



High Precision, Wide Speed Range Rotation Sensing with UFDC-1

Nikolay V. KIRIANAKI¹, Sergey Y. YURISH^{1,2}

¹International Frequency Sensor Association (IFSA), e-mail: ifsa@list.ru

²Institute of Computer Sciences and Technologies, National University Lviv Polytechnic,
Bandera str., 12, 79013 Lviv, UA

Phone: +380502280003, fax: +380 32 2971641

E-mail: syurish@mail.lviv.ua

Received: 29 July 2005 Accepted: 15 August 2005 Published: 28 September 2005

Abstract: The application specific paper describes a high precision, wide speed rotation sensing approach based on the Universal Frequency-to-Digital Converter (UFDC-1). Such design approach lets significantly simplify the design process, reduce time-to-market and production price and produce tachometers and tachometric systems with high metrological performances and digital self-adaptive smart rotation speed sensors.

Keywords: rotation speed sensors, universal frequency-to-digital converter, UFDC-1, tachometer

1. Introduction

There are many known rotation speed sensing principles and many commercially available sensors [1]. The overwhelming majority of such sensors are based on the Hall-effect and magnetoresistors sensing principles or inductive sensing principle. According to the nature, rotation speed sensors are from the frequency-time domain. Output signal is a square-wave output of an oscillator the frequency of which is linearly dependent on the rotating speed and carries the information about it (Figure 1). Its frequency is proportional to the measured parameter. The inductive rotation speed sensor is shown in Figure 2.

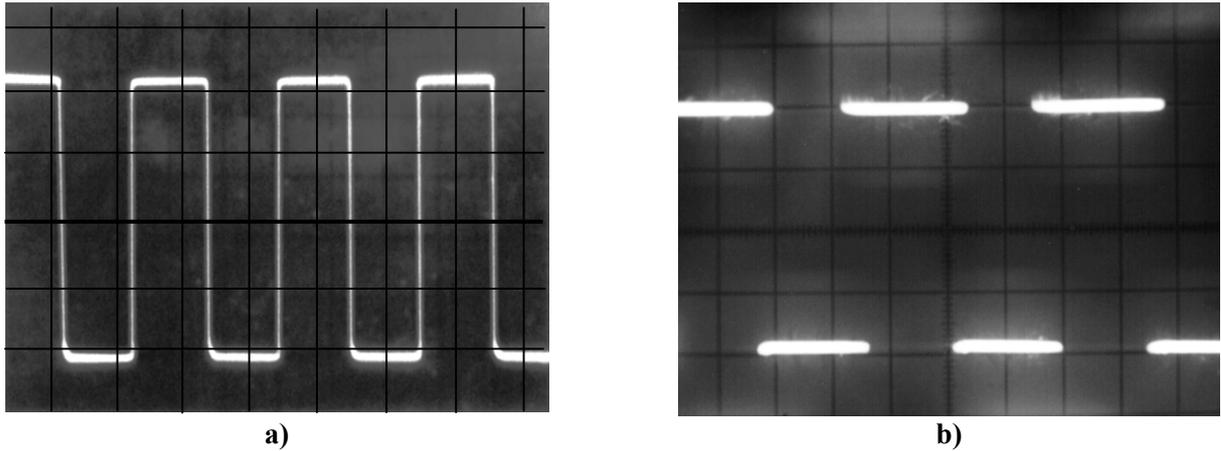
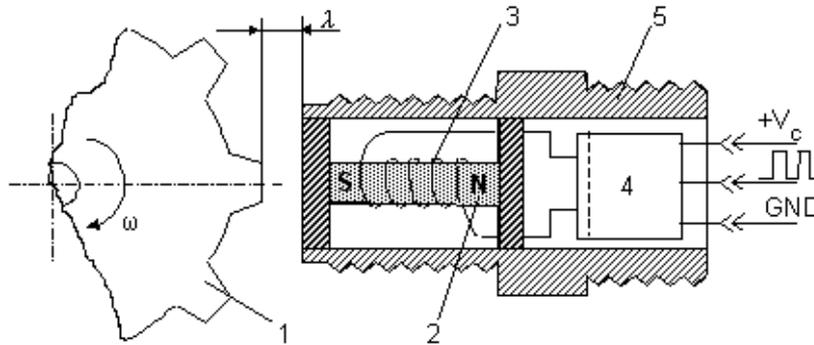


Fig.1. Waveform of rotation speed sensor's output: (a) - ASRS (Autoelectronic, Russia); (b) – BALLUFF, Germany



- 1 - gear tooth
- 2 - constant magnet
- 3 - inductance coil
- 4 - integrated circuit
- 5 - package
- λ - air gap
- ω - rotation speed (rpm)

Fig. 2. Inductive rotation speed sensor.

