# EE354 Study Guide for Exam #1

## Provided Reference Sheets

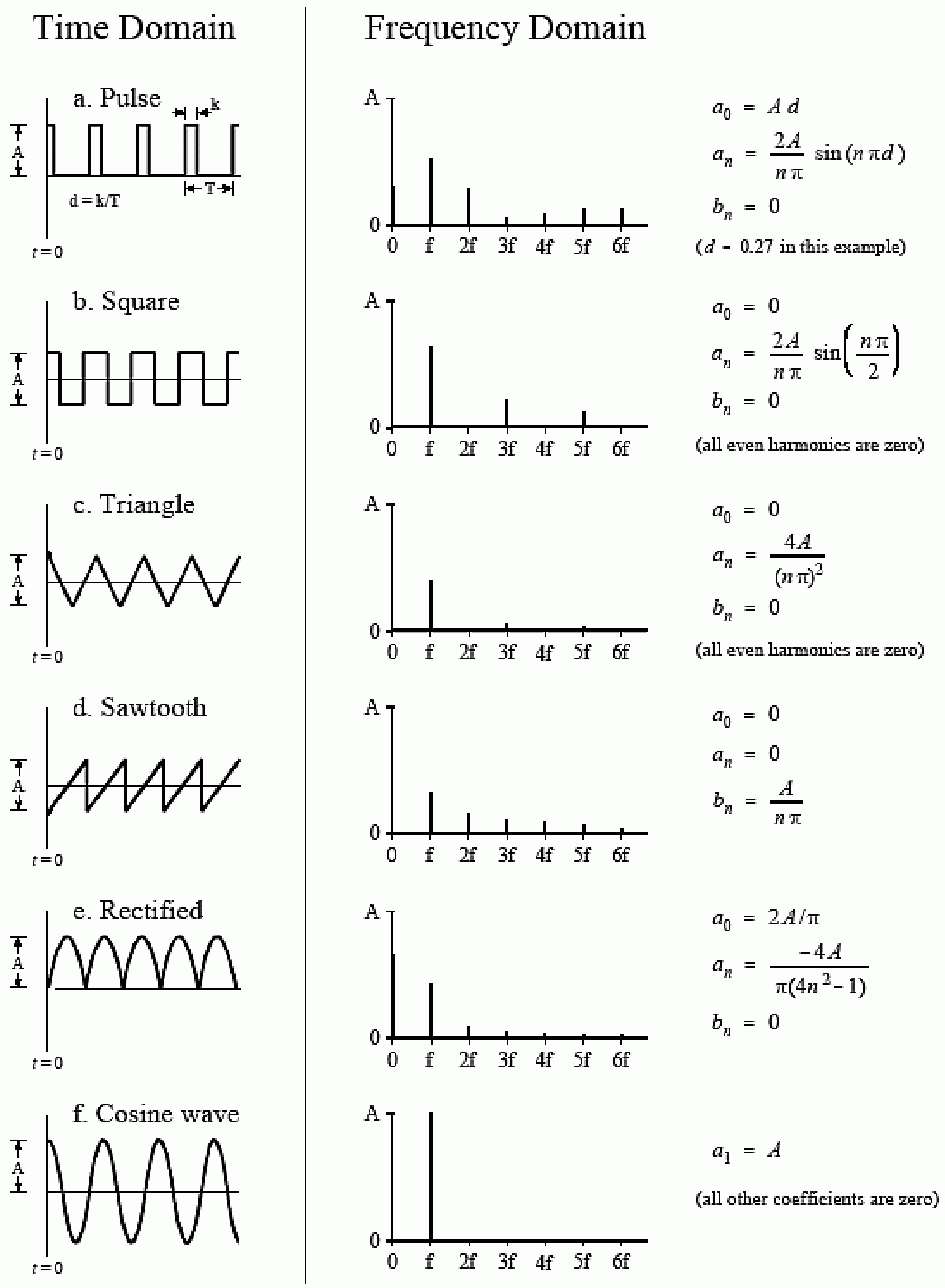


FIGURE 13-10
Examples of the Fourier series. Six common time domain waveforms are shown, along with the equations to calculate their "$a$" and "$b$" coefficients.

