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# ICU MONITORING SYSTEM USING ZYNQ ARCHITECTURE

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## ABSTRACT

Monitoring the health of the ICU patients is a very important aspect. A person should be present for monitoring the health of the ICU patients. But always a person can't be there with the patient. We are aware that when a baby is delivered prematurely, has medical problems, or had a difficult birth, they are admitted to the critical care unit of the hospital. The ICU also provides care for infants who have medical disorders such breathing difficulties, heart issues, infections, or birth abnormalities. A baby may be at high risk and have a higher possibility of being admitted to the intensive care unit due to any of the following causes. In medical applications, embedded systems play a critical role. Due to their one-time programmability, these ASIC applications are very expensive to design and have large NRE costs. They are also not amenable to modifications. Reconfigurable PLDs offer a better option as a result. There is a need for many in the midst of the Covid 19 outbreak, there is a need for more affordable medical facilities with efficient monitoring. The recommended medical usage is an ICU monitoring system as a result. built on an FPGA development board based on the Zynq architecture. The system's functionality includes monitoring and OLED display of the ICU's environmental parameters. ICUs need to be flexible and monitored effectively, therefore, such systems are helpful in both public as well as private hospitals. And we can see A slight delay in recognizing a patient's condition in the intensive care unit (ICU) might result in a lasting disability or even death. Patient monitoring is therefore the most important ICU procedure. Most monitoring errors involving people result in a delay in ICU patient recognition.

**Keywords:** Temperature, New Born Babies, Intensive Care Unit(ICU), ZYNQ Architecture, OLED display.

## Introduction

ICU is a crucial hospital department that offers critical care and life support to patients with serious illnesses. Patient monitoring is the most important ICU task because even a tiny delay in a patient's condition deteriorating can result in mortality. Failures in monitoring that are directly related to people tend to delay the recognition of ICU patients' worsening (Van Galen et al., 2016). Numerous studies show that ICU healthcare staff have a tremendous workload, which contributes to burnout. 49 ICU patients at Siloam Hospital Manado passed away in 2015, making up 265 total patients. One of the causes was a medical error brought on by a heavy workload that each employee could not handle (Nursalim et al., 2015). There ought to be a way to enhance the ICU monitoring procedure to stop delayed recognition and lessen the workload of ICU professionals. The ICU's HVAC system, also referred to as the heating, ventilation, and air conditioning system, is employed according on the environmental requirements. It should be completely air-conditioned with controls for humidity, temperature, and air flow changes It is advised that the entire air be 99% effectively filtered down to 5 microns. Each patient module in the need for enclosed patient modules in critical care units include a thermostate that can be adjusted to a temperature between 16 and 25 degrees Celsius. Although there are many embedded systems-based monitoring and controlling solutions for ICUs, more reconfigurable monitoring units with higher precision are required for such applications. Zynq A prototype for monitoring the ICU's environmental status based on architecture is used in the proposed

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project. On only one integrated circuit, Zynq's architecture blends FPGA and microcontroller technologies. Here, an ARM9 dual-core microcontroller and Artix 7 FPGA are both employed. The intricate hardware component is placed into the Artix 7 FPGA, and an ARM9 CPU manages the application software.

## Motivation

The primary goals of this project seem to be to decrease the morbidity and mortality of new born infants, protect ICU patients and calculate numerous metrics for new born infants and ICU patients, including Pmod Hygro, Pmod oled, Pmod ALS.

## Objective of the project

The primary goal of this project is to decrease the death rate of new infant babies and to protect the patients in the ICU. Using the proper sensors, monitor the baby's activity and health problems.

## Literature survey

**Prof Sachin, Shefali, Srilaxmi &Teena (2018) :** The primary goal of this study is to track patients' and elders' health problems. In this project they used MEMS module, smart sensor network and GPS/GSM technology. This project continuously monitor the health of the patient. The UI is user-friendly and it tracks a person's health status. If something goes wrong with the patient, it also transmits messages to the nearest hospital. Everyone can wear this device because it is lightweight or small. Also, it tells the exact location of the patient to their relatives. While the system constantly monitors the conditions, the patient can travel wherever they like with this method.

