EE313 ANALOG ELECTRONICS LABORATORY

2021-2022 FALL TERM PROJECT

1. Introduction

This document contains the project definition of the EE313 laboratory. Here are the important points about the project:

- Note that this is not a weekend project. Start working on it now. If you would like to test your designs, you can use the equipment in the EE313 lab in announced hours. During weekends, the laboratory will be closed.

- The aim of this project work is to make you more familiar with some subjects you were introduced to in the analog electronics class. However, you may need to do some research and study extra material to accomplish the task. This will be a good first step for 4th-year graduation projects.

- The project groups will contain at most 2 students. Although it is not recommended, you may do your project alone. So, determine your project partner as soon as possible. It is not necessary that your lab partner and project partner are the same people.

- You are free and encouraged to use your own ideas. Although your design approach is not limited, the systems are supposed to be economical.

- You are not required to implement your circuit designs on a printed circuit board, and you do not have to mount your circuits into a box. Doing so will not increase your grade, but nor will it negatively affect your grade. But your projects should have an aesthetic look (even a circuit on protoboard can have an aesthetic look).

- The early demonstration is allowed and encouraged.

- Detailed rubrics of the project demonstration, final report, and video submissions will be announced later.

- Cem Şahiner (csahiner@metu.edu.tr) and M. Berat Yüksel (mbyuksel@metu.edu.tr) are responsible assistants for the project. You can ask your questions via e-mail.

Remark: This project is proposed in a modular fashion. If you have trouble designing or implementing some parts of it, attend to other parts instead. Partial credit will be given.

Important Dates:

-9th January: Proposal Report

-5-8th February: Project Demonstrations

-9th February 17:00: Final Report and Video Submissions

2. Project Definition: Design of a Micro-Air Conditioner

Air conditioning can be described as the process of cooling, heating, moisturizing, dehumidifying, etc. This method is utilized to create a more pleasant interior environment. In this project, you are required to design an air conditioner system for small spaces. The system acquires heating, and cooling functions and consists of one variable set input and four subsystems, namely, the control unit, display unit, sensing unit, and the operation unit. The sensing unit provides the ambient temperature to the control unit, and the temperature adjustment unit provides the desired temperature to the control unit. Figure 1 shows the block diagram of the system.

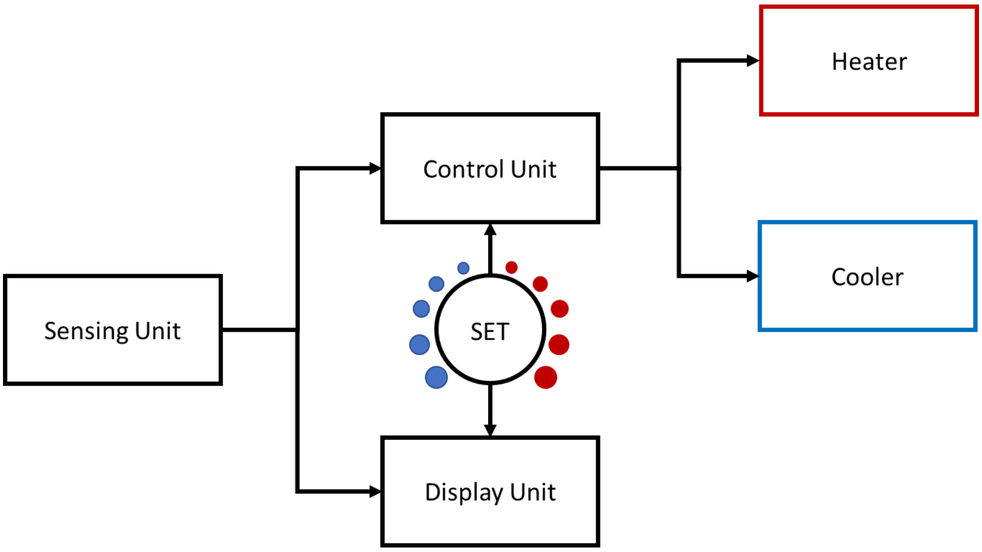

Figure 1. Micro-air conditioner system block diagram.

2.1. Control Unit

The control unit contains decision and function subunits. The decision subunit compares the ambient and desired temperatures and informs the function subunit accordingly. The function subunit, then, starts the heater or the cooler and indicates the performing action by using indicators (LEDs).

The system continues heating or cooling until the desired temperature is reached. Then, the function subunit stops the operation and enters the idle mode. In this mode, the ambient temperature is continuously checked, and if it deviates 1 degree from the desired temperature, the required operation starts automatically.

