- HDTV systems, 1080p (1920*1080), RGB color signals, 256 quantization levels, 30 frames/s, SNR=30dB.

  Transmission rate? Transmission bandwidth (binary/M-ary ISI free)

  From Capacity? $(C=B*\log_2(1+SNR))$

- TV signals (video/audio), signal bandwidth B=4.5MHz.

  If the sampling frequency is 1.2 times higher than the Nyquist rate, f_s?

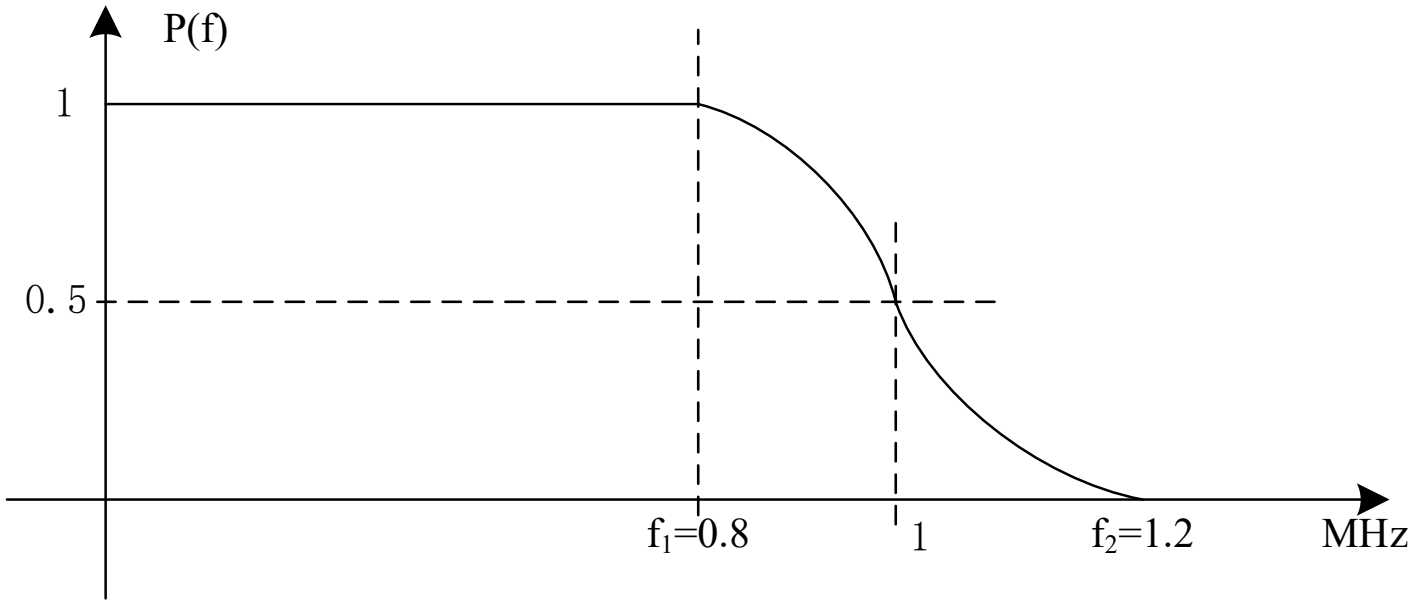
  If quantization level L=1024, minimum transmission bandwidth B_T?

Nyquist rate (3.3), quantization bits (3.16) and minimum bandwidth (4.14)

- Transmission function P(f), raised cosine, ISI free.

Nyquist bandwidth B_N, rate R_N, and roll-off factor α ?

If R_b=1Mbps, B_T=0.7MHz, then f_1, f_2, and α ?

