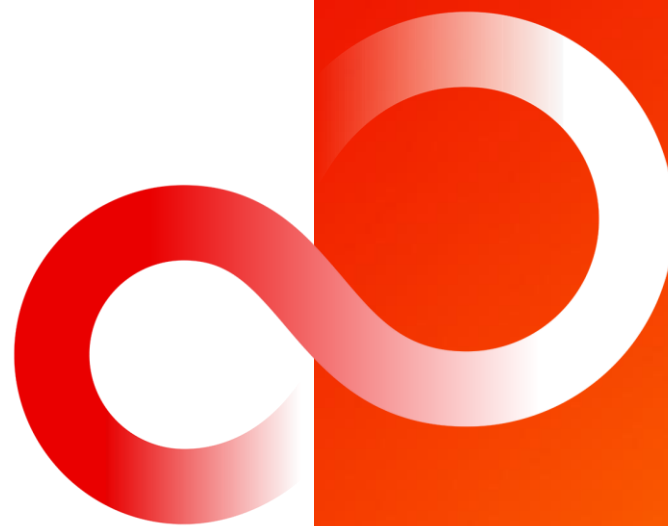


# ReRAM Overview (WhitePaper)



Fujitsu Semiconductor Memory Solution Limited

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## ● Introduction of ReRAM Overview

Since ReRAM had been introduced in the media as one of the new next-generation memory devices, some people may have heard of it.

The ReRAM is often used as embedded memory, and few companies supply mass-produced ReRAM devices as memory IC. We started offering mass-produced 4M-bit ReRAM products as individual memory IC in 2016, and today we offer 8M-bit and 12M-bit products.

To let people interested the ReRAM know it easily, this document introduces an overview of ReRAM through the table of contents below.

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- 3) ReRAM Features
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- 5) ReRAM Solutions to Customer Issues
- 6) Our Mission

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5	Solutions	<b>ReRAM Solutions to Customer Issues</b>
6	Our Mission	<b>Our Mission</b>

## ● What is ReRAM?

ReRAM is a semiconductor product in electronics components. Semiconductor products have various kinds of devices such as microprocessors, logic, analog, and memory devices. ReRAM is one of the memory devices like DRAM and Flash memory. ReRAM stands for Resistive Random Access Memory because. It is the memory storing data by changing resistance in cell material between electrodes.

## ● ReRAM, a Non-volatile Memory

Memory devices are semiconductor products to store data and they are divided into 2 types. One is the “Volatile memory” that features stored data are disappeared at power off. DRAM is famous as a volatile memory. Another type is the “Non-volatile memory” which features stored data are not disappeared at power off. This means data are written to the memory at once, the data do not change without erasing or rewriting. ReRAM is the non-volatile memory the same as Flash memory and FeRAM.

