Analysts Weigh In On Persistent Memory

Moderator:
Michael Oros, Executive Director, SNIA

Today's Presenters

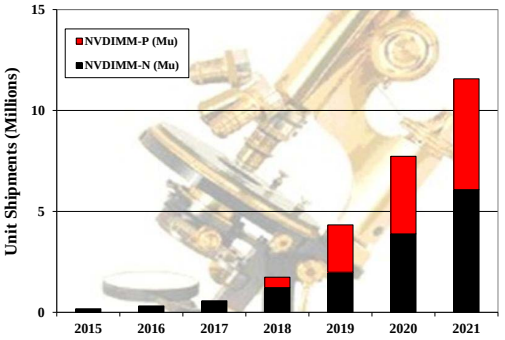
- Jim Handy and Tom Coughlin on
  How Persistent Memory Will Succeed
- Randy Kerns with
  An Analyst Perspective – IT Clients
- Gil Russell and Alan Niebel on
  Persistent Memory Dynamics

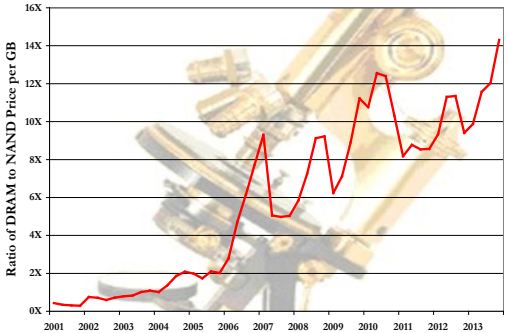
How Persistent Memory Will Succeed

Jim Handy, Objective Analysis & Tom Coughlin, Coughlin Associates

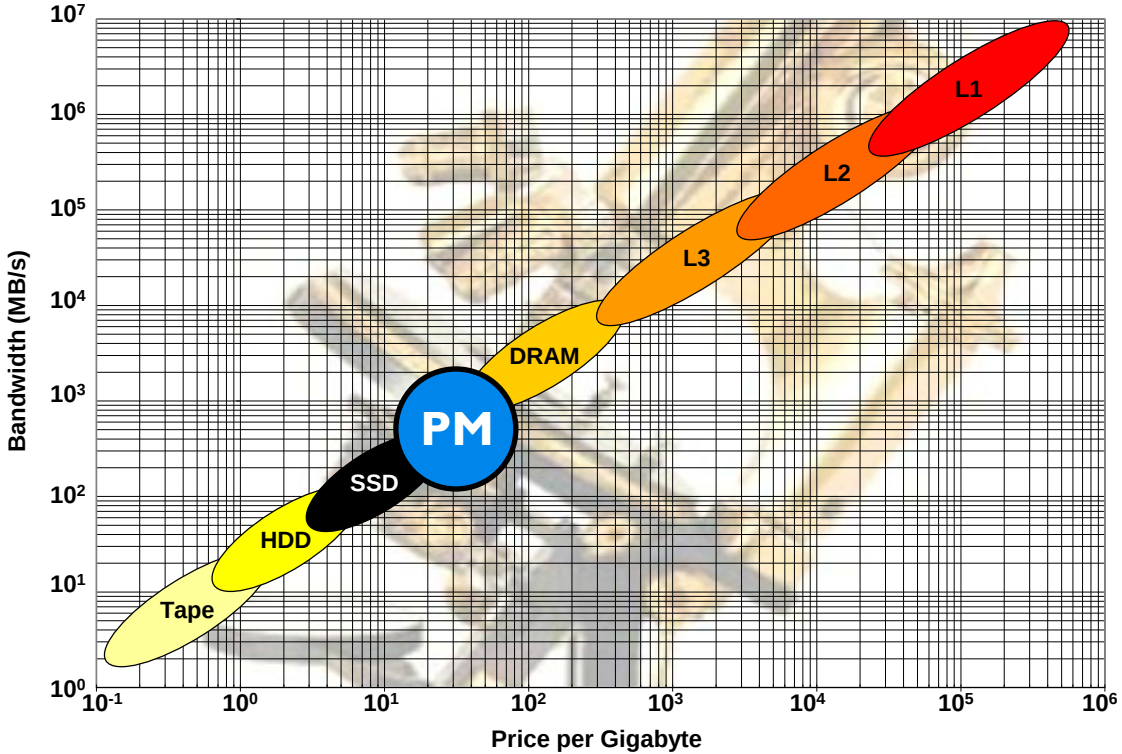
Who Wants Persistent Memory?

