Start and stop, heating buttons

For the start and stop buttons, I want the following behaviour:

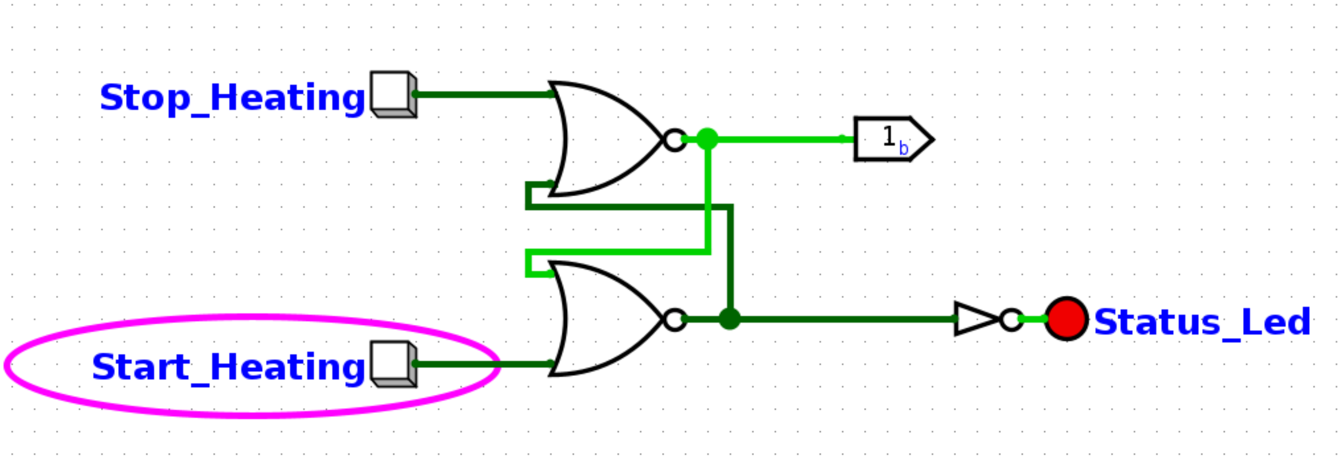
- Start is pressed and the output signal is set to high.
- The output signal stays high until stop is pressed.
  This behaviour can be achieved using a SR-Latch.

SR-Latch

Truth-table for SR-Latch

S	R	Q	Q'
0	0	Latch	Latch
0	1	0	1
1	0	1	0
1	1	0	0

Here is the logic of my SR-Latch. I used a NOR gate SR latch because it is set when the inputs go from low to high which fits nicely with buttons, and saves two NOT gates. When `Start_Heating` is pressed the bottom NOR gate output goes low, causing the top gate to output high which keeps the output of the bottom gate low creating a latch. The same mechanism happens when `Stop_Heating` is pressed but in the opposite direction.



Controlling the Temperature

The temperature is controlled with two buttons (increase and decrease) and has 11 different settings from 80-180 C. When the increase button is pressed the controller will count up from the current setting, and down when the decrease button is pressed.

