2007 CMOS Emerging Technologies Workshop

RECENT ADVANCES IN RF ID TRANSPONDER DESIGN

Faisal Mohd Yasin
Faculty of Engineering

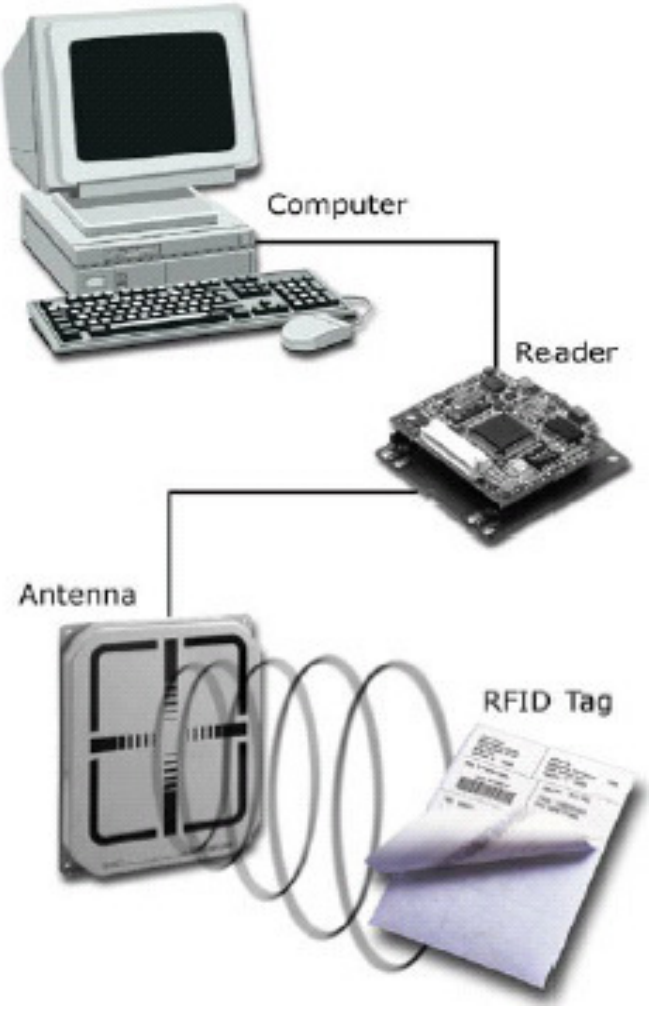
MULTIMEDIA UNIVERSITY

Brains, Knowledge, Wisdom: 10 Years and Beyond

Outline of Presentation

- Basic RFID System
- RFID Design Constraints
- Basic Building Blocks
  - Rectifier
  - Modulator
  - Demodulator
  - Digital Control
- Conclusion

Basic RFID System



Source: Weber Marking Systems Inc

- Potential successor to the bar coding technologies: Contactless & rugged.
- 3 components; an antenna, a reader and a tag.
- A reader typically contains a radio frequency module (transmitter and receiver), a control unit and an interface to forward the data received to a computer.
- Backers: DoD, Walmart, Pharmaceutical companies

