# Digital Signal Processing

## Lab 5 DSP Number Systems

## Introduction

# Lab Objectives

- Explore how several data types commonly used in DSP affect memory usage and computation speed

- Explore the effects of finite precision math on calculations

- Measure the execution speed for addition and multiplication and compare how the speed changes using the various number data types
  - Demonstrate the use of an internal timer function to measure the execution time for a section of code
  - Understand the impact of data types on execution speed and on memory usage

# Lab #5 Overview

- This lab consists of 4 main sections:
  - Basic math operations and data types
  - Illustration of round off error
  - Unexpected behavior due to finite precision effects
  - Measuring execution time and memory usage
    - Some operations take longer with different data types
    - Explore the difference of multiplication between float and long
    - Measure execution time of various operations
  - Resources
    - Review the reading and lecture notes on fixed and floating point numbers
    - http://Arduino.cc (an invaluable resource for our platform)

# Lab #5 Overview

- For this lab it will be easier to use the serial monitor than MATLAB to capture output data
  - You will make tables of results and it is easiest to use Excel for this rather than MATLAB
  - A set of blank Excel tables will be provided for you in myCourses

- Lab #5 is due at the start of your lab period in myCourses, week #7 (week of 02/27).
  - IEEE Journal Format (PDF format ONLY)
  - Also include a work-breakdown document (TXT, DOC or PDF format)

# Arduino Data Types – A Few Examples

- BYTE – 8 bit unsigned integer

0 to 255

| BYTE -- 8 Bits -- Unsigned | |
|---|---|
| Decimal | Bit Pattern |
| 255 | 11111111 |
| 254 | 11111110 |
| 253 | 11111101 |
| … | … |
| 2 | 00000010 |
| 1 | 00000001 |
| 0 | 00000000 |

# Arduino Data Types – A Few Examples

- INT – 16 bit signed integer -  2's Complement

-32,768 to 32,767

| INT -- 16 Bits 2's Complement | |
|---|---|
| **Decimal** | **Bit Pattern** |
| 32767 | 0111111111111111 |
| 32766 | 0111111111111110 |
| 32765 | 0111111111111101 |
| ... | ... |
| 2 | 0000000000000010 |
| 1 | 0000000000000001 |
| 0 | 0000000000000000 |
| -1 | 1111111111111111 |
| -2 | 1111111111111110 |
| -3 | 1111111111111101 |
| ... | ... |
| -32766 | 1000000000000010 |
| -32767 | 1000000000000001 |

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# Arduino Data Types – A Few Examples

- ## LONG Integer - 32 bits 2's complement

| LONG -- 32 Bits 2's Complement | | |
|---|---|---|
| **Decimal** | **Bit Pattern** | **HEX** |
| 2147483647 | 01111111111111111111111111111111 | 0x7FFFFFFF |
| 2147483646 | 01111111111111111111111111111110 | 0x7FFFFFFE |
| 2147483645 | 01111111111111111111111111111101 | 0x7FFFFFFD |
| ... | ... | ... |
| 2 | 00000000000000000000000000000010 | 0x00000002 |
| 1 | 00000000000000000000000000000001 | 0x00000001 |
| 0 | 00000000000000000000000000000000 | 0x00000000 |
| -1 | 11111111111111111111111111111111 | 0xFFFFFFFF |
| -2 | 11111111111111111111111111111110 | 0xFFFFFFFE |
| -3 | 11111111111111111111111111111101 | 0xFFFFFFFD |
| ... | ... | ... |
| -2147483646 | 10000000000000000000000000000010 | 0x80000002 |
| -2147483647 | 10000000000000000000000000000001 | 0x80000001 |
| -2147483648 | 10000000000000000000000000000000 | 0x80000000 |