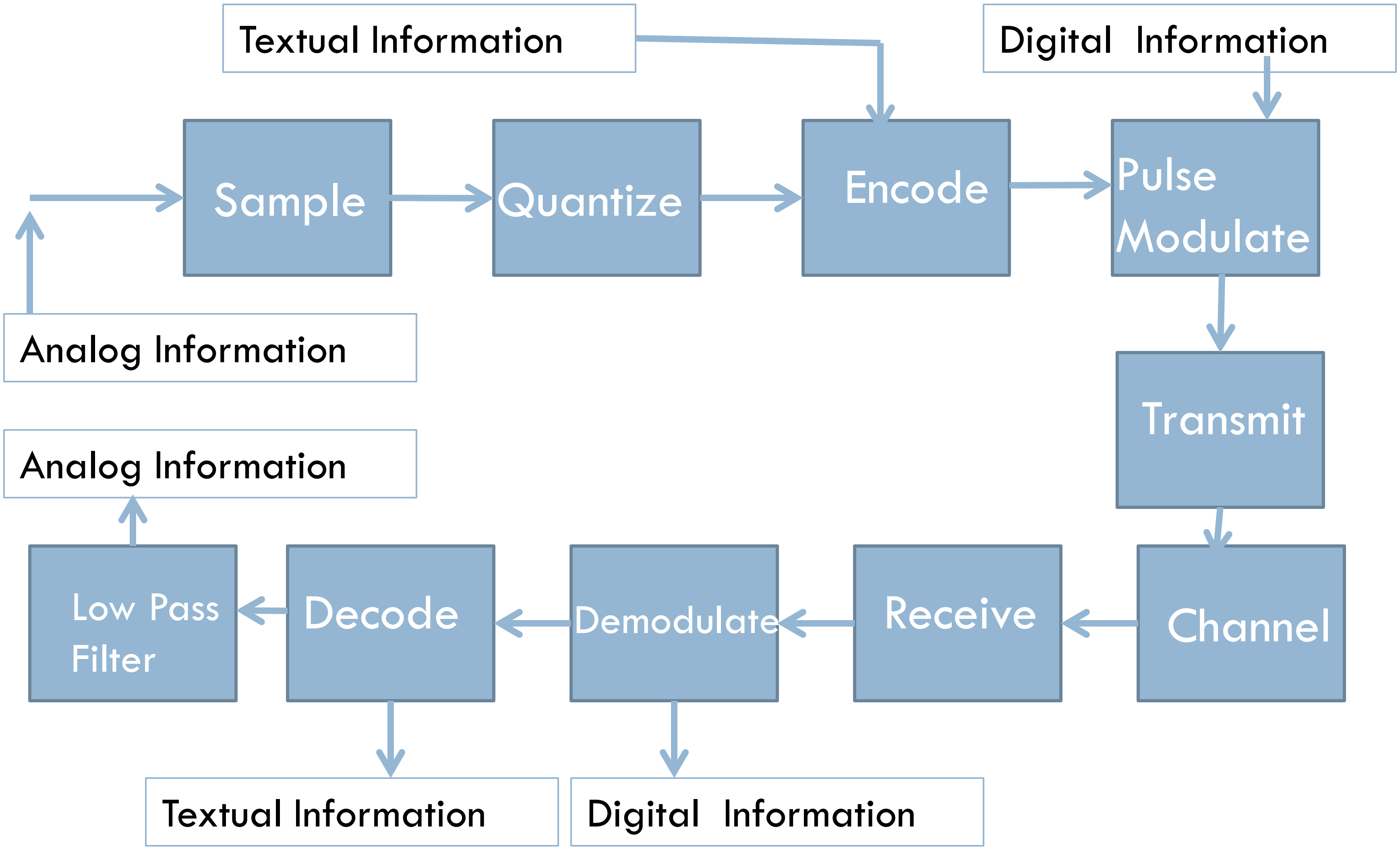
# Text

- Digital Communications

  Bernard Sklar

  Publisher : Pearson Education

# Formatting and transmission of baseband signals



# Formatting textual data

| Character | T | H | I | N | K |
|---|---|---|---|---|---|
| 6-bit ASCII | 001 010 | 000 100 | 100 100 | 011 100 | 110 100 |
| 8-ary symbols | 1 2 | 0 4 | 4 4 | 3 4 | 6 4 |
| 8 -ary waveforms | S1(t) S2(t) | S0(t) S4(t) | S4(t) S4(t) | S3(t) S4(t) | S6(t) S4(t) |

# ASCII TABLE

| Decimal | Hex | Char | Decimal | Hex | Char | Decimal | Hex | Char | Decimal | Hex | Char |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | [NULL] | 32 | 20 | [SPACE] | 64 | 40 | @ | 96 | 60 | ` |
| 1 | 1 | [START OF HEADING] | 33 | 21 | ! | 65 | 41 | A | 97 | 61 | a |
| 2 | 2 | [START OF TEXT] | 34 | 22 | " | 66 | 42 | B | 98 | 62 | b |
| 3 | 3 | [END OF TEXT] | 35 | 23 | # | 67 | 43 | C | 99 | 63 | c |
| 4 | 4 | [END OF TRANSMISSION] | 36 | 24 | $ | 68 | 44 | D | 100 | 64 | d |
| 5 | 5 | [ENQUIRY] | 37 | 25 | % | 69 | 45 | E | 101 | 65 | e |
| 6 | 6 | [ACKNOWLEDGE] | 38 | 26 | & | 70 | 46 | F | 102 | 66 | f |
| 7 | 7 | [BELL] | 39 | 27 | ' | 71 | 47 | G | 103 | 67 | g |
| 8 | 8 | [BACKSPACE] | 40 | 28 | ( | 72 | 48 | H | 104 | 68 | h |
| 9 | 9 | [HORIZONTAL TAB] | 41 | 29 | ) | 73 | 49 | I | 105 | 69 | i |
| 10 | A | [LINE FEED] | 42 | 2A | * | 74 | 4A | J | 106 | 6A | j |
| 11 | B | [VERTICAL TAB] | 43 | 2B | + | 75 | 4B | K | 107 | 6B | k |
| 12 | C | [FORM FEED] | 44 | 2C | , | 76 | 4C | L | 108 | 6C | l |
| 13 | D | [CARRIAGE RETURN] | 45 | 2D | - | 77 | 4D | M | 109 | 6D | m |
| 14 | E | [SHIFT OUT] | 46 | 2E | . | 78 | 4E | N | 110 | 6E | n |
| 15 | F | [SHIFT IN] | 47 | 2F | / | 79 | 4F | O | 111 | 6F | o |
| 16 | 10 | [DATA LINK ESCAPE] | 48 | 30 | 0 | 80 | 50 | P | 112 | 70 | p |
| 17 | 11 | [DEVICE CONTROL 1] | 49 | 31 | 1 | 81 | 51 | Q | 113 | 71 | q |
| 18 | 12 | [DEVICE CONTROL 2] | 50 | 32 | 2 | 82 | 52 | R | 114 | 72 | r |
| 19 | 13 | [DEVICE CONTROL 3] | 51 | 33 | 3 | 83 | 53 | S | 115 | 73 | s |
| 20 | 14 | [DEVICE CONTROL 4] | 52 | 34 | 4 | 84 | 54 | T | 116 | 74 | t |
| 21 | 15 | [NEGATIVE ACKNOWLEDGE] | 53 | 35 | 5 | 85 | 55 | U | 117 | 75 | u |
| 22 | 16 | [SYNCHRONOUS IDLE] | 54 | 36 | 6 | 86 | 56 | V | 118 | 76 | v |
| 23 | 17 | [ENG OF TRANS. BLOCK] | 55 | 37 | 7 | 87 | 57 | W | 119 | 77 | w |
| 24 | 18 | [CANCEL] | 56 | 38 | 8 | 88 | 58 | X | 120 | 78 | x |
| 25 | 19 | [END OF MEDIUM] | 57 | 39 | 9 | 89 | 59 | Y | 121 | 79 | y |
| 26 | 1A | [SUBSTITUTE] | 58 | 3A | : | 90 | 5A | Z | 122 | 7A | z |
| 27 | 1B | [ESCAPE] | 59 | 3B | ; | 91 | 5B | [ | 123 | 7B | { |
| 28 | 1C | [FILE SEPARATOR] | 60 | 3C | < | 92 | 5C | \ | 124 | 7C | \| |
| 29 | 1D | [GROUP SEPARATOR] | 61 | 3D | = | 93 | 5D | ] | 125 | 7D | } |
| 30 | 1E | [RECORD SEPARATOR] | 62 | 3E | > | 94 | 5E | ^ | 126 | 7E | ~ |
| 31 | 1F | [UNIT SEPARATOR] | 63 | 3F | ? | 95 | 5F | _ | 127 | 7F | [DEL] |

