

## **Fall 2024: CSCI 181RT**

### Real-Time Systems in the Real World

### **Lecture 14**

Thursday, October 10, 2024

Edmunds Hall 105

2:45 PM - 4:00 PM

Professor Jennifer DesCombes

# Agenda

- Go Backs
- Announcements
- Discussion on Reading
- Lab #6 Review
- Interrupts and OS Support - Postponed
- Data Sampling and Sampling Theory
- Look Ahead
- Assignment
- Action Items

## Go Backs

- General?
- Action Item Status
  - AI240910-2: Find recommended book on computer architecture.
  - AI240924-1: At what point as a development team grows does it make sense to have dedicated software and integration testers?

# Announcements

- Fall Break!
  - No Lecture Tuesday, October 15th
  - Lab on Wednesday, October 16th
    - Professor Clark Will Open Lab and Have Kits
    - I will appear ASAP
    - Code Snippets Will Be Sent Out Ahead of Time

## Discussion on Reading

- The Mythical Man Month
  - Chapter 13, 14 & 15: The Whole and the Parts, Hatching a Catastrophe, and The Other Face

## Lab #6 Review

- Goals for Lab
  - 5ms Loop for Polling
  - Pulse Width Modulation (PWM) of LED
  - Buttons Change LED Brightness
- Additional Goals
  - Read Digital Input (GPIO1, Connector 501-Pin 5, Processor RK4)
  - Drive LED to Match Digital Input
- Sampling Rate and Data Input Rate
  - Use Function Generator to Experiment

# Data Sampling and Sampling Theory

- Why
- Simple Monitoring of Digital Signals
  - Pushbuttons
  - Low Frequency Inputs
- Medium Frequency Inputs
- Data Sampling Theory
  - Nyquist
  - Aliasing
- Other Techniques
  - Dedicated Hardware
  - Digital Signal Processing

## Data Sampling and Sampling Theory - Why

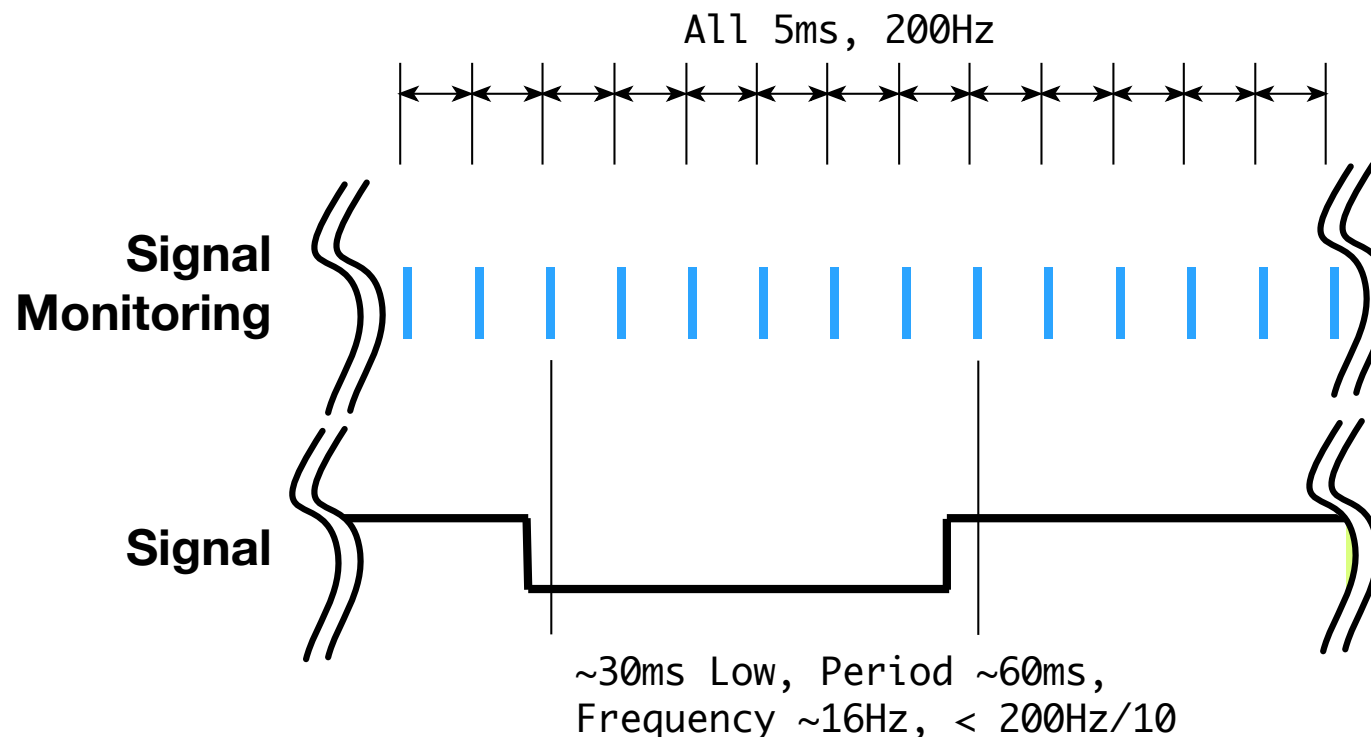
- Real-time Systems Control Things
- Control is Based on Data Inputs
  - Must be Valid
  - No (Avoidable) Erroneous Data
- Input Signal Characteristics Must Be Known

