Health Monitoring IoT System for Vehicle

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1. Introduction

1.1. Motivation

Vehicles are now a major part of our comfortable life or we can say that it is necessary, too. Automobile industries are most advanced and also developing drastically. Automobiles have complex systems, both hardware as well as software, and need the best maintenance strategy. We cannot avoid technology and advancement in our daily life, and at the same time, we are facing problems too. It is very necessary for humans to be healthy, similarly, we have to be very careful toward our vehicles too. However, most people do not pay attention to vehicle maintenance, which leads to a higher risk of serious accidents and makes users spend more time and money on repairs. These small vibrations or signals from a vehicle's component during driving may represent the early-stage failure alert. But normally this signal is hard to notice. Because of the market size of electric vehicles growing rapidly, we thought that making a health monitoring system which combines with IoT and cloud computing technology will have a great opportunity to hit the market.

1.2. Target Application

The Following shows three types of target application for our SoC design:

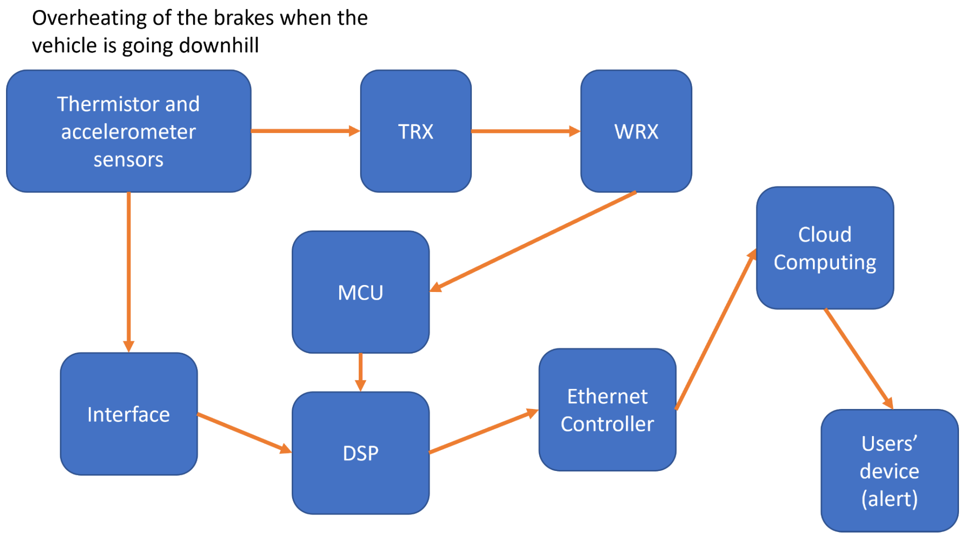
1. Detects early-stage failures:
   - Reduce the risk of breakdown
   - Improve machine performance
   - Extend machine use life
2. Predicts failures:
   - Predicting machine failure from sensors detection and users' driving style
3. Scoring machine health and your driving habits:
   - Rating how users maintain their vehicles and their driving style through cloud computing

1.3. Application Scenario

1. Vehicle failure alert system

The vehicle failure alert system focuses on cooperative alert services based on timely and reliable communication under the challenging circumstances pertaining to a highly mobile vehicular network. Through a cross-layer design, we gain the flexibility needed to adapt the system to the individual requirements of the chosen application scenarios that represent different situations where the possibility of the component failure which can make a dangerous circumstance for driving.

Here is one of example how the alerting system work:

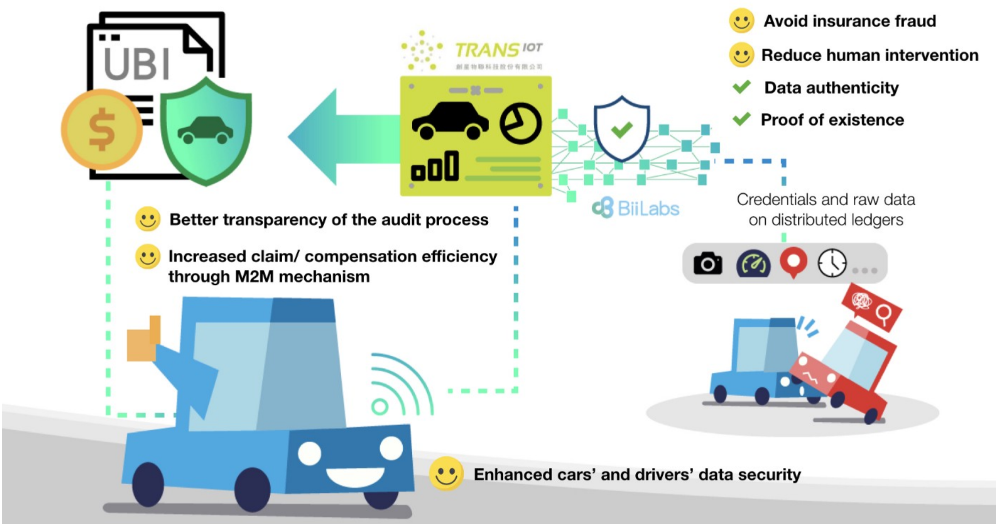


2. Usage Based Insurance

The emergence and growth of connected technologies and the adaptation of big data are changing the face of all industries. In the insurance industry, Usage-Based Insurance (UBI) is the most popular use case of big data adaptation. UBI can be categorized into the following three types:

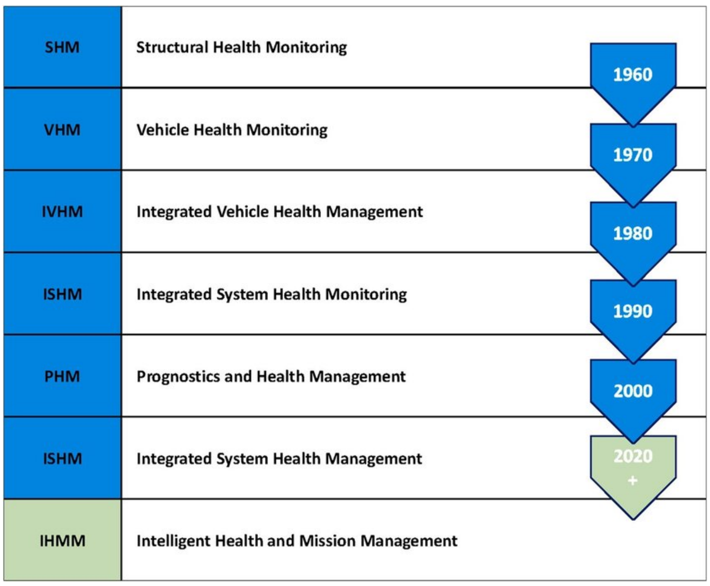
1. Pay-As-You-Drive (PAYD): The premium is calculated based on the number of miles driven based on the odometer readings. The only parameter considered is milometer reading and there is no distinction between good and bad drivers resulting in both of them paying the same premium.
2. Pay-How-You-Drive (PHYD): The premium is calculated based on the customer's driving pattern such as over speed, hard acceleration, hard braking, and hard cornering, etc. Driver score is arrived at the end of each and every trip for the particular driver. The individual scores are normalized for the policy year to arrive at the overall driver behavior to calculate the premium and discount.
3. Manage-How-You-Drive (MHYD): The premium is calculated based on the same way as PHYD in addition to the real-time alerts and suggestions to the driver for ensuring safety.

Over the years PAYD and PHYD models have reasonably stabilized with the emergence of a few dominant designs, however MHYD is still evolving and this is our target market for this SoC design.



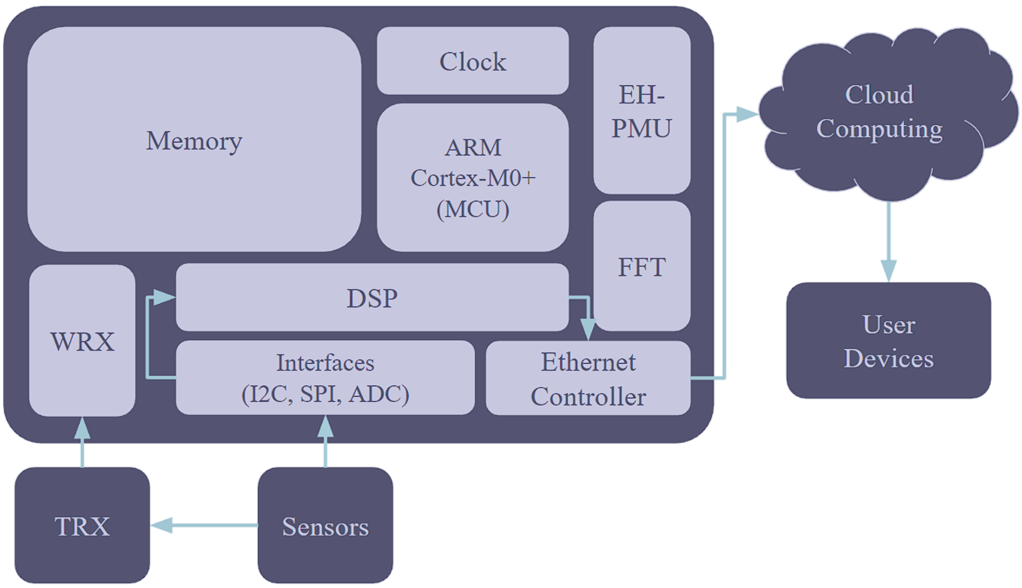
2. Evolution

The initial concept of Structural Health Monitoring (SHM) focused solely on monitoring the structural integrity of aerospace platforms and, more specifically, addressing the early detection of plastic deformations and fatigue damage. The National Aeronautics and Space Administration (NASA) introduced Vehicle Health Monitoring (VHM) which expanded this concept to include appropriate sensors and software to monitor multiple aspects of aerospace vehicles. As the data obtained began to be used for maintenance and task planning activities, the term “monitoring” was replaced by “management”, giving rise to the concept of Integrated Vehicle Health Management (IVHM). The Prognostics and Health Management (PHM) concept places more emphasis on analytical methods which can accurately predict the Remaining Useful Life (RUL) of faulty or near failure components, and on the use of this information to improve predictive maintenance practices. As the term “vehicle” was only associated with aerospace platforms, the more comprehensive term of Integrated System Health Management (ISHM) was coined to refer to the whole System-of-Systems (SoS) architecture, breaking down complex aerospace systems into their multiple constituting elements and focussing on the several interactions occurring between them. For such complex systems, the terms Intelligent Health and Mission Management (IHMM) have been used to describe a capability that focuses on determining the health condition of every element and providing data, information and knowledge to ensure safe and efficient operations.



3. System Architecture

The following figure shows a system block diagram for the SoC we planned. The SoC has an ARM Cortex-M0+ microcontroller (MCU) to execute application code, clocked by a crystal oscillator for low power. An integrated PLL scales the clock for higher speed computation and for streaming sensor data by a direct memory access block. An FFT accelerator provides power-efficient computation at the edge, which is critical to the machine health monitoring application. A wakeup receiver (WRX) with full wakeup protocol gives interference robustness and security for dense networks in industrial environments. The SoC includes SPI, I2C, and ADC to interface with external parts. A multi-modal energy-harvesting power management unit (EH-PMU) enables reliable battery-less operation from an electromagnetic (EM) coil, photovoltaic (PV) cell, thermoelectric generator (TEG), vibration, or RF energy harvesting. The interfaces in the SoC will be connected to DSP for processing the data received from the sensors. The processed data will be then transmitted to the cloud through the Ethernet controller which is responsible for managing the flow of data over the network, and can transmit the processed sensor data to the cloud through a wireless connection. After performing computing on the cloud, users can check the predicted result on their devices, such as smartphones, to be aware of vehicle component failure in an early state.

