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Mass Measuring System Using Delay-and-Add Direct Sequence (DADS) Spread Spectrum Method

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***Abstract*— In the area of mass production, the products are weighed using load cell based weighing system. A load cell is an uncontrollable weighing device. Improvement in filtering increases the speed of weighing and enhances the measurement accuracy. In this paper, a novel algorithm and architecture is proposed for the weighing system. The algorithm has been verified and implemented in the weight measurement system successfully.**

***Keywords*—accuracy, mass measurement, noise and DADS.**

I. Introduction

The weighing of articles is an essential part of modern life. There is a constant need for knowing the exact weight of many items, e.g., food, ingredients for production, pharmacology, chemistry, technology, etc. The type and the number of products that require weight control are increasing. Consequently, the government bodies are trying internationally to maintain the same constant pace. In production, this means high accuracy and efficiency of weighing are also constantly high on the agenda. Continuation of this trend brings benefits for both the customer and the producer. That is, manufacturing efficiency is increased and hence profitability while package quality and quantity are assured to the customer's satisfaction.

In the area of mass production, products are weighed using electronic weighing scale that weighs a package fast and accurately. In the mail sorting and grading machinery, the usual internal division is 1137500 accuracy at 10 pieces /sec.

In the practice, the micro-controllers using general algorithms cannot meet higher accuracy.

The main constraint in achieving higher accuracy and in increasing throughput rate of the passing products is a superimposed noise on a useful signal from the weighing system.

The common sources are: (1) constant values (2) the noises: electromagnetic pick-up, power harmonic, thermally unstable circuits and the gain programmable by software (through PWM's output of the microcontroller) (3) strain-gage based sensor (i.e., load cells) particularly sensitive to vibration.

A moving average filter algorithm [1] is particularly efficient when processing for very short-duration. It is high precision for useful signal recovery and relative simplicity of construction. But it is not suitable for long duration measurement and particularly for industry environment. However, the implementation of pipelined in low-power 6 taps adaptive filter, based on the least-mean square (LMS) algorithm [2] is useful for long duration measurement . Although this filter has more response time, whereas moving average filter response time was less than LMS filter. Mean while electronic capacitive transducer [4] was designed. But the technique for measuring [3] low-frequency and low-level capacitance variations opens the door of implementation of weighing system using capacitive sensor. For that a strong filtering circuit should be implemented with high precision and fast response time. Application of capacitive sensor without microcontroller [6] cannot meet our requirement. When microcontroller was first interfaced with sensor [5] then a programmable filter could also be designed for weighing system. But PLC based intelligent Signal Processing method for high speed weighing system [7] can tolerate impact of environmental changes. Again its average variation is bounded for higher load, although response time is improved.

In this paper, our objective is to implement new algorithm for filtering method in signal processing module for weighing system with even capacitive sensor with least average variation and fast response time with higher accuracy and precision. Then make a comparative study with other filtering algorithm used for signal processing module.

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The common sources are amplified before transferred into the A/D converter, and therefore, the noise is amplified and an error is introduced in the system.

A signal processing module (SPM) acquires the electrical signal from the weighing device and estimates a value of weight for the passing product as its output, as shown in fig. 1.

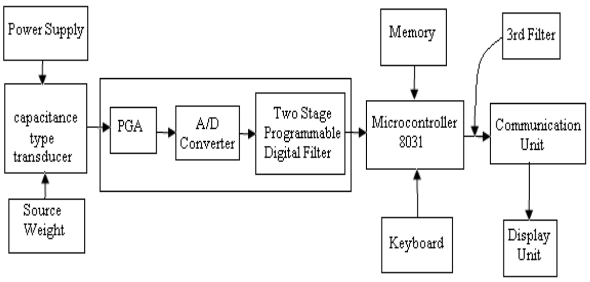

Fig.1. Signal processing module (SPM) and Mass measurement.

The two main aims for improvement are increasing the speed of weighing and achieving good measurement accuracy. Improvement in SPM that provides any one or both aims brings significant benefit to the overall static weighing system. The two main aims for improvement are increasing the speed of weighing and achieving good measurement accuracy, improvement in SPM that provides any one or both aims brings significant benefit to the overall static weighing system.

Owing to the physical characteristics, when the load cell detects the external force, it produces a weak current. The weak current is passed through AD7730 that has the PGA (Programmable Gain Amplifier), A/D converter and the two stage digital filter into digital signal. The micro-controller (8031) transfers the detected digital signal to the communication unit and the display unit according to the procedure set on the memory.

The communication unit consists of a transmitter and a receiver and it uses the Delay-and-Add Direct Sequence (DADS) spread spectrum modulation technique.

