**Universidade Estadual de Campinas**

**Faculdade de Engenharia Elétrica e de Computação**

# EE881 – PRINCÍPIOS DE COMUNICAÇÕES - 1ª LISTA - Prof. Luís Meloni

## Exercícios de Análise de Fourier

1º)

Calcule e plote a transformada de Fourier para:

a) $e^{-2(t-1)}u(t-1)$

b) $e^{-2|t-1|}$

c) $\delta(t+1)+\delta(t-1)$

d) $\frac{d}{dt}\{u(-2-t)+u(t-2)$

e) sgn($t$) – função sinal

2º)

Considere o sinal abaixo:

$$x(t)=\begin{cases} 0\,, & t<-\frac{1}{2} \\ t+\frac{1}{2}, & -\frac{1}{2}\leq t\leq\frac{1}{2} \\ 1, & t>\frac{1}{2} \end{cases}$$

a) Use as propriedades de integração e diferenciação para encontrar a transformada de Fourier de x(t).

b) Qual é a transformada de Fourier de $g(t)=x(t)-\frac{1}{2}$

3º) Calcule a transformada de Fourier de cada um dos sinais abaixo.

a) $[e^{-\alpha t}\cos\omega_0 t]u(t), \alpha>0$

b) $x(t)=\begin{cases} 1+\cos\pi t, & |t|\leq 1 \\ 0, & |t|>1 \end{cases}$

c ) $\sum_{k=0}^{\infty}\alpha^k\delta(t-kT), \quad |\alpha|<1$

d)$x(t)=\begin{cases} 1-t^2, & 0<t<1 \\ 0, & c.c. \end{cases}$

e)x(t) como mostrado na figura 1.

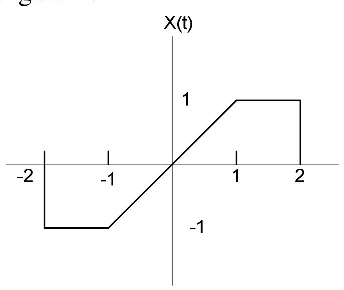


Figura 1

4º) Calcule a transforma de Fourier dos sinais discretos abaixo.

a) x[n]=u[n-2]-u[n-6]
b) $x[n] = \left(\frac{1}{2}\right)^{-n} u\,[-n-1]$
c) $x[n] = \left(\frac{1}{2}\right)^{|n|} \cos(\frac{\pi}{8}(n-1))$
d) $x[n] = x[n-6]$ e x[n]=u[n]-u[n-5] para $0 \leq n \leq 5$.

5º) Calcule a transforma de Fourier discreta inversa dos espectros abaixo.

a)$X(e^{j\omega}) = \begin{cases} 1, \frac{\pi}{4} \leq |\omega| \leq \frac{3\pi}{4} \\ 0, \ \frac{3\pi}{4} \leq |\omega| \leq \pi, \ 0 \leq |\omega| < \frac{\pi}{4} \end{cases}$
b) $X(e^{j\omega}) = 1 + 3e^{-j\omega} + 2e^{-j2\omega} - 4e^{-j3\omega} + e^{-j10\omega}$
c)$X(e^{j\omega}) = \frac{1-\frac{1}{3}e^{j\omega}}{1-\frac{1}{4}e^{-j\omega}-\frac{1}{8}e^{-2j\omega}}$

**Exercícios selecionados do livro do Lathi, *Modern Digital and Analog Communication Systems*, 3rd Ed.**

6º)

**4.2-4** You are asked to design a DSB-SC modulator to generate a modulated signal $km(t)\cos\omega_c t$, where $m(t)$ is a signal band-limited to $B$ Hz. Figure P4.2-4 shows a DSB-SC modulator available in the stock room. The carrier generator available generates not $\cos\omega_c t$, but $\cos^3\omega_c t$. Explain whether you would be able to generate the desired signal using only this equipment. You may use any kind of filter you like.

