Design Review: Wireless Level

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1.0 Introduction

1.1 Statement of Purpose

There exists an urgent need on the market for a low-cost, low-power-consumption, accurate wireless level device. The current levels available to people in need today only fulfill some of the requirements, causing people trouble and making them inefficient when performing their jobs. The device that we propose to create will be inexpensive, but also provides a handheld receiver that will allow the user to monitor the level from distance away. We choose to focus on implementing a device that will improve work quality for workers.

1.2 Objectives

1.2.1 Goals

- Develop a device that accurately measures the tri-axis tilt level
- Implement a handheld device that will allow distant monitor of the level
- Device should be suitable for common working environments while providing long battery life.
- Device should be low cost, compact an, can be easily attached to any surface.

1.2.2 Functions

- Wireless communication between handheld receiver and level module.
- LCD display panel will display the tilt angles of the mounted surface

1.2.3 Benefits

- Low cost and low energy consumption in comparison to the only product on the market that provides similar features.
- Displays the tilt angle in 3 dimensions.
- User friendly.

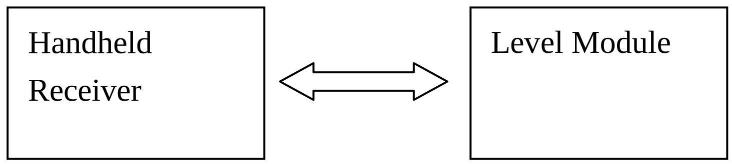
1.2.4 Features

- The device will allow up to 100 meters for monitor
- Batter lifetime up to half a year.
- The level module is waterproof and will able to sustain temperature from -10 to 50 degrees Celsius.
- Real time synchronization between receiver and level.

2.0 Design

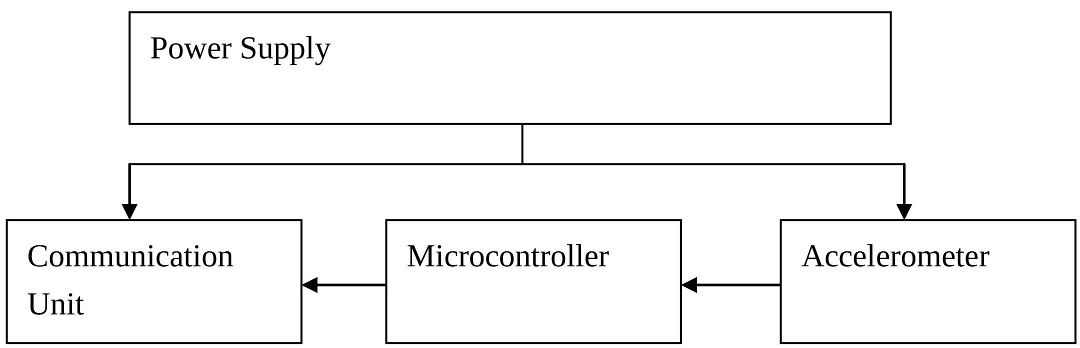
2.1 Block Diagram

Top View

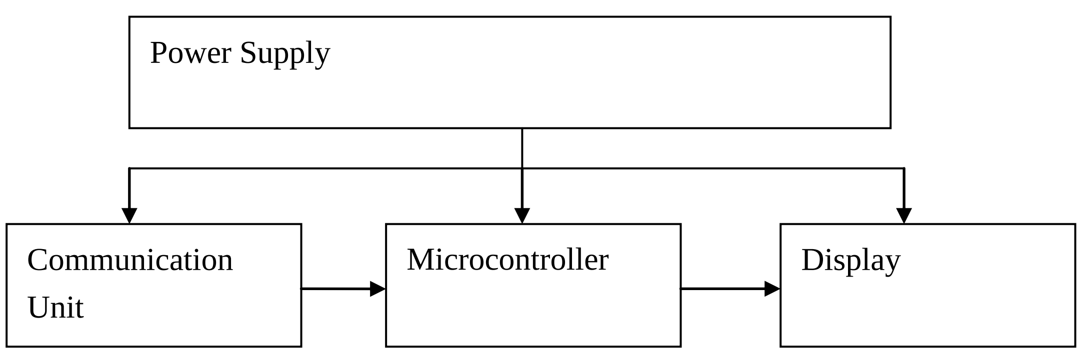


*connection between is wireless

Level Module



Handheld Receiver



2.2 Block Description

2.2.1 Level Module:

Overall Summary:

The Level module will be the measuring component of the system. It will determine the tilt level of the user's intended-to-balance surface, translate the analog data into digital and transmit it to the handheld receiver. It will consist of a MSP430, power supply, communications module, and an accelerometer.

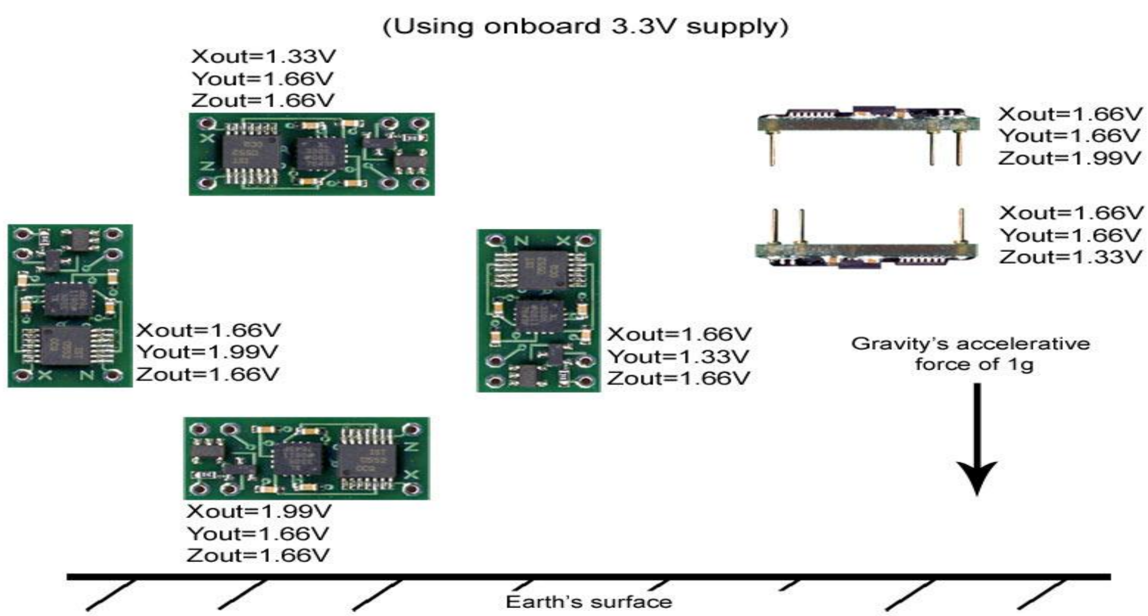
Case Design:

The primary objective is to allow sustainability in tough environments while providing accurate data. The design will be based on a black acrylic box sealed by waterproof sealant. The case will hold all of the Level module as well as the power supply. The box will have dimensions of 5 centimeter by 5 centimeter by 5 centimeter. The case can be attached to any kind of surface.