# Data rates(Analog Information)

- Analog signal

  Sampling rate = fs samples/sec

  Time between samples = Ts = 1/fs

  N bits per sample

  Data rate in bits/sec (bps) = Nfs
- Symbol rate

  k bits are grouped to form a symbol

  Data rate in symbols/sec = bps/k
- Number of possible symbols

  $M = 2^k$

  M' ary waveforms

# Data rate (Textual information)

- Data rate in characters/Sec = fch

  Time between two characters = Tch = 1/fch

  N bits /Character

  Data rate in bps = Nfch
- Symbol rate

  k bits are grouped to form the symbol

  Symbol rate = bps/k
- Number of possible symbols

  $M = 2^k$

  M' ary waveforms

# Data rate (Digital information)

- Data rates in bits /sec = bps

  k bits are grouped to form the symbol

  Symbol rate = bps/k

# Problem 2.1

- Encode the word "HOW" using 8 bit ASCII along with even parity for "1"
- How many total bits in the message?
- Partition the bit stream into k = 3 bit segments.Code each segment using an octal number.How many octal numbers?
- For 16'ary system how many symbols?
- For 256'ary system how many symbols?

# Solution P2.1

| Letter | Hex | 7 bit ASCII | 8 bit with even parity |
| --- | --- | --- | --- |
| H | 48 | 1001000 | 01001000 |
| O | 4F | 1001111 | 11001111 |
| W | 57 | 1010111 | 11010111 |

| Binary | 010 | 010 | 001 | 100 | 111 | 111 | 010 | 111 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Octal | 2 | 2 | 1 | 4 | 7 | 7 | 2 | 7 |

# Solution to 2.1

(c) Total umber of bits = 24

Number of bits per symbol = 4

Total number of symbols = 24/4 = 6

(d) Number of bits per symbol = 8

Total number of symbols = 24/8 = 3

# P 2.3

- A 100 character message is transmitted in 2 seconds with 8 bit ASCII.
- A multilevel waveform with $M = 32$ is used
- Calculate the effective transmitted bit rate and the symbol rate. Repeat for $M = 16, 8, 4$ and 2.

# Solution

- Total number of bits in 2 seconds = 8x100= 800

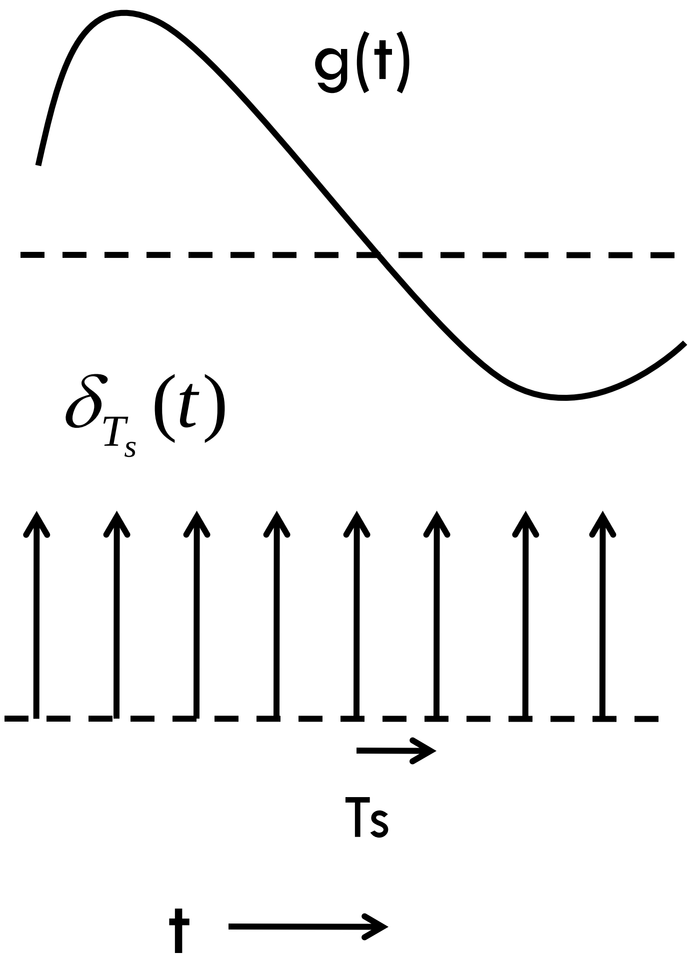
  Bit rate = 800/2 = 400 bits/sec

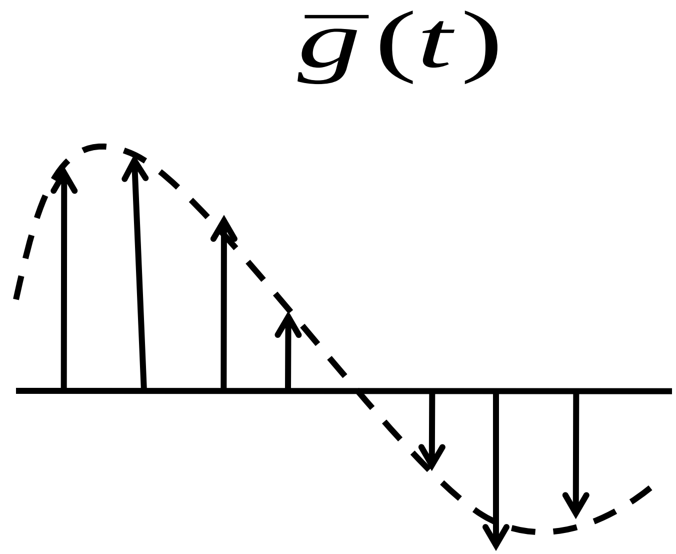
  M = 32

  Number of bits/symbol = 5

  Symbols/sec = 400/5 = 80 symbols/sec
- M = 16 : Rate = 400/4 = 100 symbols/sec
- M = 8 : Rate = 400/3= 133.3 symbols/sec
- M =4 :Rate = 400/2 = 200 symbols/sec
- M=2 Rate = 400/1 = 400 symbols/sec

