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Sega Dreamcast
Electronic Game
Performance and Design Analysis

Report #150-000105-1e

Product Description:

The Sega Dreamcast, with four controller ports, is a very high performance 3D graphics video game console. With 128-bit processing capability, the Dreamcast can shift 3 million polygons per second. It has a built-in 56k modem for on-line gaming, 24 MBytes of internal memory, and 64-voice CD-quality audio.

Report Contents:

- Detailed external and internal photos
- Detailed step-by-by step disassembly
- Power draw analysis
- Circuit board and packaging metrics
- Complete parts lists and component count
- Manufacturing cost estimates

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Table of Contents

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Product Overview

- **Fastest 3D graphics performance on a video game console**
  - Shifts over 3 million polygons per second
  - 128-bit processing capability
- **Built-in 56kbps modem for on-line gaming**
- **24 megabytes of memory built-in**
- **64-voice CD-quality audio**
- **4 controller ports**
- **Built-in high-speed expansion ports**

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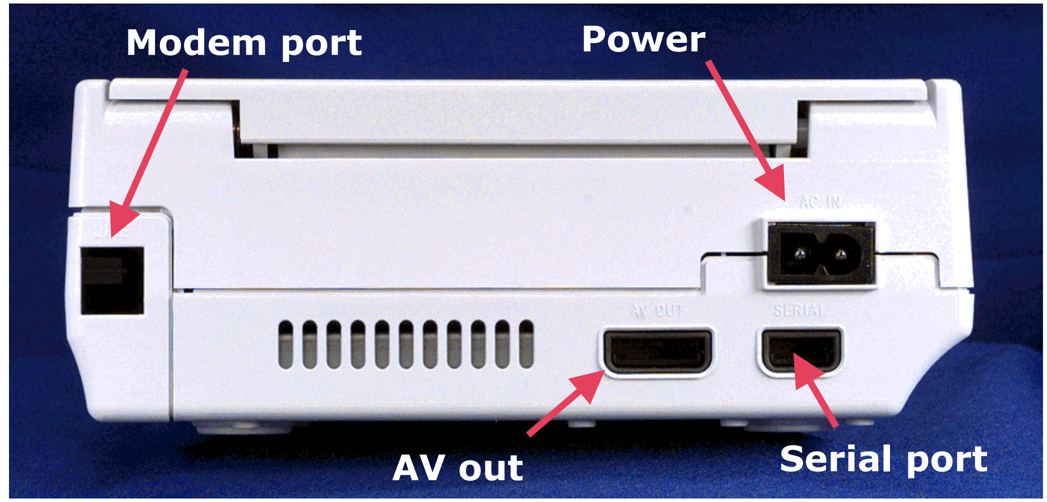
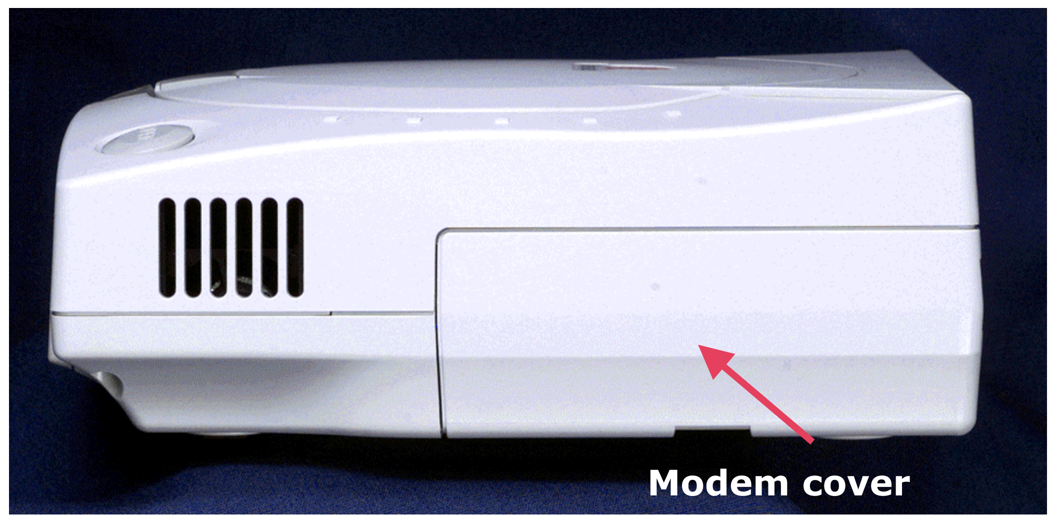
External Interface
(main console)

Front / top view with lid opened, showing the disc drive and four controller ports.



Back view of main console



Right side view

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External Interface
(main console)
Page 2 of 2

Front, lid closed

Bottom view

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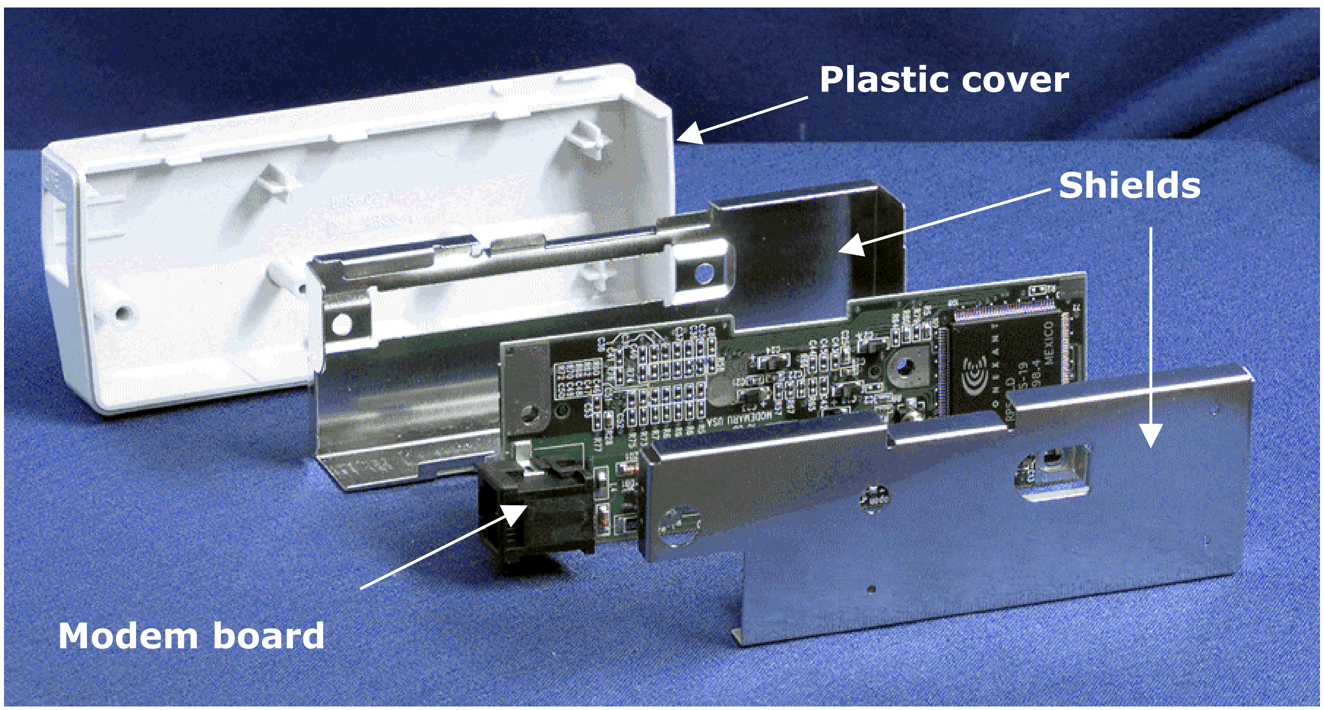
Main Console
Pluggable modem module

Side view of main console with modem and cover removed

Assembled module



Module breakdown

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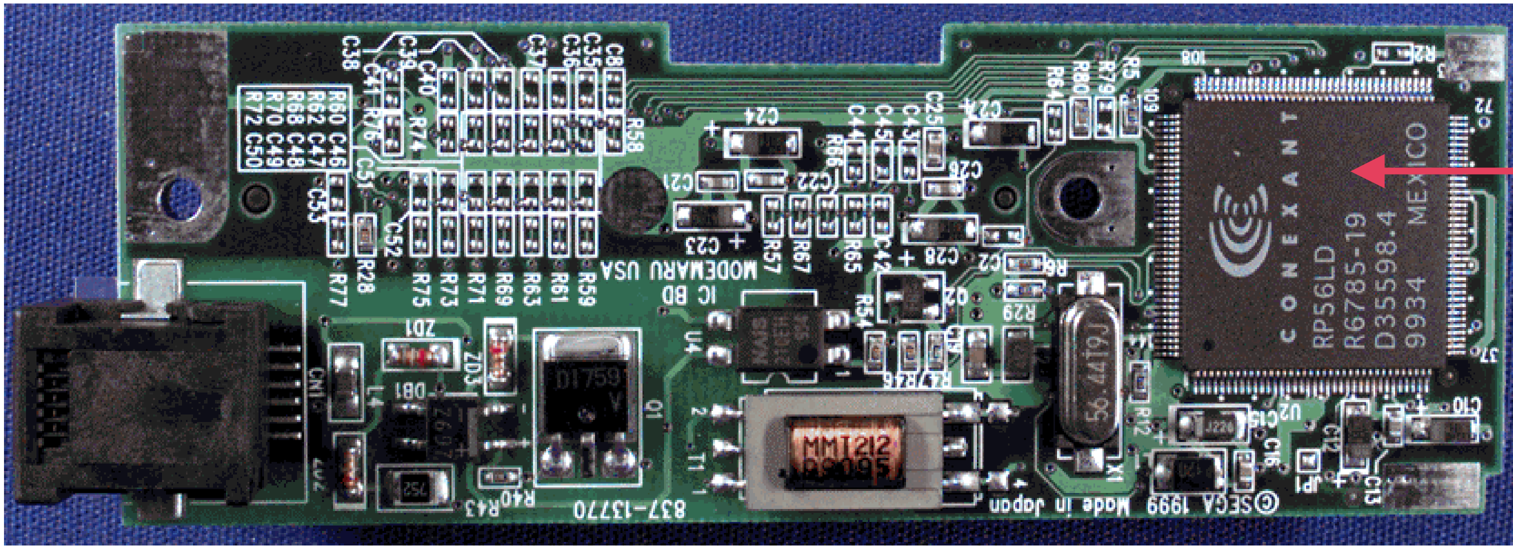
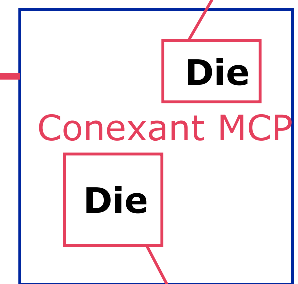
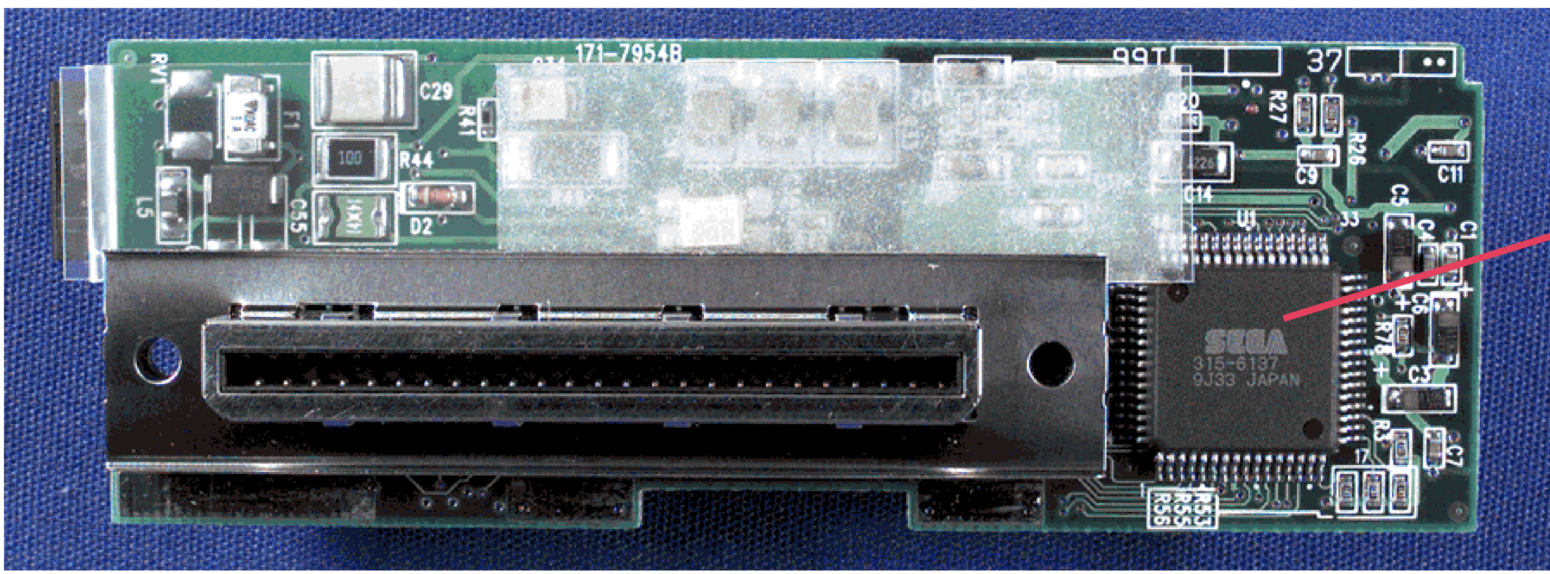
Main Console
Modem Board

Size
0.235″ x 0.140″





Size
0.250″ x 0.230″



Sega
#315-6137
Custom I.C.

Front and back view of modem board

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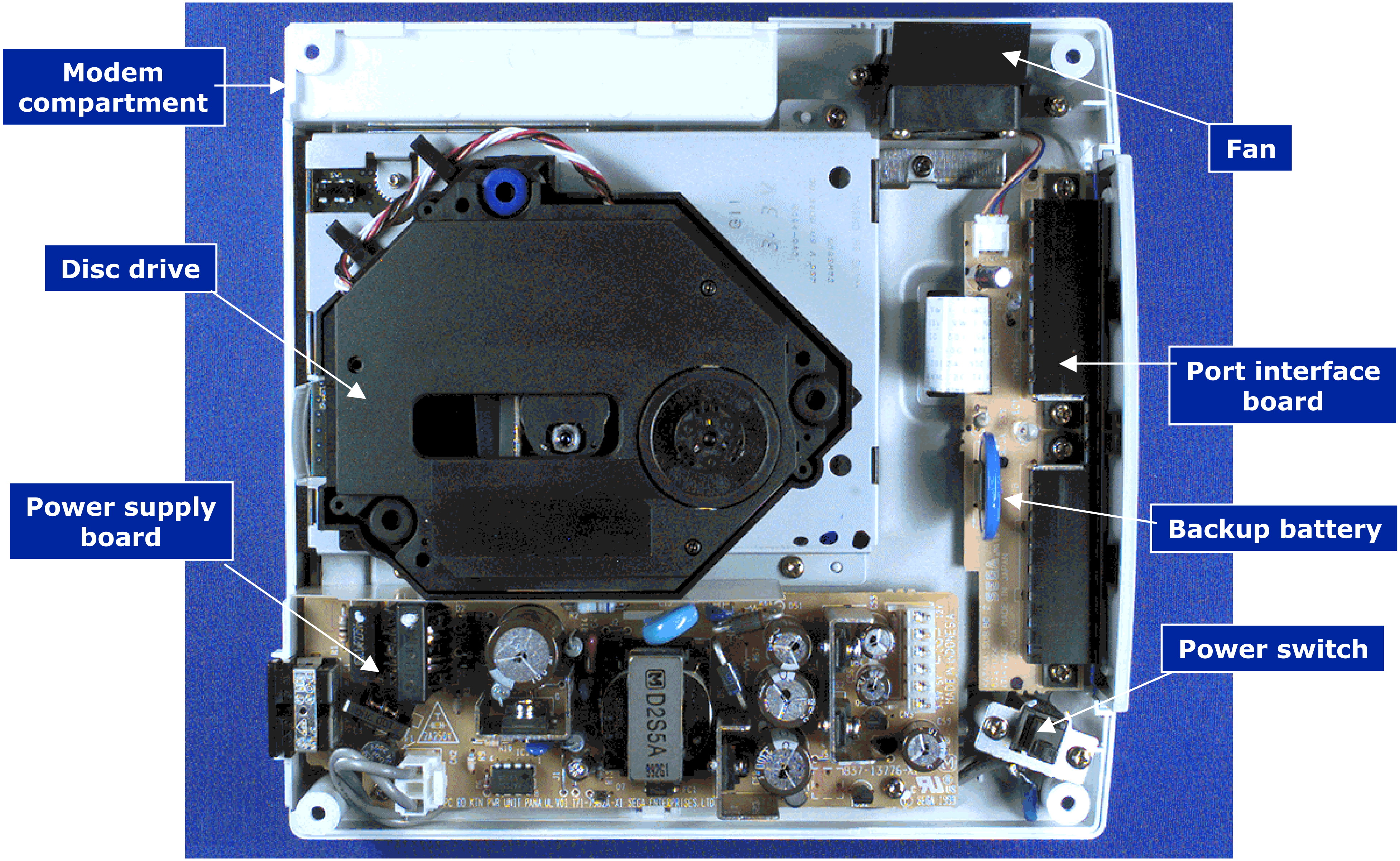
Main Console
(cover removed)



The plastic top enclosure was removed by removing three screws from the bottom of the main console (see bottom view on a previous slide) and one screw from inside the modem compartment

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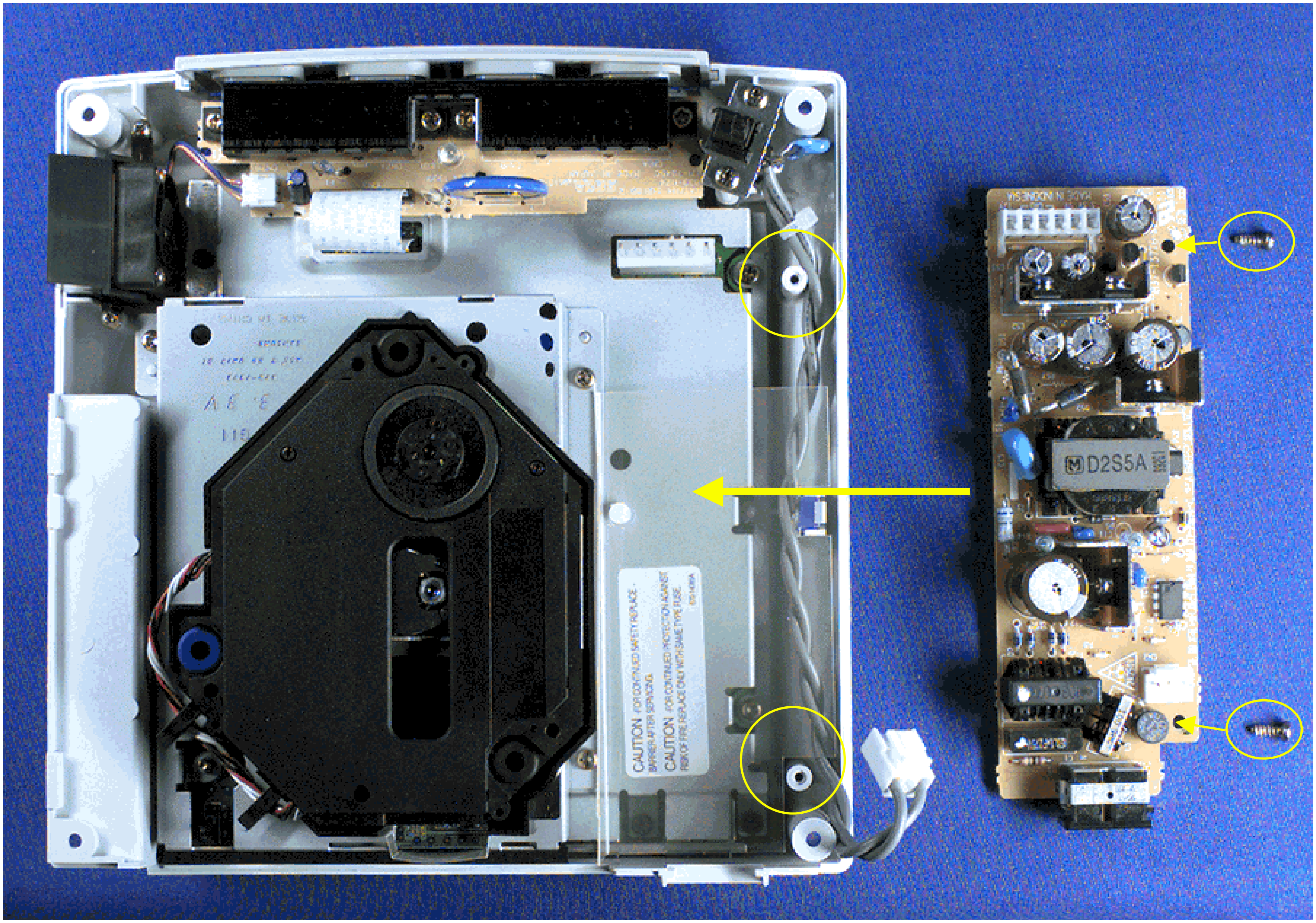
Main Console
(Power card removed)



The power supply unit was removed from the main console after removing the two screws shown and unplugging the connector on each end of the board.

