Project Report

EEE/ECE 301/302

Digital Electronics

Group No: 20

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1. Project Title

Digital Smart Room

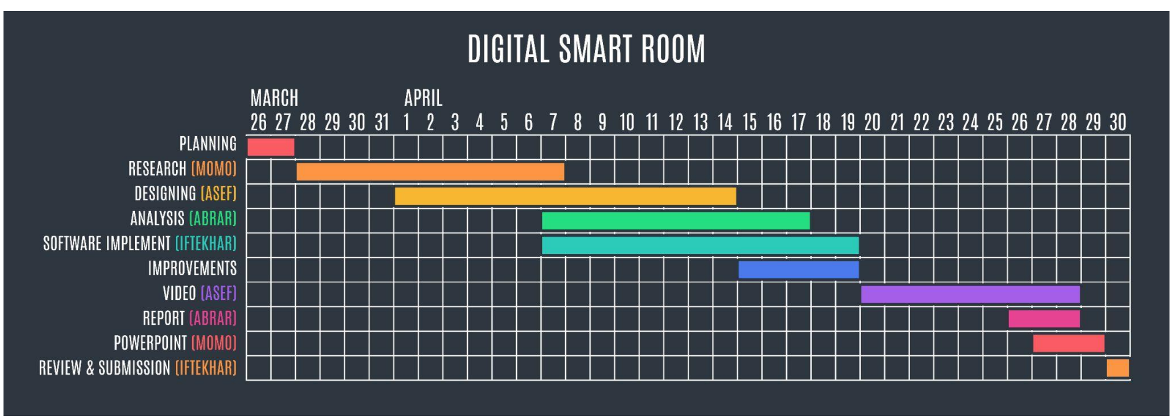
2. Tentative Problem Statement

Reduce electricity usage, prevent fires, theft and overcrowding in public/private social gathering rooms and ensure everyone gets equal access to the room

3. Tentative Objectives

Make a circuit that would automatically regulate the temperature of a room. It would automatically turn on and off the room lights based on human presence or a time trigger. It would have a fire, smoke and theft alarm. Human counter and timed room sessions would also be present.

4. Gantt Chart



5. Specifications and Requirements

Software used: Proteus 8 Professional

Equipment:

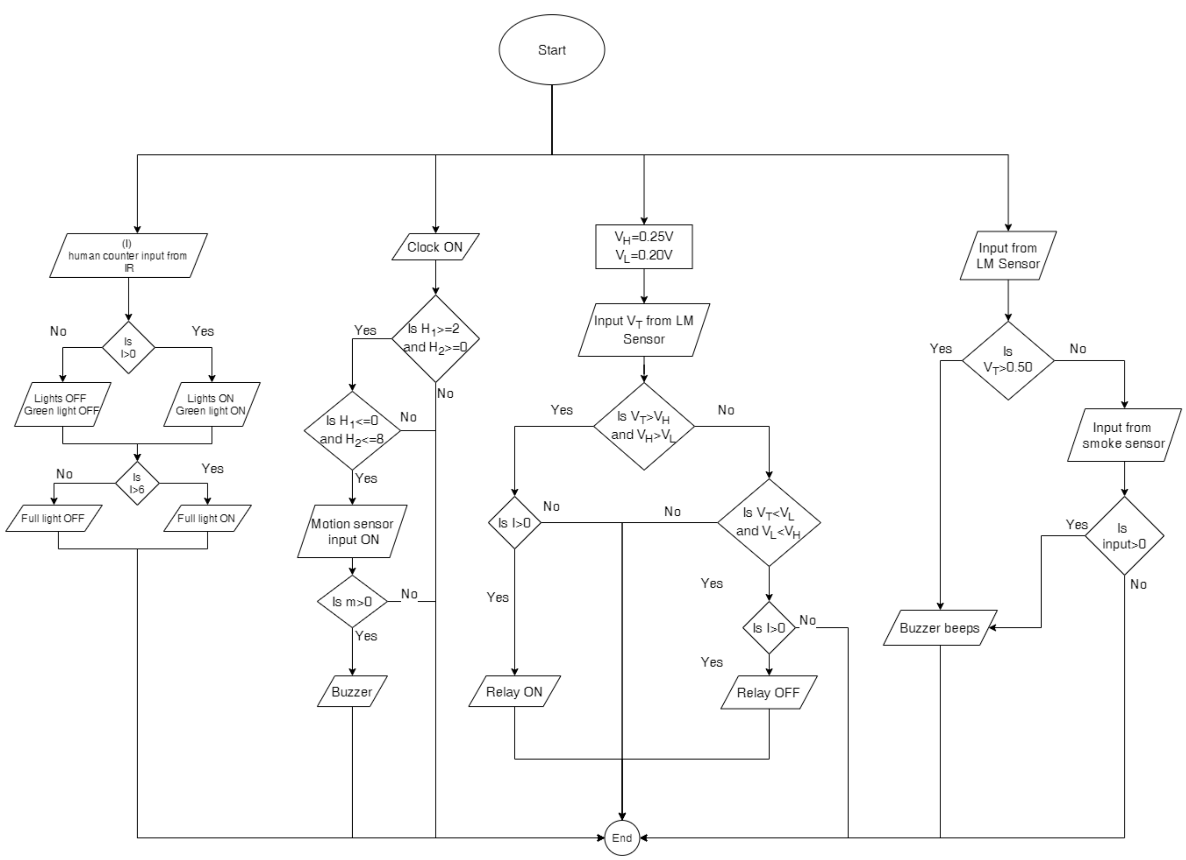
1. 555 Timer as oscillator
2. Resistor
3. Capacitor
4. Power Supply (5V)
5. Ground
6. T Flip Flop (using JK Flip Flop)
7. Logic Gates (AND, OR, NAND, NOR, NOT)
8. 74161 Counter IC
9. D Flip Flop
10. 7SEG-BCD LED Display
11. Logic Toggle
12. Logic Probe (Big)
13. LM35 Temperature Sensor
14. OP AMP as Voltage Comparator
15. VSource
16. Potentiometer
17. SR Latch
18. 1N4734A Zener Diode
19. NPN BJT
20. Relay
21. LED Lights
22. 4 bit PIPO Mode Register (using D Flip Flops)
23. 4510 Bi-directional Counter
24. IR Sensor
25. PIR Motion Sensor
26. 4063 Comparator IC
27. MQ-2 Smoke Sensor
28. Buzzer

6. Methodology

The circuit was divided into 8 parts, each serving a different purpose:

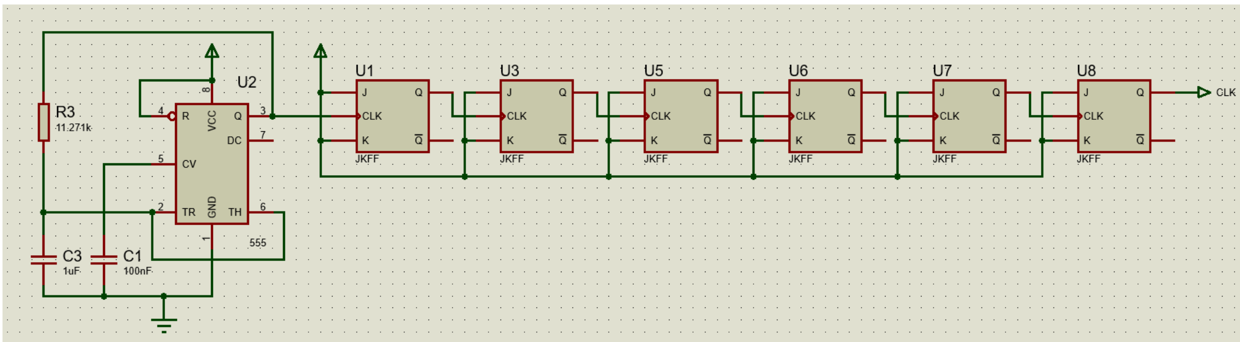
1. Clock pulse generator that outputs a pulse once every second (1 Hz)
2. A 24 hour clock (with display) using counters
3. Human Counter
4. Timed Session
5. Theft Detector
6. Temperature Sensor
7. Fire and Smoke Sensor
8. Alarm

Then the output from each circuit would be connected to another circuit if required.

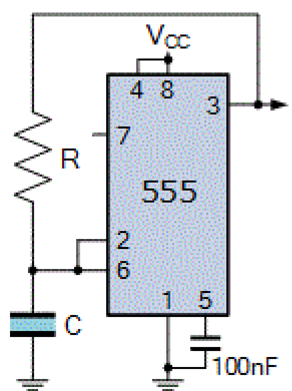


7. Results and Discussion

Clock Output:



To get a clock output in the circuit, we used a 555 timer. The 555 timer was used in a simple oscillator configuration.



The frequency of the oscillation is given by following formula

$$f = \frac{1}{2\,ln\,(2)\,RC}$$

Here a frequency of 64 Hz, or 2^6, was chosen and the capacitor was chosen to be 1µF.

$$R = \frac{1}{2\,ln\,(2)\times\frac{1}{1\,000\,000}\times 64}$$

$$\Rightarrow R = 11.271\ k\Omega$$

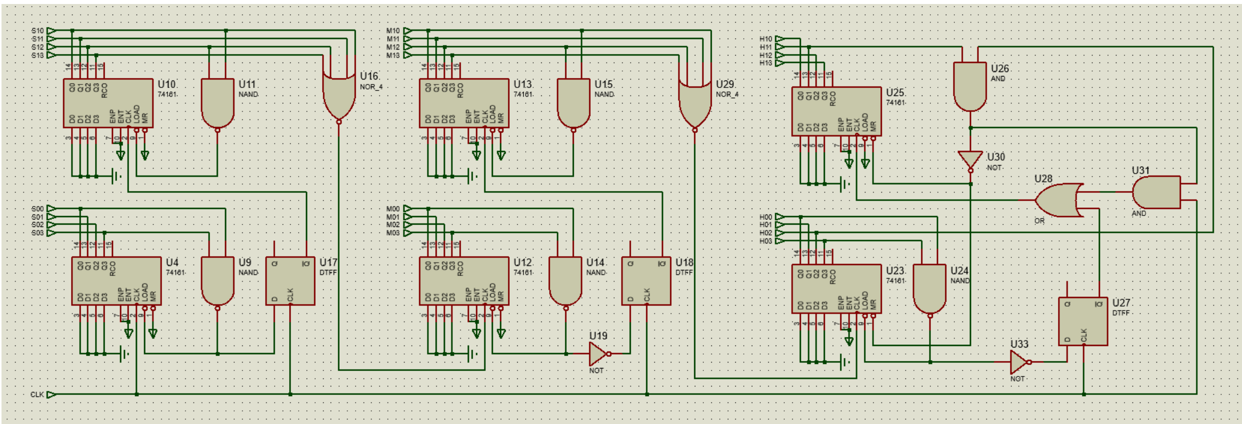
The 64 Hz pulse from the 555 timer is then passed through 6 T Flip Flops. T Flips Flops toggles the output when the input terminal T is set to HIGH. This effectively halves frequency of the pulse. Since Proteus does not have T Flip Flops, JK Flip Flops were converted to T Flip Flops by shorting the J and K terminals together.

T	J	K	Q	State
0	0	0	Previous State	No Change
	0	0	0	Reset
	1	0	1	Set
1	1	1	Previous State	Toggle

Fig: Truth Table for T Flip Flop and JK Flip Flop

The JK terminals (or T terminal) of the flip flops are set to HIGH so they are in toggle mode. By halving 64 Hz 6 times, the end output is a pulse of 1 Hz, meaning the clock ticks once every second.

