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# Crystal Oven Controller

*Build this solid state regulator for your oscillator oven assembly ...
OK, it's not for everybody!*

*There are two main ways to keep the output frequency of a crystal oscillator stable; use a temperature sensor and feedback to correct the frequency, as with a TCXO, or operate the crystal in an oven set to the crystal's turning point. Of the two, the oven is the easiest for a radio amateur to implement.*

Crystal ovens can be classed as one of two types according to the method used to regulate or control the temperature: thermostatic or proportional. Thermostatic ovens use a simple bi-metal–controlled set of contacts which open and close at the operating temperature, much the same as a common house furnace thermostat. Proportional ovens regulate the amount of heat generated until a balance is reached at the desired temperature.

Of the two types, proportional ovens are typically the more expensive and the more stable. However, thermostatic ovens are less expensive, and if there is significant insulation between the heater and the crystal, they can be as stable as proportional ovens. But, such well insulated ovens are typically larger than most popular ovens. The chief drawback to a thermostatic oven is the wear and tear on the thermostat contacts. This article presents my solution to the pitting and wear on the contacts of a particular crystal oven, but is applicable to most thermostatically controlled crystal ovens.

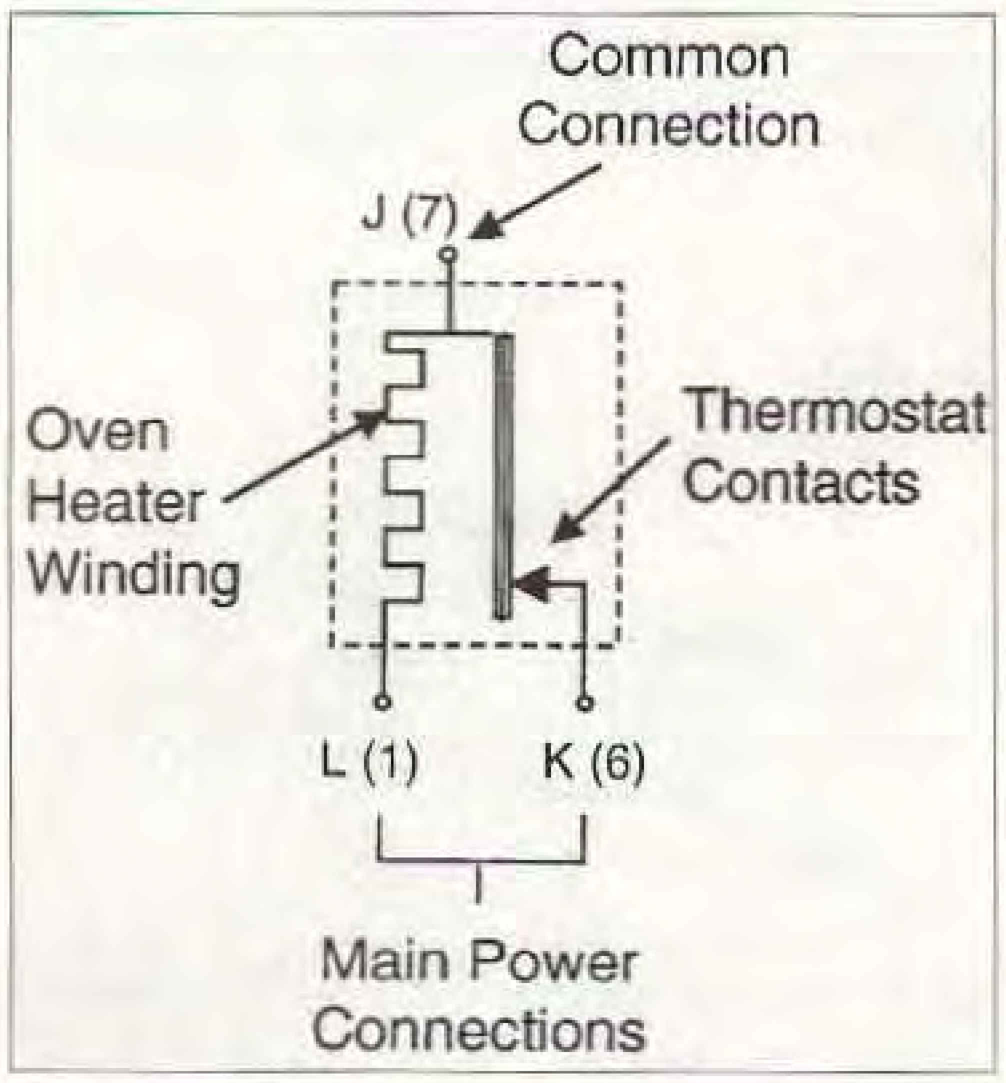

*Fig. 1(a). Typical oven wiring.*

I had been looking for a good, inexpensive, precision frequency standard for doing some oddball astronomical timing and photography when I happened upon a module from a military surplus SRT-14A. What I had found was the RFO, Unit 1 (Z-2001), 100 kHz reference oscillator — see the photographs. This oscillator generates a very stable 100 kHz that it supplies to the various synthesizer modules. The oscillator module is compact as far as hollow-state boat anchor units go and uses a 5654 (6AK5) oscillator and two 5814 (12AU7) cathode follower output tubes. The output frequency is stable to better than one part per million over weeks and the aging of the crystal is very low if for no other reason than its age. Changes in crystal frequency attributable to aging decrease with the operational age of the crystal.

Originally, the module was operated from a regulated 250 VDC supply, but I found that it would work at voltages as low as 30 VDC. I opted to run mine from a regulated 150 VDC supply. The most prominent component, the oven, is a model TC922 made by Bliley Electric Company, measuring about 4.5 inches tall by 3.75 inches in diameter. It has a seven-pin base connector

