UNIVERSITY OF ILLINOIS AT

URBANA-CHAMPAIGN

ECE 445: Project Design Document

Safe Crib with Auto-Hazard Detection

SPRING 2023

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Content

Description

1. Introduction

1.1 Problem and Solution

Ensuring a baby's safety in the crib is not an easy job, especially when the babies are athletic. Sources on the internet have indicated that babies can start climbing out of the crib when they are eight months old [1]. It is impossible to keep an eye on the baby all the time in the home setting because the parents are not in the baby's room at every moment. Therefore, we decide to make a safe crib with auto-detection of hazards to detect whether the baby is attempting to climb the crib. When a potentially dangerous event is happening, the crib system will notify the monitor system on the parent's side to draw their attention. Besides, when babies cry, they usually demand feeding or diaper change. Neglecting the former can lead to malnutrition, and neglecting the latter can cause skin irritation or even bladder infections. Moreover, crying refers to many different signals to parents, such as sickness or burping, which indicates the significance of crying for parents to take care of their babies [2].

Our team proposed a safe crib with hazard detection to solve this problem. This electrical approach to a safe crib is new to the market since it detects hazards and reports them to the parents. The crib can utilize several types of sensors to detect the state of the baby and alarm parents to take care of the baby if necessary. First, the crib contains ultrasonic sensors on the top of the guardrail, detecting if the baby is trying to climb the guardrail, which might induce falling off the crib. Second, several pressure sensors are placed above the mattress, forming a matrix to detect the approximate position of the baby and if they are crawling. Third, a sound sensor is positioned on the guardrail. If the baby is crying, indicating the need for food or a diaper change, the sound sensor will detect that voice. The microcontroller in the crib system will analyze the signals from the sensors and report any situation to the monitor system at the parent's side.

1.2 Visual Aid

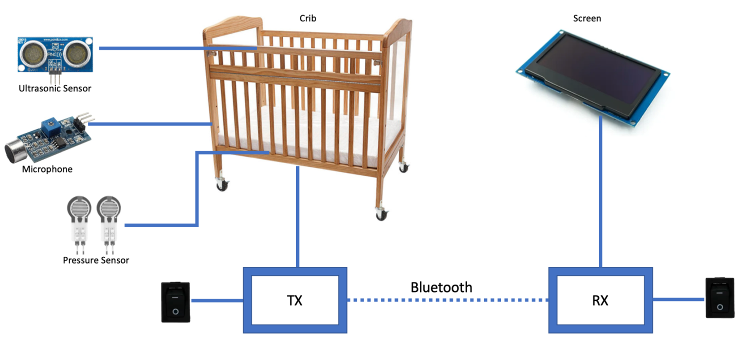

Figure 1.1 Visual Aid of Smart Crib

1.3 High-level requirements

1. The safe crib system needs to notify the parents about the baby's attempts to climb out of the crib or their crying within 1 s after a triggering event happens.

2. The crib subsystem needs to be able to send updates to the monitor subsystem when the monitor subsystem is within 10 m of the crib.

3. The sound detector needs to be able to report to the monitor subsystem when the detected sound intensity exceeds 90 dB.

2. Design

2.1 Block Diagram

There are six subsystems contributing to the smart crib. The crib and monitor power subsystems provide a steady 5 V DC voltage supply to all the components in other subsystems. The sensor subsystem is in charge of collecting the information regarding the baby's current state and sending them to the microcontroller unit (MCU) in the crib control subsystem, which processes these data and determine the baby's current state and sends an activation signal to the monitor system through Bluetooth. The monitor control subsystem will receive and decode that activation signal and recognize which state the baby is in and control the screen of the UI subsystem to display messages about the baby's situation and induce the buzzer to alarm if necessary. Both the crib power subsystem and the monitor power subsystem step down the voltage from 9 V to the required 5 V.

