

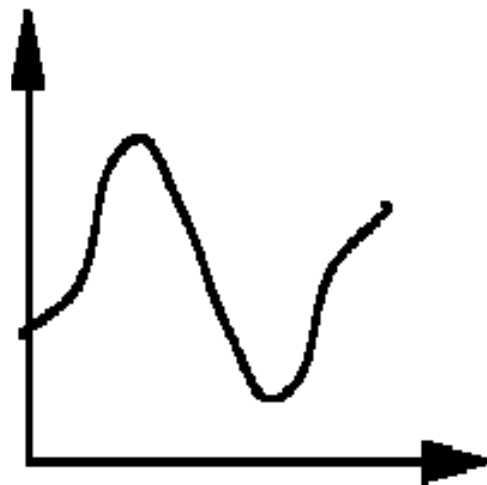
TOPIC 3 – Analog and Digital Signals

3.3 Analog to Digital Conversion (ADC)

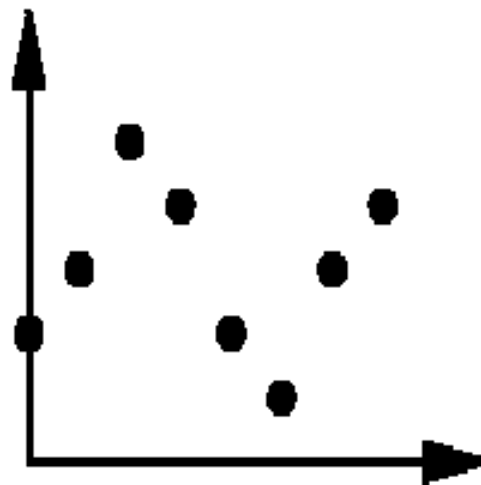
- **Analog signals are those which are naturally occurring.**
- **Any analog signal can be converted to a digital signal.**

TOPIC 3 – Analog and Digital Signals

3.3 Analog to Digital Conversion (ADC)



analog signal



sampled signal

100101010000110101

digital information

TOPIC 3 – Analog and Digital Signals

3.3 Analog to Digital Conversion (ADC)

Quantization:

- The process by which measurements of analog signals are rounded to discrete values.
- These discrete values are referred to as “bits”.
- Typically, each bit has only two possible states, 0 or 1.
- This is called the binary system.
- The number of bits available to describe these values determines the resolution or accuracy.

TOPIC 3 – Analog and Digital Signals

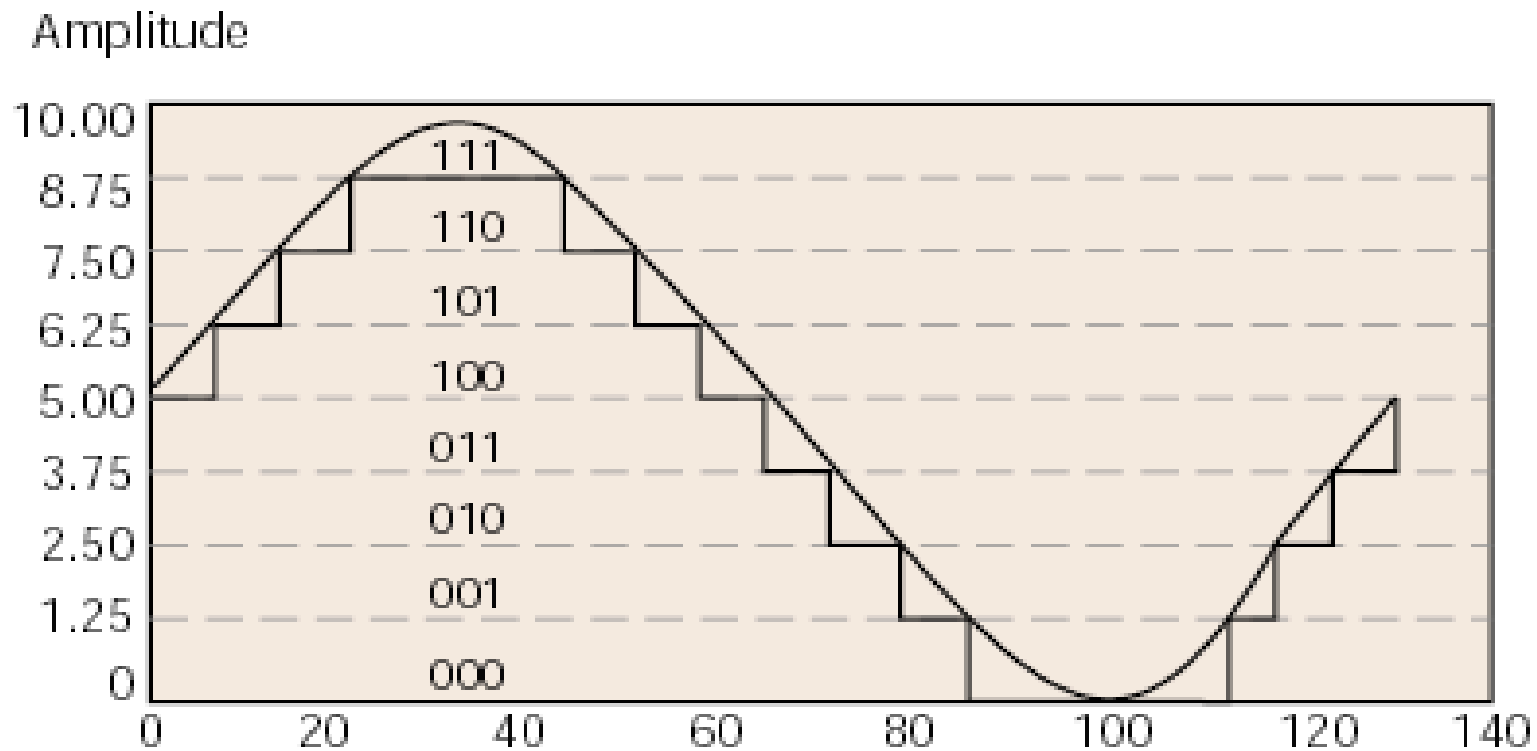
3.3 Analog to Digital Conversion (ADC)

- If you have 3-bit analog to digital converters, the varying analog signal must be quantized to 1 of 8 discrete values.
- For example, with 2 states and 3 bit conversion there are $2^3 = 8$ possible discrete values.