**Dharmavaram Asha Devi , Tirumala Satya Savithri , M Suresh Babu (2021):** On an FPGA development board based on the Zynq architecture, they created an Wi-Fi networked ICU control and monitoring system in this project. The functionality of this system is to analyse and show the ICU environmental data on an OLED screen while remotely managing several appliances close to a Wi-Fi network. In order to ensure the adaptability and efficient monitoring of ICUs, such systems are helpful in both business and public hospitals.

**Sanyadwia Ghinasni Zen, M. Dachyar :** A slight delay in recognizing a patient's deterioration in the intensive care unit (ICU) might result in a lasting disability or even death. With the use of IoT, this project aims to enhance the operational procedure of ICU monitoring. The Complex Proportional Assessment (COPRAS) method is used to rank the risks related to the current monitoring procedure in order to select the optimum IoT. Through the integration of IoT and the Business Process Reengineering methodology, this study aims to optimize the operational processes for ICU patient monitoring.

**Toshaljeet Kaur, Meenakshi Mittal, Harpreet Singh :** This project explains about the automatic caretaker room for the baby. This project can save the time of the busy parents and they can also monitor their child. So, in this project instead of small area which take care of the baby, they developed a total room which sense every activity of the child. So, in the room we will keep different sensor which sense the activities of the child and work according to the requirement. In this project they used Arduino which primarily controls all the sensors connected to it. This project also includes a Wi-Fi module to connect to the phone. The home appliances are connected to the internet which can work according to the sensors and this room is multitasking.

**Vaibhavi Bhelkar, D. K. Shedge :** In this project they designed implemented the health monitoring device using FPGA. In this project they used Spartan 3 FPGA board and it is used to calculate various parameters like temperature, heartbeat etc. The used heartbeat sensor to calculate the heartbeat and accelerometer to find the acceleration which may be due to result of motion. The patient's temperature is determined using the LM35 sensor. They  used different software's like Xilinx and visual basic to implement the project. It also sends an emergency alert message to their relatives and doctors to take care of the patient in case of any emergency.

**Dharmavaram Asha Devi, Tirumala Satya Savithri, Sai Sugun.L (2020) :** The goal of this proposed project is to design and implement reconfigurable System on Chip based data acquisition system with high performance. It is a semi-custom design that uses Zynq processing system IP, programmable logic on a reconfigurable 7-series FPGA, hygro, ambient light sensor, and OLEDrgb accessory module IPs. The approach suggested utilizes a reconfigurable SoC. with a 100MHz operating frequency intended for fast data acquisition systems. The system works well for fast and affordable real-time embedded systems.

**J.Udaykumar , M.Lakshmipathy :** The proposed project's objective is to develop a system for tracking patients' health. In this system, the patient's blood pressure, temperature, and condition are measured in real-time and processed and digitalized using an embedded Xilinx Spartan 3A FPGA system. The processed data is then transmitted via Bluetooth to an Android OS-based smartphone. In this project, they used different sensors like temperature sensors, heart rate sensors, and MEMS sensors. FPGA requires low power compared to conventional microprocessors and FPGA can be easily reconfigurable.

**Yu Wang, Sunghoon Jang :** In this project, they implemented a low-cost, reconfigurable FPGA-based IoT a multi-sensor healthcare infrastructure can be used to connect a pulse sensor interface intended for monitoring a user's pulse indicators and tell whether their heart rate is normal or abnormal. They used FPGA because it can be reconfigurable . A low-cost early validation platform design can be produced using the FPGA-based platform. They implemented a pulse sensor interface using VHDL programming and FPGA technology.

**Yogita Dubey, Sachin gajanan Damke:** In this project, they implemented the IoT-based and image processing-based baby monitoring system. This project is based on non-contact-based baby monitoring. Normally, if any unusual activity is found, they receive a warning from their parents. They also used the concept of image processing so that it sends a photo of the baby if an unusual circumstance is found. This project is developed using Raspberry pi, a mic, and image processing. They also used the face detection algorithm and installed various packages like NumPy and virtual environment. This technique will assist in lowering the likelihood that the baby will fall from the bed.

**S. Munavvar Hussain, A. Jhansi Naga Sai Surekha, D. Archana, N. Hannah Priyanka:** They implemented a project on an FPGA implementation of a health monitoring system using IoT. They designed the project using the Spartan3AN FPGA board. They interfaced different sensors like temperature sensor, pulse sensor, A/D converter, Wifi module, and LCD to the FPGA board. They used Xilinx ISE software for the project simulation. In this project, they used the advantages of FPGA and IoT technology. This project continuously monitors the temperature and heart rate of a person. This project also used the concept of IP address to monitor the health of the patient.