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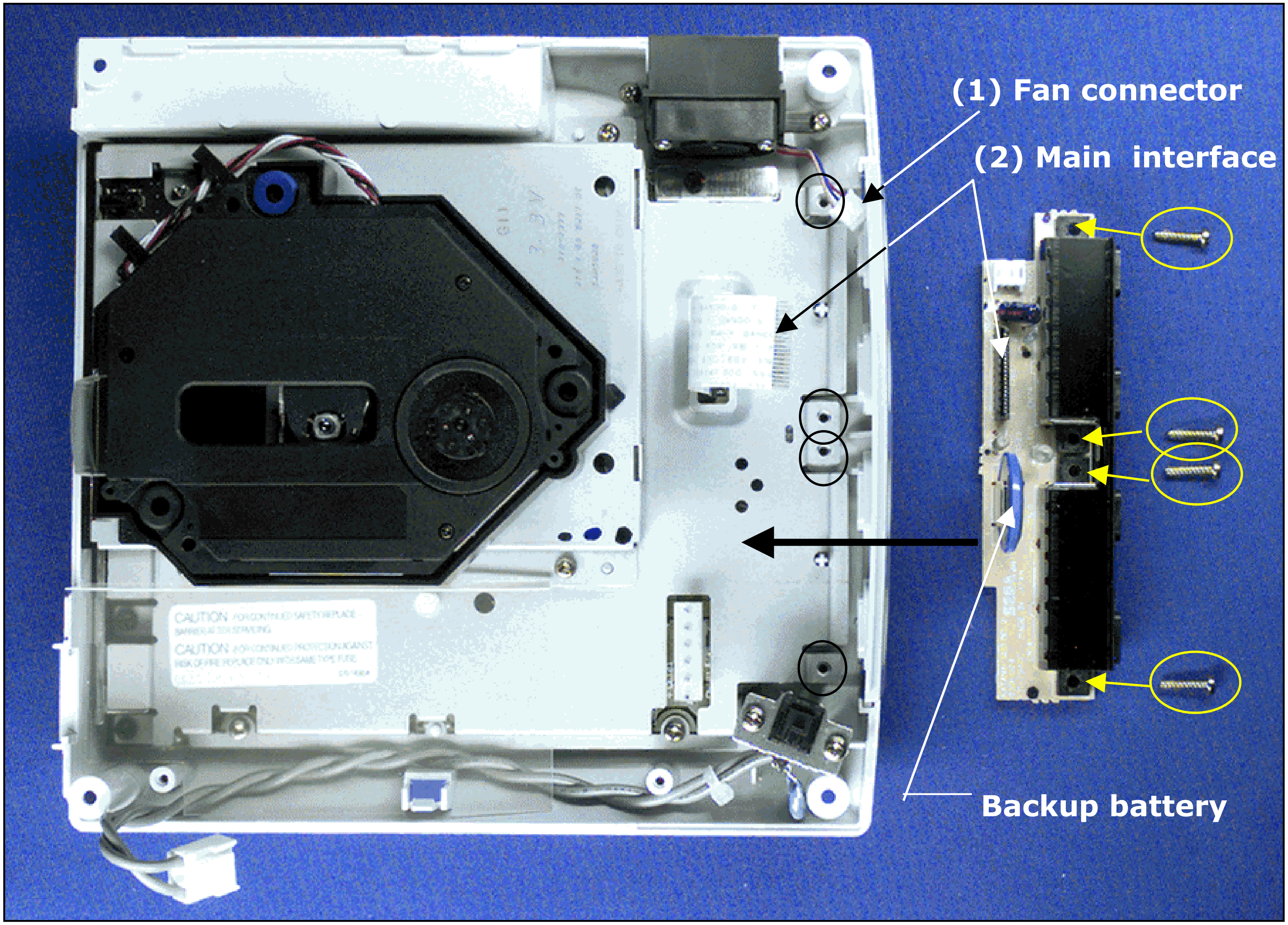
Main Console
(controller port interface board removed)



The controller port interface board was removed after removing the four screws shown and the two connectors (1 and 2).

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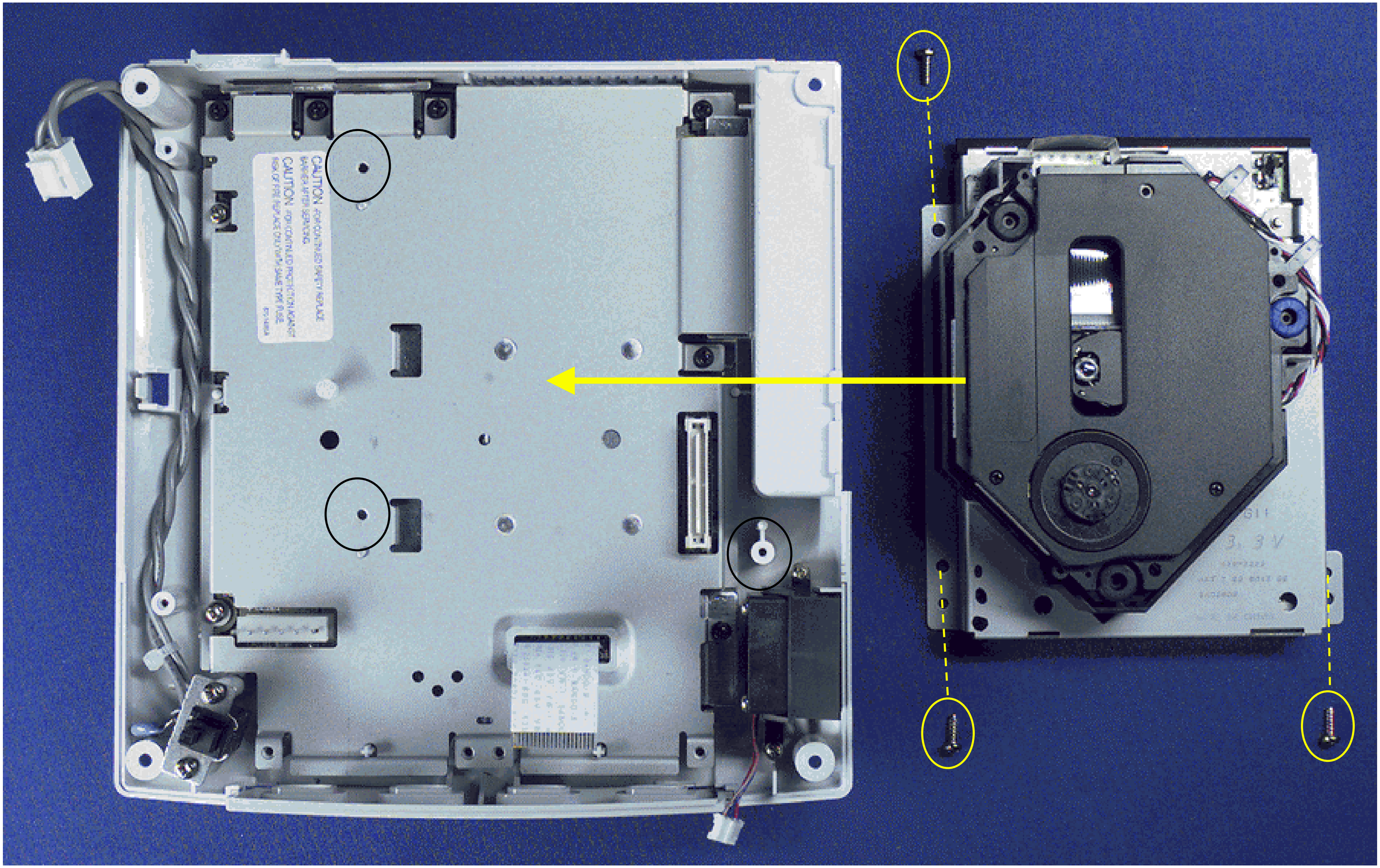
Main Console
(Disk drive removed)



The disc drive was unplugged and removed after removing the three screws shown.

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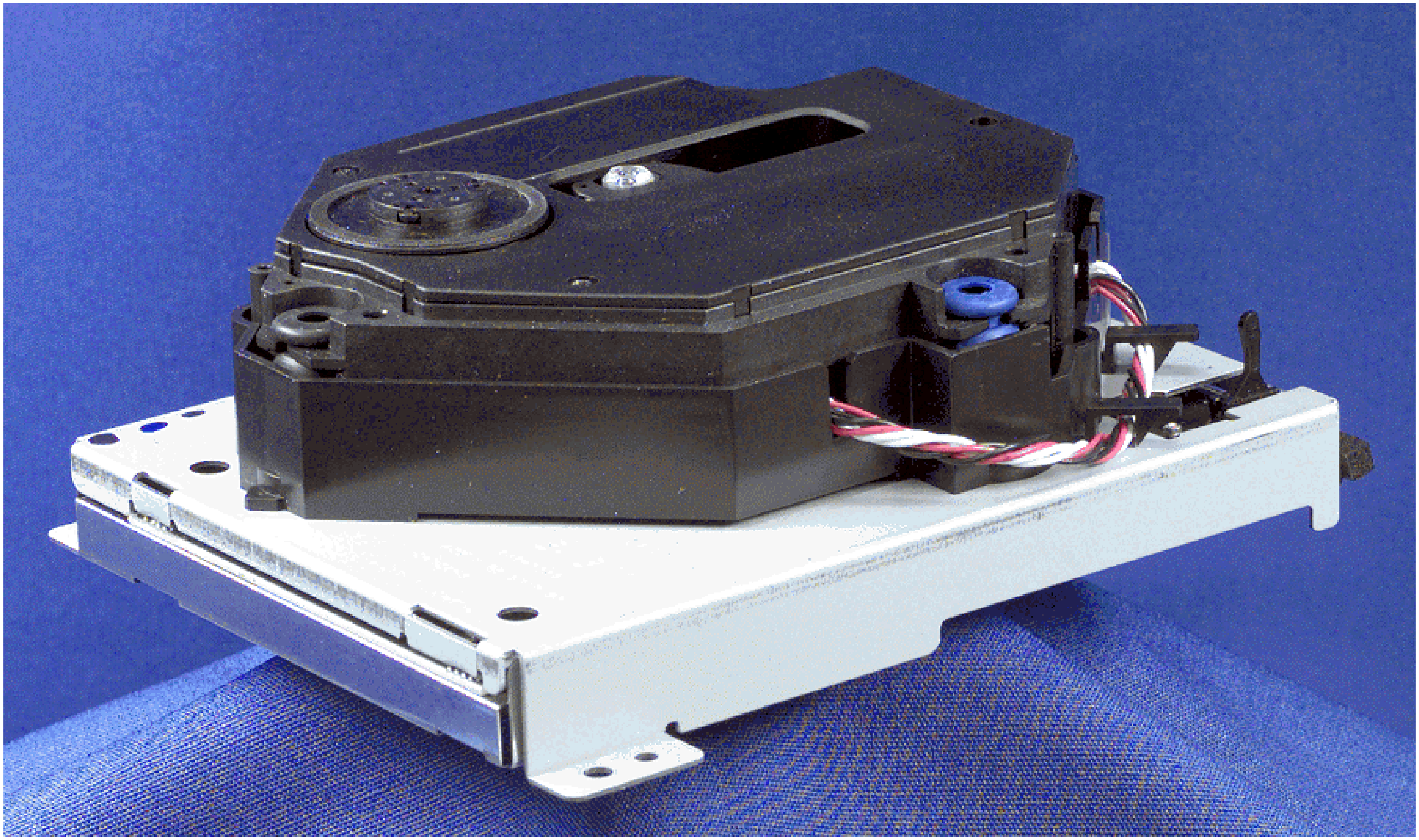
Main Console
Disk drive assembly



Disk drive removed from the main console but still attached to the drive chassis.

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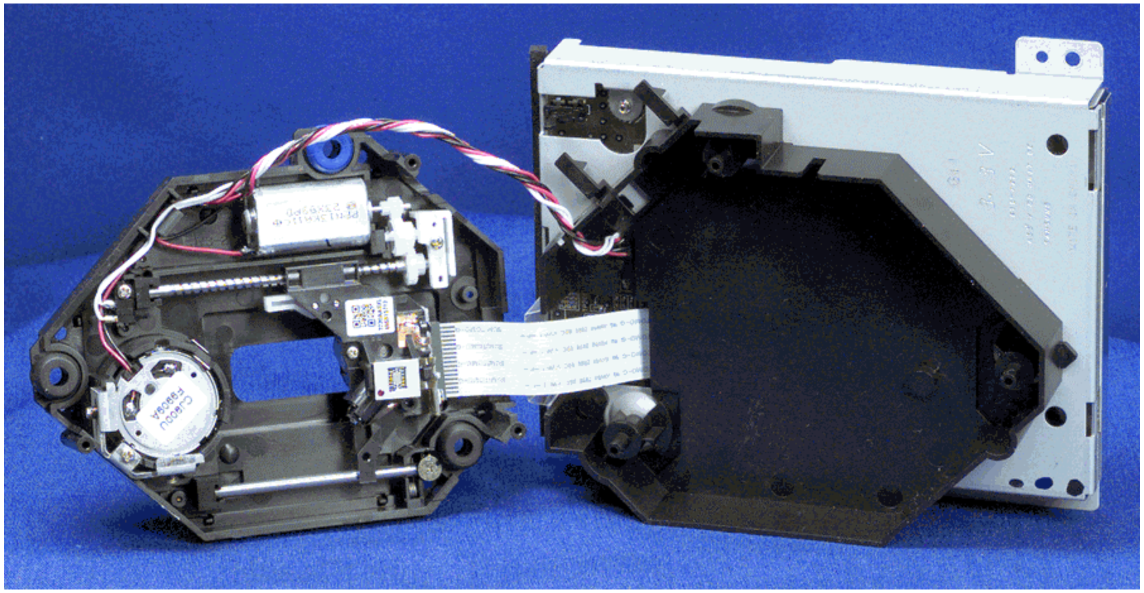
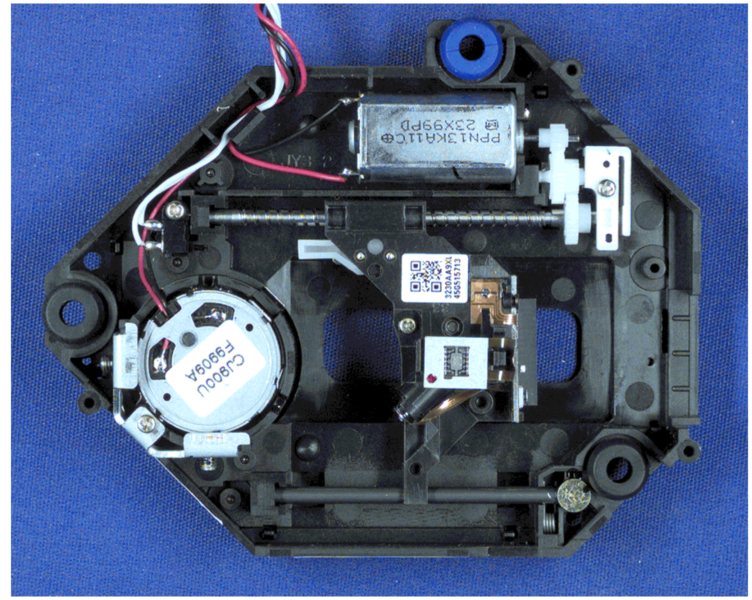
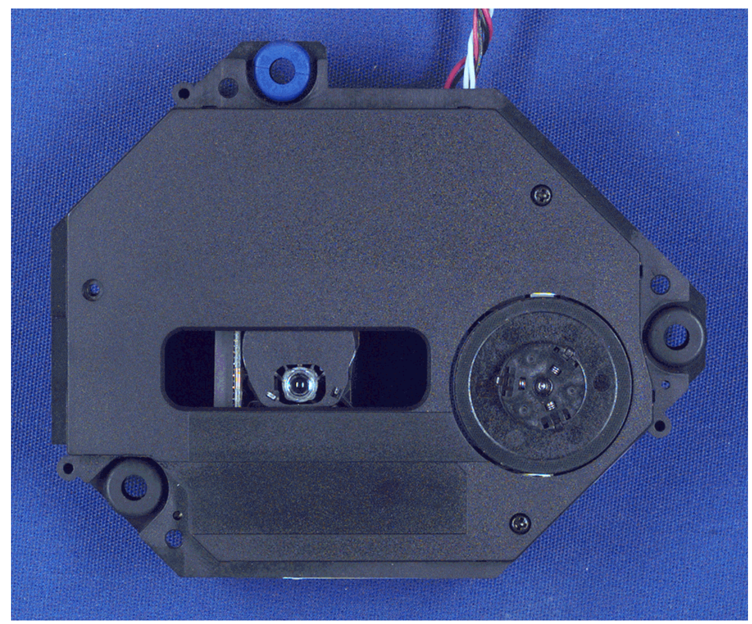
Main Console

Disk drive assembly opened







Above Disk drive mechanism removed from the drive assembly. The upper drive mechanism "floats" on grommets in the drive housing and is attach by ribbon cable to the lower chassis.

