EELE445 Exam 1 Review
In class Friday March 20
50 minutes

- One 8x11page, both sides
- 10 questions, 10 points per question, divided among 5 problems

Exam 1 EELE445

**The exam covers through lecture 16
and through homework 4.**

• Be sure to review and understand the Homework problems. The exam questions center on the material covered by the homework.

•Review the example problems worked in class

•Concepts highlighted in green or blue on the slides.

The following slides are indicative of the areas that will be covered on the exam, BUT ARE NOT ALL INCLUSIVE! You are responsible for the material in the lectures

TOPICS

- **Review of Signals and Spectra**
- **Analysis and Transmission of Signals**
- **Sampling and pulse code modulation**
- **Principles of Digital Baseband Signals**
- **Bandpass Signaling Principles and Circuits**
- **Bandpass Modulated Systems**
- **Introduction to the theory of probability**
- **Analog systems in the presence of noise**
- **Behavior of digital systems in the presence of noise**
- **Error correcting codes**
- **Example systems**

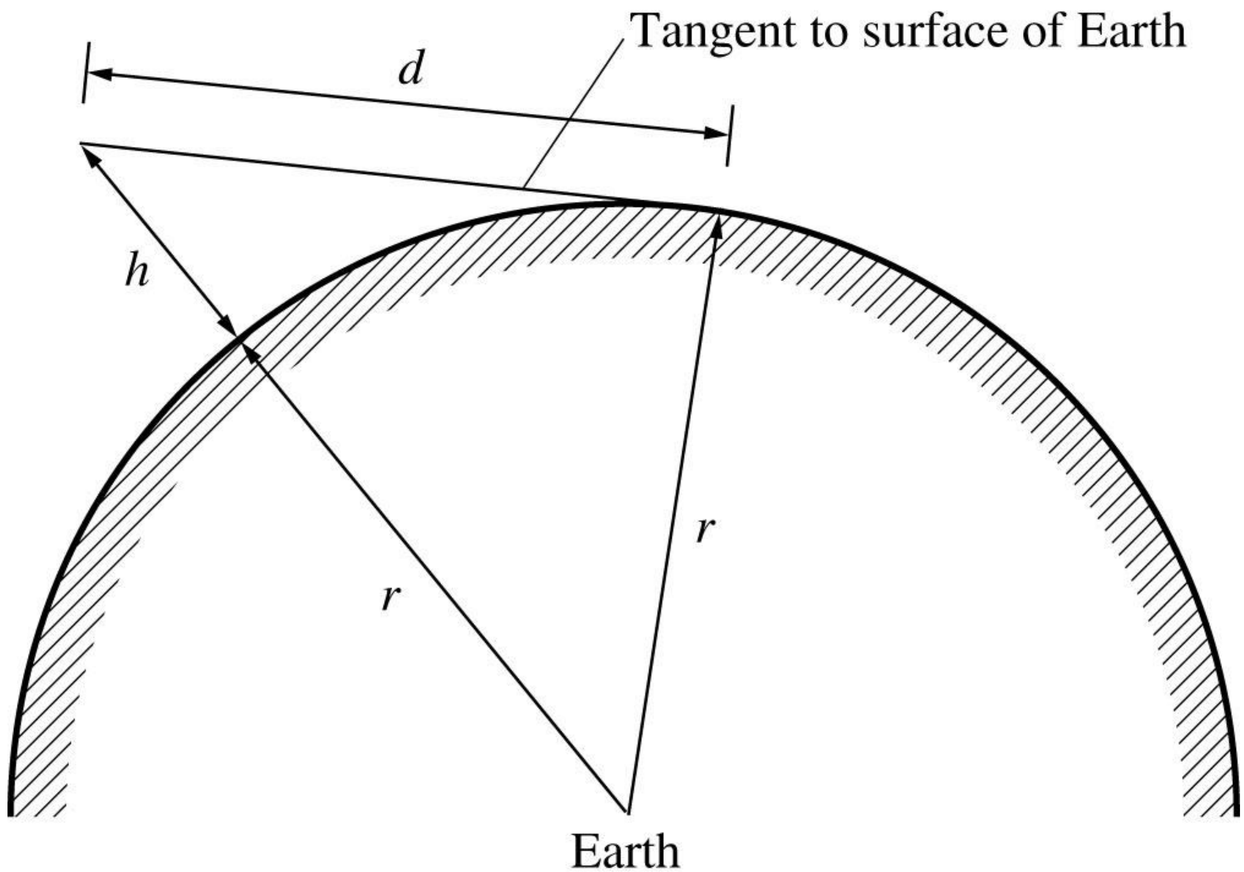
TOPICS

- **Review of Signals and Spectra and information**
  - **Shannon's Channel Capacity Law**
  - LOS tower height
  - DC, rms, power in time domain
  - voltage spectra, power spectra , PSD , Fourier series and Fourier transforms
  - continuous and discreet spectra
  - power in frequency domain
- **Analysis and Transmission of Signals**
  - dBm, dBW, dBV,
  - noise or equivalent bandwidth
  - lowpass and bandpass filters- Butterworth filter- 1 pole $B_{eq}=B_{3dB}x\pi/2$
