MRE 320 Sensor Presentation

DHT-11

ULTRASONIC RANGING

ACCELEROMETER

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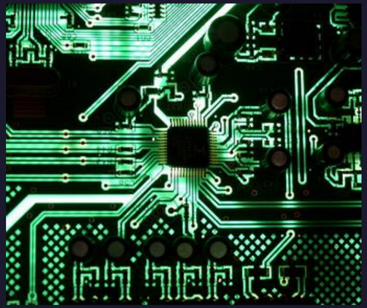

Weikun Ma

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Measured Sensors:

Sensor 1: Ultrasonic Ranging Module

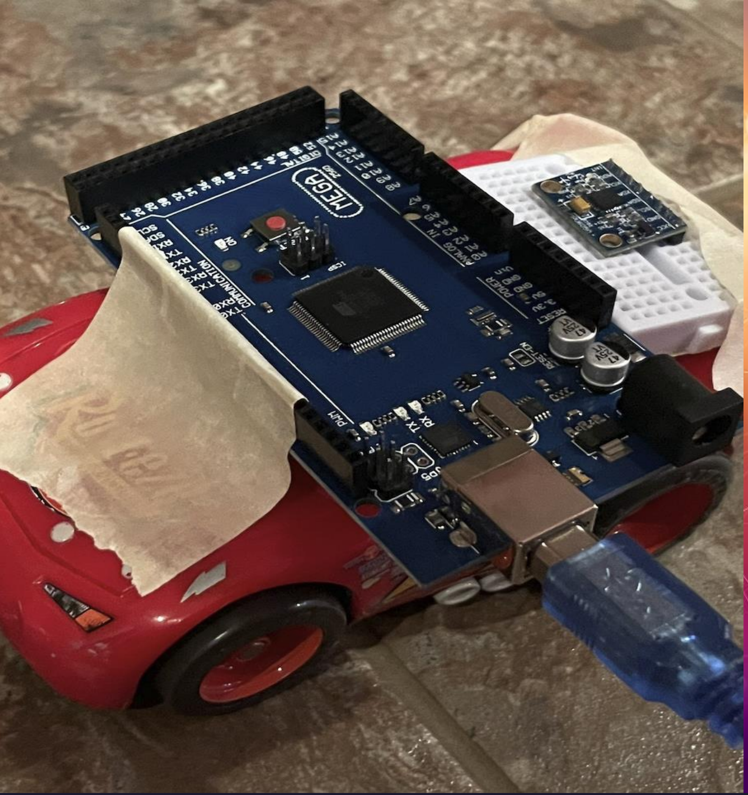
- Distance

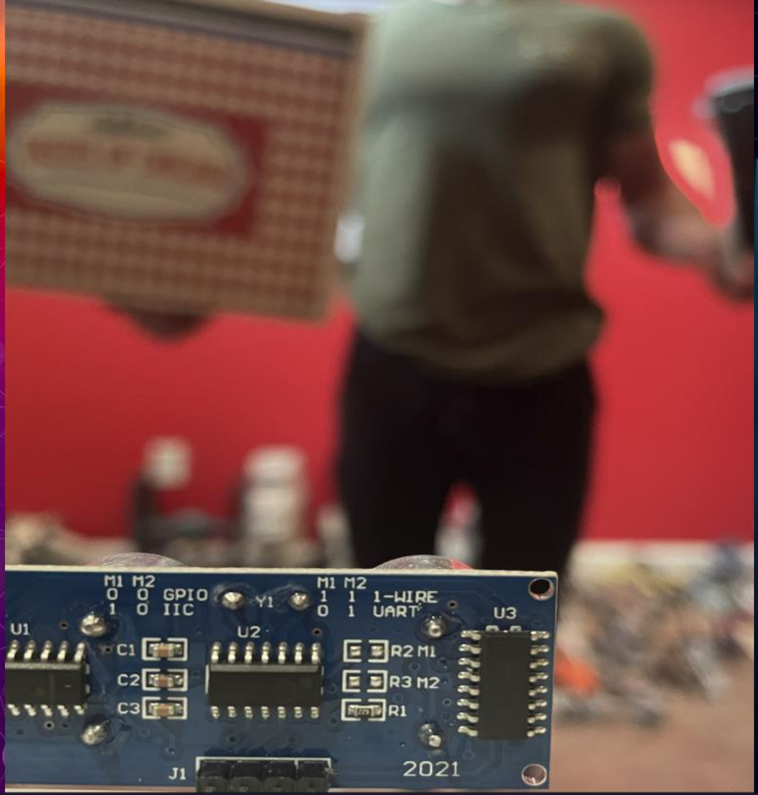
Sensor 2: MPU6050 Module

- Accelerometer

Sensor 3: DHT-11

- Temperature/humidity



Introduction

Testing sensors will continue to be a crucial component in the advancement, and cost saving, of equipment. Having the ability to find the