
2 THE DRAM MARKET

1995 FACTS

Market Size: \$40,833 million

Shipments: 2,477 million

ASP: \$16.48

1996 FORECAST

Market Size: \$29,180 million

Shipments: 2,660 million

ASP: \$10.97

Overview

Dynamic random access memory, or DRAM, is the main memory component of most computers and many electronic systems. DRAMs are among the “glamour” products in the IC industry, yet are “workhorse” devices as well. From the simplest to the most sophisticated systems, DRAMs are often on board.

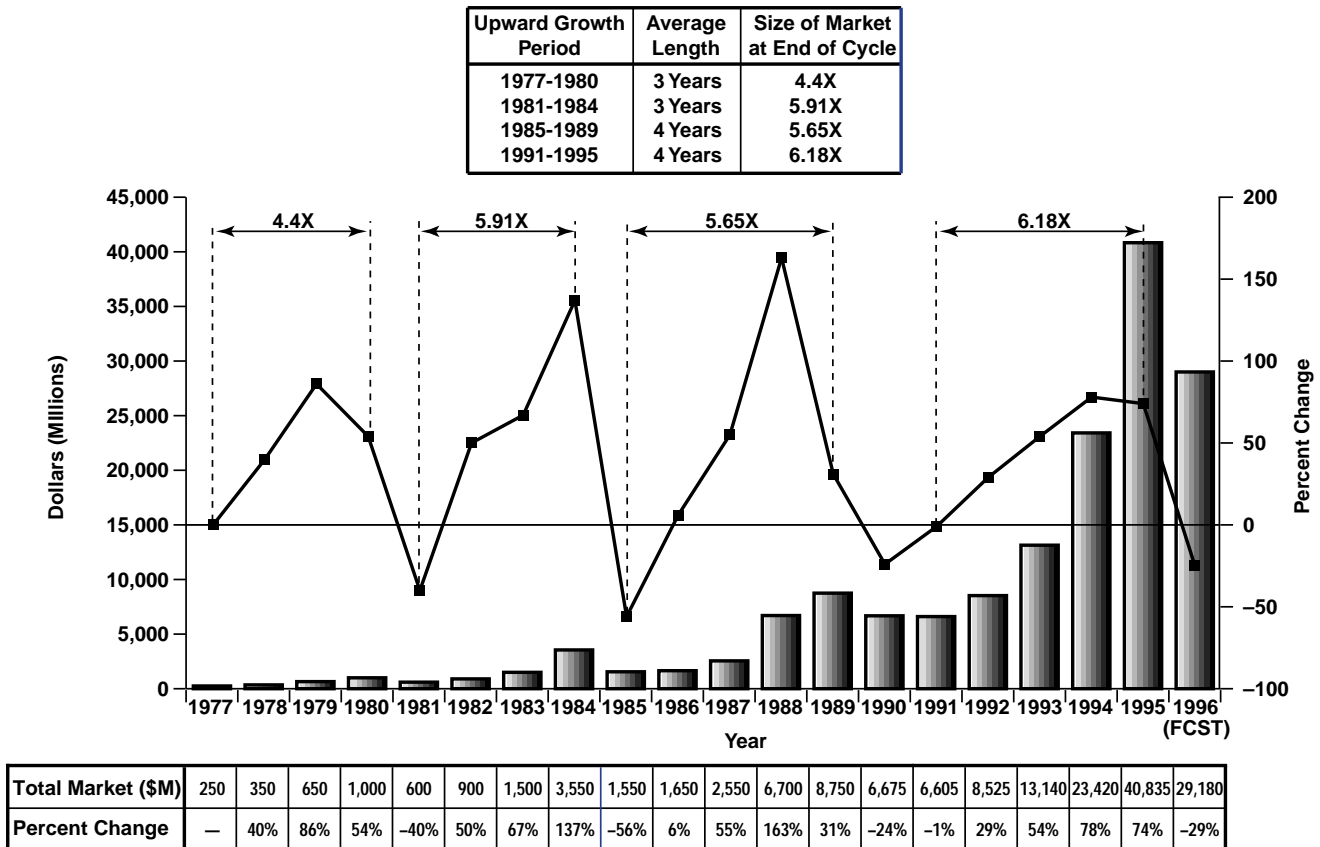
During the past three years (1993-1995), industry observers were stunned and amazed as the DRAM market displayed relentless growth. Helping the DRAM market grow at its accelerated pace was the vigorous PC market. Even as new capacity was added worldwide, memory-hungry systems manufacturers kept DRAM vendors struggling to keep pace with demand.

In 1996, a different scenario is panning out for the DRAM market and its suppliers. In 1Q96, DRAM prices started to plunge and are likely to drop even further through the balance of the year. Softer PC sales, additional worldwide capacity coming on line, Korea’s determination to more than double its 16Mbit DRAM output, and the entrance of Taiwan vendors into the DRAM market are elements that point to a much weaker DRAM market for 1996. Supply will surpass demand. 1996 will be a nail-biter for many DRAM manufacturers; one that will test their ability to make it through precarious times.

Further adding to the unsettledness is the fragmentation of the DRAM market. Rather than one DRAM architecture that covers every application, there are now EDO DRAMs, synchronous DRAMs, and Rambus DRAMs (among many others) that are much more capable of meeting the needs of specific products and applications. Several more derivatives are on the way. As systems progress toward greater complexity, the DRAM market will likely branch off in different directions to address those needs. All these factors will test the inner mettle of DRAM manufacturers in 1996.

The DRAM Market

The DRAM market has been through many up and down cycles as shown in Figure 2-1, but few suppliers remember demand ever being as strong over such a long period of time as during the recent past few years. For the already huge DRAM market to grow by such large percentages over a several year period is quite remarkable. Naturally, most DRAM suppliers were ecstatic with the growth. In fact, they could have shipped much more product during the past few years if they had the extra capacity. As the figure shows, it appears the 1996 DRAM market will not grow as it did during the past four years. In fact, ICE forecasts the DRAM market will decline a whopping 29 percent in 1996!



Source: ICE, "Memory 1996"

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Figure 2-1. DRAM Market History

Shown in Figure 2-2 is ICE's complete DRAM market forecast for the 1991-2001 time period. Displayed are the market size, unit shipments, ASPs, and price per megabit for several densities. ICE believes that because of factors already discussed, such as added DRAM capacity and softening PC sales, and the transition to the 16Mbit density, the DRAM market will take a big hit in 1996.

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
64Kbit Units (M)	30	4	—	—	—	—	—	—	—	—	—
ASP (\$)	1.33	1.45	—	—	—	—	—	—	—	—	—
Price Per Mbit (\$)	20.29	22.13	—	—	—	—	—	—	—	—	—
Market (\$M)	40	6	—	—	—	—	—	—	—	—	—
256Kbit Units (M)	272	197	107	64	32	15	7	—	—	—	—
ASP (\$)	1.80	1.70	1.80	2.15	2.00	1.95	2.00	—	—	—	—
Price Per Mbit (\$)	6.87	6.48	6.87	8.22	7.63	7.44	7.63	—	—	—	—
Market (\$M)	490	335	193	139	65	29	14	—	—	—	—
1Mbit Units (M)	827	822	596	500	463	250	175	90	45	20	10
ASP (\$)	4.50	3.01	3.10	3.60	3.00	2.85	2.70	2.65	2.60	2.65	2.75
Price Per Mbit (\$)	4.29	2.87	2.96	3.43	2.86	2.72	2.57	2.53	2.48	2.53	2.62
Market (\$M)	3,720	2,470	1,848	1,800	1,388	713	473	239	117	53	28
4Mbit Units (M)	145	457	776	1,254	1,649	1,460	950	700	450	260	150
ASP (\$)	16.05	11.72	11.91	12.00	12.85	6.17	4.00	3.75	3.65	3.75	3.85
Price Per Mbit (\$)	3.83	2.79	2.84	2.86	3.06	1.47	0.95	0.89	0.87	0.89	0.92
Market (\$M)	2,328	5,355	9,240	15,048	21,190	9,008	3,800	2,625	1,643	977	578
16Mbit Units (M)	0.1	2	20	103	333	930	1,608	1,850	1,650	1,100	800
ASP (\$)	275.00	180.00	93.00	61.85	54.41	20.15	12.25	9.00	7.50	6.25	5.80
Price Per Mbit (\$)	16.39	10.73	5.54	3.69	3.24	1.20	0.73	0.54	0.45	0.37	0.35
Market (\$M)	28	360	1,860	6,371	18,135	18,740	19,698	16,652	12,375	6,875	4,640
64Mbit Units (M)	—	—	—	0.1	0.25	5	105	410	1,010	1,750	2,150
ASP (\$)	—	—	—	575.00	225.00	135.00	70.00	40.00	26.00	17.00	13.00
Price Per Mbit (\$)	—	—	—	8.57	3.35	2.01	1.04	0.60	0.39	0.25	0.19
Market (\$M)	—	—	—	63	56	691	7,350	16,400	26,260	29,755	27,947
256Mbit Units (M)	—	—	—	—	—	—	—	0.1	5	80	355
ASP (\$)	—	—	—	—	—	—	—	1,300.00	500.00	200.00	119.32
Price Per Mbit (\$)	—	—	—	—	—	—	—	4.84	1.86	0.75	0.44
Market (\$M)	—	—	—	—	—	—	—	130	2,500	16,010	42,357
1Gbit Units (M)	—	—	—	—	—	—	—	—	—	0.1	2
ASP (\$)	—	—	—	—	—	—	—	—	—	2,500.00	1,000.00
Price Per Mbit (\$)	—	—	—	—	—	—	—	—	—	2.33	0.93
Market (\$M)	—	—	—	—	—	—	—	—	—	250	2,000
Total Market (\$M)	6,605	8,525	13,140	23,420	40,833	29,180	31,335	36,045	42,895	53,920	77,550
Total Units (M)	1,274	1,482	1,499	1,921	2,477	2,660	2,845	3,050	3,160	3,211	3,467
ASP (\$)	5.18	5.75	8.77	12.19	16.48	10.97	11.01	11.82	13.57	16.79	22.37

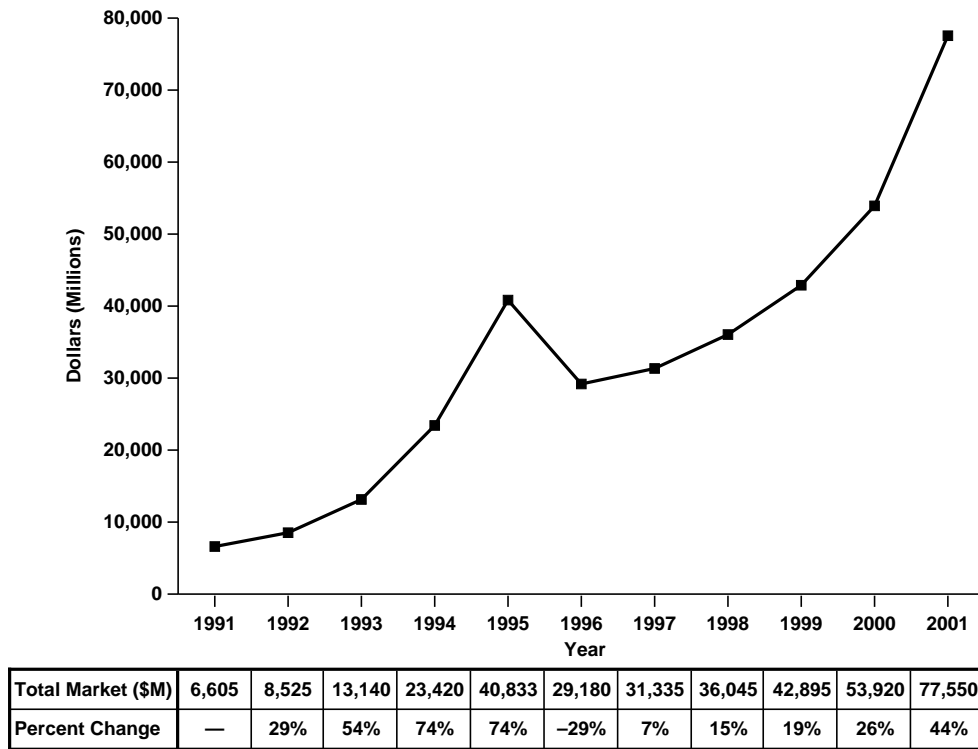
Source: ICE, "Memory 1996"

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Figure 2-2. DRAM Market Forecast

After growing at with a cumulative average annual growth rate (CAGR) of 58 percent from 1991-1995, ICE forecasts the DRAM market to “cool” to a 22 percent average growth rate from 1996-2001. Many industries would be delighted with a growth rate in the 20-percent range. For the DRAM industry, however, market growth in the 20-percent range is merely “acceptable.”

Following a 29 percent decline in 1996, ICE believes the DRAM market will rebound in 1997 with the market forecast to expand seven percent (Figure 2-3). 1996 will be a “catch up” year for the DRAM industry. ICE believes that capacity will catch up with, and surpass, demand. The potential for price wars will be greater as companies seek to grow or maintain their share of the market. As the decade closes, supply and demand will be better balanced. Early into the 2000’s, ICE forecasts that demand will once again outstrip supply, causing the market to grow at an accelerated pace.