TOPIC 3 – Analog and Digital Signals

3.3 Analog to Digital Conversion (ADC)

So for a 3-bit analog to digital conversion for an analog signal with an arbitrary maximum amplitude of 10:



TOPIC 3 – Analog and Digital Signals

3.3 Analog to Digital Conversion (ADC)

- Resolution:
 - Defined in terms of number of bits
 - 2^b where b: number of bits
 - e.g. 3 bit resolution yields 8 levels of resolution
 - 8 bit resolution yields 256 levels
 - 16 bit resolution yields 65536 levels

TOPIC 3 – Analog and Digital Signals

3.3 Analog to Digital Conversion (ADC)

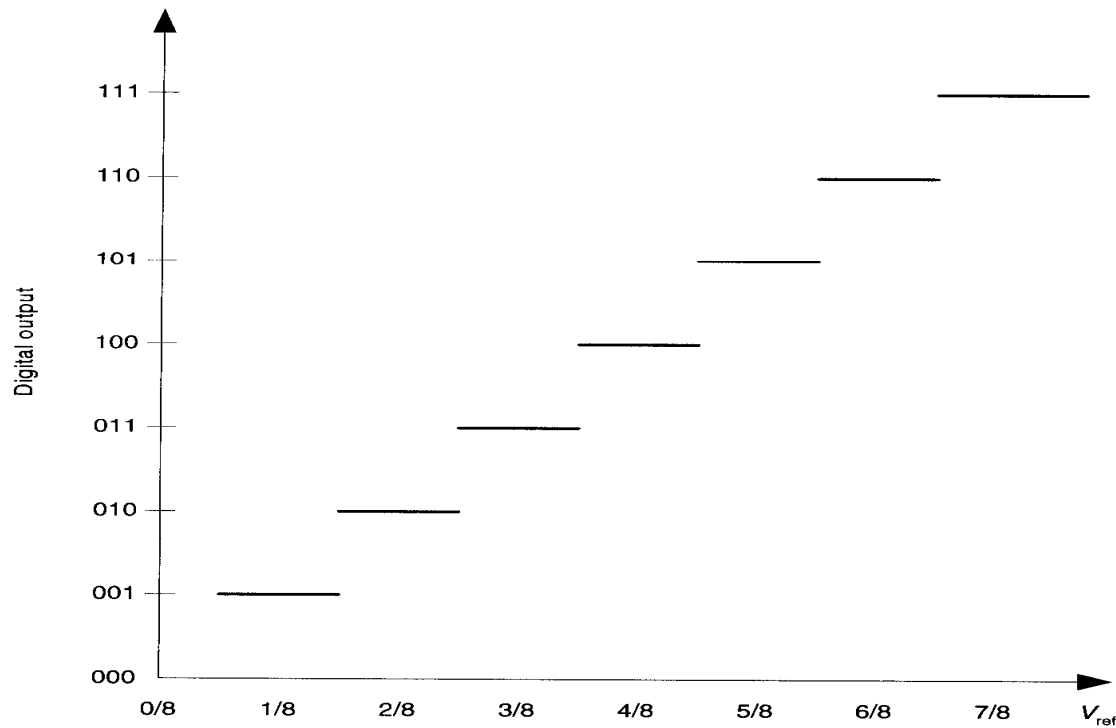


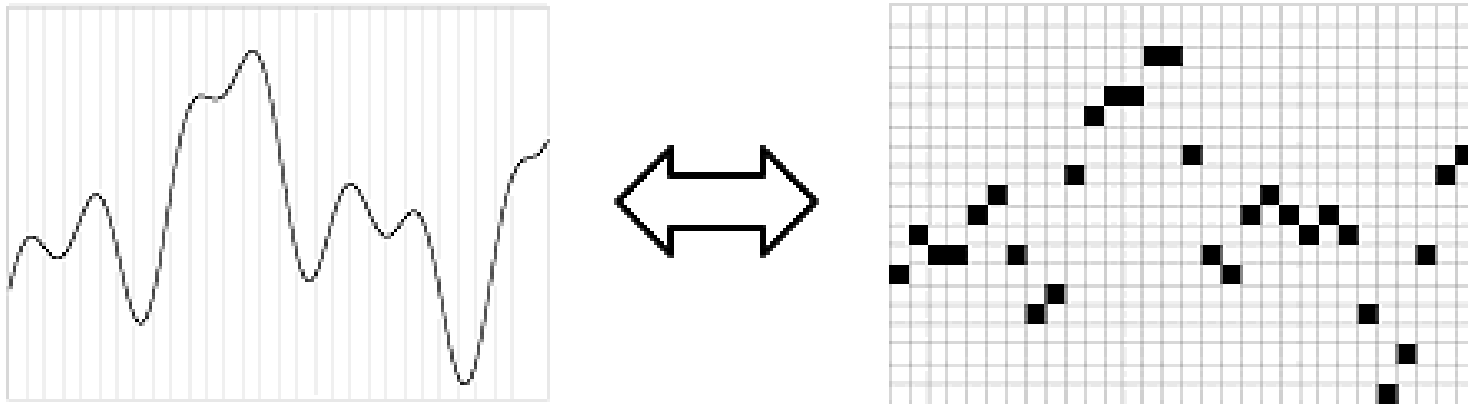
Figure 2.44 Converting characteristic of 3-bit ADC.

