How Computer Mice Work

by Marshall Brain

Mice come in all shapes and sizes. This is an older two-button mouse.

Mice first broke onto the public stage with the introduction of the Apple Macintosh in 1984, and since then they have helped to completely redefine the way we use computers.

Every day of your computing life, you reach out for your **mouse** whenever you want to move your cursor or activate something. Your mouse senses your motion and your clicks and sends them to the computer so it can respond appropriately.

In this edition of **HowStuffWorks**, we'll take the cover off of this important part of the human-machine interface and see exactly what makes it tick!

Evolution

It is amazing how simple and effective a mouse is, and it is also amazing how long it took mice to become a part of everyday life. Given that people naturally point at things -- usually before they speak -- it is surprising that it took so long for a good pointing device to develop. Although originally conceived in the 1960s, it took quite some time for mice to become mainstream.

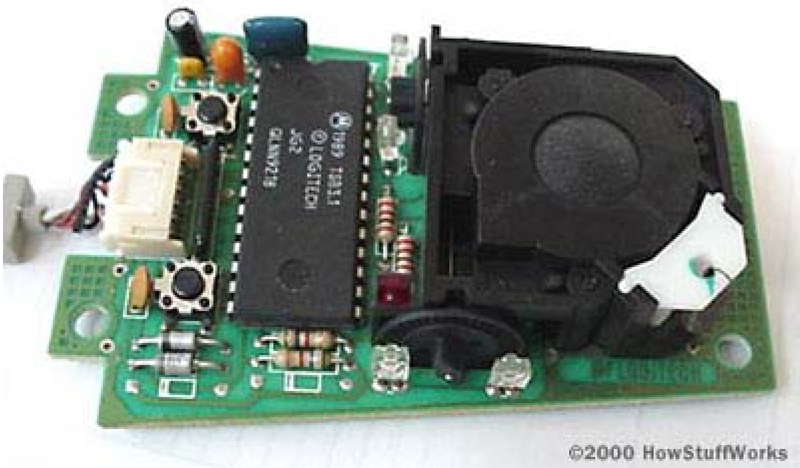
In the beginning there was no need to point because computers used crude interfaces like teletype machines or punch cards for data entry. The early text terminals did nothing more than emulate a teletype (using the screen to replace paper), so it was many years (well into the 1960s and early 1970s) before arrow keys were found on most terminals. Full screen editors were the first things to take real advantage of the cursor keys, and they offered humans the first crude way to point.

Light pens were used on a variety of machines as a pointing device for many years, and graphics tablets, joy sticks and various other devices were also popular in the 1970s. None of these really took off as the pointing device of choice, however.

When the mouse hit the scene attached to the Mac, it was an immediate success. There is something about it that is completely natural. Compared to a graphics tablet, mice are extremely inexpensive and they take up very little desk space. In the PC world, mice took longer to gain ground, mainly because of a lack of support in the operating system. Once Windows 3.1 made Graphical User Interfaces (GUIs) a standard, the mouse became the PC-human interface of choice very quickly.

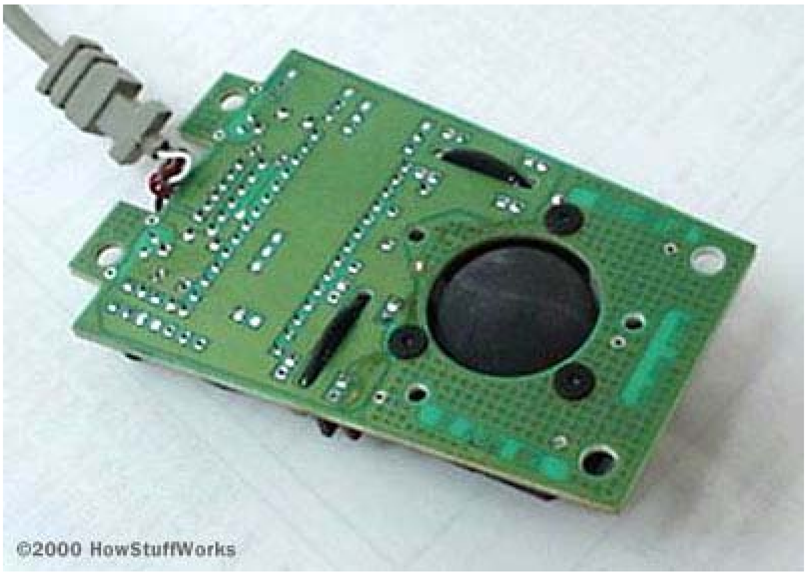
Inside a Mouse

The main goal of any mouse is to translate the motion of your hand into signals that the computer can use. Almost all mice today do the translation using five components:



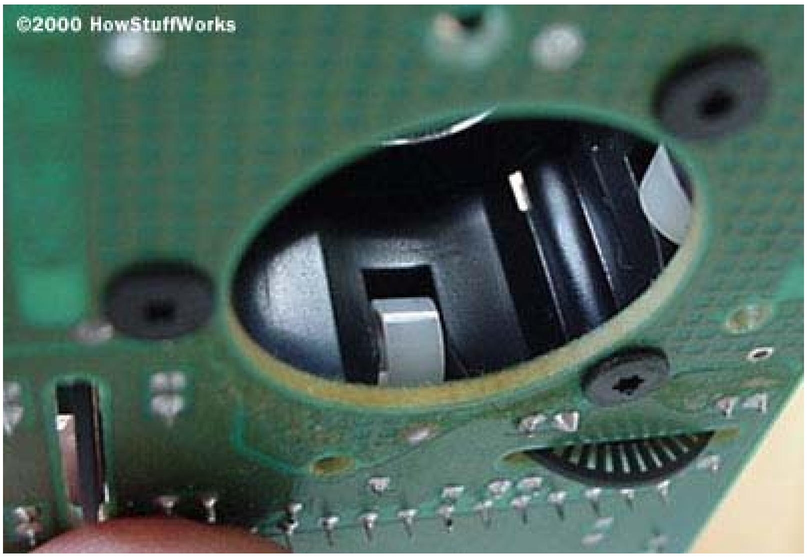
The guts of a mouse

1. A **ball** inside the mouse touches the desktop and rolls when the mouse moves.



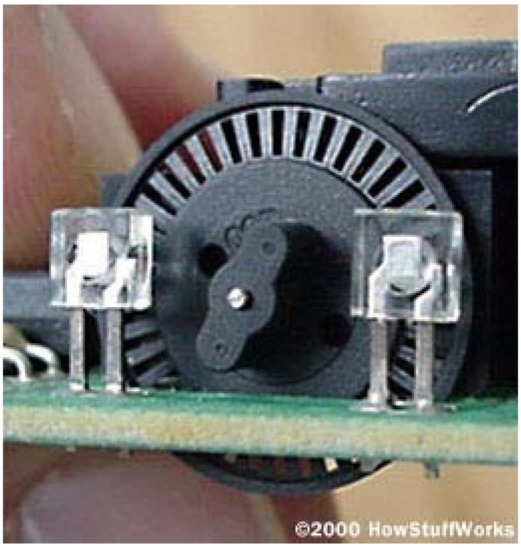
The underside of the mouse's logic board: The exposed portion of the ball touches the desktop.

2. **Two rollers** inside the mouse touch the ball. One of the rollers is oriented so that it detects motion in the X direction, and the other is oriented 90 degrees to the first roller so it detects motion in the Y direction. When the ball rotates, one or both of these rollers rotate as well. The following image shows the two white rollers on this mouse:



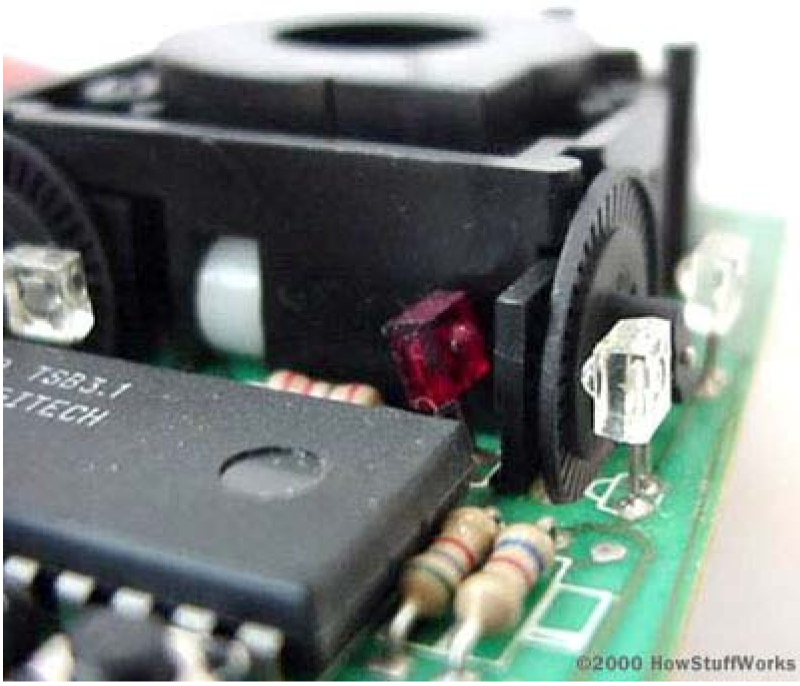
The rollers that touch the ball and detect X and Y motion

