UDC 621.3.04: 681.3

Packaging and Mechanical Technologies for Mobile Notebook PCs

●Kazuhiro Igarashi

(Manuscript received June 25,1998)

In recent years, increases in MPU speeds have brought dramatic increase in the performance and functionality of notebook PCs. For mobile notebook PCs, there have also been reductions in size, weight, and thickness. However, mobile notebook PCs must still be easy to use and reliable. We have developed techniques for achieving the following regarding packaging and mechanical technologies and implemented them for mobile notebook PCs now on the market:
– Thinner LCD, keyboard, and other devices
– Higher mounting densities to enable reductions in the size of PC boards
– Heat dissipation without a fan
– Protection of built-in hard disk from shock
– Thinner, more rigid cabinet walls
This paper describes the features of our mobile notebook PCs, the FMV BIBLO NP Series and NC Series, and explains the technologies we developed to address the above issues.
Since the circuit scale and the heat generated by mobile notebook PCs are likely to continue to increase with performance and functionality being higher, yet the demand is for further reductions in size, weight, and body thickness. To simultaneously achieve these tougher, conflicting demands, we will continue to develop new packaging and mechanical technologies.

1. Introduction

In recent years, notebook PCs have become much smaller and lighter, yet performance has been improved. There are two types of notebook PC: the desktop type, which replaces desktop PCs and saves space, and the mobile type, which is mainly designed to be carried by the user. This paper describes the packaging and mechanical technologies for our mobile notebook FMV BIBLO NP Series and NC Series PCs.

Since they are designed to be carried around, mobile notebook PCs must be compact and lightweight, but at the same time, usability must not be sacrificed when designing the screen size, keyboard size, and so forth. Mobile notebook PCs are thus now divided into two groups. The first is the A5-size products, in which the sizes of the screen and keyboard are minimized without affecting usability too seriously, and size and weight are reduced as far as possible. The other group is the A4-size products, in which the screen and keyboard are the same size as those of the desktop type, operability and performance are not compromised at all, and the body thickness and weight are reduced within a certain limit. We have developed and released the FMV BIBLO NC Series, which is an A5-size lightweight type, and the FMV BIBLO NP Series, which is an A4-size slim-body type.

2. Unit layout

The first step in the design of high-density packaging of mobile notebook PCs is to design the unit layout. The specifications and devices to be installed in order to achieve the target size and weight must be selected carefully. The required size of liquid crystal display (LCD) must be chosen first, then the keyboard, hard disk, battery, and other major units must be placed to optimize the shape and size of the printed wiring boards.

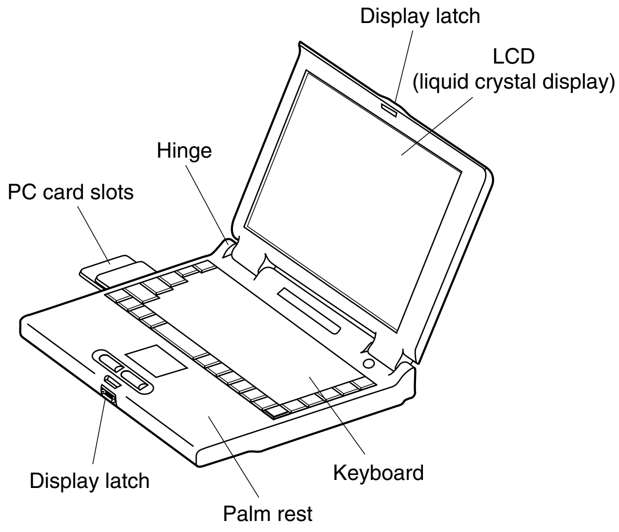


Figure 1.
Appearance of mobile notebook PC.

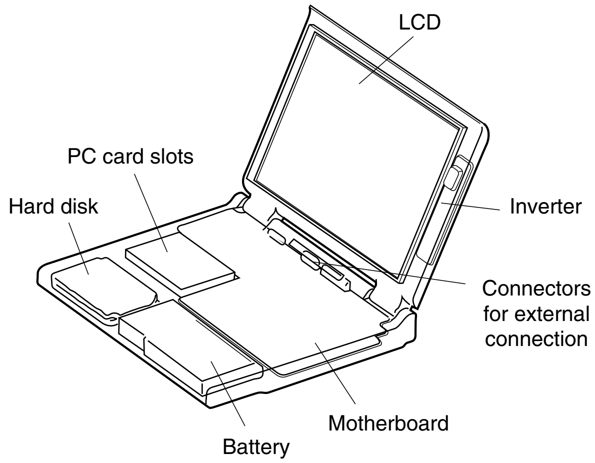


Figure 2.
Internal unit placement of mobile notebook PC.

To improve operability, the display latch, angle of tilt, and the positions of external interfaces such as connectors and PC card slots are also important factors. **Figures 1** and **2** show an example of the appearance and placement of internal devices of our mobile notebook PCs.

In front of the keyboard, sufficient space is provided for a palm rest, and the battery and hard disk are installed underneath this. By placing these heavy units in the front of the body, the PC remains stable when used on a desk with the LCD fully opened. The PC has one display latch at the center. This, as well as the rattle-free hinge that generates a uniform rolling friction torque, enables the LCD to be easily opened and closed with one hand. In principle, the connectors for external connection are provided on the rear of the body to allow a clear space beside the PC without cables. The PC card slots are placed on the left side so as not to obstruct use of a mouse. These connectors for external connection are mounted on the printed circuit board placed under the keyboard.