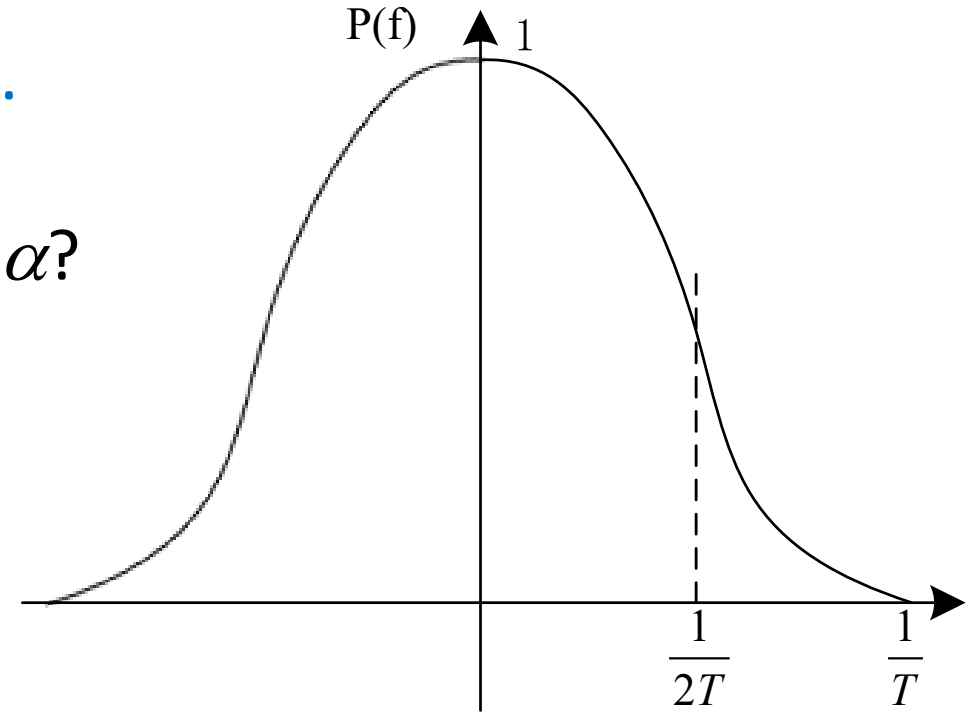


minimum bandwidth (4.14)
and roll-off factor (4.16)

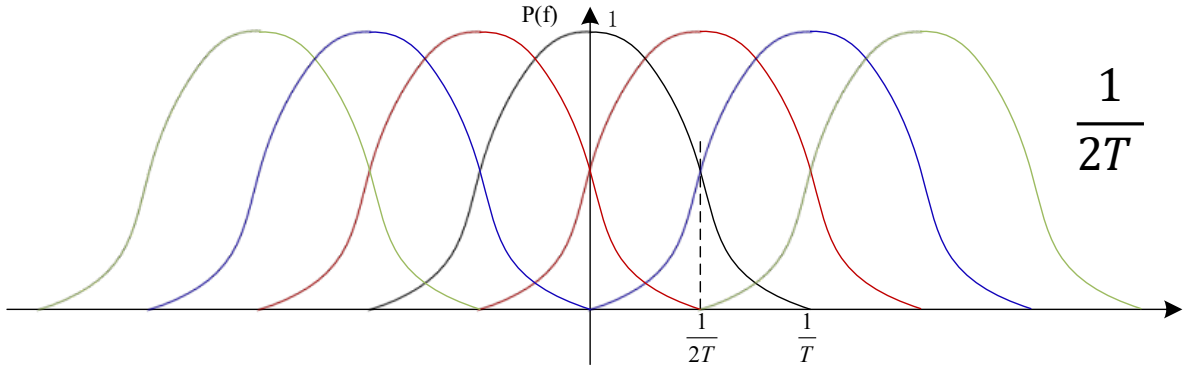
Baseband transmission system P(f), ISI free.