TOPIC 3 – Analog and Digital Signals

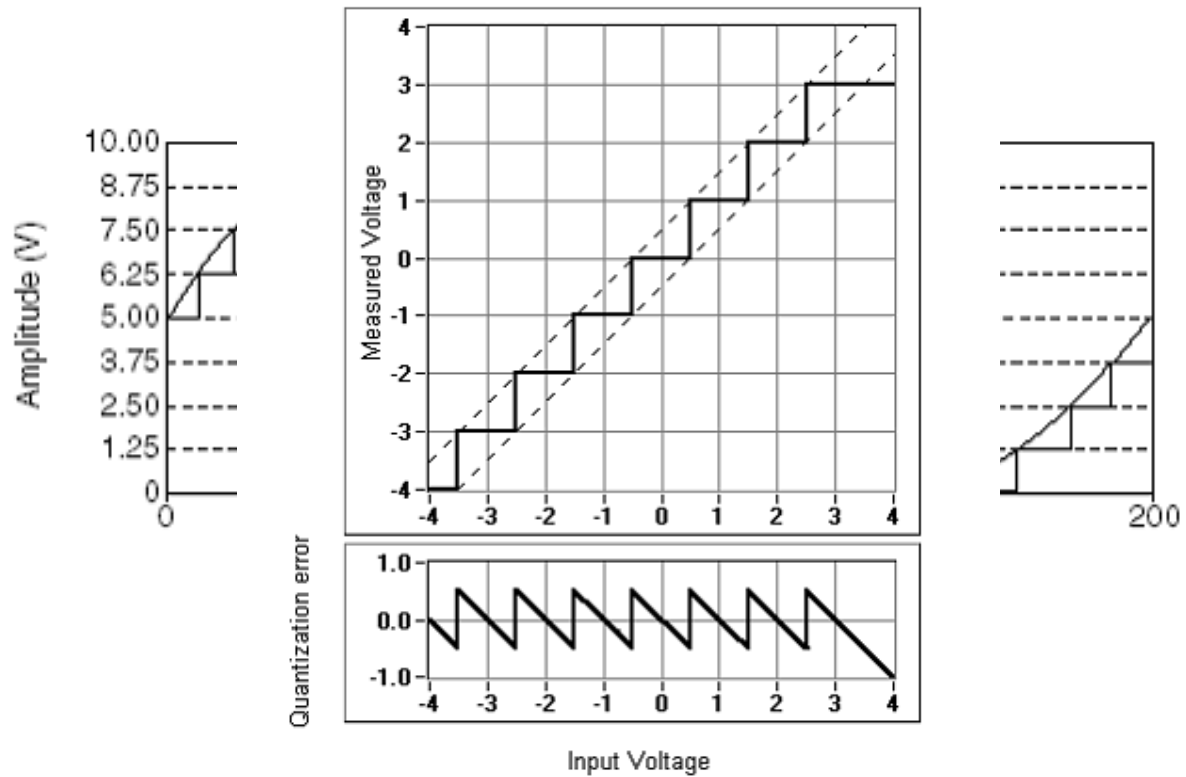
3.2 Analog Sampling Basics

Quantization

- Quantization is defined as the process of converting an analog signal to a digital representation. Quantization is performed by an analog-to-digital converter (A/D converter or ADC)

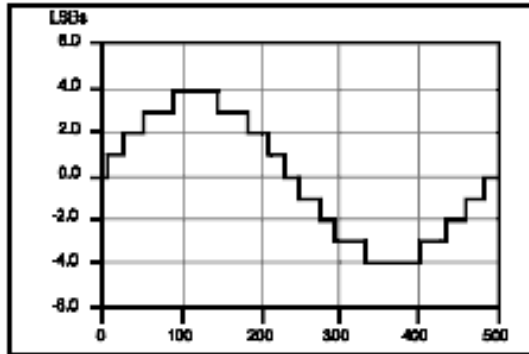


Quantization Error

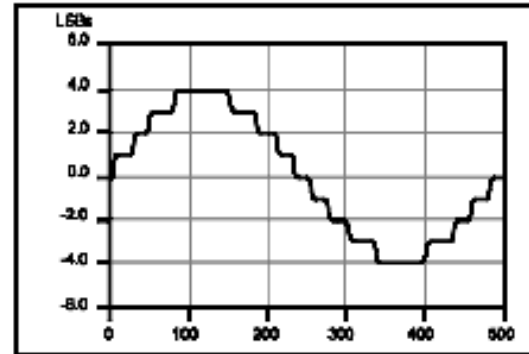


Dithering

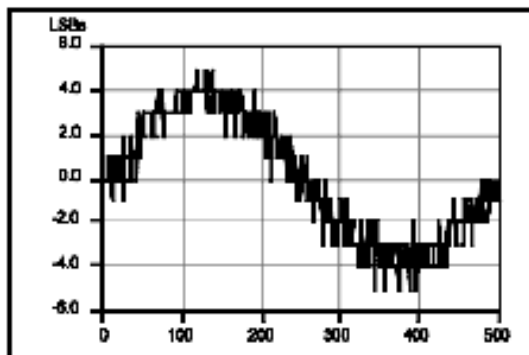
- Dithering involves the deliberate addition of noise to our input signal. It helps by smearing out the little differences in amplitude resolution