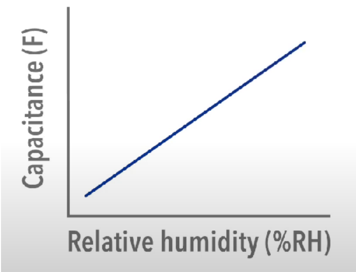


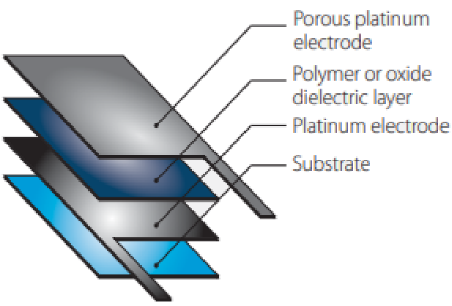
4. Technology

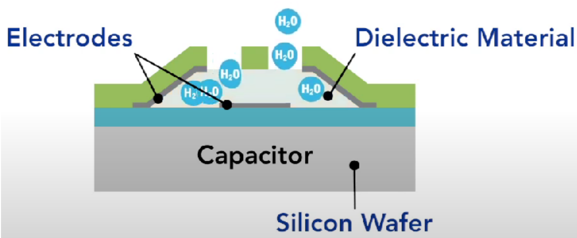
4.1. Sensor

4.1.1. Relative Humidity Sensor

A capacitive relative humidity sensor is a type of humidity sensor that uses a capacitive element to measure the relative humidity of the air. The capacitive element consists of a thin, dielectric material that is exposed to the air. The dielectric material absorbs moisture from the air, and this causes the capacitance of the element to change. The change in capacitance is then measured and used to calculate the relative humidity of the air.Capacitive humidity sensors are generally very accurate and stable, and they are often used in applications where precise humidity measurement is important. They are also relatively fast-responding and can measure humidity over a wide range of temperatures. However, they can be sensitive to contamination and may require frequent calibration to maintain their accuracy. They are also typically more expensive than other types of humidity sensors.

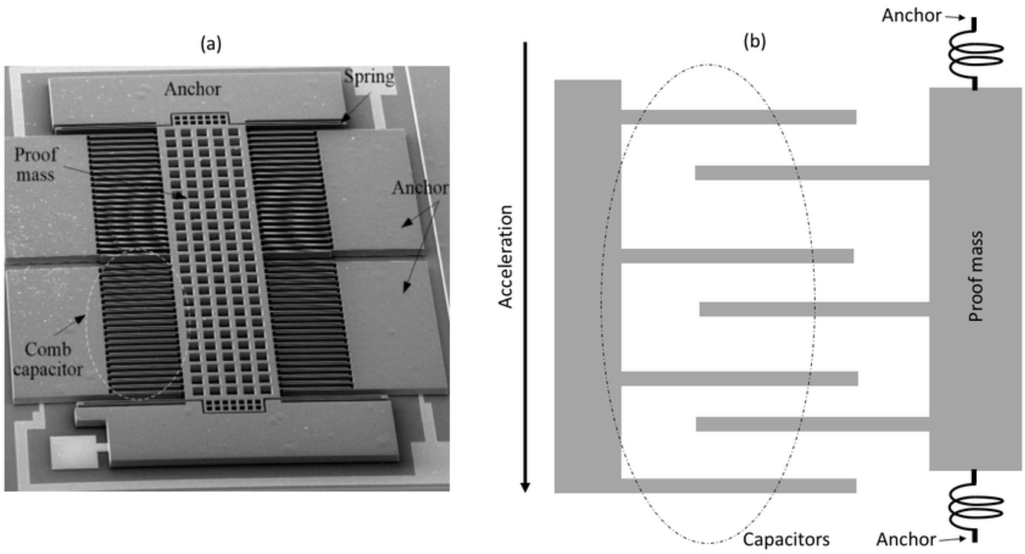






4.1.2. Accelerometer

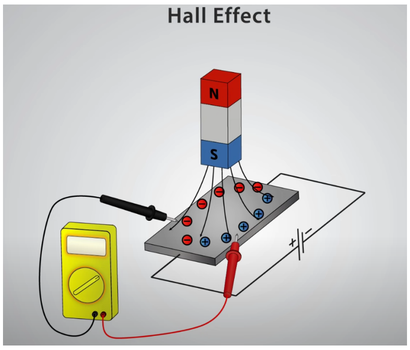
A capacitive accelerometer is a type of accelerometer that uses capacitance to measure acceleration. It works by measuring the displacement of a proof mass (a mass that moves in response to acceleration) within a capacitor (a device that stores electrical charge). The displacement of the proof mass changes the capacitance of the device, which can be measured and used to determine the acceleration.Capacitive accelerometers are commonly used in a variety of applications, including automotive systems, mobile phones, and industrial machinery. They are known for their high sensitivity and can be used to measure acceleration over a wide range. They are also relatively inexpensive to manufacture and are easy to integrate into a variety of systems. However, they can be sensitive to temperature changes and may require periodic calibration to maintain their accuracy.

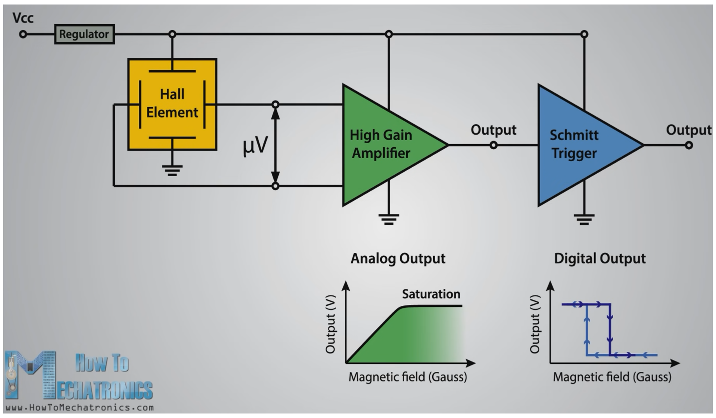


4.1.3. Hall Effect Magnetometer

A Hall effect magnetometer is a device that uses the Hall effect to measure the strength and direction of a magnetic field. The Hall effect is a phenomenon that occurs when a current-carrying conductor is placed in a magnetic field, resulting in a voltage difference across the conductor. By measuring the voltage difference, it is possible to determine the strength and direction of the magnetic field.Hall effect magnetometers are commonly used in a variety of applications, including geomagnetic field mapping, metal detection, and navigation systems. They are known for their high sensitivity and accuracy, and are often used in place of traditional magnetometers, which can be bulky and less precise. Hall effect magnetometers are also relatively immune to interference from other electrical sources, making them well-suited for use in environments where there may be other sources of electromagnetic noise.

