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A Low-Cost Microprocessor-Controlled Weighbridge

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Summary

Conventional weighbridges are expensive items and well out of the financial range of middle and small farming and carrier operations. Such operators, however, have frequently expressed the need for a low-cost, moderate accuracy, weighbridge system, which can be operated by unskilled personnel, as an essential aid to effective modern cost control. The microprocessor controlled system described in the paper aims to satisfy this need.

1 Introduction

Conventional weighbridge systems are expensive because of the high accuracy transducers required, and because of the complex analog electronics that these transducers demand. The use of a microprocessor, however, provides the intelligence to enable costs to be reduced dramatically in the following ways. Firstly, the operation of the weighbridge can be made extremely 'user-friendly' so that operation by unskilled personnel, including the lorry driver, is possible at the press of a single button. Secondly, the microprocessor can perform tasks which allow lower-cost transducers to be used by eliminating skilled setting up operations. For example, calibration can be automatic, so can zero-setting, drift can be tracked, and anomalies in transducer balance eliminated. Thirdly, the microprocessor allows flexibility in ticket printout, displays, and weighing method (eg axle weights, tare weight, static weight or rolling weight).

In this paper we will describe the design of such a weighbridge system which is based on the 6502 microprocessor. In particular, we will indicate where the microprocessor is being used to eliminate, or make automatic, processes that previously required complex analog electronics. The weighbridge system has been fully built, and two prototypes are currently undergoing extensive field trials. Also, a major British farm equipment manufacturer is considering marketing the system world-wide.

2 The Weighbridge design and Pilot Experiment

The initial steps taken in this project were to prepare a MAPCON supported feasibility study. Problem areas were identified and following completion and acceptance of the report work began on the design of a prototype weighbridge.

An essential ingredient of the low cost nature of the system is the single-axle platform (3 metres by 0.75 metres) that is used. The platform is supported by four load cells, one at each corner. Before proceeding with the system design it was necessary to carry out a pilot experiment on the effectiveness of such a platform.

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Initial trials showed good correlation between the weight obtained on a Public Weighbridge and that measured using the platform. However, it was observed that whilst static tests gave excellent correlation, inaccuracy did occur when the vehicle was allowed to pass over the narrow platform without stopping. The errors were not consistent and can be shown to be due to three major effects. Firstly, there is the inevitable overshoot which occurs when the vehicle rolls onto the platform. The dynamic system comprising of the platform and vehicle is critically dependent upon the characteristics of the suspension, tyres and weight of the vehicle. As such it cannot be accurately determined and rolling weight measurements must always be less accurate than static measurements. Errors due to bounce effects can be reduced to acceptable limits by (a) keeping the vehicle speed down to under 5 mph, (b) electronically damping the response of the system by means of low-pass filters, (c) software processing of the data. Only a limited amount of software processing can, in fact, be achieved. This is due to the time available between axle readings. However, work on this problem is continuing.

The second source of errors involved the design of the platform. In this design the load cells were placed within the perimeter of the platform. Consequently there was a degree of rocking occurring when the vehicle wheels first encountered the platform. Unequal load distribution thus occurred. Whilst it is to be expected that the load distribution will not be wholly equalised, in this case it was excessive. This tendency for the platform to rock can be overcome by positioning the load cells outside the perimeter of the platform and modifying the design of the tie-bars. The third source of error is related to the second. The load cells used in the tests were not a matched set. Subsequent tests showed a difference of almost 3% in sensitivity between them. Using a matched set, inequality in the load distribution, providing it is not so great as to cause overloading of any one cell, will have very little or no effect on the combined output. However, for the pilot experiment, this was not the case.

Based on the results of the pilot experiment it was decided that the four load cells should be paralleled and fed into a single high-quality strain gauge amplifier, to minimise costs. This obviates the need for three more (expensive) amplifiers. With four separate amplifiers, unequal load cell sensitivities can be accommodated by adjusting the gains of the amplifiers. With the single amplifier this cannot easily be done nor is it desirable to have many adjusting points to be set 'on test'. However, it has been found possible to set economically acceptable limits on the load cell and platform specifications which, if met, remove the necessity for adjustment.

3 System Specification

A low-cost weighbridge system must be capable of operation by relatively unskilled personnel. As such, its operation must be kept as straightforward as possible. Since microprocessor control is used, it is possible to remove the manual calibration and zero setting procedures commonly found on older strain gauge equipment. Setting of zero levels to accommodate drift can be made automatic, as can a simple calibration check.

An important feature of the system must be provision of 'hard copy'.

