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A transistor relay circuit for radiosonde

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ABSTRACT. The audio-modulated radiosonde used in the India Meteorological Department utilises an electro-mechanical relay in its telemetering circuit. A transistor switching circuit which replaces this relay without requiring any modification in the radiosonde is described in this paper.

1. Introduction

The audio-modulated radiosonde used in the India Meteorological Department for measurement of upper air temperature and humidity consists of a switching circuit which transmits the data in a sequence. The switching action is performed by a miniature electro-mechanical relay operated by 6 volts D.C. The relay performance has to be reliable under all conditions encountered during the balloon ascent and launching. These relays are imported at present and no indigenous substitute could be found. A transistor switching circuit utilising indigenous transistors has, therefore, been designed to replace these relays. It has the advantage of not only eliminating the mechanical relay failures but also considerably reducing the battery drain. Moreover, this change results in reduction in weight and size of the sonde without increasing the cost. These are important factors in a balloon borne equipment. The transistor relay circuit does not require any modification in the existing radiosonde including the sensors, telemetry circuit and other components so that the procurement, production as also the receiving and evaluation procedures are not affected.

2. General description

The radiosonde is released with a hydrogen filled balloon with an ascension rate of 18-20 km/hr. The balloons attain heights upto 30 km and the instrument is subject to temperature changes from +40° to −80°C, pressure changes from 1020 to 5 mb and humidity changes from 0 to 100 per cent R.H. In addition to above, all the components used in the radiosonde have to withstand the initial shock during the launching of the balloon. The radiosonde measures pressure, temperature and humidity during the ascent and also transmits these data. The principle of the system is illustrated in Fig. 1. Thermistors and hygristors are used for the measurement of temperature and humidity respectively. The resistance characteristics of these sensors are according to a specified standard curve. A fixed resistor, the value of which does not change with the changes in meteorological parameters during the sounding is used as a reference to help compensate against any drift in the characteristics of the electronic circuits both in the balloon-borne and ground equipment. An aneroid is used for the measurement of pressure. It moves a pen on a commutator consisting of alternate conducting and insulating segments. When the pen rests on any insulating segment on the commutator, the thermistor is connected to the modulator and temperature data are transmitted. The modulation frequency changes over the range 157-13 cycles/sec with changes in resistance of the thermistor over the temperature range +40° to − 80°C. When the pen rests on a conducting segment on the commutator, either the reference resistor gets connected to the modulator or as in the present radiosonde system an electro-mechanical relay is energised and hygristor gets connected to the modulator through the realy change over contact. Reference or humidity data are thus transmitted. The fixed resistance which is connected through every fifteenth contact on the commutator produces a reference modulation frequency of 194 cycles/sec called the 'high reference frequncy' while at every fifth contact (except every fifteenth contact), in conjunction with another fixed resistance, it produces a modulating frequency of 190 cycles/sec which is called the 'low reference frequency'. The change in resistance of the hygristor due to changes in humidity over the range 15 to 100 per cent R.H. varies the frequency of modulation over the range 10 to 185 cycles/sec. The radiosonde relay operates at a voltage ranging between 7·5 and 6 volts D.C. and draw about 20 mA current. The relay with its associated circuit components weighs about 50 gm and is illustrated in in Fig. 2(a). The transistor

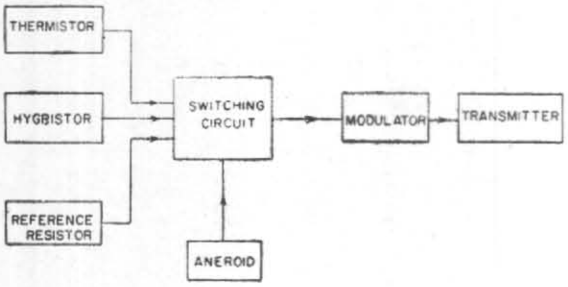

Fig. 1. Block diagram

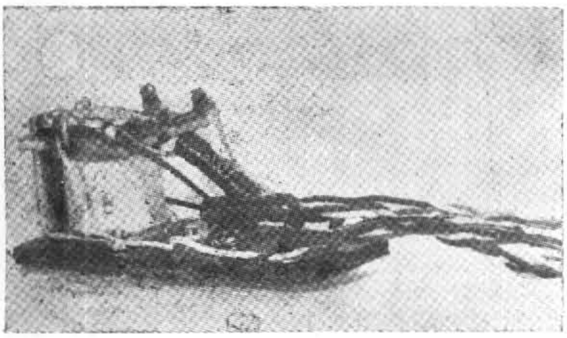

Fig. 2(a)

