CHAPTER 5

DESIGN OF CIRCUITS AND INTEGRATION INTO WEARABLE ELECTRONIC FABRICS

5.1 INTRODUCTION

This chapter concerns one of the most challenging aspects of creating wearable electronic circuits and integration with wearable electronic fabrics. The design of circuits, selection of controllers for different fabrics, types of printed circuit boards, programming methods for controlling the various signals and the testing methodology were discussed.

5.2 HEAT GENERATING CIRCUIT FOR NICHROME FABRIC

The heat generating circuit consists of Nichrome wire, temperature sensor, microcontroller, battery and temperature controller. A flexible nichrome wire of resistance 7 Ω has been used as a heating element and is capable of heat up to 1850˚ F. In this two LM35 temperature sensor is used to measure the body temperature and nichrome wire temperature. The special feature of the sensor is any change in the output voltage is directly influence the temperature in linear scale. And also it has wide temperature range of -55 to +150˚ C. PIC 12F675 microcontroller has been used to control the temperature. It consists of four channel Analog to Digital Converter (ADC) to convert the analog to digital value. This part is used to measure the body temperature using thermistor. Microcontroller power supply battery of 4 x 1.2
V with 2.3 Ah has been used and heating coil power supply battery of 6 V with 10 A and is capable of generating heat up to a maximum of 3 h.

The analog to digital converter of the microcontroller converts the analog value from the LM35 temperature sensor into digital value. For the conversion, voltage reference ($V_{ref}$) to microcontroller should be stable and has been set using a 3.3 V Zener diode. LM35 temperature sensor is capable of generating 10 mV per degree centigrade, i.e. it generates 280 mV for a room temperature of 28°C and which is used for the calibration of temperature measurements. To avoid short circuit even when the microcontroller is switched OFF, the heating power supply is connected with Normal Open (NO) pin in the 6 V relay. After soldering the components in PCB, it has been coated using resins to coat over the board for water proof. Figure 5.1 shows the diagram of temperature control circuit used for nichrome fabric.

![Temperature Control Circuit for Heating Garment](image)

**Figure 5.1 Temperature Control Circuit for Heating Garment**

5.2.1 **Operation of Heat Generating Circuit**

When the power supply is switched ON, green LED glows and it turns to orange within few seconds indicating the microcontroller is in
operation. The LM35-1 sensor which is fixed to measure body temperature converts the measured value into digital and compares with pre-set temperature value in switch off position of the heating coil. If the value is equal to or above the pre-set temperature, then there will be no action and the microcontroller will remain idle. During this cycle, LED will glow orange and the above operation continues after every second. Figure 5.2 shows the schematic diagram and connection details of the temperature control circuit.

Figure 5.2 Schematic Diagram of Temperature Control Circuit

Connection details

\[
\begin{align*}
V_{dd} & \quad \text{- Power supply of 5 V from 4x1.2 V battery} \\
V_{ss} & \quad \text{- Ground} \\
\text{GPIO.0} & \quad \text{- Used for serial transmission} \\
\text{GPIO.1} & \quad \text{- Used for serial reception} \\
\text{GPIO.2} & \quad \text{- Connected with LM35-1 to measure the body temperature} \\
\text{GPIO.3} & \quad \text{- Not used} \\
\text{GPIO.4} & \quad \text{- Connected with LM35-2 to measure the heating coil temperature} \\
\text{GPIO.5} & \quad \text{- Connected with BC547 to switch the power supply}
\end{align*}
\]
In the above process, if the measured body temperature drops below pre set temperature, microcontroller will switch ON the heating power supply by switching the 6 V relay from Normally Open port (NO) to Normally Closed port (NC). LED status will indicate green during this process and the temperature of the heating coil is also monitored by means of LM 35-2 sensor by the microcontroller. The heating coil generates heat as long as its temperature is within pre set temperature. Beyond this temperature, the microcontroller wait for 2 seconds and switches OFF the power supply to heating coil. The process re-starts once the temperature decreases below 60°C. The above heat generating circuit can be integrated with the nichrome fabric for developing the heating garment.

