Development of a Baby Care System

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***Abstract*—New-born babies require constant watch and attention by their parents or caregivers. This can be challenging since it is quite inconvenient for parents to constantly watch over their new-born baby while attending to other endeavors. For hearing-impaired parents, it can also be difficult to know, besides having a view, when a child is calling for attention by crying. The proposed baby care system addressed the aforementioned problems by featuring a voice detection system which is capable of detecting an infant's cry and a control system which can automatically initiates a soothing condition characterized by dimming lighting, lullaby play and cooling fan. The baby crying condition, wetness, body temperature, baby room ambient temperature and the state of the soothing section are all relayed to the Android device of the parent or caregiver in real-time using the Blynk platform. The baby care system is found to be effective and functional. It makes parenting easier.**

Keywords—parenting; baby care; baby condition detection; baby condition soothing; Mobile App

I. Introduction

It is often hard to understand why baby cry because they cannot express their emotions in specific words. Therefore, babies' feelings are not easily grasped. Families and physicians have always been interested in knowing why the baby is crying or the message that the baby wishes to share. Neonatal cry is a primary function of communication directly regulated by the brain and alternation in normal functioning of the human body can be represented by crying. The baby uses cry for communication purpose in the first few months after birth; later the baby communicates with signs and phrases. Understanding infants' communication is really important for parents and for baby care. A baby shows physical and psychological problems or discomfort by weeping. Decoding baby's cry requires the mother's built-in intuition or instincts about knowing and responding to their baby's needs. Physicians or paediatrics also need experience at decoding infants' communication to enhance the infant care delivery [1].

With the occurrence of new births every year, there is indeed a great need for these infants to be well catered for in order to meet their physical needs as well as enhance their emotional and psychological development. According to the January 1st 2019 report by the United Nations International Children's Emergency Fund UNICEF, it stated that an estimated 25,685 babies will be born in Nigeria on New Year's Day [2,3]. Many babies are delivered every year.

Infant crying is characterized by its rhythmic nature, that is, alternating cry utterances and inspirations, as shown in Fig. 1. By using a speedy flow of air through the vocal organ burst sound is produced, because of that there is repeated opening and closing of the vocal folds, which in turn generates oscillating excitation. This excitation is transferred through the vocal tract to produce the cry sound [3]. The waveform of an infant's cry provides important information about their physical and physiological status, including fitness, weight, age, gender and emotions.

There is need for the use of technology to assist parents in the care of their babies. In the time past, the topic of infant cry was studied by doctors and the medical personnel only. Now-a-days, baby cry study has become an interdisciplinary topic for both medical and engineering practitioners. With the help of digital signal processing of sound signal (baby's cry), it is possible to get more information by analysing such sound signal [4]. On some occasions, infants are left alone in closed apartments or vehicles because of parents' temporary unavailability; this can be dangerous for the wellbeing of such infants. A device which alerts the parents wirelessly in such circumstances will be a good help/assistance for parents and parenting.

II. Theoretical Background

Many parents are tuned in to their baby's needs. They know when their child wants food or it's time for a nap. One Australian mom and musician, Priscilla Dunstan, was unusually good at understanding what her baby wanted [3,4,5]. She noticed he made the same sounds over and over again, and that each sound corresponded to a particular need such as feeling sleepy or uncomfortable. Dunstan identified five sounds babies make just before crying. The five sounds and with their meanings in bracket are "Neh" (I am hungry), "Owh" (I am tired), "Heh" (I am not comfortable), "Eair" (Gas in my lower belly), and "Eh" (I need to burp) [3,4,5].

