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An Experimental Investigation Of A Weather Buoy-Wireless Data Acquisition Based On Microcontroller

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***Abstract*—This paper presents an experimental work to monitor data acquisition of weather buoy by applying measurement sensors and wireless communication technology. The sensors were used to measure air pressure , air temperature, humidity, wind velocity, wind direction and the global position. Specifically, the communication of data acquisition system used in the weather buoys was developed using wireless modems and data communications software. Commands were issued from a computer to instruct the data acquisition system to acquire data from sensors. The RMS of each component is recorded and entered into the measurement range of 0.28-0.69 %. This range changes slightly when they were incorporated into the data acquisition system with the error of RMS 1.761% . However this was still in a good performance since the RMS error was less than 2%.**

Keywords ; Weather Buoy, Data Acquisition, Microcontroller, Wireless, Sensor.

I. INTRODUCTION

Indonesia is a maritime country with a vast ocean area of 5.8 million km2 consisting of territorial waters, 12 nautical waters and ZEE Indonesian waters. Indonesia has 17,504 islands with a long coastline of 104,000 km[1]. It attracts Indonesian people who live around the coast to exploit the natural wealth of the sea by choosing to be a fisherman as a livelihood. Until now fishermen still rely on the wind in the sea as good information or bad weather around the beach. While information on data and weather estimates derived from BMKG is considered not accurate enough. This is because the data obtained is the result of interpolation[2].

To obtain accurate data and weather forecasts, a weather buoy device is required that will provide information on weather prediction in a water location in Indonesia. Weather buoy is a equipment used to predict the weather. The ideal number of weather monitoring radar in the whole of Indonesia is 50 units[3].

Previous research results Design Data Acquisition System Of Weather buoy Prototype Type I, provide information on wind velocity, wind direction, air temperature, air pressure and humidity. Current research provides information on the 5 types of data generated from previous research supplemented by GPS data information and ocean current data.

Maritime weather buoy is a system consisting of several sensors, data management and data processing so that it can be sent wirelessly to the work station on land. On a ground station there is a system that has a predictor system, acquisition system, monitoring system and distribution system. The acquisition system is a system that serves to retrieve, collect, display and process to get the desired data. The data will be processed to produce predictive information and weather forecasts. This data is also then used for transportation and shipping.

II. DATA ACQUISITION SYSTEM

Sensors are devices that provide information about what happens to the control system. In designing a control system, a designer must ensure that whatever parameters need to be monitored such as pressure, position, and temperature. After that determined the sensor to be used as well as its interface device[3]. In transmitting data information from sensors or sensors to a monitor or display screen, a data acquisition system is required.

Data acquisition system is a system that serves to retrieve, process, and display data until it reaches the desired condition. This system converts physical quantities into digital signals and is processed through a computer[3].

A sensor in general does not work by itself. The data acquisition system is a large system that includes the sensor itself, signal conditioning, signal processing, memory devices, data recording, and actuators[3]. If there is more than one sensor, a multiplexer is required to combine multiple inputs into one output.

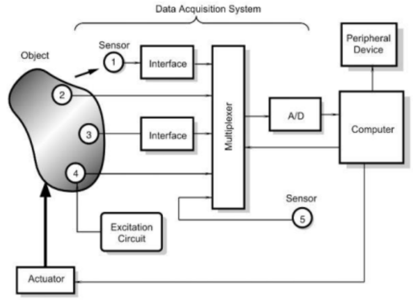

Figure 1. Data Acquisition System

There is an image of a data acquisition system consisting of 5 sensors in Figure 1. Sensors can not be directly related to electronic devices[3]. They require the use of an interface device or interface (signal conditioning) that serves to condition a weak signal to be processed in the next process.

In Figure 1 there is also a multiplexer to convert the input of the five sensors into one output. Block A / D or Analog to Digital is part of signal processing that serves to convert analog signals into digital signals to be displayed in the display. The display here is the computer. If depicted in a simple block diagram, a data acquisition system is illustrated as shown in Fig 2.