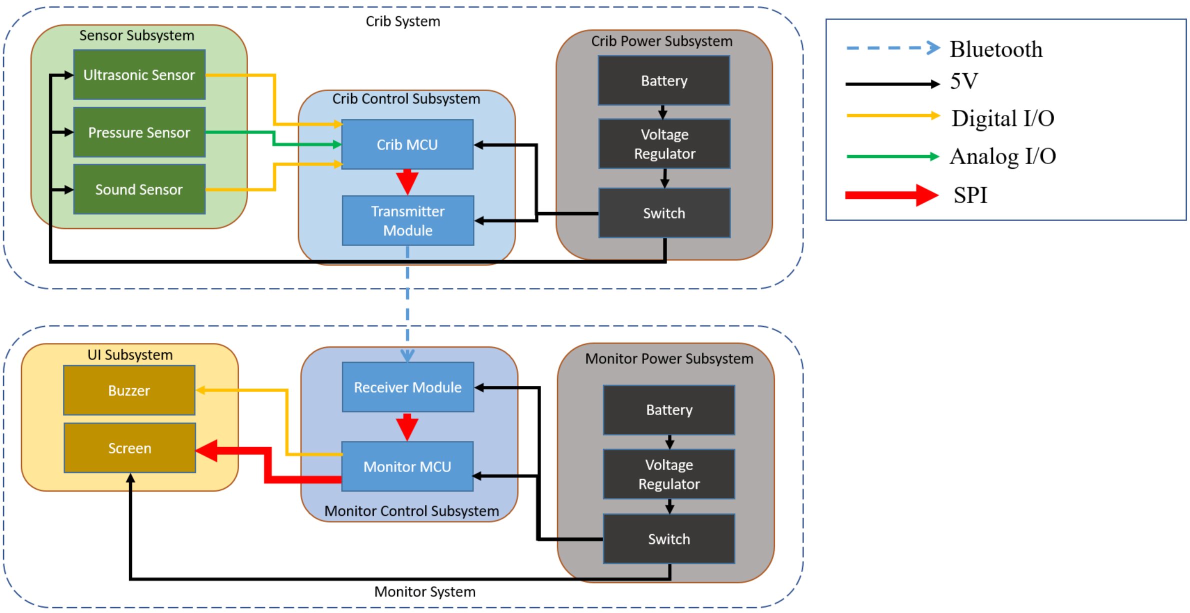

Figure 2.1 Block Diagram of Smart Crib

2.2 Physical Design

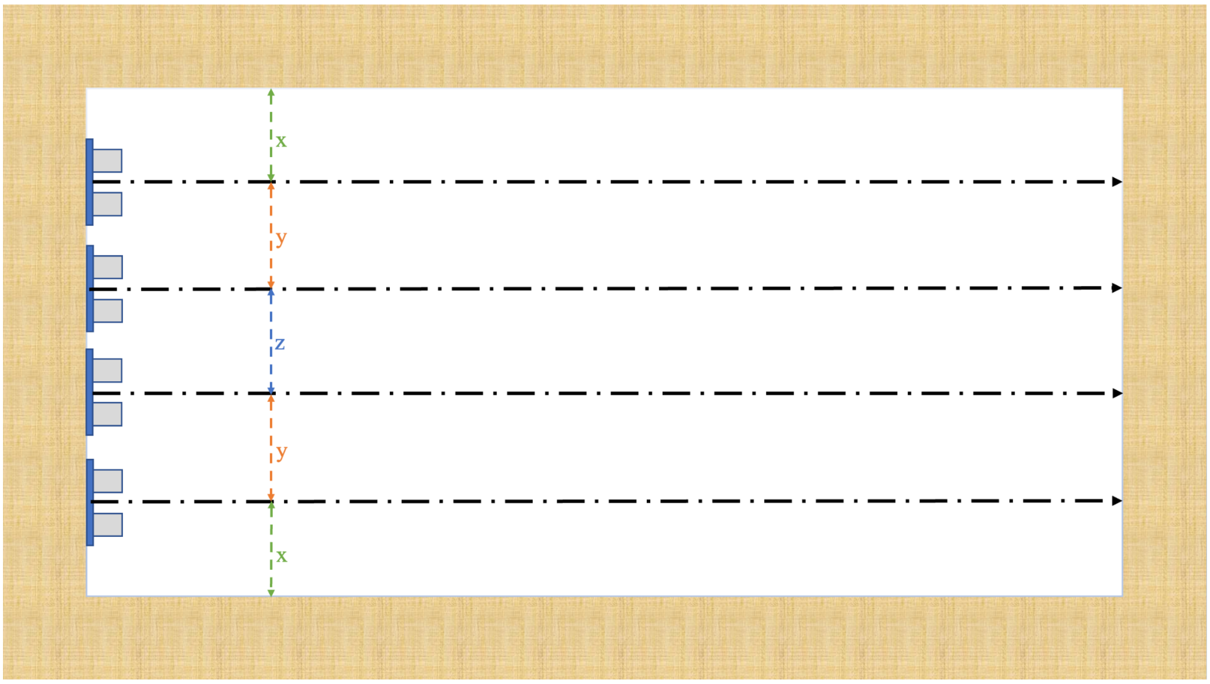

Figure 2.2 Physical Design of Smart Crib with the ultrasonic sensor array

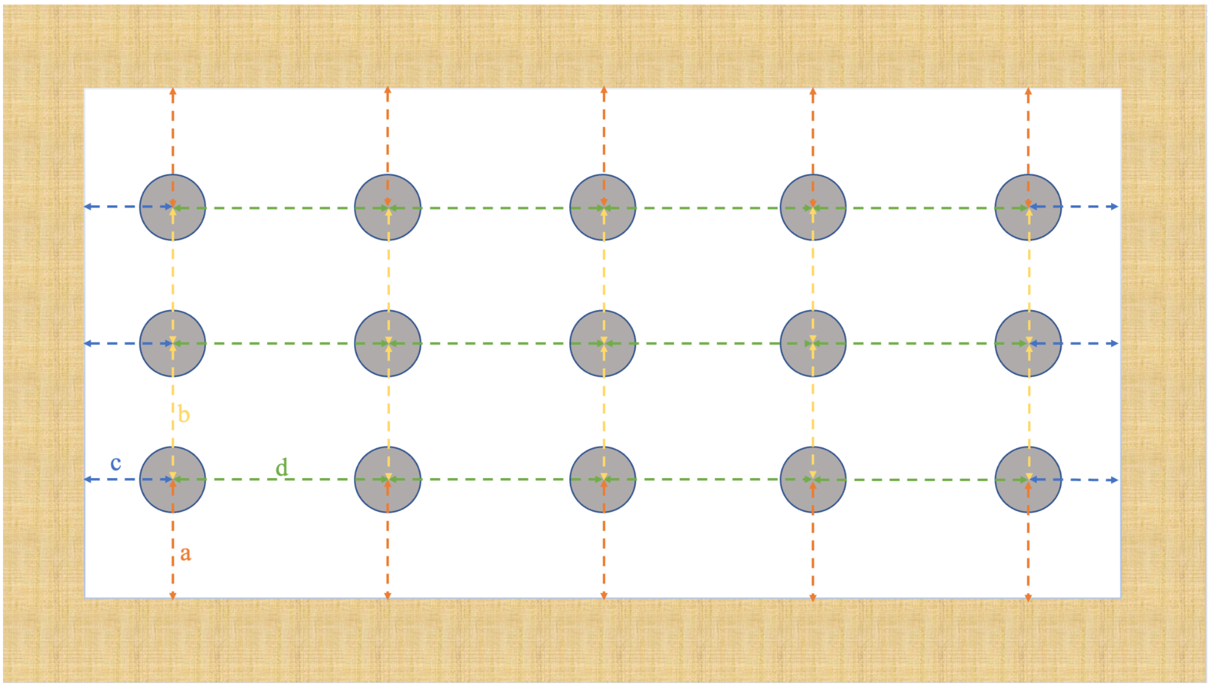

Figure 2.3 Physical Design of Smart Crib with 3-by-5 pressure sensor matrix

Figure 2.2 and 2.3 illustrates our physical design of the smart crib. We will use a big box to model the real crib and insert our sensors based on the above criteria. The distances between sensors are represented by variables. We use x, y, and z for ultrasonic sensors and a,b,c, and d for pressure sensors. The values of each distance variable are estimated in table 1, based on a Walmart moving box with dimensions listed in Table 2.2. They are subject to change based on real-life scenarios.

