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A simple system for continuous measurement of average wind speed and its digital display

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ABSTRACT. The paper describes a simple system for measurement of average wind speed at a remote place. The average wind speed is computed as frequently as desired by transistor binaries from the pulses received from a photo-transistor anemometer during each ten-minute interval and is registered on transistor decade units. Diode decoders transfer this figure to digital display tubes. The display on the indicating tubes is held through relays. The average wind speed is thus continuously displayed.

1. Introduction

It has been universally accepted that the average wind speed for aviation purposes should be the average taken over a period of ten minutes. Opinions, however, differ as to how often this average is required to be computed. Most of the present instruments measure the average wind speed only at discrete ten-minute intervals. The equipment becomes complex if the preceding ten-minute average is required to be computed more often than every ten minutes. It is generally believed that the requirements at most of the airports would be met if the preceding ten-minute average is determined every five minutes. The instrument described below has been designed to measure the wind speed at a remote place, automatically average it over ten-minute intervals and continuously display this averaged speed in digital form for five minutes, when the display changes to the average of the next preceding ten minutes. The technique used is simple and can be used for determining the preceding ten-minute average (or average over any desired interval) every minute (or any other desired frequency), without making the instrument very complex. For a meteorologist in the briefing room at the airport, the reading accuracy and conveniences of the remote digital display as compared to the indicating meters, are obvious. The accuracy of measurement in the system described depends only on the accuracy of the sensor.

2. Principle

The principle of the instrument designed earlier for measurement of wind speed at discrete ten-minute intervals is illustrated in Fig. 1.

The rotation of the anemometer cups generates electrical pulses by the use of a photocell and a light source, light being interrupted by a rotating perforated disc. The number of pulses generated per second are proportional to the speed of rotation of the disc which depends on the wind speed. It is assumed that the speed of rotation of the anemometer cups is directly proportional to the wind speed in the range of measurement. The pulses are fed through a gate unit, which consists of a gating tube and a switching circuit employing two binaries which open the gate for ten minutes during the start and stop pulses received from the timing unit. The pulses passing through the gate during this period are divided by the binary counters when the average wind speed is computed, which is registered on Decade Units. The count is decoded by a relay tree and displayed on numerical indicating tubes.

A transfer unit and a memory unit have to be incorporated between the registering and display units if the average wind speed has to remain displayed on the indicating tubes during computation of the next ten-minute average. The memory unit consists of a locking arrangement for the relays forming the tree. There is some time lag between the stop and start pulses to the gate unit during which period the gate is closed and the various operations of transfer, memory and reset are made. If the ten-minute average is to be computed every five minutes and displayed continuously, two additional parallel channels consisting of Gate, Computer, Register, Transfer and Memory units are required between the pulse shaper and indicating units as illustrated in Figs. 2 and 3.

