# Freezer Temperature Monitor and Alarm

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An electronic instrument for measuring freezer temperature in the range of +40 to -40°C is described. The salient features of the instrument are, remote display, (digital and analogue versions with an accuracy of ±0.1 and ±0.5°C respectively), and provision for continuous record of temperature. Two types of sensors using thermistor and P. N. junction of transistor were used for temperature sensing.

Measurement and control of temperature of freezers and cold storages are of great importance for maintaining the quality of the stored products. Variation of storage temperature of frozen fish adversely affect various properties of fish. Different types of instruments have already been developed using many physical as well as electrical properties of substances. For example in platinum resistance thermometers, change in resistance of a piece of platinum wire with temperature is made use of. Generation of thermo e.m. f. between the junctions of two dissimilar metals is employed in measurement of temperature using thermocouples. Difference in co-efficient of thermal expansion of two different metals is made use of in the thermostatic control of temperature. Change in resistance of a semiconductor with respect to temperature is employed in the measurement of temperature using thermistors. Large signal output for a given range of temperature can be achieved using thermistor sensors. Rao (1968) and Sivadas (1978) have described the use of thermistors for temperature measurements. The forward voltage drop across the base-emitter junction of a transistor varies linearly with temperature and this method has also been employed for measurement of temperature (O' Neil & Derrington, 1979). Recently the National Semiconductors have developed an integrated circuit which includes a temperature sensor, a stable voltage reference and an operational amplifier all housed in a single chip (Scott, 1980). The present report deals with an electronic thermometer developed to measure and control temperature in freezers and cold storages with specific advantage of remote measurement and alarm.

*Methods*

The freezer temperature monitor and alarm consists of two types of sensors, namely thermistor and P. N. Junction and the associated electronic circuits displaying temperature in digital or analogue meters. The alarm electronics give alarm as the temperature deviates away from the preset levels.

*Thermistor probe and associated electronics*

Thermistor having a resistance of 1 kilo ohm at 25°C is made use of as the sensor. This is encased properly by a metallic tubing

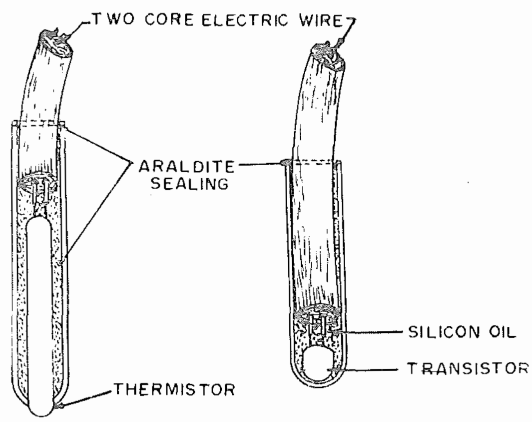


Fig. 1. Cross section of thermistor and P. N. junction probes

as shown in Fig. 1 Variation of resistance of thermistor is given by

$$R = R_o \exp. \left[ B \left( \frac{1}{T} - \frac{1}{T_o} \right) \right] - \quad (1)$$

Where $R_o$ = Resistance at reference temperature $T_o$ (°K)

R = Resistance at T (°K)

B = material parameter describing the slope of resistance *vs*. temperature.

The temperature co-efficient of resistance can be calculated from (1) as

$$a = \frac{1}{R}\frac{dR}{dt} = -\frac{B}{T^2} \qquad (2)$$

The non-linearity in temperature resistance characteristics of the thermistor is overcome by shunting with proper value of standard resistance as shown in Fig. 2. In the case of the thermistor sensor used, a resistance of 3.3 K ohm. is used as the shunt, in order to get a linear characteristic within the measuring range of 40° to —40°C. This

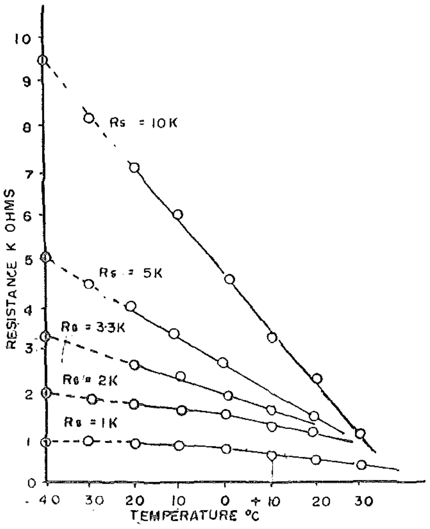


Fig. 2. Linearisation of thermistor with shunt resistance Rs.