The measuring frequency of the rotation speed is given by

$$n_x = f_x \cdot \frac{60}{Z}, \tag{1}$$

where Z is the number of teeth; f_x is the frequency of rectangular pulses.

As usually, the rotation speed range is wide enough: from zero speed up to some hundred rpm. The rotation speed measuring accuracy is determined by the frequency measurement accuracy. The classical methods for frequency measurement (standard (direct) counting technique and indirect method of measurement) can not be used in such wide frequency range because of very high quantization error at the end and beginning of the frequency range [2]. There are many advanced

methods for frequency and rotation speed measurement [3], but a customer must buy a license for the use it in his designs. It is true also for the combined conversion method [4]. In order to eliminate such kind of design problems it is expediently to use the Universal Frequency-to-Digital Converter (UFDC-1) based on advanced methods for frequency and rotation speed [5].

2. Rotation Speed Sensors Interfacing

The UFDC-1 is ideally suited for rotation speed measurements. It can measure a rotation speed and present the results in *rpm* units. The number of gear teeth Z (1...255) must be set up in advance in the Master Mode (interface RS-232, unidirectional mode), by default $Z=1$. Any rotation speed sensor with frequency output can be connected directly to the UFDC-1. The first measuring channel should be used for this purpose. The appropriate relative error of measurement should be chosen from the range $[0.001 \div 1]$ %. The appropriate set of commands is shown in Figure 2.

Through RS-232, SPI or I²C buses the UFDC-1 can be connected to the LCD or LED indicators. It lets build precise wide speed range tachometers and tachometric systems with minimum possible hardware. The UFDC-1 also can be connected to any master microcontroller or PC.

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>MA; Rotation speed measurement initialization
>Z0C; Set up  $Z=12_{(10)}=C_{(16)}$ 
>A9; Choose the conversion error 0.001 %
>S; Start a measurement
>R; Read a result of measurement in rpm
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Fig. 2. *Appropriate UFDC-1 commands (RS-232) for precision wide range rotation speed measurements with 0.001 % relative error.*

In a system, the UFDC-1 can also measure rotation acceleration. An external microcontroller or PC calculates acceleration of rotation based on two measurements n_1 and n_2 of rotation speed and time interval for the second measurement t_2 :

$$\varepsilon_x = \frac{n_1 - n_2}{t_2}, \text{ rpm}^2 \quad (2)$$

The sign "-" indicates deceleration of rotation, and "+" indicates acceleration of rotation.

3. Sensors Examples

A good example of rotation speed sensor is the inductive position, speed and direction active micro-sensor MS1200 from CSEM (Switzerland) [6]. The device has the output that can switch up to 1 mA and is compatible with CMOS digital circuits, in particular with the UFDC-1. The frequency range is $0 \div 40$ kHz, the air-gap is $0 \div 3$ mm. The core is a sensor chip with one generator coil and two sets of detection coils (Figure 3).

The detection coils are connected in a differential arrangement, to reject the common mode signal. The sensor also includes an electronic interface, which is composed of a high frequency excitation for the generator coil and two read-out channels for the two sets of detection coils (channels A and B). The read-out electronics extract the amplitude variation of the high frequency signal due to the presence of a

metallic target. The output stage is a first order low-pass filter and a comparator. For a nominal target period of 2 mm, the outputs are two channels in quadrature (A quad B) as well as a direction signal and a speed signal (4X interpolation). It is composed of two silicon chips, one for the integrated micro-coil and the other for the integrated interface circuit. The sensor produces a two-channel quasi-digital output, as well as a direction signal.