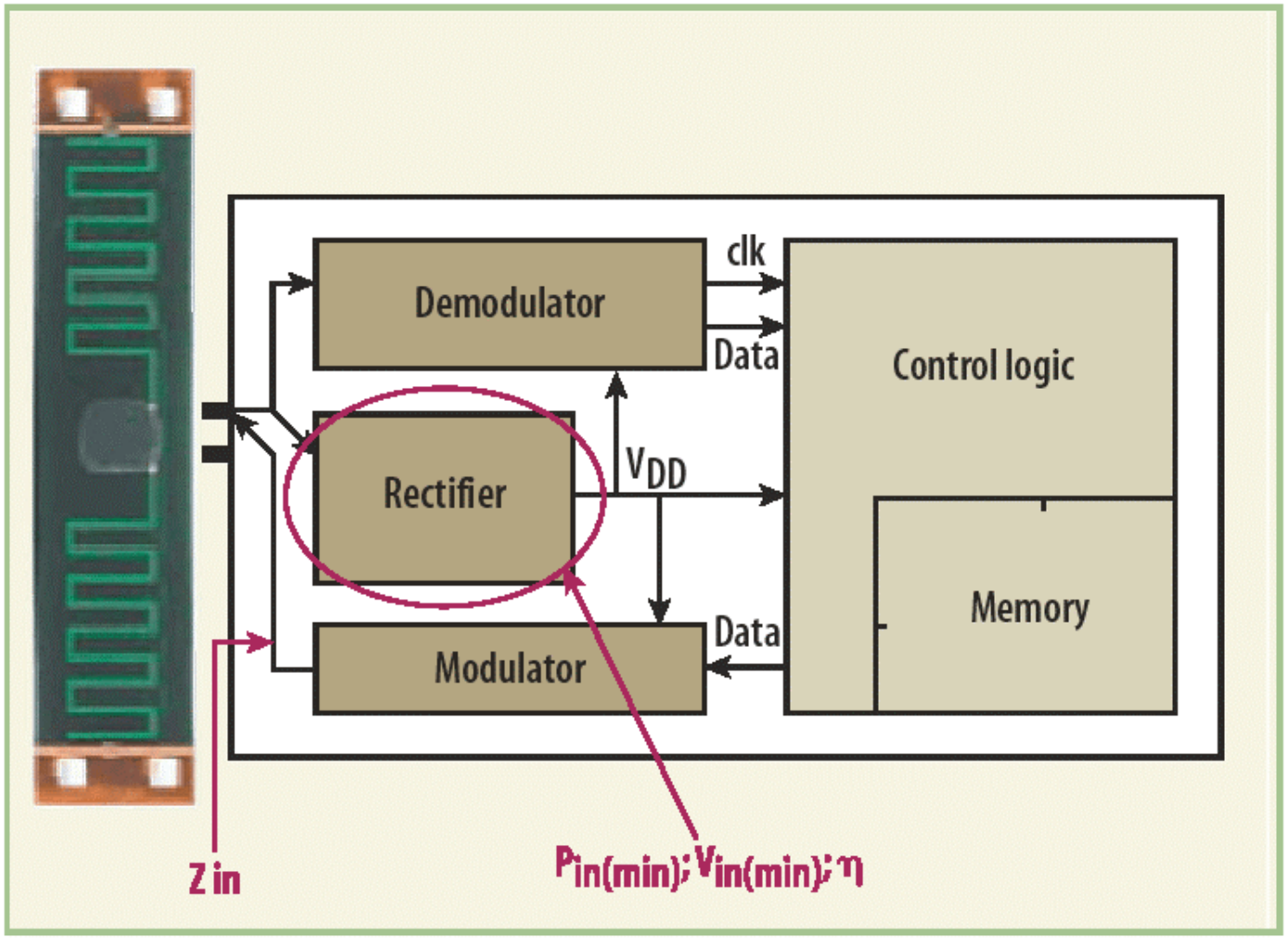
Standards

- ISO 10374: Freight Containers
- ISO 10536: Close Coupling Smart cards
- ISO 11784/5: Animal ID
- ISO 14443: Contactless Smartcards
- ISO 15693: Vicinity Cards
- ISO 18000: Item ID
  - 18000-2 (125 kHz), -3 (13.56 MHz), -4 (2.45 GHz), -6 (900 MHz), -7 (active tags, assets locating)
- EPCglobal (supply chain)

Design Constraints for UHF Passive Transponder

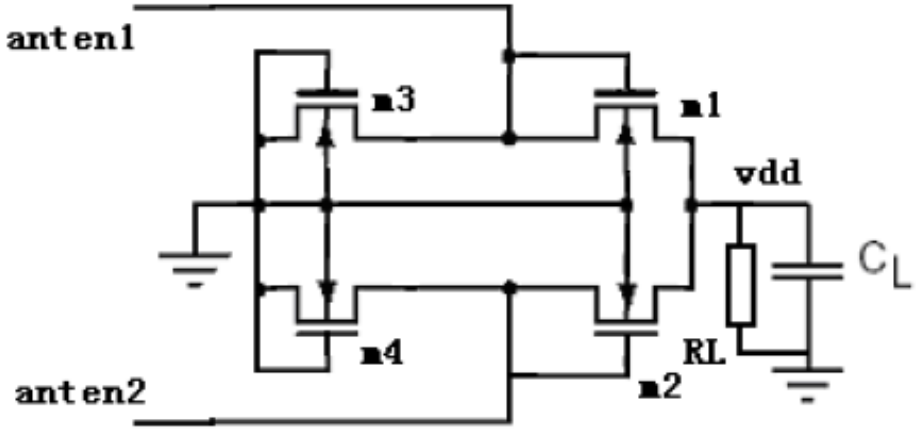
- Ultra low power (μW range)
  - Dynamic operating range
- Regulations: Allocated spectrum, bandwidth, radiated power
- Transponder complexities
- Technology
  - Schottky, Bi-CMOS, SOI, BDTMOS

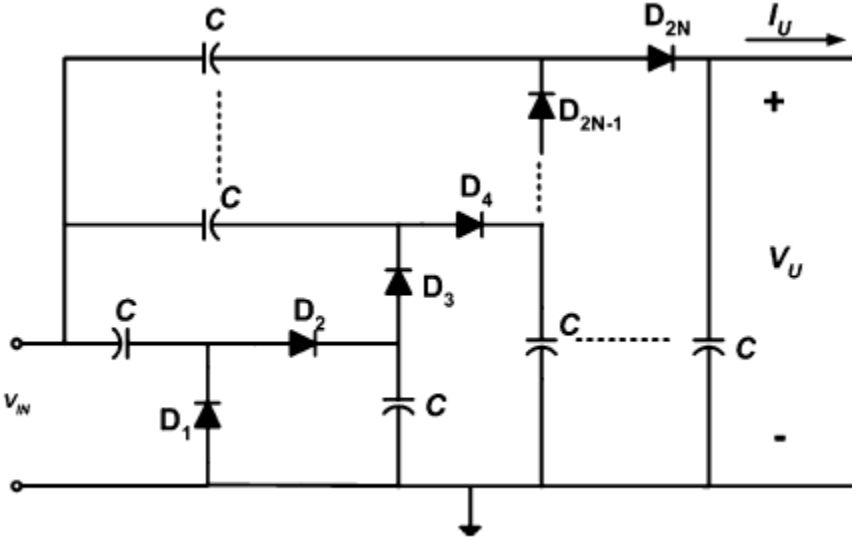
Transponder Building Blocks



Rectifier

- Convert the electromagnetic power to DC to supply the chip.