Right Top and bottom view of the upper drive mechanism.

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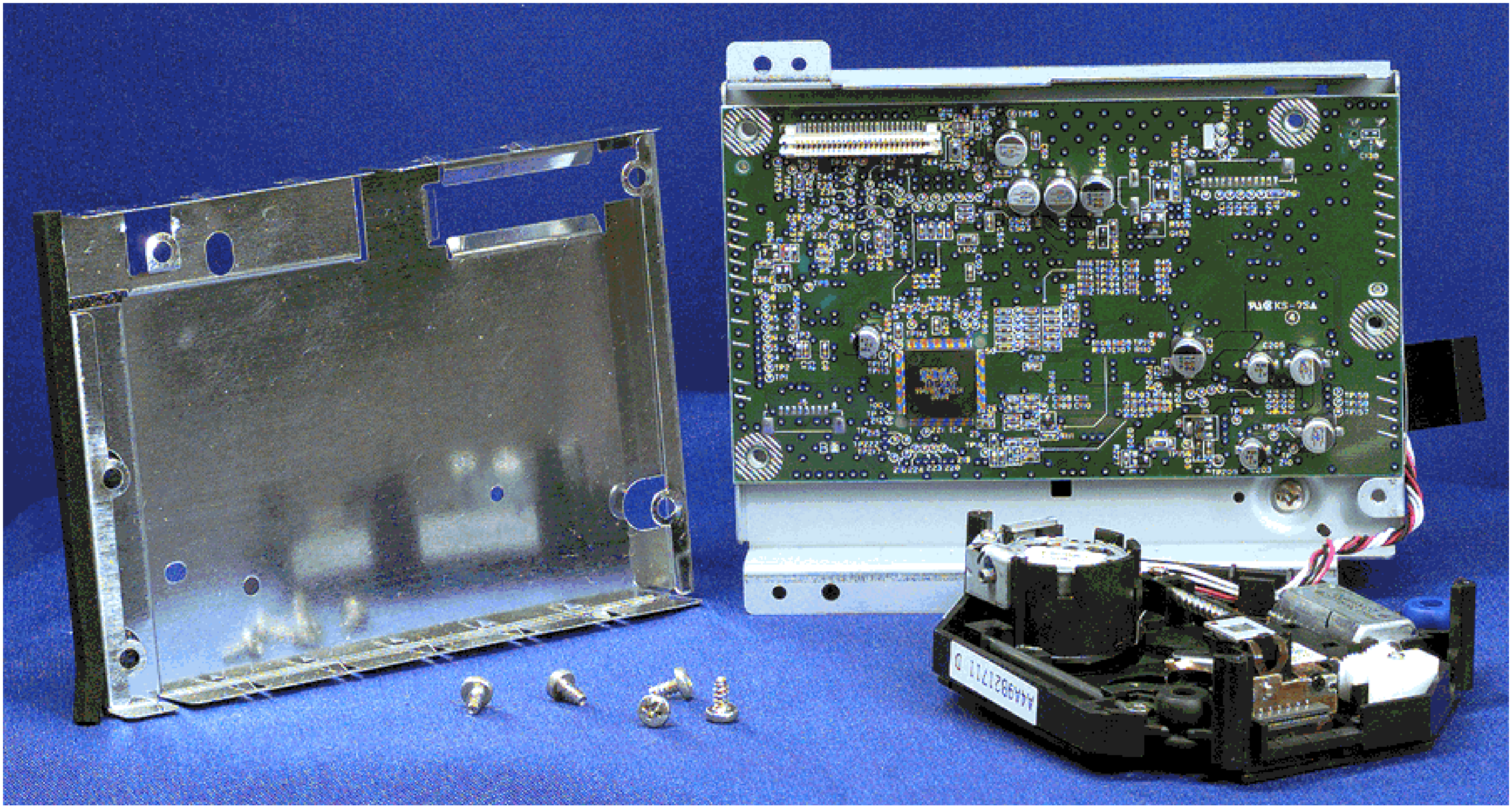
Main Console

Disk drive chassis



Bottom of the drive assembly chassis with the shield cover removed (5 screws), revealing the disk drive PC board. The board was held in the chassis with the same screws used for attaching the shield.

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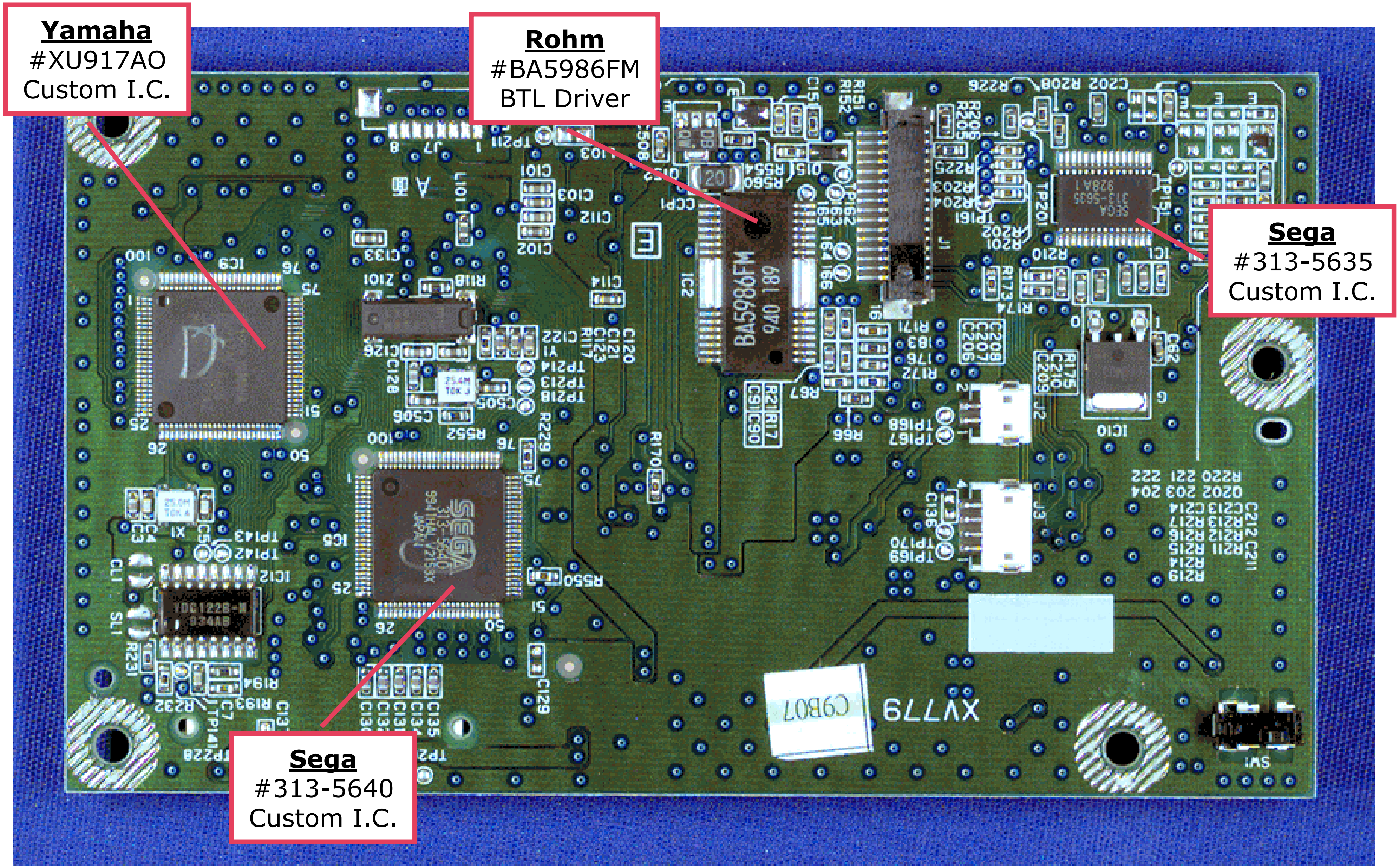
Main Console
Disk Drive PC Board (side 1)



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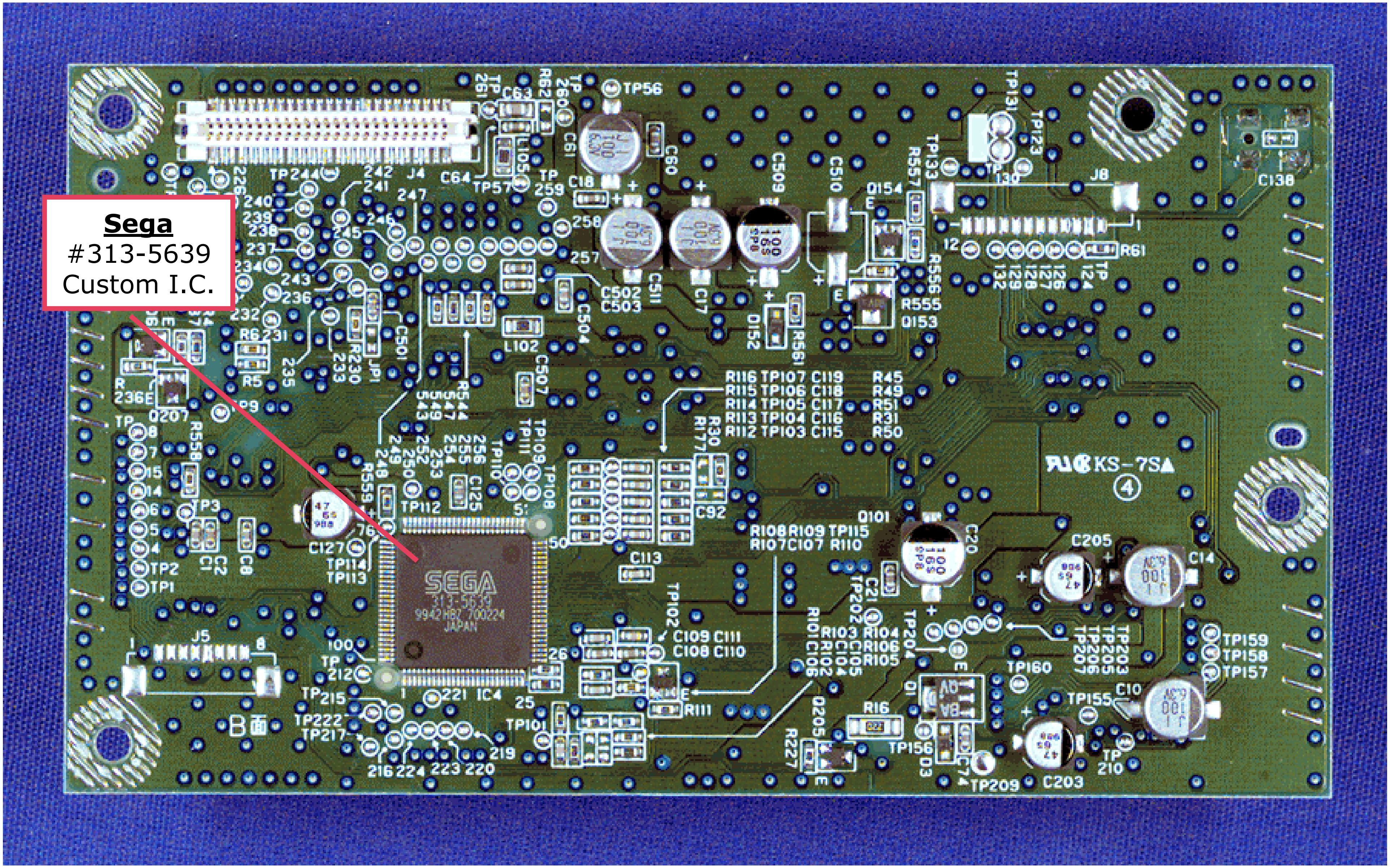
Main Console
Disk Drive PC Board (side 2)



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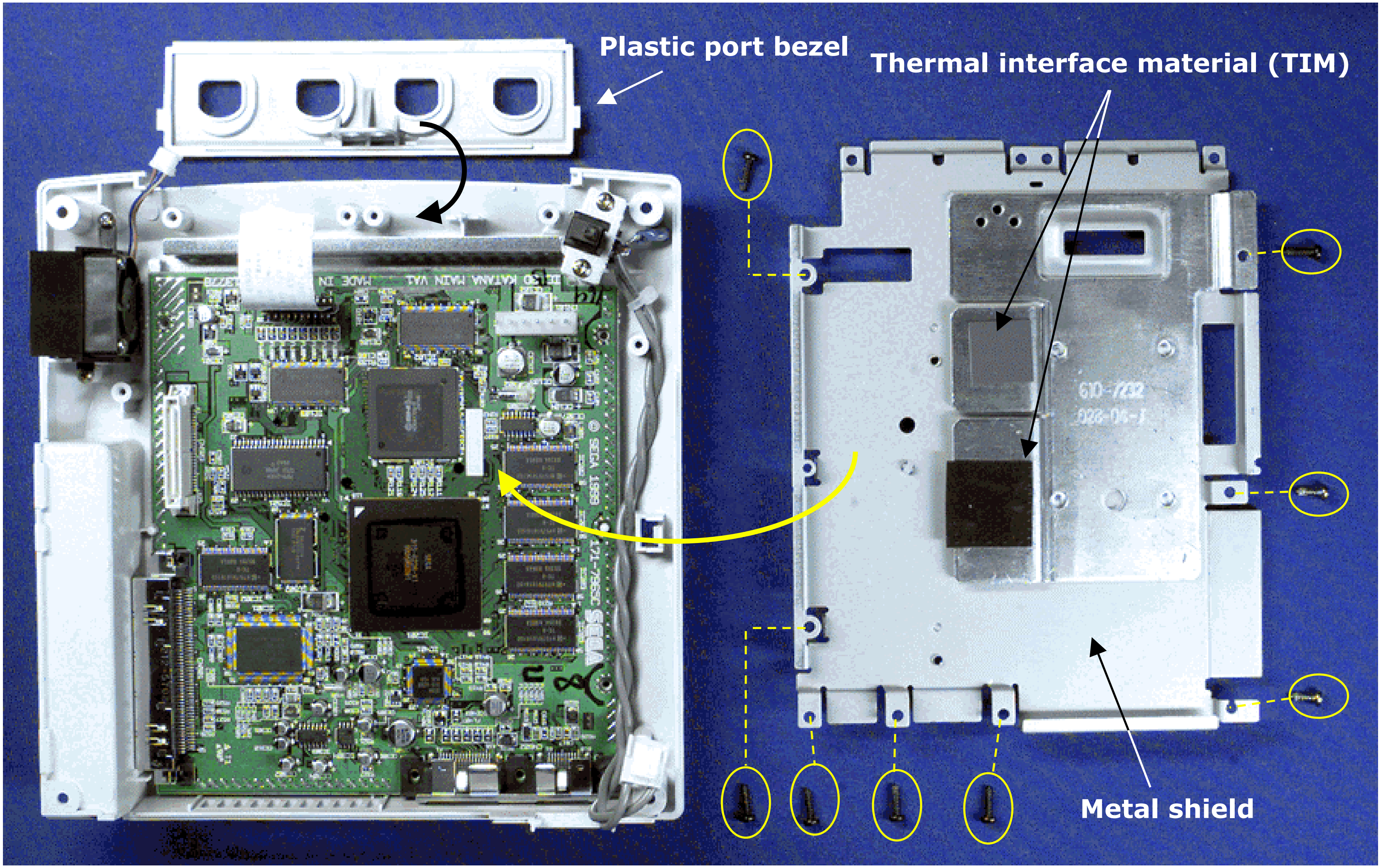
Main Console
(Upper shield panel removed)



The metal shield panel was removed, revealing the main circuit board, after removing the eight screws shown.

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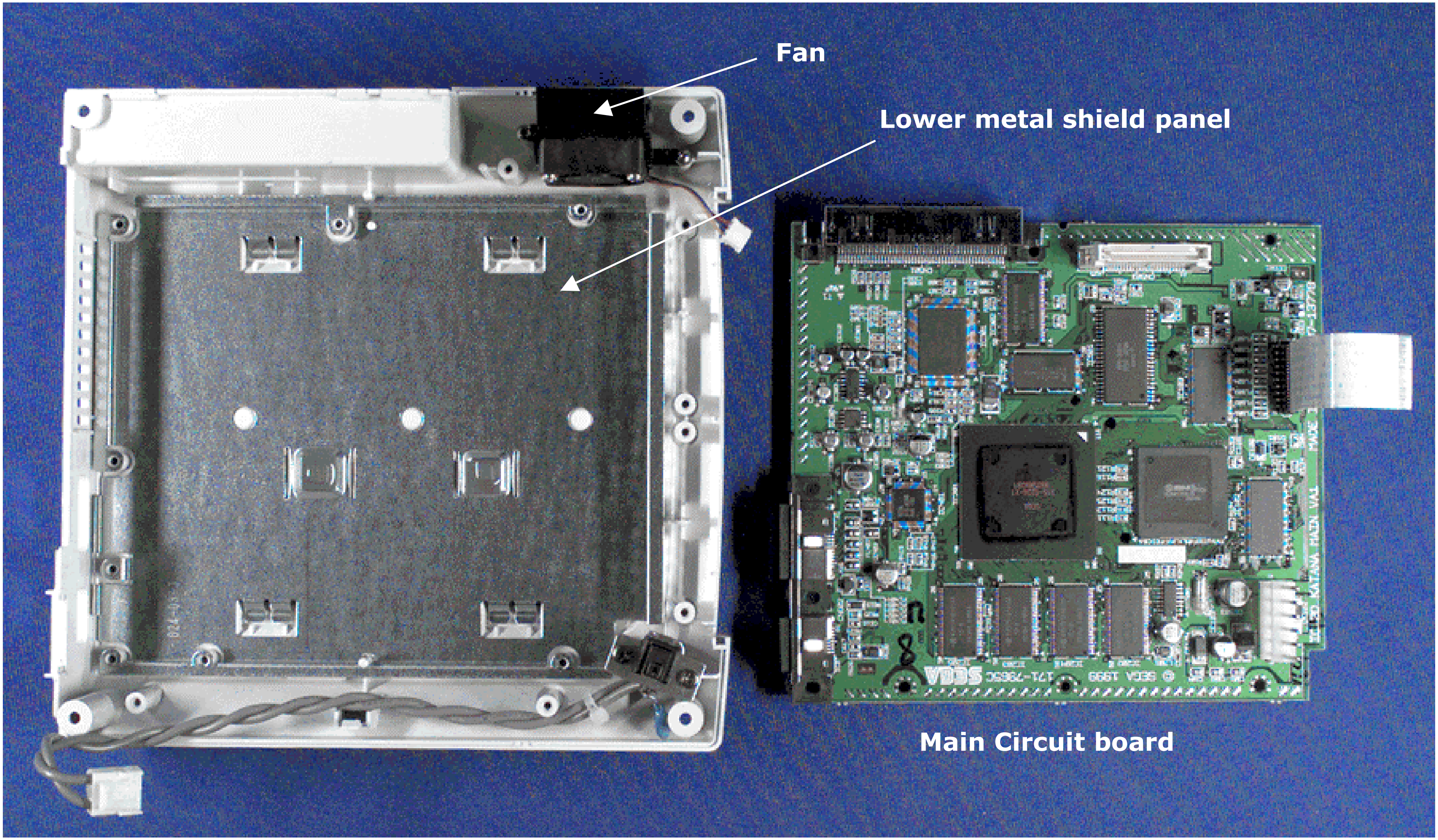
Main Console
(Main circuit board removed)



