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# FRAM-高性能存储器，是优化车载电子系统的最佳存储解决方案

## -新能源汽车和自动驾驶技术中的应用-

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Sep.2017
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# 议程

- 非易失性存储器FRAM在新能源车技术中的应用
- 非易失性存储器FRAM在自动驾驶中技术的应用
- 非易失性存储器FRAM的特点

# 议程

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- 非易失性存储器FRAM在自动驾驶中技术的应用
- 非易失性存储器FRAM的特点

# 未来汽车市场的主流：新能源汽车

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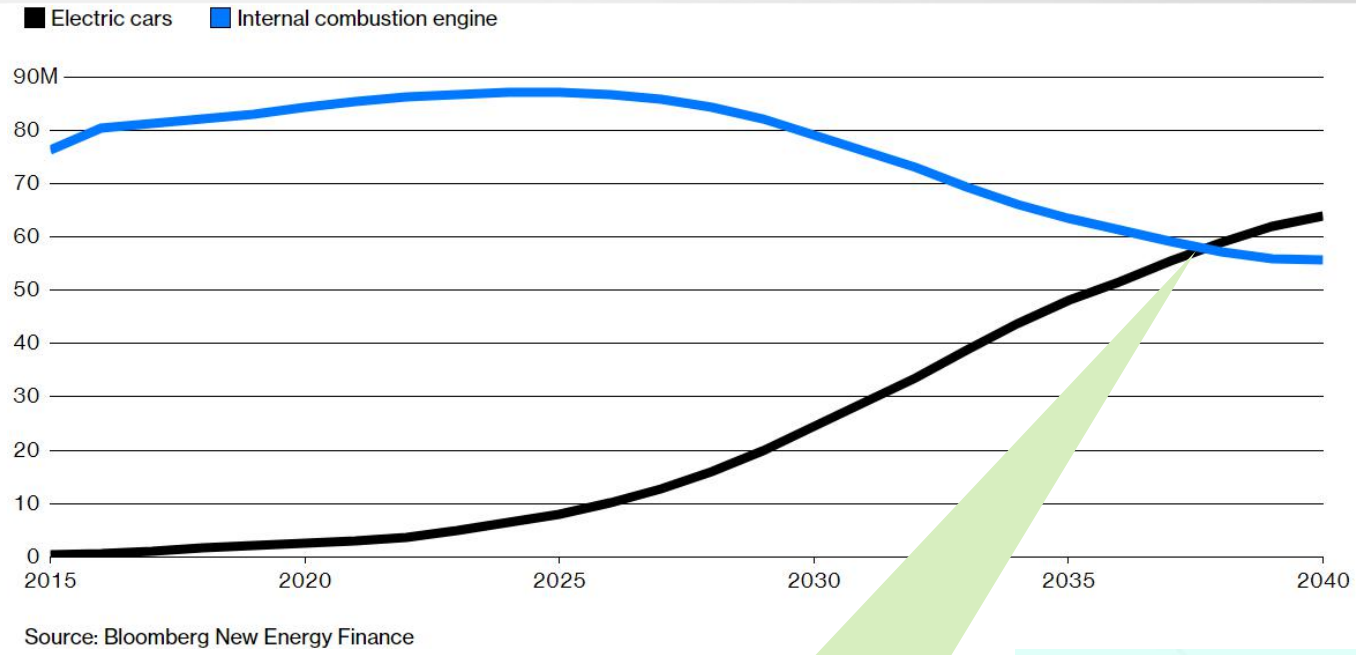
- 主要国家的新能源汽车政策
  - 2016年10月13日，德国联邦议会通过决议，2030年开始禁止燃油汽车销售。
  - 2016年12月1日，美国政府发表了关于 ‘’ 加快普及电动汽车 ‘’ 计划的声明。
  - 2017年6月4日，印度政府宣布2030年开始只销售新能源汽车。
  - 2017年7月7日，法国政府宣布2040年开始禁止销售燃油汽车。
  - 2017年7月26日，英国政府宣布2040年开始禁止销售燃油汽车。
- 主要汽车制造商的新能源汽车计划
  - 2016年6月17日，德国大众Volkswagen汽车表示，在未来10年推出30款以上纯电池驱动的电动汽车。
  - 2017年7月7日，沃尔沃Volvo表示，2019年开始将只推出出电动或混合动力汽车。
  - 2017年8月4日，丰田Toyota与马自达Mazda发表资本合作计划，共同开发电动汽车。

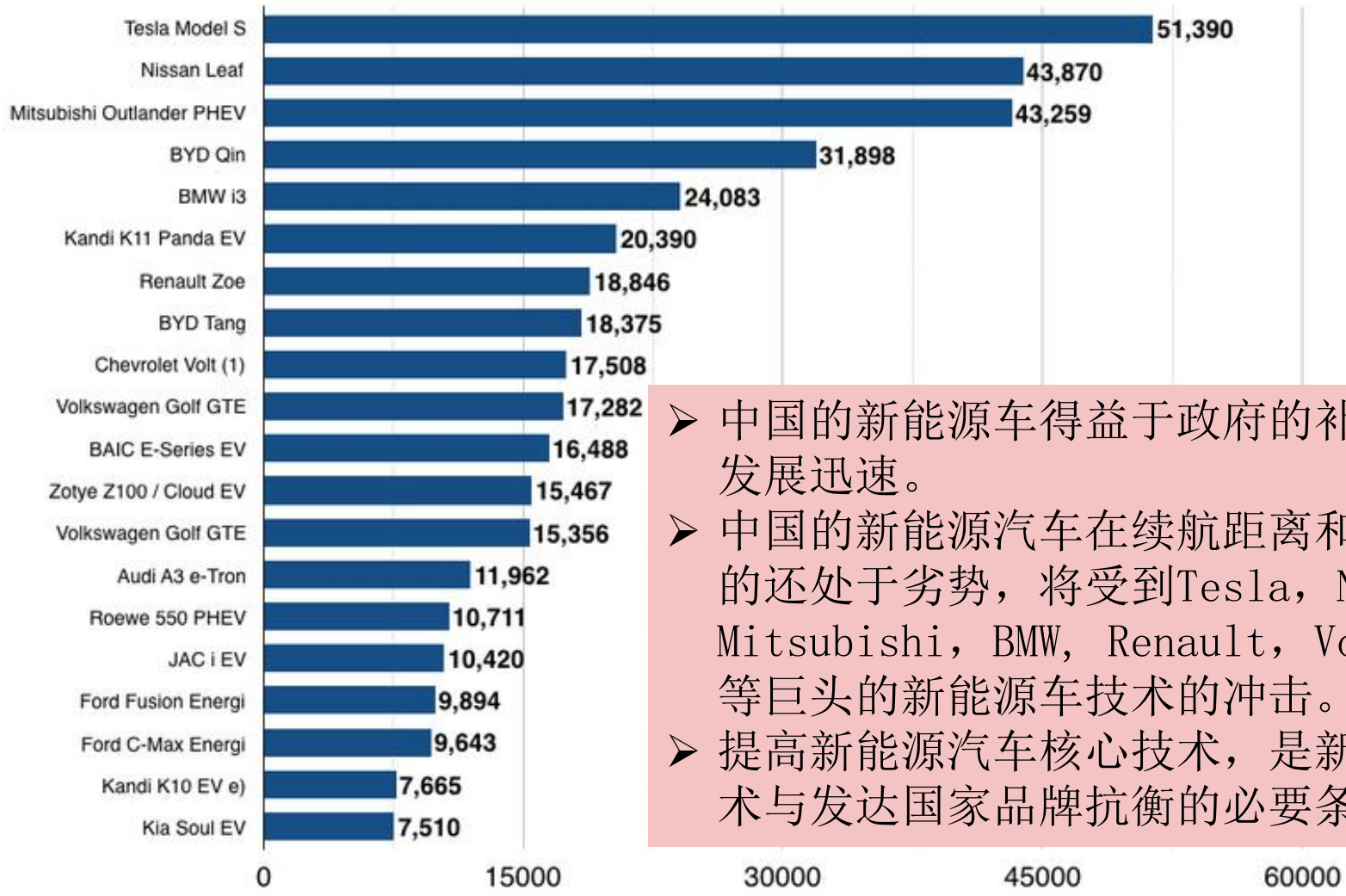
# 未来汽车市场的主流：新能源汽车




Source: Bloomberg New Energy Finance

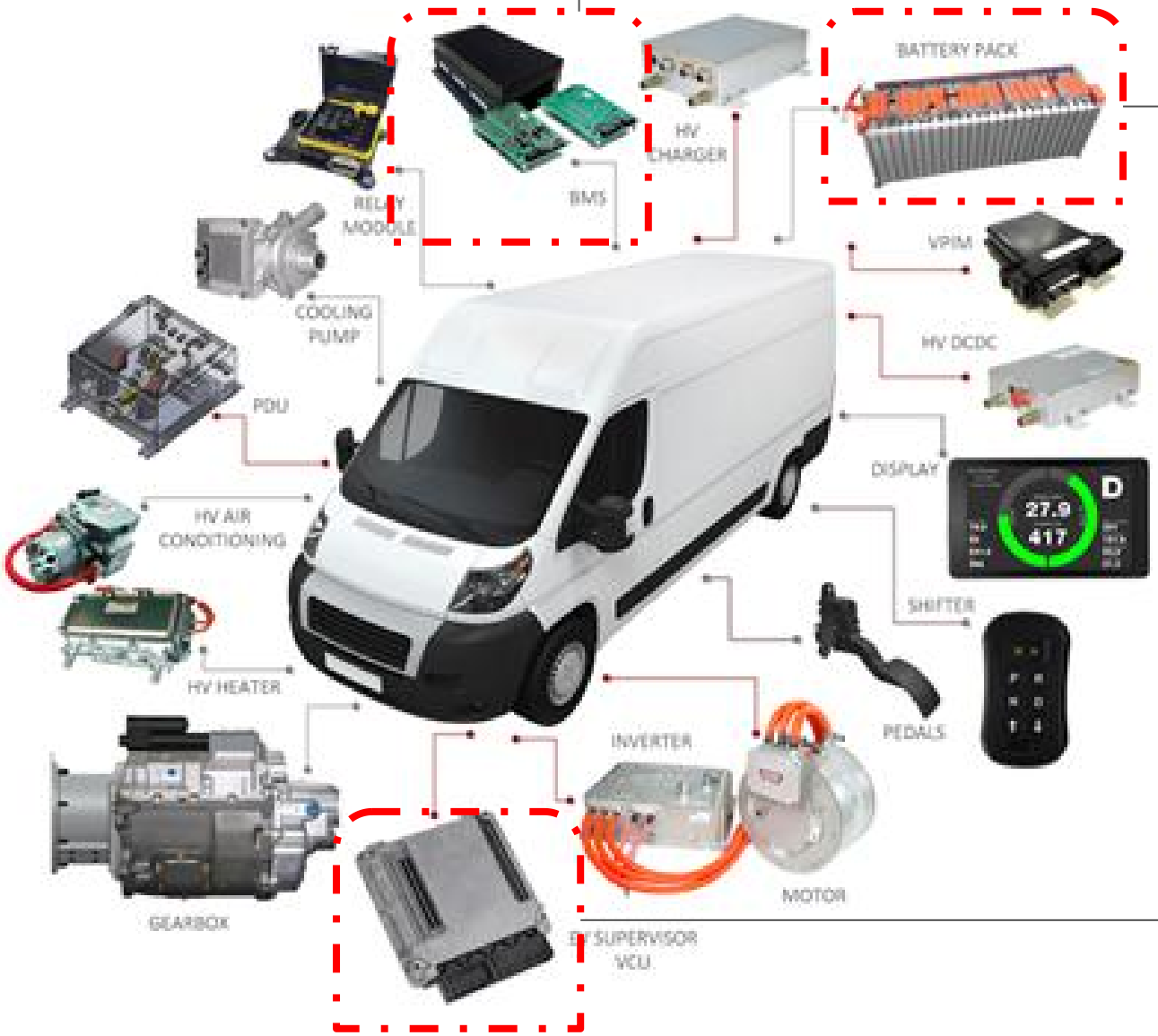
2038年后，新能源汽车将
替代燃油汽车将成为主流

# 2015年新能源车销量统计：TOP20中8款是中国牌号




- 中国的新能源车得益于政府的补贴政策，发展迅速。
- 中国的新能源汽车在续航距离和最高时速的还处于劣势，将受到Tesla，Nissan，Mitsubishi，BMW，Renault，Volkswagen等巨头的新能源车技术的冲击。
- 提高新能源汽车核心技术，是新能源车技术与发达国家品牌抗衡的必要条件。

