SMART WALK FOR THE VISUALLY IMPAIRED

Dissertation submitted in fulfillment of the requirements for the Degree of

BACHELOR OF TECHNOLOGY

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

By

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JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY, WAKNAGHAT

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DECLARATION BY SCHOLARS

We hereby declare that the work reported in the B-Tech thesis entitled **“Smart Walk for the Visually Impaired”** submitted at **Jaypee University of Information Technology, Waknaghat India,** is an authentic record of our work carried out under the supervision of **Mr. Munish Sood**. We have not submitted this work elsewhere for any other degree or diploma.

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26.05.2016

SUPERVISOR'S CERTIFICATE

This is to certify that the work reported in the B-Tech. thesis entitled "**Smart Walk for the Visually Impaired**", submitted by **Baiza Sajjad, Shalini Dogra and Swati Tiwari** at **Jaypee University of Information Technology, Waknaghat**, **India,** is a bonafide record of their original work carried out under my supervision. This work has not been submitted elsewhere for any other degree or diploma.

Mr. Munish Sood

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26.05.2016

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ABSTRACT

The thesis we are reporting here is part of our effort to develop a navigation system for the blind. Our long-term goal is to create a portable, self-contained system that will allow visually impaired individuals to travel through familiar and unfamiliar environments without the assistance of guides. This system aims at making a visually impaired person independent and swifter. Generally, the visually impaired people use a stick to avoid collisions and to locate the obstacles that come their way. But due to certain limitations, these sticks prove to be less efficient and frequent injuries are caused to the blind. To reduce the chances of any such injuries to the blind, this stick can be installed with some electronics equipments that work together to help the blind by making her/his journey easier, more comfortable and less prone to injuries.

The system, as it exists now, consists of the following functional components: (1) a module for determining the obstacles in the traveler's path, (2) a module for determining the edges and downfalls in the traveler's path, (3) a module for fall detection of the stick of the blind person. The traveler is given sound alerts by a buzzer whenever she/he encounters an obstacle. Also to help her/him find the fallen stick, a melody is produced by the buzzer. On finding the fallen stick, the melody can be stopped by pressing a button on the device.

LIST OF ACRONYMS / ABBREVIATIONS

A/D	Analog to Digital
API	Application program interface
AREF	Analog Reference
Db	Decibel
DC	Direct Current
ETA	Electronic Travel Aids
GND	Ground
GPIO	General-purpose input/output
GPS	Global Positioning System
HTTP	Hyper Text Transfer Protocol
I/O	Input/Output
I2C	Inter-Integrated Circuit
ICSP	In-Circuit Serial Programming
IOREF	Input Output Reference
IoT	Internet of Things
LED	Light Emitting Diode
MHz	Mega Hertz
MISO	Master In Slave Out
MOSI	Master Out Slave In
N/C	Not Connected
OTG	On-The-Go
PSTN	Public switched telephone network
PWM	Pulse width modulation
RX	Receiver
SCK	Clock signal
SCL	Clock line
SD	Secure Digital
SDA	Data line
SPI	Serial Peripheral Interface
TTL	Transistor Transistor Logic

TX	Transmitter
UART	Universal asynchronous receiver/transmitter
VBX	Visual Basic Extension
VIN	System Input Power
WHO	World Health Organization

LIST OF SYMBOLS

kΩ	kilo ohm
µs	micro seconds
m/s	meter per second
cm/ µs	centimeter per microsecond
G	Gravitational acceleration
V	Volt
mA	mili Amperes
Ft	Feet
mm	mili meter
kHz	kilo Hertz
Cm	Centimeter
F	Farad

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CHAPTER 1

INTRODUCTION

Figure 1.1: Visually impaired person with the walking cane

Artificial Vision is the most important part of human physiology as 83% of information human being gets from the environment is via sight. The statistics by the World Health Organization (WHO) in 2011 estimate that there are 285 billion people in the world with visual impairment, 39 billion people are blind and 246 are with low vision. The oldest and traditional mobility aids for persons with visual impairments are the walking cane (also called white cane or stick) and guide dogs. The drawbacks of these aids are small range of motion and very little information conveyed. With the rapid advances of modern technology, both in hardware and software front, there is potential to provide intelligent navigation capabilities. Recently there have been a lot of Electronic Travel Aids (ETA) designed and devised to help the blind people to navigate safely and independently. As engineers, it is our responsibility to develop technology to help them. Our vision is to design a project based on a blind person navigation system which would be easy to use and would cut down on cost.

We have used an embedded device which detects obstacles like walls, vehicles etc. The embedded device makes use of ultrasonic sensors. The disadvantage of using a single ultrasonic sensor is that the range is quite narrow. So we have used two ultrasonic sensors that not only widen the range but provide approximation of the region of obstacles. Also to detect elevations or downfalls, we have used edge detection with the help of ultrasonic sensor. The microcontroller that we have used is Intel Edison. The embedded device also includes a buzzer that makes sounds for obstacles in way. We are using ultrasound in our guidance system because of its immunity to the environmental noise. Another reason why ultrasonic sensor is popular is that it is relatively inexpensive, and also the ultrasound emitters and detectors are small enough to be carried without the need for complex circuitry. Apart from the conventional navigation systems, a blind aid system can be provided a new dimension of real time assistance and artificial vision along with dedicated obstacle detection circuitry.

The project makes use of accelerometer embedded on the stick for detecting whether the stick has fallen or not. Also live corrections are given to the user using buzzer.

CHAPTER 2

HARDWARE

2.1 INTEL EDISON

The Intel Edison is a tiny computer-on-module offered by Intel as a development platform designed to lower the barriers to entry for a range of Inventors, Entrepreneurs and consumer product designers to rapidly prototype and produce IoT and wearable computing products.

Development Boards:

- Arduino Board
- Intel Breakout Board
- Modulowo Board

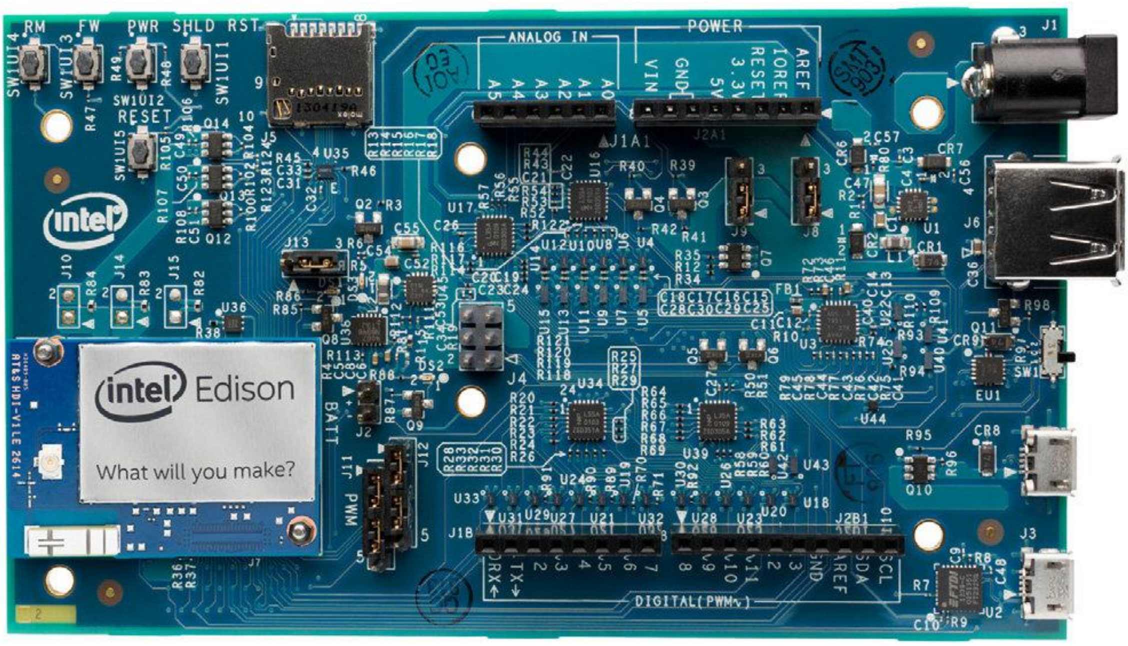

Figure 2.1: The Intel Edison Board

2.1.1 ARDUINO BOARD

EDISON FUNCTIONAL DESCRIPTION

The Intel Edison kit for Arduino expansion board is designed to be hardware and software pin-compatible with Arduino shields designed for the Uno R3. Digital pins 0 to 13 (and the adjacent AREF and GND pins), analog inputs 0 to 5, the power header, ICSP header, and the UART port pins (0 and 1) are all in the same locations as on the Arduino Uno R3. This is also known as the Arduino 1.0 pinout. Additionally, the Intel Edison kit for Arduino board includes a micro SD card connector, a micro USB device port connected to UART2, and a combination micro USB device connector and dedicated standard size USB 2.0 host Type-A connector (selectable via a mechanical micro switch).

