Solid-State Temperature Sensors

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INTRODUCTION

The TC620/621 are solid-state temperature sensors that are easy to program and interface with control equipment. The TC620 senses the temperature internally, and the TC621 uses an external thermistor. Figure 1 shows how the devices are connected.

The data sheet for the TC620/621 describes how to calculate the correct resistance value for any desired temperature. It also gives a graphical depiction of the outputs for varying temperatures.

Since the TC620 senses temperatures internally, its outputs must be limited to 1mA. The device can source or sink higher currents, but internal self-heating may cause errors in the temperature sensing. The TC621 can source or sink 10mA since it uses an external thermistor to sense a remote temperature, and internal heating will not affect the temperature sensing accuracy.

Figure 2 is a schematic of a heating and cooling controller using a single TC620 and a TC4469 Quad CMOS Driver. In this example, the TC620 is programmed for maximum and minimum temperature set points with a hysteresis of 5°.

INPUT SECTION

Typically, a heating/cooling thermostat has a wide enough temperature range to allow heating and cooling from 45°F to 85°F (7°C to 29°C). The calculations that follow show how this range was incorporated into the design. The TC620 programming inputs have a resistance to temperature ratio of approximately 782Ω per °C.

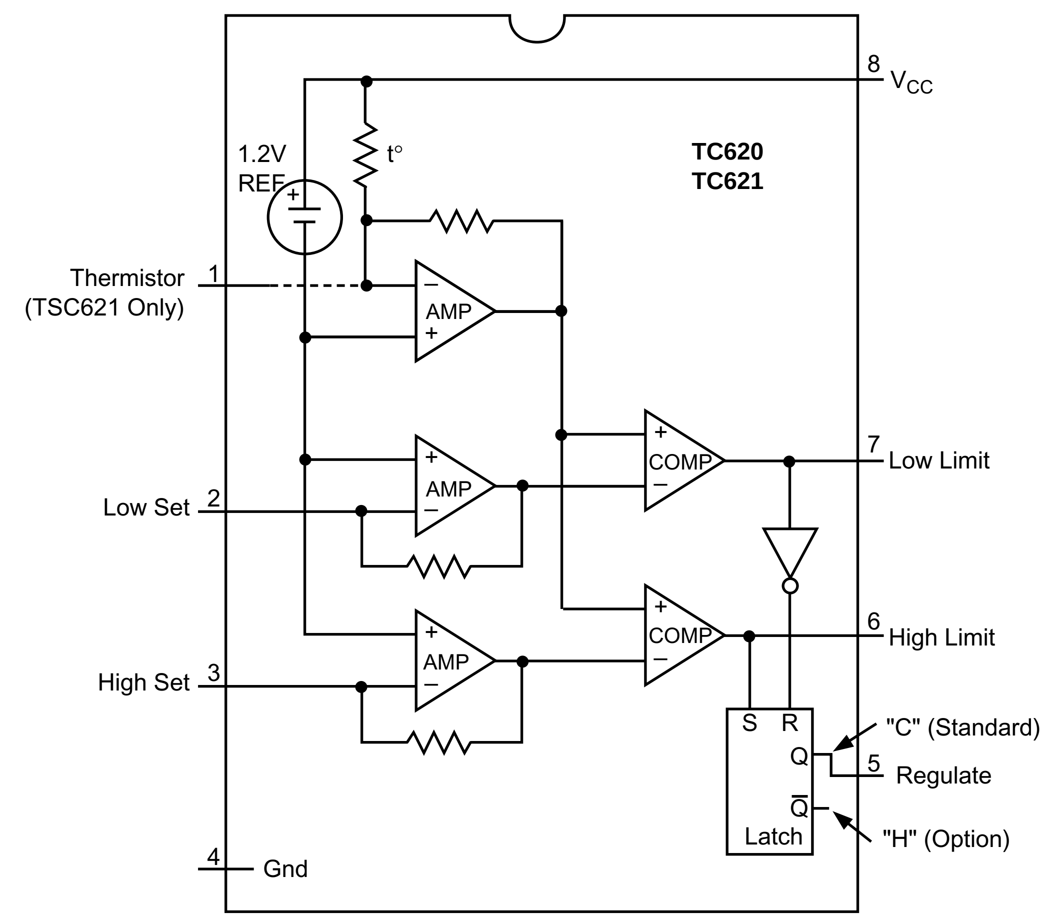

FIGURE 1: *TC620/621 block diagram.*

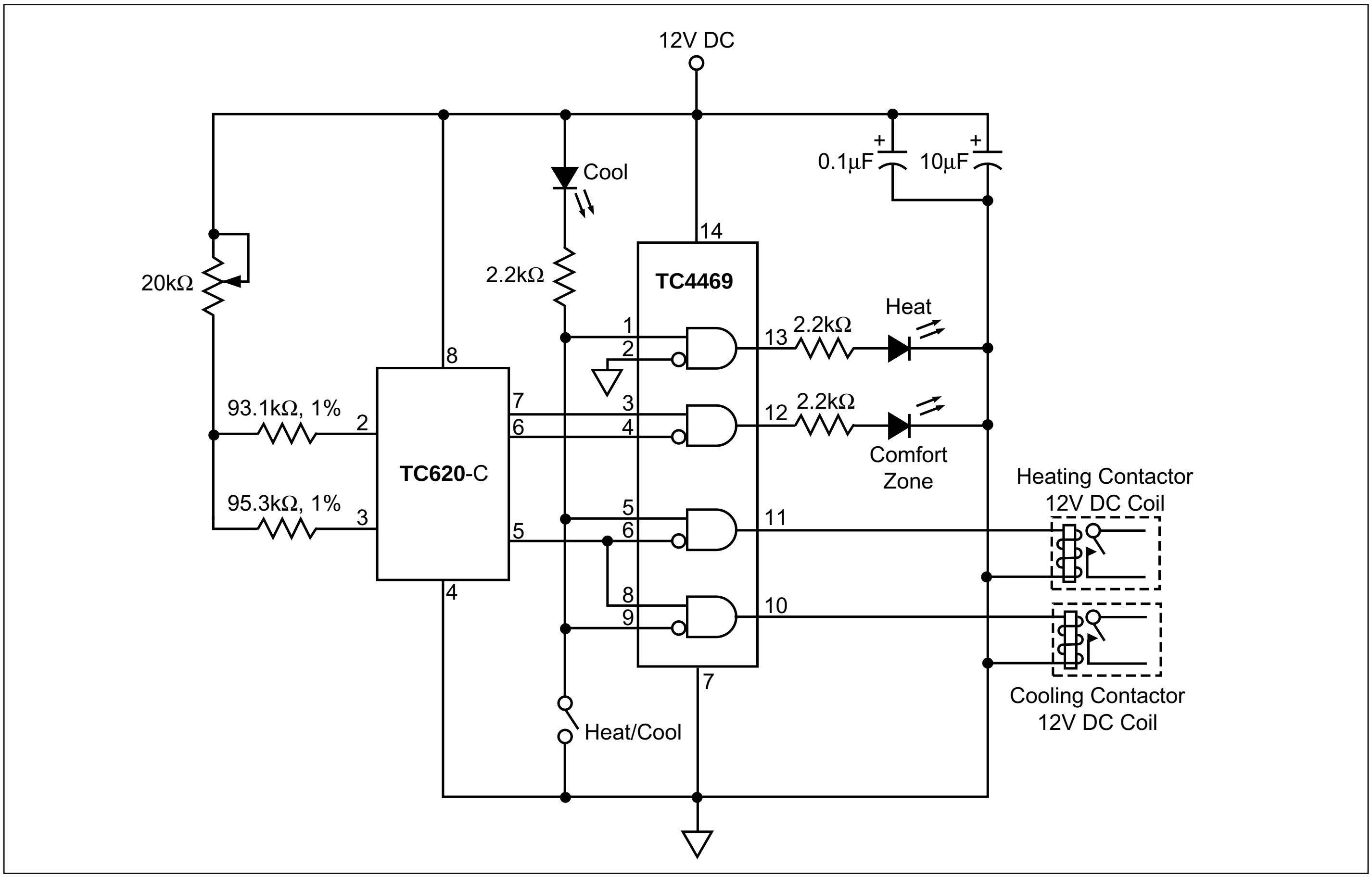

Figure 2: *Heating/cooling thermostat controller.*