Fig.1: Positioning of ReRAM

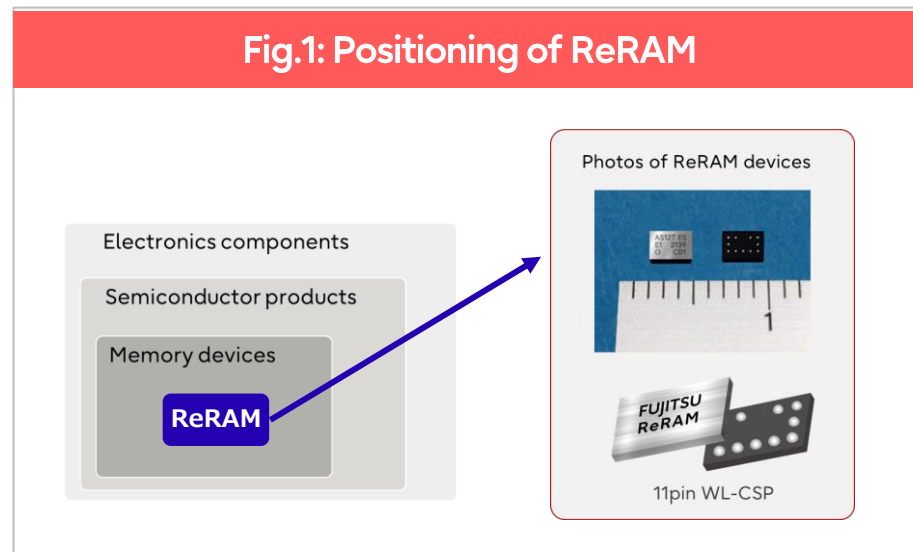
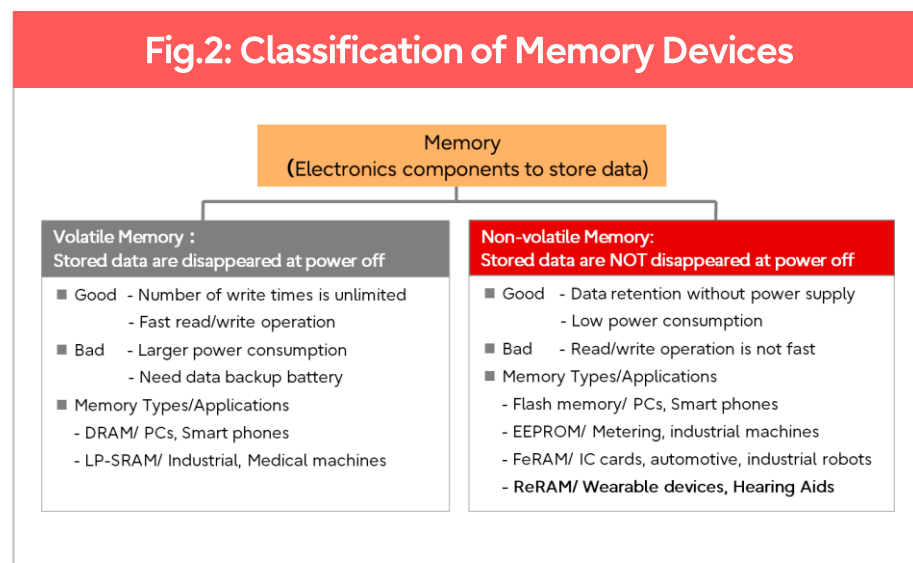


Fig.2: Classification of Memory Devices



# 1. ReRAM Overview

## ● Differences between ReRAM and FeRAM

We provide ReRAM and FeRAM as non-volatile memory. Since these two memory products have different features, each advantage is different.

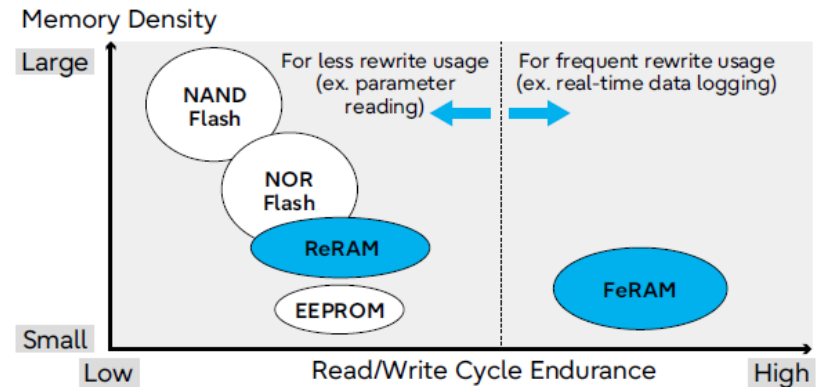
The greatest strength of ReRAM is that the operating current during a read operation is extremely small, therefore, it can be expected to extend the battery life in small battery-operated devices. In addition, since the number of data read is unlimited, it is suitable for applications where programs or parameters are frequently read out. For example, ReRAM is ideal for small wearable devices such as hearing aids and smartwatches.

