EE354 Study Guide for Exam #1

Provided Reference Sheets
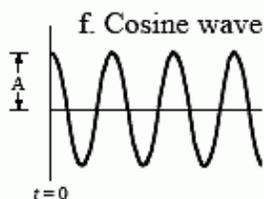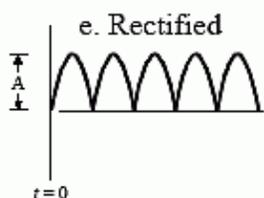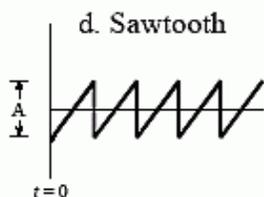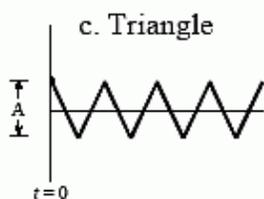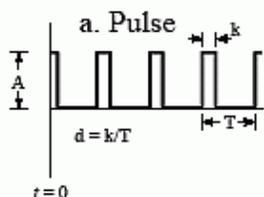
Time Domain | Frequency Domain

a. Pulse
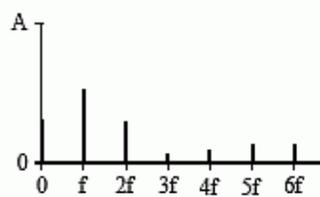
$a_0 = A\,d$

$a_n = \dfrac{2A}{n\pi} \sin(n\pi d)$

$b_n = 0$

(d - 0.27 in this example)

b. Square
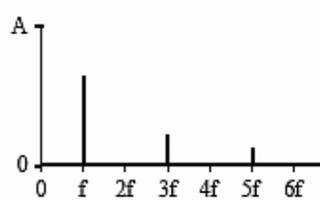
$a_0 = 0$

$a_n = \dfrac{2A}{n\pi} \sin\left(\dfrac{n\pi}{2}\right)$

$b_n = 0$

(all even harmonics are zero)

c. Triangle
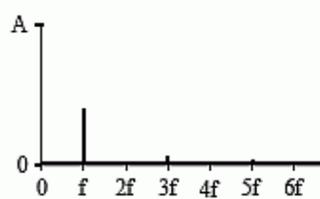
$a_0 = 0$

$a_n = \dfrac{4A}{(n\pi)^2}$

$b_n = 0$

(all even harmonics are zero)

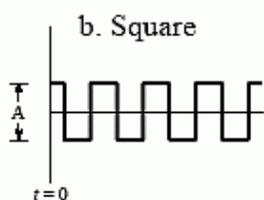### d. Sawtooth

$a_0 = 0$

$a_n = 0$

$b_n = \dfrac{A}{n\pi}$

e. Rectified

$a_0 = 2A/\pi$

$a_n = \dfrac{-4A}{\pi(4n^2 - 1)}$

$b_n = 0$

f. Cosine wave
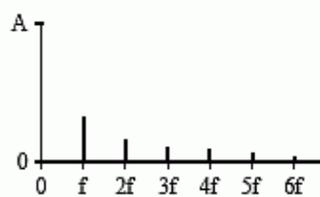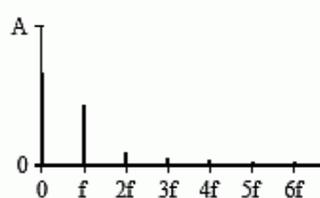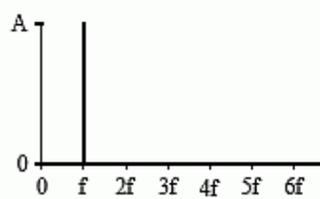
$a_1 = A$

(all other coefficients are zero)

FIGURE 13-10
Examples of the Fourier series. Six common time domain waveforms are shown, along with the equations to calculate their "a" and "b" coefficients.