- If it's more costly than DRAM (NVDIMMs)
  - High-availability systems
  - Financial databases
  - Some hyperscale applications
- If it's cheaper than DRAM (XPoint, etc.)
  - Everybody will want it!
  - It's improves cost/performance
    - Persistence is of secondary importance
  - This will drive its success



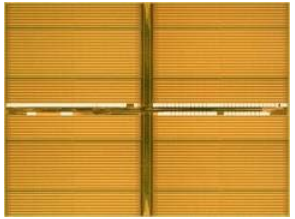


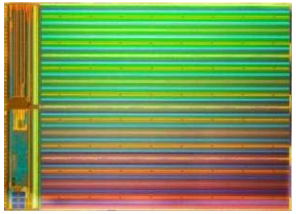
PM Must Fit Memory/Storage Hierarchy



Source: ***A Close Look at the Intel/Micron 3D XPoint Memory***, Objective Analysis 2015

A Lesson From Planar NAND



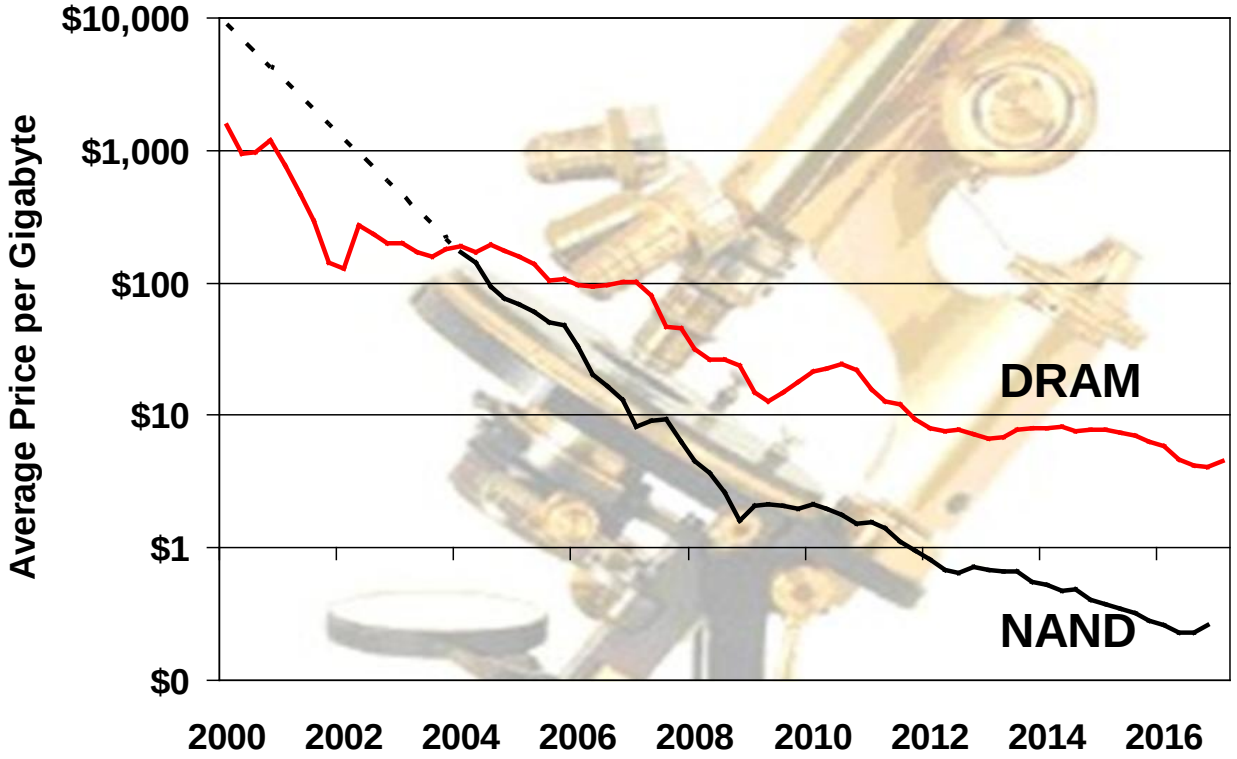


- SLC NAND vs. DRAM
  - Same die size
  - Same process geometry
  - Similar complexity
  - Twice as many bits
    - Should cost half as much

	DRAM	SLC NAND
Die Area	~100mm²	~100mm²
Process	44nm	44nm
Density	4Gb	8Gb

- Yet NAND prices were higher than DRAM's until 2004!
  - NAND wafer production reached 30% that of DRAM

Scale Drove NAND Cost Below DRAM



From: ***Hybrid Drives: How, Why, & When?***

A Lesson From 3D NAND

- Wholesale change is incredibly difficult!
  - 3D NAND is 3 years behind schedule
- Silicon itself is a challenge
  - New materials will prove even harder
- Revolutionary change is expensive!

