

An instrument system for digital display of air and dew point temperature, wind direction and speed

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(Received 15 February 1973)

ABSTRACT The article presents an instrument system designed to provide a digital display of air and dew point temperature, wind speed and direction. Certain design aspects such as the sensors for the different parameters, the signal conditioning necessary for obtaining the correct digital display etc are discussed in some detail.

1. Introduction

The article presents an instrument system assembled at the Instruments Division, India Meteorological Department, Poona to provide a digital display of air and dew point temperature, wind speed and direction. It consists of the sensors for measuring the above parameters as well as a digital display console which can be removed from the sensors by using cables. The system has the following advantages.

(1) The information is displayed in the numerical easy to read form. This feature is very helpful when observations are to be made frequently and the inherent risk of the personal error of judgement in reading the indicating type meters etc is not there.

(2) The display console is compact and it does not require much space.

(3) The system provides the Binary Coded Decimal (BCD) outputs for the parameters and these outputs can be used for implementing the digital printout if necessary.

A photograph of the system appears in Fig. 1.

2. The sensors

(a) The temperature sensor

For temperature sensor a special type of multi-thermistor element, YSI Part No. 44202 manufactured by M/s Yellow Springs Instruments Co., Yellow Springs, Ohio, 45387, U.S.A. was chosen. This element can be used with the resistances R_1 and R_2 (as shown in Fig. 2 or Fig. 3) specified by the manufacturer. For the composite network shown in Figs. 2 and 3 the manufacturer gives

the following equations, which relate either the output voltage or the resistance of the respective network to the temperature of the multi-thermistor element, in a linear manner.

For the network of Fig. 2:

$$E_{out1} = (-0.0056846 E_{in}) T + 0.805858 E_{in} \quad (1)$$

$$E_{out2} = (-0.0056846 E_{in}) T + 0.194142 E_{in} \quad (2)$$

For the network of Fig. 3:

$$R_T = -32.402 T + 4593.39 \quad (3)$$

where T is in $^{\circ}\text{C}$

The range of the composite YSI Part No. 44202 is -5° to $+45^{\circ}\text{C}$. Similar elements utilizing 2 and 3 thermistors are also available for ranges -50°C to $+50^{\circ}\text{C}$ and 0°C to 100°C respectively. (YSI Part No. 44212 and YSI Part No. 44201). The composite device YSI Part No. 44202 has an absolute accuracy and interchangeability of $\pm 0.15^{\circ}\text{C}$ in both the voltage and the resistance modes with a load resistance 1 Meg or more. The time constant in free still air is 10 sec (in well stirred oil it is only 1 sec). The device is rated to operate with a thermistor dissipation constant of a $8\text{ mW}/^{\circ}\text{C}$ and this point should be given due consideration in the circuit used for signal conditioning.

In our design, YSI thermilinear composite (resistance mode) is placed in the feed-back circuit of an operational amplifier (Fig. 4). This mode is preferred over the voltage mode on account of its simplicity. Using the Eq. (3) which is of the form $R_T = R_0 - K_T T$, where T is in $^{\circ}\text{C}$ and

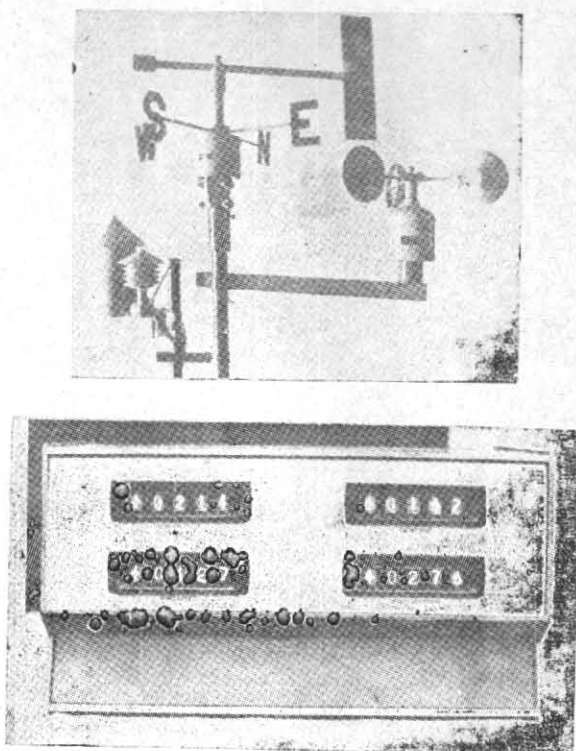


Fig. 1
Current weather sensors and the digital display panel

K a constant, the output E_0 of the circuit shown in Fig. 4 is easily determined as follows.

