Smart Clothing with Haptic Technology

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ABSTRACT

The project consists of designing and creating a portable-wearable device that can alert hearing-impaired individuals of incoming objects from the rear-blind spot as individuals cannot see what is behind them. The project consists of developing a prototype that consists of e-textiles with haptic technology, more commonly referred to as "smart clothing" or "wearable technology." An Arduino microcontroller will be used as the controller while conductive thread will be used to carry current the same way wires also carry current. The input sensors for the microcontroller will consist of using ultrasonic sensors for object detection, and the output will consist of two haptic motors as primary alerts on the wearer. A smartphone application with user settings is used to allow the setting of specific distance parameters as desired by the wearer. The Silver Mate Bluetooth module is used for wireless communication between the device and smartphone.

The device serves as an accessibility tool for individuals experiencing hearing loss or partial deafness. Without hearing, auditory situational awareness is greatly limited. The device will help alleviate the problem by detecting incoming objects approaching from behind and alerting the wearer of the presence by producing a vibrating sensation through haptic motors. A smartphone application allows wearers to monitor and control the settings of the device to distances of choice. The device is sewn onto a vest that is light, durable, and allows for mobility.

I. INTRODUCTION

The purpose of this project is to target those with hearing disabilities and design a way to assist how they function in everyday life. An issue most prevalent in America comes in the form of hearing impairment, and one in six individuals has some form of hearing loss. While only 28.5% of those with hearing loss use hearing aids [1]. But why is this percentage so low? Research indicates that most hearing aid users experience headaches, discomfort, ringing in the ears, and noisy interference [2]. To make it worse, they are not cheap. Hearing aids can cost $1,500-$3,500 per unit and double the cost for both ears [2][3]. This project is applicable to those who do and do not use hearing aids but have hearing problems. This project tackles the problem that hearing aids lack—auditory spatial awareness.

The most common problem for those hearing impaired is being unable to detect what direction a sound comes from, which often causes one to feel uneasy in unfamiliar environments. The device is to be worn by a wearer to detect the unseen rear presence of an object or individual from an array of distances in order to produce an alert via the haptic motors. Alternative positions are available to gain wider proximity coverage by placing additional sensors on the shoulder areas for side coverage. The device uses a clip-on rather than being embedded into clothing to make the device portable and allow the device to avoid any destructive circumstances such as being washed by mistake. The idea of using a vest that is lightweight and strong enough to hold many components is a plausible solution for the wearer and allows the wear to remove the device easily. The vest can be worn indoors and outdoors to accommodate multiple lifestyles as shown in Figure 1.

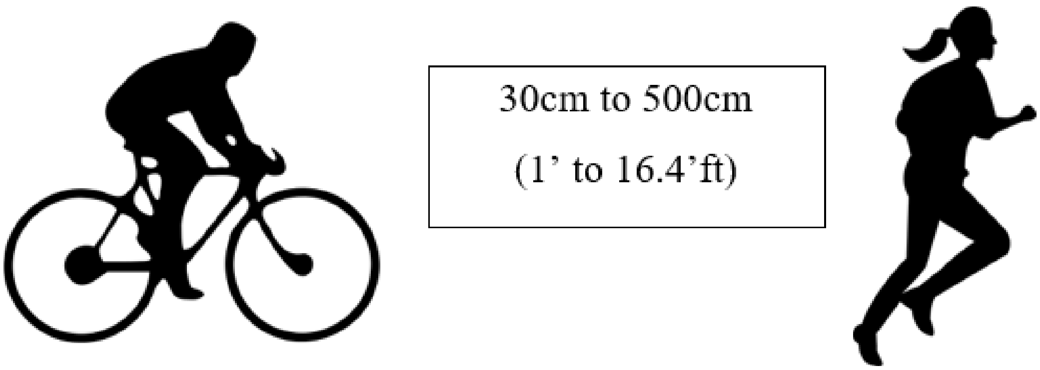

FIGURE 1: Approacher and Wearer

II. DESIGN APPROACH

The design utilizes the Arduino Uno controller and the HRLV-Maxsonar EZ0 ultrasonic sensor, as shown in Figures 2 and 3 and described in Appendix A and Appendix B [4][5]. The sensor is to be placed on the rear of the vest where the wearer has no awareness of approaching objects or individuals as shown in Figure 4. As shown in Figure 5, two haptic motors (vibrating motors) as described in Appendix C, will be placed on top of the shoulders of the vest [6]. All components will be in the vest's compartments and will be removable. The exposed conductive thread connecting the circuitry is insulated to prevent shorting out the circuit.