# Sampling theorem




$$\bar{g}(t) = g(t)\delta_{T_s}(t)$$

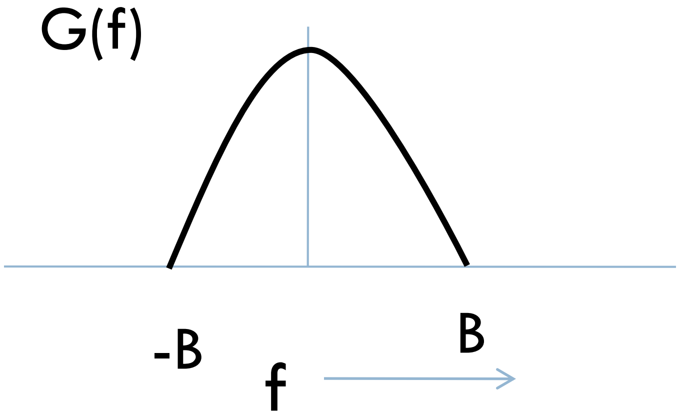
$$\delta_{T_s}(t) = \frac{1}{T_s}\sum_{n=-\infty}^{\infty} e^{jn\omega_s t}$$

$$\bar{g}(t) = \frac{1}{T_s}\sum_{n=-\infty}^{\infty} g(t)e^{jn\omega_s t}$$

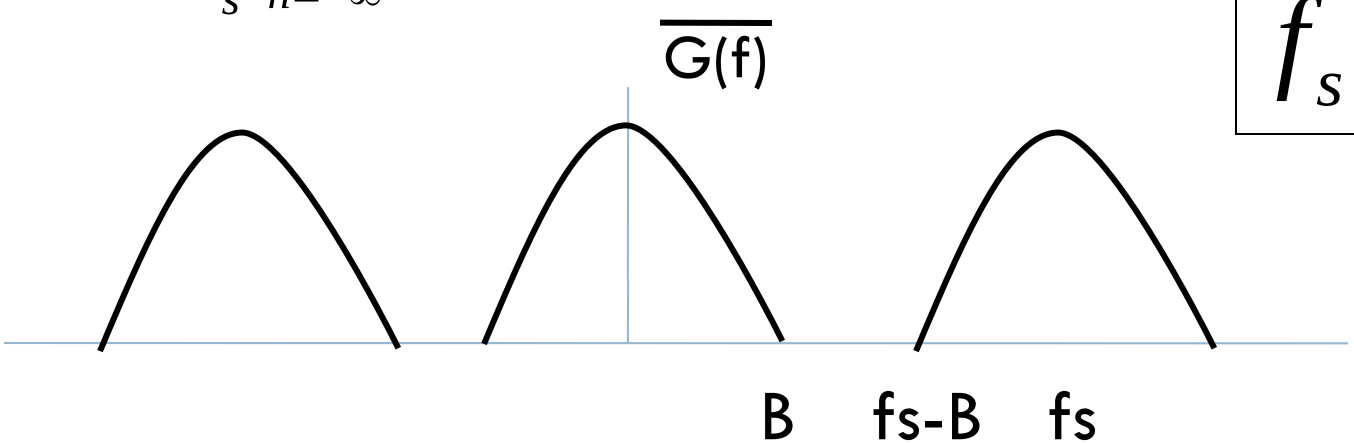
# Frequency spectrum of sampled signal

$$\bar{g}(t) = \frac{1}{T_s}\sum_{n=-\infty}^{\infty} g(t)e^{jn2\pi f_s t}$$

$$\overline{G}(f) = \frac{1}{T_s}\sum_{n=-\infty}^{\infty} G(f - nf_s)$$




$$\boxed{f_s \geq 2B}$$



# Formatting Analog Data

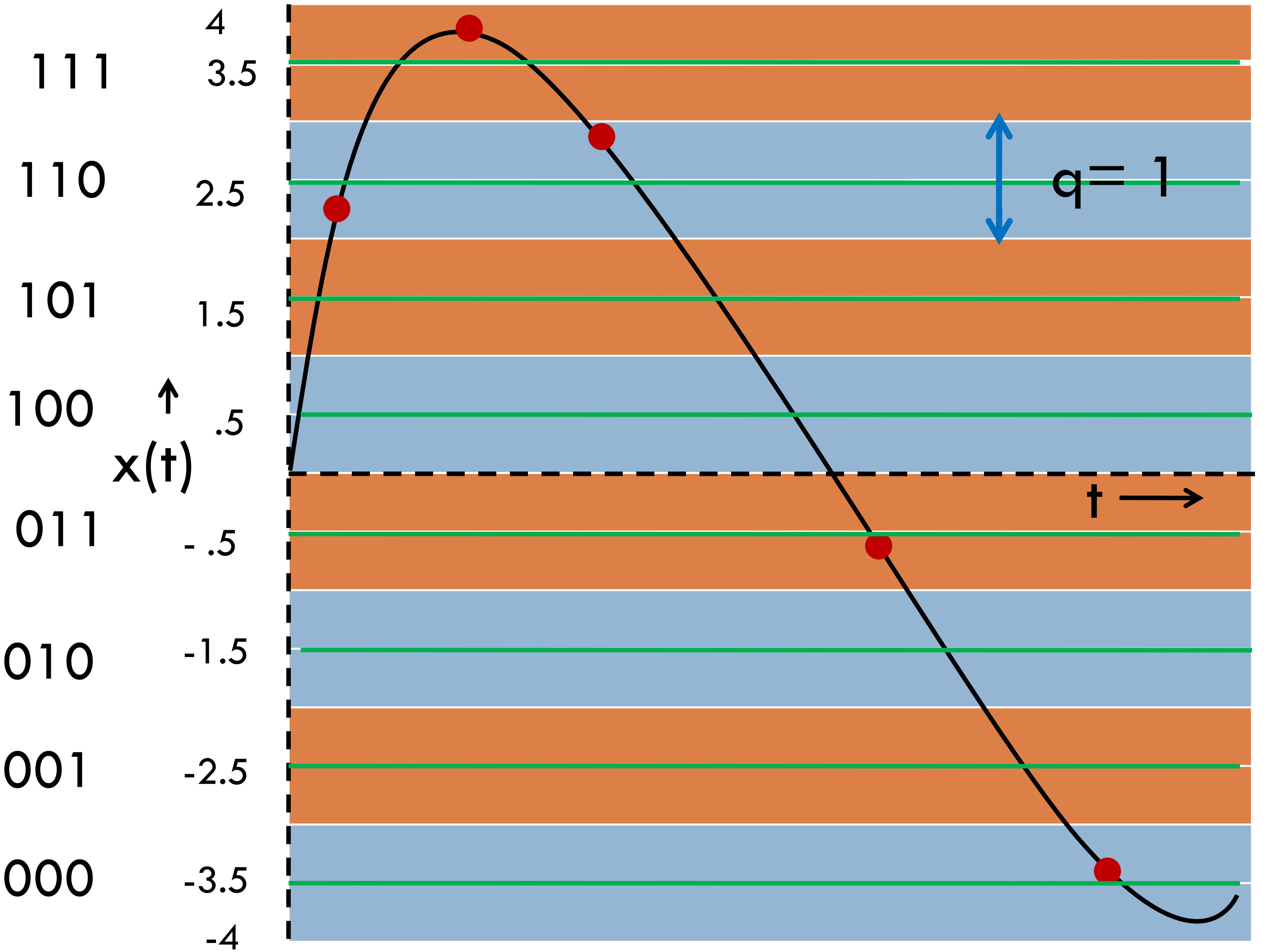
- Sampling

  Sampling frequency $\geq 2$ fm

  fm is the highest frequency in the spectrum of analog signal
- If fs< 2fm

  Aliasing occurs

# Quantization



# Quantization error(Noise)

$$x(t)_{\min} = -V_p$$

$$x(t)_{\max} = V_p$$

$$L \ : \textit{Number of quantization levels}$$

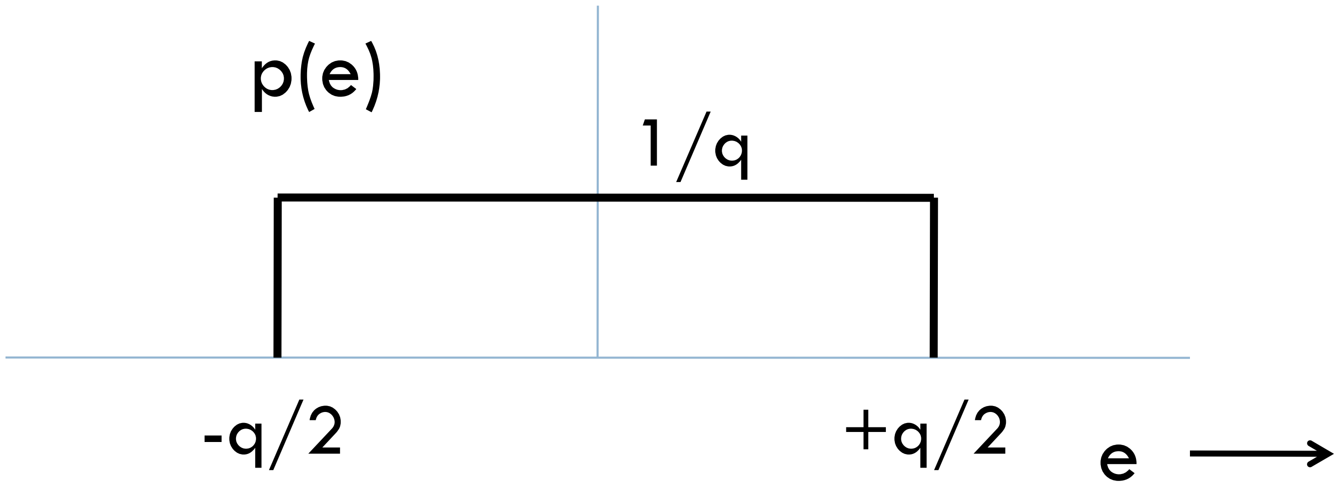
$$\textit{Quantization step} = q = \frac{2V_p}{L}$$

$$\textit{Previous Example } q = \frac{2x4}{8} = 1$$