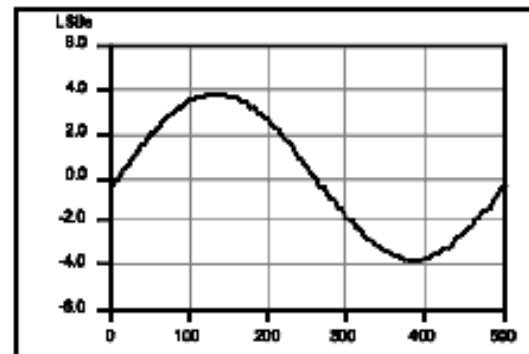
a. Dither disabled; no averaging



b. Dither disabled; average of 50 acquisitions



c. Dither enabled; no averaging



d. Dither enabled; average of 50 acquisitions

TOPIC 3 – Analog and Digital Signals

3.3 Digital to Analog Conversion (DAC)

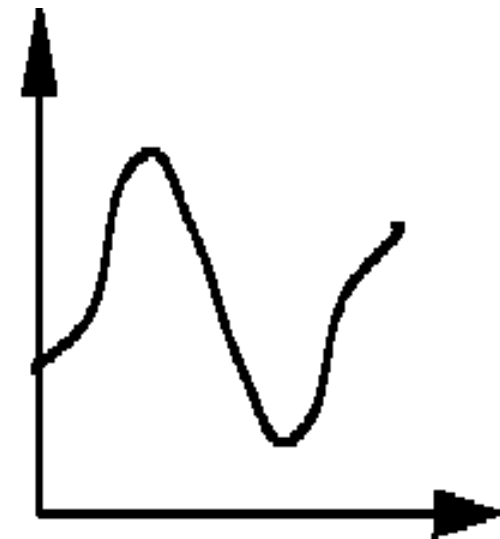
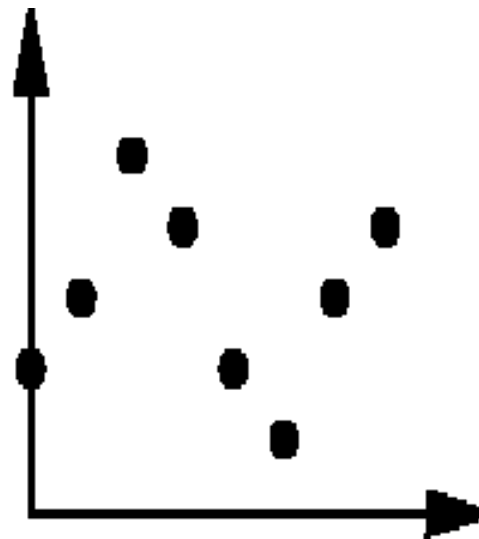
- **Digital signals are those made by humans (or other sentients)**
- **Any digital signal can be converted to an analog signal.**

TOPIC 3 – Analog and Digital Signals

3.3 Digital to Analog Conversion (DAC)

Digital to Analog Conversion

100101010000110101

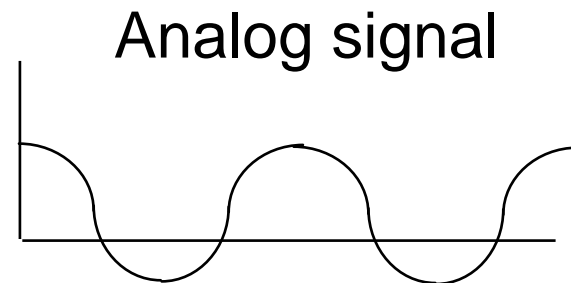
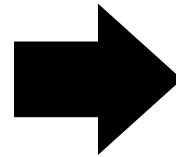
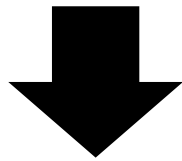
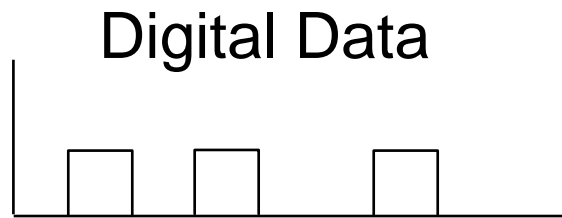


digital information

sampled signal

analog signal

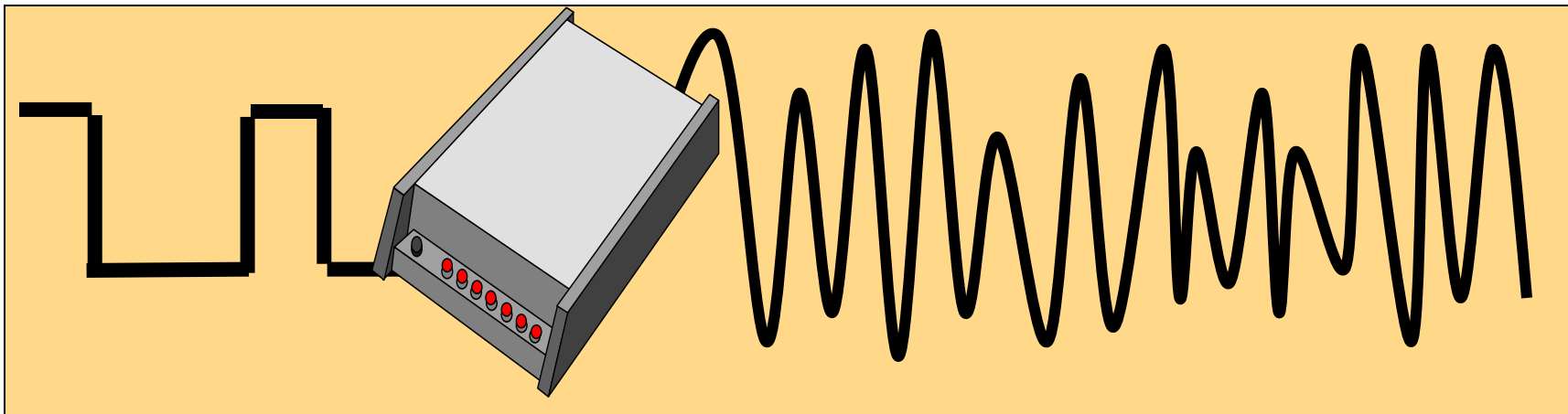
Digital to Analog Conversion



TOPIC 3 – Analog and Digital Signals

3.3 Digital to Analog Conversion (DAC)

A DAC Example: MODEM



MODEM: modulator/demodulator – digital to analog or analog to digital

TOPIC 3 – Analog and Digital Signals

3.3 Digital to Analog Conversion (DAC)

3-bit voltage scaling Digital to Analog Converter (DAC)

- A reference signal, Ref, (eg. voltage) is required.**
- The number of bits, n, fixes the resolution, R, of the DAC.**
- The resolution sets the difference between signal levels.**
- So: $R = \text{Ref}/2^n$.**

TOPIC 3 – Analog and Digital Signals

3.3 Digital to Analog Conversion (DAC)

3-bit voltage scaling DAC:

- For a 3-bit DAC, $n = 3$.**
- Let the reference signal be $Ref = 10 \text{ VDC}$.**
- Then: $R = Ref/2^n = 10/8 = 1.25\text{VDC}$.**