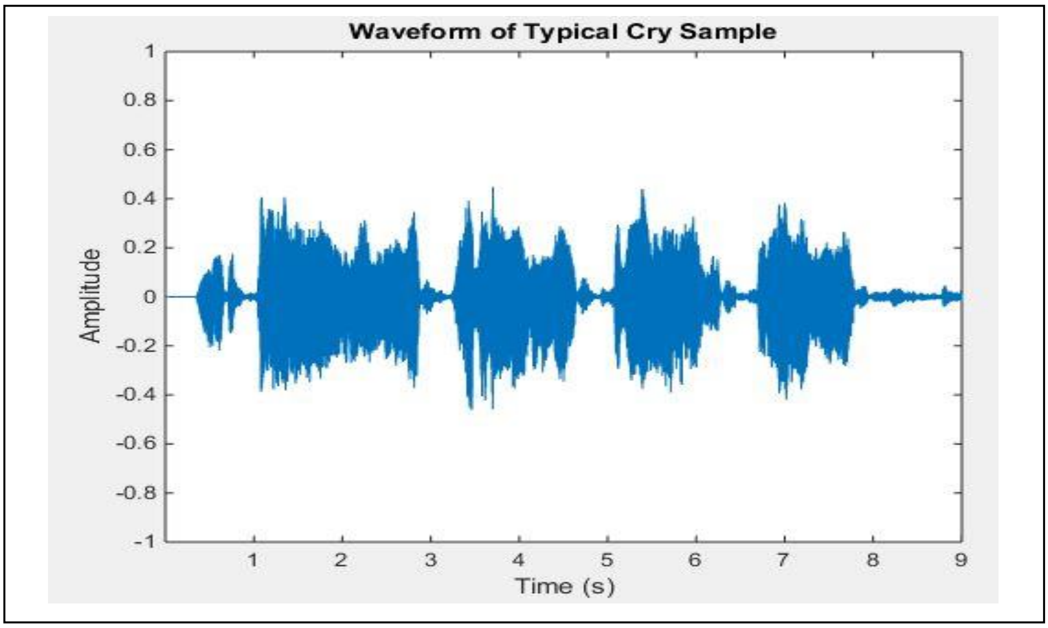

Fig. 1. *Waveform of Typical Cry Sample*

The Dunstan baby language (DBL) is said to be most accurate for babies up to 3 months old. However, Dunstan's hypothesis has not been subjected to rigorous testing or academic scrutiny. The fact remains that baby's cry need decoding to identify what message the baby intends to communicate.

One of the critical examinations in the field of biomedical engineering is the automatic recognition and synthesis of baby cry signal for the investigation of the infant's physiological conditions [6]. Kaldhone and Patil (2017) examined the automatic cry recognition of two groups of newborn children, namely hearing-impaired infants and normal hearing infants, by the use of Mel filter-bank discrete wavelet coefficients (MFDWCs) extracted from the baby cry as the feature vector [7]. The MFDWCs was gotten by applying the Discrete Wavelet Transform to logarithm of energies in each filtered-bin of a cry span. The experiment was performed on 17 normal hearing infants and 11 hearing-impaired babies using the Multi-layer Perceptron Neural Network as classifier. By executing this framework, a high correct recognition rate of 93.2% was achieved [7].

Signal modelling approach for speech recognition was presented in [8]. The signal modelling involved four basic operations: spectral shaping, feature extraction, parametric transformation, and statistical modelling. The focus was on the basic operations involved in spectral shaping, spectral analysis technique of feature extraction, and the temporal analysis techniques for feature extraction. It was observed that for the voiced speech there is a peak in the cepstrum at the fundamental period of the input speech segment but no such peak appears in the cepstrum for unvoiced speech segment. The temporal analysis techniques involved less computation, ease of implementation but they were limited to determining simple speech parameters like power, energy and periodicity of speech. Critical band filter bank decomposed the speech signal into discrete set of spectral samples containing information which was similar to information presented to higher levels processing in auditory system. Cepstral analysis isolates the speech signal into a segment representing the excitation source and another segment representing vocal tract impulse response.

Similarly, Kesarkar and Rao (2003) implemented a speech recognition system in the control of a robotic arm [9]. This study describes a signal voice processing by using Mel-Frequency Cepstrum Coefficients (MFCC) and Support Vector Machine (SVM) method based on Python 2.7 to control 5 Degree of Freedom (DoF) Robot Arm for pick and place an object. The test results showed that the average accuracy rate of speech recognition by trained respondents (inside database) is 80% while the respondents not trained (outside database) data produces an accuracy rate of 70% [9].