$$\textit{quantization error} : e = x(t) - \hat{x}(t)$$

$$e \textit{ ranges from } -\frac{q}{2} \textit{ to } \frac{q}{2}$$

# Probability density function of e




*Mean square error*

$$\sigma^2 = \int_{-\frac{q}{2}}^{+\frac{q}{2}} e^2 p(e)\,de = \int_{-\frac{q}{2}}^{+\frac{q}{2}} e^2 \frac{1}{q}\,de = \frac{q^2}{12}$$

# Ratio of peak signal power to mean square quantization noise

$$Peak\ \ signal\ \ power\ = V_p^2$$

$$\frac{S}{N} = \frac{12V_p^2}{q^2}$$

$$\frac{2V_p}{L} = q\ \ \therefore\ \ V_p = \frac{qL}{2}$$

$$V_p^2 = \frac{q^2L^2}{4}$$

$$\left(\frac{S}{N}\right) = \frac{q^2L^2/4}{q^2/12} = 3L^2$$

# P 2.6

- If signal to quantization noise ratio is 50 dB, find the required number of levels for binary coding.

# Solution to P2.6

$10 \log (3L^2) = 50$

$3L^2 \quad = 10^5$

$L = 182.57$

For binary coding $L = 256$

# P2.5

- An analog signal is sampled at its Nyquist rate Ts and quantized using L quantization levels. Show that the bit time T must satisfy the condition