The Intel Edison kit for Arduino digital signals can be configured as input or output. When programmed as an input, a GPIO can serve as an interrupt. The Intel Edison board's 1.8 V I/O are translated to 3.3 or 5 V using SN74LVC1T45 dual supply bus transceivers with 3 state outputs. Both outputs go tri state if either supply rail is at ground. The port direction is referenced to VCCA. The drive level for the transceiver is: ±4 mA at 1.8 V, ±24 mA at 3.3 V, and ±32 mA at 5 V.

The four PWM sources are wired to a PWM "swizzler". This pin header arrangement allows the four PWM sources to be routed to any four of the six Arduino header pins.

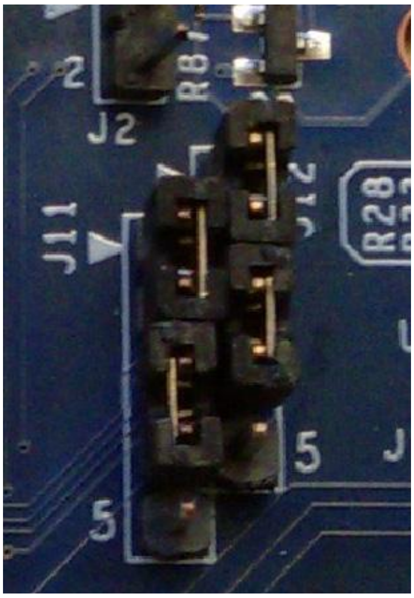

Figure 2.2: PWM swizzler on the Intel Edison board

INTEL EDISON KIT FOR ARDUINO ANALOG INPUTS

The analog inputs are fed to an ADS7951 A/D converter. This device has the following features:

- 20 MHz clock rate
- 12-bit A/D conversion
- 1 MHz sample rate
- 70 dB signal to noise ratio
- 0 to 2.5 V or 0 to 5 V input range (select either AREF or IOREF via jumper J8 onboard)

The analog inputs are multiplexed with digital I/O using SN74LVC2G53 analog switches. These switches isolate the digital I/O from the analog input to prevent crosstalk. The SN74LVC2G53 also has an inhibit pin that places the I/O in a tri state condition. The switch also has low on state resistance of 15 ohm at 4.5 V VCC.

INTEL EDISON KIT FOR ARDUINO SIGNAL PULLUP RESISTORS

The analog and digital pins can be configured to have an external pull-up resistor connected. The pullup value is fixed at 47 kohm.

INTEL EDISON KIT FOR ARDUINO USB INTERFACE

The Intel Edison module has a single USB 2.0 interface. This interface is the primary method for downloading code. The Intel Edison board is designed to support OTG, using the ID signal. Circuitry on the Intel Edison kit for Arduino board uses a USB multiplexer, and an external switch to configure the USB interface as a host port or device port.

INTEL EDISON KIT FOR ARDUINO POWER SUPPLY

The Intel Edison board is a low power device. In general it will not draw more than 200 mA (approximately 430 mA when transmitting over Wi-Fi) from the main power source. Therefore, an Intel Edison device may run on USB power (when configured as a device), or off an external power adapter from 7 to 15 V.

Power from the external power adapter goes to a DC-DC converter and down converted to 5V. This power goes to a DC-DC converter which down converts the power to 4.4 V. The charger IC is configured to detect the input power source, and to limit the input power to either 500 mA (if connected to USB micro B port) or up to 1 A if connected to the DC power jack.

BUTTONS

The Intel Edison module has the following buttons:

• **System reset.** Pressing the system reset button (SW1UI5) will reset the Intel Edison board, and reset the I/O expanders, setting all the shield pins to high impedance state with no pullups.

• **Shield reset.** Pressing the shield reset button (SW1UI1) will pull the shield signal reset to the active low state. It does not affect the state of the Intel Edison module nor its I/O.

• **Power button.** The power button (SW1UI2) is configured by software. In general, pressing and holding this button will cause the Intel Edison module to power down. (It will leave the I/O configuration in the port expanders in its current state.) Pressing this button momentarily when the Intel Edison board is powered down (but power is still applied) will cause the Intel Edison module to reboot. If the Intel Edison board is running, then a momentary press will cause the Intel Edison board to go into low power sleep mode. Pressing the button momentarily when the Intel Edison board is asleep, will bring the Intel Edison board into full power mode. We must press and hold SW1U15 for 8 seconds to reset the Intel Edison board. Pressing the reset button for 4 seconds will restart the Intel Edison board.

2.1.2 INTEL EDISON BREAKOUT BOARD

The Edison Breakout board is for non-Arduino users. This breakout board has a minimalistic set of features and is slightly larger than the Edison module.

Board I/O:

▪Exposes native 1.8V I/O of the Edison module

▪.1” grid I/O array of through-hole solder points

▪USB OTG with USB Micro Type-AB connector

▪USB OTG power switch

▪Battery Charger

▪USB to device UART bridge with USB Micro Type-B connector

▪DC power supply jack (7V –15V DC input)

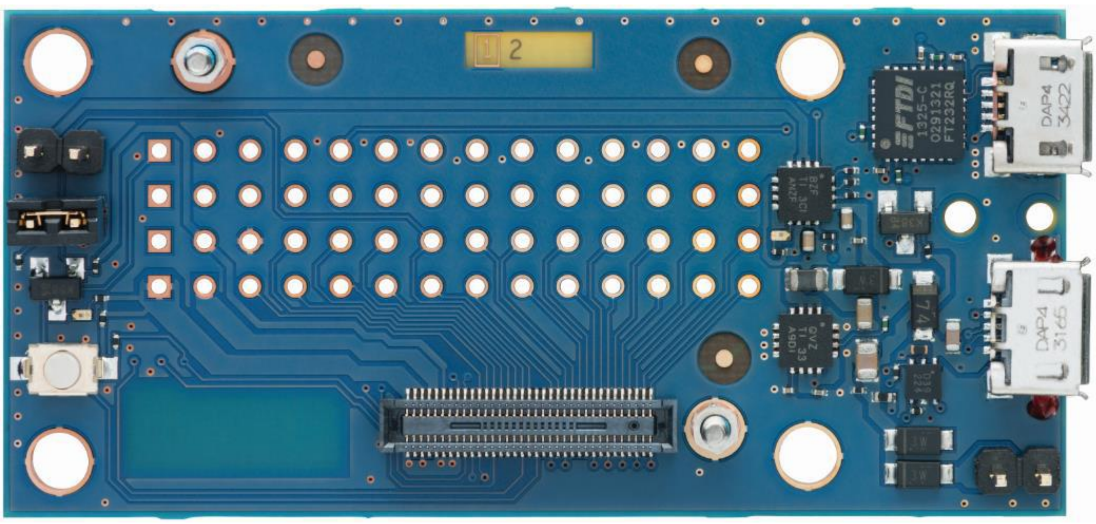

Figure 2.3: Inside view of Intel Edison Breakout Board

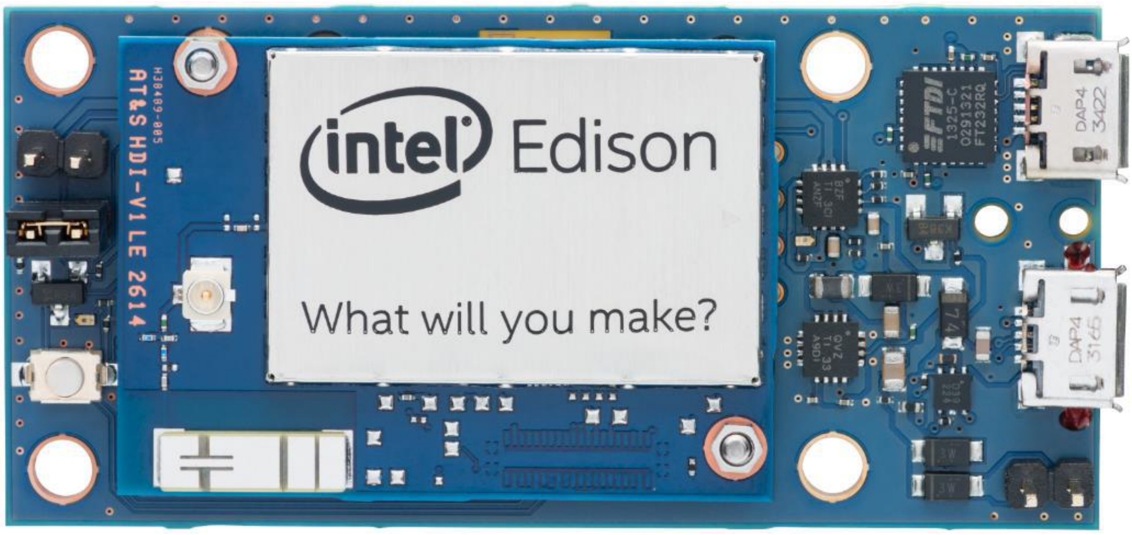

Figure 2.4: Intel Edison Breakout Board

2.1.3 MODULOWO BOARD

In October 2015, Modulowo published information about the development kit Modulowo Explore E for Intel Edison. Development Board allows for quick prototyping and designing new solutions and adding sensors, controllers lights, motor drivers, GPS modules, communication modules and more.