  - be able to calculate the power of white noise through a filter
  - waveform through a transfer function, output spectrum and output power for a given input spectrum
  - total power from a PSD
- **Sampling and pulse code modulation**
  - impulse, natural, and flat top sampling- what are the spectrum differences
  - Sample rate
  - sampled signal in frequency domain- spectra
- **Principles of Digital Baseband Signals**
  - **PAM, PCM**
  - **PCM- bit rate, SQNR vs n-bits**
  - **μ–law compression**
  - **line code spectra will not be covered this exam**

Lecture 1-2 – LOS Line of Sight

$$d = \sqrt{2h}$$

d in miles, h in feet



Lecture 1-2 – Shannon’s Law

$$R = \frac{H}{T} \;\; bits/s$$

$$Channel\ Capacity:$$

$$C = B \bullet \log_2\left(1 + \frac{S}{N}\right) \;\; bits/s$$

$$B = Bandwith\ in\ Hz$$

$$S = Signal\ \ power\ in\ watts$$

$$N = Noise\ \ power\ in\ watts$$

Lecture 1-2 – Units and dB

$$dB \therefore 10\log\left(\frac{P_1}{P_2}\right) = 10\log\left(\frac{V_{1rms}^2}{R_1}\frac{R_2}{V_{2rms}^2}\right)$$

$$dBm = 10\log\left(\frac{P\ in\ watts}{0.001\,watt}\right) = 10\log\left(\frac{P\ in\ milliwatts}{1\,milliwatt}\right)$$

$$dBW = 10\log\left(\frac{P\ in\ watts}{1\,watt}\right)$$

$$dBV = 20\log\left(\frac{V_1\ in\ rmsvolts}{1\,rmsvolt}\right)\ when\ R_1 = R_2$$

$$dB\mu V = 20\log\left(\frac{V_1\ in\ rmsvolts}{10^{-6}\ rmsvolt}\right)\ when\ R_1 = R_2$$

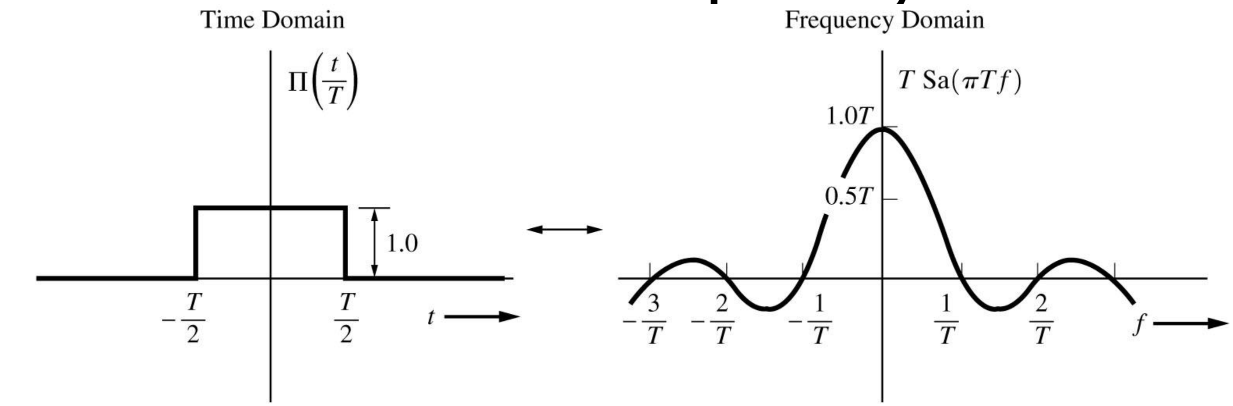
Lecture 3-4 – DC,rms, Power, Energy

$$\langle w(t) \rangle = \frac{1}{T} \int_{-\frac{T}{2}}^{\frac{T}{2}} w(t)dt \quad = DC \; or \; \underline{mean} \; of \;\; w(t)$$