**Anjali Chindham, Donthagani Rakesh, Sabavath Virisha, Racha Ganesh:** The primary goal of the project is to a dependable FPGA-based health monitoring system so that medical practitioners may keep an eye on their patients. This technique is useful for keeping track of regular physical examinations for regular people as well. An FPGA-based health monitoring system can offer actual time evaluation of data regarding the physiological state of a human body or patient. Body temperature, blood pressure, respiration rate, and pulse rate information from sensors are used as input parameters by this system. Verilog HDL and the Xilinx ISE EDA tool were used to create this system with the Spartan-3 FPGA in mind. This system will accurately track the patient's health state by considering the aforementioned factors.

**Mr.A.R.Telepatil, Miss.P.P.Patil, Miss. S.S.Yajare, Miss.S.R.Jadhav :** This project explains about the intelligent baby monitoring system. With the use of cutting-edge technology, this system helps busy parents to assure the care and safety of their infants. Work has been done to detect motion, the sound of a baby crying, and live streaming of the baby in the cradle. Parents can keep an eye on their children all the time thanks to the display unit's live broadcasting of the babies' positions and activities. In order to help with infant monitoring, the raspberry pi B+ has interfaces with a number of sensors, includes a rain droplet sensor, condenser microphone, which is and camera. In this project they developed an electronic baby cradle which can help to take care of the babies.

## Methodology

The block level design of the semi-custom Zynq SoC is implemented using the suggested design methodology. Each block is composed of soft IP cores that are integrated into a design. Once the design has been correctly connected, create output ports, and then verify for mistakes. After validation is finished, construct the lock design's associated HDL wrapper. The next three processes are synthesis, implementation, and bit stream creation. Xilinx Vivado Systems Design Suite is the software platform that is utilised throughout all of these processing phases.
Following the bitstream has been created, export the device and launch the Software Development Kit (SDK). This integrated development environment is used to create embedded programmes. The necessary application logic is constructed using C/C+ and HTML for the website's page in an application project that is built on the SDK platform. Build the project, then use programming to load the intricate layout into the programmable logic of the FPGA. It processes application software. the ARM9 dual core processor architecture. Following the hardware debugging option's execution, keep an eye on the outcomes both at the hardware level and on the results-monitoring webpage.

## Hardware components

**Zedboard:** An affordable development kit for the Xilinx Zynq 7000 SoC is the Zynq Research and Development Board. Everything required to create a Linux, Android, Windows, or any zilches/RTOS-based design is present on this board. In addition, a number of expansion connectors make the system for processing and programmable recognizing I/ zilches accessible to stoners. Utilize the tightly integrated ARM processor and 7 series customizable sensing of the Zynq-7000 SoC to create distinctive and significant designs for the Zed Board. A strong force must be attached to the Zed Board. Zed Board automatically establishes a connection with the computer's host PC for USB-JTAG programming. Over USB-UART, a new connection can be established. If using the Terminal to facilitate simple board-PC communication. Keep in mind that a third micro-USB port (USB- OTG) is also provided for connecting USB accessories.
Zed Board can be programmed in four different ways

- USB- JTAG
- Traditional JTAG
- Quadrangle- SPI flash memory
- SD card

**Fig. 1.** Zedboard

## Pmod HYGRO

A relative humidity detector with an integrated temperature detector, the Pmod HYGRO delivers substantially accurate measurements at little power. With a resolution roughly 14 bits, the TI

HDC1080 can quantify the approximate humidity of the terrain. Upon request from the host board, the Pmod HYGRO is built to electronically report the relative humidity and ambient temperature. By enabling for longer conversion periods, each detector's resolution can be increased up to 14 bits. For testing purposes or to remove condensation that forms on the detector over prolonged exposure to high moisture levels, a resistive heating part may be activated.