2.2 ULTRASONIC SENSOR

Figure 2.5: Ultrasonic Sensor HC SR-04

The HC-SR04 ultrasonic sensor uses sonar to determine distance to an object like bats or dolphins do. It offers excellent range of accuracy and stable readings in an easy-to-use package. Its operation is not affected by sunlight or black material. It is cheaper than infrared sensor.

Table 2.1: Feature of HC SR-04

Power Supply	+5V DC
Quiescent Current	<2mA
Working Current	15mA
Effectual Angle	<15°
Ranging Distance	2cm – 400 cm/1″ – 13ft
Resolution	0.3 cm
Measuring Angle	30 degree
Trigger Input Pulse width	10uS
Dimension	45mm x 20mm x 15mm

Pins

- VCC: +5VDC
- Trig : Trigger (INPUT)
- Echo: Echo (OUTPUT)
- GND: GND

These devices work on a principle similar to that of transducers used in radar and sonar systems, which evaluate attributes of a target by interpreting the echoes from radio or sound waves, respectively. Active ultrasonic sensors generate high-frequency sound waves and evaluate the echo which is received back by the sensor, measuring the time interval between sending the signal and receiving the echo to determine the distance to an object. Passive ultrasonic sensors are basically microphones that detect ultrasonic noise that is present under certain conditions, convert it to an electrical signal, and report it to a computer.

Working model of Ultrasonic sensor HC SR04

Ultrasonic ranging module HC - SR04 provides 2cm - 400cm non-contact measurement function, the ranging accuracy can reach to 3mm. The module includes ultrasonic transmitters, receiver and control circuit. The basic principle of work:

When triggered with a 10us pulse on the trigger pin, the module sends out eight 40kHz ultrasonic pulses. The module then takes the echo pin high and holds it there until it receives an echo back to the module. The length of time the echo pin is high is directly proportional to the distance to an object. In fact, this time is the time it takes the pulses to travel to the object and back and, because the speed of sound at 20°C in dry air at sea level is 343.2m/s, the following formula is used to work out the distance from the module to the object:

distance (m) = (time(s) * speed (m/s))

As time is measured in microseconds, it is easy to work out how far sound travels per microsecond and we simply multiply the measured time by this number.

343.2m/s = 0.03432cm/us

Thus

distance (cm) = (time(us) * speed(cm/us)) / 2 = (time * 0.03432)/2

distance (cm) = time(us) * 0.01716

As floating point mathematics is less efficient on a microcontroller than the integer equivalent. So, rather than multiplying the measured amount of time by a floating point number, it could be divided by an integer because 0.01716 is approximately the same as 1/58, thus:

distance (cm) = time(us) / 58(cm/us)

Timing diagram :

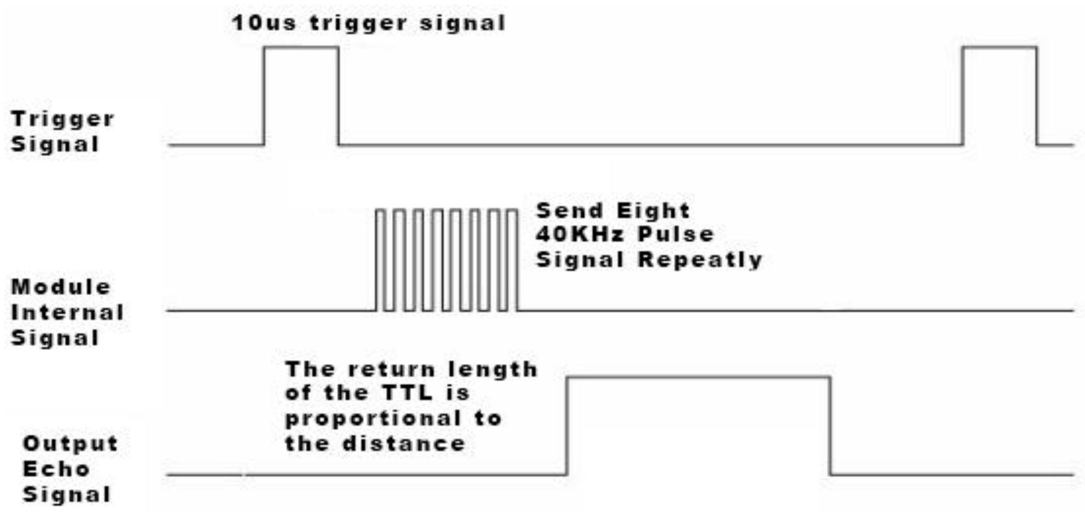

Figure 2.6: Timing Diagram for the working of Ultrasonic Sensors

2.3 ACCELEROMETER

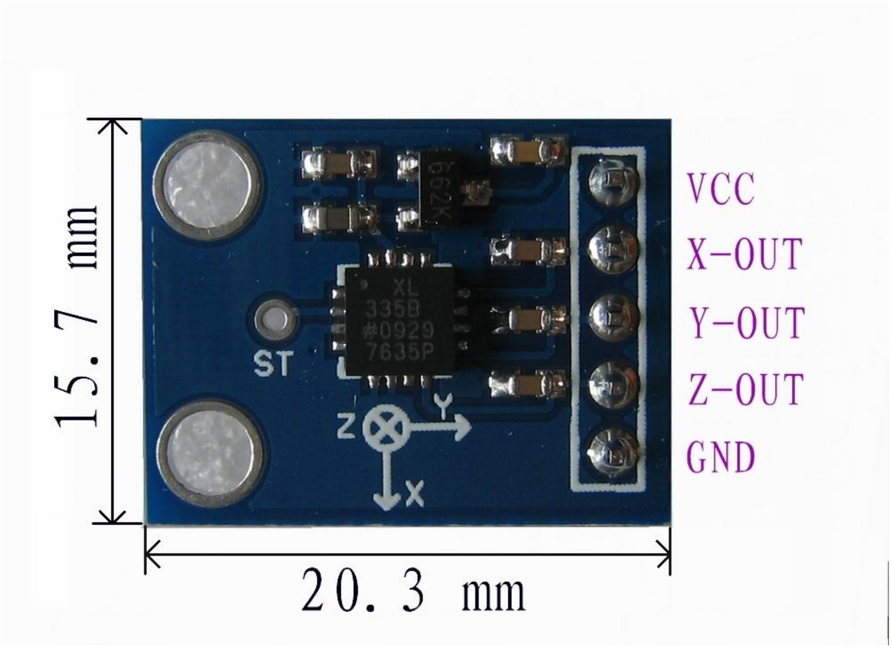

Figure 2.7: Accelerometer GY-61

Accelerometers measure force by generating electrical or magnetic signals. In piezoresistive accelerometers, the mass is attached to a potentiometer (variable resistor), a bit like a volume control, which turns an electric current up or down according to the size of the force acting on it. In some accelerometers, piezoelectric crystals such as quartz do the clever work. There is a crystal attached to a mass, so when the accelerometer moves, the mass squeezes the crystal and generates a tiny electric voltage.

Capacitors can also be used in accelerometers to measure force in a similar way: if a moving mass alters the distance between two metal plates, measuring the change in their capacitance gives a measurement of the force that's acting.

The GY-61 is a small board based on the ADXL-335 Chip.

The ADXL335 is a small, thin, low power, complete 3-axis accelerometer with signal conditioned voltage outputs. It measures acceleration with a minimum full-scale range of ±3 g. It can measure the static acceleration of gravity in tilt-sensing applications, as well as dynamic acceleration resulting from motion, shock, or vibration.

THEORY OF OPERATION

The sensor contains a polysilicon surface-micromachined sensor and signal conditioning circuitry to implement an open-loop acceleration measurement architecture. The output signals are analog voltages that are proportional to acceleration.

