# **Reinventing Memory for Things** (TM) Application specific memory solutions for integrated, connected, and high-temperature applications

Bård M. Pedersen Adesto Technologies



## **Corporate Overview**





## **Differentiated Solutions To Address The New Requirements**





# **Memory for LED lamps**



# **LED driver overview**

- Consumer LED lamps for home use mainly come in 2 categories:
  - LED lamps for 12 V halogen systems.
  - LED lamps for direct connection to 120V (or 240V) AC mains power.
- Each of these LED drivers come in 3 flavors:
  - Constant output LED lamps.
  - Dimmable LED lamps.
  - Remotely controlled LED lamps.



# **Constant output LED lamps**

- Constant output LED lamps are not made to be connected to a lamp dimmer.
  - If connected to a dimmer, they may dim a bit, but will typically start flickering or turn off completely before any significant dimming is achieved.
- LED driver/controller is either a simple analog circuit or a small microcontroller.
  - The analog solution is most common for constant output lamps, as there is really no reason not to make the driver dimmable if an MCU is used.
  - The memory requirements for the MCU in this setup is in the 1 - 2 kByte range.
  - This memory is always embedded in the MCU.



# **Dimmable LED lamps**

- Dimmable LED lamps are designed to be connected to a lamp dimmer.
  - Some may require "LED dimmers", others may work with any dimmer.
- LED driver/controller is either a slightly more complex analog circuit or a small microcontroller
  - MCUs are becoming more popular for this application as it is usually easier to adapt a complex control algorithm in firmware than in hardware. And it is much easier to update the firmware of an MCU than to change the layout of an analog driver.
  - The memory requirements for the MCU in this setup is still only in the 1-2 (4?) kByte range.
  - This memory is always embedded in the MCU.
  - A lot of the "stand alone" LED drivers sold in the market may actually have full MCUs under the hood.
    - The programming interface is usually not available to the general user.



# **Remotely controlled LED lamps**

- In this case, the LED driver/controller always contain a small or mid-size microcontroller.
- Typical remote control interfaces are
  - Wireless interfaces like Wi-Fi, Zigbee and Bluetooth.
  - (Less common) Wired interfaces like DALI or X10.
- The wireless interfaces require a lot more memory.
  - Typical memory requirements are 128 256 kBytes or more.
  - This may be embedded memory, or it may be external.

## • For over-the-air updates, additional memory is required.

- 3 memory images are stored at once:
  - The currently running firmware.
  - The new firmware being transferred.
  - The factory default.
- This additional memory is usually external memory.



# **Temperature requirements for LED lamps**

- LED lamps usually have the same form factor as the traditional incandescent lamps.
  - All the control circuitry is inside the lamp.
- Depending on the wattage of the lamp, the internal components have to withstand temperatures as high as 105°C or 125°C.
  - These are usually considered automotive grade temperatures.
  - 90% of electronic components do not meet this temperature spec.
  - Adesto offers discrete Flash Memory up to 125°C.







# **Embedded vs. Discrete Flash Memory**



# **Advantages of Embedded Flash Memory**

- No extra I/O pins for memory interface
  - On-chip memory bus can be 32 or 64 bits wide
  - No pinout restrictions
- System-on chip can be implemented as a single die
- Potentially lower power, faster





# **Disadvantages of Embedded Flash Memory (1/3)**

- Device process is a compromise between what is needed for memory and what is needed for logic
  - More complex process
    - Requires on-chip high voltage circuitry
      - 10V or more required for programming
    - Longer development time
  - The most advanced logic processes may not offer embedded flash, or flash may be on an older/larger technology node
    - Valuable high density die area used for low density memory





# **Disadvantages of Embedded Flash Memory (2/3)**

- A much higher number of masks needed for flash compared to standard logic
  - Typical 10 or more extra masks, 20-30 additional processing steps
    - Increases mask cost
    - Increases production time and time to market
- Limited number of foundry processes available
  - Pure logic processes offer more options than processes including flash



# **Disadvantages of Embedded Flash Memory (3/3)**

• A product family of multiple memory densities requires



• Lower profit margin



- Build only the largest device, use the same die for all family members
  - Wasted silicon area for the smaller densities
  - Lower profit margin





or

# **Adesto Solutions**

### Discrete Serial Flash

- DataFlash offers code storage and data storage in one device.
- Standard Flash optimized for code storage

### Embedded or Discrete CBRAM

- Scalable at least down to 20nm
- Compatible with standard logic processes
- Requires only 2 additional mask layers



# **Benefits of External Serial Flash**

- Modern serial devices only require a 4-pin interface between the CPU and the memory device
  - If DataFlash is already used for storing data, or SPI is already used in the system, no additional pins are required
  - High-speed dual or quad interfaces allow Execute-in-Place
    - Bandwidths above 400 Mbit/s may be achieved



- CPU may be built in a much more advanced logic process
  - Smaller die size, lower cost
- Flash is built in a more efficient process
  - Optimized for Flash memory



# **Product Families**

## • Same CPU may be used for multiple memory sizes

- Shorter development time
- Lower mask cost
- Lower die cost
- Smaller inventory
- Wider product offering

## For single chip solutions:

- Flash is offered in wafer form
- Stacked die is a low cost, standard offering from most assembly vendors









