An Energy Efficient Sensor for Thyroid Monitoring through the IoT

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Outline of the talk

- ❖ Introduction and Motivation
- ❖ Novel Contributions
- ❖ Proposed Architecture for Thyroid Monitoring
- ❖ Design of the sensor
- ❖ Implementation and experimental results in Simulink®
- ❖ Conclusions and Future research

Introduction

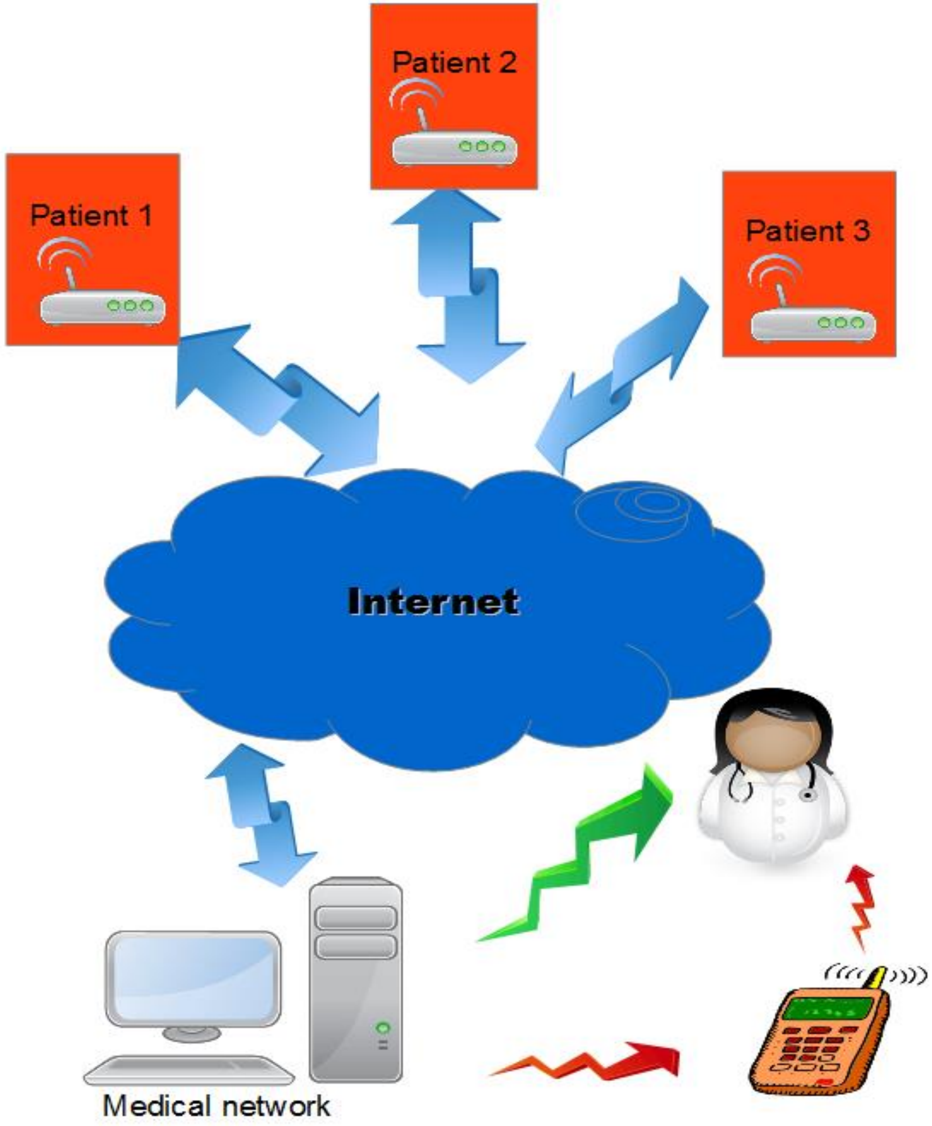
- Thyroid disease occurs due to imbalance of T3, T4 hormones regulated by thyroid-stimulating hormone (TSH) in the body.
- The imbalance of these hormones can affect metabolism, muscle strength, weight and body temperature.
- Thyroid function can be monitored by testing the thyroid hormones in the blood or to continuously monitor the basal body temperature (BBT).
- A thermal sensor for monitoring the BBT is proposed in this paper. Multiple such sensors can be integrated to form a subnet of the Internet-of-Things (IoT).

