
# SIGNAL PROCESSING BASICS



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# Analog vs. Discrete Signals

- Analog: Infinitesimal calculus (or just calculus)
  - Functions of continuous variables
  - Derivative
  - Integral
  - Differential equations

Real Life

- Discrete: Finite calculus
  - Sequences
  - Difference
  - Summation
  - Difference equations

Computer

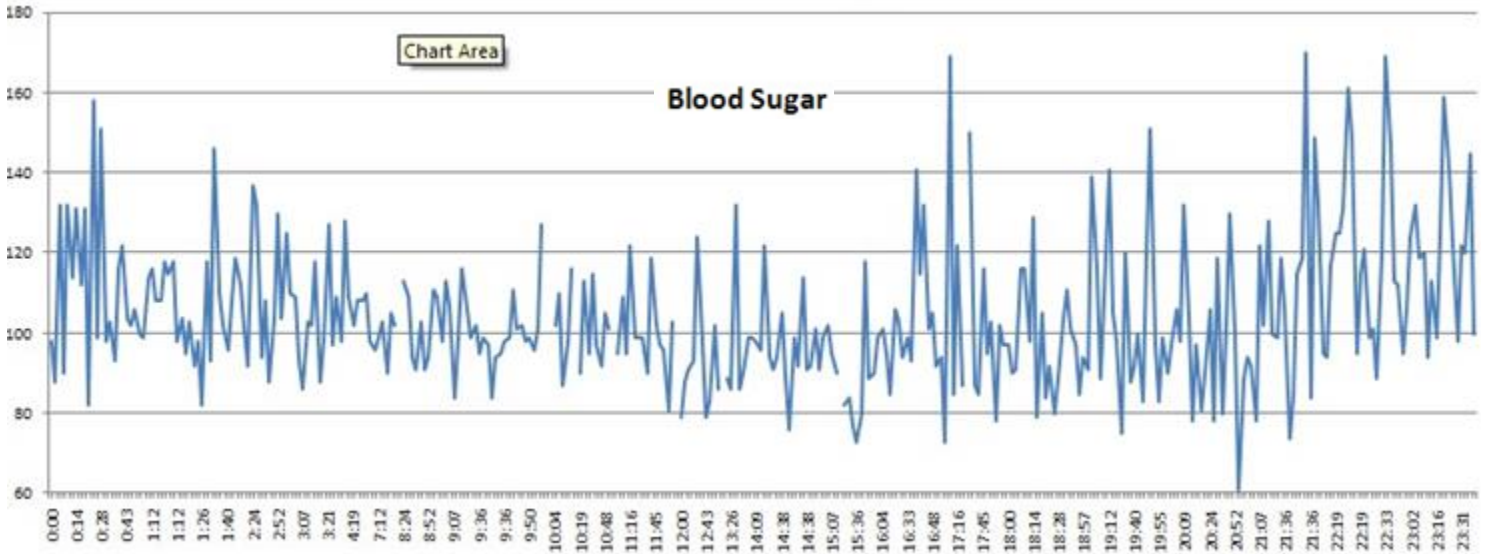
# Signal Classification: Predictability

- Predictability of their behavior
  - Random signal: amplitude varies in unpredictable manner
  - Deterministic signal: amplitude can be predicted
- In most cases, biomedical signal can be modeled as "deterministic yet unknown" signals with usually additive "random" noise

$$s(t) = x(t) + n(t)$$

# Signal Classification: Periodicity

- Periodic signal: repeats itself every period T (example: ECG)
- Aperiodic signal: does not repeat itself (example: blood sugar level)

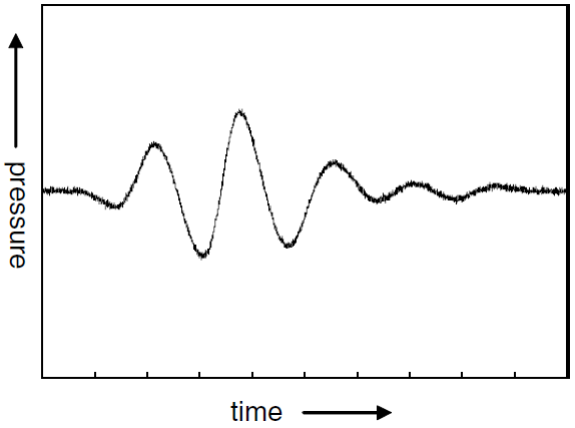


# Signal Classification: Support

- Infinite support signal: varies for all time values from -∞ to ∞
  - Example: EEG
- Finite (compact) support signal: varies only within a finite duration of time and zero outside
  - Example: ultrasound pulse