# Introducing

# **Adesto Technologies Corporation**

# **CBRAM<sup>®</sup>**



AMERICA



# **Conductive Bridging RAM (CBRAM):**

## **Next Generation Storage Technology**





# Adesto Technologies: Leading CBRAM Commercialization





### **CBRAM Basics**



Storage element scalable to <10 nanometers



- Present offering: EEPROM-compatible products
- Conductive Bridge Memory based on nanotechnology
- Integrated on industry standard CMOS Technology
  - Embedded Memory Solution
- Porting to 40 nm to enable higher density products
  - Release 64Mb Ultra low Power in 2015



# **Physical Principles for CBRAM Operation**

### CBRAM technology operating principle:

Electrically induced reversible nanoscale conductive link

Special Special Reprogrammable CBRAM Stack

Cell in High Resistance => Low Read Current (less than ~200nA) = DATA 0 Cell in Low Resistance => High Read Current (more than 10uA) = DATA 1





**OFF State** 

+V<sub>read</sub>

ANODE

Special MOX

**High Resistance** 

State

R > 10MO

Dielectric

CATHODE

V<sub>anode</sub> > V<sub>cathode</sub>

Metal Ion From

Top Electrode

Electron from Bottom Electrode

Oxidation →

lons(

SET Operation

High Resistance to

Low Resistance

Switching

Electrons(-)

Program

+Vprg

Metal Atom:

M(0)

Building Block of

Conductive Link

Reduction →

ON State

+V<sub>read</sub>

Metallic Pathway

(High Resistance) (OFF to ON State) (Low Resistance) (ON to OFF State) (High Resistance)

Low Resistance

State

R < 20KΩ

Vanode < Vcathode

Pe⁻

Dissolution

Erase

**RESET Operation** 

Low Resistance to

**High Resistance** 

Switching

ov

OFF State

+V<sub>read</sub>

ov

High

Resistance

State

# **CBRAM: Ideal Solution for Low Power Applications**



Lowest Energy Flash Memory Technology

**Battery Operated Wearable Electronics** 

**Ultra Low Power Embedded Devices** 

**Energy Harvesting Body Sensors** 



#### **Emerging Growth Markets**



#### SENSOR CHIP with CBRAM OPERATING by ENERGY HARVESTING



Parameter	Adesto's CBRAM	Today's Flash	Improvements	
Core Read Voltage (V)	0.35	1	60% Lower	
Read Energy Per Bit (fJ)	50	500	10x Lower	
Core Write Voltage (V)	0.6	10	17x Lower	
Write Energy Per Bit (pJ)	1	100	100x Lower	





# Long Term Resistance vs. Time and Temperature

Product and Technology Qualified for 10yr/85°C



- Long term 110°C retention study
  - >8000hr (11.5 month) read point no failures
  - 240 product/technology qualification units remain on long term retention bake.
  - Adding ~300 units per month starting this month collecting large long term statistical retention database
- Long term 200°C retention study
  - 800hr 200°C retention bake indicated no resistance shift for either Program (Set) or Erase (Reset) bits, after initial read point



# **CBRAM**<sup>°</sup>: New Memory with a Promising Future



Adesto's Proprietary Memory Technology

10x – 100x Faster Than Flash Memory



# **Memory For Medical Asset Tagging**

#### Application

Electronic storage of code and data in medical equipment and health care industries.

#### Problem

Today's Flash Memories are not compatible with medical sterilization processes used in health care industry.

#### Solution

CBRAM is the only memory technology proven to maintain the integrity of the data content after the sterilization processes.





Nordion is the leading provider of medical sterilization processes to the health care industry



## **Embedded Memory Die Size**



- Embedded Flash will reach its limits around 55-45 nm.
- CBRAM has been shown to work with a cell size of 20nm.



# **Embedded Memory Power Consumption**



- On-chip voltage and current requirements for Flash remain ≈unchanged as the devices shrink.
  - Pumping this power from an ever lower external voltage makes overall power consumption go *up* significantly for low supply voltages.



# **Summary of Adesto IP Portfolio**

	USA	Rest of World	Total
Patents (including patents transferred to Adesto)	70	43	103
Patents licensed	57	42	99
Adesto applications	63	28	91
New Adesto disclosures waiting to be filed	5	0	5
TOTAL	195	113	308
Patents licensed from Atmel	Full portfolio for use in discrete Flash		

Comprehensive set of broad and critical manufacturing and functional know-how on CBRAM<sup>®</sup> and RRAM technologies. Focus on "commercialization" and fundamental understanding of CBRAM



٠

# **CBRAM: NV Memory for Today and Tomorrow**

- CBRAM is a new disruptive memory technology that delivers significant advantages in power consumption, operating speed, and cost
- Boot memory products are available today and can be integrated in applications that require fast, low cost NVM solutions
- Adesto Technologies is committed to the CBRAM Technology Roadmap, a roadmap that includes enhanced products from 32 Kbit to 256 Mbit densities
- With a comprehensive portfolio of memory technologies at its disposal, Adesto offers innovative solutions to its customers in a variety of markets, including class-leading products for wearable, mobile, and other energy conscious applications.
  - Our hybrid business model of both discrete products and IP licensing allows us to address a variety of customer requirements.



٠