Commercial Product Applications for Autonomous Memory

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What is Autonomous Memory?

From an *applications* point of view, an autonomous non-volatile memory is…

An electrical or electromechanical circuit

– any circuit –

that remembers by itself.

Characteristics

Autonomous memory is a memory bit so it can can operate within a traditional memory architecture.

- *Its cost versus that of other potential technologies is the only question that need be answered.*

Or, autonomous non-volatile memory can stand alone, providing memory where no other technology can.

- *Unheard-of functionality!*

Or, autonomous non-volatile memory can combine with electro-mechanical components to create machines with memory.

- *Inherently smart machines!*

Other Characteristics

An autonomous non-volatile memory can exist in high density or *as a single bit*.

It can be fabricated in a fully integrated circuit – any FRAM process will do.

Or, it can be *added* to any non-ferroelectric IC process using bump bonding or multichip module packaging.

Even stand-alone *1,000 volt memory circuits* can be created using bulk ceramic ferroelectric disk capacitors as the memory elements!

What about FRAM?

Autonomous memory *is not a threat* to FRAM!

For an FRAM company, autonomous memory provides a path to additional - *unique* - functionality using different circuits built on the existing FRAM process.

For a non-FRAM company, autonomous memory is a way to add ferroelectric non-volatility to existing products inexpensively.

- *A path also for FRAM companies to port NV memory to process modules which do not accommodate FRAM.*

Philosophy

When the first autonomous memory bit functioned at Radiant more than 10 years ago, the first questions to me were...

For what can you use one bit?

Why use that memory instead of a flash key?

For those of us trained in traditional IC memories, these are *extremely difficult* questions….. at first!

With time, tradition falls away ... opening the door to new ways of thinking.

Contents

The eleven products listed at the beginning of Radiant's application note "Introduction to Autonomous Memory Design for Integrated Circuits" will be described in more detail below.

The list of products below is not exhaustive. The list is just an introduction to the possibilities.

Create a non-volatile analog switch for the Internet of Things

Analog switches are everywhere. Integrating *a single bit* of non-volatile memory to a standard analog switch turns it into the electronic equivalent of the ON/OFF switch on the wall. But this one is programmable and can be combined with an simple RF communications portal to be placed at the end of *every filament* of the Internet of Things (IoT).

Give non-volatility to any electromechanical component

Every already-installed electromechanical relay can be made non-volatile and programmable by adding a stand-alone non-volatile solid state switch to its coil circuit.

- Imagine a factory as an FPGA!

Create a single digital bit of non-volatile memory needing no microprocessor

A single, stand-alone, non-volatile, digital memory bit allows engineers to add a non-volatile *Enable* to any IC component or PCB they deem necessary.

- The IC component will know whether it should be enabled or disabled when power is restored after a failure.

- Add a few bits of *remotely programmable* "BIOS" for any PCB without the need to install FLASH or EEPROM *or* a microprocessor to read the FLASH or EEPROM *or* the assembly code to guide the microprocessor *or* the connector for programming the µP and so on.

Create non-volatile memory with *bipolar* transistors

There is no such thing as a non-volatile memory in a bipolar process. Autonomous memory changes that because it will work with *any* type of transistor or switch, even ferroelectric piezoMEMs relays!

Create a radiation hardened non-volatile memory

Bipolar is radiation hard. If you can make non-volatile memory in bipolar, then you can make truly hard space-qualified and medical-qualified non-volatile memory.

Add a non-volatile register to any IC circuit without having to insert a full FRAM memory

In traditional memory architecture, there will be a cut-off in the number of non-volatile bits below which it will be cheaper and more area efficient to make a non-volatile data register with autonomous memory instead of using a full FRAM array or resorting to the original six-transistor ferroelectric memory latch from 1987.

Create non-volatile memory that operates from harvested energy

The energy requirements for each autonomous memory bit is so low that it is possible to create memory bits, bytes or registers with autonomous memory that will operate from the very small amounts of intermittent energy supplied by energy harvesting power sources.

This application was the original target for which autonomous memory technology development started at Radiant!