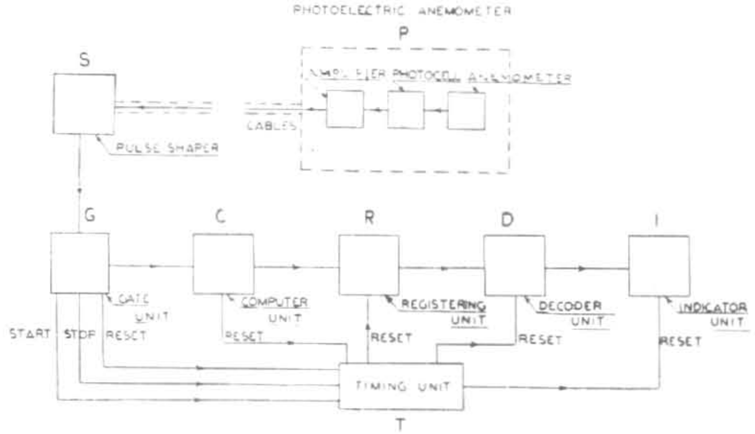

Fig. 1

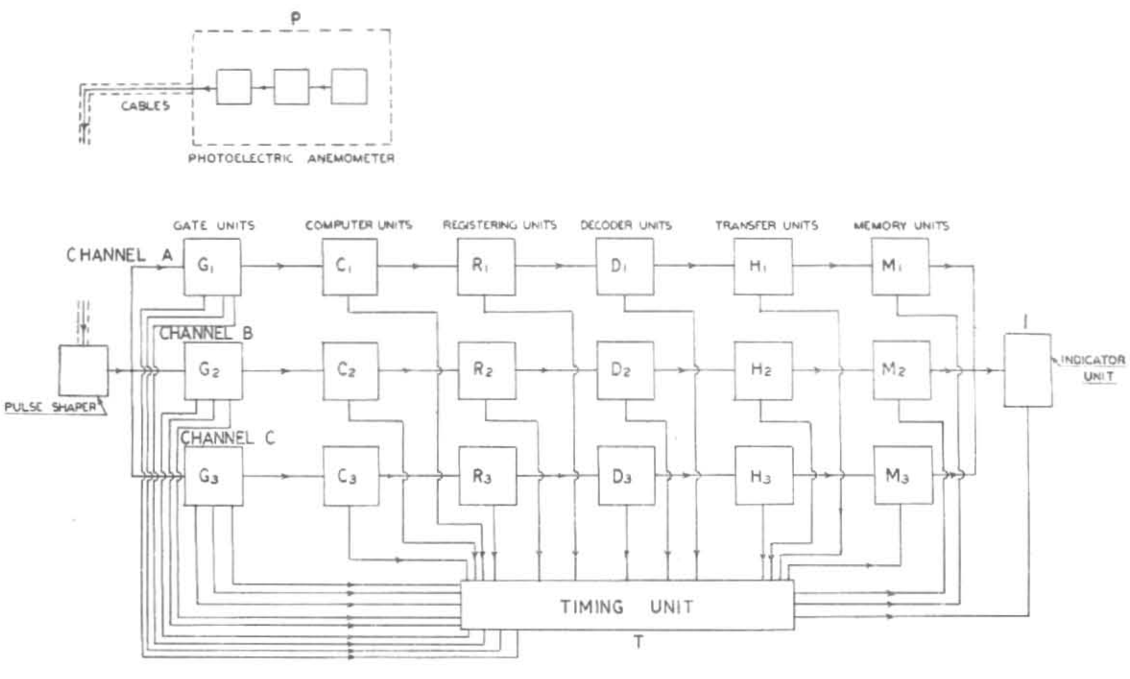

Fig. 2

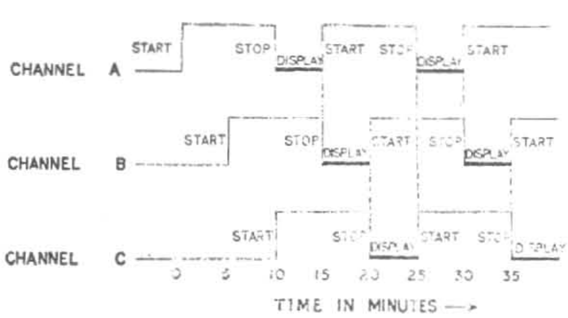

Fig. 3

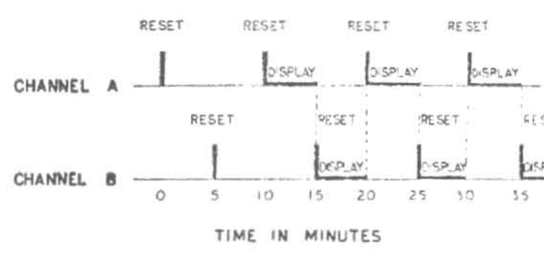

Fig. 4

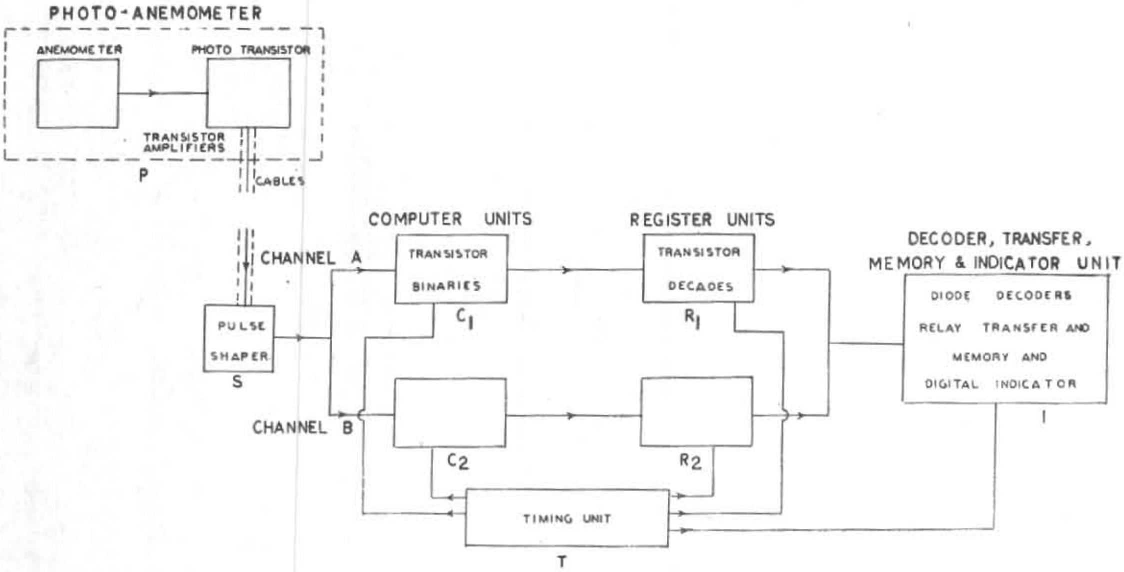

Fig. 5

The techniques used in the present system result in the following simplification —

(*i*) The gate unit is dispensed with. The function of the gate unit is done by the reset pulse itself on the respective computer unit.

(*ii*) No start and stop pulses are required from the timing unit.

(*iii*) The third channel is dispensed with. Only two computing channels are required for the continuous display as the gap between the stop and start pulses in Fig. 3 is reduced to a momentary reset pulse as shown in Fig. 4.

(*iv*) The functions of the transfer and memory units are combined in a simple way with the indicator unit.

(*v*) Simple diode decoders are used.

(*vi*) Photo-transistor and transistor amplifiers are used in the photo-electric anemometer dispensing with heavy power supply required when photocells are used.

