ELEC-8742 DESIGN FOR PORTABILITY IN ELECTRONICS

A WEB-BASED COURSE FOR SELF STUDY

P.ESKELINEN

THE CONTRIBUTION
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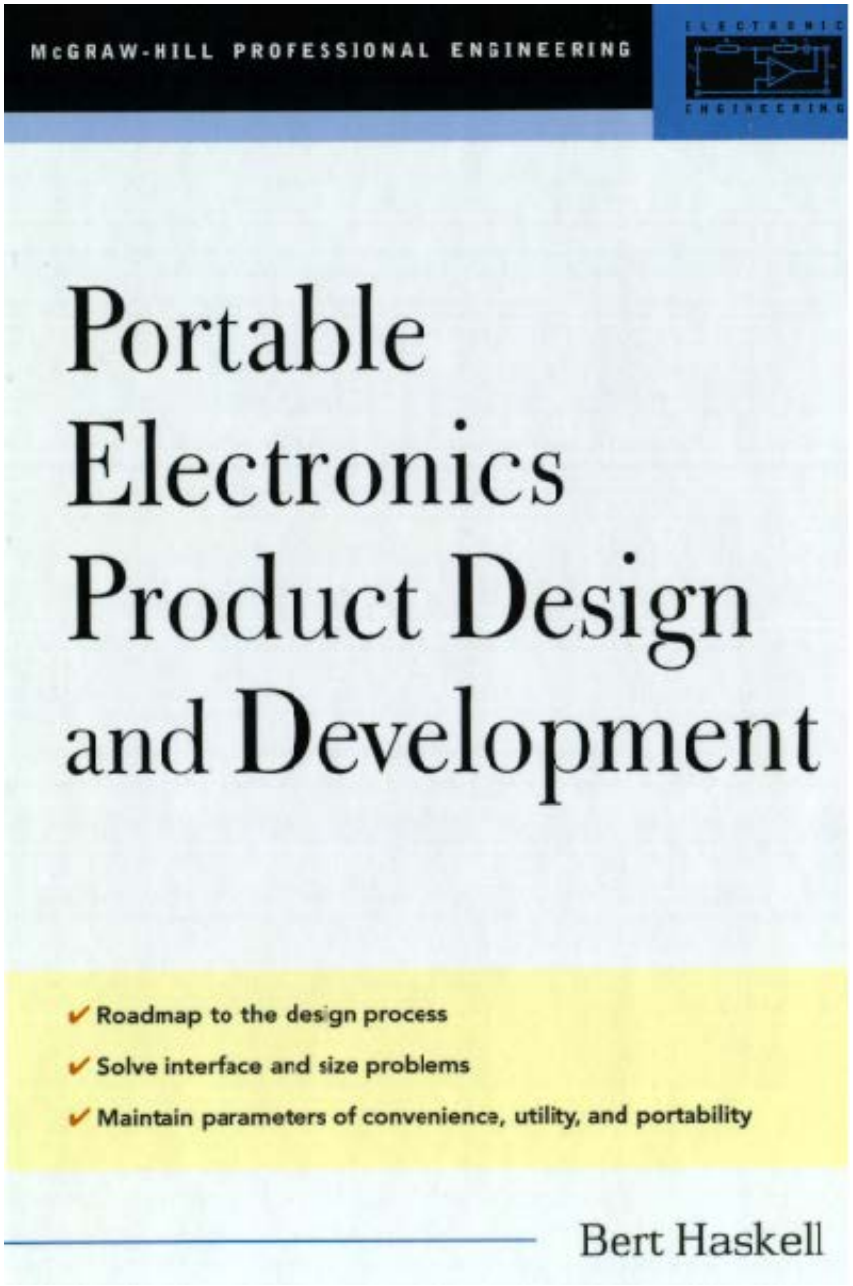
DR. HARRI ESKELINEN
MR. TIMO LEPOLA
MR. JUHANI MARTIKAINEN
MR. JUHA FORSTÉN
MR. ANTTI HÄMÄLÄINEN
MR. ESA KORPELA
MR. JAAKKO KAIRUS
MR. SAMPO OJALA

MATERIAL


McGRAW-HILL PROFESSIONAL ENGINEERING
Portable Electronics Product Design and Development
✔ Roadmap to the design process
✔ Solve interface and size problems
✔ Maintain parameters of convenience, utility, and portability
Bert Haskell

plus recommended titles:

A. Morita: **Made in Japan**
H. & P. Eskelinen: **Microwave Component Mechanics**
A. Mickelson: **Optoelectronic Packaging**
F. Jensen: **Electronic Component Reliability**
H. Cho: **Opto-Mechatronic Systems Handbook**
M. Ludvig-Becker: **Electronics Quality Management Handbook**

HOW TO PROCEED ?

- GO AND GET HASKELL'S BOOK AND HAVE IT AT HAND ALL THE TIME
- FOLLOW, SIDE-BY-SIDE, THE COMMENTED IDEAS IN THESE LECTURE NOTES AND COMPARE YOUR OWN THINKING WITH THAT PRESENTED IN THE BOOK
- MAKE "LECTURE NOTES" OF YOUR OWN
- WHEN GUIDED TO DO SO (OR WHEN EVER ADDITIONAL NEED COMES UP) STUDY THE SEPARATE THEMATIC PRESENTATIONS ON IMPORTANT TOPICS
- IF YOU RUN TO DESPERATE PROBLEMS IN UNDERSTANDING THE MATERIAL, YOU CAN CONTACT THE LECTURER THROUGH EMAIL
- INDICATE THE SLIDE NUMBER FOR REFERENCE TOGETHER WITH YOUR QUESTION
- AFTER GOING THROUGH ALL MATERIAL YOU MIGHT WANT TO HAVE A LOOK AT THE SAMPLE EXAM (THE LAST SLIDE IN THIS SET)

Contents

SEE SEPARATE THEMATIC PRESENTATION DIGITAL.PDF

SEE SEPARATE THEMATIC PRESENTATION COMPONENTS.PPT

SEE SEPARATE THEMATIC PRESENTATION POWER_SUPPLIES.PDF

Chapter 6. Mechanical Design

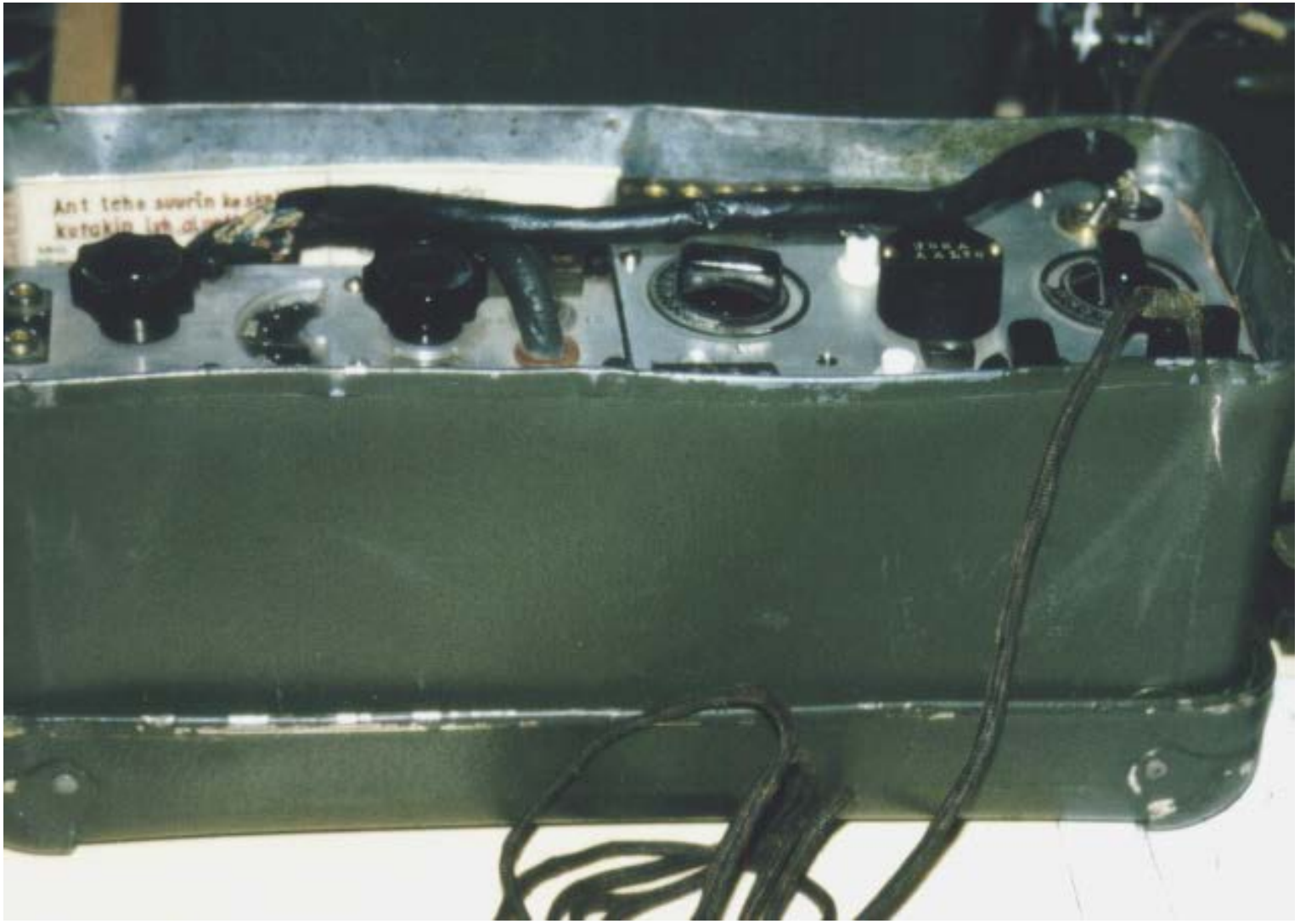
- 6.1 Housings
- 6.2 EMI Shielding
- 6.3 Thermal Management
- 6.4 Mechanical Integration
- 6.5 DFMA Analysis

Chapter 7. Software and Communications

- 7.1 Software Hierarchy
- 7.2 OSI Network Communications Model
- 7.3 Communications and System I/O
- 7.4 Wireless Standards

SEE SEPARATE THEMATIC PRESENTATIONS
ENCLOSURES_PROPERTIES.PPT
ENCLOSURES_MANUFACTURING.PPT
SHIELDING&THERMAL.PPT

ONCE UPON A TIME PORTABILITY WAS MANDATORY...



THE FINNISH ”KYYNEL” TRANSCEIVER

- DEVELOPED BY H. JALANDER AND R. LAUTKARI FROM 1939 TO 1944
- MODELS M4 TO M11X, ALL IN MODERN ARMY GREEN COLOR
- HF TRASNCEIVER, RANGE > 500 KM
- EXTREMELY DURABLE, WATER TIGHT
- FRIENDLY USER INTERFACE WITH JUST THREE KNOBS
- WEIGHT 5.6 KG (US AND GERMAN COMPETITORS 15 AND 18 KG)
- MULTIMODE: TX A0/A1 RX A1/A3
- BATTERY OPERATION DOWN TO – 40 C
- 500 UNITS SOLD TO SWEDEN IN 1944/45
- SOME VERSIONS AVAILABLE WITH BUILT-IN EXPLOSIVES

WHAT'S SO ESSENTIAL IN PORTABILITY ?

- WHO WANTS TO RUN AROUND WITH AN ELECTRONIC DEVICE ? (WHEN HE OR SHE JUST COULD SIT NEXT TO THE OPEN FIRE AND FEEL COMFORTABLE)
- WHY SUCH ACTIVITY ?
- WHAT ARE THE ULTIMATE LIMITS ?

GADGETRY

- THE MODERN LIFE IS MORE AND MORE TIED TO SMALL ELECTRONIC DEVICES
- THERE ARE NUMROUS PEOPLE WHO COLLECT EQUIPMENT (CD PLAYERS, MOBILE PHONES, PALM-TOP COMPUTERS, LASER POINTERS)
- MARKETING TRIES TO CONVINCE PEOPLE THAT THESE NEW TINY GADGETS MAKE LIVING MORE FUN
- FIRST THEY SELL YOU AN MP3 PLAYER WITH 16 MB MEMORY AND AFTER SIX MONTHS ONE WITH 128 MB

DIFFERENT APPROACHES:

- A THING IS ESSENTIALLY PORTABLE SUCH AS THE FINNISH PUUKKO
- A THING IS ESSENTIALLY ELECTRONIC SUCH AS A RADIO
- A THING IS ESSENTIALLY USED ALL AROUND SUCH AS A WRIST WATCH
- A THING IS ESSENTIALLY ESSENTIAL SUCH AS A CARDIAC PACEMAKER
- A THING IS ESSENTIALLY NONSENSE SUCH AS A TAMAGOCHI

TINY ASSIGNMENT FOR MOTIVATION

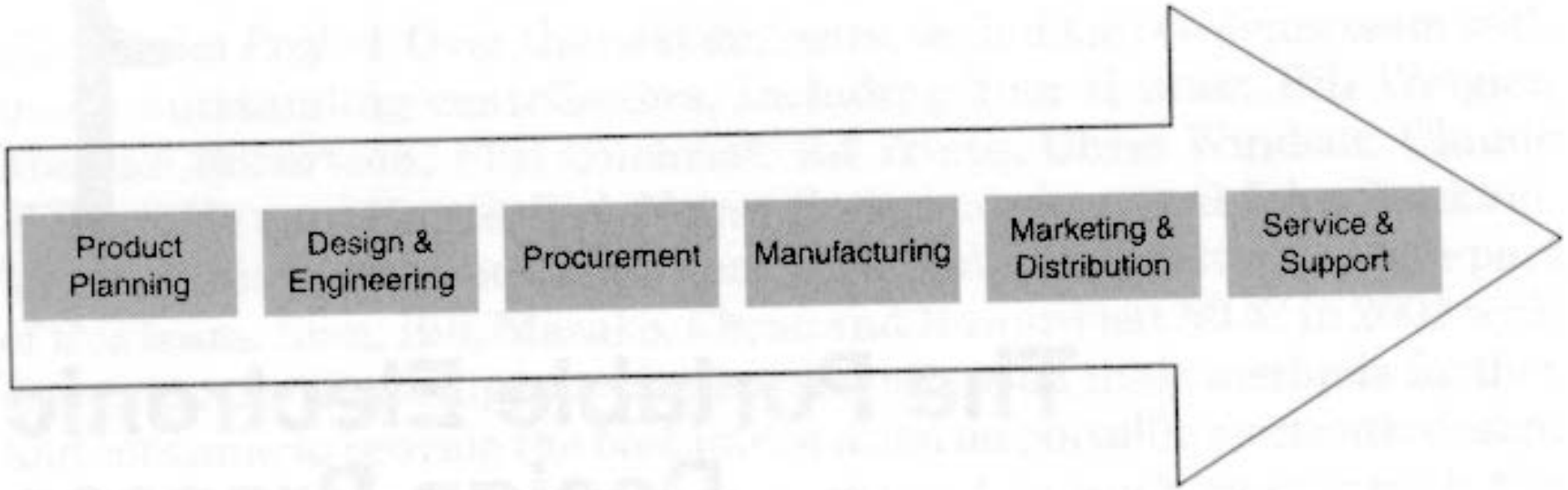
- EXAMINE A PIECE OF ELECTRONIC TRASH AT HAND, FOR EXAMPLE A SPOILED CELL PHONE
- EVALUATE ITS PURPOSE
- EVALUATE THE EXPECTED FUNCTIONS
- FIND OUT THE LEVEL OF REALIZATION COMPARED TO CURRENT STANDARDS AND PRACTICES
- PARTICULARLY: WHAT IS ”STABLE” AND WHAT WOULD BE DONE ENTIRELY DIFFERENTLY NOW
- WHICH THINGS MIGHT HAVE BEEN CHALLENGING
- PREPARE A VERY BRIEF STATEMENT AND ANALYSIS OF THE GARBAGE

CHAPTER 1

PORTABLE ELECTRONIC DESIGN PROCESS

TOPICS FOR DISCUSSION:

- PRODUCT PLANNING
- DESIGN AND ENGINEERING
- PROCUREMENT
- MANUFACTURING
- MARKETING & DISTRIBUTION
- SERVICE AND SUPPORT


Product Planning
Design & Engineering
Procurement
Manufacturing
Marketing & Distribution
Service & Support

IN PRODUCT PLANNING:

- SET OF REQUIREMENTS
- INITIAL BUSINESS PLAN
- NO SPECS

IN BUSINESS PLAN:

- CUSTOMER PROFILE
- GLOBAL FACTORS
- TIME SCALE
- COMPETITION

PORTABLE ELECTRONICS CUSTOMER PROFILE

- AGE 14-35
- MEN MORE OFTEN THAN WOMEN
- SPORTY OR NERDY
- NO CLEAR CONNECTION TO MONETARY OR SOCIAL STATUS

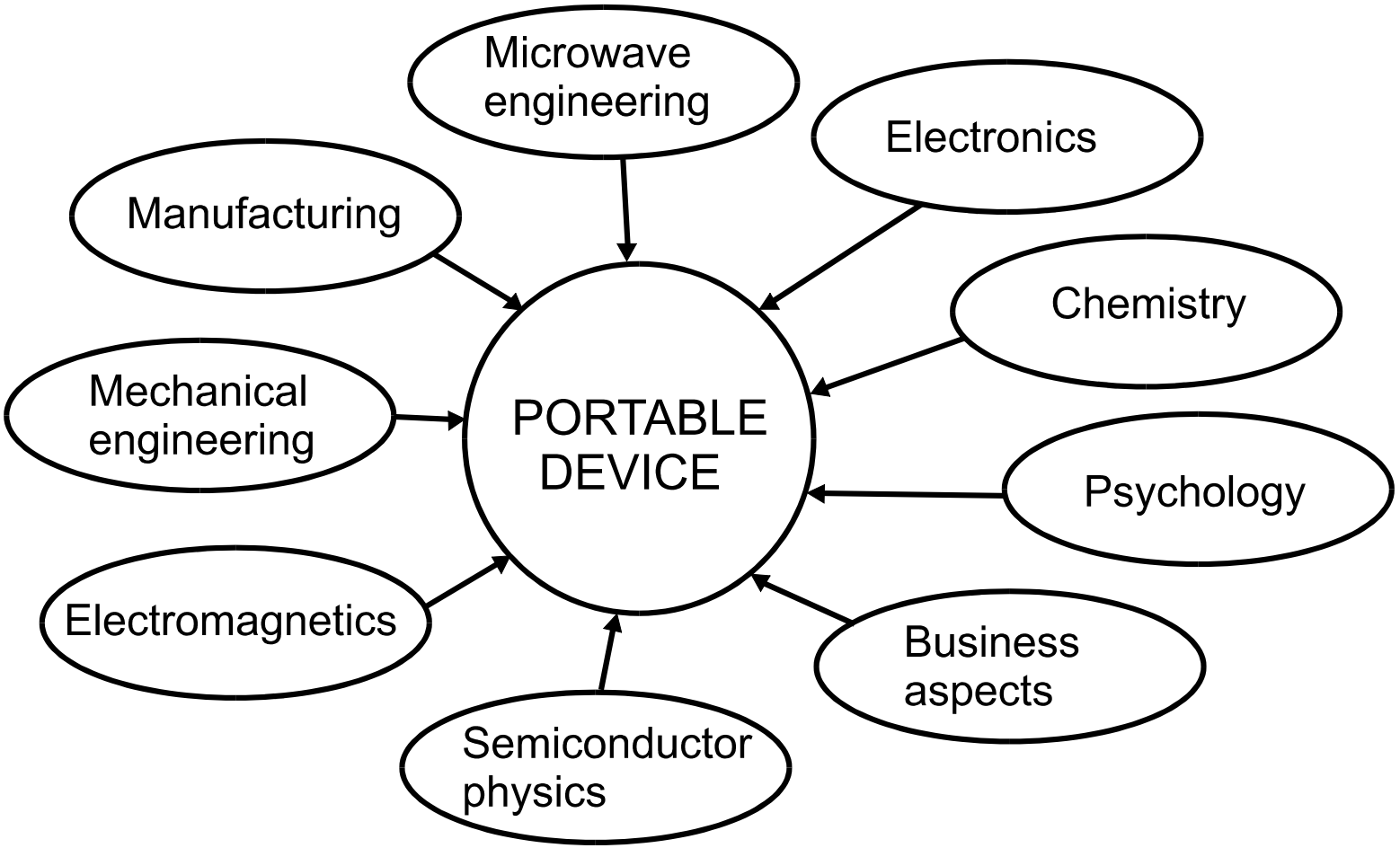
AN EXAMPLE: DATA STORAGE

- CD: SCRATCHES, DIRT, SIZE, TEMPERATURE BUT HIGH CAPACITY, VERSATILE USAGE AND KNOWN FIDELITY
- MINIDISC: PHYSICALLY PROTECTED, SPECIFICALLY FOR PORTABILITY BUT AUDIO QUALITY LOSS POSSIBLE WITH DENSE PACKING AND RESTRICTED FORMAT
- MEMORY CARD: EXPENSIVE, BEST PHYSICAL PROTECTION, LIMITED CAPACITY
- BUILT-IN: LIMITED CAPACITY, IF MALFUNCTIONING ENTIRE DEVICE USELESS, ONLY ELECTRONIC DATA REMOVAL

IN DESIGN&ENGINEERING:

- SPECIFICATION
- SYSTEM ARCHITECTURE
- CIRCUIT DESIGN
- PHYSICAL DESIGN
- CAUSES 70 % OF THE END COST

NECESSARY DISCIPLINES



ONE COMMENT:

- NEW PORTABLE DEVICES CAN INDEED BE APPLICATIONS OF RECENT TECHNOLOGICAL BREAK-THROUGHS
- MORE OFTEN NEW GADGETS ARE EFFICIENT APPLICATIONS OF RATHER PROVEN CIRCUITS AND COMPONENTS
- TESTING ENTIRELY NEW IDEAS IN CUSTOMER MARKETS MAY TURN OUT EXPENSIVE
- TIME (TIME TO MARKET) IS OFTEN AN ESSENTIAL ISSUE
- TO FIND THOSE RELEVANT TECHNOLOGIES AND WAYS OF IMPLEMENTING THEM FOR VERY LARGE PRODUCTION VOLUMES IS CHALLENGING

AN EXAMPLE: OSCILLATOR SPECS

Parameter	Consumer-grade oscillator	Military-grade oscillator
Temperature range	- 25 ... +65	-55 ...+75
Vibration	1.5 G / 500 Hz sine	6 G / 2000 Hz sine
Shocks	6 G / 11 ms half-sine	50 G / 11 ms half-sine
Magnetic field	3E-11 / Gauss	3E-11 / Gauss
Barometric pressure	3E-11 @ 12 km	3E-11 @ 12 km

A SYSTEM LEVEL EXAMPLE: PORTABLE PC

- PERFORMANCE SIMILAR TO DESK-TOP UNITS
- COMPATIBILITY WITH MODERN HYPE SOFTWARE
- ADEQUATE DISPLAY ADAPTER RESOURCES (INCL. 3D HARDWARE ACCELERATION)
- DISPLAY AND KBD SIZE OFTEN COUPLED
- DISPLAY TECHNOLOGY AFFECTS RESOLUTION LIMITS
- WIRELESS CONNECTIVITY / WIRED NETWORK INTERFACE REQUIRED, VARYING TECHNICAL SOLUTIONS AVAILABLE (STANDARD MODEMS OBSOLETE)
- FREE OPERATING SYSTEM ?

IN PROCUREMENT:

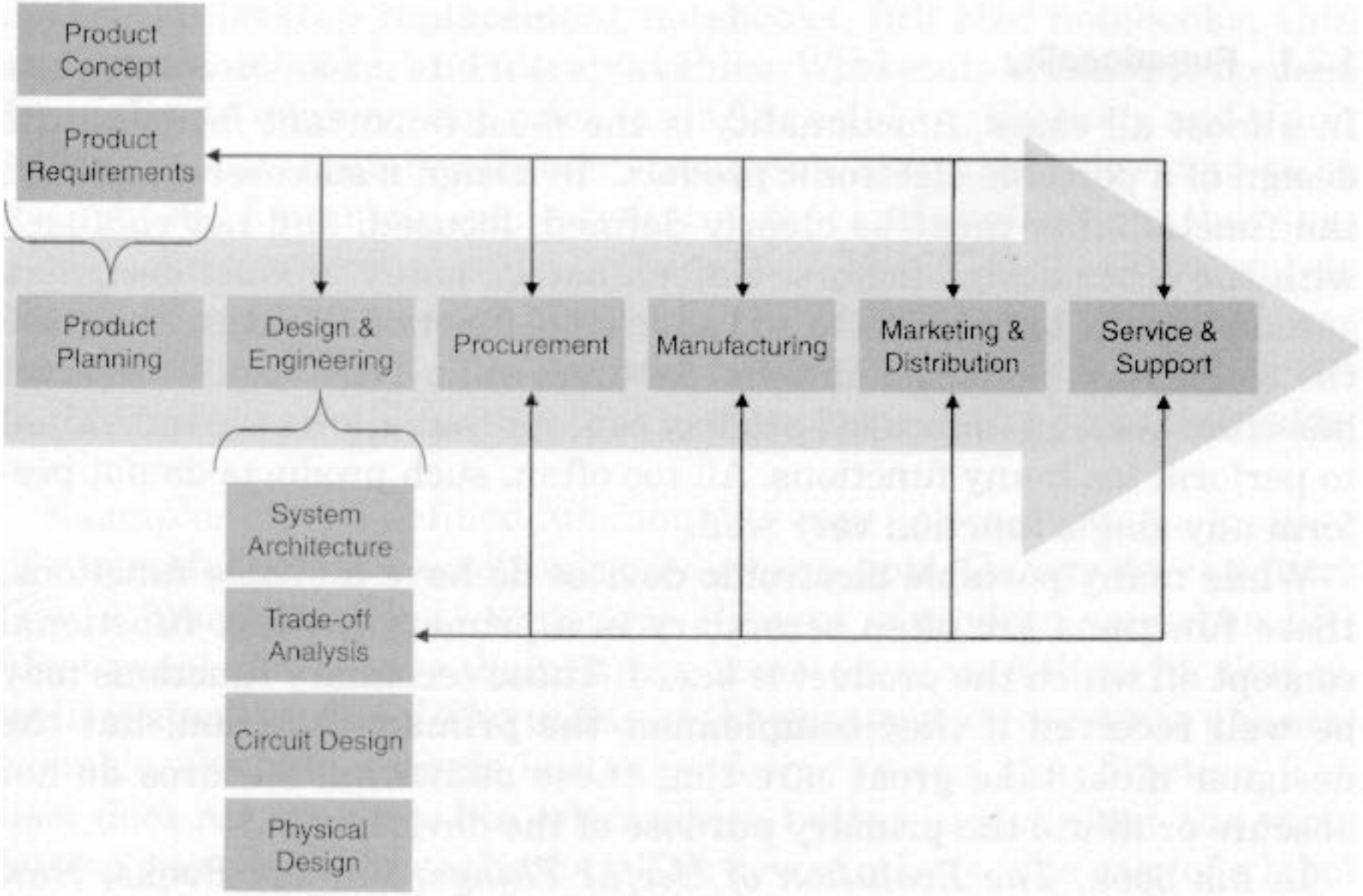
- AVAILABILITY
  - COMPONENTS OFTEN ADVERTISED MUCH BEFORE FIRST PROTOTYPE
- GLOBAL SEARCH
- PRICING
  - TYPICAL VENDOR INFORMATION IS SELDOM APPLICABLE (STARTING FROM $ 0.95....)
- HANDLING UNCERTAINTIES
- CO-OPERATION WITH DESIGNERS
  - CONFIRM COMPATIBILITY BETWEEN SUBCONTRACTED UNITS

IN MARKETING:

- CREATE THE NEED EARLY ENOUGH
- MINIMIZE INVENTORIES
- HANDLE RETAILERS ETC.
- START BEFORE ACTUAL DELIVERIES
- ADVERTISE PRODUCTS FOR THE MASS MARKET BY ”DESIGN” AND ”FUN” – ”COOLNESS FACTOR”
- SONY EXAMPLE: OWN NETWORK

IN SERVICE&SUPPORT:

- AFTER-SALES-DEPT. VS. REPAIR
- CAN WE AFFORD REPAIRS ?
- WHAT’S THE PRESTIGE LEVEL ?
- SPARE SUPPLIES CAUSE COSTS...
- WARRANTY AND CUSTOMER RIGHT ISSUES ARE IMPORTANT TO MANY BUT NOT ALL


Product Concept
Product Requirements
Product Planning
Design & Engineering
Procurement
Manufacturing
Marketing & Distribution
Service & Support
System Architecture
Trade-off Analysis
Circuit Design
Physical Design

TOPICS FOR DISCUSSION:

- FUNCTIONALITY
- PERFORMANCE
- USER INTERFACE
- FORM FACTOR
- BATTERY LIFE
- COST
- TIME TO MARKET
- RELIABILITY

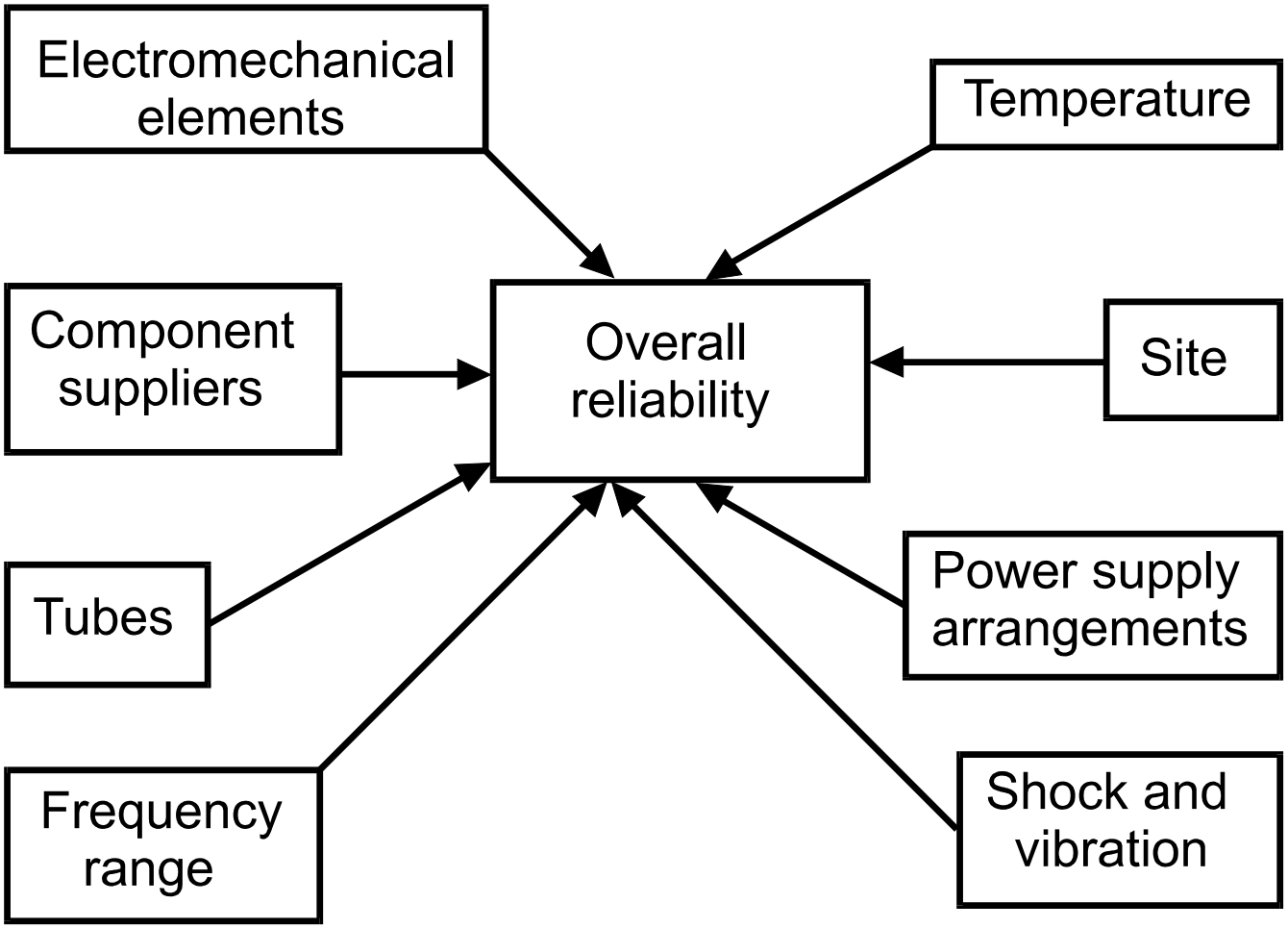
TABLE 1.1 Primary Functionality of Some Common Portable Electronic Devices

Device	Primary functionality	Comments
Cellular phone	Enables remote voice conversation	Smart phones are gradually adding secondary functionality
Walkie talkie	Enables remote voice instant messaging	Multicast is useful secondary function
Pager	Delayed text messaging	Being made obsolete by cellular phone messaging and voice mail
Watch	Displays time (& date)	Secondary functions are mostly for niche markets
Calculator	Mathematical calculations	Well-focused functionality, *not* made obsolete by the PC or the calculator watch
Garage door opener	Opens and closes garage door	Highly focused functionality
Television remote	Controls TV	Turn TV *off* and *on*; scan channels; direct access channel selection
Universal remote	Controls multiple AV devices	TV, VCR, audio system, set-top box, etc.

in 2004 !

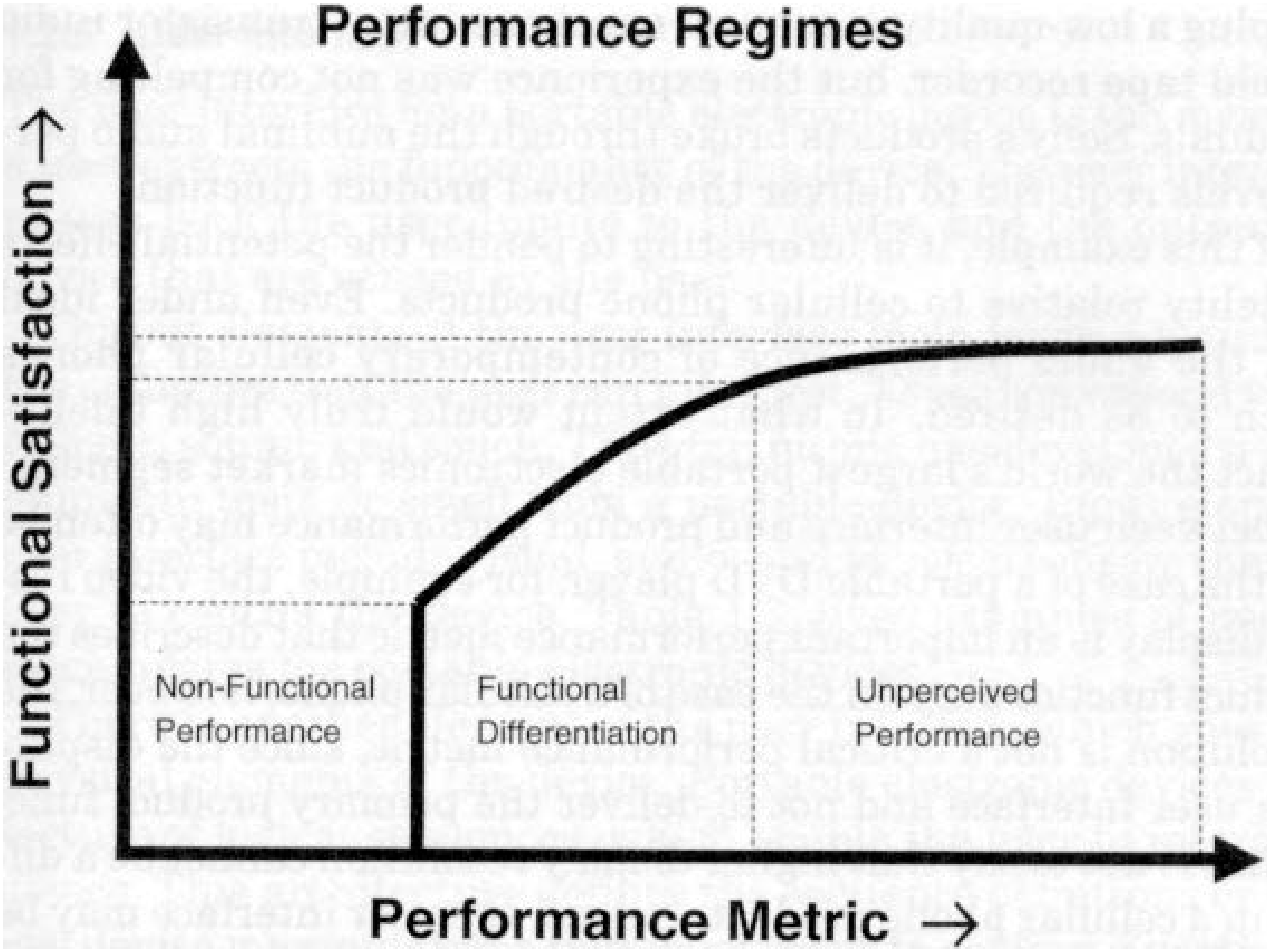
Handheld game platform (like GameBoy)	Play video games	Sega tried to add TV tuner—didn't sell
Walkman	Private enjoyment of high quality music	Volume, bass, FWD, reverse, pause—what more could you want?
Laser pointer	Presentation pointing	
Transistor radio	Shared and private broadcast music and news	Made obsolete by Walkman and boom-box
Electronic organizer	Personal contact and calendar information	Being made obsolete by palm top PCs
Palm top PC	Platform for portable *Outlook*	Outlook function made popular on the desktop PC, transferred to a smaller form-factor
Notebook PC	Platform for windows applications	Multipurpose platform for a wide range of software product functionality
Handheld GPS	A smart map	Will probably be more popular as a secondary function than as a dedicated device

SOME ITEMS AFFECTING RELIABILITY



ABOUT THE SPECS

- ONLY A MINORITY OF CUSTOMERS CONSIDER NUMERICAL SPECIFICATIONS UNLESS THEY CAN SEE OR HEAR (OR FEEL) THE REAL DIFFERENCE
- HOWEVER, ARTIFICIAL PERFORMANCE FIGURES CAN BE CREATED IN MARKETING (E.G. A 54x CD DRIVE)


Performance Regimes
Functional Satisfaction →
Non-Functional Performance
Functional Differentiation
Unperceived Performance
Performance Metric →

WAYS & PARAMETERS TO ESTIMATE PERFORMANCE

TABLE 1.2 Performance Metrics for Various Portable Electronic Devices

Device	Primary performance metrics
Cellular phone	Range, audio fidelity, latency
Walkie-talkie	Range, audio fidelity
Pager	Range
Watch	Accuracy
Calculator	Precision, number of functions
Garage door opener	Range, false signal rejection
Television remote	Range
Handheld game platform (like GameBoy)	Processing speed, graphics/video fidelity
Walkman	Audio fidelity
Transistor radio	Range, audio fidelity
Electronic organizer	Response time, content storage capacity, graphics capability
Palm top PC	Application response time, application initiation/transition speed, content storage capacity, graphics/video fidelity, network communications bandwidth
Notebook PC	Application response time, application initiation/transition speed, content storage capacity, graphics/video fidelity, network communications bandwidth
Handheld GPS	Accuracy, response time

THE MAN-MACHINE INTERFACE :

- VISION: AGING, ENVIRONMENT
- HEARING: ENVIRONMENT, AGING
- FEELING : JUST A FEELING...
- SOMETHING ELSE ?

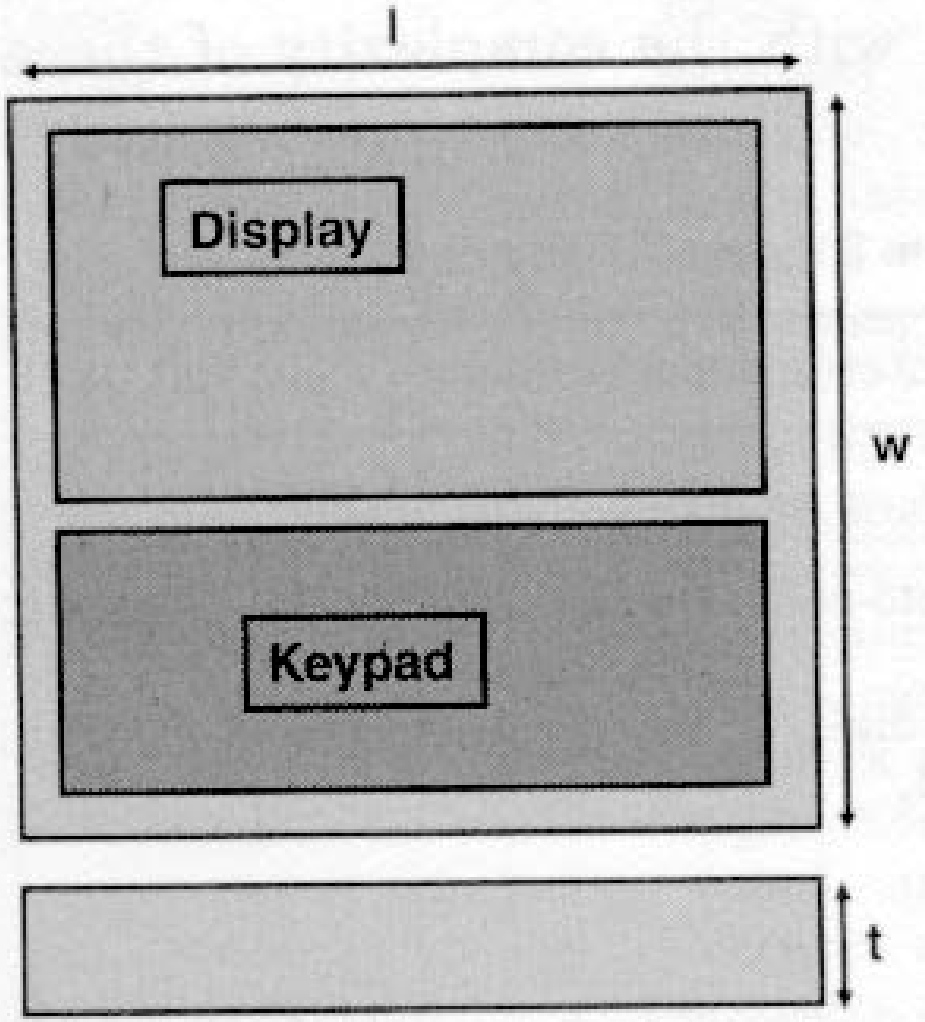
TABLE 1.3 User Interface Mechanisms for Portable Electronic Devices

Human sensory mode	User interface mechanisms	
	Input	Output
Visual	Image sensor, scanner, photo-cell	Display, indicator light, gauge
Audio	Microphone	Speaker
Tactile	Button, switch, keyboard, dial, joystick, mouse, trackball, touch-pad, touch-screen, inertial sensor	Vibration feedback
Taste	—	—
Smell	—	—

TYPICAL MARKETING JARGON:

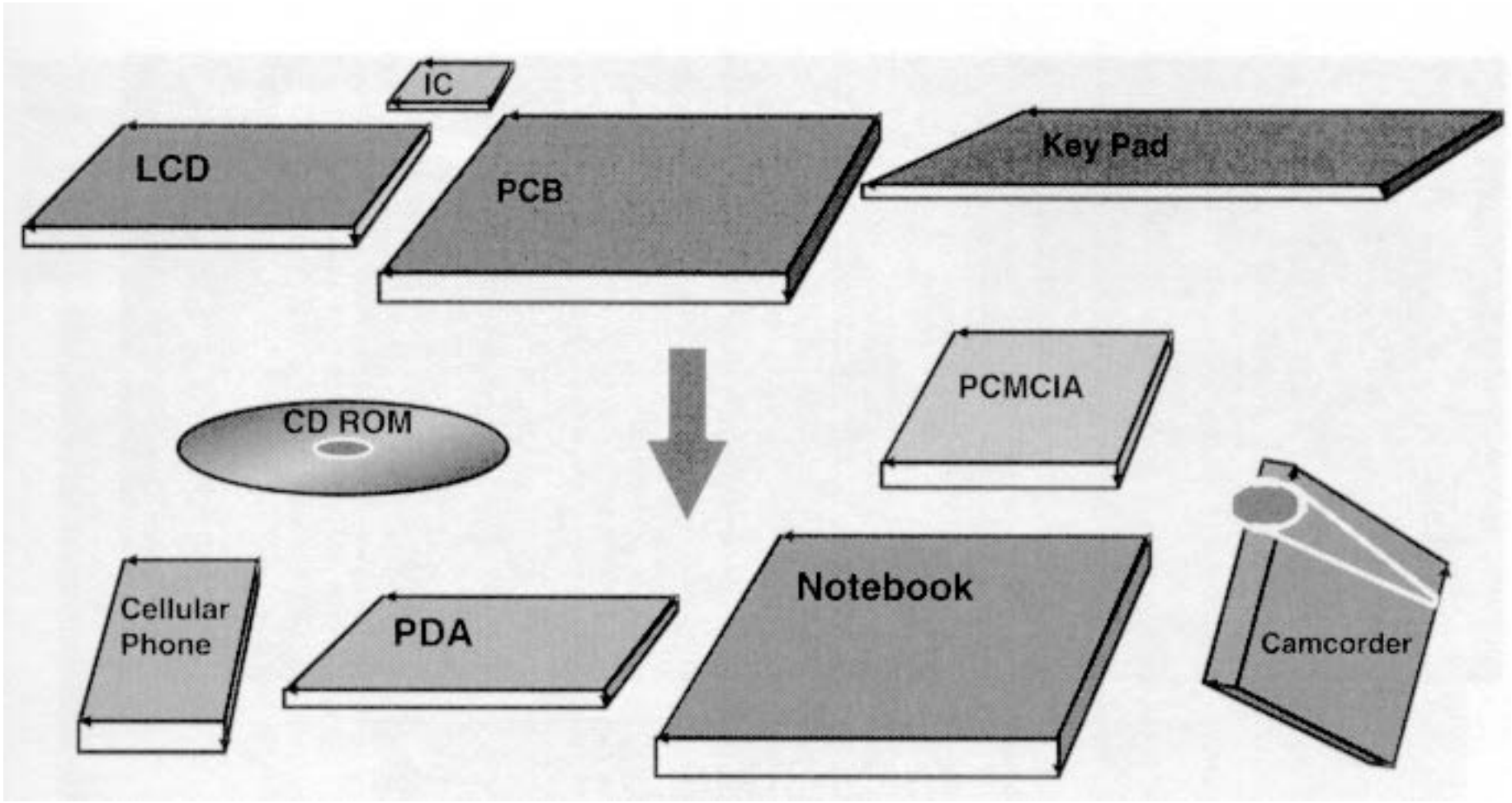
- THE FORM FACTOR OF ELECTRONIC GADGETS
- IT IS NOT SO IMPORTANT WHAT THE THING REALLY DOES AS LONG AS IT FITS THE PREDEFINED SIZE AND FORM ASSUMPTIONS
- ETHICALLY QUESTIONABLE: CIGARETTE PACK-SIZE

Area Form Factor:
Driven by User Interface

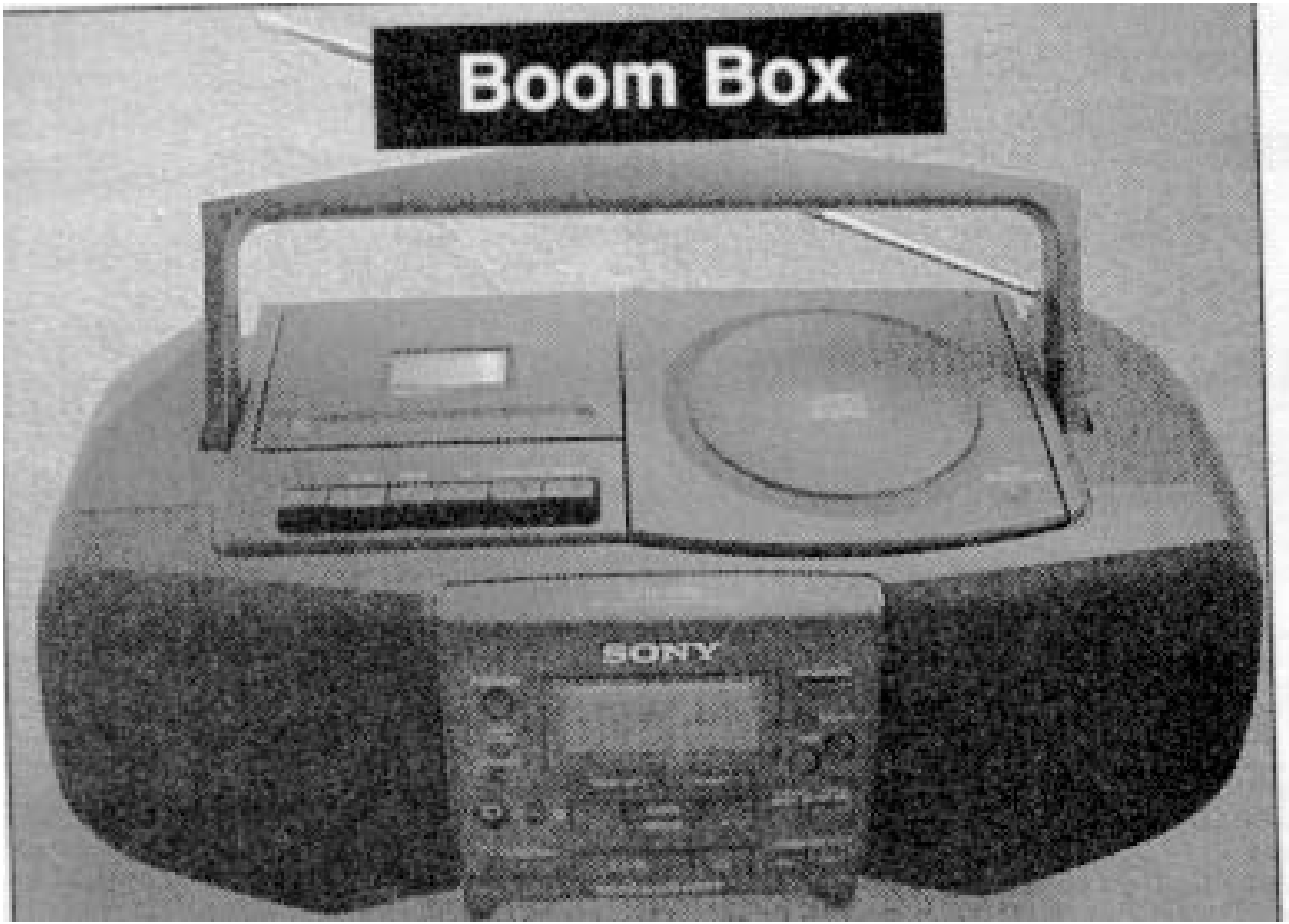


Thickness is a critical product differentiator in Portables

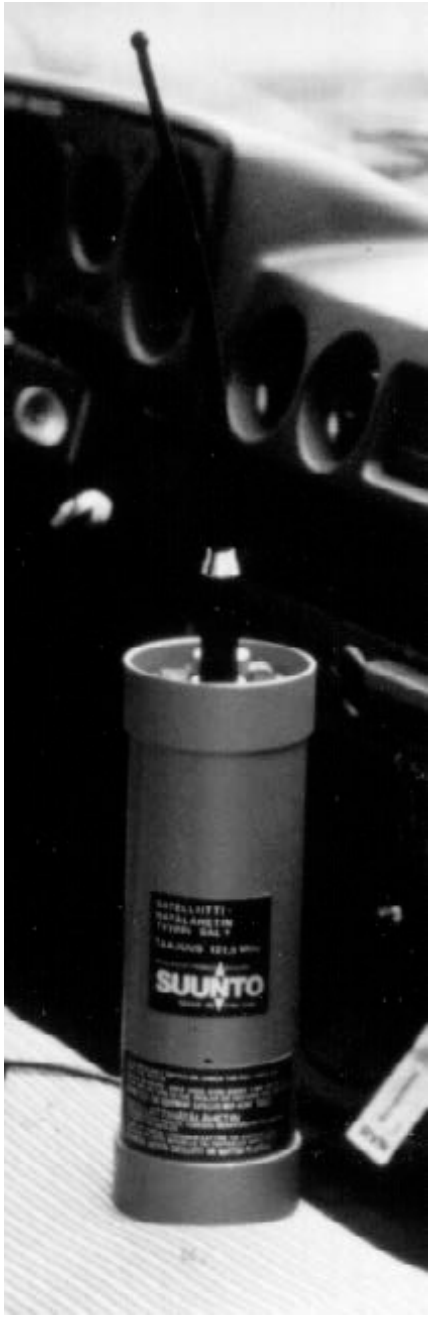
2D INTERFACES SUGGEST FLAT PRODUCTS



TOOL KIT FORM FACTOR

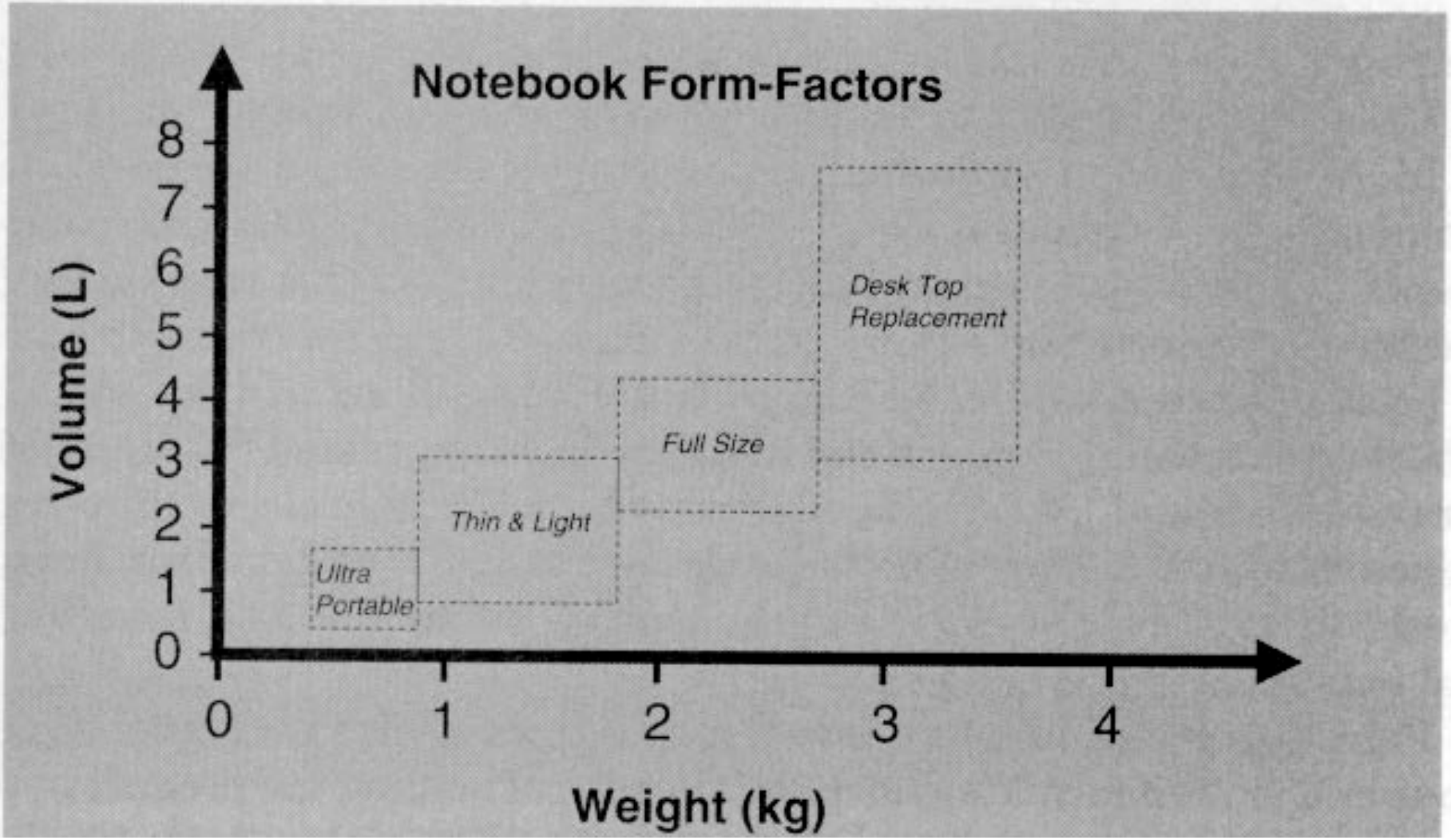



satellite
emergency
beacon
SUUNTO


SUUNTO

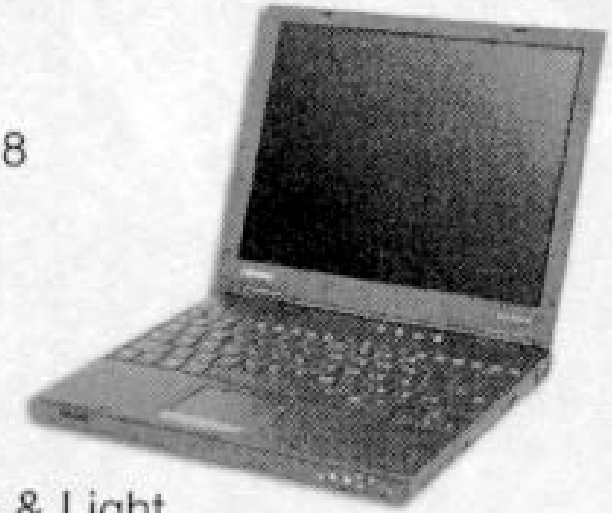

VTT
TELETEKNIIKAN
LABORATORIO
SATELLIITTIHÄTÄLÄHETIN
TAAJUUS 121.5 MHz
TEHO 300 mW PEP
MODULAATIO A3
TOIMINTA-AIKA 48 h
LÄMPÖTILA-ALUE -45 ... +55

Notebook PC Form-Factor	Max. Length (cm)	Min. Length (cm)	Max. Width (cm)	Min. Width (cm)	Max. Thickness (cm)	Min. Thickness (cm)	Max. Weight (kg)	Min. Weight (kg)	Max. Volume (L)	Min. Volume (L)	Range of Specific Gravity	
Desk Top Replacement (DTR)	38.1	30.48	30.48	25.4	6.35	3.81	3.6	2.7	7.37	2.95	0.49	0.92
Full Size	33.02	27.94	27.94	22.86	4.572	3.175	2.7	1.8	4.22	2.03	0.65	0.89
Thin & Light	33.02	22.86	27.94	19.05	3.175	1.778	1.8	0.9	2.93	0.77	0.62	1.17
Ultra Portable	22.86	17.78	21.59	16.51	3.175	1.27	0.9	0.5	1.57	0.37	0.58	1.22



- DTR
- System weight: 7.6 lbs.
- Dimensions (inches): 13 × 10.7 × 1.8

- Ultra-Portable
- System weight: 1.8 lbs.
- Dimensions (inches): 1.2 × 7.3 × 5.5

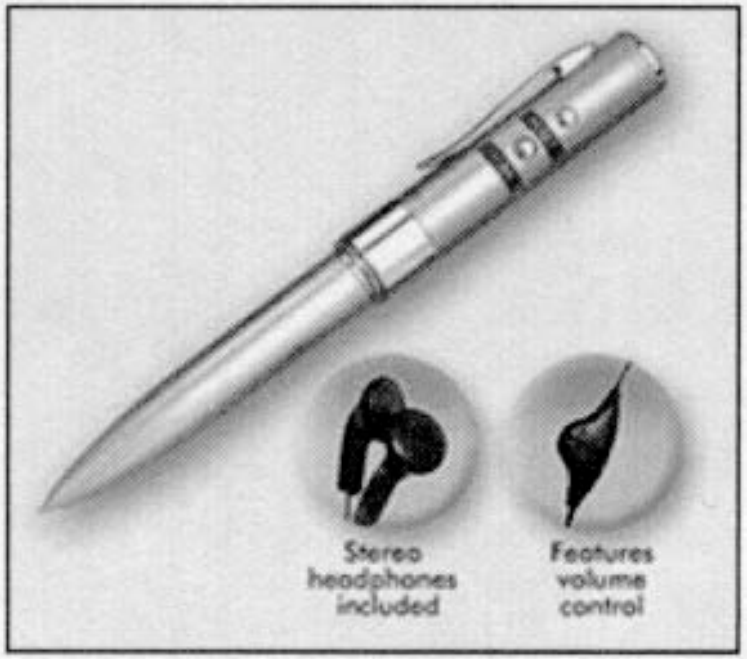


- Thin & Light
- System weight: 3.5 lbs.
- Dimensions (inches): 0.9 × 10.5 × 9.5

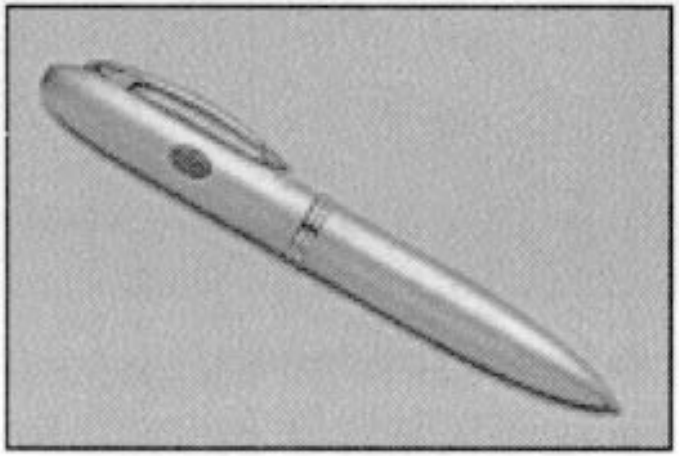

PHILIPS


WALKMAN
NOKIA
CANON
GLPH LT

Scanner/Translator



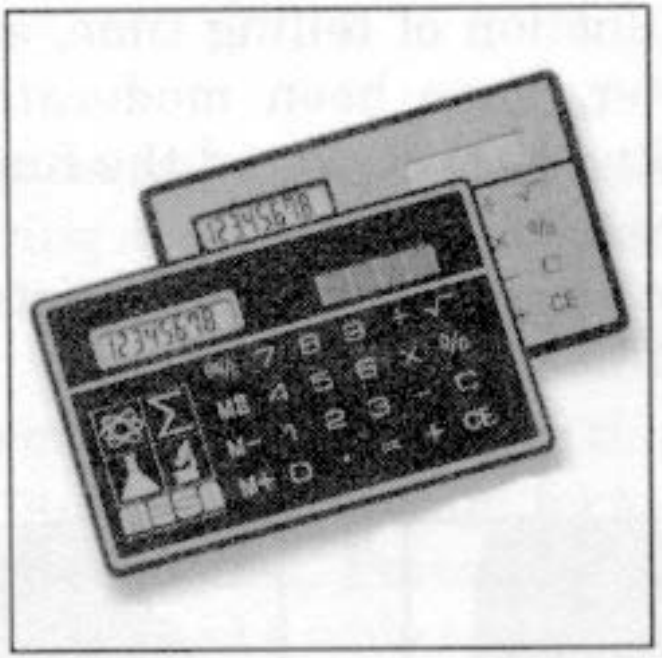
Radio



Laser Pointer


PANIC
LOCK
UN LOCK

Personal Information Device



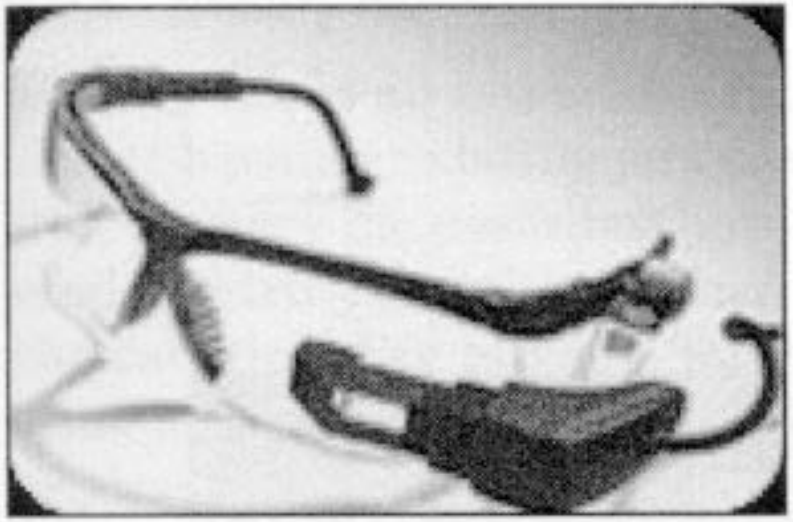
Calculators

Security Badge

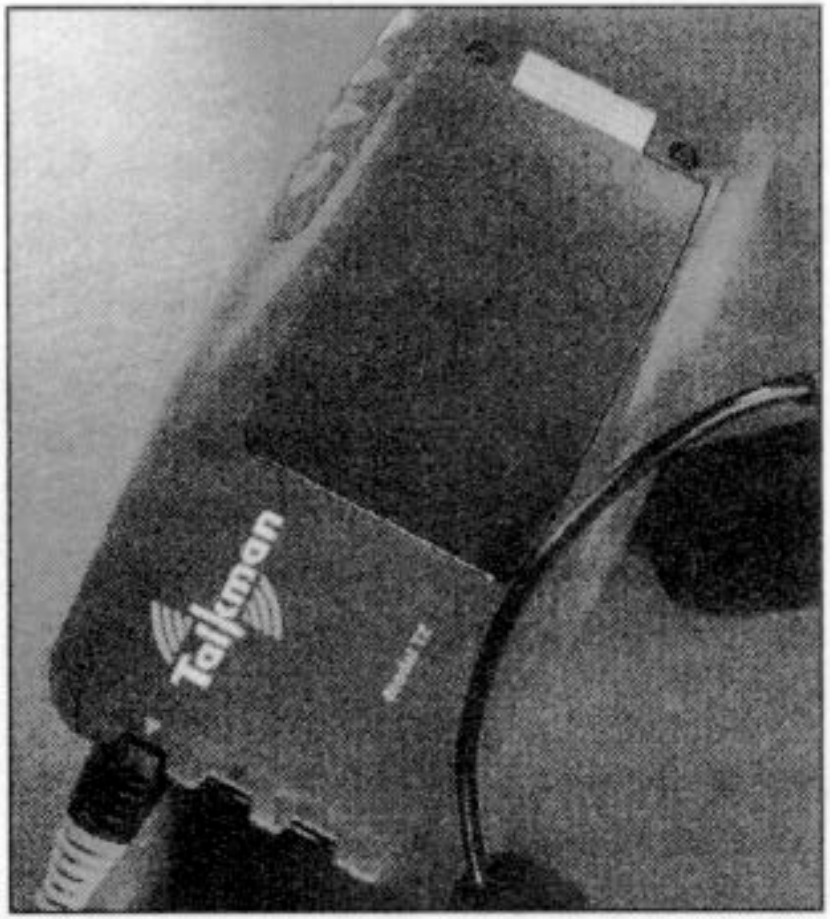
Calculator

TV Remote

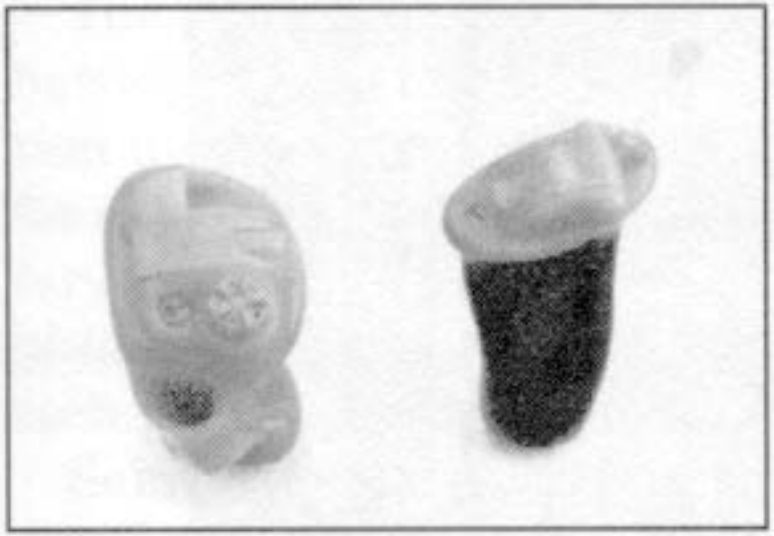
Digital Camera



Eyeglass mounted display

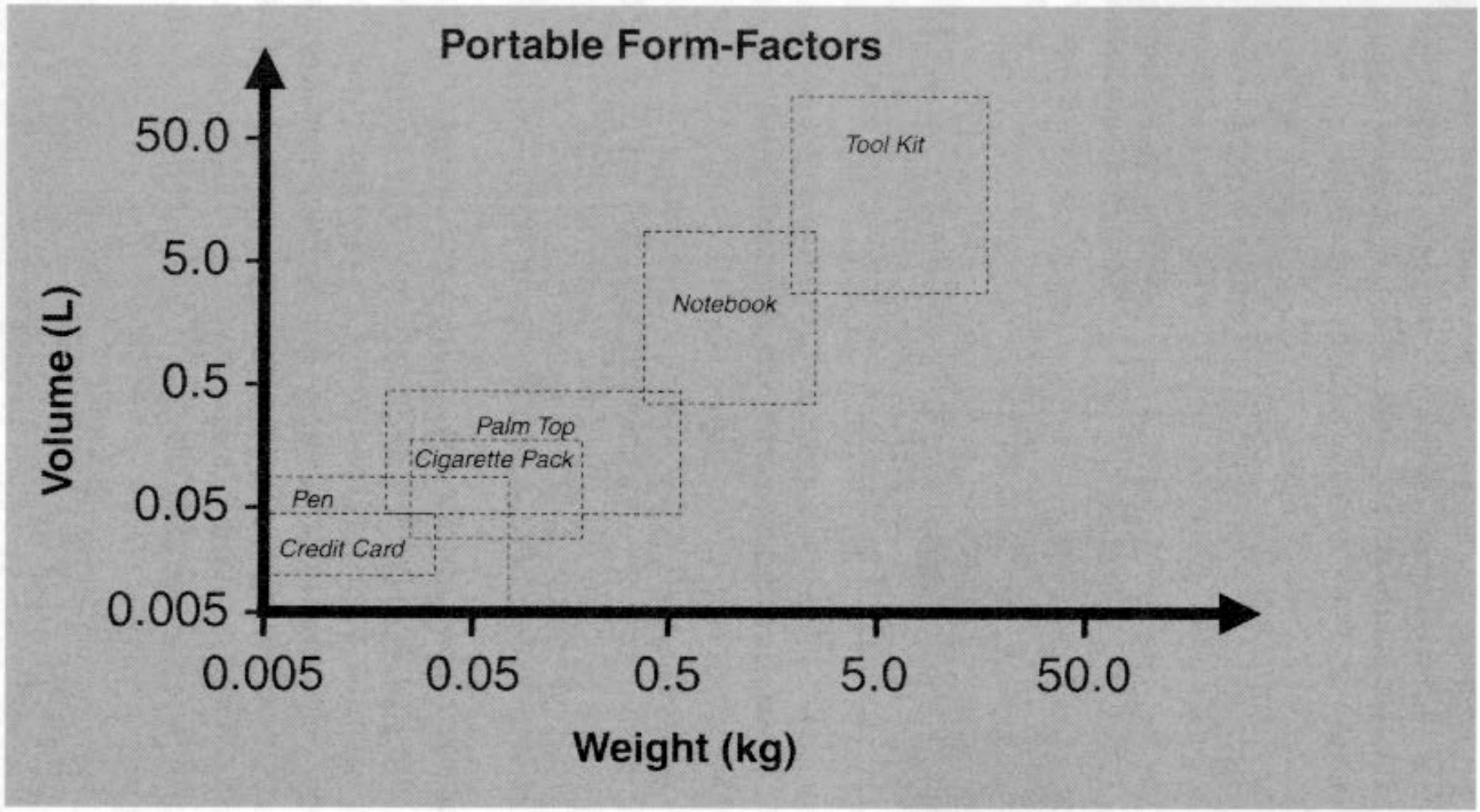


Belt Mounted–Voice Activated Computer



Hearing Aid

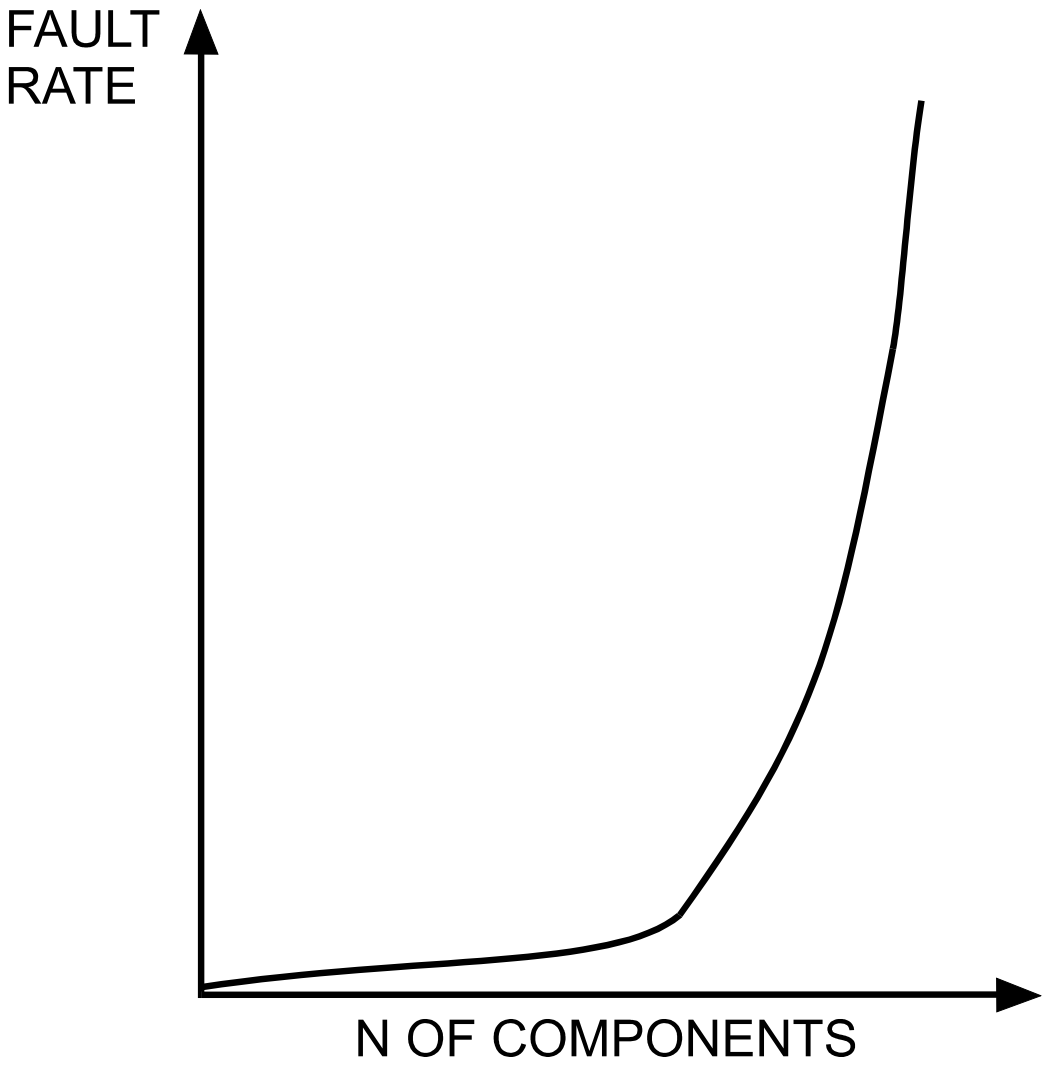
Portabe Form-Factor	Max. Length (cm)	Min. Length (cm)	Max. Width (cm)	Min. Width (cm)	Max. Thickness (cm)	Min. Thickness (cm)	Max. Weight (kg)	Min. Weight (kg)	Max. Volume (L)	Min. Volume (L)	Range of Specific Gravity	
Toolkit	61	20	30	15	30	10	18.144	2.268	56.634	3.146	0.32	0.72
Notebook (Computers)	38	18	30	17	6	1	3.629	0.454	7.374	0.373	0.49	1.22
Palm Top	11	8	10	7	4	1	0.567	0.014	0.442	0.027	1.28	0.50
Cigarette Pack	10	8	6	4	3	1	0.227	0.023	0.164	0.043	1.38	0.53
Pen	18	9	2	0.64	2	0.64	0.091	0.005	0.065	0.004	1.41	1.27
Credit Card	10	8	8	5	0.32	0.25	0.045	0.005	0.025	0.010	1.85	0.46