5.3 COMMUNICATION CIRCUIT FOR COPPER CORE CONDUCTIVE FABRIC

The copper core conductive fabric is attached with communication circuit for charging the mobile phone and also the fabric is integrated with temperature measurement circuit to measure the body temperature. The circuit diagram of mobile phone charger is as shown in Figure 5.3.
The 220-240 V AC mains supply is down-converted to 9 V AC by transformer T1. The transformer output is rectified by BR1 and the positive DC supply is directly connected to the charger’s output contact, while the negative terminal is connected through current limiting resistor R2. D2 works as a power indicator with R1 serving as the current limiter and D3 indicates the charging status. During the charging period, about 3 volts drop occurs across R2, which turns on D3 through R3. An external DC supply source (for instance, from a vehicle battery) can also be used to energize the charger, where R4, after polarity protection diode D5, limits the input current to a safe value. The 3-terminal positive voltage regulator LM7806 (IC1) provides a constant voltage output of 7.8 V DC since D1 connected between the common terminal (pin 2) and ground rail of IC1 raises the output voltage to 7.8 V DC. D1 also serves as a power indicator for the external DC supply. After constructing the circuit on a PCB, encase it in a suitable cabinet.

Charging the mobile phone battery is a big problem while travelling as power supply source is generally not accessible. If the mobile phone is switched on continuously, the battery will drain within five to six hours, making the mobile phone useless. A fully charged battery becomes necessary especially when the travelling distance is long. The circuit developed in this research work replenishes the mobile phone battery within two to three hours. The mobile phone charger circuit is a current-limited voltage source. Generally, mobile phone battery requires 3.6 to 6 V DC and 180 – 200 mA current for charging. Current of 100 mA is sufficient for charging the mobile phone battery at the slow rate. A 12 V battery containing eight pen cells gives sufficient current that is 1.8 A to charge the battery connected across the output terminals. The circuit also monitors the voltage level of the battery. It automatically cuts off the charging process when its output terminal voltage increases above the predetermined voltage level.
5.3.1  Temperature Measurement Circuit for Copper Core Conductive Fabric

The temperature measurement circuit is integrated with the copper conductive fabric and the fabric is tested for its functionality. Figure 5.4 shows the circuit to measure the body temperature. Here negative temperature coefficient sensor platinum thermistor – 100 (PT-100) is used in which the resistance value is decreased when the temperature is increased. The thermistor is connected with resister bridge network and the bridge terminals are connected to inverting and non-inverting input terminals of comparator. The comparator is constructed by TLO74C operational amplifier. Initially the reference voltage is set to room temperature level so the output of the comparator is zero. When the temperature is increased above the room temperature level, the thermistor resistance is decreased so variable voltage is given to comparator. Then the error voltage is given to next stage of preamplifier. Here the input error voltage is amplified then the amplified voltage is given to next stage of gain amplifier. Then output voltage is given to final stage of DC voltage follower through this the output voltage is given to ADC and then to LCD unit.

Figure 5.4 Circuit Diagram for Temperature Measurement
The mobile phone charging circuit and the temperature measuring circuit is integrated with the copper conductive fabric to develop communication garment.

5.4 SIGNAL TRANSFERRING CIRCUIT FOR OPTICAL CORE CONDUCTIVE FABRIC

The optical core conductive fabric is integrated with the signal transferring circuit for detecting the number and place of the bullet wounds. This optical core conductive fabric circuits can be used for developing the teleintimation garment. The block diagram for detecting the number and place of the bullet wound is shown in Figure 5.5. To detect the bullet wound and location it is decided to weave the Polymeric Optical Fiber (POF) in matrix format. The actual matrix format size for the finished garment will vary depending upon the size of the garment. The circuit consists of AT 89C52 microcontroller to test the signal loss. Using this circuit, information about the number of bullets and bullet wound location can be derived. The signal collected from the soldier who wears the garment is being transmitted to the remote end server, where the details about the soldiers are kept in a database.

