Problem	Possible cause	Repair action
Data not staying in RAM correctly	Bad RAM chip somewhere between U50 and U57	Replace and test.
Characters not generated properly	Bad MK36000 at U33	Replace and test.
	Bad 74LS166 at U32	Replace and test.
	Bad 74LS08 at U13	Replace and test.
	Bad 74LS32 at U14	Replace and test.
	Bad 74LS51 at U22	Replace and test.
	Bad 74LS32 at U23	Replace and test.
	Bad 74153 at U9	Replace and test.
	Bad 74153 at U10	Replace and test.
	Bad 74S174 at U101	Replace and test.

Troubleshooting Procedure

TURN POWER OFF.
DISCONNECT POWER CORD.

↓

WRITE DOWN WHAT
SYSTEM WAS DOING
AT TIME OF FAILURE.

↓

REMOVE TOP OF COMPUTER.
TOUCH TOP OF
POWER SUPPLY CASE.

↓

DISCONNECT COLOR/GRAPHICS
ADAPTER CARD AND
MONITOR CABLE.

↓

REPLACE MK36000 AT U33.

↓

RECONNECT ADAPTER CARD.
RECONNECT MONITOR.
RECONNECT POWER CORD.
POWER UP AND TEST.

↓

WORKS? → YES → RETURN TO FULL SERVICE.

↓ NO

TURN POWER OFF.
DISCONNECT POWER CORD.
DISCONNECT ADAPTER CARD.
AND MONITOR CABLE.

↓

REPLACE 74LS166 AT U32.

↓

RECONNECT ADAPTER CARD.
RECONNECT MONITOR.
RECONNECT POWER CORD.
POWER UP AND TEST.

↓

WORKS? → YES → RETURN TO FULL SERVICE.

↓ NO

TURN POWER OFF.
DISCONNECT POWER CORD.
DISCONNECT ADAPTER CARD
AND MONITOR CABLE.

↓

REPLACE 74LS08 AT U13.

↓

RECONNECT ADAPTER CARD.
RECONNECT MONITOR.
RECONNECT POWER CORD.
POWER UP AND TEST.

↓

WORKS? → YES → RETURN TO FULL SERVICE.

↓ NO

TURN POWER OFF.
DISCONNECT POWER CORD.
DISCONNECT ADAPTER CARD.
AND MONITOR CABLE.

↓

REPLACE 74LS32 AT U14.

↓

RECONNECT ADAPTER CARD.
RECONNECT MONITOR.
RECONNECT POWER CORD.
POWER UP AND TEST.

↓

WORKS? → YES → RETURN TO FULL SERVICE.

↓ NO

(Continued)

TURN POWER OFF.
DISCONNECT POWER CORD.
DISCONNECT ADAPTER CARD
AND MONITOR CABLE.

↓

REPLACE 74LS51 AT U22.

↓

RECONNECT POWER CORD.
RECONNECT ADAPTER CARD.
RECONNECT MONITOR.
POWER UP AND TEST.

↓

WORKS? YES → RETURN TO FULL SERVICE.

↓ NO

TURN POWER OFF.
DISCONNECT POWER CORD.
DISCONNECT ADAPTER CARD
AND MONITOR CABLE.

↓

REPLACE 74LS32 AT U23.

↓

RECONNECT ADAPTER CARD.
RECONNECT MONITOR.
RECONNECT POWER CORD.
POWER UP AND TEST.

↓

WORKS? YES → RETURN TO FULL SERVICE.

↓ NO

TURN POWER OFF.
DISCONNECT POWER CORD.
DISCONNECT ADAPTER CARD
AND MONITOR CABLE.

↓

REPLACE 74LS273 AT U35.

↓

RECONNECT ADAPTER CARD.
RECONNECT MONITOR.
RECONNECT POWER CORD.
POWER UP AND TEST.

↓

WORKS? YES → RETURN TO FULL SERVICE.

↓ NO

TURN POWER OFF.
DISCONNECT POWER CORD.
DISCONNECT ADAPTER CARD
AND MONITOR CABLE.

↓

REPLACE 74LS273 AT U34.

↓

RECONNECT ADAPTER CARD.
RECONNECT MONITOR.
RECONNECT POWER CORD.
POWER UP AND TEST.

↓

WORKS? YES → RETURN TO FULL SERVICE.

↓ NO

TURN POWER OFF.
DISCONNECT POWER CORD.
DISCONNECT ADAPTER CARD
AND MONITOR CABLE.

↓

REPLACE 74153 AT U9.

↓

RECONNECT ADAPTER CARD.
RECONNECT MONITOR.
RECONNECT POWER CORD.
POWER UP AND TEST.

↓

WORKS? YES → RETURN TO FULL SERVICE.

↓ NO

(Continued)

TURN POWER OFF.
DISCONNECT POWER CORD.
DISCONNECT ADAPTER CARD
AND MONITOR CABLE.

↓

REPLACE 74153 AT U10.

↓

RECONNECT ADAPTER CARD.
RECONNECT MONITOR.
RECONNECT POWER CORD.
POWER UP AND TEST.

↓

WORKS? YES → RETURN TO FULL SERVICE.

↓ NO

TURN POWER OFF.
DISCONNECT POWER CORD.
DISCONNECT ADAPTER CARD
AND MONITOR CABLE.

↓

REPLACE 74LS244 AT U36.

↓

RECONNECT ADAPTER CARD.
RECONNECT MONITOR.
RECONNECT POWER CORD.
POWER UP AND TEST.

↓

WORKS? YES → RETURN TO FULL SERVICE.

↓ NO

TURN POWER OFF.
DISCONNECT POWER CORD.
DISCONNECT ADAPTER CARD
AND MONITOR CABLE.

↓

REPLACE 74LS374 AT U37.

↓

RECONNECT ADAPTER CARD.
RECONNECT MONITOR.
RECONNECT POWER CORD.
POWER UP AND TEST.

↓

WORKS? YES → RETURN TO FULL SERVICE.

↓ NO

TURN POWER OFF.
DISCONNECT POWER CORD.
DISCONNECT ADAPTER CARD.

↓

CONCLUDE: Problem is likely to be in the RAM section. Replace each RAM chip starting at U50 and working through U57. Test after each replacement. When the problem is fixed, the last chip replaced is bad.

↓

WORKS? YES → RETURN TO FULL SERVICE.

↓ NO

TURN POWER OFF.
DISCONNECT POWER CORD.

↓

GO TO "KEYBOARD PROBLEMS" SECTION, "PRINTS WRONG CHARACTER," p. 121.

Circuitry Affected

Refer to Fig. 4-28 (page 109).

Chip designation	Description	Location
74LS08	Quad 2-input AND gate	U13
74LS32	Quad 2-input NAND gate	U23, U14
74LS151	8-input multiplexer	U22
74LS153	Dual 4-line to 1-line multiplexer	U9, U10
74LS166	8-bit serial/parallel-in serial-out shift register	U32
74LS244	Tri-state octal buffer	U36
74LS273	Octal-D flip-flop	U35, U34
74LS374	Octal transparent latch with 3-state output	U37
MK36000	8K × 8-bit NMOS ROM	U33
2114	RAM	U50–U57

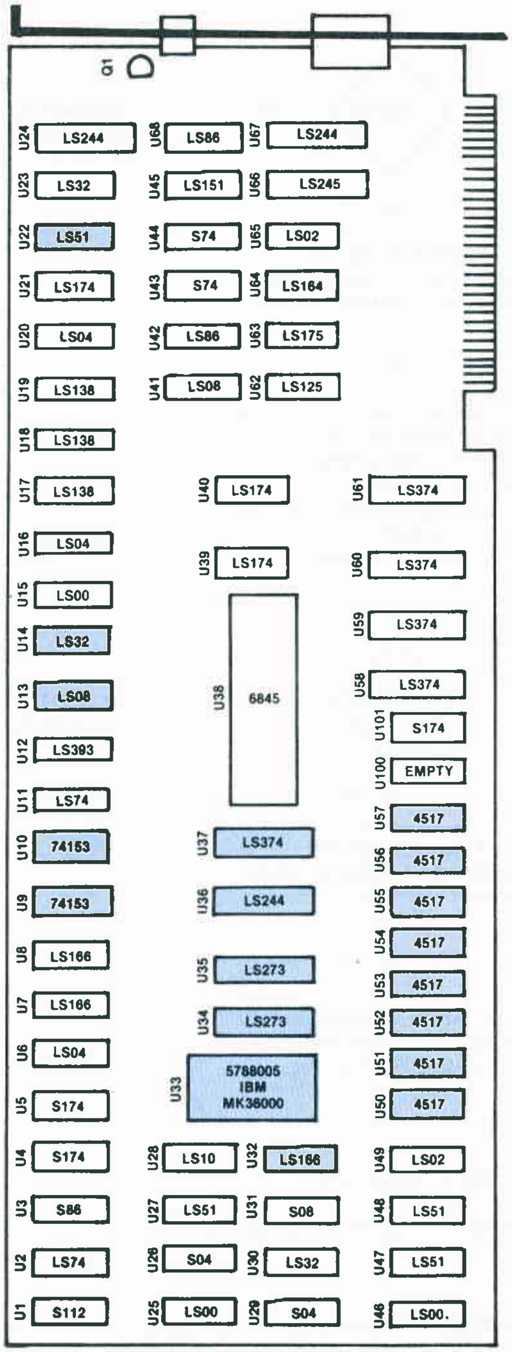


Fig. 4-33. Chip location guide. This represents the IBM PC color/graphics adapter card and is a guide to help you find the chips of interest.

SYMPTOM: Bad or no color

Problem	Possible cause	Repair action
Monitor misadjusted	Adjust monitor	Adjust monitor color controls.
Color signal improper	Bad 74S74 at U43	Replace and test.
	Bad 74S74 at U44	Replace and test.
	Bad 74S174 at U101	Replace and test.
	Bad 74LS151 at U45	Replace and test.
	Bad 74LS244 at U67	Replace and test.

Troubleshooting Procedure

ADJUST COLOR CONTROLS ON DISPLAY FOR OPTIMUM COLOR SIGNAL.

↓

WORKS? → YES → RETURN TO FULL SERVICE.

↓ NO

TURN POWER OFF.
REMOVE SYSTEM UNIT COVER.
TOUCH TOP OF POWER SUPPLY CASE.
DISCONNECT POWER CORD.
DISCONNECT COLOR/GRAPHICS ADAPTER CARD.

↓

REPLACE 74S74 AT U43 ON COLOR/GRAPHICS CARD.

↓

RECONNECT COLOR/GRAPHICS CARD. RECONNECT POWER CORD. POWER UP.

↓

WORKS? → YES → RETURN TO FULL SERVICE.

↓ NO

TURN OFF POWER.
DISCONNECT POWER CORD.
DISCONNECT COLOR/GRAPHICS CARD.

↓

REPLACE 74S74 AT U44 ON COLOR/GRAPHICS CARD.

↓

RECONNECT COLOR/GRAPHICS CARD. RECONNECT POWER CORD. POWER UP.

↓

WORKS? → YES → RETURN TO FULL SERVICE.

↓ NO

(Continued)

TURN OFF POWER. DISCONNECT POWER CORD. DISCONNECT COLOR/GRAPHICS CARD.

↓

REPLACE 74S174 AT U101 ON COLOR/GRAPHICS CARD.

↓

RECONNECT COLOR/GRAPHICS CARD. RECONNECT POWER CORD. POWER UP.

↓

WORKS? YES → RETURN TO FULL SERVICE.

↓ NO

TURN OFF POWER. DISCONNECT POWER CORD. DISCONNECT COLOR/GRAPHICS CARD.

↓

REPLACE 74LS151 AT U45 ON COLOR/GRAPHICS CARD.

↓

RECONNECT COLOR/GRAPHICS CARD. RECONNECT POWER CORD. POWER UP.

↓

WORKS? YES → RETURN TO FULL SERVICE.

↓ NO

TURN OFF POWER. DISCONNECT POWER CORD. DISCONNECT COLOR/GRAPHICS CARD.

↓

REPLACE 74LS244 AT U67 ON COLOR/GRAPHICS CARD.

↓

RECONNECT COLOR/GRAPHICS CARD. RECONNECT POWER CORD. POWER UP.

↓

WORKS? YES → RETURN TO FULL SERVICE.

↓ NO

TURN OFF POWER. DISCONNECT POWER CORD.

↓

SERVICE CENTER ACTION

Circuitry Affected

Refer to Fig. 4-35.

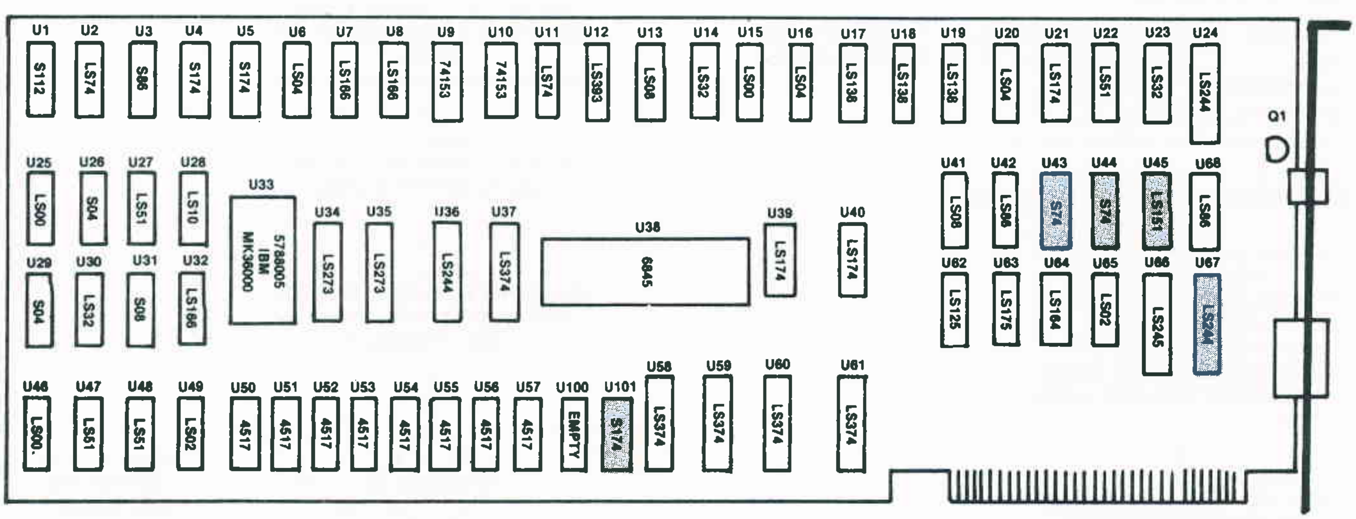


Fig. 4-34. Chip location guide. This represents the IBM PC color/graphics adapter card and is a guide to help you find the chips of interest.

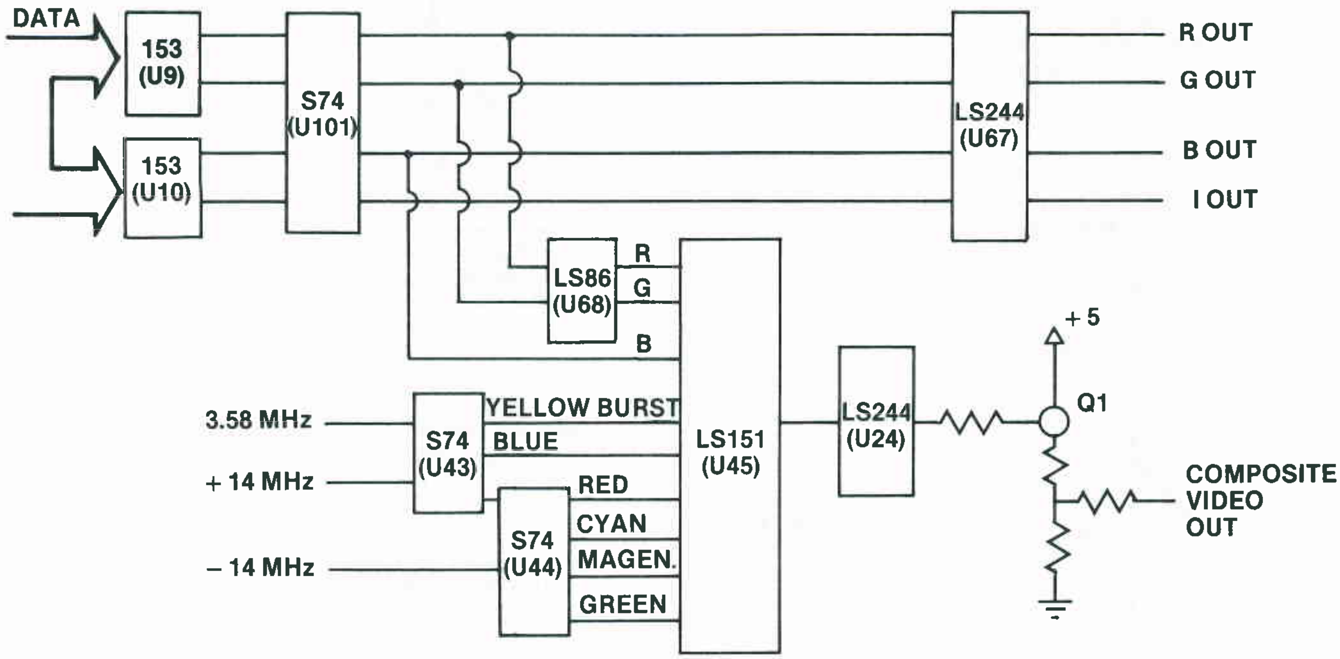


Fig. 4-35. Circuitry for "bad or no color" problem.

Chip designation	Description	Location
74S74	Dual-D flip-flop	U43, U44
74LS151	8-input multiplexer	U45
74S174	Hex-D flip-flop	U101
74LS244	Tri-state octal buffer	U67

SYMPTOM: No hi-res text, lo-res text, or no graphics

Problem	Possible cause	Repair action
No lo-res text selected or produced	Bad 74LS174 at U40 Bad 74LS04 at U16	Replace and test. Replace and test.

Troubleshooting Procedure

TURN POWER OFF. REMOVE SYSTEM UNIT COVER. TOUCH TOP OF POWER SUPPLY CASE. DISCONNECT POWER CORD. DISCONNECT ADAPTER CARD.

↓

REPLACE 74LS174 AT U40 ON COLOR/GRAPHICS CARD.

↓

RECONNECT COLOR/GRAPHICS CARD. RECONNECT POWER CORD. POWER UP.

↓

WORKS? → YES → RETURN TO FULL SERVICE.

↓ NO

TURN OFF POWER. DISCONNECT POWER CORD. DISCONNECT COLOR/GRAPHICS CARD.

↓

REPLACE 74LS04 AT U16 ON COLOR/GRAPHICS CARD.

↓

RECONNECT COLOR/GRAPHICS CARD. RECONNECT POWER CORD. POWER UP.

↓

WORKS? → YES → RETURN TO FULL SERVICE.

↓ NO

(Continued)

TURN OFF POWER.
DISCONNECT POWER CORD.

↓

SERVICE CENTER ACTION

Circuitry Affected

See Fig. 4-37.

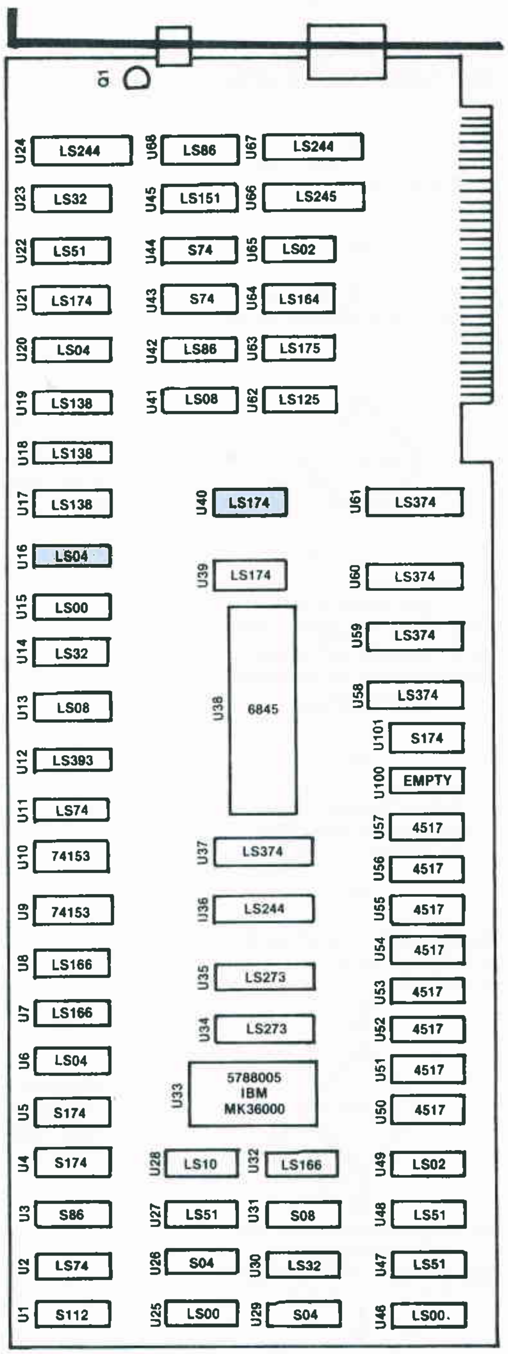


Fig. 4-36. Chip location guide. This represents the IBM PC color/graphics adapter card and is a guide to help you find the chips of interest.

Chip designation	Description	Location
74LS04	Hex inverter	U16
74LS174	Hex-D flip-flop	U40

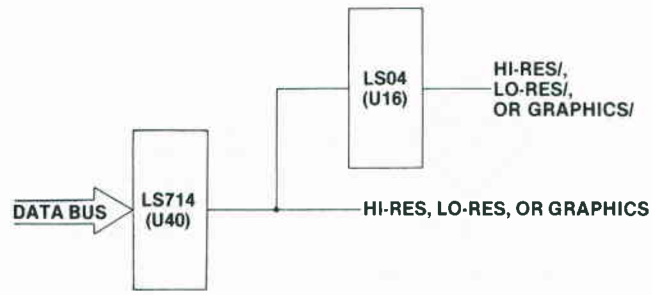


Fig. 4-37. Functional representation of high-resolution, low-resolution, and graphics circuitry. Three unique output signals are produced, each on its own line.

KEYBOARD PROBLEMS

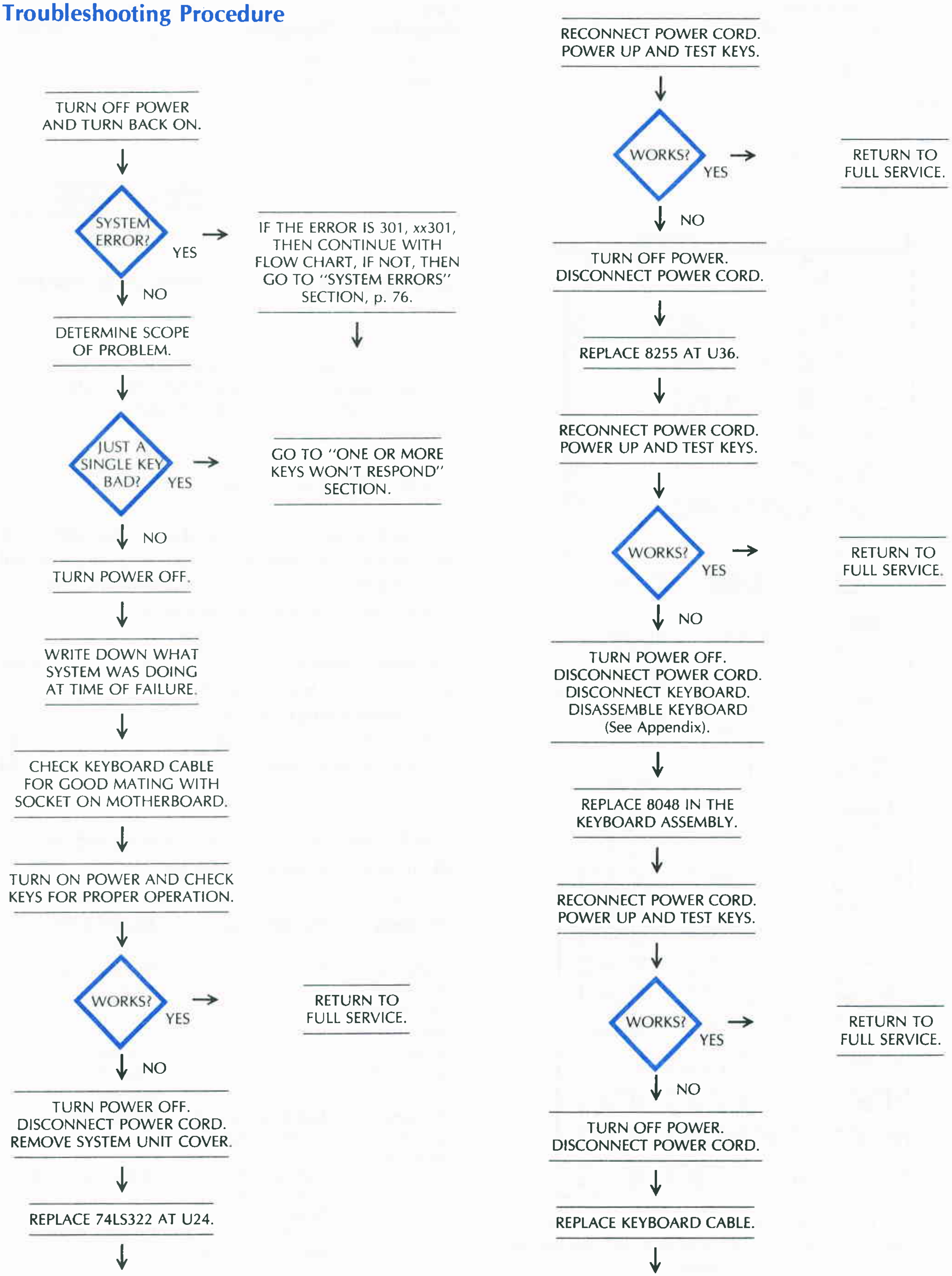
The keyboard is your line of communication with the computer. Its operation is vital to your successful use of the machine. This section is devoted to the most common key and keyboard problems.

Symptom Category	Page
Keyboard won't respond at all or prints wrong character	121
One or more keys won't work	124
Keyboard stays in upper or lower case	124

SYMPTOM: Keyboard won't respond at all or prints wrong character

Problem	Possible cause	Repair action
Signal not reaching motherboard	Bad or loose cable	Reseat or replace cable.
No character being generated	Bad video circuitry	Go to "Display Problems" section, "Bad characters displayed."
No signal getting to data bus	Bad 8048 located inside keyboard	Replace and test.
	Bad 74LS322 at U24 on system board	Replace and test.
	Bad 8255 at U36 on system board	Replace and test.

Troubleshooting Procedure



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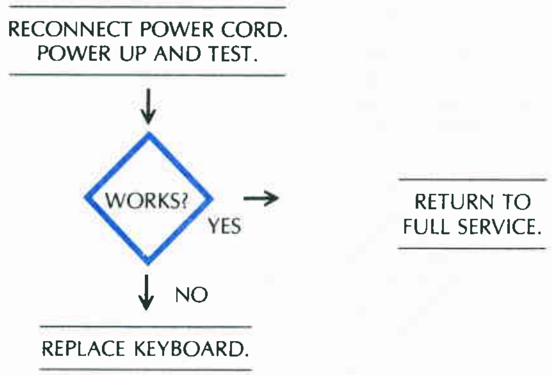


Circuitry Affected

See Fig. 4-39.

Chip designation	Description	Location
74LS322	8-bit serial/parallel in register with sign extend	U24
8048	Single chip, 8-bit microcomputer	In keyboard
8255	Programmable peripheral interface	U36

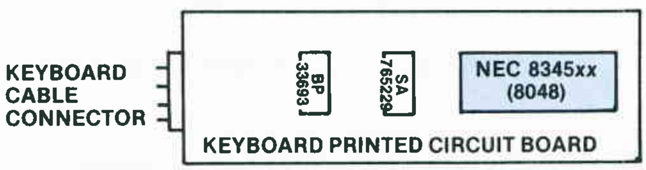


Fig. 4-38A. Chip location guide. This is a guide to help you find the 8048 IC inside the keyboard.

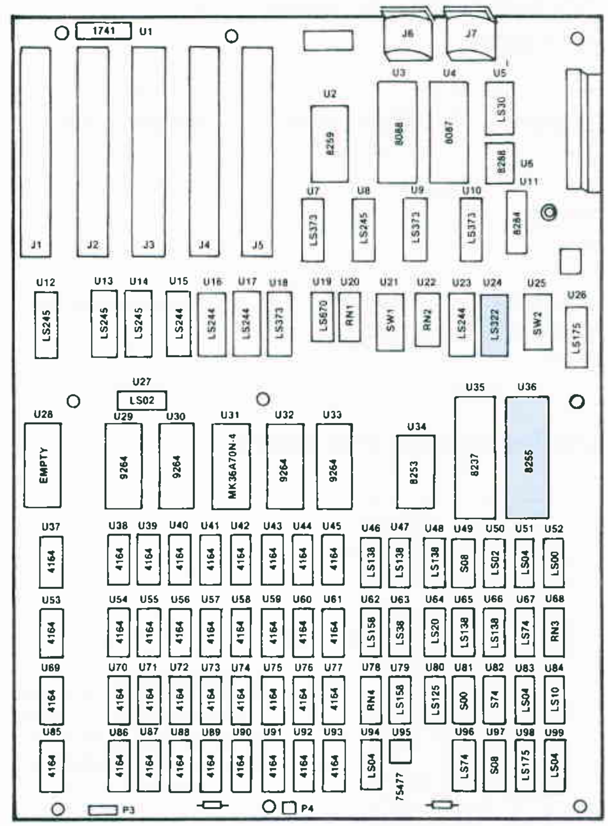


Fig. 4-38B. Chip location guide. This represents the IBM PC system board and is a guide to help you find the chips of interest.

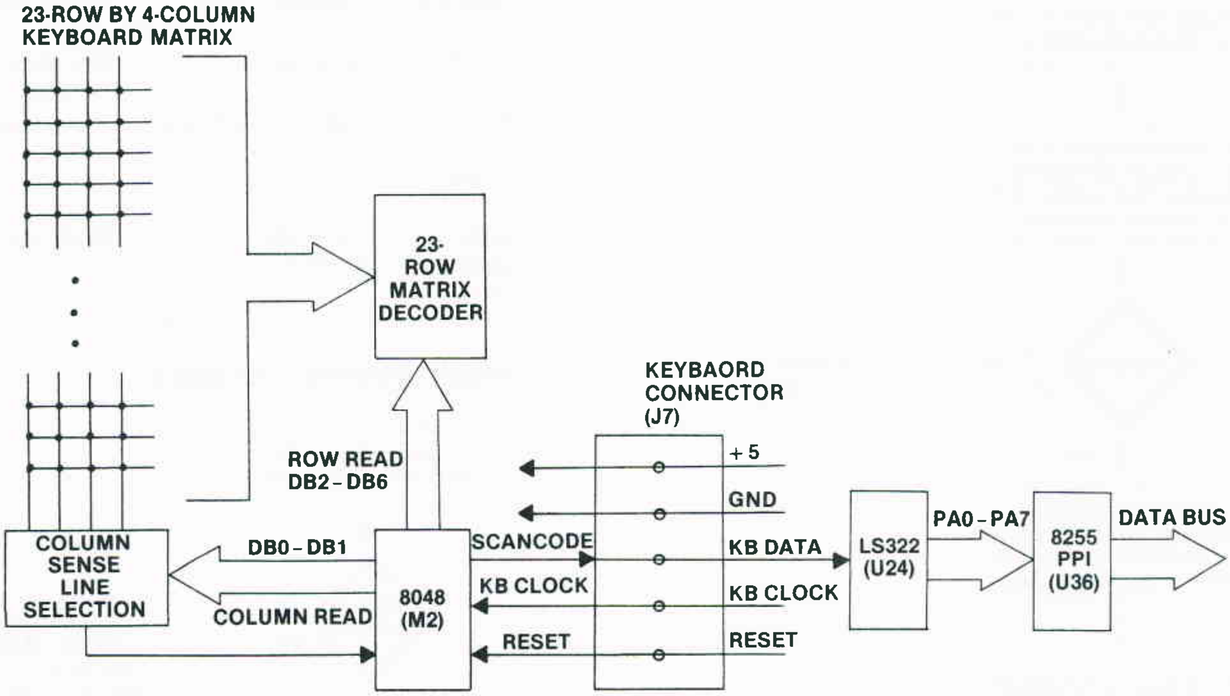


Fig. 4-39. Keyboard circuitry.

SYMPTOM: One or more keys won't work

Problem	Possible cause	Repair action
Key not making proper contact	Bad key	Replace key.
Keyboard signal not proper	Bad 8048 in keyboard	Replace and test.

Troubleshooting Procedure

TURN OFF POWER AND TURN BACK ON.

↓

SYSTEM ERROR? — YES → IF THE ERROR IS 301, xx301, THEN CONTINUE WITH FLOW CHART, IF NOT, THEN GO TO "SYSTEM ERRORS" SECTION, p. 76.

↓ NO

TURN POWER OFF.
DISCONNECT POWER CORD.
DISCONNECT KEYBOARD.
DISASSEMBLE KEYBOARD
(See Appendix).

↓

REPLACE KEY THAT IS NOT WORKING PROPERLY.

↓

REASSEMBLE KEYBOARD.
RECONNECT KEYBOARD.
RECONNECT POWER CORD.
POWER UP AND TEST.

↓

WORKS? — YES → RETURN TO FULL SERVICE.

↓ NO

TURN POWER OFF.
DISCONNECT POWER CORD.
DISCONNECT KEYBOARD.
DISASSEMBLE KEYBOARD.

↓

REPLACE 8048 IN KEYBOARD.

↓

REASSEMBLE KEYBOARD.
RECONNECT KEYBOARD.
RECONNECT POWER CORD.
POWER UP AND TEST.

↓

WORKS? — YES → RETURN TO FULL SERVICE.

↓ NO

CONCLUDE: Problem not chip or key failure.
SERVICE CENTER ACTION

Circuitry Affected

Refer to Fig. 4-39.

Chip designation	Description	Location
8048	Single chip, 8-bit microcomputer	In keyboard

For chip location guide, refer to Fig. 4-38A.

SYMPTOM: Keyboard stays in upper or lower case

Problem	Possible cause	Repair action
Key stuck	Sticky key	Dry key with hairdryer.
Key not making proper contact	Bad Caps Lock key	Replace key.
Keyboard signal not proper	Bad 8048 in keyboard	Replace and test.

Troubleshooting Procedure

TURN OFF POWER AND TURN BACK ON.

