CHAPTER 5

GSM Based Neonatal Phototherapy System

5.1 Introduction

GSM Based Neonatal Intensive Care System comprises the measurement and control of Temperature, Phototherapy, SPO2 and Blood Pressure for neonates. Among these Phototherapy is carried out for neonates suffered due to jaundice under doctor’s prescription.

Phototherapy has been in use since 1958. Phototherapy involves exposure of the skin of the jaundiced baby to blue or cool white light of wavelength 400–520 nm. Detoxification begins immediately by the production of configurational and structural photo-isomers of bilirubin in the skin and precedes the fall in serum bilirubin. Special lamps emitting light predominantly in these wavelengths are considered to be the most effective and specific for administering phototherapy [1].

GSM Based Neonatal Intensive Care Unit

Conventionally, jaundice is treated by exposing the infant to sunlight, preferably in the early morning or late evening, it is important not to expose the infant directly to sunlight as it can cause burns to the infant’s sensitive skin.

Now in general the most common medical treatment to cure jaundice is through phototherapy. Infants will be exposed under blue light for a certain period of time until their bilirubin level decreases to a level that is safe for the infant. By exposing infants under blue light, bilirubin will be discrete from the infant’s bodies through their feces and urine which changes the bilirubin to its break down compound. Lumirubin and photobilirubin[2]are compounds produced from bilirubin by exposing it to a certain wavelength of light as both are isomers of bilirubin that have been rearranged from the same atoms. In Phototherapy, when light penetrates the skin, bilirubin will be converted
into its isomers (photobilirubin and lumirubin) and removed from the body without the involvement of the liver.

For the past years, there have been significant improvements in the medical technology field, similarly in phototherapy treatments. Hospitals have been equipped with various types of phototherapy devices to treat patients with jaundice, particularly newborns. The use of these devices are proven to be able to treat jaundice more effectively while reducing the duration of treatment with less risk to the infant. The light source for these phototherapy devices ranges from fluorescent bulbs, halogen bulbs, and also fiber optics. The latest phototherapy devices now use the technology of light emitting diode (LED) which has proven to be able to reduce bilirubin level faster compared to other phototherapy device [3].

5.1.1 Applications of Phototherapy

1. Use the entire spectrum or specific wavelengths of light to treat physical & Emotional problems.
2. Treatment of Hyperbilirubinaemia (Jaundice) in Newborns.
3. Treatment of skin diseases like psoriasis, vitiligo etc. in Dermatology using UV Light.
4. Use the entire spectrum or specific wavelengths of light to treat physical & Emotional problems.
5. Treatment of Hyperbilirubinaemia (Jaundice) in Newborns.
6. Treatment of skin diseases like psoriasis, vitiligo etc. in Dermatology

5.1.2 Wavelengths of Lights Used in Phototherapy

- Red = Energize
- Orange = Spirit raising
- Yellow = Stimulates elimination of toxins.
- Green = Cooling, Relaxing. Reduces Inflammation.
- Blue = Peaceful effect
- Violet = Promotes awareness, consciousness. Improves mental ability.
- UV light = Penetrating effect. High energy to kill diseased areas.
- Infrared Spectrum = Heating ability.

From the Intensity of light level shown in Fig 5.1 evident that Blue LED light lies in the intensity range of 425-475nm so Blue LED are chosen as the source of light for the Phototherapy.

<table>
<thead>
<tr>
<th>LED</th>
<th>Standard Brightness</th>
<th>High Brightness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>Chip Material</td>
<td>IpK (NM)</td>
</tr>
<tr>
<td>Red</td>
<td>GaAsP/GaP</td>
<td>635</td>
</tr>
<tr>
<td>Orange</td>
<td>GaAsP/GaP</td>
<td>605</td>
</tr>
<tr>
<td>Amber</td>
<td>GaAsP/GaP</td>
<td>583</td>
</tr>
<tr>
<td>Yellow</td>
<td>GaP</td>
<td>570</td>
</tr>
<tr>
<td>Green</td>
<td>GaP</td>
<td>565</td>
</tr>
<tr>
<td>Turquoise</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Blue</td>
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</tbody>
</table>

Fig 5.1: Composition of LED wide ranges VS Intensity Color Distribution chart

5.1.3 Causes for Jaundice (Hyperbilirubinemia)

The Liver shown in Fig 5.2 is the largest glandular organ of the body weighing about 1.36 kg. It is reddish brown in color and is divided into 4 lobes of unequal size & shape. The liver lies on the right side of the abdominal cavity beneath the diaphragm [4].
The liver performs many essential functions related to digestion, metabolism, immunity, and the storage of nutrients within the body. These functions make the liver a vital organ without which the tissues of the body would quickly die from lack of energy and nutrients. The liver plays an active role in the process of digestion through the production of bile. Bile is a mixture of water, bile salts, cholesterol, and the pigment bilirubin [5].

Bilirubin is a brownish yellow substance found in bile. It is produced when the liver breaks down old red blood cells. Bilirubin is then removed from the body through the stool (feces) and gives stool its normal color.

When bilirubin levels are high, the skin and whites of the eyes may appear yellow (jaundice). Jaundice may be caused by liver disease (hepatitis), blood disorders (hemolytic anemia), or blockage of the tubes (bile ducts) that allow bile to pass from the liver to the small intestine [6].

Jaundice refers to the yellow appearance of the skin that occurs with the deposition of bilirubin in the dermal and subcutaneous tissue. Normally in the body, bilirubin is processed through the liver, where it is conjugated to glucuronic acid by the enzyme uridine diphosphate glucuronyl transferase (UGT) 1A1 [7]. This conjugated form
of bilirubin is then excreted into the bile and removed from the body via the gut. When this excretion process is low following birth, does not work efficiently, or is overwhelmed by the amount of endogenously produced bilirubin, the amount of bilirubin in the body increases, resulting in hyperbilirubinemia and jaundice [8].

Jaundice occurs in as many as 60% of all normal newborns within the first week of life. Jaundice in the newborn can occur from an underlying pathological condition, such as isoimmune hemolysis or an RBC enzyme deficiency. However, it is more commonly due to the normal physiological inability of the newborn infant to process bilirubin adequately due to the combined effects of increased RBC turnover and a transient deficit in bilirubin conjugation in the liver. This type of nonpathologic jaundice is referred to as physiologic jaundice of the newborn.

In most infants with physiologic jaundice, bilirubin concentrations do not rise to a point that requires treatment. However, in some infants with exaggerated physiologic jaundice, and in many infants with pathologic jaundice, bilirubin in the blood reaches very high concentrations that put the infant at risk for acute and chronic bilirubin encephalopathy (kernicterus). In these cases, treatment aimed at decreasing bilirubin concentration is required in order to avoid kernicterus. [9]

### Causes of Hyperbilirubinemia in Newborns

- **Increased Bilirubin Production**
  - Hemolytic disease
    - Immune mediated (Rh alloimmunization, ABO incompatibility)
    - Heritable (spherocytosis, G6PD deficiency, pyruvate kinase deficiency)
  - Polycythemia
  - Extravasation of blood (cephalohematoma, intraventricular hemorrhage)
  - Sepsis with disseminated intravascular coagulation (DIC)

- **Decreased Bilirubin Clearance**
  - Prematurity
  - Increased enterohepatic circulation
    - Breast milk jaundice
    - Pyloric stenosis
    - Small or large bowel obstruction
  - Inborn errors of metabolism (Gilbert syndrome, Crigler-Najjar syndrome)
  - Metabolic disorder (hypothyroidism, hypopituitarism)
Mild jaundice in newborns usually does not cause problems. But too much bilirubin (hyperbilirubinemia) in a newborn baby can cause brain damage (kernicterus) and other serious problems. So some babies who develop jaundice may need treatment to lower their bilirubin levels. Normal Bilirubin levels in adult is 1 mg/dl (micrograms/deciliter of blood) [10] [11].

