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Short Communication

A technique of temperature measurement using wire sensor

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Abstract

An instrument which measures temperature in connection with the development of rocket payload for the measurement of upper air temperature and employs a voltage controlled oscillator circuit is designed and described. The temperature sensor is made from nickel iron alloy wire. The V.C.O. shows a linear variation of frequency wit temperature. The instrument offers high accuracy in the temperature measurement up to 0.1° C and can be used for a wide range of temperature measurement.

Key words: V.C.O., sensor, bridge amplifier, integrator, timer, differential amplifier.

1. Introduction

In the present work, a voltage controlled oscillator (V.C.O.) circuit is designed and developed using nickel iron wire as sensor. The present instrument can be used to measure environmental temperature as well as in-cloud temperature during cloud seeding experiment. The V.C.O. in conjunction with a cavity type 1680 MHz transmitter tube (RCA 6562) can be used for the upper air temperature measurement in the altitude range up to 75 km.

2. Sensor

The sensing wire made of a nickel iron alloy 18 cm in length and 20μ in diameter, is stretched in a zigzag fashion between two thin nylon strings supported by two brass posts plated with nickel of 1 mm in diameter. The sensor of the V.C.O. is shown in fig. 1 The platinum resistance thermometry is employed in determining the temperature surrounding the sensor[1]. The resistance of the sensing wire increases with temperature as shown in fig. 2. The temperature on the sensor scale t_{pt} can be defined by the following relation

$$t_{pt} = \frac{R_t - R_o}{R_{100} - R_o} \times 100 \qquad (1)$$

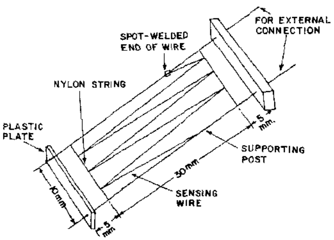

FIG 1. Sensing wire mount used in V.C.O.

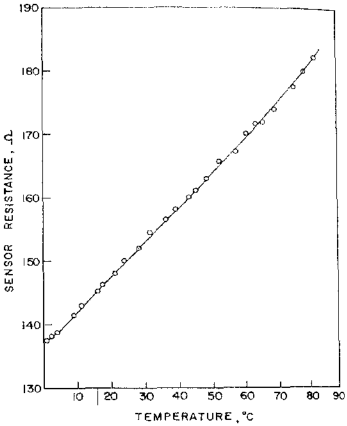

FIG 2. Temperature resistance variation of the sensing wire.

where R_o is the sensor resistance at 0° C

R_{100} is the sensor resistance at 100° C

and R_t is the sensor resistance at t° C the temperature to be measured

The sensor scale of temperature is converted into centigrade scale of temperature by the following relation[2]

$$(t - t_{pt}) = \delta \{(t/100)^2 - (t/100)\} \qquad (2)$$

where δ is a constant for our sensor. The method of successive approximation is applied in eqn. (2) to determine the value of t.

3. Electronic circuit

The electronic circuit essentially consists of a bridge amplifier followed by a voltage-controlled pulse generator. The sensor R_s is kept in one arm of the wheatstone bridge as shown in fig. 3. R_2 and R_3 are each 3.312 K-ohms precision resistances and R_1 is a 100 ohms precision resistance. The unbalance voltage of the wheatstone bridge is amplified by an operational amplifier (LM 741). The operational amplifier is used as a differential amplifier as shown in fig. 3. The gain of the present differential amplifier is 32.0. The input differential voltage of the operational amplifier is

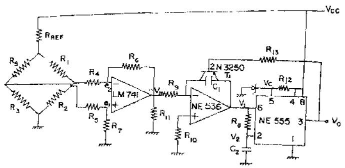

FIG 3. Electronic circuit for V.C.O.

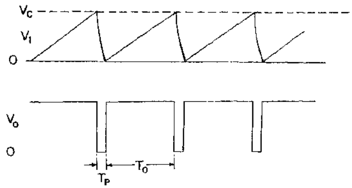

FIG 4. Wave forms at various locations in the voltage-controlled oscillator.

$$(e_2 - e_1) = -\frac{V_m}{G}$$

where $G = \frac{R_6}{R_4} = \frac{R_7}{R_5}$ is the gain of the amplifier.

and V_m is the output voltage of the differential amplifier.

Numerically from fig. 3.

$$(e_2 - e_1) = \frac{V_{RE}}{(R_1 + R_2)} R_2 - \frac{V_{RE}}{(R_s + R_3)} R_3 = \frac{V_m}{G}$$

Where V_{RE} is the D.C. voltage across the wheatstone bridge.

Thus $$\frac{V_{RE}}{(R_s + R_3)} R_3 = \frac{V_{RE}}{(R_1 + R_2)} R_2 - \left(\frac{V_m}{G}\right)$$

$$R_s = \frac{V_{RE}\, R_3}{\left[\frac{V_{RE}}{(R_1 + R_2)} R_2 - \frac{V_m}{G}\right]} - R_3 \tag{3}$$

Equation (3) is used to determine the sensor resistance R_s, when V_m is known.

