

**PHOTOTHERAPY WITH TIMER
FOR NEWBORN JAUNDICE**

**GRADUATION PROJECT SUBMITTED TO
THE BIOMEDICAL DEPARTMENT
OF
NEAR EAST UNIVERSITY**

BY

**YUSUF NCEKALAN
SÜLEYMAN ÖKSÜZ**

**PARTIAL FULFILLMENT OF THE
REQUIREMENTS
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IN
BIOMEDICAL ENGINEERING**

NICOSIA 2015

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We hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. We also declare that, as required by these rules and conduct, we have fully cited and referenced all material and results that are not original to this work.

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Date:05/01/2015

ABSTRACT

Blue-light phototherapy has been an essential therapeutic tool in the management of neonatal jaundice for decades. Rarely, it is accompanied by acute dermatological and systemic side-effects, but fortunately these are reversible and can be adequately and promptly treated in routine neonatal practice. In contrast, much less is known about the potential long-term side-effects of neonatal blue-light phototherapy (NBLP). Many of the data that are currently available on how NBLP influences melanocytic naevus (MN) development are controversial. The results of recent well-designed epidemiological surveys suggest that NBLP could well be a risk factor for MN formation, and highlight the need for additional *in vivo* and *in vitro* studies. NBLP is at present the mainstay of treatment for neonatal jaundice, but in the future greater consideration should be given to its long-term side-effects when phototherapy is indicated. It is relevant to emphasize the importance of appropriately restricted and adequate clinical guidelines, and strict monitoring of the management of hyperbilirubinaemia, in order to avoid the unnecessary overtreatment of newborn infants.

Keywords: Newborn jaundice, Phototherapy, Timing Circuit, Arduino

Dedication

We would like to dedicate this project to our beloved parents, grandparents and family for their encouragement and support. Also to our friends, I will always appreciate all they have done.

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1.INTRODUCTION

1.1 The Bilirubin

A bilirubin test measures the amount of bilirubin in a blood sample. 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.

Bilirubin circulates in the bloodstream in two forms:

- ✓ Indirect (or unconjugated) bilirubin. This form of bilirubin does not dissolve in water (it is insoluble). Indirect bilirubin travels through the bloodstream to the liver, where it is changed into a soluble form (direct or conjugated).
- ✓ Direct (or conjugated) bilirubin. Direct bilirubin dissolves in water (it is soluble) and is made by the liver from indirect bilirubin.

Total bilirubin and direct bilirubin levels are measured directly in the blood, whereas indirect bilirubin levels are derived from the total and direct bilirubin measurements.

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.

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. (Healthwise,2013)

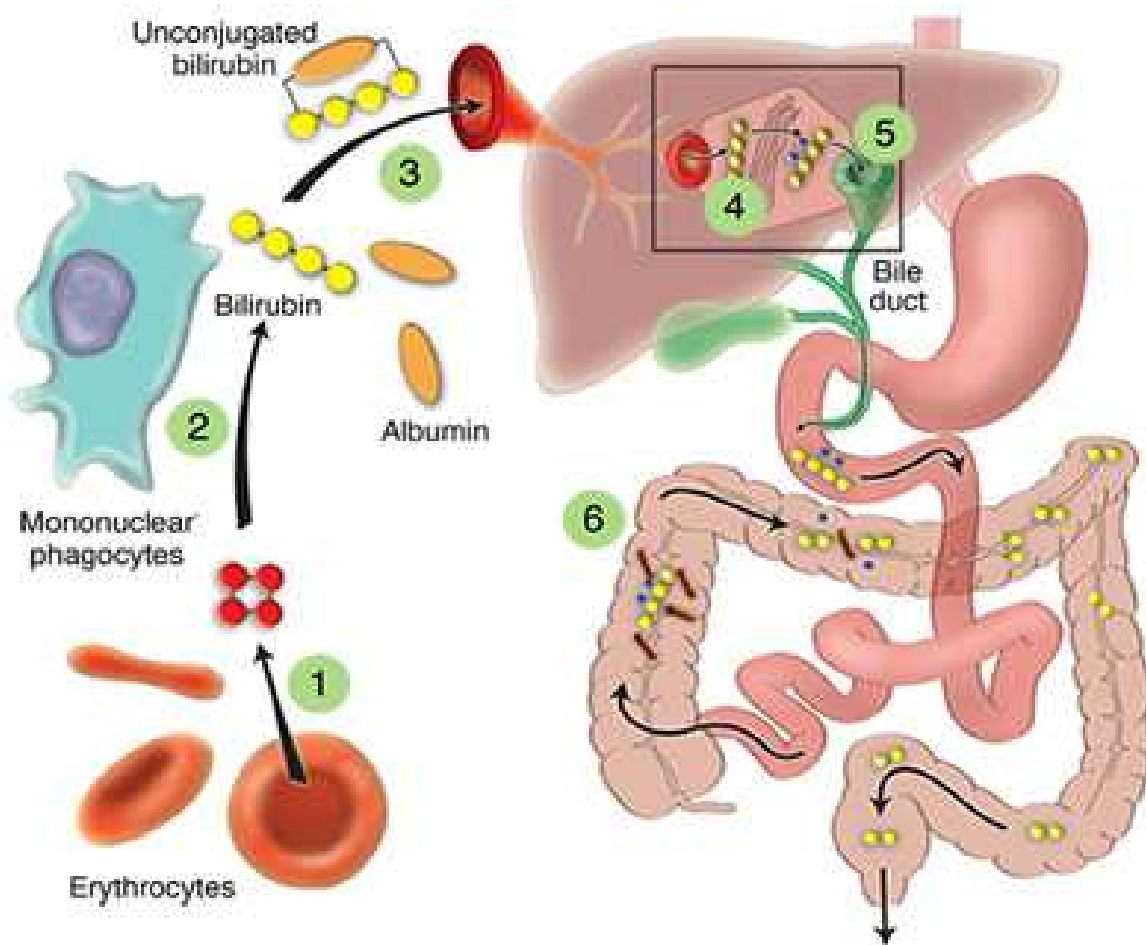


Diagram 1.1 :*The bilirubin production sequences and relations between the organs*

Bilirubin (formerly referred to as haematoidin) is the yellow breakdown product of normal heme catabolism. Heme is found in hemoglobin, a principal component of red blood cells. Bilirubin is excreted in bile and urine, and elevated levels may indicate certain diseases. It is responsible for the yellow color of bruises, the background straw-yellow color of urine via its reduced breakdown product, urobilin (the more obvious but variable bright yellow color of urine is due to thiochrome, a breakdown product of thiamine), the brown color of feces (via its conversion to stercobilin), and the yellow discoloration in jaundice. (Pirone, Cary; Quirke, J. Martin E.; Priestap, Horacio A.; Lee, David W. (2009))

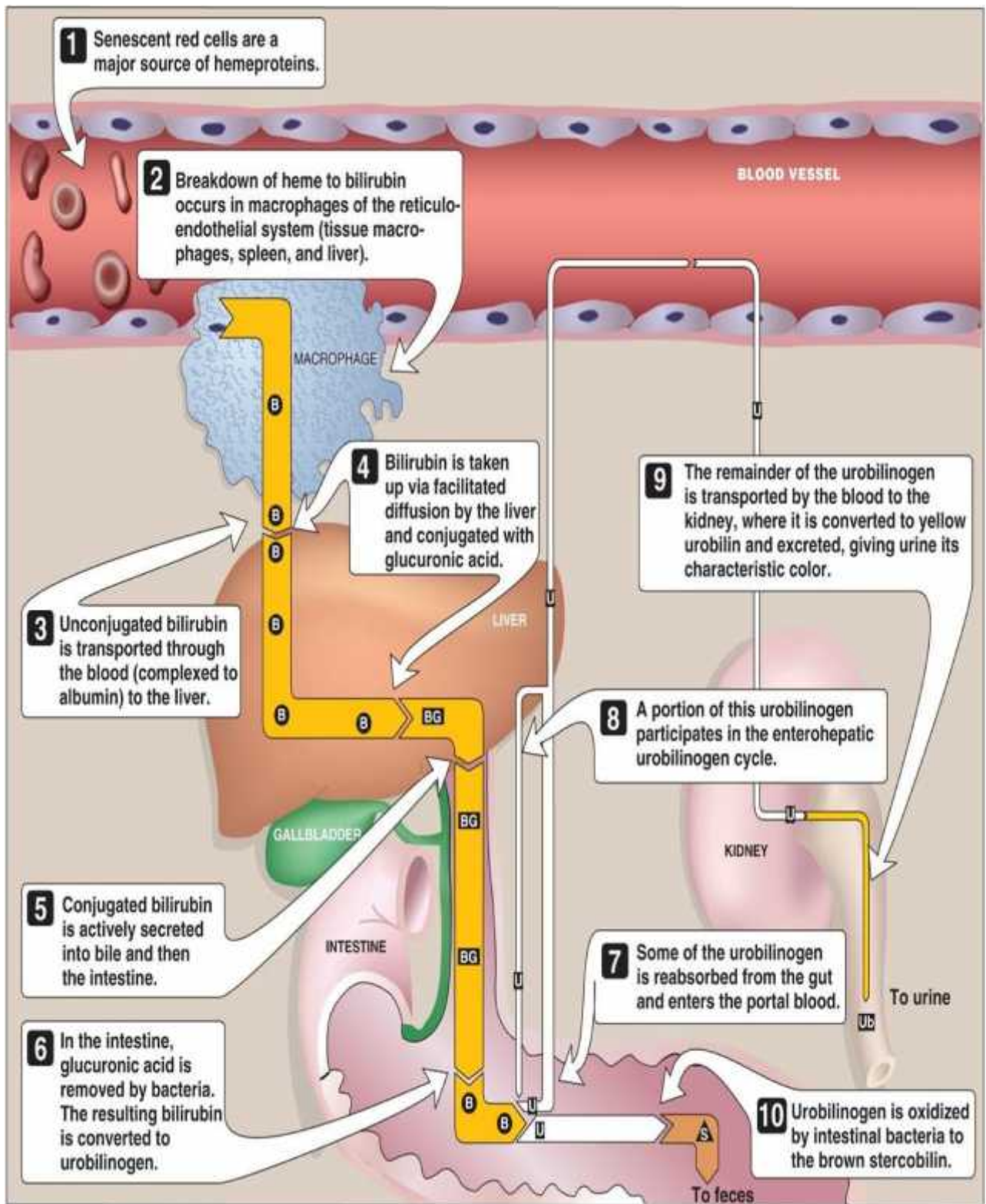


Diagram 1.2: *The bilirubin producing pathway*

1.2 What is the bilirubin test?

1.3 Why it is done?

The bilirubin test is used to:

- ✓ Check liver function and watch for signs of liver disease, such as hepatitis or cirrhosis, or the effects of medicines that can damage the liver.
- ✓ Find out if something is blocking the bile ducts. This may occur if gallstones, tumors of the pancreas, or other conditions are present.
- ✓ Diagnose conditions that cause increased destruction of red blood cells, such as hemolytic anemia or hemolytic disease of the newborn.
- ✓ Help make decisions about whether newborn babies with neonatal jaundice need treatment. These babies may need treatment with special lights, called phototherapy. In rare cases, blood transfusions may be needed.

1.4 How to prepare?

Adults should not eat or drink for 4 hours before a bilirubin test.

No special preparation is needed for children before having a bilirubin test.

Tell your doctor if you:

- ✓ Are taking any medicines.
- ✓ Are allergic to any medicines.
- ✓ Have had bleeding problems or take blood-thinners, such as aspirin, clopidogrel (Plavix), or warfarin (Coumadin).
- ✓ Are or might be pregnant.

Talk to your doctor about any concerns you have regarding the need for the test, its risks, how it will be done, or what the results will mean. To help you understand the importance of this test, fill out the medical test information form.

1.5 How it is done?

1.5.1 Blood sample from a heel stick

For a heel stick blood sample, several drops of blood are collected from the heel of your baby. The skin of the heel is first cleaned with alcohol and then punctured with a small sterile lancet. Several drops of blood are collected in a small tube. When enough blood has been collected, a gauze pad or cotton ball is placed over the puncture site. Pressure is maintained on the puncture site briefly, and then a small bandage is usually applied.

Instead of the standard heel stick, some hospitals may use a device called a transcutaneous bilirubin meter to check a newborn's bilirubin level. This small handheld device measures

bilirubin levels when it is placed gently against the skin. With this device, there may be no need to puncture the baby's skin. This is a screening test, and a blood sample will be needed if your baby's bilirubin level is high.

1.5.2 Blood sample from a vein

The health professional taking a sample of your blood will:

- ✓ Wrap an elastic band around your upper arm to stop the flow of blood. This makes the veins below the band larger so it is easier to put a needle into the vein.
- ✓ Clean the needle site with alcohol.
- ✓ Put the needle into the vein. More than one needle stick may be needed.
- ✓ Attach a tube to the needle to fill it with blood.
- ✓ Remove the band from your arm when enough blood is collected.
- ✓ Put a gauze pad or cotton ball over the needle site as the needle is removed.
- ✓ Put pressure on the site and then put on a bandage.

