P 2.1.6 "Smart" Heater

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Design Brief

Client:	Heaters INC.
Target consumer:	People who have household heaters and wish to replace them with a more economical alternative
Problem statement:	Current household heaters generally turn on whenever the temperature dips below a certain preset value or the people in the house manually turn it on. This is highly inefficient as it leads to an incredible amount of energy wastage.
Design statement:	To solve this problem, our team will create a prototype of a smart heater that makes use of multiple inputs to determine when to activate the device.
Constraints:	1. System must have at least 6 inputs 2. System must have a clear purpose and use
Deliverables:	● A gantt chart with individual logs detailing daily project contribution ● A working breadboard prototype and Multisim simulation of system to demonstrate to the client ● A final document in electronic form detailing design process and evaluation containing: ○ Input and output definitions ○ Truth table based on definitions and design specifications ○ Unsimplified and simplified logic expressions for system output ○ Estimated cost calculations

Design Definitions and Specifications

Inputs			Output
Variable	What It Stands For	Input Possibilities	0 → Heater will not turn on 1 → Heater will turn on .
P	Is the person home?	0 → no 1 → yes	
D	Is the temperature below 70 degrees in the building?	0 → no 1 → yes	
T	Is the current time in the peak energy time? *Peak energy time is the time frame when electricity is the most pricey, set by energy distributer companies	0 → no 1 → yes	
O	Is a window and/or door open?	0 → no 1 → yes	
H	Is it below 50% humidity in the building/room?	0 → no 1 → yes	
I	Has a person manually turned on the heater?	0 → no 1 → yes	

Truth Table

Since the prototype we created acts as a “smart” heater, it follows a certain set of conditions that determine whether or not it should turn on (output 1) based on the inputs it has been given. The input which we ranked as most important was the human input (I). If a person has manually turned on the heater, the heater will turn on regardless of the other inputs. Cases that would not allow the heater to turn on were a window/door being open (O), the person not being home (P), time of day being peak time (T), and being above 50% humidity (H). If a window/door was open or if the person wasn’t home, it doesn’t make sense to turn on the heater because the heat energy would just be lost or never used. The time of day matters because peak time, when energy is most demanded depending on the season, causes inefficiency in terms of cost and usage. The goal of the thermostat is to be a cost-efficient tool, so it will avoid peak time. Also for humidity (H), a room is most comfortable when it is around 50% humidity. Therefore, the smart heater wouldn’t make people feel uncomfortable by triggering a heat and humidity increase if its above this level. Lastly, the heater will only turn on if the actual temperature is below 70 degrees (D), otherwise a heater is not really needed.

With the way that we’ve created the conditions for the truth table, the heater only actually displays a high output one time in a case where there was no human input. While this is a rare occurrence, we believe that having the perfect combination of these variables is crucial for the heater to be truly “smart” and energy-efficient.

Pictures of Truth Table

Part of General Outputs

P	D	T	O	H	I	output
0	0	0	0	0	0	0
0	0	0	0	0	1	1
0	0	0	0	1	0	0
0	0	0	0	1	1	1
0	0	0	1	0	0	0
0	0	0	1	0	1	1
0	0	0	1	1	0	0
0	0	0	1	1	1	1
0	0	1	0	0	0	0
0	0	1	0	0	1	1
0	0	1	0	1	0	0
0	0	1	0	1	1	1
0	0	1	1	0	0	0
0	0	1	1	0	1	1
0	0	1	1	1	0	0
0	0	1	1	1	1	1
0	1	0	0	0	0	0
0	1	0	0	0	1	1
0	1	0	0	1	0	0

Special Case That Turns On Heater Without Human Input

1	1	0	0	0	1	1
1	1	0	0	1	0	1
1	1	0	0	1	1	1
1	1	0	1	0	0	0

Click here to access the full truth table.

Logic Expression

Unsimplified:

P'D'T'O'H'I + P'D'T'O'HI + P'D'T'OH'I + P'D'T'OHI + P'D'TO'H'I + P'D'TO'HI + P'D'TOH'I + P'D'TOHI + P'DT'O'H'I + P'DT'O'HI + P'DT'OH'I + P'DT'OHI + P'DTO'H'I + P'DTO'HI + P'DTOH'I + P'DTOHI + PD'T'O'H'I + P'DTOH'I' + PD'T'OH'I + PD'T'OHI + PD'TO'H'I + PD'TO'HI + PD'TOH'I + PD'TOHI + PDT'O'H'I + PDT'O'HI + PDT'OH'I + PDT'OHI + PDTO'H'I + PDTO'HI + PDTOH'I + PDTOHI

