March 10, 2016

Dr. Andrew Rawicz

School of Engineering Science

Simon Fraser University

Burnaby, BC V5A 1S6

Re: ENSC 440 Design Specification for a Smart Baby Cradle

Dear Dr. Rawicz,

The following document is the design specification report of the Smart Baby Cradle from BABY ROCK. We aim to design and implement a smart baby cradle that can help young parents to take care of the babies with a mobile device application.

The purpose of this design specification is to provide a design details including the test plan of a prototype of the smart baby cradle. The commercialized product will also follow this design and contains some improvement in the future.

The company, BABY ROCK, consists of four talented engineering science students: Fanchao Meng, Yu Liu, Xiaoye Lu and Kiru Sri. If you have any questions or concerns, please feel free to contact us by phone at (778) 990-3591 or by e-mail at fanchaom@sfu.ca.

Sincerely,

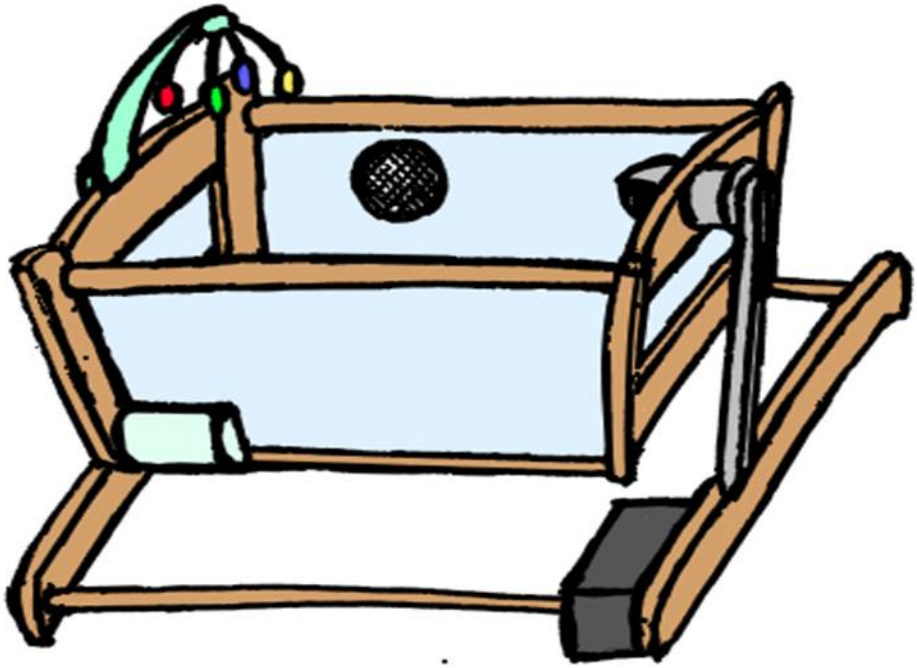
Fanchao Meng

Fanchao Meng

Chief Executive Officer

Baby Rock

Enclosure: Proposal for a Smart Baby Cradle



Functional Specifications for a Smart Baby Cradle
Simon Fraser University School of Engineer 2016

MARCH 10, 2016

SMARTY BABY CRADLE

DESIGN SPECIFICATIONS, REVISION 2.0

FANCHOU MENG, YU LIU, XIAOYE LYU, & KIRU SRI
SIMON FRASER UNIVERSITY
School of Engineering

Executive Summary

This design specification document describes the design details of the smart baby cradle prototype. The final smart baby cradle product will also follow this design document but the electronic components will be changed to more effective and integrated devices. In this document, all the designs will consider the customer and safety requirements that were mentioned in the functional specification. The requirement labels in this document corresponds to the functional specification requirement labels.

The design specification covers the four critical design aspects of the smart baby cradle: motor, speaker/mic, webcam and mobile toy. The Android application design will also be mentioned. The stepper motor controls the movement of the cradle, including the swing angle and speed. The motor is driving by the microcontroller combined with a stepper motor drive which provides power and signal to the motor. The speaker/mic provide the communication between the baby and the system (or parents in other word). Both of them are powered and controlled by the microcontroller. The webcam provides visual feature to the system. The webcam is driven by the microcontroller combined with a module shield which can adjust the resolution and delay of the video signal. The mobile toy is another main feature that can help parent to comfort the baby. It is powered by external cable and its switch is controlled by the microcontroller with a relay on it.

The mechanical design will also be mentioned during each component design details. The motor has two design options. It can connect to the cradle directly or with the belt. The speaker/mic are attached to the cradle body near to the head of the baby. The webcam is set up at the side of cradle and face to the baby in order to record the whole cradle bed. The mobile toy is attached to the cradle body and is visible to the baby. The microcontroller and other module shields are set on a flat stage under the cradle.

In this document, the selection of each component that meet the requirements will be stated during each design sections as well.

Fortunately, the process follows the company's original schedule and the prototype product can be finished before the demonstration date.