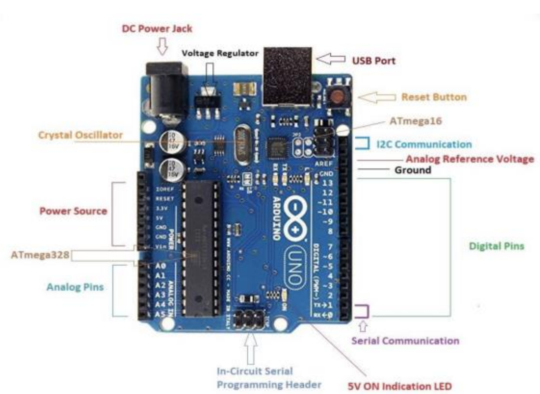

FIGURE 2: Arduino Uno

FIGURE 3: HRLV-Maxsonar EZ0

An Android smartphone is required to control the sensor's distance parameters which are based on proxemics, the study of social distance [7]. The Silver Mate Bluetooth module as shown in Figure 6 and described in Appendix D is located in one of the vest's pockets, and it receives a transmission to indicate an approaching object [8]. The exposed conductive thread connecting the circuitry is insulated to prevent shorting out the circuit.

FIGURE 4: Diagram of Smart Clothing

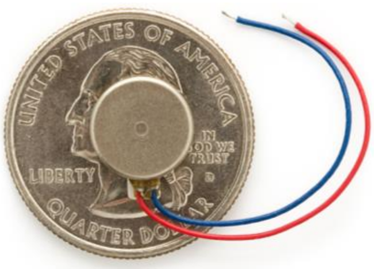

FIGURE 5: COIN TYPE HAPTIC MOTOR

FIGURE 6: SILVER MATE MODULE

III. SYSTEM DESIGN

The physical hardware of the smart clothing consists of using the Arduino Uno microcontroller and the HRLV-Maxsonar EZ0 ultrasonic sensor. The project uses a haptic motor in which the frequency of vibration can be controlled to indicate a specific range of distances between the wearer and an object or individual. The haptic motors are small with an outer diameter of 20mm and are 0.8mm thin and are removable [3]. The set up for the wireless capabilities of the Arduino Uno is performed using the Universal Asynchronous Receiver/Transmitter (UART). Figure 7 depicts a breadboard view of the system. The RX (receive) and TX (transmit) of the Silver Mate is connected to the corresponding connections of the Arduino Uno. The EZ0 sensor provides a pulse width signal for distance measurements to the Arduino Uno.

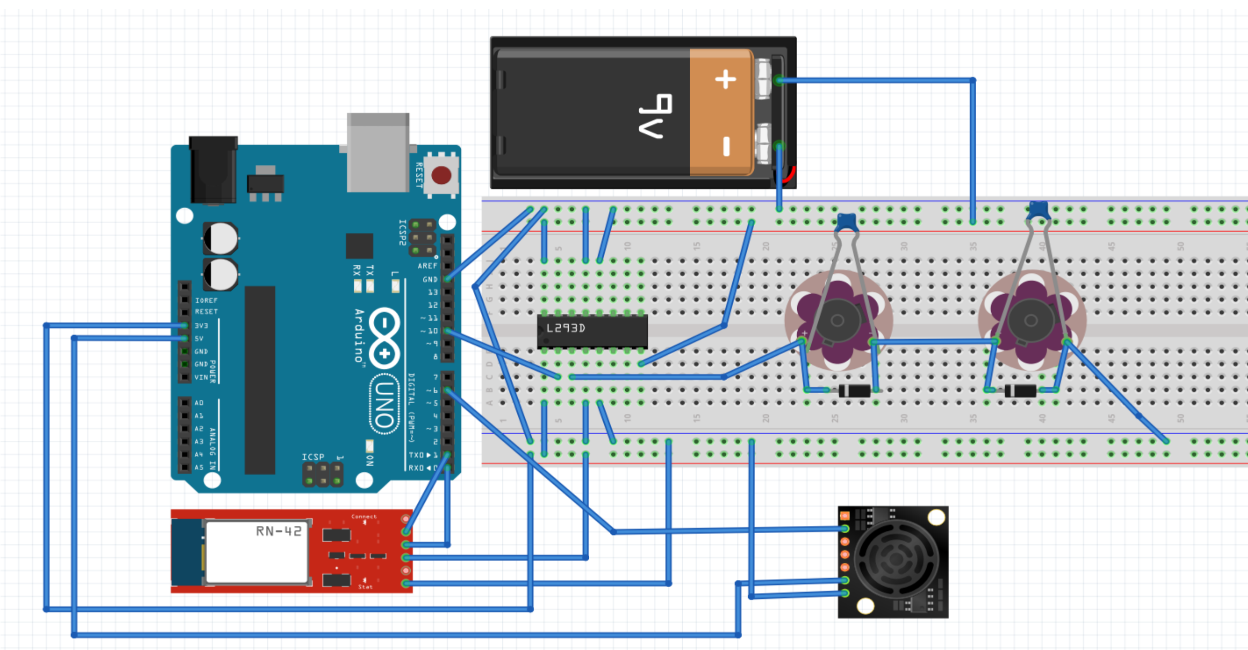

FIGURE 7: Project Breadboard

The Arduino Uno code that was implemented uses the pulse width input from the EZ0 to read the distance value. The haptic motors are connected in series and are controlled through a L293x Quadruple Half-H motor driver as described in Appendix E [9]. In future implementations, additional haptic motors can be added with unused outputs of the L293x. With the fundamental circuity set up, the coding for the Arduino is composed of five functions. In the Arduino's *void setup()* function, the Bluetooth serial connection was set up using the *Serial.begin()* method which also sets the Bluetooth baud rate. The GPIO pin modes for the haptic motors are set as outputs using the *pinMode()* method. In the Arduino's *void loop()*, the Arduino receives the values from the transducer and continuously transmits data back to the mobile device for a range of distances of 30-500cm between the transducer and objects behind the wearer. The flow diagram for the Arduino code is shown in Figure 8.