The main circuit board was lifted out of the main console in this photo, revealing the lower shield panel

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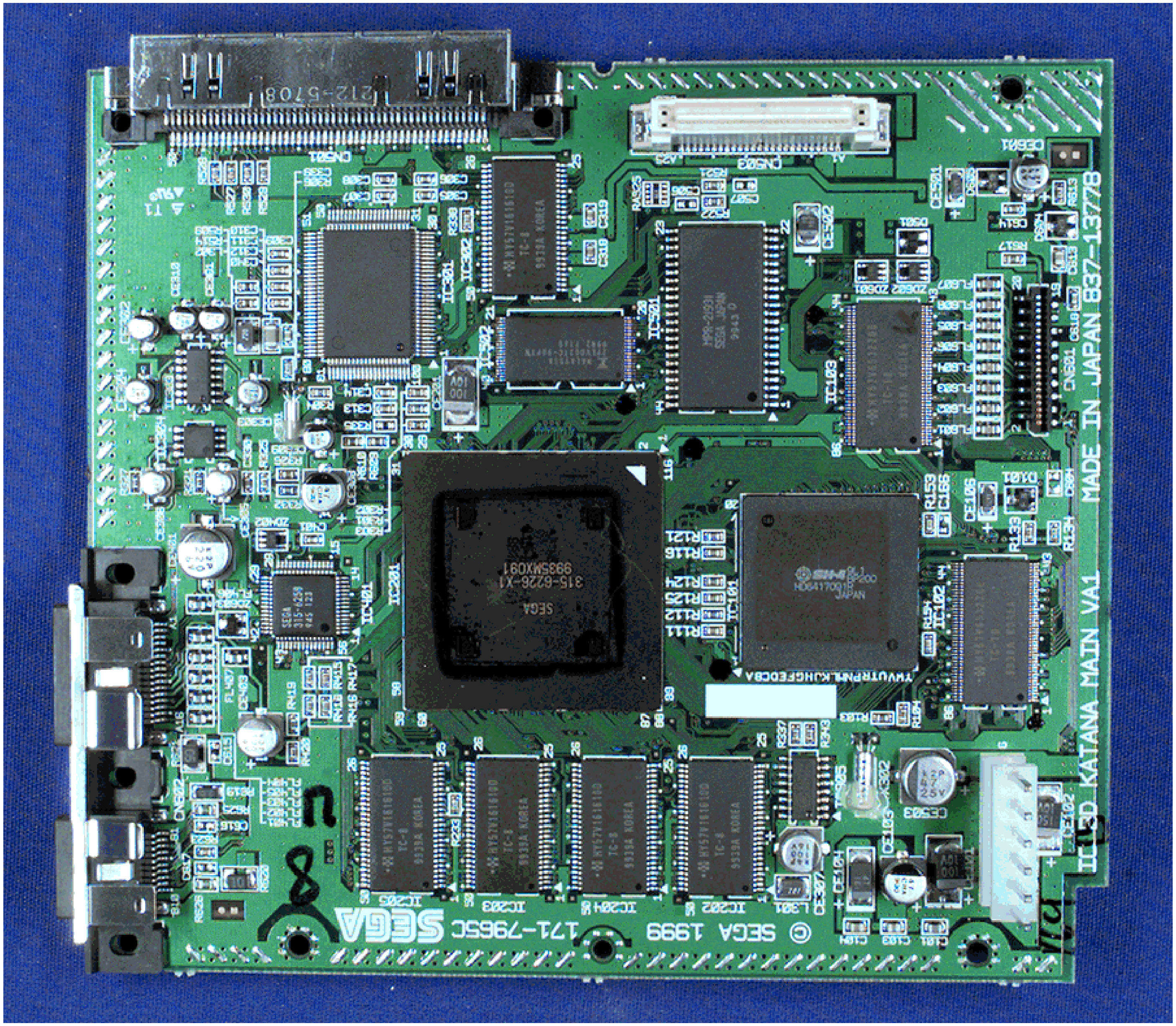
Main PC Board
Main Circuit Board (Side 1)



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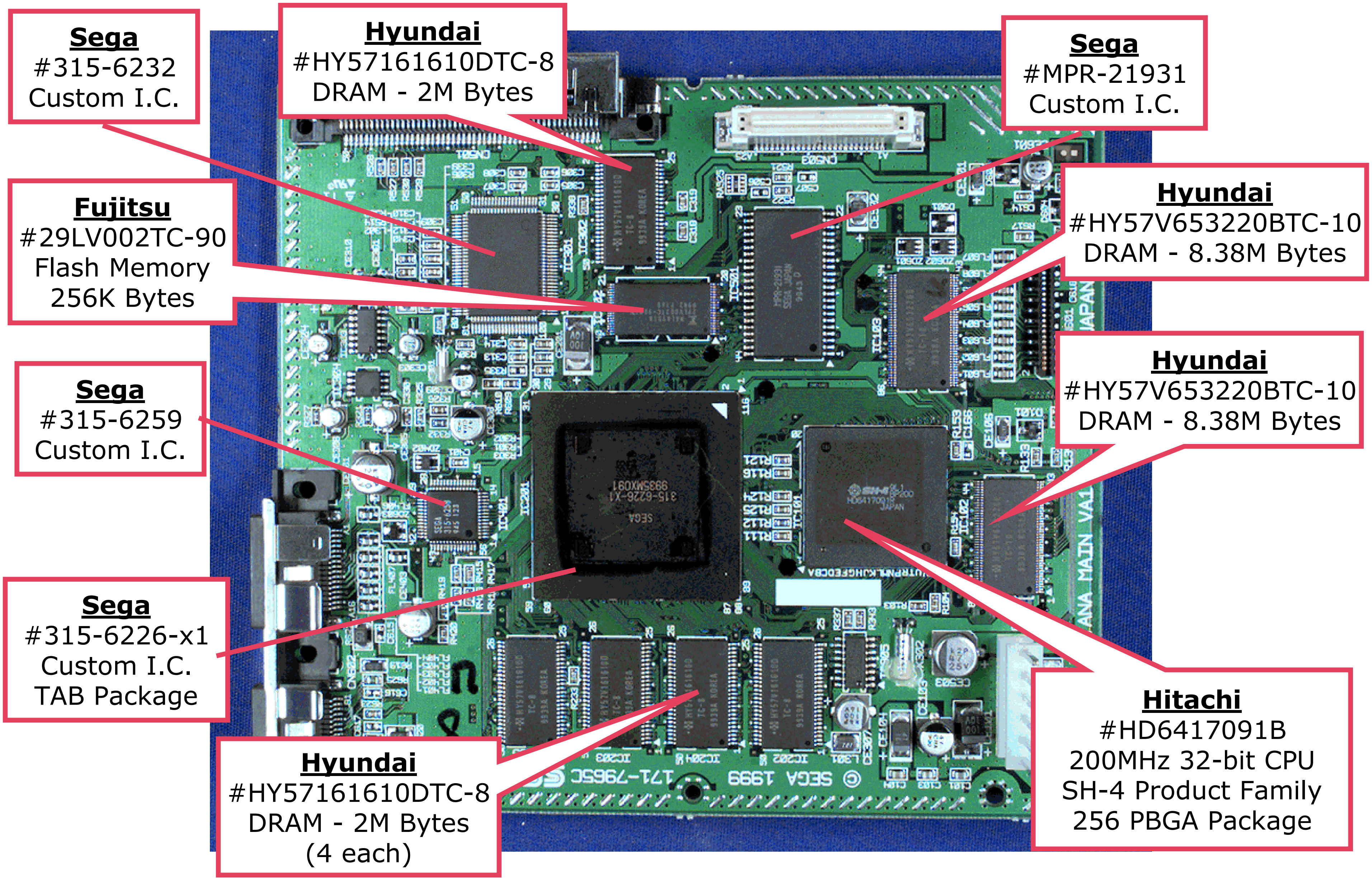
Main PC Board
I.C. Identification – Side 1



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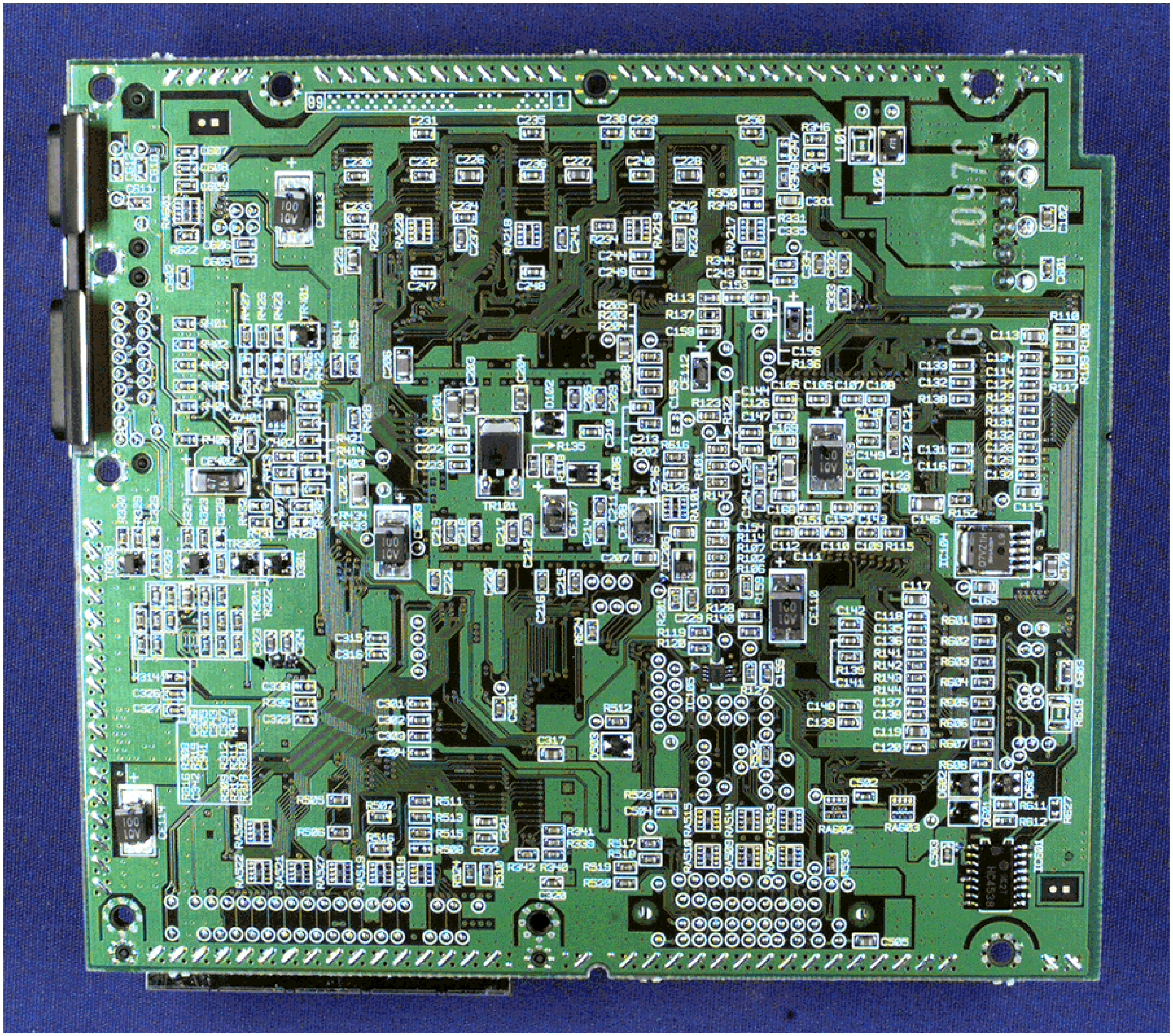
Main PC Board

Main Circuit Board (Side 2)



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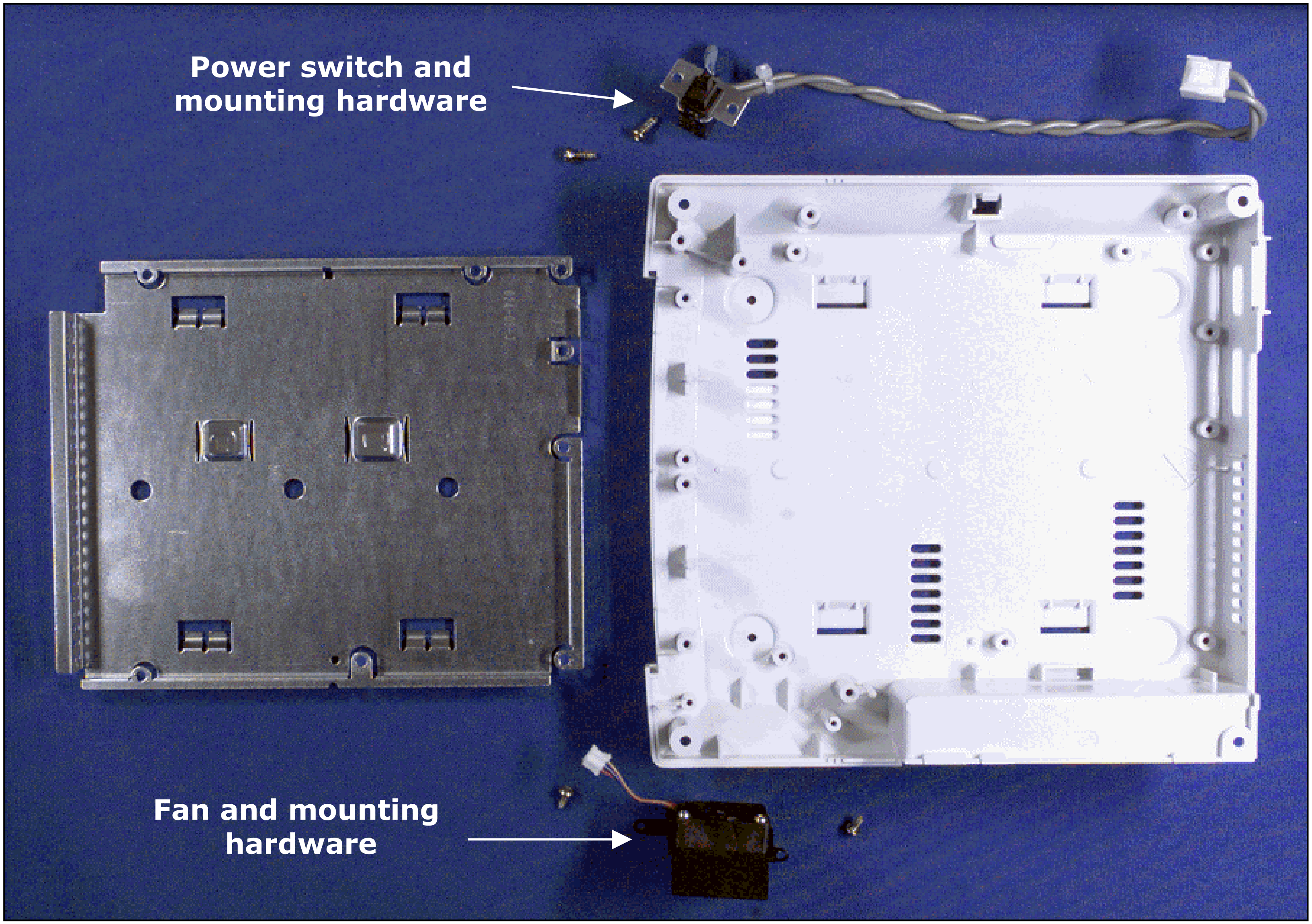
Main Console
(Lower shield removed)



The lower metal shield panel was lifted out of the lower plastic enclosure in this photo. The fan and power switch were also removed as shown.

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External Interface
(controller station)

Left

Top view of the controller station showing the left and right thumb control functions.

Right

Back view of the controller station showing the PDA slots and index finger controls.

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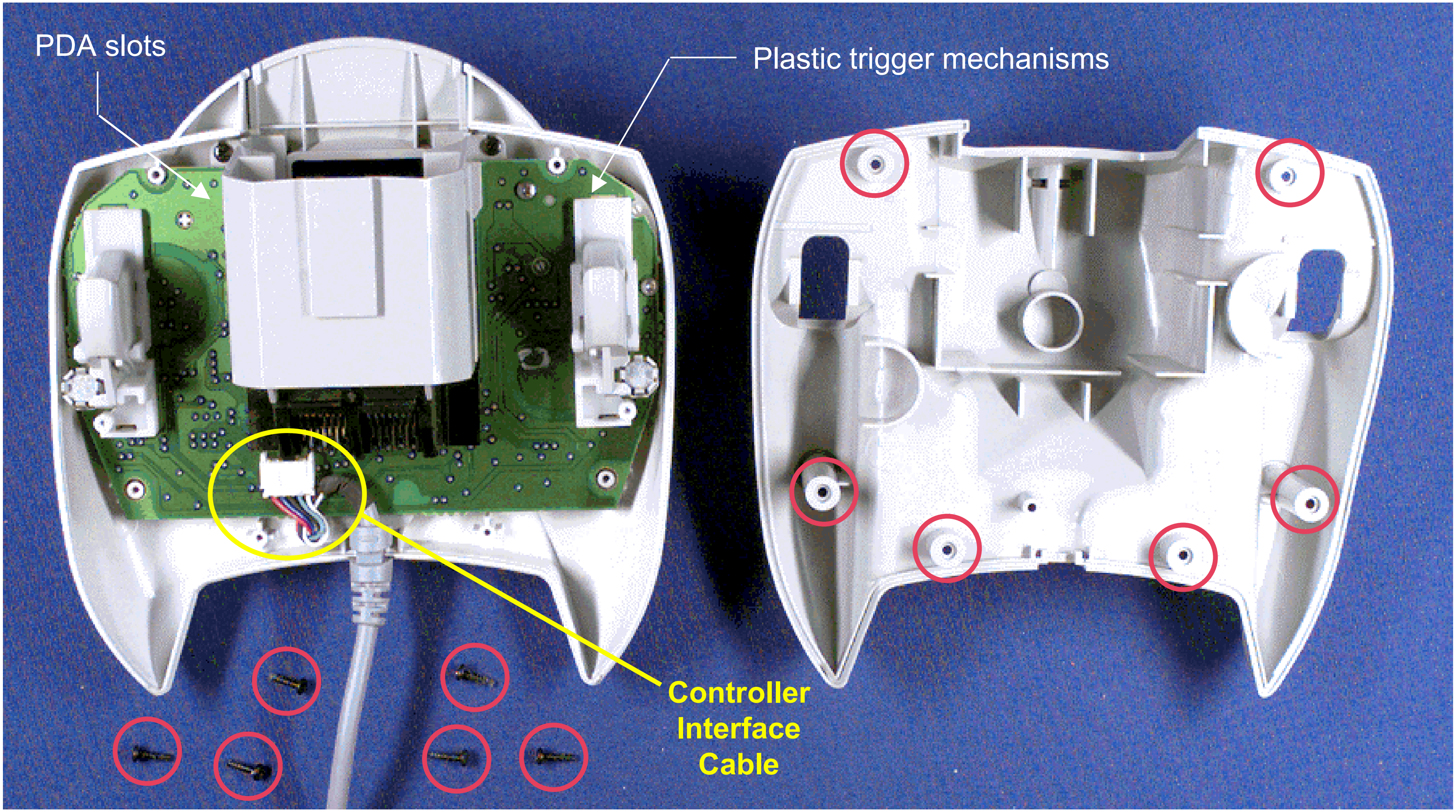
Controller Station opened



The two plastic halves of the controller station were separated by removing the six screws shown. Disconnect the pin & socket type connector from the controller PC board before PCB removal.