is achieved by sacrificing the sensitivity to some extent. Thermistor probe is connected in the circuit as one of the arms of a wheatstone bridge as shown in Fig. 3. The bridge gets unbalanced due to the variation of resistance of the thermistor depending on the temperature of freezer or cold storage. Output voltage of the bridge is amplified by an operational amplifier and fed to a 0 to 100 micro ammeter as shown in the Fig. 3.

In the digital version of the instrument the amplifier output is connected to a potential divider arrangement and a 3½ digit LED display is connected across this point and a

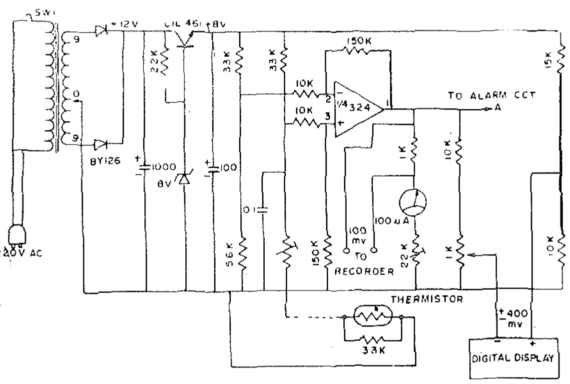


Fig. 3. Electronic circuit of the instrument using thermistor probe

fixed reference voltage as shown in the figure. Resistances of this network are chosen in such a way that a potential difference of +400 mV and —400 mV exists across the LED display at 40° and —40°C respectively.

*P. N. junction probe and associated electronics*

Base emitter junction voltage of a NPN silicon transistor is found to vary linearly with temperature. Variation of junction voltage is in the order of– 2 mV per degree centigrade in the temperature range of —40° to 40° C and this transistor junction is used as the temperature sensor. The probe is made by enclosing the transistor inside a stainless steel tube as shown in Fig. 1 and connected in the circuit as shown in Fig. 4. Voltage across the probe varies with variation of temperature of the freezer or cold storage. This voltage variation is amplified by an operational amplifier and fed to a 0 to 100 micro ammeter with proper series resistance. Sufficient bias voltage is given to the amplifier so that the out put voltage reaches the required level corresponding to the temperature range of 40° to —40° C. In digital version of the instrument, the output of the amplifier is connected to a 3½ digit LED display.

*Alarm control circuit*

This has got two differential amplifiers ICa and ICb as shown in Fig. 5. Voltage at point A varies with the temperature to be measured. As long as the temperature remains within the preset limits there is

