Dashboard controls for a typical car AC

Automobile Air Conditioning – the Journey so far

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Introduction

Car air-conditioning is a basic necessity today for motorists. However, most of us still have memories of cars with no frills such as power windows, power steering, anti-skid braking system, air bags or even air conditioning. Travelling during the hot and humid season in India meant sweaty bodies for the occupants of a car. Automotive air conditioning has played an important role in human comfort and, to some extent, in human safety also. It has now become an essential part of vehicles of all categories.

About the Author

Shripad Ghurye is in the business of car air conditioning sales and service since 1983. His company, Simran Systems, is the authorized sales and service dealer for Subros Limited in the car AC segment. In the bus AC segment, it represents KB AutoTech of Korea, and carries out the installation for Eberspacher bus AC units at Tata Motors' ACGL plant. It has also carried out retro fitment of bus ACs in Qatar for Tata Motors bus AC dealer Al Hamad. It also manufactures refrigerant recovery and recycling machines, automatic vacuuming and refrigerant charging machines used in production and servicing in the automobile and bus AC industry for the last 10 years.

Automobile Air Conditioning Over the Years

It may be interesting to know that Chrysler Imperial (*Figure 1*) was one of the first production cars to offer automobile air conditioning in the year 1953, nearly 12 years after Packard and Cadillac made their first attempts way back in 1940 and 1941, respectively.

Car air conditioning came to India sometime in the late 1970s. For cars not factory-installed with air conditioning, after-market under-dash evaporator units became a big business.

Figure 1: Chrysler Imperial 1953 was the first production car with AC

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The business for after-market installation boomed from 1980 to mid-1990. Around the early 1980s, car manufacturers in India started offering cars with factory-installed air conditioning, with Maruti 800 as the pioneer. As car sales began to boom, the demand for car air conditioning rose fast. Since there were no full-fledged car air conditioner manufacturers in India, the after-market installation business boomed. During this period, leading car AC manufacturers set up plants in India and factory-fitted ACs came into their own. The trend towards deluxe versions of cars began with ACs and tinted glasses. Then came music systems and other fancy accessories. Today, 99.9% of the cars manufactured in India are with ACs. In fact, even some of the truck cabins offered in India are now factory-fitted with AC systems.

Automobile Air Conditioning Systems

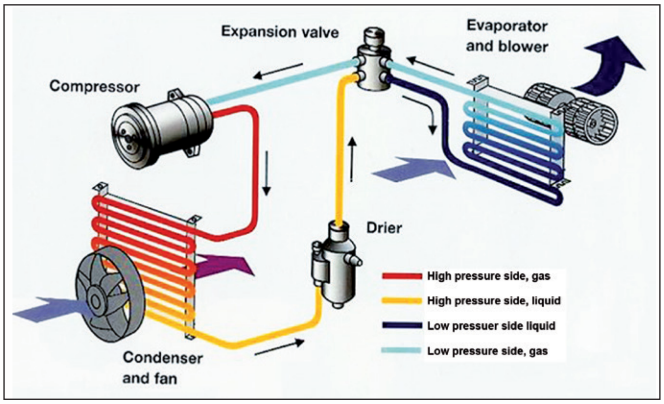

Figure 2: Automobile air conditioning schematic

The basic principle of vapor compression is used in a car AC system. Refer *Figure 2*. The fixed displacement compressor (vapor compressor) compresses low pressure low temperature vapor to high pressure high temperature vapor, to be discharged to the condenser where it is converted to high pressure high temperature liquid, which is then filtered by the filter-drier and passed through an expansion valve or orifice tube as low pressure low temperature liquid into the evaporator (cooling unit). The low pressure in the evaporator causes the refrigerant to boil. The blower passes the cabin hot air over the evaporator to cool it for the passengers. The refrigerant absorbs heat from the air, and since the boiling point of the refrigerant is achieved due to the low pressure in the evaporator, low pressure low temperature vapor gets sucked back to the compressor, thus completing the cycle. The heat gained by the evaporator in the passenger compartment is rejected by the condenser mounted outside or in front of the engine/radiator.