**Importance of Pmod HYGRO**

A temperature sensor is necessary for every process heating application because it provides temperature information about the process that can be employed to track or manage the operation. The ideal temperature for intensive care units is between 21 and 24 C. monitoring newborn babies in ICU is ineffective. Due to the serious morbidities and mortality brought on by neonatal hypothermia, it is essential to accurately monitor newborns' body temperatures. The main goal of taking a newborn's temperature is to identify any signs of cold stress because fever is a rare sign of sickness and is frequently influenced by environmental variables.

It is possible to stop the transmission of disease and maintain a secure and healthy environment by using sensors to monitor humidity levels. The function of a humidity sensor is to detect, gauge, and report the air's relative humidity (RH) or assess how much water vapour is present in a combination of gases (air) or a pure gas. Australia's recommendations for burns ICU advised a higher humidity range (30-95%) likely to speed up wound healing compared to the USA's prescription of 40-60%.Use of humidity in newborns Transepidermal water loss (TEWL) is more likely to occur in newborns who were born before 30 weeks of gestation because their stratum corneum and epidermis are still developing. Utilising ambient humidity helps to lower TEWL, which in turn improves skin integrity, fluid and electrolyte management, and temperature regulation.The way humidity affects baby incubators.

Humidification increased the regulation of body temperature from birth and decreased skin water loss, but it did not prevent the skin from developing normally after birth. Despite a high incubator air temperature, babies frequently became hypothermic when not adequately humidified when being fed. Babies thrive in environments with greater humidity levels. Even some medical professionals advise keeping the humidity in baby rooms between 50 and 70 percent. The issue with it is that excessive humidity encourages bacterial growth in the air, which can make your infant sick.

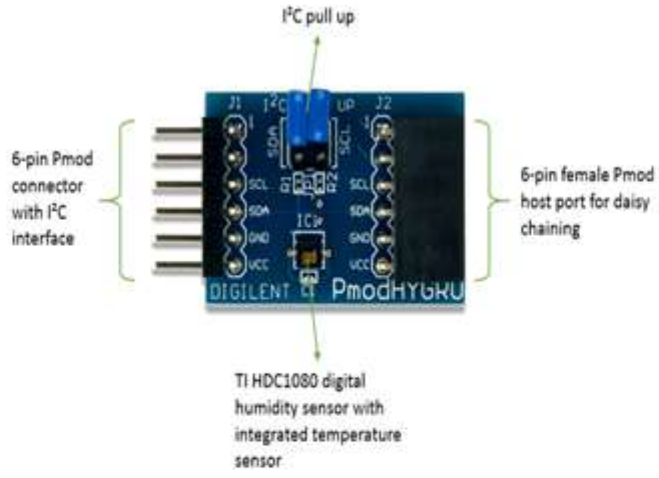


**Fig. 2.** Pmod HYGRO

**Pmod ALS**

Through a single light source detector, the Digi sophisticated Pmod ALS shows light-to-digital vision. A single ambient light detection (ALS) is used in the functional overview of PmodALS to provide stoner input. The voltage position transmitted into the ADC, which transforms it to 8 bits of data, is controlled by the quantum properties of light the ALS is exposed to. A place with a value of 0 is considered to be in low light, while a value of 255 is considered to be in high light.

**Importance of ALS**

One of the most common stressors experienced with a severe illness is sleep deprivation. Sleep loss and sleeplessness have been named by survivors as important sources of stress and nervousness while receiving treatment in the ICU. Melatonin secretion's disrupted circadian rhythm has been seen in ICU patients who were also being intensively ventilated and on drugs. According to a theory, sleepiness in critically sick patients undergoing mechanical ventilation is brought on by a decline in bloodstream melatonin levels linked to the interruption of circadian rhythms. In addition to delirium associated with critical care, neuropsychological impairment, the duration of mechanical breathing, and compromised immune system, sleep deprivation in the critically ill may also contribute to emotional distress. Both immediate and long-term sleep disruption are brought due to light, which also has an impact on circadian function, a critical mechanism supporting restful sleep. The circadian rhythm is disrupted by brief bursts of light at night and a lack of bright daylight, which impairs sleep. According to several research, bright blue light, as opposed to bright red or conventional white fluorescent light, lessens acute kidney impairment in sepsis-exposed rats.

Therefore, the monitoring light intensity is crucial for ICU patients.