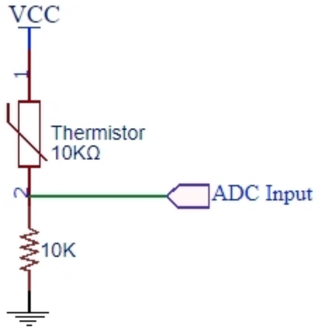
Therefore, we applies high gain amplifier and Schmitt trigger circuit to overcome noise and bounce issue.

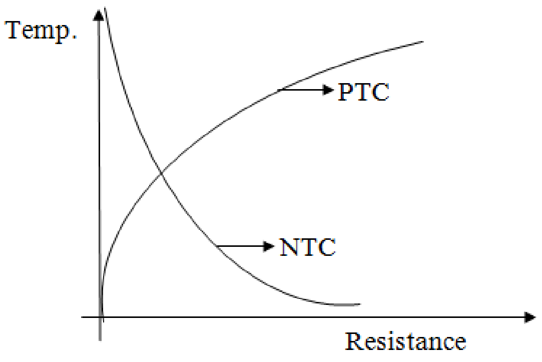




4.1.4. Thermistor

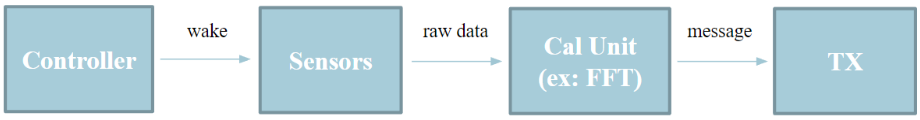
A thermistor is a type of resistor that has a resistance that changes in response to changes in temperature. Thermistors are made of materials that have a high resistance to electricity at low temperatures and a low resistance at high temperatures. This means that as the temperature increases, the resistance of the thermistor decreases, and as the temperature decreases, the resistance of the thermistor increases.Thermistors are commonly used as temperature sensors because they are small, inexpensive, and can be easily integrated into a variety of systems. They are also relatively accurate and can be used to measure a wide range of temperatures. There are two main types of thermistors: negative temperature coefficient (NTC) thermistors and positive temperature coefficient (PTC) thermistors. NTC thermistors have a resistance that decreases as the temperature increases, while PTC thermistors have a resistance that increases as the temperature increases.





4.1.5. Operation Flow

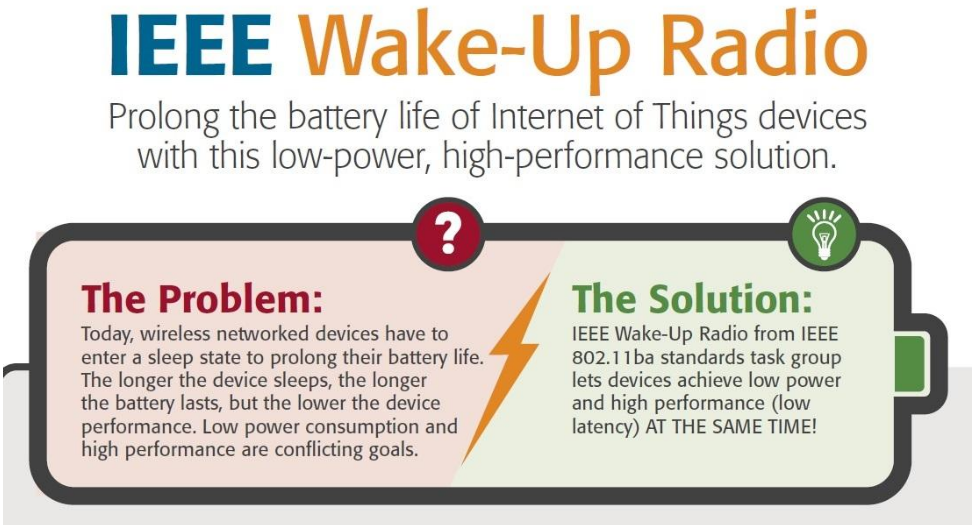
The first step of our basic operation flow for monitoring in varying conditions is that the controller (WRX) periodically transmits a wake signal to all sensor modules. After receiving the wake, the sensors wake up and start sensing the environment to get the raw data. When finishing a session of sensing, sensor modules send its raw data to a calculation or data processing unit such as FFT. Then the processing unit could extract the information from raw data and send the information as message data to TX or memory in our SOC.



4.2. Tx & Rx

4.2.1. Wake-Up Radio

As the cost for the chipsets for IoT devices decreases, a bottleneck for massive deployment of IoT may be the ability to provide these chipsets with energy, and preferably energy that will last the entire lifetime of the chipset. Many devices intended for IoT applications will only transmit and receive very small amounts of data only a few times a day. In many cases, there is sufficient energy in a coin-cell battery for all useful communication in such a device's lifetime. The problem is that in this scenario an IoT device does not know when to expect to receive data, and thus must perform energy-draining scanning to detect the presence of a packet. So, a receiver will sleep in a very low power mode that would wake up just in time for the data to be received is a goal of the Wake-Up Radio.



4.2.2. IEEE 802.11ba

In May 2016 work on the Wake-Up Radio in IEEE 802.11 was a first step towards standardizing a wake-up receiver. To reflect that a standardized solution includes important MAC features and is not just a power efficient receiver, the term Wake-Up Radio (WuR) is used rather than Wake-Up Receiver. From July to November 2016, the scope and targets of the standard were defined, which are summarized in the Project Authorization Request (PAR). There are three key requirements in the PAR:

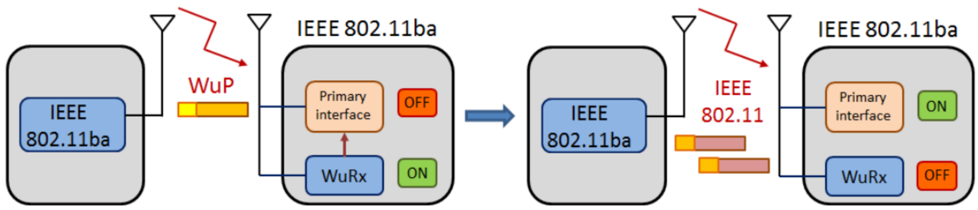
1.The WuR should have an active power consumption of less than 1mW.