Figure 5.5 Block Diagram of Signal Transferring Circuit with Microcontroller AT89C52
The optical core conductive fabric has been tested with the optical transmitter which contains light source for transmitting light to receiver. Here different light source like red LED, white LED are used for testing purpose. The optical transmitter contains light source for transmitting light to receiver. Power supply for transmitter circuit is +5 V and it is given to the LED through limiting resistor. The photo diode receives the signals from the optical core conductive fabric. Light source is used at the one end of the optical fiber and a photodiode is used at another end of the optical fiber. When there is a light illumination on the photodiode, the output of the photodiode produces 0 V and when there is an illumination, it shows 5 V output in the display unit. When there is light illumination on the photodiode the output of the photodiode produces 0 V output. Also when there is no light illumination on the photodiode the output of the photodiode produces 5 V output. The circuit set up to test the signal transferring capability of optical core conductive fabric is as shown in Figure 5.6.

![Figure 5.6 Signal Transferring Circuit set up](image)

5.5 ILLUMINATED SYSTEM FOR POF FABRIC

In the POF fabric, the system has been integrated to illuminate the fabric using different LEDs for different designs. The fabric consists of
several bundles of fibers depending upon the illuminated portion of the garment. In this work, three different designs have been carried out namely POLICE design and duck design. Each design consists of four to ten bundles of POF fibers. An electro optic transducer is used at each end of the fiber bundle to convert the electric signal into optical signal. In this system three different LEDs were used as a source element. The specifications of the LEDs were mentioned in the Table 5.1.

**Table 5.1 LED Specifications**

<table>
<thead>
<tr>
<th>Color</th>
<th>Green</th>
<th>White</th>
<th>Blue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength (nm)</td>
<td>520</td>
<td>430-700</td>
<td>470</td>
</tr>
<tr>
<td>Size (mm)</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Directivity (deg)</td>
<td>15</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>DC reverse current (A)</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>

The 3 V battery is connected with the fiber optic cable which supplies power to the LED. The selected three different designs were positioned at the centre portion of the silhouette in each garment. The positioned designs were stitched using class 300 stitches by lock stitch sewing machine.

### 5.5.1 Design of Illuminated System

The constructional detail of the fiber optic panel is shown in Figure 5.7. The illuminated system consists of a garment design made out of side emitting polymeric optic fiber which is shown as (d) in Figure 5.7. The ends of the POF represented as (c) and (e) is attached to a sleeve (b) and (f), so that LEDs can be easily attached to the system. The LEDs are represented as (a) and (g) in the Figure 5.7. The LEDs are given power supply using 3 V battery supply. Depending upon the designs used in the garment, different LEDs can be used to illuminate the fabric.
Figure 5.7  Fiber Optic Panel ((a) and (g) LED (b) and (f) Sleeve (c) and (e) POF (d) Light Emitting Portion of the Panel)
5.6 BULLET WOUND INTIMATION CIRCUIT FOR TELEINTIMATION FABRIC

The bullet wound intimation circuit was designed and developed to indicate the number and place of bullet wound. For this purpose, bullet wound intimation circuits was developed using different controllers. These circuits are fabricated using flexible PCB to give comfort and easiness to the soldiers during combat situation. The bullet wound signals are transmitted to the soldier monitoring station at the remote end.

The bullet wound intimation circuits consist of two POF matrix pattern for left and right chest by weaving POF in matrix format, it can detect the location of bullet where it got wounded, and also it count the number of bullet. Since the maximum bullet size used in military is 7.62 mm, the matrix should have the maximum pixel size of 5 mm of spacing between the fibers.

The bullet wound and location detection circuit is developed from various stages, and it was tested with different controllers with different types of circuits to achieve the maximum flexibility and robustness. The circuit concept is divided into five modules as given in Table 5.2. The processed signals from the controller will be sending to the remote station to monitor the status of the soldier.