5.2 Utilization of Light in Treating Jaundice

The ability of light to decrease serum bilirubin levels was first described by Cremer et al in 1958. This observation led to the development of light sources for use in the treatment of infants with hyperbilirubinemia, a treatment now referred to as phototherapy [12]. Since its inception, phototherapy has been effectively used as a relatively inexpensive and noninvasive method of treating neonatal hyperbilirubinemia. The decline in the number or exchange transfusions in recent years is, at least in part, likely a direct reflection of the effectiveness of phototherapy at treating hyperbilirubinemia. In modern neonatal ICUs (NICUs) exchange transfusions are rare and are only used as a rescue therapy to avoid kernicterus in newborns with severe jaundice when phototherapy is inadequate [9].

The appropriate amount of voltage, current which are the input sources for phototherapy unit are given through the GSM Based Phototherapy unit to generate sufficient amount of light to be given to neonatal unit. Apart from voltage and current, therapy time is also being set in the Phototherapy unit to ensure the amount of light is passed at given interval for specific time which is crucial for neonatal phototherapy.

Phototherapy refers to the use of light to convert bilirubin molecules in the body into water soluble isomers that can be excreted by the body. The absorption of light by normal bilirubin shown in Fig5.3 (4Z, 15Z-bilirubin) results in the creation of 2 isomeric forms of bilirubin: structural isomers and configurational isomers. The main structural isomer of bilirubin is Z-lumirubin [7]. The main configurational isomer of bilirubin is 4Z, 15 E -bilirubin. Configurational isomerization is reversible, and structural isomerization is irreversible. Both the configurational and structural isomers of bilirubin are less lipophilic than normal bilirubin and can be excreted into bile without undergoing
glucuronidation in the liver. Some of the configurational isomers of bilirubin, however, revert back to the native form after excretion into bile and can be reabsorbed via enterohepatic circulation in the gut. Structural bilirubin isomers, like Z-lumirubin, can also be excreted in the urine [8].

![Fig 5.3: Absorption of light by Bilirubin](image)

The absorptions of light by bilirubin also results in the generation of excited-state bilirubin molecules that react with oxygen to produce colorless oxidation products, or photo oxidation products. This process occurs more slowly than configurational or structural isomerization. Photo oxidation products are primarily excreted in the urine.

### 5.2.1 Phototherapy Light Sources

In the conventional and fiber optic phototherapy devices a variety of light sources may be used.

Emitted light should be filtered to remove harmful infra-red and ultraviolet radiation. Light should be focused on the baby. Mobile units are preferred because they can be used for babies nursed in cots, incubators or radiant warmers. The height should be adjustable, while a few units may be tilted on axis. Phototherapy lights may be mounted on the radiant warmers themselves.
(a) Halogen Spotlights

Spotlight phototherapy units generally use a 150 Watt, 21V halogen bulb with a specially coated reflector which absorbs infrared wave length. A fan continuously cools the hot bulb. Options for varying aperture diameter and different filters are available. Positioning of the light on the baby is critically important in maximizing the spotlight’s effectiveness. They are most effective when located directly above the infant at a distance of 45-50 cm. A few halogen spotlights incorporate a dosimeter which depicts how much dose of phototherapy the baby has received. It considers the total irradiance received by the baby and multiplies this by the duration in hours.

(b) Florescent Lamp Devices

These have optimized blue light emission at 400-520 nm wavelengths. Special blue fluorescent are labeled F20T12/BB or TL 20W/52. Regular blue fluorescent tubes (F20T12/B) deliver much less irradiance. If possible, the irradiance should be measured at regular time intervals to ensure that an adequate dose is being delivered [13] Fluorescent tubes lose about 35-40% of blue light irradiance after 1200 hours of use. Directing the light from the side of the infant significantly reduces the dose delivered. These lights can provide an irradiance of >25-30 W/cm2/nm in the 400-520 nm range when placed closely, thus making phototherapy maximally effective particularly when the greatest body surface area is exposed [14].

(c) Fiber-Optic Pads

These devices use plastic fiber-optic light guides to deliver light from a halogen lamp to illuminate a blanket or pad which is wrapped around or placed under the baby. These devices deliver light in the 400 to 550 nm spectral band. The pad is cool and can be placed in direct contact with the baby. They can be used as an auxiliary light source to increase the surface area exposed or as the sole source of phototherapy, particularly in preterm infants. In recent models, the halogen light source has been replaced by high intensity high power LED bulbs. This increases the irradiance delivered by the pads.
(d) Compact Fluorescent Tubes
These are short (approx. 5 to 7 inch) double folded tubes (9-18 Watts) that emit blue or white light. Several tubes (6-8) are housed in a panel with reflectors. As they do not produce much heat the distance to baby can be relatively short thus increasing the irradiance delivered. Most of them produce an irradiance of 20-30 W/cm2/nm when placed close to the baby.

(e) Light Emitting diodes (LED)
Blue LED devices emit a narrow spectrum that overlaps the absorption spectrum of bilirubin. They are power-efficient, portable devices with low heat production that can be kept close to the baby. They are durable and long lasting with low power consumption.

5.2.2 Mechanism of Phototherapy
Phototherapy units consist of a light source and a means of allowing the light to radiate the infant. Devices using overhead lamps can be freestanding on casters, ceiling or wall mounted, or attached to infant radiant warmers or infant incubators; some units have height and hood angle adjustments. Bassinet style units, in which the infant is placed in a plastic bassinet containing a bank of lights in an overhead case, are also available [16]. Fiber optic phototherapy pad systems use a tungsten halogen bulb in a metal case, a flexible fiber optic cable, and a light-emitting plastic pad. Filtered blue light is delivered from the source through the fiber optic cable and emitted from the sides and ends of the fibers inside the pad, which is wrapped around the infant.

Visible light, specifically the blue-light wavelengths of approximately 420 to 500 nanometers, photo chemically reduces bilirubin to water-soluble products that can be excreted. The peak absorption wavelength at which bilirubin breaks down is approximately 458 nm. By exposing patients to light of this wavelength range, hyperbilirubinemia can be treated. Irradiance level is controlled by light-intensity switches for both overhead lamps and fiber optic units and by the distance between the light source and the patient. (Decreasing the distance between the patient and the light
source increases the irradiance level.) A radiometer with an appropriate bandwidth is used to measure the irradiance that reaches the patient during phototherapy [16].