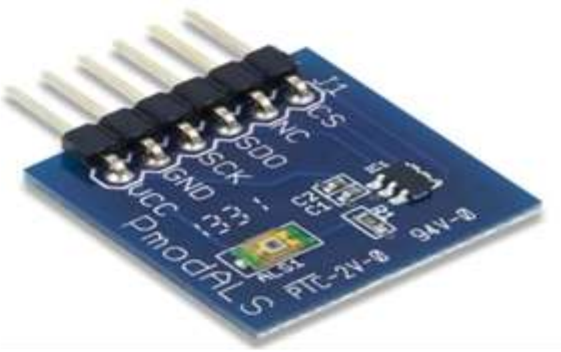


**Fig. 3.** Pmod ALS

**Pmod OLED rgb**

An organic RGB LED module from Digilent called the Pmod OLED rgb has a 96 x 64-pixel display and supports 16-bit colour resolution. Designed to work in confluence with a host board, communicating via the SPI protocol, the Pmod OLED rgb is a graphical display that allows druggies the option to light up any individual pixel on the OLED screen. The Solomon Systech SSD1331 present controllers is used by Pmod OLED RGB to receive data from the host board and show the necessary data on the OLED screen.

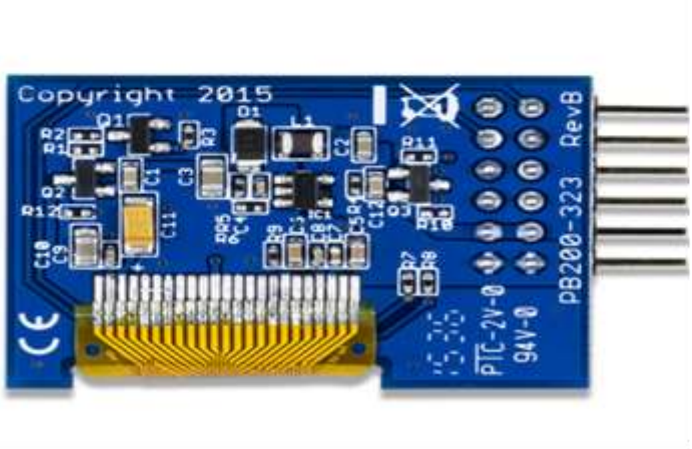


**Fig. 4.** Pmod OLED

**Hardware implementation**

The SDK is a tool for designing, constructing, and programming an FPGA. The target board must be created before creating an application project. must be connected to the computer system where it is already developed. There are two distinct types of relationships present here. The first is used for programming with USB to JTAG, whereas the additional one is for asynchronous connection with UART.

**Software development of icu monitoring using zynq architecture**

The block diagram combines the ZYNQ processing system with a number of peripheral modules that communicate with the AXI connection. The design makes use of four peripheral modules. They are the OLEDrgb, Pmod Hygro, and Ambient light sensor. The benefit of this approach is that all GPIO and peripheral modules are interfaced via AXI4. The three main benefits of AXI4 are as follows. The first is productivity because learning simply requires one common procedure. The second is flexibility in using the appropriate protocol. It permits memory-mapped interfaces and a data rate burst of 256 cycles in a single clock phase. AXI4-Lite is renowned for its portability. because it can manage a memory-mapped interface for a single transaction. Additionally, it includes a user- and design-friendly interface. The third benefit is accessibility. It is utilized globally in the creation of systems, testing methods, and performance evaluation by ARM and many other outside companies.
Following the completion of the block design using personalised IP integration, the Xilinx Vivado tool is to be used to carry out the subsequent phases.

i. Create the HDL wrapper, first.
ii. Synthesize the design
iii. Implementation
iv. Produce a bitstream and Export the hardware design to SDK together with the produced bit stream. Start SDK.
v. Create an application project at the SDK, then add a src file to the project.
vi. Once all of the steps mentioned above have been finished, link the target FPGA development board with all of the peripheral modules and the computer system using the proper connections.Build the project and program PL.
vii. Execute hardware debugging at the SDK, and confirm the outcomes.