↓

SYSTEM ERROR? — YES → GO TO "SYSTEM ERRORS DURING START-UP" SECTION, "SYSTEM ERROR CODES," p. 76

↓ NO

(Continued)

USING A HAIRDRYER, RUN HOT AIR OVER KEY THEN TEST AGAIN.

↓

WORKS? YES → RETURN TO FULL SERVICE.

↓ NO

TURN POWER OFF.
DISCONNECT POWER CORD.
DISCONNECT KEYBOARD.
DISASSEMBLE KEYBOARD.
(SEE APPENDIX).

↓

REPLACE CAPS LOCK KEY.

↓

REASSEMBLE KEYBOARD.
RECONNECT KEYBOARD.
RECONNECT POWER CORD.
POWER UP AND TEST.

↓

WORKS? YES → RETURN TO FULL SERVICE.

↓ NO

TURN POWER OFF.
DISCONNECT POWER CORD.
DISCONNECT KEYBOARD.
DISASSEMBLE KEYBOARD.

↓

REPLACE 8048 IN KEYBOARD.

↓

REASSEMBLE KEYBOARD.
RECONNECT KEYBOARD.
RECONNECT POWER CORD.
POWER UP AND TEST.

↓

WORKS? YES → RETURN TO FULL SERVICE.

↓ NO

CONCLUDE: Problem not chip or key failure.
SERVICE CENTER ACTION

Circuitry Affected

Refer to Fig. 4-39.

Chip designation	Description	Location
8048	Single chip, 8-bit microcomputer	In keyboard

For chip location guide, refer to Fig. 4-38A.

OTHER I/O PROBLEMS

This section treats the most common input/output problems.

Symptom Category — **Page**

Speaker won't work properly 125
Light pen won't work properly 128
Cassette won't load data 130
Can't write data to cassette 132

SYMPTOM: Speaker won't work properly

Problem	Possible cause	Repair action
Speaker cone won't respond	Bad speaker	Replace speaker.
No signal from circuitry to speaker	Speaker wires disconnected	Reconnect wires.
	Bad 75477 at U95	Replace and test.
	Bad 74LS38 at U63	Replace and test.
	Bad 8255 at U36	Replace and test.
	Bad 8253 at U34	Replace and test.

Troubleshooting Procedure

TURN POWER OFF.

↓

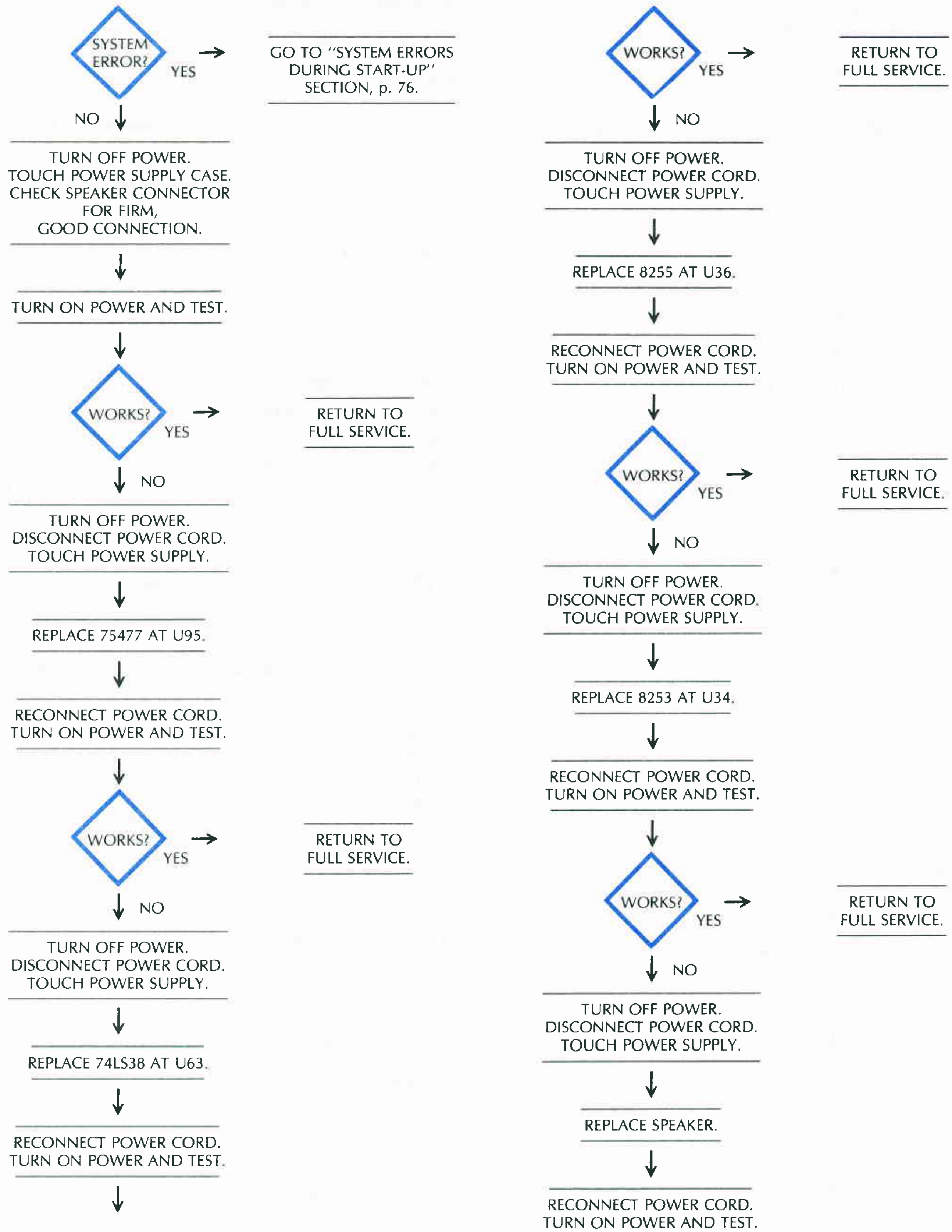
REMOVE SYSTEM UNIT COVER.
TOUCH TOP OF
POWER SUPPLY CASE.

↓

TURN ON POWER.

↓

(Continued)


SYSTEM ERROR?
YES
GO TO "SYSTEM ERRORS DURING START-UP" SECTION, p. 76.
NO
TURN OFF POWER. TOUCH POWER SUPPLY CASE. CHECK SPEAKER CONNECTOR FOR FIRM, GOOD CONNECTION.
TURN ON POWER AND TEST.
WORKS?
YES
RETURN TO FULL SERVICE.
NO
TURN OFF POWER. DISCONNECT POWER CORD. TOUCH POWER SUPPLY.
REPLACE 75477 AT U95.
RECONNECT POWER CORD. TURN ON POWER AND TEST.
WORKS?
YES
RETURN TO FULL SERVICE.
NO
TURN OFF POWER. DISCONNECT POWER CORD. TOUCH POWER SUPPLY.
REPLACE 74LS38 AT U63.
RECONNECT POWER CORD. TURN ON POWER AND TEST.
WORKS?
YES
RETURN TO FULL SERVICE.
NO
TURN OFF POWER. DISCONNECT POWER CORD. TOUCH POWER SUPPLY.
REPLACE 8255 AT U36.
RECONNECT POWER CORD. TURN ON POWER AND TEST.
WORKS?
YES
RETURN TO FULL SERVICE.
NO
TURN OFF POWER. DISCONNECT POWER CORD. TOUCH POWER SUPPLY.
REPLACE 8253 AT U34.
RECONNECT POWER CORD. TURN ON POWER AND TEST.
WORKS?
YES
RETURN TO FULL SERVICE.
NO
TURN OFF POWER. DISCONNECT POWER CORD. TOUCH POWER SUPPLY.
REPLACE SPEAKER.
RECONNECT POWER CORD. TURN ON POWER AND TEST.

(Continued)

WORKS? YES → RETURN TO FULL SERVICE.

NO

TURN OFF POWER.
DISCONNECT POWER CORD.

SERVICE CENTER ACTION

Circuitry Affected

See Fig. 4-40.

Chip designation	Description	Location
8253	Programmable interval timer	U34
8255	Programmable peripheral interface	U36
75477	Dual peripheral NAND driver	U95
74LS38	Quad 2-input NAND buffer	U63

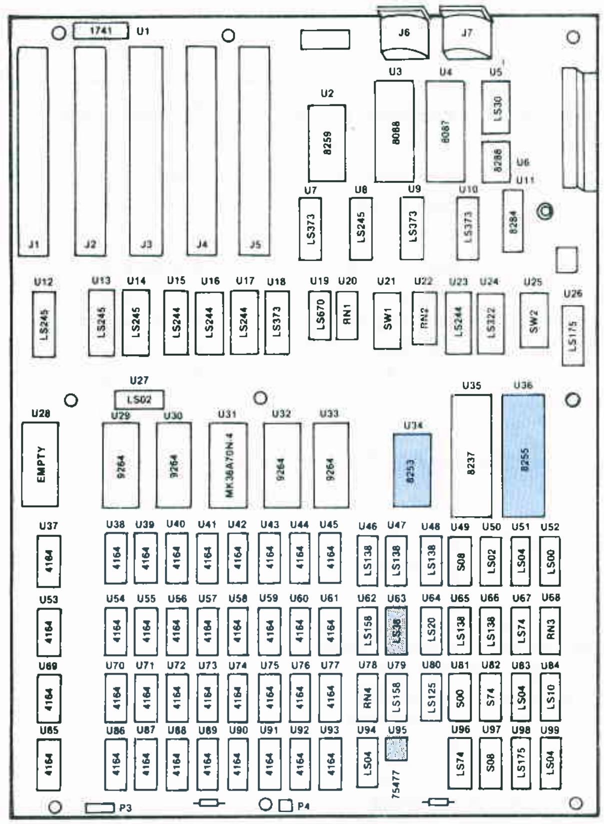


Fig. 4-41. Location guide. This represents the IBM PC system board and is a guide to help you find the components of interest.

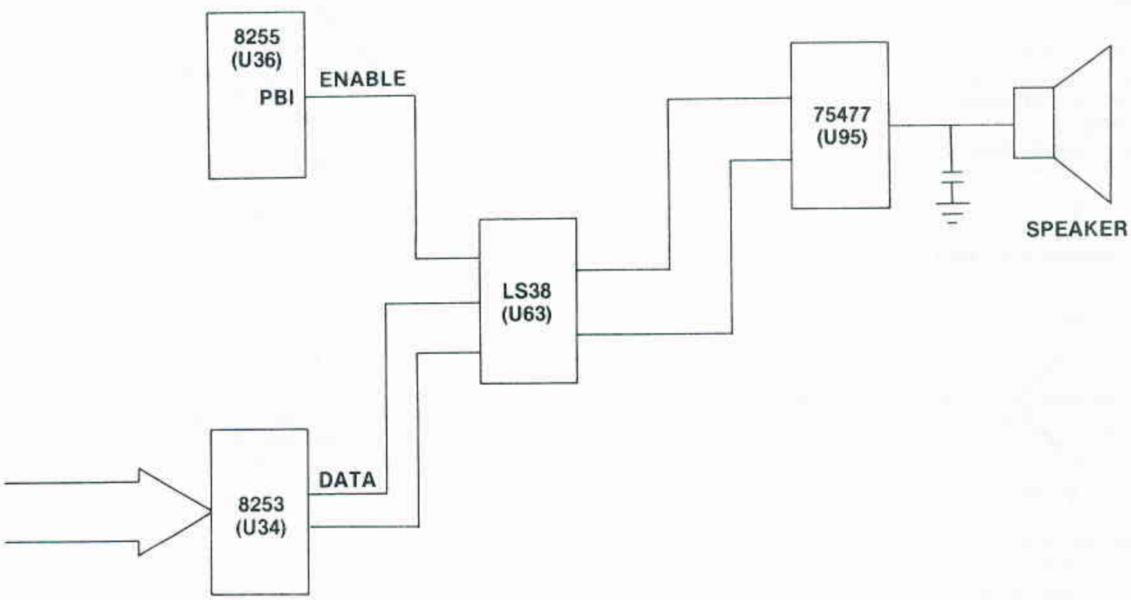


Fig. 4-40. Speaker output circuitry.

SYMPTOM: Light pen won't work properly

Problem	Possible cause	Repair action
Light pen won't respond	Bad light pen Bad or loose connector	Replace pen. Check connector.
No signal from circuitry to data bus	Bad 74S04 at U29 Bad 74LS74 at U11 Bad 74LS244 at U24 Bad 74LS138 at U18 Bad 74LS138 at U17	Replace and test. Replace and test. Replace and test. Replace and test. Replace and test.

Troubleshooting Procedure

TURN POWER OFF.

↓

REMOVE SYSTEM UNIT COVER.
TOUCH TOP OF
POWER SUPPLY CASE.

↓

TURN ON POWER.

↓

SYSTEM ERROR? YES → GO TO "SYSTEM ERRORS DURING START-UP" SECTION, p. 76

NO ↓

TURN OFF POWER.
TOUCH POWER SUPPLY.
CHECK LIGHT PEN CONNECTOR
FOR FIRM,
GOOD CONNECTION.

↓

TURN ON POWER AND TEST.

↓

WORKS? YES → RETURN TO FULL SERVICE.

↓ NO

TURN OFF POWER.
DISCONNECT POWER CORD.
TOUCH POWER SUPPLY.
DISCONNECT COLOR/GRAPHICS
ADAPTER CARD.

↓

REPLACE 74S04 AT U29
ON COLOR/GRAPHICS
ADAPTER CARD.

↓

RECONNECT ADAPTER CARD.
RECONNECT POWER CORD.
TURN ON POWER AND TEST.

↓

WORKS? YES → RETURN TO FULL SERVICE.

↓ NO

TURN OFF POWER.
DISCONNECT POWER CORD.
TOUCH POWER SUPPLY.
DISCONNECT COLOR/GRAPHICS
ADAPTER CARD.

↓

REPLACE 74LS74 AT U11
ON COLOR/GRAPHICS
ADAPTER CARD.

↓

RECONNECT ADAPTER CARD.
RECONNECT POWER CORD.
TURN ON POWER AND TEST.

↓

WORKS? YES → RETURN TO FULL SERVICE.

↓ NO

TURN OFF POWER.
DISCONNECT POWER CORD.
TOUCH POWER SUPPLY.
DISCONNECT COLOR/GRAPHICS
ADAPTER CARD.

↓

REPLACE 74LS244 AT U24
ON COLOR/GRAPHICS
ADAPTER CARD.

↓

RECONNECT ADAPTER CARD.
RECONNECT POWER CORD.
TURN ON POWER AND TEST.

↓

(Continued)

WORKS? YES → RETURN TO FULL SERVICE.

↓ NO

TURN OFF POWER.
DISCONNECT POWER CORD.
TOUCH POWER SUPPLY.
DISCONNECT COLOR/GRAPHICS
ADAPTER CARD.

↓

REPLACE 74LS138 AT U18
ON COLOR/GRAPHICS
ADAPTER CARD.

↓

RECONNECT ADAPTER CARD.
RECONNECT POWER CORD.
TURN ON POWER AND TEST.

↓

WORKS? YES → RETURN TO FULL SERVICE.

↓ NO

TURN OFF POWER.
DISCONNECT POWER CORD.
TOUCH POWER SUPPPLY.
DISCONNECT COLOR/GRAPHICS
ADAPTER CARD.

↓

REPLACE 74LS138 AT U17
ON COLOR/GRAPHICS
ADAPTER CARD.

↓

RECONNECT ADAPTER CARD.
RECONNECT POWER CORD.
TURN ON POWER AND TEST.

↓

WORKS? YES → RETURN TO FULL SERVICE.

↓ NO

TURN OFF POWER.
DISCONNECT POWER CORD.
TOUCH POWER SUPPLY.

↓

REPLACE LIGHT PEN.

↓

RECONNECT POWER CORD.
TURN ON POWER AND TEST.

↓

WORKS? YES → RETURN TO FULL SERVICE.

↓ NO

TURN OFF POWER.
DISCONNECT POWER CORD.

↓

SERVICE CENTER ACTION

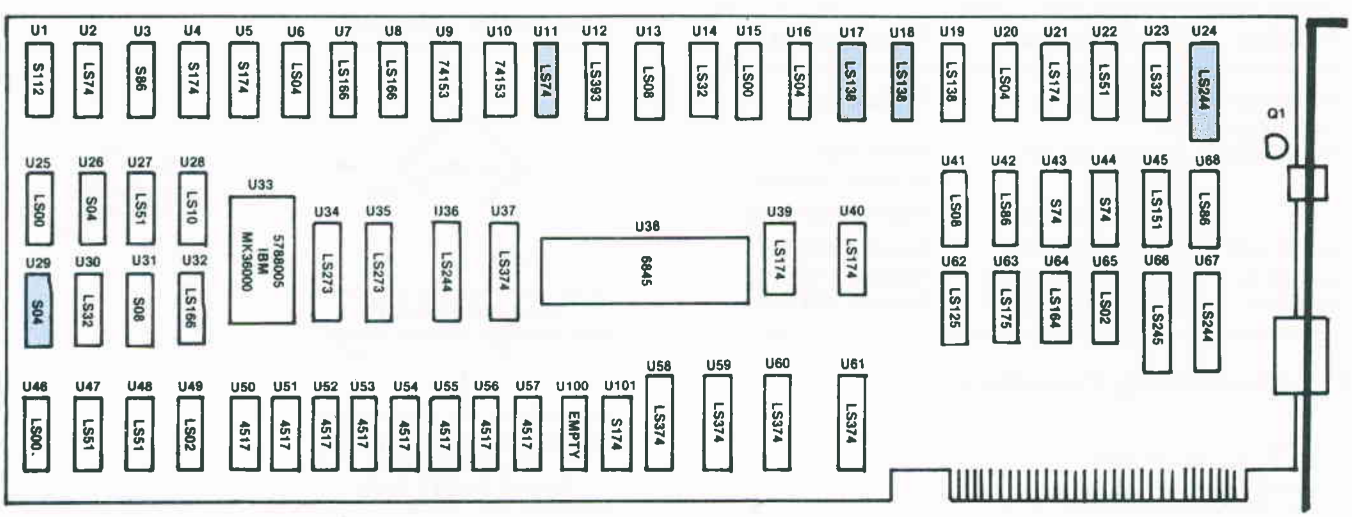


Fig. 4-42. Chip location guide. This represents the IBM PC color/graphics adapter card and is a guide to help you find the chips of interest.

Circuitry Affected

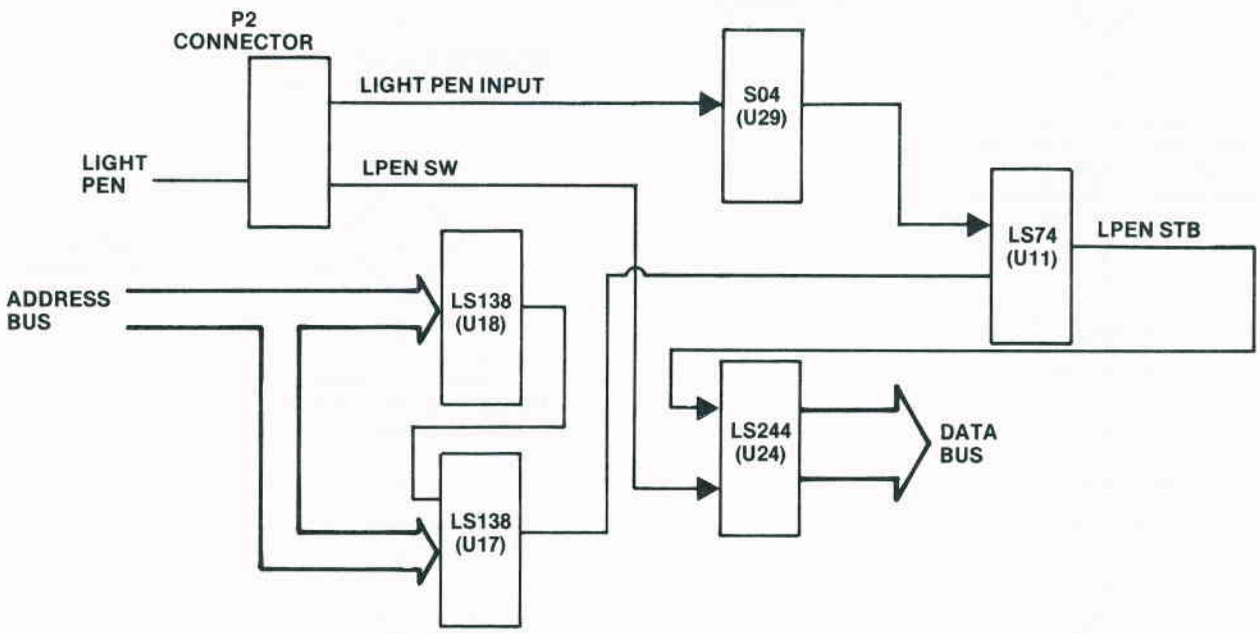


Fig. 4-43. Light pen circuitry.

Chip designation	Description	Location
74S04	Hex inverter	U29
74LS74	Dual-D flip-flop	U11
74LS138	1/8 decoder/demultiplexer	U17, U18
74LS244	Tri-state octal buffer	U24

SYMPTOM: Cassette won't load data

Problem	Possible cause	Repair action
Signal not coming in from cable	Bad cable	Replace cable.
	Volume not set properly	Adjust tape recorder volume.
	No signal on tape	Replace bad tape.
Signal not getting to data bus.	Bad 1741 at U1	Replace and test.
	Bad 74LS38 at U63	Replace and test.
	Bad 8255 at U36	Replace and test.

Troubleshooting Procedure

TURN OFF POWER
AND TURN ON AGAIN.

↓

SYSTEM ERROR? — YES → GO TO "SYSTEM ERRORS DURING START-UP" SECTION, p. 76

NO ↓

CHECK CABLE CONNECTIONS.

↓

TRY KNOWN GOOD TAPE.

↓

WORKS? — YES → RETURN TO FULL SERVICE.

NO ↓

TURN POWER OFF.
DISCONNECT POWER CORD.

↓

REMOVE SYSTEM UNIT COVER.
TOUCH TOP OF
POWER SUPPLY CASE.

↓

(Continued)

DISCONNECT ALL PERIPHERAL HARDWARE EXCEPT VIDEO ADAPTER CARD AND CASSETTE.

↓

REPLACE 1741 AT U1.

↓

RECONNECT POWER CORD. POWER UP AND TEST.

↓

WORKS? YES → RETURN TO FULL SERVICE.

↓ NO

TURN POWER OFF. DISCONNECT POWER CORD.

↓

REPLACE 74LS38 AT U63.

↓

RECONNECT POWER CORD. POWER UP AND TEST.

↓

WORKS? YES → RETURN TO FULL SERVICE.

↓ NO

TURN POWER OFF. DISCONNECT POWER CORD.

↓

REPLACE 8255 AT U36.

↓

RECONNECT POWER CORD. POWER UP AND TEST.

↓

WORKS? YES → RETURN TO FULL SERVICE.

↓ NO

CONCLUDE: Problem is not caused by chip failure. SERVICE CENTER ACTION

Circuitry Affected

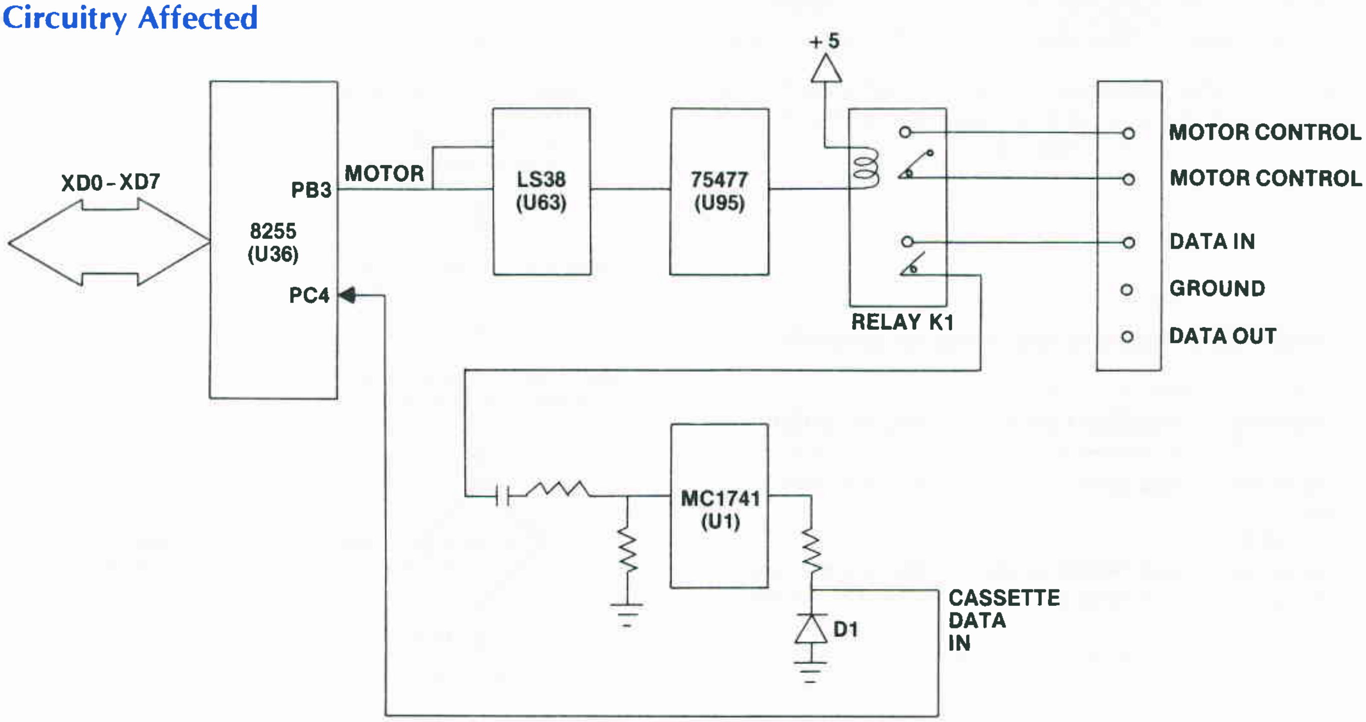


Fig. 4-44. Cassette data input circuitry.

Chip designation	Description	Location
1741	Operational amplifier	U1
74LS38	Quad 2-input NAND gate	U63
8255	Programmable peripheral interface	U36

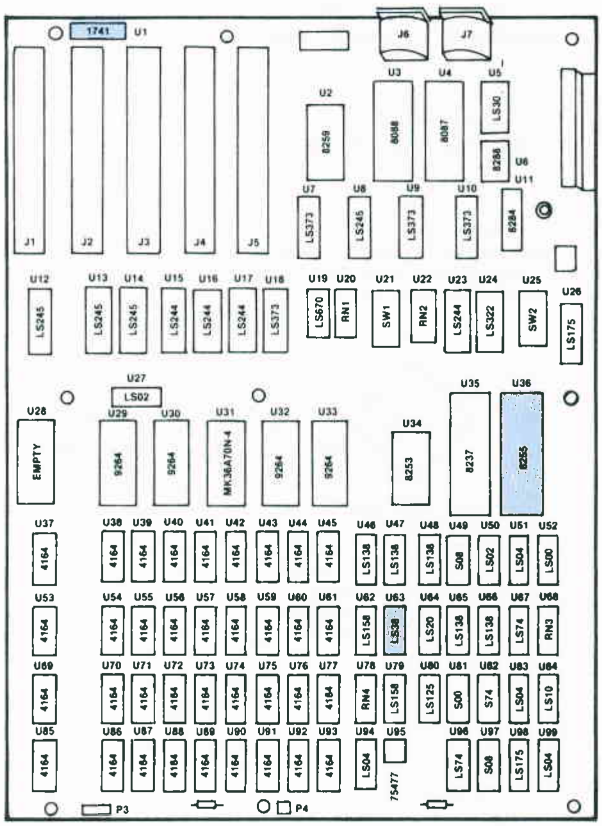


Fig. 4-45. Chip location guide. This represents the IBM PC system board and is a guide to help you find the chips of interest.

SYMPTOM: Can't write data to cassette

Problem	Possible cause	Repair action
Signal not going out the cable	Bad cable	Replace cable.
Signal not being sent to tape.	Bad 74LS38 at U63 Bad 8253 at U34	Replace and test. Replace and test.

Troubleshooting Procedure

TURN OFF POWER AND TURN ON AGAIN.

SYSTEM ERROR? — YES → GO TO "SYSTEM ERRORS" SECTION, p. 76.

NO ↓

CHECK CABLE CONNECTIONS.

TRY KNOWN GOOD TAPE.

WORKS? — YES → RETURN TO FULL SERVICE.

NO ↓

TURN POWER OFF. DISCONNECT POWER CORD.

REMOVE SYSTEM UNIT COVER. TOUCH TOP OF POWER SUPPLY CASE.

DISCONNECT ALL PERIPHERAL HARDWARE EXCEPT VIDEO ADAPTER CARD AND CASSETTE.

REPLACE 74LS38 AT U63.

RECONNECT POWER CORD. POWER UP AND TEST.

WORKS? — YES → RETURN TO FULL SERVICE.

NO ↓

(Continued)

TURN POWER OFF.
DISCONNECT POWER CORD.

↓

REPLACE 8253 AT U34.

↓

RECONNECT POWER CORD.
POWER UP AND TEST.

↓

WORKS? YES → RETURN TO FULL SERVICE.

↓ NO

TURN POWER OFF.
DISCONNECT POWER CORD.

↓

CONCLUDE: Problem is not caused by chip failure.
SERVICE CENTER ACTION

Chip designation	Description	Location
74LS38	Quad 2-input NAND gate	U63
8253	Programmable interval timer	U34

Circuitry Affected

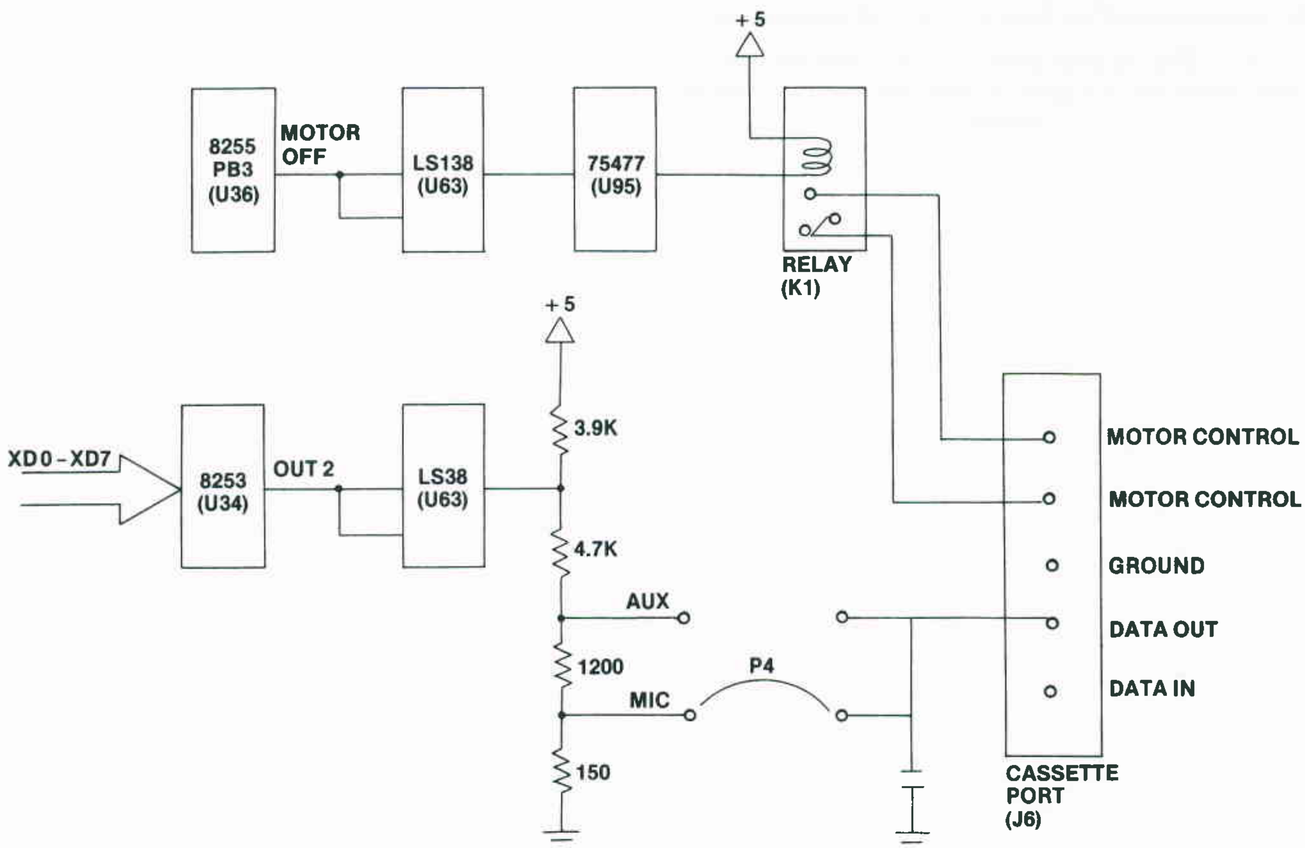


Fig. 4-46. Cassette data output circuitry.

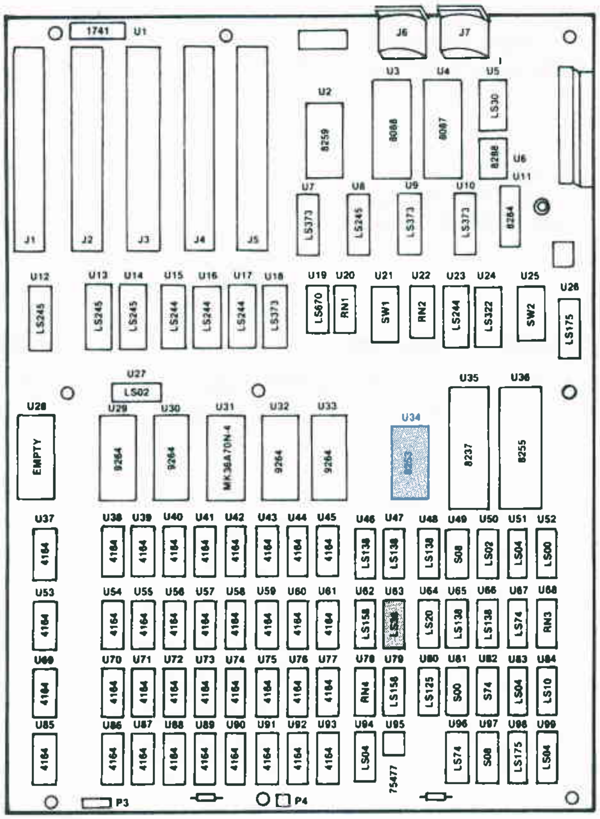


Fig. 4-47. Chip location guide. This represents the IBM PC system board and is a guide to help you find the chips of interest.