Accelerometer:

The accelerometer used in the Level Module will be the DE-ACCM3D buffered 3D accelerometer. This device will measure its tilt level using static acceleration, gravity, and outputting voltage amplitudes. The outputted voltage amplitudes will then be directed to the microcontroller for further process. The accelerometer will be powered by the power supply, which provides a constant 6V voltage to the device. The primary reason for choosing this particular accelerometer is that it provides accurate tri-axis tilt sensing.

The input voltage, Vcc, of the accelerometer can range from 3.5 volts to 15 volts. The output voltage Vx, Vy, and Vz, will be different based on the tilt angles measured using static acceleration, gravity, and orientation of the hardware in reference to the earth's surface. The voltage levels of the output are listed below. The voltage readings range from 1.33 volts to 1.99 volts with 1.66 being the "normal" orientation. The accelerometer will also provide power through a constant 3.3 volts regulator Vref.



(ref.1)

Microcontroller:

The microcontroller used in the Level Module will be the MSP430. This device is the primary control unit of the Level Module. The primary reason for using this device is the low power consumption, low cost, and versatile customization. Its objective is to translate analog input from the accelerometer into digital outputs to the communication module.

The MSP430 will be powered by the De-ACCM3D accelerometer, using the accelerometer's Vref output as its input voltage Vcc. The advantage of using the accelerometer's Vref as input is that Vref is regulated by De-ACCM3D to be a constant 3.3 volts with maximum current up to 50 mA, providing a reference voltage for the analog-to-digital conversion while providing voltage supply within the supply-voltage range of 1.8 volts to 3.6 volts that differs from the supply-voltage range of both the De-ACCM3D and the XBee.

Communication Unit:

The communication unit used in the Level Module will be the XBee. The Xbee transceiver will recognize and wirelessly communicate with its counterpart located in the handheld receiver. This part of the Xbee will be responsible for transmitting the digital output of the MSP430 to its counterpart. The primary reason for utilizing the Xbee transceiver is due to its low frequency high data transfer capability, low cost, and low power consumption.

Power supply:

The main purpose of this module is to provide constant DC voltage. A 9V battery will be used in this module.

2.2.2 Handheld Receiver Module:

Overall Summary:

The main purpose of this module is to display the wirelessly transmitted measurements of the Level Module and to display it on a LCD screen. It consists of a microcontroller, a communication unit, a power supply, a power switch, and a display unit. The LCD will display the tilt level in the x-axis, y-axis, and z-axis required. This module is connected wirelessly with the Level Module.

Power supply:

The main purpose of this module is to convert the battery voltage in to a constant 3.3 DC voltage. A 9V battery for the power supply and A DC voltage regulator UM78M33C will be used in this module.

Communication Unit:

The communication unit used in the Receiver Module will be the XBee ZB. The XBee receiver will recognize and wirelessly communicate with its counterpart located in the Level Module. This part of the Xbee will be responsible for receiving the digital output from its counterpart and directed to the microcontroller in the Receiver Module. The primary reason for utilizing the Xbee transceiver is due to its low frequency high data transfer capability, low cost, and low power consumption.

Microcontroller:

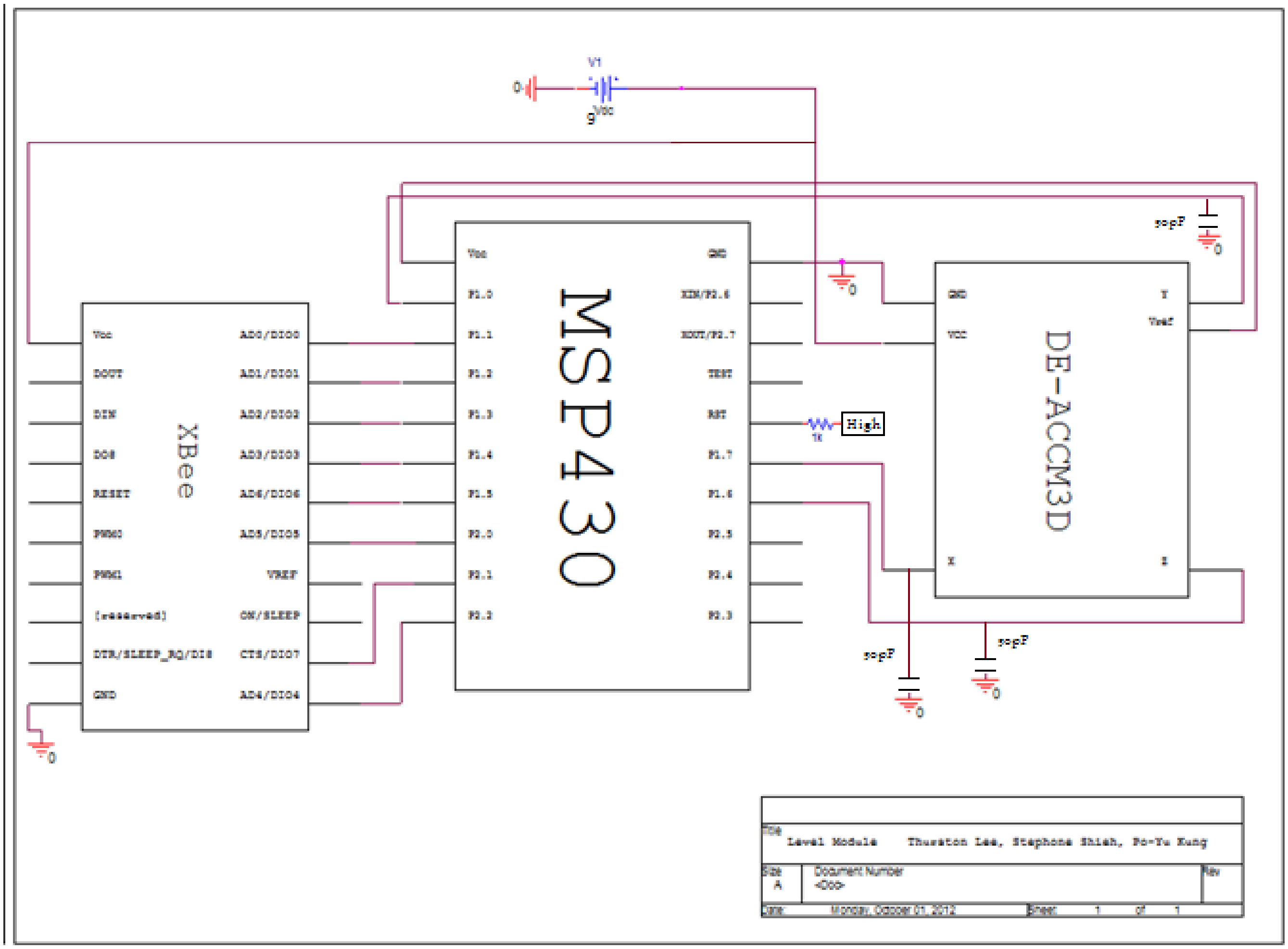
The microcontroller used in the Receiver Module will also be the MSP430. This device is the primary control unit for the Receiver Module where it will be responsible for translating the digital output from the XBee into signals for the LCD display.