(H' + H)(P'D'T'O'I + P'D'T'OI + P'D'TO'I + P'D'TOI + P'DT'O'I + P'DT'OI + P'DTO'I + P'DTOI + PD'T'O'I + PD'T'OI + P'DT'OI' + PD'TOI + PDT'O'I + PDTO'I + PDTOI + PDT'OI) + PDT'O'HI'

P'D'T'O'I + P'D'T'OI + P'D'TO'I + P'D'TOI + P'DT'O'I + P'DT'OI + P'DTO'I + P'DTOI + PD'T'O'I + PD'T'OI + P'DT'OI' + PD'TOI + PDT'O'I + PDTO'I + PDTOI + PDT'OI + PDT'O'HI'

(O' + O)(P'D'T'I + P'D'TI + P'DT'I + P'DTI + PD'T'I + PD'TI + PDTI) + PDT'O'(I + HI') + PDT'OI

(O' + O)(P'D'T'I + P'D'TI + P'DT'I + P'DTI + PD'T'I + PD'TI + PDTI) + PDT'O'(I + H) + PDT'OI

(T' + T)(P'D'I + P'DI + PD'I) + PDTI + PDT'O'I + PDT'O'H + PDT'OI

(D' + D)(P'I) + PI(D' + DT) + PDT'I(O' + O) + PDT'O'H

P'I + PID' + PIT + PDT'I + PDT'O'H

I(P' + PT) + PI(D' +DT') + PDT'O'H

I(P' +T) + PI(D' + T') + PDT'O'H

IP' + IT + PID' + PIT' + PDT'O'H

I(P' +PD') + IT + PIT' + PDT'O'H

I(P' + D') + IT + PIT' + PDT'O'H

IP' + ID' + IT + PIT' + PDT'O'H

IP' + ID' + I(T + PT') + PDT'O'H

IP' + ID' + I(T + P) + PDT'O'H

IP' + ID' + IT + IP + PDT'O'H

$I(P' + P) + ID' + IT + PDT'O'H$

$I + ID' + IT + PDT'O'H$

$I(1 + D' + T) + PDT'O'H$

Simplified:

$I + PDT'O'H$

Final Solution Description

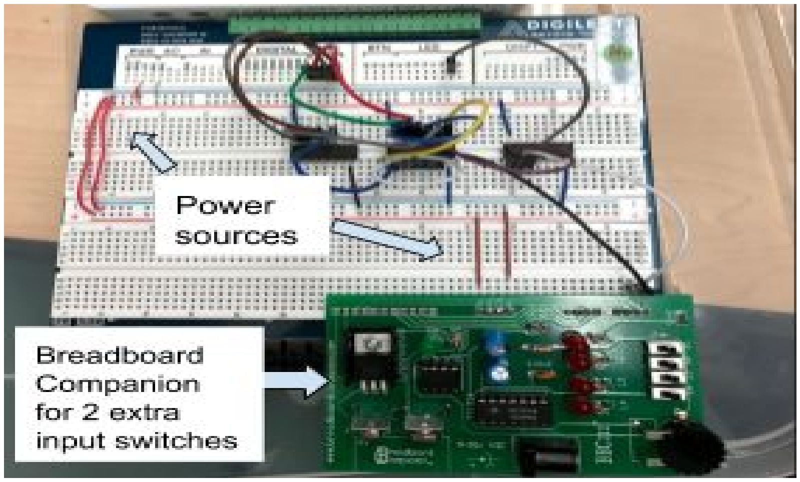
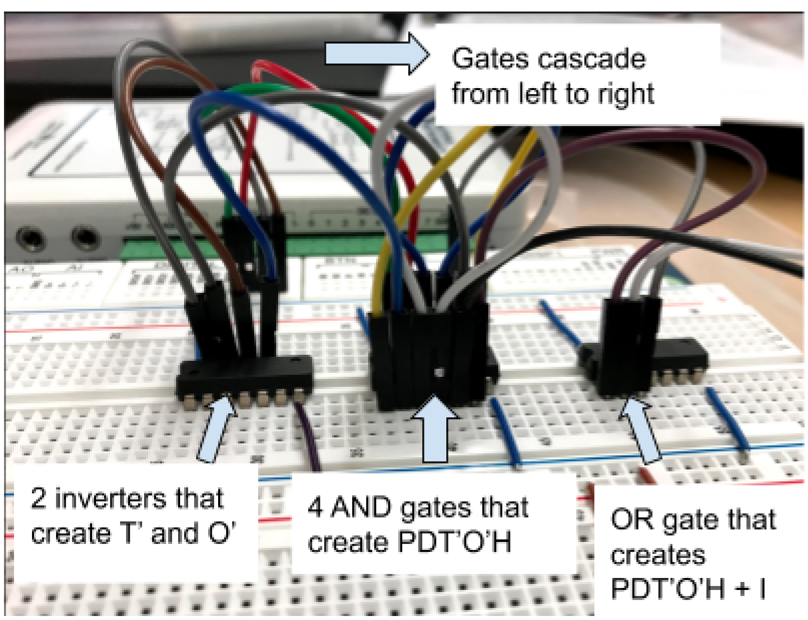
Ultimately, the goal of our “smart” heater is to be as efficient as possible. In general, it should refrain from turning on to save power. Thus, its two activation situations are any time the user requests, or when the person is home, the temperature in the room is below 70 degrees, the current time is not in the peak time frame for energy consumption, no windows or doors are open, and the humidity is below 50% (which could be quite often). To construct a prototype of this heater we needed three AOI logic gates (AND, OR, NOT), a breadboard, and jumper wires. For a more fleshed out prototype, we would require a thermometer and humidity sensor, a display for the user to see the current temperature in the room/building and whether or not the heater is on, and a button for them to manually activate the heater. The costs are detailed in the table below:

Cost Table	
Component	Price from Electronix Express
Breadboard	\$2.95
Jumper Wire Kit	\$5.50
74LS04 IC (Inverter)	\$0.45
74LS08 IC (And)	\$0.45
74LS32 IC (Or)	\$0.40
Thermometer and Humidity Sensor	\$42.95
LCD Display	\$8.95
Button	\$0.25

Thus the total price for constructing our prototype heater is \$61.90. If we are able to mass produce this “smart” heater, the production costs would be significantly reduced because we would be working with printed circuit boards. We would not be purchasing a breadboard, integrated circuits, or wires. Everything would be miniscule and implanted. In addition, electricity to power our device and the pathways would be provided by the owner of the building. So would pipelines for the air circulation system. Our “smart” heater would only replace the room/building’s current heater controls.

Final Breadboarded Circuit

Pictures of Final Breadboard Prototype

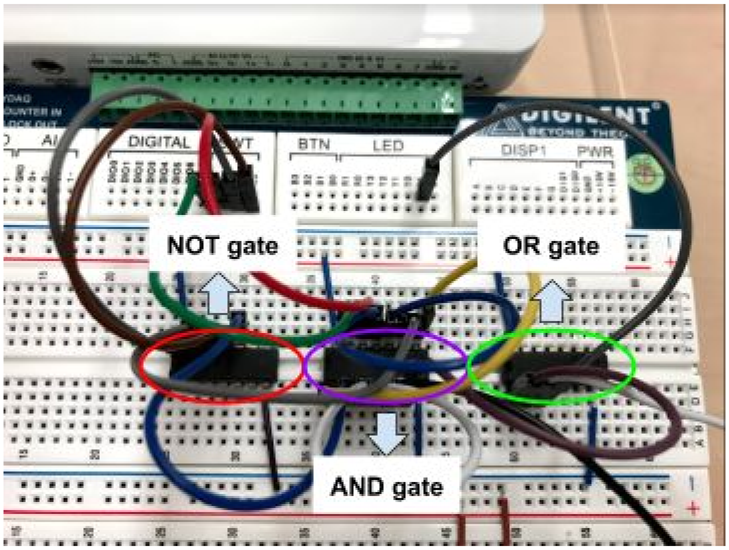
Top View

This picture shows the overall breadboard prototype that we built for our "smart" heater. It stretches across the breadboard and receives power from an external source. We connected a breadboard companion to the circuit because the existing board only had four switches. The two extra swtiches allowed us to make our board fully functionable and reflective of our desired design.
Specific Connections


Since we had five gates and two inverters in total, we had to use a 74LS04 (NOT gate), 74LS08 (AND gate), and 74LS32 (OR gate). Only one of each was required. These gates were cascaded to satisfy all of the requirements of the simplified logic expression. We cascaded them from left to right as shown in the picture.

Input Switches

This picture shows which of the six inputs corresponds to our switches. In order to create high or low signals for each input, the switch would just need to be moved. Their combinations affect the output as shown through an LED on the breadboard.