(*vii*) General purpose low cost transistors are used as the maximum pulse frequency corresponding to 100 knots is of the order of 350 pps.

(*viii*) Equipment is completely transistorised, operating on the low voltage of 6 V.D.C. obtained through the mains A.C. supply and consumes only 1·5 W besides the indicator and anemometer bulbs which consume 5 W and the clock motor energised from the mains supply.

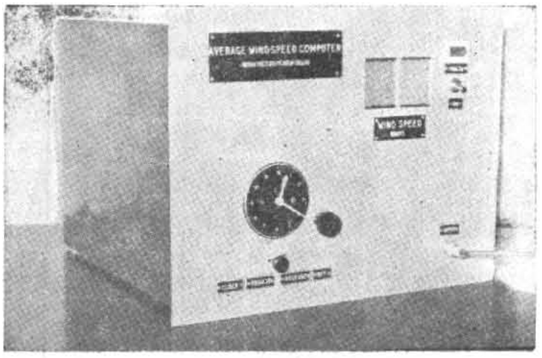

Fig. 6

The simplified system is illustrated in Fig. 5.

3. General description

The average wind speed is displayed on two projection type digital indicating tubes. The display changes every five minutes as indicated on the instrument clock. The clock is run by a mains operated synchronous motor. Time can be adjusted and the clock set so that computation of average wind speed can be started from any desired time.

Fig. 6 gives the front view of the instrument.

4. Description of circuits

(1) *Photoanemometer*

The photo-electric anemometer consists of a perforated disc fitted on a shaft which rotates