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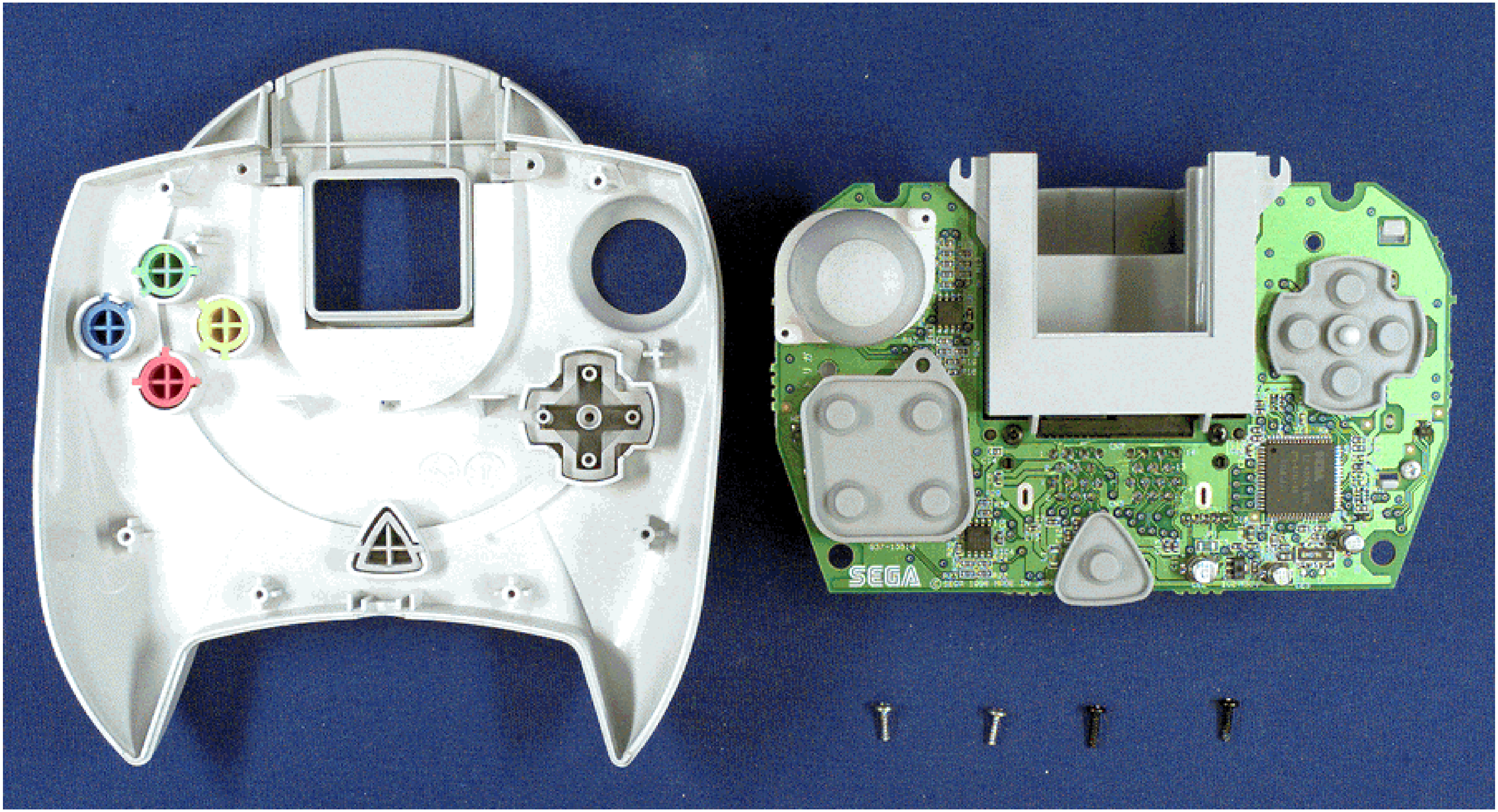
Controller
PC board removed



The controller station PC board was removed in this picture and turned over along with mating plastic pieces. The board was retained with the four screws shown.

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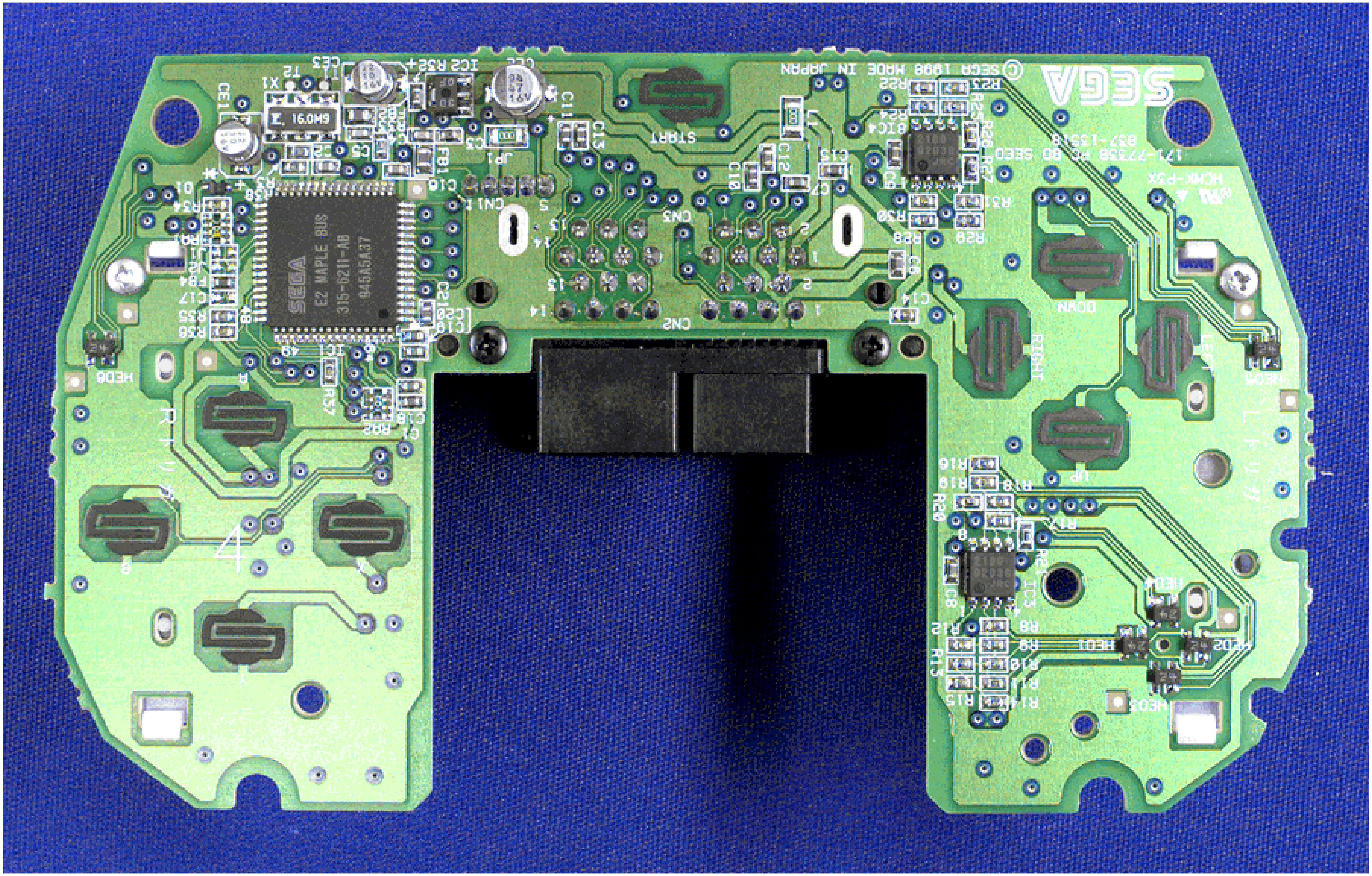
Controller - PC board (side 1)



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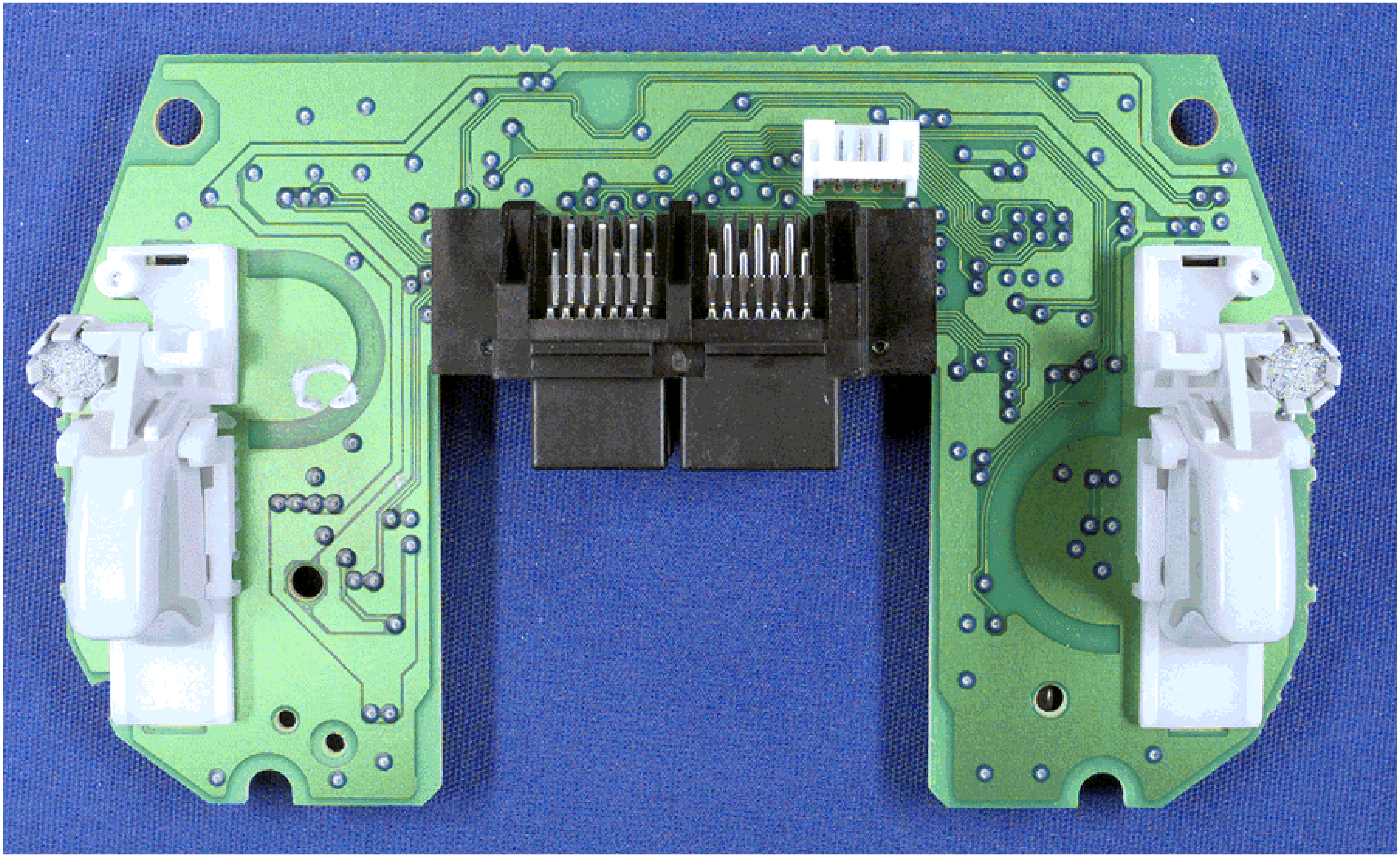
Controller - PC board (side 2)



Back side of the controller board with the plastic trigger mechanisms still attached.

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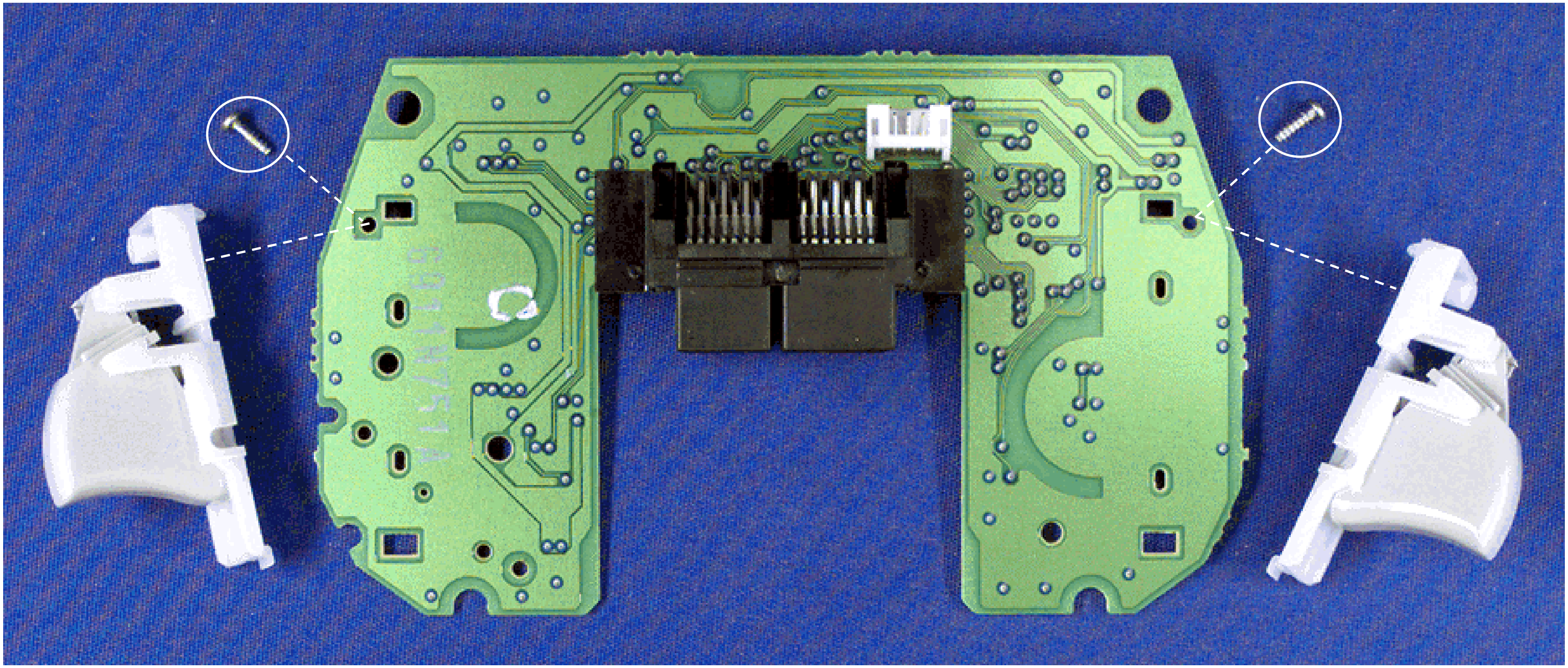
Controller

PC board triggers removed



Back side of the controller PCB with the plastic trigger mechanisms removed. Each trigger was snapped on the back side of the board and attached with one screw.