SUMMARY

This detailed troubleshooting and repair chapter has covered most of the general problems experienced by owners (and repairers) of computer systems. If following one of the guides in this chapter doesn't solve the problem, you can take the final step (Service Center Action) yourself if you feel qualified. Chapter 6 will provide assistance if you decide to really dig into your machine.

Caution: Only experienced technicians should work on power supply and monitor problems.

Remember that the information in Chapter 5, "Routine Preventive Maintenance," can help prevent many of the problems analyzed for repair in this chapter.

CHAPTER 5

Routine Preventive Maintenance

In Chapter 4 you went through a step-by-step guide for detailed troubleshooting and corrective maintenance of the IBM Personal Computer. Chapter 5 discusses another type of maintenance, one that is intended not to fix a problem but rather to prevent a problem from ever happening. Preventive maintenance is in every way as important as corrective maintenance. In this chapter you'll learn what factors damage your computer and cause it to fail and what you can do to prevent these failures.

Often, the price you pay to buy your computer system is actually only a small part of the overall system cost. The life-cycle cost of the equipment can be much larger than the initial purchase investment. This total cost increases dramatically as the costs for software, books, magazine subscriptions, extra interface boards, disks, and service center repair charges are added in. Service costs can grow to 10 to 50 percent of your system cost.

Occasionally a repair expense can exceed the value of the equipment that is broken. It's when we look at high repair costs that terms like "mean time between failures" (MTBF) and "mean time to repair" (MTTR) become important. While your IBM PC has an excellent reliability track record, the way you operate your machine and the environment in which you place it become important to the MTBF number. Another factor to consider is that those "bargain" interfaces and peripherals that you bought at such a low cost probably have a less than excellent reliability record. You get what you pay for.

Your IBM computer is sturdy and fast, and it performs work easily and accurately. Under most operating conditions, PCs are indeed very reliable machines. But, like other machines, they wear out and fail.

As your experience with computers grows and the computer becomes more and more essential in your home and business, your need for uninterrupted computer power increases. If you have to take your computer to a repair shop, you can expect your machine to be gone for 1 to 3 weeks, although many problems can be fixed within a day.

Most large companies take steps to protect their huge computer and data processing investment. Accidents and unnecessary failures cost thousands of dollars in lost business. A small business, with a single microcomputer, two disk drives, and a printer, faces just as catastrophic a loss by system failure; yet most small businesses don't take steps to prevent such failures.

Computers don't burn out. They wear out or are forced out by human error or adverse operating conditions. If you misuse your computer or don't protect it from the environmental elements, you can be the cause for its failure.

A few moments of care can result in many more hours of good, consistent performance. We call this care *preventive maintenance*, or just PM. Just as you periodically check the oil and water in your car's engine, lubricate the car, and wash and wax the body, so you should care for and protect your computer.

Futurists today feel that there are three major kinds of items each of us will purchase in our lifetime—a house, a car, and now a computer. Each is a major investment. Each deserves to receive good care. You can get good, reliable operation from your computer for many months, if not years, if you provide timely and proper maintenance to keep the system in peak condition.

CONTRIBUTORS TO SYSTEM FAILURE

Proper PM begins with an understanding of what we are fighting. Six factors that can influence the performance of your personal computer (not including the disk-eating dog or the floppy-bending baby) are:

- Excessive temperature
- Dust build-up
- Noise interference
- Power-line problems
- Corrosion
- Magnetic fields

Each acts to cause computer breakdown. This chapter tells how to successfully battle these enemies of reliable performance.

HEAT

As you learned earlier, the chips and other devices in your computer are sensitive to high temperatures. During normal operation, your PC generates heat that is generally tolerable to the circuitry. Usually, leaving your IBM PC on for long periods won't hurt it, because the slots and air vents let enough of the heat dissipate to the outside of the case. The rest of the warm air is drawn into the power supply by its built-in fan and exhausted out the rear of the chassis.

As long as the components on the system board are not too hot to touch, the amount of heat being produced should not cause any damage. However, heat can become a problem when you begin adding adapter interface boards. The power supply has plenty of voltage margin and is protected against overload, but with an increased power demand it produces more heat. The design of the PC case, with the motherboard lying flat, provides an open space for hot air to rise, but the air has a tendency to hang over the board rather than moving out the vents. Adding adapter boards that connect to the motherboard, or peripheral connectors that plug into the rear of the computer, further restricts any natural convection or fan suction. This causes the components to get even warmer. The power supply heats up more as it pumps out more current to power the piggyback boards or peripherals that derive power from the computer. The piggyback boards, the power supply, and the motherboard all give off heat, and the inside temperatures soar.

Excessive heat within a component causes premature aging and failure. The heat produced during operation is not uniform across the device, but peaks at specific locations on the chip (generally at the input/output connectors where the leads meet the chip itself). The usual effects of heating and cooling are to break down the contacts or junctions in the chip or other device, causing open-circuit failure. When hot, these devices can produce intermittent "soft errors," with loss of or incorrect data. This effect is known as "thermal wipeout," and it's a chronic problem in loaded systems that aren't sufficiently cooled. The continual heating and cooling action during normal operation also causes the socketed chips to work themselves out of their sockets.

Heat can also contribute to disk failure. Disks, those inexpensive yet extremely valuable platters, act just the way your stereo records do when exposed to heat, especially the heat of the sun. If you leave your disks setting in a hot car, you can be sure some warpage will occur. If the thin disk warps too much, you will lose whatever information you stored on that floppy. You could try to set it flat in the sun and hope to "warp" it back into shape, but the success rate for this "repair" isn't very high.

Countering the Effects of Heat

The following actions should help in preventing heat-related failures:

- Reseat the socketed chips if intermittent failures occur.
- Keep the cooling vents clear.

- Keep your system dust free inside and outside.
- Do your PMs (preventive maintenance actions) regularly.
- Keep disks in a cool, dry location.
- Install an external cooling fan if system operation becomes intermittent when the system heats up.

Many IBM PC users find the AIP PCool fan a worthwhile investment when five cards or a piggyback memory card have been installed. This fan mounts just behind the PC faceplate.

While more and more users struggle with the internal heat problem, a quiet revolution is occuring in fan technology. Brushless DC (direct current) fans are being designed with thermal sensor interfaces that can monitor the PC's system unit temperature and cause fan speed to change relative to the amount of heat sensed. These "smart" fans are also much quieter than the relatively noisy AC (alternating current) fans currently in use. As each new computer is born, another potential application for a DC fan appears. These thermal-sensing fans can yield more efficient, less costly, and longer-operating computer systems.

COLD

The effect of cold on computers is an interesting subject. The U.S. government is currently working on superfast computers that operate in supercold environments. Electronic components operate quite well in cold temperatures, but mechanical components have trouble functioning when the temperature drops. For example, the operating range for a standard floppy disk drive is approximately 40°F to 115°F. At the low end, mechanical sluggishness occurs increasing the possibility of erratic data storage and retrieval. The floppy disk itself can become brittle when it gets cold.

Countering the Effects of Cold

The rule of thumb for cold temperatures is to let the system warm up to room temperature (stabilize) before turning on the power. If the temperature is comfortable for you, it's fine for the system.

DUST AND OTHER PARTICLES

Just like flies at a picnic, dust particles descend on computer equipment. Interestingly, the dust is attracted to the display monitor in the same way it is to a television screen. If the dust is not cleaned from the screen, it will build up, and eventually someone will rub it and mar the screen surface.

The static electric charge that builds up in the computer and the display monitor attracts dust and dirt. That's why large computer systems are kept in cool, clean computer rooms. They require special air conditioning and dust-free spaces, because the large equipment generates more heat and is just as susceptible to failures caused by dust build-up.

Dust and dirt build-up insulate the circuit devices and prevent the release of the heat generated during normal operation. If the devices can't dissipate this heat, the inside temperature rises higher than normal, causing the chips and other components to wear out even faster. Dust is a major contributor to memory chip failure. It seems to be attracted to heat. Have you ever noticed that dust builds up on light bulbs in your lamps or on the tops of stereos and televisions more than it does on cooler objects? The dust particles are charged and therefore are attracted to the magnetic field around electrical equipment.

Mechanical devices such as printers and disk drives fail more often than solid-state electronic devices because mechanical and electromechanical devices have moving parts that get dirty easily, causing overheating and earlier failure. Look inside your printer and you'll see the kinds of dirt and dust that are collecting. Paper sheds tiny particles as it moves through the printer. These particles become insulators to prevent the heat generated during normal operation from escaping off the equipment and into the air.

Disk drives have more dust-related problems than printers because they are designed with read/write heads that operate on or slightly above the diskette. The space between the head and the disk is small. When the head rides on the disk surface, dust and dirt can cause major problems. Foreign particles such as dirt, smoke, ash, and tiny fibers can also cause catastrophic problems in diskette jackets and in disk drives themselves (see Fig. 5-1).

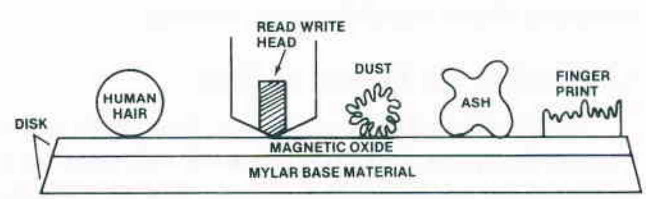


Fig. 5-1. With a read head that rides on the surface of the disk, any small piece of foreign material can cause problems.

The air we breathe is full of airborne particles, but most of these are too small even to be seen, let alone become a problem. The larger particles in the air cause computer system problems. Cigarette ash, for example, can settle on a disk surface and move from track to track inside the disk jacket, causing loss of data.

Inside the vinyl jacket surrounding each of your disks is a special lining that traps dirt and dust as the disk spins in the drive (Fig. 5-2). This doesn't mean you

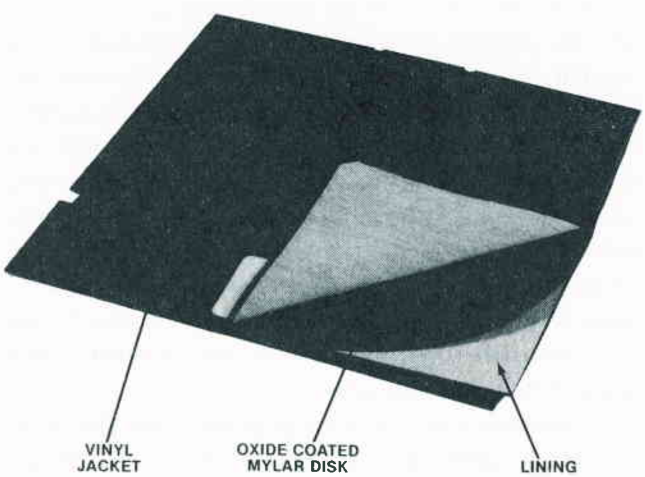


Fig. 5-2. A floppy disk, showing the vinyl jacket, jacket lining, and oxide-coated mylar disk.

can get careless about dust and dirt. Dirt on a disk can be swept off by the drive read/write head and gouge out a path on the disk surface, or it can stick on the head and cause other disks to be gouged. The dirt can also cause the head itself to corrode and wear out.

Smoke from cigarettes and cigars can coat the internal surfaces of the disk drive with a gummy soot that can not only produce data transfer errors, but also interfere with the mechanical operation, further increasing the wear on the drive. Smoke is also believed to cause rapid oxidation on pins and connectors, increasing the likelihood of intermittent errors. Most computer centers and computer rooms are off-limits for smoking.

Countering the Effects of Dust

Dust build-up can be controlled. Thoroughly cleaning your computer area every week will help keep your system in top condition. Dirt and dust can be removed from the equipment housings using a cloth slightly dampened with a mild soap solution. Clean electrical equipment with the power turned off. Be careful you don't wet or moisten the electronic components.

After washing the surface, rewipe the outside of the equipment with a soft cloth dampened with a mixture of one part liquid fabric softener to three parts water. The chemical make-up of some liquid softeners is almost the same as that of antistatic chemical spray. The chemicals in this inexpensive solution last longer than some antistatic sprays and help make your screens less susceptible to scratching. Wiping the case and screen with one of these liquids helps to keep static charges from attracting dust to the screen and tops of the hardware.

Another quite successful technique is blowing dust away from the screen with a pressurized can of antistatic dusting spray, as shown in Fig. 5-3. Using this kind of product means you don't have to wipe your equipment off first. Wiping a screen should be done carefully, because you could scratch the screen if some hard dust or dirt particles are on the screen or your cloth.

Fig. 5-3. An antistatic spray for computer equipment. (Falcon Safety Products, Inc., Mountainside, New Jersey)

The following are some manufacturer-recommended screen and cabinet cleaning methods:

- Use one part fabric softener to three parts water to clean your screen.
- Use mild soap and water; use a soft cloth for drying.
- Use a window cleaner spray.

(**Note:** Although the monitor literature from several manufacturers recommends this, be careful. Common household aerosol sprays, solvents, polishes, or cleaning agents may damage your monitor cabinet and screen. The safest cleaning solution is mild soap and water.)

- Use an antistatic spray.

Associated with cleaning advice, each manufacturer also included an important safety precaution:

Caution: Make *sure* the power is off and the plug(s) pulled out of the power socket(s). Use a damp cloth. Don't let any liquid run or get into your equipment.

You can use a long plastic nozzle on the end of your vacuum hose to reach in and around everything inside the hardware. Dust and small particles can be cleaned off the circuit board inside your PC using a soft brush. Fig. 5-4 shows a hand tool to assist in vacuuming out electronic equipment. Be careful not to damage any of the parts. Brush lightly.

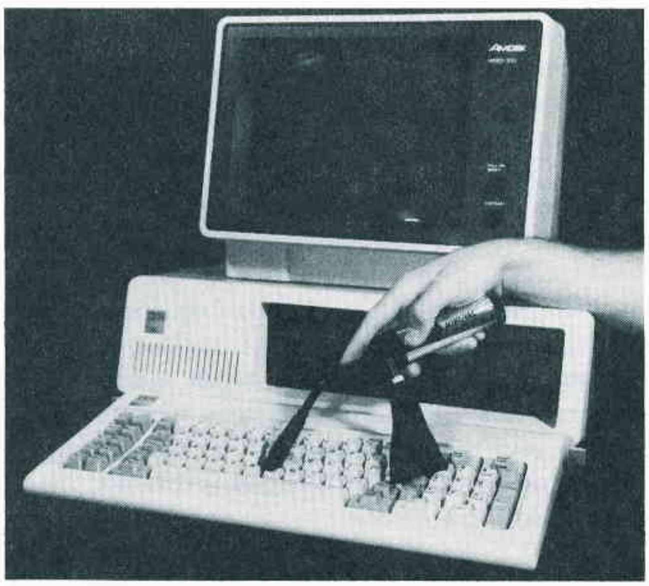


Fig. 5-4. A handy tool for cleaning dust off keyboards and circuit components. (Mini-Vac, Inc., Glendale, California)

Another control measure is the use of dust covers. You may not have an air-conditioned, air-purified room in which to use your IBM PC, so dust covers become of paramount importance. Plastic covers, made static-free with an antistatic aerosol or by wiping the surface with the fabric softener-water mixture, will provide good dust protection for your system.

Here is a summary of ways to counter dust in your IBM computer system.

- Use dust covers.
- Keep windows closed.
- No smoking near your IBM PC system.
- No crumb-producing foods near your computer.
- No liquids on any equipment.
- Don't touch the surface of any floppy disk.
- Vacuum the system and the area weekly.
- Clean your monitor screen with static-reducing material.

NOISE INTERFERENCE

Your computer and its peripherals are sensitive to interference noise, which can affect the proper operation or transfer of information. But what is noise, and where does it come from? How can you get rid of it?

Noise can be described as those unexpected or undesired random changes in voltage, current, data, or sound. Noise is sometimes called *static*. It can be a sudden pulse of energy, a continuous hum in the speaker, or a garbled display of characters.

Three types of noise cause problems: acoustic noise that affects you, the user, noise that affects your computer system, and noise that affects other electronic equipment. *Acoustic noise* includes, for example, the crying of a baby, the blare of an overpowered stereo, and the loud, consistent tap-tapping of a computer printer. Noise that affects the computer and other equipment can be radiated, conducted, or received. It takes the form of *electromagnetic radiation* (EMR). EMR noise can be further classified as low- or high-frequency radiation. Noise can be categorized as shown in Fig. 5-5. If the noise occurs in the 1 hertz to 10K hertz range, it is called *electromagnetic interference* (EMI). If it occurs at a frequency above 10 kHz, it is called *radio frequency interference* (RFI). RFI can occur in two forms: *conducted RFI* and *radiated RFI*.

If the RFI is fed back from the PC through the power cord to the high-voltage AC power line, it is classified as conducted RFI. In this case, the power line acts as an antenna, transmitting the noise interference out. When your computer system and its cabling transmit noise, the noise source is called radiated RFI.

EMI has three primary components:

- Transient EMI
- Internal EMI
- Electrostatic discharge (ESD)

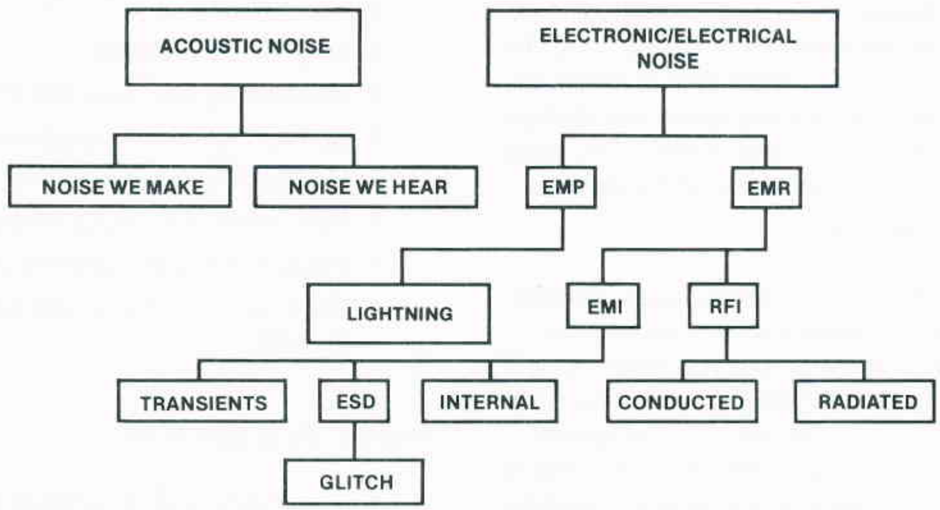


Fig. 5-5. The various forms of noise that affect computer equipment.

Transient EMI includes the undesirable response in electrical equipment when simply turning on or off a device causes a large voltage pulse, or *spike*, to occur and go smashing through the circuitry. Power-line transients and electrostatic discharge from the human body are the two most severe forms of externally generated EMI.

Internal EMI is the noise generated within the system unit by the chips and other motherboard devices. With current microelectronic designs, internal noise levels are very low. Other factors, such as connections and the length of leads, have become the main sources of noise in printed circuits. Internal noise does become a problem when the components are excessively heated or when the chips begin to fail.

The last form of EMI, the **electrostatic discharge (ESD)** is the same as the effect you get from walking across a carpet and then getting shocked upon touching a metal doorknob. ESD can cause the notorious "glitch" in electronic circuits.

All these types of noise interference can produce undesirable or damaging effects in your IBM systems. They can cause programs to stop in the middle of an operation, garbage to be read from or written to disks, garble to appear on the screen, cursors to freeze, diagonal lines to appear on the television or monitor screen, paper to jam in the printer, data to disappear, and motherboard chips to be destroyed. Noise interference must be prevented by reducing or eliminating noise. This is not an insurmountable challenge, but it is a substantial practical and analytical task.

Where Does Interference Come From?

Noise in the computer system can originate in many places, including power supplies, fans, the computer itself, other equipment, connectors, cables, fluorescent lights, lightning, and electrostatic discharge. The use of high-powered components in switching power supplies has led to widespread problems with noise being conducted back into the power lines. Switching power supplies have been found to generate EMI in the 10 to 100 kHz frequency range.

Noise can even be passed or coupled to nearby equipment that's on a different circuit and not physically connected to the noisy system. If two wires lie next to each other, one can pick up signals coupled across from the other. This is known as *crosstalk*. Just 10 volts of electricity on one wire will cause a measurable voltage (0.25 volts) on the other wire. Imagine how much crosstalk there could be if the voltage were increased to 100 volts. The induced voltage on the other wire would be 2.5 volts, which is enough to change information in a stream of data being sent through that second wire.

Everything has some capacitance associated with it. Some typical capacitance values are shown in Table 5-1. Engineers have found that even 0.1 pF of capacitance can produce 5-volt spikes in digital circuits such as those found in the IBM personal computer.

Power-line noise can feed into the computer circuits whenever it exceeds the blocking limits of the power supply. Nearby high-voltage machinery such as stamping mills, saws, air-conditioning units, or clothes dryers can produce strong magnetic fields in the area around them and in their power cords.

Table 5-1. Typical Capacitance Values

Source	Capacitance
People	700.0 pF
½-watt resistor	1.5 pF
Connector (pin-to-pin)	2.0 pF

Cables that vibrate and move in a magnetic field can also cause problems. Relays and motors can produce high-voltage transients when they are turned on or off. And televisions and radios can be affected by noise coming from the computer system.

Any digital circuit that uses a clock signal will emit, or radiate, interference off the cables connected to that circuit. The IBM personal computer CPU operates at a clock speed of over 4 MHz—inside the frequency range of radio and television signals. (Recall that RFI covers all noise that occurs at frequencies above 10 kHz.) If the PC system were not designed to correct for this type RFI, the CPU transmissions would interfere with the normal operation of nearby radios and televisions.

Note: Televisions on cable service would not be affected because the shielded cable allows only the cable TV program signals to get into the TV antenna input.

Finally, EMI can come from industrial, medical, and scientific equipment, electric motors, home appliances, drills, saws, and tool speed controls.

It's important to understand noise and how it can be generated. Our computer systems must be able to operate without causing interference with other nearby electronic equipment. They must be able to function without radiating noise; and they must be able to function even in an environment that includes noise being introduced from outside sources.

Noise Interference Countermeasures

The most effective approach to noise reduction is prevention. If you can't prevent noise, you can at least take steps to minimize its impact.

Five methods for dealing with noise are:

- Filtering
- Shielding
- Bonding originals
- Wiring improvements
- Component design improvements

Usually, the approach taken is a combination of these methods, although filtering and shielding are the most widely used ways to protect electronic equipment. Filtering involves the use of capacitors and inductors. There are many kinds of filters that respond to voltage, current, or frequency. For example, one kind of filter prevents high-frequency voltage spikes from leaking out of a switching power supply into the circuitry being supported.

The following paragraphs present countermeasures used to prevent the various forms of noise interference.

Audible Noise

Most microcomputer systems don't generate enough audible noise to require acoustic shielding or enclosure. The normal busy office can generate about 80 dB of noise. The noisiest part of a computer system is the printer. Most printers don't exceed 70 dB of noise, but the type of noise (tap-tap printing) can become so irritating that many companies purchase insulated sound-trapping enclosures that fit over the printers and cut the noise output in half. The cooling fan in your PC's power supply can be another source of audible computer system noise.

Some computer users place acoustic sound-absorbing foam around their computer system area to achieve a quieter operating place. Acoustic pads placed under disk drives and printers can significantly reduce noise.

Electromagnetic Interference (EMI)

EMI is an unplanned, extraneous electrical signal that affects the performance of your computer system. It can cause memory errors and data file destruction. It can appear as power supply drift, voltage ripple, unplanned logic signals, or circuit crosstalk.

While circuit designers try to minimize EMI, it is a natural by-product of aging components, bad solder joints, damaged or corroded connector contacts, and loose connections. It is also produced when a burst of electromagnetic or electrostatic energy is conducted or induced through the circuitry. Externally produced EMI enters the computer through the cabling or openings in the case. Sometimes it enters by static discharge through the case of the disk drive.

The IBM PC case is made of metal. It is lightweight, durable and generally rustproof. While these are good qualities, the most important feature is that metal conducts electricity, so it provides protection against EMI/RFI and even ESD noise.

The Federal Communications Commission (FCC) has established specifications for the amount of radiated noise allowed to exit the chassis of computer equipment. The FCC places any devices that conduct or radiate EMI of frequency above 10 kHz into one of two categories:

Class A—Industrial computing devices sold for use in commercial, business, and industrial environments, and not sold to the general public.

Class B—Consumer computing devices used in commercial, business, and industrial applications plus personal computers and their associated peripherals.

The IBM PC is considered a Class B consumer computing device, and the EMI emitted is strictly regulated as shown in Table 5-2.

Table 5-2. EMI requirements for class B equipment

Frequency (MHz)	Distance (meters)	Maximum EMI Field Strength (microvolts/meter)
30–88	3	100
89–216	3	150
217–1000	3	200

Both conducted and radiated EMI are regulated. Conducted EMI in frequencies between 450 kHz and 30 MHz must be reduced by 48 dB for levels above 1 microvolt. Radiated EMI must be reduced by 46 dB or more, measured 3 meters away from the source.

To meet these requirements, IBM designed a metal shield case for the PC. While this brought the EMI within limits, some EMI still leaks out of the computer, since it gets out anywhere there is an opening on the chassis—the connector slots on the front of the chassis, the vent holes, around the power plug jack, and even the key holes on top of the detachable keyboard case.

IBM PC design engineers have employed most of the following techniques to reduce EMI and RFI:

- Use decoupling capacitors (0.01 μF to 0.1 μF).
- Lay out components carefully.
- Keep traces as short as possible.
- Minimize the use of transistor-transistor-logic (TTL) chips since they tend to generate current spikes when switching logic states.
- Shield sensitive circuits.
- Reduce noise sources.
- Use fewer components.
- Carefully route wires.
- Use a shielded cabinet with as few openings as practicable.

How can you improve on IBM's efforts to counteract EMI? Since you won't be changing the circuit board design, you can reduce EMI in two ways: (a) prevent it from reaching the motherboard and interface card circuits, and (b) keep it contained within shielded enclosures. To do this, use shielding, grounded cables, filters, and transient absorbers.

Metal enclosures make the best shields. The PC's switching power supply, a high source of EMI, is enclosed in a metal can. The greater the shield thickness, the better the shield effect. While the metal computer case of your IBM PC does a decent job of shielding against EMI and RFI, you can improve on the shielding by sealing all openings that aren't being used. Compressible gaskets can be used to close slot holes. At one time IBM shipped each PC with metal gaskets over each adapter-card access hole. This practice was discontinued—apparently because the gaskets kept falling out during shipping. Metal honeycomb ventilation screens can be used over cooling vents.

Buy and use shielded cables. A shield is a conductive coat or envelope placed around a conductor wire or group of wires to provide a barrier to electromagnetic interference. Ground the shields. Have you hooked up the ground wires that are attached to some of the peripheral interface cables? If not, you really should. A shielded computer connected to a poorly shielded peripheral will enable any interference generated inside the computer to be conducted to and out through the shield weaknesses. Filtering inside the cabling or connectors will eliminate conducted noise.

Some connectors can be purchased with built-in filter pins to reduce radiated EMI count around connectors. Other EMI-reduction devices include the ferrite "shield beads" that are placed on power supply leads and connections to ground or between stages on the circuit board.

Ideally, the shielded connectors should provide a continuous shield from the device, through the connector, and into the shielded cable. Otherwise, the weak shield point becomes a transmission hole for EMI to get out and interfere with other devices or appliances in the area.

One excellent countermeasure to EMI and RFI is the use of fiber-optic cables and connectors. This technology hasn't yet become popular with PC users because the cost is still too high, but the day is coming when fiber-optic data transmission will be the norm rather than the exception.

Electrostatic Discharge (ESD)

It sometimes appears that a secret program is loaded into every computer to intermittently produce random errors to drive users wild. Chasing and catching the elusive phantom "glitch" is a challenge even for experienced repair technicians using expensive and complex troubleshooting equipment. However, you can learn more about this intermittent problem and how to prevent it from affecting your computer operation.

Glitches are electrical disturbances of short duration, but they are often are long enough to cause problems in digital circuitry. They are usually the result of an electrostatic discharge (ESD), one of the most severe sources of EMI.

People and objects such as chairs and desks can accumulate a substantial electrical charge, or potential. The human body can accumulate static charges up to 25,000 volts. It is not unusual to build up and carry charges of 500 to 15,000 volts. Charged objects or people can then discharge the voltage to a grounded surface through another object or person. Remember the times you dragged your feet across the carpet and then shocked someone nearby? This electrical charge is called *static*. It can discharge through your computer, and when it does, all sorts of undesirable things can occur. If a program is running and a computer user carrying a large electrical charge touches a key on the keyboard, the arc of discharge will find the shortest route to ground, usually through the RAM or CPU, and the program will bomb to a halt, data bits "falling away" everywhere. The screen can go wild and display strange characters. Sensitive components can be damaged or destroyed. Even a charge of only 3 volts is enough to create an erroneous bit in most logic circuits.

Electrostatic charges can be of any voltage. The following is a list of some of the sources of ESD glitches:

- People in motion
- Overheated components
- Improper grounding
- Poorly shielded cables
- Improperly installed shields
- Missing covers and gaskets
- Circuit lines too close
- Poor solder connections
- Low humidity

We know that static occurs when two objects are rubbed together. Your movement, walking while wearing wool or polyester slacks, can cause a tremendous charge of electricity to build up on your body. When this charge reaches 10,000 volts, it is likely to discharge on any grounded metal part.

Litton Systems, Inc. has developed the *triboelectric series* chart shown in Table 5-3. Cotton is the reference material since it absorbs moisture readily and can easily become conductive. If any material on the list above cotton is rubbed with any material on the list below cotton, the item listed above will give up electrons and become positively charged. The item listed below cotton will absorb electrons causing it to become negatively charged.

Table 5-3. Litton Systems, Inc. Triboelectric Series

	Air
	Your hand
	Asbestos
	Rabbit fur
	Glass
	Your hair
	Nylon
	Wool
	Fur
	Lead
	Silk
	Aluminum
	Paper
Reference material* ———→	Cotton
	Steel
	Wood
	Hard rubber
	Nickel, copper
	Brass, silver
	Gold, platinum
	Acetate, rayon
	Polyester
	Polyurethane
	Polyvinyl chloride
	Silicon
	Teflon

*When a material above cotton is rubbed with a material below cotton, the material above will become positively charged and the material below, negatively charged.

The two oppositely charged materials will tend to cling together. If they are separated, a static charge difference occurs. If Teflon is rubbed in your hands, a large electrostatic charge is built up. The greater the distance between the materials listed in Table 5-3, the larger the charge that can build up. Notice that hair is listed above cotton, paper is listed just above cotton, and hard rubber is below cotton. Have you ever pulled a rubber or plastic comb through your hair and then used the comb just like a magnet to pick up pieces of paper? This is electrostatic charge in action.

Our problem occurs when this charge builds and becomes quite large. Just walking across a carpet can generate over 1000 volts of charge. If the humidity is low and it is quite dry in the room, the charge can be substantially higher. (When the relative humidity is 50 percent or higher, static charges generally don't accumulate.) A built-up static charge will readily arc to any grounded metal, such as a disk drive chassis.

An ESD release on your disk drive case won't hurt you, but it can be very damaging to your electronics. The discharge pulse drives through the case to the read/write head and then on to the analog card circuitry, where it can burn out some of the chips. Even if no components are "fried," the damage that is done by this overvoltage spike accumulates and starts to degrade the functioning of some circuit board components. ESD damage costs have been estimated at millions of dollars annually, but this figure is even higher when we include components that are not totally destroyed, but are degraded. Even so, sooner or later the chip(s) fail completely.

In low humidity, walking across a synthetic carpet can charge your body to 35,000 volts. Walking over a vinyl floor can charge you with 12,000 volts. A clear plastic ("poly") bag picked up off a table can develop 20,000 volts. Even sliding off a urethane-foam padded chair can load you with 18,000 volts. Is this a hazard to your PC? Yes. As Table 5-4 describes, some electronic devices are very susceptible to relatively low ESD voltages.

If your computer occasionally gets the "shock treatment" or pulls the old "disappearing data" trick on you, there are some things you can do. The following list offers some specific solutions to ESD problems.

Table 5-4. Voltages that can damage electronic devices

Device	Damaging Voltage (minimum)
CMOS chips	250–3000 volts
Diodes	300–2500 volts
EPROM memory	100 volts
Operational amplifier	190–2500 volts
Resistors	300–3000 volts
Schottky (S, LS) chips	1000–2500 volts
Transistors	380–7000 volts
VMOS chips	30–1800 volts

- Use antistatic spray on your rugs, carpets, and computer equipment. The antistatic spray, applied with a soft cloth works both as a static reducer and control measure.
- Install a static-free carpet in your computer area.
- Install an antistatic floor mat beneath your computer chair. (This is a popular solution.)
- Mop hard floors with an antistatic solution. The antistatic floor finish works well, but this is really an expensive solution and better suited for electronic manufacturing facilities. Most antistatic floor finishes work for up to 6 months.
- Install a conductive table top.
- Install a humidifier to keep room humidity above 50 percent.
- Use static-free table mats.
- Keep chips in conductive foam (that black styrofoam-looking material).
- Touch a grounded metal object (power supply case) before touching the computer.

You can defeat ESD glitches by paying attention to static charge in and about the computer system. By making static charge elimination a part of your preventive maintenance program, you take one more step to extending the life of your computer system.

Radio Frequency Interference (RFI)

Radio frequency interference is much the same as EMI, except that it occurs at higher frequencies (>10 kHz). RFI is what causes five other garage doors on your street to open when you operate your new automatic garage door opener.

Although RFI isn't a health hazard, it's also controlled by the FCC. FCC Rule, Part 15, Subpart J states that any digital product that generates timing signals or pulses at rates greater than 10 kHz must comply with FCC regulations. In fact, Class B devices such as the IBM personal computer are tested over a range of 30 to 1000 MHz to ensure that their emissions fall below maximum field-strength limits. The computer is also limited in the amount of emission that it can feed back along the power lines (no more than 250 microvolts). The same standards that apply to EMI field-strength radiation also apply to RFI (see Table 5-2).

The only sure way to completely block RFI emissions is to completely enclose your computer system in a shield. This is impractical, but there are other ways to reduce the emission of RFI.

A smaller component count in a computer reduces the number of sources of RFI and improves system operation. Reliability improves in direct proportion to RFI improvements.

There are some actions that you can take yourself to improve your system's RFI condition.