Voice recognition has been used over the years for automation in heavy and light industry. Currently, it has been proposed for personal and home use. For example, Anggraeni, et al (2018) designed a voice recognition system based on Zigbee intended to control lights, fans, air conditioners, television sets, security cameras, electronic doors, computer systems, and electrical appliances in a home or office [10]. Thus, facilitating elderly and disabled people with an easy-to-use home automation system using speech commands. The overall system is controlled from a microphone which is connected with HM 2007 speech recognition chip. ZigBee Home Automation provides much higher operating range as compared to Bluetooth and other wireless sensor modules. With the use of ZigBee Home Automation circuit considerable amount of power saving is possible, and it is flexible and compatible with future technologies; it can be easily be customized for individual requirements [10]. Hence, voice recognition can also be applied to infant voice detection with a promised accuracy as proposed in this paper.

To distinguish healthy premature infants from those with specific problems, Gaussian Mixture Models (GMMs) were developed in [11]. This new-born cry-based diagnostic system (NCDS) extracted Mel-frequency cepstral coefficients (MFCCs) as a feature vector for cry patterns of new-born infants. The system discriminated a test infant's cry signal into one of two groups, namely, healthy and pathological based on MFCCs. The binary classifier achieved a true positive rate of 80.77% and a true negative rate of 86.96% which show the ability of the system to correctly identify healthy and sick infants, respectively.

Using Gaussian Mixture Models (GMM), Farsaie and Tadj (2012) proposed a framework for automatic cry sound segmentation for application in a cry-based diagnostic system [12]. The main focus was to include a post-processing stage with a set of corrective and enhancing tools to improve the classification performance. A fully automated segmentation algorithm to extract cry sound components, namely, audible expiration and inspiration, was introduced and was based on two approaches: statistical analysis based on Gaussian Mixture Model (GMM) classifier and a post-processing method based on intensity, zero crossing rate, and fundamental frequency feature extraction. Detection rates of approximately 94.29% and 92.16% of the start and end points of the expiratory and inspiratory components of cry signal were achieved by applying a tenfold cross-validation technique to avoid over-fitting [12].

Abou-Abbas, Tadj and Fersaie (2017) in [13] implemented a smart infant monitoring system. This system outputs high-quality features such as: displaying live video and audio, recording audio and playing it to the baby, measuring the room temperature and humidity, supporting Arabic language, determining if the baby is awake or asleep, and the ability to concentrate on the baby noise which is the cry detection feature.

The design and implementation of the baby cry monitoring and soothing system is presented in this paper. The proposed system supports seven different features. The system can wirelessly send notifications to the caregiver in some abnormal cases like abnormal temperature.

III. METHODOLOGY

This electronic system is intended to decode baby's cry, measure the baby's atmospheric conditions such as temperature and humidity, control or mitigate the atmospheric conditions, and then relay the baby's status to the parent via the mobile phone. The block diagram of the system design is as shown in Fig. 2.

A. Design Considerations

In designing the circuitry for the system, some factors were taken into consideration in the development and fabrication process. These include:

1. *Overall function*: The device should be able to detect a child's crying status and body temperature and respond by providing soothing conditions. Finally, it should relay information to the mobile device of the parent.

2. *Safety and Simplicity: The system should be save, simple, easy to operate and user friendly.*

3. *Performance: The system should exhibit fast response to the child's cry.*

4. *Power consumption: The system should include modules rated at low voltages of 5V and 12V.*