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Controller - Plastic hardware

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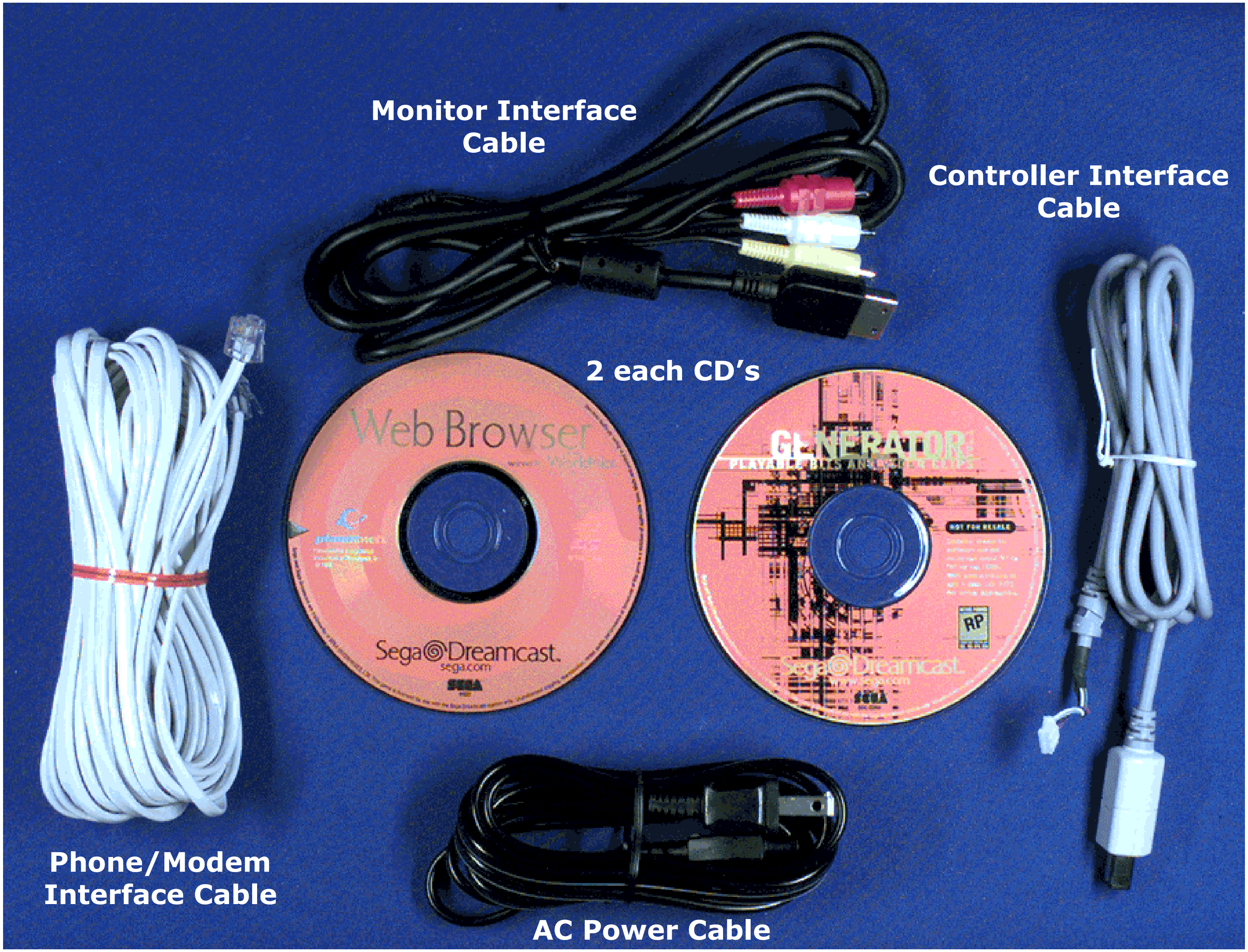
Supporting Software & Cables



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Substrate Measurements

Main PCB

Main PCB
Layers = 4
Pitch = 0.010”
Trace = 0.004”
Space = 0.006”
Via I.D. = 0.012”
Via O.D. = 0.026”
Thickness = 0.050”
Weight = 128.1 grams

35.281 Sq In
227.61 Sq cm

PCB#171-7965C

Modem PCB

5.772 Sq In
37.23 Sq cm

PCB#837-13770

Modem PCB
Layers = 4
Pitch = 0.017”
Trace = 0.007”
Space = 0.010”
Via I.D. = 0.012”
Via O.D. = 0.026”
Thickness = 0.040”
Weight = 30.1 grams

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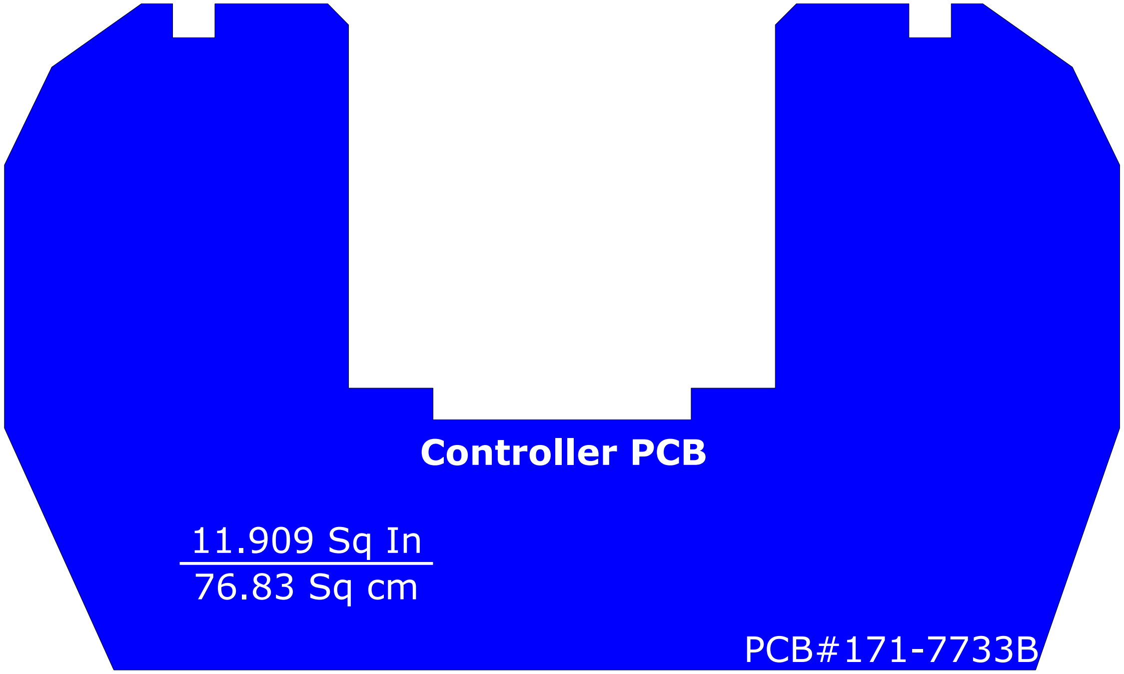
Substrate Measurements

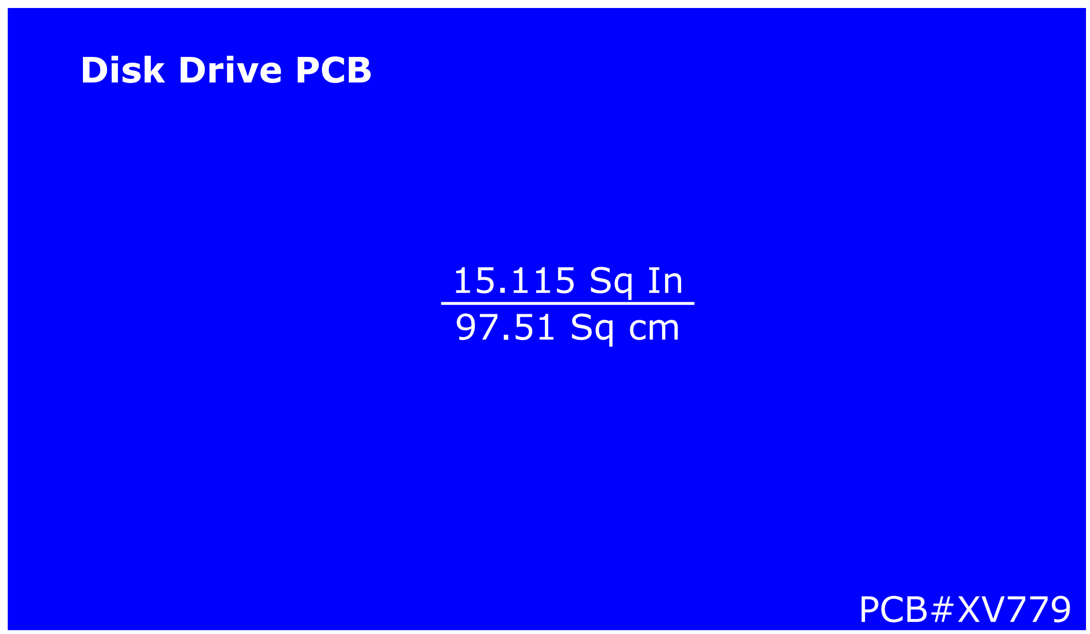


Controller PCB

Layers = 2
Pitch = 0.017”
Trace = 0.007”
Space = 0.010”
Via I.D. = 0.018”
Via O.D. = 0.060”
Thickness = 0.062”
Weight = 35.3 grams

Disk Drive PCB

Layers = 2
Pitch = 0.017”
Trace = 0.007”
Space = 0.010”
Via I.D. = 0.018”
Via O.D. = 0.042”
Thickness = 0.050”
Weight = 34.8 grams



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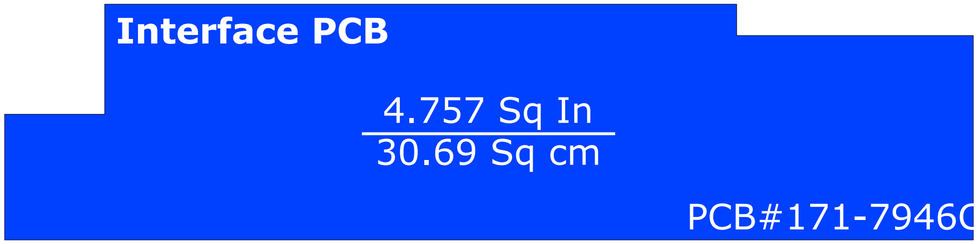
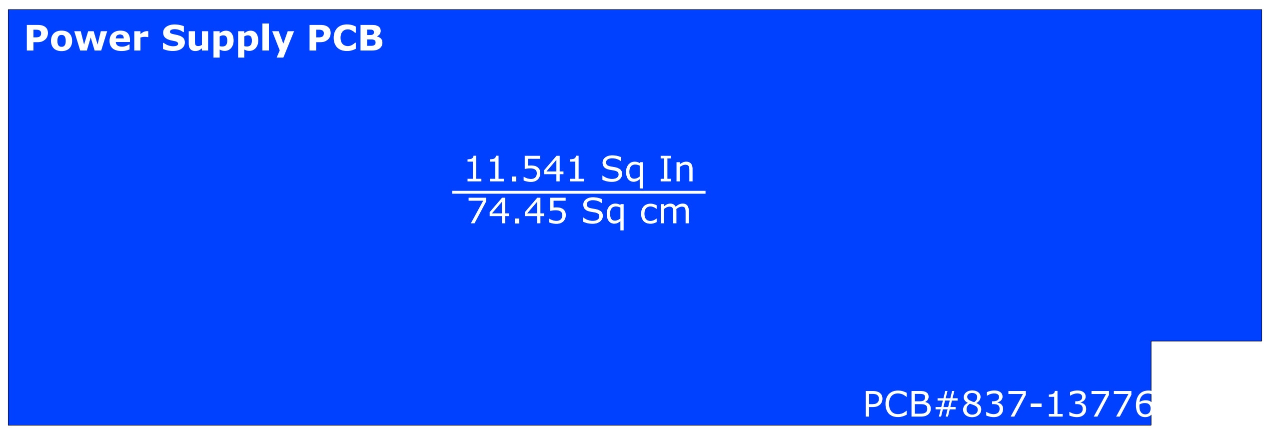
Substrate Measurements



Power Supply PCB
Layers = 1
Pitch = 0.040”
Trace = 0.020”
Space = 0.020”
Via I.D. = 0.050”
Via O.D. = 0.100”
Thickness = 0.062”
Weight = 139.2 grams

Interface PCB
Layers = 1
Pitch = 0.022”
Trace = 0.012”
Space = 0.010”
Via I.D. = 0.040”
Via O.D. = 0.060”
Thickness = 0.062”
Weight = 33.2 grams



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Parts Listing

Main PCB - Side 1										
Mfr.	Qty	Part No	Pins	Device	Pitch	Die	Die	Die	Part	Insertion
						Type	Length	Width	Cost	Cost
Sega	1	315-6226-X1	500	TAB	0.050	CMOS	0.500	0.500	$ 29.810	$ 0.500
Hitachi	1	HD6417091B	256	CSP-BGA	0.050	CMOS	0.275	0.265	$ 13.416	$ 0.150
Sega	1	315-6232	100	QFP	0.025	CMOS	0.220	0.210	$ 3.938	$ 0.200
Hyundai	2	HY57V653220BTC-10	86	TSOP II	0.020	DRAM	0.410	0.215	$ 4.999	$ 0.200
Sega	1	315-6258	56	TQFP	0.025	CMOS	0.150	0.140	$ 2.070	$ 0.200
Hyundai	5	HY5716160DTC-8	50	TSOP II	0.030	DRAM	0.325	0.235	$ 3.887	$ 0.200
Sega	1	MPR-21931	44	SOP	0.050	CMOS	0.285	0.265	$ 4.758	$ 0.060
Fujitsu	1	29LV002TC-90	40	TSOP I	0.020	Flash	0.145	0.135	$ 1.336	$ 0.200
IC Works	1	W129AG	16	SOP	0.050	CMOS	0.125	0.075	$ 0.802	$ 0.060
Burr-Brown	1	PCM1725U	14	SOP	0.050	CMOS	0.080	0.065	$ 0.575	$ 0.060
JRC	1	2100	8	SOP	0.050	CMOS	0.050	0.045	$ 0.350	$ 0.060
	15		4	Filter: Other					$ 0.120	$ 0.023
	1		2	Crystal: Metal					$ 0.500	$ 0.030
	1		8	Resistor: Chip Array 0603x4					$ 0.030	$ 0.020
	3		5	Transistor: SOT Std 5pin					$ 0.250	$ 0.030
	4		3	Transistor: SOT Std 3pin					$ 0.250	$ 0.030
	8		2	Capacitor: Al Electrolytic 160mil					$ 0.050	$ 0.030
	1		2	Capacitor: Al Electrolytic 200mil					$ 0.050	$ 0.030
	4		2	Capacitor: Al Electrolytic 250mil					$ 0.050	$ 0.030
	2		2	Capacitor: Al Electrolytic 315mil					$ 0.050	$ 0.030
	17		2	Capacitor: Ceramic Chip 0603					$ 0.008	$ 0.020
	4		2	Capacitor: Ceramic Chip 0805					$ 0.008	$ 0.020
	1		2	Capacitor: Ceramic Chip 1206					$ 0.010	$ 0.020
	3		2	Capacitor: Tantalum c 2815					$ 0.200	$ 0.020
	2		2	Capacitor: Tantalum m 1206					$ 0.200	$ 0.020
	2		2	Capacitor: Tantalum m 1411					$ 0.100	$ 0.020
	1		2	Capacitor: Tantalum p 2723					$ 0.200	$ 0.020
	2		2	Inductor: Chip 1210					$ 0.100	$ 0.030
	45		2	Resistor: Chip 0603					$ 0.005	$ 0.020
	2		2	Resistor: Chip 0805					$ 0.005	$ 0.020
	1		2	Resistor: Chip 1206					$ 0.010	$ 0.020

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Parts Listing

Main PCB - Side 1

Mfr.	Qty	Part No	Pins	Device	Pitch	Die Type	Die Length	Die Width	Part Cost	Insertion Cost
Sega	1	315-6226-X1	500	TAB	0.050	CMOS	0.500	0.500	$ 29.810	$ 0.500
Hitachi	1	HD6417091B	256	CSP-BGA	0.050	CMOS	0.275	0.265	$ 13.416	$ 0.150
Sega	1	315-6232	100	QFP	0.025	CMOS	0.220	0.210	$ 3.938	$ 0.200
Hyundai	2	HY57V653220BTC-10	86	TSOP II	0.020	DRAM	0.410	0.215	$ 4.999	$ 0.200
Sega	1	315-6258	56	TQFP	0.025	CMOS	0.150	0.140	$ 2.070	$ 0.200
Hyundai	5	HY5716160DTC-8	50	TSOP II	0.030	DRAM	0.325	0.235	$ 3.887	$ 0.200
Sega	1	MPR-21931	44	SOP	0.050	CMOS	0.285	0.265	$ 4.758	$ 0.060
Fujitsu	1	29LV002TC-90	40	TSOP I	0.020	Flash	0.145	0.135	$ 1.336	$ 0.200
IC Works	1	W129AG	16	SOP	0.050	CMOS	0.125	0.075	$ 0.802	$ 0.060
Burr-Brown	1	PCM1725U	14	SOP	0.050	CMOS	0.080	0.065	$ 0.575	$ 0.060
JRC	1	2100	8	SOP	0.050	CMOS	0.050	0.045	$ 0.350	$ 0.060
	15		4	Filter: Other					$ 0.120	$ 0.023
	1		2	Crystal: Metal					$ 0.500	$ 0.030
	1		8	Resistor: Chip Array 0603x4					$ 0.030	$ 0.020
	3		5	Transistor: SOT Std 5pin					$ 0.250	$ 0.030
	4		3	Transistor: SOT Std 3pin					$ 0.250	$ 0.030
	8		2	Capacitor: Al Electrolytic 160mil					$ 0.050	$ 0.030
	1		2	Capacitor: Al Electrolytic 200mil					$ 0.050	$ 0.030
	4		2	Capacitor: Al Electrolytic 250mil					$ 0.050	$ 0.030
	2		2	Capacitor: Al Electrolytic 315mil					$ 0.050	$ 0.030
	17		2	Capacitor: Ceramic Chip 0603					$ 0.008	$ 0.020
	4		2	Capacitor: Ceramic Chip 0805					$ 0.008	$ 0.020
	1		2	Capacitor: Ceramic Chip 1206					$ 0.010	$ 0.020
	3		2	Capacitor: Tantalum c 2815					$ 0.200	$ 0.020
	2		2	Capacitor: Tantalum m 1206					$ 0.200	$ 0.020
	2		2	Capacitor: Tantalum m 1411					$ 0.100	$ 0.020
	1		2	Capacitor: Tantalum p 2723					$ 0.200	$ 0.020
	2		2	Inductor: Chip 1210					$ 0.100	$ 0.030
	45		2	Resistor: Chip 0603					$ 0.005	$ 0.020
	2		2	Resistor: Chip 0805					$ 0.005	$ 0.020
	1		2	Resistor: Chip 1206					$ 0.010	$ 0.020

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Parts Listing

Main PCB - Side 1 (Continued)										
Mfr.	Qty	Part No	Pins	Device	Pitch	Die	Die	Die	Part	Insertion
						Type	Length	Width	Cost	Cost
	2		2	Resistor: Chip 1210					$ 0.010	$ 0.020
	2		50	Connector: Socket	0.040				$ 0.700	$ 0.030
	1		20	Connector: Socket	0.080				$ 0.800	$ 0.030
	1		16	Connector: Socket	0.040				$ 0.360	$ 0.030
	1		10	Connector: Socket	0.040				$ 0.030	$ 0.030
	1		6	Connector: Pin	0.150				$ 0.360	$ 0.050
Total	**143**		**1899**						**$ 96.314**	**$ 5.805**

Main PCB - Side 2										
Mfr.	Qty	Part No	Pins	Device	Pitch	Die	Die	Die	Part	Insertion
						Type	Length	Width	Cost	Cost
Hitachi	1	9K2T	16	SOP	0.050	CMOS	0.080	0.075	$ 0.641	$ 0.060
No Symbol	1	W41	8	TSOP II	0.025	CMOS	0.045	0.035	$ 0.361	$ 0.200
	20		8	Resistor: Chip Array 0603x4					$ 0.030	$ 0.020
	1		6	Transistor: SOT Pwr Flat-lead (89)					$ 0.300	$ 0.030
	1		5	Transistor: SOT Std 5pin					$ 0.250	$ 0.030
	2		3	Transistor: SOT Pwr J-lead (223)					$ 0.300	$ 0.030
	9		3	Transistor: SOT Std 3pin					$ 0.250	$ 0.030
	126		2	Capacitor: Ceramic Chip 0603					$ 0.008	$ 0.020
	23		2	Capacitor: Ceramic Chip 0805					$ 0.008	$ 0.020
	4		2	Capacitor: Ceramic Chip 1206					$ 0.010	$ 0.020
	5		2	Capacitor: Tantalum m 2312					$ 0.200	$ 0.020
	1		2	Capacitor: Tantalum p 2010					$ 0.200	$ 0.020
	1		2	Inductor: Chip 1812					$ 0.100	$ 0.030
	117		2	Resistor: Chip 0603					$ 0.005	$ 0.020
	2		2	Resistor: Chip 2010					$ 0.020	$ 0.020
Total	**314**		**786**						**$ 8.159**	**$ 6.640**