weaknesses of sensors, then modify the inputs to ensure the output compiles as accurate, and precise, as possible. If done properly, financial savings for an individual is possible.

Ultrasonic Ranging Module

Usage: Used to measure an object and interpret its distance from the ranging module.

Spec Data Sheet

Electric Parameter

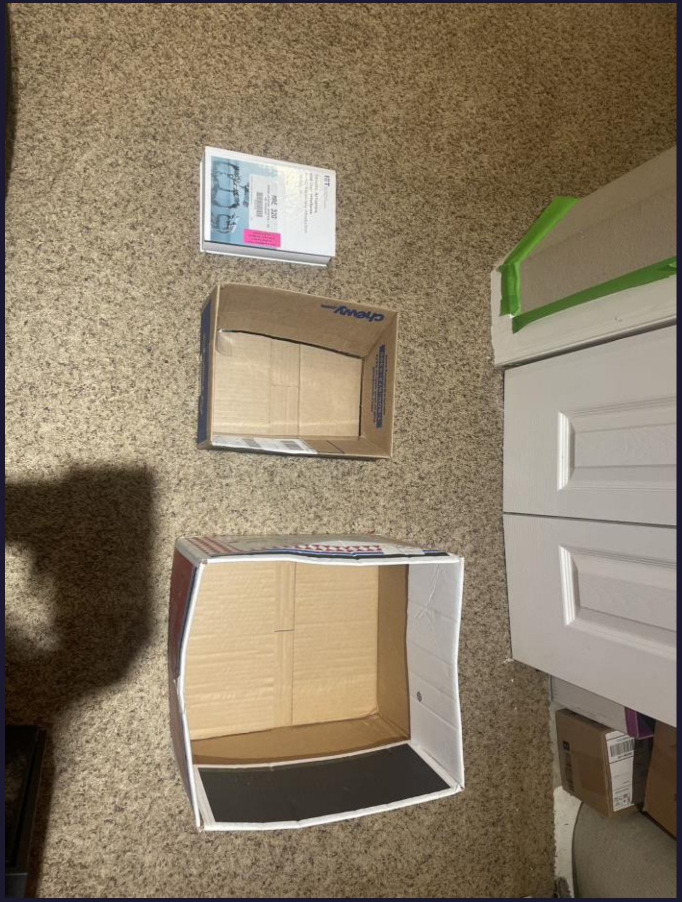
Working Voltage	DC 5 V
Working Current	15mA
Working Frequency	40Hz
Max Range	4m
Min Range	2cm
MeasuringAngle	15 degree
Trigger Input Signal	10uS TTL pulse
Echo Output Signal	Input TTL lever signal and the range in proportion
Dimension	45*20*15mm

