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IMPROVED DIGITAL SPEED MEASUREMENT METHOD

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Abstract. In the paper a modified digital speed measurement method is proposed. The method has a good static accuracy, like well known other measurement procedures, but its advantage consists in a constant sampling period. The method is implemented on single chip microcontroller. Experimental results proved good properties of the proposed concept.

Keywords: microcontroller, speed measurement , digital tachometer

I. INTRODUCTION.

A tachometer is an important part in design of feedback loop in adjustable speed drives. Many industrial drives use a DC tachometers due to their good dynamic performance and low cost. Rapid development of microprocessor speed control systems encouraged to apply digital tachometers because of such their significant advantages like:

- good accuracy,
- lack of A/D converters in the case of microprocessor control system,
- noise immunity,
- no maintenance.

Digital speed measurement methods, based on pulse train coming from a shaft encoder, are reviewed in several papers [1,2,3,4]. Two method are widely known: - counting a number of encoder pulses in a fixed period (method M), - measurement of the elapsed time between successive pulses (method T). Well known disadvantages of these method, which are pure accuracy in the range of small speed for method M and pure accuracy in the range of high speed together with variable counting (sampling) time for method T, led to development of new measurement concepts.

In [1,3] there was presented a measuring method M/T, which combines advantages of both mentioned methods. The idea of this method bases on counting pulses from the shaft encoder during a period, which is synchronised with these impulses. This can be done in a system shown in fig. 1.

A reversible counter T2 counts impulses coming from encoder meanwhile timer T3 measures time of their duration. After passing reference

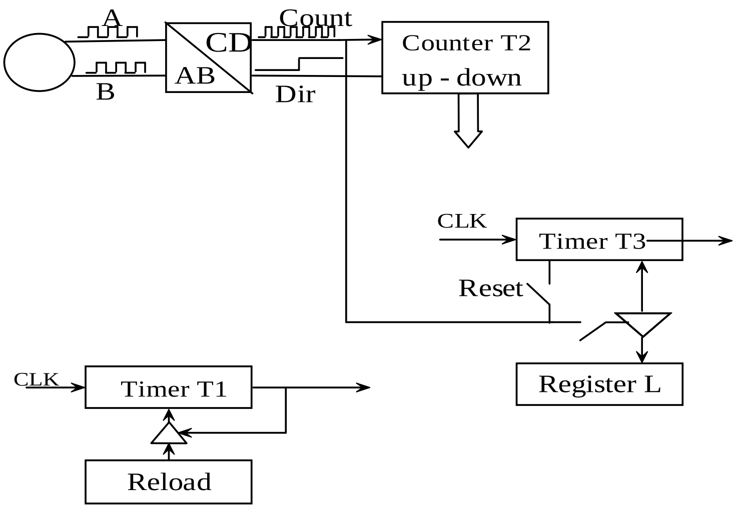

Fig. 1. Block diagram of speed measurement system - method M/T.

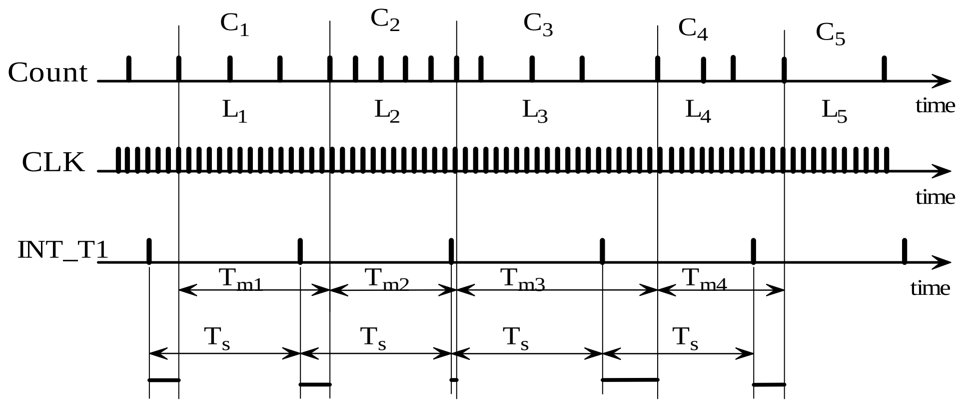

Fig. 2. Principle of speed measurement method M/T

sampling period, measured by timer T1, a first coming encoder impulse ends measurement period. This process is shown in fig. 2.