TOPICS FOR DISCUSSION:

- PRODUCT CONCEPT
- INNOVATION
- CREATION
- VALIDATION
- COMMUNICATION
- PRODUCT REQUIREMENTS
- SYSTEM ARCHITECTURE DEVELOPMENT
- TRADE-OFF ANALYSIS
- COST MODEL DISCUSSION
- CIRCUIT DESIGN
- PHYSICAL AND MECHANICAL DESIGN

FOR YOUR CONSIDERATION



THE SYSTEM DESIGN PROCESS

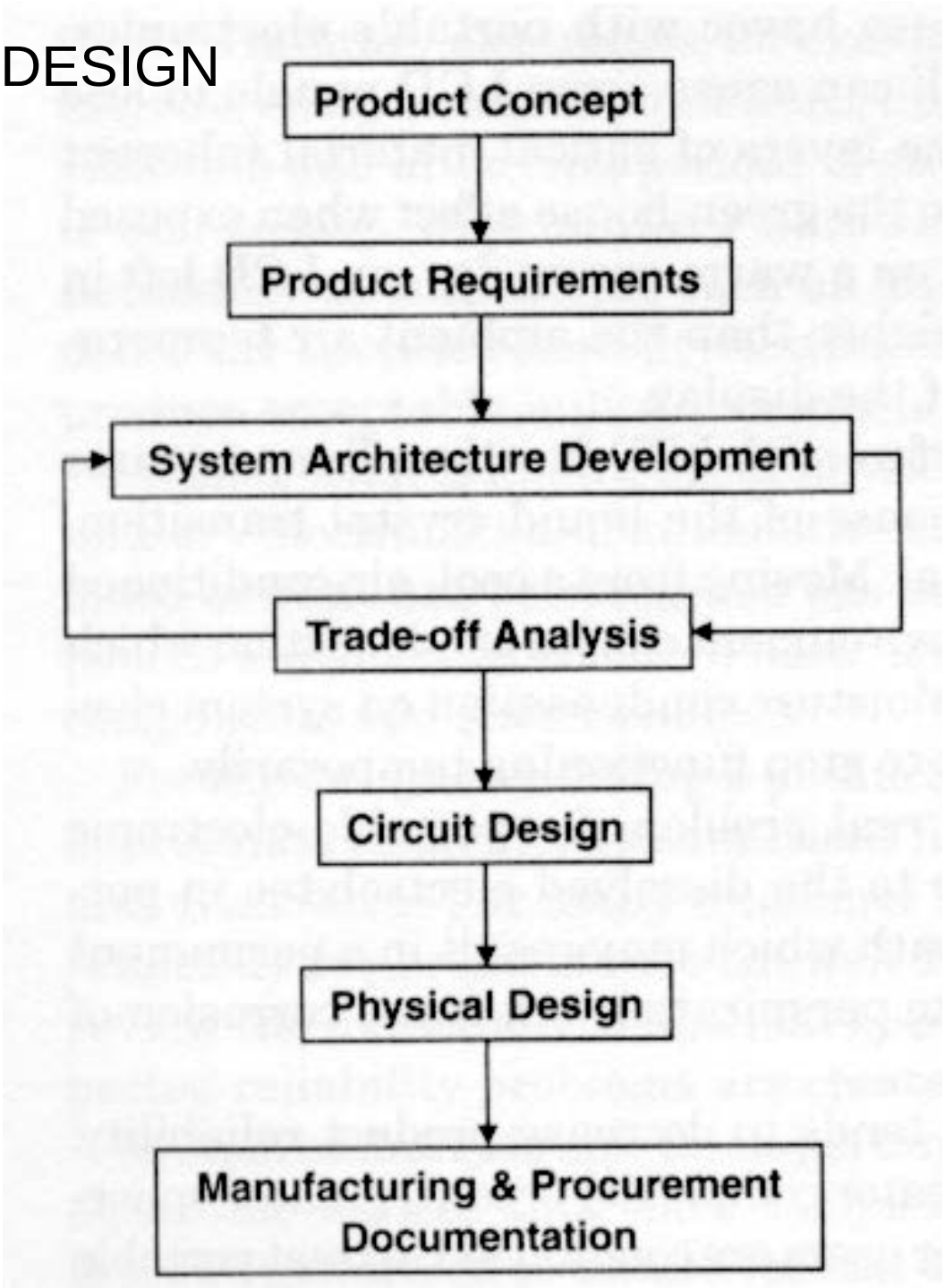
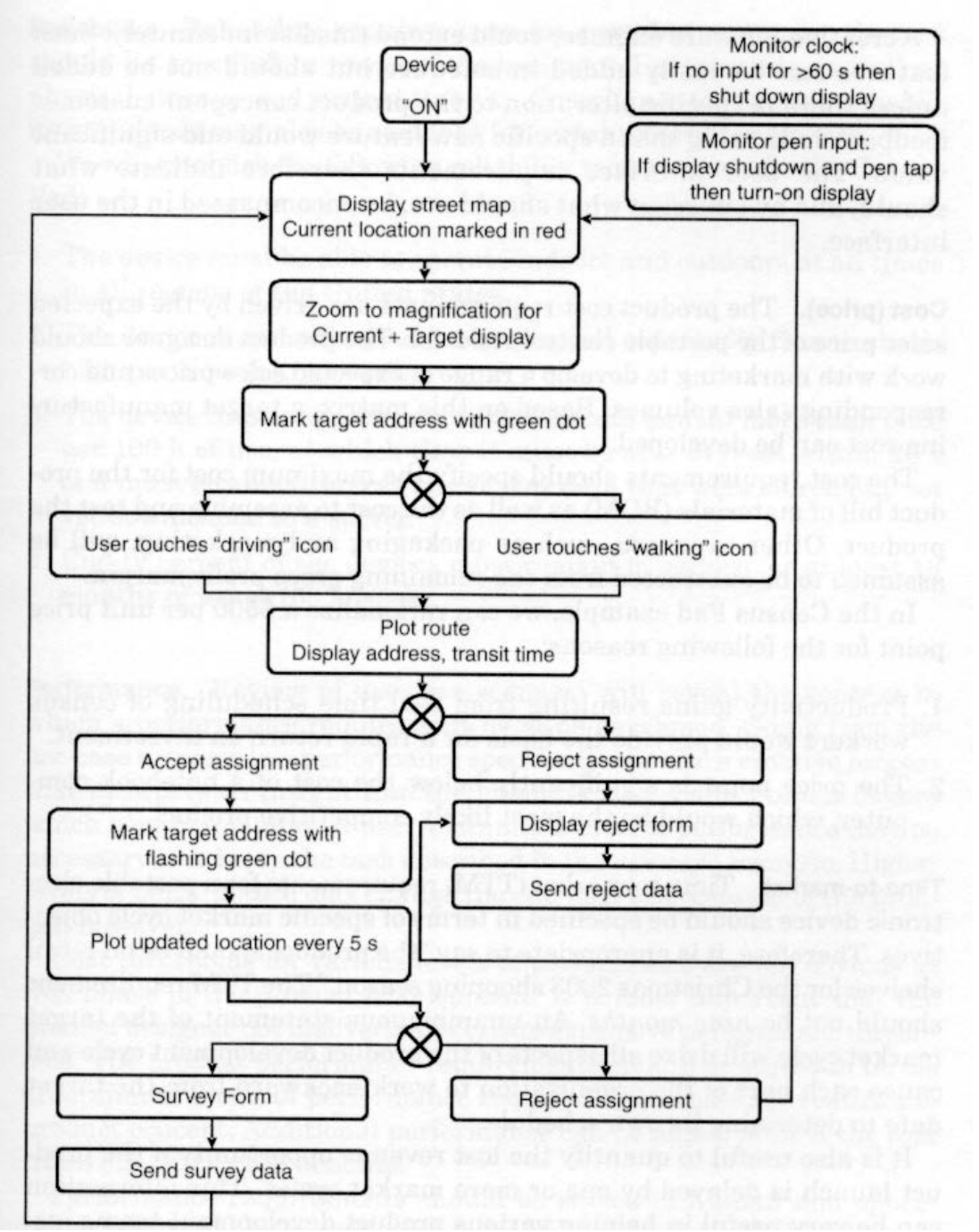


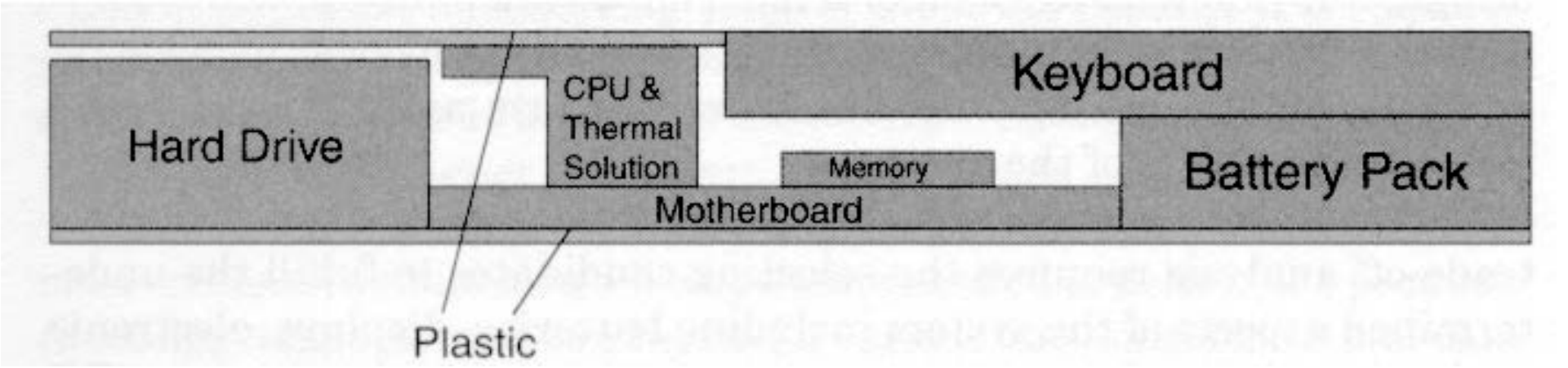
TABLE 1.4 Product Functional Enabler Matrix

	Product										
Functional enablers	Notebook computer	Digital still camera	Camcorder	Cellular phone	Walkie-talkie	One-way pager	PDA	Voice memo capsule	Concept A	Concept B	Concept C
Text display	X	X	X	X	X	X	X		X	X	
Image display	X	X	X				X		X	X	
Video display	X		X							X	
Audio speakers	X		X	X	X			X			X
Audio capture (microphone)	X		X	X	X			X			X
Still image capture		X									
Video capture			X								
Mass data storage	X	X	X				X	X			
Wired network connection	X										
WLAN connection	X										
WWAN connection				X	X	X			X		
Global positioning									X	X	
Pen text input							X		X		
Keyboard text input	X										
Voice processing											X

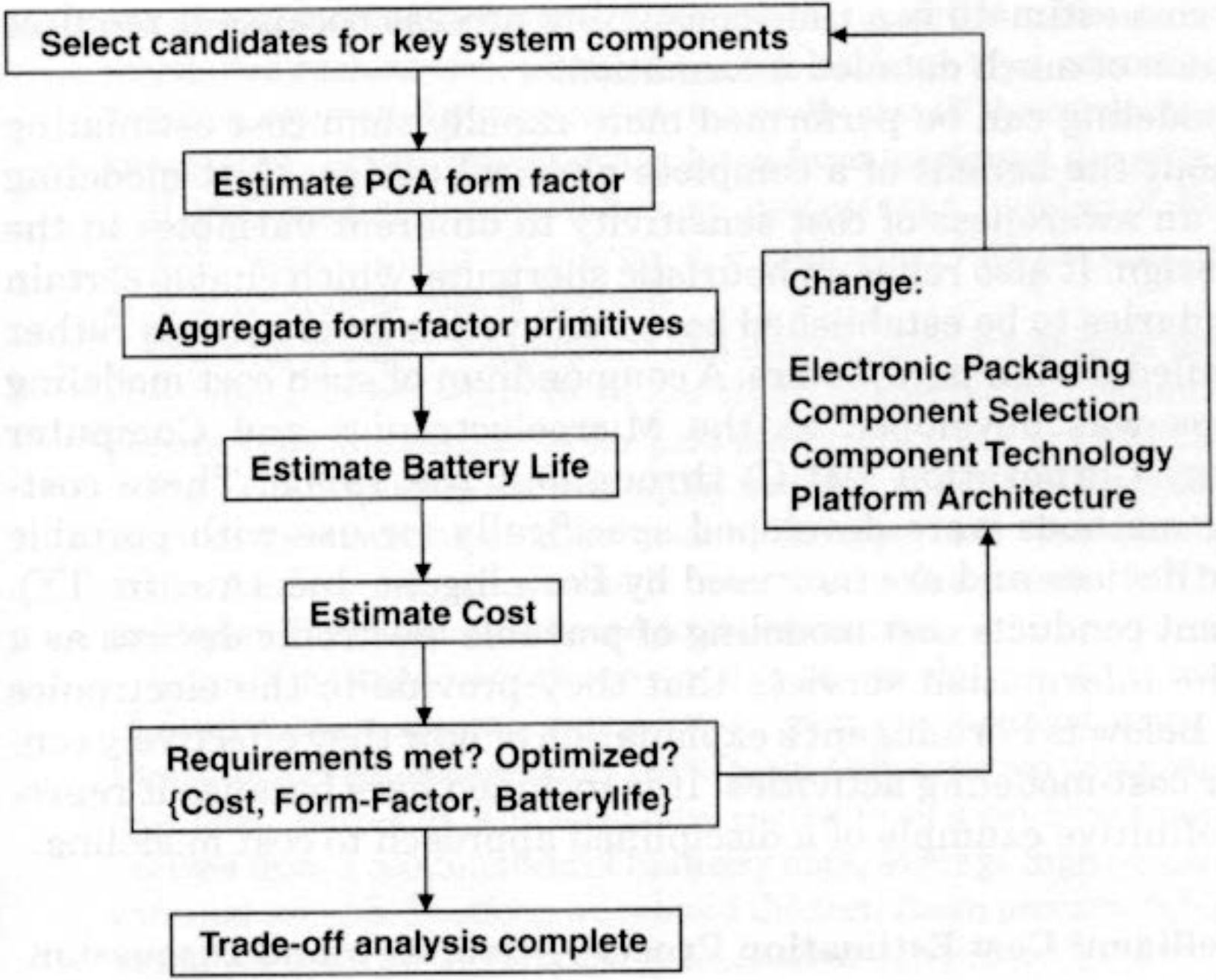
FLOW CHART OF USER INTERFACE REQUIREMENTS



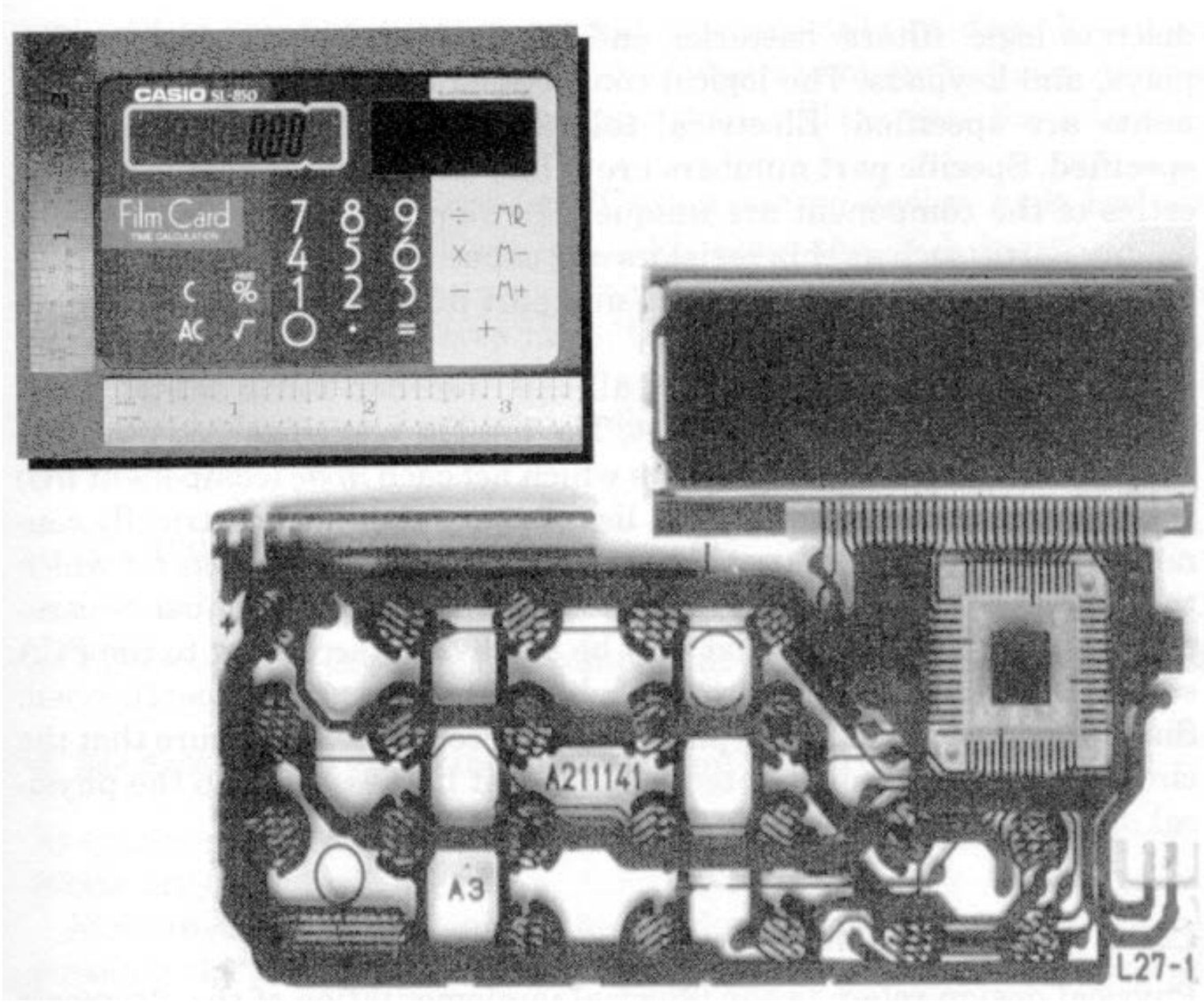
VERTICAL LAYOUT EXAMPLE: NOTEBOOK



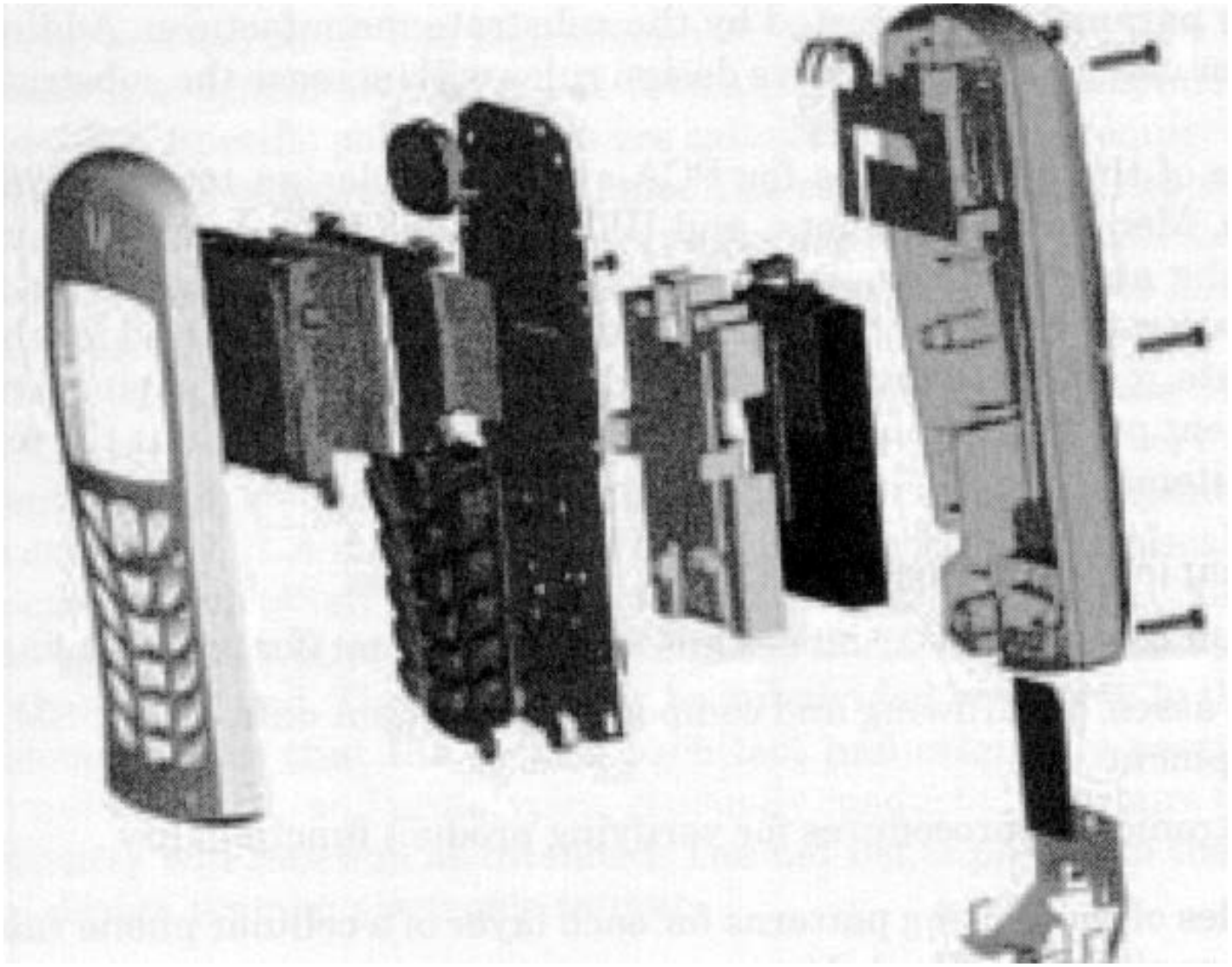
TRADE OFF ANALYSIS



CALCULATOR ON CHIP



MECHANICAL ASSEMBLY EXAMPLE



CHAPTER 2

DIGITAL AND ANALOG PROCESSING

TOPICS FOR DISCUSSION:

- MICROPROCESSORS
- LOGIC DEVICES
- MICROCONTROLLERS
- DSP
- ANALOG MODULES
- SENSORS
- WIRELESS
- MEMORIES....

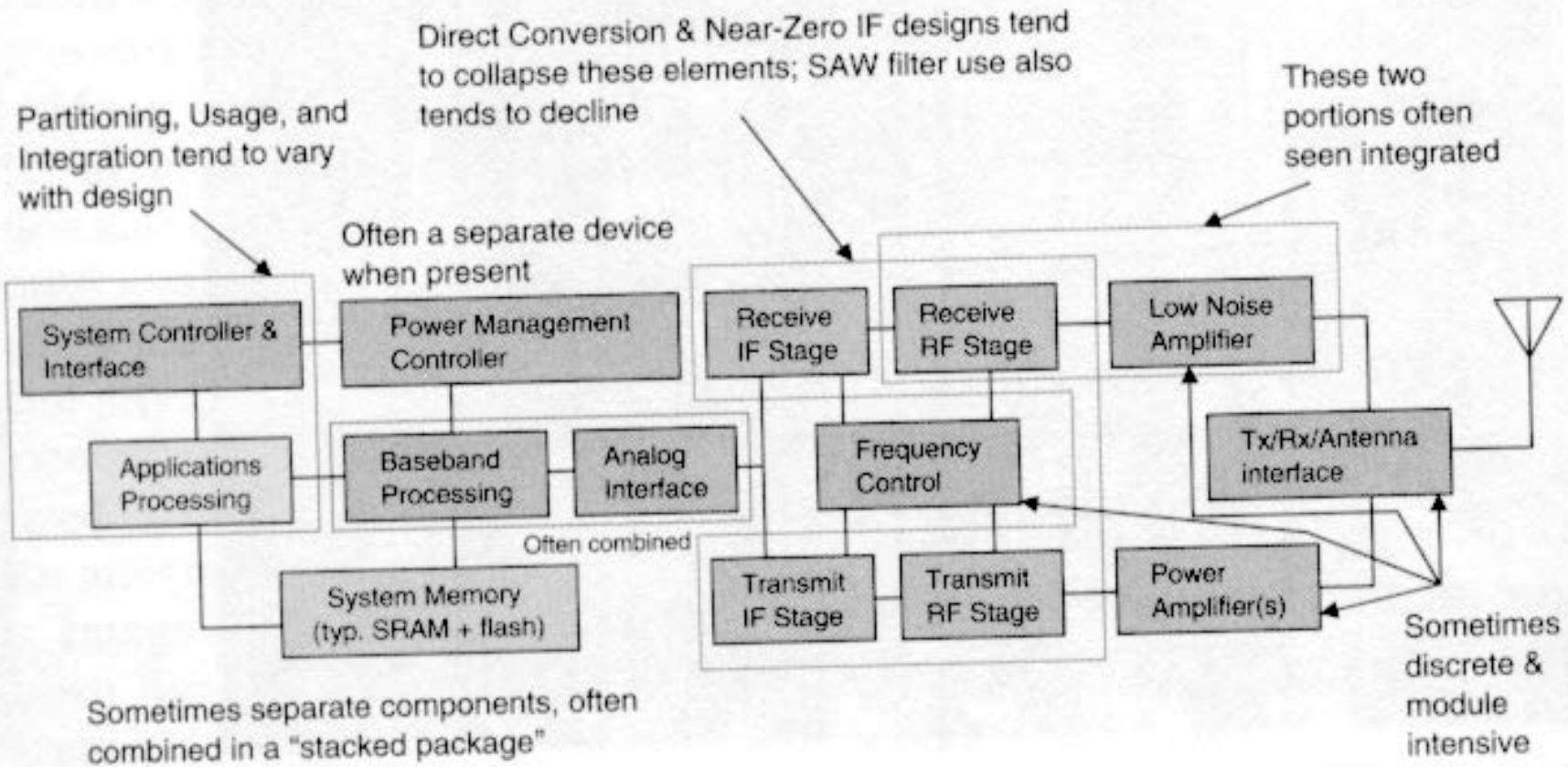


Figure 2.2 Wireless systems overview.

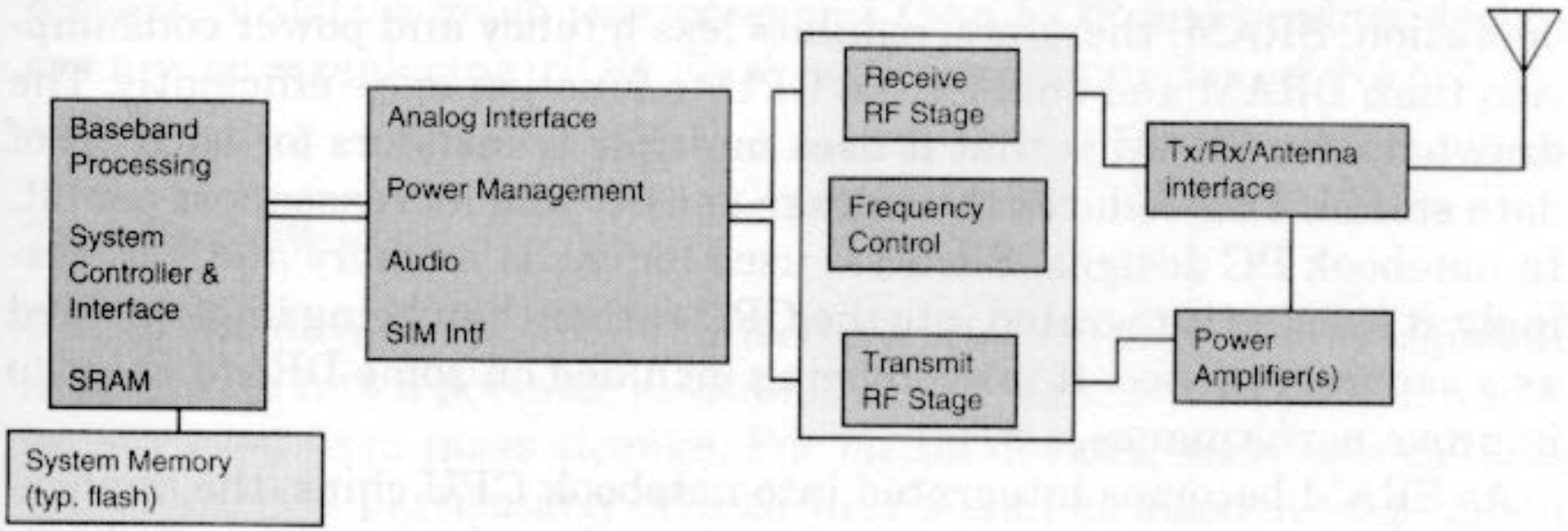


Figure 2.3 Wireless system integration.

SEE SEPARATE THEMATIC PRESENTATION DIGITAL.PDF FOR A DETAILED DISCUSSION

CHAPTER 3

ELECTRONIC PACKAGING

TOPICS FOR DISCUSSION:

- IC PACKAGING
- LEADED PACKAGE
- TAB/TCP (TAPE-AUTOMATED BONDING/TAPE CARRIER PACKAGE)
- COB (CHIP-ON-BOARD)
- FLIP-CHIP
- BGA (BALL GRID ARRAY)
- CSP (CHIP SCALE PACKAGE)

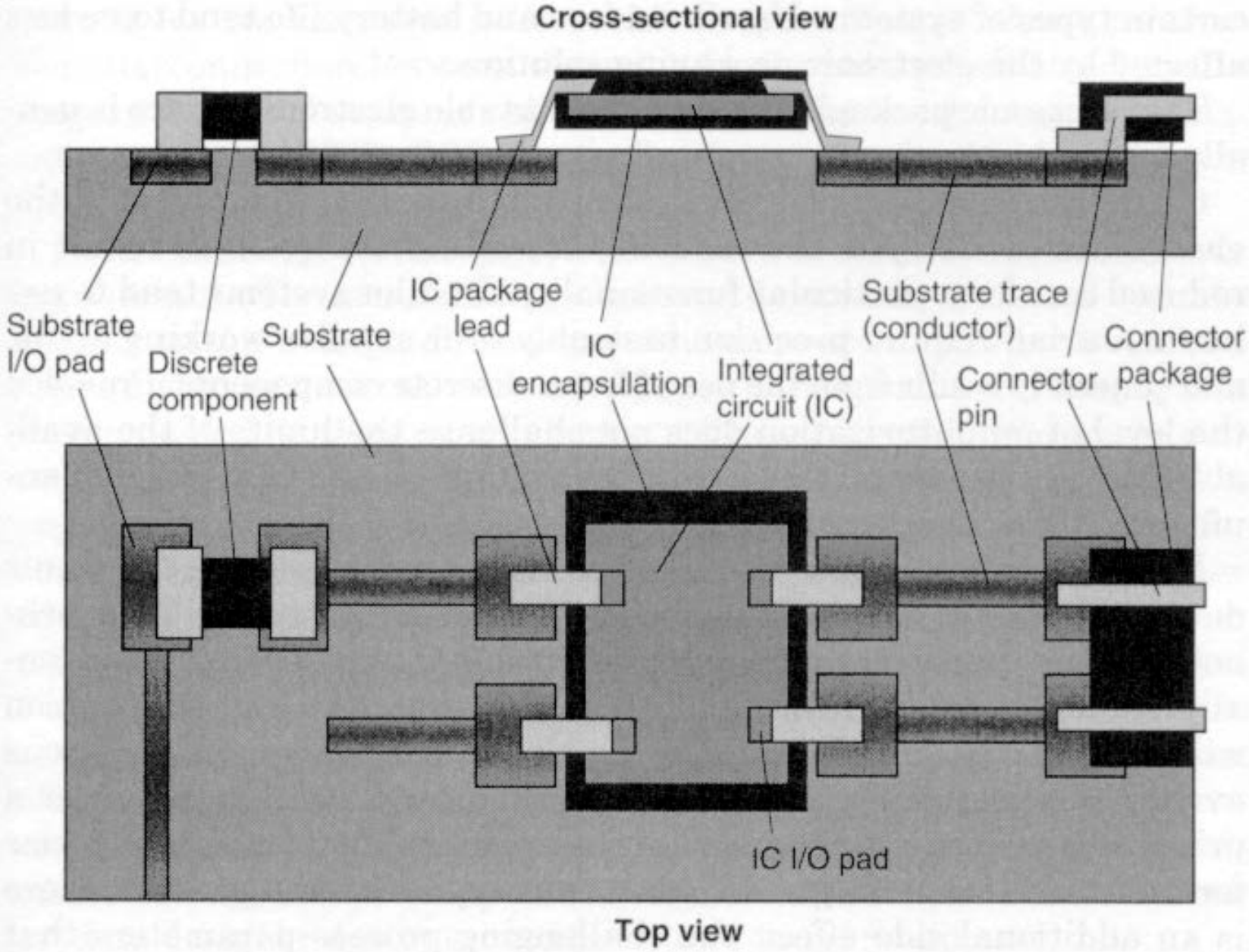


Figure 3.1 Electronic packaging elements.

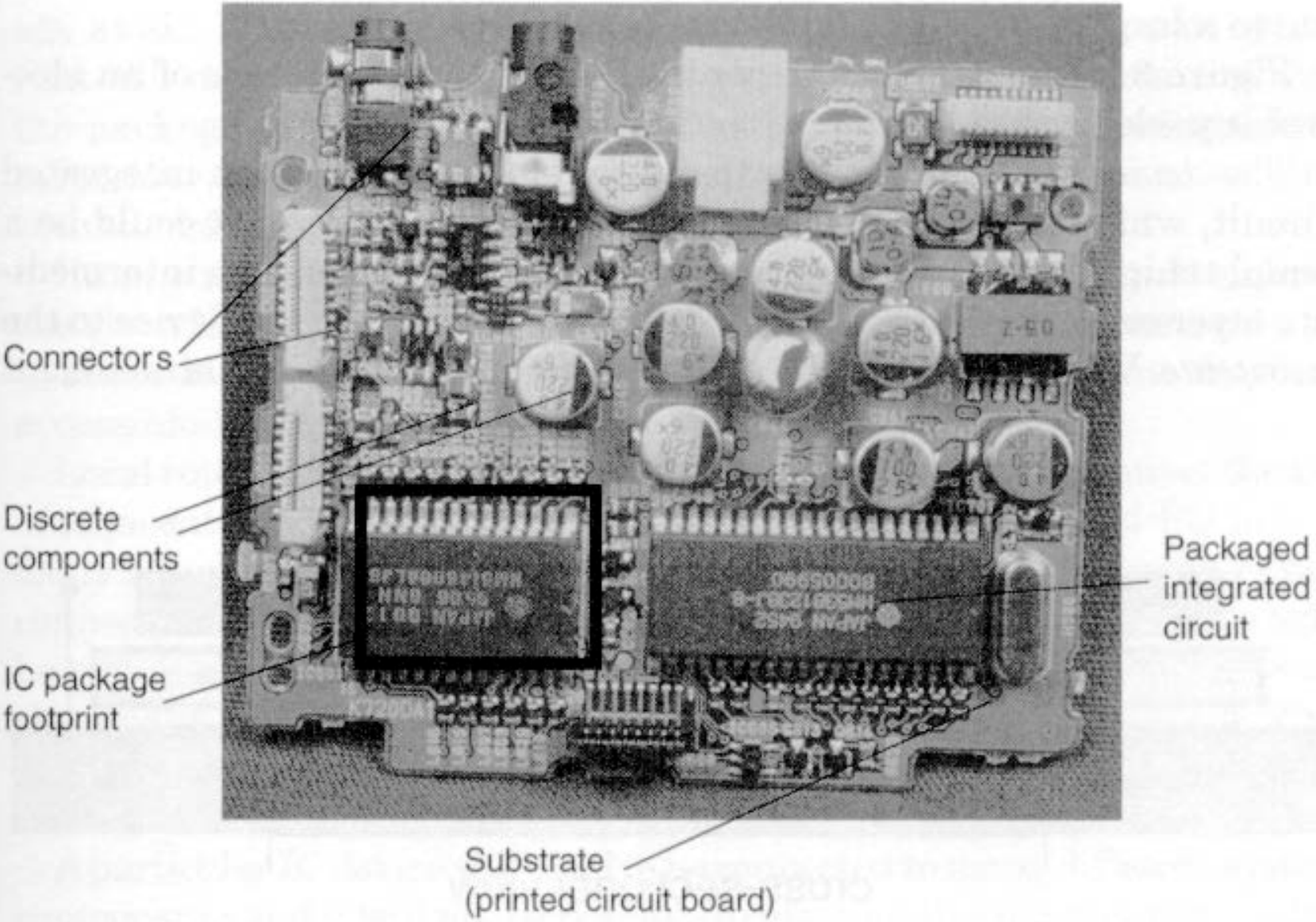


Figure 3.2 Electronic packaging assembly.

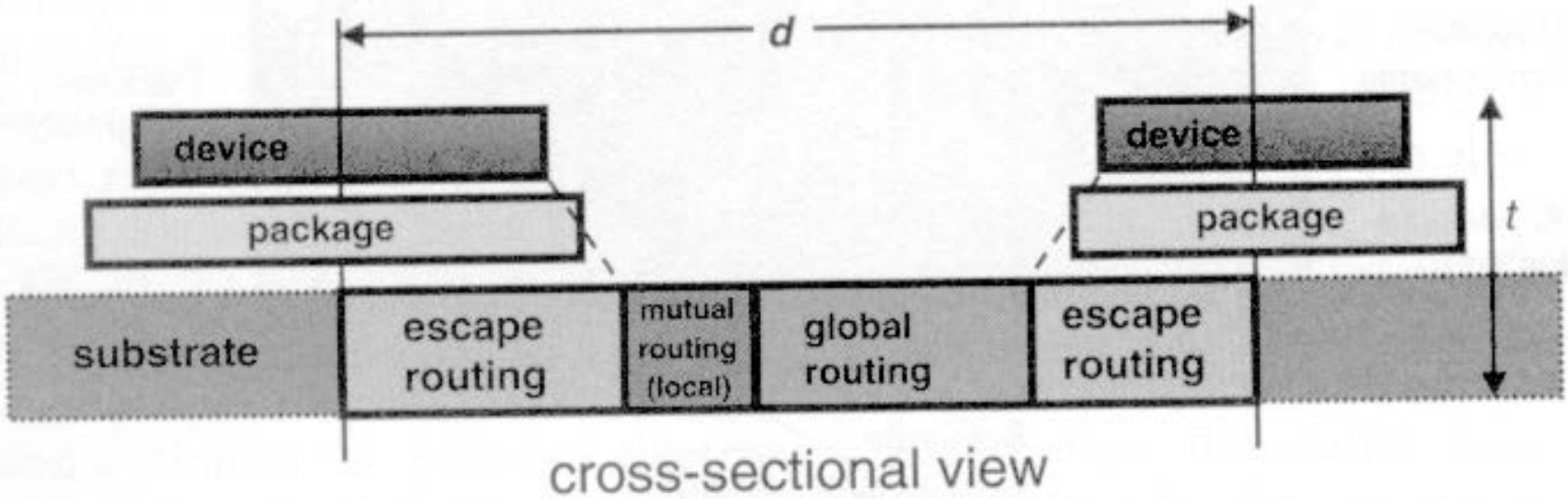


Figure 3.3 Electronic packaging and mean distance.

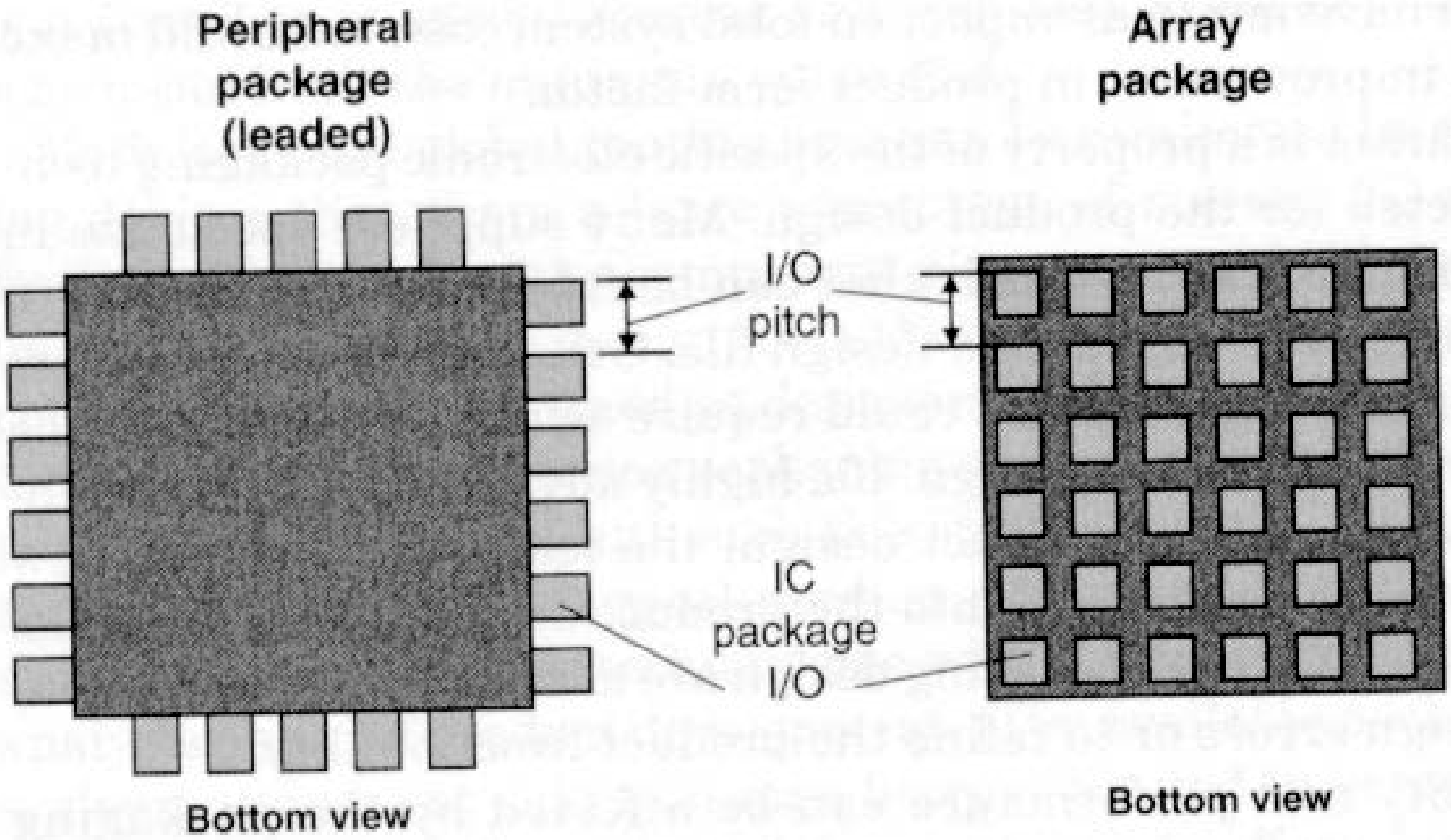


Figure 3.4 IC package connection pattern and pitch.

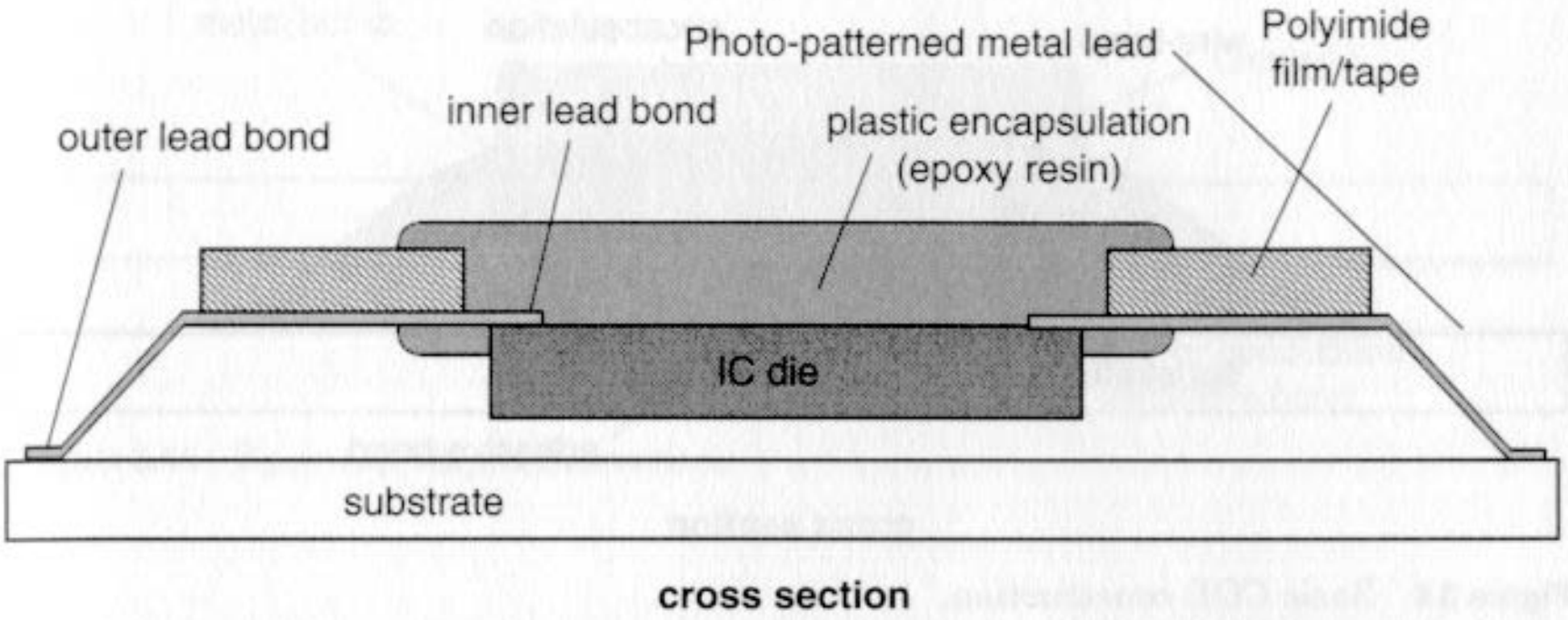


Figure 3.6 Basic construction of a TAB package.

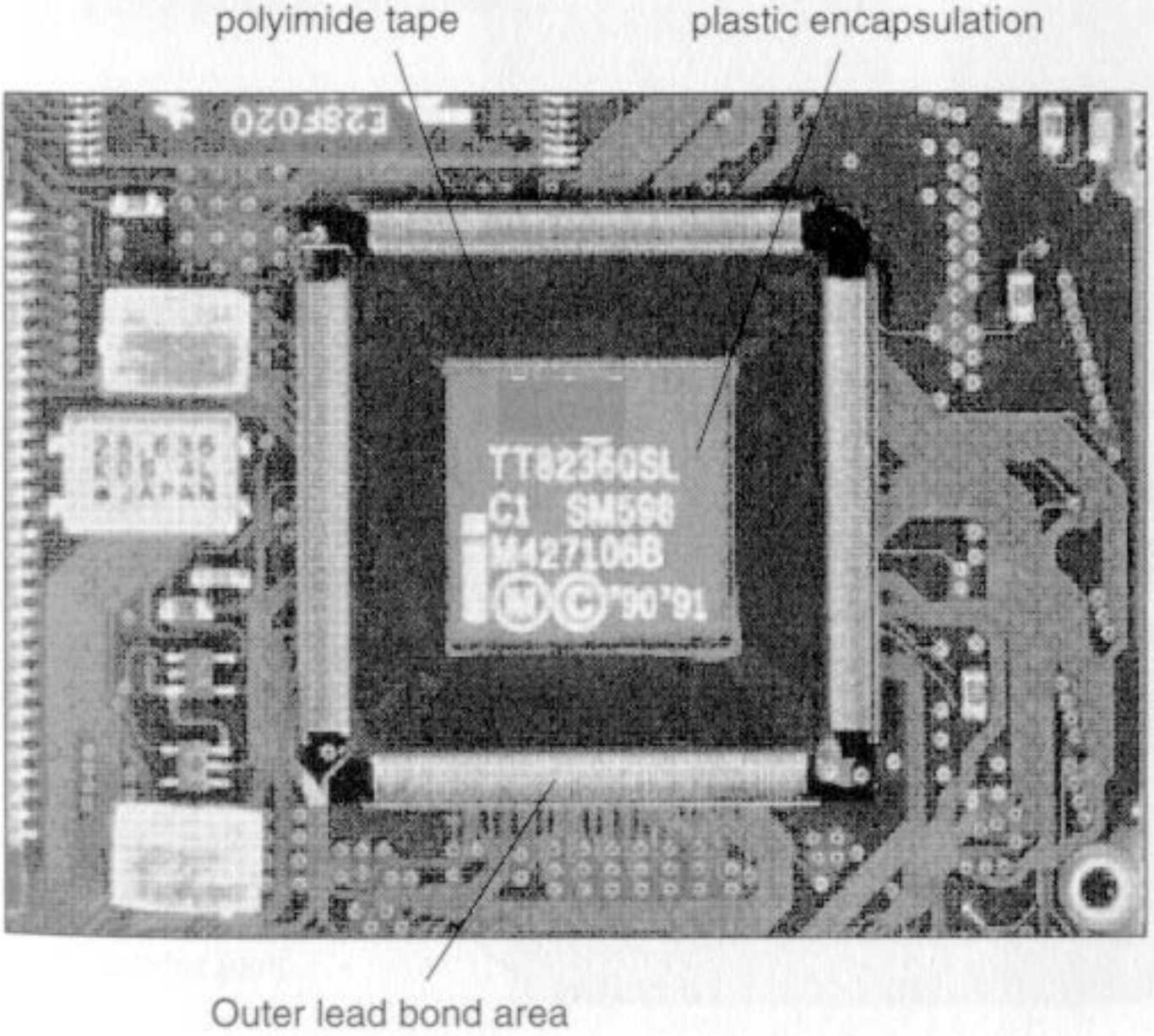


Figure 3.7 TAB package attached to a PC card substrate.

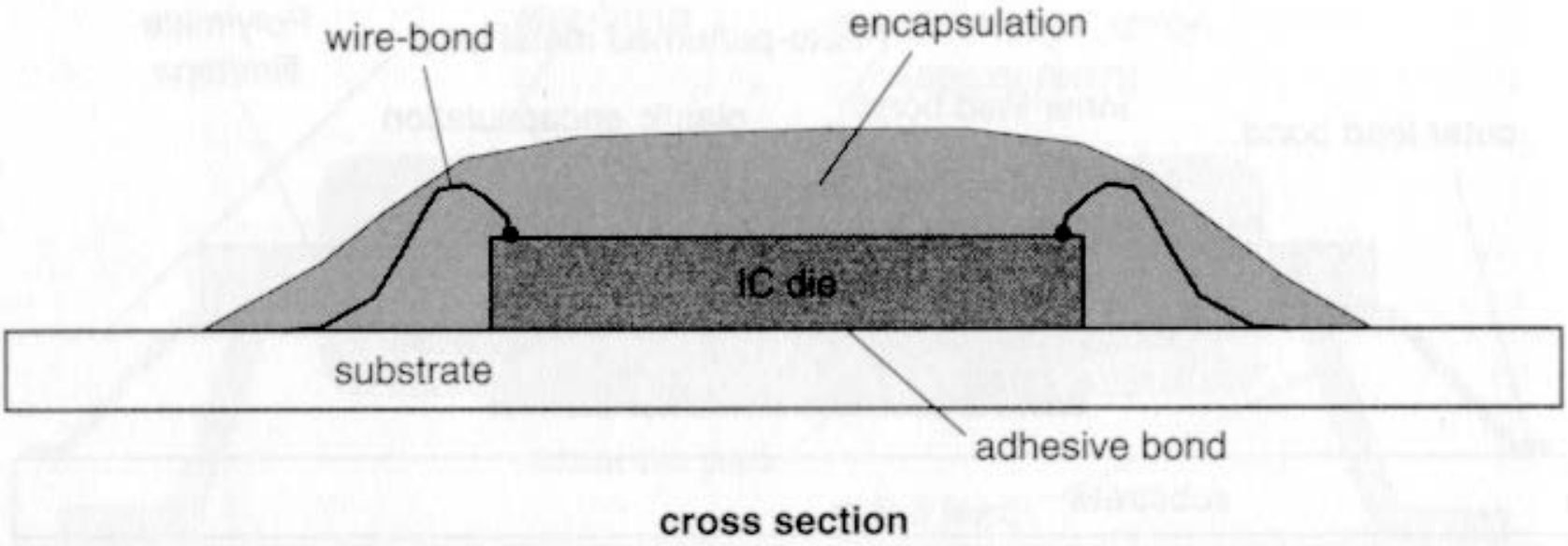


Figure 3.8 Basic COB construction.

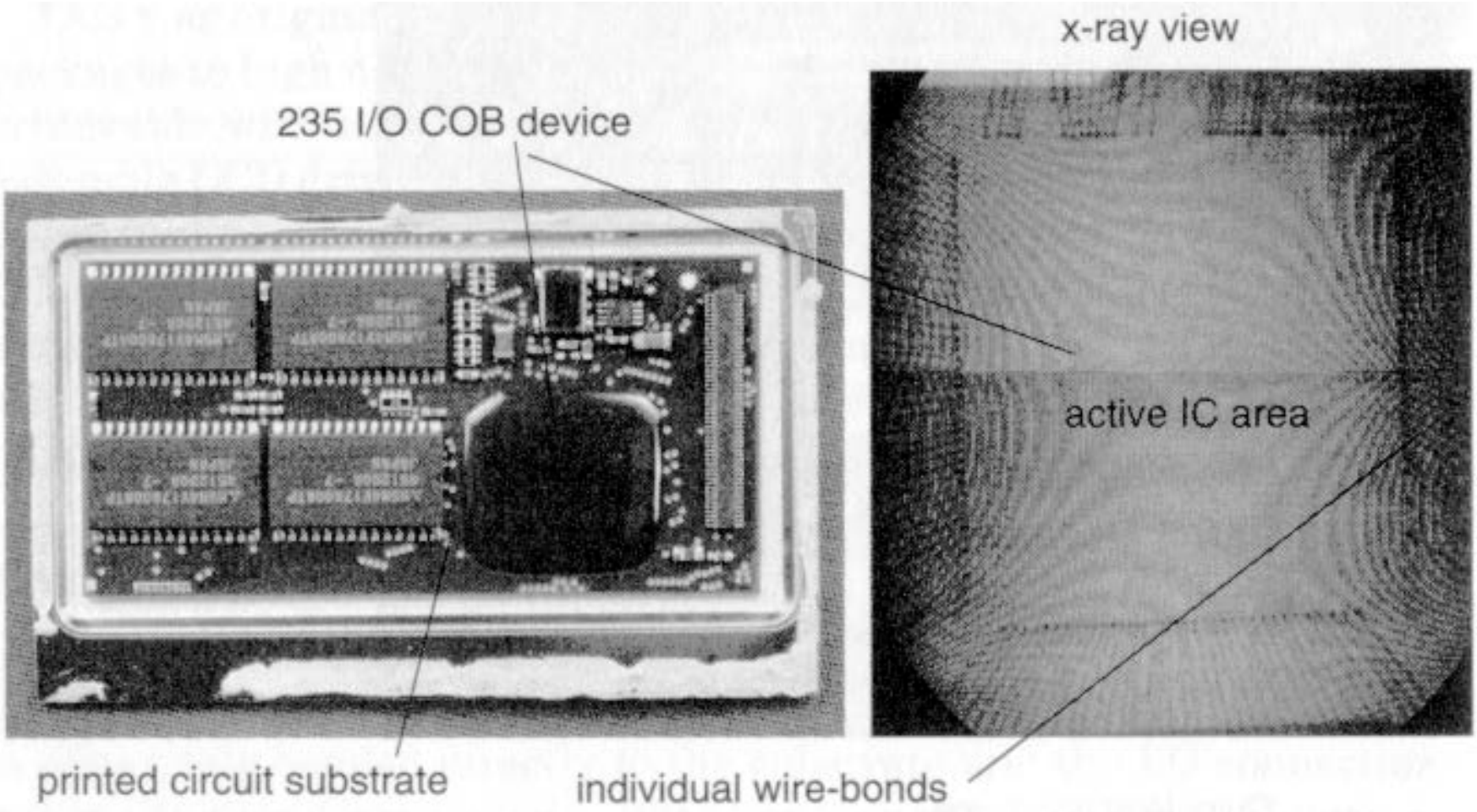


Figure 3.9 COB implementation on miniaturized PC motherboard.

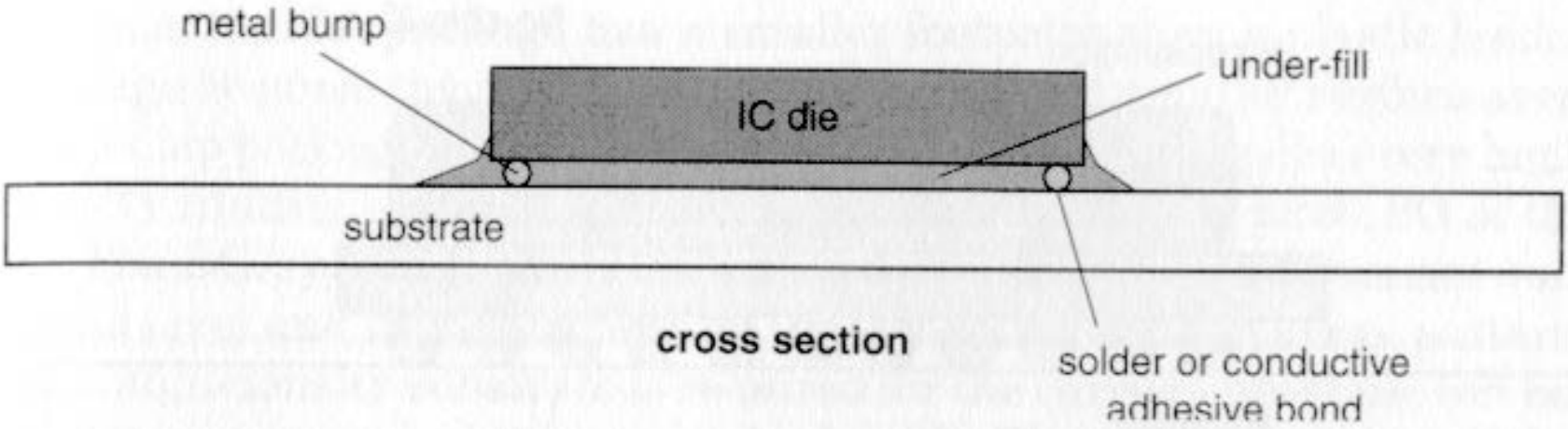


Figure 3.10 Basic flip-chip construction.

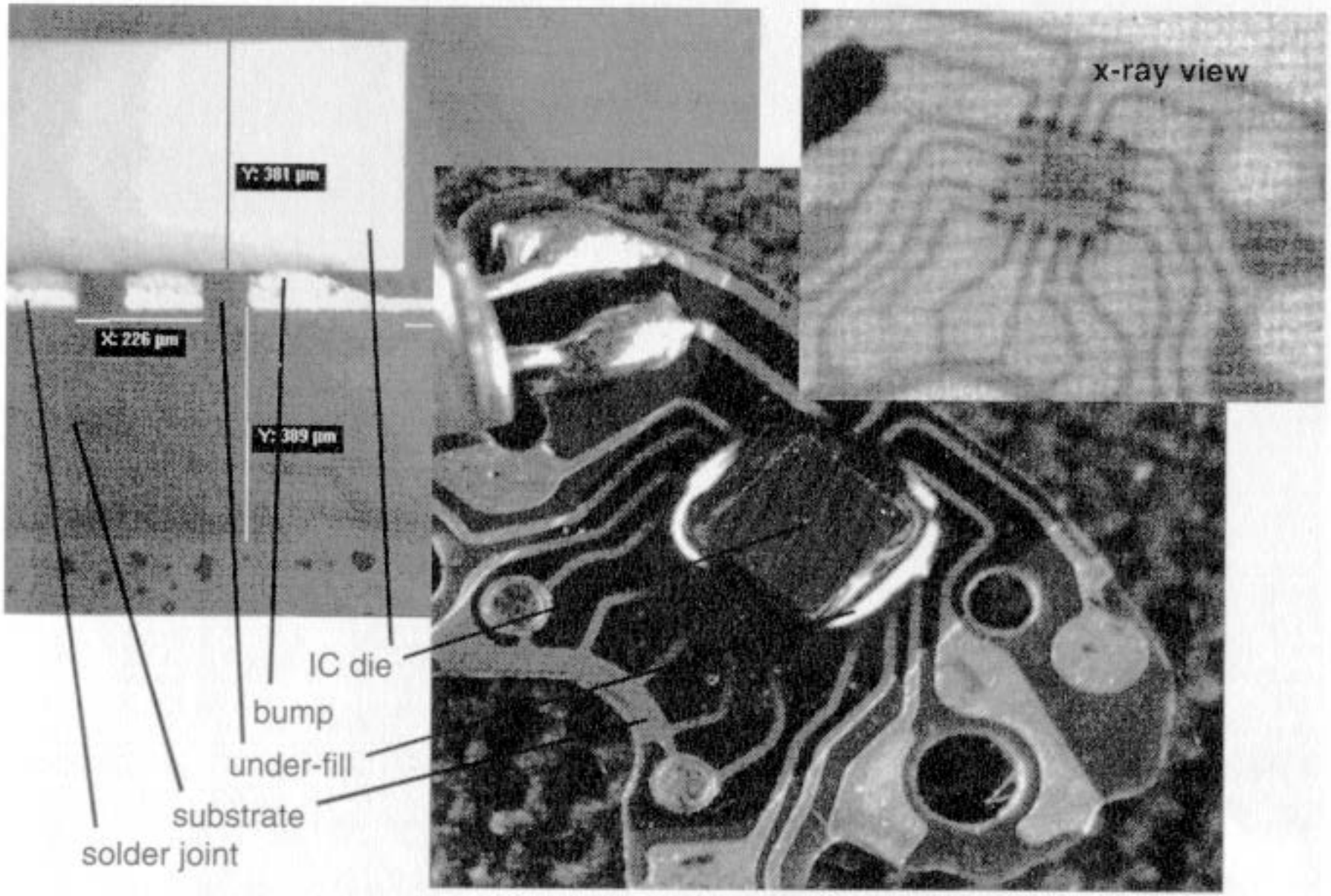


Figure 3.11 Flip-chip technology in a wristwatch.

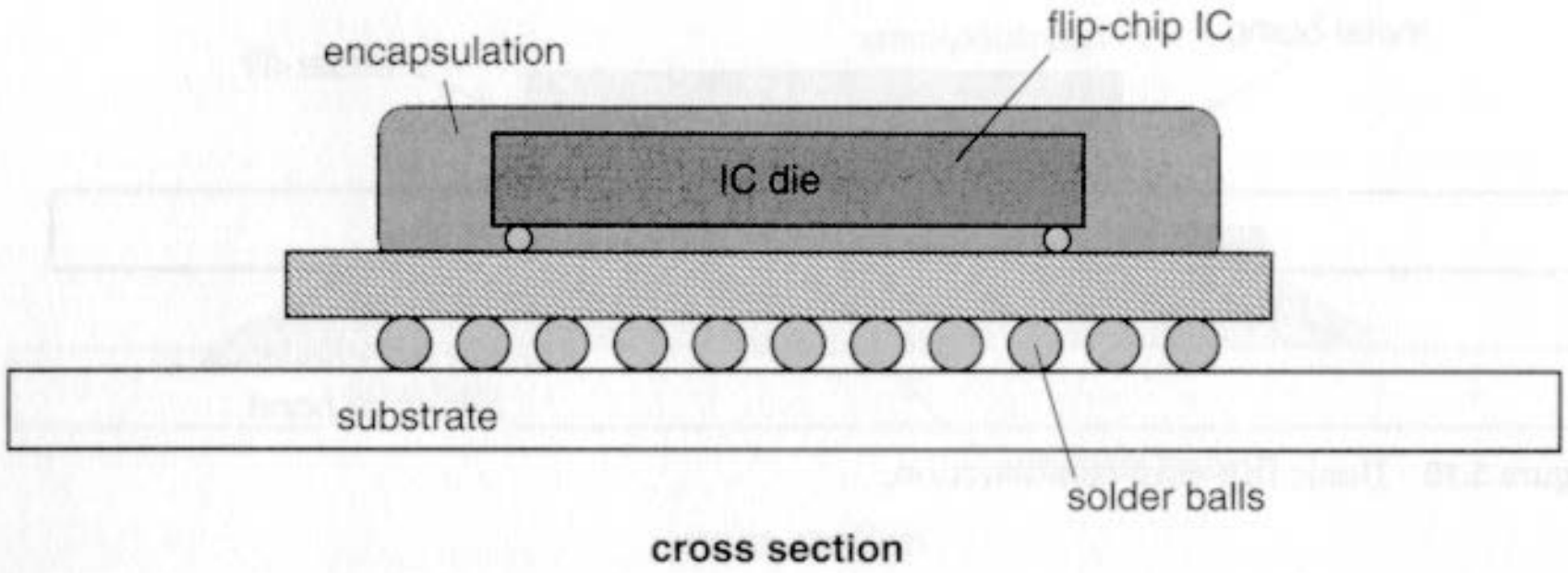


Figure 3.12 Basic BGA construction.

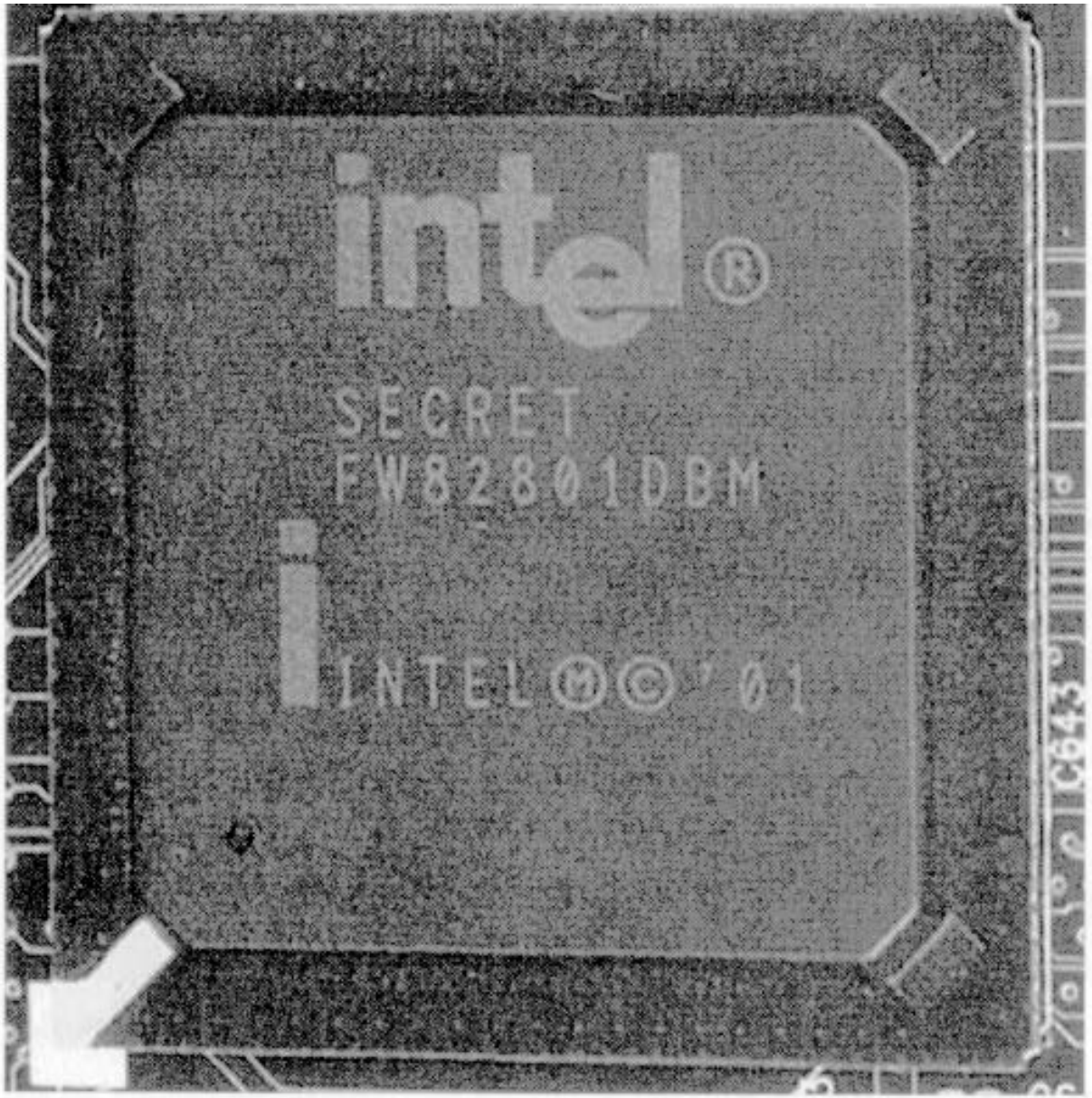


Figure 3.13 BGA package on notebook computer motherboard.

