Microcomponents *Worldwide*

Source: Dataquest

Dataquest

Dataquest Incorporated
1290 Ridder Park Drive
San Jose, CA 95131-2398
(408) 437-8000
Telex: 171973
Fax: (408) 437-0292

United Kingdom
Dataquest UK Limited
Roussel House,
Broadwater Park
Denham, Nr Uxbridge,
Middx UB9 5HP
England
0895-835050
Telex: 266195
Fax: 0895 835260-1-2

France
Dataquest Europe SA
Tour Galliéni 2
36, avenue du Général-de-Gaulle
93175 Bagnolet Cedex
France
(1)48 97 31 00
Telex: 233 263
Fax: (01)48 97 34 00

Germany
Dataquest GmbH
Kronstadter Strasse 9
8000 Munich 80
West Germany
011 49 89 93 09 09 0
Fax: 011 49 89 930 3277

Japan
Dataquest Japan Limited
Shinkawa Sanko Building 2 Fl
1-3-17 Shinkawa
Chuo-kuTokyo 104
Japan
011-81-3-5566-0411
Telex: 781-32768
Fax: 011-81-3-5566-0425

Korea
Dataquest Korea
Dacheung Building Room 1105
648-23 Yorksam-dong
Kangnam-gu, Seoul 135-80
Korea
011-82-2-552-2332
Fax: 011-82-2-552-2661

Dataquest Incorporated
Ledgeway/Dataquest
The Corporate Center
550 Cochituate Road
Framingham, MA 01701
(508) 370-5555
Fax: (508) 370-6262

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Market Statistics

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Microprocessor Market Statistics
1990

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1990

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Notes to Market Share Tables

1. Mitsubishi's unit shipments for 1989 have been restated.
2. The following products have been added to the 1989 tables:
   - Performance's R2000
   - Zilog's Z1600
3. The following abbreviations have been used within the tables:
   - P represents PMOS
   - N represents NMOS
   - C represents CMOS
4. Some table columns do not add to totals shown because of rounding.

Chapter 1

Microprocessor Market Overview

The tables in this section are organized as follows:

Table 1	Estimated Market Share by Word Length for Microprocessors, 1989-1990
Table 2	Estimated Market Share by Manufacturer Base, 1989-1990
Table 3	Estimated Market Share by Process Technology, 1989-1990

Table 1
Estimated Market Share by Word Length, 1989-1990
(Thousands of Units)

Company: All
Product: Microprocessors
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: Word Length

	1989	1990
8-Bit		
Shipments	64,790	74,926
Percent of Total	59.4	58.8
16-Bit		
Shipments	23,964	26,257
Percent of Total	22.0	20.6
16/32-Bit		
Shipments	13,934	17,734
Percent of Total	12.8	13.9
32-Bit		
Shipments	6,357	8,490
Percent of Total	5.8	6.7
Total Shipments	109,045	127,407

NM = Not meaningful

Source: Dataquest (May 1991)

Table 2
Estimated Market Share by Manufacturer Base, 1989-1990
(Thousands of Units)

Company: All
Product: Microprocessors
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: Word Length

	1989	1990
8-Bit Shipments	64,790	74,926
U.S. Companies (%)	48.3	51.9
Japanese Companies (%)	34.5	35.6
European Companies (%)	17.2	12.5
16-Bit Shipments	23,964	26,257
U.S. Companies (%)	67.6	68.7
Japanese Companies (%)	21.3	22.6
European Companies (%)	11.1	8.7
16/32-Bit Shipments	13,934	17,734
U.S. Companies (%)	88.8	88.2
Japanese Companies (%)	9.6	9.5
European Companies (%)	1.6	2.3
32-Bit Shipments	6,357	8,490
U.S. Companies (%)	93.8	92.2
Japanese Companies (%)	3.0	5.0
European Companies (%)	3.2	2.8
Total Shipments	109,045	127,407
U.S. Companies (%)	60.4	63.1
Japanese Companies (%)	26.6	27.2
European Companies (%)	13.0	9.7

NM = Not meaningful

Source: Dataquest (May 1991)

Table 3
Estimated Market Share by Process Technology, 1989-1990
(Thousands of Units)

Company:	All
Product:	Microprocessors
Region of Consumption:	Worldwide
Distribution Channel:	NM
Application:	All
Specification:	Word Length

	1989	1990
8-Bit Shipments	64,790	74,926
Percent NMOS	66.4	61.0
Percent CMOS	33.6	39.0
16-Bit Shipments	23,964	26,257
Percent NMOS	74.3	66.2
Percent CMOS	25.7	33.8
16/32-Bit Shipments	13,934	17,734
Percent NMOS	81.5	68.6
Percent CMOS	18.5	31.4
32-Bit Shipments	6,357	8,490
Percent NMOS	5.4	.0
Percent CMOS	94.5	99.9
Percent Bipolar	.1	.1
Total Shipments	109,045	127,407
Percent NMOS	66.5	59.4
Percent CMOS	33.5	40.6
Percent Bipolar	.0	.0

NM = Not meaningful

Source: Dataquest (May 1991)

Chapter 2

8-Bit Microprocessors

The tables in this section are organized as follows:

Table 1	Estimated Market Share by Manufacturer, 1989-1990
Table 2	Estimated Market Share by Manufacturer Base, 1989-1990
Table 3	Estimated Market Share by Product Type, 1989-1990
Table 4	Estimated Market Share by Instruction Set, 1989-1990
Table 5	Estimated Market Share by Process Technology, 1989-1990
Table 6	Estimated Market Share by Process Technology by Manufacturer Base, 1989-1990
Table 7	Estimated Unit Shipments by Quarter, 1989
Table 8	Estimated Unit Shipments by Quarter, 1990

Table 1
Estimated Market Share by Manufacturer, 1989-1990
(Percentage of Units)

Company:	Each
Product:	Microprocessors
Region of Consumption:	Worldwide
Distribution Channel:	NM
Application:	All
Specification:	8-Bit

Rank 1990	Rank 1989	Companies	Market Share (%) 1989	Market Share (%) 1990
1	1	Zilog	20.9	26.4
2	3	Hitachi	8.9	11.0
3	2	SGS-Thomson	14.1	10.8
4	4	NEC	8.8	9.4
5	6	Intel	7.4	7.7
6	7	Toshiba	6.4	7.6
7	9	AMD	4.0	6.2
8	5	Motorola	8.6	6.1
9	8	Sharp	4.1	3.4
10	10	Oki	3.6	2.9
11	12	Harris	2.2	1.9
12	11	Siemens	3.1	1.8
13	13	California Micro Devices	2.0	1.0
14	16	National	1.1	.9
15	14	Fujitsu	1.6	.8
16	15	Rockwell	1.6	.8
17	17	Mitsubishi	.9	.6
18	18	Texas Instruments	.5	.5
19	20	Hughes	.1	.2
20	19	Matsushita	.2	*
21	22	Sony	*	*
22	21	NCR	*	*
		Total 8-Bit MPUs	100.0	100.0

NM = Not meaningful
*Calculated value is less than 0.1 percent.

Source: Dataquest (May 1991)

Table 2
Estimated Market Share by Manufacturer Base, 1989-1990
(Thousands of Units)

Company:	All
Product:	Microprocessors
Region of Consumption:	Worldwide
Distribution Channel:	NM
Application:	All
Specification:	8-Bit

	1989	1990
U.S. Companies		
Shipments	31,280	38,850
Percent of Total	48.3	51.9
Japanese Companies		
Shipments	22,379	26,680
Percent of Total	34.5	36.6
European Companies		
Shipments	11,131	9,396
Percent of Total	17.2	12.5
Total 8-Bit MPUs	64,790	74,926

NM = Not meaningful

Source: Dataquest (May 1991)

Table 3
Estimated Market Share by Product Type, 1989-1990
(Percentage of Units)

Company: All
Product: Microprocessors
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 8-Bit

	1989	1990
1802	1.3	1.0
1805/06	.9	.6
64180/Z180	7.4	10.9
6502	1.6	.8
6800	.4	.3
68008	1.2	1.2
6802/08	5.4	3.5
6809	7.2	5.3
80188	2.3	3.2
8085	11.5	8.7
8088	9.1	7.9
NSC800	1.1	.9
TMS9995	.5	.5
V20/V40	4.0	5.9
Z80	42.8	44.7
Others	3.5	4.7
Total 8-Bit MPUs	100.0	100.0

NM = Not meaningful

Source: Dataquest (May 1991)

Table 4
Estimated Market Share by Instruction Set, 1989-1990
(Percentage of Units)

Company: All
Product: Microprocessors
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 8-Bit

	Instruction Set	1989	1990
Group 1	Z80, NSC800, 64180	51.4	56.7
Group 2	8085	11.5	8.7
Group 3	6800, 6802/08, 6809	13.0	9.1
Group 4	650X, 65SC8XX	3.6	1.8
Group 5	8088, 80188, V20	16.6	19.5
	Others	4.0	4.2
Total 8-Bit MPUs		100.0	100.0

NM = Not meaningful

Source: Dataquest (May 1991)

Table 5
Estimated Market Share by Process Technology, 1989-1990
(Thousands of Units)

Company: All
Product: Microprocessors
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 8-Bit

	1989	1990
NMOS		
Shipments	43,020	45,672
Percent of Total	66.4	61.0
CMOS		
Shipments	21,770	29,254
Percent of Total	33.6	39.0
Total 8-Bit MPUs	64,790	74,926

NM = Not meaningful

Source: Dataquest (May 1991)

Table 6
Estimated Market Share by Process Technology by Manufacturer Base, 1989-1990
(Percentage of Units)

Company: All
Product: Microprocessors
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 8-Bit

	1989	1990
NMOS		
U.S. Companies	57.5	67.9
Japanese Companies	19.9	14.3
European Companies	22.6	17.8
Total NMOS	100.0	100.0
CMOS		
U.S. Companies	30.2	26.8
Japanese Companies	63.4	68.8
European Companies	6.4	4.4
Total CMOS	100.0	100.0

NM = Not meaningful

Source: Dataquest (May 1991)

Table 7
Estimated Unit Shipments by Quarter, 1989
(Thousands of Units)

Company: Each
Product: Microprocessors
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 8-Bit

	Product	Process	Q1/89	Q2/89	Q3/89	Q4/89	1989
AMD	8085	N	55	51	61	70	237
	8088	N	365	374	538	540	1,817
	80188	N	148	138	117	120	523
California Micro Devices	65SC802	C	2	4	8	7	21
	65SC816	C	128	135	143	140	546
	65SCXX	C	163	175	187	185	710
Fujitsu	6802	N	45	45	45	45	180
	6809	N	80	80	80	80	320
	8088	N	90	100	110	100	400
	80C88	C	15	15	15	15	60
	80188	N	18	20	22	24	84
Harris	1802	C	200	175	182	197	754
	1805/06	C	231	147	124	87	588
	80C88	C	10	10	33	18	71
Hitachi	6309	C	18	20	23	22	83
	64180	C	800	900	1,000	1,050	3,750
	6800	N	12	12	12	12	48
	6802	N	260	260	270	260	1,050
	6809	N	200	210	225	220	855
Hughes	1802	C	15	18	22	25	80
Intel	8085	N	500	470	440	400	1,810
	8088	N	210	185	140	100	635
	80C88	C	180	160	180	185	705
	80188	N	200	210	175	200	785
	80C188	C	120	150	220	340	830
Matsushita	146802	C	70	80	0	0	150
Mitsubishi	8085	N	120	80	90	80	370
	80C85	C	64	60	60	46	230
Motorola	6800	N	60	50	31	30	171
	6802/08	N	400	348	500	568	1,816
	6809	N	610	728	750	850	2,938
	68008	N	155	165	175	170	665
National	NSC800	C	195	170	130	196	691
NCR	65C02	C	0	0	1	1	2

(Continued)

Table 7 (Continued)
Estimated Unit Shipments by Quarter, 1989
(Thousands of Units)

	Product	Process	Q1/89	Q2/89	Q3/89	Q4/89	1989
NEC	8085	N	480	485	400	390	1,755
	8088	N	20	20	10	10	60
	V20/V40	C	430	440	800	900	2,570
	Z80	N	60	80	100	90	330
	Z80C	C	250	250	240	230	970
Oki	80C85	C	440	450	420	340	1,650
	80C88	C	115	120	200	230	665
Rockwell	6502	N	150	150	145	140	585
	65C02	C	50	200	105	85	440
SGS-Thomson	6800	N	2	6	1	0	9
	6802	N	71	123	94	47	335
	6809	N	127	160	132	102	521
	68008	N	18	21	29	35	103
	Z80	N	1,961	1,981	1,472	1,353	6,767
	Z80C	C	309	330	416	335	1,390
Sharp	V20	C	7	8	9	9	33
	Z80	N	585	560	540	530	2,215
	Z80C	C	90	100	110	100	400
Siemens	8085	N	130	150	110	80	470
	8088	N	373	363	365	360	1,461
	80188	N	15	20	20	20	75
Sony	V20	C	0	0	0	1	1
Texas Instruments	TMS9995	N	95	75	75	75	320
Toshiba	8085	N	300	300	200	100	900
	Z80C	C	950	800	800	700	3,250
Zilog	Z80	N	2,890	3,150	3,240	3,130	12,410
	Z180	C	173	266	308	315	1,062
	Z280	C	15	16	17	20	68
Total 8-Bit MPUs			15,845	16,369	16,467	16,110	64,790

NM = Not meaningful

Source: Dataquest (May 1991)

Table 8
Estimated Unit Shipments by Quarter, 1990
(Thousands of Units)

Company: Each
Product: Microprocessors
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 8-Bit

	Product	Process	Q1/90	Q2/90	Q3/90	Q4/90	1990
AMD	8085	N	80	110	130	160	480
	8088	N	600	700	800	900	3,000
	80188	N	150	250	350	450	1,200
California Micro Devices	65SC802	C	5	4	3	3	15
	65SC816	C	11	18	33	20	82
	65SCXX	C	144	153	160	160	617
Fujitsu	6802	N	30	30	10	10	80
	6809	N	60	60	50	50	220
	8088	N	50	30	25	20	125
	80C88	C	35	35	30	30	130
	80188	N	25	22	10	10	67
Harris	1802	C	123	128	151	175	577
	1805/06	C	106	99	98	120	423
	6805	N	93	99	47	34	273
	80C88	C	23	49	16	60	148
Hitachi	6309	C	50	80	160	160	450
	64180	C	1,100	1,500	1,700	1,800	6,100
	6800	N	10	10	0	0	20
	6802	N	240	200	220	250	910
	6809	N	220	220	160	160	760
Hughes	1802	C	35	45	50	50	180
Intel	8085	N	400	435	445	450	1,730
	8088	N	125	130	125	120	500
	80C88	C	170	165	150	140	625
	80188	N	200	215	375	300	1,090
	80C188	C	350	400	450	650	1,850
Mitsubishi	8085	N	85	75	60	50	270
	80C85	C	30	35	40	40	145
Motorola	6800	N	41	49	55	67	212
	6802/08	N	400	315	285	260	1,260
	6809	N	582	599	615	621	2,417
	68008	N	170	175	180	180	705
National	NSC800	C	150	135	190	170	645

(Continued)

Table 8 (Continued)
Estimated Unit Shipments by Quarter, 1990
(Thousands of Units)

	Product	Process	Q1/90	Q2/90	Q3/90	Q4/90	1990
NEC	8085	N	350	330	320	310	1,310
	8088	N	10	10	10	10	40
	V20/V40	C	1,000	1,050	1,100	1,200	4,350
	Z80	N	90	100	90	90	370
	Z80C	C	230	220	240	250	940
Oki	80C85	C	440	380	380	390	1,590
	80C88	C	130	130	140	160	560
Rockwell	6502	N	50	50	51	50	201
	65C02	C	120	100	121	55	396
SGS-Thomson	6802	N	68	57	63	170	358
	6809	N	127	170	110	154	561
	68008	N	33	34	46	48	161
	Z80	N	1,461	1,656	1,553	1,024	5,694
	Z80C	C	353	358	311	263	1,285
Sharp	V20	C	10	13	15	15	53
	Z80	N	510	500	450	410	1,870
	Z80C	C	120	140	160	180	600
Siemens	8085	N	110	116	115	150	491
	8088	N	310	237	180	50	777
	80188	N	22	19	18	10	69
Texas Instruments	TMS9995	N	75	95	130	110	410
Toshiba	8085	N	150	150	120	100	520
	Z80C	C	1,000	1,200	1,500	1,500	5,200
Zilog	Z80	N	3,953	4,423	4,545	4,600	17,521
	Z180	C	464	500	535	555	2,054
	Z280	C	30	54	66	89	239
Total 8-Bit MPUs			17,109	18,662	19,542	19,613	74,926

NM = Not meaningful

Source: Dataquest (May 1991)

Chapter 3

16-Bit Microprocessors

The tables in this section are organized as follows:

Table 1	Estimated Market Share by Manufacturer, 1989-1990
Table 2	Estimated Market Share by Manufacturer Base, 1989-1990
Table 3	Estimated Market Share by Product Type, 1989-1990
Table 4	Estimated Market Share by Instruction Set, 1989-1990
Table 5	Estimated Market Share by Process Technology, 1989-1990
Table 6	Estimated Market Share by Process Technology by Manufacturer Base, 1989-1990
Table 7	Estimated Unit Shipments by Quarter, 1989
Table 8	Estimated Unit Shipments by Quarter, 1990

Table 1
Estimated Market Share by Manufacturer, 1989-1990
(Percentage of Units)

Company: Each
Product: Microprocessors
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 16-Bit

Rank 1990	Rank 1989	Companies	Market Share (%) 1989	Market Share (%) 1990
1	1	Intel	39.2	35.6
2	2	AMD	23.5	23.8
3	3	NEC	11.2	15.1
4	4	Siemens	7.2	6.3
5	7	Harris	2.9	5.6
6	6	Oki	3.7	3.8
7	9	Zilog	1.7	3.5
8	5	SGS-Thomson	4.0	2.4
9	8	Fujitsu	1.8	1.9
10	12	Matsushita	1.2	1.2
11	11	Toshiba	1.4	.3
12	13	Sharp	.4	.3
13	15	Performance	.1	.1
14	17	National	*	.1
15	10	Hitachi	1.5	*
16	14	Microchip Technology	.2	*
17	18	Mitsubishi	*	*
18	16	Sony	*	*
		Total 16-Bit MPUs	100.0	100.0

NM = Not meaningful
*Calculated value is less than 0.1 percent.

Source: Dataquest (May 1991)

Table 2
Estimated Market Share by Manufacturer Base, 1989-1990
(Thousands of Units)

Company: All
Product: Microprocessors
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 16-Bit

	1989	1990
U.S. Companies		
Shipments	16,188	18,030
Percent of Total	67.6	68.7
Japanese Companies		
Shipments	5,106	5,939
Percent of Total	21.3	22.6
European Companies		
Shipments	2,670	2,288
Percent of Total	11.1	8.7
Total 16-Bit MPUs	23,964	26,257

NM = Not meaningful

Source: Dataquest (May 1991)

Table 3
Estimated Market Share by Product Type, 1989-1990
(Percentage of Units)

Company: All
Product: Microprocessors
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 16-Bit

	1989	1990
80186	14.0	16.3
80286	48.8	49.6
8086	16.1	11.5
V30/33/50	10.7	14.8
Z8000	7.4	6.4
Others	3.0	1.4
Total 16-Bit MPUs	100.0	100.0

NM = Not meaningful

Source: Dataquest (May 1991)

Table 4
Estimated Market Share by Instruction Set, 1989-1990
(Percentage of Units)

Company: All
Product: Microprocessors
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 16-Bit

	Instruction Set	1989	1990
Group 1	9900/80	*	*
Group 2	CP1600	.2	*
Group 3	Z8000	7.4	6.4
Group 4	8086, 80186, 80286, V30	89.6	92.2
	Others	2.8	1.4
Total 16-Bit MPUs		100.0	100.0

NM = Not meaningful
*Calculated value is less than 0.1 percent.

Source: Dataquest (May 1991)

Table 5
Estimated Market Share by Process Technology, 1989-1990
(Thousands of Units)

Company: All
Product: Microprocessors
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 16-Bit

	1989	1990
NMOS		
Shipments	17,817	17,390
Percent of Total	74.3	66.2
CMOS		
Shipments	6,147	8,867
Percent of Total	25.7	33.8
Total 16-Bit MPUs	23,964	26,257

NM = Not meaningful

Source: Dataquest (May 1991)

Table 6
Estimated Market Share by Process Technology by Manufacturer Base, 1989-1990
(Percentage of Units)

Company: All
Product: Microprocessors
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 16-Bit

	1989	1990
NMOS		
U.S. Companies	79.7	81.2
Japanese Companies	5.3	5.6
European Companies	15.0	13.2
Total NMOS	100.0	100.0
CMOS		
U.S. Companies	32.3	44.0
Japanese Companies	67.7	56.0
European Companies	.0	.0
Total CMOS	100.0	100.0

NM = Not meaningful

Source: Dataquest (May 1991)

Table 7
Estimated Unit Shipments by Quarter, 1989
(Thousands of Units)

Company: Each
Product: Microprocessors
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 16-Bit

	Product	Process	Q1/89	Q2/89	Q3/89	Q4/89	1989
AMD	80186	N	170	200	142	165	677
	80286	N	700	1,000	1,206	1,442	4,348
	8086	N	120	165	145	162	592
	Z8000	N	2	1	1	1	5
Fujitsu	80186	N	45	45	45	45	180
	80286	N	22	25	28	32	107
	8086	N	30	33	36	40	139
Harris	80C286	C	140	194	135	191	660
	80C86	C	13	10	8	6	37
Hitachi	HD641016	C	80	85	90	110	365
Intel	80186	N	400	330	300	315	1,345
	80C186	C	120	170	270	370	930
	80286	N	1,500	1,420	1,360	1,320	5,600
	80C286	C	75	75	75	75	300
	8086	N	410	325	250	190	1,175
	80C86	C	10	8	12	15	45
Matsushita	MN1610/13	N	70	70	70	70	280
Microchip Technology	CP1600	N	46	0	0	0	46
Mitsubishi	8086	N	1	1	2	0	4
National	9445	N	1	1	0	0	2
	9450	N	2	1	2	3	8
NEC	V33	C	3	3	9	9	24
	V30/V50	C	390	430	800	900	2,520
	8086	N	40	50	30	30	150
Oki	80C86	C	150	230	230	280	890
Performance	PACE 1750	C	2	3	3	4	12
SGS-Thomson	Z8000	N	261	212	242	236	951
Sharp	V30	C	5	5	6	6	22
	Z8000	N	25	22	20	17	84
Siemens	80186	N	67	50	45	55	217
	80286	N	187	162	165	170	684
	8086	N	250	318	150	100	818
Sony	V30	C	0	0	0	1	1
Toshiba	Z8000	C	110	100	70	60	340

(Continued)

Table 7 (Continued)
Estimated Unit Shipments by Quarter, 1989
(Thousands of Units)

	Product	Process	Q1/89	Q2/89	Q3/89	Q4/89	1989
Zilog	Z1600	C	0	0	0	1	1
	Z8000	N	74	96	115	120	405
Total 16-Bit MPUs			5,521	5,840	6,062	6,541	23,964

NM = Not meaningful

Source: Dataquest (May 1991)

Table 8
Estimated Unit Shipments by Quarter, 1990
(Thousands of Units)

Company: Each
Product: Microprocessors
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 16-Bit

	Product	Process	Q1/90	Q2/90	Q3/90	Q4/90	1990
AMD	80186	N	180	200	180	200	760
	80286	N	1,350	1,250	1,150	1,025	4,775
	8086	N	160	170	180	190	700
	Z8000	N	2	2	2	2	8
Fujitsu	80186	N	45	45	30	30	150
	80286	N	50	50	40	40	180
	8086	N	42	46	40	40	168
Harris	80C286	C	238	373	354	475	1,440
	80C86	C	9	9	11	10	39
Intel	80186	N	310	300	350	350	1,310
	80C186	C	370	380	500	700	1,950
	80286	N	1,300	1,270	1,250	1,200	5,020
	80C286	C	90	95	95	90	370
	8086	N	180	160	145	135	620
	80C86	C	15	15	18	22	70
Matsushita	MN1610/13	N	80	80	80	80	320
National	9445	N	1	1	0	0	2
	9450	N	2	3	4	6	15
NEC	V33	C	10	12	15	20	57
	V30/V50	C	800	900	1,000	1,100	3,800
	8086	N	30	30	20	20	100
Oki	80C86	C	290	170	270	280	1,010
Performance	PACE 1750	C	5	6	6	5	22
SGS-Thomson	Z8000	N	141	145	196	140	622
Sharp	V30	C	6	8	8	8	30
Sharp	Z8000	N	15	15	12	12	54
Siemens	80186	N	20	19	49	25	113
	80286	N	260	290	338	340	1,228
	8086	N	87	88	50	100	325
Toshiba	Z8000	C	30	20	10	10	70
Zilog	Z1600	C	1	2	3	3	9
	Z8000	N	150	220	265	285	920
Total 16-Bit MPUs			6,269	6,374	6,671	6,943	26,257

NM = Not meaningful

Source: Dataquest (May 1991)

Chapter 4

16/32-Bit Microprocessors

The tables in this section are organized as follows:

Table 1	Estimated Market Share by Manufacturer, 1989-1990
Table 2	Estimated Market Share by Manufacturer Base, 1989-1990
Table 3	Estimated Market Share by Product Type, 1989-1990
Table 4	Estimated Market Share by Process Technology, 1989-1990
Table 5	Estimated Market Share by Process Technology by Manufacturer Base, 1989-1990
Table 6	Estimated Unit Shipments by Quarter, 1989
Table 7	Estimated Unit Shipments by Quarter, 1990

Table 1
Estimated Market Share by Manufacturer, 1989-1990
(Percentage of Units)

Company: Each
Product: Microprocessors
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 16/32-Bit

Rank 1990	Rank 1989	Companies	Market Share (%) 1989	1990
1	1	Motorola	60.7	50.3
2	2	Intel	15.6	27.3
3	3	Signetics	7.9	6.9
4	4	Hitachi	6.6	5.4
5	6	Toshiba	2.9	4.1
6	5	National	4.7	3.8
7	7	SGS-Thomson	1.6	2.3
		Total 16/32-Bit MPUs	100.0	100.0

NM = Not meaningful

Source: Dataquest (May 1991)

Table 2
Estimated Market Share by Manufacturer Base, 1989-1990
(Thousands of Units)

Company: All
Product: Microprocessors
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 16/32-Bit

	1989	1990
U.S. Companies		
Shipments	12,377	15,647
Percent of Total	88.8	88.2
Japanese Companies		
Shipments	1,330	1,680
Percent of Total	9.6	9.5
European Companies		
Shipments	227	407
Percent of Total	1.6	2.3
Total 16/32-Bit MPUs	13,934	17,734

NM = Not meaningful

Source: Dataquest (May 1991)

Table 3
Estimated Market Share by Product Type, 1989-1990
(Percentage of Units)

Company: All
Product: Microprocessors
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 16/32-Bit

	1989	1990
32000	4.7	3.8
68000/68010	79.8	68.9
80386SX	15.2	26.8
80376	.4	.5
Total 16/32-Bit MPUs	100.0	100.0

NM = Not meaningful

Source: Dataquest (May 1991)

Table 4
Estimated Market Share by Process Technology, 1989-1990
(Thousands of Units)

