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Pregnancy Health Diagnostics, Information and Data Loggers for Supporting Virtual Pregnancy Clinic

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Abstract: Monitoring the health of pregnant women is crucial throughout the entire pregnancy to ensure the proper development of the fetus. In gynecology clinics and hospitals, specialized instruments are utilized to assess the health conditions of both the mother and the fetus. Typically, a hospital-based monitoring system is used, requiring pregnant women to visit the relevant center for health evaluations. This can be challenging for them as it involves traveling and enduring long wait times. To address this challenge, a device has been created to track vital parameters such as ECG (Electrocardiogram), respiratory rate, heart rate, and dehydration levels. All parameters can be tracked on an IoT-enabled computer screen, allowing the doctor to oversee these metrics whenever the patient uses the device at home by scheduling an appointment with the doctor. This technology positively influences automation in industries and hospitals. The project's hardware is based on a printed circuit board that includes a PIC microcontroller 16 F 877A. It is a flexible microcontroller equipped with built-in capabilities like a 10-bit multi-channel ADC, USART, synchronous serial port, programmable low voltage detection circuit, etc., intended to connect with a PC system via RS232C. The software can be readily adjusted for any alarm configuration or recording periods, as it is developed in Visual Basic.

I. Introduction

Limited access to hospitals in rural areas and the long distances required to reach them often discourage people from seeking medical care, especially for minor injuries and routine check-ups. This lack of accessibility also affects pregnant women, many of whom tend to skip regular antenatal check-ups during the early stages of pregnancy. Regular monitoring is essential, as it helps reduce the risk of abnormal births and fetal mortality.

Pregnancy typically lasts about 42 weeks and is divided into three trimesters of approximately 14 weeks each. Throughout this period, women may experience various complications, including maternal sepsis, bleeding, and fluctuations in blood pressure. These conditions can lead to issues such as gestational diabetes and excessive weight gain. Some women may also develop gestational hypertension, which can adversely affect vital organs such as the kidneys and may result in complications like low birth weight or premature delivery.

Elevated blood sugar levels during pregnancy can cause the baby to gain excess weight, while underweight mothers may face risks such as reduced amniotic fluid levels and an increased likelihood of preterm birth. Additionally, traveling long distances during pregnancy is generally not recommended by physicians, making access to nearby healthcare facilities even more critical.

To address these challenges, establishing regular check-up facilities at nearby primary healthcare centers can be highly beneficial. These centers can monitor key health parameters using sensors that measure heart rate, body temperature, respiration rate, oxygen saturation (SpO_2), and ECG. The collected data can then be transmitted via the internet to specialists located at distant hospitals. Based on this information, specialists can assess the patient's condition and provide timely medical advice, ensuring better maternal and fetal health outcomes

Here are key pregnancy (maternal health) statistics in India that can be used for reports or literature sections:

1. Maternal Mortality Rate (MMR)

- India's Maternal Mortality Ratio: 97 deaths per 100,000 live births (2020–22)
- Significant improvement from 130 (2014–16)
- Target (SDG): <70 by 2030

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2. Institutional Deliveries

- Around 88–90% of births now occur in healthcare institutions
- Still lower in rural and remote regions due to accessibility issues

3. Antenatal Care (ANC) Coverage

- About 58–65% of pregnant women receive at least 4 antenatal check-ups
- Early registration (first trimester): ~70%
- Gap still exists in rural areas

4. Anemia in Pregnant Women

- Nearly 52–57% of pregnant women in India are anemic
- Major cause of maternal complications and low birth weight babies

5. High-Risk Pregnancies

- Around 20–30% of pregnancies are categorized as high-risk
- Common issues:
  - i. Gestational hypertension
  - ii. Gestational diabetes
  - iii. Malnutrition

6. Infant and Neonatal Mortality

- Infant Mortality Rate (IMR): ~27 per 1,000 live births
- Neonatal Mortality Rate: ~20 per 1,000 live births
- Many deaths linked to poor maternal health and lack of monitoring