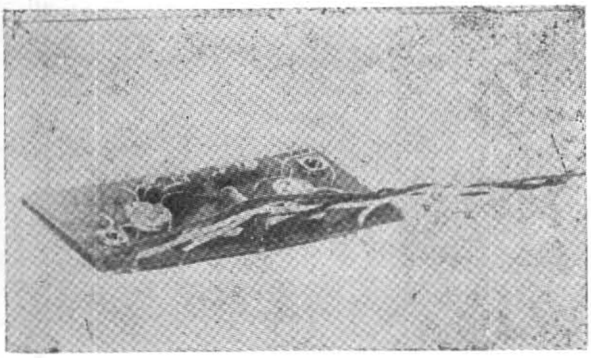

Fig. 2(b)

switching circuit described below performs exactly the same functions through the aneroid operated pen and commutator as the change-over mechanical contacts of the relay. The circuit does not interfere with the frequency of modulation under all the conditions encountered during the balloon ascent. The resistance-frequency characteristics of the modulator circuit are thus unaffected. As already stated, the same thermistors and hygristors as in the present radiosonde are used and the evaluating procedure for determining temperature and humidity from the transmitted data needs no modification. The current drawn by the transistor circuit is less than 5 mA at 7·5 volts. With its associated components, it weighs about 20 gm and is illustrated in Fig. 2(b). The power at 7·5 and 1·5 volts required in the circuit is supplied by the filament batteries of the transmitting and modulating tubes respectively.

3. Transistor relay circuit

The complete circuit diagram of the audio-modulated radiosonde using the transistor relay is illustrated in Fig. 3. The modulator is a blocking oscillator. The period of blocking is determined by the condenser C_1 and the resistance in the grid circuit of the modulator tube type 5875 through which the condenser discharges. Whenever the pen rests on a High Reference contact the condenser C_1 discharges through the fixed reference resistor R_1, and the frequency at which the blocking oscillator pulses are produced is 194/sec. When the pen rests on a Low Reference contact, the total resistance in the discharge path of the condenser C_1 is increased to $R_1 + R_2$ and the period of blocking between the pulses is increased such that the frequency of pulses becomes 190/sec. It is when the pen is resting either on the insulating portion or on the humidity contact of the commutator that the transistor relay circuit becomes operational for transmission of meteorological data. The circuit ensures that either the thermistor or the hygristor (in parallel with 1·2 Megohm resistor which prevents generation of very low frequencies that cause motorboating in recorder) is connected in series with fixed resistors R_1 and R_2 in the discharge path of condenser C_1 and the blocking rate depends either on the resistance of the thermistor alone or the resistance of hygristor alone.

The transistor relay circuit consists of four transistors. The transistors T_1 and T_2 perform the switching action through the pen contact. Low cost switching transistors type 2N404 have been employed. Transistors T_3 and T_4 which are in series with thermistor and hygristor respectively ensure that one presents an effective short circuit while the other practically an open circuit. Transistors type 2N869 which are also low cost and have a collector cut-off current I_{CBO} of only 10 nA max, have been used for the purpose. When either of the transistors T_3 or T_4 is conducting, the resistance across its collector and emitter terminals which appears in series with the thermistor or hygristor element, is of the order of 50Ω. This is negligible when compared with even the minimum value of resistance of thermistor or hygristor element used in the radiosonde