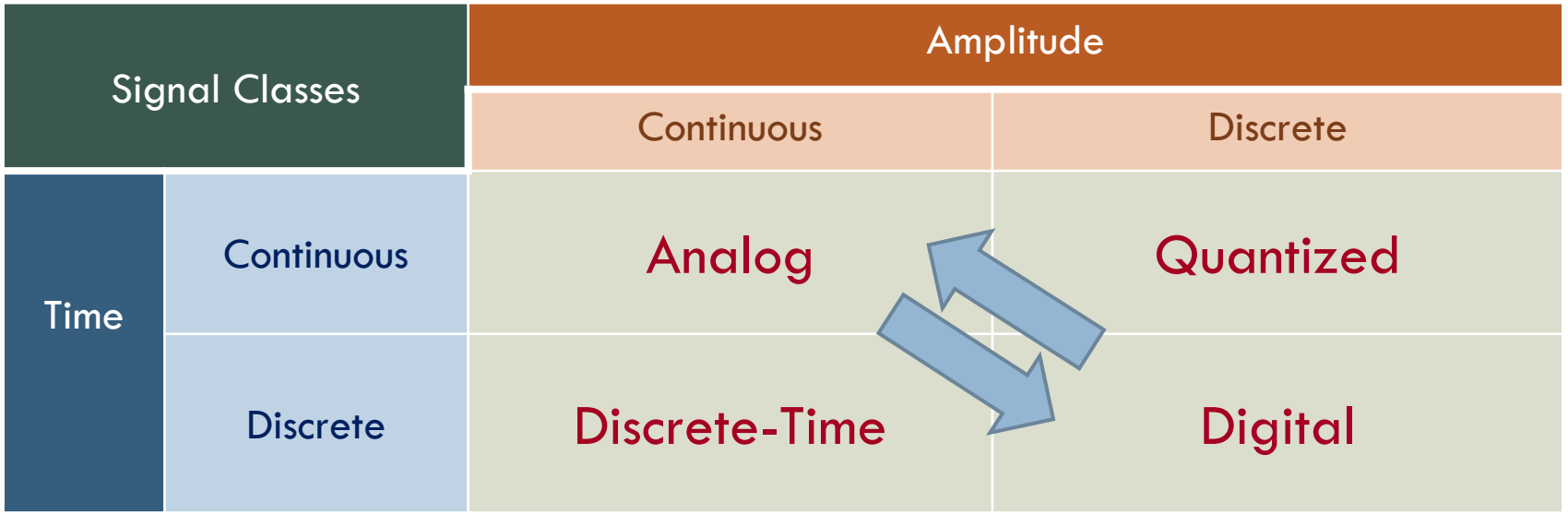
EEG

Ultrasound Pulse



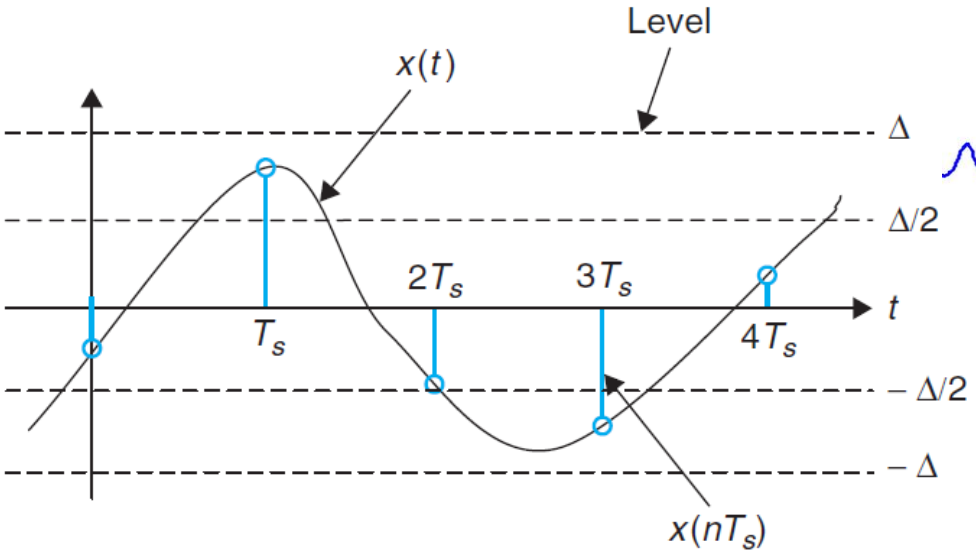
# Signal Classification: Time and Amplitude

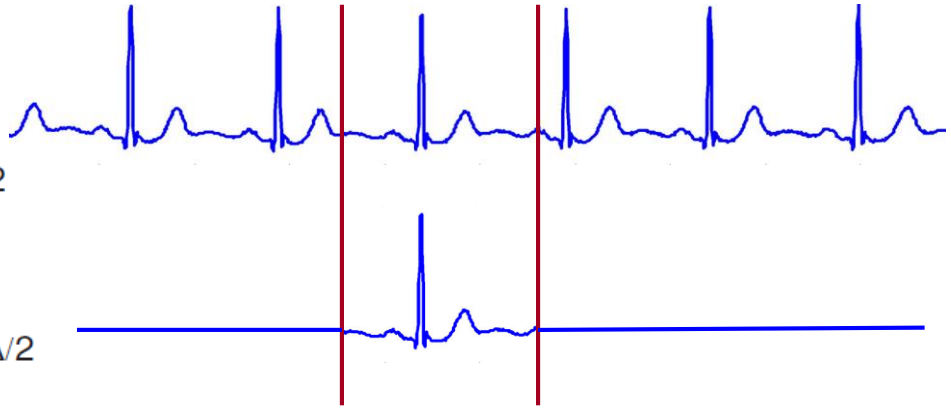
- Analog signal: Continuous-amplitude, continuous-time (Natural)
- Quantized signal: Discrete-amplitude, continuous-time
- Discrete-time signal: Continuous-amplitude, discrete-time
- Digital signal: Discrete-amplitude, discrete-time (Computer)