Clock pulse to a 24-hour clock:

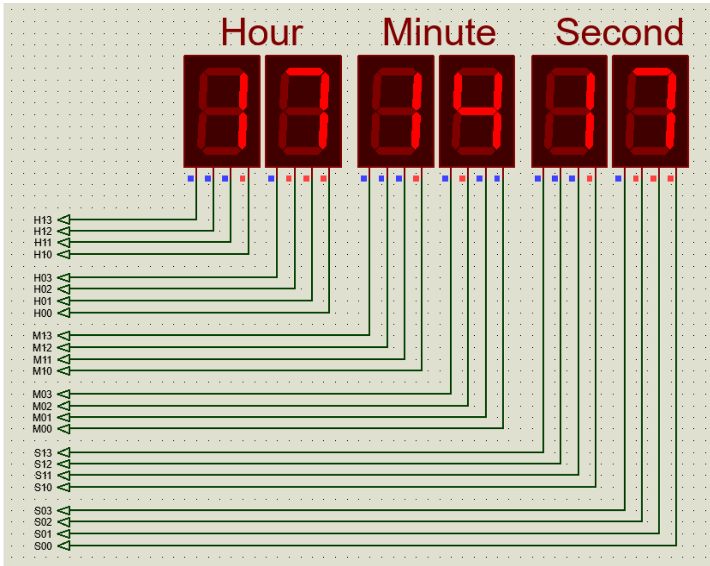


The 1 Hz pulse is attached to the CLK pin of a 74161 Counter IC. This is responsible for counting the last digit of the *second* segment of the clock display. The counter is limited to count from 0 to 9. The input D pins are all grounded. When the 1001_2 (9_{10}) is reached, the LOAD pin is set to HIGH. In the next clock cycle, the data from the D pins are loaded. Since the D pins are all grounded, the counter is set to 0000_2 (0_{10}). Here, a NAND gate is used to detect when 1001_2 is reached.

When the 1001_2 (9_{10}) is reached, a D Flip Flop is set to HIGH as well. In the next clock cycle, a clock pulse is sent to the CLK of the next counter. The D Flip Flop is used to keep sync with the digits and the main 1 Hz clock pulse. This counter is responsible for counting the first digit of the *second* segment of the clock display. Using the same concepts as above, the counter is limited to count from 0 to 5.

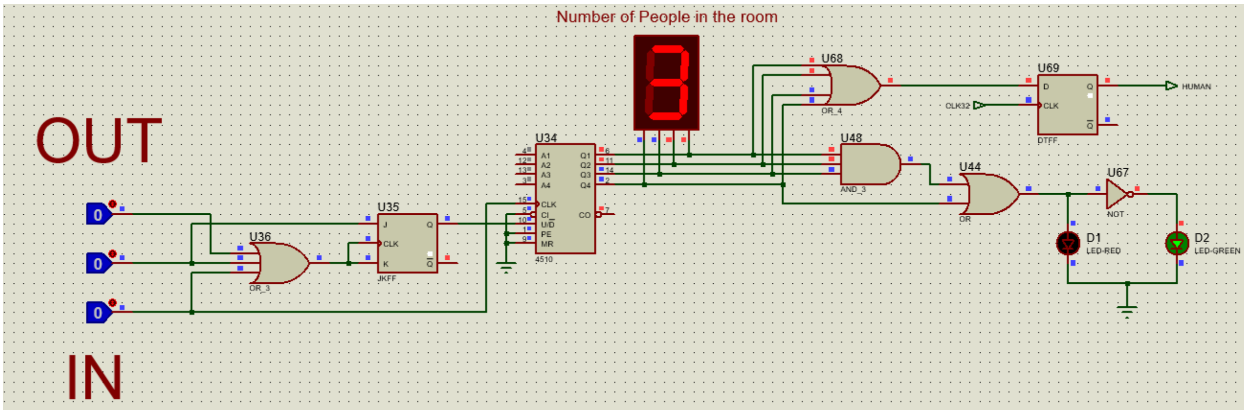
When the 2nd counter reaches 0 after crossing 5, a pulse is sent to the *minute* segment of the circuit. A NOR gate is used to detect when the *second* segment outputs 00. The circuit for the *minute* segment is similar to the circuit of the *second* segment. After 60 minutes has passed, a pulse is sent to the *hour* segment.

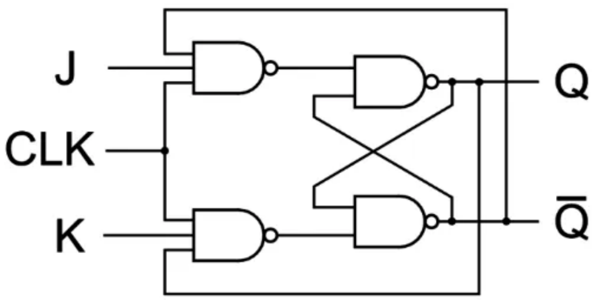
The *hour* segment is slightly more complicated than the previous two segments. The last part of the *hour* segment counts from 0 to 9. However, the counter has to reset to 00:00:00 after 24 hours. So a 2nd set of gates were used to reset the counter, specifically when the first digit of the *hour* segment is 2 (0010_2) and the last digit is at 4 (0100_2).



The outputs of these counters are then connected to a display. 7SEG-BCD LED displays were used as it directly converts the binary to 7 segment format.

Human Counter:





CP	J	K	Q_{+1}	State
1	0	0	Q_n	NO CHANGE
1	0	1	0	RESET
1	1	0	1	SET
1	1	1	$\overline{Q}_n$	TOGGLES

Fig: JK Flip Flop

Fig:Truth Table for JK Flip Flop

An event detector is a circuit which is capable of determining the occurrence of a particular event. These detectors change their state when an event occurs and remain in the same state till that event gets cleared. Flip flops are well known to preserve their state until the appearance of a suitable condition at their inputs, which means they can act as event detectors. Here, we have used the JK Flip Flop as an event detector whose diagram along with its truth table is attached above.

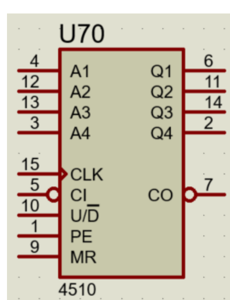


Fig: 4510 Up and Down Counter

MR	$\overline{PL}$	UP/DN	CE	CP	MODE
0	1	X	X	X	PARALLEL LOAD
0	0	X	1	X	NO CHANGE
0	0	0	0	·	COUNT DOWN
0	0	1	0	·	COUNT UP
1	X	X	X	X	RESET

Fig: Up and Down Counter Operation Table

If the input at $U/\overline{D}$pin is LOW the circuit works as a DOWN counter but when this same input pin is HIGH the circuit works as a UP counter. This feature is especially useful as our design requires a bi-directional counter and to switch between these two modes we have used JK Flip Flop.

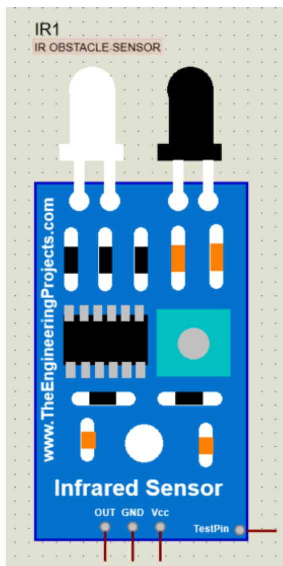


Fig: Infrared (IR) Sensor

Three IR sensors are placed in series close to each other at the entry point of the room. Depending on which sensor is triggered first the system adds or subtracts the count of people inside this room.

These above mentioned JK Flip Flop along with 4510 UP and Down Counter and 3 Infrared Sensors makes up our human counter system.

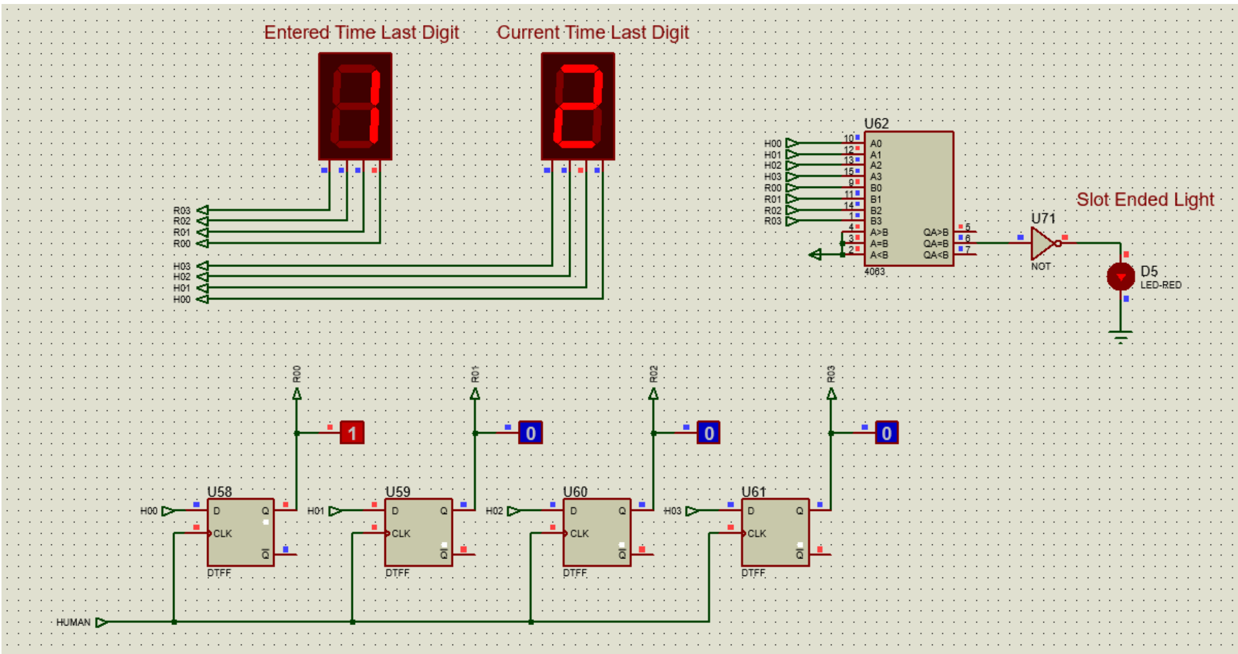
The IR sensors are triggered if a person enters or exits the room. If the outermost sensor with respect to the room gets triggered first followed by the two consecutive innermost sensors, the counter gets raised by 1 indicating that a person has entered the room. If the innermost sensor gets triggered first followed by the consecutive outermost sensors (all with respect to someone inside the room), the counter reduces by 1, indicating that a person has left the room.

When someone enters the room, the outermost sensor with respect to someone inside the room is cut first which causes no change in this case but as the middle sensor is triggered the JK Flip Flop goes into toggle mode and its output Q is now HIGH. This output is connected to the U/$\overline{D}$ pin and thus now the 4510 IC acts as an UP counter. Subsequently, the innermost IR is now triggered which again gives HIGH input to J, K and Clock. Thus, the counter moves up by ONE and the JK Flip flop goes into reset mode causing its output to return to its original state, which is LOW. This new LOW output turns the 4510 IC to a DOWN counter. If someone enters the room, the same process occurs again.