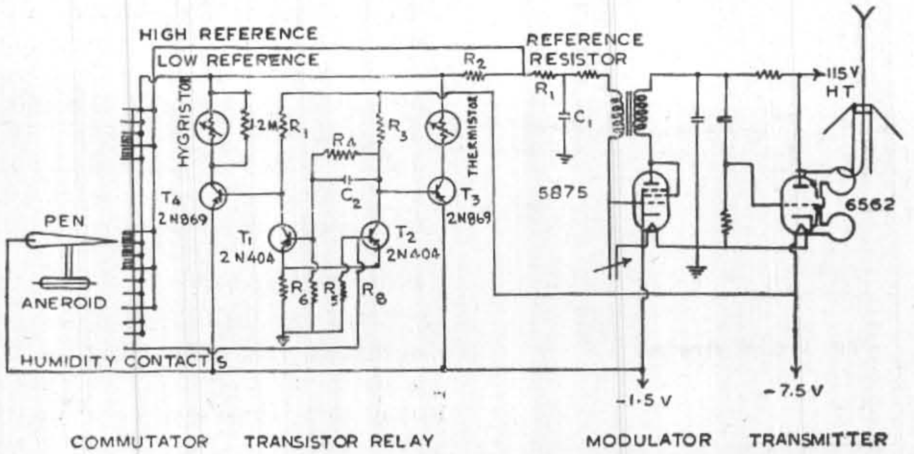

Fig. 3. Circuit diagram

which under the extreme operating conditions is greater than 10KΩ. The normal operating range is 14 to 500 KΩ. In the quiescent condition of the switching circuit, transistor T_1 is in saturation while transistor T_2 is held at cut-off. The base of transistor T_1 is provided with a negative potential with respect to the emitter through the voltage divider network consisting of resistors R_3, R_4 and R_5. The emitter-base junction is thus forward biased. The flow of current from the emitter of transistor T_1 through the common-emitter resistor R_6 maintains the emitter of transistor T_2 at a negative potential with respect to its base. The emitter-base junction of transistor T_2 is thus reverse biased. The collector current of transistor T_1 through the resistor R_7 causes a voltage drop such that the base of transistor T_4 is provided with a positive potential with respect to its emitter. Transistor T_4 is thus cut-off and I_{CBO} being extremely small, collector to emitter is effectively an open circuit. Transistor T_2 being cut-off, the voltage drop across resistor R_3 is very small and the base emitter junction of transistor T_3 is forward biased. While the transistor is in saturation, collector to emitter is practically a short-circuit. Thus, when the pen is resting on an insulating segment on the commutator, the thermistor is connected in series with R_1 and R_2 while the parallel circuit containing hygristor is open. The temperature data are then transmitted.

When the pen rests on a humidity contact on the commutator, —1·5 volts is applied to the base of swtiching transistor T_2 and it begins to conduct. The negative voltage at the collector of transistor T_2 starts to fall. This change in voltage is coupled to the base of transistor T_1 decreasing its forward bias. The collector current of transistor T_2 increases till it is in saturation. The voltage at the collector of transistor T_2 and the emitter current in this transistor through resistor R_6 cause a reverse bias in the emitter-base junction of transistor T_1. The collector current of transistor T_1 thus decreases till the transistor is cut-off. The change over in the states of the transistors T_1 and T_2 is fast because of the use of common emitter resistor. So long as the pen rests on the humidity contact on the commutator, transistor T_2 remains in saturation and transistor T_1 in cut-off condition. Transistor T_4 now simulates a short-circuit while transistor T_3 an open circuit. Hygristor is thus connected in series with R_1 and R_2 and the parallel circuit containing thermistor becomes open. Humidity data are transmitted.

When the pen moves away from the humidity contact to the insulating segment on the commutator, the negative voltage is withdrawn from the base of transistor T_2, its collector current decreases till it is cut-off, while its collector voltage coupled to the base of transistor T_1 drives that transistor in saturation. This results in the switching of the states of transistors T_3 and T_4 and temperature data are transmitted again.

When the pen rests on a High Reference or a Low Reference contact transistors T_1 and T_3 are 'on' and transistors T_2 and T_4 are 'off' but so far as the modulator is concerned, the transistor relay circuit is short-circuited.