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Glossary

AC	Alternating Current
CSA	Canadian Standards Association
CPU	Central Processing Unit
GPIO	General Purpose Input Output
I/O	Input/Output
IEEE	Institute of Electrical and Electronics Engineers
RAM	Random Access Memory
User	The parent who are the target audience of this product
WLAN	Wireless Local Area Network
Mic	Microphone
App	Android Appication
DAC	Digital to Analog Convertor
ADC	Analog to Digital Convertor

1. Introduction

1.1 Purpose

The Smart Baby Cradle is a complete system, which provides instant wireless remote to monitoring and comforting the baby. Through Android smart phone, parents is capable to control the whole system, including rocking the bed, speaking to baby, turning on the toy and seeing the baby. This document will demonstrate the requirements and design specification, as proposed by Baby Rock.

1.2 Scope

This document will describe the requirement the Smart Baby Cradle has to obtain with the detailed design content as the reason how the company make the project achieve all functions. It explains design of overview system, the cradle mechanics, microcontroller, motors, webcam, speaker, microphone, Wi-Fi connection, and mobile toy specifically. Furthermore, requirements listed in this document will be used ad guidelines for the design, development, and testing for the Smart Baby Cradle to ensure safety and reliability.

1.3 Intended Audience

The intended audience are designed to be all members of Baby Rock. The team will refer to this document as overall design goals through development. Justifying any design decisions, creating template for future modification and upgrades, and quality assurance have to follow this document as reference.

2. System Overview

2.1 Overall description

The system contains a microcontroller, Arduino Uno board which controls all five components: Microphone, Motor, Speaker, Mobile Toy and Webcam (Figure 1). The microphone receives baby's crying and sends signal to microcontroller to activate the whole system. After the signal is received, parents will be notified through android phone with Wi-Fi module connection between the microcontroller and smart phone. Parents should be able to control all functions: playing relaxing music through speaker, turning on the mobile toy to distract the baby, rocking the cradle, also most importantly monitoring the baby continuously through webcam with their android application on phone. The system will be in initial position without operation, with the cradle bed parallel to the ground.

