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# Development of Mixed Signal Based SoC for Monitoring of Neonatal Intensive Care Unit (NICU) Parameters

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***Abstract :*** *Now a days the lifestyle is changes and health issues are becoming serious problem. The advance technology may be providing satisfactorily effects to face such problems. However, the new born babies are also facing different issues. On site survey of different hospitals, it is found that, the new born babies are treated under Neonatal Intensive Care Unit, which helps to monitor some specific medical parameters such as temperature, Phototherapy lamps intensity of light, humidity, body temperature of baby, oxygen, heart rate, pulse rate, X-ray, CT scan etc. However, they are very costly and not affordable to the ruler area. Some time it is observed that mother is admitted in one hospital and new born baby is admitted to nearby hospital where NICU is available. To provide it in affordable cost by deploying innovative mixed signal technology is the prime aim of the present research work.*

***Keywords :*** *Baby Incubator, Neonatal Intensive Care Unit (NICU), Phototherapy, SmartFusion, System-on-Chip(SoC), X-ray*

## I. Introduction

Nowadays the lifestyle is changes and health issues are becoming serious problem. The advance technology may be providing satisfactorily effects to face such problems. However, the new born babies are also facing different issues. On site survey of different hospitals, it is found that, the new born babies are treated under Neonatal Intensive Care Unit, which helps to monitor some specific medical parameters such as temperature, Phototherapy lamps intensity of light, humidity, body temperature of baby, oxygen, heart rate, pulse rate, X-ray, CT scan etc. However, they are very costly and not affordable to the ruler area. Some time it is observed that mother is admitted in one hospital and new born baby is admitted to nearby hospital where NICU is available. To provide it in affordable cost by deploying innovative mixed signal technology is the prime aim of the present research work.

The mix signal based VLSI design is an innovating field, which shows wide angle of application in embedded world. The analog devices have lot of difficulties also accuracy are not sufficient to give readings. The solution for these is uses digital design technology. The FPGA provide better solution only for digital design. Therefore, designing of mixed signal based SoC for dedicated application is recent trend for the researchers.

## II. Mixed Signal Based Monitoring and Controlling of NICU

*2.1 Development of system:*

This paper main aim is to designing the embedded system based on VLSI design. The embedded system design consist of two parts name as hardware and software. Both hardware and software are designed and details regarding their design are following two points.

- Hardware
- Software

*2.2 Hardware:*

The analog and mixed signal technology of VLSI design consist of analog as well as digital cores are reconfigured. For development of such system a VLSI device of great reconfigurability is required. The present system is constructed about Smart Fusion technology based on customizable system-on-chip, A2F200M3F, from Microsemi USA. The organization of the system is represented by block diagram shown in figure 1. It consist of

1. Sensors Array
2. Customizable System-on-Chip(CSoC) device

3. Display unit

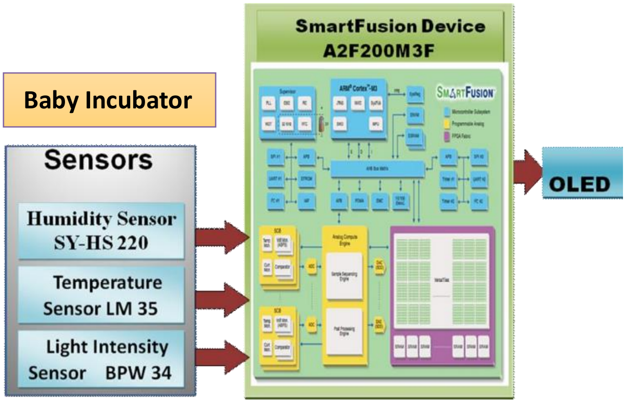


*Figure 1 Block diagram of monitoring the NICU*

*2.2.1. Sensors Array:*

For baby incubator the parameters such as humidity, temperature, in case of light therapy intensity of light, Oxygen etc., these is primary need to monitor and control. To measure these parameters the quality sensors are used. The humidity sensors such as SY-HS-220 module, Temperature sensor LM 35 and light intensity sensors BPW34 is used. These sensors are interfacing to cSoC device. The output of each sensor is given to cSoC for processing. The each sensor array are described.