AOI Logic Gates

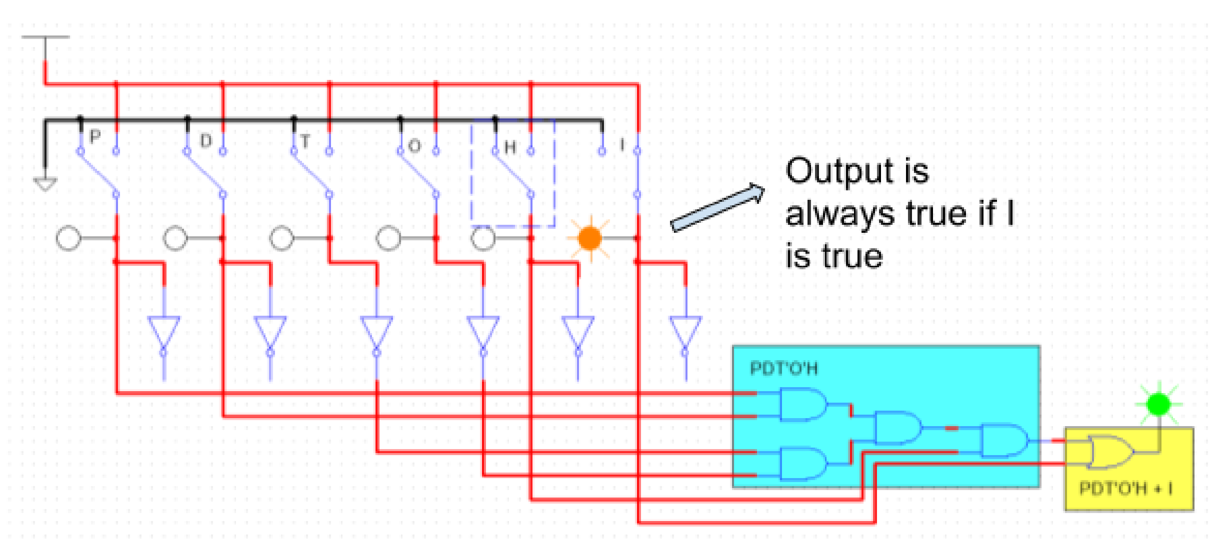


The three different AOI logic gates are shown here. This just shows where the specific gates were laid out in their corresponding positions.

Final Simulation

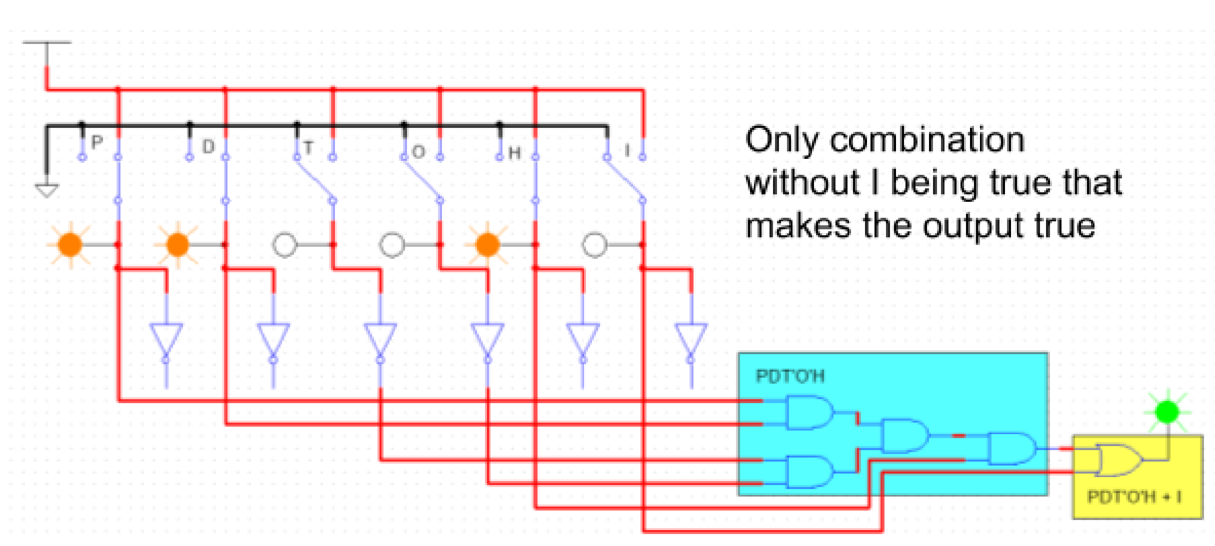
Pictures of Final Multisim Simulation

General Layout and Output



In any situation where the I switch is activated (whenever the user turns on the heater), the heater turns on.

Special Case Output



Whenever the person is home (P), the temperature in the room is below 70 degrees (D), the current time is not in the peak time frame for energy consumption (T’), no windows or doors are open (O’), and the humidity is below 50% (I).