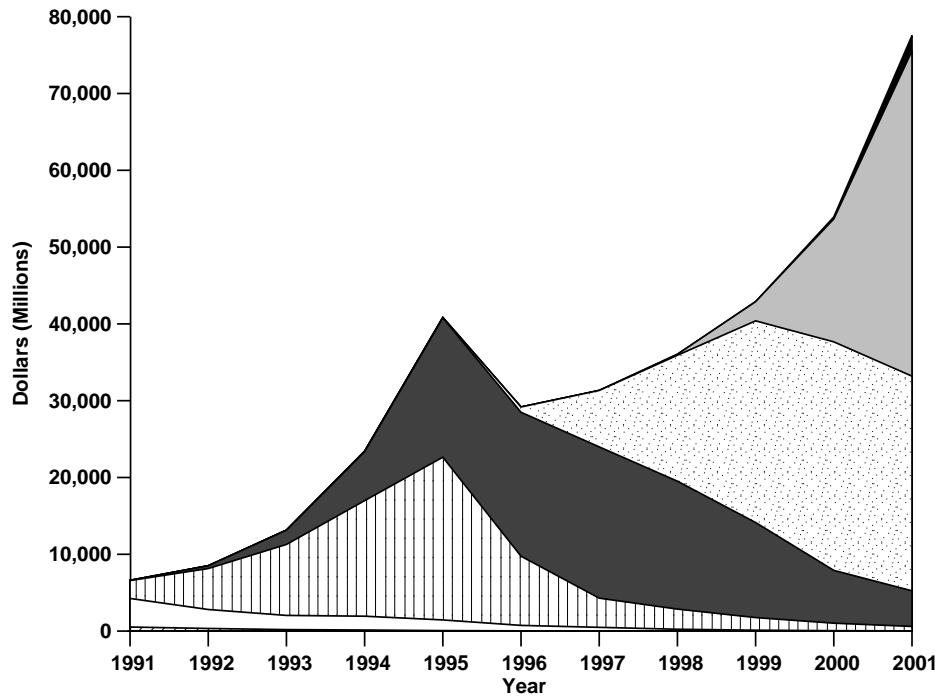
Source: ICE, "Memory 1996"

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Figure 2-3. DRAM Market Growth

The market size for DRAMs based on their density is shown in Figure 2-4. From 1992 through 1995, 4Mbit DRAMs were the best selling DRAM density. ICE believes, however, that the 4Mbit market will decline dramatically in 1996. In 1Q96, average selling prices for this density started on a steep downward path. ICE anticipates further ASP erosion through 1996 (discussed later in this section), resulting in a 4Mbit market that is forecast to be 43 percent the size it was in 1995.

Meanwhile, the 16Mbit density will take over as the largest DRAM market in 1996. However, prices for this density are falling rapidly too. Unit shipments are forecast to greatly increase. Factoring shipments and ASPs, the 16Mbit market is forecast to grow three percent in 1996 to \$18.7 billion.



64Kbit	40	6	—	—	—	—	—	—	—	—	—	—
256Kbit	490	335	193	139	65	29	14	—	—	—	—	—
1Mbit	3,720	2,470	1,848	1,800	1,388	713	473	239	117	53	28	—
4Mbit	2,328	5,355	9,240	15,048	21,190	9,008	3,800	2,625	1,643	977	578	—
16Mbit	28	360	1,860	6,371	18,135	18,740	19,698	16,652	12,375	6,875	4,640	—
64Mbit	—	—	—	63	56	691	7,350	16,400	26,260	29,755	27,947	—
256Mbit	—	—	—	—	—	—	—	130	2,500	16,010	42,357	—
1Gbit	—	—	—	—	—	—	—	—	—	250	2,000	—
Total Market (\$M)	6,605	8,525	13,140	23,420	40,833	29,180	31,335	36,045	42,895	53,920	77,550	—

Source: ICE, "Memory 1996"

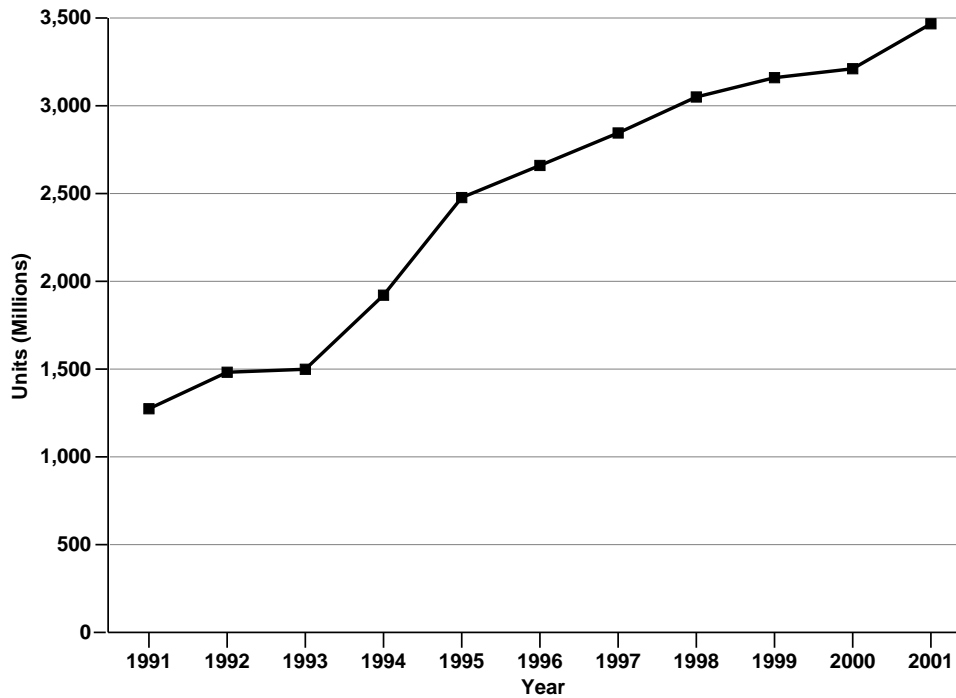
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Figure 2-4. Dollar Volume of Select DRAM Densities

The 64Mbit DRAM market is forecast to grow to nearly \$700 million in 1996, almost surpassing the 1Mbit density, which has entered into the decline/obsolete stage of its product lifecycle.

DRAM Unit Shipments

The history and forecasted growth of DRAM unit shipments during the 1991-2001 period is displayed in Figure 2-5. With the exception of 1993, when units increased a mere one percent, shipments of DRAMs grew well through the first half of the 1990's. A slowing growth rate for PC systems coupled with the transition from 4Mbit to 16Mbit devices will keep unit growth small, but upward, for 1996. Unit growth is forecast to average five percent annually from 1996 to the year 2001.



Total Units (M)	1,274	1,482	1,499	1,921	2,477	2,660	2,845	3,050	3,160	3,211	3,467
Percent Change	—	16%	1%	28%	29%	7%	7%	7%	4%	2%	8%

Source: ICE, "Memory 1996"

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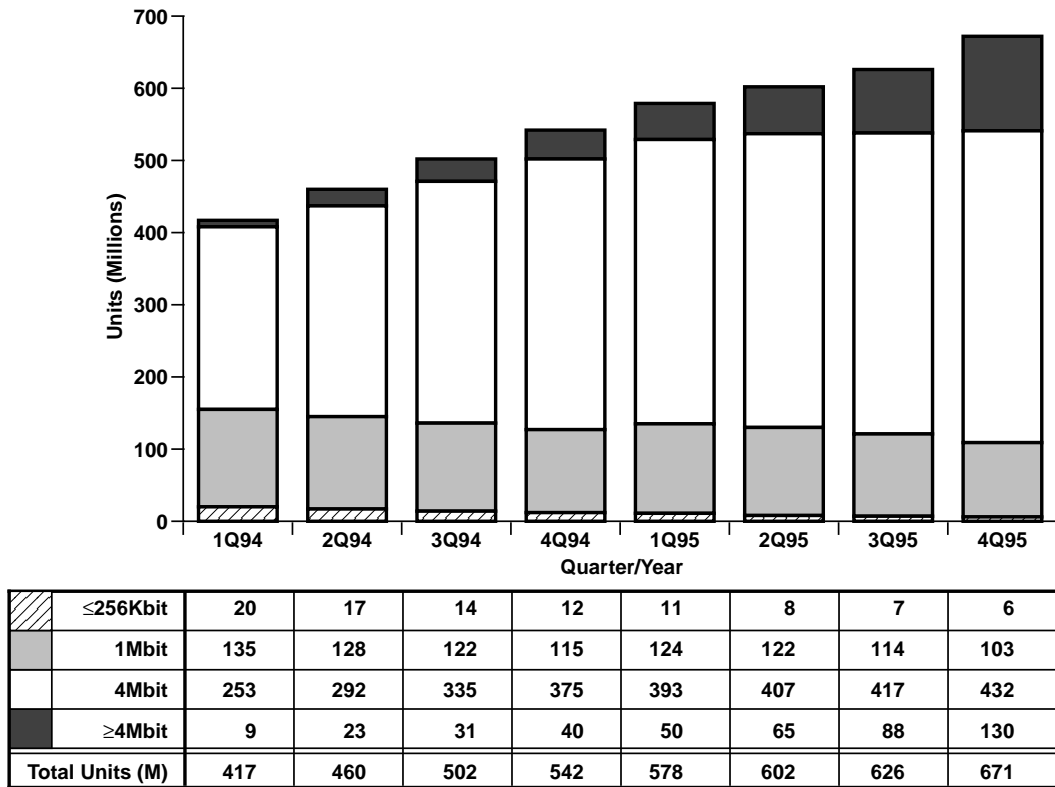
Figure 2-5. DRAM Unit Shipments (M)

Quarterly DRAM shipments during 1994 and 1995 are displayed in Figure 2-6. During the eight-quarter span, total DRAM shipments increased 61 percent. 4Mbit devices, which accounted for 61 percent of total shipments in 1Q94, represented 64 percent of shipments in 4Q95. Over the same time period, shipments of DRAMs with densities greater than 4Mbit grew from two percent to 20 percent of total shipments.

Total DRAM shipments by density are graphed in Figure 2-7. Here, the annual unit growth is shown along with most dominant memory density for the year. In 1996, ICE forecasts 4Mbit shipments will remain greater than 16Mbit shipments. However, beginning in 1997 and continuing through 1999, 16Mbit DRAMs are forecast to be the dominant density in terms of unit shipments, followed by 64Mbit DRAMs beginning in the year 2000.

Figure 2-8 provides a look at the typical lifecycle curve for DRAM unit shipments. The 1Mbit density took a long, slow decline on its way out of the market spotlight after peaking in 1991. 4Mbit shipments reached their maximum in 1995 and almost doubled the highest yearly 1Mbit output. 16Mbit and 64Mbit devices are shown ramping up in 1996. ICE forecasts that shipments of 16Mbit DRAMs will peak in 1998 and that 64Mbit devices

should top out in 2001. Whether by a few hundred million or several hundred million units, each successive DRAM generation is forecast to continue to ship more units than its predecessor.



Source: ICE, "Memory 1996"

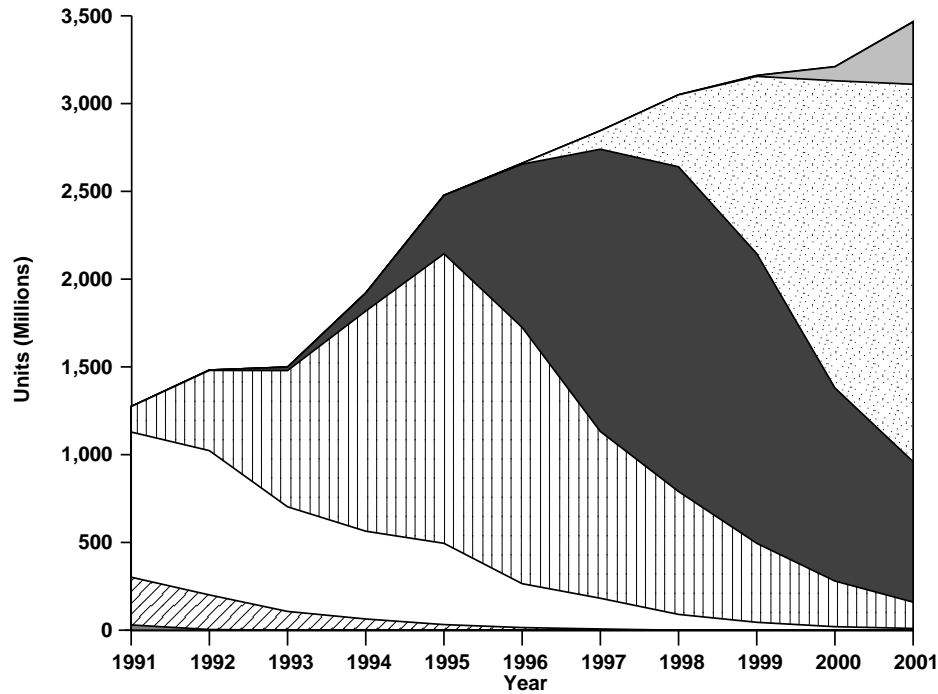
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Figure 2-6. Quarterly DRAM Shipments by Density

DRAM Unit Shipments by Architecture

In 1995, almost all DRAMs were made using the same fast-page mode (FPM) architecture. However, FPM devices have been unable to keep pace with rapidly increasing clock frequencies of microprocessors. Therefore, OEMs and suppliers now demand greater speed from their DRAMs.

As a result of FPM DRAM's inability to keep pace with high-speed microprocessors, and since almost three-fourths of all DRAMs wind up in PC systems with high-speed microprocessors, DRAM architectures have changed. Though there are numerous revolutionary and evolutionary alternatives (Figure 2-9), three architectures appear to be the main contenders to grab the largest share of the market. Figure 2-10 shows the three—extended data out (EDO) DRAM, synchronous DRAM, and Rambus DRAM—and how they will influence the market in the coming years.