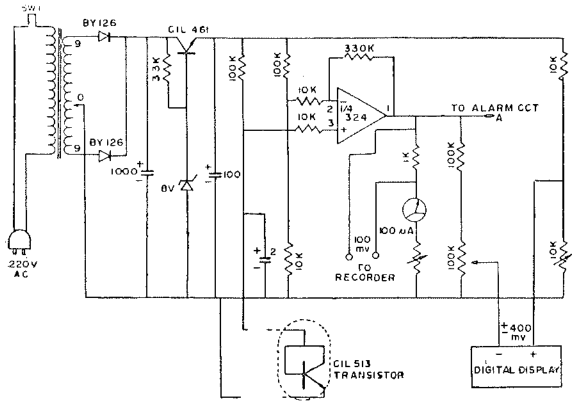


Fig. 4. Electronic circuit of the instrument using P. N. junction probe

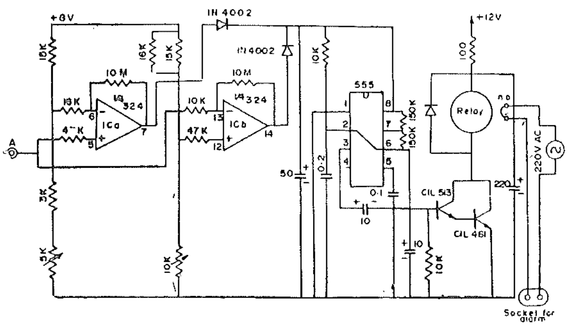


Fig. 5. Electronic circuit operating the alarm

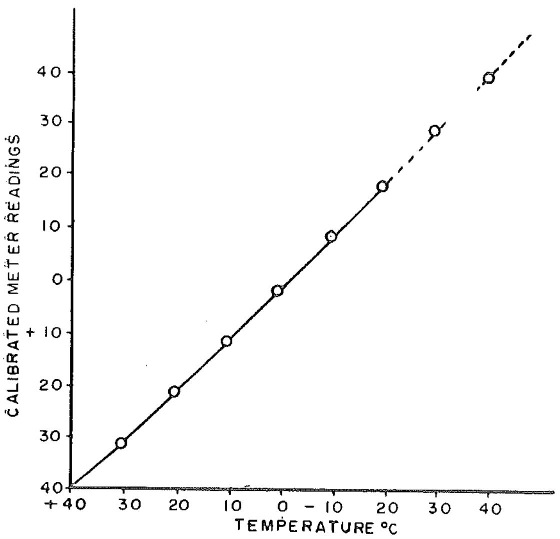


Fig. 6. Calibration curve of the instrument with thermistor probe

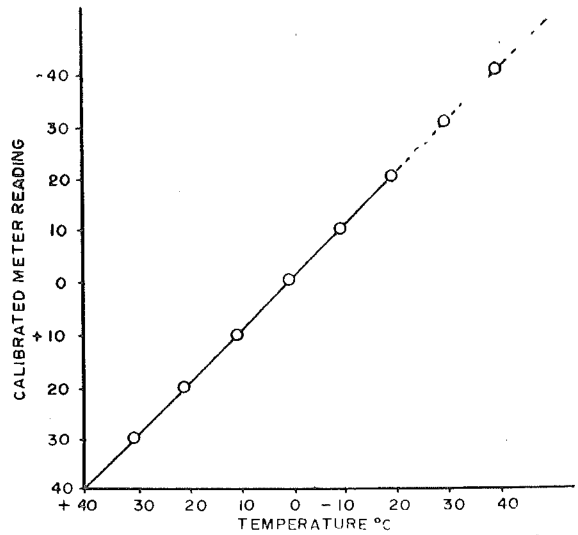


Fig. 7. Calibration curve of the instrument with P. N. junction probe

no output from any of these amplifiers. But once the temperature crosses the limit, an output voltage is produced by either one of the amplifiers. This voltage is used to operate the associated circuit which drives a 6V relay. An alarm operating at 230 V. AC is connected to the relay. The upper and lower temperature points at which the alarm has to be operated is set by adjusting the reference voltage to the amplifiers with the help of corresponding alarm set potentiometers.

*Calibration*

Calibration of the instrument was done by keeping the probe in different constant temperature baths and noting the corresponding meter readings. Temperature in the negative range upto —20°C was obtained from the deep freezer. Hence the curves after —20° C are extrapolated considering the theoretical linearity in the case of P. N. junction probe and nature of curves in the case of thermistor probe.

## Results and Discussion

Calibration curves of the instrument with thermistor and P. N. junction probes are shown in Figs. 6 and 7 respectively. In the case of P. N. junction, output signals came linearly proportional to temperature. But in thermistor, some nonlinearity is observed which is found to increase with wider range of temperature scale. An accuracy of ±0.1°C is obtained in the instrument with P. N. junction probe. In thermistor version the accuracy is reduced to ±0.5°C due to the nonlinear characteristics though it has got a resolution of 0.1°C with digital display.

The P. N. junction probe has got a very high response time compared to the thermistor probe. Response time of thermistor probe in the temperature range from 30° to 0°C is nearly 20 sec and that of P. N. junction probe is nearly 2.5 min. Since temperature of freezers and cold storages do not fluctuate very fast, the above high response time is quite acceptable and both types of probes can be used in them for temperature measurements.

Remote display of temperature is an advantage of the instrument over the conventional thermometers fitted in freezers and cold storages, where temperature can be observed only at close distance ranges from the instrument. In the case of thermistor probe a distance of even kilometers between the sensor and display unit is possible because of the high resistance of the thermistor compared to the resistance of the connecting wire. The instrument works at 9 V DC supplied by built in power supply operating from 230 V AC with a current consumption of 40 mA in analogue version and 100 mA in the digital LED version.

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