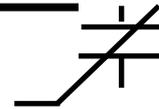# Event Detection with a Ferroelectric Capacitor

Joe T. Evans, Jr.
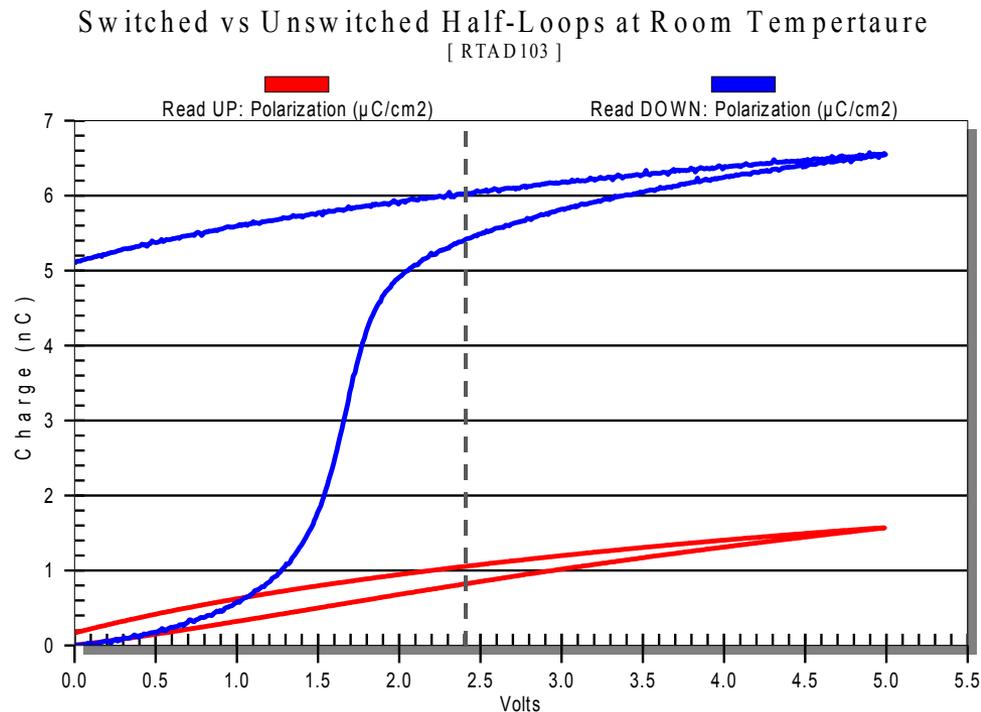
Radiant Technologies, Inc.

May 31,2013

Ferroelectric Capacitor

The ferroelectric capacitor has two memory states that are stored as mechanical and electrical stresses inside the dielectric material.

Switched vs Unswitched Half-Loops at Room Tempertaure
[RTAD103]

Read UP: Polarization (µC/cm2)   Read DOWN: Polarization (µC/cm2)
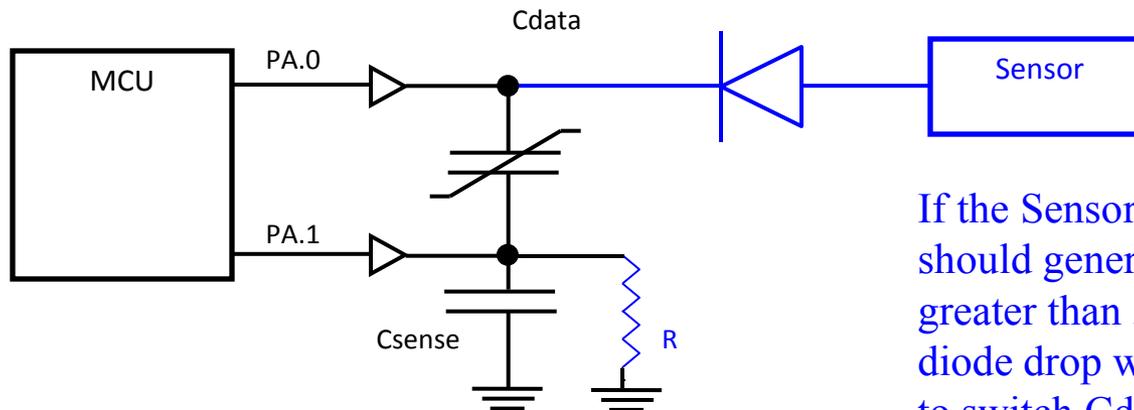
Since the memory is intrinsic to the material, the memory state may be changed by *any* voltage application made to the capacitor higher than its saturation voltage.