2.2. Operation Unit: Heating and Cooling

The heating element is an electrical resistor. To achieve a high temperature, the current passing through the resistor should be sufficiently high. Since the resistors used in the laboratory cannot endure high currents, stone resistors can be used. The heating element can be placed close to the sensing device for ease of implementation.

The cooling element is a DC electric fan. For this purpose, you may use 5 or 12 Volts computer case fan, or you can make your own fan with a DC motor and a small propeller that fits to your DC motor. The cooling element can be placed close to the sensing device for ease of implementation.

2.3. Sensing Unit

The sensing unit contains an analog temperature sensor in order to sense the ambient temperature. The sensor represents the decrease or increase in temperature by a variable parameter level that will be fed to the control unit. (As a temperature sensor, resistive temperature detectors (RTDs), LM35…)

2.4. Display Unit

The display unit contains a RGB led and a switch to show the set or the ambient temperature level. The display unit must cover the visible spectrum continuously, which means it must be designed with an analog perspective.

3. Design Specifications

- The system must be modular to test individual parts.
- Temperature range: 24°C - 40°C.
- The RGB Led indicator for both set temperature and ambient temperature should cover the visible spectrum in a continuous manner. Figure 2 illustrates the spectrum.

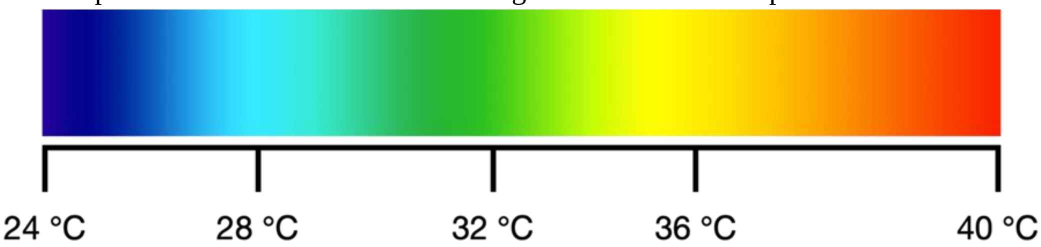

Figure 2. Temperature and color spectrum.

- The SET value will be adjusted with a potentiometer.
- The heater and cooler cannot work simultaneously.
- The system must be autonomous when there is a 1°C difference.
- You must use blue led for cooler and red led for heater operations.
- The system must reach the desired condition with at least a 5°C/min rate.
- Not required but you can cover the system with a visible material.
- The display unit must show ambient/set temperature.
- Selection in the display unit can be arranged with any kind of switch, sensor, button, etc.
- Your circuit must be capable of delivering at least 3W power. The allowed maximum total power is 15 W.
- Allowed Voltage range: ±12 V

4. Components Allowed

- You can use any kind of temperature sensor,
- You can use a 5 or 12 Volts computer case for cooling.
- You can use general-purpose op-amps, any transistor (BJT, MOSFET, JFET, etc.), regulators, diodes, resistors, stone resistors, capacitors, inductors, LEDs, relays.
- You are not allowed to use motor drivers.
- For components of optical transmission and receiving part, please refer to the "Full Specifications" part of this manual.
- The instruments are available in the laboratory. You can use all terminals of the DC supply.
- If you are not sure whether you can use a component you consider, please contact Cem Şahiner (csahiner@metu.edu.tr) or M. Berat Yüksel (mbyuksel@metu.edu.tr) before using it.

5. Remarks and Tips

- To be able to continuously show the set and ambient temperature, you somehow need to control the current in an analog fashion through the 3 individual LEDs contained in a single RBG Led.

  As a guideline, for $T = 24$, 32 and 40 °C, only the blue, green, and red LED is lit up, respectively, while, for example, for $T = 28$ °C, blue and green LED are ON with same amounts of optical power so that we get cyan color.

- If the temperature is lower than 24 °C, the LED should continue to show blue, and if the temperature is greater than 40 °C, it should continue to light up red—as these values are out of range.
- RGB LEDs are available in two configurations of common-anode or common-cathode. Select the proper one to suit your design.
- Note that you should be able to sustain any temperature between 24–40 °C with an error margin of ±1 °C. If a set temperature is 30 °C, ambient temperature should be sustained within 29–31 °C after the steady-state is reached.
- You can either use two different RGB LEDs for showing ambient and set temperature settings or use a single RGB LED and utilize a switch to show one of them at a time depending on the switch direction.
- You can glue your temperature sensor onto the heating element to have a precise control over the temperature. Note that we only care about the temperature of the sensor itself, not the surroundings of it. You may think that our temperature sensor itself is our 'room' to be air-conditioned.