# Computer Interfacing of Biomedical Signals

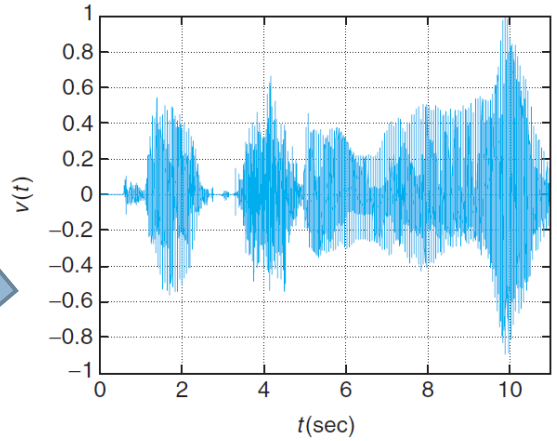
- Conversion from continuous to discrete time: Sampling
- Conversion from continuous to discrete amplitude: Quantization
- Computer Can only handle compact support signals
  - Use Windowing to take short part of the signal within a finite duration



Windowed ECG Signal

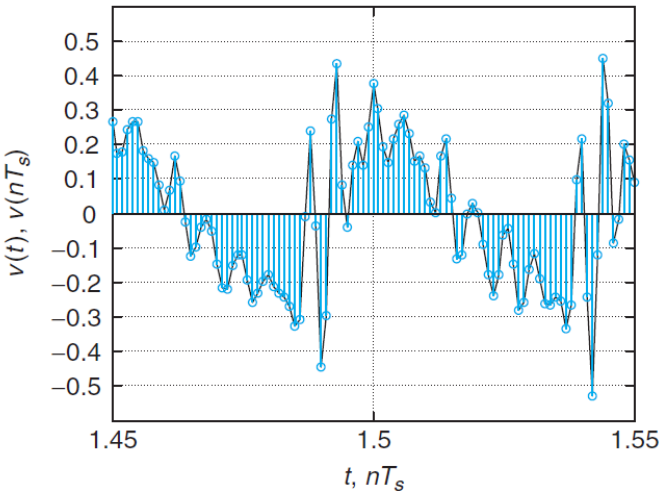
# Example: Digital Signal for Speech

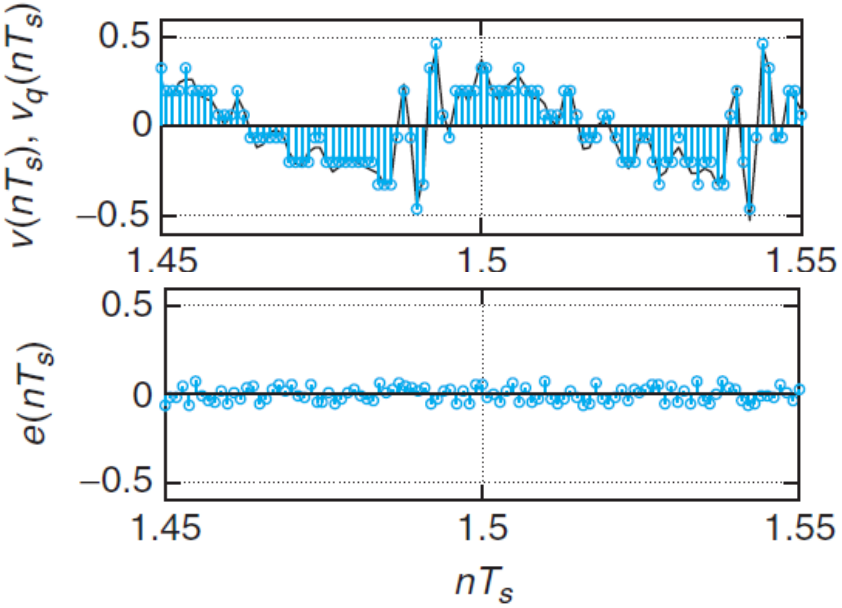



Windowed Analog Signal

Sampling