1.6 How It Feels?

1.6.1 Blood sample from a heel stick

A brief pain, like a sting or a pinch, is usually felt when the lancet punctures the skin. Your baby may feel a little discomfort with the skin puncture.

1.6.2 Blood sample from a vein

The blood sample is taken from a vein in your arm. An elastic band is wrapped around your upper arm. It may feel tight. You may feel nothing at all from the needle, or you may feel a quick sting or pinch.

1.7 Risks

1.7.1 Heel stick

There is very little chance of a problem from a heel stick. A small bruise may develop at the site.

1.7.2 Blood test

There is very little chance of a problem from having a blood sample taken from a vein.

- ✓ You may get a small bruise at the site. You can lower the chance of bruising by keeping pressure on the site for several minutes.

- ✓ In rare cases, the vein may become swollen after the blood sample is taken. This problem is called phlebitis. A warm compress can be used several times a day to treat this.
- ✓ Ongoing bleeding can be a problem for people with bleeding disorders. Aspirin, warfarin (Coumadin), and other blood-thinning medicines can make bleeding more likely. If you have bleeding or clotting problems, or if you take blood-thinning medicine, tell your doctor before your blood sample is taken.

1.8 Results

A bilirubin test measures the amount of bilirubin in a blood sample. The results are usually available in 1 to 2 hours.

1.8.1 Normal values in adults

The normal values listed here—called a reference range—are just a guide. These ranges vary from lab to lab, and your lab may have a different range for what’s normal. Your lab report should contain the range your lab uses. Also, your doctor will evaluate your results based on your health and other factors. This means that a value that falls outside the normal values listed here may still be normal for you or your lab.

Bilirubin levels in adults	
Bilirubin type	Bilirubin level
Total bilirubin	0.0–1.4 mg/dL or 1.7–20.5 μmol/L
Direct bilirubin	0.0–0.3 mg/dL or 1.7–5.1 μmol/L
Indirect bilirubin	0.2–1.2 mg/dL or 3.4–20.5 μmol/L

Table 1.1: Normal bilirubin levels

1.8.2 High values

High levels of bilirubin in the blood may be caused by:

- ✓ Some infections, such as an infected gallbladder, or cholecystitis.
- ✓ Some inherited diseases, such as Gilbert’s syndrome, a condition that affects how the liver processes bilirubin. Although jaundice may occur in some people with Gilbert’s syndrome, the condition is not harmful.

- ✓ Diseases that cause liver damage, such as hepatitis, cirrhosis, or mononucleosis.
- ✓ Diseases that cause blockage of the bile ducts, such as gallstones or cancer of the pancreas.
- ✓ Rapid destruction of red blood cells in the blood, such as from sickle cell disease or an allergic reaction to blood received during a transfusion (called a transfusion reaction).
- ✓ Medicines that may increase bilirubin levels. This includes many antibiotics, some types of birth control pills, diazepam (Valium), flurazepam, indomethacin (Indocin), and phenytoin (Dilantin).

1.8.3 Low values

Low levels of bilirubin in the blood may be caused by:

- ✓ Medicines that may decrease bilirubin levels. This includes vitamin C, phenobarbital, and theophylline.

1.8.4 Normal values in newborns

Normal values in newborns depend on the age of the baby in hours and whether the baby was premature or full term.

In a newborn, higher bilirubin is normal due to the stress of birth. Normal bilirubin in a newborn would be under 5 mg/dL, but up to 60 percent of newborns have some kind of jaundice and bilirubin levels above 5 mg/dL.

1.9 What affects the test?

Reasons you may not be able to have the test or why the results may not be helpful (except in newborns) include:

- ✓ Caffeine, which can lower bilirubin levels.
- ✓ Not eating for a long period (fasting), which normally increases indirect bilirubin levels.

Bilirubin can be measured in amniotic fluid if your doctor thinks that your unborn baby may have a condition that destroys red blood cells (erythroblastosis fetalis). For more information, see the topic Amniocentesis.

Bilirubin may also be measured in the urine in some cases. Normally, urine does not contain any bilirubin. If bilirubin is detected in urine, additional testing may be needed to determine the cause. High amounts of bilirubin in urine may indicate that the bilirubin is not being removed from the body by the liver.

Using a transcutaneous bilirubin test, doctors can screen all newborns for jaundice. They place a device gently against the skin to check bilirubin levels before a baby goes home from the hospital.

1.10 Understanding the bilirubin

Jaundice typically occurs because newborns normally produce increased levels of bilirubin which is referred to as "physiologic jaundice." Bilirubin, which is yellowish in color, is produced when red blood cells are broken down. Bilirubin is removed from the bloodstream by the liver. In newborns, the body may produce more bilirubin than the liver can process.

Physiologic jaundice usually appears within a few days after birth and resolves within two weeks. Other types of newborn jaundice can be due to prematurity, problems related to breastfeeding, infection, blood type mismatch between mom and baby as well as other blood or liver problems.

Since many mothers and babies leave the hospital soon after delivery, jaundice may not appear until babies are at home. A newborn check is typically scheduled with your pediatrician within the first few days of going home from the nursery to check for jaundice.

It is important to contact your doctor if you notice signs of jaundice in your baby. If you suspect jaundice you will likely need to see your doctor that same day. While jaundice is usually very treatable, in the most extreme cases it can cause brain damage.

The ventricles then relax, and the heartbeat process starts all over again in the SA node. A problem with any part of this process can cause an arrhythmia. For example, in atrial fibrillation, a common type of arrhythmia, electrical signals travel through the atria in a fast and disorganized way. This causes the atria to quiver instead of contract.

1.11 Abnormalities of bilirubin

1.11.1 Gilbert's Syndrome

- ✓ Partial block in bilirubin conjugation

- ✓ Benign elevation in total and unconjugated bilirubin

1.11.2 Criglar-Najjar Syndrome, Type I

- ✓ Absence of bilirubin conjugation enzyme
- ✓ Marked unconjugated hyperbilirubinemia & jaundice
- ✓ May cause death in infancy

1.11.3 Criglar-Najjar Syndrome, Type II (Arias Syndrome)

- ✓ Defect uncertain
- ✓ Moderate hyperbilirubinemia
- ✓ Bilirubin decreases with phenobarbital treatment, which increases the amount and activity ("induces") the conjugating enzymes in hepatocytes

1.11.4 Dubin-Johnson Syndrome

- ✓ Defect in transport of bilirubin into bile
- ✓ Mild conjugated and unconjugated hyperbilirubinemia; conjugated predominates
- ✓ Jaundice may be precipitated by other illnesses
- ✓ Urinary coproporphyrin I is elevated.

1.11.5 Rotor Syndrome

- ✓ Defect in transport of bilirubin into bile
- ✓ Mild conjugated hyperbilirubinemia
- ✓ Jaundice may be precipitated by other illnesses
- ✓ Serum bile acid levels are increased

1.12 Hyperbilirubinemia

Diseases that reduce the rate of secretion of conjugated bilirubin into the bile or the flow of bile into the intestine produce a mixed or predominantly conjugated hyperbilirubinemia due to the reflux of conjugates back into the plasma. Elevated conjugated bilirubin levels usually indicate hepatobiliary disease.

Laboratory assays for bilirubin typically involve its cleavage in the presence of diazotized sulfanilic acid to generate a colored azodipyrrole that can be assayed spectrophotometrically. Because of its limited aqueous solubility, unconjugated bilirubin reacts slowly in the absence of an accelerator, such as ethanol, whereas conjugated bilirubin reacts rapidly. Total bilirubin is measured in the presence of an accelerator, whereas directly reacting bilirubin is measured without an accelerator. Indirectly reacting

bilirubin is calculated by subtracting the directly reacting bilirubin score from the total bilirubin score.

Although the directly reacting bilirubin concentration approximates the conjugated bilirubin concentration in most cases, the 2 terms do not mean the same thing. Similarly, indirect bilirubin is not the same as unconjugated bilirubin.

The kidneys do not filter unconjugated bilirubin because of its avid binding to albumin. For this reason, the presence of bilirubin in the urine indicates the presence of conjugated hyperbilirubinemia.

Normal serum values of total bilirubin typically are 0.2-1 mg/dL (3.4-17.1 $\mu\text{mol/L}$), of which no more than 0.2 mg/dL (3.4 $\mu\text{mol/L}$) are directly reacting.

2. NEWBORN JAUNDICE

2.1 Newborn jaundice

Newborn jaundice is when a baby has a high level of bilirubin in the blood. Bilirubin is a yellow substance that the body creates when it replaces old red blood cells. The liver helps break down the substance so it can be removed from the body in the stool.

High levels of bilirubin make your baby's skin and whites of the eyes look yellow. This is called jaundice.

2.2 Causes

It is normal for a baby's bilirubin level to be a bit higher after birth.

When the baby is growing in the mother's womb, the placenta removes bilirubin from the baby's body. The placenta is the organ that grows during pregnancy to feed the baby.

After birth, the baby's liver starts doing this job. It may take some time for the baby's liver to be able to do this efficiently.

Most newborns have some yellowing of the skin, or jaundice. This is called "physiological jaundice." It is often most noticeable when the baby is 2 - 4 days old. Most of the time it does not cause problems and goes away within 2 weeks.

Two types of jaundice may occur in newborns who are breastfed. Both types are most often harmless.

- ✓ Breastfeeding jaundice is seen in breastfed babies during the first week of life. It is more likely to occur when babies do not nurse well or the mother's milk is slow to come in.
- ✓ Breast milk jaundice may appear in some healthy, breastfed babies after day 7 of life. It is likely to peak during weeks 2 and 3 but may last at low levels for a month or more. The problem may be due to how substances in the breast milk affect the breakdown of bilirubin in the liver. Breast milk jaundice is different than breastfeeding jaundice.

Severe newborn jaundice may occur if your baby has a condition that increases the number of red blood cells that need to be replaced in the body, such as:

- ✓ Abnormal blood cell shapes
- ✓ Blood type mismatch between the mother and baby
- ✓ Bleeding underneath the scalp (cephalohematoma) caused by a difficult delivery
- ✓ Higher levels of red blood cells, which is more common in small-for-gestational-age babies and some twins
- ✓ Infection
- ✓ Lack (deficiency) of certain important proteins, called enzymes

Things that make it harder for the baby's body to remove bilirubin may also lead to more severe jaundice, including:

- ✓ Certain medicines
- ✓ Infections present at birth, such as rubella, syphilis, and others
- ✓ Diseases that affect the liver or biliary tract, such as cystic fibrosis or hepatitis
- ✓ Low oxygen level (hypoxia)
- ✓ Infections (such as sepsis)
- ✓ Many different genetic or inherited disorders

Babies who are born too early (premature) are more likely to develop jaundice than full-term babies.

2.3 Symptoms

Jaundice causes a yellow color of the skin. The color sometimes begins on the face and then moves down to the chest, belly area, legs, and soles of the feet.

Sometimes, infants with a lot of jaundice may be very tired and feed poorly.

2.4 Exams and Tests

Doctors, nurses, and family members will watch for signs of jaundice at the hospital and after the newborn goes home.

Any infant who appears jaundiced should have bilirubin levels measured right away. This can be done with a blood test.

Many hospitals check total bilirubin levels on all babies at about 24 hours of age. Hospitals use probes that can estimate the bilirubin level just by touching the skin. High readings need to be confirmed with blood tests.

Tests that will likely be done include:

- ✓ Complete blood count
- ✓ Coomb's test
- ✓ Reticulocyte count

Further testing may be needed for babies who need treatment or whose total bilirubin levels are rising more quickly than expected.

2.5 Treatment

Treatment is not needed most of the time.

When treatment is needed, the type will depend on:

- ✓ The baby's bilirubin level
- ✓ How fast the level has been rising
- ✓ Whether the baby was born early (babies born early are more likely to be treated at lower bilirubin levels)
- ✓ How old the baby is

A baby will need treatment if the bilirubin level is too high or is rising too quickly.

A baby with jaundice needs to be kept well hydrated with breast milk or formula.

- ✓ Feed the baby often (up to 12 times a day) to encourage frequent bowel movements. These help remove bilirubin through the stools.

- ✓ Ask your doctor before giving your newborn extra formula.

Some newborns need to be treated before they leave the hospital. Others may need to go back to the hospital when they are a few days old. Treatment in the hospital usually lasts 1 to 2 days.

Sometimes special blue lights are used on infants whose levels are very high. These lights work by helping to break down bilirubin in the skin. This is called phototherapy.

- ✓ The infant is placed under artificial light in a warm, enclosed bed to maintain a constant temperature.
- ✓ The baby will wear only a diaper and special eye shades to protect the eyes.
- ✓ The American Academy of Pediatrics recommends that breastfeeding be continued through phototherapy, if possible.
- ✓ Rarely, the baby may have an intravenous (IV) line to deliver fluids.