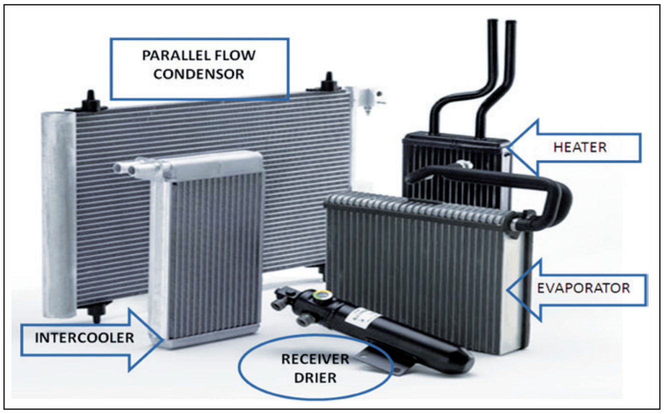

Figure 3: Parts of a car AC

Refer *Figure 3*. In the earlier days, a car AC system consisted of a fixed displacement compressor with electromagnetic clutch, two heat exchangers (condenser and evaporator) mostly made of copper tubes and fins, and an expansion valve – all components connected with rubber or aluminum pipe lines with a desiccant filter-drier-receiver on the liquid line. A simple mechanical thermostat controlled the cabin temperature. The compressor was belt driven, taking the drive from the engine crank pulley, and the electromagnetic clutch was controlled by the mechanical thermostat; hence there were only two options – on and off. The refrigerant used for decades was R12, a chlorofluorocarbon known as CFC-12 or its brand name Freon-12. A lot has changed since then.

Refrigerants

After using R12, a CFC, for nearly 4 decades, it was found that this refrigerant was damaging the ozone layer and was responsible for ozone depletion. R12 has an ozone depletion potential (ODP) of 1 and a high global warming potential (GWP) of 2400. So R12 was banned from being manufactured in the United States from 1996, and an alternative refrigerant R-134a was mandated for all cars manufactured after 1996. In India, R-134a was introduced by all car manufacturers from the year 2000. Then it turned out that while R134a has zero ODP, it has a high GWP of 1300. Billions of dollars had already been spent on the change from R12 to R134a.

> The refrigerant for the future is R1234yf, a synthetic HFO refrigerant developed by two leading multinational companies as a successor to R134a in the automobile air conditioning industry. Its GWP is very low – below 1, meaning that a kilogram of R1234yf has a lower greenhouse effect than a kilogram of carbon dioxide. So compared to R12 with GWP of 2400, R134a has a GWP of 1400 and R1234yf has a GWP of below 1.

Despite the new refrigerant being mandated for use by the European Commission, car manufacturers initially refused to replace R134a refrigerant with it over concerns about its flammability following crash tests. The issue was the A2L flammability rating of R1234yf, which means it is mildly flammable. This has implications for workplace health and safety procedures and means that rules about dangerous goods apply to the storage, transportation and handling of R1234yf gas. Component design changes, upgrades for quality and robustness as well as compliance with a number of SAE standards have delayed the switch over to R1234yf. The systems are designed to prevent potential refrigerant leakage into the cabin. From the service point of view, R1234yf has thermal properties similar to R134a.

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Evaporator Unit for HVAC

Figure 4: Louvres in the air outlet

The simple under-dash or in-dash mounted evaporator soon became a thing of the past. To increase space and make the driver cabin more comfortable, centrally mounted HVAC systems came into vogue. Most of the cars manufactured today have in-dash centrally mounted HVAC unit. This led to the introduction of climate control and dual zone temperature control systems in the same car cabin. Dual AC systems, front and rear cooling units for multi-purpose vehicles (MPVs) and passenger cars were introduced around the same time. The HVAC system has the heater, evaporator and blower unit all in one. With the option to set the desired temperature using the climate control unit on the dashboard, passengers can have a comfortable journey. The cabin temperature and fresh air input is automatically controlled by flaps/dampers (*Figure 4*), through the electronic control module (ECM).