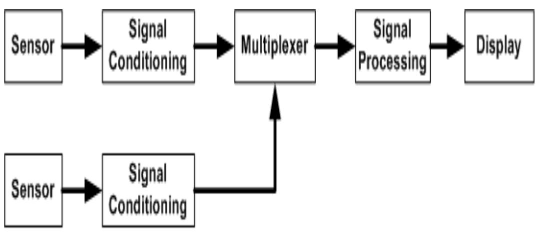

Figure 2. Block Diagram Data Acquisition System More Than One Sensor

The basic principle of the data acquisition system is the "time shared" variable to be measured, the technique used is time division multiplexing. In addition, the data acquisition system also requires a communication system to transmit the measured data to a data storage area, eg from the instrument field to the control room if the data acquisition system is used in the industry.

Time division multiplexing technique can be done using multiplexer equipment pair and demultiplexer, component is composed of switch which function to select input data. The multiplexer is used to select multiple input data for one output line, whereas demultiplexer is used to select one input data to one of the output data paths from multiple output data lines. At time division multiplexing selecting input data alternately based on certain time interval. In addition to using multiplexer and demultiplexer,

III. Wireless Data Acquisition System Equipment

A. Microcontroller

Microcontroller is a single chip that can be used to control and control a system. Microcontrollers have several components of computer formation consisting of CPU, RAM, ROM, and Port I / O. Microcontroller can work if already contains a program that first put into microcontroller memory. The image of the Arduino Microcontroller is shown in Fig 3.

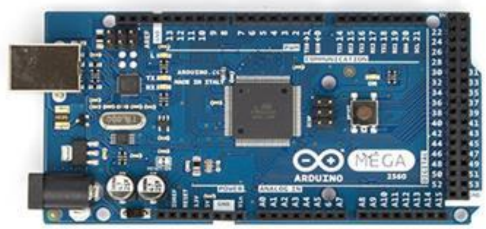

Figure 3. Arduino Mega

B. Microcontroller

To measure the air pressure, required air pressure sensor that is BMP085 to measure the air pressure in the atmosphere. BMP085 design is done by connecting the sensor pins VCC, GND, SDA, and SCL on the sensor on the microcontroller. In addition to measuring air pressure, the BMP085 sensor can also be used in atmospheric temperature measurements. So BMP085 measured two weather variables in this study. The image of the Air Pressure and Temperature Sensor is shown in Fig 4.

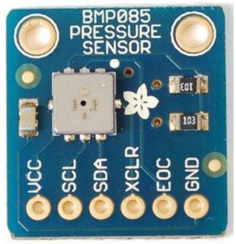

Figure 4. BMP085 Sensor

C. Humidity Sensor

Humidity in the atmosphere is measured using a DHT22 sensor. This humidity sensor has a sensor characteristics consisting of a voltage that requires 3.3 volts. DHT22 sensor has a very slow delay, so the data received will be longer than other sensors. This sensor also has special treatment during soldering. The image of the Humidity Sensor is shown in Fig 5.

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Figure 5. DHT22 Sensor

D. Wind Velocity Sensor

To measure wind velocity, an optocoupler is connected to a lattice plate which will calculate the number of holes in the disc. This circuit is called a counter. On the device used, one lattice has 22 holes, if in one second the counter circuit detects 22 holes, the calculation is detected lattice rotation with frequency of 22 holes per second or one full rotation per second. The optocoupler form used is T-shape optocoupler. The output of this optocoupler will be connected to the microcontroller. The image of the Optocoupler Sensor is shown in Fig 6.

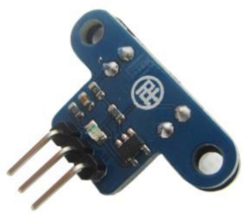

Figure 6. Optocoupler

E. Wind Direction Sensor

To know the direction of the wind, then needed a sensor that can work the same as the compass. Magnetometer is a digital compass sensor that communicates with microcontroller using I2C communication. HMC5883L is a three-axis sensor of measurement (X, Y, Z). In I2C communication there is a master and save that is assigned to send and receive data by specifying the addressing of each pin called degan addressing.

Addressing the pin can be seen in the datasheet of this sensor. The pins used in this communication are SCL and SDA, where SCL is a Serial Clock that provides clock and SDL signals which are Serial Data. Both pins work by giving the start and stop signal commands defined by changing the numbers "1" to "0" or vice versa. The image of the Magnetometer Sensor is shown in Fig 7.