When someone leaves the room, the innermost sensor with respect to someone inside the room is cut first. Before this stage, the output of flip flop is already LOW which makes the 4510 IC act as a DOWN counter. This happens as for someone to come out of the room they must have entered first cutting the three IR sensors and resulting in the procedure explained above. Now as the innermost sensor is triggered the count decreases by ONE as it pulses the CLK of the counter. Subsequently, as the middle sensor is activated the JK Flip Flop goes into toggle mode causing the 4510 IC to be an UP counter. Lastly as the outermost sensor with respect to the room is called in action the JK Flip flop is in reset mode providing a LOW output to the U/$\overline{D}$pin and making the IC a DOWN counter again, resetting the JK Flip Flop back to its original state.

We went with a maximum of 7 people allowed in the room. If the room has space for more people to enter, a green light would be shown. When the limit is reached, a red light would be shown. Also, if there is at least 1 person in the room, the HUMAN trigger would be set to HIGH, indicating there is human presence for other circuits (such as temperature control) to function.

Timed Session:



Symbol

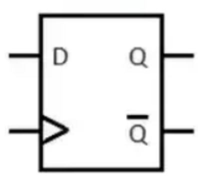


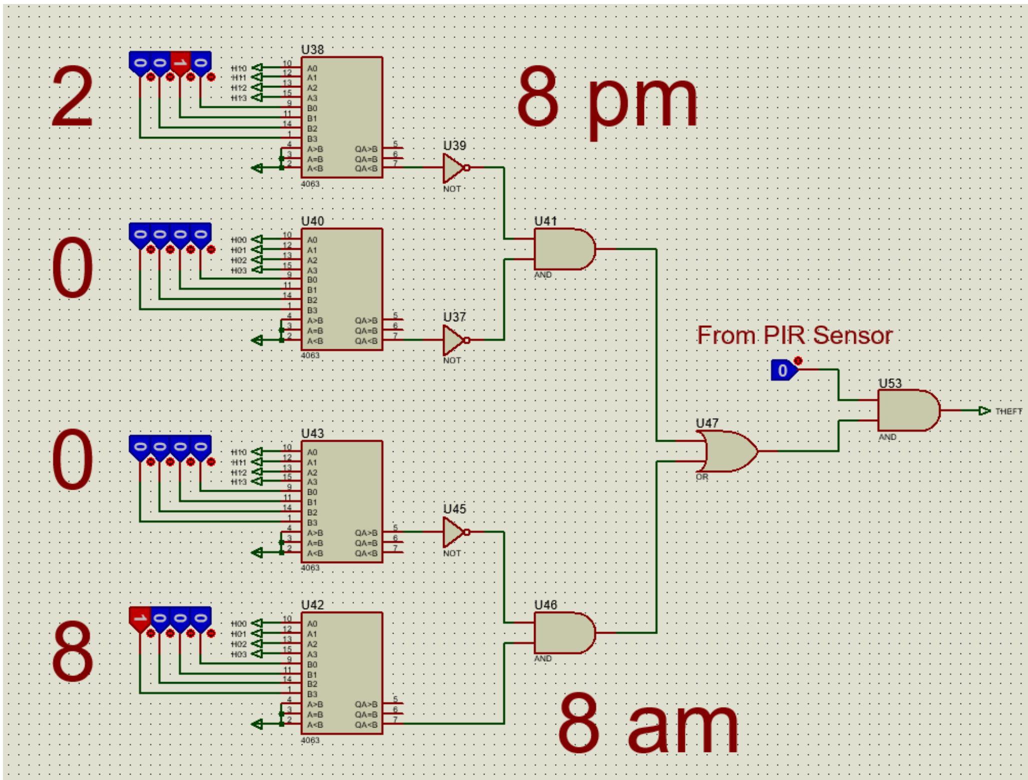
Table of truth:

clk	D	Q	$\overline{Q}$
0	0	Q	$\overline{Q}$
0	1	Q	$\overline{Q}$
1	0	0	1
1	1	1	0

Fig: D Flip Flop and Truth Table

A register is added in PIPO Mode (Parallel In Parallel Out) to the circuit. When someone enters the rooms, the HUMAN presence sensor is set from LOW to HIGH. This pulses the register to load the data into memory. We went for a 1 hour session (from 8 am to 9 am, 9 am to 10 am etc). The data that is loaded to the register is the last bit of the *hour* segment. This means if the time is 08:00:00, the data loaded is 8 (1000_2) and if the time is 16:00:00, the data loaded is 6 (0110_2). This last digit of the *hour* segment implies the slot at which the group has entered the room. These 4 saved bits in the register were called R00, R01, R02 and R03. It was then compared to the current last digit of the *hour* segment using a 4063 comparator circuit. If the entered time does not match the current time, it means that the 1 hour slot they were designated is over and a RED LED would light up to ask the group to leave. When the group leaves, the HUMAN presence sensor is set to LOW again. When another group enters, the HUMAN presence sensor is triggered again. The register loads the new time into the memory and the cycle repeats.

Theft/Suspicious Activity Detection:



A theft detector was added that would detect suspicious activity during off hours. We went with the detection system that would arm from 8 pm (20:00:00) to 8 am (08:00:00). 2 pairs of comparators were used to see if the system should be activated. The first pair checks if the time is equal to or over 8 pm. This is done by comparing the first and last digits of the current time of the *hour* segment with 2 (0010_2) and 0 (0000_2) respectively. If the comparison sees the time is equal to or over 8 pm, the theft detector is armed. In the same way, another pair checks if the time is under 8 am. The first and last digits of the current time of the *hour* segment is compared with 0 (0000_2) and 8 (1000_2) respectively. If the time is less than 8 am, the detector is armed.

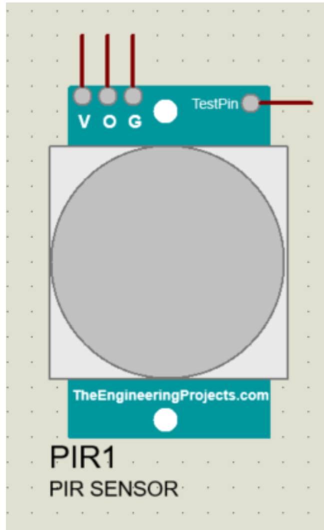
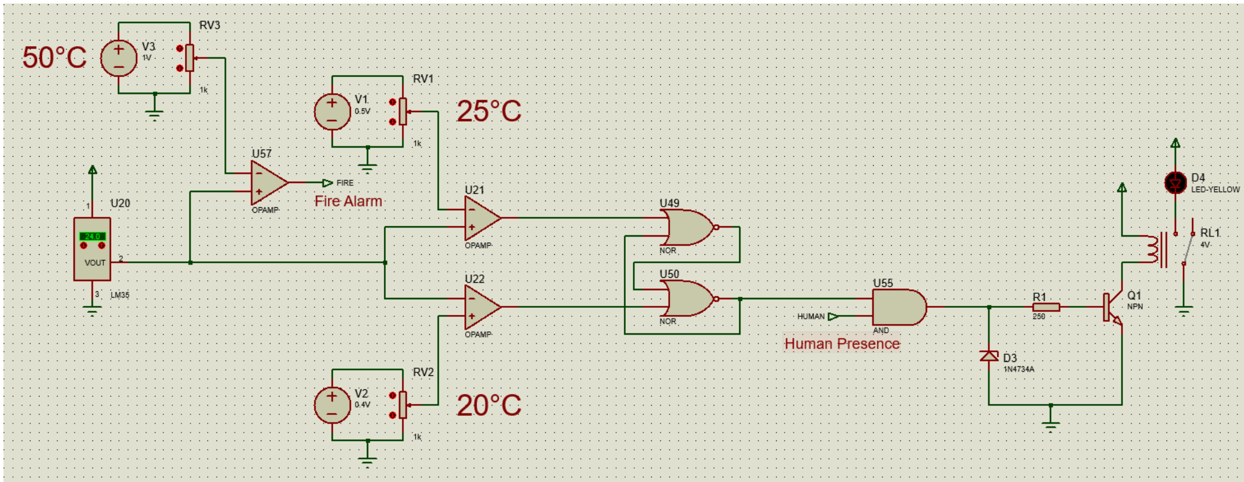


Fig: PIR Motion Sensor

When the detector is armed, the PIR motion sensor checks for any movement in the room. Any motion in the room would trigger the PIR sensor, which in turn, would trigger the THEFT pin. The alarm/buzzer would go off, alerting the authorities/security guards.

<u>Temperature Sensor:</u>



The temperature sensor would be used to control the Air Conditioner (AC) in the room. It would also be used as a fire alarm, as in case of a fire, the temperature in the room would be very high. We chose to trigger the AC ON if the temperature is 25°C and turn OFF the AC if the temperature is below 20°C. The FIRE trigger would be HIGH if the temperature exceeds 50°C. We chose to use the LM35 temperature sensor for our application.

LM35 Sensor Specifications:

- Precision Centigrade Temperature Sensor
- Range (-55 to 150)° Celsius
- Linear relationship between degree Celsius and output voltage
- Output varies by 0.01 Volts per degree Celsius Needs between 3.5 to 30 Volts to operate

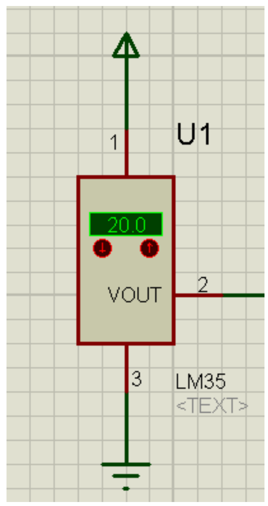


Fig: LM35 Sensor

If V_T is greater than V_H then Then A equals to $+V_{sat}$ (Digitally 1)

At this stage B equals to $–V_{sat}$ (Digitally 0)

If V_T is less than V_L then Then B equals to $+V_{sat}$ (Digitally 1)

At this stage A equals to $–V_{sat}$ (Digitally 0)

When V_T in between V_H and V_L then both A and B equals to $–V_{sat}$ (Digitally 0)

Both A and B simultaneously bring digitally 1 is not possible.

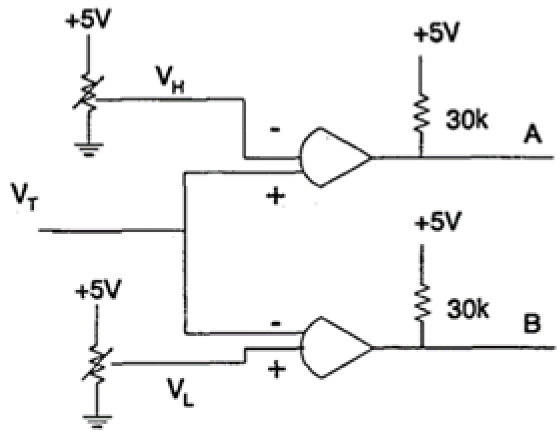


Figure 3: Op-amp comparators for the comparison block.

Voltage Input at Comparison Circuit (for 20°C) = 0.20 Volts

Voltage Input at Comparison Circuit (for 25°C) = 0.25 Volts

Voltage Input at Comparison Circuit (for 50°C) = 0.50 Volts

The input voltages vary as the sensor detects any change in the temperature.

The set V_H and V_L are changeable due to potentiometers used thus the user can set the temperature range they want and the system will automatically work to keep it in between that range.

Digital Implementation

$A = (V_T > V_H)$

$B = (V_T < V_L)$

When V_T greater than V_H Then A = 1 and B = 0

When V_T less than V_L Then B = 1 and A = 0

If V_T between V_H and V_L then A = B = 0

Other combinations are not possible.