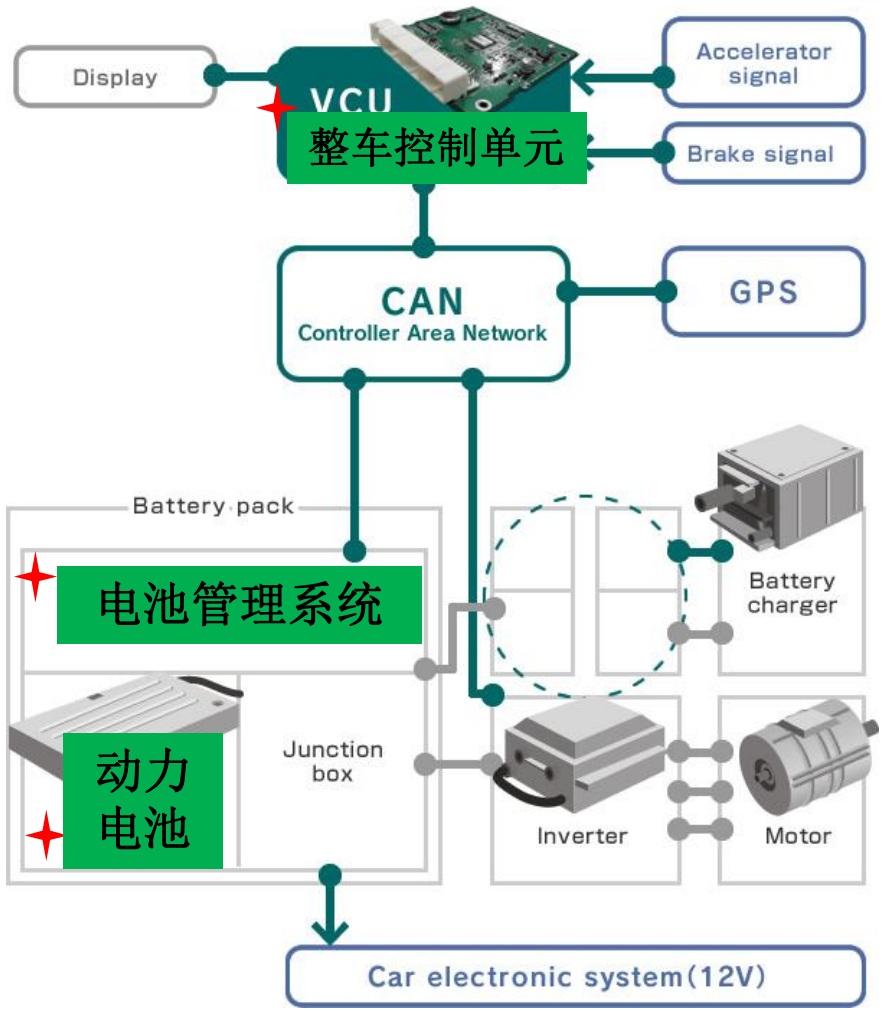
# 新能源的核心技术：Battery pack，BMS,VCU




Key technologies

- Battery pack
- BMS
- VCU

# FRAM是支持EV的主要系统存储的关键元件




- 1. Battery Pack:是新能源车的心脏,它的寿命和续航里程直接决定汽车的性能。
- 2. BMS:**实时**监控电池使用状态，通过必要措施缓解电池组的不一致性，为新能源车的使用安全提供保障，并延长动力电池的使用寿命。
- 3. VCU：主要功能是解析驾驶员需求，**实时**监控汽车行驶状态，协调控制单元如BMS、MCU、EMS、TCU 等的工作，实现整车驱动控制、能量回收控制、附件控制和故障诊断等功能。

这些子系统(BMS, VCU等)都需要实时和连续地对当前状态信息进行监控、记录、分析处理。因此需要提高存储器性能和耐久性设计。

只要高性能（非易失性·高速·高读写耐久性的车载级存储器）FRAM才可以满足所要求的可靠性和无迟延的要求。

# Battery Management System电池管理系统

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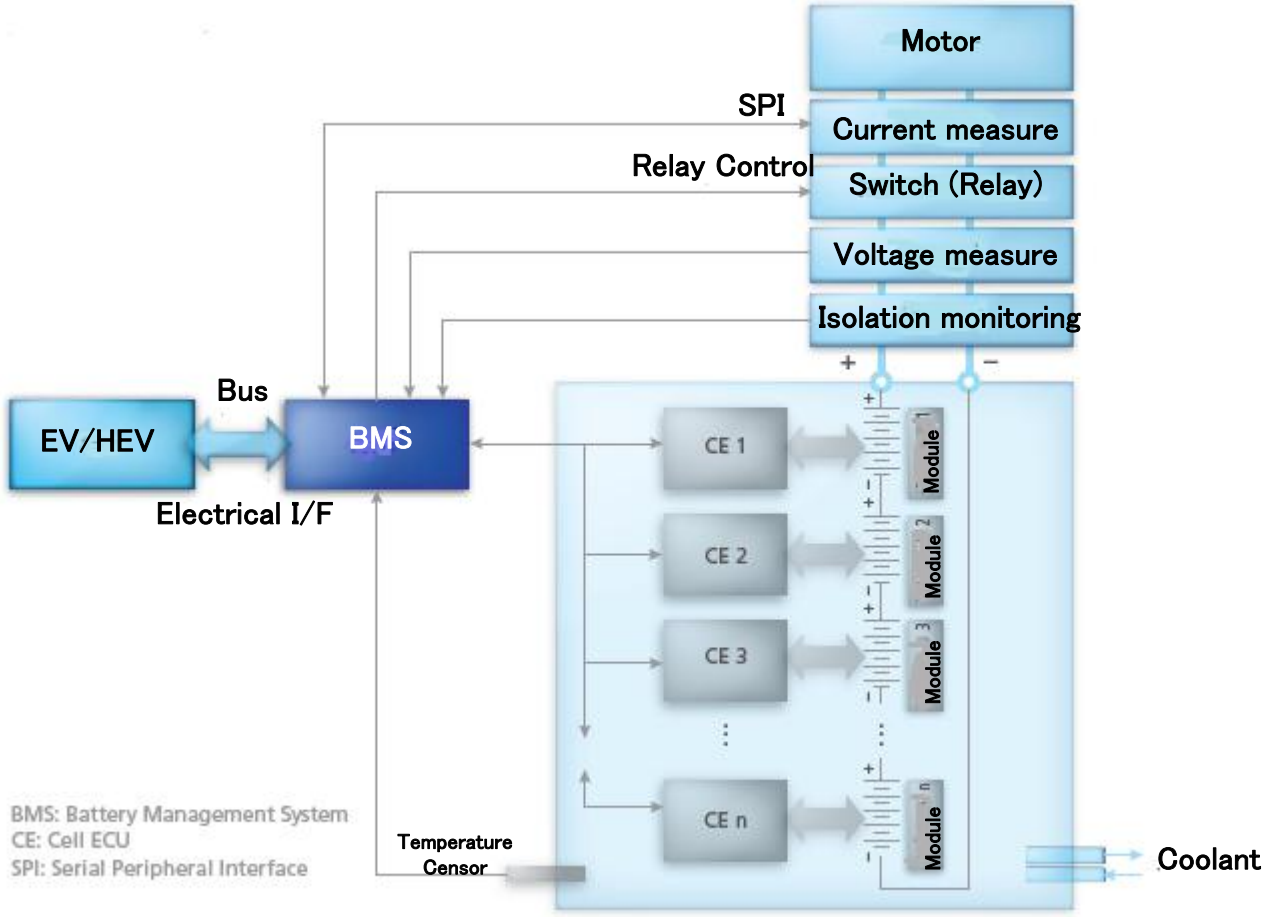
**BMS**

# BMS的主要信息数据

BMS
(Battery Management System)

- 保护功能/Protection
- 均衡管理/Cell Balance Management
- 健康状态/SOH:Sate of Health
- 电量计量/SOC:State of Charge
- 后备态管理/SOB:State of Back-up
- 内置充电管理/Charge management
- 实时通信/communication
- 电压，温度检测/Voltage&Temperature Measurement
- 数据存储/Data Storage

# BMS系统构成

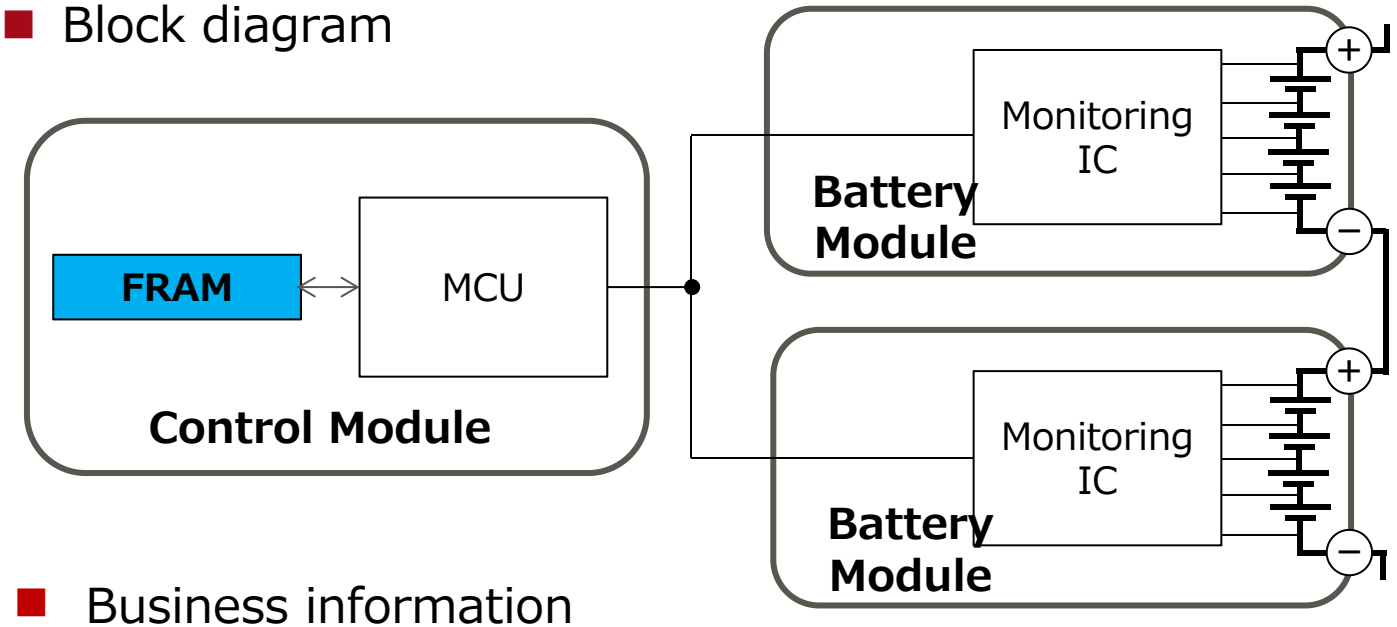



- ECU collects temperature and voltage information from each cell and directs the equalizer to maintain a balanced charge on the cells.
- Weak cells will get charged more often and stronger cells will discharge more.This balanced control helps to increase the total life of the battery pack.

# Benefit of FRAM usage in BMS

- Why FRAM?-high endurance, high speed
  - To frequently record (e.g. every second or 0.1s) important data such as voltage, current and temperature of battery cell to optimize the battery pack. FRAM is used to record long term and short term history of battery cell, and user for the preparation for power down. **High endurance is key.**

- Block diagram




- Business information
  - Some customers in China are using 256Kbit SPI and I2C FRAM.
  - China government decides to create infrastructure for 5 million electric vehicle in 2020 to boost popularization of EV car.
  - Many countries such as France, India, Norway and Denmark have a target to eliminate engine car and accept only EV car.