2.The WuR should coexist with legacy IEEE 802.11 devices in the same band.

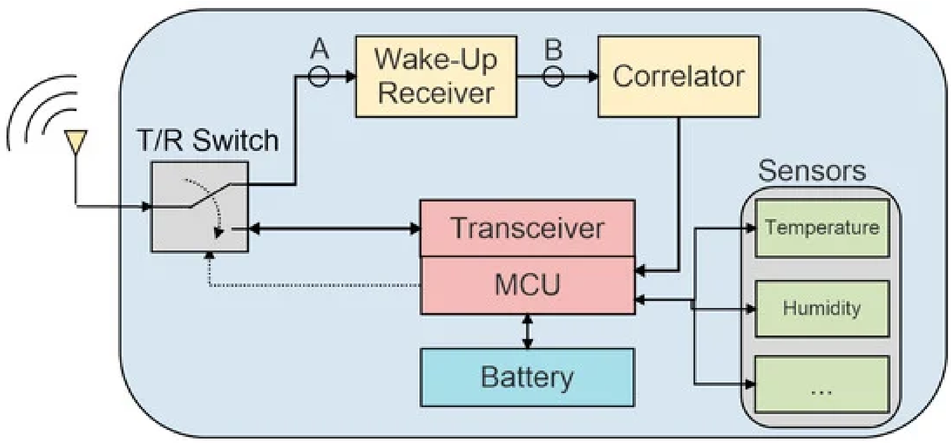
3.The WuR should meet the same range requirement as the primary connectivity radio.

4.2.3. Wake-Up Radio system architecture

In order to foresee the requirements that future IEEE 802.11ba technology is expected to meet, engineers try to imagine different scenarios where the use of IEEE 802.11-based WuR will bring evident benefits. A normal IEEE 802.11 communication happens through the primary radio as shown in picture below. This basic operation poses three requirements that are common to all studied cases. First, since primary radios are responsible for sending WuR packet (WuP), coexistence of these new frames with legacy IEEE 802.11 transmissions must be enabled. Second, the range of WuR communication should be the same as the one of the primary radio so that normal IEEE 802.11 operation is possible after the wake-up. Third, WuR-capable devices must be uniquely identified so that the WuP has effect only on the intended recipient.

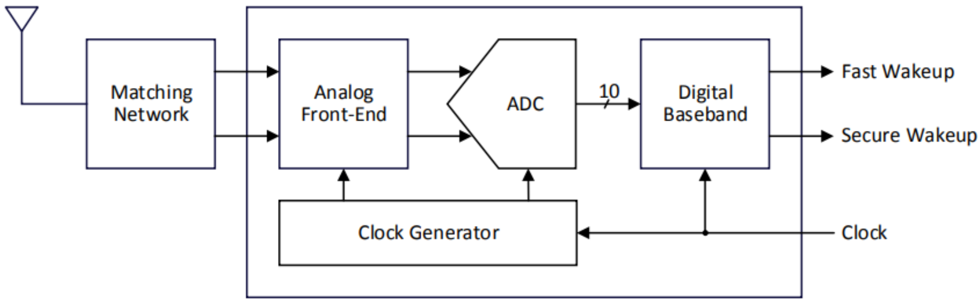


The implementation of a WuR apart from the main radio interface can ensure a low latency along with a very low power consumption. With the following circuit design, the WuR is always listening to the communication channel while the main transceiver remains in sleep-mode. The WuR must be constantly listening to the communication channel to be able to detect wake-up signals coming from other nodes in order to maintain a reasonable latency. The nodes can be individually addressed with the exchange of wake-up signals or packets, employing distinctive identifiers to avoid waking up other sensor nodes. Only after reception of the wake-up signal with the right identifier are the main microcontroller (MCU) and the conventional radio interface awakened to begin data exchange via conventional radio communications.



4.2.4. WuRx wake-up circuit

The WRX circuit that we used comprises an off-chip matching network to provide passive gain into a rectifier-first analog front-end with baseband gain before conversion by a differential, 10b SAR ADC. The protocol supports both fast wakeups with shorter time-on-air and secure wakeups with in-band burst and continuous wave interference robustness, data payload, and protection against energy or replay attacks. If the digital baseband correlates the received sync word above a threshold, it issues a fast wakeup to the MCU. For secure wakeups, the baseband demodulates a header in the physical layer and passes the secure payload through a cryptographic checksum before issuing a wakeup.



4.3. Power Management

4.3.1 Microcontroller

Cortex-M0+ is a 32-bit microcontroller architecture developed by ARM Holdings. It is a low-power and low-cost version of the Cortex-M3 and Cortex-M4 architectures, and is intended for use in microcontrollers, automotive devices, and other low-power IoT devices. Cortex-M0+ microcontrollers are widely used in a variety of applications, including consumer electronics, industrial control, and medical devices.

Since the Cortex M0+ uses a two-stage pipeline, the Cortex M0+ consumes less power than the Cortex M0. Moreover, the Cortex-M0+ processor also supports a Memory Protection Unit (MPU), which is a hardware feature that protects the system from unauthorized memory access. The MPU allows the system administrator to define protected memory regions and ensure that only specific software components can access these regions.

The MPU works by triggering a memory protection exception when a program tries to access a protected memory region. The exception handler can then check the cause of the exception and decide whether to allow access to the region. This prevents unauthorized software from accessing critical parts of the system, helping to secure the system.

The Cortex-M0+ processor has several low-power sleep modes that can be used to reduce power consumption when the processor is idle.

The available sleep modes for Cortex-M0+ are:

1. Normal sleep mode

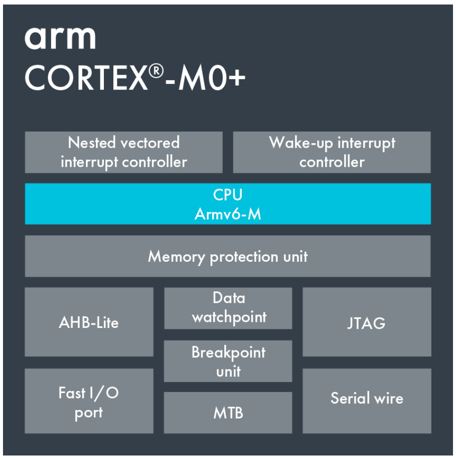
   In this mode, the processor clock is stopped, and all peripherals are halted. This is the lowest power sleep mode, but it takes the longest to wake up from.