Generally desktop type notebook PCs have many units that have a multilayer structure. In a multilayer structure, the hard disk, battery, and other units are placed over or under printed wiring boards. In contrast, our mobile notebook PCs have a single-layer structure, as shown in Figure 2, which greatly reduces the thickness of the PC body and promotes heat dissipation. To develop a compact, lightweight, slim body as well as high reliability for the mobile notebook PC, we must do the following:

1) Thinner LCD, keyboard, and other devices and make their bodies compact.
2) Increase their mounting densities and reduce the size of the printed circuit boards.
3) Dissipate heat without a fan.
4) Protect the built-in hard disk from shock.
5) Make the cabinet walls thinner and more rigid.

We describe below the technologies we developed to solve these problems and the features of our mobile notebook PCs.

3. Compact, Slim-body Units

3.1 LCD

The size of a PC depends largely on the size of its LCD. We use a 12.1-inch LCD for the A4-size slim-body type mobile notebook PC and an 8.4-inch LCD for the A5-size lightweight type. We have reduced the thickness of our 12.1-inch TFT LCD to 7.5 mm, thus making the overall body of the PC thinner. Also, the frame of the LCD, which contains the interface circuits and mounting parts, is narrow relative to the screen size, which allows

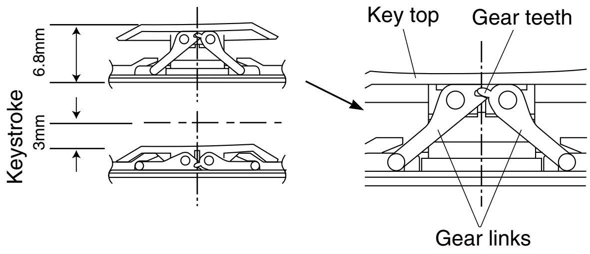


Figure 3.
Gear link-type key.

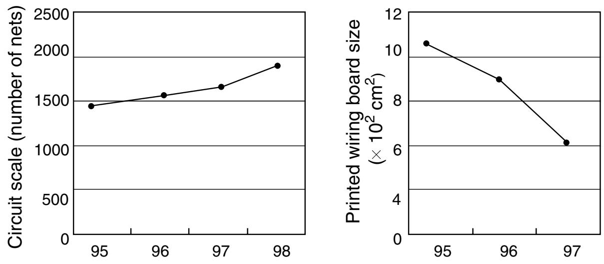


Figure 4.
Circuit scale and printed wiring board size.

the screen to be wider despite the compact PC body.

3.2 Keyboard

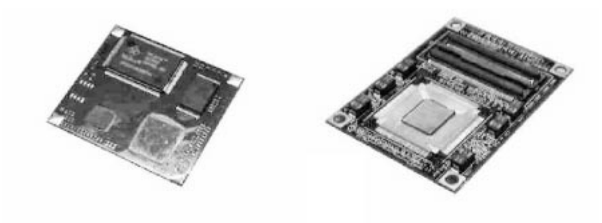
The keyboard is an important part that determines the operability of a mobile notebook PC. Also, because it takes up a large area of the unit, its thickness greatly affects the overall thickness of PC. The thinner the better in principle, but thin keyboards have inherent disadvantages such as a degraded keystroke and key touch that affect the ease of use. Conventional keyboards use the slider method based on the vertical movement of a shaft, while our keyboards for A4-size slim-body type mobile notebook PCs use a method based on turning U-shape linking parts (gear links) with gear teeth, which we specially developed (**Figure 3**). A pair of gear links is linked to the key top, and vertical movement of the key top causes both gear links to turn around the gear while transferring power to each other. This enables the grading of the key tops to be reduced and ensures a smooth action. As a result, the slide shaft used in the conventional method for operability is no longer needed, and combined with the thin-keyboard design of components, the keyboard offers a 19 mm key pitch, 3 mm keystroke, and 6.8 mm thickness, which make it as easy to use as the desktop notebook PC. In addition to a thinner body, use of this design also reduces the keyboard weight.

4. High-density Printed Wiring Boards

Figure 4 shows the transition of the circuit scale and printed wiring board size of mobile notebook PCs. The number of circuit components and wirings have increased as MPU speed and functionality have grown, while the board size has been reduced, thus requiring higher component mounting densities and wiring pattern densities. The demand for a compact and slim-body PC makes component positioning difficult: tall components cannot be positioned freely due to obstructions in the cabinet structure. On the other hand, the surface of the MPU and the power supply circuit generate the most heat, and the placement of these parts is key to improving heat dissipation. In addition, the layout and wiring pattern design must be optimized to prevent noise from affecting circuit performance.

In general, the common method of raising the density of printed wiring boards is to use finer wiring patterns and an ultra-multilayer structure (10 or more layers) of boards. This method may be adequate for small-scale boards, but for large-scale printed wiring boards like the motherboard (called the “main board” hereafter) of a notebook PC that contain thousands of components, using a finer pattern or an ultra-multilayer structure reduces the yield and makes it difficult to achieve economies of mass production, which pushes up the cost.

To satisfy these various conflicting requirements, the following techniques are used in the main board of our mobile notebook PCs:



(a) MCM (b) MPM

Figure 5.
Appearance of MCM and MPM.

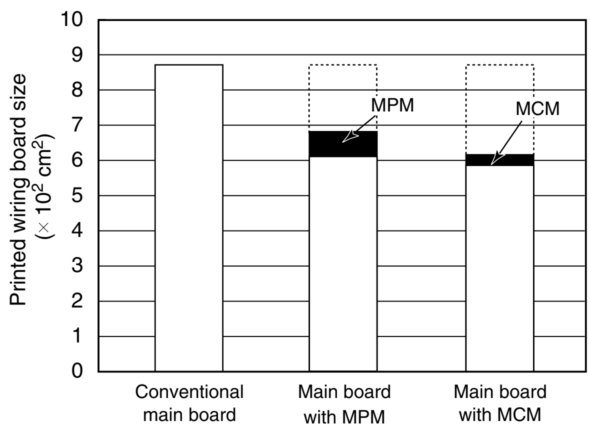


Figure 6.
Space saving by MPM and MCM.