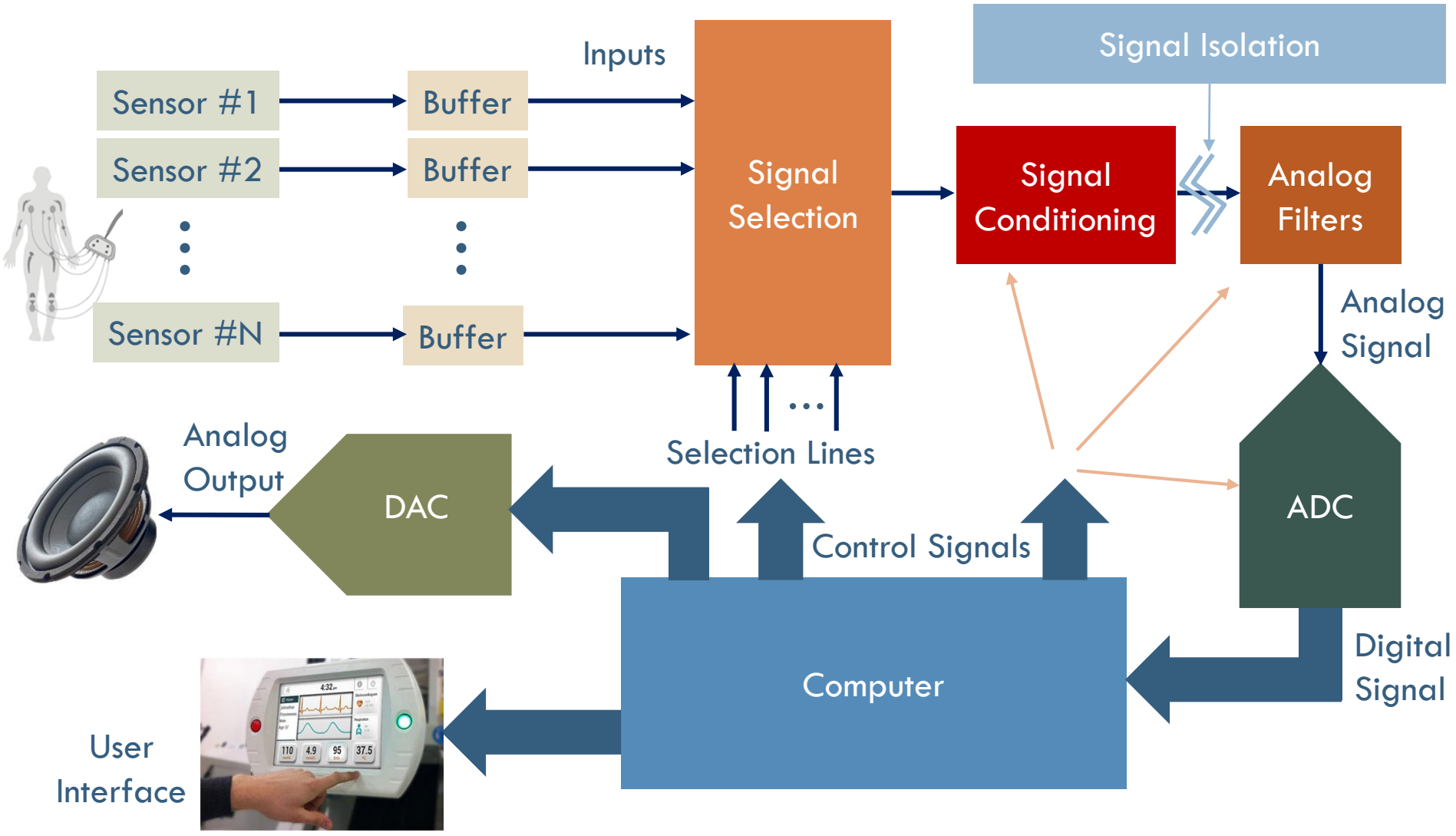
Quantization




Error

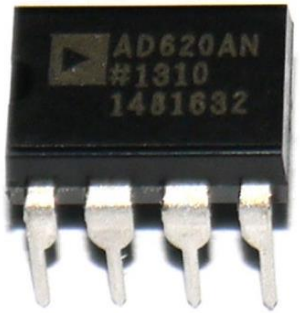
# Typical Signal Processing Chain

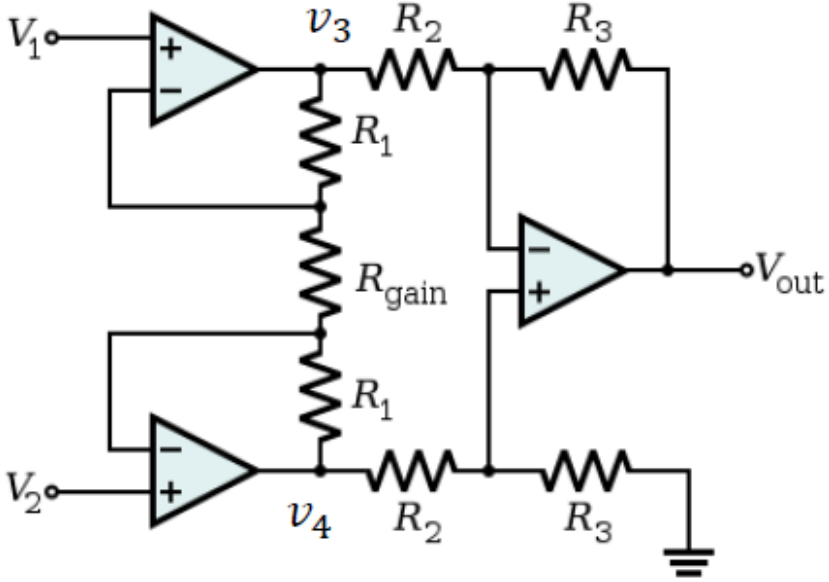


# Signal Conditioning

- Signals from biosensors is often very weak
  - Very low amplitude
  - Very High output impedance
- Also, in many cases, the signal from biosensors is differential
- Example signal conditioning: instrumentation amplifier

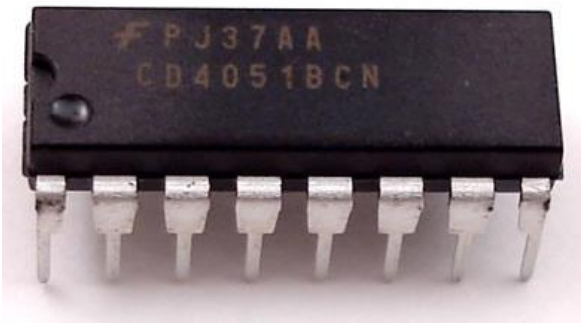
$$v_o = \frac{v_1 - v_2}{R_{gain}} \cdot \left(2R_1 + R_{gain}\right) R_3/R_2$$