Table 5.2 Bullet Wound Detection Circuit Types

<table>
<thead>
<tr>
<th>S. No</th>
<th>Circuit Matrix type</th>
<th>Controller</th>
<th>Transmission system Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>8 x 8</td>
<td>AT89C51</td>
<td>RF</td>
</tr>
<tr>
<td>2.</td>
<td>64 x 64</td>
<td>AT89C52</td>
<td>RF</td>
</tr>
<tr>
<td>3.</td>
<td>64 x 64 with SMD Components</td>
<td>AT89S52</td>
<td>RF</td>
</tr>
<tr>
<td>4.</td>
<td>Detachable Circuits</td>
<td>PIC 18F877A</td>
<td>RF</td>
</tr>
<tr>
<td>5.</td>
<td>80 x 80 Flexible PCB</td>
<td>PIC18F4550</td>
<td>GSM</td>
</tr>
</tbody>
</table>
5.6.1 Circuits using 8x8 Matrix Format

A prototype with 8x8 matrix format was developed since the actual matrix format size for the finished garment varies with the size of the garment. This prototype serves as a basic platform from which required modification could be made.

The transmitter unit detects the number of bullet and bullet wound location. This circuit is attached in a fabric, integrated with POF. A light source is used to transmit the signals and the fabric was continuously monitored for the signal transmission. 89C51 microcontroller was used to get the information about the number of bullets and bullet wound location, if there is any signal loss because of the broken POF. Also the information about the bullet detection is displayed in the LCD and the same is being transmitted to the remote end receiver. The block diagram and components specifications are as shown in Figures 5.8 and 5.9 shows the circuit integrated with the garment.
5.6.2 Circuit Using 64x64 Matrix Format

In this module the same circuit concept has been brought to 64x64 matrix. It has totally IRF14F 128 optical receivers arranged in 64x64 formats. The 74LS151 decoder/multiplexer has 8 inputs and 1 output with 3 control lines, totally 16 decoders were used for this matrix. Each 8 lines are coupled and given as input to the 74LS151 decoder. Output from each decoder is given as input to one port of the microcontroller AT89C52. RF communication technique is used to send the signals to the remote location. When a POF is broken, microcontroller will count the number and location of the broken POF and bullet penetrations is counted and displayed using LCD as shown in Figure 5.10. This circuit can be modified with the required input lines according to the exact measurement of the garment.

Figure 5.9 Transmitter Circuit for 8 x 8 Matrix
5.6.3  Circuit using SMD Components

The circuit size of the 64x64 is reduced to give comfort to the wearer by implementing the same 64x64 circuit using SMD components and AT89S52 microcontroller was used. The circuit is designed in L shape so that the row and column lines of POF could be directly connected to the circuit. The light source is given at one end of the POF and microcontroller AT89S52 is used with the 20 ports being connected to the 20 decoder units. Each decoder unit will connect to the 8 photodiodes which in turn makes 160 photodiodes to be connected to the circuit. The RF module with frequency range of 300 to 433 MHz is being used at the transmitter end. The Figure 5.11 shows the circuit integrated with the POF garment.
Figure 5.11 Teleintimation Fabric with Circuit

5.6.4 Circuits using PIC Microcontroller with Detachable Circuits

The circuit is developed based on the flexibility and robustness with respect to the wearability issues. The detachable circuits can be easily removed and fixed into the garment. In this module the bullet wound and location detection circuit using PIC microcontroller was developed and the block diagram is shown in Figure 5.12. The optical transmitter is used at one end of the POF and another end is connected with the optical receiver. The comparator unit compares the reference voltage with the output voltage of the photodiode. Depending on the presence or absence of illumination of light on the photodiode, high or low output is produced from the comparator respectively. In this module totally 20x8 optical receiver units are being used. The parallel in serial out shift register is used to serialize the data and it is transmitted using 433.92 MHz RF transmitter.
5.6.5 Circuits Using Flexible PCB

