Title: Humidity Controller

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Degree: Electrical and Information Engineering

Year Of Study: Second

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Submission Date: 16 October 2020

Abstract: This document outlines the decisions and steps taken in designing a humidity controlling unit. It is used to ensure the comfort and well-being of the users of a lecture theatre in which it is to be installed. The humidity in the lecture theatre is controlled by turning ON or OFF the fan or heater when the humidity reaches certain predefined humidity levels. The Schmitt triggers are used to switch the fan and heater states when certain predefined threshold levels are reached. The resistive humidity sensor model HR202 is used in the design, which is replaced with a resistor for simulation purposes. The fan and heater are replaced with relay, which will be responsible for changing the states of the actual higher power fan heater. It is best to have the Schmitt trigger resistors set and then adjust its reference voltage accordingly if the switching is not accurate enough.

I. Introduction

This document details the steps and approach taken in designing a humidity controlling unit. This unit is a subsystem to a 'Lecture Theatre Environment Control' system, which is responsible for controlling the physical environment of a lecture theatre for the comfort and well-being of the users.

This humidity controlling unit helps in providing this comfort and well-being of the lecture theatres' users by switching ON the fan or the heater when the relative humidity reaches certain predefined levels. These predefined levels are different for the Summer and Winter.

As the lecture theatre's ambient temperature changes, so does the relative humidity, which is reflected in the change in resistance across the humidity sensor[1]. This unit uses an analog resistive humidity sensor, more specifically the HR202 model.

The first section covers the design of the unit. It details the decisions made and the thoughts behind them. After that section follows a section with the outcomes from the simulation and a comparison between the expected results and the simulation results. Following that are the future recommendations for the improvement of the design. Which is then followed by the overall design overview, comparing the proposed outcome against the obtained outcome.

II. Implementation

A. Design

Figure 1 shows the flow diagram of the designed unit.

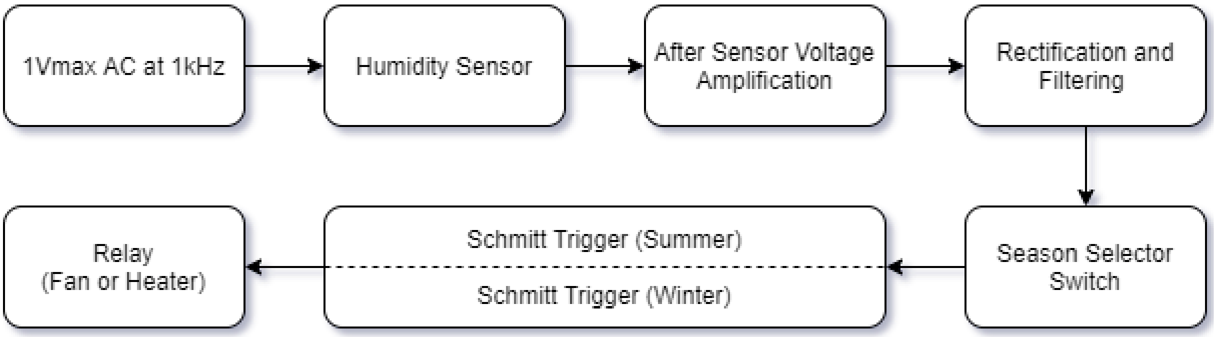

Figure 1: Humidity dependent fan and heater

This unit consists of one resistive humidity sensor, which for simulation simplification was replaced by a resistor. This resistor represents the resistance that will appear across the actual humidity sensor during operation.

Figure 2 below shows the sensor's set-up as well as the power supplies simulation setup. As can be seen in the figure, the sensor is replaced with a resistor. The input voltage into the sensor's resistor was chosen to be a 1.0 V max at 1kHz. This was chosen because all the known behaviors of the sensor concerning temperature were recorded at those conditions. It was then thought time-efficient to use the already available data under those conditions to extract the necessary data to get accurate results.