FIGURE 8: Flow Diagram for Arduino Code

The mobile application was built using Android Studio. The app runs in the background and transmits and receives data even when the wearer is not using the app. The coding segments for Bluetooth connectivity and data transmission are stored in an Android Service Class [10]. The Android Service Class allows Bluetooth connectivity and data transmission to run on the Backend Service, as shown in Figure 9.

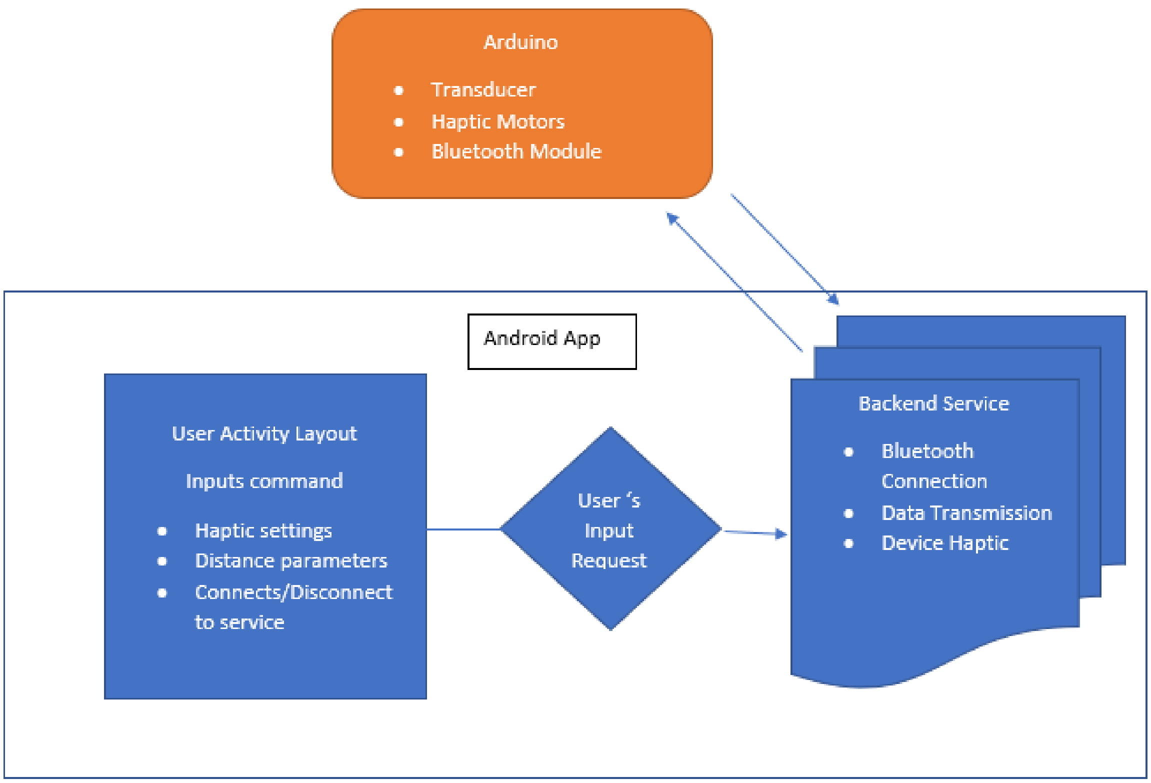

FIGURE 9: Android Chart Diagram

In the Service class, there are two separate threads for Bluetooth [10]. One thread establishes the connection with the Bluetooth module that contains the MAC address of the Bluetooth module. With the MAC address from the Bluetooth module, the thread establishes a socket connection with the hardware module and sets up the communication with a Serial Port

Protocol (SPP) to transmit the data serially with the Arduino Uno's UART [11]. Once a socket connection is established, a second thread is called for data transmission. This thread reads and writes data to and from the Arduino. When dealing with reading the data, a handler parses the incoming information [10]. The parsed information goes to a separate function initially created in the Service class that provides a signal to the phone to vibrate. A message is then sent to the function to turn on or off the Android's haptics and the smart clothing's haptics. However, the Service Class requires user input through the user Activity layer.

The user Activity layer was created on a separate Activity Class [10]. This layer activity communicates with the Service Class. This is called a Bond Service, where a Service is bounded to other Android components like an Activity [10]. The bound service allows activities and services, run in different processes, to bind, send and receive data. The Inter-Process Communication (IPC) was employed for this application [10]. In the IPC method, a service handler and a Messenger Class are used to allow other Android components to communicate with the service. The messenger is used to create an object implementing the IBinder interface (part of the Service class) in order to allow a client to interact with the service. The service handler supports the deliverance of an incoming request from the clients (e.g., user layout activity) to the service. Implementing this approach, a one-way communication was established by having the user layout activity sending requests to the Service and having the Service executing the user's commands through the Bluetooth connection and data transmission as shown in Figure 8. The user layout within the Android smartphone allows control of the sensor's distance parameters which are based on distance, as shown in Figure 10.