Phototherapy reduces the serum concentration of bilirubin and the risk of bilirubin toxicity. It has been found to be effective in treating hyperbilirubinemia in hemolytic as well as in non-hemolytic settings. Unconjugated bilirubin in skin gets converted into water-soluble photo-products on exposure to light of a particular wavelength (400-520 mm) [15]. These photo-products are water soluble, nontoxic and excreted through the intestine and in the urine. Phototherapy acts upon bilirubin bound in the skin and subcutaneous tissue up to a depth of around 2 mm. For phototherapy to be effective bilirubin needs to be present in skin, hence there is no role for prophylactic phototherapy.

(a) **Configurational Isomerization:** The normal Z-isomer of bilirubin is converted into yellow E-isomers. (Z and E are chemical terms, akin to the terms cis and trans that denote the stereochemistry of double bonds). Although this reaction is instantaneous upon exposure to light, the clearance of E-isomers is slow. These photo isomers revert to native bilirubin in bile. Depending on the light dosage and spectral quality up to about 25% of total bilirubin (TB) may be converted to the presumably less toxic E-isomers within a few hours.

(b) **Structural isomerization:** This is a relatively slow, but irreversible reaction whereby bilirubin is converted into another yellow isomer, lumirubin, which is excreted rapidly. The formation of lumirubin is directly proportional to the dose of phototherapy.

(c) **Photo-oxidation:** This is an even slower reaction which leads to colorless water-soluble photo-products that are excreted in urine.

### 5.3 Criteria for effective phototherapy

Effectiveness of the Phototherapy depends upon:

- Wavelength of the spectrum.
- Intensity of the Light.
• Duration of the therapy.
• Area of skin exposed to the light. More the area, more the effectiveness [3].

5.3.1 Effective spectrum

For phototherapy to be effective photons of light from the lamp must be absorbed by the bilirubin molecule. Bilirubin appears yellow because it strongly absorbs blue and green light. Blue light around 450nm is absorbed most readily if bilirubin is in a test tube. In a baby other factors, including skin penetration and albumin binding, combine causing a colour shift of the most effective light toward the blue-green region. Debate over the most effective wavelengths of light to use still produces many research papers. Blue light has been investigated intensively and has been shown to be effective. However, Pratesi et al proposed the use of blue-green light and demonstrated its effectiveness.

5.3.2 Irradiance

Once an effective waveband has been found the light available must then be sufficiently intense, that is, have a high enough irradiance, to produce an appreciable effect in reducing the neonate’s bilirubin level. The Department of Health (DH) recommended a minimum level of 1mW.cm-2 in 1992 but unfortunately did not specify a waveband in which to measure the irradiance. As Metherall points out, it is impossible to compare published reports of irradiance because of the different wavebands and radiometers that have been used to measure it. This problem has been discussed several times. MHRA( Medicines and Healthcare products Regulatory Agency) evaluation reports on phototherapy devices have maintained consistency by stating measured irradiance in the waveband 400nm to 550nm, which although a little wide, includes all of the wavebands used by clinical workers in the field. It is also the waveband specified in the international standard for neonatal phototherapy devices.

More recently, higher minimum levels of irradiance have been proposed as more realistic in order to provide effective treatment. The irradiance of different phototherapy devices varies widely and is dependent on a number of factors, including the number of
bulbs, tubes or light sources [11], distance of the light source from the neonate and quality of the bulb/tube – variation has been observed [17].

5.3.3 Effective Surface Area

During phototherapy as much of the neonate’s skin as possible should be illuminated by light of an effective waveband and sufficient irradiance. When applied to devices this concept may be thought of as the ‘effective light field’; ‘effective surface area’ is the term used by IEC24 and DH17. The surface area of a full term baby is approximately 2100cm², and for a 32 week premature baby approximately 1300cm². A planar (horizontally flat) overhead phototherapy lamp illuminates up to one third of a baby’s skin surface area, i.e. 700cm² and 430cm² for a full term and a premature baby respectively. Illuminating as much skin surface area as possible has been shown to increase the speed of bilirubin clearance; that is increase it above the rate at which the bilirubin is produced by the infant, thereby, producing a reduction in the overall bilirubin level.

Metherall also raises the important practical issue of the clothing worn by the infant during phototherapy. As much of the neonate’s skin surface as possible should be exposed to the therapeutic light. Eye protection for the infant is very important but the rest of the baby’s clothing should be minimal; small or transparent nappies are sometimes used [18].

5.3.4 Phototherapy Duration

During phototherapy, neonate’s temperature will be monitored to ensure they are not getting too hot and they will be checked for signs of dehydration. Neonate’s need to have intravenous fluids if they are becoming dehydrated and are not able to drink a sufficient amount. The bilirubin levels will be tested every four to six hours after phototherapy has started. Once levels start to fall, they will be checked every 6 to 12 hours. Phototherapy will be stopped when the bilirubin level falls to a safe level, which usually takes a day or two.
The most suitable wavelength ranges around 400nm - 520nm with a peak of 460nm ± 10nm and blue light was found to be the closest that approaches the bilirubin absorbance spectrum. In order to maximize exposed body surface area, an infant’s postures need to be changed in every 2 to 3 hours. The greater the exposed surface area the greater the rate of total bilirubin declination. Infants with thick and highly pigmented skin may prevent the effectiveness of phototherapy. The longer an infant is exposed to the phototherapy light, will increase the effectiveness of the treatment. For an effective treatment, serum bilirubin concentration should show a decrease of more than 2mg/dL (34µmol/L) within 4 to 6 hours of initiation and treatment should be stopped once bilirubin level is below 200µmol/L. Fig 5.4 shows the effective optical administration of Phototherapy.
Fig 5.4: Optimal Administration of Phototherapy

### 5.4 Types of Phototherapy device

Two types of phototherapy devices are currently available: the conventional phototherapy light which has been used for over 40 years and the fiber optic phototherapy device which has been available for nearly 15 years.
5.4.1 Conventional phototherapy

These devices shown in Fig 5.5(a) and Fig 5.5(b) typically use one or more tungsten halogen bulb, a metal halide gas discharge tube, long or compact (or folded) fluorescent lamps, or most recently, light emitting diodes (LEDs). The light source is positioned above or below the baby and the irradiance is dependent on the distance between the baby and the lights. The relationship is related to the inverse square law, that is, the intensity of light decreases as the square of the distance.

![Fig 5.5(a): Conventional Phototherapy Device](image)

![Fig 5.5(b): Fiber optic Phototherapy Device](image)

5.4.2 Fiber optic phototherapy

These devices use a standard light source, usually a quartz halogen bulb. The light from the bulb may then be passed through a filter before being channeled down a fiber optic bundle into a pad of woven optic fibers. The pad can then be placed next to the neonate’s skin. Several fiber optic devices are available worldwide, but only the Ohmeda Biliblanket.
5.5 Hardware Development

Nowadays, the most common medical treatment to cure jaundice is through phototherapy. Infants will be exposed under blue light for a certain period of time until their bilirubin level decreases to a level that is safe for the infant. By exposing infants under blue light, bilirubin will be discrete from the infant’s bodies through their feces and urine which changes the bilirubin to its break down compound. Lumirubin and photo bilirubin are compounds produced from bilirubin by exposing it to a certain wavelength of light as both are isomers of bilirubin that have been rearranged from the same atoms. In phototherapy, when light penetrates the skin, bilirubin will be converted into its isomers (photo bilirubin and lumirubin) and removed from the body without the involvement of the liver [2].