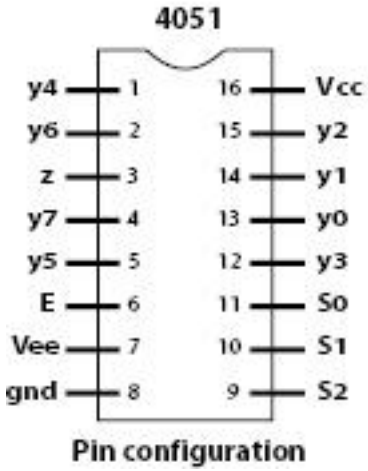


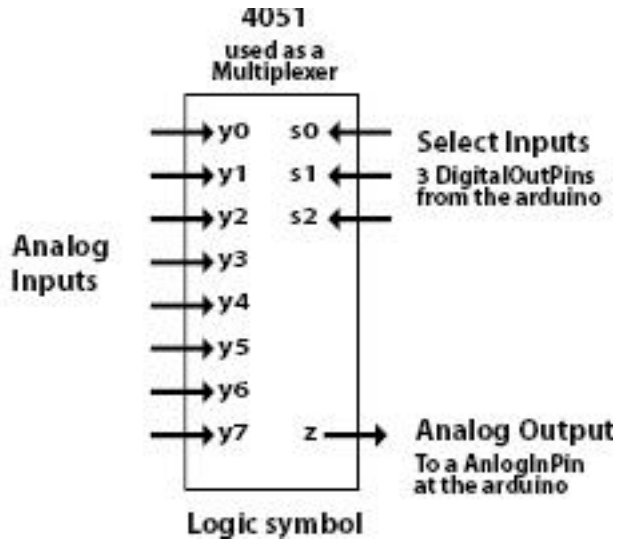
# Signal Selection (Multiplexing)

- Sometimes, we have multiple signals to measure with only one chosen to be displayed by the doctor
  - Example: ECG
- Use analog multiplexers (MUX) to allow the desired signal to be selected for further processing
  - Example: 4051 8-Channel MUX/DeMUX



Pin configuration

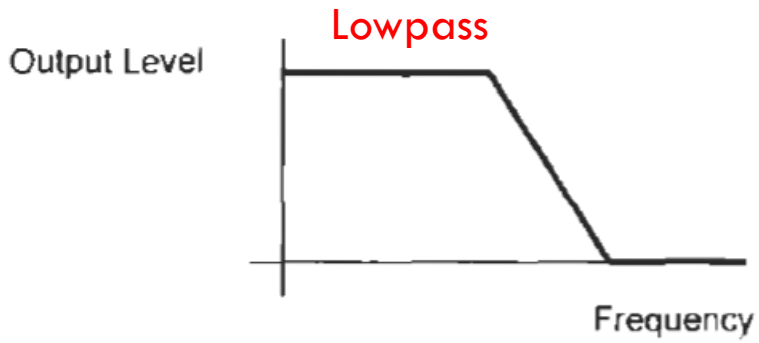


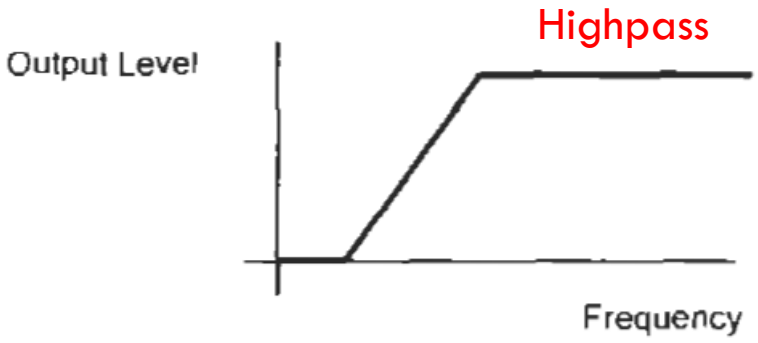
Logic symbol

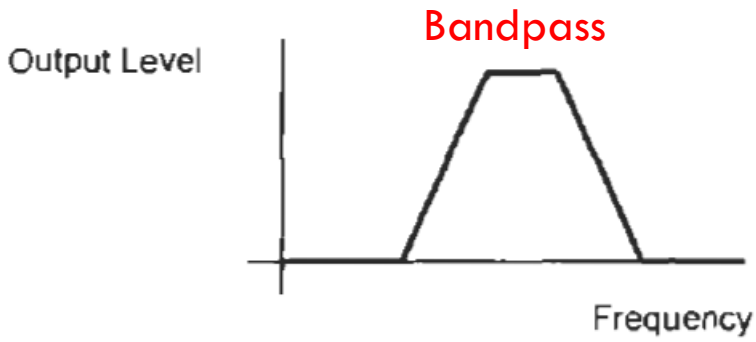
# Analog Filters

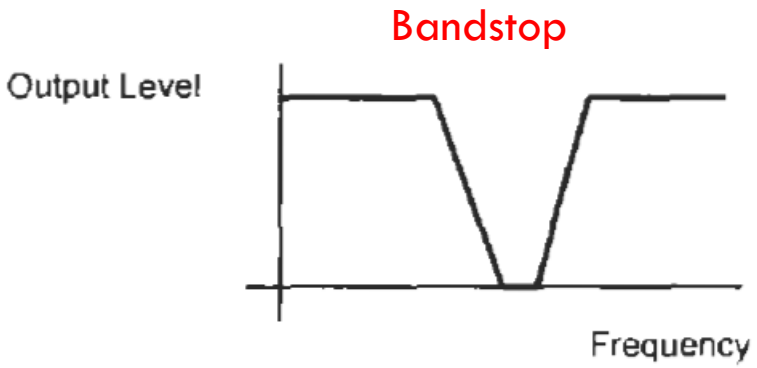


- Analog filters allow some signal frequencies to pass, but stop others
  - Many applications such as smoothing and anti-aliasing filters
- Standard types: low-pass, high-pass, band-pass and band-reject