- Along the same lines, you can enclose your heater element and temperature sensor in a very small box with vents where the fan is directed upon to have a better control over the temperature.

- Typically, small fans are enough to cool down the sensor with a minimal power consumption.

- You may use +6V terminals of out power supplies to drive your power consuming elements of stone resistors and fans. Note that +6V terminal can supply up to 5A while ±25V terminals can supply up to 1A of current.

- Do not exceed the wattage specified on the resistor. For instance, if you decide to use 15Ω, 5W resistor, you should not apply more than 0.57A through it or 8.6V across it $P = I^2R = V^2/R$.

- Select a proper resistance value for your stone resistor depending on the drive voltage of your design.

- If you use an IC temperature sensor such as LM35 take precaution not to overload and burn the sensor—as they are a bit expensive. LM35 has a very low output resistance so any misconfiguration of terminals, such as applying a high DC voltage directly to the output terminal, can result in burning out of the sensor.

- Try to separate your power circuitry from the control circuitry. For example, high current paths (going to heater or fan) should be taken directly (or from the vicinity) of the DC supply terminals.

- Protoboards and your wires typically has some nonnegligible resistance—if a large current passes through it, your entire control circuitry might be affected (For instance, your temperature readout might change when the heater is working since the voltage of ground might raise above 0V upon high current draw).

- You can use different types of control methods for driving fan and heater. Depending on the difference between the set and ambient temperature, you can utilize, for example, ON/OFF control, multi-level discrete control or some sort of proportional control to drive your heater and fan.

- ON/OFF control methodology is easy yet might show oscillating behavior (e.g., heater and fan working consecutively even though you reach the set temperature).

- You may utilize a dead band in your controller since you have the ±1 ℃ tolerance for the difference between set and ambient temperature. At this dead band, neither the heater nor the fan works to achieve a smoother operation.

- Note that your heater and fan should not be working at the same time instance.

6. Report Format

Proposal Report: The aim of the proposal report is for you to start your research early on so that you can have a solid idea about the project. This report will contain preliminary work on your project. A good report should include your proposed way to solve the problem, the equipment required for the solution, some block diagrams of the overall system, and any additional info (circuit schematics, mathematical calculations etc.) you see fit. The maximum page limit for the preliminary report is 2 pages (Times New Roman, 10-point font, no cover page). Longer reports will be rejected. It is crucial that you determine your project partner, and do some brainstorming to come out with solutions well before the preliminary report deadline. You have to upload your proposal report in pdf format to ODTUCLASS by the 9th of January, 23:59. Late submissions will not be accepted.

Final Report: The final report should be in the IEEE double-column paper format (please check the IEEE paper format) and it should not exceed 10 pages in total, any more pages will decrease your grade. The formatting is one of the most important parts of the project. If the final report is not in the IEEE paper format, the project will not be graded, and you will get zero from the whole project. Any formatting mistake (such as no figure captions, not a referral to the figure in your main text, etc.) will result in a grade deduction. You have to upload your proposal report in pdf format to ODTUCLASS by the 9th of February, 17:00. Late submissions will not be accepted. Your report should include the following items:

- Theoretical background and literature research
- Design methodology and mathematical analysis of the subsystems
- Simulation results verifying that your subsystems and the overall system is working properly.
- Experimental results
- Comparison of the experimental results with the simulation results and mathematical calculations and explanation of any discrepancies.

Project Video: Each group must submit a video about their project. This video must be in English. The evaluation of the video will be based on the oral skills not the technical situation of the project. You do not have to show a working project. The explanation of the overall project, the solution method, and the final situation of the project are the main criteria. The total time of the video should be around 5 minutes and each group member must talk in this duration.

Grading

- Proposal Report: 10 pts
- Project Demonstrations: 50 pts
- Project Video: 5 points
- Final Report: 35 pts

Note: Cheating is strongly forbidden and will be severely punished. This project can be implemented in many different ways. Hence, it will be easy to detect cheating. This does not mean that you cannot collaborate with your friends. However, the allowed form of collaboration is exchanging ideas, not copying the design details. Using the design of another group with slightly modified component values will also be regarded as cheating.

Also note that at the demonstration, both members of the group are responsible for every single detail of their circuit.