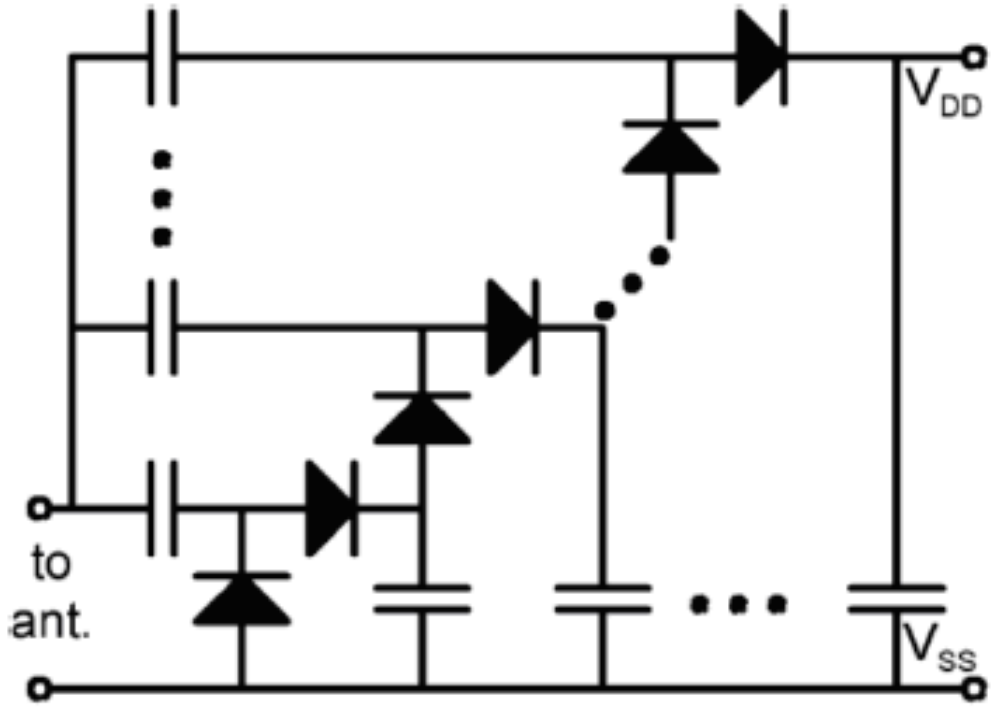
o **Full wave rectifier**

o**V input > 3 Vth**

o **Dickson Charge Pump Voltage Multiplier using Diode or low Vth device**

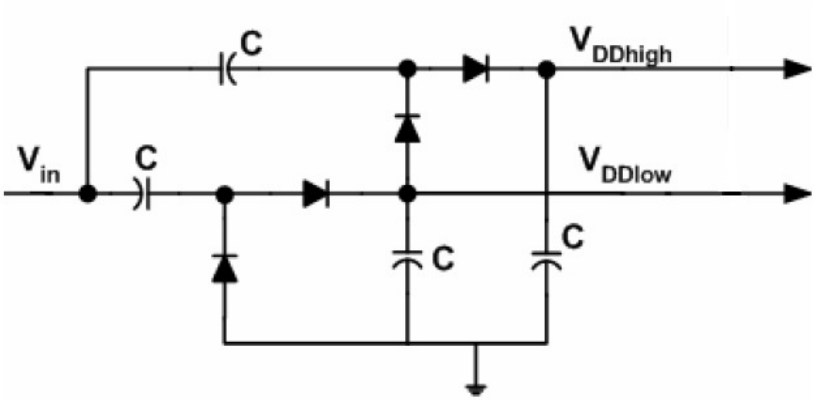
o **Mostly employ in EEPROM**

Rectifier – Implementation using Schottky Diodes

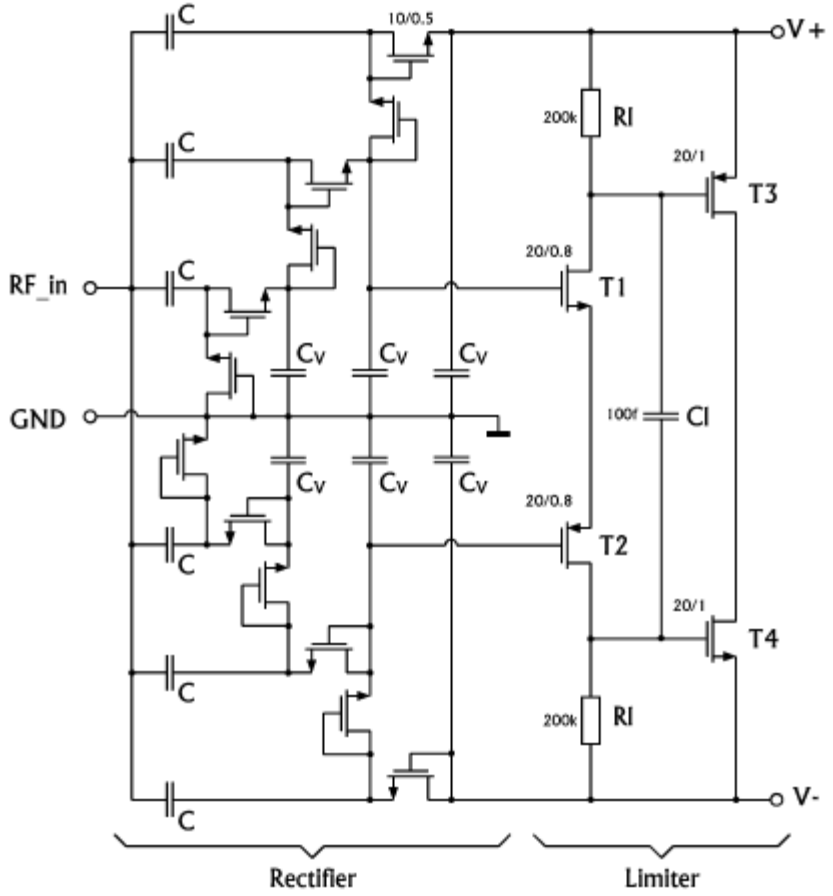


U Karthaus, M Fischer; "Fully integrated passive UHF RFID transponder IC with 16.7uW minimum RF input power"; IEEE J. Solid-State Circuits, Vol 38, Issue 10, Oct. 2003; pp: 1602-1608.

Implementation using BiCMOS and SOS



G. De Vita, G. Iannaccone; "Ultra Low Power RF Section of a Microwave Passive RFID Transponder in 0.35 um BiCMOS", IEEE ISCAS 2005, pp: 5075-5078-2990.