Display:

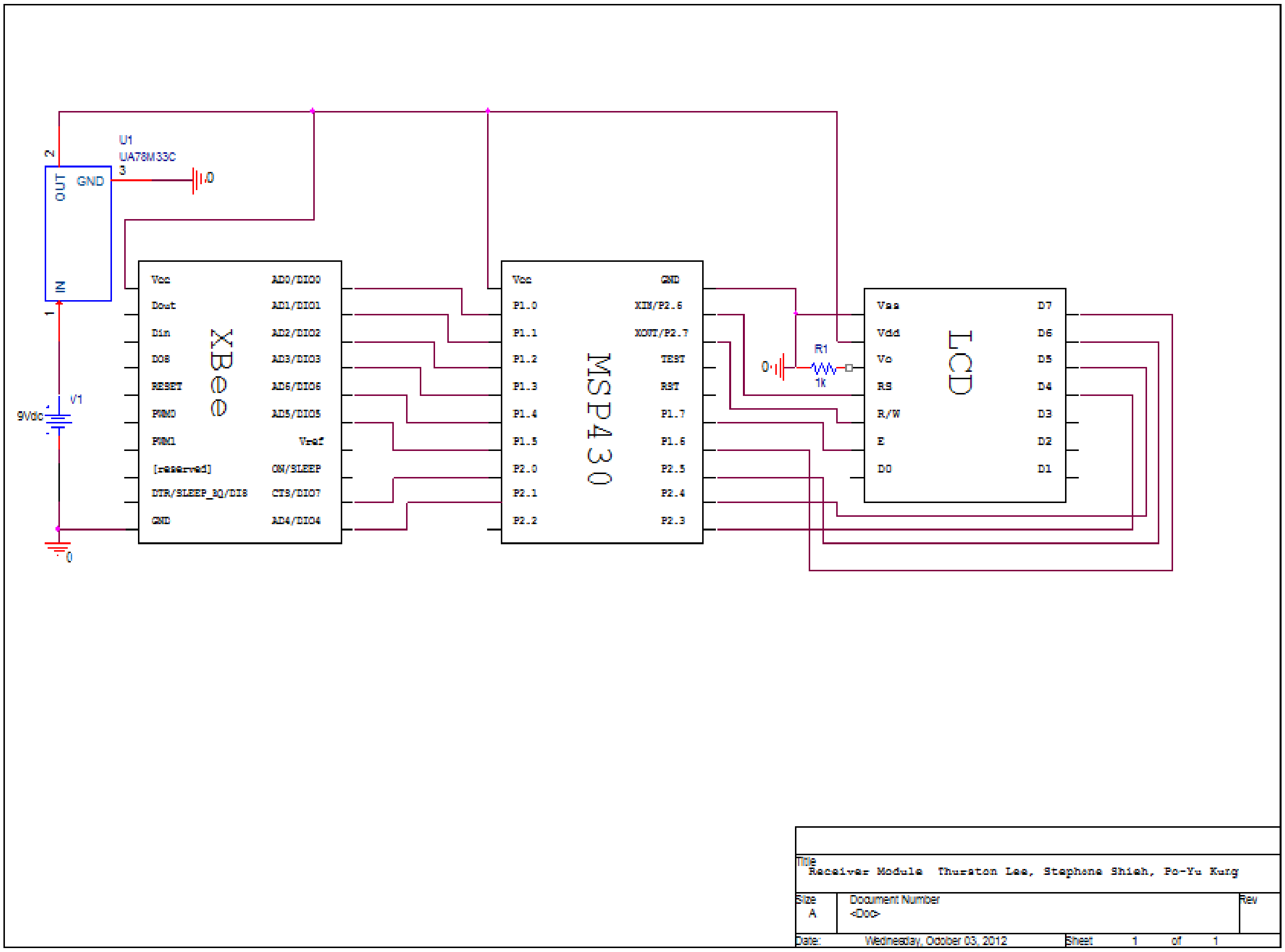
The display used in the Receiver Module will be the hitachi HD 44780 dot matrix LCD module. This certain LCD display allows 2 lines of 16 character disaply. The screen will take inputs from the microcontroller and display it on the screen for user. It will display the tilt angles of the x-axis, y-axis, and z-axis, and temperature on screen and will be simultaneously change in accordance to the current condition of the Level Module.