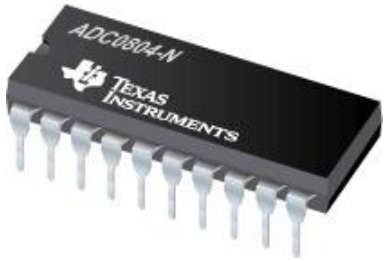



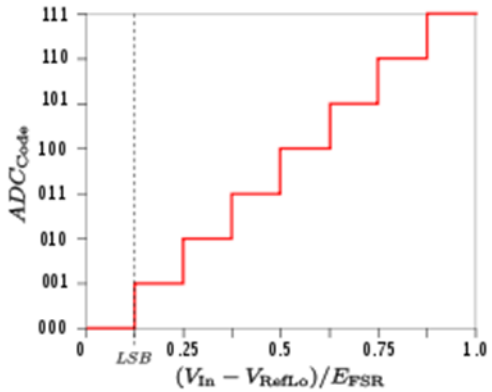



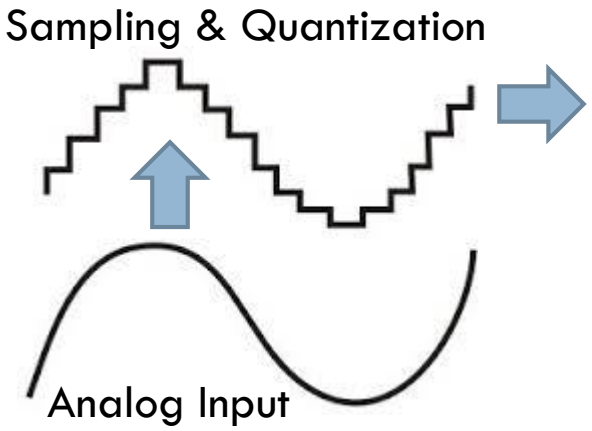



# Analog to Digital Conversion (ADC)

- Converts input analog signal level to a digital value
- Resolution (number of bits): Quantization level
  - 12 bit ADC has less quantization error than 8-bit ADC
- Speed (Samples/s): Sampling period
  - Sampling period (s) = 1/sampling frequency (Sa/s)
  - 50 MSa/s ADC has shorter sampling period than 1 MSa/s ADC

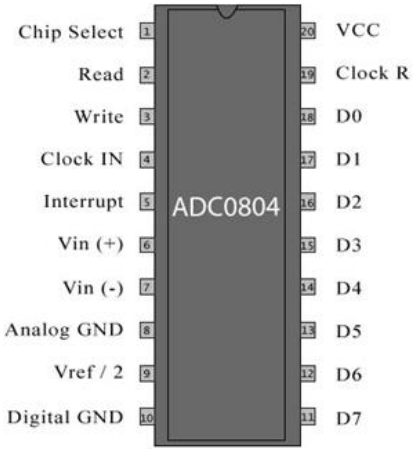


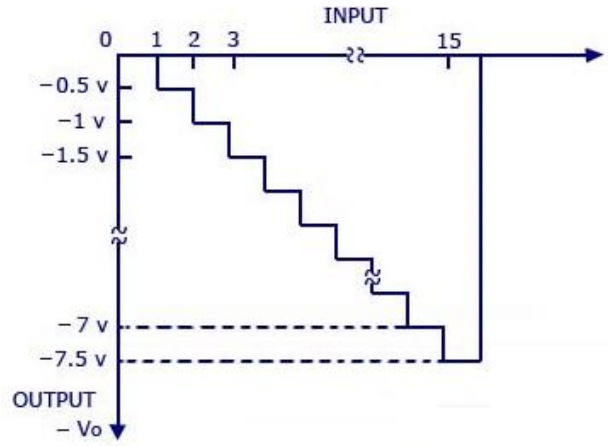

Output

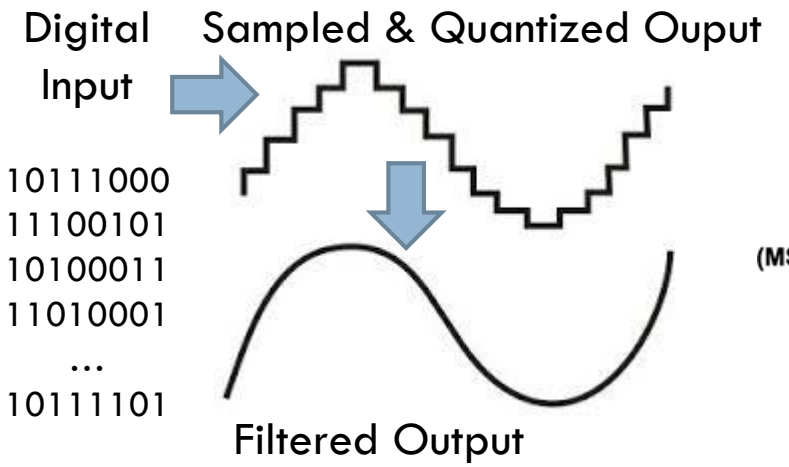
10111000
11100101
10100011
11010001
…
10111101