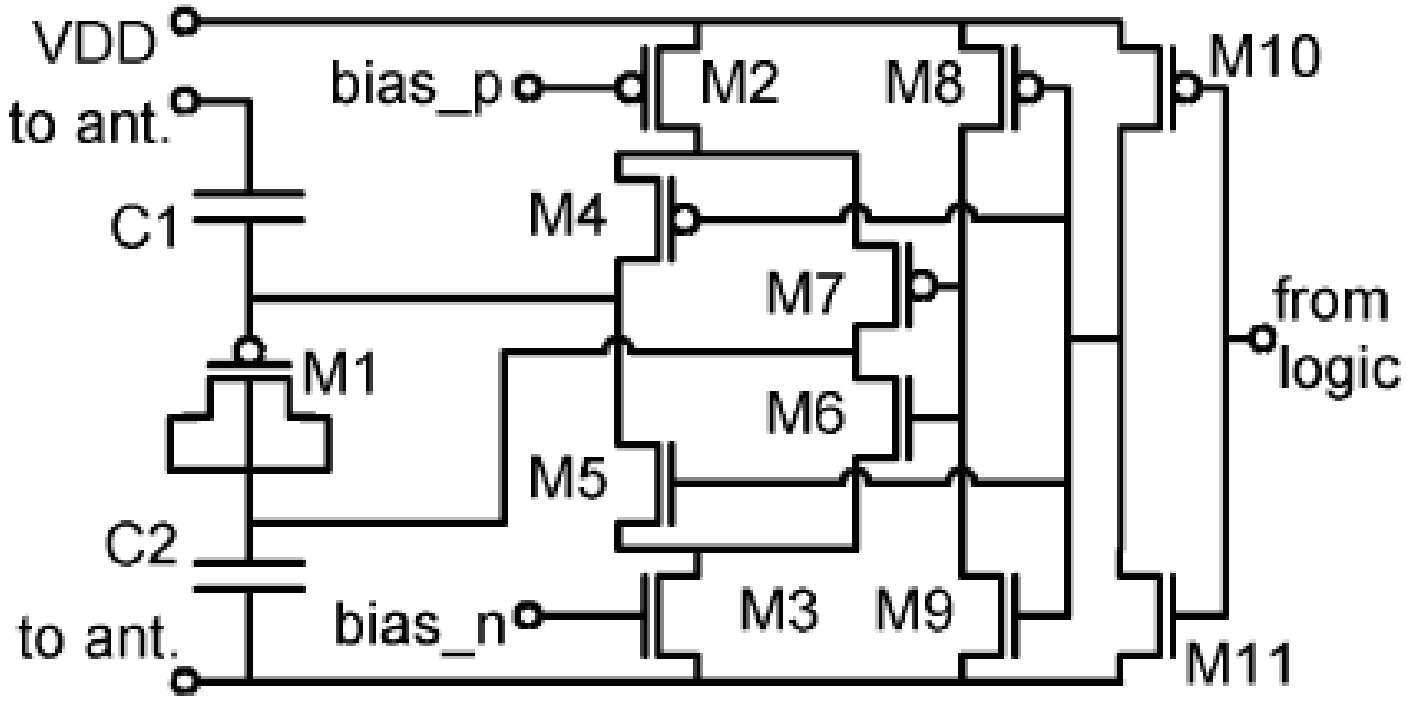


J.P. Curty, N. Joehl, C. Dehollain, M.J. Declercq, "Remotely powered addressable UHF RFID integrated system", IEEE Journal of Solid-State Circuits, Vol 40, Issue 11, Nov. 2005, pp:2193 – 2202.

Modulator

- Transmit data back to reader.
- Passive transponder use back-scattered radiation for the downlink
- Two modulation scheme: ASK and PSK
- ASK: Two impedance states are switch using pure resistance (preferred choice)
- PSK: Two impedance states are switch but using imaginary components

PSK Modulator



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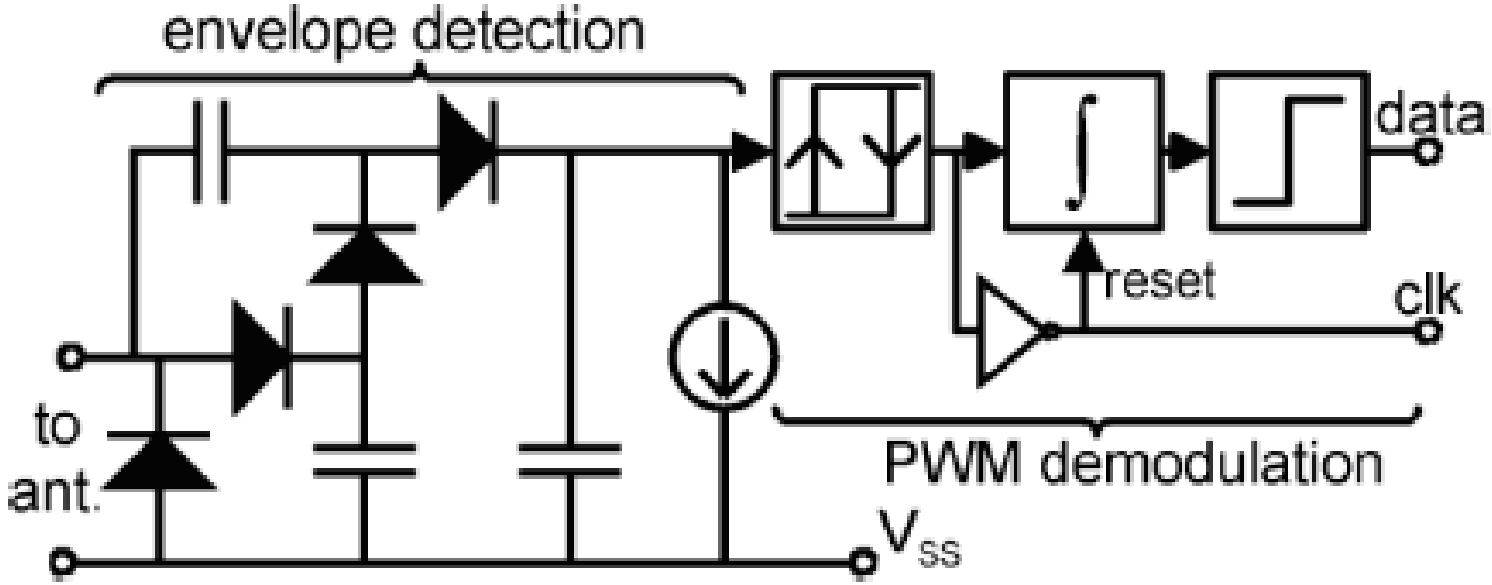
Demodulator

- Demodulate digital data embedded in the RF carriers
- Cost & area prohibit coherent/super heterodyne detection
- AM/ASK compatible schemes is the choice (DSB-ASK, SSB-ASK, PR-ASK).
- Decode using envelope detector, in some system using PWM
- PSK demodulation is not preferred – require oscillators, mixer and filter.