Company:	All
Product:	Microprocessors
Region of Consumption:	Worldwide
Distribution Channel:	NM
Application:	All
Specification:	16/32-Bit

	1989	1990
NMOS		
Shipments	11,355	12,172
Percent of Total	81.5	68.6
CMOS		
Shipments	2,579	5,562
Percent of Total	18.5	31.4
Total 16/32-Bit MPUs	13,934	17,734

NM = Not meaningful

Source: Dataquest (May 1991)

Table 5
Estimated Market Share by Process Technology by Manufacturer Base, 1989-1990
(Percentage of Units)

Company:	All
Product:	Microprocessors
Region of Consumption:	Worldwide
Distribution Channel:	NM
Application:	All
Specification:	16/32-Bit

	1989	1990
NMOS		
U.S. Companies	89.9	88.8
Japanese Companies	8.1	7.9
European Companies	2.0	3.3
Total NMOS	100.0	100.0
CMOS		
U.S. Companies	84.1	87.1
Japanese Companies	15.9	12.9
European Companies	.0	.0
Total CMOS	100.0	100.0

NM = Not meaningful

Source: Dataquest (May 1991)

Table 6
Estimated Unit Shipments by Quarter, 1989
(Thousands of Units)

Company: Each
Product: Microprocessors
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 16/32-Bit

	Product	Process	Q1/89	Q2/89	Q3/89	Q4/89	1989
Hitachi	68000	N	230	230	230	230	920
Intel	80376	C	8	12	15	18	53
	80386SX	C	320	395	601	800	2,116
Motorola	68000	N	1,860	1,910	1,970	1,975	7,715
	68010	N	170	180	190	200	740
National	320XX	N	149	157	169	177	652
SGS-Thomson	68000	N	78	42	38	69	227
Signetics	68000	N	250	260	265	262	1,037
	68010	N	10	17	19	18	64
Toshiba	68000	C	60	90	120	140	410
Total 16/32-Bit MPUs			3,135	3,293	3,617	3,889	13,934

NM = Not meaningful

Source: Dataquest (May 1991)

Table 7
Estimated Unit Shipments by Quarter, 1990
(Thousands of Units)

Company: Each
Product: Microprocessors
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 16/32-Bit

	Product	Process	Q1/90	Q2/90	Q3/90	Q4/90	1990
Hitachi	68000	N	250	250	240	220	960
Intel	80376	C	20	23	26	23	92
	80386SX	C	1,000	1,150	1,250	1,350	4,750
Motorola	68000	N	1,980	2,000	2,050	2,100	8,130
	68010	N	210	212	185	175	782
National	320XX	N	160	166	170	173	669
SGS-Thomson	68000	N	56	118	133	100	407
Signetics	68000	N	260	275	282	290	1,107
	68010	N	19	25	33	40	117
Toshiba	68000	C	150	120	150	300	720
Total 16/32-Bit MPUs			4,105	4,339	4,519	4,771	17,734

NM = Not meaningful

Source: Dataquest (May 1991)

Chapter 5

32-Bit Microprocessors

The tables in this section are organized as follows:

Table 1	Estimated Market Share by Manufacturer, 1989-1990
Table 2	Estimated Market Share by Manufacturer Base, 1989-1990
Table 3	Estimated Market Share by Product Type, 1989-1990
Table 4	Estimated Market Share by Instruction Set, 1989-1990
Table 5	Estimated Market Share by Process Technology, 1989-1990
Table 6	Estimated Market Share by Process Technology by Manufacturer Base, 1989-1990
Table 7	Estimated Unit Shipments by Quarter, 1989
Table 8	Estimated Unit Shipments by Quarter, 1990

Table 1
Estimated Market Share by Manufacturer, 1989-1990
(Percentage of Units)

Company: Each
Product: Microprocessors
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 32-Bit

Rank 1990	Rank 1989	Companies	Market Share (%) 1989	1990
1	1	Intel	44.8	47.8
2	2	Motorola	38.4	30.5
3	3	National	5.4	5.1
4	5	LSI Logic	2.1	3.7
5	4	Inmos	3.1	2.8
6	7	Fujitsu	1.2	2.6
7	6	NEC	1.8	2.2
8	14	AMD	.1	1.1
9	8	Performance	1.1	1.0
10	10	IDT	.6	1.0
11	9	VLSI Technology	.6	.8
12	11	Cypress	.3	.8
13	12	Intergraph APD	.3	.3
14	16	Mitsubishi	*	.1
15	18	Bit	*	.1
16	17	Sony	*	*
17	13	Hitachi	.1	*
18	15	Toshiba	*	*
		Total 32-Bit MPUs	100.0	100.0

NM = Not meaningful
*Calculated amount is less than 0.1 percent.

Source: Dataquest (May 1991)

Table 2
Estimated Market Share by Manufacturer Base, 1989-1990
(Thousands of Units)

Company: All
Product: Microprocessors
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 32-Bit

	1989	1990
U.S. Companies		
Shipments	5,965	7,826
Percent of Total	93.8	92.2
Japanese Companies		
Shipments	192	424
Percent of Total	3.0	5.0
European Companies		
Shipments	200	240
Percent of Total	3.2	2.8
Total 32-Bit MPUs	6,357	8,490

NM = Not meaningful

Source: Dataquest (May 1991)

Table 3
Estimated Market Share by Product Type, 1989-1990
(Percentage of Units)

Company: All
Product: Microprocessors
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 32-Bit

	1989	1990
32X32	5.4	5.1
68020	20.8	13.4
68030	17.1	16.3
68040	*	.1
80386	44.2	42.1
80486	.5	4.8
C100	.2	*
RX000	2.3	3.1
T4XX	1.4	1.4
T8XX	1.8	1.5
V60/70	1.8	2.2
VL86C010	.6	.8
Others	3.9	9.2
Total 32-Bit MPUs	100.0	100.0

NM = Not meaningful
*Calculated value is less than 0.1 percent.

Source: Dataquest (May 1991)

Table 4
Estimated Market Share by Instruction Set, 1989-1990
(Percentage of Units)

Company:	All
Product:	Microprocessors
Region of Consumption:	Worldwide
Distribution Channel:	NM
Application:	All
Specification:	32-Bit

	Instruction Set	1989	1990
Group 1	68020, 68030, 68040	37.9	29.8
Group 2	80386, 80486	44.7	46.9
Group 3	32X32	5.4	5.1
Group 4	MIPS RX000	2.3	3.1
Group 5	SPARC	3.1	6.0
Group 6	Transputer	3.2	2.8
	Others	3.4	6.3
Total 32-Bit MPUs		100.0	100.0

NM = Not meaningful

Source: Dataquest (May 1991)

Table 5
Estimated Market Share by Process Technology, 1989-1990
(Thousands of Units)

Company: All
Product: Microprocessors
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 32-Bit

	1989	1990
NMOS		
Shipments	344	.0
Percent of Total	5.4	.0
CMOS		
Shipments	6,009	8,485
Percent of Total	94.5	99.9
Bipolar		
Shipments	4	5
Percent of Total	.1	.1
Total 32-Bit MPUs	6,357	8,490

NM = Not meaningful

Source: Dataquest (May 1991)

Table 6
Estimated Market Share by Process Technology by Manufacturer Base, 1989-1990
(Percentage of Units)

Company:	All
Product:	Microprocessors
Region of Consumption:	Worldwide
Distribution Channel:	NM
Application:	All
Specification:	32-Bit

	1989	1990
NMOS		
U.S. Companies	100.0	.0
Japanese Companies	.0	.0
European Companies	.0	.0
Total NMOS	100.0	100.0
CMOS		
U.S. Companies	93.5	91.7
Japanese Companies	3.2	5.3
European Companies	3.3	3.0
Total CMOS	100.0	100.0
Bipolar		
U.S. Companies	75.0	100.0
Japanese Companies	25.0	.0
European Companies	.0	.0
Total Bipolar	100.0	100.0

NM = Not meaningful

Source: Dataquest (May 1991)

Table 7
Estimated Unit Shipments by Quarter, 1989
(Thousands of Units)

Company: Each
Product: Microprocessors
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 32-Bit

	Product	Process	Q1/89	Q2/89	Q3/89	Q4/89	1989
AMD	AM29000	C	1	1	1	1	4
Bit	B5000	B	0	0	1	2	3
Cypress	CY7C601	C	2	3	8	8	21
Fujitsu	MB86900	C	10	7	5	4	26
	MB92XXX	C	1	1	1	1	4
	S-20/25	C	5	9	13	17	44
Hitachi	H32/200	C	1	1	1	1	4
IDT	R3000	C	6	10	12	12	40
Inmos	T4XX	C	15	20	25	26	86
	T8XX	C	24	30	30	30	114
Intel	80386	C	495	750	720	845	2,810
	80486	C	0	1	3	29	33
	80860	C	0	0	1	2	3
Intergraph APD	C100	C	3	2	4	3	12
	C300	C	1	1	2	2	6
LSI Logic	LR64801	C	8	20	33	39	100
	R3000	C	4	7	9	15	35
Motorola	68020	C	350	340	330	300	1,320
	68030	C	220	255	300	315	1,090
	88100	C	4	7	11	10	32
National	32X32	N/C	77	81	89	97	344
NEC	V60	C	19	20	20	22	81
	V70	C	5	6	10	11	32
Performance	R2000	C	3	3	3	3	12
	R3000	C	9	15	17	19	60
Sony	R6000	B	0	0	0	1	1
VLSI Technology	VL86C010	C	4	14	15	7	40
Total 32-Bit MPUs			1,267	1,604	1,664	1,822	6,357

NM = Not meaningful

Source: Dataquest (May 1991)

Table 8
Estimated Unit Shipments by Quarter, 1990
(Thousands of Units)

Company: Each
Product: Microprocessors
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 32-Bit

	Product	Process	Q1/90	Q2/90	Q3/90	Q4/90	1990
AMD	AM29000	C	15	20	25	30	90
Bit	B5000	B	1	1	1	2	5
Cypress	CY7C601	C	8	12	16	30	66
Fujitsu	MB92XXX	C	1	1	2	2	6
	S-20/25	C	30	45	60	80	215
Hitachi	H32/200	C	1	1	1	1	4
IDT	R3000	C	16	18	24	26	84
Inmos	T4XX	C	27	30	25	33	115
	T8XX	C	30	32	28	35	125
Intel	80386	C	840	875	900	960	3,575
	80486	C	90	95	105	115	405
	80860	C	8	11	12	14	45
	80960	C	2	4	8	20	34
Intergraph APD	C100	C	2	2	1	0	5
	C300	C	3	3	5	6	17
LSI Logic	LR64801	C	40	50	62	70	222
	R3000	C	16	20	26	32	94
Mitsubishi	M32/100	C	1	1	3	3	8
Motorola	68020	C	285	276	285	295	1,141
	68030	C	330	340	350	360	1,380
	68040	C	0	0	0	10	10
	88100	C	10	15	17	20	62
National	32X32	N/C	100	107	110	115	432
NEC	V60	C	25	30	35	40	130
	V70	C	12	15	15	15	57
Performance	R2000	C	3	4	2	2	11
	R3000	C	12	16	22	28	78
Toshiba	TX1	C	1	1	1	1	4
VLSI Technology	VL86C010	C	30	15	14	9	67
	VL86C020	C	0	1	1	2	4
Total 32-Bit MPUs			1,939	2,041	2,155	2,355	8,490

NM = Not meaningful

Source: Dataquest (May 1991)

Dataquest

Dataquest Research and Sales Offices:

Dataquest Incorporated
1290 Ridder Park Drive
San Jose, California 95131-2398
Phone: (408) 437-8000
Telex: 171973
Fax: (408) 437-0292

Technology Products Group
Phone: (800) 624-3280

Dataquest Incorporated
Ledgeway/Dataquest
The Corporate Center
550 Cochituate Road
Framingham, MA 01701
Phone: (508) 370-5555
Fax: (508) 370-6262

Dataquest Incorporated
Invitational Computer Conferences Division
3151 Airway Avenue, C-2
Costa Mesa, California 92626
Phone: (714) 957-0171
Telex: 5101002189 ICCDQ
Fax: (714) 957-0903

Dataquest Australia
Suite 1, Century Plaza
80 Berry Street
North Sydney, NSW 2060
Australia
Phone: (02) 959 4544
Telex: 25468
Fax: (02) 929 0635

Dataquest GmbH
Kronstadter Strasse 9
8000 Munich 80
West Germany
Phone: 011 49 89 93 09 09 0
Fax: 49 89 930 3277

Dataquest Europe Limited
Roussel House, Broadwater Park
Denham, Uxbridge, Middx UB9 5HP
England
Phone: 0895-835050
Telex: 266195
Fax: 0895 835260/1/2

Dataquest Europe SA
Tour Galliéni 2
36, avenue du Général-de-Gaulle
93175 Bagnolet Cedex
France
Phone: (1) 48 97 31 00
Telex: 233 263
Fax: (1) 48 97 34 00

Dataquest Hong Kong
Rm. 401, Connaught Comm. Bldg.
185 Wanchai Rd.
Wanchai, Hong Kong
Phone: 8387336
Telex: 80587
Fax: 5722375

Dataquest Israel
59 Mishmar Ha'yarden Street
Tel Aviv, Israel 69865
or
P.O. Box 18198
Tel Aviv, Israel
Phone: 52 913937
Telex: 341118
Fax: 52 32865

Dataquest Japan Limited
Shinkawa Sanko Building
1-3-17 Shinkawa, Chuo-ku
Tokyo 104 Japan
Phone: (03) 5566-0411
Fax: (03) 5566-0425

Dataquest Korea
Daeheung Bldg. 1105
648-23 Yeoksam-dong
Kangnam-gu
Seoul, Korea 135
Phone: (02) 556-4166
Fax: (02) 552-2661

Dataquest Singapore
4012 Ang Mo Kio Industrial Park 1
Ave. 10, #03-10 to #03-12
Singapore 2056
Phone: 4597181
Telex: 38257
Fax: 4563129

Dataquest Taiwan
Room 801/8th Floor
Ever Spring Building
147, Sect. 2, Chien Kuo N. Rd.
Taipei, Taiwan R.O.C. 104
Phone: (02) 501-7960
Telex: 27459
Fax: (02) 505-4265

Dataquest West Germany
In der Schneithohl 17
6242 Kronberg 2
West Germany
Phone: 06173/61685
Telex: 418089
Fax: 06173/67901

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Microcontroller Market Statistics
1990

Source:
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Semiconductors *Worldwide*
Microcomponents

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Microcontroller Market Statistics
1990

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Semiconductors *Worldwide*
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Notes to Market Share Tables

1. The following companies' unit shipments for 1989 have been restated:
   - Fujitsu
   - Matsushita
   - Mitsubishi
   - NEC
   - Sanyo
   - Sharp
2. For 1989, NEC's uPD78XXX has been restated and recategorized as the uPD78K/1.2 and the uPD78K/3.4.
3. For 1989, Hitachi's H8/532 has been restated and recategorized as the H8/300 and the H8/500.
4. The following products have been added to the 1989 tables:
   - Mitsubishi's M342X/343X
   - Mitsubishi's M371X/374X
   - Oki's OLMS-50/60
   - Oki's OLMS-62K
   - Oki's OLMS-66K
5. The following abbreviatons have been used within the tables:
   - P represents PMOS
   - N represents NMOS
   - C represents CMOS
6. Some table columns do not add to totals shown because of rounding.

Chapter 1

Microcontroller Market Overview

The tables in this section are organized as follows:

Table 1	Estimated Market Share by Word Length, 1989-1990
Table 2	Estimated Market Share by Manufacturer Base, 1989-1990
Table 3	Estimated Market Share by Process Technology, 1989-1990

Table 1
Estimated Market Share by Word Length, 1989-1990
(Thousands of Units)

Company:	All
Product:	Microcontrollers
Region of Consumption:	Worldwide
Distribution Channel:	NM
Application:	All
Specification:	Word Length

	1989	1990
4-Bit		
Shipments	682,100	777,170
Percent of Total	59.2	57.3
8-Bit		
Shipments	461,314	562,873
Percent of Total	40.0	41.5
16-Bit		
Shipments	9,428	17,289
Percent of Total	.8	1.3
Total Shipments	1,152,842	1,357,332

NM = Not meaningful

Source: Dataquest (May 1991)

Table 2
Estimated Market Share by Manufacturer Base, 1989-1990
(Thousands of Units)

Company: All
Product: Microcontrollers
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: Word Length

	1989	1990
4-Bit Shipments	682,100	777,170
U.S. Companies (%)	6.5	5.6
Japanese Companies (%)	92.4	93.6
European Companies (%)	1.1	.8
8-Bit Shipments	461,314	562,873
U.S. Companies (%)	47.8	47.6
Japanese Companies (%)	41.4	42.4
European Companies (%)	10.8	10.0
16-Bit Shipments	9,428	17,289
U.S. Companies (%)	75.8	50.5
Japanese Companies (%)	23.6	48.8
European Companies (%)	.6	.7
Total Shipments	1,152,842	1,357,332
U.S. Companies (%)	59.2	57.2
Japanese Companies (%)	40.0	41.5
European Companies (%)	.8	1.3

NM = Not meaningful

Source: Dataquest (May 1991)

Table 3
Estimated Market Share by Process Technology, 1989-1990
(Thousands of Units)

Company: All
Product: Microcontrollers
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: Word Length

	1989	1990
4-Bit Shipments	682,100	777,170
Percent PMOS	.0	.0
Percent NMOS	13.9	12.4
Percent CMOS	86.1	87.6
8-Bit Shipments	461,314	562,873
Percent NMOS	48.5	38.0
Percent CMOS	51.5	62.0
16-Bit Shipments	9,428	17,289
Percent NMOS	50.3	62.7
Percent CMOS	49.7	37.3
Total Shipments	1,152,842	1,357,332
Percent PMOS	.0	.0
Percent NMOS	28.1	23.6
Percent CMOS	71.9	76.4

NM = Not meaningful

Source: Dataquest (May 1991)

Chapter 2

4-Bit Microcontrollers

The tables in this section are organized as follows:

Table 1	Estimated Market Share by Manufacturer, 1989-1990
Table 2	Estimated Market Share by Manufacturer Base, 1989-1990
Table 3	Estimated Market Share by Product Type, 1989-1990
Table 4	Estimated Market Share by Process Technology, 1989-1990
Table 5	Estimated Unit Shipments by Quarter, 1989
Table 6	Estimated Unit Shipments by Quarter, 1990

Table 1
Estimated Market Share by Manufacturer, 1989-1990
(Percentage of Units)

Company: Each
Product: Microcontrollers
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 4-Bit

1990 Rank	1989 Rank	Companies	Market Share (%) 1989	1990
1	1	NEC	16.3	16.3
2	2	Sharp	12.5	12.7
3	3	Toshiba	12.9	12.3
4	4	Mitsubishi	11.9	11.8
5	5	Sanyo	9.0	9.5
6	6	Matsushita	8.8	8.7
7	7	Hitachi	8.5	8.1
8	8	Fujitsu	6.0	7.0
9	9	National	4.9	4.7
10	11	Oki	3.2	3.9
11	10	Sony	3.4	3.3
12	12	Texas Instruments	1.5	.9
13	13	SGS-Thomson	1.1	.8
14	14	Rockwell	*	*
		Total 4-Bit MCUs	100.0	100.0

NM = Not meaningful
*Calculated value is less than 0.1 percent.

Source: Dataquest (May 1991)

Table 2
Estimated Market Share by Manufacturer Base, 1989-1990
(Thousands of Units)

Company:	All
Product:	Microcontrollers
Region of Consumption:	Worldwide
Distribution Channel:	NM
Application:	All
Specification:	4-Bit

	1989	1990
U.S. Companies		
Shipments	44,035	43,897
Percent of Total	6.5	5.6
Japanese Companies		
Shipments	630,420	727,340
Percent of Total	92.4	93.6
European Companies		
Shipments	7,645	5,933
Percent of Total	1.1	.8
Total 4-Bit MCUs	682,100	777,170

NM = Not meaningful

Source: Dataquest (May 1991)

Table 3
Estimated Market Share by Product Type, 1989-1990
(Percentage of Units)

Company: All
Product: Microcontrollers
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 4-Bit

	1989	1990
	----	----
uPD75XXX	12.5	13.0
Sharp (Custom)	7.2	7.9
HMCS-400	6.3	7.0
MN1500	7.1	6.9
TLCS-47	6.4	6.1
LC57/58	5.1	5.9
COPS	6.0	5.5
SM (4-Bit)	5.3	4.7
M5046X/56X	4.8	4.0
MB8850X	2.6	3.5
LC65/66XX	3.5	3.4
TLCS-470	3.1	3.4
SPC500	3.4	3.3
OLMS-50/60	1.8	2.6
uPD75XX	2.9	2.5
M342X/343X	0.0	2.3
M5072/76	2.7	2.2
M5043X/44X	2.5	2.0
MB885X	1.5	1.8
MN1700	1.1	1.8
T Series	2.2	1.5
M509X	1.9	1.3
Series-40	1.4	1.3
TLCS-42	1.0	1.2
HMCS-40	2.2	1.1
TMS1000	1.5	.9
uCOM-4	.9	.8
MB884X	1.1	.5
MB882XX	.2	.4
LM64XX	.5	.3
MB887XX	.1	.3
MB886XX	*	.3

(Continued)

Table 3 (Continued)
Estimated Market Share by Product Type, 1989-1990
(Percentage of Units)

	1989	1990
MB8840X	.4	.2
MN1400	.6	*
TLCS-43	.1	*
PPS-4	*	*
TLCS-46	*	*
Total 4-Bit MCUs	100.0	100.0

NM = Not meaningful
*Calculated value is less than 0.1 percent.

Source: Dataquest (May 1991)

Table 4
Estimated Market Share by Process Technology, 1989-1990
(Thousands of Units)

Company: All
Product: Microcontrollers
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 4-Bit

	1989	1990
PMOS		
Shipments	235	97
Percent of Total	.0	.0
NMOS		
Shipments	94,925	95,963
Percent of Total	13.9	12.4
CMOS		
Shipments	586,940	681,110
Percent of Total	86.1	87.6
Total 4-Bit MCUs	682,100	777,170

NM = Not meaningful

Source: Dataquest (May 1991)

Table 5
Estimated Unit Shipments by Quarter, 1989
(Thousands of Units)

Company: Each
Product: Microcontrollers
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 4-Bit

	Product	Process	Q1/89	Q2/89	Q3/89	Q4/89	1989
Fujitsu	MB886XX	C	0	0	100	200	300
	MB887XX	C	0	100	200	400	700
	MB882XX	C	360	365	370	375	1,470
	MB8840X	N	580	600	620	640	2,440
	MB884X	N	1,830	1,875	1,915	1,800	7,420
	MB8850X	C	3,520	3,680	4,900	5,800	17,900
	MB885X	C	2,400	2,480	2,600	3,000	10,480
Hitachi	HMCS-40	P/N/C	4,300	4,000	3,500	3,000	14,800
	HMCS-400	C	9,000	10,000	11,500	12,500	43,000
Matsushita	MN1400	P/N/C	2,000	2,100	0	0	4,100
	MN1500	N	10,700	12,000	14,000	12,000	48,700
	MN1700	C	1,600	1,700	2,000	2,000	7,300
Mitsubishi	M342X/343X	C	0	10	50	80	140
	M5043X/44X	C	4,500	4,300	4,400	3,800	17,000
	M5046X/56X	C	6,500	7,900	9,200	8,800	32,400
	M5072/76	C	4,500	3,900	5,500	4,800	18,700
	M509X	C	3,000	2,500	3,800	3,400	12,700
National	COP400	N/C	7,600	8,400	7,400	10,000	33,400
NEC	uCOM-4	P/C	1,500	1,600	1,600	1,600	6,300
	uPD75XX	N/C	4,800	4,900	4,900	4,900	19,500
	uPD75XXX	C	19,500	21,000	23,000	22,000	85,500
Oki	OLMS-50/60	C	2,200	2,700	3,300	3,900	12,100
	Series-40	C	2,300	2,400	2,400	2,700	9,800
Rockwell	PPS-4	P	90	90	15	40	235
Sanyo	LC57/58	C	9,200	9,800	7,100	8,900	35,000
	LC65/66XX	C	5,800	6,500	5,900	5,400	23,600
	LM64XX	N	800	900	900	500	3,100
SGS-Thomson	COPS	N	2,173	2,010	1,855	1,607	7,645
Sharp	CUSTOM	C	10,000	12,000	13,000	14,000	49,000
	SM-Series	C	8,900	9,500	8,900	8,800	36,100
Sony	SPC500	C	5,300	5,800	6,000	5,900	23,000
Texas Instruments	TMS1000	P/C	3,300	2,600	2,000	2,500	10,400

(Continued)

Table 5 (Continued)
Estimated Unit Shipments by Quarter, 1989
(Thousands of Units)

	Product	Process	Q1/89	Q2/89	Q3/89	Q4/89	1989
Toshiba	T-Series	C	4,800	4,000	3,600	2,800	15,200
	TLCS-42	N/C	1,600	1,300	1,800	1,900	6,600
	TLCS-43	N	170	100	120	500	890
	TLCS-46	C	150	30	30	20	230
	TLCS-47	N	650	300	600	500	2,050
	TLCS-47	C	9,000	10,500	11,000	11,000	41,500
	TLCS-470	C	3,900	5,000	6,000	6,500	21,400
Total 4-Bit MCUs			158,523	168,940	176,075	178,562	682,100

NM = Not meaningful

Source: Dataquest (May 1991)

Table 6
Estimated Unit Shipments by Quarter, 1990
(Thousands of Units)

Company: Each
Product: Microcontrollers
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 4-Bit

	Product	Process	Q1/90	Q2/90	Q3/90	Q4/90	1990
Fujitsu	MB886XX	C	500	600	700	700	2,500
	MB887XX	C	500	600	600	600	2,300
	MB882XX	C	550	600	800	800	2,750
	MB8840X	N	650	600	400	200	1,850
	MB884X	N	1,500	1,200	800	400	3,900
	MB8850X	C	6,400	6,800	6,900	7,000	27,100
	MB885X	C	3,200	3,700	3,500	3,500	13,900
Hitachi	HMCS-40	P/N/C	2,550	2,400	1,900	1,700	8,550
	HMCS-400	C	12,500	12,500	14,600	14,800	54,400
Matsushita	MN1500	N	12,500	13,000	13,500	14,500	53,500
	MN1700	C	2,000	3,600	3,900	4,500	14,000
Mitsubishi	M342X/343X	C	2,500	5,000	5,600	5,100	18,200
	M5043X/44X	C	3,200	4,200	4,200	4,000	15,600
	M5046X/56X	C	6,300	8,100	8,500	8,300	31,200
	M5072/76	C	4,900	3,800	4,000	4,100	16,800
	M509X	C	1,700	2,400	3,000	3,000	10,100
National	COP400	N/C	8,500	9,500	9,500	9,000	36,500
NEC	uCOM-4	P/C	1,600	1,600	1,500	1,400	6,100
	uPD75XX	N/C	4,900	4,900	4,900	4,800	19,500
	uPD75XXX	C	23,000	25,000	26,000	27,000	101,000
Oki	OLMS-50/60	C	4,400	5,000	5,500	5,400	20,300
	Series-40	C	2,500	2,600	2,500	2,300	9,900
Rockwell	PPS-4	P	50	25	15	7	97
Sanyo	LC57/58	C	10,000	12,700	11,000	12,000	45,700
	LC65/66XX	C	5,100	6,900	7,000	7,100	26,100
	LM64XX	N	600	700	500	500	2,300
SGS-Thomson	COPS	N	1,975	1,899	995	1,064	5,933
Sharp	CUSTOM	C	15,000	15,500	16,000	15,200	61,700
	SM-Series	C	9,000	9,200	9,500	9,100	36,800
Sony	SPC500	C	6,100	6,100	6,500	7,000	25,700
Texas Instruments	TMS1000	P/C	1,600	1,900	1,800	2,000	7,300