3. The rollers each connect to a **shaft**, and the shaft spins a **disk** with holes in it. When a roller rolls, its shaft and disk spin. The following image shows the disk:



A typical optical encoding disk: This disk has 36 holes around its outer edge.

4. On either side of the disk there is an **infrared LED** and an **infrared sensor**. The holes in the disk break the beam of light coming from the LED so that the infrared sensor sees pulses of light. The rate of the pulsing is directly related to the speed of the mouse and the distance it travels.



A close-up of one of the optical encoders that track mouse motion: There is an infrared LED (clear) on one side of the disk and an infrared sensor (red) on the other.

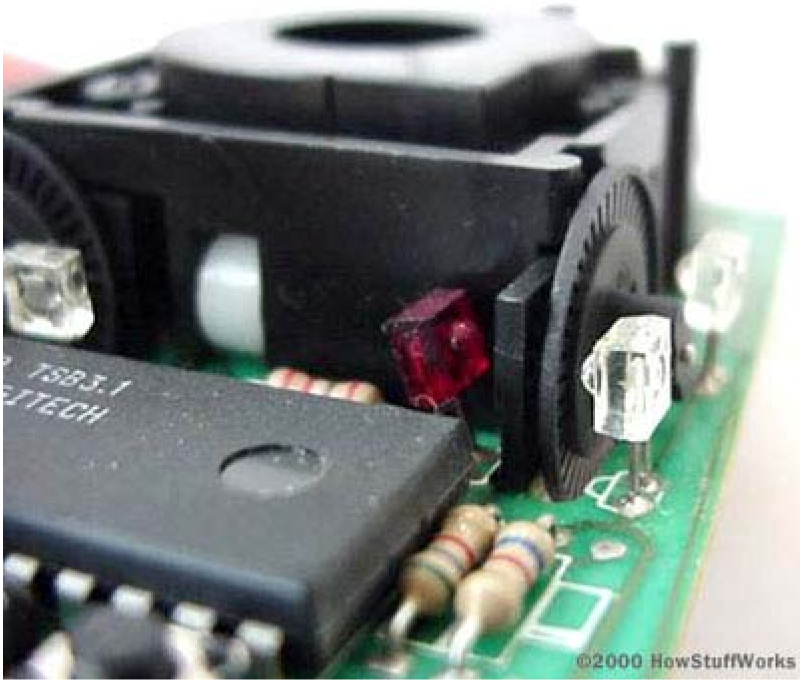
5. An **on-board processor chip** reads the pulses from the infrared sensors and turns them into binary data that the computer can understand. The chip sends the binary data to the computer through the mouse's cord.

The logic section of a mouse is dominated by an encoder chip,

a small processor that reads the pulses coming from the infrared sensors and turns them into bytes sent to the computer. You can also see the two buttons that detect clicks (on either side of the wire connector).

In this **optomechanical** arrangement, the disk moves mechanically, and an optical system counts pulses of light. On this mouse, the ball is 21 mm in diameter. The roller is 7 mm in diameter. The encoding disk has 36 holes. So if the mouse moves 25.4 mm (1 inch), the encoder chip detects 41 pulses of light.

You might have noticed that each encoder disk has two infrared LEDs and two infrared sensors, one on each side of the disk (so there are four LED/sensor pairs inside a mouse). This arrangement allows the processor to detect the disk's **direction of rotation**. There is a piece of plastic with a small, precisely located hole that sits between the encoder disk and each infrared sensor. It is visible in this photo:



A close-up of one of the optical encoders that track mouse motion: Note the piece of plastic between the infrared sensor (red) and the encoding disk.