  $T <= Ts/\text{Log}_2 L$

# Solution P2.5

- Suppose L is an integer power of 2

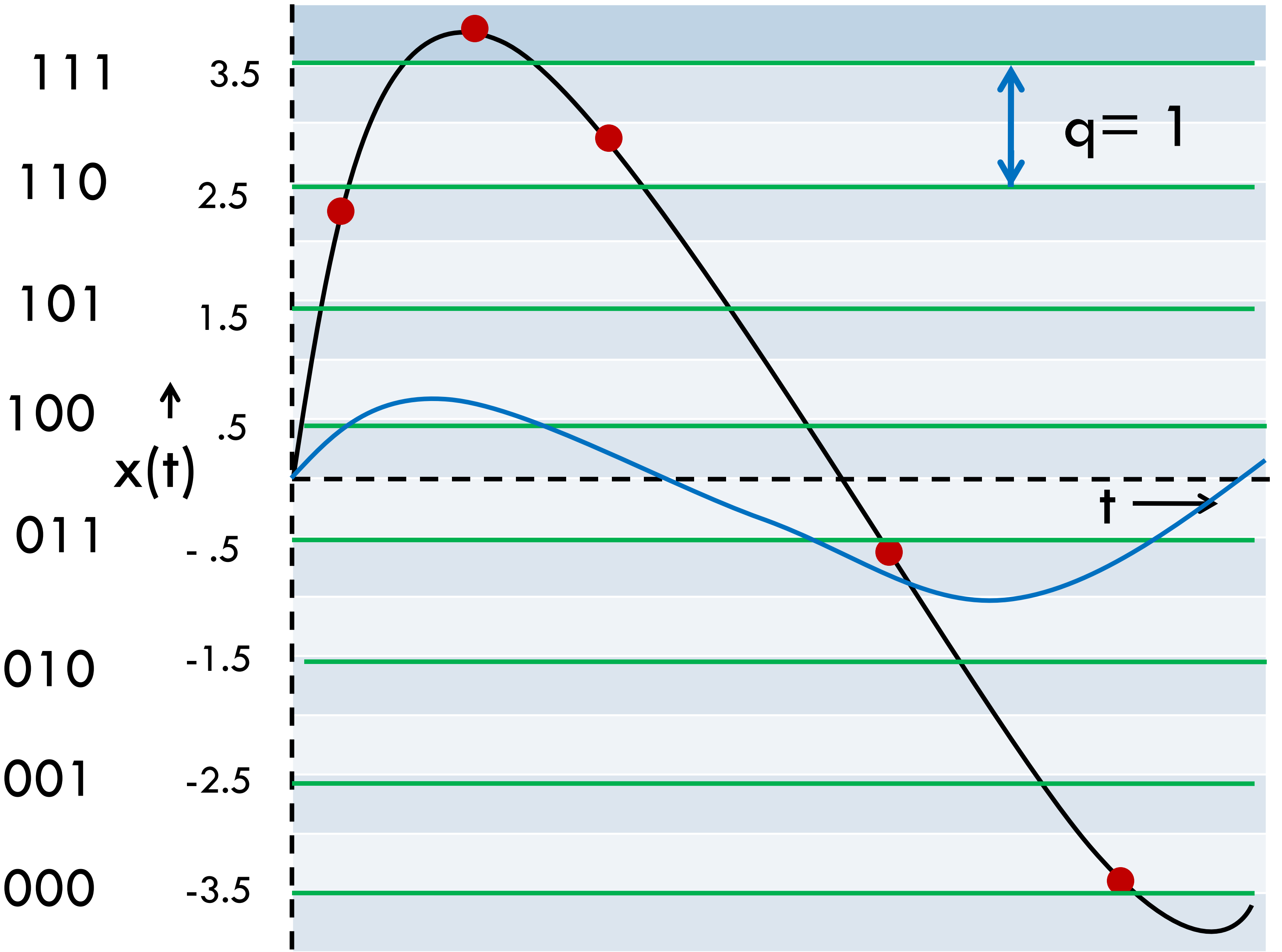
  Then $k = \log_2 L$ is the number of bits per sample

  Bit time $T = Ts/k = Ts/ \log_2 L$
- If L is not an integer power of 2 then $\log_2 L$ is not an integer and you chose the next higher integer say k' such that $k' > \log_2 L$
- $T = Ts/k'$
- $T < Ts/ \log_2 L$

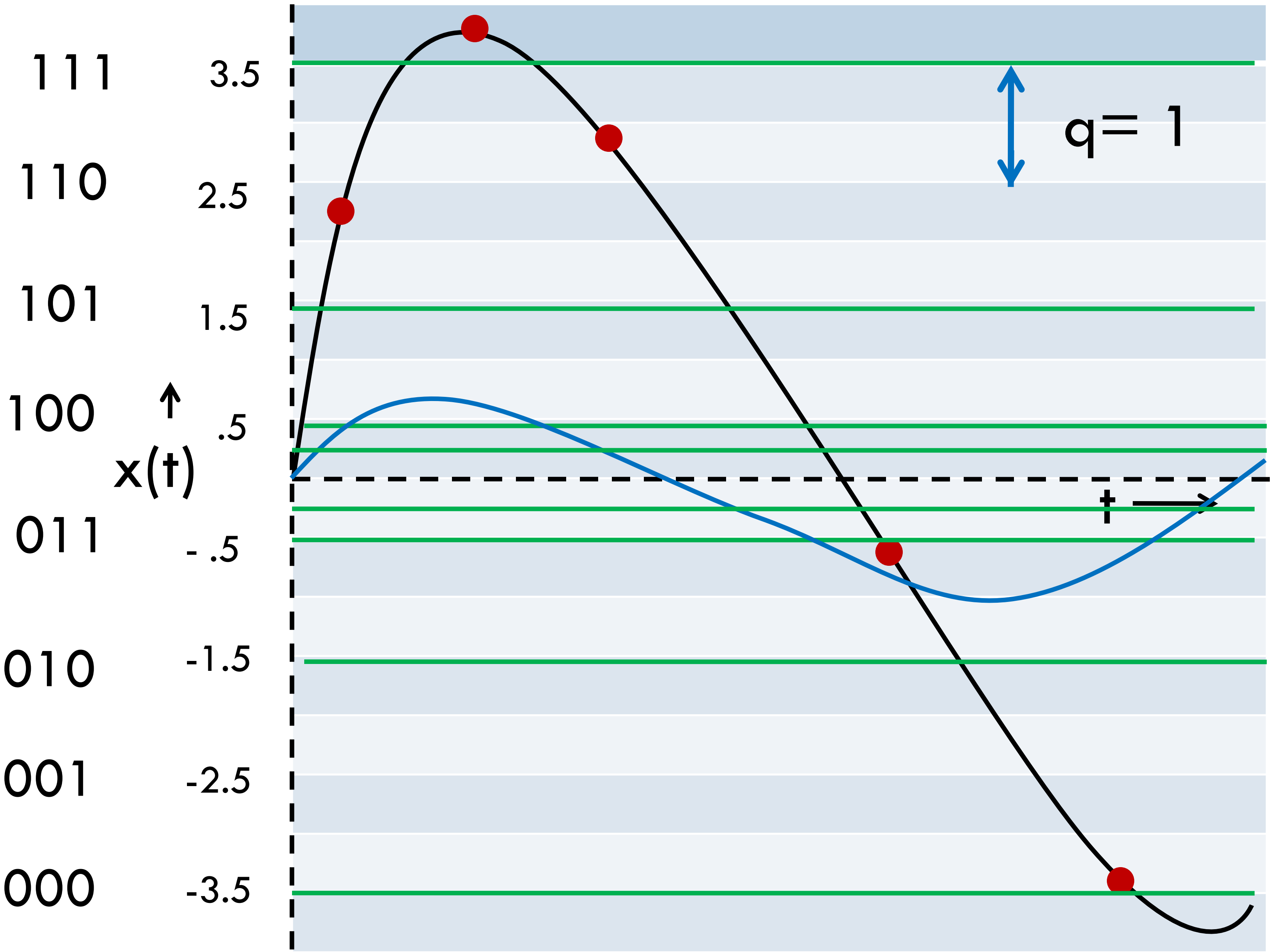
# Non-uniform quantization

- Speech signals are low most of the time.
- S/N ratio will be low.