# VCU新能源车整车控制单元

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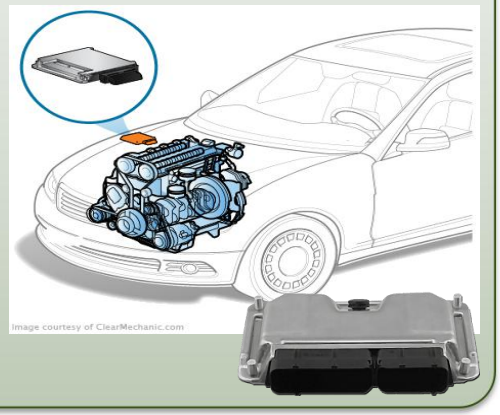
**(Vehicle Control Unit)**

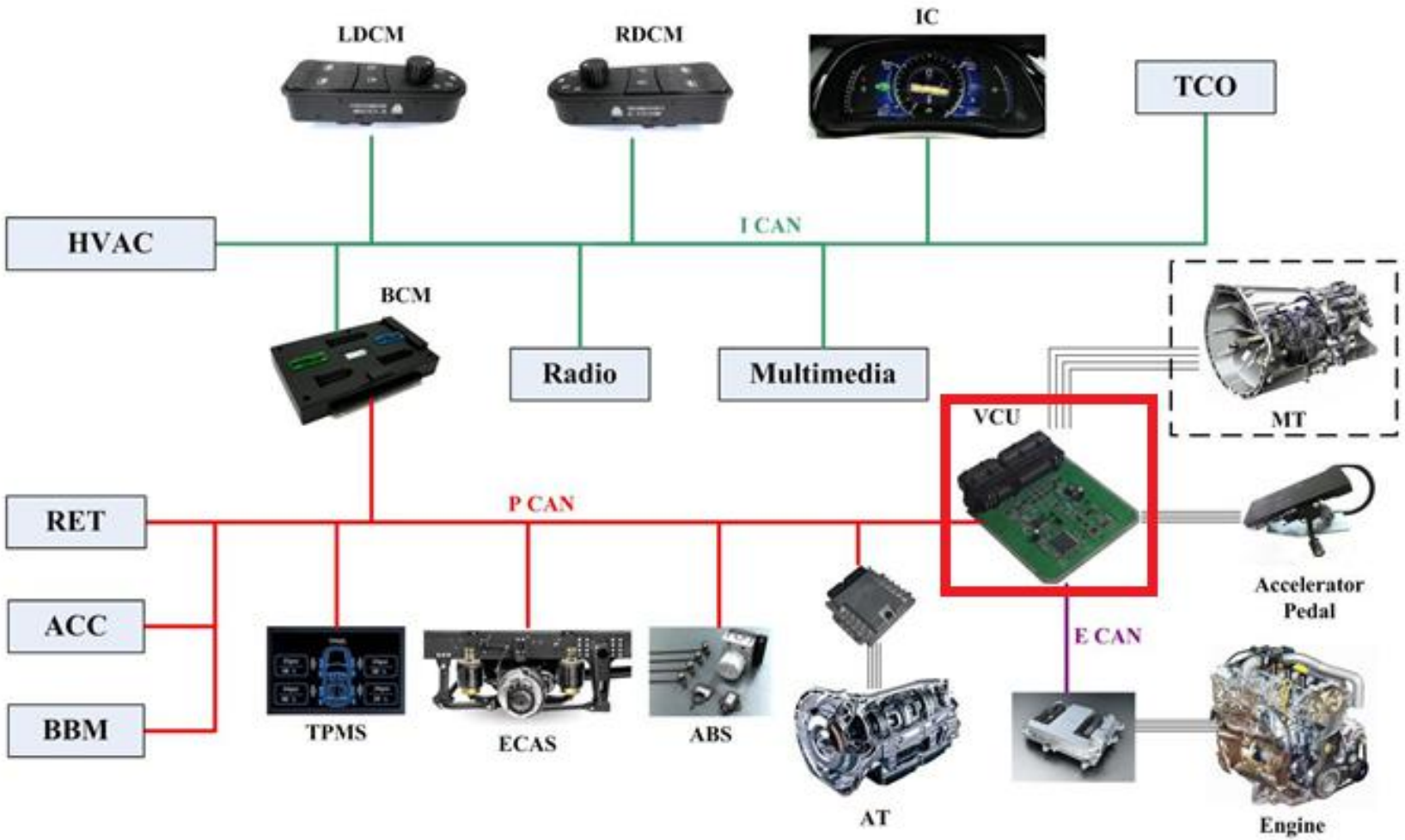



## About VCU

VCU is the core controller for the electric and hybrid vehicles.
VCU receives the driver input signals, like pedal inputs, vehicle speed signals, and other inputs, manages the system energy, commands the driver demanded torque, coordinates the motor, battery pack, as well as the conventional powertrain in case of hybrid vehicles, and determines the overall vehicle drivability.
VCU is the master of the vehicle control network, or CAN bus based vehicle control network.

# What is VCU?

- 整车控制器是整个新能源汽车的核心控制部件，主要功能是解析驾驶员需求，监控汽车行驶状态，协调控制单元如BMS、MCU、EMS、TCU 等的工作，实现整车驱动控制、能量回收控制、附件控制和故障诊断等功能.

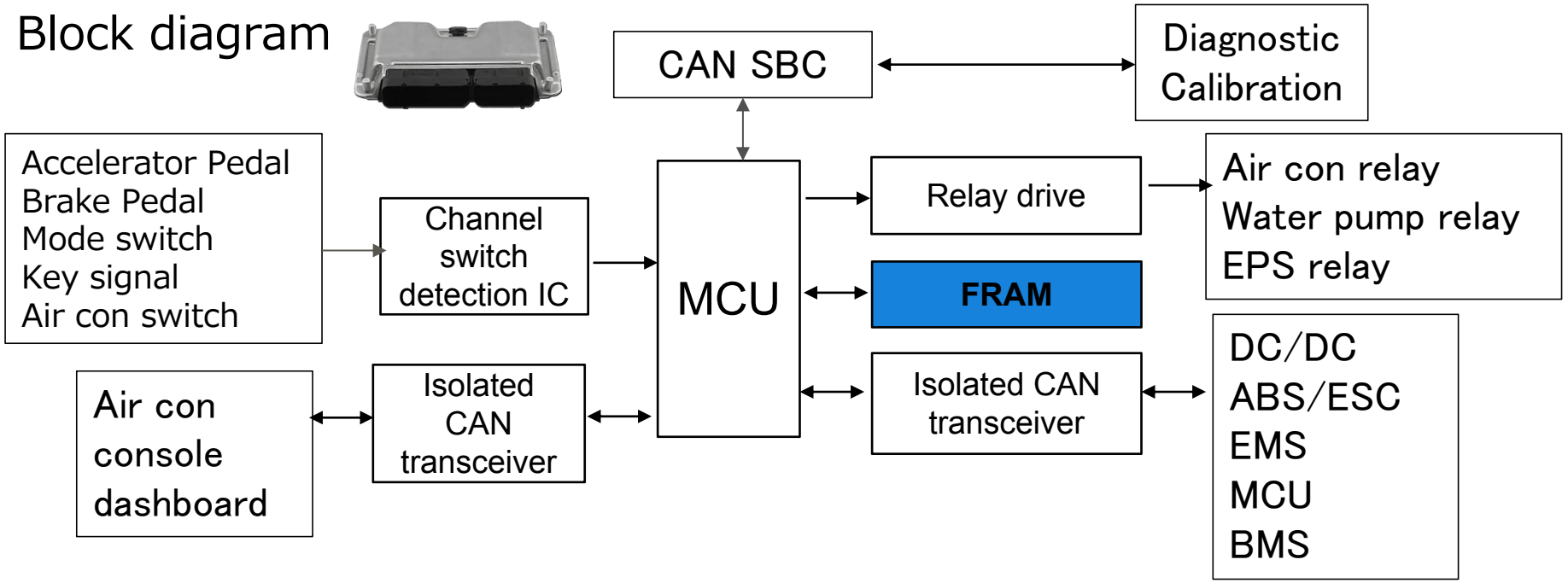


# Benefit of FRAM usage in VCU

- Why FRAM?-**high endurance, high speed**
  - To frequently log (e.g. every second) event or failure data about PRND, acceleration, brake, output torque etc
  - Simpler SW without Wear Leveling to improve endurance when EEPROM or NOR Flash is used.

- Block diagram






- Business information
  - Some customers in China adopted 64Kbit SPI FRAM for EV car and low speed EV.

# T-BOX/TCU

**T-BOX(Telematics –BOX)**
**TCU(Telematics-Control Unit)**

车载T-BOX，车联网系统包含四部分，主机、车载T-BOX、手机APP及后台系统。主机主要用于的影音娱乐，以及车辆信息显示；车载T-BOX主要用于和后台系统/手机APP通信，实现手机APP的车辆信息显示与控制

Internet of Vehicles includes four parts, host, car T-BOX, mobile phone APP and background system. Host is mainly used for infotainment as well as vehicle information display; car T-BOX is mainly used to communicate with server and mobile phone APP, to achieve the mobile APP vehicle information display and control.

T-BOX is used in not only New Energy Vehicle but also in gasoline vehicle.

# Benefit of FRAM usage in T-BOX

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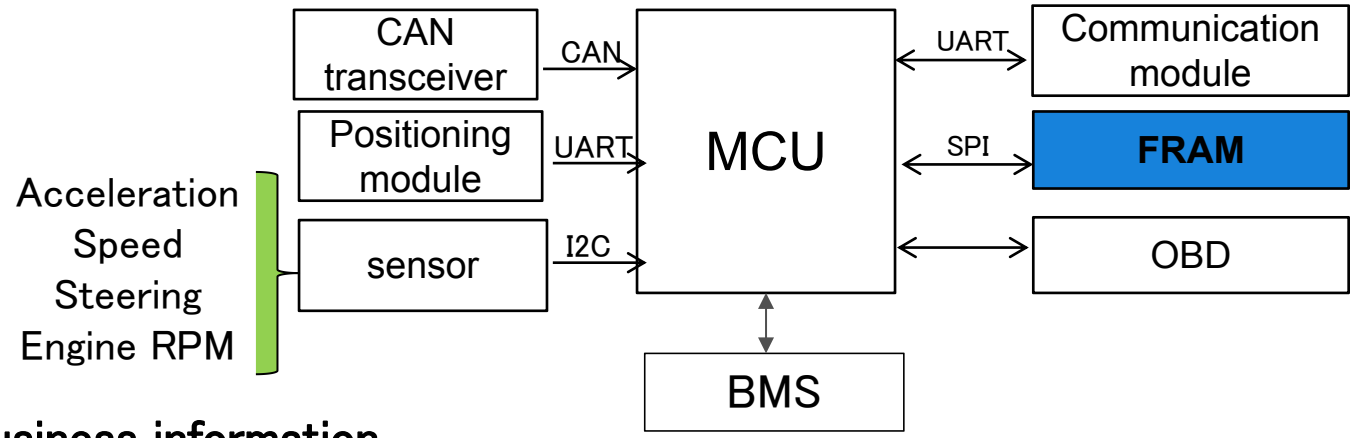
- **Why FRAM?–High endurance,High speed.**
  - ✓ CAN communication data is stored into memory every 0.2s.
  - ✓ Positioning data is stored into memory every second.
  - ✓ Running data like brake, engine rotation speed etc is logged into memory for 10s at the accident.
  - ✓ Data being stored in FRAM is transferred to Flash every 10s.

- **Block diagram**




- **Business information**
  - Some customers in China adopted SPI FRAM from 4kbit to 256kbit.
  - China government regulate T-BOX to be installed in every EV car.
  - European Parliament establishes eCall regulation requiring all new cars to be equipped with eCall technology from April 2018.

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# 自动驾驶的核心技术与高性能存储器要求

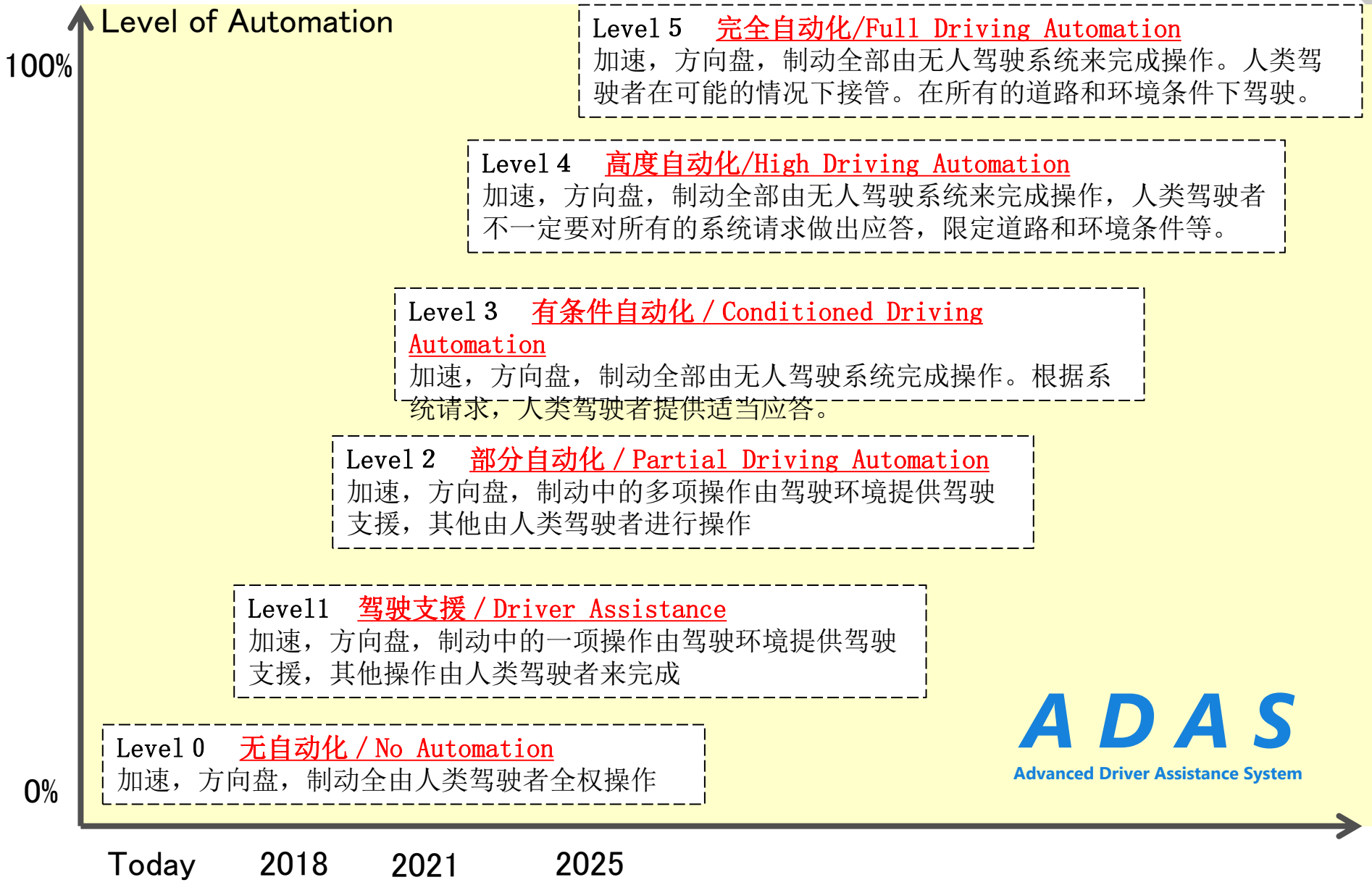




所有子系统（传感器，摄像机，CAN通信，GPS 等）需要**实时和持续地存储当前状态信息，**并进行实时监控，记录，分析或处理。因此**需要提高存储器的性能和耐久性设计**。