name	x	y	z	a	b	c	d
value(cm)	10	15	10	15	15	15	11.25

Table 2.1. Estimated Distance between Sensors

L(inch)	W(inch)	H(inch)
18	18	24

Table 2.2 Crib Dimensions

2.3 Crib System

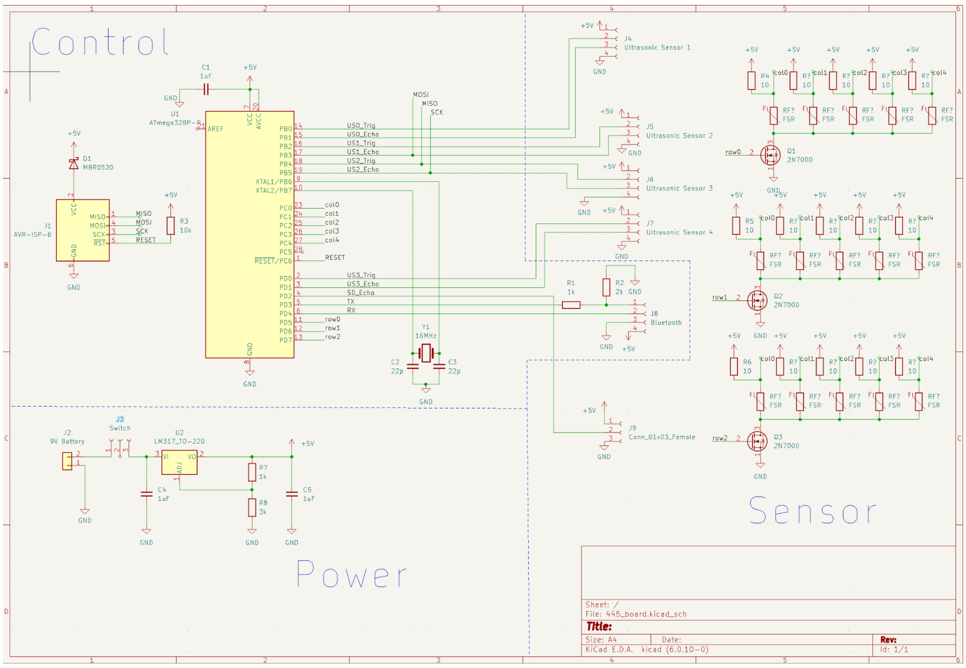

Figure 2.4 Crib PCB Schematic

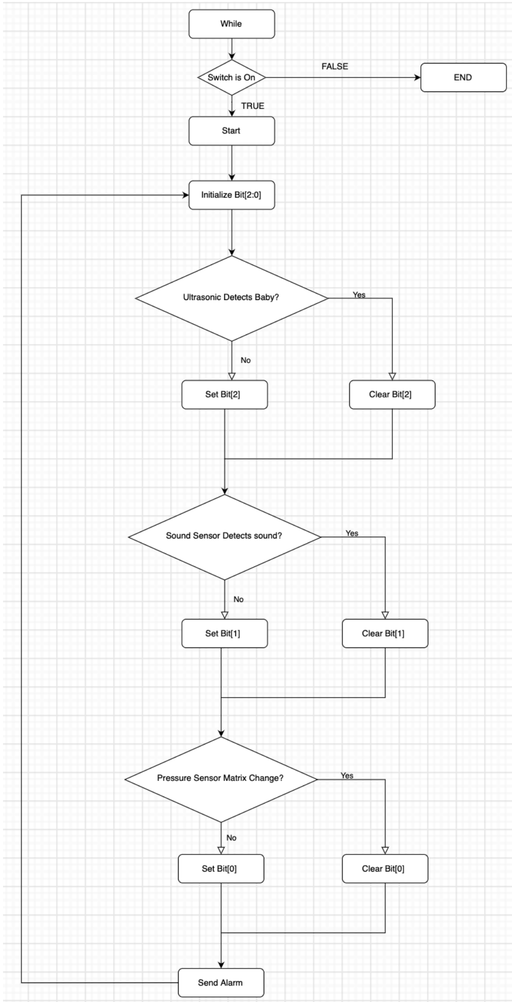

Figure 2.5 Sensor Flowchart and Algorithm

2.3.1 Subsystem 1: Crib Control Subsystem

The crib control subsystem mainly consists of a microcontroller and a Bluetooth module.