4.1 Partial density increase by MCM or MPM

To reduce the cost of mass-producing the main board on which high-density mounting is inevitable, we have removed the MPU and surrounding circuits and packaged them at a high density in an MCM (multichip module) or MPM (multipackage module). **Figure 5** shows the appearance of the MCM and MPM. For the MCM, the flip chip mounting of a bare-chip MPU (Pentium) and chip set on a fine printed wiring board using the resin buildup method are achieved. Using smaller chips and a finer traces greatly reduces the size and weight of the printed wiring board (**Figure 6**). For the MPM, a TCP (tape carrier package)-type MPU (Pentium) and BGA (ball grid array)-type chip set, which are cheaper and

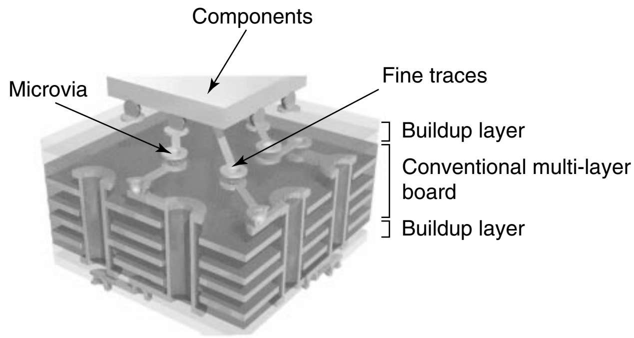


Figure 7.
Structure of LD board.

for general-purpose use, are mounted together with other components at a high density on the same fine buildup printed wiring board. We use the MCM in the A5-size lightweight mobile notebook PCs, which must be made as small and light as possible, and the MPM in the A4-size slim-body mobile notebook PCs, which require a low profile but allow a comparatively wide mounting space.

4.2 LD board

Our proprietary LD board is used for the main board, which offers, in addition to low profile and light weight, a high-density mounting, reduced number of layers (8 or less), and cheaper mass production. "LD" is an abbreviation of Laminate/Deposit, and this board is a printed wiring board manufactured using the buildup technology. This board, as shown in **Figure 7**, has conventional multilayer printed wiring boards sandwiched between buildup layers and has the following features.

i) High-density wiring by a fine traces and laser-processed microvias

High-density wiring is reguired for more wirings in a certain area. To realize this, it is essential to reduce trace width and spacing. However, in the case of the conventional printed wiring boards, which traces are formed by etching copper foil, the thickness of the copper foil makes it difficult to form fine traces. On the other hand, the buildup technology by using copper plating enables fine traces to be formed. Furthermore, the laser-processed microvias enable layers adjacent to be connected together at any point, which increases the wiring flexibility, the wiring density and facilitates high-density mounting.

ii) Low profile and light weight

The high-density wiring in the buildup layers enables less layers than in the conventional printed wiring boards. The buildup technology can be thinner than the conventional boards with the same amount of wiring, which reduces the board weight. Also, because the buildup layers are made of resin only, the dielectric constant is lower than that of the conventional board material, which contains glass fabric reinforcement. We can achieve superior electrical performance with this LD boards, which can handle such a high performance notebook PCs main board applications.

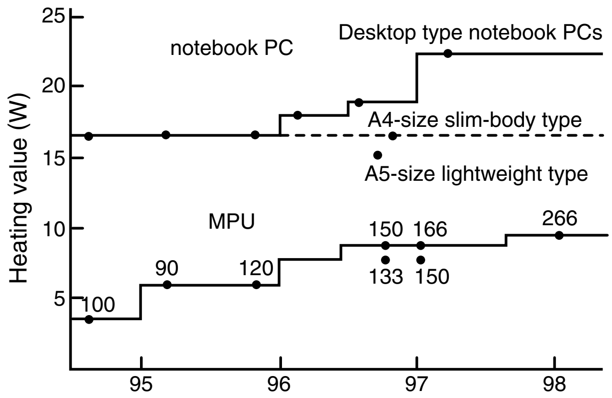
5. Technologies for Fan-less Heat Dissipation

Figures 8(a) and **8(b)** show the transition of the heating value and body volume of notebook PCs. The heating value increases with MPU speed, while the body volume decreases. Good heat dissipation is an important consideration when designing the packaging of a mobile notebook PC.

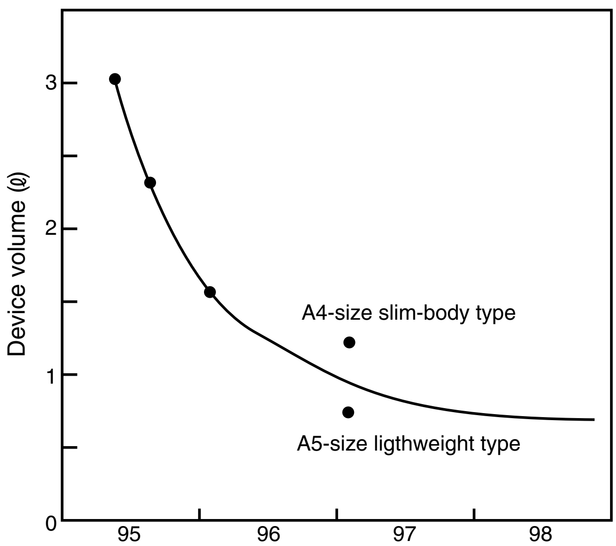
Forced air cooling by a miniature fan is the dominant heat dissipation method in recent desktop notebook PCs, but fans present the problems of space, rotation noise, and power consumption, which are critical factors for mobile notebook PC users. For this reason, we have used natural air cooling only, rather than a fan, to dissipate the heat for mobile notebook PCs. Fan-less heat dissipation requires the following:

1) A structure that efficiently dissipates the heat from heating components,
2) heat insulation for heat-vulnerable units, or placement far from heat sources, and
3) heat dissipation from the cabinet surface and a cabinet that is cooler to the touch.