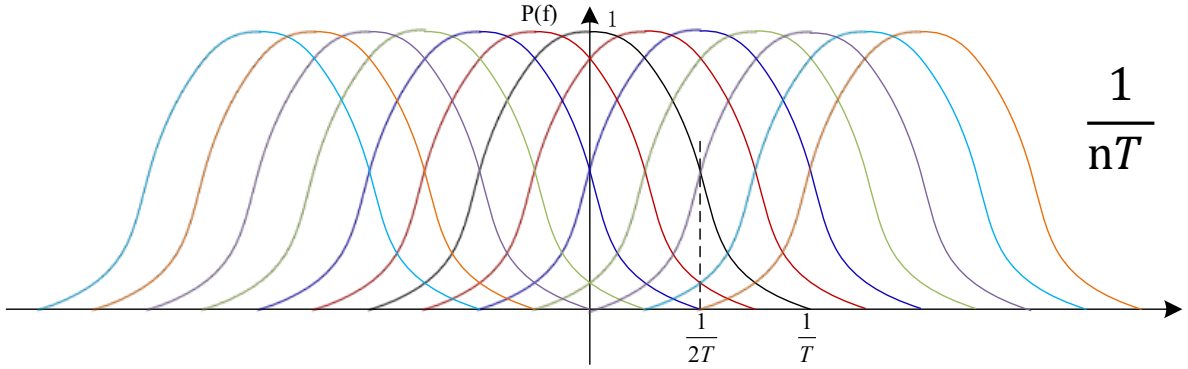
Nyquist R_N, efficiency η, and roll-off factor α?

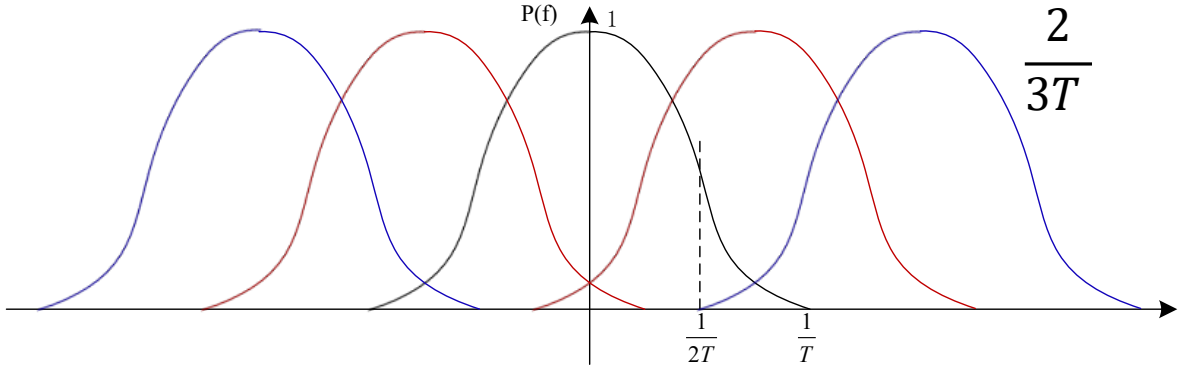
$R_b = \frac{2}{3T}, \frac{1}{2T}, \frac{1}{T}, \frac{3}{T}$, ISI free?



minimum bandwidth (4.14)
and roll-off factor (4.16)







- M-ary Baseband system, raised cosine, roll-off factor α=0.4, B_T=7kHz.

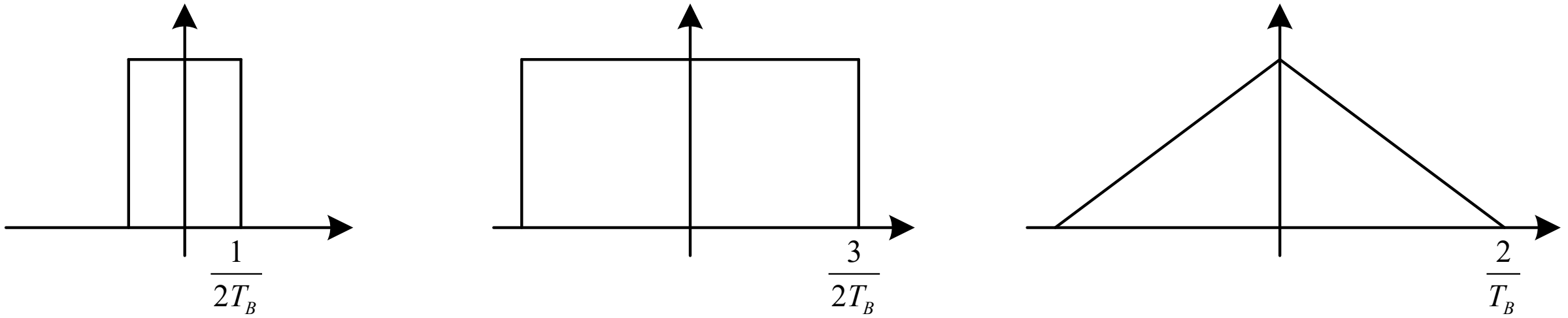
  For ISI free transmission, maximum bit rate, $R_{b,\,max}$, η_{max}?