TOPIC 3 – Analog and Digital Signals

3.3 Digital to Analog Conversion (DAC)

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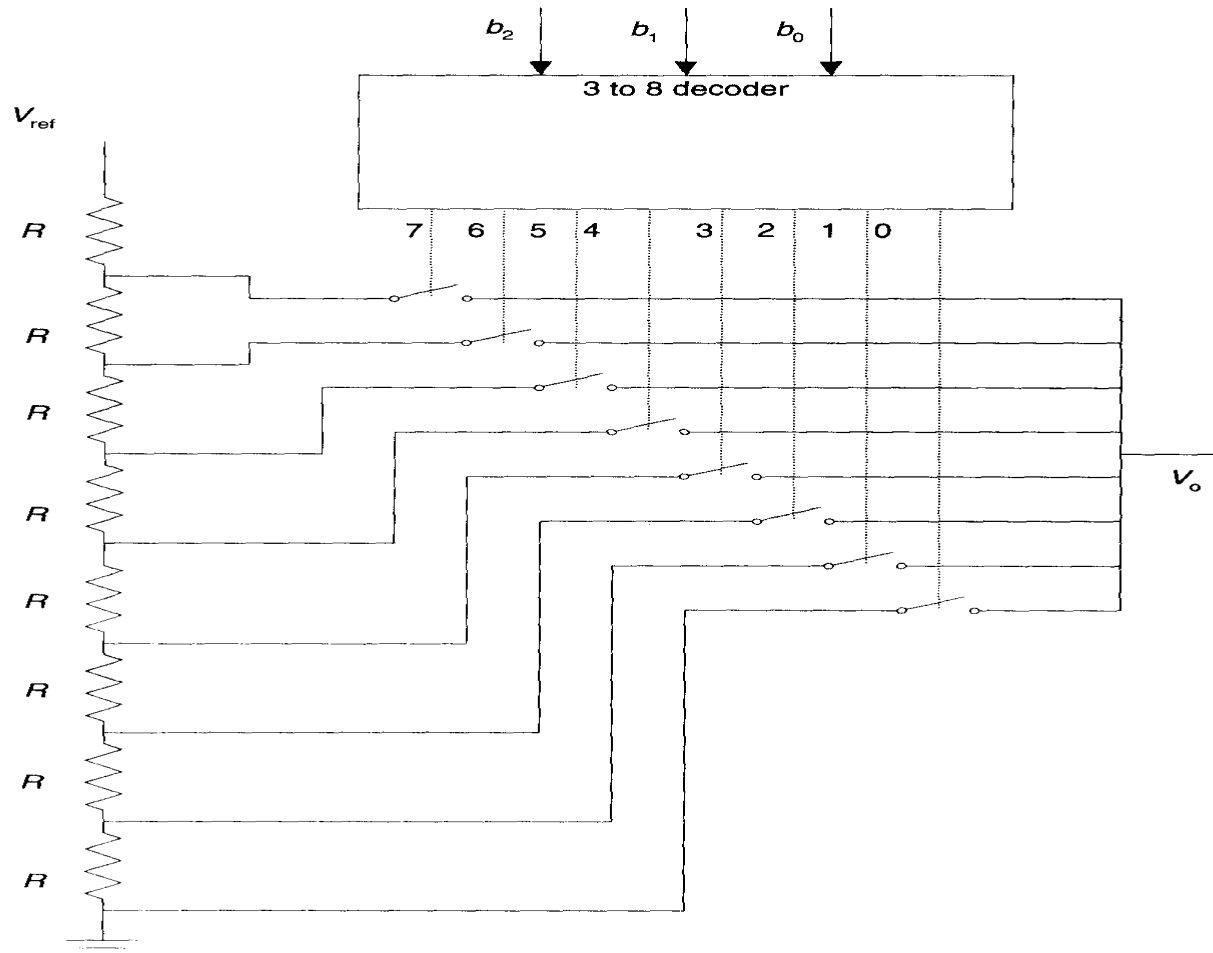


Figure 2.43 A 3-bit voltage scaling DAC converter.