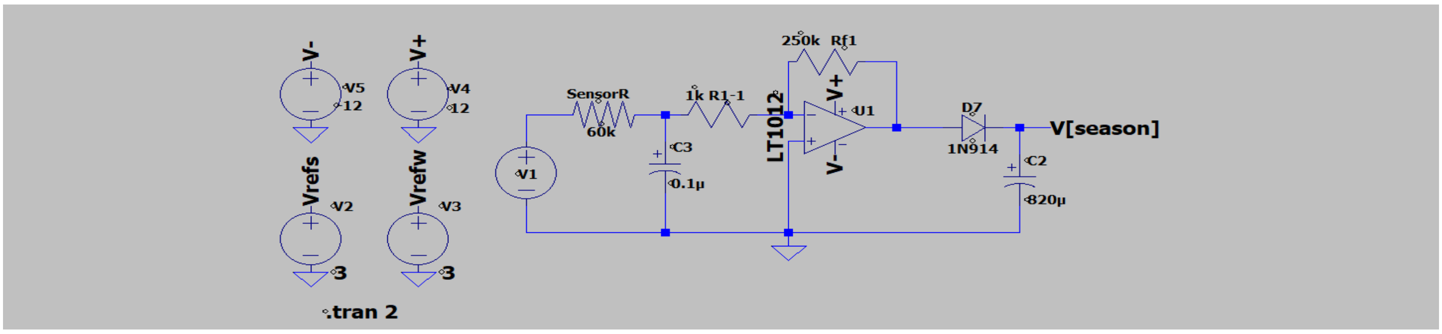

Figure 2: Sensor and power supplies setup.

On the left are all the power supplies needed for the unit. They were set aside to increase circuit' readability and clarity. The power supplies 12V and 3V were specifically chosen because they are already available on the main system. This voltage availability eliminates the need for extra circuitry for amplifying and/or dropping down the voltage to suit the needed voltage. That in turn simplifies the circuit. It also makes the circuit cheaper to build as relatively fewer components are needed for its construction. The lower number of components means lower malfunction possibility in the circuit since fewer components mean fewer components to possibly fail or misbehave.

Right after the sensor's resistor is the 0.1 μF capacitor. It ensures constant current drawn by the load discharging its current when the input voltage is unusual.

To avoid the Op Amp's high internal input impedance, which will lead to a significantly low current across the sensor, the inverting Op-Amp configuration is used.

The voltage after the Op Amp is defined by equation 1.

$$V = -\frac{Rf}{R1}Vin \tag{1}$$

The Op Amp's AC output is rectified using the 1N914 diode. Assisting it to convert the AC voltage to DC voltage to ensure controlled switching is the 820 μF filtering capacitor. The relatively large capacitor size 820 μF was chosen to reduce the ripple voltage, making the output voltage more direct.

The switching circuits were created using the Schmitt triggers, which means the voltage cannot be alternating at all times as that will result in premature switchings. The 1N914 diode was specifically chosen for its low voltage drop. Which meant less voltage loss.

After the voltage has been made direct, it gets to a switch, which gets manually switched to either supply the voltage to the summer or the winter circuit depending on the season.

B. Triggers

The summer circuit uses an inverting Schmitt trigger. The winter circuit on the hand uses a non-inverting Schmitt trigger.

Since the switching was only at specific given percentage humidity levels (RH), it was decided that only those threshold levels will be considered instead of every possible humidity level. This was to make the unit simpler.

In summer, the thresholds are defined at the RH values 50% at 23 °C and 60% at 20 °C. In winter, they are defined at 60% at 24 °C and 70% at 21 °C. Since the sensor is represented by a resistor, the sensor's resistance at those RH values and temperatures was extracted from the plotted graph. The graph was a Resistance vs Temperature graph at specific RH values.

Table 1 contains the resistances corresponding to given RH values at given temperatures. They were obtained through extrapolation.

Table 1: Resistance values at given relative humidity levels

Relative Humidity	**Temperature(°C)**	**Resistance(kΩ)**
50%	23	97.3
60%	20	39.0
70%	21	15.0
60%	24	32.3

These threshold resistances are used to determine the threshold voltages at the Op Amp's output side.

Figure 3 below shows the circuit diagram for the summer conditions. In this case, the inverting Schmitt trigger is used to switch ON and OFF the fans at predefined threshold levels. These thresholds were extracted from the known %RH, Temperatures, and Resistance values from the sensor's datasheet.