If the bilirubin level is not too high or is not rising quickly, you can do phototherapy at home with a fiberoptic blanket, which has tiny bright lights in it. You may also use a bed that shines light up from the mattress.

- ✓ You must keep the light therapy on your child's skin and feed your child every 2 to 3 hours (10 to 12 times a day).
- ✓ A nurse will come to your home to teach you how to use the blanket or bed, and to check on your child.
- ✓ The nurse will return daily to check your child's weight, feedings, skin, and bilirubin levels.
- ✓ You will be asked to count the number of wet and dirty diapers.

In the most severe cases of jaundice, an exchange transfusion is required. In this procedure, the baby's blood is replaced with fresh blood. Giving babies with very bad jaundice intravenous immunoglobulin may also be effective at reducing bilirubin levels.

2.6 Outlook (Prognosis)

Newborn jaundice is not harmful most of the time. For most babies, jaundice will get better without treatment within 1 to 2 weeks.

Very high levels of bilirubin can damage the brain. This is called kernicterus. However, the condition is almost always diagnosed before levels become high enough to cause this damage.

For babies who need treatment, the treatment is very often effective.

Possible Complications

Rare, but serious complications from high bilirubin levels include:

- ✓ Cerebral palsy
- ✓ Deafness
- ✓ Kernicterus -- brain damage from very high bilirubin levels

2.7 When to Contact a Medical Professional ?

All babies should be seen by a health care provider in the first 5 days of life to check for jaundice.

- ✓ Infants who spend less than 24 hours in a hospital should be seen by age 72 hours.
- ✓ Infants who are sent home between 24 and 48 hours should be seen again by age 96 hours.
- ✓ Infants who are sent home between 48 and 72 hours should be seen again by age 120 hours.

Jaundice is an emergency if the baby has a fever, has become listless, or is not feeding well. Jaundice may be dangerous in high-risk newborns.

Jaundice is generally NOT dangerous in babies who were born full term and who do not have other medical problems. Call the infant's health care provider if:

- ✓ Jaundice is severe (the skin is bright yellow)
- ✓ Jaundice continues to increase after the newborn visit, lasts longer than 2 weeks, or other symptoms develop
- ✓ The feet, especially the soles, are yellow

2.8 Prevention

In newborns, some degree of jaundice is normal and probably not preventable. The risk of serious jaundice can often be reduced by feeding babies at least 8 to 12 times a day for the first several days and by carefully identifying infants at highest risk.

All pregnant women should be tested for blood type and unusual antibodies. If the mother is Rh negative, follow-up testing on the infant's cord is recommended. This may also be done if the mother's blood type is O+, but it is not needed if careful monitoring takes place.

Careful monitoring of all babies during the first 5 days of life can prevent most complications of jaundice. This includes:

- ✓ Considering a baby's risk for jaundice

- ✓ Checking bilirubin level in the first day or so
- ✓ Scheduling at least one follow-up visit the first week of life for babies sent home from the hospital in 72 hours

2.9 Alternative Names: Jaundice of the newborn; Neonatal hyperbilirubinemia; Bili lights – jaundice.

3.PHOTOTHERAPY

3.1 Phototherapy

Phototherapy is the most common treatment for reducing high bilirubin levels that cause jaundice in a newborn.

In the standard form of phototherapy, your baby lies in a bassinet or enclosed plastic crib (incubator) and is exposed to a type of fluorescent light that is absorbed by your baby's skin. During this process, the bilirubin in the baby's body is changed into another form that can be more easily excreted in the stool and urine.

Effective treatments to decrease bilirubin levels in infants with severe jaundice include phototherapy and exchange transfusion.

The effect of light on jaundice in neonates, and 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. Since its inception, phototherapy has been effectively used as a relatively inexpensive and noninvasive method of treating neonatal hyperbilirubinemia.

The decline in the number of 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.

At its most basic, 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 (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. 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.

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 photooxidation products. This process occurs more slowly than configurational or structural isomerization. Photooxidation products are primarily excreted in the urine. The image below provides a schematic of the conversion of normal bilirubin to configurational isomers, structural isomers, and photooxidation products and the respective routes of excretion from the body.

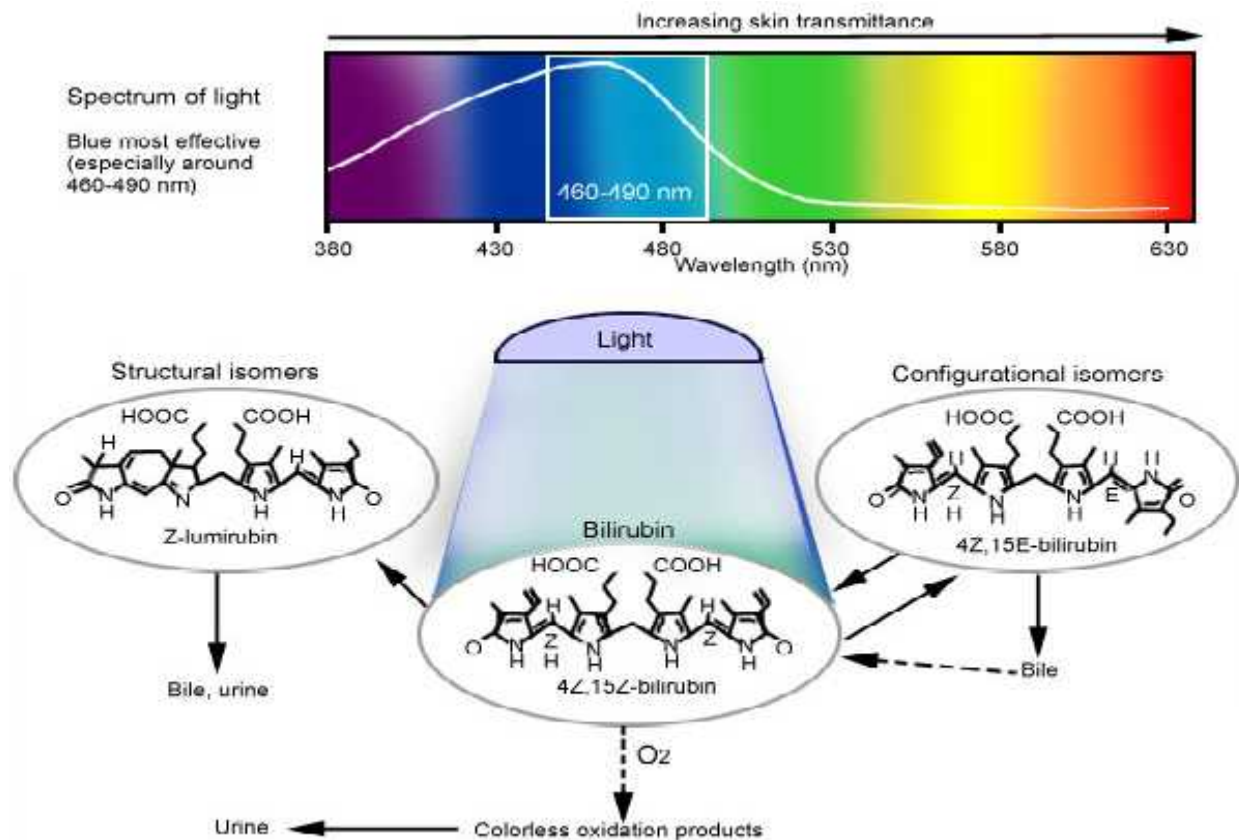


Diagram 3.1 : Mechanism of phototherapy: Blue-green light in the range of 460-490 nm is most effective for phototherapy. The absorption of light by the normal bilirubin (4Z,15Z-bilirubin) generates configuration isomers, structural isomers, and photooxidation products. The 2 principal photoisomers formed in humans are shown. Configurational isomerization is reversible and much faster than structural isomerization. Structural isomerization is slow and irreversible. Photooxidation occurs more slowly than both configurational and structural isomerization. Photooxidation products are excreted mainly in urine.

3.2 Indications

Prior studies have shown that approximately 5-40 infants per 1,000 in the United States require phototherapy in the newborn nursery, and an equal number require readmission to the hospital for phototherapy after discharge from the nursery. The specific total serum bilirubin concentration at which phototherapy should be initiated varies and depends on several factors, including the total serum bilirubin level, the infants gestational age, age of

the infant in hours at the time of testing, and any individual risk factors for hyperbilirubinemia.

Risk factors for the development of severe hyperbilirubinemia and kernicterus include isoimmune hemolytic disease, glucose-6-phosphate deficiency, asphyxia, significant lethargy, temperature instability, sepsis, acidosis, and hypoalbuminemia (< 3g/dL). To aid physicians in the decision on when to initiate phototherapy, the American Academy of Pediatrics Subcommittee on Hyperbilirubinemia developed guidelines on the management of hyperbilirubinemia in newborns 35 or more weeks' gestation. This guideline includes an algorithm for the management of jaundice in the newborn nursery as well as guidelines for the initiation of phototherapy based on total serum bilirubin levels, gestational age, age of the infant in hours, and individual risk factors.

No evidence-based guidelines are available on the indication for phototherapy in premature infants less than 35 weeks' gestation. However, several commonly used reference texts provide tables. A commonly used rule of thumb in the NICU is to start phototherapy when the total serum bilirubin level is greater than 5 times the birth weight. Thus, in a 1-kg infant, phototherapy is started at a bilirubin level of 5mg/dL; in a 2-kg infant, phototherapy is started at a bilirubin level of 10mg/dL and so on.

3.3 Contraindications

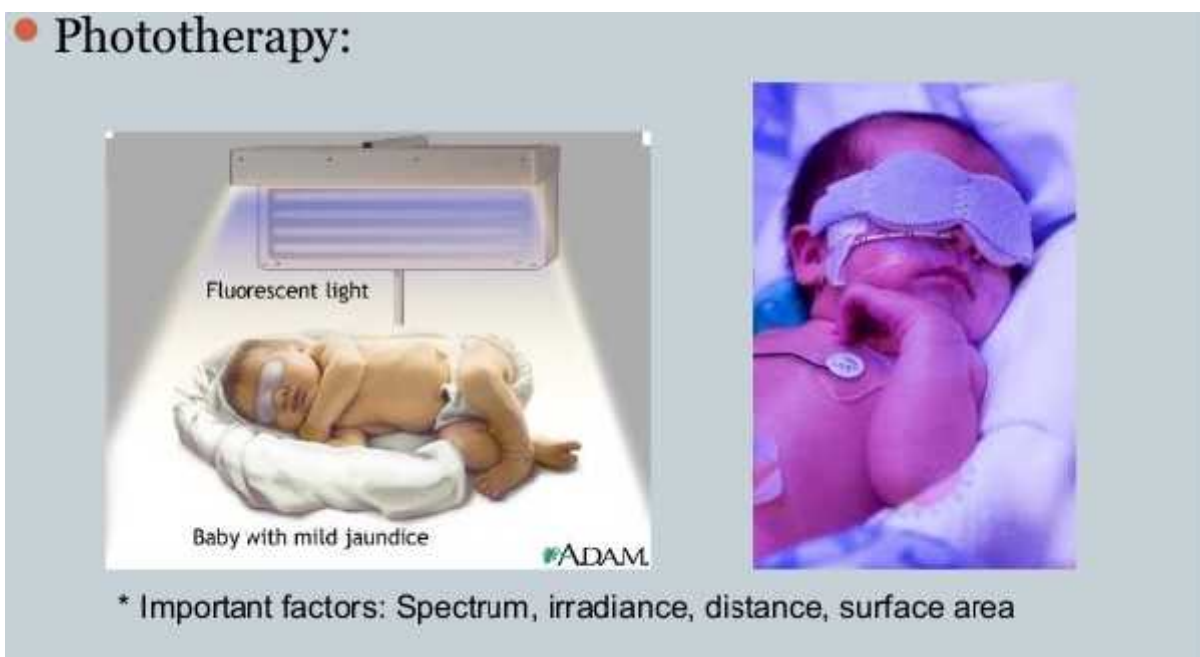
Few contraindications to phototherapy are recognized. These include the concomitant use of photosensitizing medications, a diagnosis of congenital erythropoietic porphyria, or a family history of porphyria. Infants with cholestatic jaundice and direct hyperbilirubinemia who are exposed to phototherapy may experience a dark, gray-brown discoloration of the skin, commonly known as "bronze-baby syndrome." The etiology of this discoloration is unknown but is possibly due to porphyrin accumulation. The skin discoloration that occurs with bronze-baby syndrome is transient and disappears with the discontinuation of phototherapy. The presence of direct hyperbilirubinemia is not a contraindication to phototherapy.

