Process control Engineering

End-semester Project

Automotive Air-conditioning System

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Introduction

In the past century, cars for personal use exploded in popularity.Because of the exponential growth rate of technology, the standards for comfort of today's vehicles are very high. One of the most important factors for comfort inside an automobile's habitat is the temperature. Imagine a hot summer day, it does not matter if we are driving in MexicoCity,London or Rio de Janeiro, most likely our car is equipped with a cooling system popularly known as A/C or air conditioning.

Background

The air conditioning technology refers to the process of modifying properties of the atmosphere, such as temperature and humidity,of an occupied space with the purpose of meeting the needs of the user.
An air conditioning has two connected coils, the evaporator,which is placed inside the chamber that the user intends to cool, and the condenser which is placed outside. Inside the coils, there is a continuously flowing refrigerant. The working principle states that the evaporator should be kept colder than the room and the condenser hotter than the surroundings. The continuously flowing fluid will absorb heat from the cabin with the help of the evaporator coil and the condenser will release that heat to the exterior. To increase the pressure of the refrigerant, a compressor is used. The temperature at the condenser outlet will be far higher than that of the atmosphere; therefore this gas being passed through the condenser will release heat.

Background

During this heat exchanging phase the gas will be condensed into a liquid. At the output of the condenser, an expansion valve is added to control the flow of the refrigerant, therefore regulating the pressure of the fluid. This drop in pressure causes part of the refrigerant liquid to be evaporated. For this evaporation to take place, some energy should be supplied to the process. This energy comes from the refrigerant in the form of heat. Consequently, the refrigerant's temperature drops. This is how the cold refrigerant that runs in the evaporator is obtained. Air from the cabin passing through the evaporator coil will give away heat converting all the refrigerant to vapor. This vapor is the initial input of the compressor, completing the functioning cycle of this system.

