# Apple Pro Mouse

**Apple Pro Mouse**
**Design Innovations**

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# Contents

# Introduction

Apple popularized the mouse as an easy-to-use input device for a graphical user interface with the introduction of Macintosh in 1984. Continuing its tradition of bringing innovative technologies to the personal desktop, Apple now offers the optical Apple Pro Mouse across its entire professional and consumer lines.

Featuring a fluid, elliptical shape that intuitively simplifies mouse movement, the Apple Pro Mouse houses patent-pending technologies that increase ease of use and performance over competing products. Specifically, the Apple Pro Mouse tracks more smoothly at faster speeds, tracks more accurately on low-contrast and soft surfaces, and uses a completely new clicking actuator.

This paper explains these innovations and optimizations.

# Optical Mouse Advantages

An optical mouse differs from a standard mouse in that during tracking, it uses no mechanical parts that could wear out, clog, or jam. An optical mouse also offers ultraprecise tracking during fast movement, especially on surfaces that are not flat, such as a pants leg or a magazine cover.

Any mouse determines the X-Y coordinates of motion and passes them to the operating system to indicate cursor movement. A mechanical mouse measures these differences using mechanical rollers, which, over time, can become clogged and sticky from particles of dust and dirt that adhere to its moving parts.

In contrast, the optical mouse measures differences in movement using an *LED* light to illuminate the surface it's on, a *lens* to focus the illuminated area, a *camera* to acquire sequential microscopic pictures of that illumination area, and an onboard *digital signal processor (DSP)* to determine direction and distance of motion. Apple's implementation of the optical mouse is superior because we enabled the onboard controller to capture all data reported by the DSP and we redesigned the lens assembly.

Optical mice depend on the ability to retain a 50 percent overlay between images captured by the camera to deliver fluid motion onscreen (see "Inner Workings of the Optical Mouse" on the next page). That means the mouse must maintain a minimum resolution of 400 counts per inch, a measurement determined by the optics manufacturer to quantify this overlay. Users will notice if the mouse exceeds this limit: The mouse will move in a random direction—backwards, up, or down—similar to the way helicopter blades appear to rotate slowly backwards. The optical system erroneously reports a pattern of motion calculated from images captured too quickly for it to identify the correct motion.

Users initiate mouse movement in quick, accelerated bursts. The Apple Pro Mouse can withstand acceleration of 250 inches per second per second and still maintain the correct resolution of 400 counts per inch. Once the mouse is in motion, users can move it at rates of speed up to 14 inches per second without losing fluid tracking.

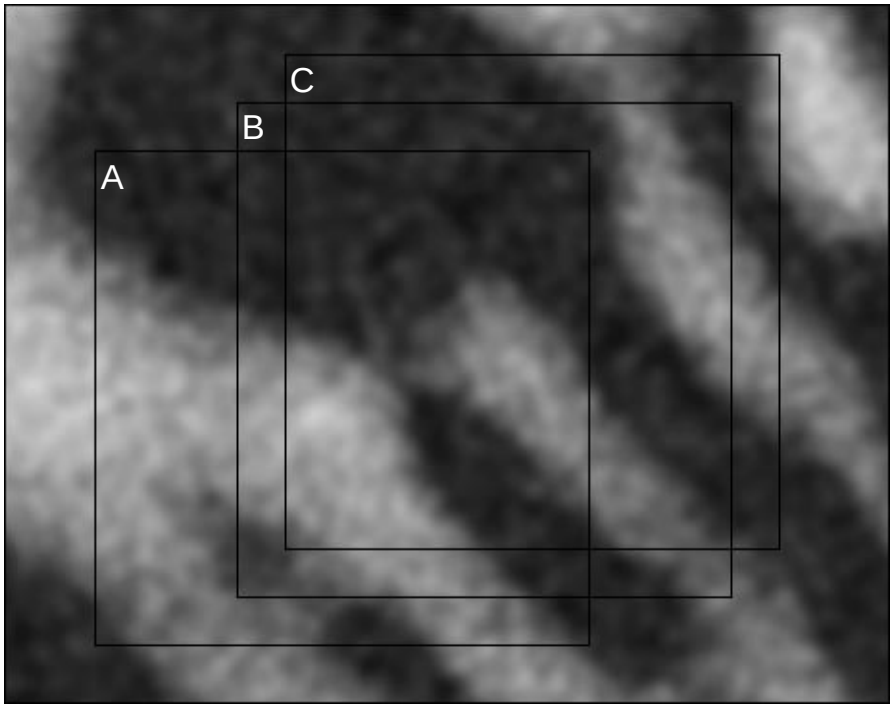
To maintain support for legacy products, other mice on the market today use only a subset of the data reported by the system and are thus unable to maintain the same resolution as the Apple Pro Mouse during faster motion. These mice can deliver only 225 inches per second per second acceleration and 12.5 inches per second velocity before losing tracking ability. Because the onboard controller collects all data reported from the DSP, the Apple Pro Mouse delivers up to 10 percent better acceleration and up to 15 percent higher velocity.