3.4 Technical Considerations

3.4.1 Important factors of the phototherapy

The 3 factors that affect the dose of phototherapy include the irradiance of light used, the distance from the light source, and the amount of skin exposed. Standard phototherapy is provided at an irradiance of 8-10 microwatts per square centimeter per nanometer (mW/cm² per nm). Intensive phototherapy is provided at an irradiance of 30 mW/cm² per nm or more (430–490 nm). For intensive phototherapy, an auxiliary light source should be placed under the infant. The auxiliary light source could include a fiber-optic pad, a light-emitting diode (LED) mattress, or a bank of special blue fluorescent tubes. Term and near-term infants should receive phototherapy in a bassinet and the light source should be brought as close as possible to the infant, typically within 10-15 cm. However, if halogen or tungsten lights are used, providers should follow the manufacturer recommendation on the distance of the light from the infant to avoid overheating. Preterm infant can be treated in an incubator, but the light rays from the phototherapy device should be perpendicular to the surface of the incubator to minimize light reflectance. Adapted from Maisel MJ, McDonagh AD. Phototherapy for Neonatal Jaundice. N Engl J Med. 2008;358:920-928.

The effectiveness of phototherapy at converting bilirubin into configurational isomers, structural isomers, and photooxidation products is determined by the dose of phototherapy provided to the infant. The dose of phototherapy depends on several factors, including the spectral wave length of light, the spectral irradiance delivered to the infant's skin, and the total spectral power (average spectral irradiance delivered across the surface area of the infant). Factors that affect phototherapy are described in the image below.



Picture 3.1: *Light in the blue region of the spectrum, near 460 nm, is most strongly absorbed by bilirubin.*

However, only light that penetrates the skin and is absorbed by bilirubin provides the needed photochemical effect. Tissue penetration increases as the wavelength of the light increases. Thus, one must balance the use of a higher wavelength of light, which more readily penetrates tissue, with the use of a wavelength that is more readily absorbed by bilirubin, which may penetrate less deeply. With this in mind, light in the 460-490 nm wavelength is probably the most effective for use during phototherapy.

Spectral irradiance is measured in watts per centimeter, or microwatts per square centimeter per nanometer (mW/cm^2 per nm) over a wavelength band. Higher spectral irradiance results in a more rapid decline in the bilirubin levels. Spectral irradiance increases as the distance from the light source to the infant's skin decreases. Different phototherapy devices deliver significantly different levels of irradiance. The American Academy of Pediatrics defines standard phototherapy as 8-10 mW/cm^2 per nm and intensive phototherapy as more than 30 mW/cm^2 per nm in the 430-490 nm band.

Spectral power increases as the amount of skin exposed to phototherapy increases. Ways to increase surface area exposure include removal of clothing and increasing the number of lights/lighting devices used to deliver phototherapy. Infants receiving phototherapy should be left only in their diaper, allowing adequate surface area exposure for phototherapy. The use of lights both above and below an infant effectively doubles the area of exposure. Several manufacturers produce fiberoptic pads that can be placed under the infant. The Bili Bassinet (Olympic Medical; Seattle, WA) is one commercial device that provides special blue fluorescent tubes that emit light in the 460-490 nm wavelength, both above and below the infant.

The dose of phototherapy, in mW/cm^2 per nm, should be measured during phototherapy using a commercially available radiometer. These devices typically measure the spectral irradiance of phototherapy in the 425-475 or 400-480nm band wavelength. The radiometer used to measure irradiance should be the one recommended by manufacturer of the light source. Due to variance in the strength of phototherapy over the surface of the infant, and because measurements of spectral irradiance can differ greatly depending on

where on the infant the measurement is made, taking several measures in different locations on the infant and averaging the values is important.

3.5 Complication Prevention

Eye protection should be placed on all infants receiving phototherapy. The need for eye protection is based on animal data that phototherapy may be damaging to the retina. Various commercially available infant eye shields are available for use. In addition to eye shields, many centers also prescribe lubricating eye drops (carboxymethylcellulose sodium) for infant receiving phototherapy. The infant's temperature should be closely monitored while receiving phototherapy. This is especially important in infant under halogen lights because these emit significant amounts of heat and can cause hyperthermia. Unclothed infants in basinet under fluorescent or light-emitting diode (LED) devices are at risk for hypothermia, especially if they are in an area with a low ambient temperature. Premature infants and infants unable to maintain body temperature in a basinet should be placed on a radiant warmer or in an isolette while receiving phototherapy in order to maintain normothermia.

The use of photosensitizing medications should be avoided while infants are receiving phototherapy. Medications used in the newborn period that have been linked to phototoxic reactions include nonsteroidal anti-inflammatory drugs (ibuprofen), diuretics (furosemide, hydrochlorothiazide), and certain antibiotics (doxycycline, tetracycline, ciprofloxacin, ofloxacin, levofloxacin, and sulfonamides). In general, however, photosensitivity from medications are most likely to occur after exposure to light in the UV-A (320- 400 nm) and UV-B (290-302 nm) ranges. Because phototherapy does not produce significant UV-A or UV-B light, phototoxic reactions in infants receiving these medications are rare

3.6 Outcomes

Phototherapy has been safely used for the treatment of neonatal jaundice for over 40 years. Complications from phototherapy are rare and generally mild. The two most notable complications include increased insensible water loss and cutaneous reactions in infants with cholestatic jaundice receiving phototherapy.

Phototherapy with halogen spot lights can increase cutaneous blood flow and increase insensible water loss through the skin. This is especially important in premature infants

whose skin barrier function is compromised due to immaturity and is more permeable to water. Contemporary studies in premature infants undergoing phototherapy with halogen spot lights have shown transepidermal water loss increases of 20-26%, despite constant temperature and relative humidity. Phototherapy is thought to increase skin blood flow by a mechanism known as photorelaxation. The pathway of this mechanism is not completely understood but is believed to be caused by S-nitrosothiols mediated nitric oxide release.

Due to this increase in insensible water loss, recommendations have been made to increase maintenance fluid by 10 mL/kg/d in premature infants exposed to conventional phototherapy. Additional intravenous fluids are not required in term infants who are maintaining adequate oral intake. Increases in transepidermal water loss in premature infants have not been documented with LED-based phototherapy.

A dark, greyish-brown discoloration of the skin may develop in infants with cholestatic jaundice and direct hyperbilirubinemia exposed to phototherapy. This reaction is commonly referred to as bronzed-baby syndrome. This discoloration of the skin is transient and resolves with cessation of phototherapy. Bolus and purpuric reactions of the skin have also been reported in infants with severe cholestatic jaundice receiving phototherapy. This is thought to be due to sensitization by accumulation of porphyrins

3.7 Patient Education & Consent

3.7.1 Patient instructions

According to the American Academy of Pediatrics Clinical Practice Guidelines on the management of hyperbilirubinemia in infants 35 or more weeks' gestation, all hospitals should provide verbal or written information to parents explaining jaundice, the need to monitor infants for jaundice, and details on how that monitoring should be done. An example of such a handout is provided by the American Academy of Pediatrics.

3.8 Patient Preparation

3.8.1 Positioning

Infants receiving phototherapy should be placed lying flat on a radiant warmer or in a bassinet. Small or premature infants can remain in an infant incubator during

phototherapy. The infant should be naked with the exception of eye protection and a diaper to maximize the surface area of skin exposed to light. The phototherapy device should be placed at the side of the infant's bed with the light shining on the infant and covering as much surface area as possible.

When fluorescent tubes or LED devices are used, the infant should be placed as close as possible to the light source, typically within 10 cm.^[4] This increases the spectral irradiance of the light delivered. Halogen-based devices emit greater amounts of heat than fluorescent or LED devices and therefore need to be positioned at a greater distance from the infant. Providers should follow the manufacturer's recommendations on how far to position the halogen light source from the infant.

Fiberoptic pads can be positioned directly underneath the infant to provide an additional source of phototherapy. The fiberoptic pads do not emit significant heat. Due to their relatively hard surface, phototherapy pads should be used with caution in extremely low birth weight infants or other infants who are at risk for skin break down from pressure sores.

If phototherapy is provided through the top of an infant, incubator the light source should be kept perpendicular to the surface of the isolette to decrease light reflectance off the plastic, which diminishes the amount of light that reaches the infant inside the isolette. In cases of severe hyperbilirubinemia, white towels or aluminum foil can be placed around the interior of the bassinet to reflect light back on the infant and increase surface area exposure.

3.9 Monitoring & Follow up

Monitoring of serial bilirubin values in infants on phototherapy is important to confirm that the therapy is effective. With intensive phototherapy ($>30 \text{ mW/cm}^2$ per nm), a decrease in bilirubin concentration by 30-40% can be expected within the first 24 hours. The most significant drop in bilirubin concentration is typically seen within the first 4-6 hours of phototherapy. Thus, bilirubin concentrations are typically checked prior to the start of phototherapy, after 4-6 hours of phototherapy to confirm effectiveness, and then repeated at 12-24 hour intervals until levels are low enough to stop phototherapy.

Although no standard is noted for the discontinuation of phototherapy, current guidelines suggest stopping phototherapy on infants 35 or more weeks' gestation at birth readmitted after their birth hospitalization when the levels of total bilirubin fall below 13-14 mg/dL.

For infants with hemolytic disease, and in those younger than 3-4 days, a "rebound" bilirubin should be checked within 24 hours after discontinuation of phototherapy.^[4] This 24-hour rebound bilirubin check can also be considered in infants 35 or more weeks' gestation at birth with nonhemolytic jaundice who are readmitted with hyperbilirubinemia.

No evidenced-based guidelines to indicate when phototherapy should be discontinued in premature infants. In general, phototherapy is stopped when the total serum bilirubin level is several points lower than when it was started. Most practitioners routinely check a rebound bilirubin in all premature infants within 24-48 hours after discontinuation of phototherapy, or sooner if a hemolytic process is present.

3.10 Approach considerations

- ✓ Determine if the infant requires phototherapy based on the infant total serum bilirubin level, the gestation age, hours of life, and individual risk factors using established guidelines from the American Academy of Pediatrics.^[4]
- ✓ Place infant on warmer or in bassinet with diaper on and eye protection in place.
- ✓ Position phototherapy device at bedside with lights set at recommended distance from the infant. For fluorescent and LED lights, this is as close as possible to the infant's skin, typically less than 10 cm.^[4] If using a halogen spot light, the light should be kept at the manufacturer recommended distance to avoid overheating.
- ✓ Turn on the phototherapy lights.
- ✓ Direct light towards the infant with exposure of maximal surface area. If halogen spotlights are used, more than one light may be required to cover the entire infant with light. This is typically done with one light directed at the chest and head, with the second directed at the abdomen and legs.
- ✓ Measure the spectral irradiance of the phototherapy setup with a commercially available radiometer in several areas over the surface of the infant and average the results. See the image below.



Picture 3.2 : *neoBLUE light-emitting diode (LED) phototherapy radiometer.*

- ✓ Follow serial bilirubin levels to ensure the phototherapy is effectively decreasing the bilirubin level.
- ✓ Intermittently repeat measurements of the spectral irradiance and maintain the lights in the proper position to provide maximum benefit.

3.11 Device Summary

Several devices can be used to provide phototherapy. These include tungsten-halogen lamps, fluorescent tubes, fiberoptic systems, and gallium nitride LED lights. All these devices are capable of emitting light in the 430-490 nm band at standard spectral irradiance levels of 8-10 mW/cm² per nm. However, when intensive phototherapy is required either "special blue" fluorescent tubes or specially designed LED devices should be used because these are the only devices that can reliably provide more than 30 mW/cm² per nm in the 430-490 nm band.

3.12 Halogen-based phototherapy lamps

Halogen-based phototherapy lamps, or spotlights, use a commercially available tungsten-halogen light bulb and direct a strong beam of white/yellow light towards the infant. These devices are typically free-standing on a pole, or available as part of a radiant warmer. Halogen-based spot lights are the most heat producing of all the available phototherapy lights. Care must be taken not to place the devices closer to the infant than recommended by the manufacturer to avoid overheating the infant. Additionally, due to the associated heat output, halogen lights may result in increased insensible water loss in infants receiving phototherapy.

See the image below.



Picture 3.3 :*Infant under Ohmeda halogen lamp with eye protection.*

3.13 Fluorescent tubes

Fluorescent tubes used to deliver phototherapy have been classified as "daylight," "blue," and "special blue." A commercially available daylight tube is the F20T12/D (General Electric, Westinghouse, Sylvania). A commercially available blue fluorescent tube is the F20T12/B (General Electric, Westinghouse, Sylvania). Special blue fluorescent tubes include those labeled TL52/20W (Philips, Eindhoven, The Netherlands) or F20T12/BB (General Electric, Westinghouse, Sylvania).

