3. EXPERIMENTAL PROCEDURE

The experimental procedure pertaining to the research work "**Design, Develop and Evaluate the Smart Wearable Electronic Fabric for Monitoring Healthcare**" was conducted under the following headings:

3.1 Phase I: A Survey on awareness of Smart Wearable Kids Health Monitoring System

3.2Phase II: Development of Conductive Fabric through different methods of Fabrication process

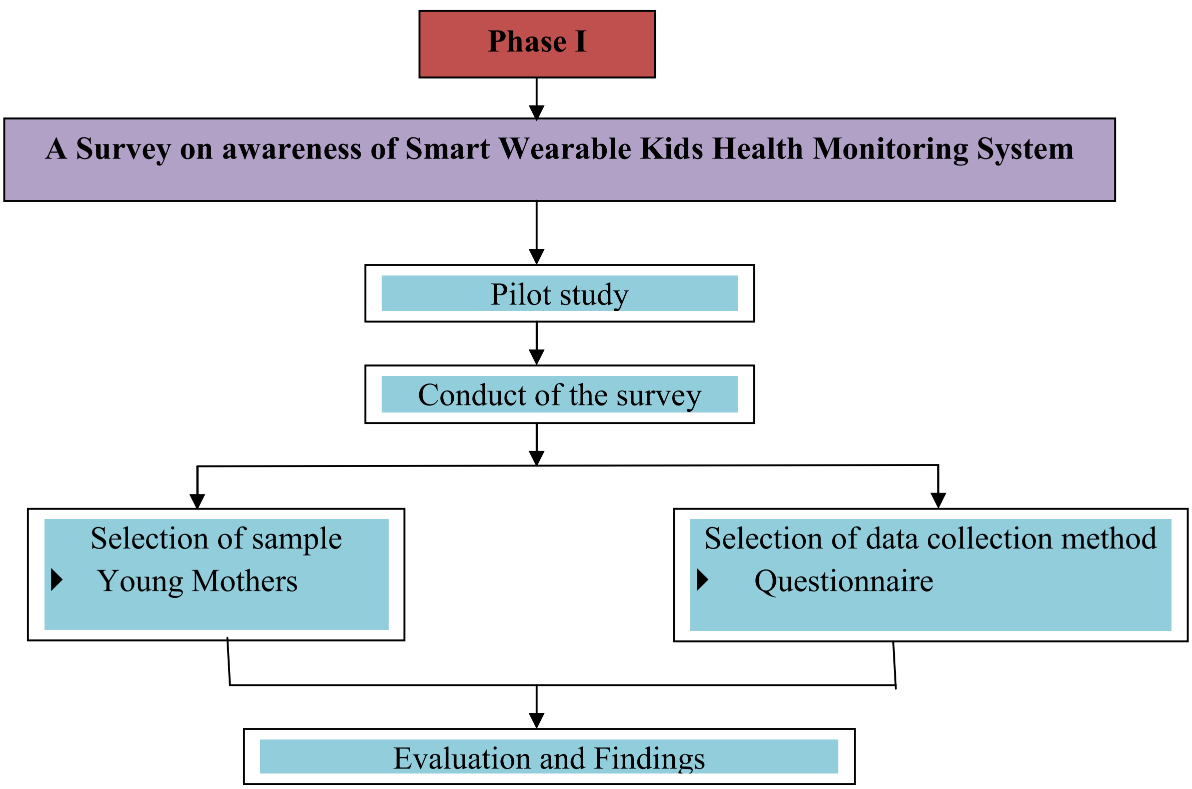
3.3PhaseIII: Designing of System for Integrating Sensors into Wearable Electronics

3.4 Phase IV: Product development and Analysis of Wearable Electronics for Monitoring Infants Healthcare

Phase I

3.1. A Survey on Awareness of Smart Wearable Kids Health Monitoring System

Data serves as the base for any type of research. This also helps the researcher to understand the past and present status of his/her work. Therefore the investigator planned a survey among young mothers to know their level of interest and further to explore awareness in them.



3.1.1 Selection of Sample:

Healthy children are the first step to a healthy adult population. In the past few decades, women participation in the labor force mainly in the industrialized nations has greatly increased in present society. Subsequently, infant health care has become a challenge to many families in their daily life. Mothers are always worries about the well being of her baby (Garcia and Torres, 2013). A mother, with new born baby if needs to be away from baby due to employment, household work or emergency during the wards ill health status this intensifies stress on the mothers. The number of approximately 7,00,000 life births in the world is overshadowed by a large number of infant deaths for various reasons like apparently life threatening events (ALTE) or sudden infants death syndrome(Dhumalet al., 2016). So, it's understandable that they will be interested in a product that promises to help them to monitor and care.

Hence for this research,100 young mothers were interviewed to know about their awareness and willingness on Smart Wearable Kids Health monitoring system for their infants. It was a purposeful study to design the garment for healthcare monitoring of infants based on the result of this study.

3.1.2 Selection of Data Collection Method:

Research is considered to be widely diverse, branching out to different fields and methodologies. In the early 1930s, research through the use of surveys was introduced by Paul Lazarsfeld, one of the most well-known sociologists of his time. Among the different methods of data gathering for research purposes, the survey method is preferred by many researchers due to its various advantages, strengths and benefits. The research principles of data gathering, processing, analysis and interpretation are incorporated in surveys (Sincero, 2012).

A field of applied statistics of human research surveys, methodology studies, the sampling of individual units from a population and the associated survey data collection techniques, such as questionnaire construction and methods for improving the number and accuracy of responses to surveys. Survey methodology includes instruments or procedures that ask one or more questions that may, or may not, be answered (George

Beam, 2012). Surveys are relatively inexpensive. Surveys are useful in describing the characteristics of a large population. No other research method can provide this broad capability, which ensures a more accurate sample to gather targeted results in which to draw conclusions and make important decisions. Surveys can be administered in many modes, including: online surveys, email surveys, social media surveys, paper surveys, mobile surveys, telephone surveys, and face-to-face interview surveys. For remote or hard-to-reach respondents, using a mixed mode of survey research may be necessary (e.g. administer both online surveys and paper surveys to collect responses and compile survey results into one data set, ready for analysis) says Wyse, 2012.

A systematic method of gathering information from a target population, a survey makes use of statistical techniques mainly used in quantitative research. Hence, the researcher selected Structured survey method to carry out this research study among the young mothers with infants. The personal interviews were conducted by the researcher, and it took place at the pediatric clinic and hospitals among the young mothers who came there, for their infant's regular health checkup.

3.1.3 Selection of method to conduct research:

Questionnaires are the most commonly used tool in survey research. However, the results of a survey are worthless if the questionnaire is not written completely. Questionnaires must be worth full with adequate information and should produce valid reliable demographic variable measures. Survey researchers should carefully formulate the order of questions in a questionnaire. For questionnaires that are self-administered, the most attracting and involved questions should be at the beginning to catch the respondent's attention, while demographic questions should be pushed to the end remark Shaughnessy et al., (2011).

Therefore, questionnaire was prepared to conduct the survey in data collection method. The data collection questionnaires could also be administered through face-to-face interviews. Some of the interviews were conducted by sending questionnaire through private e-mails after getting contact information through hospitals. All the above types of interviews had more flexibility more than only a paper survey as both the interviewer and the interviewee were able to clarify their doubts.

In this study, the researcher framed the questionnaire using a combination of both open ended and close ended questions. Care was also taken to maintain the individual's privacy.

3.1.4 Pilot study:

One of the key elements in conducting surveys and other data gathering methods is efficiency. It is important to utilize money, time and effort in the most efficient way possible to achieve success in performing surveys, especially those that require a large number of participants. To promote efficiency in conducting surveys, researchers usually perform a pilot survey. A pilot survey is a strategy used to test the questionnaire using a smaller sample compared to the planned sample size. In this phase of conducting a survey, the questionnaire is administered to a percentage of the total sample population, or in more informal cases just to a convenience sample say Sincero, (2012).

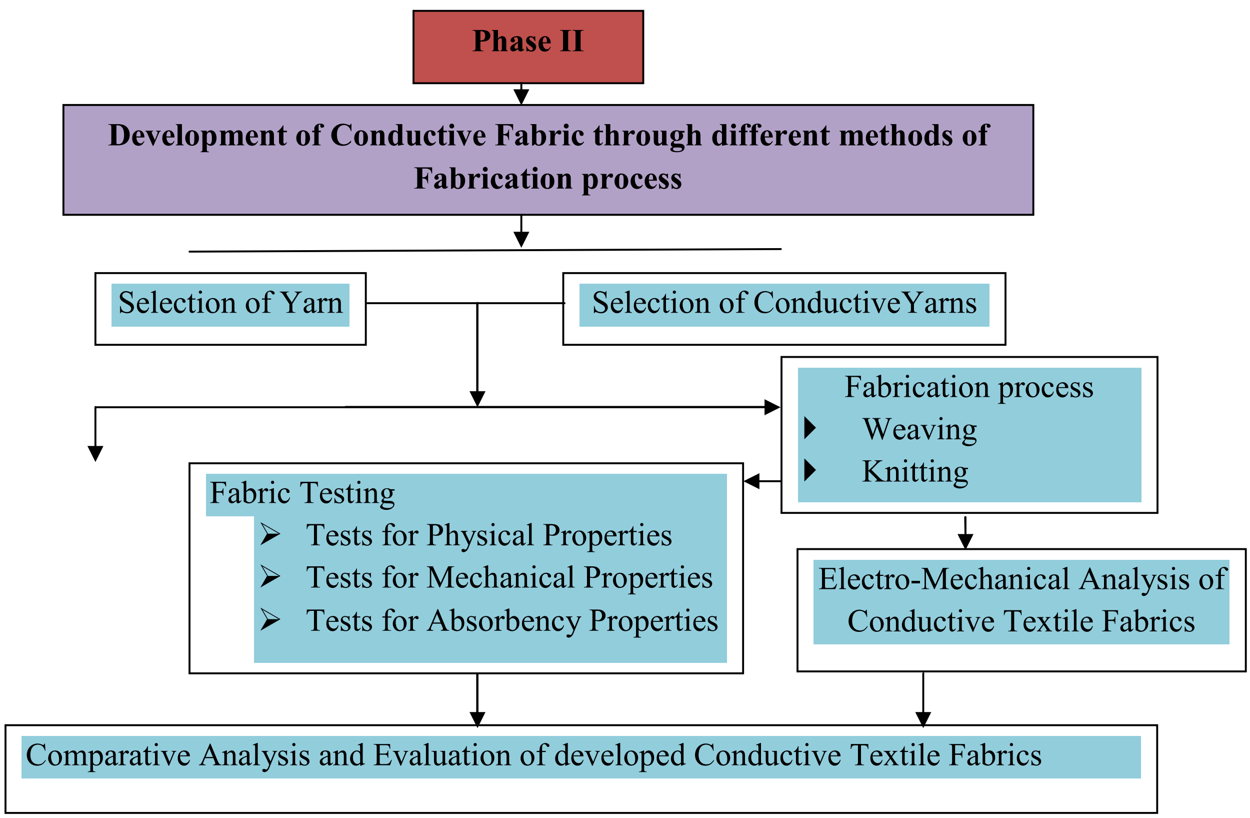
Therefore the researcher conducted a pilot study for this research with ten graduate young mothers. This helped to know about the clarity of the questions and to identify difficulties in answering. After analyzing the pilot study, corrections and clarifications were done. The final questionnaire is presented in Annexture-I.

3.1.5 Conduct of the survey:

Examining the unique roles of the mother and the father, researches has proved the fact that mothers spend more time in everyday care giving activities with their children and are most often the primary source of physical comfort and safety for the child (Melanie et al., 2010). A questionnaire based study was conducted in pediatric clinics and hospitals of Coimbatore and Pollachi after getting the permission approval from the local authorities. Young mothers having infants where enquired below three years of age based upon their willing to participate in the research, were included in the study. The study was planned and carried out for a period of month with an average of 4-5 participants per day; making a convenient sample of 100 participants. A self-administered questionnaire, written in English language is personally distributed to the young mothers who had visited the pediatric clinics and hospitals. The first part of the questionnaire includes demographic information regarding mother's age and level of education. The second part had questions related to the awareness of mothers regarding smart textiles and interest of wearable Kids health care monitoring devices for their children. The duly filled questionnaire was collected from the participants on the same day after 15 to 30 minutes.

PHASE II

3.2 Development of Conductive Fabric through different methods of Fabrication process



3.2.1 Selection of Yarn

Cotton is the backbone of the world's textile trade. It is also known as "king of fibers" and "white gold". It is said that cotton is the fiber which has no season and is equally good for every season (Bhat and Choudhari, 2012). Cotton is a cool, soft, comfortable and principle clothing fiber of the world.