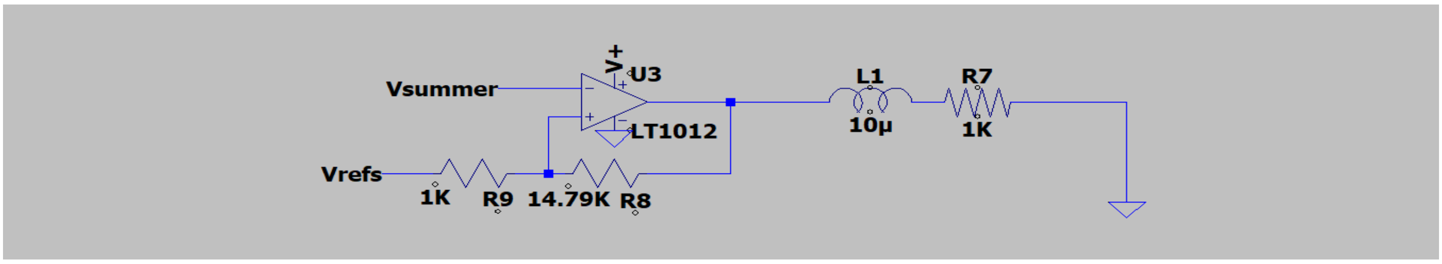

Figure 3: Summer trigger circuit setup.

Figure 4 below shows a circuit diagram for the winter conditions.

For both the summer (fan) and the winter (heater) circuits, a relay equivalent is used. This is because the fan and the heater for an actual theatre work with much more power than the circuit. This unit is only for controlling when the fan or heater should turn ON or off. Since relays can link lower power circuits to higher power circuits, they were chosen to link this unit and the actual fan and heater.

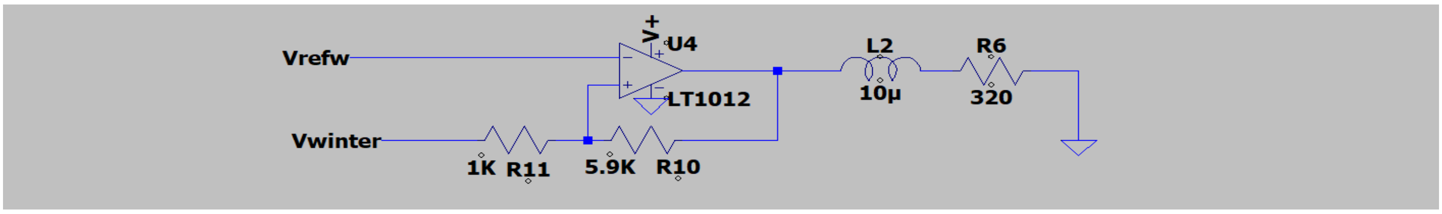

Figure 4: Winter trigger circuit setup

Using the resistance values obtained for the conditions where the fan and heater were to switch ON and OFF, the voltage values after the sensor's resistor were obtained. These voltages were amplified and used to define the threshold voltages at which the fan and heater will switch ON and OFF. Table 2 contains the voltage after the sensor before amplification, rectification, and filtering.

Table 2: Summer and winter equivalent voltage.

	Resistance (kΩ)	**Input Voltage (mV)**
Summer	92.3	12.00
	39.0	28.01
Winter	15.0	83.04
	32.3	33.80

III. Simulation

A. Results

Figure 5 shows the input voltage waveform for when the resistance is 92.3 kΩ in summer for the first 12ms. It can be observed that this voltage of significantly weak to work with.

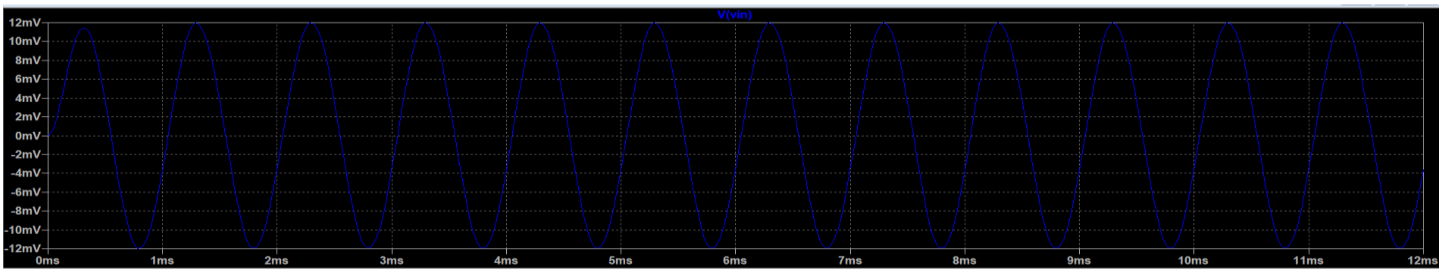

Figure 5: Input voltage when the resistance across the sensor is 92.3 kΩ

Figure 6 shows the amplified and inverted input voltage. It is slightly lower than calculated. Along it is the voltage after the rectification and filtering. This on the other hand is slightly above the calculated value.

