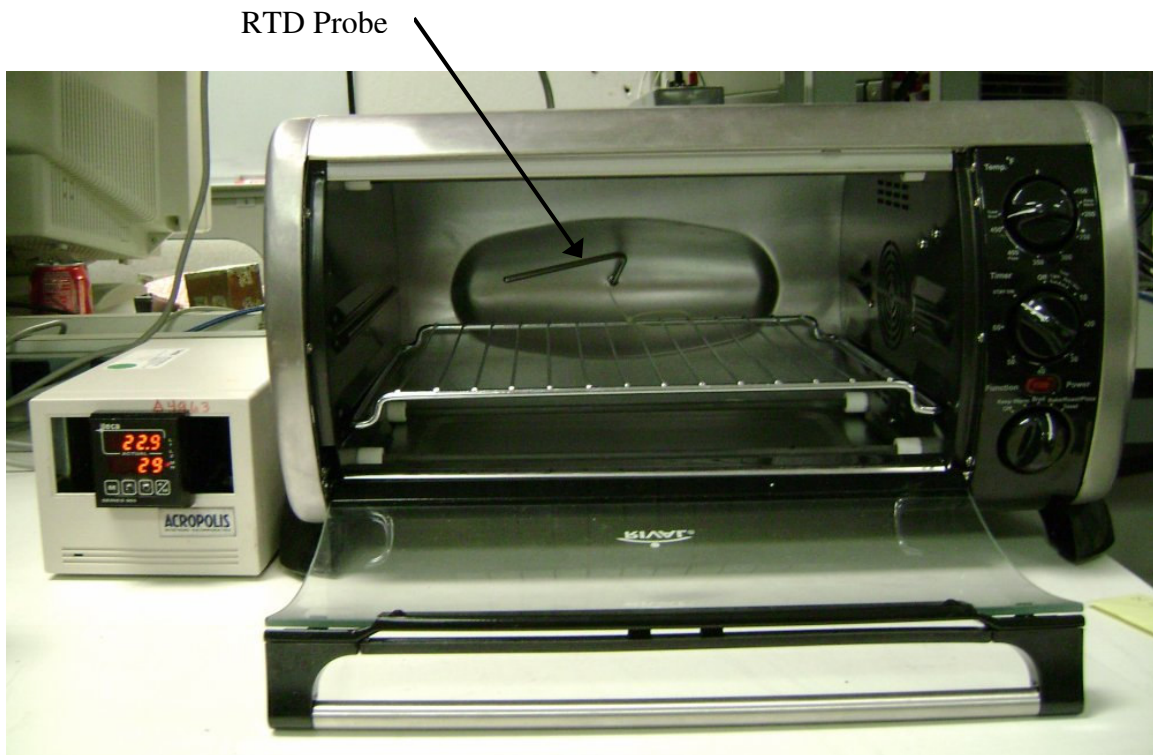


How to Make a Precision Temperature Controlled Chamber

This project was born out of necessity. The authors were developing a measurement circuit that relies heavily on matched temperature drifts of certain components to remove overall temperature drift. When the circuit appeared to be working reasonably well at room temperature, it was time to see how it performed over large temperature excursions. There were several temperature chambers in the lab, however they were constantly in use and camping out in one for weeks on end is generally frowned upon.

There are plenty of other applications for such a chamber. It can be used for forming and melting craft materials and drying stuff. There have even been several articles on how to reflow circuit boards in a toaster. And such a chamber is essential for developing precision electronic circuits as it allows drift to be measured quantitatively, as opposed to using freeze spray and a heat gun.