Figure 7. Magnetometer

F. GPS (Global Positioning System)

Global Positioning System (GPS) is a sensor used to determine the location or position of an object, in this case the weather buoy. This location is based on the value displayed by GPS, Latitude and Longitude.

The output of this GPS sensor data is standard NMEA, where the output data consists of a series of very long numbers. To specify a position, only Longitude and Latitude data is required. Data Longitude and Latitude form a series of letters and numbers that have its own meaning. The image of the GPS Sensor is shown in Fig 8.

Figure 8. GPS

G. Radio Telemetry

Radio telemetry is a hardware that serves to transmit a data using a wireless communication system. Radio telemetry used is 3DR radio telemetry type, where this telemetry radio has some features such as having transmit power up to 20 dBm with maximum power output reaching 100 mW, having sensitivity of -117 dBm, requiring voltage reaching 3,7 - 6 VDC , Has a frequency of 433 Mhz. The image of the Radio Telemetry is shown in Fig 9.

Figure 9. Radio Telemetry

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IV. Results Obtained On Experimental Test

This test is done in two stages of hardware testing and wireless data acquisition system testing. Hardware testing is done to ascertain whether technically the sensor is working properly, so that if it will do troubleshooting it can focus on the problem that has not been identified.

Wireless data acquisition system testing is done to find out whether the system is designed to run properly and the necessary data can be obtained.

a. Hardware Testing

1. Pressure Air Sensor Testing

Hardware testing of the sensors BMP085 used to determine the conditions of air pressure and atmospheric temperature by using I2C circuit that connects SDA, SCL, VCC and GND on the sensor to the microcontroller.

Table 1. Result BMP085 For Air Pressure

Data	Standart Barometer (mBar)	Sensor Results (mBar)	E	E^2
1	1004.43	1005.04	0.61	0.37
2	1004.51	1005.03	0.52	0.27
3	1004.41	1004.87	0.46	0.21
4	1004.46	1004.96	0.50	0.25
5	1004.42	1004.87	0.45	0.20
6	1004.43	1004.86	0.43	0.18
7	1004.52	1005.03	0.51	0.26
8	1004.60	1005.12	0.52	0.27
9	1004.47	1004.97	0.50	0.25
Average	1004.47	1004.97	0.50	0.25

Table 1 describes the results of air pressure sensor testing. The difference between the data is an error from the sensor. Of the nine data test results, will be taken average error and average squared error to find the RMS (root mean square).

$$\text{RMS} = \sqrt{Average\ (E^2)}$$
$$= \sqrt{0.25}$$
$$= 0.5$$

Table 2. Result BMP085 For Temperature

Data	Standart Termometer (C)	Sensor Results (C)	E	E^2
1	31.10	31.50	0.40	0.16
2	31.10	31.60	0.50	0.25
3	30.80	31.50	0.70	0.49
4	30.80	31.50	0.70	0.49
5	30.80	31.50	0.70	0.49
6	30.70	31.40	0.70	0.49
7	30.70	31.40	0.70	0.49
8	30.70	31.50	0.80	0.64
9	30.60	31.50	0.90	0.81
Average	30.81	31.49	0.68	0.48

Table 2 describes the results of temperatur sensor testing. The difference between the data is an error from the sensor. Of the nine data test results, will be taken average error and average squared error to find the RMS (root mean square).

$$\text{RMS} = \sqrt{Average\ (E^2)}$$
$$= \sqrt{0.48}$$
$$= 0.69$$

2. Humidity Sensor Testing

Hardware testing of the sensors BMP085 used to measure atmospheric humidity. The sensor is connected to the arduino by connecting VCC, GND, S and D. the voltage used is 3.3 V.

