EE493
ENGINEERING DESIGN-1

Test and Measurement Techniques

Outline

- Test and Measurement
- Measurement
  - What is Measurement?
  - Measurement Reliability
- Test Plan
  - Test Plan Examples
- Some tests recommended for EE493-EE494

Test and Measurement

- Measurement: The act of measuring something
  - Current
  - Voltage
  - Speed
  - Weight

- Test: A procedure intended to establish
  - Quality
  - Performance
  - Reliability

Test can be a combination of various measurements.

Measurement

- Measurement is
  - Systematic
  - Replicable

  by which objects or events are quantified.

- Usually achieved by the assignment of numerical values.
  - International System of Units (SI)

- Measurement is more than reporting whether something is simply
  - Working or
  - Not working

International System of Units (SI)

Base Units

Quantity	SI unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Temperature	kelvin or degree Celsius	K or °C
Luminous intensity	candela	cd
Amount of substance	mole	mol

International System of Units (SI)-2

Derived Unit Examples

Quantity	SI unit	Symbol
Area	square meter	m^2
Volume	cubic meter	m^3
Speed	meter per second	ms^{-1} or m/s
Acceleration	meter per second per second	ms^{-2} or m/s^2
Force	newton	N
Energy	joule	J
Power	watt	W

What about Volt?

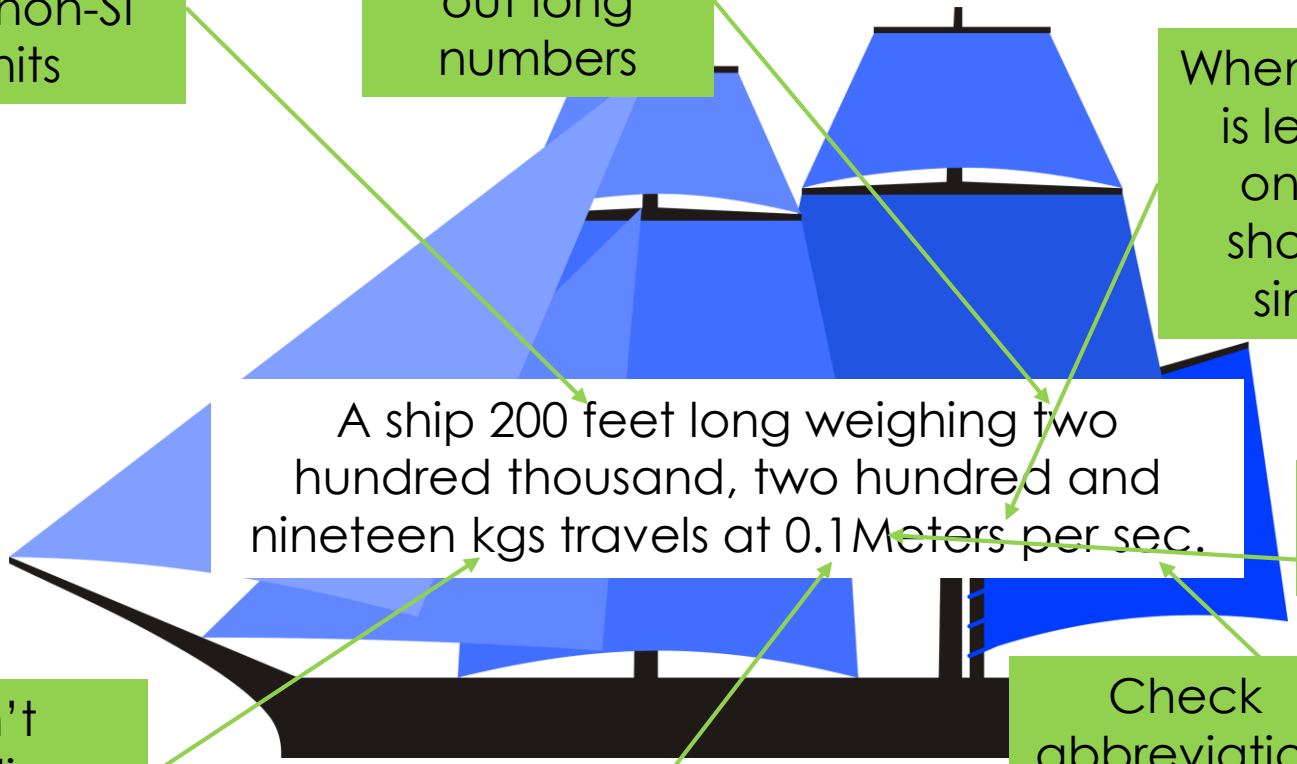
Voltage is W/A or J/C which equals to $kg.m^2.s^{-3}.A^{-1}$

