Precision Weight Scale Without Expensive Analogue Circuits and Voltage Reference

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As compared with other methods for weight measurements the strain gauge bridge sensor gives high precision and excellent stability. Unfortunately the output signal is very low (2 mV / V). An expensive instrumentation amplifier with a very high gain is normally used in order to preamplify that signal for precision measurements.

An alternative to that approach is to use an Universal Transducer Interface (UTI) chip, developed in the Delft University, Netherlands. It gives the possibility to connect the resistive bridge sensor directly to its inputs. The output of the UTI is period modulated square wave pulses that represent the bridge supply voltage, the bridge output voltage and the offset. That output is compatible with the microcontroller input that can measure the pulse duration and calculate the ratio between the supply voltage and the output voltage. The last in fact represent the physical signal (weight).

Using the UTI a precision 1000 kg weight scale was created without any expensive analogue circuits and voltage reference. The output is calculated by a single chip microcontroller (PIC16C73) and the result is shown on a 3 1/2 digit LCD display.

Conclusions: The use of the UTI greatly simplifies the interface between the resistive bridge sensor and the microcontroller and reduces the overall system cost. The precision achieved satisfies Bulgarian government standard for weight scales for commercial use.

Nevertheless their high precision and excellent thermal and long-term stability the application of strain gauge bridge sensors has also some serious disadvantages. Because of the low sensitivity (2 mV/V) the signal to noise ratio is quite low. If a DC supply is used for the bridge voltage reference an expensive instrumentation amplifier should be used to preamplify the output signal.

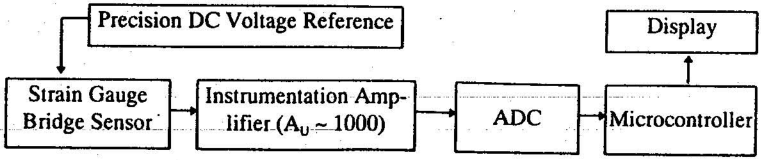

Figure 1. A classic strain gauge bridge sensor measurement system

That classic solution has rather high price and still a lot of problems because of the offset and drift of the high gain amplifier, parasitic thermocouples, etc. The chopper amplifier could solve part of this problems but its inherent noise degrades the system performance. Another approach is to use an AC supply for the bridge voltage reference. It gives a very good results resolving the offset and drift problems but requires another expensive component - RMC conversion circuit. Both solutions require also a precision ADC thus increasing the total system cost.

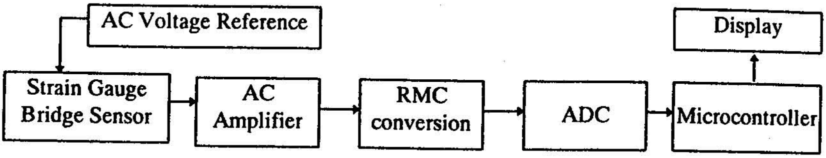

Figure 2. A strain gauge bridge sensor with an AC voltage reference measurement system

An alternative to the above well known solutions is the use of the Universal Transducer Interface. That integrated circuit, developed in Delft University, Netherlands, combines the advantages of the classic methods.

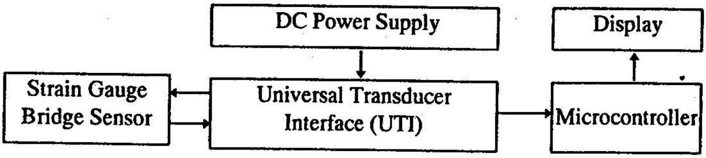

Figure 3. A strain gauge bridge sensor with the UTI measurement system

It uses a square wave pulse as a bridge voltage reference. The measurements in one phase is similar to the DC bridge supply application but the averaging of the positive and the negative phases eliminates the offset and all parasitic thermocouples. Moreover there is no need for a precision voltage reference because the reference signal is also measured.

A modified Martin oscillator is used as an AD converter. The output of the measurement circuit is a sequence of period modulated square wave pulses that represent the offset voltage Vo, reference voltage Vref and output voltage Vout. The final result is calculated according to the equation:

$$M = \frac{1}{32}\,\frac{T_{phase\ 3} - T_{phase\ 1}}{T_{phase\ 2} - T_{phase\ 1}} = \frac{V_{out}}{V_{ref}} \qquad (1)$$

Because of the very big difference Vref >>Vout the reference voltage Vref is divided by 32, thus reducing the requirements for the front-end linearity. Also the bridge output voltage Vout could be preamplified. The UTI has a build in preamplifier with a very precise gain of 15. It uses the dynamic element matching technic to achieve that gain precision. Unfortunately the internal noise of that amplifier is rather high due to the resistor switching network. An alternative to this approach is to switch of the internal amplifier and to use an external one.

The output period modulated square wave pulse has logic levels directly compatible with a CMOS input. The shape of the output signal is shown in figure 4.

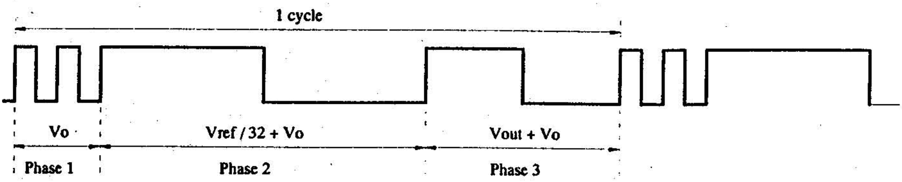

Figure 4. The period modulated square wave output signal of the UTI

The first phase representing the offset voltage Vo is divided in two equal pulses that have the lowest duration. This phenomena should be used by the microcontroller in order to recognise the first phase and make a correct calculation.

