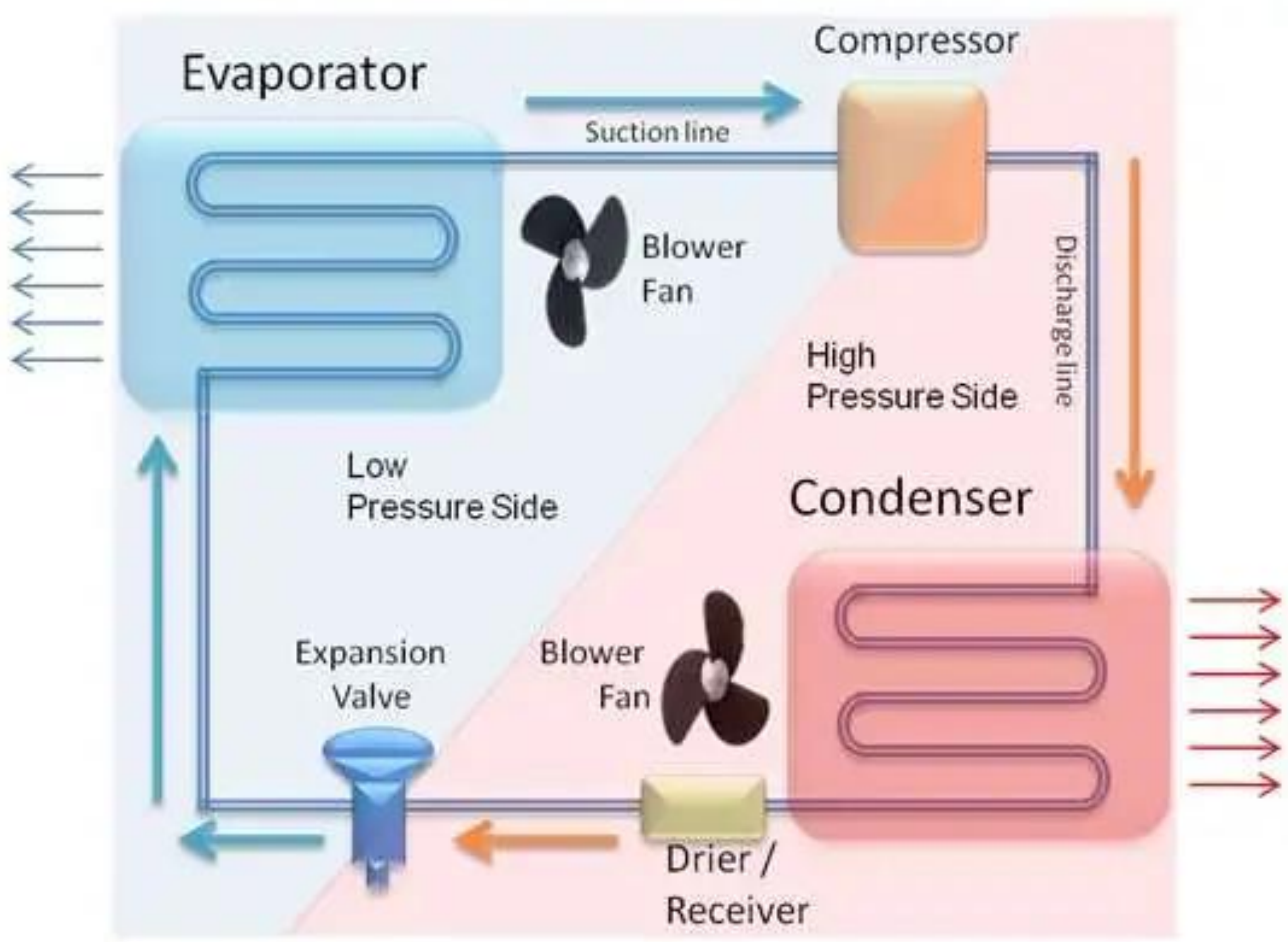
1.10 AUTOMATIC TEMPERATURE CONTROL IN HVAC SYSTEMS

Heating, Ventilation, and Air Conditioning (HVAC) systems are the most critical systems in any built environment, directly affecting thermal comfort, indoor air quality and energy consumption. At the heart of these systems lies the control - the process by which HVAC operations are adjusted dynamically in response to changing environmental conditions, occupancy needs and system performance data.