64Kbit	30	4	—	—	—	—	—	—	—	—	—	—
256Kbit	272	197	107	64	32	15	7	—	—	—	—	—
1Mbit	827	822	596	500	463	250	175	90	45	20	10	—
4Mbit	145	457	776	1,254	1,649	1,460	950	700	450	260	150	—
16Mbit	0.1	2	20	103	333	930	1,608	1,850	1,650	1,100	800	—
64Mbit	—	—	—	0.1	0.25	5	105	410	1,010	1,750	2,150	—
256Mbit	—	—	—	—	—	—	—	—	0.1	5	80	355
1Gbit	—	—	—	—	—	—	—	—	—	—	0.1	2
Total Units (M)	1,274	1,482	1,499	1,921	2,477	2,660	2,845	3,050	3,160	3,211	3,467	—

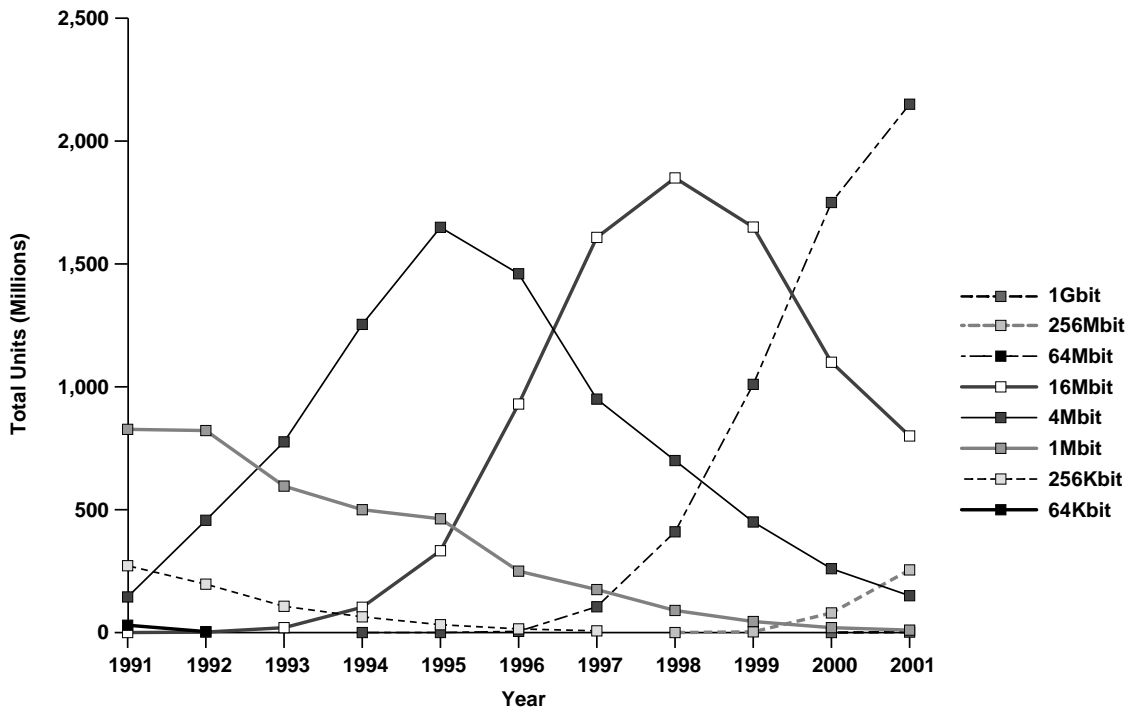
Source: ICE, "Memory 1996"

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Figure 2-7. DRAM Unit Shipments

Many leading DRAM manufacturers have quit, or nearly quit, producing fast-page mode DRAMs. Samsung, NEC, Hitachi, and Toshiba are a few of the firms that have turned off the supply of fast-page mode devices. Approximately 50 percent of Samsung's 1995 16Mbit DRAM production was for extended data out (EDO) DRAMs. Toshiba's shipment schedule by architecture is shown in Figure 2-11.

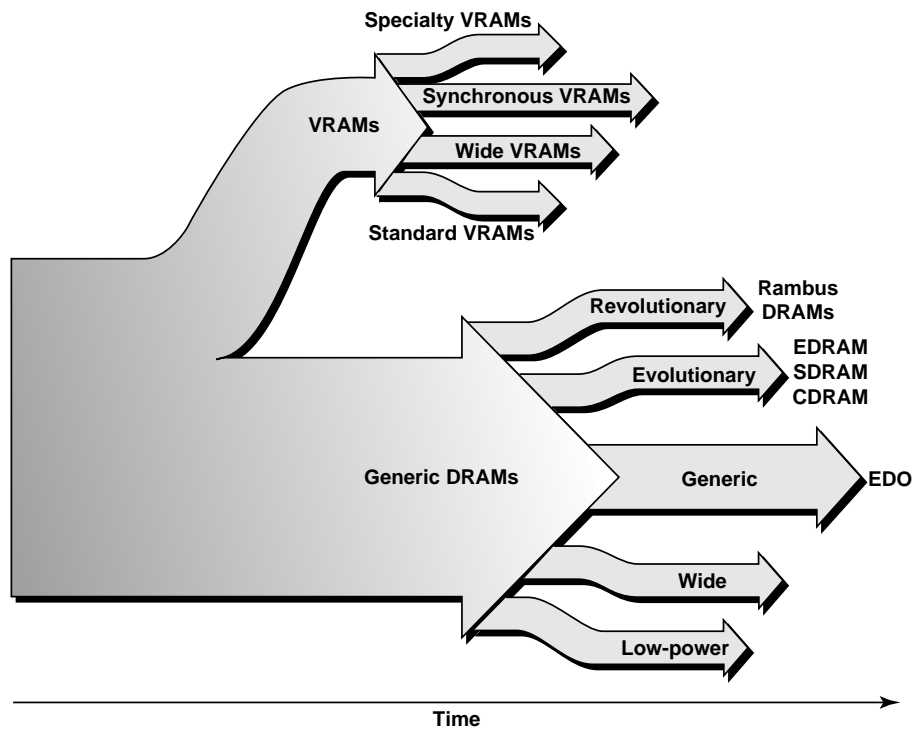
EDO is a reasonably cheap and easy upgrade from fast page mode DRAMs. ICE believes that these devices will be the first to overtake FPM DRAMs. The peak year for EDO shipments will be 1997.



Source: ICE, "Memory 1996"

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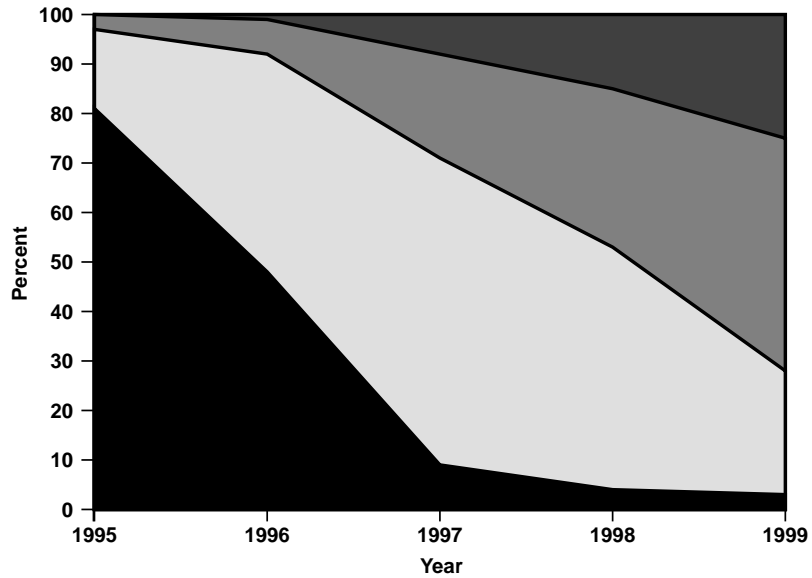
Figure 2-8. DRAM Unit Shipments by Density



Source: Micro Design Resources/Computer Design/ICE, "Memory 1996"

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Figure 2-9. DRAM Market Moving Toward Fragmentation

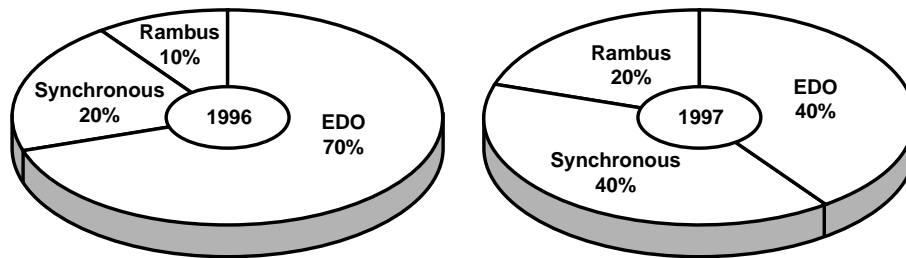


Architecture	1995	1996	1997	1998	1999
Fast Page Mode	81	48	9	4	3
EDO	16	44	62	49	25
Synchronous	3	7	21	32	47
Rambus and Other	—	1	8	15	25

Source: ICE, "Memory 1996"

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Figure 2-10. DRAM Shipments by Architecture (Percent)



Source: ICE, "Memory 1996"

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Figure 2-11. Toshiba's DRAM Shipments by Architecture

A step beyond EDO in performance is synchronous DRAM. SDRAMs will eat into both the high and low ends of the DRAM market by the turn of the decade once EDO and other architectures have reached their speed limits. Typically, an SDRAM costs around 10-15 percent more than an EDO part with similar packaging and configuration. However, to move SDRAM sales along, Hitachi announced in 1Q96 that prices of its SDRAMs would match those for its EDO parts.

Hitachi is working to have 50 percent of its DRAM sales from synchronous parts in the end of 1997 (Figure 2-12). Hyundai will allocate 25 percent of its memory product mix to SDRAM beginning in 1Q97. Texas Instruments expanded its SDRAM family in 1Q96 to support more PC applications. Its x32 solution (available in 1997, Figure 2-13) is targeted to support the demands of graphics in low-power applications.

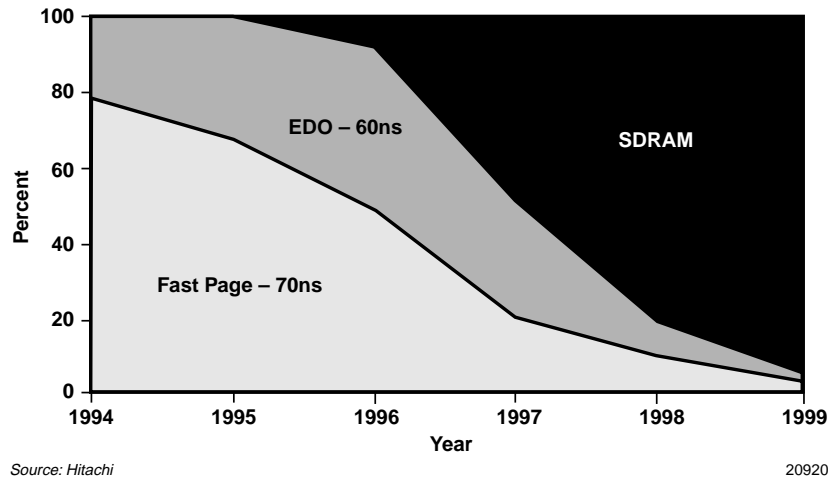


Figure 2-12. Hitachi's Main Memory Solutions Shift to SDRAM

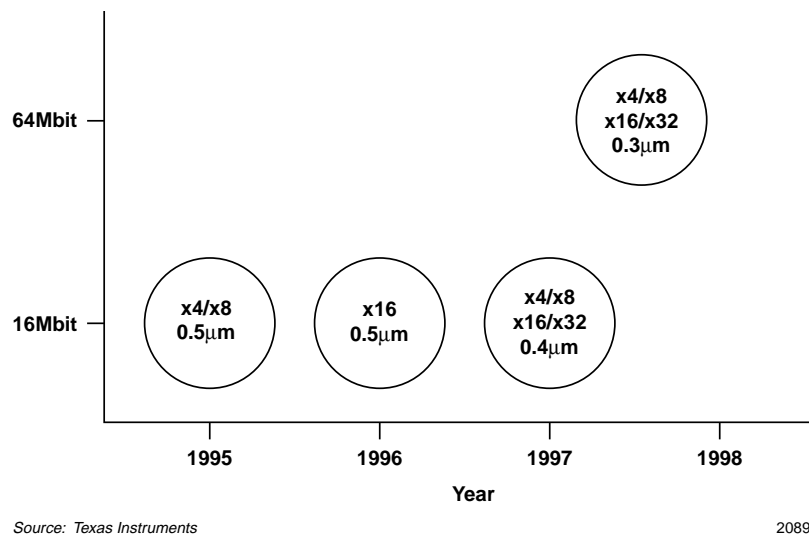


Figure 2-13. Texas Instruments' SDRAM Roadmap

Rambus DRAMs will serve more specialized needs, especially where a specific amount of DRAM density and bandwidth are required without high chip count. Toward the year 2001, there will be more systems such as games, set-top boxes, and graphics frame buffers that require the Rambus architecture.

Rambus anticipates that at the 64Mbit generation, its architecture (Rambus DRAM) will account for a greater share of the DRAM market. Rambus has signed on many leading DRAM manufacturers including Samsung, NEC, Toshiba, Hitachi, LG Semicon, and IBM, to license its proprietary technology, which enables rapid transfer of data (up to 600MHz) over a narrow, byte-wide channel.

With these leading DRAM manufacturers supporting the Rambus architecture, and with computer systems moving to 200MHz and 300MHz processors, it is easy to believe the Rambus and other advanced architectures may command 25 percent of the DRAM market in 1999.

DRAM ASPs

The annual DRAM average selling price (ASP) from 1991 through 2001 is shown in Figure 2-14. Tight production capacity and strong demand kept ASPs rising quickly during the first part of the decade. The overall DRAM ASP increased an average of 34 percent annually from 1991 to 1995. The big reduction of 4Mbit and 16Mbit ASPs in 1996 is certain to impact the overall DRAM selling price. During the next few years, substantial DRAM capacity should lead to light to moderate increases in the overall DRAM ASP.