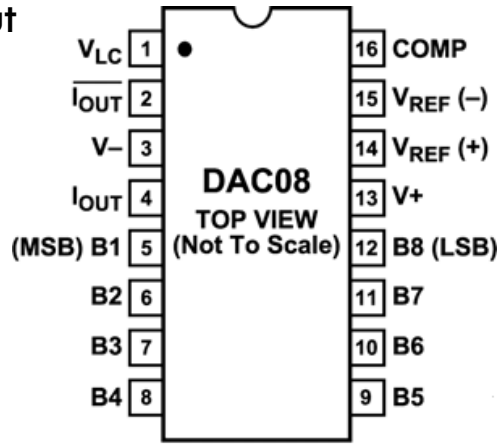


# Digital to Analog Converter (DAC)

- Converts input digital signal level to an analog value
- Resolution (number of bits): Quantization level
  - 12 bit DAC has less smaller quantization step than 8-bit DAC
- Speed (Samples/s): Sampling period
  - Sampling period (s) = 1/sampling frequency (Sa/s)
  - 50 MSa/s DAC has shorter sampling period than 1 MSa/s DAC

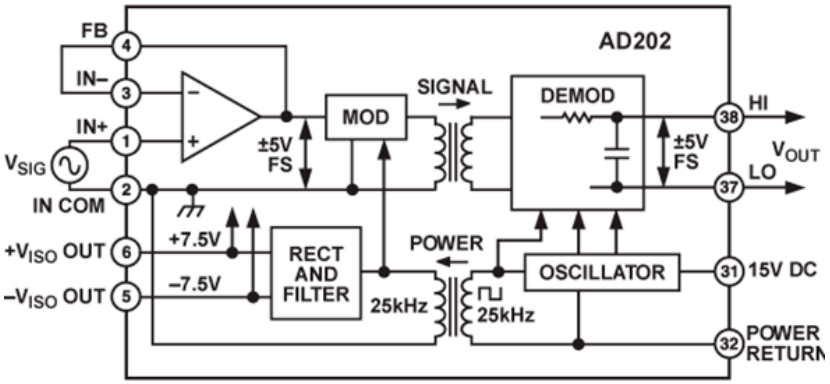


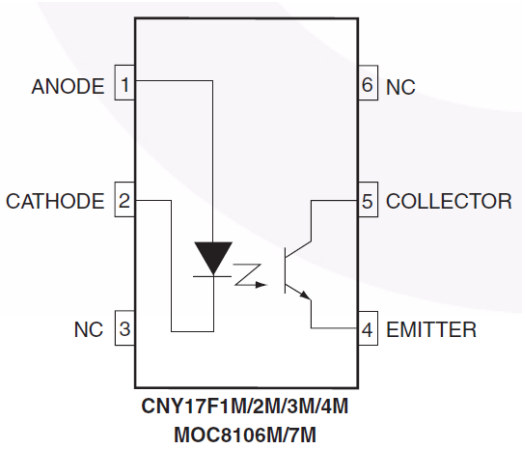



# Signal Isolation

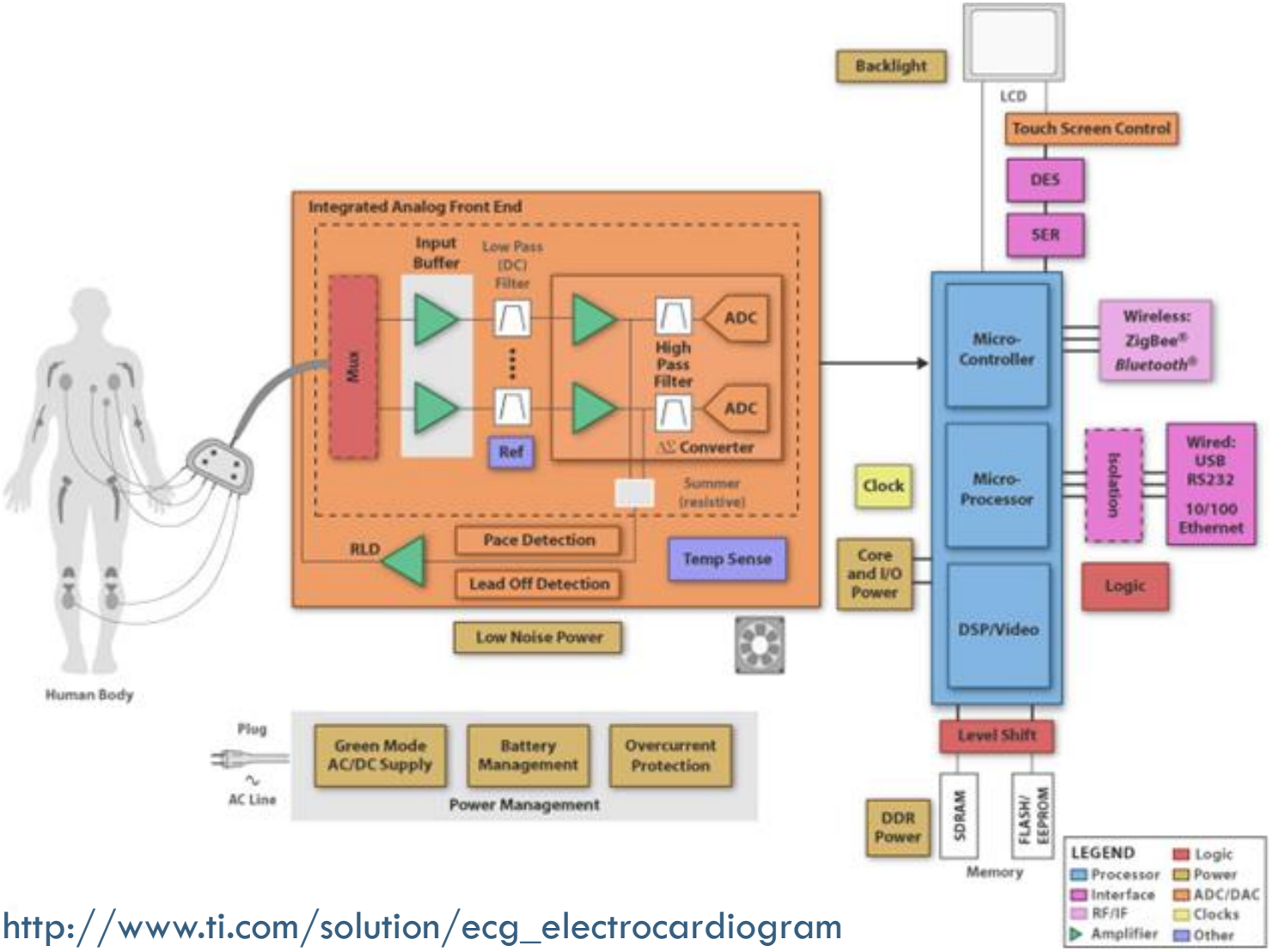
- Isolation breaks ohmic continuity between patient and electrical mains
  - Isolation of both signal and DC power supply and ground between its input and output
- Transformer isolation