Over the years, there have been significant improvements in the medical technology field, similarly in phototherapy treatments. Hospitals have been equipped with various types of phototherapy devices to treat patients with jaundice, particularly newborns. The use of these devices are proven to be able to treat jaundice more effectively while reducing the duration of treatment with less risk to the infant. The light source for these phototherapy devices ranges from fluorescent bulbs, halogen bulbs, and also fiber optics. The latest phototherapy devices now use the technology of light emitting diode (LED) which has proven to be able to reduce bilirubin level faster compared to other phototherapy device [3].

The schematic diagram of GSM based real time Phototherapy system for the treatment of Jaundice of a neonatal is shown in Fig 5.6 and the in photograph 5.1. The system hardware consists of different units and explanation for each unit is given individually. They are

1. UV LEDS light unit
2. Signal conditioning unit
   a. LED driver with digital and PWM control (TPS61161-Q1)
   b. Square wave generator (DAC 0800)
   c. Microcontroller Unit (ARM11J6JZF)
d. Analog to Digital converter

3. Graphical LCD Display.

4. Universal Serial Bus

5. GSM-SIM500
Fig 5.6: Schematic Diagram of GSM Based Phototherapy System
5.5.1. UV LEDs Light Unit

In the present work we used the UV LED’s of 5mm Ultraviolet (UV) LED, is able to emit UV light which will help in reducing the bilirubin level in an infant’s. The UV blue LED was chosen to be used due to its characteristic. It has the capabilities to emit up to 80mW, never overheats and most importantly, the wavelength is 450 which is standard and suitable for reducing the bilirubin. The LEDs are generally bandage embodiments that target a small area of the tissue. The phototherapy treatment depends on the intensity of light and the surface area of light exposure.

The LED’s are placed as shown in the Fig 5.7. It sides so made sure that light don’t interfere bright spots at certain areas of the sheet and the same is accomplished by LED placements. Unlike other instruments, this does not dissipate heat which avoids dehydration in neonates. The entire prototype works with 5V, consuming less than an Ampere which is backed up by a battery with a solar charging circuit.
The phototherapy unit constructed with a total of 24 LED’s which are arranged in a 4 x 6 matrix form that covers the body of the neonate to be treated for Jaundice. A transparent sheet of thickness around 1.5cm, length 75cm and width 50cm was chosen. Using the property of light, an obstruction to its pathway was created along with total internal reflection makes the sheet glow at a specific area of interest. A standard blue color LED of 450nm has been chosen as the source of illumination. Unlike conventional medical equipment’s, heat dissipation, requires no eye goggles, no water loss in babies, portable and solar powered battery operated with a uniform heat distribution. All one set of 6 LED’s are connected in series and for the control of intensity and ON/OFF Dimming control the output of Pin number SW of LED Driver IC of TPS is connected to the anode of of LED array. And FB Pin is connected to cathode of LED array. The output of DAC 0800 is given to the LED commonly for giving squarewave for controlling the LED current using 1-wire digital interface. The four GPIO14, GPIO15, GPIO16 and GPIO17 lines of Raspberry processor are connected to CTRL pin for ON/OFF of LED Driver by Dimming control by sending either 0 or 1. The DAC 0800 interface with the GPIO6-GPIO13 with Raspberry Pi Processor for square wave generation of the required frequency of upto 300 KHz to control UV LEDS intensity and the circuit diagram is shown in Figure 5.7 (a).
Figure 5.7(a) : Circuit diagram of UV LEDS intensity control with TPS61161

(b) **Square wave generator (DAC 0800)**

In the present work the Digital to analog converter of DAC 0800 can be used as square wave generator for the UV LED intensity control which is capable of generating different waveforms such as square, Triangular and saw tooth waveforms in the range upto 300 KHz. The DAC0800 series are monolithic 8-bit high-speed current-output digital-to-analog converters (DAC) featuring typical settling times of 100 ns. When used as a multiplying DAC, monotonic performance over a 40 to 1 reference current change is possible. The DAC0800 series also features high compliance complementary current outputs to allow differential output voltages of 20 Vp-p with simple resistor loads. The reference-to-full-scale current matching of better than ±1 LSB eliminates the need for full-scale trims in most applications, while the nonlinearities of better than ±0.1%over temperature minimizes system error accumulations. The noise immune inputs will accept a variety of logic levels. The performance and characteristics of the device are essentially unchanged over the ±4.5V to ±18V power supply range and power consumption at only 33 mW with ±5V supplies is independent of logic input levels. The DAC0800, DAC0802, DAC0800C and DAC0802C are direct replacement for the DAC-08, DAC-08A, DAC-08C, and DAC-08H, respectively.
Features

- Fast settling output current: 100 ns
- Full scale error: ±1 LSB
- Nonlinearity over temperature: ±0.1%
- Full scale current drift: ±10 ppm/°C
- High output compliance: −10V to +18V
- Complementary current outputs
- Interface directly with TTL, CMOS, PMOS and others
- 2 quadrant wide range multiplying capability
- Wide power supply range: ±4.5V to ±18V
- Low power consumption.

The required square wave form can be generated through software program using C++ with QT GUI in Linux environment. The circuit connections are made with UV LED Matrix as shown in schematic diagram above.

(c) Microcontroller UNIT (ARM11J6JZF)

The signals from analog digital converter are processed by using RASPBERRY Pi ARM11J6JZF micro controller. ARM stands for Advanced RISC Machine. The ARM11 is based on the ARMv6 instruction set architecture. The block diagram of the internal architecture of the micro controller ARM11J6JZF is shown in fig 5.12. The Raspberry Pi uses the Broadcom BCM2835 system on a chip (SoC). The Raspberry Pi model B has 512MB of primary memory (RAM). Clock speed is 700MHz. The Broadcom BCM2835 is the specific implementation of an ARM11 processor. The CPU core is the ARM11J6JZF-S which is a member of the ARM11 family (ARMv6 architecture with floating point). The GPU is a Videocore IV GPU. This is mainly consists of the following units embedded inside the chip

The important features of the ARM11J6JZF-S core is of the following

- Eight stage pipeline
- Internal coprocessors CP14 and CP15
Three instruction sets
- 32-bit ARM instruction set (ARM state)
- 16-bit Thumb instruction set (Thumb state)
- 8-bit Java byte codes (Janelle state)

Data path consists of three pipelines:
- ALU, Shift, Sat pipeline (Sat implements saturation logic)
- MAC pipeline (MAC executes multiply and multiply-accumulate operations)
- Load or store pipeline

The ARM Memory Management Unit (MMU) translates virtual addresses to physical addresses using page information. The MMU supports four page sizes: 4KB small pages, 64KB large pages, 1MB sections and 16MB super sections. Address mapping is performed using two levels of translation look aside buffers: the Main TLB and two micro TLBs. The Main TLB backs separate micro TLBs for each of the instruction and data caches. Address translation is first attempted in a Micro TLB. If the address cannot be translated in the Micro TLB, then the Main TLB is tried. If the address cannot be translated through the Main TLB, then hardware page walking is invoked. The functional block diagram of the ARM11J6JZF is as shown in fig 5.12. and the CPU Board of Raspberry PI is shown Photograph 5.2.