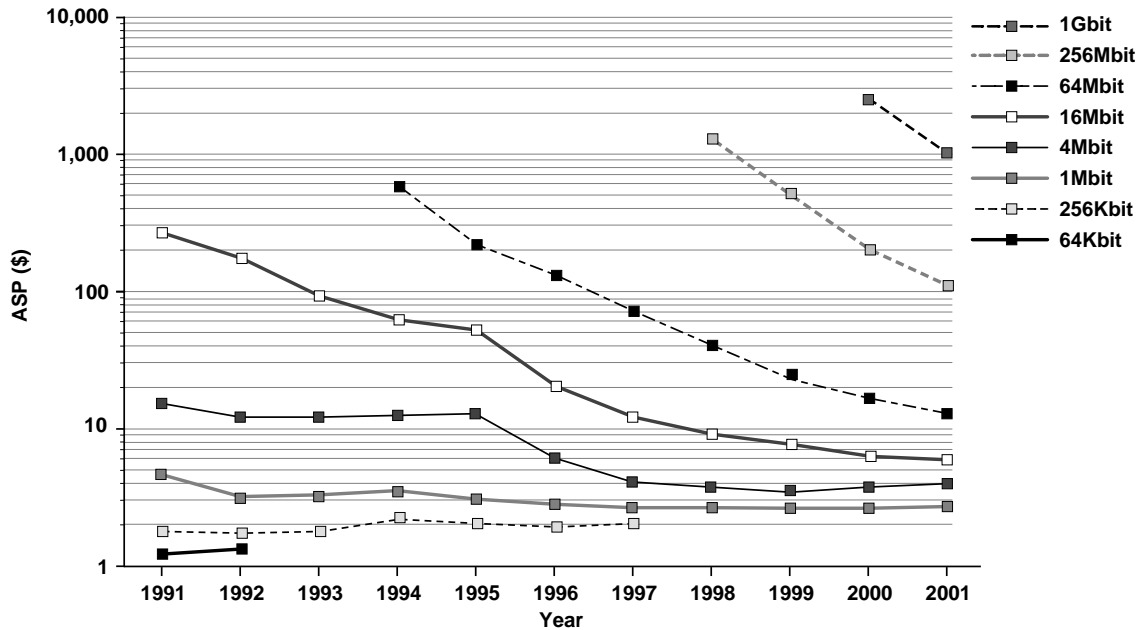
Total ASP (\$)	5.18	5.75	8.77	12.19	16.48	10.97	11.01	11.82	13.57	16.79	22.37
Percent Change	—	11%	52%	39%	35%	-33%	0%	7%	15%	24%	33%

Source: ICE, "Memory 1996"

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Figure 2-14. DRAM ASP (\$)

ASPs for several DRAM densities are plotted in Figure 2-15. It is interesting to note that ASPs for both the 1Mbit and 4Mbit densities were essentially flat or slightly up for four years (1992-1995). A closer look at the 4Mbit density reveals that when the market decided to move on to the next DRAM generation, prices fell in a hurry. ICE forecasts that the 4Mbit ASP will drop 52 percent in 1996 compared to its 1995 average.



64Kbit	1.33	1.45	—	—	—	—	—	—	—	—	—
256Kbit	1.80	1.70	1.80	2.15	2.00	1.95	2.00	—	—	—	—
1Mbit	4.50	3.01	3.10	3.60	3.00	2.85	2.70	2.65	2.60	2.65	2.75
4Mbit	16.05	11.72	11.91	12.00	12.85	6.17	4.00	3.75	3.65	3.75	3.85
16Mbit	275.00	180.00	93.00	61.85	54.41	20.15	12.25	9.00	7.50	6.25	5.80
64Mbit	—	—	—	575.00	225.00	135.00	70.00	40.00	26.00	17.00	13.00
256Mbit	—	—	—	—	—	—	—	1,300.00	500.00	200.00	119.32
1Gbit	—	—	—	—	—	—	—	—	—	2,500.00	1,000.00
Total ASP (\$)	5.18	5.75	8.77	12.19	16.48	10.97	11.01	11.82	13.57	16.79	22.37

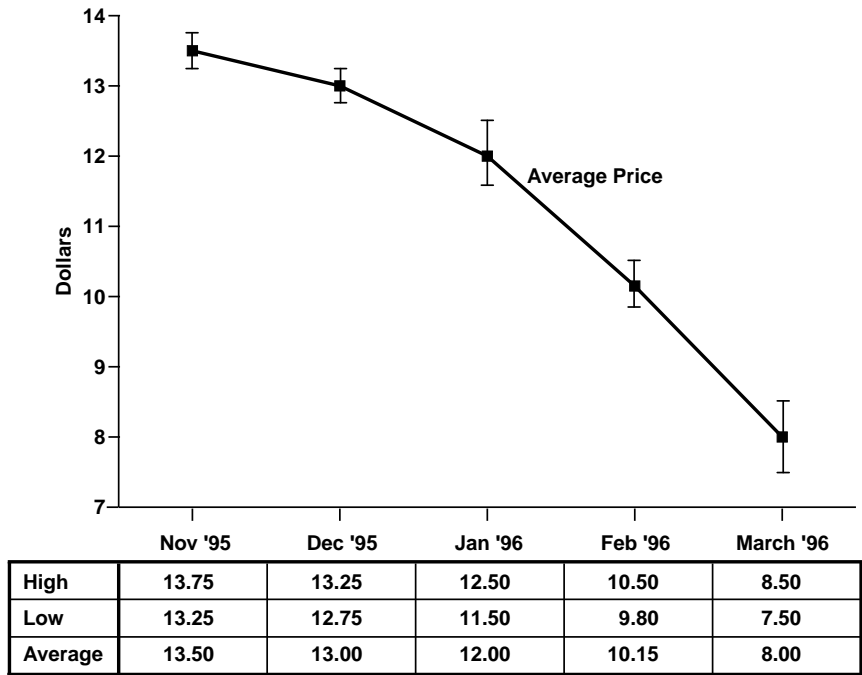
Source: ICE, "Memory 1996"

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Figure 2-15. DRAM ASPs (\$) by Density

During 1Q96, prices for 4Mbit devices varied widely. Prices for standard fast-page mode (FPM) devices fell quickly. Spot prices for 4Mbit FPM devices were as much as 30 percent lower than contract prices during the quarter. Furthermore, spot prices for FPM devices were 30 percent lower in March than they were in January.

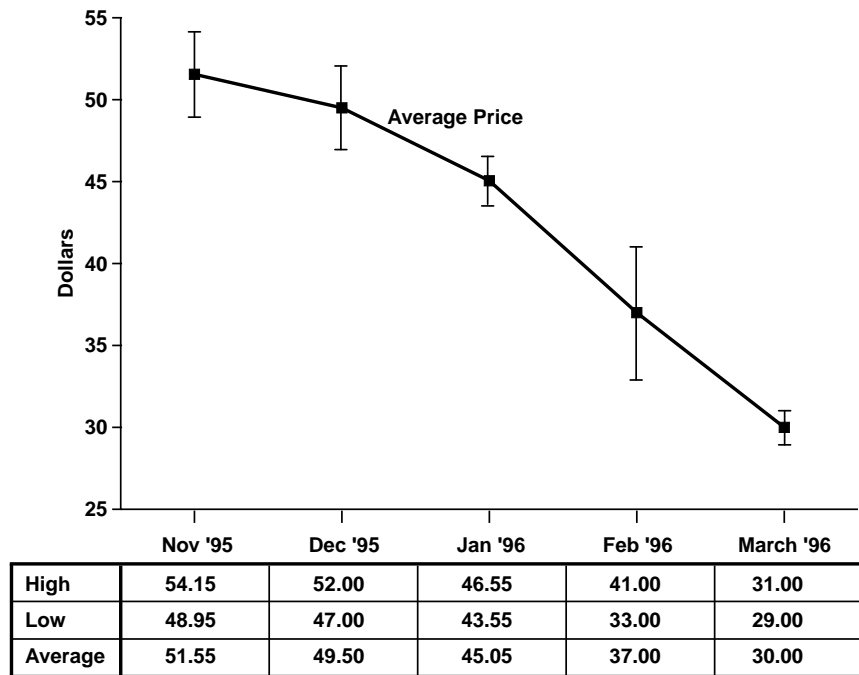
Figure 2-16 notes how quickly the 4Mbit DRAM density fell in average selling price from November, 1995 through March, 1996. Figure 2-17 shows the decline for the 16Mbit generation.



Source: ICE, "Memory 1996"

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Figure 2-16. 4Mbit DRAM Price Trend (\$)



Source: ICE, "Memory 1996"

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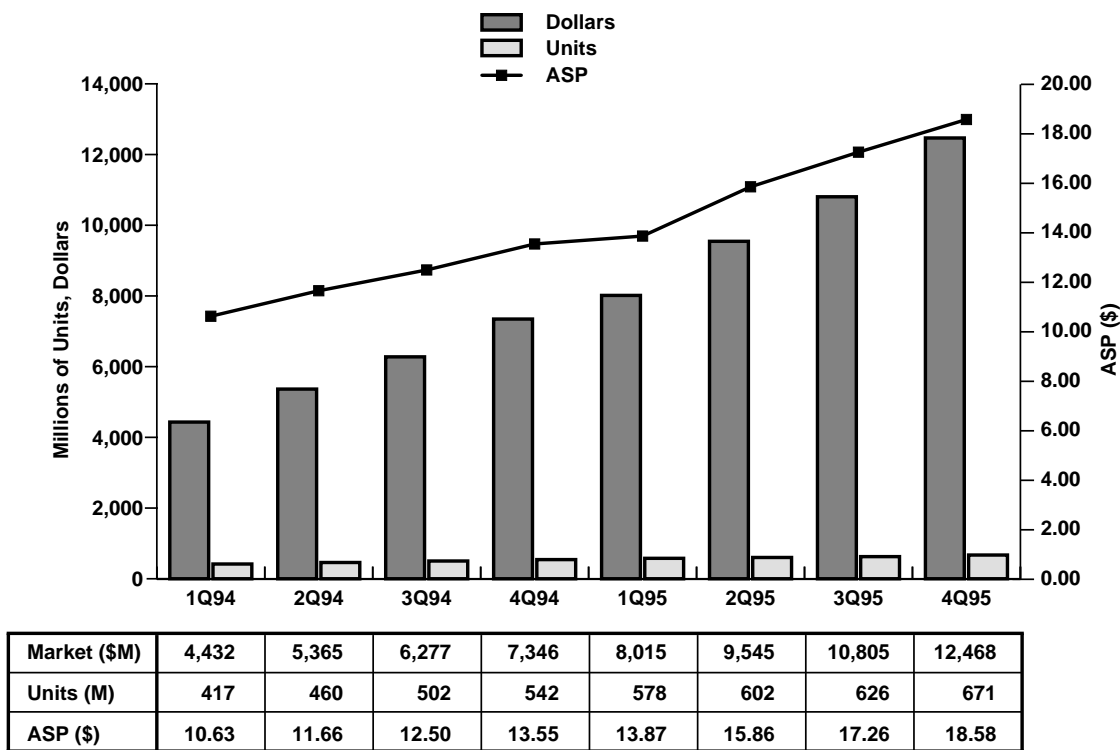
Figure 2-17. 16Mbit DRAM Price Trend (\$)

Price declines in 4Q95 and 1Q96 accelerated due in part to an oversupply of FPM DRAMs in both 4Mbit and 16Mbit densities. Customers converted to extended data out (EDO) DRAMs more quickly than expected. However, manufacturers did not convert to building EDO devices quickly enough, leaving them with surplus inventories of FPM devices.

DRAM suppliers wanted to lower prices of their fast-page-mode devices and at the same time keep ASPs of EDO DRAMs higher. That did not happen. Though EDO devices were (and continue) in short supply, prices for them declined because customers held suppliers to promises made in 1995 of zero premiums for EDO devices.

Quarterly DRAM Market

The 1994 and 1995 quarterly performance of the DRAM market is shown in Figure 2-18. All categories—dollars, units, and ASP—surged upward during the two-year period. Specifically, dollar volume increased 181 percent, unit shipments were up 61 percent, and the average selling price rose 75 percent! It is hard to believe, but the 4Q95 market (\$12.5 billion) was nearly as large as the DRAM market for all of 1993!



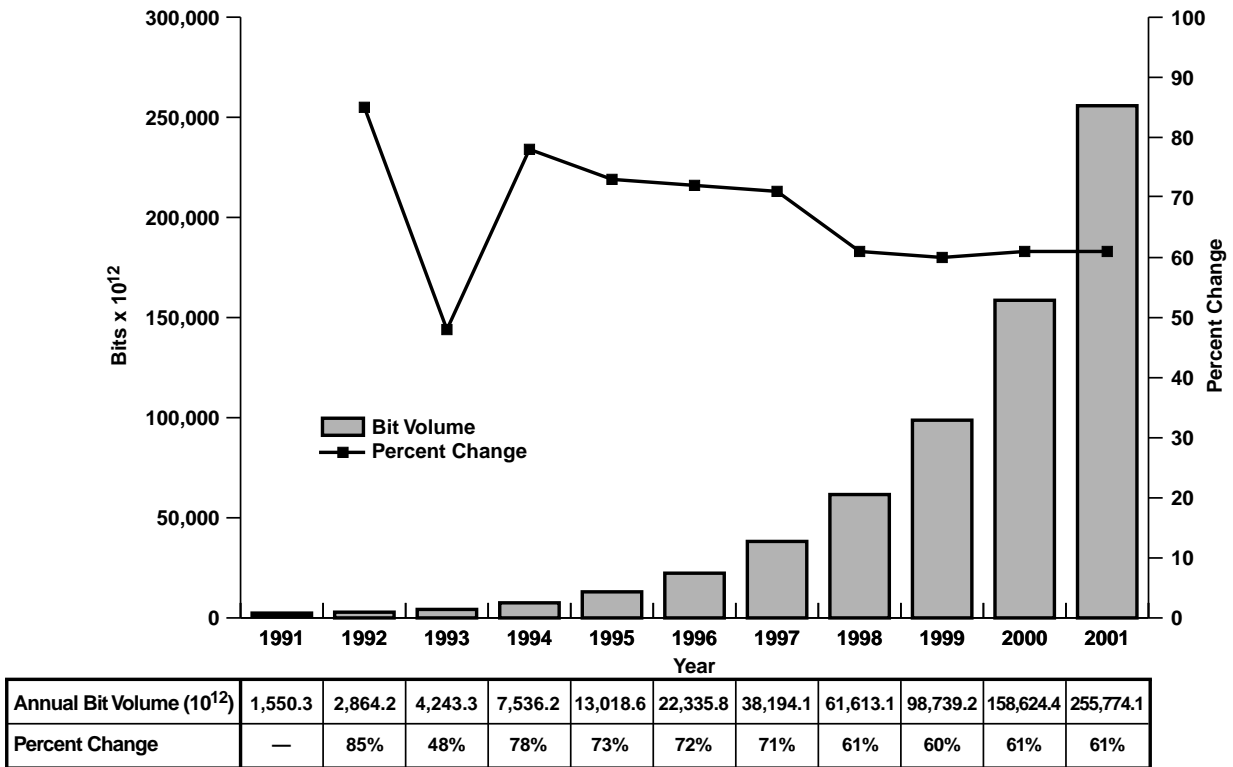
Source: ICE, "Memory 1996"

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Figure 2-18. Quarterly DRAM Market

DRAM Bit Volume

Bit volume for the complete DRAM market and for specific densities is provided in Figures 2-19 and 2-20, respectively. The second half of the 1990's is forecast to be a period of steady bit-volume growth. Annual bit volume increases are forecast to average 63 percent through 2001.