This design directly translates into tangible user benefits: When moving the mouse quickly, users are able to hit onscreen targets with less frustration using the Apple Pro Mouse compared with competing products.

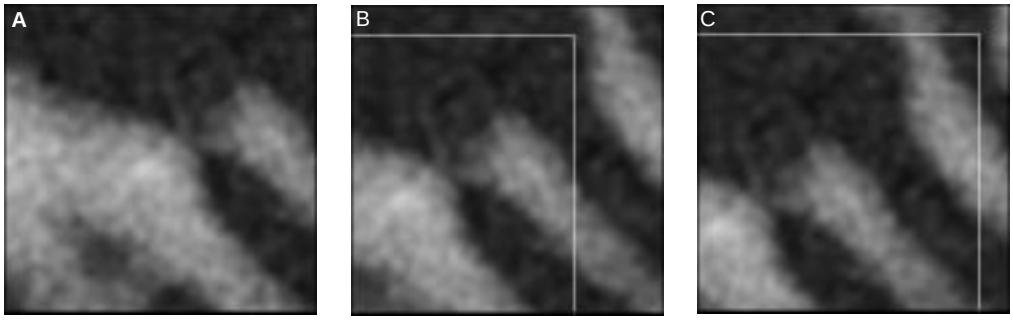
## Inner Workings of the Optical Mouse

The onboard digital signal processor (DSP) analyzes images and determines differences in what it sees. It converts this analysis into X-Y coordinates and velocity from vectors measured by comparing the overlap in the pictures.

The illustration at right represents the surface underneath the mouse. As the mouse is moved, the camera captures 1,500 images per second.




Artist's rendition of the surface area under the camera.




Corresponding series of images fed to the DSP for processing. The white lines mark the overlap with the previous image.

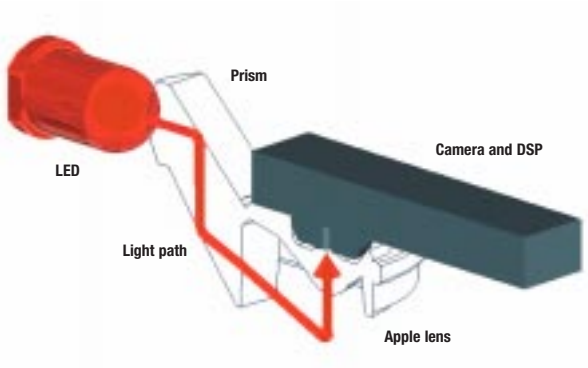
# Optical Assembly

Fitt's Law and Motion Characterization testing show that the Apple Pro Mouse tracks more smoothly and with better accuracy than competing products on low-contrast surfaces, varied surfaces such as stacks of paper, and soft surfaces such as Lycra mousepads. On white paper especially, mouse users are able to reach targets up to twice as quickly as with other products. Apple achieved these performance gains through a redesign of the optical assembly, resulting in a superior depth-of-field performance.

If the lens in front of the camera is out of focal length, the blurry images make it difficult for the camera to detect motion, reducing maximum speed. If the image is too far out of focus, the mouse does not move at all. Thus, design of the optical path is critical to the accuracy of the camera images. Apple designed and developed a new lens in order to optimize the optical path to achieve an improved depth of field, which feeds better data to the DSP.

