How an Embedded Non-Volatile Memory Can Be a Differentiator

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IP-SoC Conference 22
Outline

Bottlenecks at the Edge

Intro to Weebit ReRAM

The State of Weebit ReRAM Today

ReRAM: Why Now?

Where ReRAM Can Provide Differentiation
Bottlenecks at the Edge

Innovative new technologies can overcome memory bottlenecks

- Bandwidth
- Speed
- Power Consumption
- Security
Who Is Weebit Nano?

Leading developer of innovative next-generation memory technology: Resistive RAM (ReRAM)

- Founded: 2015
  - Located in Israel & France, ASX:WBT

- CEA-Leti: R&D partner
  - Leveraging years of research experience in NVM & ReRAM

- Current business model
  - IP licensing to semiconductor companies & fabs

- Silicon-proven technology
  - Mbit arrays avail @ 28-130nm
  - Fully qualified, production-ready

Timeline:

- 2017
  - Q1 2018: 1T1R
  - Q2 2018: 16Kb
  - Q4 2018: FMS AI Demo

- 2018
  - Q1 2018: 4Kb
  - Q4 2018: 1Mb

- 2019
  - Q3 2019: Successfully Scaled to 28nm

- 2021
  - Q4: IP Module in Silicon Live Demonstration

- 2022
  - June: 1st Production Fab Wafers
  - Oct.: Scaling to 22nm FD-SOI
  - Nov.: IP Module Fully Qualified
Weebit ReRAM 101

- Weebit’s ReRAM is based on oxygen vacancies filament (OxRAM)
  - Depositing a dielectric layer between 2 metal layers at the BEOL
  - By applying different voltage levels, a filament is created (“1”) or dissolved (“0”)
- Data retained within the stack is resilient to environmental conditions
  - High-temperatures, radiation, EMI
- Most cost-effective NVM technology
  - Only two additional masks
  - Fab-friendly materials, no special handling
  - Using existing tools and equipment
- Power efficient NVM
  - Digital-core-voltage read
  - <2V write voltage
- High performance
  - Fast access time
  - High endurance, long retention

![Oxygen Vacancy Filament](image)

![Low Resistive State (LRS) and High Resistive State (HRS)](image)
State of Weebit ReRAM Today: Technology is Qualified

- Weebit’s ReRAM successfully passed the JEDEC industry standards for non-volatile memories (NVMs)
  - Confirms the suitability of Weebit’s embedded technology for volume production
  - JEDEC standards impose rigorous testing of many silicon dies blindly selected from three independent wafer lots
  - All dies successfully passed the entire set of qualification tests for industrial-grade conditions

![Write Endurance (NVCE) and Data Retention (UCHTDR) charts]

![Schematic diagram of ReRAM Memory Module with RISC-V MCU, ReRAM Array, Decoder, EGC, CTRL, and High Voltage components]
Weebit ReRAM Now Available in SkyWater Fab

- **256Kb ReRAM module available for customers’ designs**
  - Optimized for SkyWater 130nm node

- **Initial applications**
  - Analog, power management, mixed-signal designs
  - IoT, industrial, automotive
  - Aerospace, defense and military
  - Data logging
  - Heterogenous computing

- **Benefits**
  - Excellent endurance and retention, even at high temperatures
  - Ultra-low power consumption
  - Tolerant to ionizing radiation and electromagnetic interference
  - Inherently secure technology

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[Image of ReRAM module]

**Weebit Nano ReRAM Preliminary Key Features**

<table>
<thead>
<tr>
<th>Technology</th>
<th>130nm, SkyWater S130</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mask Adder</td>
<td>2</td>
</tr>
<tr>
<td>Supply Voltage</td>
<td>1.8V Read</td>
</tr>
<tr>
<td></td>
<td>1.8V+3.3/3.6V Program</td>
</tr>
<tr>
<td>Cell Programming Voltage</td>
<td>1.4V – 1.8V Set &amp; Reset</td>
</tr>
<tr>
<td>Read Access Time</td>
<td>&lt;20nsec</td>
</tr>
<tr>
<td>Operation Temp.</td>
<td>-40°C – 85°C (Can be extended to -55°C – 125/150°C)</td>
</tr>
<tr>
<td>Capacity</td>
<td>256 Kbit (Can be customized for 128Kbit – 2Mbit)</td>
</tr>
</tbody>
</table>


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ReRAM: Why Now?