# Quantization



# Non-Uniform Quantization

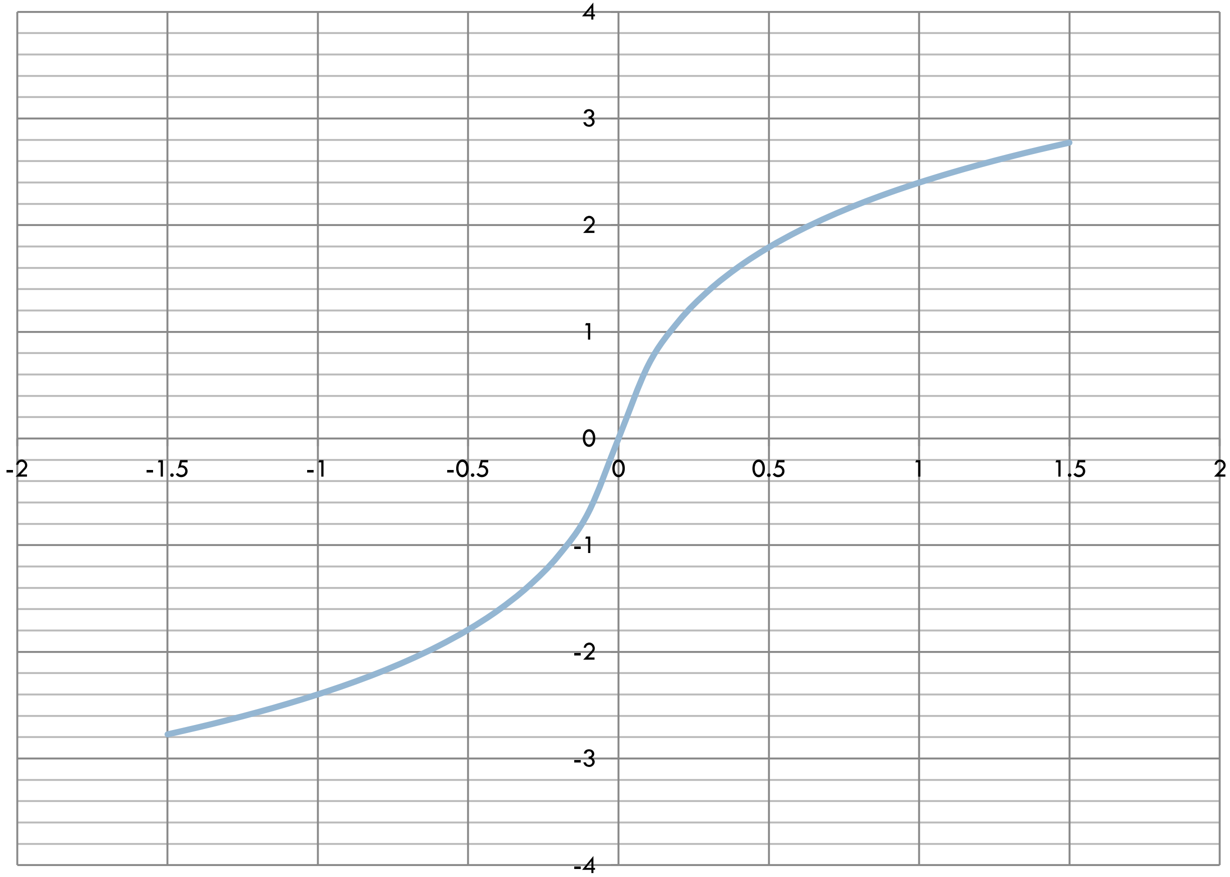


# Why non-uniform

- For a given number of bits outputted the quantization levels are fixed. For 8 bit --- 256 levels
- If we use small step size for all levels the number of bits required will increase.
- So more steps for smaller amplitudes and less number of steps for larger amplitudes