In this method flexible PCB was developed using PIC18F4550 controller to reduce the size of the circuit. All the sensing circuits are connected with microcontroller through 74HC573 latch and 74HC154 decoder are used to detect the cut from the connected optical cables. The block diagram is shown in Figure 5.13. It has 22 latches to collect input from photo diodes and the outputs from the latches are fed to controller for processing to determine both the horizontal and vertical latch numbers. GSM module is used to send information to remote station if the controller finds any break in optical cable. GSM module is interfaced to controller through UART interface. The Flexible PCB and the circuit integrated garment are as shown in Figure 5.14.
Figure 5.13 Block Diagram of Flexible PCB Circuit

Figure 5.14 Flexible PCB Integrated in the Teleintimation Fabric

5.6.6 Method of Bullet Count

To count the number of bullet wounds in the soldier’s body, voltage level at the receiver end of the POF is continuously monitored. If any POF is interrupted between the transmitter and receiver end, logic high signal is
given to the microcontroller. A variable with a count increment will be made in the microcontroller if any port gives a logic high signal. This count is taken as number of bullet penetration into the garment, which is the bullet wound in the soldier’s body. When there is no breakage, the microcontroller ports will be in logic low. The POF Matrix format coordinates could do the bullet detection mechanism. This matrix format is shown in Figure 5.15. Whenever there is a bullet penetration in the garment, the particular co-ordinates will be affected and the location of bullet penetration can be detected.

5.6.7 Bullet Location and Bullet Count Technique

The number of POF lines required for the efficient number of bullet counts and bullet wound location is 80 POF lines with 0.5 cm distance each in vertical section and 80 POF lines with 0.5 cm in the horizontal section. The data received from the PIC Microcontroller is in the form of Hexadecimal values. The corresponding binary value for $(07)_{16}$ is $(0000\ 0111)_2$ and it represents 3 bullets at $2^{nd}$, $1^{st}$ and $0^{th}$ location of the wearer and similarly for the other hexadecimal values ranging from 00 to 0F.

5.6.8 Problems Faced in Detecting the Bullet Location

When a fiber got cut at the location (1, 1) the location could be displayed, but at the same time when a bullet hits at the location (2,2) the new bullet wound location could be displayed. In addition to this two more locations (1, 2) and (2, 1) are also displayed even though there is no bullet penetration. This is because already the location (1, 1) got wounded hence whenever another bullet hits at the different row or column the previously wounded row and column are taken into account. This gives the false reading of the bullet location. To overcome this issue the bullet wound location in terms of rows and columns are displayed individually.
5.7 CIRCUITS FOR SMART SHIRT

In the smart shirt to monitor the vital signs like body temperature, pulse rate, and respiratory rate circuits were developed to integrate into the garment and the measured signals were sent to the remote station by mobile communication technology using telemonitoring system.

5.7.1 Circuits for Body Temperature Measurement

In the garment, temperature of the wearer can be determined by placing the sensor in the armhole of the soldier. The accurate body temperature measurement was tested using Thermistor Type – Wire Wound Resistor. This sensor transfers the measured body temperature into analog voltage and in turn it is then converted to digital voltage by means of analog to digital converter. The measured temperature signal is displayed in the monitoring device to indicate the body temperature.

The conventional system of measuring instrument, thermometer is replaced by Thermistor temperature sensor of model FVT-UI with measurement range from 90º F to 109º F. This sensor is made up of base metal – nickel chromium and tungsten alloy, it is the heat sensor which can
sense both the maximum and minimum temperature and also transmits these signals in terms of digital values with operating voltage of 1.5 V DC, 300-600 mA. The main advantage of this body heat sensor is that the temperature measured is accurate and the sensitivity and response time of the sensor is very high compared to other type of sensors. The Figure 5.16 shows the circuit diagram to measure the body temperature. The body heat sensor measures value in the analog form and this signal is sent to ADC 0804 converter which converts these analog signals to digital signals. The output from the ADC is sent to 8085 microprocessor through 8255 PPI. After processing, the microprocessor displays the value in the LCD unit.