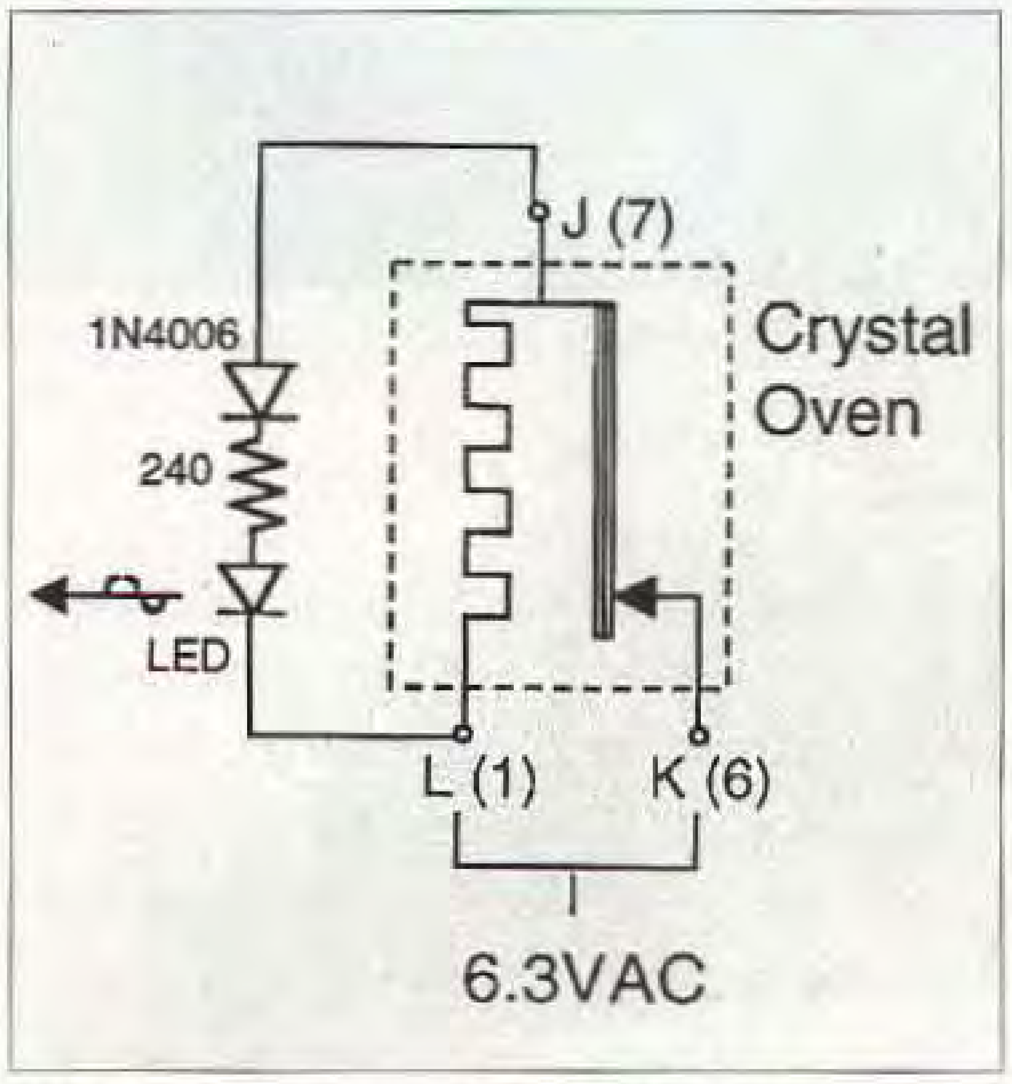

*Fig. 1(b). Oven with LED indicator.*

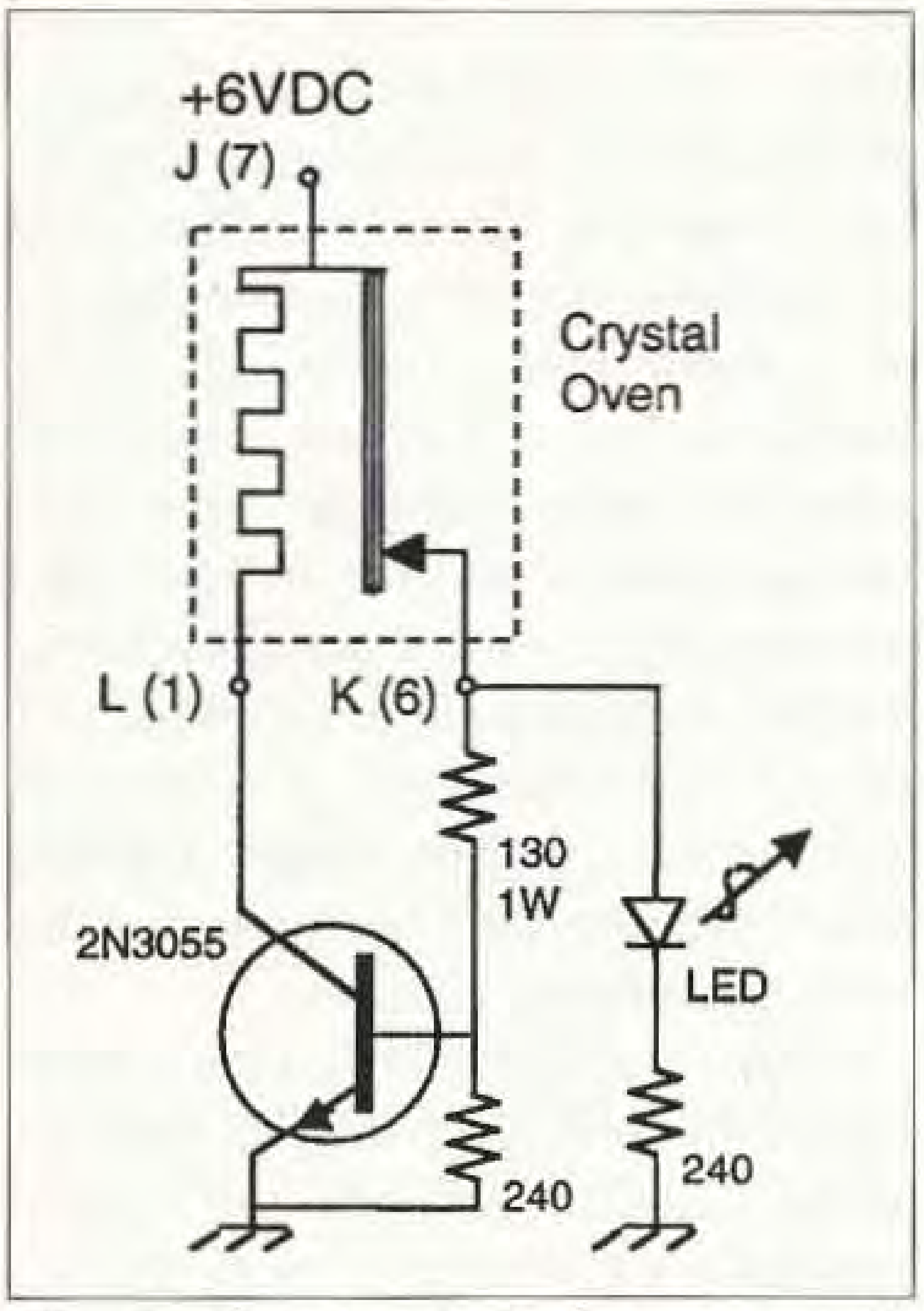

*Fig. 2. Transistorized thermostat with LED indicator.*

and is mechanically clamped in place. The oven was designed to operate at the upper temperature turning point of the 100 kHz crystal, 70° C. The TC922 oven was designed to draw a maximum power of ten watts, or 1.58 A at 6.3 VAC.

Actually, I eventually found two complete oscillator modules. But, the thermostat contacts in the second module oven were pitted and worn. Burnishing the contacts brought temporary relief, but it was soon obvious that the thermostat was beyond repair.

An E-mail to the Bliley Electric Company confirmed my fears — they no longer stocked the original oven or replacement thermostats. Months later, at a hamfest, I found a matching oven complete with crystal. It was missing a large portion of the Bakelite upper cap, but the asking price was very reasonable. Combining parts, I now had a complete second oven and oscillator module. Not wanting to lose either of my working units to further contact pitting and wear, I needed to find a way to reduce the contact current.