The component in a mobile notebook PC that generates the most heat is the MPU chip. Intel's Pentium processor is used for the MPU, which is a TCP type and is mounted directly on the printed wiring board. Some LSIs used in the surrounding circuits and image processing circuits also generate much heat, so most components in a mobile notebook PC that produce heat are mounted on the printed wiring board. Therefore, to efficiently dissipate the heat from such components, the components must be layed out on the printed wiring board so that the heat is dissipated easily. For example, heat dissipation could be made easier by gathering all the main heat-generating components in one part of the board, but in terms of



(a) Heating values



(b) Body volumes

Figure 8.
Characteristics of notebook PCs.

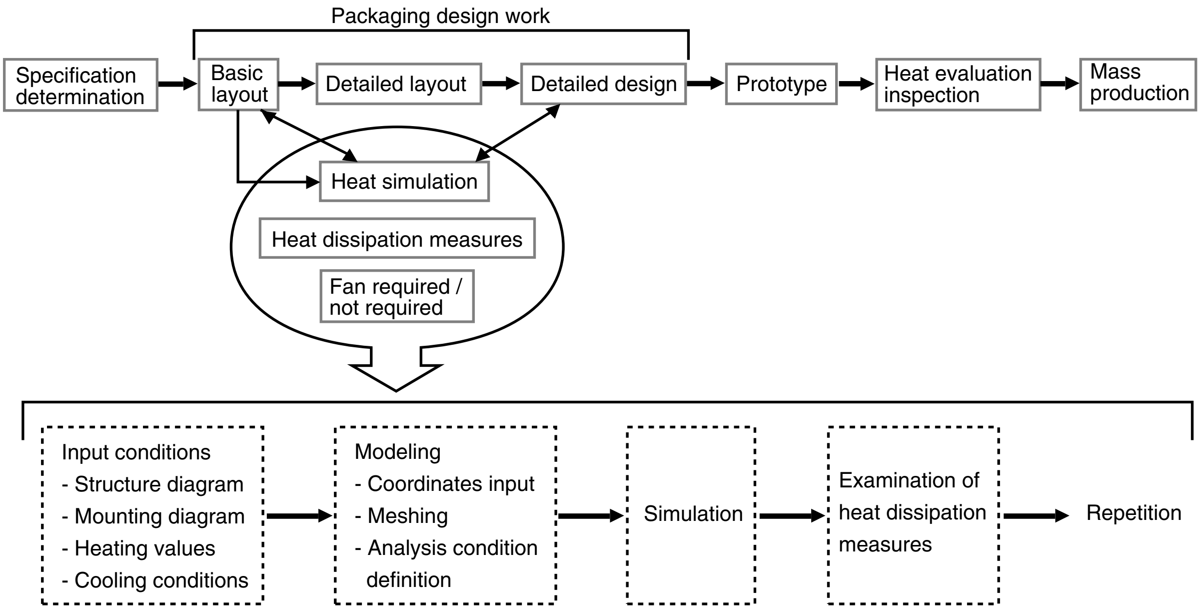


Figure 9.
Designing process including heat simulation.

the printed wiring board design, such positioning is practically impossible because there are many other considerations, for example, the problems of noise and delay, restrictions on component mounting due to the compact and thin cabinet, and ease of wiring pattern designing and board fabrication.

In the unit layout stage, heat insulation must be provided for heat-vulnerable units such as the hard disk and battery, or these units must be located far away from heat sources. However, this is not easy to achieve because the units must also be connected together with the shortest length of cabling and the size and shape of the printed wiring board must make the board easy to manufacture.

Efficient heat dissipation from the cabinet surface is essential for fan-less heat dissipation, which can be achieved using a high-heat conductivity metal for the cabinet. But mobile notebook PCs are carried by their users, are often used on the lap, and palms are usually placed on the palm rest when using the PC. Excessive cabinet heat will make the PC uncomfortable to use, and so must be avoided.

To satisfy these conflicting requirements, we have adopted the following solutions for our mobile notebook PCs:

5.1 Heat simulation in the design stage

In the past, heat simulations used to be carried out after the unit layout had been designed and the component mounting on the printed wiring board had progressed to a certain point to check whether they were adequate. But the development cycle for PCs is now very short, so there is not sufficient time to find and correct problems after the packaging design, component layout on PWB and unit layout, has been finished. For this reason, as shown in **Figure 9**, we carry out heat simulations in parallel with the packaging design work from an early stage. The finite volume method is used for the simulation. We must consider many factors from the early stage of packaging designing, and carry out repeated simulations to optimize the heat-producing components on the printed wiring board which are difficult to design, and the structure for efficient heat dissipation. To conduct this