Cotton production is one of the major factors in the world prosperity and economic stability (http://www.fabrics/net/cotton.asp).The most common properties of cotton are comfort, absorbency, ability to arrest microorganism's entry and its easy care, as remarked by Gupta and Laha (2007). Cotton is strong, reasonably low in price, cool to wear, good conductor of heat, and hydrophilic. It absorbs moisture up to 2.7 times of its own weight (8 per cent moisture regain), due to its unique fiber structure. Cotton helps to keep body cool in summer and is also good for underwear and children's wear. Cotton has good abrasion resistance, wet strength and softness making it suitable for frequent laundering at high temperatures. (Mudnoor and Laga, 2012).

Cotton is non-allergic since it does not irritate skin or cause allergies and its softness makes it a preferred fabric for garments worn close to the skin (Parikh et al., 2007). Considering the major quality attributes of the cotton yarn, the investigator selected 2/20 counts of cotton yarn for the study (Plate I). A total quantity of 50 kilograms of cotton yarn was procured from Kumar store, Karur for carrying out the study. The plain cotton fabric is shown in the Appendix II.

3.2.2 Selection of Conductive Yarn

Initially, conductive threads were mainly used in technical areas like military apparel, medical application and electronics manufacturing. Textile structures that exhibit conductivity or serve an electronic function are called electro-textiles.

Conductivity is defined as the ease through which an electric charge or heat passes through a metal. A conductor gives little resistance to the passage of electric current or heat that means a conductor allows an electric charge to flow freely through it. The conductivity of all metals is compared to that of silver. On a scale of zero to hundred, where hundred represents the most conductive, silver ranks first. In addition to its strong electrical conductivity, silver will not sparks easily and used in electrical components like contacts and circuits. Next to this, Copper and Aluminium ranks with high conductivity (https://www.reference.com/science/conductive-metals-23c3aa1fbbaa72dd). Therefore, the investigator selected the commercially available metal wires namely copper, aluminum and silver threads as conductive yarns for the study (Plate II). These types of conductors are based on ohmic response that always follows Ohm’s Law.

PLATE-I

Cotton Yarn

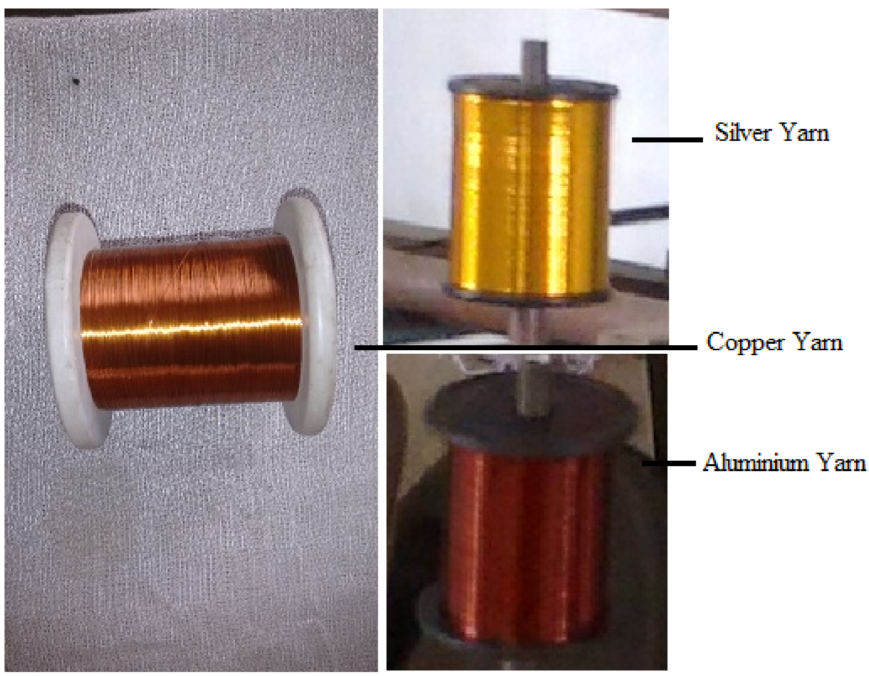


PLATE II

Conductive Yarns

3.2.3 Preparation of Conductive Yarn- Twisting

Twisting is applied to the yarn through friction contact with the surface of rotating discs with friction disc technology. The twisting process is really the heart of thread (yarn) manufacture. The twist of any thread can either be in the clockwise direction or anticlockwise (Hayes and Loughlin, 2008). The selected conductive yarns are first twisted with cotton yarns each separately by automatic twisting machine for free flow and to avoid friction and breaking during fabrication methods and the twisted conductive yarns are shown in Plate III.

3.2.4 Selection of Fabric Formation

The yarn is made into fabric through different manufacturing processes such as weaving, knitting and non-woven (Vidyasagar, 2005). The fabric forming process contributes to the fabric's appearance and texture, performance and cost. Many different interlacing patterns give interest to the fabric (Kadoph et al., 2002). Fabric properties such as texture, flexural rigidity, density, surface friction, moisture management related to wicking and air permeability of comfort properties are attributed to raw materials selected for yarn and fabric production (Thayumanavan *et al.,* 2006).

The investigator selected weaving and knitting as they are considered as most common fabric manufacturing processes.

3.2.5 Weaving

In this fabrication process, weaving is more popular than others. Weaving is an age old craft and is probably as old as human civilization. Weaving is still considered the best of all even though amidst uncountable techniques used in the textile industries for production of fabric (Sangama and Rani, 2012). The woven products are in huge demand from the past till the present whether they are woven on power looms or handlooms. Woven fabrics has a face and back side. The face usually looks more attractive in appearance and is the side viewed during wear or use (Dai et al., 2006).

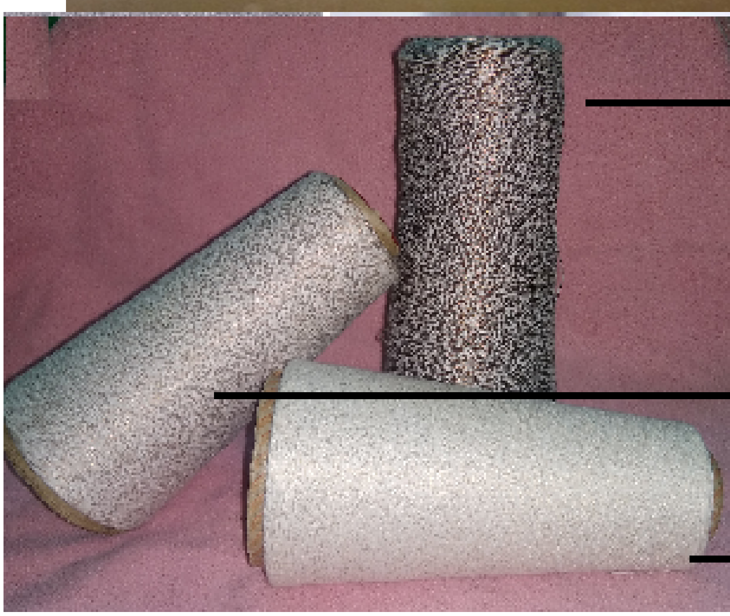


PLATE-III

Twisting

Weaving is the method of interlacement of warp and the filling (weft) in many different ways. The particular method that is used to interlace the warp and filling at right angles to each other is called the weave (Mahadevan, 2001). Fabrics are classified according to the manner in which warp and weft cross each other. The warp threads run the length of the fabric and the weft thread run across the width of the fabric. The three fundamental weaves of the plain, twill and satin weave (Thomas, 2006). For this present research work, weaving technique was chosen to produce plain cotton and conductive fabrics since it is considered to be one of the best methods of fabrication.

3.2.5.1 Selection of Weave Type

Plain weave is the simplest and most frequently used weave, says Jacquie (2005). The fabric produced with plain weave gives more compact structure, resulting in lower thickness, as compared to the other basic weave structures, express Fan and Hunter (2008). The plain weave is sometimes referred to as the tabby, homespun, or taffeta weave. It is the simplest type of construction and is consequently inexpensive to produce. Plain weave fabrics range in weight and compactness from thin light weight to compact heavy weights (Canndown, 2006).

In plain weave fabrics each warp yarn goes alternately over and under each weft yarn. Plain weave is characterized by a regular interlacing of warp and weft yarns in a 1/1 order whereas each weft yarns moves alternately over and under adjustment warp ends, and the process is reversed for the alternate weft (Jacquie, 2005). Therefore the investigator selected the plain weave structure for the study.

3.2.5.2 Actual Weaving

Weaving procedure is a process that interlacing two perpendicular sets of yarns namely the weft and warp on a machine called looms. The investigator produced conductive fabrics and plain cotton fabric in power loom (Plate-IV). Before the start of weaving process, the loom needs to be set up with warp yarn. During the weaving process, some of the warp yarns are moved up and some moved down using a harness, and this opening created between the up and down warp yarns is called shed. The investigator used 100% cotton yarns in this warp to make shed. The raising and lowering sequence of this warp yarns gives rise to interlacing weft yarns to make possible weave structure.

In the weaving process, the weft yarns are rolled around several spools called bobbins and inserted into the textile architecture perpendicularly to the warp yarns by a device called shuttle. The investigator planned to interlace the twisted conductive yarns namely aluminium yarns, copper yarn and silver yarns each separately at regular intervals in between cotton yarns in the weft direction. The intervals of cotton yarns are divided into three types namely 15 cm cotton yarn width, 10 cm cotton yarn width and 5 cm cotton yarn width. Also the width of conductive yarns is divided into 5cm, 2cm and 1cm respectively. The investigator produced nine combinations of conductive fabrics in each aluminium, copper and silver yarns using the above mentioned division of width. The conductive woven fabric samples are shown in the Appendix III – XI the nomenclature of woven samples are given in Table-II

3.2.6 Knitting

Knitting is the second major method of fabric construction. Knitting is a process of manufacturing a fabric by the inter messing of loops of yarns. When the loop is drawn through another loop a stitch is formed (Saville, 2004). Knitting is a method of converting yarn into fabric by intermeshing loops, which are formed with the help of a set of needles. Knitted technology is more flexible than weaving technology and hence can give quick response to changes in apparel market. By this method, fabric is made by transforming continuous strands of yarn into a serious of interlocking loops (www.geocities.com). It is the production of fabric by forming loops with yarn. The popularity of knitting has grown tremendously in recent years because of the increased versatility of techniques, the adoptability of the many new man made fibres and growth in consumer demand for wrinkle resistance, stretch ability, snug fitting garments says Vadhani (2001). Knitted garments today mean comfort to the consumer, versatility to the manufacturer, better unit price realization to the exporter, and a best medium for the fashion designer expresses Dhattha (2003). There are two basic forms of knitting technology such as warp and weft knitting.

PLATE-IV WEAVING

PLATE-V KNITTING

3.2.6.1 Selection of Knitting Technique

Weft knitting is defined as process of forming a fabric. Knitting means loop formation in horizontal way from a single yarn for interlocking of loops. This can take place in a circular or flat form on a crosswise manner. In this method one or more yarns are being fed one at a time to a number of knitting needles placed in either lateral or circular fashion. Most of the weft knitted structures comes out in a tubular form (Srinivasan, 2003). Weft knitted fabric is porous and comfortable both for outer garments and under garments. The yarn may be fed as to traverse back and forth across the fabric or it may be fed continually in the same direction, giving rise to a tubular fabric (Khare et al, 2004). Weft knitting is a method of creating a fabric by interlocking of loops in a cross wise in direction. Weft knits accounts for approximately eighty to eighty five percentage of all the knitted fabrics produced.

Weft knitting techniques are divided into three structures as single jersy, rib and interlock. Each type prepared by combination of face reverse meshed stitches, knitted on a particular arrangement of needle beds (Shaikh, 2006). Hence the investigator selected knitting also a method to produce conductive fabrics and plain cotton fabric.

3.2.6.2 Selection of Knit Type

Plain single-jersey is the comfortable and simplest weft knitted structure and is possible to produce with one set of needles explain (Padma and Subramaniam, 2003). The single-jersey structure is widely used in the manufacture of knitted outer wear, foot wear and all type of fashioned garments. Therefore single-jersey structure for knitting the selected conductive yarns and cotton yarn were selected for the study.

3.2.6.3 Selection of Knitting Machine

Circular knitted fabrics cover the spheres of outerwear as well as underwear, sportswear and leisure wear feels (Klinger, 2001). Shilpa and Ela (2001) say the predominant machines for producing weft knitted fabric is a circular knitting machines. Circular knitting machines basic configuration consists of machine cylinders, cylinder cam and gauges and needles with the number of needles, needle type and sinker type varying for different machines as per their specifications. The resulting fabric is formed in a tubular shape. Circular knitting machines produce weft knits almost exclusively say (Nawaz et al., 2000). Shah (2003) emphasizes that the knit fabrics are highly delicate, sensitive to distortion on mechanical stress and strain, sensitive to curling, skewing, unpredictable high shrinkage, poor dimensional stability, pulling of thread and hole formation. Hence selection of knitting machine, processing sequence and careful engineering of process mechanism are important.