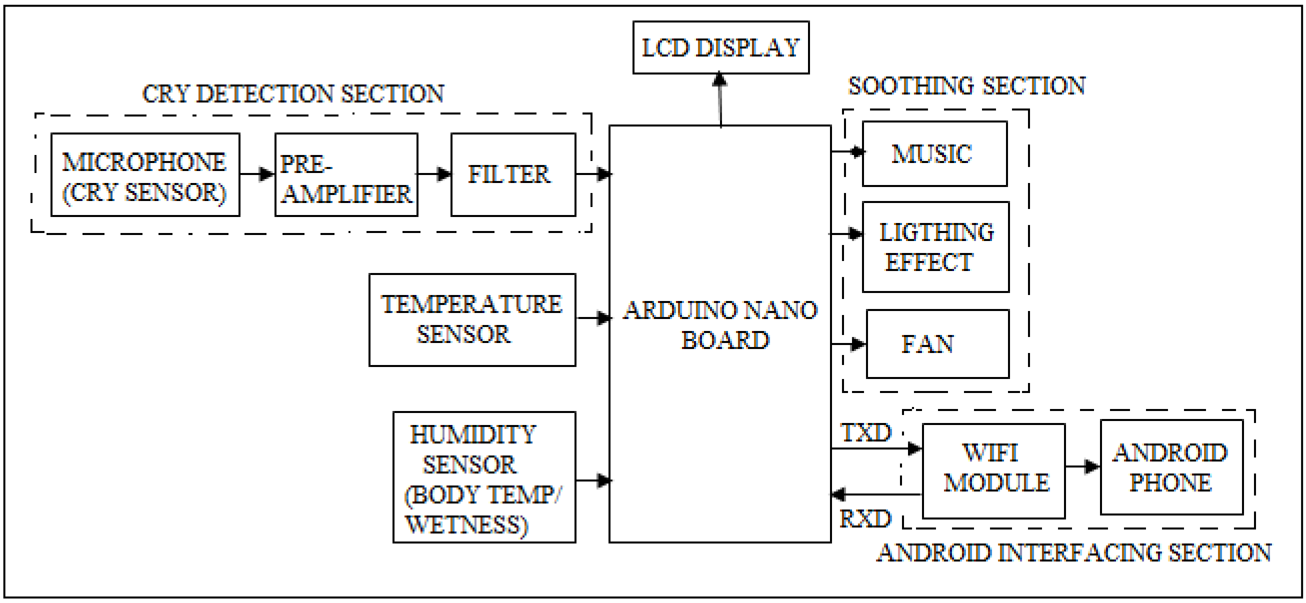

Fig. 2. Baby Care System

B. Power Supply Unit

In the design of the power supply unit, a 50Hz, 230/12V transformer which steps down the AC voltage from the mains supply to 12V sinusoidal voltage. This is followed by a full-bridge rectification, filtering and voltage regulation. The power supply circuit diagram is shown in Fig. 3.

The total voltage drop, V_{drop}, for the two diodes involved in the rectification process in either of positive or negative half cycles is given as

$$V_{drop} = 2V_{BE} \quad (1)$$

where $V_{BE} = 0.7V\ for\ Silicon$

$$V_{drop} = 2 \times 0.7 = 1.4\text{V} \quad (2)$$

The actual peak output voltage,

$$V_o = V_{peak} - V_{drop} \quad (3)$$

$$V_o = 12 - 1.4 = 10.6\text{V} \quad (4)$$

Change in peak output voltage over the discharge period is,

$$\delta V = V_o - V_{dc} \quad (5)$$

where V_{dc} is $5.1V$.

$$\delta V = 10.6 - 5.1 = 5.5V$$
(6)

Total current consumption for this design is not expected to exceed 1000mA as per rating of the step-down transformer. Hence the value of the filter capacitor is obtained as

$$C_1 = \frac{I}{2f\delta V} \quad (7)$$

where C_1 is the capacitance of the filter capacitor, f is the supply frequency and δV is the maximum ripple voltage

$$C_1 = \frac{1000mA}{2 \times 50Hz \times 5.5V} = 1818\ \mu\text{F} \quad (8)$$

To provide a safety margin, the capacitor value chosen is more than the calculated value which implies a value greater than 1818µF. The nearest available capacitor value of 2200µF is used as the filter capacitor.

The LM7805 IC regulates the voltage output from the filtering capacitor. The LM7805 is a member of the 78XX series of fixed linear voltage regulator ICs. The voltage source in a circuit may have fluctuations and would not give the fixed voltage output. The voltage regulator IC maintains the output voltage at constant value. The XX in 78XX indicates the fixed output it is designed to provide. Hence the 7805 provides +5V regulated power supply. This particular voltage regulator requires a minimal value of 7.3V dc voltage to create a steady 5V dc supply.