Assuming there is human presence in the room and the HUMAN trigger is active,

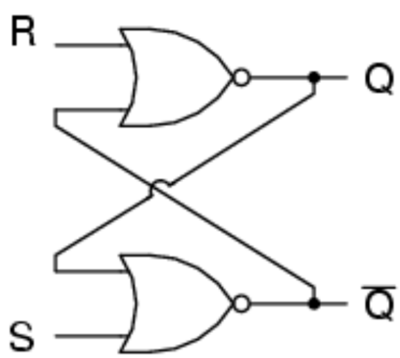
Relay will be ON for $V_T > V_H > V_L$

Relay will be OFF for $V_T \leq V_L < V_H$

Relay will be UNCHANGED for $V_L < V_T < V_H$

A	B	Output
0	0	AC stays previous state
0	1	AC is turned on
1	0	AC is turned OFF

The above truth table resembles the one produced by a typical active HIGH SR Latch



S	R	Q	$\overline{Q}$
0	0	latch	latch
0	1	0	1
1	0	1	0
1	1	Invalid Condition	Invalid Condition

Fig: SR NOR Latch and Truth Table

If the temperature is above 50°C, the FIRE trigger would be set HIGH, triggering the alarm.

Smoke Detector:

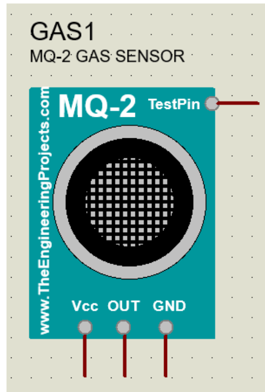
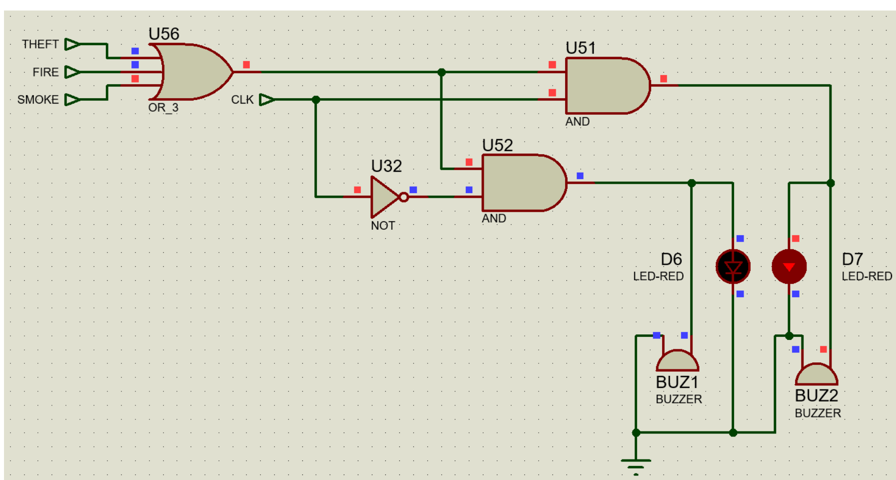


Fig: MQ-2 Smoke Sensor

Along with a fire alarm, there would also be a smoke sensor. In case it detects any smoke, it would trigger the alarm.

Alarm Circuit:



The buzzer receives input from 3 different segments - THEFT, FIRE and SMOKE. If either of these triggers sends an output of HIGH, the alarm is active. There are 2 buzzers, each with a different tone. The 1 Hz clock is used to switch between the 2 buzzers. When the alarm is active, the buzzers output a loud, alternating sound of 2 different tones which would signify an emergency, such as a fire alarm or theft detection.

8. Project Validation

Clock Circuit:

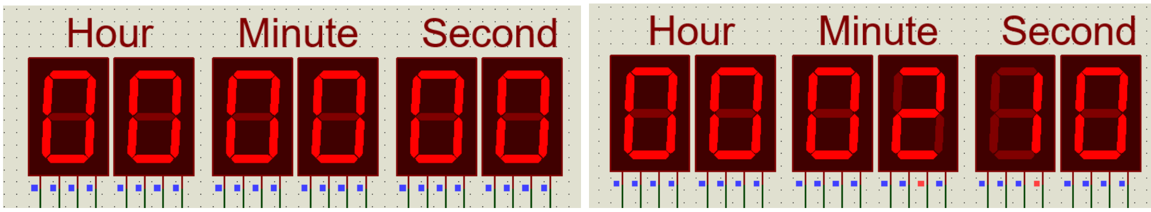


Fig: Clock just started and after running for 2 minutes 10 seconds

Human Counter:

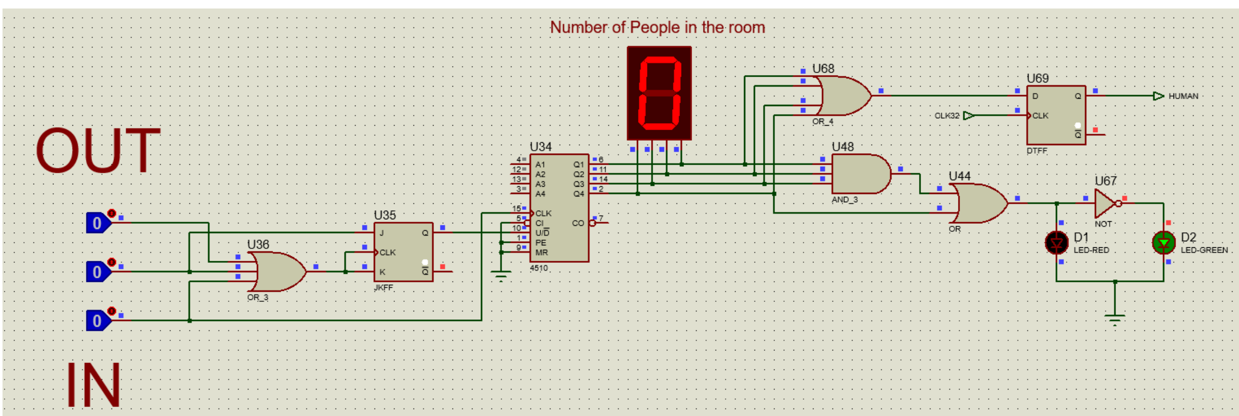


Fig: Human Counter in Normal State

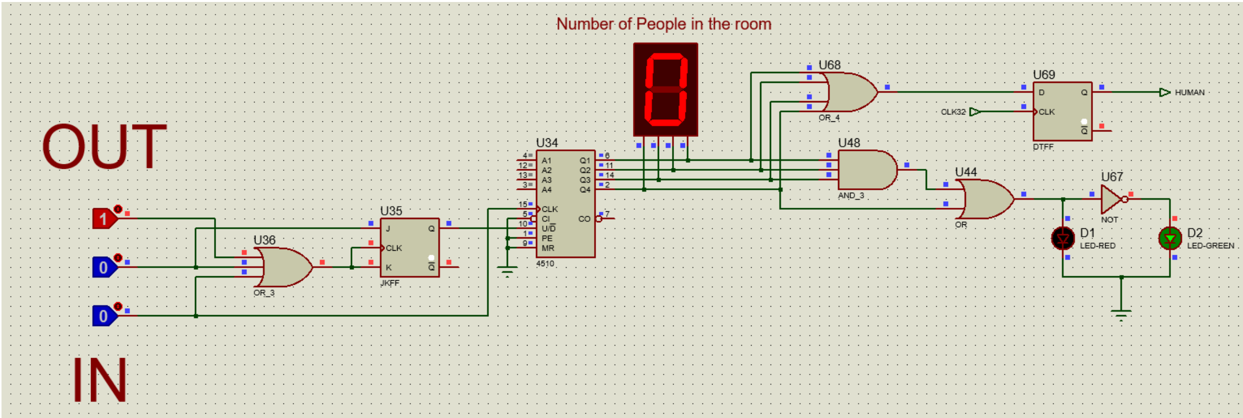


Fig: Person entering - Outermost sensor triggered

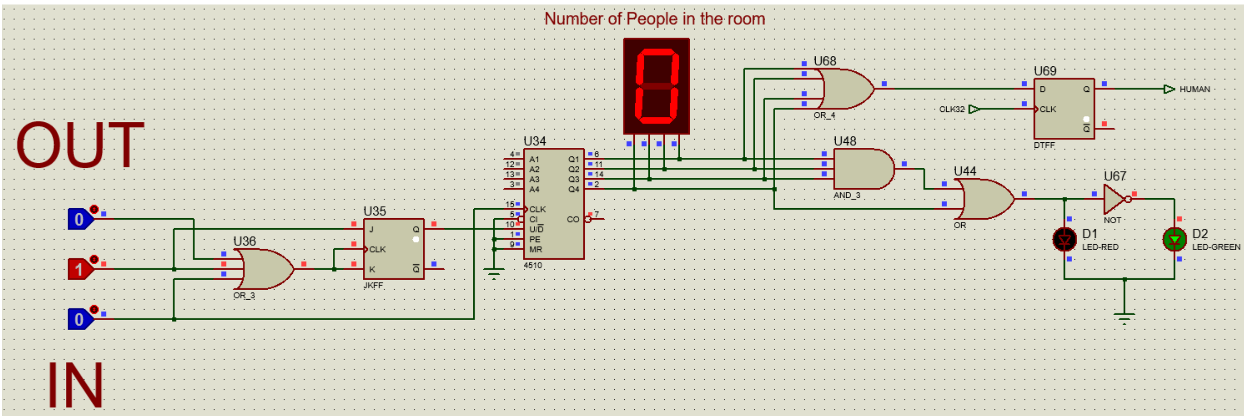


Fig: Person entering - Middle sensor triggered

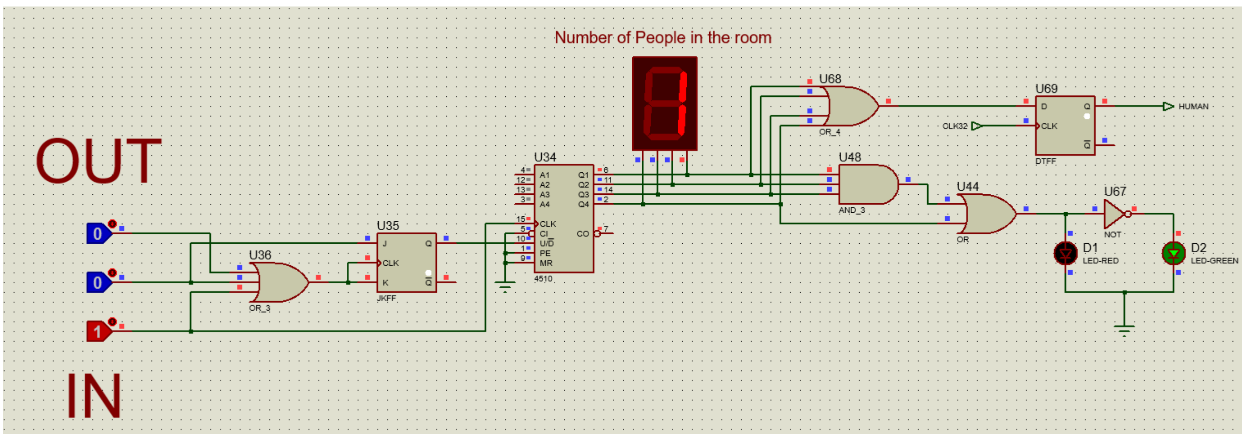


Fig: Person entering - Innermost sensor triggered

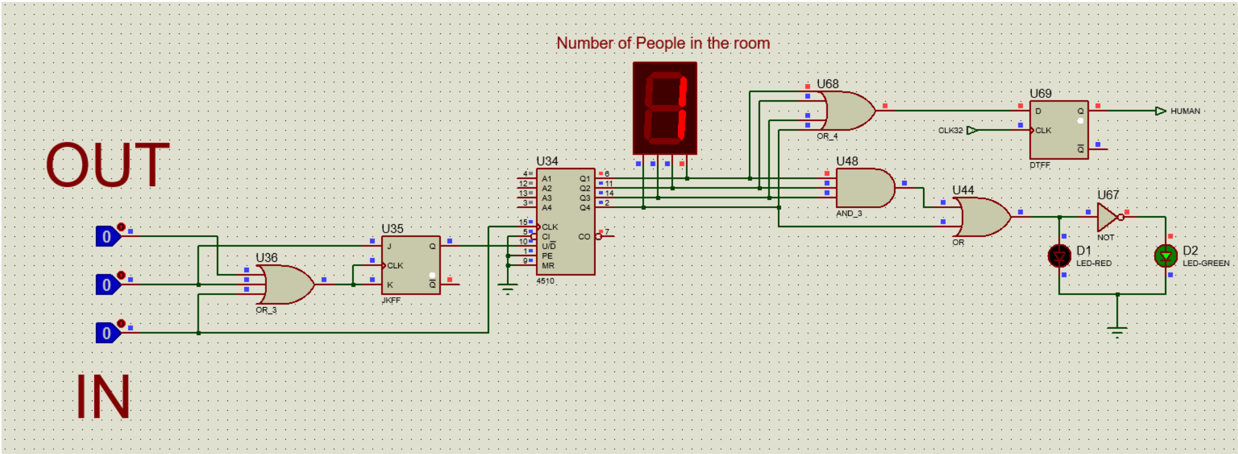


Fig: Person entered - Counter increases by one

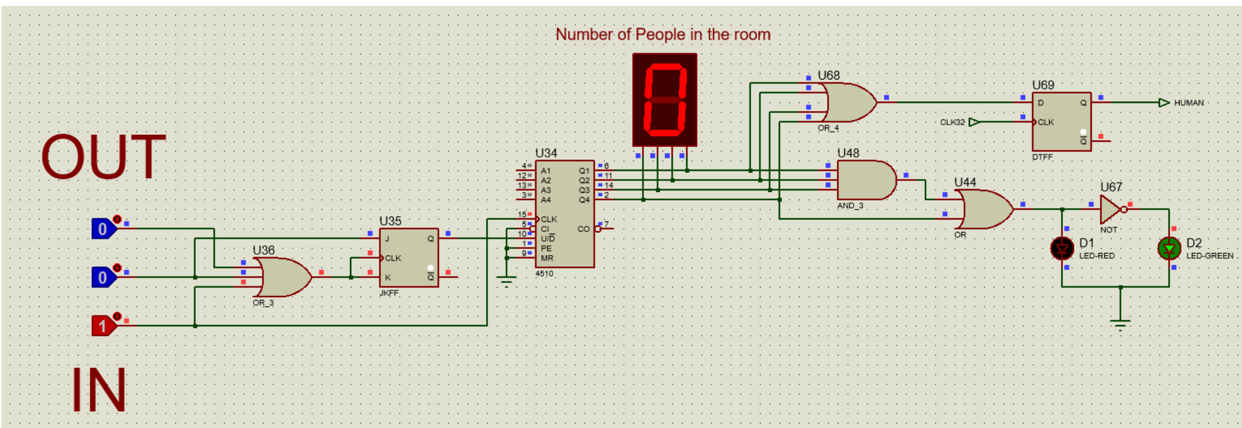


Fig: Person exiting - Innermost sensor triggered

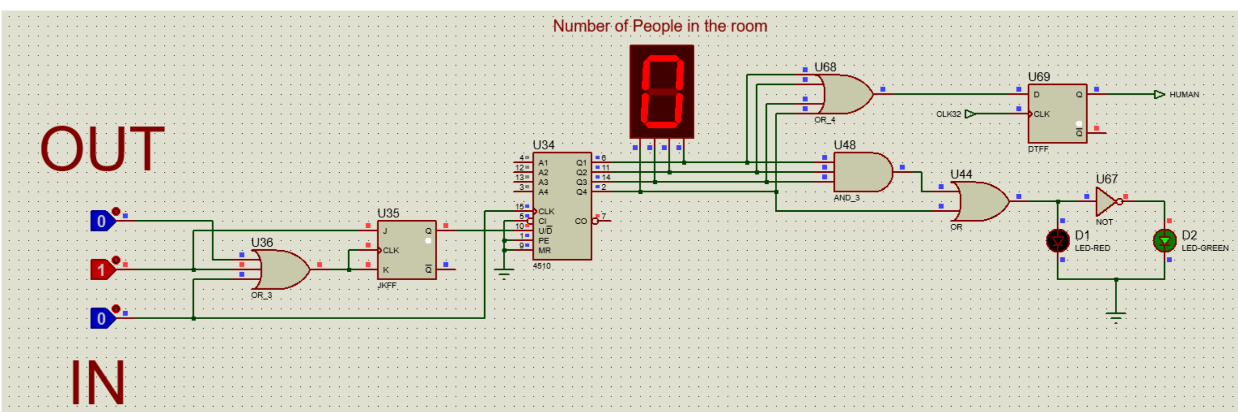


Fig: Person exiting - Middle sensor triggered

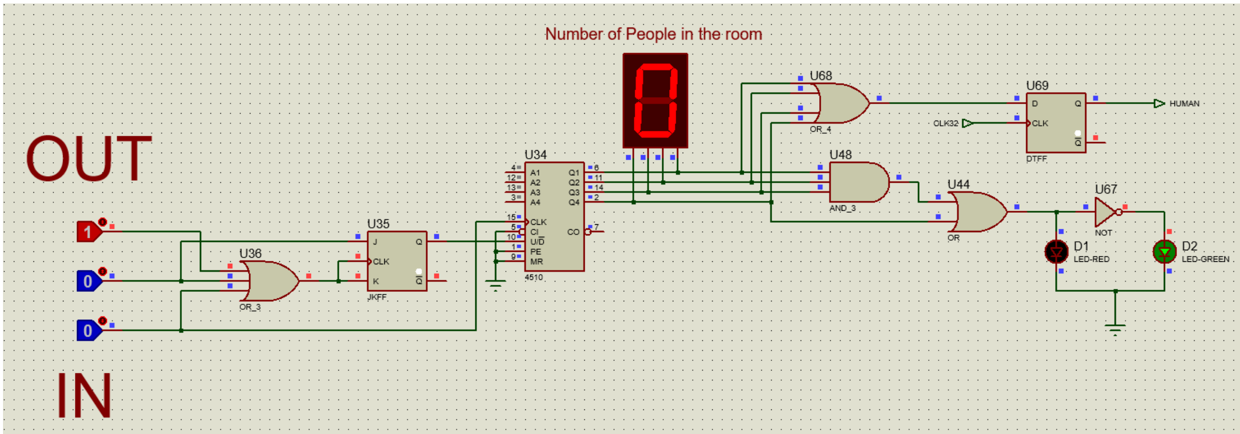


Fig: Person exiting - Outermost sensor triggered

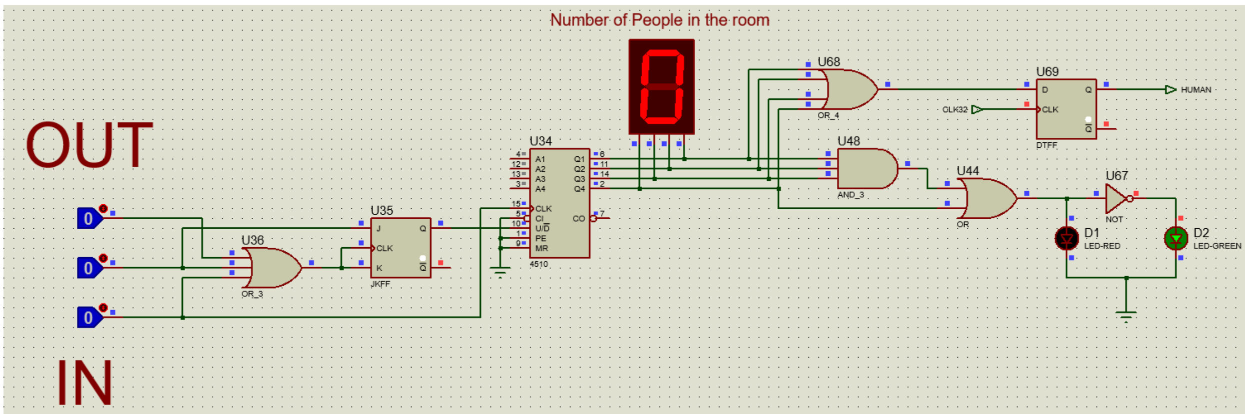


Fig: Person exited - Counter decreases by one

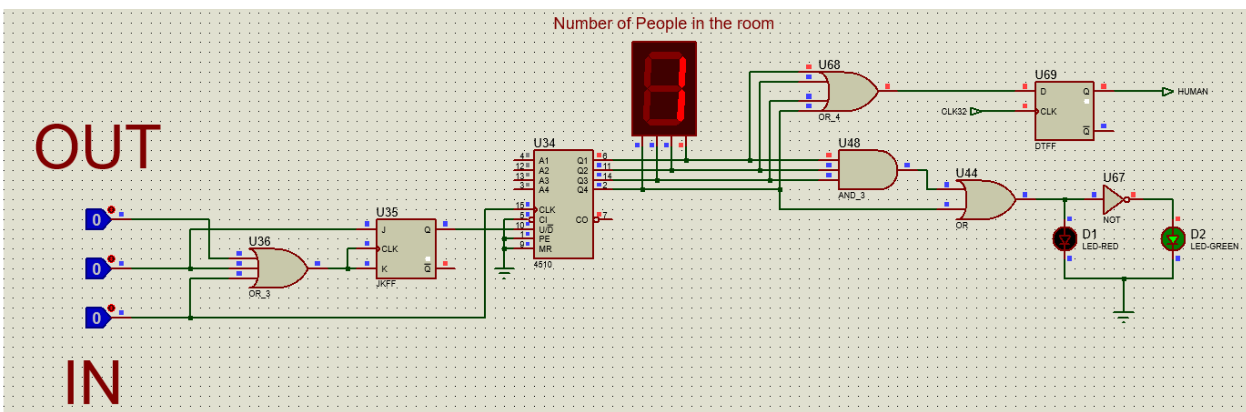


Fig: Room has space - Green light shown

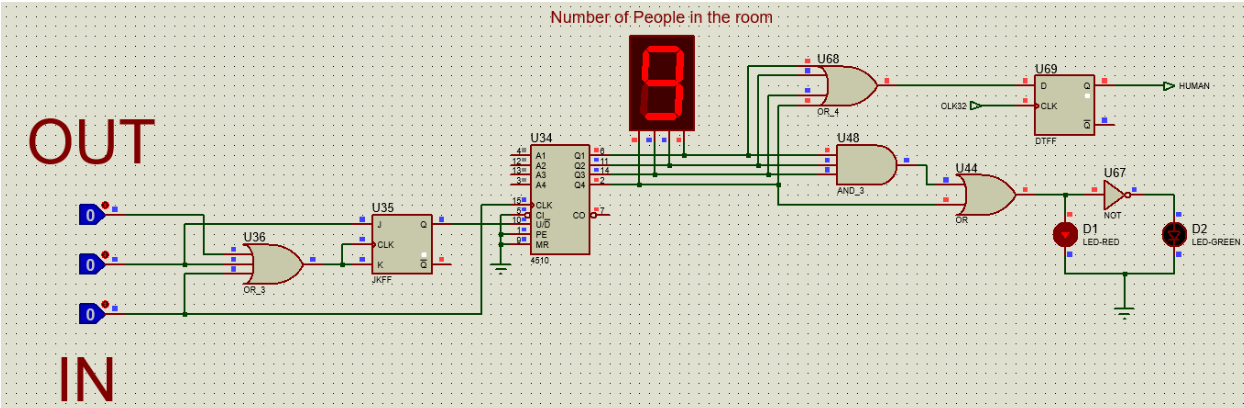


Fig: Room capacity exceeded - Red light shown

Temperature Sensor Circuit:

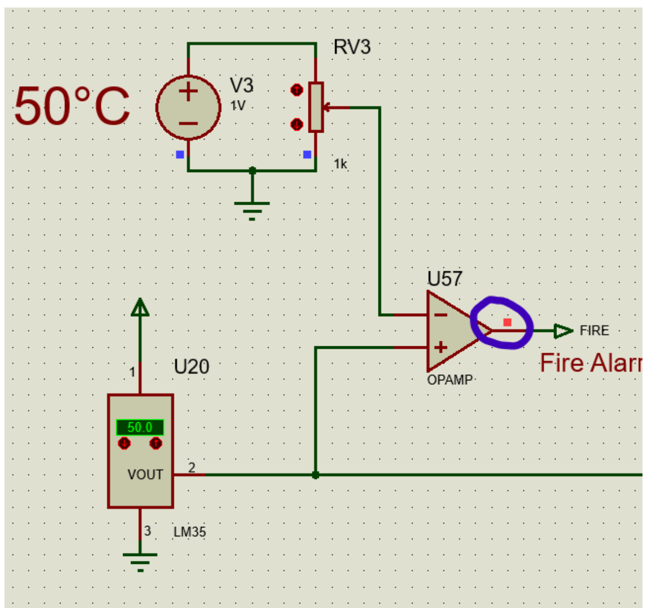


Fig: Temperature 50°C, FIRE trigger is HIGH

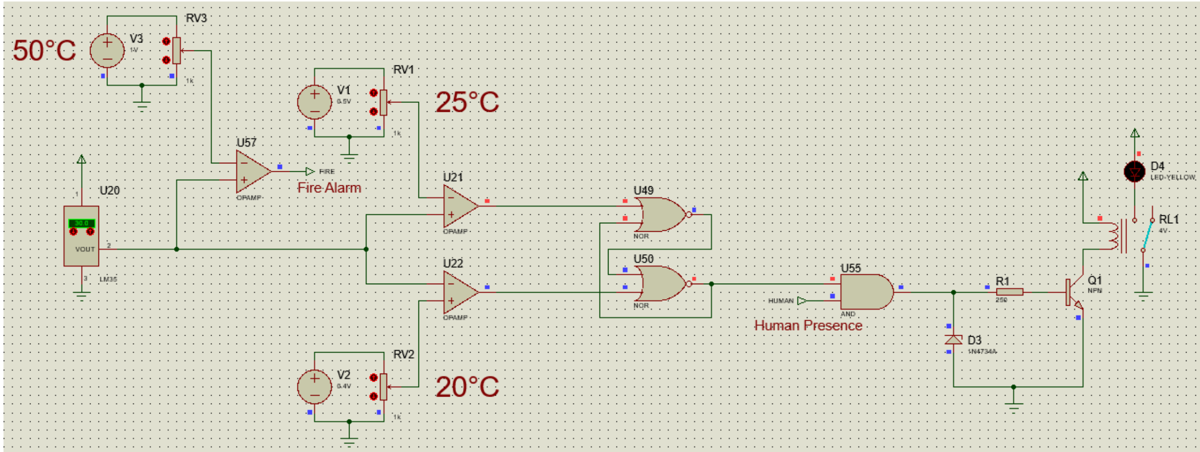


Fig: No human presence, relay is OFF

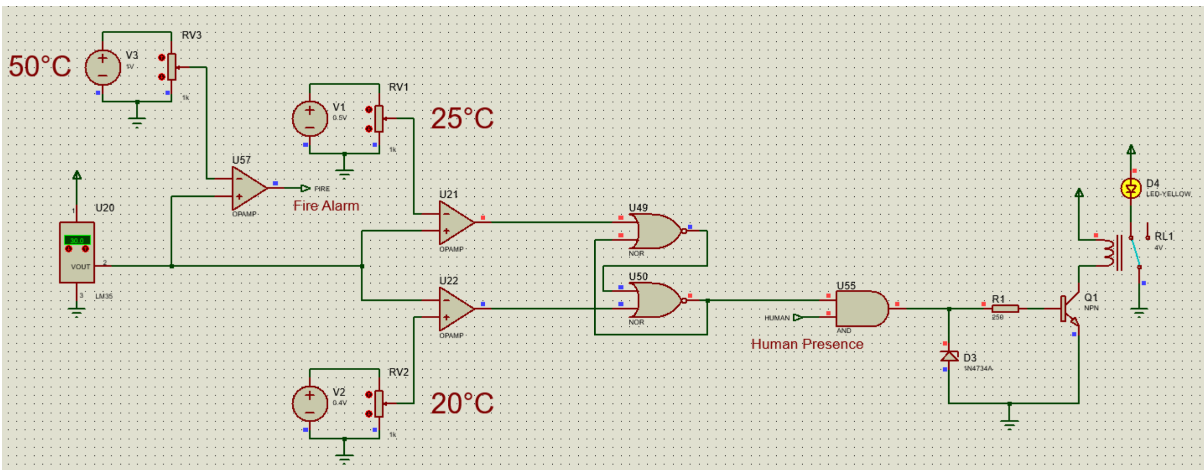


Fig: Human presence, temperature is 30°C, relay is ON

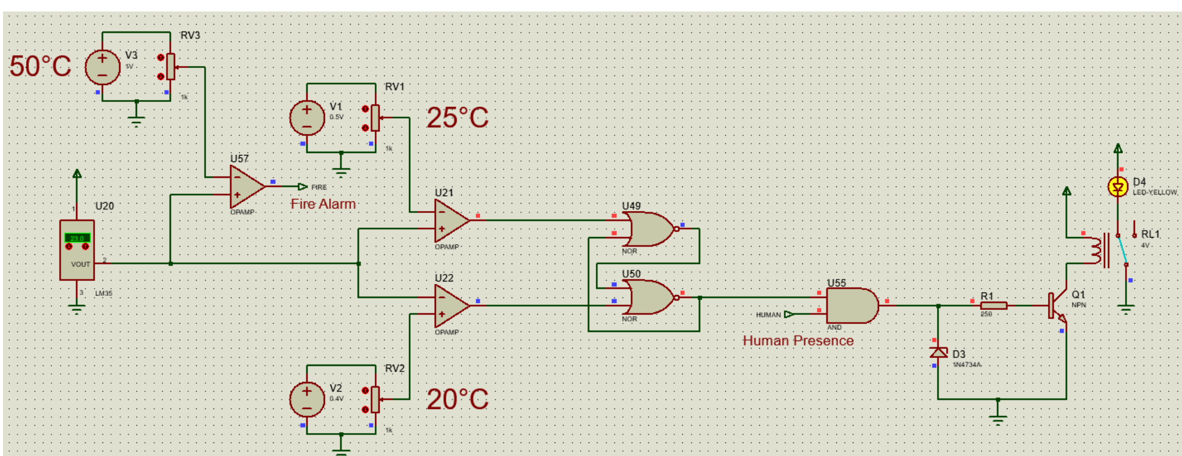


Fig: Human presence, room is cooling, temperature is 23°C, relay is still ON

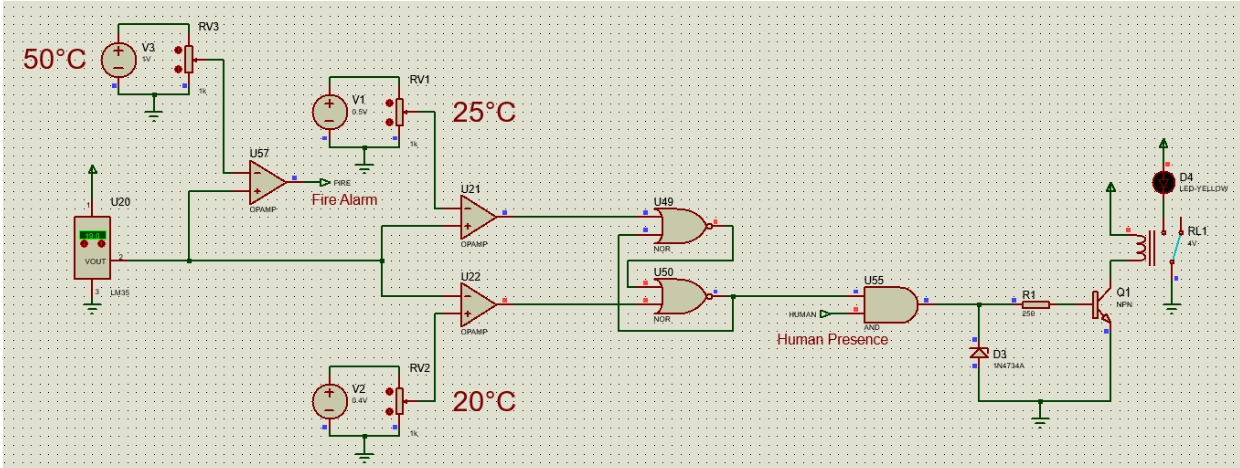


Fig: Human presence, room has cooled, temperature is 19°C, relay turned OFF