The speed is calculated according formula:

$$\omega(k) = \frac{C(k)}{N \cdot L(k) \cdot T_{clk}} \qquad (1)$$

Where

- $C(k)$ is a number of encoder pulses counted by T2,
- $L(k)$ is number of clock system pulses counted by T3,
- N is a number of encoder impulses per rotation,
- T_{clk} is a period of clock impulses.

Accuracy of this method is high and can be given by :

$$\Delta\omega = \frac{T_{clk}}{T_m} \cdot \omega_{max} \qquad (2)$$

where T_m is a measurement period

Measurement of small speed values ($C(k) = 1$) leads to counting a time distance between successive impulses like in the method T. Disadvantage of method M/T is variable measurement time, which varies between:

$$T_S \le T_m \le T_S + \frac{2\pi}{N \cdot \omega} \qquad (3)$$

where T_s is desired sampling period.

From formula (3) is visible that the measurement time T_m depends on actual value of measured speed and that the worst case appears for the smallest speed value.

In signal processor dedicated for motion control (ADMC 300) there is some other concept, which can be treated as modification of M/T. The method is realised by means of peripheral block – encoder interface unit (EIU) and bases on evaluating a change of position between successive measurements. This requires assumption that speed does not change significantly between two successive measurements. This condition is a reason of slightly less accuracy then in original M/T method.

In the paper a new modification of method M/T is proposed, which ensure constant sampling period with measurement accuracy equal to M/T. The proposed approach eliminates disadvantage of original M/T method, which is variable measurement period.

2. DESCRIPTION OF PROPOSED MEASUREMENT METHOD

The proposed method is a modification of M/T principle. Like in the original method the measuring period is variable and synchronised with encoder impulses but in opposition to that method it is shorter than sampling period. This is done by limiting the measurement period to the last encoder impulse, which is coming just before the end of sampling period. The principle of the method is shown in fig. 3.

The proposed method was implemented by means of single chip microcontroller SAB80C166. This unit contains 16 bit microprocessor equipped with

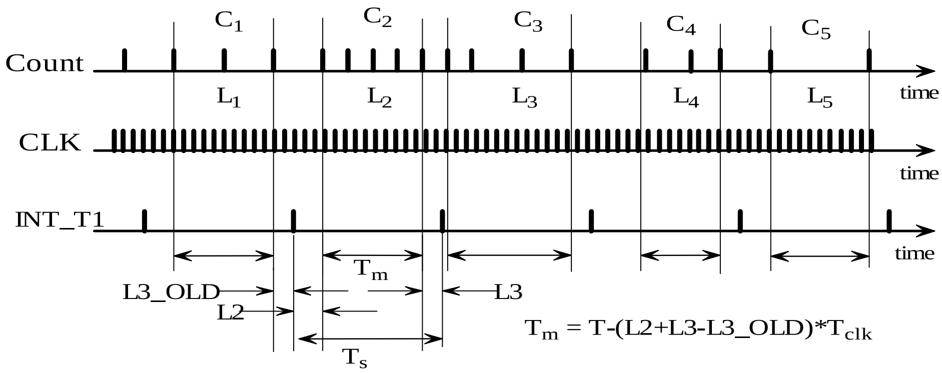

Fig.3. Principle of modified speed measurement method

such peripherals like counters and timers with compare and capture registers controlled by external signals. Important feature of applied microcontroller is hierarchical interrupt system. Block diagram of control system realisation is shown in fig. 4.