2.3 Schematic

2.3.1 Level Module



2.3.2 Handheld Receiver Module



2.4 Flow Chart

2.4.1 Instruction Sets

Instruction sets for Microcontrollers

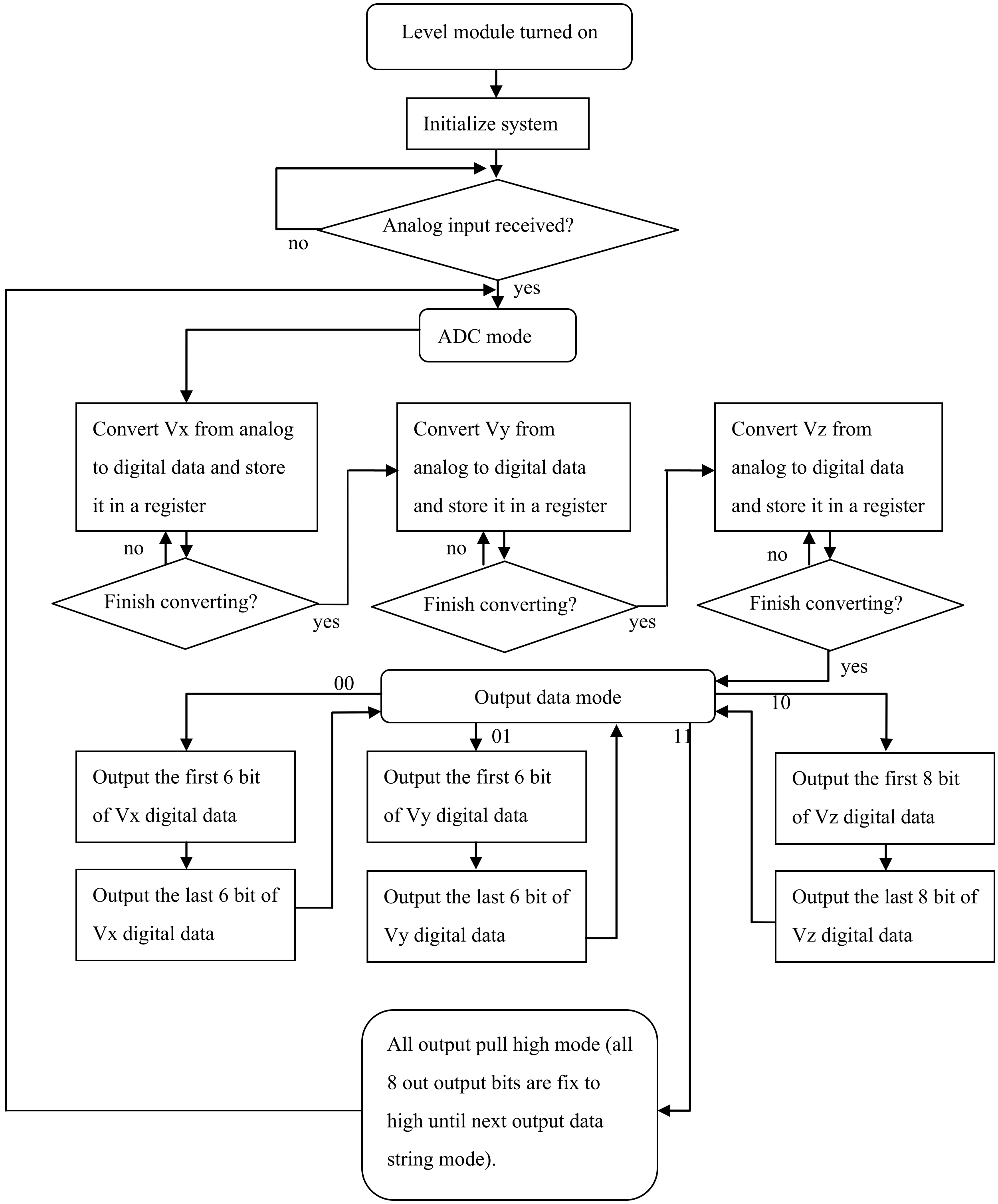
Transfer signal bits	I	D6	D5	D4	D3	D2	D1	D0
Initialize Mode	1	1	1	1	1	1	1	1
ADC Mode	1	1	1	1	1	1	1	1
Output data mode	1	0	0	0	0	1	0	0
Output data mode (Vx)	1	0	0	0	0	0	0	0
Output data mode (Vy)	1	0	0	0	0	0	0	1
Output data mode (Vz)	1	0	0	0	0	0	1	0
Output data mode (done)	1	0	0	0	0	0	1	1
Vx first 6 bits	0	1	X11	X10	X9	X8	X7	X6
Vx last 6 bits	0	0	X5	X4	X3	X2	X1	X0
Vy first 6 bits	0	1	Y11	Y10	Y9	X8	Y7	Y6
Vy last 6 bits	0	0	Y5	Y4	Y3	Y2	Y1	Y0
Vz first 6 bits	0	1	Z11	Z10	Z9	Z8	Z7	Z6
Vz last 6 bits	0	0	Z5	Z4	Z3	Z2	Z1	Z0

Instruction sets for LCD HD44780

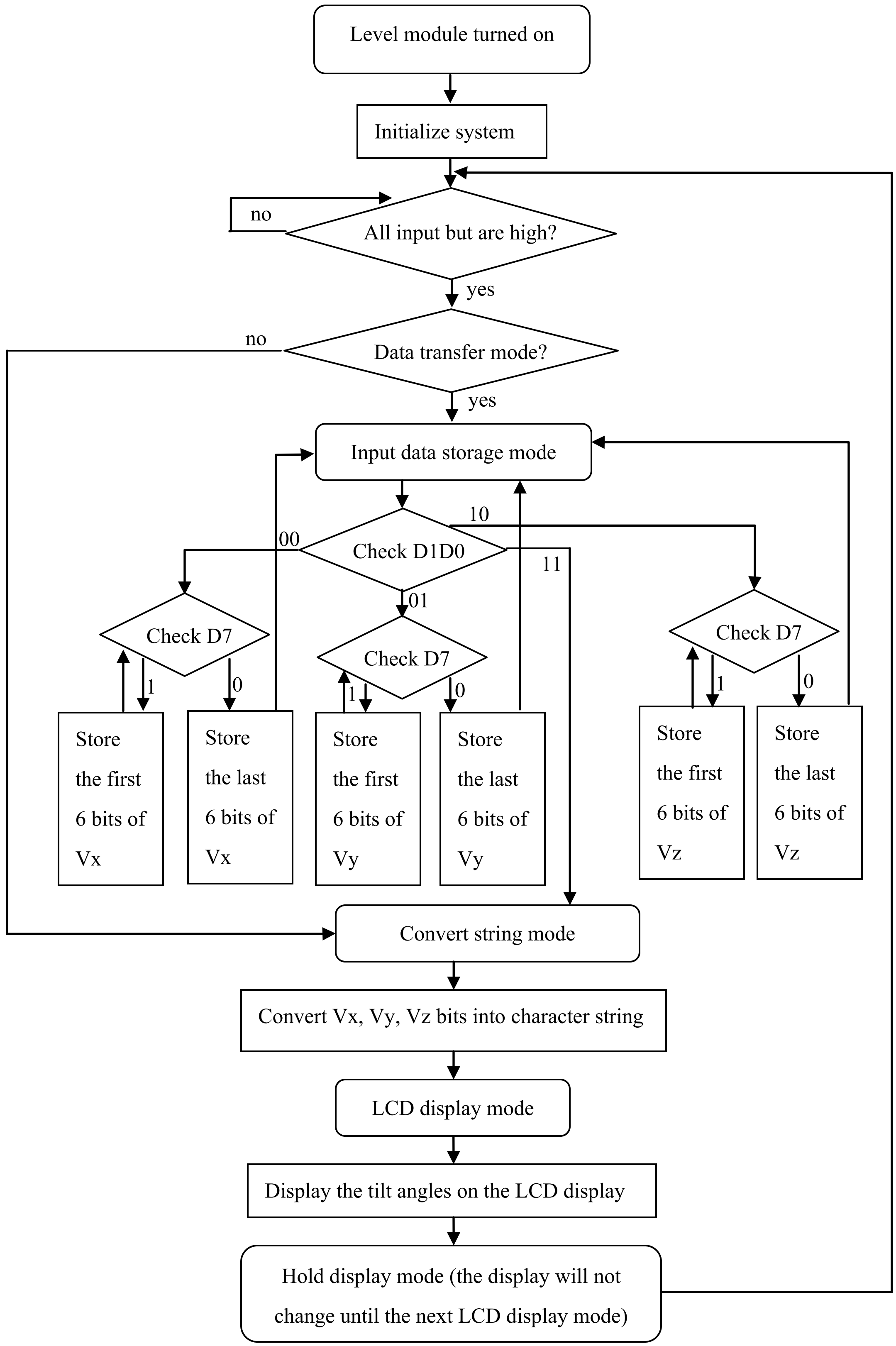
FUNCTION	WRITE	D7	D6	D5	D4	D3	D2	D1	D0	WAIT TIME
Clear Display	Instruction	0	0	0	0	0	0	0	1	5 ms after write
Cursor Home	Instruction	0	0	0	0	0	0	1	N/A	5 ms after write
Entry mode	Instruction	0	0	0	0	0	1	I/D	S	120 µs
Display on/off	Instruction	0	0	0	0	1	D	C	B	120 µs
Cursor & display shift	Instruction	0	0	0	1	S/C	R/L	N/A	N/A	120 µs
Function set	Instruction	0	0	1	DL	N	F	N/A	N/A	120 µs
Set cursor address	Instruction	1	A	A	A	A	A	A	A	120 µs
Write data to cursor location	Data	D	D	D	D	D	D	D	D	120 µs