  For example, 4-ary transmission, R_b=15kbps, ISI free?

  Symbol time slot, T_s=0.2ms, ISI free?

M-ary transmission minimum bandwidth (4.14) and roll-off factor (4.16)

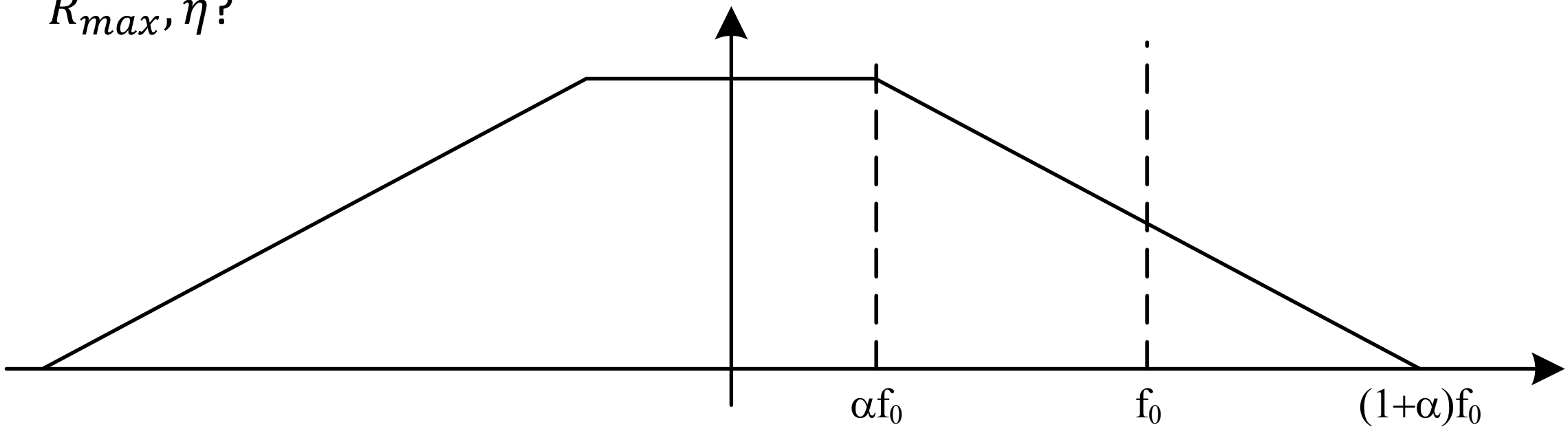
- Baseband system P(f), $\frac{2}{T_B}$ ISI free transmission?



minimum bandwidth (4.14)
and roll-off factor (4.16)

- Baseband system P(f), roll-off factor $0 < \alpha \leq 1$, ISI free transmission?

R_{max}, η?



minimum bandwidth (4.14)
and roll-off factor (4.16)

- 4-PAM Baseband system, raised cosine, ISI free, R_b=2400bps.

  If roll-off factor α=0, B_T, η?

  If roll-off factor α=1, B_T, η?

  If R_b=800bps, ISI free?

M-ary transmission minimum bandwidth (4.14) and roll-off factor (4.16)

- Requirement R_b=12kbps, using 16-ary PAM baseband transmission.

  For ISI free, Nyquist bandwidth B_N?