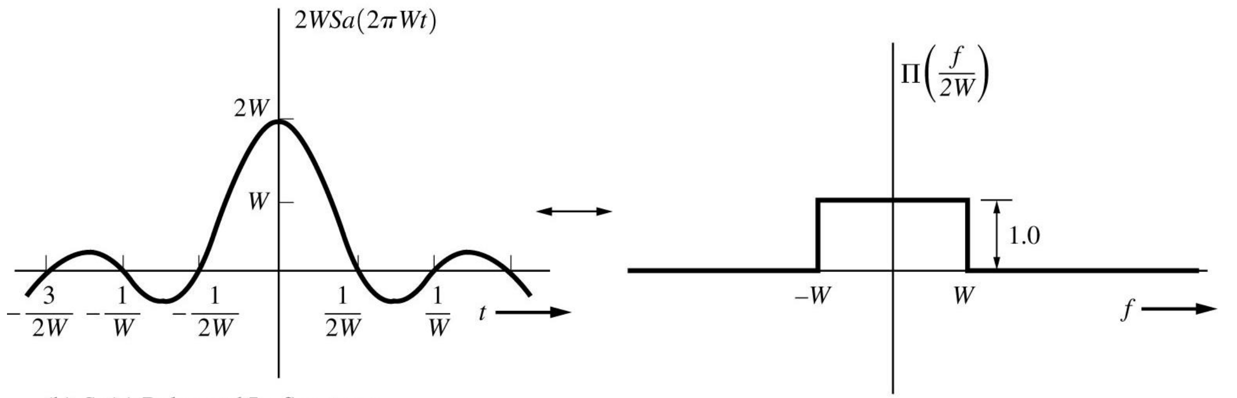
$$\sqrt{\langle w^2(t) \rangle} = \sqrt{\frac{1}{T} \int_{-\frac{T}{2}}^{\frac{T}{2}} w^2(t)dt} \quad = rms \; value \; of \;\; w(t)$$

$$E = \frac{1}{R} \int_{-\frac{T}{2}}^{\frac{}{2}} v^2(t)dt = \;\; R \int_{-\frac{T}{2}}^{\frac{}{2}} i^2(t)dt$$

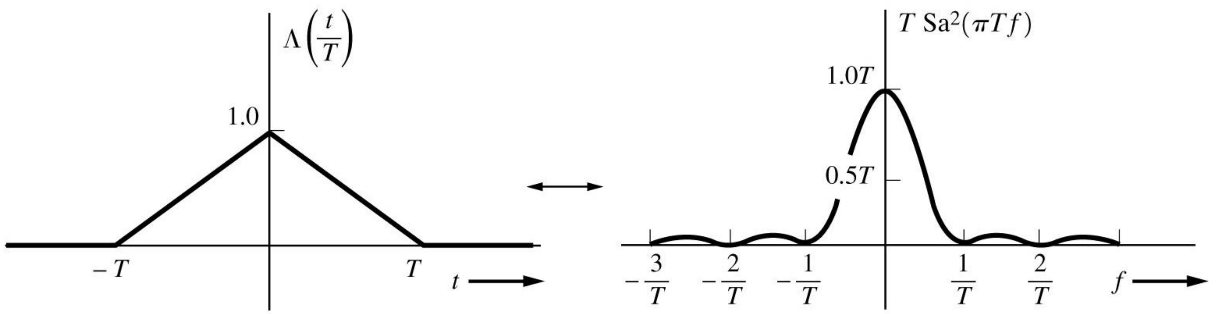
Lecture 5-7 – Frequency Domain



(a) Rectangular Pulse and Its Spectrum



(b) $Sa(x)$ Pulse and Its Spectrum



(c) Triangular Pulse and Its Spectrum

Lecture 5-7

TABLE 2–1 SOME FOURIER TRANSFORM THEOREMS[a]

Operation	Function	Fourier Transform
Linearity	$a_1 w_1(t) + a_2 w_2(t)$	$a_1 W_1(f) + a_2 W_2(f)$
Time delay	$w(t - T_d)$	$W(f)\, e^{-j\omega T_d}$
Scale change	$w(at)$	$\frac{1}{\lvert a \rvert} W\left(\frac{f}{a}\right)$
Conjugation	$w^*(t)$	$W^*(-f)$
Duality	$W(t)$	$w(-f)$
Real signal frequency translation [$w(t)$ is real]	$w(t)\cos(w_c t + \theta)$	$\frac{1}{2}[e^{j\theta} W(f - f_c) + e^{-j\theta} W(f + f_c)]$
Complex signal frequency translation	$w(t)\, e^{j\omega_c t}$	$W(f - f_c)$
Bandpass signal	$\mathrm{Re}\{g(t)\, e^{j\omega_c t}\}$	$\frac{1}{2}[G(f - f_c) + G^*(-f - f_c)]$
Differentiation	$\frac{d^n w(t)}{dt^n}$	$(j2\pi f)^n W(f)$
Integration	$\int_{-\infty}^{t} w(\lambda)\, d\lambda$	$(j2\pi f)^{-1} W(f) + \frac{1}{2} W(0)\, \delta(f)$
Convolution	$w_1(t) * w_2(t) = \int_{-\infty}^{\infty} w_1(\lambda) \cdot w_2(t - \lambda)\, d\lambda$	$W_1(f) W_2(f)$
Multiplication[b]	$w_1(t) w_2(t)$	$W_1(f) * W_2(f) = \int_{-\infty}^{\infty} W_1(\lambda)\, W_2(f - \lambda)\, d\lambda$
Multiplication by t^n	$t^n w(t)$	$(-j2\pi)^{-n} \frac{d^n W(f)}{df^n}$

[a] $\omega_c = 2\pi f_c$.