http://www.df.unipi.it/~flaminio/laboratori/pdf_files/hd44780.pdf

2.4.2 Level module microcontroller



2.4.3 Receiver Module microcontroller



3.0 Test and Verification

3.1 Requirements and Verification

In order to have this project working, there is a vital requirement for all of the components to function properly. The table below lists both the requirements and requirement verifications of each component in this project

	Requirements	Verifications
De-ACCM3D	1. The measured voltage of Vx, Vy, and Vz must, after calculation, match the current xyz level of the hardware. 2. Stable and constant 3.3 volts Vref	1. Labview will be used to measure the voltage. A. the magnitude of the output voltages will be first be simulated based on different Vcc. Vx, Vy, Vz will be observed and should remain within the ranges of 1.33 volts to 1.99 volts regardless of input voltage level. B. The device will be placed at 30, 45, and 90 degrees angle in all three orientations and the voltage outputs will be collected. The collected voltages should match, after calculation, the angles. 2. Labview will be used to measure the voltage. A. Vref will be measured over a long period with constant voltage input. B. Vref will be measured over a long period with varying voltage inputs. C. Vref will be measured over a long period with different load resistances, ranging from 330 ohms to 1000 ohms. A

Accelerometer to MSP430 (Level Module)	1. Correctly converts the analog inputs in to digital signals. 2. Correctly transfer the digital signals in to a digital output string in order for communication.	1. Program the msp430 to output 1 set of digital signals. 2 binary bits are used for identifying the converted axis, and 12 binary bits are used for representing the angle. The msp430 is programmed to make 1 receive analog signal in to 14 binary bits. The output digital signals are tested by LEDs. 2. Program the msp430 to output a string of digital signals with 3 analog inputs. The programmed clock cycle will be made very slow for observation. LEDs are used at output for observation. 3. Program the MSP430 to output a known analog signal. 4. Connect the MSP430 to an oscilloscope and see whether the signal shown matches the signal that we programmed.
MSP430 to Xbee (transmission)	1. Xbee receives the data from MSP430 and is capable of transmitting the data to its counterpart in the handheld receiver level. 2. Ensure the Xbee is capable of correctly transmitting the data stream to its counterpart.	1. Program the MSP430 such that when a switch is turned on, a digital high signal will be inputted to the Xbee. The Xbee will then communicate with its counterpart in the handheld receiver module. To check whether the communication is effective, we would connect an LED to the Xbee in the handheld receiver and it will light up when the switch is turned on, vice versa. 2. Program the MSP430 to transform analog inputs into a string of digital outputs (8 bits) and slow down the

		clock cycle to observe the output of the Xbee (handheld receiver) with LED.
MSP430 to Xbee (receiving)	1. Correctly convert the digital string into 3 sets of 16 bits of digital data that represents the 3 tilt angles. 2. Convert the 3 sets of digital data into three angles corresponding to the tilt in the x, y, and z axis.	1. Program the MSP430 such that if we feed it an input string it would be stored in the registers. We will then output the stored data in registers to LEDs to examine whether it matches with the fed input. 2. Program the MSP430 to convert the digital inputs to analog outputs.
MSP430 to LCD (receiving)	1. See whether the LCD can output the desired string of characters. 2. See whether the LCD can output the tilt angles.	1. Program the MSP430 to output character string "Hello world!" The LCD should display this string correctly. 2. Program the MSP430 such that it stores the digital data in the register and see whether it can convert the digital data into tilt angles and outputted to the LCD. We will check whether the angle is correct by using the formula sheet provided by the accelerometer package.
Xbee	1. Test the Xbee for the distance of communication. 2. Test the Xbee under various environment to ensure the quality of communication.	1. We would be testing the Xbee all the way up to 100m. 2. We would test the Xbee in both outdoor and indoor. For outdoor, we will do the testing on the quad. For indoor, we will perform the testing in the Everitt Lab. We will also be testing it in the underground tunnel in the Chemistry annex.
MSP430	1. Test the MSP430 to see if not broken	1. Connect to computer through launchpad and check if broken or

		not
LCD	1. Test if LCD screen works or not	1. Power on the LCD and see if it works or not

3.2 Tolerance Analysis

1. It is extremely vital for the accelerometer of our project to function within tolerance level in order to ensure accurate measurements. The tolerance of the accelerometer's measurements should be within 2% of the actual tilt angle. The tolerance level will be affected by the amount of decimals taken from the voltage outputs of Vx, Vy, and Vz. This tolerance will be met by taking enough decimals places from the voltage outputs.