In the fabrication process of knitting, the interlocking of loops is done with the help of needles to produce the fabric. The investigator selected four types of yarns namely cotton yarn, aluminium conductive yarn, copper conductive yarn and silver conductive yarn to knit the fabric with each separately. In this process, the investigator had done twisting of conductive yarns before taking them for knitting to avoid friction during the process. Since the conductive yarns level to bend during knitting was low, the investigator selected hand operated knitting machine (Plate-V) for the study. The selected yarns are carefully taken through the feeder from the spools and knitted manually. The details of the hand operated knitting machine are given in the Table I. The conductive knitted samples are shown in the Appendix XII and the nomenclature of knitted samples are given in Table-III. The plain cotton knitted sample is shown in the Appendix II.

Table I- Knitting Machine Settings

S.NO	PARAMETERS	DETAILS
1	Name of the Machine	Hand Operated Knitting Machine
2	Machine Gauge	9
3	Machine Diameter	3.75”
4	No of needles	108
5	Feeders	Single

Table-II

Nomenclature of Woven Fabrics

Conductive Yarn	**Aluminum**			**Copper**			**Silver**			**Original Cotton Woven Fabric**
Distance / Cotton distance	5 CM	2 CM	1CM	5 CM	2 CM	1CM	5 CM	2 CM	1CM	OW
15 CM	AA	AB	AC	CA	CB	CC	SA	SB	SC	
10 CM	AD	AE	AF	CD	CE	CF	SD	SE	SF	
5 CM	AG	AH	AI	CG	CH	CI	SG	SH	SI	

Table-III

Nomenclature of Knitted Fabrics

S.No	**Sample**	**Fabric**
1	OK	Original cotton knitted fabric
2	AK	Aluminum knitted fabric
3	CK	Copper knitted fabric
4	SK	Silver knitted fabric

3.2.7 Evaluation

Testing is a valuable aid for judging the product quality, ensuring regulatory compliance leads to assessing the performance of textile materials. Textile testing is the effective testing method done on textile materials which may be in room temperature or in its natural setting, or in the day-to-day uses, using various testing equipments (Jewel, 2005).

The objective of textile testing lies with the fact that the results of testing in research help the researcher to decide which route to follow next. Besides, the findings on different properties of textiles, gives a better line to select what type of fabric is appropriate for the end use of the products (Paul and Devi, 1997). In addition, many companies around the world have their own standards and test methods. Methodology and equipment may vary but the basic objective remains the same (Srikrishnan et al., 2012). The evaluation includes laboratory tests like physical, mechanical, comfort, absorbency and functional property tests. The tests were carried out to study the various properties of the fabric samples by laboratory examination using suitable instruments.

3.2.7.1 Yarn Testing

Textile testing is the process of inspecting, measuring and evaluating the characteristics and properties of textile materials. The quality of yarn is defined in terms of various yarn parameters but it is based principally on the two measures namely yarn strength and mass variation along the length (Gowda, 2003).

3.2.7.1.1 Yarn Thickness

The yarn thickness has a huge impact on the look of woven or knitted fabrics. Thickness Gages (Plate-VI) was used for its quick and efficient means of measurement of thickness of yarn accurately with their convenient grip handle, thumb trigger and spring loaded spindle. Ten readings were noted for all the types of yarns.

3.2.7.1.2 Yarn Strength and Elongation of Conductive yarn

Annealing test method for wires is normally carried out to determine the elongation properties of annealed copper, aluminum for welding cables and solid conductors of electric power cables. Annealing test for conductors were performed to confirm the durability of conductive wire during twisting and bending.

A sample of conductive yarn is taken and its Gauge Length is calculated. Original length of specified portion of the test specimen over which strain or change of length is measured to determine gauge length. The total length of the sample was calculated by adding gauge length with the lengths at each ends which are used for holding the sample by tensile test machine holder grips. The Tensile Testing Machine (Plate-VII) used for testing elongation is an automatic machine, with capacity to satisfy the requirement of the test and the rate of separation of jaws as specified. The grips should firmly hold the test sample and the apparatus requires a plane faced micrometer with scale division at least 0.01 mm is required for performing this test. Moreover the sample does not require treatment before testing.

The test specimen is fixed between two heads of the machine by grips, tensile stress is applied gradually and uniformly that means the gap between the grips is increased gradually and uniformly till the specimen conductor having an original gauge length of 250mm gets fractured. The rate of elongation of sample i.e. rate of increase of gap between holding grips of the machine should be less than 100 mm per minute. The elongation is measured on the gauge length tester after the fractured and the determination shall be valid irrespective of the position of the fracture, if the specified value is reached. If the value is not reached, the determination shall be valid only if the fracture occurs between the gauge marks and not closer than 25 mm to either mark. The elongation is expressed as a percentage of the original specimen gauge length is calculated by

$$\text{Elongation } \% = L/L_1 \times 100$$

Where, L = elongation, and L_1 = original gauge length.

In this manner, the selected yarns namely aluminium yarn, copper yarn and silver yarn were tested. Ten reading were noted and the mean elongation percent was calculated.

3.2.7.2 Fabric Testing

3.2.7.2.1 Tests for Physical Properties

The Conductive fabrics both woven and knitted were evaluated and compared with plain cotton fabrics for its physical properties namely weight and thickness.

3.2.7.2.1.1 Fabric Weight (ASTM D 3776)

The weight of the fabric can be described in two ways either as the "weight per unit area" or the "weight per unit length", - (Textile Committee, 1993). Saini (2004) describes fabric weight as the relative weight of the fabric and expressed as the weight of a particular size of piece, such as grams per square meter or ounces per square yard. The simplest unit is ounce per square yard. The weight of the fabric can be expressed as weight per unit area in terms of ounces per square yard or grams per square meter, weight per unit length in terms of ounces per yard or grams per meter, as remarked by (Booth, 1996).

All weighing tests were made in standard atmosphere for testing textiles with the temperature of 21 ± 1ºC. The paramount GSM cutter shown in Plate VIII is a specialized instrument to determine the GSM of the fabric (knitted, woven, non-woven). It has four blades that cut the fabric when the hand wheel is rotated by applying slight pressure. The samples were cut randomly for testing by placing the fabric over the GSM board and GSM die cutter was used to cut the samples. The handle of the cutter was pressed downwards, then turned from left to right and released gently to cut the fabric swatch. The area of the circular GSM die cutter is 100 cm^2.

Ten fabrics swatches were cut from different places of the fabric and the samples were weighed in an electronic balance within + 0.1 per cent of mass. The weight of the sample was measured in grams and multiplied into 100 to get the Grams per Square Meter value. In this study, the evaluation of fabric weight of the samples was carried out in accordance with the standard ASTM D 3776 (option C) reapproved 2013. The inference obtained was calculated using the formula:

$$\text{Grams per Square meter (GSM)} = \frac{\text{Weight of the fabric x Square metre}}{\text{Area of square}}$$

Weight of the fabric = x (g)

Square meter = 100 cm x 100 cm = 10,000 cm^2

Area of square = length x breadth square units

The same procedure was followed to find out the fabric weight of all other samples used in the present study. Fabric weights were carefully recorded and the mean value was calculated. The dimensions and mass was determined in SI units and reported in grams per square meter.

3.2.7.2.1.2 Fabric Thickness (ASTM D 1777)

Fabric thickness is defined as the distance between the upper and lower surface of the material measured under a standard pressure, using the Sherley "Batty Thickness Tester" with an accuracy of 0.01 mm, as explained by (Stoker et al., 2005) and (Paul, 2005). The thickness tester helps to determine the thickness of woven, knitted, coated narrow fabrics, tapes, ribbons, braids, films, glass fabrics and glass tapes. Fabric thickness is defined as the distance between two parallel surfaces while exerting a specific pressure on the material by the pressure foot of the tester (Sood et al., 2014).

The Thickness tester (Plate-IX) is a hand operated instrument which has a dial gauge that reads the thickness of the samples. Two clamps (pressure foot and anvil) were attached to the dial gauge. The specified pressure foot with the diameter of 28.7mm was fitted on the mounting rod. The fabric was placed randomly between the two clamps, then the lifting lever was pressed and the pressure foot top of the dial gauge was lifted. The lifting lever was then released to gently down the pressure foot pressed on the sample. The reading was noted from the dial of the Thickness gauge by precisely measuring the distance between the plates. The readings were taken at ten different places of the fabric and care was taken to see the places were away from the selvedges and free from wrinkle. The mean is calculated for all the test samples and the thickness is expressed in millimeter. The same procedure was followed to find out the fabric thickness of all other samples used in the present study.

3.2.7.2.2 Tests for Mechanical Properties

Fabric tensile strength and elongation, abrasion resistance and bursting strength were carried out in this study to assess the mechanical properties of all the fabric samples.

3.2.7.2.2.1 Tensile strength and Elongation (ASTM D 5034)

Tensile strength is the most common mechanical properties for woven fabrics. The breaking strength is a measure of the resistance of the fabric to a tensile load or stress in either warp or weft direction. Stretching of the fabric when loaded is called elongation states Chattopadhyay (2008). Breaking length and elongation of the specimen is defined as the length of the specimen where mass is equal to the breaking force. Tensile Strength is the ratio between the maximum load that can a material support without fracture and the original cross-sectional area of the material. Originally quoted as tons/sqand is now measured as Newton/sq.mm. (Nasrin et al, 2014) . Literature also reveals that the tensile strength of a fabric not only depends on the strength of the constituent yarns, but also depends on the structure of yarn and fabrics and many other factors.

The method is applicable to all the textile fabrics irrespective of their composition that is whether natural or manmade fibers or blends or two or more such fibres, manufacturing process and finishing treatments. Tensile strength of a woven fabric is one of the most important properties, which makes it superior in many applications as compared to knitted and non-woven fabrics (Gabrijelcic et al, 2008). The tensile strength and breaking load of the samples for this study were carried out using Eureka Pendulum type Tensile strength tester (Plate-X).

The test was performed in both the warp and weft directions. The specimens were cut out randomly in the warp and weft direction. The sample was cut 50mm in width and 200mm Length with the long dimension accurately parallel to the direction of testing and force application. Each specimen was clamped between the two jaws provided in the equipment. The sample was centrally located in a way that the long dimension was as nearly parallel as possible to the direction of force application. It was made sure that the tensions on the specimens were uniform across the clamped width. Uniform and equal tensions were achieved by attaching an auxiliary clamp to the bottom of the specimen and at the point below the lower clamp of the testing machine. The lower clamps were tightened and auxiliary clamp was removed. The load was applied and as soon as the specimen broke, the breaking load in kg and the elongation in inches were recorded. The mean value and elongation percentage were calculated. The test was carried out in a similar manner for all the samples.

3.2.7.2.2.2 Fabric Abrasion Resistance (ASTM D 3885)

Abrasion resistance is the ability of a material to resist the action of abrasive forces. Abrasion is one of the major points to assess the durability of the fabric, as stated by Kadolph, (2007). Abrasion is one criteria of wear and is rubbing away of the component fibres and yarns of the fabric. Abrasion is the physical damage of fibers, yarns, and fabrics due to rubbing of a textile surface over another surface (Abdullah et al., 2006). Abrasion caused by wearing and washing process may lead to damage the fabric by pulling out fibers or yarns from the surface (Hu, 2008). Knitting structure also has an important effect on abrasion characteristics of the fabrics. Average abrasion resistance values of interlock knitted fabrics are higher than rib and single jersey fabrics (Ozguney et al., 2008). Abrasion may be classified as plane or flat abrasion, edge abrasion or flex abrasion (Kota and Megeid, 2011). Abrasion is measured by a narrow line that becomes a gradually widened ellipse, until it forms another narrow line in the another direction and traces the same figure against under known condition of pressure and abrasion (ASTM Standards, 2005). According AATCC (2006), abrasion is the wearing a way of any part of the material by rubbing against any other surface.

The Flex Abrasion Resistance Tester (Plate- XI) was used to determine abrasion resistance of the samples. Emery paper or Universal carborundum (120 QT - C 104) paper was used as abrading surface and fitted to the reciprocating abrader head. Ten samples were cut from different places of the same material at random using the template in both warp and weft direction. They were placed and clamped at the centre of the upper plate, and the reciprocating plate at the rear of its stroke. Loading the pressure plate and the bar was done with great care such that it was sufficient to produce rupture in excess of at least 100 cycles. Preferably 300 cycles should be used, in combination with the lowest head load sufficient to prevent vibration of the upper plate at the start of the test. Before every test the blade need was rinsed with chemical agent. The end point is determined by abrading the sample until rupture and number of cycles recorded. The process was repeated for all the samples and ten readings were noted for each sample.