ONLY FRAM才可以满足自动驾驶所要求的可靠性和无迟延的要求。

# Roadmap of autonomous driving level




Level 5　完全自动化/Full Driving Automation
加速，方向盘，制动全部由无人驾驶系统来完成操作。人类驾驶者在可能的情况下接管。在所有的道路和环境条件下驾驶。

Level 4　高度自动化/High Driving Automation
加速，方向盘，制动全部由无人驾驶系统来完成操作，人类驾驶者不一定要对所有的系统请求做出应答，限定道路和环境条件等。

Level 3　有条件自动化 / Conditioned Driving Automation
加速，方向盘，制动全部由无人驾驶系统完成操作。根据系统请求，人类驾驶者提供适当应答。

Level 2　部分自动化 / Partial Driving Automation
加速，方向盘，制动中的多项操作由驾驶环境提供驾驶支援，其他由人类驾驶者进行操作

Level1　驾驶支援 / Driver Assistance
加速，方向盘，制动中的一项操作由驾驶环境提供驾驶支援，其他操作由人类驾驶者来完成

Level 0　无自动化 / No Automation
加速，方向盘，制动全由人类驾驶者全权操作

ADAS
Advanced Driver Assistance System

# ADAS自动驾驶辅助系统

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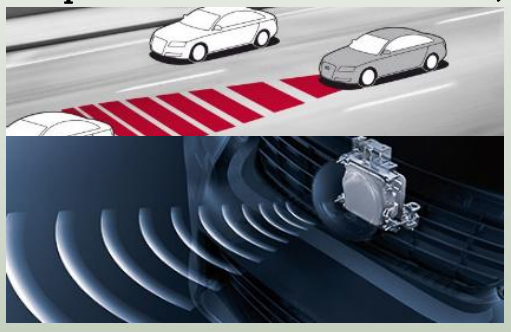
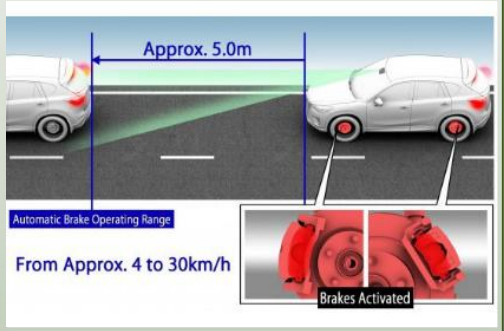
ACC/自适应巡航控制
(Adaptive Cruise Control)



LDW/车道检测警告系统
(Lane Departure Warning)
LKS/车道保持辅助系统
(Lane Keeping Assit)


AEB/自动紧急刹车系统
(Autonomous Emergency Brake)




ADAS(The Automatic Drive Assistance System)is a collection of safety systems designed to prevent the driver of a vehicle from getting into a accident. These system include AEB,LDW and ACC,which need to be able to log real-time data and store it

ADAS是一个安全系统集，包括AEB/LDW/ACC,用于支持安全行驶，避免发生车祸。**这些系统必须能够实时记录并存储当前数据**。

**高性能FRAM**才可以满足自动驾驶所要求的可靠性和无迟延的要求。

# Sensor/Camera传感器/摄像

# ADAS (Autonomous car)

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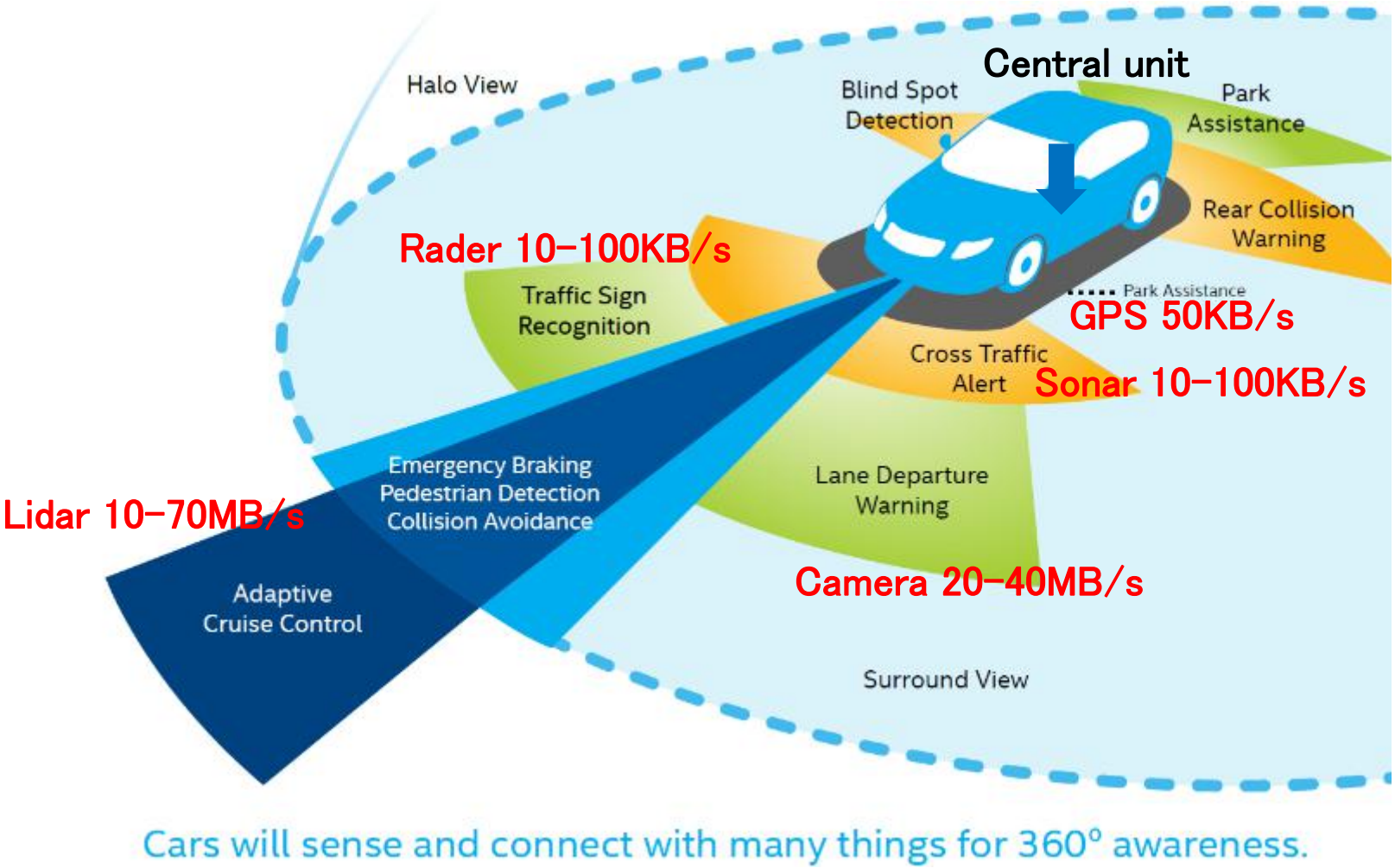
Central unit in vehicle must process the data for autonomous car at 1GB/s.

**For efficient data processing, a lot of sensor data need to be processed at the edge of vehicle before transmitting the data to the central unit.**




source : Intel

# ADAS (Autonomous car)

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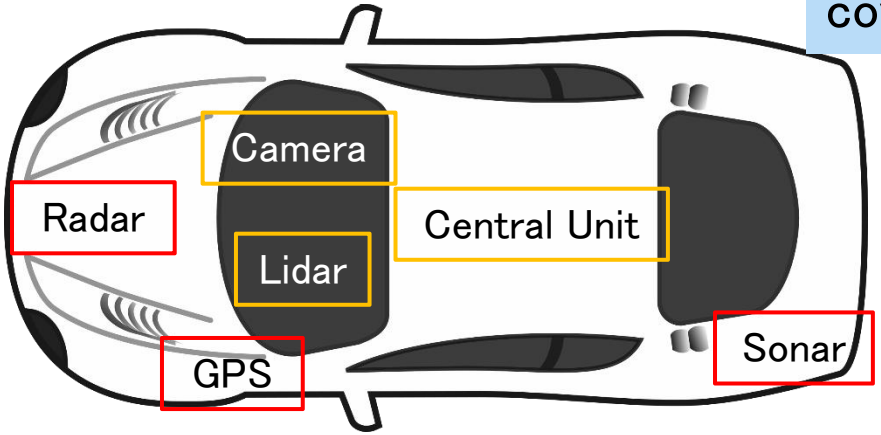
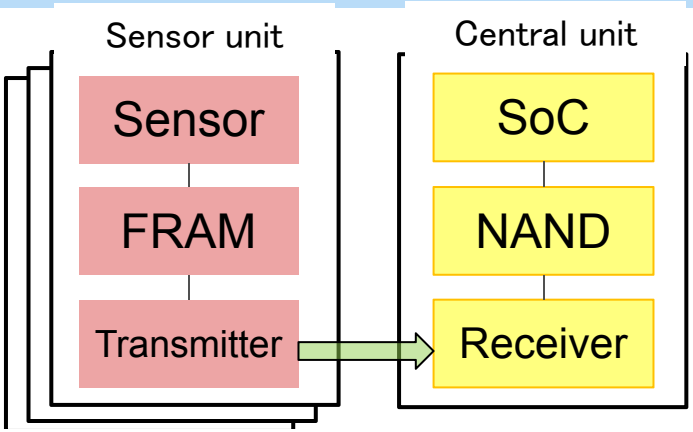
- Where is FRAM needed?

FRAM is needed as data buffer (temporary storage) near sensors such as radar, sonar or GPS.Fujitsu will improve memory speed to cover all of applications of ADAS.



