

White Paper on Adesto Technologies' *CBRAM*

Capitalizing on the Market Transition

The abandonment of the DRAM model trend epitomizes how OEMs are identifying and finding new opportunities for memory technologies within an expanding set of performance attributes for non-volatile memory technologies.

Table of Contents

Capitalizing on the Market Transition	i
OEM Trends Enhancing Value of Emerging Memory Technologies.....	1
Traditional Computing Architecture	1
The Mobile Market	2
Memory Device Requirements for Mobile Applications	5
About Convergent Semiconductors:.....	6
About the Authors: Bob Merritt and Sherry L. Garber	6

Figures and Tables

Figure 1. Traditional Computing Architecture and Memory Hierarchy	2
Figure 2. Explosive Growth in Mobile Data Applications.....	3
Table 1. Projected DRAM Units per Mobile Device	4
Table 2. Mobile Memory Unit Requirements	5

OEM Trends Enhancing Value of Emerging Memory Technologies

During the last five years a remarkable shift has occurred in both the usage and the value of semiconductor memory technologies. These changes are the result of a transition in consumer demand to mobile products that stimulated the interest in and the need for new memory technologies.

This significant usage shift to mobile multi-media applications has now replaced desktop data processing as the primary target for many new semiconductor technologies. There is every indication that the utilization of nonvolatile memory technologies will increase in these applications due to the requirement to lower the total power consumption, reduce the weight and size of the battery source, and to extend the time between refreshing the energy source of the device.

One of the most dramatic changes in the support of computing applications has been the replacement of DRAM by non-volatile memory in some computing applications. This replacement, brought about by OEMs motivated to reduce the memory-related power consumption in some applications, has been generally categorized as a continuation of the growth of NAND.

This abandonment of the DRAM model trend epitomizes how OEM's are identifying and finding new opportunities for memory technologies within an expanding set of performance attributes for non-volatile memory technologies.

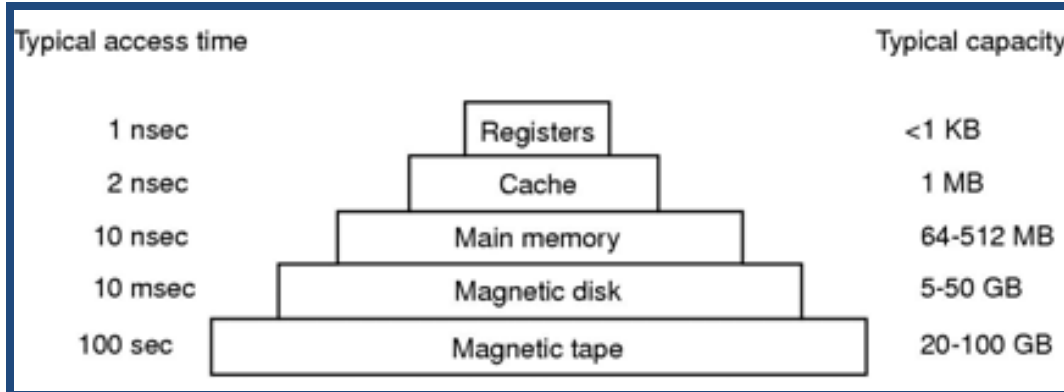
The distinction acknowledges a major split in the traditionally monolithic DRAM product base, and provides an opportunity in the renewed interest in other types of high performance non-volatile memory technologies. This split in the traditional DRAM product base becomes more apparent with the memory interface.

Traditional Computing Architecture

Due to the almost singular utilization of DRAM as a commodity product in support of large computing architectures, a characteristic of previous DRAM generations was the focus on a single high-volume interface. This architecture has remained in vogue with DRAM fulfilling the role of "main memory," with an industry-standard interface in other high volume applications. Interface evolution generally occurred at the transition to the next-higher DRAM density, and market pressures kept the technology confined within the supply/demand boundaries of a commodity.

This architecture, a remnant of the 1970's along with disco and platform shoes, is depicted in the following figure.