HVAC control systems comprise a network of interconnected hardware and software elements working in unison to maintain environmental conditions within a building. Automatic Temperature Control (ATC) in HVAC systems uses sensors, controllers (like thermostats), and actuators to maintain a set temperature by automatically turning heating or cooling on/off, providing comfort, energy savings, and equipment protection without constant manual adjustment. These systems use feedback loops, comparing sensed temperature to a set point, and adjusting system output (heating/cooling) to correct deviations, often employing logic like ON-OFF or advanced PID (Proportional-Integral-Derivative) control for precision.



The basic principle behind the operation of HVAC unit is conduction and convection. Heat is transferred from a low-temperature region to a high-temperature region in the car, due to the pressure difference. This process of heat transfer is called Refrigeration. Figure 1 shows the cycle diagram of the complete refrigeration process. An air conditioning system comprises five major components:

Evaporator

Compressor

Condenser

Receiver/Drier

Expansion device

The five major components are divided into two pressure regions: the high-pressure side is the condenser and receiver/drier unit, and the low-pressure side is the air conditioning evaporator. The dividing point between high and low pressure cuts through the compressor and the expansion valve.

Evaporator

An evaporator is a heat exchange device in the refrigeration cycle. The liquid refrigerant, coming out of expansion value and entering into the evaporator, is at lower temperature and lower pressure. On passing through the evaporator coils refrigerant absorbs the heat from the air that is blown through the coils and gets converted to low temperature, low pressure vapour. The liquid refrigerant is made to flow from the bottom to the top of the evaporator coils to ensure that liquid refrigerant boils before it leaves the evaporator coils

The tasks performed by the evaporator can be summarized as follows:

Absorption of heat

Boiling of all the refrigerant to vapors

The air blown by the blower in turn gets cooler, on transferring the heat, and is passed into the cabin through the vents.

Compressor

The air conditioning compressor is known as the heart of the central air conditioning units. The compressor absorbs vapor refrigerant from the suction line and compresses the vapors to high superheat vapor. The temperature of the vapor is normally two and a half times higher than the temperature of the outside air.

Since heat always flows from hot to cold, the refrigerant must be much hotter than the outside air to be able to move heat out of the system. As the refrigerant flows across the compressor, it also removes heat of compression, motor winding heat, mechanical friction, and other heat absorbed in the suction line. Another key task of the air conditioner compressor is to generate the flow of refrigerant in the system.

The tasks performed by compressor can be summarized as follows:

Superheat

Remove latent heat or (condense)

Remove more sensable heat or (subcooled)

Generate the flow of refrigerant

Condenser

The hot, high-pressure vapor makes its next stop at the condensing coil. The condenser is just like the evaporator – it is a heat exchanger. Inside the condensing coil the refrigerant flows from top to the bottom of the coil.

Since the refrigerant is at much higher temperature than ambient temperature it cools down as it passes through the coil. By the time the super heat refrigerant reaches the lower third of the coil, it cools down enough to change back into a liquid. This process is known as sub-cooling.

As the refrigerant condenses to liquid form by releasing the heat, the outside temperature of the copper tube becomes very high and with the help of the blower/radiator fan heat is blown out of the system. This heated air in some vehicles becomes the source of warm air in cooler climate conditions.

The placement of the condenser is also important for better efficiency, as it is very hot, so maximum surface area needs to be exposed to ensuring cooling at a faster rate.

Drier/Receiver

Drier/Receivers are located in the high-pressure section of the system, usually in the plumbing between the condenser outlet and the expansion valve inlet, although some may be connected directly to the condenser.

The drier/receiver serve three very important functions:

They act as storage containers for extra refrigerant during periods of low cooling demand. This is the “receiver” function of the receiver/drier.

They contain a filter that can trap contaminants inside the A/C system.

The Drier/Receiver contains a material called a desiccant. It is used to absorb moisture (water) that may have gotten inside the A/C system during manufacture, assembly or service. This is the “drier” function of the drier/receiver.

Expansion Device

The expansion device is required to generate the pressure difference for liquid refrigerant to boil off into gas. The expansion device creates a pressure drop by restricting the flow of refrigerant around the system.

Slowing down the flow of refrigerant causes the compressor to partially evacuate one side of the system. This low pressure void is called the “suction side” or the “low side” of the system.