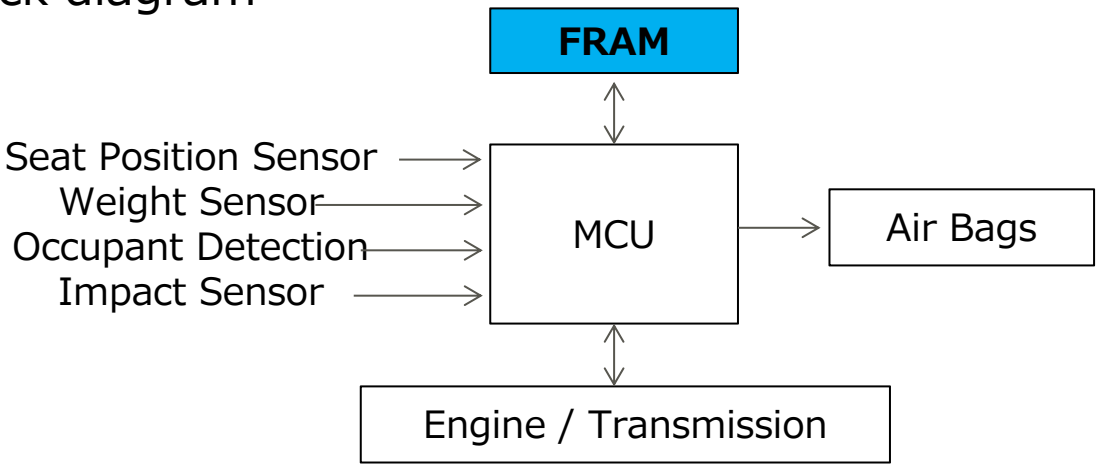




| Applications | Requirement Spec | FRAM Spec (33Mbps = 4MB/s) |
|---|---|---|
| Central unit | 1GB/s | Not enough |
| Camera | 20-40MB/s | Not enough |
| Lidar | 10-70MB/s | Not enough |
| Radar | 10-100KB/s | Good |
| Sonar | 10-100KB/s | Good |
| GPS | 50KB/s | Good |

# Benefit of FRAM usage in Air Bag

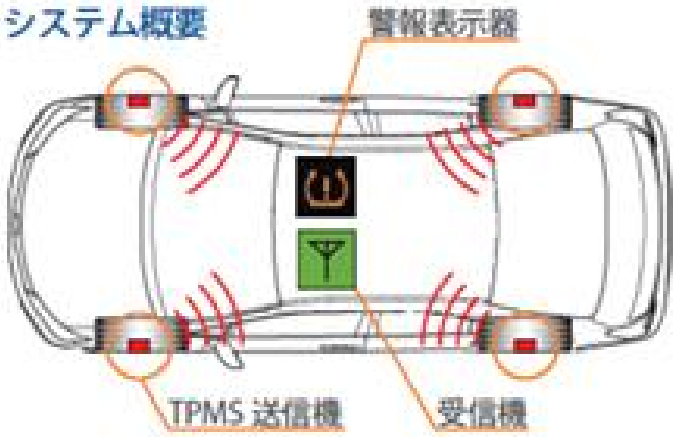
- Why FRAM?-High speed, low power,and High endurance
  1. To store record about whether air bag properly operated just after air bag is actuated. The record will be used to solve legal issue after accident. **High speed writing and low power consumption are key.**
  2. To continuously log passenger's weight and actuate air bag by appropriate strength. **High endurance is key.**

- Block diagram




- Business information
  - Continental,Tier1 in Germany, is using FRAM for their smart air bag.
  - Several customers in China are using 16Kbit I2C,16Kbit SPI FRAM.

# TPMS (Tire Pressure Monitoring System)





- TPMS monitors the internal tire pressure of all tires, reports if any tires are underinflated.
- The module, which is composed of a battery, a pressure sensor and a wireless transmitter, are installed inside a tire wheel.

**① Hard to change the battery when the battery life ends.**
**② Need low power memory  enable battery life to be long.**
**③ Need a high speed memory to log underinflated information real timely.**

**FRAM**

# 人机交互系统HCI

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Human-computer interaction

# Car Infotainment

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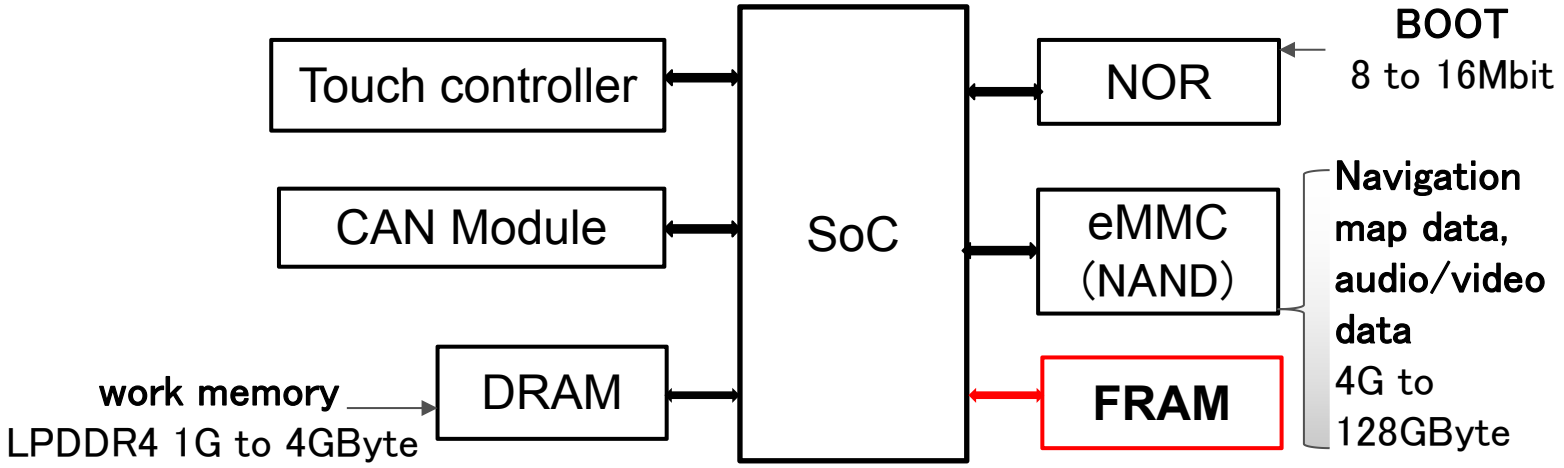
- Why FRAM
  - System needs to store user's "last mode（or current data）" when engine off or interrupted by navigation, back-monitor or phone. High speed and high endurance memory is needed.
  - Need to store and update telephone directory quickly from Smart Phone to infotainment.it takes 300s-360s if EERPOM or Flash is used,too slow for Car makers.
  - Some are using EEPROM + Super-capacitor due to cost being concerned that Super-capacitor is weak against high temperature.⇒Reliability issue




# Benefit of FRAM usage in Infotainment

- Why FRAM-High speed write, High endurance
  - System needs to store user presets data and the current data.
  - Advanced infotainment in Japan and Korea needs to store real-time and then restore current data(current mode,operation log and GPS)

- Block diagram

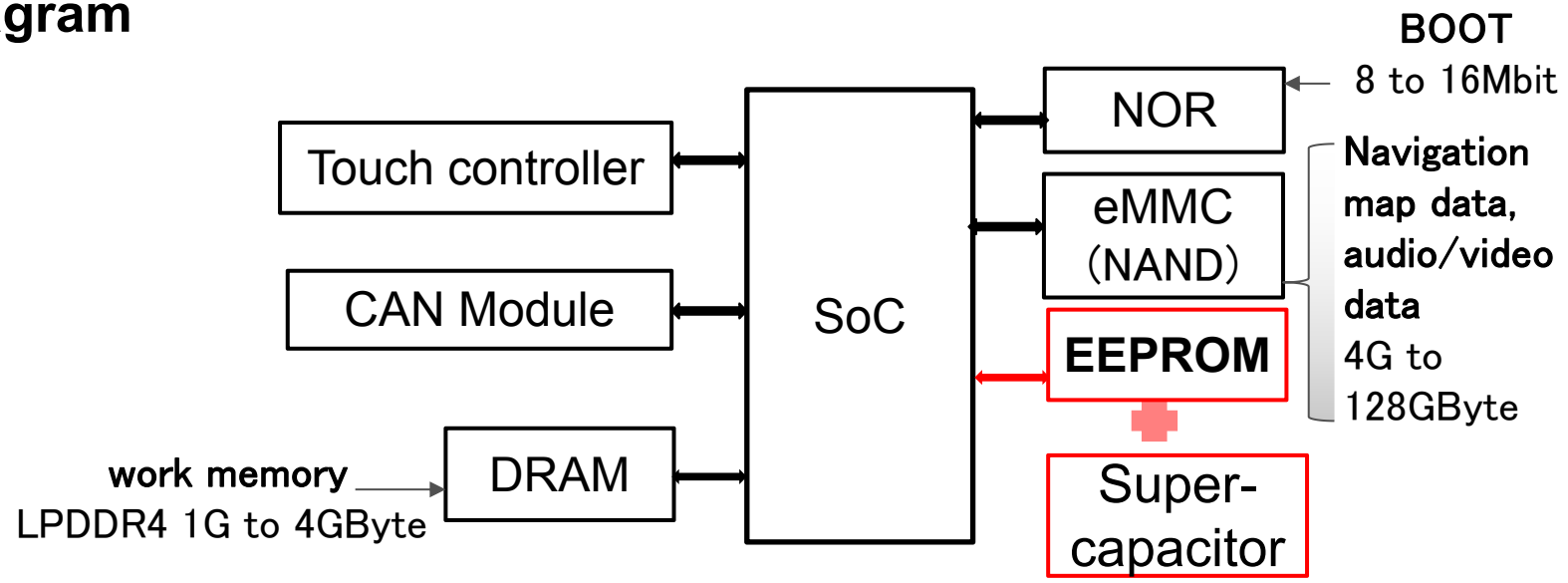



- Business information
  - Some customers in Japan are using FRAM from 16kbit to 1Mbit
  - Some customers in Korea adopted FRAM from 128kbit to 256Kbit

# Car infotainment (EEPROM+Super Cap use case)

- **Use EEPROM+Super capacitor**
  - System needs to store user presets data and the current data.
  - Using EEPROM，Mid-range infotainment needs to store real-time and then restore current data(current mode,operation log and GPS) with in case of power down.but EEPROM needs super-capacitor to secure the data for long write cycle time.
  - Cost of EEPROM+Super capacitor is higher than FRAM

- **Block diagram**




- **Business information**
  - Some customers in Japan are using FRAM from 16kbit to 1Mbit
  - Some customers in Korea adopted FRAM from 128kbit to 256Kbit

# Cost comparison:FRAM < EEPROM+Super cap

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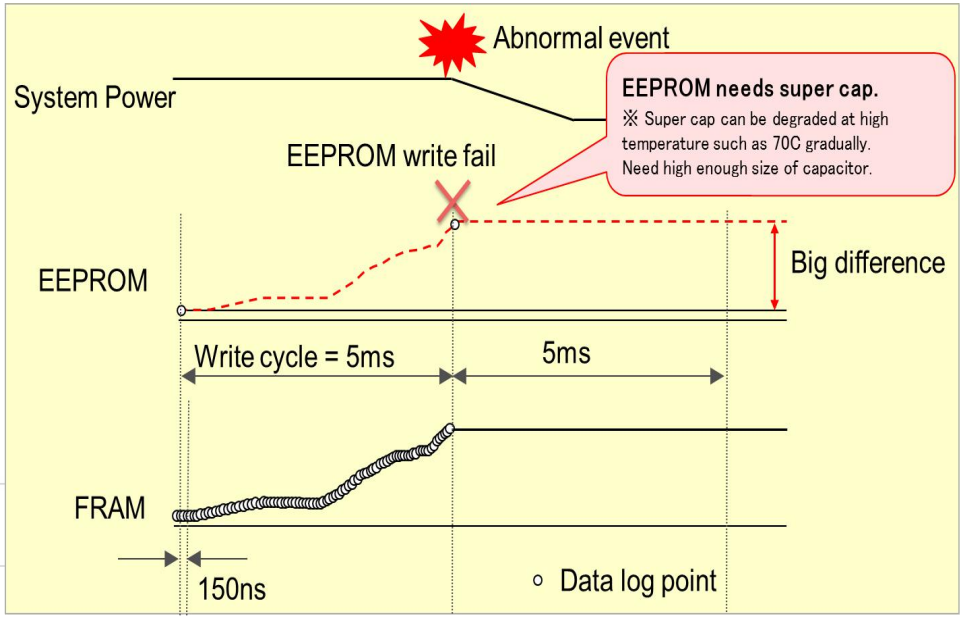
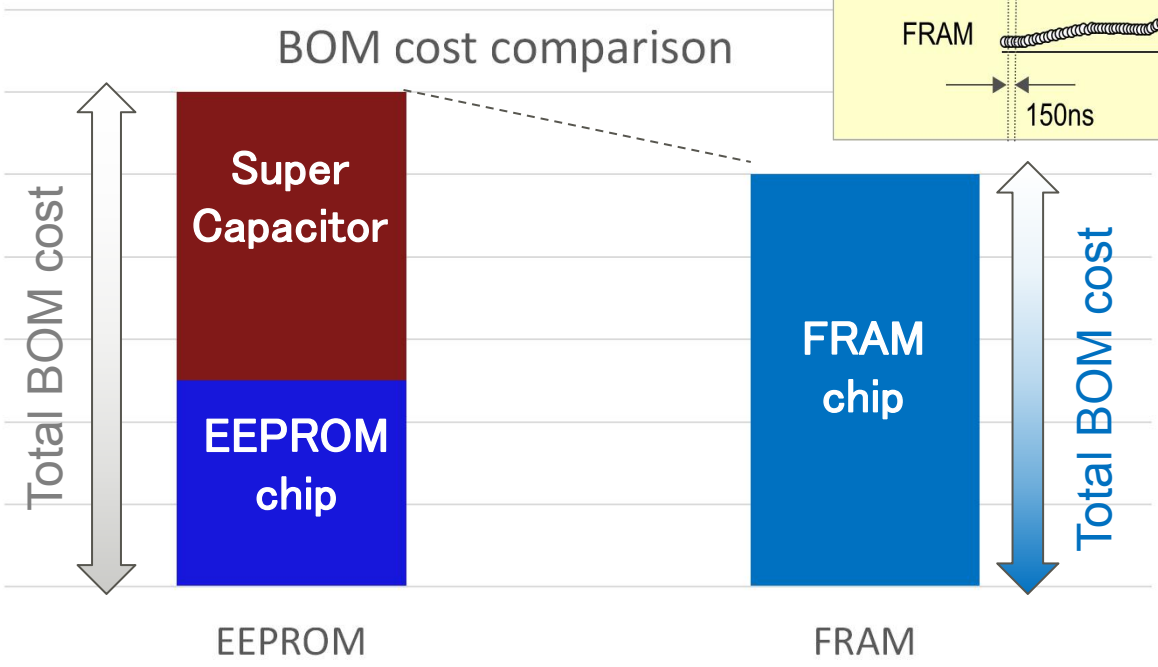
EEPROM needs super-cap/battery to secure data written just before power failure.
FRAM does not need super-cap/battery.

