ANVO-SYSTEMS DRESDEN

ADVANCED NON-VOLATILE SYSTEMS

Hibernate – Energy Saving for the Internet of Things

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1. Introduction

"Hibernation is a state of inactivity and metabolic depression in endotherms. Hibernation refers to a season of heterothermy that is characterized by low body temperature, slow breathing and heart rate, and low metabolic rate." **Source: http://en.wikipedia.org/wiki/Hibernation**

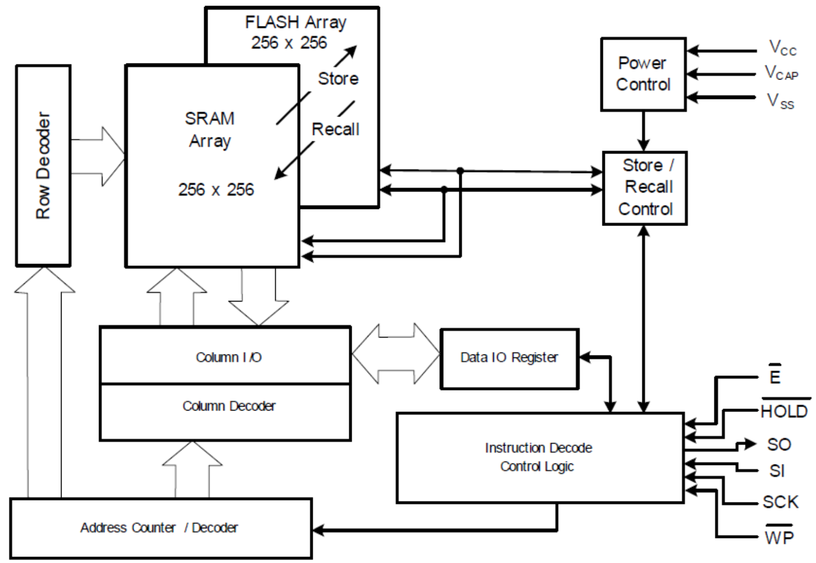
Example Bear:

- *Power Consumption in active state:*
  5000kcal/d – 8000kcal/d
  = 0.24kW – 0.38kW
- *Power Consumption in hibernation:*
  < 4000kcal/d
  = 0.19kW
  (Reduced power consumption by 40%)

Photo: REUTERS

2. nvSRAM Working Principle

- nvSRAM has two memory arrays an SRAM and a Flash array of the same size
- During normal operation the device acts like a regular SRAM
- Data automatically transferred from SRAM to Flash during brownout / when VCCX drops below a define threshold
- When brown-out occurs device is powered from a capacitor (VCAP) to allow the completion of data transfer
- Transfer from Flash to SRAM is executed during power up
- Data transfer can also be initiated by the user



Operating Modes:

– *Standby:* SRAM + Register access + supply voltage observation

– *nvOperation:* internal state machine executes data transfer between the two memories