To get the desired range, we need a potentiometer that will provide a 22°C variation (29°C – 7°C = 22°C). Multiply this temperature range by the resistance versus temperature ratio to get the needed resistance for the potentiometer:

$$782 \cdot 22 = 17.2k\Omega$$

A 20kΩ potentiometer will meet this requirement. Now each programming resistor can be calculated. For the low end of the window, the minimum programming resistor value should be:

$$R_{TRIP} = 0.783 \cdot T + 91 \ldots R_{TRIP} = 96.5k\Omega$$
$$T = 7°C\ (45°F)$$

By adding the 20kΩ potentiometer value to this we get:

$$96.5k\Omega + 20k\Omega = 116.5k\Omega \text{ total resistance}$$

Plugging this value back into the resistance calculation formula we will verify that the maximum trip temperature is greater than the desired high end of the window:

$$T = \frac{(R_{TRIP} - 91)}{0.783} \qquad T = 32°C\ (89.6°F)$$

The previously calculated resistance values will span both ends of the desired heating and cooling window (45°F to 85°F).

To program an acceptable hysteresis for the thermostat, the Low Set resistor must be lower in value than the High Set resistor. A resistance versus temperature ratio of 782Ω per °C for temperatures below 70°C will give a good guideline for calculating the hysteresis. For a hysteresis of 5°, the difference in resistance is:

$$R_{DIFF} = 782 \cdot 5 \ldots R_{DIFF} = 3.91k\Omega$$

Subtracting the 3.91K from the 96.5K will give the Low Set resistor value:

$$96.5k\Omega - 3.91k\Omega = 92.6k\Omega$$

Choosing standard 1% resistance values closest to the calculated values gives:

$$R_{HIGH}\ Set = 95.3k\Omega$$
$$R_{LOW}\ Set = 93.1k\Omega$$