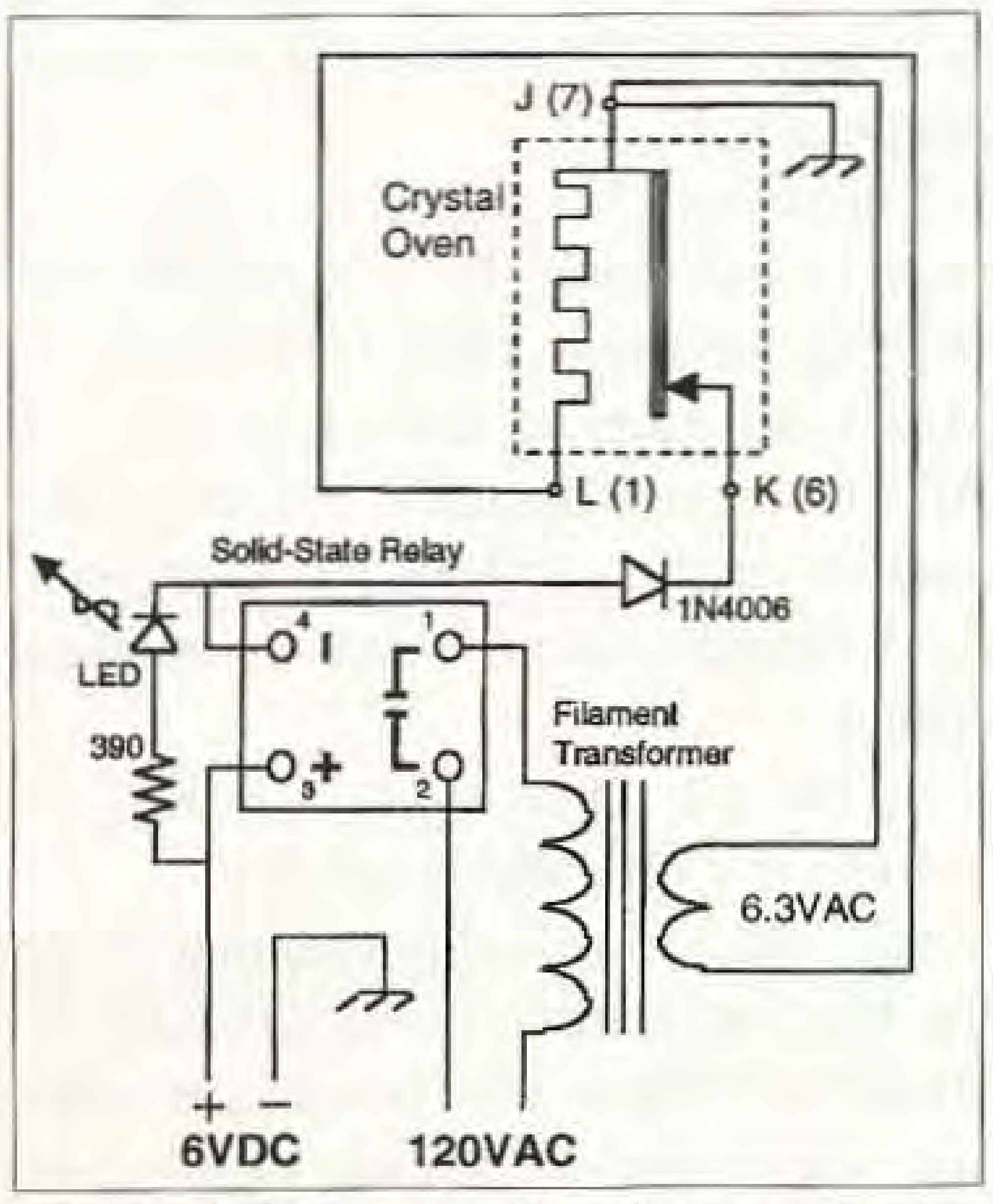

*Fig. 3. Solid state relay thermostat controller with LED indicator.*

I considered converting the ovens to full proportional control, but I did not want to change any of the module wiring (so that boat anchor fanatics/purists would not hunt me down). I did want to reduce the thermostat contact current to extend the life of units already over forty-five years old. Seriously, amateur radio operators, me included, have been too eager to tear into surplus equipment and make modifications rather than work with and use the original design. When someone examines a piece of surplus equipment at a hamfest and notes the presence of a new control or hole, the first word that comes to their mind is "butchered," not "enhanced." All modifications in this article are external to the original oscillator module.

Every thermostatically controlled oven I have run across connects the thermostat contacts in series with the resistive heater windings or element as shown in **Fig. 1(a)**. The small letters in the figure correspond to the SRT-14A oscillator module connector pins. The numbers in parentheses correspond to the oven pin numbers. Most, if not all, oven designs bring the common connection out to serve as a part of an indicator circuit for contact closure or oven cycling. The easy access to the common connection is what allowed me to treat the thermostat contacts and the oven heater windings separately.