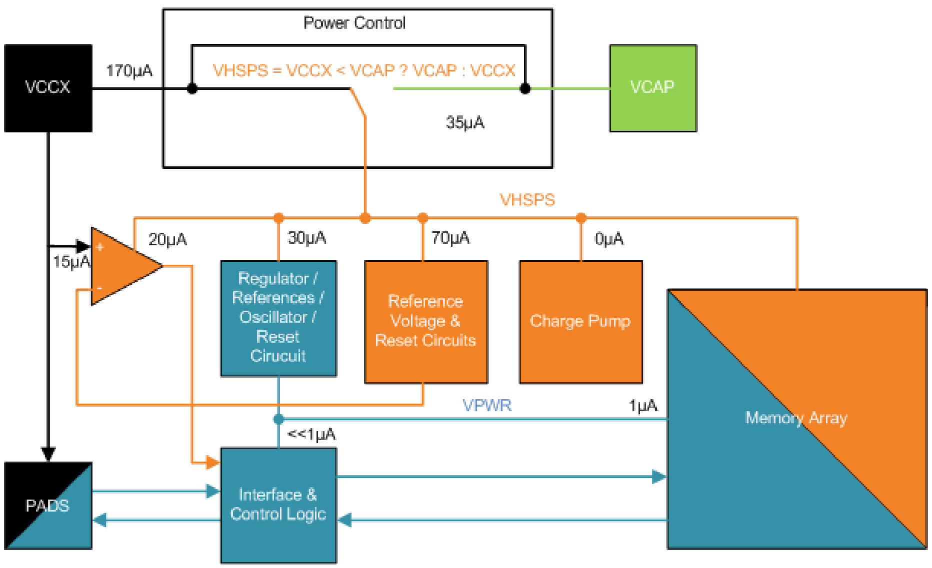
3. nvSRAM Power Analysis

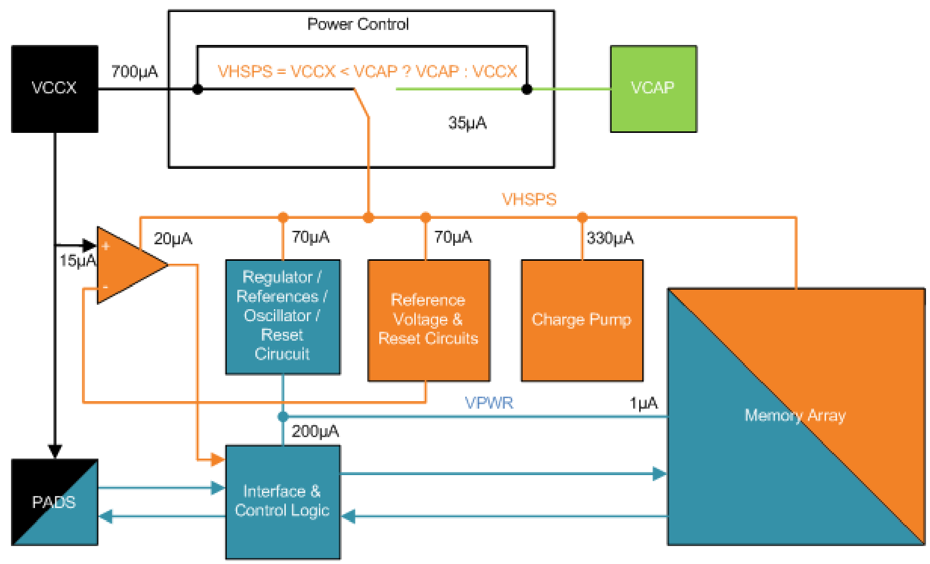
Standby:

- Current consumption:
  - IDLE: 170µA
  - SRAM: 170µA + 360µA/MHz

nvOperation:

- Current consumption
  - Store: 8ms @ 700µA
  - Recall: 500µs @ 700µA





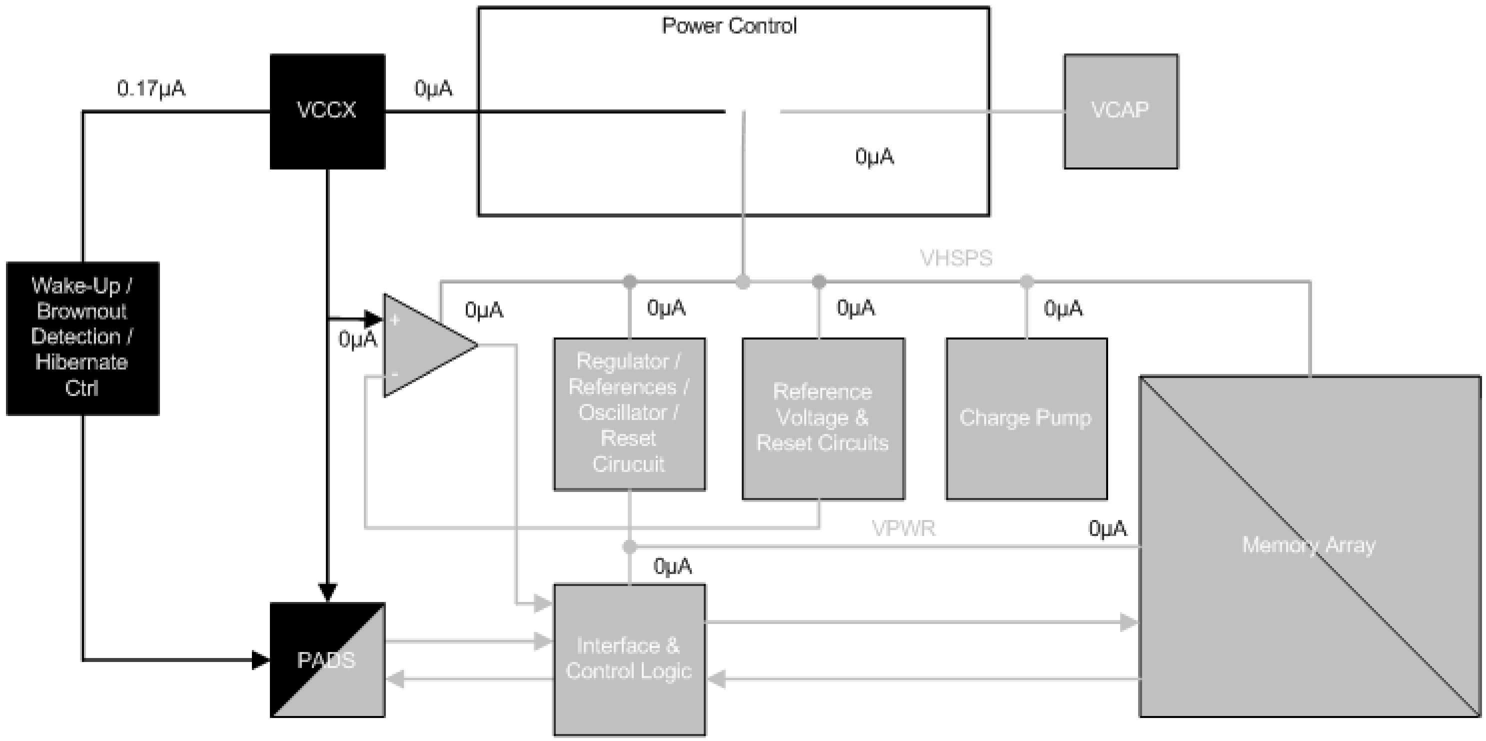
4. Requirements for Hibernate

- Minimal power consumption in Hibernate (<1µA)
- Quick Response time (enter & exit hibernate fast)
- Easy way to enter and leave hibernate
- Data security (data written to nvSRAM needs to be retained)

