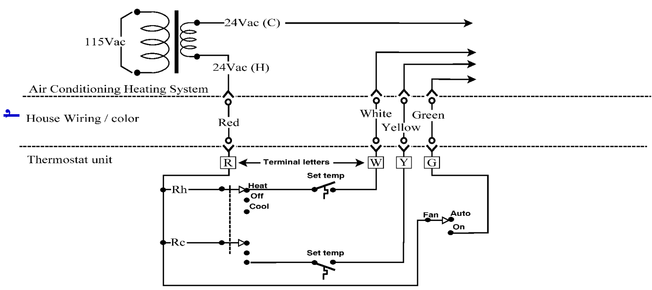
Thermostat signals and color code

Lack of standards makes this interesting.

While there isn't an official standard for thermostat circuit wiring colors, there is a general pattern. Your best bet is to see the manufacturer's documentation (both thermostat and HVAC).



Thermostat Schematic

Wire colors

If you only have 4 wires they are typically (Red, Yellow, Green & Black). If you have (Blue, White & Blue stripe, Orange, White & Orange stripe, and possibly Green & Brown pairs as well) coming out of the wall then it is probably phone or networking wire and it isn't good because it is too thin for the current. If there is a short then the current through the tiny wires could cause a fire (Thermostat wires are usually #18 gauge.) These colors are not standard for thermostats.

If you need an inexpensive meter to work with thermostat wiring see M300

We also have meters that can display thermocouple temperature Process Control Meters

Older systems and base signals on newer ones			
Terminal	**Probable wire Color**	**Signal**	**Description**
C	Blue	24 Vac Common	From one side of the 24Vac transformer (Think of this as 24Vac neutral
R or V	Red	24 Vac Power to be switched	From other side of the 24Vac transformer (Think of this as 24Vac L1)
Rh or 4	Red	24 Vac Heat call switch power	Same as R, but dedicated to the Heat call switch
Rc	Red	24 Vac Cooling call switch power	Same as R, but dedicated to the cooling call switch
G	Green	Fan	Fan switch on thermostat - is connected to R when Fan /Auto switch is in the fan position
W	White	Heating call	Is connected to R or Rh when

			themostat calls for heat. (Might be jumpered to Y on a heat pump. On others might be second stage heating
Y	Yellow	Cooling call	Is connected to R or Rc when themostat calls for cooling. Also Cooling or 1st stage heating on a heat pump Most often connected to G when Fan switch is set to auto
New signals - for heat pumps and staged systems			
Terminal	**Probable wire Color**	**Signal**	**Description**
Y2	Blue or Orange	2nd stage Cooling	
W2	Varies	Second Stage Heating	First stage Auxiliary heating on a heat Pump
E	Varies, blue, pink, gray, tan	Emergency heat relay on a heat pump. Active all the time when selected, usually not used.	Disable the heat pump and turn on first stage Aux heating
O	Varies, orange, black	Reversing valve (relay switch energized to cool)	Energize to cool (changes from heat to cool on heat pumps)
B	Varies, blue, black brown, orange	Sometimes common side of transformer. Needed on some electronic thermostats or if you have indicator lamps OR Reversing valve (relay switch energized to heat) in contrast to (O) above.	Might be heating changeover from cooling or, on older stuff, the common of transformer. York and Trane sometimes use (B) as common.
X	Varies	SEE NOTES BELOW	Might be common but sometimes emergency heat relay
X2	Varies	Second stage heating or indicator lights on some thermostats	Might be emergency heat relay
T	Varies, tan or gray	Outdoor anticipator reset	Used on GE/Trane/American Standard and some Carrier Products.
K	Varies	Combined Y + G	
L , S1 , S2	Varies	Service Light	
U1, U2	Varies	hum, dehum, or a stage of heating/cooling	
F	Varies	heat anticipator / sensor / fault light	

Conventional thermostats

(Single stage heating and cooling using gas, electric or oil heat)

This is often referred to as a 1H/1C conventional thermostat

Terminal designations

The usual terminals are:

- G – Fan, usually a green wire
- R – 24 VAC usually a red wire (Rc and Rh are discussed later)
- C – 24 VAC Common
- Y – Compressor, usually a yellow wire
- W – Heat, usually a white wire

The thermostat is a set of contacts where G, W and Y are connected to R based on the following rules.

Cooling

If there is a call for cool, R is connected to Y (compressor). In air conditioning mode the thermostat controls the fan, so G (Fan) is also connected to R. For cooling, the furnace usually selects the high speed of the blower.

Heating

In conventional heating which is oil or gas, the furnace controls the fan, so only R is connected to W (heat). For electric heating, the thermostat controls the fan (G), thus in this case both G (Fan) and W (heat) are connected to R (24 VAC). For heating applications, a lower blower speed is used and the furnace selects it.