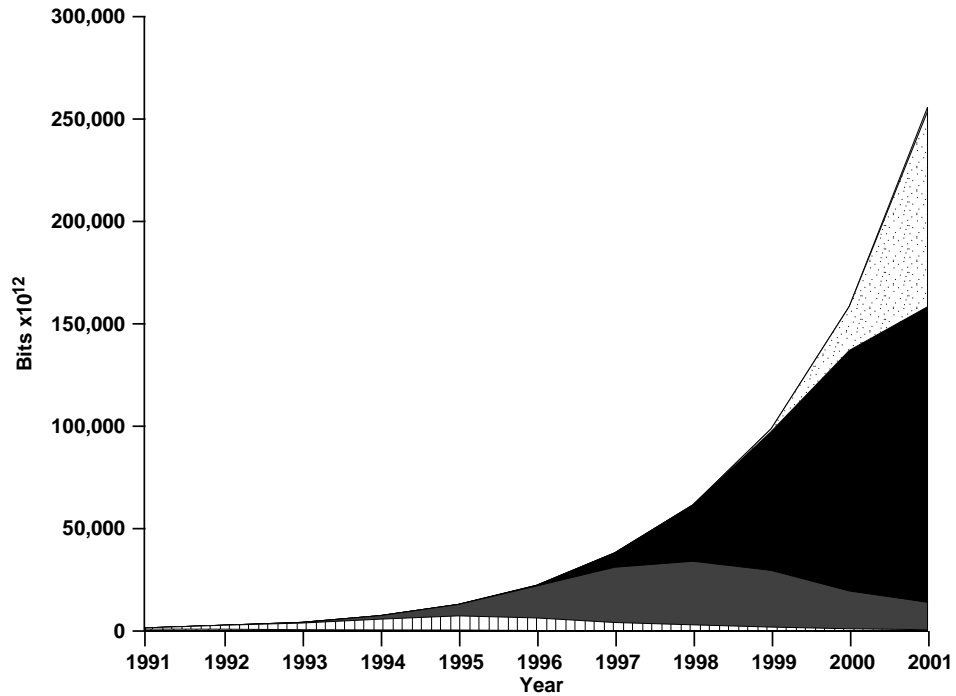
Source: ICE, "Memory 1996"

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Figure 2-19. DRAM Bit Volume (10¹²)

In Figure 2-21, the DRAM bit volume lifecycle by density is plotted for several generations. Bit volume for each generation follows an arc-shaped curve through its lifecycle, with each arc being slightly higher on the scale than the previous generation. When total bit volume is amassed and plotted for each year, a rather straight line appears.

A line representing total yearly bit volume for the DRAM market dating from 1973 is shown and plotted in Figure 2-22. With two exceptions (1975 and 1981) DRAM bit volume grew by triple-digit digit amounts from 1973 through 1984. Double-digit increases, averaging 64 percent per year, are shown as the norm from 1985 through the year 2001.



	64Kbit	2.0	0.3	—	—	—	—	—	—	—	—	—	—
	256Kbit	71.3	51.6	28.0	16.9	8.5	3.9	1.8	—	—	—	—	—
	1Mbit	867.2	861.9	625.0	524.3	485.1	262.1	183.5	94.4	47.2	21.0	10.5	—
	4Mbit	608.2	1,916.8	3,254.8	5,259.7	6,916.4	6,123.7	3,984.6	2,936.0	1,887.4	1,092.2	629.1	—
	16Mbit	1.7	33.6	335.5	1,728.1	5,591.8	15,602.8	26,977.8	31,041.2	27,682.4	18,454.9	13,421.8	—
	64Mbit	—	—	—	7.4	16.8	343.3	7,046.4	27,514.6	67,780.0	117,460.6	144,270.6	—
	256Mbit	—	—	—	—	—	—	—	26.8	1,342.2	21,488.3	95,294.6	—
	1Gbit	—	—	—	—	—	—	—	—	—	107.4	2,147.5	—
	Total Bit Volume (10¹²)	1,550.3	2,864.2	4,243.3	7,536.2	13,018.6	22,335.8	38,194.1	61,613.1	98,739.2	158,624.4	255,774.1	—

Source: ICE, "Memory 1996"

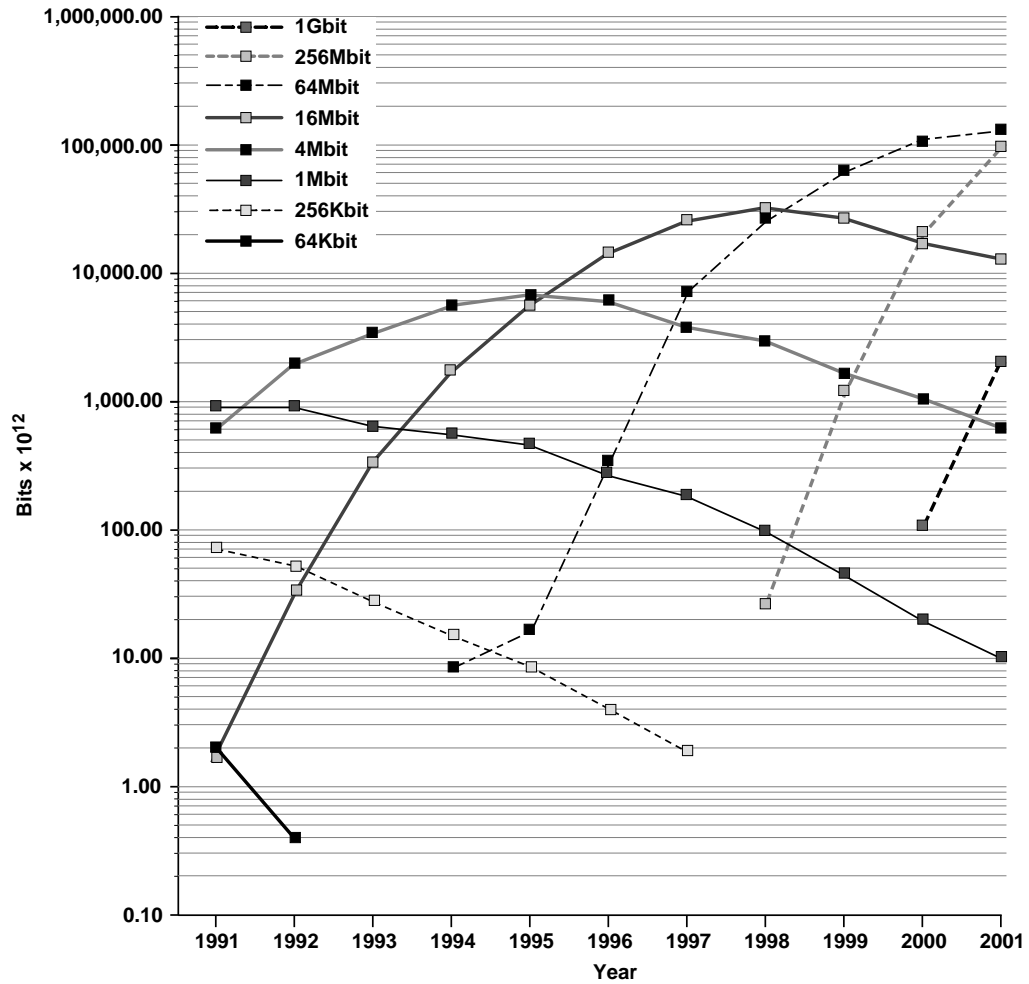
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Figure 2-20. DRAM Bit Volume (10¹²) by Density

DRAM Price Per Megabit

DRAM price per megabit values for several densities are plotted in Figure 2-23 for the 1991-2001 time period. 1991 was the crossover year for the 4Mbit generation. It became the lowest-priced device and held that distinction through 1994. In a rare case, the 1Mbit density replaced 4Mbit devices as the low-price leader in 1995. In this case, demand, coupled with limited capacity, for 4Mbit devices kept the ASP (and price per megabit value) high, while that of 1Mbit devices continued to move downward.

The price per megabit of the 4Mbit device is forecast to drop significantly in 1996, but ICE forecasts that the 16Mbit generation will become the new cost-effective DRAM during the year. ICE expects 16Mbit DRAMs to have the lowest price per megabit for three years. Then, in 1999, the 64Mbit generation is forecast to take over as the price per megabit leader.

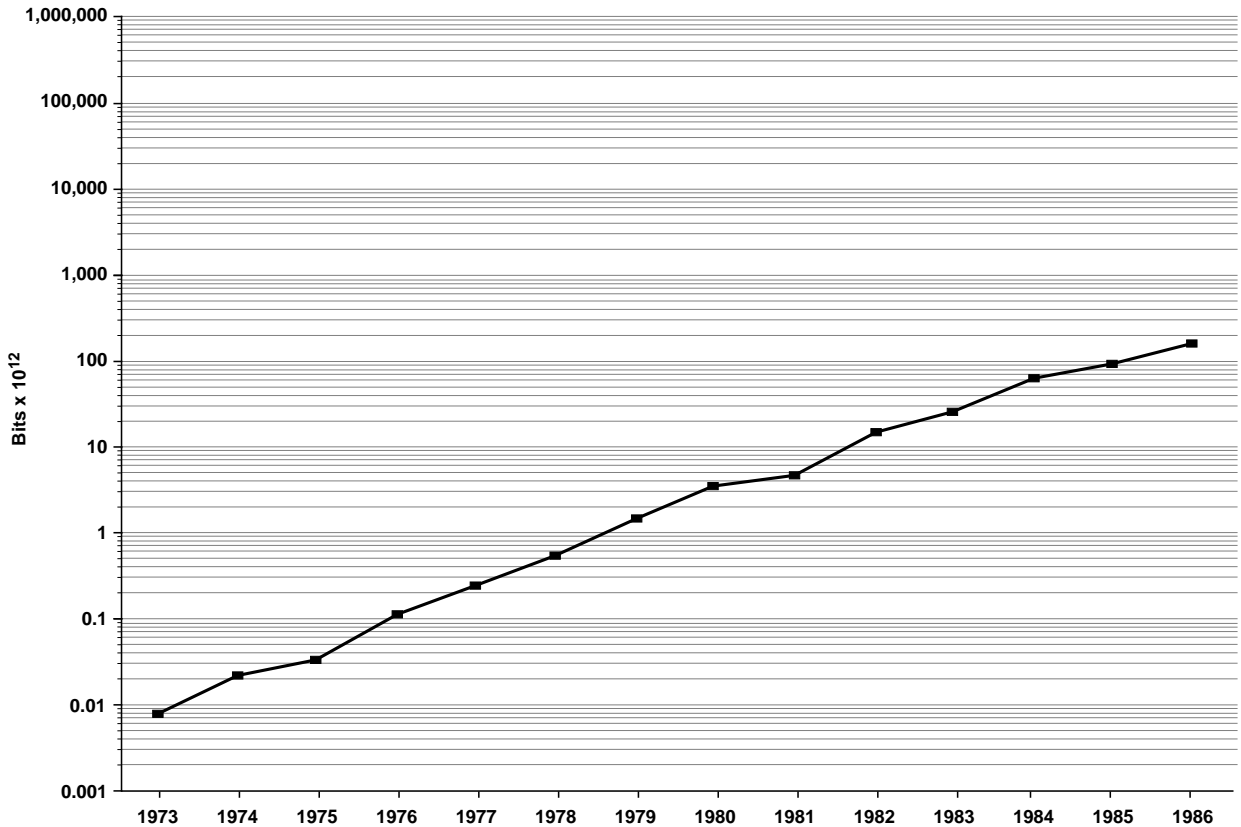


64Kbit	2.0	0.3	—	—	—	—	—	—	—	—	—	—
256Kbit	71.3	51.6	28.0	16.9	8.5	3.9	1.8	—	—	—	—	—
1Mbit	867.2	861.9	625.0	524.3	485.1	262.1	183.5	94.4	47.2	21.0	10.5	—
4Mbit	608.2	1,916.8	3,254.8	5,259.7	6,916.4	6,123.7	3,984.6	2,936.0	1,887.4	1,092.2	629.1	—
16Mbit	1.7	33.6	335.5	1,728.1	5,591.8	15,602.8	26,977.8	31,041.2	27,682.4	18,454.9	13,421.8	—
64Mbit	—	—	—	7.4	16.8	343.3	7,046.4	27,514.6	67,780.0	117,460.6	144,270.6	—
256Mbit	—	—	—	—	—	—	—	26.8	1,342.2	21,488.3	95,294.6	—
1Gbit	—	—	—	—	—	—	—	—	—	107.4	2,147.48	—
Total Bit Volume (10¹²)	1,550.3	2,864.2	4,243.3	7,536.2	13,018.6	22,335.8	38,194.1	61,613.1	98,739.2	158,624.4	255,774.1	—
Percent Change	—	85%	48%	78%	73%	72%	71%	61%	60%	61%	61%	—

Source: ICE, "Memory 1996"

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Figure 2-21. DRAM Bit Volume Life Cycle by Density

