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Temperature Controller by Continuous Heating of a Metallic Mass for the 77-300 °K Range

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We report a temperature controller working in the range between 77 °K and 300 °K by continuous heating of the metallic mass. It was designed to prevent oscillations around the equilibrium temperature and then it is particularly useful when large increases in the temperature are needed during experiments.

Apresentamos um controlador de temperaturas no intervalo dos 77 aos 300 °K por aquecimento contínuo de uma massa metálica. Foi desenhado para evitar oscilações ao redor da temperatura deequilíbrio quando mudanças grandes na temperatura são necessãrias durante os experimentos.

Most heating systems based on continuous control of the electrical power use amplifiers, and the error in temperature is inversely proportionisl to the amplifier gain. Their main problem is thesaturation of the amplifier when large increases of the equilibrium temperature are needed. During the saturation time, the metallic mass is heated with a constant voltage, and the system follows a temperature law similar to that shown in fig. 3. When the temperature of the thermometer is near the equilibrium value T_0 the amplifier becomes linear, but at this time the temperature at the calefactor is higher than T_0, because of the temperature gradient between calefactor and thermometer. If the amplifier has a convéinient high gain, it saturates again in the opposite sense, and the system cools fast. This situation repeats and the system oscillates.

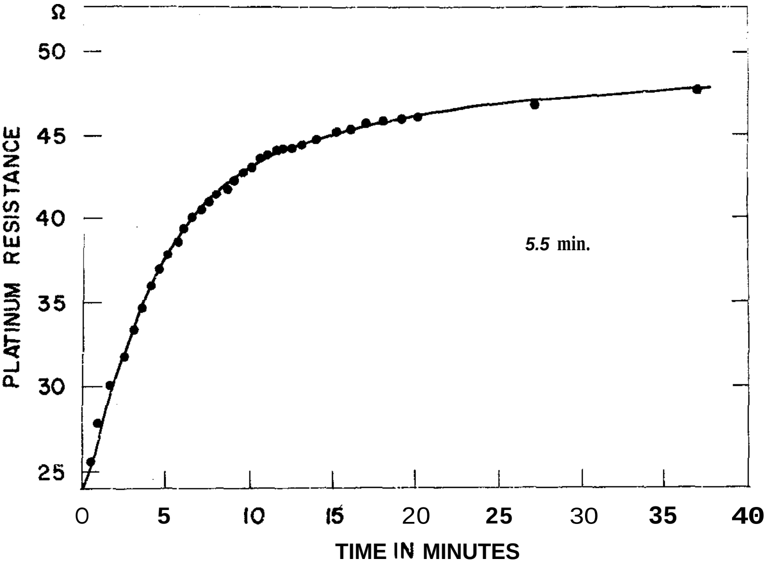

Fig. 1 - 24 GHz EPR *cavitv* controlled with our system.

We are reporting a system that avoids this inconvenience by connecting an integrator in parallel with the first amplifier stage. The time constant of the integrator is greater than the characteristic response time of the system to be controlled; so, during the heating period before the stabilization, energy is supplied to the system in such a rate that no part of it becomes warmer than the desired equilibrium temperature T_0. When the system warms up to temperatures near T_0, the amplifier operates, and the whole system works like a normal controller.

The Fig.1 shows the circuit of our device; the regulated power supplies are not shown, because they are conventional. The integrator (I_1) and the first amplifier (I_2) are connected in parallel and receive the control signal from a bridge; a constant current supply (I_5, and the 2N4220 transistor) feeds the bridge. The *Pt* thermometer in series with a variable high accuracy resistence are a branch of the bridge. In this way we get uniform sensitivity in the whole temperature range.

We included in the circuit a protected instrument, which fulfils all the necessary measurements. It measures the zero points of the amplifier and integrator in positions 1 and 2 of the function switch S_1; it allows the direct temperature measurement with the bridge, with the power disconnected in position 3 of S_1; it indicates the arrival to the equilibriiim of temperature in position 4, and measures the integrator output, proportional to the electrical power, in position 5.

The time constant of the integrator must be selected according the system whose temperature have to be controlled, its thermal conductivity and specific heat. In practice we choose it empirically inour apparatus. We used two microwave cavities for EPR experiments; one of them is shown in Fig. 2. Fig. 3 shows the rate of growth of the temperature as a function of time in Fig. 2 cavity system, in front of a constant voltage excitation. This can be approximated to an exponential function with time constant τ = 5.5 minutes for one cavity and 10 minutes for the other. We obtained in this way the integrator constant; we selected a value which is good for both cavities. In this situation the equilibrium time obtained for an increase of 130 ^{0}K and for temperatures raising between 160 and 260 ^{0}K, was about 30 minutes for both cavities.

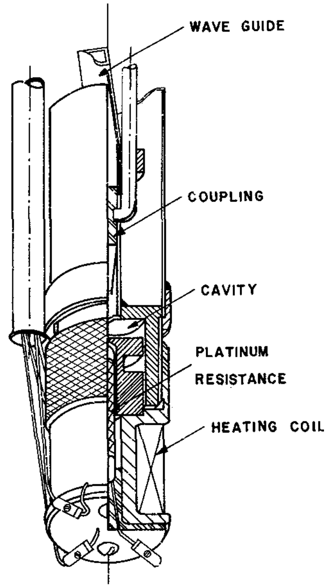

Fig. 2 - The electronic circuitry. All the resistances are 1/2 watt type, except specified.