TOPIC 3 – Analog and Digital Signals

3.3 Digital to Analog Conversion (DAC)

2.4 Analog-to-Digital (ADC) and Digital-to-Analog (DAC) Conversion 73

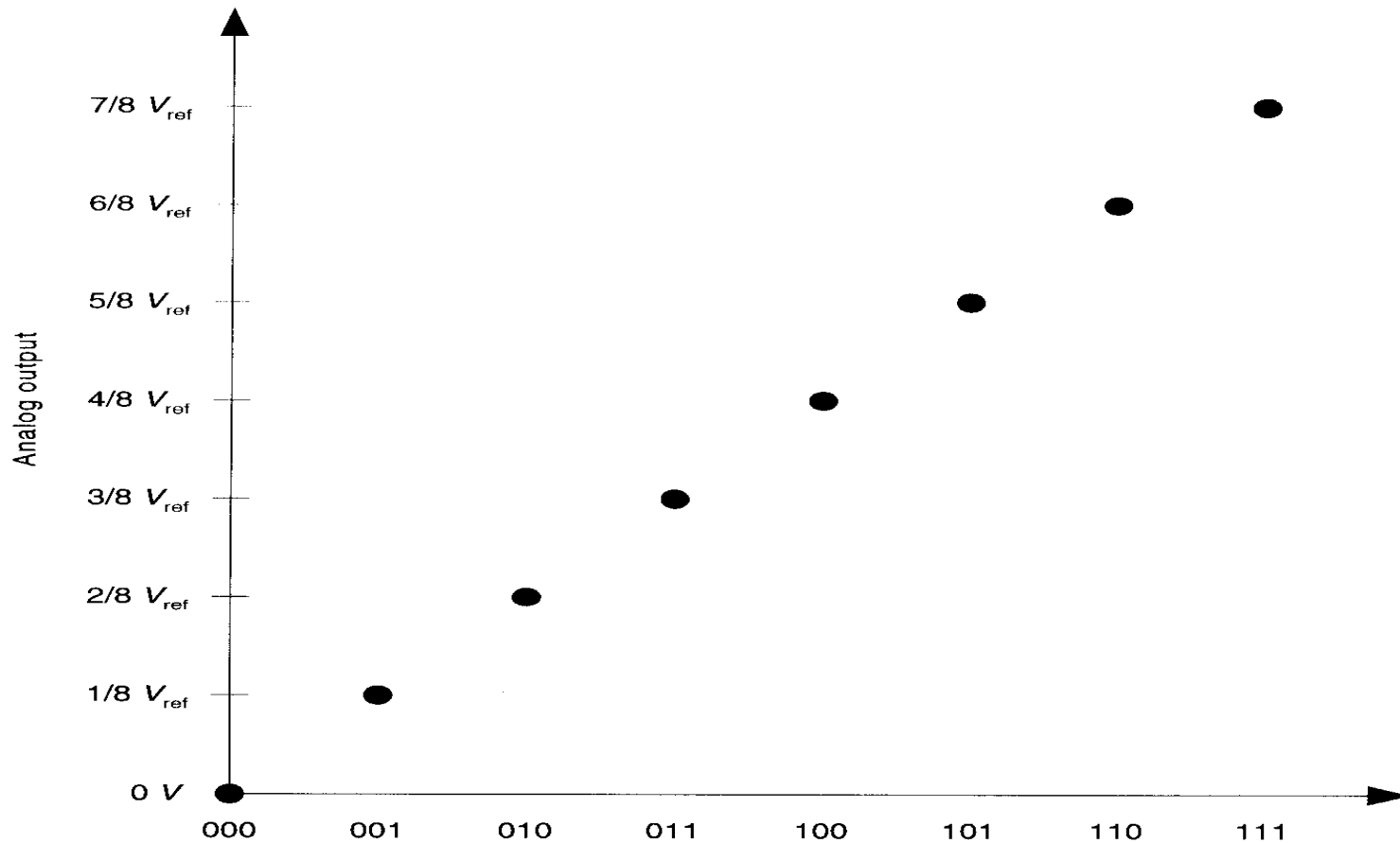


Figure 2.42 The ideal static behavior of a 3-bit DAC. For each digital input, there is a unique analog output.

TOPIC 3 – Analog and Digital Signals

3.4 Filters

- **Filters are devices which alter the frequency characteristics of an electronic signal.**
- **Filters may be designed to be either passive or active.**
- **Filters are designed from capacitors, inductors and resistors.**
- **There are several common types of filters such as: low-pass, high-pass, band-pass and notch.**

TOPIC 3 – Analog and Digital Signals

3.4 Filters

BLOCK DIAGRAM



TOPIC 3 – Analog and Digital Signals

3.4 Filters

Remember Impedance:

- Electrical components have responses that vary with frequency.
- This frequency response is known as impedance, Z .
- Impedance has both a real and a complex part and is of the form:
 $Z = R + jX$ where X is called Reactance.
- So the following relationships hold:
 - Resistor: $Z = R + 0*j = R$
 - Capacitor: $Z = 0 - j/\omega C = 1j/\omega C$
 - Inductor: $Z = 0 + \omega L = \omega L$
 - Where $\omega = \text{omega} = 2 * \text{Pi} * \text{frequency in Hz}$

TOPIC 3 – Analog and Digital Signals

3.4 Filters

Low Pass Filter (LPF) Circuits

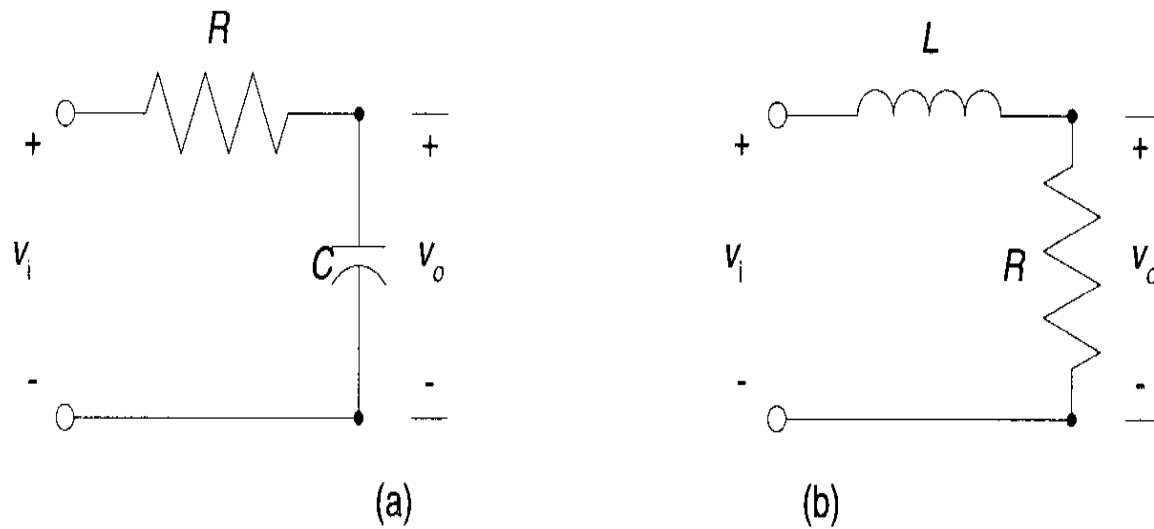


Figure 2.37 Low-pass filter. (a) RC circuit. (b) RL circuit.

TOPIC 3 – Analog and Digital Signals

3.4 Filters

Low Pass Filter (LPF) Response

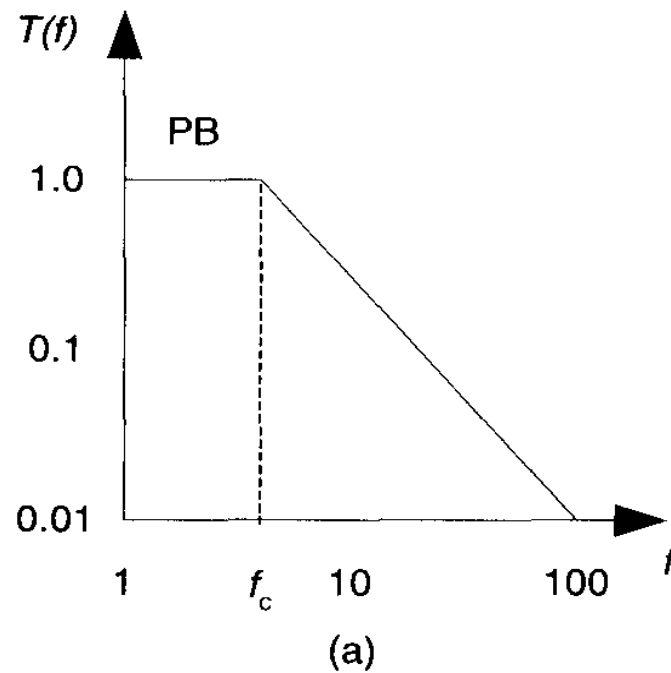
Filter response, $T(\omega)_{\text{out}}$ for either the RC circuit or the RL circuit is:

- $T(\omega)_{\text{out}} = 1/(1+j \omega/\omega_c)$
- Where the ω_c = cutoff frequency is:
 - $\omega_c = 1/RC$ for the RC circuit and
 - $\omega_c = R/L$ for the RL circuit

TOPIC 3 – Analog and Digital Signals

3.4 Filters

Low Pass Filter (LPF) Response



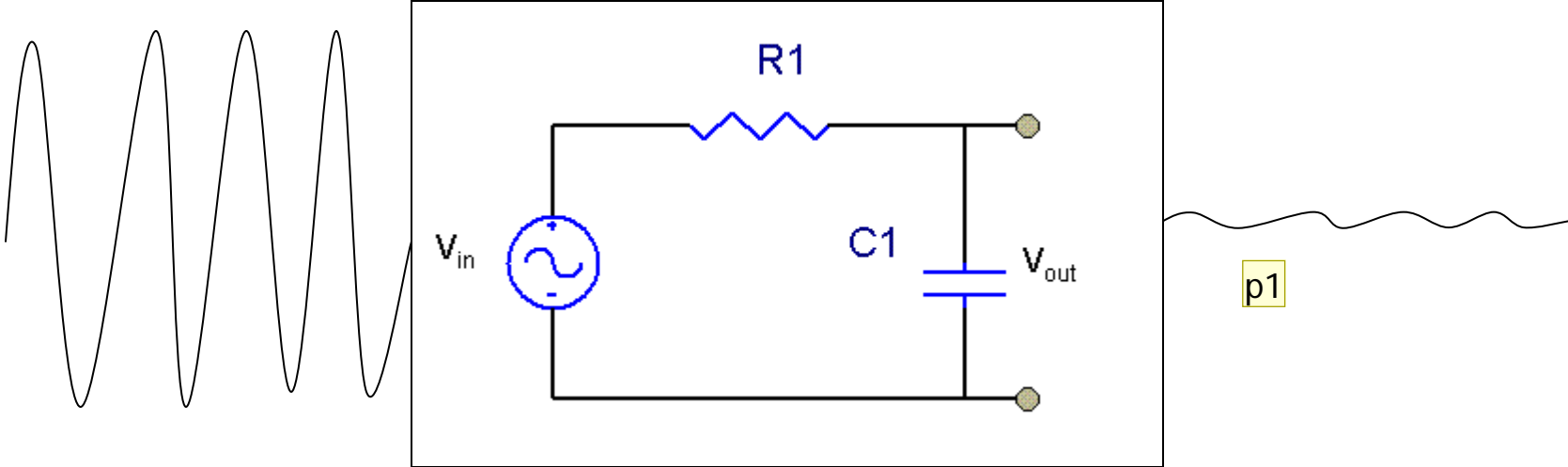
TOPIC 3 – Analog and Digital Signals

3.4 Filters

Low Pass Filter (LPF) Uses

- Typical use in bioinstrumentation; remove RF interference from an EKG signal.
- Source of RF: unshielded leads or long connecting wires/cables.
- Typical cutoff frequency is 150 Hz

Low Pass RC Filters



p1

Changes.

pcourtoi, 12/20/2004

TOPIC 3 – Analog and Digital Signals

3.4 Filters

High Pass Filter (HPF) Circuits

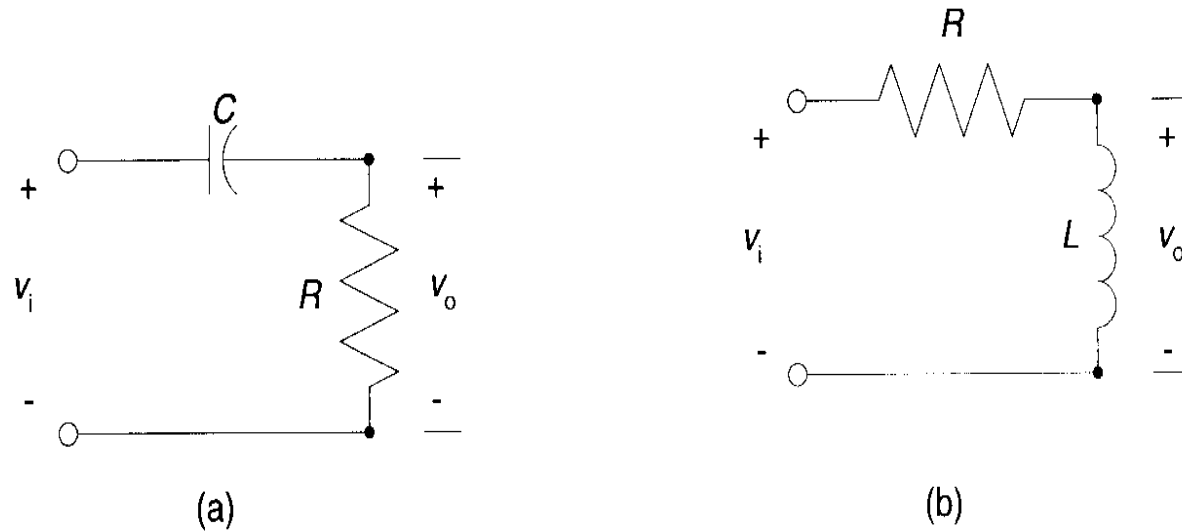


Figure 2.38 High pass filter. (a) RC circuit. (b) RL circuit.