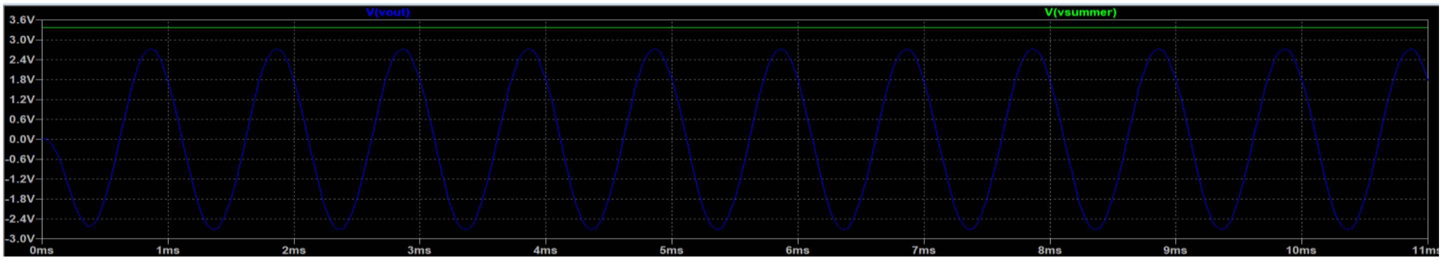

Figure 6: Amplified and rectified and filtered voltage waveforms

The two figures above, namely figure 5 and figure 6, show that the signals are successfully amplified and filtered as expected. It also shows that the outputs are not exactly as expected but are only off by a tolerable amount for this specific design.

Table 3 contains the voltage values at that the triggers are expected to switch states. These are obtained experimentally for different resistance values. These voltages were found to have peak-to-peak ripple voltages in the order of millivolts. They are dismissed as the switches are set to work with values in orders of hundreds of times the order that of the ripple voltage.

Table 2: Summer and winter threshold voltages

	Resistance (kΩ)	**Threshold Voltage level (V)**
Summer	92.3	3.3720
	39.0	5.4063
Winter	15.0	9.9414
	32.3	6.6072

Figure 7 shows the voltage across the relay being high for resistance greater than the threshold resistance in summer, 92.3 kΩ. That dropped the voltage below the lower threshold level, thus switched ON the relay (fan) as expected since the inverting Schmitt trigger was used.

The opposite happens when the voltage above the upper threshold voltage.