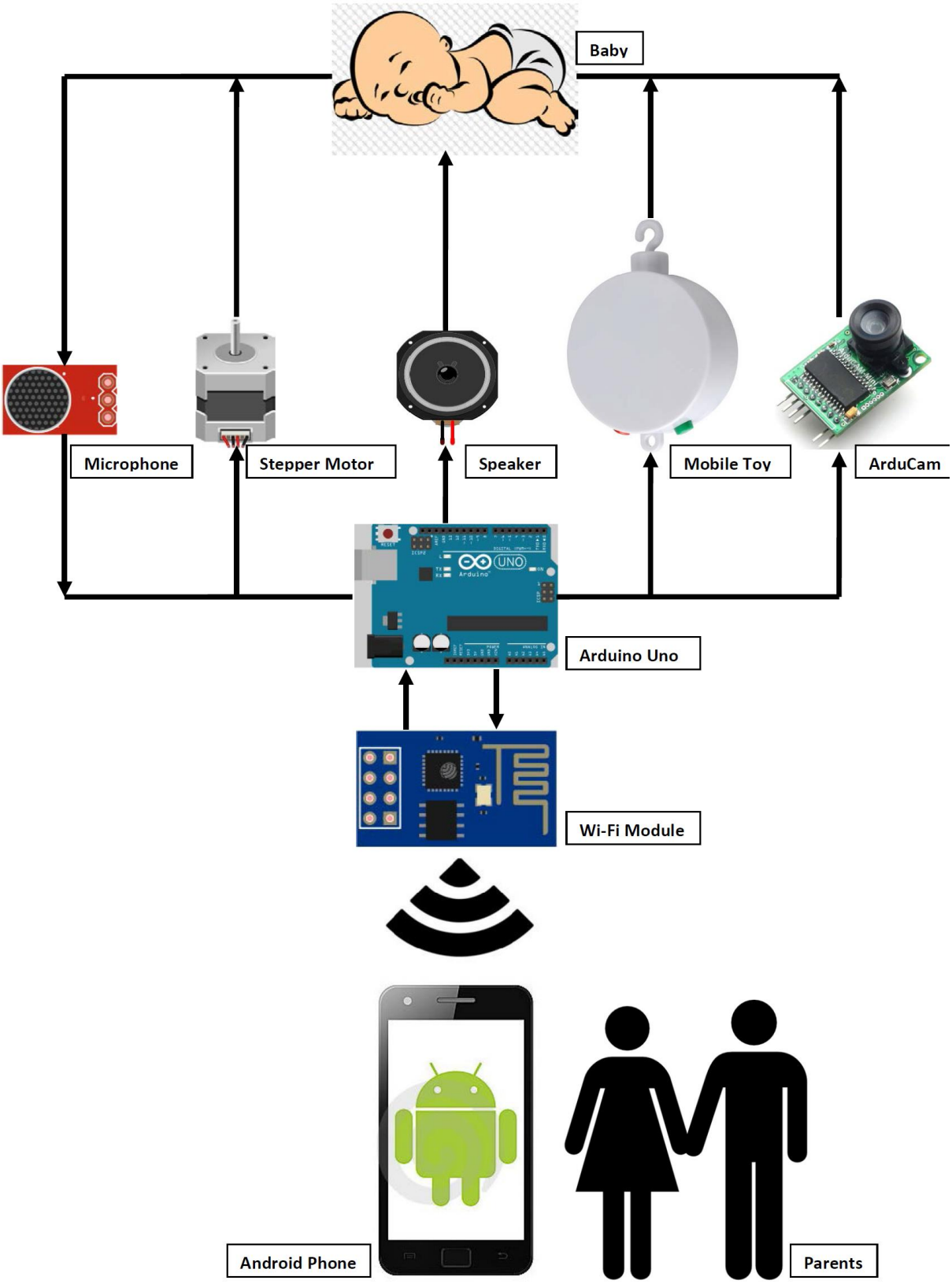

Figure 1: The overall system connection

2.2 Customer Requirements

The requirements listed below are the critical ones to the whole system. In order to meet [R0.01-I] and **[R0.02-I]**, an ESP 8266 serial to Wi-Fi 2.4GHz module was selected for all design phases of system for its simplicity of use, well encapsulated library and low power consumption compared to the Arduino Wi-Fi Shield. Equipped with external pins, it can be connected to the Arduino Uno via jumper wires or soldering board together and it is also an SMT (Surface Mount Technology), suitable for PCB designs in the product phase. Both mobile toy and Arduino Uno need external AC power supply to operate, that meets **[R0.04-I]**. Furthermore, all electric and electronic components are covered and located below the cradle bed by nontoxic material to avoid baby's touch to satisfy **[R3.01-I], [R3.02-I], [R3.08-I], [R3.09-I], [R3.10-I], [R3.12-I], and [R3.13-I].**