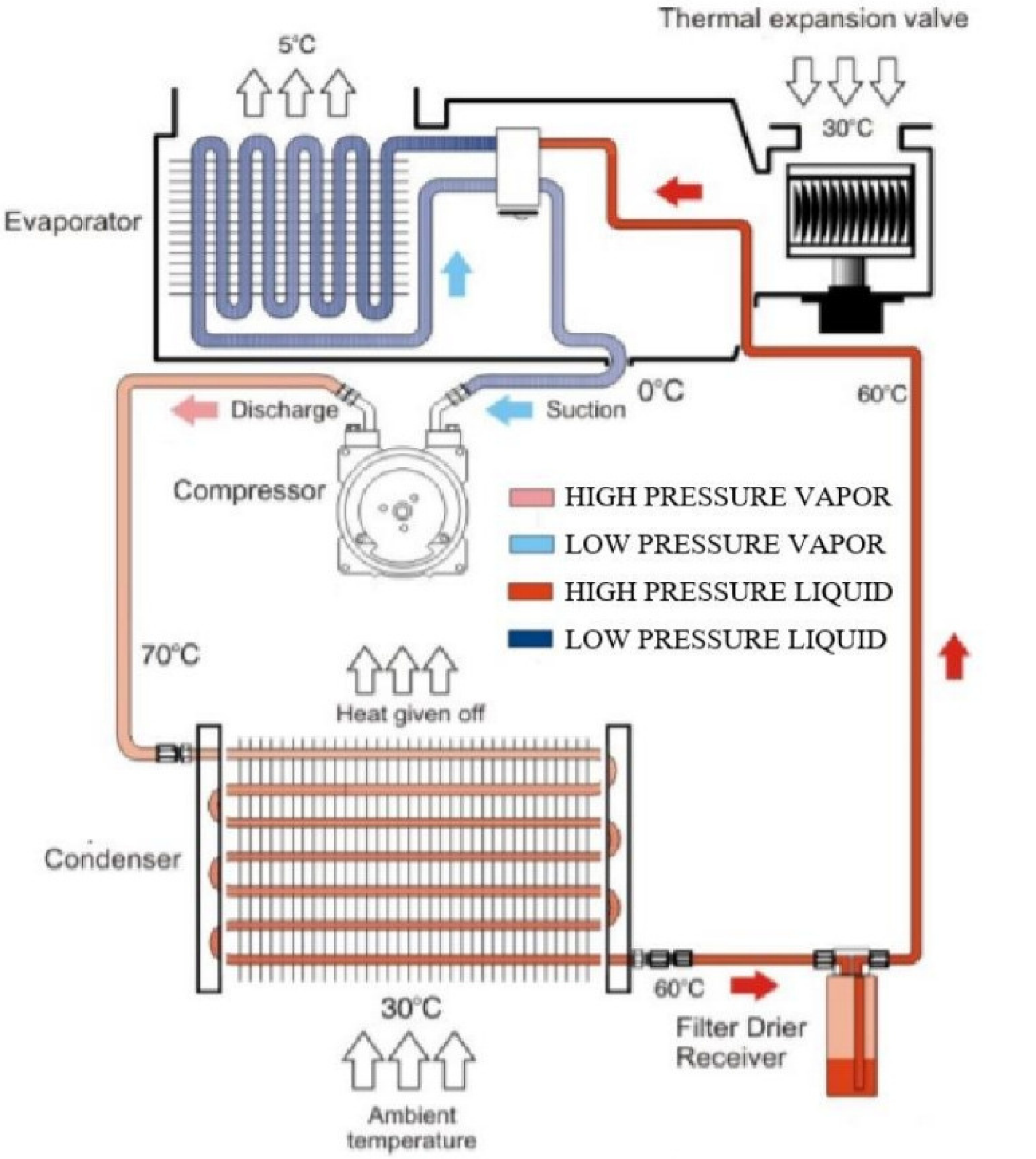

Figure 1.1 General layout of an air conditioning cycle (Ariazone)

Problem Definition

- *To understand the functioning of the entire process, it is required to create a working simulink model of the air conditioning system.*

- *Verify if the designed system is suitable for the provided powertrain.*

- *Theoretical comparison for the refrigerant is to be performed.*

Objectives

Goals of control:

• *The main goal of the process is for the temperature inside the cabin to be kept constant at a set point.*

Process output:

• *Temperature inside the cabin (Thermocouple) [°C].*

Control inputs:

• *Power supplied to the compressor (from the motor) [W].*

Major disturbances:

• *Temperature outside the cabin of the vehicle [°C].*

Approach

For a comprehensive model the whole process must be divided in smaller sub-processes, the relationships between these sub-processes must be identified and the energy storages must be recognized. Energy is stored in the form of heat in the refrigerant and this heat is later released outside with the help of the condenser.