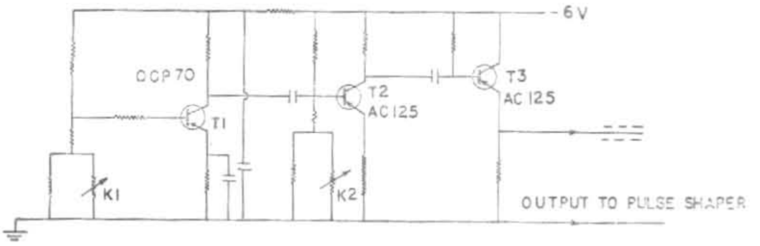

Fig. 7. Photo-electric Anemometer

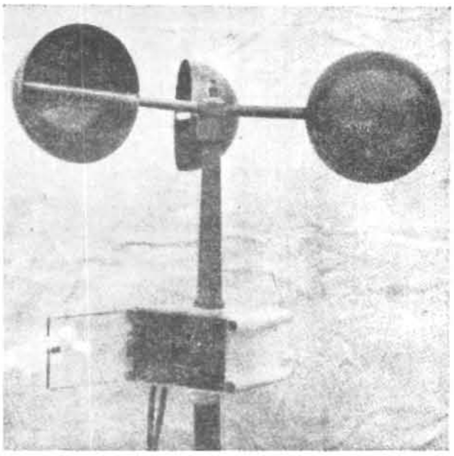

Fig. 8

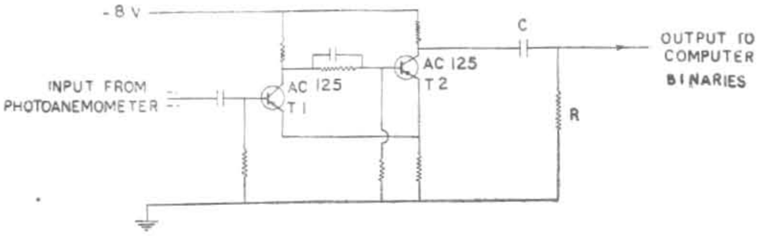

Fig. 9. Pulse Shaper Unit

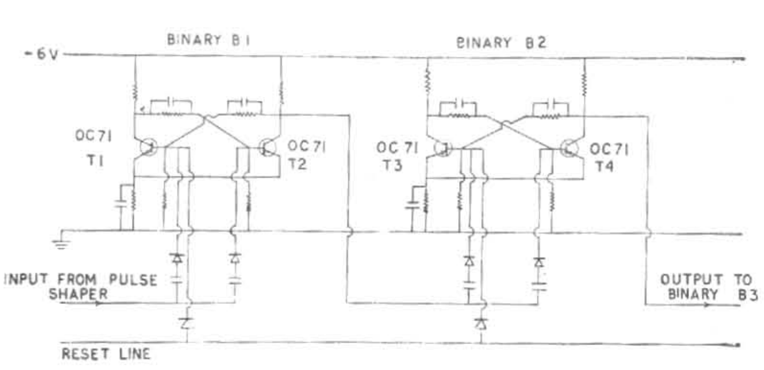

Fig. 10. Binary Dividers

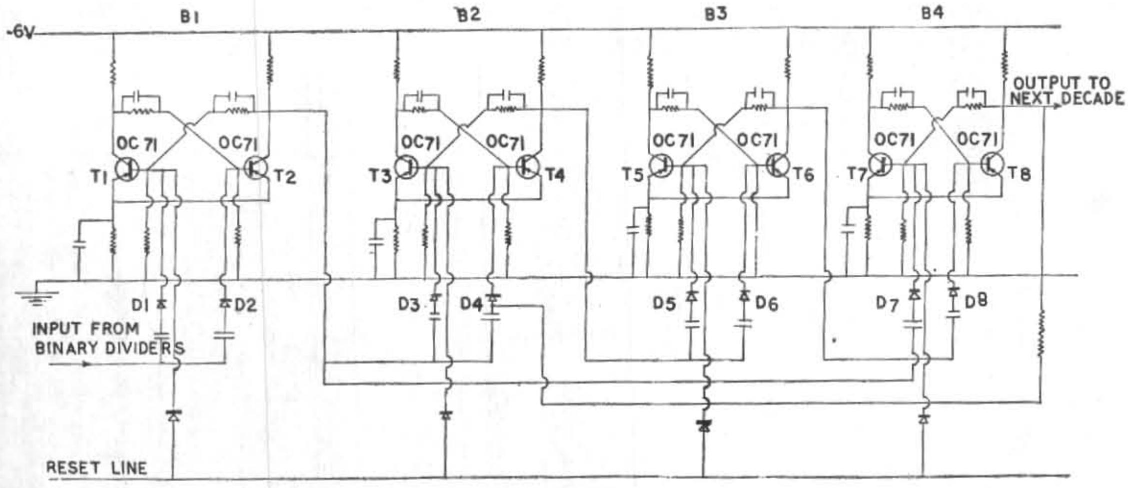

Fig. 11. Decade Register

with the anemometer cups. A light source (6V pilot lamp) is fitted on one side of the disc and photo-transistor OCP 70 on the other, such that the perforations permit the light beam to fall on the photo-transistor. The disc has 22 circular holes, the diameters of which are equal to the width of the gaps between them. The disc rotates due to wind and the output of photo-transistor is in the form of pulses (distorted sine waves), the number of which per second is proportional to wind speed. The photo-transistor and its associated amplifier circuits are illustrated in Fig. 7.

The pulses from T_1 are amplified by transistor T_2 and the output is taken through cables from the common collector amplifier T_3. Thermistors K_1 and K_2 are used in the base circuits of the transistors for temperature compensation. The whole unit consisting of light source, perforated disc, photo-transistor, amplifiers and power supply is housed in a small $4'' \times 4'' \times 3''$ chamber below the anemometer cups as shown in Fig. 8.

(2) *Pulse Shaper*

The unit consists of two transistors T_1 and T_2 forming a Schmitt Circuit shown in Fig. 9. When pulses of any shape and of amplitude greater than 1·5 V are received from the photoanemometer, they are converted into rectangular pulses in the output. The rectangular pulses are differentiated by the R. C. Circuit and the resulting positive and negative sharp pulses are fed to the two computing units.