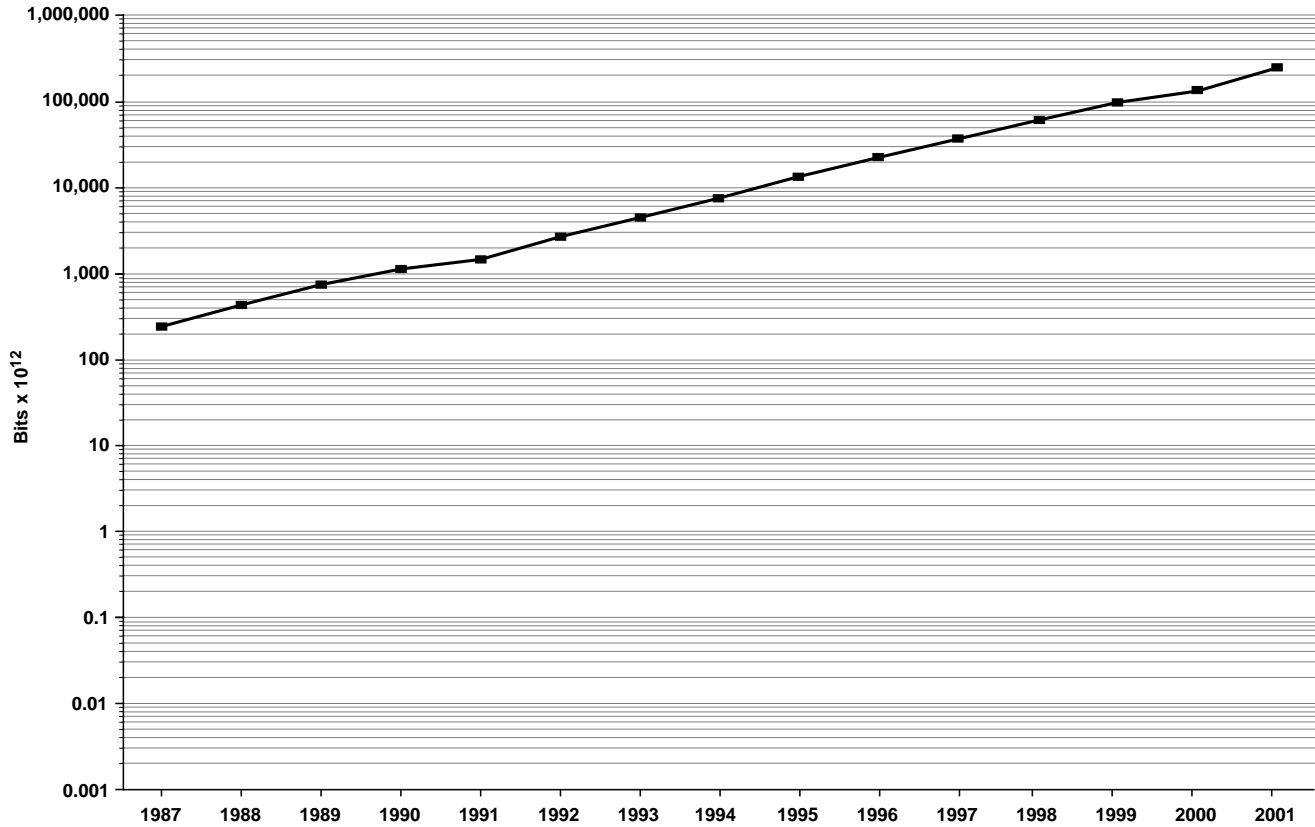


Units	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
1Kbit	8	21	19	13	10	5	1	1	1	—	—	—	—	—
4Kbit	—	—	3	24	50	67	70	31	15	10	5	—	—	—
16Kbit	—	—	—	—	2	17	71	184	230	240	220	120	35	10
64Kbit	—	—	—	—	—	—	—	1	11	100	330	820	500	380
256Kbit	—	—	—	—	—	—	—	—	—	—	2	40	240	520
1Mbit	—	—	—	—	—	—	—	—	—	—	—	—	—	4
4Mbit	—	—	—	—	—	—	—	—	—	—	—	—	—	—
16Mbit	—	—	—	—	—	—	—	—	—	—	—	—	—	—
64Mbit	—	—	—	—	—	—	—	—	—	—	—	—	—	—
256Mbit	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1Gbit	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total Units (M)	8	21	22	37	62	89	142	217	257	350	557	980	775	914
Percent Change	—	163%	5%	68%	68%	44%	60%	53%	18%	36%	59%	76%	-21%	18%
Bits														
1Kbit	0.0082	0.0215	0.0195	0.0133	0.0102	0.0051	0.0010	0.0010	0.0010	—	—	—	—	—
4Kbit	—	—	0.0123	0.0983	0.2048	0.2744	0.2867	0.1270	0.0614	0.0410	0.0205	—	—	—
16Kbit	—	—	—	—	0.0328	0.2785	1.1633	3.0147	3.7683	3.9322	3.6045	1.966	0.573	0.164
64Kbit	—	—	—	—	—	—	—	0.0655	0.7209	6.5536	21.6269	53.740	32.768	24.904
256Kbit	—	—	—	—	—	—	—	—	—	—	0.5243	10.486	62.915	136.315
1Mbit	—	—	—	—	—	—	—	—	—	—	—	—	—	4.194
4Mbit	—	—	—	—	—	—	—	—	—	—	—	—	—	—
16Mbit	—	—	—	—	—	—	—	—	—	—	—	—	—	—
64Mbit	—	—	—	—	—	—	—	—	—	—	—	—	—	—
256Mbit	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1Gbit	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total Bits (10 ¹²)	0.0082	0.0215	0.0317	0.112	0.248	0.558	1.45	3.21	4.55	10.53	25.78	66.19	96.26	165.58
Percent Change	—	163%	48%	252%	122%	125%	160%	121%	42%	131%	145%	157%	45%	72%

Source: ICE, "Memory 1996"

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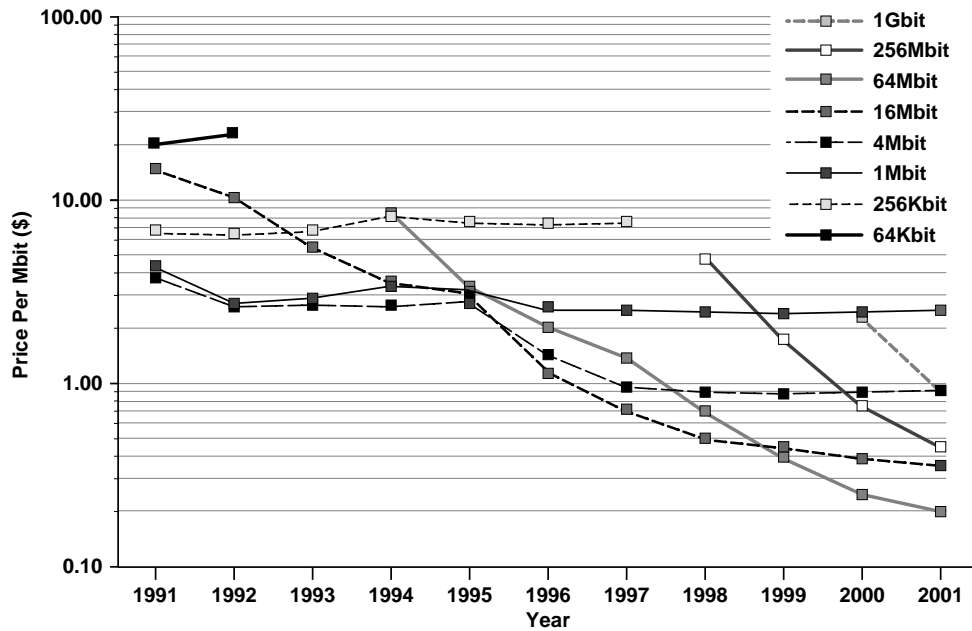
Figure 2-22. Annual DRAM Bit Volume Growth



Units	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
1Kbit	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4Kbit	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
16Kbit	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
64Kbit	150	150	110	60	30	4	—	—	—	—	—	—	—	—	—
256Kbit	680	875	775	600	272	197	107	64	32	15	7	—	—	—	—
1Mbit	45	180	470	670	827	822	596	500	463	250	175	90	45	20	10
4Mbit	—	—	1	35	145	457	776	1,254	1,649	1,460	950	700	450	260	150
16Mbit	—	—	—	—	0.1	2	20	103	333	930	1,608	1,850	1,650	1,100	800
64Mbit	—	—	—	—	—	—	—	0.1	0.25	5	105	410	1,010	1,750	2,150
256Mbit	—	—	—	—	—	—	—	—	—	—	—	0.1	5	80	355
1Gbit	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	2
Total Units (M)	875	1,205	1,356	1,365	1,274	1,482	1,499	1,921	2,477	2,660	2,845	3,050	3,160	3,211	3,467
Percent Change	-4%	38%	13%	1%	-7%	16%	1%	28%	29%	7%	7%	7%	4%	2%	8%
Bits															
1Kbit	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4Kbit	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
16Kbit	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
64Kbit	9.83	9.83	7.21	3.9	2.0	0.3	—	—	—	—	—	—	—	—	—
256Kbit	178.26	229.38	203.16	157.3	71.3	51.6	28.0	16.9	8.5	3.9	1.8	—	—	—	—
1Mbit	47.19	188.74	492.83	702.5	867.2	861.9	625.0	524.3	485.1	262.1	183.5	94.4	47.2	21.0	10.5
4Mbit	—	—	4.19	146.8	608.2	1,916.8	3,254.8	5,259.7	6,916.4	6,123.7	3,984.6	2,936.0	1,887.4	1,092.2	629.1
16Mbit	—	—	—	—	1.7	33.6	335.5	1,728.1	5,591.8	15,602.8	26,977.8	31,041.2	27,682.4	18,454.9	13,421.8
64Mbit	—	—	—	—	—	—	—	7.4	16.8	343.3	7,046.4	27,514.6	67,780.0	117,460.6	144,270.6
256Mbit	—	—	—	—	—	—	—	—	—	—	—	26.8	1,342.2	21,488.3	95,294.6
1Gbit	—	—	—	—	—	—	—	—	—	—	—	—	—	107.4	2,147.5
Total Bits (10 ¹²)	235.27	427.95	707.40	1,010.6	1,550.3	2,864.2	4,243.3	7,536.2	13,018.6	22,336	38,194	61,613	98,739	158,624	255,774
Percent Change	42%	82%	65%	43%	53%	85%	48%	78%	73%	72%	71%	61%	60%	61%	61%

Source: ICE, "Memory 1996"

Figure 2-22. Annual DRAM Bit Volume Growth (Continued)



64Kbit	20.29	22.13	—	—	—	—	—	—	—	—	—
256Kbit	6.87	6.48	6.87	8.22	7.63	7.44	7.63	—	—	—	—
1Mbit	4.29	2.87	2.96	3.43	2.86	2.72	2.57	2.53	2.48	2.53	2.62
4Mbit	3.83	2.79	2.84	2.86	3.06	1.47	0.95	0.89	0.87	0.89	0.92
16Mbit	16.39	10.73	5.54	3.69	3.24	1.20	0.73	0.54	0.45	0.37	0.35
64Mbit	—	—	—	8.57	3.35	2.01	1.04	0.60	0.39	0.25	0.19
256Mbit	—	—	—	—	—	—	—	4.84	1.86	0.75	0.44
1Gbit	—	—	—	—	—	—	—	—	—	2.33	0.93

Source: ICE, "Memory 1996"

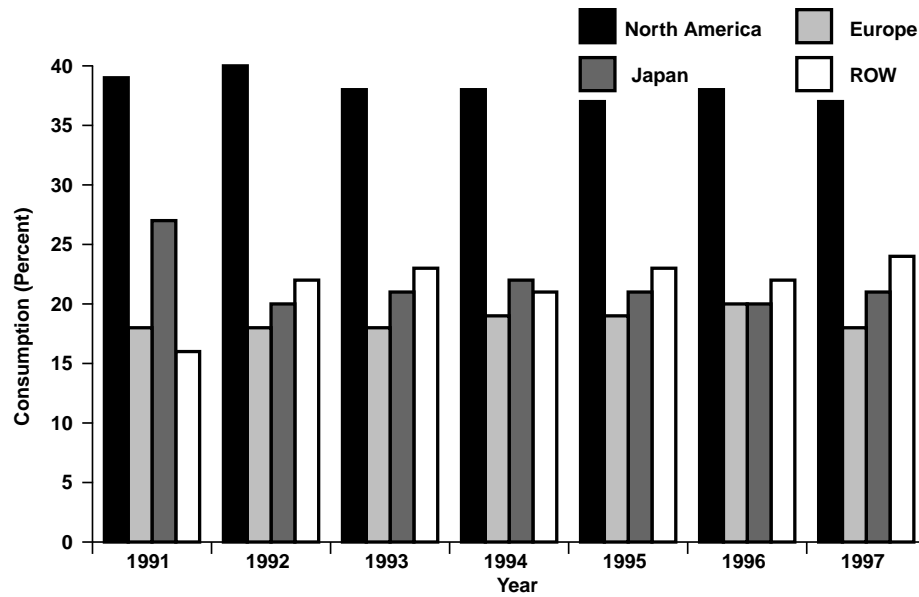
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Figure 2-23. DRAM Price Per Mbit (\$) by Density

DRAM Consumption and Production

As has been the case through the 1990's, DRAM consumption (Figure 2-24) was led by the North American region with 37 percent of the 1995 market. Consumption of DRAMs in the ROW region (Asia-Pacific countries excluding Japan) first surpassed Japan's consumption in 1992. Strong consumer electronic consumption in the developing economies of the region along with PC-related work (assembly, packaging, test) provided the major impetus for this growth.

In contrast, DRAM production remained firmly in the hands of the Japanese companies (Figure 2-25), although their marketshare dropped considerably from 1991. The biggest threat to the Japanese companies' production lead comes from the ROW companies, which continued to build more facilities and harvest additional marketshare in 1995.