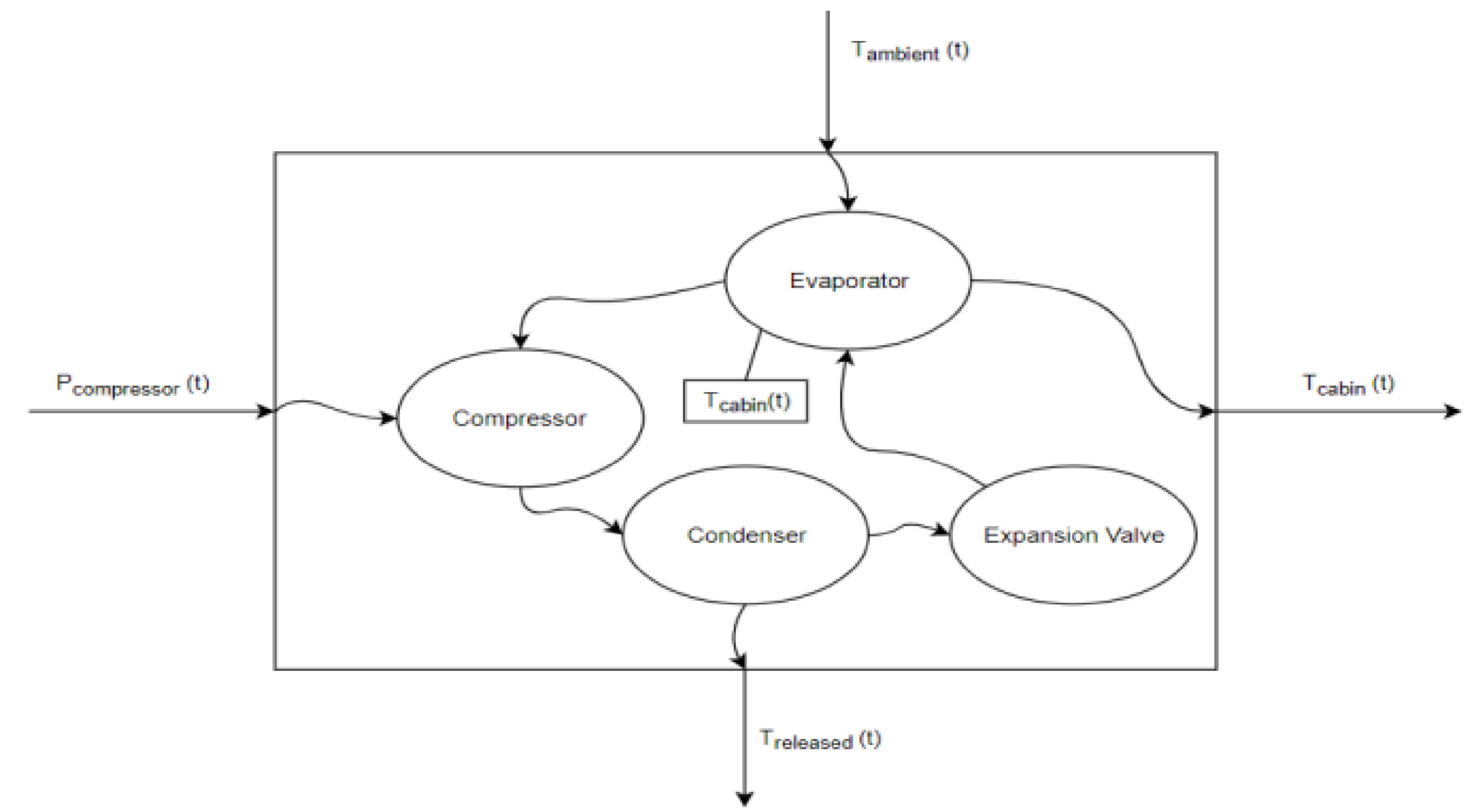

Figure 1.3 Data flow diagram of the process

Methods

The main tool that was used for the development of this project is MATLAB Simulink from MathWorks. MATLAB is a programming platform widely used in the engineering industry. The heart of MATLAB is the MATLAB language, a language based on matrixes that allows a natural way of computing mathematics. Simulink is a matlab based graphical programming environment designed for modelling, simulation and analysis of multiple system domains.

All the values for all the variables were declared in the matlab environment for them to be later imported to the simulink blocks. The block used in simulink are basic mathematic blocks like multiplication, summing, integration, gain and for another method of modelling we used the transfer function block. In order to visualise the results, the scope block was used which acts as a virtual osciloscope. The matlab command 'plot' gave freedom of representing the results in any required manner.

Methods

Refrigerant R134a was chosen because of its cooling performances, cost efficiency and widespread use in the automotive industry and based on the fact that documentation is widely available for it. The differential equations model was built because that it is the first step in determining the transfer function of a system. The transfer function is a very useful modelling technique because it is very easy to analyse a system just by looking at its transfer function. Since the transfer function is derived from the differential equations, a comparison between the two models is crucial to verify that the systems have the same behaviour.

Results

On a successful run of the Simulink model, meaningful results were observed. Graphs were plotted for every major component to study the performance in detail at the end of each process.

Figure 3.1 shows that the air-conditioning system has gradually lowered the temperature of air inside the cabin from an initial value of 27.3°C to around 22°C which is considered to be the most comfortable temperature for humans. And the time taken to reachthe cooling temprature approximately takes 4–5 minutes.