3. Motor and Motor Driver Design

3.1 Motor Driver

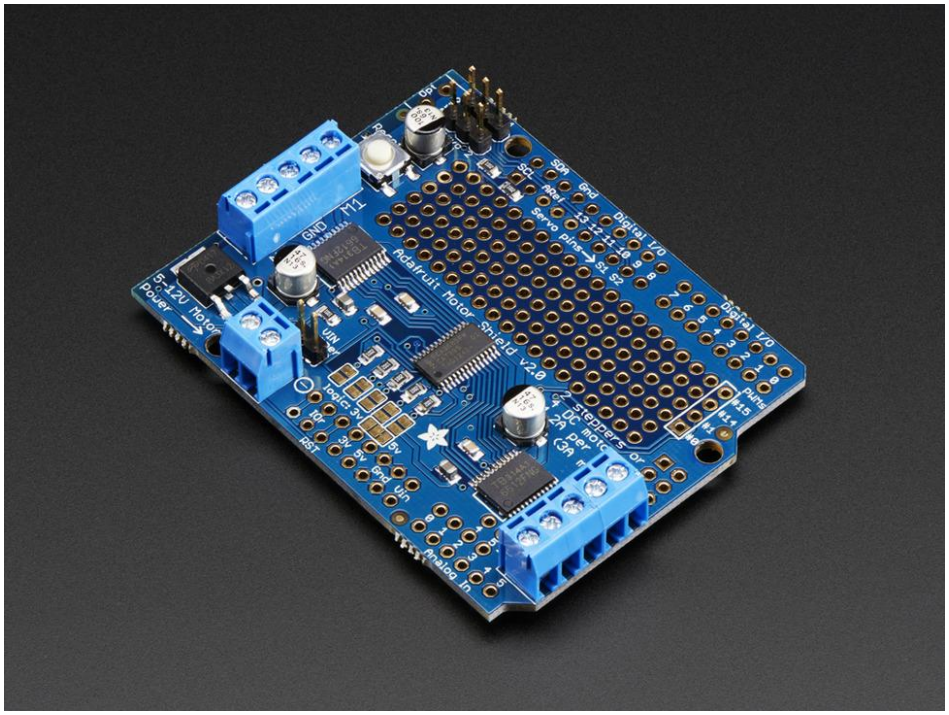

Figure 2: The motor driver for the Arduino

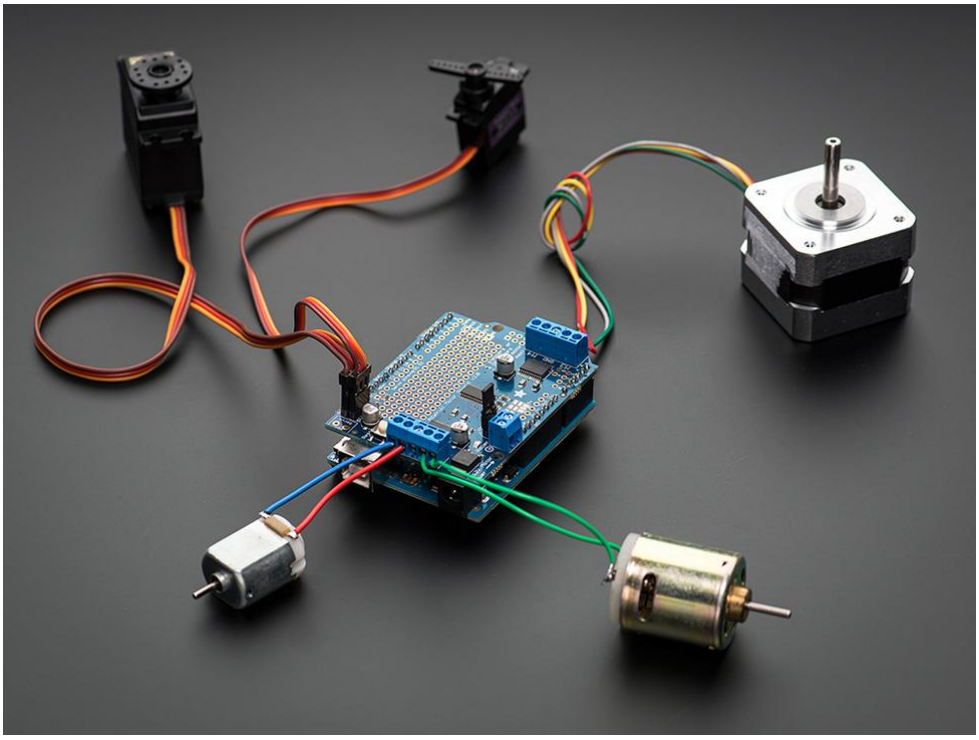

Figure 3: Motor Driver mounted to Arduino and connected to Motors

The motor driver that is used for the project. It is mounted to the microcontroller as shown in the above image. The Tangled green, yellow, Red and White wires, seen connected to the square metal motor will be the port being used to control the rotation of the stepper motor.

3.2 Motor

$$\tau = F * D * \sin \emptyset$$

D is the Center of Mass; assuming the center of mass is at the very edge of the bottom of the crib, and the maximum weight of the crib + baby to around 20 kg. The distance to the bottom is around 22 cm. For the prototype we are using a weaker motor. The Figure 4 describes the motor equation [1].

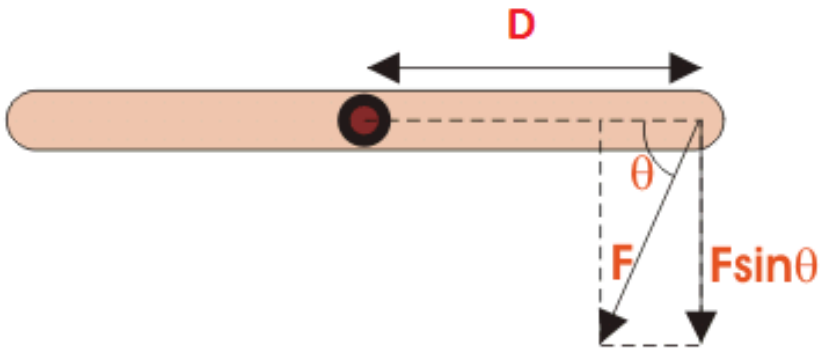

Figure 4: Method used to calculate torque

The Maximum torque required would be when Ø is 90^{o}.

$$\tau = F * D$$
$$\tau = 20 * 9.8 * 0.22$$
$$\tau = 43.12\ Nm$$

Our system requires a motor that can handle a minimum of 43.12 Nm in the final product.
The motor will meet the following requirement that was set in the Functional Specifications: **[R0.13-I] [R0.14-II] [R0.15-I] [R1.05-II]** [**R0.16-I]**.

It does not meet [**R0.17-II]** due to the motor being operational at 3 V DC not 24 V DC.
If the motor was directly attach to the cradle to rock the cradle. Since the motor has 400 steps, IT will reach a maximum of 34 steps which is equivalent to 30^{o} (**[R0.09-I]**) in either direction from starting position. The maximum speed the motor will step up by is 34 steps per second in order to meet **[R0.12-I]** (30 rocks per minute). Otherwise if the motor is not strong enough we can use a belt to increase the strength using gear ratio.

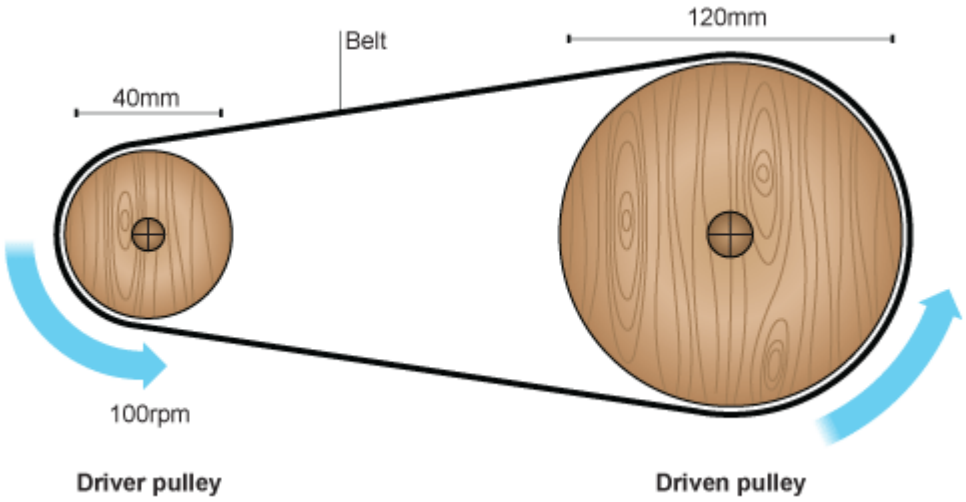

Figure 5: Gear Ratio to Increase torque example

The gear ratio shown in Figure 5 is a 4 to 1 ratio [2], it would increase the torque 4 times while decreasing its rotation speed by a factor of 4. This would require the motor to move 4 Times as many steps and increase the number of steps in between the 30^{o} movement of the cradle. The gear ratio being used in the smart Baby Cradle is a 10 to 1 ratio.