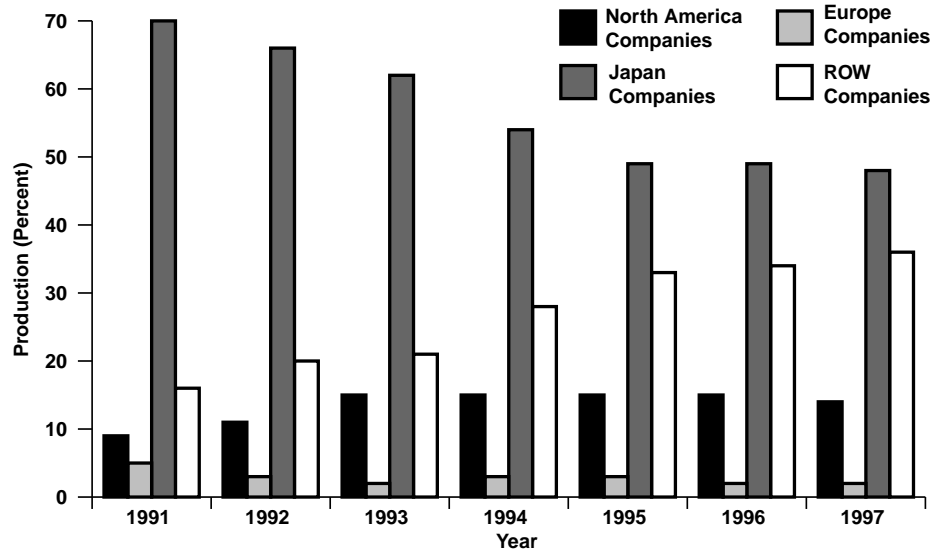


North America	39	40	38	38	37	38	37
Europe	18	18	18	19	19	20	18
Japan	27	20	21	22	21	20	21
ROW	16	22	23	21	23	22	24

Source: ICE, "Memory 1996"

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Figure 2-24. Regional DRAM Consumption (Percent)



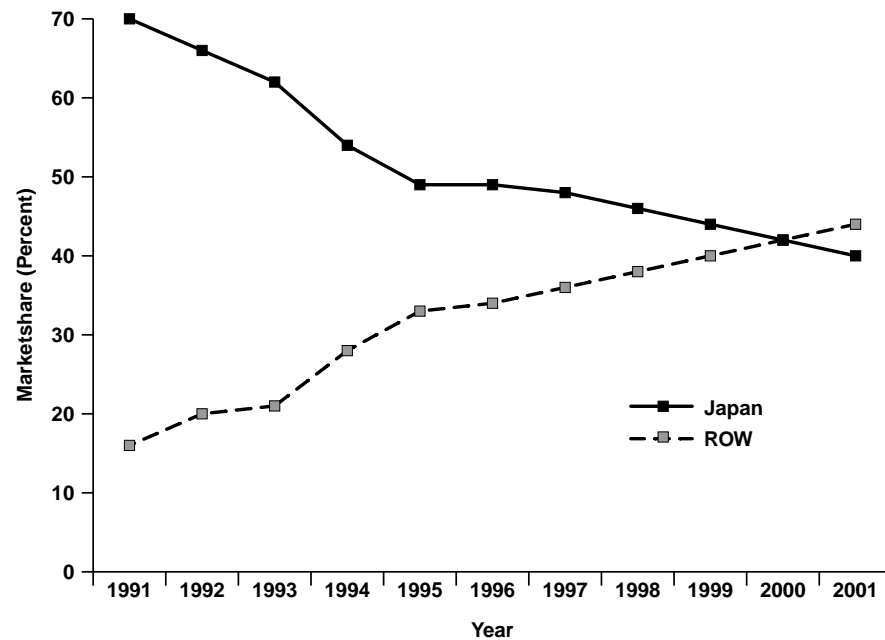
North America	9	11	15	15	15	15	14
Europe	5	3	2	3	3	2	2
Japan	70	66	62	54	49	49	48
ROW	16	20	21	28	33	34	36

Source: ICE, "Memory 1996"

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Figure 2-25. Regional DRAM Production (Percent)

Projecting out current trends in production through the year 2001, it appears that ROW-based manufacturers could very well be supplying a greater percentage of DRAMs to the worldwide market than their Japanese counterparts (Figure 2-26). Equally-efficient manufacturing prowess, generally lower labor costs, and a market clamoring for electronic goods are factors that will contribute to the growth in DRAM production by the ROW suppliers.



Japan	70	66	62	54	49	49	48	46	44	42	40
ROW	16	20	21	28	33	34	36	38	40	42	44

Source: ICE, "Memory 1996"

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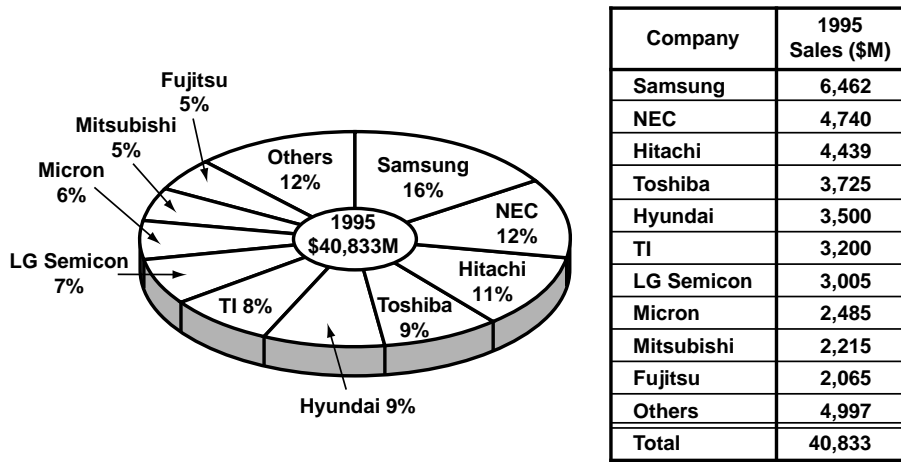
Figure 2-26. ROW to Overtake Japan in DRAM Production

Another interesting note was the increased output from North American DRAM producers. After reaching a low point (nine percent) in 1991, it grew to 15 percent in 1995.

DRAM Sales Leaders

Shown in Figure 2-27 are the leading DRAM suppliers for 1995. Those companies on the list are typically very solid from a financial standpoint and very advanced in terms of design and manufacturing.

Leading the list was Samsung, which came a long way in a relatively short period of time to take command of the huge DRAM market. It is easily the world's leading supplier of DRAMs and shows no sign of relinquishing that position. Its DRAM research and development activity pushes the technology envelope.



Source: ICE, "Memory 1996"

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Figure 2-27. 1995 DRAM Sales Leaders

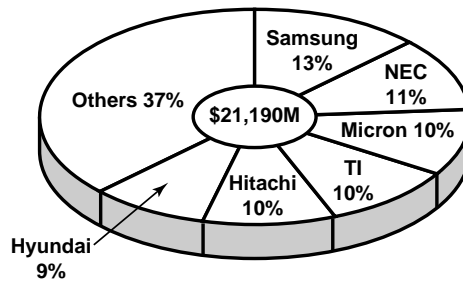
Likewise, NEC is at the forefront of design and manufacturing development in the DRAM industry. Through the 1990's, it followed an aggressive path of investing in fabrication facilities worldwide that helped it achieve global influence in the memory IC market. Showing its ability to quickly meet market demands, NEC announced that in 1Q96, 50 percent of its 4Mbit DRAM output was for EDO versions.

Toshiba also began sampling 4Mbit EDO DRAMs in 4Q95. Volume shipment of its devices were slated to start in 1Q96.

4Mbit DRAMs

The top suppliers of 4Mbit DRAMs in 1995 and an estimate of leaders for 1996 are shown in Figures 2-28 and 2-29. In 1995, vendors cashed in on the voracious appetite of OEMs to use 4Mbit devices in their systems. Samsung, though directing its focus on the 16Mbit generation, enjoyed another outstanding year of 4Mbit DRAM sales. The other two large Korean DRAM manufacturers, LG Semicon and Hyundai, substantially increased their overall sales and became greater forces in the DRAM market with the 4Mbit generation.

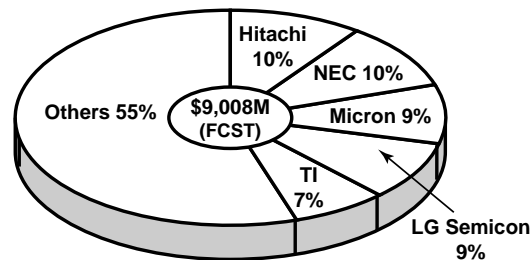
Meanwhile, NEC, Hitachi, and Toshiba performed well in this market segment during 1995. These and other Japanese manufacturers squeezed out every last bit of capacity to produce 4Mbit parts. U.S. manufacturers TI and Micron were also among the top five suppliers of 4Mbit DRAMs in 1995. These two companies accounted for nearly all of the 1995 North American DRAM marketshare (15 percent).



Source: ICE, "Memory 1996"

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Figure 2-28. 1995 Leading 4Mbit DRAM Suppliers



Source: ICE, "Memory 1996"

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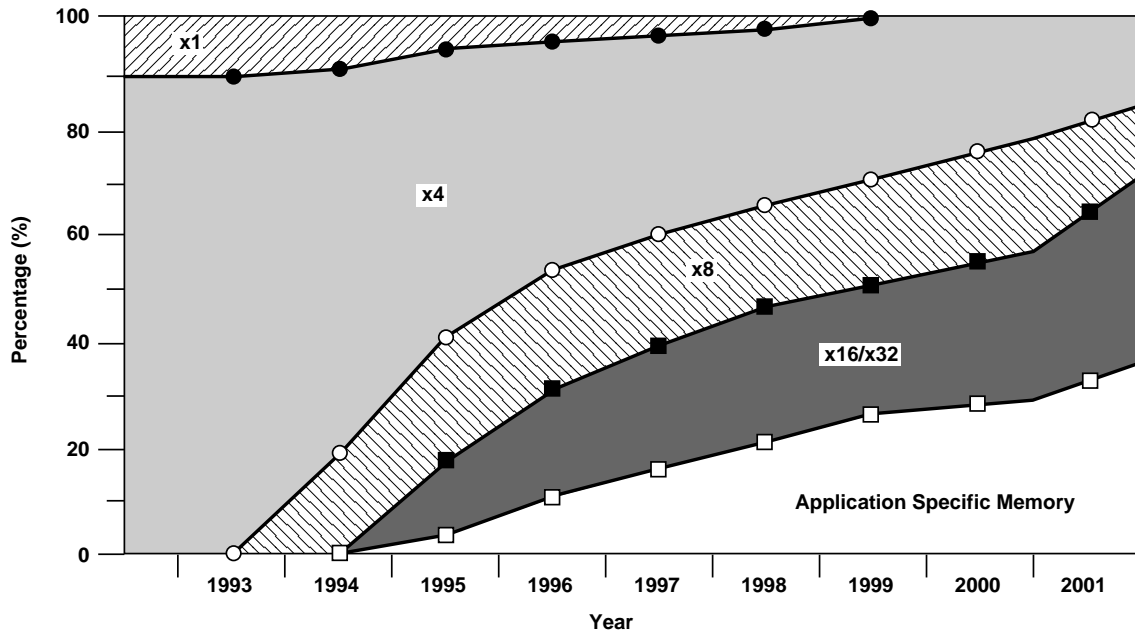
Figure 2-29. 1996 Leading 4Mbit DRAM Suppliers

For 1996, it appears the leading DRAM suppliers will all dramatically reduce their output of 4Mbit devices. The "big five" suppliers from Japan experienced their first decline of 4Mbit shipments in 1Q96. Together, these five companies have planned to decrease 4Mbit output by approximately 33 percent in 1996. Though there remains plenty of demand for 4Mbit DRAM devices, the market is quickly shifting to the 16Mbit generation.

16Mbit DRAMs

The move to 16Mbit DRAMs accelerated in 1995. Prolonged 4Mbit demand and some early yield problems with 16Mbit devices did not allow the market to escalate quite as quickly as originally forecast. But with factors such as the introduction of Windows95 and 16Mbyte main memory becoming standard in PCs, this generation is poised to move forward.

On the whole, 16Mbit DRAMs remained higher priced on a per-bit basis in 1995 than their 4Mbit predecessors. However, as prices declined for the more popular 1Mbit x 16 and 2Mbit x 8 configurations, 16Mbit demand took a sharp upswing. Greater affordability and availability of the wide configurations helped to jump start this market. Figure 2-30 provides an indication of the organizational trends of 16Mbit DRAMs. The graph shows that in 1996, about half of all 16Mbit devices will be organized as x8, x16/x32, or be one of application-specific DRAMs discussed earlier.

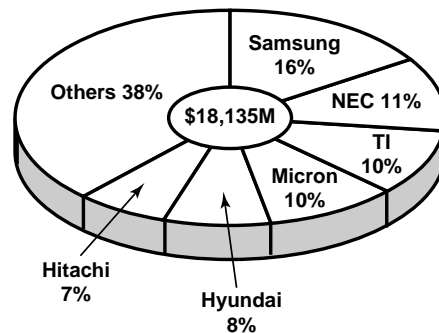


Source: Mitsubishi/ICE, "Memory 1996"

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Figure 2-30. Organization Trend of 16Mbit DRAM

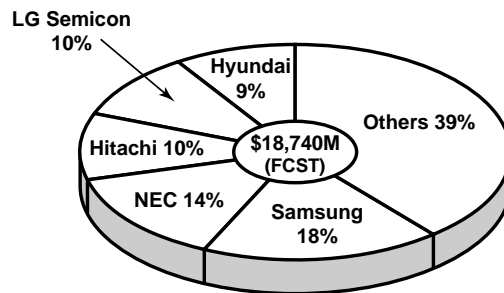
Whether manufacturers of conventional or specialty devices, Figures 2-31 and 2-32 show the leading 16Mbit DRAM suppliers of 1995 and an estimate of 1996 leaders. Samsung established an early lead in this market segment. Samsung ramped down its production of 4Mbit DRAMs in early 1995 and increased its level of 16Mbit production throughout the year. With prices of 16Mbit devices dropping, Samsung has already accelerated production of its 64Mbit products.