- Locate your computer system at least 6 feet away from any television set.
- Reposition the outside TV antenna if interference occurs.
- Use a directional outdoor TV antenna.
- Subscribe to cable TV.
- Connect traps or line filters on your TV.
- Replace the antenna twin-lead wire with 75-ohm coaxial cable.

With current computer designs and FCC direction, the RFI emissions from personal computers are so low that interfering with your neighbor's TV set is no longer a problem. However, they can still interfere with your own TV set.

There have been reports of interference problems with cordless telephones. The PC has been known to cause low power telephones to dial or lift off hook. High power telephones in the vicinity of the PC have caused characters to appear on the monitor screen. Usually the keyboard is the source of the problem. If you use a cordless telephone, you might consider investing in a better shielded keyboard such as the Keytronics board.

POWER-LINE PROBLEMS

Probably the most important environmental factor for your computer system is good, clean power. If you depend on your local utility to supply this power with steady, reliable consistency, you may be disappointed.

While room lighting systems can tolerate line voltage problems that momentarily dim the lights when a large power-hungry machine is switched on, computer systems cannot. Your IBM computer, like most electronic computers today, is more sensitive to power-line disturbances than other electrical equipment is. Even well-designed machines such as your IBM PC are affected by the quality of power provided. Undervoltage or overvoltage puts severe stress on computer components. The effect accelerates the conditions under which a device gradually weakens, becomes marginal, and finally wears out.

There are four types of power-line problems that cause concern:

- Brownouts
- Blackouts
- Transients
- Noise (discussed previously)

Brownouts

Brownouts are those planned (and sometimes unplanned) voltage sags, when less voltage is available to drive your IBM PC power supply, display CRT, and printer motor. Brownouts are far more common than you may realize. Voltage dips are common if you operate your computer near some large electrical equipment such as air conditioners or arc welders. Your line voltage can be drawn down as much as 20 percent by the heavy momentary drain caused when this equipment is turned on.

The PC should still work with line voltages that drop and remain as much as 20 percent below the 117 volt rating. But if the supply voltage gets too low, the regulators in your power supply won't be able to pump adequate power into your motherboard, and data can get garbled. During brownouts, computer systems can operate intermittently, overheat, or simply shut down and lock up.

By the way, your power supply can also handle a voltage "brown-up," or increased line voltage. The power supply will provide proper power to your circuit, but its regulators will generate a lot more heat as they handle the higher incoming voltage level.

Blackouts

Power-line blackout, a total loss of line voltage, can be caused by storms and lightning. It can be caused by vehicles accidentally knocking down power lines or even by improper switching action by a power station operator.

When power is lost, whatever you had in RAM is gone. If you are writing to the disk when power fails, you will have only a partial save—the information that was still in RAM and not yet copied over to your disk is lost. If a scheduled power outage is planned, postpone using your computer. If the weather turns bad and thunder is echoing across the sky, don't turn your computer on. If a blackout occurs or if you see lightning, turn your machine off and pull the plug(s) until the storm passes.

And when the power goes out, be careful. While the room lights are out and you're muttering under your breath as you feel around for a flashlight, remember what is sure to happen when power is restored—a tremendous voltage spike will be produced as lights and motors go back on all over the neighborhood. This could damage the IBM PC system. Always unplug your computer system when blackout occurs. Wait until power has been restored for a few minutes, then turn your system back on. Don't test your power supply filters on these kinds of spikes.

Transients

Other than electrostatic discharge, power-line transients are the most devastating form of noise interference in computer circuits. Transients are large, potentially damaging spikes of voltage or current that are generated in the power lines feeding electrical power to your community. Spikes can be caused by lightning striking a power line somewhere, utility company equipment failure, or the ON/OFF switching action common to using any electrical tool or appliance.

Most of these spikes are small and are barely noticeable, but some voltage spikes as large as 1700 volts have been measured in home wiring. Residential areas experience more large spike transients than commercial areas. The line filters in your IBM power supply will protect your system from most high-voltage transients, but occasionally a spike overcomes the power supply protection and gets to the logic circuitry. The general effect is erased or altered data, but if the spike is too large, sensitive circuit devices can be destroyed.

Your PC power supply is normally not affected by the transients generated by ON or OFF switching actions. These actions can produce a short-lived spike that is five times normal line voltage.

Not all spikes are generated outside the computer. When you save a program or file you've developed, activating the disk drive produces a voltage spike inside your computer. IBM engineers have placed capacitors in strategic locations on the motherboard and in the disk drive electronics to carry spikes harmlessly away to ground, preventing component damage. If any part of the spike reaches the circuit components, the devices are stressed and can become marginal.

Preventing Power-Line Problems

If you live in an area where power outages or brownouts are common, or where electrical storms frequently occur or if your computer system occasionally hangs up, you need protection. There are two kinds of approaches to preventing power-line problems. You can condition the power being supplied, or you can provide an auxiliary, or backup, power source.

Power-Line Conditioners

The various forms of **power-line conditioners** include the isolator, the regulator, and the filter.

Isolators provide protection from voltage and current surges and include transient suppressors, surge protectors, and isolation devices. These devices can keep line voltage at a proper level even when the line supply is 25 percent over normal. Some surge protectors can filter out high-frequency spikes but cannot respond to slow, low-frequency transients. One form of surge protector is called a *metal oxide varistor* (MOV), a form of diode that will clamp the line voltage at a certain level, preventing overvoltage spikes from getting into your system. These devices are installed across the power-line wires leading into your computer. The December 1983 issue of *Byte* magazine has a good article on the installation of MOV devices, should you be interested in using them. Isolators cannot provide protection against brownouts or complete loss of electrical power.

Regulators act to maintain the line voltage within prescribed limits. They are essential if line voltage varies more than 10 percent at the computer, but they don't provide protection against voltage spikes and blackouts.

Filters remove noise from the input power line. They short EMI and RFI signals to ground and remove high-frequency signals from the low-frequency 60 Hz power line. Power-line filters work best when they are located immediately next to or at the front end of the power supply. Filters don't stop spikes. Nor are they effective during low- or high-voltage conditions.

Auxiliary Power Sources

When power availability is in question, an **auxiliary power source** is a necessity. An **uninterruptible power supply (UPS)** is used to store energy when line power is present and then deliver power to the computer when a blackout occurs. These power supplies cost between $300 and $15,000, but they are a dependable source of auxiliary power. A UPS is composed of a motor, a generator, and a battery. The motor is driven by power from the utility line while local power is available. The motor turns a generator that produces electricity to charge a battery. When the local line power is lost, the battery turns the generator to produce AC electricity that can be used by the computer.

There are four types of UPS equipment that can be used to power your computer system:

- Continuous-service UPS
- Motor generator
- Forward-transfer UPS
- Reverse-transfer UPS

A **continuous-service UPS** changes the AC line voltage to DC to charge a set of batteries. When power is lost, the batteries operate an inverter that changes the DC battery power back to AC to run your computer.

Portable and fixed **motor generators** are powered by electricity, gasoline, or diesel motors. The generator is turned by the motor and supplies a regulated AC voltage to operate your computer system (and probably many other appliances and lights in your house or business). These devices are often used as emergency backup power for hospitals, police departments, and radio stations. Generators can be expensive, but they can provide backup power throughout the period line power is not available.

A **forward-transfer UPS** supplies power to your computer system only when line power is lost. It is the classic UPS, in which the line power drives a motor that rotates a generator that charges a battery (or set of batteries). When line power is lost, the batteries take over and provide AC power to the computer through an inverter.

A **reverse-transfer UPS** provides power to the computer from a battery most of the time, and switches to line power only if the UPS fails or is turned off.

Some UPS equipment provides much more than just a power source. One company markets a UPS that provides protection not only against complete power loss, but also against power transients, undervoltage and overvoltage fluctuations, brownouts, and dirty (noisy) lines. Most UPS devices can switch to battery power very quickly. One UPS makes the transfer from primary power to battery power in about 4 milliseconds.

Once the transfer occurs, the next important consideration is the length of time the backup will be able to provide power. Some units will keep your computer system running long enough to save what you had in RAM and to conduct a normal system shutdown. A unit from Topaz Inc. in San Diego, California can provide up to an hour of reliable AC power. It sells for about $800.

How important is a UPS and the length of time it can provide power? If you are in an area that suffers frequent power outages, consider this: what effect would losing power at the time you were updating your disk directory have on your system? You'd probably lose your directory and not be able to retrieve whatever you had on your disk. The problem can be much worse when you connect a hard disk into your system. If a power outage occurs when the hard disk is activated or even simply powered up, there is no way for you to conduct a normal power-down sequence. If your hard disk requires the read/write heads to be in a certain position, you can't achieve this unless you have a UPS that switches in instantaneously. Failure to properly position the heads can cause drive damage as well as loss of valuable data.

You have some choices. What level of insurance do you need? Can you manage adequately without standby power—making backup copies of all your data and saving to disk often during computer operation? Power-line protection can prevent damage, expensive data loss, and unnecessary down-time.

When selecting a power-line conditioner or a backup power supply, consider the following parameters:

For a power-line conditioner

- Speed of response in handling voltage spikes
- Ability to filter out high-frequency noise
- Ability to handle repeated transients
- Amount of line power it can handle
- Range of input voltages from which it will produce clean power out
- Number of outlets (to handle several devices)

For a backup power supply

- Total backup power required
- Time to switch to standby power
- Length of time backup will provide power
- Availability of built-in line conditioning
- Availability of undervoltage and overvoltage protection
- Battery life cycle

To determine how much backup power you may require, add the amperage ratings on the label plates of all the computer system equipment (computer, external display monitor, printer, drives, plotters, etc.) and multiply by 120. The result is the approximate wattage, or power, you will require to operate the entire system. Since the larger the amount of power required, the higher your cost, you may want to consider only the power required to operate the basic system (computer, monitor, and disk drives). You can leave the other peripheral equipment plugged into your standard wall socket and let these fail off when power is lost. If you do this, don't forget to turn these machines off and unplug the power cords before power is restored to prevent a big transient from damaging them.

How much power protection to provide is up to you. Many computer users are able to get along quite well with unprotected systems. Others prefer to operate their systems knowing that unseen environmental upheavals won't affect access to their IBM PC.

CORROSION

The metal connector pins on cables, interface cards, and chip pins are subject to corrosion, a chemical change in which the metal plating of the pins and sockets is gradually eaten away. Corrosion can be very damaging.

There are three types of corrosion that can affect the IBM PC system:

- Direct oxidation by chemicals
- Atmospheric corrosion
- Galvanic electrical corrosion

Direct Oxidation

In direct oxidation a chemical corrosion occurs. A film of oxide forms on the metal surface, reducing the pin's contact with the socket. At high temperatures this oxidation process accelerates. The metal is slowly worn away as the electrical contact surface is converted to an oxide and the oxide crumbles.

Atmospheric Corrosion

Chemicals in the air attack the metals in computer system circuitry, causing pitting and a "rust" build-up. In the early stages of this corrosion, sulfur compounds in the atmosphere are converted to tiny droplets of sulfuric acid that lie on the surface of the connector pins. This acid eats away the metal, causing pits to form.

When atmospheric corrosion is just forming, the contacts can be wiped clean, restoring the metal brightness. But if the sulfuric acid is allowed to remain, the long exposure converts the acid to a sulfate layer that can no longer be wiped away.

The effect is to reduce electrical contact between the pins and their sockets. A layer of discolored rust that prevents any contact between the pins and their sockets causes an open circuit and is easy to locate. It's the in-between stage, when an "almost-open" condition exists, that produces those horrible intermittent failures that can be so hard to find.

Near the ocean the presence of salt spray or increased levels of chlorides can cause severe pitting of some metals.

Galvanic Corrosion

In galvanic corrosion, a tiny crack or hole in the metal plating on a pin or connector lets a moisture-borne electrolyte such as salt (sodium chloride) penetrate between the metal plating and the underlying base metal.

A kind of battery forms, with a tiny electric current flowing between the two metals. The plating surface becomes scaly and rough as the plating is slowly eroded away and an oxide forms. The corrosive action is concentrated on the underlying metal exposed at the breaks in the scale since this is where the galvanic battery exists.

The effect is the same as for the other forms of corrosion—the amount of electrical contact between pin and socket decreases, causing intermittent problems, until the scale is so complete the electrical circuit is broken and signals are blocked entirely.

You can cause this corrosive action to start if you handle your connectors and boards improperly. The wrong way to handle printed circuit boards is shown in Fig. 5-6.

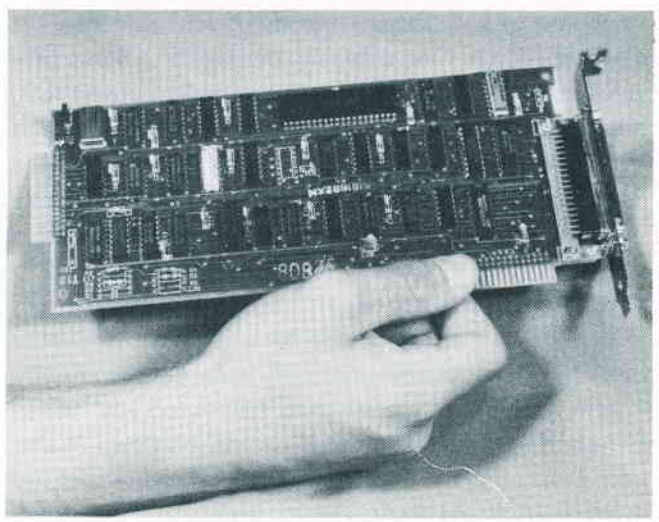


Fig. 5-6. Handling a printed-circuit board the WRONG way can cause corrosion.

Note: Never touch contacts with your fingers. The oil on your fingers contains enough sodium chloride to begin oxidation action on those pins.

Corrosion Prevention

While metal gates and cars can be spray painted to prevent rust (oxidation), this is not an option for preventing corrosion on circuit pins and connectors. The best preventive action is cleaning. By keeping the contacts clean, you can deter oxidation build-up.

You can clean the pins on some chips by reseating the chips periodically. Chips have a habit of working up out of the sockets after extended use. Turning off all the power and carefully pushing these devices back down into their sockets will act to clean the pin surface, restoring (or ensuring) good electrical contact.

Caution: Always turn off the power and touch a grounded surface before touching anything inside the IBM PC.

Oxidation of the contacts of connectors on the motherboard and disk electronics boards can be cleaned with a soft rubber eraser, a solvent wipe, or a contact cleaner spray.

Caution: When rubbing to clean contacts, always rub along the pin (lengthwise). Rubbing lengthwise on the pins prevents accidentally pulling a pin contact up off the board.

Do not use emery cloth or any abrasive cleaners to clean the contacts. If you use a rubber eraser, keep eraser dust away from the computer.

Solvent wipes are available as part of cleaning kits sold by many computer supply companies. These wipes can clean and then lubricate the contact surface with a film that helps seal out atmospheric corrosion without interfering with signal flow. Most solvent wipes are individually wrapped in small packages much like the hand towelettes you get in some restaurants or on some airplane flights.

Spraying the pins with a contact cleaner spray (available at most electronic parts stores) is also an effective corrosion preventive. Contact cleaner wipes and spray are the best methods for removing an oxidation layer.

There is a trade-off between preventing corrosion and preventing electrostatic discharge, because corrosive action is reduced with a reduction in the relative humidity, but ESD increases.

Manufacturers of electronic equipment are aware of the effects of corrosion, and most connectors are made of a combination of metals that resist corrosion but are good conductors of electrical signals. You can choose the type of connectors to use for your cables. You can buy cables and connectors with tin alloy plating on the pins or with a thin gold plating. Although you will pay more for the gold-plated connectors, they provide superior contact reliability. Gold-plated contacts don't wear out as tin alloy surfaces do, but even the tin surfaces take a long time to wear away; so a sound, consistent cleaning program can really help.

One final note on the subject of corrosion: high temperatures will increase the corrosive action in the IBM PC system. It helps to keep your computer tuned up and running cool.

MAGNETISM

The effects of magnetism are especially important in disks and disk drives, since these two parts of the computer system are designed to operate on magnetic principles.

Each floppy disk is coated with a magnetic oxide with millions of tiny pole magnets randomly positioned on its surface. As the drive write head passes over the disk surface, a magnetic force is induced in the head by the disk drive electronics, causing the pole magnets on the disk surface to line up according to the digital information being converted to voltage pulses in the head. This is "good" magnetism.

Sources of Magnetism

The voltages used in monitors and television receivers produce strong magnetic fields. These can be bad. If you accidentally place one of your disks in the field, the tiny pole magnets on your disk's tracks can change their alignment. Then, when your disk drive tries to read the disk, the head cannot understand or can misinterpret the information on the disk, and you get garbage or BDOS read errors.

Magnetic flux is caused by the presence of a high (115 V) voltage in computer display monitors and televisions. A color television produces the strongest magnetic flux, but high-voltage areas of monitors, printers, telephones, ballasts in fluorescent lights, and even power strips can be sources of offensive flux and can cause intermittent data loss. The strength of the flux field depends on the strength of the voltage, which can fluctuate with the amount of power being required by the equipment.

Preventing the Damaging Effects of Magnetism

To avoid the damaging effects of magnetism, keep your diskettes, and even your information cables, away from power sources and magnets.

DISK MAINTENANCE

Two valuable components in any computer system are the mass storage devices (disks) and the disk drives. IBM PC systems use 5¼-inch floppy disks as the mass storage medium. Technically they are called *diskettes* to differentiate them from the *disks* used in 8-inch drives, but the terms "floppy" and "disk" are so commonly used with the 5¼-inch diskettes that the term "disk" will suffice. Since disks and disk drives are such critical components in computer systems, it makes sense to do all you can to protect and maintain them.

The read/write head in an IBM PC disk drive rides on the surface of the most vulnerable part of the mass storage system, the floppy disk. Floppy disks are made of Mylar or polyethylene terephthalate and coated with a magnetic iron (ferric) oxide. The oxide-coated Mylar disk or "cookie" is placed in a protective polyvinylchloride jacket (refer to Fig. 5-2).

Disks make different sounds in the disk drive, depending on the type of liner used. Some types of liners provide more wiping action than others. The disk may sound like coarse sandpaper when it spins in the drive, but that doesn't mean the disk surface or the drive is being harmed. A louder disk may actually be doing a better job than a quieter disk.

Harmful Substances

Disks are pretty sturdy things, but they are sensitive to magnetic and electrical fields, high temperature, low temperature, pressure, bending, and dust. Dust and little airborne fibers are particularly bad for your disks. With the drive read/write head riding on the surface of the disk, any tiny piece of "junk" lying on your disk looks like a huge boulder to the head. A piece of your own hair is about 40 microns (.0015748 inch) thick. A hair is a huge obstruction to the disk drive head. Even dust and fingerprints on the disk surface can be obstacles to the even movement of the disk under the head. To protect the disk medium and the head, each disk jacket is lined inside with a dust catching synthetic fiber. As the disk is rotated inside the drive at a whopping 300 rpm, dust and other particles that may have slipped inside the jacket or settled on the disk are quickly swept off the disk by the liner material. But a build-up of too many particles can overload this protective system.

Another substance that is harmful to disks and disk drives is tobacco smoke. The tars and nicotine that filter up into the air from the ends of cigarettes and cigars (or out of the lungs of smokers) can settle on your computer system. These sticky chemicals form a gummy ash build-up on any exposed surface—including your disks and your disk drives. This material gums up the drive, eats into the read/write head, and scratches the surface of your disks. The effect is similar to taking a metal file to your favorite record album. Avoid smoking or allowing smoking in your computer area. If you can't do this, then clean your system more often.

Disks are further protected by the paper storage envelopes, or sleeves, into which the square disk jackets are inserted. Use these envelopes. Don't let your disks lie around outside their envelopes inviting dust and dirt trouble.

Not all disks are created equal. Some disks are manufactured to better standards and with thicker magnetic oxide coatings. Naturally, these disks are more expensive. Less expensive disks have thinner oxide coatings and shed their oxide layers easily, further reducing their effective life. Compare disk specifications before you buy.

Depending on the quality of your disks, the cleanliness of your computer area, and the condition of your disk drive, your disk life could be as short as a week or as long as 17 years (70 million revolutions). Assuming the quality, cleanliness, and condition factors are favorable, disk life is estimated on actual rotations while the disk read/write head is in contact with the disk surface, rather than on total time of existence.

As the drive head rides on the disk's oxide surface, it causes tiny bits of oxide to rub off the disk. Most of these loose oxide particles are caught and held by the liner, but some of the oxide sticks to the head. Gradually an oxide layer builds up. This oxide layer has two effects on system operation: (a) it makes the head less sensitive to reading and writing data, and (b) it causes an abrasive action on the disk surface. As the oxide layer builds up, it becomes ragged. This roughness scratches even more oxide off the disks, until the oxide on the disk surface is too thin to support data storage. When oxide is missing from the surface, "drop-outs," or spots where data can no longer be stored, develop. Then the disk fails to read or write properly, and it becomes useless.

Keeping this oxide layer from building on the read/

write head will help extend the life of your disks. The better disks are less likely to spin off oxide particles, so the head stays cleaner longer, and the disks last longer.

Extending Disk Life

Here is a summary of what you can do to help extend disk life.

1. Buy name-brand disks. Avoid "bargain" disks. The $7 disk should last 7 times as long as the $1.50 disk.
2. Never touch the disk surface.
3. Never slam the disk drive door closed on a disk. You could press the disk-centering hardware into the disk surface instead of the disk hole.
4. Store disks in their protective jackets.
5. Never write on a label that's already mounted on a disk. Ball-point pens and pencils can cause indentations in the disk surface. Mark the label first, and then put it on the disk jacket.
6. Store disks in a cool, clean place.
7. Back up everything.
8. Store working disks and backup disks in different places.
9. Don't lay disks in the sun. They warp just as stereo records do.
10. Never allow smoking near your disks or your drive. Smoke lets tars settle on the disk surface (and inside your drive), gumming up the works.
11. Never set disks by monitors or televisions. The magnetic fields can erase data.
12. Avoid placing disks near vacuum cleaners or large motors. Even freezers and refrigerators have compressor motors that can alter data on your disks.
13. Don't bend or fold disks.
14. Store disks vertically. Storing disks horizontally can cause the disk to bind in the jacket, preventing proper speed of rotation, causing scratching of the disk surface, and resulting in intermittent failure.
15. Don't put disks through airport x-ray machines. Hand them to the security guard for inspection, so that they can bypass the x-ray inspection process.

Flipping the Floppy

Before we get into PM for disk drives, for those of you with single-sided drives, let's clear up a few misconceptions about disk use in a single-sided disk drive system. Many people believe that you can flip your disk over, cut an additional write-protect slot into the jacket, and then use the flip side of the disk to store more programs and data. They contend that using the back side of a disk in a single-sided drive system won't cause any problems with either the disk or the drive. Some reputable magazines and IBM users groups support this idea. Disk drive manufacturers strongly disagree. Who is correct?

When the door is closed on a single-sided disk drive, a pressure pad comes in contact with the disk, pushing it against the drive read/write head, which rides on the surface of the inserted disk. The drive motor rotates the disk in only one direction, at a speed of 300 rpm. As the disk wears, tiny bits of oxide come off the disk and are swept up and held by the liner inside the disk jacket; or they build up on the drive read/write head. Some oxide even builds up on the pressure pads.

Disk manufacturers test both sides of a disk, and if one side fails they often place the defective side in the disk jacket so that only the good side is exposed when the platter is marketed as a single-sided disk.

The disk jacket liner, catching up most of the oxides, dust, and dirt that gets on the disk surface, functions the same way as a lint brush being used on a dark wool suit. Brushing in one direction removes the lint and hair, but brushing in the opposite direction, wipes the collected lint back onto the suit. The same thing happens with disks in lined jackets. As the drive spins the disk in one direction, the lint, dust, and whatever else is on the disk surface is wiped up by the liner. If the disk is turned over and rotated in the opposite direction, the "junk" collected by the liner gets wiped off and back onto the disk. The excess dirt in the liner scratches more oxide off the disk. You begin to experience "drop-outs" in the areas of the disk that no longer have enough oxide left to store digital information. The read/write head gets dirty even faster; even the pressure pad build-up increases.

Even the act of cutting an additional write-protect notch in the disk jacket causes problems. The polyvinyl chloride jacket material shatters when cut, producing tiny shards of polyvinyl chloride that can scratch the disk surface and add to the material collected by the liner.

Another problem occurs with the pressure pads themselves. When you flip your disk, you are placing the "good" side of your disk in contact with the rough, oxide layers built up on the pads. Rotation of the disk now causes scratches on that side of your disk.

One last additional hazard caused by writing data on both sides of a disk is the potential for magnetic field "bleed-through." Writing on one side of the disk creates a magnetic field which affects the data stored on the opposite side of the disk. Bleed-through is one indication that a disk is wearing out. Disks that are manufactured for two-sided storage have slightly thicker magnetic oxide coating, reducing the risk of bleed-through.

The evidence seems clear. You can use both sides of a disk, but you do so at a certain risk.

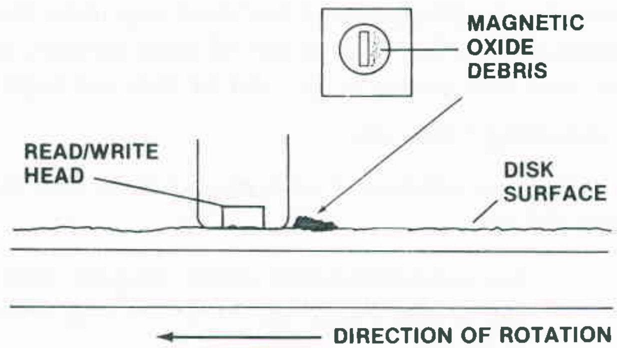


Fig. 5-7. Oxides are wiped off the disk surface and build up on the head surface.

DISK DRIVE MAINTENANCE

What kinds of PM are there for disk drives? If you owned a $100-million-a-year company using hundreds of disk drives, you could plan for and purchase a $50,000 disk drive tester that tests four drives at a time using dual microprocessers. But you probably don't own a $100-million company. So how can you test and maintain your own disk drive(s) without this expensive equipment?

Disk drive manufacturers' representatives insist that "officially" there isn't any PM required for disk drives. They describe head cleaning as the only routine maintenance that can be done by a novice, although even this is not officially recommended. Why not? Suppose you were a disk drive manufacturer with lots of repair and testing facilities. Would you be inclined to recommend owner-conducted maintenance that would make your drives last years longer before repair was required? The repair business is big business. The less maintenance you do, the sooner your system will start giving read/write errors and the more work you will provide for repair companies.

Here are some facts about disk maintenance procedures:

1. Heads need cleaning to remove the oxides from your disks that build up on the leading edge of the head (the side facing the direction of disk rotation), as shown in Fig. 5-7.
2. Head cleaning is a PM procedure you can do. Head-cleaning diskettes of various kinds are available. The "wet" diskette kind works with a cleaning solvent.
3. Some head cleaners are abrasive and can damage the head if they are used for too long. If you buy this type of cleaner, you must use the cleaner just long enough to remove the oxide build-up but not long enough to damage the head.
4. New nonabrasive head cleaners are being marketed. Two examples are Verbatim's Datalife head-cleaning kit, and Innovative Computer Products' Perfect Data head-cleaning kit. Both products use fabric-covered disks which are dampened with a cleaning solvent. With the one kit, you sprinkle cleaning solvent on the disk fabric and then insert the disk into your drive for spinning action head cleaning. The head-cleaning disk can be used as many as 13 times. The other kit has cleaning disks that are predampened and individually sealed. With this kind of system, you use a cleaning disk once and then throw it away, using another the next time. Both of these products work well.

   Since any cleaning disk works by rubbing action and chemical action between the disk fabric and the drive head, there is potential for abrasion to occur. So you must be careful not to leave the disk spinning in the drive for too long. A cleaning disk can be allowed to spin in a disk drive for 30 seconds with no apparent damage. With most cleaning disk kits, 45 seconds is too long to keep the cleaning solvent in contact with the drive head.
5. Drive heads can also be cleaned with alcohol and a cotton swab wrapped in a lint-free material (see Fig. 5-8). With manual alcohol-and-swab cleaning, you could accidentally scrub the pressure

pads by mistake, causing more problems than you're preventing. But if you're careful, manual cleaning can be effective.

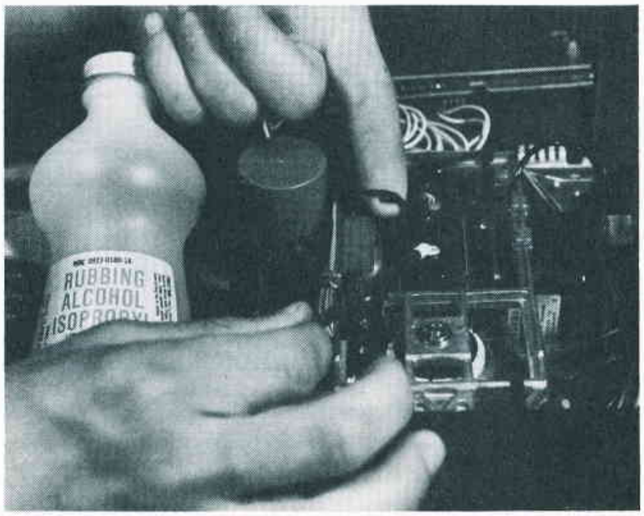


Fig. 5-8. Drive read heads can be cleaned using isopropyl alcohol and a lint-free swab.

Special cleaning material such as cellular-foam swabs and chamois leather cloth are good materials to use for manual head cleaning. Or you can use a piece of bed sheet wrapped around the cotton swab. Uncovered cotton swabs are dangerous because the cotton fibers can catch or pull away and lie in the drive or on the head, becoming cotton logs on a disk-surface highway, waiting to get swept into the drive head that rides on the surface of the disk. These fibers can also catch on the ferrite chip in the middle of the ceramic head, loosening it from its mounting and ruining the head.

Surgical isopropyl alcohol or methanol can be used as the cleaning solvent. The solvent used must not leave a residue when it evaporates, so most other alcohol solvents should be avoided. You can also use typewriter cleaner or trichloroethane. In all cases use plenty of ventilation and make sure the solvent has evaporated before you operate the drive.

6. How often the head must be cleaned depends on how much the drive is used and what types of diskettes are used. A high-quality diskette is good for about 3 million passes, or rotations, against a read/write head before enough oxide is worn off so that the head needs cleaning. The "bargain" disks are good for one tenth the rotational life. This means that instead of 167 hours of access time, you might get 16 hours or less before the head gets caked with oxide or your disk surface gets too worn to write to or read from. Now you know why your bargain disks don't seem to last very long.

   A useful rule of thumb for head cleaning is to clean the read/write head every 40 hours of disk operation. This means clean after 40 hours of rotational life if you're using standard disks. You could clean more often or even wait until you start getting read/write errors and then replace or clean the head.

7. Keeping the drive door closed unless you are inserting or removing a disk will help keep dust and dirt out. It also keeps unwelcome visitors (such as insects) from climbing into the drive.

Cleaning the Disk Drive Head

To clean the drive head using a cleaning disk:

1. Turn the computer power on.
2. Dampen the cleaning disk with the solvent supplied.
3. Insert the dampened cleaning disk in the drive.
4. Close the drive door.
5. If you are working in BASIC, reset the system (Ctrl-Alt, Del). With the cleaning disk inside the drive, the disk will simply spin, cleaning as it whirs along.
6. After 20 or 30 seconds, open the drive door, and remove the disk.
7. Turn off the computer.
8. Let the drive read/write head dry thoroughly before operating the system.

To Clean the Drive Head Manually

Tools required: Flat-head screwdriver
Phillips screwdriver
Protective pad
Adequate lighting
Tray to hold loose screws

1. Turn off power to the computer.
2. Disassemble the computer using the procedures found in the Appendix.
3. Disconnect the disk drive cable from the back of the drive.

4. Remove the two silver flat-head screws holding the drive tight to the chassis as shown in Fig. 5-9.

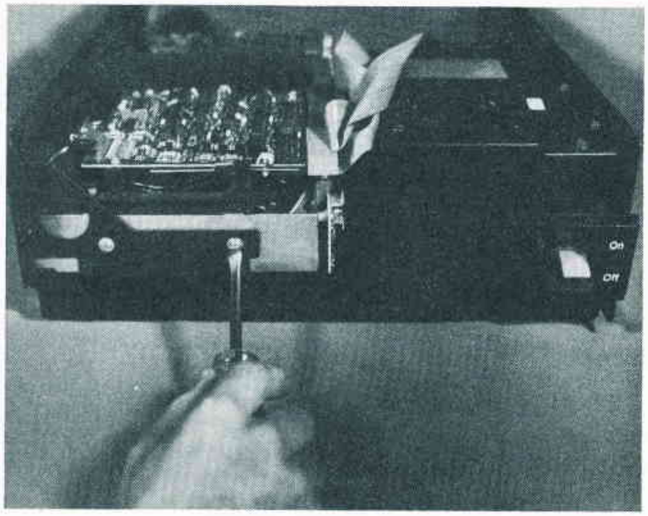


Fig. 5-9. Remove the two silver-colored flat-head screws holding the disk drive to the chassis.

5. Gently pull the drive forward approximately 2 inches from the front of the chassis.
6. Disconnect the power supply cable from back of the analog card.
7. Gently remove the drive from the chassis.
8. Carefully remove head cable(s) from the connector (located in the front right corner).
9. Carefully remove the two Phillips screws holding the analog card on the drive (located in the front on both sides) as shown in Fig. 5-10.
10. Slide the analog card toward the back of the drive until the card is free of the grooves in the drive mechanism. (You may have to wiggle the card gently to get it to slide.)
11. Lift up the analog card from the front.
12. Carefully lift the black head-load arm as shown in Fig. 5-11, and look for discoloration (build-up) on the surface of the pad, or on the read/write head below.
13. Using a special foam or wrapped cotton swab dampened with cleaning solvent, gently rub the head and the pad (refer to Fig. 5-8).
14. Let the surfaces dry completely before reassembling.

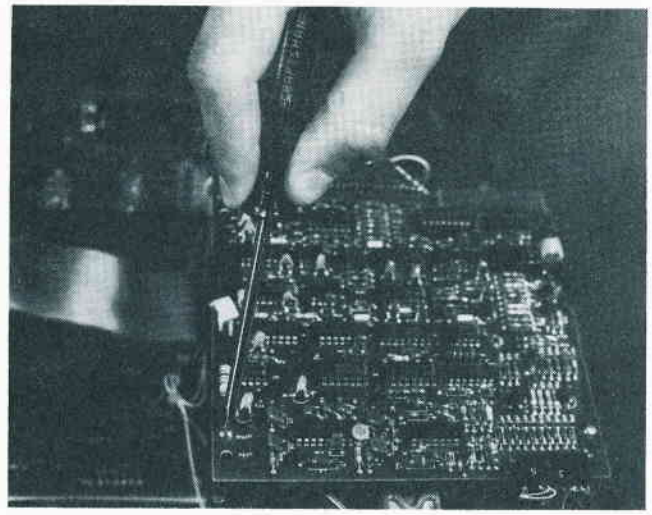


Fig. 5-10. Remove the two Phillips screws holding the analog card on the drive mechanism.