Figure 5.8: Block Diagram of the ARM11J6JZF
The circuit diagram of interfacing motor, filter, memory...Etc to a micro controller is as shown in fig 6.8. In the present design ARM11J6JZF is the central processing unit to do the total processing. The micro controller is connected to all external devices like motor’s, filter, amplifier, ADC, USB, Graphical LCD. Every external device has their own input/ output lines. The motors, sensor output are connected to the GPIO pins of the micro controller. LCD communicates serially with the micro controller. 5 lines are used to interface with the micro controller. Universal Serial Bus uses Differential lines to communicate between micro controller and Personal Computer.

5.5.2 Graphical LCD Display (Touch Screen – AT070TN92)

The output of the device is sent to a liquid crystal display to display the data of systolic and diastolic blood pressure. In present design we are using GRAPHICAL LCD DISPLAY TOUCH SCREEN - AT070TN92 [36]. The pin description and the specification of AT070TN92 are as shown in table 2 and 3. The Graphical LCD and its driver, ADC and GSM Module interfacing with Raspberry Pi is as shown in photograph 2.
AT070TN92 is 800x480 dots 7” color TFT LCD module display with OTA7001A controller, optional 5 points capacitive multi-touch panel with connector and 4-wire resistive touch panel screen with connector. A thin-film-transistor liquid-crystal display (TFT LCD) is a variant of a liquid-crystal display (LCD) that uses thin-film transistor (TFT) technology to improve image qualities such as addressability and contrast. A TFT LCD is an active-matrix LCD, in contrast to passive-matrix LCDs or simple, direct-driven LCDs with a few segments. It has superior display quality, super wide view angle and easily controlled by MCU ARM. It can be used in any embedded systems, car, mp4, gps, industrial device, security and hand-held equipment which require display in high quality and colorful image. It supports RGB interface. FPC with zif connector is easily to assemble or remove. The pin description of AT070TN92 is as shown in the below table 5.2.
Table 5.2 : The pin Discription of AT070TN92

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Symbol</th>
<th>I/O</th>
<th>Function</th>
<th>Remark</th>
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<tbody>
<tr>
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<td>Power for LED backlight (Anode)</td>
<td></td>
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<td>2</td>
<td>VLED-</td>
<td>P</td>
<td>Power for LED backlight (Cathode)</td>
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</tr>
<tr>
<td>3</td>
<td>VLED</td>
<td>P</td>
<td>Power for LED backlight (Cathode)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>VLED</td>
<td>P</td>
<td>Power for LED backlight (Anode)</td>
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</tr>
<tr>
<td>5</td>
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<td>Power ground</td>
<td></td>
</tr>
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<td>6</td>
<td>VCC</td>
<td>I</td>
<td>Common voltage</td>
<td></td>
</tr>
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<td>7</td>
<td>D1OE</td>
<td>P</td>
<td>Power for Digital Circuit</td>
<td></td>
</tr>
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<td>MOSI</td>
<td>I</td>
<td>DE/IN, mode select</td>
<td>Note 1</td>
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<td>CE</td>
<td>I</td>
<td>Data input Enable</td>
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<td>10</td>
<td>VSS</td>
<td>I</td>
<td>Vertical Sync input</td>
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<td>HSS</td>
<td>I</td>
<td>Horizontal Sync input</td>
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<td>12</td>
<td>B0</td>
<td>I</td>
<td>Blue data, M1B</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>B1</td>
<td>I</td>
<td>Blue data</td>
<td></td>
</tr>
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<td>B2</td>
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<td>B3</td>
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<td>I</td>
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<td>B5</td>
<td>I</td>
<td>Blue data</td>
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<td>B6</td>
<td>I</td>
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<td></td>
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<td>I</td>
<td>Blue data, M0B</td>
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<td>Green data</td>
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<td></td>
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<td>25</td>
<td>G2</td>
<td>I</td>
<td>Green data</td>
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<th>I/O</th>
<th>Function</th>
<th>Remark</th>
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<td>26</td>
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<td>Green data</td>
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<tr>
<td>27</td>
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<td>I</td>
<td>Green data (LSB)</td>
<td>Note 2</td>
</tr>
<tr>
<td>28</td>
<td>R7</td>
<td>I</td>
<td>Red data</td>
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<td>I</td>
<td>Red data</td>
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<td>I</td>
<td>Red data</td>
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</tr>
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</tr>
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<td>I</td>
<td>Red data</td>
<td></td>
</tr>
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<td>I</td>
<td>Red data</td>
<td></td>
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<td>I</td>
<td>Red data</td>
<td>Note 2</td>
</tr>
<tr>
<td>35</td>
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<td>I</td>
<td>Red data (MSB)</td>
<td>Note 2</td>
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</tr>
<tr>
<td>37</td>
<td>DCLK</td>
<td>I</td>
<td>Sample clock</td>
<td>Note 5</td>
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<td>38</td>
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<td>Power Ground</td>
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<td>39</td>
<td>L/R</td>
<td>I</td>
<td>Left/Right selection</td>
<td>Note 4.5</td>
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<tr>
<td>40</td>
<td>UID</td>
<td>I</td>
<td>Up/down selection</td>
<td>Note 4.5</td>
</tr>
<tr>
<td>41</td>
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<td>Gate ON Voltage</td>
<td></td>
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<tr>
<td>42</td>
<td>VCC</td>
<td>P</td>
<td>Gate OFF Voltage</td>
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</tr>
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<td>43</td>
<td>A18</td>
<td>P</td>
<td>Power for Analog Circuit</td>
<td></td>
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<tr>
<td>44</td>
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<td>Note 6</td>
</tr>
<tr>
<td>45</td>
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<td>Note 6</td>
</tr>
<tr>
<td>46</td>
<td>VSS</td>
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<td>Common Voltage</td>
<td></td>
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<td>47</td>
<td>VDD</td>
<td>I</td>
<td>Differing function</td>
<td>Note 7</td>
</tr>
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<td>48</td>
<td>GND</td>
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<td>49</td>
<td>NC</td>
<td>-</td>
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</tr>
<tr>
<td>50</td>
<td>NC</td>
<td>-</td>
<td>No connection</td>
<td>Note 6</td>
</tr>
</tbody>
</table>

5.5.3. Analog to Digital Converter PCF8591

The PCF8591 [35] is a single-chip with four analog inputs, one analog output and a serial I2C-bus interface. Three address pins A0, A1 and A2 are used for programming the hardware address, allowing the use of up to eight devices connected to the I2C-bus without additional hardware. Address, control and data to and from the device are transferred serially via the two-line bidirectional I2C-bus. The functions of the device include analog input multiplexing, on-chip track and hold function, 8-bit analog-to-digital conversion and an 8-bit digital-to-analog conversion. The functional block diagram of analog to digital converter is as shown in fig 5.9.
The A/D converter uses the successive approximation conversion technique. The on-chip D/A converter and a high-gain comparator are used temporarily during an A/D conversion cycle. The I2C-bus is for bidirectional, two-line communication between different ICs or modules. The two lines are a Serial Data line (SDA) and a Serial Clock line (SCL). Both lines must be connected to a positive supply via a pull-up resistor. An I2C-bus is activated by sending a address to the PCF8591 device. The address consists of address pins A0, A1 and A2. The address is always sent as the first byte after the start condition in the I2C-bus protocol. The last bit of the address byte is the read/write-bit which sets the direction of the data transfer. A/D conversion cycle is started after sending read mode address to a PCF8591 device. The A/D conversion cycle is triggered at the trailing edge of the acknowledge clock pulse. Once a conversion cycle is triggered, an input voltage sample of the selected channel is stored on the chip and is converted to the corresponding 8-bit binary code. The conversion result is stored in the ADC data register and awaits transmission. The first byte transmitted in a read cycle contains the conversion result code of the previous read cycle. An on-chip oscillator generates the clock signal required for the A/D conversion cycle.