Counting

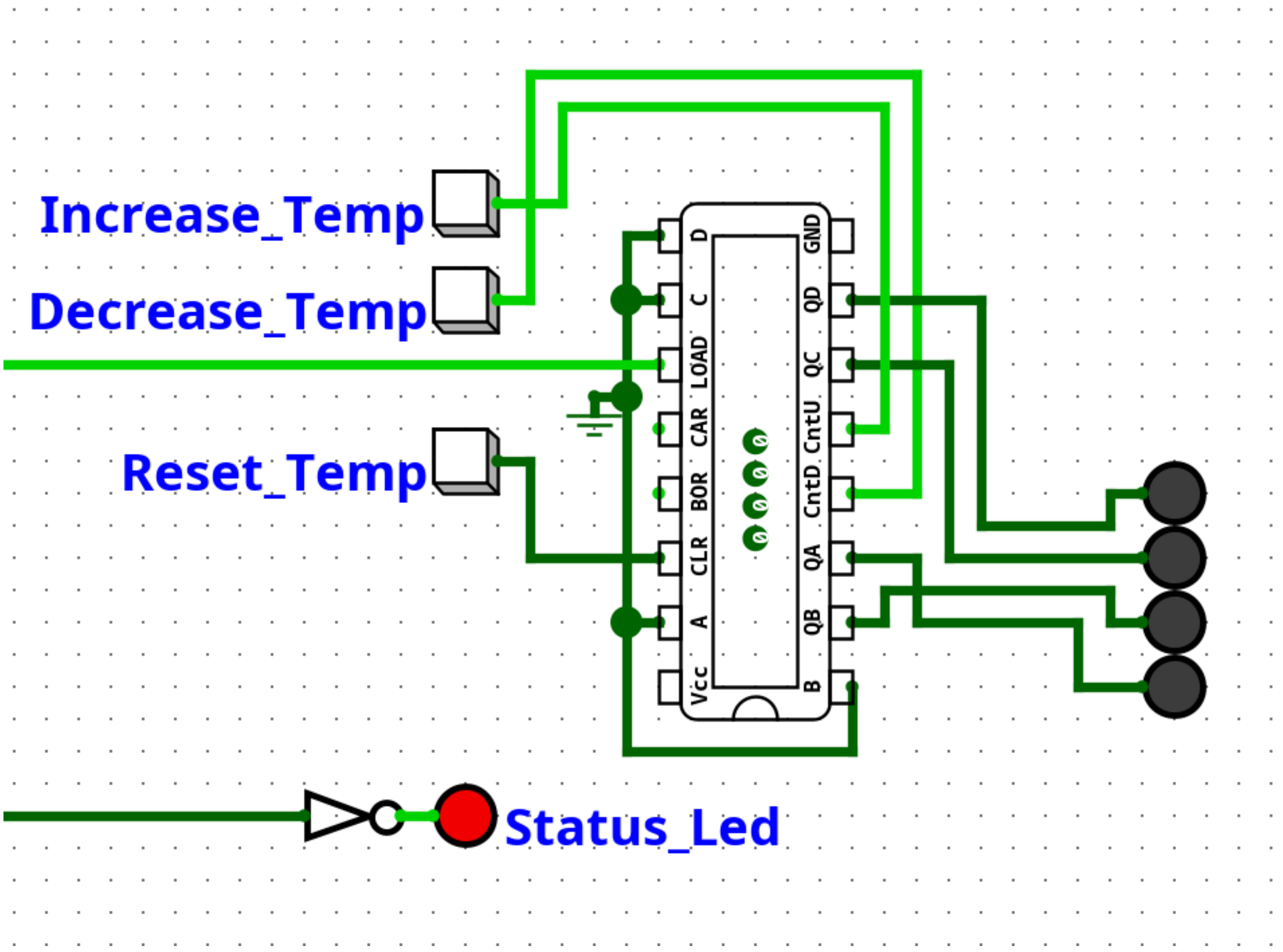
I will use a `74193` 4-bit up/down binary counter using the temperature control buttons to actuate a count up and down cycle.

The `74193` chip has the following pins:

- `CLR`: Active high, immediately clears the count to zero.
- `DATA`: A, B, C, D are input pins, the value of these will be loaded into the counter.
- `LOAD`: Active low, the value on the DATA inputs is loaded into the counter overriding counting.
- Count `CntU/CntD`: These pins count up and down. They activate on a low-to-high transition when the other pin is also set to high.
- `Q` Outputs: `QA`, `QB`, `QC`, `QD` 4 bit-binary output of the current count.
- `BORROW`: Output goes LOW when the counter underflows (e.g., counts down past 0).
- `CARRY`: Output goes LOW when the counter overflows (e.g., counts up past 15/F).