7. Rural vs Urban Gap

- Rural women are:
  - i. Less likely to receive full antenatal care
  - ii. More likely to deliver at home
  - iii. More exposed to pregnancy complications due to delayed care

8. Low Birth Weight Babies

- Around 18–20% of babies in India are born with low birth weight
- Linked to:
  - i. Poor maternal nutrition
  - ii. Lack of regular check-ups

9. Teenage Pregnancy

- About 6–8% of women (15–19 years) are already mothers or pregnant
- Higher risks:
  - i. Premature birth
  - ii. Maternal complications

10. Access to Healthcare

- Many rural areas still lack:
  - i. Nearby hospitals
  - ii. Skilled healthcare providers
  - iii. This leads to delayed diagnosis and treatment

Despite significant progress, India continues to face challenges in maternal healthcare, particularly in rural regions. Limited access to healthcare facilities, high anemia prevalence, and insufficient antenatal monitoring contribute to maternal and neonatal risks. Strengthening primary healthcare systems and integrating remote monitoring technologies can help bridge this gap. Based on the studies in India, a most modern computer based intelligent pregnancy monitoring system designed for Virtual clinic application.

Literature Review on Pregnancy Data Acquisition Systems for Virtual Clinic:

Recent advancements in healthcare technologies have significantly improved maternal monitoring through efficient data acquisition systems. Various studies have focused on the development of real-time monitoring solutions using sensors, Internet of Things (IoT), and telemedicine to enhance maternal and fetal healthcare, especially in rural and remote areas.

Smith et al. (2021) proposed an IoT-based maternal health monitoring system that collects physiological parameters such as heart rate, body temperature, and blood pressure using wearable sensors. The data is transmitted to cloud platforms, enabling healthcare professionals to monitor pregnant women remotely. Their study demonstrated improved early detection of complications like gestational hypertension.

Kumar and Singh (2022) developed a wireless sensor network for continuous pregnancy monitoring. Their system integrates sensors for measuring SpO_2, ECG, and uterine contractions. The collected data is processed using embedded systems and transmitted via GSM modules to healthcare providers. This approach reduced the need for frequent hospital visits and ensured timely medical intervention.

Patel et al. (2020) focused on remote health monitoring using mobile health (mHealth) applications. Their system allows pregnant women to record and upload vital health parameters through smartphones. Doctors can analyze trends and provide recommendations. The study highlighted the effectiveness of mobile-based solutions in improving antenatal care in low-resource settings.

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Reddy and Lakshmi (2023) introduced a cloud-based pregnancy monitoring framework that integrates IoT devices with machine learning algorithms. The system predicts potential risks such as gestational diabetes and preeclampsia by analyzing historical and real-time data. Their results showed increased accuracy in risk prediction and improved maternal outcomes.

Sharma et al. (2021) designed a low-cost health monitoring system specifically for rural areas. The system uses basic sensors to measure blood pressure, temperature, and fetal heart rate, and transmits data through internet-enabled devices to nearby health centers. This study emphasized affordability and accessibility as key factors in rural healthcare implementation.

Ali et al. (2022) explored the use of wearable devices for continuous maternal monitoring. Their research demonstrated that wearable technology can provide real-time tracking of vital parameters and alert healthcare providers in case of abnormalities. This reduces maternal and neonatal mortality by enabling early diagnosis.

The reviewed literature indicates that pregnancy data acquisition systems play a crucial role in reducing maternal and fetal risks by enabling continuous monitoring and early detection of complications. Future research should focus on developing cost-effective, reliable, and scalable solutions tailored for rural populations, ensuring better accessibility and healthcare delivery.