The sensor is a polysilicon surface-micromachined structure built on top of a silicon wafer. Polysilicon springs suspend the structure over the surface of the wafer and provide a resistance against acceleration forces. Deflection of the structure is measured using a differential capacitor that consists of independent fixed plates and plates attached to the moving mass. The fixed plates are driven by 180° out-of-phase square waves. Acceleration deflects the moving mass and unbalances the differential capacitor resulting in a sensor output whose amplitude is proportional to acceleration. Phase-sensitive demodulation techniques are then used to determine the magnitude and direction of the acceleration. The demodulator output is amplified and brought off-chip through a 32 kΩ resistor. The user then sets the signal bandwidth of the device by adding a capacitor. This filtering improves measurement resolution and helps prevent aliasing.

MECHANICAL SENSOR

The ADXL335 uses a single structure for sensing the X, Y, and Z axes. As a result, the three axes' sense directions are highly orthogonal and have little cross-axis sensitivity. Mechanical misalignment of the sensor die to the package is the chief source of cross-axis sensitivity. Mechanical misalignment can, of course, be calibrated out at the system level.

Calibration

Calibration is based around the assumption that the sensor response is linearly proportional to the acceleration, and that we know three values of acceleration for which we can measure the sensor response on each of the axes.

When the sensor is at rest, positioned flat on a horizontal surface then the Z axis will be measuring the force of gravity -1g and the X and Y axes will each be measuring zero. The sensor can be rotated so that each of the axes is in turn parallel to the force of gravity and a reading for zero acceleration, 1g and -1g is obtained for each axis.

Pins

- VCC: 1.8-5V DC
- X-OUT: X Channel Output
- Y-OUT : Y Channel Output
- Z-OUT: Z Channel Output
- GND: GND

Table 2.2: Features of Accelerometer

Name	Description
Operating Voltage Range	1.8~5 V
Supply Current	350uA
Interfaces	Analog
Operating Temperature	-40°~ 85°
Dimension	20.3mm×15.7mm×11.6mm

2.4 BUTTON

Figure 2.8: Push Button

This is a momentary button. A pushbutton is a simple switch mechanism which permits user generated changes in the state of a circuit. It usually comes with four legs. When the pushbutton is pressed, all the 4 legs are connected. That means it only outputs HIGH when pressed on. And once released, it no longer outputs HIGH but LOW.

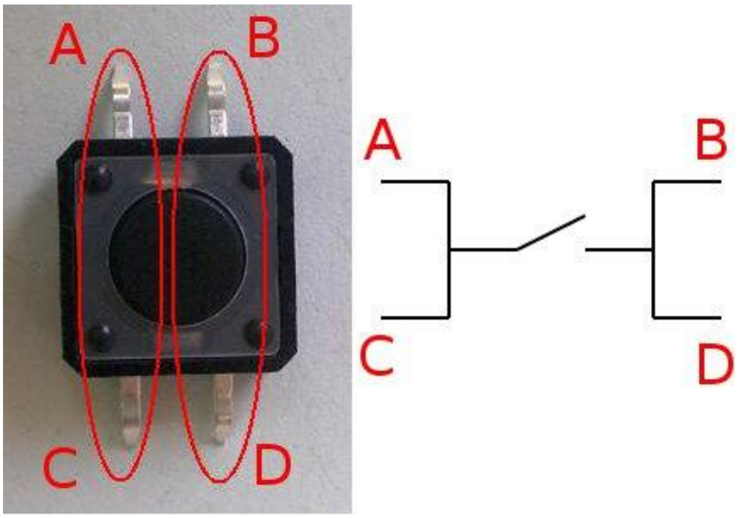

Figure 2.9: Working of Push Button

2.5 BUZZER

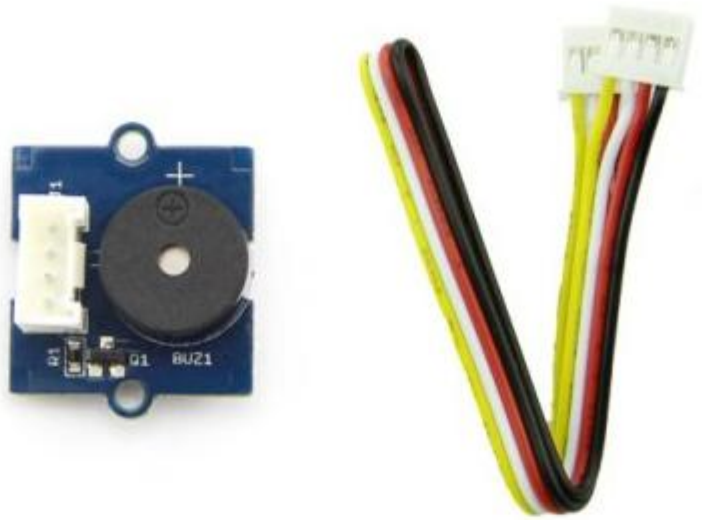

Figure 2.10: Buzzer

Piezo buzzer is an electronic device commonly used to produce sound. Light weight, simple construction and low price make it usable in various applications. It uses the phenomena of generating electricity when mechanical pressure is applied to certain materials and the vice versa is also true. Such materials are called piezo electric materials. Piezo electric materials are either naturally available or manmade. Piezoceramic is class of manmade material, which poses piezo electric effect and is widely used to make disc, the heart of piezo buzzer. Usually there are two ceramic discs in each Piezo buzzer. When subjected to an alternating electric field, they stretch or compress, in accordance with the frequency of the signal thereby producing sound. Besides being used as an alarm or indicator, buzzer is totally capable of singing a song.

2.6 BASE SHIELD

The base shield plugs into an Arduino and is the foundation of the Grove system. All I/O ports of the Arduino are exposed and adapted into 22 Grove connectors which include digital I/O, analog I/O, and specialized ports (I2C, SPI, UART).

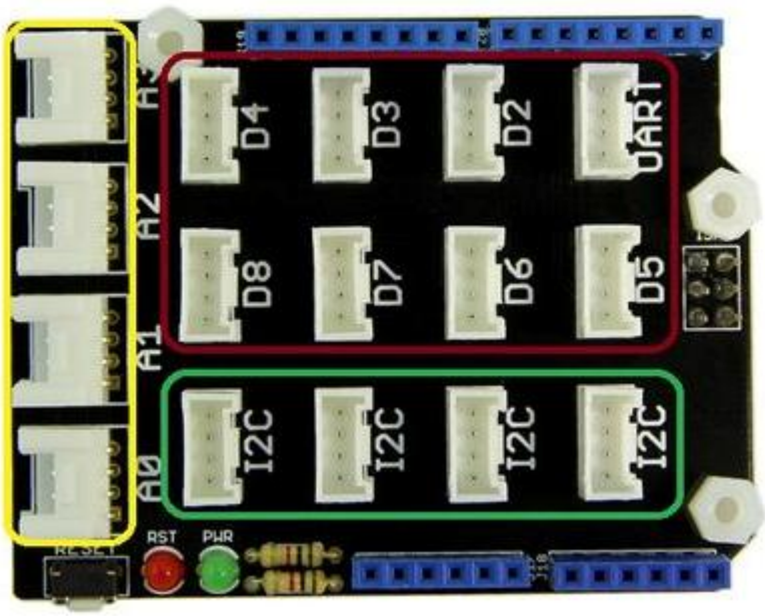

Figure 2.11: Base Shield

In the center, surrounded by the yellow lines, are 13 digital I/O ports. These can be used to read and control digital Grove modules, such as the light sensor and LEDs. Some of the digital I/O ports can also be used as PWM (pulse width modulation) outputs. By generating PWM waves, the Arduino can control the movement of a stepper motor or fade an LED. Within the green lines, on the left-hand side, are 5 analog input ports. Analog inputs are typically used to read analog sensors, like a potentiometer or a temperature sensor but these ports can also be used as digital I/O ports. Lastly, the specialized ports are outlined in red: two I2C ports, one SPI port, and one UART port. We can use these special ports with more sophisticated Grove modules, like the 3-axis accelerometer and the serial Bluetooth module.