From Mechanical Controls to Sensors and Thermistor Controls

With the advent of electronic temperature sensors and pressure transmitters, the way a car AC functions has changed over the past decade. Cabin temperature sensors, outside temperature sensor and sun load sensor (*Figure 5*) give inputs to the ECM, which ensures air temperature as per the desired setting.

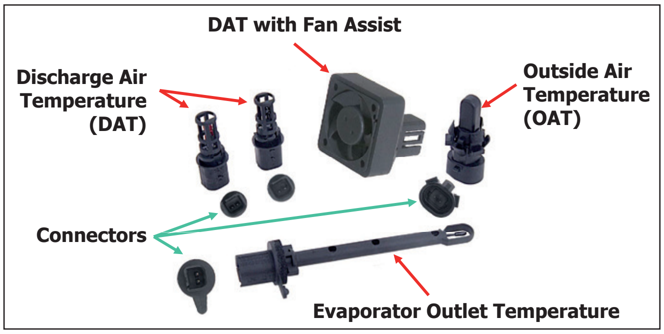

Figure 5: Types of sensors

Refer *Figure 6*. The ECM also gets inputs from the mechanical side – engine speed, coolant temperature and oil pressure. These inputs are important, as in case of any eventuality or failure on the engine side the AC system is immediately turned off by the ECM for safety. Switching off the compressor in case of 'no refrigerant' resulting in low pressure; high pressure in case of condenser fan failure; protecting the engine in case of overheating – all these safety steps are taken by the ECM. The ECM makes a decision on what outputs must be operated using signals from the inputs. The inputs are sensors or switches that measure different parameters.

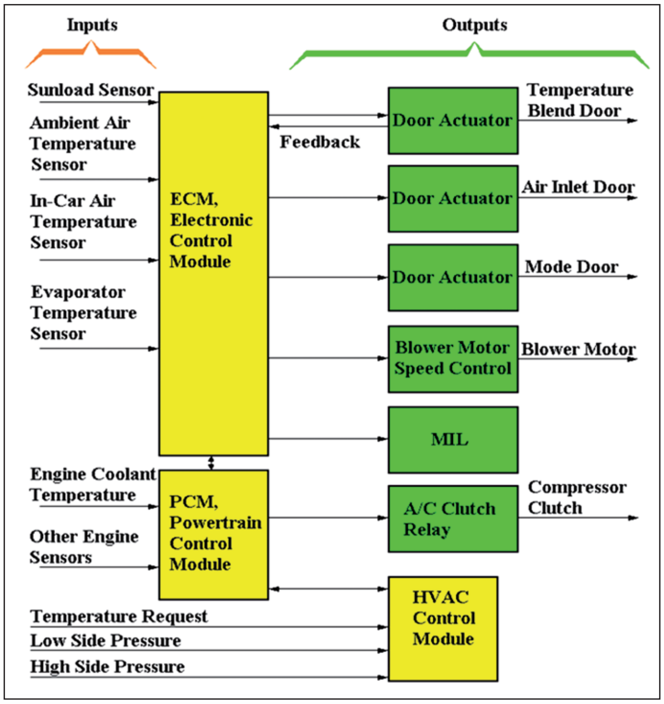

Figure 6: Electronic control

High end cars offer dual zone or three zone automatic climate control systems that allow temperature and air flow to be controlled in all three (or either) zones independently. Sensors for air quality and harmful gases monitor the quality of outside air drawn in. The system moves to fresh air mode periodically to allow fresh air in the passenger compartment. Some of these features are available only in high end cars, but the basic HVAC and automatic climate control system is provided by most of the OEMs today.