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Parts Listing

Controller PCB										
Side	Mfr.	Qty	Part No	Pins	Device	Pitch	Die Type	Die Length	Die Width	Part Cost	Insertion Cost
2	Sega	1	315-6211-AB	64	QFP	0.030	CMOS	0.165	0.155	$ 2.359	$ 0.200
2	JRC	2	2100	8	TSOP II	0.050	CMOS	0.050	0.045	$ 0.395	$ 0.060
2	Fujitsu	1	16.0Mg	6	Crystal: Ceramic					$ 0.500	$ 0.030
2		2		8	Resistor: Chip Array 0603x4					$ 0.030	$ 0.020
2		1		4	Transistor: SOT Pwr Flat-lead (89)					$ 0.300	$ 0.030
2		6		4	Transistor: SOT Std 4pin					$ 0.250	$ 0.030
2		3		2	Capacitor: Al Electrolytic 160mil					$ 0.050	$ 0.030
2		18		2	Capacitor: Ceramic Chip 0603					$ 0.008	$ 0.020
2		2		2	Capacitor: Ceramic Chip 1206					$ 0.010	$ 0.020
2		1		2	Diode: Chip 0805					$ 0.100	$ 0.020
2		1		2	Filter: Ferrite 0603					$ 0.016	$ 0.020
2		2		2	Filter: Ferrite 0805					$ 0.016	$ 0.020
2		33		2	Resistor: Chip 0603					$ 0.005	$ 0.020
1		1		28	Connector: Other	0.050				$ 0.760	$ 0.150
Total		**74**		**278**						**$ 6.896**	**$ 1.980**

Interface PCB											
Side	Mfr.	Qty	Part No	Pins	Device	Pitch	Die Type	Die Length	Die Width	Part Cost	Insertion Cost
1		1		2	Battery: Secondary					$ 1.500	$ 0.050
1		1		2	Capacitor: Al Electrolytic 200mil					$ 0.050	$ 0.030
1		1		2	LED: Throughhole					$ 0.050	$ 0.010
1		1		2	Resistor: Throughhole 1506					$ 0.010	$ 0.010
1		1		2	Resistor: Throughhole 2609					$ 0.010	$ 0.010
1		1		20	Connector: Socket	0.040				$ 0.400	$ 0.030
1		4		5	Connector: Socket	0.050				$ 0.250	$ 0.030
1		1		3	Connector: Socket	0.050				$ 0.230	$ 0.030
Total		**11**		**53**						**$ 3.250**	**$ 0.290**

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Parts Listing

Disk Drive PCB

Side	Mfr.	Qty	Part No	Pins	Device	Pitch	Die Type	Die Length	Die Width	Part Cost	Insertion Cost
2	Sega	1	313-5639	100	TQFP	0.020	CMOS	0.255	0.245	$ 4.856	$ 0.200
2		2		5	Transistor: SOT Std 5pin					$ 0.250	$ 0.030
2		1		4	Transistor: SOT Pwr Flat-lead (89)					$ 0.300	$ 0.030
2		6		3	Transistor: SOT Std 3pin					$ 0.250	$ 0.030
2		3		2	Capacitor: Al Electrolytic 200mil					$ 0.050	$ 0.030
2		7		2	Capacitor: Al Electrolytic 250mil					$ 0.050	$ 0.030
2		25		2	Capacitor: Ceramic Chip 0603					$ 0.008	$ 0.020
2		1		2	Capacitor: Ceramic Chip 0805					$ 0.008	$ 0.020
2		2		2	Diode: Chip 0603					$ 0.100	$ 0.020
2		41		2	Resistor: Chip 0603					$ 0.005	$ 0.020
2		2		2	Resistor: Chip 0805					$ 0.005	$ 0.020
2		1		2	Resistor: Chip 1206					$ 0.010	$ 0.020
2		1		50	Connector: Socket	0.040				$ 0.700	$ 0.030
1	Sega	1	313-5640	100	TQFP	0.020	CMOS	0.360	0.315	$ 8.229	$ 0.200
1	Yamaha	1	XU917AO	100	TQFP	0.020	CMOS	0.320	0.305	$ 7.106	$ 0.200
1	No Symbol	1	BA5986FM	30	SOP	0.030	CMOS	0.125	0.115	$ 1.232	$ 0.200
1	Sega	1	313-5635	30	TSOP II	0.025	CMOS	0.100	0.100	$ 1.046	$ 0.200
1	No Symbol	1	YDC122B-M	16	SOP	0.050	CMOS	0.095	0.090	$ 0.761	$ 0.060
1		1		4	Switch: Throughhole					$ 0.030	$ 0.010
1	No Symbol	1	33.868M	4	Crystal: Plastic					$ 0.500	$ 0.030
1	TDK	2	25.4M-25.0M	4	Crystal: Ceramic					$ 0.500	$ 0.030
1		1		4	Transistor: SOT Pwr Flat-lead (89)					$ 0.300	$ 0.030
1		2		3	Transistor: SOT Mini 3pin					$ 0.150	$ 0.030
1		1		3	Transistor: SOT Pwr J-lead (223)					$ 0.300	$ 0.030
1		37		2	Capacitor: Ceramic Chip 0603					$ 0.008	$ 0.020
1		1		2	Capacitor: Ceramic Chip 1812					$ 0.010	$ 0.020
1		1		2	Diode: Chip 0603					$ 0.100	$ 0.020
1		1		2	Filter: Ferrite 0603					$ 0.016	$ 0.020
1		44		2	Resistor: Chip 0603					$ 0.005	$ 0.020

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Parts Listing

Disk Drive PCB (Continued)											
Side	Mfr.	Qty	Part No	Pins	Device	Pitch	Die Type	Die Length	Die Width	Part Cost	Insertion Cost
1		1		2	Resistor: Chip 0805					$ 0.005	$ 0.020
1		1		16	Socket: Other	0.035				$ 0.330	$ 0.050
1		1		4	Connector: Socket	0.060				$ 0.240	$ 0.030
1		1		2	Connector: Socket	0.060				$ 0.220	$ 0.030
Total		194		843						$ 31.230	$ 5.130

Power Supply PCB											
Side	Mfr.	Qty	Part No	Pins	Device	Pitch	Die Type	Die Length	Die Width	Part Cost	Insertion Cost
1	No Symbol	1	KA7552	8	SOP	0.100	CMOS	0.095	0.070	$ 0.561	$ 0.060
1		1		12	Transformer					$ 1.350	$ 0.030
1		1		4	Inductor: Large					$ 0.500	$ 0.030
1		1		4	Inductor: Mutual					$ 0.800	$ 0.030
1		1		4	Transistor: SOT Std 4pin					$ 0.250	$ 0.030
1		4		3	Transistor: TO-202					$ 0.300	$ 0.010
1		3		3	Transistor: TO-5					$ 0.050	$ 0.010
1		1		2	Capacitor: Al Electrolytic 160mil					$ 0.050	$ 0.030
1		2		2	Capacitor: Al Electrolytic 250mil					$ 0.050	$ 0.030
1		3		2	Capacitor: Al Electrolytic 315mil					$ 0.050	$ 0.030
1		2		2	Capacitor: Al Electrolytic 400mil					$ 0.050	$ 0.030
1		6		2	Capacitor: Throughhole 2020					$ 0.150	$ 0.010
1		1		2	Coil: 1410					$ 0.200	$ 0.020
1		1		2	Diode: mini-MELF					$ 0.100	$ 0.020
1		6		2	Diode: Throughhole 2009					$ 0.080	$ 0.010
1		1		2	Discrete: Other Throughhole					$ 0.180	$ 0.010
1		1		2	Fuse					$ 0.500	$ 0.020
1		7		2	Resistor: MELF 1206					$ 0.010	$ 0.020
1		8		2	Resistor: MELF 2308					$ 0.020	$ 0.020
1		1		6	Connector: Socket	0.150				$ 0.260	$ 0.030
1		1		2	Connector: Pin	0.300				$ 0.120	$ 0.050
1		1		2	Jack: Power-DC	0.325				$ 0.180	$ 0.020
	Total	54		141						$ 8.361	$ 1.080

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Electronics Assemblies Metrics

IC Summary

Board Description	# IC's Total	# Analog ICs	# Digital ICs	# of IC Ios	Die Area [in2]	IC Footprint Area [in2]	IC IO's / (IC Ftprnt Area)
Modem PCB	2	-	2	208	0.10	1.16	180
Interface PCB	-	-	-	-	-	-	-
Power Supply PCB	1	1	-	8	0.01	0.14	59
Controller PCB	3	2	1	80	0.03	0.53	152
Disk Drive PCB	6	1	5	376	0.31	1.74	216
Main PCB	18	4	14	1,480	1.07	8.71	170
IC Totals:	**30**	**8**	**22**	**2,152**	**1.51**	**12.27**	**175**

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Electronics Assemblies Metrics

Summary of Electronic System

Board Description	Board Area	Number of PCB Layers	# of Parts	# of Connections	PCB Tiling Density Die Area/Bd	Connection Density Conn/Bd Area	Routing Density Trace Length/Bd Area	Part Density Parts/Bd Area	Avg Pin Count # of Conn/# of Parts
Modem PCB	5.77	4	76	419	1.68%	73	60	13	5.51
Interface PCB	4.76	1	11	53		11	22	2	4.82
Power Supply PCB	11.54	1	54	141	0.06%	12	17	5	2.61
Controller PCB	11.91	2	74	278	0.25%	23	28	6	3.76
DiskDrive PCB	15.11	2	194	843	2.03%	56	47	13	4.35
Main PCB	35.28	4	457	2,685	3.03%	76	63	13	5.88
System Totals:	**84.37**	**-**	**866**	**4,419**	**1.79%**	**52**	**---**	**10**	**5.10**

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Electronics Assemblies Metrics

Connection Distribution

Board Description	Opportunity Count	IC IO's	*% IC IO's*	Module IO's	*% Module IO's*	Discrete IO's	*% Discrete IO's*	Connector IO's	*% Connector IO's*
Modem PCB	495	208	*50%*	-		152	*36%*	59	*14%*
Interface PCB	64	-		2	*4%*	8	*15%*	43	*81%*
Power Supply PCB	195	8	*6%*	-		123	*87%*	10	*7%*
Controller PCB	352	80	*29%*	6	*2%*	164	*59%*	28	*10%*
DiskDrive PCB	1,037	376	*45%*	16	*2%*	379	*45%*	72	*9%*
Main PCB	3,142	1,480	*55%*	62	*2%*	991	*37%*	152	*6%*
Connection Totals:	**5,285**	**2,152**	***49%***	**86**	***2%***	**1,817**	***41%***	**364**	***8%***

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Electronics Assemblies Metrics

Cost Distribution (Parts & Labor)

Board Description	Total Cost	IC Cost	Module Cost	Discrete Cost	Connector Cost	Substrate Cost	Assembly & Board Test Cost
Modem PCB	$20.06	$ 8.63	$ -	$ 6.02	$ 1.10	$ 1.62	$ 2.69
Interface PCB	$4.37	$ -	$ 1.50	$ 0.12	$ 1.63	$ 0.33	$ 0.79
Power Supply PCB	$10.40	$ 0.56	$ -	$ 7.24	$ 0.56	$ 0.46	$ 1.58
Controller PCB	$11.28	$ 3.15	$ 0.50	$ 2.49	$ 0.76	$ 1.91	$ 2.48
Disk Drive PCB	$39.28	$ 23.23	$ 1.53	$ 4.98	$ 1.49	$ 2.42	$ 5.63
Main PCB	$135.26	$ 87.49	$ 2.30	$ 11.73	$ 2.95	$ 18.35	$ 12.44
Cost Totals:	**$220.66**	**$ 123.07**	**$ 5.83**	**$ 32.58**	**$ 8.49**	**$ 25.08**	**$ 25.61**

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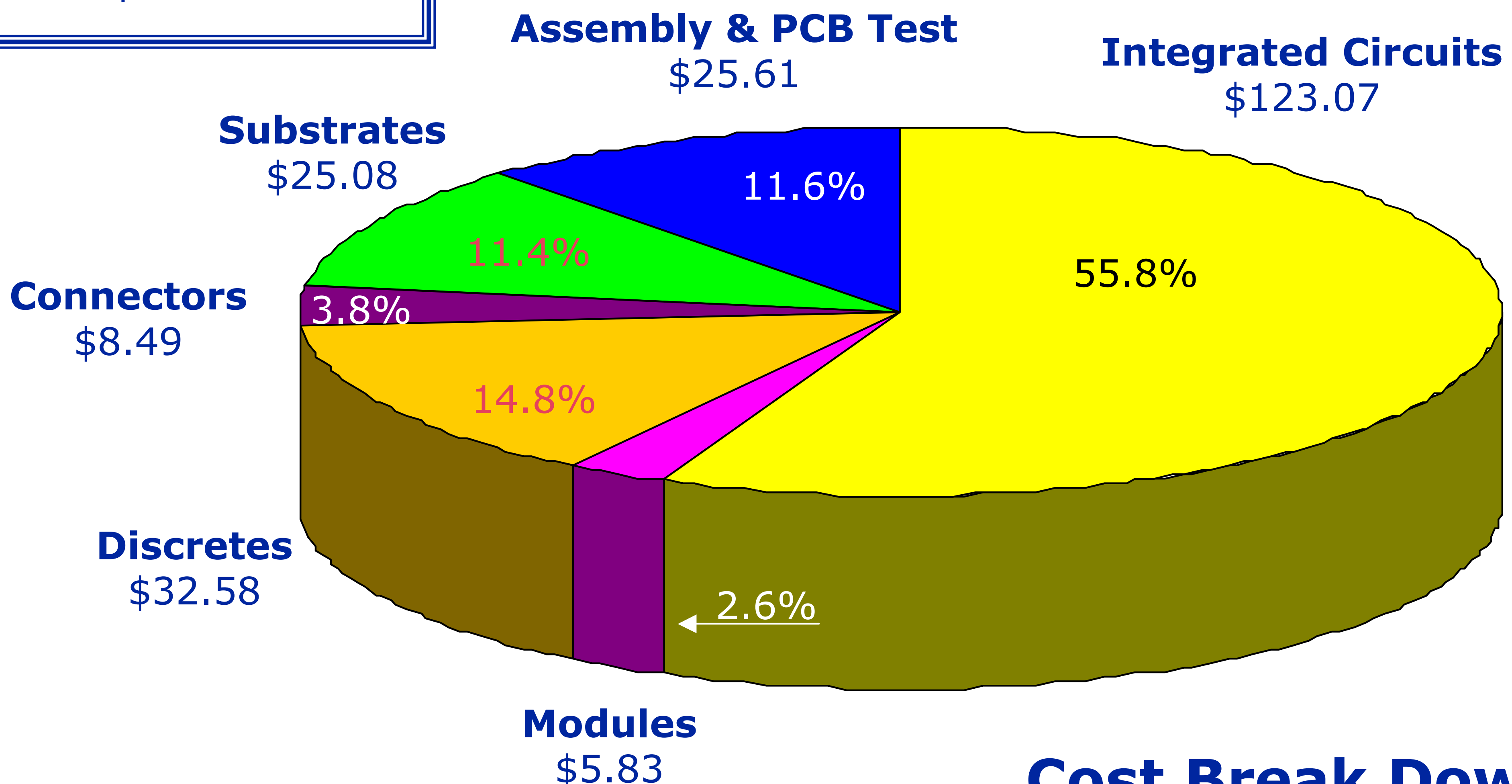
Electronics Assemblies Metrics

Total Estimated Cost
$220.66



Cost Break Down

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Board Metrics By Surface Area

Page 1 of 2

Main PCB (Side 1)

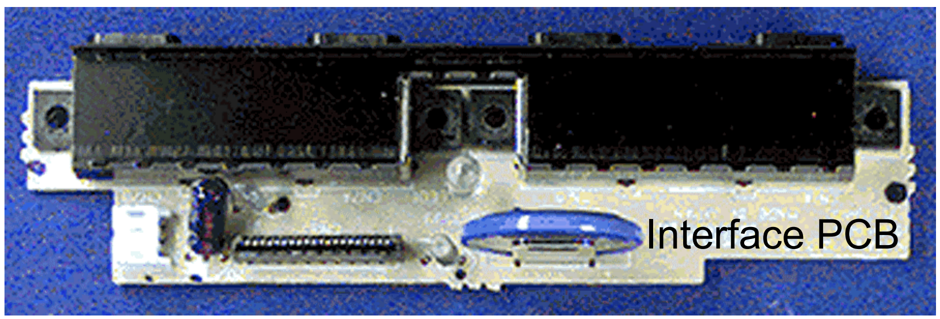
Board Area:	35.28 sq in
No. Of Parts:	143
No. Of IOs:	1899
Min. Pitch	0.020 in
Die Area:	1.060 sq in
Memory:	27016K Bytes

Interface PCB (Side 1)

Board Area:	4.76 sq in
No. Of Parts:	11
No. Of IOs:	53
Min. Pitch	0.040 in
Die Area:	0 sq in
Memory:	0 Bytes

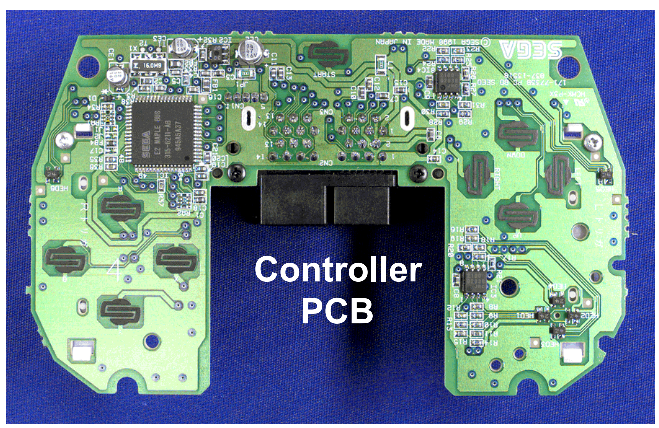
Main PCB (Side 2)

Board Area:	35.28 sq in
No. Of Parts:	314
No. Of IOs:	786
Min. Pitch	0.025 in
Die Area:	0.008 sq in
Memory:	0 Bytes



Controller PCB (Side 1)

Board Area:	11.91 sq in
No. Of Parts:	1
No. Of IOs:	28
Min. Pitch	0.050 in
Die Area:	0 sq in
Memory:	0 Bytes



Controller PCB (Side 2)

Board Area:	11.91 sq in
No. Of Parts:	73
No. Of IOs:	250
Min. Pitch	0.030 in
Die Area:	0.030 sq in
Memory:	0 Bytes

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Board Metrics By Surface Area

Page 2 of 2

Modem PCB (Side 1)

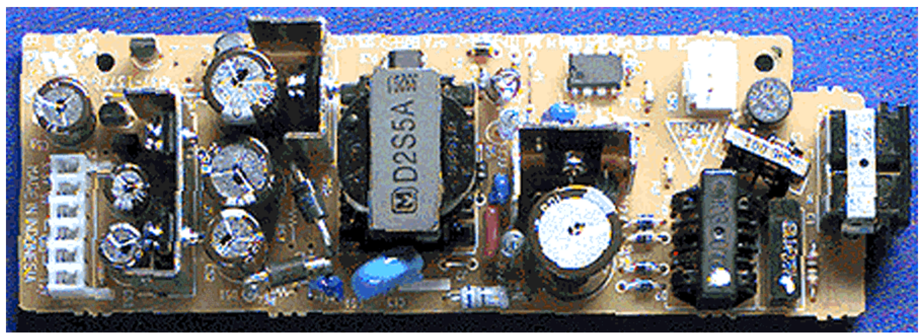
Board Area:	5.77 sq in
No. Of Parts:	37
No. Of IOs:	228
Min. Pitch	0.020 in
Die Area:	0.090 sq in
Memory:	0 Bytes