**(a)** What kind of filter is required in Fig. P4.2-4?

**(b)** Determine the signal spectra at points $b$ and $c$, and indicate the frequency bands occupied by these spectra.

**(c)** What is the minimum usable value of $\omega_c$?

**(d)** Would this scheme work if the carrier generator output were $\cos^2\omega_c t$? Explain.

**(e)** Would this scheme work if the carrier generator output were $\cos^n\omega_c t$ for any integer $n \geq 2$?

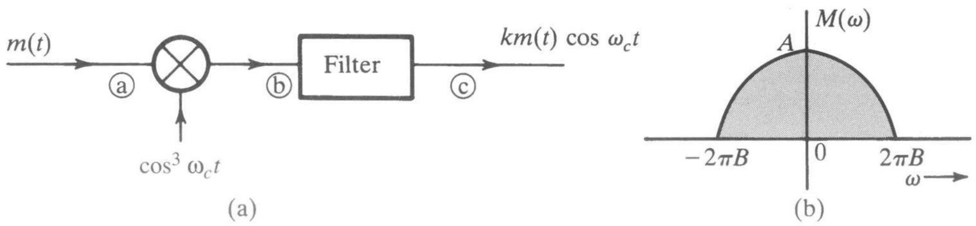


Figure P4.2-4

7º)

**4.2-8** Two signals $m_1(t)$ and $m_2(t)$, both band-limited to 5000 rad/s, are to be transmitted simultaneously over a channel by the multiplexing scheme shown in Fig. P4.2-8. The signal at point $b$ is the multiplexed signal, which now modulates a carrier of frequency 20,000 rad/s. The modulated signal at point $c$ is transmitted over a channel.

**(a)** Sketch signal spectra at points $a$, $b$, and $c$.

**(b)** What must be the bandwidth of the channel?

**(c)** Design a receiver to recover signals $m_1(t)$ and $m_2(t)$ from the modulated signal at point $c$.

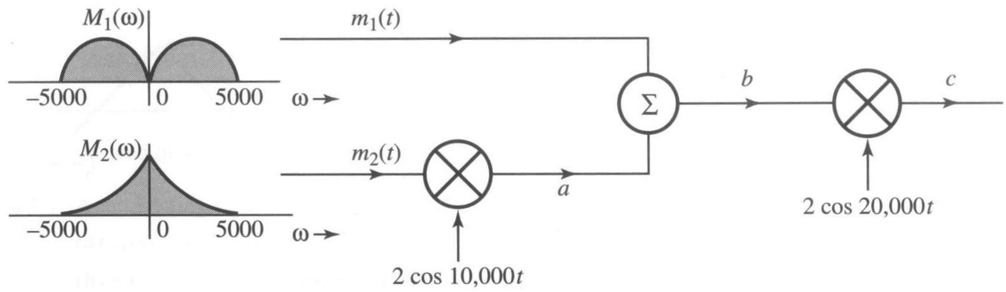


**Figure P4.2-8**

8º) e 9º)

**4.3-1** Figure P4.3-1 shows a scheme for coherent (synchronous) demodulation. Show that this scheme can demodulate the AM signal $[A + m(t)] \cos \omega_c t$ regardless of the value of $A$.

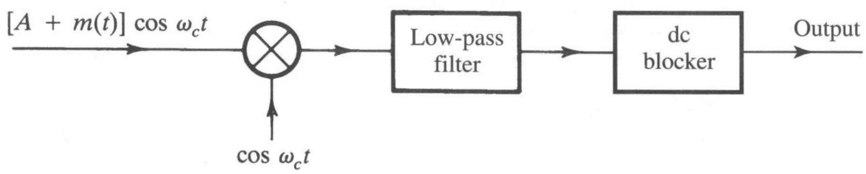


**Figure P4.3-1**

**4.3-2** Sketch the AM signal $[A+m(t)] \cos \omega_c t$ for the periodic triangle signal $m(t)$ shown in Fig. P4.3-2 corresponding to the modulation index: **(a)** $\mu = 0.5$; **(b)** $\mu = 1$; **(c)** $\mu = 2$; **(d)** $\mu = \infty$. How do you interpret the case $\mu = \infty$?