AUTOMATIC CLIMATE CONTROL

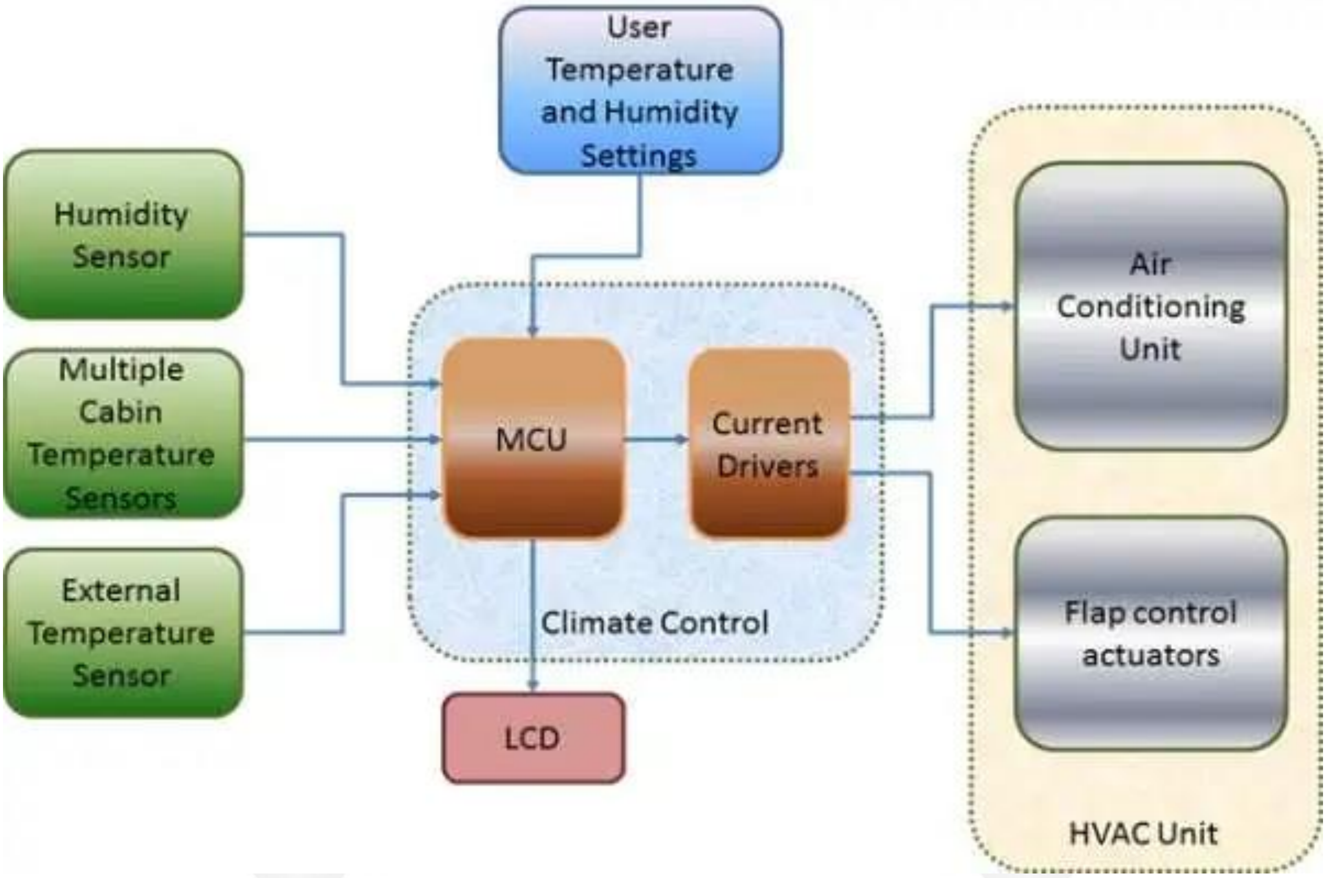
Automatic climate control is the ability to monitor and control the temperature of a specified space without manual intervention. The vehicle passengers specify the required cabin temperature and humidity. These values are taken as inputs by the climate control system and it electronically controls the temperature and humidity and maintains them at user-specified values. This eliminates the human effort to regulate the cabin temperature by switching on/off the AC or by sliding warmer or cooler control.