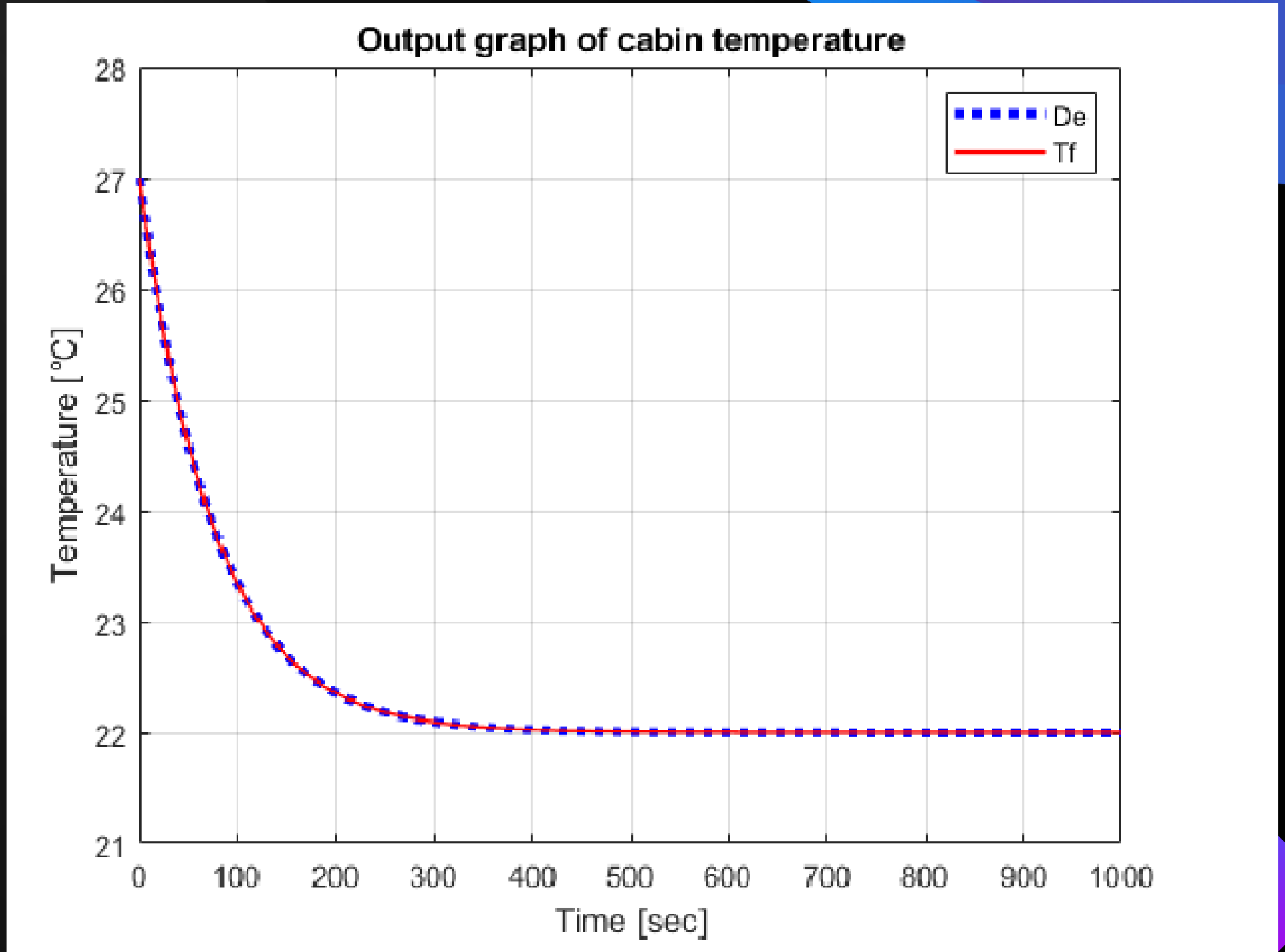

Figure 3.1 Cabin temprature

Results

Figure 3.2 It is here that the liquid refrigerant is expanded and evaporated. It acts as a heat exchanger that transfers heat from the substance being cooled so there is temprature drop to 16°C.