First, I tested each oven by adding an LED with a rectifier diode and a current limiting resistor in parallel with the heater windings to indicate when the oven was heating [see **Fig. 1(b)**]. This works whether the oven is operated from DC or from the original AC.

Once I knew the two ovens were operational and cycled normally, I decided

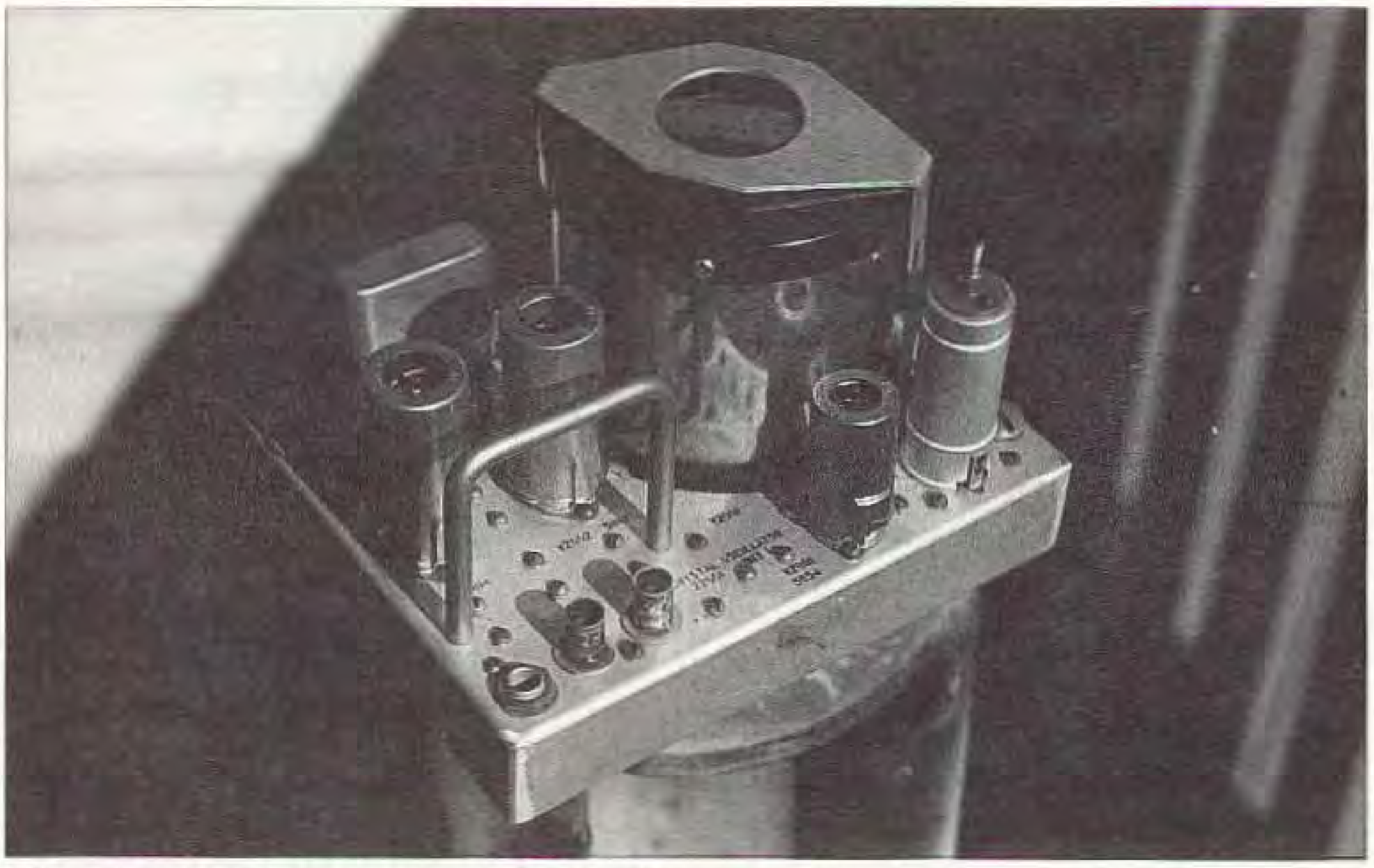

*Photo A. View of the complete SRT-14 reference oscillator.*

to use a transistor to reduce the current through the oven thermostat contacts. I had already decided to operate the three vacuum tubes from a regulated 6 VDC filament power supply. This would extend the life of the tubes and remove any concerns about line voltage fluctuations. I used a simple 2N3055 circuit, complete with an LED oven heating indicator as shown in **Fig. 2**. The LED circuit is no longer connected across the oven heater windings but is instead connected to the thermostat.

The 2N3055 needed only a couple of square inches of heat sink, so a simple aluminum "L" mounting bracket worked very well. However, it seemed as if the oven would never cycle off. I believe the problem was that the voltage drop across the 2N3055 was too high and the supply voltage too low. For a constant heater resistance, the heating is proportional to the heater voltage squared — hence a small voltage drop has a magnified effect. This problem could have been overcome by increasing the oven supply voltage to compensate, requiring me to build another power supply just for the oven — something I did not want to tackle.

I decided to take a different approach. I borrowed a solid state relay to use in experiments with the SRT-14A oscillator oven. Solid state relays are remarkable devices. For AC loads, they behave the same as low voltage relays. The control and switching circuitry are very well isolated. The actual control is done by LEDs deep within the device. They can be thought of as optoisolators for AC circuits. I wanted to see if I could control the solid state relay using the oven thermostat contacts and the 6 VDC filament supply. I worked out a schematic for how it might be done (see **Fig. 3**). I already had a 6.3 VAC, 3 A filament transformer (Stancor model P-6466) that was more than adequate for the 10 W oven heater circuit.