The furnace controls the fan because oil and gas heat is not instantaneous. In order to avoid a blast of cold air, the furnace controls the fan. It can do this with a simple delay or by temperature set by the limit switch in the plenum.

Humidification

Humidification is a fan-only function; humidifiers may be controlled by the G (fan) terminal.

Rc, Rh and R

Rc and Rh have been added to accommodate separate transformers for cooling and heating, respectively. Thus, for single transformer systems, Rc and Rh are jumpered together and assume the function of the R terminal. Some systems use R and Rc; so consider R to be Rh in this case. Rc is defined as R (cooling) and Rh is defined as R (heating). Often, both letters are in uppercase as in RC and RH.

The Fan (G) terminal

To run the fan, the thermostat connects the Fan (G) terminal to R. On thermostats with multiple R terminals (for example Rh and Rc), G is usually switched to Rc, although the "Gas/Electric" switch, if it exists, may change this.

The Common terminal

The Common (C) terminal has been a recent addition because modern electronic thermostats need power to operate. (Early thermostats did not require power because they used either mechanical snap-action switches or switches containing the liquid metal mercury. Mercury is a hazardous material and must be disposed of properly.)

Together with the R terminal, Common provides always-on power to run the thermostat.

There is a technology called “power sharing” where unopened switches can power the thermostat. The current available is limited by the resistance of the furnace relays and may not be sufficient to run some thermostats (e.g. Nest).

Some electronic thermostats are powered by a set of batteries. In this case no C terminal is required, but when the batteries die you have no air conditioning or heating.

The Clock

Programmable thermostats require a way to know the time and it needs to know the time during power outages. A thermostat may contain a small lithium battery just as your laptop or PC does. The manufacturer usually doesn’t even tell you about them. “Remove/pull this paper” before use is a good indication that the thermostat contains an internal battery. The battery may be rechargeable or it can be implemented using a supercap or Super capacitor. These are very high value capacitors which can run the clock for maybe a day or so.

Setpoints/programs/configuration parameters

Your setpoints in an electronic thermostat are not susceptible to being lost when the power fails because they are stored using a different technology. The technology is continually evolving, but the lifetime may be 10 years or more with say 15,000 write cycles.

Anticipator/thermal lag

In many heating systems (especially those with heavy radiators), there is a great deal of "stored heat" in the system once it's hot, so the inside temperature will continue to rise for some time after the system turns off. If the thermostat were to wait until the desired temperature were reached before shutting off the system, that stored heat would continue to heat the building, overshooting the desired temperature by several degrees.

To prevent this, old mercury thermostats used to pass a specific current through the bi-metallic spring to artificially raise its temperature, so the heat cuts off sooner. This way, when the heating system releases its stored heat into the building, the desired temperature is reached. The spring tension provided the hysteresis so that if the stat was set at 72, it would turn on for heat at 70 and it would turn off at say 71. The system would then "coast" up to the desired 72 or 73 due to the stored heat.

Modern thermostats often control this in a different way, using settings like "swing" or "cycles per hour". Some thermostats will calculate the stored heat automatically and adjust themselves accordingly.

Algorithms

While not likely used on a home furnace - One of the most used methods of control is the PID algorithm. PID stands for Proportional Integral Derivative. The proportional term operates directly on the difference between the current value and the setpoint. This gets you close set point.

The Integral terms operates on a running summation between setpoint and the current current value. This essentially ensures you get to the setpoint. The Derivative term operates on the rate of change of the difference between the set point and the current value. This allows a final tuning of the algorithm so to remove over/undershoot of the set point for maximum comfort.

Thermostats can automatically find the values of P, I and D, but it may take it some time. This is called auto-tuning. By using auto-tune algorithms the thermostat can have a better chance of being at say 68 deg at 8:00 when you program that time and temperature.

Temperature measurement (heat pump and conventional)

Thermistors are a common way to measure temperature. These are temperature dependent resistors with a non-linear known behavior and they are cheap and not polarity sensitive. They may be used as external temperature sensors so that it can measure the outside temperature or control the temperature at a different place than where the thermostat is located.

Solid state sensors could also be used and would most likely be used inside the thermostat.

The outside temperature should be known to a heat pump control so it can measure what's called a "balance point". The balance point is when the heat pump output is just equal to the heat loss required to heat the home. At the balance point the heat pump will run all the time just to break even. If the outside temperature gets below this balance point, then supplementary electric or other heat is required to maintain the inside temperature. There is also an outside cut-off temperature where below that temperature the heat pump is no longer economical and only the supplementary heat should be used. Dual fuel systems cannot allow the heat pump and a gas or oil furnace to operate at the same time.

Controls - Fan (Auto/On)

Controls Mode – Auto/Heat/Off/Cool

Controls - Setpoint

Disclaimer

This information may have errors; It is not permissible to be read by anyone who has ever met a lawyer.
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