FRONT END TEMPERATURE CONTROL

GENERAL DESCRIPTION

The temperature sensitive components of the front end are located in a chamber whose temperature is well regulated. The chamber consists of a flat aluminum plate, of dimension 30 by 60 cm, with an insulated metal cover to complete the enclosure. Below the plate and in close contact with it is a thin flat electrical heating element, the same size as the plate, which can heat the plate uniformly. Below the heater is a thin layer of insulation, and below that is a flat metal heat exchanger through which flows water from the chiller.

The plate and the chamber are much more strongly thermally coupled to the heat exchanger than to their other surroundings. In the absence of any current in in the heater, the plate temperature would closely follow the slow up and down oscillations of the heat exchanger as the chiller cycles on and off. Adding current to the heater raises the temperature of the plate above that of the heat exchanger. The regulating circuit measures the plate temperature and continuously adjusts the current in the heater to maintain the plate temperature constant as the heat exchanger temperature slowly cycles up and down. The chiller provides a reservoir whose temperature changes slowly and over a maximum range of about 5 C. This is much more stable than the day/night and seasonal temperature changes in the surroundings. The other feature of this heat exchanger is that it provides a uniform reservoir temperature over a large flat surface to go with the plane uniform heater, permitting fast response of the control system.

The heat input from the electronic components is approximately 20 watts. The heater resistance is 9 ohms, so that with the controller using a 36 volt supply, the maximum control heat is 144 watts. With the present choice of insulator, a thin layer of cardboard, this heat range permits regulation with a cold reservoir temperature range as large as 19 C. Nominal operation is with the average cold water temperature at 15 C and the plate temperature set at about 25 C.

The regulator circuit is shown below. The plate temperature is sensed by a thermistor. The difference between the thermistor drop and that of a reference resistance drives a balanced amplifier. The temperature at which a null output occurs is set by adjustment of the reference resistor. The amplifier feeds an integrator through a gain adjustment pot. Following the integrator is a circuit whose output is proportional to the square root of its input. This circuit then drives a power amplifier which supplies current from the 36 volt supply to heat the plate. Since the heater power is proportional to current squared, the square root circuit makes the output power proportional to input temperature error. This makes the control linear and the circuit band width independent of the temperature at which the system is regulating.

The integrator ensures that the system will regulate at a null; the single feedback element makes the adjustment simple.

TECHNICAL PROPERTIES

1. Since the plate is closely coupled to the cold reservoir, the interesting question is: How does the plate temperature respond to changes in the reservoir temperature? Because the heat flow is one dimensional and the control circuit is simple, it is straightforward to work out the sinusoidal response of the plate temperature to a sinusoidal fluctuation in the reservoir temperature. The graph below shows how this response depends on the frequency of the fluctuation. The different curves are for different values of a parameter p which is proportional to the loop gain. The system is stable independent of p, but the respone is very peaked. Thus, when it is operating, noise fluctuations make the output go through small random fluctations at the peak frequency of the response.

Increasing the gain lowers the response. However, if the gain is set too high, the response to a small reservoir temperature fluctation will be for the controller to either shut off the control current or turn it full, thereby losing control. At the present setting, where the gain is about its highest without losing control, the curve drawn with x's is appropriate. Its peak is at a period of about 4 minutes. The cycle time of the chiller is typically 20 minutes. Note that the predicted response is a reduction in the plate fluctuation by a factor of about 50 over that of the reservoir. Thus, a peak to peak water temperature variation of about 3 C, which is typical, is expected to result in a plate temperature variation of about .06 C, which is consistent with the observed operation.

2. Adjustments. The plate temperature is set with the balance pot at the input of the controller to a value near 25 C. The gain control should be set as high as possible, consistent with the heater current being on at all times (or at least most of the time).