Workbook Tables (B.3 and B.4)

Left column pairs:

$$\Pi\left(\frac{t}{\tau}\right) \Leftrightarrow \tau \operatorname{sinc}(f\tau)$$

$$e^{j\omega_o t} \Leftrightarrow \delta(f - f_o)$$

$$\delta(t - t_o) \Leftrightarrow e^{-j2\pi f t_o}$$

$$\sum_{k=-\infty}^{\infty} \delta(t - kT_o) \Leftrightarrow f_o \sum_{k=-\infty}^{\infty} \delta(f - kf_o)$$

$$\delta(t) \Leftrightarrow 1$$

$$K \Leftrightarrow K\delta(f)$$

$$\operatorname{sinc}(2Wt) \Leftrightarrow \frac{1}{2W}\Pi\left(\frac{f}{2W}\right)$$

$$\cos(\omega_o t) \Leftrightarrow \frac{1}{2}\delta(f - f_o) + \frac{1}{2}\delta(f + f_o)$$

$$\sin(\omega_o t) \Leftrightarrow \frac{1}{2j}\delta(f - f_o) - \frac{1}{2j}\delta(f + f_o)$$

$$u(t) \Leftrightarrow \frac{1}{j2\pi f} + \frac{1}{2}\delta(f)$$

$$\Lambda\left(\frac{t}{\tau}\right) \Leftrightarrow \tau\operatorname{sinc}^2(f\tau)$$

$$\sum_{k=-\infty}^{\infty} \Pi\left(\frac{t - kT_o}{\tau}\right) \Leftrightarrow \tau f_o \sum_{k=-\infty}^{\infty} \operatorname{sinc}(kf_o\tau)\delta(f - kf_o)$$

$$\operatorname{sinc}^2(2Wt) \Leftrightarrow \frac{1}{2W}\Lambda\left(\frac{f}{2W}\right)$$

$$e^{-at}u(t) \Leftrightarrow \frac{1}{a + j2\pi f}$$

$$te^{-at}u(t) \Leftrightarrow \frac{1}{(a + j2\pi f)^2}$$

Right column properties:

$$ax(t) + by(t) \Leftrightarrow aX(f) + bY(f) \qquad \text{Superposition (or Linearity)}$$

$$X(t) \Leftrightarrow x(-f) \qquad \text{Duality}$$

$$\sum_{n=-\infty}^{\infty} c_n e^{jn\omega_o t} \Leftrightarrow \sum_{n=-\infty}^{\infty} c_n \delta(f - nf_o) \qquad \text{F.T. of periodic function}$$

$$\frac{d^n}{dt^n}x(t) \Leftrightarrow (j2\pi f)^n X(f) \qquad \text{Differentiation in time}$$

$$x(t - t_o) \Leftrightarrow e^{-j2\pi f t_o}X(f), \qquad \text{Time shifting}$$

$$x(at) \Leftrightarrow \frac{1}{|a|}X\left(\frac{f}{a}\right) \qquad \text{Time scaling}$$

$$\int_{-\infty}^{t} x(\lambda)d\lambda \Leftrightarrow \frac{1}{j2\pi f}X(f) + \frac{X(0)}{2}\delta(f) \qquad \text{Integration}$$

$$x(t) * y(t) \Leftrightarrow X(f)Y(f) \qquad \text{Convolution}$$

$$x(t)y(t) \Leftrightarrow X(f) * Y(f) \qquad \text{Multiplication}$$

$$e^{j\omega_o t}x(t) \Leftrightarrow X(f - f_o) \qquad \text{Frequency shifting}$$

$$t^n x(t) \Leftrightarrow (-j2\pi)^{-n}\frac{d^n}{df^n}X(f) \qquad \text{Differentiation in frequency}$$

$$x(t)\sum_{k=-\infty}^{\infty}\delta(t - kT_s) \Leftrightarrow f_s \sum_{k=-\infty}^{\infty} X(f - kf_s) \qquad \text{Impulse sampling}$$

$$x(t)\cos(\omega_c t) \Leftrightarrow \frac{1}{2}X(f + f_c) + \frac{1}{2}X(f - f_c) \qquad \text{Modulation}$$

Fourier Series

- Given an *arbitrary* time-domain signal, compute the trigonometric and exponential Fourier Series Coefficients, write the Fourier Series approximation of the signal, and draw the Fourier Spectrum.
- Given an *arbitrary* set of Fourier Coefficients, draw the Fourier Spectrum and write the time domain trigonometric or exponential Fourier Series.
- Given a Fourier Series or Fourier Spectrum of an arbitrary signal, compute the Fourier Series or Fourier Spectrum after passing the signal through a high-pass, low-pass, or bandpass filter.