*2.2.1.1Humidity sensor(SY-HS-220)*

The amount of water molecules dissolved in the air of baby incubator or NICU is measured using humidity sensor SY-HS-220[12].

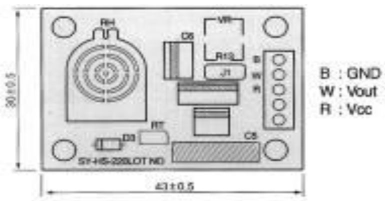


Figure 2. Humidity sensor

The humidity sensor is shown in figure 2. The sensor module consist of humidity sensor and signal Conditioning stages. The humidity sensor module is Capacitive type sensor elements and chip signal conditioner.These module mounted on PCB, which also consist of other Stages employed to make sensor module smarter than other.Sensor module output is DC voltage depending on the Humidity of the NICU in %RH. Typically, the sensor module Exhibits current consumption less than 3mA. The operating humidity range is 30%RH to 95%RH.The DC voltage provided is 1980mV with accuracy ±5%. There are three pins for interfacing, blue (B), white (W) and red(R). The DC output voltage at pin W, ground pin is B and power supply (+5V) at apply to pin R.The DC voltage linearly changes with change in humidity, these DC voltage is given to SmartFusion device for further processing.

*2.2.1.2 Temperature sensor (LM35)*

The temperature sensor provides the output voltage is proportional to the degree Celsius temperature scale. The monolithic temperature sensors available are LM135,LM235(10mv/°K),LM34 (10mv/°F) and LM35 (10mv/°C). These devices are available in hermetic TO-46 transistor packages[13].The temperature sensor LM35 is used in these systemfor sensing temperature. It is precision integratedcircuit temperature sensor whose output voltage proportional to the degree Celsiustemperature scale. Figure 3 shows the temperature sensor.

Figure 3.LM35

The temperature coefficient is mv/°C, there is no any complexity for scale conversion.The LM35 does not require any external components. It draws only 60µA current from its power supply, it has very low self-heating, less than 0.1°C in air.Because of these it is suitable for measurement of temperature in baby incubator. The sensor operates with single +5V power supply. The 18KΩ resistor is connected to load , it provides typical accuracy over full -55°C to +150°C temperature range[13]. The temperature dependent voltage is measured and given to the ABPS3 pin of the SmartFusion device for further processing.
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*2.2.1.3Light intensity Sensor (BPW34)*

Figure 4 shows the light intensity sensor BPW 34. The sensor Is a PIN photodiode with high speed and high radiant sensitivity. It is sensitive to visible as well as infrared radiation and the angle of sensitivity is ±65°[14].

Figure 4. Light Intensity sensor

The semiconductor material is sensing element of BPW34 sensor. The current flowing through these sensor is directly proportional to light intensity of baby incubator. By connecting 1KΩ resister to achieve output in voltage form these voltage is given to ABPS7 pin of SmartFusion device for further process.

*2.2.2 Customizable System-on-Chip (cSoC) device (A2F200M3F):*

The mixed signal FPGA is first introduced in fusion technology in which in addition to FPGA, the programmable analog blocks, configurable digital cores and soft processor cores are available. This technology is extended to SmartFusion on inclusion of ARM CortexM3 processor core on a flash semiconductor. Figure 5 shows the architecture of SmartFusion A2F200M3F device. It contains three main parts.

I) Programmable Analog Block
II) Microcontroller Subsystem
III) FPGA fabric.