(Continued)

Table 6 (Continued)
Estimated Unit Shipments by Quarter, 1990
(Thousands of Units)

	Product	Process	Q1/90	Q2/90	Q3/90	Q4/90	1990
Toshiba	T-Series	C	2,500	3,000	3,500	3,000	12,000
	TLCS-42	N/C	2,000	2,300	2,700	2,300	9,300
	TLCS-43	N	200	60	0	0	260
	TLCS-46	C	20	10	0	0	30
	TLCS-47	N	600	800	700	500	2,600
	TLCS-47	C	10,000	11,000	12,000	12,000	45,000
	TLCS-470	C	6,000	6,500	6,900	7,000	26,400
Total 4-Bit MCUs			177,095	196,294	201,910	201,871	777,170

NM = Not meaningful

Source: Dataquest (May 1991)

Chapter 3

8-Bit Microcontrollers

The tables in this section are organized as follows:

Table 1	Estimated Market Share by Manufacturer, 1989-1990
Table 2	Estimated Market Share by Manufacturer Base, 1989-1990
Table 3	Estimated Market Share by Product Type, 1989-1990
Table 4	Estimated Market Share by Instruction Set, 1989-1990
Table 5	Estimated Market Share by Process Technology, 1989-1990
Table 6	Estimated Market Share by Process Technology by Manufacturer Base, 1989-1990
Table 7	Estimated Unit Shipments by Quarter, 1989
Table 8	Estimated Unit Shipments by Quarter, 1990

Table 1
Estimated Market Share by Manufacturer, 1989-1990
(Percentage of Units)

Company: Each
Product: Microcontrollers
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 8-Bit

Rank 1990	Rank 1989	Companies	Market Share (%) 1989	Market Share (%) 1990
1	1	Motorola	23.2	23.9
2	4	Mitsubishi	10.1	11.9
3	3	Intel	11.1	10.3
4	2	NEC	11.5	10.1
5	5	Hitachi	9.1	8.3
6	6	Philips	4.1	3.5
7	9	Matsushita	2.6	3.0
8	11	National	2.3	3.0
9	8	Siemens	2.9	2.9
10	7	Signetics	3.4	2.8
11	14	Texas Instruments	2.2	2.6
12	12	Oki	2.3	2.2
13	13	Toshiba	2.2	2.2
14	10	SGS-Thomson	2.5	1.9
15	18	Zilog	1.3	1.8
16	16	Matra MHS	1.3	1.6
17	20	Sony	1.2	1.6
18	17	Fujitsu	1.3	1.5
19	22	Sharp	.8	1.4
20	15	AMD	1.4	1.3
21	19	Microchip Technology	1.3	1.0
22	21	Rockwell	.9	.5
23	23	Harris	.6	.3
24	24	Sanyo	.3	.3
25	25	NCR	.1	.1
		Total 8-Bit MCUs	100.0	100.0

NM = Not meaningful

Source: Dataquest (May 1991)

Table 2
Estimated Market Share by Manufacturer Base, 1989-1990
(Thousands of Units)

Company:	All
Product:	Microcontrollers
Region of Consumption:	Worldwide
Distribution Channel:	NM
Application:	All
Specification:	8-Bit

	1989	1990
U.S. Companies		
Shipments	220,335	268,245
Percent of Total	47.8	47.6
Japanese Companies		
Shipments	191,282	238,477
Percent of Total	41.4	42.4
European Companies		
Shipments	49,697	56,151
Percent of Total	10.8	10.0
Total 8-Bit MCUs	461,314	562,873

NM = Not meaningful

Source: Dataquest (May 1991)

Table 3
Estimated Market Share by Product Type, 1989-1990
(Percentage of Units)

Company: All
Product: Microcontrollers
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 8-Bit

	1989	1990
146805	1.0	1.4
6301	3.0	4.0
6305	2.3	1.5
6500/XX	1.0	.6
6801/03	2.8	.9
6804	1.1	.4
6805/68HC05	18.8	18.5
68HC11	3.7	4.9
8048/35	1.9	1.1
8049/39	7.5	6.4
8050/40	.9	.7
8051/31	11.0	10.1
8052/32	5.0	5.1
80C154	1.0	1.1
84XX	3.0	2.5
COP800	1.1	1.7
F8/387X	.8	.5
M371X/374X	*	3.2
M507XX	4.4	3.7
M509XX	5.2	4.8
PIC1652/54	.9	*
TMS7000	2.1	2.3
SPC700	1.2	1.6
uPD78XX	7.8	6.9
MN18XX	2.6	3.0
Z8	1.6	2.1
Others		
Total 8-Bit MCUs	100.0	100.0

NM = Not meaningful
*Calculated value is less than 0.1 percent.

Source: Dataquest (May 1991)

Table 4
Estimated Market Share by Instruction Set, 1989-1990
(Percentage of Units)

Company: All
Product: Microcontrollers
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 8-Bit

	Instruction Set	1989	1990
Group 1	6500/1, 6511 5074X	5.4	4.2
Group 2	6801/03, 6301	6.7	6.1
Group 3	6804	1.1	.4
Group 4	6805, 68HC05, 6305, 146805	22.8	21.8
Group 5	68HC11	3.7	4.9
Group 6	8048/35, 8049/39, 8050/40, 84XX, 8041, 802X	15.0	12.0
Group 7	8051/31, 8052/32, 8053, 80515/35, 80C451, 80C154	18.0	17.6
Group 8	387X, 38P7X, F8	.8	.5
Group 9	PIC165X	1.2	1.0
Group 10	TMS7000, PIC70XX	2.2	2.4
Group 11	uPD78XX	8.4	7.8
Group 12	Z8	1.6	2.1
	Others	12.9	19.1
	Total 8-Bit MCUs	100.0	100.0

NM = Not meaningful

Source: Dataquest (May 1991)

Table 5
Estimated Market Share by Process Technology, 1989-1990
(Thousands of Units)

Company: All
Product: Microcontrollers
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 8-Bit

	1989	1990
NMOS		
Shipments	223,668	214,061
Percent of Total	48.5	38.0
CMOS		
Shipments	237,646	348,812
Percent of Total	51.5	62.0
Total 8-Bit MCUs	461,314	562,873

NM = Not meaningful

Source: Dataquest (May 1991)

Table 6
Estimated Market Share by Process Technology by Manufacturer Base, 1989-1990
(Percentage of Units)

Company: All
Product: Microcontrollers
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 8-Bit

	1989	1990
NMOS		
U.S. Companies	54.5	52.9
Japanese Companies	28.5	28.0
European Companies	17.0	19.1
Total NMOS	100.0	100.0
CMOS		
U.S. Companies	41.4	44.5
Japanese Companies	53.7	51.2
European Companies	4.9	4.3
Total CMOS	100.0	100.0

NM = Not meaningful

Source: Dataquest (May 1991)

Table 7
Estimated Unit Shipments by Quarter, 1989
(Thousands of Units)

Company: Each
Product: Microcontrollers
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 8-Bit

	Product	Process	Q1/89	Q2/89	Q3/89	Q4/89	1989
AMD	8051/31	N	525	530	450	250	1,755
	80515/535	N	6	10	8	10	34
	8053	N	270	300	350	300	1,220
	80C51/31	C	450	350	360	390	1,550
	80C521/321	C	30	100	130	175	435
	80C5292/3292	C	100	275	310	355	1,040
	8751	N	75	75	75	70	295
	8753	N	25	45	45	40	155
	89C51	C	0	10	30	65	105
Fujitsu	8048/35	N	30	30	30	30	120
	8049/39	N	70	70	70	70	280
	8051/31	N	60	60	60	60	240
	80C49/39	N	290	300	290	350	1,230
	MB897XX	C	970	1,050	1,100	1,200	4,320
Harris	6805	N	53	88	65	60	266
	68HC05	C	355	600	750	1,000	2,705
Hitachi	6301	C	3,200	3,300	3,500	4,000	14,000
	6305	C	2,800	2,700	2,600	2,500	10,600
	63701	C	300	400	550	700	1,950
	63705	C	160	180	200	230	770
	63P01	C	275	280	285	290	1,130
	63P05	C	380	385	390	395	1,550
	6801/03	N	1,300	1,100	1,000	900	4,300
	6805	N	1,800	1,600	1,300	1,000	5,700
	68P01	N	245	250	255	260	1,010
	68P05	N	265	250	240	220	975
	H8/300	C	10	40	50	100	200
	H8/500	C	0	0	0	10	10

(Continued)

Table 7 (Continued)
Estimated Unit Shipments by Quarter, 1989
(Thousands of Units)

	Product	Process	Q1/89	Q2/89	Q3/89	Q4/89	1989
Intel	8048/35	N	400	290	250	200	1,140
	8049/39	N	2,400	2,320	2,000	2,000	8,720
	8050/40	N	400	320	450	350	1,520
	8051/31	N	2,600	3,120	3,500	3,000	12,220
	8052/32	N	2,200	2,460	3,200	2,700	10,560
	80C51/31	C	2,100	2,800	3,000	2,900	10,800
	8748	N	200	180	175	135	690
	8749	N	600	670	1,000	815	3,085
	8751	N	200	230	265	210	905
	8752	C	90	40	210	340	680
	87C51	C	100	260	200	260	820
Matra MHS	8052/32	N	150	100	60	0	310
	80C51/31	C	625	640	690	655	2,610
	80C52/32	C	370	590	875	1,110	2,945
	80C752	C	0	0	10	35	45
	83C154	C	55	75	70	90	290
Matsushita	MN1800/70/80	C	2,300	2,600	4,000	3,000	11,900
Microchip Technology	PIC1652/54	N	1,192	1,232	992	649	4,065
	PIC1670/72	N	88	81	58	42	269
	PIC16C52/C54	C	168	350	355	456	1,329
	PIC70XX	N	66	64	54	91	275
Mitsubishi	8048/35	N	40	40	40	10	130
	8049/39	N	200	150	170	110	630
	8050/40	N	40	40	40	40	160
	80C49/39	C	240	260	260	160	920
	M371X/374X	C	0	10	50	100	160
	M507XX	C	4,800	4,600	5,300	5,800	20,500
	M509XX	C	5,800	5,500	6,300	6,600	24,200
Motorola	146805	C	1,224	1,120	1,228	1,230	4,802
	6801/03	N	2,101	1,988	1,600	1,500	7,189
	6804	N	1,402	1,578	1,100	900	4,980
	6805	N	7,316	6,825	7,000	7,000	28,141
	68HC05	C	5,256	7,613	14,000	17,700	44,569
	68HC11	C	3,404	4,116	4,500	5,200	17,220
National	8048/35	N	65	40	75	65	245
	8049/39	N	450	800	1,300	1,500	4,050
	8050/40	N	375	350	350	360	1,435
	COP800	C	710	720	1,550	1,950	4,930
NCR	6500/1	N	0	2	71	257	330
	6500/11	N	6	2	0	6	14

(Continued)

Table 7 (Continued)
Estimated Unit Shipments by Quarter, 1989
(Thousands of Units)

	Product	Process	Q1/89	Q2/89	Q3/89	Q4/89	1989
NEC	8021/22	N	10	7	5	3	25
	8041	N	270	270	230	230	1,000
	8048/35	N	600	550	500	470	2,120
	8049/39	N	900	910	800	750	3,360
	80C48/35	C	240	270	300	290	1,100
	80C49/39	C	800	850	900	890	3,440
	8741	N	165	170	185	182	702
	8748	N	150	155	160	155	620
	8749	N	440	445	400	350	1,635
	uPD78K/1.2	N	500	600	700	900	2,700
	uPD78XX	N	8,800	8,900	9,200	9,200	36,100
	V25	C	10	30	40	70	150
Oki	80C154	C	750	1,000	1,200	1,500	4,450
	80C48/35	C	100	100	100	100	400
	80C49/39	C	900	700	500	500	2,600
	80C51/31	C	700	800	700	760	2,960
	OLMS-62K	C	10	20	50	100	180
Philips	8048/35	N	50	55	65	60	230
	8049/39	N	230	255	275	272	1,032
	8050/40	N	20	25	35	30	110
	8051/31	N	275	295	320	315	1,205
	80C49/39	C	170	180	190	185	725
	80C51/31	C	355	415	475	470	1,715
	84CXX	C	825	830	840	835	3,330
	84XX	N	2,550	2,600	2,650	2,645	10,445
Rockwell	6500/XX	N	980	1,200	850	1,150	4,180
Sanyo	LC86XXX	C	300	400	500	200	1,400
	LM88XX	N	10	30	20	40	100
SGS-Thomson	387X	N	1,047	986	912	816	3,761
	38P7X	N	18	20	13	12	63
	6801/03	N	475	370	268	315	1,428
	6805	N	915	1,248	1,245	1,890	5,298
	Z8	N	202	301	212	140	855
Sharp	CUSTOM	C	400	400	450	500	1,750
	SM-Series	C	300	380	400	420	1,500
	Z8	N	130	133	137	135	535
Siemens	802XX	N	9	4	15	11	39
	8048/35	N	334	409	320	160	1,223
	8051/31	N	1,175	1,010	1,260	1,500	4,945
	80515/35	N	733	950	900	990	3,573
	8052/32	N	752	739	795	1,234	3,520

(Continued)

Table 7 (Continued)
Estimated Unit Shipments by Quarter, 1989
(Thousands of Units)

	Product	Process	Q1/89	Q2/89	Q3/89	Q4/89	1989
Signetics	8049/39	N	526	810	988	1,473	3,797
	8051/31	N	635	691	830	765	2,921
	8052/32	N	1,000	1,156	1,052	825	4,033
	80C451	C	7	8	6	23	44
	80C51/31	C	912	1,256	1,303	779	4,250
	87C451	C	27	16	25	30	98
	87C51	C	125	103	43	45	316
	87C751	C	10	24	14	29	77
Sony	SPC700	C	1,000	1,300	1,500	1,600	5,400
Texas Instruments	TMS370	C	1	25	50	100	176
	TMS7000	N	2,800	2,500	2,500	2,000	9,800
Toshiba	8048/35	N	170	130	100	100	500
	8049/39	N	250	190	150	150	740
	80C48/35	C	700	500	250	250	1,700
	80C49/39	C	950	800	750	750	3,250
	80C50/40	C	220	200	240	240	900
	TLCS-870	C	0	0	30	100	130
	TLCS-90	C	500	650	800	900	2,850
Zilog	Z8	N/C	1,408	1,501	1,408	1,783	6,100
Total 8-Bit MCUs			102,618	109,426	121,997	127,273	461,314

NM = Not meaningful

Source: Dataquest (May 1991)

Table 8
Estimated Unit Shipments by Quarter, 1990
(Thousands of Units)

Company: Each
Product: Microcontrollers
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 8-Bit

	Product	Process	Q1/90	Q2/90	Q3/90	Q4/90	1990
AMD	8051/31	N	400	450	370	350	1,570
	80515/535	N	10	14	10	15	49
	8053	N	325	320	300	290	1,235
	80C51/31	C	400	450	425	450	1,725
	80C521/321	C	160	180	170	170	680
	80C5292/3292	C	320	350	350	375	1,395
	8751	N	75	85	80	80	320
	8753	N	40	50	45	40	175
	89C51	C	45	50	40	35	170
Fujitsu	8048/35	N	30	30	30	30	120
	8049/39	N	70	70	60	60	260
	8051/31	N	60	60	40	40	200
	80C49/39	C	330	360	360	360	1,410
	MB897XX	C	1,350	1,480	1,630	1,750	6,210
Harris	6805	N	38	47	20	33	139
	68HC05	C	229	250	344	524	1,347
Hitachi	6301	C	4,500	5,000	6,000	7,000	22,500
	6305	C	2,200	2,200	2,100	1,900	8,400
	63701	C	900	1,100	1,300	1,300	4,600
	63705	C	250	0	0	0	250
	63P01	C	290	290	200	140	920
	63P05	C	395	395	280	190	1,260
	6801/03	N	600	500	200	150	1,450
	6805	N	800	600	500	550	2,450
	68P01	N	260	260	180	130	830
	68P05	N	220	220	160	110	710
	H8/300	C	550	580	720	900	2,750
	H8/500	C	50	60	120	200	430
Intel	8048/35	N	185	150	100	175	610
	8049/39	N	2,000	2,100	2,100	2,200	8,400
	8050/40	N	340	330	350	425	1,445
	8051/31	N	2,800	2,900	2,995	2,800	11,495
	8052/32	N	3,000	3,610	3,500	3,900	14,010
	80C51/31	C	2,900	3,500	3,600	4,100	14,100
	8748	N	150	130	160	175	615
	8749	N	800	900	800	700	3,200
	8751	N	275	300	300	250	1,125
	8752	C	500	500	450	200	1,650
	87C51	C	275	330	475	525	1,605

(Continued)

Table 8 (Continued)
Estimated Unit Shipments by Quarter, 1990
(Thousands of Units)

	Product	Process	Q1/90	Q2/90	Q3/90	Q4/90	1990
Matra MHS	80C51/31	C	840	980	1,009	1,081	3,910
	80C52/32	C	960	1,150	1,237	1,346	4,693
	83C154	C	75	112	119	124	430
Matsushita	MN1800/70/80	C	3,140	4,250	4,500	5,100	16,990
Microchip Technology	PIC165X/7X	N	646	642	630	600	2,518
	PIC16C5X	C	460	610	819	1,010	2,899
	PIC70XX	N	82	80	76	75	313
Mitsubishi	8048/35	N	15	10	10	10	45
	8049/39	N	100	80	50	50	280
	8050/40	N	25	20	20	20	85
	80C49/39	C	220	200	170	160	750
	M371X/374X	C	3,500	4,400	5,000	5,000	17,900
	M507XX	C	5,300	4,600	5,200	5,500	20,600
	M509XX	C	6,200	6,900	7,100	7,000	27,200
Motorola	146805	C	2,575	2,214	1,750	1,600	8,139
	6801/03	N	767	859	865	725	3,216
	6804	N	546	536	547	489	2,118
	6805	N	5,366	5,222	4,819	4,572	19,979
	68HC05	C	14,433	17,774	19,467	21,972	73,646
	68HC11	C	5,098	6,860	7,625	8,120	27,703
National	8048/35	N	155	85	310	430	980
	8049/39	N	1,300	1,600	900	1,250	5,050
	8050/40	N	280	250	230	300	1,060
	COP800	C	1,700	2,240	2,650	2,985	9,575
NCR	6500/1	N	137	91	103	106	437
	6500/11	N	9	14	23	0	46
NEC	8041	N	200	200	190	180	770
	8048/35	N	400	450	400	350	1,600
	8049/39	N	700	750	700	650	2,800
	80C48/35	C	270	250	260	280	1,060
	80C49/39	C	800	800	900	900	3,400
	8741	N	190	190	180	180	740
	8748	N	150	140	130	120	540
	8749	N	350	400	400	400	1,550
	uPD78K/1.2	N	1,000	1,100	1,300	1,400	4,800
	uPD78XX	N	9,500	9,500	10,000	10,000	39,000
	V25	C	80	100	110	110	400
Oki	80C154	C	1,400	1,400	1,600	1,800	6,200
	80C48/35	C	70	60	80	100	310
	80C49/39	C	570	500	500	600	2,170
	80C51/31	C	800	700	800	900	3,200
	OLMS-62K	C	150	90	120	150	510

(Continued)

Table 8 (Continued)
Estimated Unit Shipments by Quarter, 1990
(Thousands of Units)

	Product	Process	Q1/90	Q2/90	Q3/90	Q4/90	1990
Philips	8048/35	N	60	70	80	90	300
	8049/39	N	275	285	289	294	1,143
	8050/40	N	30	40	50	55	175
	8051/31	N	315	320	326	330	1,291
	80C49/39	C	185	195	200	207	787
	80C51/31	C	475	485	492	500	1,952
	84CXX	C	835	850	860	865	3,410
	84XX	N	2,650	2,700	2,735	2,750	10,835
Rockwell	6500/XX	N	1,400	600	585	200	2,785
Sanyo	LC86XXX	C	300	300	400	400	1,400
	LM88XX	N	10	10	0	0	20
SGS-Thomson	387X	N	870	770	742	629	3,011
	38P7X	N	16	11	14	9	50
	6801/03	N	162	133	125	138	558
	6805	N	1,754	1,094	1,759	1,417	6,024
	Z8	N	196	333	288	315	1,132
Sharp	CUSTOM	C	900	1,500	1,500	1,600	5,500
	SM-Series	C	450	500	550	580	2,080
	Z8	N	137	140	150	150	577
Siemens	8048/35	N	59	23	20	21	123
	8051/31	N	1,552	1,612	1,780	1,750	6,694
	80515/35	N	1,019	1,118	1,030	1,700	4,867
	8052/32	N	1,200	1,296	1,020	1,250	4,766
Signetics	8049/39	N	1,425	1,500	1,555	1,598	6,078
	8051/31	N	760	740	721	711	2,932
	8052/32	N	800	775	770	770	3,115
	80C451	C	23	25	27	29	104
	80C51/31	C	780	765	760	758	3,063
	87C451	C	30	35	39	43	147
	87C51	C	45	55	59	63	222
	87C751	C	30	45	55	60	190
Sony	SPC700	C	1,700	1,800	2,000	3,500	9,000
Texas Instruments	TMS370	C	230	310	480	550	1,570
	TMS7000	N	2,800	3,300	3,300	3,600	13,000
Toshiba	8048/35	N	60	50	20	20	150
	8049/39	N	120	100	100	80	400
	80C48/35	C	200	200	180	100	680
	80C49/39	C	700	900	800	800	3,200
	80C50/40	C	240	280	250	250	1,020
	TLCS-870	C	150	200	300	400	1,050
	TLCS-90	C	1,000	1,200	1,300	1,700	5,200
	68HC05/11	C	100	150	150	150	550
Zilog	Z8	N/C	2,390	2,492	2,606	2,812	10,300
Total 8-Bit MCUs			127,114	137,917	144,230	153,611	562,873

NM = Not meaningful
Source: Dataquest (May 1991)

Chapter 4

16-Bit Microcontrollers

The tables in this section are organized as follows:

Table 1	Estimated Market Share by Manufacturer, 1989-1990
Table 2	Estimated Market Share by Manufacturer Base, 1989-1990
Table 3	Estimated Market Share by Product Type, 1989-1990
Table 4	Estimated Market Share by Process Technology, 1989-1990
Table 5	Estimated Market Share by Process Technology by Manufacturer Base, 1989-1990
Table 6	Estimated Unit Shipments by Quarter, 1989
Table 7	Estimated Unit Shipments by Quarter, 1989

Table 1
Estimated Market Share by Manufacturer, 1989-1990
(Percentage of Units)

Company: Each
Product: Microcontrollers
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 16-Bit

Rank 1990	Rank 1989	Companies	Market Share (%) 1989	1990
1	1	Intel	35.5	40.9
2	3	NEC	16.6	30.8
3	6	Mitsubishi	1.9	10.7
4	4	National	6.6	9.6
5	5	Oki	4.7	6.6
6	7	SGS-Thomson	.6	.7
7	8	Hitachi	.4	.5
8	10	Matsushita	*	.1
9	9	Fujitsu	*	*
10	2	Various	33.7	*
		Total 16-Bit MCUs	100.0	100.0

NM = Not meaningful
*Calculated value is less than 0.1 percent.

Source: Dataquest (May 1991)

Table 2
Estimated Market Share by Manufacturer Base, 1989-1990
(Thousands of Units)

Company: All
Product: Microcontrollers
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 16-Bit

	1989	1990
U.S. Companies		
Shipments	7,148	8,730
Percent of Total	75.8	50.5
Japanese Companies		
Shipments	2,223	8,439
Percent of Total	23.6	48.8
European Companies		
Shipments	57	120
Percent of Total	.6	.7
Total 16-Bit MCUs	9,428	17,289

NM = Not meaningful

Source: Dataquest (May 1991)

Table 3
Estimated Market Share by Product Type, 1989-1990
(Percentage of Units)

Company: All
Product: Microcontrollers
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 16-Bit

	1989	1990
8096	32.9	31.4
uPD78K/3.4	16.4	30.7
M377XX	1.9	10.7
HPC	6.6	9.6
80C196	2.3	9.5
OLMS-66K	4.7	6.6
Others	.9	.9
68200	.6	.7
8061	33.7	*
Total 16-Bit MCUs	100.0	100.0

NM = Not meaningful
*Calculated value is less than 0.1 percent.