From the above studies, it is evident that:

- Most systems rely on IoT and wireless communication for data transmission.
- Real-time monitoring significantly improves maternal healthcare outcomes.
- However, challenges remain in terms of cost, network availability, and system scalability in rural areas.
- There is a need for more integrated, low-cost, and user-friendly systems that can function effectively in low-resource environments.

II. Proposed Research

The primary objective of this proposed research is to provide a comprehensive profile of biomedical variables rather than relying on a single value measured at a specific point in time. Current practices typically involve collecting physiological data from pregnant women and processing it into a single output, which represents only a momentary condition. However, this approach may not effectively address real-world scenarios, as these parameters can change rapidly due to varying physiological conditions during pregnancy.

To address this limitation, a high-quality dynamic data acquisition system is essential, particularly during emergency situations. Such a system should incorporate intelligent mechanisms for efficient time-sharing among multiple variables. Specifically, when any parameter deviates from its predefined normal range, it must be given higher priority, enabling more frequent and faster data collection for that parameter.

Therefore, a priority-based data acquisition strategy is required, supported by advanced data processing techniques. This can be achieved using ONNX-based artificial intelligence, which can be easily interfaced with commercially available microcontrollers. The proposed approach aims to significantly reduce uncertainty in prenatal data collection by enabling continuous, adaptive, and intelligent monitoring of critical biomedical variables.

BLOCK DIAGRAM OF THE PROPOSED RESEARCH

The proposed research is structured into five key modules, as illustrated in the block diagram (Figure 1):

1. **Data Acquisition System (DAS):** This module is responsible for collecting real-time physiological data from patients at the required speed and appropriate time intervals.
2. **Data Processing System (DPS)**: The DPS receives inputs from various sensors and processes them using suitable signal conditioning and conversion circuits. It also ensures protection against external interferences such as EMI, RFI, and harmonics. The system outputs a standardized 0–5V DC signal corresponding to the full range (zero to span) of biomedical variables.
3. **Data Conversion System (DCS):** This module converts multiple analog signals into digital form with 10-bit accuracy. The digital data is then serialized and transmitted to the host system at a baud rate of 9600. The DCS is implemented using an embedded microcontroller equipped with multiple integrated features.
4. **Data Manipulator:** This is a user-friendly software interface that visually represents the measured parameters. It displays accurate values, provides graphical interpretations, simulates biological activities, and offers a comprehensive GUI for easy monitoring.
5. **Data Transmission System (DTS):** This module enables remote access by sharing the system interface with healthcare providers, facilitating virtual patient monitoring and consultation, thereby supporting safe pregnancy management.

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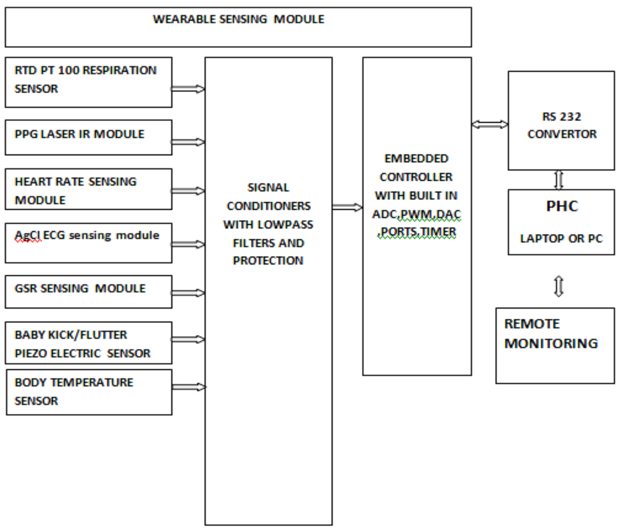

Figure .1 Block Diagram of the Proposed

The primary physiological parameters considered in this research include respiration profile, ECG, heart rate, photo-plethysmo-graphy (PPG), galvanic skin resistance (GSR), body temperature, and piezoelectric-based fetal movement monitoring. Each of these parameters is described in detail along with their corresponding circuit designs.