The output of the first stage, E_1 is

$$E_1 = \frac{E_{in}}{R_0} (R_0 - KT) \quad (4)$$

and the output E_0 is, therefore,

$$\begin{aligned} E_0 &= -(E_1 - E_{in}) R_3 / R_2 \\ &= \frac{E_{in}}{R_0} (R_3 / R_2) KT \text{ volts} \end{aligned} \quad (5)$$

i.e., E_0 is directly proportional to T in $^{\circ}\text{C}$.

By proper choice of E_{in} , R_2 and R_3 (*i.e.*, E_1 E_{in} should not exceed the maximum value consistent with the power rating of the thermilinear device) one can achieve the required slope E_0/T which would make the instrument direct reading when E_0 is measured on a digital voltmeter (DVM). Thus for the instrument to be direct reading from 0 to 50°C , let E_{in} be 2.0 volts,

and E_0/T be required to have a value $100 \text{ mv}/^{\circ}\text{C}$ say. Then from Eq. (5)

$$\frac{R_3}{R_2} = \frac{R_0}{K} \cdot \frac{1}{E_{in}} \cdot \frac{E_0}{T} = 0.05 (R_0/K) \quad (6)$$

The sensor output is thus conditioned to accomplish an accurate and direct reading instrument using any commercially available DVM. In the present design a dual slope integration type DVM described in a later paragraph was used (out of several makes available in Indian market, the one manufactured by M/s APLAB Ltd., Bombay was found very suitable after making some modifications, namely, the introduction of a hold circuit, provision for placing the decimal point in the digital display after any digit externally, repositioning of all the switches/controls to the back etc). The sensor is mounted in a radiation shield (Fig. 1).

(b) The dew point sensor

A dewcell is used as the dew point sensor. It makes use of the hygroscopic properties of the salt lithium chloride for the measurement of dew point through a unique temperature system,

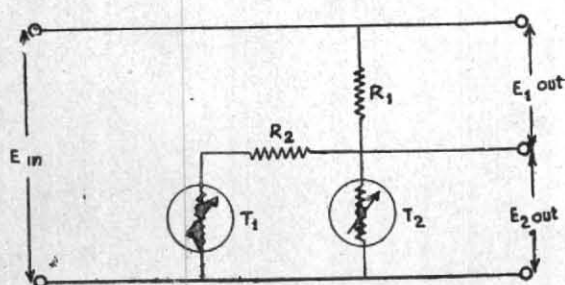


Fig. 2]

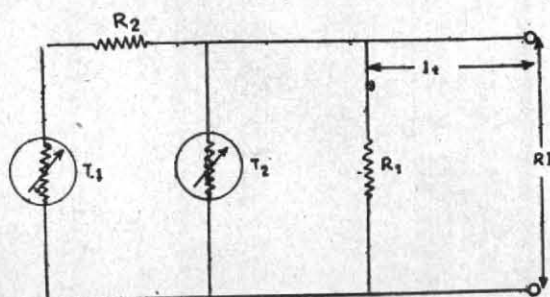


Fig. 3

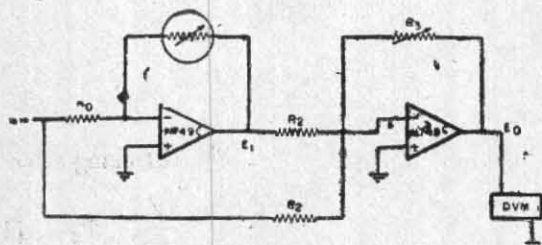


Fig. 4

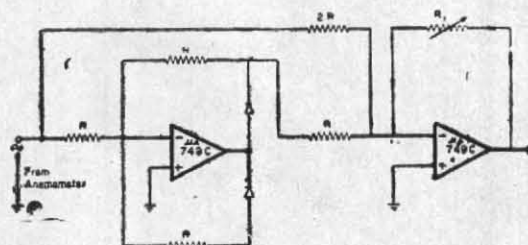


Fig. 5

The information relating to the construction and use of dewcel appears in the work reported earlier by Datar and Pakkir Mohammed (1967, 1970). In the present system instead of the ordinary thermistor the thermilinear-thermistor composite is used to sense the dewcel equilibrium temperature by utilizing a circuit similar to the one shown in Fig. 4.

For this purpose the thermilinear element (YSI Part No. 44201) having a range 0°C to 100°C was chosen.

For the normal usage, the dew point range -20°C to 50°C is considered adequate for all the Indian international airports. The ambient temperature range corresponding to the dew point range -20°C to 50°C is nearly 5°C to 105°C and once this is recognized, it follows that the signal conditioning becomes quite similar to that for temperature, as described in detail in the earlier paragraph. It must be mentioned that for obtaining improved results by way of stable instrument performance and high accuracy, good quality operational amplifiers should be used for circuit of Fig. 4. These should have a very low drift and possess all the other merits which one usually associates with high performance grade operational amplifiers. In the system described, $\mu\text{A} 749\text{C}$ served well.