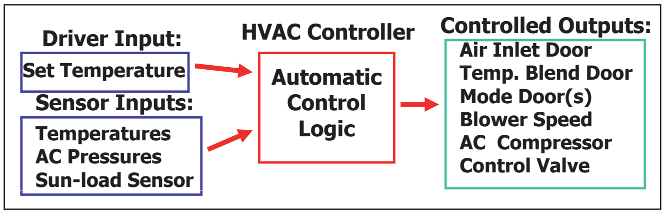

Figure 7: Automatic temperature control

Air Filtration

To enhance the quality of air circulating inside the cabin, air filters or pollen filters are provided by most OEMs as standard feature with the car. The cabin air filter keeps out dust, soot and pollen, and restricts the impurities from flowing with the air over the evaporator into the passenger compartment. It not only helps in maintaining the quality of air but also prevents frequent

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clogging of the evaporator due to the dusty conditions in the country.

Compressor Technology: From Fixed to Variable Displacement

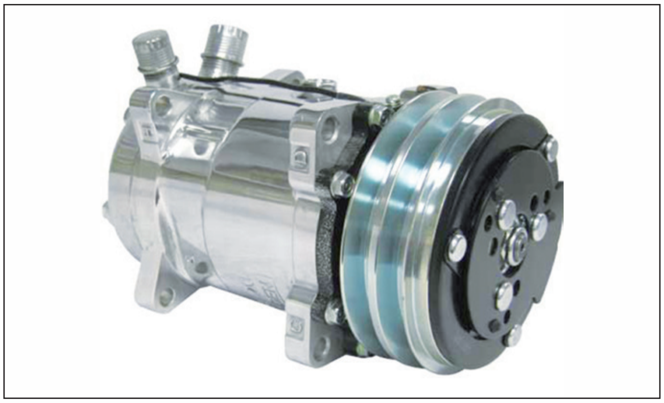

Figure 8: A car AC compressor

The compressor technology has also come a long way from fixed displacement compressors (FDC) to variable displacement compressors (VDC), from electromagnetic clutch to clutch-less variable displacement compressors. Unlike the old FDC, the VDC automatically varies its pumping capacity to meet the air conditioning demand as per the temperature selected inside. When the cabin temperature is high, the compressor increases its displacement until the desired temperature is reached; thereafter it automatically reduces its displacement to maintain the desired temperature.

Another advantage of the VDC is that there is no jerking of the engine due to the switching on and off of the compressor clutch, unlike in an FDC. In fact, some VDCs have no clutch at all. This results in a very smooth operation. The most important advantage of VDCs is the improvement in fuel efficiency, as the load of the compressor is modulated to the demand.

There are two commonly used types of VDCs – the Internally Controlled Variable Displacement Compressor (ICVDC) and the Externally Controlled VDC (ECVDC). In an ICVDC, the control valve is actuated by the refrigerant pressure at the suction chamber of the compressor by means of a bellows or diaphragm, and the ICVDC is mounted inside or on the compressor. The ICVDC causes the wobble plate angle of the compressor to change as per the cooling, thus modulating compressor displacement from minimum to maximum for minimum or maximum cooling. In an ECVDC, actuation of the control valve is done by the engine's ECM. Based on the cooling requirement as per the setting on the climate control dash panel, input signals from various sensors or thermistors are processed by the ECM to adjust the control valve on the compressor to modulate the pressure in the compressor crank case, thus modulating the displacement between minimum and maximum. Some of the sensors and thermistors are: cabin air temperature, outside temperature, sun load sensor, discharge air temperature, and evaporator temperature thermistor.

In the author's experience so far, ECVDC is a far better control of piston displacement compared to ICVDC, though failures of the ECVDC are higher. From the service perspective, since ECVDC is mounted on the outside of the compressor, it is easy to replace in case of failure, unlike ICVDC where the entire compressor has to be dismantled. The other advantage of ECVDC is that it facilitates the use of clutch-less compressor design.