Source: Dataquest (May 1991)

Table 4
Estimated Market Share by Process Technology, 1989-1990
(Thousands of Units)

Company:	All
Product:	Microcontrollers
Region of Consumption:	Worldwide
Distribution Channel:	NM
Application:	All
Specification:	16-Bit

	1989	1990
NMOS		
Shipments	4,742	10,845
Percent of Total	50.3	62.7
CMOS		
Shipments	4,686	6,444
Percent of Total	49.7	37.3
Total 16-Bit MCUs	9,428	17,289

NM = Not meaningful

Source: Dataquest (May 1991)

Table 5
Estimated Market Share by Process Technology by Manufacturer Base, 1989-1990
(Percentage of Units)

Company: All
Product: Microcontrollers
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 16-Bit

	1989	1990
NMOS		
U.S. Companies	66.1	50.0
Japanese Companies	32.7	48.9
European Companies	1.2	1.1
Total NMOS	100.0	100.0
CMOS		
U.S. Companies	85.6	51.3
Japanese Companies	14.4	48.7
European Companies	.0	.0
Total CMOS	100.0	100.0

NM = Not meaningful

Source: Dataquest (May 1991)

Table 6
Estimated Unit Shipments by Quarter, 1989
(Thousands of Units)

Company: Each
Product: Microcontrollers
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 16-Bit

	Product	Process	Q1/89	Q2/89	Q3/89	Q4/89	1989
Hitachi	H16	C	5	5	10	15	35
Intel	8096	N	600	780	825	900	3,105
	8098	N	30	0	0	0	30
	80C196	C	20	40	55	100	215
Mitsubishi	M377XX	C	10	20	50	100	180
National	HPC	C	105	90	180	250	625
NEC	V35	C	4	4	5	5	18
	uPD78K/3.4	N	250	300	400	600	1,550
Oki	OLMS-66K	C	20	60	120	240	440
SGS-Thomson	68200	N	19	26	1	11	57
Various	8061	C	867	909	619	778	3,173
Total 16-Bit MCUs			1,930	2,234	2,265	2,999	9,428

NM = Not meaningful

Source: Dataquest (May 1991)

Table 7
Estimated Unit Shipments by Quarter, 1990
(Thousands of Units)

Company: Each
Product: Microcontrollers
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: 16-Bit

	Product	Process	Q1/90	Q2/90	Q3/90	Q4/90	1990
Fujitsu	MB907X	C	0	0	1	5	6
Hitachi	H16	C	15	20	30	30	95
Intel	8096	N	925	1,250	1,350	1,900	5,425
	80C196	C	150	200	500	800	1,650
Matsushita	MN10300	C	0	0	10	10	20
Mitsubishi	M377XX	C	380	400	400	670	1,850
National	HPC	C	275	390	400	590	1,655
NEC	V35	C	6	6	8	8	28
	uPD78K/3.4	N	900	1,100	1,600	1,700	5,300
Oki	OLMS-66K	C	270	290	280	300	1,140
SGS-Thomson	68200	N	34	28	3	55	120
Total 16-Bit MCUs			2,955	3,684	4,582	6,068	17,289

NM = Not meaningful

Source: Dataquest (May 1991)

Dataquest

Dataquest Research and Sales Offices:

Dataquest Incorporated
1290 Ridder Park Drive
San Jose, California 95131-2398
Phone: (408) 437-8000
Telex: 171973
Fax: (408) 437-0292

Technology Products Group
Phone: (800) 624-3280

Dataquest Incorporated
Ledgeway/Dataquest
The Corporate Center
550 Cochituate Road
Framingham, MA 01701
Phone: (508) 370-5555
Fax: (508) 370-6262

Dataquest Incorporated
Invitational Computer Conferences Division
3151 Airway Avenue, C-2
Costa Mesa, California 92626
Phone: (714) 957-0171
Telex: 5101002189 ICCDQ
Fax: (714) 957-0903

Dataquest Australia
Suite 1, Century Plaza
80 Berry Street
North Sydney, NSW 2060
Australia
Phone: (02) 959 4544
Telex: 25468
Fax: (02) 929 0635

Dataquest GmbH
Kronstadter Strasse 9
8000 Munich 80
West Germany
Phone: 011 49 89 93 09 09 0
Fax: 49 89 930 3277

Dataquest Europe Limited
Roussel House, Broadwater Park
Denham, Uxbridge, Middx UB9 5HP
England
Phone: 0895-835050
Telex: 266195
Fax: 0895 835260/1/2

Dataquest Europe SA
Tour Galliéni 2
36, avenue du Général-de-Gaulle
93175 Bagnolet Cedex
France
Phone: (1) 48 97 31 00
Telex: 233 263
Fax: (1) 48 97 34 00

Dataquest Hong Kong
Rm. 401, Connaught Comm. Bldg.
185 Wanchai Rd.
Wanchai, Hong Kong
Phone: 8387336
Telex: 80587
Fax: 5722375

Dataquest Israel
59 Mishmar Ha'yarden Street
Tel Aviv, Israel 69865
or
P.O. Box 18198
Tel Aviv, Israel
Phone: 52 913937
Telex: 341118
Fax: 52 32865

Dataquest Japan Limited
Shinkawa Sanko Building
1-3-17 Shinkawa, Chuo-ku
Tokyo 104 Japan
Phone: (03) 5566-0411
Fax: (03) 5566-0425

Dataquest Korea
Daeheung Bldg. 1105
648-23 Yeoksam-dong
Kangnam-gu
Seoul, Korea 135
Phone: (02) 556-4166
Fax: (02) 552-2661

Dataquest Singapore
4012 Ang Mo Kio Industrial Park 1
Ave. 10, #03-10 to #03-12
Singapore 2056
Phone: 4597181
Telex: 38257
Fax: 4563129

Dataquest Taiwan
Room 801/8th Floor
Ever Spring Building
147, Sect. 2, Chien Kuo N. Rd.
Taipei, Taiwan R.O.C. 104
Phone: (02) 501-7960
Telex: 27459
Fax: (02) 505-4265

Dataquest West Germany
In der Schneithohl 17
6242 Kronberg 2
West Germany
Phone: 06173/61685
Telex: 418089
Fax: 06173/67901

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MOS Microcomponent Forecast

May 1991

Source:
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Semiconductors *Worldwide*

Microcomponents

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MOS Microcomponent Forecast

May 1991

Source: Dataquest

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Microcomponents

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Table of Contents

This booklet is divided into three major sections.

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Chapter 1

Microcomponents

The following section includes forecast and historical MOS microcomponent revenue by product type.

The tables are organized as follows:

Table 1.1	Estimated MOS Microcomponent Consumption Forecast by Product Type, 1990-1995
Table 1.2	Estimated MOS Microcomponent Consumption Forecast by Region, 1990-1995

Table 1.1
Estimated MOS Microcomponent Consumption Forecast by Product Type, 1990-1995
(Factory Revenue in Millions of U.S. Dollars)

Company:	All
Product:	Each
Region of Consumption:	Worldwide
Distribution Channel:	NM
Application:	All
Specification:	All

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Microprocessors	2,413	2,939	3,518	4,243	4,896	5,209	16.6
Growth (%)	28.3	21.8	19.7	20.6	15.4	6.4	
Percent of Total	24.0	24.3	23.6	23.7	24.4	24.1	
Microcontrollers	4,472	5,138	6,032	7,027	8,024	8,955	14.9
Growth (%)	24.3	14.9	17.4	16.5	14.2	11.6	
Percent of Total	44.4	42.4	40.5	39.2	40.0	41.5	
Microperipherals	3,183	4,041	5,357	6,647	7,156	7,440	18.5
Growth (%)	16.9	27.0	32.6	24.1	7.7	4.0	
Percent of Total	31.6	33.3	35.9	37.1	35.6	34.4	
Total Microcomponents	10,068	12,118	14,907	17,917	20,076	21,604	16.5
Growth (%)	22.8	20.4	23.0	20.2	12.1	7.6	

NM = Not meaningful
Note: Some columns do not add to totals shown because of rounding.

Source: Dataquest (May 1991)

Table 1.2
Estimated MOS Microcomponent Consumption Forecast by Region, 1990-1995
(Factory Revenue in Millions of U.S. Dollars)

Company:	All
Product:	Total Microcomponent
Region of Consumption:	Each
Distribution Channel:	NM
Application:	All
Specification:	All

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
North America	3,563	4,003	4,784	5,613	5,960	6,254	11.9
Growth (%)	19.9	12.3	19.5	17.3	6.2	4.9	
Percent of Total	35.4	33.0	32.1	31.3	29.7	28.9	
Japan	3,210	3,835	4,615	5,293	5,928	6,422	14.9
Growth (%)	13.5	19.5	20.3	14.7	12.0	8.3	
Percent of Total	31.9	31.6	31.0	29.5	29.5	29.7	
Europe	1,836	2,225	2,873	3,706	4,447	4,847	21.4
Growth (%)	25.0	21.2	29.1	29.0	20.0	9.0	
Percent of Total	18.2	18.4	19.3	20.7	22.2	22.4	
Asia/Pacific-Rest of World	1,459	2,055	2,635	3,305	3,741	4,081	22.8
Growth (%)	56.4	40.8	28.2	25.4	13.2	9.1	
Percent of Total	14.5	17.0	17.7	18.4	18.6	18.9	
Worldwide	10,068	12,118	14,907	17,917	20,076	21,604	16.5
Growth (%)	22.8	20.4	23.0	20.2	12.1	7.6	

NM = Not meaningful

Source: Dataquest (May 1991)

Chapter 2

Microprocessors

The following section includes forecast and historical MOS microprocessor revenue, unit shipments, and average selling prices (ASPs).

The tables are organized as follows:

Table 2.1	Estimated MOS Microprocessor Revenue Forecast, 1990-1995
Table 2.2	Estimated MOS Microprocessor Unit Shipments Forecast, 1990-1995
Table 2.3	Estimated MOS Microprocessor Average Selling Price Forecast, 1990-1995

Table 2.1
Estimated MOS Microprocessor Revenue Forecast, 1990-1995
(Factory Revenue in Millions of U.S. Dollars)

Company: All
Product: Microprocessors
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: Word Length

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
8-Bit	170	192	193	187	184	174	.4
Growth (%)	11.1	12.9	.5	-3.1	-1.6	-5.4	
Percent of Total	7.0	6.5	5.5	4.4	3.8	3.3	
16-Bit	416	443	493	492	486	479	2.8
Growth (%)	12.4	6.5	11.3	-.2	-1.2	-1.4	
Percent of Total	17.2	15.1	14.0	11.6	9.9	9.2	
16/32-Bit	405	603	690	738	751	746	13.0
Growth (%)	68.8	48.9	14.4	7.0	1.8	-.7	
Percent of Total	16.8	20.5	19.6	17.4	15.3	14.3	
32-Bit	1,422	1,701	2,028	2,643	3,164	3,415	19.2
Growth (%)	27.2	19.6	19.2	30.3	19.7	7.9	
Percent of Total	58.9	57.9	57.6	62.3	64.6	65.6	
64-Bit	0	0	114	183	311	395	51.3
Growth (%)	NM	NM	NM	60.5	69.9	27.0	
Percent of Total	0	0	3.2	4.3	6.4	7.6	
Total MPU	2,413	2,939	3,518	4,243	4,896	5,209	16.6
Growth (%)	28.3	21.8	19.7	20.6	15.4	6.4	

NM = Not meaningful
Note: Some columns do not add to totals shown because of rounding.

Source: Dataquest (May 1991)

Table 2.2
Estimated MOS Microprocessor Unit Shipments Forecast, 1990-1995
(Millions of Units)

Company: All
Product: Microprocessors
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: Word Length

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
8-Bit	74.9	73.5	75.0	73.0	73.0	71.0	-1.1
Growth (%)	15.6	-1.9	2.0	-2.7	.0	-2.7	
Percent of Total	58.8	52.8	48.6	43.4	39.8	36.7	
16-Bit	26.3	29.7	33.5	36.5	38.0	39.0	8.2
Growth (%)	9.6	12.9	12.8	9.0	4.1	2.6	
Percent of Total	20.6	21.3	21.7	21.7	20.7	20.1	
16/32-Bit	17.7	24.4	28.9	32.5	35.0	37.0	15.9
Growth (%)	27.3	37.9	18.4	12.5	7.7	5.7	
Percent of Total	13.9	17.5	18.7	19.3	19.1	19.1	
32-Bit	8.5	11.7	16.7	26.0	37.0	46.0	40.2
Growth (%)	34.9	37.6	42.7	55.7	42.3	24.3	
Percent of Total	6.7	8.4	10.8	15.5	20.2	23.7	
64-Bit	0	0	.1	.2	.4	.7	91.3
Growth (%)	NM	NM	NM	100.0	100.0	75.0	
Percent of Total	.0	.0	.1	.1	.2	.4	
Total MPU	127.4	139.3	154.2	168.2	183.4	193.7	8.7
Growth (%)	16.9	9.3	10.7	9.1	9.0	5.6	

NM = Not meaningful

Source: Dataquest (May 1991)

Table 2.3
Estimated MOS Microprocessor Average Selling Price Forecast, 1990-1995
(Factory ASP in U.S. Dollars)

Company: All
Product: Microprocessors
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: Word Length

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
8-Bit	2.27	2.61	2.57	2.56	2.52	2.45	1.5
Growth (%)	-3.4	15.0	-1.5	-.4	-1.6	-2.8	
16-Bit	15.82	14.92	14.72	13.48	12.79	12.28	-4.9
Growth (%)	2.4	-5.7	-1.3	-8.4	-5.1	-4.0	
16/32-Bit	22.88	24.71	23.88	22.70	21.46	20.16	-2.5
Growth (%)	32.5	8.0	-3.4	-4.9	-5.5	-6.1	
32-Bit	167.29	145.38	121.44	101.65	85.51	74.24	-15.0
Growth (%)	-5.8	-13.1	-16.5	-16.3	-15.9	-13.2	
64-Bit	0	0	1,140.00	915.00	777.50	564.29	-20.9
Growth (%)	NM	NM	NM	-19.7	-15.0	-27.4	
Total MPU	18.94	21.10	22.81	25.23	26.70	26.89	7.3
Growth (%)	9.7	11.4	8.1	10.6	5.8	.7	

NM = Not meaningful

Source: Dataquest (May 1991)

Chapter 3

Microcontrollers

The following section includes forecast and historical MOS microcontroller revenue, unit shipments, and average selling prices.

The tables are organized as follows:

Table 3.1	Estimated MOS Microcontroller Revenue Forecast, 1990-1995
Table 3.2	Estimated MOS Microcontroller Unit Shipments Forecast, 1990-1995
Table 3.3	Estimated MOS Microcontroller Average Selling Price Forecast, 1990-1995

Table 3.1
Estimated MOS Microcontroller Revenue Forecast, 1990-1995
(Factory Revenue in Millions of U.S. Dollars)

Company: All
Product: Microcontrollers
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: Word Length

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
4-Bit	1,713	1,769	1,952	2,092	2,176	2,269	5.8
Growth (%)	20.8	3.3	10.3	7.2	4.0	4.3	
Percent of Total	38.3	34.4	32.4	29.8	27.1	25.3	
8-Bit	2,597	3,100	3,525	3,930	4,164	4,546	11.8
Growth (%)	23.7	19.4	13.7	11.5	6.0	9.2	
Percent of Total	58.1	60.3	58.4	55.9	51.9	50.8	
16-Bit	160	255	485	856	1,462	1,805	62.4
Growth (%)	100.0	59.4	90.2	76.5	70.8	23.5	
Percent of Total	3.6	5.0	8.0	12.2	18.2	20.2	
32-Bit	2	14	70	149	222	335	178.5
Growth (%)	NM	600.0	400.0	112.9	49.0	50.9	
Percent of Total	.0	.3	1.2	2.1	2.8	3.7	
Total MCU	4,472	5,138	6,032	7,027	8,024	8,955	14.9
Growth (%)	24.3	14.9	17.4	16.5	14.2	11.6	

NM = Not meaningful
Note: Some columns do not add to totals shown because of rounding.

Source: Dataquest (May 1991)

Table 3.2
Estimated MOS Microcontroller Unit Shipments Forecast, 1990-1995
(Millions of Units)

Company: All
Product: Microcontrollers
Region of Consumption: Worldwide
Distribution Channel: NM
Application: All
Specification: Word Length

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
4-Bit	777.2	822.0	936.0	1,029.0	1,125.0	1,200.0	9.1
Growth (%)	13.9	5.8	13.9	9.9	9.3	6.7	
Percent of Total	57.3	53.6	52.8	49.8	47.4	45.5	
8-Bit	562.9	681.0	780.0	925.0	1,050.0	1,175.0	15.9
Growth (%)	22.0	21.0	14.5	18.6	13.5	11.9	
Percent of Total	41.5	44.4	44.0	44.8	44.2	44.6	
16-Bit	17.3	29.0	55.6	103.4	185.7	239.3	69.1
Growth (%)	84.0	67.6	91.7	86.0	79.6	28.9	
Percent of Total	1.3	1.9	3.1	5.0	7.8	9.1	
32-Bit	.1	.4	2.6	7.0	13.0	23.0	196.7
Growth (%)	NM	300.0	550.0	169.2	85.7	76.9	
Percent of Total	.0	.0	.1	.3	.5	.9	
Total MCU	1,357.5	1,532.4	1,774.2	2,064.4	2,373.7	2,637.3	14.2
Growth (%)	17.7	12.9	15.8	16.4	15.0	11.1	

NM = Not meaningful

Source: Dataquest (May 1991)

Table 3.3
Estimated MOS Microcontroller Average Selling Price Forecast, 1990-1995
(Factory ASP in U.S. Dollars)

Company:	All
Product:	Microcontrollers
Region of Consumption:	Worldwide
Distribution Channel:	NM
Application:	All
Specification:	Word Length

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
4-Bit	2.20	2.15	2.09	2.03	1.93	1.89	-3.0
Growth (%)	5.8	-2.3	-2.8	-2.9	-4.9	-2.1	
8-Bit	4.61	4.55	4.52	4.25	3.97	3.87	-3.4
Growth (%)	1.3	-1.3	-.7	-6.0	-6.6	-2.5	
16-Bit	9.24	8.79	8.72	8.28	7.87	7.54	-4.0
Growth (%)	8.7	-4.9	-.8	-5.0	-5.0	-4.2	
32-Bit	20.00	35.00	26.92	21.29	17.08	14.57	-6.1
Growth (%)	NM	75.0	-23.1	-20.9	-19.8	-14.7	
Total MCU	3.29	3.35	3.40	3.40	3.38	3.40	.7
Growth (%)	5.4	1.8	1.5	.0	-.6	.6	

NM = Not meaningful

Source: Dataquest (May 1991)

Dataquest

Dataquest Research and Sales Offices:

Dataquest Incorporated
1290 Ridder Park Drive
San Jose, California 95131-2398
Phone: (408) 437-8000
Telex: 171973
Fax: (408) 437-0292

Technology Products Group
Phone: (800) 624-3280

Dataquest Incorporated
Ledgeway/Dataquest
The Corporate Center
550 Cochituate Road
Framingham, MA 01701
Phone: (508) 370-5555
Fax: (508) 370-6262

Dataquest Incorporated
Invitational Computer Conferences Division
3151 Airway Avenue, C-2
Costa Mesa, California 92626
Phone: (714) 957-0171
Telex: 5101002189 ICCDQ
Fax: (714) 957-0903

Dataquest Australia
Suite 1, Century Plaza
80 Berry Street
North Sydney, NSW 2060
Australia
Phone: (02) 959 4544
Telex: 25468
Fax: (02) 929 0635

Dataquest GmbH
Kronstadter Strasse 9
8000 Munich 80
West Germany
Phone: 011 49 89 93 09 09 0
Fax: 49 89 930 3277

Dataquest Europe Limited
Roussel House, Broadwater Park
Denham, Uxbridge, Middx UB9 5HP
England
Phone: 0895-835050
Telex: 266195
Fax: 0895 835260/1/2

Dataquest Europe SA
Tour Galliéni 2
36, avenue du Général-de-Gaulle
93175 Bagnolet Cedex
France
Phone: (1) 48 97 31 00
Telex: 233 263
Fax: (1) 48 97 34 00

Dataquest Hong Kong
Rm. 401, Connaught Comm. Bldg.
185 Wanchai Rd.
Wanchai, Hong Kong
Phone: 8387336
Telex: 80587
Fax: 5722375

Dataquest Israel
59 Mishmar Ha'yarden Street
Tel Aviv, Israel 69865
or
P.O. Box 18198
Tel Aviv, Israel
Phone: 52 913937
Telex: 341118
Fax: 52 32865

Dataquest Japan Limited
Shinkawa Sanko Building
1-3-17 Shinkawa, Chuo-ku
Tokyo 104 Japan
Phone: (03) 5566-0411
Fax: (03) 5566-0425

Dataquest Korea
Daeheung Bldg. 1105
648-23 Yeoksam-dong
Kangnam-gu
Seoul, Korea 135
Phone: (02) 556-4166
Fax: (02) 552-2661

Dataquest Singapore
4012 Ang Mo Kio Industrial Park 1
Ave. 10, #03-10 to #03-12
Singapore 2056
Phone: 4597181
Telex: 38257
Fax: 4563129

Dataquest Taiwan
Room 801/8th Floor
Ever Spring Building
147, Sect. 2, Chien Kuo N. Rd.
Taipei, Taiwan R.O.C. 104
Phone: (02) 501-7960
Telex: 27459
Fax: (02) 505-4265

Dataquest West Germany
In der Schneithohl 17
6242 Kronberg 2
West Germany
Phone: 06173/61685
Telex: 418089
Fax: 06173/67901

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MOS Microcomponent Market Share Estimates

1988–1990

Source: Dataquest

Semiconductors *Worldwide*
Microcomponents

Dataquest

MOS Microcomponent Market Share Estimates 1988-1990

Source: Dataquest

Dataquest

Semiconductors *Worldwide*
Microcomponents

Published by Dataquest Incorporated

MOS Microcomponent Market Share Estimates, 1988-1990

The following tables represent Dataquest's MOS microcomponent market share estimates for 1988 through 1990. The tables are organized as follows:

Table 1	Worldwide Market Share Rankings
Table 2	Worldwide Market Share Estimates
Table 3	North American Market Share Estimates
Table 4	Japanese Market Share Estimates
Table 5	European Market Share Estimates
Table 6	Asia/Pacific-Rest of World Market Share Estimates
Table 7	Estimated Revenue by Regional Market and Regional Company Base

Table 1
Estimated Worldwide MOS Microcomponent Market Share Rankings
(Factory Revenue in Millions of U.S. Dollars)

Company:	Top 40
Product:	Total MOS Microcomponent
Region of Consumption:	Worldwide
Distribution Channel:	NM
Application:	All
Specification:	All

1990 Rank	1989 Rank		1989 Revenue	1990 Revenue	Percent Change	1990 Market Share (%)
1	1	Intel	1,929	2,726	41	27.1
2	2	NEC	937	1,083	16	10.8
3	3	Motorola	803	1,009	26	10.0
4	4	Hitachi	554	607	10	6.0
5	5	Mitsubishi	435	464	7	4.6
6	6	Toshiba	407	441	8	4.4
7	7	Texas Instruments	252	320	27	3.2
8	8	Matsushita	217	250	15	2.5
9	11	National Semiconductor	172	248	44	2.5
10	9	Chips & Technologies	216	240	11	2.4
11	10	Fujitsu	211	239	13	2.4
12	17	Philips	131	192	47	1.9
13	12	Advanced Micro Devices	172	178	3	1.8
14	13	SGS-Thomson	161	175	9	1.7
15	16	Western Digital	135	148	10	1.5
16	14	Oki	149	147	-1	1.5
17	15	AT&T	141	145	3	1.4
18	19	Sharp	112	138	23	1.4
19	31	Cirrus Logic	29	129	345	1.3
20	22	Siemens	92	116	26	1.2
21	18	Harris	115	110	-4	1.1
22	21	VLSI Technology	94	105	12	1.0
23	20	Zilog	99	100	1	1.0
24	24	LSI Logic	67	93	39	.9
25	23	Sanyo	70	80	14	.8
26	25	Weitek	49	57	16	.6
27	26	Sony	47	49	4	.5
28	28	Rockwell	42	40	-5	.4
28	29	Standard Microsystems	34	40	18	.4
30	27	United Microelectronics	43	39	-9	.4
31	30	Appian Technology	30	38	27	.4
32	32	Matra MHS	28	33	18	.3
33	35	NCR	22	31	41	.3

(Continued)

Table 1 (Continued)
Estimated Worldwide MOS Microcomponent Market Share Rankings
(Factory Revenue in Millions of U.S. Dollars)

1990 Rank	1989 Rank		1989 Revenue	1990 Revenue	Percent Change	1990 Market Share (%)
34	33	ITT	25	28	12	.3
35	40	Performance Semiconductor	13	24	85	.2
36	34	Ricoh	22	23	5	.2
37	44	Samsung	8	22	175	.2
38	36	Analog Devices	20	20	0	.2
38	41	Integrated Device Technology	13	20	54	.2
40	38	Rohm	16	18	13	.2
		All Others	90	103	14	1.0
		North American Companies	4,526	5,912	31	58.7
		Japanese Companies	3,190	3,551	11	35.3
		European Companies	433	538	24	5.3
		Asia/Pacific Companies	53	67	26	.7
		Total Market	8,202	10,068	23	100.0

NM = Not meaningful

Source: Dataquest (May 1991)

Table 2
Market Share Estimates
(Factory Revenue in Millions of U.S. Dollars)

Company:	Each
Product:	Total MOS Microcomponents
Region of Consumption:	Worldwide
Distribution Channel:	NM
Application:	All
Specification:	All

	Revenue			Market Share (%)		
	1988	1989	1990	1988	1989	1990
Total Market	7,144	8,202	10,068	100.0	100.0	100.0
North American Companies	3,872	4,526	5,912	54.2	55.2	58.7
Advanced Micro Devices	183	172	178	2.6	2.1	1.8
Analog Devices	20	20	20	.3	.2	.2
Appian Technology	17	30	38	.2	.4	.4
AT&T	39	141	145	.5	1.7	1.4
California Micro Devices	1	8	8	.0	.1	.1
Chips & Technologies	130	216	240	1.8	2.6	2.4
Cirrus Logic	NA	29	129	NA	.4	1.3
Cypress Semiconductor	7	11	15	.1	.1	.1
General Electric	48	0	0	.7	.0	.0
Harris	62	115	110	.9	1.4	1.1
Holt	0	0	1	.0	.0	.0
Hughes	2	2	2	.0	.0	.0
IMI	1	0	0	.0	.0	.0
Integrated Device Technology	15	13	20	.2	.2	.2
Intel	1,835	1,929	2,726	25.7	23.5	27.1
ITT	15	25	28	.2	.3	.3
LSI Logic	18	67	93	.3	.8	.9
Microchip Technology	18	18	16	.3	.2	.2
Motorola	699	803	1,009	9.8	9.8	10.0
National Semiconductor	150	172	248	2.1	2.1	2.5
NCR	6	22	31	.1	.3	.3
Performance Semiconductor	NA	13	24	NA	.2	.2
Rockwell	51	42	40	.7	.5	.4
SEEQ Technology	0	0	12	.0	.0	.1
Sierra Semiconductor	1	1	1	.0	.0	.0
Standard Microsystems	34	34	40	.5	.4	.4
Texas Instruments	234	252	320	3.3	3.1	3.2
TRW	0	5	6	.0	.1	.1
VLSI Technology	54	94	105	.8	1.1	1.0
WaferScale Integration	0	2	2	.0	.0	.0
Weitek	35	49	57	.5	.6	.6
Western Digital	100	135	148	1.4	1.6	1.5
Zilog	90	99	100	1.3	1.2	1.0
Other North American Companies	7	7	0	.1	.1	.0

(Continued)

Table 2 (Continued)
Market Share Estimates
(Factory Revenue in Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1988	1989	1990	1988	1989	1990
Japanese Companies	2,817	3,190	3,551	39.4	38.9	35.3
Fuji Electric	0	0	1	.0	.0	.0
Fujitsu	202	211	239	2.8	2.6	2.4
Hitachi	525	554	607	7.3	6.8	6.0
Matsushita	230	217	250	3.2	2.6	2.5
Mitsubishi	381	435	464	5.3	5.3	4.6
NEC	790	937	1,083	11.1	11.4	10.8
Oki	134	149	147	1.9	1.8	1.5
Ricoh	19	22	23	.3	.3	.2
Rohm	16	16	18	.2	.2	.2
Sanyo	70	70	80	1.0	.9	.8
Seiko Epson	12	12	11	.2	.1	.1
Sharp	54	112	138	.8	1.4	1.4
Sony	37	47	49	.5	.6	.5
Toshiba	346	407	441	4.8	5.0	4.4
Other Japanese Companies	1	1	0	.0	.0	.0
European Companies	401	433	538	5.6	5.3	5.3
Eurosil	2	2	4	.0	.0	.0
GEC Plessey	0	0	8	.0	.0	.1
Inmos	57	0	0	.8	.0	.0
Matra MHS	21	28	33	.3	.3	.3
MEDL	1	3	0	.0	.0	.0
Philips	114	131	192	1.6	1.6	1.9
Plessey	0	3	0	.0	.0	.0
SGS-Thomson	118	161	175	1.7	2.0	1.7
Siemens	88	92	116	1.2	1.1	1.2
TMS	0	13	10	.0	.2	.1
Asia/Pacific Companies	54	53	67	.8	.6	.7
Goldstar	4	2	3	.1	.0	.0
Samsung	15	8	22	.2	.1	.2
United Microelectronics	35	43	39	.5	.5	.4

NA = Not available
NM = Not meaningful

Source: Dataquest (May 1991)

Table 3
Market Share Estimates
(Factory Revenue in Millions of U.S. Dollars)

Company:	Each
Product:	Total MOS Microcomponent
Region of Consumption:	North America
Distribution Channel:	NM
Application:	All
Specification:	All