The motor used is from Spark fun it is displayed below (Figure 6) [3].

Figure 6 : Stepper Motor purchased for the Smart Baby Cradle

This motor will be controlled by the motor driver. Commands are send to it from the Arduino.

4. Mobile Toy Design

As Smart Baby Cradle's functional specification of **[R0.28-III]** and **[R0.29-III]** is already covered by Health Canada on children's toy regulations [4], So, any toys on Canada Market will satisfy [R0.28-III] and **[R0.29-III]**. Furthermore, according to **[R0.33-III]**, the ON/OFF state of toy should be controlled by microcontroller, but the selected microcontroller (Arduino Uno Rev 3) for Smart Baby Cradle is not capable on control other switches directly. Therefore, a medium is desired to enable Arduino Uno on switching the Mobile Toy.

In order to achieve **[R0.33-III]**, a relay is introduced as medium between Arduino Uno and Mobile Toy as shown in Figure 7 [5]. Firstly, after removed existing switch from Mobile toy, and place the relay on it. Then, connect the Arduino's digital output pins to relays' control pins.

From perspective of electrical, 5V TTL active channel control logic is required as it is the default logic level from Arduino, and the passive channel should satisfy wide voltage range from 5V-30V for potential Mobile Toy replacement.

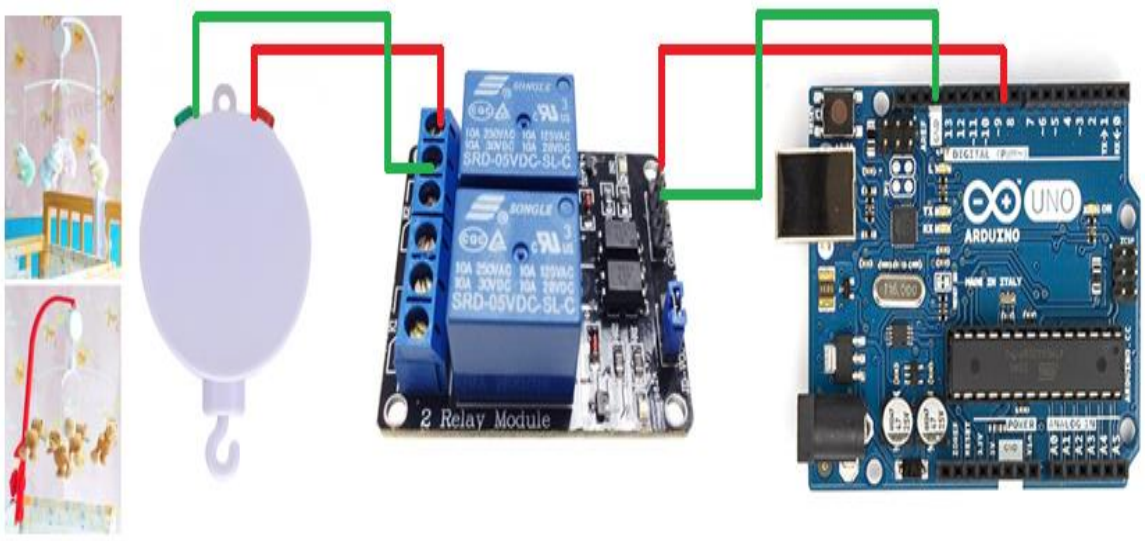

Figure 7: The System that controls the motor for the mobile toy

In order to satisfy **[R1.14-III]** and **[R1.15-III]**, the dimension and weight of the relay module is also constrained to a smaller searching range.

5. Speaker Design

5.1 Property

The speaker allows parent to play a period of relaxing melody to comfort baby when the baby is crying. The speaker needs to be small in size and also easy to be connected and controlled by the microcontroller (Arduino UNO). The speaker used for the project has a manufacturer part number of AS02808MR-2-R which also has the following properties (Figure 8).

Category	Audio Products
Family	Speakers
Series	-
Type	Magnetic
Frequency Range	600Hz ~ 20kHz
Impedance	8 Ohm
Sound Pressure Level	85dB
Power - Rated	500mW
Power - Max	1W
Port Location	Top
Shape	Round
Material - Cone	PET
Material - Magnet	Nd-Fe-B
Termination	Solder Pads
Size / Dimension	28.00mm Dia
Height	4.70mm
Other Names	668-1397

Figure 8: Datasheet of Speaker (AS02808MR-2-R)

Since the speaker is only 28mm in diameter and 4.4mm in thickness, it meets the requirement **[R1.09-II]** of the function specification. The small speaker can be easily mounted on the sideboard of the cradle where it can't be reachable for the baby. Therefore, it also meets the **[R1.10-I]** and **[R3.09-I]** from the function specification. The speaker also has a lead free status/RoHS status which means it doesn't contain any hazardous substances.