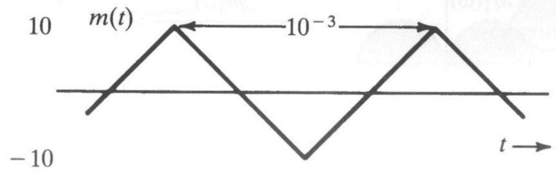


**Figure P4.3-2**

10º)

**5.1-2** A baseband signal $m(t)$ is the periodic sawtooth signal shown in Fig. P5.1-2. Sketch $\varphi_{FM}(t)$ and $\varphi_{PM}(t)$ for this signal $m(t)$ if $\omega_c = 2\pi \times 10^6$, $k_f = 2000\pi$, and $k_p = \pi/2$. Explain why it is necessary to use $k_p < \pi$ in this case.

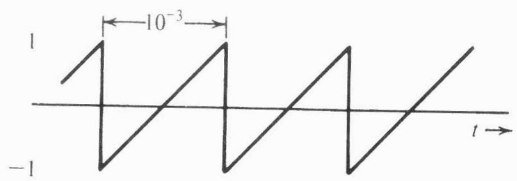


**Figure P5.1-2**

11º)

**5.2-6** Given $m(t) = \sin 2000\pi t$, $k_f = 200,000\pi$, and $k_p = 10$.

**(a)** Estimate the bandwidths of $\varphi_{FM}(t)$ and $\varphi_{PM}(t)$.

**(b)** Repeat part **(a)** if the message signal amplitude is doubled.

**(c)** Repeat part **(a)** if the message signal frequency is doubled.

**(d)** Comment on the sensitivity of FM and PM bandwidths to the spectrum of $m(t)$.

12º)

**5.4-2** A periodic square wave $m(t)$ (Fig. P5.4-2a) frequency-modulates a carrier of frequency $f_c = 10$ kHz with $\Delta f = 1$ kHz. The carrier amplitude is $A$. The resulting FM signal is demodulated, as shown in Fig. P5.4-2b by the method discussed in Sec. 5.4 (Fig. 5.11). Sketch the waveforms at points $b$, $c$, $d$, and $e$.

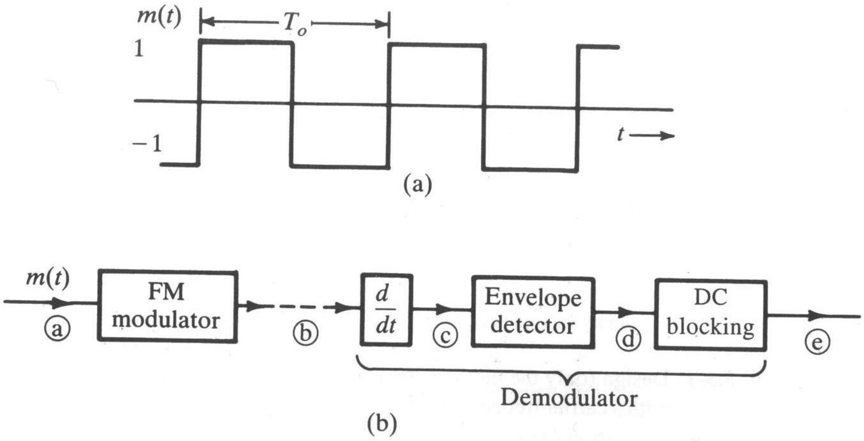


**Figure P5.4-2**

13º)

**6.1-6** A zero-order hold circuit (Fig. P6.1-6) is often used to reconstruct a signal $g(t)$ from its samples.

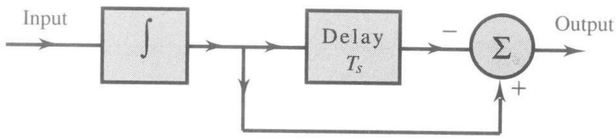


**Figure P6.1-6**

**(a)** Find the unit impulse response of this circuit.

**(b)** Find the transfer function $H(\omega)$ and sketch $|H(\omega)|$.

**(c)** Show that when a sampled signal $\overline{g}(t)$ is applied at the input of this circuit, the output is a staircase approximation of $g(t)$. The sampling interval is $T_s$.