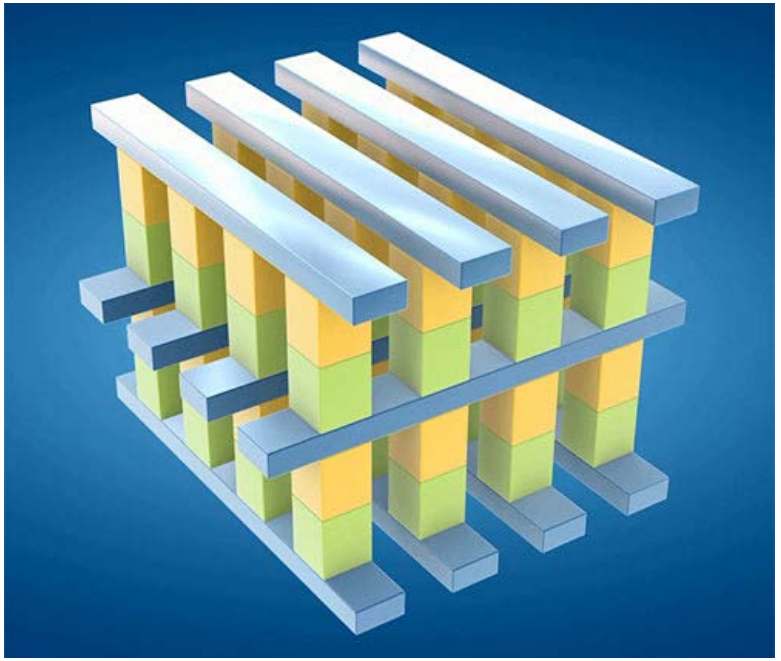
How Will PM Reach Ubiquity?

- It must approach DRAM volume
  - Wafer production within an order of magnitude
  - This will drive sub-DRAM prices
  - Only Intel is motivated to do this
- Persistence requires software support
  - SNIA & others are making this happen
- Other applications will use it for cost/performance
  - Initially persistence won't be used

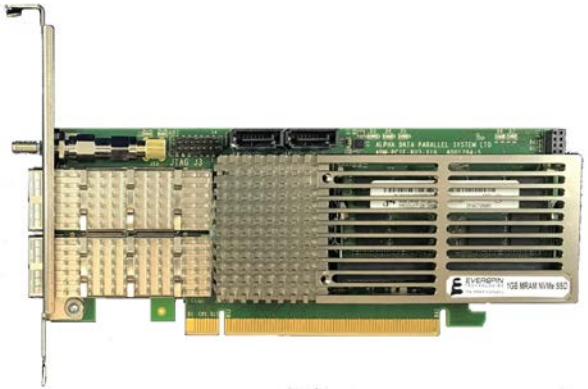
Phase Change Memory (PCM)

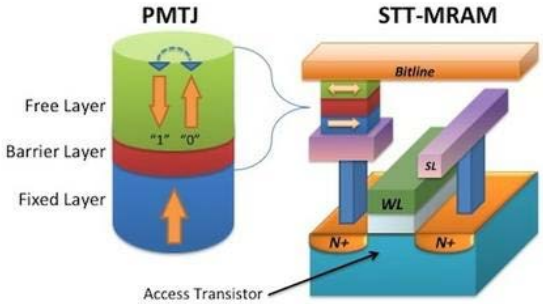
3D XPoint

- Optane NVMe SSDs available ($31.39 for 480 GB, $1.32/GB at Amazon)
- Intel plans to launch Optane DIMM in 2H 2018
- Micron hasn't announced a ship date for its QuantX Technology
- New Micron/Intel Fab JV focuses on 3D XPoint rather than 3D flash



Magnetic RAM (MRAM)