Introduction

✓ Internet of Things

- The Internet of Things is a network of devices where each device in the network is recognizable and connected.

- It can be thought of as the interconnection of uniquely identifiable smart objects and devices.



Novel Contributions of This Paper

1. The first ever architecture proposed for thyroid monitoring.

2. A thermal sensor to monitor the basal body temperature is proposed.

3. A Simulink® based prototype of the architecture is implemented.

Energy Efficient Sensor module

- The proposed monitoring system can be used at the patient's end to monitor the thyroid hormones periodically.

- The results of the tests can be logged into a database which can be used by the doctor.

- The doctor can analyze the pattern of hormone fluctuations and address the issues based on their severity.

- It can be used by all women of child bearing age, thus increasing the quality of life.

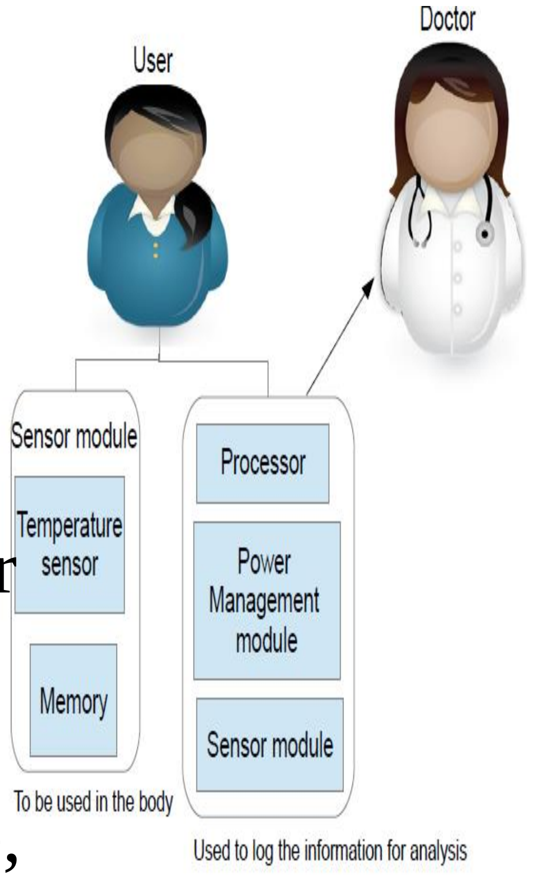


Fig. 1. Sensor module to obtain Basal Body Temperature (BBT).

Basic Architecture

✓ **Ideal Components**

- Sensor/ transducer for data Acquisition.
- Memory.
- Processor.
- Wireless components.
- Personal Computer.
- Battery Source.

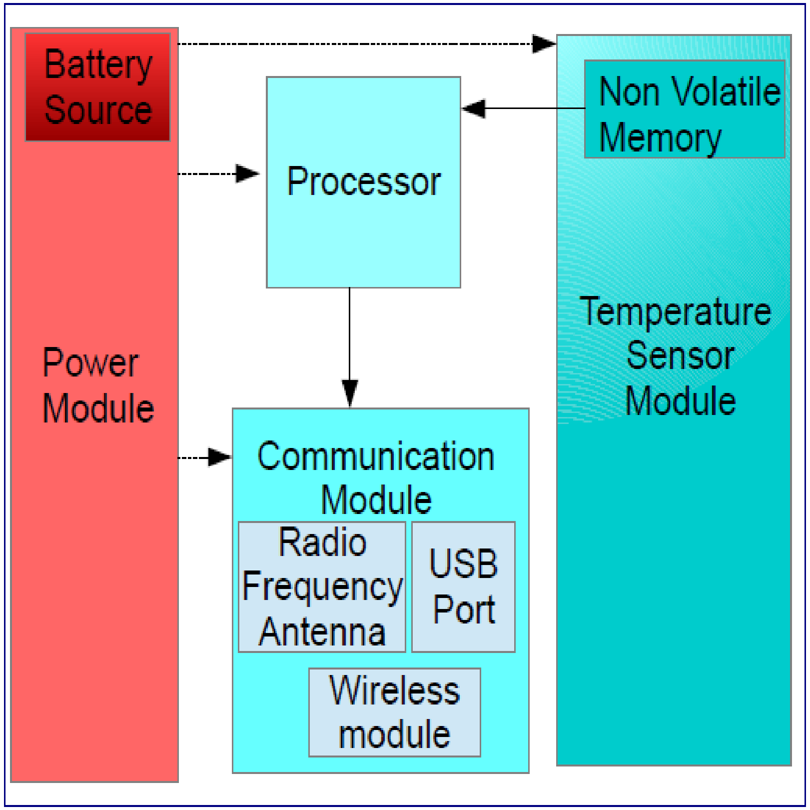


Fig. 2. Basic architecture for smart health monitoring device.