- Optical isolation

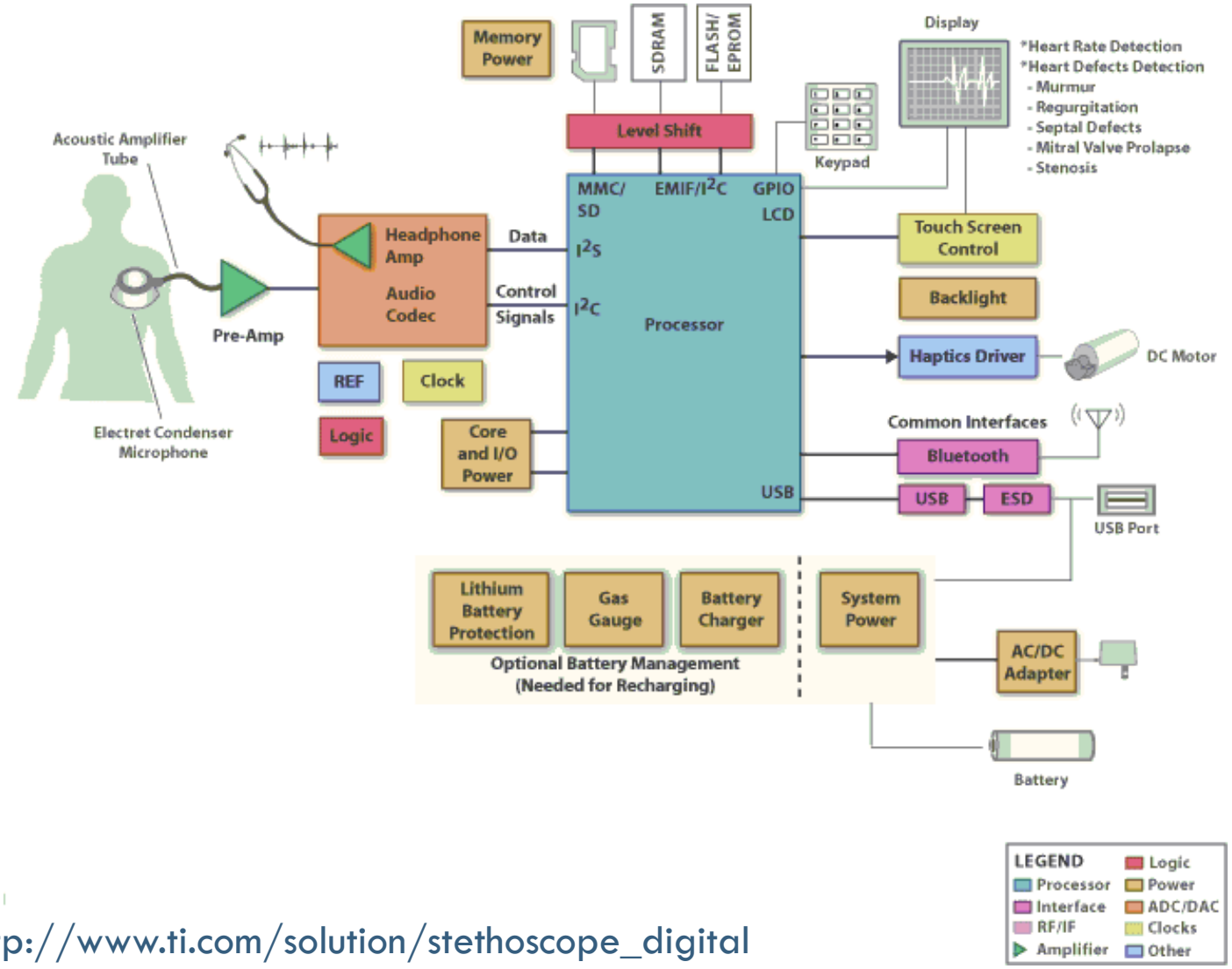


# Example: ECG




Source: http://www.ti.com/solution/ecg_electrocardiogram

# Example: Digital Stethoscope




Source: http://www.ti.com/solution/stethoscope_digital

# Suggested Readings and Assignments

- Handouts for download  on class web site

- Homework posted on web site