2. The communication modules are also of extreme importance. It will be important for us to fully test the capabilities of the XBees in all types of environmental scenarios. There will be two main tests for the Xbees: the distance test and the interference test. The distance test will be measuring the XBee transmission through incremental distance. The interference test will include testing the XBee transmission at various locations. Locations such as Everitt Lab, the underground tunnels at Chem Annex will provide useful test results due to the high similarities between them and the actual places this device will be used.The tolerance distance of the XBee after interferences should be at least 90% of the given specifications of the certain XBee that we are utilizing in this project, which 100m*0.9=90m. The Xbee should be able to work from 0m to at least 90m.

3.3 Simulations

Accelerometer

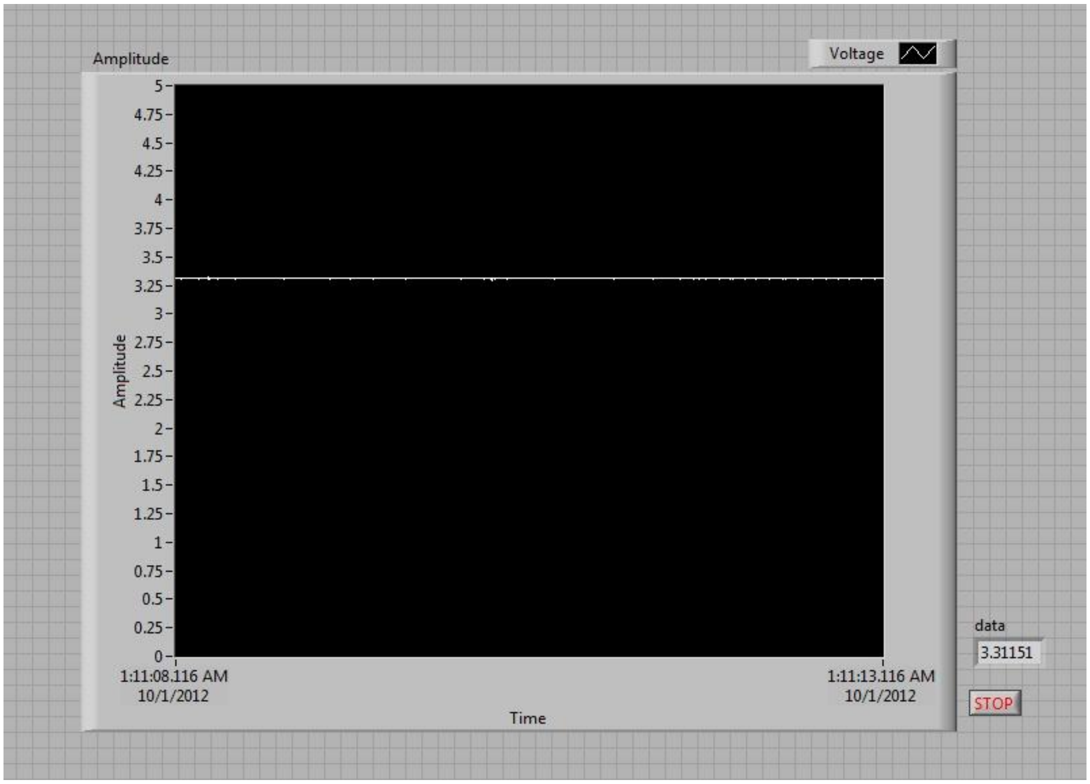
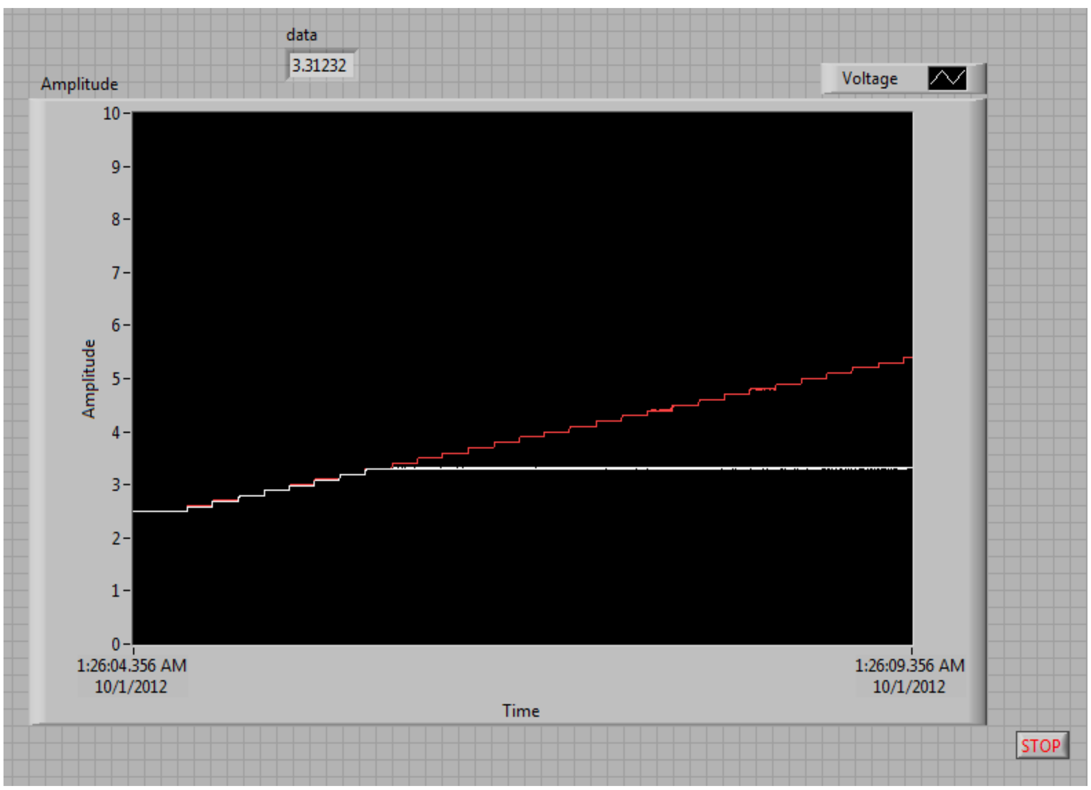


Fig.1.

Vref of DE-ACCM3D relatively constant at 3.3V

Fig.2.

Vref matches Vcc when Vcc is less than 3.3V and remains constant at 3.3V when Vcc is over 3.3V.