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With the 20kΩ potentiometer connected to both programming resistors, the Low Set resistor's 5° hysteresis will track the High Set resistor, as the potentiometer is manually adjusted by the user for different temperatures.

OUTPUT SECTION

The Low Limit and High Limit outputs will go high when the device (or thermistor, TC621) reaches the programmed temperature for each corresponding input. The Regulate output is a latch that goes high when both programmed temperatures have been reached, and goes low when the device temperature decreases to below both set points. Figure 3 shows the outputs with respect to input set points and temperature changes.

Figure 2's application uses a TC4469 Quad CMOS Driver. This device has four independent drivers, each with a logic AND gate as an input. The AND gate has one noninverting input and one inverting input. The first driver is used to drive an LED indicator. Depending on the position of the Heat/Cool selector switch, either the Heat or Cool LED indicator will be lighted. The second driver is used to drive the "Comfort Zone" LED indicator. When the temperature is between the two set points (our previously calculated 5° hysteresis), this indicator will be lighted. The third driver controls the heating contactor. It is enabled when the Heat/Cool selector switch is open and the "Regulate" output is low. When the Heat/Cool selector switch is closed, the third driver is disabled and the fourth driver will be enabled to control the cooling contactor. This driver will turn on the cooling contactor when the "Regulate" output is high. The logic features of the TC4469 CMOS Driver are used to prevent the heating and cooling contactors from operating simultaneously.