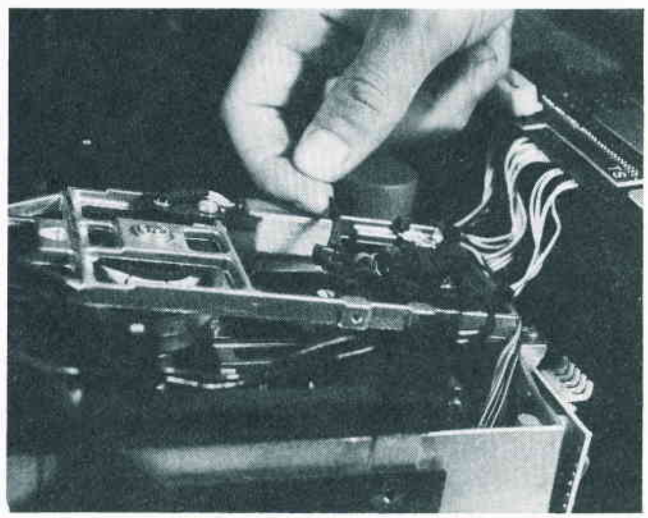


Fig. 5-11. Carefully lift the head load arm to expose the read head below.

15. When the head and pressure pad are dry, carefully slide the analog card back into the grooves in the drive mechanism.
16. Reinstall the two Phillips screws into the analog card (in the front on both sides.)
17. Reconnect the head cable(s), being very careful not to break or short connector pins.
18. Carefully push the drive mechanism back into the chassis until approximately 2 inches of the drive housing is still exposed.

19. Connect the power supply cable to the back underside of the analog card.
20. Push the drive all the way into the chassis housing.
21. Replace the two silver flat-head screws on the sides of the drive (refer to Fig. 5-9).
22. Reconnect the ribbon cable to the drive.
23. Power up the computer.
24. Place a copy of a program disk in the cleaned drive. (Have you waited until all the surfaces are dry?)
25. Close the drive door.
26. Load and run a program.
27. Reassemble the computer.
28. Restore the system to full operation.

Note: If you have any problems, refer to Chapter 4 in this book.

Disk Drive Head-Cleaning Interval

Cleaning your drive head is like changing the oil in your car, which you do when you feel you've driven enough miles or when the oil looks dirty. Some software manufacturers recommend cleaning heads every other week. Some repair technicians say clean every 6 months. Others suggest you don't clean your heads until the disk drive makes mistakes trying to read or write data. Since no hard and fast rule has been offered, I defer to experience as shown in Table 5-5.

Table 5-5. Disk drive head-cleaning interval

System Usage	Cleaning Interval
Over 6 hours each day	Weekly
Daily	Monthly
Light to moderate	Twice monthly
Occasionally	Every 6 months

If you live in an area that gets a lot of smog, you may want to clean the heads more often. In any case, it won't hurt for you to clean at least annually. Keep an operational time log, so if you begin to get read/write errors, you can check it to see whether the drive head is due to be cleaned. Some recommended operational log sheets are included in the Appendix.

Disk Speed Tests and Adjustments

Although this isn't mentioned by disk drive manufacturers as one of the PM operations you and I could do, a somewhat more detailed, yet handy, process is adjusting the disk drive speed. Variation in speed is caused by normal mechanical drive wear or by excessive moving and reconnecting of the drives.

Just as automobile engines need periodic checkup and engine retuning, disk drives benefit from correctly adjusting the drive motor speed. Your IBM PC disk drives rotate at 300 rpm and work with soft-sectored disks; the computer software identifies the beginning and end of each of the sectors on each of the tracks. No timing holes are used, as they are with hard-sectored disks. This makes the speed of rotation critical to the accurate synchronization of the software with the signals stored on the disk. If the speed is off by only 10 rpm, the drive may not be able to correctly read the disk.

Should the speed be incorrect, the data will be written in the wrong location on the disk. The next time you access that area on the track again, the computer will hang up and give you a disk error. While disk speeds between 291 rpm and 309 rpm should be acceptable for read/write operation, speeds outside this range cause intermittent or disastrous results. If the speed becomes slower than 270 rpm or faster than 309 rpm, any write action will erase the synchronization timing marks on the disk, making the disk useless unless you reinitialize it (wiping out the data you had already stored).

There are two ways to tune up your drive speed. You can adjust the speed using a disk speed test program or a standard room lamp. Both techniques require your removing the disk cover.

Disk Drive Disassembly

Tools Required: Phillips screwdriver
Flat-head screwdriver
Jeweler's flat-head screwdriver
Protective pad
Tray to hold loose screws

Note: If any of this seems difficult, have a repair service shop do the speed adjustment.

1. Turn power off to your computer.
2. Ground yourself to remove any electrostatic charge by touching a grounded surface, such as the metal switch on a nearby lamp.
3. Disassemble computer as shown in the Appendix.
4. Disconnect the drive cable from the rear of the drive.

5. Remove the two silver flat-head screws holding the drive tight (refer to Fig. 5-9).
6. Gently pull the drive forward approximately 2 inches out of the chassis.
7. Disconnect the power supply cable in the back of the analog card.
8. Pull the drive completely out of the chassis.
9. Set the drive mechanism on its side crossways on the top of the power supply.
10. Reconnect the drive cable and the power supply cable to the drive.
11. Locate the speed adjustment control potentiometer in the back middle of the drive as shown in Fig. 5-12.

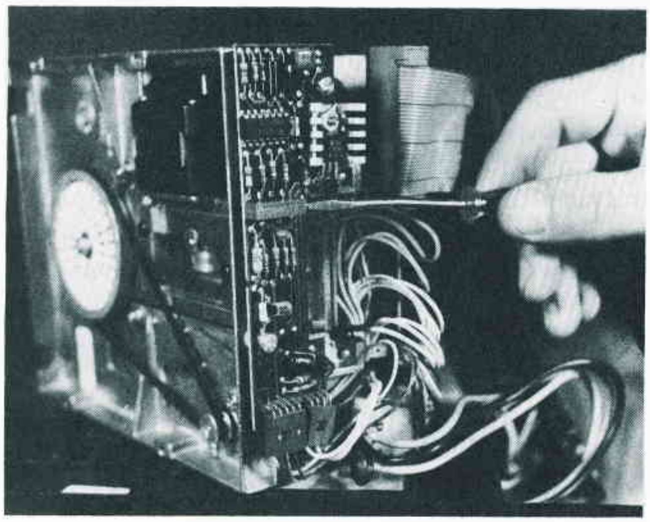


Fig. 5-12. The screwdriver is inserted in the speed adjustment potentiometer (R23).

You are now ready to conduct drive speed adjustment.

Method 1—Disk Speed Program

1. Reconnect the power cord to the computer.

   Caution: Be careful not to touch inside the drive mechanism or the electronics with power on.
2. Turn on the power to your computer.
3. Insert the disk containing a disk speed test program in the drive to be adjusted.
4. Close the disk drive door.
5. Boot the disk in the drive.
6. Follow the test procedures.
7. Most speed test programs display a graduated scale of some sort as shown by the example in Fig. 5-13. Using a jeweler's screwdriver or a "tweaker" (small screwdriver), slowly turn the speed control adjustment pot screw until the speed display shows the actual rotation time to be as close to 300 rpm as possible—within ±6 milliseconds.

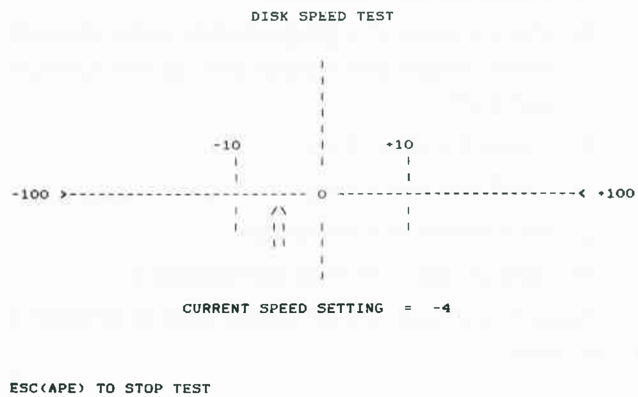


Fig. 5-13. Sample disk-speed test screen display.

8. Remove the disk.
9. Turn off the power to the IBM PC.
10. Disconnect the disk drive cable and power supply cable from the drive mechanism.
11. Push the drive mechanism into the front of the chassis until about 2 inches of the mechanism is left exposed.
12. Reconnect the power supply cable to the back of the analog card.
13. Push the drive all the way into the chassis.
14. Reinstall the two flat-head screws on the side of the drive.
15. Reconnect the disk drive cable to the drive.
16. Turn on the computer and test operate the drive.
17. Restore the system to full operation.

Method 2—Tuning Lamp

1. Disassemble the drive and set on its side as shown in Fig. 5-14.
2. Place a fluorescent light near the drive so it illuminates the speed strobe wheel on the bottom of the drive mechanism. An ordinary incandescent room lamp will work, but a fluorescent light is easier to use.

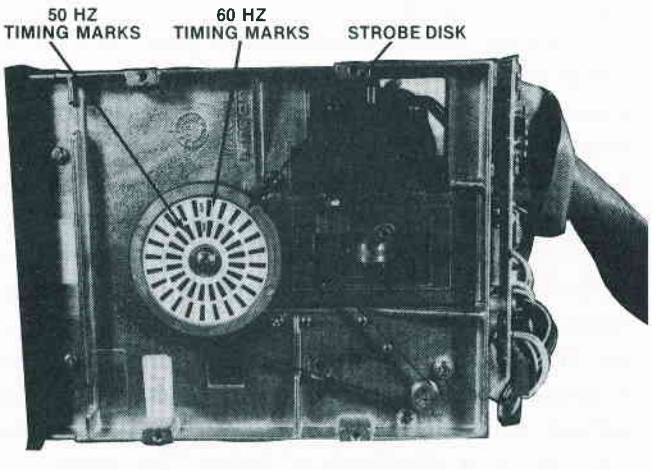


Fig. 5-14. The disk drive set on its side with the strobe wheel facing you.

3. Locate the timing marks on the strobe disk (see Fig. 5-14). The outer circle of markings is used for 60 Hz electrical systems such as that common in the United States. The inner circle of strobe markings is used with 50 Hz line power such as that found in Europe. This concept of speed adjustment is amazingly simple, and quite accurate. When you place the strobe disk in the light of a fluorescent lamp and cause the disk to spin, you will notice that the strobe disk marks slowly rotate in one direction or another, depending on whether the disk speed is fast or slow. This action is much like the effect seen with movie film when stagecoach wheels seem to be rotating in the direction opposite the movement of the coach. The wheels are rotating at a different speed than the film is moving through the projector so you see this strange effect. The marks on the strobe disk are spaced so they appear stationary when the speed is exactly 300 rpm.
4. With a lighted lamp near the drive, reconnect the disk interface cable to your computer.
5. Reconnect the power supply cable to the drive in back of the analog card.
6. Power up your computer.
7. Insert a blank, uninitialized disk in the drive and close the drive door.
8. After the computer goes into BASIC, reset the system (Ctrl-Alt, Del).
9. Observe the strobe wheel as the disk spins in the drive.
10. Using a jeweler's screwdriver or a "tweaker" (small screwdriver), adjust the speed control pot until the strobe disk seems to be sitting still.
11. Open the drive door and remove the disk.
12. Turn off the computer power.
13. Disconnect the disk drive cable from your drive.
14. Disconnect the power supply cable from the back of the drive.
15. Gently push the drive mechanism into the front of the chassis until about 2 inches of the drive remains exposed.
16. Connect the power supply cable to the back of the drive analog card.
17. Gently push the drive mechanism all the way into the chassis.
18. Reinstall the two screws holding the drive into the chassis.
19. Reconnect the drive cable to the IBM PC drive.
20. Turn on the computer and test operate the drive.
21. Restore the system to full operation.

Disk Drive Alignment

This procedure is not recommended for the novice. The alignment adjustments in the IBM drives set the positioning of the read/write head correctly over the tracks on the disk, adjust the disk stop guide, or adjust the collet hub that fits in the hole in your disks. These procedures require special equipment, including a dual-trace oscilloscope, special alignment disks, and various disk alignment tools usually available only to IBM repair technicians. If speed adjustment and cleaning don't clear up any read/write problems you may have had, take your drive into a service center for maintenance.

The most critical alignment adjustment is adjustment of the read/write head alignment, or tracking. Some programs require very accurate alignment of the head over the track. If the program loads fine but won't read data and the disk just spins, you may have a track alignment problem.

If you have to replace the electronics analog card in the drive, you should have the tracking checked. Each card is tuned for the drive, and a new card could affect the head tracking.

Alignment should be checked every year. The easiest way to accomplish this is to format two disks on two different drives whose speeds have been verified to be correct. Save some programs on each disk, using the same drive on which formatting was done. Read and write each disk with its own drive to make sure the individual drives work satisfactorily. Then switch disks and see if each disk works properly in the alternate drive. If one drive reads correctly while the other can't find the data or reads out "garbage," you know you have alignment problems.

Hard Disk Maintenance

Since hard disks are sealed in dust-tight enclosures, the only PM you can do on these devices is exterior cleaning and proper location to minimize noise interference problems. Improperly connecting peripheral interface cables has been known to generate so much RFI that some hard disk units over 6 feet away have failed to operate correctly.

USING HEAT TO SPOT POTENTIAL TROUBLES

There are two techniques you can use that employ heat detection to diagnose failing components inside your PC before they fail completely.

Thermal Imaging

A new troubleshooting and preventive maintenance technique uses the temperature of the components to determine the condition of the system much as a mother takes the temperature of her child to see if the child is ill. This technique is called *thermal imaging*, or *thermography*, and is proving to be a remarkably accurate preventive maintenance tool.

Imagine having an infrared picture taken of your personal computer system board, new and shiny, and operating on a certain program. Comparing this to a second photo taken a year later, when the system has started acting "flaky," shows you a new "hot spot" right in the middle of the board's RAM indicating that one of the memory chips is about to give out. Replacing this one chip will bring the system back up to peak operating potential.

Standard photography produces images or pictures from visible light; thermal imaging produces pictures from the invisible heat coming up off the surface of objects. It's a cost-effective maintenance procedure in many large industrial plants.

Several companies sell expensive thermograph machines that produce heat images, or "heat maps," in vivid color on high-resolution red-green-blue (RGB) monitors. These units can measure temperatures all over a printed-circuit board with a sensitivity of 0.1° C over a temperature range of 0–200 degrees. If any board has an area on it with a temperature outside specific limits, a computer comparison of the suspected board temperature image with normal board baseline temperatures will immediately point out the fault. Faults can be shorts, opens, and even marginally defective components. These thermograph units can even diagnose failures in high-density circuit boards—all without touching the board. Unfortunately, these machines cost thousands of dollars. But there's an alternative.

If you own a 35mm camera, you could try your own thermal imaging using infrared (IR), heat-sensitive film. Either color or black and white should work. A good black-and-white candidate is Kodak HIE-135-36, ASA-25 IR film. Color IR film is about 50 percent more expensive. A special filter (Wratten number 87, 88A, or 89B) makes the picture more effective.

With the PC open, and running a simple program that continuously repeats, let the computer warm up for about 2 minutes so that the components reach their usual operating temperatures. Then take a picture of the motherboard. Background light won't matter, because the film is sensitive to heat, not light. Take several shots.

Then periodically, every 6 months for example, or when the system starts acting up, take another series of pictures with the same program running in the computer. A comparison of the before and after pictures will quite likely point out where your system is wearing out or has failed already.

Heat-Sensitive Liquid Crystal

Another useful technique for finding potential or actual troublespots in your computer is the use of *liquid crystals* (LCs). These organic compounds, derived from cholesterol, react to changes in temperatures by changing color. They provide a visual method for testing and evaluating the IBM PC circuit boards.

Liquid crystal is available as a laminated (pressed layer) film or as a liquid solution. The liquid solution is recommended for circuit boards. The temperature range for measurement can be specified in increments of 1 to 50° C within an operating range up to 150° C.

Two types of these liquid crystals are available today—the *temperature-limited liquid crystal* (TL-LC), which returns to its original shade upon cooling, and the *recording temperature limit liquid crystal* (RTL-LC), which remains an ash-gray color until you brush or rub it, causing the original shade to return.

The nondrying opaque liquid is applied by brushing it directly on the surface of solder joints, chips, other circuit board components, and connectors. The solution has a very high resistance, so it won't short out anything on the board.

When the PC is energized, the heat generated as the circuits function causes the liquid crystal solution to change color according to the temperature sensed by the solution. Hot spots turn indigo blue, cooling to blue, turquoise, green, through yellow and orange, to red and finally gray.

This LC solution is useful for testing printed-circuit components for failing chips, solder shorts, and even solder connection bonds that are breaking apart. The completeness of a bond can be detected by the color changes during normal operation; air in the bond cools more slowly than the surrounding metal. A dark surface shows the color changes best so the manufacturer adds black dye to the LC solution.

Typically the surface to be tested is first cleaned of all oils and dirt, since these contaminants will give incorrect color readings. Then it is dried, and the LC solution is brushed or sprayed onto the components and board, leaving a thin, even coat. When the circuit is powered up, the rainbows of colors pinpoint the hot spots on the board or components. If the heat generated at one place on the board doesn't follow the normal circuit heat-up pattern, a failure in that component area can be predicted. Excessive heat generation from connectors indicates a poor connection.

When the test is complete, the solution can be wiped off with a lint-free cloth. The solution won't short out or contaminate the circuit board or the components.

A testing kit including sheets of film, different temperature-range liquid solutions, an aerosol can of black paint, applicator brushes, a sprayer, and solvent for surface and sprayer cleaning is available from Liquid Crystal Applications, Inc. in Clark, New Jersey for about $250.

DISPLAY SCREENS AND HEALTH PROBLEMS

This subject has been bantered about for 15 years as hobbyists, military and civilian radar operators, and, currently, word processing operators struggle for answers to some nagging questions. Will long periods of staring at the face of a CRT screen damage the eyes? Is the radiation emitted by the CRT tube dangerous to the user? Let's take these questions in reverse order.

CRT Radiation

A CRT that makes characters and shapes on its screen by sending streams of electrons toward a phosphor-coated surface (the back or inside of the screen) does produce radiation. Two types of radiation are produced. Light radiation, which becomes the characters we look at, and low-level x-radiation.

The U.S. government has placed limits on the amount of x-radiation that can be allowed to escape from the face of a CRT. This limit is 0.5 milliroentgens per hour, measured about 2 inches out from the screen. Manufacturers of CRTs added strontium and lead to the glass panels in televisions and monitors to eliminate almost all escape of x-radiation. Many intense tests were conducted by government and civilian organizations to determine how much radiation is emitted by video display terminals. The results were very encouraging. There was no evidence of damaging radiation coming out of any of the displays tested. Measuring instruments recorded more radiation in the sunlight than in the CRT display light. The overwhelming conclusion of these researchers is that radiation from video displays doesn't threaten our vision.

Eyestrain and Neck and Back Strains

Eyestrain and neck and back strains can be related to how we use our computer systems. Eyestrain can also be caused by what type display we use. Older screens display harsh white letters. Looking at a high-contrast screen of letters and numbers for a long time can cause eye fatigue, headaches, and neck and back strain. The development of new CRT phosphors has made green and now amber displays possible, significantly reducing eyestrain problems.

Room light reflections were also linked to eyestrain. Display terminal users should work in a well-lighted room and use nonreflective surfaces on their CRT display screens.

There is a feeling among some optometrists that many computer operators do not naturally point both eyes so the eyes focus on the screen surface. Their eyes actually point (converge) a few inches in front of, or behind, the screen. The brain compensates for this and makes the eye muscles work to focus the eyes at the screen. Since this is an unnatural condition for the eye muscles, strain occurs and can cause headaches. Special glasses for computer use can correct this problem.

Eyestrain can also occur when you set your display monitor to one side of your keyboard so that you view the screen at a slight angle. The distance from eye to screen is slightly different for each eye, causing the eyes to focus separately. This places strain on eye muscles. If the user works for an extended period of time in this position, the eye muscles become fatigued. You can also get neck and back strain from working like this. It's best to position the CRT so that you look straight ahead to view the display screen.

Neck and back strain, and even some emotional problems, have been related to long periods of using a display screen. These issues are being resolved by redesigning the operator station, the desk, or even the room itself. Poorly designed desks and poor working environments affect the quality of the work done by display terminal operators. In addition, managers sometimes fail to apply good work practices for people "stuck" on a console for hours on end. Since most managers use computer screens a limited part of each day, they don't appreciate the problems that full-time computer operators experience. This may explain why many managers don't understand how display screens affect workers and why they may be unsympathetic to complaints.

To solve workers' problems, new displays are being designed and work concepts are being revised. There are more display monitors that can tilt and swivel to improve user comfort. More computers are being introduced with detachable keyboards. Monitor height positions are becoming adjustable. Glare-reducing screens have become standard in new displays. Room lighting is being redesigned for optimum display-screen viewing. Work conditions are being modified to include frequent rest breaks, training classes are being conducted to educate management and employees in the proper use of video terminals, and company-provided computer-use glasses are being offered. Business has made great strides in reducing user problems.

You can learn from the long-term experiences of computer users and act to reduce the probability of your own eyestrain or neck or back strain:

- Use a hard-back chair instead of a soft, "cushy," slouch-inducing recliner.
- Look straight ahead at the screen (line of sight perpendicular to screen).
- Take frequent, short rest breaks.
- Take a moment to stretch. Develop some simple physical exercises to move unused muscles.
- Move away from your computer system for a few minutes each hour. This gives the eyes a rest and can often clear the brain for the arrival of another great idea.
- Keep the room well lighted but not harshly bright. Try a desk lamp with an incandescent bulb shining on your work and keyboard area from the side. You can also keep an overhead light on for background lighting and to cut glare.
- Set your display unit at a height that feels comfortable for viewing. You'll know if it's correct after a few hours at the keyboard. Adjust the display height as necessary.
- Have your eyes examined at least annually (every 6 months is better). If you wear glasses, the doctor can prescribe lightly tinted lenses (light blue or light green), which help to reduce eyestrain.
- Increase your intake of foods high in vitamin A (carrots and squash, for example—the "yellow" foods).
- Keep your equipment clean and in good operating condition.

There are over 10 million video display units in use today, and twice this many are expected to be in use within 2 years. As prices come down, perhaps it's time to consider trading in that old, clunky black-and-white display for a new $100 green or amber unit that will serve you better.

SUMMARY

This chapter has covered aspects of routine preventive maintenance that can be used to keep the IBM PC system in peak operating condition. It discussed six major contributors to computer system failures: excessive temperature, dust build-up, noise interference, power-line problems, corrosion, and magnetic fields. For each of these factors, one or more preventive countermeasures was presented. You learned that floppy disks are uniquely constructed to be protected from dust and dirt, discovered how disks and disk drive read heads can be damaged, and, most important, learned how to extend the life of disks and disk drive systems. You also learned two interesting ways to use heat for locating potential or existing circuit failures. Finally, you learned that display-screen-caused eye, neck, and back problems can be prevented.

CHAPTER 6

Advanced Troubleshooting Techniques

In Chapter 6 you will learn advanced troubleshooting techniques. You'll be introduced to the repair technician's "tools of the trade." Like other parts of this guide, Chapter 6 is full of "meat and potatoes" information to help you keep your PC system in peak operating condition.

In earlier chapters you learned the basic techniques for troubleshooting most IBM PC failures. You learned how to recognize the various components of your computer, and you discovered three ways to find failures.

- The hardware approach
- The software approach
- The IBM-Easy approach

In the **hardware approach**, you use troubleshooting tools such as logic probes and logic pulsers to step through a circuit. This requires test equipment and some knowledge of digital electronics.

The **software approach** is a troubleshooting method used widely by IBM PC repair technicians As long as the disk drive boots up properly, diagnostic software is effective at finding chip failures.

The **IBM-Easy approach** is to use the troubleshooting guides in Chapter 4 to quickly pinpoint what might be chip failures. If you conclude that the problem is not a chip and you still want to locate the failed part, you can use the techniques discussed in this chapter to test the rest of the components in the suspected failure area.

TOOLS OF THE TRADE

When the problem can't be solved using flowcharts and pictures, repair technicians reach for help—they reach for their "tools." These tools are not only the tiny screwdrivers (tweakers), the diagonal cutters (dykes), and the soldering pencil. They also include electronic test equipment—various meters (VOM, DVM, DMM), logic probes, logic pulsers, current tracers, clips, oscilloscopes, and logic and signature analyzers.

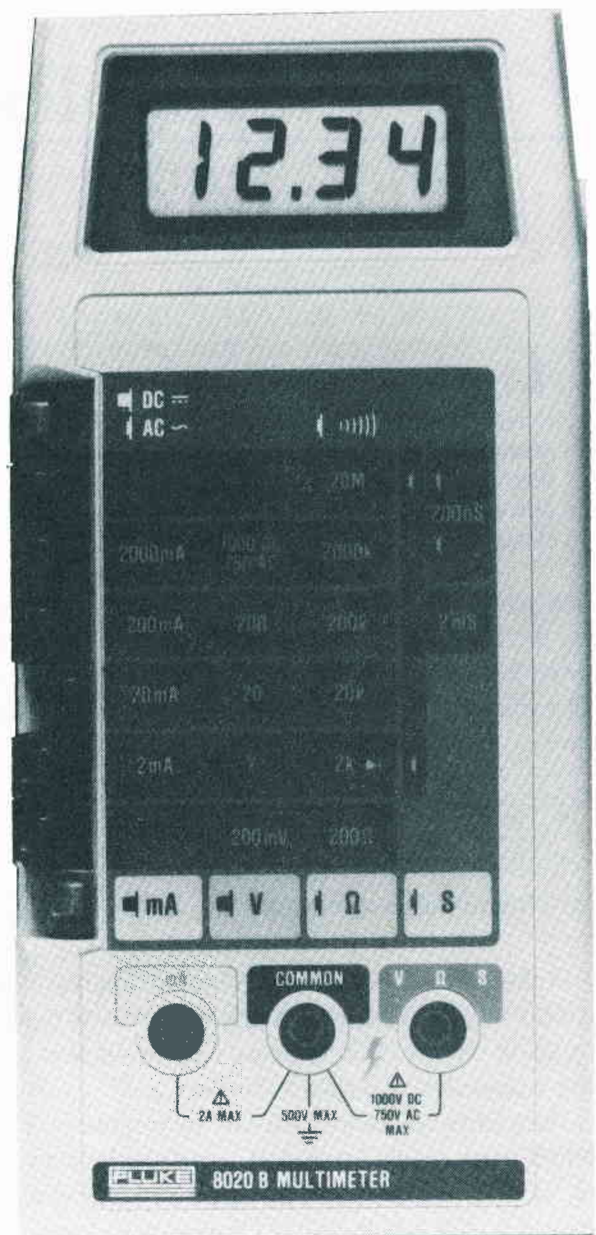
Meters

Electronic measurement equipment has improved a great deal over the years, markedly improving your ability to test and to locate circuit troubles. Twenty years ago, a meter called a VOM (volt-ohm-milliammeter) was used to measure the three parameters of an electric circuit—voltage, resistance, and current (Fig. 6-1A). Then came the VTVM (vacuum-tube-voltmeter). It wasn't long before electric circuits made room for electronic circuits. Digital circuits replaced analog circuits in many applications, and new meters appeared for troubleshooting, using some of the new digital capability in their design. The DVM (digital voltmeter) and DMM (digital multimeter) (Fig. 6-1B) quickly became the preferred measurement devices for many technicians because they offered capabilities better suited for electronic circuit testing, including increased accuracy. These meters have characteristically high input impedances (resistances), so they don't load down or draw down a digital circuit, in which the voltages and currents are far lower than those found in analog circuits.

Two kinds of changes affected the types of tools used in troubleshooting and repair. First, vacuum tubes were replaced by solid-state devices such as transistors and the integrated circuit (IC), or chip. Second, circuits themselves became smaller, with more components packed compactly into less board area. One needs only compare the early radios and televisions (standing 4 feet tall and weighing 40 pounds) with the wrist radios and now the wrist televisions of today to recognize that electronic circuits are smaller, more complex, and more difficult for test-probe access.

Electronic advances always lead to electronic opportunities, and clever test equipment designers soon came up with devices that allowed digital circuit testing without fear of inaccurate readings caused by circuit overload, or circuit failure caused by bulky test

A. Volt-ohm-milliammeter (VOM);



B. Digital multimeter (DMM).

Fig. 6-1. Two types of meters commonly used in troubleshooting.

probes shorting two pins or wires on a packed printed-circuit board.

The Logic Clip

The logic clip, a digital circuit testing device, is shown in Fig. 6-2. This handy tool fits over an IC and has exposed pins at the top. Measuring or monitoring probes or tiny clips can be attached to the pins to determine the logic level on any pin of the device under test.

Another type of logic clip has a built-in monitoring capability (Fig. 6-3). Instead of exposed pins, the top of the clip is lined with two rows of light-emitting diodes (LEDs), which continuously display the logic condition of each pin on the chip. The LEDs are turned on (indicating a logic 1) by power from the circuit under test. All the pins are electrically buffered so the clip doesn't load down the circuit being tested.

Caution: When using a logic clip, turn power to the circuit off, attach the clip, and then turn power on. (This helps prevent accidentally shorting out the chip.)

Logic clips can be obtained in several varieties—to work with almost all logic families, including TTL and CMOS—and in voltages up to 30 volts DC.

To use the clip, squeeze the top (LED) end to spread the pin contacts, and slip the clip over the top of the chip to be tested. When power is applied to the circuit, the LEDs will indicate the logic level at each pin on the chip.

Logic clips can be used on ICs with up to 16 pins, or 80 percent of the ICs on your IBM PC system board.

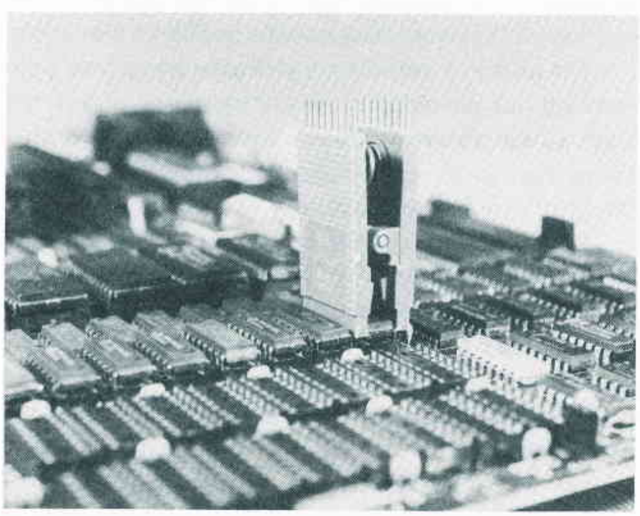


Fig. 6-2. A popular type of logic clip. (Pomona Electronics Division of International Telephone and Telegraph Corporation)

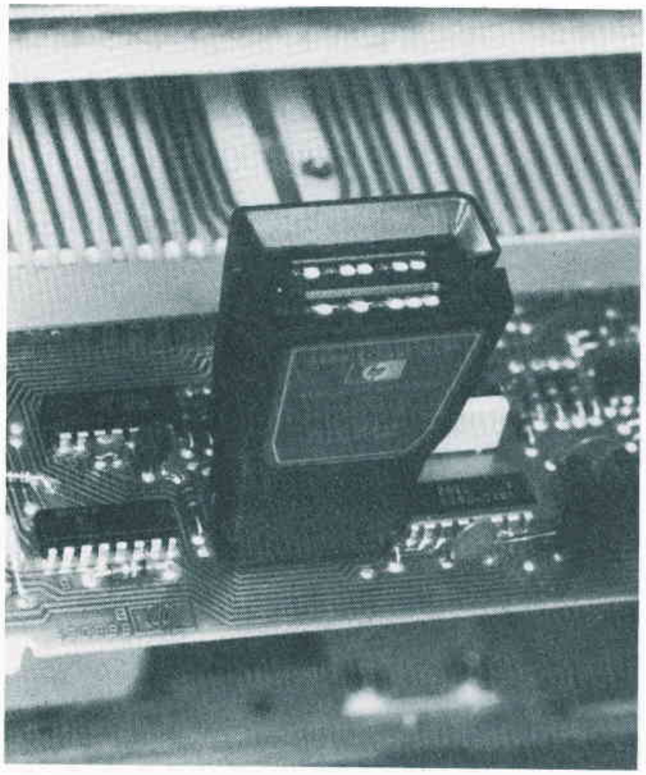


Fig. 6-3. This logic clip gives visual indication of the logic condition at each pin. (Hewlett-Packard)

The Logic Probe

When you want to really "get into" your circuit, you can use a logic probe. A blown chip can't be repaired, but the logic probe can tell you which chip has failed so you can replace it.

The logic probe shown in Fig. 6-4 is the most widely used tool for this kind of analysis. It can't do many of the things complex test equipment such as logic analyzers can do. However, the high frequency of chip failures in electronic circuits, the simplicity of the probe, and the ability to rapidly troubleshoot in an energized circuit make this tool ideal for 90 percent of your fault-isolation needs.

When the tiny tip of the probe is placed against a pin on a suspected bad chip, a test point, or even a trace on a circuit board, an indicator light near the tip of the probe tells you the logic state (level) at that point. The metal tip on most logic probes sold today is protected against damage from accidentally touching a source of higher voltage (up to 120 volts AC for 30 seconds) than that of logic gates (+5 volts).

Some probes have two lights built in near their tip—one for logic HIGH and the other for logic LOW. The better probes can also tell you whether the test

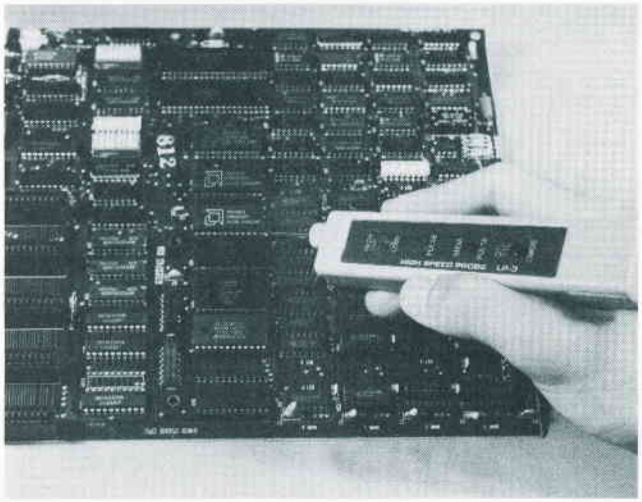


Fig. 6-4. The logic probe is the most widely used tool for circuit-board analysis.

point has a pulsing signal present. They can also store a short pulse burst to tell you if a glitch or spike has occurred at that point. If you're planning to buy a logic probe, be sure it will work with the logic families of the chips you plan to analyze.

