

ROTOR CURRENT METER

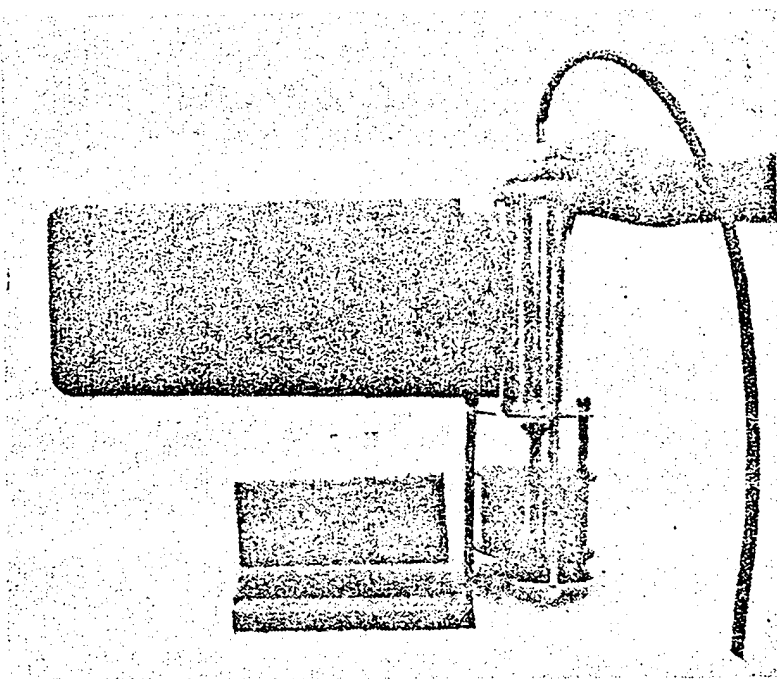
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1. INTRODUCTION

Water velocity is one of the important oceanographic parameters that are commonly measured. Among the different types of current meters widely used at present, are the acoustic current meter, the electromagnetic current meter and the rotor current meter. In acoustic current meters the current is sensed by measuring the differential travel time of acoustic signals travelling with and against the fluid flow. The electromagnetic current meter operates on Faraday's Law of Electromagnetic Induction. The rotor current meter uses the technique of counting the number of rotations of the rotor for a specified period of time. The electromagnetic current

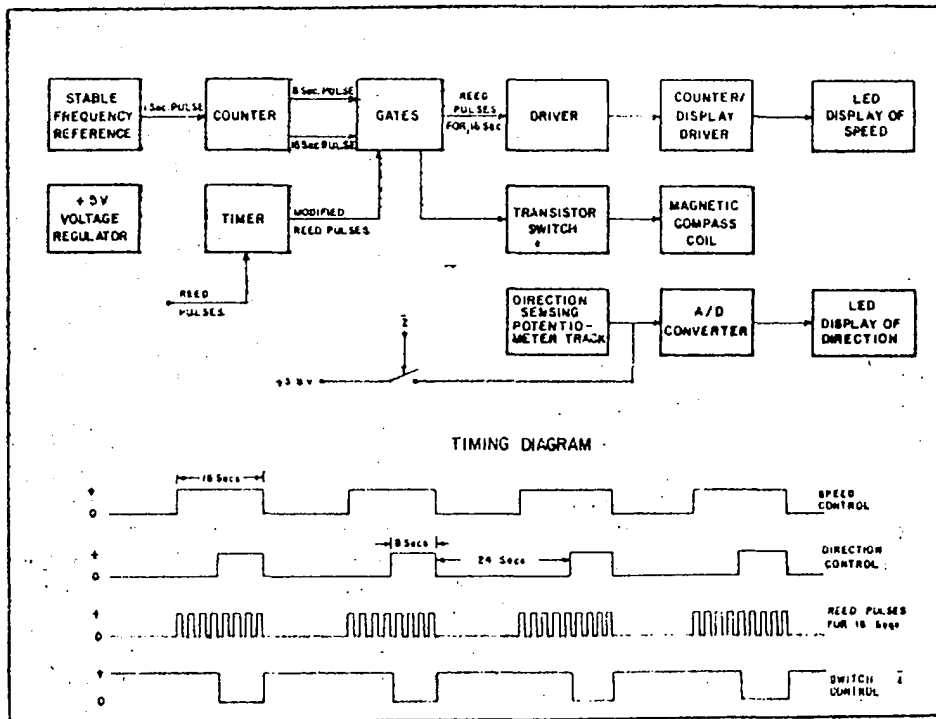
meter is well-known for its excellent linearity for a wide range of water velocities. It has got the advantage that there are no moving parts in it. As inertia does not come into the picture at all, there is no upper limit of water current above which the electromagnetic current meter does not respond linearly. This, however, has the disadvantage that its electrical output is proportional to the magnetic field. This field decreases rapidly with distance from the coil. Consequently, it is sensitive only to fluid flow in the immediate vicinity of the coil. Theoretically, in an electromagnetic flowmeter, the sensed voltage is a linear function of flow velocity. However, as we have observed, there is a "zero flow" which varies with time(1). We have also observed



1. Rotor Current Meter.

that the electromagnetic flowmeter, has got a "boundary effect" which deteriorates its use to accurately measure the fluid flow through nar-

the number of voltage pulses generated for 16 seconds is a direct measure of the fluid velocity.