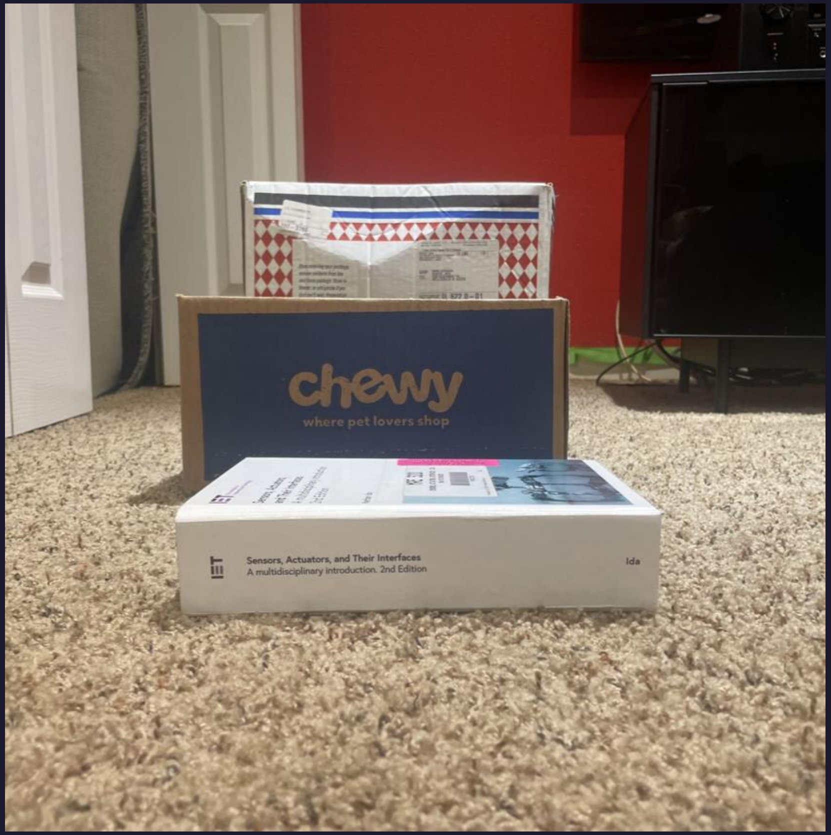
Sensor Characteristics Measured

- **Accuracy**
- **Range**
- **Precision**
- **Repeatability**

Different medium

1. The book
2. A small box
3. A large box





Data Found

initial reading	Reading {60in=152cm Book}	Reading {30in=76.2cm Book}	Reading {15in=38.1cm Book}	Reading {5in=12.7cm Book}	Reading {1in=2.54cm Book}
			TEST 1		
1203.71cm	154.88cm	78.12cm	38.86cm	12.48cm	2.67cm
1203.88cm	154.84cm	77.78cm	39.09cm	12.02cm	2.76cm
1203.84cm	155.33cm	77.66cm	38.98cm	12.38cm	2.76cm
1203.83cm	156.59cm	77.86cm	38.62cm	12.38cm	2.78cm
1203.55cm	156.34cm	77.95cm	39.78cm	12.38cm	2.76cm
1203.74cm	156.76cm	78.29cm	37.93cm	12.84cm	2.66cm
1203.64cm	156.12cm	78.31cm	38.62cm	12.67cm	2.78cm

			TEST 2		
initial reading	Reading {60in=152cm Small Box}	Reading {30in=76.2cm Small Box}	Reading {15in=38.1cm Small Box}	Reading {5in=12.7cm Small Box}	Reading {1in=2.54cm Small Box}
1204.34cm	149.64cm	78.22cm	39.55cm	16.55cm	2.12cm
1204.09cm	149.62cm	78.12cm	40.16cm	17.83cm	4.62cm
1204.00cm	149.59cm	78.14cm	39.55cm	17.83cm	4.40cm
1204.21cm	149.52cm	78.16cm	39.57cm	20.40cm	2.43cm
1204.41cm	152.24cm	77.95cm	40.26cm	16.53cm	2.78cm
1204.40cm	151.42cm	787.14cm	40.14cm	17.83cm	2.76cm
1204.59cm	153.50cm	77.95cm	39.33cm	18.78cm	2.76cm

			TEST 3		
initial reading	Reading {60in=152cm Large Box}	Reading {30in=76.2cm Large Box}	Reading {15in=38.1cm Large Box}	Reading {5in=12.7cm Large Box}	Reading {1in=2.54cm Large Box}
1204.21cm	151.78cm	72.55cm	42.09cm	11.67cm	3.00cm
1204.31cm	153.10cm	71.83cm	43.53cm	13.43cm	3.09cm
1204.40cm	116.79cm	72.98cm	43.62cm	12.03cm	3.09cm
1204.43cm	153.33cm	70.84cm	43.52cm	11.43cm	3.76cm
1204.28cm	151.93cm	70.01cm	43.22cm	12.48cm	2.78cm
1204.22cm	152.03cm	72.66cm	43.22cm	12.03cm	2.78cm
1204.40cm	151.95cm	73.90cm	43.24cm	11.67cm	2.76cm