CHAPTER 3

WORKING

3.1 BLOCK DIAGRAM

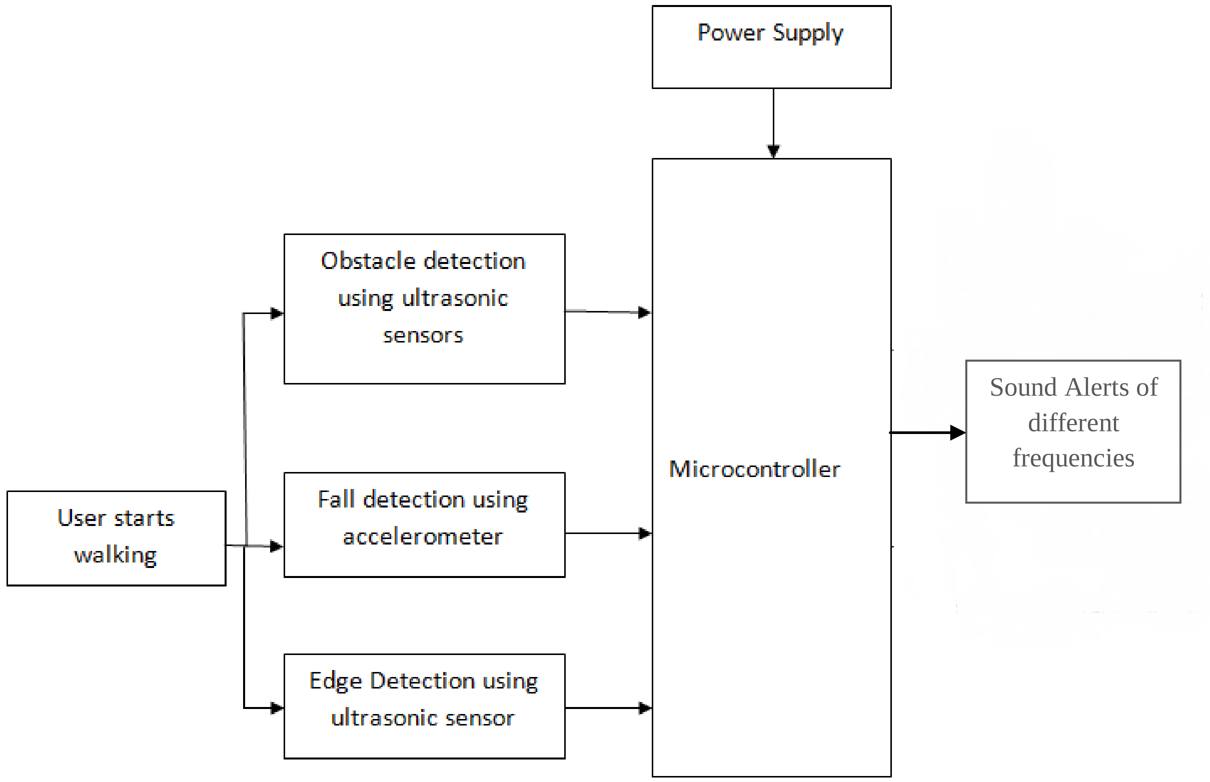

Figure 3.1: Block Diagram

3.2 HIERARCHY OF PROGRESSION

3.2.1 OBSTACLE DETECTION

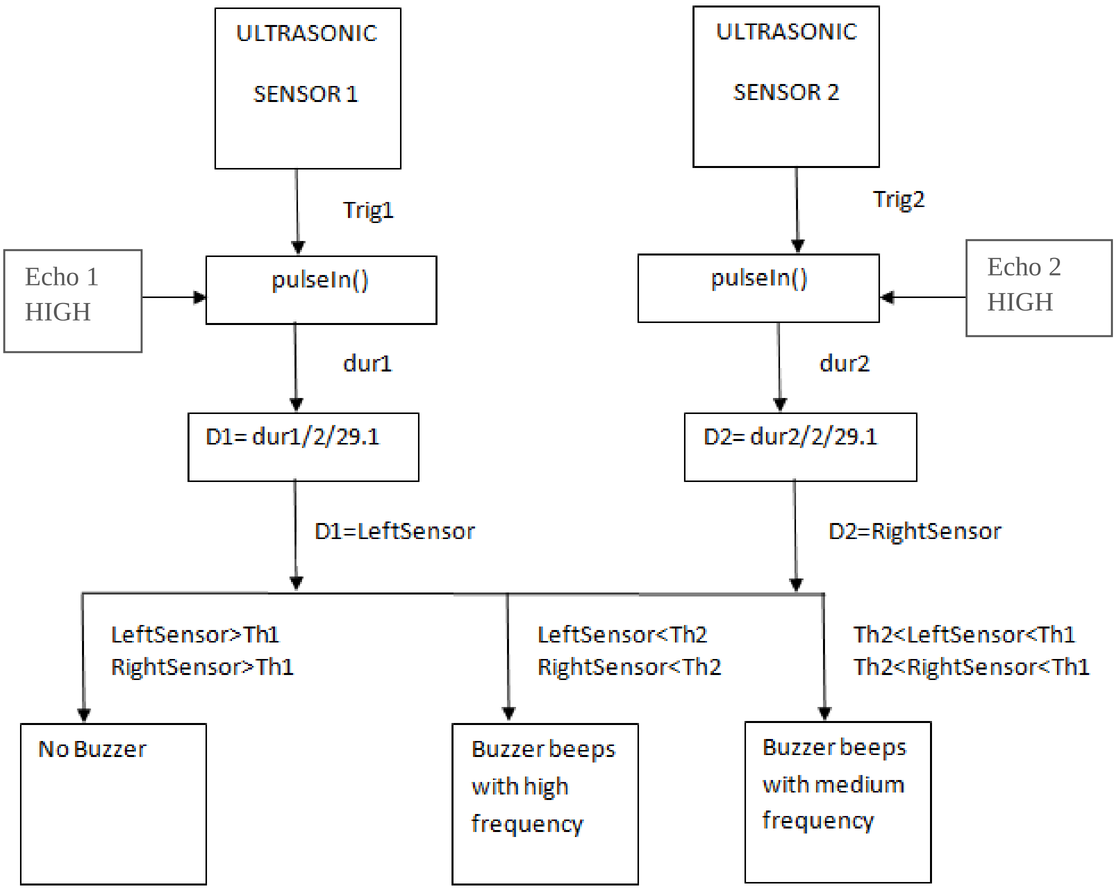

Figure 3.2: Mechanism of Obstacle Detection

3.2.2 FALL DETECTION

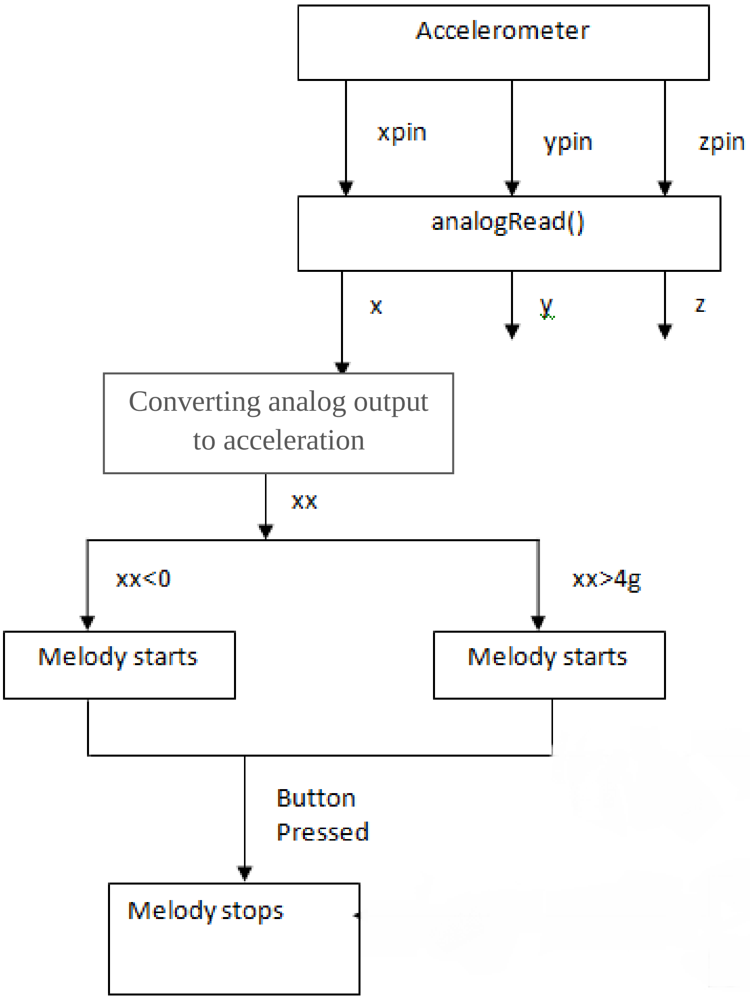

Figure 3.3: Mechanism of Fall Detection

3.2.3 EDGE DETECTION

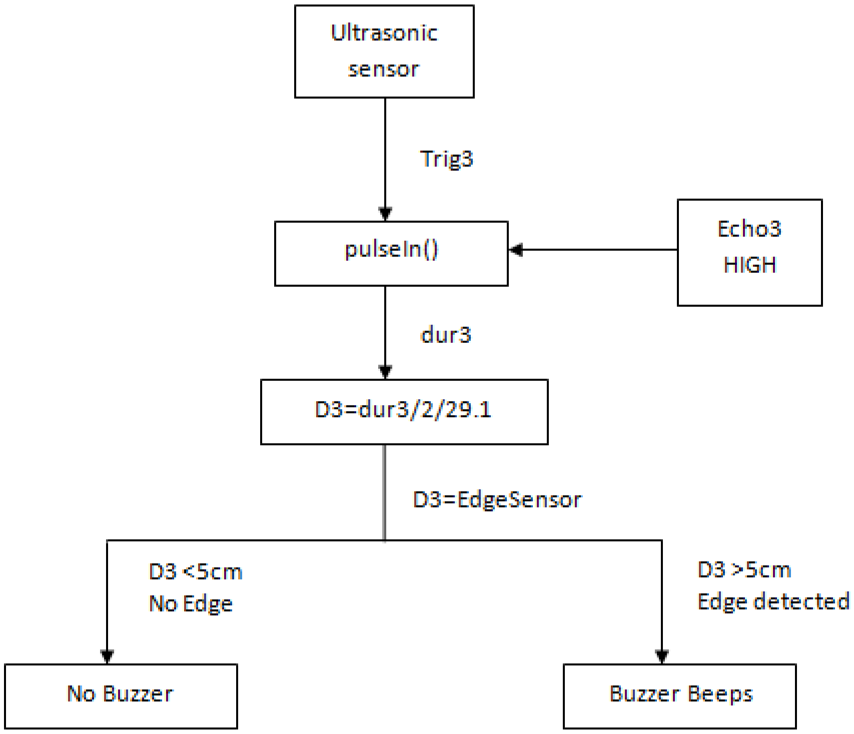

Figure 3.4: Mechanism of Edge Detection

3.3 THEORY OF WORKING

As soon as the person starts walking and gives power supply to the device, all the three ultrasonic sensors and the accelerometer are also set to work. The ultrasonic sensors on the right and left mounted on the top of the stick, are used to detect the obstacles. As soon as an obstacle is encountered, the sensors evaluate the echo of the high-frequency sound waves received back, measuring the time interval for the received echo using pulseIn() function then we determine the distance to the object by using a pre-defined function (distance=(dur/2)/29.1). The values of the distance from obstacles in front, right, or left is stored in the variables LeftSensor, RightSensor. By comparing the distances with a threshold value, we conclude whether the obstacle is near the user or far off. If the obstacle is near the user, a buzzer mounted on the device beeps and produces high frequency sounds to alert the blind person. If the obstacle is at a distance from the user, the buzzer beeps with low frequency sounds. Thus, the blind person gets an idea about the location of the obstacle.

For the edge detection, the ultrasonic sensor is placed in such a way that it detects edges and downfalls so that the blind person does not fall. The sensor is placed facing downwards. Therefore, it will not produce alert till the time it detects the obstacle, i.e. floor. The value of the distance from the floor is stored in the variable EdgeSensor. As soon as the value of EdgeSensor exceeds the threshold value (the edge is detected), the buzzer beeps.

