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A high-resolution electronic rainfall intensity recorder and totaliser

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ABSTRACT. An electronic distant-reading rainfall intensity recorder capable of measuring minute-to-minute values of the intensity of rain and recording them on a strip-chart recorder has been designed and constructed at the Instruments Division of the Meteorological Office, Poona. The system measures the intensity of rainfall by converting rain water into drops of equal size and counts the number of drops by an optical-cum-electronic device. The number of counts during every minute interval which constitutes a measure of the intensity of rainfall are recorded on a conventional strip-chart recorder. To measure the total rainfall during any given interval of time, an additional mark is printed on the chart for every 1 mm of rainfall. The system which has a resolution of 1/2 mm of rain/hour has been tested during several spells of rainfall at Poona and found to record quite accurately.

1. Introduction

A knowledge of the fine structure of the intensity of rainfall is essential in the study of a variety of problems relating to physical meteorology, cloud physics, operational hydrology, attenuation of radio signals etc. The instruments used currently to measure the rainfall intensity are the syphon recording raingauge and the tilting bucket raingauge. The former gives only approximate values of the intensity of rainfall and the data lacks resolution. The tipping bucket raingauge too has certain drawbacks. With normal rainfall intensities, it takes several minutes for the bucket to get filled and tilt and so the raingauge is not capable of giving the intensity of rainfall with adequate resolution. Mechanical linkages also introduce errors in the calibration in the long run. To overcome these limitations a new raingauge system capable of measuring and remotely recording rainfall intensities every minute, down to a resolution of 1/120 mm/min (1/2 mm/hr) has been developed. In this system, the rainfall received in the main collector is converted into drops of equal size and the number of drops so produced is counted by an optical-electronic device for successive predetermined fixed time intervals, normally, a minute. The digital output of the counter is converted into an analogue voltage and recorded continuously on a conventional strip-chart recorder so as to constitute intensity of rainfall during the interval. An additional mark is made on the chart for every 120 drops of rain (*i.e.* for every mm of rainfall) through a relay mounted inside the same recorder. The block diagram of the rainfall recorder system is given in Fig. 1. This has three main components *viz.* (*a*) the sensor (*b*) the system electronics and (*c*) the recorder.

2. Description of the system

2·1. The sensor which is installed in the open consists of a circular rain collector of 200 mm diameter with a funnel through which the rain water flows into a siphoning arrangement which ensures a constant pressure head for the drop forming mechanism. The drops are formed in an 'U' tube filled with kerosene in one arm and water in the other, the two fluids retaining their immiscible characteristics (Fig. 2). As the rain drops fall through the kerosene column, an equal amount of water drains from the U-tube through the outlet tube. The siphon from the funnel is kept filled with water and its outlet nozzle just dips into kerosene. The size of the drops depends solely on the diameter of the nozzle which in the present design, is 4 mm giving 120 drops for every mm of rain (31·5 ml of water).

2.2. Drop-forming Unit

The drops falling vertically through the column of kerosene are counted by a light and photosensor arrangement. An incandescent lamp could be used as a light source but its limited life makes it unsuitable for dependable operation over extended periods. Therefore a light emitting diode (LED) which has practically an indefinite life was chosen in the present design. Since the intensity of light emitted by LED's is very small, a focussing