Figure 1. Traditional Computing Architecture and Memory Hierarchy



Source: Convergent Semiconductors, LLC, and IBM

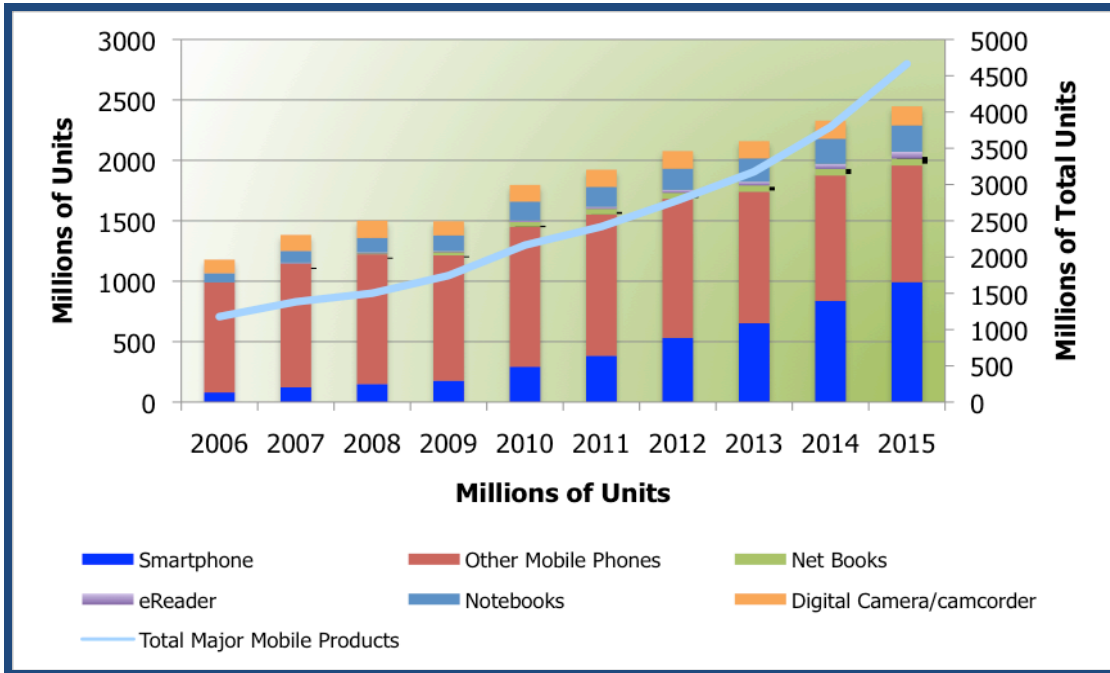
These previous constraints on the value of memory technologies are rapidly changing, with the emergence of NAND Enterprise SSD as the leading example of the ability of OEMs to modify long-standing architectural structures in order to accommodate new and enhanced value propositions.

The Mobile Market

The magnitude and extent of these industry-changing product trends provide the market entry opportunities for Adesto's technology, with the first real test to be found in mobile low-power applications.

The following chart illustrates the explosive growth of this market segment, and this is a conservative view. Convergent believes the worldwide economic recovery, in concert with the development of new markets in emerging nations, will drive this growth even higher.

Figure 2. Explosive Growth in Mobile Data Applications



Source: Convergent Semiconductors 2011

Looking at the highest growth mobile products—Smartphone, Tablet, eReader, and other similar Mobile products, the 6-year CAGR is 39%. These product families are part of the mobile transition opportunity—as the overall semiconductor market struggled in 2009, these products grew by 138%. In 2011, Convergent Semiconductors projected growth to exceed 33% and maintain growth greater than 35% each year through 2016.

This device growth does not include the growth of revenue generated by the sale of software applications that accompany each of these products and make them attractive for all investors.

At first glance, the memory content of the mobile devices is relatively low compared to applications that would generally be categorized as data-oriented computational devices (PCs). However, this is the innovative growth segment where both the volume of existing and introduction of new mobile devices are growing at a double-digit rate.