Refrigerant Leakage

Another emphasis has been to ensure that design and technology supports the reduction of frequent leakages from the car AC. One of the weak areas in the older design was that the normal flare end fittings and rubber hoses used were prone to leakage due to repeated opening and refitting done by technicians in the aftermarket service or repair sector. Hoses and pipes (*Figure 9*) are used in car air conditioning for interconnecting the compressor, condenser, receiver-drier and evaporator as a closed circuit. Predesigned aluminum pipes with minimum rubber hose are used in today's car ACs, with bead lock or pad type end fittings. Hoses have their own rate of permeability and thus are prone to refrigerant leakage over a period of time. Refrigerant characteristics make it necessary to use nylon barrier hoses to reduce the permeability rate. High burst pressure, low refrigerant permeability, joints with seals and pad fittings are some of the technology upgrades seen in the recent past. To ensure minimum release of refrigerant in the atmosphere, the normal ¼ charging valve pins were changed to quick release coupler (QRC) ports on both the low pressure and high pressure side. This ensures that zero or minimal refrigerant is discharged while connecting and disconnecting the manifold gauge or QRC.

Figure 9: Hoses used in car AC

Minimizing System Weight and Enhancing COP

The need to reduce the number of parts and their weight and to improve the efficiency of parts has brought in a sea change in nearly every component used in the car AC. With the demand to reduce the overall weight of the car, component suppliers have a challenge to upgrade and redesign their components. Gone are the days of copper and fin tube condenser and evaporator technology. In the quest to improve fuel efficiency, reduce overall weight and reduce system size, many OEMs started using aluminum serpentine and parallel flow condensers.

Refer *Figure 10.* A and C are round tube condensers; B is an oval/flat tube, serpentine condenser; and D is an oval/flat tube, parallel flow condenser. Flat tube condensers are more efficient.

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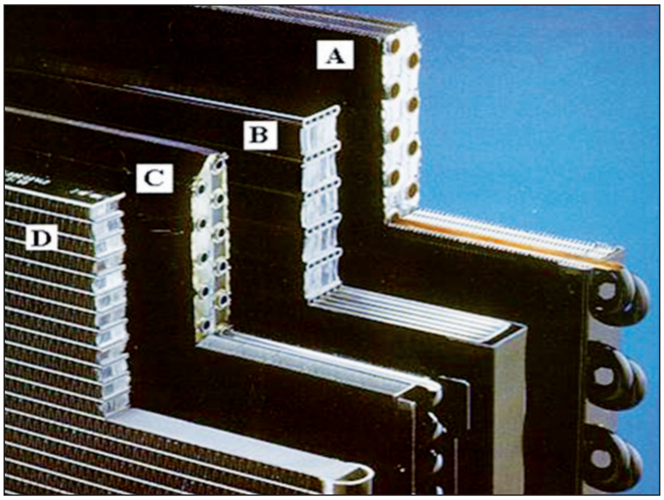

Figure 10: Types of condensers

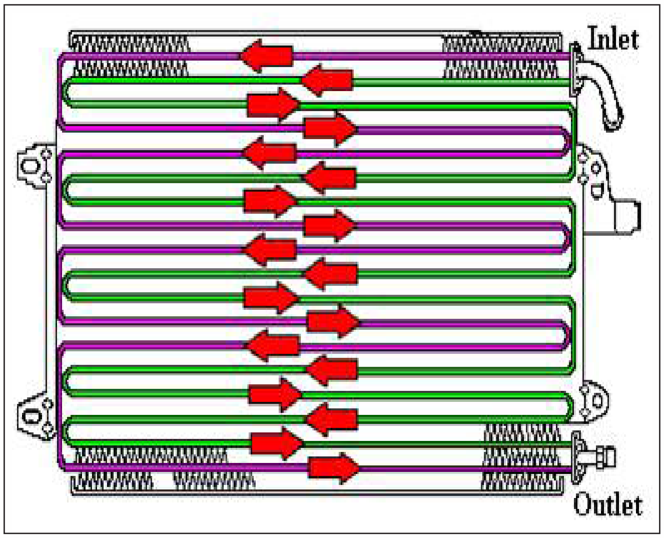

Figure 11: Serpentine condenser

In the serpentine design, one long tube is folded back and forth, compressed with fins in between, with just a single path for the refrigerant to flow through. Refrigerant flows from the upper inlet to the bottom outlet through two tubes. These tubes wind back and forth though the condenser.