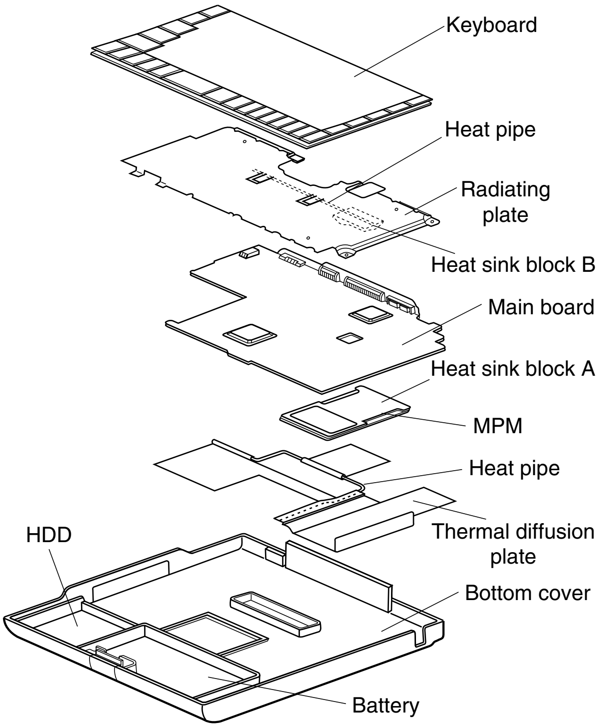


Figure 10.
Fan-less heat dissipation structure of A4-size slim-body mobile notebook PC.

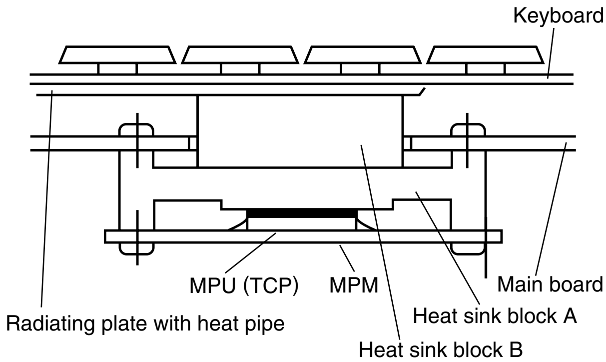


Figure 11.
Heat dissipation structure of MPM.

design process in the short term, the following points must be considered:

1) The simulated and actual temperature rise must agree closely; high accuracy of the simulation system is essential, and
2) efficient simulation must reflect the results of many simulations in the actual packaging design on a real-time basis.

By repeatedly carrying out simulations by this method and reviewing the results over many years, we have increased accuracy and efficiency. As a result of understanding factors such as the input parameters and making improvements in model division efficiency, we have recently achieved a simulation accuracy of within 5%.

5.2 Heat dissipating structure

Figure 10 shows the structure of the A4-size slim-body mobile notebook PC for dissipating heat without a fan. The MPU, which generates the most heat, and the surrounding circuits are removed and mounted on a small printed circuit board, and this module, called MPM, is placed between the main circuit board and the bottom cover. **Figure 11** shows the heat dissipating structure of the MPM. The TCP-type MPU is mounted on the MPM upside down with its die cast facing upward to improve the heat dissipation, which greatly enhances the efficiency of heat transfer to the heat sink block. A radiating plate containing a heat pipe is placed over the main board, covering its whole area. This radiating plate is designed by heat simulation to be heated uniformly with no localization of heat, and its thickness, shape, and the position of the heat pipe are chosen to ensure efficient heat dissipation.

To reduce the temperature to the touch while using the keyboard, the hard disk, battery, and other devices that do not produce much heat are placed under the palm rest and the inside of the cabinet is partitioned. The heat from the circuit board does not cause problematic hot spots because it is dissipated through the keyboard from the whole area of the radiating plate that runs under the whole of the keyboard.

Figure 12 shows the structure of the A5-size lightweight mobile notebook PC for dissipating heat without a fan. Bare chips are used for the MPU and surrounding circuits to reduce the size, and they are mounted on a printed circuit board with higher-density wiring to form the MCM. Because there is not sufficient space for

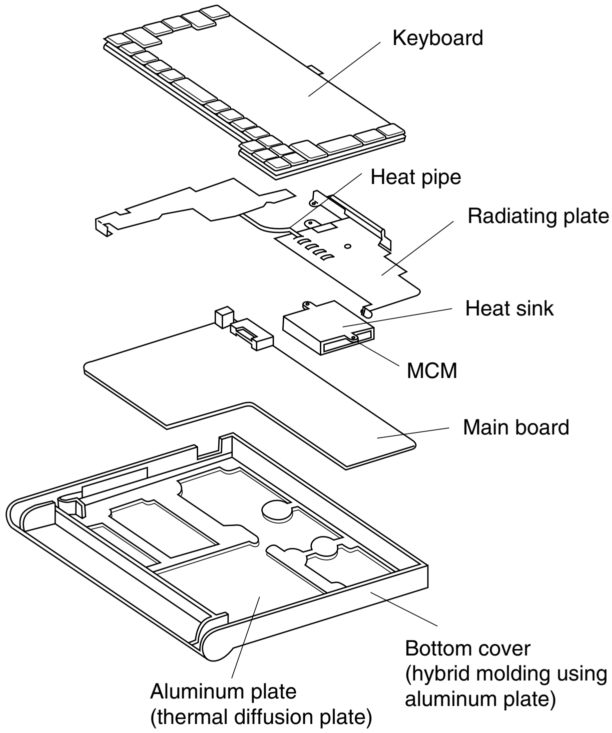


Figure 12.
Fan-less heat dissipation structure of A5-size lightweight mobile notebook PC.