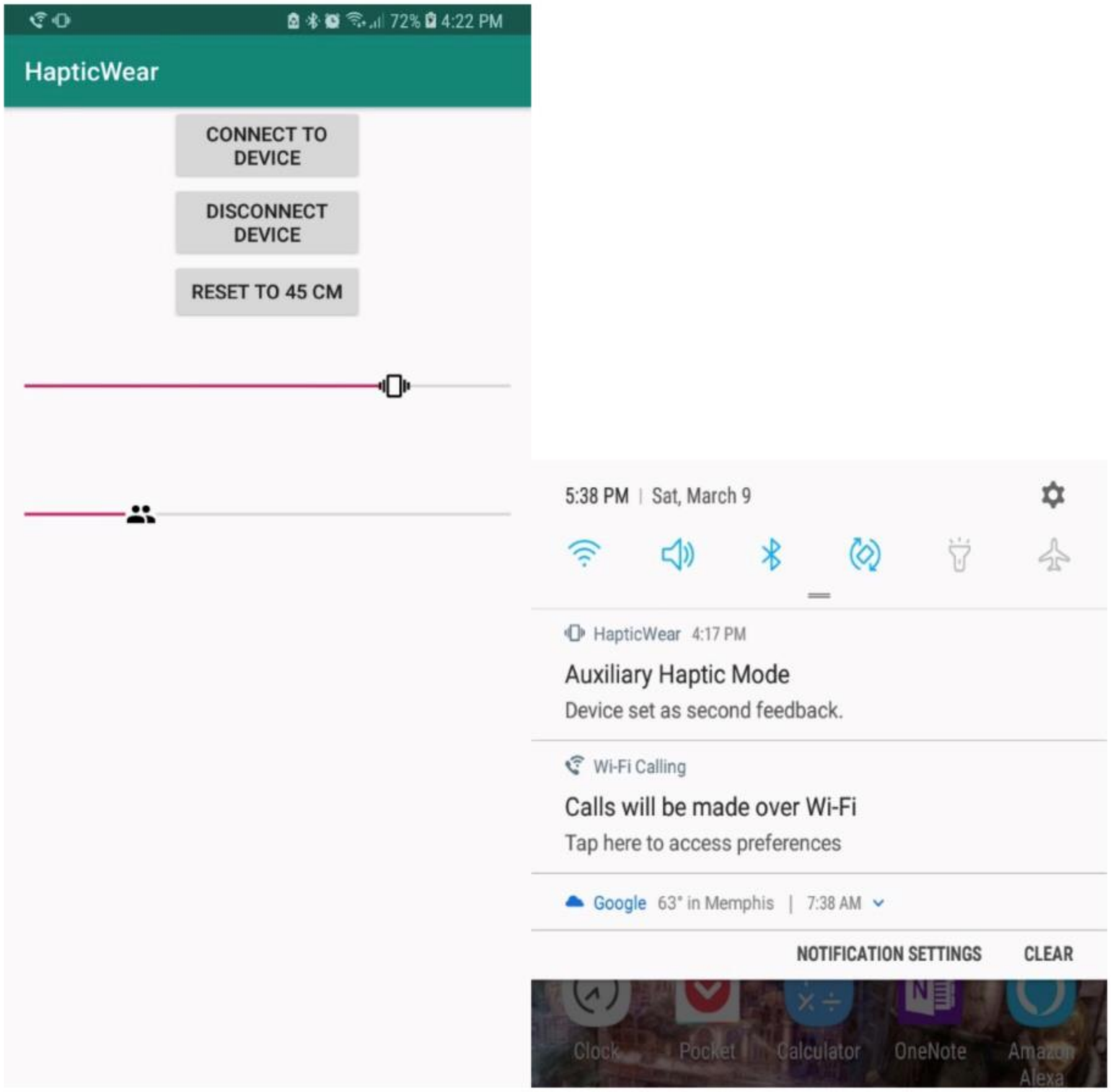

FIGURE 10: Android Application User Interface

IV. ECONOMIC AND TIME ANALYSIS

The smart clothing with haptic technology project had an estimated total cost of $112.59 (tax not included), as shown in Figure 11. The project started in August of 2018 and was completed in February of 2019, as shown in Figure 12.