**The total BOM cost including EEPROM and super-cap is higher than FRAM.**



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- **非易失性存储器FRAM的特点**

# Advantages of FRAM

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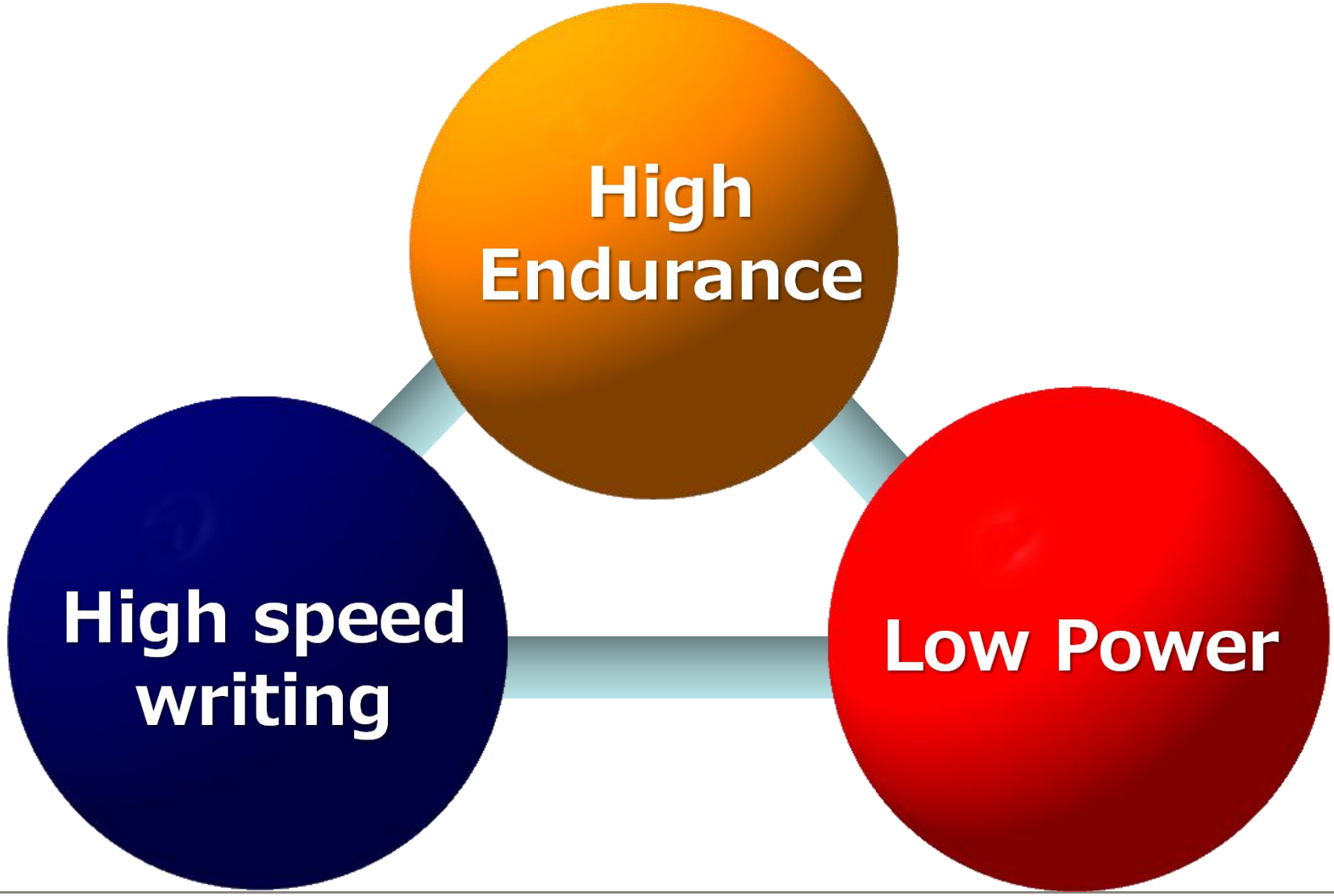
## Three big advantages of FRAM



# Benefits of Automotive FRAM

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| | |
|---|---|
| **Low Power** | ✓ **Lowest operating power consumption** in Non-volatile memory<br>✓ **1.8V operation** at 125°C |
| **For Data logging** | ✓ **$10^{13}$ endurance**, 10 million times longer endurance than EEPROM. |
| **High Speed** | ✓ **33MHz operation**<br>✓ **NO wait time** during writing |
| **Robustness** | ✓ **Strong data retention** in case of unexpected power down due to high speed writing<br>✓ **Strong magnetic immunity** |
| **Quality &Reliability** | ✓ **AEC-Q100 Grade1**<br>✓ **PPAP**<br>✓ **100% Shipping test** at cold, Hot and Room temperature |

# High Endurance – Required Spec

FUJITSU

Example of storing period:

**Once a 1 second**

Simple Calculation :

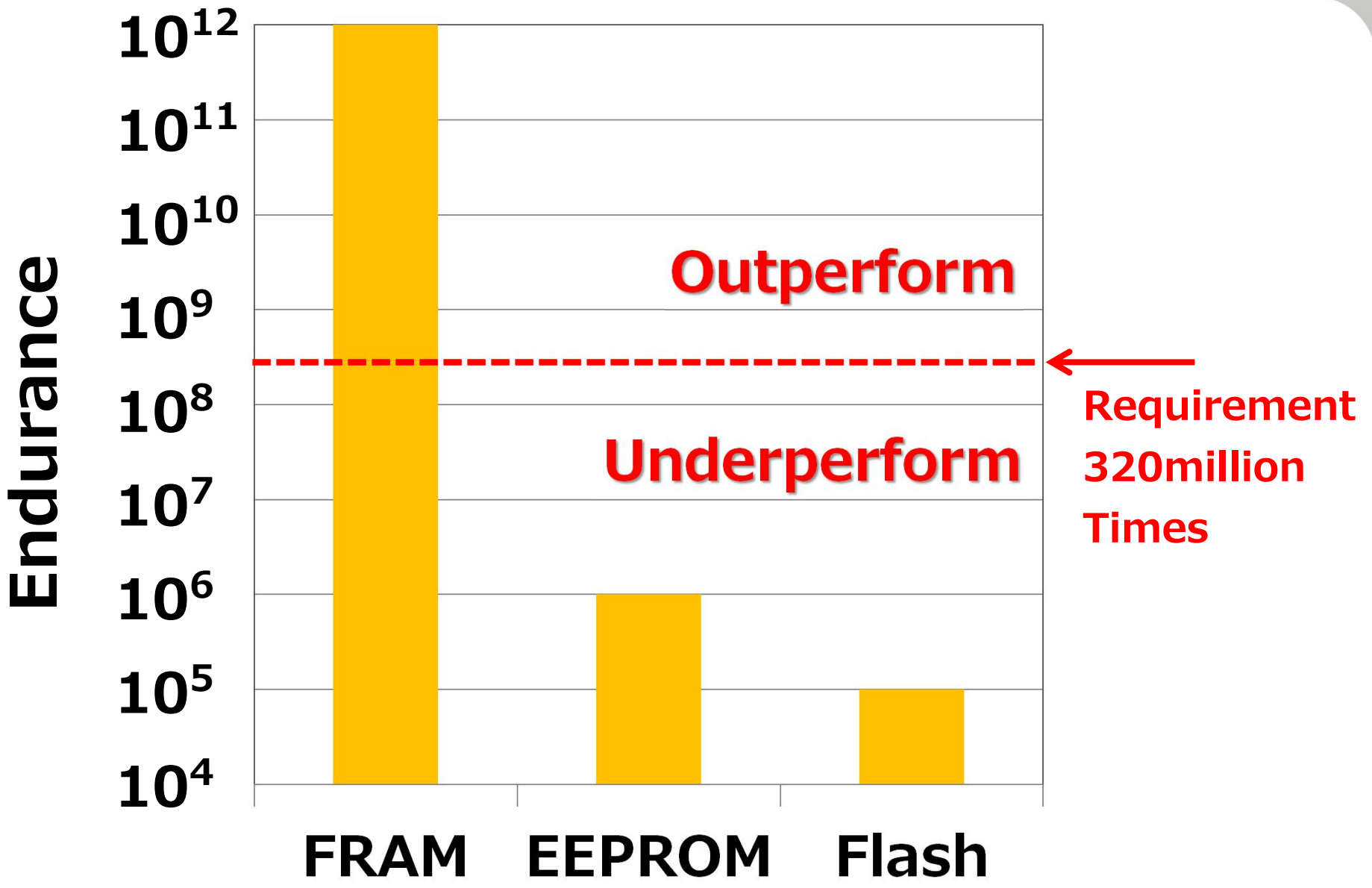
Required endurance to memory is

**320,000,000**

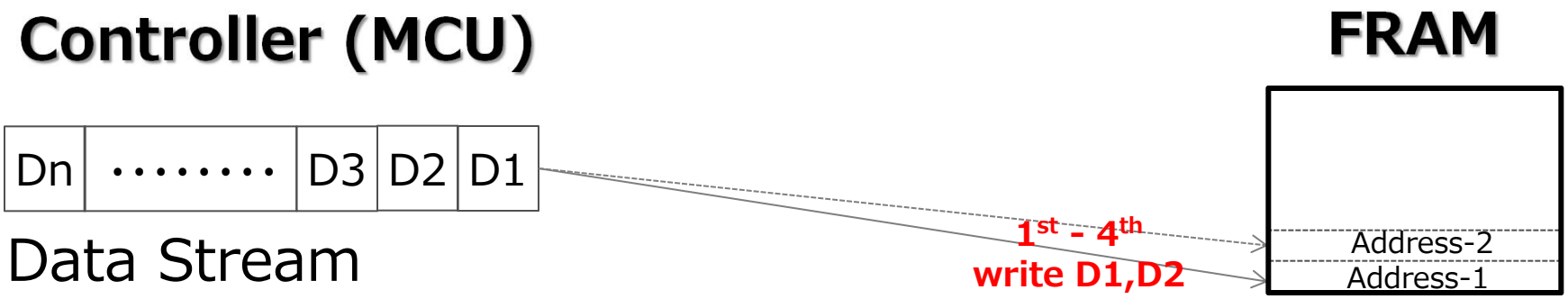
for 10years operation

(60sec x 60min x 24 hour x 365 days x 10 years)