II. DESIGN METHOD

In fig. 2, the amplitude spectra reveal the significant noise components of the weighing system. The first peak is centered at approximately *2.2* Hz, and the second and third peaks appear to be integer multiples of this noise. Hence we can assume that there are no significant harmonic components beyond 40 Hz. Any sampling rate selected must therefore be greater than 80 Hz.

From the filter theory, it is known that linear phase filters are the best with respect to transient response time. In order to reject the high-frequency random oscillatory component in the circuit, there is always a RC low pass filter in the output of the circuit. This kind of filters can restrain high frequency noise, but its effect on low frequency noise is less. Digital filters are ideal for the treatment of low frequency noise. They can be implemented in real time or as post processed applications. In this paper, we discuss the development of a load cell based static weighing system. In particular, the focus is on using digital filtering techniques to remove measurement noises from the extremely low frequency noise of the static weighing system and make a comparative study with other filter.

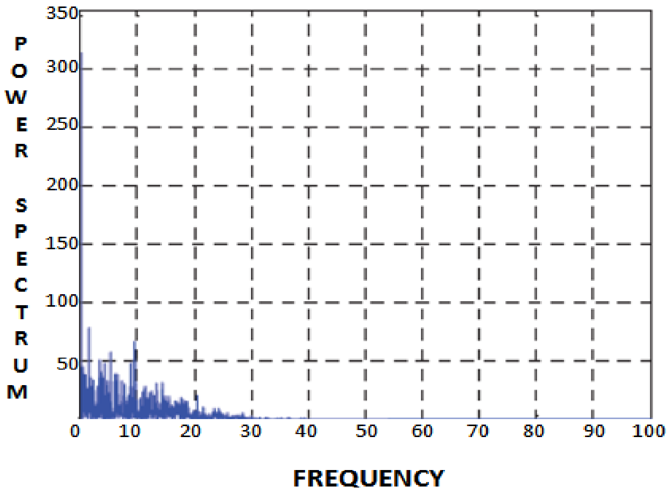

Fig. 2. Noise spectra of Mass Indicator system.

In this paper, a new spread spectrum technique (i.e., DADS) in the measuring system is proposed. With this novel method, the proposed novel DADS filter algorithm used in weighting system can meet the requirements of speed, stability, and precision.

In fig. 3, the schematic block diagram of DADS transmitter is shown, in which a pseudo-random bit sequence (PRBS) generator generates a bipolar spreading code $x=\{x_i\}$. In the lower branch of the modulator, this spreading code is multiplied with the digital data $d_k \in \{-1,+1\}$ with data rate 1/M, coming from the sensor . In the upper branch, the same spreading code is delayed by L, with L<<M. And finally the two signals are added together, resulting in a signal $s_k = \{s_{k,i}\}$ with,

$$s_{k,I} = d_k x_i + x_{i-L} \qquad (1)$$

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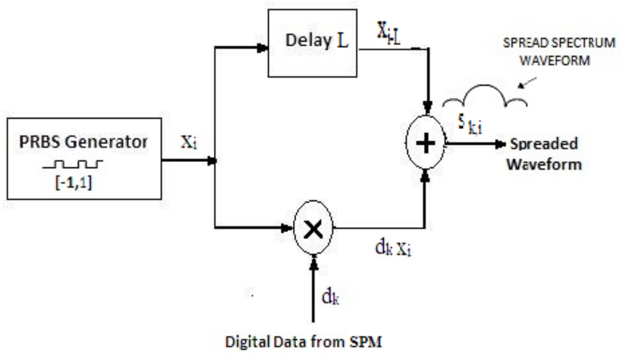

Fig.3. Block diagram of DADS modulator.

The signal s_k will be up-converted by the RF front-end and sent out.

The base band signal $s_k=\{s_{k,i}\}$ has two important characteristics. First of all, $s_{k,i}$ is a three level signal $\epsilon\{+2, 0,+2\}$. The second characteristic is of essential importance for the receiver. Every 2 non-zero samples $s_{k,i}$, separated by L, will have the same sign if the data bit $d_k = +1$ and will have opposite signs if $d_k = -1$.

Fig. 4 shows the first 15 samples of a modulated signal $\{s_{k,i}\}$ for $d_k= +1$ and a delay L=2. Every non-zero sample will have, 2 samples to the left and to the right, a value that equals zero, or a value with the same sign, e.g., $s_{k,2} = s_{k,4}$ or $s_{k,9} = s_{k,11}$. Fig. 5 shows the same for L = 2 and $d_k = -1$. In this case, every 2 non-zero samples, separated by 2, will always have opposite signs, e.g., $s_{k,1} = -s_{k,3}$. This important property will be used for the demodulation. And also this property has eliminated the bit synchronization technique.