  Using raised cosine with roll-off factor α=0.2, B_T?

M-ary transmission minimum bandwidth (4.14) and roll-off factor (4.16)

- Audio signal, f_H=10kHz, sampling frequency f_s=24kHz, quantization levels L=256, raised cosine with α=0.2, B_T=30kHz,

  For ISI free, M-art PAM, best M?

  Nyquist rate (3.3), quantization bits (3.16), minimum bandwidth (4.14) and roll-off factor (4.16)

- Polar RZ (half-width, $0.5T_b$) binary signal, (A/2, -A/2), R_b

  E_b and P_b?

  M-ary signals, ($\pm$A/2, $\pm$3A/2, …, $\pm$(M-1)A/2)

  E_M and P_M?

  M-ary signals energy (5.2)

- In a digital communication system, the Nyquist interval of signal g(t) = $\text{sinc}^2(400t)$ + sinc(400t) is 2.5 millisecond (ms).

Nyquist rate and Nyquist interval (3.3)

- In a voice transmission system, the sampling frequency is 8000Hz, and it is used to multiplex 12 independent voice inputs based on an 8-bit PCM word. The bit duration is T_b=____(s). Assuming the use of an ideal Nyquist channel, it follows that the minimum transmission bandwidth B_T is _____ (Hz). However, a more realistic value for transmission is obtained by using a full-cosine roll-off factor with α=0.5. In this case, the transmission bandwidth B_T is _____(Hz).

Nyquist rate (3.3), multiplexing (3.9), quantization bits (3.16), minimum bandwidth (4.14) and roll-off factor (4.16)

- 32 voice signals are sampled uniformly and then time-division multiplexed. The sampling operation uses flat-top with 1 μs duration. The highest frequency component of each voice signal is 3.4 kHz. Assuming a sampling rate of 8 kHz, the spacing between successive pulses of the multiplexed signal is _____μs. If the Nyquist rate sampling rate is used, repeat the calculation is _____μs.

Nyquist rate (3.3), flat-top sampling(3.5) and multiplexing (3.9)

- An analog signal m(t) with zero mean is a stationary process. Its frequency range is 200Hz ~ 8000Hz and its amplitude range is -5 ~ +5 V. Then the minimum Nyquist sampling frequency for this signal m(t) is _____ (Hz) , the average power is _____(W). Assuming a uniform quantizer for this signal and the step size is Δ=0.04V, the minimum number of quantization bits is ____.

Stationary process, Nyquist rate (3.3) and quantization bits (3.16)

- Four different message signals, each with a bandwidth of 64 kHz, are to be multiplexed and transmitted. If the multiplexing method used is TDM and the modulation method used is pulse-amplitude modulation (PAM), the minimum bandwidth required for this method is _____kHz.

TDM multiplexing with PAM (3.9)

- A computer puts out binary data at the rate of 64 kb/s. The computer output is transmitted using a baseband binary PAM system that is designed to have a raise-cosine spectrum. The transmission bandwidth required when the rolling factors α=0.75 is _____Hz.

minimum bandwidth (4.14) and roll-off factor (4.16)

- A linear delta modulator is designed to operate on speech signals limited to 3.4 kHz. The sampling rate is 12 $f_{Nyquist}$, where $f_{Nyquist}$ is the Nyquist rate of speech signal. The step size Δ=100 mV. The modulator is tested with a 1 kHz sinusoidal signal. The maximum amplitude of this test signal required to avoid slope overload is _____V.

Nyquist rate (3.3) and slope overload of ΔM (3.27)

- A signal $s(t)=3\cos(20\pi t)$ V is quantized by a uniform quantizer, the step size of the quantizer is 0.1V, then the minimal number of quantization level is L_{min}=_____, the number of bits per sample is at least R_{min}=_____, and the variance of the quantization error is _____V^2.