3.2.7.2.2.3 Fabric Bursting Strength (ISO)

Burst strength testing refers the application of a perpendicular force to a fabric until it bursts that means rupture on the fabric. The bursting strength is the strength of the fabric when multi-directional force of pressure is applied on it defines Mohammad et al, (2016).Bursting strength is calculated for the fabrics by the textile industry to evaluate its wide variety of end application. In knitted fabrics, it is an alternative method of measuring tensile strength in which the material is pressed in all directions at the same time and measured in units of pressure express Bharathi and Arun (2004). The hydraulic bursting strength tester (Plate-XII) was used in this study. In this method the sample was clamped over an expandable diaphragm. The diaphragm was expanded by fluid pressure to the point of specimen rupture, the pressure being indicated by the gauge.

The upper and lower clamping surfaces has a circular opening at least 75mm (3") in diameter and co-axial aperture of 31±0.75mm in diameter. The surfaces of the clamps were metallic. A diaphragm of molded synthetic rubber has thickness of 1.80+0.05mm was clamped between the lower clamping plate and the rest of the apparatus so that before the diaphragm was stretched by pressure underneath it the centre of its upper surface was below the plane of the clamping surface. The pressure required to raise the force surface of the diaphragm plane was 30±5 K.pa. All the conductive fabrics as well as plain fabrics were cut as per the specifications and placed on the diaphragm. Pressure was raised and the bursting point was noted. Ten readings was taken for all the samples.

3.2.7.2.3 Tests for Water Absorbency Properties

3.2.7.2.3.1 Sinking test

Sinking time test is a simple test that helps to measure the wettability of a fabric (AATCC, 2008). Determining the time required for a textile material to sink is one of the methods to find out its absorbency. Sinking test (Plate-XIII) is a simple test that helps to measure the wettability of a fabric (Kavitha and Selvakumar, 2010). In this method, each fabric was cut into a number of equal sized squares of 1” x 1” and added to a 1000 ml beaker which was filled with distilled water. The stop watch was started when the fabric struck the surface of water and stopped when the last corner was sunk below the water surface. The test was repeated ten times for all the fabrics and the mean time for the sinking was calculated and recorded.

3.2.7.2.3.2 Drop test

The drop test is a count of the number of drops required to penetrate through to the under scale of the fabric completely when all the drops fall on the same spot (AATCC Technical Manual, 2008). The wettability is the time taken in seconds for a drop of water to sink into the fabric. If any fabric takes more than 200 seconds to absorb the water then it is considered as unwettable.

As per the AATCC Test method 79 (2007), the fabric sample was tightly mounted in an embroidery hoop circularly free of wrinkles and kept 10±1.0mm below a burette but without stretching or distorting the structure of the fabric. A burette filled with distilled water was clamped on a stand at constant distance between the sample and burette nozzle. The nozzle of the burette was opened just to allow a drop of water to fall on the fabric sample (Plate-XIV). The timer was started simultaneously and it was stopped when the drop of water fully sank into the material. The time required for the drop of water to lose its reflectivity and dull wet spot was noted. The time was recorded in seconds when the water drops no longer reflected light. The process was repeated for all the samples and ten readings were noted.

3.2.7.2.3.3 Vertical Wicking Test

Wicking is the transportation of liquid water by capillary action. The ability of the fabric for wicking depends on the surface properties of the constituent fibres type, denier, yarn structure, fabric structure and their total surface area. Wicking ability of fabrics is extremely important from the point of view of comfort characteristics of fabrics, as remarked by Phukon and Phukon (1998). Wicking is the result of capillary flow of the fluid through a porous medium as an effect of capillary forces and without any external pressure. Wicking is important for fabrics for their high performance and comfort (McDonald, 2006). The ability of the fabric to absorb water especially by a wicking or capillary action may be observed by timing the rate at which water climbs up a narrow strip of fabric suspended vertically with its lower end dipping into the water. Wicking test was conducted as per the procedure given by Saville (1999).

Ten samples of dimension were cut from each fabric, 1 cm and 5cm were marked at one end of the fabric strips. Other end of the sample strip was pasted with a glass rod which was placed on heavy wooden blocks. The marked edge is allowed to immerse up to 1cm in the distilled water in a breaker (Plate-XV). Stopwatch was used to measure the time taken by the fluid to rise until marked point of five cm. Reading was taken for ten specimens of all fabric samples and the time required was marked in minutes (Chatterjee and Singh, 2014).

Plate-VI Thickness gauge

Plate-VII Yarn Elongation

Plate-VIII GSM cutter

Plate-IX Thickness Tester

Plate-X Tensile Tester

Plate-XI Flex Abrasion Tester

Plate-XII Bursting Strength Tester

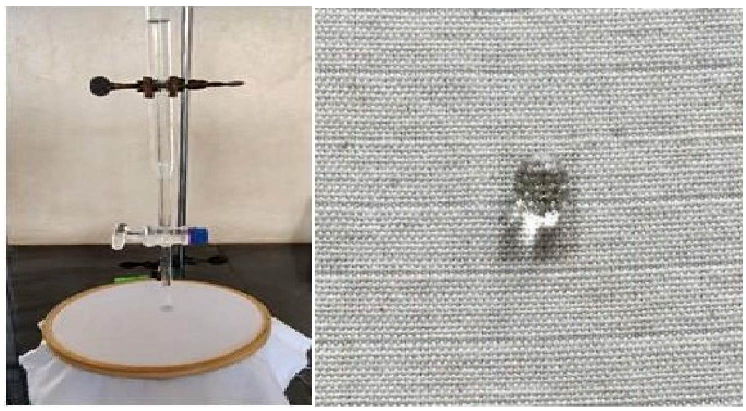


Plate-XIII Sink Test

Plate-XIV Drop Test

Plate-XV Vertical Wicking Test

3.2.7.3 Electrical Analysis of Conductive Yarns

This test is used to determine the direct correct resistance of copper, aluminum or any metal conductors. Resistance of a conductor determines the flow of current through a conductor. Higher resistance denotes lesser the current will flow though the conductor. Resistance of a conductor is determined by its dimension, conditions like temperature, resistivity and structure is expressed in ohms per km. The test was carried out either in Kelvin Double Bridge or Wheatstone Bridge machine with accuracy 0.2 - 0.5 percent.

The test specimen is connected to the resistance measuring bridge shown in Plate-XVI. Adequate care is to be taken in this connection to minimize Contact resistance. The resistance of the test specimen is measured and the ambient temperature recorded. The measured resistance is converted to the standard temperature and standard length. The value of resistance R shall be calculated from observed resistance at a particular temperature as indicated below:

$$R = {}^{(Rt \times k)}/_{L} \times 1000 \ \Omega/km \text{ at } 20°C$$

Where,

R_t = Observed Resistance

K = Temperature correction factor

L = Length of specimen in m.

Following the above method, the selected conducive yarns were tested.

3.2.7.4 Electro-mechanical Analysis of Conductive Textile Fabric

Surface resistivity is defined as the electrical resistance of the surface of an insulator material. The measurement is taken from one electrode to another electrode along the surface of the insulator sample. Since the surface length is fixed, the measurement of material is independent of the physical dimensions like thickness and diameter of the insulator sample. Insulation resistance quality of an electrical system degrades with many aspects like time, environment condition, temperature and moisture and dust particles. It is necessary to check the Insulation resistance of equipment at a constant regular interval to avoid electrical shock. The Megger MIT1020/2 is a microprocessor controlled 10 kV insulation tester shown in Plate-XVII allows measurement capability of up to 35 TΩ. The instrument performs test automatically with data storage and data retrieval facilities.

The test specimen is connected to the insulation resistance measuring equipment and the conductor is connected to the high voltage terminal and the screen/armor. The insulation resistance of the test specimen is measured after electrification has continued in a regular manner for one min. The ambient temperature is recorded when the test is performed at ambient temperature. The apparatus shall be checked by comparing the values with standard resistance before taking every set of reading. The volume resistivity and insulation resistance constant is calculated from the measured insulation resistance value and expressed in KΏ. This test was conducted for the conductive fabrics samples with 5cm, 2cm and 1cm conductive yarns and the readings were noted.

3.2.8 Statistical analysis

The results of the survey of the study and objective evaluation of all the samples were analyzed with the help of statistical tools. The collected data was analyzed using the software package known as Statistical Package for the Social Sciences (SPSS). The statistical tools used for this study included per cent analysis, 'F' test, 't" test, Analysis of Variance(ANOVA), and for the ranking questions, Henry Garret ranking technique was applied.

The variable behavior of data collected from research lead to the application of statistics in research. Statistics is a tool that can be applied to evaluate the nature of an observed variable, to decide whether it is the outcome of chance or due to real effect it is used in research to analyze the obtained data (Gray, 2001). The data obtained from various tests were statistically analyzed with Microsoft excel to find out the arithmetic mean, standard deviation and CV % and one way ANOVA. The significance change in fabric qualities were also analyzed for treated and untreated samples at 0.05%confidence level.