(3) *Computing Unit*

The unit consists of 11 binary dividers in cascade. This division of pulses received from the photoanemometer during the ten-minute period between two resets, in conjunction with the 22 perforations on the rotating disc of the photoanemometer gives the average wind speed during the period for the particular anemometer used in the instrument. General purpose, low cost transistors type OC71 have been used in the binaries.

Two binaries in cascade are illustrated in Fig. 10. A positive pulse on the reset line causes the left hand sections of each binary to become non-conducting. The negative pulses received in the input of the binaries from the pulse shaper unit are ineffective. The first positive pulse through the steering diodes changes the state of binary B_1, when its left section (transistor T_1) becomes conducting. The second positive pulse brings it to the original condition, *i.e.*, right section conducting, when the voltage at Collector of T_2 rises from -6V to 0V and a positive pulse is produced in the output of B_1. This is fed to binary B_2 through its steering diodes, causing a change in its state such that the left section of B_2 becomes conducting. The third pulse changes the state of B_1 so that the left sections of B_1 and B_2 become conducting. With the fourth pulse both B_1 and B_2 return to the original condition and a positive pulse is fed to the next binary. For two positive pulses in the input of each binary there is one positive pulse in its output. Eleven binaries in cascade thus divide the pulses by 2^{11}.

(4) *Registering Unit*

The unit consists of two decade units in cascade. Each decade consists of four binaries similar to those used in computer unit. The conversion from the scale of 16 from the four cascaded binaries to the scale of ten is achieved through feed back as shown in Fig. 11. The counting proceeds in the

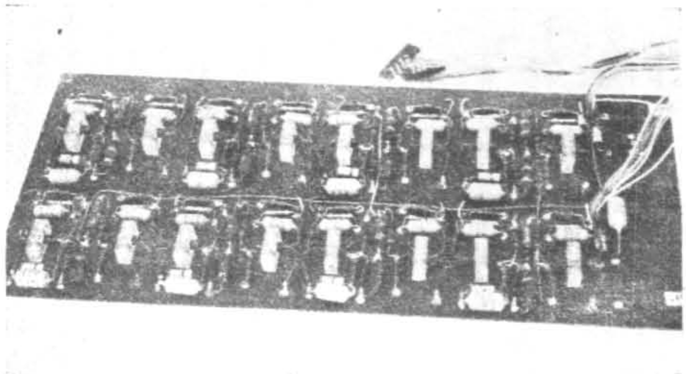

Fig. 12

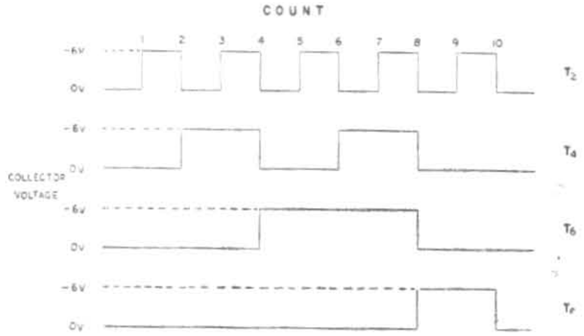

Fig. 13. Collector voltage of output transistors of Decade binaries for various counts (0V = conducting state)

COUNT	B1	B2	B3	B4
1	1	0	0	0
2	0	1	0	0
3	1	1	0	0
4	0	0	1	0
5	1	0	1	0
6	0	1	1	0
7	1	1	1	0
8	0	0	0	1
9	1	0	0	1
10	0	0	0	0

Fig. 14. Code Table

0 = Output transistor of binary conducting
1 = Output transistor of binary non-conducting