Common Implementation

- Multiple stages, each stage has their issues.
- 3 factors in edge detection design: low pass filter parameters, hysteresis level, comparator sensitivity



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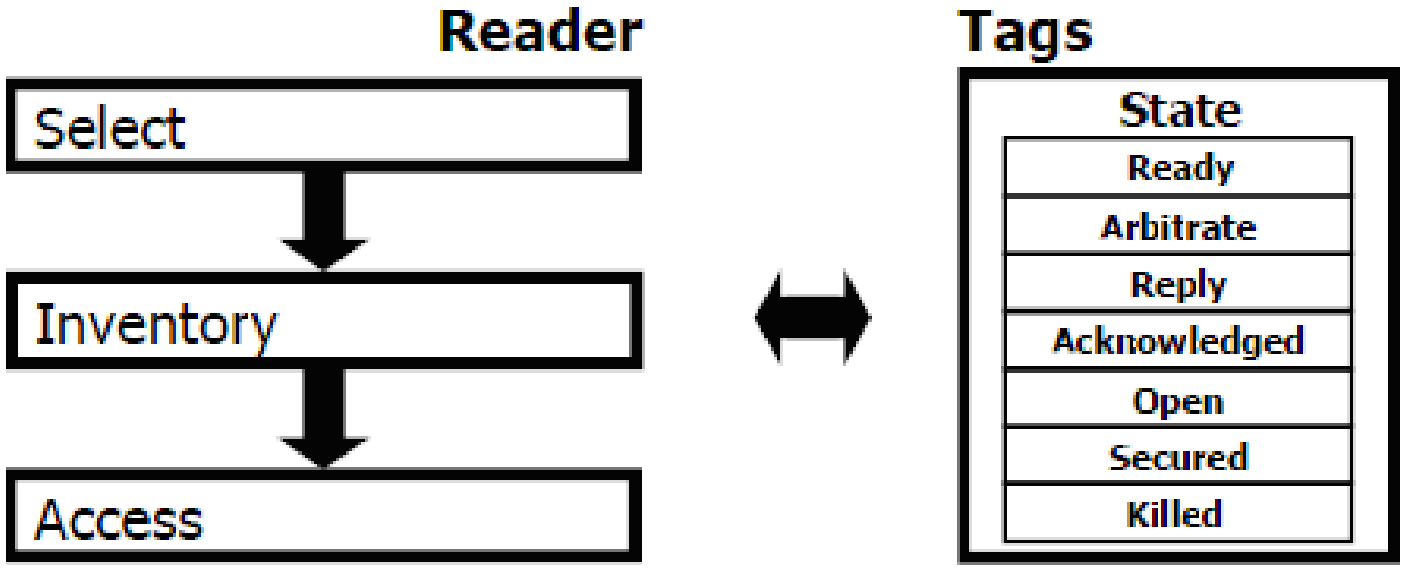
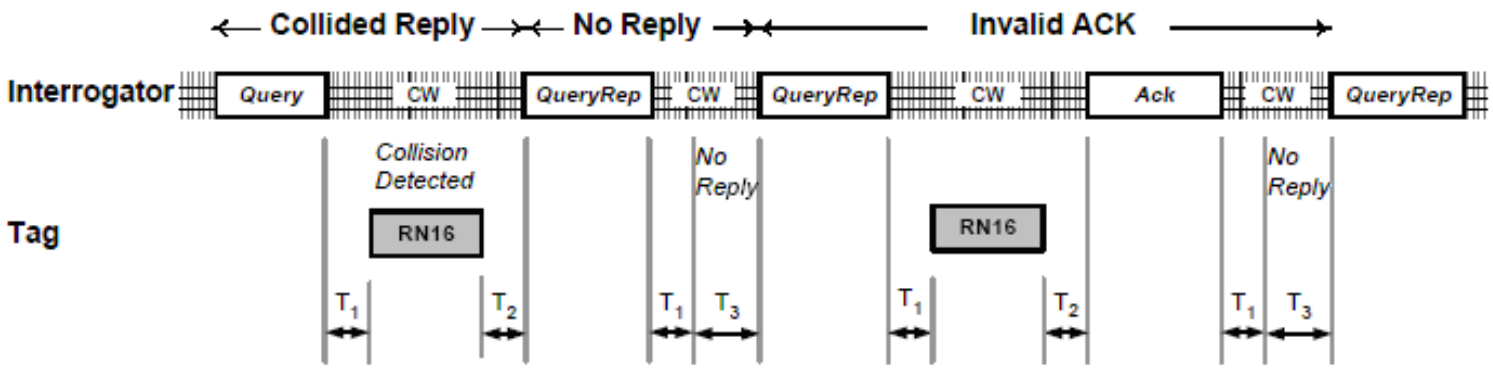
Digital Control

- Handle interrogating command, perform anti-collision protocols, data integrity check, memory read-write, output control and data flow.
- Specification-dependent.
- EPC Gen-2 has sophisticated command set – requiring complex digital core.