Components	Quantity	Individual Cost	Vendor
Arduino UNO R3	1	22	Arduino
HRLV-MaxSonar-EZ0	1	34.95	SparkFun
3.7 Li-ion Battery-110mAh	2	6.95	SparkFun
Mate Silver with RN-42 Class 2 Module	1	26.95	Amazon
Coin Type Vibration Motor	2	4.30	SparkFun
Vest	1	12.97	Amazon
Rit DyeMore – Synthetic Fiber Dye	1	4.47	Walmart
Ceramic Capacitor	1	0	CBU
Diode	1	0	CBU
L293x Quadruple Half-H Driver	1	0	CBU
		Total cost (no tax) =	112.59

FIGURE 11: Cost of Components

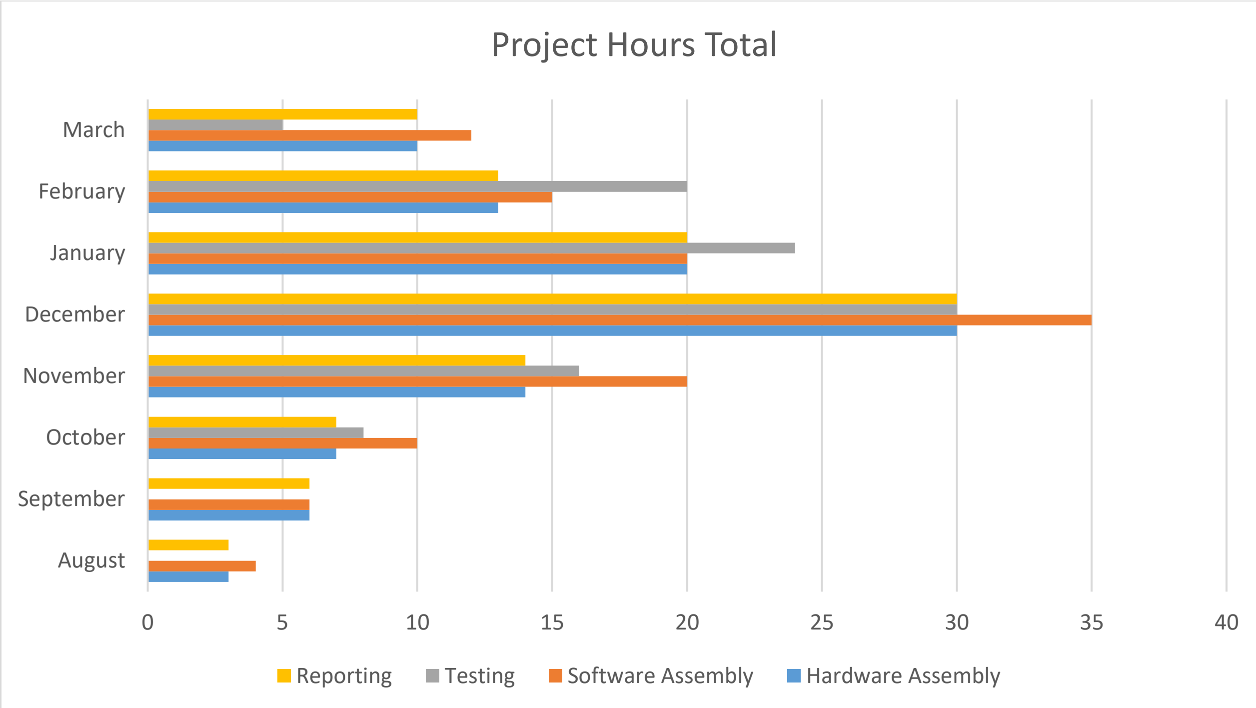

Figure 12: Project Timeline

V. HEALTH AND SAFETY

There were no National Fire Protection Association (NFPA) codes related to low voltage portable devices. Although this project is not considered a medical device, Underwriters Laboratories (UL) offers service for testing of medical devices. "UL provides medical device manufacturers with a complete offering of third-party regulatory approvals, product testing, certification, and usability testing [12]." The use of UL guidelines will ensure a safer operational device.

VI. CONCLUSION AND RECOMMENDATIONS

The project consists of e-textiles with haptic technology, more commonly referred to as "smart clothing" or "wearable technology" for those who are hearing impaired. The smart clothing project performed well when individuals who used traditional hearing aids tested the device. The device benefits the wearer by providing a means to detect objects approaching from the rear. In unfamiliar environments, the wearer will feel more secure than if he/she were not wearing the device. The circuit's minimalist design allows the best integration for mobility of smart clothing. In addition, an interactive mobile application connected via a Bluetooth modem bridges the prototype clothing and wearer while allowing the wearer to control specific functions of the smart clothing and receive distance measurements. The overall project closes the gap between those hearing impaired and those not experiencing hearing problems. The device will provide a satisfying experience to the hearing impaired in a fast-paced world.