[b] $*$ denotes convolution as described in detail by Eq. (2–62).

Lecture 5-7

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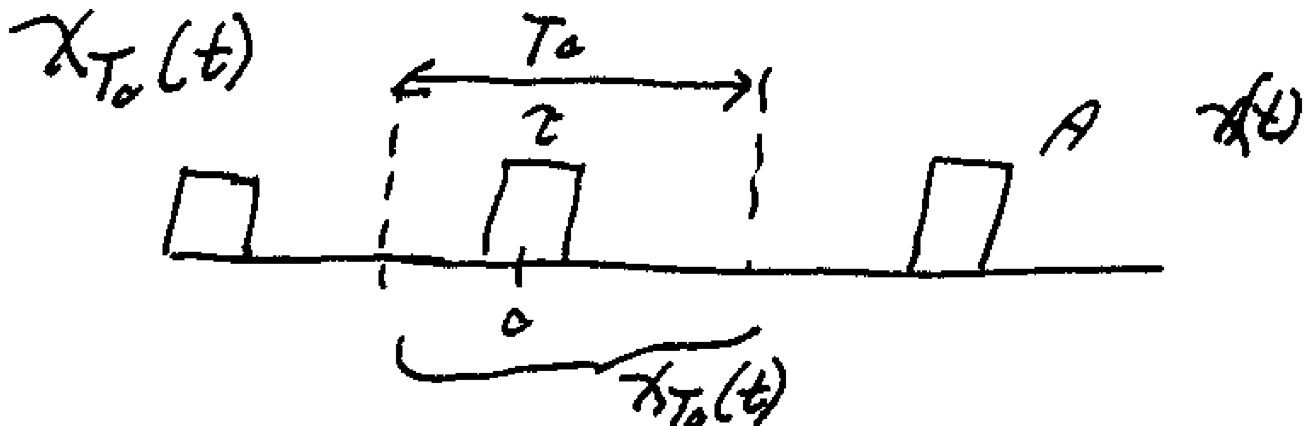
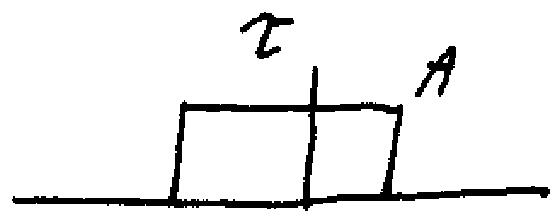
Fourier Series from Fourier Transforms

1) find truncated signal period.



2) determine the Fourier Transform of $x_{T_0}(t)$



$\Rightarrow A\tau \operatorname{sinc} f\tau$

Fourier Series from Fourier Transforms

3) set $f = \frac{n}{T_0}$ and scale by $\frac{1}{T_0}$

$$x(f) = \frac{A\tau}{T_0} \operatorname{sinc}\left(\frac{n\tau}{T_0}\right) = x_n$$

$$X(f) = X_{T_0}(f) \left[* \sum_{n=-\infty}^{\infty} \delta\left(f - \frac{n}{T_0}\right) \right.$$

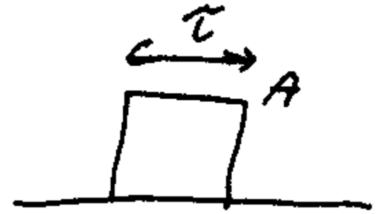
$$= x_{T_0}(f) \left[\frac{1}{T_0} \sum_{n=-\infty}^{\infty} \delta\left(f - \frac{n}{T_0}\right) \right.$$

$$= \frac{1}{T_0} \sum x_{T_0}\left(\frac{n}{T_0}\right) \delta\left(f - \frac{n}{T_0}\right)$$