The TC620/621 will operate with any supply between 4.5VDC and 18VDC. The TC4469 Quad CMOS Driver can source 300mA continuously. The coils on the Heating and Cooling contactors must be of the appropriate type and voltage rating for the circuit.

24VAC EQUIPMENT

Most heating and cooling equipment is designed to operate with a 24VAC secondary voltage. The schematic in Figure 4 is an example of a 24VAC system that drives 24VAC relays and operates on an internally self-generated 15VDC. Because the TC620 and the TC4469 are CMOS devices, their current requirements are extremely low. Using triac switches to energize the relays keeps the component costs to a minimum, while reliability stays high.

This design requires only four wires from the thermostat to the main control for a heating/cooling system. An additional fifth wire for a manual fan switch would make it compatible with standard 5-wire residential and commercial heating/cooling systems.

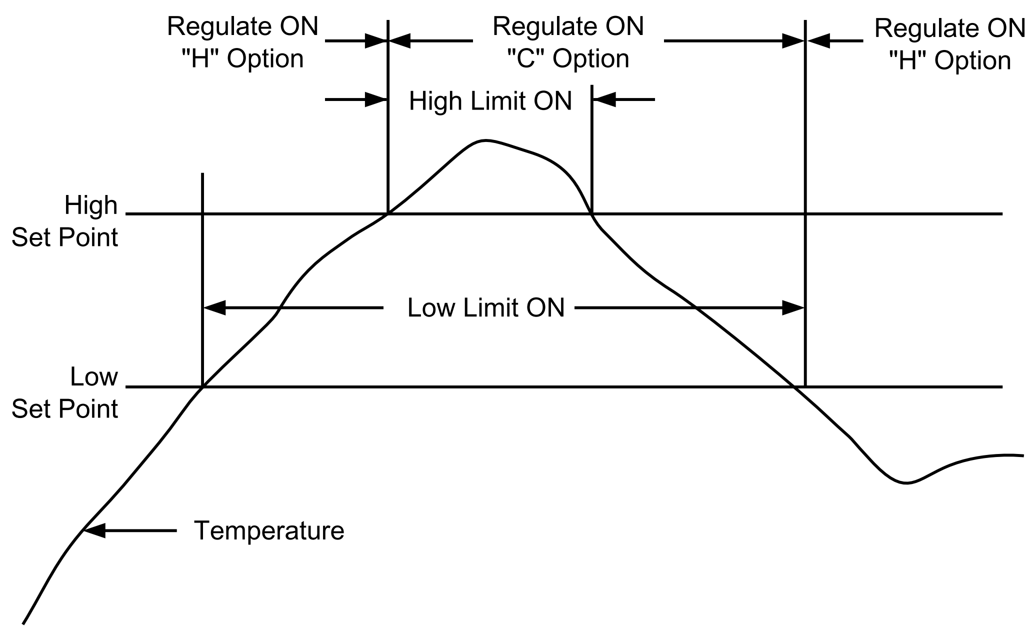

Figure 3: *TC620/621 input vs. output logic.*

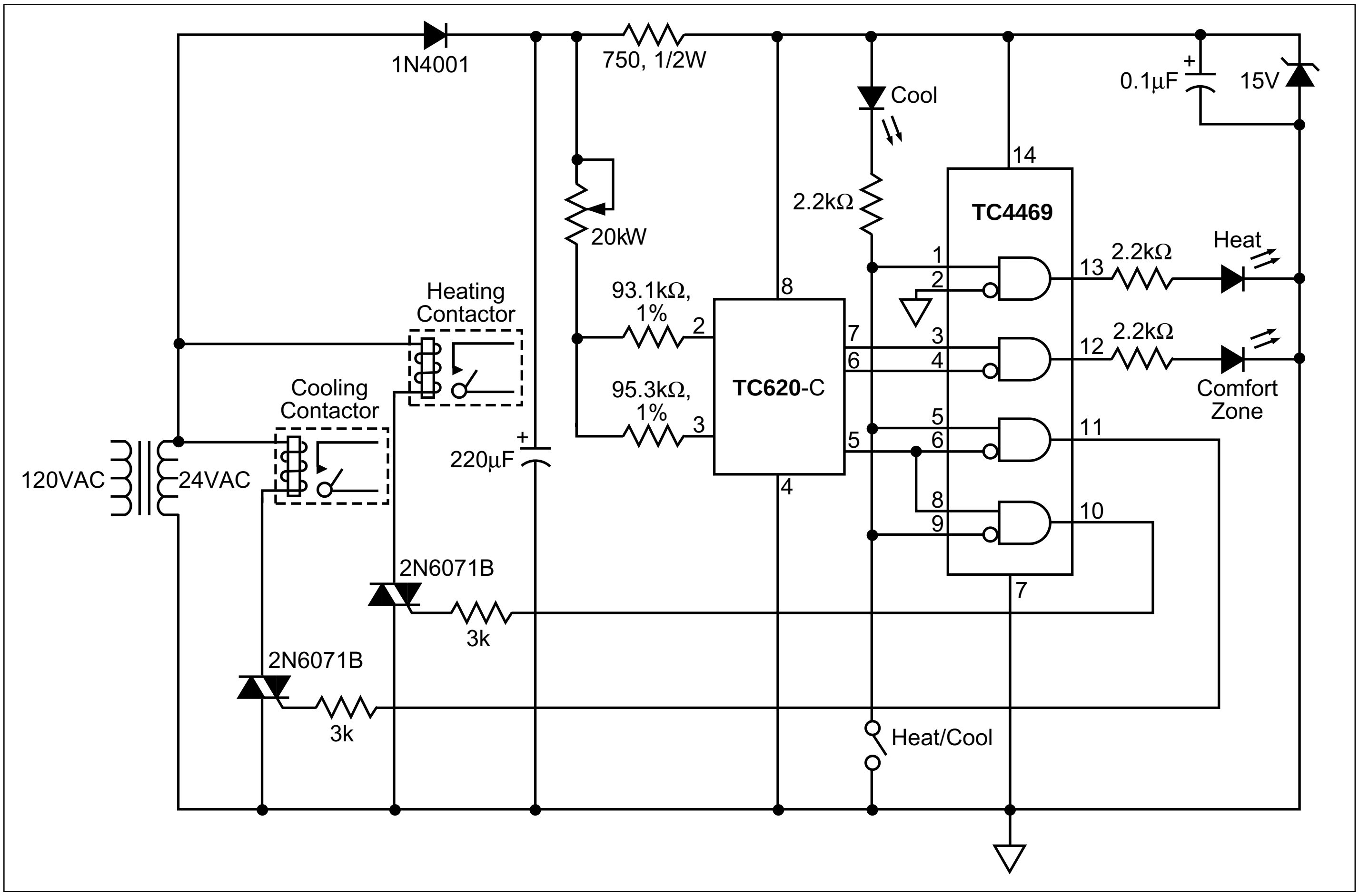

Figure 4: *24VAC heating/cooling thermostat controller.*

SOLAR HEAT CONTROLLER

Figure 5 is an example of an external temperature sensor for a pool solar heating panel pump control. The TC620 should be a part with the "H" option bonding. This inverts the "Regulate" output logic. This is necessary when using "NTC" type thermistors because the internal logic is designed to function with a "PTC" type thermistor. The external thermistor used in this design is an NTC (negative temperature coefficient) thermistor. One manufacturer is Keystone Carbon. Their part is RL1006-53.4K-140-D1. It has a resistance of 100kΩ at 25°C. Another vendor is Thermometrics. Their part is D200B104L. This thermistor assembly is attached to the solar panel in a manner that will allow it to sense heat generated by direct exposure to the sun.

This, then, energizes the pump when the sun is heating the panels, and turns off the pump when the sky becomes cloudy or the sun goes down. To prevent rapid cycling of the controller during partly-cloudy skies, the hysteresis is set for a wide (20°F) span.