EPC-Gen 2 Basic Operations

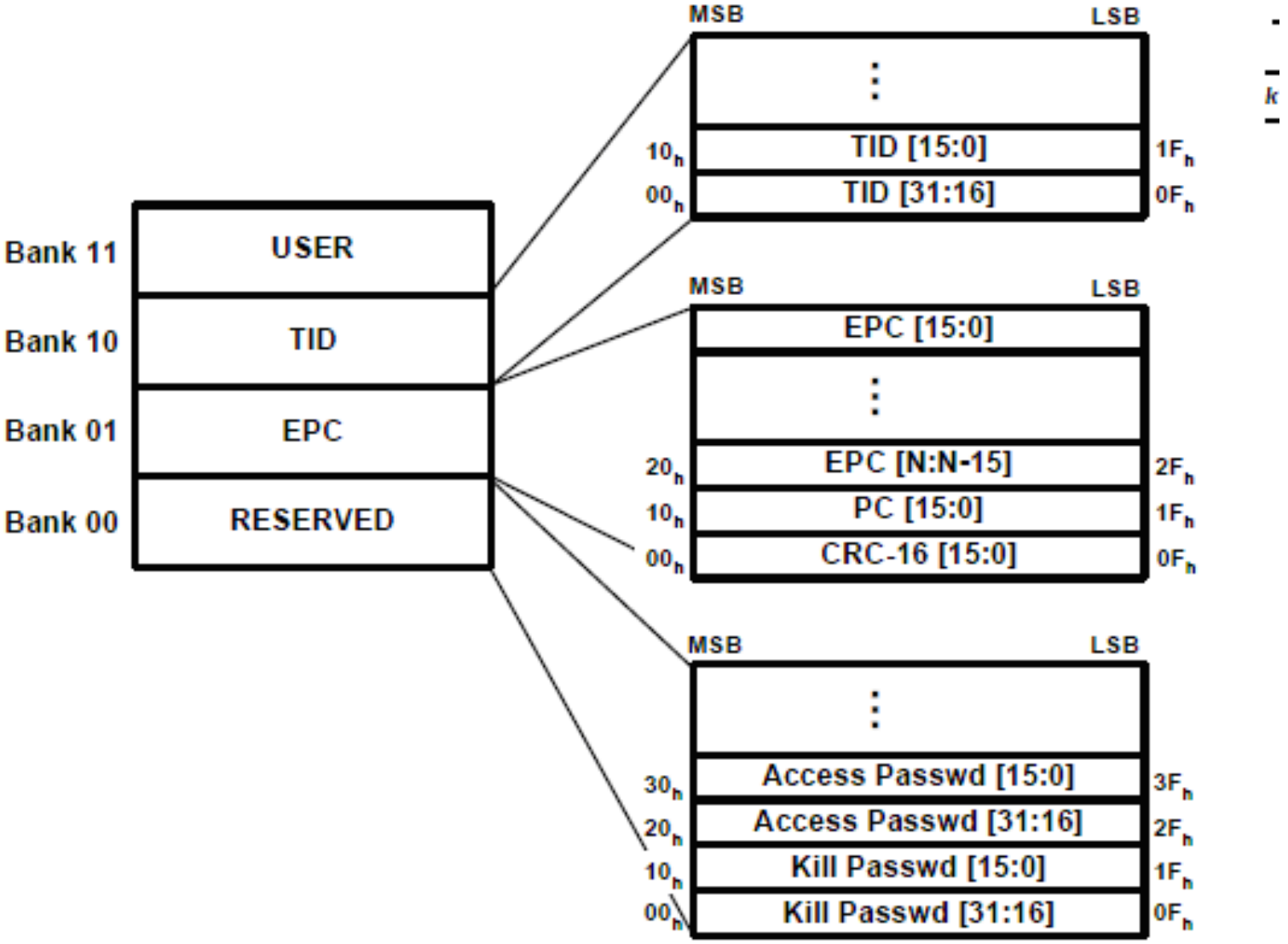


Tag operations and states



Collision Detection

Memory

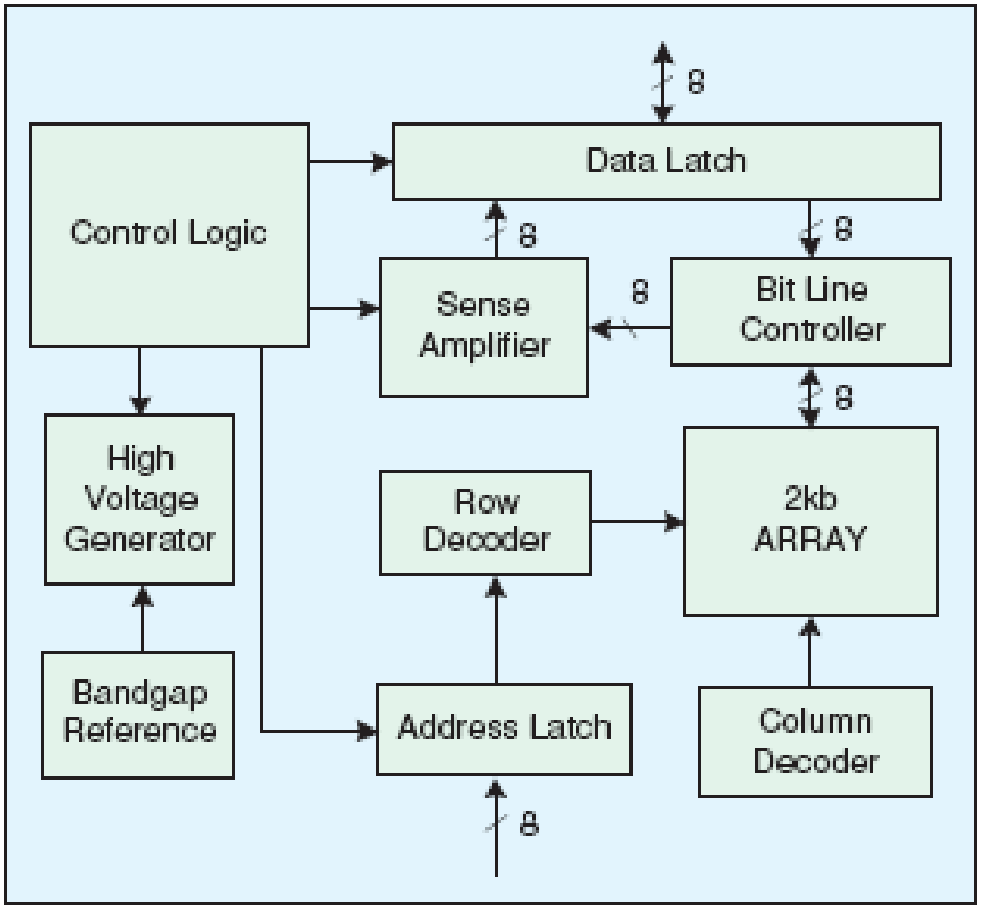


Logical Memory Map

Digital Block Implementation

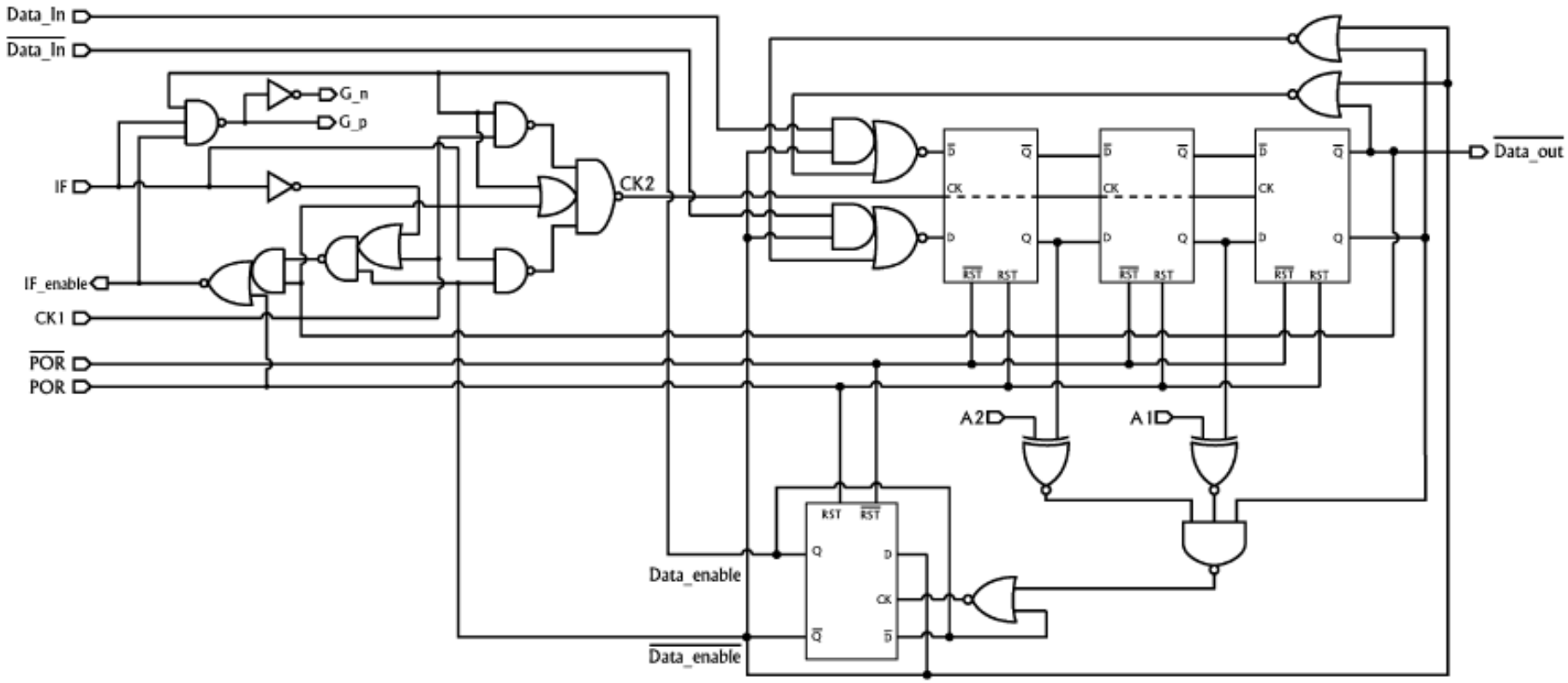
- The most power hungry module, besides rectifier
- 3 components: memory, FSM, I/O cells
- Usually standard cell libraries is used.