The ability to touch a point with the probe tip and directly determine the condition at that point for diagnostic analysis, and the ability to store pulses make this device easy to use and universally accepted as the proper diagnostic tool for all but the most complex digital troubleshooting. Other tools force you to attach the measurement probe and then look away at some display to read the condition. The logic probe displays the condition near the tip of the probe itself.

The logic probe in Fig. 6-4 provides four indications:

- Lamp OFF for logic LOW (logic 0)
- Lamp ON bright for logic HIGH (logic 1)
- Lamp DIM for floating or tri-state
- Lamp flashing for pulsing signals

Power for the probe comes from a clip attached to a voltage point on the circuit under test. Another clip attaches to ground, providing improved sensitivity and noise immunity.

Probes are ideal for finding short-duration, low-frequency pulses difficult to see on an oscilloscope, but more often they're used to quickly locate gates whose output is hung, or locked, in a HIGH or LOW condition.

A useful method of circuit analysis with the probe is to start at the center of the suspected circuit and check for the presence of a signal. (This of course assumes you have and can use a schematic of the circuit.) Move backward or forward toward the failed output as shown in Fig. 6-5. It doesn't take long to find the faulty chip whose output isn't changing.

The only limitation of logic probes is their inability to monitor more than one line.

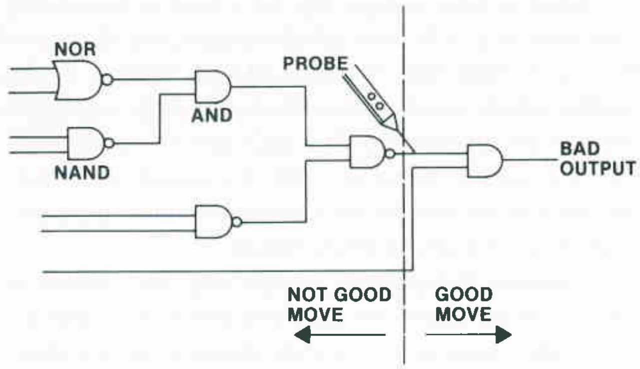


Fig. 6-5. Circuit analysis starting at the center of a suspected circuit.

The Logic Pulser

If the circuit under test doesn't have a pulsing or changing signal, you can inject controlled pulses into the circuit using a logic pulser (Fig. 6-6). These handy devices are portable logic generators.

When activated by a pushbutton or slide switch, the pulser will sense the logic level at the point touched by the tip and automatically generate a pulse or series of pulses of the opposite logic level. The pulses can be seen on an LED lamp built into the handle of the pulser.

The ability to introduce a changing signal into a circuit without unsoldering or cutting wires makes the logic pulser an ideal companion to the logic probe. These two tools used together permit step-by-step stimulus/response evaluation of sections of a circuit.

Fig. 6-7 shows several ways to test logic gates using the probe and pulser. Assume the output of the NAND gate remains HIGH. Testing inputs 1, 2, and 3, you find them all HIGH. This condition should cause the AND gate output to go HIGH, producing a LOW out of the NAND gate. Something is wrong. Placing a probe at the AND gate output, you discover the level is LOW. It should be HIGH. Now, which gate is bad?

To find out, place the probe on the NAND (gate B) output and the pulser on the AND (gate A) output (NAND gate input) as shown in Fig. 6-8. Pulse this line.

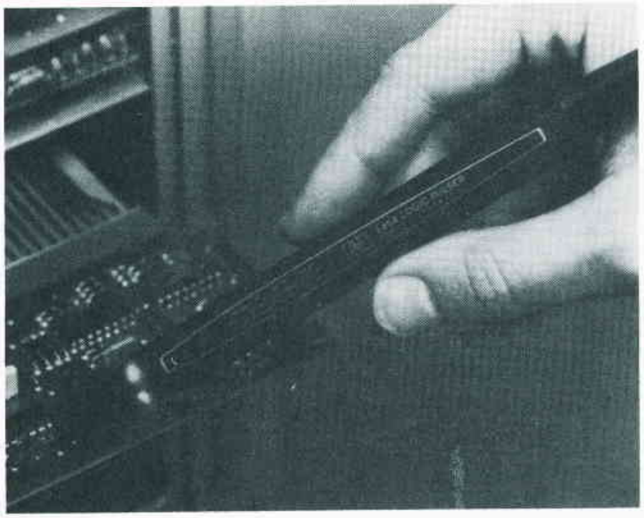


Fig. 6-6. A logic pulser can be used to inject a signal into a circuit.

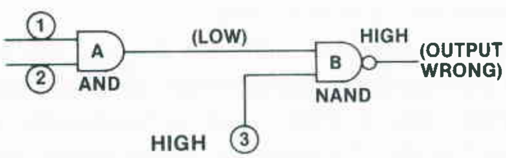


Fig. 6-7. There are several ways to test logic gates like these.

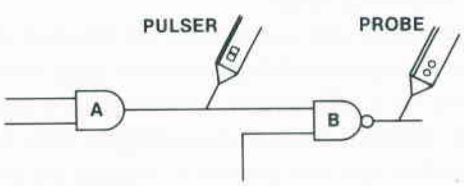


Fig. 6-8. Place the probe on the NAND gate output and the pulser on the AND gate output.

The probe should blink, indicating a change at the input to the NAND. If it doesn't blink a change, the NAND may be bad. But what if the LOW was caused by a short to ground at the AND output or the NAND input?

Place both the probe and the pulser on the AND output trace as shown in Fig. 6-9, and pulse this line. If the probe blinks, the NAND is bad; its input changed state, so its output should have changed state also.

If the probe doesn't blink, you know this line is shorted to ground. One way you can determine which chip is shorted is by touching the chip case. A shorted chip gets pretty hot, while a chip hung at one level seems to be normal but just won't change state.

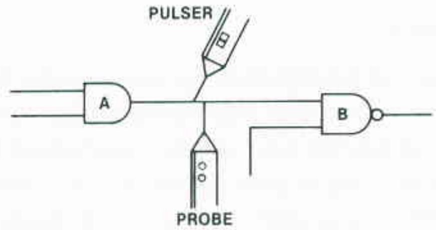


Fig. 6-9. Place the probe and the pulser on the AND gate output.

The Current Tracer

A fourth handy troubleshooting aid is the current tracer probe. This portable device lets you precisely locate shorts on your computer's motherboard (or on a peripheral card). The current tracer senses the magnetic field produced by the flow of electrical current in the circuitry. The logic pulser can be used to generate a pulsing signal that will make the current tracer LED blink, indicating the presence of current.

If you set the tip of the tracer on a printed circuit line and slide the tracer along the line, an LED in the tip end of the tracer will pulse as long as there is a current present. When you slide past a shorted point, the lamp will dim or go out, and you've found the short.

Fig. 6-10 shows an easy way to determine which gate has the short to ground in a logic circuit. Assume gate B has a shorted input. Place the pulser and the tracer midway between the two gates. Adjust the LED in the current tracer so that it just lights. Pulse the line as you place the tracer on the output of A and then on the input to B. The gate with the short to ground will pulse brightly because most of the current is going to ground here. Therefore, if the input to B is shorted, it causes the tracer lamp to pulse brightly, while the A side of the line doesn't cause the LED to light.

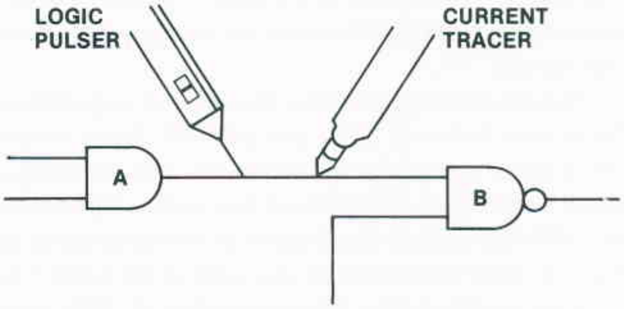


Fig. 6-10. Following the LED light with your tracer will lead you to the short.

IC Testers

Advanced troubleshooting equipment is becoming very sophisticated (and expensive). Today, for between $1,000 and $2,000, you can buy equipment that tests almost every chip in your system. For $10,000 you can even conduct your tests from a remote location.

Micro Sciences, Inc. in Dallas, Texas makes an IC tester that can test over 100 7400 TTL and 4000 CMOS series devices. Options for this tester include RAM and ROM tests.

Microtek Lab in Gardena, California makes a tester that can do complete functional pin tests of all 900 devices in the 54/74 TTL series chips. This test tool displays the condition of the chip under test on a liquid crystal display (LCD). It uses LEDs to signal GO/NO GO test results.

VuData Corporation in San Diego, California markets an in-circuit component tester that's actually a 50 MHz CRT to display the voltage-versus-current characteristics for virtually all circuit components, including capacitors, diodes, integrated circuits, resistors, and transistors. With this tester, the shape displayed on the CRT indicates the condition of the component under test. Using this test machine, you can easily pick out open circuits, shorts, leaky diodes, leaky transistors, and marginal ICs. The tool is valuable because it can test a wide selection of components while they're still mounted in the circuit.

The Oscilloscope

The oscilloscope has been with us for years, although recent advances in the state of the art have added a great many capabilities to the instrument.

Simply put, an oscilloscope (Fig. 6-11) is an electronic display device that draws a graph of signal voltage amplitude versus time or frequency on a CRT screen. A scope is used to analyze the quality and characteristic of an electronic signal sensed by a probe that touches a test point in a circuit. It is also used as a measuring device to determine the voltage level of certain signals.

Scopes come in all sizes, shapes, and capabilities. Prices vary between $500 and $20,000. Some scopes use a single test probe for displaying and analyzing a single trace signal. Others have two probes and display two different signals (dual trace) at the same time. As many as eight traces can be analyzed at the same time on some oscilloscopes. The November 17, 1983 issue of *Electronic Products* magazine described the newest in oscilloscope technology, a seven-color digital scope

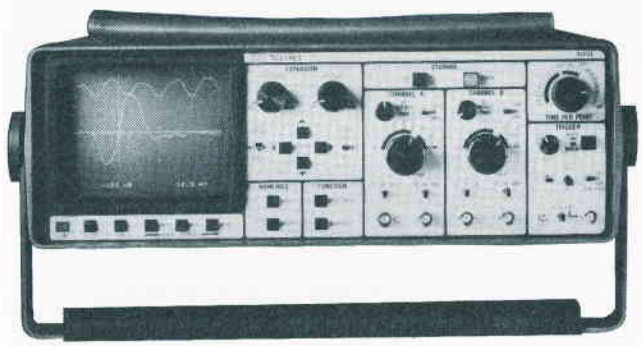


Fig. 6-11. A digital oscilloscope. (Nicolet Oscilloscope Division)

from Test & Measurement Systems Company. Colors make it possible to compare signals at different locations in the circuitry very rapidly. Some scopes even have built-in memories to let the machine store a signal of interest for future evaluation.

Besides sensitivity and trace display, one of the major distinguishing characteristics of oscilloscopes is that they allow a great range of frequencies to be observed on the CRT screen as frozen images. We call the range of frequencies *bandwidth*. Bandwidths vary between 5 MHz and 300 MHz, and price is proportional to frequency range.

Oscilloscopes are useful tools for freezing an analog or varying signal and displaying this static waveform on the face of a CRT screen covered with a measurement grid. While it is time consuming to learn how to use an oscilloscope, the analytical rewards are substantial. Not only can you measure voltage amplitudes and frequencies of test signals, you can also measure delay times and signal rise and fall times, and even locate the intermittent glitch.

If you're not trying to set the world on fire as a system designer, you can probably get along fine with a dual-trace, 25–30 MHz scope. Investment in an oscilloscope is not cost effective if you intend to use it only for analyzing your PC system board during troubleshooting a component failure. You'd be better off saving the money and spending a comparatively small portion of it to have a service center fix your machine.

The nice thing about dual-trace, quad-trace, and even eight-trace capability is the ability to look at different signal paths or different signals simultaneously. For example, you could look at the input and output of a gate and actually see and be able to measure the delay time for the signal passing from input to output of the chip. Another useful technique is simultaneously displaying all or parts of the data bus or part of the address bus to see what the logic level (HIGH = +5 V, LOW = 0 V) is and what binary number it represents.

Logic Analyzers

The logic analyzer is a multichannel oscilloscope with a memory. It captures and stores a number of digital signals, letting you view the signals simultaneously. If each signal is a bit on the data bus, you can see the entire data bus at one time. This means you can analyze the logic level for each bit on the bus for any instant in time. The bus signals are frozen for your display and analysis. The ability to freeze a single event or data pattern so you can determine the information present on a digital bus at any moment is a distinct advantage for troubleshooting.

Logic analyzers, like oscilloscopes, cost between $500 and $20,000. And, again like the scopes, logic analyzers come in a range of bandwidths, between 2 MHz and 200 MHz.

These analyzers can display many signals (channels of input) simultaneously. Arium Corporation in Anaheim, California recently announced an analyzer that handles 32 channels of input data at frequencies up to 100 MHz. Nicolet offers a 48-channel, 200 MHz analyzer with built-in microcomputer and dual, double-density floppy disk drives. Each channel has associated with it a probe clip for connecting to some test point in the circuitry. The clip probes are tiny and easy to install.

A sampling of the capabilities currently available in logic analyzers reveals one configuration that provides 104 channels at 25 MHz, another with 32 channels at 100 MHz, and yet another with 16 channels at 330 MHz. Another configuration has 8 channels of input and can operate at 600 MHz! (Recall that your IBM PC clock is 4.77 MHz.)

Where would logic analyzers be useful? One place is in debugging software. You can read the data in machine code and trace its flow through the circuit. You could analyze the input and output of memory simultaneously for locating a bad RAM chip. Or you could uncover intermittent glitches, those phantom spikes that can cause havoc in your system. There are many more uses for logic analyzers, including analysis of disk I/O operation.

The logic analyzer has been called the oscilloscope of the digital domain. It can be a valuable tool for the software or hardware designer. But for the home or small business computer owner who simply wants to fix his or her own computer when it fails, the logic analyzer is expensive overkill.

The Signature Analyzer

Logic probes can be effective in detecting logic levels and pulses at single points. Oscilloscopes can extend the number of points to be monitored even though the data pulses all tend to look alike. And logic analyzers extend the number of test points even further to include buses the size of the data and address buses. However, as the sophistication and capability of the measurement device increases, so does the expertise required to operate the test tool. Logic analyzers, in particular, can be very capable but they can also be difficult to understand and operate. The signature analyzer was developed to allow easy detection of hardware failures.

Signature analysis is a comparison method of troubleshooting. It works by running a diagnostic program in the system being tested and evaluating a coded signal at specific test points in the circuitry. If the coded signal matches the code observed when the system was running properly, the malfunction is not in that part of the circuitry. When a test point signature fails to match the baseline correct code, this indicates that you have located the faulty area. Then you can probe backward or forward from this point to locate the component that has failed.

The key to the success of this test technique is in the signature code. The first codes were developed by Hewlett-Packard and with slight modification are still being used today. A test code is a 16- or 24-bit repeatable value that represents a stream of data passing a test point during an interval of time. This known stream of data, when sampled at different places on a good circuit board by a signature analyzer, produces a unique 16- or 24-bit code at each test point.

These codes can be documented or stored in a programmable read-only memory (PROM) and recalled later for comparison during troubleshooting. The PROM then becomes a custom memory module containing every signature sampled from a properly working system that was being stimulated or pulsed with a known data stream.

Signature analysis has not been a popular troubleshooting tool because it takes lots of time to identify the test points, or nodes, probe the nodes, produce a signature, and then document the code. Once this task is completed, however, the task of locating a failure becomes easy. And the introduction of PROM modules has made the setup task much easier.

More improvements in this analysis technique can be expected in the near future. One analyzer already on the market uses a mode called "backtrace" to prompt the troubleshooter through a series of test points, guiding the tester to trace bad signatures back to the failed part.

The investment for a signature analyzer is between $400 and $10,000. Signature analysis uses a simple, nontechnical approach to troubleshooting, so even untrained people can use the equipment and the technique.

COMPONENTS AND HOW THEY FAIL

While the use of troubleshooting equipment makes the analysis and isolation of computer problems much easier, many failures can be found without expensive equipment. In fact, an understanding of how electronic components fail can make troubleshooting and repair relatively simple.

Now that you understand what kinds of tools are available, let's look at the kinds of components you'll be analyzing in your troubleshooting efforts and how these components can fail. Other than those that result from operator error, failures generally occur in the circuits that are used or stressed the most. These include the RAM and ROM chips, the 8088 CPU, and the I/O chips between the motherboard and the disk drive. The CPU is a highly reliable device and doesn't fail very often. Most failures involve the other chips. Except for the ROMs, which are preprogrammed by IBM, these other chips are standard off-the-shelf devices and are so common they're called "plain vanillas" or "jelly beans"—inexpensive easy-to-replace products. There are other components on your computer's motherboard that may someday require replacement. These require soldering and are not as easy to replace.

Integrated Circuits—Chips

A chip or integrated circuit is constructed out of silicon with some other tiny particles of metal (impurities) embedded in specific positions in the silicon. By positioning the metals in certain ways, the manufacturing process forms tiny transistors. Applying a voltage to certain places on the chip allows the device to invert a voltage level (+5 volts, logic 1, to 0 volts, logic 0) and to enable all sorts of logic gates (AND, NAND, OR, NOR, etc.) to function. These chips can be made with silicon/metal junctions so tiny that today thousands of transistors can be placed on one chip. A memory chip the size of a fingernail can hold over 470,000 transistors.

The problem for chip manufacturers is how to get voltages and signals into and out of such a tiny chip. Very thin wires are used as inputs and outputs to the chip. These wires are glued or bonded to tiny pads on the chip. The other end of each wire is bonded to a larger pad on a supporting material (the big part of what we call the integrated circuit, as shown in Fig. 6-12). This supporting structure includes the pins we plug into the sockets on our printed-circuit boards.

These tiny silicon and metal chips are placed in environments that really put them under a lot of stress. First they heat up when you use your computer. Then they cool down when you turn off your machine. Then they heat up again. This hot-cold-hot effect is called "thermal stress." It affects those tiny strands of wire, or leads, going between the chip and the supporting structure that includes the large pins that are inserted into sockets. After a period of time, the thermal stress can cause the bonding of the wire lead to break away from the pad on the chip. This disconnect causes an input or output to become an "open" circuit, and chip replacement is required.

Another failure in these chips is caused by a phenomenon called "metal migration." The chip can be compared to an ocean of atoms. Some tiny particles of metal float about in this sea, migrating in directions perpendicular to electrical current flowing through the chip. Problems occur when these metal particles begin to collect in parts of the chip. If they concentrate in the

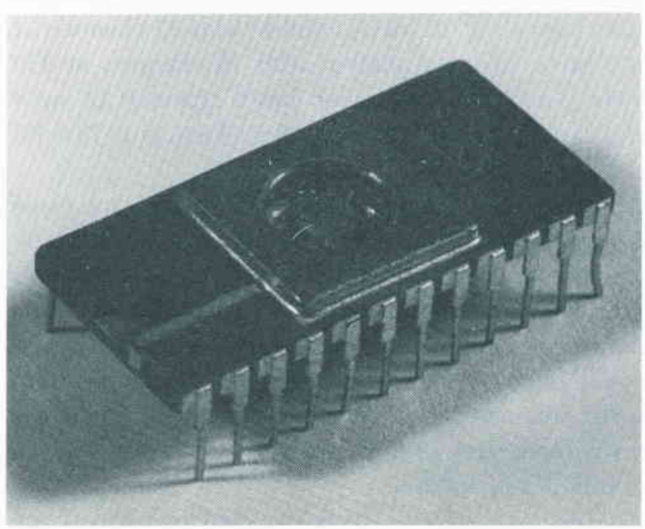


Fig. 6-12. The tiny leads from the chip to the pins of the chip package are clearly seen in this photo.

middle of one of those microelectronic transistors, they cause the transistor to operate differently or not at all. If the resistance of these collected metals gets high enough, it causes the device to operate intermittently or to simply refuse to work. Since the failing transistor is part of a logic gate, the gate malfunctions and the output may become "stuck at 1" or "stuck at 0," no matter what the input signal is. Theoretically, a wear-out failure won't occur until after several hundred years of use. However, we shorten the life span of our chips by placing them in high-temperature, high-voltage, or power-cycling environments. These cause the devices to fail sooner.

Other problems occur outside the chip, between the chip leads and the support structure pin leads, the inputs and outputs of the device. These types of failures include inputs or outputs shorted to ground, pins shorted to the +5-volt supply, pins shorted together, open pins, and connectors with intermittent defects. The most common trouble (assuming power is available) are opens or shorts to ground. Under normal use, chips finally fail with an input or output shorted to ground.

Capacitors

An understanding of the way a standard capacitor is constructed will aid in your understanding of how these devices fail.

In Chapter 3 you discovered that there are several types of capacitors on the PC system board and adapter cards. The capacitor is constructed of two separated plates. A voltage is placed across the plates, and for an instant current flows across the gap. But electrons immediately build up on one plate and cause the current flow to stop, leaving the capacitor charged to some voltage potential. In addition to storing a charge, capacitors are used to filter unwanted signal spikes (sharp, quick peaks of voltage) to ground.

The electrolytic capacitor is constructed as shown in Fig. 6-13. Two aluminum foils or plates are separated by a layer of porous paper soaked with electrolyte solution, a conductive liquid. On one plate (the positive plate) a thin layer of aluminum oxide is deposited. This layer is called the *dielectric*. A capacitor has an *anode* (the positive plate), and a *cathode* (the electrolyte). Electrons build up on one plate, causing it to become so negative that it prevents further current flow (remember that electrons have a negative charge).

Another type of capacitor is the *film capacitor*. It is constructed of alternating layers of aluminum foil and a

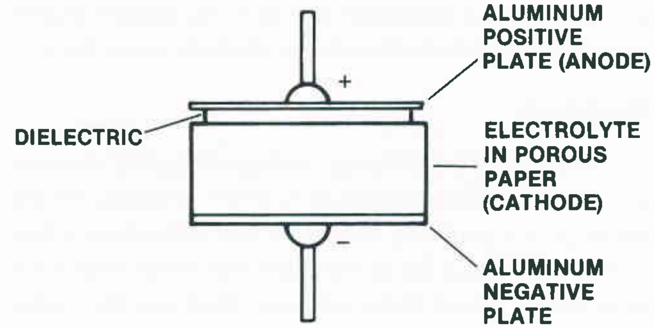


Fig. 6-13. The electrolytic capacitor.

plastic (usually polystyrene) insulation. The pieces of metal foil act as the plates, and the plastic insulation acts as the dielectric between the plates. A film capacitor is shown in Fig. 6-14. Film capacitors are coated with epoxy and have tinned copper leads.

Capacitors fail open or shorted depending on the operating conditions and on their age. Electrolytic capacitors are especially susceptible to the aging process. One effect of aging is drying out of the electrolyte insulator. As the insulator dries out, the capacitance value increases and circuit performance decreases. Finally, the capacitance value drops dramatically as the plates fold toward each other, and shorting of the plates can occur.

Another kind of failure occurs when some of the dielectric oxide dissolves into the moist electrolyte, causing the thickness of the dielectric to shrink. This deforming usually occurs when the electrolytic capacitor sits for a long time without voltage applied. In this case, the capacitance value increases but a large leakage of electrons occurs across the plates, making the capacitor useless.

The leads of the capacitor can physically detach from its plate, causing an open in the circuit. Also, the plates can short together when a large area of one plate is stripped of its dielectric oxide layer by the application of too much voltage.

Despite the potential for several kinds of failure, capacitors in our PC digital logic circuitry will seldom fail. A momentary power surge through the power sup-

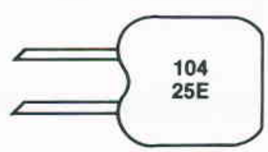


Fig. 6-14. The film capacitor.

ply can "fry" a capacitor on your PC system board. Excessive temperatures can also damage capacitors.

Resistors

These current-limiting, voltage-dropping devices are quite reliable and should function properly for the life of your computer. However, the same factors that shorten the useful life of the chips also act to reduce the operational life of these resistors. High temperatures, high voltage, and power cycling all affect the materials of which the resistors are made. These stresses cause breaks in the carbon, resistive paste, or resistive layers, producing an open conduction path in the circuit. Excessively high voltages can produce electrical current so large that it actually chars resistors to burnt ash. This is rare, especially in a digital circuit, in which the highest voltage seen is 12 volts (usually 5 volts) and the currents are very tiny indeed (milliamps).

Resistor failures are almost always associated with catastrophic failure of some other circuit component. Resistor failures, when they occur, are usually located in printer electronics rather than in the system unit.

Diodes and Transistors

The diodes and transistors on your computer's system board and adapter cards are made of solid material and act much alike. In fact, the transistor can be considered to be made up, in part, of two diodes.

Diodes are one-way valves for electric current, allowing current flow in only one direction. Diodes are usually made of either silicon or germanium. They are used in power supplies as rectifiers and in some circuits to maintain a constant voltage level. Other diodes are made of gallium arsenide and react by giving off light when biased in a certain way. These are called light-emitting diodes, or LEDs.

Transistors are used in various places in your computer circuitry as amplifiers or electronic switches.

Diodes and transistors fail in the same ways and for the same reasons as chips, but chips fail far more often than diodes or transistors. One reason is that there are many more tiny transistors on a chip the same size as a single (discrete) diode or transistor. This produces more heat and hence more thermal wear in the chip.

USING TOOLS TO FIND FAILED COMPONENTS

Most chips on the IBM PC motherboard are TTL (transistor-transistor-logic) chips. If you know the logic gates in a chip to be tested (NAND, NOR, OR, AND, etc.) you can test for opens or shorts by applying a known logic level to the inputs while monitoring the output. For example, if you were to place a slowly pulsing +5-volt to 0-volt signal on the input to the AND gate in Fig. 6-15, with both inputs shorted, you should see the output voltage level change (pulse) along with the input. Whenever the input is a logic 1, the output becomes a logic 1 (between +5 volts and +2.4 volts). The tool you use on the input is a logic pulser. The monitor tool on the output is a logic probe. The pulser places a cyclical logic level on the input to the device and the probe measures the presence or absence of a logic signal on the output of the chip.

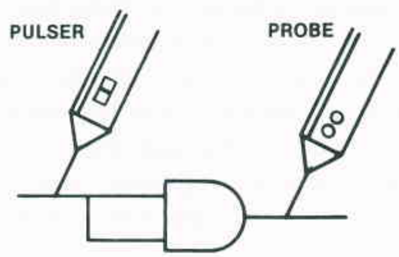


Fig. 6-15. Pulsing the input should cause a change in the output as indicated by the logic probe.

If the input to the AND gate becomes shorted to ground, the pulser cannot cause the gate to react to its signal and the output remains at a logic 0, or LOW (about 0 volts). Even if just one of the inputs shorts to ground, the output cannot change and remains at a logic 0.

A short to the gate supply voltage (+5 volts) will have the effect of qualifying or enabling one input to the gate all the time. This means that each time the other input receives a logic 1, the input set is correct and causes the output to change to a logic 1 even though only one input signal was actually correct. This produces incorrect circuit operation and strange results. This is the kind of problem that shows up in memory circuits: only one of the inputs to a particular gate is shorted or opened; whenever this gate is used, the resulting output may or may not be correct—a difficult problem to trace down.

Shorting an input pin to +5 volts can have potentially disastrous results. When the previous gate tries to deliver a logic 0, or LOW, a huge current is produced which usually causes catastrophic failure of the driving chip. The same result occurs when the input pin is shorted to ground and the previous gate tries to deliver a logic 1, or HIGH. The +5-volt logic HIGH is shorted directly to ground, producing an unusually high current with equally disastrous results.

Open connections prevent logic levels from being transferred and prevent the affected gate from being able to respond. If one input of a two-input NAND gate is open at the input as shown in Fig. 6-16, all but one of the four possible input combinations will be correct. This means that with this type of failure, the system could operate correctly most of the time with only some of the inputs good. The failure would be intermittent.

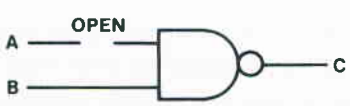
As shown in Fig. 6-17, if the device being tested is a NOR logic gate, the output would be a logic 1 only when both inputs are at logic 0. Should one of the inputs become open, it would float to logic 1 and cause none of the input conditions to produce a logic 1 output. Thus, the output would be LOW all the time—just as though the output were shorted to ground.

If the chip has an open pin at its output, it cannot deliver any logic 1 or 0 to the next gate. You can measure a voltage at the input to the next gate since it is providing the potential, a logic 1, or HIGH level (something around +4 volts). The key here is that any time an input to a TTL gate opens (a condition we call *floating*), the gate will act as though a logic 1 were constantly applied to that input. The voltage on this floating input will drift between the high supply voltage of +5 volts and a level (about 1.5 volts) somewhere between a valid HIGH and a valid LOW. (A valid HIGH is usually above +2.4 volts; a valid LOW is below +0.4 volts.)

A voltmeter reading of about +1.7 volts at the output pin of a gate on a chip is a clue that the output is floating open and the voltage is actually being provided by the next chip or the following gate.

All these kinds of failures can be located using a logic pulser and a logic probe with backup from a VTVM for voltage measurement.

Since the PC system board is flexible at certain points, replacing chips or depressing the board without supporting it from beneath could cause a break to occur, opening a trace on the circuit board. A hairline crack such as this is often difficult to find, but looking at the board with a magnifying glass and a strong light (or a magnifying lamp) can sometimes reveal a suspected failure. A resistance test can be conducted with a VOM or VTVM by placing a probe at either side of the suspected bad trace, as shown in Fig. 6-18, and observing whether a 0-ohm reading is measured. Another way to ascertain whether a trace is open is to compare the logic states at both ends of the trace.



INPUT		OUTPUT
A	B	C
L	L	GOOD
L	H	BAD
H	L	GOOD
H	H	GOOD

Fig. 6-16. An open at the input to a NAND gate is only a problem in one of four logic-state cases.

INPUT		OUTPUT
A	B	C
L	L	L
L	H	L
H	L	L
H	H	L

Fig. 6-17. An open at the input to a NOR gate will prevent the output from ever changing state or going HIGH.

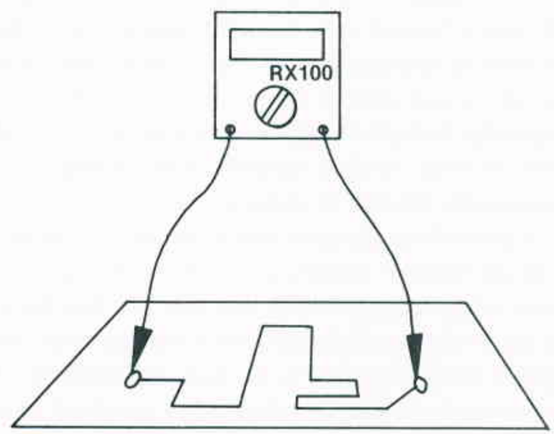


Fig. 6-18. A trace can be tested for an open using an ohmmeter to test the electrical resistance from one end to the other.

An important fact to keep in mind when testing for individual shorted or open gates in the IBM PC system board circuitry is that more than one gate may use the same input or output lines to or from another gate. This is called *fan-in* or *fan-out*. When studying the gate circuitry, remember, the failure could be located at the other end of the board. One long trace from the end of the board to the chip you are looking at may be shorted or open at the distant end. Use of the schematics in the IBM PC technical reference manual will be of value here.

OTHER TROUBLESHOOTING TECHNIQUES

There are some interesting tricks you can use to aid in finding chip failures.

Use Your Senses

Look, smell, and feel. Sometimes failed components become discolored or develop bubbles or charred spots. Blown devices can produce some distinctive smells—the smell of a ruptured electrolytic capacitor, for example. Finally, shorted chips can get really hot. By using a "calibrated finger," you can pick out the hot spots on your board.

Heat It, Cool It

Heating and then cooling is a fast technique for locating the cause of intermittent failures. Frequently, as an aging device warms up under normal operation, it becomes marginal and then intermittently quits working. If you heat the energized area where a suspected bad chip is located until the intermittent failures begin, and then methodically cool each device with a short blast of canned coolant spray, you can quickly cause a marginally defective chip to function again. By alternately heating, cooling, heating, and cooling, you can pinpoint the trouble in short order.

You can heat the area with a hair dryer or a focused warm-air blower designed for electronic testing. Be careful using this technique, because the thermal stress you place on the chips being tested can shorten the life of good components. A 1- or 2-second spray of freeze coolant is all you should ever need to get a heat-sensitive component working again.

Most coolant sprays come with a focus applicator tube. Use this to pinpoint the spray. And avoid spraying electrolytic capacitors, because the spray soaks into the cap, destroying the electrolyte in some aluminum capacitors. Also be careful not to spray your own skin. You could get a severe frost burn.

Piggybacking

Fig. 6-19 shows another way you can chase down intermittents caused by a break in a chip bond (wire) inside the chip housing that allows good contact only when the chip is cool. Place a good chip over the top of a suspected chip and energize the circuitry. You may need to squeeze the pins of the good chip in slightly so they make good contact with the pins of the suspected device.

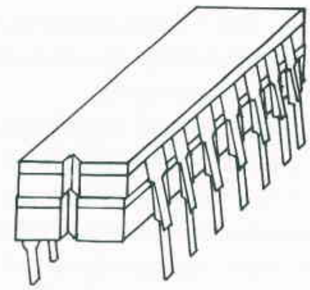


Fig. 6-19. Some IC failures can be found by piggybacking a good device on a suspect device.

If the intermittent failure is caused by an open connection, the new chip will react to input data and cause its output to work properly. Use your stock of spare parts as your piggyback source.

The Easter Egg Approach

Quite often we can quickly locate a fault to a couple of chips but need further testing to determine which chip is the culprit. When time is of essence, take an "Easter egg" approach. Just as a youngster used to pick up and examine Easter eggs one at a time to see whether his or her name was marked on it, you can try replacing the chips one at a time to determine whether the chip replaced was causing the problem. You have a fifty-fifty chance of selecting the right chip the first time. If it doesn't work, replace the other chip.

If the chips involved are inexpensive "jelly beans" (7400 series TTL), why not replace them both? For 30 cents more, go ahead and splurge. If the problem's gone, but you're still curious, you can always go back later and test each chip individually.