$$x_n = \frac{x_{T_0}\left(\frac{n}{T_0}\right)}{T_0} \quad \therefore$$

Fourier Series from Fourier Transforms

Fourier Series from Fourier Transform

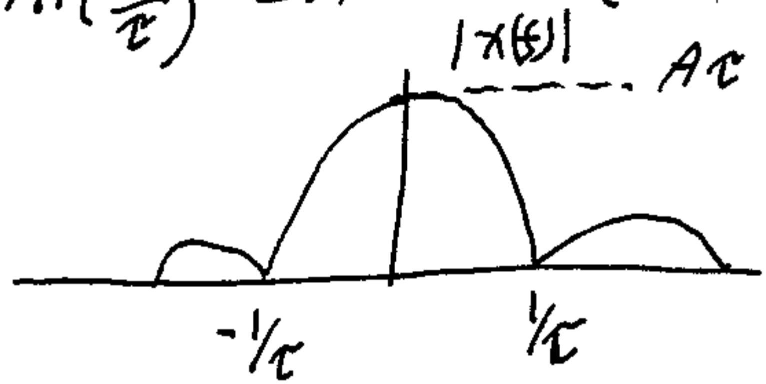


from table 2.1

$$\mathcal{F}\ \Pi(t) = \text{sinc}(f)$$

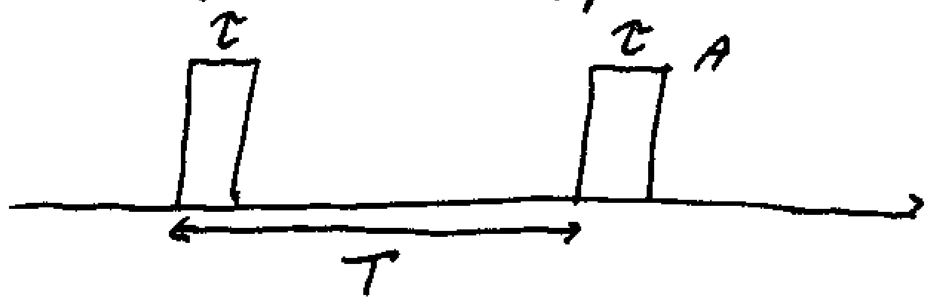
using the properties of transform:

$$\mathcal{F}\ A\Pi\left(\frac{t}{\tau}\right) \Rightarrow A\tau\,\text{sinc}(f\tau) = X(f)$$



Fourier Series from Fourier Transforms

now make a repetative pulse period T



Let $f = \frac{n}{T}$ + scale by $\frac{1}{T}$

$$x_n = \frac{A\tau}{T}\,\mathrm{sinc}\left(\frac{n\tau}{T}\right) \quad \therefore$$

Lecture 8-10 – Power Through a Filter

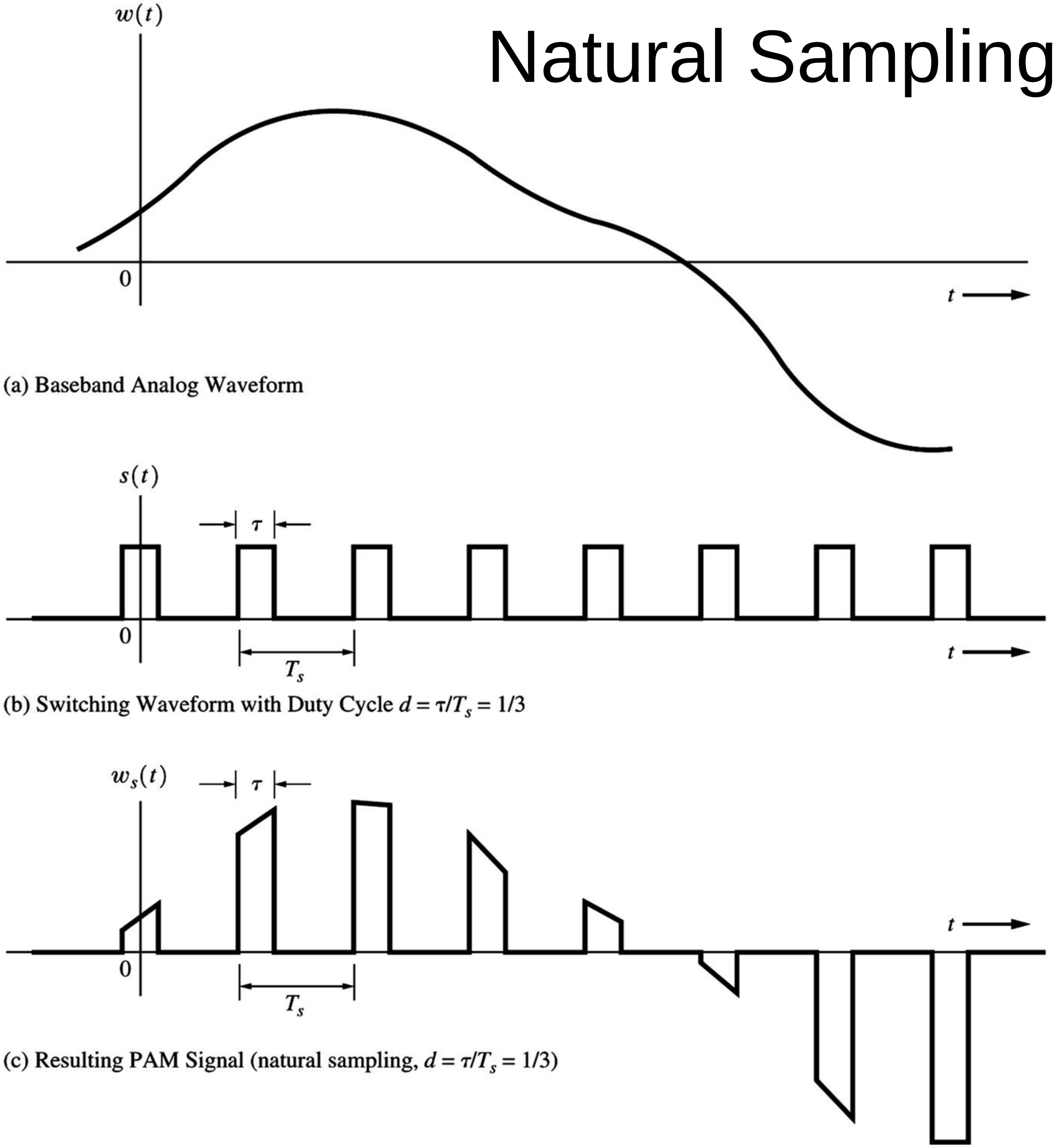
$$P_y = \sum_{n=-\infty}^{\infty} \left|x_n\right|^2 \left|H\left(\frac{n}{T_0}\right)\right|^2 = \int_{-\infty}^{\infty} S_x^2(f) \left|H(f)^2\right| df$$