	Revenue			Market Share (%)		
	1988	1989	1990	1988	1989	1990
Total Market	2,707	2,972	3,563	100.0	100.0	100.0
North American Companies	2,274	2,578	3,159	84.0	86.7	88.7
Advanced Micro Devices	92	75	71	3.4	2.5	2.0
Analog Devices	11	11	11	.4	.4	.3
Appian Technology	6	22	25	.2	.7	.7
AT&T	38	137	141	1.4	4.6	4.0
California Micro Devices	1	5	5	.0	.2	.1
Chips & Technologies	73	122	123	2.7	4.1	3.5
Cirrus Logic	NA	25	94	NA	.8	2.6
Cypress Semiconductor	6	9	12	.2	.3	.3
General Electric	32	0	0	1.2	.0	.0
Harris	54	68	47	2.0	2.3	1.3
Hughes	2	2	2	.1	.1	.1
Integrated Device Technology	9	9	15	.3	.3	.4
Intel	1,087	1,088	1,445	40.2	36.6	40.6
ITT	5	5	5	.2	.2	.1
LSI Logic	18	61	89	.7	2.1	2.5
Microchip Technology	10	10	7	.4	.3	.2
Motorola	421	459	500	15.6	15.4	14.0
National Semiconductor	75	79	136	2.8	2.7	3.8
NCR	5	20	29	.2	.7	.8
Performance Semiconductor	NA	10	18	NA	.3	.5
Rockwell	34	24	22	1.3	.8	.6
SEEQ Technology	0	0	9	.0	.0	.3
Sierra Semiconductor	1	1	1	.0	.0	.0
Standard Microsystems	13	13	15	.5	.4	.4
Texas Instruments	101	102	133	3.7	3.4	3.7
TRW	0	5	5	.0	.2	.1
VLSI Technology	45	45	39	1.7	1.5	1.1
WaferScale Integration	0	2	2	.0	.1	.1
Weitek	28	42	50	1.0	1.4	1.4
Western Digital	50	68	56	1.8	2.3	1.6
Zilog	50	52	52	1.8	1.7	1.5
Other North American Companies	7	7	0	.3	.2	.0

(Continued)

Table 3 (Continued)
Market Share Estimates
(Factory Revenue in Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1988	1989	1990	1988	1989	1990
Japanese Companies	293	278	293	10.8	9.4	8.2
Fujitsu	14	14	19	.5	.5	.5
Hitachi	66	67	68	2.4	2.3	1.9
Matsushita	7	7	8	.3	.2	.2
Mitsubishi	22	10	11	.8	.3	.3
NEC	105	83	83	3.9	2.8	2.3
Oki	18	19	18	.7	.6	.5
Sanyo	0	4	4	.0	.1	.1
Sharp	2	4	5	.1	.1	.1
Toshiba	59	70	77	2.2	2.4	2.2
European Companies	131	107	102	4.8	3.6	2.9
GEC Plessey	0	0	2	.0	.0	.1
Inmos	32	0	0	1.2	.0	.0
Matra MHS	3	6	7	.1	.2	.2
MEDL	0	2	0	.0	.1	.0
Philips	39	39	38	1.4	1.3	1.1
Plessey	0	1	0	.0	.0	.0
SGS-Thomson	30	43	35	1.1	1.4	1.0
Siemens	27	14	18	1.0	.5	.5
TMS	0	2	2	.0	.1	.1
Asia/Pacific Companies	9	9	9	.3	.3	.3
Samsung	0	0	2	.0	.0	.1
United Microelectronics	9	9	7	.3	.3	.2

NA = Not available
NM = Not meaningful

Source: Dataquest (May 1991)

Table 4
Market Share Estimates
(Factory Revenue in Millions of U.S. Dollars)

Company:	Each
Product:	Total MOS Microcomponent
Region of Consumption:	Japan
Distribution Channel:	NM
Application:	All
Specification:	All

	Revenue			Market Share (%)		
	1988	1989	1990	1988	1989	1990
Total Market	2,573	2,828	3,210	100.0	100.0	100.0
North American Companies	444	496	633	17.3	17.5	19.7
Advanced Micro Devices	35	23	18	1.4	.8	.6
Analog Devices	3	3	3	.1	.1	.1
Appian Technology	0	0	1	.0	.0	.0
Chips & Technologies	10	17	18	.4	.6	.6
Cirrus Logic	NA	2	23	NA	.1	.7
Harris	2	7	9	.1	.2	.3
Integrated Device Technology	0	1	2	.0	.0	.1
Intel	235	250	332	9.1	8.8	10.3
ITT	2	0	0	.1	.0	.0
LSI Logic	0	0	2	.0	.0	.1
Motorola	73	82	124	2.8	2.9	3.9
National Semiconductor	6	28	27	.2	1.0	.8
Performance Semiconductor	NA	0	1	NA	.0	.0
Rockwell	0	1	0	.0	.0	.0
SEEQ Technology	0	0	2	.0	.0	.1
Standard Microsystems	1	1	1	.0	.0	.0
Texas Instruments	60	59	45	2.3	2.1	1.4
VLSI Technology	1	2	2	.0	.1	.1
Weitek	4	4	4	.2	.1	.1
Western Digital	8	11	13	.3	.4	.4
Zilog	4	5	6	.2	.2	.2

(Continued)

Table 4 (Continued)
Market Share Estimates
(Factory Revenue in Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1988	1989	1990	1988	1989	1990
Japanese Companies	2,116	2,309	2,562	82.2	81.6	79.8
Fuji Electric	0	0	1	.0	.0	.0
Fujitsu	169	172	190	6.6	6.1	5.9
Hitachi	350	365	408	13.6	12.9	12.7
Matsushita	215	202	233	8.4	7.1	7.3
Mitsubishi	350	328	360	13.6	11.6	11.2
NEC	533	669	770	20.7	23.7	24.0
Oki	70	78	77	2.7	2.8	2.4
Ricoh	19	22	23	.7	.8	.7
Rohm	16	16	17	.6	.6	.5
Sanyo	55	48	39	2.1	1.7	1.2
Seiko Epson	12	12	11	.5	.4	.3
Sharp	45	94	117	1.7	3.3	3.6
Sony	37	47	49	1.4	1.7	1.5
Toshiba	244	255	267	9.5	9.0	8.3
Other Japanese Companies	1	1	0	.0	.0	.0
European Companies	13	23	15	.5	.8	.5
Inmos	4	0	0	.2	.0	.0
Matra MHS	1	0	0	.0	.0	.0
Philips	1	11	4	.0	.4	.1
SGS-Thomson	0	7	5	.0	.2	.2
Siemens	7	5	6	.3	.2	.2

NA = Not available
NM = Not meaningful

Source: Dataquest (May 1991)

Table 5
Market Share Estimates
(Factory Revenue in Millions of U.S. Dollars)

Company:	Each
Product:	Total MOS Microcomponent
Region of Consumption:	Europe
Distribution Channel:	NM
Application:	All
Specification:	All

	Revenue			Market Share (%)		
	1988	1989	1990	1988	1989	1990
Total Market	1,212	1,469	1,836	100.0	100.0	100.0
North American Companies	735	890	1,145	60.6	60.6	62.4
Advanced Micro Devices	33	34	47	2.7	2.3	2.6
Analog Devices	6	6	6	.5	.4	.3
Appian Technology	1	4	5	.1	.3	.3
AT&T	1	4	4	.1	.3	.2
California Micro Devices	0	1	1	.0	.1	.1
Chips & Technologies	6	11	14	.5	.7	.8
Cirrus Logic	NA	0	3	NA	.0	.2
Cypress Semiconductor	1	2	3	.1	.1	.2
General Electric	15	0	0	1.2	.0	.0
Harris	6	21	31	.5	1.4	1.7
Holt	0	0	1	.0	.0	.1
Integrated Device Technology	6	3	3	.5	.2	.2
Intel	351	416	528	29.0	28.3	28.8
ITT	7	18	21	.6	1.2	1.1
LSI Logic	0	6	2	.0	.4	.1
Microchip Technology	4	4	5	.3	.3	.3
Motorola	150	179	233	12.4	12.2	12.7
National Semiconductor	40	45	50	3.3	3.1	2.7
NCR	0	1	1	.0	.1	.1
Performance Semiconductor	NA	2	4	NA	.1	.2
Rockwell	11	9	9	.9	.6	.5
SEEQ Technology	0	0	1	.0	.0	.1
Standard Microsystems	5	5	7	.4	.3	.4
Texas Instruments	48	60	99	4.0	4.1	5.4
TRW	0	0	1	.0	.0	.1
VLSI Technology	5	17	28	.4	1.2	1.5
Weitek	3	3	3	.2	.2	.2
Western Digital	17	23	18	1.4	1.6	1.0
Zilog	19	16	17	1.6	1.1	.9

(Continued)

Table 5 (Continued)
Market Share Estimates
(Factory Revenue in Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1988	1989	1990	1988	1989	1990
Japanese Companies	253	310	327	20.9	21.1	17.8
Fujitsu	9	10	12	.7	.7	.7
Hitachi	71	75	77	5.9	5.1	4.2
Mitsubishi	8	48	10	.7	3.3	.5
NEC	109	122	151	9.0	8.3	8.2
Oki	16	18	19	1.3	1.2	1.0
Sanyo	12	1	1	1.0	.1	.1
Sharp	1	1	1	.1	.1	.1
Toshiba	27	35	56	2.2	2.4	3.1
European Companies	220	265	362	18.2	18.0	19.7
Eurosil	1	1	3	.1	.1	.2
GEC Plessey	0	0	6	.0	.0	.3
Inmos	21	0	0	1.7	.0	.0
Matra MHS	14	20	24	1.2	1.4	1.3
MEDL	1	1	0	.1	.1	.0
Philips	55	62	112	4.5	4.2	6.1
Plessey	0	2	0	.0	.1	.0
SGS-Thomson	77	101	126	6.4	6.9	6.9
Siemens	51	67	83	4.2	4.6	4.5
TMS	0	11	8	.0	.7	.4
Asia/Pacific Companies	4	4	2	.3	.3	.1
United Microelectronics	4	4	2	.3	.3	.1

NA = Not available
NM = Not meaningful

Source: Dataquest (May 1991)

Table 6
Market Share Estimates
(Factory Revenue in Millions of U.S. Dollars)

Company:	Each
Product:	Total MOS Microcomponent
Region of Consumption:	Asia/Pacific-Rest of World
Distribution Channel:	NM
Application:	All
Specification:	All

	Revenue			Market Share (%)		
	1988	1989	1990	1988	1989	1990
Total Market	652	933	1,459	100.0	100.0	100.0
North American Companies	419	562	975	64.3	60.2	66.8
Advanced Micro Devices	23	40	42	3.5	4.3	2.9
Appian Technology	10	4	7	1.5	.4	.5
California Micro Devices	0	2	2	.0	.2	.1
Chips & Technologies	41	66	85	6.3	7.1	5.8
Cirrus Logic	NA	2	9	NA	.2	.6
General Electric	1	0	0	.2	.0	.0
Harris	0	19	23	.0	2.0	1.6
IMI	1	0	0	.2	.0	.0
Intel	162	175	421	24.8	18.8	28.9
ITT	1	2	2	.2	.2	.1
Microchip Technology	4	4	4	.6	.4	.3
Motorola	55	83	152	8.4	8.9	10.4
National Semiconductor	29	20	35	4.4	2.1	2.4
NCR	1	1	1	.2	.1	.1
Performance Semiconductor	NA	1	1	NA	.1	.1
Rockwell	6	8	9	.9	.9	.6
Standard Microsystems	15	15	17	2.3	1.6	1.2
Texas Instruments	25	31	43	3.8	3.3	2.9
VLSI Technology	3	30	36	.5	3.2	2.5
Western Digital	25	33	61	3.8	3.5	4.2
Zilog	17	26	25	2.6	2.8	1.7

(Continued)

Table 6 (Continued)
Market Share Estimates
(Factory Revenue in Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1988	1989	1990	1988	1989	1990
Japanese Companies	155	293	369	23.8	31.4	25.3
Fujitsu	10	15	18	1.5	1.6	1.2
Hitachi	38	47	54	5.8	5.0	3.7
Matsushita	8	8	9	1.2	.9	.6
Mitsubishi	1	49	83	.2	5.3	5.7
NEC	43	63	79	6.6	6.8	5.4
Oki	30	34	33	4.6	3.6	2.3
Rohm	0	0	1	.0	.0	.1
Sanyo	3	17	36	.5	1.8	2.5
Sharp	6	13	15	.9	1.4	1.0
Toshiba	16	47	41	2.5	5.0	2.8
European Companies	37	38	59	5.7	4.1	4.0
Eurosil	1	1	1	.2	.1	.1
Matra MHS	3	2	2	.5	.2	.1
Philips	19	19	38	2.9	2.0	2.6
SGS-Thomson	11	10	9	1.7	1.1	.6
Siemens	3	6	9	.5	.6	.6
Asia/Pacific Companies	41	40	56	6.3	4.3	3.8
Goldstar	4	2	3	.6	.2	.2
Samsung	15	8	20	2.3	.9	1.4
United Microelectronics	22	30	30	3.4	3.2	2.1

NA = Not available
NM = Not meaningful

Source: Dataquest (May 1991)

Table 7
Estimated Revenue by Regional Market and Regional Company Base
(Factory Revenue in Millions of U.S. Dollars)

Company:	All, by Regional Base
Product:	Total MOS Microcomponent
Region of Consumption:	Each
Distribution Channel:	NM
Application:	All
Specification:	All

	Revenue			Market Share (%)		
	1988	1989	1990	1988	1989	1990
Worldwide Market	7,144	8,202	10,068	100.0	100.0	100.0
North American Companies	3,872	4,526	5,912	54.2	55.2	58.7
Japanese Companies	2,817	3,190	3,551	39.4	38.9	35.3
European Companies	401	433	538	5.6	5.3	5.3
Asia/Pacific Companies	54	53	67	.8	.6	.7
North American Market	2,707	2,972	3,563	37.9	36.2	35.4
North American Companies	2,274	2,578	3,159	31.8	31.4	31.4
Japanese Companies	293	278	293	4.1	3.4	2.9
European Companies	131	107	102	1.8	1.3	1.0
Asia/Pacific Companies	9	9	9	.1	.1	.1
Japanese Market	2,573	2,828	3,210	36.0	34.5	31.9
North American Companies	444	496	633	6.2	6.0	6.3
Japanese Companies	2,116	2,309	2,562	29.6	28.2	25.4
European Companies	13	23	15	.2	.3	.1
Asia/Pacific Companies	0	0	0	.0	.0	.0
European Market	1,212	1,469	1,836	17.0	17.9	18.2
North American Companies	735	890	1,145	10.3	10.9	11.4
Japanese Companies	253	310	327	3.5	3.8	3.2
European Companies	220	265	362	3.1	3.2	3.6
Asia/Pacific Companies	4	4	2	.1	.0	.0
Asia/Pacific Market	652	933	1,459	9.1	11.4	14.5
North American Companies	419	562	975	5.9	6.9	9.7
Japanese Companies	155	293	369	2.2	3.6	3.7
European Companies	37	38	59	.5	.5	.6
Asia/Pacific Market	41	40	56	.6	.5	.6

NM = Not meaningful

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest (May 1991)

Dataquest

Dataquest Research and Sales Offices:

Dataquest Incorporated
1290 Ridder Park Drive
San Jose, California 95131-2398
Phone: (408) 437-8000
Telex: 171973
Fax: (408) 437-0292

Technology Products Group
Phone: (800) 624-3280

Dataquest Incorporated
Ledgeway/Dataquest
The Corporate Center
550 Cochituate Road
Framingham, MA 01701
Phone: (508) 370-5555
Fax: (508) 370-6262

Dataquest Incorporated
Invitational Computer Conferences Division
3151 Airway Avenue, C-2
Costa Mesa, California 92626
Phone: (714) 957-0171
Telex: 5101002189 ICCDQ
Fax: (714) 957-0903

Dataquest Australia
Suite 1, Century Plaza
80 Berry Street
North Sydney, NSW 2060
Australia
Phone: (02) 959 4544
Telex: 25468
Fax: (02) 929 0635

Dataquest GmbH
Kronstadter Strasse 9
8000 Munich 80
West Germany
Phone: 011 49 89 93 09 09 0
Fax: 49 89 930 3277

Dataquest Europe Limited
Roussel House, Broadwater Park
Denham, Uxbridge, Middx UB9 5HP
England
Phone: 0895-835050
Telex: 266195
Fax: 0895 835260/1/2

Dataquest Europe SA
Tour Galliéni 2
36, avenue du Général-de-Gaulle
93175 Bagnolet Cedex
France
Phone: (1) 48 97 31 00
Telex: 233 263
Fax: (1) 48 97 34 00

Dataquest Hong Kong
Rm. 401, Connaught Comm. Bldg.
185 Wanchai Rd.
Wanchai, Hong Kong
Phone: 8387336
Telex: 80587
Fax: 5722375

Dataquest Israel
59 Mishmar Ha'yarden Street
Tel Aviv, Israel 69865
or
P.O. Box 18198
Tel Aviv, Israel
Phone: 52 913937
Telex: 341118
Fax: 52 32865

Dataquest Japan Limited
Shinkawa Sanko Building
1-3-17 Shinkawa, Chuo-ku
Tokyo 104 Japan
Phone: (03) 5566-0411
Fax: (03) 5566-0425

Dataquest Korea
Daeheung Bldg. 1105
648-23 Yeoksam-dong
Kangnam-gu
Seoul, Korea 135
Phone: (02) 556-4166
Fax: (02) 552-2661

Dataquest Singapore
4012 Ang Mo Kio Industrial Park 1
Ave. 10, #03-10 to #03-12
Singapore 2056
Phone: 4597181
Telex: 38257
Fax: 4563129

Dataquest Taiwan
Room 801/8th Floor
Ever Spring Building
147, Sect. 2, Chien Kuo N. Rd.
Taipei, Taiwan R.O.C. 104
Phone: (02) 501-7960
Telex: 27459
Fax: (02) 505-4265

Dataquest West Germany
In der Schneithohl 17
6242 Kronberg 2
West Germany
Phone: 06173/61685
Telex: 418089
Fax: 06173/67901

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Dataquest Perspective

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Market Analysis

The Coming Revolution in Computing Platforms

The combination of several interrelated trends will result in dramatic changes for both the computer industry and the microcomponent vendors that service it. This article analyzes the most important of these trends and presents a long-term projection of volumes for RISC- and CISC-based microprocessors.
By Ken Lowe *Page 2*

Technology Analysis

Visualizing Changes in 3-D Graphics

Advances in computational power and innovative applications have turned 3-D graphics and visualization into one of the fastest-growing segments of the technical computing market. This article examines the functions performed by 3-D graphics, the standards affecting its use, and the types of architectures currently used.
By Ken Lowe *Page 7*

Market Analysis

The Coming Revolution in Computing Platforms

New Directions

As we look toward the end of this century, a mere eight years away, we see three new conceptual directions shaping the computing platform microcomponent market: virtualization, standardization, and integration.

Virtualization, using innovative techniques to maintain application software compatibility without native hardware instructions or I/O devices, is being driven by new technologies within microprocessors and operating systems. Standardization, gaining widespread adoption of interfaces and protocols, is being driven by the need for interoperability and cost-effectiveness. Integration, moving complete system architectures down to the semiconductor level, is being driven by the new classes of computing devices from hand-held units to supercomputers. The combination of these three trends will result in dramatic changes for both the computer industry and the microcomponent vendors that service the industry.

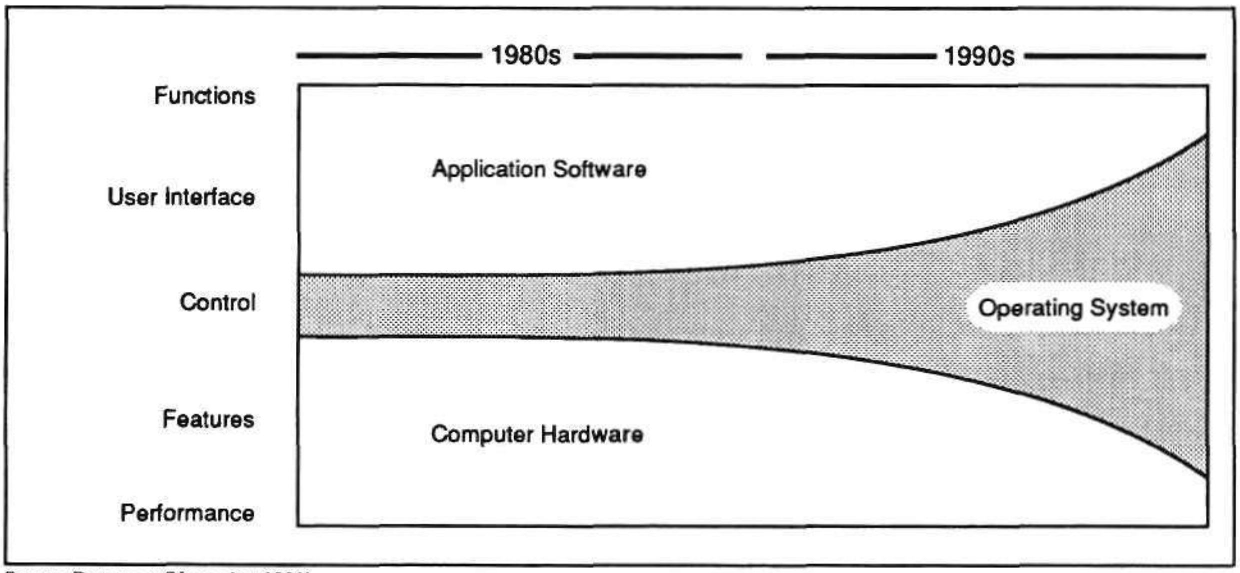
Shifting from Hardware-Based to Software-Based Architectures

One of the most fundamental changes taking place is a gradual shift from a hardware-based to a software-based compatibility. This shift is evidenced by the movement toward graphical user interfaces (GUIs) such as Windows and Macintosh. Additionally, new techniques in processor design are enabling direct emulation of instruction sets or I/O device interaction. By far the most significant are the advanced operating systems, some of which employ object-oriented structures, and all of which separate the application software from the underlying hardware.

Three major operating systems currently control the computer platform market. They are DOS, Macintosh (MAC), and UNIX. The very most pervasive, DOS-based systems represent well over 80 percent of the installed desktop units (and 99 percent of the portable units). However, this fact is somewhat misleading because DOS system compatibility is based on a combination of three elements: the 80X86 instruction set; the I/O device structure including basic input/output system (BIOS), registers, and interrupts; and the DOS operating system. Thus, in the past, DOS represented a thin thread of control for the computing environment, simply launching applications to run on the underlying hardware.

As shown in Figure 1, future operating systems will provide a complete framework for the

Figure 1
The Shift from Hardware to Software Architecture



Source: Dataquest (November 1991)

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scope of compatibility between applications software and hardware platforms. These operating systems will not only maintain complete execution control but will encompass a complete GUI and support the wide range of hardware features required for mainstream use. This trend is evidenced by the two most significant industry efforts currently under way—NT Windows and PowerOpen.

NT Windows, Microsoft Corporation's next-generation operating system, will feature the Windows GUI and will provide uniform compatibility with DOS, Windows, and OS/2 applications. NT Windows is based on a completely new operating system kernal and is currently being ported to Intel 386/486- and MIPS R4000-based systems. NT Windows was first demonstrated at the R4000 announcement in September this year and is expected to ship sometime around mid-1992. Under similar goals, IBM Corporation's OS/2 2.0 is expected to ship in this same time frame and directly compete with both DOS/Windows and NT Windows for 80X86 desktop dominance.

PowerOpen, the first new operating system resulting from the IBM/Apple Computer Inc. alliance, will feature the Macintosh user interface and will provide uniform compatibility with current MAC and AIX (IBM's version of UNIX) applications. PowerOpen is based on IBM's AIX and is being ported to the new RS/6000 PowerPC chip and Intel 386/486-based systems. PowerOpen is expected to be demonstrated at the end of 1993 and ship sometime around mid-1994. This system should not be confused with the IBM/Apple joint venture future operating system based on Apple's Pink project, which will not be available until probably 1995.

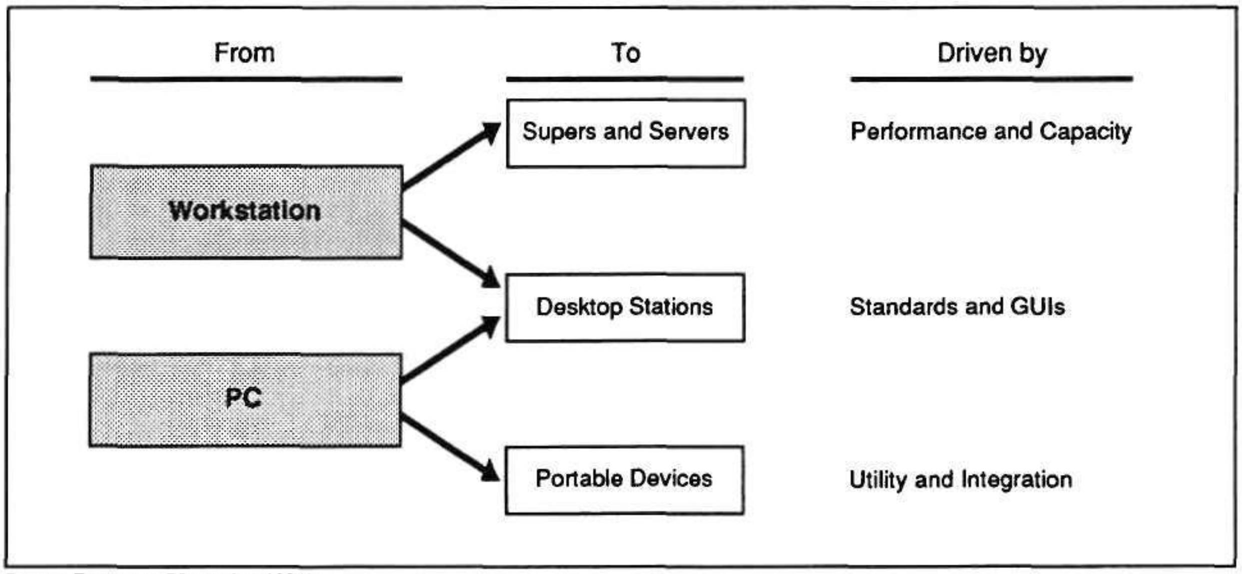
Based on a more detailed analysis, Dataquest believes that DOS/Windows and NT Windows will become the most dominant forces in the desktop and portable computing markets. This development in turn will eventually allow complete freedom of movement between supported hardware architectures with vendor differentiation focused on performance, packaging, and pricing.

The Blurring and Separating of Computer Classes

From a technical viewpoint, we have already seen the barriers breaking down between what constitutes a PC and what constitutes a workstation. However, the trend toward GUI-based, multitasking operating systems will result in a uniform class of computers being marketed as desktop stations (see Figure 2). At the same time, the market will be shifting to more distinctive lines of segmentation by product form, separating out the fast-growing portable devices at the low end and the supercomputers and servers at the high end. The significance of these changes is the effect they will have on market-targeting decisions for microcomponent vendors, opening up new opportunities and breaking down previously existing barriers.