On the other hand, the strength of FeRAM is the large number of guaranteed data writing. Since the data can be rewritten up to 100 trillion times, it is suitable for applications that continue to write data in real-time. For example, it is used as a memory for recording information in meters, industrial robots, and automobiles.

Table 1: Features of ReRAM and FeRAM

ReRAM	FeRAM
<b>Non-volatility</b> - Keep stored data at power off	<b>Non-volatility</b> - Keep stored data at power off
<b>Very Small Read Current</b> - Average 0.15mA (@5MHz) - Max. 0.7mA (@10MHz)	<b>High Read/Write Endurance</b> - Guarantees 100 trillion read/write cycles
<b>Large Density</b> - Max. 12Mbit	<b>Fast Write Speed</b> - Enable to overwrite data without erasing
<b>Very Small Package</b> - 2mm x 3mm, WL-CSP	<b>Low Power Consumption</b> - No Booster circuit - Less power consumption by short writing time

Fig.3: Position of Non-volatile Memory



## ● ReRAM Structure

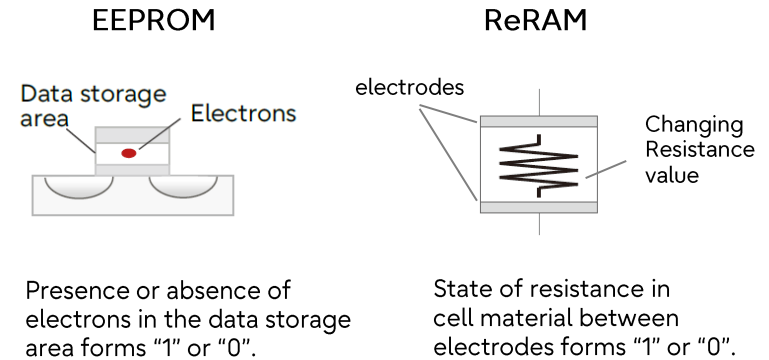
ReRAM is a memory using change in the resistance of semiconductor elements. Its cell structure and method to store data are different from other conventional non-volatile memory devices such as EEPROM and Flash memory. Of course, the judgment method of stored data "1" and "0" is also different.

EEPROM of conventional non-volatile memory judges "1" or "0" data by state of the memory cell being charged or discharged. (Left figure in Fig.4)

While, ReRAM judges it by the state of resistance in the memory cell, large resistance or small one. The change method of resistance in the memory cell is to apply pulse voltage to a thin metal oxide film placed between electrodes, creating massive changes in the resistance to record "1" or "0". (Right figure in Fig.3)

ReRAM has a limit to the number of data writes because the stress of applying a voltage to change the resistance state is applied to the cell element in a write operation. On the other hand, since it only reads the state of the resistance in the cell in a read operation, the guaranteed number of data read is unlimited.

Fig.4: Cell Structure of EEPROM and ReRAM



# 2. ReRAM Lineup

- ReRAM Lineup

Today, many ReRAM is spread out in the market as embedded memory. While we provide ReRAM devices in production as individual memory IC, not embedded memory.

Our ReRAM family has an SPI interface and the memory density ranges 8Mbit and 12Mbit. The two products have compatible power supply voltage, interface, package size, and pin assignment.

Regarding the specifications of each ReRAM device, please confirm its datasheet respectively.

- Remarkable Product –  
12Mbit ReRAM Lineup

We offer 12Mbit ReRAM MB85AS12MT, which has the largest density of our ReRAM products. This product can store character data for approx. 90 pages of newspaper in a small package size of about 2mm x 3mm.

Since the ReRAM has an extremely small read current, it is expected to extend battery life in small battery-operated devices. by using this product for memory.