Table 3. Result DHT22 For Hunidity

Data	Standart Hygrometer (Bar)	Sensor Results (Bar)	E	E^2
1	72.89	73.50	0.61	0.37
2	72.94	73.30	0.36	0.13
3	73.04	73.50	0.46	0.21
4	72.89	73.41	0.52	0.27
5	72.97	73.73	0.76	0.58
6	72.67	73.37	0.70	0.49
7	72.85	73.48	0.63	0.40
8	72.50	73.71	1.21	1.46
9	72.52	73.15	0.63	0.40
Average	72.81	73.46	0.65	0.48

Table 3 describes the results of humidity sensor testing. The difference between the data is an error from the sensor. Of the nine data test results, will be taken average error and average squared error to find the RMS (root mean square).

$$\text{RMS} = \sqrt{Average\ (E^2)}$$
$$= \sqrt{0.48}$$
$$= 0.69$$

3. Wind Velocity Sensor Testing

Hardware testing of the sensors Optocoupler used to measure wind velocity. Installed between the encoder holes that have 22 holes. This sensor output is pulse per second. Then used the formula to convert into RPM ie PPS x 60. Because anemometer standard has output with unit m / s, for that need to know relation between RPM with wind velocity m / s. The wind source in this wind velocity measurement comes from a wind tunnel that has a frequency output. The wind velocity of the wind tunnel is measured using an anemometer. The following results show the relationship between wind velocity and RPM of the tool.

Table 4. Result Wind Velocity Sensor in Wind Tunnel

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Data	Standart Anemometer (m/s)	Sensor Results (m/s)
1	1.02	0.00
2	1.51	5.55
3	2.02	16.26
4	2.53	31.33
5	3.02	50.33
6	3.51	74.00
7	4.00	110.80
8	4.52	142.03
9	5.00	162.33
Average	3.01	65.85

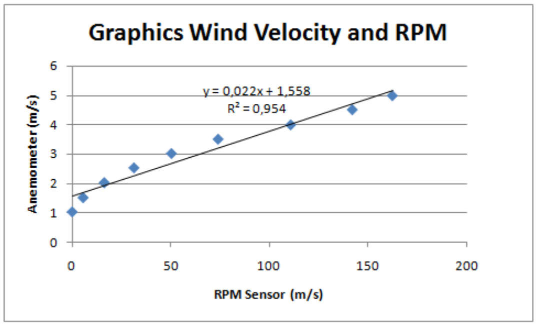

Figure 10. Graphics Wind Velocity and RPM

From Figure 10 obtained equation to find the calibration factor. The equation for wind velocity is v = 0.022 * RPM + 1.558.

After obtained regression equation, then performed processing data received by serial monitor arduino which then applied calibration factor. Then re-tested by using calibration factor to the actual value measured by a standard anemometer. This test is performed on the m / s scale.

Table 4. Result Wind Velocity Sensor After Regrresion

Data	Standart Anemometer (m/s)	Sensor Results After Regresion (m/s)	E	E2
1	1.02	1.56	-0.54	0.29
2	1.51	1.68	-0.17	0.03
3	2.02	1.92	0.10	0.01
4	2.53	2.25	0.28	0.08
5	3.02	2.67	0.35	0.13
6	3.51	3.19	0.32	0.10
7	4.00	4.00	0.00	0.00
8	4.52	4.68	-0.16	0.03
9	5.00	5.13	-0.13	0.02
Average	3.01	3.01	0.01	0.08

Table describes the results of wind velocity sensor testing with calibration factor. The difference between the data is an error from the sensor. Of the nine data test results, will be taken average error and average squared error to find the RMS (root mean square).

$$RMS = \sqrt{Average\ (E^2)}$$
$$= \sqrt{0.08}$$
$$= 0.28$$

4. Wind Direction Sensor Testing

Hardware testing of the sensors Rotary Encoder used to measure wind direction The first step determines the cobination of the LED lights of each wind direction.

Table 5. LED With Range

No	Standard reading	Binary output	Direction
1	0	0000	North
2	22.5	0001	North East
3	45	0101	Northeast
4	67.5	0100	East northeast
5	90	0110	East
6	112.5	0111	East northwest
7	135	1111	Southeast
8	157.5	1110	South southeast
9	180	1100	South
10	202.5	1101	South southwest
11	225	1111	Southwest
12	247.5	1000	Western southwest
13	270	1010	West
14	292.5	1011	West northwest
15	315	0011	Northwest
16	337.5	0010	North northwest
17	360	0000	North

After the LED flame test, LED output is appropriate based on Table 5. Therefore can be ascertained LED sensor is running well.

5. GPS Sensor Testing

Hardware testing of the sensors GPS used to position of buoy.