Setting Eq. (2–190) equal to Eq. (2–191), the formula for the *equivalent noise bandwidth* is

$$B_{eq} = \frac{1}{|H(f_0)|^2} \int_0^{\infty} |H(f)|^2 \, df \qquad (2\text{–}192)$$

Be able to calculate the noise power at the output of a RC filter with a white noise input

Natural Sampling



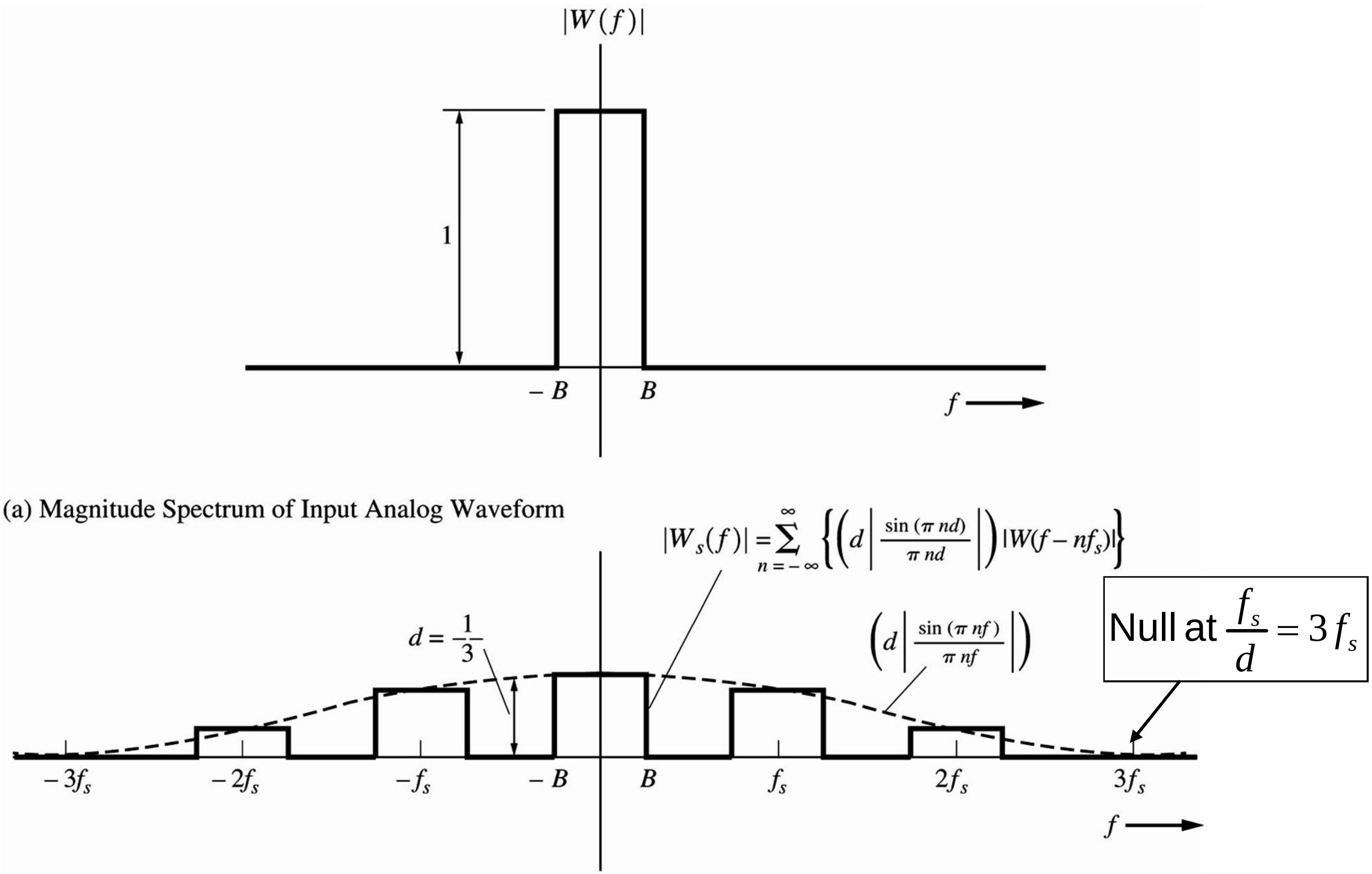
(a) Baseband Analog Waveform

(b) Switching Waveform with Duty Cycle $d = \tau/T_s = 1/3$

(c) Resulting PAM Signal (natural sampling, $d = \tau/T_s = 1/3$)