The parallel flow condenser has many flat multi-pass tubes stacked horizontally, connected to a vertical tube at each end. Refrigerant flows from the upper inlet to the bottom outlet through groups of parallel tubes. Some tubes carry the refrigerant from right to left, and others move it back to the right side. It has better heat rejection capacity compared to the normal tube and fin or serpentine fin and tube type condensers. Since the refrigerant can travel thorough more tubes, this increases the efficiency and thus the size and weight of the condenser is drastically reduced for the required capacity. Such condensers are also called sub-cool condensers. The only problem is that in the event of compressor failure, or any failure that causes debris, sludge or foreign material to circulate through the system, the smaller condenser tube

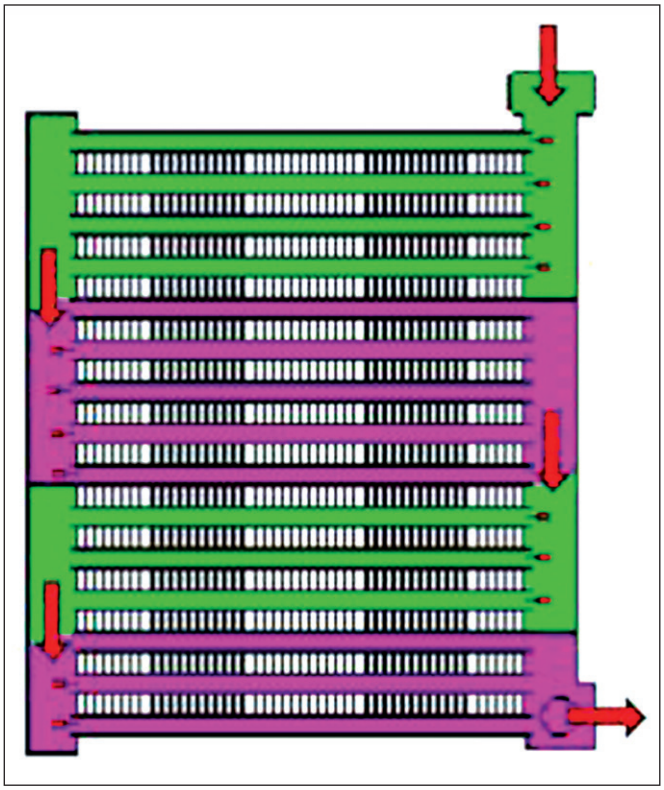

Figure 12: Parallel flow condenser

design makes it difficult or impossible to flush for reuse. It is often impossible to completely flush contaminants out of condensers with small passages, since the multi pass design allows the flushing agent to circulate around the blockage. Replacing the condenser remains the only option.

Like the condenser, the evaporator design also saw technology changes. From the normal pipe and fin type to serpentine tube and fin type, to parallel flow single tank, to multi super slim evaporators making them lighter and more efficient. The only disadvantage, similar to multi pass condenser, is that these evaporators cannot be flushed and reused in case of any debris or sludge entering the system due to compressor failure. Replacing the whole system is the only safe option.

The modern car AC system thus comes at a price, as some of the components are not repairable or reusable. Maintenance and servicing is more complicated and difficult. The need for proper diagnostic tools and scan tools is a must. In some models, adoption of new parts with ECU makes it mandatory for the car to be taken to the dealership when it needs attention.

Conclusion

The journey of car AC in the last three decades has been very rapid. Gone are the days of non-AC cars, and when the AC needed to be switched off while climbing a steep mountain road. Modern car AC systems are more efficient, less taxing on the vehicle engine, and come with smarter support systems. This also underlines the need for updated service centers and knowledgeable technicians.