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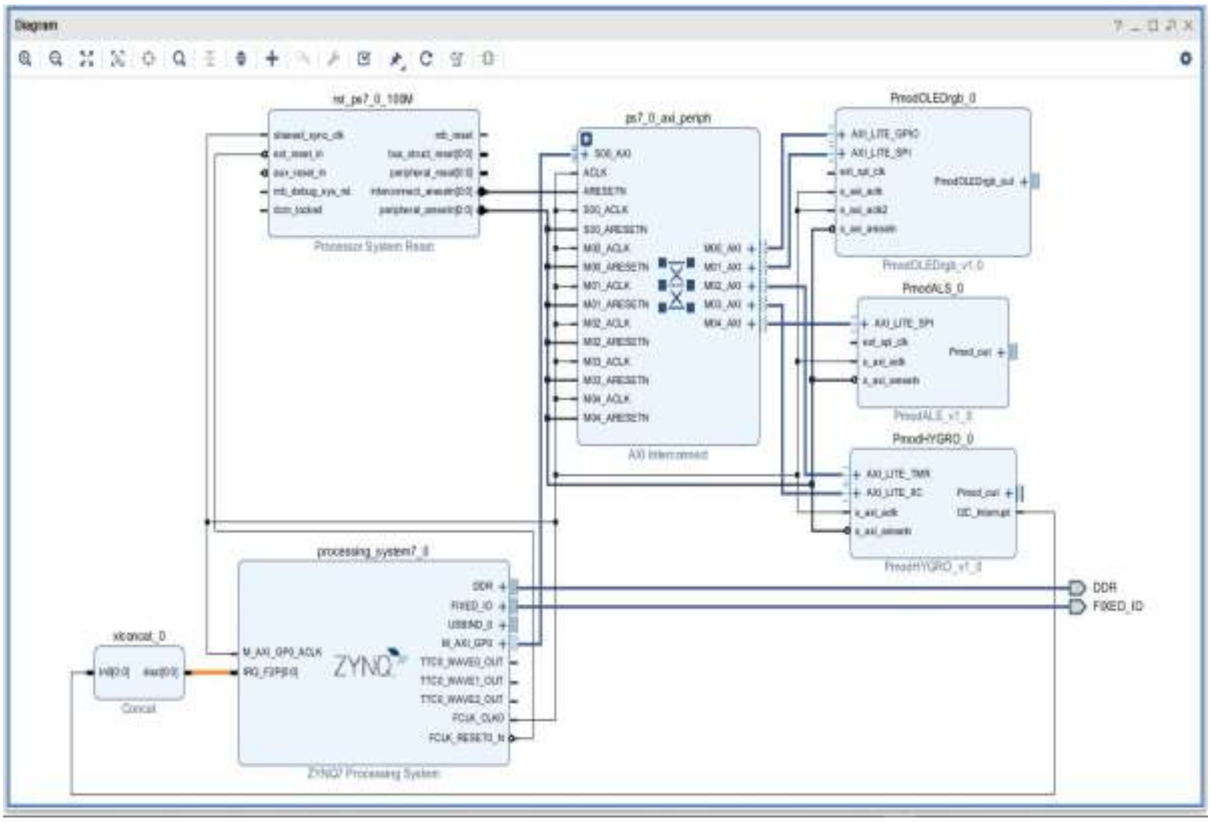


**Fig. 5.** Architectural Block Diagram of ICU Monitoring System

The components of the ICU Monitoring system's block diagram are the ZYNQ7 Processing System, processor system reset, Pmod OLED, Pmod ALS, Pmod HYGRO, and Concat. Programmable logic (FPGA) and an ARM7 dual-core CPU make up the ZYNQ7 processing system. All of the Pmods are connected to the ZYNQ7 processing system using the AXI interface. When necessary, the system can be reset using the processor system reset. Temperature and humidity sensors are built into Pmod HYGRO. Concat is used to relatively flip between the two sensors.

## Results


**Fig.6.** Zed Board connections

In the above PMOD OLED, PMOD ALS and PMOD HYGRO are connected to the ZED BOARD.