The thermal time constant of the solar panel will also aid in the prevention of rapid pump cycling if the thermal resistance between the thermistor assembly and the solar panel itself is low. The Low Set temperature is set for 26.7°C (80°F) and the High Set temperature is set for 37.8°C (100°F). The resistor values are calculated:

$$R_{TRIP} = 0.783 \cdot T + 91$$

$$R_{TRIP}\ Low = 111.9k\Omega \approx 113k\Omega\ 1\%$$

$$R_{TRIP}\ High = 120.6k\Omega \approx 121k\Omega\ 1\%$$

As the sun heats the thermistor assembly, the pump will turn on at 100°F and stay on until the thermistor assembly temperature decreases to 80°F. This ensures that the solar panel has time to heat up before the pump is energized, and that the pump will turn off before the solar panel has cooled below the pool temperature. The complete controller consists of nine low-cost components.

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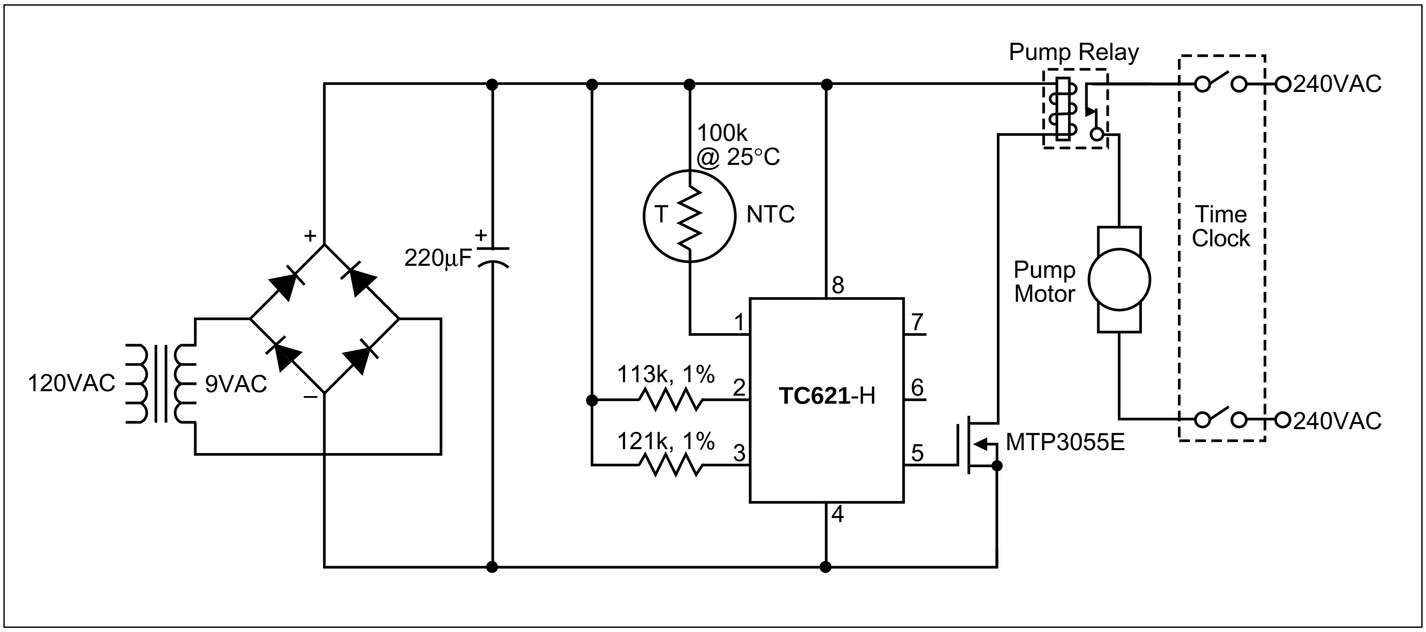

Figure 5: *Pool solar heat control.*

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