Characteristic/Data Findings

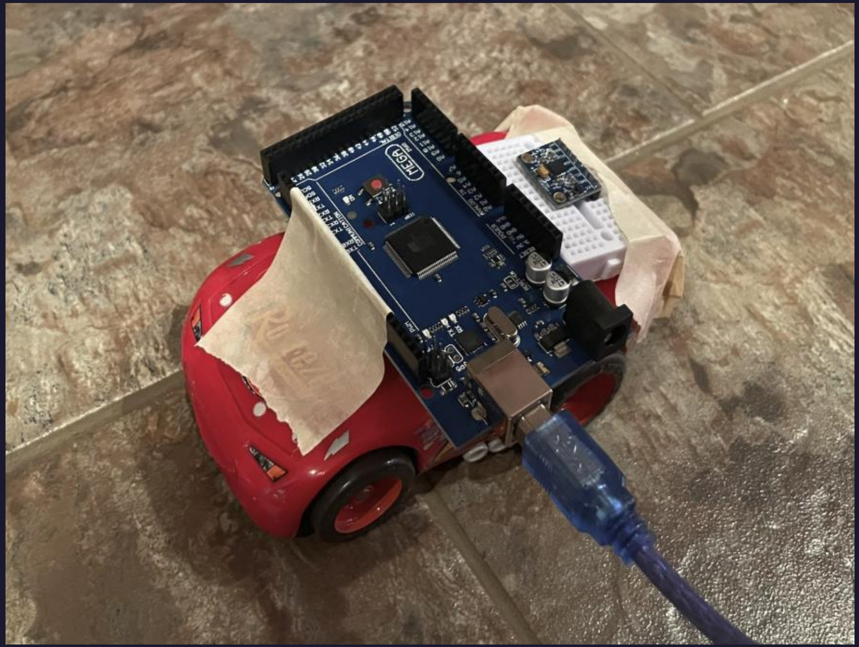
- Accuracy
  - Utilizing the larger objects, the accuracy/precision **increases** with greater distance. However, it **decreases** as the distance **decreases.**
  - Utilizing the smaller objects, the accuracy/precision **decreases** with greater distance. However, it **increases** as the distance **decreases.**
- Range
  - Range follows data sheet of 2cm-4m.
  - Precision
  - Precision is good. The outputted values are always relatively the same range if the object is kept in the same spot.
- Repeatability
  - Repeatability is incredibly easy with the sensor. As seen in the data, all outputs are within a relatively close range.
- Accuracy < 2cm
  - Accuracy is consistent with the data sheet. If object is closer than 2cm, the accuracy drops extensively. The output values are unpredictable.

MPU6050 Module

Usage: Used to measure accelerations in the x, y, z directions. Also measures the angular accelerations in the x, y, z.

Spec Data Sheet

Methodology of Sensing



InvenSense	MPU-6000/MPU-6050 Product Specification	Document Number: PS-MPU-6000A-00 Revision: 3.4 Release Date: 08/19/2013

5 Features

5.1 Gyroscope Features

The triple-axis MEMS gyroscope in the MPU-60X0 includes a wide range of features:

- Digital-output X-, Y-, and Z-Axis angular rate sensors (gyroscopes) with a user-programmable full-scale range of ±250, ±500, ±1000, and ±2000°/sec
- External sync signal connected to the FSYNC pin supports image, video and GPS synchronization
- Integrated 16-bit ADCs enable simultaneous sampling of gyros
- Enhanced bias and sensitivity temperature stability reduces the need for user calibration
- Improved low-frequency noise performance
- Digitally-programmable low-pass filter
- Gyroscope operating current: 3.6mA
- Standby current: 5µA
- Factory calibrated sensitivity scale factor
- User self-test