The sensor used can measure up to 377 mmHg; the gain of the amplifier was adjusted so that 1 mmHg coincides with each one of the possible values of the converter. The value obtained from A/D converter in binary code is applied to the micro controller.
5.5.4 Universal Serial Bus - USB

The LDO Regulator generates the 3.3V reference voltage for driving the USB transceiver cell output buffers. The main function of this block is to power the USB Transceiver and the Reset Generator Cells rather than to power external logic. The USB Transceiver Cell provides the USB 1.1 / USB 2.0 full-speed physical interface to the USB cable. The output drivers provide 3.3V level slew rate control signalling, whilst a differential receiver and two single ended receivers provide USB data in, SEO and USB reset condition detection. The USB DPLL cell locks on to the incoming NRZI USB data and provides separate recovered clock and data signals to the SIE block. The Serial Interface Engine (SIE) block performs the Parallel to Serial and Serial to Parallel conversion of the USB data. In accordance to the USB 2.0 specification, it performs bit stuffing / un-stuffing and CRC5 / CRC16 generation / checking on the USB data stream. The USB Protocol Engine manages the data stream from the device USB control endpoint. It handles the low level USB protocol requests generated by the USB host controller and the commands for controlling the functional parameters of the UART. Data from the USB data out endpoint is stored in the FIFO TX buffer and removed from the buffer to the UART transmit register under control of the UART FIFO controller. Data from the UART receive register is stored in the FIFO RX buffer prior to being removed by the SIE on a USB request for data from the device data in endpoint. The UART FIFO controller handles the transfer of data between the FIFO RX and TX buffers and the UART transmit and receive registers.

Together with the UART FIFO Controller the UART Controller handles the transfer of data between the FIFO RX and FIFO TX buffers and the UART transmit and receive registers. It performs a synchronous 7 / 8 bit Parallel to Serial and Serial to Parallel conversion of the data on the RS232 (RS422 and RS485) interface. Control signals supported by UART mode include RTS, CTS, DSR, DTR, DCD and RI. The UART Controller also provides a transmitter enable control signal pin option (TXDEN) to assist with interfacing to RS485 transceivers. RTS / CTS, DSR / DTR and X-On / X-Off handshaking options are also supported. Handshaking, where required, is handled in hardware to ensure fast response times. The UART also supports the RS232 BREAK
setting and detection conditions. A new feature, programmable in the internal EEPROM allows the UART signals to each are individually inverted. Another new EEPROM programmable feature allows high signal drive strength to be enabled on the UART interface and CBUS pins.

5.5.5 SIM MODEM – SIM500

The Global System [37] for Mobile communications (GSM: originally from Group Special Mobile) is the most popular standard for mobile phones in the world. A GSM modem is a specialized type of modem which accepts a SIM card, and operates over a subscription to a mobile operator, just like a mobile phone. From the mobile operator perspective, a GSM modem looks just like a mobile phone. A GSM modem can be a dedicated modem device with a serial, USB or Bluetooth connection, or it may be a mobile phone that provides GSM modem capabilities. The term GSM modem is used as a generic term to refer to any modem that supports one or more of the protocols in the GSM evolutionary family, including the 2.5G technologies GPRS and EDGE, as well as the 3G technologies WCDMA, UMTS, HSDPA and HSUPA.

GSM module is the kernel part to realize wireless data transmission. Wireless communication module SIM500 based on standard of GSM produced by SIMCOM Company is used in the developed application. SIM500 module consists of main frame, antenna, serial communication line, power line. It provides services of wireless modem, wireless fax, short message and speech communication. The short message service is suitable to apply in the situation of frequent transmittance of small data flow.

SIM500 is a Tri-band GSM/GPRS engine that works on frequencies EGSM 900 MHz, DCS 1800 MHz and PCS1900 MHz. With a tiny configuration of 40mm x 33mm x 2.85 mm, SIM500 can fit almost all the space requirement in your application, such as Smart phone, PDA phone and other mobile device. The physical interface to the mobile application is made through a 60 pins board-to-board connector, which provides all hardware interfaces between the module and customers’ boards except the RF antenna interface. The keypad and SPI LCD interface will give you the flexibility to develop
customized applications. Two serial ports can help you easily develop your applications. Two audio channels include two microphones inputs and two speaker outputs. This can be easily configured by AT command. SIM500 provide RF antenna interface with two alternatives: antenna connector and antenna pad. The antenna connector is MURATA MM9329-2700. And customer’s antenna can be soldered to the antenna pad. The circuit of SIM500 is shown in Photograph 5.4.

Photograph 5.4: SIM500 Circuit

The SIM500 is designed with power saving technique, the current consumption to as low as 2.5mA in SLEEP mode. The SIM500 is integrated with the TCP/IP protocol, Extended TCP/IP AT commands are developed for customers to use the TCP/IP protocol easily, which is very useful for those data transfer applications. The leading features of SIM 300 make it ideal for virtually unlimited applications, handheld devices and much more. It is compatible with AT cellular command interface.

The features of SIM500 are

- Tri-Band GSM/GPRS 900/1800/1900 MHZ
- Complaint to GSM phase 2/2+
- Dimensions: 40mm x 33mm x 2.85mm
- Weight : 8g
- Control via AT commands
- SIM application tool kit
- Supply voltage range 3.4 …. 4.5v
- Low power consumption
All hardware interfaces except RF interface that connects SIM500 to the customers’ cellular application platform is through a 60-pin 0.5mm pitch board-to-board connector. Sub-interfaces included in this board-to-board connector are Dual serial interface, two analog audio interfaces, SIM interface

SIM500 provides two unbalanced asynchronous serial ports. The GSM module [38] is designed as a DCE (Data Communication Equipment), following the traditional DCE-DTE (Data Terminal Equipment) connection, the module and the client (DTE) are connected through the following signal as shown in fig 5.11. Auto bauding supports baud rate from 1200 bps to 115200bps.

Serial port 1
Port/TXD @ Client sends data to the RXD signal line of module
Port/RXD @ Client receives data from the TXD signal line of module

Serial port 2
Port/TXD @ Client sends data to the DGBRXD signal line of module
Port/RXD @ Client receives data from the DGBTXD signal line of module

![Fig 5.11: Interface of serial ports](image)

The TXD, RXD, DBG_TXD, DBG_RXD, GND must be connected to the IO connector when user need to upgrade software and debug software, the TXD, RXD should be used for software upgrade and the DBG_TXD, DBG_RXD for software debug. The PWRKEY pin is recommended to connect to the IO connector. The user also can add a switch between the PWRKEY and the GND. The PWRKEY should be connected to the GND when SIM500 is upgrading software.