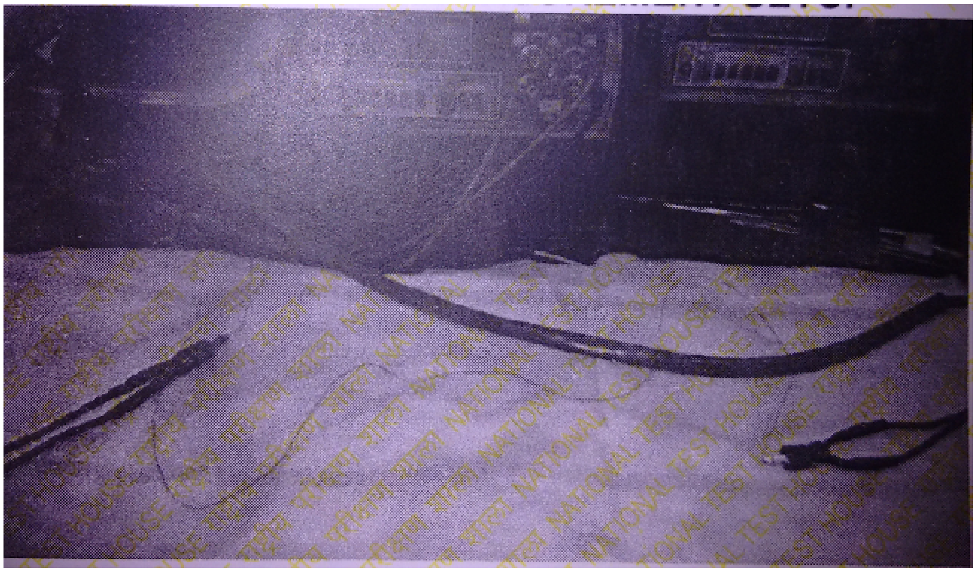


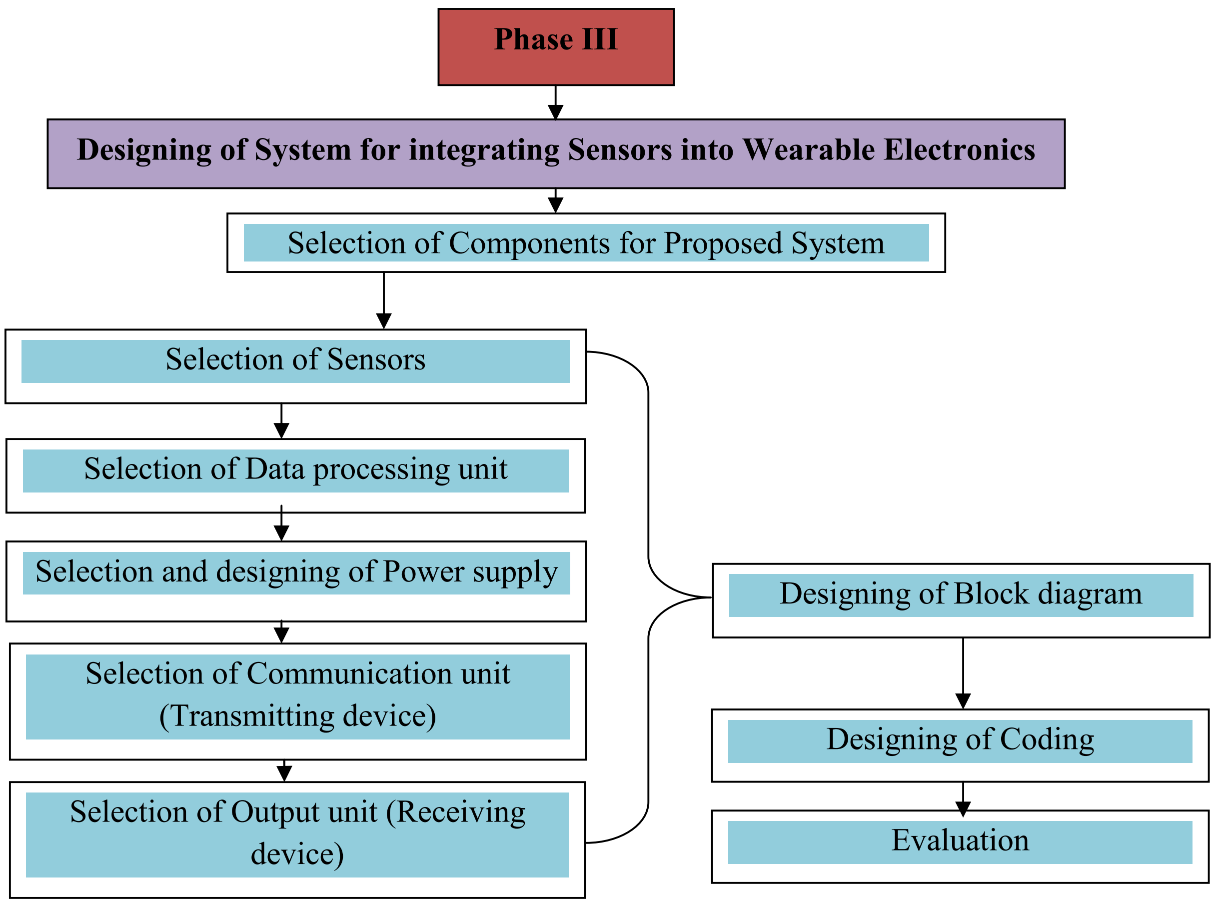
Plate-XVI Resistance Measurement setup

Plate-XVII Megger MIT 1020/2

Phase III

3.3 Designing of System for Integrating Sensors into Wearable Electronics

In the continuous pursuit of innovation, academic and industrial researchers alike have opened up floodgates in the development of wearable electronics. Wearable and ultraportable electronics joined with pervasive computing technique is a revolution in healthcare service. The potential cost savings in both treatment, as well as preventive care are the focus of several research efforts across the globe. The focus of the research is to design a wearable unobtrusive continuous monitoring system for the healthcare of the infants. In order to realize this system, sensor networks and wireless communication are combined for providing reliable health monitoring as well as a comfortable clinical environment for infant health care and parent-child interaction. It also promotes the concept of preventative healthcare.



3.3.1 Selection of components for Proposed System

The system architecture of wearable garment includes a wide variety of hardware as well as software components like sensors, wearable materials, smart textiles, actuators, power supplies, wireless communication modules and links, control and processing units, an interface for the user and advanced algorithms for data extraction and decision-making. The hardware unit is further split into two units as transmitter & receiver (Ghosh et al, 2017). Therefore keeping below mentioned factors the investigator framed the components for the design of a wearable electronic system as shown in the Figure-4.

- Integration of sensors for monitoring necessary vitals
- Data Acquisition is performed by integrated sensors that measures vital physiological parameters
- Designing a platform for data processing and wireless communication system to transmit the processed data.
- Obtains sense of trust by the user (Example: Young Working Mothers).

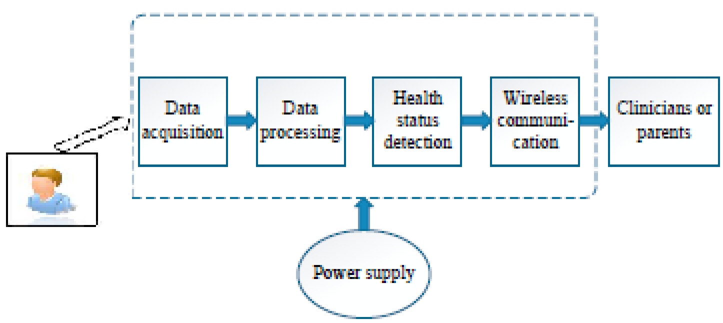


Figure.4 Framework of Wearable Sensor System

3.3.2 Selection of Sensors

A Sensor is a device that receives a stimulus and responds with an electrical signal (Fraden, 2010). Sensors cover a wide spectrum of transducer and signal transformation approaches with corresponding variations in technical process. These range varies from relatively simple physiological measurement to the detection of specific bacteria species using sophisticated optical systems. Sensor is a device that responds to a physical input of interest with a recordable, functionally related output that is usually electrical or optical (Jones, 2010). The aim of the research is to design a system which can continuously monitor the health care, in order to do this the investigator selected two sensors to monitor body temperature sensor and heart rate.

3.3.2.1 Body Temperature Sensor

Body Temperature changes depend upon on the time to time and day to day activities and the normal body temperature is about 37^o C or 98.6^o F (Das, 2014). Body temperature has a vital importance for wellbeing of the person its shows the real human state and is affects by several diseases that need to be routinely monitored to indicate the emergency situation (Zukav, 2013).

LM35 sensor is semiconductor based sensor that means it has conductivity level is somewhere between the extremes of an insulator and conductor. The LM35 is integrated-circuit temperature sensor suitable for body temperature measurement and its output voltage in linearly proportional to the Celsius temperature. The LM35 has tremendous advantage in linear temperature sensors type which is calibrated in Kelvin, because it helps the user by automatically doing subtraction of a large constant voltage from its output to obtain convenient centigrade scaling (Goswami et al, 2009).

The main advantage of LM35 sensor is its memory, processing and communication capabilities more than other temperature sensors. LM35 can be used with single power supplies, or with plus and minus supplies. As it draws only 60μA from its supply, it has very low self- heating, less than 0.10 in still air and its operating temperature range is from −55° to +150°C. This temperature sensor has linear output, low output impedance and provides accurate inbuilt calibration so that the control circuit is becomes easy. The LM35 sensor circuitry portion is sealed and therefore it is not subjected to oxidation and other processes (Poonam and Yusuf Mulge, 2013). Human body needs special type of sensors for reliable readings. Since this LM35 temperature sensor (Plate-XVIII) is accurate, does not require calibration to work under any environmental conditions with 4 to 30 volts and is cheap and easy to use, the investigator selected the commercially available LM35 sensor for the study.

3.3.2.2 Heart Rate Sensor

The human heart is a vital organ in the human body that provides continuous blood circulation throughout the cardiac cycle. Pulse caused by the compression of the heart sends blood around the body (Lalitha and Achanuphab, 2014). Heartbeat rate is one of the most needed parameters of the cardiovascular system and a healthy adult at rest is around 72 bpm. Pulse rate or Heart rate is formulated by counting the number of heartbeats per unit of time, universely expressed as beats per minute (bpm). Babies have a much higher heart rate at around 120 bpm, while older children have heart rates at around 90 bpm (Riddington, 2013).

Current heart rate monitoring devices or electrocardiogram monitoring devices are more effective than manual methods in accurately assessing the heart condition over less period of time and finding the abnormalities through heart beats. Pulse rate sensor shown in Plate-XIX contains crystal for piezo electric effect and it is responsible for accurate measurement of heart beat. The Pulse Sensor is based on Photoplethysmography (PPG) technique which is a simple optical method to detect volumetric changes in blood in peripheral circulation. Amped is a plug and it plays heart-rate sensor for Arduino. It ties a simple optical heart rate sensor with amplification together with noise cancellation circuitry to make it quick, reliable and easy for reliable readings. Also, it operates power with just 4mA current draw at 5V so it’s great for mobile applications (Shu et al, 2015). Considering these facts, the investigator selected the commercially available pulse sensor to measure the heart rate for the research study.

3.3.3 Designing of Block diagram

A block diagram is a geometric presentation of the principal areas or functions by blocks connected through lines that show the relationship between the blocks. They are mostly used in engineering for hardware designing, software design, electronic-design, and process flow diagrams (SEVOCAB, 2008). Block diagrams are used to understand complete circuits of the design by breaking them down into smaller blocks.

Each block performs a unique function and the block diagram shows the way connection between each together and this way of looking at circuits is called the systems approach. Electronic systems are usually constituted schematically as a series of interconnected blocks and signals entitling an individual component or complete sub-system with each block having its own set of inputs and outputs. This system of interconnected blocks is commonly known as block diagram representation (electronicsclub.info/blockdiagrams.htm). Therefore the investigator designed the block diagram of smart wearable electronics for wireless health monitoring system with all essentials components and it is shown in Figure.5.

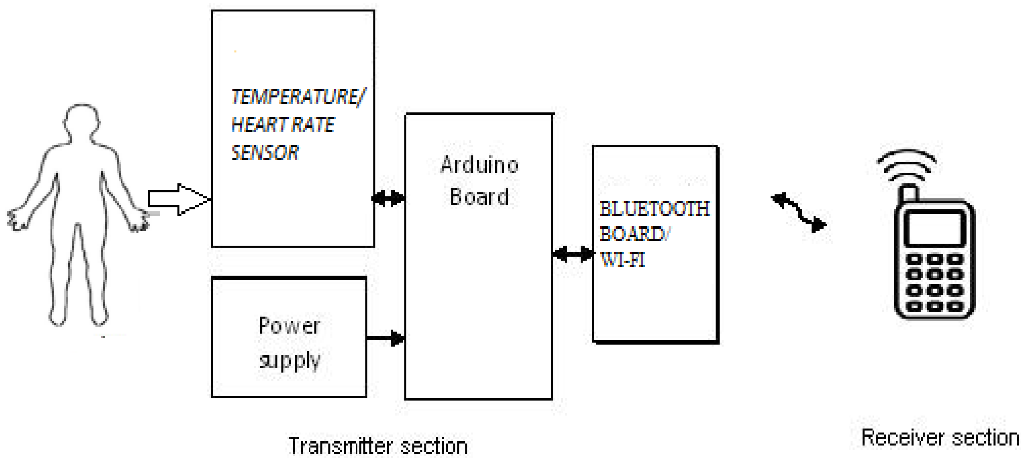
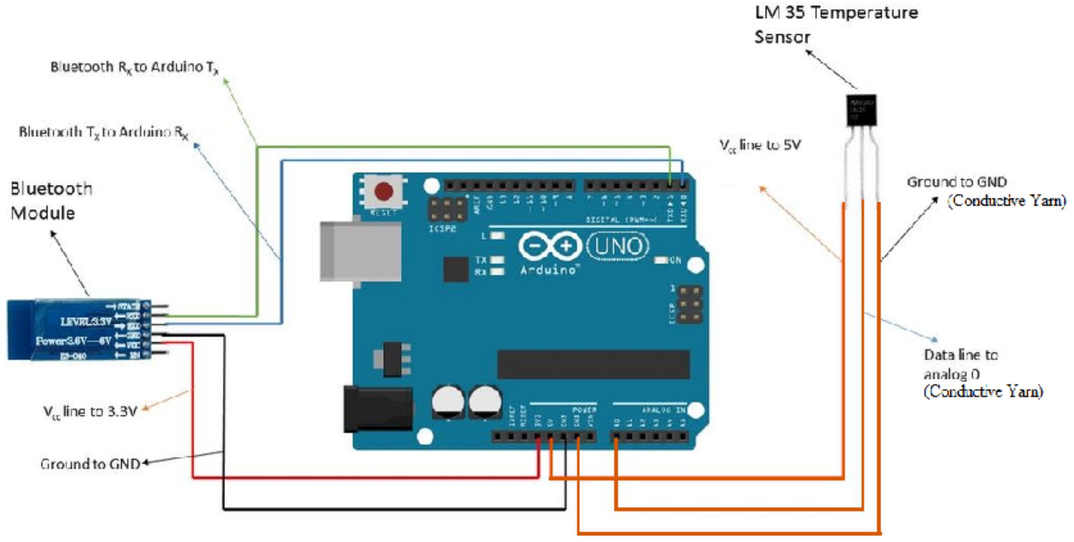
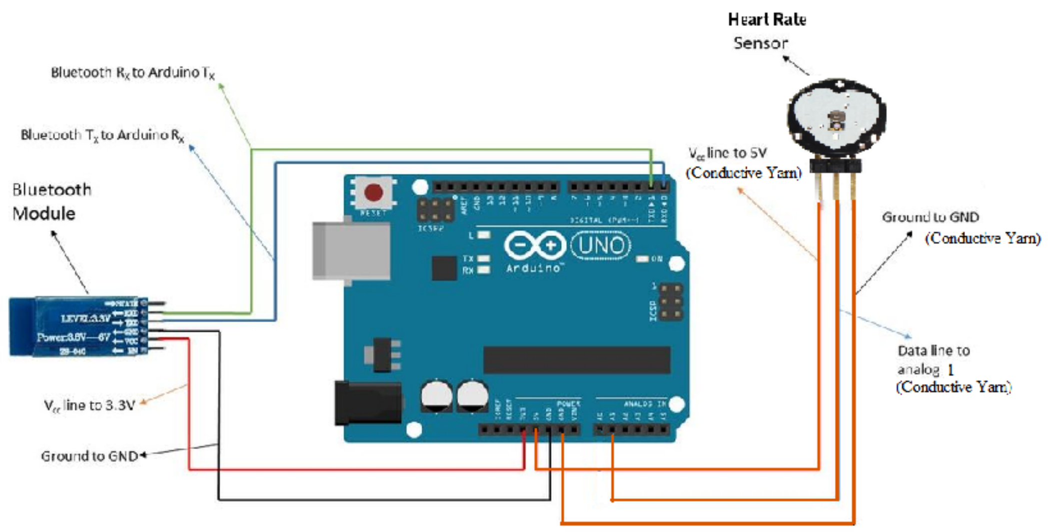


Figure .5 Block diagram of the proposed system

The connection diagrams are easy modified conventional pictorial representation of an electrical circuit to neatly shows the components of the circuit as simplified shapes, and the power and signal connections between the devices and shows the actual electrical connections (Khandpur, 2005). Hence the investigator designed the connection diagram as shown in the Plates- XX.