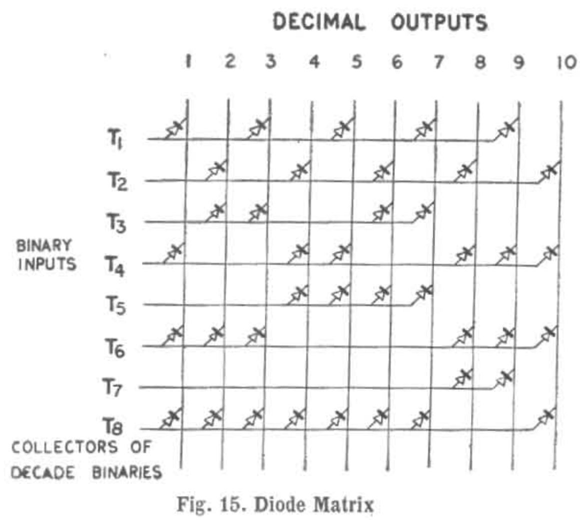

Fig. 15. Diode Matrix

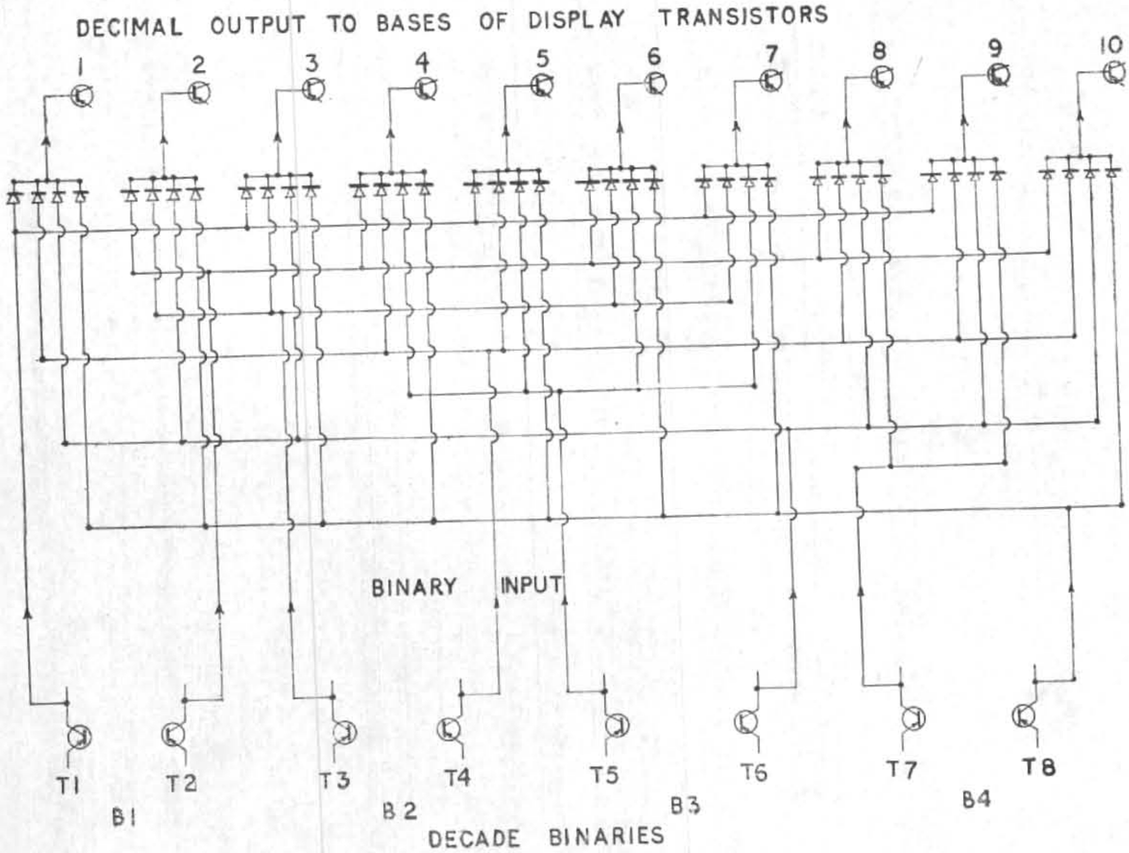

Fig. 16. Diode Decoder

normal manner till the eighth pulse which restores binaries B_1, B_2 and B_3 to their original condition and causes the last binary B_4 to change its state when diode D_4 in the second stage is biased to $-6V$. B_2, therefore, cannot change its state till the last binary is recycled. The ninth pulse makes the left section of B_1 conducting and the tenth pulse, while bringing B_1 to its reset condition, feeds a positive pulse to B_4 through diode D_7 causing the right section of B_4 to conduct. Thus ten pulses cause a complete recycling and produce an output pulse which is fed to the next decade unit. The second pulse cannot cause a change in state of B_4 since diode D_7 is coupled only to the left section which is already non-conducting at the time this pulse is received.

The number of pulses from the output of the computer unit between the two resets during ten-minute interval, represents the average wind speed and is registered as a count on the two decades. Fig. 12 gives a view of the Register Unit.

(5) *Decoder*

The average wind speed is registered on the decades as conducting and non-conducting states of the various sections of the binaries. The states of the binaries for different counts are illustrated in Figs. 13 and 14.