External Event Detection

A ferroelectric capacitor attached to the I/O pins of a microprocessor can be connected to external voltage generators or sensors that will change the capacitor state if an event occurs.

➢ The only requirement is that the I/O pins of the microprocessor be high impedance at the time of the detection so as not to affect the write operation.

➢ This requires the microprocessor to put the I/O pins in Hi-Z *or be powered off!*

The circuit elements in blue below add an external event detection capability to the nonvolatile memory bit.

If the Sensor detects an event, it should generate a voltage pulse greater than 3 volts plus one diode drop with sufficient charge to switch Cdata to UP. The write pulse must be shorter than R times Csense.

R discharges Csense after the event.

Detection Procedure
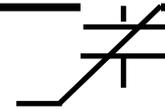
Procedure:

I. Set the state of Cdata DOWN by setting PA.1 High and PA.0 low.
II. Return PA.0 and PA.1 to low.
III. Isolate PA.0 and PA.1 as Hi-Z.
IV. Power down the microprocessor (optional)

EVENT: If the event occurs, the sensor will switch Cdata UP.

V. Power up the microprocessor if it is off.
VI. Execute a read operation. If UP is detected, the event occurred.

MCU | PA.0 | Cdata | Sensor | PA.1 | Csense | R

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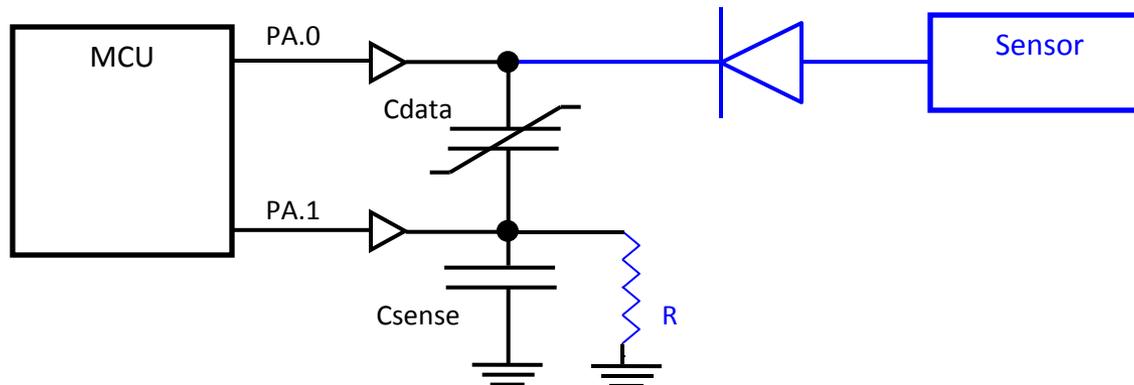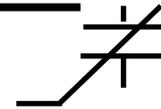
Detection Procedure
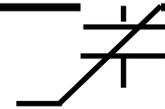
Power:

> ➤ The microprocessor need not be powered off for event detection to take place.

> ➤ PA.0 and PA.1 must both be high impedance for the sensor to write Cdata.

> ➤ If the microprocessor remains powered, it can execute other functions while Cdata keeps watch!

MCU — PA.0 — Cdata

MCU — PA.1 — Csense — R
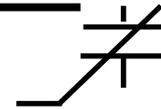
Sensor

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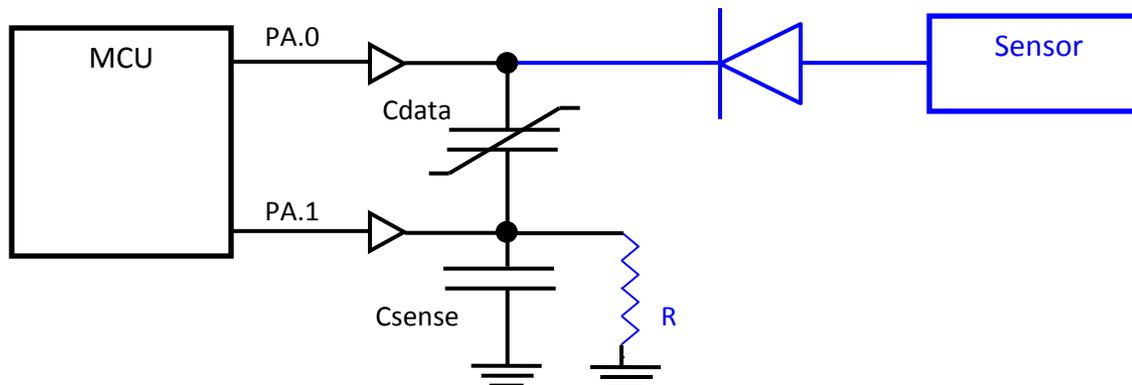
I/O Protection

- The design of the I/O pin may affect the Cdata write operation when the microprocessor is unpowered.