Accordingly, a printer is included. The printer format, using 6 cm wide paper, is as follows:

NAME:
DATE:
NO:
AXLE 01 = XX.XX TONNES
AXLE 02 = XX.XX TONNES
TOTAL = XX.XX TONNES

A capacity of 99.99 tonnes is the maximum allowed for the totaliser, with a maximum axle weight of 20.00 tonnes. This is well above the present legal limit for axle weight but the system could conceivably be used for other purposes. Whilst a four-figure display is used, giving a resolution of 0.01 tonnes, an accuracy of $\pm$ 20 kgms is considered to be adequate. In order that the system can be operated by a single person, eg the vehicle driver, readings must be taken automatically when the vehicle moves over the weighing platform. Under these circumstances the large external display giving visual indication of the read-out is an advantage.

4 The Microprocessor System

The consideration here is chiefly one of cost. There are many microcomputer systems to choose from, though an important factor is the need for a compatible printer. It is possible to buy a complete microcomputer system, the Rockwell AIM-65, based on the popular 6502 microprocessor, which comes complete with its own 20 character printer. This was the system chosen. The printer is a thermal 'tally-roll' type, of simple and robust construction. A drawback is that special paper is required, though in our opinion the print quality is superior to that obtained from electrosensitive paper, with the added advantage that it can be written on with pen or pencil. As far as we were aware at the time of development, the Rockwell AIM 65 was the only readily available low-cost system on the market with an integral printer of any sort. As such it is already used extensively for OEM purposes, and for quantities up to a hundred or so, unit price compares very favourably with the cost of developing a special purpose system. A further point to bear in mind when incorporating commercial microprocessor development systems in a product is that advantage can be taken of all available software and in this case the existing monitor was adapted for use. Also, as an aid during development and modification 'in the field' the program, though held in EPROM, is downloaded into RAM for execution on power-up. The total size of the program is just under 2K words, the extra RAM requirement being of negligible cost compared to the convenience it imparts.

5 Measurement Technique

The prime requirement is for automatic operation. Four distinct procedures can be identified:

a) Calibration
b) Zero setting
c) Measurement
d) Display

Considering (a) and (b) together, this system carries out calibration and zero adjustment prior to each weighing operation. With the proviso that the vehicle is not on the weighing platform at the commencement of the weighing sequence, the arrival of the 'start' signal causes the microprocessor to take a reading from the load cells. This provides the 'zero' or 'datum' level. A calibration resistor, set to simulate full load, is then switched across the load cells and the corresponding output measured. A simple calculation gives calibration and zeroing for subsequent axle load measurements.

The output from the summing amplifier is fed to a 12 bit A/D converter giving a resolution of better than 1 in 4000 ie 0.005 tonnes, thus allowing the quoted accuracy to be easily maintained. Automatic operation is ensured because after the datum has been measured and calibration has been carried out, the microprocessor continuously monitors the load cell amplifier and notes when the output rises above a predetermined minimum. The system then tracks the increase in load and when full load is definitely sensed, it is displayed. Static weighing can also be carried out, a switch on the control panel allows the operator to select either mode at any time. It is in this, static, mode that the accuracy of $\pm$ 20 kgms can be readily obtained.

6 Operation of the System

Operation has been kept very simple. On switch on, a warm-up period of a few minutes is indicated by a flashing light. The warm-up was found to be necessary to allow the load cells and amplifiers to stabilize. As this is an accurate measuring instrument, it is a reasonable requirement to expect that once switched on, it should remain on for lengthy periods. Once the light has ceased to flash, operation can commence. Pressing the start button initiates the following sequence of operations:

a) datum level is obtained
b) calibration of the load cells is carried out
c) print-out of preamble - manufacture's name etc
d) start light switched on

Weighings can now take place. If the machine is switched to automatic mode, axle weights will be recorded and displayed as the vehicle/s move over the weighpad. If the machine is in static mode, a reading will not be taken unless the start button is pressed once again. The total weight recorded can be found by pressing 'totalise'. This initiates a print out of all axle weights recorded and the total weight, which is also displayed. After this has occurred no further weighings can take place until the start button is pressed, which also initiates a recalibration. Thus any drift due to temperature changes throughout the day, or long term effects, can be taken account of without the operator being aware.

7 Conclusions

A microprocessor weighing system has been described which, by means of an automatic calibration and zero adjustment procedure, enables a speedy and convenient form of measurement, to an acceptable degree of accuracy, to be taken by unskilled operators. Inherent to the automatic calibration is the tolerance of low-cost load cells which do not need to be accurately matched or carfully balanced. The use of the microprocessor also, and importantly, allows a user-friendly operating system to be implemented. By basing the design on an existing microprocessor system, the AIM-65, development costs have been kept to a minimum and, for medium-quantity production, such an approach also offers considerable economic advantages.