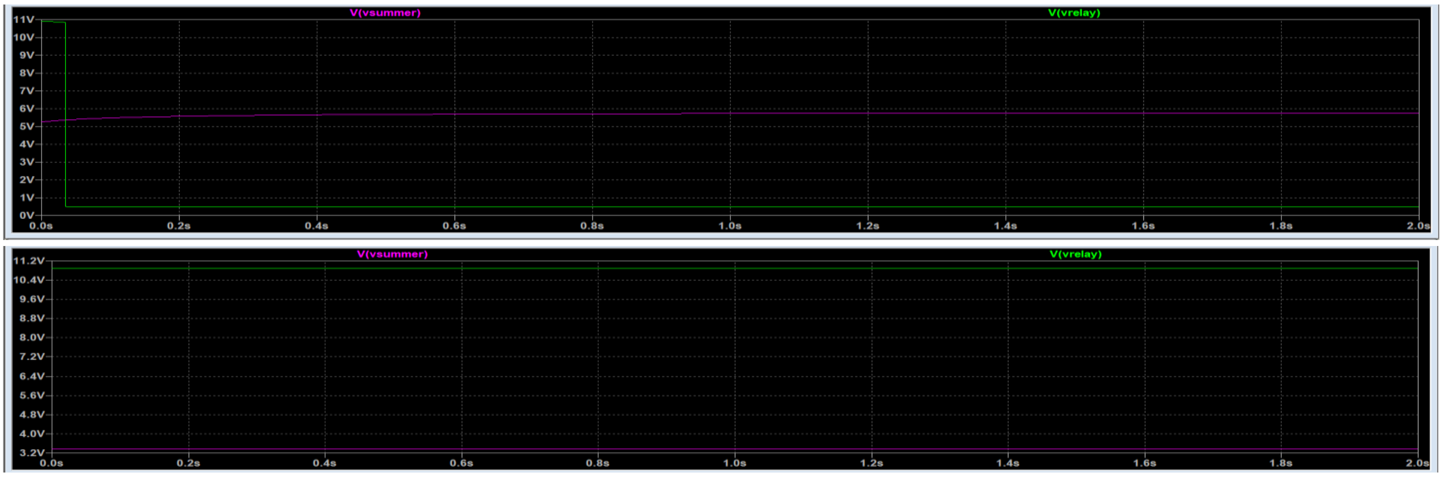

Figure 7: Summer triggering patterns.

Figure 8 shows the triggering patterns for a heater in winter. It can be observed that the heater turns ON when the voltage goes above the upper threshold voltage and turns OFF when in the voltage goes below the lower threshold voltage, as expected.

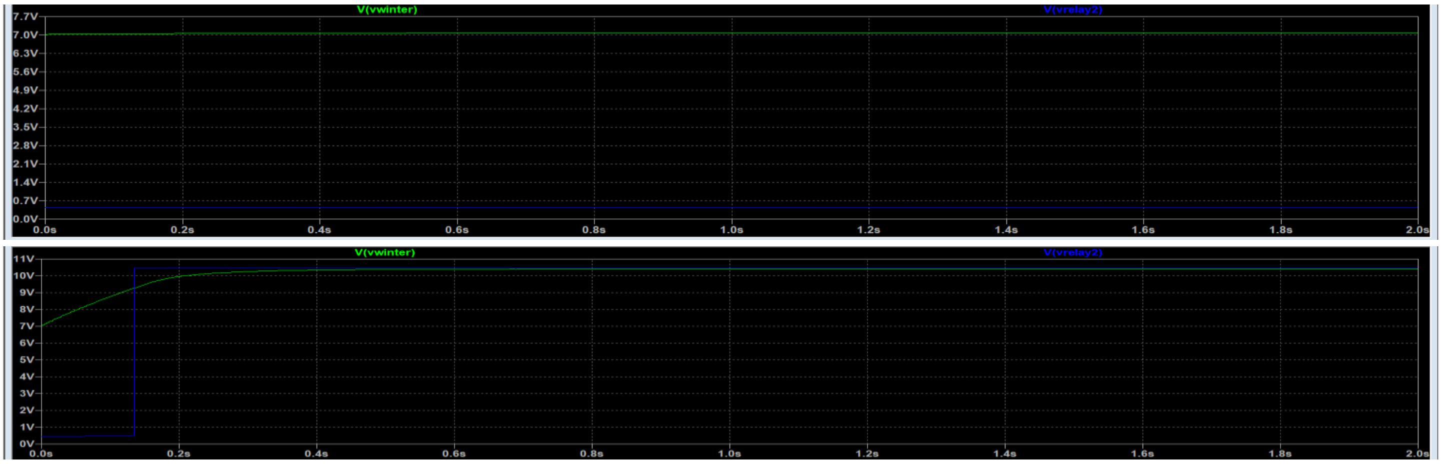

Figure 8: Winter triggering waveforms

B. Future recommendations

Since resistors can only have certain discrete values, specific available or archivable resistors should be added so that the threshold levels depend only on the input voltage and the reference voltage.

IV. Conclusion

The simulation ran well. Both the fan and the heater switched ON and OFF as expected. Only resistance and voltage values at the conditions where the fan and heater change state are necessary to create a humidity controller of this kind. The Schmitt trigger reference voltages had to be readjusted for more precise triggering levels. It is best to set the Schmitt trigger resistors and adjust the reference voltage accordingly to get the desired threshold voltage levels.

References

[1]. Resistive humidity sensor, Model: HR202, Available online: https://www.elecrow.com/download/HR202%20Humidity%20Sensor.pdf, Last accessed: 14 October 2020