- Power and cost pressures are increasing
  - Advanced nodes are necessary

- Flash scaling complexity & cost are growing
  - Some solutions evolve but are sub-optimal

- Investment in emerging memory tech is increasing
  - Resolving some key challenges in ReRAM (e.g., variability)

- Embedded emerging NVM market expected to reach $2.9B by 2027
  - ReRAM expected market share: 33%

Embedded ReRAM Market Size 2021 - 2027

- Source: Yole Emerging Non-Volatile Memory 2022
- Note: The embedded emerging NVM market size is evaluated based on assumptions of the average chip area occupied by a given memory technology (Yole)
ReRAM Fits a Broad Range of App Requirements

Based on a back-end-of-line (BEOL) technology, ReRAM nicely scales:

- 130 nm → 65 nm → 28/22 nm → 1X nm
- Bulk CMOS, FD-SOI, FinFET
- Mixed-signal, High-Voltage, Low Leakage, RF CMOS, High-Performance
ReRAM – a Differentiator for PMICs

- Growing interest in emerging NVM for mixed-signal & PMIC designs
  - 130nm and below: flash too expensive; difficult to integrate
  - 65nm and below: + MCU integration becomes a reality; MTP cell too large

- Low-density NVM required for:
  - Tables and coefficients, trimming, configuration, MCU firmware

- Weebit ReRAM is:
  - Back End of Line (BEOL) NVM: no interference with FEOL components
  - Reliable at high temperatures
  - Cost-effective, only 2-mask adder
MCU/IoT: A Natural Fit for ReRAM Integration

- Billions of battery-operated edge devices
  - By 2026*: 55.7B connected devices worldwide; 73.1 ZB of data generated from connected IoT devices

- Name of the game: System Integration
  - Flash not scaling below 28nm

- Embedded ReRAM has significant advantages over external NOR flash
  - **Power:** eliminate external memory interfaces
  - **Speed:** Avoid data fetching from external memory
  - **Cost:** Cut expensive SRAM or external flash
  - **Reliability:** Handles high temps; built for longevity
  - **Endurance:** Enables new use-cases
  - **Secure:** Instantiated on-chip, difficult to hack

* Source: IDC Research 2021
New NVM Technologies Enable Automotive Differentiation

- Automotive ICs have unique requirements
  - Design for safety, security and longevity
  - Reliable at extreme temperatures, EMI, vibration, humidity, etc.
  - Support fast boot, instant response, frequent OTA updates
  - Advanced process nodes are adopted quickly

- Growing needs for emerging NVM
  - Needed for code storage, trimming, data logging

- Weebit ReRAM
  - High-temp reliability, immunity to EMI, endurance, fast switching speed, longevity, secure
  - Can effectively scale to the most advanced process nodes

Some Places Where NVM is Found in a Car

- Touch Screen Controller
- Keyless Entry
- Anti-lock Brake System
- Engine Control
- Lighting/Window/Mirror Controllers
- Power Management
- Airbag Sensors
- Temp/Pressure Sensors
- Pressure/Flow Sensors
- Temp/Pressure Sensors
Aerospace & Defense: Demanding Apps Need New NVM

- Growing interest in emerging NVM for aerospace and defense ICs
  - Flash can’t withstand radiation
  - Flash isn’t easily scalable into advanced nodes
  - Limited endurance and energy efficiency
  - Other emerging technologies sensitive to temperature and EMI

- Low density NVM required for:
  - MCU firmware, logging, configuration

- Immunity to high-dose radiation
- Broad operating temp range (-55°C-125°C)
- Longevity for ICs that must last years without maintenance
- High endurance & retention (1M cycles, >20 years)
- Fast access time, quick boot time
- Immunity to electromagnetic fields
ReRAM for Secured Applications

- In today’s connected world, security is #1 threat
  - Smartcards, mobile payments
  - IoT devices, automotive, other connected systems

- ReRAM is more secure than other embedded NVMs
  - Keeps memory content including data, logs, and code safe from hacking
  - Much more difficult to intrude, read or modify

- ReRAM is also ideal for HW security mechanisms
  - Physical unclonable functions (PUFs)
  - True random number generators (TRNGs)
ReRAM to Drive Innovation for Edge AI and Future Neuromorphic Compute

Requirements
❖ High capacities (10MB-100MB), >SRAM
❖ Non-volatile behavior for synaptic weight storage
❖ Short latency / high bandwidth

Near Memory Compute
❖ ReRAM brings NVM closer to compute

Current Systems

Brain Inspired Systems

Near Memory Compute (NVM)
ReRAM replaces expensive/power hungry SRAM

Analog In-Memory Compute (ReRAM)
ReRAM does storage and compute in the same place

Future systems will mimic the behavior of the human brain for fast real-time processing on massive amounts of data

Orders of magnitude improved energy efficiency
The Evolution of ReRAM: The Next NVM is Here

- ReRAM spent decades in research and development until the industry recognized the limitations of flash.
- Weebit founded.
- Partnering with Leti to drive development of innovative NVM based on 10+ years of research.
- Weebit’s first demonstrations of small ReRAM arrays.
- Focus on fab-friendly and easy-to-integrate technology.
- Weebit’s technology matures.
- IP productization.
- First commercial deal.
- Starting to scale technology to smaller process nodes.
- Customers requesting ReRAM now.
- Weebit ReRAM is industry-qualified, ready for production.
- Multiple fabs considering Weebit ReRAM.
- Weebit & Leti continue to innovate.

1960s – 2010s
2015 – 2016
2017 – 2018
2019 – 2021
2022 – onwards
Thank You!

www.weebit-nano.com