Source: ICE, "Memory 1996"

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Figure 2-31. 1995 Leading 16Mbit DRAM Suppliers



Source: ICE, "Memory 1996"

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Figure 2-32. 1996 Leading 16Mbit DRAM Suppliers

Led by NEC, Japan's top five DRAM manufacturers expect to triple their collective 16Mbit output in 1996. NEC is determined to match Samsung's aggressive 16Mbit DRAM schedule. It plans to switch all its U.S. fabs to 16Mbit production by the end of the year. In addition, the ramp up of 16Mbit DRAM production in Japan and Scotland was moved up three months. The new lines will begin production in 3Q96.

In 1995, NEC targeted 65 percent of its DRAM business to PC main memory in the U.S. alone. The company anticipates digital set-top boxes as the memory application to watch in 1996.

Mitsubishi planned to start 16Mbit synchronous DRAM production with x4, x8, and x16 configurations in 2Q96. Matsushita, citing the fact that DRAMs are critical to its communication business, also planned to begin 16Mbit production in 2Q96. Matsushita plans to invest \$4 billion through the year 2000 on DRAM facilities and equipment.

Siemens hopes to be among the leading 16Mbit DRAM suppliers soon after it opens and ramps production at its new 200mm wafer fab in Dresden in 1H96. The facility will make 16Mbit and, later, 64Mbit DRAMs.

Taiwan's UMC planned to initiate 16Mbit production in 2Q96, while Winbond will produce 16Mbit devices under a license from Toshiba. It expects to build a 30,000 (200mm) wafer-per-month fab outside Taipei by April, 1997 for the production of its DRAMs.

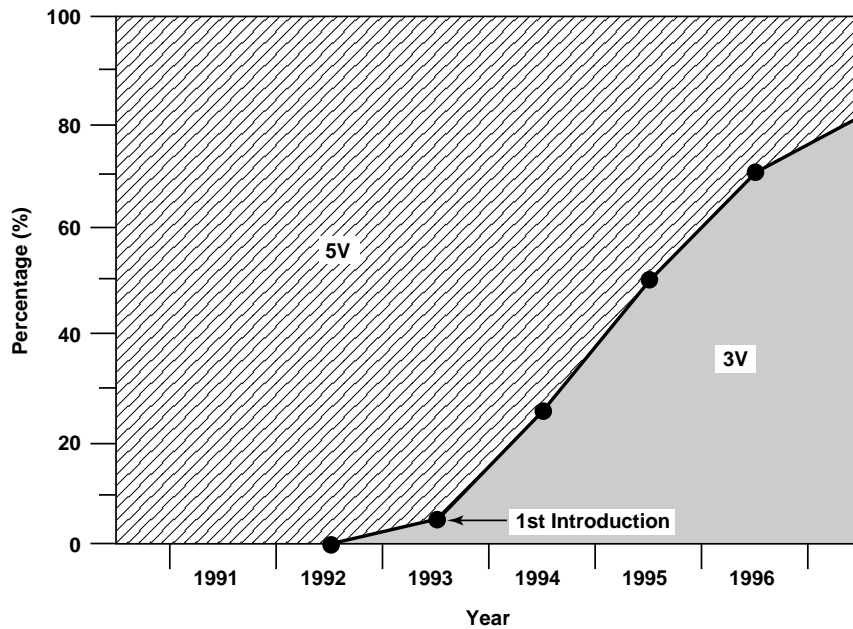
Noting the success of companies (and countries) with a strong DRAM manufacturing base (especially during the past several years), other Taiwan-based firms established their own DRAM manufacturing plans.

Among the companies making plans were Taiwan's Vanguard International Semiconductor Corp., a new company based in Hsinchu. Beginning in 1995, it made 4Mbit and 16Mbit DRAMs on a small scale. Also, Nan Ya Plastics Corp., Taiwan's largest

printed circuit board manufacturer, started producing high-density DRAMs in late 1995 as part of a technology agreement with Oki Semiconductor. Further, a group headed by Taiwan's Elitegroup Computer Systems Co. Ltd. said it would spend approximately \$800 million to build a 200mm wafer fab and enter into the 16Mbit DRAM market beginning in 1996 or 1997. Lastly, Tatung Company, one of Taiwan's largest consumer electronic businesses, hopes to be in production of 16Mbit and 64Mbit DRAM with a joint-venture partner in 1996 or 1997.

Additional company and product highlights surrounding the 16Mbit DRAM market are listed below.

Projected volume increases, as well as manufacturing cost savings, resulted in there being little or no premium charged for 3V 16Mbit DRAMs compared with 5V 16Mbit devices at the end of first quarter 1996. 3V price reductions, averaging about 10 to 15 percent, will encourage the rapid conversion of PC main memory to pure 3V systems. The trend for low-voltage 16Mbit DRAMs is shown in Figure 2-33.



Source: Mitsubishi/ICE, "Memory 1996"

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Figure 2-33. Low Voltage Trends of 16Mbit DRAM

Fujitsu

Fujitsu initiated 0.35µm 16Mbit DRAM production at its Iwate plant. The new line will be able to produce 200mm wafers using a 0.5µm process. Meanwhile, citing uncertainty in the memory IC market, Fujitsu postponed the launch of 16Mbit DRAM production from its Durham, UK fab until 1998.

Hyundai

Hyundai's 1996 DRAM plans call for it to build 16Mbit EDO and burst EDO DRAMs as a way to bridge the performance and price chasm between memory devices and the CPUs they serve. Hyundai will keep synchronous DRAMs (SDRAMs) on the back burner until later in 1996 while it feeds the market with beefed-up conventional DRAMs.

Kobe Steel

Kobe Steel ceased 4Mbit DRAM production in 2H95, shifting all its production over to 16Mbit DRAMs.

Mitsubishi

Mitsubishi completed construction of its 16Mbit DRAM production line at the Kumamoto facility. The company plans to install 0.4 μ m processing equipment to build 1.5-2.0 million units/month on 200mm wafers.

Mitsubishi also started construction on a 16Mbit DRAM line at its subsidiary in Germany. The new 0.35 μ m line is scheduled for operation in 1Q97 and will have a monthly output of 1.5 million units. Mitsubishi became the fourth Japanese chip maker to have a 16Mbit DRAM wafer processing facility in Europe.

NEC

At end of 1995, about 75 percent of NEC's 16Mbit DRAM shipments were configured 1Mbit x 16 and 2Mbit x 8. The other 25 percent were configured in a 4Mbit x 4 architecture.

NEC's Kyushu facility will supply 4.0 million 16Mbit units per month in 1996, while its Roseville, California, plant is expected to supply 3.5 million 16Mbit units per month. Hiroshima will add another 2.5 million devices and two other facilities will supply additional production.

NEC developed a super-small 16Mbit DRAM chip using the 0.25 μ m CMOS process that it used to develop a 1Gbit DRAM prototype. It will sample the 16Mbit chip in 1H96 and start production of the small chips in 2H96.

Nippon Steel

Nippon Steel Semiconductor plans to invest approximately \$410 million to complete a new 0.35 μ m, 200mm wafer fab for 16Mbit DRAM production in June 1997.

Oki

Oki will invest \$700 million to build a 16Mbit/64Mbit DRAM production facility in the U.S. The 0.35 μ m 200mm wafer processing line will be located in Oregon.

Tohoku

Tohoku Semiconductor (Toshiba-Motorola joint venture) completed construction of a new 0.5 μ m, 200mm wafer fabrication facility for 16Mbit DRAMs in Sendai, Japan. At full capacity (1996), the facility will be able to produce 3.0 million units per month.

Toshiba

Toshiba announced the availability of its 60ns and 70ns 16Mbit DRAMs featuring a x32 organization. The wide organization will be useful as a low-power, high-performance solution for embedded applications including printers and set-top boxes.

Twinstar Semiconductor

Twinstar Semiconductor, the TI-Hitachi joint-venture DRAM company, installed chip-making equipment in February, 1996. It scheduled initial 16Mbit DRAM production from the Dallas, Texas, facility for May, 1996.

64Mbit DRAMs

While the 16Mbit DRAM is in the growth stages of its lifecycle, always forward-looking IC suppliers are already planning their 64Mbit DRAM volume production strategies. The market's first 64Mbit DRAM engineering samples, fabricated in 0.32 μ m processes, emerged from DRAM leaders NEC and Samsung in 2Q95. Each company shipped several units to workstation, server, and mainframe-computer makers. In the second half of 1995, NEC Kyushu produced sample quantities on its newest line, while Samsung's third 200mm line increased 64Mbit DRAM output in 4Q95.

Figure 2-34 shows various characteristics of 64Mbit DRAMs that ICE analyzed in 1995. All of the devices operated at 3V. Nearly all vendors agree that 64Mbit market acceptance will be determined by granularity. Following the bungled granularity issue at the 16Mbit level (vendors delivering x1 and x4 products, but customers wanting x8 and x16 parts), suppliers have taken extra steps to deliver 64Mbit products to match the needs of the market. Presently, most chip makers believe their 64Mbit devices will be readily accepted in the 4Mbit x 16 and 2Mbit x 32 configurations.

Hitachi	Die Size: 445 mils x 800 mils = 356K mils ² Feature Size: 0.35 μ m Memory Cell Area: 0.9 μ x 1.8 μ = 1.62 μ ² Package: 34-pin 500 mil plastic SOJ
Mitsubishi	Die Size: 416 mils x 810 mils = 337K mils ² Feature Size: 0.35 μ m Memory Cell Area: 0.9 μ x 1.8 μ = 1.62 μ ² Package: 34-pin 500 mil plastic SOJ
Samsung	Feature Size: 0.32 μ m Access Time: 50ns or 60ns Package: 34-pin 400 mil plastic TSOP or SOJ
NEC	Die Size: 251K mils ² Feature Size: 0.35 μ m Package: 34-pin 400 mil plastic SOJ
Fujitsu	Die Size: 360K mils ² Feature Size: 0.35 μ m
Micron	Die Size: 272K mils ² Feature Size: 0.35 μ m Access Time: 60ns

Source: ICE, "Memory 1996"

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Figure 2-34. Sampling of 64Mbit DRAM Devices

Taiwanese companies want to play a significant role in the 64Mbit DRAM market and have laid out plans to begin production of these parts. For instance, Mosel-Vitellic announced that its 64Mbit production would start in 1997 or early 1998. The company would like to develop its own 64Mbit design. However, it has negotiated with Siemens and other parties to form a DRAM alliance. Under the proposed plan, Siemens would transfer 64Mbit DRAM technology in exchange for foundry capacity and a possible 30 percent equity stake in Mosel-Vitellic.

The announcement followed similar plans described by Powerchip Semiconductor, Nan Ya Technology Corporation, Vanguard International Semiconductor Corporation (VISC), and TI-Acer (Figure 2-35).

Highlights from the 64Mbit DRAM market are shown below.

- Based on a preliminary survey of DRAM manufacturers, production costs for 64Mbit DRAMs will be about three times higher than the cost of producing 4Mbit chips due to the higher integration levels.

- Fujitsu announced its synchronous 64Mbit DRAM. The move puts the company among the leaders in the competition for high-density SDRAMs. The 3V, 100MHz device is fabricated using 0.35 μ m CMOS technology. The company plans to bypass the conventional 64Mbit DRAM market in favor of the faster and more profitable synchronous market.
- IBM demonstrated its 32Mbyte small outline dual-in-line memory module (SO DIMM) using 64Mbit DRAMs in the IBM ThinkPad 701C notebook computer. The 32Mbyte SO DIMM allows expanded memory capacity without increasing system board size. Several thousand 64Mbit DRAM units a month are coming off the pilot production line at IBM's Advanced Semiconductor Technology Center in New York.
- NEC plans to construct Europe's first 64Mbit DRAM plant at a cost of over \$800 million. It will be built next to NEC's current facilities in Scotland and will initially produce 10,000 200mm wafers per month. Plans call for the eventual output of 20,000 wafers per month.
- Rambus announced that its Rambus DRAM licensees—Hitachi, LG Semicon, NEC, Oki, Samsung, and Toshiba—have developed 64Mbit Rambus DRAM (RDRAM). The 64Mbit RDRAMs are aimed at the main-memory market, where high bandwidth is necessary but not yet sufficient.

Company	Design Development	First Shipments	Comments
Mosel-Vitelic	Wants to develop its own 64Mbit design. Negotiating with Siemens for added 64Mbit technology.	4Q97/1Q98	—
Nan Ya Technology	Joint-development with Oki	1997	Will sell DRAMs under its own logo, but with technology licensed from Oki. Building its initial 200mm wafer fab near Taipei.
Powerchip Semiconductor	DRAM design/technology assistance from Mitsubishi	4Q96/1Q97	Japan's Mitsubishi and Kanematsu have one-third ownership in Powerchip.
TI-Acer	Designs from TI, manufacturing from Acer	1997	TI sells the output under its own logo. Spending \$1.2 billion to build a 64M DRAM fab in Taipei. Operations are due to begin in the spring of 1997.
Vanguard International	Joint-development with Mitsubishi	1997	Formerly government sponsored Industrial Technology Research Institute. First Taiwan-based company to develop and show a fully functional 64Mbit DRAM. The part was made using a 0.4 μ m process.

Source: ICE, "Memory 1996"

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Figure 2-35. Taiwan's Ambitious 64Mbit DRAM Plans

1Gbit DRAMs

Work has started toward the design, development, and manufacturing of 1Gbit DRAMs. Some leading DRAM companies have demonstrated bits and pieces of a potential 1Gbit structure, but there remains much work to do before devices will be available.

Samsung completed a prototype circuit design for a 1Gbit synchronous DRAM. It hopes to sample chips in 1997. Fabricated using a 0.16 μ m process, the 500-square-millimeter IC was designed for low power consumption and features a redundancy scheme to fix failing bits, which should make the devices easier to mass produce.

Perhaps the greatest effort to produce 1Gbit devices so far is a joint-development team involving four of the world's leading IC manufacturers—IBM, Motorola, Siemens, and Toshiba. Together, the companies will pool their considerable resources to bring 1Gbit DRAMs to market (if only in sample form) by the year 2000. Mass production of the devices may take more time. Improved—even new—manufacturing techniques remain a point of concern.

The alliance points out that larger companies are willing to work together to protect their own interests. Moreover, it shows how costs and risks to produce new-generation chips have escalated. But for the four firms, the potential rewards are extremely attractive.