- Memory: EEPROM or flash.
- Digital control: Using hardwired (save space) or programming (flexible).

Embedded EEPROM



Liu et al, "New Design of EEPROM Memory for RFID Tag IC", IEEE Circuits and Devices Magazine, Nov-Dec 2006, pp:53-59.

Digital Control - Hardwired



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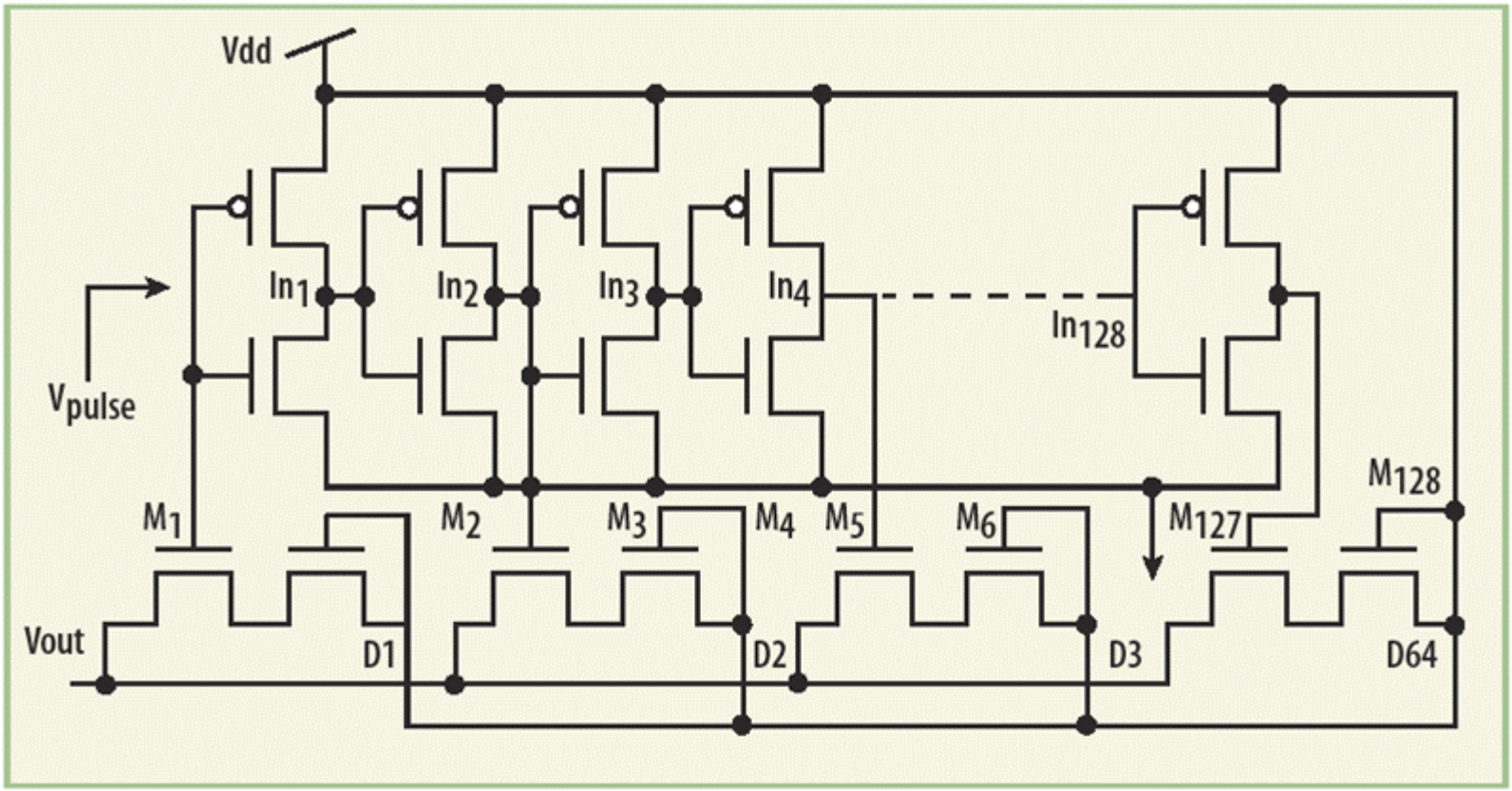
Novel Data Readout