The all these three main parts are briefly discussed below.
It consist of two main parts a) Analog front End b) Analog compute engine

*2.3Analog Front-End (AFE)*

Smartfusion cSoCs offer an enhanced analog front end compared to Fusion devices. It have high performance analog signal conditioning blocks (SCB), ADC`s and DAC`s. The SCB consists of more flexibility and configurability, highly reduced power consumption. It gives platform for embedded and VLSI developers. The SmartFusion A2F200M3F device from microsemi is used presently in systems. active bipolar prescalers (ABPS), comparators, current monitoring and temperature monitoring. The ABPS modules allow larger bipolar

voltages to be fed to the ADC. Current monitors take the voltage across an external sense resistor and convert it to a voltage suitable for the ADC input range. Similarly, the temperature monitor reads the current through an external PN junction (diode or transistor) and convert it internally for the ADC. The SCB also includes comparators has up to 15ns high speed. The comparator monitor fast signal threshold without using ADC. The output of comparator can be fed to the analog compute engine or the ADC. The integrated ADC`s and DAC`s have one percent accuracy. They have 12/10/8 bit mode ADC`s with 500/550/600 Kbps sampling rate.
They have up to 32 analog inputs and 3 outputs. The successive approximation register analog to digital converters and first order sigma-delta digital to analog converters.

*2.4Analog Compute Engine(ACE)*

The mixed signal blocks found in SmartFusion cSoCs are controlled and connected to the rest of the system via a dedicated processor called the analog compute engine (ACE). The role of the ACE is to offload control of the analog blocks from the Cortex-M3. The ACE performs the functions such as handle sampling, sequencing and post processing of the ADCs, DACs and SCBs

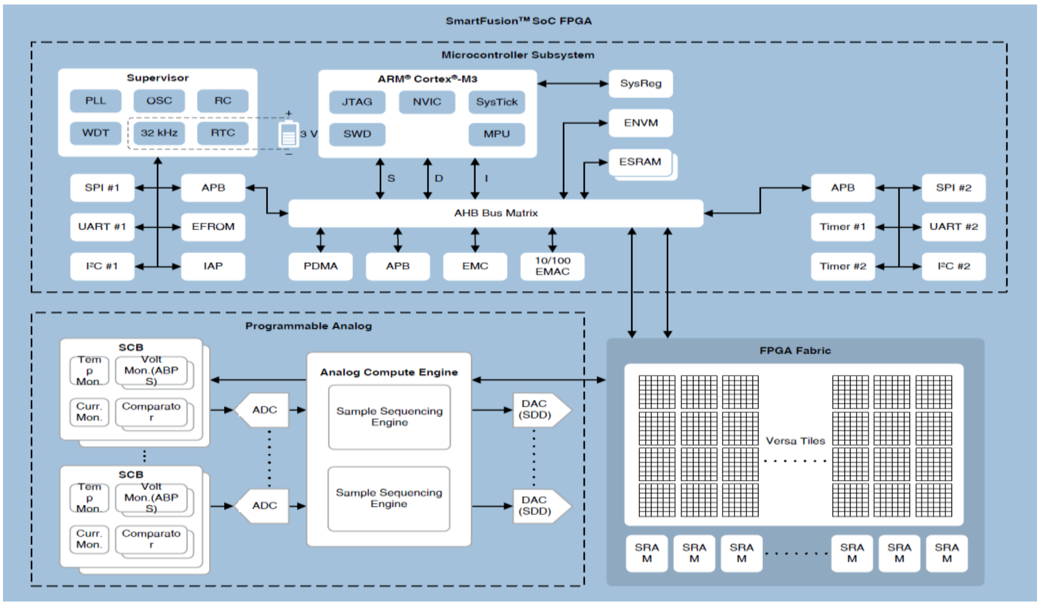


Figure 5. Architecture of SmartFusion A2F200M3F

*2.5Microcontroller Subsystem(MSS)*

The MSS is composed of a 100MHz, 32 bit ARM cortex-M3 CPU and integrated peripherals, which are interconnected via a multi-layer AHB bus matrix (ABM). This matrix allows the cortex-M3 processor, FPGA fabric master, 10/100 Ethernet media access controller (mac) with RMII interface. The 8 channel peripheral DMA (PDMA) controller to act as masters to the integrated peripheral FPGA fabric, embedded non-volatile memory (eNVM), embedded synchronous RAM (esRAM), external memory controller (EMC) and analog compute engine (ACE) blocks. The up to 512KB flash and 64 KB of SRAM. SmartFusion cSoCs of different densities offer various sets of integrated peripherals. Available peripherals include SPI,$I^2C$, and UART serial ports, embedded Flash ROM (EFROM), timers, Phase locked loops (PLLs) Oscillators, real time counters (RTC), They have up to 41 MSS I/Os with Schmitt trigger inputs, the 25 I/Os can be used as FPGA I/Os.