Proposed Architecture for Thyroid monitoring

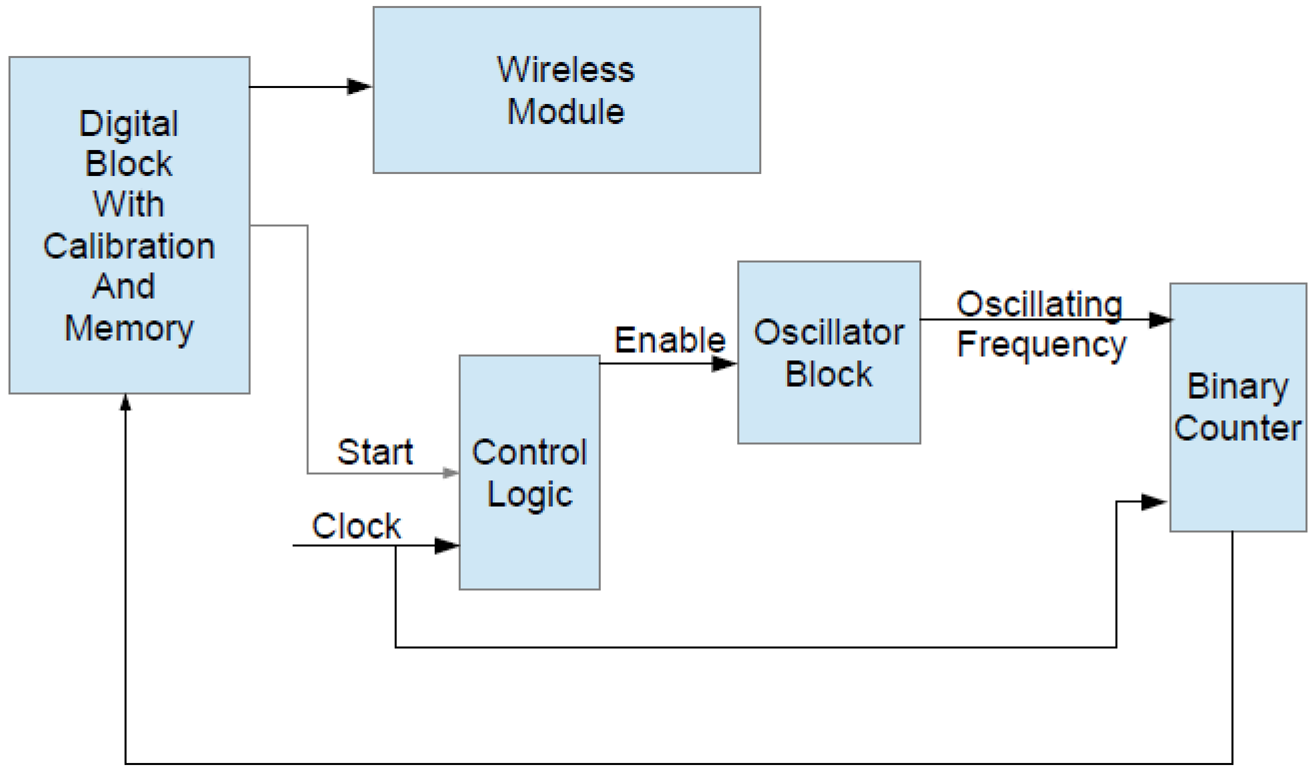


Fig. 3. Block diagram of proposed sensor architecture.