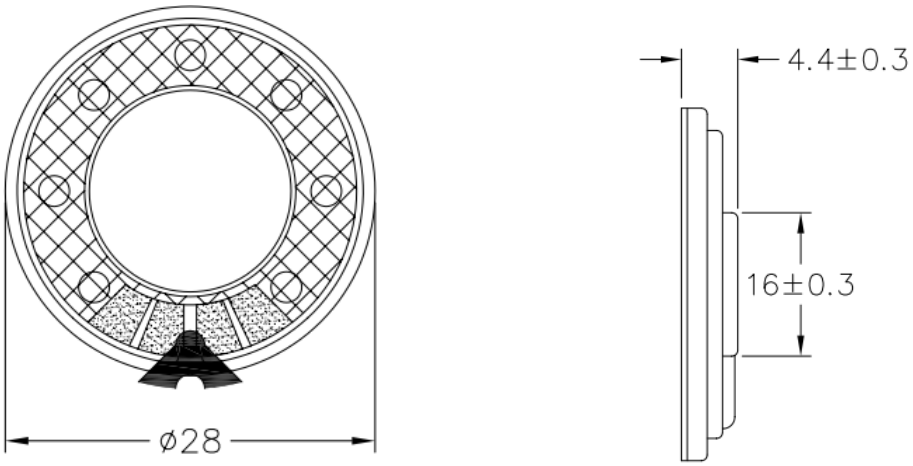

Figure 9: The speaker Dimensions

5.2 Circuit Connection

The speaker is directly connected with the Arduino UNO port8 and ground by using hook-up wires. The detailed connection graph and schematic are shown below (Figure 10):