14º) e 15º)

**6.2-2** A compact disc (CD) records audio signals digitally by using PCM. Assume the audio signal bandwidth to be 15 kHz.

**(a)** What is the Nyquist rate?

**(b)** If the Nyquist samples are quantized into $L = 65,536$ levels and then binary coded, determine the number of binary digits required to encode a sample.

**(c)** Determine the number of binary digits per second (bit/s) required to encode the audio signal.

**(d)** For practical reasons discussed in the text, signals are sampled at a rate well above the Nyquist rate. Practical CDs use 44,100 samples per second. If $L = 65,536$, determine the number of bits per second required to encode the signal, and the minimum bandwidth required to transmit the encoded signal.

**6.2-3** A television signal (video and audio) has a bandwidth of 4.5 MHz. This signal is sampled, quantized, and binary coded to obtain a PCM signal.

**(a)** Determine the sampling rate if the signal is to be sampled at a rate 20% above the Nyquist rate.

**(b)** If the samples are quantized into 1024 levels, determine the number of binary pulses required to encode each sample.

**(c)** Determine the binary pulse rate (bits per second) of the binary-coded signal, and the minimum bandwidth required to transmit this signal.

16º)

**7.3-4** The Fourier transform $P(\omega)$ of the basic pulse $p(t)$ used in a certain binary communication system is shown in Fig. P7.3-4.

**(a)** From the shape of $P(\omega)$, explain if this pulse satisfies the Nyquist criterion.

**(b)** Find $p(t)$ and verify that this pulse does (or does not) satisfy the Nyquist criterion.

**(c)** If the pulse does satisfy the Nyquist criterion, what is the transmission rate (in bits per second) and what is the roll-off factor?

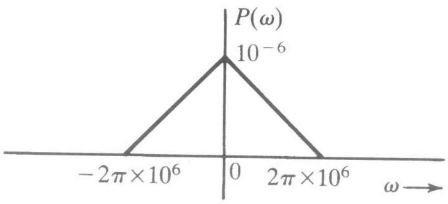


**Figure P7.3-4**

17º)

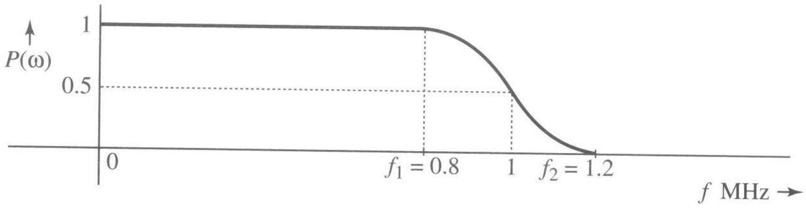


**Figure P7.3-5**

**7.3-6** Binary data at a rate of 1 Mbit/s is to be transmitted using Nyquist criterion pulses with $P(\omega)$ shown in Fig. P7.3-5. The frequencies $f_1$ and $f_2$ (in hertz) of this spectrum are adjustable. The channel available for the transmission of this data has a bandwidth of 700 kHz. Determine $f_1$ and $f_2$ and the roll-off factor.

18º)

**7.7-1** In multiamplitude scheme with $M = 16$,

**(a)** Determine the minimum transmission bandwidth required to transmit data at a rate of 12,000 bit/s with zero ISI.

**(b)** Determine the transmission bandwidth if Nyquist criterion pulses with a roll-off factor $r = 0.2$ are used to transmit data.

19º)

**7.7-3** Binary data is transmitted over a certain channel at a rate of $R_b$ bit/s. To reduce the transmission bandwidth, it is decided to transmit this data using 8-ary multiamplitude signaling.

**(a)** By what factor is the bandwidth reduced?

**(b)** By what factor is the transmitted power increased, assuming the minimum separation between pulse amplitudes to be the same in both cases? *Hint:* Take the pulse amplitudes to be $\pm A/2$, $\pm 3A/2$, $\pm 5A/2$, and $\pm 7A/2$ so that the minimum separation between various amplitude levels is $A$ (the same as in the binary case pulses $\pm A/2$). Assume all the eight levels equally likely.