2. Schematic Block Diagram of Rotor Current Meter.

row channels. Also, as observed by Kanwisher and Lawson(2) the electromagnetic flowmeter can give good results only if the sensor is perfectly symmetrical and of extremely high impedance (which is very unlikely). We therefore, thought of the design and development of a rotor current meter which can fairly accurately measure the horizontal fluid velocity. As the speed sensor provides a pulsed signal (see Section 3) this can be digitally processed effectively eliminating the inherent drift and offset of analog circuitry. Fig. 1 is a photograph of the instrument developed incorporating these characteristics. The schematic block diagram of the rotor current meter is given in Fig. 2.

2. THEORY OF OPERATION

2.1 Speed measurement

The rotor current meter described here employs the technique of counting for 16 seconds the number of voltage pulses generated by the rotations of the rotor. For the dimensions and shape of the rotor used, we observed from our calibration data that

2.2 Direction measurement

The direction of water flow is measured by the use of an Aanderaa magnetic compass placed in the water-proof housing of the sensor unit. A mechanical vane fitted with the sensor unit aligns itself with flow direction. The housing of the magnetic compass has a coil embedded in its wall. When an excitation voltage is applied to this coil, the magnetic assembly of the compass will tilt, causing a wiper of the magnet assembly to make contact with a potentiometer ring attached to the lid of the compass. As 360 mV is applied across the potentiometer (one end of which is grounded), the voltage at the wiper with respect to ground is a direct measure of the direction of flow with reference to the earth's magnetic north.

3. MECHANICAL DESIGN OF THE SENSOR

The sensor consists of a water-proof housing which houses the magnetic compass and a mechanical rotor which is free to rotate between two

teflon bearings made on two flat round brass plates. The rotor is placed in such a way that its axis is collinear to the axis of the sensor bottle. A hook is provided at the bottom of the sensor to enable it to be held down vertically by attaching a suitable weight. A Savonius type rotor is employed. There is a special reason for adopting this type of design. Oceanographic current meters are normally deployed to measure horizontal ocean currents. The measurement of mean horizontal ocean currents requires accurate sensing of horizontal components of water flow and rejection of influences induced by the vertical components of water flow. As the axis of the rotor remains vertical, the rotor responds to horizontal flow only. The ability to reject vertical flow component is an important concern in the design of the sensor. The placement of the rotor between two flat plates whose diameter is more than the diameter of the rotor ensures that the rotations of the rotor due to vertical pumping action is eliminated. Thus, the sensor described here achieves good vertical tilt response as well as good horizontal azimuth response.

The direction sensor namely, the magnetic compass is located inside the top portion of the water-proof bottle to eliminate any magnetic interference between the magnet assembly in the direction sensor and the magnet embedded in the rotor shaft. A reed-switch and the rotor is correctly maintained so that when the magnet embedded in the rotor is in line with the normally open reed-switch, the reed-switch closes.

4. ELECTRONIC CIRCUITRY

The unit has been designed to display both speed and direction. The number of pulses for 16 seconds are counted and displayed and the display of the last count is held for the next 16 seconds. At the elapse of this 16 seconds period, the counter starts counting up from one for 16 seconds and the speed is displayed again for 16 seconds. Eight seconds after the speed display starts incrementing, the direction is displayed for 8 seconds. At the elapse of 8 seconds the direction display is blanked out and it comes on again after 24 seconds.