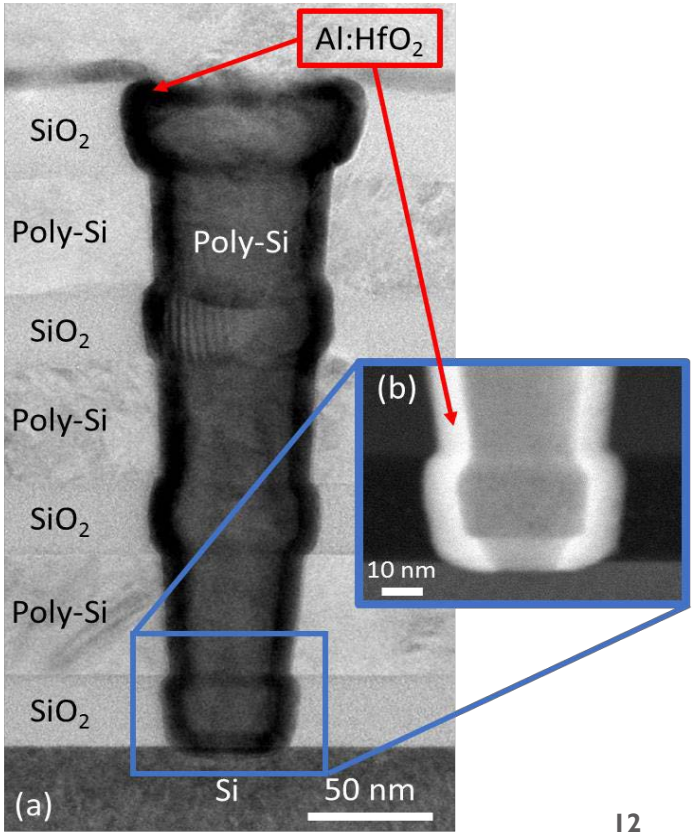


Michael Ofstedahl, Avalanche Tech, EE Times, 8/2014

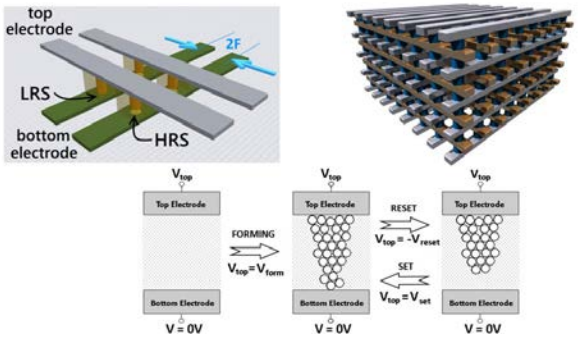
- Everspin received revenue for 256Mb STT-MRAM products in Q4—production ramp to follow
- Samples of 28nm 1 Gb chips from Everspin
- First 1-2 GB MRAM PCIe SSDs
- Global Foundries shipping MRAM for many embedded apps.
- Spin Transfer Tech. samples 80nm OST-MRAM chips
- Planned MRAM intros in 2018 by TSMC, Samsung, Tokyo Electron

Ferroelectric RAM (FRAM)

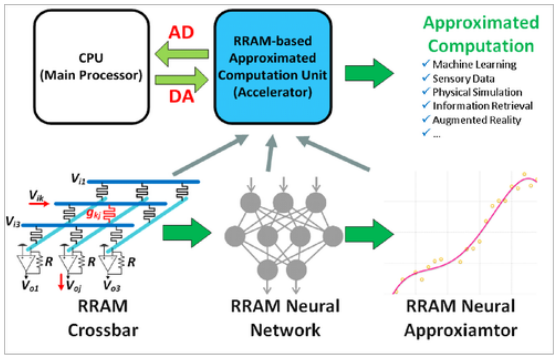
- Long history of niche products (caches, buffers), but has been difficult to scale
- IMEC's work with HfO_2 ferroelectric has put new life into FRAM
- Possible NAND-like devices possible



Resistive RAM (RRAM or ReRAM)



Shahar Kvatinsky, DevelopEx2015, 11/2015



https://nicsefc.ee.tsinghua.edu.cn/projects/emerging/neural/

Many varieties of ReRAM

- Fujitsu and Panasonic offer chip solutions
- Crossbar sampling 40nm ReRAM, made by China's SMIC
- TSMC and UMC put ReRAM on their roadmaps
- ReRAM still touted for storage class memories—e.g. HPE's "The Machine" although solutions still elusive
- Neuromorphic computing is touted as ReRAM application