The diode matrix shown in Fig. 15 is based on the Code Table given in Fig. 14 and indicates the sections of the binaries (which are non-conducting) to which the diodes must be connected for the decimal output. This is illustrated in Fig. 16. Thus for the registered count of 5 on the decade (Fig. 11), the right hand sections of B_1 and B_3 and left hand sections of B_2 and B_4 are non-conducting and their collectors are at $-6V$. All the four diodes connected to these collectors will be reverse biased while at least one of the diodes of the other sets illustrated in Figs. 15 and 16 will be forward biased. Hence in the decoded output only the transistor representing the digit 5 will be conducting.

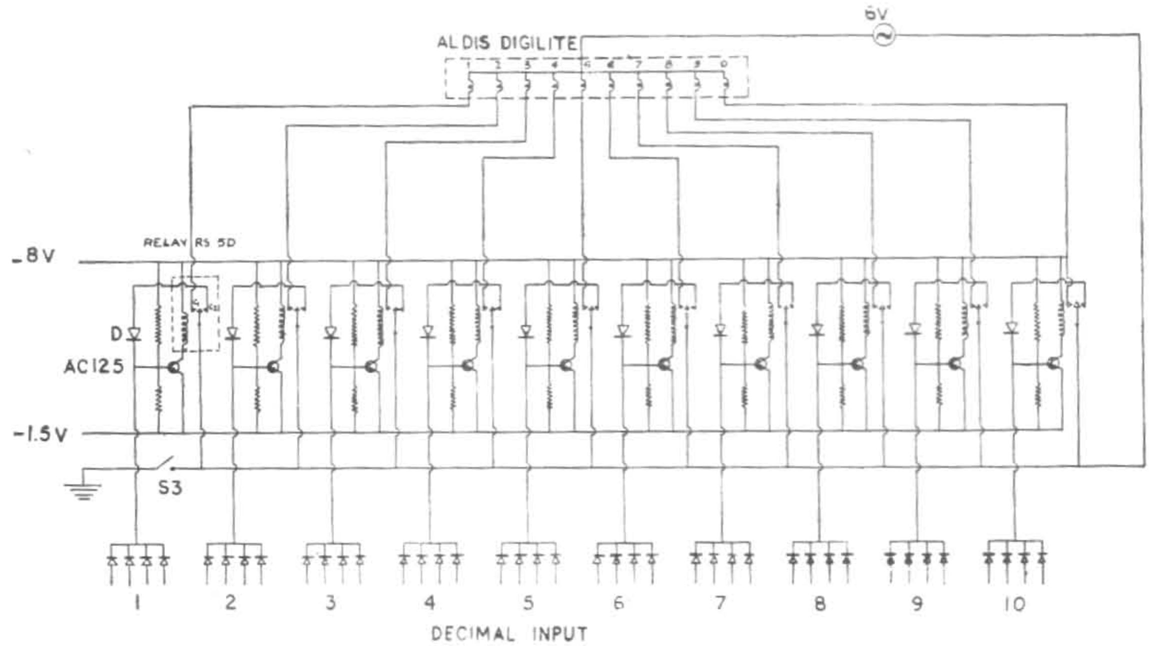

Fig. 17. Transfer, Memory and Indicator Circuit

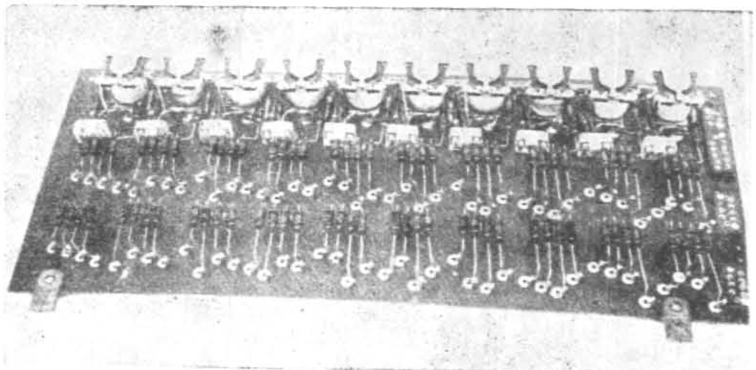

Fig. 18

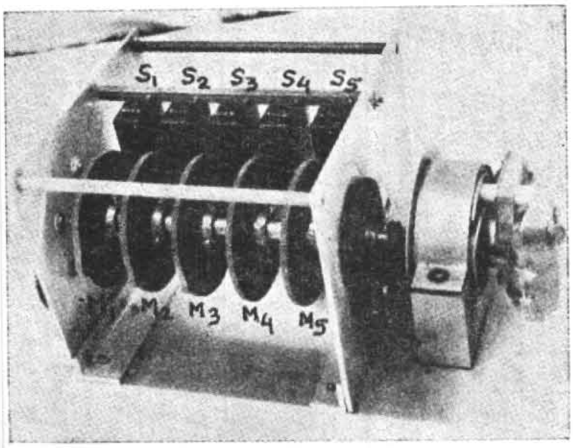

Fig. 19

Diode NAND logic is used in the decoder transistor circuit illustrated in Fig. 17 so that only if all the four diodes are non-conducting, the transistor is conducting.