Understanding of Data  
Sampling Concepts Is a  
Must to Avoid Erroneous  
Data



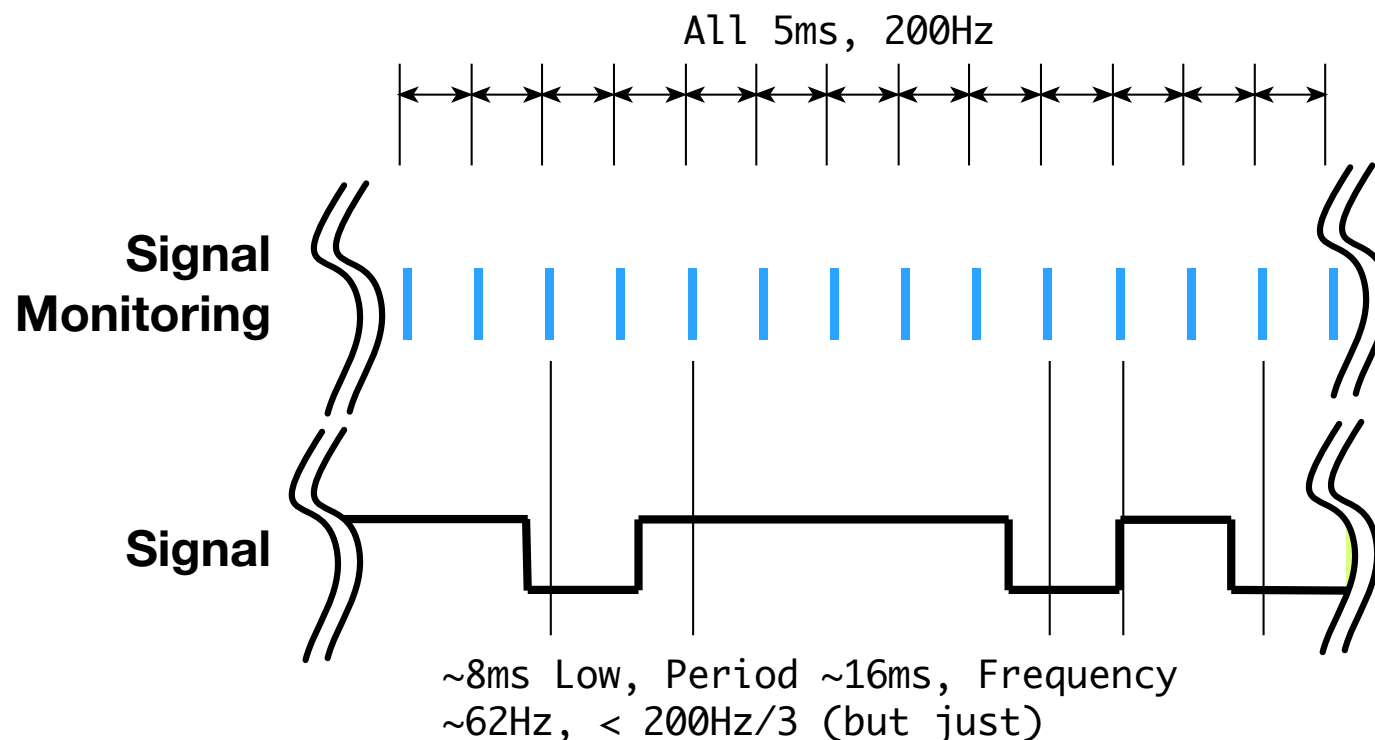
## Simple Monitoring of Digital Signals

- If Sampling Rate is  $>10\times$  Event Rate - Easy to Poll