For fall detection, an accelerometer is mounted on the stick. An accelerometer is an electromechanical device used to measure acceleration forces. The technique is based on the principle of detecting changes in motion and body position of an object, wearing a sensor, by tracking acceleration changes in three orthogonal directions. The data is continuously analyzed algorithmically to determine whether the stick is falling or not. If the stick of the user has fallen then there is a sudden change in acceleration of accelerometer and we measure the change in x-axis. As soon as the stick has fallen, the buzzer produces a melody and the user can locate the fallen stick by hearing the melody. When the user finds the stick, she/he can press a button mounted on the stick to stop the melody sound.

3.4 PINOUT AND HARDWARE INTERFACING

3.4.1 EDISON ARDUINO KIT WITH ULTRASONIC SENSORS AND ACCELEROMETER

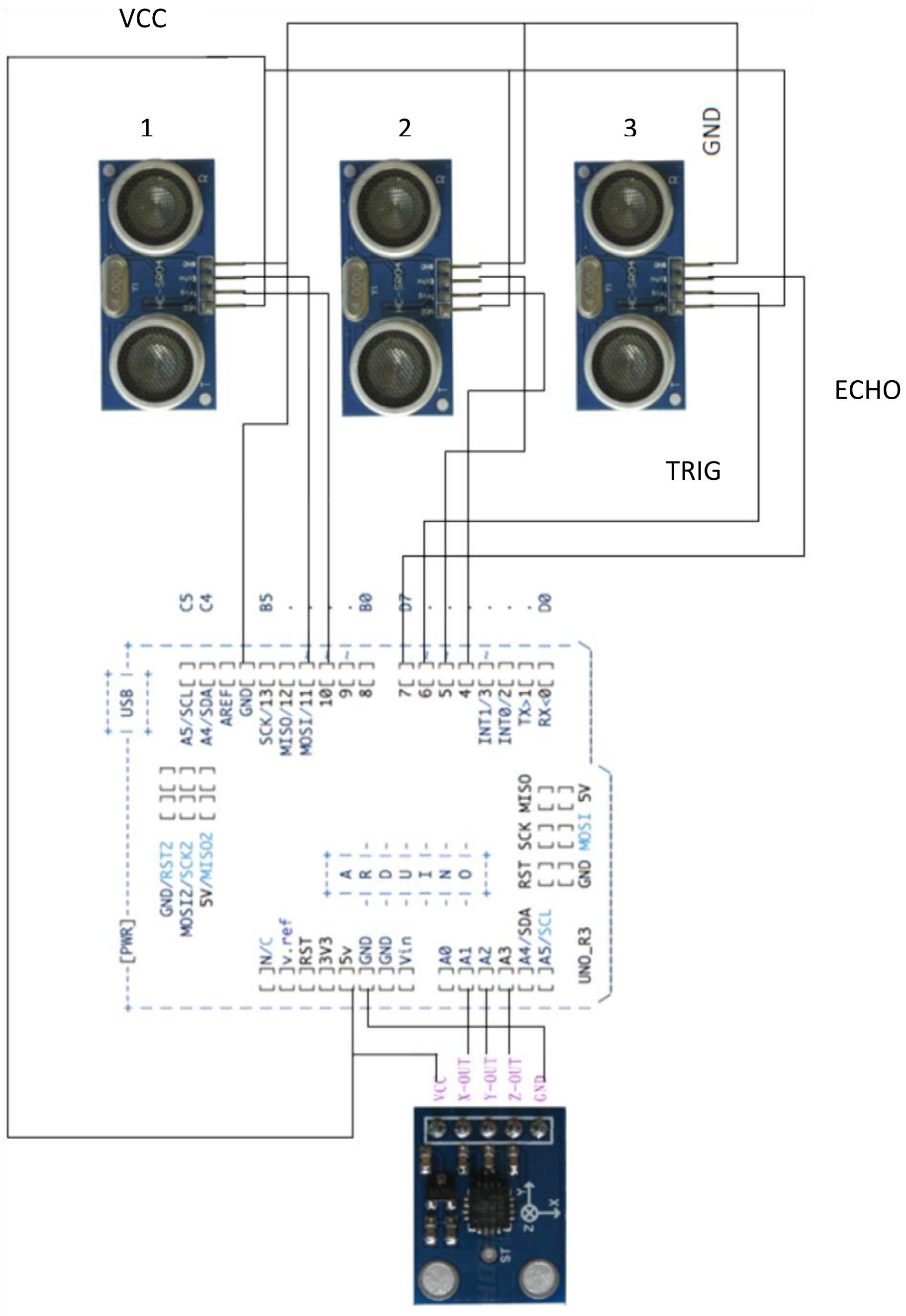

Figure 3.5: Intel Edison interfacing with sensors

3.4.2 EDISON BASE SHIELD WITH BUZZER AND BUTTON

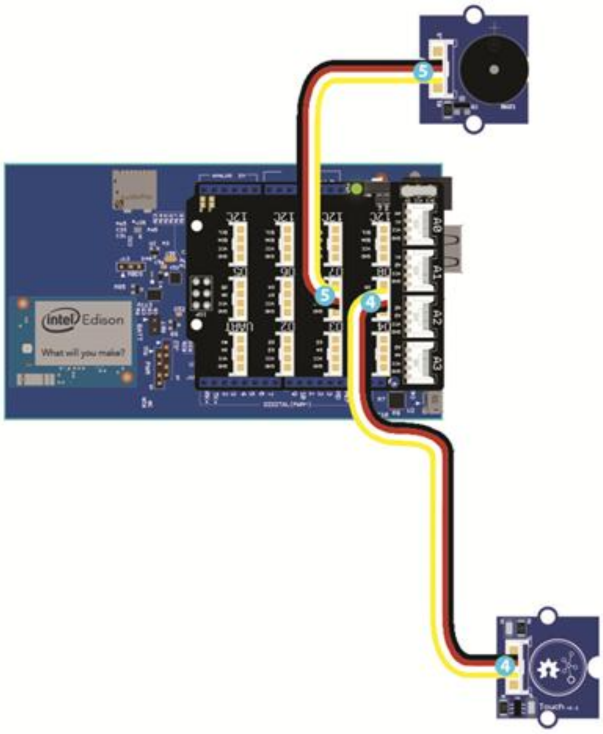

Figure 3.6: Base Shield with Buzzer and Button

CHAPTER 4

CONCLUSION

India is home to the world's largest number of blind people and India’s current population is over 1.22 billion. Earlier, majority of visually impaired people preferred not to use electronic aids and use only canes or guide dogs. The underlying reasons for this include the relatively high costs and relatively poor levels of user satisfaction associated with existing electronic systems. So we tried to develop a low cost and user friendly system for blind people with greatest possible accuracy. We have designed an intelligent device which alerts the person on occurrence of obstacles based on distance between the person and the obstacle. This method offers innovative solutions in order to replace the conventional methods of guiding visually impaired people.