# High Endurance – Spec of memory



# High Endurance – W/O Wear Leveling

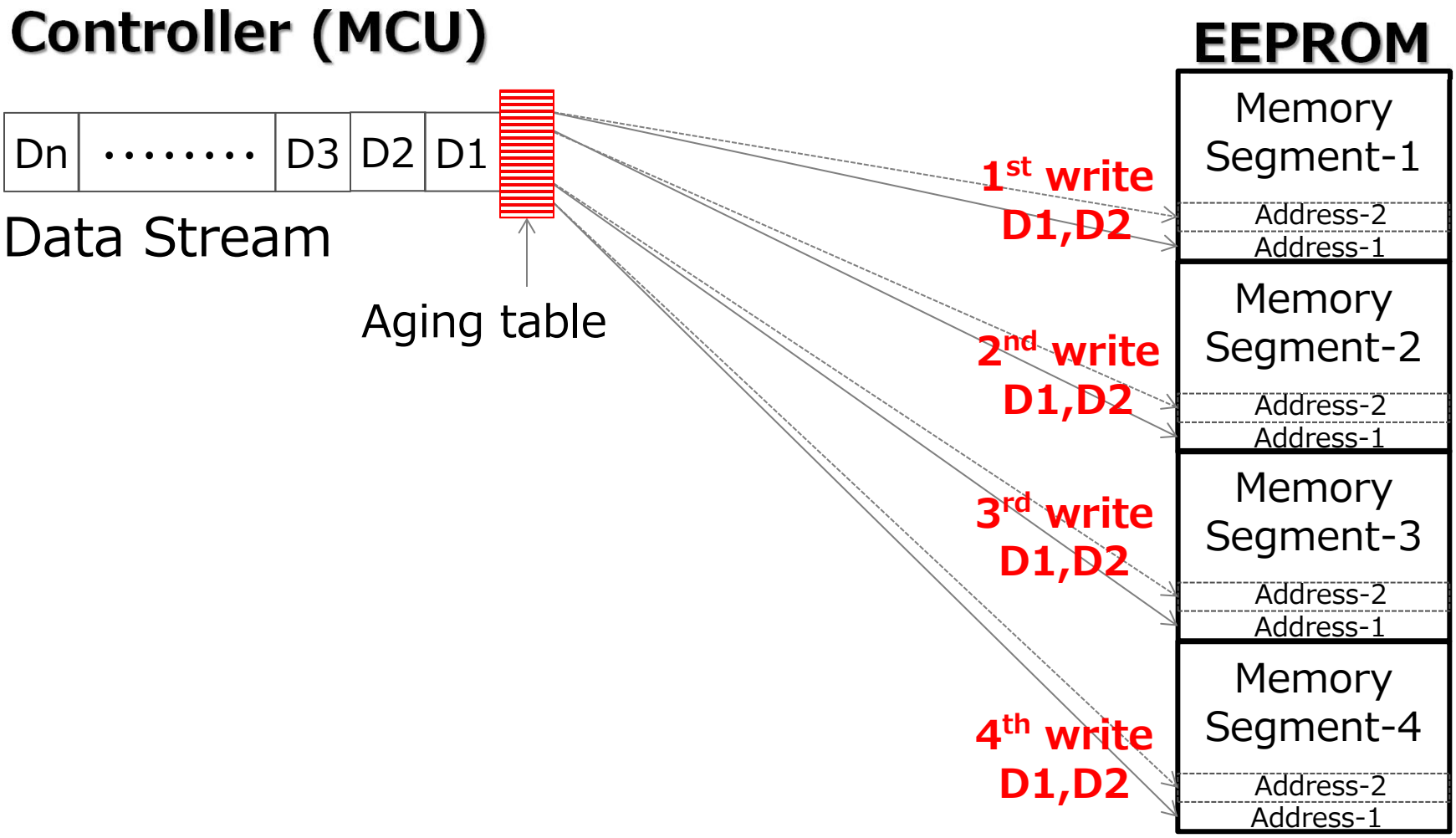



## Benefit for customers

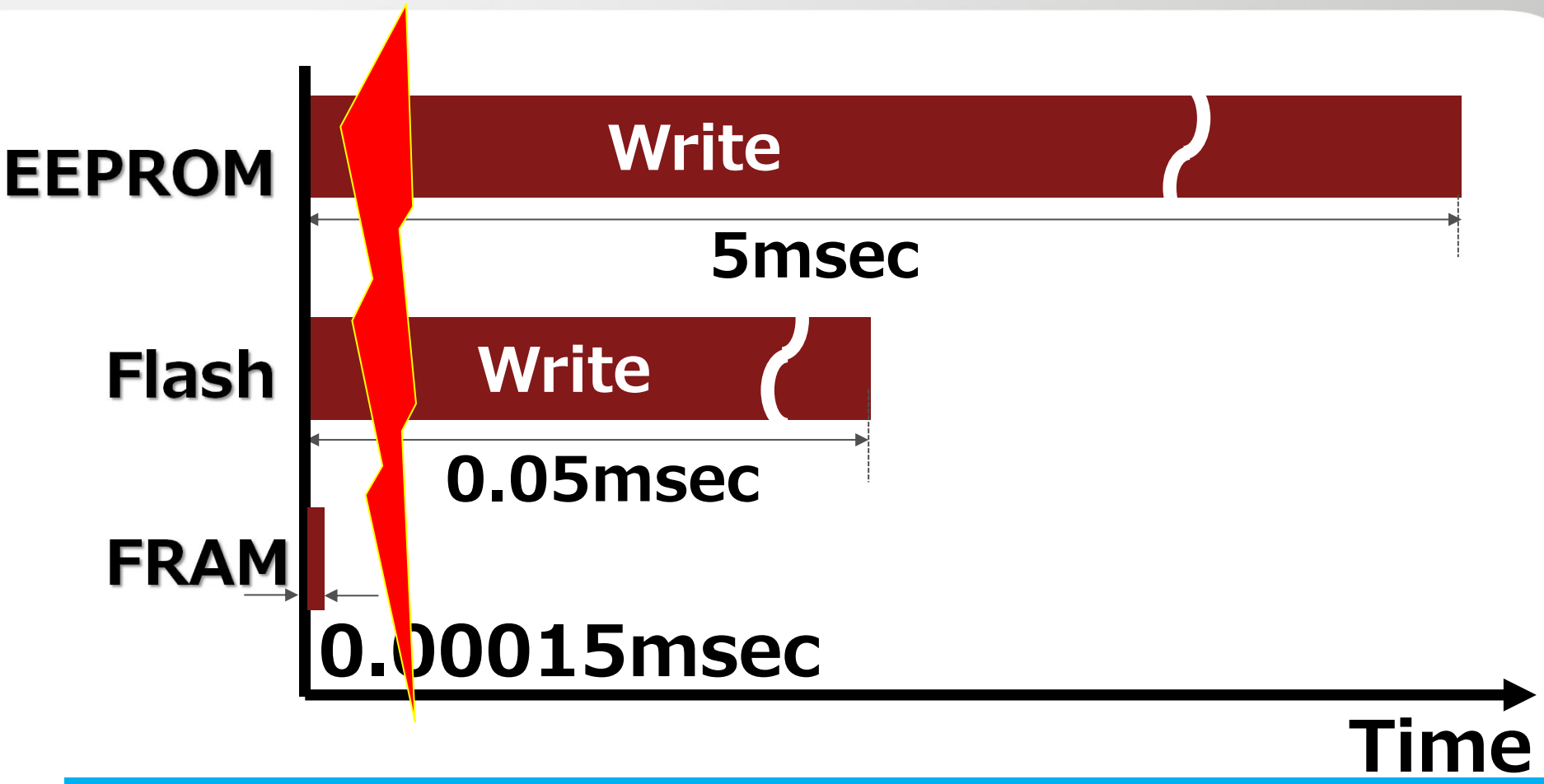
1. FRAM with smaller density can be used.
2. FRAM enables Simplification of the software.

# High Endurance – With Wear Leveling

- Some EEPROM users adopt wear leveling to avoid reaching endurance limit of EEPROM.  Here is an example.



# High Speed Writing



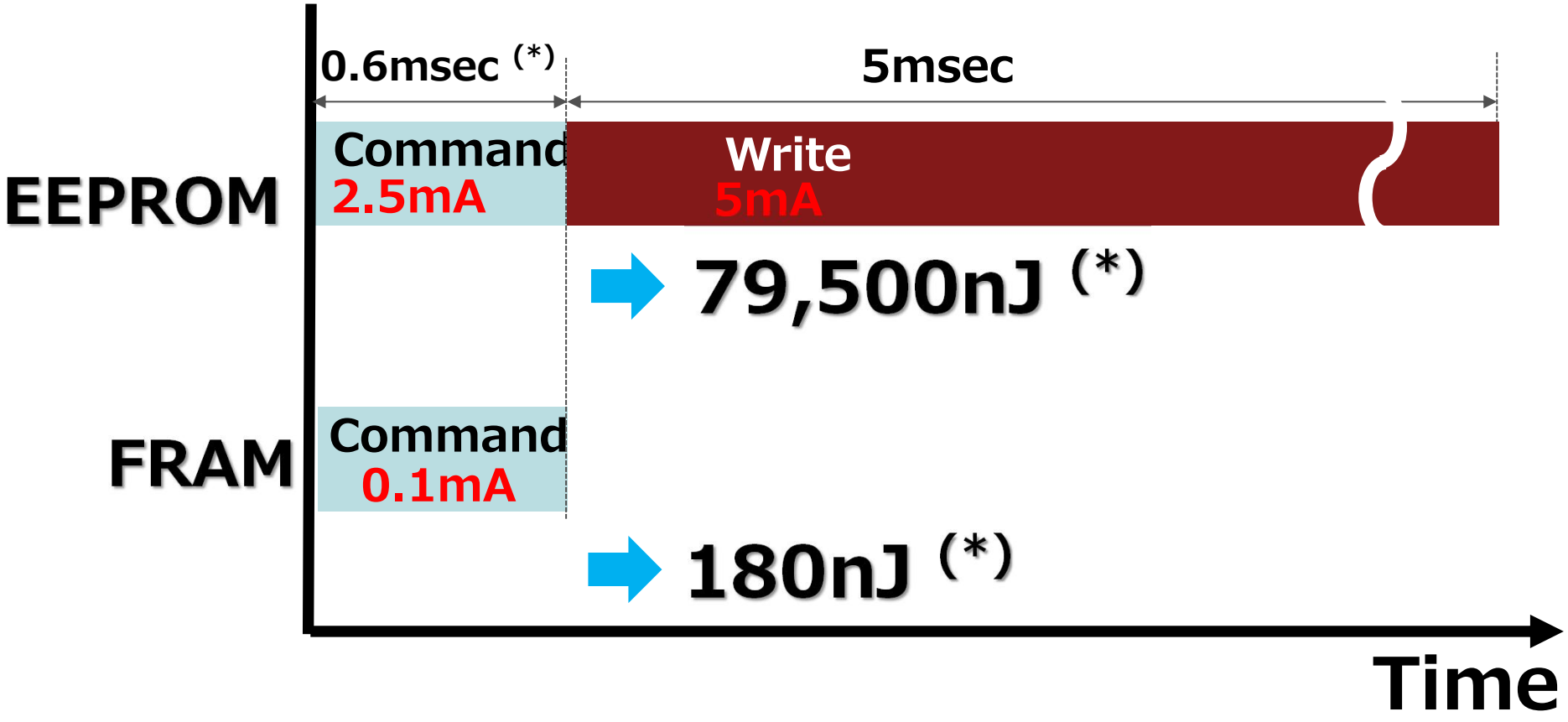

If power down happens during writing,

FRAM : Data stored

Other : Data lost

# Low Power

## Example: 64Byte data writing (I2C I/F)




**More than 400 times lower power, Enable longer battery life**

* 1MHz, 3V Operation

# Summary of FRAM advantages

| | FRAM | EEPROM | Flash |
|---|---|---|---|
| 1. Endurance | ✔ $10^{13}$ times | ✘ $10^{6}$ times | ✘ $10^{5}$ times |
| 2. Write Cycle Time (1Byte) | ✔ 0.00015msec (Figure 1) | ✘ 5ms | ✘ 0.05msec |
| 3. Power Consumption (1Byte Writing) | ✔ 0.0007uJ (Figure 2) | ✘ 83uJ | ✘ 3uJ |
| 4. Writing method | ✔ Over write | ✘ Erase and Write | ✘ Erase and Write |