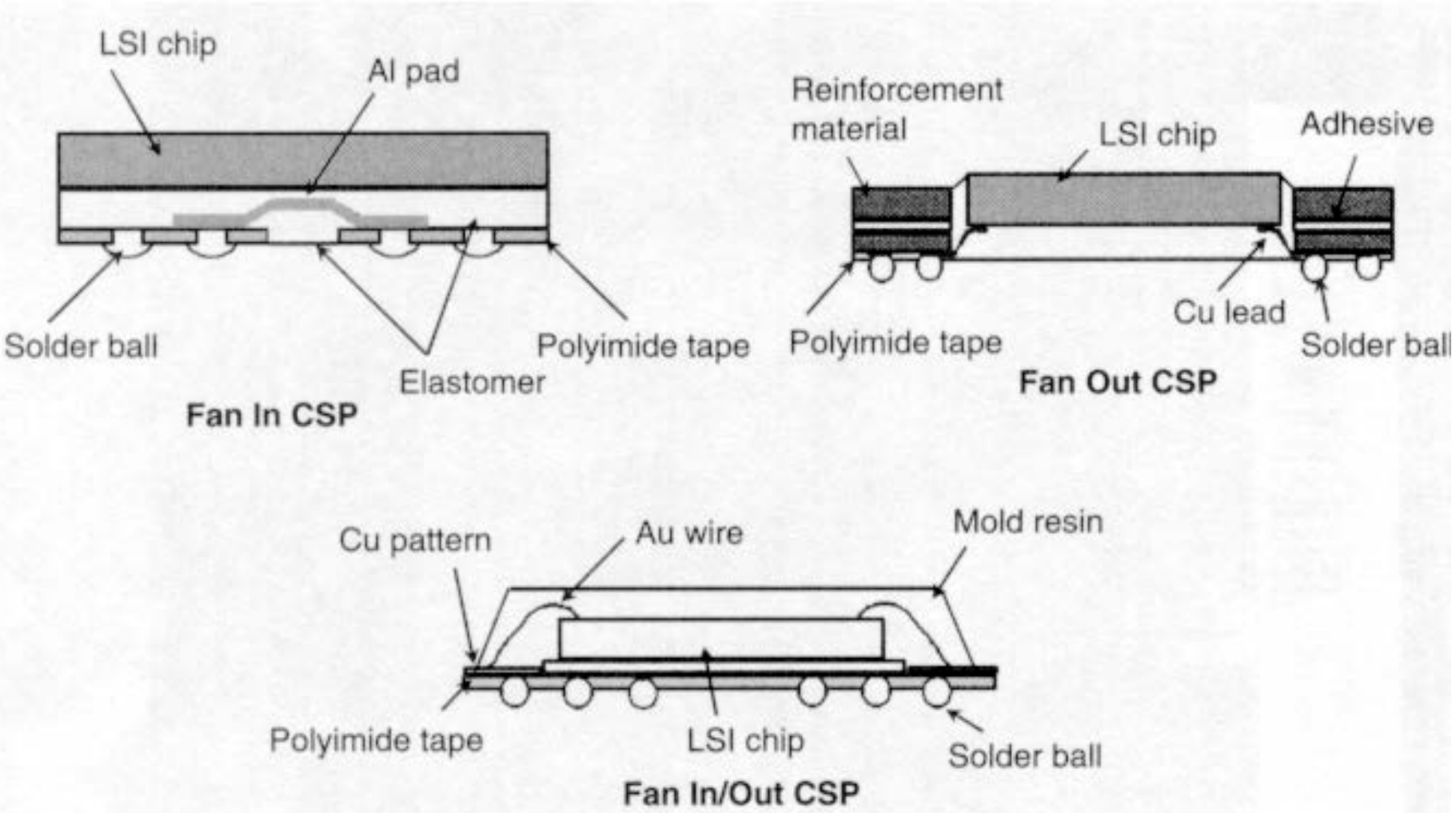


Figure 3.16 CSP variations.

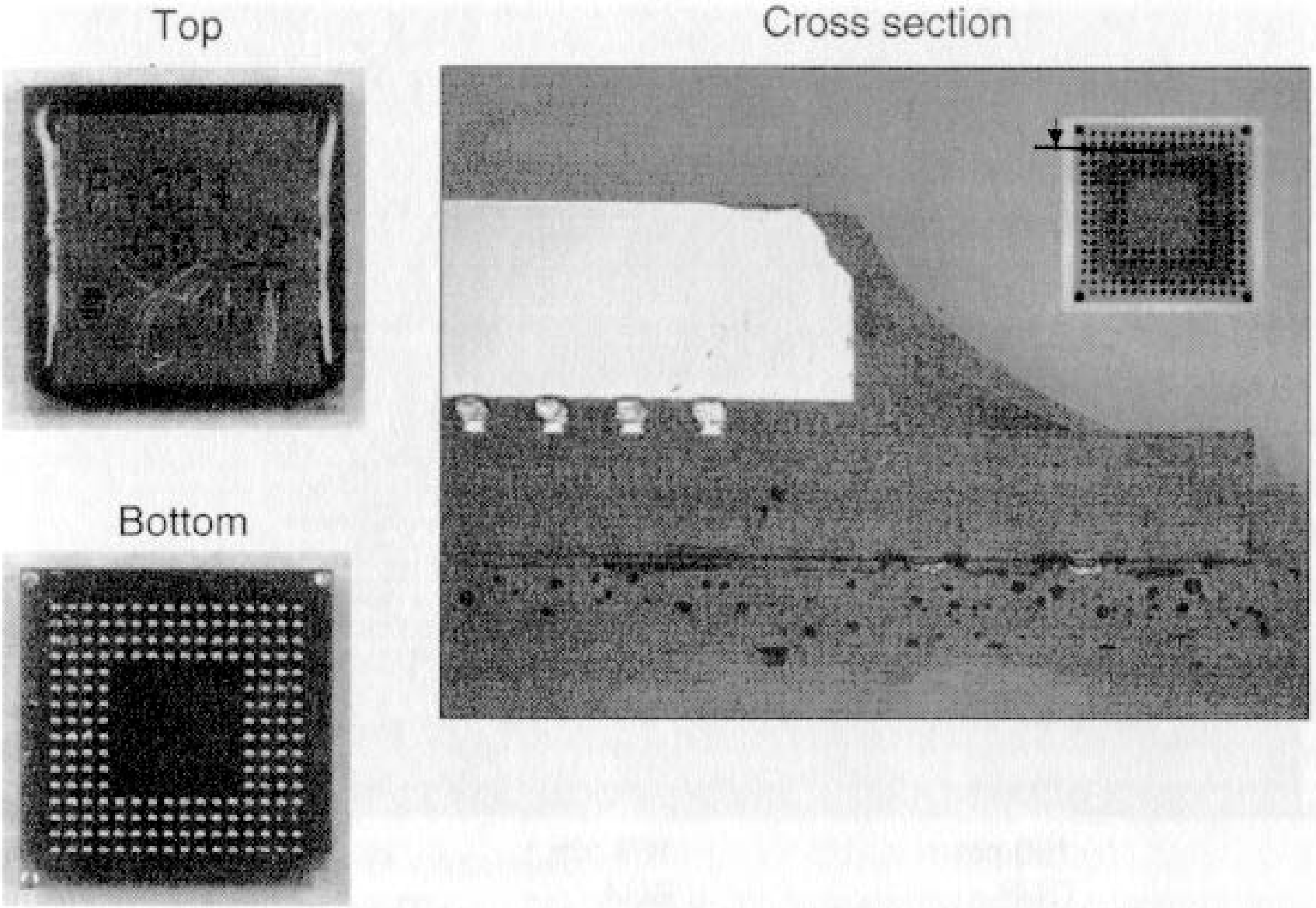


Figure 3.17 CSP photographs.

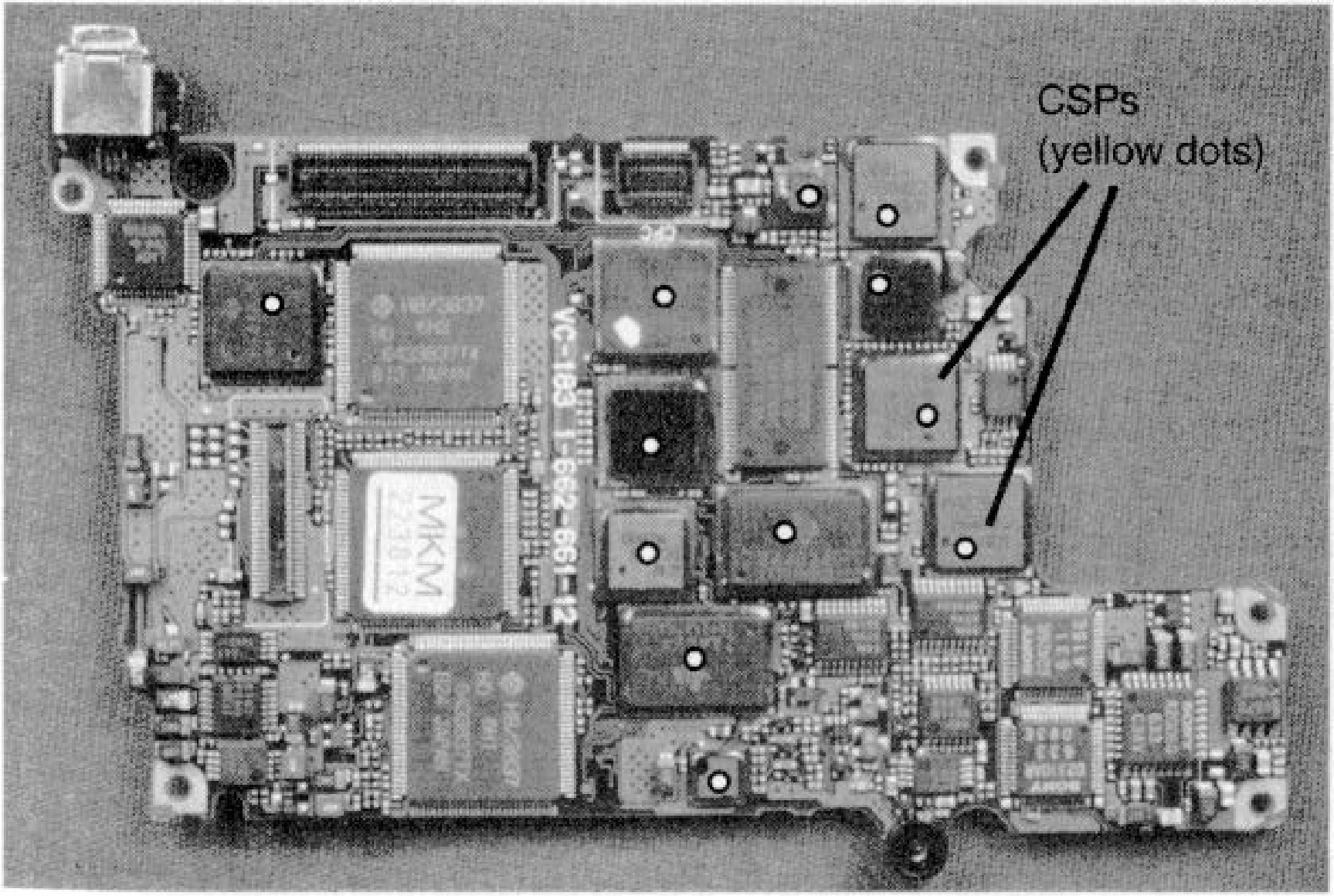


Figure 3.18 CSPs in a digital camcorder product.

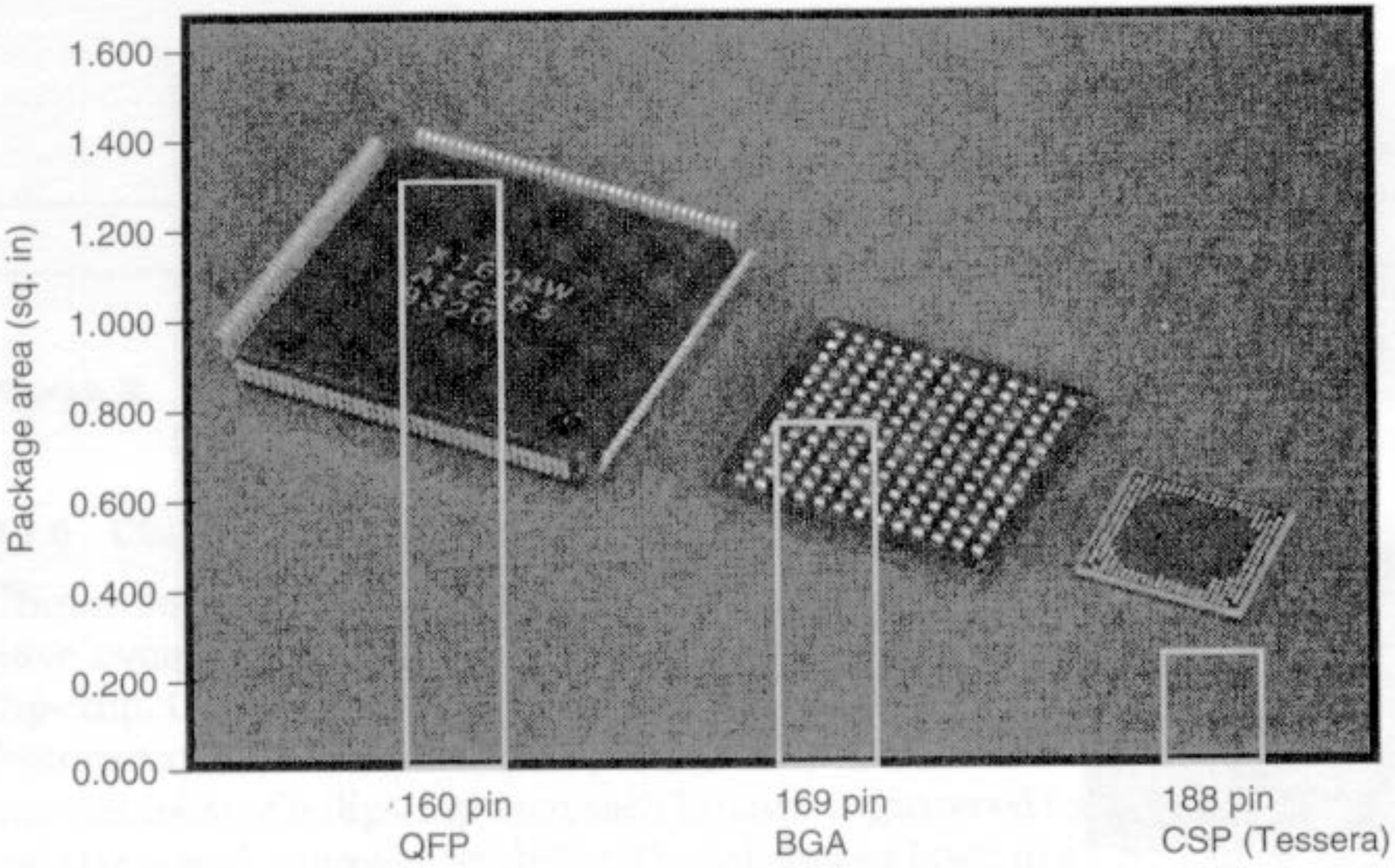


Figure 3.19 Package footprint comparisons.

TOPICS FOR DISCUSSION:

- DISCRETE COMPONENTS
- BOARD-TO-BOARD CONNECTIONS
- SUBSTRATES
- ESCAPE ROUTING
- MODULE DESIGN METRICS
- ELECTRONIC PACKAGE METRICS
- I/O HARDWARE

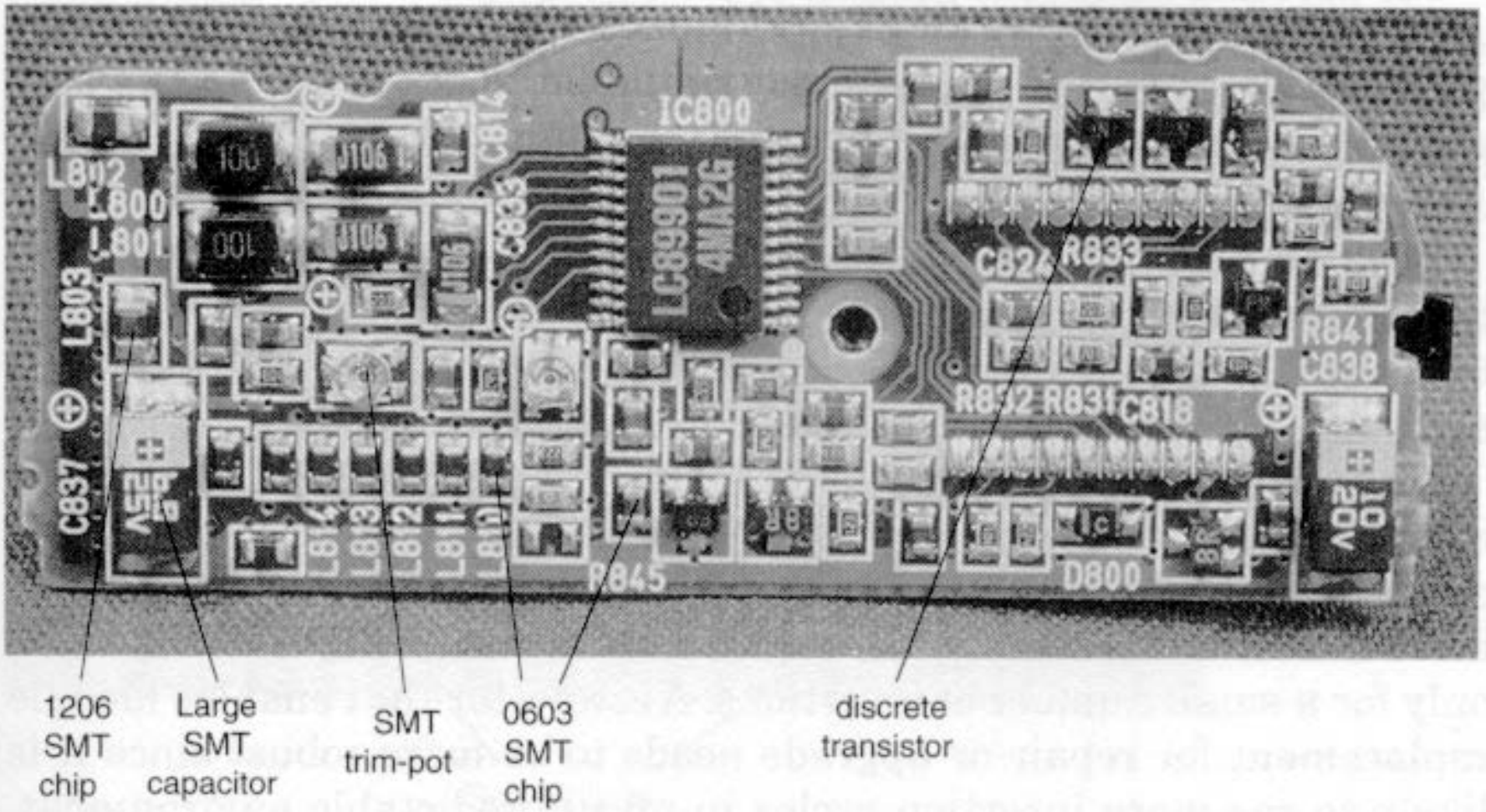


Figure 3.20 Discrete components on digital camera PCA.

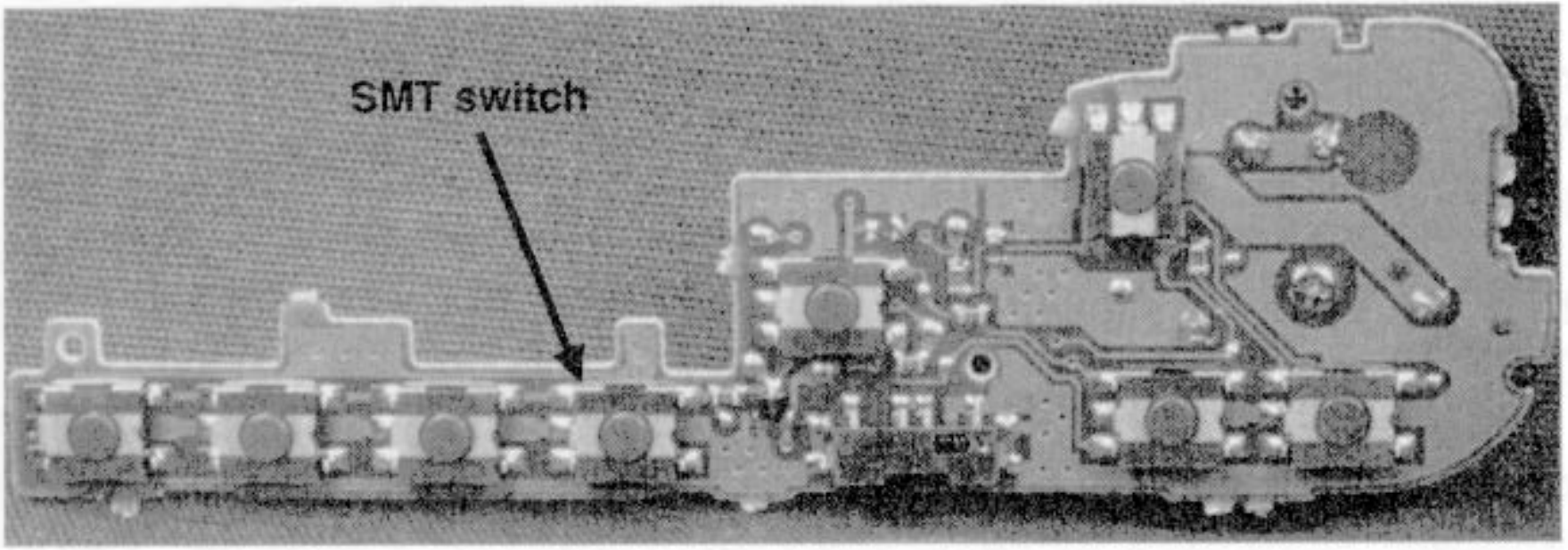


Figure 3.21 SMT switches on digital camera PCA.

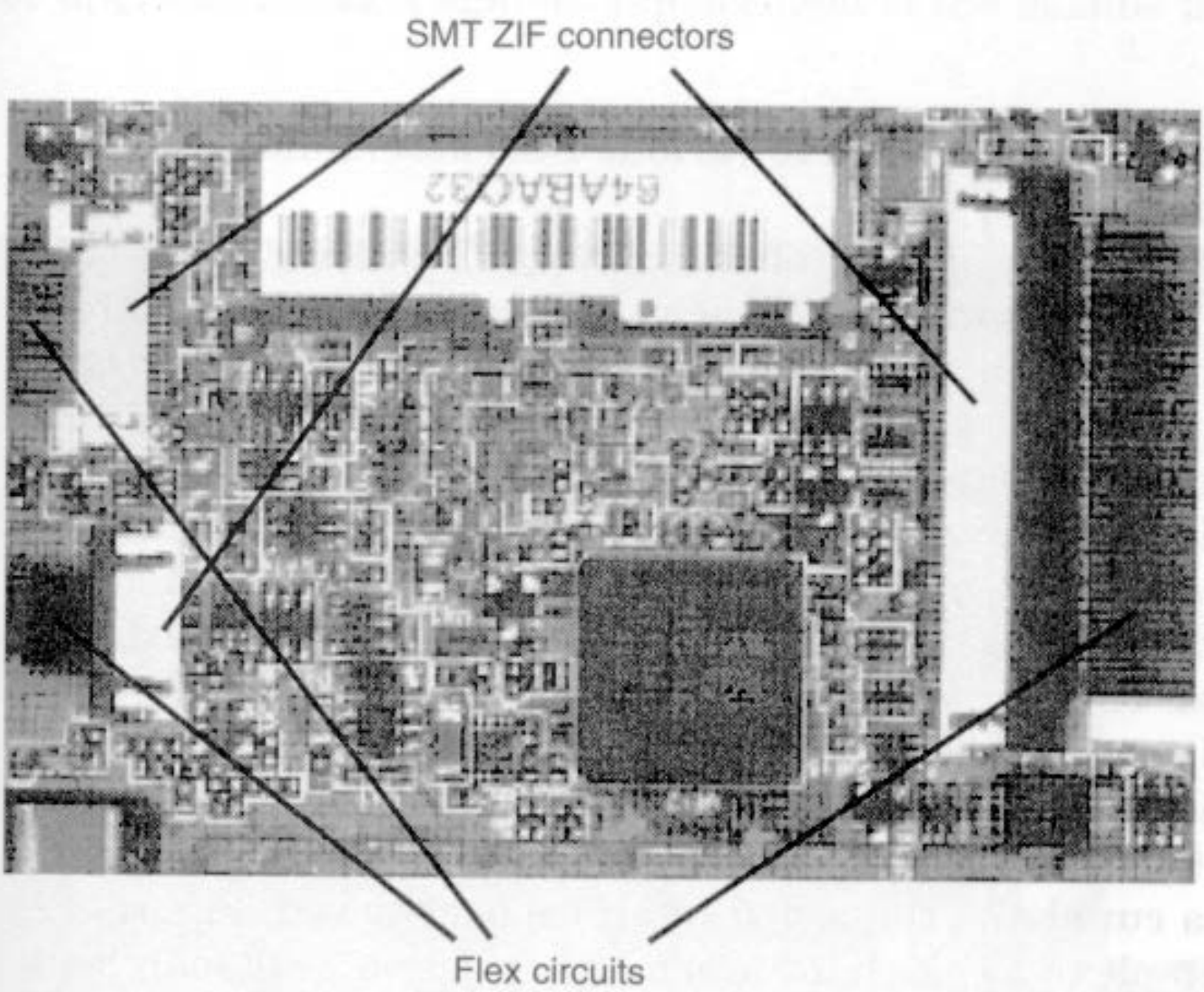


Figure 3.22 SMT ZIF connectors.

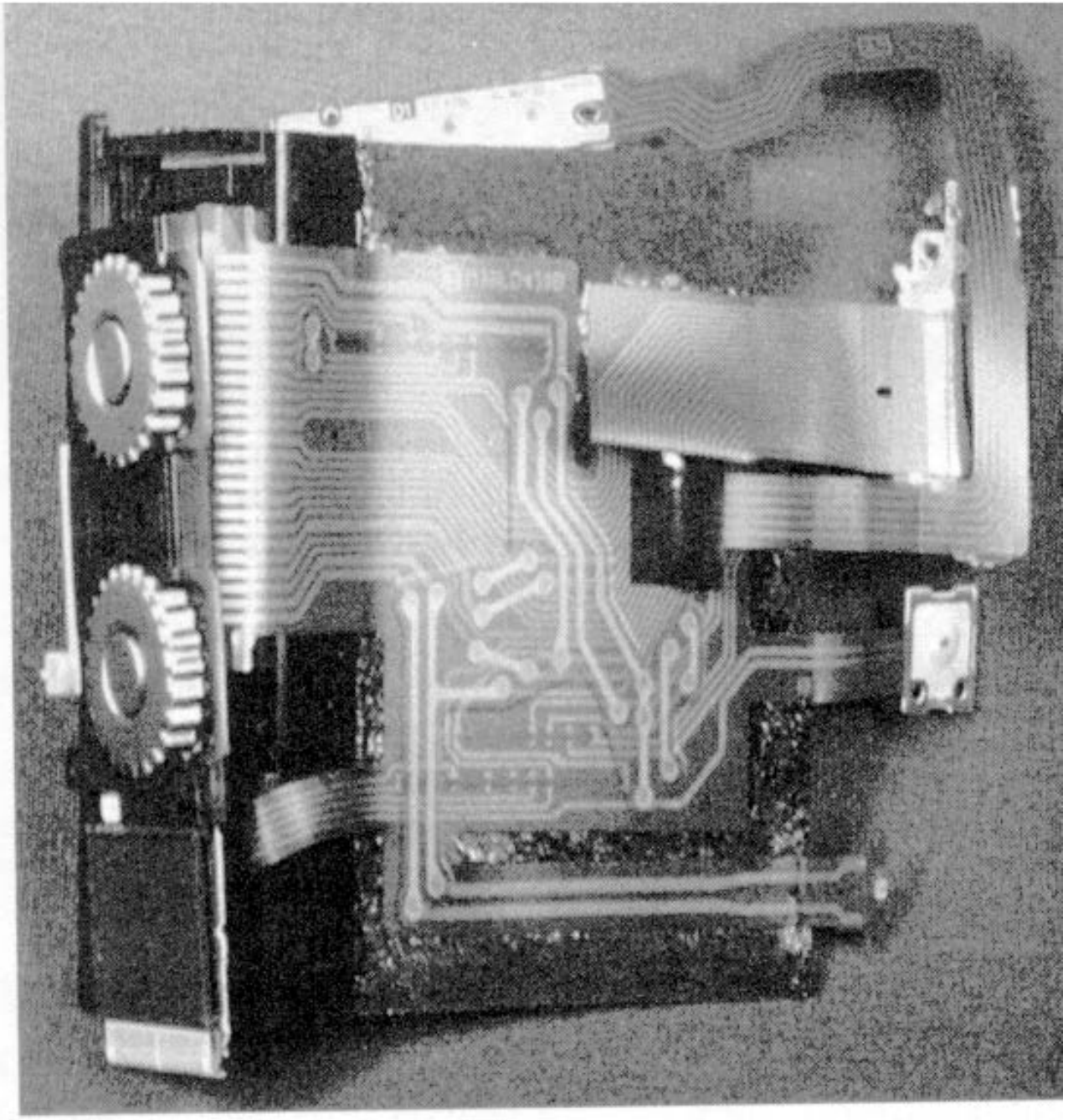


Figure 3.23 Polyester flex in camcorder product.

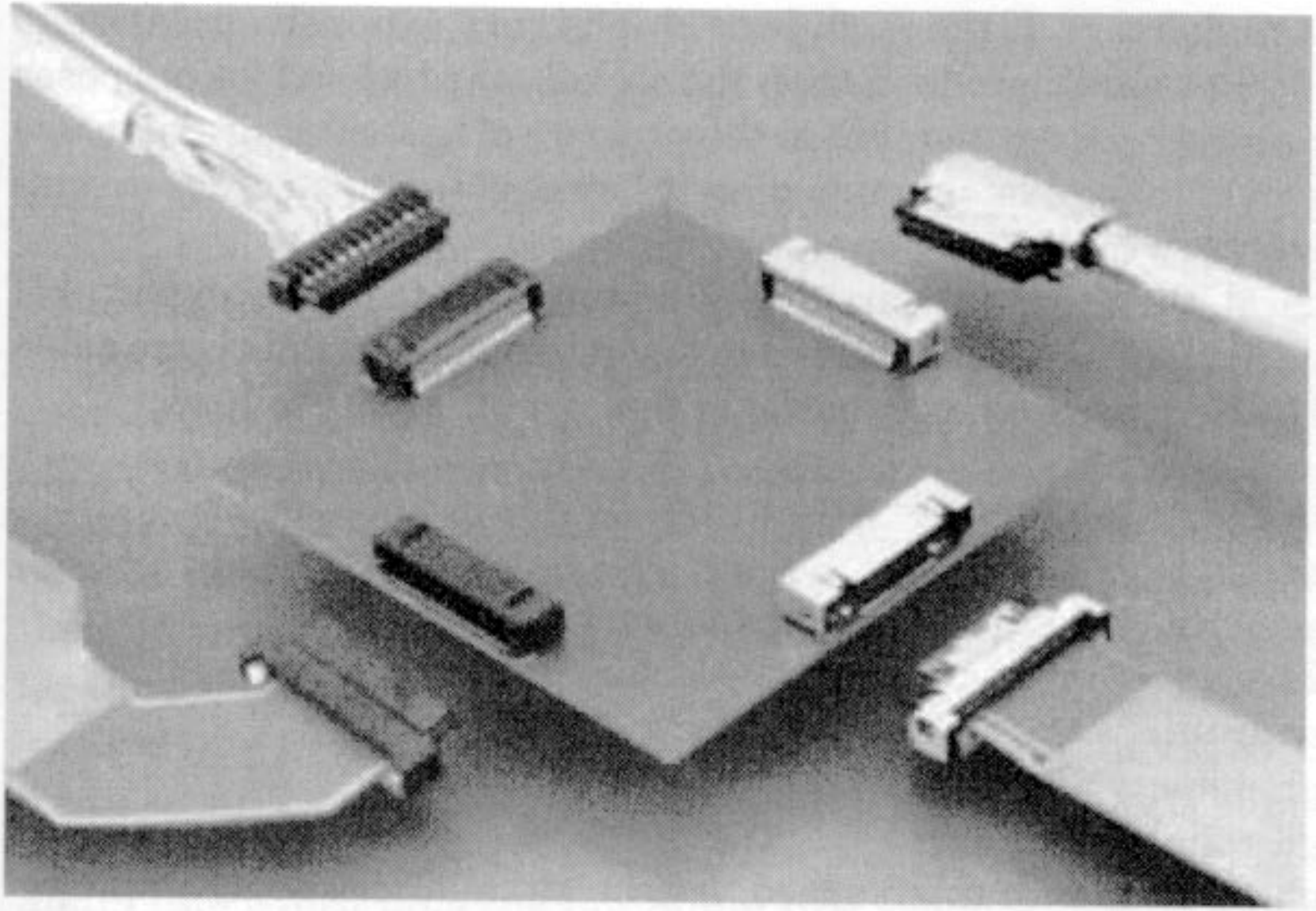


Figure 3.24 Flex connector cables with pin and socket connectors.

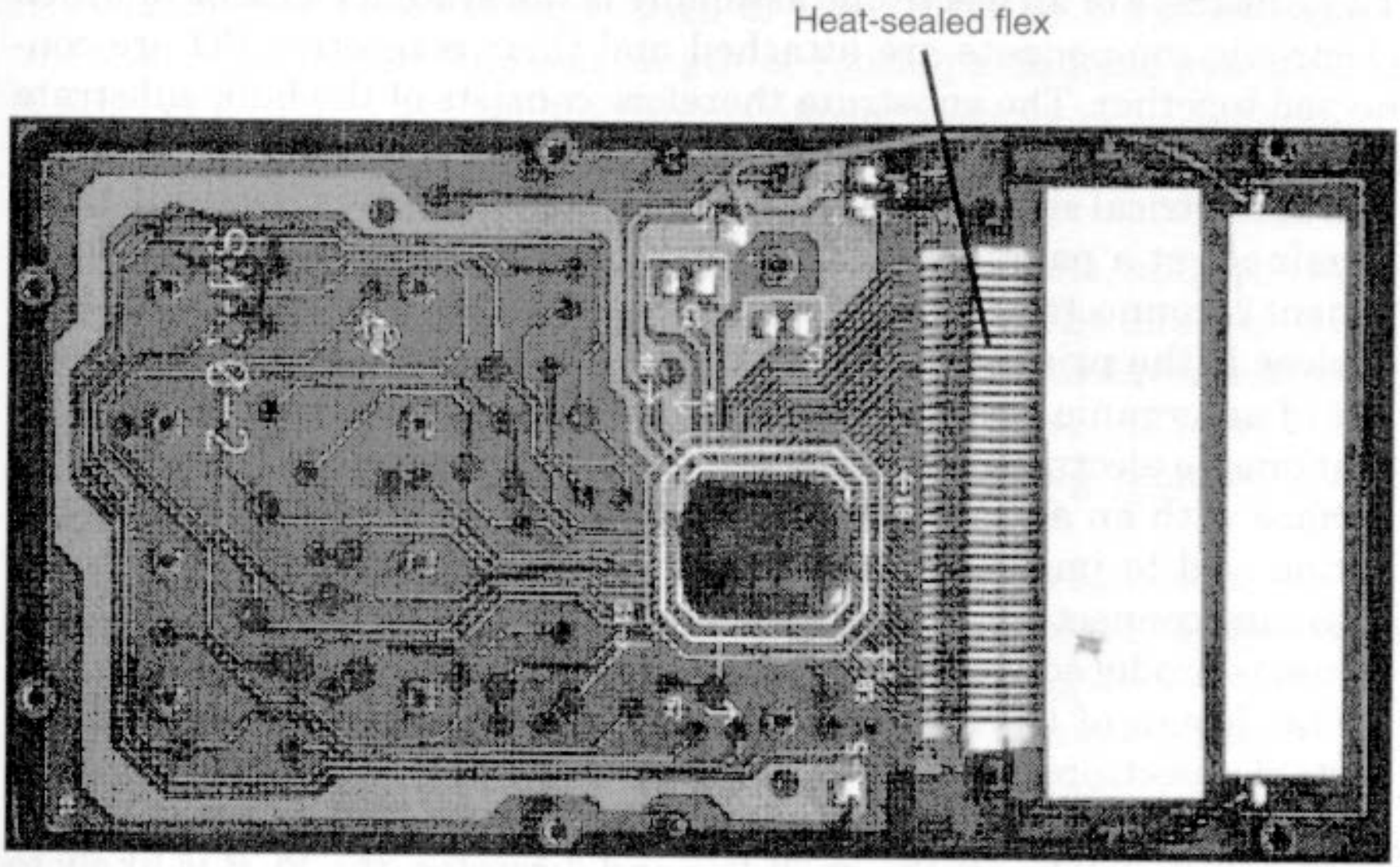


Figure 3.25 Heat sealed flex.

In general, the use of flex circuitry is an important enabler in portable electronic devices as an alternative to discrete wiring or multiwire cable strips. The benefits and drawbacks of flex circuit are as follows:

1. Advantages over discrete wire interconnect
   - Size
   - Fine pitch (0.3 mm pitch and smaller)
   - SMT
   - Low profile
   - High density
   - High reliability
   - High performance (high speed, less cross talk, less delay in propagation)
   - Design flexibility
   - Easy to route
2. Disadvantages
   - More expensive than discrete wire types
   - Flex is custom made (takes long to design)

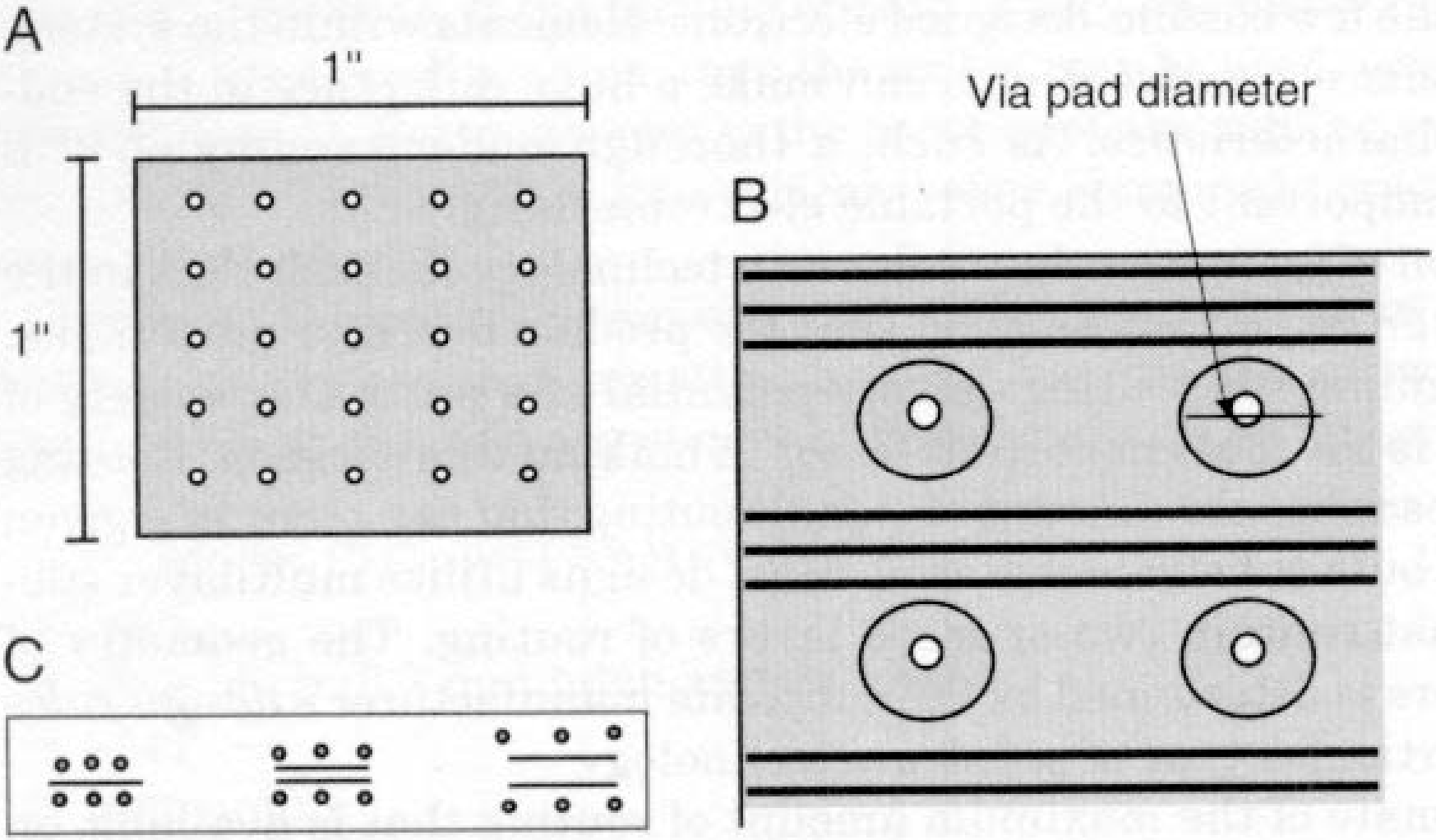


Figure 3.26 Via geometry impacts routing density.

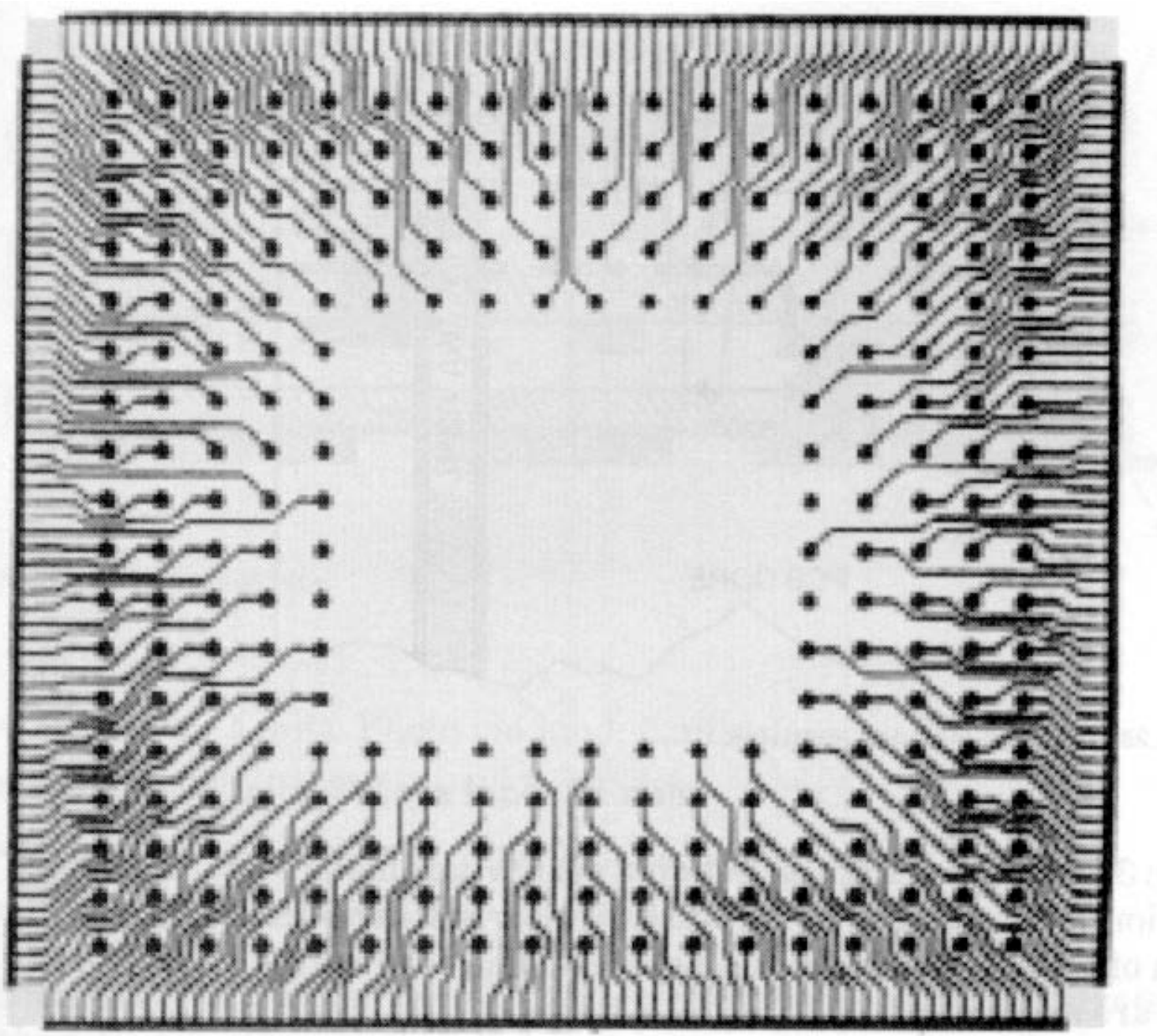


Figure 3.27 CSP footprint for escape routing.

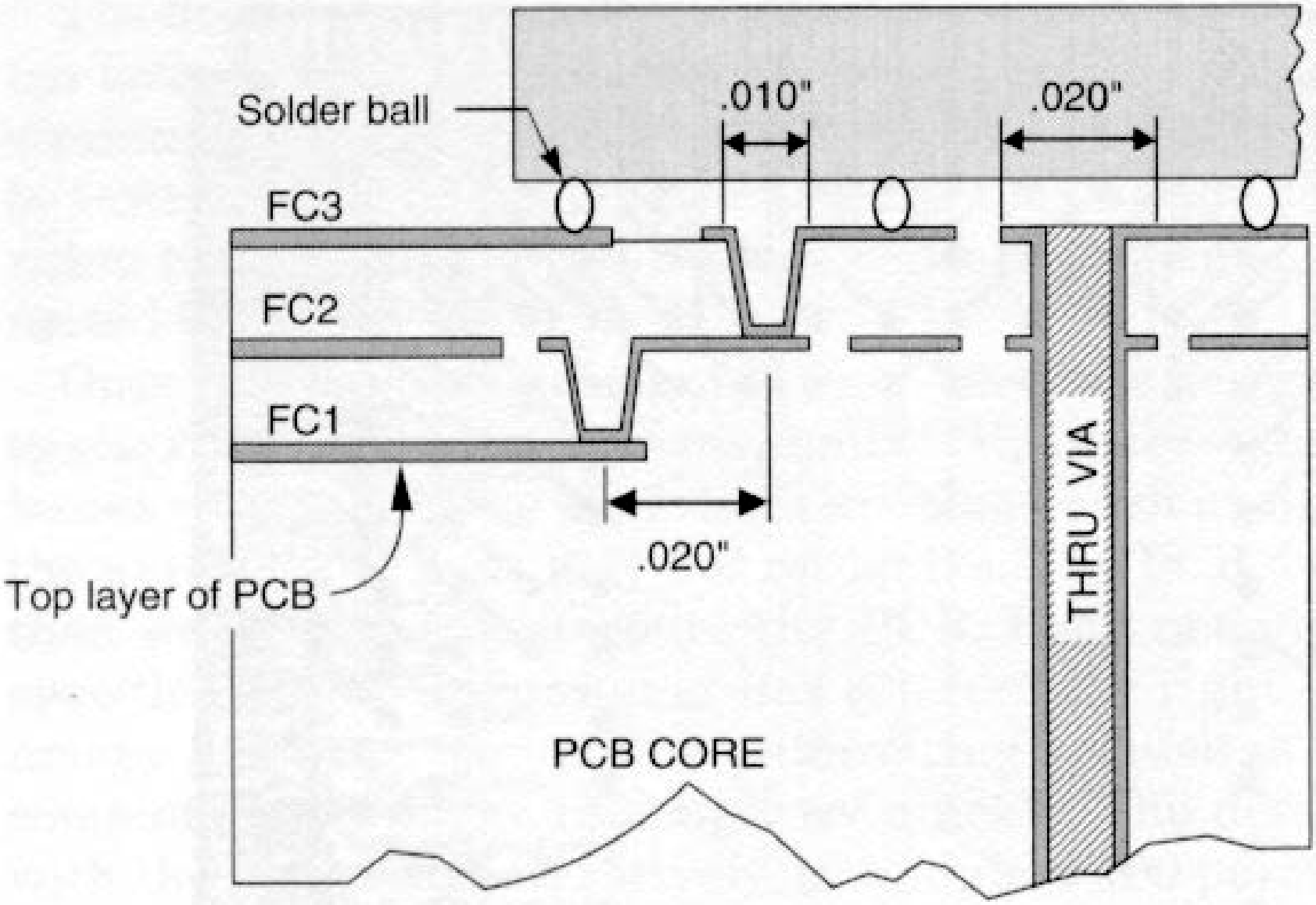


Figure 3.28 Surface laminar circuitry.

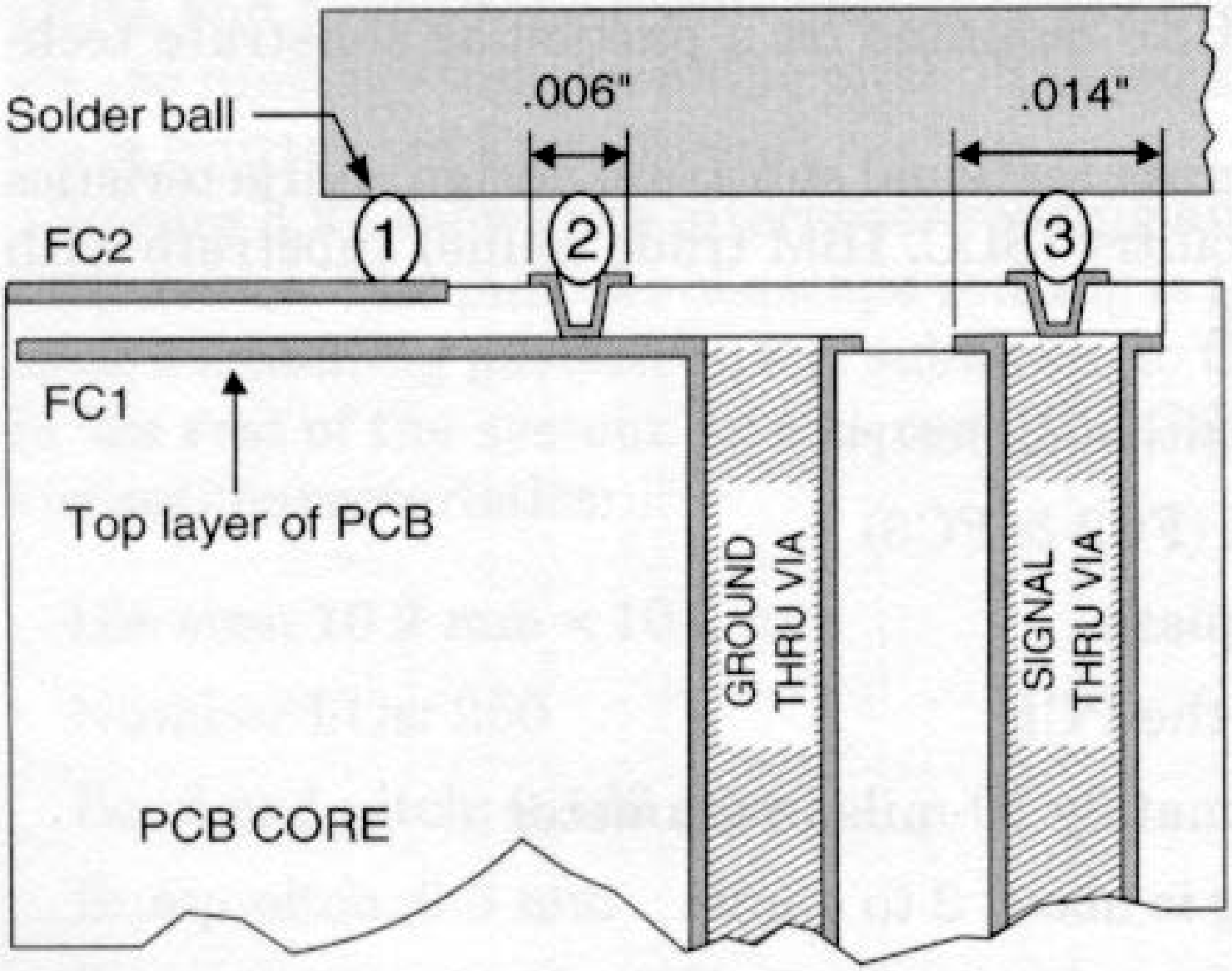


Figure 3.29 Film redistribution layer.

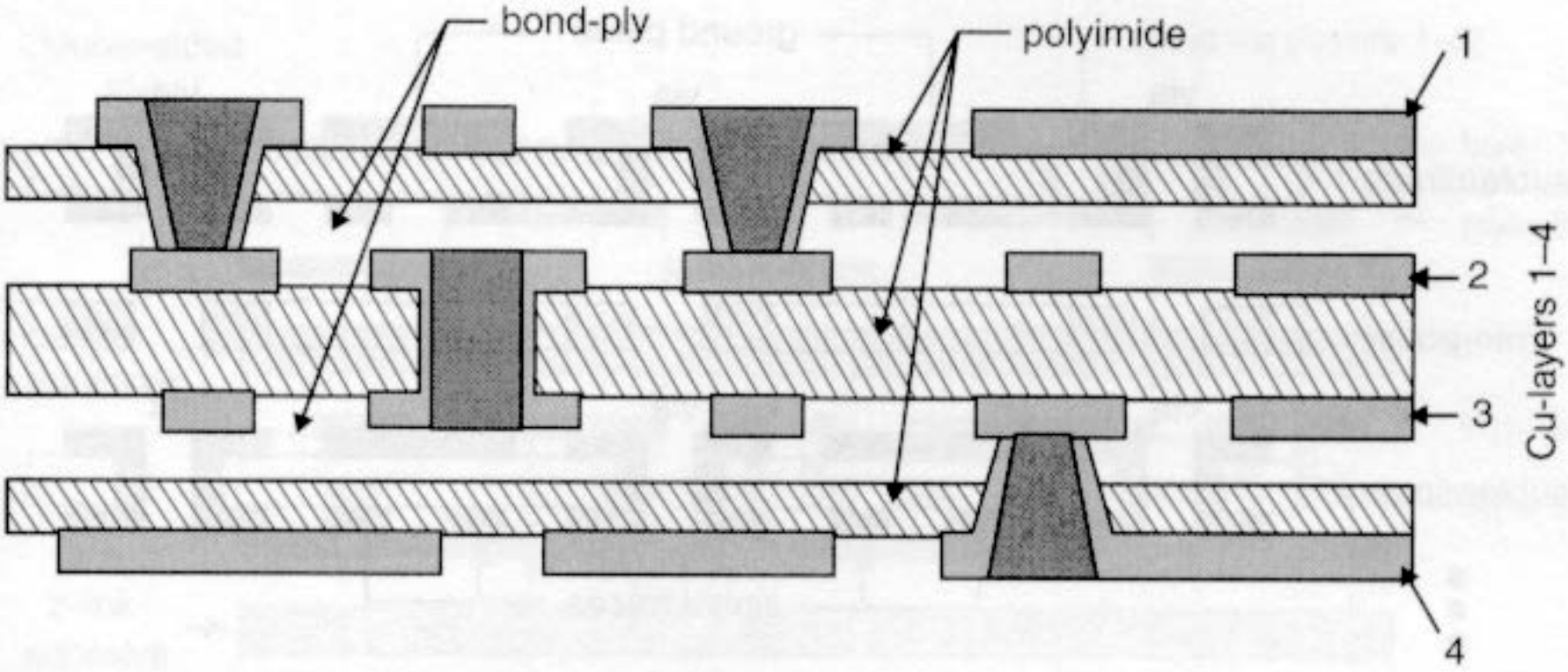


Figure 3.30 Dycostrate.

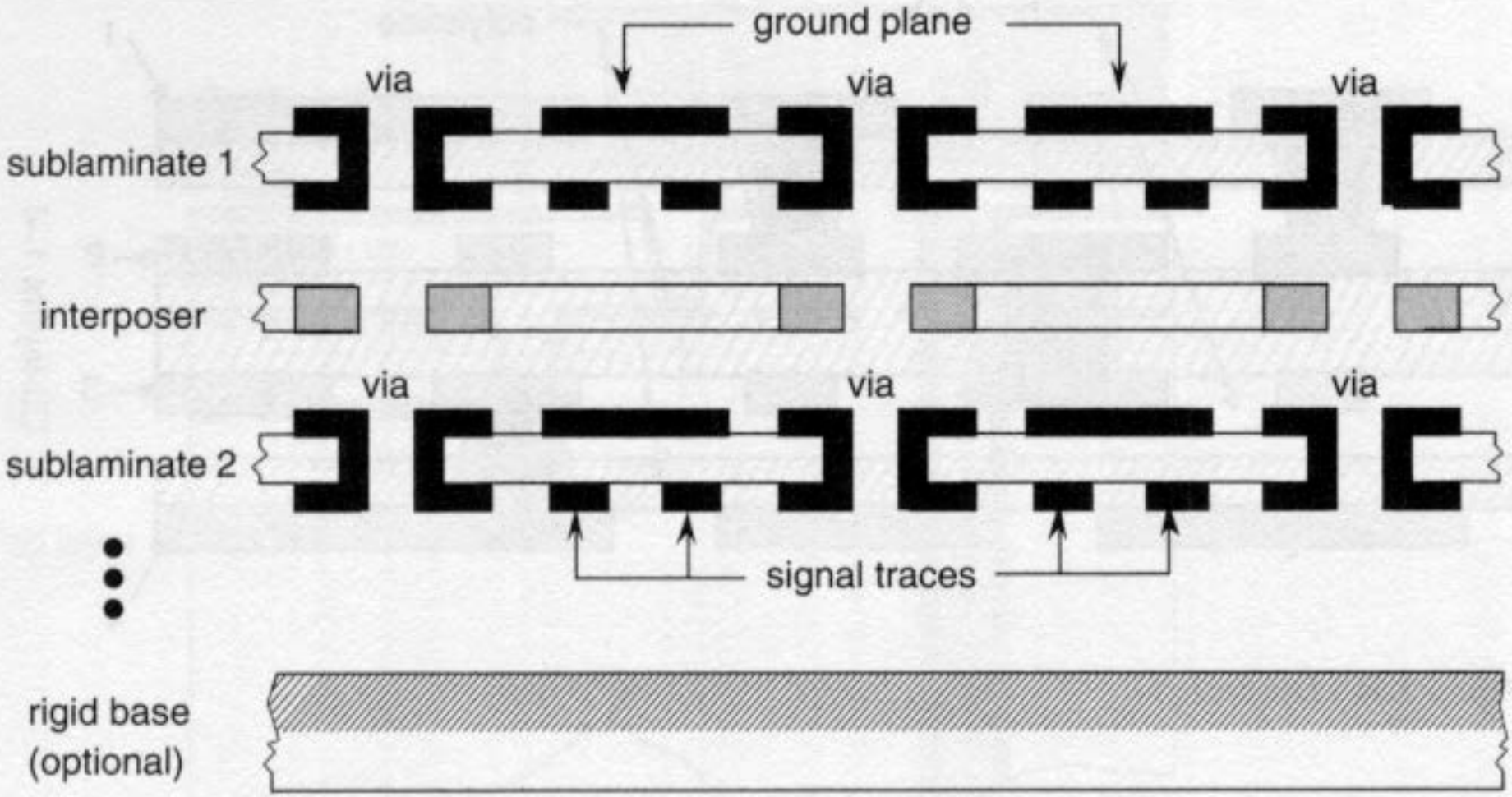


Figure 3.31 Tessera laminated substrate.

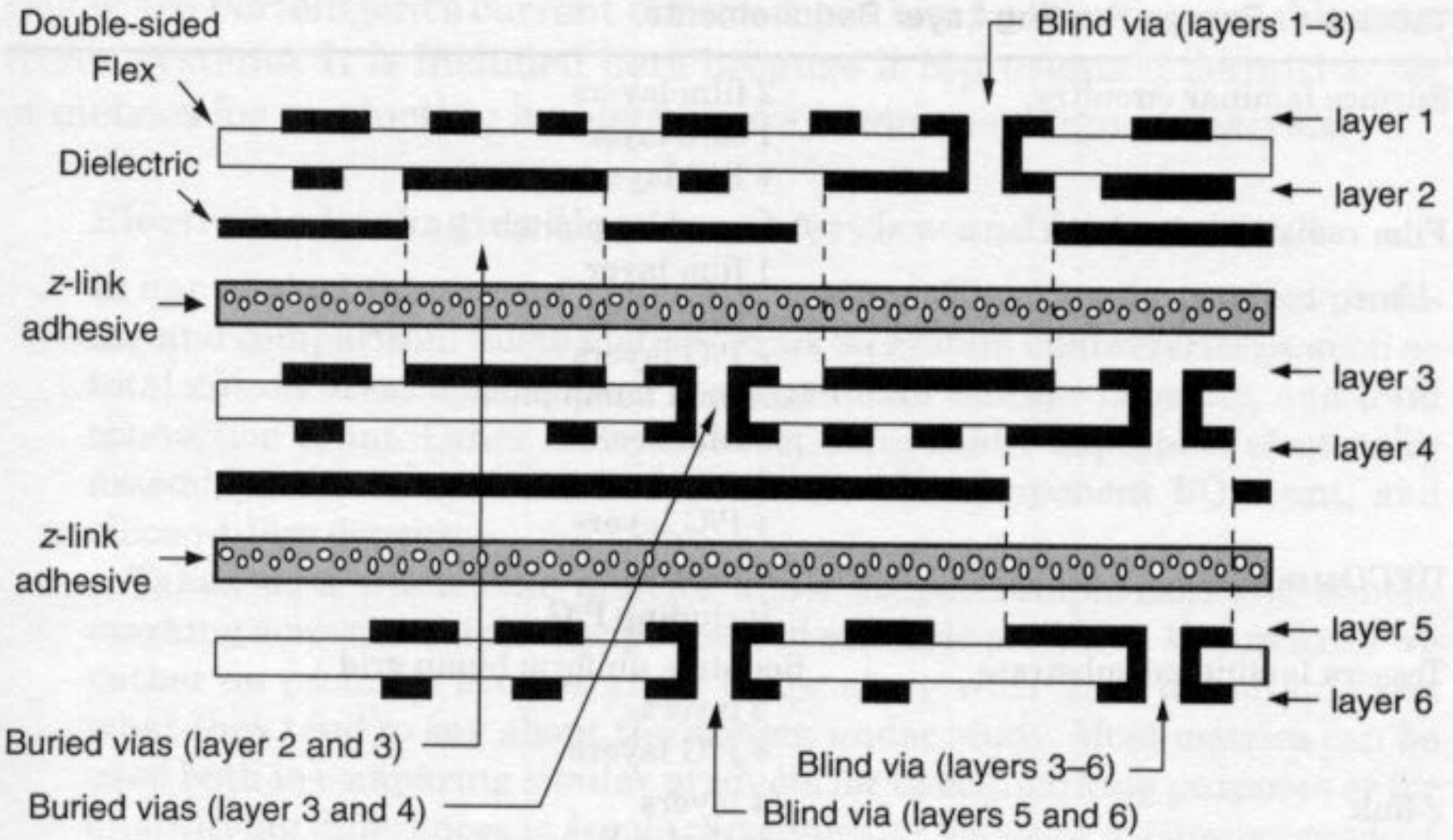


Figure 3.32 Sheldahl *z*-link.

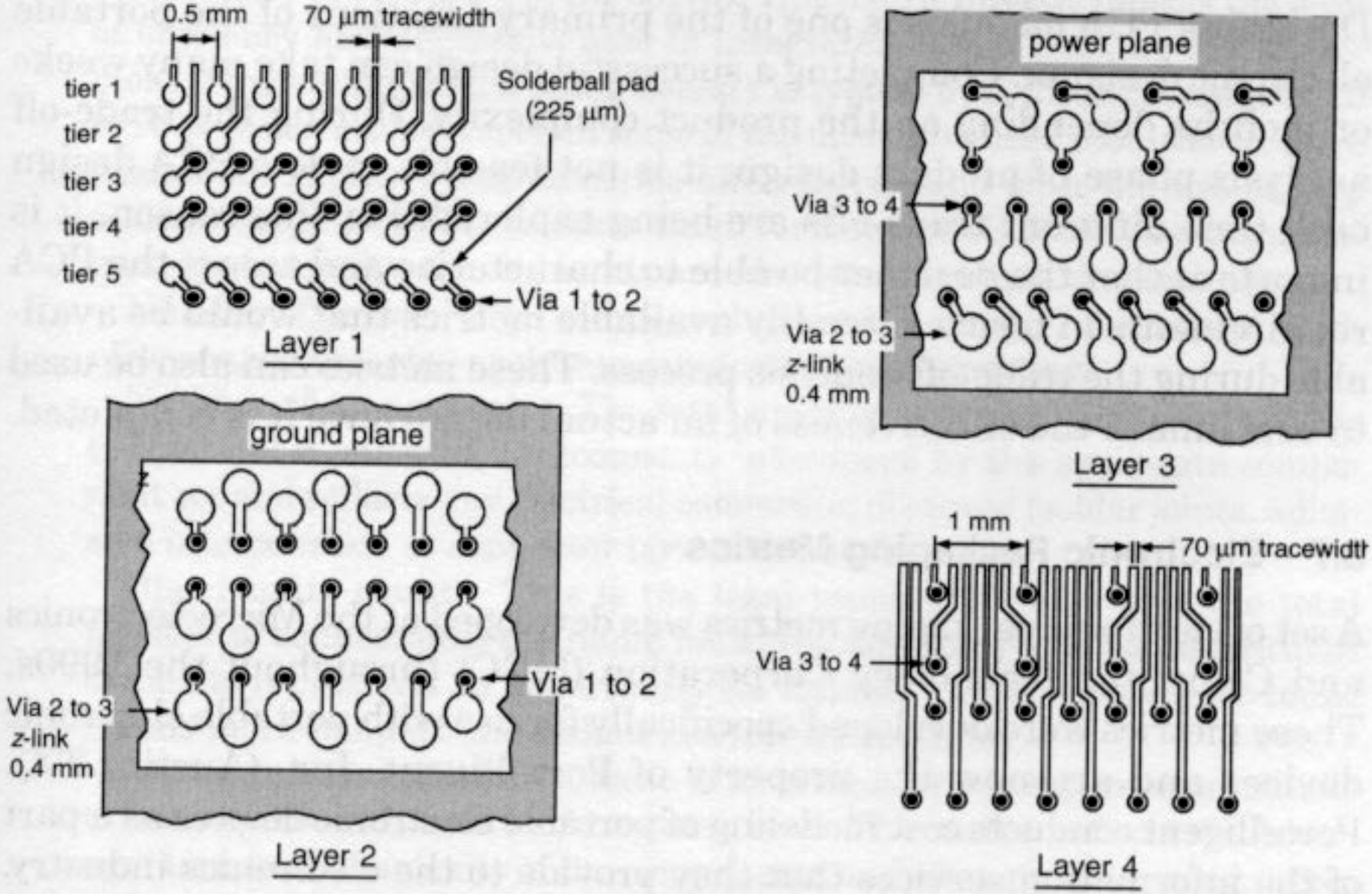


Figure 3.33 Escape routing.

TABLE 3-2 Comparison of Packaging Metrics for Different Product Types

Product category	Cell phone	Digtal camera	PDA	Notebook PC
Routing density (cm/cm^2)	33	73	40	38
Part density ($parts/cm^2$)	12	29	7	5.9
Average pin count	3.2	4.5	5.2	5.3
Connection density ($conn./cm^2$)	38	132	34	30
Total silicon area (mm^2)	170	130	473	774
Silicon-tiling density	4.0%	14.1%	7.3%	2.8%
Number of parts	500	270	420	1650
Number of connections	1,600	1,200	2,200	8,700
Opportunity count	2,100	1,505	2,600	10,000

BUTTONS AND SWITCHES:

- SIZE TO FIT USER AND ENVIRONMENT
- SIZE TO FIT EQUIPMENT MECHANICS
- SPECIAL PROBLEMS IN Z AXIS
- PROPER TACTILE FEELING
- AVOIDING UNITENDED ACTIVATION
- ANALOG PARAMETERS VS. DIGITAL CONTROL

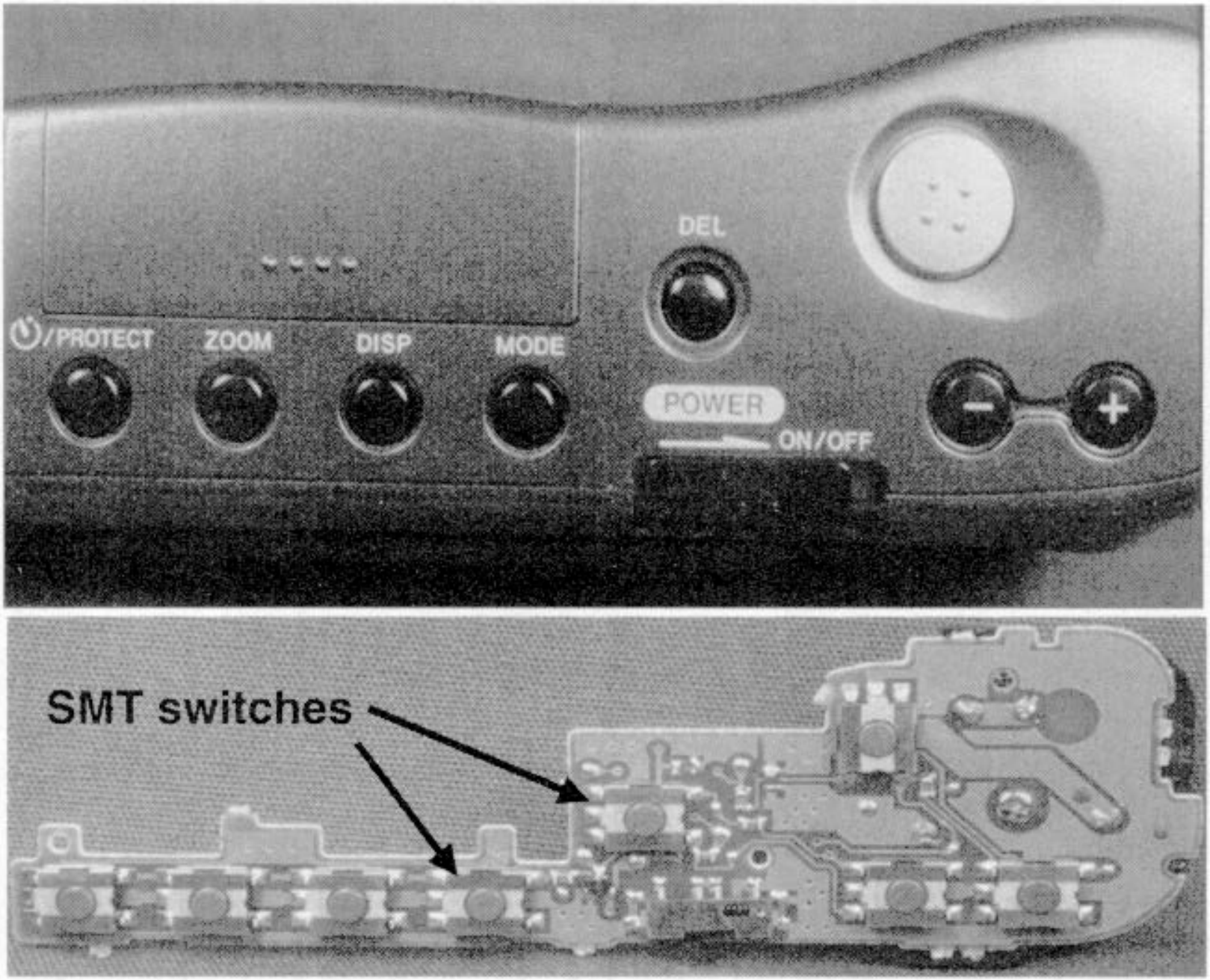


Figure 3.34 SMT switches.