  - Would Support Debounce If Necessary
  - Would Support Other Software Processing



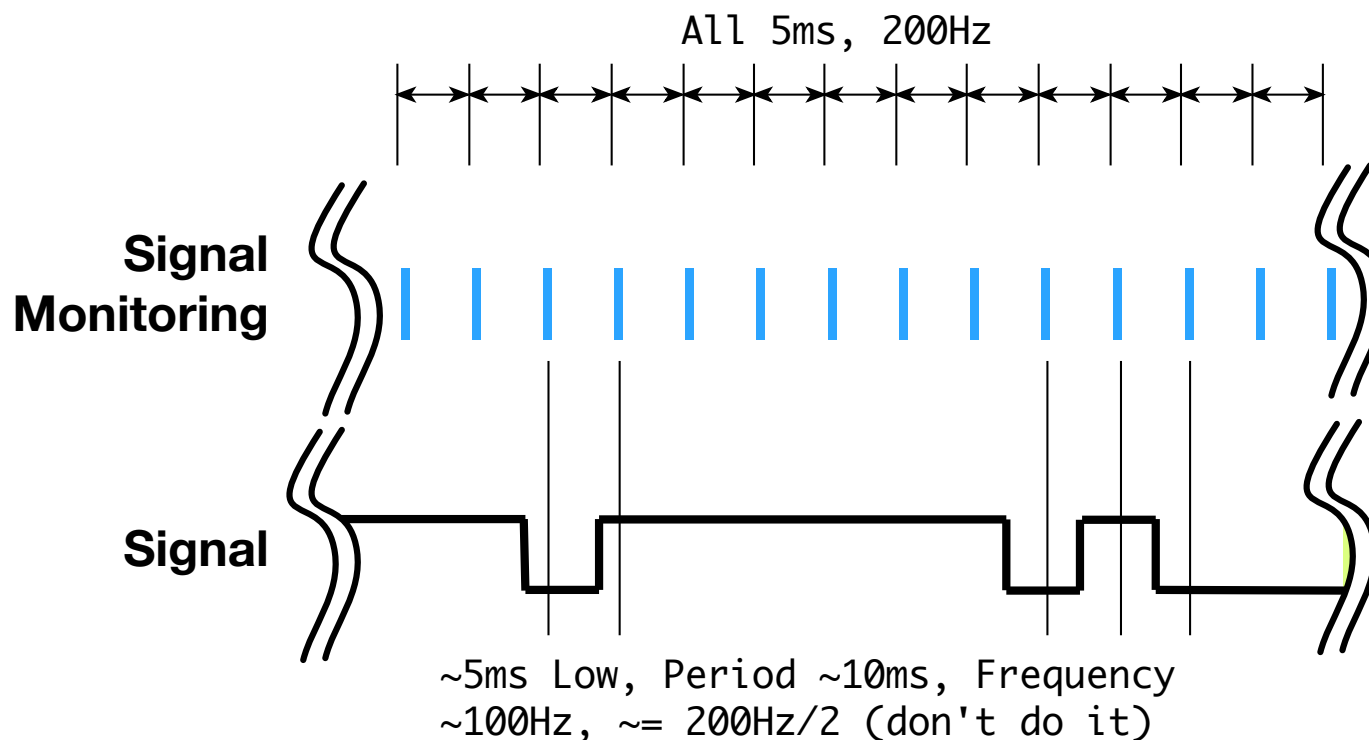
## Monitoring of Medium Frequency Inputs