For optimum focal length, the light must hit the surface at a 30-degree angle to the prism lens that sits inside the LED. Just as light hitting the earth at sunset or dusk is different from the light of the noonday sun, this low angle is necessary to pick up greater differences in the surface picture.

The Apple prism design captures and directs light to the imaging chip better than other imaging lens designs. Providing more light to the imaging lens gains more definition in the picture. The better the camera can pick up surface image differences, the better it will be able to track user motion and provide smooth tracking.




The Apple lens design directs light to the imaging chip better than other lens designs.

About the diameter of a half-dollar, the standard lens used in most optical mice is significantly wider than the lens built into the Apple Pro Mouse.

This improved depth of field directly translates into perceivable benefits: When tested on a black plastic mousepad, the Apple Pro Mouse delivered 85 percent accuracy at 1 mm from the nominal focus, while other products could deliver this accuracy only at 0.5 mm from the nominal focus. If a competing mouse were on a stack of papers, it might not be able to report the accurate motion that the Apple Pro Mouse can.

The superior dark sensitivity of Apple's optical implementation will extend the life of the Apple Pro Mouse compared with other products on the market. With this custom design, Apple also reduced its lens assembly to less than the diameter of a quarter. Which, not surprisingly, is just the size necessary to make the other innovations in the Apple Pro Mouse possible.

# Industrial Design Innovations

With the lens assembly occupying a smaller space, Apple's award-winning industrial design team could focus its attention on crafting a better breed of mouse. That work yielded a mouse that fits any user. Whether left-handed or right-handed, heavy-handed or light-handed, any mouse user will find that pointing works intuitively. Any part of the hand, from finger to thumb to palm, can move the mouse or trigger a click.

The entire top enclosure is the actual button. To achieve this effect, Apple invented a new, patent-pending clicking mechanism. The whole upper surface moves—that is, pressing on any portion of the upper surface creates a click. This design also accommodates a wide variety of hand sizes and shapes. Clicking can be performed with one finger, two fingers, three fingers, the palm of a hand, or even the side of a hand. Users can vary their method of clicking as often as they like during use.

To move or drag the cursor across larger distances, the user picks up the mouse by its sides, which locks the mouse movement and keeps the drag in place. A thinner cable—over 20 percent thinner than the cables of previous Apple USB mice—makes movement easier thanks to its greater flexibility.

# Adjustable Tension

This novel mouse button presented the design team with an interesting challenge. Different-sized hands might click accidentally or find the mouse too hard to click. To resolve this issue, the team invented another patent-pending technology: adjustable tension.

Located on the bottom of the mouse is a switch that rotates between three positions: "–," "0," and "+." A spring hidden under the ring acts as a cantilever.

In the "–" position, the tension is lower to accommodate smaller or lighter hands, making clicking easier.

When rotated to the medium ("0") position, the ring presses up on the spring in the middle to stiffen it.

In the "+" position, the spring is moved higher, making it even stiffer for heavier or bigger hands.

# Durability

A mouse is an extension of the user's will. With its solid, dependable, yet fluid feel, the Apple Pro Mouse reassures the user that it will react with pinpoint accuracy. This encouraging touch will be felt every time the user holds the crystal-clear polycarbonate shell surrounding the optical assembly and forming the seamless top button.

This shell can withstand 700 pounds of force. Put in perspective, an elephant stepping on the shell would just mush it into the ground (but might break the pieces underneath). Yet the mouse also feels light and airy—an effect produced through painstaking attention to the clarity of the material. To achieve this clarity, and to prevent dust from getting into the internals, the Apple Pro Mouse is built in a special clean-room environment. Comparable environments are required for the production of other precision devices such as semiconductors and hard drives.

# Conclusion

Because Apple redesigned the lens assembly and enabled the onboard controller to use all data from the DSP, the Apple Pro Mouse offers greater tracking accuracy on a wider variety of surfaces over a longer period of time than competing optical mice, and it delivers these benefits at faster speeds. In addition, the fluid, elliptical shape of the mouse houses innovations in industrial design that improve both ease of use and durability.

And yes, this mouse glows in the dark.

Apple

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