In prior clinical studies, only the special blue fluorescent tubes were able to reliably emit light at more than 30 mW/cm^2 per nm in the 430-490 nm band. Special blue tubes are most effective because they emit light in the blue-green spectrum, which penetrates skin

well and is maximally absorbed by bilirubin. Fluorescent tubes are typically housed in a commercially available device which holds 4-8 tubes that are 24 inches. The device is typically attached to a pole and the height of the lighting device can be adjusted up and down. One commercially available device, the Bili Bassinet (Olympic Medical; Seattle, WA), contains special blue fluorescent tubes in a housing both above and below the infant.

3.14 Fiberoptic phototherapy

Fiberoptic phototherapy devices deliver light from a high intensity lamp to a fiberoptic blanket. These BiliBlanket devices are typically used in conjunction with overhead halogen, fluorescent, or LED systems. These devices are also commonly used to provide home phototherapy. A disadvantage of using fiberoptic pads is that they cover a fairly small surface area. Therefore, 2-3 pads may be needed to provide effective phototherapy. This is one reason why home phototherapy is reserved only for use in low-risk infants with total bilirubin levels 2-3 mg/dL lower than that recommended for intensive phototherapy. See the image below.



Picture 3.4: *Infant under neoBLUE phototherapy light and lying on fiberoptic phototherapy blanket.*

3.15 LED phototherapy

LED phototherapy systems, which use gallium nitride LEDs, are the newest devices used to provide phototherapy. Gallium nitride LEDs emit high-intensity light in the blue-green portion of the spectrum within a narrow wavelength (460-485 nm). LEDs offer some

advantages to other phototherapy sources. Their narrow wavelength of emission is close to the wavelength at which light is maximally absorbed by bilirubin. Additionally, the spectral quality of the LED device can be customized by the use of varying proportions of blue, blue-green, and green LEDs. Also, LEDs generate less heat than either halogen or fluorescent lamps, and can thus be positioned very close to the skin without significant risk of overheating or burns.

Prior studies have shown that using an array of 600, 3-mm blue LEDs, at a short distance from an infant can achieve an irradiance of more than 200 mW/cm² per nm. Specially designed LED systems, such as the neoBLUE LED Phototherapy system (Natus Inc; San Carlos, CA), are recommended by the American Academy of Pediatrics for use during intensive phototherapy. See the image below.

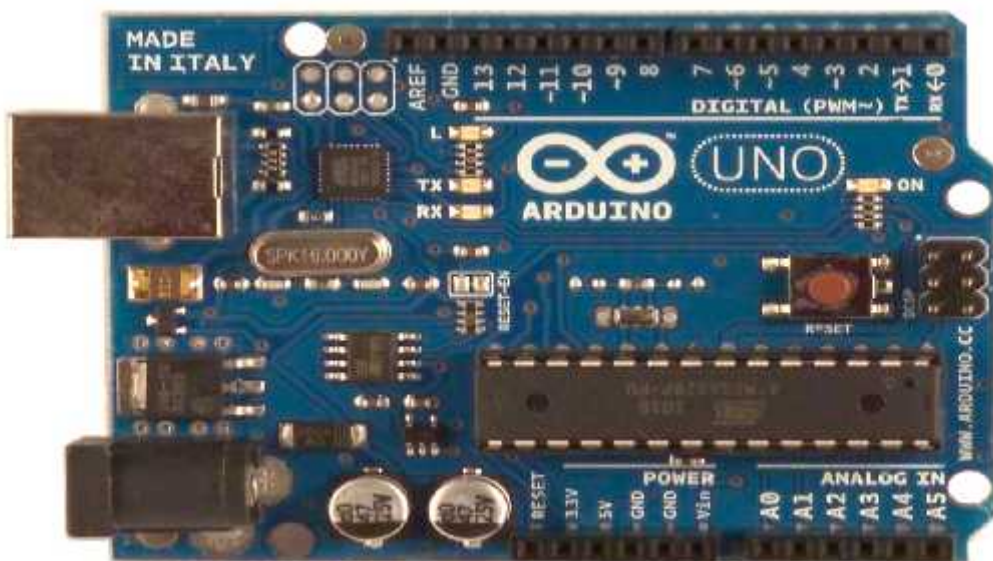


Picture 3.5: neoBLUE light-emitting diode (LED) phototherapy system.

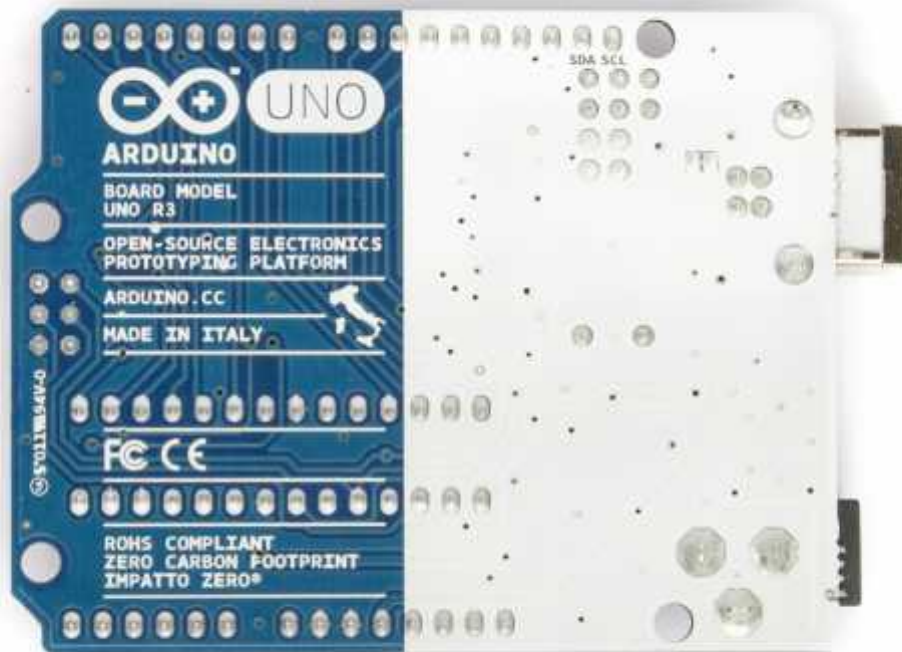
4. 'ARDUINO' PROGRAMMABLE CIRCUIT BOARD

4.1 Arduino

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.



Picture 4.1 : Arduino R3 front



Picture 4.2: Arduino R3 back

- Revision 2 of the Uno board has a resistor pulling the 8U2 HWB line to ground, making it easier to put into DFU mode.
- Revision 2 of the board has the following new features:
 - ✓ 1.0 pinout: added SDA and SCL pins that are near to the AREF pin and two other new pins placed near to the RESET pin, the IOREF that allow the shields to adapt to the voltage provided from the board. In future, shields will be compatible with both the board that uses the AVR, which operates with 5V and with the Arduino Due that operates with 3.3V. The second one is a not connected pin, that is reserved for future purposes.
 - ✓ Stronger RESET circuit.
 - ✓ Atmega 16U2 replace the 8U2.

"Uno" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Uno is the latest in a series of USB Arduino boards, and the reference model for the

Arduino platform; for a comparison with previous versions, see the index of Arduino boards.

4.2 Summary

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz
Length	68.6 mm
Width	53.4 mm
Weight	25 g

Table 4.1: Technical properties of the ‘Arduino’ programmable circuit board

4.3 Schematic & Reference Design

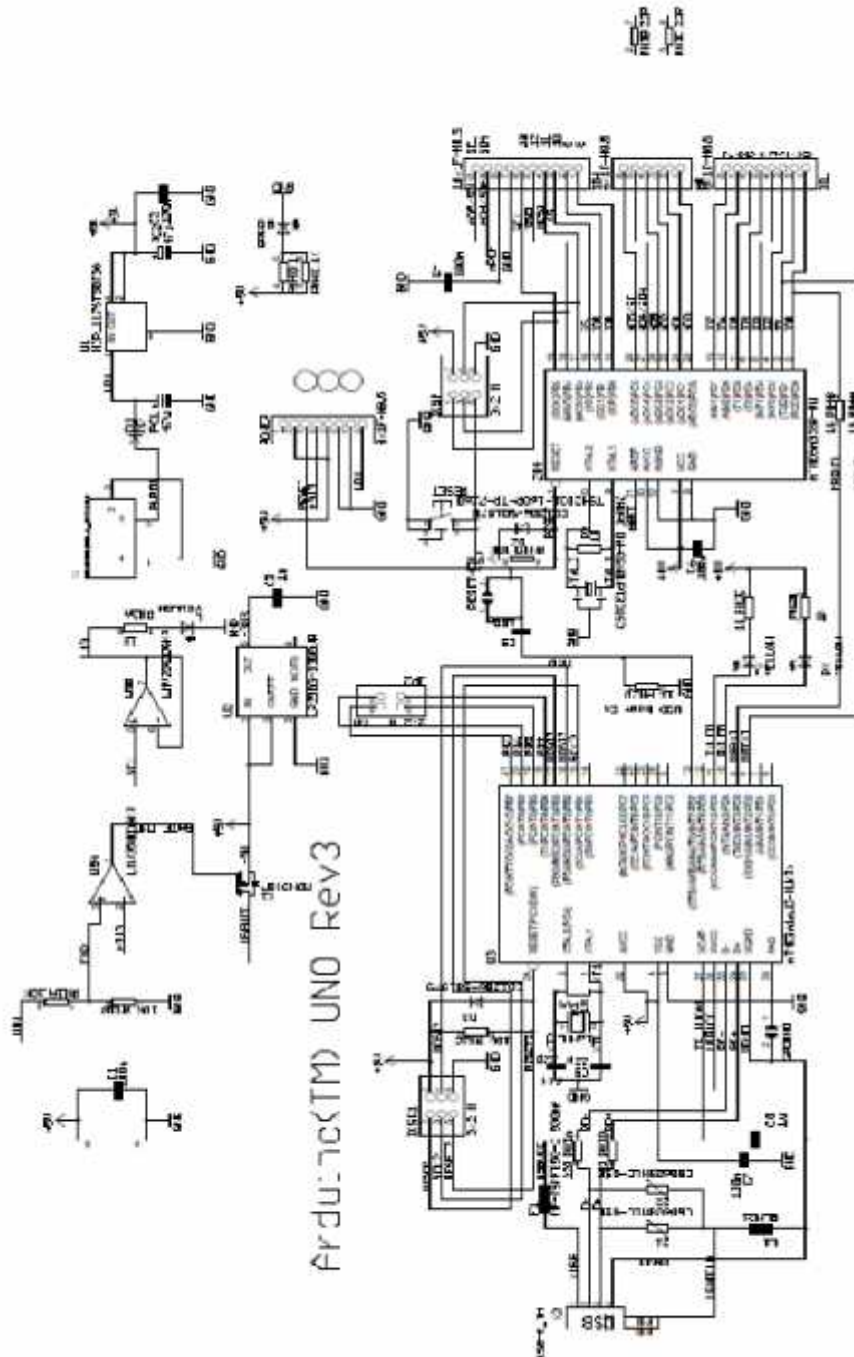


Diagram 4.3: Schematic & Reference Design

Reference Designs ARE PROVIDED "AS IS" AND WITH ALL FAULTS. Arduino DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING PRODUCTS, INCLUDING BUT NOT LIMITED TO, IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. Arduino may make changes to specifications and product descriptions at any time, without notice. The Customer must not rely on the absence or characteristics of any features or instructions marked "reserved" or "undefined." Arduino reserves the right to alter specifications or instructions at any time without notice, and shall have no responsibility whatsoever for conflicts or incompatibilities arising from future changes to them. The product information on the web site or materials is subject to change without notice. Do not finalize a design with this information. ARDUINO is a registered trademark. Use of the ARDUINO name must be compliant with <http://www.arduino.cc/en/Main/Policy>

Note: The Arduino reference design can use an Atmega8, 168, or 328, Current models use an ATmega328, but an Atmega8 is shown in the schematic for reference. The pin configuration is identical on all three processors.

4.4 Power

The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically.

External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

4.4.1 The power pins are as follows:

- ✓ VIN. The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.
- ✓ 5V. This pin outputs a regulated 5V from the regulator on the board. The board can be supplied with power either from the DC power jack (7 - 12V), the USB connector (5V), or the VIN pin of the board (7-12V). Supplying voltage via the 5V or 3.3V pins bypasses the regulator, and can damage your board. We don't advise it.
- ✓ 3V3. A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- ✓ GND. Ground pins.
- ✓ IOREF. This pin on the Arduino board provides the voltage reference with which the microcontroller operates. A properly configured shield can read the IOREF pin voltage and select the appropriate power source or enable voltage translators on the outputs for working with the 5V or 3.3V.

4.5 Memory

The ATmega328 has 32 KB (with 0.5 KB used for the bootloader). It also has 2 KB of SRAM and 1 KB of EEPROM (which can be read and written with the EEPROM library).