This product is ideal for use in wearable devices such as hearing aids and smartwatches. (Fig.5)

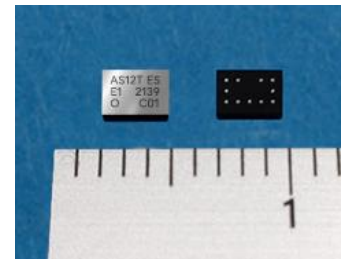
Table 2: ReRAM Lineup

Part Number	MB85AS12MT	MB85AS8MT
Density	12Mbit	8Mbit
Supply Voltage	1.6 to 3.6V	1.6 to 3.6V
Read Current	Max. 0.7mA	Max. 0.7mA
Read Cycles	Unlimited	Unlimited
Write Cycles	0.5 million times	1 million times
Package	11pin WL-CSP	11pin WL-CSP

(As of March 2023)

Fig.5: 12Mbit ReRAM

Package Photos



Suitable Applications (Wearable Devices)



## ● Four ReRAM Features

ReRAM has four superior features non-volatility, very small read current, large density, and very small package. In other words, it is a non-volatile memory that has a large memory density of 12Mbit with a very small read current in a very small package.

Due to these features, it is suitable for small precision devices with frequent data read operation.

## ● Comparison to Other Memory

Table 2 shows the comparison to other memory devices of EEPROM, Flash memory, and SRAM which are replaceable with ReRAM.

You can see that ReRAM has a lower read current and write current than the other memory devices. Since it operates from a power supply voltage of 1.6V, power Consumption during operation can be kept low. In addition, although SRAM needs a data backup battery for data retention, ReRAM does not need it. For the above reason, ReRAM has advantages especially on the point of power consumption during operation compared to the other memory devices.

Fig.6: ReRAM Features

### Non-volatility

- Keep stored data at power off
- No battery for data retention

### Large Density

- Memory density of 12Mbit

### Very Small Read Current

- Ave. 0.15mA at 5MHz operation
- Max. 0.7mA at 10MHz operation

### Very Small Package

- 2mm x 3mm, 11pin WL-CSP

Table 3: Comparison to Other Memory

Item	ReRAM	EEPROM	Flash Memory	SRAM
Memory Type	Non-volatile	Non-volatile	Non-volatile	Volatile
Data Backup Battery	No	No	No	Yes
Read Current	0.15mA (@5MHz)	3mA (@5MHz)	4mA (@33MHz)	20mA (@55ns)
Write Current	1.5mA	3mA	15mA	20mA (@55ns)
Read Cycles	Unlimited	Unlimited	Unlimited	Unlimited
Write Cycles	1 million	1 million	0.1 million	Unlimited
Supply Voltage (Low side)	1.6V	1.8V	2.7V	2.7V