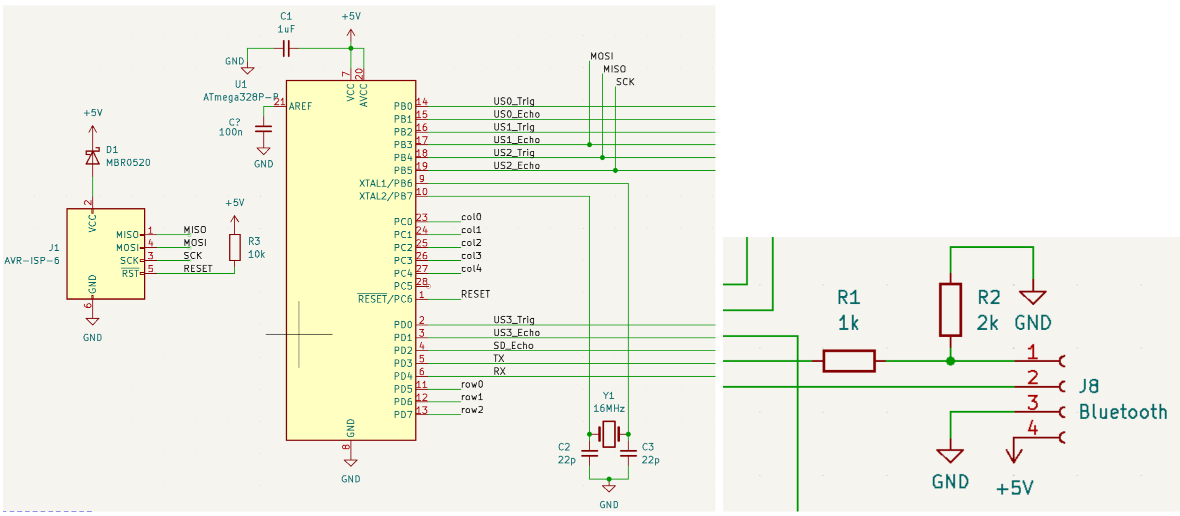

Figure 2.6 Crib Control Subsystem with Bluetooth Module Schematic

The microcontroller aims to implement several functionalities, such as data collection and analysis from the sensors. It receives the distance measurements from ultrasonic sensors, the analog voltage output from pressure sensors, and the confirmation of sound detection TTL pulse through digital and analog pins. Then it determines whether the baby is crying based on if the sound sensor is returning a TTL signal. It also uses the results from the ultrasonic sensors to decide whether the baby is trying to climb the guardrail if the measured distance is smaller than the length of the crib. Finally, when the microcontroller receives measurements from each pressure sensor array, the internal Analog-to-Digital Converter converts analog outputs from 0 V to 5 V into integers from 0 to 1023. Finally, the subsystem sends a message indicating the baby's current state to the receiver end of the monitor subsystem. There is a 16 MHz Quartz crystal oscillator with two 22 pF capacitors for clock generation. A programmer connector is wired to the microcontroller, so we can connect the computer to the controller through a USB programmer to flash our own code into the chip.

The Bluetooth module connects the digital pinout from the microcontroller. It sends out the message regarding the baby's current state, such as whether they are safe, crawling, crying, or trying to climb the guard rail, to the other Bluetooth module on the monitor control subsystem. Therefore the monitor control subsystem receives these messages and implements the corresponding display and alarm.

-0.2

Requirement	Verification
The voltage supplied to each MCU needs to be between 2.7 V and 5.5 V. Power Subsystem requirement	We can apply a multimeter to measure the DC voltage of the sound detector supply when the sensor is connected to the power supply. If the reading is between 2.7 V and 5.5 V, then the requirement is satisfied.
The MCU in the crib system needs to work at a clock frequency of at least 10 kHz. Manufacturability	When the digital pin connected to the sensor is operating, we will connect that pin with an oscilloscope and derive a transient voltage plot. And the frequency can be calculated by deriving the period of the TTL signal. If the calculated frequency is equal to or higher than 10 kHz, then the MCU can work properly.
The MCU in the crib system needs to have all I/O pins available. X	We can program the code into the input pin we want to test and set the output we want to test to become high once the input becomes high. The output is connected to a LED with a resistor. If the LED blinks, then the I/O pins become available for use.
The Bluetooth module in the crib system must be able to establish a connection and correctly transmit information to the other Bluetooth module. ✓	We can test a single Bluetooth module with a phone by downloading a Bluetooth-receiving application. Then we can program the Bluetooth module such that it sends out messages to the phone. If the

Make mathematical by writing freq or latency or speed of communication

	phone receives the right messages, then the module is functioning correctly.

Table 2.3 Requirements and Verifications for Crib Control Subsystem

2.3.2 Subsystem 2: Crib Sensor Subsystem

The sensor subsystem contains three types of sensors: ultrasonic sensors, pressure sensors, and a sound sensor. Each of them is responsible for recording information regarding the baby's behaviors and reporting to the microcontroller.

The ultrasonic sensors collect the distance measurement between themselves and the closest object from them. In principle, the sensor sends an ultrasound, which will soon be echoed back if it hits some objects. The programmable MCU in the control subsystem records the period it takes for the ultrasound to propagate and reflect back to the sensor and calculates the distance based on the recorded time multiplied by the sound speed [3]. The calculation is based on the following approach:

$$distance = speed \times time = \frac{34cm}{ms} \times duration(ms) \tag{2.1}$$

The pressure sensors are responsible for collecting the baby's weight. If the baby is on top of the pressure sensor, the sensor will act as a force-sensing resistor, which corresponds to a decrease in its internal resistance. In this case, the voltage can be sent to the MCU on the crib control subsystem for further analysis.

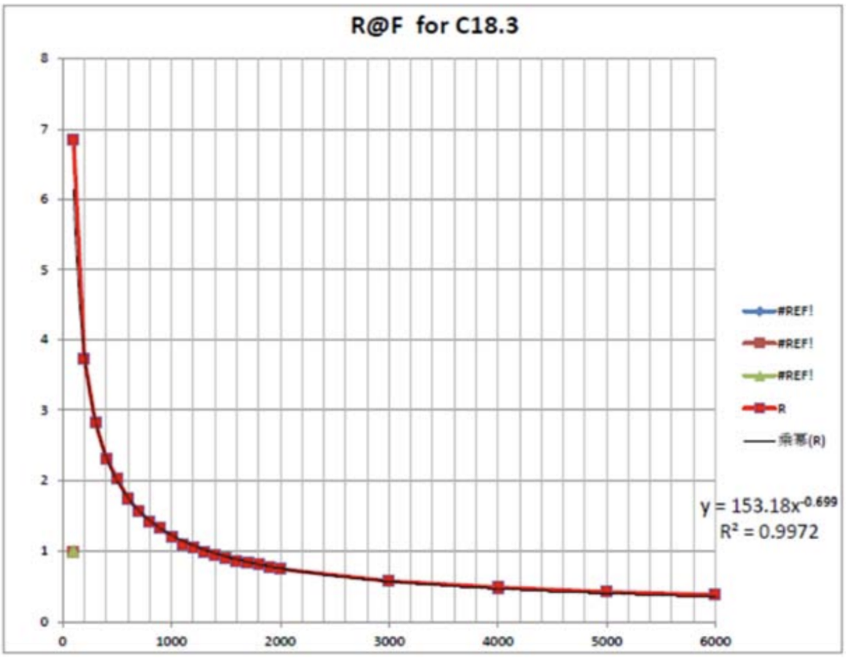

Figure 2.7 Force vs. Resistance of SEN0294 Pressure Sensor [4]

Since the MCU we demand lacks enough analog pins for simultaneously receiving the data from more than six pressure sensors, we construct three pressure sensor arrays, each controlled by an N-channel MOSFET, to receive the measurements with a negligible amount of timestamp.