(c) The wind speed sensor

A conventional 3 cup, cup-generator type anemometer is used as the wind speed sensor. The AC output of the anemometer is 'hard limit' rectified by the circuit shown in Fig. 5. This has the advantage that it provides a very linear output scale for the wind speed in contrast with the common rectification by a diode bridge which gives a nonlinear output characteristic for lower inputs, *i.e.*, low wind speeds. The hard limiting action is quite clear from Fig. 5 where the output is seen to be $-e$ irrespective of whether the input voltage is $+e$, when the feed back resistor $R_1 = 2R$. The value of the feedback resistor R_1 can be varied to provide necessary scale factor, to match this output to the DVM to accomplish a direct digital display of the wind speed. Also, the wind speed sensor works practically unloaded on account of the high input impedance of the OP-amps used ($\mu\text{A} 749\text{C}$).

(d) The wind direction sensor

A windvane with its shaft driving the contact arm of a linear potentiometer is used as the sensor for wind direction. The linear potentiometer is wire wound type. The resistance wire is uniformly wound on a cylindrical former to cover almost 360° with a very small gap (1°)

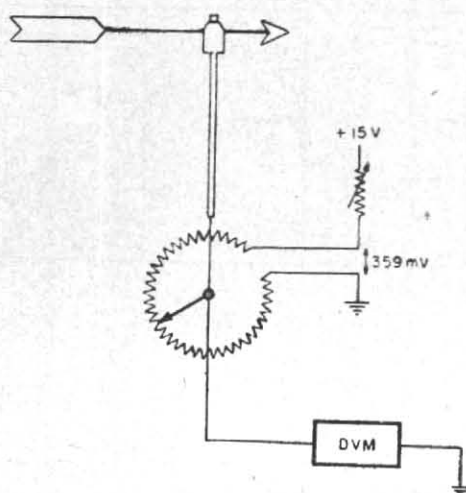


Fig. 6

and a DC voltage of 359 mV is applied between its ends (Fig. 6). The output from the variable contact arm (which is driven by the wind vane) is directly fed to the DVM, and the arrangement provides a resolution of 1° in azimuth. The 359 mV is derived from the regulated 15V DC power supply by simple potentiometric division. Since the DVM has very high input impedance, this simple arrangement is quite adequate for the digital display of the wind direction.

2. The display

The display unit utilizes four dual slope digital voltmeters for simultaneous display of all the parameters (see Ref.). Their principle of operation is described briefly (Fig. 7 a,b). The input signal has been assumed -ve for simplicity. In Fig. 7(a) the points to be noted are the integrator, the zero crossing comparator, the counter, the reference voltage and the digital logic gate. The A/D conversion takes place in the following manner—with the reset pulse the flipflops of the binary counter are reset to zero. A zero in the last stage of the binary counter causes switch S_2 to open and switch S_1 to close, thus connecting the -ve input signal to the integrator. The condenser C_1 now starts charging from a -ve voltage towards a positive voltage and crosses 0 level. The moment the integrator voltage crosses zero, the comparator output goes LOW allowing the clock pulses through the NAND gate to the counter. During the interval T_1 the counter counts upto 0111 - - - - - 1 and on the next clock pulse the counter reading becomes 10000 - - - - - 0. Let the time be reckoned with reference to this instant. A '1' in the 1st stage of the binary counter

causes the switch S_2 to close and S_1 to open. This connects the reference voltage to the integrator and the condenser C_1 now starts discharging from a +ve towards a -ve voltage and in the process crosses the zero level at time T_2 , say. At this zero crossing moment the comparator voltage goes HIGH inhibiting the clock pulse to the counter. This completes one cycle and the cycle restarts with the next reset pulse.

With reference to Fig. 7(b), the output e_0 changes from $-T_1$ to 0 by

$$\Delta e_0 = + \frac{1}{RC} \int_{-T_1}^0 e_1 dt = \frac{-e_1}{RC} T_1 \quad (10)$$

where $e_1 < 0$

From 0 to T_2 the output e_0 (Fig. 7b) changes by—

$$\Delta e_0 = \frac{1}{RC} \int_0^{T_2} V_R dt = \frac{V_R}{RC} T_2 \quad (11)$$