Technology Comparison

Technology	FeRAM	MRAM	ReRAM	PCM	DRAM	NAND Flash
Nonvolatile	Yes	Yes	Yes	Yes	No	Yes
Endurance	10^{12}	10^{12}	10^{6}	10^{8}	10^{15}	10^{3}
Write Time	100ns	~10ns	~50ns	~75ns	10ns	10µs
Read Time	70ns	10ns	10ns	20ns	10ns	25µs
Power Consumption	Low	Medium/Low	Low	Medium	Very High	Very High
Cell Size (f^2)	15-20	6-12	6-12	1-4	6-10	4
Cost ($/Gb)	$10/Gb	$30-70/Gb	Currently High	$0.16/Gb	$0.6/Gb	$0.03/Gb

Upcoming Emerging Memory Report

- Covers all major solid state memory/storage technologies and companies
- Describes major solid-state memory driving applications and formats
- Projections for volatile and persistent memory (embedded and discrete)
- Projections for capital investments
- Finish target date is **May 2018**

Summary

- PM needs to fit the storage/memory hierarchy
- It won't all be used for its persistence
- There are many types of PM
- Different PM technologies will fill different market niches

THANK YOU

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Analyst Perspective – IT Clients

Randy Kerns, Evaluator Group

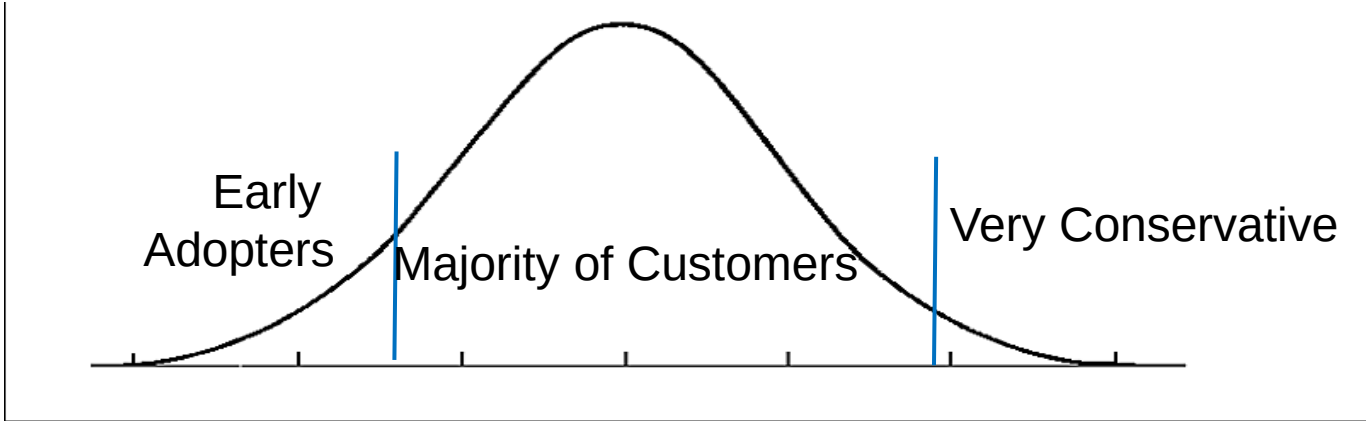
Persistent Memory

- Enterprise customers perception in general
  - Part of transition away from electro-mechanical primary storage
  - Transformational for storing information
    - Performance
    - Longevity
      - Change in technology updating
      - Change in plans for migrating data
      - Amortization schedules

- Enterprise customers biggest issue
  - Quantification of value – has not been expressed well
    - Vendor and reseller sales and marketing still using a measure of data at rest - $/GB
    - Real value is how much work can get done
    - How to express to enterprise customers?
    - How to help them justify purchases?
  - Not a simple answer

- Data at rest economics – if $/GB is your measure
  - Just use tape
  - Lowest cost of media acquisition

- Enterprise customer perception of use of PM beyond Flash in storage systems
  - Expect as cache in storage – rather than large DRAM
  - Economics discussion – what is the value – cost vs performance
  - Usage beyond that – beyond majority of customer's horizons



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Persistent Memory Dynamics

GIL RUSSELL & ALAN NIEBEL - WEBFEET RESEARCH, INC.

