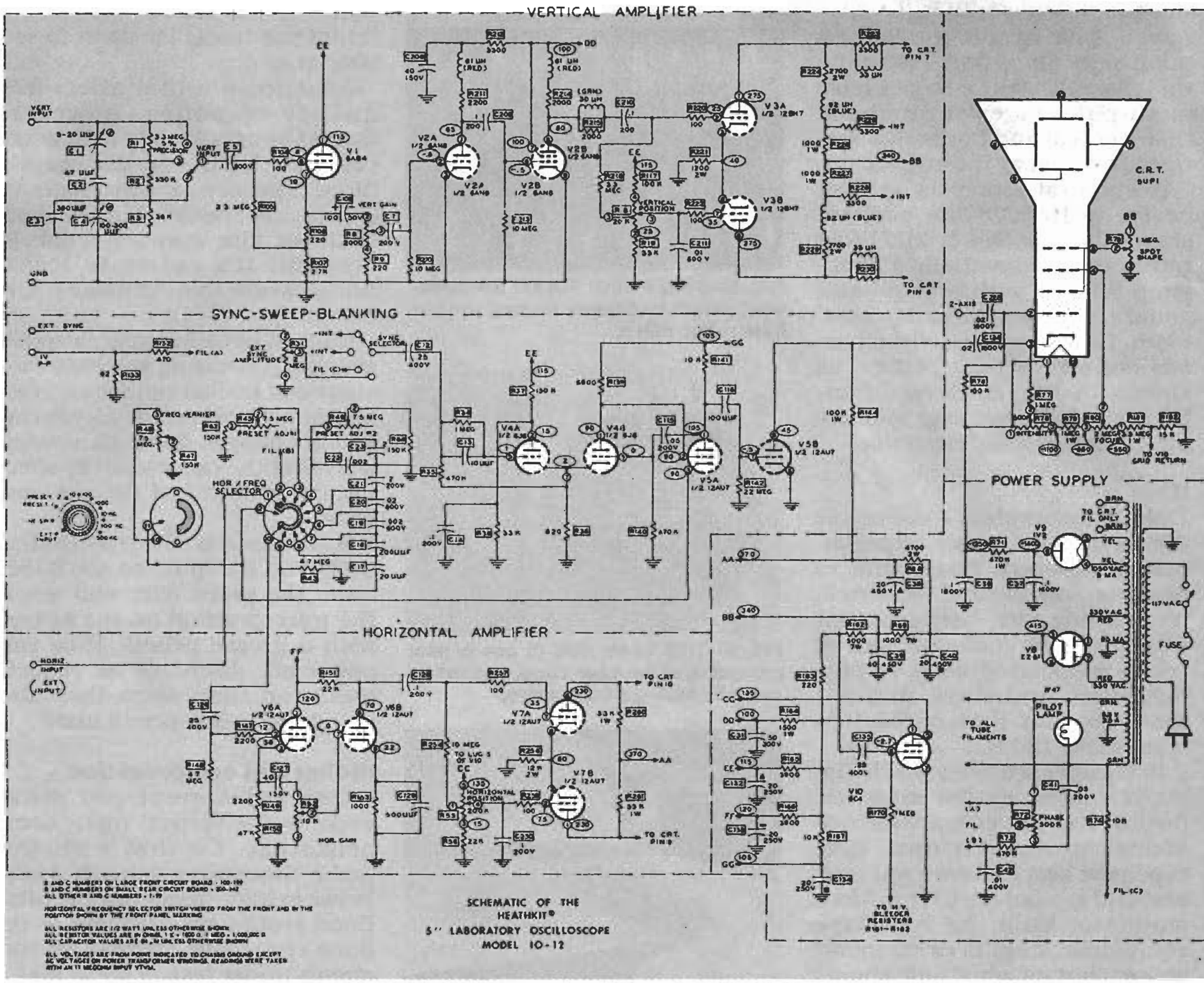

FIG. 2—THIS IS THE SCHEMATIC OF THE Heath IO-12, a popular wideband oscilloscope with recurrent (synchronized, not triggered) sweep.

slides under them. If necessary, you can bend a contact back, clean it with fine sandpaper, and then bend it back into position, but that's tricky. An ohmmeter can tell you whether you've gotten the switch good and clean. Take comfort in the fact that dirty switches and controls usually get cleaner when used regularly.