Design of the Sensor

✓ ***Basic blocks:***

1. Control logic.

2. Thermal Sensor.

3. Counter.

4. Controller.

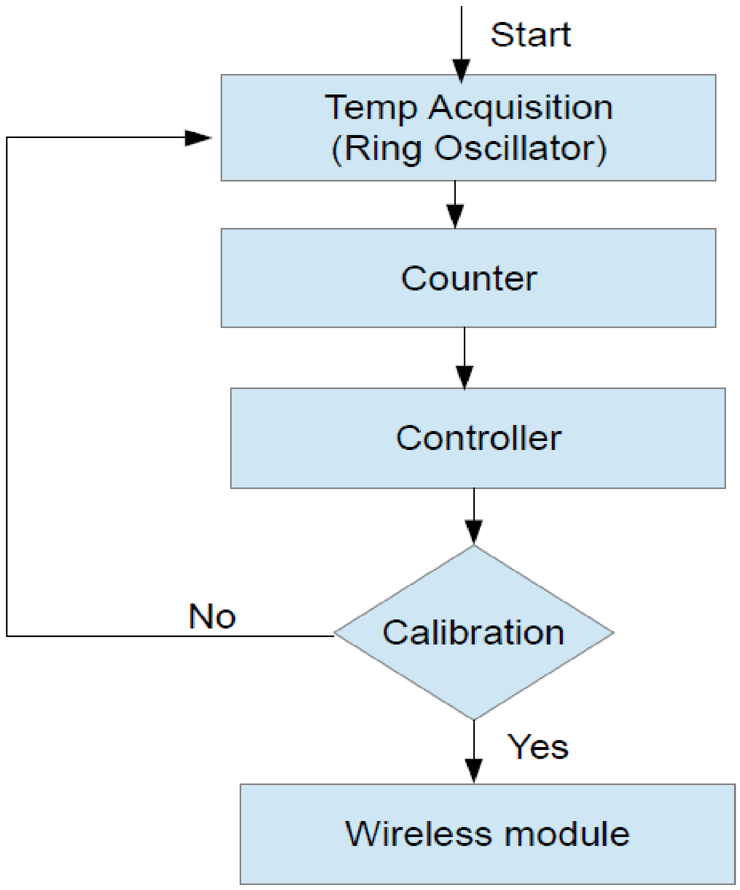


Fig. 5. Design flow of the Thyroid Monitoring Sensor.

Design of the Sensor

1. Control logic

1. It operates synchronously with the binary counter and the control block.

2. When the start signal is provided by the controller, the control logic triggers the ring oscillator by providing enable “high”.

3. This initiates the temperature acquisition process.

Design of the Sensor

2. *Thermal Sensor*

1. The temperature acquisition is done by using a ring oscillator.

2. In order to oscillate the ring should provide a 2π phase shift and have unity voltage gain at the oscillating frequency.

3. The oscillating frequency is given as

$$f = \frac{1}{N_{stage}(Tpd_{,LH} + Tpd_{,HL})}$$

where N_{stage} = number of stages in the ring oscillator
$T_{pd,L}$ *and* $T_{pd,HL}$ = propagation delays

Design of the Sensor

2. Thermal Sensor

4. The threshold voltage is very sensitive to temperature fluctuations.

5. As temperature increases, the oscillating frequency decreases and the time increases.

6. This is used to analyze the variation of temperature based on the oscillating frequency.

7. A 13 stage ring oscillator was designed and the first inverter was replaced with a NAND gate.

Design of the Sensor

3. *Counter*

1. The oscillating frequency produced by the ring oscillator is compared with the system clock using the counter.

2. As temperature increases, the oscillating frequency decreases and the time increases.

3. The ring oscillator output is given as a clock pulse and the system clock is given as input to the counter.

Design of the Sensor

4. Controller

1. The threshold voltage is very sensitive to temperature fluctuations.
2. As temperature increases, the oscillating frequency decreases and the time increases.
3. This is used to analyze the variation of temperature based on the oscillating frequency.