## III. FPGA Fabric

The FPGA fabric based on microsemi`s proven proAsic 3 architecture 200,000 to 500,000 systemgates with 350MHz system performance. They have a embedded SRAMs and FIFOs. The blocks organizations are x1, x2, x4, x9 and x18. The SRAM are true dual port. They have up to 128 FPGA I/Os supporting LVDS, PCI, PCI-X and LVTTL/LVCMOS standards. The FPGA fabric has great features like low power, firm error immune.

*3.1Display Unit*

In display unit uses a organic light emitting diode. The organic light emitting diode (OLED) is a light emitting diode (LED), in which the emissive electroluminescent layer is a film of organic compound that emits light in response to an electric current. The OLED display devices use organic carbon based films, sandwiched together between two charged electrodes. The one is a metallic cathode and another a transparent anode. The transparent anode is glass. The OLED display have two types passive matrix OLED (PMOLED) and active matrix OLED (AMOLED). In OLED display works without a backlight; thus it can display deep black levels and can be thinner and lighter than a liquid crystal display (LCD). In low ambient light conditions, an OLED screen can achieve a higher contrast ratio than an LCD.

During working, a voltage is applied across the OLED such that the anode is positive with respect to cathode. Anodes are picked based upon the quality of their optical transparency, electrical conductivity and chemical stability. The electrons and holes recombination are takes place in organic layer and light energy is produced, display the characters.

### *3.2Software*

After successfully designing of the hardware part on the system, the application code is developed for a IDE SoftConsole. The software required for synchronization of hardware and for data processing to real unit is developed in embedded C environment using SoftConsole. The FlashPro programmer device is programmed with Hex file. The system-on-chip is co-developed to monitor various environment parameters.

## IV. Results and Discussion

The system is developed to measure the Neonatal Intensive Care Unit parameters such as humidity, temperature and light intensity. The result are discussed in three parts.

a) Measurement of temperature
b) Measurement of light intensity
c) Measurement of humidity

### *4.1Measurement of Temperature*

In NICU temperature sensor LM35 is placed near to baby. The LM35 output in the form of EMF, these emf calibrated into the degree Celsius. The designing system is implemented of Temperature range are 25°C to 95°C. The output of LM35 is given to the Active Bipolar Prescaler (ABPS) block, which is voltage monitoring block of the SCB of SmartFusion device. The ABPS is an analog block, which is composed of continuous time Op-Amp in an inverting configuration. The output of SCB0 is given to analog multiplexer, after to ADC0. The digital output is given to advanced Peripheral Bus (APB) and then cortex M3 for processing the data.

### *4.2Measurement of Light Intensity*

In some baby are require a light therapy, at the time of light therapy the light intensity are measure by using temperature intensity sensor BPW34. The output of sensor is in the form of emf, these emf is calibrated into Lux. The light intensity sensor exhibits linear variation in the current with respect to the intensity of light. The current are converted into voltage and then interfaced. These output is given to ABPS of SCBs. The output of ABPS is given to multiplexer and multiplexer output given to ADC. The digital output is given to cortex M3 based microcontroller subsystem for processing the data.

### *4.3 Measurement of Humidity*

The humidity of the NICU is measure by using smart sensor SY-HS-220. The humidity sensor output is emf, these emf is calibrated into RH%. The output is given to ABPS of SCBs. These output is given to multiplexer and multiplexer output is given to ADC. The digital output is given to microcontroller subsystem for processing the data.

## V. Conclusion

The research project is designed in mind the medical conditions available in rural areas. This equipment used in small health care centre. It is lifesaving machine for baby. The all sensors can be easily fixed in NICU. The electronics part is separated from baby`s compartment baby can be assured safe. The project is simple and efficient in monitoring and controlling of temperature, humidity and light intensity of NICU

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