![Figure 5.16 Temperature Measurement Circuit Diagram](image)

5.7.2 Circuits for Pulse Rate Measurement

The pulse rate is measured by IR transmitter and receiver. Figure 5.17 shows the circuit to measure the pulse rate in the blood flow.
Infrared transmitter is one type of LED which emits infrared rays generally called as IR Transmitter. Similarly IR Receiver is used to receive the IR rays transmitted by the IR transmitter. Both the IR transmitter and receiver should be placed straight line to each other. The IR transmitter and receiver are placed in the pulse rate sensor. To measure the pulse rate, the pulse rate sensor has to be clipped in the finger. The IR receiver is connected to the \( V_{cc} \) through the resistor which acts as potential divider. The potential divider output is connected to amplifier section.

Figure 5.17 shows the pulse rate sensor circuit diagram and the testing method. When the supply is ON, IR transmitter passes the rays to the receiver. Depending on the blood flow, the IR rays are interrupted. Due to that IR receiver conduction is interrupted and then the final square wave signal is given to microcontroller or other interfacing circuit in order to monitor the pulse rate.
5.7.2 Circuits for Respiration Rate Measurement

The circuit in Figure 27 is designed to measure the respiration rate. In this circuit two thermistors are used for the respiration measurements which are connected in the resistor bridge network. Here one thermistor is used for the respiration measurement. Another thermistor is used as reference which measures the room temperature. Then the error voltage is amplified by the next stage of the amplifier and then the final TTL pulse is given to microcontroller in order to monitor the respiration rate. Figure 5.19 shows the respiration rate sensor circuit diagram.

![Respiratory Rate Measurement Circuit Diagram](image)
5.7.4 Circuits for Telemonitoring System

The measured vital signs are transmitted to the remote system using telemonitoring system. Figure 5.20 shows the general block diagram of the Telemonitoring systems. The measured vital signs, temperature, respiration rate and pulse rate were sent to microcontroller unit. Microcontroller sends these signals to the LCD display and to modem (mobile) through RS 232 cable using MAX 232 IC, the level logic converter. The remote station can receive these data by using mobile phone and know the status of the wearer. The vital signs measuring circuitry and the microcontroller unit need a power supply. The microcontroller unit needs 5 V regulated dc source and the measuring circuits requires regulated dc source of 12 V, -12 V and 5 V.

Figure 5.20 Block Diagram of Telemonitoring System

PIC16F877A microcontroller is used for processing the signals received from the measurement circuits. Figure 5.21 shows the block diagram of microcontroller unit interfaced with LCD to display the measured values. In the microcontroller, Port A receives the input from the temperature sensor unit and the respiration and pulse rate sensor input is given to Port B. The Port
B sends output data through MAX 232 and the mobile phone. Port D is connected to the LCD unit. The microcontrollers read the vital signs and sent the data through modem so that the doctor can get the status of the patients in the mobile phone. The status of the microcontroller that, whether it has transmitted or not can be displayed in the LCD unit.

![Diagram of Microcontroller Interfaced with LCD for Telemonitoring System](image)

**Figure 5.21**  Microcontroller Interfaced with LCD for Telemonitoring System

**5.7.4.1**

**4RS232 Communication Unit**

In telecommunication, RS-232 is a standard for serial binary data interconnection between a DTE (Data terminal equipment) and a DCE (Data Circuit-terminating Equipment). It is commonly used in computer serial ports. In the circuit shown in Figure 5.22, MAX 232 IC used as level logic converter. The MAX232 is a dual driver/receiver that includes a capacitive
voltage generator to supply EIA 232 voltage levels from a single 5 V supply. In this circuit the microcontroller transmitter pin is connected to the MAX232 T2IN pin which converts input 5 V TTL/CMOS level to RS232 level.
Figure 5.22 Circuit Diagram of RS232 Communication Unit
5.7.4.2 **Mobile Phone (MODEM)**

Mobile phone with GPRS enabled like Nokia 6070 can be used as a modem to send data to other mobile using mobile network. This can be achieved using RS232 cable and AT commands for connection of mobile and microcontroller unit. It is also possible to record and transmit vital signal in combat situations thus mobile connection allows continuous monitoring of the soldier. Figure 5.23 shows the complete set up with the mobile phone. 2 x 16 Liquid Crystal Display (LCD) is used for displaying the vital parameters. Figure 5.24 shows the vital signs displayed in the LCD unit.