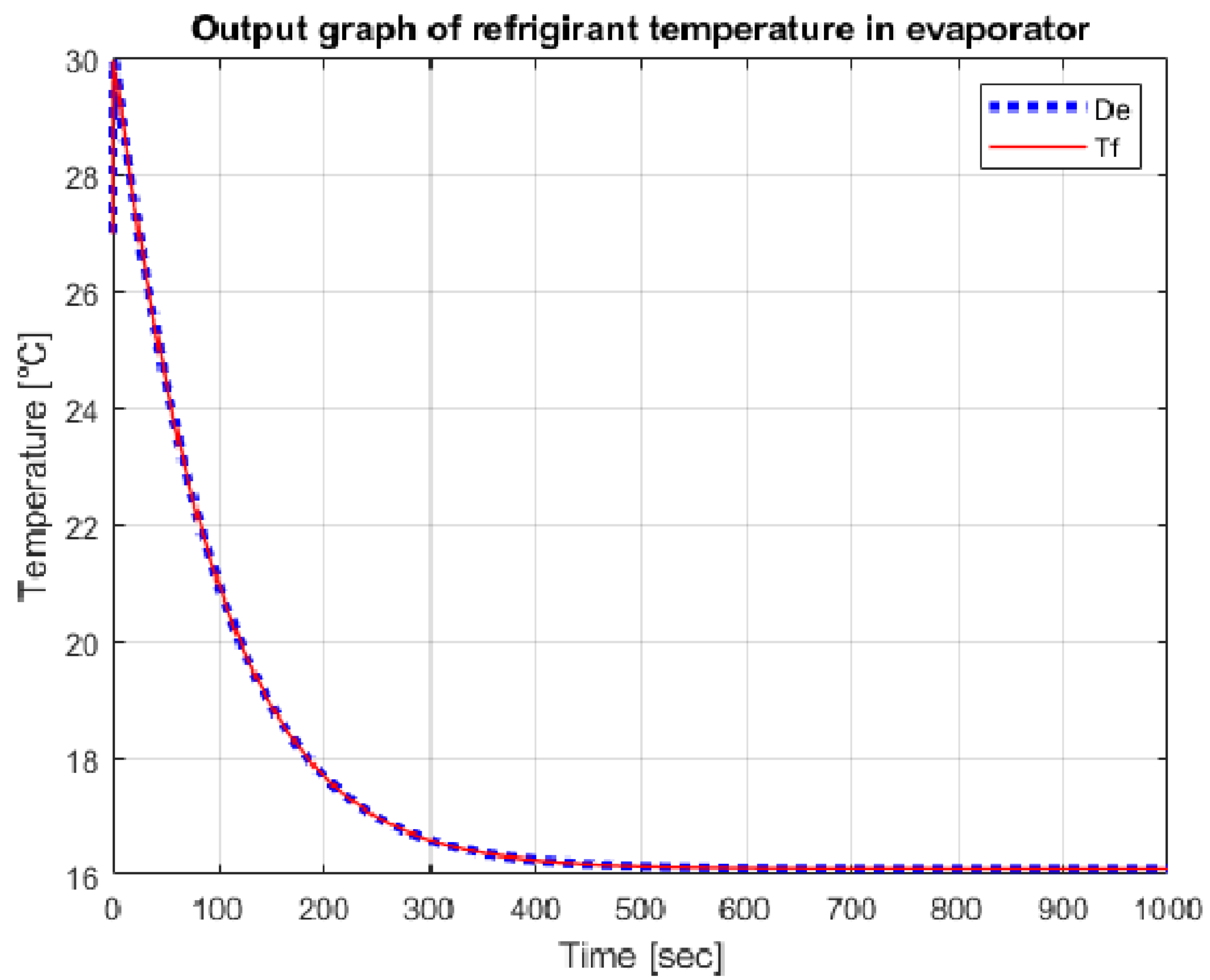

Figure 3.2 Evaporator output

Results

Figure 3.3 The compressor increases the pressure, and corresponding saturation temperature (boiling point) of the refrigerant vapor to high enough level so the refrigerant can condense by rejecting its heat through the condenser, it can be seen that the temprature is increased upto 60°C.