- If Sampling Rate is  $>3\times$  Event Rate - Marginal
  - Does Not Support Debounce If Necessary
  - Probably Would Not Support Other Software Processing



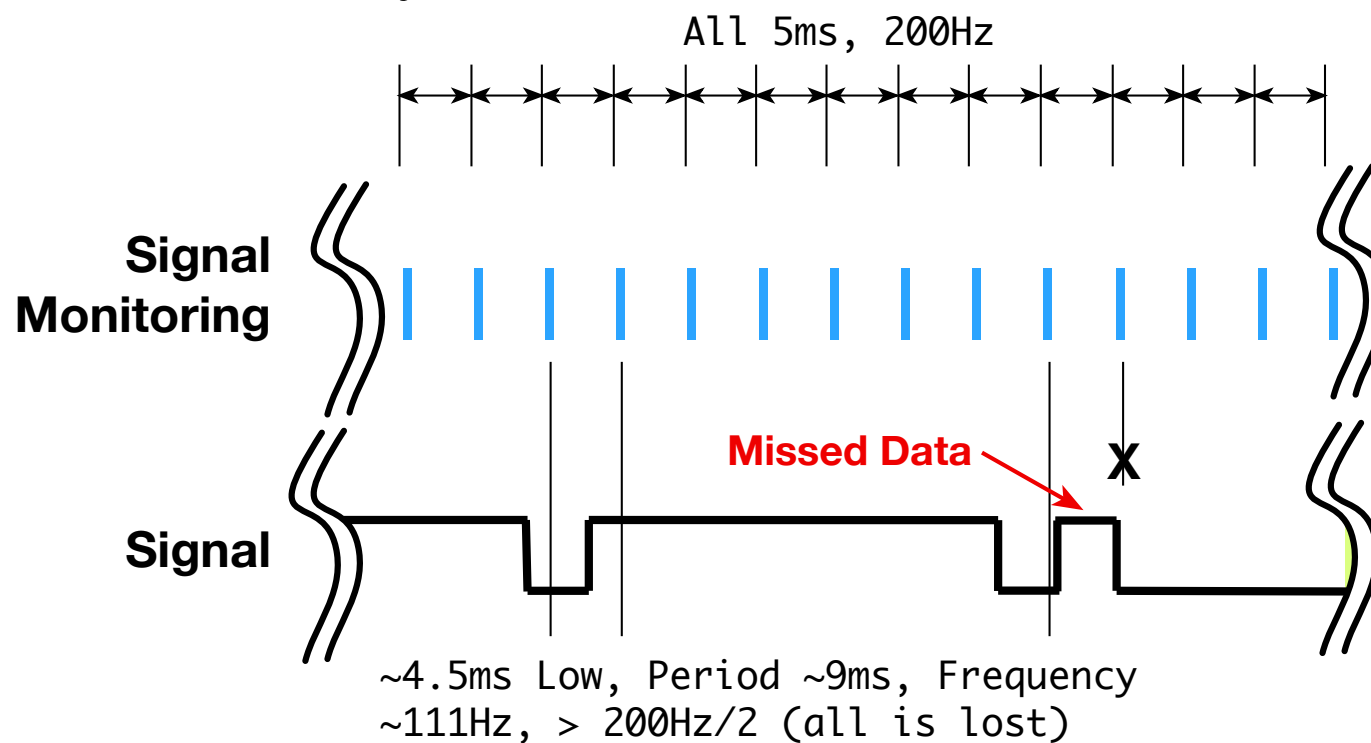
## Monitoring of Medium Frequency Inputs

- If Sampling Rate is  $\sim 2\times$  Event Rate - Risky
  - On the Verge of Missing Data
  - Unreliable System



# Monitoring of Medium Frequency Inputs

- Why Risks - Lost Data
  - Two Transitions Possibly Missed
  - Unreliable System



# Data Sampling Theory - Nyquist & Aliasing

- Data Sampling Theory
  - Nyquist

**Theorem** — If a function  $x(t)$  contains no frequencies higher than  $B$  hertz, then it can be completely determined from its ordinates at a sequence of points spaced less than  $1/(2B)$  seconds apart.