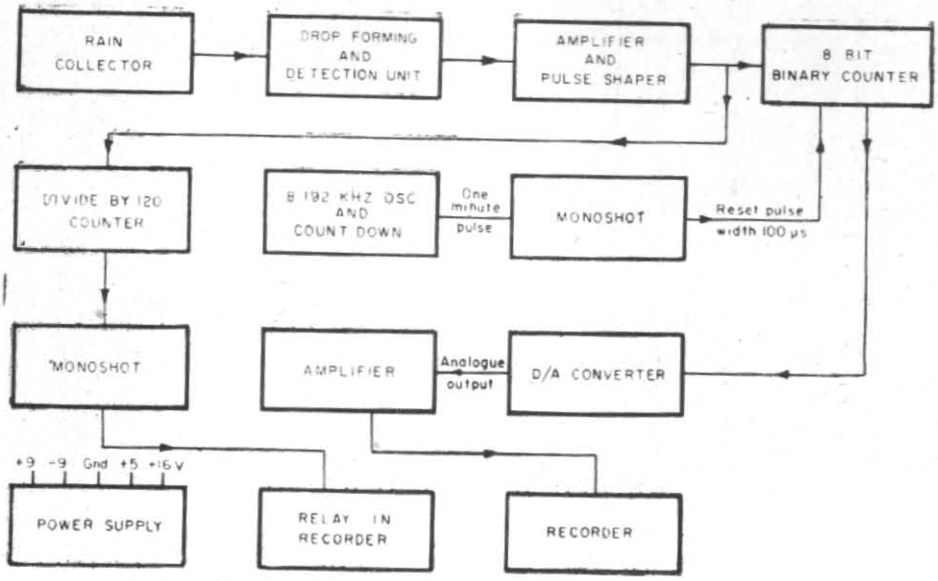

Fig. 1. Block diagram of intensity raingauge

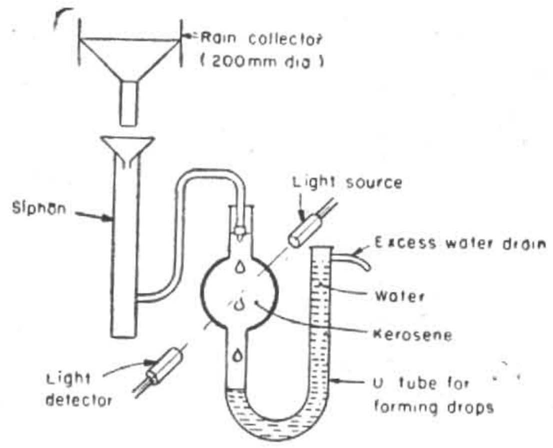

Fig. 2. Bubble of formation and detection device

arrangement was evolved. This consists of the lens on the LED holder and a spherical liquid (kerosene) lens forming part of the U tube. The light emitted by the LED is focussed on to the silicon photodiode sensor. The LED and the photodiode are mounted on either side of the kerosene medium so that the drops on their descent through the kerosene column interrupt the light falling on the photodiode. As each drop falls, a pulsating current output is produced.

2·3. *System Electronics*

Detailed circuit diagram of the system electronics is given in Fig. 3. The output from the photodiode is amplified by a saturating amplifier into a square pulse of 5V amplitude. These pulses trigger a one-shot multivibrator to provide a pulse output of uniform width. An NE 555 timer integrated circuit is used as the multivibrator and gives a pulse of width 100 microseconds for each drop.

Two TTL binary counters (7493) connected as an eight bit ripple counter with a counting capacity of 256 is used to count the pulses received from the amplifier. As every 120 drops correspond to 1 mm of rainfall, the counter is capable of registering a maximum of 256/120 mm of rain per minute *i.e.*, 128 mm/hr. The resolution of the instrument is 1 count *i.e.*, 1/120 mm/min or 1/2 mm/hr. As the instrument is designed to give minute to minute intensity, the counter is reset every minute using a 100 microsecond pulse derived from an 8·192 KHz crystal used along with a CMOS integrated circuit CD 4009. By using three 4 bit-binary counters, a divide-by-twelve counter and a decade counter in succession the