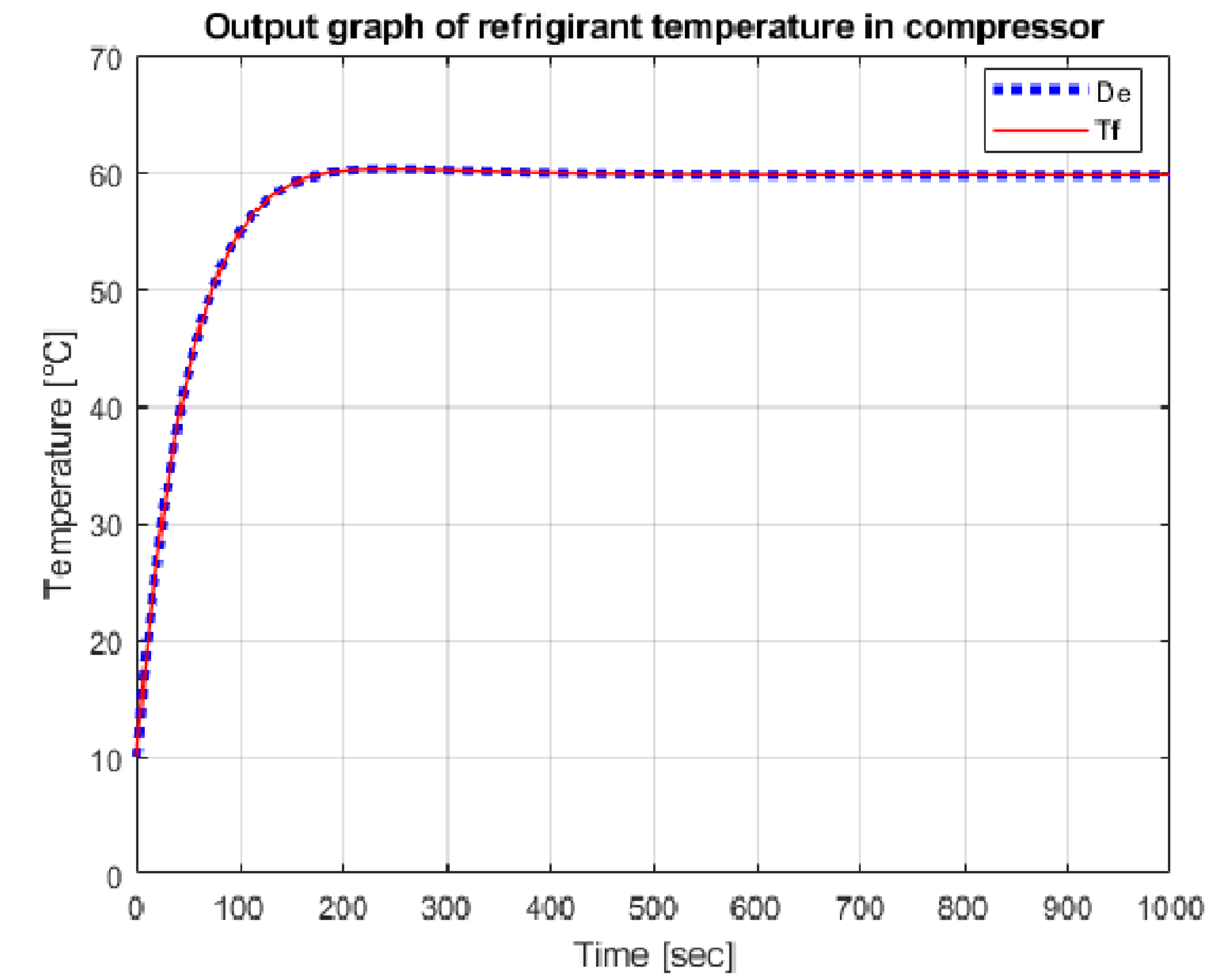

Figure 3.3 Compressor output

Results

Figure 3.4 In a cooling cycle of a refrigeration system, heat is absorbed by the vapor refrigerant in the evaporator followed by the compression of the refrigerant by the compressor. The high pressure and high temperature state of the vapor refrigerant is then converted to liquid at the condenser. It is designed to condense effectively the compressed refrigerant vapor. The temperature is increased from 15 degrees to approximately 48°C after 8.3 minutes.