For the next few years, there will be overall consolidation in capabilities used in common

Figure 2
Distinctions Are Blurring and Separating



Source: Dataquest (November 1991)

desktop stations, although there will be a wide range of price/performance levels. Accelerated graphics will be the rule (as in current workstations) as a result of the requirements within a GUI environment. We will also soon see video compression coprocessors and 3-D graphics engines used as socketed options much like math coprocessors in the 1980s.

Built-in networking will become commonplace (as in current workstations) in response to interoperability and communication requirements. More application software will become available across a multitude of architectures as a result of the new operating systems. In short, desktop station hardware will look more like today's workstations while the application software base will look like today's PCs. This situation represents an opportunity both for well-integrated chip sets targeted at new microprocessors and for individual high-performance microperipheral components.

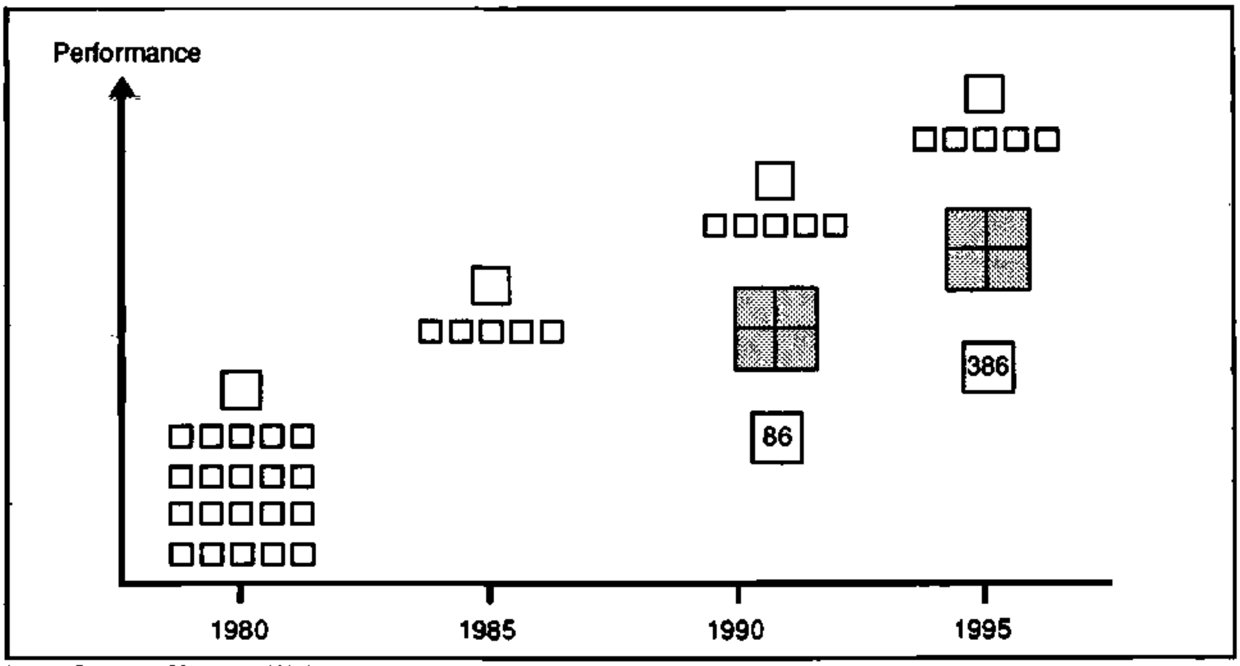
Portable devices represent a distinct set of problems associated with delivering complete computers with low power, small size, and light weight. With these devices constantly moving up in performance and down in size, the entry barriers are becoming even greater. The most popular configuration today is the 5- to 6-pound notebook computer, taking over the initial surge started by its heavier laptop counterparts. Notebook units typically feature an Intel 386SL with built-in power management, 2MB RAM (expandable to 8MB), 40MB hard disks (IDE interface), 1.44MB floppy, 640×480 VGA graphics with LCD display and direct CRT output port, full-size keyboard, serial port, mouse port, and optional modem module.

Another type of portable device with growing popularity is the hand-held or palmtop computer. These units are typified by the new HP95LX, which is essentially an 80286-based DOS computer but with limited memory, calculator-style keypad, small LCD display, serial interface port, and several built-in software programs such as Lotus 1-2-3 and an appointment calendar. Some analysts believe that these units, combining the best of an electronic daytimer and programmable calculator/spreadsheet, will move quickly to high volumes as consumer-oriented models begin to hit the market.

Increasing the Levels of Integration

Three major forces are driving the increased integration of system components: standardization, size requirements, and performance. As shown in Figure 3, integration resulted in the number of microcomponents comprising a PC steadily moving downward over the past 10 years. We are now seeing three distinct forms of architecture: single-chip PC, tightly coupled chip set (including processor), and custom high-end designs.

Figure 3
Increasing Levels of Integration



Source: Dataquest (November 1991)

The increase in mainstream standardization allows more capabilities to be integrated without risking obsolescence. As vendors integrate more value-added microperipherals into a chip set (or single chip), it will increase both average selling price and the barrier to entry for other vendors, which further protects price erosion. Applicable standards include graphics, networking, storage, and expansion bus.

For the portable segment, small size coupled with the movement to 3V power is the most pressing issue, driving downward to a handful of chips for a notebook PC and one or two chips for a hand-held. As the standards begin to coalesce and circuit density increases, it begins to make more sense to integrate down toward single-chip architectures containing all relevant I/O functions. As we reach this level of integration, we will see a reduction in the field of vendors capable of producing a competitive offering.

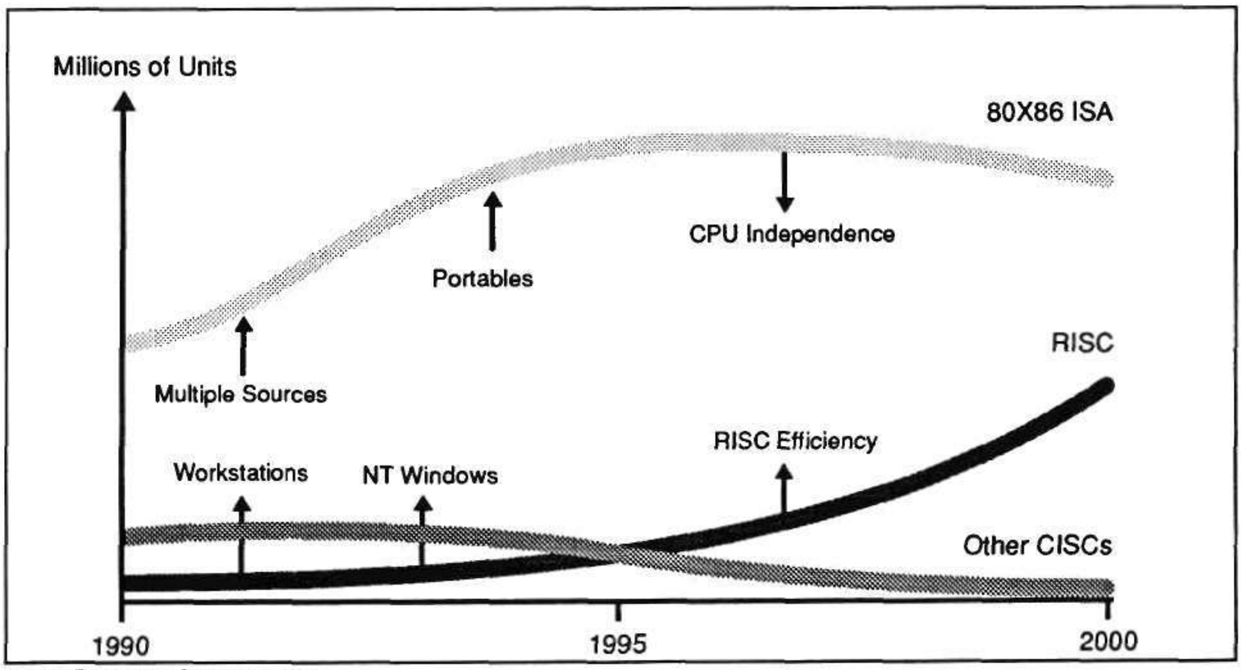
Even performance requirements in some cases are pushing the need for integration. Execution speed, data caching, multiprocessing, and pipelining are all forces driving toward shorter trace lengths and thus on-chip (or multichip module) functions. This fact is evidenced by all the new microprocessors integrating on-board cache, floating-point processors, and memory management units. As a case in point, Intel's new 586 processor has an estimated 4.5 million transistors with 75-mips performance, pushing the envelope in this direction. Eventually, ultimate speed pushes the need for ultimate integration.

Projecting Long-Term Processor Trends

So how does all this affect the outlook for the core microprocessor architectures during the next several years? As shown in Figure 4, the trend of 80X86 instruction-set architecture dominance will continue unabated for the next three to four years, after which the newer reduced-instruction-set computing (RISC) technology-based architectures begin to ramp-up and the other complex-instruction-set computing (CISC) technology-based architectures begin to decline. Analyzing the major industry driving forces provides the essential support to these conclusions.

To set the stage, 1990 saw shipments of about 20 million 80X86-based systems (more than 95 percent DOS PCs), 4 million other CISC-based systems (over 70 percent 68XXX systems dominated by Apple Macintoshes), and 200,000 RISC-based systems (dominated by the Sun Microsystems SPARCs). The dominance of the 80X86, as is widely known, is based on IBM's introduction of the PC in 1981, the broad software base that developed to support it, and the widespread compatibles industry that grew up around it. Then in May 1990 the phenomenon of Windows 3.0 occurred, giving this aging platform a new, graphics-oriented environment on

Figure 4
Long-Term Platform Processor Outlook



Source: Dataquest (November 1991)

which an improved class of application software would grow. The new Windows environment, perhaps 20 percent less effective than current Macintosh or workstation environments, is 200 percent more productive than DOS and is found on nearly 4 million DOS systems.

Moving through the early part of the 1990s, two additional forces will come into play, increasing the momentum of the 80X86 instruction-set architecture. First is the availability of multiple sources of the Intel 80386 microprocessor, currently the highest volume component in the family. Outside of Intel, we presently have AMD and Chips and Technologies offering 386 processors, and we expect to see at least two additional vendors enter the fray by the end of 1992. In addition to competitive pressures reducing the price of 386SX and 386DX processors, we expect to see faster versions of the 486, completely integrated versions of the 386SX, and low-power (3-volt) versions for both within the next two years.

Portable computers, which Dataquest expects to be over 50 percent of the entire PC volume by 1995, will also become a major driving force for the 80X86 during the 1990s. As previously discussed, this segment will create pressures to increase integration and reduce power while offering compatible desktop-level performance. The 80X86 processors have an overwhelming advantage here due to the current momentum as well as the breadth of innovative notebook, hand-held, and pen-based products being introduced. The highest-growth processor in this arena, the Intel 386SL, has design wins in nearly 40 notebook computers as demonstrated at COMDEX/Fall '91. To service this growing demand, large investments and alliances are being made to deliver integrated solutions of microprocessors, microperipherals, and memory.

Two forces are also developing momentum for new architectures based on RISC technology. For our purposes, RISC microprocessors are defined as providing an externally accessible direct hardware instruction set without microcode (includes microprocessors with multiple instruction sets, one of which is native nonmicrocoded). The acronym RISC (reduced-instruction-set computing) has little real meaning as a definition.

Widespread adoption by workstation vendors is the first major force driving the RISC curve upward. However, adoption has turned into a plethora of open systems alliances aimed at destroying current CISC microprocessor dominance, supported by multiple chip, software, and hardware vendors. Four major alliances have been created to proliferate a new computing environment based on RISC microprocessors:

- The MIPS camp—architected by MIPS Computer; operating systems by Microsoft and SCO; chips from Integrated Device Technology, LSI Logic, NEC Corporation, Performance, Siemens, and Toshiba; and systems from Compaq Computer, Digital Equipment Corporation, SGI, and some 50-plus others
- The PowerPC camp—architected by IBM (RS/6000); operating systems by Apple and IBM (Mac/UNIX); chips from Motorola (IBM for its own product); systems from Apple, IBM, potentially others
- The SPARC camp—architected by Sun; operating systems by Sun (UNIX); chips from Fujitsu, Cypress Semiconductor, LSI Logic, Texas Instruments, and others; and systems from Amdahl Corporation, CompuAdd, Sun, and some 20-plus others
- The HP-PA camp—architected by Hewlett-Packard Company (HP), operating systems by HP (UNIX), chips from Hitachi and Samsung; systems from HP and potentially others

The first major camp to result in mainstream adoption of RISC microprocessors due to NT Windows is the MIPS camp. NT Windows will bridge the gap for the enormous base of DOS/Windows users to select either a 386/486-based system or a MIPS R4000-based system. The second major push to RISC growth will occur when Apple and IBM begin marketing their next-generation PCs based on the PowerPC chip and power open.

Entering the second half of the 1990s, we will be in an era of software-based compatibility or CPU independence, which effectively eliminates the entry barrier in the DOS PC market erected by the 80X86 family. Thus, given that the new operating systems will support multiple architectures, competition will be based on the performance/integration/cost efficiency of a given approach. At this time, with widespread availability of third-generation RISC microprocessors, RISC efficiency will form a key driving force. The result will be a sharp upward climb of RISC processors in the last half of the 1990s.

While these battles are taking place, other CISC processors, dominated by the Motorola 68XXX family, will have difficulty staying competitive beyond 1993/1994. New levels of performance, competitive multisourced pricing, and completely integrated portable chip sets will set the stage for slowly declining life in the last half of the 1990s.

Dataquest Perspective

The basis for competition in the PC and workstation business is changing; so is the market for microcomponents. Volumes will go up and average selling prices will drop as mainstream products approach commoditization. Sales channels will be streamlined, allowing only the most efficient merchandisers to survive. Systems vendors will be greatly consolidated as larger vendors use their clout and smaller vendors are cut off from limited channels. Finally, the microcomponent market will fall into alignment as the field of available system vendors is reduced by tenfold from today's 300-plus vendors.

Delivering an increasing range of computing capabilities, most of which are built onto the motherboard, will require a new strategy for many microcomponent vendors to remain competitive. Shifting volumes and evolving architectures will form new barriers for companies that do not recognize the long-term direction. Opportunities will exist for those that satisfy the three-dimensional requirements of performance/integration/cost for a given platform segment. ■

By Ken Lowe

Technology Analysis

Visualizing Changes in 3-D Graphics

Computer-generated three-dimensional (3-D) graphics use was first commercialized in the early 1970s and, until recently, has remained relatively a niche market. During the last two years, however, advances in computational power and innovative applications have turned it into one of the fastest-growing segments of the technical computing market. During this same time frame, Dataquest has also seen the emergence of more advanced technology that integrates the best of 3-D graphics, imaging, and numeric processing. That technology is visualization, which begins with 3-D graphics and broadens its market potential to address applications never before imagined.

Expanding the Dimensions of Graphics

Moving from the simplest two-dimensional (2-D) screens to the most complex scientific visualization dramatically increases the complexity of both software and hardware required. As depicted in Figure 1, graphics technology can be divided into essentially four different levels, each of which encompasses the previous functions. Any of these levels could involve either still images or animated motion.

Displaying visual images at any level of graphics essentially involves the following three functions (animation is optional):

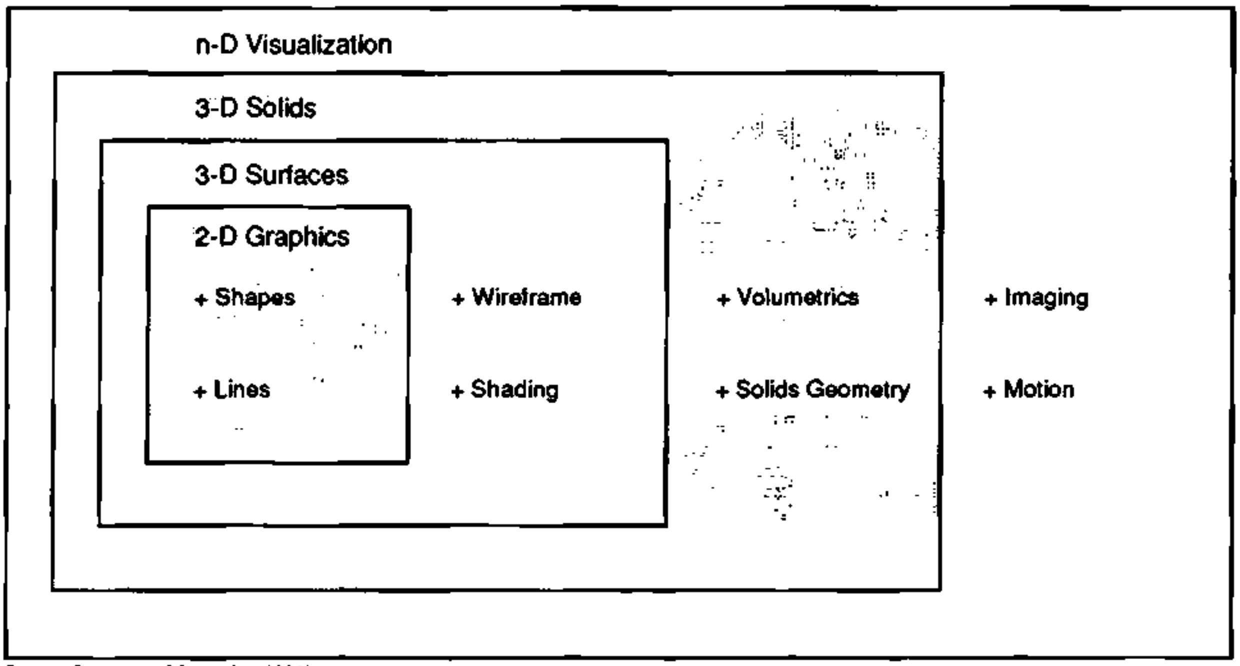
- Modeling—Defining the primitives, structure, and environment of the image to be displayed (This generally involves assembling a library of elements, assigning attributes, and editing the scene composition.)
- Rendering—Generating the image by drawing every displayable object in correct perspective (Typically a trade-off is made between the photorealism of the image and level of interactivity or animation.)
- Animating—Creating motion through a sequence of movements to either objects or viewing perspective (It can include motion of any type graphics or images and involve trade-offs in image accuracy vs. motion speed.)

Moving from 2-D graphics to n-D visualization, software complexity and hardware performance requirements for each step increase exponentially.

The innermost element, 2-D graphics, deals with vector-based objects from simple character strings to collections of lines, shapes, and images. However, these objects have no inherent volume or thickness, so the underlying database representing the objects on screen carries only X and Y coordinates. This makes programming models and hardware accelerators relatively simple. It involves 2-D primatives being directly mapped onto a 2-D display screen with just scaling and clipping.

In 3-D surfaces, each object is assigned a Z coordinate to provide depth information to enable orthogonal views to be computer-generated from the underlying database. The surface description starts with a geometric model of 3-D objects. Models are commonly represented either using polygon meshes (a collection of vertices, edges, and polygons) or bicubic patches (a set of curved surface equations). Rendering these models requires geometric transformations to map 3-D primatives onto a 2-D display screen and shading the surfaces appropriately. Popular shading techniques, in order of accuracy, include flat, Gouraud, and Phong. Also becoming popular is texture mapping, a technique for increasing visual reality by adding surface details to geometric objects without adding geometry to the model.

Figure 1
Dimensions of Visual Computing



Source: Dataquest (November 1991)

When rendered, a 3-D surface model creates the appearance of solid objects (or wireframes) but in fact is simply closed surfaces that enclose a volume of space. Moving to 3-D solids involves dealing directly with solid objects using primatives such as cubes, cones, and spheres. Rendering the models takes even more compute power and floating-point calculations.

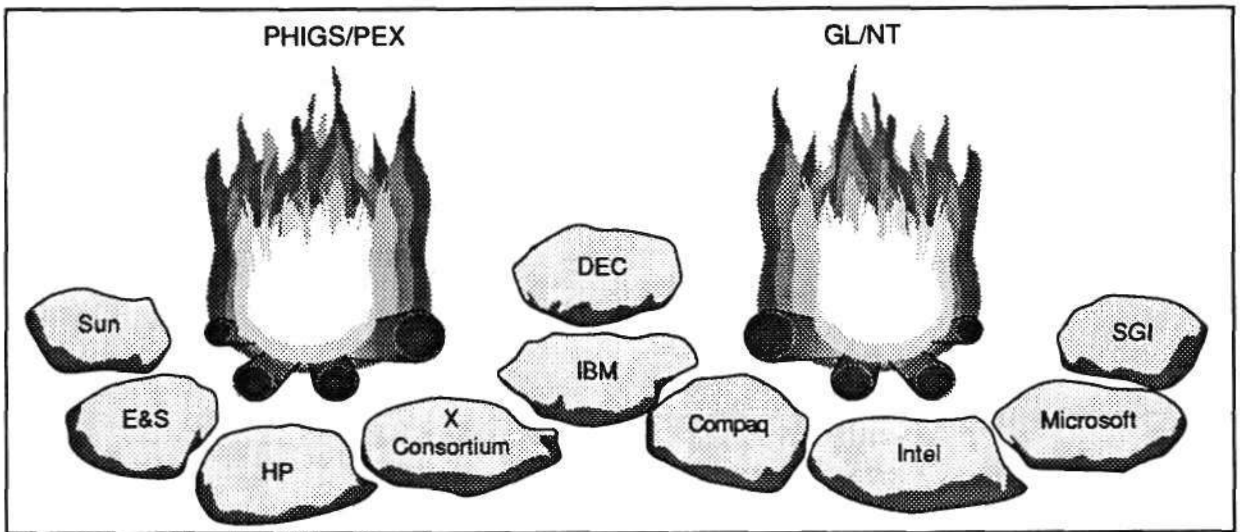
Finally, n-D visualization is integration of computer graphics and image processing. It involves capturing images or measurement data, synthesizing a model, and rendering an appropriate visual image. For instance, volume rendering is the direct display of data sampled in three dimensions, showing 3-D objects as collections of cube-like building blocks called voxels (volume elements). Each voxel is a sample of the original volume identified by X, Y, and Z coordinates. To render a view of the original volume, voxels are projected on the screen to rebuild an entire volumetric object.

Standards Are Paving the Way for Growth

During the last 20 years, many standards for 3-D graphics software have been proposed, adopted, and dropped. During this period, many applications have emerged that employ 3-D graphics. These include computer-aided design (CAD), scientific visualization, and animation. To support modeling of 3-D databases, a software vendor had to choose one (or more if resources allowed) of the 3-D graphics application program interfaces (APIs) including PHIGS, GKS, DORE, and the GL from Silicon Graphics Inc. (SGI). Unfortunately, this restricted the systems on which the application would run to a subset of the workstations supporting that standard.

In the past two years, the battle has heated up between the two predominant standards—GL (proprietary to SGI) with the largest number of applications (over 1,200 titles) and PHIGS, an American National Standards Institute (ANSI) standard, with the widest workstation vendor support. PHIGS and GL have gained significant momentum because of endorsements and joint developments, respectively; however, their respective camps are not mutually exclusive (see Figure 2). As a 3-D communication protocol, PEX has taken a substantial lead. Originally targeted as an X Window extension that would accommodate PHIGS 3-D applications, PEX only defines the communication protocol; thus, it is capable of supporting any other 3-D API. However, because the X consortium's X Window system will be competitive to NT Windows, we believe that the standards groups will break up along those lines also.

Figure 2
The 3-D Graphics Camps



Source: Dataquest (November 1991)

PHIGS recently gained additional momentum because of the completion of the PEX extensions and its joint endorsement by several key workstation vendors, evidenced by a joint interoperability demonstration of PEX by eight workstation companies at Siggraph in August. The PHIGS/PEX camp comprises Digital Equipment Corporation (DEC), Evans and Sutherland Computer Company, Hewlett-Packard Company, IBM Corporation, Sun Microsystems Inc., and several other high-end workstation and supercomputer suppliers. Apart from the breadth of workstation supporters, PHIGS and PEX are at the center of 3-D graphics support for X Window systems.

In September, SGI and several other key vendors announced open licensing and adoption of the IRIS GL 3-D graphics API. Until now, the GL was a proprietary interface, only available on SGI workstations and a few select licensees, including IBM. However, the GL has now blossomed into an open-licensed standard with support announced by Compaq Computer Corporation, Digital Equipment Corporation, Intel Corporation, and Microsoft Corporation. By far the highest potential for GL proliferation will be through NT Windows, Microsoft's soon-to-be-released operating system for both Intel 80X86 and MIPS Computer RX000 processors.

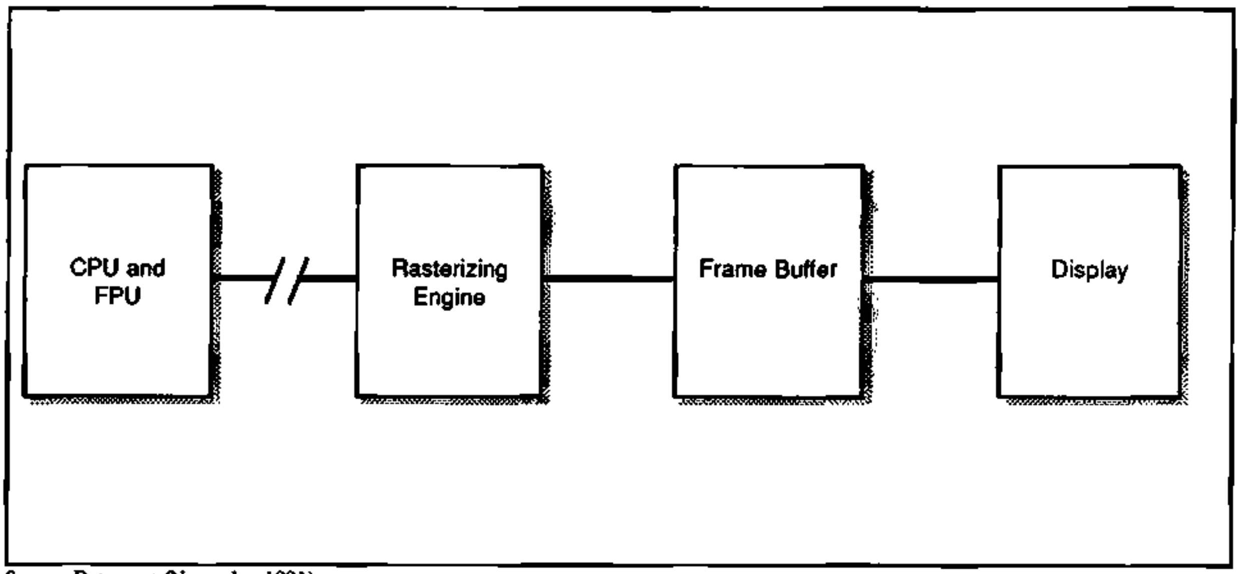
Other 3-D graphics movements are also under way, although less likely to become pervasive standards. DORE, a high-level API written by Kubota Pacific, was recently licensed by Apple Computer for eventual use in its 3-D extensions. On the PC platform, Renderman, a 3-D rendering program by Pixar Corporation, continues to gain momentum as a standard and is supported by Autodesk 3D Studio. Hoops by Ithica Software has been on the PC scene for some time, although starting to lose momentum as have its older workstation counterparts.

