River Flow Measurement using Salt Gulp Conductivity

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Abstract

A meter has been built in order to measure the volume flow rate of water through a river. A known quantity of salt should be thrown into the river upstream of the meter, then the meter automatically measures flow by integrating conductivity until it returns to normal and taking the reciprocal. The meter comprises an Intel 87C51 microcontroller which reads measurements from the display driver lines of a conventional conductivity meter, performs the integration, then displays the result on a separate liquid crystal display.

1. INTRODUCTION

The flow rate of water through a river is conventionally measured by damming the river and guiding the flow over a V notch weir. This becomes laborious and intrusive when the aim is merely to survey the rivers within an area, as for example when attempting to determine where best to site a micro-hydroelectric generation station. An alternative is the dilution method where a known quantity of a solute such as a die, radioactive fluid or salt is dumped in the river and its passage measured as it passes a fixed point on the river bank downstream. No construction is needed for this method, but it requires that a series of readings be taken at precise intervals over a considerable period and multiple readings of this kind can stretch the patience of the surveyor.

The Intermediate Technology Development Group proposed that a meter be made which automatically takes conductivity readings during the passage of a known quantity of salt then uses this to calculate the flow rate [1]. This has been done using a lap-top computer and a conductivity meter with a computer interface, but the cost, bulk and weight of this set-up is considerable and the lap-top batteries need regularly to be recharged. Reported here is the construction of a small hand-held meter powered by four 1.5 volt batteries and designed automatically to measure the conductivity readings and calculate the volume flow rate. Performance limitations are described, and a general method is proposed of interfacing a microcontroller to any meter with a digital display, even if the meter has no digital output.

2. THE DILUTION METHOD OF MEASURING VOLUME FLOW

The dilution method was proposed early in the last century and the excellent summary given in [1] is partially reproduced here for the convenience of the reader. The surveyor should find a stretch of river which is free of inlets or outlets (so that the volume flow along this stretch is constant) and where there is sufficient turbulence to give good mixing. A known quantity of, for example, salt should be mixed in a bucket of water, then the water poured into the upstream end of the chosen stretch. Readings of conductivity should be taken at regular intervals at the downstream end and the surveyor will detect a rise then fall of conductivity as the salt gulp passes. The surveyor can calculate the integral of conductivity with respect to time by plotting a graph of conductivity versus time on squared paper and counting the number of squares underneath the curve, or by performing the equivalent operation numerically.

If the rate of flow down a stream were uniform at all points, then the volume flow rate would be equal to the rate of flow times the cross-sectional area of the stream. The greater the flow rate, the quicker the gulp passes hence the shorter the period of integration and the less the integral of conductivity. Similarly, the greater the area, the more the salt is diluted before it passes the point of measurement and hence the lower will be the integral of conductivity. Volume flow rate is therefore proportional to the reciprocal of the integral of conductivity. This can be shown to be the case even when the flow-rate is not uniform at all points across the cross-section of the river, provided that the concentration of salt itself is uniform across the cross-section.

3. THE DESIGN OF THE METER

Microcontrollers with analogue inputs exist so it might seem that the simplest way of designing a meter which integrates conductivity would be to construct a conductivity meter and microcontroller on a single circuit board. However the conductivity of fluids is much less easily measured than that of solids: an alternating current and platinum coated electrodes are required so that the fluid is not electrolysed, and fluid temperature must be simultaneously measured in order that the conductivity can be adjusted to what its value would be at 25^{0}C. Furthermore, microcontrollers with analogue to digital interfaces typically only discriminate between 256 levels, and are difficult to source.

In contrast, farm suppliers will readily deliver even to quite remote regions small hand-held conductivity meters which cost approximately US$30 and contain appropriate electrodes and temperature compensation. The meters are built around the same integrated circuit as that used in a digital volt meter so that a large range of conductivity magnitudes can be measured with excellent discrimination, but meters as basic as this have no serial interface over which data might be passed to a microcontroller.

Data from the integrated circuit inside the conductivity meter was instead extracted by reading the logic state of the pins driving the liquid crystal display. Liquid crystal cells are not simple logic devices and care must be exercised with design. The conductivity meter is driven by a 6 volt supply (from four 1.5 volt batteries), so the lines driving each alphanumeric segment of the liquid crystal display swing between 0 and 6 volts whereas the microcontroller expects a 5 volt transition. Furthermore, in order to avoid electrolyzing the liquid crystal, conventional liquid crystal cells are driven by alternating voltage in the on state, versus zero voltage in the off-state. How is this interface achieved?