- The static discharge protection transistor for the pin may turn on when the pin is raised in voltage while power is off. The transistor will attempt to raise the internal power bus of the microprocessor, acting as a diode.

- If the sensor write operation does not work, as a test disconnect the two microprocessor pins from Cdata during the write operation and then re-connect the pins to conduct the read operation.

- Diodes *cannot* be used on PA.0 and PA.1. They will interfere with memory operations.

- The sensor write operation will *always* work with microprocessor power on and the I/O pins in Hi-Z as long as the write voltage does not exceed the μP supply voltage.
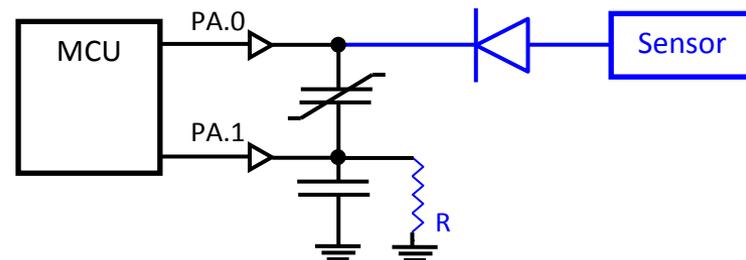
Applications

The event detection may be of an ambient environmental effect:

> ➢ Using a solar cell as a sensor will indicate if a light came on or the sun came up and set while the microprocessor was asleep.

> ➢ A battery or super capacitor powered water detector can indicate if it rained while the microprocessor was powered off.

> ➢ Did peak wind exceed a specified limit?

The detected event may indicate a system condition:

> ➢ The battery to the clock/calendar chip was removed and replaced so its time/date are not valid.

> ➢ Soft selection of the startup mode before power-on.

> ➢ On power-up, the μP can determine if an un-commanded shutdown occurred due to bad power (NVbit1) or a bad power supply (NVbit2).
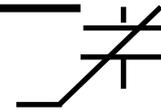
Sensor Detectors

For event detection to function, the sensor must generate a voltage pulse of at least 3.7 volts and enough charge to switch the ferroelectric capacitor.

➢ 3.0 volts needed to write the capacitor plus 0.7 volts for the diode drop.

➢ Solar cell

➢ A battery or a charged super capacitor connected to a switch

➢ A piezoelectric actuator

➢ A water, air, finger, or foot driven generator

➢ Static discharge to a metal plate

➢ The spark generator from a barbecue grill or cigarette lighter.

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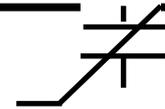
Spark Generators

➢ Spark generators generate up to 3000 volts but only into an open circuit, the spark gap. Normally that should destroy Cdata and the I/O. However, if the spark generator produces less charge that the amount the capacitor absorbs to reach 5 volts, Cdata will not allow the spark generator voltage to rise to damaging levels.

➢ Placing a TVS across the sensor output is another way to protect Cdata and the microprocessor input.
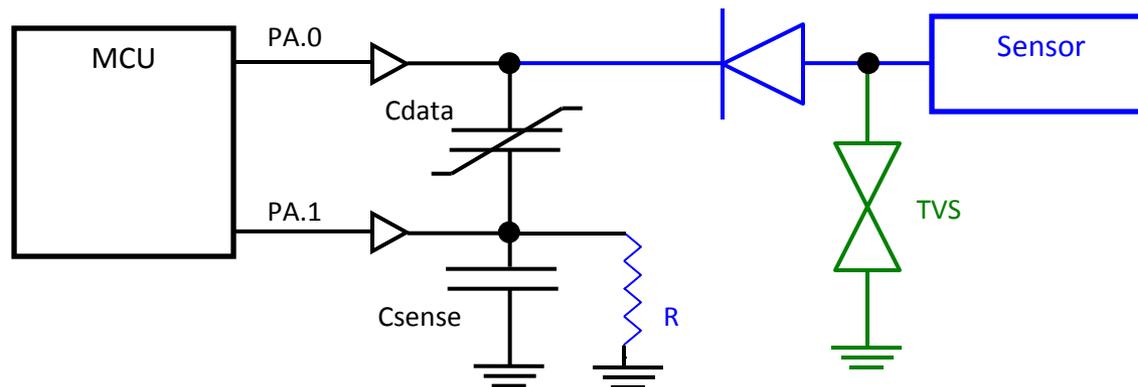
Note: the spark generator component that produces the spark is an electroceramic that is of the same material family as the Type AD capacitor!