Using that information I wired the chip in Logisim as follows:

- I connected the load to the SR-Latch's output signal and all the inputs to ground. That way when `Stop_Heating` has been pressed 0 is loaded to all bits.
- I placed a button to clear the counter, for testing purposes. Note the controller design doesn't include a reset temp button, it could be a useful addition.
- For `Increase_Temp` and `Decrease_Temp` I inverted the buttons so they output high passively and low when pressed.



Displaying the Temperature

Now that the counter is implemented I need to convert the output of the counter into a signal for 6 `LED` s. This can be achieved with a decoder, specifically I will be using the ROM component. In a ROM is Read-Only Memory and I can use it to map the 4-bit counter value to the specific 6 signal pattern for that setting.
I chose a ROM because it is easy to setup for this exact kind of custom decoding.

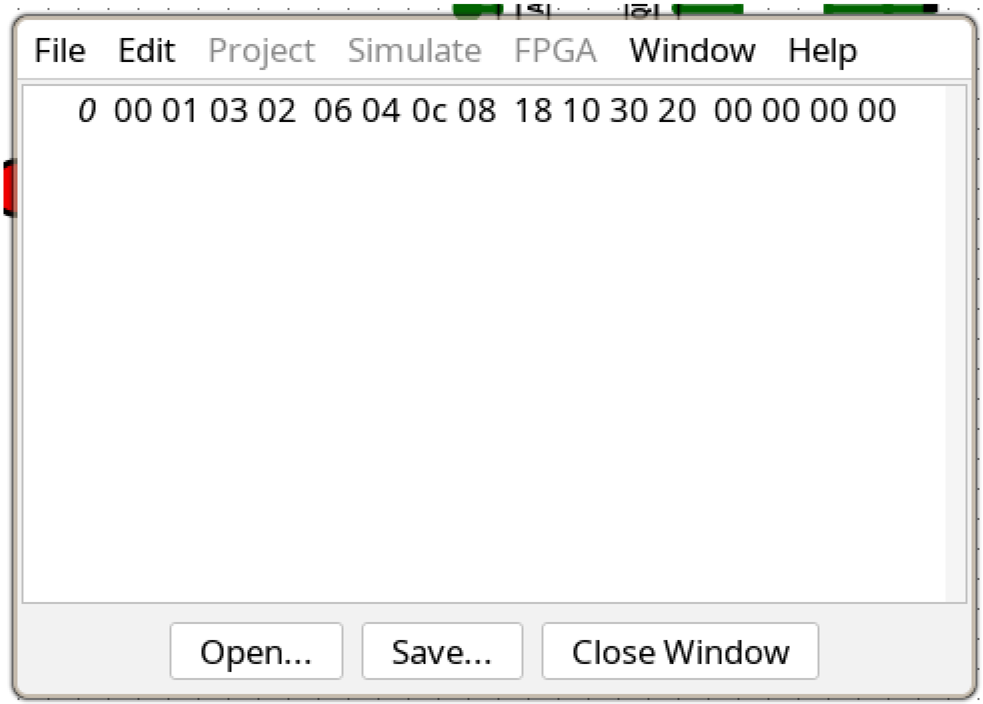
Setting up the ROM.

1. I set the address bit width to 4 and the data bit width to 6.
2. I used a splitter to combine the 4 outputs of the counter and hooked it up to the address input. To test if this was working I incremented the counter and the selected address on the ROM incremented each time.
3. I put another splitter on the output of the ROM to split the outputs into 6 lines for each LED. Now with the ROM wired I need to program the address table. Each address will output the hexadecimal number stored there in binary.