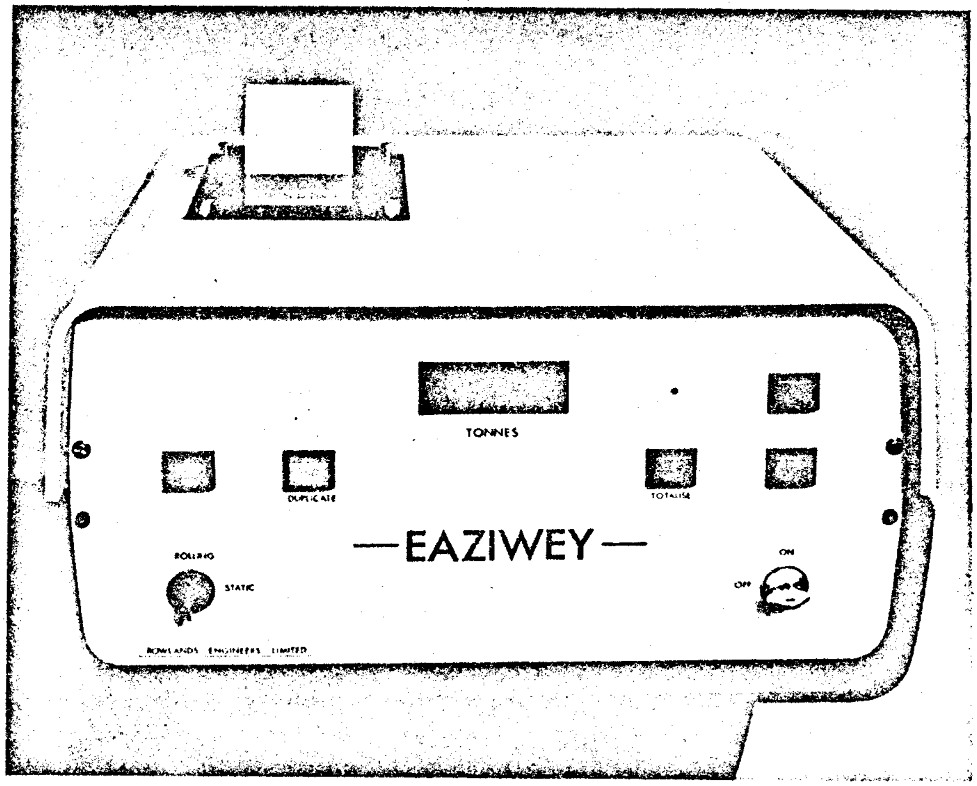

Figure 1 The prototype instrument.

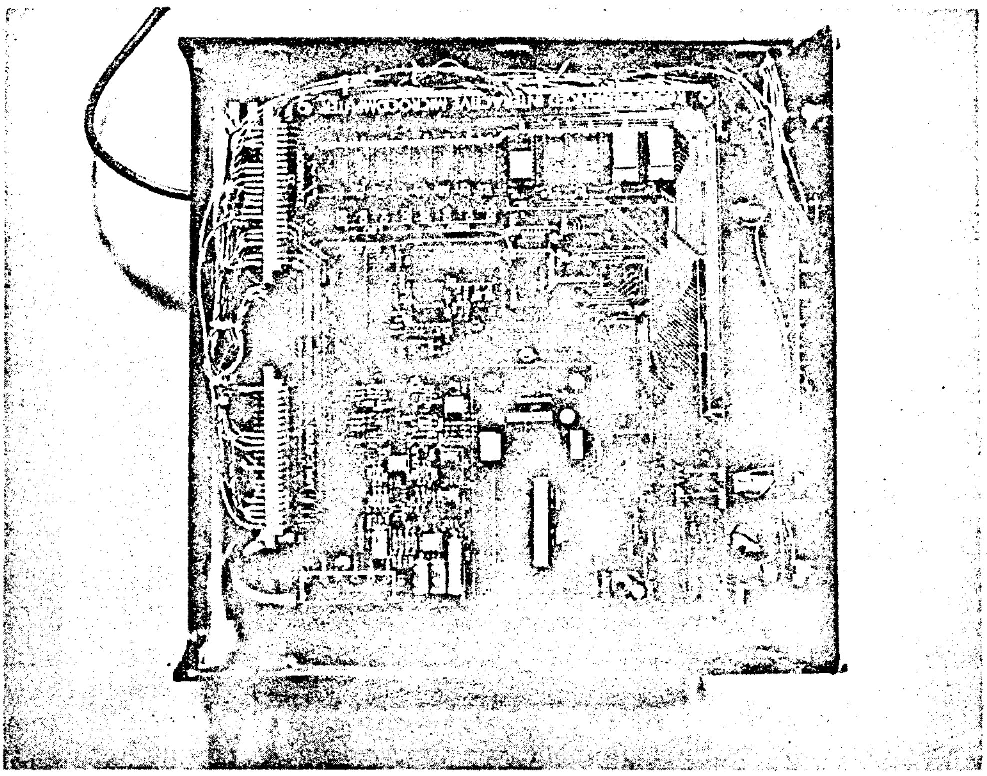

Figure 2 Showing the AIM-65 microcomputer mounting.