Simply stated, the **Nyquist criterion** requires that the sampling frequency be at least **twice the highest frequency contained** in the signal, or **information** about the signal will be **lost**. If the sampling frequency is less than twice the maximum analog signal frequency, a phenomenon known as **aliasing** will occur.

# Data Sampling Theory - Nyquist & Aliasing

- Nyquist Applies to All Sampled Systems
- Nyquist Typically Discussed in Reference to Analog Signals
  - Data Capture and Encoding
  - Audio, Video, Medical - Everything
- Nyquist Applies to Digital Signal Sampling As Well

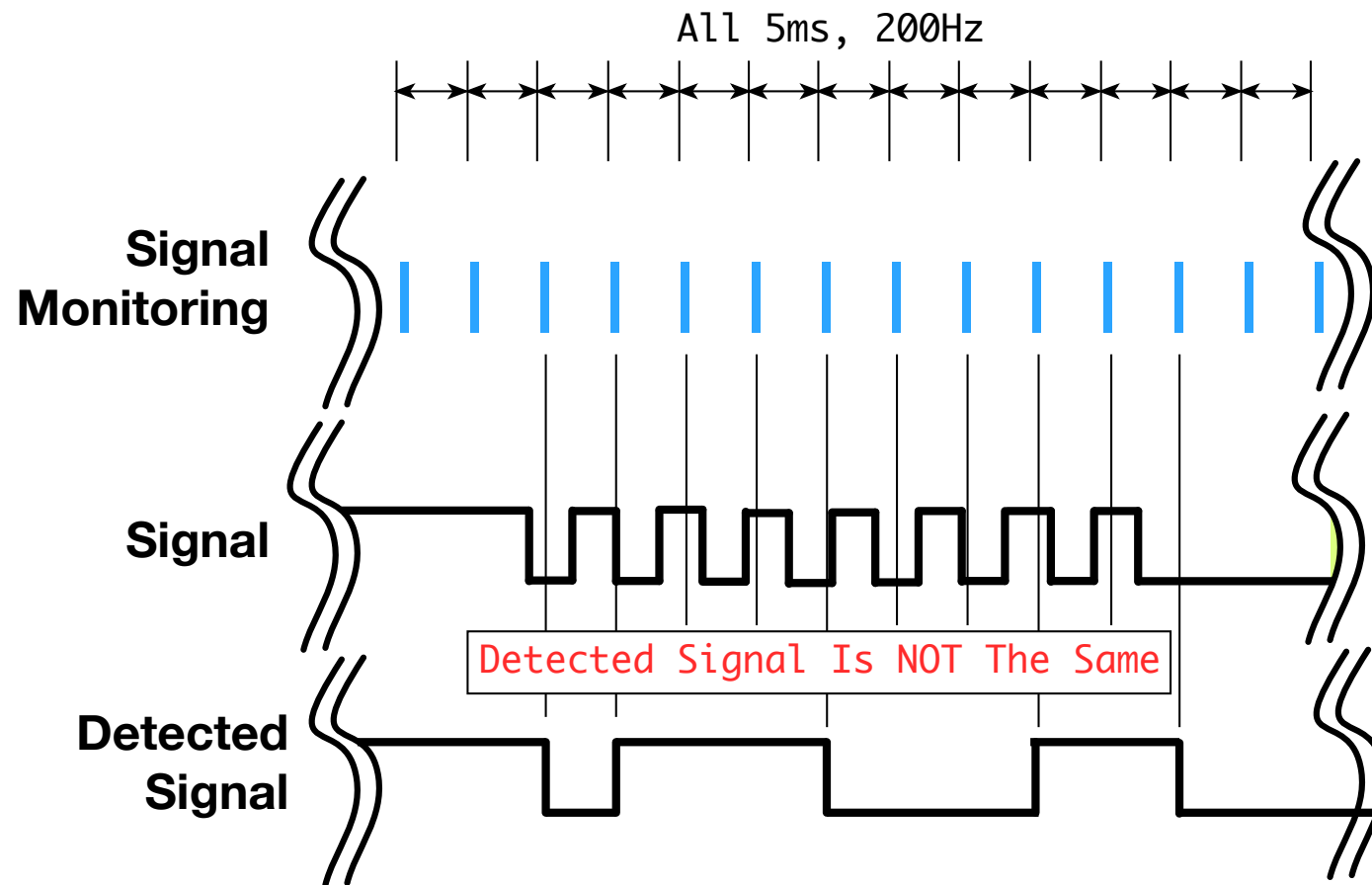
## Data Sampling Theory - Nyquist & Aliasing

- If Break Rules, Results are Aliased

Signal aliasing is a phenomenon that occurs when a signal's sampled data has a false lower frequency component. This can happen when the sampling rate is too low, causing the signal to be undersampled.

