

Re: Could someone please explain how this works?

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*Source:* <http://sci.tech--archive.net/Archive/sci.electronics.basics/2007-06/msg00990.html>

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- *From:* Eric R Snow <[etpm@xxxxxxxxxxxx](mailto:etpm@xxxxxxxxxxxx)>
  - *Date:* Wed, 27 Jun 2007 16:49:53 -0700
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On Mon, 25 Jun 2007 16:15:29 -0500, John Fields  
<[johnfields@xxxxxxxxxxxxxxxxxxxxxxxx](mailto:johnfields@xxxxxxxxxxxxxxxxxxxxxxxx)> wrote:

On Sun, 24 Jun 2007 13:54:17 -0700, Eric R Snow <[etpm@xxxxxxxxxxxx](mailto:etpm@xxxxxxxxxxxx)>  
wrote:

Greetings All,  
This link:  
[http://www.vellemanusa.com/downloads/0/manual\\_mk138.pdf](http://www.vellemanusa.com/downloads/0/manual_mk138.pdf)  
is the schematic for a thermostat kit I built. Even though it works I  
don't understand how it works. The high temperature limit is too low  
for what I want to use it for. But I think that using less resistance  
for R5 will raise the upper temperature limit. Am I right?

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Yes.  
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And if I am, why?  
Thank You,  
Eric

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Why...?

IC1 is an LM324, which is four low power operational amplifiers, one  
of which (IC1C) is being used as a non-inverting buffer for the 5.1V  
reference being generated by ZD1 and R1, and another (IC1D) as a  
voltage comparator. IC1B and IC1C aren't being used and are wired  
to force all inputs and outputs to zero volts.

SK1 is used to connect the DC supply to the circuit, and D2 is used  
to provide protection in case the supply is connected backwards, in

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which case D2 will be reverse biased, cutting off the supply of current to the circuit and preventing IC1 from being destroyed.

C4 is used as a reservoir capacitor and serves to help remove ripple from the input DC.

The LM324 draws about 2mA, worst case, per opamp, for a total of 8mA.

The relay has a 360 ohm coil so, subtracting the drop across D2 and VCE(sat) of T1 from the 12V supply it draws about:

$$I = \frac{E - V_{D2} - V_{CE(sat)}}{R} = \frac{12V - (0.7V + 0.1V)}{360\Omega} \sim 31mA$$

D1 draws:

$$I = \frac{(+V) - V_{zk}}{R1} = \frac{11.3V - 5.1V}{1000\Omega} \sim 6mA$$

Finally, IC1D supplies about:

$$I = \frac{(+V) - 2V}{R3} = \frac{11.3V - 2V}{10k\Omega} \sim 1mA$$

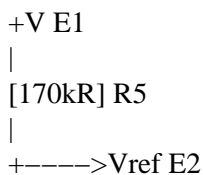
The total current needed, then, would be about 46mA with the relay closed and the ripple across C4 would be:

$$V = \frac{I \cdot dt}{C} = \frac{4.6E-2A * 8.3E-3s}{1.0E-4F} \sim 3.82 \text{ volts}$$

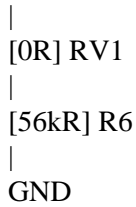
That's assuming a 12V peak, 60Hz full-wave rectified sine wave into D2, so a previously filtered 12VDC supply would make the ripple essentially nonexistent.

Looking at the divider comprising R5 RV1 R6, you have two limits:

A. When RV1 is at zero ohms, the reference voltage into IC1-13 will be:

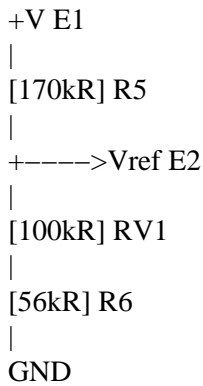


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$$E1 * (RV1 + R6) \frac{11.3V * (0R + 5.6E4R)}{R5 + RV1 + R6} = \frac{1.7E5R + 0R + 5.6E4R}{1.7E5R + 0R + 5.6E4R} = 2.8V, \text{ and:}$$

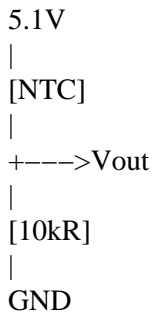
B. When RV1 is set to the maximum resistance, the reference voltage into IC1-13 will be:



and E2 will be:

$$E1 * (RV1 + R6) \frac{11.3V * (1.0E5R + 5.6E4R)}{R5 + RV1 + R6} = \frac{1.7E5R + 1.0E5R + 5.6E4R}{1.7E5R + 1.0E5R + 5.6E4R} = 5.41V$$

Since the circuit is using an NTC (Negative Temperature Coefficient) thermistor as a sensor, the thermistor's resistance will decrease as its temperature increases, and since it's connected like this:



Vout will increase as temperature increases.

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Now, since the output of the thermistor is connected to the – input of the comparator, the output of the comparator will go high and the relay will be energized whenever the voltage corresponding to the temperature the thermistor is sensing drops \_below\_ the voltage on the comparator.