USER CONVENIENCE MAY BOUNCE BACK

- DESPITE (EVEN) HONEST ATTEMPTS, THINGS TARGETTED TO MAKING BUTTONS EASIER MAY LEAD TO ADDED GADGETRY
- HUMAN USERS SEEM TO HAVE CERTAIN INHERITED PRACTICES SUCH AS PUSHING BUTTONS – ANYTHING REQUIRING NEW MOTORICS IS IN DANGER OF BEING RIDICULED
- VOICE ACTIVATION NOT IN WIDE USE ALTHOUGH MIGHT HAVE TECHNICAL POTENTIAL

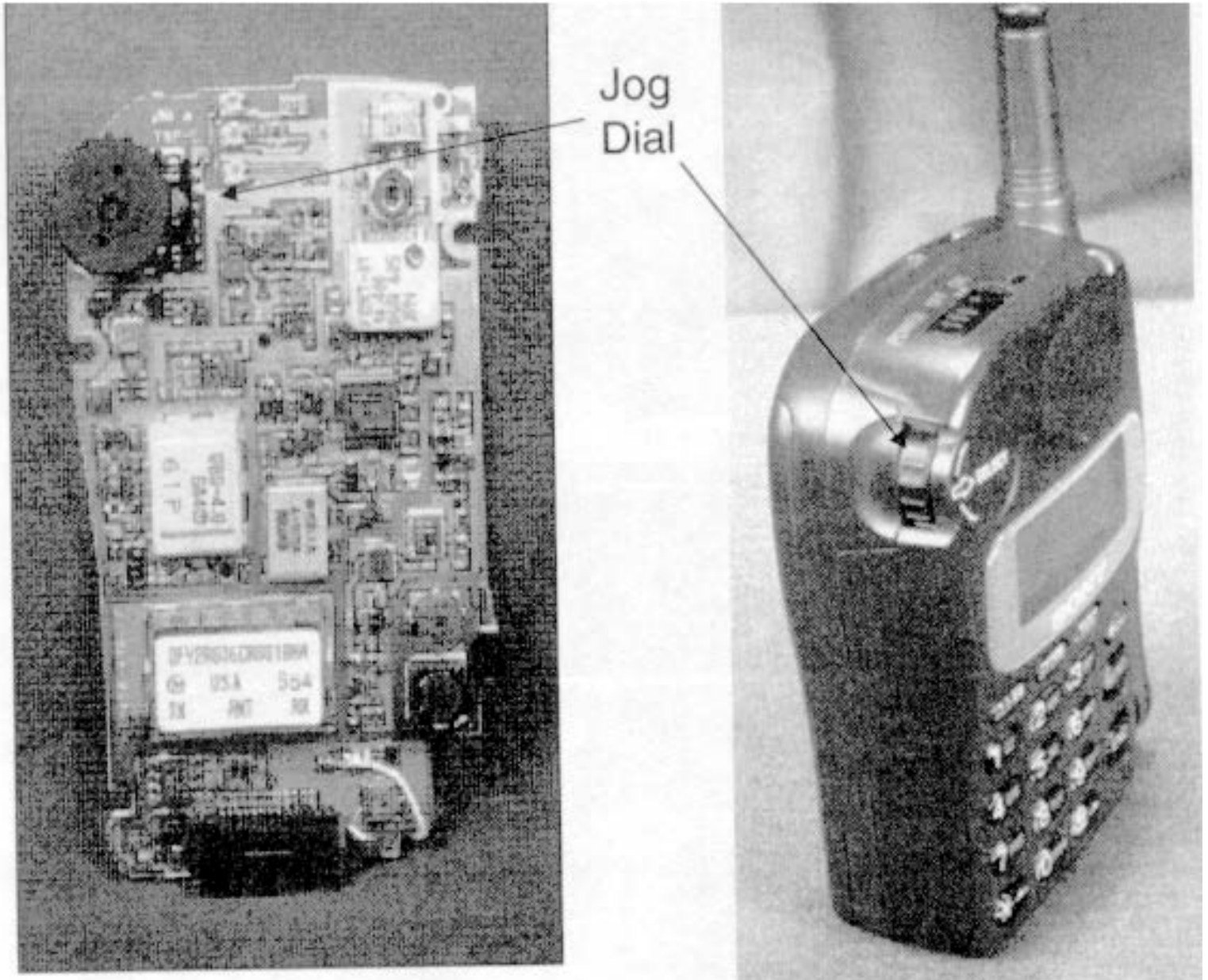


Figure 3.35 Jog dial.

SEE SEPARATE THEMATIC PRESENTATION COMPONENTS.PPT FOR A DETAILED DISCUSSION

CHAPTER 4

DISPLAYS

TOPICS FOR DISCUSSION:

- TECHNOLOGY OVERVIEW
- LCD
- OTHER DISPLAYS
- MICRODISPLAYS
- PEN INPUT
- DEFINITIONS

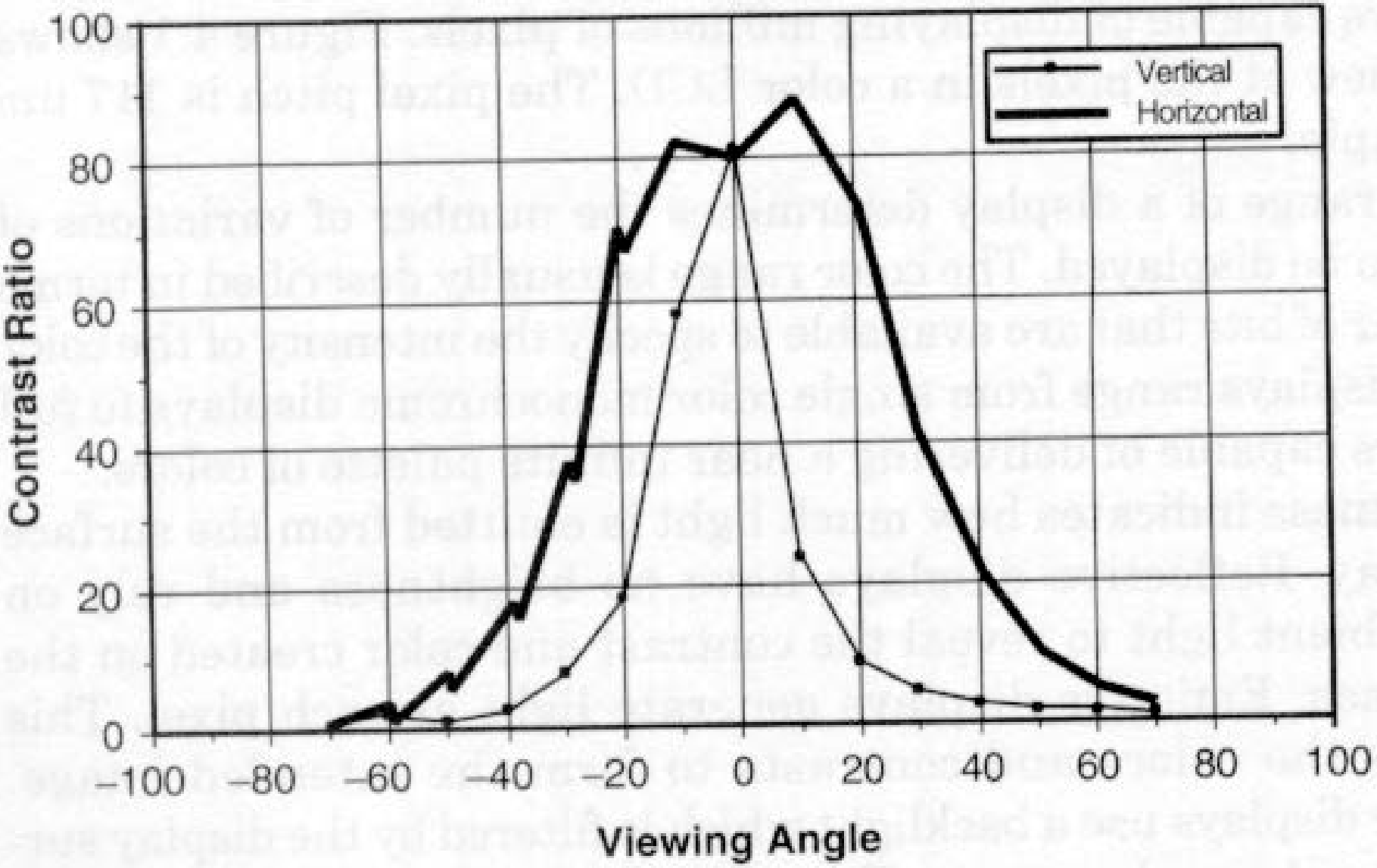


Figure 4.2 Contrast ratio vs. viewing angle.

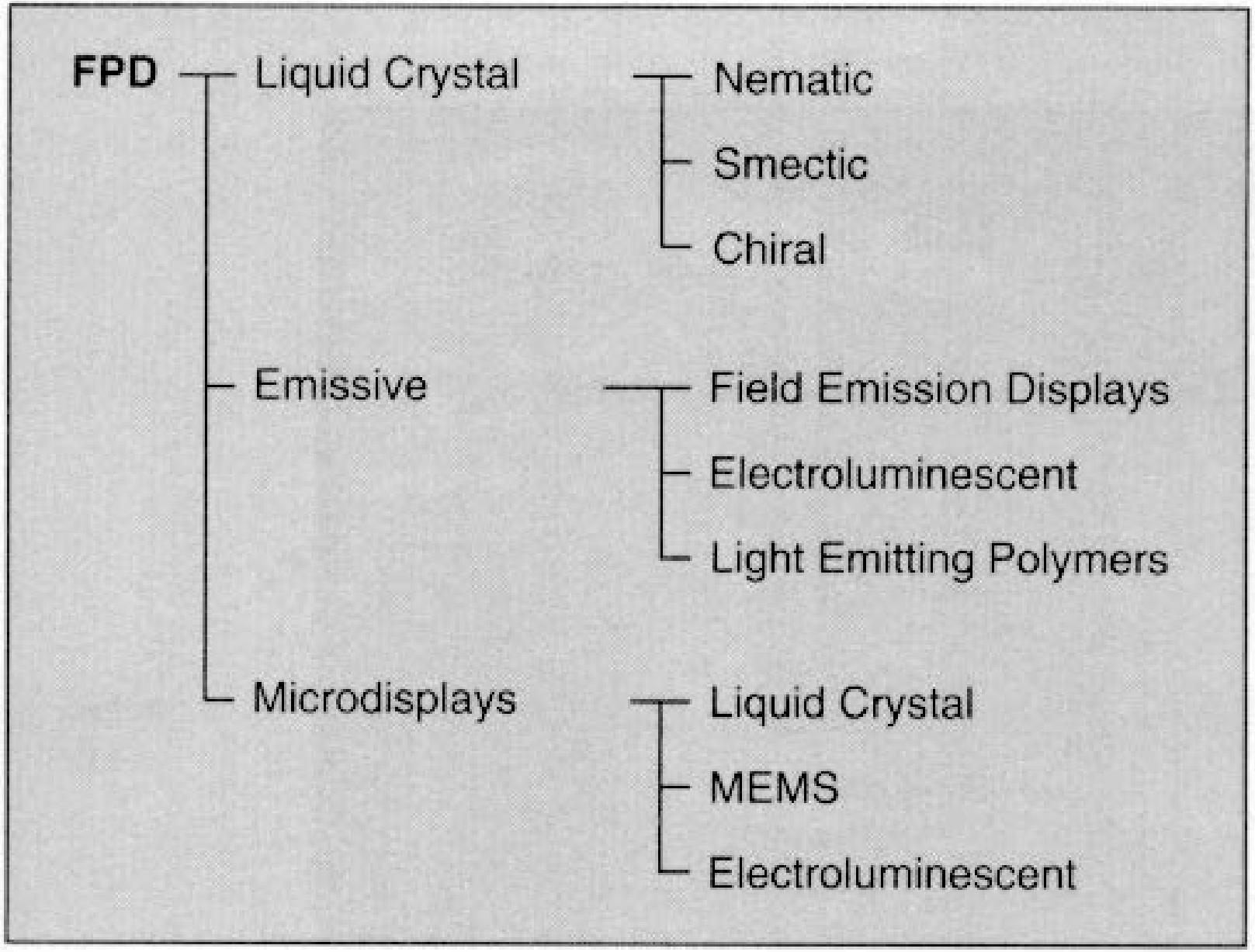


Figure 4.3 Major types of FPD.

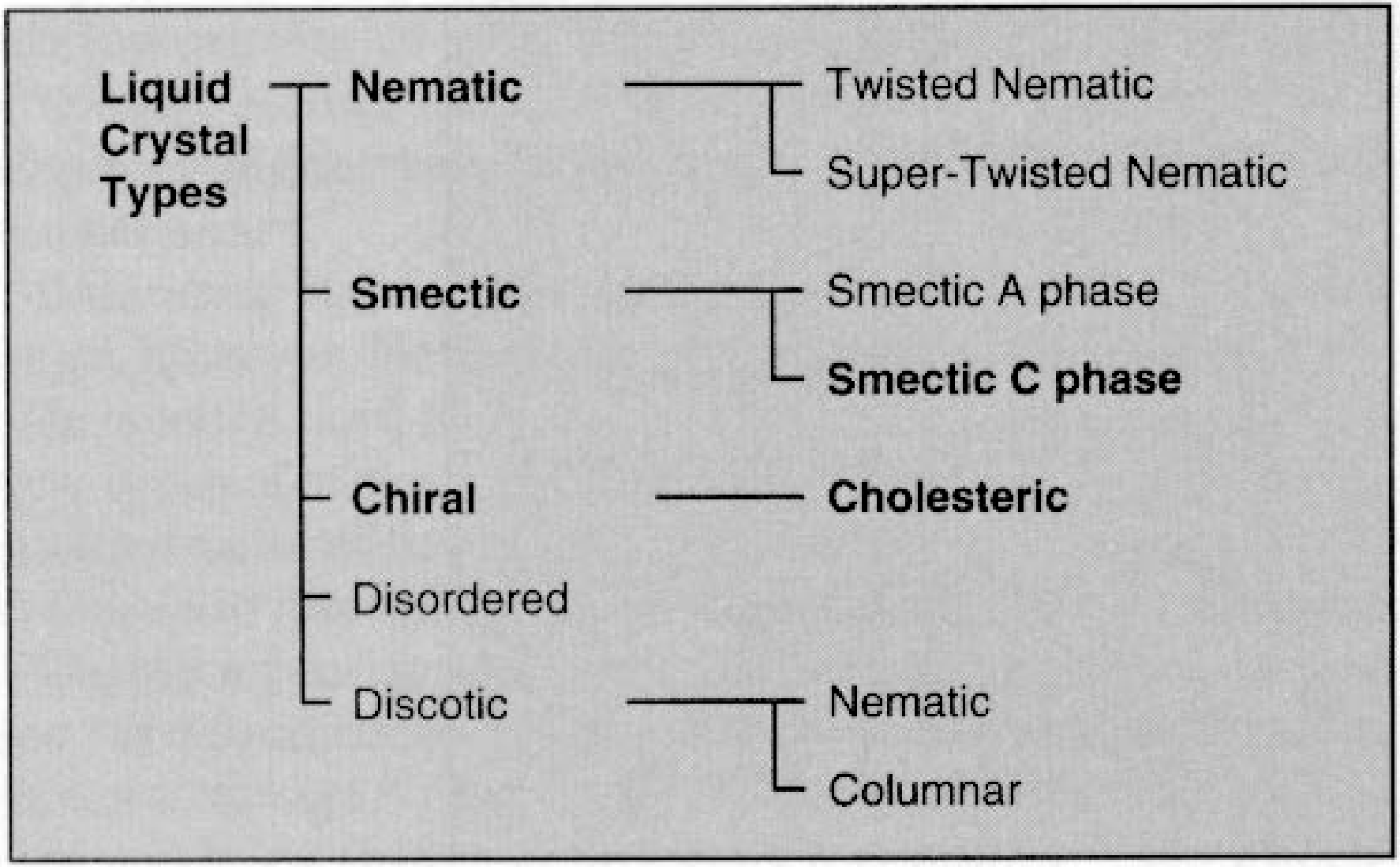


Figure 4.4 Liquid crystal types.

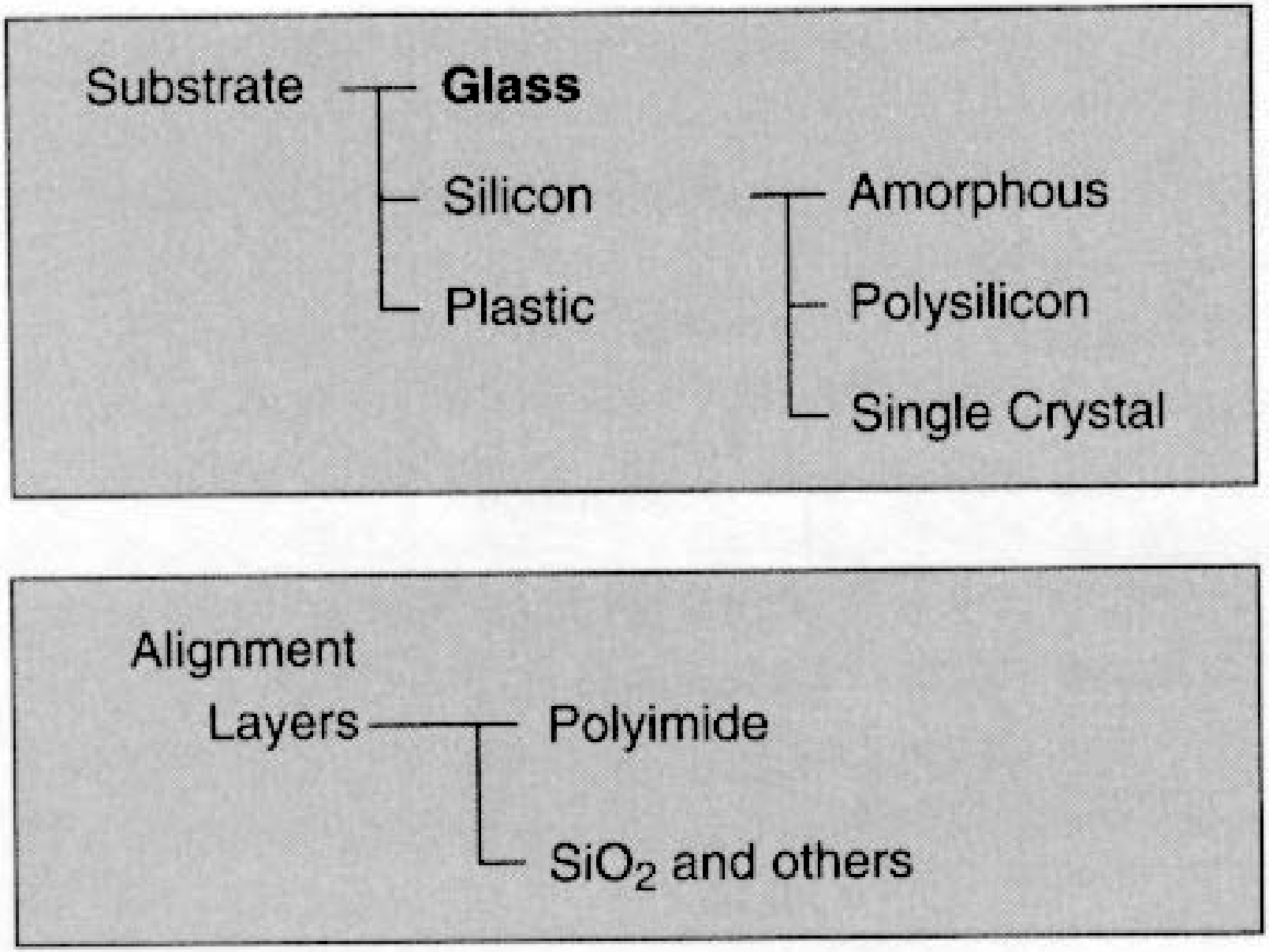


Figure 4.8 LCD substrate materials.

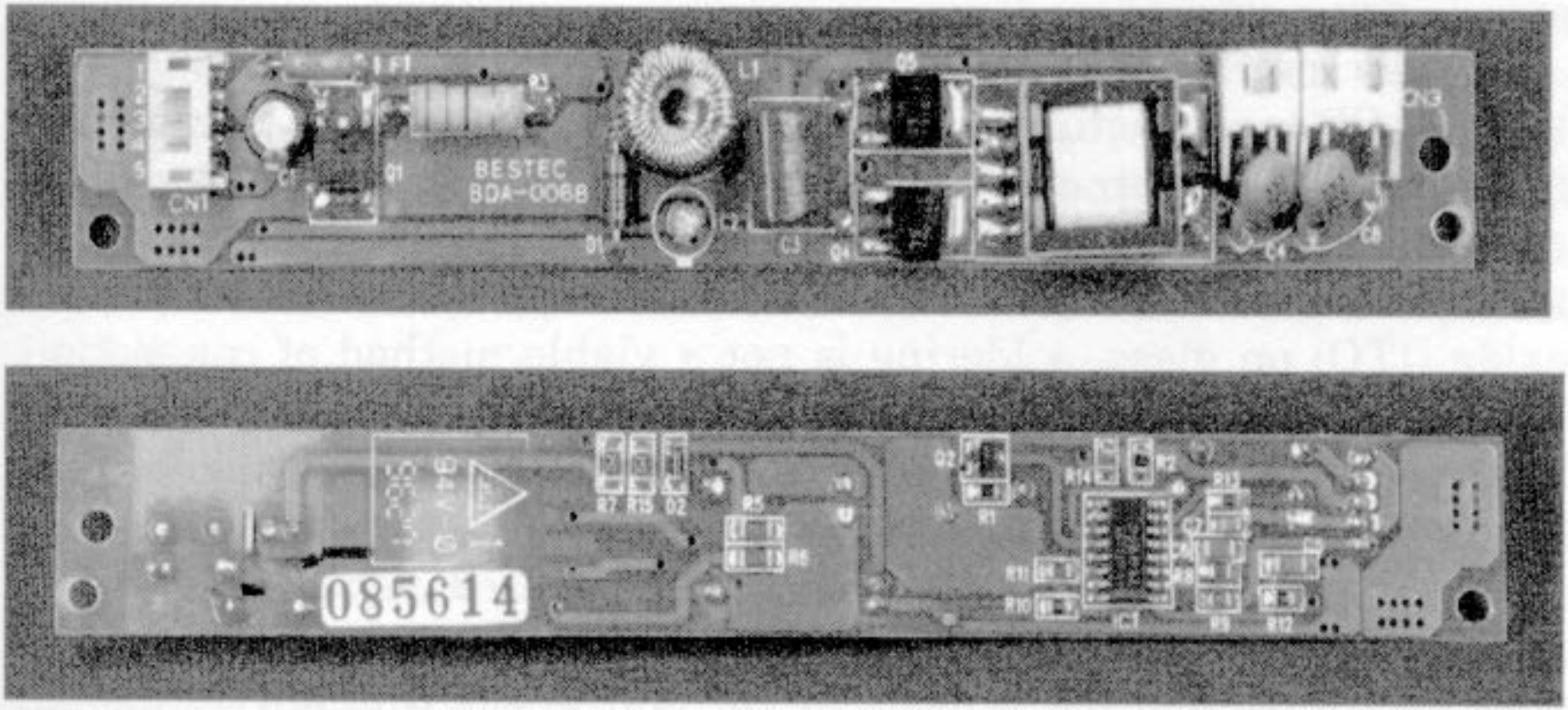


Figure 4.9 Backlight inverter board.

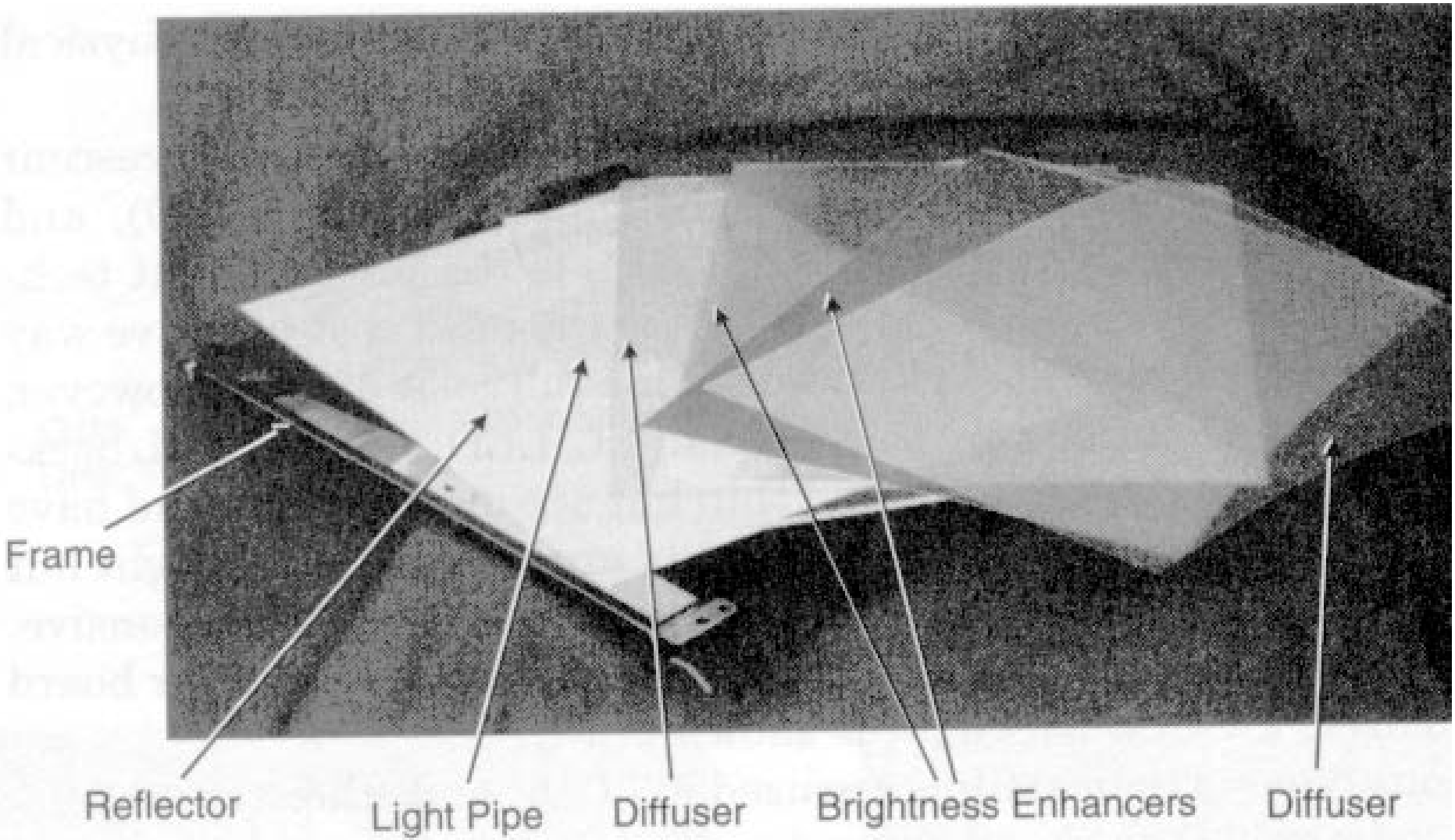


Figure 4.10 Optical films.

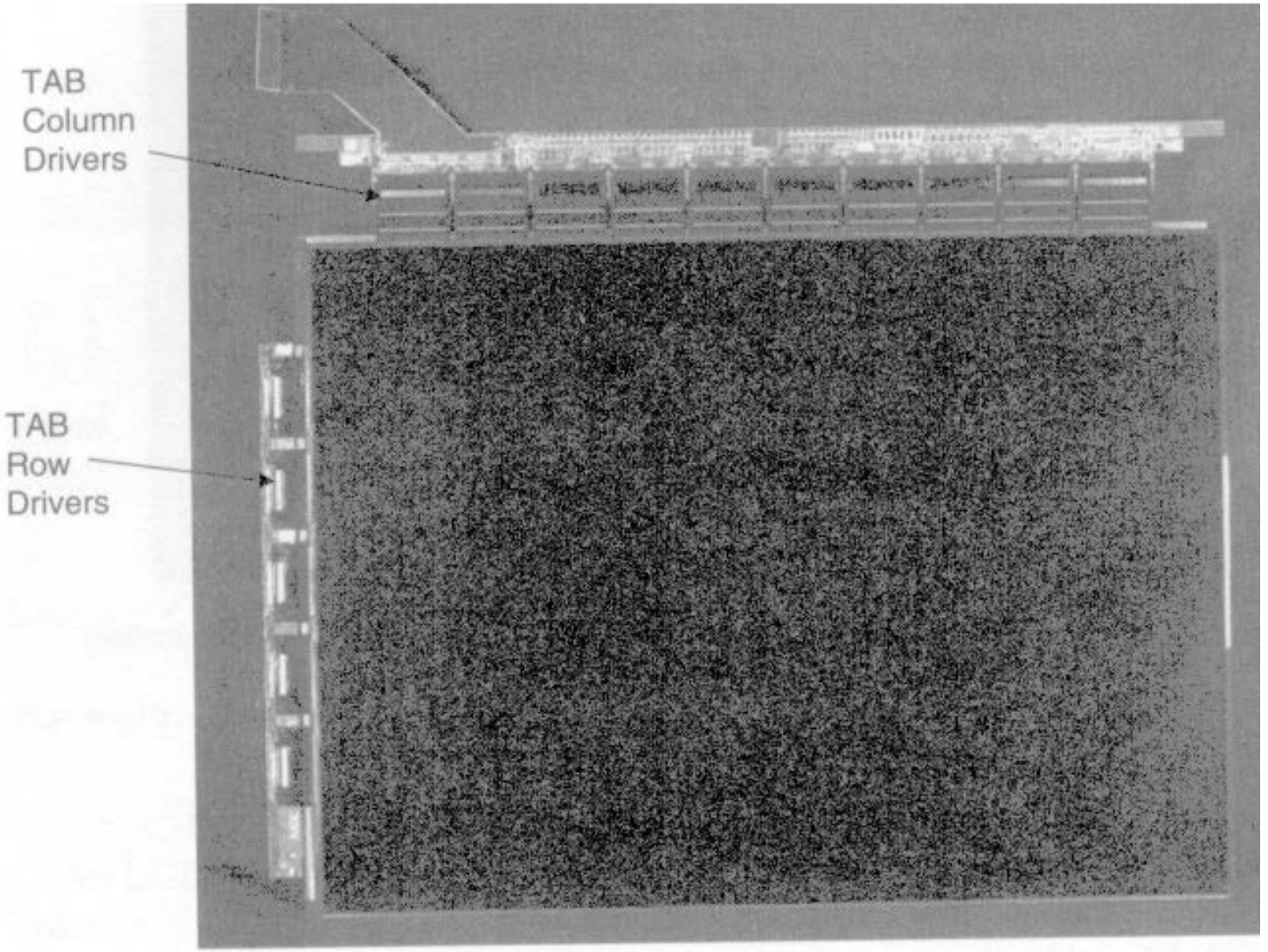


Figure 4.12 TAB-based notebook display module.

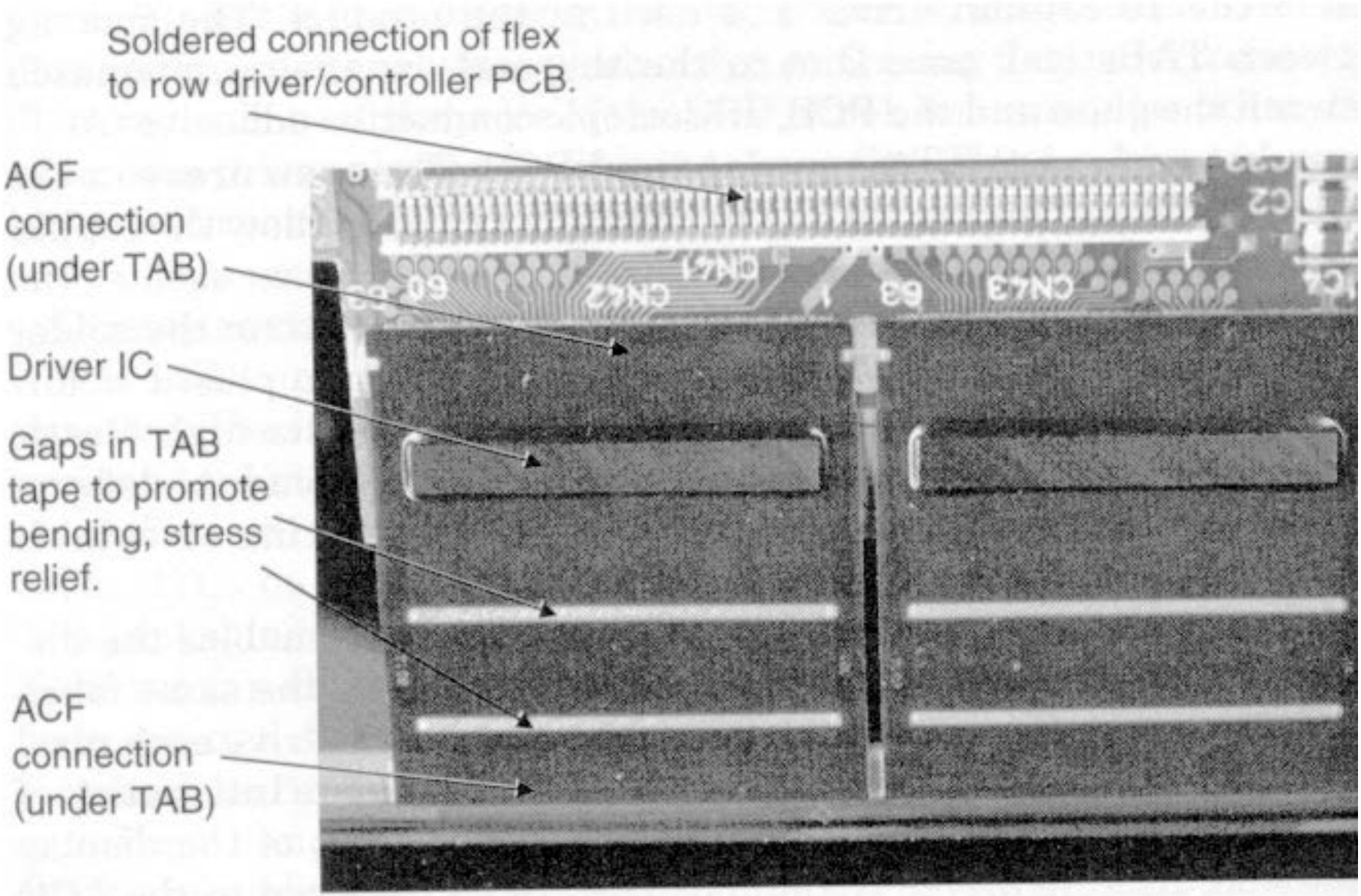


Figure 4.13 TAB driver close-up.

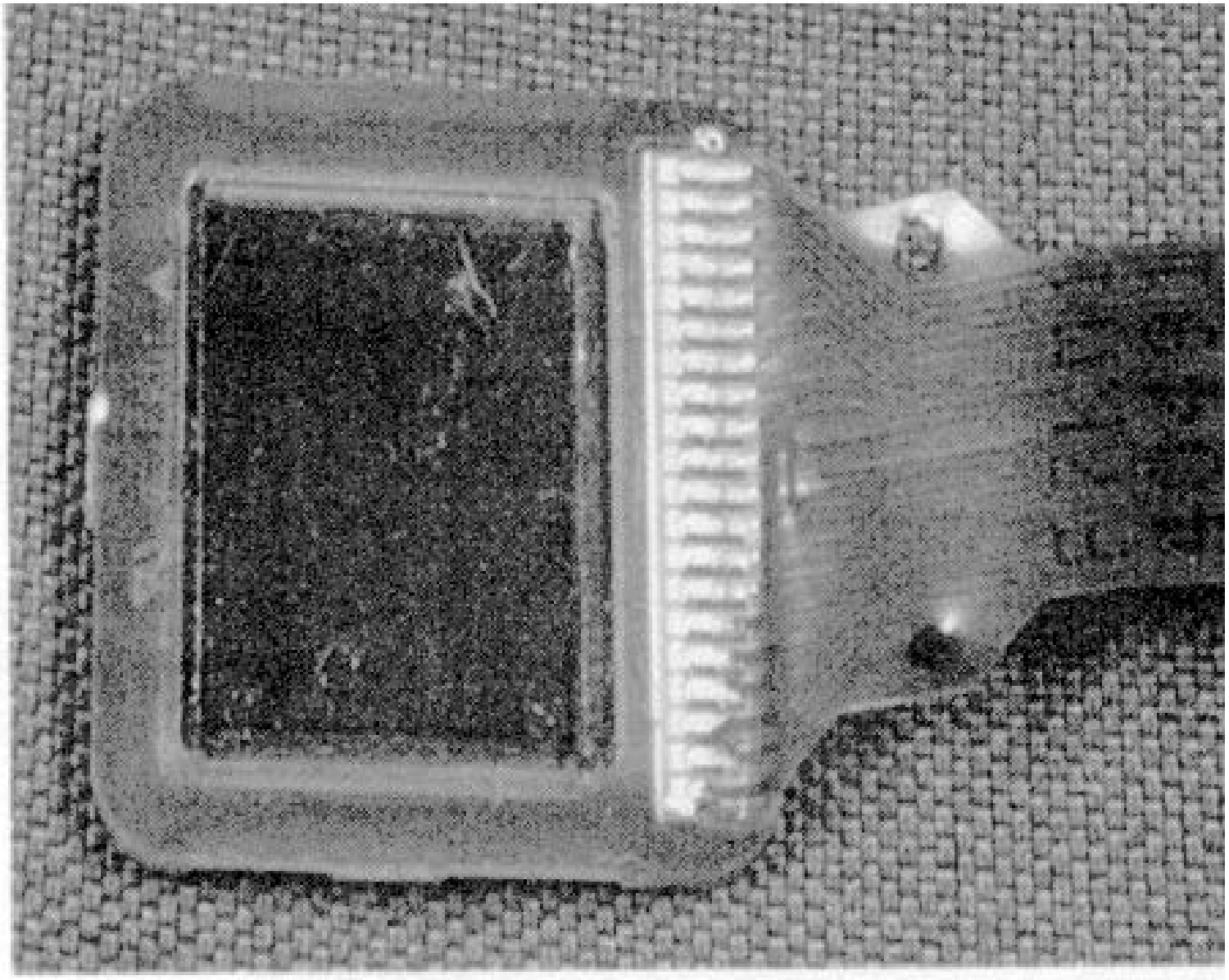


Figure 4.14 Polysilicon LCD microdisplay—viewfinder.

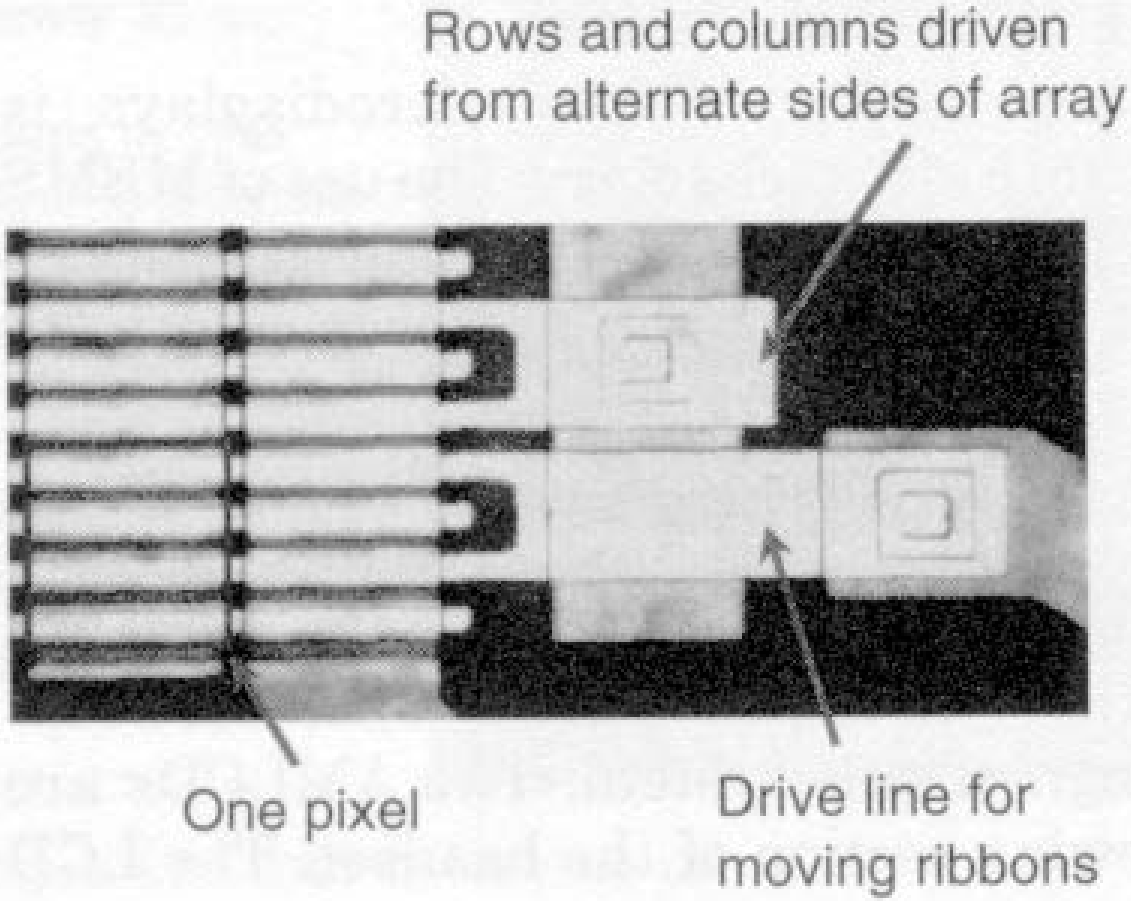


Figure 4.15 MEMS display.

Figure 4.16 Head-mounted display system.

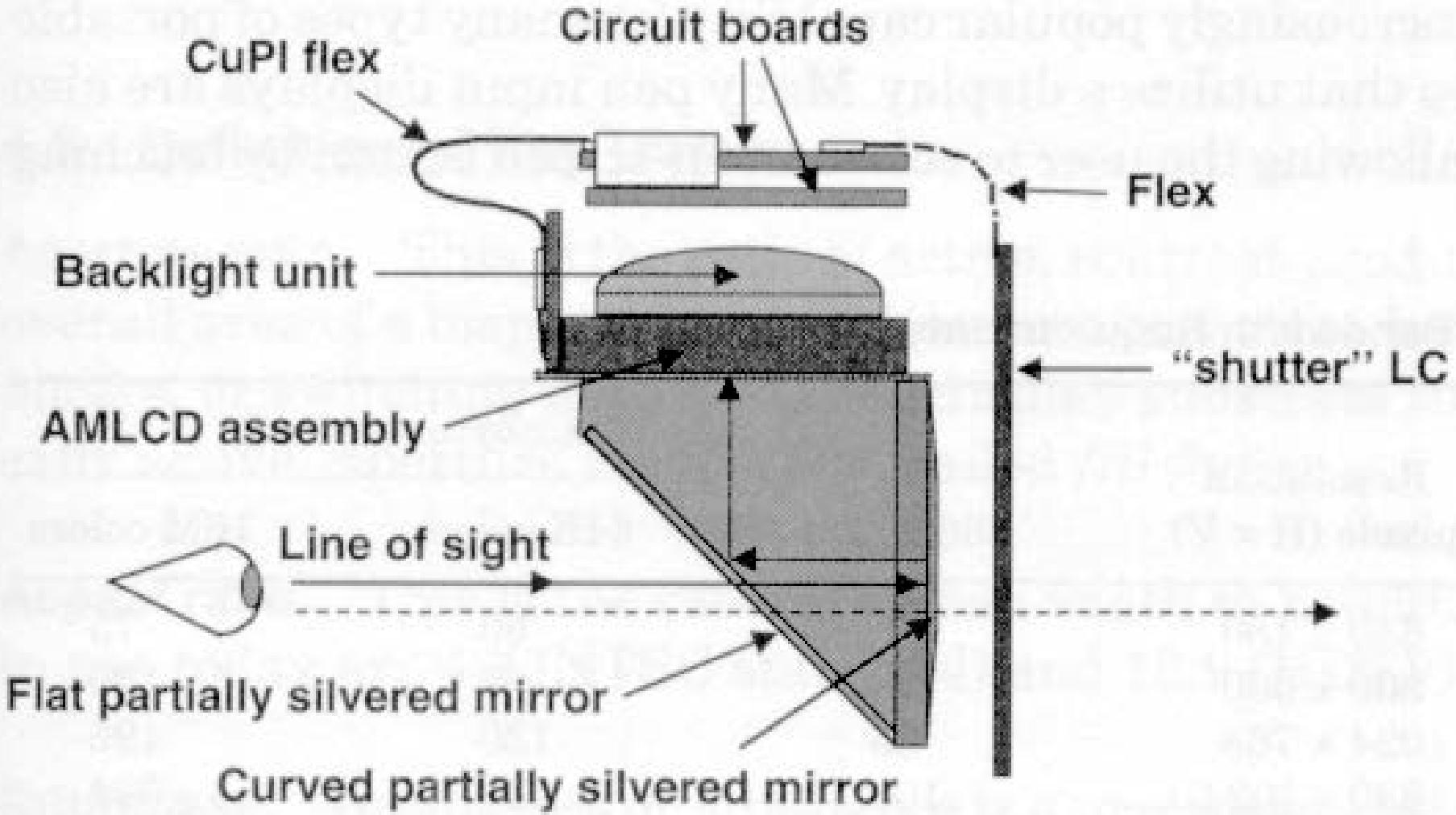


Figure 4.17 Sony Glasstron PLM-50.

TABLE 4.1 Display Technology Comparisons

	LC						
	TN	DSTN	TFT	EL	Plasma	OLED	FED
Matrix	Passive	Passive	Active	Passive	Passive	Passive	Passive
Resolution	80°	10°	140°	160°	160°	160°	160°
Contrast ratio	Poor	Better	Best	Best	Best	Poor	Best
Brightness	n/a	n/a	n/a	Good	Best	Fair	Best
Viewing angle	Poor	Poor	Better	Best	Best	Best	Best
Switching speed	Slow	2x TN	Fast	Very	Very	Fast	Very fast
Linearity	Good	Better	Fair	Best	Best	Too early	Best
Refresh	Slow	2x TN	Fast	Fast	Medium	Fast	Medium
Drive voltage	Low	Low	Medium	High	Very high	Medium	Very high
Temperature range	OK	OK	Better	Best	Best	Too early	Best
Lifetime	Long	Long	Long	Long	Long	Too early	Medium
Maturity	Very	Very	Very	Very	New	Evelopmen	New

TABLE 4.2 Display Bandwidth Requirements

Graphics std. acronym	Resolution pixels (H × V)	Bandwidth(mbytes/second)		
		256 colors	64K colors	16M colors
VGA	640 × 480	25	50	75
SVGA	800 × 600	40	80	120
XGA	1024 × 768	65	130	195
SXGA	1280 × 1024	108	216	324
UXGA	1600 × 1200	162	324	486

Source	Temperature (K)
Sky (north)	7,500
Daylight (average)	6,500
Carbon arc	5,000
Flash bulb	3,780
Fluorescent lamp	3,500
Tungsten halogen	3,300
Tungsten lamp	2,900
Sunset light	2,000
Candle flame	1,900

Item:	Contrast
CRT next to window	200:1
Newspaper	50:1
Photocopy	500:1

Item	Illuminance (lux)
Bright Sun	50,000–100,000
Hazy Sun	25,000–50,000
Cloudy, bright	10,000–25,000
Cloudy, dull	100–2,000
Office	200–300
Living room	50–200
Sunset	1–100
Full moon	0.01–0.1
Star light	10^{-4}–10^{-3}

HUMAN VISION CAPABILITIES

- DYNAMIC RANGE 1 LX TO 100 KLX
- LINEAR RANGE 100 TO 1000 LX
- F MAX 30 TO 60 Hz
- ADAPTATION TIME UP TO 20 MINUTES
- STRONG AFTERGLOW
- 100 TO 4000 COLORS, 10 TO 100 SATURATION LEVELS
- COLORS IN USE FROM 100 TO 10 KLX
- FOOLED BY SURROUNDING COLORS
- ANGULAR RESOLUTION 0.3 MRAD

VISION PECULARITIES:

- DIFFERENCES IN SEEING PRINTED OR SCREEN IMAGES
- CONNECTION TO READING
- CONNECTION TO BODY BALANCE AND STABILIZATION
- CORRECTION OF PERSPECTIVE
- ERRORS IN FOCAL AND COLOR CHARACTERISTICS

SELECT IN DISPLAY DESIGN:

- PROPER TECHNOLOGY
- GEOMETRY (CIRCULAR, RECTANGULAR, SQUARE)
- PLANE GEOMETRY (CONVEX, CONCAVE, PLANAR)
- FONTS
- ATTRIBUTES (BLINKING ETC.)
- SCALE LINES, SIZES
- GRAPHIC SYMBOLS, COLORS

CHAPTER 5

POWER

TOPICS FOR DISCUSSION:

- BATTERIES
- Ni-Cd
- ALKALINE
- Ni-MH
- LITHIUM ION
- LITHIUM POLYMER
- PHOTOCELLS
- FUEL CELLS
- IMPLEMENTATION
- HIGH LEVEL POWER ANALYSIS

WHAT'S THE PROBLEM THEN ?

- LESS WEIGHT
- MORE ENERGY
- SHORTER RECHARGE TIMES
- LONGER STORAGE TIMES
- LONGER LIFE IN USE
- ALL SIMULTANEOUSLY !

PARTICULARLY IN RF DEVICES:

- SPECTRUM - A NATURAL RESOURCE
- TIGHT SPECTRUM LIMITATIONS
- HIGH SIGNAL CHAIN LINEARITY
- LOW EFFICIENCY
- HIGH POWER CONSUMTION
- HIGH TEMPERATURES

TABLE 5.1 Critical Metrics for Battery Technology

	Ni-Cd	Ni-MH	Li-ion	Li-polymer
Working voltage (V)	1.2	1.2	3.6	3
Energy density (Wh/L)	120	240	260	264
Energy density (Wh/kg)	50	60	115	250
Cycle life	300–800	300–800	1200	1200
Memory effect	Yes	Yes	No	No
Cost ($/Wh)	1	1.3	2.5	2

AN EXAMPLE : MINIDISC

- ITS SO COOL TO HAVE SOMETHING NEW AND EVEN COOLER IF IT IS MINIDISC...
- BETTER SOUND REPRODUCTION THAN CASETTE OR MP3, SMALLER SIZE THAN CD
- SPECIAL DATA FORMAT TO REDUCE FILE SIZE (ATRAC 4.5)
- TRULY PORTABLE
- ALSO HOME AND CAR VERSIONS, BUT MINIMAL SUCCESS THERE
- NOISY MECHANICS WHILE LOADING NEW DATA TO PLAY
- VERY LIMITED AVAILABILITY OF MD RELEASES

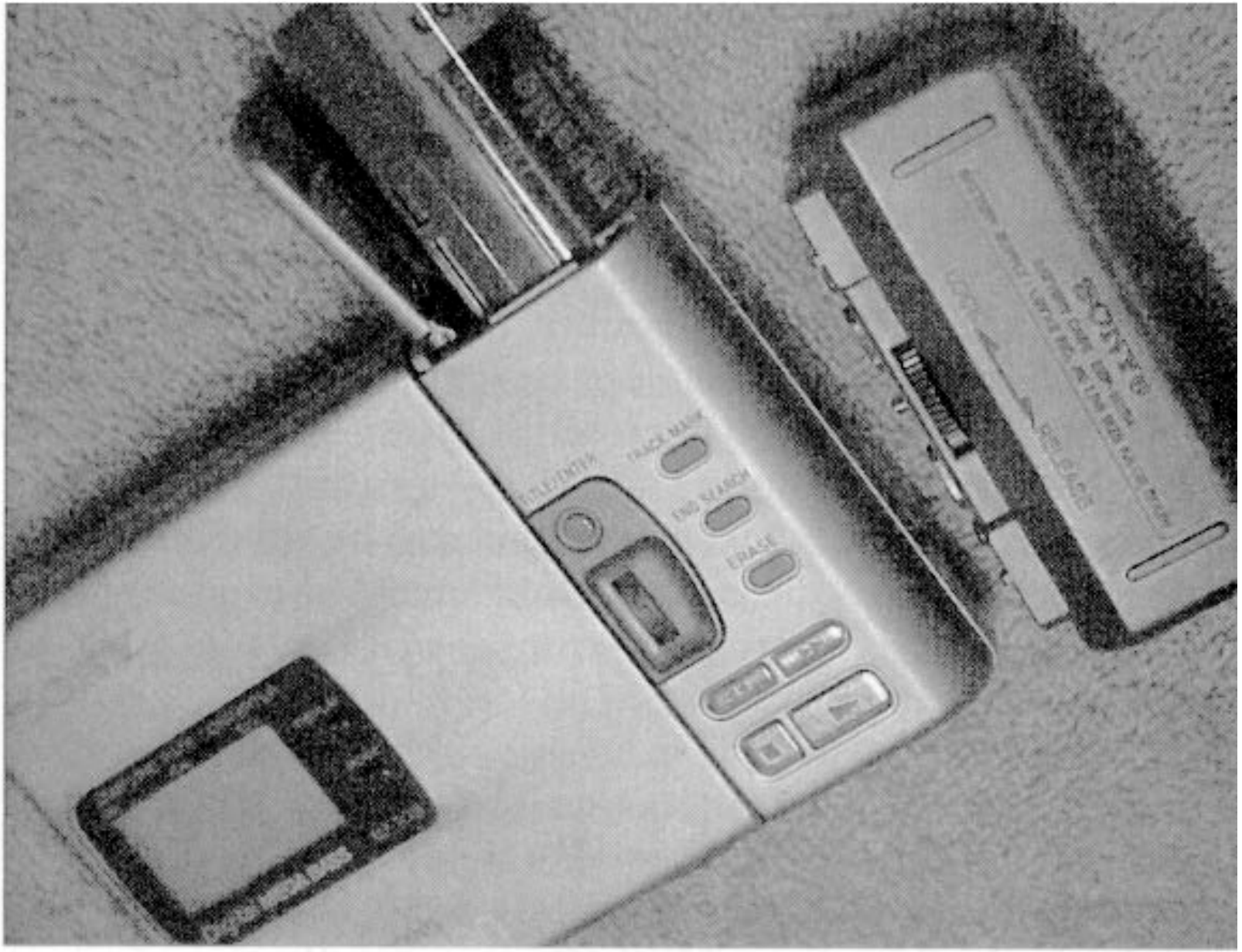


Figure 5.1 Mini-disc music player with attachable AA battery pack.

TYPICAL BATTERY COMPARTMENT PROBLEMS

- BAD CONTACT DUE TO SPRINGS
- BAD CONTACT DUE TO OXIDES
- BAD CONTACT DUE TO TOLERANCES
- BAD CONTACT DUE TO DIRT
- BAD CONTACT DUE TO OTHER REASONS
- INSERTION/REMOVAL PROBLEMS
- SHORT CIRCUITS DUE TO SPRINGS
- SHORT CIRCUITS DUE TO OXIDES
- SHORT CIRCUITS DUE TO TOLREANCES
- SHORT CIRCUITS DUE TO FOREIGN MATERIAL
- SHORT CIRCUITS DUE TO OTHER REASONS

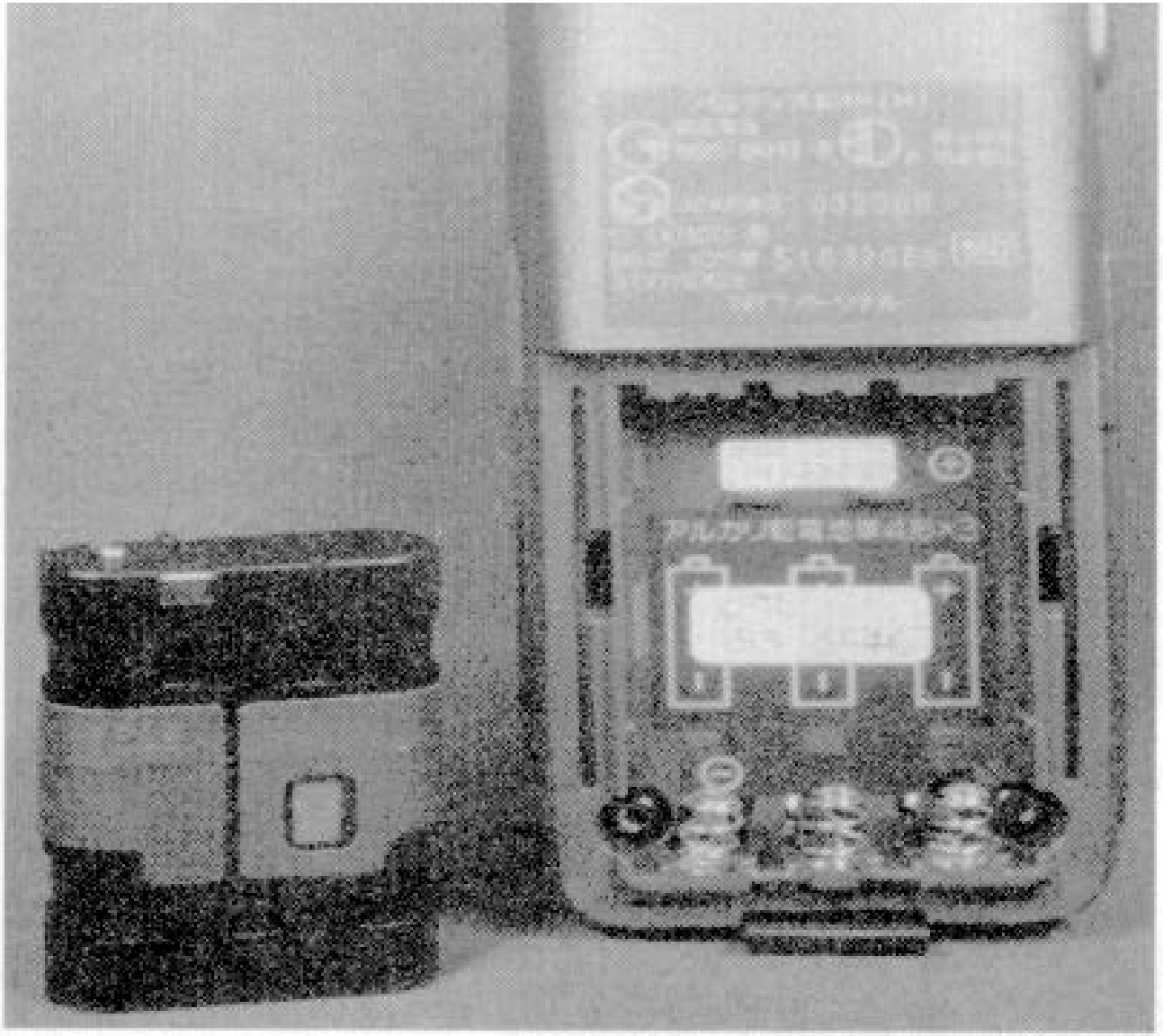


Figure 5.2 Cell phone battery pack interchangeable with AA cells.

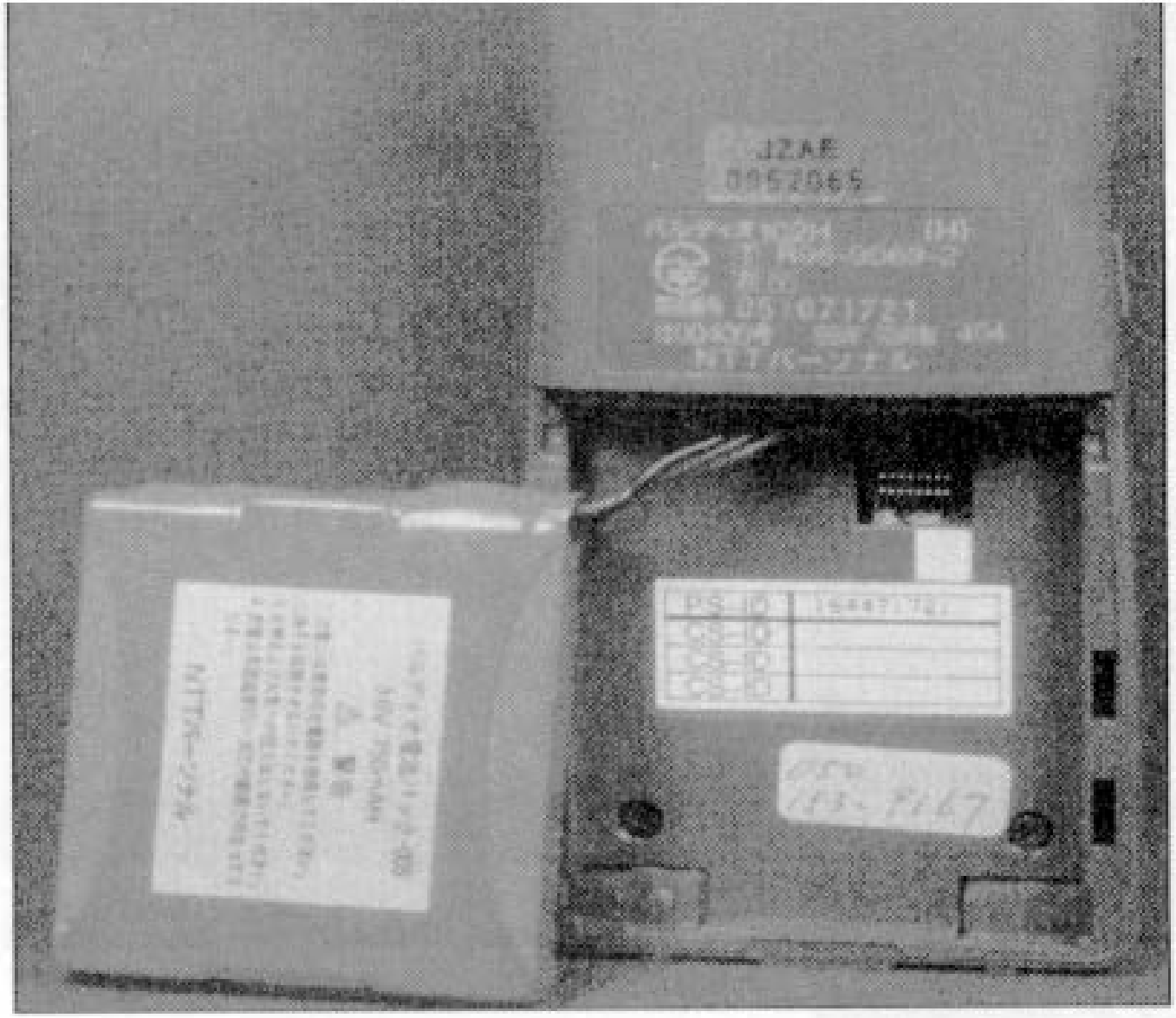


Figure 5.3 Cell phone battery with wired connection.

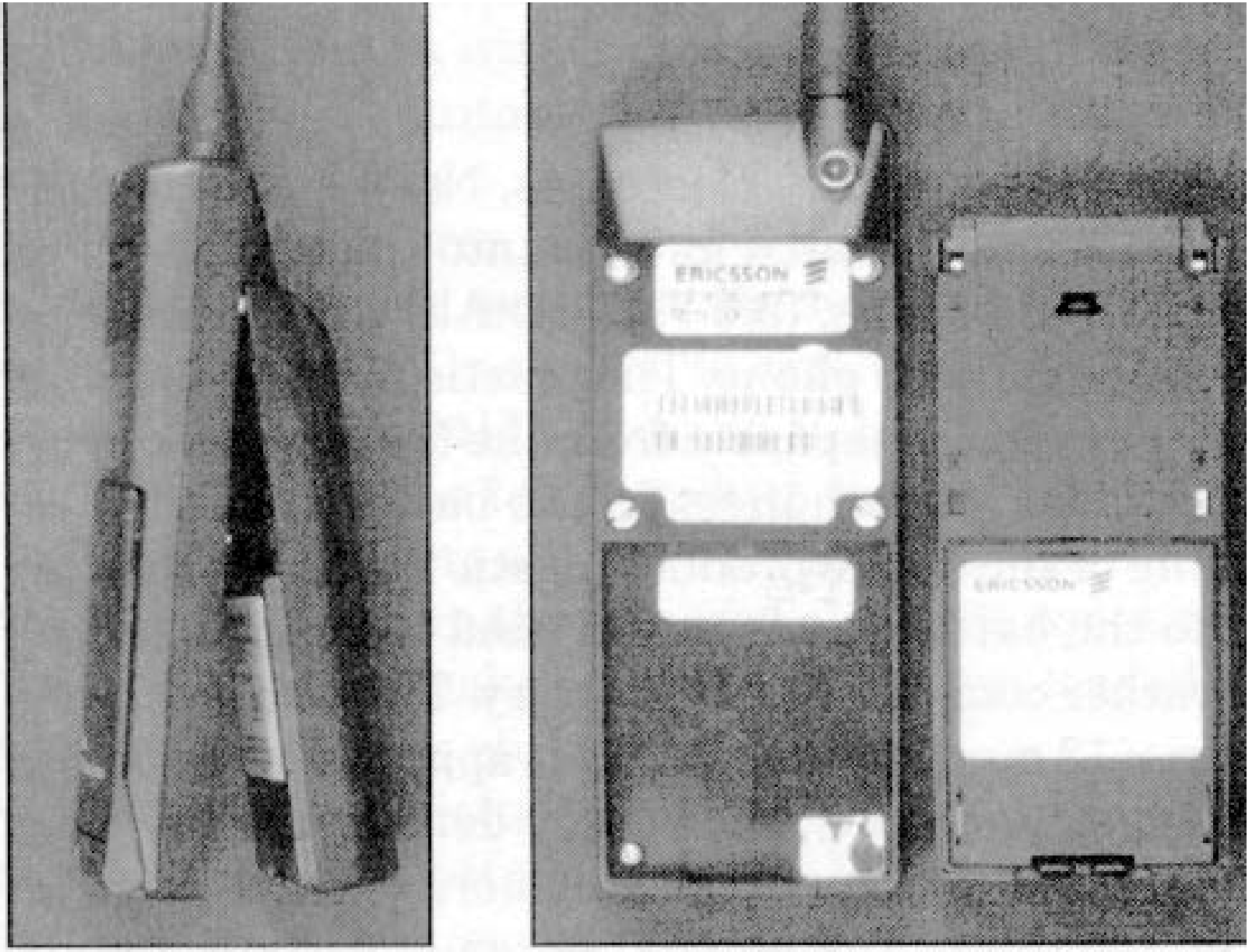
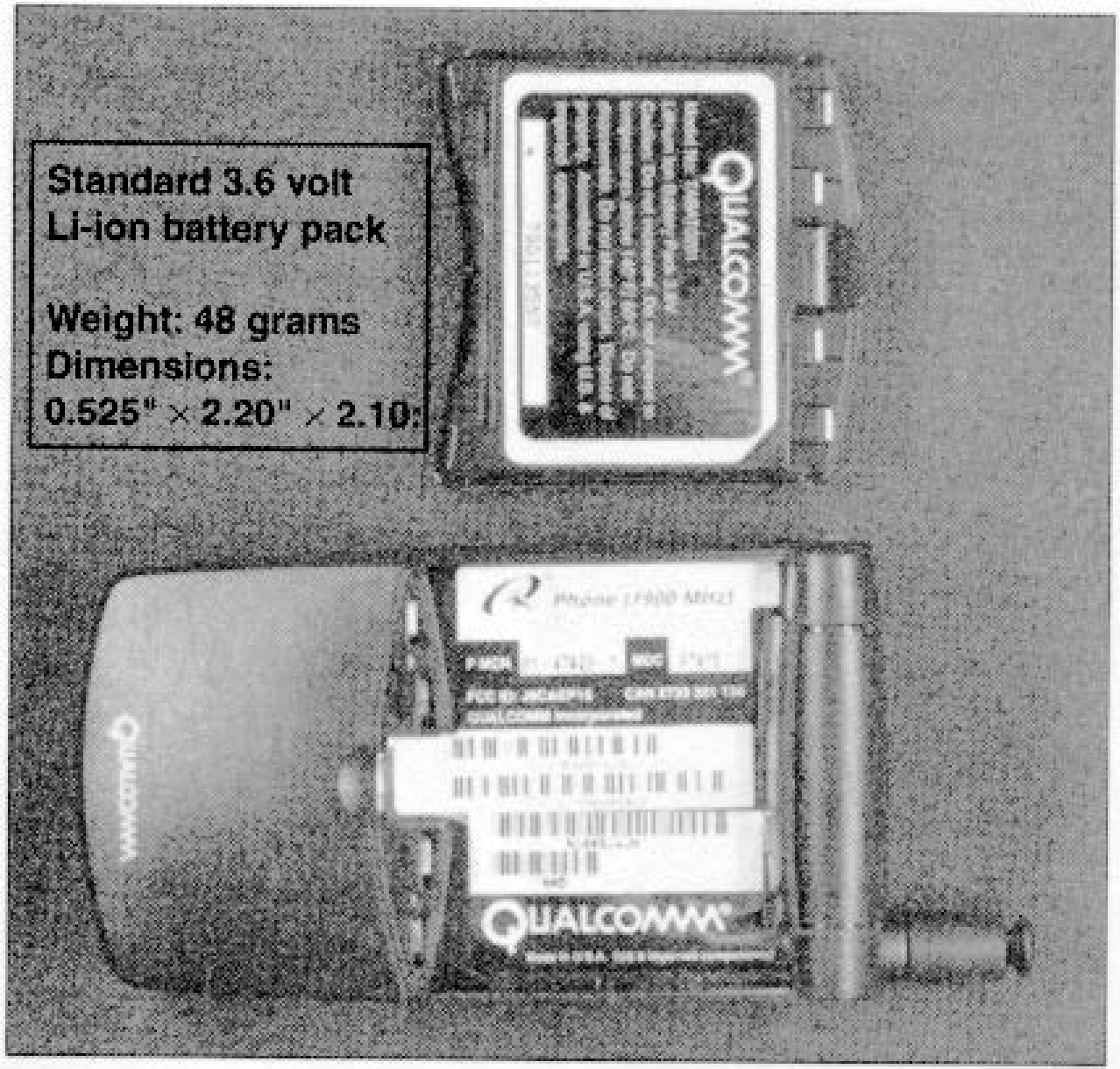


Figure 5.4 Large cell phone battery pack.