Timer T0 generates periodically interrupt impulses INT_T0 with proper periods Ts. Signals A/B from the encoder are converted to form C/D (counting impulse/direction) by external electronic module and are send to the input of reversible counter T3. Simultaneously the input impulses comes to the CAPREL register and are used to control of counter T5 operation. The T5 counts clock impulses of frequency 5 MHz (T=200 ns). The first impulse coming from the encoder generates interrupt signal INT_CR and reload actual value of counter T5 to the register CAPREL. Interrupt procedure (INT_CR) blocks itself starting till the end of running measurement period and stops reloading a value of counter T5 to the CAPREL. Interrupt procedure INT_T0, generated with constant period, initiates algorithm of speed calculation described by following formula:

$$\omega(k) = \frac{M(k)}{N \cdot T_m(k)} \qquad (4)$$

where M is

$$M(k) = L1(k) - L1(k-1) \qquad (5)$$

and T_m is

$$T_m(k) = T_s - T_{clk} * (L2(k) + L3(k) - L3(k-1)) \qquad (6)$$

For very small values of speed the timer T5 can be overflow what is not accepted in the algorithm (4). This situation is avoided due to interrupt procedure INT_T5, which is generated when T5 reaches its maximum state. The interrupt procedure stops T5 counting and generates the output signal of measured speed with information that speed is equal zero. This means that measurement procedure reaches its minimum value of measured range. For example if overload time of T5 is 13 ms and N=4000 ppr then the minimum speed is 1.2 rpm. The new coming encoder impulse starts counting