I tested and characterized the control side of the solid state relay, an Opto-22 model 240-D10, over the full recommended control voltage range from 3 to 25 VDC. This particular solid state relay is rated for 10 A resistive loads and is certainly overkill, but it was available, easy to mount, physically compact, and has convenient screw terminal connections.

It turns out that the control side circuitry of the solid state relay could be modeled as a fixed 1.5 V drop (the internal LED) in series with a 1 k resistor. With a 6 VDC supply, the control current is only (6 – 1.5)/1 k = 4.5 mA. Allowing another 12 mA for the oven indicator LED, the oven thermostat contact current would only be 16.5 mA, versus 1.6 A under the original configuration (about a 100x reduction). Putting the LED indicator back in parallel with the oven heater windings would reduce the contact current to a mere 4.5 mA, but did not seem necessary.

I breadboarded the solid-state relay oven heater controller. It worked great the very first time! The 1N4006 diode serves no purpose except to prevent AC from accidentally entering the control circuitry side of the solid state relay during testing; it can be replaced with a wire.

By the way, it turns out that my line voltage is a bit on the high side of 120 VAC. The no-load output voltage from the filament transformer is 20 Vp-p or about 7.07 Vrms. The oven heater voltage waveform is a nice clean sine

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*Photo B. Bliley crystal oven removed from SRT-14.*

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wave. When the controller is switched off, there is still a low level (0.7 Vp-p) voltage on the transformer secondary. This residual voltage produces only about 15 milliwatts of heat. With the new control circuit, after a one-hour warm up, the oven heater cycles on for 4-1/2 minutes, off for 3-1/2 minutes. The average power is only 5.6 watts. For this low power application, the solid state relay stays cool to the touch and requires no additional heat sink.

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With the help of a few solid state components, a very well designed and reliable vacuum tube circuit continues to live and serve a useful purpose. Overall, I am very pleased with the circuit and plan to use it in the final system for a very long time. I might even incorporate the oven controller design into several other pieces of equipment having thermostatically controlled ovens. 73