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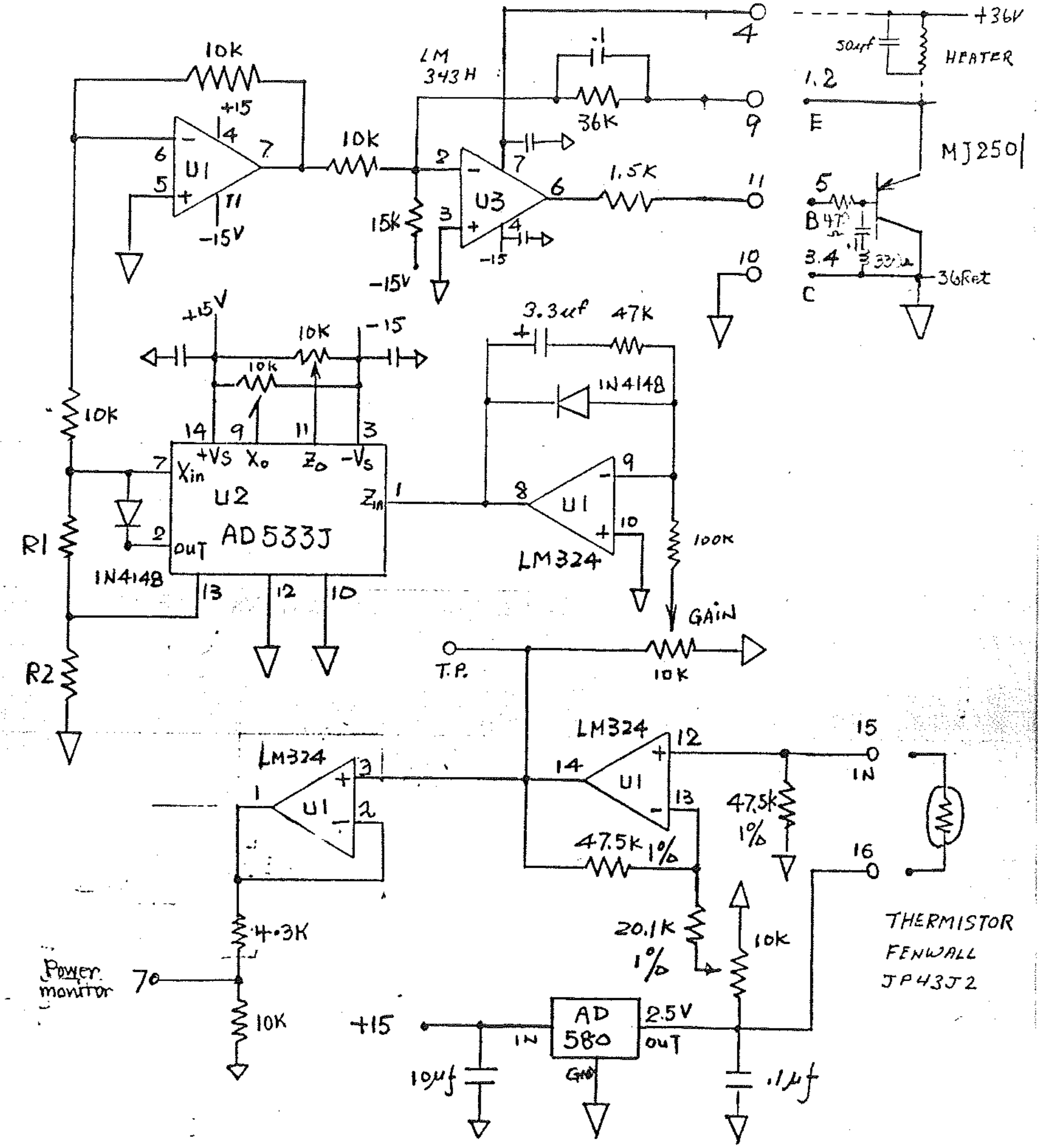
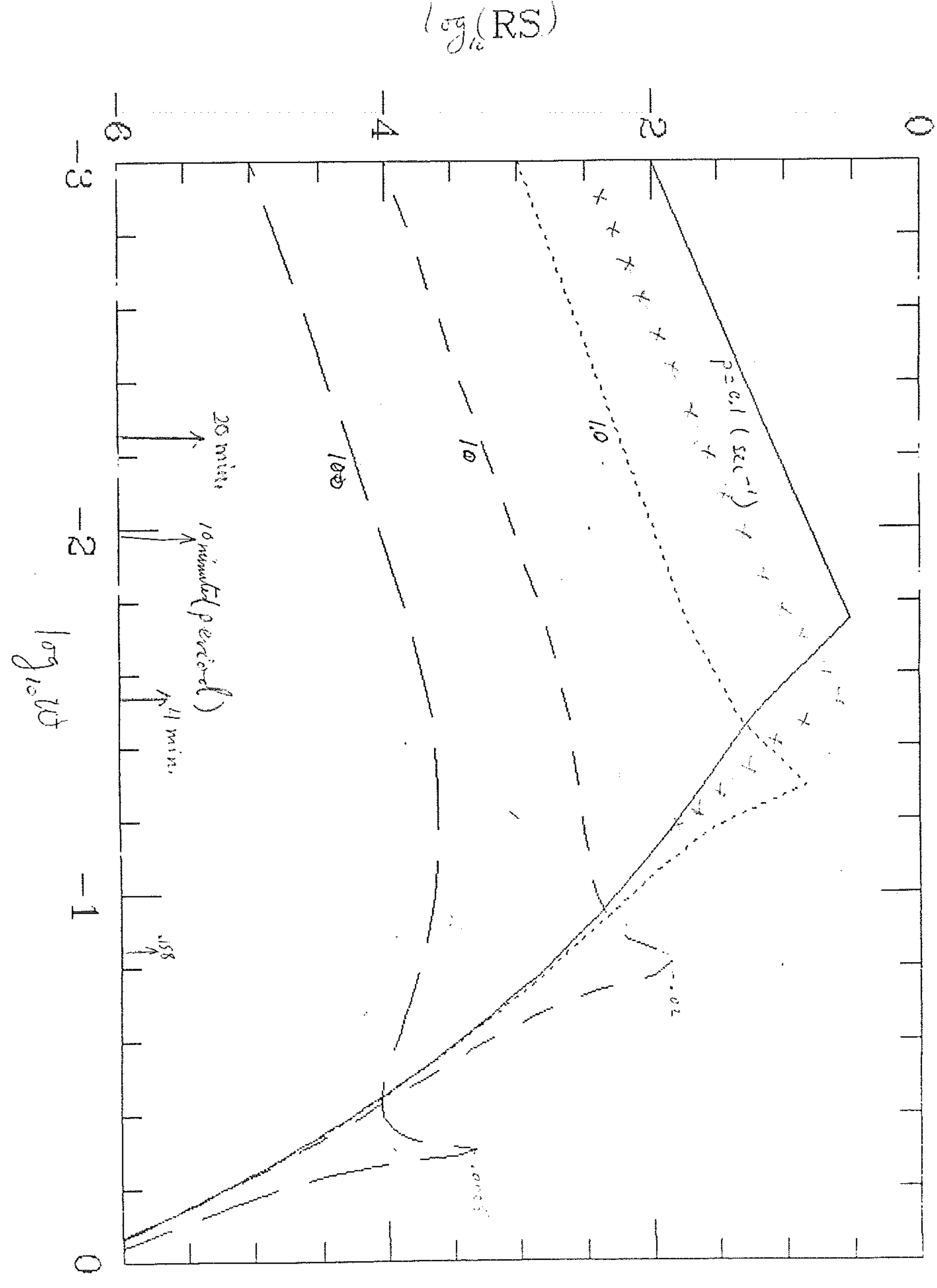
HEATER CONTROLLER #541 1-28-85





log10(RS)
0
-2
-4
-6
-3
-2
-1
0
log10 ωt
ρ = 0.1 (sec^-1)
.01
10
100
20 min.
10 minute (period)
41 min.
.158