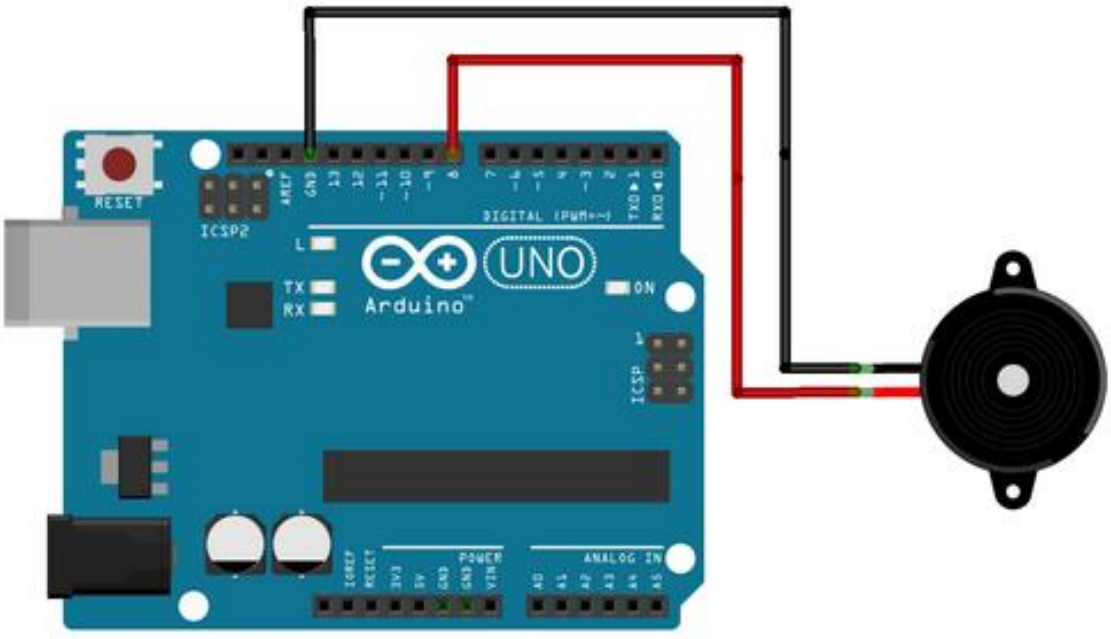

Figure 10 : Arduino and Mic Connected

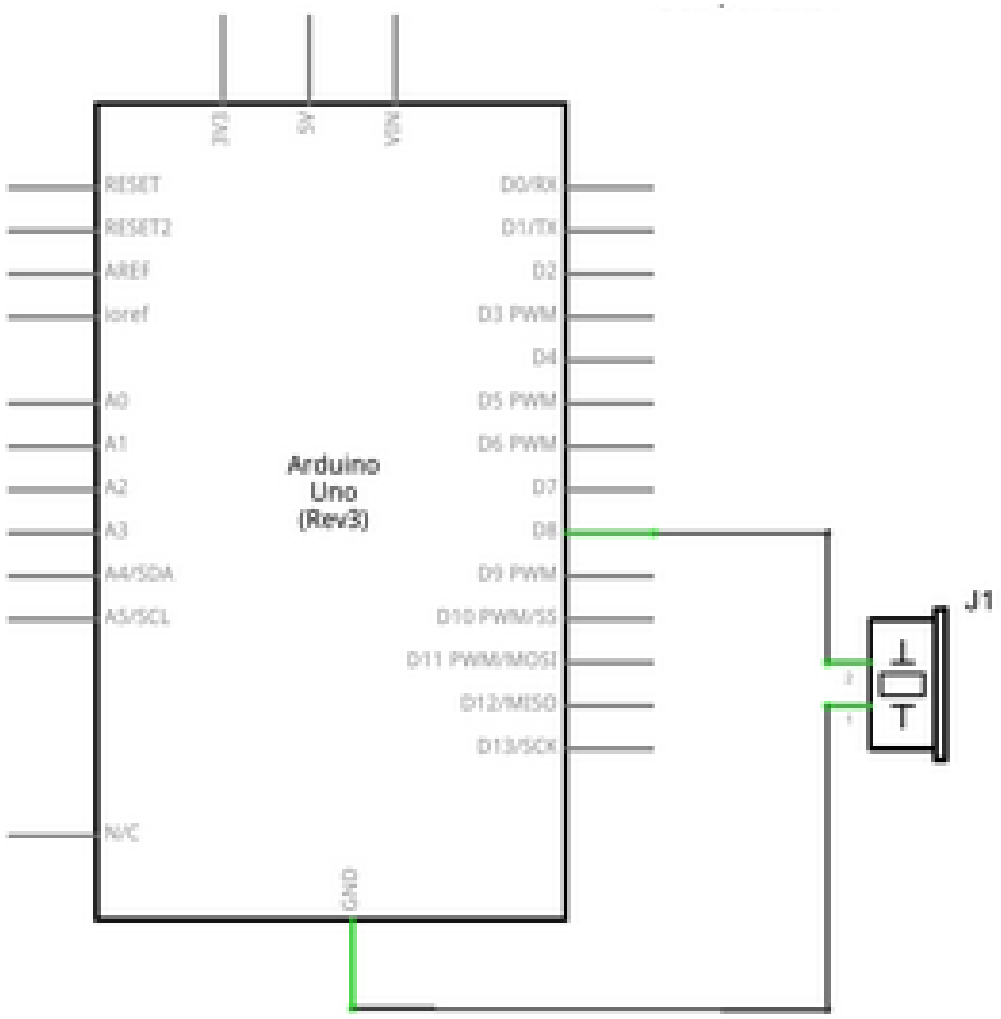

Figure 11: Schematic for the Mic and Arduino

In order to use Arduino to control the speaker, the tone command can be used to generate musical notes. In the code, a note variable has to be declared to store different notes. A note duration variable also needs to be declared, so duration of each note can be calculated and stored in the variable. Then the Arduino sends signals containing the notes and their durations to trigger the speaker [6].

6. Webcam Design

The webcam in the smart baby cradle system allows users/parents to monitor the baby's condition using a mobile device application. In order to perform the task easily, the camera has to be compact so it can be easily installed on the top of the footboard. In order to control it using Arduino, it also needs to be easy to use hardware interface and open source code library. The

camera used in the project is ArduCam Mini 2MP OV2640. The key specifications of the ArduCam Mini are shown below (Figure 12):

Key Specification	2MP
Image Sensor	OV2640
Active array size	1600×1200
Shutter	rolling shutter
Lens	1/4 inch
SPI speed	8MHz
Frame buffer Size	384KB
Board Size	34 x 24 mm
Weight	20g
Temperature	-10°C~+55°C
Power Consumption	Normal :5V/70mALow power mode: 5V/20mA

Figure 12: key specifications of the ArduCam Mini

Comparing with other camera model, ArduCam Mini best meets the [R0.20-II], [R1.07-I], [R1.08-II] requirements of our function specification. It has an operational voltage range between 3.3v to 5v for all of its IO ports which meets Arduino UNO's operational voltage 5V. It also has 9 different resolution selections from 160x120p to 1600x1200p. Since higher the resolution can results the larger delay time, at 352x280p resolution, the output video has a relatively clear resolution with acceptable time delay under 0.5 second.

The connection of the ArduCam Mini and the Arduino UNO is shown below (Figure 13 and Table 1):