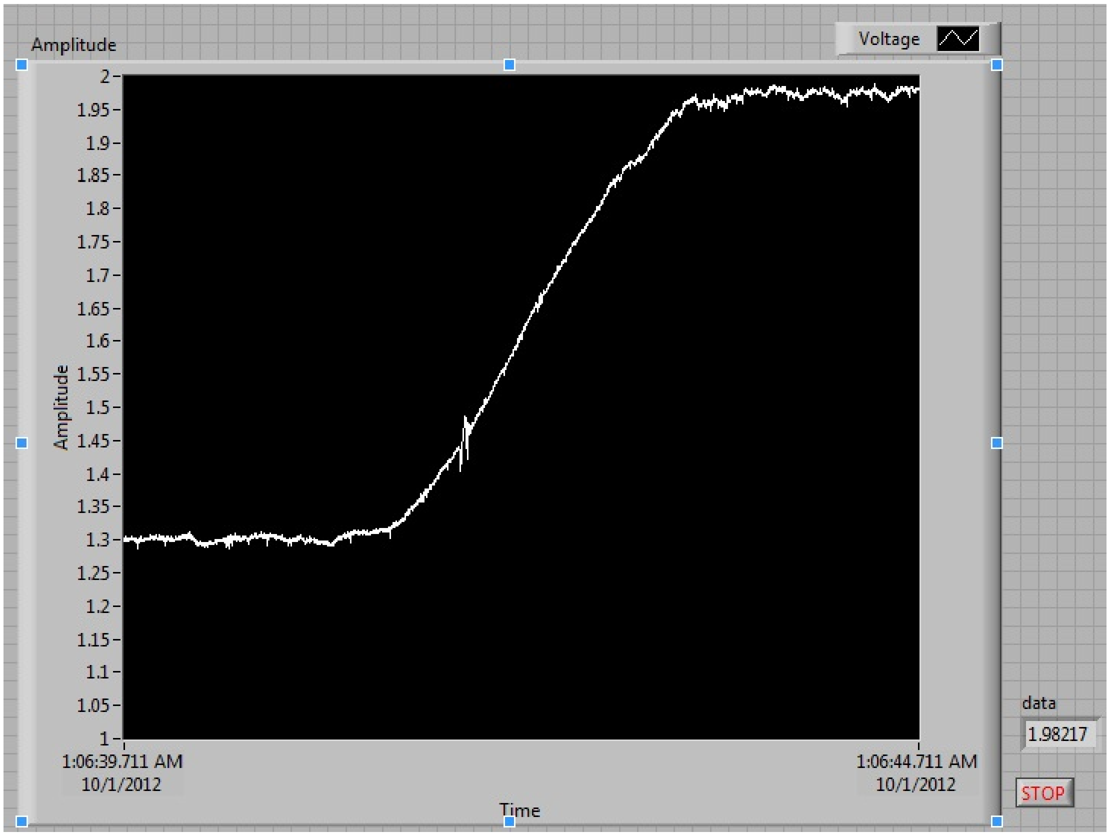


Fig.3

Vx, Vy, Vz will fluctuate from 1.3 volts to 1.99 volts based on -9. Degress to 90 degrees

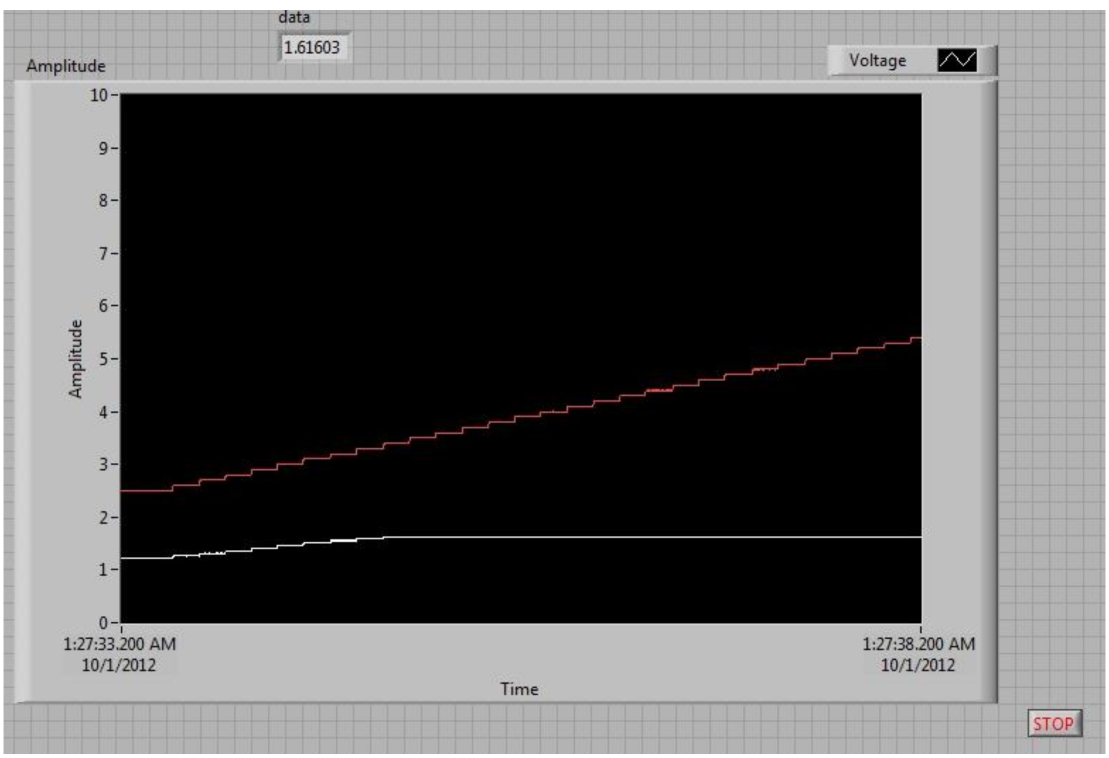


Fig.4 Vx, Vy, Vz remains constant at 1.66 regardless of Vcc change.

(ref: http://www.dimensionengineering.com/datasheets/DE-ACCM3D.pdf)