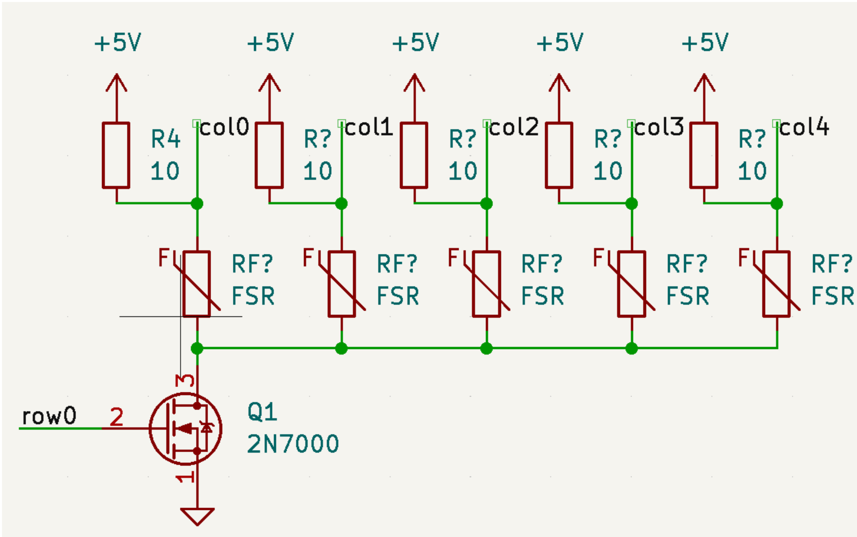

Figure 2.8 One Pressure Sensor Array Controlled by an NMOS

Each pressure sensor array is composed of five pressure sensors. Therefore a three-by-five pressure sensor matrix is constructed. The pins from row0 to row2 are connected to the digital pins on the MCU of the crib control subsystem, which sends the activation signal to each row in a serial manner. Once the gate of the N-Channel transistor receives a TTL signal, it will soon become a pull-down device and generate current from the drain to the source. So all five pressure sensors will be powered and form a resistance array, and the voltage array will be correspondingly generated and sent to the analog pins of the MCU through the connections from col0 to col4.

The sound sensor detects the nearby noise amplitude. Once the noise level reaches its threshold, the sensor will send a TTL signal through a digital pin to the MCU, which considers the signal as the baby is crying. The threshold is usually represented by the voltage gain inside the amplifier, which can be tuned manually by a potentiometer or soldering an additional resistance onto the board. In our design, we utilized a three-pin female connector with the sensor.

To generalize the interfacing, we construct a table to illustrate the output types from the sensors to connect them to the correct pin of the MCU.

Sensors	Ultrasonic Sensor	Pressure Sensor	Sound Sensor
Output Type	Digital(TTL)	Analog	Digital(TTL)

Table 2.4 Sensor Output Category

In the TTL standard, the data is considered as a “1” as the voltage is between 2.4 V and 5 V and a “0” as the voltage is between 0 V and 0.4 V. Based on this protocol, the digital outputs can be directly connected with the digital pins of the MCU. The analog output, on the other hand, needs to be connected to the MCU pins with analog-to-digital converters (ADC), which convert the analog voltage to a digital quantitative number that can be read and processed by the MCU.

Requirement	Verification
The pressure sensor must be able to tell 5 N differences of changes in force.	We can put a small item with a weight of around 50 kg on the pressure sensor and observe if the result after ADC changes on the serial monitor.
Power The voltage supplied to the ultrasonic and sound sensor needs to be between 3.5 V and 5 V.	We can measure the DC voltage of the sound detector supply when it is connected to the power supply.
The output coming from the sound sensor needs to be in the range of 2.4 V to 5 V when the ambient noise goes above the threshold.	The output voltage can be measured through a multimeter once the ambient noise is produced.
The voltage supplied to the ultrasonic sensor needs to be between 3.5 V and 5 V.	We can measure the DC voltage of the sound detector supply when the sensor is connected to the power supply.
Improve it The ultrasonic sensor needs to be able to detect a change in distance within 2 m. Specific	Once the sensor is operating, we put it within the 2-meter range and watch the change in the display on the serial monitor.

Table 2.5 Requirements and Verifications for Crib Sensor Subsystem

2.3.3 Subsystem 3: Crib Power Subsystem

This subsystem provides power to the crib PCB board, which is composed of a 9 V-1300 mAh battery source and a linear voltage regulator. The regulator converts the DC 9 V source into a voltage of 5 V based on the following formula [5]:

$$V_{OUT} = 1.25\,V \times \left(1 + \frac{R_2}{R_1}\right) \quad (2.2)$$

Therefore, we choose the value of R2 and R1 such that the proportion is three, so the output voltage is 5 V. The sensors and MCU are the majorities to be powered, and they all require 5 V as the supply.

This was 5V ± 0.1V in Project proposal

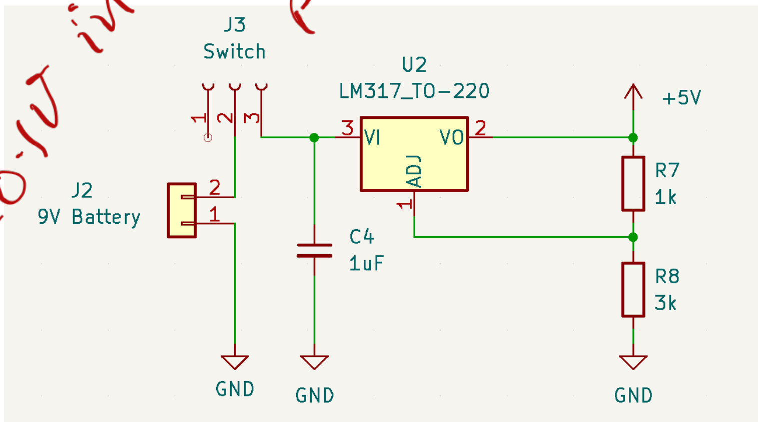

Figure 2.9 Crib Power Subsystem

large tolerance,

Requirement	Verification
The voltage supplied to the crib subsystem needs to be at 5 V ± 1 V.	We will measure the output voltage coming from the regulator on the crib system.
The voltage supplied to the monitor subsystem needs to be at 5 V ± 1 V.	We will measure the output voltage from the regulator on the monitor system.