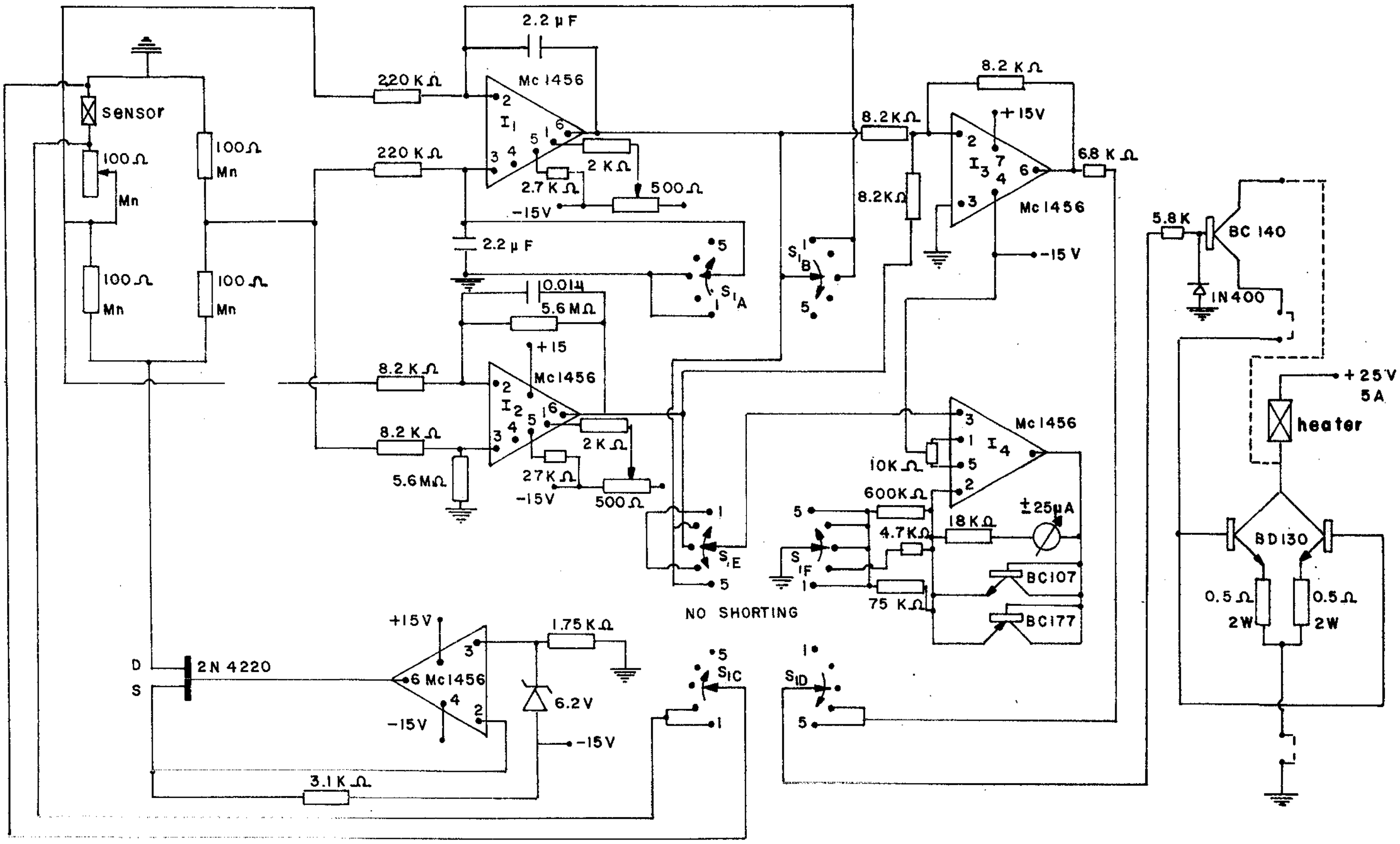

Fig. 3 - Temperature response to constart voltage excitation of the 24 GHz cavity.

We cooled our cavities by enclosing them in a vessel containing an exchange gas and the vessel is in a dewar container filled with liquid nitrogen; the 7 ohms calefactor is coiled in a non-inductive way.

The *Pt* thermometer was calibrated using the method described by Pratt *et al.*[1]. Other thermometers different from Pt resistance can be used; we tried a copper thermometer[2] with good results.

A permanent displacement ΔT from T_0 was observed, coincident with the permanent error calculated in the design. The later is necessary to mantain the integrator "memory". It can be corrected when reading the temperature by direct measurement on the instrument. In all cases this permanent displacement was les than 0.2 °K.

The average displacements from the equilibrium point $T_0 - \Delta T$ in one hoiir of work are less than 0.02 °K (real error of T) for the whole range of temperatures.

This system has also proved to be useful to control a cold finger apparatus for research in nuclear physics with similar τ. It can be used, with a few modifications in the sensor and power amplifier, in the range of 4.2 to 77 °K, using liquid helium.

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