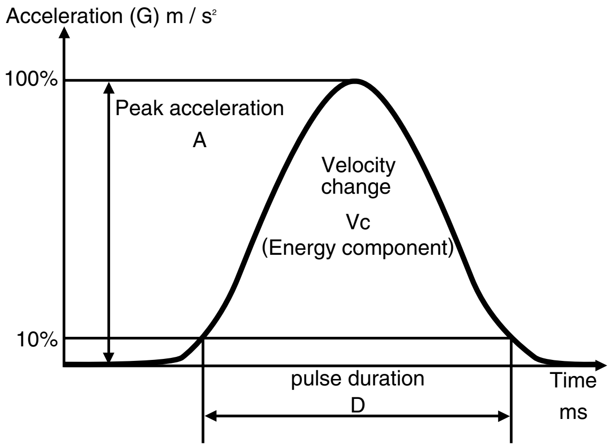


Figure 13.
Half sine wave shock pulse.

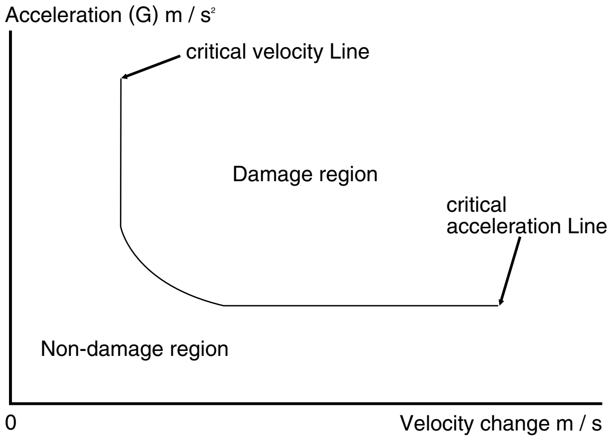


Figure 14.
Damage boundary curve.

the radiating plate in an A5-size device, we have developed a hybrid molded bottom cover in which metal and plastic are molded into one piece; this is the first time in the world this has been applied for a PC cabinet. This has achieved both a uniform spread of heat from the printed circuit board and a thin-walled, highly-rigid cabinet.

6. Structure for Protecting Built-in Hard Disk from Shock

The hard disk is vulnerable to shock, and mobile notebook PCs must be carried carefully to avoid shock even when the hard disk is not running. If a PC is dropped on the floor or hit strongly against a wall, the hard disk receives a shock of approximately 500 to 1,000 G and this may cause failure, so a commercially available cushioned protective case should be used to carry a mobile PC.

When using a mobile notebook PC on a desk, it is rather easy to give it a shock accidentally, such as when giving a presentation to a customer and trying to turn the PC in order to show the screen to the customer. In such cases, according to circumstances, the hard disk may receive a shock of around 300 G while it is running, when it is particularly vulnerable. There are many other ways in which a PC may receive a large shock accidentally that causes the hard disk to fail without user knowing it. To minimize the likelihood of failure in such cases, we developped the cabinet of the mobile notebook PC, which is the shock absorption structure for protecting hard disk from shock and vibration.

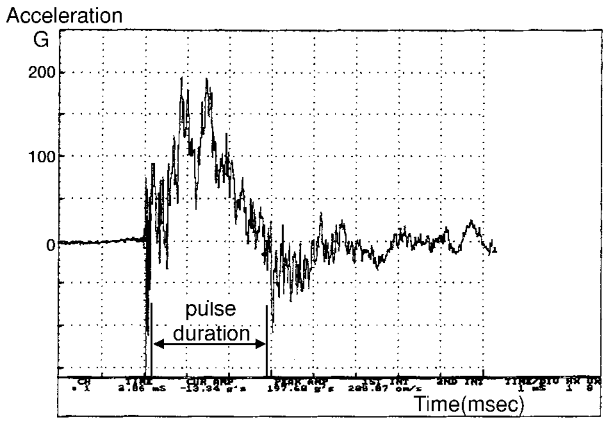


Figure 15.
Shock pulse applied to hard disk by tilt-dropping from desktop.

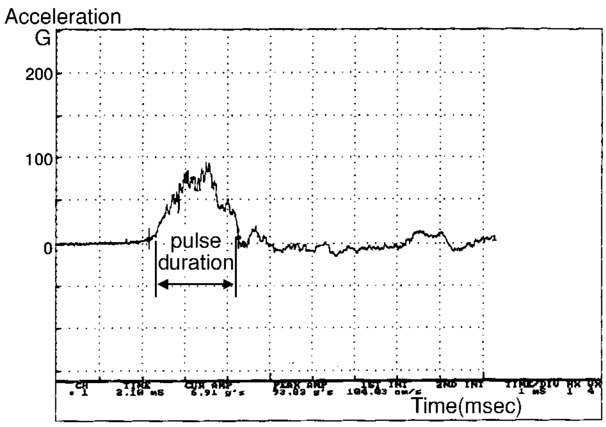


Figure 17.
Shock pulse with shock absorption structure.

The damage that a shock causes to a structure is analyzed by accurately measuring the shock waveform. **Figure 13** shows a half sine wave shock pulse. A shock causing damage has two aspects: acceleration (G) and velocity change (energy component), and it is important to not only check the acceleration but also accurately measure the pulse duration and determine the velocity change. This theory is called the damage boundary theory and is shown in **Figure 14**. In the small velocity change zone, no damage occurs however high the acceleration is because there is not enough energy to inflict damage; in other words, the structure does not respond to the shock.