The instrument is designed to work on 6 V battery. A voltage regulator chip regulates the battery voltage to $+5 \pm 0.3$ Volts, which is the operating voltage of the instrument. Most of the IC chips for processing both speed and direction

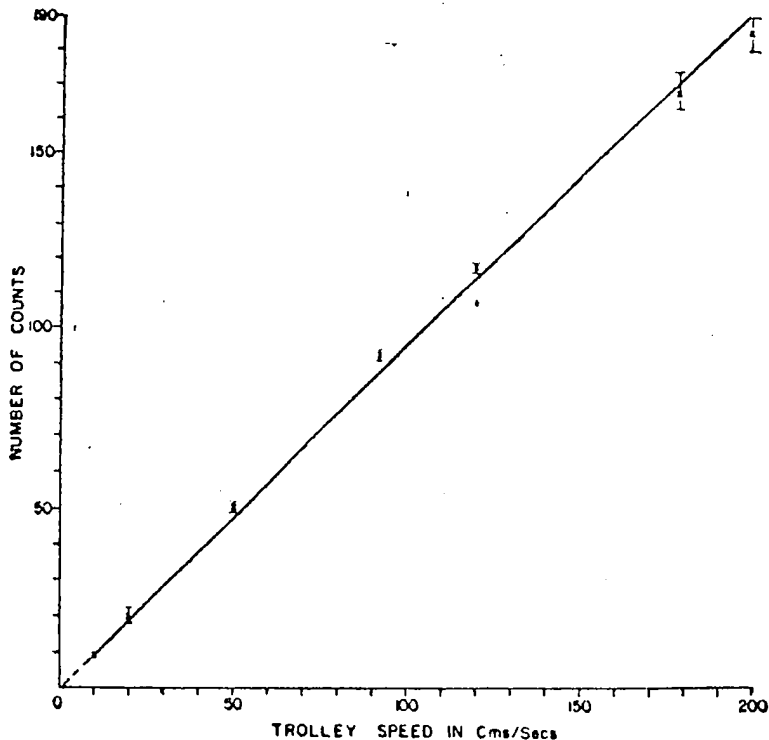
signals have been chosen to be CMOS type to reduce power consumption to a minimum. The various waveforms required have been derived from a highly accurate frequency source consisting of an oscillator utilizing 2.097152 MHz crystal. This frequency standard has been divided by 221 to derive a 1 second pulse. This has been further divided by a counter to derive 8 seconds and 16 seconds pulses, where 16 seconds pulse is used for speed display control and 8 seconds pulse used for the display of both speed and direction.

5. OPERATION

The circuit functions as follows :

Each rotation of the rotor results in the closure of the reed-switch two times. Each closure of the reed switch, in turn, results in a -ve going trigger pulse to the input of the Timer which is configured in the monostable mode. The RC time constant of the Timer is kept very small so that each closure of the reed-switch results in a +ve pulse of small width at the output of the Timer. These reed-pulses are gated with the 16 seconds ON pulse. The reed-pulses for 16 seconds are energised by a transistor driver and are counted by a counter|display driver configured in the up-counter mode. The counter|display driver is configured to hold the last reading (which is the speed in cms/sec) for 16 seconds. At the elapse of 16 seconds the counter is reset and is ready to display the next set of counts.

As the direction signal is analog in nature, this is digitised by an A-to-D converter to facilitate digital display of direction. The magnetic compass coil is excited by a -|5V control waveform of 8 seconds duration. During this time the direction signal is accepted by the A/D converter. As the coil is excited for 8 seconds there is ample time for the potentiometer to take true reading in case of a sudden tilt of the sensor when the coil was excited. After the elapse of 8 seconds it is desirable to blank out the direction display to avoid display of random readings. This is achieved by switching the input of the A/D converter to +3.9V after the elapse of the 8 seconds direction display. As the A/D converter is configured to display a maximum of +2V, an input greater than +2V automatically blanks out the direction display. A CMOS switch has been employed to achieve the automatic switching of the A/D converter input.



3. Calibration Curve for Rotor Current Meter.

A 7-core underwater cable is used to excite the underwater unit; two wires for reed-switches, two wires for compass coil and three wires for potentiometer track.

6. CALIBRATION

The unit was calibrated at the Ship Hydrodynamic Division, Central Water and Power Research Station, Khadakwasla, Poona. The calibration chart is given in Fig. 3.

7. SOURCES OF ERROR

If the sensor is not held vertically down, the vertical component of the flow can contribute an error of speed measurement. At very low velocities, the mechanical vane may not align itself properly and can contribute a small error to the direction reading. As the direction is sensed by a magnetic compass, it is necessary that the sensor must be kept away from the

influence of any external magnetic field. The rotor bearing should be periodically checked for friction. Provided that these precautions are taken good results can be expected from this unit.

8. ACKNOWLEDGEMENT

Thanks are due to Dr. V. V. R. Varadachari, Acting Director of the National Institute of Oceanography for permitting liberal use of laboratory facilities. Thanks are also due to Shri D. Rodrigues for fabricating the mechanical design and to Shri O. D'Souza for initiating the work on the unit.

9. REFERENCES

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2. Kanwisher, J. & Lawson, K. (1975) : Electromagnetic Flow Sensors, Limnol. Oceanogr., 26, 174-182.