In the 7805 IC, the difference between the input and output voltage is dissipated as heat. Hence, the greater the difference between the input the output voltages, the greater the heat dissipation. Thus, the power dissipated can be expressed as

$$Power\ dissipated = (V_{in} - 5V) \times I_{out}$$
$$= (10.6 - 5)V \times 1000mA \quad (9)$$
$$= 5.6\text{W}$$

C. The Sensing Unit

The sensing unit plays an important role in the automatic monitoring and care of the baby. It is mainly responsible for the sound signal acquisition, pre-amplification, filtering and signal conditioning. This sub-unit in the sensing unit, termed the baby cry detection circuit is designed and implemented according to the characteristics of the baby crying frequency which provides the automated data

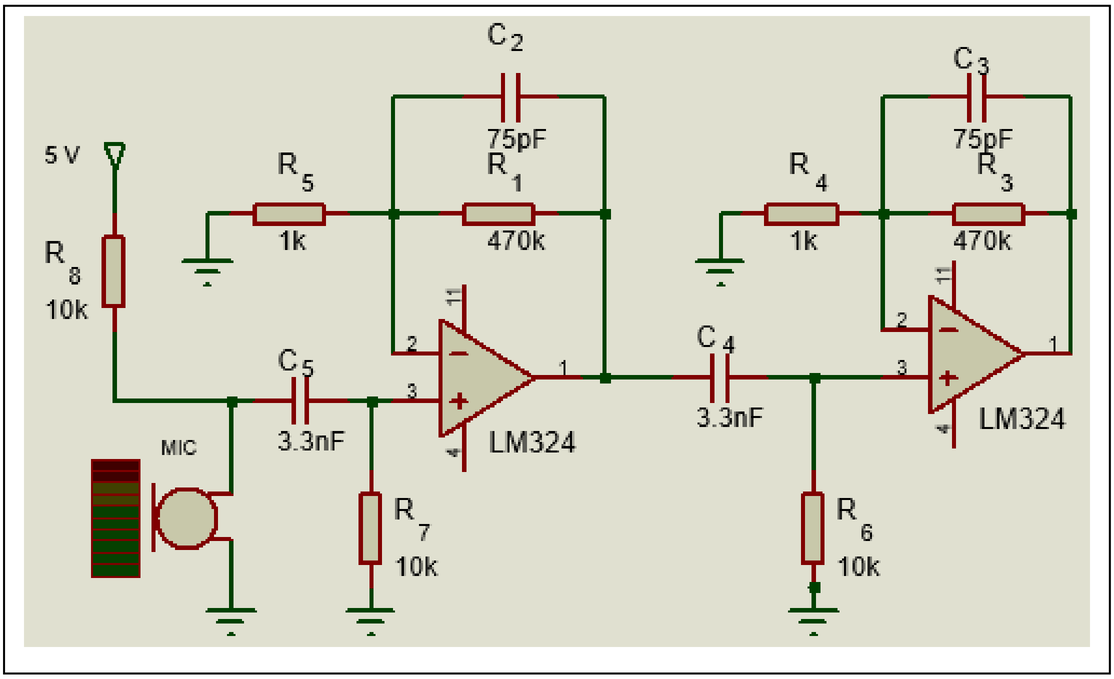

Fig. 4. Baby Cry Detection Circuit

The cry detection circuitry has a two-stage passive low pass filter. For the first stage, R_7 and C_5 configuration forms a high pass filter with the transfer function $H(s)$

$$H(s) = \frac{sR_7C_5}{1+sR_7C_5} \quad (10)$$

The cut-off frequency f_c is given as

$$f_c = \frac{1}{2\pi R_7 C_5} \quad (11)$$

With $R_7 = 10k\Omega$ and $f_c = 4500\ Hz$,

$$C_5 = \frac{1}{2\pi f_c R_7} \quad (12)$$

$$C_5 = \frac{1}{2\pi \times 4500 \times 10000} = 3.537\ nF \quad (13)$$

The closest available capacitor of capacitance 3.3nF was chosen.

The combination of resistors R_5, R_1, capacitor C_2 and LM324N IC form a stage of non-inverting amplifier. The transfer function H(s) of this block is given as

$$H(s) = 1 + \frac{R_1}{R_5}\frac{1}{(1+sR_1C_2)} \quad (14)$$

At low frequencies, this stage is a non-inverting op-amp with a closed loop gain of 470. However, at high frequencies, the capacitor becomes a short, bypassing resistor R_1.