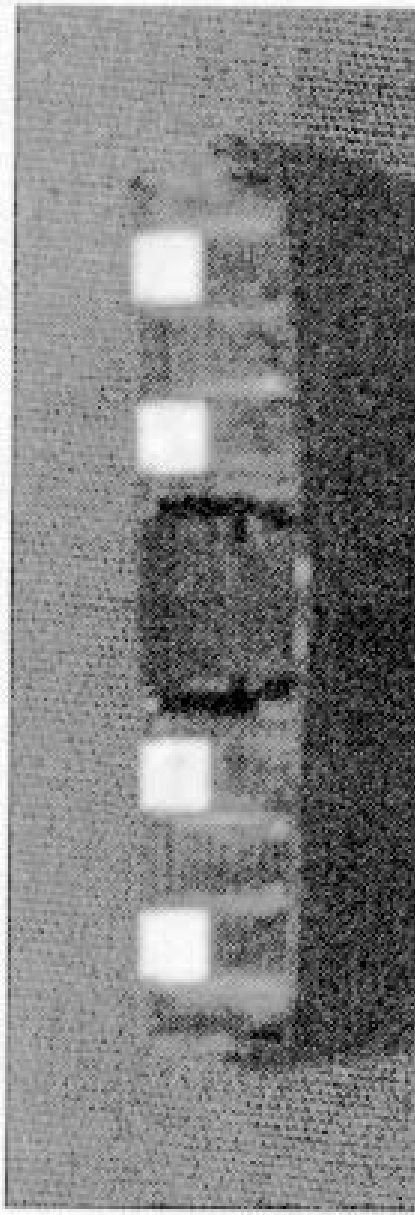
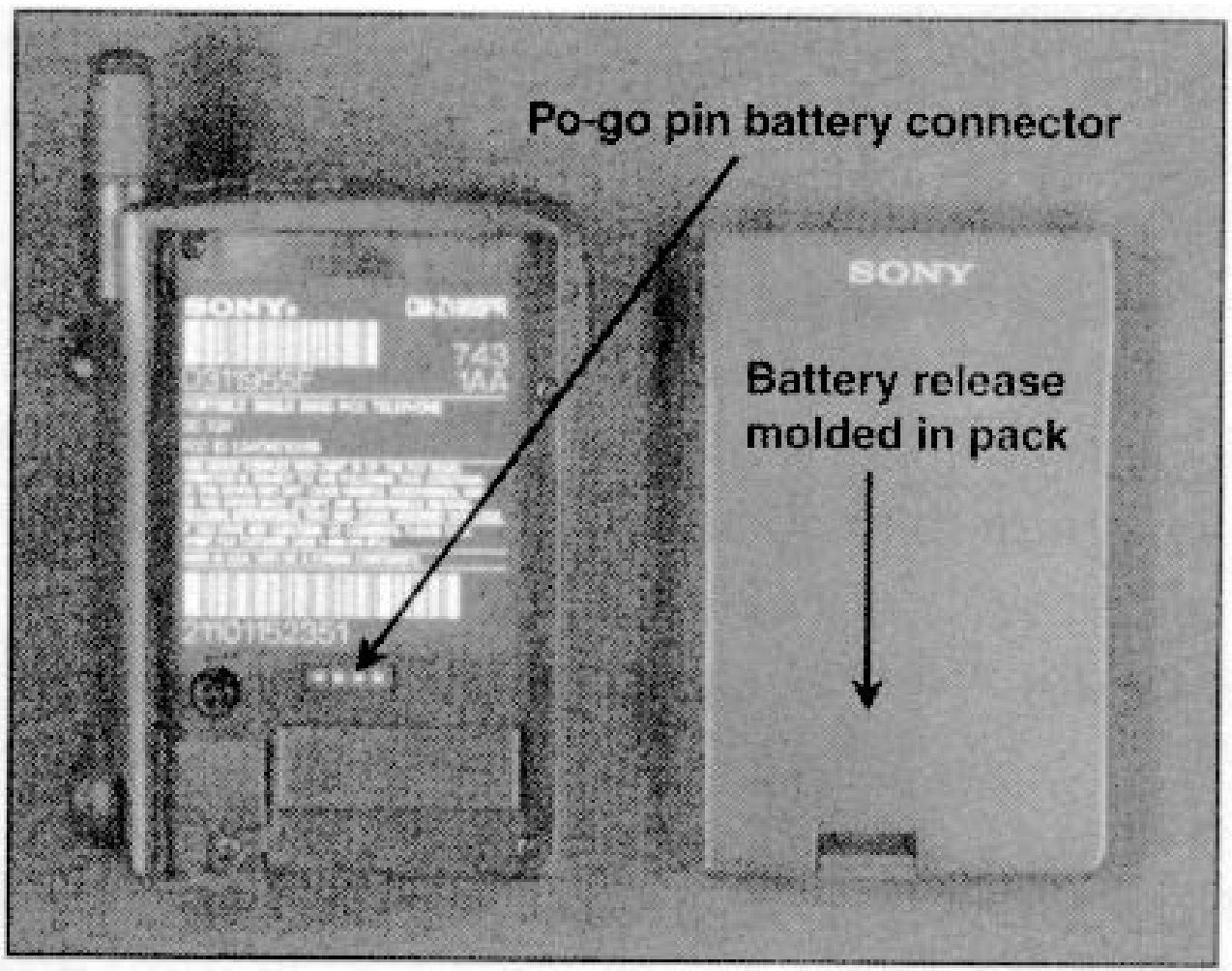


Figure 5.5 Flip phone style battery pack design.



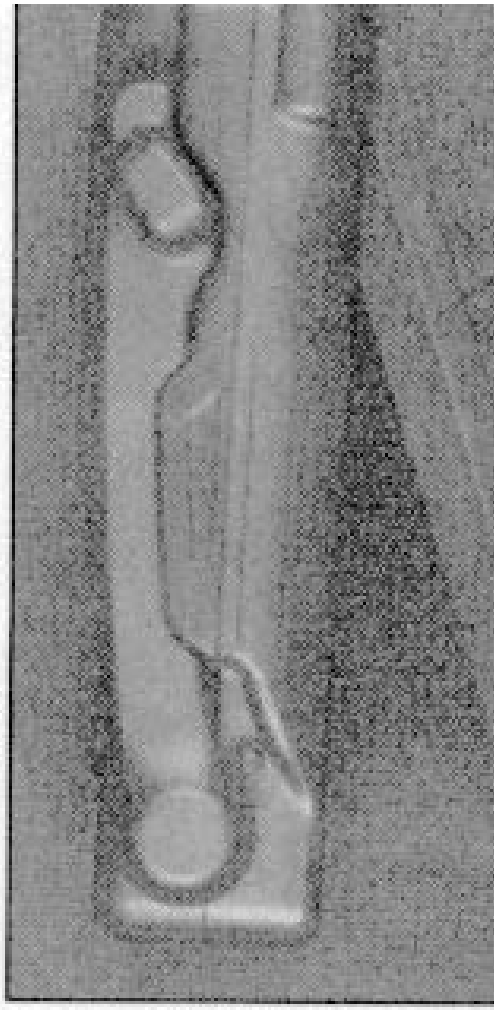


Figure 5.6 Compact lithium-ion battery pack.

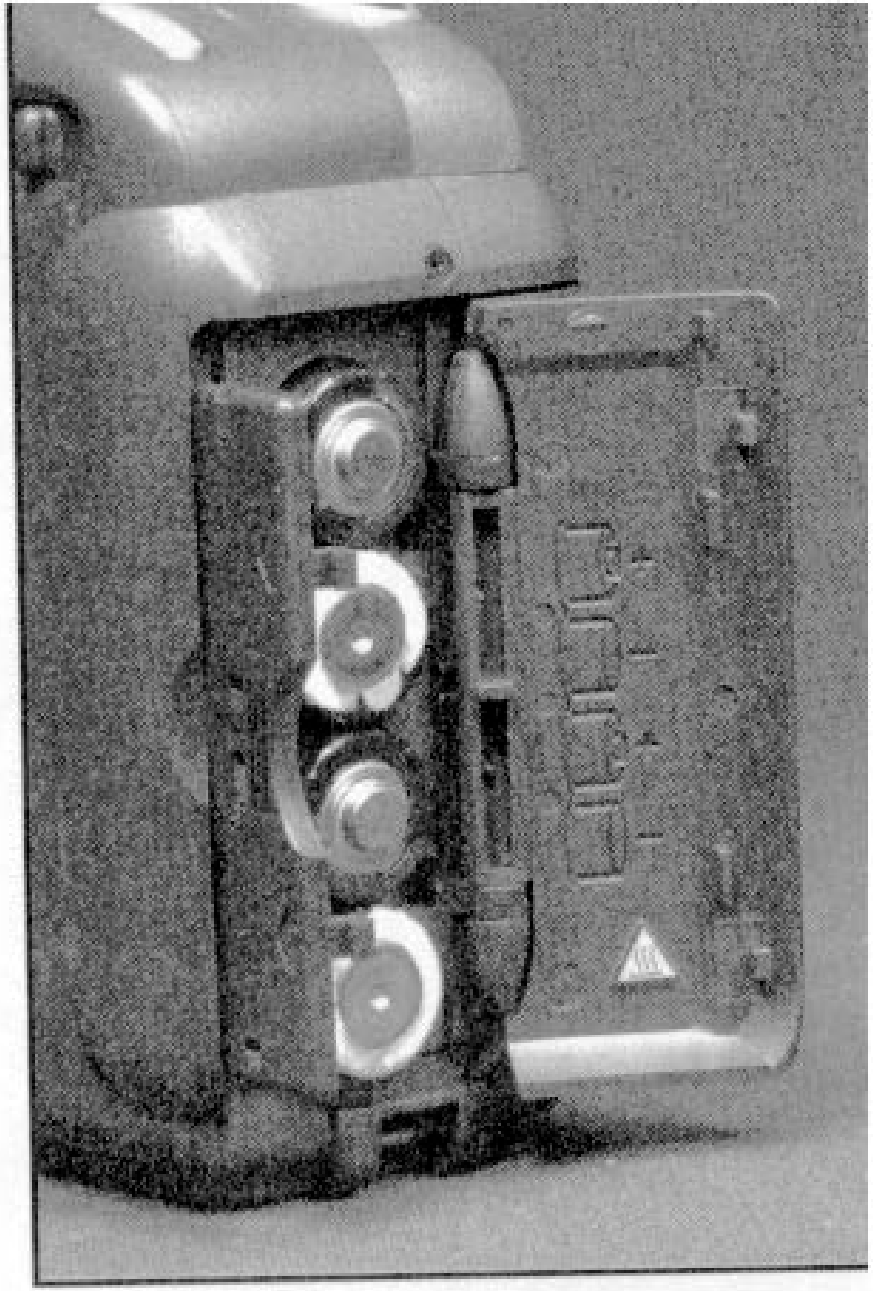


Figure 5.10 Digital camera using four AA cells.

ONLY A MATTER OF TASTE ?

- DRY CELLS
- RECHARGEABLE BATTERIES

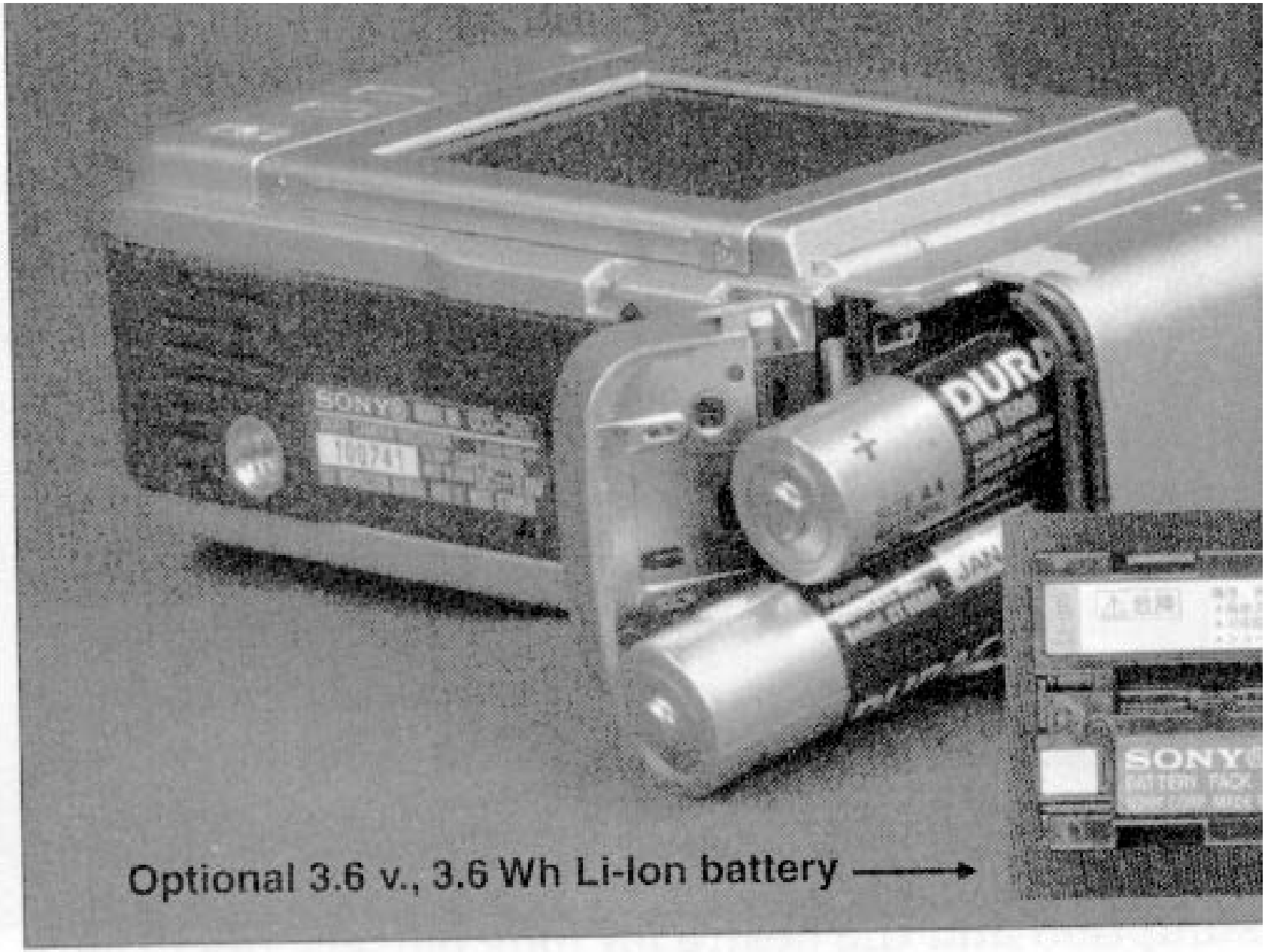


Figure 5.11 Digital camera using AA cells or lithium-ion cell.

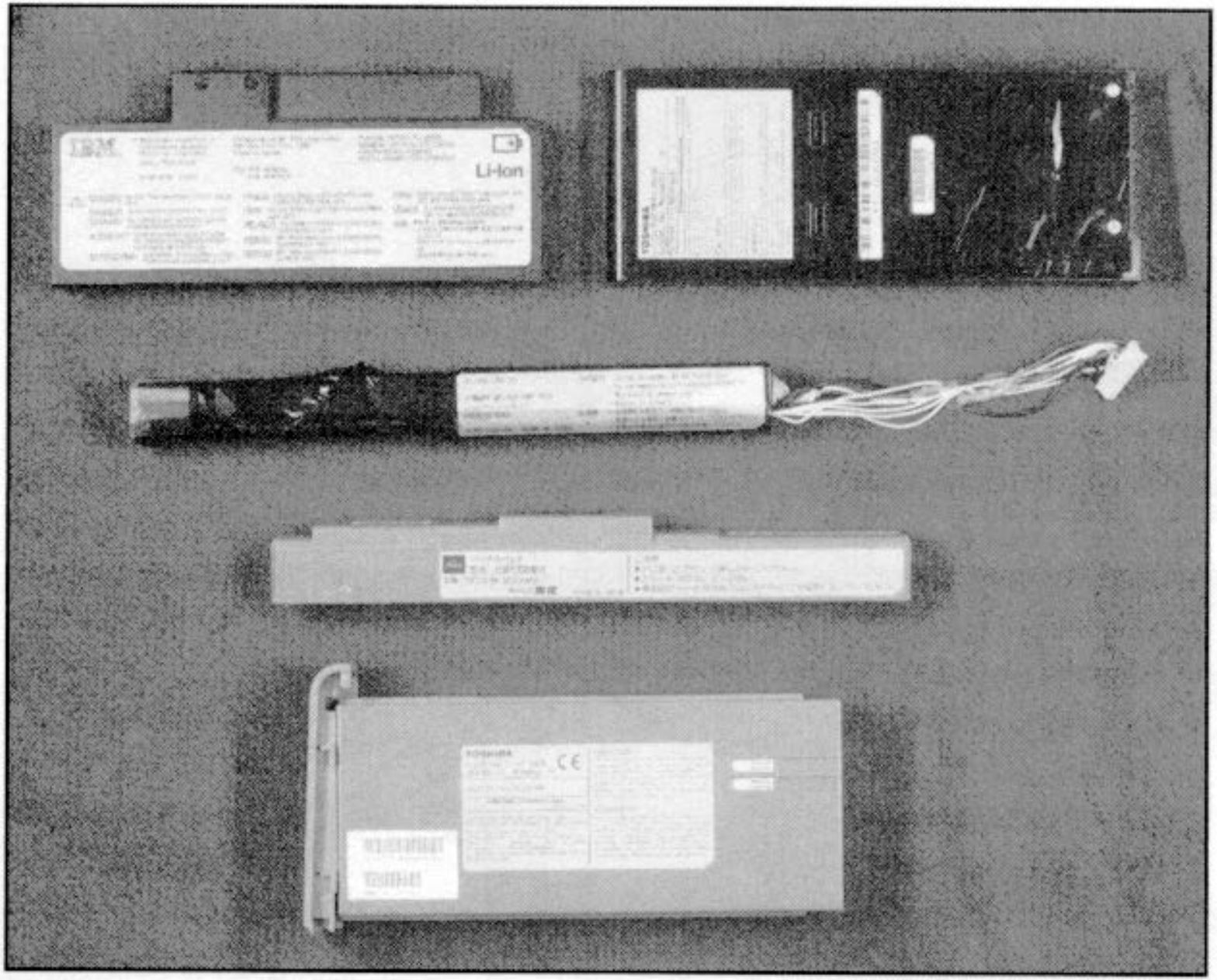


Figure 5.12 Assorted notebook computer battery packs.

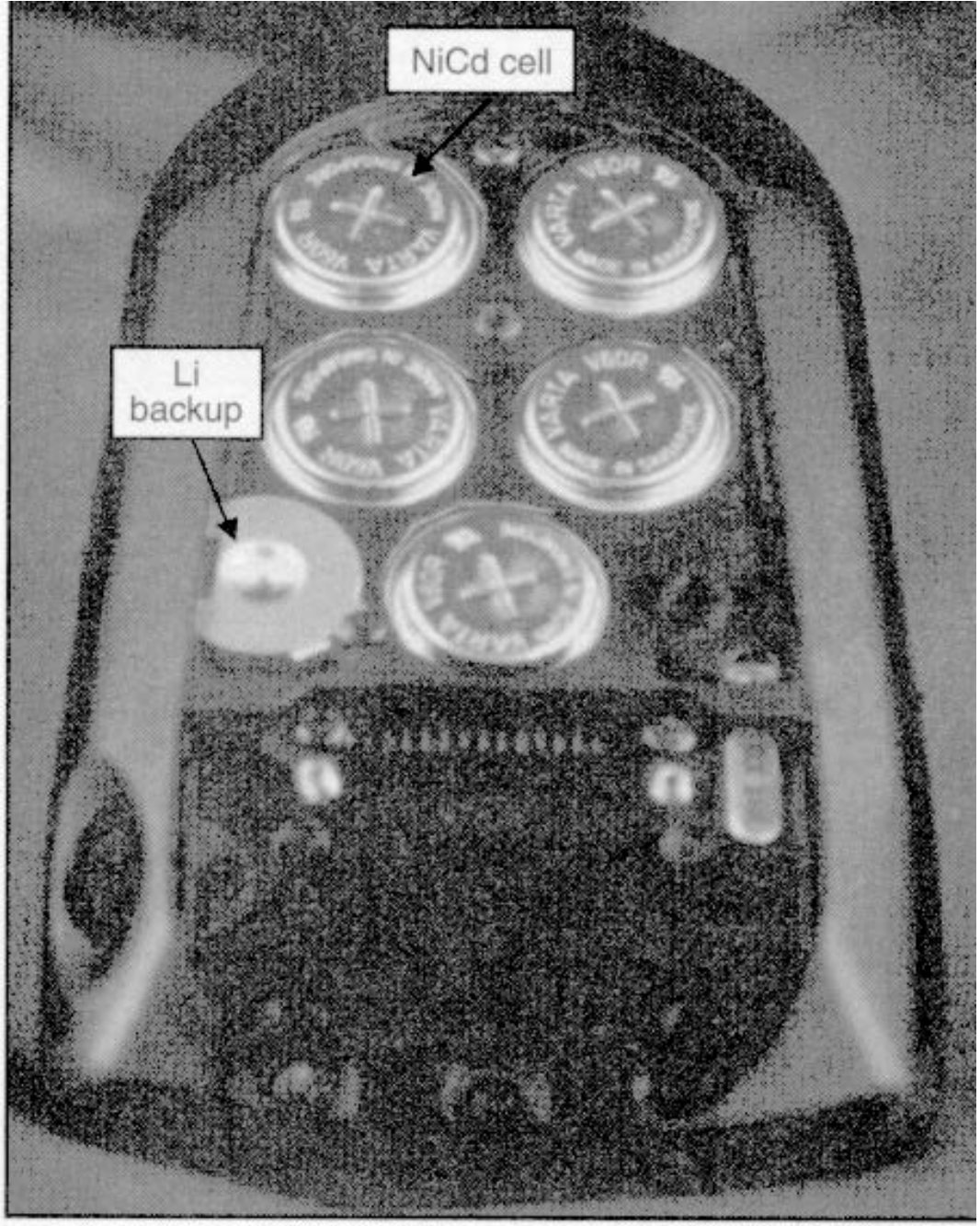


Figure 5.14 Voice recorder with button cell batteries.

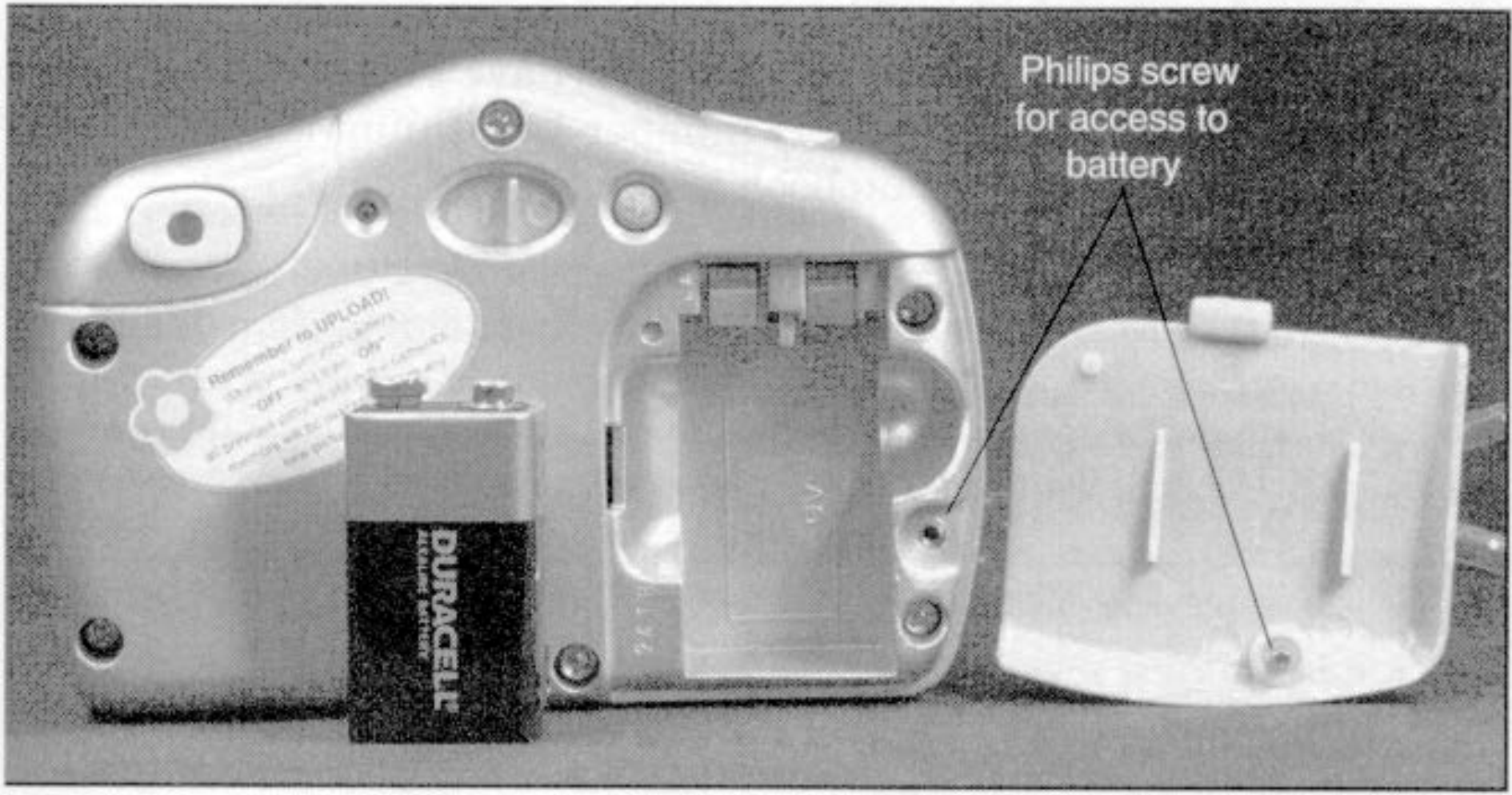


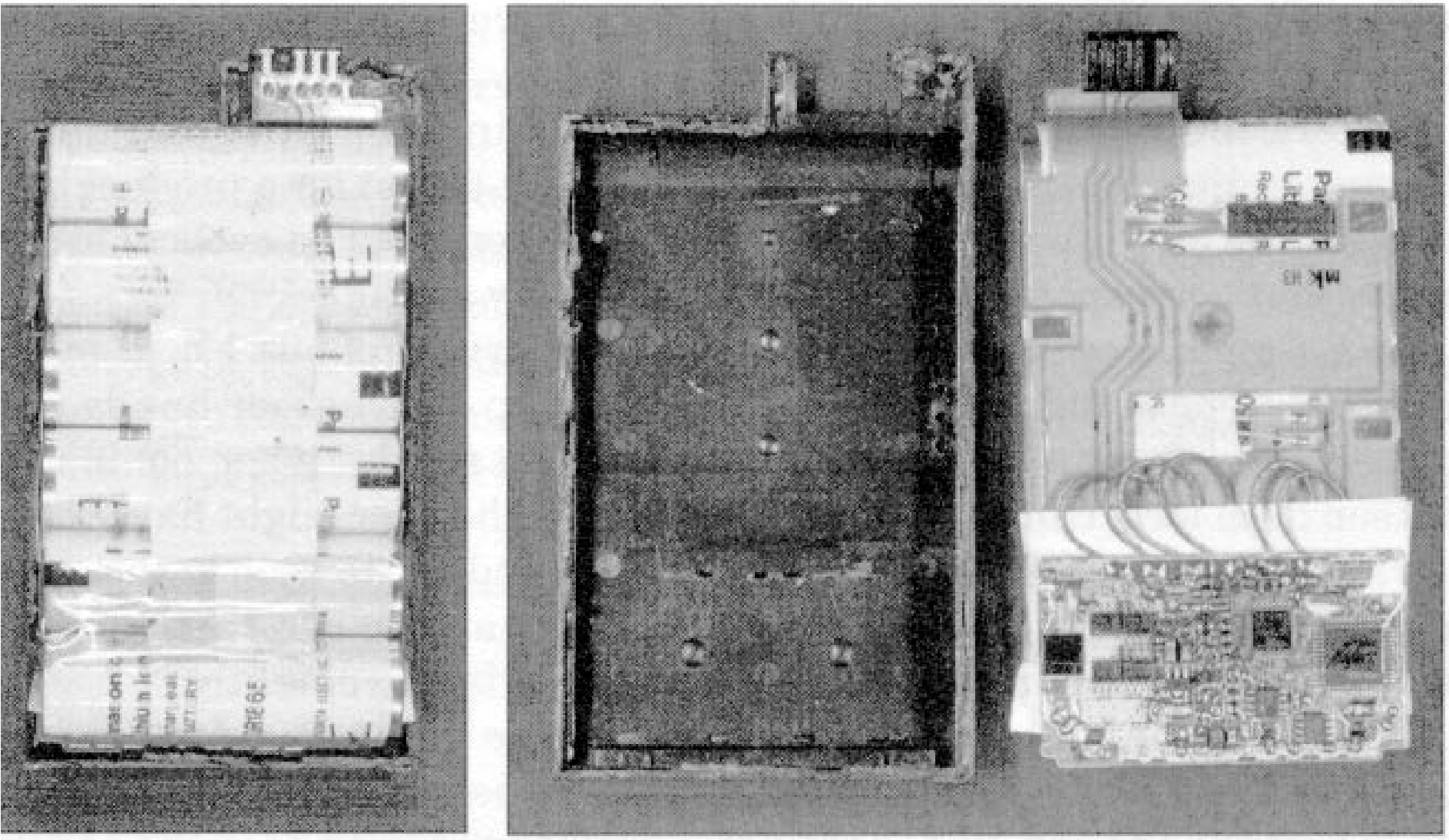
Figure 5.15 Batteries sold separately.

TABLE 5.2 Notebook Battery Metric Comparisons

No.	Technology	Voltage (V)	Capacity (Ah)	Mass (g)	Energy density (Wh/kg)
1	Li-polymer	11.1	1.7	194	97
2	Li-ion	10.8	3.2	314	110
3	Li-ion	14.4	2.7	408	95
4	Ni-MH	9.6	3.5	488	69
5	Li-ion	14.4	2.7	402	97
6	Li-ion	11.1	1.55	159	108

PC BATTERIES – A REAL INNOVATION ?

- LAP-TOP BATTERY UNIT WITH BUILT-IN CHARGE CONTROL ELECTRONICS
- TEMPERATURE REGULATION
- CHARGE CURRENT AND VOLTAGE MONITORING
- GENERALLY FAILS TO WORK WITH AGING CELLS OR IN ELEVATED ENVIRONMENTAL TEMPERATURES
- ALLOWS CONSIDERABLE PROFIT IN AFTER-SALES BY REDUCING THE USE OF ”UNKNOWN” BATTERIES



The 10.8 V Li-ion battery pack is rated at 3200 mAh(34.56 Wh) and weighs 313.7 g. The six
.6 V cells (Panasonic CGR18650) are connected in a series-parallel combination.

igure 5.17 Notebook battery pack and internal electronics.

WHERE DOES ALL THE POWER GO ?

- EFFICIENCY ?
- RF MODULES ?
- DISPLAYS WITH BACKLIGHT ?
- FEEL THE HEAT ?

Subsystem	Watts ($P_n D_n$)
Processor	2.0
Chipset and memory	4.0
GFX (integrated in chipset)	0
LCD 14.1" SXGA+ and backlight	6.0
HDD	1.2
DVD	0.5
LAN (wired or wireless)	0.5
Power supply loss	2.0
Fan	0.5
Clock generation	0.7
Rest of platform	1.5
Platform total (P_A)	18.9

SEE SEPARATE THEMATIC PRESENTATION
POWER_SUPPLIES.PDF
FOR A DETAILED DISCUSSION

CHAPTER 6

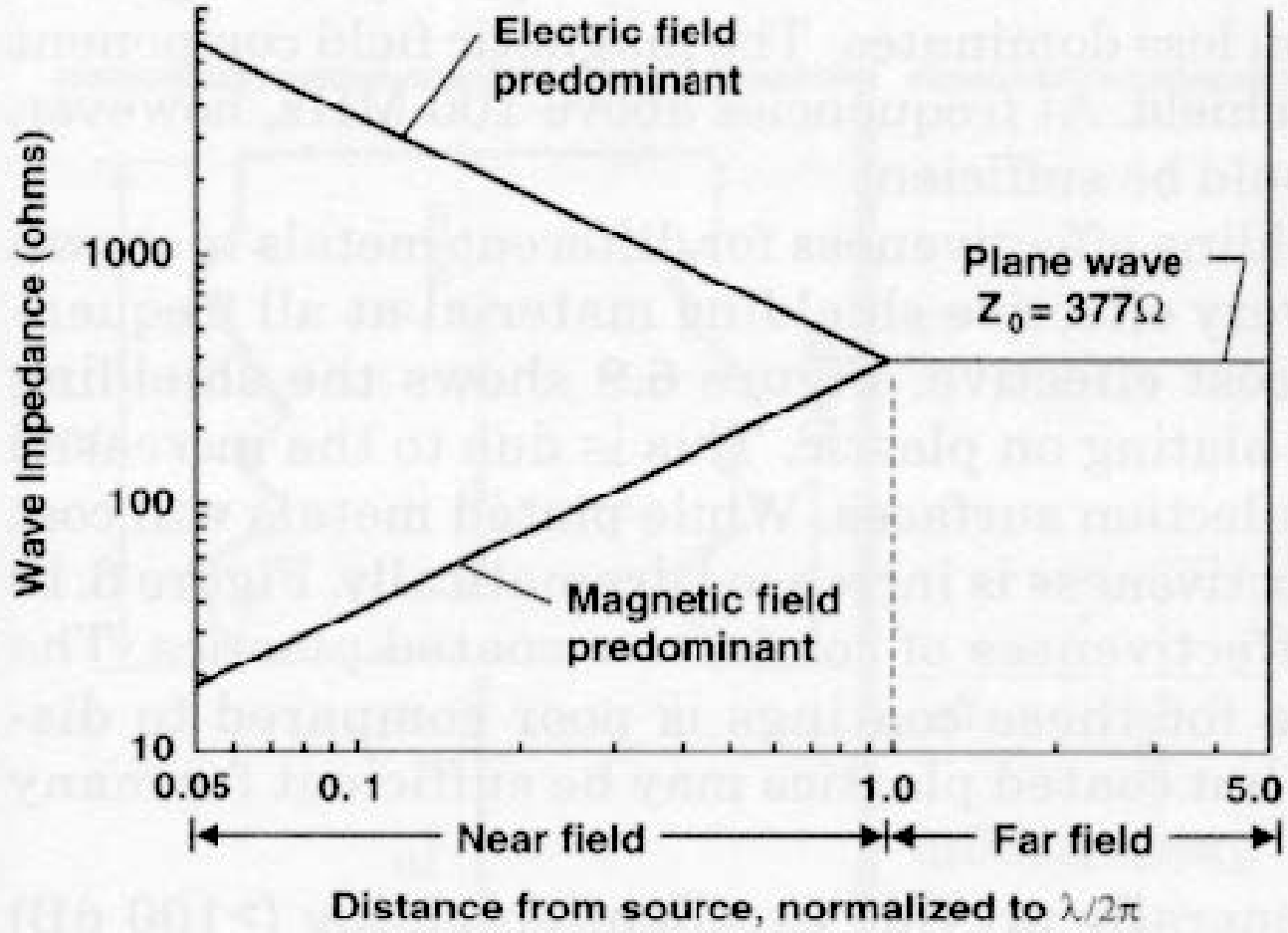
MECHANICAL DESIGN

MAIN FACTORS

- PHYSICAL PROTECTION (DUST, DIRT)
- REDUCING SHOCKS AND VIBRATION
- PROTECTION AGAINST HUMIDITY
- THERMAL LOADS
- ELECTROMAGNETIC COMPATIBILITY

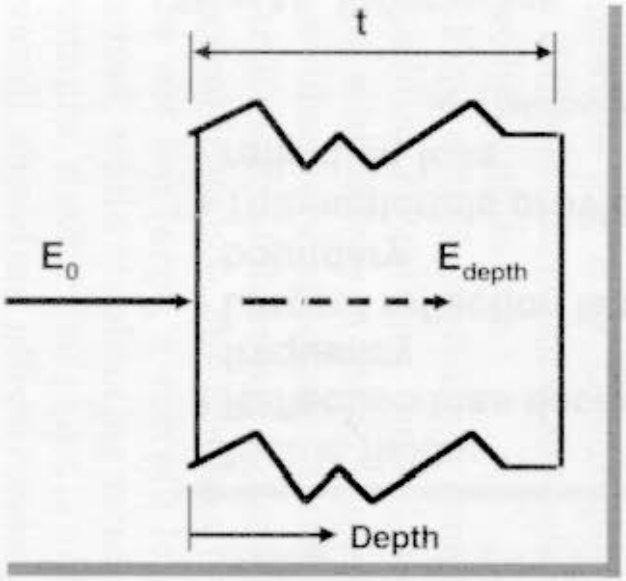
AN EXAMPLE : PORTABLE CD PLAYER

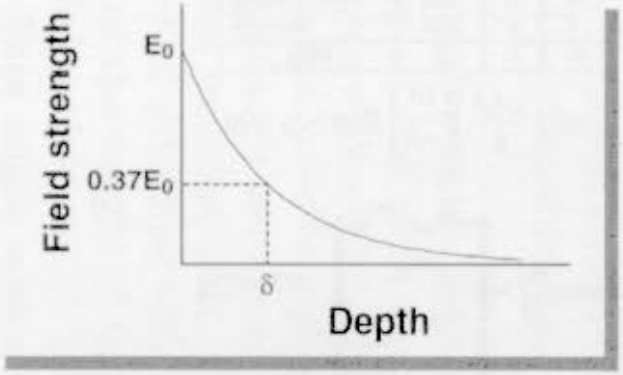
- THE MOST ANNOYING FEATURE IS THE LOSS OF PROPER AUDIO OUTPUT DURING MINIMAL PHYSICAL DISTURBANCES
- ALTERNATIVES: ADD RUBBER DAMPERS AND GELS OR RE-ARRANGE THE BUFFER MEMORY CONCEPT
- THE PLAYER CAN BE PROTECTED AGAINST DUST AND DIRT BUT WHAT ABOUT THE CD’S (COMPARE: MINIDISC)



Frequency	$\lambda/2\pi$
60 Hz	795 km
3 kHz	15,915 m
30 kHz	1,591.5 m
300 kHz	159.1 m
3 MHz	15.9 m
30 MHz	1.59 m
300 MHz	15.9 cm
900 MHz	5.30 cm
3 GHz	1.59 cm
30 GHz	1.59 mm

Figure 6.2 Near field vs. far field.





- Applies to electric fields, magnetic fields, and plane waves $A = 3.34\,t\sqrt{f\mu_r\sigma_r} = 8.69\,t/\delta$ dB
- Thin materials provide effective absorption losses at high frequencies
- Skin depth (δ): $\delta = 1/\sqrt{\pi f \mu \sigma}$ in
  - —Distance needed for wave to be attenuated to 37% of its original strength
  - —Varies with material and frequency

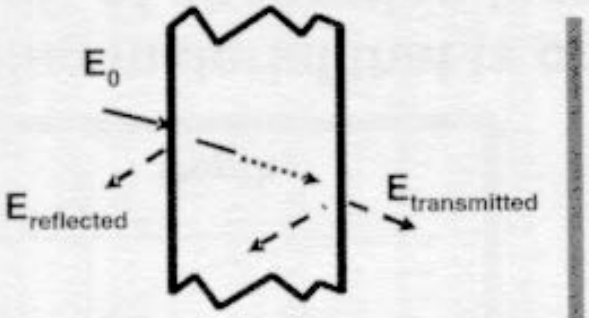
Frequency	δ, *copper*	δ, *aluminum*	δ, *steel*	δ, *mumetal*
60 Hz	0.335	0.429	0.034	0.019
100 Hz	0.260	0.333	0.026	0.011
1 kHz	0.082	0.105	0.008	0.003
10 kHz	0.026	0.033	0.003	—
100 kHz	0.008	0.011	0.0008	—
1 MHz	0.003	0.003	0.0003	—
10 MHz	0.0008	0.001	0.0001	—
100 MHz	0.00026	0.0003	0.00008	—
1 GHz	0.00008	0.0001	0.00004	—

Thicknesses in inches

Shielding material that is one skin depth thick ($t/\delta = 1$) provides approximately 9 dB of absorption loss; doubling the thickness doubles the dB loss

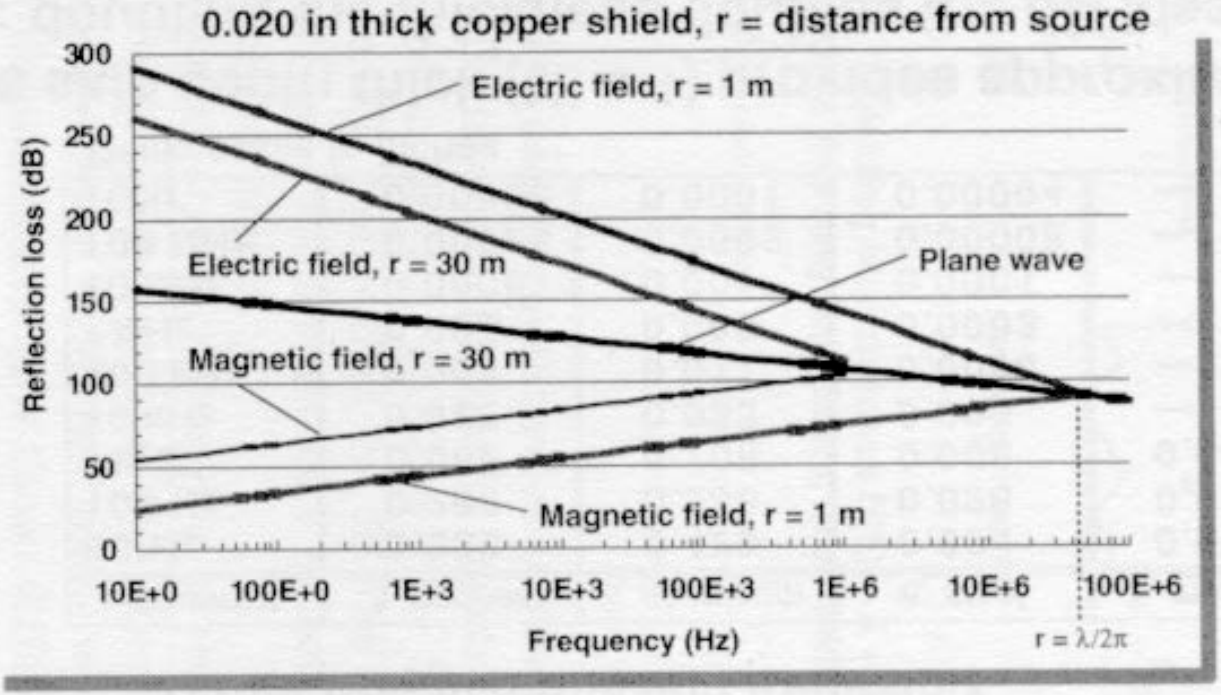
f = frequency (Hz), μ = permeability (H/in), σ = conductivity (mho/in), t = thickness (in), μ_r = relative permeability (free space), σ_r = relative conductivity (copper)

Figure 6.4 Absorbtion loss.



$$R = C + \log\left(\frac{\sigma_r}{\mu_r}\right)\left(\frac{1}{f^n r^m}\right) \text{ dB}$$

Field	*C*	*n*	*m*
Electric	322	3	2
Plane wave	168	1	0
Magnetic	14.6	-1	-2



Electric fields:

- Reflection loss decreases with frequency
- Largest reflection is at first shield boundary
- Thin materials provide good reflection loss

Magnetic fields:

- Reflection loss increases with frequency
- Largest reflection is at second shield boundary
- Multiple reflections must be accounted for

μ_r = relative permeability (free space), σ_r = relative conductivity (copper), f = frequency (Hz), r = distance from source (m)

Figure 6.5 Reflection loss.

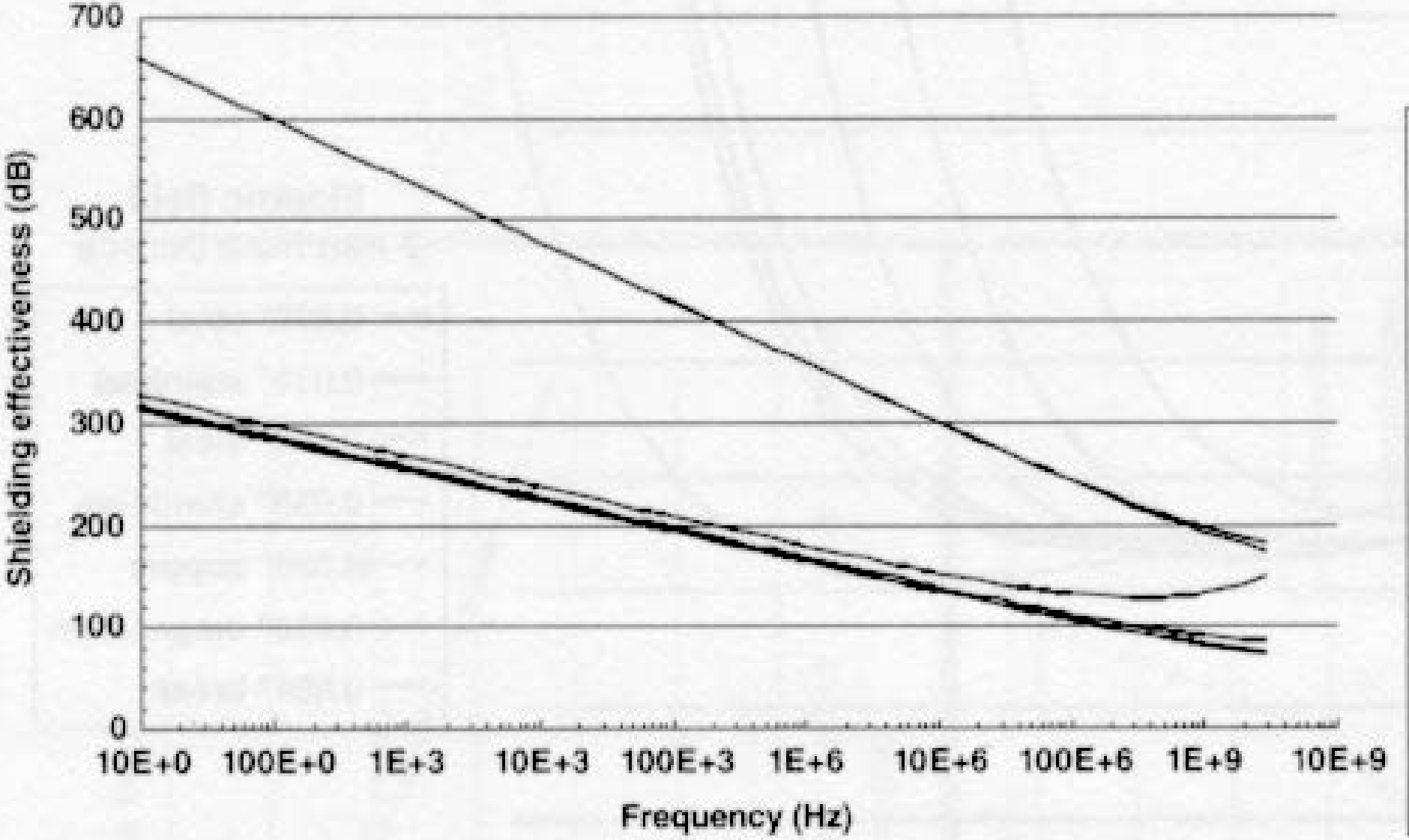
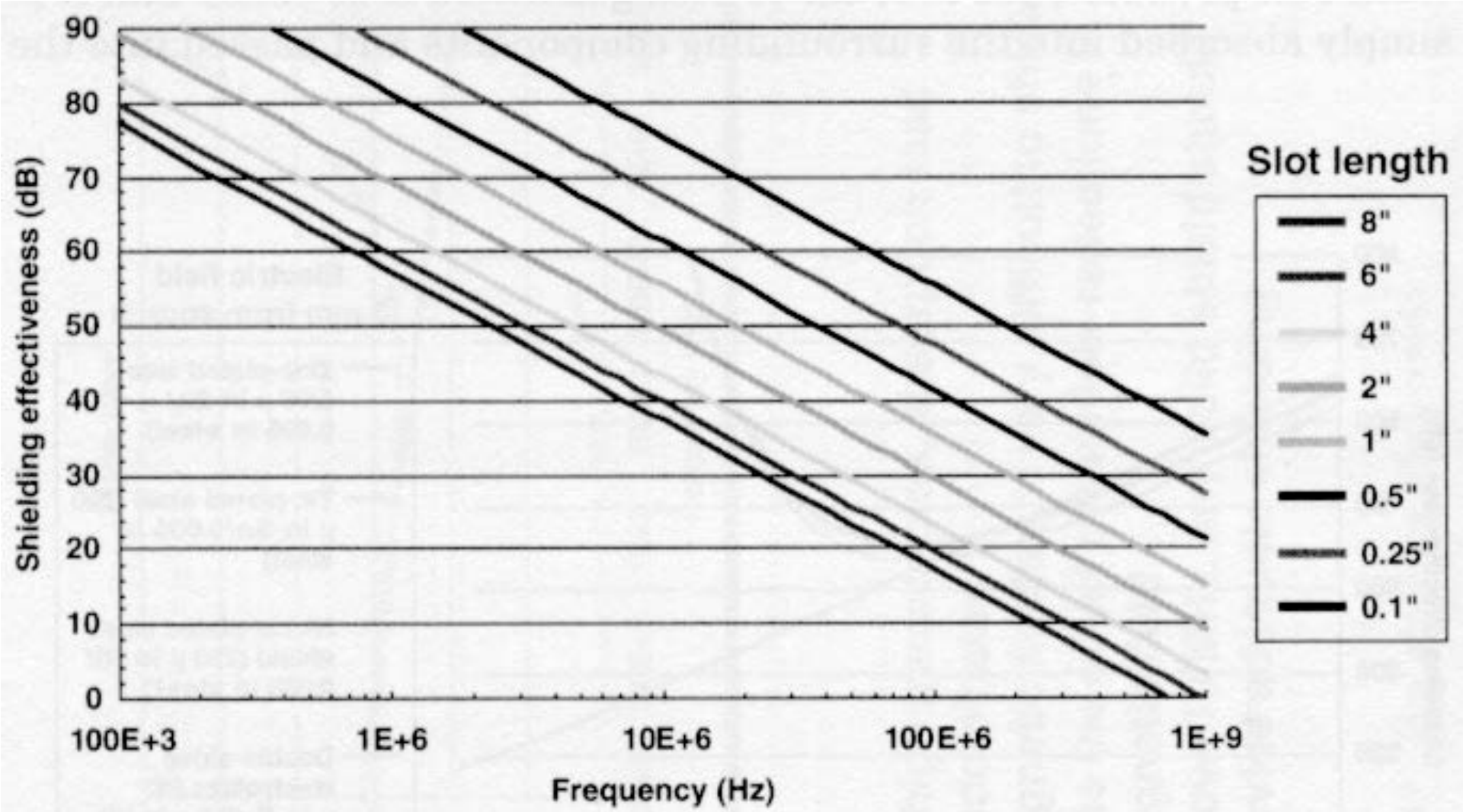


Figure 6.10 Shielding performance for conductive coated plastics.



$$SE = 20 \log \left(\frac{\lambda}{2L} \right) dB$$

SE = Shielding Effectiveness (dB)
λ = wavelength
L = maximum dimension of slot

Figure 6.11 Shielding effectiveness of various slot dimensions.

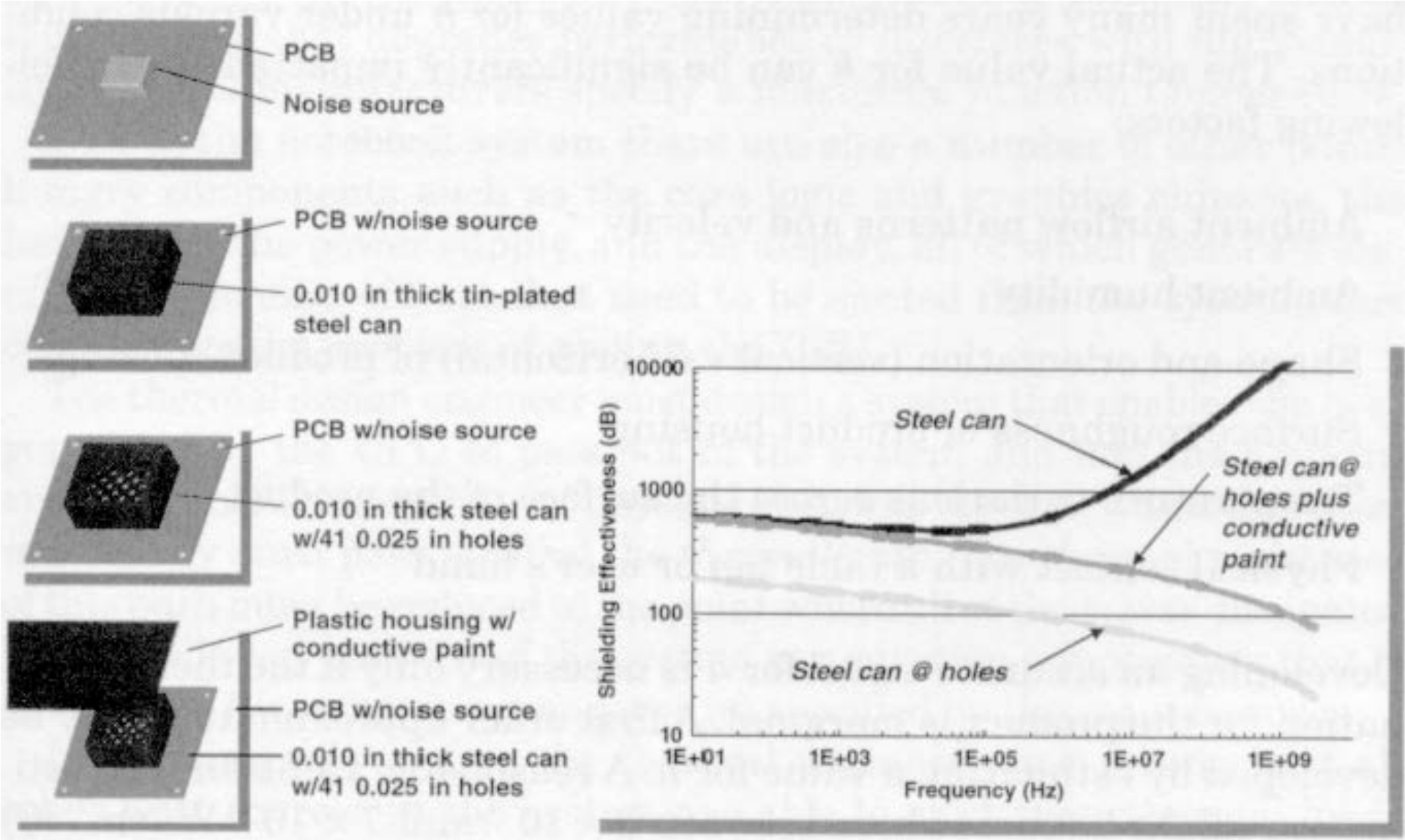


Figure 6.13 Comparison of shielding techniques.

SEE SPERATE THEMATIC PRESENTATION
SHIELDING&THERMAL.PPT
FOR A DETAILED DISCUSSION

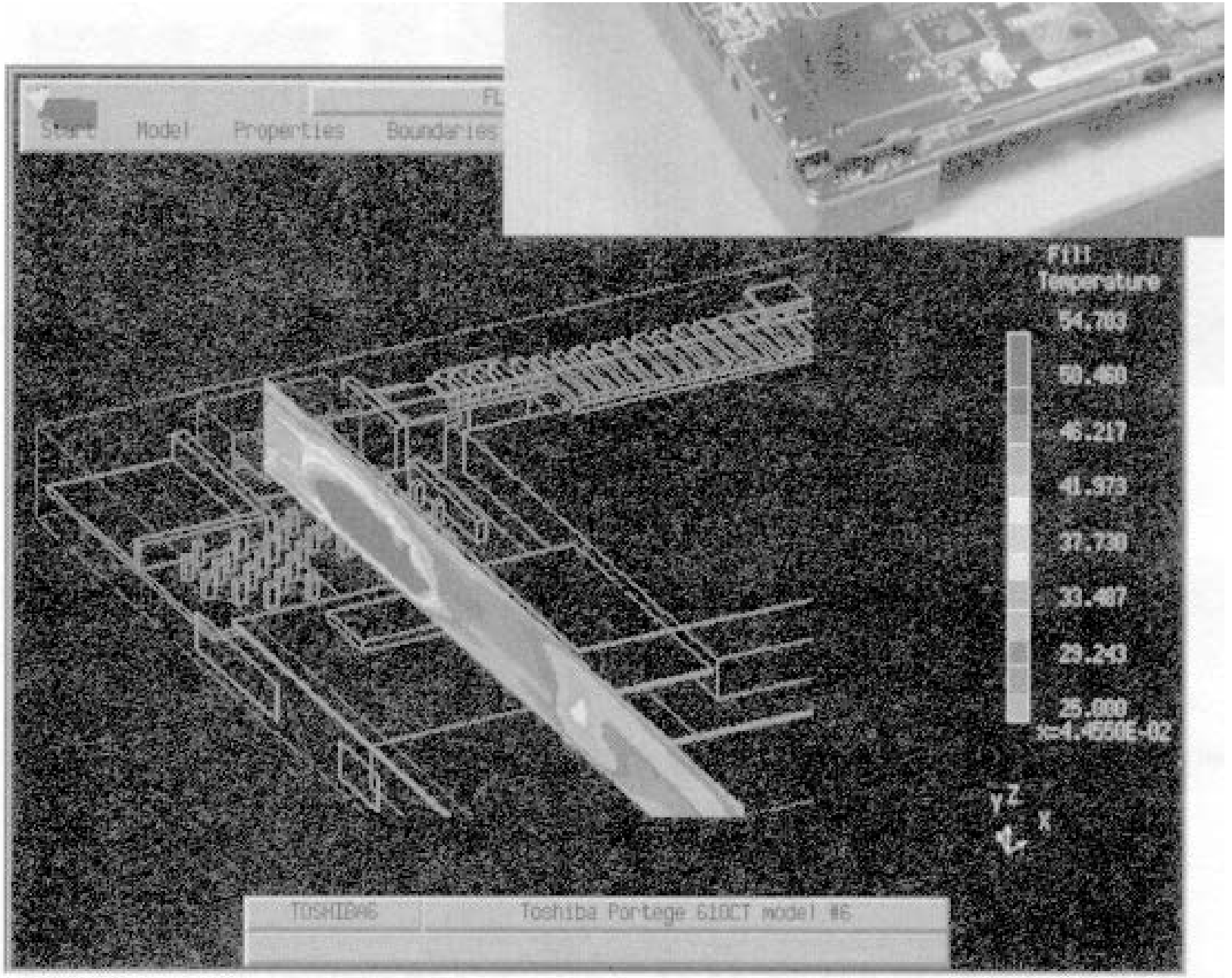


Figure 6.14 CFD thermal design tool.

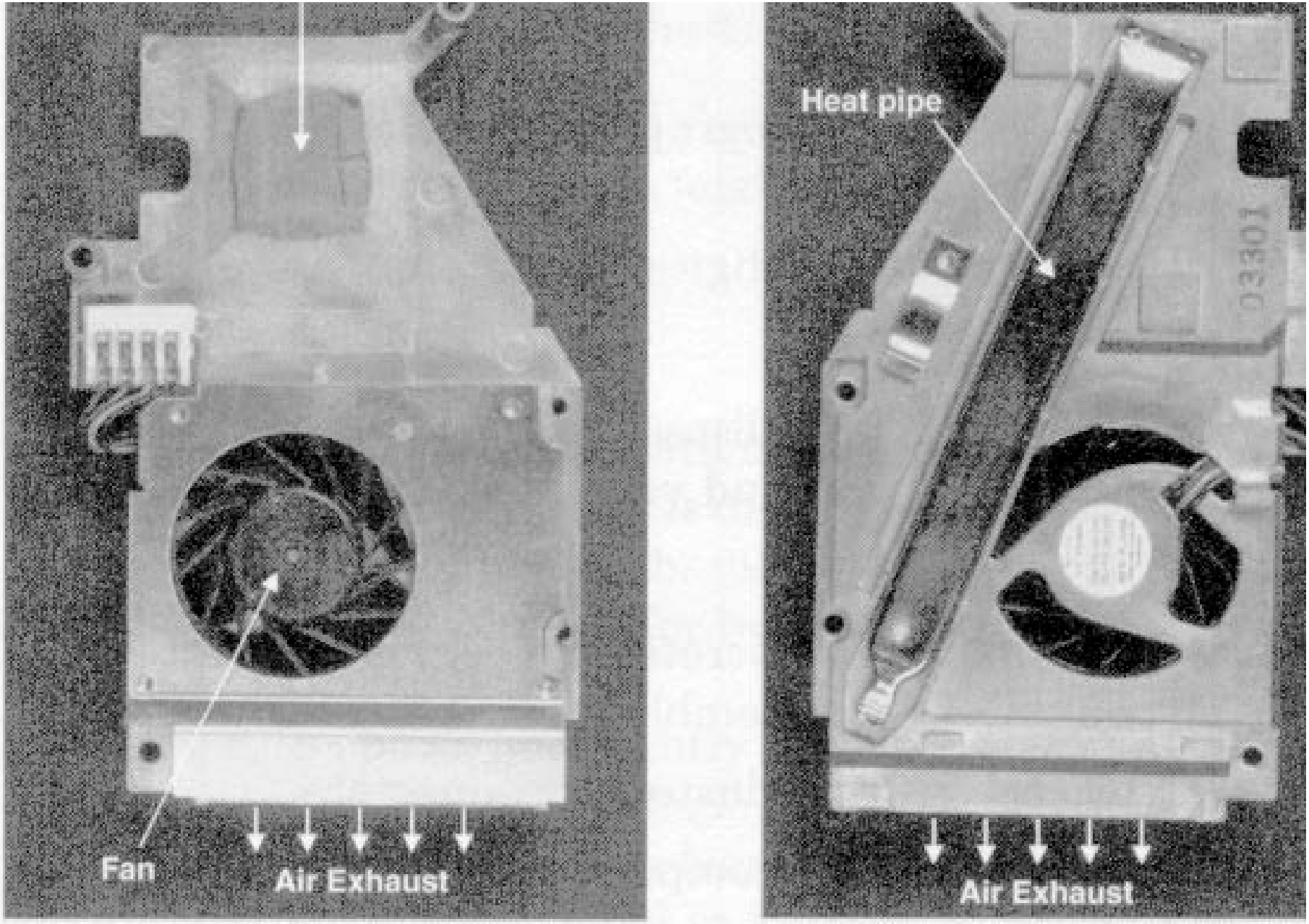


Figure 6.15 Integrated thermal solution.

SEE SEPARATE THEMATIC PRESENTATION
SHIELDING&THERMAL.PPT
FOR A DETAILED DISCUSSION

WRIST WATCH EXAMPLE

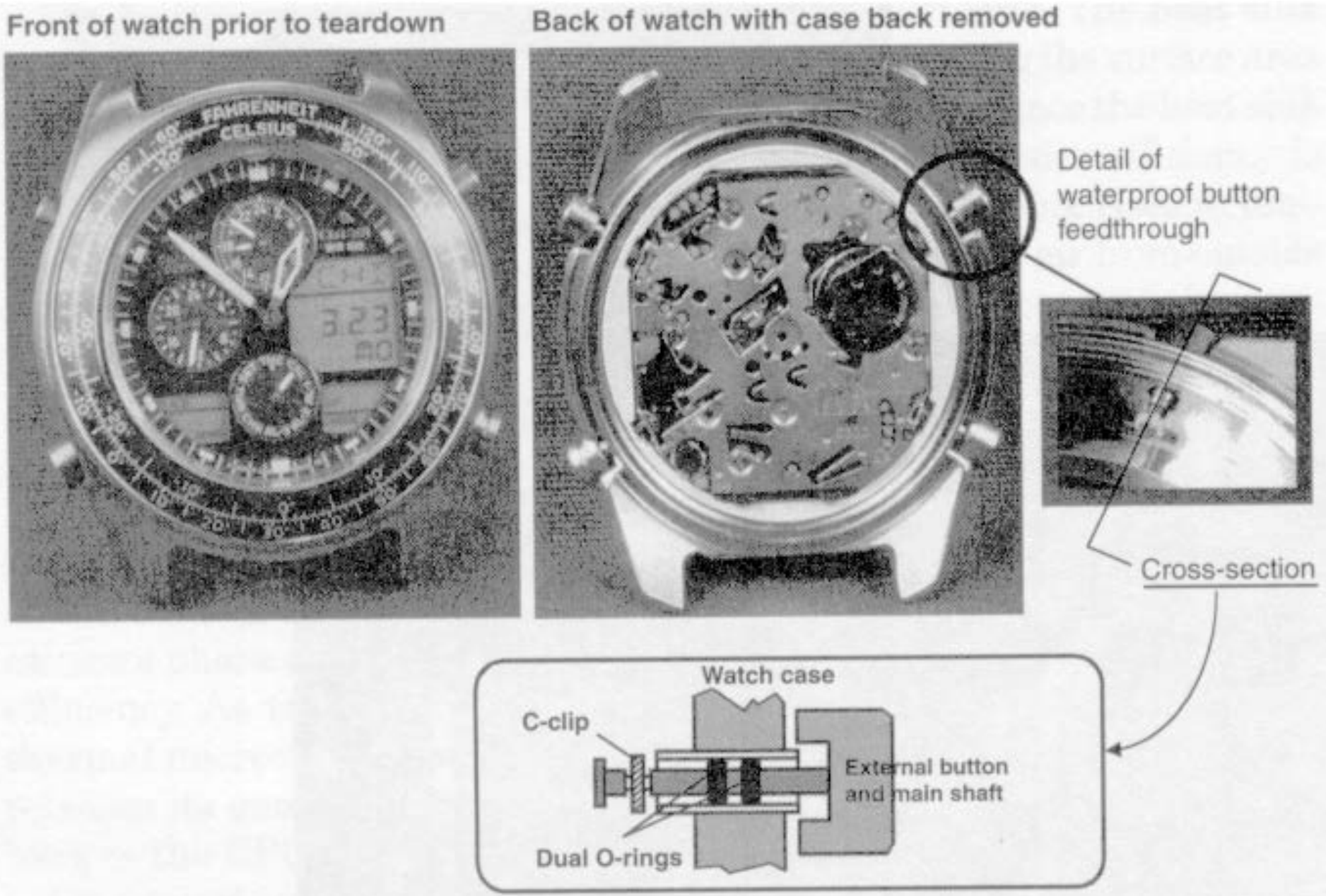


Figure 6.16 Citizen electromechanical watch.

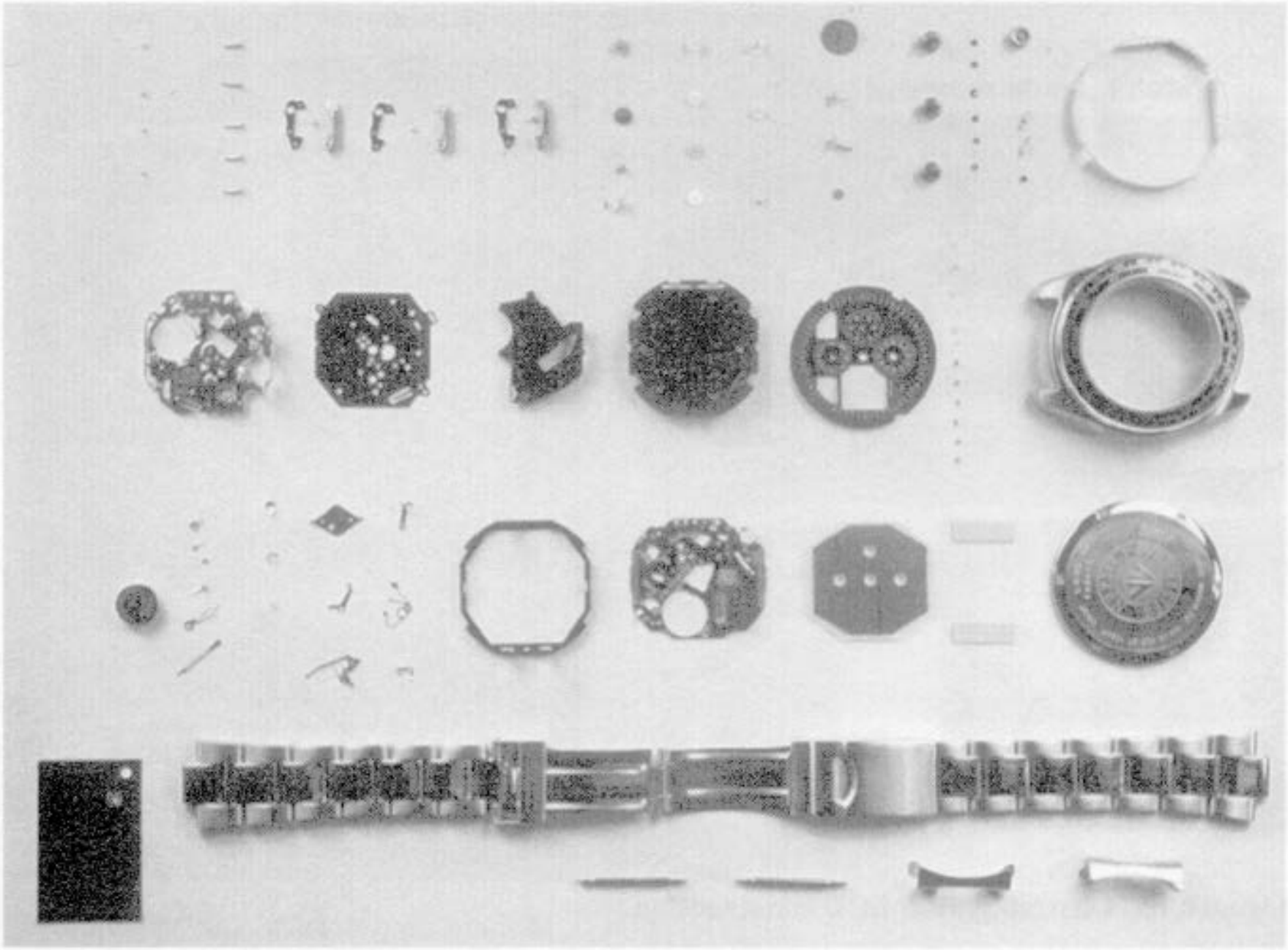


Figure 6.17 Parts of citizen watch.

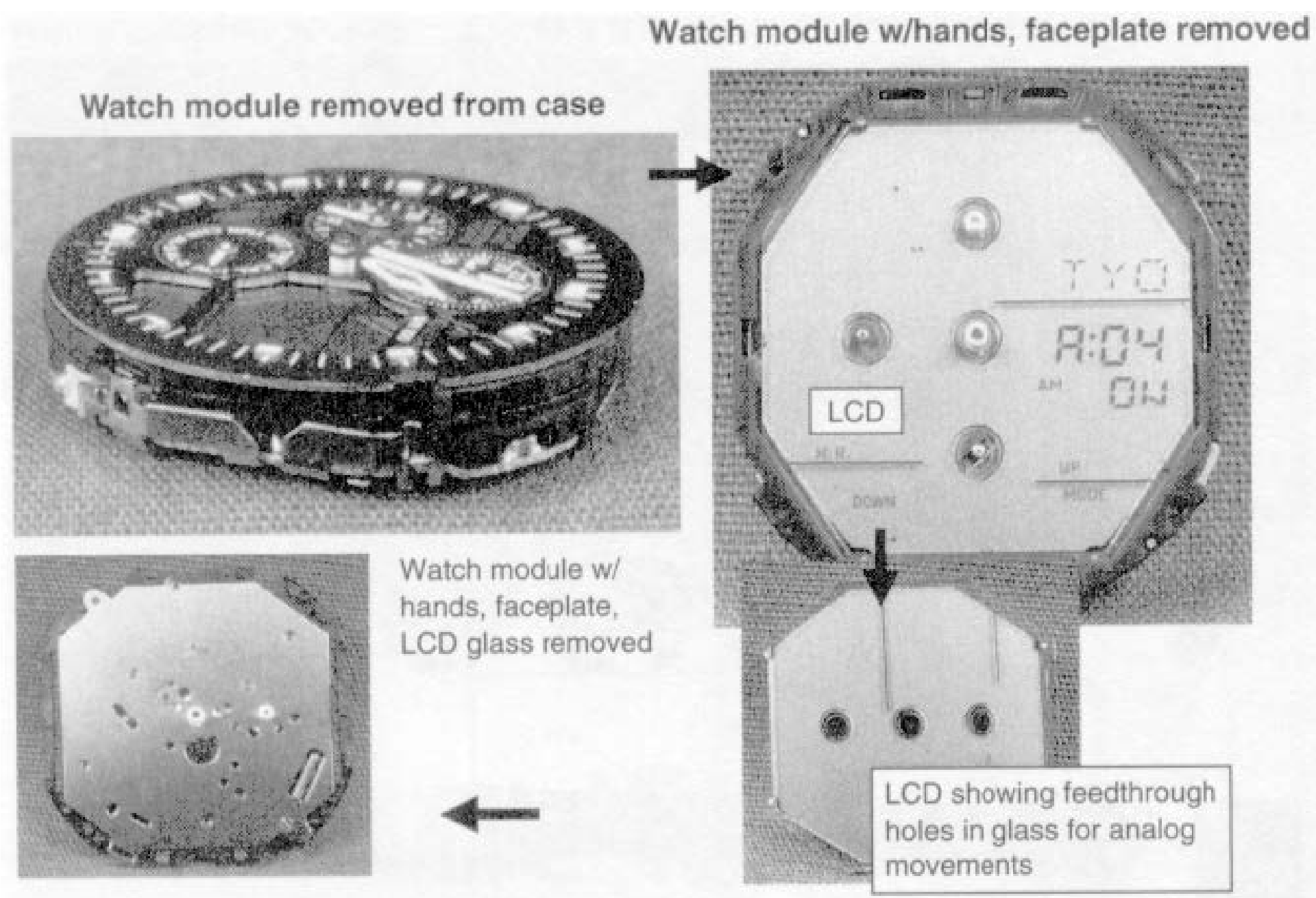


Figure 6.18 Custom Watch LCD construction.