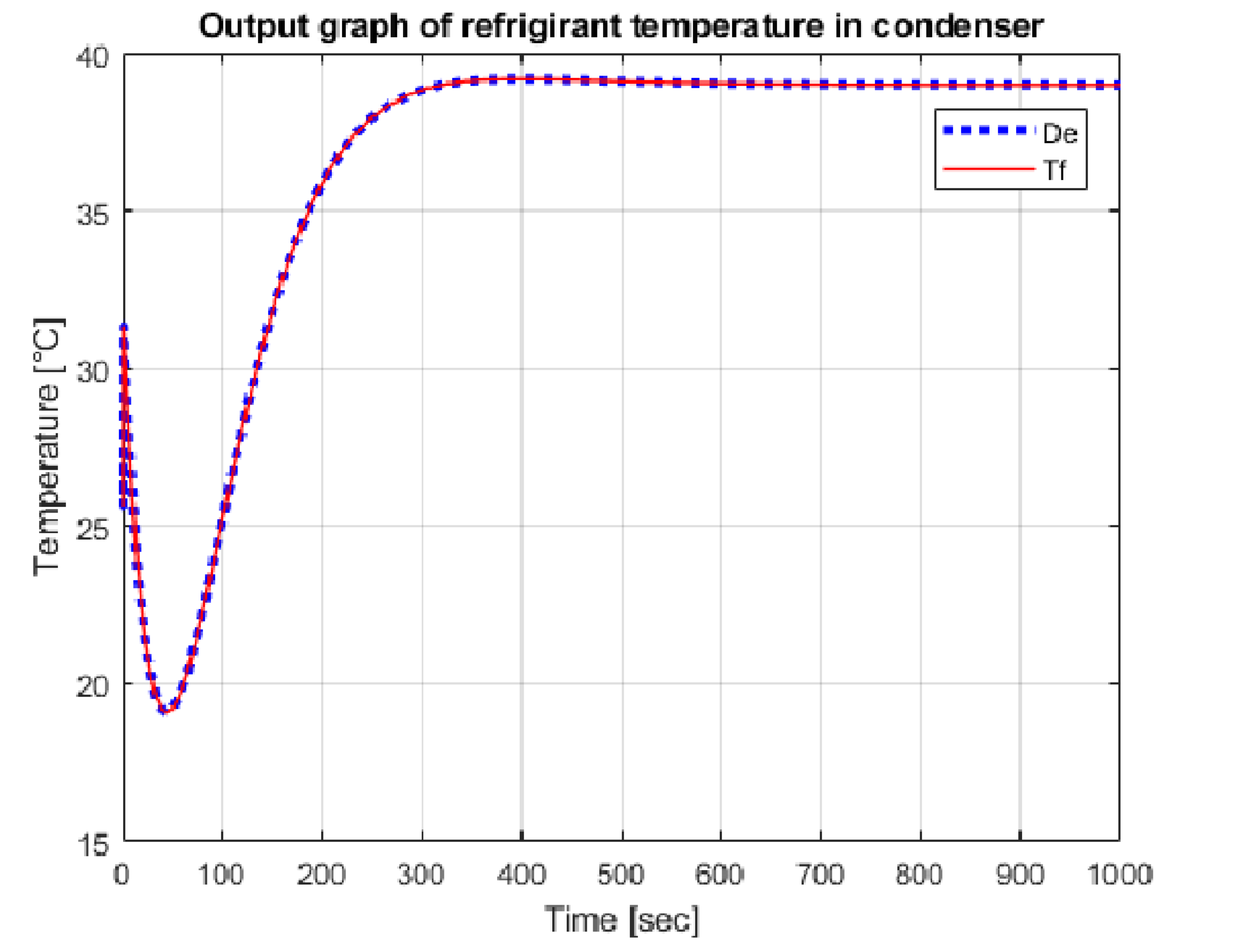

Figure 3.4 Condernser output

Results

The expansion valve removes pressure from the liquid refrigerant to allow expansion or change of state from a liquid to a vapor in the evaporator. The high-pressure liquid refrigerant entering the expansion valve is quite warm.

In figure 3.5, the graph shows a drop suggesting temperature drop compared to condenser temperature due to expansion. The temperature drops from 40°C to 5.8°C.