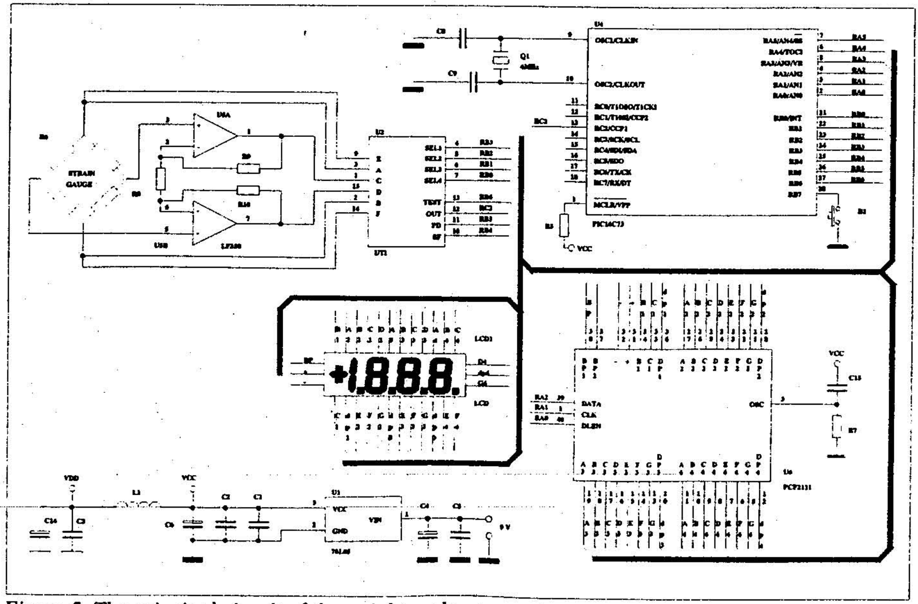

Figure 5. The principal circuit of the weight scale

Using the UTI a precision 1000 kg weight scale with a 300 Ω strain gauge bridge sensor was created. The duration of the different phases is measured with a Microchip's singlechip microcontroller PIC16C73. Because of its hardware Input Capture capability the precision of that measurements is ± 1 μs with a 4 MHz crystal oscillator thus making the quantisation noise insignificant. In order to achieve the desired 0.1 % accuracy the external differential amplifier was created using a standard low-cost single supply dual operational amplifier. The slow mode of the UTI was used thus increasing the system precision. The principal circuit of the device is shown in figure 5.

The flow chart of the program algorithm is shown in figure 6.

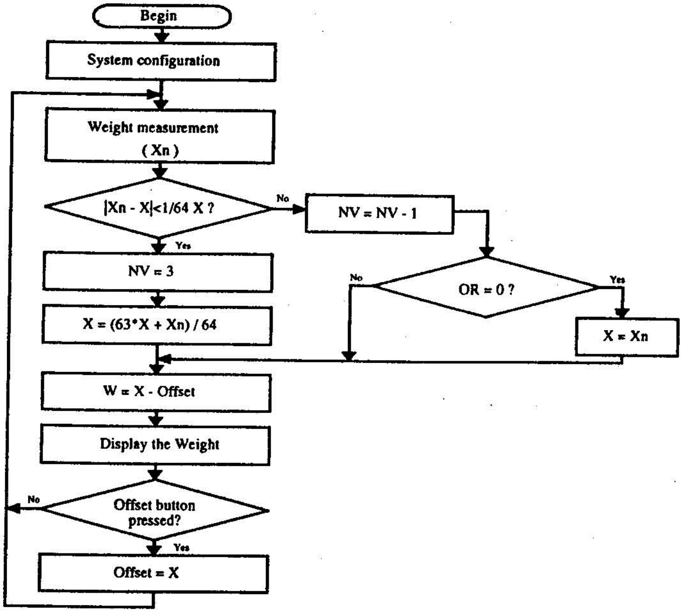

Figure 6. The program algorithm

The main program loop includes four base parts: current weight measurement, adaptive filtering, low-pass filtering and offset correction.

The weight measurement is done by calculation of the measured duration of the different phases according to the formula (1).

The adaptive filtering is a window filter that throws away all the values that differ with more then 1/64 from the medium value. In case of a weight change the old medium value is discarded immediately and a new medium value is created. Three successive measurements are needed for such a change so the occasional noise spikes will not disturb the proper system functioning.

The low-pass filtering is done by medium value calculation according to the formula:

$$X = (63*X + Xn) / 64 \qquad (2)$$

Before displaying the result the offset is subtracted from the mean value. The operator can change that offset by pressing the button, so the current medium value becomes an offset. That gives the possibility to adjust the zero of the scale to any weight.

The duration the main loop is less than 100 ms, so more than 10 measurements per second are done. The achieved accuracy is 0.1% (10 bit) and completely satisfies the requirements of the Bulgarian government standard for weight scales for commercial use (0.25% precision).