Table 1. Projected DRAM Units per Mobile Device

M-units:	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Smartphone	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Other Mobile Phones	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Tablet	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
eReader	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Digital Camera /Camcorder	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Other Mobile Products	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Net Books	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.6	1.6
Notebooks	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0

Source: Convergent Semiconductors, LLC, 2011

The point to consider is that while the mobile applications are the fastest-growing segment of DRAM applications, mobile applications are not driven by the existing DRAM technology alone. Volatile DRAM cell structures are not a natural fit with mobile applications, but have been included due to their bit-oriented data structure. Of particular importance is that the value proposition of the ideal memory technology would be significantly enhanced with a data refresh cycle on the order of days and weeks, rather than milliseconds.

This is a window of transition from DRAM to non-volatile that fills a need in the mobile device arena. Additionally, this is an interface that will be industry-approved, but not controlled by a single vendor as in the glory days of the PC. The value of memory subsystems is increased by the transition to mobile system design by OEMs. A broad base of mobile applications will drive the technology, and its designers will implement memory subsystems to differentiate product by region, price point and performance.

This shift in emphasis is already reflected in the discussions regarding the next generation of DRAM interfaces for high-performance computing devices. The traditional single computing interface has been replaced by a lower-power interface available now, followed by the all-important mainstream product in the next generation of DRAM.

Memory Device Requirements for Mobile Applications

The flexibility of Adesto’s memory technology easily fulfills low-power requirements for existing applications, and we anticipate a rapid acceptance of Adesto’s technology in these applications. Current forecasts of these applications relative to the general forecast of memory technologies are shown in the following table.

Table 2. Mobile Memory Unit Requirements

M-units	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Memory Units for Mobile Products	1,393	1,558	1,791	2,235	2,516	2,902	3,332	3,982	4,894	6,346
% of Combined DRAM/NAND Units	9.4%	9.3%	10.6%	10.8%	11.1%	11.1%	11.1%	11.3%	12.8%	14.9%
% of Total DRAM Units	11.4%	11.6%	13.7%	14.3%	15.2%	15.9%	16.7%	17.3%	21.3%	27.7%

Source: Convergent Semiconductors 2011

We conclude that Adesto’s technology provides a real opportunity to extend DRAM-like performance into the growing market for low-power mobile applications. Based on the established market support for low-power DRAM products, as well as the growing presence of low-power memory technologies for mobile applications, we believe that the potential of its technology will allow Adesto to reasonably attain up to 20% of existing DRAM forecasts.

About Convergent Semiconductors:

Clarifying the Vision of Change - Identifying the Complexities of Transition

As the target applications for new semiconductor technologies change, the value proposition of the critical technologies changes as well. Tactical issues become heavily influenced by asset allocation strategies, and strategic issues become dominated by design, test, and packaging infrastructure considerations. Convergent Semiconductors specializes in illuminating the impact of broader semiconductor strategies and significant industry-wide changes before those transitions occur.

About the Authors: Bob Merritt and Sherry L. Garber

Mr. Merritt and Ms. Garber are memory specialists of global product/technology strategies and issues and a proven track record of published accurate trend analysis and forecast. Mr. Merritt is an authority in the non-volatile memory new technologies arena. Both have extensive semiconductor Industry experience in memory cycle/infrastructure experience gained by over 40 years of semiconductor participation including market research, sales, product marketing, operations support, and system R&D program management for a range of global companies. They are published and quoted in all the major semiconductor industry publications and international electronics, financial and technical publications.

Market/Technology Reports include: DRAM, NAND Flash, NOR Flash, ReRAM, PCM, CBRAM, FRAM, MRAM, Spin Torque Transfer (STT) Magnetic RAM, Thermally Assisted MRAM, Hybrid Memory Devices, Hybrid Packaging, Multi-Die Packages, System-Level Test and Design of Multi-Die Configurations, System in Package (SiP), Battery and other power sources, and trends in OEM product strategies and system design.

The report was specifically prepared for Adesto Technologies.