Table 2.6 Requirements and Verifications for Crib Power Subsystem

2.4 Monitor System

2.4.1 Subsystem 4: Monitor Control Subsystem

The monitor control subsystem controls the functional peripherals in the monitor subsystem and communicates with the crib subsystem. It consists of an ATMega328P microcontroller and an HC-06 Bluetooth module. To make the microcontroller work, we need to use an in-circuit programmer to load a program into the chip, so we place an ISP connector on our board. Our schematics have the minimum connections needed to program the chip [6]. The Bluetooth only needs 5 V as its power, and TX and RX pins are connected to two I/O pins on the microcontroller. A flowchart that can demonstrate the working logic of the monitor control subsystem is below.

Power off check?

remove red underline

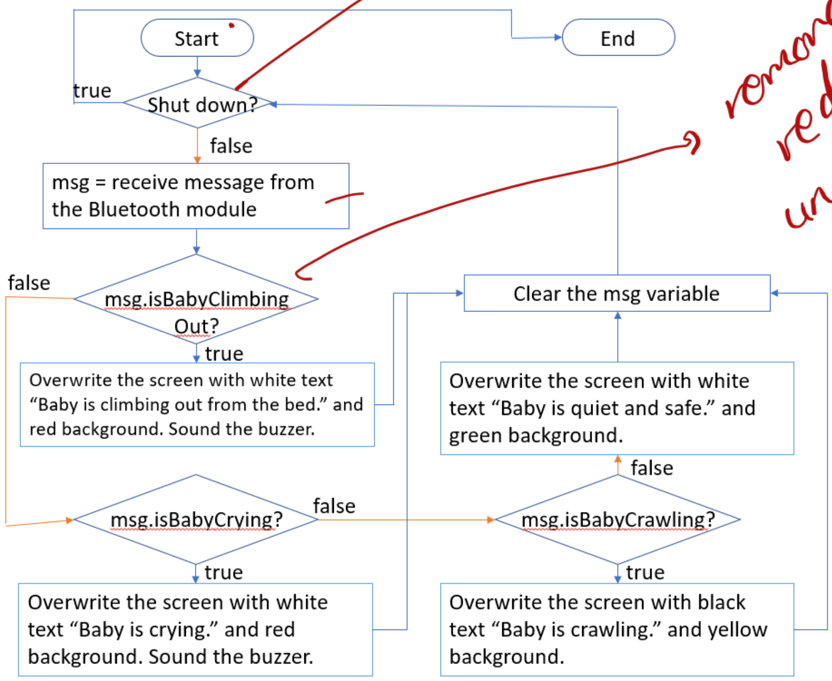

Figure 2.10 Monitor System Flow Chart

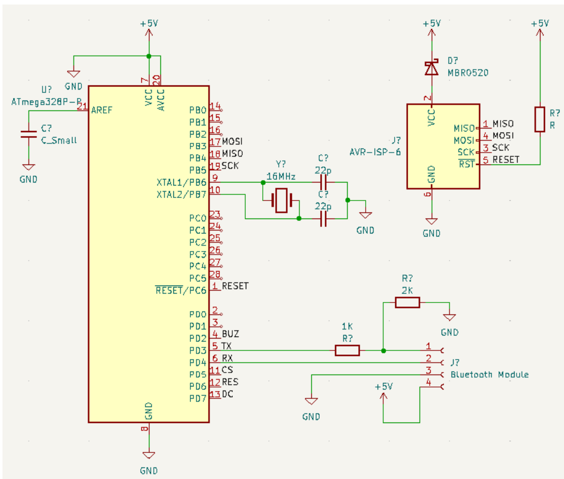

Figure 2.11 Monitor Control Subsystem Flow Chart

Requirement	Verification
I/O pins being used in the project can work properly as inputs or outputs.	1. Connect the chip to a 5 V ± 1 V supply and use a multimeter to verify the voltage. 2. Connect output pins to a 1 kΩ resistor connected to an LED, programmatically control it to output a voltage, and check whether the LED emits light.

	3. Connect input pins to a 5 V input gated by a debounced switch, choose any other I/O pin as an output pin, program the board such that the input pin can control the output pin, and check whether the tested input pin can control an LED.
The Bluetooth module can receive messages from another Bluetooth device. X Specific rate of transfer	1. Connect the Bluetooth module to 5 V ± 1 V and use a multimeter to verify the voltage. 2. Write a short program to make another Bluetooth module to send the message “Hello World!” to the Bluetooth module being tested and compare the message sent and the received message on a computer terminal.

Table 2.7 Requirements and Verifications for Monitor Control Subsystem

2.4.2 Subsystem 5: UI Subsystem

The UI subsystem is responsible for notifying the guardian about any event happening in the crib. The LCD Screen provides a striking visual prompt for the parent. In order to differentiate the level of emergency, we assign different background colors to different levels of emergency. For instance, the screen will display white text with a red background when the baby is attempting to climb out of the crib or crying (code red). The screen will display black text with a yellow background when the baby is climbing or rolling from tummy to back (code yellow). The screen will display white text with a green background when nothing is happening (code green); for example, the baby is asleep. In terms of the auditory stimuli, we will place a buzzer along with the screen. The buzzer will only sound when the screen turns red. In other words, it alarms when the most emergent situation happens. Ideally, the reaction time of the screen and the buzzer is counted in the 1 s reaction time specified in the high-level requirements.

These two requirements when combined doesn't guarantee the success of UI

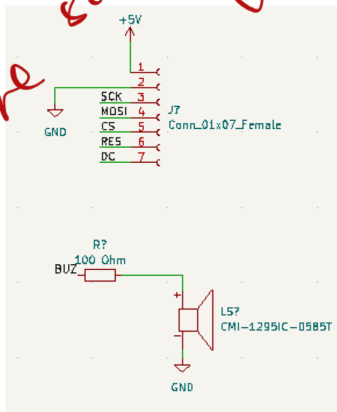

Figure 2.12 Buzzer and Monitor Schematic

Requirement	Verification
The ST7789 screen can be controlled by a microcontroller when provided a 5 V ± 1 V supply.	1. Connect the screen to any working programmable board such as an Arduino and use a multimeter to check if the power supply to the screen is 5 V ± 1 V. 2. Load a screen flashing program into the programmable board, and check if the screen flashes the way intended by the program.
The buzzer can emit a sound greater than 80 dB when supplied a 5 V ± 1 V power and connected in series with a 100 Ω ± 10 Ω.	1. Connect the buzzer in series with a 100 Ω resistor and a power supply of 5 V ± 1 V 2. Use a multimeter to verify that the power supply is 5 V ± 1 V 3. Use a sound pressure level detector on a phone to verify that the emitted sound is above 80 dB.