The output of the bridge amplifier is connected to an integrator which is constructed with the help of an NE 536 operational amplifier. The integrator circuit is constantly attempting to drive its output high and produce a ramp generator of the following relation

$$V_1 = \frac{V_m}{R_9 C_1} \int dt \tag{4}$$

whenever V_1 rises to V_c, the control voltage of the timer (NE555), the threshold input of the timer (Pin 6) causes the output terminal to drop to the low state. But this output terminal is attached to the base of a P.N P. transistor (type 2N3250). A low voltage at this point turns the transistor on, discharges the condenser C_1 completely and lower V_1 to approximately zero. The timer trigger voltage (Pin 2) attached to the threshold terminal through R_8, also slews downward. When the trigger terminal drops to $V_c/2$, the timer output changes to high state (fig. 4). This turns the transistor T_1 off and charges the condenser C_1 again. The process is repeated and an oscillation is generated in the circuit. Figure 4 shows the nature of the output wave form. The R_8C_2 delay network is required so that trigger action does not occur until C_1 is fully discharged. This requires that $R_8C_2 > R_{ON}C_1$ where R_{ON} is the on resistance of the transistor T_1.

The width of the low state output pulse as indicated in fig. 4 is

$$T_p = 0.7\ R_8C_2 \tag{5}$$

The high state output pulse width can be written directly from eqn. (4) as

$$T_a = \frac{V_cR_9C_1}{V_m} \tag{6}$$

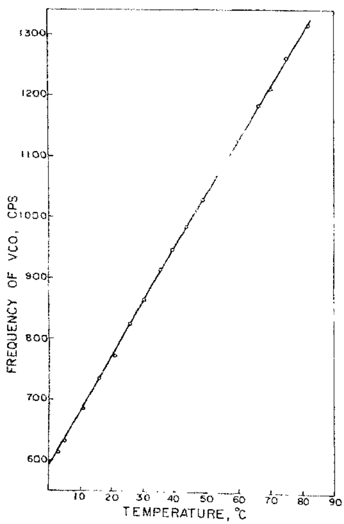

FIG 5. The linear calibration of V.C.O.

The frequency of oscillation of V.C.O. is

$$f_o = \frac{1}{(T_a + T_p)} = \frac{1.0}{0.7\ R_8 C_2 + \left[\frac{V_c R_9 C_1}{V_m}\right]} \quad (7)$$

Equation (7) is used to measure the bridge output voltage V_m directly from the observed frequency f_o of V.C.O. The value of sensor resistance at that instant is computed directly from eqn. (3), knowing the value of V_m. Finally eqns. (1) and (2) are employed to measure the corresponding temperature.

4. Calibration

An example of our sensor resistance variation with temperature is shown in fig. 2. The resistance of the sensor can be expressed as a quadratic equation of the sensor temperature[1]. The V.C.O. is calibrated using standard thermometer in the temperature range from 0 to 80° C. Table I shows the data obtained during calibration of V.C.O. Figure 5 shows the linear calibration of V.C.O. The temperature frequency relationship is linear over the entire range of temperature measurement.

Table I

Data during calibration of V.C.O.

Frequency recorded at the output of V.C O in C P S	Computed bridge output voltage V_m in volt	Computed resistance of the sensor in ohm	Computed temperature in °C	Temperature recorded in thermometer in °C.
612	2 174	137.595	2.810	1 9
632	2.245	138 820	4.950	4.0
685	2.435	142.123	10.739	11.5
735	2 615	145.242	16.194	16.0
772	2.779	148.098	21.234	21.0
825	2 940	150.899	26.158	26.0
865	3.083	153 399	30 574	31.4
914	3.260	156.492	35.854	36 2
947	3 379	158.579	39 730	40.0
986	3.521	161.054	44 109	45 0
1030	3 680	163 854	49.074	50 3
1102	3 879	167.340	55 264	56 6
1127	4 033	170.051	60.086	60.0
1183	4.236	173.649	66.498	67 7
1210	4.355	175 742	70.233	70.8
1260	4.517	178.616	75.369	78.0
1316	4 721	182.245	82.044	82 0

5. Conclusions

This method shows an excellent linearity in the entire range of temperature measurement. The method can be used over wide range of temperature measurement. The main sources of error in this instrument is the offset voltage of the operational amplifiers. The offset voltages are adjusted by using 10 KΩ preset potentiometers. Thermometer and sensor temperature are not exactly identical inside the oil bath container during calibration of V.C.O. as indicated in Table I. This is because the area of the wire sensor is larger than the thermometer bulb. However, when the environmental or in-cloud temperature is to be measured, the temperature over the entire sensor is more or less constant.

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