(6) *Transfer, Memory and Indicator Circuit*

The circuit combining the functions of transfer, memory and indicator units is illustrated in Fig. 17. With the reset pulse of computer unit, the Register Unit is connected to the display transistors through the diode decoders. The display transistors are thus connected alternately to each channel every 5 minutes. While thus connected, the holding contact S_3 is momentarily broken, when the two transistors corresponding to the particular count registered on the two decades representing the average wind speed conduct. The wind speed is then displayed on the indicating tubes, which are energised through the relay contacts C_1. The Register Unit is now disconnected, when the two transistors which were conducting remain conducting since their emitter base junction is forward biased. The relay is thus locked. The relay, being in the Collector Circuit of the transistor, is energised when the transistor conducts and contact C_1 is made. When the relay is off, contact C_1 is broken and C_2 is made. The eighteen transistors which were non-conducting, remain so because their emitter to base junction is reverse biased through diode D and relay contact C_2. The speed is thus held displayed for 5 minutes till the next reset pulse in the second computer unit. The digital indication goes off momentarily during the change over unless the average speed remains constant. The decades are reset through a momentary pulse after the Registering Unit is disconnected from the Indicators. The reset of decade units takes place within 6 seconds of the reset of divider binaries so that no pulse is missed by these units for wind speeds upto 100 knots. In the circuit only two of the twenty output transistors conduct at a time while 18 remain non-conducting. The miniature relay with a change over contact used in the circuit operates on 6 V and consumes only 20 mA and combines the functions of transfer and memory circuits besides energising the indicator circuit. The display tubes are projection type digital indicators using multiple bulbs, one each for illuminating each digit. Only one bulb in each of the two display tubes is energised at a time. The bulbs of the digital indicators are energised by 6V AC from the mains. The bulbs corresponding to particular digits representing wind speed are connected to the power source through the relay contact C_1 in the respective transistor circuit. Fig. 18 gives a view of the combined decoder, transfer, memory and indicator unit.

(7) *Timing Unit*

The unit illustrated in Fig. 19 consists of a synchronous motor operated from 220 V, 50 cycles mains supply. It operates the clock and drives 5 cams which are mounted on the same shaft. Each cam operates a microswitch which makes contact for short duration. The shaft makes one rotation every ten minutes. Cam M_3 which operates the display microswitch S_3 makes two contacts every cycle while the others operate only once every ten minutes.

The operation of the first microswitch S_1 applies a positive pulse to the reset line of its computer unit. The binaries of the Computer Unit thus start receiving the pulses from the anemometer afresh from the zero state while the count on the decades is maintained. Microswitch S_2 connects the registering unit of channel A to the indicator unit. While S_2 is on, microswitch S_3 operates, when the holding contact is momentarily broken and the count is transferred to the indicating tubes and held through contacts S_3, C_1 and C_2 (Fig. 17). When the contact S_2 breaks, it feeds a momentary positive pulse to the reset line of the decades. This happens before any pulse in the new cycle can reach the decades from the dividing binaries. After 5 minutes the above sequence is repeated through cams 4, 5 and 3 which connect the Register Unit of Channel B to the Indicator Unit. Average wind speed thus computed from each channel is alternately displayed.

5. Performance

The performance of the instrument has been tested by illuminating the photo-transistor by a modulated light source. The equipment responds satisfactorily over the entire range from 1 cps to 340 cps corresponding to wind speeds of 0·3 knot to 100 knots. The reset pulse fed to the binary dividers in the computer unit, in addition to its other functions, produces an extra pulse which is fed to the decades in the Registering Unit if the last binary of the Computer Unit had changed its state before the reset. This means that the count on the Register Unit representing the average wind speed, before it is transferred to the indicators, is advanced by one unit in case the fractional wind speed computed is $\geqslant$ 0·5 knot. The accuracy of the average wind speed computed is thus $\pm$ 0·5 knot.

The techniques described above can be used in the design of instruments for the measurement of average wind speeds over any desired range and to any desired accuracy. The accuracy and sensitivity of the instrument depends only on the response of the anemometer and the linearity of its speed of rotation with the wind speed in desired range.

6. Acknowledgements

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