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## SOLID STATE SWITCH FOR RADIOSONDE SENSORS

1. Electromechanical relay had been in use for the last two decades in radiosondes to switch temperature and humidity sensors to telemetry system in conjunction with the baroswitch. The electromechanical relay had inherent problems of high rate of failure and switching noise causing mutilation in the data reception. In this paper, design of a simple solid state switch using TTL IC (open-collector-quad-nand gate) and alternatively using C-MOS IC (bilateral analog switch) has been discussed which has successfully replaced the mechanical relay. The present solid state switch is a cheaper and reliable and found to work satisfactorily meeting all the stringent requirements of radiosonde measurements.

Balloon-borne radiosonde is a universal technique for the measurement of upper air meteorological parameters, viz., pressure, temperature, humidity and wind velocity up to a height of 35 km. As the radiosonde goes aloft with hydrogen filled balloon, the meteorological sensors, viz., thermistor and hygistor are switched in turn to intelligence converter, i.e., modulator through an electromechanical relay which is actuated by a pressure switch and 7.5 V battery. The electromechanical relay in radiosonde formed an important and vulnerable component of the radiosonde system. The failure of this component resulted in premature termination of radiosonde ascent and this contributed to the major percentage in the statistics of unsuccessful radiosonde ascents in the national upper air network. In view of the above, the Instrument Division (IMD) had undertaken the development of an alternate electronic switching device compatible with radiosonde system to replace the electromagnetic relay. In this paper, the details of the design and development of solid state switching device using TTL/C-MOS IC are discussed.

2. *Circuit description and working* — Fig. 1 shows the schematic circuit diagram of a switching device using a TTL/C-MOS IC for switching meteorological sensors, viz., thermistor and hygistor in conjunction with the baroswitch.

2.1. *Circuit using TTL ICs (open collector-quad-nand gate)* — Open collector-quad-nand gate TTL ICs (7403, 74LS03, 7438 & 74LS38) having the same pin configuration can be used for this purpose. The NAND gates are used as inverters. The resistance  $R_3$ , hygistor and thermistor are connected as load to the open collector output stages of gates 'a', 'b' and 'c' respectively. The input of gates 'a' and 'c' are connected to +5 V supply through a resistance  $R_0$  and also to one of the conducting segments, viz., hygistor contacts of the commutator plate of the pressure switch. The output of gate 'a' which is functioning as a simple inverter, is connected to the input of gate 'b'. The +5 V power for the IC is derived from 22.5 V supply of the transmitter using a resistance  $R_1$  and a zener diode (of 5.1 volts) combination.

The pen arm of the pressure switch which is connected to the ground, moves over the commutator plate with the decrease of atmospheric pressure, resulting in

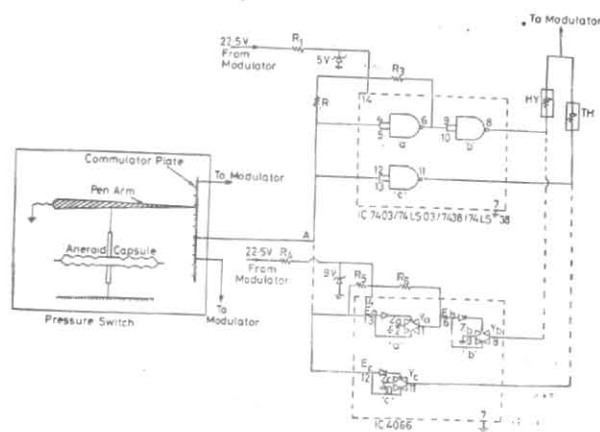


Fig. 1. Schematic diagram of solid state switching device

the change in input conditions of gate 'a' and 'c'. Whenever the pen arm rests over a conducting segment, prelocated for hygistor, the input is low. The output stages of gate 'b' and 'c' become conducting and non-conducting respectively, thereby connecting hygistor and disconnecting thermistor from modulator circuit. Similarly, whenever the pen rests over a non-conducting segment of the commutator plate, the output stages of gates 'b' and 'c' become non-conducting and conducting respectively, thereby disconnecting hygistor and connecting thermistor into modulator circuit. When the pen arm rests over the reference contacts, the modulation input is directly grounded through point A shown in Fig. 1 and thus by-passes the switching circuit.

2.2. *Circuit using C-MOS IC (Quad-bilateral Analog switch)* — The similar circuit functioning has been achieved by use of a C-MOS IC 4066 which has four independent bilateral analog switches as shown in Fig. 1. Each has two input/output terminals Y & Z and an active HIGH Enable input. HIGH on the Enable input makes the switch conducting and a LOW makes it non-conducting. The resistance  $R_0$ , hygistor and thermistor are connected to terminals  $Y_a$ ,  $Y_b$  and  $Y_c$  respectively. The terminal  $Z_a$ ,  $Z_b$  and  $Z_c$  are connected to ground. The IC gets a fixed +9V supply derived from 22.5 V transmitter supply using a resistance  $R_1$  and Zener diode combination.

When the pen arm rests over a conducting contact, prelocated for hygistor, the Enable input to switch 'a' and 'c' becomes LOW, thereby making them non-conducting. The thermistor is thus open circuited and the switch 'c' get a HIGH at its Enable input  $E_c$  due to non-conduction in switch 'b'. This causes the switch 'c' to conduct and bring hygistor into circuit. The exactly reverse conditions are established when the pen arm rests over a non-conducting portion on the commutator plate. Input to the switching circuit becomes HIGH at switch 'a' non-conducting, which in turn makes the switch 'b' non-conducting, thereby hygistor goes out of circuit. At the same time, the switch 'c' is also in the conducting stage due to HIGH at Enable Input, thereby the thermistor is brought into circuit.