Prefixes Used for Multiples of Units

Prefix	Symbol	Power of 10
yotta	Y	10^{24}
zetta	Z	10^{21}
exa	E	10^{18}
peta	P	10^{15}
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
deci	d	10^{-1}
centi	c	10^{-2}
Milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}
atto	a	10^{-18}
zepto	z	10^{-21}
yocto	y	10^{-24}

Expressing Measurement Results

In the example below the most important rules are broken!



Don't mix SI and non-SI units

Don't write out long numbers

When a value is less than one, unit should be singular

Units are not capitalized

Check abbreviation rules: not sec, s

Leave a space between the number and unit

Don't pluralize symbols

Quality of the Measurement

Low accuracy,
but high precision

Higher accuracy,
but low precision

High accuracy and
high precision

- In order to get high accuracy and precision,
  - You need to have your measurement system calibrated
  - You need to calculate (and possibly reduce) your error margin

Measurement Reliability

- Measurement yields consistent scores over repeated measurements.
- Three criteria for reliability
  - Test-Retest Reliability

    Measure the same item, do you get the same result?

    You need to repeat measurement and take average

  - Inter-item Reliability

    Measure a different item, using the same setup, do you get the same result?

    This will show you the process variation

  - Inter-observer Reliability

    Let someone to measure it for you, do you get the same result?

    You need to have a test-plan.

Test-Retest Reliability

- Variation in test-retest can be due to
  - Noise
  - Unreliable measurement technique or setup
  - Change in the environment or conditions
  - Faulty parts

Inter-item Reliability

- Variation can be due to
  - Part to part variation
    - Check the data-sheet to confirm
  - Testing method and testing system problems

Inter-Observer Reliability

- Variation can be due to
  - Part to part variation
    - Check the data-sheet to confirm
  - Testing method and testing system problems

Uncertainty Analysis-1

- Measuring the length of an object with an electronic callipers

Date and Name

Conditions

Possibly a mistake

16th April 2013 A. J. P

Workshop Temperature 21°C
Caliper Set 7:
Calibrated 23rd March 2013

Measurement	Reading / mm
1	21.53
2	21.51
3	~~20.52~~
4	21.47
5	21.43
6	...
24	21.67
25	21.55

Uncertainty Analysis-2

- Take the average of all measurements

  (21.53+21.51+21.47+21.43+…)/24=21.493 mm

- Calculate standard deviation as

$$standard\ deviation = \sqrt{\frac{\sum_{i=1}^{n}(reading_i - average)^2}{n-1}}$$

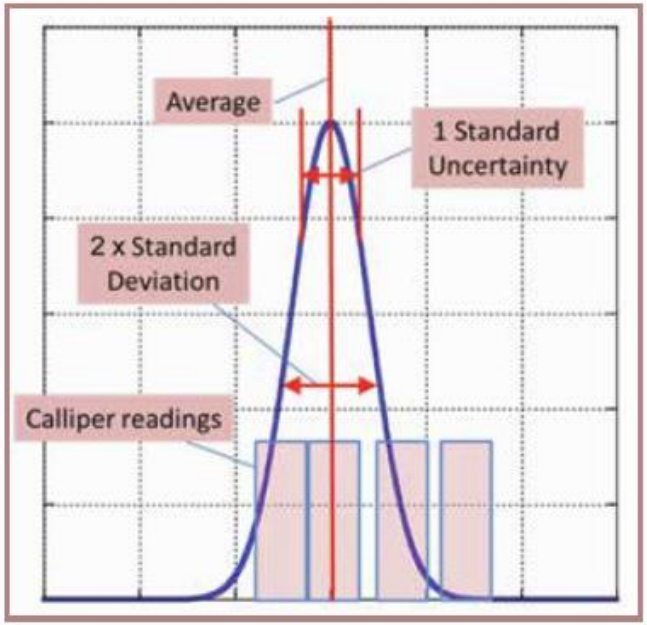
Measurement	Reading / mm	(Reading-Average)	(Reading-Average)^2
1	21.53	0.0375	0.0014
2	21.51	0.0175	0.0003
3	~~20.52~~		
4	21.47	-0.0225	0.0005
5	21.43	-0.0625	0.0039
6	…		…
…	…	…	…
25	21.55	0.0575	0.0033
Average	21.493	Sum	0.2505
		(Sum/23)	0.0109
		Standard Deviation =√(Sum/23) =	0.1044