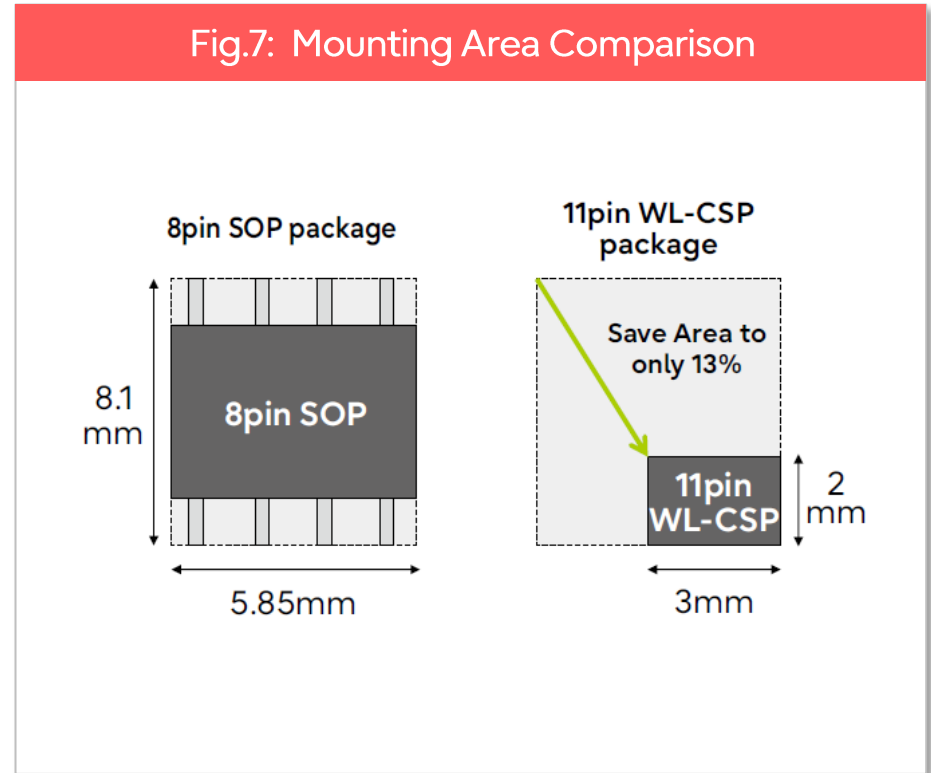
# 3. ReRAM Features

- Large Density & Small Package

The package of our ReRAM products is WL-CSP (Wafer Level Chip Size Package) with a size of 2mm x 3mm (6 square millimeters).

In 8-pin SOPs, which are often found in non-volatile memories with SPI interfaces, leads are located on the outside of the black resin of the package. However, in WL-CSP, the balls for contact are located on the bottom side of the package, so the mounting area is small. For example, compared to 8-pin SOP 4Mbit FeRAM, 12Mbit ReRAM triples the memory density and reduces the mounting area by more than 80%.

If the customers require a large memory density in a small package for their applications that read data more frequently than write data, we propose the ReRAM as one of the strong options.



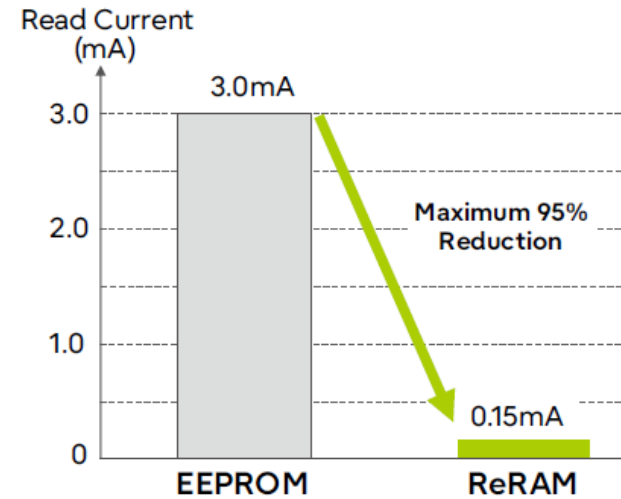


- **Small Read Current**

ReRAM read current averages 0.15mA at 5MHz operation. This is about 95% lower than the EEPROM's average 3.0mA at the same 5MHz operation.

This feature is ideal for wearable devices that run on batteries. Specifically, on the hearing aids, after initial setting data (=parameter) is recorded in the memory chip, the data is frequently read out during use. In such applications, a lower read current can contribute to reducing battery consumption and extending the battery life.

Fig.8: Read Current Comparison



- Usage – Wearable Devices

As introduced so far, ReRAM's greatest strength compared to other memories is "lower read current". Especially battery-operated electric products require a small operating current and the feature of lower read current is the most helpful for them.

Among these electric products, wearable devices are the most suitable applications for our ReRAM. That is because the usage requires a small package size for electronic devices and frequent data read-out.

In recent years, there has been a strong demand for power-saving electrical products for a sustainable society. We suggest our ReRAM, which can contribute to reducing power consumption, not only for wearable devices but also for electric devices in general.