The next step is to test the tubes. Be warned that tubes in scopes are more critical than in other equipment; matched pairs or selected tubes may be required in some places. If you don't have a tube tester, look for tubes that don't light and try swapping tubes of the same type to see if there is a change in performance. Quite often, a bad tube is all that's wrong.

Oddly enough, if a tube goes bad in a Tektronix vertical amplifier, you may not notice it; the circuit is direct-coupled at low frequencies and the only effect a dead tube has is to decrease bandwidth.

Circuit analysis

Figure 2 shows the circuit of the Heath IO-12, a typical wideband scope. Most troubles are easy to localize because each function of the scope corresponds to a particular circuit—vertical and horizontal amplifiers, sync, sweep, and so forth.

Most failures occur in the power-supply. Look for open or leaky filter capacitors and burned-out resistors. Reduced voltages and excessive ripple may indicate that a selenium rectifier has increased in resistance; you can wire a silicon diode in parallel with it, and all the current will go through the silicon. Remember, too, that you can replace a rectifier tube with silicon diodes.

Lab scopes have regulated supplies in which a 150-volt reference voltage controls all the regulators. If the reference voltage is even slightly off, many other circuits will malfunction. You can correct slight errors with "150-volt adjust" potentiometer.

Lower-cost scopes get their high voltage from the power transformer. Lab scopes, however, use a separate 60- to 100-kHz oscillator, high-frequency transformer, and voltage multiplier. Loss of high voltage is often caused by a shorted high-voltage capacitor. In a Tektronix scope, you can check for that by disconnecting capacitors, one by one, until the filaments of the high voltage rectifiers light up.

If the power supply is okay but you can't center the trace on the screen, look for a bad tube in a push-pull amplifier, and note that more expensive scopes have push-pull stages throughout their vertical and horizontal sections, not just at the output.

Horizontal sweep is seldom perfectly linear. The earliest scopes used an 884 or 2D21 thyratron tube—essentially a neon-lamp blinker with a grid—and generated a poor-quality sawtooth. Later models used dual triods but still weren't perfect, as shown in Fig. 3. Severe non-linearity, however, may indicate a bad tube or leaky capacitor.

Hum

Many scopes show a noticeable 60- or 120-Hz ripple superimposed on every trace, due to power-supply trouble. To check, try bridging each filter capacitor with a known good one, test all tubes associated with voltage regulation, and check that rectifiers are okay. Hum of that type is normally 120 Hz.

In cheaper scopes, a 60-Hz ripple is caused by the magnetic field of the power transformer, and is considered normal. More expensive scopes have a mu-metal shield around the CRT to block magnetic hum. In tube-type equipment, hum is never totally absent, but its amplitude should be one millimeter of screen deflection or less.

Hum can also come from poor grounding. Mechanical contact between pieces of metal does not always make a good electrical connection, especially if the scope is old. I cured the hum in my Heath IO-14 (Fig. 4) by adding solder lugs to ground PC boards to the chassis, and a grounding strap, made of copper braid, for the vertical attenuator.

Another source of hum is heater-to-cathode leakage in a tube. Regardless of the cause, you can detect where hum is entering the system by removing tubes stage by stage until the hum stops.