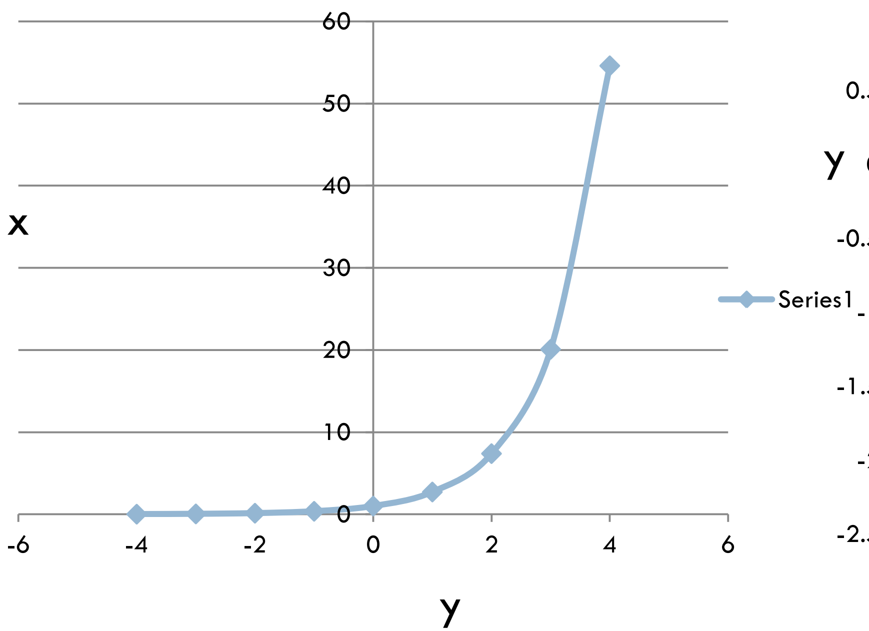
# Compressor

- High gain for low amplitudes

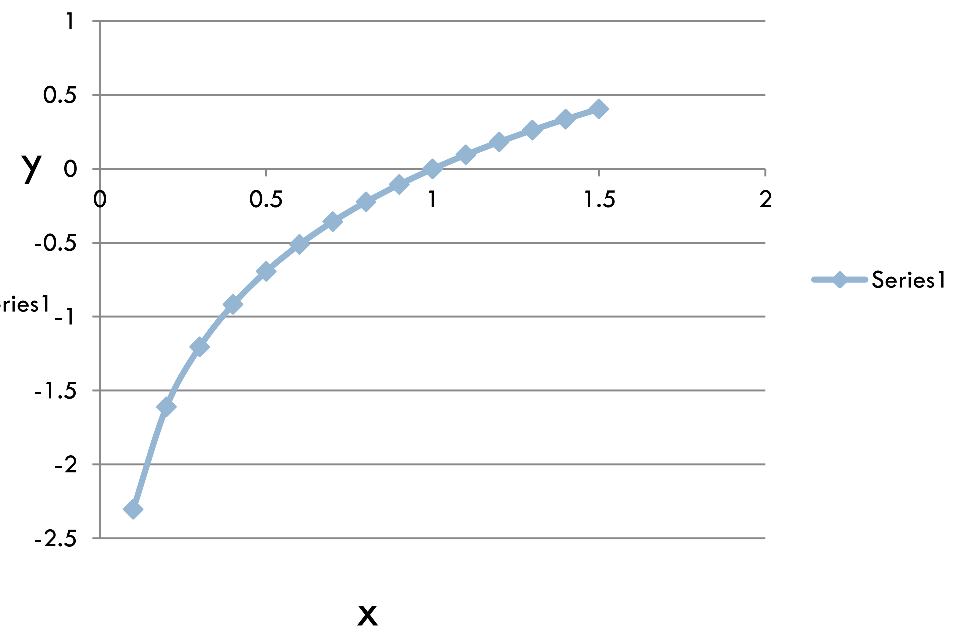


# Exponential functions

$$x = e^{y}$$



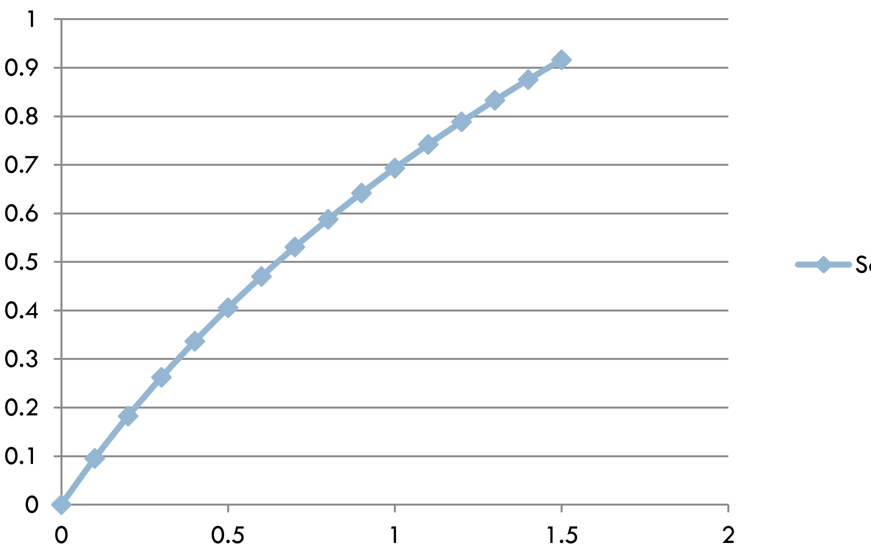

$$y = \log_e x$$

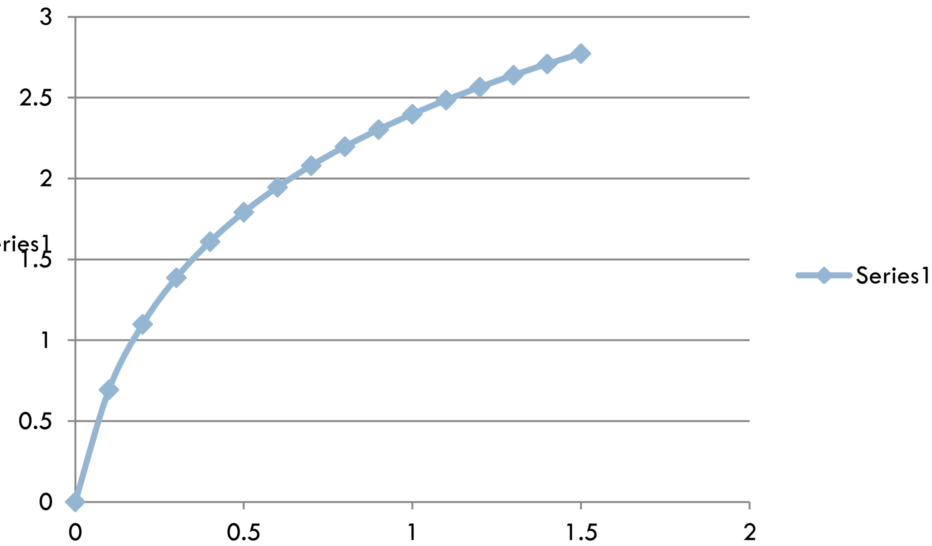


# Characteristics passing through origin

$$y = \log_e(1 + x)$$

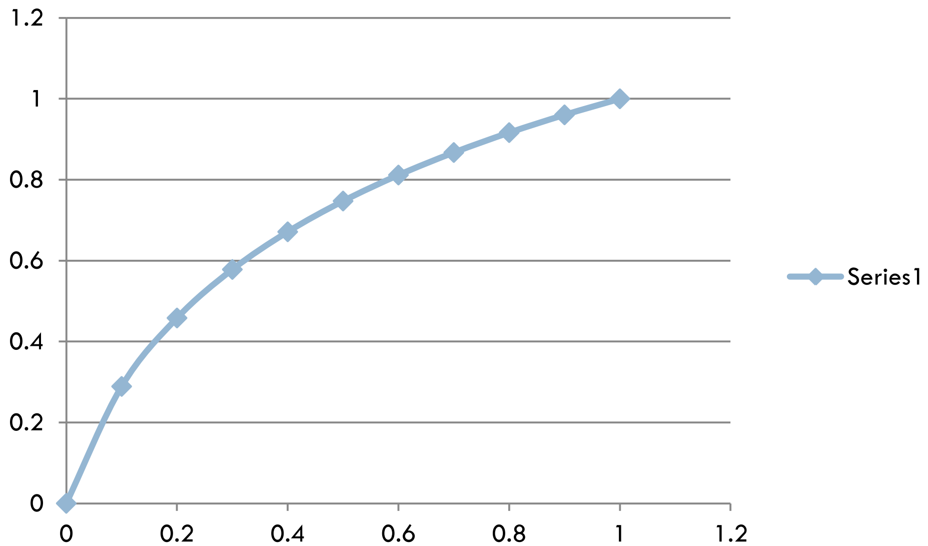
$$y = \log_e(1 + \mu x) \; : \mu = 10$$



# Normalized characteristics

$$y = \frac{\log_e(1+\mu x)}{\log_e(1+\mu)}$$



# Max values

$$y = \frac{\log_e(1+\mu x)}{\log_e(1+\mu)}$$

$$when \;\; x = x_{\max} \;\; : y = y_{\max}$$

$$y = y_{\max} \frac{\log_e\left(1+\mu \dfrac{x}{x_{\max}}\right)}{\log_e(1+\mu)}$$

# For negative values

$$y = -y_{\max} \frac{\log_e\left(1 + \mu \dfrac{|x|}{x_{\max}}\right)}{\log_e(1 + \mu)}$$