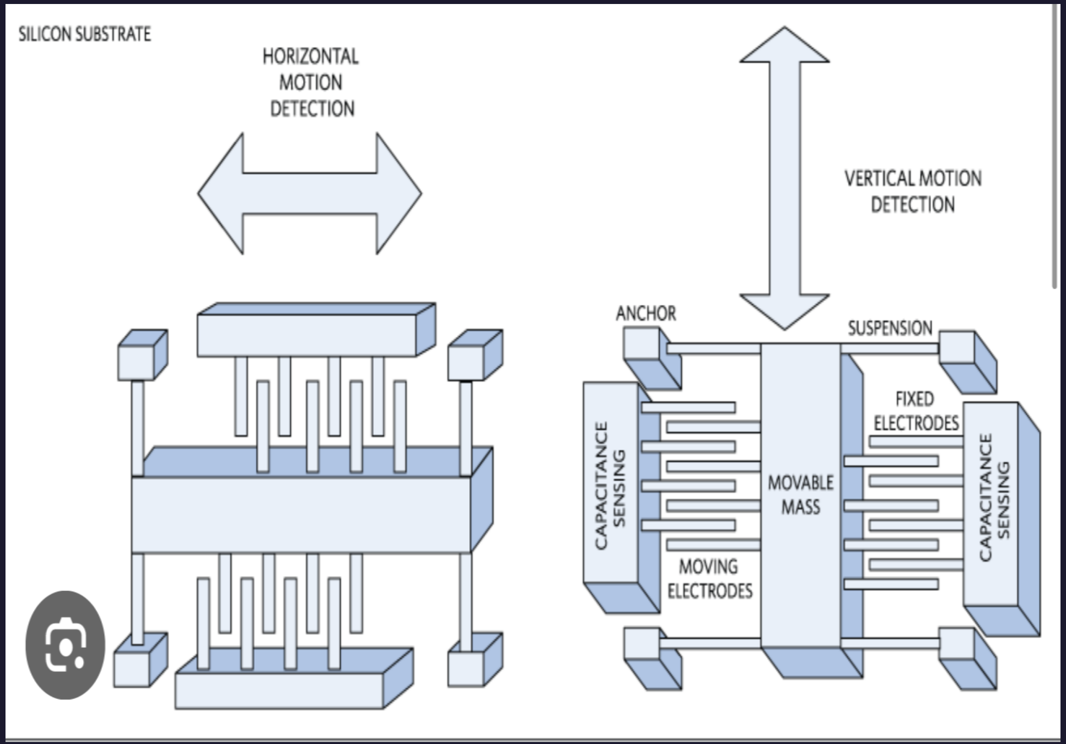
5.2 Accelerometer Features

The triple-axis MEMS accelerometer in MPU-60X0 includes a wide range of features:

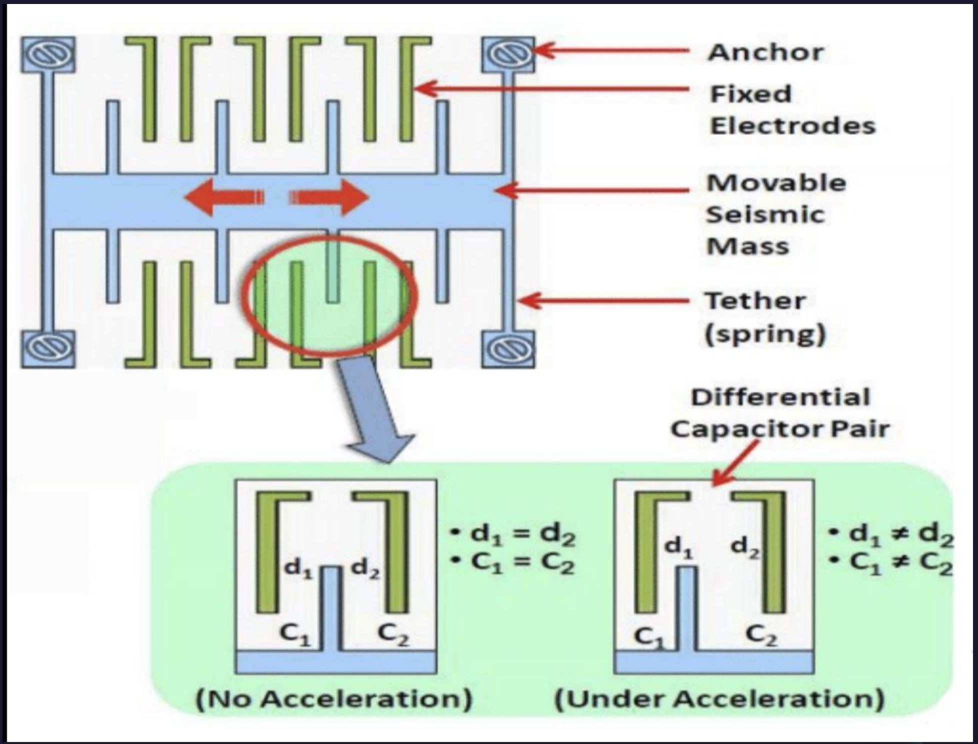
- Digital-output triple-axis accelerometer with a programmable full scale range of ±2*g*, ±4*g*, ±8*g* and ±16*g*
- Integrated 16-bit ADCs enable simultaneous sampling of accelerometers while requiring no external multiplexer
- Accelerometer normal operating current: 500µA
- Low power accelerometer mode current: 10µA at 1.25Hz, 20µA at 5Hz, 60µA at 20Hz, 110µA at 40Hz
- Orientation detection and signaling
- Tap detection
- User-programmable interrupts