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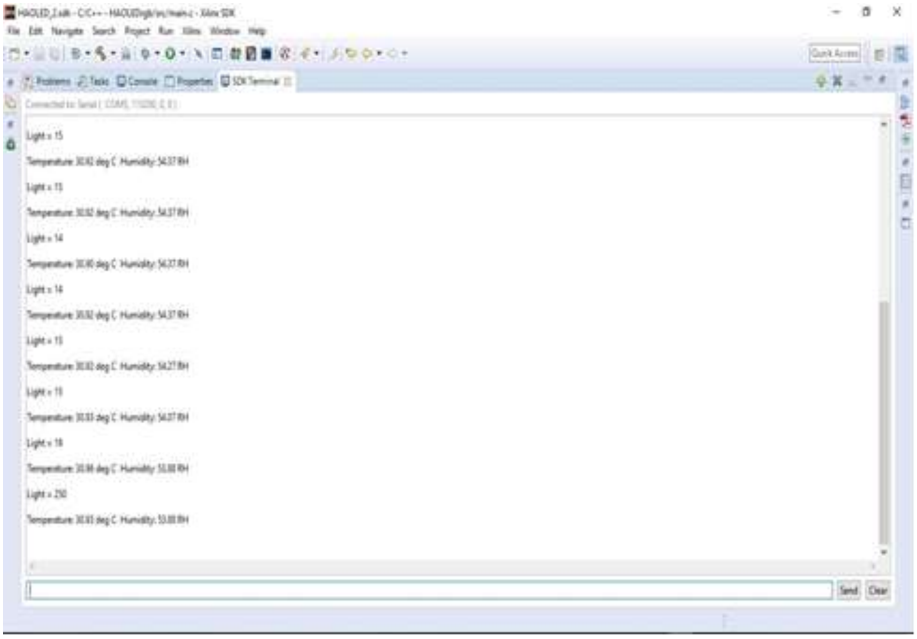

**Fig. 7.** Output terminal

The above figure is the output of the project. We can see the output in the SDK Terminal of various parameters values of the ICU Patients and New born babies. We are measuring the various parameters like temperature, humidity and light.

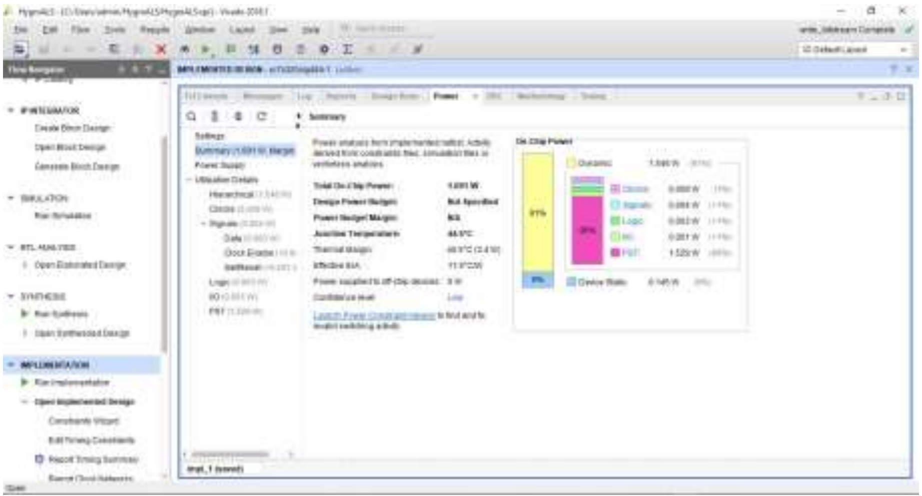

**Fig. 8.** Power Report

- The above figure tells about the utilization of the power. Here the dynamic power is utilized 91%. And the various power parameters like clock, signal, IO, Logic and PS7 utilized the remaining 9%.
- The device static has 0.145w. and the total on chip power is about the 1.691w. the junction temperature utilized 44.5 degree Celsius.
- The thermal margin power is utilized 40.5 degree Celsius.

## Advantages

- Patients/Elder's safety can be assured.
- Low power
- Reconfigurable
- High speed

## Conclusion

The suggested study has a solid track record of using an embedded programme to monitor and regulate the ambient light, humidity, and temperature parameters. For real-time ICU, a comparable technique can be applied. Microprocessors and microcontrollers can both implement the same kind of application. Flexible reconfigurability, yet is lacking. The Zynq architecture-based SoC design is executed in this method with a significant number of benefits, as mentioned. The monitoring and control of ICU parameters have a lot of room for improvement in the future. Additionally, in the upcoming work, the patient monitoring can be established.

**Future scope**

For the upcoming work, we plan to construct a different type of handheld device and implement a power-efficient medium access control (MAC) convention within the smaller measured sensor organisation for the information consistency.

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