Persistent Memory - Background

- Technology is "*thought*" to be most relevant to the In-Memory Computing and Cognitive Computing Market Segments (Fat Memory Segment)
- Storage Class Memory (SCM) 2008
  - SCM fiction based on cost per bit;

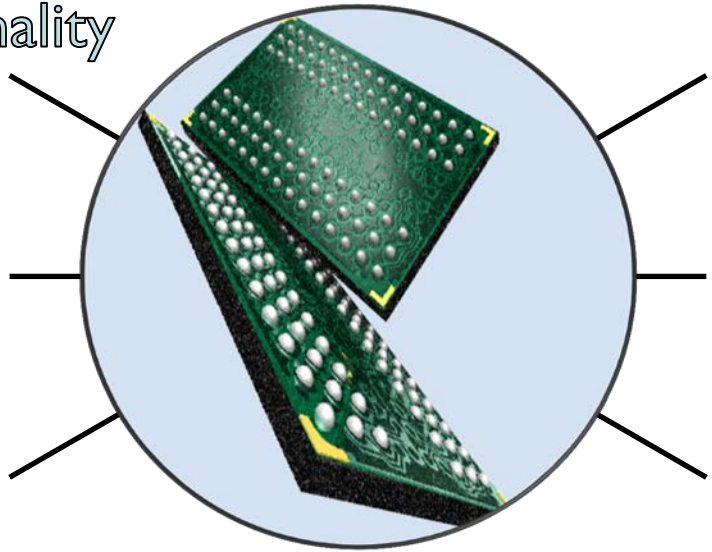
  ".., ultimately such a storage-class memory (SCM) device could potentially replace magnetic hard-disk drives (HDDs) in enterprise storage server systems." – G.W. Burr et al, IBM 2008
- Rapid growth of NAND-Flash SSDs delayed market demand for Persistent Memory
- Then came IMC and Cognitive Computing
  - Byte addressability added to SCM
  - Presto! "***Persistent Memory!***"
  - Now called **NVRAM** when applied as a DRAM replacement

Non-Volatile RAM - NVRAM

DDR4 Functionality

Low latency
CL ≤ 13.5

Higher Density
Roadmaps
8 – 32 Layers



Persistence
≤ 10 years

Endurance
10^{11} - 10^{12} PE

Zero Refresh
(or very low overhead)

NVRAM Memory Transition

- DRAM has had a good run (Toshiba 1966)
- CPU performance gains limited by memory size (and cost)
  - DRAM density has not improved fast enough to fill the need
  - NVRAM fulfills density improvements (long term roadmap)
    - XY Square Geometry shrink density improvements
    - Multi Layer introductions provide linear improvements
    - Substantial power reduction
    - Opens market for MLC, TLC, and QLC type devices

NVRAM – Market Synopsis

- NVRAM competitive product positioning
  - Dependent on System Level Context
  - Price competitive with XPoint in a $71B Market?
  - Competitive performance comparisons?
  - Secondary supply suggests an open standard
- 3D XPoint will dominate market beginning in the 2H ’18
  - Introduction of competing NVRAM products expected to begin ramp in 2H ’19
- NVRAM replacing DRAM & NAND in mobile space in 2020

Persistent Memory Trends

- Persistent Memory coupled with Cognitive Computing Architectures enables:
  - Very Large Persistent Memory Arrays
  - AI Algorithms to reduce compute times (hours to minutes)
- Processor In Memory – PIM (or Bottleneck Be Gone)
  - Beginning of Data Execution in Memory
  - Data motion progresses from inches to microns and data rates from 1TB/s to 10's of PB/s
- Heteroassociative memory
  - The human brain is fully associative
  - One item is able to recall a totally different item

NVRAM Revenue

Smartphone	2016	2017	2018	2019	2020	2021	2022
Apple iOS Munits	234	252	269	277	290	306	322
NVRAM Attachment Rate				5%	35%	75%	85%
Apple iOS NVRAM units				14	101	229	274
Smart Phone DRAM $M	4,524	12,707	15,986	19,321	21,142	21,867	22,509
Smart Phone NAND	12,524	17,651	16,277	18,786	21,202	22,156	25,817
iPhone DRAM	733	2,033	2,446	2,879	3,044	3,171	3,331
iPhone NAND	2,029	2,824	2,490	2,799	3,053	3,213	3,821
iPhone DRAM savings NVRAM $M				144	1,066	2,378	2,832

NVDIMM	2016	2017	2018	2019	2020	2021	2022
Total - MLC NAND		1	1	0	0	0	0
Total - 3D NAND		1	4	8	12	11	12
Total - NVRAM		0	0	0	79	750	2,029
Total - XPoint		0	171	1,369	3,596	4,301	3,127
Total RAM $M		2	175	1,377	3,688	5,061	5,168
Total - NVRAM $M		0	0	144	1,145	3,128	4,860

Thank You

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