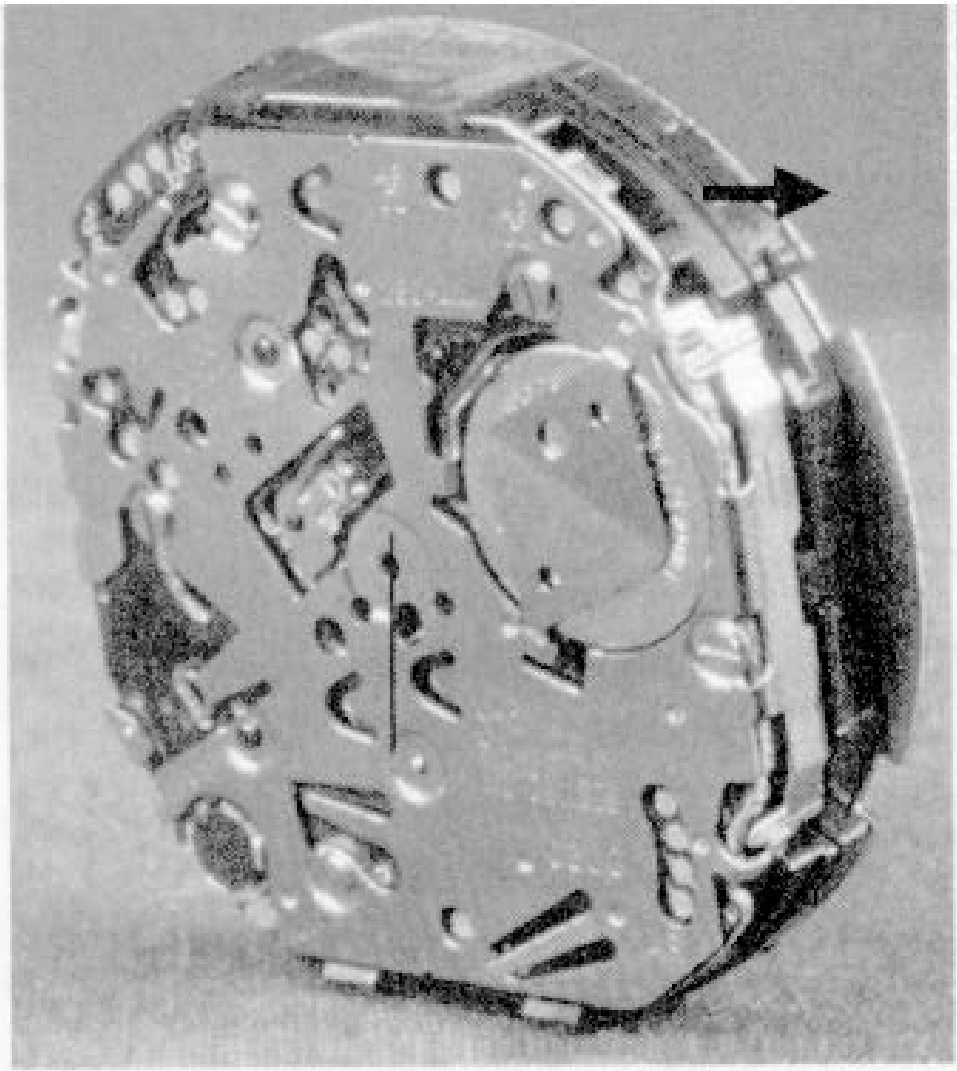


Figure 6.19 Integrated electromechanical watch module.

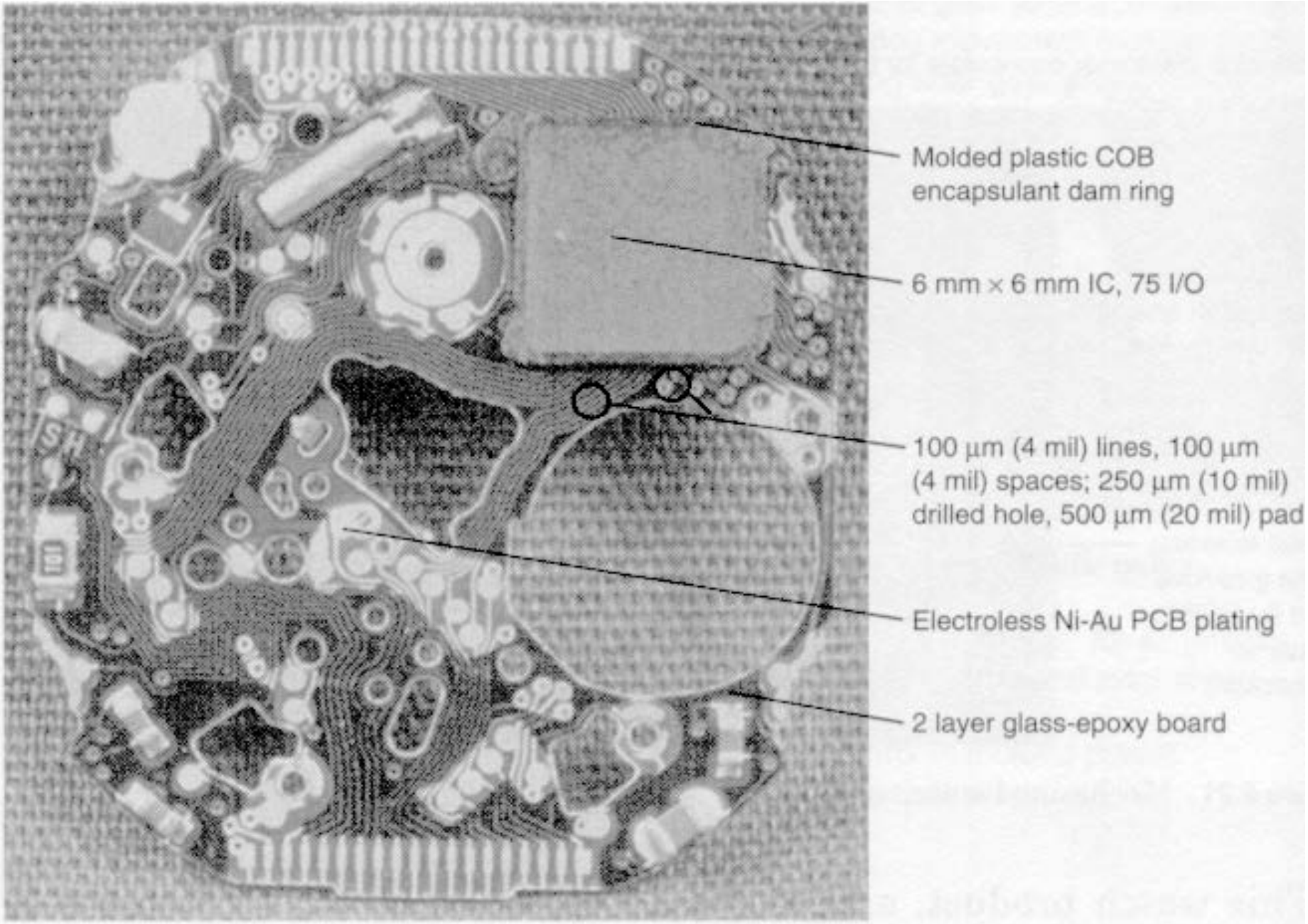


Figure 6.20 Electronic watch module.

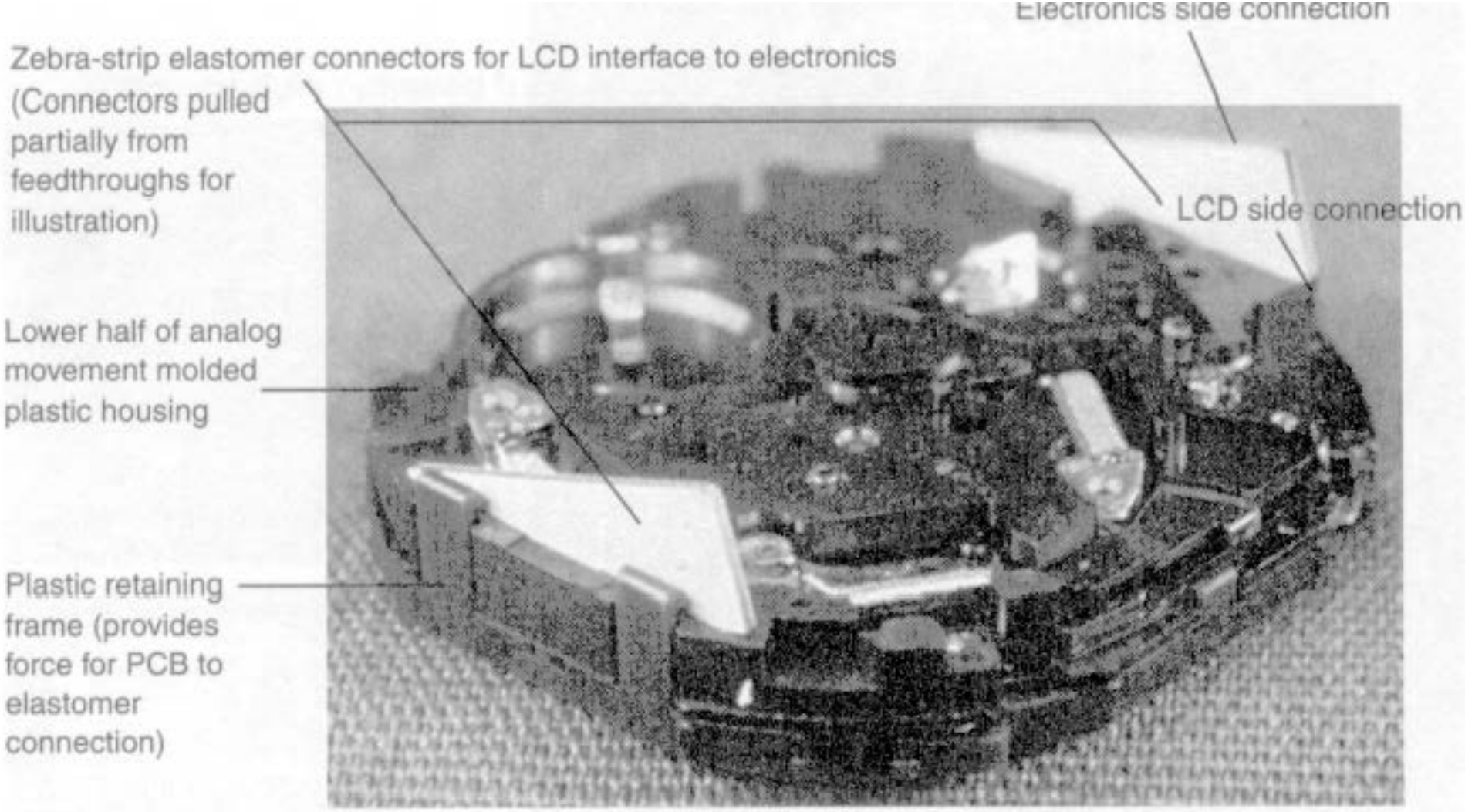


Figure 6.21 Mechanical watch module.

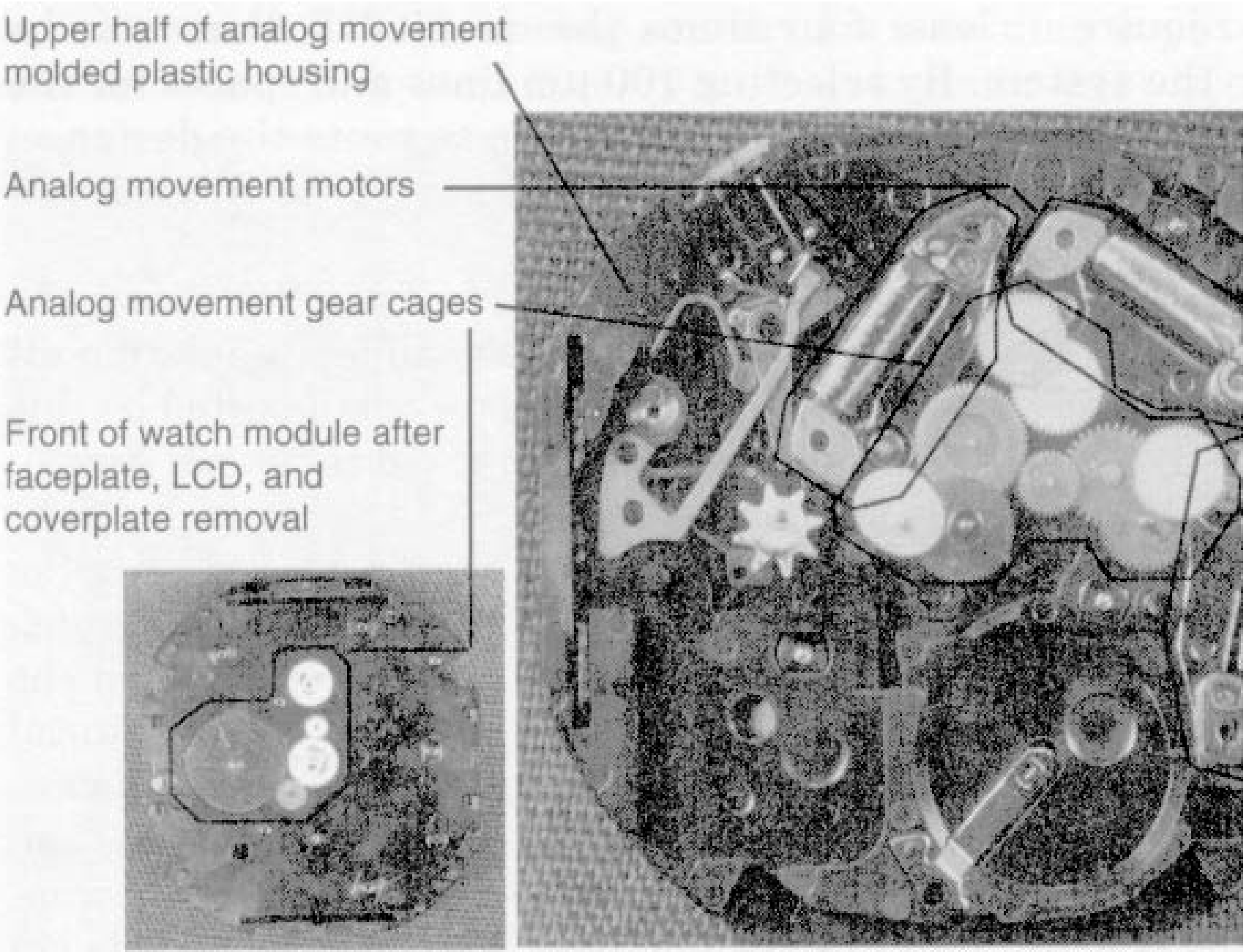


Figure 6.22 Analog movement gear train in mechanical watch module.

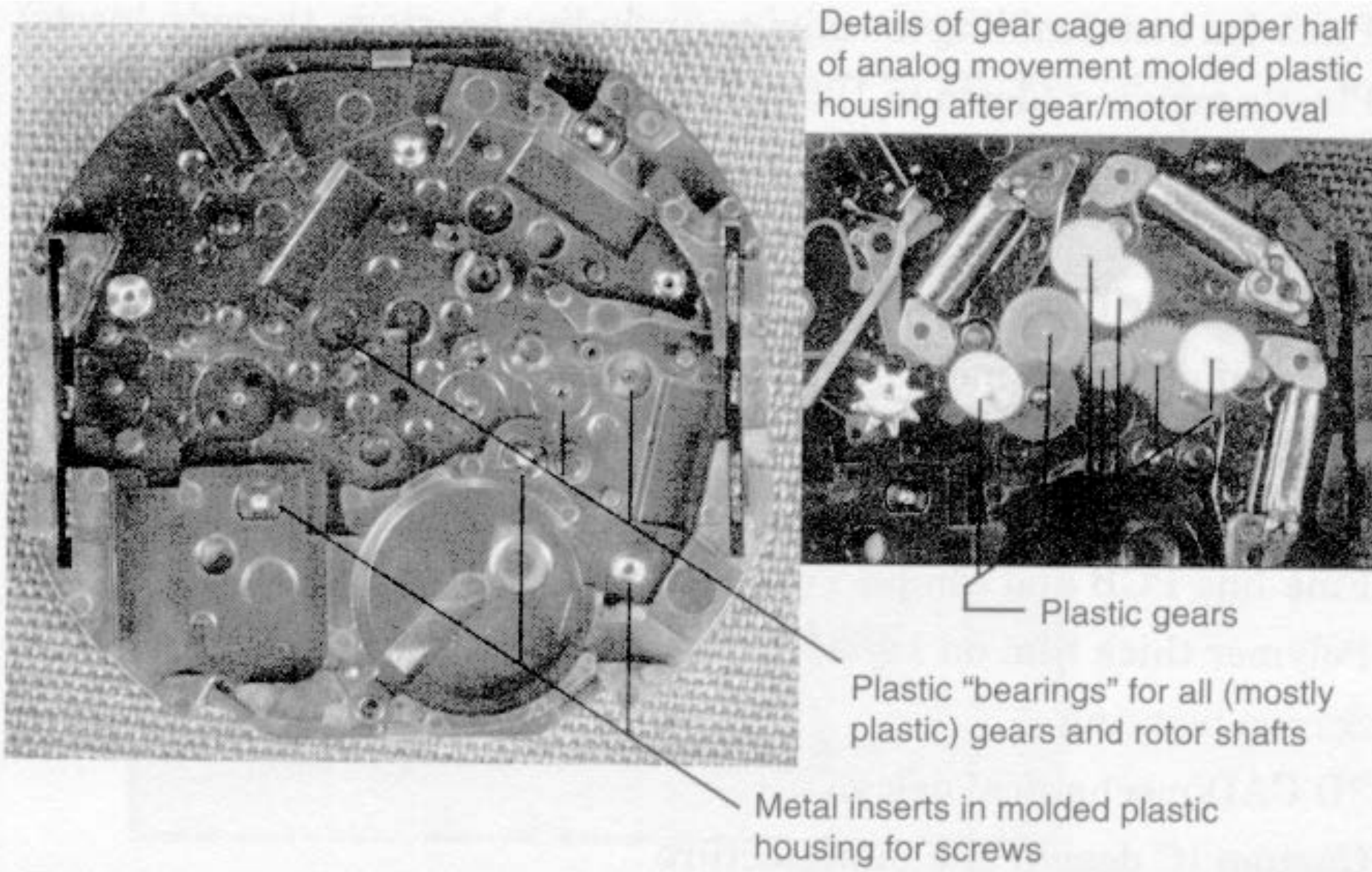


Figure 6.23 Mechanical substrate.

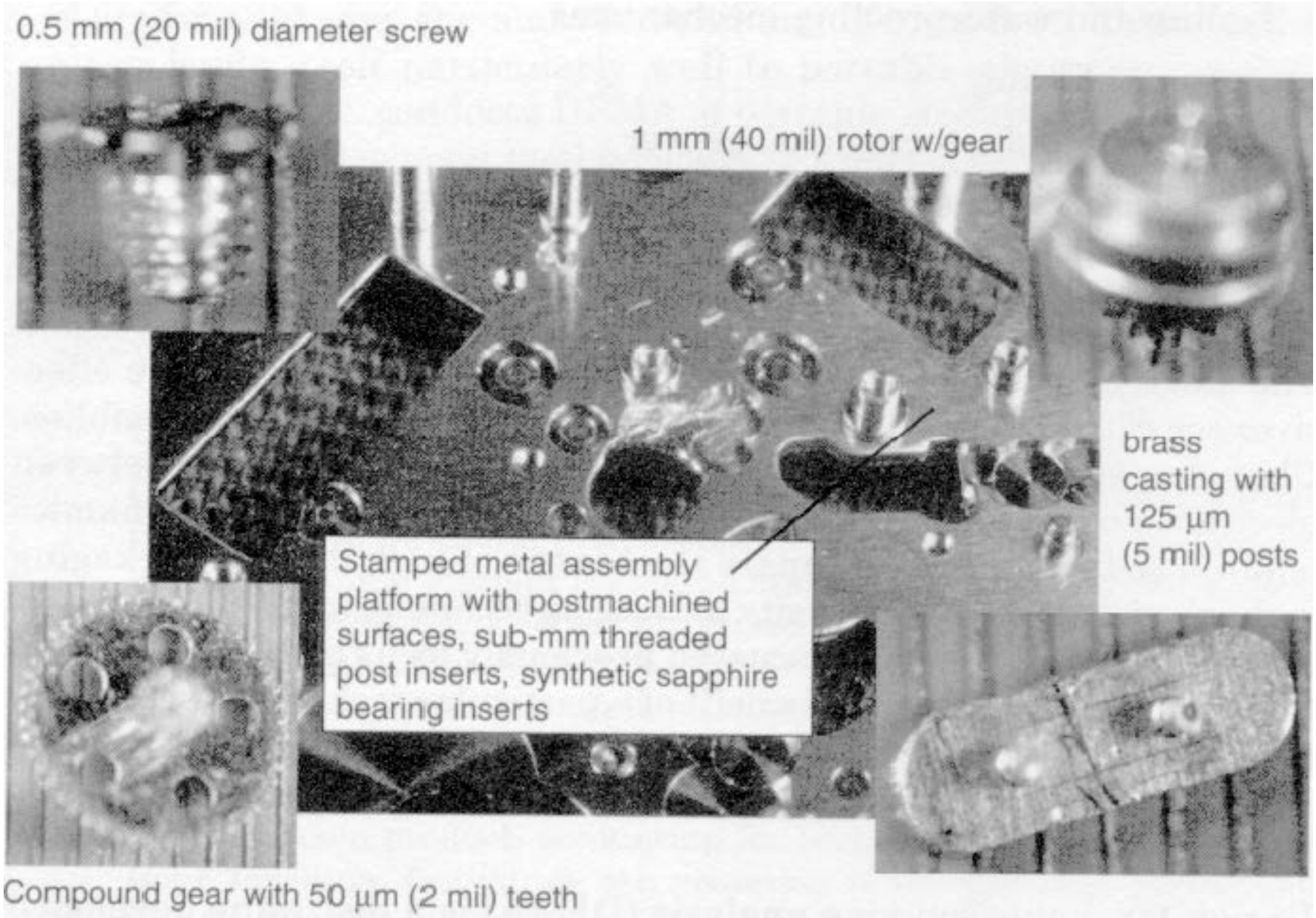


Figure 6.24 Precision miniature mechanical components.

Design Characteristics

Device Area

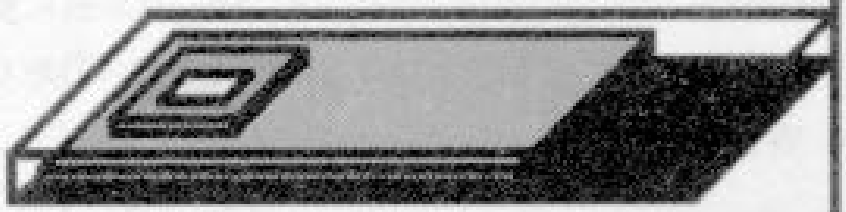
Total area of all bare die in the product

PCB Area

Total 1-sided area of PCB's

Product Area

Product Length x Product Width (when product is "folded")



Electronic Packaging Metrics

$$\text{PCB Tiling Density} = \frac{\text{Device Area}}{\text{PCB Area}}$$

$$\text{Product Tiling Density} = \frac{\text{Device Area}}{\text{Product Area}}$$

$$\text{Stack Factor} = \frac{\text{PCB Area}}{\text{Product Area}}$$

Figure 6.25 Stack factor.

SEE SEPARATE THEMATIC PRESENTATIONS
ENCLOSURES_PROPERTIES.PPT
AND
ENCLOSURES_MANUFACTURING.PPT
FOR A DETAILED DISCUSSION

SIMILAR MATERIAL IS AVAILABLE IN ENGLISH IN

Harri Eskelinen & Pekka Eskelinen: ***Microwave Component Mechanics***

CHAPTER 7

SOFTWARE AND COMMUNICATIONS

TOPICS FOR DISCUSSION:

- SOFTWARE HIEARCHY
- THE ULTIMATE PURPOSE OF SW
- OPERATING SYSTEM
- SPEED VERSUS CONVENIENCE
- SPEED VERSUS CAPACITY
- APPLICATION-SPECIFIC ISSUES
- COMMUNICATION TOPICS

JUST A COMMENT:

- HAVE YOU SEEN A DESIGNER OF VACUUM CLEANERS USING MOST OF HIS OR HER FREE TIME IN VACUUM CLEANING THE HOUSE AND GARDEN ?

MORE COMMENTS:

- COMING OPERATING SYSTEMS ARE ABOUT TO OVERLOAD ANY FORESEEN HARDWARE PLATFORMS
- CONSIDER USER SEGMENT BEFORE SELECTING OPERATING SYSTEM AND BUNDLED SOFTEWARE
- TYPICAL BOTTLENECKS IN INTERNAL BUS SPEED AND THEN IN MEMORY
- PROCESSOR SPEED SELDOM SEEN AS SOFTWARE CONVENIENCE
- DIFFICULT TO SEPARATE HARDWARE AND OPERATING SYSTEM EFFECTS

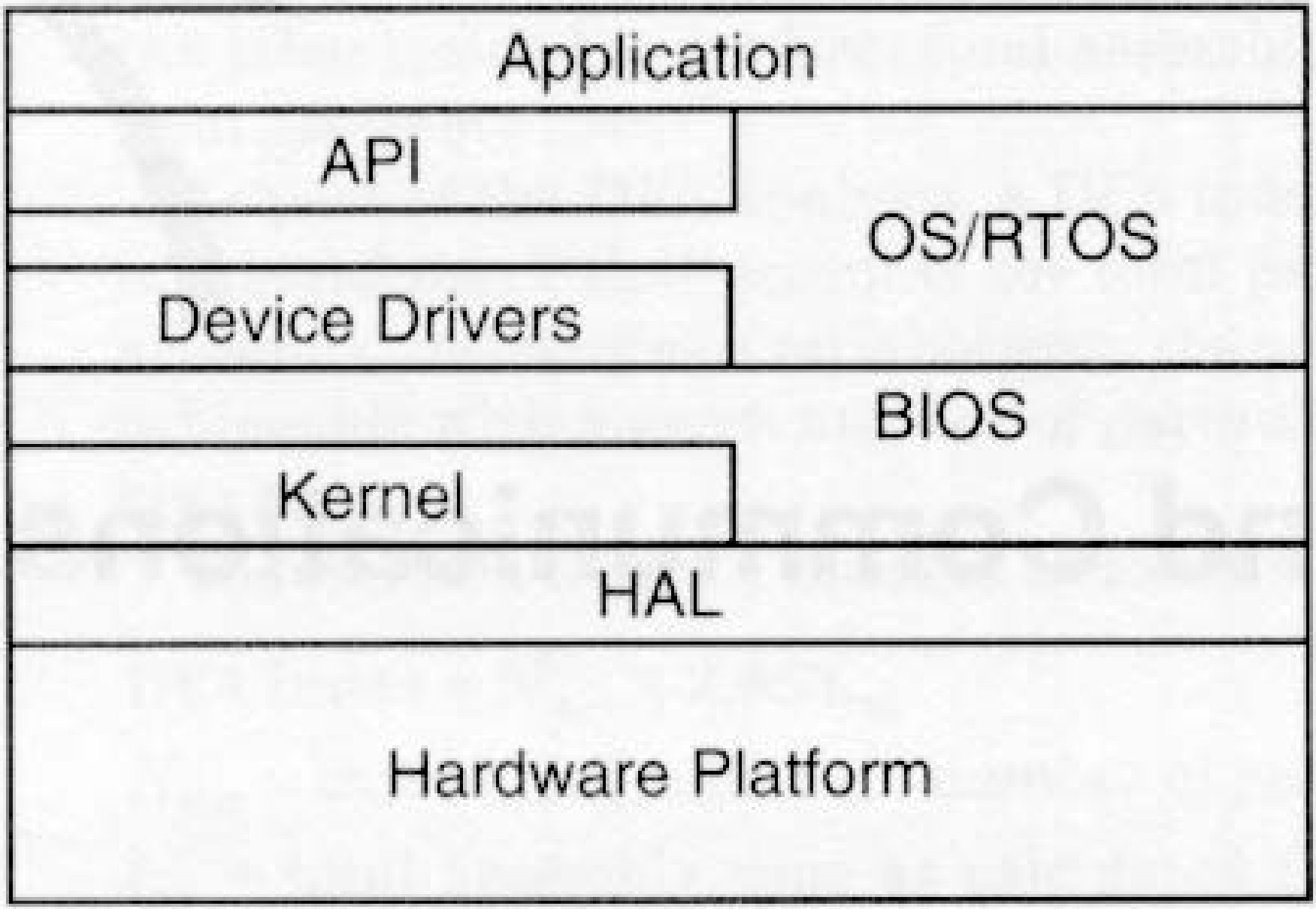


Figure 7.1 System software hierarchy.

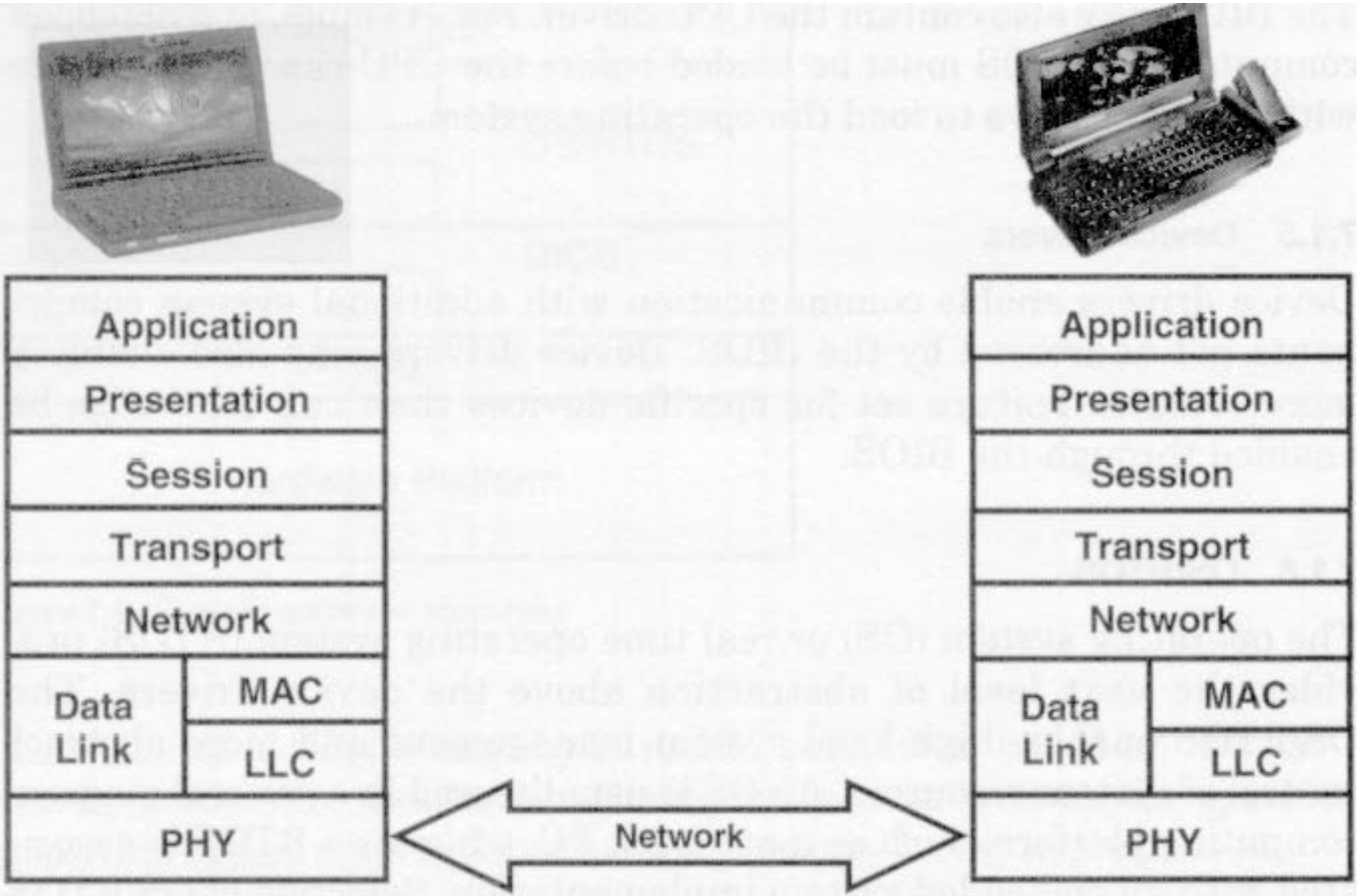


Figure 7.2 OSI network stack.

AND THAT’S IT !

CHAPTER 8

CELLULAR EXAMPLE

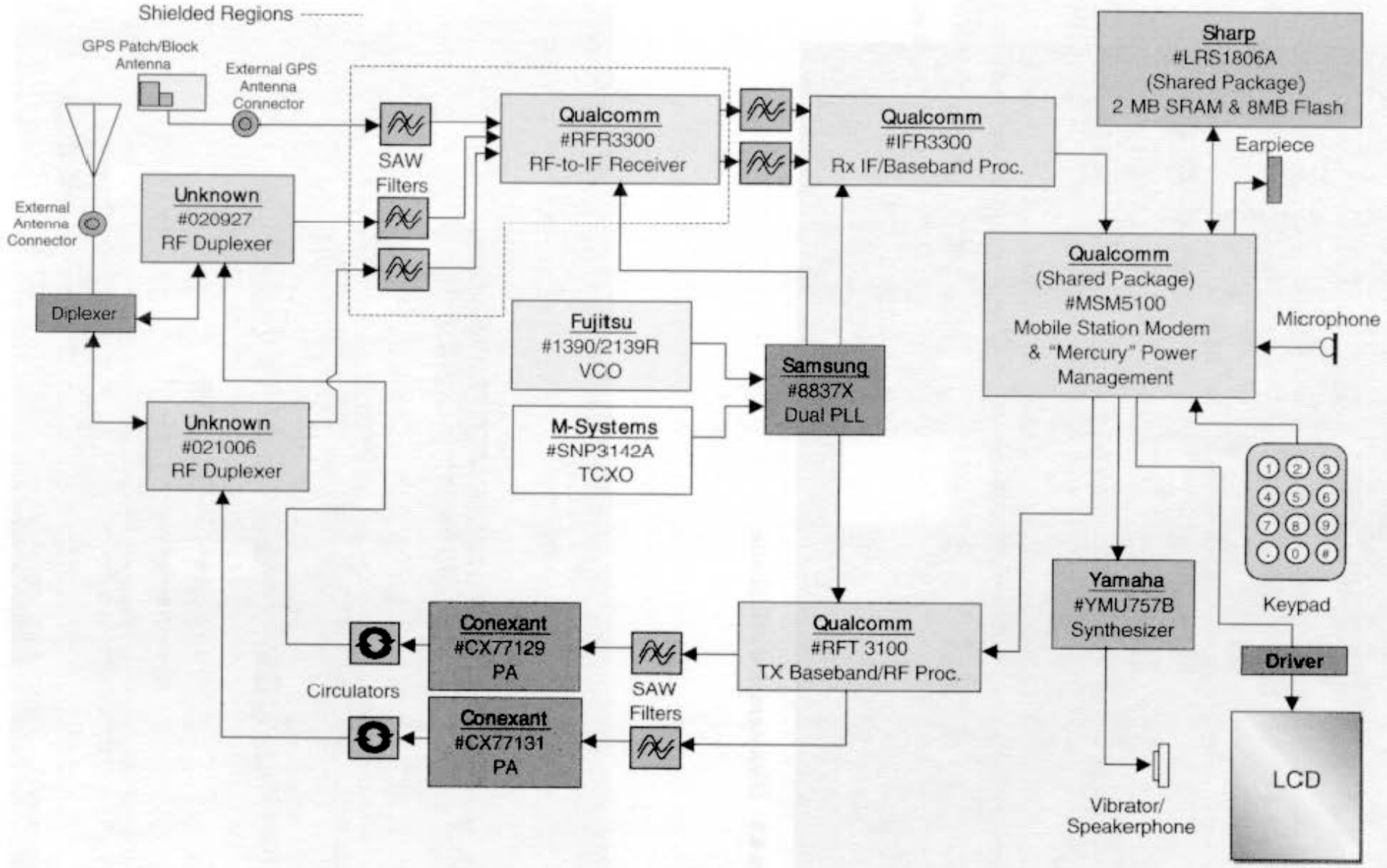


Figure 8.8 Simplified block diagram.

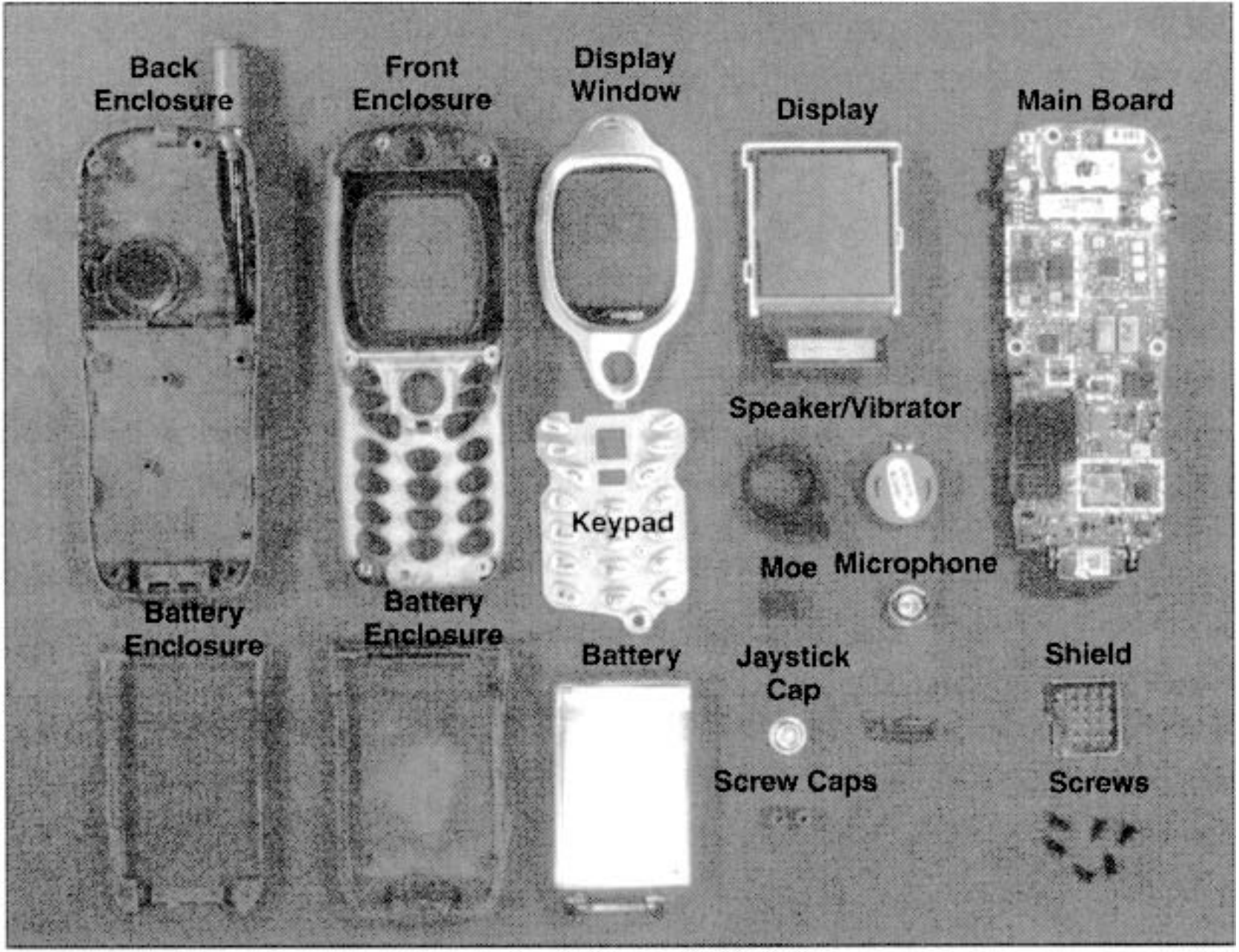


Figure 8.9 Disassembled cell phone.

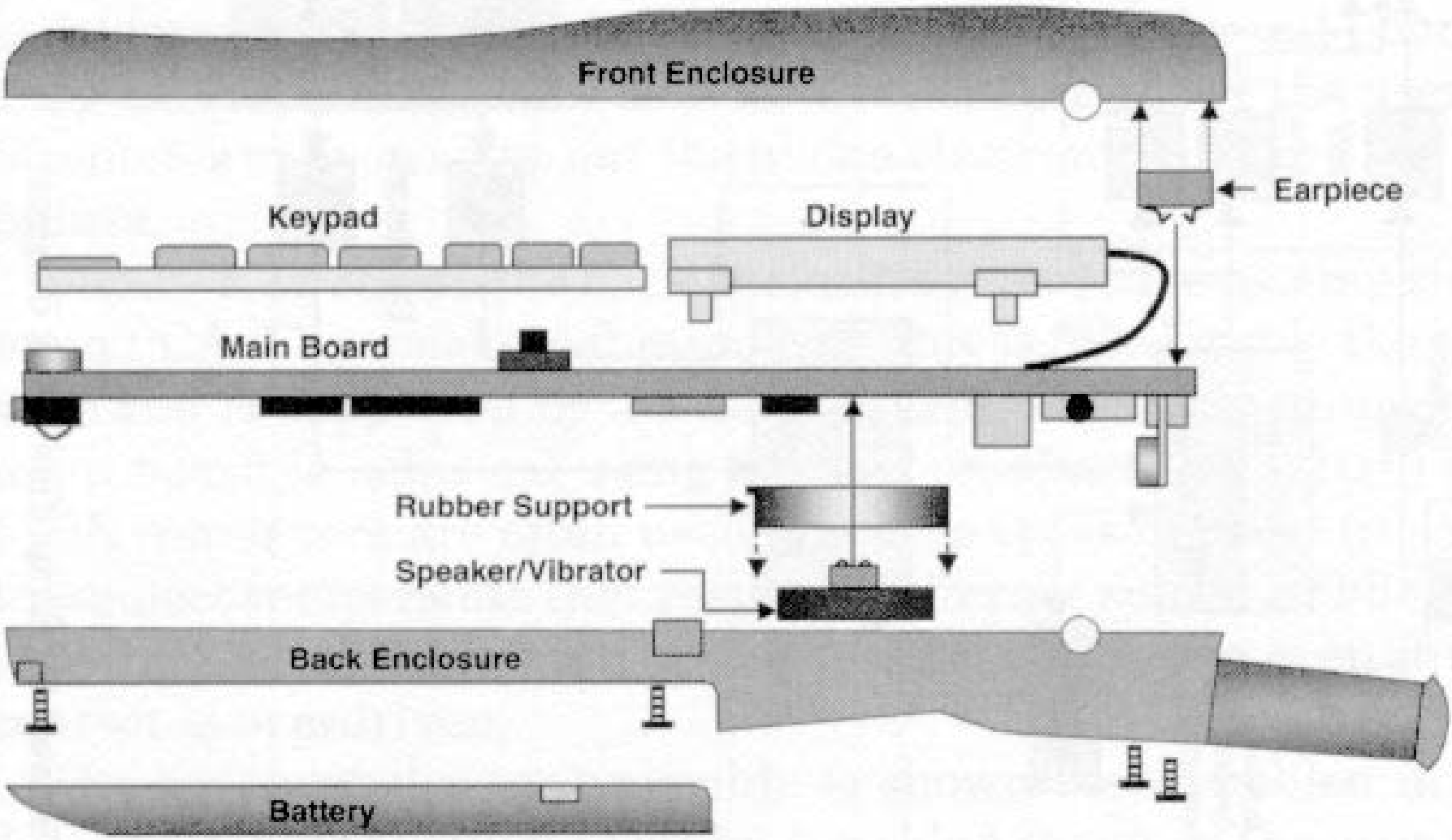


Figure 8.10 Component arrangement.

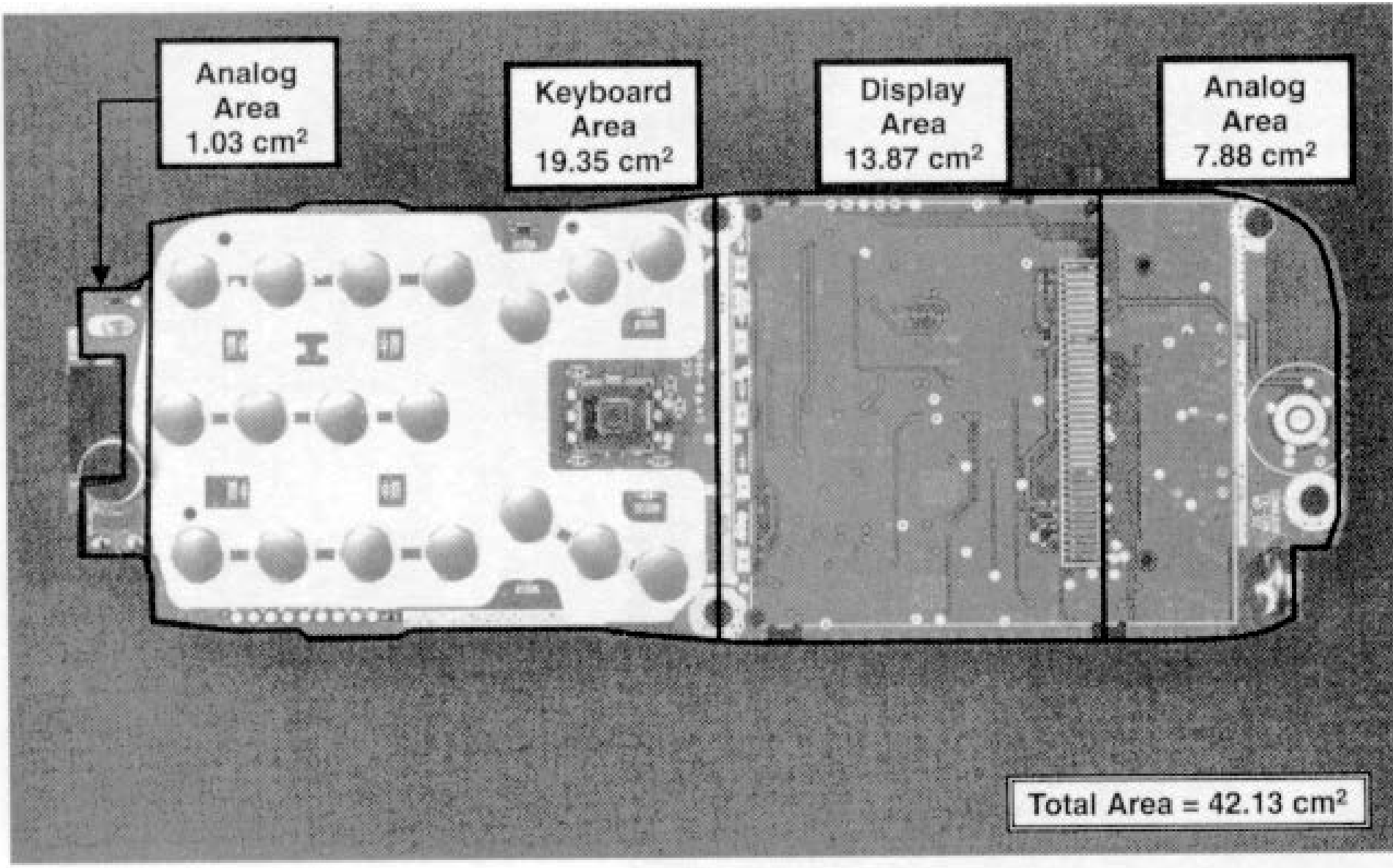


Figure 8.24 Main board—functional area photo side 1.

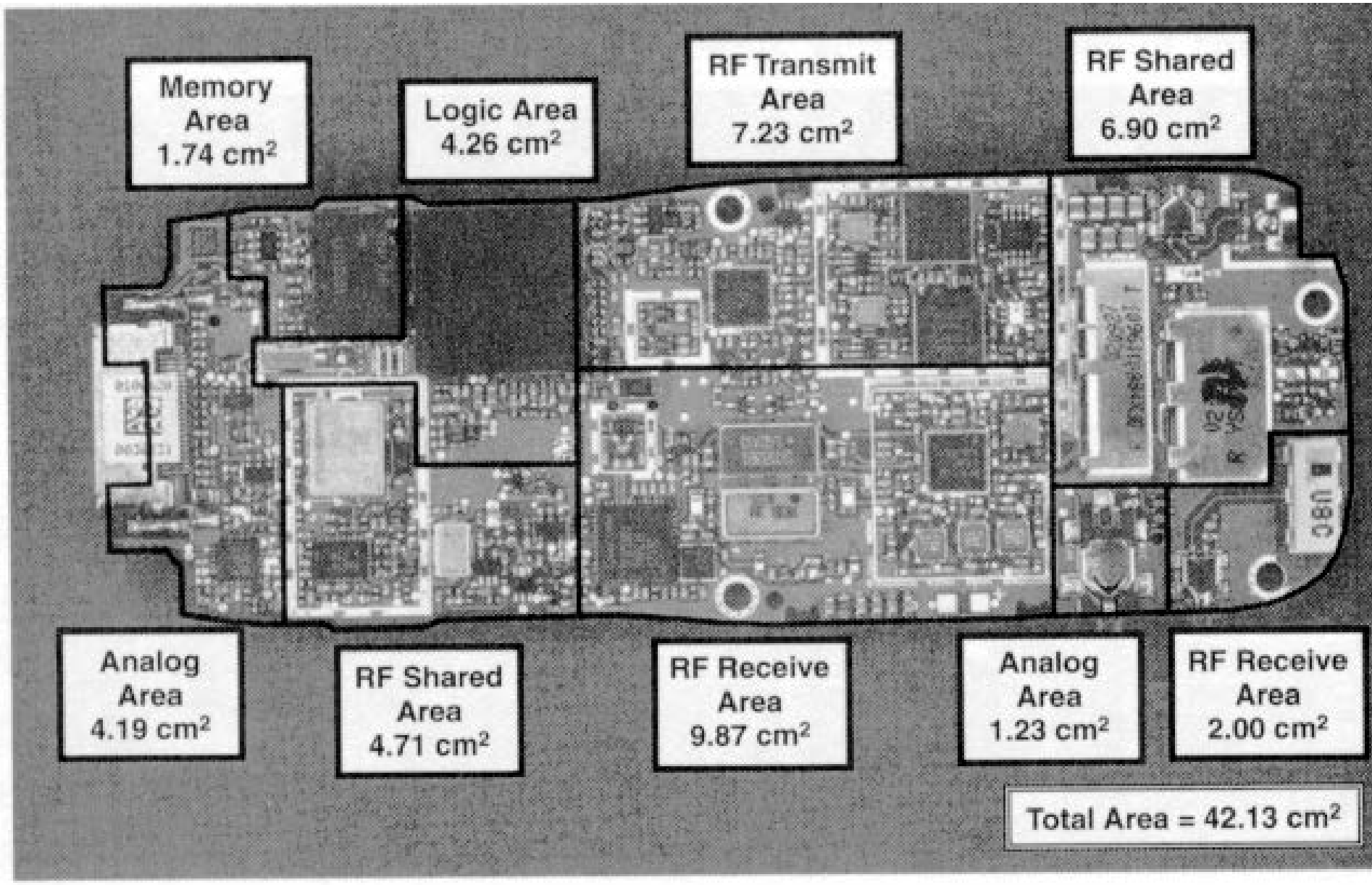


Figure 8.25 Main board—functional area photo side 2.

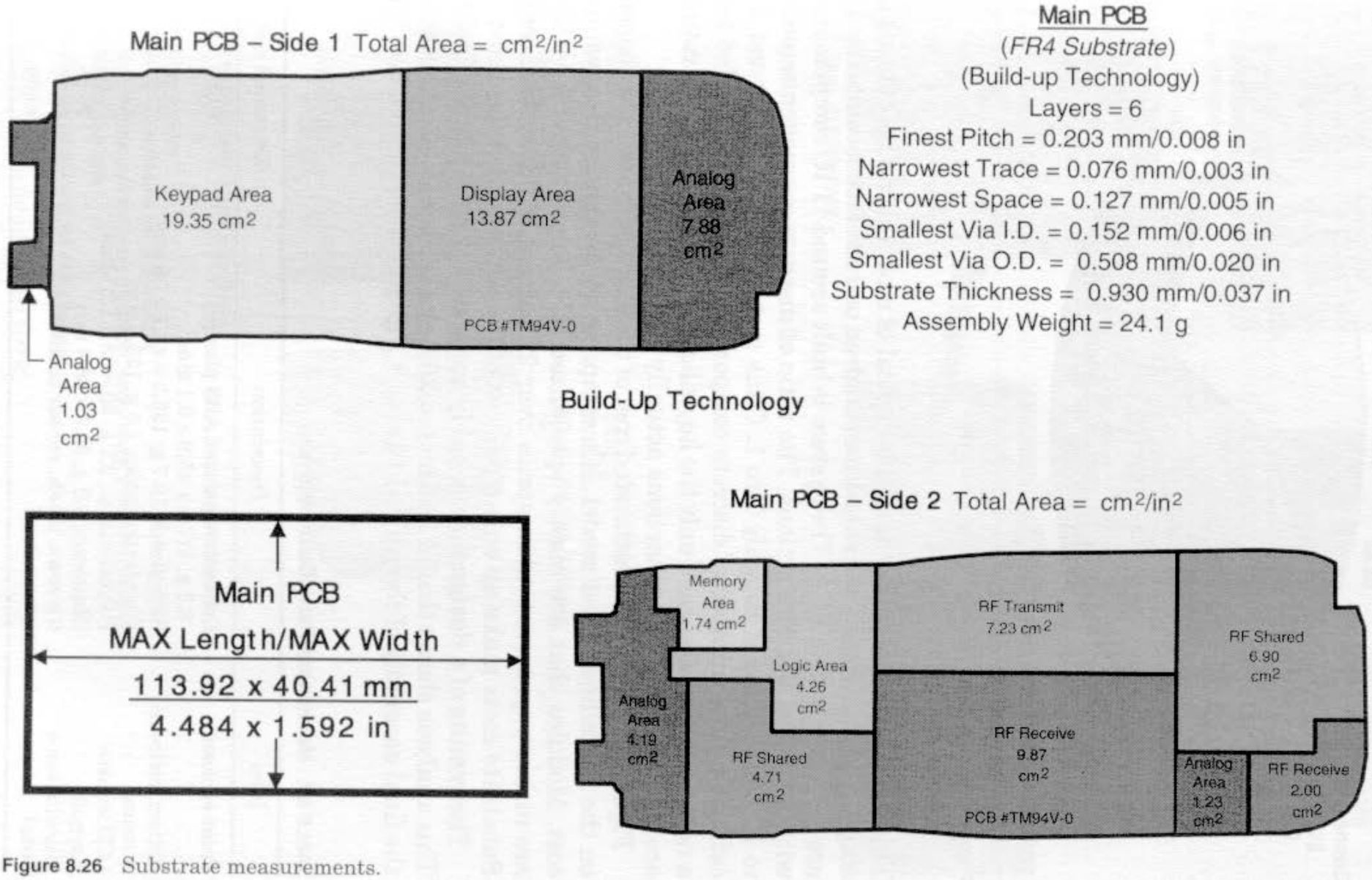


Figure 8.26 Substrate measurements.

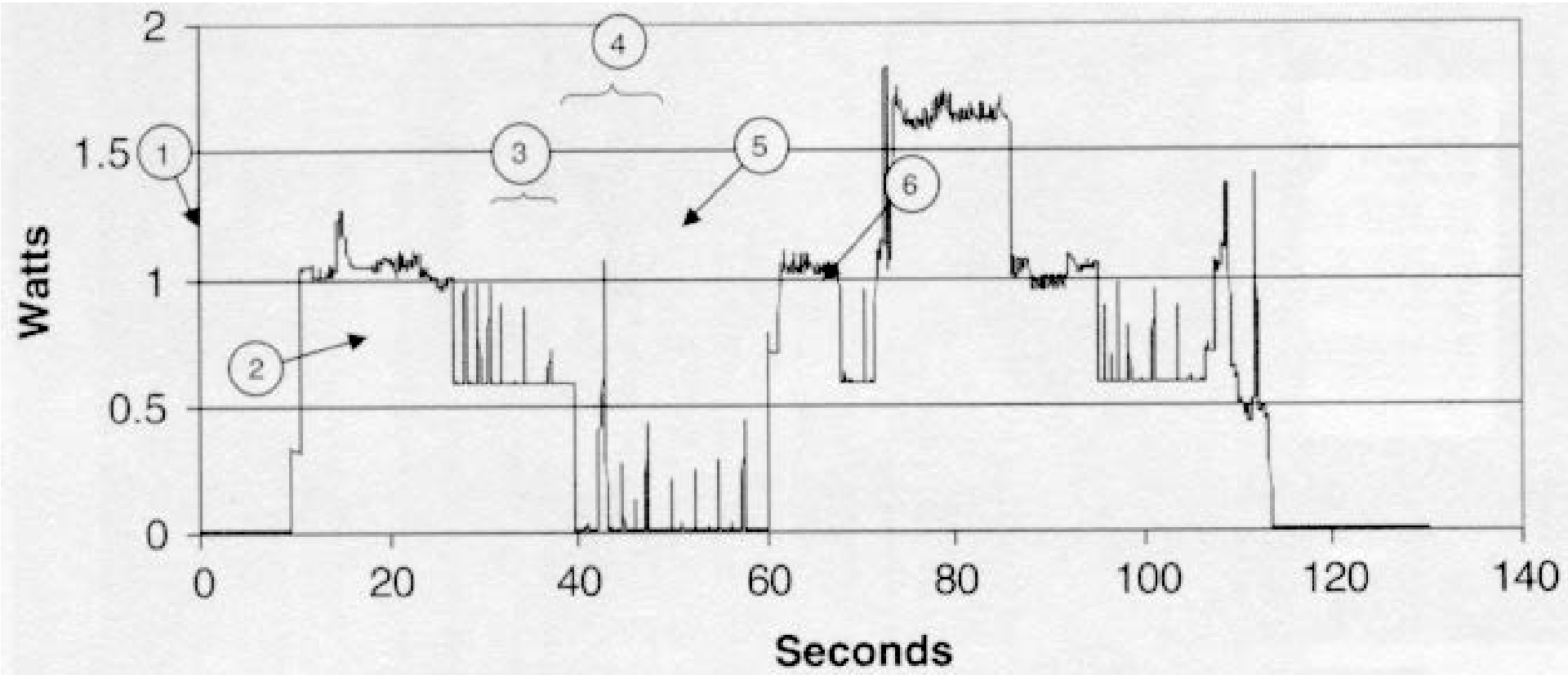


Figure 8.7 Power measurements.

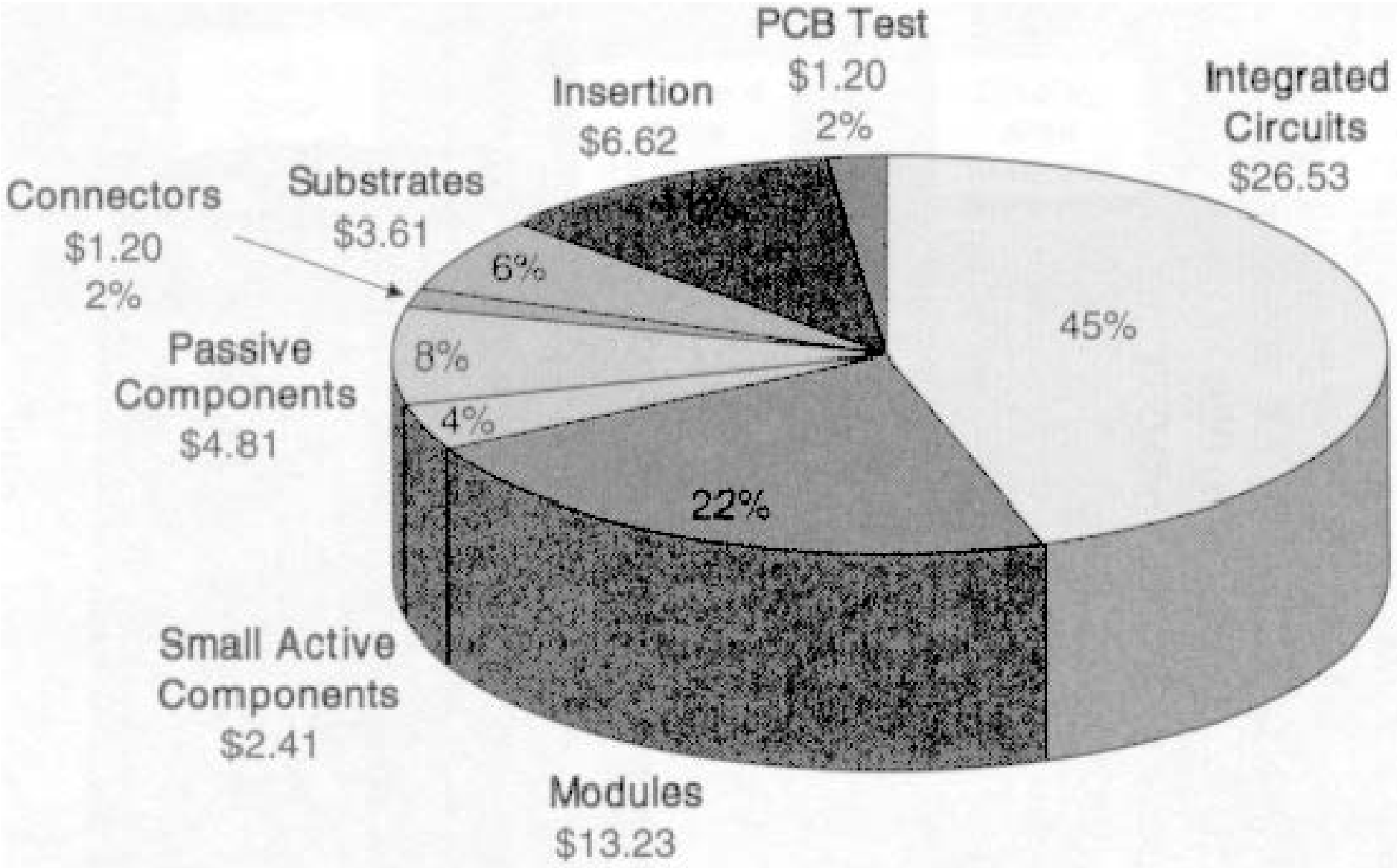
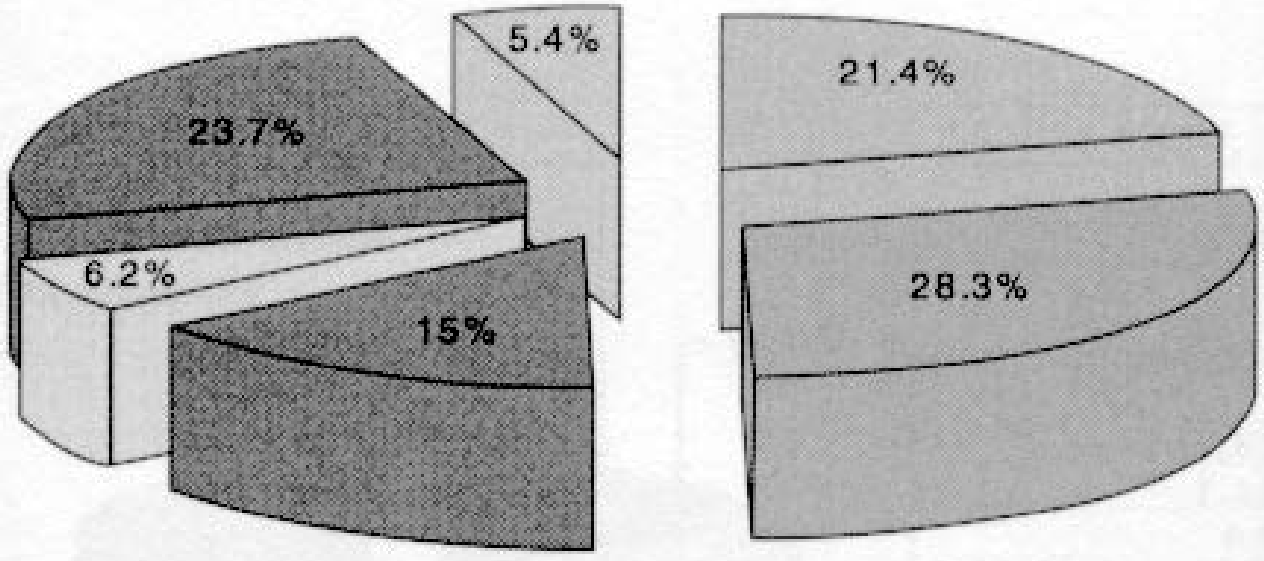


Figure 8.27 Electronic assembly cost estimates.

TABLE 8.2 Mechanical Parts Cost Estimates

Item	Description	Estimated cost
Front enclosure	Conductive painted ABS plastic, 8.2 g, 117.6 × 45.9 × 9.1 mm	$0.80
Bottom enclosure	ABS plastic 12.7 g, 135.2 × 43.1 × 18 mm	$0.46
Antenna	Wire (extendable), 3.5 g, 123.8 mm	$0.35
LCD window	Polycarbonate, 2.7 g, 39 × 38 × 1.25 mm	$0.48
Keypad	Elastomer, 3.2 g, 55.5 × 36.9 mm	$0.65
Miscellaneous	6 screws, labels, rubber buttons, etc.	$0.30
Total		**$3.04**

DFA Index (%)	10.58%
Total Assembly Time (s)	249.28 s
Total Assembly Cost ($)	$0.69 (@$10/h, Taiwan)
Total Number of Steps	26



- Theoretically necessary items
- Fasteners
- Connectors
- Other candidates for elimination
- Operations (adhesive application, secondary soldering, staking)
- Reorientations

*From Boothroyd Dewhurst, Inc. DFMA Software

Figure 8.29 Design for assembly (DFA).

Total Cost	
Electronic Assemblies	$59.50
Display	$3.68
Housing/Hardware (DFM)	$3.04
Battery Pack	$4.86
Final Assembly (DFA)	$0.69
Total	**$71.77**

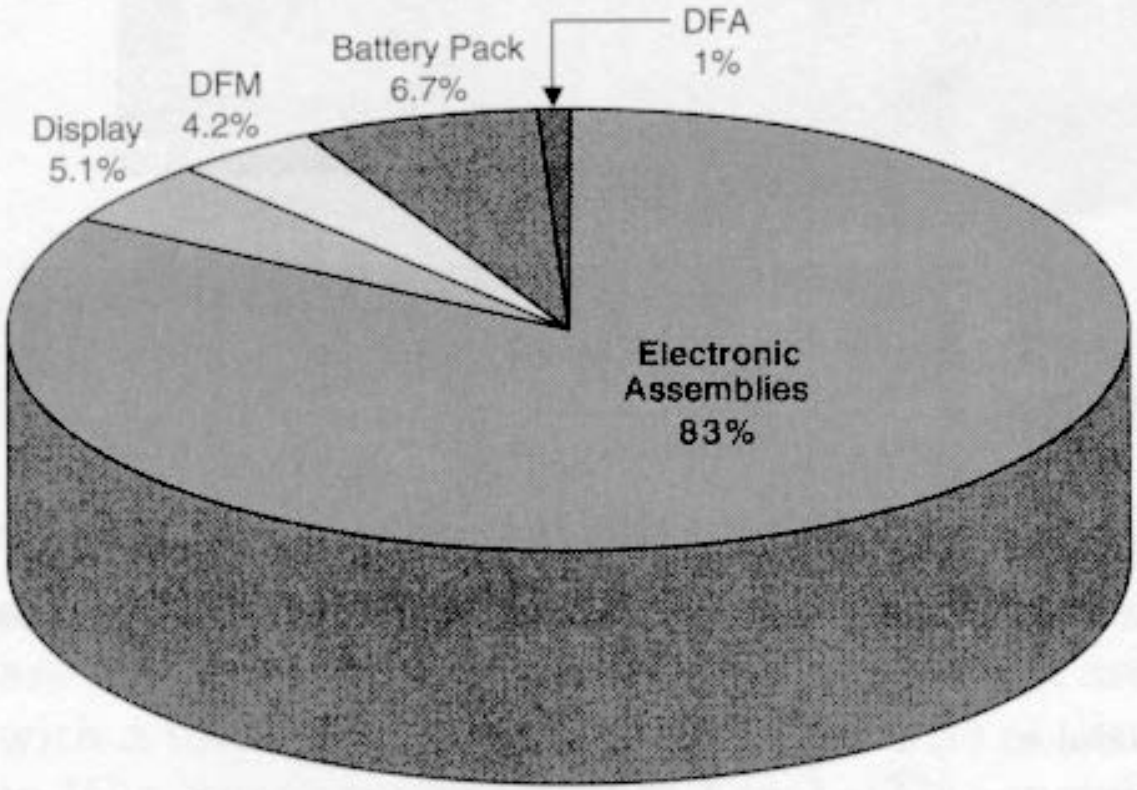


Figure 8.30 Cost estimate summary.

Item (CDM-8300)	Weight (g)	
Enclosures	23.6	
Front Enclosure		8.2
Back Enclosure (Incl. Ant.)		12.7
Display Window		2.7
Battery	28.1	
Main Board	24.1	
Display Assembly	6.4	
Keypad	3.2	
Miscellaneous	5.3	
Earpiece		0.7
Speaker/Vibrator Assembly		3.8
Screws (6), rubber pieces, etc.		0.6
Total	90.7	

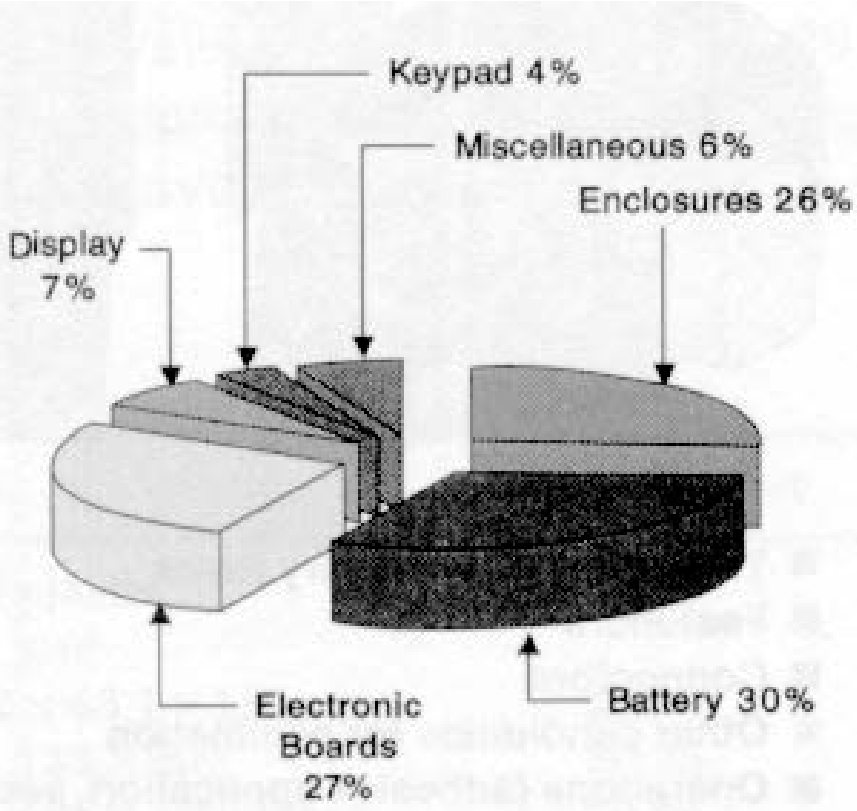


Figure 8.31 Component weights.