Uncertainty Analysis-3

- If you take 100 more measurements you will improve your confidence level.
- For n readings standard uncertainty is given as

$$standard\ uncertainty = \frac{standard\ deviation}{\sqrt{n}}$$

- For 24 measurements the standard uncertainty would be 0.021 mm.



Test Plan

- Strategy document to verify a system meets its specifications
  - Must test the limits
  - Not used to verify your design in your design comfort zone
- Must Include
  - Detailed test methodology
  - Number of samples to be tested
  - The variation to be applied (e.g., temperature, supply voltage)
  - Expected results

Test Plan Example

Test Description: Switching Time: Test#4

Test Type	Test Conditions	# Samples		
		Room	+85 ° C	-45 ° C
Switching Time	Vdd = 5.0 V • Use Tune-1 board • Measure from RFIN to RFOUT • Measure from minimum atten to Maximum attenuation case in parallel mode. • Switching period 100uS • Duty cycle 50% • RF input power TBD	5	3	3

Test Setup(s)

(TTL level, Vlow=0.8V, Vhigh=2V).
Measure from 50% control to 90% RF.(Trise)
Measure from 50% control to 10% RF (Tfall)
Calibration Method: Standard

Test Plan Examples 'ctnd

Test Results

Store in separate sub-directories by Serial No./Temp/Voltage. Make sure file names are consistent from directory to directory.

Expected Results

Rise Time and Fall Time is expected around 1uS.

Due Date	
Approved	
Priority	

Some Tests Recommended for EE493-EE494

Some Common Subsystems

- Object Detection Subsystem
  - Ex: Image processing, sensors, micro-computer, etc.
- Movement Subsystem
  - Motors, motor drivers, wheels, chassis, microcontrollers, etc.
- Holding and Dropping Subsystem
  - Motors, motors drivers, wheels, arms, microcontrollers, etc.
- Power Supply
  - Battery, power controllers, low power indicators, etc.

Important Remarks

- All of the components must be tested separately and they must be combined for overall testing.
- Measure of success must be defined
  - Ex: The object detection subsystem must not be affected by lighting conditions.
- Test results must be provided to verify the measurable objectives.
- Number of trials and statistical properties such as mean and stdev. must be given.

Example: Distance Sensor

- Any applicable test to provide the following:
  - Plots, tabulated data or measurement results showing measured distance (cm) vs real distance (cm) with error values in percentage.

Example: Our sensor measures the distance of objects that are about 30 cm away. It has a 50% detection error over 30 cm distance. Under controlled lighting conditions (florescent light with uniform lighting) our result has 60% accuracy over the same distance. These data are collected over 5 repeated measurements with direct line of sight.

This claim should be supported by measurement results on a plot or in a table.

Example: Motor, Motor Driver, and Controller

- For the operating voltage range, the current ratings must be measured; durability tests must be performed by applying high voltage in the operation range for enough time.
- In order to observe the accuracy of the movement of the robot, speed, deviation, and rotation tests must be applied.
- Hardware PWM outputs of the microcontroller with different duty cycles at different frequencies must be provided.

Example: Movement Subsystem

- The robot must be checked whether it can travel without a significant deviation through a linear path.

Test Results for the Final Product

- The number of trials and the success rate must be provided.