The SIM interface supports the functionality of the GSM Phase 1 specification and also supports the functionality of the new GSM Phase 2+ specification for FAST 64 kbps SIM. Both 1.8V and 3.0V SIM Cards are supported. The SIM interface is powered
from an internal regulator in the module having nominal voltage 2.8V. All pins reset as outputs driving low.

The Fig 5.12 is the reference circuit about SIM interface. The 22Ω resistors showed in the figure should be added in series on the IO line between the module and the SIM card for matching the impedance. The pull up resistor (about 10KΩ) must be added on the SIM_I/O line. The SIM_PRESENCE pin is used for detecting the SIM card removal. We can use the AT command “AT+CSDT” to set the SIMCARD configure. We can select the 8 pins SIM card.

![Figure 5.12: SIM interface reference circuit with 8 pins SIM card](image)

The GSM 07.05 AT commands are for performing SMS and CBS related operations. The Overview of AT Commands According to GSM07 [39] is listed in Fig 5.13.

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT+CMOD</td>
<td>DELETE SMS MESSAGE</td>
</tr>
<tr>
<td>AT+CMGE</td>
<td>SELECT SMS MESSAGE FORMAT</td>
</tr>
<tr>
<td>AT+CMGL</td>
<td>LIST SMS MESSAGES FROM PREFERRED STORE</td>
</tr>
<tr>
<td>AT+CMGR</td>
<td>READ SMS MESSAGE</td>
</tr>
<tr>
<td>AT+CMGS</td>
<td>SEND SMS MESSAGE</td>
</tr>
<tr>
<td>AT+CMGW</td>
<td>WRITE SMS MESSAGE TO MEMORY</td>
</tr>
<tr>
<td>AT+CMSS</td>
<td>SEND SMS MESSAGE FROM STORAGE</td>
</tr>
<tr>
<td>AT+CMGC</td>
<td>SEND SMS COMMAND</td>
</tr>
<tr>
<td>AT+CMHI</td>
<td>NEW SMS MESSAGE INDICATIONS</td>
</tr>
<tr>
<td>AT+CPMS</td>
<td>PREFERRED SMS MESSAGE STORAGE</td>
</tr>
<tr>
<td>AT+CRE5</td>
<td>RESTORE SMS SETTINGS</td>
</tr>
<tr>
<td>AT+CSA5</td>
<td>SAVE SMS SETTINGS</td>
</tr>
<tr>
<td>AT+SCCA</td>
<td>SMS SERVICE CENTER ADDRESS</td>
</tr>
<tr>
<td>AT+SCSB</td>
<td>SELECT CELL BROADCAST SMS MESSAGES</td>
</tr>
<tr>
<td>AT+CSOH</td>
<td>SHOW SMS TENT MODE PARAMETERS</td>
</tr>
<tr>
<td>AT+CSMP</td>
<td>SET SMS TENT MODE PARAMETERS</td>
</tr>
<tr>
<td>AT+CSMS</td>
<td>SELECT MESSAGE SERVICE</td>
</tr>
</tbody>
</table>

*Fig 5.13: Overview of AT Commands According to GSM07*
5.5.6. Power Supply

For the present work the phototherapy system consists of different units as discussed above of LED’s Unit, microcontroller, the LED driver TPS61161-q1 and DAC 0800 unit and Display unit requires different voltages of 3.3V, 5V and 12V. RS-232 uses 5V power supply and the remaining parts of the design used 3.3 V. The circuit diagram of the power supply is given below. All these voltages are derived from the power supply designed for the entire system/9v Battery package. The circuits of 5V, 12v and 3.3 V are as shown in fig 5.14, 5.15, 5.16 respectively.

![Fig 5.14: 5v Power supply circuit](image)

![Fig 5.15: 12-v Power supply circuit](image)

![Fig 5.16: 3.3-v Power supply circuit](image)
5.6 Software development for Phototherapy System

In the present study the c++ with QT GUI programming in Linux environment used for the software development of Phototherapy system. The C programming language is growing in importance and has become the standard high-level language for real-time embedded applications. To develop the of C++ programs for an ARM11J6JZF executing on a PC is embedded Linux and its GUI design with QT. This largely due to the inherent language flexibility, the extent of support and its potential for portability across a wide range of hardware [37]. The developed software program for the above parameter presented in Annexure I.

5.6.1 EMBEDDED LINUX - QT Programming

In the present work the software development for the development of phototherapy unit was developed using the software of embedded Linux and its GUI design developed is QT. Linux itself is a kernel, but ‘Linux’ in day to day terms rarely means so. Embedded Linux generally refers to a complete Linux distribution targeted at embedded devices. There is no Linux kernel specifically targeted at embedded devices, the same Linux kernel source code can be built for a wide range of devices, workstations, embedded systems, and desktops though it allows the configuration of a variety of optional features in the kernel itself. In the embedded development context, there can be an embedded Linux system which uses the Linux kernel and other software or an embedded Linux distribution which is a pre-packaged set of applications meant for embedded systems and is accompanied by development tools to build the system.

The Qt framework first became publicly available in May 1995. It was initially developed by Harvard Nord (Troll tech's CEO) and Eirik Chambe-Eng (Trolltech's Chief Troll). Qt has long been available to non-C++ programmers through the availability of unofficial language bindings, in particular Py.Qt for Python programmers. In 2007, the Qyoto unofficial bindings were released for C# programmers. In 2007, Troll tech launched Qt Jambi, an officially supported Java version of the Qt API. Since Troll tech's birth, Qt's popularity has grown unabated and continues to grow to this day. This success is a reflection both of the quality of Qt and of how enjoyable it is to use. In the past decade, Qt has gone from being a product used by a select few "in the know" to one that
is used daily by thousands of customers and tens of thousands of open source developers all around the World.

The signals and slots mechanism is fundamental to Qt programming. It enables the application programmer to bind objects together without the objects knowing anything about each other. We have already connected some signals and slots together, declared our own signals and slots, implemented our own slots, and emitted our own signals. Let's take a moment to look at the mechanism more closely.

Slots are almost identical to ordinary C++ member functions. They can be virtual; they can be overloaded; they can be public, protected, or private; they can be directly invoked like any other C++ member functions; and their parameters can be of any types. The difference is that a slot can also be connected to a signal, in which case it is automatically called each time the signal is emitted.

QT provides a complete set of built-in widgets and common dialogs that cater to most situations. We present screenshots of almost all of them. A few specialized widgets are deferred. Main window widgets such as Q Menu Bar, Q Toolbar and Q Status Bar and layout-related widgets such as Q Splitter and Q Scroll Area. In the screenshots shown in figure, all the widgets are shown using the Plastique style.