3-D Graphics Strategies Merge at the Low End

Until recently, a wide disparity of graphics hardware strategies was used to deliver 3-D graphics capability, regardless of the standards being supported. Now Dataquest is finding that 3-D graphics architectures are merging into a simple graphics rasterizer at the low end, a relatively consistent structure for the midrange, and endless differences at the high end. Figures 3, 4, and 5 illustrate types of architectures encountered for the levels of capability.

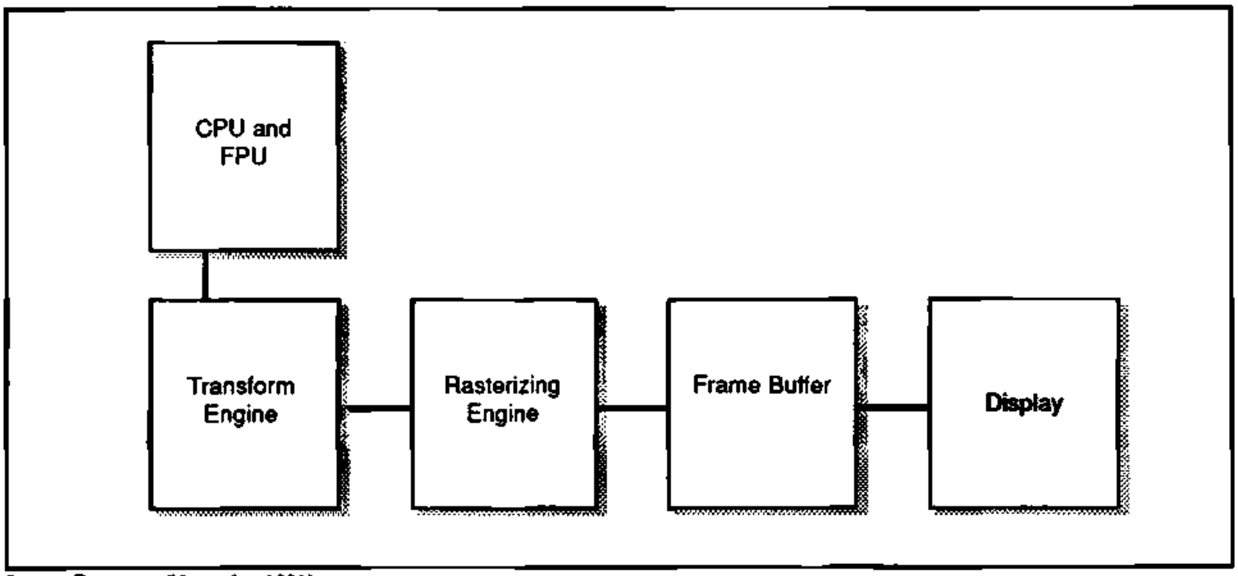
Enabled by increases in performance of processors and floating-point units, entry-level 3-D graphics can be delivered using a simple rasterizing engine and single frame buffer. This architecture leverages the central processor complex to form a virtual geometry engine to perform all 3-D transformations and rendering operations and, in many cases, a software-emulated Z-buffer. Output is a set of 2-D primatives accelerated by the rasterizing engine, which performs scan conversion and pixel processing including line drawing, area filling, triangle synthesis, and blitting (raster operations). Using CPUs with 30-plus million instructions per second (mips) can produce a low-cost, moderate-performance system with

Figure 3
Entry-Level 3-D Graphics Architecture



Source: Dataquest (November 1991)

Figure 4
Midrange 3-D Graphics Architecture



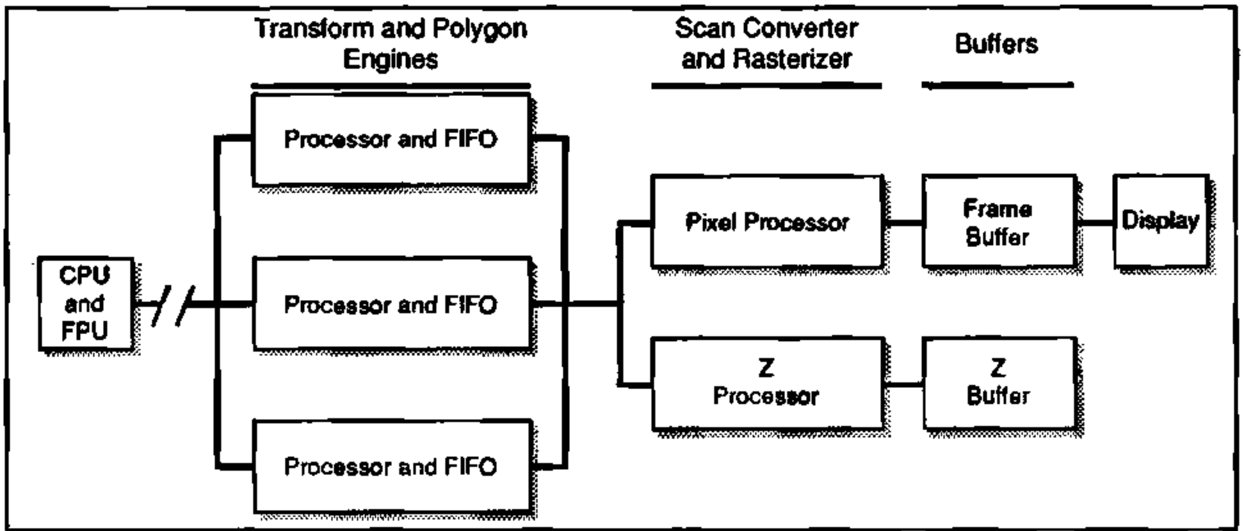
Source: Dataquest (November 1991)

more than 200,000 3-D vectors per second and 20,000 polygons per second (100-pixel, Gouraud-shaded, Z-buffered triangles).

Although midrange 3-D graphics architectures take on many variations, their basic structure is beginning to look much like Figure 4, which shows a central processing complex dedicated to running application code and a separate graphics pipeline for processing 3-D graphics structures. In this case, the transform engine performs nearly all the 3-D transformations, clipping, and some depth cueing and shading acceleration. The rasterizing engine performs many of the same functions as before, but also maintains a separate Z buffer. Using a powerful transform engine (most popular is the Intel i860), these systems can yield about 300,000 3-D vectors per second and 50,000 polygons per second (100-pixel, Gouraud-shaded, Z-buffered triangles).

At the high end are as many different designs as systems; however, most of the facilities shown

Figure 5
High-End 3-D Graphics Architecture



Source: Dataquest (November 1991)

in Figure 5 are commonly found. A high degree of parallelism in transform engines is universal in high-end 3-D graphics. As many as eight engines are used, sometimes splitting functions between transformations and polygon processing. All engines have their own first-in/first-out (FIFO) or local memory. Resultant output is piped into a rasterizer, often split between a pixel processor and a Z processor, each feeding into a separate frame buffer and Z buffer, respectively. Using a mixture of digital signal processors (DSPs), i860s, and custom engines, the structure can yield up to 1 million 3-D vectors per second and 200,000 polygons per second (100-pixel, Gouraud-shaded, Z-buffered triangles).

Measuring Graphics Performance

Graphics is one of many areas where lack of a standardized measure for graphics performance has frustrated both users and vendors. The selection of parameters to promote or use in comparisons is driven either by the vendor's area of strength or the user's convenience of data gathering. In attempting to compare performance, the two most common parameters are vectors per second and polygons per second.

Vectors per second defines rate at which point-to-point lines can be drawn onto a screen. Vector rates are often separated into 2-D and 3-D but even then are subject to vagaries regarding length of the vectors such as whether or not they are antialiased. Although high vector rates are important, they do not readily translate into expected response time for redrawing complex wireframes.

Polygons per second defines rate at which closed multisided shapes, normally triangles, can be drawn. Polygon rates are also subject to variances such as flat-shaded versus Gouraud-shaded and polygon area. Again, high water marks in polygon performance are essential for fast rendering but just one piece of the total puzzle.

Starting in late 1986, major workstation vendors organized an effort to address the problem of graphics benchmarks. This effort led to formation of the Graphics Performance Characterization (GPC) committee, now administrated through the National Computer Graphics Association. The GPC's first product is the Picture-Level Benchmark, a software package that provides a direct "apples-to-apples" performance comparison between hardware platforms. The current test uses a set of files representing applications such as 2-D design, 3-D wireframe, 3-D solid modeling, and 3-D animation.

Table 1 shows four different systems and their performance characteristics. These systems are each representative of one architectural level described before. Note that in some cases, all measurements do not apply to that type of system.

Dataquest Perspective

The market for 3-D graphics is experiencing rapid growth, currently in workstations, as more

Table 1
3-D Performance Comparisons (Thousands)

Benchmark Type	SGI Indigo	DEC 5000 PXG	IBM RS/6000 GTO	HP 730 TVRX
3-D Vectors per Second	225	274	800	730
Shaded Polygons per Second	20	51	80	200
GPC-2D ECAD Drawing (PC board)	NA	10.00	18.75	31.70
GPC-3D Wireframe (system chassis)	NA	10.58	27.14	43.20
GPC-3D Solid (cylinder head)	NA	10.26	14.46	81.20

NA = Not applicable
Source: Dataquest (November 1991)

applications are providing increased benefits from rendering and visualization techniques. This growth in turn is bringing increased investments into hardware technologies capable of delivering the required performance.

Microsoft's adoption of the GL, which makes 3-D graphics support part of the enormous potential of NT Windows users, should bring forth a new wave of innovative 3-D applications. In addition, widespread support of the X Window system and PEX will enable PHIGS to remain viable and its applications to continue to exist and proliferate. With this level of standardization, opportunities are now opening for innovative high-performance components in three segments to service the system and add-in board market.

The first segment is the central processor complex, currently a hotbed of activity. It carries the highest potential but also the highest competitive rivalry. Already taking positions to establish a core for premium desktop graphics stations are offerings from MIPS (R4000), Sun (SPARC), IBM (RS/6000/PowerPC), HP (PA-RISC, and Intel (80586). This level of competition leaves little room for casual entrants (or any other entrants, for that matter).

The next is a battlefront for the role of transform engine, key element of the geometry pipeline. Currently, this field is led by Intel with its i860 (used by Digital, HP, and Sun), followed by a host of disparate designs using DSPs, TI's 34020/34082 combination, and custom processors. Next-generation transform engines will have to provide better multiprocessor linkages and faster overall throughput to be competitive.

The final opportunity, with perhaps the highest-volume potential, is for fast rasterizing engines. In high-end 3-D graphics machines, rasterizing is the final stage; rasterizing engines must be exceptionally fast in order not to bottleneck output of multiple engine pipelines. At the low end, however, these units could be constructed with value-added features to off-load additional functions such as texture-mapping from a central CPU complex. If correctly designed, these rasterizers could also service accelerated VGA and XGA graphics controllers that are becoming mainstream in the PC market. Gaining a foothold in the PC segment would provide the types of volumes necessary to drive toward a position of high overall profitability. ■

By Ken Lowe

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Market Analysis

Expanding Opportunities in Network Controllers

Opportunities are expanding for network controllers as widespread connectivity becomes a reality, encompassing desktop PCs, portable computers, and workstations. This article analyzes the market dynamics from an applications and standards perspective to present a forecast of unit and revenue opportunities within the network controller market.

By Ken Lowe *Page 2*

IBM PC Graphics Standards and Segmentation

This article presents a new product segmentation scheme aimed at providing a more insightful market model for analyzing trends and forecasting future directions.

By Ken Lowe *Page 7*

Technology Analysis

Is XGA on Its Way to Becoming an Industry Standard?

Although IBM's XGA standard may not have every imaginable feature and its cost is still high, this new standard is expected to have an increasing impact on the PC market. This article examines the key issues related to its acceptance.

By Ken Lowe *Page 10*

Market Analysis

Expanding Opportunities in Network Controllers

As technology continues moving closer to creation of the semicomputer, connectivity remains an unresolved issue. Will network controllers be built into the desktop PC? How will this decision affect workstations? Will portable computers need to support networking? How do the answers to all these questions fit together to form a standard for network controllers?

Network controllers come in several flavors, with two major standards competing for dominance. They will be used in four major application segments and are affected by various technical, marketing, and environmental factors. Unlike with most other computing features, the selection of a network interface is a centralized decision, simply implemented at each desktop. This article examines the market for network controllers from an applications perspective to reveal the real dynamics behind the silicon.

Setting the Stage for Comparison

Here we define a network controller as an integrated chip or chip set that provides all the media access control functions. This definition does not include transceiver chips sold separately. For the purposes of analysis and forecasting, we have created three general categories of network controller based on the media access method: ethernet, token-ring, and others.

Ethernet controllers were first introduced in 1982 by Advanced Micro Devices Inc. (AMD) as a result of a joint technology pact with Digital Equipment Corporation. They have evolved to highly integrated chips that support the standard Institute of Electrical and Electronics Engineers (IEEE) 802.3 interface specification. These controllers can be subcategorized into low-end and high-end chips corresponding to 8/16-bit and 32-bit host interfaces, respectively. Both generally support the full 10-Mbps ethernet standard; the primary difference is in the system bus bandwidth consumed in supporting transmission of information. Thus we find 32-bit chips commonly used in workstations and servers and 8/16-bit chips dominant for PC add-in cards. Leading vendors of ethernet controller chips are National Semiconductor Corporation, AMD, Intel Corporation, and Fujitsu.

Token-ring controllers were first developed by IBM and further enhanced through joint development with Texas Instruments Inc. (TI). They are also highly integrated chips supporting the standard IEEE 802.5 interface specification, but with a major twist. To be reliable, these controllers must also be compatible with the IBM implementation, for which the only verified sources are IBM and TI. Token-ring controllers and their transceivers can support either 4-Mbps or 16-Mbps and represent a slightly higher bandwidth capability than ethernet.

The "others" category includes several standards and proprietary interfaces not considered serious contenders for the mainstream standard race. Among these is AppleTalk, the Apple Computer Inc. interface standard built into all Macintosh computers except the latest system, Quadra, which has ethernet. Arcnet is supported by Standard Microsystems and represents a substantial number of installed systems. The fiber-distributed data interface (FDDI) includes copper and twisted pair versions and is on its way to becoming a standard. Because FDDI offers both high bandwidth and determinism (a token-passing scheme), it will be used for all types of high-performance applications such as a LAN backbone or a dedicated workstation network. Each of these networks currently takes a share of available nodes away from the standards battle between the two described earlier.

As a side note, we would like to review the issues regarding physical layer (cabling) methods not covered in the body of this article. Most projections show unshielded twisted pair (UTP) becoming largely dominant because of lower costs and maintained bandwidths. The recent announcement of UTP support for 16-Mbps token-ring has little effect on the market forecast, with one exception: Widespread adoption of twisted pair allows fully integrated single-chip network controllers, decreasing cost and real-estate requirements, both of which are crucial to moving onto PC motherboards.

Application Markets Expand as Networking Flourishes

The complexion of network controller applications will be changing quite dramatically during the next four to five years as complete office connectivity becomes a reality. Figure 1 depicts network controller application segments as a percentage of total available market. Unit volumes start with 11.8 million units in 1991 and grow to more than 30 million units by 1995.

In order to effectively study the driving forces and estimate market potential, we have segmented the network controller market into four primary applications: desktop PCs, portables, workstations, and network resources.

As Figure 1 shows, the network controller market (in units) to date has been dominated by sales into desktop PC applications. Desktop PCs will remain the largest segment in 1995. However, portable computers, workstations, and network resources will become sizable opportunities as well.

The potential for each application segment is based on each application's total unit shipment forecast multiplied by the estimated network penetration. Network penetration is defined as the percentage of total units shipped that result in a network controller shipment, either built-in or optional add-in card.

Driving Forces by Application

Desktop PCs

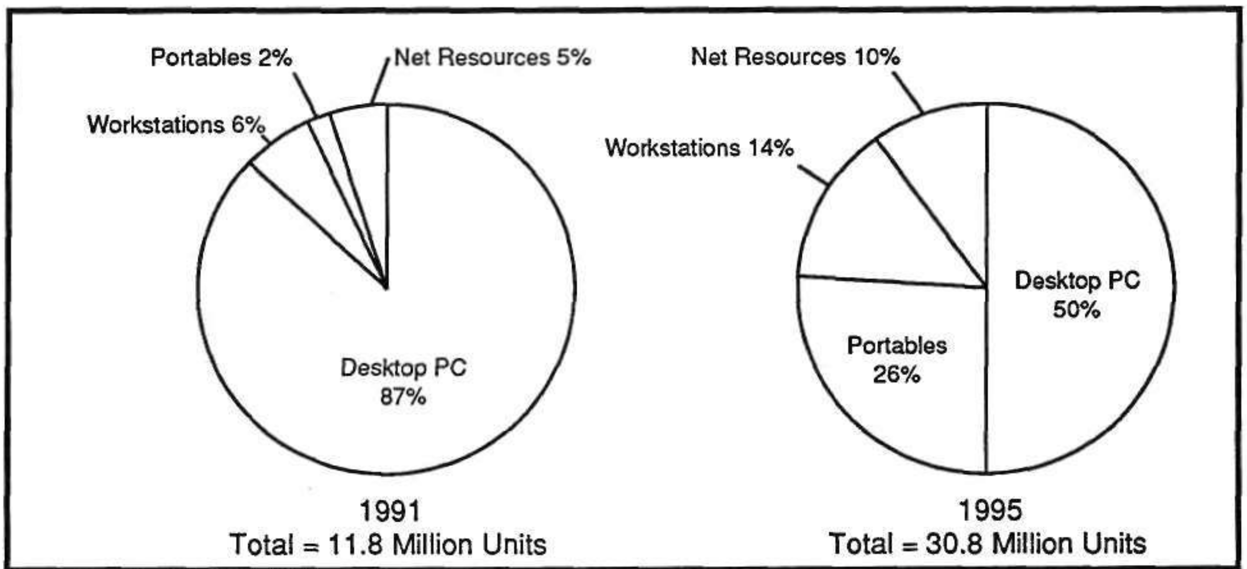
Desktop PCs include all types of PCs (such as IBM-compatibles and Apple) and represent the use of network controller chips built directly on motherboards or as add-in cards. Though the forecast growth of desktop PCs is nearly flat through 1995, network penetration will increase dramatically. This penetration will be a direct result of the coming trend of standard built-in connectivity on desktop PCs, which will drive network penetration from 48 percent in 1991 to 78 percent in 1995, a yield of 15.4 million units. This evolutionary trend is quite similar to that of the graphics controller market in the late 1980s.

To date, most network controllers in desktop PC applications were sold as optional third-party add-in cards. The major exception to this is Apple; AppleTalk has been included with every Macintosh since 1987. By connection standard, a desktop PC is currently 54 percent ethernet, 23 percent token-ring, and 23 percent others (dominated by AppleTalk and Arcnet). Because mainstream desktop PC end-user needs are relatively simple, cost-sensitive, and not performance critical, this connection mix will also change dramatically.

Portables

Portables include all types of portable computers (such as laptops and hand-held) and represent network controllers built directly on motherboards, as add-in cards (including tiny Personal Computer Memory Card International Association, or PCMCIA, cards), or in docking stations. Portable computers are forecast to grow substantially during the next five years and will represent more than 50 percent of the total PC volume. Network penetration is also

Figure 1
Network Controller Applications Market Share, 1991 and 1995



Source: Dataquest (December 1991)

forecast to grow about 30 percent by 1995, resulting in a total of 8 million units. This penetration will be driven by the use of laptops as a primary computer but will be limited by the percentage of hand-held devices not requiring networking. The standards and driving forces for portables are expected to follow those of desktop PCs, with the addition of wireless connection, which will become important in the 1994 to 1995 time frame.

Workstations

The workstations category includes technical workstations, X Window terminals, and other high-end systems and represents network controllers built directly on motherboards or as add-in cards. Workstations and X terminals are forecast to grow dramatically during this time frame. Assuming that network penetration remains at nearly 100 percent, direct unit growth will be more than 4 million units by 1995. This segment is almost exclusively standardized on ethernet, with expected future growth in FDDI for high-bandwidth uses.

Network Resources

Network resources include dedicated servers, hubs and repeaters, internetwork equipment (such as bridges and routers), and network peripherals (printers, scanners, fax machines, and multimedia devices). Because these devices are services for networks, their growth is driven by the overall growth in networking nodes and the topology of networks. We expect network peripherals to be one of the largest growth subsegments. As the cost of adding a network interface drops below $20, we expect to see the interface as a standard feature on $1,000 laser printers. The standards mix within these devices is expected to track that of the overall network trends.

Moving toward Standardization

Within most companies, the choice of networking standard has been affected by political factors as much as technical factors. In some cases, it was driven by the dominance of mainframe and minicomputer vendors (primarily IBM and Digital) within the customer's environment, using centralized network management to gain control of MIS decisions. In other cases, it was driven by the ease of a built-in connection method such as AppleTalk for Macintosh. The result has generally been a heterogeneous computing environment with multiple connectivity standards. These multiple standards are then bridged to form one integral network, often limited by its weakest link, and typically fraught with problems.

Our outlook for the future is toward more uniformity in networking and a consolidation among standards. Figure 2 shows the direction of the consolidation. Underlying trends are as follows:

- Ethernet will become the dominant standard for mainstream connectivity, accounting for 74 percent of nodes in 1995.
- Token-ring will slowly decay, being relegated to networks where IBM dominates or where there are dual protocols (16 percent in 1995).
- FDDI (part of Others) will become the high-end standard where high bandwidth and/or determinism are essential.
- All other standards (such as AppleTalk and Arcnet) will decay to minor proportions (each less than 4 percent).

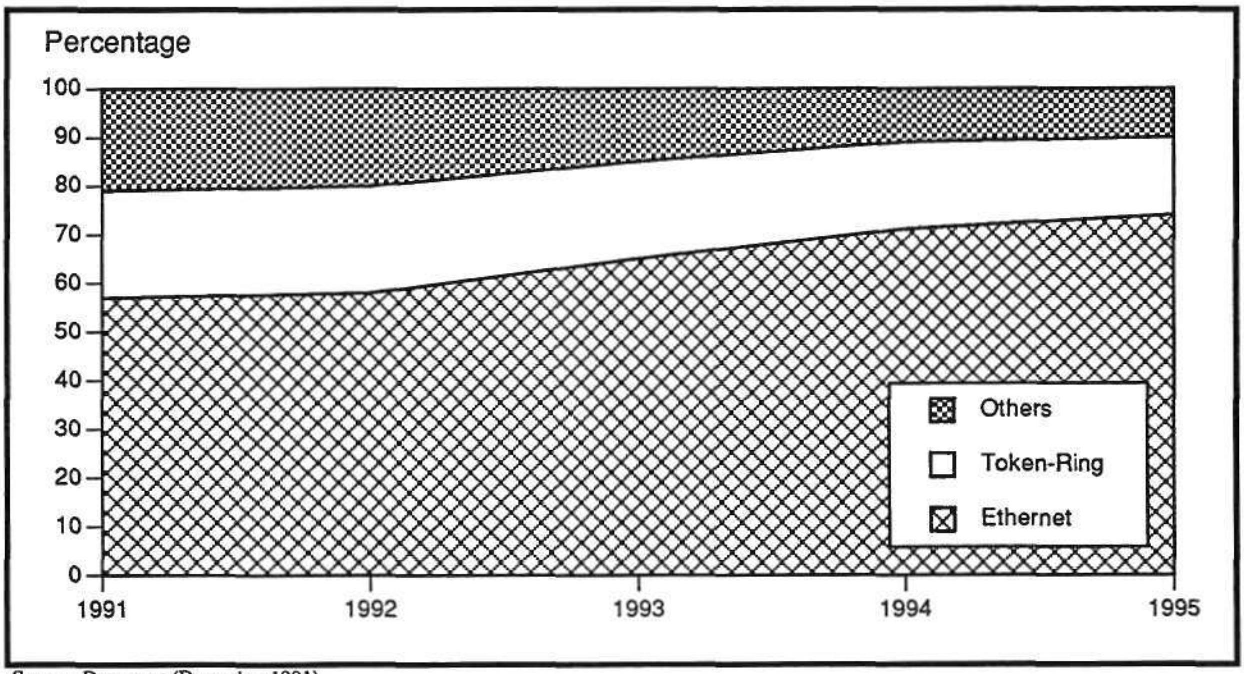
One basic assumption underlying the projection in Figure 2 is that ethernet or token-ring can both satisfactorily meet the connectivity needs of the mainstream market (mainstream being desktop PC, portable, and entry-level workstations). A second related assumption is that FDDI will begin to take over the upcoming high-end connection needs, such as distributed 3-D graphics, multimedia, or an internet backbone. A detailed technical analysis comparing bandwidths, determinism, and topologies is beyond the scope of this article.

Supply-Side Support

From a chip supply viewpoint, ethernet is supported by more than 10 chip vendors, including AMD and Intel, both of which will eventually integrate its function into single-chip computer systems. Token-ring, on the other hand, is only shipped in volume by IBM and TI (although other potential entrants are appearing). As for component cost, token-ring controllers are more than double the gate count of ethernet controllers. Combined with the level of competitiveness, the average selling price of ethernet controllers will remain at about half that of token-ring controllers (see Figure 3).

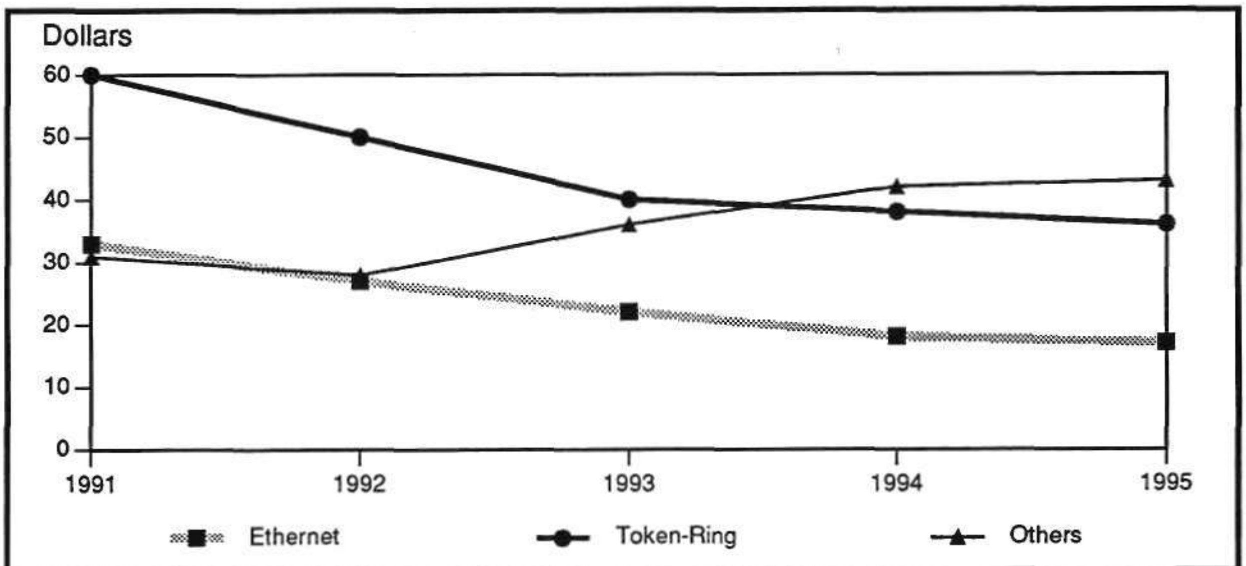
Perhaps even more significant than unit differences is the difference in merchant chip revenue: The total is more than $200 million for ethernet controllers and less than $40 million for token-ring controllers. The difference can be attributed to the fact that a large portion of token-ring shipments is captive because IBM

Figure 2
Network Controller Forecast, by Access Method



Source: Dataquest (December 1991)

Figure 3
Network Controllers Average Selling Price Forecast

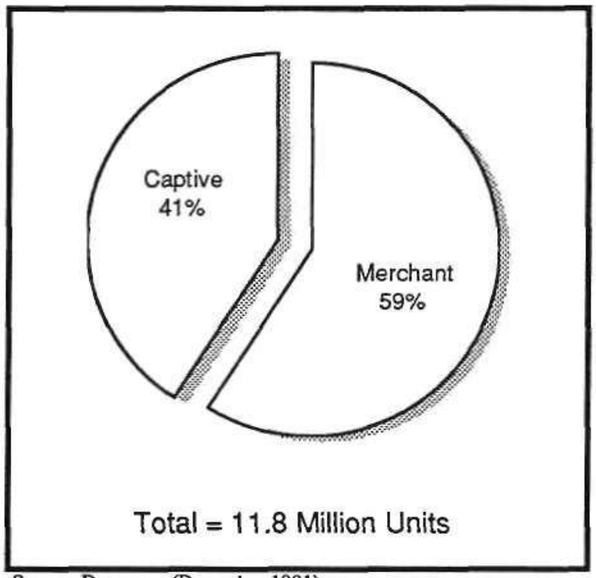


Source: Dataquest (December 1991)

owns 75 percent of the token-ring adapter market and produces its own chips. The overall portion of captive network controllers is about 40 percent (see Figure 4). Captive represents all network controller chips produced and consumed by the same vendor (for example, IBM chips used in IBM adapters).