Table 2.8 Requirements and Verifications for UI Subsystem

2.4.3 Subsystem 6: Monitor Power Subsystem

We need this subsystem to ensure that other subsystems in the monitor system can acquire their required voltage. We use a voltage regulator to step down from a 9 V battery because the rated voltage of other components in the circuit is mostly 5 V. We referred to the datasheet to draw the connections to the voltage regulator such that the output voltage is around 5 V [5].

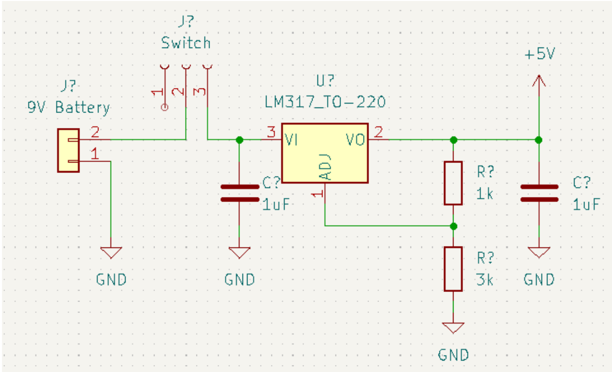

Figure 2.13 Monitor Power Subsystem

Requirement	Verification
The input to the VI pin of the voltage regulator is 9 V ± 2 V. recheck tolerance	1. Connect the anode of the battery to VI and the cathode to the ground. 2. Close the switch. 3. Use a multimeter to check if the input to VI is 9 V ± 2 V.
The output of the VO pin of the voltage regulator is 5 V ± 1 V.	1. Connect the anode of the battery to VI and the cathode to the ground. 2. Close the switch. 3. Use a multimeter to check if the output from VO is 5 V ± 1 V.

Table 2.9 Requirements and Verifications for Monitor Power Subsystem

2.5 Tolerance Analysis

The most likely error in this project is the measurement of accuracy and error of the pressure sensor. Tolerance analysis is therefore required to analyze the extent to which potential measurement errors affect the operation of pressure sensors. We can take the fifth percentile of the target population as the worst-case scenario, a seven-month-old baby whose weight is 6.66 kg [7]. According to the formula $G = mg$ with $g = 9.8\ m/s^2$, the pressure exerted by the baby on the bed surface is $6.66\ kg \times 9.8\ m/s^2 = 65.268\ N$. We will determine the baby's posture by analyzing the peak values measured by the pressure sensor matrix. Since the weight is distributed to different body parts of the baby, the weight values felt by a single sensor under different posture of the baby gets closer. Therefore, we concern about whether it is easy to differentiate a crawling posture from a lying posture such that the event reported

I think you need to measure force differences with way more precision. If the baby crawls,

from the crib system to the monitor system is as accurate as possible. We can estimate the maximum possible average force felt by a pressure sensor for the crawling posture and the lying posture. Our pressure sensors form a three-by-five matrix, where the row spacing is 15 cm, and the column spacing is 11.25 cm. If the length of a seven-month-old baby is 68.5 cm, then they are most likely to cover six sensors. The estimated maximum average force felt by a pressure sensor under the crawling posture is

5N difference will not be there.

$$\frac{65.268N}{6} = 10.88\ N \tag{2.3}$$

And that under the lying posture is

$$\frac{65.268N}{11} = 5.93\ N \tag{2.4}$$

The measurement error of the pressure sensor is 2 N at maximum, while the difference between (2.3) and (2.4) is 5 N. We can use hypothesis testing to examine the probability that a single sensor's error is 5 N. Our null hypothesis H0 is that the observed mean is greater than 2 N. If we assume the standard deviation is one and use 2 N as the true mean, the test statistics of H0 is $Z = \frac{(\bar{x} - \mu)}{\sigma / \sqrt{n}} = \frac{(5-2)}{1 / \sqrt{1}} = 3$, which corresponds to a probability of 0.00135 under the z-distribution. Therefore, it is not likely that the pressure sensor will not be able to differentiate between 10.88 N and 5.93 N.

3. Cost and Schedule

3.1 Cost Analysis

3.1.1 Labor

We assume the salary per hour is \$ 35. And each of us contributes to the project for 12 hours every week. Since there are 15 weeks in a semester, then the labor cost for each member is:

$$Labor\ Cost = 35\frac{dollars}{hour} \times 2.5 \times 12\frac{hours}{week} \times 15\ weeks = \$\ 15750 \tag{3.1}$$

The total labor cost for a group of three is also calculated:

$$Total\ Labor\ Cost = 3 \times \$\ 15750 = \$\ 47250 \tag{3.2}$$

3.1.2 Parts

Description	Manufacturer	Part #	Quantity	Individual Cost (\$)	Bulk Cost (\$)
Ultrasonic Sensor	EPLZON	HC-SR04	4	\$ 2.60	\$ 10.40
Pressure Sensor	DFRobot	SEN0294	15	\$ 5.00	\$ 75.00
Sound Sensor	Sparkfun	SEN-14262	1	\$ 13.25	\$ 13.25
Microcontroller	Microchip Technology	ATMega328p	2	\$ 7.70	\$ 15.40

Bluetooth Module	DEVMO	HC-06	2	$ 9.49	$ 18.98
Buzzer	CUI Devices	CMI-1295IC-0585T	1	$ 1.18	$ 1.18
Screen	Adafruit	ST7789	1	$ 17.50	$ 17.50
Battery	TQTHL	N/A	2	$ 5.22	$ 10.44
Voltage Regulator	Texas Instruments	LM317KCT	1	$ 0.69	$ 0.69
Switch	Adafruit	805	2	$ 0.95	$ 1.90
NMOS Transistor	ONSEMI	2N7000	3	$ 0.51	$ 1.53
Total					$ 166.27

Table 3.1 Parts Cost

Since all of the components are non-fabricated, the machine shop labor does not need any hour to work on the project; thus, their costs are zero.