Microvolt Measuring a Piece of Wire

If you have a meter with microvolt sensitivity and have isolated a "stuck LOW" problem to two chips, you can try the technique shown in Fig. 6-20. Measure the voltage drop between input pin 1 of gate B and output pin 3 of gate A. This means measuring the opposite ends of the same trace or piece of wire! You're interested in determining which end of that trace is the more negative. The end nearest a bad chip will be more negative because the defective chip will short the trace voltage to ground, causing this point to be more negative than at pin 3.

Testing Capacitors

How do you check out a capacitor that you believe has failed? If the device has shorted, resulting in severe

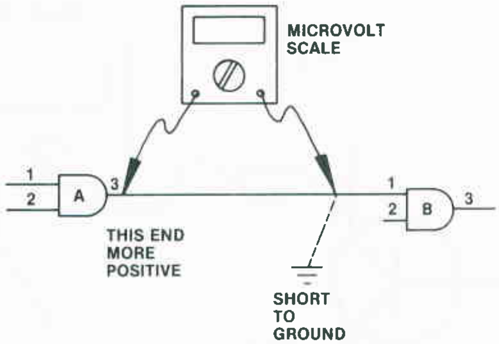


Fig. 6-20. A short circuit that is sinking current can be found using a meter with microvolt sensitivity.

leakage of current, you can spot this easily by placing an ohmmeter across the capacitor and reading the resistance. At first you'll notice a low reading, because the capacitor acts as a short until it charges; but then, if the capacitor is working properly, it will charge and the resistance will rise to a nominally high value. If the device is shorted, the initial low resistance reading continues and the capacitor won't charge.

Should the component be open, you'll not see the instantaneous short at T_0, the moment charge starts to build. An open circuit has infinite resistance. An in-circuit capacitance tester is helpful here.

Total failure as a short or open is pretty easy to find. But how about the device whose leakage depends on temperature or whose dielectric has weakened, changing the capacitance value? To test this capacitor requires a different level of analysis.

Capacitance Measuring

If you have an ohmmeter whose face has the number 10 in the middle of the scale, you can easily use it to approximate the capacitance of a device. Using the time-constant formula, $T = RC$, where T equals the time in seconds for a capacitor to charge to 63.2 percent of supply voltage, R equals resistance in ohms, and C equals capacitance in farads. Using a 22-μF capacitor and a 1 megohm (1,000,000 ohm) resistor, the charge time for one time constant is .000022 × 1,000,000 = 22 seconds.

Transposing the formula to read

$$C = T/R,$$

we can determine the value of capacitance by knowing the resistance and counting the seconds required for the charge to cause the ohmmeter needle to reach 63.2 percent of full scale (infinite resistance). This point is at about 17 on the meter's scale.

To do this, disconnect one end of a capacitor from the circuit, turn on your meter, and let it warm up for a minute. Zero adjust the ohms scale reading. Then estimate the ohms scale multiplier needed to let the capacitor charge in some acceptable time period. For microfarad capacitors use the "× 100K" scale because this will let the capacitor charge in less than a minute. The 17 on the scale represents 1.7 megohms on the × 100K scale.

Short a low-ohm-value resistor across the two capacitor leads for several seconds to thoroughly drain off any charge. Then connect the meter's ground lead to the negative side of the capacitor (either side if the capacitor is not electrolytic), and touch the positive meter probe to the other side of the capacitor. Using a stopwatch to count seconds and tenths of a second, watch the face of the ohmmeter as the capacitor charges, moving the resistance needle up. When the needle gets to 17 on the scale, stop the clock and read the time. This will give you the capacitance value in microfarads.

This technique will give you a close enough approximation of the capacitance value to determine whether the device is good or should be replaced.

Replacing Capacitors

Always try to use the same type and value capacitor as the one being replaced. Keep the leads as short as possible and solder the capacitor into the solder connector holes with the proper iron. The soldering process should not take longer than 1.5 seconds per lead; otherwise, heat damage to the component may result.

A good technique to use is to tin the capacitor leads just before poking them through the circuit-board holes. This speeds the solder bond process.

Testing Diodes

If you have a digital multimeter (DMM) with a diode test capability, you can quickly determine whether a suspected diode is bad or good. Placing the meter on the ohmmeter setting and positioning the probes across the diode causes the meter to apply a small amount of current through the diode if the diode is forward biased. The voltage drop across a diode is normally 0.2–0.3 volts for germanium diodes and 0.6–0.7 volts for silicon diodes. Reversing the leads should result in no current flow, so a higher resistance reading should be observed. A low resistance reading when the diode is biased in either direction indicates that the device is leaking or shorted. A high resistance reading in both directions indicates the diode bond has opened. In either case, replace the diode immediately.

Diodes can also be tested in circuit, using the ohmmeter to check the resistance across a diode in both directions. With one polarity of the meter probes, you should get a reading different from that obtained when the probes are reversed—not just a few ohms different but several hundred ohms different. For example, in the forward-biased direction, you could read 50–80 ohms; in the reverse-biased direction, 300K ohms. This difference in readings is called DE for "diode effect" and is useful for evaluating transistors. When diode readings in both directions show low resistance, you can be sure the leaky short is present.

Testing Transistors

It's no fun to unsolder a transistor to test it for failure, and then, finding it good, solder it or a new device back into the circuit board. Fortunately, there is a way to determine the quality of silicon transistors without removing them from the circuit. In 90 percent of the tests, this procedure will accurately determine whether a device is bad.

A transistor acts like a configuration of diodes (Fig. 6-21). PNP and NPN transistors have opposite-facing diodes. The transistor functions by biasing certain pins and applying a signal to one of the leads (usually base) while taking an output off the collector or emitter.

The following tests apply to both PNP and NPN transistors. If an ohmmeter is placed between the collector (C) and the emitter (E) as shown in Fig. 6-22, it effectively bridges a two-diode combination in which the diodes are opposing. You should get a high resistance reading with the leads applied both ways. (It's possible to wire the transistor in a circuit that makes the transistor collector-emitter junction act like a single diode. In this case you could get a DE. Both results are O.K.)

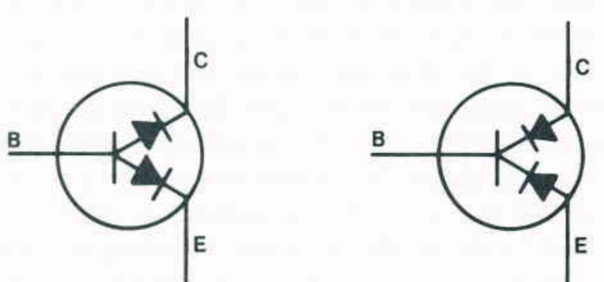


Fig. 6-21. A transistor acts like a pair of diodes.

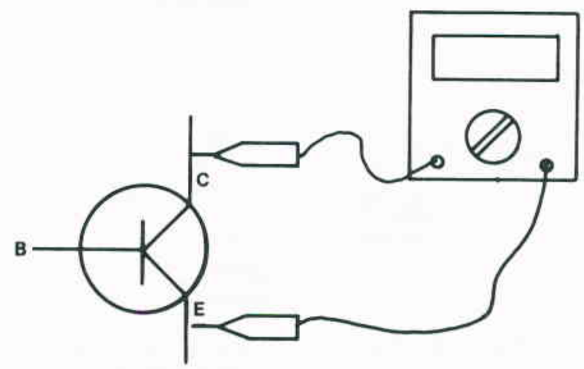


Fig. 6-22. A transistor can be tested using an ohmmeter placed across the collector-to-emitter junction.

Typical C-E resistance readings for germanium transistors are as follows:

Forward biased = 80 ohms

Reverse biased = 8000 ohms (8K)

For silicon transistors you might read

Forward biased = 22 megohms

Reverse biased = 190 megohms

The high/low ratio is evident and is about the same for both types.

Place the probes across the collector-to-base junction leads. Reverse the probes. You should observe a low reading in one case and a high reading with the test probe leads reversed (the diode effect).

Try the same technique on the base-to-emitter (B-E) junction leads (Fig. 6-23). Look for the DE. If the DE is not present in all the above steps, you can be certain the transistor is bad and needs replacing.

Another way to evaluate a transistor is to measure the bias voltage from base to emitter on an energized circuit. Confirm the correct supply voltage first; power supply problems have been known to trick troubleshooters into thinking a certain component has failed.

The B-E forward bias for silicon transistors should be between 0.6 and 0.7 volts DC. If the reading is below 0.5 volts, replace the diode—the diode junction is leaking too much current. If the reading is almost a volt, the junction is probably open, and again the device should be replaced:

B-E Voltage (forward biased)	Action
0.5	Replace
0.6–0.7	Good, keep
0.9	Replace

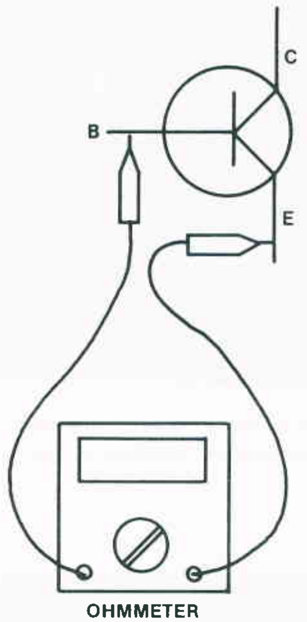


Fig. 6-23. Check the base-to-emitter junction for diode effect (DE).

Although in some isolated cases some other failure could cause the low reading, the most common cause of low bias voltage is failure in the transistor itself.

If the previous tests are inconclusive, there is something else you can try. Measure the voltage across the collector-to-emitter (C-E) junction. If the reading is the same as the source supply (+5 volts for Q1 on the color/graphics adapter) and you notice on the schematic that there's plenty of resistance in the collector-base circuit, the junction is probably open. Replace the device.

If your reading is close to 0 volts, take a small length of wire and short the base to the emitter, removing all the transistor bias. The C-E meter reading should instantly rise. If it doesn't, the transistor is shorting internally and should be replaced. If C-E voltage does rise, it suggests a failure in the bias circuitry, perhaps a leaky coupling capacitor.

SOLDERING AND UNSOLDERING

Removing Solder

One way to remove residual solder is to use a "solder sucker"—a hand held vacuum pump with a spring-driven plunger to pull the hot, melted solder off a connector (Fig. 6-24). The process involves heating the old solder until it melts, placing the spring-propelled vacuum pump in the hot solder, and then quickly removing the soldering iron while releasing the vacuum pump's spring, sucking the solder up into a storage chamber in the pump. This technique works fine until you try to use it around CMOS chips. Some vacuum pumps produce static electricity, and by now you know what that can do to an MOS or CMOS chip.

A safer way to remove solder is to touch the solder with the end of a strip of braided copper. Then heat the braid just a short distance from the solder (Fig. 6-25). The copper braid heats quickly, transferring the heat to the solder, which melts and is drawn into the braid by capillary action. Then, cut off the solder-soaked part of the braid and throw it away.

If any solder remains in the circuit-board hole, heat the solder and push a toothpick into the hole as the solder cools. The toothpick will keep the hole open so you can easily insert another wire lead for resoldering.

Another way to remove the residual solder blocking a hole is to drill out the hole with a tiny drill bit. Be sure to remove any debris, filings, or pieces of solder before energizing the circuit board. Use a magnifying glass to confirm that nothing unwanted remains on the board.

Be careful not to overheat the board during the solder-removal process. Excessive heat can cause part of the circuitry to come away from the board. It can also damage good components nearby.

If you remove the solder from a component and a lead is still stuck on some residual solder, pinch the

Fig. 6-24. The spring-driven plunger in the solder vacuum pump is used to pull hot solder off a connection.

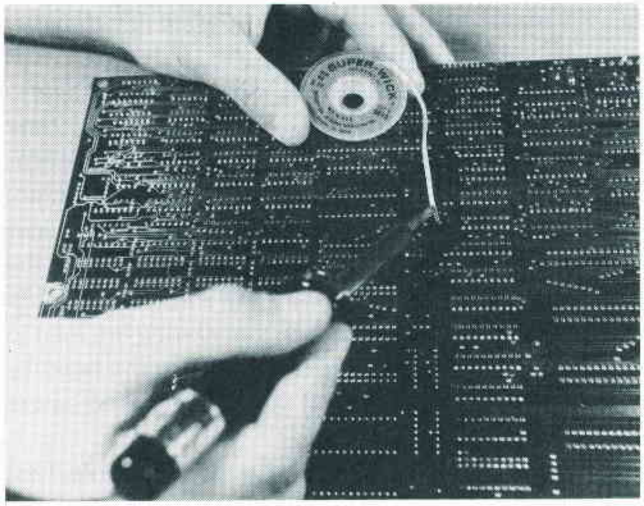


Fig. 6-25. Use of a solder wick is another way to remove solder from a connection.

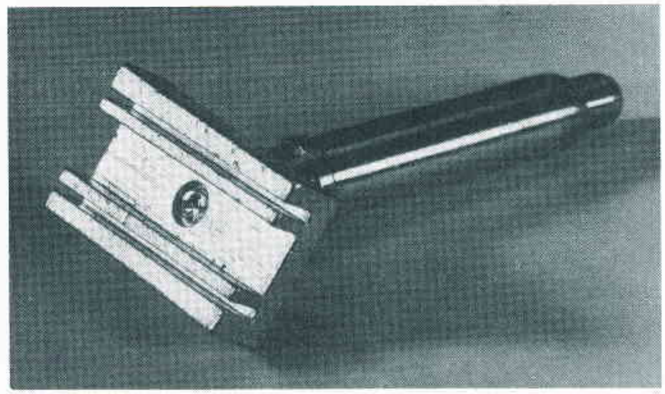


Fig. 6-26. A desoldering tip for removing chips that are soldered to the circuit board.

lead with a pair of needle-nose pliers as you gently wiggle it to break it loose from the solder bond.

The pins of some chips are bonded to the circuit board by a process called wave soldering. Wave soldering produces an exceptionally good bond without the added manufacturing expense of a socket. This process helps keep the fabrication costs down, but it makes it more difficult for you to replace the chip.

One effective way to remove wave-soldered chips is to cut the chip leads or pins on the sides of the component and remove the bad chip. Then remove the pieces of pin sticking through the board using a soldering iron and solder braid or a vacuum pump.

Some special tools are available to help you in removing soldered components. Fig. 6-26 shows a desoldering tip that fits over all the leads of a chip socket or dual in-line package (DIP) device. Fig. 6-27 is a photograph of a spring-loaded DIP extractor tool. By attaching this device to the chip and then applying the DIP tip shown in Fig. 6-26 to the soldered connections on the opposite side of the board, you can easily remove the chip. Press the load button downward and engage the clips, causing the extractor to place an upward spring pressure on the chip. When the solder on the reverse side melts enough, the chip will pop up and off the board.

When you replace a chip that was soldered to the printed-circuit board, always solder in a socket and then plug the replacement chip into this socket. This will make future replacements a lot easier. Be careful to maintain the correct pin 1 alignment.

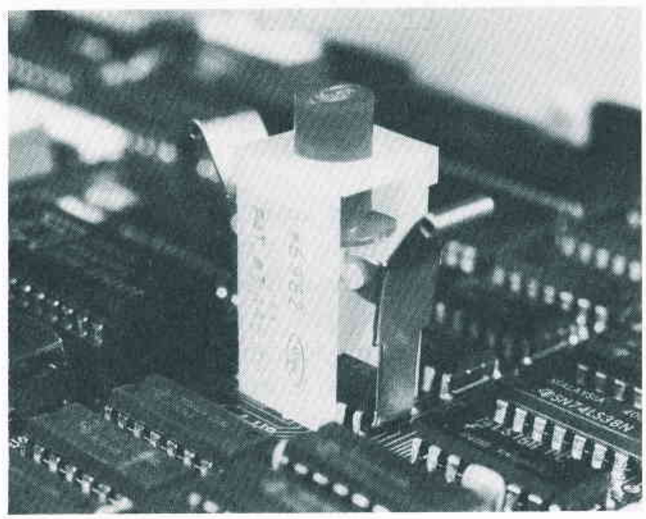


Fig. 6-27. A spring-loaded dual-in-line extractor tool.

Soldering Tips

No pun intended. Hand soldering is the most misunderstood and most often abused function in electronics repair. Not only do many people use poor soldering techniques, but they also use the wrong soldering irons.

Solder isn't simply an adhesive making two metals stick together. It actually melts and combines with the metals to form a consistent electrical as well as mechanical connection. Time and temperature are critical in this process. The typical hand-soldering job can be accomplished in 1.5 seconds or less if the soldering iron and tip are properly selected and then properly maintained.

The nominal solder melting temperature is 361° F. Metal combination between the solder and the metals being joined occurs at temperatures between 500 and 600° F.

Most soldering jobs join the metals copper and tin, but both of these metals are easily oxidized. Poor or no solder connections are made if the surfaces to be connected are covered by contaminants such as oils, dirt, or even smog, so be sure to use solder with a good cleaning flux. The flux prepares the surfaces for best solder metalization. The flux melts first and flows over the metal surfaces, removing oxidation and other contaminants. Then the metal heats so that the solder melts and flows, producing a good, shallow bond.

The key to successful soldering is in the soldering iron tip. Most people selecting their first soldering iron buy a low-wattage iron, but this is a mistake. Instead, pick an iron whose tip operating temperature is suited for the circuit board you're to repair. If the tip temperature is too low, the tip sticks to the surface being soldered. If it's too high, it damages the board surface. The ideal working temperature for soldering on your computer's circuit board is between 600° and 700° F.

The soldering iron tip is used to transfer the heat generated in the iron out to the soldering surface. The iron should heat the tip quickly, and the tip should be as large as possible, yet slightly smaller than any soldering pad on the board.

Tips are made of copper. Copper conducts heat quickly, but it dissolves in contact with tin. Solder is made of tin and lead. To keep the tin from destroying the copper tip, manufacturers plate a thin layer of iron over the soldering tip. The hot iron (now you know where the term "iron" came from) still melts the solder, but now the tip lasts longer. The iron melts above 820° F, so if the heat produced by the iron stays below 700° F, the solder melts, but not the iron plating.

The disadvantages of the iron plating are that it doesn't conduct heat as well as copper, and it oxidizes rapidly. To counteract this, you can melt a thin coat of solder over the tip. This is called "tinning." This solder layer helps the soldering iron heat quickly and also prevents oxidation.

The tip of an old soldering iron is usually black or dirty brown with oxidation. And it doesn't conduct heat very well. These "burned-out" tips can be cleaned with fine emery cloth and then can be retinned and used.

Wiping the hot tip with a wet sponge just before returning the iron to its holder is a mistake. This removes the protective coating, exposing the tip surface to atmospheric oxidation. It's much better to add some fresh solder to the tip instead. Keep your iron well tinned.

Fig. 6-28 shows the proper way to solder a socket or connector lead. Place the tip of the iron on one side of the lead and the solder on the other side.

As the solder pad heats, the tin-lead solder melts and flows evenly over the wire and the pad. Keep the solder shallow and relatively even. When you think your soldering job is complete, carefully inspect your work. Sometimes, if you aren't careful, you can put too much solder on the joint, so that there's not enough solder on the top or bottom of the connection. It's also possible to get internal voids or hollow places inside the solder joint. Large solder balls or mounds invite "cold solder joints" where only partial contact is made. Fig. 6-29 shows some examples of inadequate soldering. These kinds of solder joints can be a source for intermittent failure.

Good soldering takes patience, knowledge, and the right tools—a temperature-controlled soldering iron whose tip temperature is maintained in the 500–600° F range for optimal soldering effect.

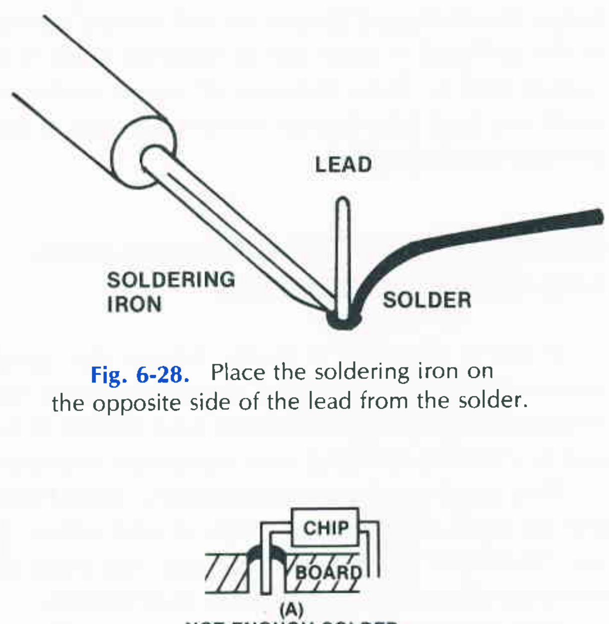


Fig. 6-28. Place the soldering iron on the opposite side of the lead from the solder.

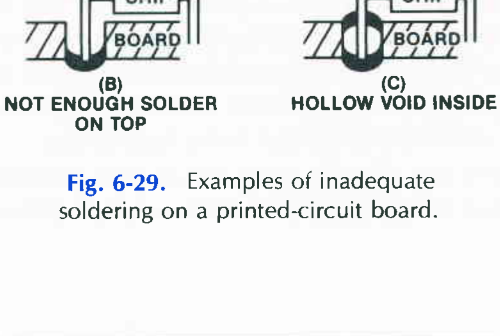


Fig. 6-29. Examples of inadequate soldering on a printed-circuit board.

Before You Solder It In

A useful thing to do before you solder in a replacement part is to test the device in the circuit. Simply insert the chip or other device into the solder holes and wedge each lead in its hole with a toothpick. Then energize the circuit and test. After proper function is assured, remove the toothpicks and solder the component into the board.

CIRCUIT BOARD REPAIR

Repairing damaged circuit boards is a lucrative business, and several companies have developed around this activity. For some board failures, you can repair your own circuitry and save money.

Before soldering in new components, check over the board for broken traces or pads lifting off the board. If a trace is open and is starting to lift away from the board surface, jumper across the broken spot from one component solder pad to another pad. Use solid #18 or #20 wire tinned at both ends before soldering.

If a pad or trace lifts free, replace it with an adhesive-backed pad or trace overlapping the damaged area. Scrape the coating off the pad or both ends of the trace so the new pad or trace can be soldered firmly to the existing pad or trace. Remove all excess solder and redrill any lead hole that has become covered or plugged with residual solder.

RECOMMENDED TROUBLESHOOTING AND REPAIR EQUIPMENT

If you're planning to tackle failures that usually require service center support, you can minimize your investment costs and yet optimize your chance of success by carefully selecting your equipment and tools.

First, get a set of good screwdrivers—both Phillips and flat-head. Get a broad range of sizes—from the tiny "tweakers" to an 8-inch flat-head. You might also find a set of jeweler's screwdrivers quite helpful.

Then get several sizes of long-nose or needle-nose pliers. Get several sizes of diagonal cutters, or "dykes," for cutting wire and pins. A good soldering iron whose tip temperature is automatically controlled is a must if you intend to replace nonsocketed components. A simple 3½-digit DVM or DMM is useful for test measurements. Another handy tool is the logic probe.

If you can afford it, get a 15–25 MHz oscilloscope with dual trace and a time-base range of 200 nanoseconds to a half second. Select a scope with a vertical sensitivity of 10 millivolts per division or better.

Table 6-1 shows an approximate price list for troubleshooting and repair equipment.

Table 6-1. Approximate prices for troubleshooting and repair equipment

Tool	Price ($)
Screwdrivers—12	15
Pliers 4½-inch short-nose 5¾-inch long-nose	15
Diagonal cutters 4½-inch flush 4½-inch midget	10
DMM (3½ digit)	80
Logic probe	85
Logic pulser	85
Current tracer	200
Logic clip	80
Oscilloscope	1200
Logic analyzer	1100

You can get by quite nicely for less than $500 using the probe, pulser, tracer, and DMM as your primary equipment. Prices vary from one manufacturer to another.

SPARE PARTS

Because of the cost involved you will probably want to maintain only a minimal stock of repair parts; yet you want to be able to fix your machine quickly when it breaks down.

The optimal backup bit would include one each of every type of chip on your PC's system board and adapter cards. This represents an investment of $100 to $200 in 150 or more chips. Currently, IBM PC custom chips—the ROMs—are available from authorized IBM service centers. The total number of chips in the PC is higher than the number of chips you need as spares because many of the same types of chips are used in different places on the system board. In addition, you only need one of the RAM chips as a spare. Your largest expense in chips will probably be for the ROMs (unless you are using a $140 8087 coprocessor chip).

Several companies market spare-parts packages with schematics, diagnostic tests, and one each of the chips for the IBM PC.

In the Appendix you'll find a listing of each chip in your computer including its designation, name, and location.

SUMMARY

There are four possible ways to optimize your computer system's operational life:

1. Buy a highly reliable computer with a good performance track record.
2. Buy a good on-site repair contract.
3. Buy a second identical computer to use as a backup during repair of the first.
4. Become a knowledgeable repair technician yourself.

Armed with the knowledge in this manual, you'll be able to spot downright poor troubleshooting—the "tech" using a bare cotton swab with low-grade alcohol, to "clean" a disk drive read head, the repair person wiping his or her soldering iron on a wet sponge just before putting it in its holder. These are mistakes of poorly trained (or poorly motivated) people working on someone else's machine. You'll also be able to recognize the sharp, highly trained technician who uses the right tools and the right procedures to troubleshoot and repair in minimum time. Then you'll smile to yourself, knowing that you were smart enough to buy this book and do your own repair the right way—the IBM-Easy way.

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IBM PC DATA SHEET

Computer: IBM Personal Computer

Manufacturer: IBM Corporation
Armonk, New York

Size: 19.6″ × 16.1″ × 5.5″

Weight: 20.9 lb without disk drive installed

Power Required: 63.5 watts (maximum)
110/220 volts

CPU: 8088 microprocessor

Data Word Size: 8 bits

CPU Clock Speed: 4.77 MHz

Memory Size: 40K ROM
16K–256K bytes on system board
1 Mbyte directly addressable memory

Mass Storage Capability: Two disk drives internally
Two disk drives externally
160K bytes—single density
320K bytes—double density

Keyboard Size: 83 keys
256 character codes

Display: 25 lines of 40 characters, 16 colors
25 lines of 80 characters, 16 colors

Graphics Capability: 100 rows of 160 picture elements (pixels), 16 colors
200 rows of 320 pixels, 4 colors
200 rows of 640 pixels, black and white
32 special graphics characters

Input/Output: Five 62-pin expansion slots
Cassette connector
2¼-inch speaker
Auxiliary power connection
Detachable keyboard

Standard Software: Cassette BASIC

Optional Software: PC-DOS
Cassette BASIC
MS-DOS
Advanced BASIC

IBM PC CHIP INFORMATION CHART (Refer to Fig. A-1)

Label	Integrated Circuit	Description
U1	MC1741	General-purpose operational amplifier
U2	8259	Programmable interrupt controller
U3	8088	Microprocessor
U4	8087	Numeric data processor
U5	74LS30	8-input NAND gate
U6	8288	Bus controller
U7	74LS373	Octal transparent latch
U8	74LS245	Tri-state octal transceiver
U9	74LS373	Octal transparent latch
U10	74LS373	Octal transparent latch
U11	8284	Clock generator
U12	74LS245	Tri-state octal transceiver
U13	74LS245	Tri-state octal transceiver
U14	74LS245	Tri-state octal transceiver
U15	74LS244	Tri-state octal buffer
U16	74LS244	Tri-state octal buffer
U17	74LS244	Tri-state octal buffer
U18	74LS373	Octal transparent latch
U19	74LS670	Tri-state 4 × 4 register file
U20	RN1	4.7K ohm DIP resistor network
U21	SW1	DIP switch
U22	RN2	2K-ohm DIP resistor network
U23	74LS244	Tri-state octal buffer
U24	74LS322	8-bit serial/parallel-in register with sign extend
U25	SW2	DIP switch
U26	74LS175	Quad-D flip-flop
U27	74LS02	Quad 2-input NOR gate
U28	empty	Spare ROM socket
U29	9264 ROM	8K × 8-bit static ROM
U30	9264 ROM	8K × 8-bit static ROM
U31	9264 ROM (MK36A70N-4)	8K × 8-bit static ROM
U32	9264 ROM	8K × 8-bit static ROM
U33	9264 ROM	8K × 8-bit static ROM
U34	8253	Programmable interval timer
U35	8237	DMA controller
U36	8255	Programmable peripheral interface
U37	4164 RAM	64K × 1-bit dynamic RAM
U38	4164 RAM	64K × 1-bit dynamic RAM
U39	4164 RAM	64K × 1-bit dynamic RAM
U40	4164 RAM	64K × 1-bit dynamic RAM
U41	4164 RAM	64K × 1-bit dynamic RAM
U42	4164 RAM	64K × 1-bit dynamic RAM
U43	4164 RAM	64K × 1-bit dynamic RAM
U44	4164 RAM	64K × 1-bit dynamic RAM
U45	4164 RAM	64K × 1-bit dynamic RAM
U46	74LS138	1/8 decoder/demultiplexer
U47	74LS138	1/8 decoder/demultiplexer
U48	74LS138	1/8 decoder/demultiplexer
U49	74LS08	Quad 2-input AND gate
U50	74LS02	Quad 2-input NOR gate
U51	74LS04	Hex inverter
U52	74LS00	Quad 2-input NAND gate
U53	4164 RAM	64K × 1-bit dynamic RAM
U54	4164 RAM	64K × 1-bit dynamic RAM
U55	4164 RAM	64K × 1-bit dynamic RAM
U56	4164 RAM	64K × 1-bit dynamic RAM
U57	4164 RAM	64K × 1-bit dynamic RAM
U58	4164 RAM	64K × 1-bit dynamic RAM
U59	4164 RAM	64K × 1-bit dynamic RAM
U60	4164 RAM	64K × 1-bit dynamic RAM
U61	4164 RAM	64K × 1-bit dynamic RAM
U62	74LS158	Quad 2-input data selector/multiplexer
U63	74LS38	Quad 2-input NAND buffer
U64	74LS20	Dual 4-input NAND gate
U65	74LS138	1/8 decoder/demultiplexer
U66	74LS138	1/8 decoder/demultiplexer
U67	74LS74	Dual-D flip-flop
U68	RN3	4.7K ohm DIP resistor network

Label	Integrated Circuit	Description
U69	4164 RAM	64K × 1-bit dynamic RAM
U70	4164 RAM	64K × 1-bit dynamic RAM
U71	4164 RAM	64K × 1-bit dynamic RAM
U72	4164 RAM	64K × 1-bit dynamic RAM
U73	4164 RAM	64K × 1-bit dynamic RAM
U74	4164 RAM	64K × 1-bit dynamic RAM
U75	4164 RAM	64K × 1-bit dynamic RAM
U76	4164 RAM	64K × 1-bit dynamic RAM
U77	4164 RAM	64K × 1-bit dynamic RAM
U78	RN4	30-ohm DIP resistor network
U79	74LS158	Quad 2-input data selector/multiplexer
U80	74LS125	Quad tri-state buffer
U81	74S00	Quad 2-input NAND gate
U82	74S74	Dual-D flip-flop
U83	74LS04	Hex inverter
U84	74LS10	Triple 3-input NAND gate
U85	4164 RAM	64K × 1-bit dynamic RAM
U86	4164 RAM	64K × 1-bit dynamic RAM
U87	4164 RAM	64K × 1-bit dynamic RAM
U88	4164 RAM	64K × 1-bit dynamic RAM
U89	4164 RAM	64K × 1-bit dynamic RAM
U90	4164 RAM	64K × 1-bit dynamic RAM
U91	4164 RAM	64K × 1-bit dynamic RAM
U92	4164 RAM	64K × 1-bit dynamic RAM
U93	4164 RAM	64K × 1-bit dynamic RAM
U94	74LS04	Hex inverter
U95	75477	Relay driver
U96	74LS74	Dual-D flip-flop
U97	74S08	Quad 2-input AND gate
U98	74LS175	Quad-D flip-flop
U99	74LS04	Hex inverter

Other Components

Location	Device	Description
D1	Type FC	Silicon diode
X1	Crystal	14.31818 MHz crystal oscillator

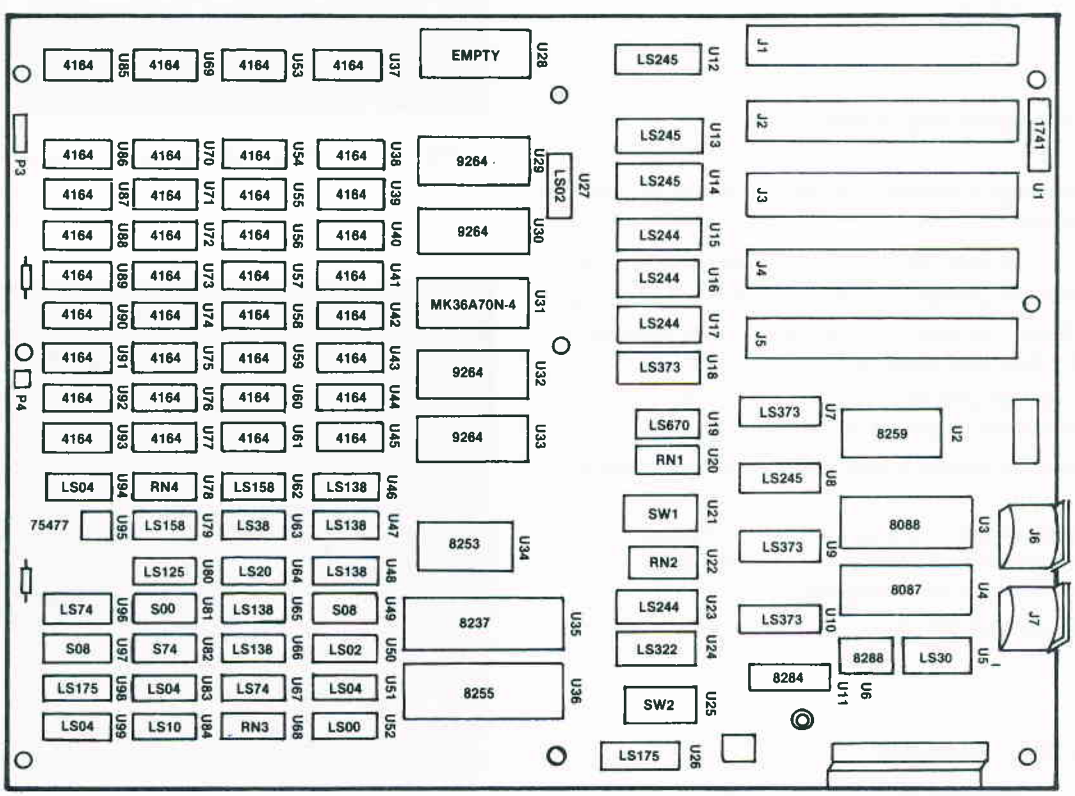

Fig. A-1. IBM Personal Computer motherboard chip location map.