Power module simulations

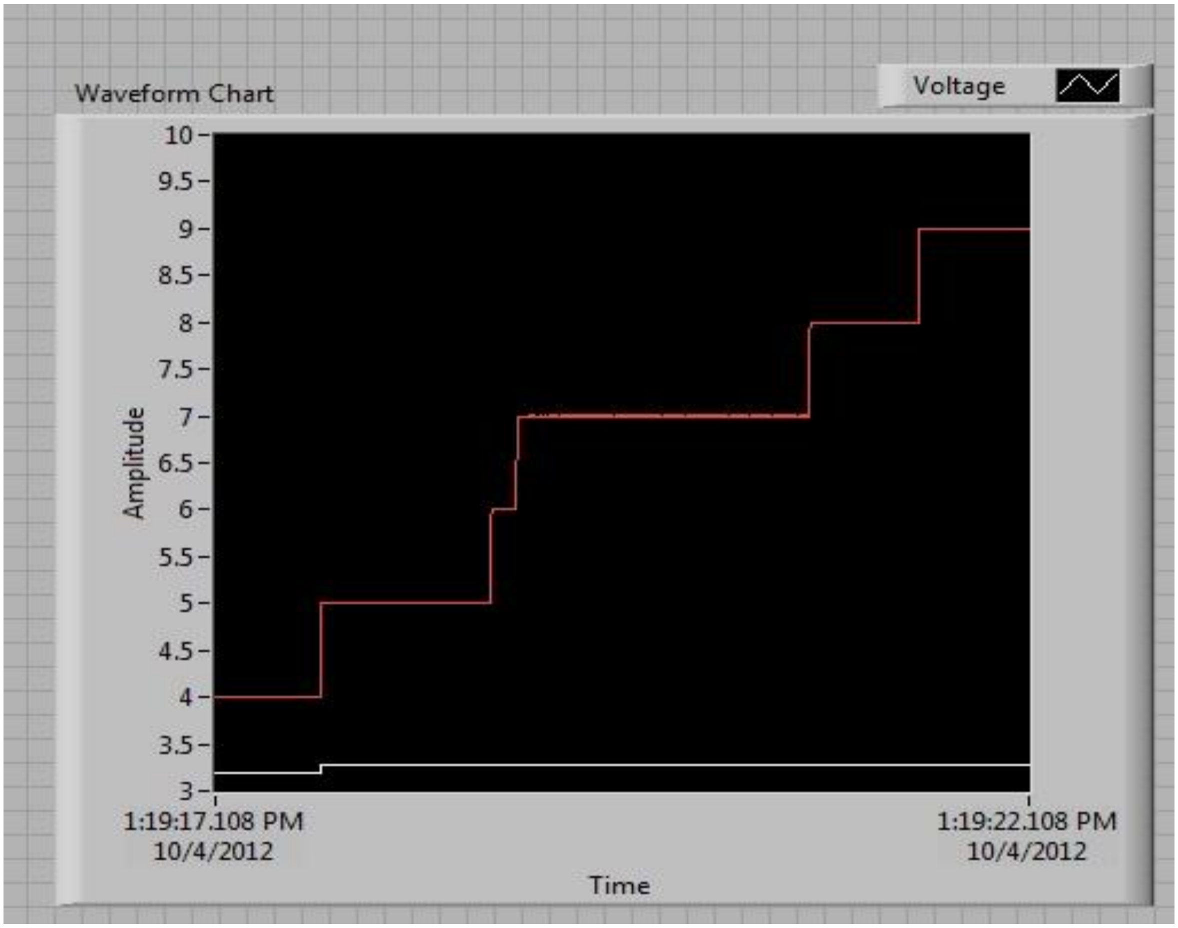


Fig.5 Vout is steady at 3.3V regardless of Vin change.

4.0 Cost Analysis and Schedule

4.1 Cost Analysis

4.1.1 Labor

Name	Hourly Rate	Total hour Invested	Total cost
Stephone Shieh	$35.00	150	$13,125
Thurston Lee	$35.00	150	$13,125
Po-Yu Kung	$35.00	150	$13,125
Total	$135.00	450	$39,375

4.1.2 Parts

Item	Quantity	Cost($)
Voltage regulators	2	8.00
Resistor, Capacitor, Diode		5.00
LCD Display	1	15.00
MSP-EXP430G2	1	5.00
Accelerometer	1	35
Wireless Units	2	100
Total		168

4.1.3 Grand Total

Section	Total
Labor	39375.00
Parts	168.00
Total	39543.00

4.2 Schedule

Date:	Thurston Lee	Po-Yu Kung	Stephone Shieh
9/16~9/22	Order Components	Finalize proposal	Research components
9/23~9/29	Accelerometer testing/design	Finalize design review	Microcontroller design
9/30~10/6	Program MSP430 (Receiver Module) – receiving inputs	XBee Testing/Design	Program MSP430 (Level Module) – receiving inputs/translating inputs
10/7~10/13	Program MSP430 (Receiver Module) – outputting to LCD	LCD Testing/Design	Program MSP430 (Level Module) – outputting to XBee
10/14~10/20	Test MSP430 (Receiver Module)	Program XBee XBee tests and simulations	Test MSP430 (Level Module)
10/21~10/27	Test receiver module	Design and build cases/ Test cases for durability and sustainability and integrate device into cases	Test level module
10/28~11/3	Work on design and introduction section in final report	Work on economic analysis and schematic section in final report	Work on schematic design and verification section in final report
11/4~11/10	Work on mock presentation	Work on mock demo	Work on mock demo and mock demo
11/11~11/17	Fix communication unit bugs	Fix display unit bugs	Fix microcontroller bugs
11/18~11/24	Presentation	Presentation	Presentation
11/25~12/1	Work on communication and accelerometer analysis	Work on economic and power consumption analysis	Work on microcontroller analysis
12/2~12/8	Demo + finalize paper	Demo + finalize paper	Demo + finalize paper
12/9~12/15	Turn in paper do presentation	Turn in paper do presentation	Turn in paper do presentation

5.0 Ethical Issues

We ensure that we will comply with the standards of the IEEE Code of Ethics

Ethic	
1. to accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment	Using our project will not create harm to the safety, health, and welfare of the public through inconsistent data output that might lead to dangerous actions.
2. to avoid real or perceived conflicts of interest whenever possible, and to disclose them to affected parties when they do exist	All of our design and data will be available for public view.
3. to be honest and realistic in stating claims or estimates based on available data	We will not falsify data through programming simplifications. We will also give credit, and cite our sources whenever sources are used through IEEE citation.
4. to reject bribery in all its forms	We will not be bribed. We will design our products based on the best solution instead of choosing parts or designs based on bribery.
6. to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others	We will seek and accept criticism of technical work from all to ensure an error-free product. We will also credit properly the contributions of others.
7. to treat fairly all persons regardless of such factors as race, religion, gender, disability, age, or national origin	All will be treated fairly regardless of personal factors. The product that we intend on pursuing will be a product for all.
8. to avoid injuring others, their property, reputation, or employment by false or malicious action	We will avoid injuring others, their properties, reputation through any usage of our product.

6.0 References

1. http://www.dimensionengineering.com/datasheets/DE-ACCM3D.pdf
2. http://www.df.unipi.it/~flaminio/laboratori/pdf_files/hd44780.pdf
3. http://www.digi.com/products/wireless-wired-embedded-solutions/zigbee-rf-modules/point-multipoint-rfmodules/xbee-series1-module#overview
4. http://pdf1.alldatasheet.com/datasheet-pdf/view/82072/TI/UA78M33C.html