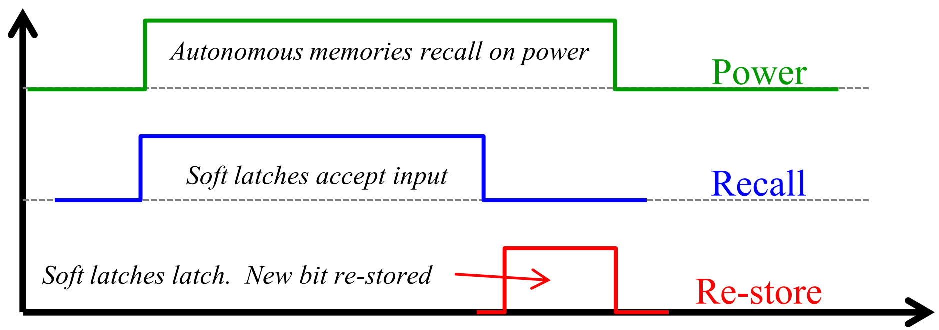
Create fully static CMOS circuits

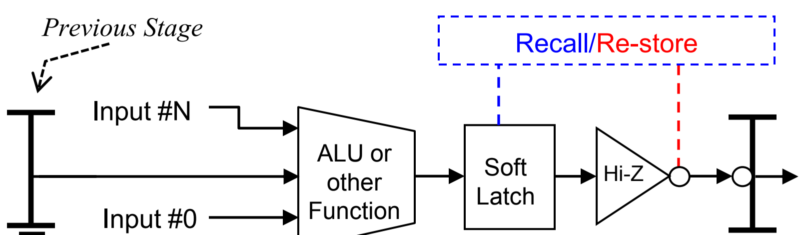
Fully static *microprocessors* made with CMOS can execute a program even though the microprocessor clock stops and starts again but they must have power to hold each state when the clock stops. Imagine a fully static microprocessor that *does not need power* to hold its state between clock pulses. Even simpler than a microprocessor, how about a fully static synchronous clocked logic circuit?

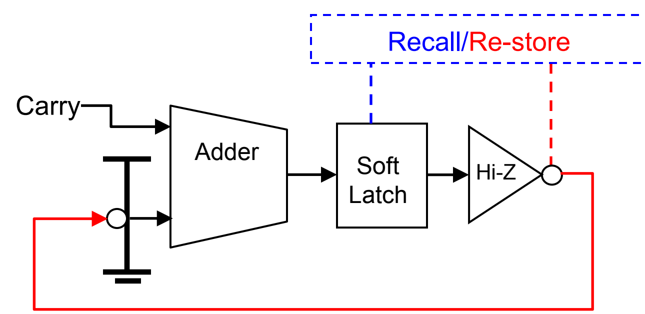
- *Simply put an autonomous memory in the output of every logic element in the circuit.*
- *Power can be shut down between each clock pulse.*

Autonomous Registers and Dataflow

The autonomous counter and other autonomous dataflow circuits would use either of these two non-volatile register-based architectures:







Create autonomous counters for metering without a battery.

Design a digital counter with an autonomous memory bit at every stage that

1. Recalls the stored count when the clock pulse occurs,
2. Increments the recalled count, and
3. Re-stores the incremented count

using only the energy supplied by the clock pulse!

Create autonomous mailboxes for microprocessors to leave messages.

Add an 8-bit wide, 512-byte deep, dual-port autonomous shift register to a microprocessor die:

- One port is connected to package pins so the memory can be powered by an external component to be read or written by that external component.
- The second port opens to the microprocessor so the microprocessor can read messages from or leave messages in the mailbox.

Connect an embedded ferroelectric capacitor to the outside world so it can record events.

A single pin on a microprocessor can be defined as an autonomous event detector that will *record* the occurrence of an event *even when the microprocessor is off!*

- The energy of the event writes the capacitor.
- The microprocessor can monitor the security of a door *especially when power to the security system fails.*
- How many server enclosures are there in the world?

Give an RF tag the ability to record multiple events or types of events in its surroundings.

The RF tag could record occurrences around it even though it has no battery!

The RF tag could report those occurrences when powered up by the traditional RF tag reader.

The combination of all recorded events could act as a start-up interrupt vector for the tag.

Give an RF tag the ability to communicate with its wearer!

Embed piezoelectric sensors in the RF tag to allow the wearer to activate event detectors buried in the tag so the wearer can send messages to the RF tag reader when it powers up the tag – still with no battery in the tag.

Create a new standard for computers and controllers to record system failures

Ferroelectric capacitors are fast. Some are faster than *one nanosecond*. Establish new system standards to create a simple *autonomic* nervous network within systems that captures reports and warnings from subsystems prior to an enforced shutdown or system crash. Subsystem status or crash reports can be examined by the primary controller on re-start to determine the cause of the shut-down and take appropriate action.

Closing

In this document, we explored the application of autonomous non-volatile memory to existing products as well as the creation of new functionality not possible with traditional non-volatile memory.

Autonomous memory will be revolutionary!