![Complete set up of Telemonitoring System](image)

**Figure 5.23 Complete set up of Telemonitoring System**

![LCD Unit Displays the Vital Signs from the Telemonitoring System](image)

**Figure 5.24 LCD Unit Displays the Vital Signs from the Telemonitoring System**
5.8 CONCLUSION

In this chapter the design of circuits, selection of controllers for different fabrics, types of printed circuit boards, programming methods for controlling the various signals and the testing methodology were discussed. The heat generating circuit has been developed for heating garment and it consists of Ni-Chrome wire, LM35 temperature sensor which is capable of generating 10 mV per degree centigrade, i.e. it generates 280 mV for a room temperature of 28°C and which is used for the calibration of temperature measurements, PIC 12F675 microcontroller has been used to control the temperature. The LM35 temperature sensor and heating coil power supply battery of 6 V with 10 A and is capable of generating heat up to a maximum of 3 hours. This heat generating circuit has been integrated with the nichrome fabric to develop heating garment.

The mobile phone charging circuit and body temperature measurement circuit has been developed to integrate with the copper core conductive fabric for communication garment. The mobile phone charging circuit consists of 3-terminal positive voltage regulator LM7806 (IC1) provides a constant voltage output of 7.8 V DC. A 12 V battery containing eight pen cells provides 1.8 A to charge the battery connected across the output terminals. The temperature measurement circuit is integrated with the copper conductive fabric and the fabric is tested for its functionality. The temperature measurement circuit consists of PT-100 temperature sensor to measure the body temperature. Here negative temperature coefficient is used in which the resistance value is decreased when the temperature is increased. The measured values from the temperature sensor is sent to ADC and then to LCD unit.
The signal transferring circuit has been developed to integrate with optical core conductive fabric to develop communication garment. It consists of AT 89C52 microcontroller to test the signal loss. Here different light source like red LED, white LED are used for testing purpose. Using this circuit, information about the number of bullets and bullet wound location can be derived.

The illuminated system has been developed for illuminated garment. It consists of several bundles of fibers and an electro optic transducer is used at each end of the fiber bundle to convert the electric signal into optical signal. In this system three different LEDs were used as a source element. A 3 V battery is connected with the fiber optic cable which supplies power to the LED. The system has been integrated to illuminate the fabric using different LEDs for different designs. In this work, three different designs have been carried out namely STOP design, POLICE design and duck design. Each design consists of four to ten bundles of POF fibers.

The bullet wound intimation circuit was designed and developed to indicate the number and place of bullet wounds in the teleintimation fabric. For this purpose, bullet wound intimation circuits was developed using different controllers like AT89C51, AT89C52, AT89S52, PIC 18F877A and PIC 18F4550 for different POF matrix arrangements. The bullet wound and location detection circuit is developed from various stages, and it was tested with different controllers with different types of circuits to achieve the maximum flexibility and robustness. The processed signals from the controller has been send to the remote station using RF and GSM technology for monitoring the status of the soldier. From the test results it was concluded that, the number of POF lines required for the efficient number of bullet counts and bullet wound location is 80 POF lines with 0.5 cm distance each in vertical section and 80 POF lines with 0.5 cm in the horizontal section.
The body temperature, pulse rate measurement and respiratory rate measurement circuits have been developed for smart shirt. The accurate body temperature measurement was tested using thermistor type – wire wound resistor. The measured temperature signals were processed using 8085 microprocessor to display it in LCD unit. The pulse rate is measured by IR transmitter and receiver and respiratory rate is measured using the circuit with two thermistors connected in the resistor bridge network. The measured vital signs are transmitted to the remote system using telemonitoring system consisting of PIC16F877A microcontroller is used for processing the signals received from the measurement circuits. Mobile phone with GPRS enabled like Nokia 6070 can be used as a modem to send data to the remote station.