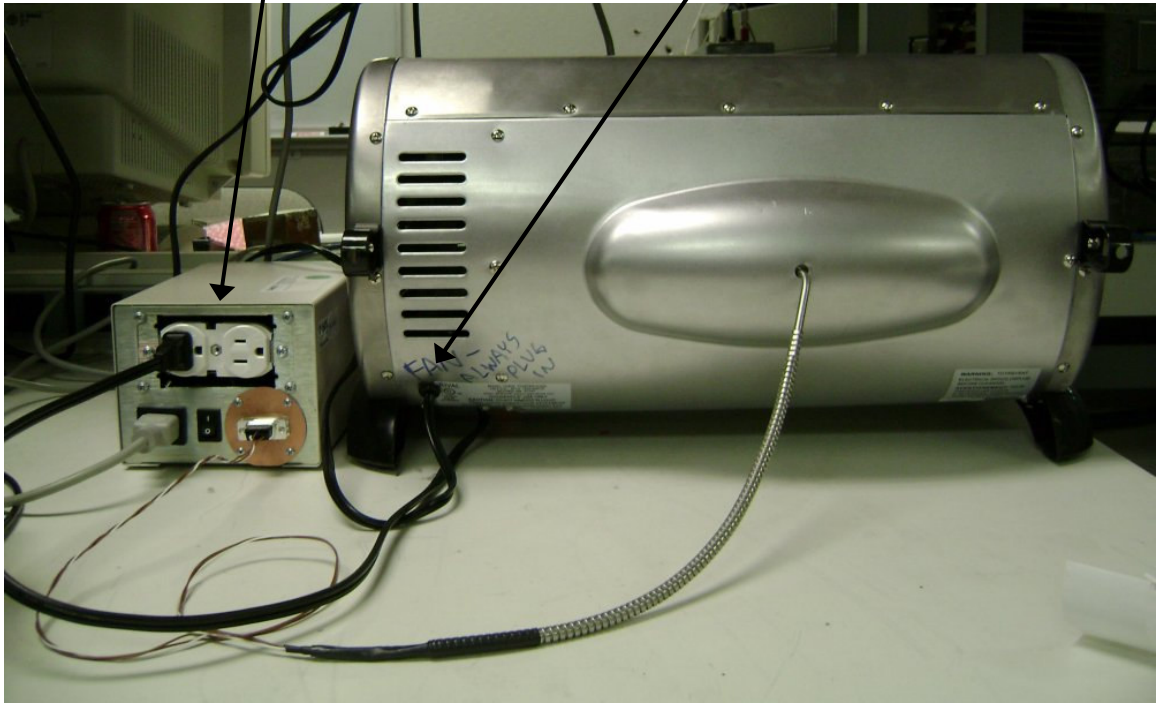
Refer to the block diagram and pictures below for this project. The exact schematic will vary slightly for each implementation. Follow the schematic in your controller's manual exactly.