SMART WALK for blind people will help them overcome above mentioned difficulties. This blind aid system can be rendered a fresh dimension of useful assistance and gives a sense of artificial vision along with dedicated obstacle detection. This cost effective and light weight device has portable components mounted on it that can help the blind person carry the stick anywhere with ease. The aimed combination of several working sub-systems makes a time demanding system that monitors the environmental scenario of static and dynamic objects and provides necessary feedback forming navigation more precise, safe and secure. This method offers innovative solutions in order to replace the conventional methods of guiding visually impaired people. Also, it can be easily applied anywhere and it can handle places like malls, airports etc. This method improves mobility, gives independence & boosts self- esteem. It has a system designed as a detachable unit mounted on the blind stick.

CHAPTER 5

LIMITATIONS

1) Our blind person navigation system is not efficient for outdoor environment as the user can’t walk through traffic.
2) This device may not detect fast moving objects.
3) This device detects downfalls and edges but detection of all stairs of a staircase may not be possible.

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APPENDIX A

DATA SHEET FOR ADXL335

T_A = 25°C, V_S = 3 V, $C_X = C_Y = C_Z$ = 0.1 μF, acceleration = 0 *g*, unless otherwise noted. All minimum and maximum specifications are guaranteed. Typical specifications are not guaranteed.

Parameter	Conditions	Min	Typ	Max	Unit
SENSOR INPUT	Each axis				
Measurement Range		±3	±3.6		*g*
Nonlinearity	% of full scale		±0.3		%
Package Alignment Error			±1		Degrees
Interaxis Alignment Error			±0.1		Degrees
Cross-Axis Sensitivity[1]			±1		%
SENSITIVITY (RATIOMETRIC)[2]	Each axis				
Sensitivity at X_{OUT}, Y_{OUT}, Z_{OUT}	V_S = 3 V	270	300	330	mV/*g*
Sensitivity Change Due to Temperature[3]	V_S = 3 V		±0.01		%/°C
ZERO *g* BIAS LEVEL (RATIOMETRIC)					
0 *g* Voltage at X_{OUT}, Y_{OUT}	V_S = 3 V	1.35	1.5	1.65	V
0 *g* Voltage at Z_{OUT}	V_S = 3 V	1.2	1.5	1.8	V
0 *g* Offset vs. Temperature			±1		m*g*/°C
NOISE PERFORMANCE					
Noise Density X_{OUT}, Y_{OUT}			150		μ*g*/√Hz rms
Noise Density Z_{OUT}			300		μ*g*/√Hz rms
FREQUENCY RESPONSE[4]					
Bandwidth X_{OUT}, Y_{OUT}[5]	No external filter		1600		Hz
Bandwidth Z_{OUT}[5]	No external filter		550		Hz
R_{FILT} Tolerance			32 ± 15%		kΩ
Sensor Resonant Frequency			5.5		kHz
SELF-TEST[6]					
Logic Input Low			+0.6		V
Logic Input High			+2.4		V
ST Actuation Current			+60		μA
Output Change at X_{OUT}	Self-Test 0 to Self-Test 1	−150	−325	−600	mV
Output Change at Y_{OUT}	Self-Test 0 to Self-Test 1	+150	+325	+600	mV
Output Change at Z_{OUT}	Self-Test 0 to Self-Test 1	+150	+550	+1000	mV
OUTPUT AMPLIFIER					
Output Swing Low	No load		0.1		V
Output Swing High	No load		2.8		V
POWER SUPPLY					
Operating Voltage Range		1.8		3.6	V
Supply Current	V_S = 3 V		350		μA
Turn-On Time[7]	No external filter		1		ms
TEMPERATURE					
Operating Temperature Range		−40		+85	°C

1. Defined as coupling between any two axes.
2. Sensitivity is essentially ratiometric to V_S.
3. Defined as the output change from ambient-to-maximum temperature or ambient-to-minimum temperature.
4. Actual frequency response controlled by user-supplied external filter capacitors (C_X, C_Y, C_Z).
5. Bandwidth with external capacitors = 1/(2 × π × 32 kΩ × C). For C_X, C_Y = 0.003 μF, bandwidth = 1.6 kHz. For C_Z = 0.01 μF, bandwidth = 500 Hz. For C_X, C_Y, C_Z = 10 μF, bandwidth = 0.5 Hz.
6. Self-test response changes cubically with V_S.

7. Turn-on time is dependent on C_X, C_Y, C_Z and is approximately 160 × C_X or C_Y or C_Z +1ms, where C_X, C_Y, C_Z are in microfarads (μF).

INTEL EDISON KIT FOR ARDUINO HEADER SIGNAL LIST

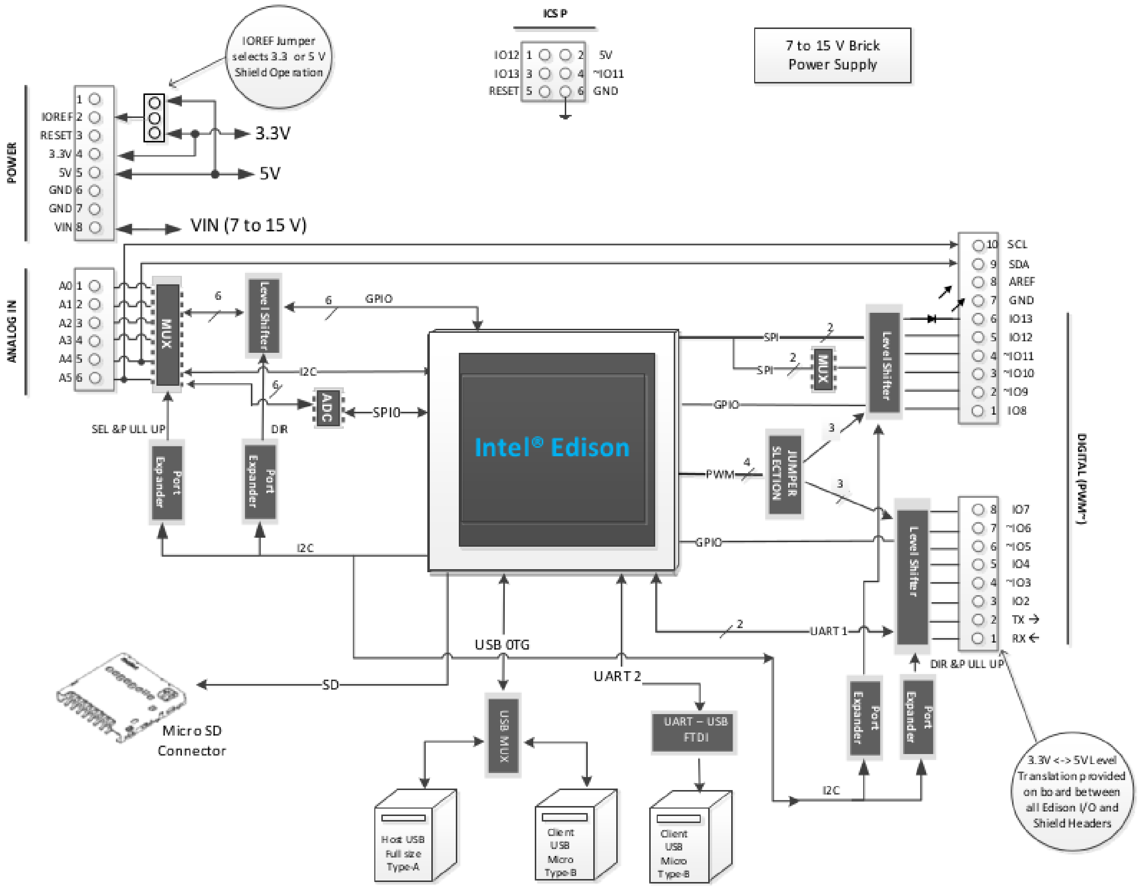
Header	**Arduino pin name**	**Signal function**
Power	N/C	Not connected
Power	IOREF	Shield I/O reference voltage (select 3.3 or 5 V via jumper on board)
Power	RESET	Shield reset (programmable via software or manual push button)
Power	3.3 V	System 3.3 V output
Power	5 V	System 5 V output
Power	GND	Ground
Power	GND	Ground
Power	VIN	System input power (7 to 15 V)
Analog	A0	Analog input or digital I/O
Analog	A1	Analog input or digital I/O
Analog	A2	Analog input or digital I/O
Analog	A3	Analog input or digital I/O
Analog	A4 / SDA	Analog input, digital I/O, or I2C data (also connected to digital header)
Analog	A5 / SCL	Analog input, digital I/O, or I2C data (also connected to digital header)
Digital	SCL	I2C clock
Digital	SDA	I2C data
Digital	AREF	ADC reference voltage (select AREF or IOREF via jumper J8