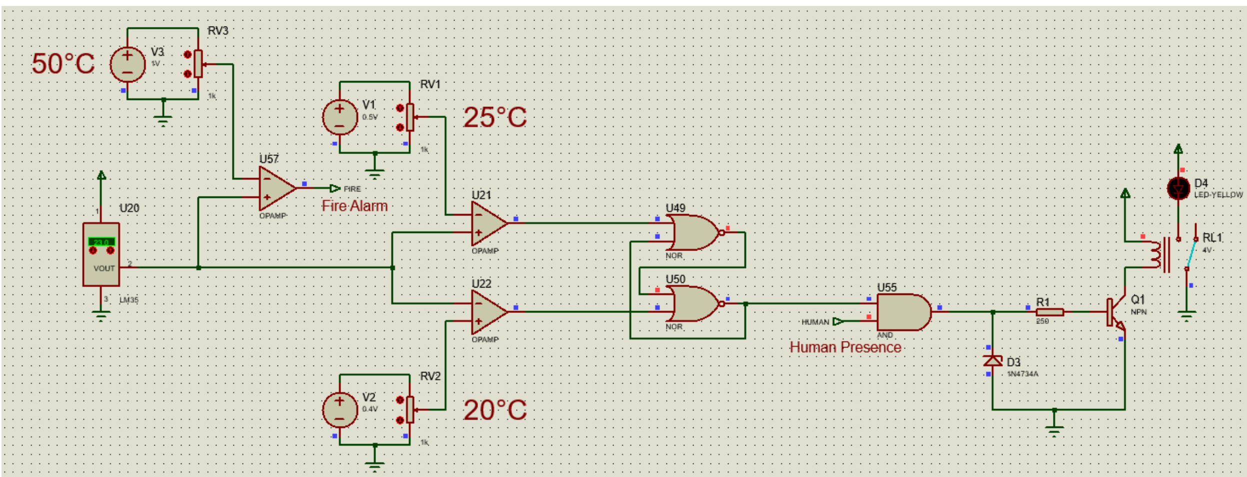


Fig: Human presence, room is heating up, temperature is 23°C, relay stays OFF

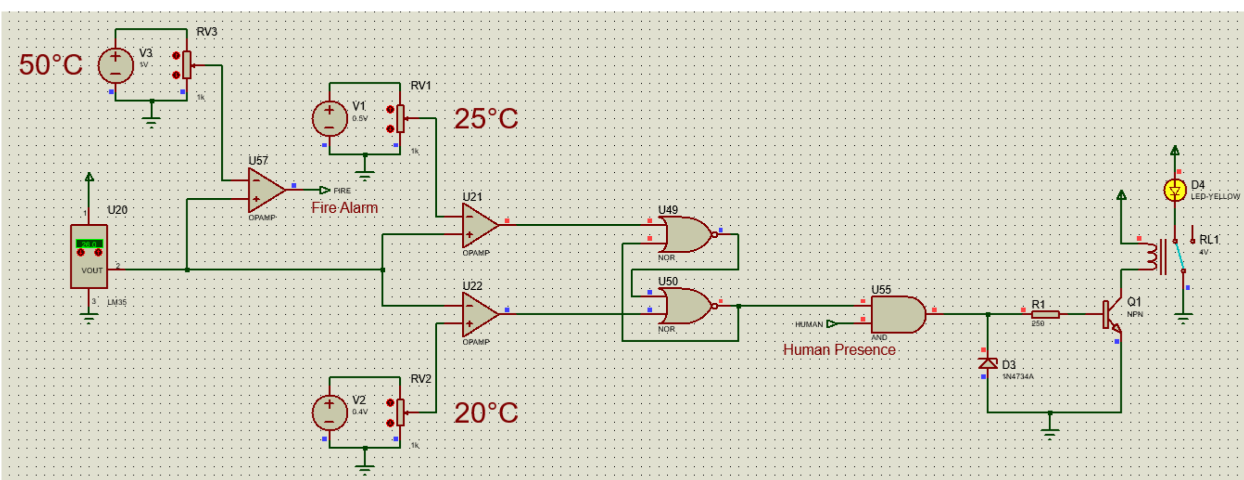


Fig: Human presence, room has heated up, temperature is 26°C, relay turned ON

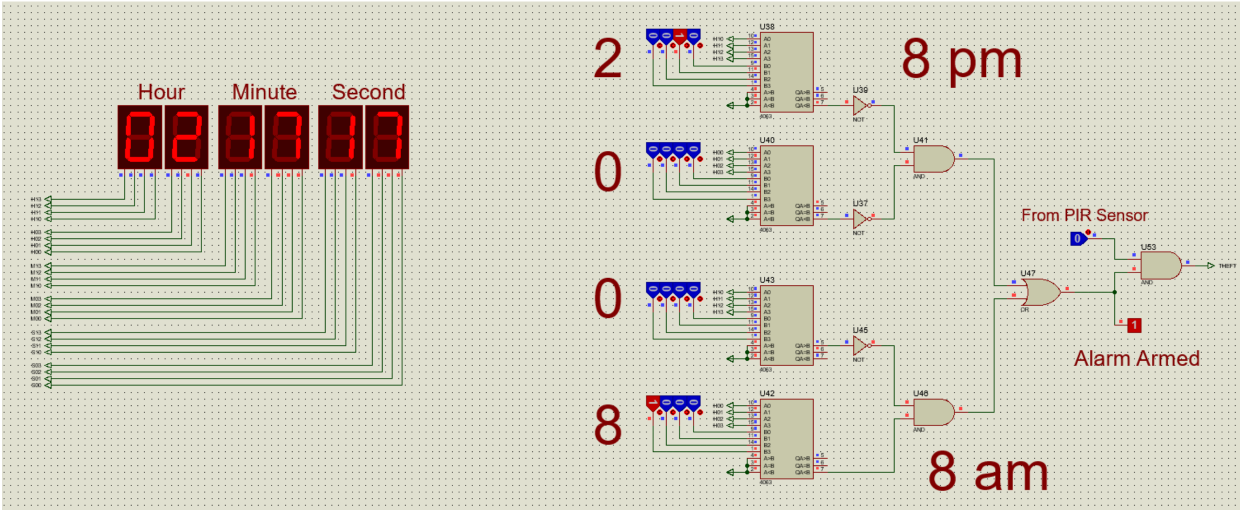


Fig: 2 am, Alarm armed

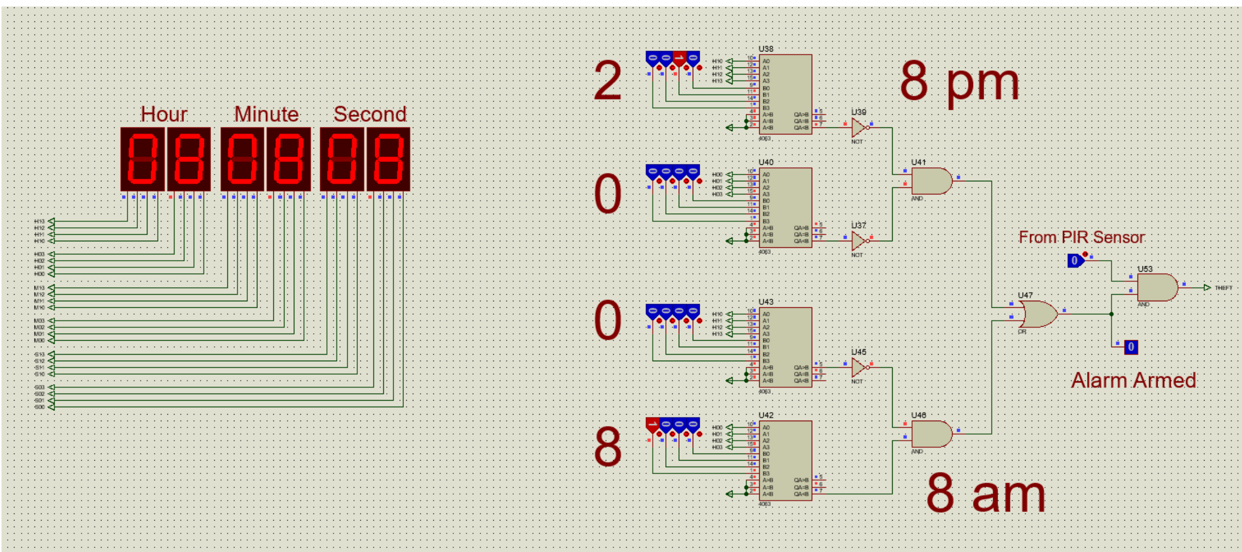


Fig: 8 am, Alarm disarmed

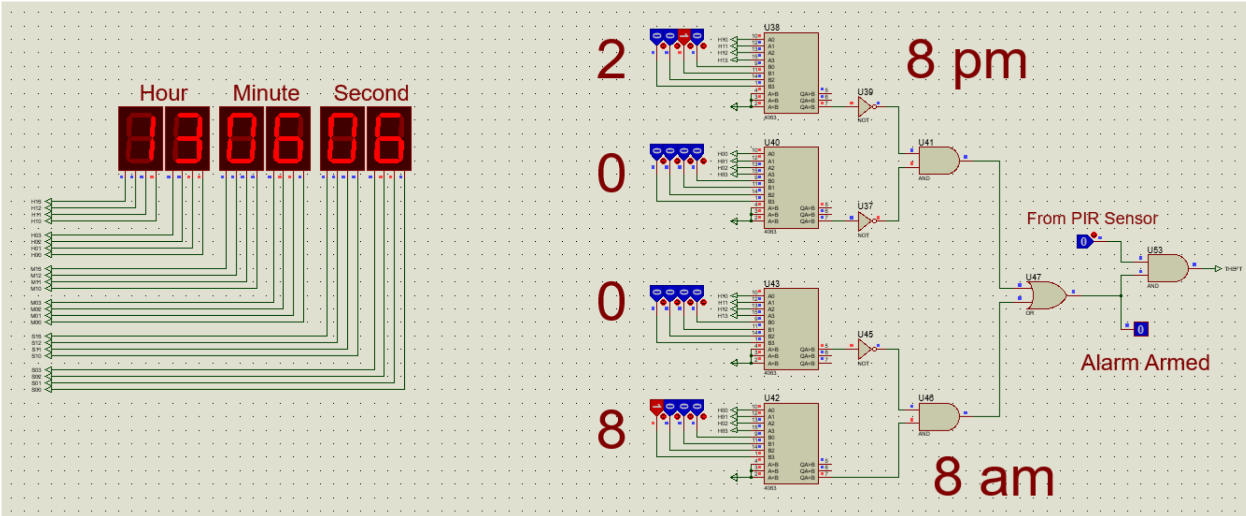


Fig: 1 pm, Alarm disarmed

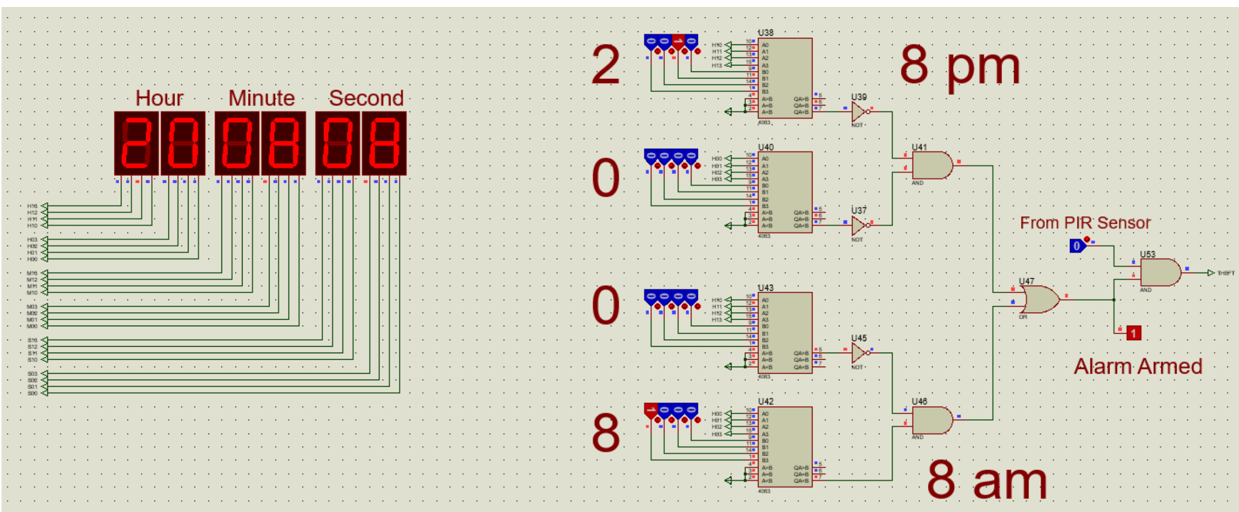


Fig: 8 pm, Alarm armed

Timed Session:

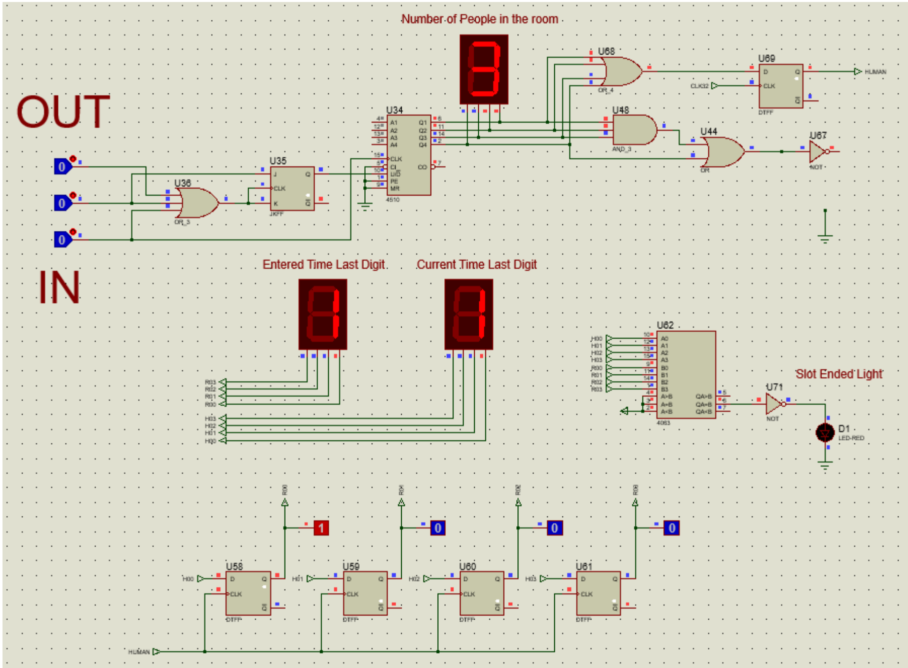


Fig: People in room, entrance time saved

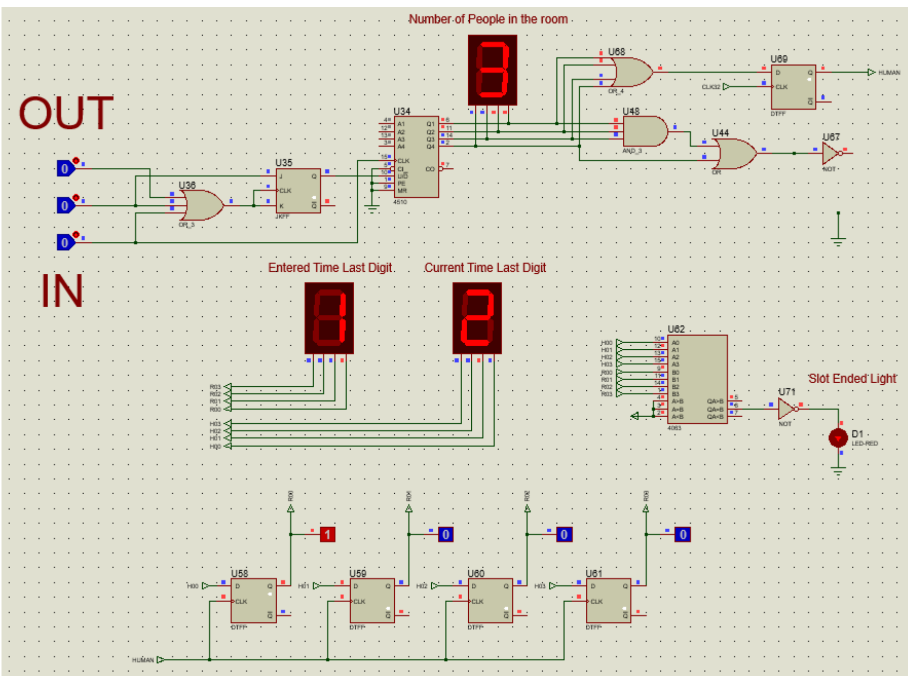


Fig: Slot has expired, light lit up to ask group to leave

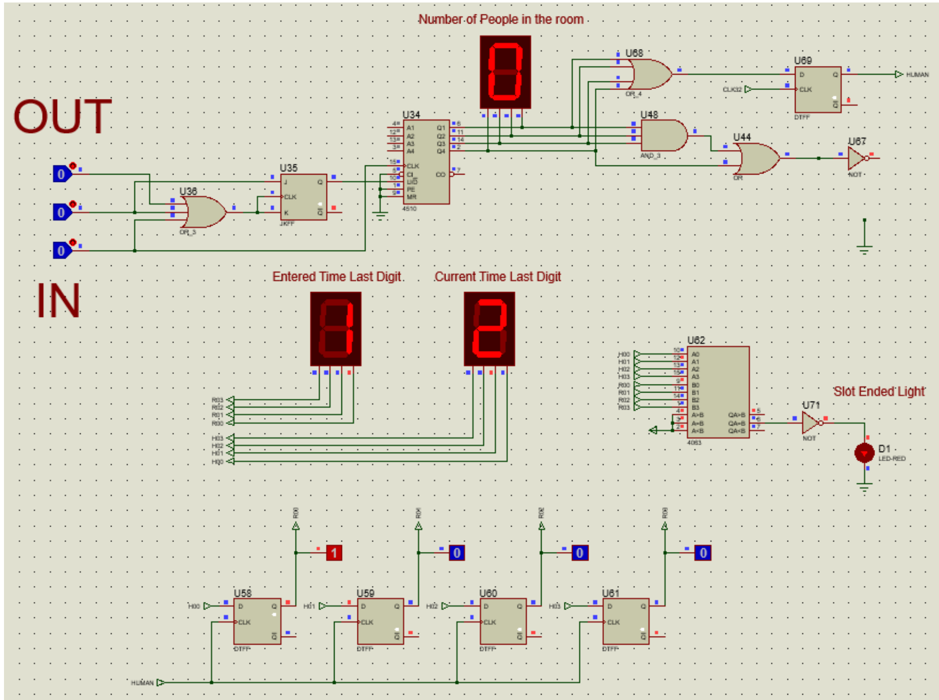


Fig: Room cleared

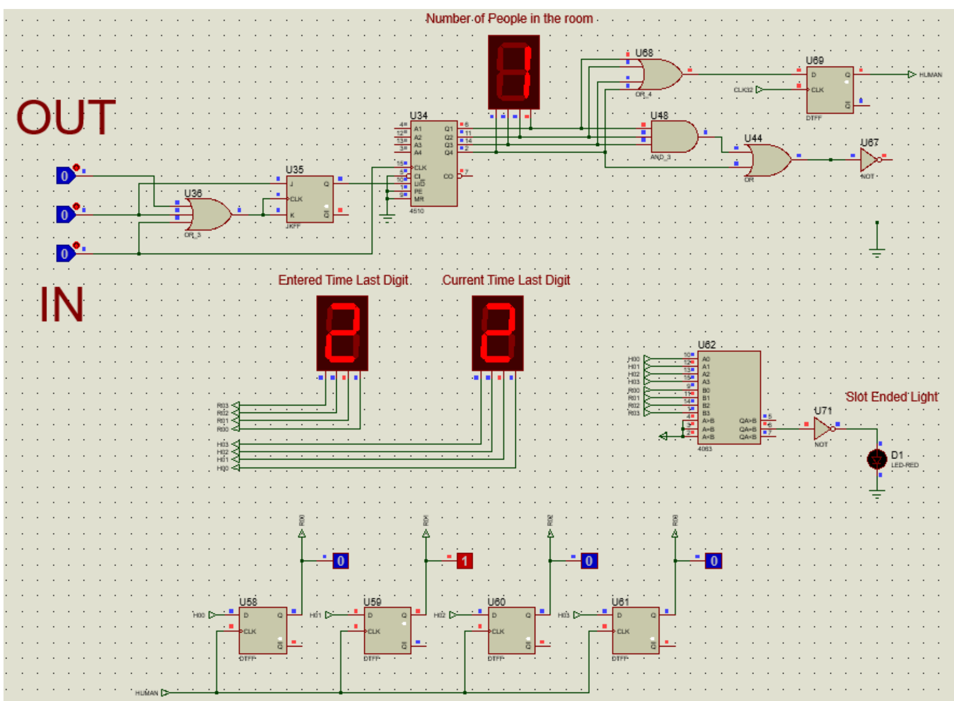


Fig: Next person enters, new time saved

<u>Alarm Circuit:</u>

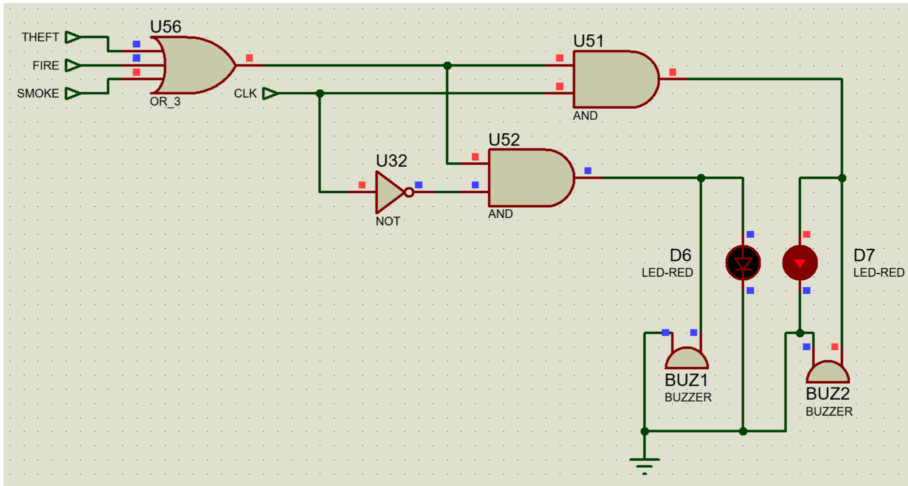


Fig: Smoke sensor triggered, alarm active

9. Impact

a. Efficient use of electricity since air conditioning and lights would turn off if the room is empty (environmental)

b. Prevention of fire and theft as it would detect fire or suspicious human presence and alert the authorities (safety)

c. Warns when a room is over crowded for proper social distancing and prevent the spread of COVID-19 (health)

d. Timed room usage sessions to help others get access to the room by alerting the people currently in the room to kindly exit as their designated time is over (societal)

10. Conclusion and Future Work

The 555 timer along with the T Flip Flops is able to generate an output of 64 Hz reasonably precisely. In future, it would be better to use a quartz crystal oscillator as it is much more accurate.

The clock circuit works as expected. The digits change in sync and the clock resets back at midnight after 24 hours. However, there is still a lot of room for improvement. The current circuit when powered on starts at 00:00:00 or midnight. It would be convenient to be able to load time into the counters to change the time.

Although the human counter is able to count the people entering and exiting a room, it cannot count in case a group of people enters together at once. All the IR sensors would remain active and the circuit would not work. Thus, improvement is essential in this area.

The fire and smoke alarm works as expected by sounding an alarm in case of an emergency. However, one improvement would be made where the alarm would have an automatic fire suppression system (such as water sprinklers) that would extinguish the fire.

11. Reference

https://www.electronics-tutorials.ws/waveforms/555-circuits-part-1.html

https://www.electrical4u.com/application-of-flip-flops/