Function of Accelerometer

PLATE SHIFT



CAPACITOR EXPLANATION



CALCULATED DATA

Equations of motion used:

$$V = V_0 + a*t$$

$$R = R_0 + V_0*t + \tfrac{1}{2}*a*t^2$$

KNOWNS:

1) $R = 20$ ft
2) $t = 3.875$ s
3) $R_0 = 0$ ft

@ END DISTANCE {20 ft}

$$R = R_0 + V_0*t + \tfrac{1}{2}*a*t^2$$

$$20\text{ft} = 0\text{ft} + 0\text{ft/s}*(3.875\text{s}) + \tfrac{1}{2}*a*(3.875\text{s})^2$$

$$a = 2.7875 \text{ ft/s}^2$$

$$a = .850 \text{ m/s}^2$$

General Equation for Finding Velocity at Specific Point in Time:

$$V = V_0 + a*t$$

$$V = 2.7875*(\text{Time}) \text{ [ft/s]}$$

Initial Reading {NOT MOVING}

data before running:				
AcX	0.01	0.16	0.17	0.16
AcY	0.03	0.04	0.03	0.04
AcZ	1.16	1.17	1.17	1.16
GyX	-3.76	-3.71	-3.71	-3.53
GyY	-1.14	-1.14	-1.1	-0.97
GyZ	0.1	0	0.04	-0.07

NOTE: The first column of each "Test" are relatively the same. The car started from rest before accelerating. So, first column of readings for ALL tests should be the same.

NOTE 2: Notice there is angular velocities at a linear movement. This reading is due to the attachment of the accelerometer. The sensor was attached on the spoiler of the car. This leaves the accelerometer not completely level. So, according to the sensor, it has angular velocities. Also, uneven surfaces.

Test #1				
AcX	0.01	0.16	-13	1.12
AcY	0	0.02	0.21	-2
AcZ	0.05	1.15	-0.6	-0.55
GyX	1.7	-4	-7.15	-85.49
GyY	-1.7	-0.08	-32.27	-71.17
GyZ	0.25	-5.97	-30.28	-77.44

Test #2				
AcX	-0.01	-0.58	-0.94	-1.64
AcY	0.08	0.08	0.54	-1.04
AcZ	1.2	0.27	-0.27	1.16
GyX	-4.1	-10.88	24.78	-152.52
GyY	-1.51	-24.01	-4.93	-42.83
GyZ	0.02	-20.53	-21.94	20.86

Test #3				
AcX	-0.01	0.12	0.54	1.63
AcY	0	0.7	-1.46	2
AcZ	1.18	1.18	-48	2.02
GyX	1.7	-3.85	2.07	-62.41
GyY	-1.7	-1.16	57.97	-19.61
GyZ	0.25	-0.18	-0.99	45.31

Characteristic/Data Findings

- Accuracy
  - TEST 1: Acceleration = 1.755 m/s^2
  - TEST 2: Acceleration = 1.45 m/s^2
  - TEST 3: Acceleration = 2.6 m/s^2
  - As seen in the "Calculation" slide, ACCEPTED acceleration = 2.7883 ft/s^2, or .850 m/s^2. Accuracy is a bit random. The average accelerations are shown above. Compared to actual calculated acceleration we get the flowing percent errors.