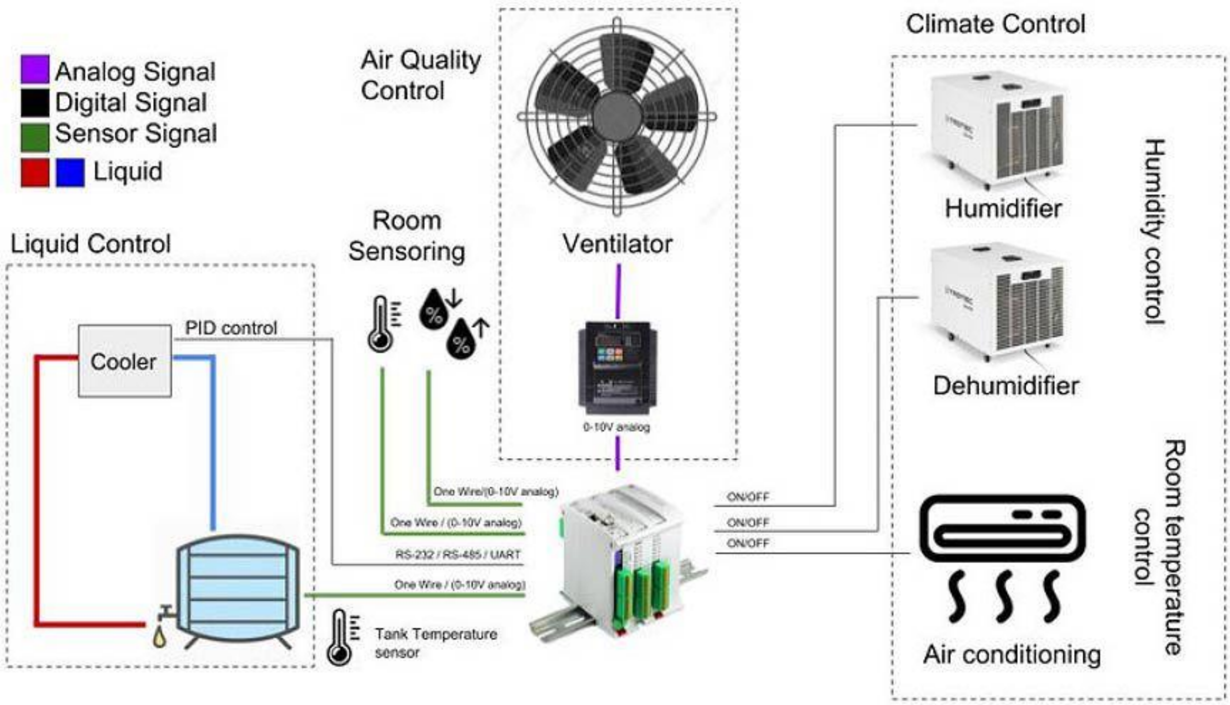
The mechanics of automated climate control require temperature and humidity sensors to be placed in the cabin. These sensors continuously read the temperature and humidity values of the area and feed it to the microcontroller (MCU). These readings are then compared by the MCU to the setting defined by the occupants and the heating/cooling is adjusted appropriately (see Figure 2).

There was a time when everyone riding in a vehicle had to agree on a single temperature setting – some would feel it was freezing cool while others were left sweating. Advances in automatic climate control in automobiles have evolved into zoned climate control. In this type of implementation, each occupant can adjust the temperature of the seating area in which he or she is seated.

Each area within the defined zones has a separate temperature sensor that reads the current temperature of the specified area. Each temperature sensor data is compared to the temperature setting defined for the particular zone and the appropriate cooling or warming action is initiated.

An automatic climate control system also includes a computer that regulates the entire air system within the compartment. This is achieved by regulating the fan speed, engagement of air conditioning compressor, and overall air temperature to be disbursed into the compartment. Typically, these processes are integrated into the overall computer system within modern automobiles.





Key Components

Sensors (Thermistors, RTDs): Measure actual room/duct temperature.

Controllers (Thermostats, PLCs): The "brain" that compares sensor data to the setpoint and makes decisions.

Actuators (Valves, Dampers, Relays): Control the flow of heating/cooling medium (e.g., water, refrigerant) or air.

How It Works (Feedback Loop)

Sensing: A sensor detects the current temperature.

Comparing: The controller compares this to the desired (setpoint) temperature.

Actuating: If too hot, cooling turns on; if too cold, heating turns on.

Modulating (Advanced): Instead of just on/off, advanced systems modulate output (like varying fan speed or valve opening) for smoother, more precise control, reducing fluctuations.

Types of Control Logic

On-Off: Simple; turns heating/cooling fully on or off at set thresholds, creating temperature swings.

PID (Proportional-Integral-Derivative): Highly precise; uses proportional response, integral correction for past errors, and derivative anticipation for future changes.

Benefits

Energy Efficiency: Avoids constant full-blast operation, saving energy.

Comfort: Maintains stable, consistent temperatures.

Safety & Protection: Prevents overheating/freezing, protecting equipment and environments (e.g., labs).

Applications

Residential & Commercial Buildings

Industrial Processes

Automobiles (Climate Control)