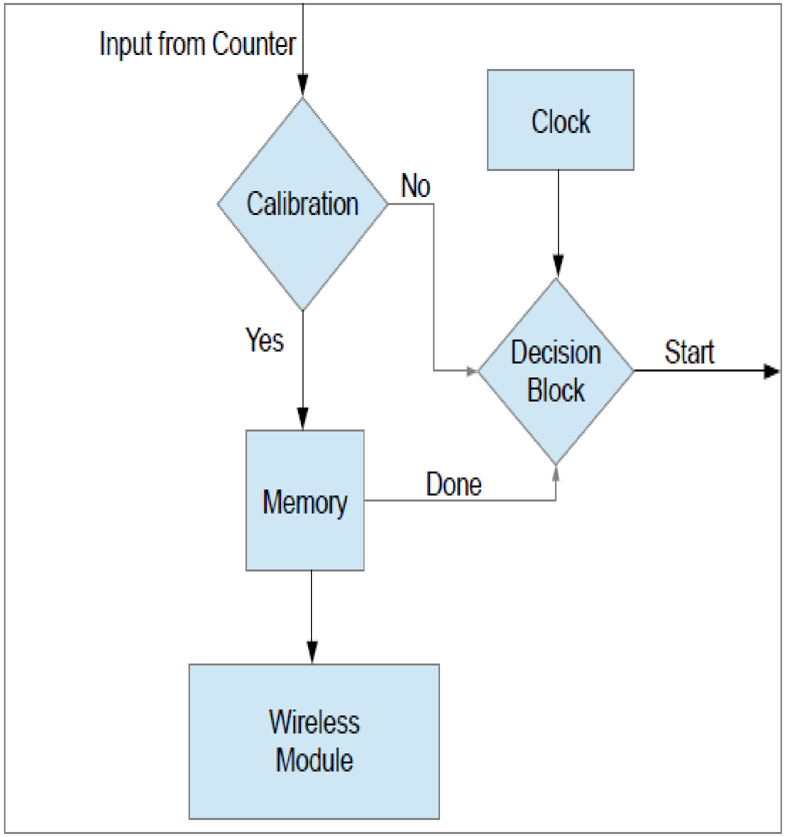


Fig. 4. Block diagram for the control block.

Experimental results

1. The 13 stage ring oscillator and 10 bit binary counter were implemented using circuit components available in the Simulink® library.

2. The temperature dependence feature is modeled for performing temperature analysis.

3. The error signal is triggered whenever the error in calibration is less than or equal to the tolerance level.

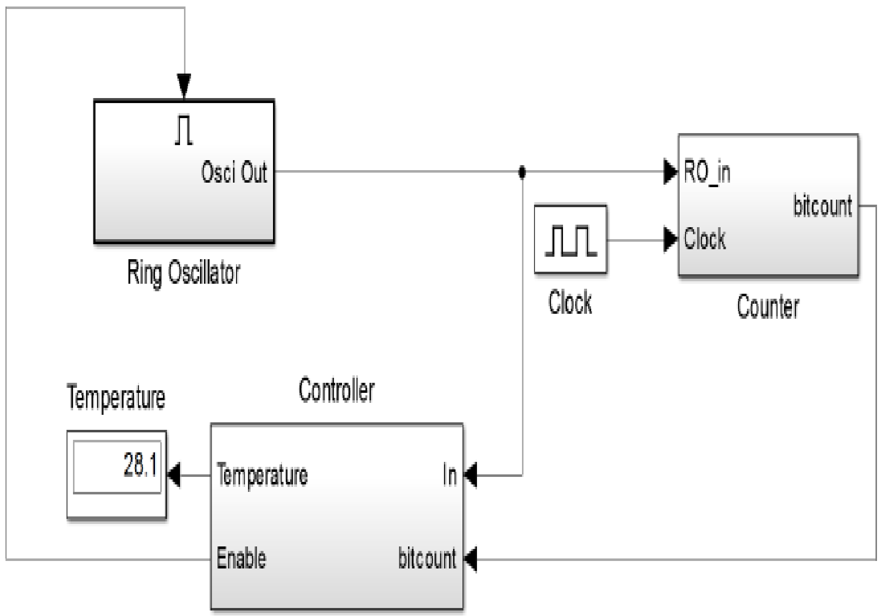


Fig. 6. Prototype of the sensor in Simulink®.