Uniform quantizer (3.16)

- In a Delta Modulation(DM) system, A sinusoidal test signal of amplitude A=1 and frequency f_m = 1 kHz is applied to the system. The sampling rate is f_s = 8 kHz， to avoid slope overload, the step size Δ is____V.

slope overload of ΔM (3.27)

- A compact disk(CD) is used to store music. Suppose that both the two independent channels of the true stereo music with the highest frequency 22.05 kHz are sampled at the Nyquist sampling rate, then the sampling rate for each channel is ____(kHz). The encoded PCM is to have an average SNR of at least 96 dB. Then, the minimum number of the uniform quantization of the sampled data should be _____ bits. If the Beethoven's Symphony No. 9 with 74 minutes in PCM data can be stored in CD, the minimum storage capacity of the CD should be ____ (MB, Megabyte). (Hint: SNR = $1.5*2^{2R}$)

Nyquist rate (3.3), multiplexing (3.9), quantization bits (3.16),

A compact disc (CD) records audio signal digitally by using PCM. Assuming that the audio signal bandwidth $\mathrm{B_T} = 15kHz$

If the Nyquist samples are uniformly quantized into L=65536 levels and then binary coded. Determine the number of digits required to encode a sample and the Nyquist sampling rate.

$\mathrm{n} = \log_2 65536 = 16$ (**1%**)

$\mathrm{f_n} = 2B_T = 30kHz$ (**1%**)

If the audio signal has average power $\mathrm{P_s} = 0.1$(watt) and peak voltage of 1 (volt). Find the resulting signal-to-quantization-noise ratio (SQNR) of the uniform quantizer output in question (a).

$\Delta \mathrm{V} = \frac{2\mathrm{m_p}}{L}$ (**1%**)

$\mathrm{P_n} = \frac{1}{12}(\Delta V)^2 = m_p^2/(3L^2)$ (**1%**)

$\mathrm{SQNR} = 10\lg\left[\frac{3\mathrm{L}^2\mathrm{P_s}}{\mathrm{m_p^2}}\right] = 91.1(\mathrm{dB})$ (**2%**)

Nyquist rate (3.3), multiplexing (3.9), uniform quantization, minimum bandwidth (4.14)

For practical reasons, signal is sampled at a rate well above the Nyquist rate. Practical CDs use the sampling frequency $\mathrm{f_s} = 44.1kHz$. Determine the number of bits per second required to encode the signal and the minimum bandwidth required to transmit the encoded signal.

$\mathrm{R_b} = 16\mathrm{f_s} = 705.6kbps$ (**1%**)

$\mathrm{B_T} = \frac{1}{2}R_b = 352.8kHz$ (**1%**)

Suppose that both the two independent channels of the true stereo music are stored in CD. If 74 minutes music with PCM signals can be stored, determine the minimum storage capacity of the CD.

2*74*60*R_b/8 = 783.216 (MB, Megabyte) (**2%**)

An analog signal is sampled, quantized and encoded into a binary PCM wave. The number of representation levels used is 2048. A synchronizing bit is added at the end of each codeword representing a sample of the analog signal. The resulting PCM wave is transmitted over a channel of bandwidth 28kHz, using a 8-ary PAM system with raised-cosine spectrum, where the roll-off factor is 0.75. Then, the information is transmitted at the rate R_b=_____ (bit/s) through the channel. The analog signal is sampled at the rate f_s=_____(Hz). The maximum possible value for the highest frequency component of the analog signal is f_H=____ (Hz).

Nyquist rate (3.3), multiplexing (3.9), quantization bits (3.16), M-ary transmission minimum bandwidth (4.14) and roll-off factor (4.16)

There are eight analog signals, each of bandwidth B=2kHz. Samples of these signals are time-division-multiplexed, quantized and binary-coded. The step size Δ of the quantizer cannot be greater than 0.5% of the peak amplitude m_{max}. Then the minimum number of quantization levels should be_____. The transmission bandwidth B_T is _____ if Nyquist criterion pulse with roll-off factor r=1/3 are used, where the sampling rates must be at least 50% above the Nyqusit rate.