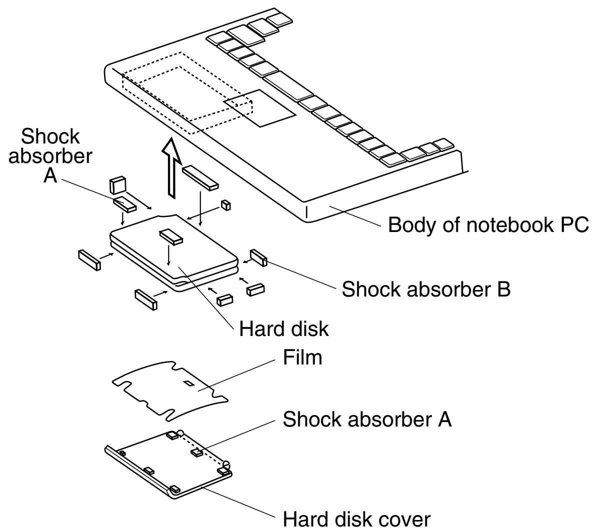


Figure 16.
Shock absorption structure of mobile notebook PC for protecting hard disk from shock and vibration.

This indicates that the minimum velocity change (energy) that damages the structure must be known. Based on this, a target can then be set for the external shock absorption capability of the hard disk protection structure. The recent general view about the shock resistance of an operating hard disk itself is that it can be given a shock that causes a maximum acceleration of 100 G (pulse duration 2 ms) without causing failure. Based on this, we aimed to protect the hard disk from shocks stronger than 100 G and the velocity change (energy) waveform having a 2 ms pulse duration.

Figure 15 shows the waveform of the shock to the hard disk caused by tilt-dropping a notebook PC on a desktop. The pulse duration of the shock waveform is about 2 to 3 ms. Unless a special shock absorption structure is provided, small variations in the mounting structure around the hard disk do not affect the action time, though they may affect the acceleration. **Figure 16** shows the shock absorption structure of the A4-size slim-body mobile notebook PC for protecting the hard disk from shock and vibration. In the conventional structure, hard disks are generally secured to cabinets using metal brackets and the like, but this

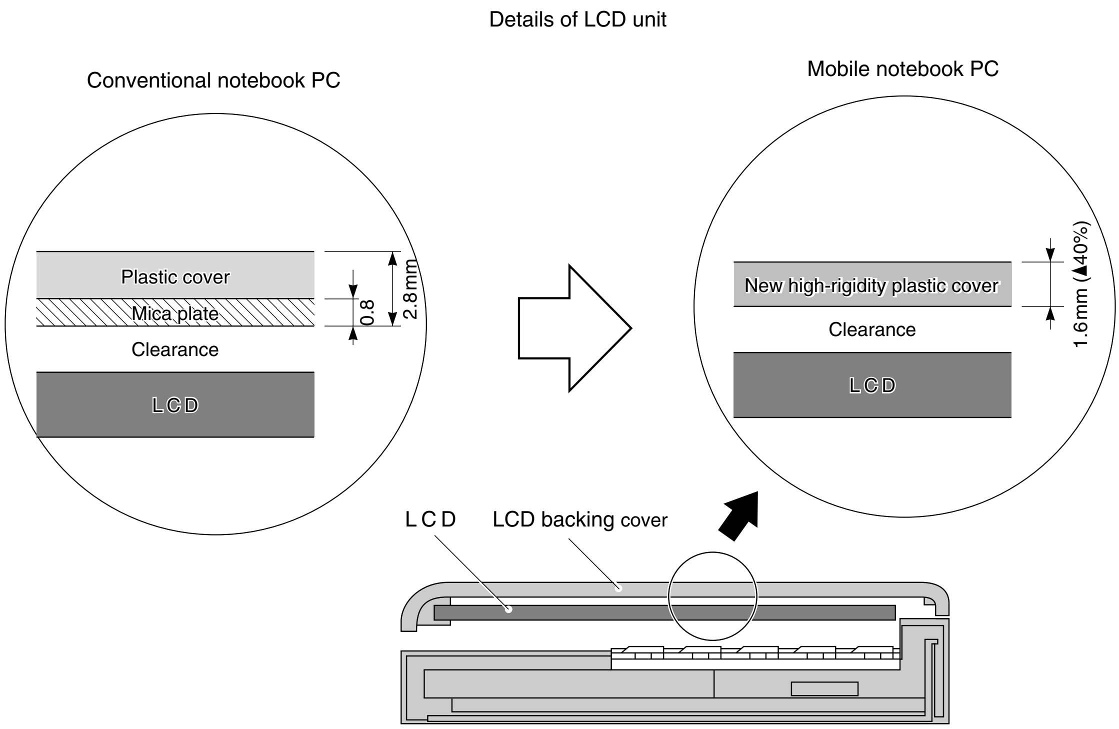


Figure 18.
Cross section of LCD unit.

structure features shock absorbers that suspend the hard disk. However, a floating structure, though resistant to shock, often presents vibration problems, so we considered the following points when selecting the shock absorber material, designing the shape and thickness of the shock absorbers, and setting the pre-pressure to apply to them:

1) Focus on shock resistance when designing the top and bottom shock absorbers to protect against drops from a desktop,
2) ensure easy assembly and good vibration resistance when designing the side shock absorbers, and
3) limit the thickness of the shock absorbers to 2 mm so as not to increase the size and body thickness.

Figure 17 shows the effect of this structure on protection from shock for a hard disk. The pulse duration and velocity change are almost the same as figure-15, and the acceleration is reduced to about one-third.

7. Thin-wall and High-rigidity Cabinet

ABS or another plastic is commonly used for the cabinets of notebook PCs. The demand for a small, lightweight, and thin PC body makes it necessary to reduce the thickness of the plastic cabinet walls, yet the larger, thinner LCD screen makes it mechanically weak. Because users typically carry their mobile notebook PCs in bags, the cover backing of the LCD must be rigid enough not to crack LCD even under a high load.