Experimental results

	Temperature (˚C)	Frequency (MHz)	Time Period (ns)
1.	25	42.906	23.307
2.	28	42.942	23.287
3.	30	42.967	23.274
4.	32	42.991	23.261
5.	34	43.013	23.249
6.	36	43.035	23.237
7.	36.5	43.043	23.233
8.	37.2	43.05	23.229
9.	38	43.059	23.224

Table 1. Frequency and Time period values for various Temperatures

Experimental results

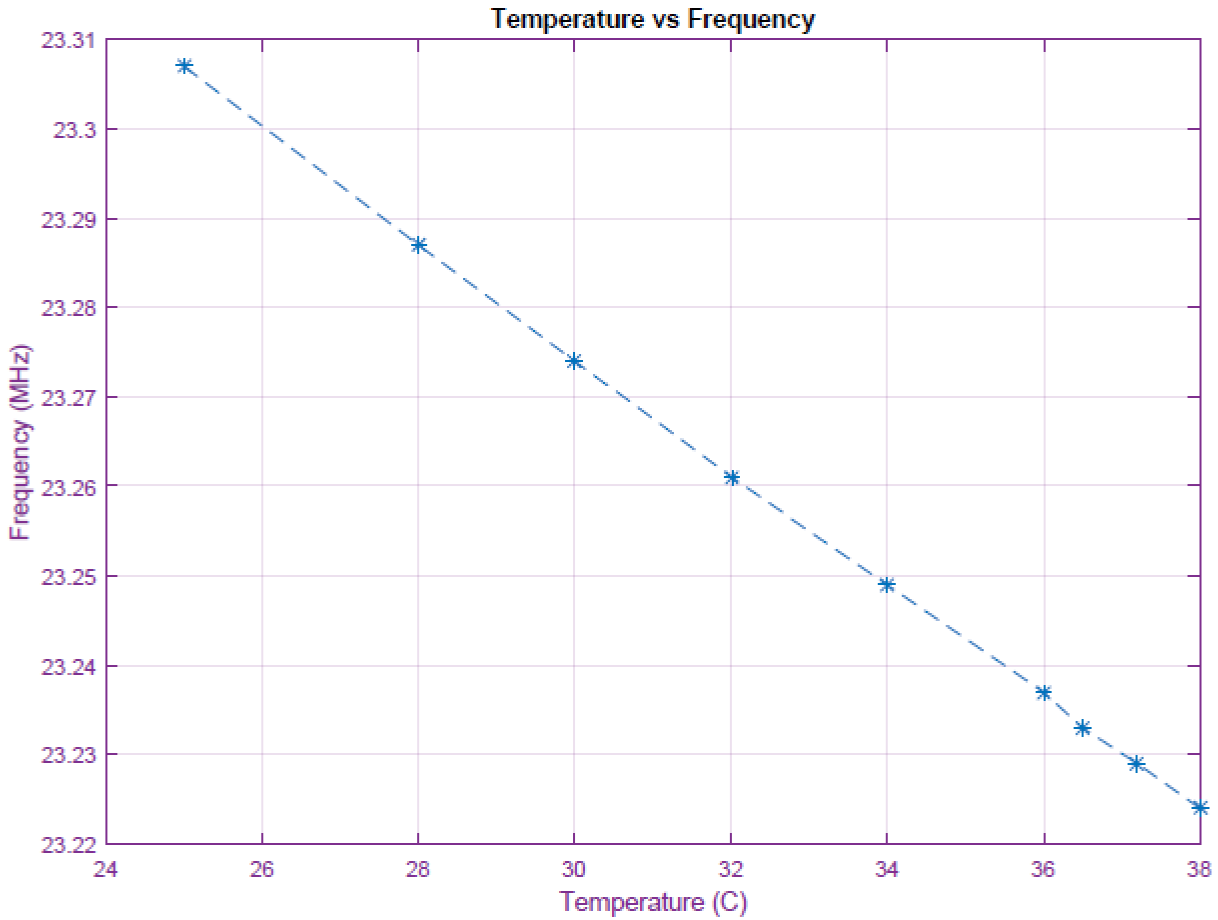


Fig. 7. Temperature versus frequency plot.

Characterization of Thyroid Monitoring Sensor

Characteristics	Values
Temperature range	25˚C to 40˚C
Power Supply	4 V
Accuracy	$\pm$ 0.1˚C
Power dissipation	28.5 e^{-6} W
Frequency range	42.906 – 43.5 MHz

Conclusions and Future work

- A prototype of a temperature sensor for thyroid monitoring is implemented in Simulink® .
- The proposed architecture proved to be energy efficient in the required temperature range.
- Future research involves implementing this architecture in real time and further integrating many such blocks for IoT applications.

THANK YOU