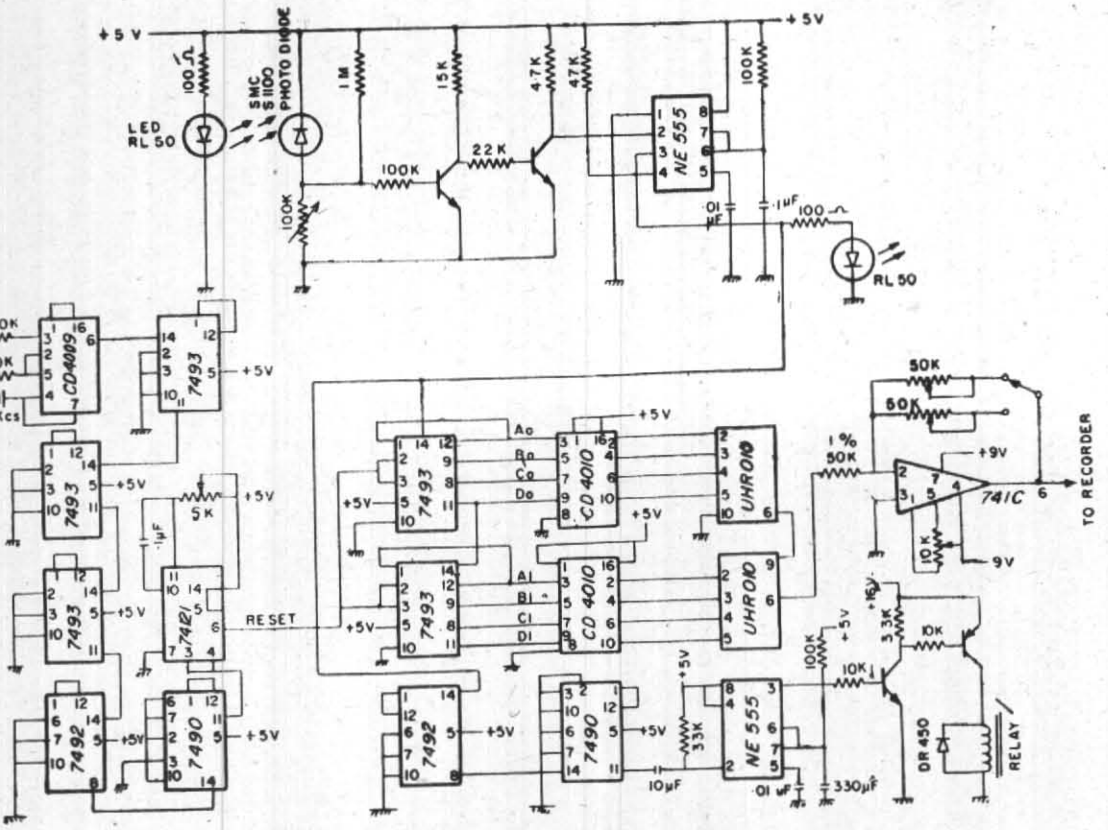

Fig. 3. Circuit diagram of intensity raingauge

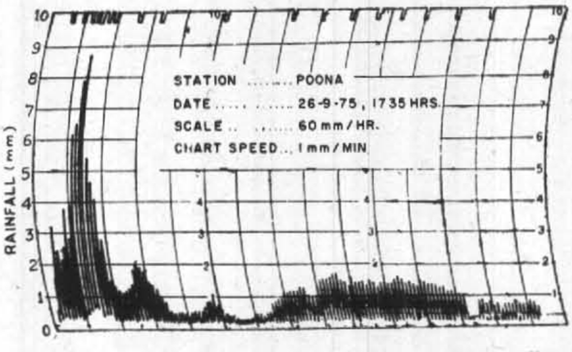

Fig. 4. Record of intensity and total rainfall

8·192 KHz is scaled down by a factor 419520 to get a pulse every minute. This pulse triggers a one-shot multivibrator to produce a 100 micro-second pulse once every minute.

2.4. *Recording system*

The output from the counter is fed to a digital to analogue converter using an R—2R network through analogue CMOS switches CD 4010 and the analogue output from the R—2R network is amplified by a linear amplifier and made compatible with a 0—1mA recorder which together with the system electronics can be conveniently mounted inside the office or observatory building. The amplifier is provided with a scale factor switch which allows a full scale recording of rainfall intensities either 60 mm/hr or 120 mm/hr. The record appears as discrete lines on the chart, the length of each line representing the intensity of rainfall during that minute.

2.5. *Rainfall totaliser*

In addition to the intensity of rainfall, information on the total rainfall during any given interval of time can also be registered on the chart. For this purpose, the input to the 8-bit binary counter which counts the number of raindrops is fed in parallel to a divide-by-120 counter. This counter gives a pulse output for every 120 drops of rain which corresponds to 1 mm of rainfall. This pulse drives a one-shot multivibrator which energises a small relay mounted inside the recorder. The relay in turn actuates an additional recording pen which records a click mark. By counting the number of such marks, the total amount of rain fall within any specific period can be read out easily. Fractions of a mm at the beginning and end of the period can be estimated from the intensity records during this period.

A sample record taken on 26 September 1975 at Poona during a passing shower is reproduced in Fig. 4.

The instrument which has been proved to be of operational reliability will find extensive use in a number of research applications. The time constant can be altered to suit individual applications.

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