# Data Sampling Theory - Nyquist & Aliasing

- If Break Rules, Results are Aliased





## Data Sampling Theory - Other Techniques

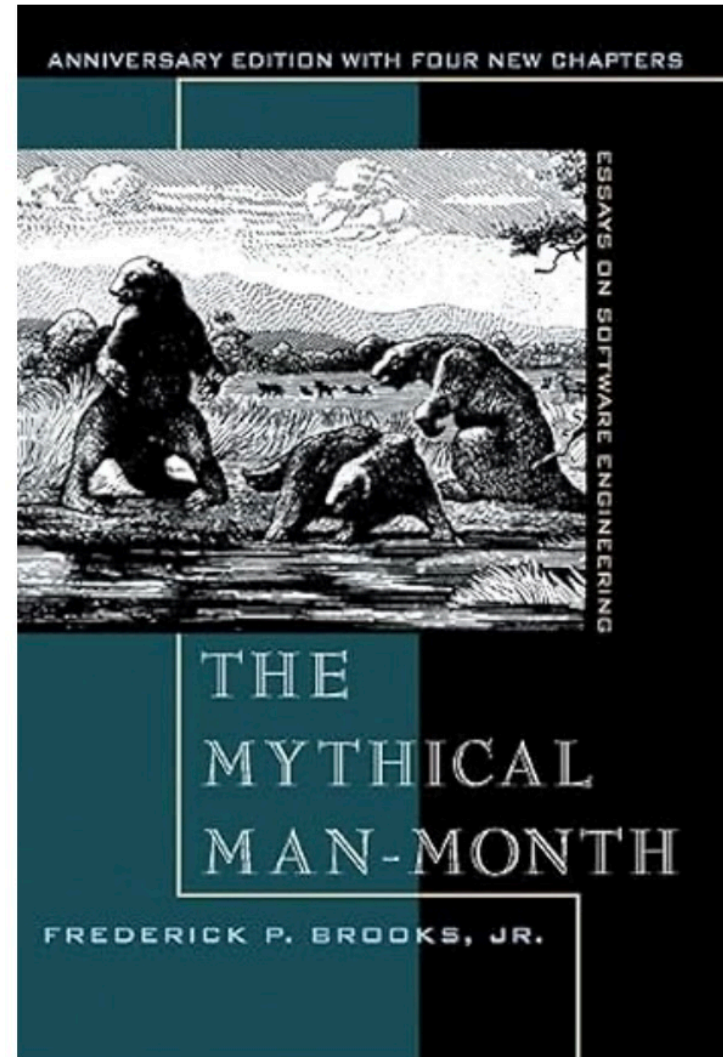
- Dedicated Hardware for Digital Signal Capture
  - Simple Counters if Regular (fixed frequency) Signal
  - Edge Detect Hardware - Processor Interrupt When Detected
  - Time Stamp with Buffered Data
- Digital Signal Processing
  - Decimation Filters
  - FPGA Implementations
  - Compression Algorithms

## Look Ahead

- Review of Reading
- Review of Lab 7
- Interrupts and OS Support - Maybe
- More on Data Sampling

## Assignment - Readings

- The Mythical Man Month
  - Chapter 16: No Silver Bullet - Essence and Accident
  - Send Me Discussion Topics by 10:00 AM on Thursday, Oct. 17, 2024.
  - Additional Reading: Prof Alfred Hero EECS206 F02 Lect 20
  - 20 Minutes Independent Research on Nyquist and Signal Aliasing



## Action Items and Discussion

AI#:	Owner	Slide #	Document	Action