Adjustments

Every scope has an astigmatism control to ensure that the beam spot is round, not oval. In some Heath models, that's on the inside (Fig. 5), but it's a good idea to adjust it. Bear in mind that it

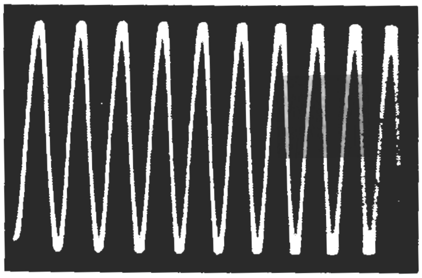

FIG. 3—SWEEP AND FOCUS are somewhat uneven on cheaper scopes; you just have to live with it.

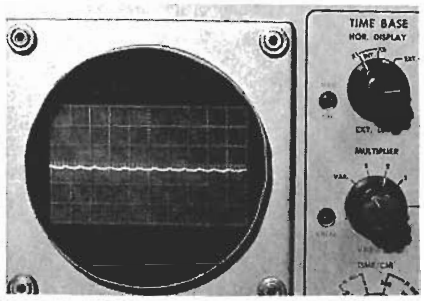

FIG. 4—THIS 60-Hz HUM IS due to poor grounding of the input stage, and can be cured by adding a copper strap.

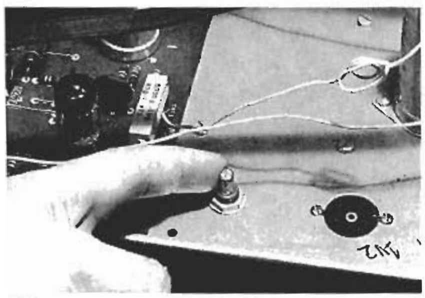

FIG. 5—THE ASTIGMATISM CONTROL of the Heath IO-12 is inside; you may want to make it more accessible.

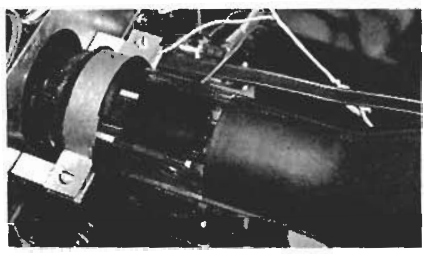

FIG. 6—IF THE TRACE IS TILTED, mark its position on the screen with a grease pencil, then turn the power off, loosen screws, and rotate the CRT.

interacts with focus and intensity controls.

Most lab scopes have one or more vertical balance controls to keep the trace from moving up and down as you switch from range to range, or from "normal" to "invert." Those controls are well worth adjusting. There may also be internal adjustments to center the trace. Try them to see what they do.

Adjustments that affect frequency response, however, should be approached with great caution. Tektronix lab scopes have numerous adjustment points that shouldn't be touched without the manufacturer's manual. It's easier to make things worse than to make them better.

Calibration adjustments aren't as tricky, providing you have test signals of known voltage and frequency. Remember, anything which changes the high voltage will affect the calibration by altering the stiffness of the electron beam.

If the trace is tilted, rotate the CRT (Fig. 6). To do so safely, remove the green filter and mark the trace position on the screen with a grease pencil. Turn the power off, discharge all capacitors, and then align the tube using the grease pencil mark.

Probes and compensation

One adjustment you must make is the vertical input compensation. Do that with the probe that you're actually going to use in high-frequency circuits. Good probes are designed to reduce capacitive loading on the circuit under test.

Figure 7 shows the circuit of a typical low-capacitance probe. On the ×1 setting, the 10K resistor keeps the cable capacitance from loading the circuit under test, but high-frequency response is poor. On the ×10 setting, the 9-megohm resistor forms a voltage divider with the 1-megohm impedance of the scope. The 9-megohm resistor is bypassed with a small capacitor so that more signal can get through at high frequencies.

To adjust compensation, first set the probe to "direct" (×1) or temporarily set it aside and connect the scope directly to a good square-wave source, such as the circuit in Fig. 8. Adjust the trimmer capacitors in the vertical input circuit so the top of the square-wave is flat. There may be as many as a dozen trimmers, each for a different range. Set the probe to 10:1 and adjust the capacitor on the probe itself.