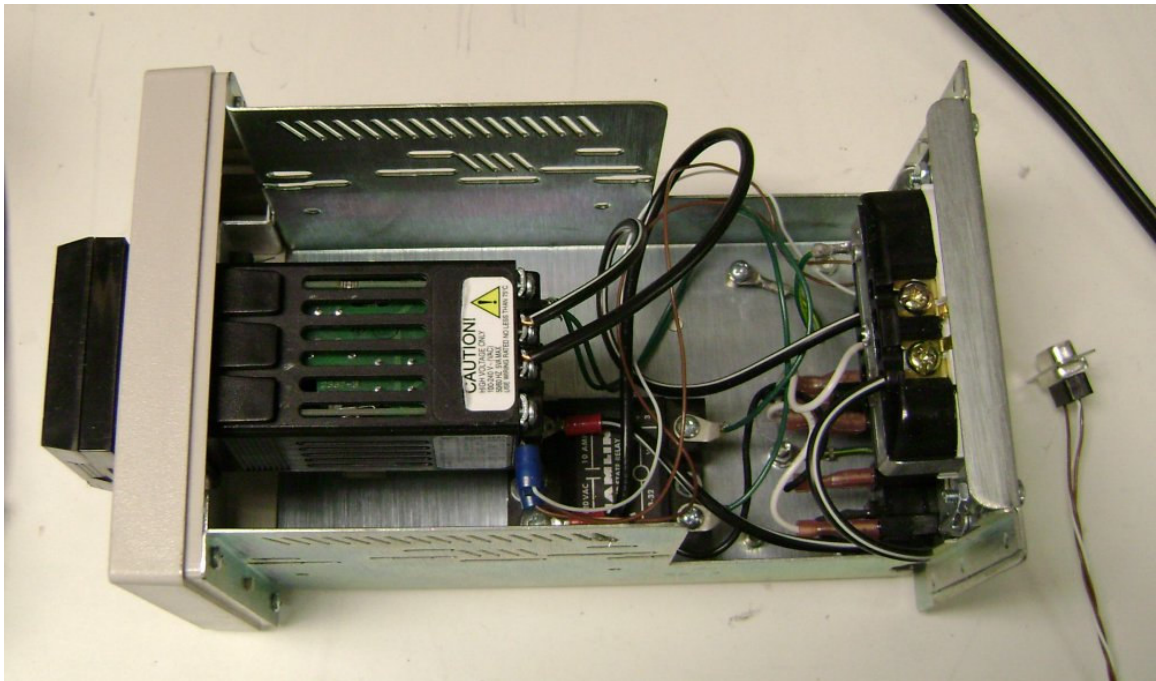
Front View

Duplex outlet

Extra cord for circulation fan



Rear View



Controller

Part 1: The Toaster

The circuit under test was small enough to fit into a toaster oven, but could a toaster oven be easily modified to provide precisely controlled temperature? The built-in thermostat is perfectly adequate for producing a desired darkness of toast, but the 10 degrees C hysteresis in oven mode will not produce meaningful test results in our application. But there are numerous advantages to starting with a toaster:

- 1) Safety – it's already built to be plugged into the wall and operated at high temperatures.
- 2) Convenience – It's the perfect size and shape for testing small circuits, power and data cables can be routed through the side of the front door, and the front door is glass so you can see what's going on.
- 3) Built-in temperature limiting – the oven's thermostat lets you set the maximum temperature if something in the controller goes wrong. Normally the thermostat does not cycle, and the heating element is cycled by the controller.

One feature to look for in your oven is a circulation fan. The only modification made to the toaster was the addition of a second power cord connected directly to the fan. This allows the fan to run continuously, whether or not the controller is applying power to the main power cord.

Part 2: Temperature Controller

Nearly every engineer has a rough idea of how to make a temperature controller. You could make a bang-bang controller using a thermistor, comparator, and a TRIAC. You could use an LM75 and a microcontroller to generate a PWM signal and take a stab at a software Proportional-Integral-Derivative (PID) loop. Or... you can spend a fairly modest amount of money on a tiny off the shelf controller that has more features than you will ever use. This need not hurt your pride – it can be justified in two ways.

- 1) If you are building your oven for your “day job”, you would be hard-pressed to build a reliable controller for the same price. So using a carefully selected off the shelf controller will make you look smart and efficient.
- 2) If this is “just for fun”, it will get you to the project you want to stick in the oven MUCH quicker.

Both of these assume, of course, that neither your day job nor your idea of fun is designing little temperature controllers.

There are quite a few controllers that will work, such as the Red Lion T4811100 or Watlow model 96. There are a myriad of options to choose from, but several that very useful are as follows:

- Powered by 120VAC – avoids the need for an external power supply.
- Support multiple sensor types (thermocouple, 3-wire RTD, 0-5V from a transmitter)
- DC voltage output to heater controller (not a mechanical relay or open collector)
- Two DC outputs to allow both heating and cooling control.
- Auto tuning of proportional-integral-derivative (PID) control parameters.

Other not so obvious features are minimum / maximum cycle time, which lets you set an upper limit on how fast the heating element will be cycled, and maximum duty cycle. The maximum duty cycle effectively reduces the power of the heating elements, which in turn prevents them from getting too hot as the oven is initially ramping to the setpoint temperature. You can look at this as a “software variac”.

By far the most impressive feature of these controllers is auto-tuning of the control constants. During auto-tuning, the controller steps the temperature up and down a few times, measuring the response of the system. When it is finished, it optimizes the response of the controller so that it reaches the setpoint quickly without overshooting.

Part 3: Temperature Sensor

Another necessity is a temperature sensor. A 100 ohm RTD probe happened to be available for this project, but there are lots of alternatives. Thermocouples are very reliable and work at high temperatures, but accuracy and precision are lower than an RTD. Other options are temperature transmitters with 0-5V or 4-20mA output, if you happen to have one lying around.

Part 4: Solid State Relay

This falls into the same category as the controller itself. You could use a TRIAC or even a mechanical relay, but the advantages of an SSR are worth the cost. Solid state relays are extremely easy to use and very reliable. They also help keep your project safe by providing another layer of electrical isolation between line power and the controller.

Part 5: Enclosure

Life is too short to troubleshoot a rat’s nest of wires, so put your controller in a nice enclosure. An old 5-1/4 inch external hard drive case works perfectly – by coincidence, a 1/16 DIN form factor temperature controller will fit perfectly in the hard drive slot. It also has a power switch and a receptacle for a standard power cord. A standard duplex outlet was installed on the rear of the enclosure, so the toaster plugs in directly.

Part 6: Future Expansion

The controller also has provision for controlling temperature in the other direction (cooling). Experiments with a large 600W Peltier cooler are looking promising.