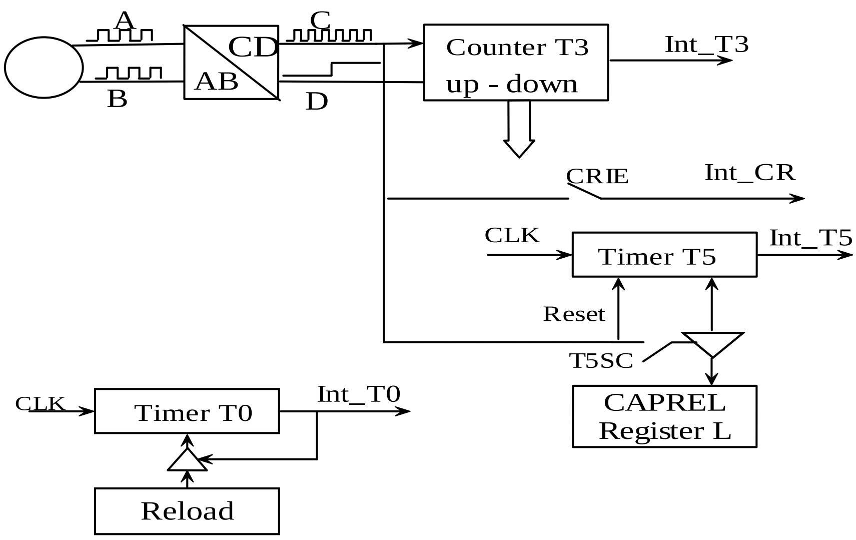

Fig.4. Block diagram of measurement system

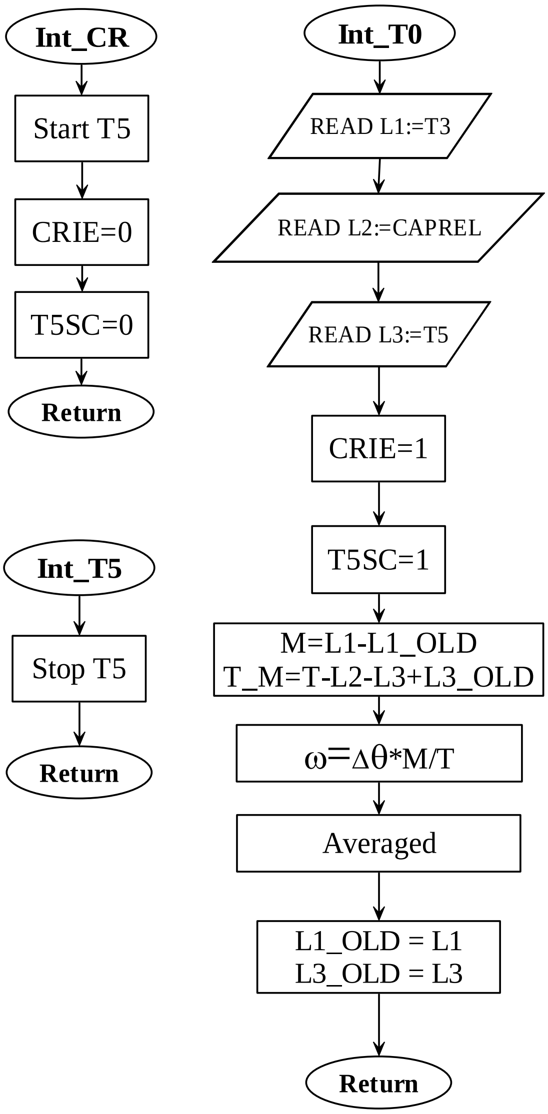

Fig. 5 Algorithms of interrupt procedures.

process of T5. Algorithms of interrupt procedures are presented in fig. 5.

Optionally the output signal of measured speed can be averaged to reduces some distortions. Dynamic buffer of FIFO type with length equal power of 2 enables fast calculation of average value. This procedure is reduced to one instruction of adding and one instruction of shifting.

3. EXPERIMENTAL RESULTS

The proposed measurement method was tested on a laboratory stand, which block diagram is shown in fig. 6. During the experiment the speed of induction motor supplied from frequency converter was measured in digital an analogue way. The digital measurement bases on proposed method and applies shaft encoder with N=4000 ppr. The result of microprocessor speed calculation was converted to the voltage by means of D/A converter and compared with voltage output signal of DC tachometer. The sampling period of speed measurement was assumed equal 0.25 ms.

Fig. 7 shows results of speed measurement during motor starting till rated speed value (1450 rpm). Motor starting time was equal 250 ms. The results confirm correct dynamic of speed measurement of proposed digital method. Distortion visible in both speed signals comes from non ideal coupling between induction motor and DC motor. The most difficult conditions for digital tachometer exists in the range of small speed. For this reason the second test was made for motor starting till 5% of rated speed value (75 rpm). The results of this test are shown in fig. 8.

High level of distortion (pulsation) in digital tachometer signal is caused by limited accuracy of encoder construction, which results in variable distance between markers generating encoder impulses. A possible way to eliminate this effect is averaging measured signals or

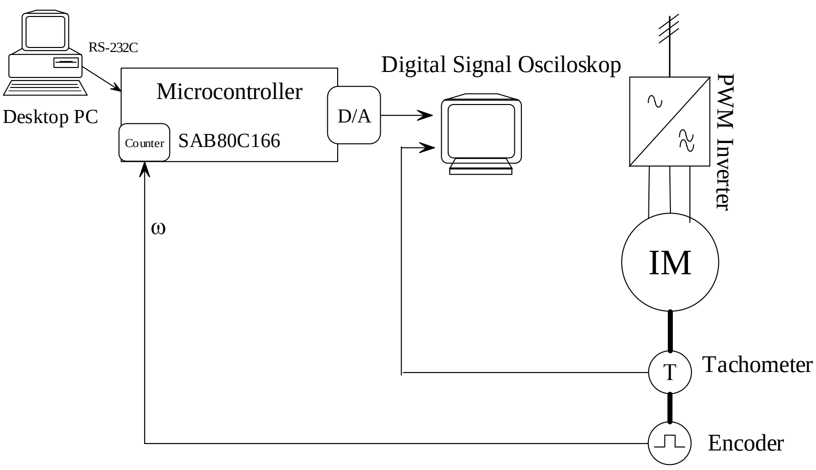

Fig. 6. Block diagram of a laboratory stand

enlarging measurement period. Assuming an output signal as an average of 8 samplings gives improved results (fig. 9). This signal is smooth but dynamic becomes slightly worst.