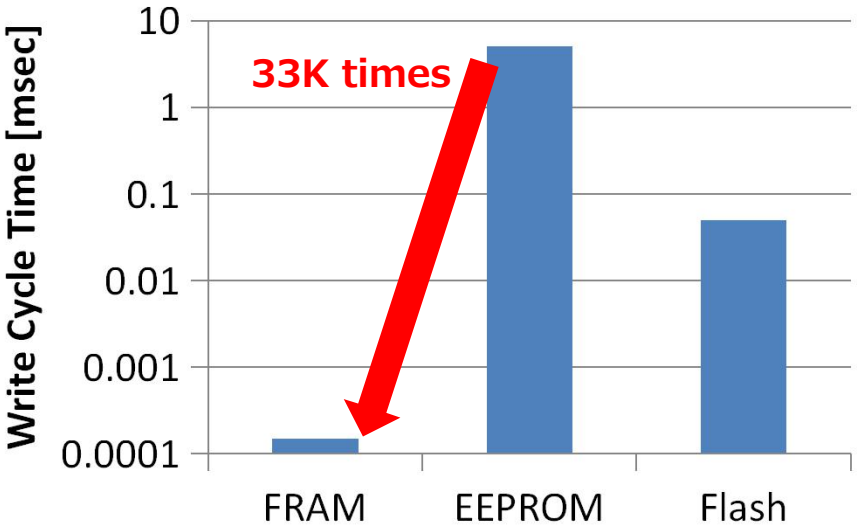



Figure1 Write Cycle Time

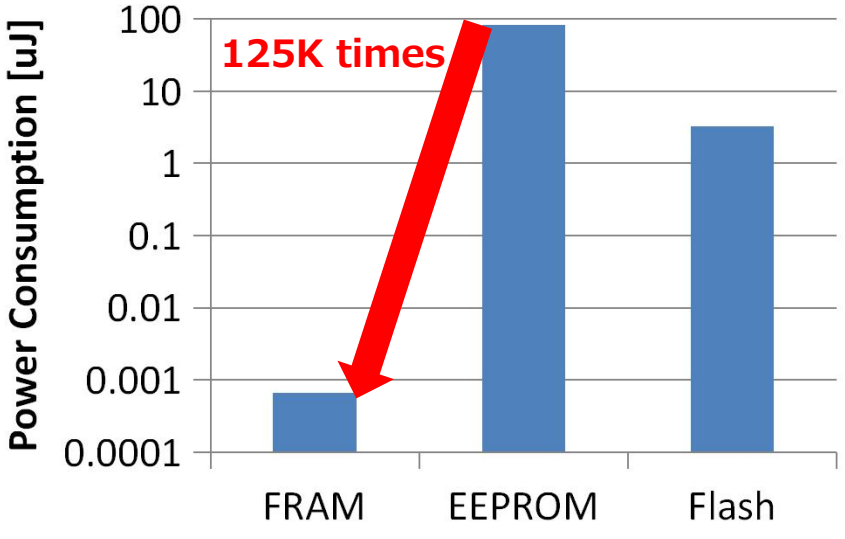
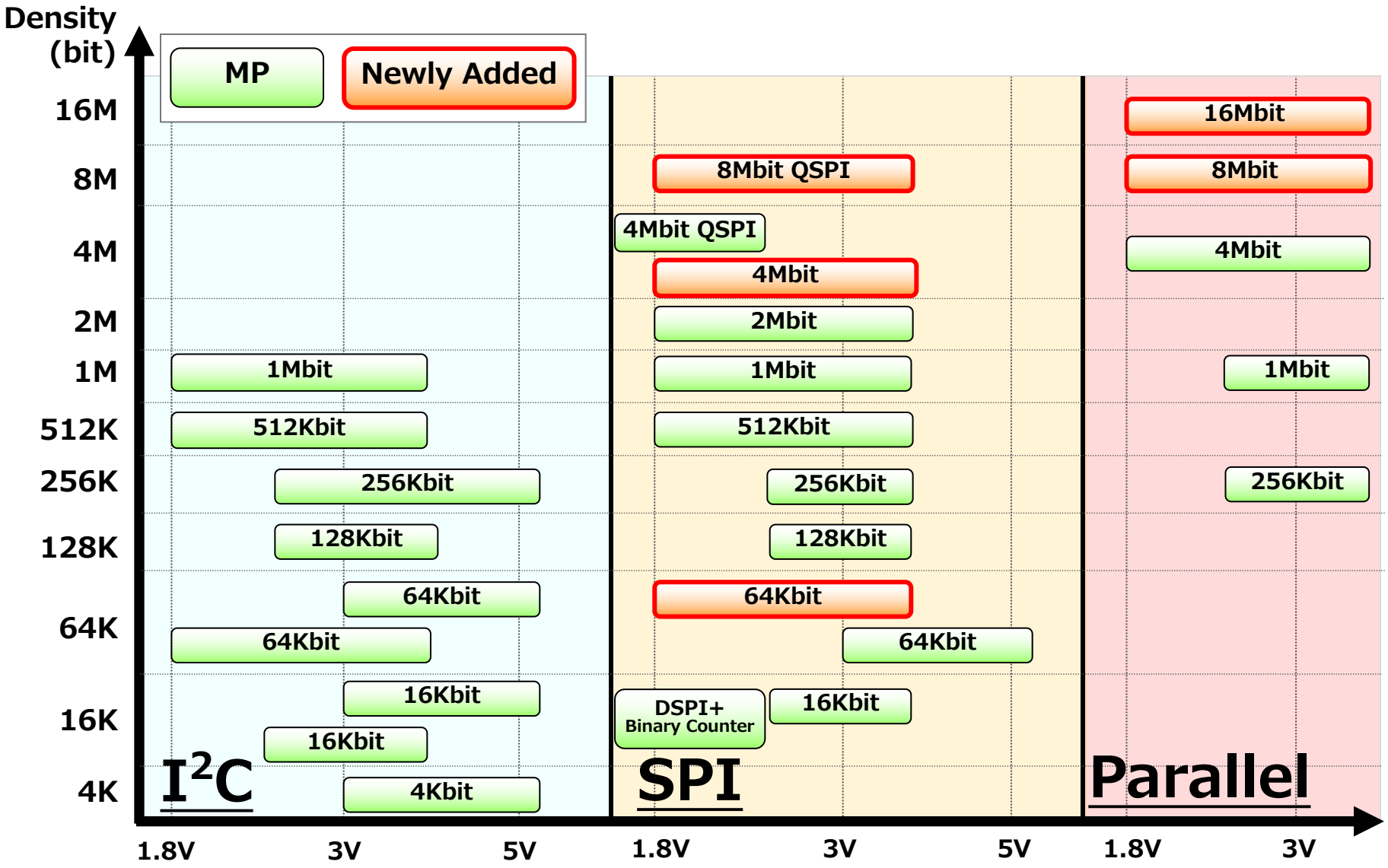


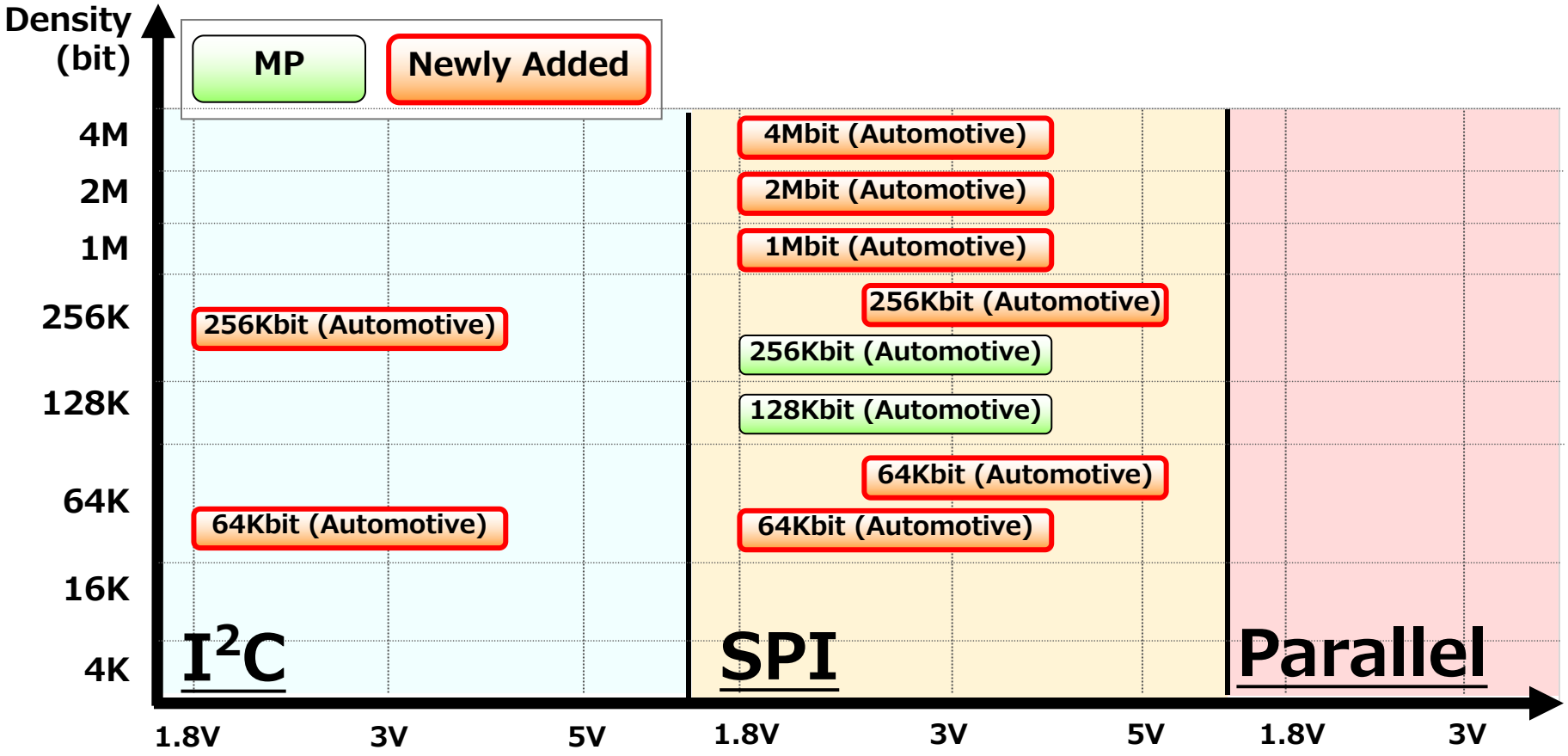

Figure2 Power Consumption

# Non-Automotive FRAM Lineup



# Automotive FRAM Lineup

- Automotive products:125℃, AEC-Q100 Grade 1



# Automotive FRAM production location

FUJITSU

HQ
Wafer Manufacturing
Assembly and Final test

**Assembly and Final test**

Tongfu Microelectronics

**Assembly and Final test**

SFA

**Assembly and Final test**

MTEX

**Assembly and Final test**

Katoh Denki

**Wafer Process**

Aizu Fujitsu Semiconductor

**Assembly and Final test**

J-Device

**Assembly and Final test**

MTEX (VN)

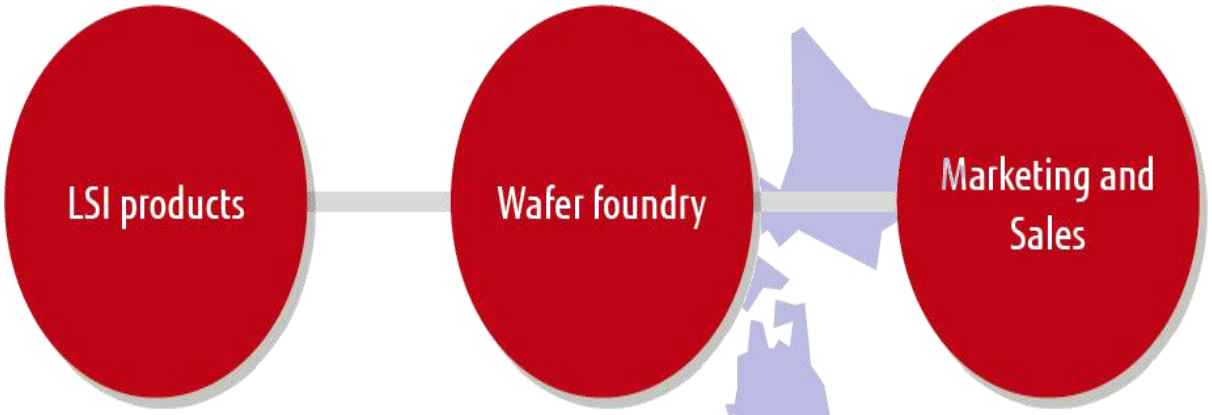
**Wafer Process**

Mie Fujitsu Semiconductor

**HQ,R&D**

Fujitsu Semiconductor

# Fujitsu FRAM support team


## High Quality and High Performance Memory

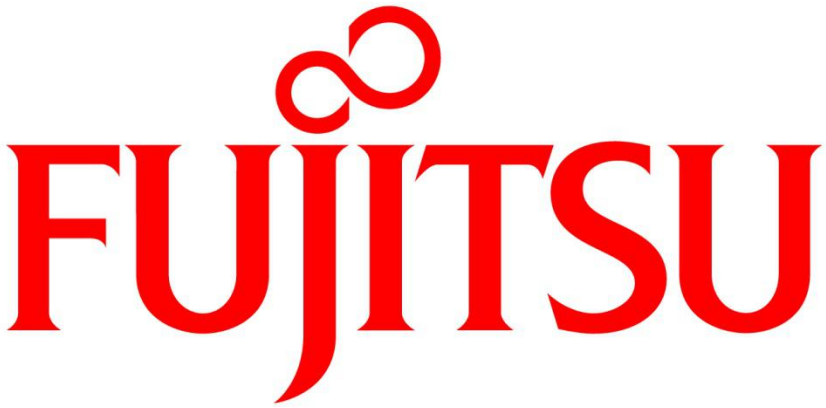
- **FUJITSU SEMICONDUCTOR LTD.**

## High Reliable Technology and Services

- **MIE FUJITSU SEMICONDUCTOR LTD.**
- **AIZU FUJITSU SEMICONDUCTOR LTD.**
- **AIZU FUJITSU SEMICONDUCTOR WAFER SOLUTION LTD.**
- **AIZU FUJITSU SEMICONDUCTOR MANUFACTURING LTD.**

## Global support

- **FUJITSU ELECTRONICS (SHANGHAI) CO.,LTD.**
- **FUJITSU ELECTRONICS PACIFIC ASIA CO.,LTD.**
- **FUJITSU ELECTRONICS INC.**

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