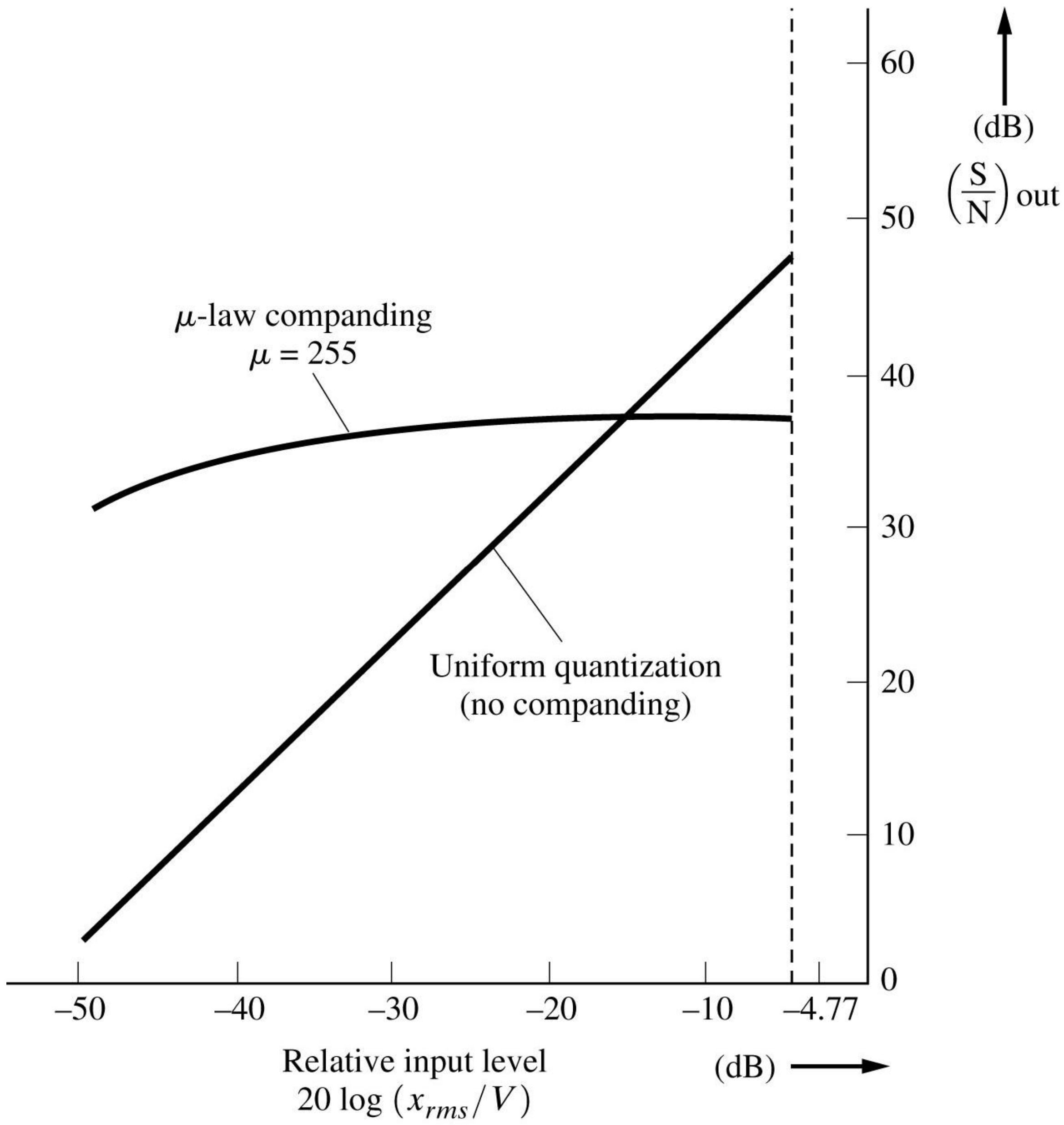
Duty cycle =1/3

Natural Sampling

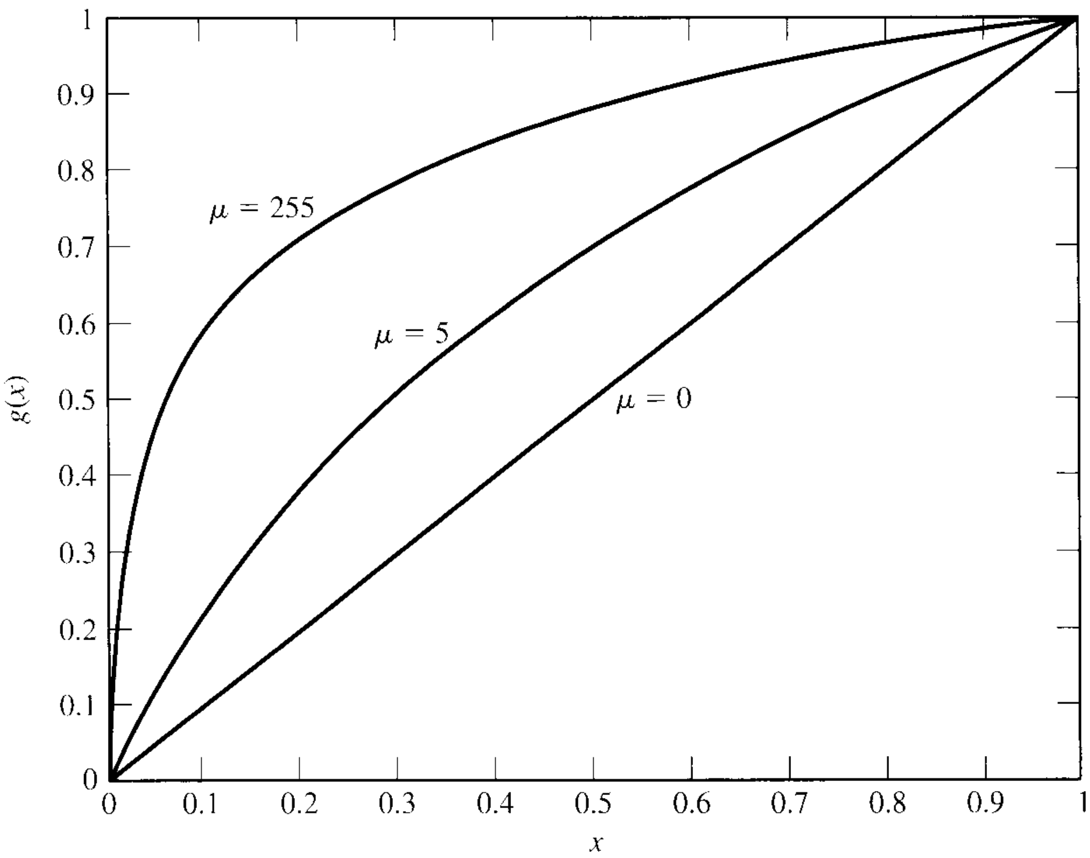


(b) Magnitude Spectrum of PAM (natural sampling) with $d = 1/3$ and $f_s = 4$ B

Lecture 11-13 companding



Lecture 11-13 Companding



$$g(x) = \frac{\log(1 + \mu|x|)}{\log(1 + \mu)} \operatorname{sgn}(x).$$

U=255 U.S

Lecture 11-13 Quantization noise

$$\langle q^2 \rangle = \frac{1}{\Delta} \int_{\frac{-\Delta}{2}}^{\frac{\Delta}{2}} q^2 dq$$

$$= \frac{\Delta^2}{12}$$

$$= \frac{(V_{\max})^2}{3M^2} = P_{nq} \quad \textit{the quantization noise}$$

SQNR - summary

$$P_{nq} = \frac{V_{\max}^2}{3M^2} \quad \textit{quantization noise power}$$

$$SQNR = \frac{P_x}{P_{nq}} = \frac{3M^2 P_x}{V_{\max}^2} = \frac{3 \times 4^n P_x}{V_{\max}^2}$$

- **M is the number of quantization levels**
- **n is the number of bits**
- **V_{max} is ½ the A/D input range**

SQNR_{dB}

$$P_x \le V_{\max}^2$$