IBM PC SYSTEM UNIT DISASSEMBLY INSTRUCTIONS

These procedures apply to those repairs that require access to the internal subassemblies of the IBM PC system unit.

System Board Removal

Tools and Equipment Required

- #2 flat-head screwdriver
- Uncluttered workspace
- Container to hold screws until reassembly

Procedure for System Board Access

1. Turn power off.
2. Unplug the power cord and any peripherals from the rear of the computer.
3. Position the system unit so the rear is facing you.
4. Using a flat-head screwdriver, remove the five screws from the rear plate. (Refer to Fig. A-2.)

   Note: The older model IBM PC's have only three screws on the back plate.
5. Position the system unit so that the front is facing you.
6. Place your hands on either side of the cover and slide the cover off the main unit, pulling toward you as shown in Fig. A-3.

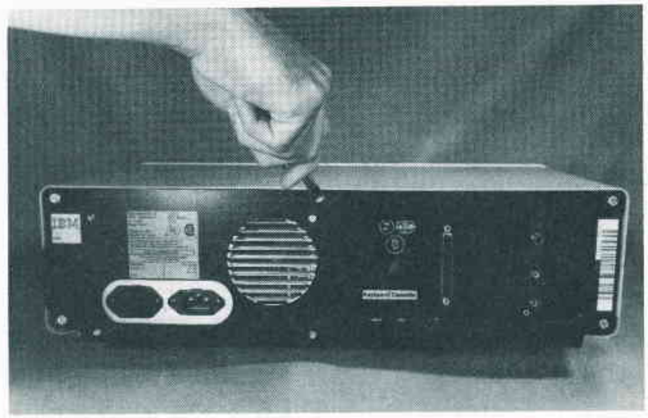

Fig. A-2. Remove these screws to disassemble the IBM PC.

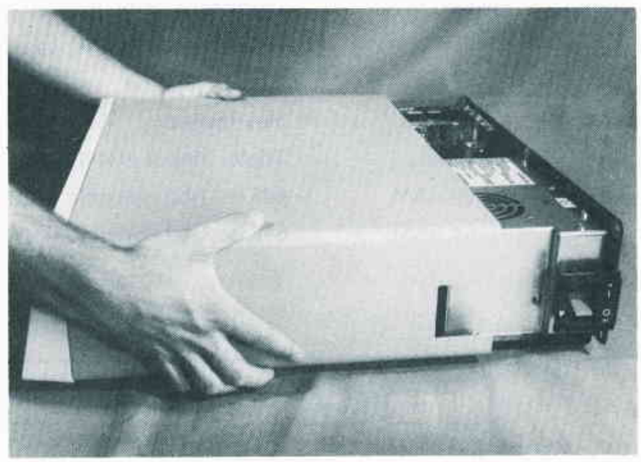

Fig. A-3. Gently slide the system unit cover forward.

Procedure for Removing System Board

1. Follow steps 1 through 6 in the procedure for system board access.
2. Remove all peripheral cards from the system board.
3. Remove the power connector from the system board.

   Note: The power connector is located in the back on the right side (looking from the front).
4. Remove the speaker cable from the connector on the lower middle section of the system board.
5. Remove the system board mounting screws as shown in Fig. A-4.
6. Slide the system unit board away from the power supply approximately 2 inches until the stand-offs can be lifted from their mounting slots.
7. Lift the system board from the system unit.

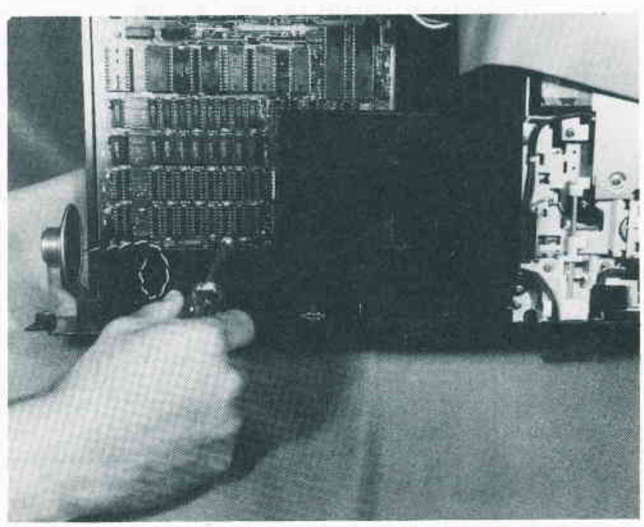

Fig. A-4. Remove the system-board mounting screws.

Power Supply Removal

This section describes the steps required to remove the power supply from the chassis.

Tools and Equipment Required

- #2 flat-head screwdriver
- Uncluttered workspace
- Container to hold screws until reassembly

Procedure

1. Turn the power off.
2. Unplug the power cord and any peripherals from the rear of the computer.
3. Position the system unit so the rear is facing you.
4. Remove the system unit cover.

   Note: See "Procedure for system board access."
5. Remove the power connector from the system board.

   Note: This is located in the back on the right side looking from the front.
6. If you have drives hooked to your system, disconnect the power cables going to the drive analog cards.
7. Remove the four power supply screws on the back of the chassis.
8. Push the power supply forward about ½-inch.
9. To remove the supply, lift up and pull the power supply away from the motherboard.

IBM PC SYSTEM UNIT REASSEMBLY INSTRUCTIONS

After the repair is complete, follow these steps to put your system back together.

Reinstalling the System Board

Tools and Equipment Required

- #2 flat-head screwdriver
- Uncluttered workspace
- Container to hold screws until reassembly

Procedure for Replacing the System Board

1. Position all the stand-offs hooked to the system board above the mounting holes.
2. Gently push the system board toward the power supply until you can see that the mounting screw holes line up.
3. Reinstall the mounting screws in the system board.
4. Reconnect the signal wires to the speaker.
5. Install the adapter cards.
6. Reconnect the system board power supply connectors.

Power Supply Installation

This section describes the steps needed to reinstall a power supply in the chassis.

Tools and Equipment Required

- #2 flat-head screwdriver
- Uncluttered workspace
- Container to hold screws until reassembly

Procedure

1. Hold the power supply unit approximately ½-inch from the rear of the chassis, and push the supply toward the motherboard and then back to align the screw holes in the chassis.
2. Replace the four mounting screws for the power supply.
3. Reconnect the disk drive power supply connectors.
4. Reconnect the motherboard power supply connectors.
5. Reconnect the power cord.
6. Power up and test.

Reassembling the System Unit Case

1. Gently slide the system unit case forward over the system unit.
2. Reinstall the five flat-head screws on the back of the chassis.

   Note: The older model IBM PC has only three screws on the back plate.
3. Reconnect all peripherals and the power cord.

KEYBOARD DISASSEMBLY AND REASSEMBLY INSTRUCTIONS

Keyboard Disassembly

This section explains the proper procedures for disassembling the keyboard.

Tools and Equipment Required

- Small Phillips screwdriver
- Uncluttered workspace
- Container to hold screws until reassembly

Disassembly Procedure

1. Turn the system unit off.
2. Remove the keyboard from the connector in the back of the system unit.

3. Turn the keyboard upside down.
4. Remove the two Phillips screws from the bottom of the keyboard plate.
5. Lift the top of the plate up and out of the retaining slots in the chassis of the keyboard.
6. Disconnect the cable from the keyboard assembly.
7. Lift the rear of the keyboard out of the chassis.

Keyboard Reassembly

This section explains the proper procedures for putting the keyboard back together after repairs have been made.

Tools and Equipment Required

- Small Phillips screwdriver
- Uncluttered workspace
- Container to hold screws until reassembly

Reassembly Procedure

1. Position the front of the keyboard assembly into the front of the keyboard chassis.
2. Lower the back of the keyboard down into the chassis.
3. Reconnect the cable to the keyboard assembly.
4. Put the tabs on the front of the base into the slots on the front of the keyboard chassis.
5. Slowly lower the back down—don't forget to include the adjustable legs on the bottom of the keyboard.
6. Install the two Phillips screws into the mounting holes on the bottom of the keyboard.
7. Reconnect the cable to the system unit assembly.
8. Power up and test.

DISK DRIVE DISASSEMBLY AND REASSEMBLY INSTRUCTIONS

These procedures are covered in Chapter 5, "Routine Preventive Maintenance," page 135.

REPLACING SURFACE-MOUNTED COMPONENTS ON THE SYSTEM BOARD

Desoldering and soldering on the IBM PC system board is not easy—the board construction is such that damage to the board traces and solder points can easily occur if you aren't extremely careful.

Caution: Proceed at your own risk.

1. Reread the section on soldering techniques found in Chapter 6.
2. Be sure you're using a temperature-controlled iron.
3. Disassemble the machine and remove the system board.
4. Place the board on its edge and locate the component to be replaced.
5. If possible, during chip removal, attach an extractor tool to the component to be replaced and use a DIP tip on your soldering iron to heat the pins and remove the chip. Or use a vacuum "solder sucker," or braided-copper wick and the temperature-controlled iron to heat the pins (start at the corners first, then desolder every other pin to avoid overheating one area of the board trace) until the component comes free.
6. Clean the solder holes using the techniques described in Chapter 6.
7. If a chip was removed, install an IC socket in its place on the system board. This lets you install a replacement chip into an already soldered connection, eliminating the need to solder directly to the chip pins themselves.
8. If a transistor is being replaced, install a transistor socket in the system board connection holes.
9. If a resistor, diode, or capacitor is being replaced, solder the leads directly in the opened holes in the board.
10. Reinstall the system board in the computer's housing.
11. Reassemble the computer.
12. Reconnect the power cord.
13. Power up and test.
14. Return the computer to service (or break back down again to replace another possibly faulty component).

Reminder: If your efforts didn't solve the problem, and you've replaced all the suspected components with *good* components, you have little recourse—pack it up, and take the system to a repair service center.

USEFUL RECORDKEEPING FORMS

Equipment History Record

EQUIPMENT HISTORY RECORD
(Repair Action Log)

Name of Unit	Model	Serial Number	Card Number

Manufacturer ______________________________

Date Installed ______________________________

Date	Nature of trouble	Cause of failure, description of work done	Name of part	Circuit symbol

(SAMPLE) EQUIPMENT HISTORY RECORD (Repair Action Log)

Name of Unit	Model	Serial Number	Card Number
IBM PC	5150	9373985150	1

Manufacturer IBM

Date Installed July 15, 1982

Date	Nature of trouble	Cause of failure, description of work done	Name of part	Circuit symbol
1982				
09/22	Keys won't work	Bad keyboard cable	Cable	None
12/25	PM	Cleaned	—	—
1983				
03/01	PM	Cleaned	—	—
06/01	PM	Cleaned	—	—
09/01	PM	Cleaned	—	—
11/23	Read error	Disk speed off. Readjusted speed.	Drive A	Speed
1984				
01/03	PM	Cleaned, checked speed of disk drives.	—	—

Record of Configuration Changes

RECORD OF CONFIGURATION CHANGES

Name of Equipment	Serial Number	Model	Date Installed	Card Number

Number	Kind of Change	Date of Change

(SAMPLE) RECORD OF CONFIGURATION CHANGES

Name of Equipment	Serial Number	Model	Date Installed	Card Number
IBM PC	9373985150	5150	07/15/82	1

Number	Kind of Change	Date of Change
1	Filled on-board RAM to 256K	02/20/83
2	Added CP/M interface adapter	04/05/84

System Description

SYSTEM DESCRIPTION

Hardware:

System: **Model:** **Serial Number:**

Memory Size:

	Type	Serial Number
Disk Drives:		
Printer:		
Display:		
Modem:		

Software:

System Utilities	Languages	Data Management Tools	Applications Software

Communications software:

(SAMPLE) SYSTEM DESCRIPTION

Hardware:

System: IBM PC **Model:** 5150 **Serial Number:** 9373985150

Memory Size: 256K

	Type	Serial Number
Disk Drives:	Tandon	5306553
	Tandon	5306554
Printer:	Okidata Microline 92	840040
	Typrinter 221	1901
Display:	AMDEK Video 300	3285340
Modem:	Hayes SMARTMODEM 1200	162124063

Software:

System Utilities	Languages	Data Management Tools	Applications Software
PC-DOS	Adv BASIC	SuperCalc	WordStar
Quickcode	PASCAL/MT CP/M 86	dBase II	Stock Base

Communications software:
Modem 7
Smartcom II

Operational Log Sheet

OPERATIONAL LOG SHEET

Name of Equipment: **Serial Number:**

Configuration:

DATE	ON	OFF	DATE	ON	OFF	DATE	ON	OFF

ROUTINE PREVENTIVE MAINTENANCE

Preventive maintenance, or PM, is one of the least used techniques for operational cost reduction, yet the savings that results can be substantial. If the equipment doesn't fail, you can't evaluate the bottom-line savings in conducting proper PM. But after your first mind-boggling repair bill, the fact will sink in: you might have prevented this failure by doing some easy, routine maintenance.

Someone once said "Time is money." Failure to take the time to do routine preventive maintenance can indeed cost money. Do your PMs!

Many manufacturers are not sure what an optimum PM schedule should be. Some companies prefer you don't do any PMs. (The effect is to cause more equipment repair business for their service people.) Among those who recommend PMs, there is great variation in recommended schedules for similar hardware (e.g., disk drives).

The listing that follows is a consensus of recommendations from manufacturers, dealers, and users and the author's own experience.

Optimum PM Schedule

Note: Modify the schedule below if intermittents occur frequently.

Daily

Log operational time.
    Estimate disk drive "run-light-ON" time; estimate printer "printing" time; estimate computer "power-ON" time.
Monitor humidity (a measure of static electricity).

Weekly

Clean computer system work area.
    Pick up all loose trash; reshelve scattered books; restore magazines; toss out old printed paper; toss those "bad" disks you've been saving; wipe down hardware with anti-static, dust-absorbing cloth; wipe desk and bench space with antistatic cloth; vacuum shelves, desk, and floor.
Clean equipment housings and cases.
    Wipe chassis with antistatic cloth; "wash" with lightly soaped damp cloth.
Clean display screens.
    Use antistatic "dust-off" type spray or damp cloth of anti-static solution.
Clean drive read head (after 40 hours of "run-light-ON" use).

Monthly

Clean inside computer.
    Disassemble according to the procedures in this Appendix; use soft brush and long narrow vacuum cleaner hose nozzle (it helps to spray the nozzle with antistatic solution first).
Clean inside printer.
    Use same technique as for cleaning inside computer.
Check ventilation filters in equipment.
    Replace if cleaning is not practical (filter becomes worn or badly soiled).
Check connector contacts.
    Look for signs of corrosion, pitting, or discoloration; clean if necessary; the corrosion-removing wipes that also coat the surface with a lubricating coating to protect it from atmospheric corrosion are strongly recommended.
Some manufacturers recommend that you also demagnetize the drive read head (after 40 hours of "run-light-ON" use).

Every Other Month

Reseat socketed chips on the motherboard.
    Disassemble according to the procedures in this Appendix.
Disconnect and reconnect cable and connector plugs.
    This removes corrosion buildup.
Apply antistatic treatment to computer work area.
    See Chapter 6 for details.
Clean inside printer.
    Use nonmagnetic, plastic vacuum hose nozzle and soft camel hair brush; spray or wipe nozzle with antistatic spray or solution first.

Every Six Months

Replace vent filters.
    Do this only if you have filters; none are standard in the IBM PC.
Check disk drive speed.
    Speed test programs are advertised in computer publications; remember the fluorescent light, strobe mark test (see Chapter 6).
Check head alignment.
    Do this only if you suspect a disk problem.
Clean connector contacts.
    If you haven't done this during earlier inspection checks, conduct this PM now; do this PM more often if your computer system is used in a smoggy part of the country or near salt air.
Clean disk drive read head.
    If you use your system daily, your drive heads may need cleaning about now, but this depends very much on the kind and quality of disks you use.
Conduct routine inspection of printer.
    Do this every 6 months or 500,000 lines of print; check the tightness of the screws and connectors; conduct a printer self test as described in the printer owner's manual.

Annually

Take routine maintenance infrared photo (optional).

SUMMARY OF CAUTIONS AND NOTES

The following is a listing of the **Caution** and **Note** statements used in this troubleshooting and repair guide. They are repeated here so you can review them quickly. It's a good idea to review them periodically.

- Never insert or remove a peripheral connector without first turning off the power to the computer, grounding yourself, and then reaching around in back of the computer and pulling the power plug out.
- Any time you open the computer, ensure that the power is off and that you have grounded any stray static electricity you might have been carrying.
- For any procedures conducted with the IBM PC open and with the computer operating, be careful not to short out any connectors or pin leads. Use only a nonmetallic or wooden object inside an energized computer.
- Keep out of the display chassis.
- Stay out of the power supply.
- Use a power strip. Plug the IBM PC and all peripherals (except a hard disk drive) into a switch-controlled strip.
- Keep liquids away from the computer.
- Handle components with care.
- When cleaning, make *sure* that the power is off and that all plugs are pulled out of the power sockets. Use a damp cloth. Don't let any liquid run or get into your equipment.
- When rubbing to clean contacts, always rub *lengthwise* along the pin.
- When using a logic clip, turn the power to the circuit off, attach the clip, and then turn the power on. This helps prevent accidentally shorting out a chip.
- In the event of a lightning storm, unplug your entire system.
- Don't use power tools near your computer while it's operating.
- IBM PC-Easy steps to success:
  1. Don't panic.
  2. Observe the conditions.
  3. Use your senses.
  4. Retry.
  5. Document.
  6. Assume one problem.
  7. Diagnose to a section (fault identification).
  8. Consult the symptom index (error code interpretation and problem matching).
  9. Localize to a stage.
  10. Isolate to a failed part.
  11. Repair.
  12. Test and verify.
- Keep cables clear and away from power cords, especially coiled power cords.
- Be careful not to flex the system board or other boards too much.
- It's a good idea to log the repair action in a record book to develop a history of the maintenance conducted on the machine (see pages 186–187 for "Equipment History Records").
- Don't wait for lightning to strike before you protect your computer system investment from electrical surges.
- Always unplug your computer system when blackout occurs.
- Never touch contacts with your fingers.
- Keep your diskettes, and even your information cables, away from power sources.
- You can damage the disk drive electronics if you attach the cable incorrectly (see your disk drive owner's manual).
- Handle diskettes carefully. Don't leave the disks lying around. Keep the disks in protective jackets. Don't touch the disk surface with your fingers. Keep the disks out of the hot sun.
- Don't use both sides of your disks in a single-sided drive.
- To extend disk life
  - Buy name brand disks.
  - Never touch the disk surface.
  - Never slam the disk drive door closed on a disk.
  - Store disks in their protective jackets.
  - Never write on a label that's already on a disk.
  - Store disks in a cool, clean place.
  - Back up all data disks.
  - Store working disks and backup disks in different places.
  - Never allow smoking near your disks or your drive.
  - Never set disks near monitors or televisions.
  - Avoid placing disks near vacuum cleaners and large motors.
  - Don't bend or fold disks.
  - Don't put disks through airport X-ray machines.
- Clean the read/write heads after every 40 hours of disk operation.
- Provide adequate ventilation when cleaning read heads with solvent.
- Make sure the solvent evaporates before you operate the drive.
- If disk drive speed adjustment seems difficult (see Chapter 5), have a repair service shop do it.

ASCII CODE CHART

The following table lists all the ASCII codes (in decimal) and their associated characters. These characters can be displayed using PRINT CHR$(*n*). where *n* is the ASCII code. The column headed "Control Character" lists the standard interpretations of ASCII codes 0 to 31 (usually used for control functions or communications).

Each of these characters may be entered from the keyboard by pressing and holding the Alt key, then pressing the digits for the ASCII code on the numeric keypad. Note, however, that some of the codes have special meaning to the BASIC program editor—the program editor uses its own interpretation for the codes and may not display the special character listed here.

ASCII value	Character	Control character	ASCII value	Character	ASCII value	Character	ASCII value	Character
000	(null)	NUL	032	(space)	064	@	096	`
001	☺	SOH	033	!	065	A	097	a
002	●	STX	034	"	066	B	098	b
003	♥	ETX	035	#	067	C	099	c
004	♦	EOT	036	$	068	D	100	d
005	♣	ENQ	037	%	069	E	101	e
006	♠	ACK	038	&	070	F	102	f
007	(beep)	BEL	039	'	071	G	103	g
008	■	BS	040	(	072	H	104	h
009	(tab)	HT	041	)	073	I	105	i
010	(line feed)	LF	042	*	074	J	106	j
011	(home)	VT	043	+	075	K	107	k
012	(form feed)	FF	044	,	076	L	108	l
013	(carriage return)	CR	045	-	077	M	109	m
014	♫	SO	046	.	078	N	110	n
015	☼	SI	047	/	079	O	111	o
016	►	DLE	048	0	080	P	112	p
017	◄	DC1	049	1	081	Q	113	q
018	↕	DC2	050	2	082	R	114	r
019	!!	DC3	051	3	083	S	115	s
020	¶	DC4	052	4	084	T	116	t
021	§	NAK	053	5	085	U	117	u
022	▬	SYN	054	6	086	V	118	v
023	↨	ETB	055	7	087	W	119	w
024	↑	CAN	056	8	088	X	120	x
025	↓	EM	057	9	089	Y	121	y
026	→	SUB	058	:	090	Z	122	z
027	←	ESC	059	;	091	[	123	{
028	(cursor right)	FS	060	<	092	\	124	¦
029	(cursor left)	GS	061	=	093	]	125	}
030	(cursor up)	RS	062	>	094	^	126	~
031	(cursor down)	US	063	?	095	_	127	⌂

ASCII value	Character	ASCII value	Character	ASCII value	Character
128	Ç	177	▒	226	Γ
129	ü	178	▓	227	π
130	é	179	│	228	Σ
131	â	180	┤	229	σ
132	ä	181	╡	230	μ
133	à	182	╢	231	τ
134	å	183	╖	232	Φ
135	ç	184	╕	233	Θ
136	ê	185	╣	234	Ω
137	ë	186	║	235	δ
138	è	187	╗	236	∞
139	ï	188	╝	237	Ø
140	î	189	╜	238	ε
141	ì	190	╛	239	∩
142	Ä	191	┐	240	≡
143	Å	192	└	241	±
144	E	193	┴	242	≥
145	æ	194	┬	243	≤
146	Æ	195	├	244	⌠
147	ô	196	─	245	⌡
148	ö	197	┼	246	÷
149	ò	198	╞	247	≈
150	û	199	╟	248	°
151	ù	200	╚	249	•
152	ÿ	201	╔	250	·
153	Ö	202	╩	251	√
154	Ü	203	╦	252	ⁿ
155	¢	204	╠	253	²
156	£	205	═	254	■
157	¥	206	╬	255	(blank 'FF')
158	Pt	207	╧		
159	ƒ	208	╨		
160	á	209	╤		
161	í	210	╥		
162	ó	211	╙		
163	ú	212	╘		
164	ñ	213	╒		
165	Ñ	214	╓		
166	ª	215	╫		
167	º	216	╪		
168	¿	217	┘		
169	⌐	218	┌		
170	¬	219	█		
171	½	220	▄		
172	¼	221	▌		
173	¡	222	▐		
174	«	223	▀		
175	»	224	α		
176	░	225	β		

HEXADECIMAL-TO-DECIMAL CONVERSION CHART

Hex	Dec	Hex	Dec	Hex	Dec	Hex	Dec	Hex	Dec
$00	00	$34	52	$68	104	$9C	156	$D0	208
$01	01	$35	53	$69	105	$9D	157	$D1	209
$02	02	$36	54	$6A	106	$9E	158	$D2	210
$03	03	$37	55	$6B	107	$9F	159	$D3	211
$04	04	$38	56	$6C	108	$A0	160	$D4	212
$05	05	$39	57	$6D	109	$A1	161	$D5	213
$06	06	$3A	58	$6E	110	$A2	162	$D6	214
$07	07	$3B	59	$6F	111	$A3	163	$D7	215
$08	08	$3C	60	$70	112	$A4	164	$D8	216
$09	09	$3D	61	$71	113	$A5	165	$D9	217
$0A	10	$3E	62	$72	114	$A6	166	$DA	218
$0B	11	$3F	63	$73	115	$A7	167	$DB	219
$0C	12	$40	64	$74	116	$A8	168	$DC	220
$0D	13	$41	65	$75	117	$A9	169	$DD	221
$0E	14	$42	66	$76	118	$AA	170	$DE	222
$0F	15	$43	67	$77	119	$AB	171	$DF	223
$10	16	$44	68	$78	120	$AC	172	$E0	224
$11	17	$45	69	$79	121	$AD	173	$E1	225
$12	18	$46	70	$7A	122	$AE	174	$E2	226
$13	19	$47	71	$7B	123	$AF	175	$E3	227
$14	20	$48	72	$7C	124	$B0	176	$E4	228
$15	21	$49	73	$7D	125	$B1	177	$E5	229
$16	22	$4A	74	$7E	126	$B2	178	$E6	230
$17	23	$4B	75	$7F	127	$B3	179	$E7	231
$18	24	$4C	76	$80	128	$B4	180	$E8	232
$19	25	$4D	77	$81	129	$B5	181	$E9	233
$1A	26	$4E	78	$82	130	$B6	182	$EA	234
$1B	27	$4F	79	$83	131	$B7	183	$EB	235
$1C	28	$50	80	$84	132	$B8	184	$EC	236
$1D	29	$51	81	$85	133	$B9	185	$ED	237
$1E	30	$52	82	$86	134	$BA	186	$EE	238
$1F	31	$53	83	$87	135	$BB	187	$EF	239
$20	32	$54	84	$88	136	$BC	188	$F0	240
$21	33	$55	85	$89	137	$BD	189	$F1	241
$22	34	$56	86	$8A	138	$BE	190	$F2	242
$23	35	$57	87	$8B	139	$BF	191	$F3	243
$24	36	$58	88	$8C	140	$C0	192	$F4	244
$25	37	$59	89	$8D	141	$C1	193	$F5	245
$26	38	$5A	90	$8E	142	$C2	194	$F6	246
$27	39	$5B	91	$8F	143	$C3	195	$F7	247
$28	40	$5C	92	$90	144	$C4	196	$F8	248
$29	41	$5D	93	$91	145	$C5	197	$F9	249
$2A	42	$5E	94	$92	146	$C6	198	$FA	250
$2B	43	$5F	95	$93	147	$C7	199	$FB	251
$2C	44	$60	96	$94	148	$C8	200	$FC	252
$2D	45	$61	97	$95	149	$C9	201	$FD	253
$2E	46	$62	98	$96	150	$CA	202	$FE	254
$2F	47	$63	99	$97	151	$CB	203	$FF	255
$30	48	$64	100	$98	152	$CC	204		
$31	49	$65	101	$99	153	$CD	205		
$32	50	$66	102	$9A	154	$CE	206		
$33	51	$67	103	$9B	155	$CF	207		

Glossary

A

Adapter A printed-circuit card or board used to connect peripheral equipment such as disk drives and display monitors to the IBM PC.

Address A number that represents a unique location in IBM PC memory.

Address bus The collection of 16 wires that carry the memory address from the CPU to the memory or to an external storage device.

Alphanumeric A character set containing letters and digits.

ALU Arithmetic logic unit.

American Standard Code for Information Interchange A code representing the character symbols possible for specific hexadecimal codes.

Analog An electrical signal in which information is represented by the level of voltage (e.g., 0 volts, 1.5 volts, and 3.7 volts all carry information). This is the opposite of binary, a digital system that has only two levels—0 volts for logic 0 and +5 volts for logic 1.

AND A logic gate used in the IBM PC computer; the output is HIGH, or logic 1, if, and only if, all inputs are also logic HIGH.

Arithmetic logic unit The portion of the CPU that performs arithmetic and logical operations.

ASCII American Standard Code for Information Interchange.

B

BASIC Beginner's All-purpose Symbolic Instruction Code; an easy-to-learn high-level language.

Basic input/output system The part of the operating system that controls the input and output functions other than those involving the disk drive.

Baud A unit of measurement for the speed of digital communications; 1 baud equals 1 bit per second.

Binary A condition in which only two states can exist. Binary numbers are 0 and 1. These can be related to OFF (0) and ON (1) or FALSE (0) and TRUE (1).

BIOS Basic input/output system.

Bit Bit is a contraction of binary digit. It is the smallest unit of information storage and is combined with other bits to form the address and data words in your IBM PC.

Blackout The complete loss of electrical power.

Boot (bootstrap) A technique for loading a routine into main memory by loading several instructions that then bring the entire routine into main memory. The program, in effect, pulls itself up to completion by its "bootstrap."

Brownout A deliberate reduction in the electrical line voltage; usually caused by excessive electrical demand or insufficient power generation capability.

Buffer A storage location in an electronic chip that is used to temporarily hold data during electronic communication between two devices that are operating at different speeds. It may also be used to temporarily hold data until a data path is clear.

Bus The main communication circuit in a computer. Each register and location in memory is connected to the bus. The bus needs to consist of as many wires as there are bits in the computer words. For instance, there are 16 wires in the address bus to carry 16 bits of information.

Byte The size of the data word in your computer. A byte is 8 bits wide and represents a numerical value between 0 and 255 (decimal).

C

Cathode ray tube The display screen used in computer systems for viewing data and graphics.

Central processing unit The 8088 microprocessor, which is the heart of your computer. This portion of the computer is composed of the ALU and the control unit. It fetches, decodes, and executes instructions and controls the overall activity of the computer is controlled.

Channel A pathway for input or output of information. The expansion slots are called the PC's I/O channel.

Chip An integrated circuit created on a small silicon flake. It consists of a large number of gates and the paths connecting them, formed by very thin films of metal acting as wires. The term "chip" includes the silicon flake as well as the plastic support package.

Clock A circuit that sends a consistent, periodic signal that is used to step logic information through a computer circuit.

Cold boot Initializing the start-up conditions in your IBM PC computer. The cold boot process assumes no previous activity in the computer and sets all the registers in the machine to initial conditions.

Control bus The circuit along which control signals are transmitted.

Control unit The part of the IBM PC that receives and decodes instructions from a program in main memory, and then signals the appropriate units to execute the instructions.

CPU Central processing unit.

CRT Cathode ray tube.

Cursor The symbol on the display screen that indicates the position in which the next character will appear.

D

Data Computer information such as numbers, letters, or special symbols.

Data bus The collection of wires or traces that carry the 8-bit data word from one location to another in your IBM PC computer.

Diagnostic An action or program that detects and isolates malfunctions or failures in computer hardware or software.

DIN A standard for computer equpment; the Deutsche Industrie Norm.

DIP Dual in-line package

Direct memory access A method for transferring data directly to and from main memory, bypassing the CPU.

Disk The magnetic medium on which computer data is stored.

Disk operating system A disk drive controller program.

Display The device on which visual information is displayed on a screen. The monitor in your IBM PC.

DMA Direct memory access.

DOS Disk operating system.

Driver A short subroutine or program that controls the I/O interaction between two devices (e.g., between the disk drives and the computer's CPU).

Dual in-line package The most common type of integrated circuit chip package, having two parallel rows of seven pins each.

E

Erasable programmable read-only memory A type of ROM that can be erased and reprogrammed by applying a specified voltage to a certain pin on the chip.

EPROM Erasable programmable read-only memory.

F

Firmware Programs that are stored in hardware, such as ROM.

Flip-flop An electronic device that maintains a value of 1 or 0 until acted on by a signal on a certain input pin.

H

Hardware The physical components of a computer system. The computer itself, the printer, the monitor display unit, and so on.

Head The electromagnetic device that transfers data to and from your disks.

Hertz A unit of frequency; one cycle per second.

Hexadecimal The numbering system based on 16 digits, in which the values above 9 become A, B, C, D, E, and F. Each hexadecimal number can be represented as a 4-bit code.

I

IC Integrated circuit, see chip.

Initialize To set a storage location, counter, or variable, for example, to a starting value.

Input/output The process of entering information into the computer or of transferring data from the computer to the outside world; for example, disk drives, keyboard, and display unit are input/output devices.

Interface A boundary shared by two or more devices.

I/O Input/output.

K

K Stands for *kilo*, and in computer jargon is equal to 1024. K is the symbol used to represent the size of memory in your computer. The term 64K actually means 65,536.

L

Location A place in memory where information may be stored.

M

Main storage The storage located in the computer for programs, along with their data, while they are executing. The main storage in the PC is the RAM memory.

Memory The hardware in or on which programs are stored. Memory can be RAM or ROM chips, magnetic disks, magnetic tape, or magnetic bubbles (in bubble memory).

MHz Megahertz; a frequency of 1 million cycles per second.

Microprocessor An integrated circuit device that executes coded instructions that are entered, integrated, or stored within the device.

Modem A device (Modulator-Demodulator) that converts digital information into tones so it can be transmitted and received over communications lines such as telephone lines.

Monitor 1. A high-resolution display unit that produces sharper images than a standard television display. 2. A special program that is stored permanently in ROM; it enables interaction between you and the computer.

Motherboard The large printed-circuit board (system board) in the computer on which most of the electronic devices are mounted. The motherboard is the primary or main board in the computer. All other interfaces receive control signals or information from the motherboard.

N

Noise The electrical interference that distorts the transmission of data and results in errors in the data. Noise can be caused by the presence of an electrical field such as that generated by data busses or TV/radio in the vicinity of electrical signals.

NOR A logic gate whose output is a logic 0 if any input is a logic 1, and a logic 1 only if all inputs are logic 0.

O

Operating system A collection of system programs that controls the operation of a computer system. It can also handle the interaction between parts of the computer system.

P

Peripheral A device, often sold as part of the computer, that is connected to the computer to enhance its operation. Examples of peripherals include disk drives, monitor display units, printers, and modems.

Pin Any of the leads on a device, such as a chip, that plug into a socket and connect it to a system.

Pixel A picture element. The smallest unit in a display. Usually, this is a dot on the screen.

Port A connection between the CPU and another device, such as main memory or an I/O device, which allows data to enter or leave the computer or to be transferred between the CPU and memory.

R

RAM Random-access memory.

Random-access memory Memory that can be directly read from or written to by your IBM PC's CPU. This memory is lost once the computer is turned off.

Read-only memory A type of memory chip that can be read from but cannot be written to or altered. ROM provides permanent storage for program instructions.

Resolution The measure of sharpness of a display image.

ROM Read-only memory.

S

Serial One after the other; sequential.

Software The programs that determine or control the actions of your computer.

Spike A short, high-energy burst of electrical energy that, if not bypassed (or shorted) to ground, can cause damage to electronic components.

Surge A temporary increase in electrical voltage lasting long enough for its effect to be noticed on a meter.

T

Transient Brief fluctuations in voltage.

Troubleshoot To systematically locate a computer hardware failure. Software failures are found by systematic debugging.

W

Warm boot The process of restarting the computer without reloading the operating system.

Word A grouping of binary information that represents a unique value or character. A word in the IBM PC can be an 8-bit data word, or byte, or it can be a 16-bit address word.

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