Nyquist rate (3.3), multiplexing (3.9), uniform quantization, quantization bits (3.16), minimum bandwidth (4.14) and roll-off factor (4.16)

- A 1G bytes flash memory is used to store PCM data. Suppose that a VF (voice-frequency) signal is sampled at 8kHz and encoded PCM is to have an average SNR of at least 30dB. _____seconds of VF signal in PCM data can be stored in this flash memory. (Hint: SNR = $1.5*2^{2R}$)

quantization bits (3.16)

- There are ten analog signals, each of bandwidth B=4kHz. Samples of these signals are time-division-multiplexed, quantized and binary-coded. If the number of quantization levels L is 200, the step size Δ of the quantizer is equal to ____(%) of the peak amplitude m_{max}. If the transmission bandwidth B_T is 640kHz, the Nyquist criterion pulse with roll-off factor r=____ should be used, where the sampling rates must be at least 50% above the Nyqusit rate.

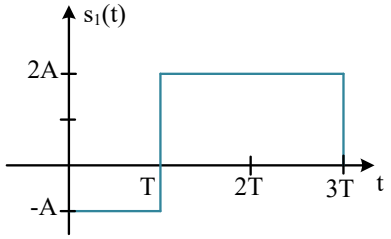
Nyquist rate (3.3), multiplexing (3.9), uniform quantization, quantization bits (3.16), minimum bandwidth (4.14) and roll-off factor (4.16)

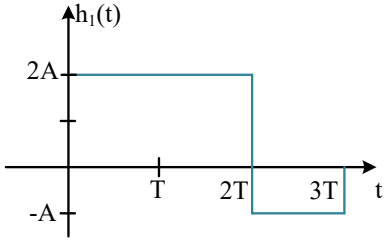
In a differential encoding system, a transition denotes symbol 0 and no transition denotes symbol 1. Symbol **1** is used as reference bit. If the binary sequence {0 0 0 0 1 1 0 1 1} is the output of the differential encoder, the original input data is {**1**, _ _ _ _ _ _ _ _}.

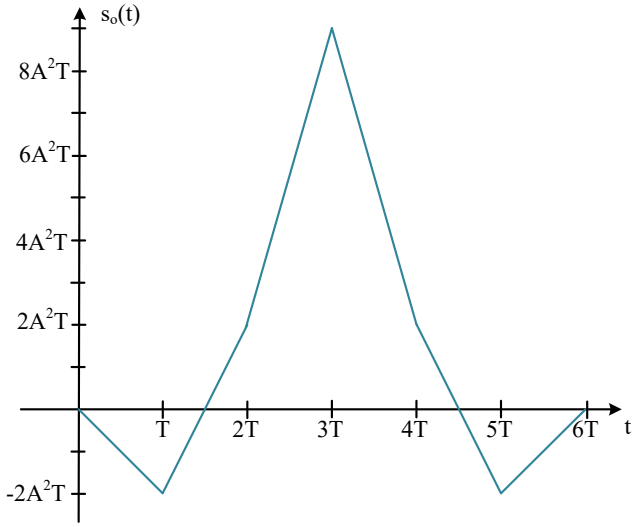
In a differential encoding system, a transition denotes symbol 0 and no transition denotes symbol 1. Symbol 1 is used as reference bit. If a binary data sequence {0 1 1 0 __ __ __ __}is the input to this system, the output sequence is {**1**, _ _ _ _ 1 0 1 0 }.

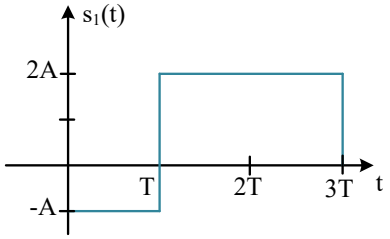
In a differential encoding system, a transition denotes symbol 0 and no transition denotes symbol 1. Symbol **1** is used as reference bit. If a binary data sequence {1 __ 0 __ 1 __ 1 __} is the input to this system, the output sequence is {**1**, __ 0 __ 1 __ 0 __ 0}.