Fig.9: Suitable Usage for ReRAM



Smartwatch



Smart Glasses



Hearing Aids

## Customer Issues and Solutions

If you are using conventional ReRAM, EEPROM, or SRAM in your products and have any of the following issues, please consider our 12Mbit ReRAM for your solutions.

### [ Issues ]

- 1) Insufficient memory density by 8Mbit
- 2) Need to keep a package size small due to restriction of the mounting area
- 3) Difficult to reduce power consumption by conventional non-volatile memory

### [ Solutions ]

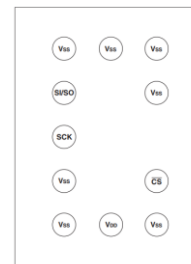
- 1) 12Mbit ReRAM having 1.5 times more density than 8Mbit is available.
- 2) 12Mbit ReRAM has a very small package size of 2mm x 3mm. Since it has the same pin assignment and package size as 8Mbit ones, our 8Mbit ReRAM can be easily replaceable with 12Mbit ReRAM.
- 3) Read current is less than 10% of that of other non-volatile memories and it operates from 1.6V of power supply voltage, so power consumption can be reduced.

Fig.10: Customer Issues and Solutions

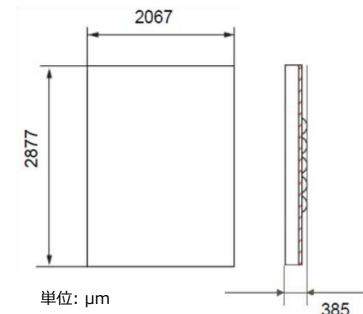
Case	Case 1	Case 2	Case 3
Issues	8Mbit is not enough to use ReRAM ...	Don't use ReRAM in larger package ...	Difficult to reduce power consumption...
Solutions	12Mbit ReRAM is available.	12Mbit ReRAM has a very small package size.	ReRAM with very small current is available.
Benefits	Enhancing performance of end-product	Small size while enhancing performance	Extending battery-life of end-product

Fig.11: Pin Assignment and Package for ReRAM

### Pin Assignment



### WL-CSP Package



## ● Our mission using ReRAM products

ReRAM is just one of the memory devices in electronic components.

However, we believe that we can contribute to society if we can offer ReRAM products to customers as factors maximizing features and functions of end products.

Overview of the contribution of ReRAM to society are:

### 1) Fulfilling the wishes of design engineers

By providing unprecedented memory;

- Improve customer product performance
- Develop ideal products

### 2) Improving corporate value

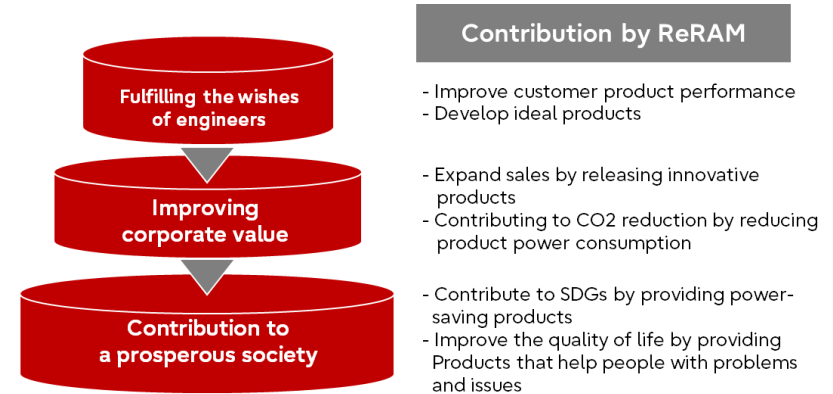
- Expand sales by releasing innovative products
- Contributing to CO2 reduction by reducing product power consumption

### 3) Contribution to a prosperous society

- Contribute to SDGs by providing power-saving products
- Improve the quality of life by providing products that help people with problems and issues

We think one of the missions of our ReRAM is to contribute to society through customer applications.

Fig.12: Contributing to Society by ReRAM



**Thank you**