4.6 Input and Output

Each of the 14 digital pins on the Uno can be used as an input or output, using `pinMode()`, `digitalWrite()`, and `digitalRead()` functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions:

- ✓ Serial: 0 (RX) and 1 (TX). Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.
- ✓ External Interrupts: 2 and 3. These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the `attachInterrupt()` function for details.
- ✓ PWM: 3, 5, 6, 9, 10, and 11. Provide 8-bit PWM output with the `analogWrite()` function.
- ✓ SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). These pins support SPI communication using the SPI library.
- ✓ LED: 13. There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.

The Uno has 6 analog inputs, labeled A0 through A5, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though it is possible to change the upper end of their range using the AREF pin and the `analogReference()` function. Additionally, some pins have specialized functionality:

- ✓ TWI: A4 or SDA pin and A5 or SCL pin. Support TWI communication using the Wire library.
- ✓ There are a couple of other pins on the board:
- ✓ AREF. Reference voltage for the analog inputs. Used with `analogReference()`.

- ✓ Reset. Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

4.7 Communication

The Arduino Uno has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX).

An ATmega16U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer. The '16U2 firmware uses the standard USB COM drivers, and no external driver is needed. However, on Windows, a .inf file is required. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the USB-to-serial chip and USB connection to the computer (but not for serial communication on pins 0 and 1).

A SoftwareSerial library allows for serial communication on any of the Uno's digital pins. The ATmega328 also supports I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus; see the documentation for details. For SPI communication, use the SPI library.

4.8 Programming

The Arduino Uno can be programmed with the Arduino software (download). Select "Arduino Uno from the Tools > Board menu (according to the microcontroller on your board). For details, see the reference and tutorials.

The ATmega328 on the Arduino Uno comes preburned with a bootloader that allows you to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol (reference, C header files).

You can also bypass the bootloader and program the microcontroller through the ICSP (In-Circuit Serial Programming) header using Arduino ISP or similar; see these instructions for details.

The ATmega16U2 (or 8U2 in the rev1 and rev2 boards) firmware source code is available

The ATmega16U2/8U2 is loaded with a DFU bootloader, which can be activated by:

- ✓ On Rev1 boards: connecting the solder jumper on the back of the board (near the map of Italy) and then resetting the 8U2.
- ✓ On Rev2 or later boards: there is a resistor that pulling the 8U2/16U2 HWB line to ground, making it easier to put into DFU mode.

You can then use Atmel's FLIP software (Windows) or the DFU programmer (Mac OS X and Linux) to load a new firmware. Or you can use the ISP header with an external programmer (overwriting the DFU bootloader). See this user-contributed tutorial for more information.

4.9 Automatic (Software) Reset

Rather than requiring a physical press of the reset button before an upload, the Arduino Uno is designed in a way that allows it to be reset by software running on a connected computer. One of the hardware flow control lines (DTR) of the ATmega8U2/16U2 is connected to the reset line of the ATmega328 via a 100 nanofarad capacitor. When this line is asserted (taken low), the reset line drops long enough to reset the chip. The Arduino software uses this capability to allow you to upload code by simply pressing the upload button in the Arduino environment. This means that the bootloader can have a shorter timeout, as the lowering of DTR can be well-coordinated with the start of the upload. This setup has other implications. When the Uno is connected to either a computer running Mac OS X or Linux, it resets each time a connection is made to it from software (via USB). For the following half-second or so, the bootloader is running on the Uno. While it is programmed to ignore malformed data (i.e. anything besides an upload of new code), it will intercept the first few bytes of data sent to the board after a connection is opened. If a sketch running on the board receives one-time configuration or other data when it first starts, make sure that the software with which it communicates waits a second after opening the connection and before sending this data.

The Uno contains a trace that can be cut to disable the auto-reset. The pads on either side of the trace can be soldered together to re-enable it. It's labeled "RESET-EN".

You may also be able to disable the auto-reset by connecting a 110 ohm resistor from 5V to the reset line; see this forum thread for details.

4.10 USB Overcurrent Protection

The Arduino Uno has a resettable polyfuse that protects your computer's USB ports from shorts and overcurrent. Although most computers provide their own internal protection, the fuse provides an extra layer of protection. If more than 500 mA is applied to the USB port, the fuse will automatically break the connection until the short or overload is removed.

4.11 Physical Characteristics

The maximum length and width of the Uno PCB are 2.7 and 2.1 inches respectively, with the USB connector and power jack extending beyond the former dimension. Four screw holes allow the board to be attached to a surface or case. Note that the distance between digital pins 7 and 8 is 160 mil (0.16"), not an even multiple of the 100 mil spacing of the other pins.

5.WHY DO WE NEED TO USE TIMER ON PHOTOTHERAPY?

5.1 At the normal conditions

Phototherapy is a harmless treatment since it is used properly. But it may be hazardous for the baby if it is overused.

5.2 Main risks of the phototherapy

5.2.1 It may cause skin rash and burns

This affect described in the image below.



Picture 5.1: *A hazardous type of the phototherapy to overused.(Burns)*

5.2.2 It damages the nerve layer at the back of the eye (retina)

This affect described in the image below.

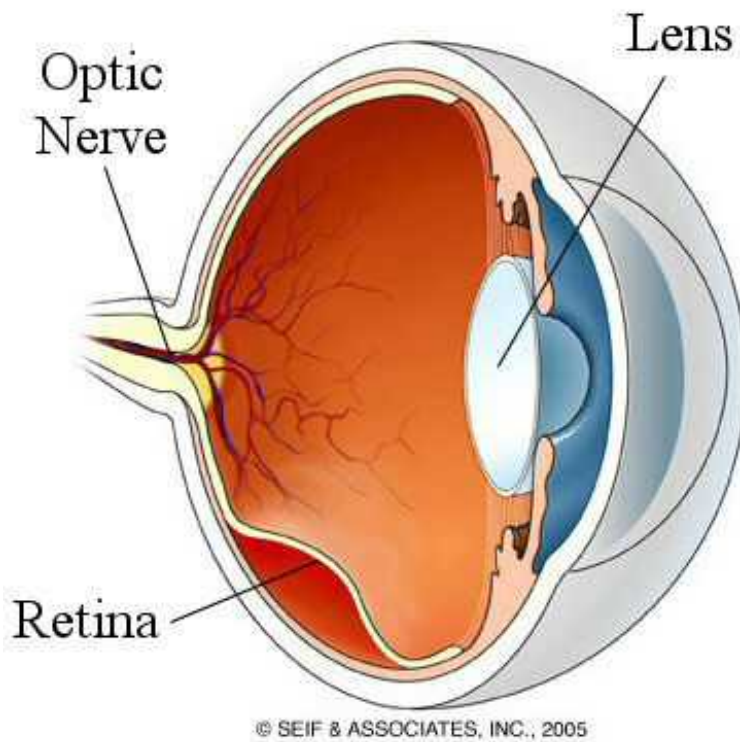


Diagram 5.1: *A hazardous type of the phototherapy to overused.(Optic nerve damaging)*

5.2.3 Dehydration

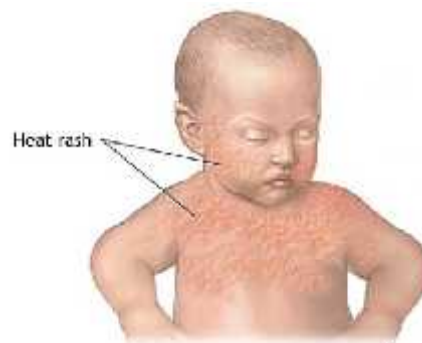
Dehydration, if the infant does not receive adequate fluids when feeding. This affect described in the image below.



Picture 5.2: A hazardous type of the phototherapy to overused.(Dehydration)

5.2.4 Skin Rash

Difficulty in maintaining the proper body temperature. And it may cause permanent diseases. This affect described in the image below.



Picture 5.3: A hazardous type of the phototherapy to overused.(Skin rash)

5.3 Improvements

- There are TWO important factors for the newborn babies health.
- ✓ 1-Temperature
- ✓ 2-Noise

For this reasons, we have decided to add sensors to measure temperature. If the temperature is higher than limit; the cooler fan will start working. Also we add desibelmeter (microphone) that gives warning to the staff to notify them that the room is too noisy for the baby.

5.4 Advantages

- ✓ Phototherapy process for babies generally used in newborn or premature care units. Sometimes the staff may forget the phototherapy's starting time or the time that they should end the phototherapy because of some reasons such as changing the shift, workload (emergencies) or omission. Timing circuit ensures the baby will be exposed to phototherapy exact required time.
- ✓ After staff starts the process by adjusting the time, timing circuit will stop the process instead of waiting the staff to stop it.
- ✓ Timing circuit prevents all the negative effects that overdosed phototherapy may cause and it provides maximum efficiency.

5.5 The flowchart of the our innovative project

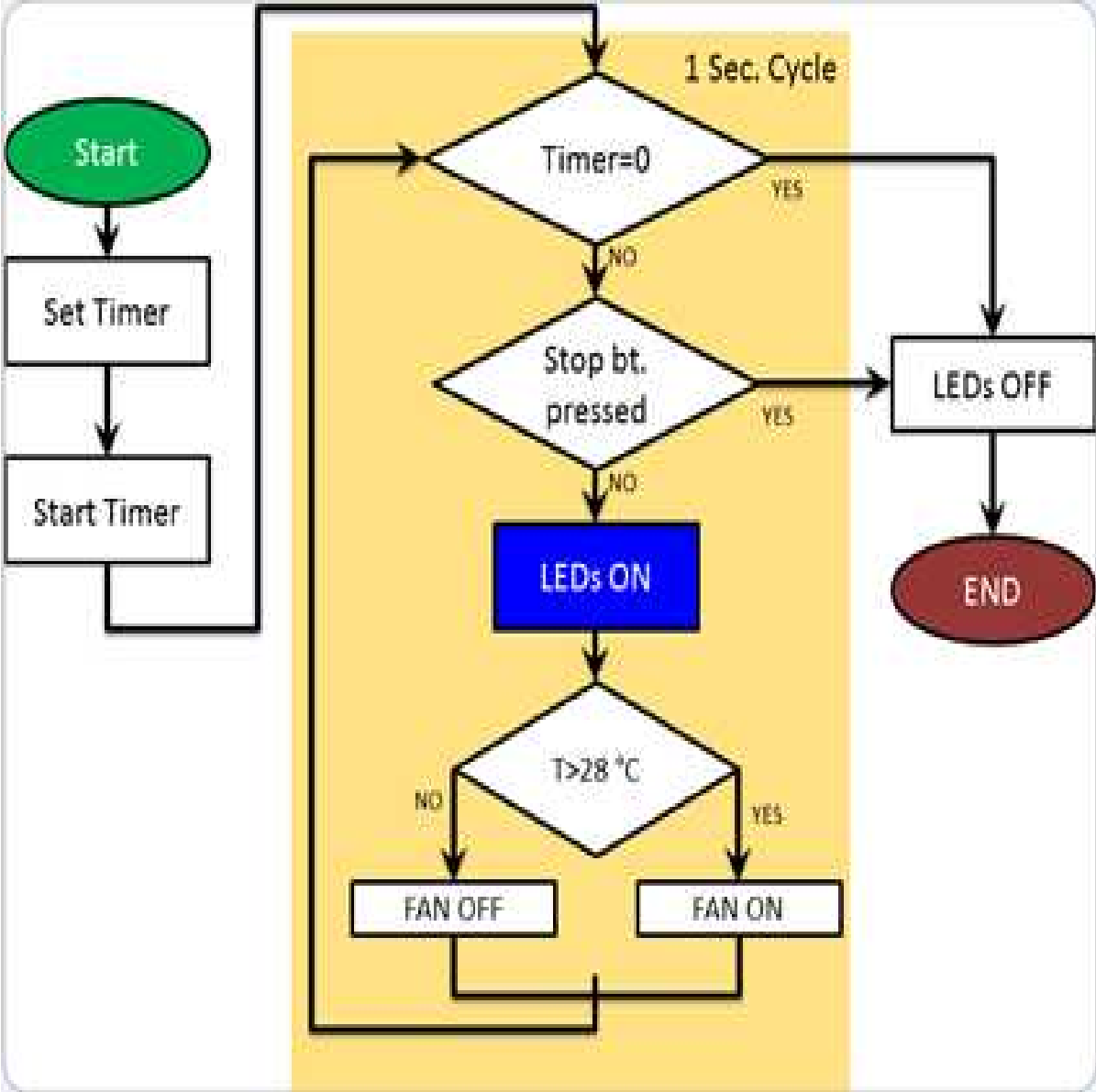
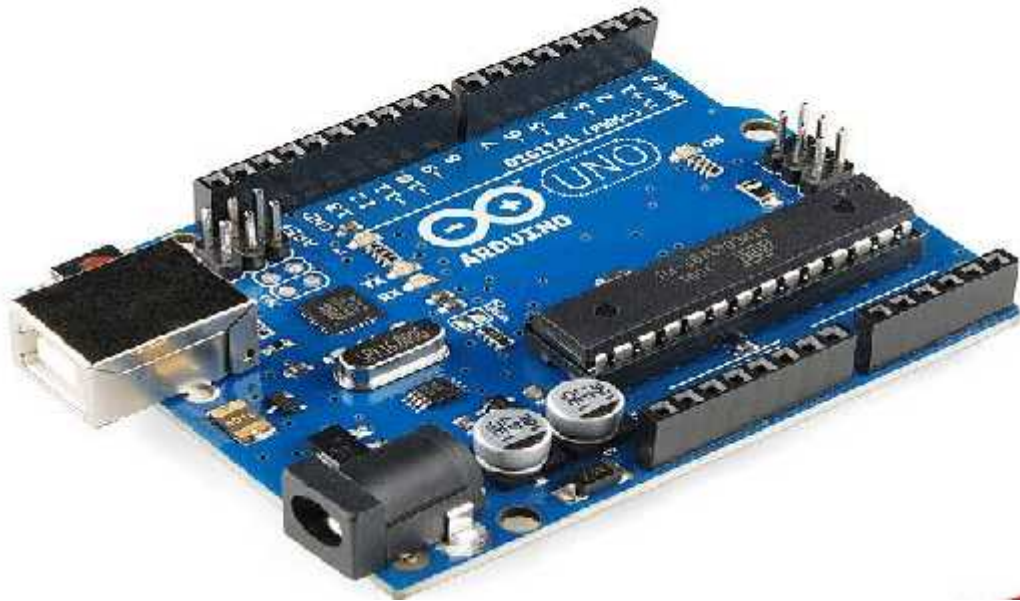