VII. REFERENCES

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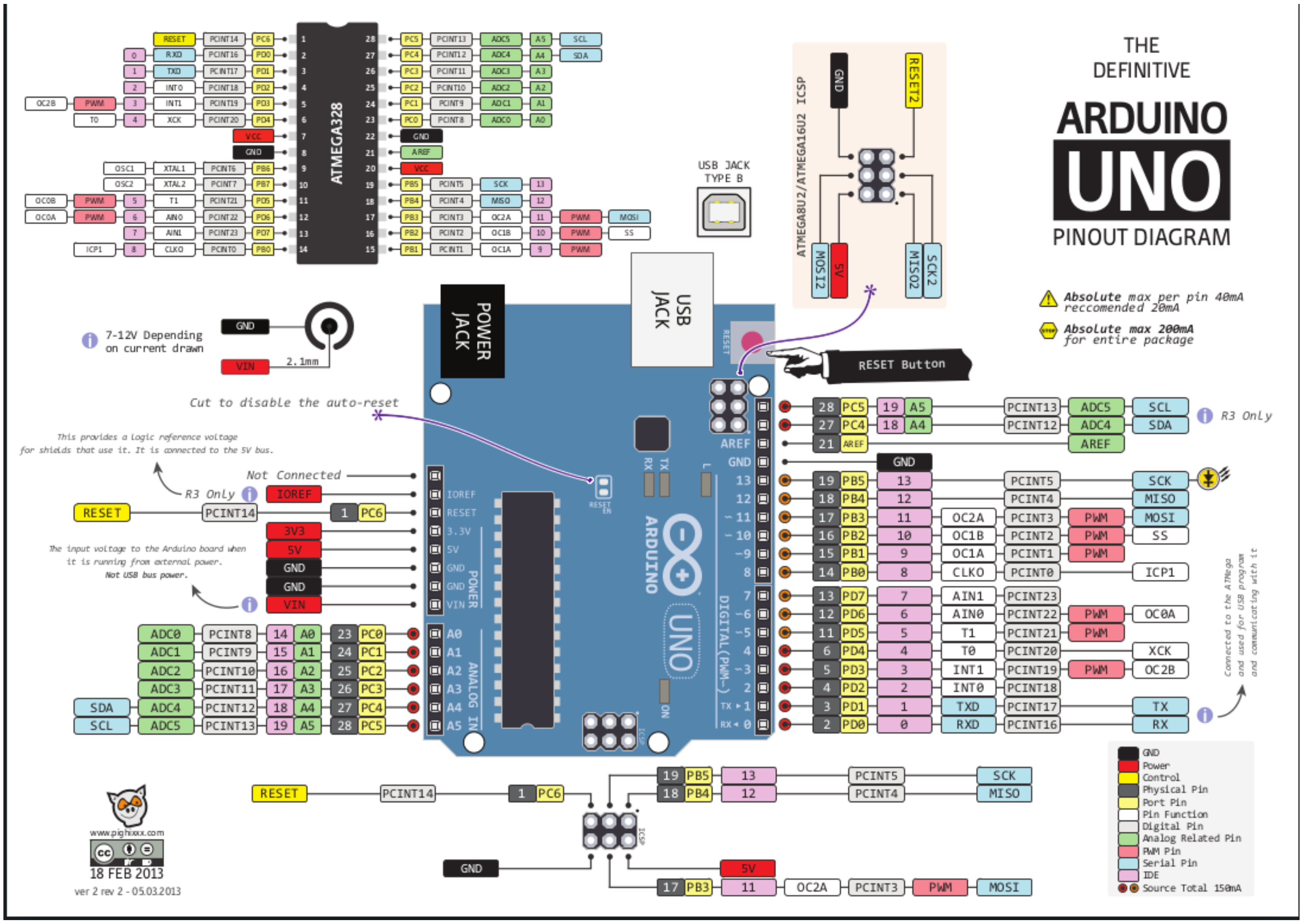
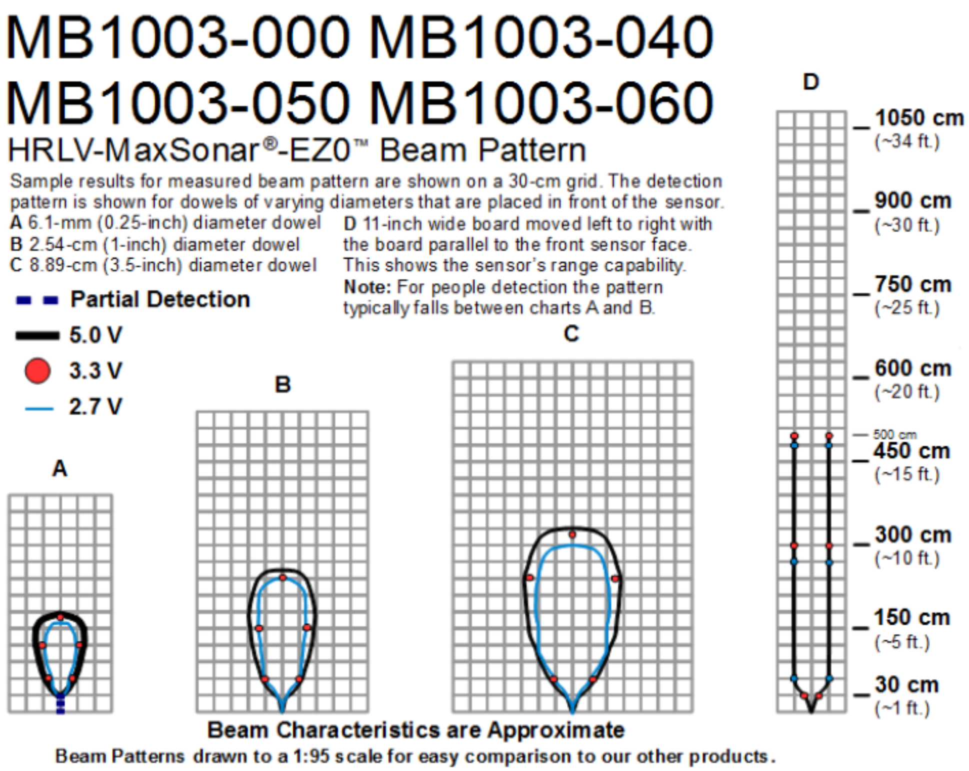
Appendix A: Arduino Microcontroller