Fourier Transforms

- Know (memorize) the following Fourier Transform Pairs:
    a. Rect / Sinc
    b. Delta / Constant
    c. Cosine / Even Delta
    d. Sine / Odd Delta
    e. Triangle / $Sinc^2$
    f. Impulse Train / Impulse Train
- Given an *arbitrary* signal in the time-domain, use the provided tables to compute the Fourier Transform and draw the signal spectrum.
- Given an *arbitrary* signal spectrum, use the provided tables to compute the Inverse Fourier Transform and write the signal in the time-domain.

Convolution

- Given two *arbitrary* (but simple) signals, *a(t)* and *b(t)*, compute the result of *a(t)*b(t)*.
- Apply the properties of convolution in the frequency domain to simplify and solve convolution of *a(t)*b(t)*.
- Understand and be able to apply the following convolution properties:
    a. Identity
    b. Commutative
    c. Associative
    d. Distributive
- Apply the properties of convolution with special functions (e.g., delta-functions or constants) to simplify and solve convolution of an arbitrary signal with the special function.

Energy/Power and Filtering

- Convert between gain as a linear ratio and gain expressed as a dB quantity.
- Convert between powers expressed as Watts and powers expressed as dBm.
- Use Parseval's Theorem to calculate the total energy/power in a signal given either the time-domain or frequency-domain representation of the signal.
- Given an *arbitrary* signal, apply the frequency domain version of convolution to determine the output (time-domain or frequency domain) of a high-pass, low-pass, or bandpass filter.

Sampling Theorem

- Explain the difference between natural, flat-top, and impulse sampling a signal.
- For an arbitrary signal (expressed in either the time-domain or as a frequency spectrum), calculate the Nyquist sampling frequency.
- Define aliasing and explain how aliasing is related to the Nyquist sampling frequency. Calculate the output spectrum when a signal is sampled at a rate that would cause aliasing.
- For an arbitrary signal which is impulse sampled at a sampling frequency of f_s, apply the sampling theorem and calculate the frequencies present in the sampled signal's spectrum.
- Draw the frequency spectrum for an arbitrary signal that is impulse sampled at a sampling frequency of f_s.
- Apply a filter to the sampled signal and determine the time domain and frequency domain output of the filter.

A/D Conversion and PCM

- Define Quantization and explain how quantization introduces error into a sampled signal.
- Given an ADC (analog-to-digital converter), determine the number of bits of quantization required to obtain a specified SQNR (i.e., Dynamic Range); given the number of bits for an ADC, determine the resulting SQNR.
- Given an ADC with a specified full-scale input range (V_{fs}) and number of bits of quantization, determine the quantization error (resolution) of the ADC.
- Given an arbitrary signal, design a PCM modulation system by calculating the required sampling frequency and number of bits of quantization necessary to achieve a specified SQNR.
- Given a PCM system, calculate the bit rate necessary to transmit the PCM encoded signal.

Amplitude Modulation

- Explain in words the difference between DSB-SC, DSB-TC, and SSB Amplitude Modulation.
- Given an arbitrary modulating signal, express mathematically a DSB-SC and DSB-TC signal in both the time-domain and frequency-domain.
- Given an arbitrary modulating signal, illustrate the resulting Amplitude Modulated signal in both the time-domain and frequency-domain.
- Given an arbitrary modulating signal, calculate the bandwidth of the resulting DSB-TC, DSB-SC, or SSB AM signal.
- Given a sinusoidally modulated DSB-TC AM signal, calculate the modulation index, carrier power, sideband power, total power, and power efficiency.
- Explain in words how to demodulate a DSB-TC AM signal with a modulation index less than 1.0.

Frequency Modulation

- Explain in words the difference between Amplitude Modulation and Angle Modulation.
- Explain in words the difference between Frequency Modulation and Phase Modulation.
- For an arbitrary signal, calculate the instantaneous frequency of the signal using the definition of instantaneous frequency.
- Explain in words the difference between narrowband FM and wideband FM.
- Given an arbitrary modulating signal, express mathematically a PM or FM signal in both the time-domain and frequency-domain.
- Given an arbitrary modulating signal, illustrate the resulting FM or PM signal in both the time-domain and frequency-domain.
- Given a sinusoidally modulated FM or PM signal, calculate the modulation index, total power in the signal, power in a given sideband, and power efficiency.
- Given a sinusoidally modulated FM or PM signal, calculate both the Absolute Bandwidth and Carson's Rule Bandwidth. Explain in words the difference between the two bandwidths.