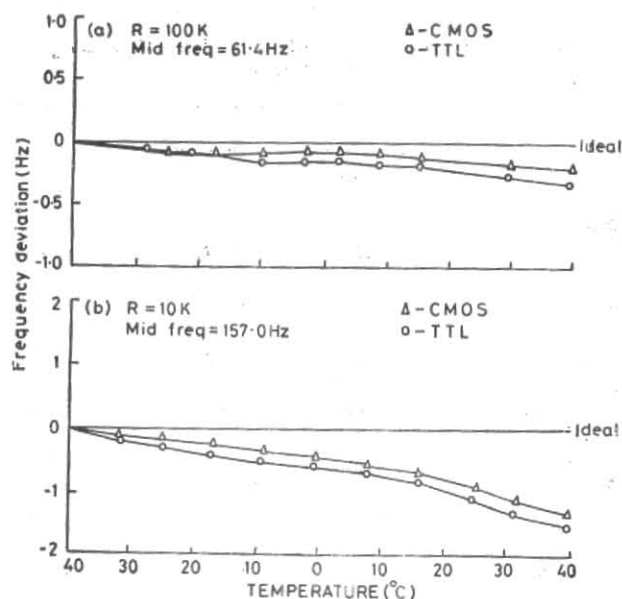


Fig. 2. Frequency deviation from standard modulator curve (a)  $R=100\text{ K}$  and (b)  $R=10\text{ K}$ .

3. *Discussion*—Introduction of any component in radiosonde system has to be viewed very critically for its reliability, cost, compatibility and performance under different environmental conditions. In this section, we will discuss these aspects of the present design in details.

The switching circuit is physically located inside the closed polystyrene compartment of radiosonde, the lowest temperature experienced by the switching circuit is  $-40^\circ\text{C}$  even though the environmental temperature is as low as  $-80^\circ\text{C}$  (Rao & Verma 1970). Hence, it may be worthwhile to investigate the effect of temperature in the range  $+50^\circ\text{C}$  to  $-40^\circ\text{C}$  on the characteristics of the switching circuit and in turn its contribution towards the measurement accuracies of the radiosonde.

For this purpose, switching circuit is placed inside an environmental chamber. Two fixed resistances of  $10\text{ K}$  and  $100\text{ K}$  ohms, typical representative of thermistor resistance at  $+50^\circ\text{C}$  and  $-40^\circ\text{C}$  respectively, are connected in temperature and humidity channels. Fig. 2 shows the effect of temperature on frequency characteristics of modulator. It is seen that up to  $-20^\circ\text{C}$  the frequencies remained practically unaltered. Beyond  $-20^\circ\text{C}$  a frequency change of about  $1.5\text{ Hz}$  (maximum) was observed for the value of  $10\text{ K}$  ohms. This decrease in frequency is due to the increase of forward switching resistance with the decrease of ambient temperature. One can translate the change in frequency in terms of change in series resistance utilising predetermined standard frequency resistance curve of the modulator. This is done and the forward switching resistance is found to be of the order of  $100\text{ ohms}$  at  $+30^\circ\text{C}$  and  $600\text{ ohms}$  at  $-40^\circ\text{C}$ . Since the resistance of thermistor is around  $14\text{ K ohms}$  and  $1\text{ Mega ohms}$  at  $+30^\circ\text{C}$  and  $-80^\circ\text{C}$  respectively, the percentage contribution of change of forward switching resistance which is of the order of  $100\text{ ohms}$  to  $600\text{ ohms}$  in this temperature range is negligible at a given temperature. This is evident as we could not observe any detectable frequency shift in  $100\text{ K ohms}$  resistance value.

Same argument is valid in case of hygristor also. This has been cross checked by using the switching circuit in actual radiosonde ascents and using fixed value of resistance in place of thermistor and hygristor. The results of these trial ascents also lead to the same conclusions as discussed earlier. These trials have been done on all the TTL/C-MOS ICs and the identical results are obtained.

In addition, in-built procedure of adjustment of reference values which occur in predetermined sequence in radiosonde ascent completely eliminates the possibility of errors in the measurement of meteorological parameters due to any small change in forward switching resistance values. Thus, it is concluded that the solid state switching device in the radiosonde does not vitiate the measurement accuracies of meteorological parameters.

It may also be argued that the utilisation of MIL specification ICs could have avoided the problem of temperature dependence, because of the greater temperature stability in the range  $-55^\circ\text{C}$  to  $+125^\circ\text{C}$  as compared to commercial version. The choice of commercial range ICs is justified because the indigenous availability of military range IC is doubtful and even if it is available, it would add considerably to the cost which is a very important factor where mass manufacture is involved. Moreover, from the earlier discussions it has been seen that the commercial range of ICs are able to meet all our requirements. Therefore, MIL range ICs were not considered necessary.

4. *Conclusion*—Unlike electromagnetic relay, the solid state switch is free from switching noise and time delay. In addition, once tested on the ground, the probability of its failure during ascent is negligible. This has considerably improved the quality of data reception and significantly reduced the rate of failures of radiosonde ascents. In addition, it is cheaper and easy to mass manufacture. This switching circuit is in operational use in the national upper air network for last few years and its performance has been found to be satisfactory.

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#### Reference

- Rao, P.R. and Verma, V.P., 1970, 'Temperature lag in aneroid compartment of A-Type Radiosonde', Tech. Rep. No. 179, India Met. Dep., New Delhi.

S. K. SRIVASTAV  
S. K. BINDRA  
M. K. GUPTA  
M. P. BHARDWAJ

India Meteorological Department,  
New Delhi  
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