TOPIC 3 – Analog and Digital Signals

3.4 Filters

High Pass Filter (HPF) Response

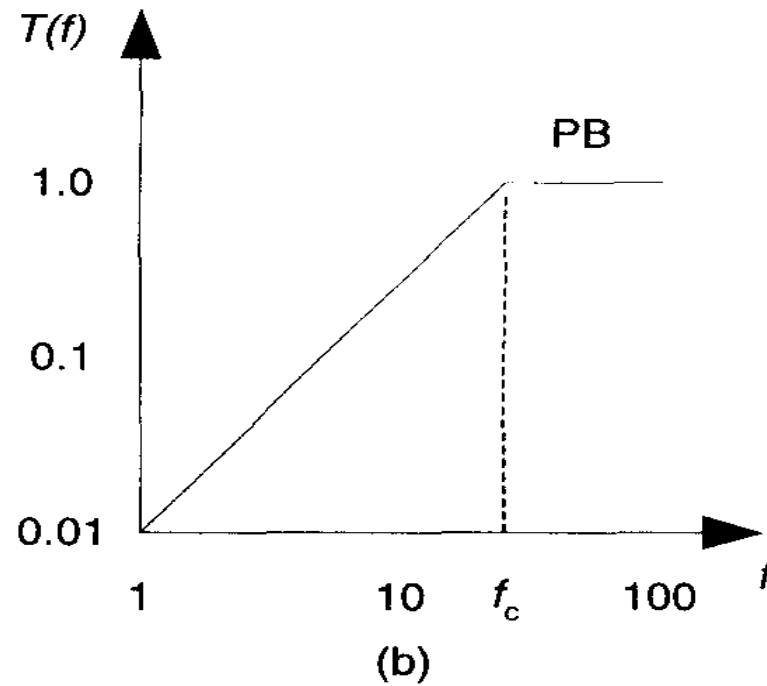
Filter response, $T(\omega)_{\text{out}}$ for either the RC circuit or the RL circuit is:

- $T(\omega)_{\text{out}} = 1/(1-j \omega_c/\omega)$
- Where ω_c = cutoff frequency is:
 - $\omega_c = 1/RC$ for the RC circuit and
 - $\omega_c = R/L$ for the RL circuit

TOPIC 3 – Analog and Digital Signals

3.4 Filters

High Pass Filter (LPF) Response



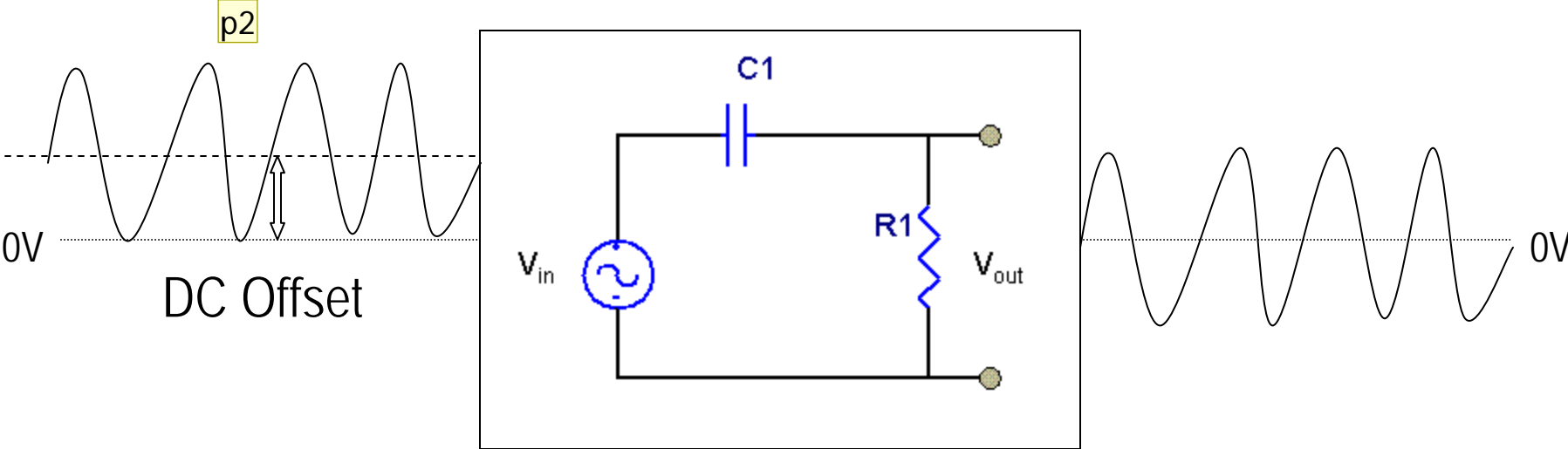
TOPIC 3 – Analog and Digital Signals

3.4 Filters

High Pass Filter (HPF) Uses

- Typical use in bioinstrumentation: remove dc offset and other low frequency interference from an EKG signal.
- Typical cutoff frequency: .5 Hz

High Pass RC Filters



Slide 13

p2

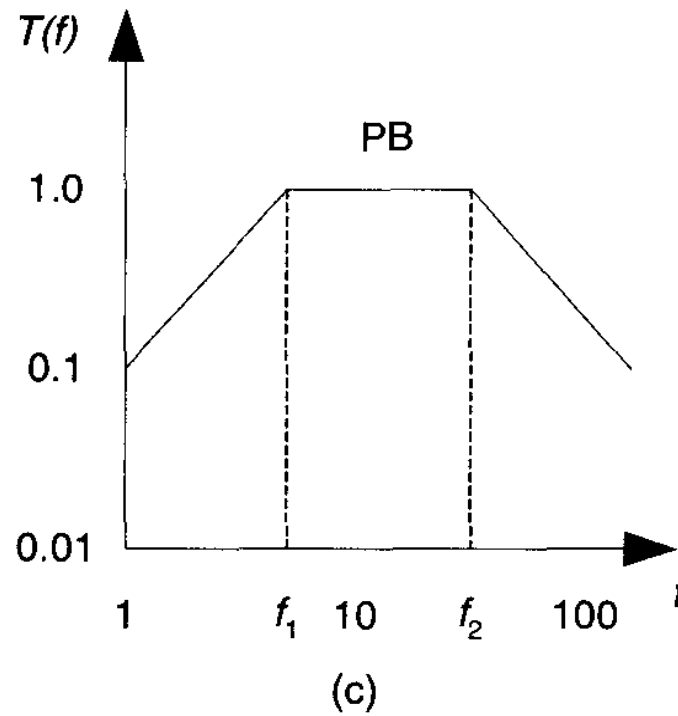
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pcourtoi, 12/20/2004

TOPIC 3 – Analog and Digital Signals

3.4 Filters

Bandpass Filter (BPF) Response



TOPIC 3 – Analog and Digital Signals

3.4 Filters

Notch (Bandstop) Filter (NPF) Response