Conversely, When the output voltage from the sensor rises to a voltage higher than the voltage on the + input of the comparator the comparator's output will go low and the relay will be de-energized.

If you need the upper temp trip of your circuit to be increased, then you need to either make the voltage from the sensor lower or the voltage from the reference divider into the comparator's + input higher at that temperature.

In order to lower the voltage from the sensor, the value of R4 could be decreased. However, that's not a good idea because it might increase the self-heating of the thermistor, leading to erroneous switching of the comparator.

That leaves fiddling with the reference divider, and in order to increase the voltage into the + input of the comparator R5 can be made smaller or R6 can be made larger, both at the expense of raising the lower temp limit.

A better way would be to determine what you wanted the upper and lower temp limits to be and then to choose R5 and R6 (while keeping the 100k pot in place) in order to meet those criteria.

If you have the R/T specs for the thermistor or a manufacturer and part number and can get the data, then you can do it like this:

Assume your temp limits are 0C and 100C and you want to use a YSI P/N 44016:

[http://www.ysitemperature.com/techdocs/R\\_vs\\_T%20std%20part.xls](http://www.ysitemperature.com/techdocs/R_vs_T%20std%20part.xls)

with a 10k ohm resistance at 25C, you'll have 678.5 ohms at 100C and 32660 ohms at 0C, so for 100C you'll have:

```
5.1V E1
|
[678.5R] R1
|
+----> E2
|
[10kR] R2
|
GND
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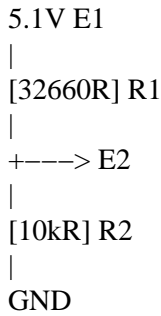
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Then, solving for E2:

$$E2 = \frac{E1 R2}{R1 + R2} = \frac{5.1V * 10kR}{678.5R + 10kR} = 4.776V$$

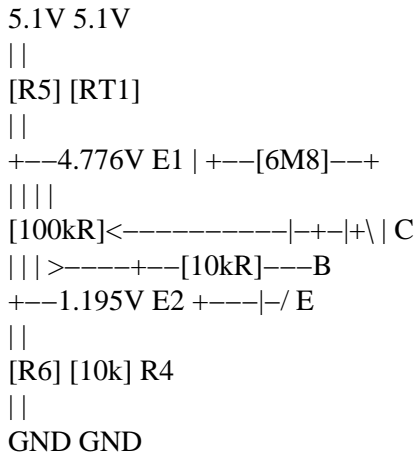
Likewise, for 0C:



Then, solving for E2:

$$E2 = \frac{E1 R2}{R1 + R2} = \frac{5.1V * 10kR}{32660R + 10kR} = 1.195V$$

Now what you have to do is to set up your reference divider so that with the pot cranked to one end the voltage into IC1-12 is 1.195V, and with it cranked to the other end the voltage is 4.776V, like this:



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In order to do that, you can calculate the current through the pot:

$$E1 - E2 = 4.776V - 1.195V$$

$$I = \frac{E1 - E2}{R} = \frac{3.581V}{100k\Omega} \sim 3.58E-5A \sim 36\mu A$$

Since the current in a series circuit is everywhere the same, and the drop across R6 needs to be 1.195V, then:

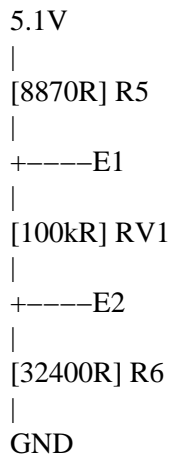
$$R6 = \frac{E2}{I} = \frac{1.195V}{3.6E-5A} = 33194.4 \text{ ohms}$$

The closest standard 1% resistor smaller than 33194 is 32400 ohms, so let's use that to start off with.

Now, since the same current is in R5, we can say:

$$R5 = \frac{5.1V - 4.776V}{3.6E-5A} = 9000 \text{ ohms}$$

The closest standard 1% resistor smaller than 9000 ohms is 8870 ohms, so our divider now looks like this:



Checking:

$$I = \frac{E}{R_t} = \frac{5.1V}{8870R + 100kR + 32400R} = 36.1\mu A$$

So:

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$$E2 = I_t * R6 = 3.61E-5A * 3.24E4R = 1.17 \text{ volts}$$

and:

$$E1 = I_t * (R6 + RV1) = 4.78 \text{ volts}$$

E1 is off, but not by a lot and it can be fixed by diddling with the values of R5 and R6, but there's another issue which hasn't been dealt with yet, and that's the resistance tolerance of the pot.

Most pots are +/- 10%, so in order to make sure that the desired voltage range can be accommodated by cranking the pot between its limits, the calculations should be made with RV1 equal to 90k. That way, if it's actually more than that the voltage range will always be within the range of the pot if enough leeway is given by the end resistors the rest of the circuit tolerances are paid attention to.

Thank You Jamie, John and John,

All of your answers helped me to understand what's going on. And John Field's lengthy explanation was really helpful. Thanks especially for taking the time to write it all.

Cheers,

Eric R Snow

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