A liquid crystal display comprises a sandwich of glass – liquid crystal – glass and the passage of light is blocked when a voltage is placed across the liquid crystal. Transparent electrodes are placed on the surface next to the liquid crystal of each sheet of glass. On an alphanumeric panel, the electrodes on the front sheet comprise segments of the alphanumeric pattern while on the back sheet is a single electrode which covers the whole sheet. The back electrode is driven with a signal which alternates between six and zero volts. Each electrode segment on the front sheet is also driven with a signal which alternates between six and zero volts, but the electrode segment is either in phase with the back-plane or out of phase. If in phase, the voltage across the liquid crystal next to the segment is zero and it is transparent: if out of phase, there is an alternating voltage across the liquid crystal next to the segment and it goes opaque.

By experiment, it was found that an Intel 87C51 microcontroller can read the six volt logic levels coming out of the conductivity meter integrated circuit if V_{cc} to both integrated circuits is wired in common, then a regulator is used to keep the earth of the microcontroller one volt higher than that of the conductivity meter. Further work is needed to determine whether this is viable in general or whether it came about by a fortuitous combination of microcontroller and conductivity meter integrated circuit.

The state of each segment can be found by measuring the segment voltage immediately after the back-plane has gone from high to low. While a standard 1888 alphanumeric display has 24 segments – two for the "1", seven for each "8" and one for the back plane – the 87C51 has 32 input/output ports, so a few are spare for the 3 pin interface to a serial input liquid crystal display such as RS 257-543. It helps that both the integrated circuit in a standard digital volt meter and the 87C51 come in identical 40 pin packages, and that if they are placed back to back, ports 0, 1 and 2 of the 87C51 directly overlie one '8' each of the segment drivers from the volt meter integrated circuit. This feature is used to simplify the packaging of the combination.

4. SOFTWARE

The software is designed to measure the conductivity at switch-on, wait for the rise in conductivity as the salt gulp passes, continue making conductivity measurements until the conductivity has fallen to its initial value or less (which can be forced by pulling the probe out of the water) then the meter calculates and displays the volume flow rate. It is assumed that 1kg of salt is used in each measurement.

The software must read the data from the display of the conductivity meter, integrate and take the reciprocal of the result, then drive the output liquid crystal display. Intel's PLM51 (Programming Language for Microcontrollers '51) automates the manipulation of 16 bit words, but it has no floating point arithmetic so an ad hoc version of this had to be written for the integration and reciprocal.

5. PACKAGING

The meter was made by first extracting the circuit board from a commercial off-the-shelf handheld conductivity meter, sawing off the section of board containing the platinum electrode and thermistor, attaching a 5 metre cable between the circuit board and sawn off section, then inserting the latter back into the original housing. The housing was filled with lead shot and potting agent so that it would sink when thrown into a river.

The conductivity meter circuit board was then flipped over and mounted on top of a circuit board containing the microcontroller and associated components. 12 mm pins were connected adjacent to each input/output of the microcontroller and were in an appropriate position and long enough to be soldered directly to the integrated circuit of the conductivity meter. A serial input liquid crystal display was glued inside the transparent top of a water-proof box, connected to the circuit board which was also mounted to the top, and the cable was run out through the side of the box via a water-proof grommet.

6. RESULTS

There was a serious drought in Zimbabwe as this meter was completed, and no appropriate river near Harare had sufficient flow for a test. However the flow meter gave the same conductivity readings as unaltered conductivity meters, and performed the integration and reciprocal calculation accurately. A brief attempt was made to test the meter in the UK but the author did not have access to data about river flow rates from V notch weirs so was unable to validate the meter.

Several meters were made and on one or two of them, one segment of the conductivity meter's liquid crystal display became inoperative. This may have been due merely to poor circuit construction, but it would be useful to check more thoroughly that the two integrated circuits can interface reliably despite their slightly different drive voltages.

7. CONCLUSIONS

The drive pins of an alphanumeric liquid crystal display have been used as a digital interface to a microcontroller with more than 24 input pins. The integrated circuit in a standard digital voltmeter has been converted in this way into a low cost and highly accurate analogue to digital input. A cheap, hand-held conductivity meter has been combined with an Intel 87C51 microcontroller to make a hand-held flow meter which uses four 1.5 volt batteries and costs a fraction of the price of a lap-top.

8. ACKNOWLEDGEMENTS

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REFERENCES

[1] Brown A., (December 1984) "'Salt Gulp': measuring flows in small streams and channels", Appropriate Technology, Vol 11 No 3, pp 14 and 15