Since these changes are both considered from the level of the first to the second zero crossing, their magnitudes are equal. Hence

$$\frac{V_R}{RC} T_2 = \frac{|e_1| T_1}{RC}$$

$$\text{i.e., } |e_1| = (T_2/T_1) V_R \quad (12)$$

Now suppose the counter has a maximum capability of N counts,

$$\text{Then } T_1 = N/f \quad (13)$$

where the clock has a frequency f . During this time, the condenser charges with a slope e_1/RC and hence at the time 0 (i.e., a period beginning at $-T_1$ and ending at 0) the condenser voltage becomes $(N/f) \times (e_1/RC)$. During the time from 0 to T_2 , the condenser discharges with a slope $-V_R/RC$ and hence the time T_2 for the condenser to discharge from $(N/f) \cdot (e_1/RC)$ volt to 0 volts is given by

$$T_2 = \frac{N}{V_R} \cdot \frac{e_1}{f} \quad (14)$$

In a typical DVM the count acquired by the counter in the time T_2 , for a frequency f should correspond to the value of the input voltage expressed in millivolts (say). In that case from Eq. (14), we have

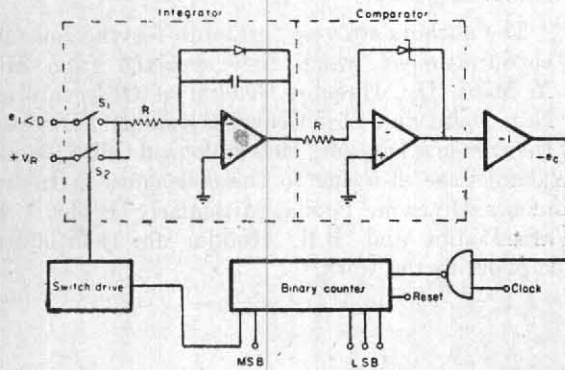


Fig. 7(a)
Block diagram of DVM

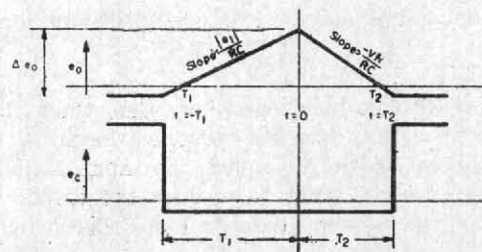


Fig. 7(b)
Timing diagram

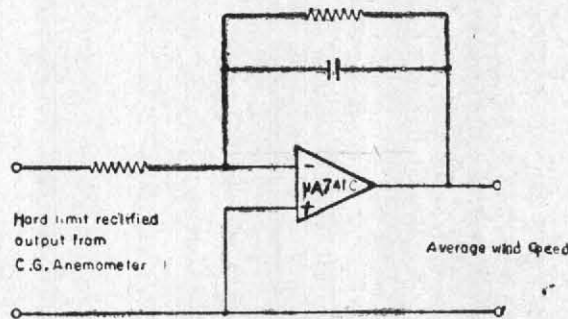


Fig. 8
Wind averaging

$$T_2 f = 1000 \frac{e_1 N}{V_R}$$

i.e., $V_R/N = 1/1000$ (14a)

Thus for example if $V_R=2$ volts, N becomes 2000.

Eqns. (13), (14) and (14 a) are included here to give some idea about the way a dual slope DVM works. The value of R , C and f are required to be chosen suitably for the lowest voltage to be measured and for obtaining good resolution. The long term drifts in these values do not affect the measurement significantly.

The small voltage and current offsets of the comparator do not cause any error because the zero is crossed twice.

4. Power supply

Conventional 220 V, 50 Hz mains and the derived ± 15 V and $+5$ V stabilized DC power supplies are used. The total power requirement for the system is less than 100 watts.

It is not difficult to alter or extend such a system by incorporating other digital displays for rainfall intensity, mean wind speed etc. Thus for example the mean wind speed could be approximated by feeding the hardlimiter output (Fig. 4) to an RC averaging circuit (see Fig. 8), in which the RC time constant is $\frac{1}{2}$ to $\frac{1}{3}$ of the averaging time. The output of this RC averaging circuit would then be displayed digitally as the mean wind speed. It would also appear easy at the first sight to incorporate still other parameters such as visibility, pressure etc in a system like the one described above. The linear sensors for those

parameters, however, are probably more complicated and not too well known or common at present.

The system was found to be very stable in operation and it operated satisfactorily for long periods.

It may also be mentioned here that when the number of input variables becomes large, it is probably easier to multiplex the input signals and use a single DVM to operate the displays. However the system described in this article

is more easily constructed and adequate for displaying a few parameters.

Acknowledgements

The authors are very grateful for the constant encouragement which they received from Miss A. Mani, Dy. Director General of Observatories, New Delhi and Shri George Alexander, Director, Instruments Division, Meteorological Office, Poona. Thanks are also due to the colleagues in Instruments Division, Poona particularly S/Shri C.R. Sreedharan and B.B. Huddar for their active support in the work.

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