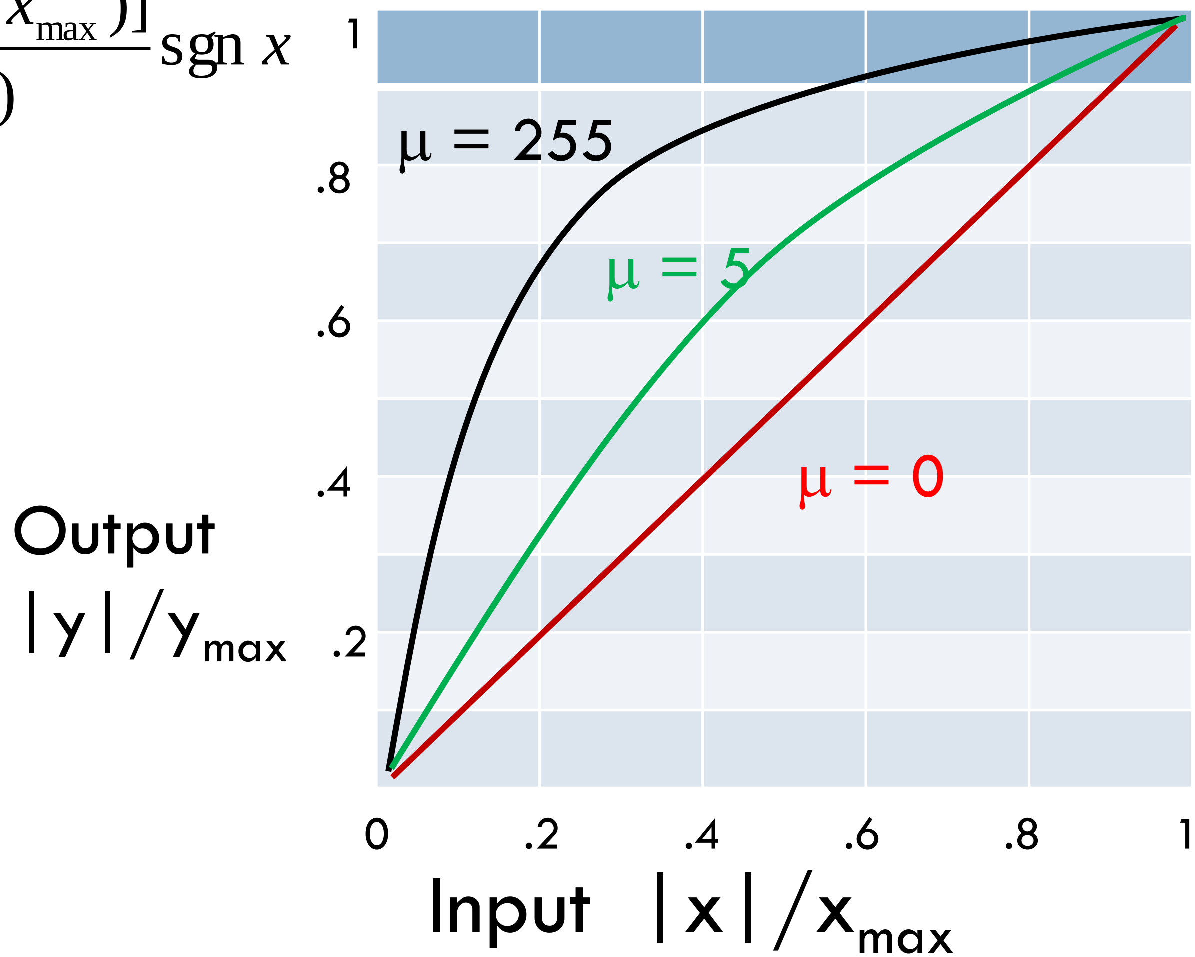
# μ-law characteristic

$$y = y_{\max} \frac{\log_e[1+\mu(|x|/x_{\max})]}{\log_e(1+\mu)} \operatorname{sgn} x$$

*where*

$$\operatorname{sgn} x = \begin{cases} +1 & \text{for } x \geq 0 \\ -1 & \text{for } x < 0 \end{cases}$$

Used in North America and Japan. Another law called A law is used in Europe and the rest



# Types of Pulse modulation

- When $k = 1$

  $M = 2$

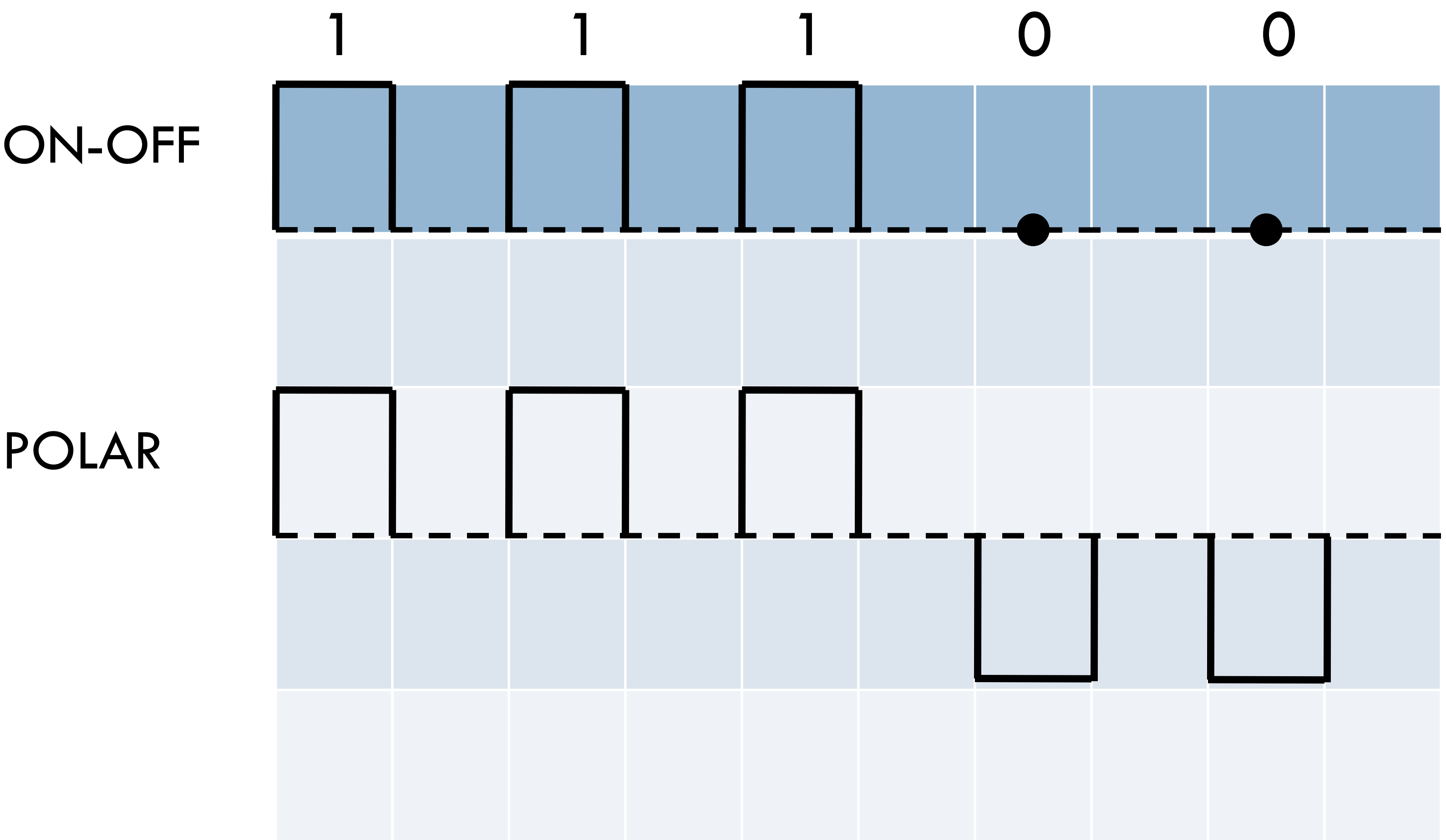
  The resulting binary waveform is called Pulse code modulation waveform

- When $k>1$ : 2,3,4 etc

  $M = 4, 8, 16$ etc

  The resulting waveform is called M-ary pulse- modulation waveform

# PCM waveforms(line codes)



# Important parameters of line codes

- D.C.Component
- Clock component
- Error detection
- Bandwidth
- Noise immunity