Connection diagram of Temperature Sensor



Connection diagram of Heart rate Sensor

Plate-XX

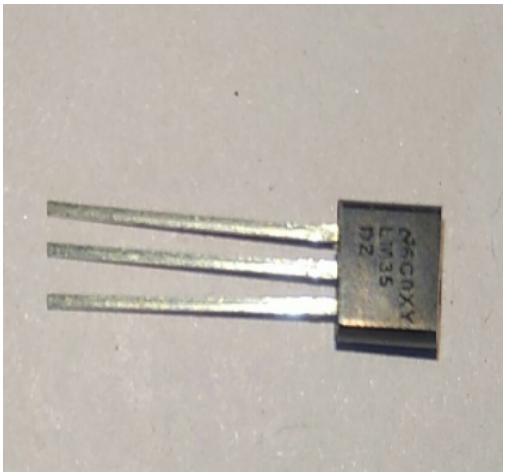
3.3.4 Selection of Data processing unit

A microcontroller is a small low cost embedded system with a data processor, memory and peripheral. Microcontroller is used in number of products and electronic items like mobiles, vehicles and almost in number of day to day required household equipment. Micro-controllers can be interfaced input and output devices like relays, solenoids, latches, LCD display, monitors, switches, and sensors like light, temperature humidity, water level and gas sensors (Poonam, 2013).

Arduino was found by Massimo Banzi, David Cuartielles and David Mellis in 2005 and first project started by students at the Interaction Design Institute Ivrea in Italy. Arduino family consists of UNO, LILYPAD, DIECIMILA, NANO, and DUEMILANOVE. Arduino basically uses the Harvard architecture where the designed program code and noted data are stored each separately in Program memory and the data memory. The code is stored in the flash program memory, whereas the data is stored in the data memory. (Berglin, 2008).

The Arduino Uno is a microcontroller board based on the ATmega328. Arduinouno board with Ethernet shield is a device that offers more processing power and memory (in terms of both EPROM and flash) than many similarly sized platforms. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), a 16 MHz crystal oscillator, 6 analog inputs, a USB connection, an ICSP header, a power jack and a reset button. This board contains necessary parts needed to support the microcontroller while connecting it to a computer with a USB cable. It uses the Atmega8U2 programme as a USB to serial converter and other Arduino use the FTDI USB to serial driver chip (Evans, 2005).

The microcontroller on the board is programmed with ultimate care using the Arduino programming language and the Arduino development environment. Arduino projects can be unique that can communicate with software on running of a computer. The Arduino is referred to as open source hardware and designed around an 8- bit Atmel AVR microcontroller, or a 32-bit Atmel ARM. It can pre-program into the microcontroller chip on the board (boot-loader) that allows uploading of programs into the microcontroller memory (Bhoomika and Muralidhara, 2016).Therefore the investigator selected Arduino Uno (Plate-XXI) as the data processing unit for the research.



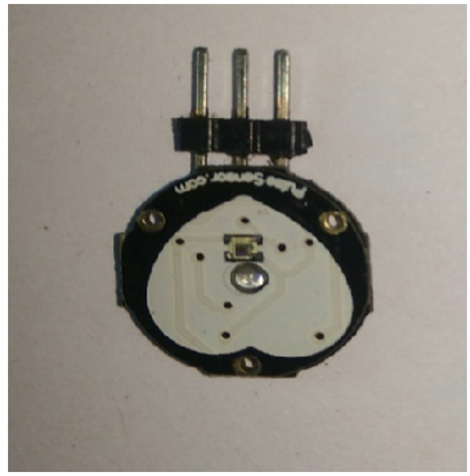


Plate-XVIII LM35 Sensor **Plate-XIX Heart Rate Sensor**

Plate-XXI Arduino Uno

3.3.5 Designing of Coding

Arduino is one of the very popular microcontroller based electronics prototyping platforms commercially available in the market. Arduino's applications various from huge ranging LED driving circuits to complex internet based weather and moist monitoring circuits. The codes which are written in **C++** language on the Arduino are known as Arduino sketches. The basic structure of Arduino programming language is simple and a basic sketch consists of 3 parts

- Declaration of variables
- Initialization/Preparation: It is written in the setup ( ) function.
- Control code/Execution: It is written in the loop ( ) function.

The basic coding in the Arduino sketch will be like as given below

```
void setup ( )
{
Statements;
}
void loop ( )
{
Statements;
}
```

The setup function should initiate the declaration of any variables at the very beginning start of the program and to execute in the program but for only one time. It is used to set pinMode or initialize a serial communication. The loop function takes to next step that includes the code to be executed continuously like reading inputs, triggering outputs and so on. This function is the core of any Arduino programme and performs lots of work (Shah and Agam, 2011). The screenshot of Arduino sketch window after designing and entering the coding is shown in the Plate-XXII. The Arduino tool window comprises of the toolbar with the options like new, verify, open, save, upload, serial monitor. Text editor is available to write the code, a message area to displays the feedback like showing the errors, the text console to displays the output.

The sketch is then saved with .ino extension. Operations like verifying, opening and saving can be made using the buttons on the toolbar or using the tool menu.

Plug the Arduino UNO board in to the USB cable and then into the computer. Now go back to the **Tools > Serial Port** menu and check for at least one new option and select the new one that appears. Click on the serial option and then pin the button with the arrow pointing to the right and leading to the communication between the computer and the Arduino. Click right button for compiling. If the code is without error then it will show compiling done at the bottom of the Arduino sketch window. The screenshot of the compiling window is shown in the Plate-XXIII.

Once the coding is compiled without error, it can be send to selected microprocessor o execute. Select the suitable Arduino board from the tools menu and the serial port numbers as shown in Plate-XXIV. Click on the upload button or chose upload from the tools menu. Thus the code is uploaded to Arduino UNO through Arduino sketch application onto the microcontroller.

3.3.6 Selection and designing of Power supply

A important factor to be notified for health monitoring with wearable sensors is to acquire reliable electrical power for the sensors, signal amplifiers, filters and transmitters. The deployment of new sensing and monitoring devices for non-invasive healthcare and clinical applications requires effective selecion of power source. The power supply should be either long lasting or easy to recharge during usage to perform near-real-time continuous monitoring (Tao, 2005). The need to minimize maintenance and replacement costs of batteries drives the selection of innovative power solutions, encompassing energy scavenging (i.e. energy harvesting) technologies that exploit renewable and ambient sources of energy, such as solar energy, energy harvested from body heat and movement (Paradiso, 2005), and wireless power supplies (Ma, 2007).