Variables and its importance during pregnancy duration

Respiration monitoring in the gestation period is essential for ensuring safe pregnancy outcomes. It enables early diagnosis, continuous assessment, and timely medical intervention, ultimately protecting both mother and baby. Heart rate monitoring during gestation is essential to ensure proper blood circulation and adequate oxygen delivery to the fetus. Heart rate analysis helps in the early detection of complications such as Fetal Distress and Preeclampsia, which can pose risks to both mother and baby. Continuous monitoring also provides valuable information about maternal and fetal cardiovascular health, allowing timely identification of any abnormalities. Variations in heart rate may indicate stress, infection, or insufficient oxygen supply, requiring immediate attention. Furthermore, during labor, heart rate monitoring plays a crucial role in assessing fetal well-being and guiding prompt medical intervention to ensure a safe delivery.

Photoplethysmography (PPG) is important during gestation as it provides a non-invasive and continuous method to monitor vital cardiovascular parameters such as heart rate and blood flow. It helps in assessing maternal circulatory health and ensures adequate blood perfusion to the fetus. PPG signals can assist in the early detection of abnormalities related to Preeclampsia and Fetal Distress by identifying irregular pulse patterns and changes in blood volume. Additionally, it enables real-time monitoring, making it useful for both routine check-ups and critical care situations. Its non-invasive nature makes it safe, cost-effective, and suitable for continuous monitoring throughout pregnancy. Galvanic Skin Response (GSR) is important during gestation as it helps in monitoring the physiological stress and emotional state of the mother by measuring skin conductivity changes. Increased stress levels during pregnancy can negatively affect both maternal health and fetal development, making continuous monitoring essential. GSR can assist in identifying conditions such as anxiety, pain, or discomfort, which may indirectly contribute to complications like Preeclampsia. It also provides real-time insights during labor, where stress and pain levels are significantly elevated. Being a non-invasive and continuous monitoring technique, GSR is useful for improving maternal care and ensuring better pregnancy outcomes.

Baby flitter analysis, also known as fetal movement monitoring, is important during gestation as it helps in assessing the health and well-being of the fetus. Regular fetal movements indicate adequate oxygen supply and proper neurological development. A decrease or sudden change in movements may be an early sign of complications such as Fetal Distress or reduced oxygen supply. Monitoring baby flutters enables early detection of potential risks, allowing timely medical intervention. It is a simple, non-invasive method that provides valuable insight into fetal activity, especially in the later stages of pregnancy.

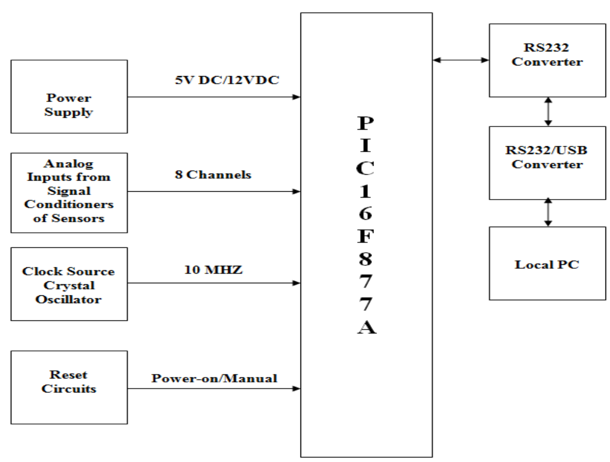

Figure.2 Embedded Microcontroller and block Diagram.

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ONNX model for ADC data processing (ONNX for priority ADC signal Acquiring)

For rapid acquisition of medical parameters, this research adopts an advanced deep learning framework known as ONNX (Open Neural Network Exchange). It is an open-source standard developed by Microsoft and widely used by researchers across the globe. Compared to conventional TensorFlow models, ONNX offers significantly faster performance. Its strong framework interoperability enables seamless integration across different platforms while meeting high-speed data analytics requirements.