Other sensors or transducers used in the sensing unit include the LM35 temperature sensor and the DHT11 humidity sensor. The LM35 temperature sensor monitors the ambient temperature while the DHT11 humidity sensor is inserted in the outer layer of the baby diaper to monitor the infant's wetness, as well as the body temperature. The LM35 and DHT11 sensors are interfaced with the Arduino Nano board as shown in the circuit diagram of Fig. 5. The data pin 2 of the DHT11 is connected to D13 and analogue output pin of the LM35 is connected to pin A0 on the Arduino board.

D. The Soothing Unit

The Soothing unit is essential in providing comfort to the child. It is this section of system that provides care. It comprises of a speaker, lighting and cooling fan. The electronic circuit showing the interfacing of these elements is shown in Fig. 6.

The Arduino Nano is loaded with the Arduino Tone Library which produces a 50% duty cycle waveform of a specified frequency on Arduino pin A2. A speaker connected to the Arduino pin results in a lullaby play. A lullaby or berceuse is a soothing song that is played for, or sometimes sung to children. The purposes of lullabies vary. Lullabies are often used for the development of communication skills, indication of emotional intent, maintenance of infants' undivided attention, modulation of infants' arousal, and regulation of behaviour. One of the most important uses of lullabies is as a sleep aid for infants. In addition to pitch tendencies, lullabies share several structural similarities. The most frequent tendencies are intermittent repetitions and long pauses between sections. This dilutes the rate of material and appeals to infants' slower capacity for processing music. Whenever baby cry is detected, the 8-ohm speaker is activated by the analogue pin A2 of the Arduino Nano to play the lullabies.

The fan also plays a role in keeping the infant calm in that it cools its body temperature when the temperature becomes unbearable. The fan is activated whenever the temperature of the room or the baby's body is above the set threshold. When the set temperature threshold of the sensor LM35 or the humidity sensor DHT11 is exceeded, the Arduino Nano sends a HIGH signal to energize the coil of relay

RL1 through the 2N2222 transistor in other to activate the circuitry for the fan.

An added feature to the soothing unit of the baby care system is the lighting. It is activated whenever the baby cry is detected. This means that the coloured lighting effect is activated alongside the speaker playing the cradle song. The lighting load is an a.c. load and is switched on by exciting the coil of relay RL2 through the base-biased 2N2222 transistor.

Since the relay coils of the 30A relays are excited by 12V signal, a driver is utilized as an interface between the Arduino output pin and the relay. As shown in Fig. 6, this driver is an NPN transistor (2N2222) with its base terminal connected to the output pin of the controller through a 10kΩ resistor.

