

FIRMA DR. E. STEINWEG  
LYONER STR 14  
60528 FRANKFURT  
TEL: 06644 820 895 FAX: 820 894  
e-mail [steinweg@dr-steinweg.de](mailto:steinweg@dr-steinweg.de)  
[www.dr-steinweg.de](http://www.dr-steinweg.de)

## **The TS-530A Temperature Controller**

### **A remotely programmable analogue instrument**

The TS-530A is a digitally programmable, analogue PID (Proportional-Integrate-Differentiate, or Three-term) control unit, which has been designed to cooperate with the AVS-47 AC Resistance Bridge in order to manage ultralow temperatures. The main application of the TS-530A is with dilution refrigerators, and therefore the heating power has been limited to 1 watt.

The TS-530A can be operated as a purely manual instrument, by using its front panel switches, or it can be controlled remotely via the AVS-47 and its computer interface. The fact that the two instruments can be handled as single not only saves one computer interface, but it also makes the computer program shorter and easier to write.

## TS-530A Key Features

- Set point from 500uV to 4.2V
- Analog input range from 500uV to 4.2V. Both positive and negative dR/dT
- 7 heater power ranges from 1uW to 1W (decade steps, 100 ohm heater assumed)
- Short-circuit proof linear current-source type heater output
- 12 discrete, logarithmically spaced proportional gain values, selectable in 5dB steps
- 9 discrete, logarithmically spaced integrator time constants in 1:2:5 sequence
- The integrator can be set in temporary HOLD-position to improve step response
- The derivator has 7 logarithmically spaced time constants. The effect of the derivator has been limited to low frequencies in order to reduce its sensitivity to noise
- 5 power bias values in steps of 20% of full power.
- Analog meters for control error and output power are convenient to read
- Analog square-root approximation has been used to make the  $R \cdot I^2$  heater power a linear function of the error signal

## About the Design Principles

The TS-530A was designed to be a companion for the AVS-47 Resistance Bridge. Because of our stringent EMI requirements, the digital electronics inside the TS-530A had to be limited to a minimum. Consequently, the controller has only limited sets of PID parameter values which can be selected both manually, using the front panel switches, and remotely from a computer.

The set point is given in 100 microvolt steps. This resolution corresponds to the readout resolution of the AVS-47. Manual setting is made conveniently using old-fashioned but reliable code switches (thumbwheels).

Because of the total absence of digital intelligence, the integrator and derivator were made purely analog. And because the overall control loop is analog, there is no danger of small oscillations around the set point, which may happen with a digital controller because of the digitising step.

With a typical analog controller, the output current or voltage is a linear function of the error signal. But because the heating power is proportional to  $I^2$  or  $U^2$ , the overall gain of the control loop (= resulting temperature change / measured temperature deviation) would be different at various power

levels, even if all the controls are kept intact. In order to prevent this effect from disturbing the optimisation of the system, a simple analog square-root approximation was inserted between the PID output and the heater power stage.

The power output was made safe to the heater: it cannot deliver more than 100 mA on the highest power range, and its compliance voltage cannot exceed 9 volts. And because the output is a current source, it is inherently short-circuit proof.

### **Compatibility with the AVS-47 Resistance Bridge**

In manual operation, the analogue output of the AVS-47 is connected to the analogue input of the TS-530A using a BNC/BNC coaxial cable. In order to enable computer-interfacing, an additional 37-pole ribbon cable between the two instruments is needed.

In addition to selecting the PID-parameters and setting the control point, one can also measure approximately the heater output current and voltage using the A/D converter of the bridge.

Two features of the TS-530A, the "Hold"-position of the integrator and the "Shorted"- position of the error signal, make it possible to connect the AVS-47 temporarily (using the multiplexer) to measure other sensors than the control sensor. Although there is no active temperature control during that time, the heater output remains constant. This method shall be used only when the control system is in a steady state.

Both the TS-530A and the AVS-47 use similar 19" enclosures, which are also stackable on top of each other.

### **Emi Considerations**

With the aid of our shielded room, the TS-530A was designed and tested for minimum RF emissions, so that it would not disturb other sensitive instruments, like the AVS-47. Analog electronics in the control loop, effective mains input filter, linear power supply, large ground areas on the circuit boards and the linear heater output with an RF filter reduced the RF emissions to a level where they are almost nonmeasurable.