This approach supports the advancement of open-source artificial intelligence in science, engineering, and technology. In the proposed system, the AI model is implemented to save critical time, thereby contributing to life-saving interventions (Figure no.). Most of the parameters considered in this study are vital; however, during situations such as labor, certain parameters may suddenly fluctuate or become abnormal. These changes require continuous and careful monitoring, which is currently performed through manual observation or basic alarm-based methods.

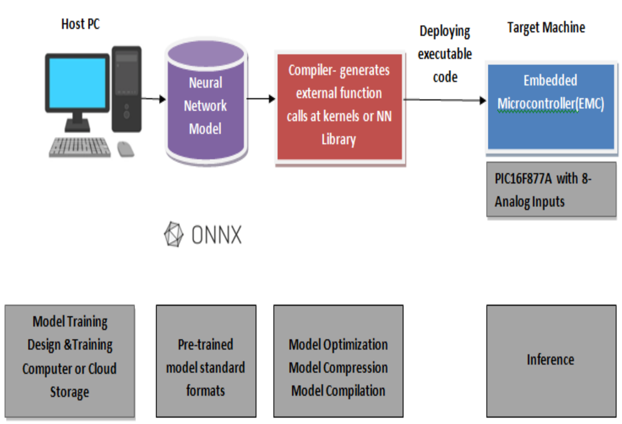
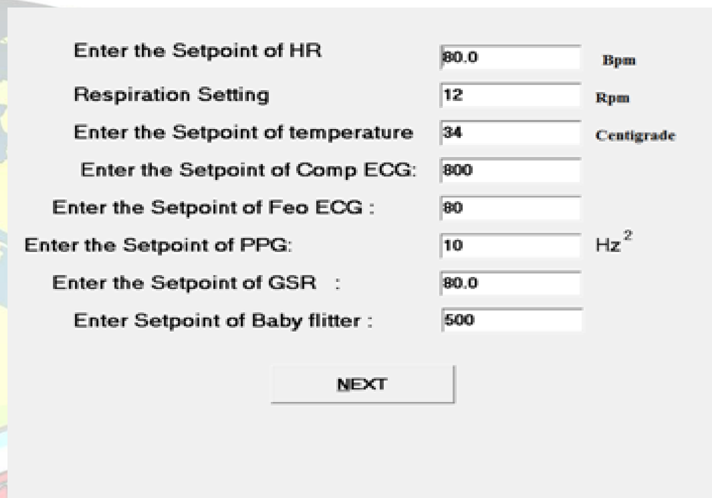


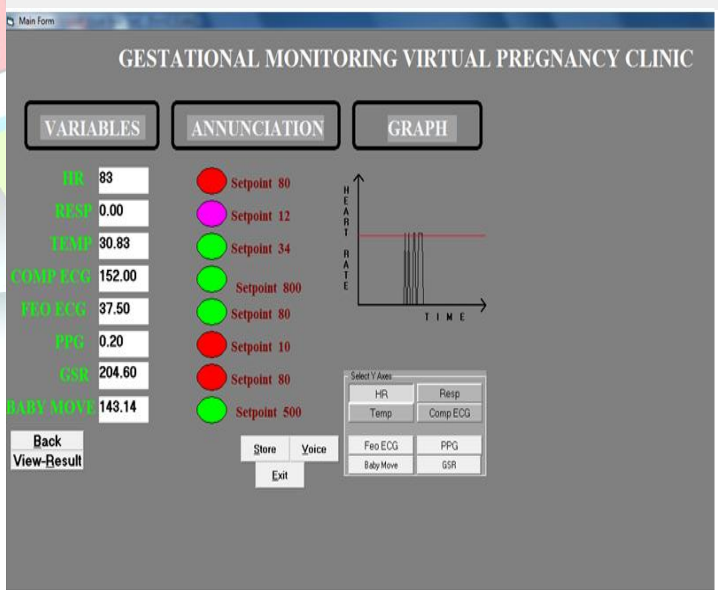
Figure.3. ONNX DNN model for ADC data processing