3.1.3 Sum of Costs

$$Sum\ of\ Costs = \$\,47250 + \$\,166.27 = \$\,47416.27 \tag{3.3}$$

3.2 Schedule

	Yuhao	Xinlong	Feng
2/5/2022-2/11/2022	Research part number of the microcontroller & voltage regulator (Including writing the design document)	Research how the screen works. Draw the schematics of the UI system	Prepare all three types of sensors. Research about the testing parameter of the sensor system
2/12/2022-2/18/2022	Design the Schematics of the Microcontroller & Power Subsystem (Including writing the design document)	Draw the schematics of the UI subsystem & PCB layout. Write design document	Design the connection to the Microcontroller & Power Subsystem and signal processing method
2/19/2022-2/25/2022	Draw the PCB Layout of the Microcontroller & Power subsystem. Write design	Design PCB layout of the UI subsystem. Write design	Design a supporting circuit to operate as a central terminal for all pressure sensors.

	document	document	Write team contract document and design document
2/26/2022-3/4/2023	Prepare for the design review. Design prototype of the crib control subsystem	Prepare for the design review. Design prototype of the monitor control subsystem	Prepare for the design review. Design prototype of the crib control subsystem and adjust sensor parameters.
3/5/2023-3/11/2023	Adjust the prototype of the crib control and power subsystems	Adjust the prototype of the monitor control and power subsystems	Adjust the prototype of the crib control and power subsystems
3/12/2023-3/18/2023	Spring Break	Spring Break	Spring Break
3/19/2023-3/25/2023	Fix the crib control and power subsystem PCB design if errors are identified in the prototype	Fix the monitor system PCB design if errors are identified in the prototype	Fix the sensor subsystem and PCB design if errors are identified in the prototype
3/26/2023-4/1/2023	Order a new PCB in the second round if needed. Write the individual progress report. Integrate parts into the crib system on PCB	Order a new PCB in the second round if needed. Write the individual progress report. Integrate parts into the monitor system on PCB	Order a new PCB in the second round if needed. Write the individual progress report. Integrate parts into the crib system on PCB
4/2/2023-4/8/2023	Integrate parts into the crib system PCB. Verify the hardware on the same system	Integrate parts into the monitor system PCB. Verify the hardware on the same system	Integrate parts into the crib system PCB. Verify the hardware on the same system
4/9/2023-4/15/2023	Finish hardware verification. Put subsystems together, and prepare for the mock demo	Finish hardware verification. Put subsystems together, and prepare for the mock demo	Finish hardware verification. Put subsystems together, and prepare for the mock demo

4/16/2023-4/22/2023	Work on project revision based on the feedback from the mock demo	Work on project revision based on the feedback from the mock demo	Work on project revision based on the feedback from the mock demo
4/23/2023-4/29/2023	Prepare for the final demo and start the final report	Prepare for the final demo and start the final report	Prepare for the final demo and start the final report
4/30/2023-5/3/2023	Prepare for the final presentation and finish the final report	Prepare for the final presentation and finish the final report	Prepare for the final presentation and finish the final report

Table 3.2 Parts Cost

4. Discussion of Ethics and Safety

We will thoroughly discuss any ethical issues related to this project in this section. The IEEE Policies [8] have recognized the possible impact of new technologies on the world and emphasized the standard that IEEE members should hold in professional activities. Those more relevant to our project include putting public safety, health, and welfare in the first place, maintaining sustainability, and disclosing possible harms during the use of our product.

We will discuss possible ethical issues related to the product and its development process and will first go through those about the product. When a user considers our product, a primary concern is its safety. Due to the lack of studies on the influence of ultrasound on post-natal infants, we can learn some insights from how ultrasound affects humans in general. We will use sensors that emit ultrasounds with a frequency of around 40 kHz. According to [9], there has been no demonstration showing that ultrasound with 40 kHz and below 120 dB sound pressure level can affect human hearing. Ultrasound with the same scale will also not affect cognitive functions [10]. The working power of our ultrasonic sensor is 75 mW. Assuming all the power is converted to sound, the sound pressure level is 108 dB, which is less than 120 dB. In terms of the influence on biological tissues, ultrasonic devices used at the diagnostic level will not damage human tissue because the produced heat is negligible compared to physiological thermal temperature [11]. Since our product controls the angle and pattern of ultrasound emissions, the baby will not be directly radiated by the ultrasound unless they go beyond the guardrail of the crib, at which time the guardian alarm will sound. The ultrasound radiation time will be less than five minutes per day, assuming the product is turned on for 24 hours per day. In order to prevent fire caused by a short circuit in the pressure sensor lining, we will use special fireproof, waterproof, and insulating materials to package the circuit. When the user wants to wash the lining, they should only wash the waterproof layer after separating it from the lining. When the crib system is not in use, the guardian should unplug the system and put the power cable away so that the baby does not get tripped or entangled by the cable or injured by electricity.

There are fewer concerns in terms of ethical issues in the product development process. The ultrasonic transducer will not cause damage to the developers, as indicated by [9-11]. The ultrasonic sensor will not directly radiate the developers 99 % of the time. The developers will need to ensure safe operation and insulation measures when using 5 V power. We will ensure that the development process reflects sustainable development. We will plan ahead all the materials needed and avoid as much waste as possible.

There is no safety and regulatory standard on the limit of the frequency and acoustic intensity of ultrasound for non-clinical and consumer products. If we compare our product against the limit specified in part 2 of IEC 60601 for clinical-use products [12], our estimated ultrasound intensity – which is 0.0133 W/cm^2 – is much less than the 3 W/cm^2 limit, and the frequency is much higher than human audible range while in the low-frequency ultrasound range which is safe for human.

You can also ~~discuss~~ discuss that no one will be harmed during testing or operation of the product.

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