This piece of plastic provides a window through which the infrared sensor can "see." The window on one side of the disk is located slightly higher than it is on the other -- one-half the height of one of the holes in the encoder disk, to be exact. That difference causes the two infrared sensors to see pulses of light at slightly different times. There are times when one of the sensors will see a pulse of light when the other does not, and vice versa. This page offers a nice explanation of how direction is determined.

The Optical Mouse

With advances it mouse technology, it appears that the venerable wheeled mouse is in danger of extinction. The now-preferred device for pointing and clicking is the **optical mouse**.

This Microsoft Intellimouse uses optical technology.

Developed by Agilent Technologies and introduced to the world in late 1999, the optical mouse actually uses a tiny **camera** to take 1,500 pictures every second.

Able to work on almost any surface, the mouse has a small, red **light-emitting diode** (LED) that bounces light off that surface onto a complimentary metal-oxide semiconductor (CMOS) sensor. The CMOS sensor sends each image to a **digital signal processor (DSP)** for analysis. The DSP, operating at 18 MIPS (million instructions per second), is able to detect patterns in the images and see how those patterns have moved since the previous image. Based on the change in patterns over a sequence of images, the DSP determines how far the mouse has moved and sends the corresponding coordinates to the computer. The computer moves the cursor on the screen based on the coordinates received from the mouse. This happens hundreds of times each second, making the cursor appear to move very smoothly.

In this photo, you can see the LED on the bottom of the mouse.

Optical mice have several benefits over wheeled mice:

- No moving parts means less wear and a lower chance of failure.
- There's no way for dirt to get inside the mouse and interfere with the tracking sensors.
- Increased tracking resolution means smoother response.
- They don't require a special surface, such as a mouse pad.

Apple has transformed its optical mouse into a modern work of art.

Although LED-based optical mice are fairly recent, another type of optical mouse has been around for over a decade. The original optical-mouse technology bounced a focused beam of light off a highly-reflective mouse pad onto a sensor. The mouse pad had a grid of dark lines. Each time the mouse was moved, the beam of light was interrupted by the grid. Whenever the light was interrupted, the sensor sent a signal to the computer and the cursor moved a corresponding amount.

This kind of optical mouse was difficult to use, requiring that you hold it at precisely the right angle to ensure that the light beam and sensor aligned. Also, damage to or loss of the mouse pad rendered the mouse useless until a replacement pad was purchased. Today's LED-based optical mice are far more user-friendly and reliable.

Data Interface

Most mice in use today use the standard **PS/2** type connector, as shown here:

A typical PS/2 connector: Assume that pin 1 is located just to the left of the black alignment pin, and the others are numbered clockwise from there.

These pins have the following functions (refer to the above photo for pin numbering):

1. Unused
2. +5 volts (to power the chip and LEDs)
3. Unused
4. Clock
5. Ground
6. Data

Whenever the mouse moves or the user clicks a button, the mouse sends 3 bytes of data to the computer. The first byte's 8 bits contain:

1. Left button state (0 = off, 1 = on)
2. Right button state (0 = off, 1 = on)
3. 0
4. 1
5. X direction (positive or negative)
6. Y direction
7. X overflow (the mouse moved more than 255 pulses in 1/40th of a second)
8. Y overflow

The next 2 bytes contain the X and Y movement values, respectively. These 2 bytes contain the number of pulses that have been detected in the X and Y direction since the last packet was sent.

The data is sent from the mouse to the computer serially on the data line, with the clock line pulsing to tell the computer where each bit starts and stops. Eleven bits are sent for each byte (1 start bit, 8 data bits, 1 parity bit and 1 stop bit). The PS/2 mouse sends on the order of 1,200 bits per second. That allows it to report mouse position to the computer at a maximum rate of about 40 reports per second. If you are moving the mouse very rapidly, the mouse may travel an inch or more in one-fortieth of a second. This is why there is a byte allocated for X and Y motion in the data protocol.

Some mice use **serial** or **USB** type connectors. See How Serial Ports Work and How USB Ports Work for information on these technologies.

For more information on mice and related topics, including troubleshooting and repair, check out the links on the next page.