4. Relay Performance

The transistor relay circuit performance was tested in Laboratory and its resistance—audio-modulation frequency characteristics were determined. Different values of standard resistances

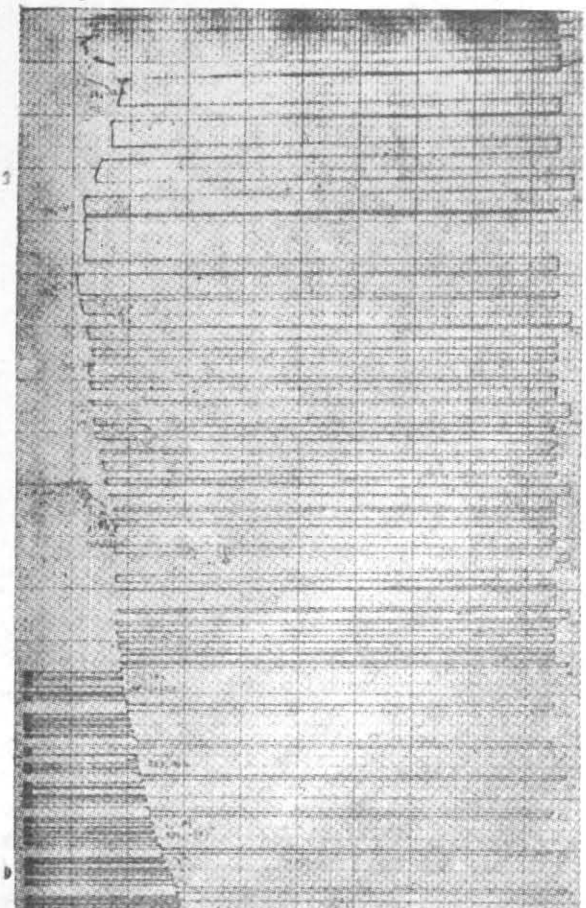

Fig. 4

Record of trial ascent made at 1415 IST on 15 January 1968 at New Delhi

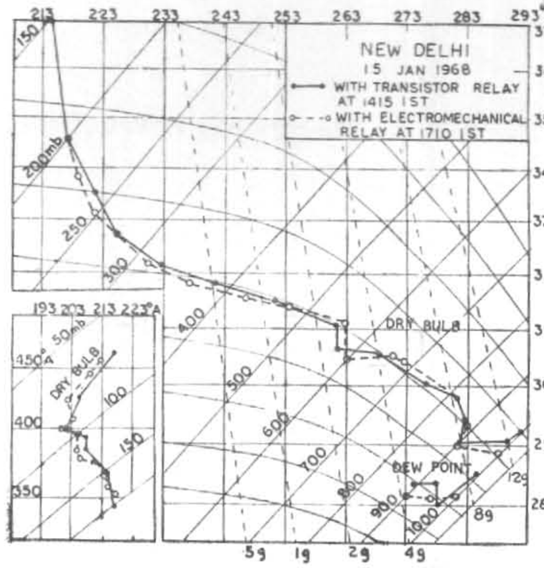

Fig. 5

were connected in the arm meant for thermistor and a variable resistance in place of hygristor. The frequencies of modulation were found at extreme values of the variable resistor. The process was repeated by interchanging the positions of standard and variable resistances and at battery voltage reduced to 5·5 from 7·5 volts and also at low temperatures. This was done because towards the end of balloon ascent, the battery voltage is liable to fall in all the cases, the audio frequencies were found to be according to the specified value for the particular standard resistance.

5. Performance in actual balloon sounding

The transistor relay was used in radiosondes. The record obtained during the first trial sounding made on 15 January 1968 at 1415 IST is illustrated in Fig. 4. The frequencies depicting temperature, humidity and reference data have been indicated in the record. The data computed from the record have been plotted on the T-ϕ gram illustrated in Fig. 5. This indicates the dry bulb and dew point temperatures at various levels in the atmosphere. The data obtained from the routine sounding made three hours later at 1712 IST using the conventional relay have also been plotted on the same T-ϕ gram. The agreement between the data proves that the performance of the transistor circuit in radiosondes is satisfactory.

Records from a large number of subsequent trial soundings show similar results. It is now proposed to introduce this relay in routine radiotrnde ascents at departmental observatories.