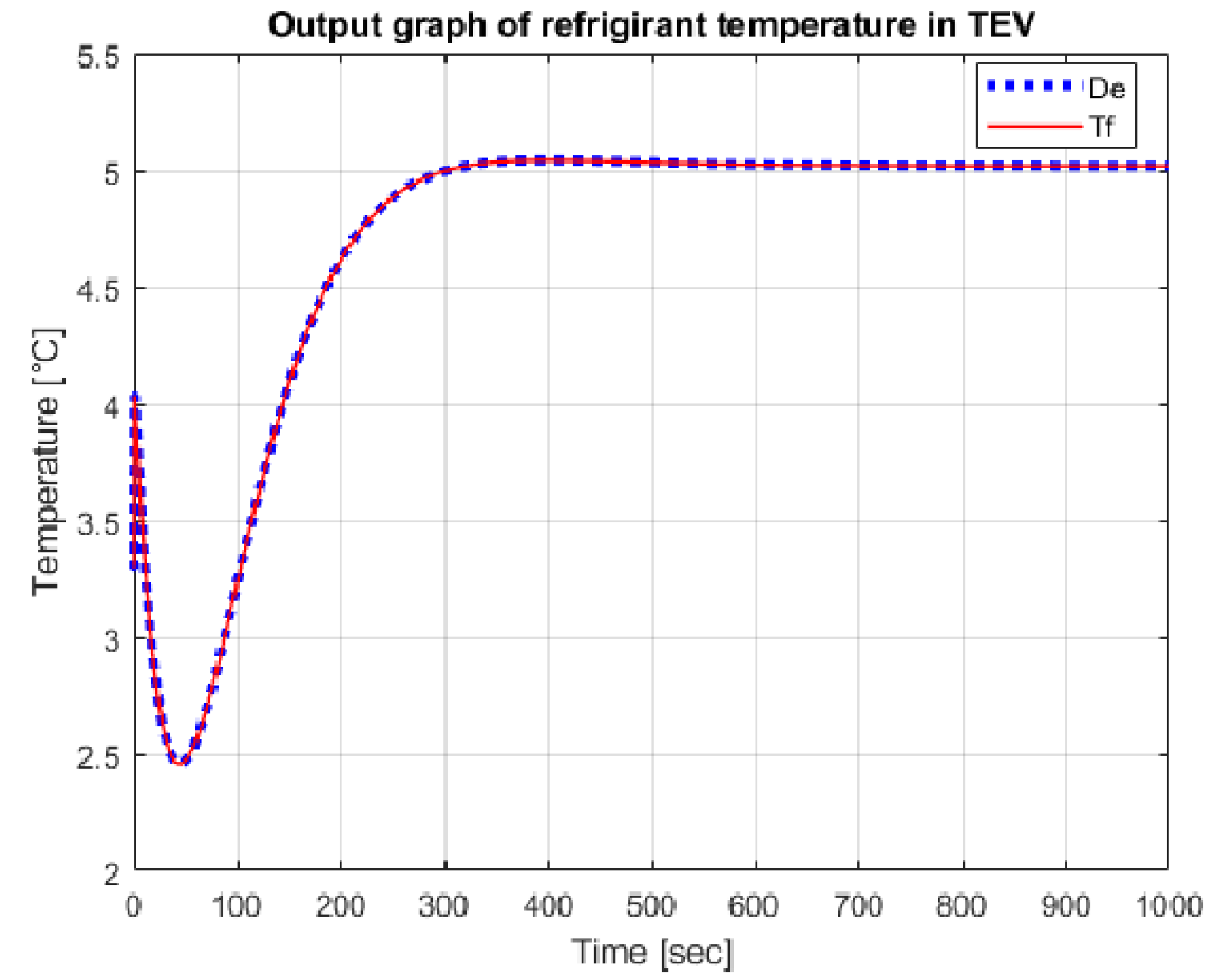

Figure 3.5 Thermal expansion valve output

Results

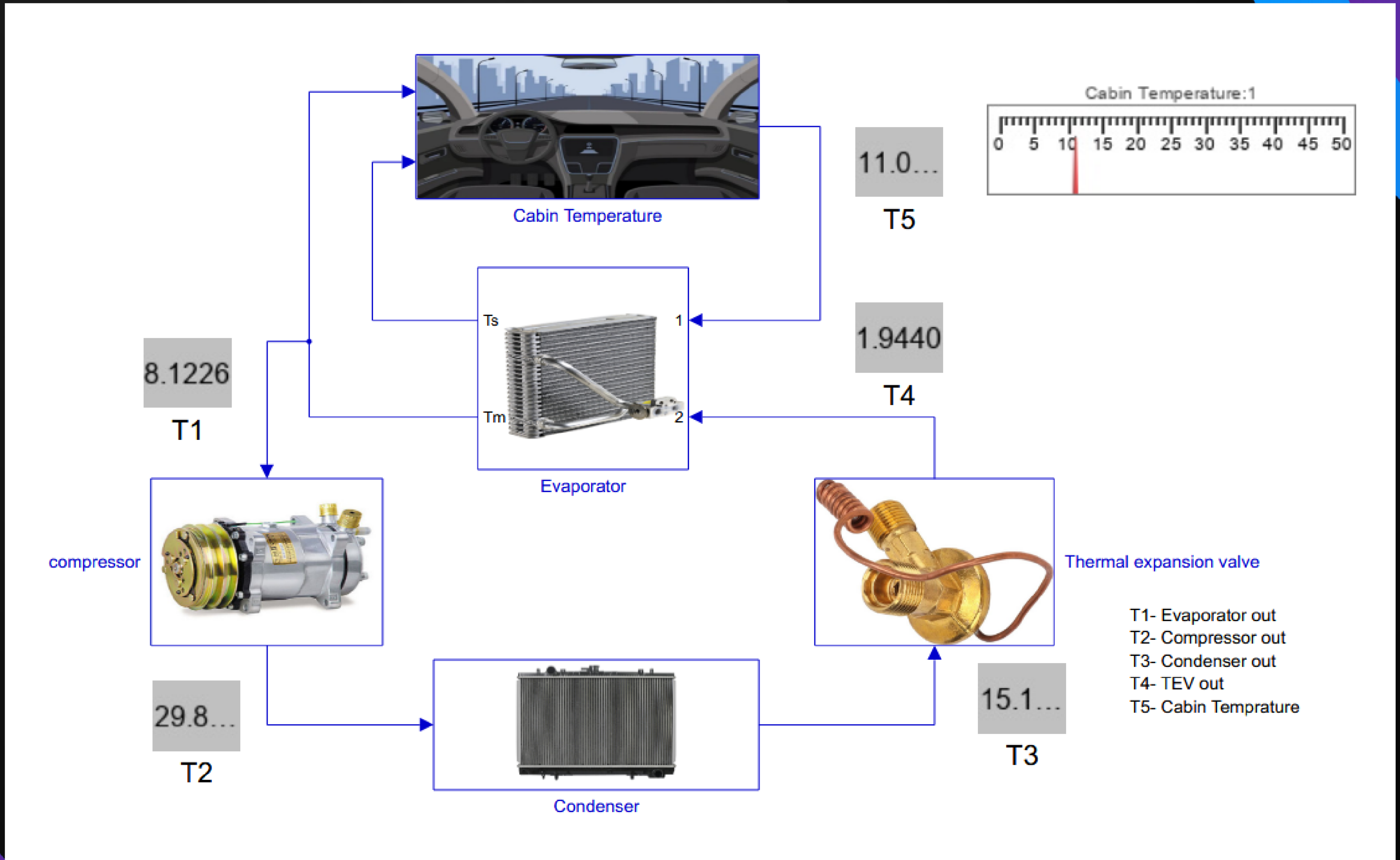

Figure 3.6 Simulink block showing the temperature across all the components

Conclusion

The main goal of maintaining the temperature inside the cabin constant at a certain set point has been achieved in a satisfying time period by the designed model.The model includes the cabin and every component of an air conditioning system.

Validation of the model was performed by changing few parameters of the system while verification of the system was performed by varying the input of the system, which is power supply to the compressor.