5. Hibernate Concept

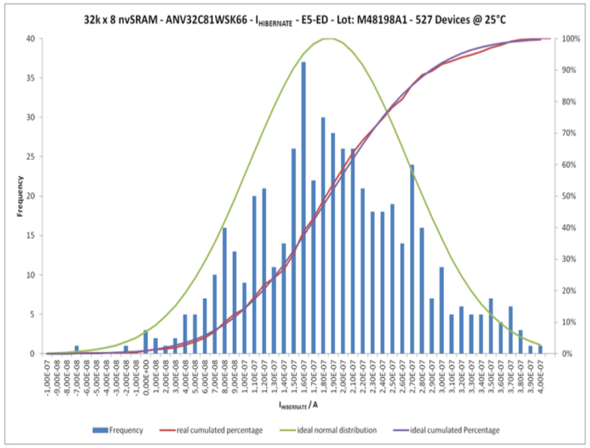
- Reduce current consumption by turning off the supply voltage for unused internal blocks
- Hibernate is entered by an Instruction (e.g SPI)
  - The following sequence is then executed:
    - If necessary, backup data from internal volatile SRAM to internal non-volatile Memory of the Device within 8 ms
    - Switch off all power domains
    - Monitor the /E Input for further operation
- Hibernate is left by changing the state of an IO Pin (/E)
  - Restore data from non-volatile memory within 500µs
- Supply Voltage monitoring during hibernate to detect brownouts
  - Guarantee returning to a known device state if supply voltage glitches

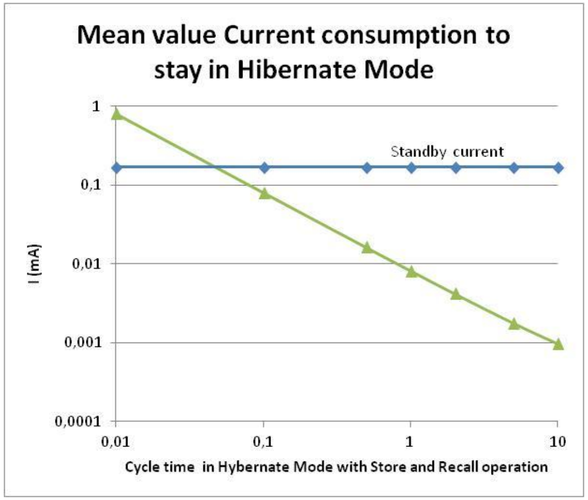
5. Hibernate Concept cont'd



6. Power Consumption

- Standby Mode current I_{ccsb} ~ 170µA
- Hibernate current I_{hib} ~ 170nA @ RT, Vcc=3V
- For Hibernate, in addition to the operation current, the currents for Store when entering Hibernate, and Recall when escaping from Hibernate have to be considered
- $I = I_{store} + I_{hib} + I_{recall} + I_{operation}$
  (700µA @ 8ms) + 170nA + (700µA @ 500µs) + 360µA/MHz @ t)
- Best application performance is a balance between the ratio of Hibernate mode and Operation, and wear out time (Endurance)





7. Hibernate in Battery systems

Best Application is a mix between the measurement period in Operation and Standby, and interruption by hibernate period

Application	Measurements	Endurance	Power	Operation time
Health monitoring	1 Measure per 15 minutes	28 Years	0,5mAh	19d w 230mAh
Energy monitoring	1 Measure Minute	~2 Years	0,03mAh	0,8 Year w 230mAh
Car (Tire Pressure)	5 x 1h unlimited per Day	547 Years	0,003mAh	8 Years w 230mAh
Car black box application	Permanent overwrite / power off + emergency store	>>20 Years	Car system	Car lifetime
ID Tag	100 Measures a Day	27 Years	0,04mAh	0,7 Years w 230mAh
Medical Applications (Pulsometer)	1 Measure per Month	32000 Years / lifelong	0,3µAh	94 Years w 230mAh
Balanced operation	22 Measures per Hour	~ 5Years	0,1mAh	~ 1 Year

8. Summary

- Standby current reduction in Hibernate is 99.9% compared to normal standby current
- By supplying the device from a common lithium battery the device can survive and keep data valid for more that 100 years and after wake up continue to work
- Different to the animal's Hibernation, the customer can define when the device wakes up as soon as they want to communicate. The data are then available again after a short period of some tens of microseconds
- A trade off has to be found between the time the device is active and the time it is sent into hibernate mode, as entering hibernate can cause one endurance cycle.

Thank You!

Questions?