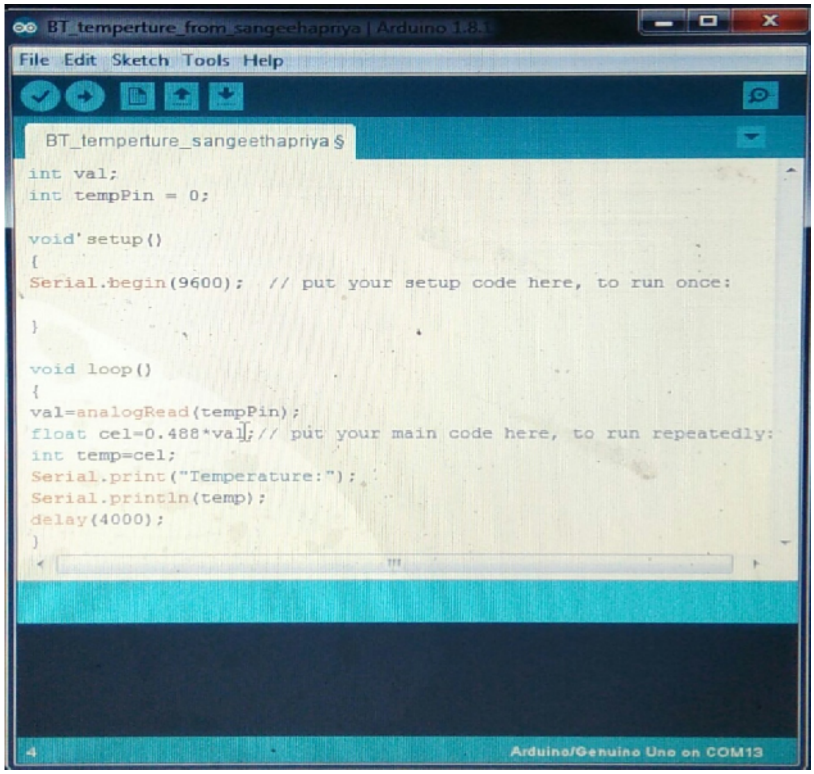


Plate-XXII Arduino Sketch with coding

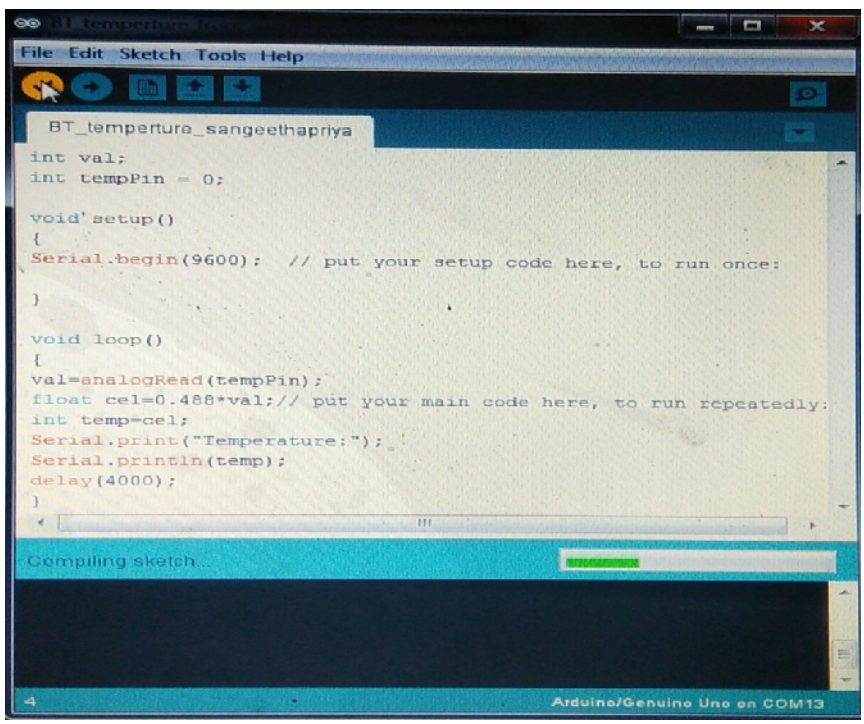


Plate-XXIII Arduino compiling Screenshot

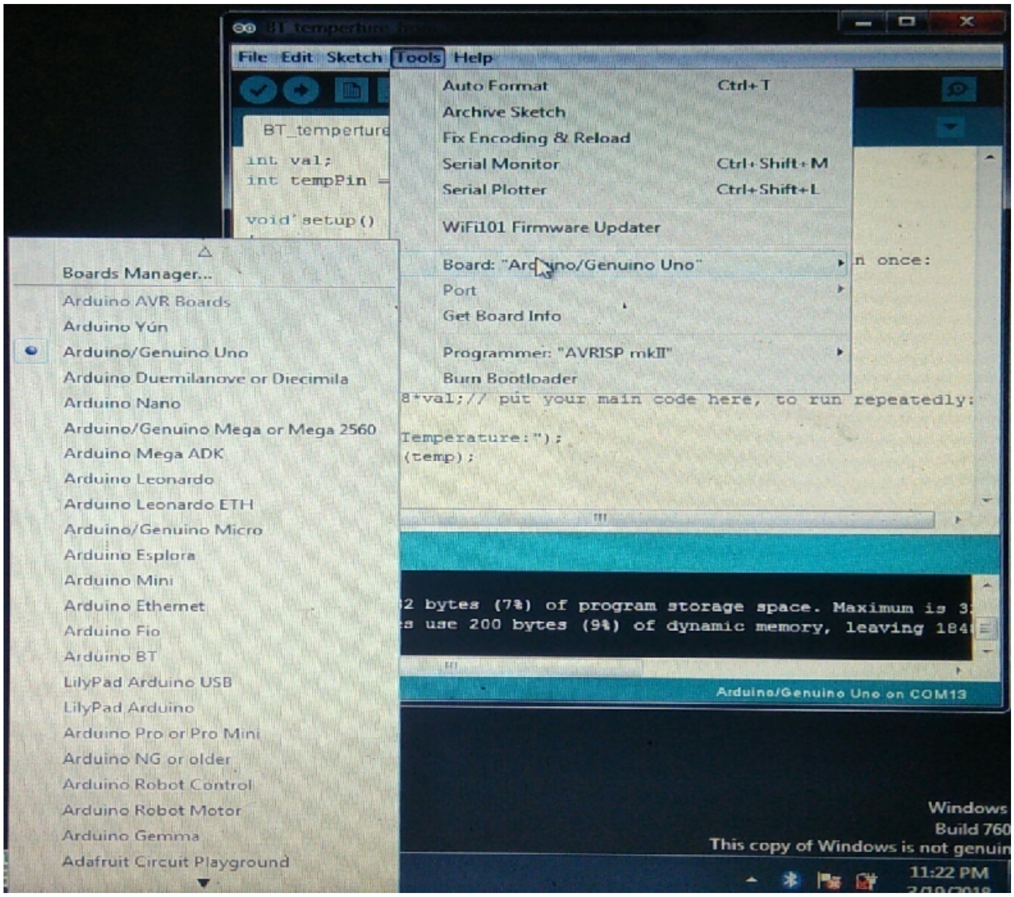


Plate-XXIV Arduino Uno selection window

Plate-XXV Battery

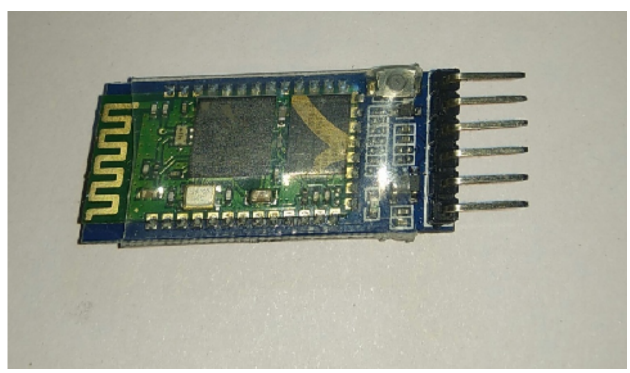


Plate-XXVI Bluetooth module

Fundamental physiological parameters that needs ultimate care and must be continuously monitored are electrocardiogram (ECG), respiration, pulse rate, oxygen saturation of the blood), and body temperature. The amount of power required by different health monitoring sensors and processors is important for selection the power supply (Qin, 2008).

Therefore based on the information of power consumption, the investigator selected the power supply (Plate-XXV) which is able to deliver 150-200 mW for the health monitoring functions.

3.3.7 Selection of Communication unit (Transmitting device)

Wireless communication gives tremendous mobility to the sensor equipment and reduces the cost instead of using multi-transmitting sections. In some wearable monitoring systems, the data interaction between sensors, computers and clinicians or parents is through electrical wires. These electrical wires can comforably hamper the individual's movement through minimizing the distance between the individual and external circuits. The advancement in the areas of wireless sensing technologies like Bluetooth, Wi-Fi, wireless monitoring sensors, antenna and mobile phones with wireless protocols leads the health monitoring as more portable, convenient, economical and easier (Catrysse, 2004). With the application of wireless communication, the health monitoring is more convenient effective mode of warning clinicians or person's immediately through mobile phones when the health condition of an individual is at risk.

Therefore the investigator selected HC- 05 Bluetooth Module for her research which is. shown in the Plate-XXVI. Bluetooth module consists of four pins for connecting to VCC (5V), ground, transmitter and receiver. This type of Bluetooth module can be used with Bluetooth enabled mobile phone or tablet or laptop and the range of this module is approximately ten meters. In Arduino board, the sensors and Bluetooth are interfaced and the output is serially transmitted using Bluetooth device.

Operating an Arduino board with the use of an Android phone with the help of Bluetooth communication is very useful as it can be applied to various range of applications and the most important one is home automation.

3.3.8 Selection of Output unit (Receiving device)

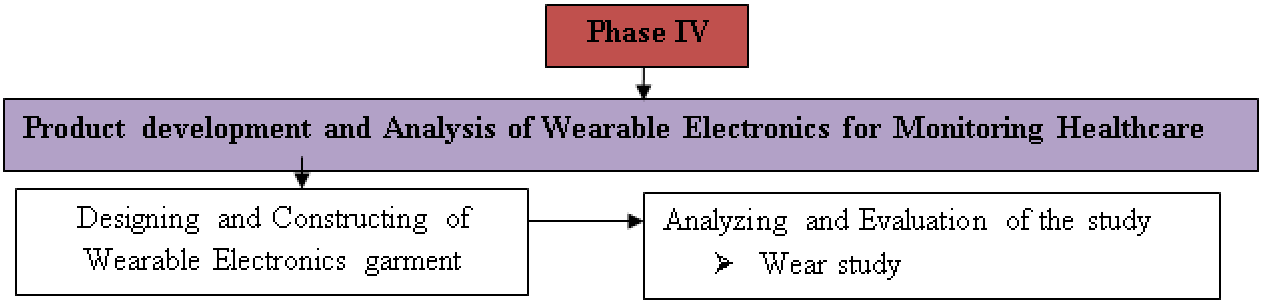
Android software development is the process through which innovative applications are produced for the operating system. Applications are usually developed in Java programming language using the Android software development kit that composed a comprehensive set of manufacturing aids like debugger, libraries, documentation, sample code, and tutorials. In previous researches, smart phones are widely used in various fields of healthcare monitoring applications. The data of vital signs from the sensors was sent to smart phone by Bluetooth support. In critical situations the medical personnel and parents will be given a notification via smart phone (Megalingam et al, 2014). Therefore the investigator selected smart phone for the study as receiving medium.

Phase IV

3.4 Product development and Analysis of Wearable Electronics for Monitoring Healthcare

The overall design aspect of developing smart wearable electronic garment is to assist continuous monitoring of healthcare through wireless data communication and to easily share and access the physiological data across a wide variety of output device especially smart phone using Android application. The three aspects 'Technology, user focus and design' are strongly interwoven along the process.

A wide range of wearable smart fabrics with sensors, actuator, wireless communication, data capturing technology for processing and decision support and power supplies have been developed for health monitoring and clinical research during the recent years (Chan et al, 2012). Many innovative products have appeared in the market to meet the expectations of the users mainly to detect the life threatening changes in daily activities of an individual (Yoo, 2013).



3.4.1 Designing of Wearable Electronic garment.

The main purpose of the research is to design a wearable electronic garment to monitor healthcare especially to detect the variations in the temperature and heart rate. This was achieved by the conductive fabrics which were made by the investigator during the research by combining the cotton yarns with three types of conductive yarns each separately.

Many healthcare systems are available but monitoring by them are specially designed for the adults and patients. Such systems can automatically monitor their health status and send even emergency signals during critical conditions. Female participation in the work force in the developing nations is increased in order to generate more income for the happy family. Subsequently infant care has become a great challenge for the parents especially mothers (Virkki and Raumonen, 2013).

Also in the concept of health monitoring, the major problem starts with the people who are unable to express their discomfort and health complaints especially infants. Based upon high mortality rate of infants, a smart wearable electronic fabric for them is the need of the hour. Considering the above facts, first a survey was conducted by the investigator to collect the information regarding the awareness and willing of the smart wearable electronic clothing to the young mothers. Since the survey reveals that infants find difficult to express their health condition and also willingness of mother's for safe wearable electronic garments were taken into account and the investigator decided to design infant garment for the research.

3.4.2 Designing of infants garment

The design of the wearable device should be done with lots of care in order to make it suitable for infants. Tak et al., (2016) in his studies implemented wearable system in hand gloves, locket, socks and vest. Also user aspect and technical functions are the main concept to be met in the design with following requirements.

- support the effective vital health monitoring functions
- be safe to use in the healthcare environment
- should support continuous monitoring
- gain the feeling of trust by the medical person and the parents especially mothers through an effective design
- be scalable to provide appropriate feedback about correct functioning of system components to the parents and medical persons in interpretable aspect
- non-washable electronic parts must be easy to remove
- look friendly, safe and familiar

3.4.3 Constructing procedure for wearable electronic garment

Previous researches and patents are taken into account to find novelty in designing the infant care monitoring garment. Based on the standard measurement chart, the investigator designed infant garment like jabla with front open as shown the Plate-XXVII.

The Smart wearable electronic garment for infants is constructed using three types of woven conductive fabrics separately with two variations in each depending on the width of conductive yarns. The design is planned in such a way that to have the conductive yarns to run across the chest line of the infants garments in order to connect the electronic module and sensor to have better and effective sensing capacity (Plate-XXVIII). Based on the sensor type, two sets of infants garment using the above designs were constructed separately to incorporate LM 35 temperature sensor and Pulse rate heat sensor respectively. The placement of sensors in the garment is more important factor to be considered for accurate measurement of vital parameters. Therefore with the assistance of an expert in the field of electronics, the placements of the sensors were finalized.