CHAPTER 9

PC EXAMPLE

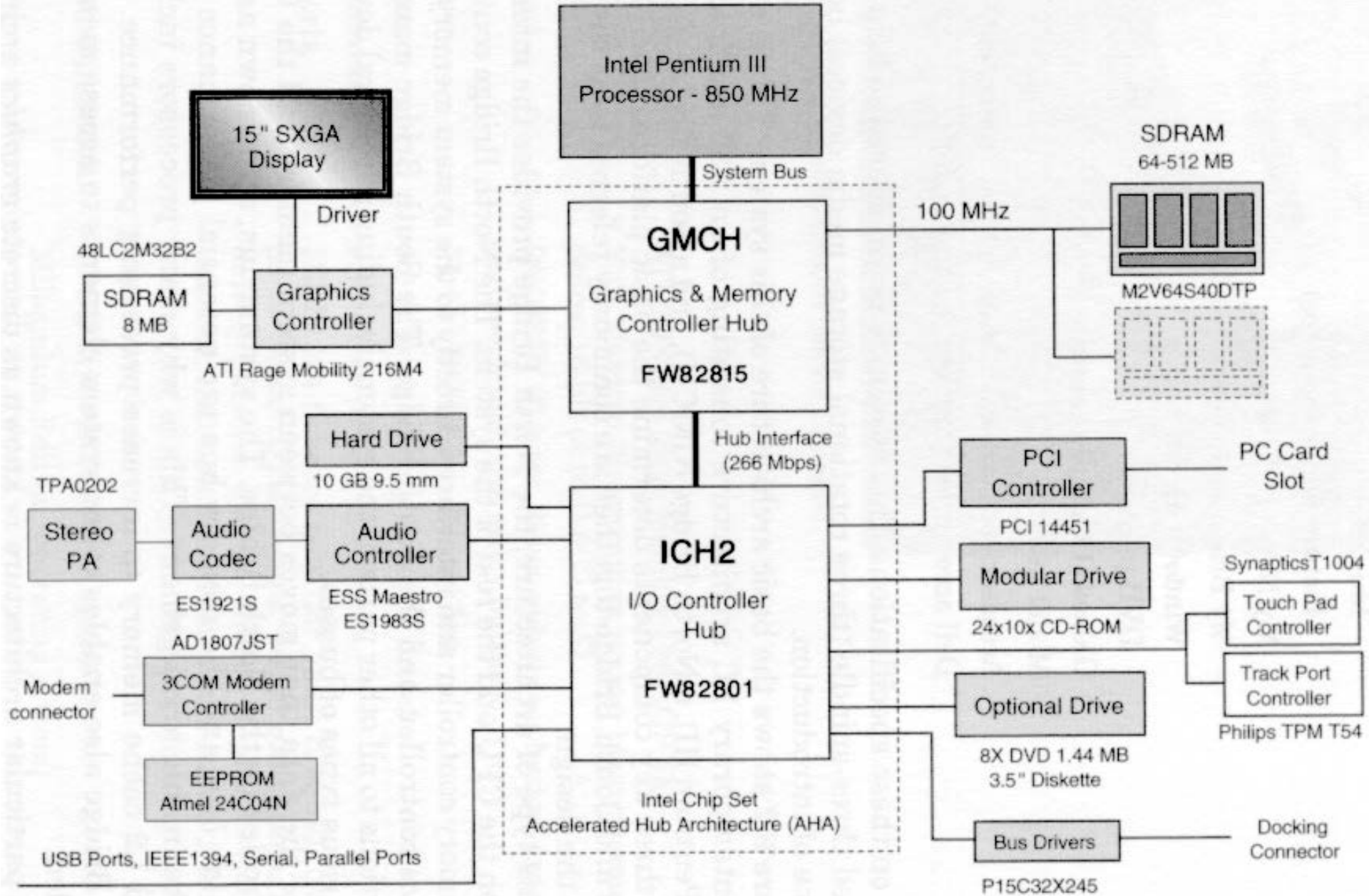


Figure 9.2 Basic block diagram.

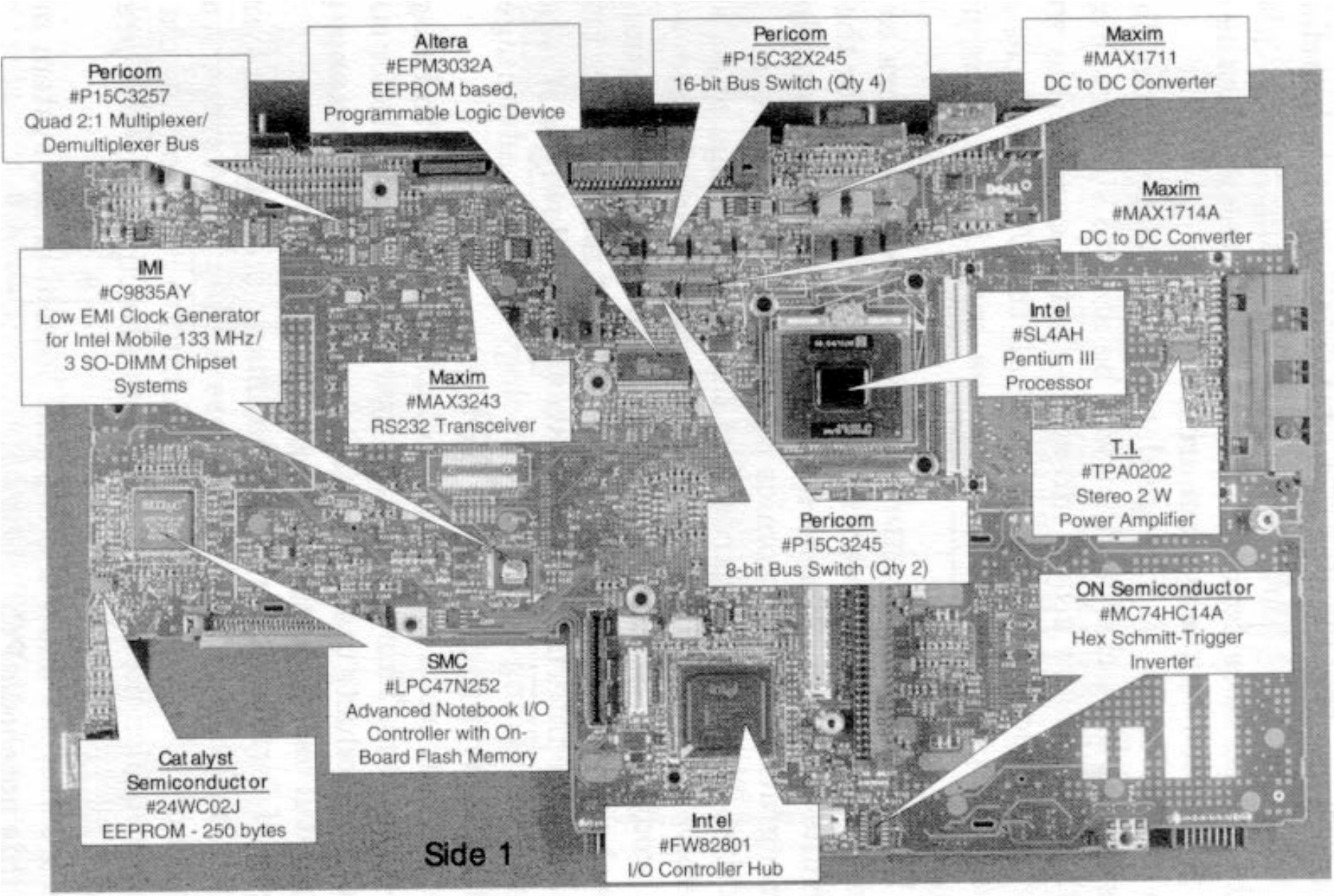


Figure 9.3 Main board (top).

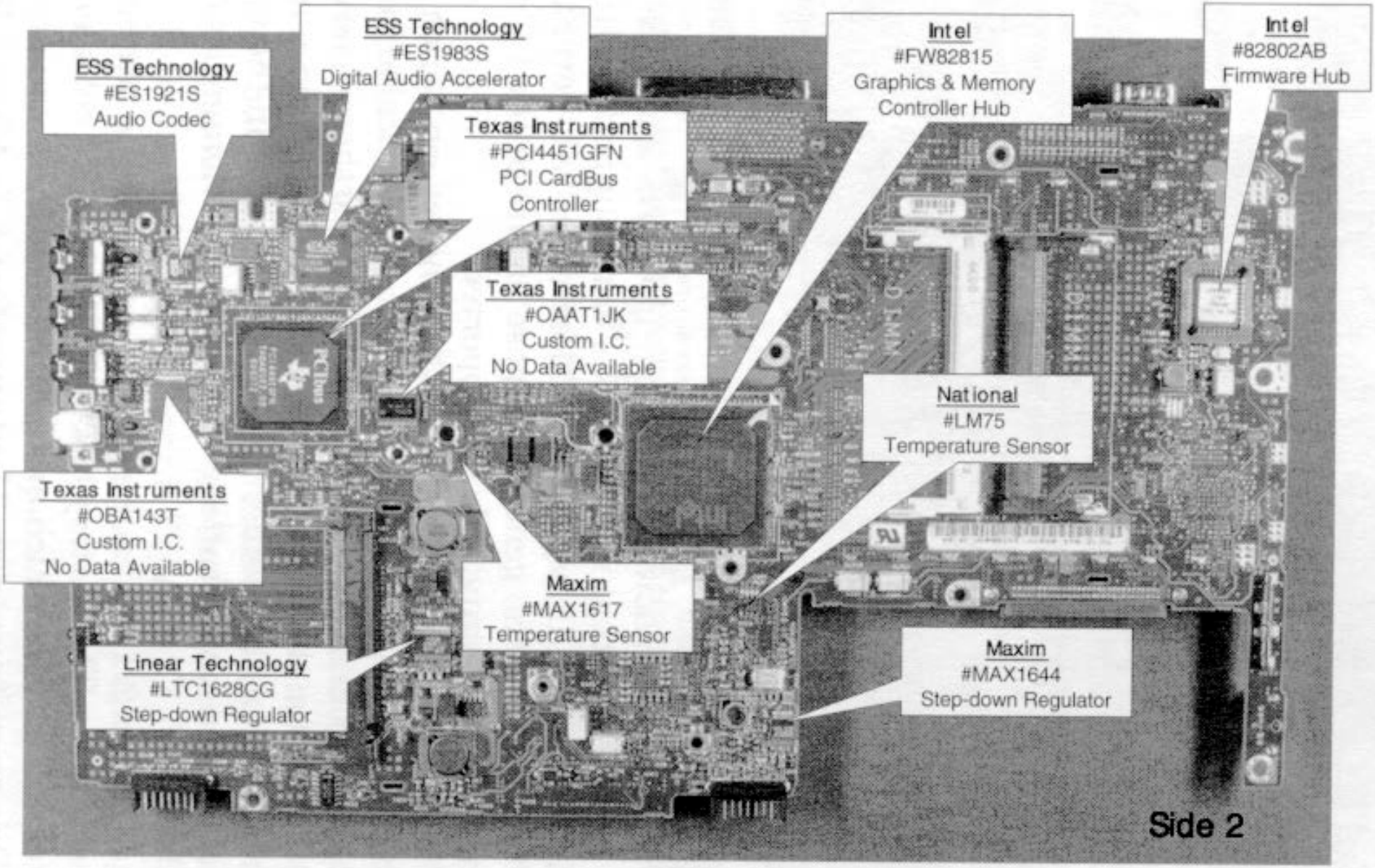
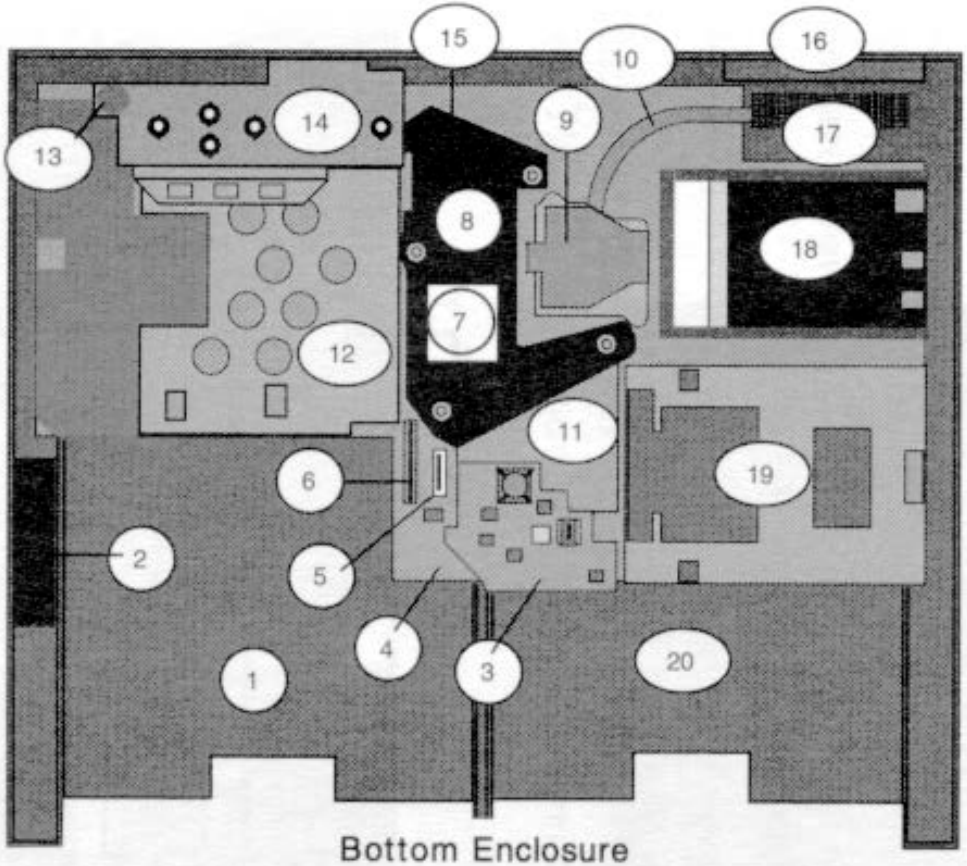


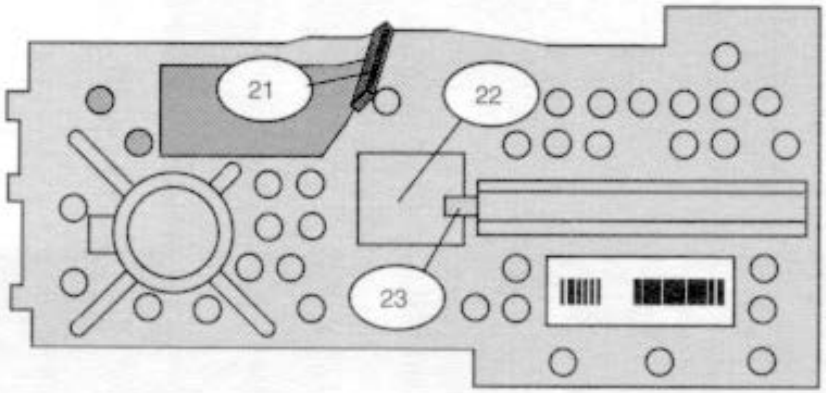
Figure 9.4 Main board (bottom).



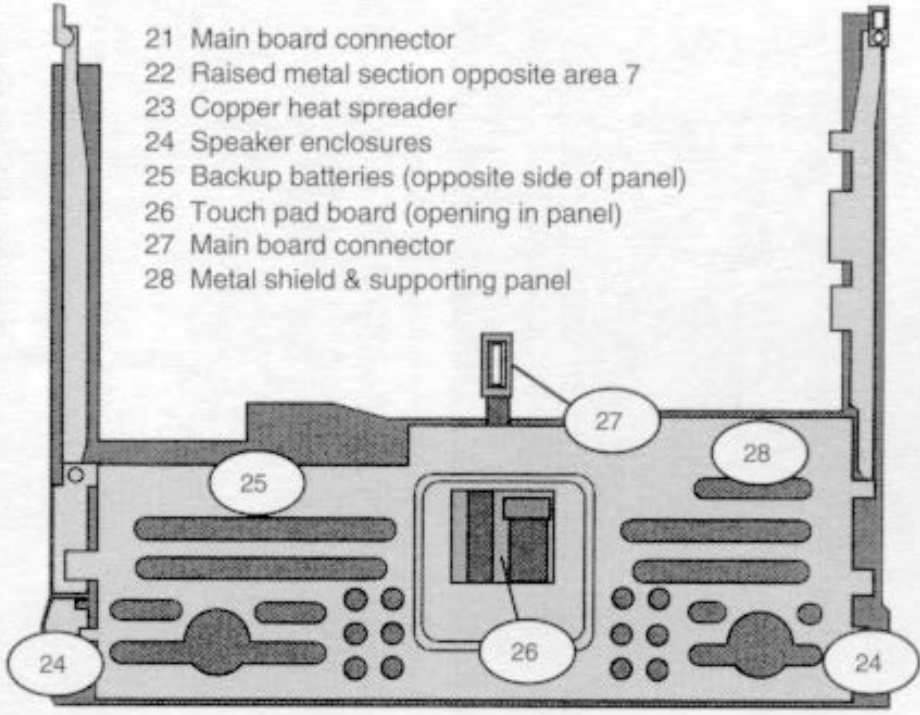
Bottom Enclosure

1 Modular bay
2 Antenna cover
3 Power board
4 Main board
5 Touch panel connector
6 Keyboard connector
7 TIM over graphic chip
8 Graphics board cover
9 Pentium III heat exchanger
10 Copper heat pipe
11 Graphics board
12 Modular bay
13 Microphone
14 Control board
15 Display connector
16 Dual fans
17 Exchanger fins
18 PC card slots
19 Hard drive bay
20 Battery bay

Bottom Side of Keyboard



21 Main board connector
22 Raised metal section opposite area 7
23 Copper heat spreader
24 Speaker enclosures
25 Backup batteries (opposite side of panel)
26 Touch pad board (opening in panel)
27 Main board connector
28 Metal shield & supporting panel



Bottom Side of Touch Pad Panel

Figure 9.9 Component arrangement.

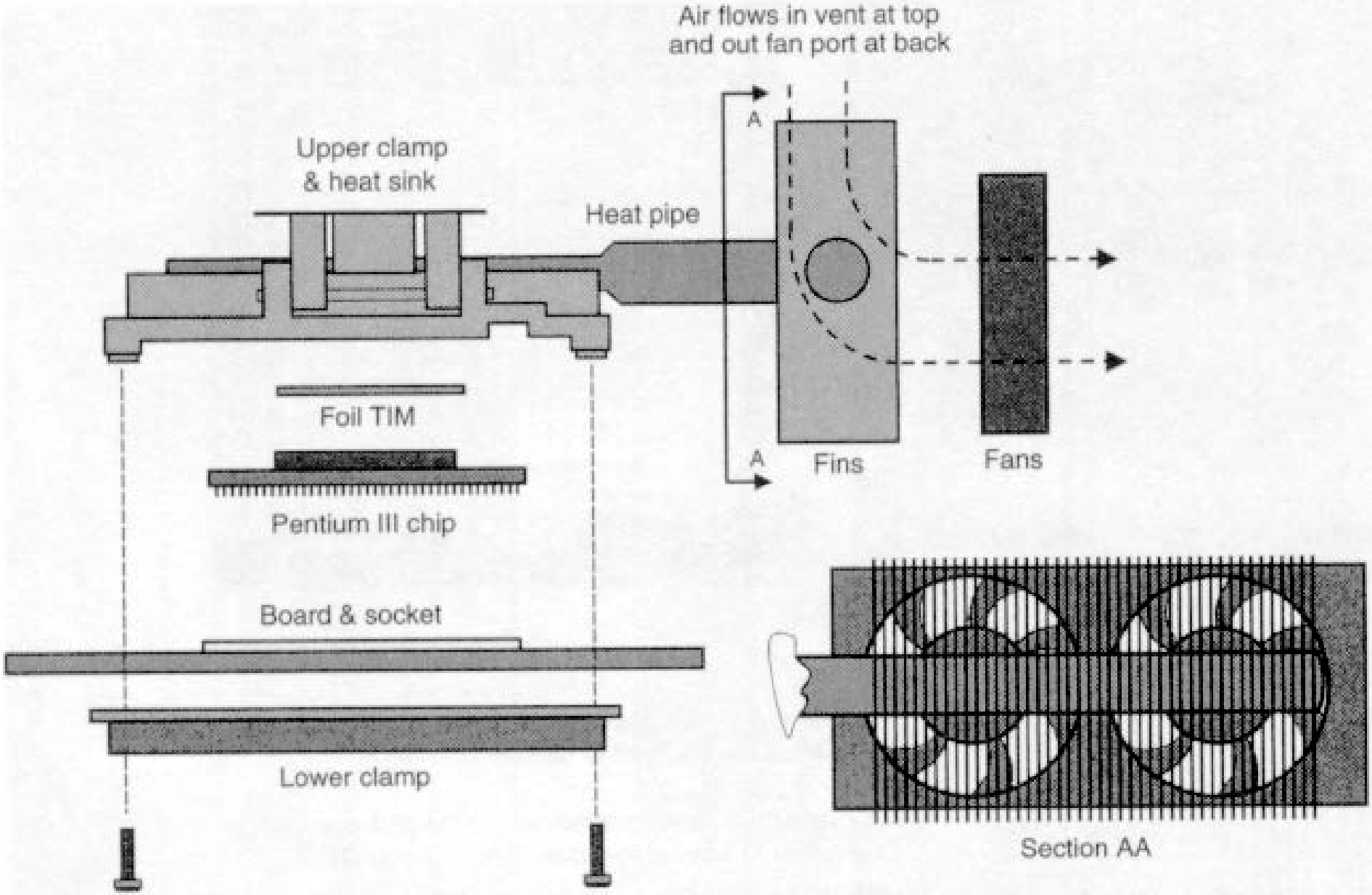


Figure 9.37 Thermal diagram.

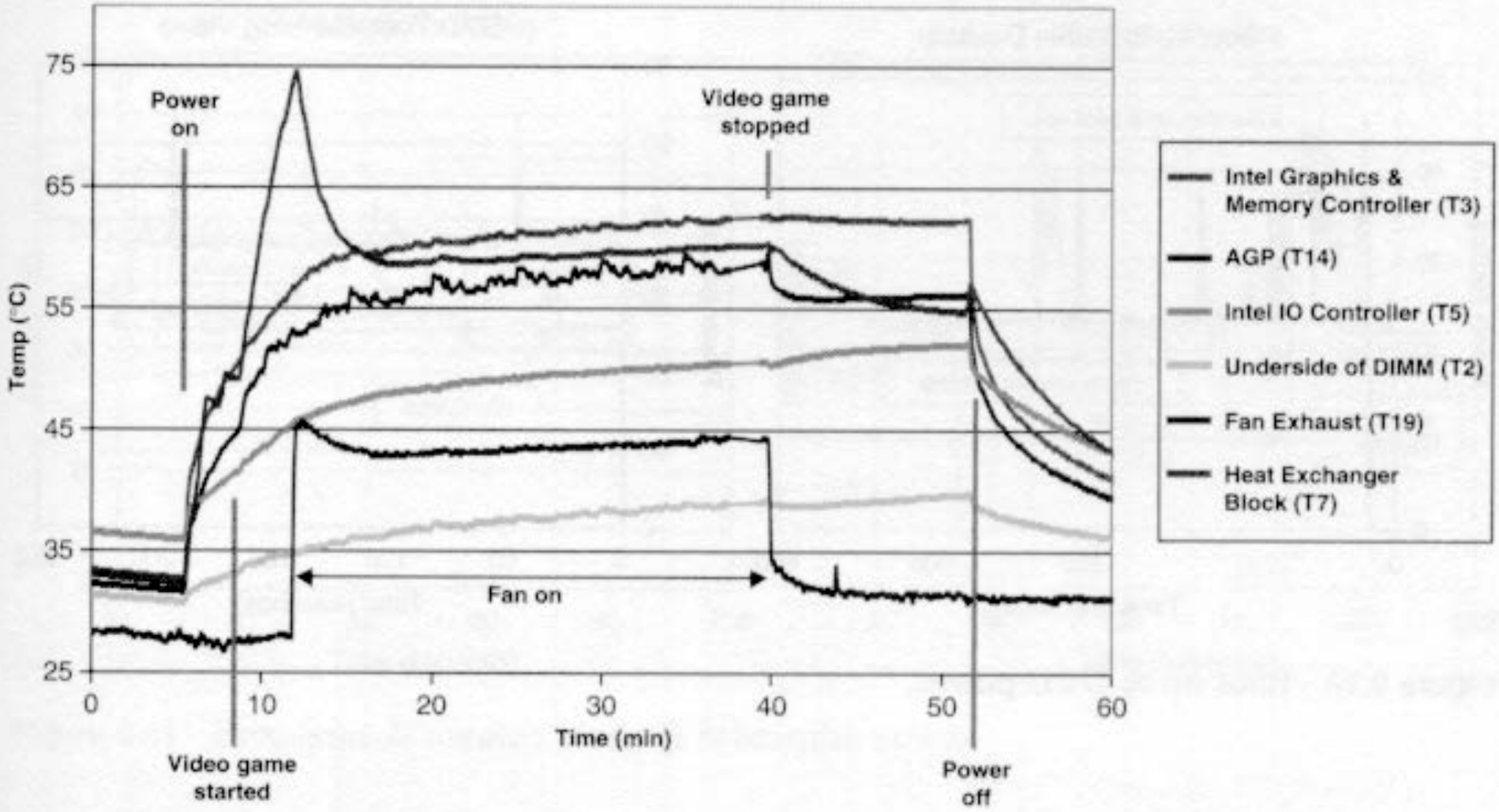


Figure 9.38 Thermal test results.

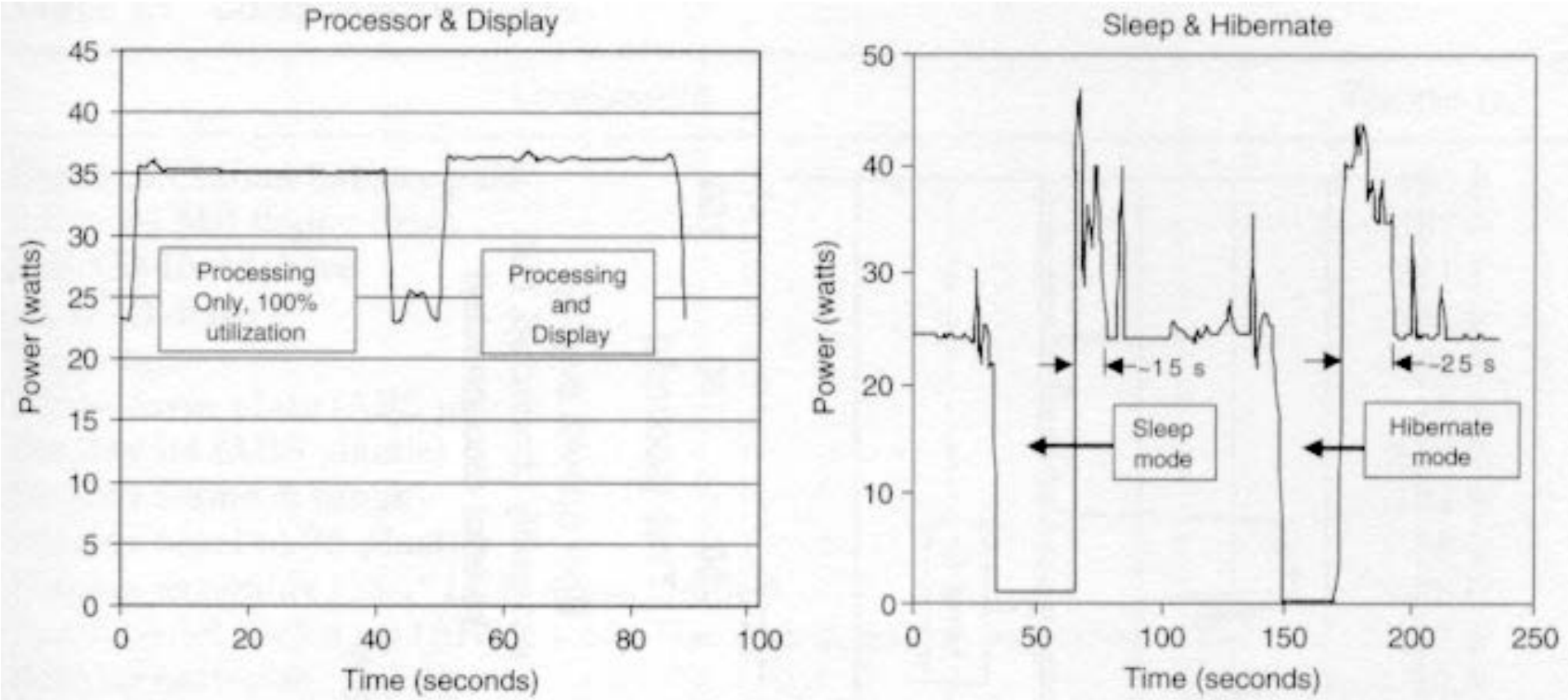


Figure 9.41 Processor & display/sleep & hibernate power.

TABLE 9.1 Component Weights

Component	Weight (g)
Eight cell Li-ion battery pack	420.8
3.5" 1.44 MB floppy drive	237.0
24X CD-ROM drive	231.1
8X DVD drive	344.9
Keyboard	173.9
Hinge cover plate (ABS plastic)	33.2
Display lid (ABS plastic)	237.2
Display frame & hinge	194.9
Display bezel (ABS plastic)	38.0
Display assembly (15.1" LCD & electronics)	698.0
Touch panel enclosure (ABS plastic, less frame, board, batteries)	127.3
Backup batteries	12.5
Touch pad board	8.8
Touch pad frame & speaker enclosures	74.5
Graphics board	35.4
Power/interface board	14.0
Control board	9.7
Graphic board cover (shield & TIM)	4.0
Control board shield	3.6
Heat exchanger (including copper heat pipe & fins)	45.9
Bottom enclosure (ABS plastic, less back connector frame & fans)	229.6
Back connector frame (aluminum, less fans)	22.0
Dual fans	12.0
Modem & memory expansion covers (ABS plastic)	64.0
3COM modem card	9.6
Memory board (DIMM)	9.8
Heat exchanger clamps (2 pieces)	30.5
Drive bay metal enclosure/shields (HD & CD-ROM)	66.8
PC card slots	25.3
Main board	334.1
Miscellaneous (80 screws, tape, springs, etc.)	21.0
Total	**3769.4 (8.29 lb)**

TABLE 9.2 Notebook Computer IC Metrics

Board description	No. of IC's total	No. of analog ICs	No. of digital ICs	No. of IC IO's	Die area (in^2)	IC footprint area (in^2)	IC IO's/(IC footprint area)
Memory PCB	9	—	9	440	1.25	3.48	126
Power PCB	7	6	1	72	0.06	0.38	188
Track Flex PC	—	—	—	—	—	—	—
Graphics PCB	8	3	5	584	0.54	2.67	219
Control PCB	1	1	—	8	0.00	0.05	167
Track pad PCB	3	—	3	106	0.05	0.41	260
Modem PCB	4	—	4	168	0.08	0.80	210
Main PCB	50	16	34	2,827	0.81	10.00	283
IC total	**82**	**26**	**56**	**4,205**	**2.79**	**17.79**	**236**

TABLE 9.3 Notebook Computer Electronic Packaging Metrics

Board description	Board area	No. of PCB layers	No. of parts	No. of connections	PCB tiling density (die area/Bd) (%)	Connection density (conn./ Bd area)	Routing density (trace length/ Bd area)	Part density (parts/ Bd area)
Memory PCB	3.29	6	50	618	37.90	188	145	15
Power PCB	3.12	4	105	351	2.06	113	58	34
Track Flex PC	8.40	2	23	82		10	18	3
Graphics PCB	9.39	10	226	1,479	5.80	158	96	24
Control PCB	5.09	2	37	125	0.04	25	27	7
Track pad PCB	4.91	4	43	200	0.97	41	41	9
Modem PCB	4.02	4	94	364	1.89	91	56	23
Main PCB	74.79	10	1,427	7,956	1.08	106	73	19
System total	**113.01**	—	**2,005**	**11,175**	**2.47**	**99**	—	**18**

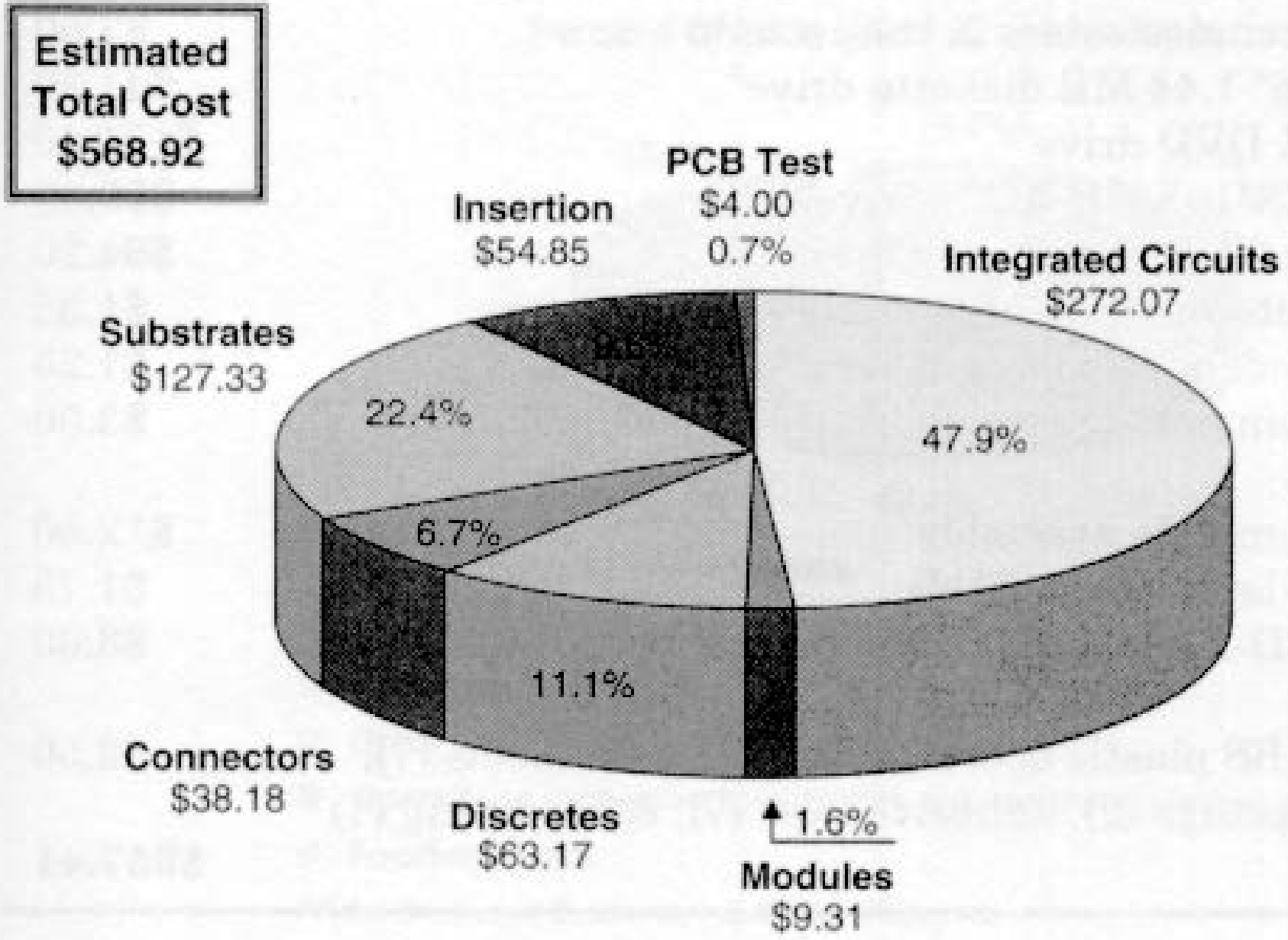
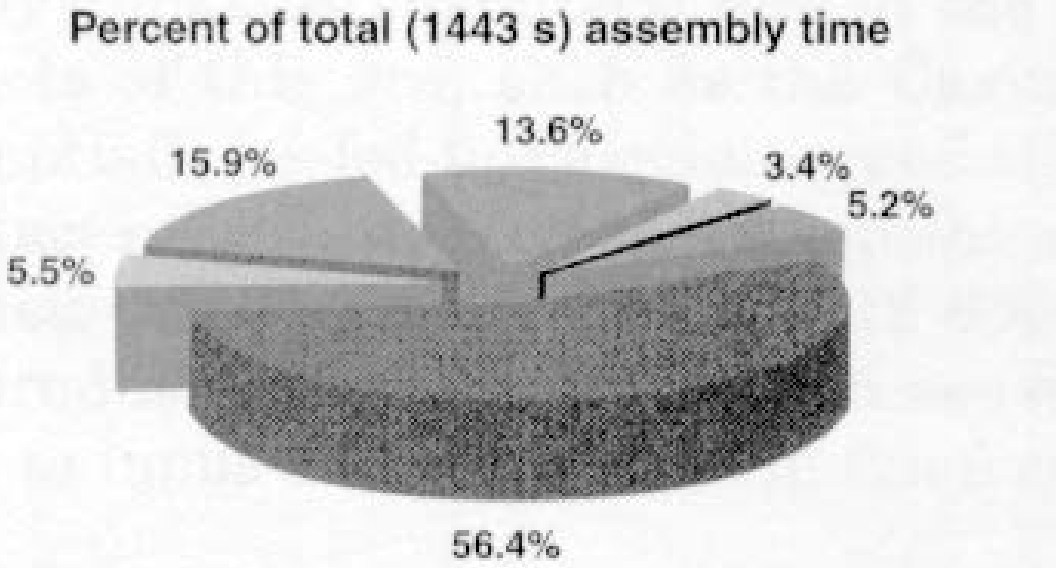


Figure 9.47 System electronics cost estimates.

TABLE 9.4 Cost Estimates for Mechanical Components and Mass Storage Modules

Item	Description	Estimated cost
ABS plastic enclosures		
Bottom enclosure	(includes metal shield, antenna, connector frame)	$3.28
Touch pad enclosures	(includes metal support frame)	$2.85
Display lid	(includes shielding, support bracket, hinge assembly)	$5.13
Hinge cover plate	(Includes light pipes)	$0.80
Display Bezel	(Includes adhesive tabs)	$0.60
Heat exchanger	(includes heat pipe, fins, 2-piece clamp assembly)	$15.00
Dual fan assembly	(includes cables & connectors)	$7.50
Drive modules	3.5" 1.44 MB diskette drive[a]	$41.40
	8X DVD drive[a]	$101.40
	24X/10X CD-ROM drive[a]	$59.40
	10 GB 9.5 mm hard drive[b]	$94.20
Cable assemblies	Antenna coaxial assembly w/connectors	$1.35
	Modem cable assembly w/connectors	$1.25
PC card slot (2 card slots)	Complete assembly	$3.50
Keyboard	Complete assembly	$12.50
Graphics board cover	(3-layer cover, TIM)	$1.75
Metal enclosures/ shielding	(CD-ROM & HD bays, control board shield)	$3.00
Miscellaneous	(ABS plastic doors (2), screws (80), labels (7), springs (2), adhesive tape (7), & foil lining (1)	$2.50
Total		**$357.41**

DFA index (%)	2.7%
Total assembly time (s)	1443
Total assembly cost ($)	$12.02 (@$30/h)



*From Boothroyd Dewhurst, Inc. DFMA release 8.0

Figure 9.48 Design for assembly.

Dell Latitude C800 Laptop	Cost
Electronic assemblies	$568.92
Display	$398.85
Housing/hardware (DFM)	$357.41
Battery pack	$69.40
Final assembly (DFA)	$12.02
Total	$1,406.60

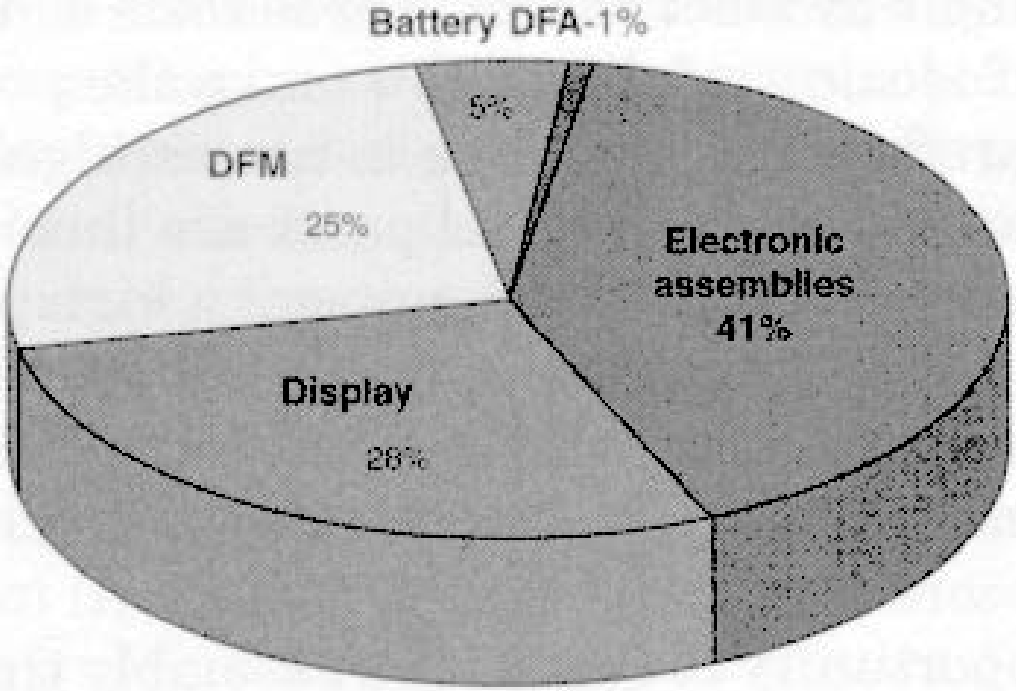


Figure 9.49 Notebook cost summary.

CHAPTER 10

ASSISTANT EXAMPLE

Figure 10.6 Pilot PDA.

Figure 10.8 Nokia 9000 Communicator.

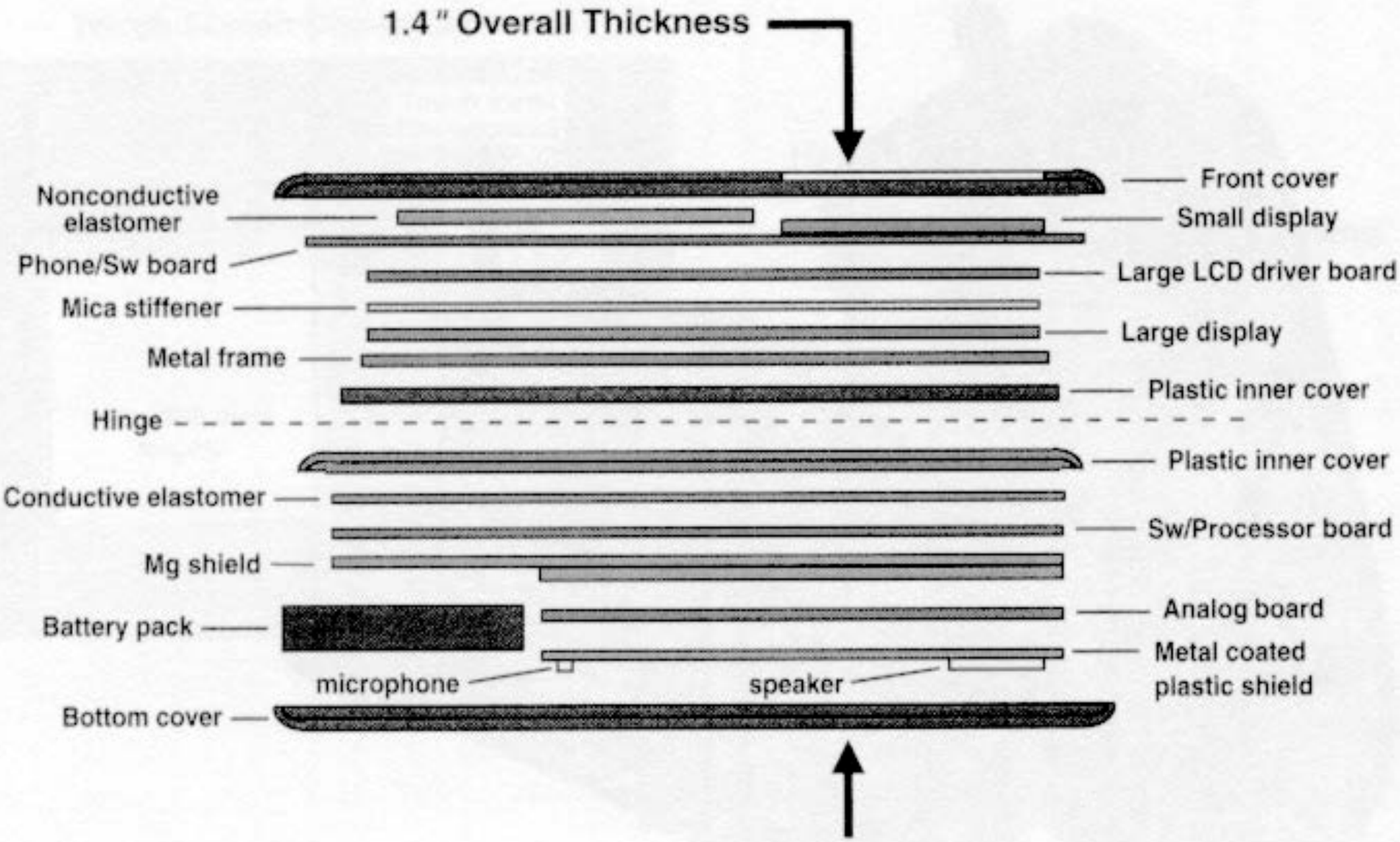


Figure 10.10 Subassembly stacking.

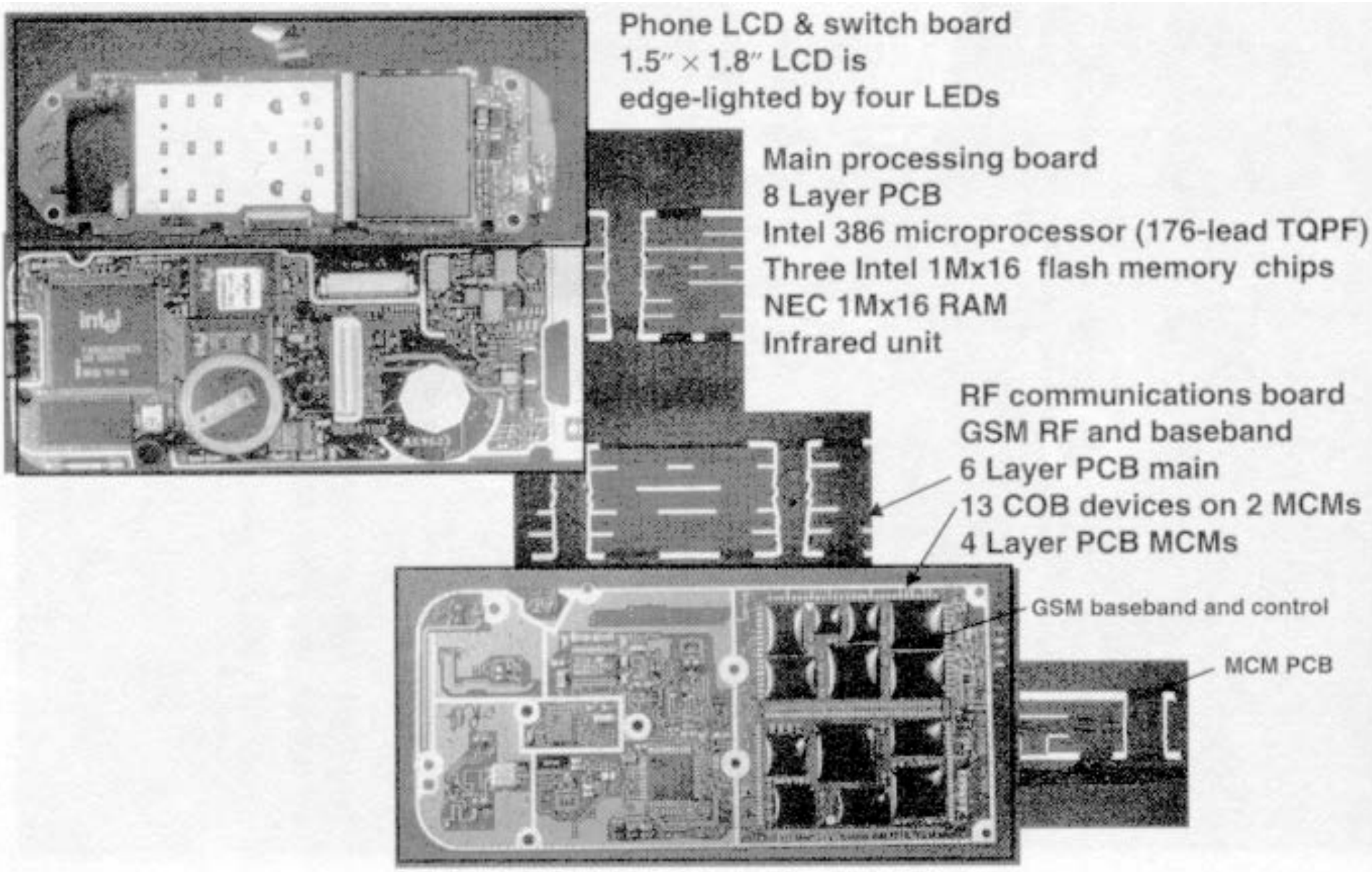


Figure 10.11 Nokia 9000 electronic assemblies.

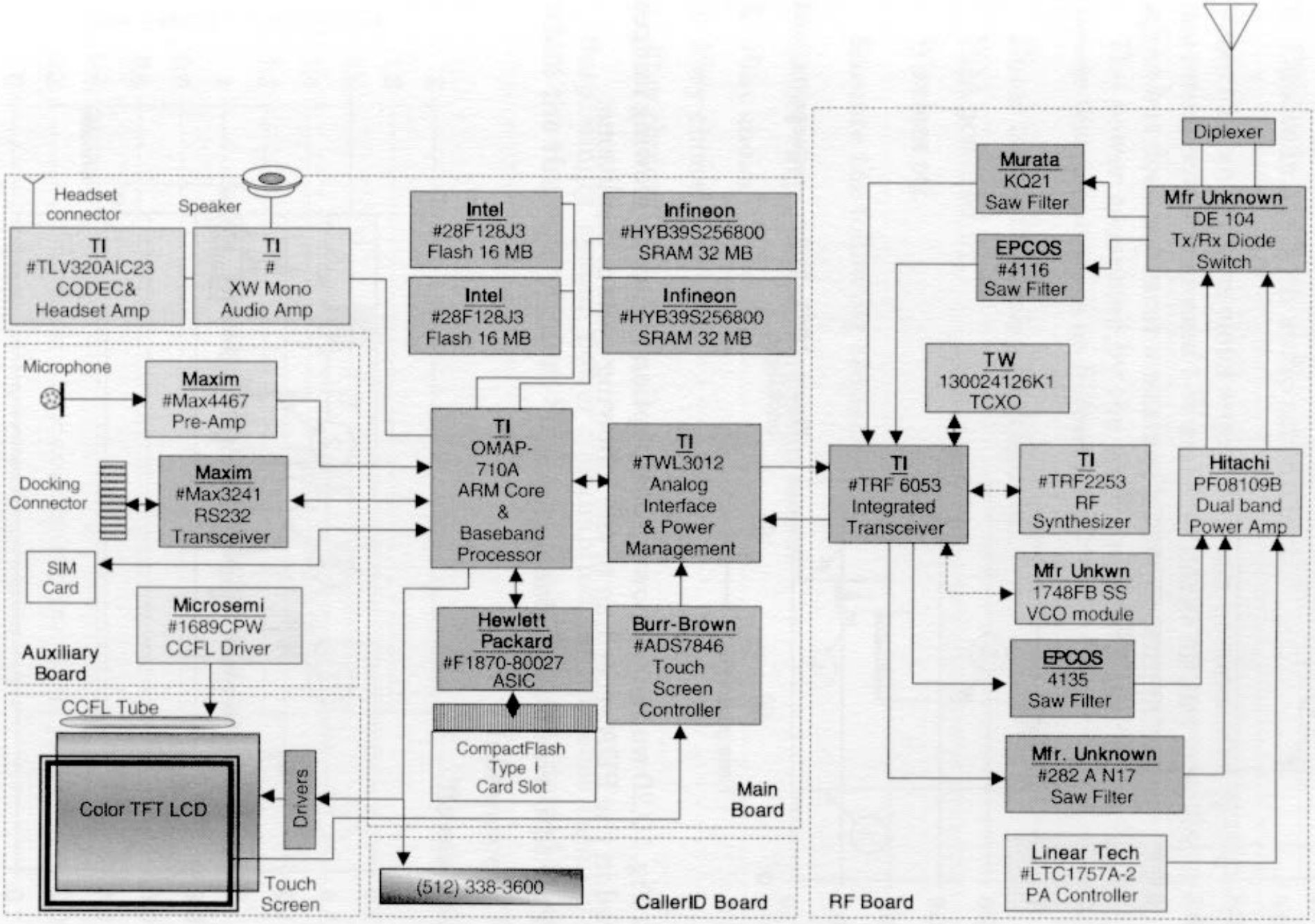


Figure 10.18 Simplified block diagram.

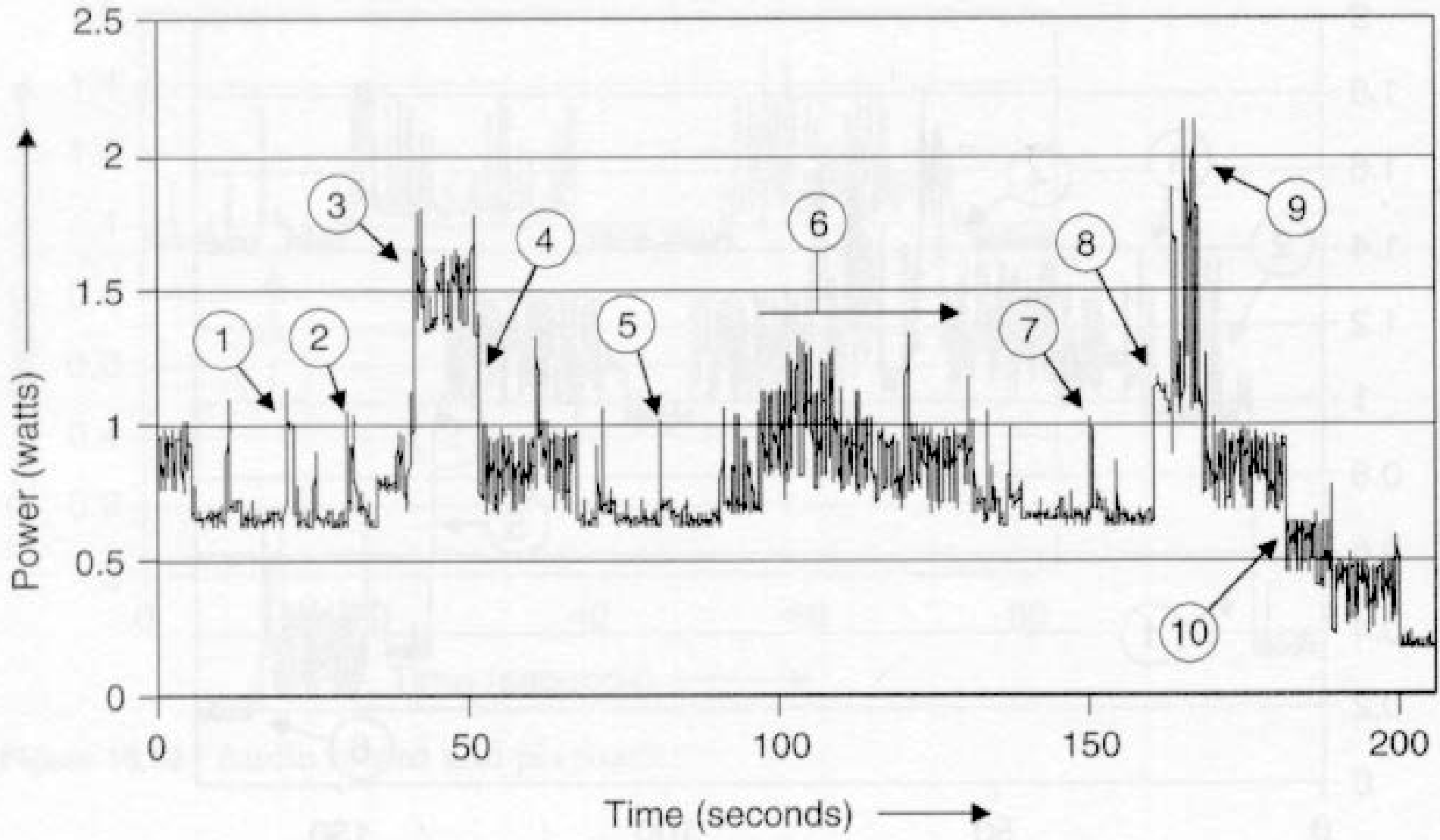


Figure 10.24 PDA applications.

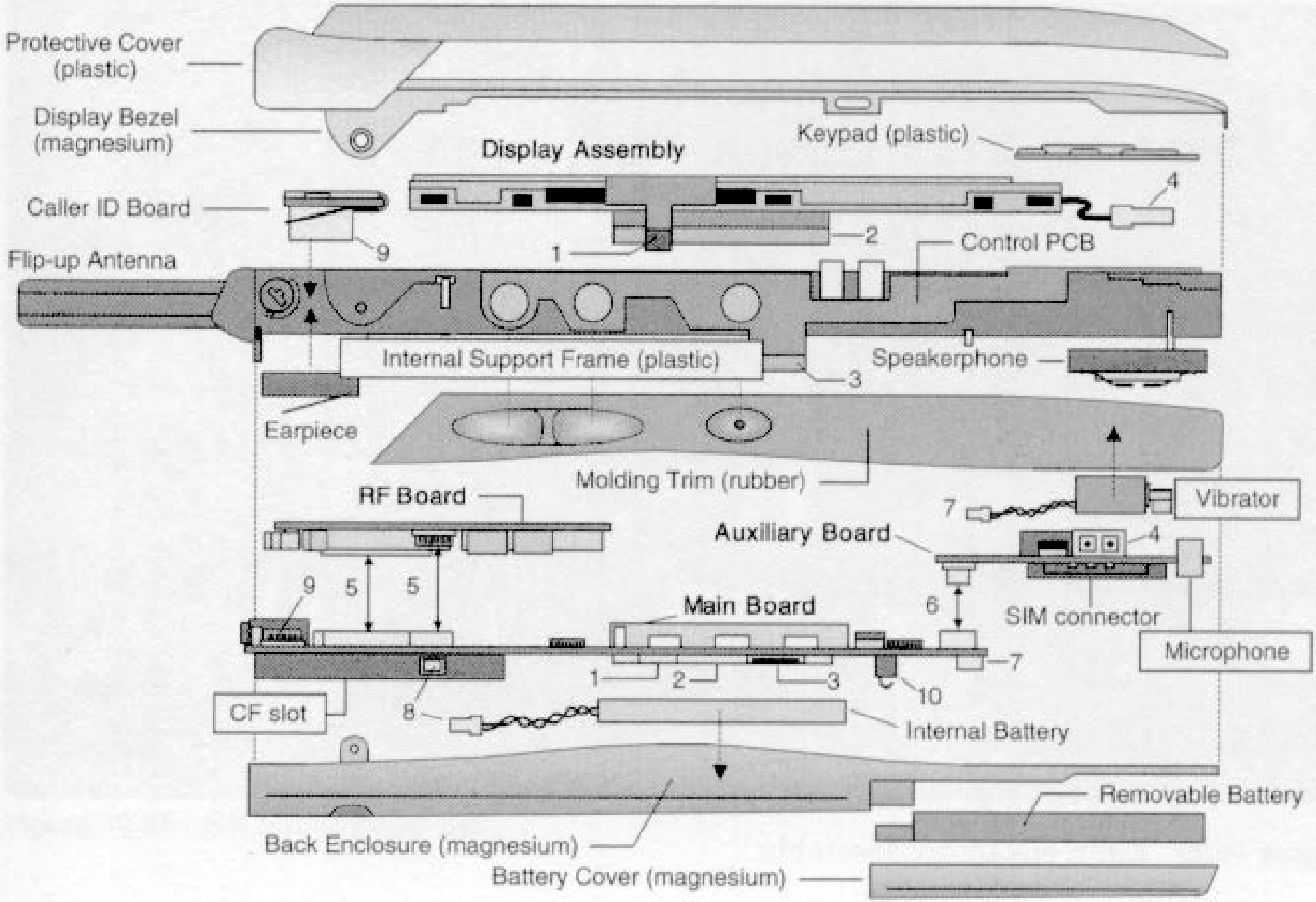


Figure 10.28 Component stack-up.

Item	Weight (g)
Enclosures	67.6
Back enclosure (magnesium)	13.7
Protective cover (plastic)	22.1
CF Slot cover (plastic)	2.1
Battery cover (magnesium)	.2
Rubber trim	3.3
Display bezels (magnesium)	7.9
Main frame & antenna (plastic)	13.3
Electronic Boards	56.4
Main board	34.8
RF board	13.4
Auxiliary board	8.2
Display Assembly	48.6
Color TFT	33.9
Touch screen	11.1
Caller ID & board	3.6
Batteries	36.5
Internal	16.5
External	20
Miscellaneous	12.5
10 screws, tape, buttons, speaker, earpiece, stylus, vibrator, connector frame, keypad, etc	
Total	221.6

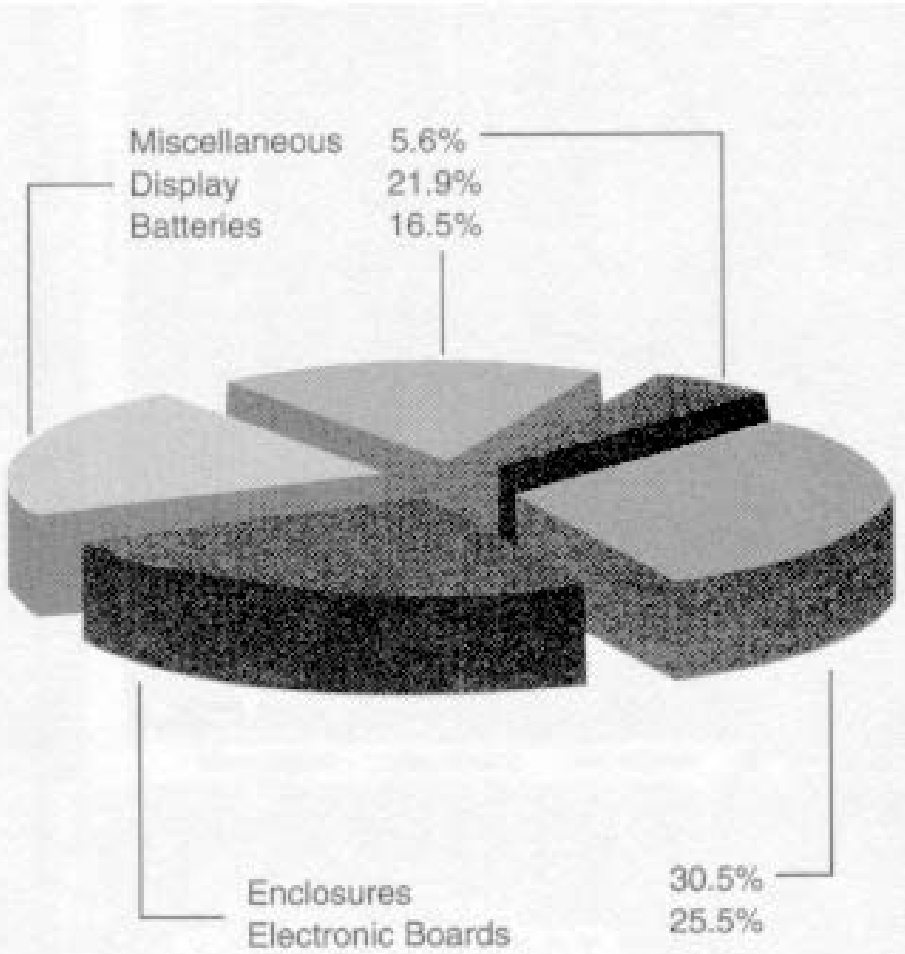


Figure 10.43 Component weights.

TABLE 10.1 IC Metrics (IC Summary)

Board description	No. of IC's total	No. of IC IO's	Die area (mm^2)	IC footprint area (mm^2)	IC IO's/ (IC footprint area)
ID display PCB	1	8	2	15	0.5
Main PCB	21	1,030	473	1,536	1
Auxiliary PCB	4	70	23	115	1
Control PCB	—	—	—	—	—
RF PCB	3	86	19	135	1
IC total	**29**	**1,194**	**517**	**1,801**	**0**

TABLE 10.2 **Electronics Assemblies Metrics (Summary of Electronic System)**

Board description	Board area (cm^2)	No. of PCB layers	No. of parts	No. of connections	PCB tiling density (%)	Connection density
ID display PCB	8.8	2	31	98	0.2	11
Main PCB	65.0	8	426	2,222	7.28	34
Auxiliary PCB	21.1	6	78	318	1.11	15
Control PCB	18.3	1	1	26		1
RF PCB	21.3	8	134	507	0.90	24
System total	**134.5**	—	**670**	**3,171**	**3.8**	**24**

TABLE 10.3 Connection Metrics (Component and Connection Counts)

Board description	Opportunity count	IC's	IC IO's	Modules	Module IO's	Discretes	Discrete IO's
ID display PCB	129	1	8	3	10	26	60
Main PCB	2,648	21	1,030	7	28	386	884
Auxiliary PCB	396	4	70	1	2	70	178
Control PCB	27	—	—	1	26	—	—
RF PCB	641	3	86	9	78	117	277
Total	**3,841**	**29**	**1,194**	**21**	**144**	**599**	**1,399**

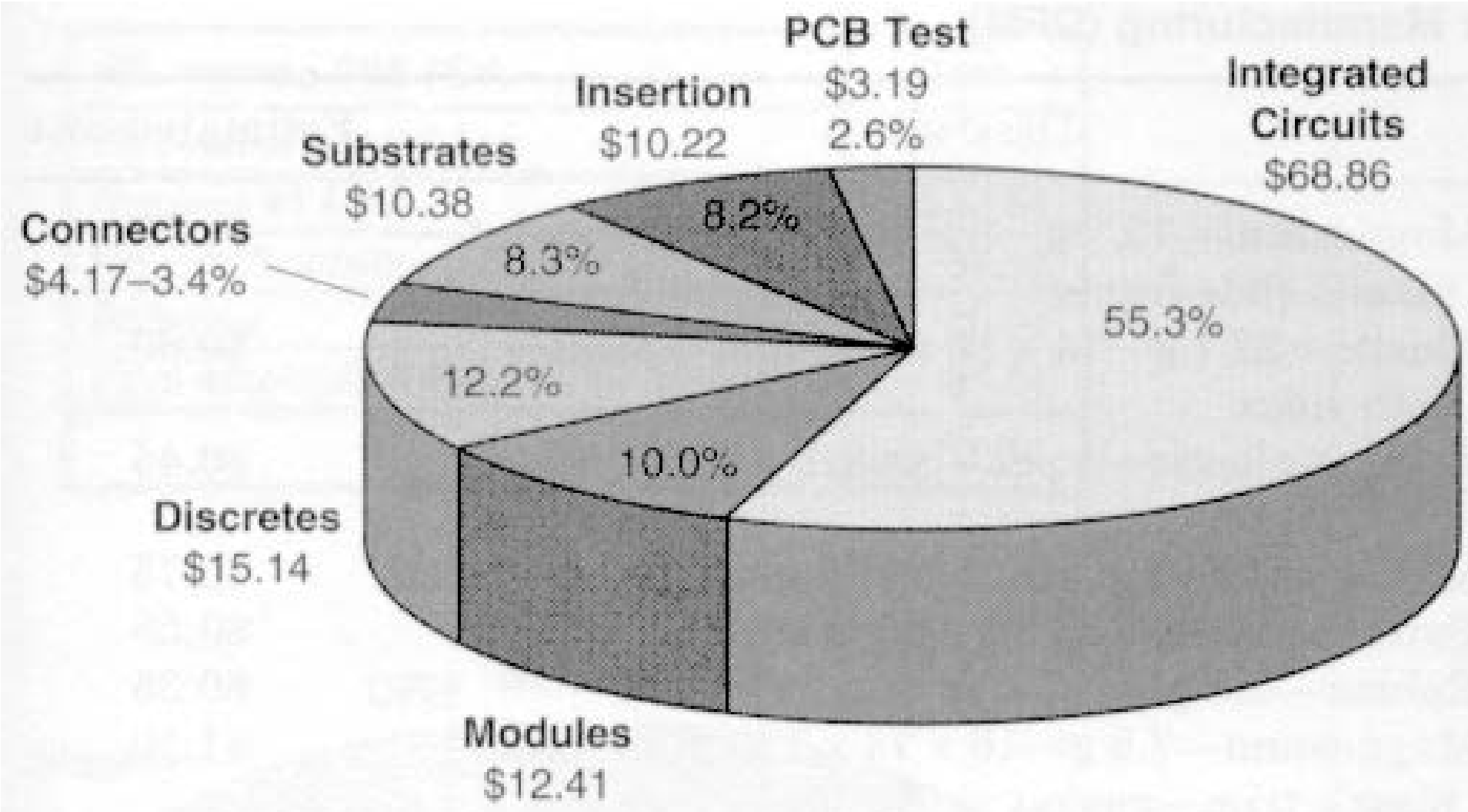


Figure 10.44 Electronic system cost estimate.

TABLE 10.4 Design for Manufacturing (DFM)

Item	Description	Estimated cost
Back enclosure	Magnesium—13.7 g—8 × 76 × 130 mm—paint—plastic slide frame	$1.79
Protective cover	Plastic—22.1 g—14 × 80 × 130 mm—paint both sides	$0.60
Caller ID bezel & buttons	Painted plastic—3 pcs—gasket—1.9 g	$0.45
Battery cover	Magnesium 5.2 g—6 × 50 × 76 mm—paint—latch	$0.75
Antenna	External flip-up—3.2 g—48 mm	$0.55
Molding	Rubber—3.3 g—116 × 76 mm	$0.35
Main display bezel	Magnesium—7.9 g—10 × 74 × 120 mm—paint—plastic trim—gasket	$1.10
Main frame	Plastic—13.3 g 10 × 74 × 135 mm—screw insets—cover bushing/locks	$0.72
Miscellaneous	11 screws—tape—labels—stylus—keypad—small plastic parts	$0.85
Total		**$7.16**

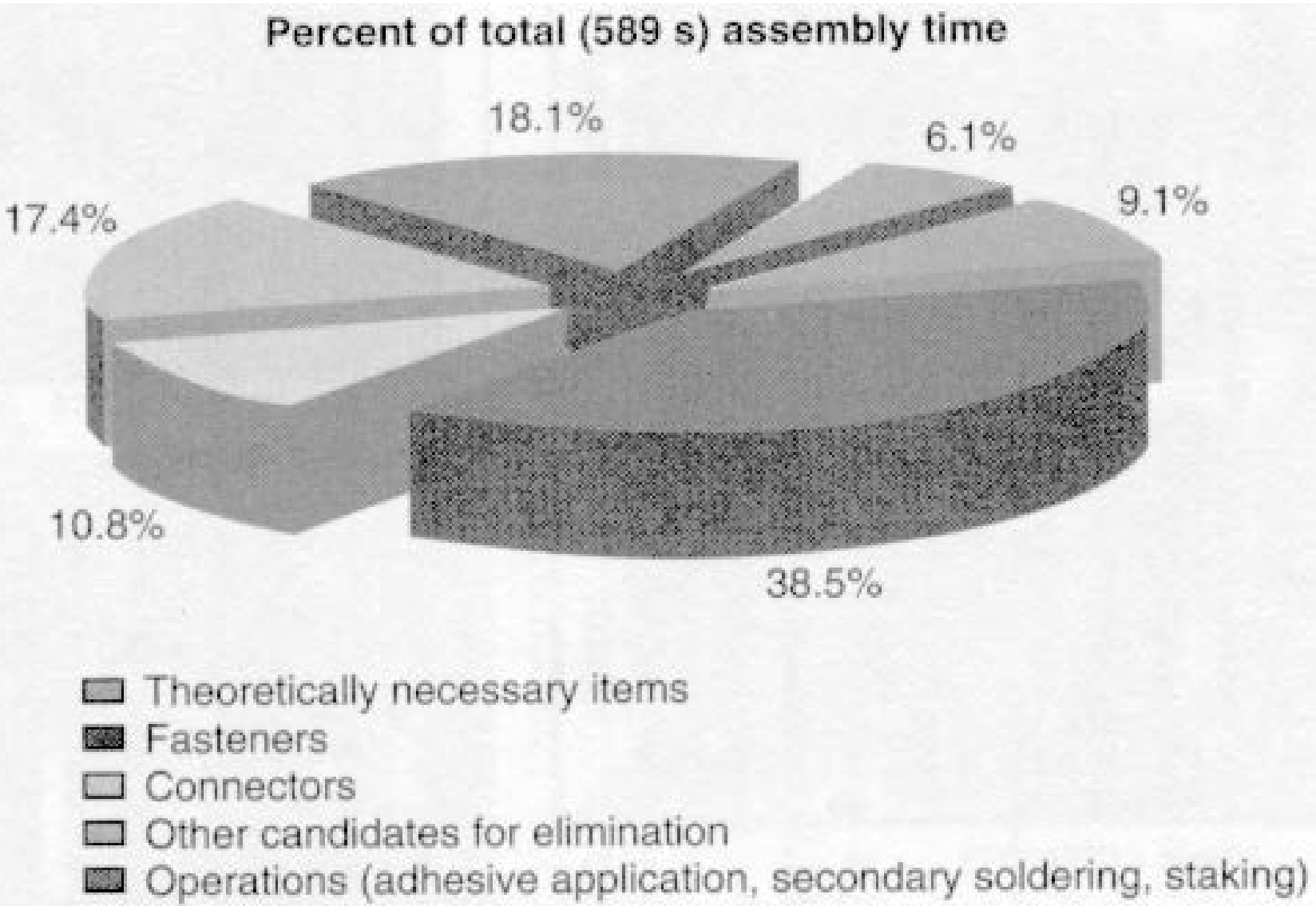


Figure 10.46 Design for assembly (DFA).