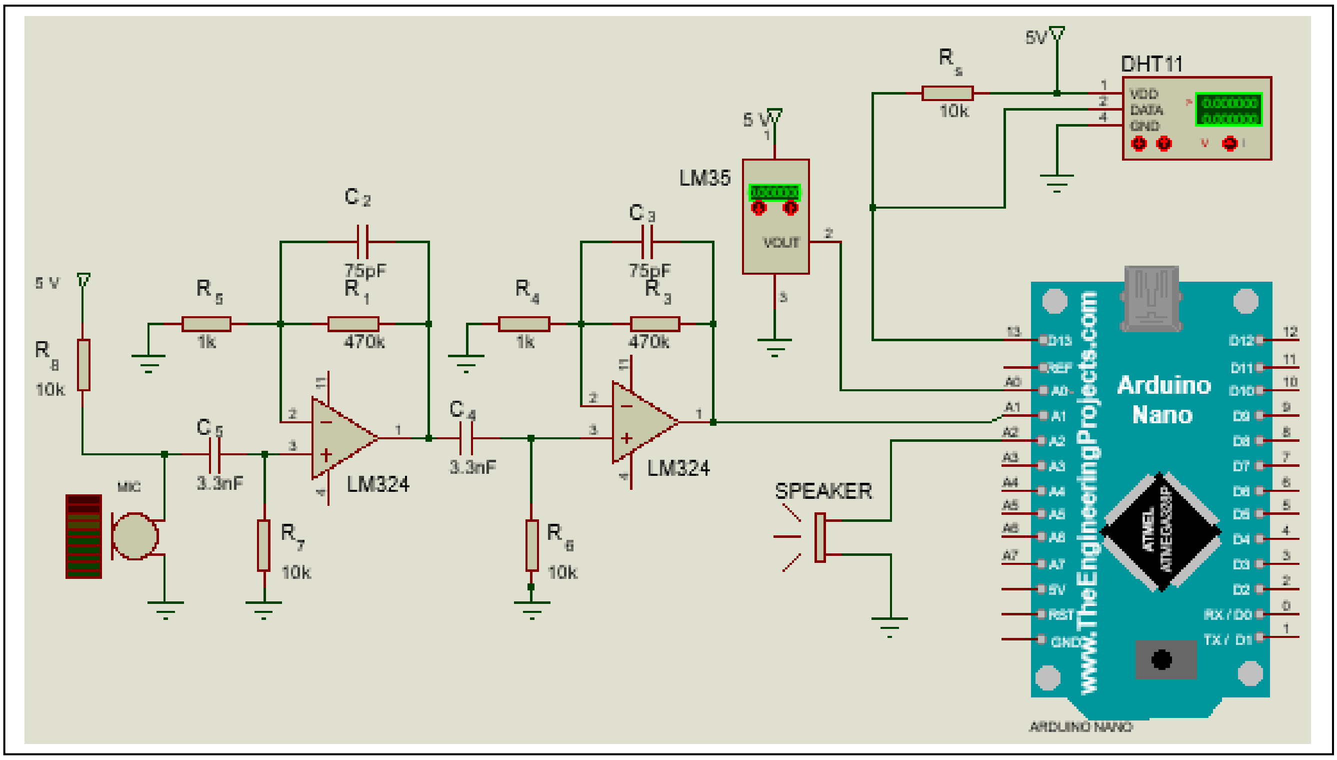

Fig. 5. Schematic of Sensors Interface with the Arduino Nano

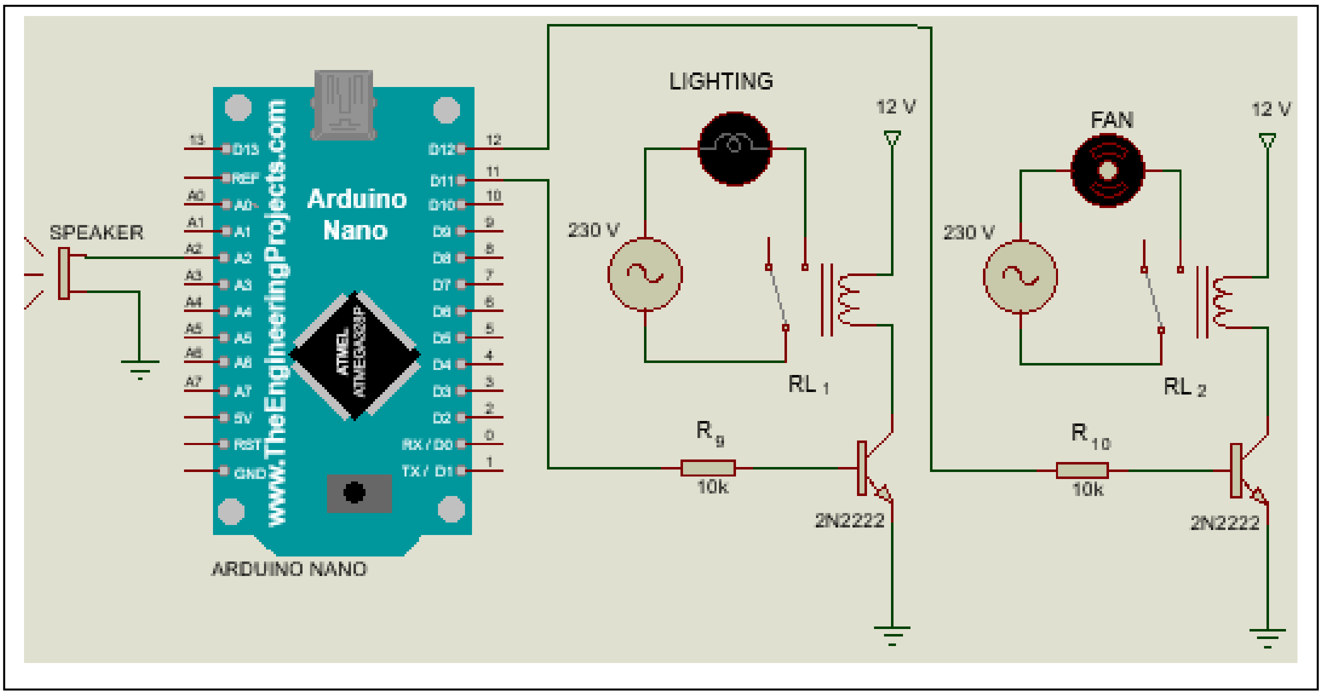

Fig. 6. Schematic showing interface between soothing devices and Arduino board

IV. RESULTS

The Baby Care System was tested by playing different audio samples of recorded baby cries under different crying conditions. The waveform of the audio sample in time domain was obtained as shown in Fig. 7. This was utilized to develop the infant cry and voice recognition system.

The detection system responds by energizing the relays so that the lighting and fan turns on and the speaker outputs a lullaby. The status of baby crying condition, whether it is crying or not crying, is displayed locally on the 20x4 Liquid Crystal Display (LCD). Additionally, the Arduino Nano board sends this information wirelessly to a mobile device and it is displayed by the Blynk Application. Fig. 8 indicates the information as displayed on the LCD while Fig. 9 shows the Blynk App interface on the mobile device.