MB1003 HRLV-MaxSonar-EZ0 Beam Pattern and Uses

The HRLV-MaxSonar-EZ0 is the highest sensitivity and widest beam sensor of the HRLV-MaxSonar-EZ sensor series. The wide beam makes this sensor ideal for a variety of applications including people detection, autonomous navigation, and wide beam applications.



MB1003 Features and Benefits

- Factory calibrated wide beam width
- Low operating voltages from 2.5V to 5.5V
- All range outputs are active simultaneously
- High acoustic sensitivity
- Detects small targets to longer distances
- Widest beam width for the HRLV-MaxSonar-EZ sensors

MB1003 Applications and Uses

- People detection
- Small target detection
- High sensitivity applications
- Obstacle avoidance

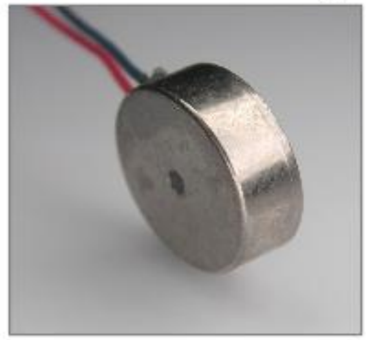
Appendix C: Haptic Motors

PRECISION MICRODRIVES™

310-101

10mm Shaftless Vibration Motor
3.4mm Button Type

Specification	Value
Voltage [V]	3
Frame Diameter [mm]	10
Body Length [mm]	3.4
Weight [g]	1.2
Voltage Range [V]	2.5~3.8
Rated Speed [rpm]	12000
Rated Current [mA]	75
Start Voltage [V]	2.3
Start Current [mA]	85
Terminal Resistance [Ohm]	75
Vibration Amplitude [G]	0.8



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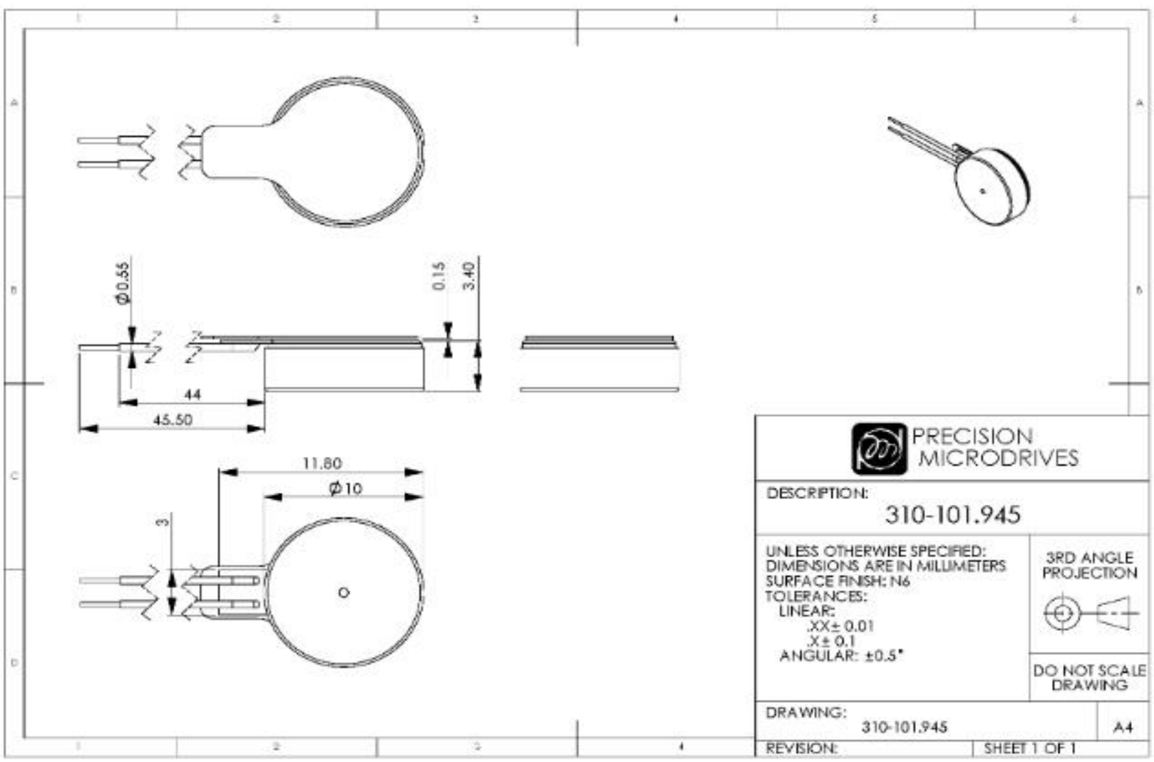