Pwr Supply PCB (Side 1)

Board Area:	11.54 sq in
No. Of Parts:	54
No. Of IOs:	141
Min. Pitch	0.100 in
Die Area:	0.007 sq in
Memory:	0 Bytes

Modem PCB (Side 2)

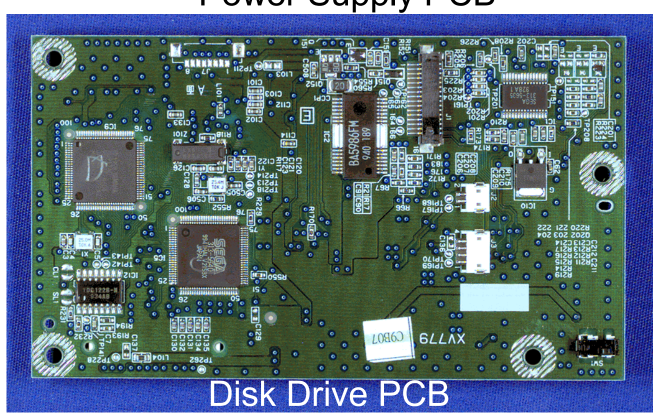
Board Area:	5.77 sq in
No. Of Parts:	39
No. Of IOs:	191
Min. Pitch	0.030 in
Die Area:	0.007 sq in
Memory:	0 Bytes



Power Supply PCB

Disk Drive PCB (Side 1)

Board Area:	15.11 sq in
No. Of Parts:	101
No. Of IOs:	497
Min. Pitch	0.020 in
Die Area:	0.244 sq in
Memory:	0 Bytes



Disk Drive PCB

Disk Drive PCB (Side 2)

Board Area:	15.11 sq in
No. Of Parts:	93
No. Of IOs:	346
Min. Pitch	0.020 in
Die Area:	0.062 sq in
Memory:	0 Bytes

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Design for Manufacturing

Item	*weight (grams)*	*estimated cost*
Plastic controller top enclosure	49.5	$0.65
Plastic controller bottom enclosure	56.4	$0.56
Plastic controller PDA housing	19.9	$0.25
Plastic trigger assemblies (2)	11.3 (total)	$1.00
Controller misc plastic, elastomer, hardware	14.4	$0.90
Plastic joystick	- -	$0.95
Interface cable (controller/main console)	- -	$1.25
Plastic main console bottom enclosure	139.7	$1.04
Plastic main console top enclosure + cover	258.8	$1.93
Misc screws, plastic buttons, springs, etc	- -	$0.90
Steel heat sink plate assembly	208.7	$0.80
Bottom metal shielding panel	66.4	$0.20
Disk Drive assembly (less housing)	109.8	$9.50
Drive metal chassis,shield cover, plastic housing	168.8	$0.75
Fan & shoot assembly	12.4	$1.50
Power switch and cable	13.3	$0.60
Plastic interface connector plate	12.4	$0.25
Total		**$21.99**

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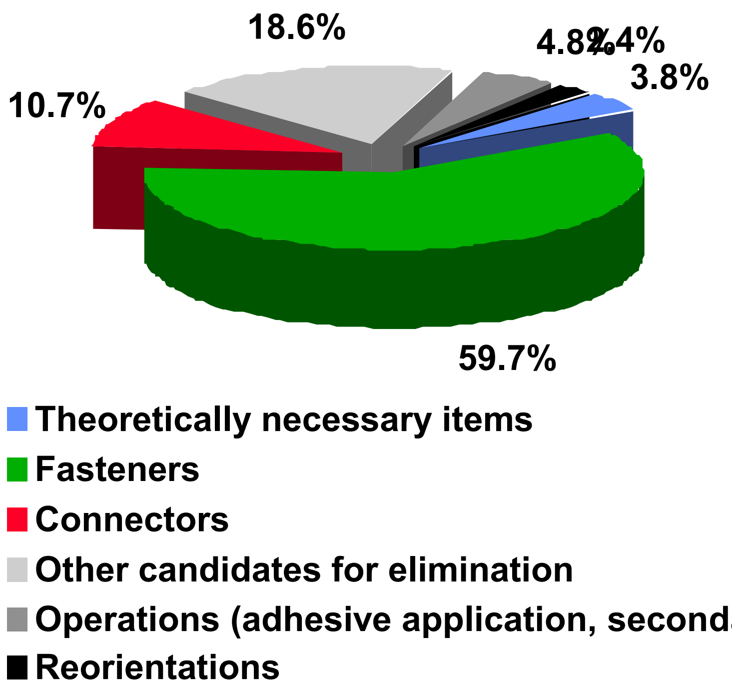
Design for Assembly

DFA Index (%)	**2.5%**
Total Estimated Assembly Time (Sec.)	**930**
Total Estimated Assembly Cost (@$30/hr)	**$7.75**

Percent of total (1250 sec) assembly time



Note:

Assembly time includes final assembly of both the main console and the controller station. Detail assembly of major components such as the disk drive are included in the cost estimate of the component.

This information was generated using Boothroyd Dewhurst, Inc. DFMA software, release 8.0.

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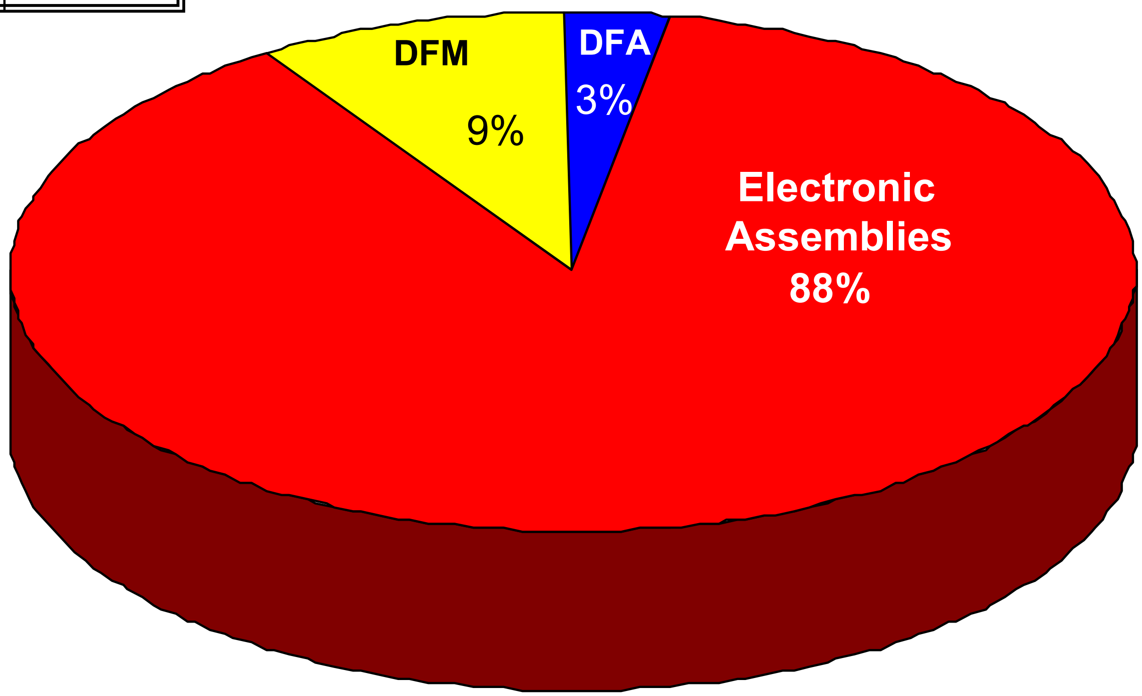
Cost Summary

Sega DreamCast 3020	Cost
Electronic Assemblies	$220.66
Housing/Hardware (DFM)	$21.99
Final Assembly (DFA)	$7.75
Total	$250.40

To view the Supporting Accessories

See Page 30



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Metrics

Battery

Not Required

Direct Material Cost

Bare Board Cost	$ 25.08
IC Cost	$123.07
Passives	$ 46.90
Housing (DFM)	$ 21.99

Conversion Cost

Board Assembly Cost	$25.61
Final Assembly Cost (DFA)	$7.75
DFM / DFA Score	2.50%
Opportunity Count	5,285

Electrical Performance

Circuit Block Diagram	NA
Current Drain	NA
Voltage	NA
Battery type	NA
Shielding	NA
Antenna	NA

Component Integration

Number of I.C.'s	30
Analog	8
Digital	22
Silicon Tiling Factor	1.79%
Component pitch	0.020 in
Component Count by Type	see pages 34-39

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Metrics

Display

Not Required

MMI

Usability index NA
Technology NA

Substrate

IOs per sq.in.	52
Pitch	0.010 in
Via Pad Size	0.024 in/0.012 in

Board Thickness:

6 each PCB's

View Substrate Layouts - Pages 31-33

Quality

Plastic Fit / Finish See page 47

Environmental

Recycle Value	NA
Green Score	NA

Time to Market

Models per FCC 740 Form Filing	NA
Product Development Cycle Time	NA
Time to Market	NA

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Cost Estimation Process

Overview and Discussion

Cost modeling is tricky business. Multiple variables affect the actual production costs a manufacturer will experience, including development expenses, unit volumes, supply-and-demand in component markets, die yield-curve maturity, OEM purchasing power, and even variations in accounting practices. Different cost modeling methods employ different assumptions about how to handle these and other variables, but we can identify two basic approaches: that which seeks to track short-term variations in the inputs to the production process, and that which strives to maintain comparability of the output of the model across product families and over time.

Portelligent's philosophy in cost modeling is to emphasize consistency across products and comparability over time, rather than to track short-term fluctuations. During the past eight years, we have developed an estimation process that, while necessarily lacking an insider's knowledge of the cost factors that impact any one manufacturer, is reasonably accurate in its prediction of unit costs in high-volume production environments. We do not claim that the model will produce the "right" answer for your firm's environment. However, Portelligent does give customers a key analytical tool with a complete set of data in our Bill of Materials (BOM). The BOM allows readers to 1) scrutinize the assumptions behind our cost model and 2) modify the results based on substitution of their own component cost estimates where they have better information based on inside knowledge.

Our estimation process decomposes overall system cost into three major categories: Electronics, Mechanical, and Final Assembly. We begin by creating a complete electronics bill-of-materials (BOM). Each component from the largest ASIC to the smallest discrete resistor is entered into a BOM table with identifying attributes such as size, pitch, I/O count, package type, manufacturer, part number, estimated placement cost, and die size (if the component is an IC). Integrated circuit costs are calculated from measured die area. Using assumptions for wafer size, process type, number of die per wafer, defect density, and profit margin in combination with die area, an estimate of semiconductor cost is derived. Costs for discrete components and interconnect are derived from assumption tables which relate BOM line items to specific cost estimates by component type and estimates for part placement costs are included. For LCD display costs, we employ a model which tabulates expected cost from measurements of glass area, LCD type, and total pixel resolution. When market costs are available from alternative sources, LCD panel costs are taken from and referenced to these sources.

Costs of mechanical enclosures and fasteners along with the cost estimates of final system assembly and integration are modeled using Boothroyd Dewhurst design-for-assembly (DFx) tools (see next slide for further detail). Other system items such as optics, antennae, batteries, and so on are costed from a set of assumption tables derived from a combination of industry data, average high volume costs, and external sources. In effect, we re-build the torn-down product, tabulating final assembly costs as the process of reconstruction proceeds.

The three major categories for system cost contributors can be broken down into the subcategories of ICs, other electronics parts, displays (as appropriate), printed circuit boards, electronics assembly, mechanical/housing elements, and final assembly. By adding the cost estimates for each of these subcategories, an overall estimated cost is derived for the system under evaluation. Product packaging and accessories (CDs, cables, etc.) are also documented and estimated for their contribution to total cost as appropriate.

We believe our cost estimates generally fall within ±15 percent of the "right answer," which itself can vary depending on the market and OEM-specific factors mentioned earlier. While the Portelligent cost model is imperfect, it yields important insights into technology and business dynamics along with good first-order contributions to system cost by component type. Additionally, the consistency of approach and gradual modification to assumptions (smoothing out frequently-shifting pricing factors) hopefully yields a credible, but user-modifiable, view of OEM high volume cost-to-produce.

Please feel free to contact us at info@portelligent.com with any comments, questions, or proposed corrections with respect to our cost estimates. We welcome your input.

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Design for Manufacturing & Design for Assembly (DFx)

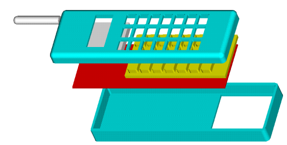
Methodology, Metrics, and Discussion

Mechanical aspects of the system under evaluation are analyzed using Boothroyd Dewhurst Inc. software (http://www.dfma.com).

Costs of injection molded plastics and sheet metal parts are modeled using the Boothroyd Dewhurst (BD) design-for-manufacturing (DFM) software. Each mechanical element is entered into the BD DFM software package, providing measured/observed attributes of geometry, weight, size, thickness, material, and secondary operations from which the BD DFM software derives an estimated cost of manufacture.

The cost of final system assembly and integration is projected from Boothroyd Dewhurst design-for-assembly (DFA) tools. In effect, we re-build the torn-down product, accounting for each of the placements, orientations, labelings, fastenings, etc. necessary to integrate all subassemblies into the complete product. Each step in final assembly corresponds to a specific estimate of time to perform the operation. Integrating each time-step, a total time for assembly is achieved. We then assume an hourly rate for the labor needed to perform final assembly operations and tabulate total final assembly cost.

As part of the DFA analysis, a DFA index is calculated. The DFA index is a benchmark that accounts for total part count and efficiency of part assembly, and creates a ratio between the optimal theoretical assembly time achievable with a given number of parts and the the actual estimated assembly time. The formula for DFA Index is as follows;



DFA Index = N_{min} x 2.93 / tma

N_{min} = theoretical minimum number of parts

tma = total assembly time as calculated from the reconstructive process and BD software estimates.

Nmin describes (somewhat subjectively) the minimum number of parts that could be theoretically used to implement the products mechanical aspects. The 2.93 in the above formula reflects BDs empirically-derived "ideal" for per-part assembly times. For example, a cell phone could theoretically require only a upper case, lower case, display, battery, antenna, circuit board assembly, earphone, microphone, vibrator, and keypad for a total of 10 parts. At 2.93 seconds per part assembly, the 'best' possible time for final assembly of our sample product would be (10parts*2.93sec/part) or about 30 seconds. Of course phones frequently have additional parts to satisfy styling issues, shock/vibration resistance, interface characteristics, etc. Additionally our experience is that assembly times of 6-14 seconds per part typify many of the products we examine. So if in our example the phone actually had 30 parts with say 10 sec/part of estimated assembly time a total assembly time of (30parts*10sec/part) or 300 seconds would be needed. The resulting DFA index in this case would be 30/300 or 10%. In essence the higher the DFA index, the closer the product has come to achieving a 'perfect' design for final assembly. While the DFA is a subjective process where results might vary from user to user, when the analysis is performed in a consistent manner over multiple products, relative comparisons become valid.

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Metrics: Overview and Discussion

In our product teardowns, we gather a series of metrics for product profiling and comparison. Some metrics focus on system characteristics such as total silicon area, total system semiconductor storage capacity, and total connection count. Other metrics reflect more subtle aspects of electronics assembly such as connection density, average component I/O count, and silicon tiling density. Taken as a whole, the metrics allow deeper comparison and benchmarking across multiple disciplines and multiple products. Key metrics we gather on products are described below along with their definitions and what they tend to say about the system under study. Most metrics can be used both in comparing similar products for benchmarking purposes or for quantifying differences in levels of complexity between dissimilar product types. Data fall into two categories; either "raw" measured data or ratios of these measured data sets.

Total Silicon Area : This metric describes the total area of silicon as measured from X-ray or direct measurement of ICs. The area is an expression of the enclosed bare die area and excludes packaging area. The aggregate silicon area is a good benchmark to show how integrated a design might be when making comparisons to similar systems. Total silicon area also reflects the major cost driver for most systems we examine.

Silicon Tiling Density : Ratio of Total Silicon Area to total printed circuit board "projected" area (i.e. the simple board area and not the cumulative surface area of both sides of the board). This metric directly reflects the level of efficiency and aggressiveness in integrated circuit packing and placement. Single digit Silicon Tiling Density is typical but silicon coverage of 10% - 20% has been seen in some of the most advanced products we have examined. Higher Tiling Densities often correspond with the use of chip scale packaging (CSPs) or other small form-factor IC packaging technologies. High density circuit boards are also often a supporting technology.

Number of Parts : Total component count including ICs, passives, modules, connectors, etc., each separated out in our reporting.

Number of Connections : The total number of connections corresponds to the total number of interconnects introduced by the aggregate component set and reflects any electrical connection observed (solder joints, adhesive interconnect, or connector terminal interfaces).

Opportunity Count : Opportunity Count is the total number of parts plus the total number of connections; the name reflects that each of these constituent elements represents an opportunity for failure. A high opportunity count means more complex and riskier electronics assembly.

Average Pin Count (APC) : Ratio of total number of component terminals to total number of parts, at the system level. This metric reflects the 'average' terminal complexity of the components and often provide a signature of integration level and/or "digital-ness" of the overall product. Low APCs reflect a high number of discretes or other low-pincount devices often characteristic of analog circuitry. Conversely, high APCs are characteristic of highly integrated, high-pincount assemblies, often those composed largely of digital integrated circuits.

Connection Density : This metric is a ratio of the total Number of Connections to total printed circuit board assembly area, in units of connections per sq. inch. The metric provides data related to the Silicon Tiling Density above, but with an emphasis on complexity of I/O interconnect. For example, with a fixed Connection Density, high tiling density of low-pincount memory chips is more readily achieved than comparable silicon tiling of high pincount logic.

Part Density : This metric is a ratio of the total Number of Parts to total printed circuit board assembly area, in units of components per sq. inch. The metric provides data related to the Silicon Tiling Density and Connection Density as described above, but with an emphasis on density and complexity of component packing efficiency. For example, low Part Density of high-pincount devices can pose an equal challenge in Connection Density to high Part Density of low-pincount devices. High Part Density does reflect challenges in surface mount assembly in terms of (typically) precision of placement, number of placements, and engineering of part clearances.

Routing Density (heuristic estimate) = 3*(Average Pin Count)*$\sqrt{\text{Part Density}}$. The Routing Density metric is a empirically derived relationship that characterizes the wiring density of the interconnect used to support the interconnection of components in a planar electronic assembly (i.e. the circuit board). Architectural issues such as bussing or other factors affecting the regularity of wiring impact the actual Routing Density needed to support a given application, but the metric provides a ready measure of wiring complexity.

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