%ERROR 1 = 10.2% ; %ERROR 2 = 24.8% ; %ERROR 3 = 53.3%

  - The error is relatively close to accepted error of 10%. Error 3 is due to misreading of device.

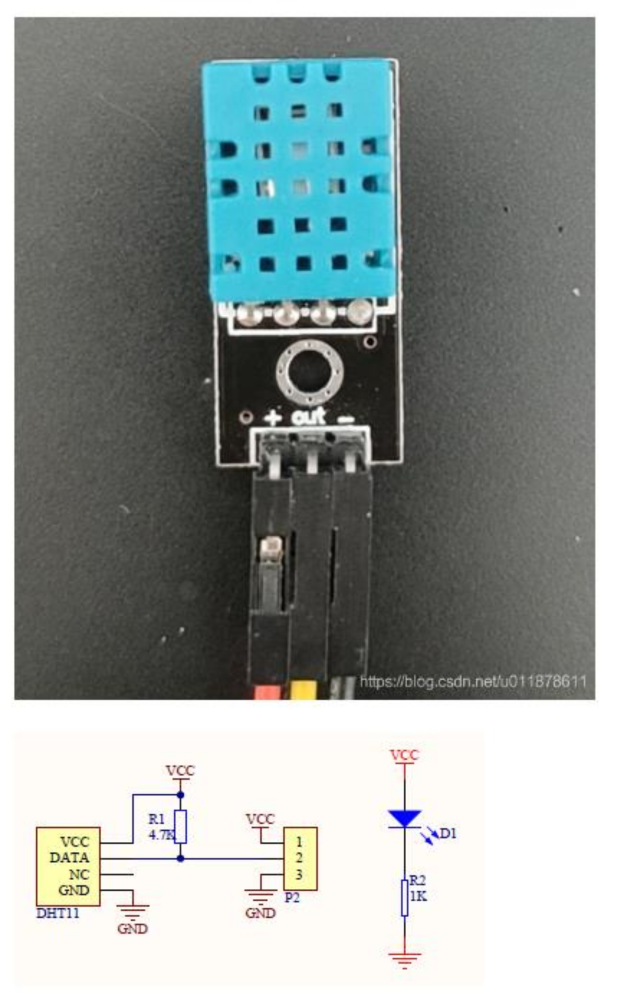
Characteristic/Data Findings CONT.

- Repeatability
  - The repeatability of sensor's acceleration was relatively consistent disregarding a few measurements that were obviously incorrect.
  - The sensor's angular velocities were a bit more on the faulty side. These readings were not precise or accurate making readings or angular velocities difficult.
    - This could be due to a few attributes such as unexpected bumps in the tested linear path, or inconsistent shifting of the sensor when collision with end barrier.
- Drift
  - As stated in NOTE 2, the first column of all readings is from an initial resting position. These three tests and initial test readings are relatively the same besides the reading for GyX. This could be due to jostling the sensor between each test. The car did collide with a barrier that was set to keep the car from colliding with hard surfaces.

DHT-11 Sensor

Usage: Used in measuring temperature and humidity in the current climate.

DHT-11 physical diagram and schematic diagram



DHT11 Product Overview

The sensor includes a resistive humidity sensing element and an NTC temperature measuring element, and is connected to a high-performance 8-bit microcontroller.