Diagram 5.2 :The flowchart of the our innovative project

5.6 Requirements

5.6.1 An 'Arduino Uno R3' programmable circuit board (x1)



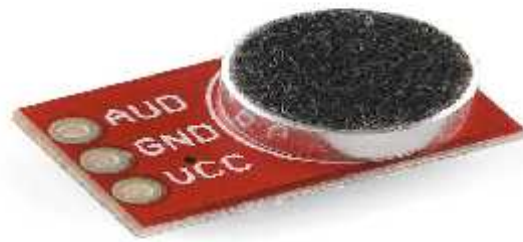
Picture 5.4: Arduino

5.6.2 2x16 LCD screen shield V2 for 'Arduino Uno R3'(x1)



Picture 5.5: 2x16 LCD screen shield V2 for 'Arduino Uno R3'

5.6.5 Sparkfun electret microphone (x1)



Picture 5.8: Sparkfun electret microphone

5.6.6 Relays (x2)



Picture 5.9: Relays

5.6.7 Adapter (220VAC to 12VDC) (x1)



Picture 5.10: Adapter (220VAC to 12VDC)

5.7 Diagram of Phototherapy With Timer

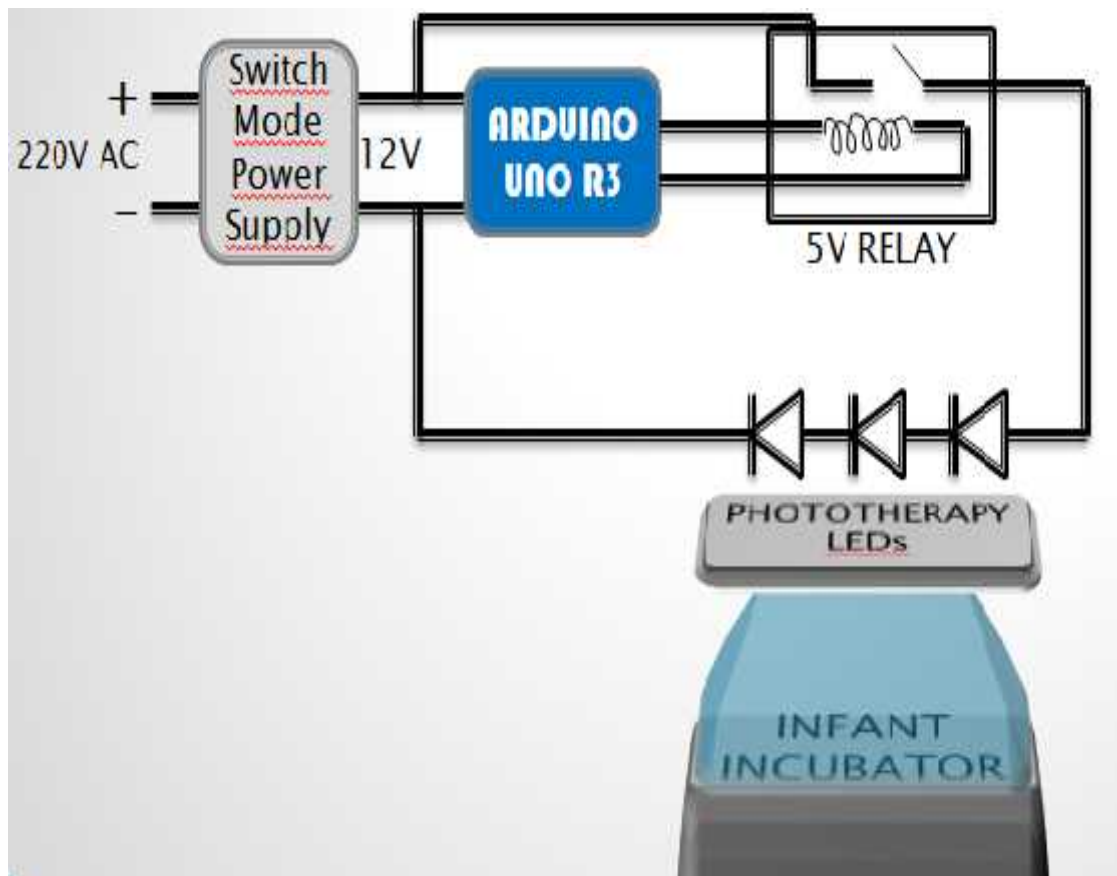


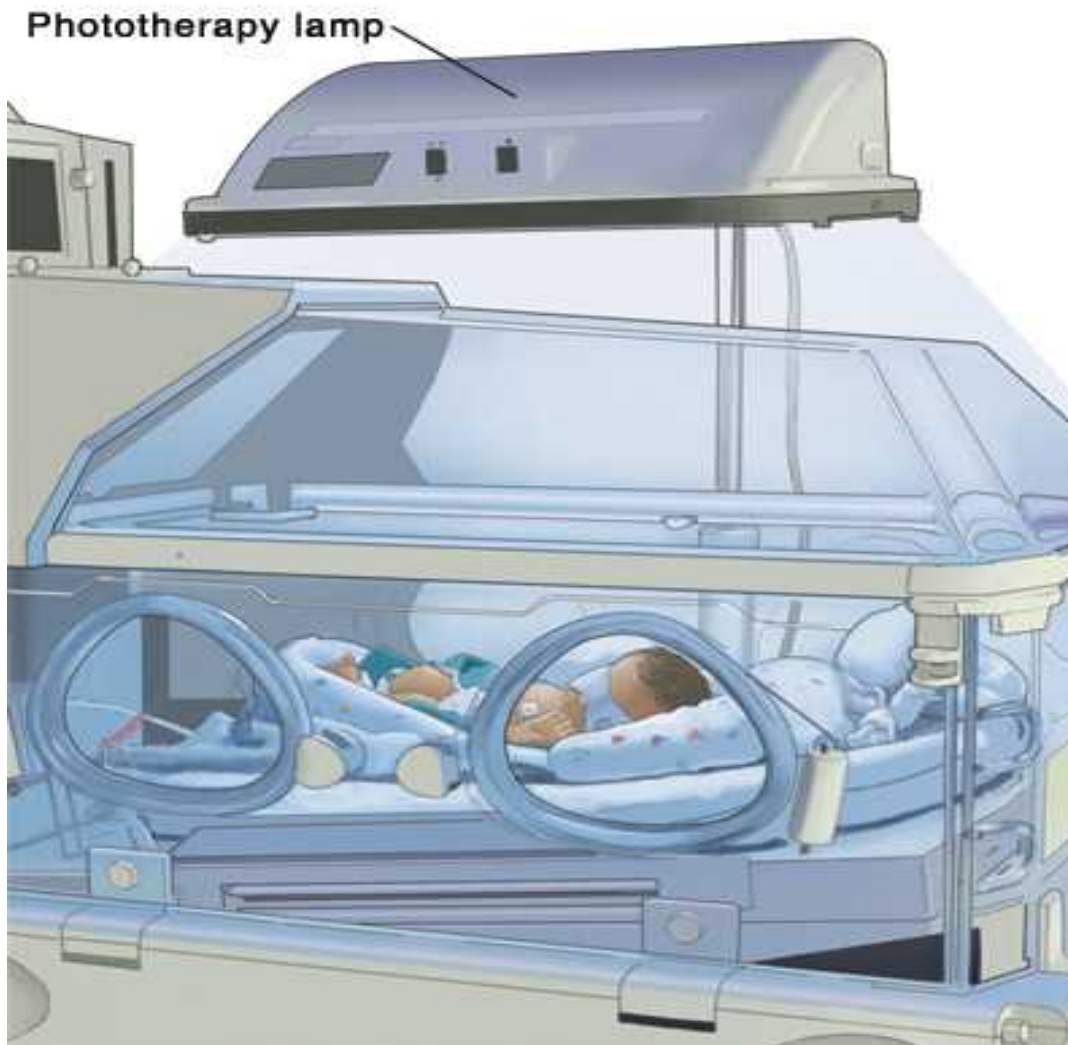
Diagram 5.3: Diagram of Phototherapy With Timer

5.8 How it used?

- ✓ The 'STANDBY' LED shows if there is a power in the timing device.
- ✓ Applying time is adjusted by the arrow buttons on the device and will be activated by using 'START/STOP' button. When it's activated
- ✓ After the time runs out, the circuit will stop working automatically.

5.9 Innovation for Phototherapy

- ✓ As timer can be inserted to new phototherapy device designs, also it can be assembled to the old devices as an upgrade.
- ✓ By this way the upgraded old device also provides maximum efficiency.



Picture 5.11: It can apply to in front of the old phototherapy.

5.10 Purpose

- ✓ To recuperate newborns with hyperbilirubinemia as fast as possible without any harm and allow parents to grow healthy generations.
- ✓ The timing circuit will help a lot to phototherapy applying management to overcome newborn's disease.

REFERENCES

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- 2) <http://www.muschealth.com/lab/content.aspx?id=150157>
- 3) <http://www.nlm.nih.gov/medlineplus/ency/article/003479.htm>
- 4) <http://www.nlm.nih.gov/medlineplus/ency/article/001559.htm>
- 5) <http://www.webmd.com/parenting/baby/understanding-newborn-jaundice-basics>
- 6) <http://www.hepatitiscentral.com/hcv/labs/disorder.html>
- 7) <http://emedicine.medscape.com/article/178757-overview>
- 8) <http://www.webmd.com/digestive-disorders/bilirubin-15434>
- 9) <http://www.healthline.com/health/bilirubin-blood#Risks5>
- 10) <http://emedicine.medscape.com/article/1894477-overview#aw2aab6b2b2>
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- 12) http://www.pennmedicine.org/encyclopedia/ency_images/encymulti/images/en/7088.jpg
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- 14) http://upload.wikimedia.org/wikipedia/commons/c/c1/Structure_of_bilirubin.png
- 15) <http://models.street-artists.org/wp-content/uploads/2010/05/bilirisk.png>
- 16) <http://www.nlm.nih.gov/medlineplus/ency/images/ency/fullsize/22694.jpg>
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- 19) http://www.transitioning.org/wp-content/uploads/2012/05/wires-maternity_full_600.jpg
- 20) http://img.medscape.com/pi/emed/ckb/clinical_procedures/79926-1413466-1894477-2009779tn.jpg
- 21) <http://www.rch.org.au/uploadedImages/Main/Content/rhcpg/Skin%20care%201.JPG?n=1701>
- 22) <http://www.sw.org/misc/health/images/%7B2BA00BA1-2F4B-4D41-8A4D-46278D9D0E41%7D.jpg>
- 23) <http://medicine.um.edu.my/images/fom/Acad%20Prog/medInfo/image/baby.jpg>
- 24) <http://profahmet.wordpress.com/dikkat/>
- 25) <http://www.mountainstar.kramesonline.com/HealthSheets/86055.img>
- 26) <http://www.medscape.com/viewarticle/809580>