The problem of small speed measurement was tested by involving motor reverse from -2% to +2% of rated speed value (28 rpm). Results of this test are shown in fig. 10. Signal of digital tachometer has small distortion in area near zero speed.

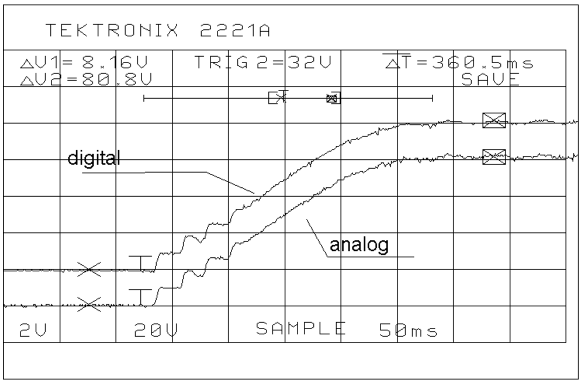

Fig 7. Transients of speed during motor start till 1450 rpm, measured by analogue and digital tachometers.

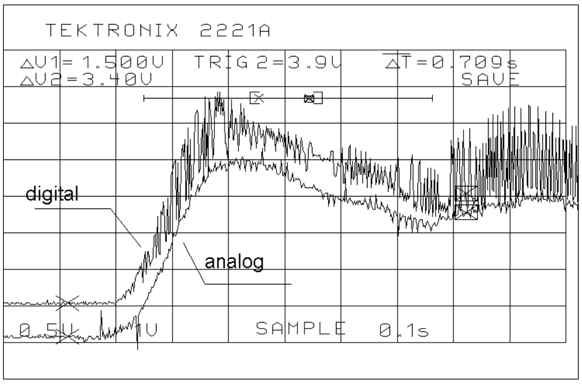

Fig 8. Transients of speed during motor start till 75 rpm, measured by analogue and digital tachometers.

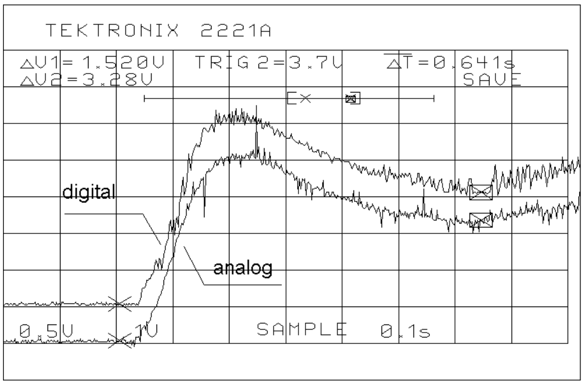

Fig 9. Transients of speed during motor start till 75 rpm, measured by analogue and digital tachometers; digital signal with filter

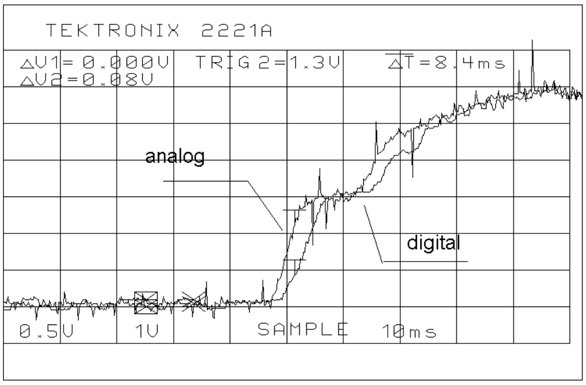

Fig10. Transients of speed during motor reverse from -28 to 28 rpm, measured by analogue and digital tachometers.

4. CONCLUSIONS

The proposed measurement method of digital tachometer enables to obtain good static and dynamic properties with applying ordinary shaft encoder. The method ensures speed feedback signal of digital control system without using expensive A/D converter necessary in case of DC tachometer. The presented system guarantees constant sampling period together with high accuracy, what is its significant advantage in comparison with all other known concepts of digital tachometers.

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