Figure 18 shows the cross section of the LCD unit of a notebook PC. Conventionally, a mica plate is laid over the LCD backing cover to reinforce it. The mica plate is manufactured by spraying thermosetting epoxy resin on several sheets of mica flakes and putting them through a hot laminate press. Having a flexural strength about twice that of aluminum plates and a specific gravity of about one-third, mica plates are widely used as lightweight, strong reinforcing plates. However, a mica plate is not suitable for mobile notebook PCs, which must be more slim and light. For

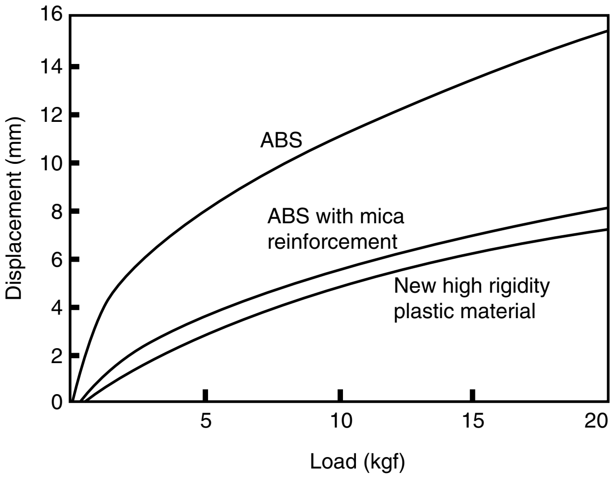
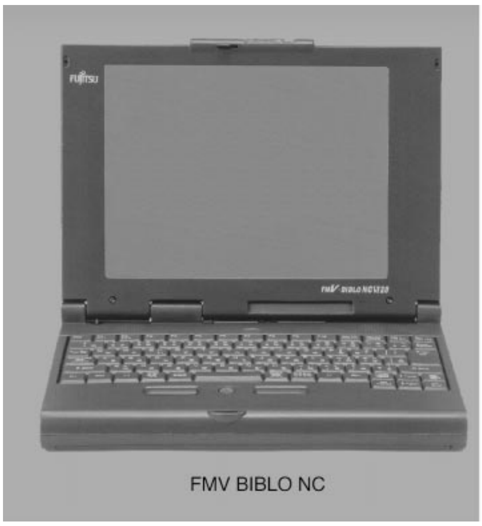


Figure 19.
Load centralization of LCD backing cover (4-size support).

this reason, we have instead developed new high-rigidity plastic material that enables thin-walled moldings to be produced, and have used it for the LCD backing cover. This material has to satisfy the following requirements:

1) The material must have a modulus of rupture at bending of at least 100,000 kg/cm^2 for sufficient rigidity,
2) it must be highly viscous and shock-resistant so that it does not shatter into sharp pieces,
3) it must be capable of being molded to form 1 mm thin walls,
4) it must not suffer from warping or other molding problems,
5) it must not allow surface faults to occur during molding and coating,
6) because it will be held by hand, the material must have good coat adhesion and peeling resistance,
7) it must allow electroless plating or ion plating because electromagnetic shielding treatment may be applied to the back of the cover, and
8) it must be based on a general-purpose material and not present a cost or mass-supply problem.

We developed PPE (polyphenylene ether) as the base resin metamorphosed by PS (polystyrene) to improve the moldability, and added 45% glass flakes to improve the elastic modulus. Glass flakes, compared with glass fiber, generally increase the rigidity, have the advantage that the fiber orientations during molding prevent warps, and offer excellent moldability. **Figure 19** shows the relationship between load and bending. We have succeeded in reducing the thickness of the LCD backing cover by about 40%, including the



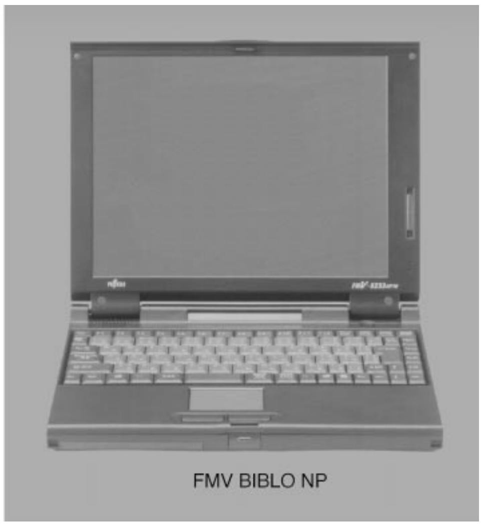


Figure 20.
Notebook PCs.

thickness of the removed mica plate, and achieving a rigidity equal to that of a conventional mica-reinforced cover. We have also achieved a 40% weight reduction by removing the mica plate, making the plastic walls thinner, and lowering the specific gravity of the base resin.

8. Conclusion

This paper has described various packaging and mechanical technologies that we have used to develop compact, lightweight, slim-body, and highly reliable mobile notebook PCs. **Figure 20** shows our A4-size slim-body mobile notebook FMV BIBLO NP Series PC and A5-size lightweight mobile notebook FMV BIBLO NC Series PC.

The mobile notebook PCs of the future will inevitably have larger circuits and generate more heat as the MPU speed and functionality are further enhanced. On the other hand, the demand for portability is expected to increase, so the bodies of mobile notebook PCs will have to be more compact, thinner, and lighter. In response, we will develop next-generation packaging and mechanical technologies to create an attractive product range.

Kazuhiro Igarashi received the B.E. degree in Mechanical Engineering from Keio University , Tokyo, Japan in 1979. He joinded Fujitsu Ltd., Kanagawa , Japan in 1979 and has been engaged in development of mechanical and packaging technology.