APPENDIX

THE COMPLETE PROGRAM LISTING

```
/*=====
    KUVEZ V1.0
=====*/
#include <LiquidCrystal.h> // LCD library
/*=====
    ADC DEFINING
=====*/
#define DS1307_ADDRESS 0x68
byte zero = 0x00; //workaround for issue #527
/*=====
    BUTTON ADC DEFINING
=====*/
#define BUTTON_ADC_PIN    A0 // A0 is the button ADC input
#define LCD_BACKLIGHT_PIN  2 // D2 controls LCD backlight
// ADC readings expected for the 5 buttons on the ADC input
#define RIGHT_10BIT_ADC    0 // right
#define UP_10BIT_ADC       64 // up
#define DOWN_10BIT_ADC     158 // down
#define LEFT_10BIT_ADC     288 // left
#define SELECT_10BIT_ADC   533 // select
#define BUTTONHYSTERESIS  10 // hysteresis for valid button sensing window
/*=====
    BUTTON DEFINING
=====*/
#define BUTTON_NONE        0 //
```



```

#define BUTTON_RIGHT      1 //
#define BUTTON_UP        2 //
#define BUTTON_DOWN      3 //
#define BUTTON_LEFT      4 //
#define BUTTON_SELECT    5 //

/*=====
          BACKLIGHT DEFINING
=====*/

#define LCD_BACKLIGHT_OFF()  digitalWrite( LCD_BACKLIGHT_PIN, LOW )
#define LCD_BACKLIGHT_ON()   digitalWrite( LCD_BACKLIGHT_PIN, HIGH )
#define LCD_BACKLIGHT(state) { if( state ){digitalWrite( LCD_BACKLIGHT_PIN, HIGH
);}else{digitalWrite( LCD_BACKLIGHT_PIN, LOW );}}

/*=====
          BUTTON VARIABLES
=====*/

byte buttonJustPressed = false;    //this will be true after a ReadButtons() call if triggered
byte buttonJustReleased = false;   //this will be true after a ReadButtons() call if triggered
byte buttonWas         = BUTTON_NONE; //used by ReadButtons() for detection of button
events

/*=====
          TIMER VARIABLES
=====*/

int time[4]; // Time array
int time_fake[4]; // Fake Time Array

int cur = 3; // Cursor Variables
int start = 0; // Start- stop control variable

/*=====
          TEMPERATURE LDR & SOUND VARIABLES
=====*/

```

```

int temp_avg[10];
int temp = 0;

int ldr_avg[10];
int ldr = 0;

int sound_avg[10];
int sound = 0;
/*=====
                RELAY & FAN VARIABLES
=====*/
int relay = 13;
int fan = 12;
/*=====
                LCD SETUP
=====*/
LiquidCrystal lcd( 8, 9, 4, 5, 6, 7 );  //( RS, E, LCD-D4, LCD-D5, LCD-D6, LCD-D7 )

void setup()
{
  Serial.begin(9600);
  //button adc input
  pinMode( BUTTON_ADC_PIN, INPUT );    //ensure A0 is an input
  digitalWrite( BUTTON_ADC_PIN, LOW ); //ensure pullup is off on A0
  //lcd backlight control
  digitalWrite( LCD_BACKLIGHT_PIN, HIGH ); //backlight control pin D3 is high (on)
  pinMode( LCD_BACKLIGHT_PIN, OUTPUT ); //D3 is an output

  // Relay & Fan pin output
  pinMode(relay, OUTPUT);
  pinMode(fan, OUTPUT);
  digitalWrite(relay, LOW);

```

```

digitalWrite(fan, LOW);

//set up the LCD number of columns and rows:
lcd.begin( 16, 2 );
lcd.setCursor(0, 0);
lcd.print("Yusuf Incekalan");
lcd.setCursor(0, 1);
lcd.print("Suleyman Oksuz");
delay(2000);
LCD_BACKLIGHT_OFF();
}

/*=====
                MAIN LOOP
=====*/

void loop()
{
  byte button;
  byte timestamp;

  LCD_BACKLIGHT_OFF();

  //get the latest button pressed, also the buttonJustPressed, buttonJustReleased flags
  button = ReadButtons();

  // Control Buttons
  switch (button) {
  case 0: // your hand is on the sensor
    lcd.setCursor(0, 1); // cursor bir alt satıra yönlendiriliyor

```

```

if(start % 2 == 1){
  print_time_fake();}
if(start % 2 == 0){
  print_time();}
break;
case 1: // your hand is close to the sensor
  lcd.setCursor(0, 1);// cursor bir alt satıra yönlendiriliyor
  cur++;
  if (cur < 0)
    cur = 3;
  else if (cur > 3)
    cur = 0;
  print_time();
  curs();
  break;
case 2: // your hand is a few inches from the sensor
  lcd.setCursor(0, 1);// cursor bir alt satıra yönlendiriliyor
  time[cur]++;
  if (time[cur] < 0)
    time[cur] = 0;
  print_time();
  LCD_BACKLIGHT_ON();
  break;
case 3: // your hand is nowhere near the sensor
  lcd.setCursor(0, 1);// cursor bir alt satıra yönlendiriliyor
  time[cur]--;
  if (time[cur] < 0)
    time[cur] = 0;
  print_time();
  LCD_BACKLIGHT_ON();
  break;
case 4: // your hand is nowhere near the sensor

```

```

lcd.setCursor(0, 1); // cursor bir alt satıra yönlendiriliyor
cur--;
if (cur < 0)
    cur = 3;
else if (cur > 3)
    cur = 0;
print_time();
curs();
break;
case 5: // your hand is nowhere near the sensor
    //lcd.clear();
    lcd.setCursor(0, 1); // cursor bir alt satıra yönlendiriliyor
    LCD_BACKLIGHT_ON();
    if(start % 2 == 0){
        lcd.print ("  START  ");
        lcd.print(" ");
        delay(1000);
    }

    else if(start % 2 == 1){
        lcd.print ("  STOP  ");
        delay(1000);
    }

    start++;
    break;
}

//clear the buttonJustPressed or buttonJustReleased flags, they've already done their job
now.
if( buttonJustPressed )
    buttonJustPressed = false;

```

```

if( buttonJustReleased )
    buttonJustReleased = false;

temper_ldr_sound();
times();
}
/*=====
                TEMPERATURE LDR & SOUND
=====*/
void temper_ldr_sound(){
for(int i=0; i<10; i++){ // Sicaklik Sensoru Ortalamasi
    temp_avg[i] = analogRead(A2);
    temp = temp_avg[i] + temp;
    delay(20);
}
for(int i=0; i<10; i++){ // LDR Sensoru Ortalamasi
    ldr_avg[i] = analogRead(A1);
    ldr = ldr_avg[i] + ldr;
    delay(20);
}
for(int i=0; i<10; i++){ // Ses Sensoru Ortalamasi
    sound_avg[i] = analogRead(A5);
    sound = sound_avg[i] + sound;
    delay(20);
}
temp = temp/25;
sound = sound / 10;
ldr = ldr / 10;
print_temp();
}
/*=====
                PRINT TIME FUNCTION
=====

```

```

=====*/
void print_time(){
    lcd.setCursor(0,1);
    lcd.print ("Timer: ");
    lcd.print (time[0]);
    lcd.print (time[1]);
    lcd.print (":");
    lcd.print (time[2]);
    lcd.print (time[3]);
    lcd.print (" ");
}
/*=====
    PRINT TIME FAKE FUNCTION
=====*/
void print_time_fake(){

    int timer = 0;
    int tenmin = 0;
    int minute = 0;
    int tensesc = 0;
    int second = 0;
    byte buttons;
    for(int i=0; i<4; i++){
        time_fake[i] = time[i];
    }
    while((((time_fake[0]*600) + (time_fake[1]*60) + (time_fake[2]*10) +
time_fake[3])!=timer){
        int sec = ((time_fake[0]*600) + (time_fake[1]*60) + (time_fake[2]*10) + time_fake[3])-
timer;
        buttons = ReadButtons();
        lcd.setCursor(0,0);
        temper_ldr_sound();

```

```

tenmin = (sec % 3600)/600;
minute = (sec % 600)/60;
tensec = (sec % 60)/10;
second = (sec % 10);
lcd.setCursor(0,1);
lcd.print("  ");
lcd.print (tenmin);
lcd.print (minute);
lcd.print (':');
lcd.print (tensec);
lcd.print (second);
digitalWrite(relay, HIGH);
if (temp > 20)
  digitalWrite(fan, OUTPUT);
else
  digitalWrite(fan, LOW);
if(buttons == 5)break;
delay(400);
timer++;
}
delay(600);
start++;
lcd.clear();
lcd.setCursor(0,0);
lcd.print ("  THERAPY  ");
lcd.setCursor(0,1);
LCD_BACKLIGHT_ON();
lcd.print ("  COMPLETED!  ");
digitalWrite(relay, LOW);
digitalWrite(fan, LOW);
delay(1000);
}

```



```

/*=====
      PRINT TEMPERATURE FUNCTION
=====*/
void print_temp(){
    lcd.clear();
    lcd.print ("T:");
    lcd.print (temp);
    lcd.print ("C");
    lcd.print (" ");
    lcd.print ("L:");
    ldr=map(ldr,0,1023,0,100);
    lcd.print (ldr);
    lcd.print (" ");
    lcd.print ("S:");
    sound=map(sound,0,1023,0,100);
    lcd.print (sound);
}

```

```

/*=====
      TIME CONTROL FUNCTION
=====*/
void times(){

    if(time[0] > 9)
        time[0] = 0;
    if(time[1] > 9)
        time[1] = 0;
    if(time[2] > 5){
        time[2] = 0;
        time[1]=time[1]+1;}
    if(time[3] > 9){
        time[3] = 0;
        time[2]=time[2]+1;}
}

```

```

}
/*=====
          CURSOR FUNCTION
=====*/
void curs(){

    if(cur == 0){
        lcd.setCursor(0, 1);
        lcd.print ("Timer: ");
        lcd.print (" _");
        lcd.print (time[1]);
        lcd.print (":");
        lcd.print (time[2]);
        lcd.print (time[3]);
        lcd.print ("  ");
        LCD_BACKLIGHT_ON();}

    else if(cur == 1){
        lcd.setCursor(0, 1);
        lcd.print ("Timer: ");
        lcd.print (time[0]);
        lcd.print (" _");
        lcd.print (":");
        lcd.print (time[2]);
        lcd.print (time[3]);
        lcd.print ("  ");
        LCD_BACKLIGHT_ON();}

    else if(cur == 2){
        lcd.setCursor(0, 1);
        lcd.print ("Timer: ");

```

```

    lcd.print (time[0]);
    lcd.print (time[1]);
    lcd.print (":");
    lcd.print ("_");
    lcd.print (time[3]);
    lcd.print (" ");
    LCD_BACKLIGHT_ON();}

else if(cur == 3){
    lcd.setCursor(0, 1);
    lcd.print ("Timer: ");
    lcd.print (time[0]);
    lcd.print (time[1]);
    lcd.print (":");
    lcd.print (time[2]);
    lcd.print ("_");
    lcd.print (" ");
    LCD_BACKLIGHT_ON();}
}

/*=====
                BUTTON FUNCTION
=====*/

byte ReadButtons()
{
    unsigned int buttonVoltage;
    byte button = BUTTON_NONE; // return no button pressed if the below checks don't write
to btn

    //read the button ADC pin voltage
    buttonVoltage = analogRead( BUTTON_ADC_PIN );
    //sense if the voltage falls within valid voltage windows
    if( buttonVoltage < ( RIGHT_10BIT_ADC + BUTTONHYSTERESIS ) )

```

```

{
    button = BUTTON_RIGHT;
}
else if( buttonVoltage >= ( UP_10BIT_ADC - BUTTONHYSTERESIS )
    && buttonVoltage <= ( UP_10BIT_ADC + BUTTONHYSTERESIS ) )
{
    button = BUTTON_UP;
}
else if( buttonVoltage >= ( DOWN_10BIT_ADC - BUTTONHYSTERESIS )
    && buttonVoltage <= ( DOWN_10BIT_ADC + BUTTONHYSTERESIS ) )
{
    button = BUTTON_DOWN;
}
else if( buttonVoltage >= ( LEFT_10BIT_ADC - BUTTONHYSTERESIS )
    && buttonVoltage <= ( LEFT_10BIT_ADC + BUTTONHYSTERESIS ) )
{
    button = BUTTON_LEFT;
}
else if( buttonVoltage >= ( SELECT_10BIT_ADC - BUTTONHYSTERESIS )
    && buttonVoltage <= ( SELECT_10BIT_ADC + BUTTONHYSTERESIS ) )
{
    button = BUTTON_SELECT;
}
//handle button flags for just pressed and just released events
if( ( buttonWas == BUTTON_NONE ) && ( button != BUTTON_NONE ) )
{
    //the button was just pressed, set buttonJustPressed, this can optionally be used to trigger
a once-off action for a button press event
    //it's the duty of the receiver to clear these flags if it wants to detect a new button change
event
    buttonJustPressed = true;
    buttonJustReleased = false;
}

```

```
}  
if( ( buttonWas != BUTTON_NONE ) && ( button == BUTTON_NONE ) )  
{  
    buttonJustPressed = false;  
    buttonJustReleased = true;  
}  
  
//save the latest button value, for change event detection next time round  
buttonWas = button;  
  
return( button );  
}
```