A widget is a user interface component such as a button or a scroll-bar are Reusable, Well defined interface, Uses C++ inheritance, All widgets derive from a common base, Widgets may contain other widgets, Custom widgets can be created from existing widgets or they can be created from scratch

5.6.2 QT DESIGN
- Written using Qt so it is available on all platforms where Qt is available
- Used to speed design of Qt applications
- Supports all Qt widgets and can be used to incorporate custom widgets
FEATURES

- Fully object-oriented
- Consistent interfaces
- Rich set of widgets (controls)
  - Have native look and feel
  - Drag and drop
  - Customizable appearance
- Utility classes
- OpenGL support
- Network support
- Database support
- Plugin support
- Unicode/Internationalization support
- GUI builder

Based on all the above advantages, we developed the software program for the present GSM based Phototherapy system using the C++ and Qt in Linux environment. The algorithm and flow chart already given below. The steps for the phototherapy treatment for jaundice treatment of the system are shown with photos and screen shots. The monitoring and control of GSM based neonatal phototherapy system is shown in photograh1. The main window is as shown in Photograph 5.5 and Photograph 5.6 shows...
complete system window menu of GSMNICS. It consists of the following parameters to be monitored and control. They are

- Temperature
- Phototherapy
- \( \text{SPO}_2 \)
- NIBP
- Total system
- Exit

*Photograph 5.5 : Main Window of Neonatal Monitoring system for Phototherapy*
As discussed earlier the software development done as a part of the other health parameters such as Temperature measurement and control, Pulse oxygen and NIBP measurement for the present work of GSM based Phototherapy unit for the Jaundice treatment to the neonate with Raspberry PI. The main functions performed by the processor is

1. To control the intensity of the UV LED’s interfaced with LED driver device of TPS 61611 –Q1 to Switch OFF/ON the CTRL pin connected GPIO’s for the dimming control of LEDS arranged in 4 X 6 Matrix array.

2. To generate the square wave of frequency with DAC 0800 interfaced with RPI to control the light intensity of LED’S with DAC output where the square wave to be applied common to all LEDS.

3. To provide the facility to put set time of duration required for the phototherapy by the increment and decrement counter using touch button on display unit and display the same. The algorithm and flow chart of phototherapy process required for Jaundice treatment of Neonate is presented below and Flowchart in Fig 5.18.
5.6.3. Algorithm

1. Initialize the central processing unit
2. Initialize the GPIO Port, Serial Port, ADC and GSM Modem.
3. Open TCP/IP Socket and display the total menu with Title and Neonate Photograph
4. Initialize LCD, memory and set the counter for the required time.
5. Enable the interrupts
6. Switch on the PIN CTRL HIGH and give DAC Output to the LEDs.
7. Read the counter time whether it is zero or not, if not continue the process.
8. Display the result on GLCD if it is selected individual or display the result on one of the Display on total system.
9. Send the data to the user mobiles through GSM Modem by alerting the concerned Doctor and nurses who take care about the Neonate in NICS.
Fig 5.18: Flow chart of GSM Based Phototherapy measurement and control System
When the button of Phototherapy on touch screen selected, then the window related to photo therapy displays as shown in photograph 5. The below picture shows the time duration set for phototherapy was 20 minutes and over that the time elapsed was 8 minutes and 9 seconds. According to this time duration, the phototherapy will be stopped after 11 minutes and 51 seconds and the treatment can be continued or dropped depending upon the neonate’s condition and based on doctor’s advice.

The therapy time can be monitored and controlled in the GSM Based Neonatal Phototherapy system as shown in photograph 5.7, it’s reliable and easy to increase or decrease the therapy time according to the neonates improved or worsened health condition with doctor’s advice. The total therapy time set and the time elapsed can be seen in the monitor for reference of concerned staff nurse and doctors.

![Photograph 5.7: Measurement display window of Phototherapy system](image)

Photograph 5.7: Measurement display window of Phototherapy system

The window consists the set point values of Voltage and current required for the UV LED intensity of Light for the jaundice treatment to the neonate. It also having the easy operation provision of the system by the user to set the require values by selecting the up button for incrementing the value and down button for decrementing the value by touching the touch screen which is an advanced feature of the system by avoiding the hardware switches which require more hardware for connecting them with the system. The phototherapy measurement window shows the current values of the parameters and
the time remaining for the completion of phototherapy given to the newborn baby. The complete measurement records of the patient are stored in the meter for further analysis. The measurement values are also displayed if the option of total system is selected. The records are shown in photograph 5.8.

Photograph 5.8: The measurement record display of GSM Phototherapy system

The system performance tested for different neonates for calibration purpose. The total measurements were corrected with an accuracy of +1%. The actual measurements carried out with designed instrument as well as with standard phototherapy system values also.

The measurements were carried out on the present developed system is good agreement with values measured with standard system. The empirical calibration process, the measurements exhibited slight deviation, but all these measurements are within the tolerance range. The response time of the instrument was also equal with standard meter. As the system is compact it can be used at ambulance services also. The system is accurately working for the set time values and sending the alert messages if any deviations in the measurement or even power failure of the unit by giving an audible alert.
with buzzer sound and SMS message to the concerned doctors and nurses who are authenticated to operate the entire GSMNICS.

### 5.7 Usage of Phototherapy

The key to the success of the Phototherapy is being consistence in the treatment. Long term use can lead to skin damage, such as aging, wrinkles & even rarely skin cancers.

#### 5.7.1 Caution about NICU Phototherapy

1. Do not use phototherapy without trying to find the cause of jaundice.
2. Phototherapy results in dehydration and iatrogenic hyperthermia/hypothermia.
3. Blue light may interfere with monitoring of cyanosis. Blue light causes nausea, giddiness and headache, which may disturb the staff.
4. In direct hyperbilirubinemia, phototherapy results in Bronze Baby syndrome (green color).

#### 5.7.2 Risks in NICU Phototherapy

The predominant adverse effects of phototherapy include rash, overheating, dehydration and diarrhea. Retinal damage is prevented by shielding the eyes. In vitro studies have suggested that DNA damage may be caused by phototherapy. Recently, the effect of phototherapy on cerebral blood flow velocity (CBFV) has been reported. Phototherapy increased mean CBFV in all preterm infants, which returned to pre-therapy values after discontinuation of phototherapy only in non-ventilated babies. Even in term babies, phototherapy increased CBFV, which returned to pre-therapy level upon discontinuation of phototherapy. In addition, phototherapy influences cytokine production by peripheral mononuclear blood cells. Phototherapy also has photo-oxidative effects on intravenous lipids, proteins and drugs like amphotericin B. Phototherapy has been shown to affect short-term behavior of the term infant, which has been attributed to maternal separation. This least discussed and often overlooked aspect, is the most common side effect. So one should encourage the mother to breast-feed and interact with her baby regularly during phototherapy.
5.8 Results and Discussion

The main aim and objective of this work is to develop a GSM based Neonatal Intensive Care Monitoring system with Temperature, Phototherapy, Blood Pressure and Pulse Oximetry measurement. Hence an attempt has been made by the author to develop a GSM Based Phototherapy system for the neonatal jaundice treatment using the advanced micro controller ARM11J6JZF or Raspberry PI (Broad com 2835) and GSM Mobile Technology. The instrument is a handheld, rugged, low cost, wearable device and also it is cost effective compared to other systems with all advanced features that are not available with other operated with minimum power consumption by the device also with a touch screen GUI display which reduces hardware circuit.