Appendix D: Silver Mate

www.rovingnetworks.com

RN-42/RN-42-N Data Sheet

DS-RN42-V3.2 6/21/2011

Overview

- Baud rate speeds: 1200bps up to 921Kbps, non-standard baud rates can be programmed.
- Class 2 radio, 60 feet (20meters) distance, 4dBm output transmitter, -80dBm typical receive sensitivity
- Frequency 2402 ~ 2480MHz,
- FHSS/GFSK modulation, 79 channels at 1MHz intervals
- Secure communications, 128 bit encryption
- Error correction for guaranteed packet delivery
- UART local and over-the-air RF configuration
- Auto-discovery/pairing requires no software configuration (instant cable replacement).
- Auto-connect master, IO pin (DTR) and character based trigger modes

Digital I/O Characteristics

2.7V ≤ VDD ≤ 3.0V	Min	Typ.	Max.	Unit
Input logic level LOW	-0.4	-	+0.8	V
Input logic level HIGH	0.7VDD	-	VDD+0.4	V
Output logc level LOW	-	-	0.2	V
Output logic level HIGH	VDD-0.2	-	-	V
All I/O's (except reset) default to weakpull down	+0.2	+1.0	+5.0	uA

Environmental Conditions

Parameter	Value
Temperature Range (Operating)	-40 °C ~ 85 °C
Temperature Range (Storage)	-40 °C ~ 85 °C
Relative Humidity (Operating)	≤90%
Relative Humidity (Storage)	≤90%

Electrical Characteristics

Parameter	Min	Typ.	Max.	Unit
Supply Voltage (DC)	3.0	3.3	3.6	V
Average power consumption				
Radio ON* (Discovery or Inquiry window time)		40		mA
Connected Idle (No Sniff)		25		mA
Connected Idle (Sniff 100 milli secs)		12		mA
Connected with data transfer	40	45	50	mA
Deep Sleep Idle mode		26		uA

* If in SLAVE mode there are bursts of radio ON time which vary with the windows. Depending on how you set the windows that determines your average current.

Appendix E: L293 Motor Driver

recommended operating conditions

			MIN	MAX	UNIT
	Supply voltage	V_{CC1}	4.5	7	V
		V_{CC2}	V_{CC1}	36	
V_{IH}	High-level input voltage	$V_{CC1} \leq 7$ V	2.3	V_{CC1}	V
		$V_{CC1} \geq 7$ V	2.3	7	V
V_{IL}	Low-level output voltage		–0.3†	1.5	V
T_A	Operating free-air temperature		0	70	°C

† The algebraic convention, in which the least positive (most negative) designated minimum, is used in this data sheet for logic voltage levels.

electrical characteristics, V_{CC1} = 5 V, V_{CC2} = 24 V, T_A = 25°C

PARAMETER			TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_{OH}	High-level output voltage		L293: I_{OH} = –1 A L293D: I_{OH} = –0.6 A		V_{CC2}–1.8	V_{CC2}–1.4		V
V_{OL}	Low-level output voltage		L293: I_{OL} = 1 A L293D: I_{OL} = 0.6 A			1.2	1.8	V
V_{OKH}	High-level output clamp voltage		L293D: I_{OK} = –0.6 A			V_{CC2} + 1.3		V
V_{OKL}	Low-level output clamp voltage		L293D: I_{OK} = 0.6 A			1.3		V
I_{IH}	High-level input current	A	V_I = 7 V			0.2	100	µA
		EN				0.2	10	
I_{IL}	Low-level input current	A	V_I = 0			–3	–10	µA
		EN				–2	–100	
I_{CC1}	Logic supply current		I_O = 0	All outputs at high level		13	22	mA
				All outputs at low level		35	60	
				All outputs at high impedance		8	24	
I_{CC2}	Output supply current		I_O = 0	All outputs at high level		14	24	mA
				All outputs at low level		2	6	
				All outputs at high impedance		2	4	

switching characteristics, V_{CC1} = 5 V, V_{CC2} = 24 V, T_A = 25°C

PARAMETER		TEST CONDITIONS	L293NE, L293DNE			UNIT
			MIN	TYP	MAX	
t_{PLH}	Propagation delay time, low-to-high-level output from A input	C_L = 30 pF, See Figure 1		800		ns
t_{PHL}	Propagation delay time, high-to-low-level output from A input			400		ns
t_{TLH}	Transition time, low-to-high-level output			300		ns
t_{THL}	Transition time, high-to-low-level output			300		ns

switching characteristics, V_{CC1} = 5 V, V_{CC2} = 24 V, T_A = 25°C

PARAMETER		TEST CONDITIONS	L293DWP, L293N L293DDWP, L293DN			UNIT
			MIN	TYP	MAX	
t_{PLH}	Propagation delay time, low-to-high-level output from A input	C_L = 30 pF, See Figure 1		750		ns
t_{PHL}	Propagation delay time, high-to-low-level output from A input			200		ns
t_{TLH}	Transition time, low-to-high-level output			100		ns
t_{THL}	Transition time, high-to-low-level output			350		ns