As shown in Fig. 9, the green indicator shows that cry signal is detected and the fan has been switched on by the system automatically. The soothing section, as well as the display unit, does not respond to only the baby's audio signal but also responds to the room and body temperature. Generally, when the room is hot, there is a need to provide a means of cooling the room. The hotness or coldness of the room, as well as the body temperature and wetness conditions of the infant are indicated on the LCD and mobile app.

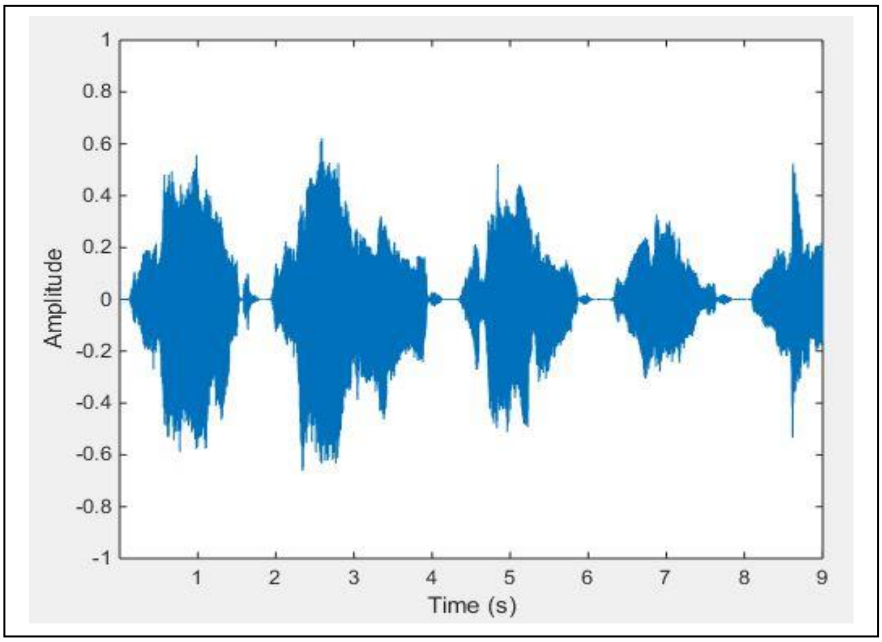

Fig. 7. Waveform of audio sample

Fig. 8. Baby Crying Status as displayed on LCD

Fig. 9. Baby Cry Status on Blynk App

V. Conclusion

A baby care system which monitors a baby cry, body and ambient temperature and provides a soothing relief for the baby while communicating the baby's condition to the mobile device of the parent or caregiver when they are not physically present in the baby's room has been developed. The various crying conditions of an infant and their associated bandwidth were studied and used for the development of the system. The cry detection circuitry, the soothing unit and the associated mobile App provide parenting assistance and support for mothers and caregivers.

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