I came up with the following address table:

Addr	Data	Desc
0	000000	Off
1	000001	80C
2	000011	90C
3	000010	100C
4	000110	110C
5	000100	120C
6	001100	130C
7	001000	140C
8	011000	150C
9	010000	160C
10	110000	170C
11	100000	180C

Converting the binary data to hexadecimal I got the following address table in Logisim:



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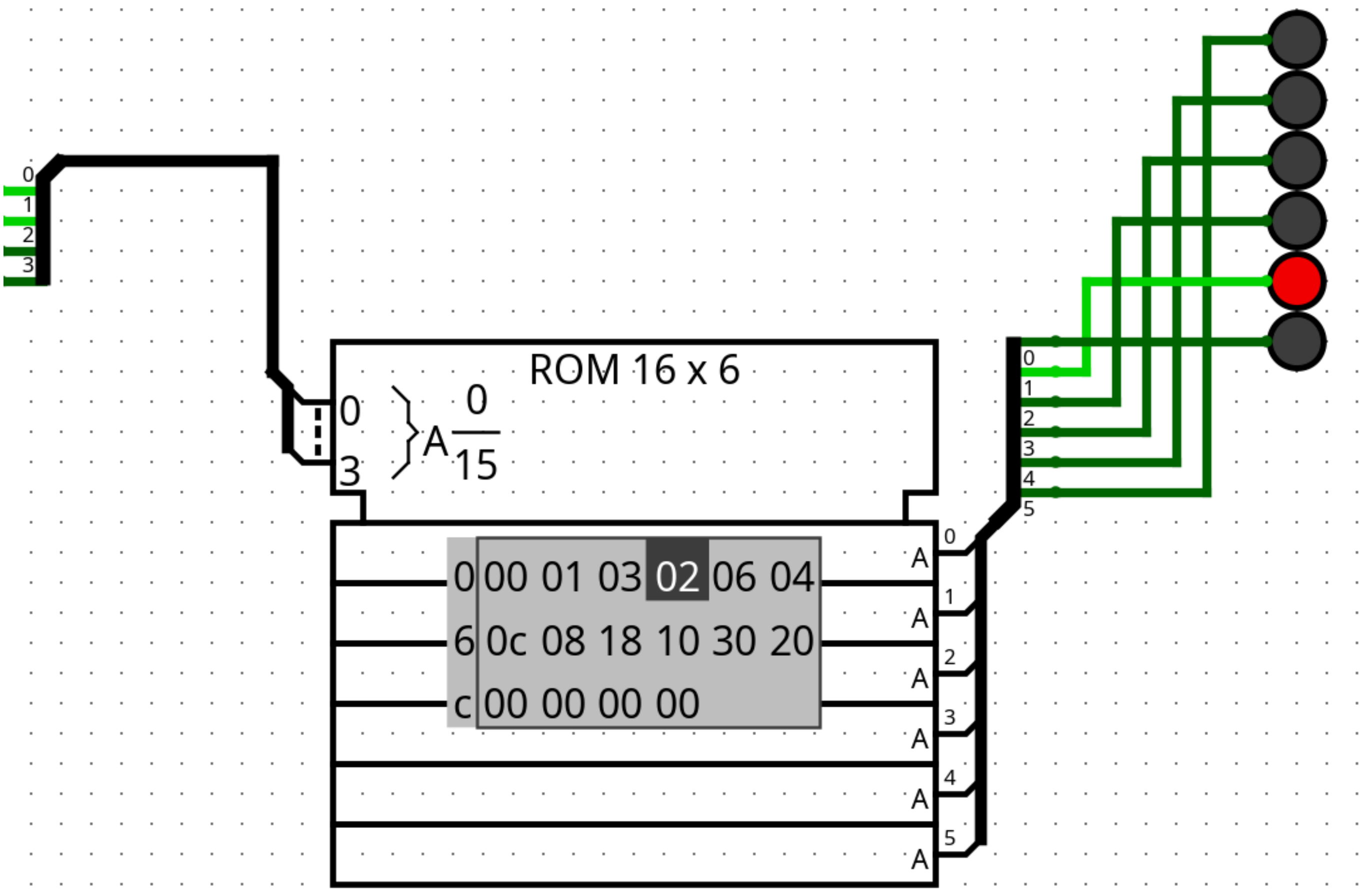
0  00 01 03 02  06 04 0c 08  18 10 30 20  00 00 00 00
```

Testing this address table produced the expected output and the `LED`s lit up in the correct pattern as the counter was incremented.



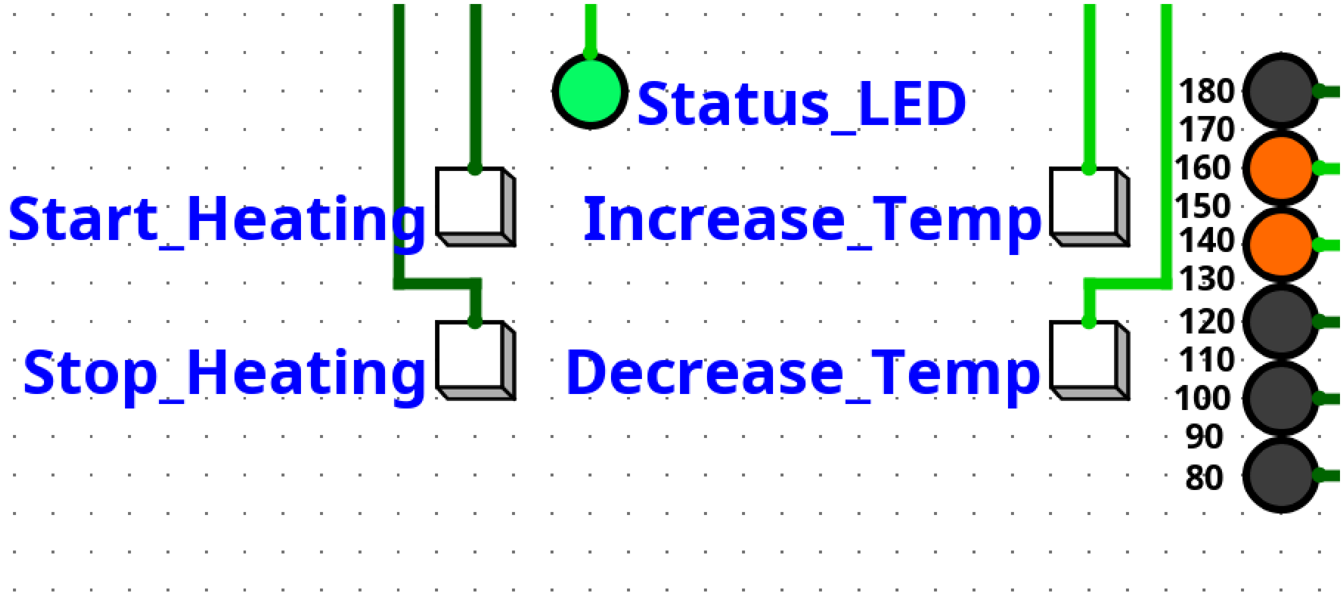
Handling overflow

Now that we have the counters signal converting to a signal for the `LED` display, theirs one problem that needs to be addressed. What should happen when the counter goes above the final temperature setting? I reckon once the highest temperature setting is gone beyond the counter should reset to 0.

I have come up with an elegant solution, that doesn't require any new components. To solve this problem I set the output of the ROM to a width of 7 bits and hooked the 7th bit into the counter's `CLR` pin. Then in the 13th entry of the address table I set the value `0x40` which means that once the counter increments past the last temperature setting the 7th output bit will actuate the `CLR` pin in the counter resetting it.
Note: Decrementing the counter below zero won't set the temperature to high, it will instead address the last 3 empty entries before hitting `0x40` and going back to zero. This gives the controller a shortcut to cutting off heating while not letting the user go straight to full heat going back the other way.

Finishing Up

Now that all the controls are implemented I moved the controls and display to an easily accessed location.


Status_LED
Start_Heating
Increase_Temp
Stop_Heating
Decrease_Temp
180
170
160
150
140
130
120
110
100
90
80