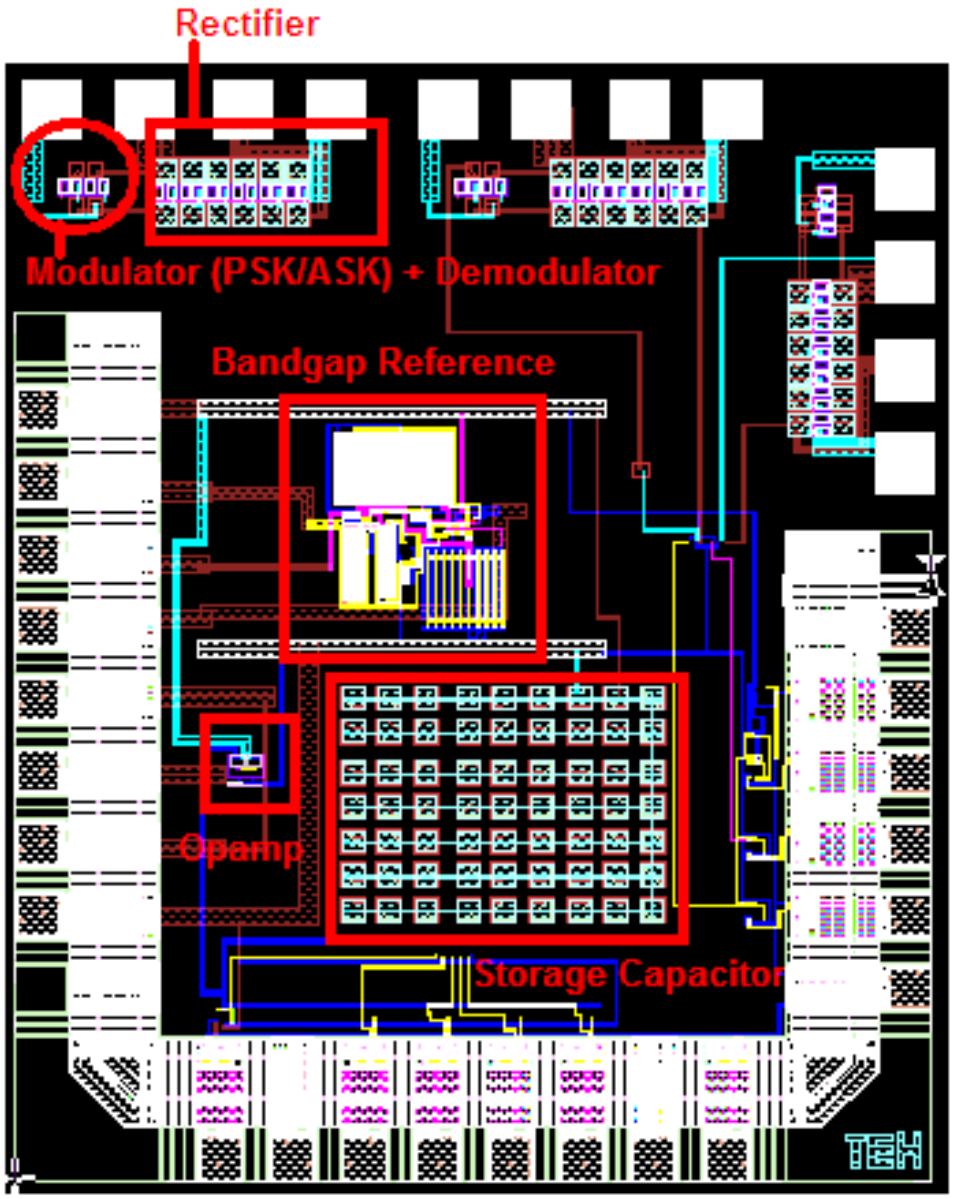


W. Jeon, J. Melngailis, R. W. Newcomb "Passive RFID Transponder with Read-Only Memory for Low Cost Fabrication", Proceedings of IEEE Systems-On-Chip Conference, September 2005, Herndon, USA.

Our Approach - DTMOS

- Power-hungry modules such as rectifier must be designed with low power requirement.
- Dynamic Threshold MOSFET (DTMOS) – Available in standard process.
- Operation: Low VTH in ON state yet in OFF state, the steep subthreshold slop of those non-scaled conventional MOSFETs is maintained to minimize reverse leakage current.
- It is done by varying VBS component in the body effect equation in ON and OFF state.

DTMOS-based Analog Front End



- **Collaboration work with Silterra.**
- **Silterra provided experimental DTMOST, support in device modeling and testing.**
- **Show low power performances.**

Conclusion

- RFID passive transponder is the most active research.
- Latest research trends:
  - Semi-passive transponder (Intel etc)
  - Organic-based transponder (Phillips)
- Other active areas:
  - A single chip RFID reader.
  - Antenna