The proposed ONNX-based model is capable of performing operations at speeds far beyond human capability, enabling rapid detection of abnormalities and facilitating quicker response and recovery. This is achieved by assigning logical binary values (such as 001 for one parameter and 111 for another) through GUJ software, which processes deployable BCD-based data. Using this data, a predictive intelligence system is implemented with the ONNX model to dynamically control and optimize the speed of data acquisition. The system adjusts the data collection rate within a 10–100% time frame based on the importance of each parameter. The entire concept is executed at the backend using Embedded C programming, with the ONNX model converted into a compatible format for deployment on microcontrollers.

III. Results and Discussions

The proposed Hardware with software for the above said Doctors can prefix their set point according to the patient health grounds and their trimester. The below set point screen will appear as first front end.





Above Figure Indicates the Heart rate Profile,

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Temperature and GSR values. Pink color Indicates no sensor connectivity, Red indicates not with in the Range and Green indicates the correct value as per the set point.

mdctab

Date	Time	HR	RESP	TEMP	C ECG	F ECG	PPG	GSR	BM
06-08-2025	15:23:31	0.00	0.05	30.17	185.00	34.20	0.22	136.71	204.60
06-08-2025	15:23:32	0.00	0.00	30.33	192.00	32.40	0.19	137.71	204.60
06-08-2025	15:23:33	0.00	0.08	30.83	164.00	33.30	0.22	138.00	204.60
06-08-2025	15:23:33	0.00	0.00	30.17	185.00	34.20	0.20	136.86	204.60
06-08-2025	15:23:34	0.00	0.00	31.17	186.00	31.40	0.17	136.86	204.60
06-08-2025	15:23:35	0.00	0.00	31.00	171.00	33.50	0.22	137.43	204.60
06-08-2025	15:23:35	0.00	0.05	31.00	188.00	34.20	0.19	136.43	204.60
06-08-2025	15:23:36	0.00	0.00	30.17	179.00	31.50	0.22	137.29	204.60
06-08-2025	15:29:03	0.00	0.00	30.17	202.00	32.70	0.20	144.43	204.60
06-08-2025	15:29:04	0.00	0.05	30.33	168.00	33.60	0.22	145.29	204.60
06-08-2025	15:29:05	0.00	0.00	31.00	191.00	34.30	0.22	145.14	204.60
06-08-2025	15:29:05	0.00	0.00	30.50	200.00	31.30	0.22	144.43	204.60
06-08-2025	15:29:06	0.00	0.00	31.00	169.00	33.50	0.20	144.86	204.60
06-08-2025	15:29:07	0.00	0.00	31.00	189.00	34.40	0.19	144.57	204.60
06-08-2025	15:29:07	0.00	0.00	31.00	202.00	30.90	0.19	143.29	204.60
06-08-2025	15:29:08	0.00	0.05	30.17	169.00	33.70	0.21	144.00	204.60
06-08-2025	15:29:09	0.00	0.05	30.67	188.00	34.60	0.15	143.00	204.60
06-08-2025	15:29:09	0.00	0.08	30.83	199.00	31.20	0.22	143.14	204.60
06-08-2025	15:29:10	0.00	0.13	30.50	174.00	33.80	0.20	142.57	204.60
06-08-2025	15:29:11	0.00	0.00	30.17	189.00	34.60	0.22	142.57	204.60
06-08-2025	15:29:12	0.00	0.00	30.83	198.00	31.20	0.23	142.00	204.60
06-08-2025	15:29:12	0.00	0.03	30.83	164.00	33.70	0.20	142.43	204.60

Above Figure Indicates the database created for future Reference about all the variables involved in Gestation period with date and time.

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