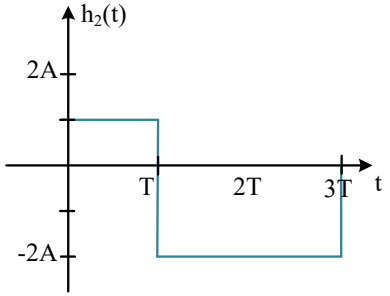
differential encoding in DPSK (6.33)

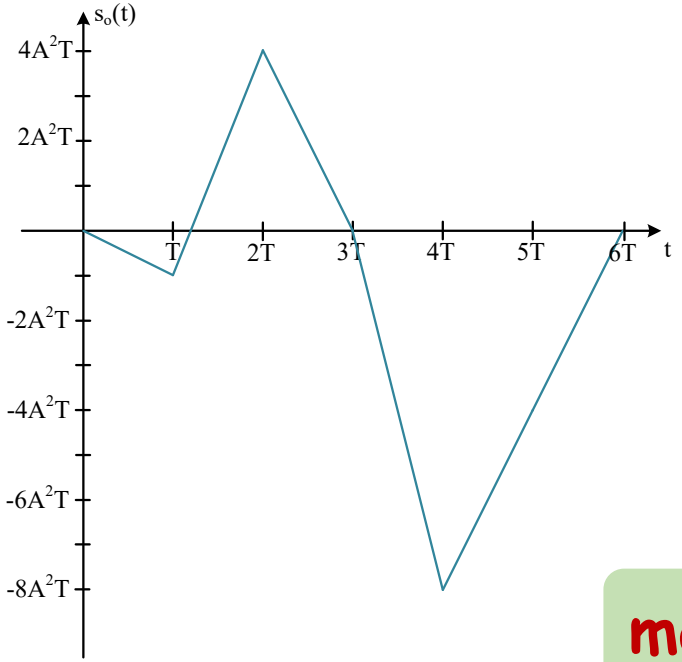


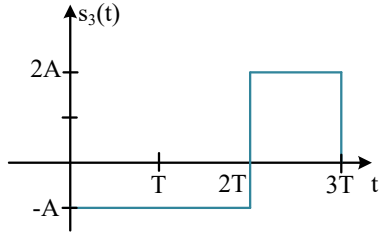


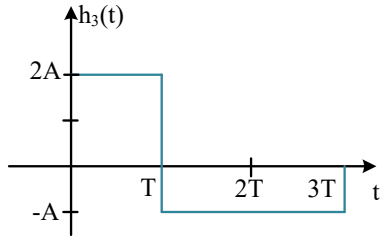


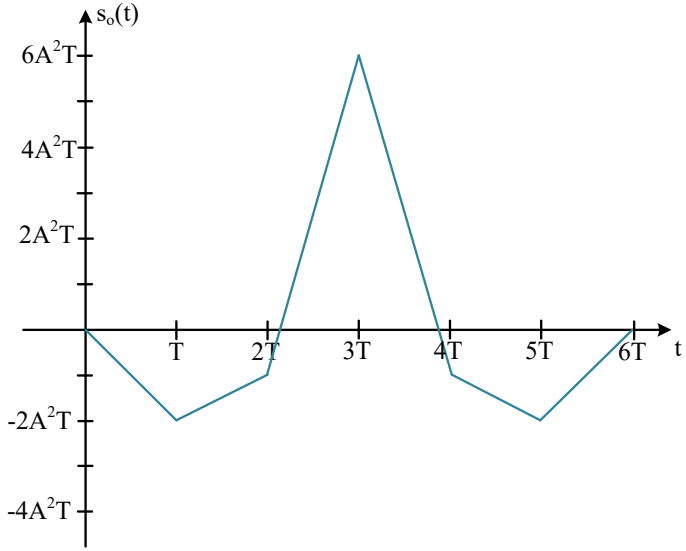












matched filter (4.1&4.2)

- Practical matched filter, H(f)=1/(j2πfRC+1), AWGN channel, PSD N0/2

  maximum η_{max}, RC= ?