2. Deep sleep mode

   Similar to sleep mode, but in addition to stopping the processor clock and halting peripherals, the voltage to the processor is also reduced, further reducing power consumption. This mode has a slightly longer wake-up time than sleep mode.

3. Deep sleep with SRPG (State Retention Power Gating)

   Similar to deep sleep mode, but in addition to reducing the voltage to the processor, the SRPG feature is used to completely power off the processor. This is the lowest power sleep mode available, but it has the longest wake-up time.

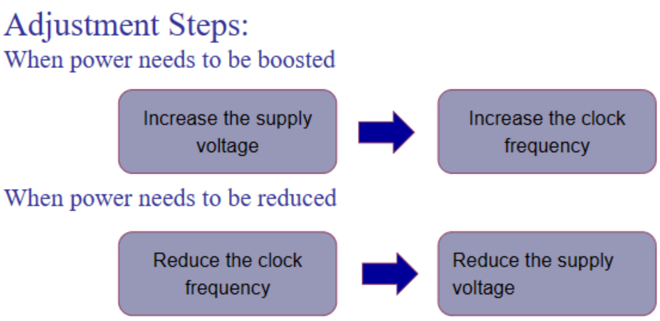


4.3.2 DVFS

DVFS (Dynamic Voltage and Frequency Scaling) is a technique used to adjust the voltage and frequency of a microprocessor or system-on-chip (SoC) in order to save power.

In a system with DVFS, the voltage and frequency of the processor can be dynamically adjusted based on the workload. For example, if the processor is idle or running a low-power task, the voltage and frequency can be reduced to save power. If the processor is running a resource-intensive task, the voltage and frequency can be increased to improve performance.

DVFS can be implemented in a variety of ways, including using on-chip voltage and frequency regulators or off-chip regulators. It can also be controlled by software or hardware. Overall, DVFS is a useful technique for reducing power consumption in IOT systems that need to balance performance and power efficiency.



4.3.3 Energy Harvesting

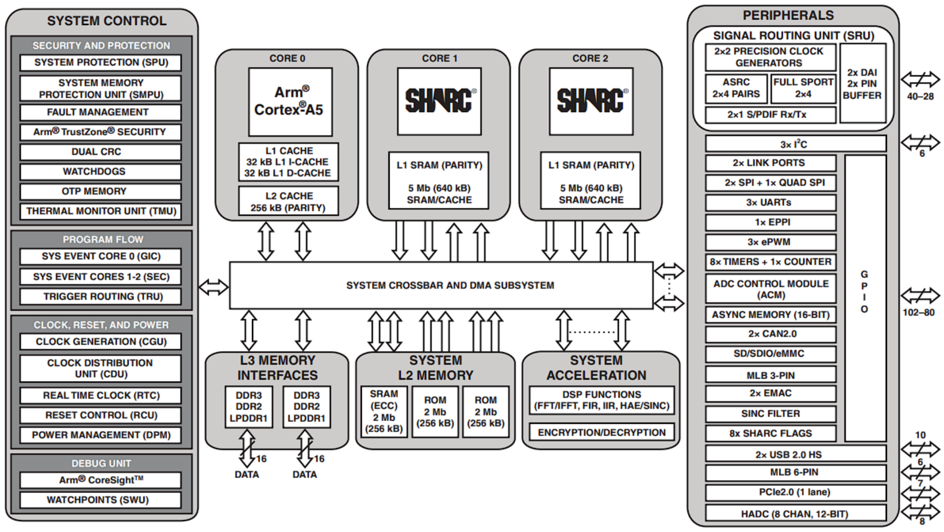
A multi-modal energy-harvesting power management unit is a device that is used to manage the power generated from multiple energy-harvesting sources. Energy-harvesting technologies convert ambient energy sources, such as solar or kinetic energy, into electrical energy that can be used to power devices. A multi-modal energy-harvesting power management unit can help to optimize the use of these energy sources by intelligently distributing the power generated among different devices or storing it in a battery for later use. The unit may also include features such as power conversion and regulation to ensure that the power delivered to devices is stable and meets their specific power requirements. In this system, we plan to harvest energy from electromagnetic(EM) coil, photovoltaic (PV) cell, thermoelectricgenerator (TEG), vibration, and RF energy, and then store the energy into supercapacitors.

4.4. AIoT System

The AIoT system is constructed with a DSP for processing data received from the sensor, an Ethernet controller to manage the flow of data over the network and transmit the processed sensor data to the cloud through wireless connection. Inside the DSP, there is a machine learning model for predicting automotive component failure.

4.4.1. Digital Signal Processor

The DSP we chose to apply is ADSP-SC58x from Analog Devices.



The DSPs are high-performance, low-power digital signal processors that are designed for use in a variety of applications, including automotive, industrial, and consumer applications. They are part of the Analog Devices SHARC+ family of DSPs, which are known for their high performance and low power consumption. The DSPs are capable of operating at data rates up to 1.5 Gbps and also include features and peripherals that are useful for automotive applications, such as support for Ethernet, CAN, and other protocols.

Key features:

- **Dual-core architecture:** The DSPs include two SHARC+ cores, which can operate independently or be used in a lock-step configuration to provide redundant processing. This makes them well-suited for safety-critical applications that require high reliability.
- **High-speed interfaces:** The ADSP-SC58x DSPs include a variety of high-speed interfaces, including Ethernet, USB, and serial interfaces, which can be used to connect to external devices and networks.
- **Low power consumption:** The ADSP-SC58x DSPs are designed for low-power operation, and they include various power-saving features, such as dynamic voltage and frequency scaling, to help reduce power consumption.
- **On-chip peripherals:** The ADSP-SC58x DSPs include a variety of on-chip peripherals, including memory controllers, DMA controllers,

and timer/counters, which can be used to improve the performance and efficiency of the DSP.