**<u>Workbook Tables (B.3 and B.4)</u>**

| | | |
|---|---|---|
| $\Pi\left(\frac{t}{\tau}\right)$ | $\Leftrightarrow$ | $\tau \operatorname{sinc}(f\tau)$ |
| $e^{j\omega_o t}$ | $\Leftrightarrow$ | $\delta(f-f_o)$ |
| $\delta(t-t_o)$ | $\Leftrightarrow$ | $e^{-j2\pi f t_o}$ |
| $\sum_{k=-\infty}^{\infty} \delta(t-kT_o)$ | $\Leftrightarrow$ | $f_o \sum_{k=-\infty}^{\infty} \delta(f-kf_o)$ |
| $\delta(t)$ | $\Leftrightarrow$ | $1$ |
| $K$ | $\Leftrightarrow$ | $K\,\delta(f)$ |
| $\operatorname{sinc}(2Wt)$ | $\Leftrightarrow$ | $\frac{1}{2W}\Pi\left(\frac{f}{2W}\right)$ |
| $\cos(\omega_o t)$ | $\Leftrightarrow$ | $\frac{1}{2}\delta(f-f_o)+\frac{1}{2}\delta(f+f_o)$ |
| $\sin(\omega_o t)$ | $\Leftrightarrow$ | $\frac{1}{2j}\delta(f-f_o)-\frac{1}{2j}\delta(f+f_o)$ |
| $u(t)$ | $\Leftrightarrow$ | $\frac{1}{j2\pi f}+\frac{1}{2}\delta(f)$ |
| $\Lambda\left(\frac{t}{\tau}\right)$ | $\Leftrightarrow$ | $\tau \operatorname{sinc}^2(f\tau)$ |
| $\sum_{k=-\infty}^{\infty} \Pi\left(\frac{t-kT_o}{\tau}\right)$ | $\Leftrightarrow$ | $\tau f_o \sum_{k=-\infty}^{\infty} \operatorname{sinc}(kf_o\tau)\delta(f-kf_o)$ |
| $\operatorname{sinc}^2(2Wt)$ | $\Leftrightarrow$ | $\frac{1}{2W}\Lambda\left(\frac{f}{2W}\right)$ |
| $e^{-at}u(t)$ | $\Leftrightarrow$ | $\frac{1}{a+j2\pi f}$ |
| $te^{-at}u(t)$ | $\Leftrightarrow$ | $\frac{1}{(a+j2\pi f)^2}$ |

| | | | |
|---|---|---|---|
| $ax(t)+by(t)$ | $\Leftrightarrow$ | $aX(f)+bY(f)$ | Superposition (or Linearity) |
| $X(t)$ | $\Leftrightarrow$ | $x(-f)$ | Duality |
| $\sum_{n=-\infty}^{\infty} c_n e^{jn\omega_o t}$ | $\Leftrightarrow$ | $\sum_{n=-\infty}^{\infty} c_n \delta(f-nf_o)$ | F.T. of periodic function |
| $\frac{d^n}{dt^n}x(t)$ | $\Leftrightarrow$ | $(j2\pi f)^n X(f)$ | Differentiation in time |
| $x(t-t_o)$ | $\Leftrightarrow$ | $e^{-j2\pi f t_o}X(f)$, | Time shifting |
| $x(at)$ | $\Leftrightarrow$ | $\frac{1}{\lvert a\rvert}X\left(\frac{f}{a}\right)$ | Time scaling |
| $\int_{-\infty}^{t} x(\lambda)d\lambda$ | $\Leftrightarrow$ | $\frac{1}{j2\pi f}X(f)+\frac{X(0)}{2}\delta(f)$ | Integration |
| $x(t)*y(t)$ | $\Leftrightarrow$ | $X(f)Y(f)$ | Convolution |
| $x(t)y(t)$ | $\Leftrightarrow$ | $X(f)*Y(f)$ | Multiplication |
| $e^{j\omega_o t}x(t)$ | $\Leftrightarrow$ | $X(f-f_o)$ | Frequency shifting |
| $t^n x(t)$ | $\Leftrightarrow$ | $(-j2\pi)^{-n}\frac{d^n}{df^n}X(f)$ | Differentiation in frequency |
| $x(t)\sum_{k=-\infty}^{\infty} \delta(t-kT_s)$ | $\Leftrightarrow$ | $f_s \sum_{k=-\infty}^{\infty} X(f-kf_s)$ | Impulse sampling |
| $x(t)\cos(\omega_c t)$ | $\Leftrightarrow$ | $\frac{1}{2}X(f+f_c)+\frac{1}{2}X(f-f_c)$ | 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 / $\text{Sinc}^2$
    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.