HP Jornada 928 PDA	Cost
Electronics assemblies	$124.38
Displays #1 & #2	$30.68
Housing/hardware (DFM)	$7.16
Batteries	$6.64
Final assembly (DFA)	$1.64
Total	$170.50

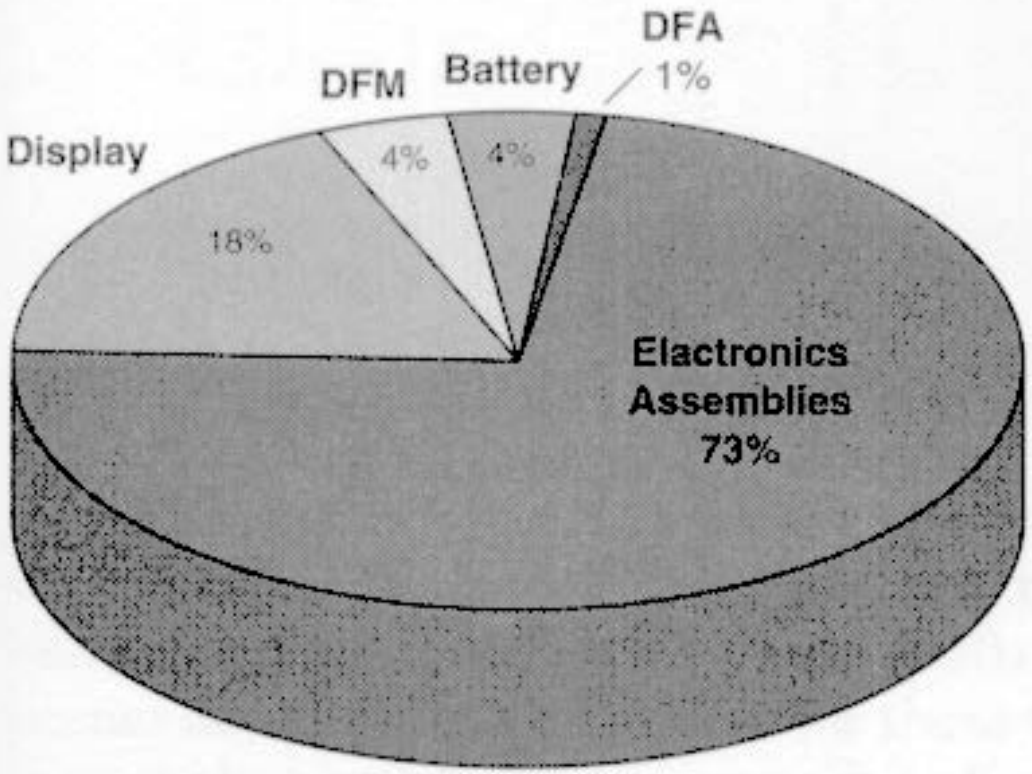


Figure 10.47 Cost summary.

CHAPTER 11

DIGITAL CAMERA EXAMPLE

Figure 11.1 QV-10 front view.

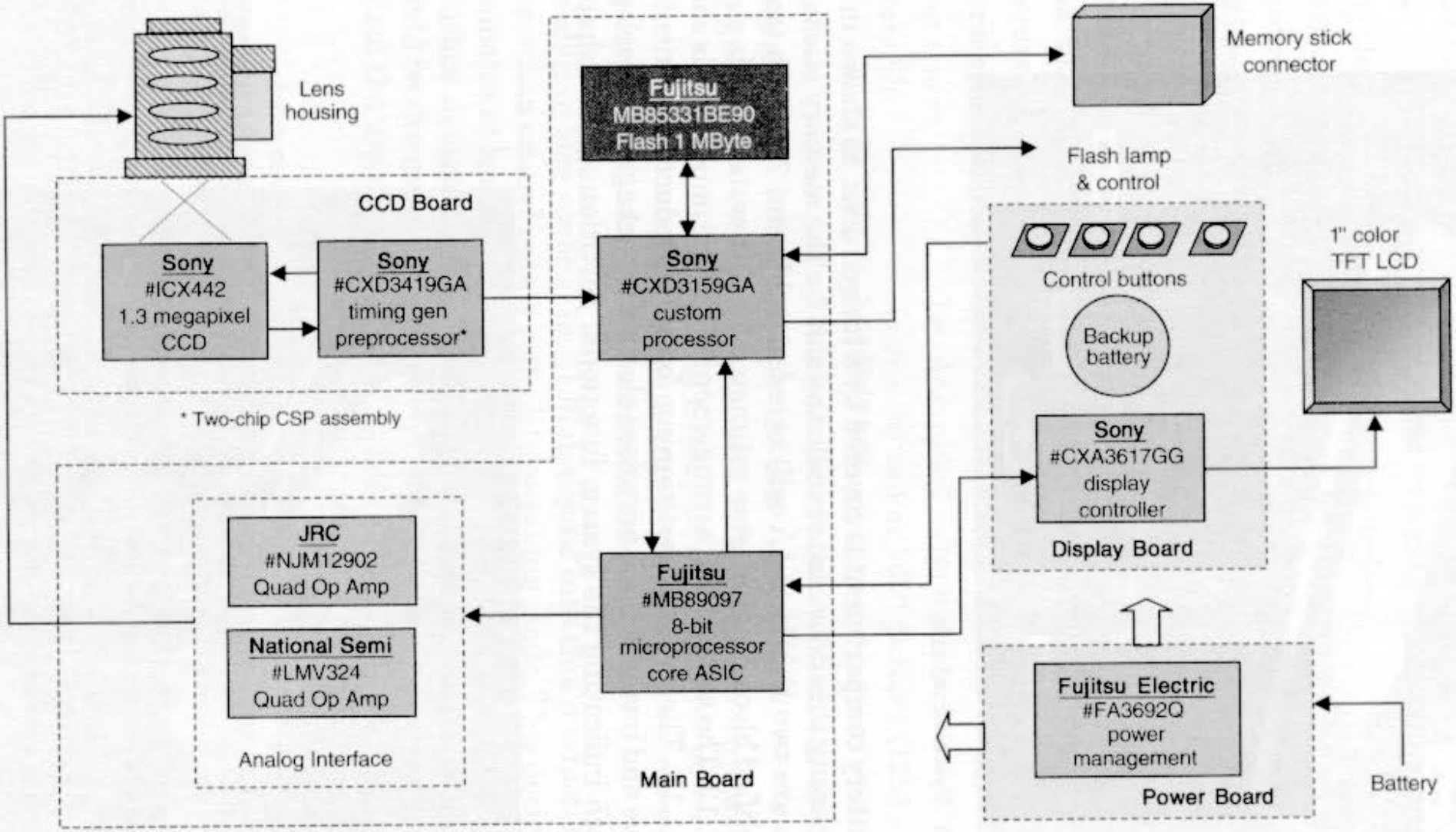


Figure 11.12 Simplified block diagram—estimated.

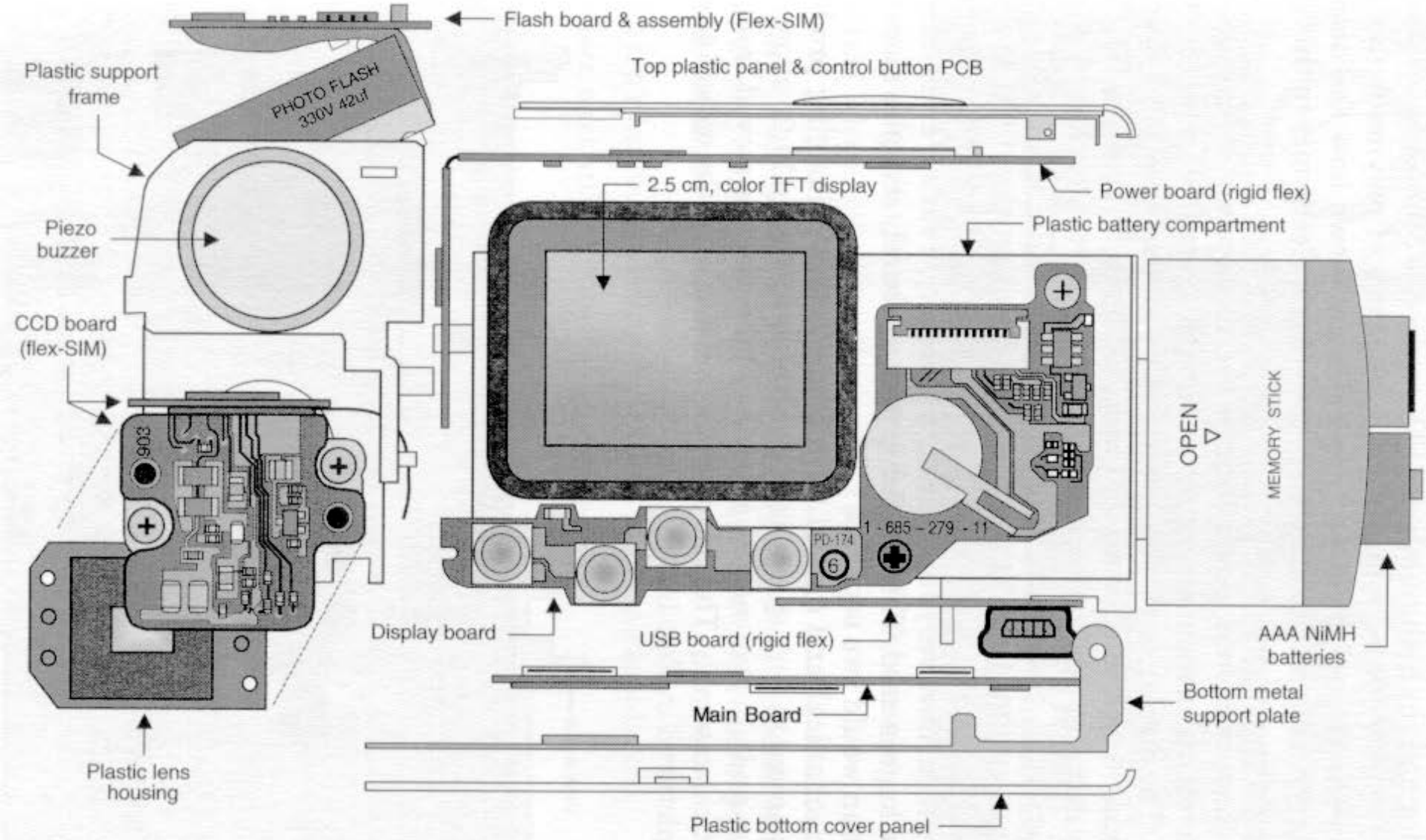


Figure 11.13 Component arrangement.

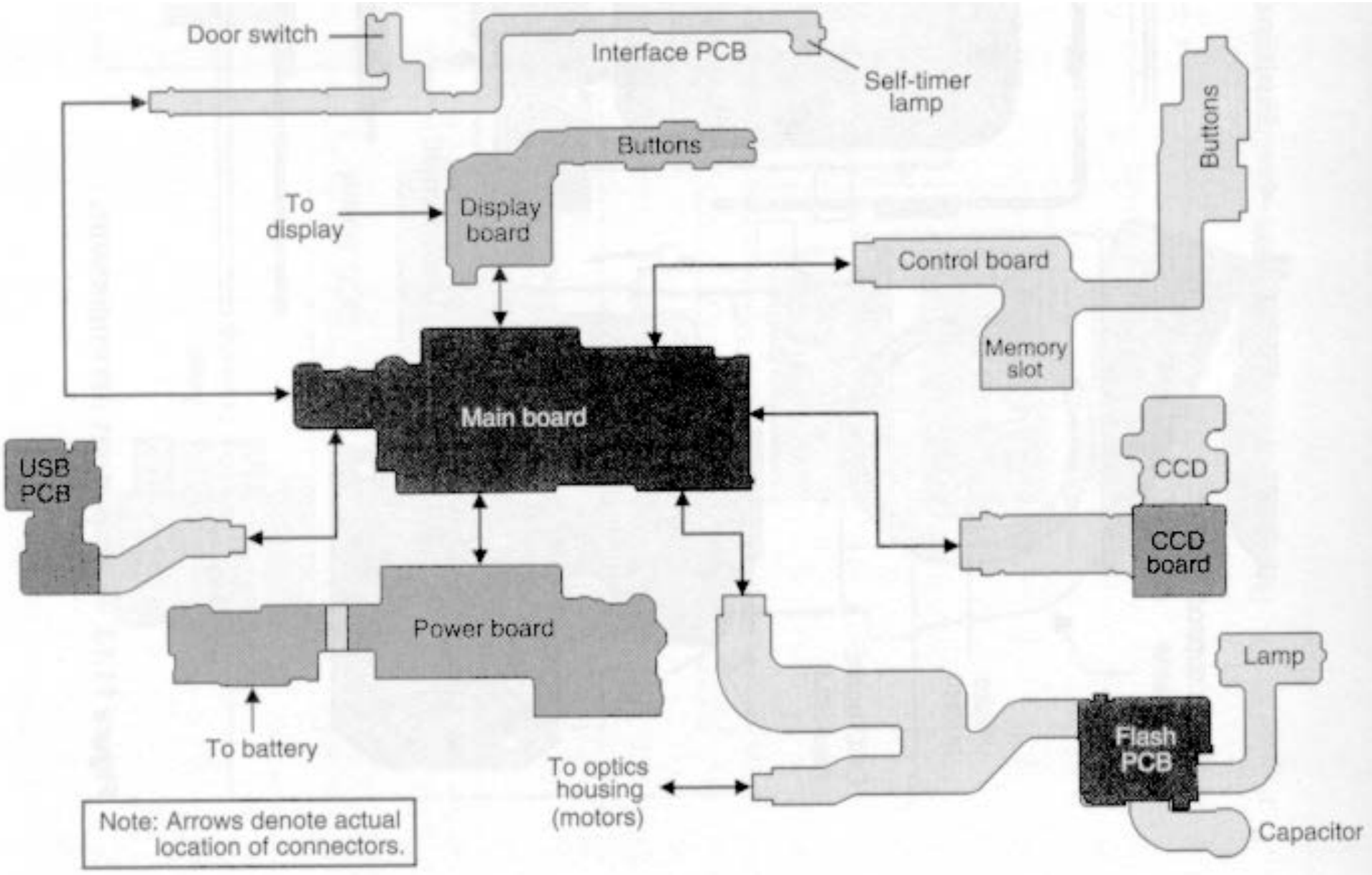
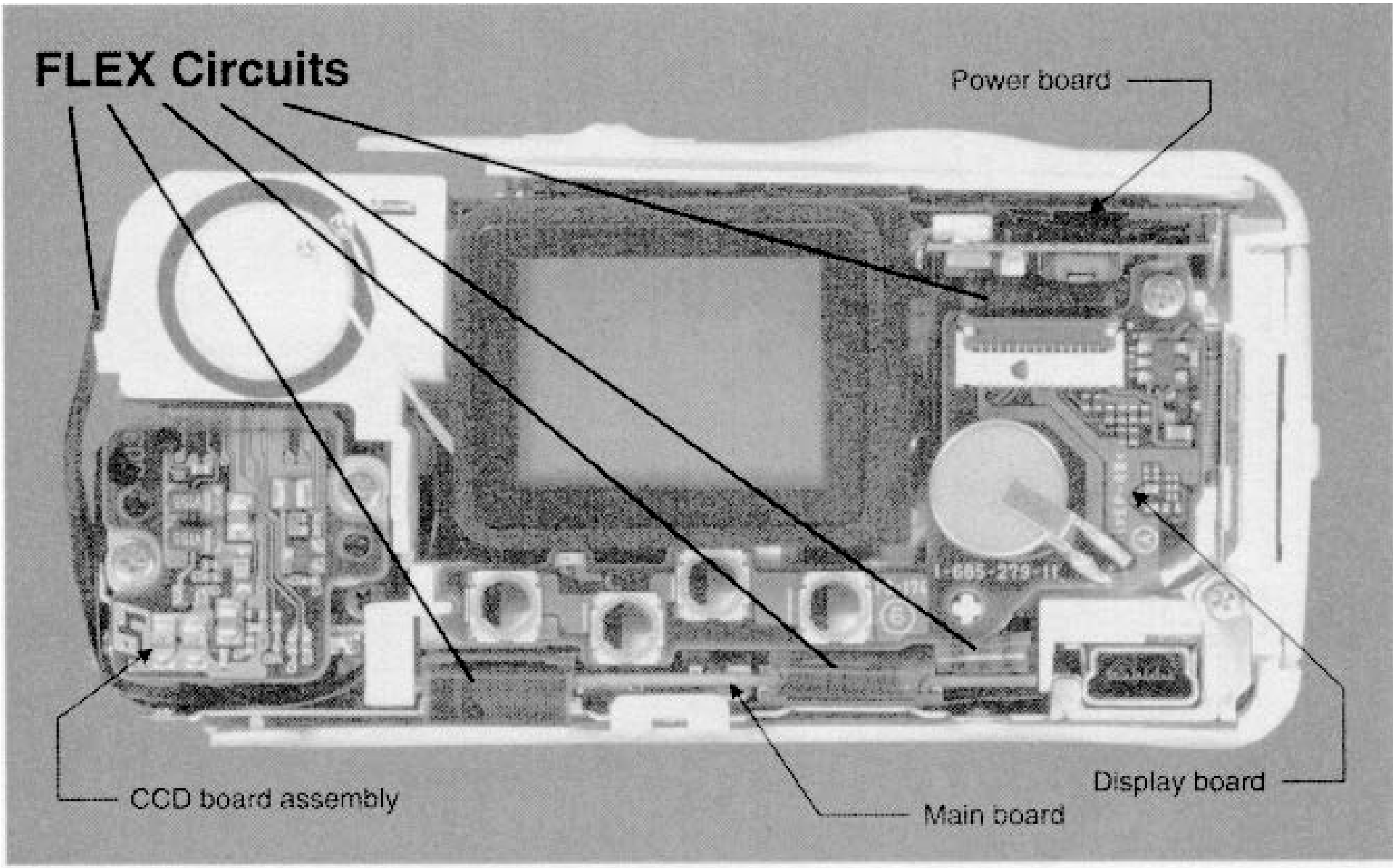


Figure 11.14 Board interconnect routing.



Back side of the assembled electronics with the back enclosure removed.

Figure 11.15 Flex circuits.

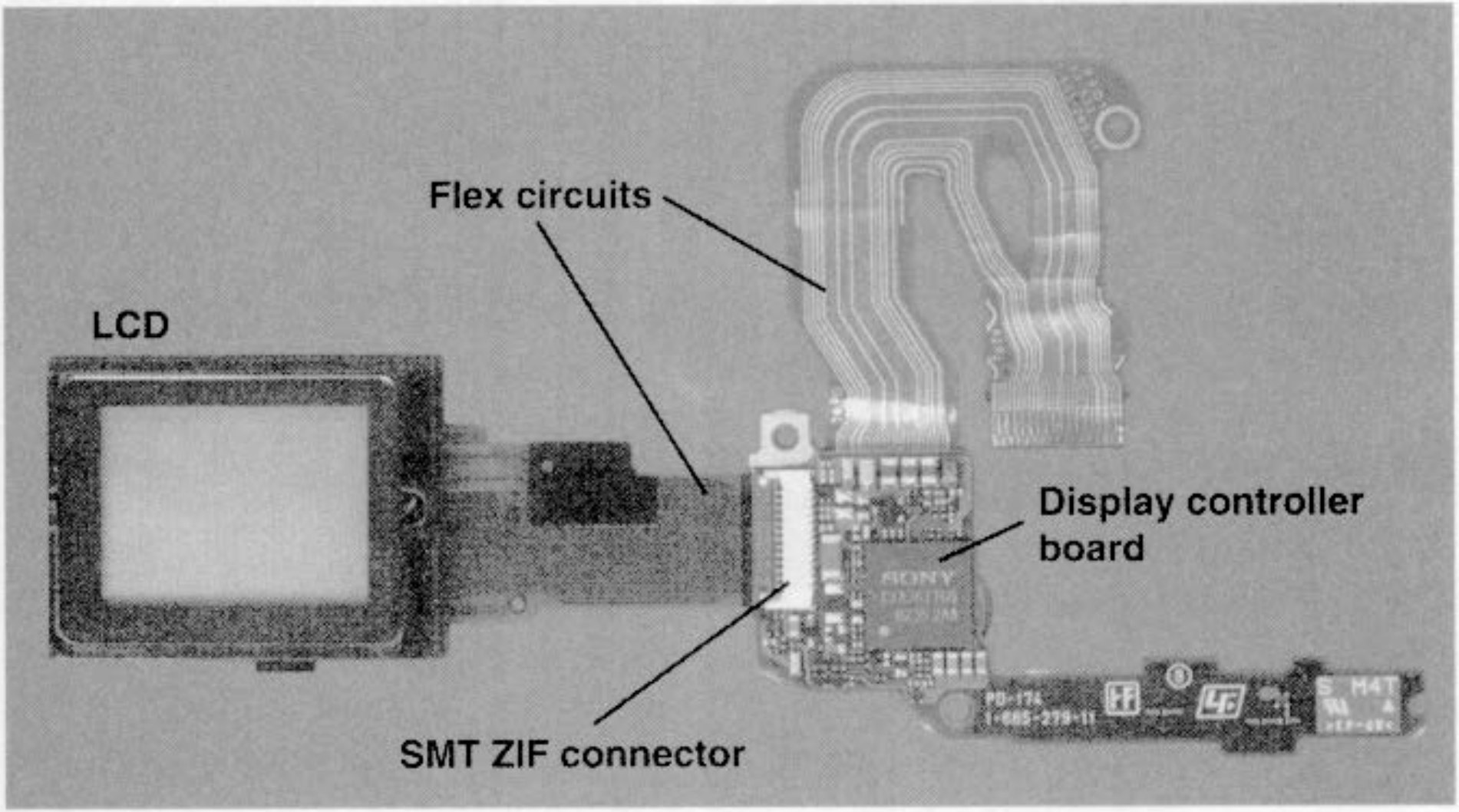
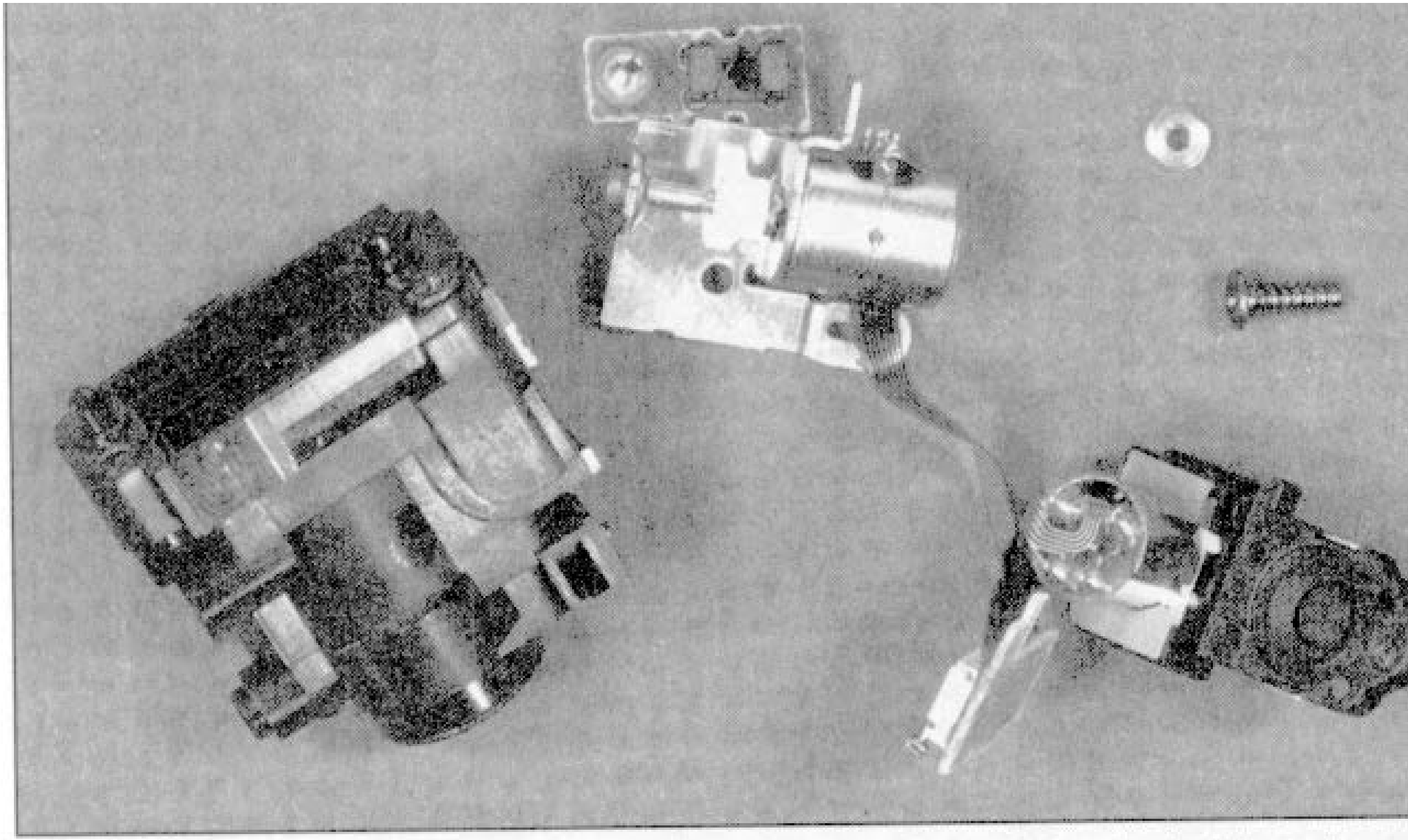


Figure 11.16 Display and board assembly.



The autofocus and shutter motors were removed from the optics housing in this photo.

Figure 11.20 Focus and shutter motors removed.

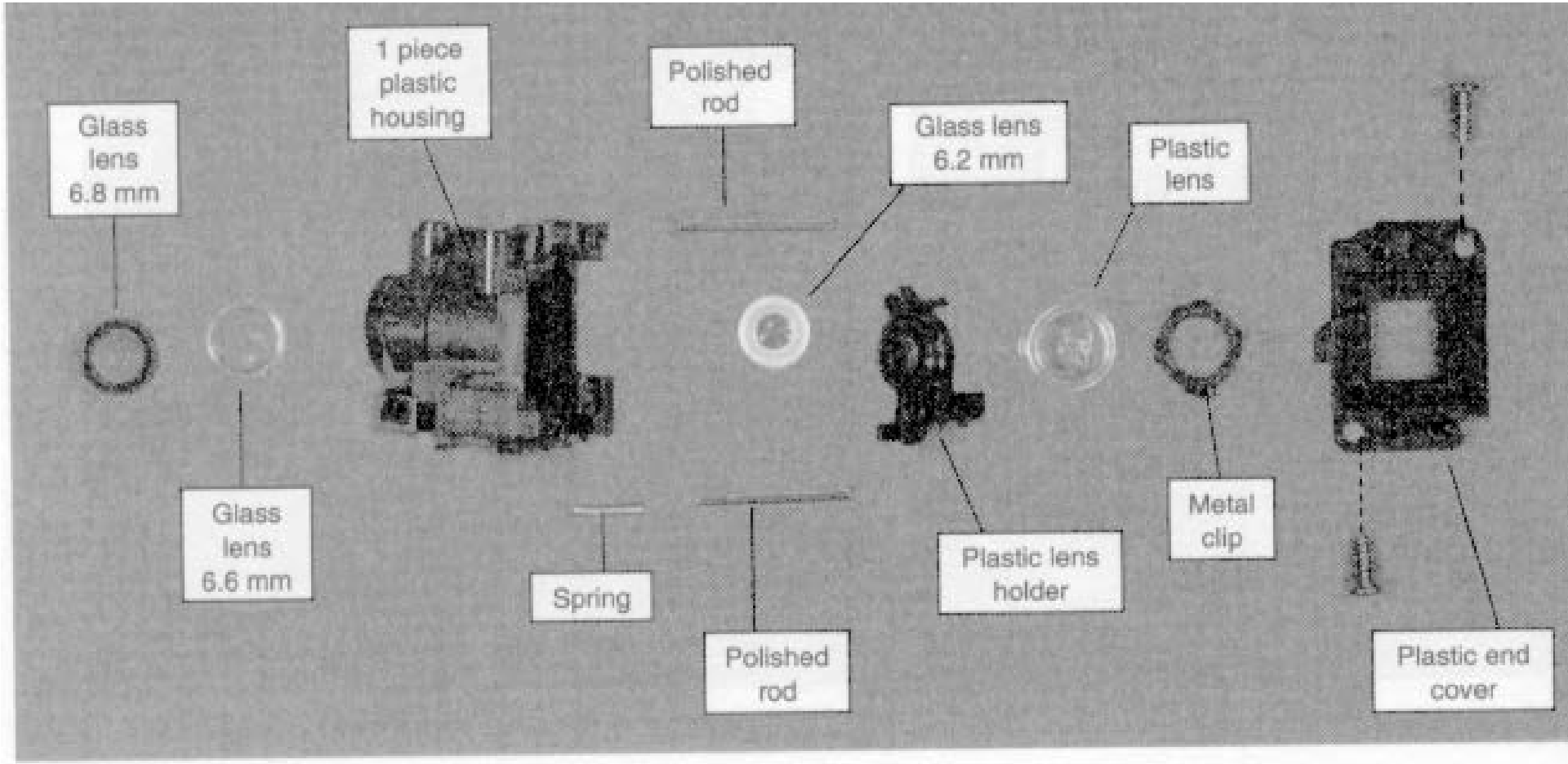
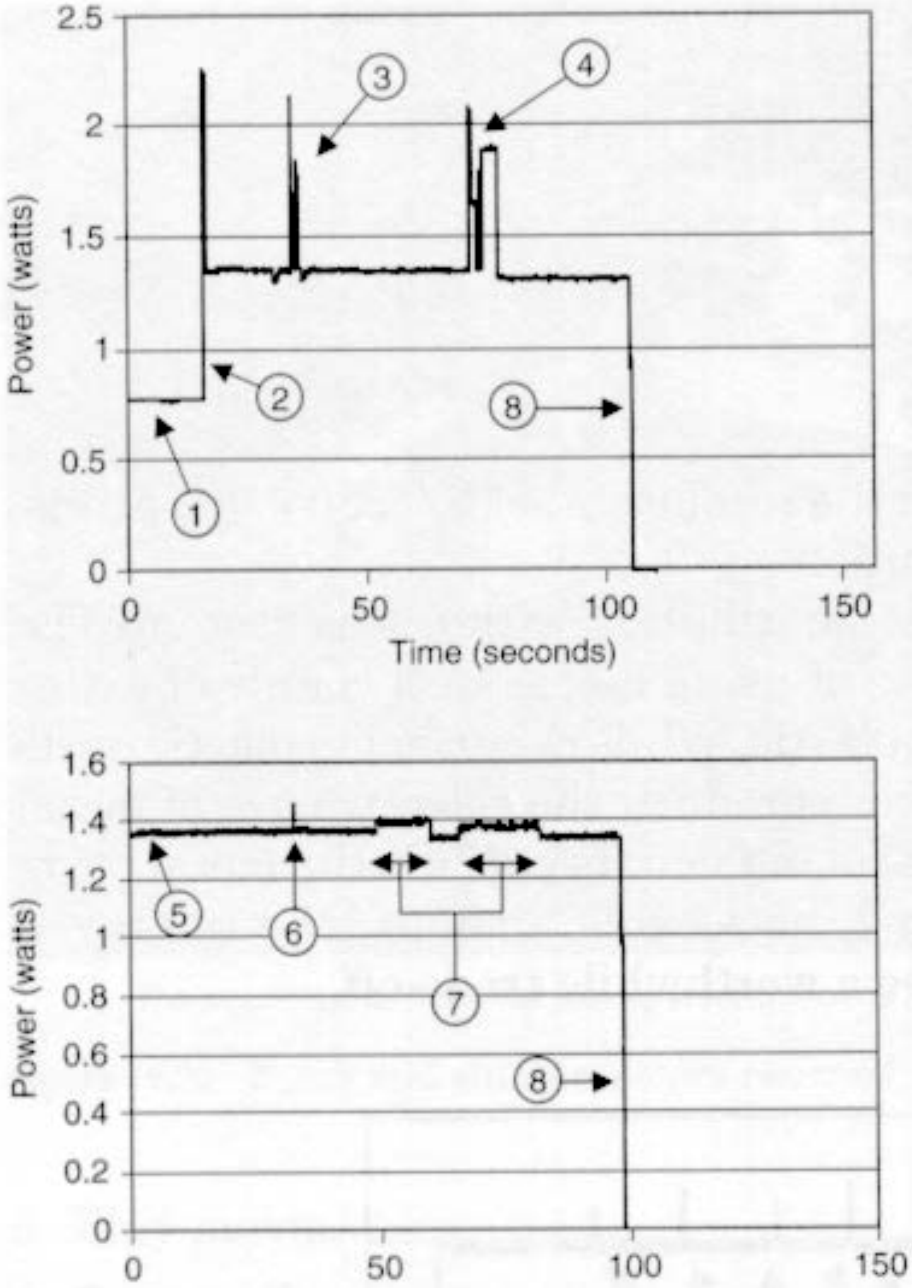


Figure 11.21 Lens housing disassembled.



Take Still Pictures
Take Movie

1. Start test in "Play" mode
2. Switch mode to "Still"
3. Take picture (no flash)
4. Take picture (with flash)
5. Enter test in "Still" mode
6. Switch mode to "Movie"
7. Take movie
8. Power off

All still pictures were taken with the resolution set to 1280 × 960 pixels. The movie uses 116 × 112 resolution.

Figure 11.23 Power measurements (set 2).

Item	Weight (g)
Enclosures	**45.2**
Back metal enclosure	11.1
Front metal enclosure & door	12.3
Bottom plastic cover	1.7
Bottom metal support plate	4.2
Top plastic panel	2.2
Inner plastic support frame	2.2
Plastic battery compartment	11.5
Electronic Boards	**25.4**
Main board	4.5
Display board & interface	2.4
Flash board & flash circuitry	6.3
Power board	5.1
CCD board	3.1
USB board	1.1
Control button board	2.9
Battery	**23.7**
Memory Stick Support	**7.4**
Memory stick slot	4.1
Memory stick (8 MB)	3.3
Optics	**7.1**
Display Assembly	**5.2**
Miscellaneous	**1**
24 screws, tape, etc.	
Total	**115**

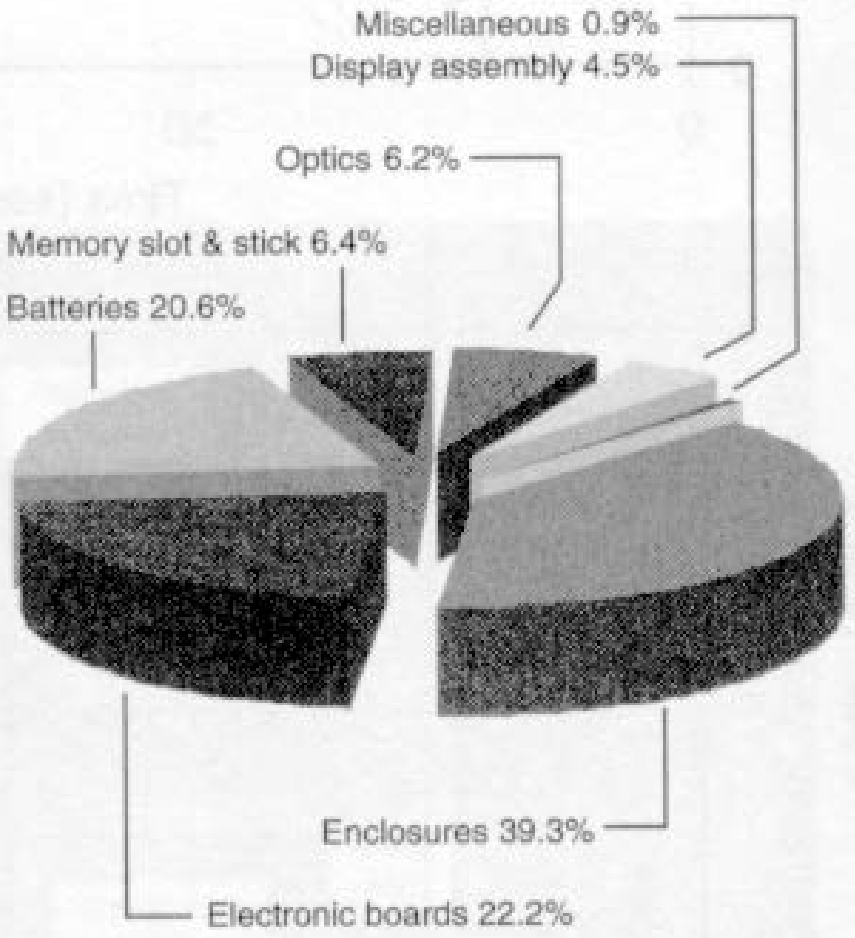


Figure 11.24 Component weights.

TABLE 11.1 IC Metrics (IC Summary)

Board description	No. of IC's total	No. of IC IO's	Die area (mm^2)	IC footprint area (mm^2)
Display PCB	1	81	9	64
Main PCB	8	496	132	411
CCD PCB	3	112	65	219
Control PCB	—	—	—	—
Flash PCB	1	8	8	32
Interface PCB	—	—	—	—
Power PCB	4	104	25	86
USB PCB	—	—	—	—
IC total	**17**	**801**	**238**	**811**

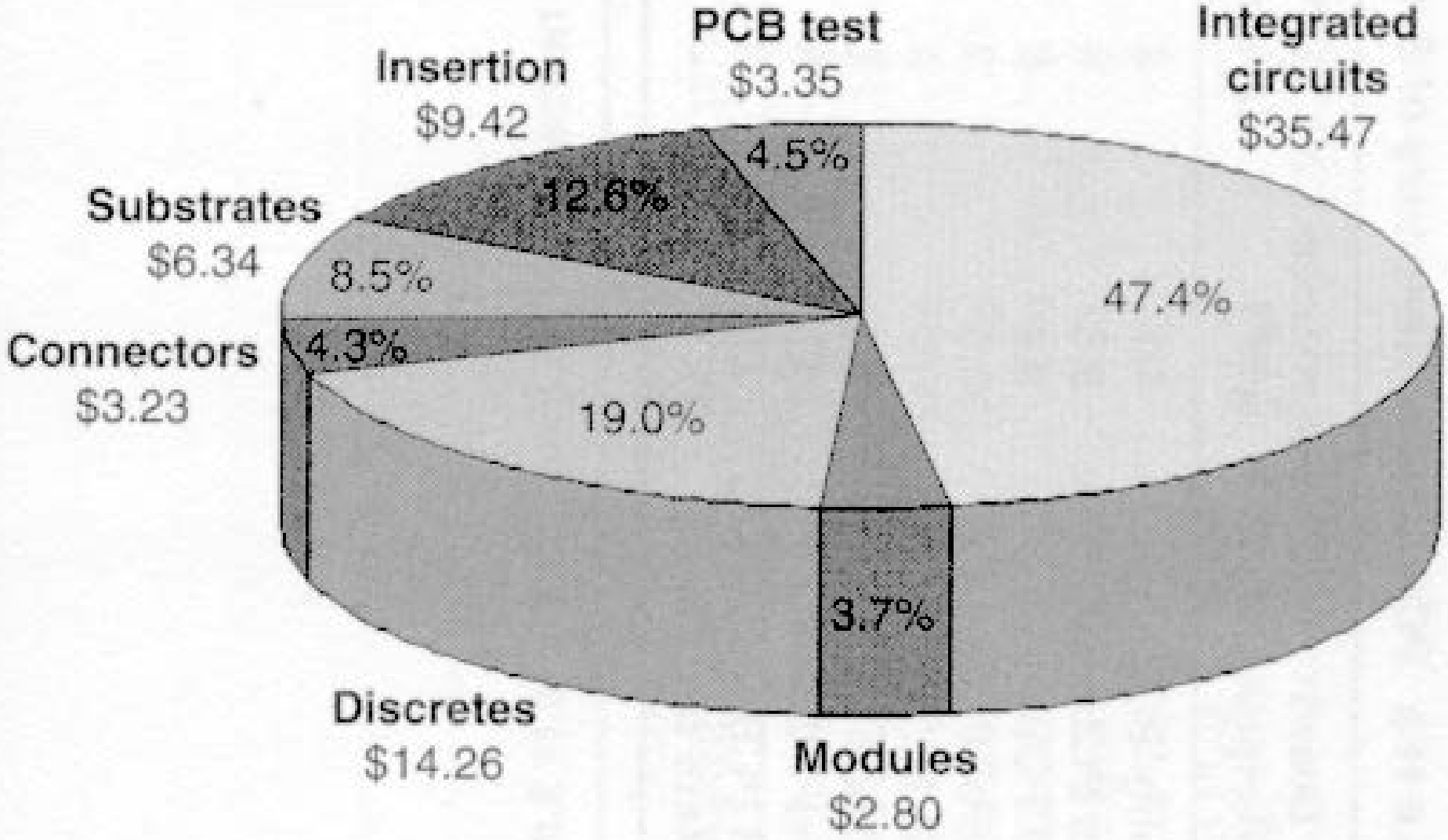


Figure 11.25 Estimated electronics cost.

TABLE 11.2 PCA Metrics (Summary of System PCA Metrics)

Board description	Board area (cm^2)	No. of PCB layers	No. of parts	No. of connections	PCB tiling density (%)
Display PCB	5.7	6	93	371	1.50
Main PCB	9.3	8	273	1,232	14.11
CCD PCB	9.4	6	84	275	6.96
Control PCB	13.1	2	15	46	
Flash PCB	20.0	5	56	138	0.41
Interface PCB	5.1	1	4	10	
Power PCB	10.3	8	159	558	2.38
USB PCB	4.8	3	11	34	
System total	**77.8**	—	**695**	**2,664**	**3.1**

TABLE 11.3 Component and Connection Metrics (Component and Connection Counts)

Board description	Opportunity count	IC's	IC IO's	Modules	Module IO's	Discretes
Display PCB	464	1	81	5	18	84
Main PCB	1,505	8	496	4	12	254
CCD PCB	359	3	112	—	—	81
Control PCB	61	—	—	3	18	11
Flash PCB	190	1	8	1	3	54
Interface PCB	14	—	—	1	4	3
Power PCB	717	4	104	—	—	152
USB PCB	45	—	—	—	—	9
Total	**3,359**	**17**	**801**	**14**	**55**	**648**

TABLE 11.4 Design for Manufacturing (DFM)

Item	Description	Estimated cost
Front enclosure	Anodized aluminum—sliding door—12.1 g spring & plastic hardware—1.5 × 4 × 8 cm	$0.90
Back enclosure	Anodized aluminum—plastic buttons—strap lock—1.5 × 4 × 8 cm—11.1 g	$0.55
Battery compartment	ABS—Main compartment—door & hinge—battery terminals—metal clip—11.5 g	$0.94
Support frame	ABS—2.5 × 2.5 × 3.5 cm—2.2 g	$0.30
Top cover	Plastic cover & buttons—metal support panel—1.5 × 1 × 6.5 cm—5.3 g	$0.35
Bottom cover	Plastic cover—metal support panel—1.5 × 2 × 8 cm—5.8 g	$0.35
Memory stick	8 MB	$4.80
Lens housing	2-piece plastic housing—CCD gasket—CCD filter—2 small motors—3 glass lenses—1 plastic lens—2 polished rods—spring, metal clip & screws	$7.13
Miscellaneous	21 screws—tape—labels—memory slot connector cover, etc.	$0.62
Total		**$15.94**

DFA Index (%)	3.8%
Total Assembly Time (s)	762*
Total Assembly Cost ($)	$6.35 (@$30/h, Japan)

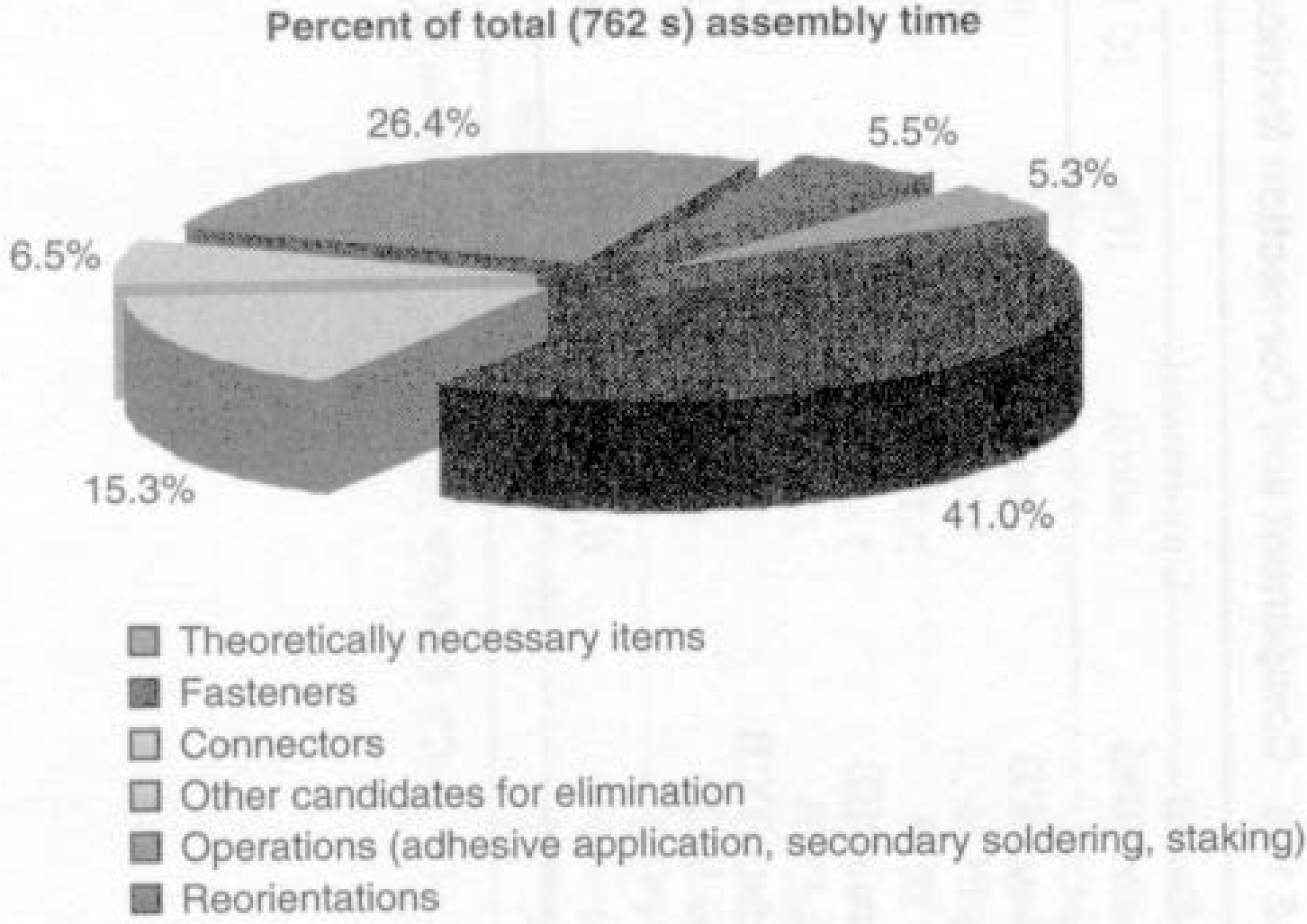


Figure 11.26 Design for assembly (DFA).

Sony DSC-U10 Digital Camera	Cost
Electronics assemblies	$74.87
Display	$10.32
Housing/Hardware (DFM)	$15.94
Batteries – AAA type/Qty 2	$1.48
Final assembly (DFA)	$6.35
Total	$108.96

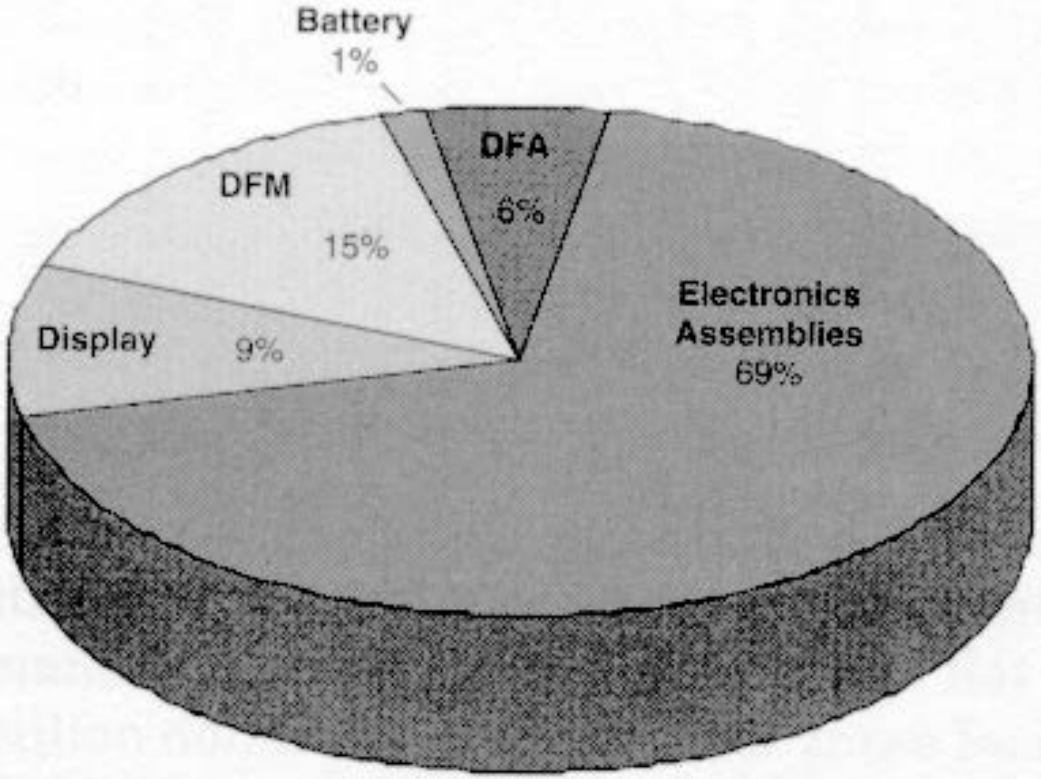


Figure 11.27 Cost summary.

CHAPTER 12

ECONOMICS AND HOW SOMEONE MAKES BUSINESS OUT OF THIS

POINTS TO CONSIDER

- HIGH PRODUCTION VOLUMES NEEDED
- LABOR COST DOWN – BRUTE FORCE ?
- LOW-COST COMPONENTS
- CLEVER OUTSOURCING

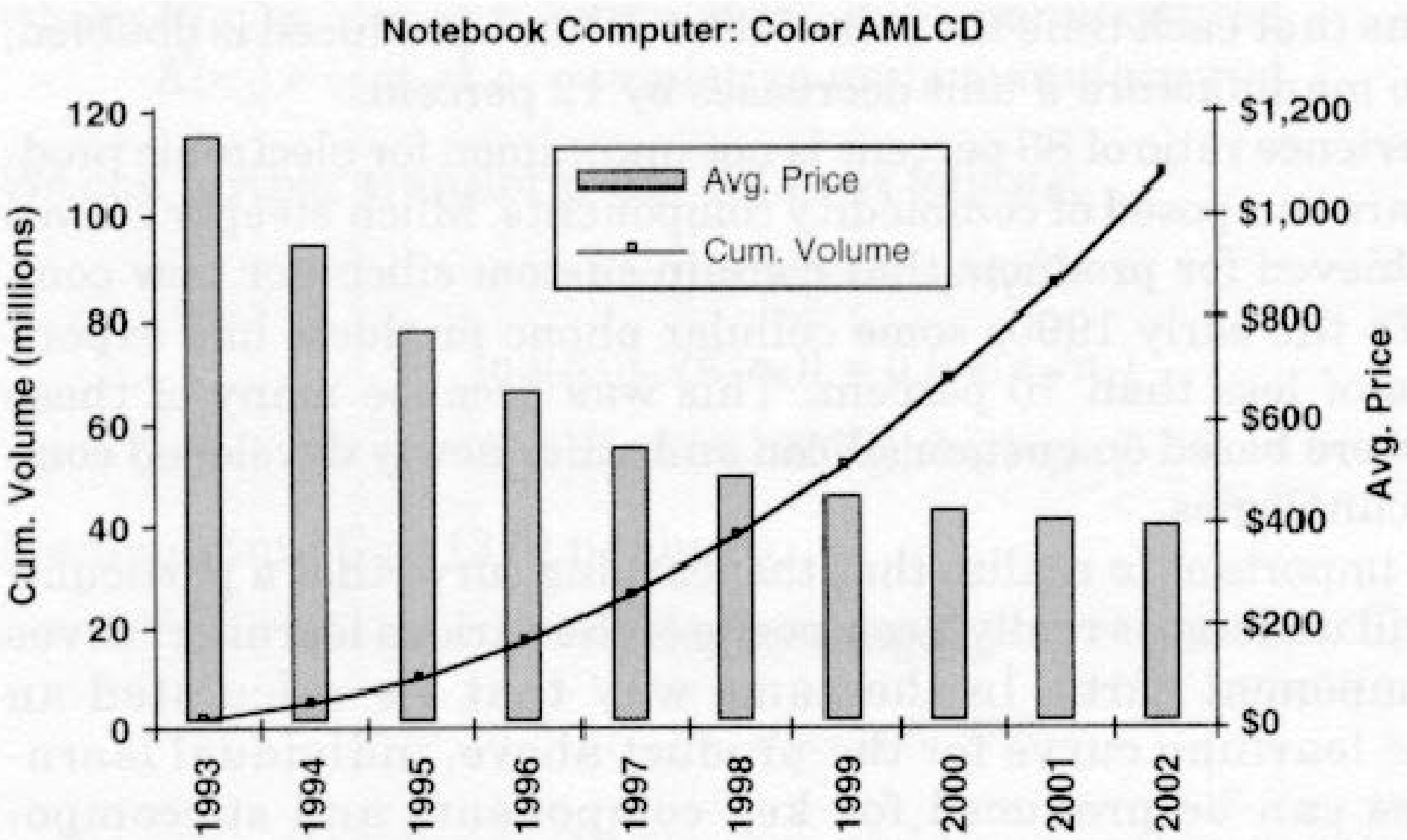


Figure 12.1 Learning curve for flat panel display.

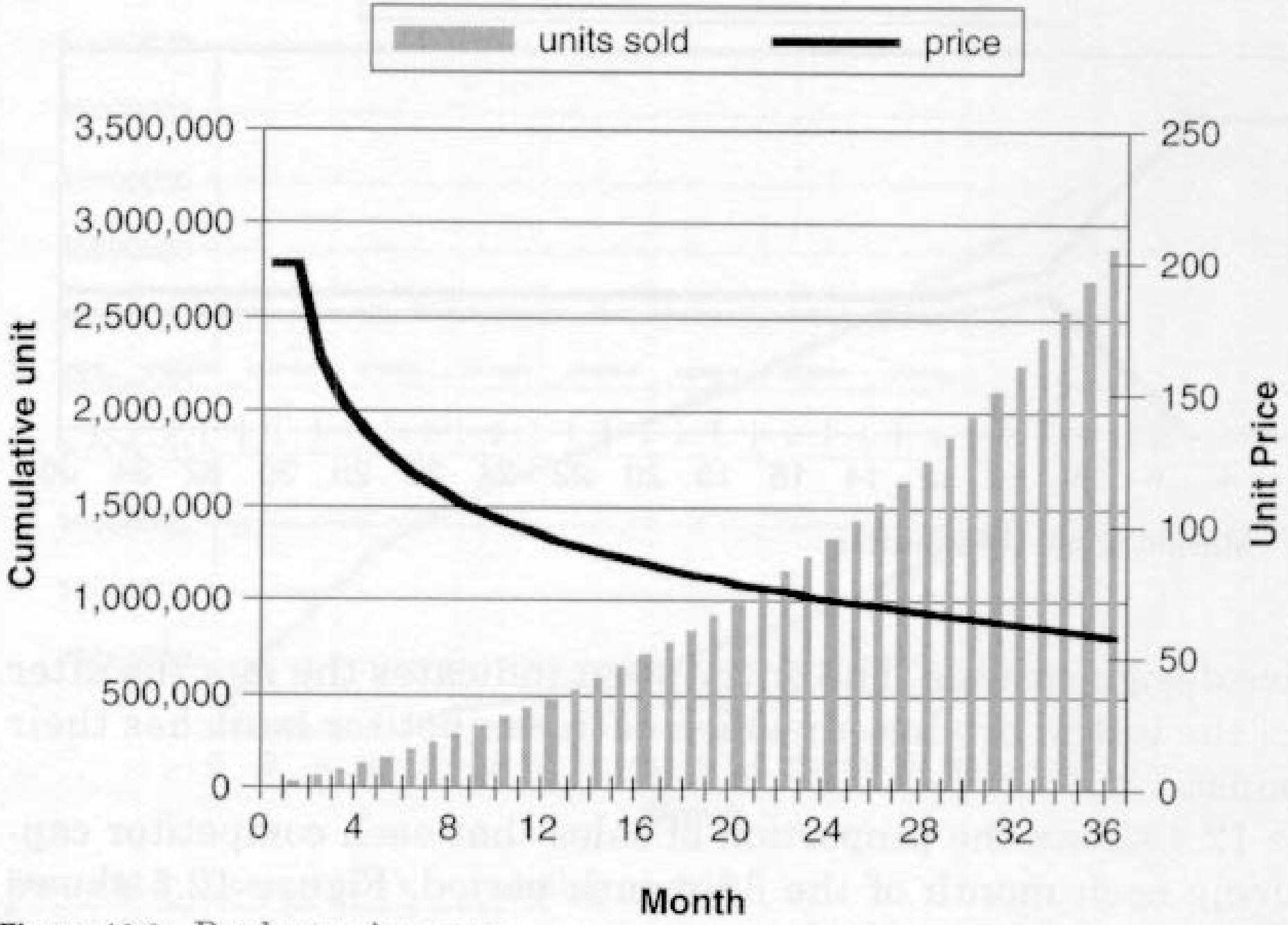


Figure 12.2 Product price curve.

NEXT:

THE COMPETITORS STRIKE

Acme	
Initial unit cost	$89
Experience rate	80%
Design rating	70%
Entry point	0
b	–0.32

x	
Initial unit cost	$80
Experience rate	80%
Design rating	60%
Entry point	6
b	–0.32

y	
Initial unit cost	$70
Experience rate	60%
Design rating	30%
Entry point	9
b	–0.74

Figure 12.3 Product competitor parameters.

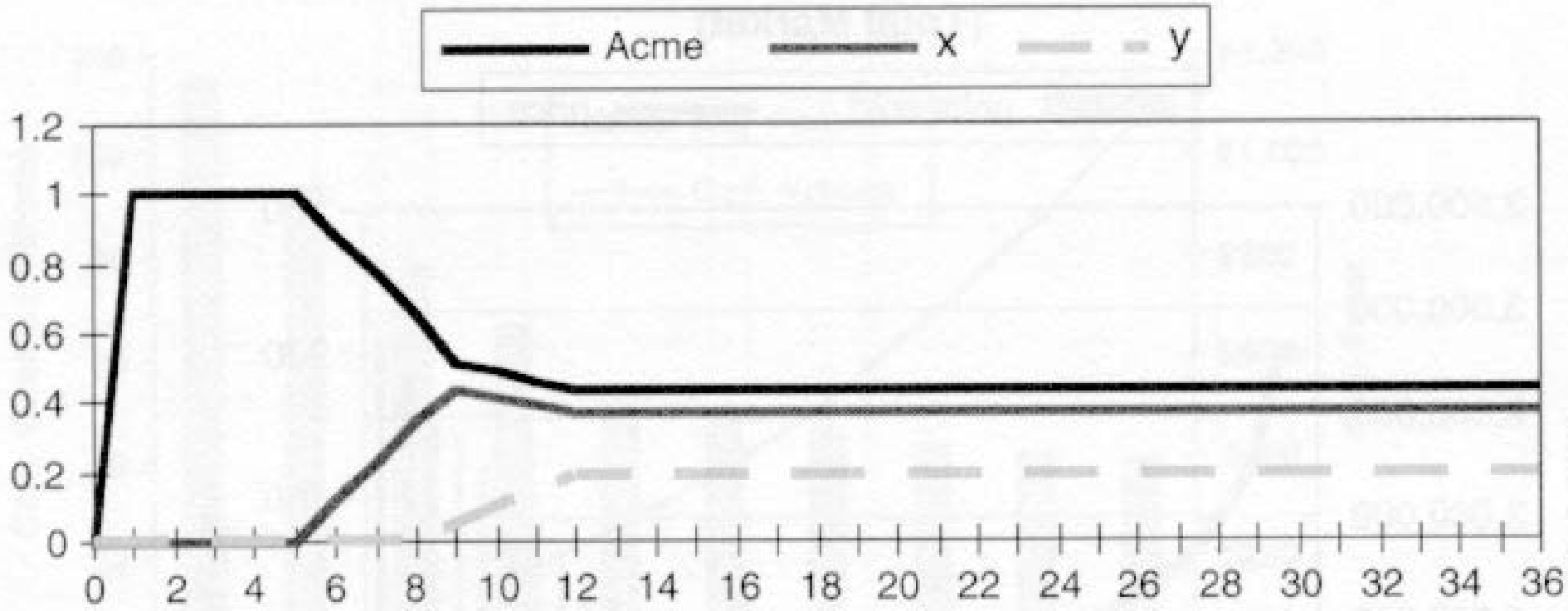


Figure 12.4 Market share distribution.

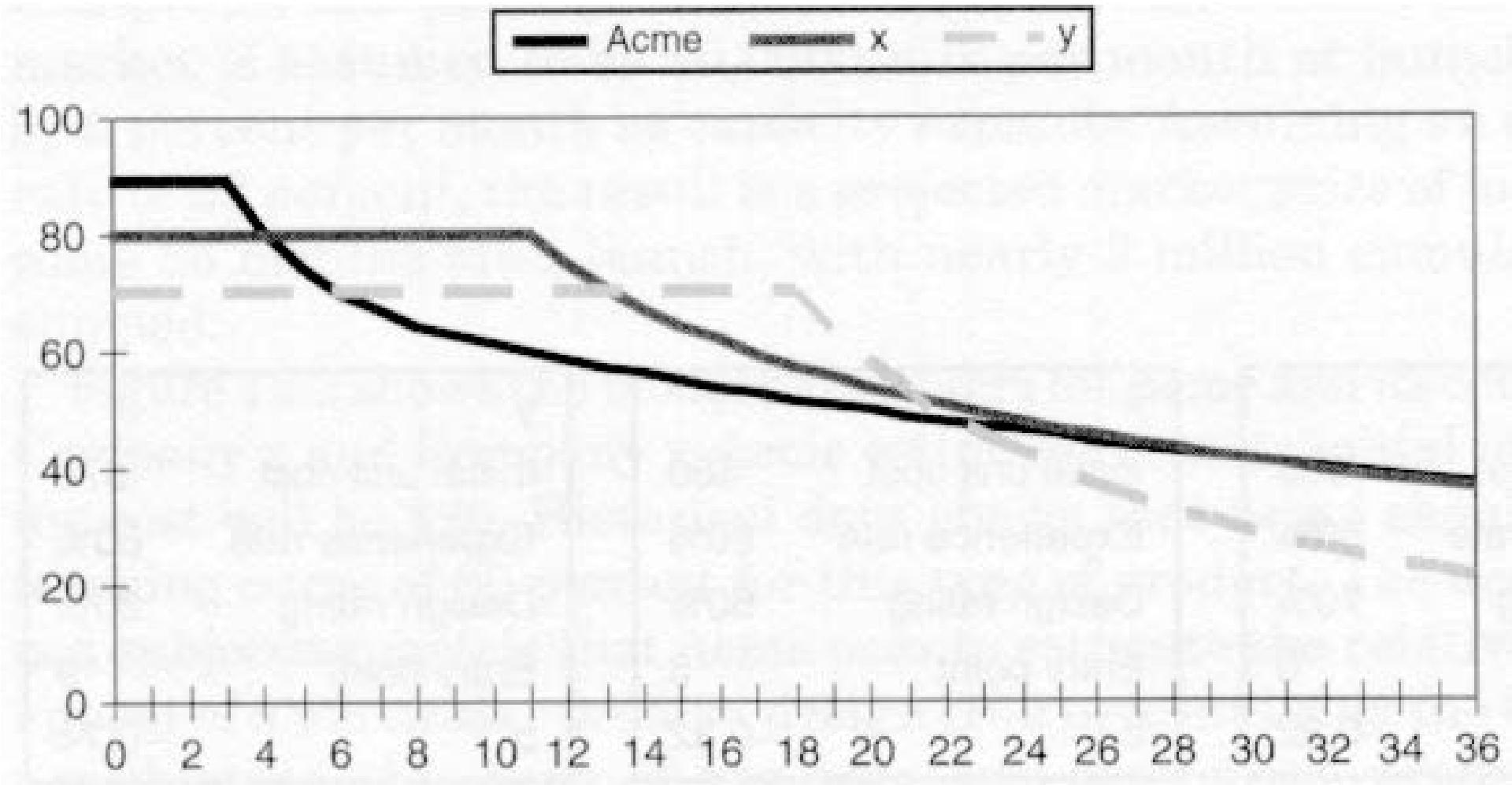


Figure 12.5 Competitor's production costs.

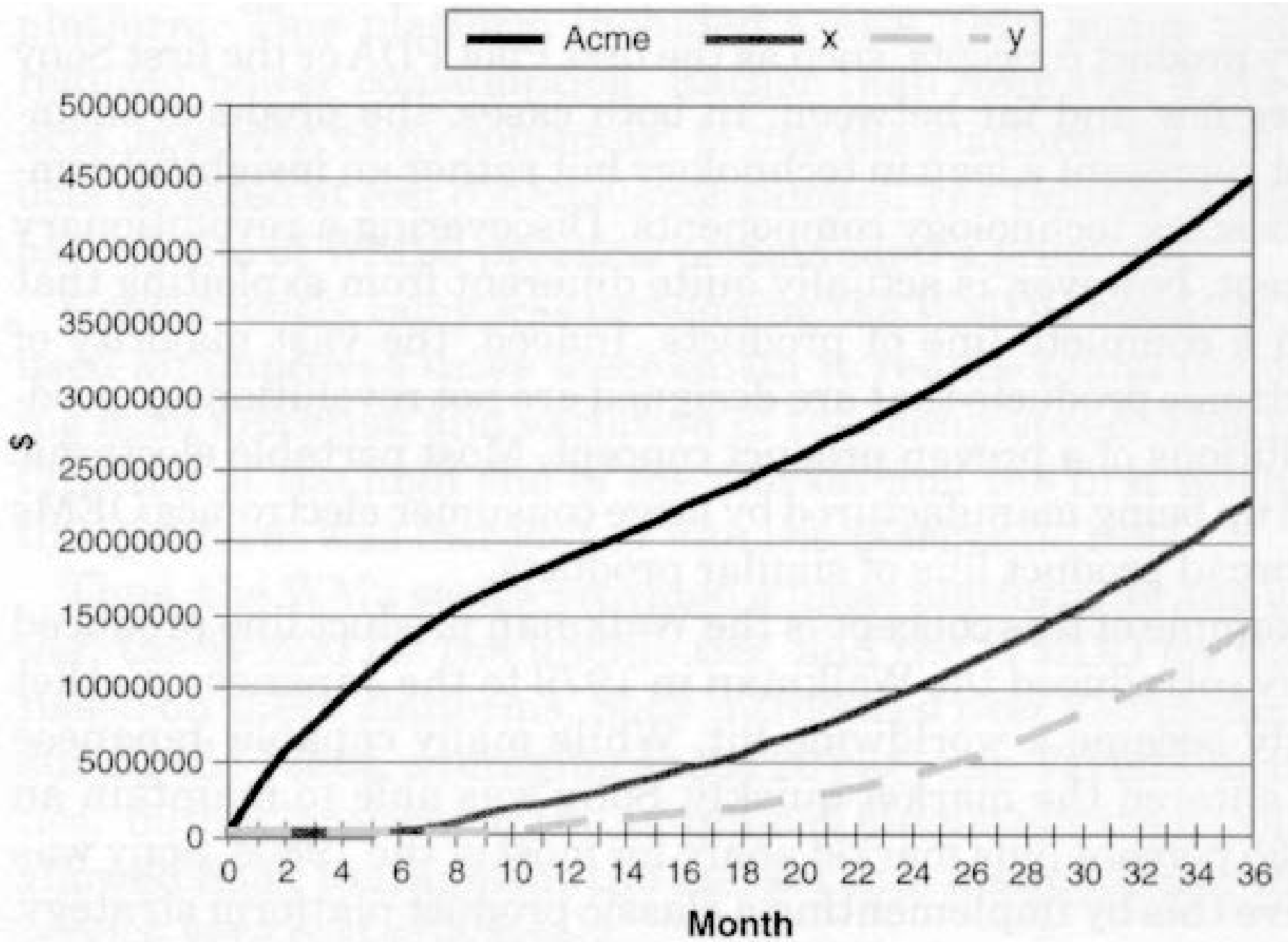


Figure 12.6 Competitor's cumulative profits.

THE SONY SAGA, part one

Sony developed Walkman products tailored to appeal to particular demographics and lifestyles. Japanese models were equipped with remote controls in the headphone cord, allowing for the control of the system in the confines of a crowded train. Many U.S. models were equipped with a radio tuner, and ruggedized versions were introduced in the United States for people that lead an athletic lifestyle. European models were more classically styled with the emphasis on sound quality.

THE SONY SAGA, part two

Sony does appear to invest more in developing a high-quality design than does its competitors. Sony products consistently demonstrate very ergonomic features and are constructed with a high-quality finish. Sony's brand recognition virtually guarantees market share provided they can field a competitive product in a proven market. Thus, investing in high-quality designs is a low-risk proposition.

CHAPTER 13

THE PAST
THE PRESENT
THE FUTURE

FAT OR THIN ?

Cheaper, more compact mass storage favors fat client architecture.

Improved network performance favors thin-client architecture.

Improved information compression technology favors thin clients.

Diminishing performance returns, with respect to memory latency and processing, favors thin-client architecture for a given application space.

Time-sensitive access to remote sources of data is favored by the thin-client approach.

SAMPLE EXAM

Answer only four questions

1. Define the concept ”form factor”.

2. Different power supplies, their benefits and problems in portable electronics.

3. Ways to achieve or spoil mechanical stiffness and rigidity of small hand-held devices.

4. User profiles and their impact on portable gear human interfaces.

5. Consider the possibility of conflict between quality and features in portable electronics.

6. Typical manufacturing methods for small-to-medium series production of enclosures for electronic devices.

THE END