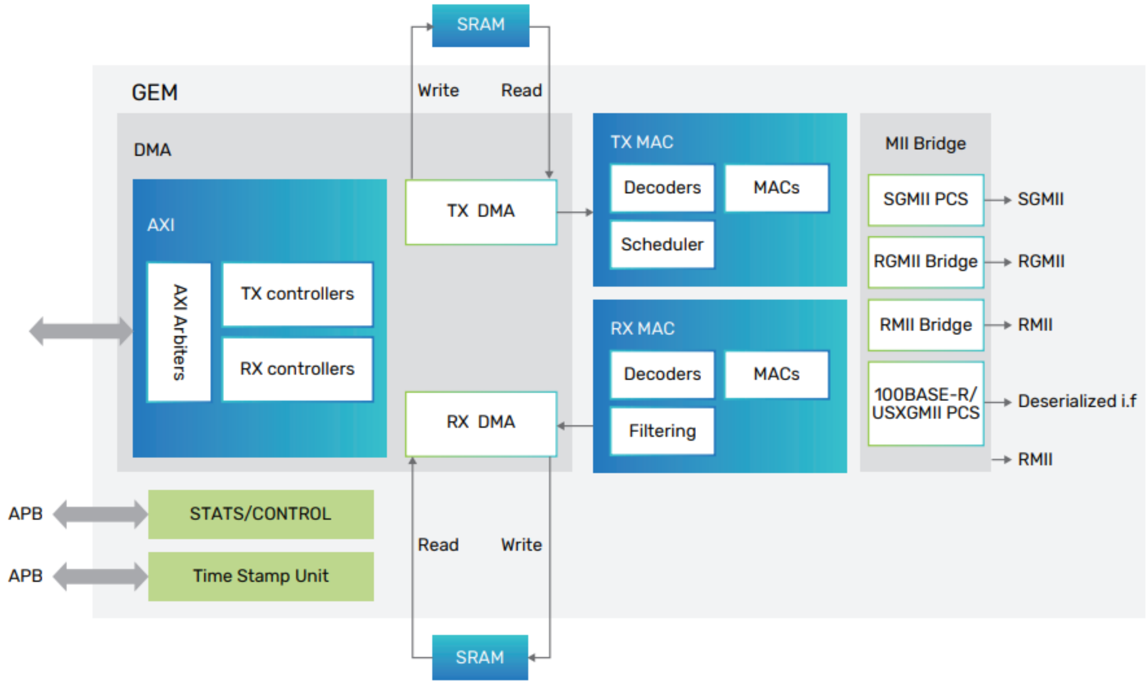
- **Wide operating temperature range:** The ADSP-SC58x DSPs are designed to operate over a wide temperature range, from -40°C to +105°C, which makes them well-suited for use in harsh environments.

4.4.2. Ethernet Controller

10G/2.5G/1G Multi-Speed Ethernet Controller IP for Automotive Applications from Cadence will be integrated in this design. It is a specialized integrated circuit that is designed for use in automotive networks. It is a high-performance Ethernet controller that is capable of supporting data rates of up to 10 Gigabits per second (Gbps), 2.5 Gbps, or 1 Gbps, depending on the specific configuration.

The Ethernet controller IP is intended for use in automotive applications, and it includes various features and technologies that are optimized for use in vehicles. For example, it includes support for time-sensitive networking (TSN) and other protocols that are commonly used in automotive networks, and it is designed to withstand the harsh operating conditions found in vehicles.

The Ethernet controller IP is available from Cadence as an intellectual property core, which means that it can be easily integrated into a larger SoC design. This can be a convenient and cost-effective solution, as it allows us to easily incorporate the Ethernet controller into another SoC and customize it to meet the specific requirements of our application.



As shown above, the Controller IP for Automotive connects to a PHY through standard media independent interfaces such as MII, RMII, GMII, RGMII, XGMII, SGMII, or USXGMII. The host layer access to the Controller IP for Automotive is through industry-standard AXI or AHB interfaces when the DMA is being used or through an external FIFO interface. A separate APB interface allows the host applications to configure the Controller IP for Automotive.

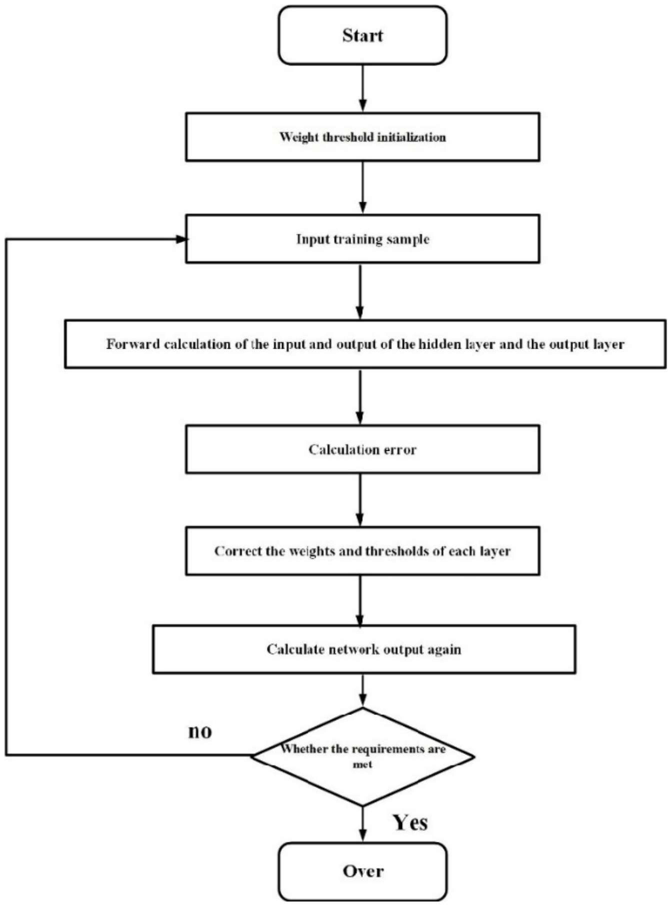
4.4.3. Communication Protocols

To allow our SoC to easily communicate with other electronic control units (ECUs) and systems in the vehicle, we chose to use Controller Area Network (CAN) protocol when designing an Soc for use in vehicles.

