How Home Thermostats Work

You've probably seen or used a thermostat a thousand times. This device controls the heating and air-conditioning systems in your house -- the two pieces of equipment that use the most energy. In these days of rising energy prices, you might be interested to see how your thermostat works. It is surprisingly simple, and contains some pretty neat technology.

In this article, we'll take apart a household thermostat and learn how it works. We'll also learn a little about digital thermostats. Let's start by taking a look at the parts.

Dissection

Let's take a look at the parts of a typical thermostat. Underneath the cover, there are two layers.

The top layer houses the **mercury switch** and the **thermometer coil**. The bottom layer houses the **circuit card**, the **mode switch** and the **fan switch**.

> **Cutting Costs**
>
> If you turn down the heat 1 degree Fahrenheit (0.6 degrees Celsius) for 8 hours a day, you can save about 1 percent of your heating energy costs. Turn it down 10 degrees F (6 degrees C) to save about 10 percent. The same goes with the air-conditioning: Turn the temperature up 10 degrees F for 8 hours a day to save approximately 10 percent on your energy bill.

Mercury Switch

The **mercury switch** is a glass vial with a small amount of mercury in it. Mercury is a liquid metal -- it conducts electricity and flows like water. Inside the glass vial are three wires. One wire goes all the way across the bottom of the vial, so the mercury is always in contact with this wire. One wire ends on the left side of the vial, so when the vial tilts to the left, the mercury contacts it -- making contact between this wire and the one on the bottom of the vial. The third wire ends on the right side of the vial, so when the vial tilts to the right, the mercury makes contact between this wire and the bottom wire.

Thermometer

There are two thermometers in this thermostat. One displays the temperature and is located in the cover. The other controls the heating and cooling systems and is located in the top layer of the thermostat. These thermometers are nothing more than coiled bimetallic strips.

A **bimetallic strip** is a piece of metal made by laminating two different types of metal together. The metals that make up the strip expand and contract when they are heated or cooled. Each type of metal has its own particular rate of expansion, and the two metals that make up the strip are chosen so that the rates of expansion and contraction are different. When this coiled strip is heated, the metal on the inside of the coil expands more and the strip tends to unwind.

The center of the coil is connected to the temperature-adjustment lever, and the mercury switch is mounted to the end of the coil so that when the coil winds or unwinds, it tips the mercury switch one way or the other.

Circuit Card and Switches

This thermostat contains two **switches**. The switches move small metal balls that make contact between different traces on the **circuit card** inside the thermostat. One of the switches controls the **mode** (heat or cool), while the other switch controls the **circulation fan**.

Let's see how these parts work together to make the thermostat work.

> **Thermostat Location**
>
> Ideally, the thermostat should be located in the part of the house where people spend the most time. It should be about 5 feet (1.5 meters) off the ground and at least 18 inches (46 cm) away from an outside wall. It should not be exposed to any heat sources other than the air in the room, such as sunlight, other appliances, heater vents, windows or hot-water pipes. It is also best not to put a thermostat near a stairway or in a corner because they affect the circulation of air.

Making It Work

When you move the lever on the thermostat to turn up the heat, this rotates the thermometer coil and mercury switch, tipping them to the left.

As soon as the switch tips to the left, current flows through the mercury in the mercury switch. This current energizes a relay that starts the **heater** and circulation fan in your home. As the room gradually heats up, the thermometer coil gradually unwinds until it tips the mercury switch back to the right, breaking the circuit and turning off the heat.

When the mercury switch tips to the right, a relay starts the air conditioner. As the room cools, the thermometer coil winds up until the mercury switch tips back to the left.

Heat Anticipator

This thermostat has a neat device called a **heat anticipator**. The heat anticipator shuts off the heater before the air inside the thermostat actually reaches the set temperature. Often, some parts of the house will reach the set temperature before the part of the house containing the thermostat does. The anticipator shuts the heater off a little early to give the heat time to reach the thermostat.

This loop of wire is actually a **resistor**. When the heater is running, the current that controls the heater travels from the mercury switch, through the yellow wire to the resistive loop. It travels around the loop until it gets to the **wiper**, and from there it travels through the hub of the anticipator ring and down to the circuit board on the bottom layer of the thermostat. The farther the wiper is positioned (moving clockwise) from the yellow wire, the more of the resistive wire the current has to pass through. Like any resistor, this one generates heat when current passes through it. The farther around the loop the wiper is placed, the more heat is generated by the resistor. This heat warms the thermometer coil, causing it to unwind and tip the mercury switch to the right so that the heater shuts off.

Now let's take a more detailed look at the electrical circuits in the thermostat.

Wired

This thermostat is designed for a system with five wires -- the wire terminations are marked as follows:

- **RH** - This wire comes from the 24VAC transformer on the heating system.
- **RC** - This wire comes from the 24VAC transformer on the air-conditioning system.
- **W** - This wire comes from the relay that turns on the heating system.
- **Y** - This wire comes from the relay that turns on the cooling system.
- **G** - This wire comes from the relay that turns on the fan.

The two transformers provide the power the thermostat uses to switch on the various relays. The relays in turn switch on the power to the fan and the air-conditioner or furnace. Let's see how this power flows through the thermostat when the air-conditioner is running.

Power from the air-conditioning transformer comes into the terminal labeled RC. The ball controlled by the mode switch jumps the current onto a trace that leads to the terminal in the lower-right corner of the circuit board.

This terminal connects to the top layer of the thermostat through a screw. It connects to the pink wire (see below), which leads to the bottom wire in the mercury switch. If the switch is tilted to the right (as it would be if the air-conditioning were on), the current travels through the mercury into the blue wire.

Through a screw, the blue wire (see above) connects to a lug in the lower-left corner of the circuit card.

From there, it goes through a trace on the circuit card to the other branch of the mode switch. The ball in the mode switch jumps the current onto a trace that connects to the terminal marked G, which energizes the fan, and the terminal marked Y, which energizes the air-conditioning.

Now that we know how a mechanical thermostat works, let's take a quick look at a digital one.

Digital Thermostats

Digital thermostats use a simple device called a **thermistor** to measure temperature. A thermistor is a resistor whose electrical resistance changes with temperature. The microcontroller in a digital thermostat can measure the resistance and convert that number to a temperature reading.

A digital thermostat can do a few things that our mechanical thermostat cannot. One of the most useful features of a digital thermostat is programmable settings. With the above thermostat, you can set four different temperatures for each day of the week. For instance, in the winter, you can program it to automatically turn up the heat for an hour or two in the morning while you get ready for work, turn down the heat until you get home, turn up the heat in the evening and then turn down the heat while you sleep. This feature can save you money by turning down the heat when it isn't needed.