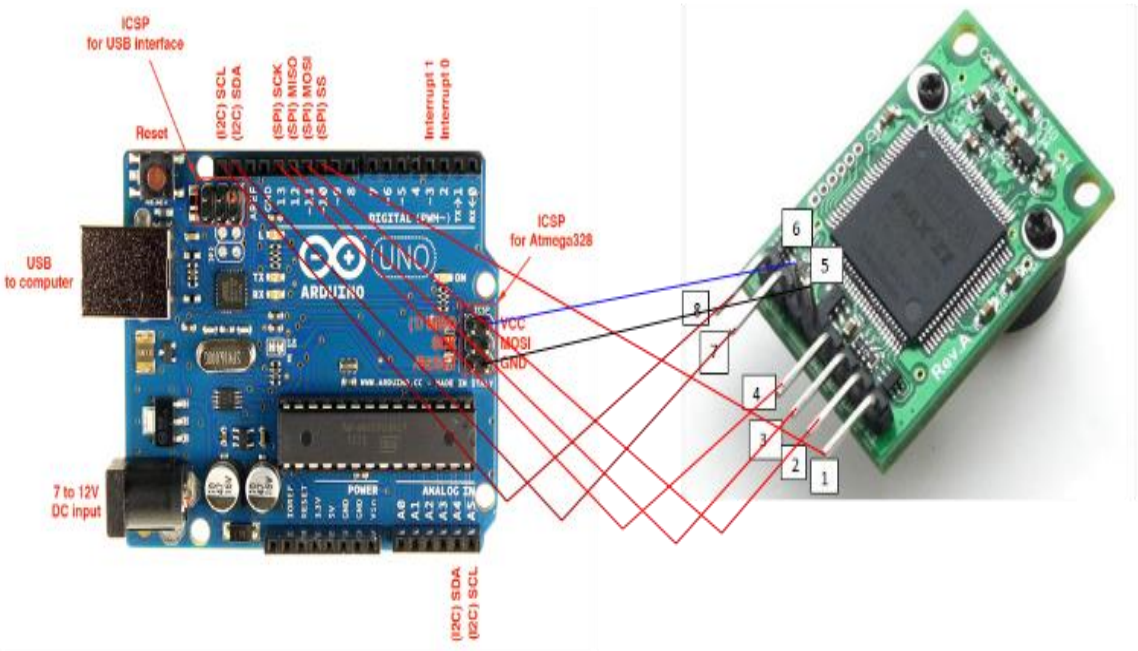

Figure 13: Arduino UNO and ArduCam Mini ping connection

Table 1: ArduCam Mini Pin Definition

Pin No.	PIN NAME	TYPE	DESCRIPTION
1	CS	Input	SPI slave chip select input
2	MOSI	Input	SPI master output slave input
3	MISO	Output	SPI master input slave output
4	SCLK	Input	SPI serial clock
5	GND	Ground	Power ground
6	+5V	POWER	5V Power supply
7	SDA	Bi-directional	Two-Wire Serial Interface Data I/O
8	SCL	Input	Two-Wire Serial Interface Clock

The ArduCam Mini manufacturer provides an open source library for Arduino which can be used directly with only minor modifications [7].

7. Test pan

The smart baby cradle is to help parents to monitoring the baby and comfort the baby. All features relate to each other. In order to test the system performance, some integrated test have to be done. For some component, such as motor, the functionalities need to be tested as well.

7.1 Integrated test

In order to test the system performance, the following conditions have to be made and considered:

1. All the electronic components need to be connected to the microcontroller
2. The power for the microcontroller, the motor and the mobile toy need to be supplied properly
3. All signals can be detected by the microcontroller and be received by the phone

The overall performance test can be done by following steps:

1. Power the microcontroller, the motor and the mobile toy
2. Simulate the baby crying sound to the mic
3. Check if the phone application sends a notification
4. Select webcam feature in the phone and check if the phone can display the real time video from webcam
5. Turn off the webcam
6. Turn on the motor by the phone and check if the cradle starts to rock smoothly
7. Turn off or stop rocking the cradle
8. Turn on the speaker and check if the music melody is played through the speaker
9. Turn off the speaker of stop playing the music
10. Turn on the mobile toy by the phone and check if the toy starts to work
11. Turn off the mobile toy
12. Repeat steps 4-11 to check if the system can work properly steadily and stably

7.2 Motor test

Test case 1

Preconditions:

1. All the electronic components need to be connected to the microcontroller
2. The power for the microcontroller, the motor and the mobile toy need to be supplied properly
3. All signals can be detected by the microcontroller and be received by the phone
4. Put weight in the cradle

Input:

Turn on the motor and rock the cradle for 10 minutes.

Expected result:

The motor keeps rocking the cradle with fixed speed and swing angle

Test case 2

Preconditions:

1. All the electronic components need to be connected to the microcontroller
2. The power for the microcontroller, the motor and the mobile toy need to be supplied properly
3. All signals can be detected by the microcontroller and be received by the phone
4. Put weight in the cradle
5. The motor is rocking the cradle smoothly

Input:

Turn off the power of the motor or turn off the power of the microcontroller

Expected result:

The cradle will be set to the original horizontal positon

7.3 Webcam test

Test case 1

Preconditions:

1. All the electronic components need to be connected to the microcontroller
2. The power for the microcontroller, the motor and the mobile toy need to be supplied properly
3. All signals can be detected by the microcontroller and be received by the phone
4. Put moving object in front of the webcam

Input:

Select the lowest resolution option (320X240)

Expected result:

The phone can clearly display the object

Test case 2

Preconditions:

1. All the electronic components need to be connected to the microcontroller
2. The power for the microcontroller, the motor and the mobile toy need to be supplied properly
3. All signals can be detected by the microcontroller and be received by the phone
4. Put moving object in front of the webcam

Input:

Select the highest resolution option (1600X1200)

Expected result:

The phone can clearly show the movement of the object

8. Conclusion

This document provides the design specifications for Smart Baby Cradle to meet the functional specifications. These specifications include: system overview, cradle mechanics, stepper motor design, webcam, speaker, microphone, mobile toy, microcontroller unit and android application.

The detailed electric designs and mechanical ideas are all include as well. Furthermore, system test plan is designed ensure product quality and functionality of the overall system. By following the requirements in this document, Baby Rock is confident to claim that Smart Baby Cradle will be designed to the highest quality and ensured safety to the future customers.

References

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http://www.electrical4u.com/torque-equation-of-dc-motor/ [Accessed: Mar 9, 2016]

[2] “*Design & Technology*”
http://www.bbc.co.uk/schools/gcsebitesize/design/systemscontrol/mechanismsrev7.shtml [Accessed: Mar 9, 2016]

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[4] “*Industry guide to health Canada’s safety requirement for children’s toy and related products, 2012*”
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