CAN is the most commonly used communication protocol in in-vehicle networks. It is a message-based protocol, using a fixed format for transmitting data between devices, that was developed in the 1980s for use in the automotive industry. The protocol is used to facilitate communication between ECUs in a vehicle and allows for real-time exchange of data between these units. CAN is designed to be highly robust and resistant to noise and interference. It uses a differential signaling scheme and a bit-wise arbitration mechanism to ensure reliable communication even in harsh environments.

4.4.4. Neural Network

The machine learning model stored in the DSP will be an Improved Back Propagation (BP) neural network. It is a type of artificial neural network that is trained using the backpropagation algorithm. The backpropagation algorithm is a common method for training feedforward neural networks, which are networks that have a fixed input layer, one or more hidden layers, and an output layer.



The main difference between the BP neural network and Improved BP neural network is that the later neural networks incorporate additional techniques to improve the performance and efficiency of the network. These techniques can include the use of momentum, weight decay, and adaptive learning rates. The Improved BP neural networks are widely used due to their ability to learn and adapt to new data and their ability to perform well on many different types of problems.

4.4.5. Wireless Connection to Cloud

We will utilize the built-in modem in the automotive system to transmit the data from the DSP through an Ethernet controller. The data will be sent through Wi-Fi to the cloud for more complex computing such as recommending the near repairing spots. Users can check the predicting result of the vehicle component failure, components that should be repaired, and near-by repair spots on their own devices since AT&T's in-car Wi-Fi service will be applied in this system. The vehicle and the user's devices will become a network communicating and sharing information about the vehicle components.

5. Industry Analysis

5.1. Porter’s 5 Forces

5.1.1. Competition in the industry

Medium,

Because this product is a relatively new field, most of the technical aspects are still under development, so there are relatively few competitors in the initial stage.

5.1.2. Potential of new entrants into the industry

High,

Although there are not many competitors now, there may be many potential competitors or manufacturers who are researching and developing this type of product.

5.1.3. Bargaining power of suppliers & Bargaining power of customers

High for suppliers and low for customers,

For both sides of the bargaining power, the supplier's advantage should be greater, not only because it is a relatively new product, but also because The safety of the vehicle is a very important issue, and most consumers will consider the safety features as the most important factor, and will not lower the quality of the product in order to lower the price.

5.1.4. Threat of substitute products

Medium,

Although IoT for monitoring the health of the car is very important, there are other alternatives that can do the same thing, for example, some of the chips on diagnostic health functions can be integrated directly into the chip of the car, this part may depend on which method of lower cost, better performance, in order to win over the competition.

5.2. SWOT

5.2.1. Strength

There are two main advantages, the first is that it can respond faster to problems in car parts than the manual inspection method, and the second advantage is that a safe driving environment is very important and cannot be ignored.

5.2.2. Weakness

The disadvantage is that it has a long life cycle, which may result in lower margins for the company, and the second disadvantage is that the strict safety standards make it more expensive.

5.2.3. Opportunity

In terms of opportunities, the market for EVs is expanding rapidly, which is good for the development of the product.
And because it is a safety-related product, it can also attract relevant insurance companies to cooperate with them.

5.2.4. Threat

Regarding the threat of alternative products, as mentioned in Porter's five forces analysis above, because some features can be integrated directly into the car chip, he needs to outperform the other side in terms of performance and cost to eliminate this threat.

6. Conclusion

This SoC that we designed is concerned with the health of vehicles and their monitoring. The information given by the device includes vehicles' performance on various parameters of their subsystems. The SoC provides a comprehensive solution for modern vehicle health monitoring systems. Including multiple sensors to monitor and analyze the health and obtain their real-time results. Energy-Harvesting system enables continuously active battery-less self-powered products. WRX coordinates low-latency and high-density network communication. AIoT application makes it possible for users to access the vehicle data fast and friendly.

7. References

Sensors

- https://www.allaboutcircuits.com/technical-articles/mems-ic-capacitive-humidity-sensor-basics/
- https://www.siliconsensing.com/technology/mems-accelerometers/
- https://www.youtube.com/watch?v=wpAA3qeOYiI
- https://www.analog.com/en/design-notes/a-simple-thermistor-interface-to-an-adc.html

Tx & Rx

- “IEEE 802.11-Enabled Wake-Up Radio: Use Cases and Applications”
- https://wics.engin.umich.edu/wp-content/uploads/sites/35/2020/05/Brown_ISSCC2020.pdf
- https://innovationatwork.ieee.org/wake-up-radio-infographic/
- https://www.ericsson.com/en/blog/2017/12/wake-up-radio--a-key-component-of-iot
- “Low-Power RFED Wake-Up Receiver Design for Low-Cost Wireless Sensor Network Applications”
- "Communication Integrated Circuits."

AIoT System

- https://www.hindawi.com/journals/wcmc/2022/2287776/
- https://www.cadence.com/zh_TW/home/solutions/automotive-solution.html
- https://community.cadence.com/cadence_blogs_8/b/breakfast-bytes/posts/tensilica-security
- https://www.cadence.com/content/dam/cadence-www/global/en_US/documents/tools/ip/design-ip/multi-speed-ethernet-automotive-application-ip-br.pdf
- https://prodigytechno.com/difference-between-lin-can-and-flexray-protocols/
- https://www.2cm.com.tw/2cm/zh-tw/archives/4E0D19A85F744843ADB63C5D2C65F080
- https://www.allaboutcircuits.com/technical-articles/mems-ic-capacitive-humidity-sensor-basics/
- https://link.springer.com/chapter/10.1007/978-981-16-2354-7_34

Power Management

- The definitive guide to ARM Cortex-M0/M0+: Low-power states - Embedded.com
- Arm Cortex-M0+ Sleep Modes - Developer Help (microchipdeveloper.com)
- Dynamic Voltage and Frequency Scaling (DVFS) - Semiconductor Engineering (semiengineering.com)
- https://zh.wikipedia.org/zh-tw/%E5%8A%A8%E6%80%81%E6%97%B6%E9%92%9F%E9%A2%91%E7%8E%87%E8%B0%83%E6%95%B4

8. Team Member Task Partition

- **Introduction** *-all*
- **System Architecture** *-all*
- **Technology**
  - Sensors *-徐詠祺*
  - Tx & Rx *-張睿紘*
  - DVFS *-張文彥*
  - AIoT System *-楊文彣*
- **Industry Analysis** *-王瑞賢*
- **Conclusion** *-all*