		on board)
Digital	GND	Ground
Digital	13 / SCK	Digital I/O, or SPI clock
Digital	12 / MISO	Digital I/O, or SPI receive data
Digital	~11 / MOSI	Digital I/O, SPI send data, or PWM (configured with PWM swizzler)
Digital	~10	Digital I/O, SPI signal select, or PWM (configured with PWM swizzler)
Digital	~9	Digital I/O, PWM (configured with PWM swizzler)
Digital	8	Digital I/O
Digital	7	Digital I/O
Digital	~6	Digital I/O, PWM (configured with PWM swizzler)
Digital	~5	Digital I/O, PWM (configured with PWM swizzler)
Digital	4	Digital I/O
Header	Arduino pin name	Signal function
Digital	~3	Digital I/O, PWM (configured with PWM swizzler)
Digital	2	Digital I/O
Digital	1 / TX	Digital I/O
Digital	0 / RX	Digital I/O
ICSP	MISO	SPI receive data (connected to digital pin 12)
ICSP	5V	System 5 V output
ICSP	SCK	SPI clock (connected to digital pin 13)
ICSP	MOSI	SPI send data (connected to digital pin 11)

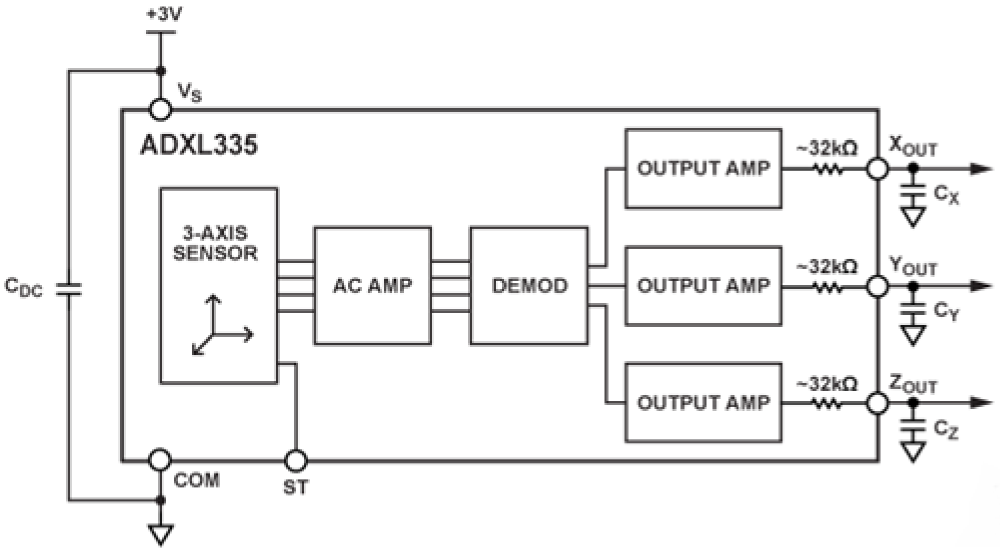
ICSP	RESET	Shield reset (programmable via software or manual push button)
ICSP	GND	Ground

APPENDIX B

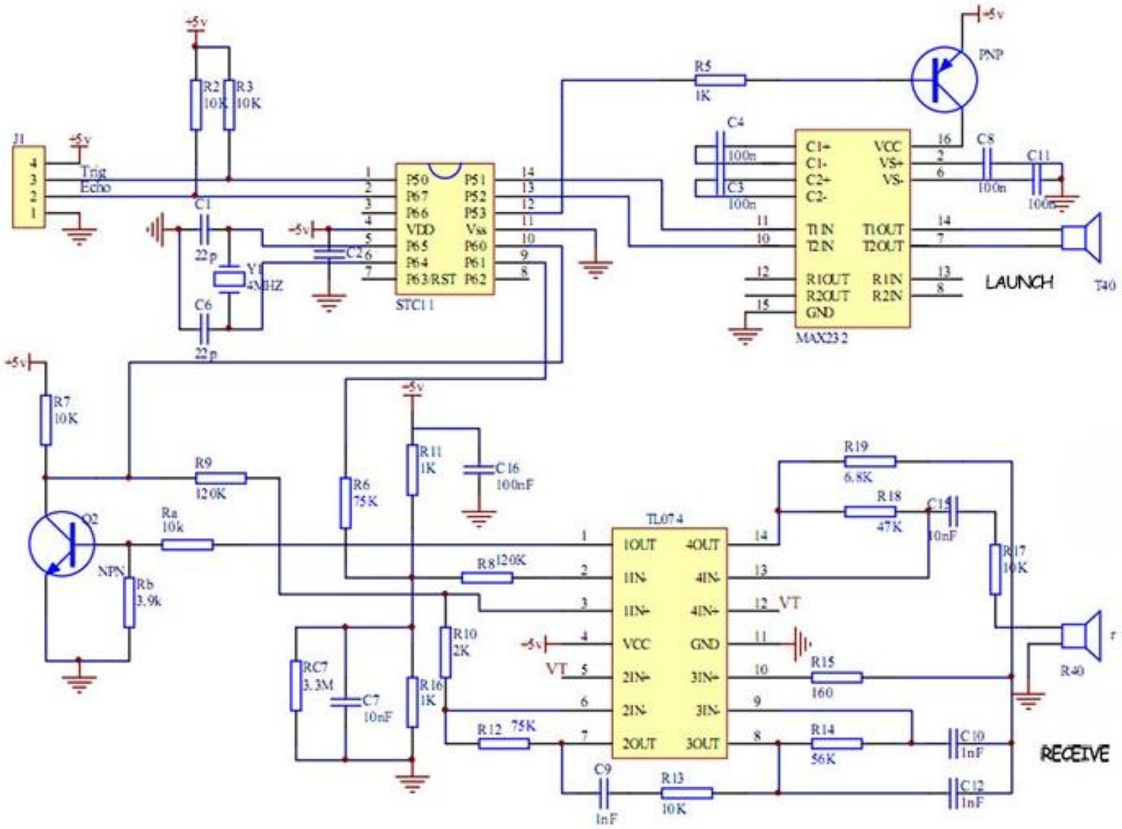
INTEL EDISON WITH BREAKOUT BOARD



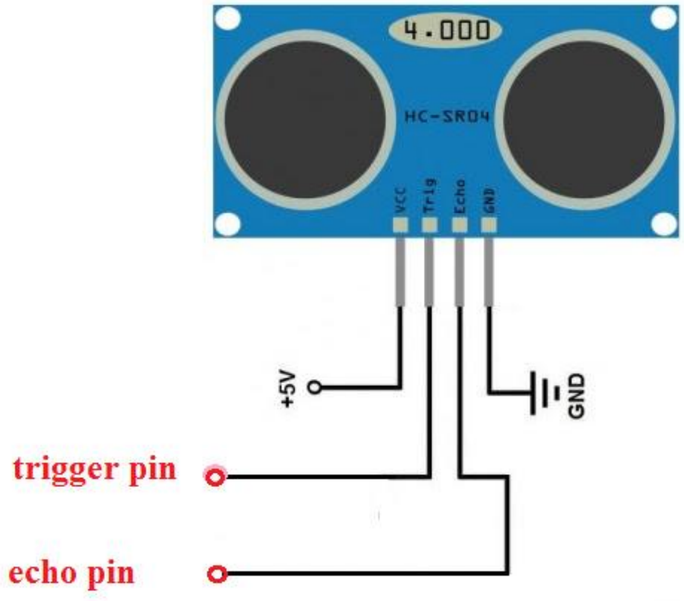
FUNCTIONAL DIAGRAM FOR ADXL335



SCHEMATIC DIAGRAM FOR HC SR04



PIN DIAGRAM OF ULTRASONIC SENSOR (HC SR04)



PIN DIAGRAM OF ACCELEROMETER (GY-61)