Ethernet's current momentum and standardization in systems is overwhelming and represents more than 60 percent of the current DOS PC add-in market. It will become the replacement for AppleTalk in Macintosh during the next five years (it was recently introduced in the new Macintosh Quadra product). It is the

Figure 4
1991 Network Controllers Unit Shipments



Source: Dataquest (December 1991)

standard specified for the new ACE initiative ARC-compatible systems and is the only standard (95 percent) used in workstations and X Window terminals (including support by IBM's RS/6000).

Based on this momentum, ethernet is forecast to move to the motherboard of DOS PCs in a similar fashion as the evolution of VGA graphics onto the DOS PC motherboard during the last four years. Networking is becoming necessary for the vast majority of computing devices purchased for business use. Ethernet is the most prolific, lowest-risk standard covering the largest quantity of installed networks. Driver support required is minimal when all top chip suppliers support the primary network operating systems. The cost of embedding ethernet with a twisted pair interface (less than 4 square inches) is less than $30. The bottom line is that the benefit of built-in connectivity will soon begin to outweigh its cost.

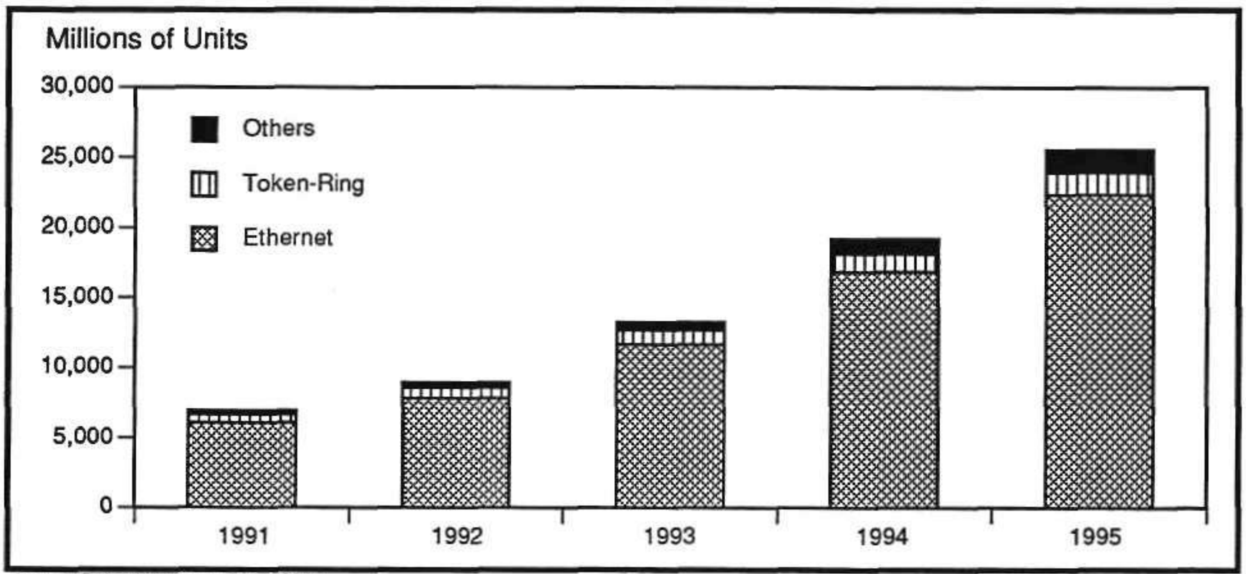
Merchant Chip Market Forecast

Focusing only on the merchant chip market, Figure 5 shows shipments growing from just under 7 million units to more than 25 million units by 1995. These shipments are dominated by ethernet for two main reasons. First is the substantial growth in adoption of ethernet as the mainstream connectivity standard, including built-in motherboard use. Second is the percentage of captive business within the token-ring and others categories, which decreases the available merchant market.

Key forecast assumptions are as follows:

- Most companies will prefer to consolidate the number of different networks used within their environment.
- Ethernet provides a satisfactory solution for mainstream connectivity at half the cost of token-ring solutions.

Figure 5
Merchant Network Controllers Unit Shipments Forecast



Source: Dataquest (December 1991)

- Workstations will remain primarily ethernet, except for FDDI used in performance-critical situations.
- Apple will move to ethernet as a replacement standard for AppleTalk on most Macintoshes by the end of 1993.
- IBM does not have a sufficient share of the PC market to force token-ring as a connectivity standard.
- Built-in PC connectivity, using ethernet controllers, will begin in late 1992 and become the norm by 1995.
- FDDI will begin to take over where performance (bandwidth and determinism) is an issue.
- All other standard and proprietary access methods will begin eroding severely after 1992.

From this analysis, Dataquest forecasts the network controller merchant chip market doubling in size over the next five years. Figure 6 shows this growth in revenue, from about $250 million in 1991 to $525 million in 1995. Because of decreasing average selling prices for controller chips, compound revenue growth is about half that of shipment growth.

Dataquest Perspective

Opportunities in the network controller market are very clear, and relatively few issues remain. Ethernet controllers will be the dominant standard and PC motherboard designs and will be the largest application segment by 1994. This is the place to be with a low-cost, highly integrated, 16- and 32-bit controller design.

FDDI will begin to gain a foothold in the market in 1993 when technology will be proven, costs lower, and demand large enough to profitably market products. This is the place to be with a high-performance, high-reliability, 32- and 64-bit controller design.

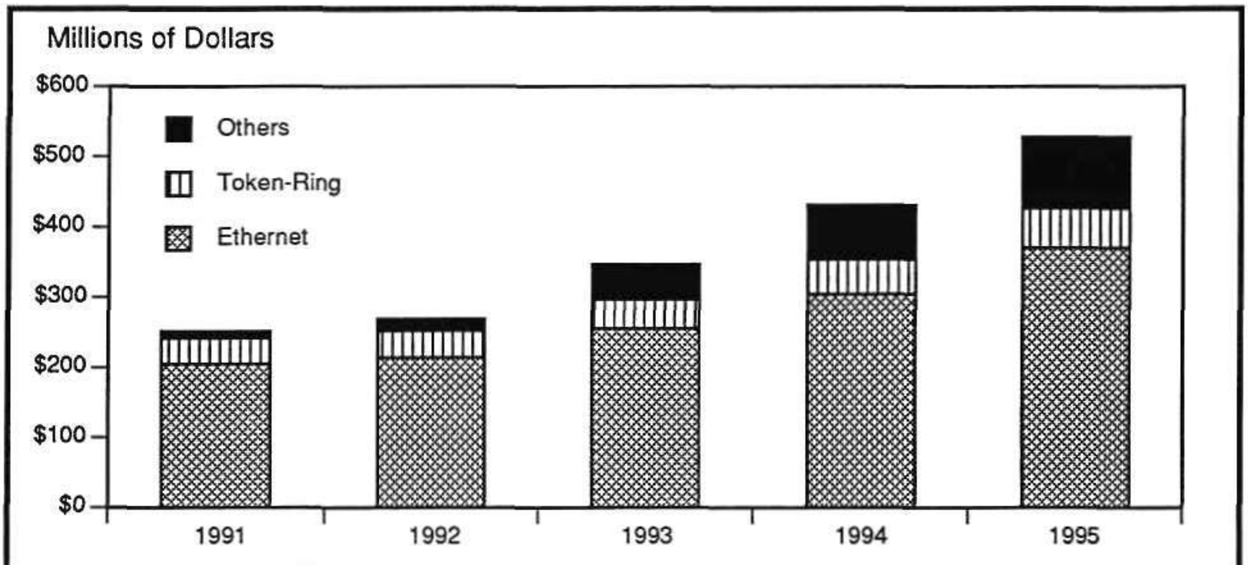
Token-ring will be squeezed between ethernet and FDDI; with 65 to 75 percent of the chip volume remaining captive to IBM, this does not look like an attractive market. Dual-protocol controllers will be too costly to build onto motherboards or to replace standalone ethernet controllers but will be attractive to replace token-ring adapters (or perhaps within IBM systems). Of course, this would result in an increase in ethernet-capable nodes as a percentage of total as well.

By Ken Lowe

IBM PC Graphics Standards and Segmentation

Until now, Dataquest has defined and tracked PC graphics in two major subsegments: low-end PC graphics and high-end PC graphics. However, two current trends are changing the way Dataquest segments the market. Nearly

Figure 6
Merchant Network Controllers Revenue Forecast



Source: Dataquest (December 1991)

90 percent of all PC graphics cards are currently VGA-based architectures. Future trends toward windowing user interfaces are driving use of intelligent architectures for next-generation PC graphics. In fact, this move toward intelligent architecture is a cross-platform trend, affecting not only the PC (through MS-Windows), but workstations (through X Windows) and display terminals (through multiple alphanumeric windows). So we are adapting our segmentation to provide more meaningful data and analysis. Our new segmentation divides the world of PC graphics into three subsegments according to the type of architecture involved.

Nonintelligent Standard Controllers

These are the traditional low-end PC graphics where the architectures are based on a previous IBM PC bit-mapped graphics standard (without hardware graphics acceleration or drawing assistance). This segment includes VGA (super VGA) and other bit-mapped controllers (that is, EGA, CGA, MDA, and HGC). Typically features include the following:

- Are accessed as a screen bit map with no graphics drawing, BLTing, or processing
- Are totally dependent on the system CPU for performance
- Support primary DOS (BIOS) modes for boot-up (80 × 25 characters)
- Support a limited range of display resolutions up to 1024 × 768 pixels
- Are predominantly color, most 4-bit (16 colors)
- Use primarily DRAM display memory (256K to 1MB)
- Sell at very low prices ($50 to $250 street price) with little real differentiation
- Are so integrated that one chip and two DRAMs make a VGA controller
- Are more commonly implemented on system motherboards than add-in boards

These controllers came into use as the IBM PC was introduced in 1981, with MDA and later CGA providing 80 × 25-character text and very primitive graphics. IBM introduced a new-generation, bit-mapped graphics standard every three years (EGA in 1984 and VGA in 1987). However, in 1990, XGA was introduced, becoming the first (real) intelligent graphics standard by IBM and signaling a new direction in mainstream PC graphics. Demand for these bit-mapped standard controllers will come primarily from chip sales to motherboard vendors as the controllers continue serving the truly low-end desktop DOS-user segment and the fast-growing laptop/notebook PCs segment.

Fixed-Function Controllers

These are taken from a portion of traditional high-end PC graphics and feature a fixed set of graphics acceleration functions (with BITBLT as a minimum). The category includes XGA and other fixed-function controllers (such as 8514A, Windows graphics accelerators, and VGA with BLT engines). Typical features include the following:

- Have some fixed combination of graphics BLTing, drawing, and processing functions
- Are significantly independent of the system CPU for graphics performance
- Offer support for primary DOS (BIOS) modes through "VGA pass-through" or, for more recent products, built-in VGA compatibility
- Support a reasonable range of display resolutions up to 1280 × 1024 pixels
- Are predominantly color, about half 4-bit and half 8-bit (16 to 256 colors)
- Use VRAM or DRAM display memory (512K to 2MB)
- Have a wide price range ($350 to $1,200 street price) with a high degree of differentiation
- Are being integrated so that 1 to 3 chips plus VRAM will constitute a solution
- Are implemented mainly as add-in boards, IBM being one exception (The XGA is built into models 90 and 95.)

This controller type was first used on the PC many years ago as proprietary line-drawing engines and BLT engines for low-volume high-end applications. With IBM's 1987 introduction of the 8514A, the controllers began to sell in more moderate volume, gaining momentum from clone-industry support—only recently (last two years) being sold in any substantial volume on the PC.

These controllers will form a basis for next-generation graphics standards, following the lead set by IBM with XGA and alternative Windows graphics accelerators, both positioned to serve the fast-growing power-user market of Windows users. Fixed-function controllers will far outsell programmable processor controllers because of their sufficiently high performance under Windows, much greater availability, and lower implementation cost.

Programmable and Miscellaneous Controllers

This segment encompasses the remaining portion of traditional high-end PC graphics, where graphics acceleration is achieved through a fully programmable processor or other high-end architecture. This segment includes the TI-340xx family, other CISC/RISC processors, and miscellaneous high-end controllers (such as ultrahigh-resolution monochrome). Typical features include the following:

- Have a fully programmable processor, which may contain graphics-specific functions to perform BLTing, drawing, and processing (except the miscellaneous category)
- Are nearly independent of the system CPU for graphics performance
- Are mixed in support for primary DOS (BIOS) modes (from built-in VGA, to VGA pass-through, to built-in MDA for boot-up only)
- Support a wide range of display resolutions up to 2048 × 1536 pixels
- Are predominantly color for programmable processors, with 8-bit (256 colors) being dominant
- Use primarily VRAM display memory and DRAM program memory in a wide range
- Sell at relatively high prices ($500 to $4,000 street price) with a high degree of differentiation
- Are being integrated but to a lesser degree than other controllers
- Are currently implemented as add-in boards, with only minor exceptions

This type of controller began to be implemented about five years ago with the introduction of the TI-34010 graphics system processor, which has dominated the high-end graphics area ever since. Competition stepped up considerably in the last two years from two distinct areas, the 8514A controllers and the movement toward RISC processors.

The outlook is good. Although much volume will move to fixed-function controllers, programmable processors are being strengthened in the high end through aggressive actions by Advanced Micro Devices Inc. with the 29K family, Intel Corporation with the i860, and Texas Instruments with the 34020.

Dataquest Perspective

Based on intensive research for the last six months, we believe that major issues in the IBM PC graphics field are as follows:

- The application environment for PC users will move rapidly to Windows, with sales of DOS systems running Windows outnumbering sales of non-Windows DOS systems by the end of 1993.
- Dramatic growth will take place in portable PCs (such as laptops and notebooks) based on flat panel displays, in turn creating a continued market for VGA chips.
- The basic PC engine will become more powerful each year, the average CPU being a 386 by end of 1991 and a 486 by end of 1993, driven upward by user demand for increased power (at a small price).
- With the major issue between IBM compatibility and Windows compatibility, at least six vendors will deliver fixed-function controller chips by second quarter 1992—mostly non-XGA—making price competition fierce.
- Resolution will be driven toward 1024 × 768 pixels for mainstream use, in turn driving demand for larger screen sizes and resulting in rapid growth of 15- to 17-inch monitors (prices will drop as volume increases) in the next three years, becoming dominant by 1994.
- End-user economics will force prices for graphics cards (or built-in graphics) to fall below $500 (list price) for real growth in mainstream use, with appropriate monitors available for well below $1,000.
- Multimedia technology will slowly start to find its way into more systems, requiring graphics controllers to accommodate motion video (compression being the key enabler). Expect audio I/O to become a standard system feature by 1994.
- The industry will begin moving more toward built-in motherboard graphics in both low-end (because of price) and high-end (because of performance resulting from wide, high-speed local bus interface) systems. ■

By Ken Lowe

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Technology Analysis

Is XGA on Its Way to Becoming an Industry Standard?

Given all the excitement generated for Windows and graphical user interface (GUI) for mainstream PC users, one can expect widespread activity to continue in graphics hardware. But with consolidation of graphics applications written to APIs under these GUIs, will there be a need for hardware standards? If so, does IBM's XGA provide the features and price/performance level to satisfy this need for the mainstream? Here we examine details of the XGA architecture and the status of industry movements for offering clone products.

Many critics take the position that the XGA architecture delivers the wrong feature set, with unimpressive performance, and at a cost too high for the mainstream PC market. Although many of these points have their merits, taking them one at a time allows us to cite reasons in support of the architecture chosen for XGA. Figure 1 shows the basic XGA block architecture as reference.

Starting with a Market Perspective

Before probing into architectural details, let us examine the basic goals of the architecture and what is required to meet those goals. The XGA controller was designed to meet a wide range of graphics and display needs for the mainstream PC market of the 1990s. This range encompasses current compatibility needs in the DOS environment, growing performance needs of the GUI environments, and upcoming needs for accommodating multimedia environments.

Assuming that graphic applications are beginning to consolidate under two or three GUIs led by Windows 3.0, will the market recognize the need for a hardware-level standard? This need seems obvious yet painful to admit, as shown by the following questions:

- Will there continue to be enhanced DOS-based applications from major software vendors that need better graphics?
- Will there be at least three different GUI environments, each of which must create and maintain its own fleet of drivers?
- Will there be scores of new multimedia-driven applications that need to work intimately with the hardware?
- Will there be many new accelerated graphics architectures, each having a unique interface and special drivers?
- Will users prefer to use standard hardware, listed as basic installation options for their software, over special hardware with custom drivers?

Readers answering yes to all or most of these questions have arrived at the same conclusions as Dataquest. Yes, hardware standards make it easier on software developers, end users, and systems integrators to ensure plug-and-play solutions. The issue really becomes how much will they pay for the standard solution and what do they sacrifice by its use.

Graphics Feature Sets and the XGA

Most critics agree that the basic graphics feature set the XGA supports forms a good target level of capability as follows:

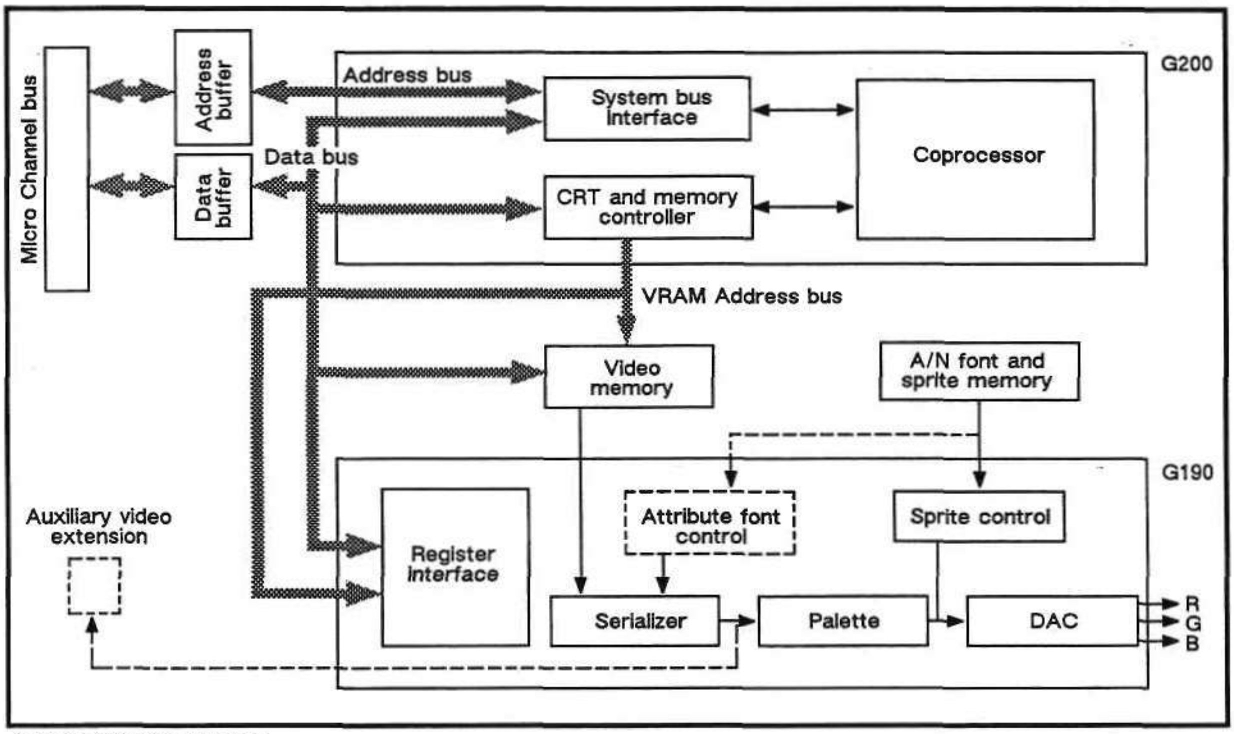
- 1024 × 768-pixel resolution providing the essential mode for mainstream windowing/ GUI environment users
- Direct 16-bit (65,000 colors) color, currently at 640 × 480-pixel resolution providing deep color needed for multimedia applications
- A 132-column mode providing a standard for servicing enhanced DOS character-mode applications and certain terminal emulation
- VGA compatibility maintaining the standard that all users will demand as a minimum

As well as the issue surrounding MCA-only bus support, a primary feature-set complaint is the interlaced video format, which conflicts heavily with flicker-free requirements that even U.S. consumers will demand. On the positive side, interlaced video support allows the higher-resolution mode to be used with very inexpensive monitors ($300 range) compatible with the 8514. However, because of the flicker in interlaced displays, buyers will demand at least the option of higher-refresh noninterlaced modes. Addressing this issue, Inmos Corporation states that noninterlaced versions of the XGA will be available in future versions of the chip set, for which we assume that IBM Corporation is the developer.

Performance and the XGA Architecture

Although general DOS business applications are adequately served by VGA compatibility, we need to address new GUI requirements as well as vertical DOS applications (such as AutoCAD). GUI environments such as Windows and PM, as well as dedicated graphics applications such as AutoCAD, require hardware support of certain key functions along with sufficient off-screen

Figure 1
XGA Block Architecture



Source: IBM Corporation

memory to optimize graphics performance. Most technical experts in the industry generally agree that BITBLT (including pattern selection for text font color expansion), hardware cursor, line drawing, and, to a certain extent, clipping (masking) form those key functions. Again, the major complaint lodged against XGA is the inclusion of bus mastering (and certain other less significant features), which adds excessive complexity, gate count, and cost to the chip set. However, the bus-mastering function, aimed at servicing multimedia applications, provides a substantial increase in the image transfer rates from system memory to the display buffer. This increased transfer rate will become critical as content-intensive applications involving bit-mapped images begin to gain widespread use in two to three years.

VRAM and Display Mode Extensibility

Because the XGA register interface supports extensible display modes up to 4096 × 4096 pixels and 16 bits per pixel, applications can provide software support without any significant limitations. This feature is a big advantage to high-end applications always hungry for increased resolutions or colors. However, it imposes an extensibility of the architecture that takes it above current limits of DRAM technology to service the bandwidth requirements.

The key issue here is that using video RAM (VRAM) memory, which currently sells at approximately twice that of DRAM, places XGA into a cost category too high for the mainstream PC market.

The issue surrounding use of VRAM is very simple, assuming that 1024 × 768-pixel resolution (8-bit) or greater is the target. As refresh rates move to 75Hz (or resolutions move above 1024 × 768 pixels), video bandwidth goes beyond 80 MHz, exceeding data transfer rates available with standard 70ns DRAMs. This situation means using either wider DRAM arrays (perhaps doubling the amount of DRAM) or faster (and more expensive) DRAMs or switching to VRAM. Further complicating this decision is that the VRAM-to-DRAM cost ratio is heading downward, nearing 1.5:1 by the end of 1992. Looking at future directions for displays and projected cost differences from DRAM to VRAM, the choice to offer support for both DRAM and VRAM would provide the flexibility required.

Proliferating XGA Chips to the Industry

In the first of a series of actions expected to center around the new XGA standard, SGS-Thomson/Inmos announced the first commercially available XGA chip sets. Under the IBM product line, these are the same chips introduced in October 1990 on PS/2 models 90, 95, and P75. Under the Inmos product line, these are the IMS G200 XGA Display Controller and IMS G190 XGA Serializer Palette DAC available through standard Inmos sales channels. In addition, the new Inmos brochure (entitled *XGA*, designed by IBM, and delivered by Inmos) describes future versions of the XGA for the AT bus (the current version is MCA), confirming IBM's spoken intentions on the issue. By this partnership arrangement, Inmos has exclusive rights to market the IBM XGA chips for an undisclosed period. It intends to aggressively take advantage of this opportunity, beginning heavy promotion and selling efforts immediately, including an advertising campaign and national technical seminars held jointly with IBM.

Inmos realizes that although its arrangement with IBM is currently exclusive, several graphics chip manufacturers are developing their own designs of the XGA architecture and all expect to deliver parts sometime in 1992. Also, each vendor is taking a slightly different approach to designing XGA chip sets, setting the stage for feature differentiation rather than straight cloning.

XGA Growth within IBM's Line

XGA is IBM's latest graphics chip set and is intended to become its standard graphics architecture for the future. The level of XGA proliferation as a built-in standard within IBM's product line will form a critical part of industry perception and establish performance levels that must be met by other system manufacturers. Already several indicators show IBM's intent to proliferate XGA, including the following:

- Strategic nature of OS/2 and XGA's role in its GUI environment
- Integration of XGA with PS/2 models 90, 95, and P75
- Release of register-level definitions of the XGA architecture
- Involvement with the VESA subcommittee on XGA
- Licensing of chip sets for sale through Inmos
- Stated intention to develop AT bus versions of XGA

From a historical perspective, we see XGA positioned (IBM's line) as the new mainstream standard, flanked by the more esoteric Image Adapter/A in the same manner as previous pairings of VGA with 8514A and EGA with PGC. We expect to see the XGA implemented in many new PS/2 systems and some AT-bus systems introduced by IBM the next year.

Dataquest Perspective

Based on the previous analysis, Dataquest believes that XGA will become a significant standard in the next five years. Although certain accelerated VGA solutions will sell well in the next two years, the forces behind XGA will place it in a clearly dominant position. Our forecast for this product's future is as follows:

- By the end of 1991, XGA offerings will be announced by at least two add-in board vendors.
- By the end of 1992, XGA will be shipping from at least three major chip vendors and three top systems vendors.
- By the end of 1993, XGA designs including 1MB of display memory will cost $100 in materials and be supported by most high-performance DOS applications.
- By the end of 1994, XGA will be shipped with 35 percent of the desktop PC systems.
- By the end of 1995, XGA will be the predominant graphics standard within the PC market, representing 50 percent of the desktop PC unit volume and nearly 10 percent of the laptop/notebook unit volume. ■

By Ken Lowe

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