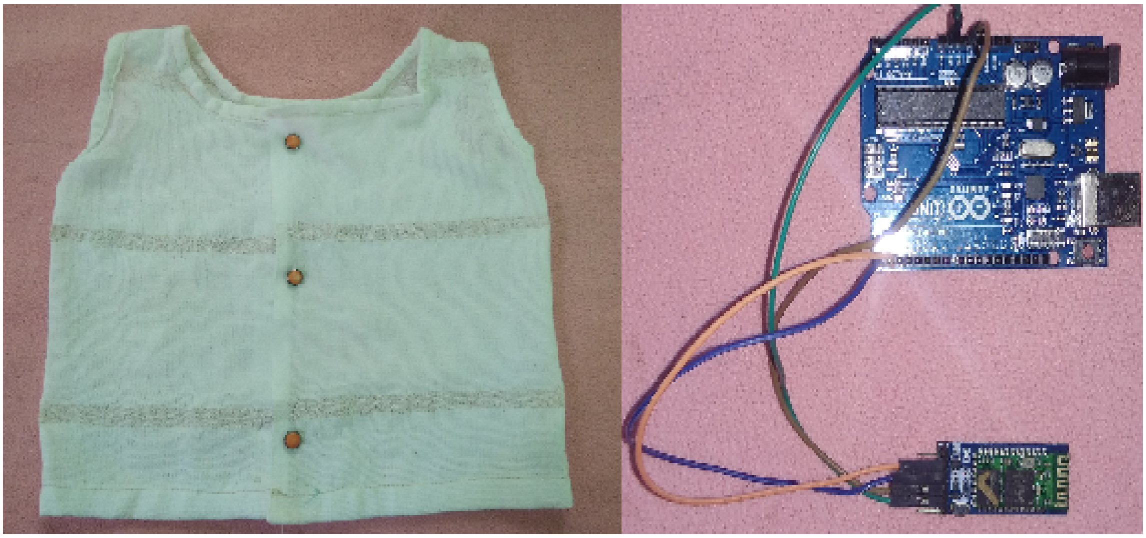


Plate-XXVII Wearable Electronic Garment Design and Electronic module

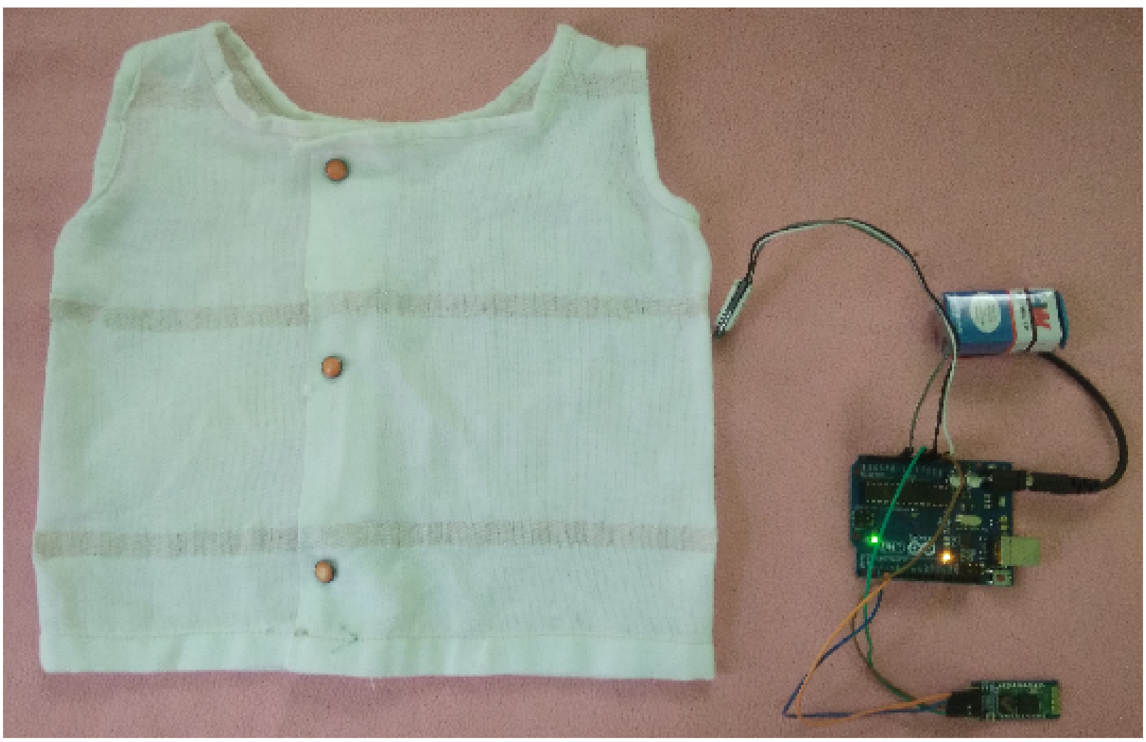


Plate-XXVIII Joining of Electronic module in Chest line of the Garment

Body temperature Monitor

In one set of conductive fabric garments, LM35 temperature sensor is mounted on the reverse side of the placket opening in order to touch the skin surface. A set of three connecting pins are soldered with the conductive yarns on the placket opening where the sensor need to be placed. This side is called as female pin side in the electronics. Another set of three connecting pins are soldered with conductive yarns at the side seam area of the garment and is called as male pin side. LM35 temperature sensor is plugged into female connecting pins to ensure effective contact with the body of the infants as shown in picture.

Electronics components responsible for data processing (Arduino Uno), wireless communication (Bluetooth) and power supply (Lithium ion battery) are joined together using soldering and connections by the investigator are called as electronic module for the research. This electronic module is plugged into the male connecting pin on the wearable electronic garment to get contact with the sensor through conductive yarns (Plate- XXIX).

Heart rate Monitor

For monitoring the heart rate, pulse rate sensor is connected with the another set of conductive fabric garments on to the female connecting pins in the reverse side/inside of the placket opening as the same method stated above. And the electronic module for healthcare monitoring is joined with male connecting pins.

In order to get heart rate sensed, the sensor was joined in a way that the front side of the sensor with the heart logo got contact with the skin (Plate-XXX). A small round hole on the front side of the sensor, where the LED shines through from the back and a little square just under the LED is an ambient light sensor. Thus the proposed system of smart wearable electronic garment for the infants by the investigator was designed to give a peace of mind to the loved ones when they are away from their infants as they can get healthcare updates of their well-being in their smart phone.

The evaluations of the wearable electronic garment constructed with conductive yarns are given in chapter IV of Result and Discussion. But considering the aspects of safety, it is not advisable to directly conduct a wear study on infants. Therefore the investigator selected the animal wear study for her research.

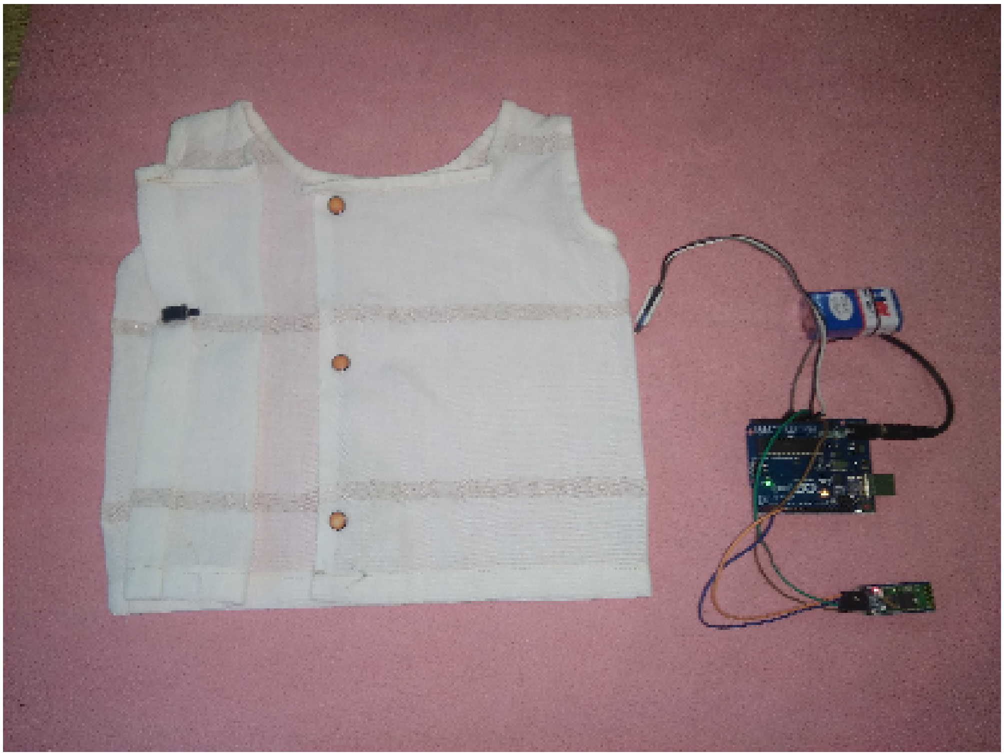


Plate-XXIX Wearable Electronic Garment with LM35 Sensor

Plate-XXX Wearable Electronic Garment with Heart Rate Sensor

3.4.4 Development of Wearable Electronic Band

In order to study the usage of the developed conductive fabrics, the investigator selected rat study. Based on the veterinary doctor's advice, the investigator planned to develop an electronic band using the three conductive fabrics designed. Care was taken to make the band with 5cm width, 2cm width and 1cm width of conductive yarns namely aluminium, copper and silver yarns in the center each separately. The code for the Wearable electronics band made by the investigator is presented in the Table-IV .

Table-IV

Coding of Wearable electronic bands

S.No	Conductive Yarns	Width of Conductive Yarns		
		5 cm width	2 cm width	1 cm width
1	Aluminium	Band AA	Band AB	Band AC
2	Copper	Band CA	Band CB	Band CC
3	Silver	Band SA	Band SB	Band SC

For developing an electronic band, a long strip of conductive fabric was taken and constructed into wearable electronic band. In order to maintain good fit, neat finish and to ensure continuous contact of sensor with the skin, the raw edges of the conductive fabrics were neatly machined with Velcro tapes which enables the band to remain snug on animals at all times. A set of three connecting pins are soldered at two ends of conductive yarns that is one at the center of wearable electronic band on the reverse side of the band in order to make sensor to touch the skin and other set is soldered near the placket opening to attach the electronic module as shown in the Plate-XXXI .

3.4.4.1 Animal studies

Animal experiment was conducted for evaluating the efficiency of the developed Wearable Electronic Band. The experimental protocol was approved by the Institutional Animal Ethical Committee (IAEC) of the Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, Tamilnadu, India with approval No. AIW: IAEC.2017: TC: 01, [Appendix-XIV]. Twelve male Albino Wister rats weighing between 150-200g were selected by the investigator. They were housed in clean polypropylene cages and fed with commercially pelleted rat chow and water (Plate-XXXII). Paddy husk was provided as bedding material to the rats (Joshua, *et al*., 2008).

The animals were divided into two groups with six animals in each group as follows.

Group I: Control

Group II: Experimental animals

Each group containing six animals were selected and anesthetized with diethyl ether. The animals were mounted on a frame and the dorsal hair was removed with a trimmer to care out the study.

The experimental rats were divided into 3 groups accordingly to wrap around the wearable electronic bands AB, AB, AC respectively (Two rats were wrap with each type of band). At the start, the bands were attached with LM35 temperature sensor to measure the body temperature. It was wrapped on the rats at normal conditions. The full setup of rats with bands was done by putting them in a small cage each separately with the help of veterinary assistant as shown in the Plate-XXXIII to avoid mishappenings of the rats. The reading for every twenty minutes was noted using the smart phone by the investigator. This was repeated for three times for each day. Later the rats were left free without band to have its normal activities.

Next day fever was induced in the evening for all the experimental rats and from the following morning, the readings of the fever temperature was noted by the investigator in the smart phone at an interval of one hour for twenty minutes continuously. During this period, the actual body temperatures of the rats were also assessed by the veterinary assistant using common medical tool for experimental group of rats. The body temperatures for controlled rats were also noted. Then the mean values were calculated for both the noted readings of experimental rats. This was compared to find the accuracy of the wearable electronic band.

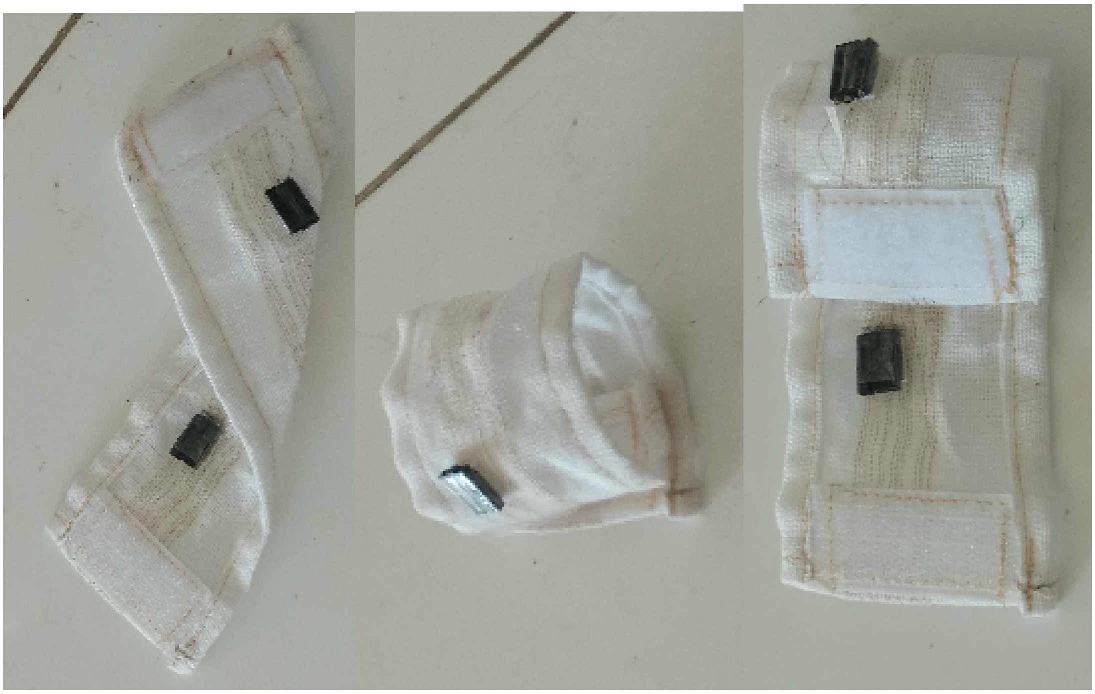


Plate-XXXI   Wearable Electronic Band

Plate:XXXII Housed Rats

Plate-XXIII   Animal Wear Study

In the same method as started above, the pulse rate sensor was plugged into one set of connecting pins in the conductive yarns to note the heart rate of the experimental group of rats. Then the readings were noted for the heart rate by the investigator at an interval of one hour in the smart phone for twenty minutes continuously. The heart rate for controlled group of rats and experimental rats were also noted by the veterinary assistant using common medical tool. The mean value was calculated. Later both the noted readings of experimental and controlled rats were compared to find the accuracy of the wearable electronic band.

The process for monitoring temperature and heart rate was repeated for three days alternatively, where in on the $1^{st,}$ 3^{rd} and 5^{th} days the rats temperature and heart rate was noted at normal condition. On the 2^{nd}, 4^{th} and 6^{th} days the temperature and heart rate was noted after inducing of fever. The results are discussed in the chapter IV "Results and Discussion".

After the study, rats were tested to assess its health condition with the help of veterinary assistant and then were sent to the rehabilitation center.