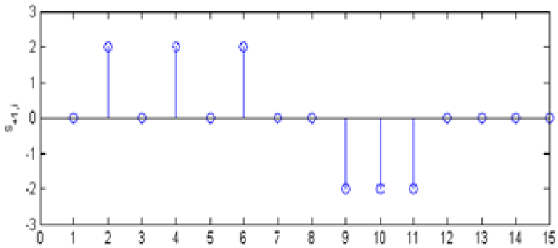

Fig.4. Structure of modulated signal s_k for $d_k = +1$ with delay L= 2.

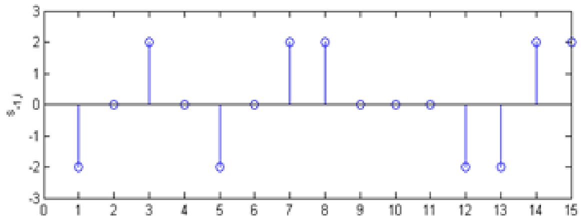

Fig.5. Structure of modulated signal s_k for $d_k = -1$ with delay L= 2.

The block diagram of DADS demodulator is shown in Fig. 6.

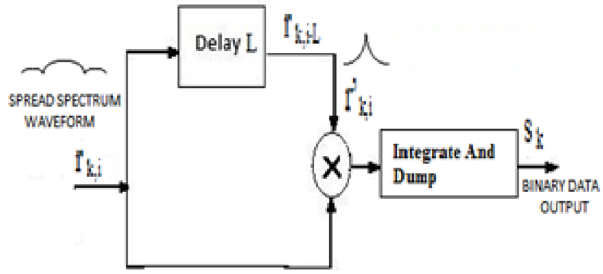

Fig.6. Block diagram of DADS demodulator.

In the DADS demodulator, the received signal $r_k=\{r_{k,i}\}$ will be delayed by the same delay L as in transmitter and multiplied with its non-delayed version, resulting in a signal$\{r'_{k,i}\}$. The mathematical expression for $r'_{k,i}$ will be given by,

$$r'_{k,i} = (d_k x_i + x_{i-L})(d_k x_{i-L} + x_{i-2L}) \qquad (2)$$

$$= d_k (x^2_{i-L} + x_i x_{i-2L}) + x_{i-L}(x_i + x_{i-2L})$$

It can be verified that $r'_{k,i}$ has only two possible values $\epsilon\ \{4d_k,0\}$. This is a direct consequence of the second characteristic of s_k, as described above.

The signal s_k after the integration and dump will be

$$S_k = \sum_{i=1}^{M} r'_{k,i}\, r'_{k,i-L}$$

$$S_k = d_k \sum_{i=1}^{M} x^2_{i-L} + d_k \sum_{i=1}^{M} x_i x_{i-2L} + \sum_{i=1}^{M} x_{i-L}(x_i + x_{i-2L}) \qquad (3)$$

The first term in equation (3) is the useful signal. The second and the third term tend to zero, as there is no correlation between x_i, x_{i-L} and x_{i-2L} for any value of i.

In this paper, we present the comparison between the proposed digital filters in PC and the other filters which can achieve the main features the mass measuring system needs. Then, we present (1) Moving average filter algorithm [2], (2) LMS adaptive filter algorithm [3], (3) conventional FIR filter algorithm discusses the development of a microcontroller based measurement system.

III. RESULTS AND DISCUSSION

In this paper, we present the comparison between the proposed digital filters and the other filters which can be implemented in the mass measuring system.

Such as Moving average filter algorithm, LMS adaptive filter algorithm, Conventional FIR filter algorithm and Intelligent signal processing which can be used in the development of microcontroller based mass measurement system. It is found that using DADS filter, the average variation and response time are reduced drastically. Hence, accuracy of the system will be increased and the system will become very fast.

Table I
Comparison of digital filters.

	ZERO CALIBRATION	FULL CALIBRATION	AVERAGE VARIATION	DIVISION K=1000	RESPONSE TIME (Sec)
UNFILTERED	148,580-524,287		-5-+5	37.5K	
64 TAPS MOVING AVERAGE FILTER			-1-+4	75.1K	5
LMS FILTER			-3-+1.5	83.4K	10
101 TAPS FIR WITH HAMMING			-2-+2	93.9K	7
DADS FILTER	135,563-487,304		-1-+1	172K	0.8-1

IV. CONCLUSION

In the mass measurement systems, conventional filtering method employed have limitation in improving the accuracy and in throughput rate. In this case, an alternative technique has been explored to find a solution. It will enable measurement accuracy to be 1/172000. The result shows that new DADS filter can be employed in a practical high accuracy mass measuring system.

In DADS, a copy of the spreading code, delayed by L, is embedded in the transmitted signal. At the receiver, the signal is again delayed by L and multiplied with the non-delayed signal for dispreading, without the need for code synchronization. This results in a very simple receiver structure, without losing the benefits of a spread spectrum modulation. From the experimental study, it is evident that the repeatability, linearity, and resolution are satisfactory within the tolerable limit of industrial mass measurement.

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