Table 6. GPS Sensor

Lattitude	Longitude
717.02893S	11247.78710E
717.02838S	11247.78710E
717.02838S	11247.78710E
717.02862S	11247.78710E
717.02884S	11247.78710E
717.02884S	11247.78710E
717.0286S	11247.78710E

Latitude is the coordinate for degrees south latitude whereas longitude is the coordinate for east longitude degree. Both coordinates are averaged, then incorporated into Google Earth. Google Earth is a software that can detect location by entering the coordinates of the location you want to find.

b. Wireless Data Acquisition System Testing

Testing wireless data acquisition transmission is the most important thing to know the accuracy of data

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transmission. Testing of this transmission is done by sending as much data as possible during the running process to find out how much data is damaged or loses. The corrupted data referred to here is data sent by incomplete or truncated microcontroller. The result of data acquisition testing is table 7 and display for transmitted data is show in Fig 11

Table 7. The Data Transmission Test Results

Variable	Number of Data	Correct Data	Broken Data	Lose Data	Error Data	Error Data^2
Air Pressure	3600	3532	8	60	1.8889	3.5679
Air Temperature	3600	3540	0	60	1.6667	2.7778
Humidity	3600	3534	6	60	1.8333	3.3611
Wind Velocity	3600	3540	0	60	1.6667	2.7778
Wind Direction	3600	3538	2	60	1.7222	2.9660
GPS	3600	3536	4	60	1.7778	3.1605
Average					1.7593	3.1019

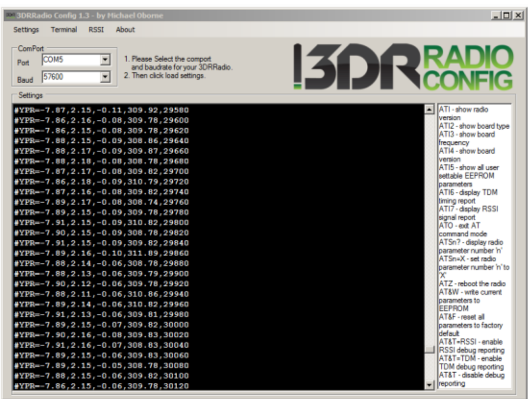

Figure 11. Radio Telemetry Transmitted Data

Table 7 informs how much data should be received, data received correctly, data received in damaged condition (broken), data not received, and error percentage from data of each variable received. The amount of data that should be accepted is as much as 3600 data. Each variable has different amounts of correct data and broken data.

For air pressure sensor from 3600 amount of data, 3532 correct amount of data, 8 broken amount of data, 60 lose amount of data and has an error percentage from data is 1.889%. For temperatur sensor from 3600 amount of data, 3540 correct amount of data, 0 broken amount of data, 60 lose amount of data and has an error percentage from data is 1.667%. For humidity sensor from 3600 amount of data, 3534 correct amount of data, 6 broken amount of data, 60 lose amount of data and has an error percentage from data is 1.833%. For wind velocity sensor from 3600 amount of data, 3540 correct amount of data, 0 broken amount of data, 60 lose amount of data and has an error percentage from data is 1.667%. For wind direction sensor from 3600 amount of data, 3538 correct amount of data, 2 broken amount of data, 60 lose amount of data and has an error percentage from data is 1.722%. And last for GPS sensor from 3600 amount of data, 3536 correct amount of data, 4 broken amount of data, 60 lose amount of data and has an error percentage from data is 1.778%. Of all the tests of each sensor will be taken average error and average squared error to find the RMS (root mean square).

$$\begin{aligned} RMS &= \sqrt{Average\ (E^2)} \\ &= \sqrt{3.1019} \\ &= 1.761 \end{aligned}$$

V. CONCLUSION

This paper presents an experimental work to monitor data acquisition of weather buoy by applying measurement sensors and wireless communication technology used in the weather buoy. Data acquisition of multiple sensors were sent through a wireless system. The testing was conducted in 1 hour with a delay time of a second. Results of wireless data acquisition system has differences with individual sensor reading. This occurs because at the time of testing each sensor, the microcontroller only process one sensor, while on the data acquisition system the microcontroller has to proceed all of the sensors installed. That is the cause of the broken data or lost data. The RMS error of each component is have range of 0.28-0.69 %. This range changes slightly when they were incorporated into the data acquisition system with the error of RMS 1.761% . However this was still in a good performance since the RMS error was less than 2%.

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