Spec Data Sheet

Item	Measurement Range	Humidity Accuracy	Temperature Accuracy	Resolution	Package
DHT11	20-90%RH 0-50 ℃	±5%RH	±2℃	1	4 Pin Single Row

Parameters	Conditions	Minimum	Typical	Maximum
Humidity				
Resolution		1%RH	1%RH	1%RH
			8 Bit	
Repeatability			±1%RH	
Accuracy	25℃		±4%RH	
	0-50℃			±5%RH
Interchangeability	Fully Interchangeable			
Measurement Range	0℃	30%RH		90%RH
	25℃	20%RH		90%RH
	50℃	20%RH		80%RH
Response Time (Seconds)	1/e(63%)25℃, 1m/s Air	6 S	10 S	15 S
Hysteresis			±1%RH	
Long-Term Stability	Typical		±1%RH/year	
Temperature				
Resolution		1℃	1℃	1℃
		8 Bit	8 Bit	8 Bit
Repeatability			±1℃	
Accuracy		±1℃		±2℃
Measurement Range		0℃		50℃
Response Time (Seconds)	1/e(63%)	6 S		30 S

Data Found

Weather Data Ground (21.6667 C & 30%)

Humidity	Temp (°C)	% Err Humidity	% Err Temp
34.4	22.3	14.66666667	2.92291858
34.4	22.3	14.66666667	2.92291858
34.4	22.3	14.66666667	2.92291858
34.3	22.3	14.33333333	2.92291858
34.5	22.2	15	2.461380829
34.4	22.2	14.66666667	2.461380829
34.4	22.1	14.66666667	1.999843077
34.4	22.1	14.66666667	1.999843077
34.4	22.1	14.66666667	1.999843077
34.4	22.1	14.66666667	1.999843077
34.6	22	15.33333333	1.538305326
34.5	22	15	1.538305326
34.6	22	15.33333333	1.538305326
35.1	21.9	17	1.076767574

Thermostat Ground (18.333 C & 50%)

Humidity	Temp (°C)	% Err Humidity	% Err Temp
41.7	20.9	16.6	14.00020727
41.8	20.8	16.4	13.45475174
41.9	20.8	16.2	13.45475174
41.9	20.8	16.2	13.45475174
41.9	20.8	16.2	13.45475174
42	20.8	16	13.45475174
42.1	20.8	15.8	13.45475174
42.1	20.8	15.8	13.45475174
42.1	20.8	15.8	13.45475174
42.2	20.8	15.6	13.45475174
42.4	20.7	15.2	12.9092962
42.4	20.8	15.2	13.45475174
42.5	20.7	15	12.9092962
42.5	20.7	15	12.9092962

Sensor Characteristics Measured

- **Accuracy**
- **Drift**
- **Precision**
- **Repeatability**

Characteristic/Data Findings

Accuracy

The measured humidity error is between 7.3%-7.9%, slightly higher than the 5% in the parameter

Atmospheric humidity	Measure humidity	Humidity error
34.4	41.7	7.3
34.4	41.8	7.4
34.4	41.9	7.5
34.3	41.9	7.6
34.5	41.9	7.4
34.4	42	7.6
34.4	42.1	7.7
34.4	42.1	7.7
34.4	42.1	7.7
34.4	42.2	7.8
34.6	42.4	7.8
34.5	42.4	7.9
34.6	42.5	7.9
35.1	42.5	7.4

Drift

During the test, when the atmospheric temperature and humidity were the same, the measured temperature difference of the thermostat was less than 0.1°, so the deflection of the instrument is very small

Precision

The repeatability of the test data provided is very standard. Temperature range that provides repeatability within parameters

Repeatability

The temperature error is between 1.2°-1.5°, meeting the accuracy standards given by the parameters.

atmospheric temperature	measure temperature	temperature error
22.3	20.9	1.4
22.3	20.8	1.5
22.3	20.8	1.5
22.3	20.8	1.5
22.2	20.8	1.4
22.2	20.8	1.4
22.1	20.8	1.3
22.1	20.8	1.3
22.1	20.8	1.3
22.1	20.8	1.3
22.1	20.7	1.4
22	20.7	1.3
22	20.8	1.2
22	20.7	1.3
21.9	20.7	1.2

Summary

To properly utilize sensors in the industry, it is crucial to understand the characteristics of sensors and how each sensor has their own strengths and weaknesses. If properly understood, even the cheapest of sensors can be assigned to complex tasks and assignments.

Thank You!

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