$$\frac{P_x}{V_{\max}^2} \le 1$$

The SQNR decreases as The input dynamic range increases

$$SQNR\,|_{dB} \cong 10\log_{10}\left(\frac{P_x}{V_{\max}^2}\right) + 6n + 4.8$$

- $V_{\max}$ is $\frac{1}{2}$ the peak to peak range of the quantizer
- n is the number of bits in the full scale quantizer range

Lecture 14-15 SQNR

$$SQNR_{dB} = 6.02n + \alpha \qquad (3\text{-}25)$$

$$\alpha = 4.77 - 20\log\left(\frac{V_{\max}}{x_{xrms}}\right) \qquad \text{(uniform quantizing)} \quad (3\text{-}26a)$$

$$\alpha \cong 4.77 - 20\log[\ln(1+\mu)] \qquad (\mu\text{-law companding}) \quad (3\text{-}26b)$$

$$\alpha \cong 4.77 - 20\log[1+\ln A] \qquad (A\text{-law companding}) \quad (3\text{-}26c)$$

$P_x = x_{xrms}^2$ is the input signal power

$V_{\max}$ is the <u>peak</u> design voltage level of the quantizer

Exam 1 EELE445

- **Review the slides for lectures up to and including L16**
- **concentrate on highlighted information**
- **HW solutions 1-4**