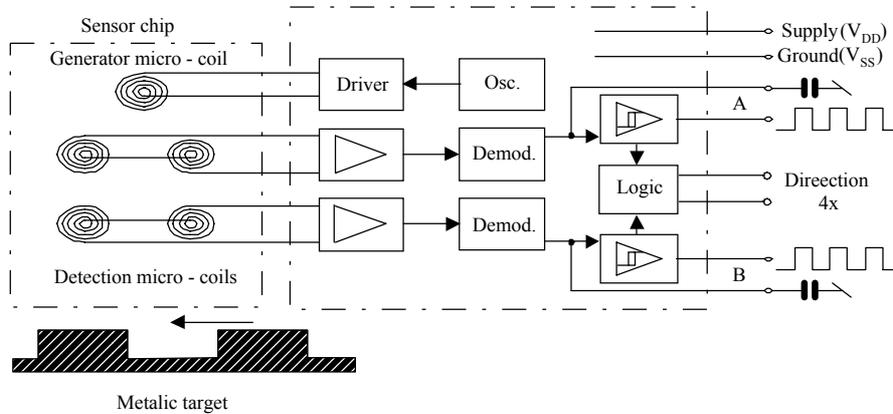


Fig.3. MS 1200 Functional Block Diagram.

Another example is the quasi-digital inductive position, speed and direction sensor PO1210. This inductive micro-sensor is an integrated version of the LVDT and resolver type of sensors. The frequency range is 0 ÷ 40 kHz, the air-gap is 0 ÷ 0.9 mm [7]. It is a versatile position sensor for multiple applications. It is particularly well suited for gear tooth sensing in harsh environments. The sensor can operate in combination with a wide range of linear or angular target gears. However, sensing characteristics (duty cycle, phase) and maximum working distance will depend on the target form.

In both case these sensors can be easily connected to the UFDC-1 to produce real digital output according to the RS-232 interface, SPI or I²C serial buses. Due to minimum possible circuitry necessary for sensor output processing, the UFDC-1 can be embedded into microsystems (MEMS) or system-on-chip (SoC) (Figure 4).

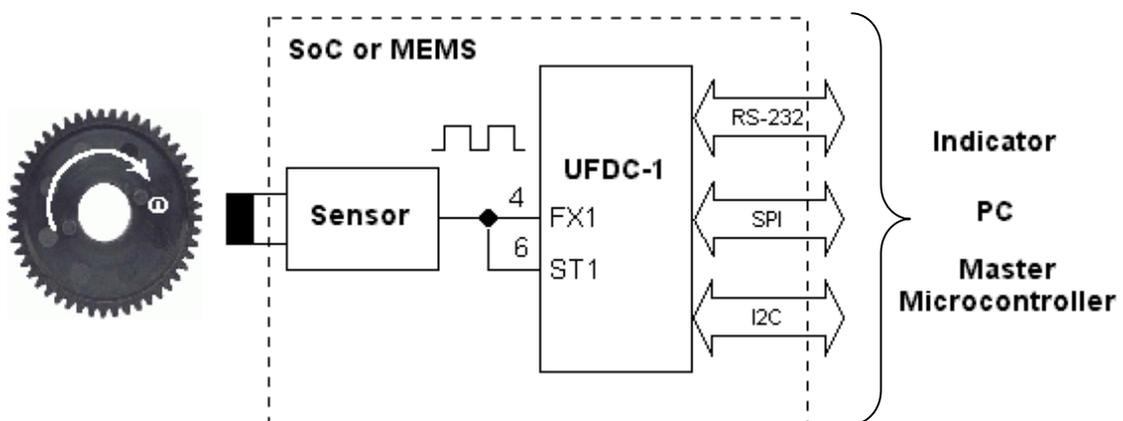


Fig.4. SoC for rotation speed measurement.

4. Smart Rotation Speed Sensors Based on the UFDC-1

One more interesting design approach application based on the UFDC-1 is self-adaptive smart rotation speed sensors. In such sensors, some parameters can be changed according to measurement conditions and algorithms. Therefore, due to programmable accuracy and non-redundant conversion time of the UFDC-1, rotation speed sensors on its basis can change accuracy for speed and opposite. This smart possibility is very useful for Antilock Braking System (ABS). It lets choose the minimum possible conversion time at critical rotation speed of wheels and maximum possible accuracy for the best engine optimization at nominal rotation speed of wheels.

5. Software

There are many ways to display the rotation speed measurement results. Any terminal software for Windows can be used with the UFDC-1 using the serial port of a PC [5]. One of the possible choices is Terminal V1.9b (<http://bray.velenje.cx/avr/terminal>) free software (Figure 5). Other possibilities are Component Works 2.0 (ActiveX control) or LabView. Both software products are from *National Instruments*.

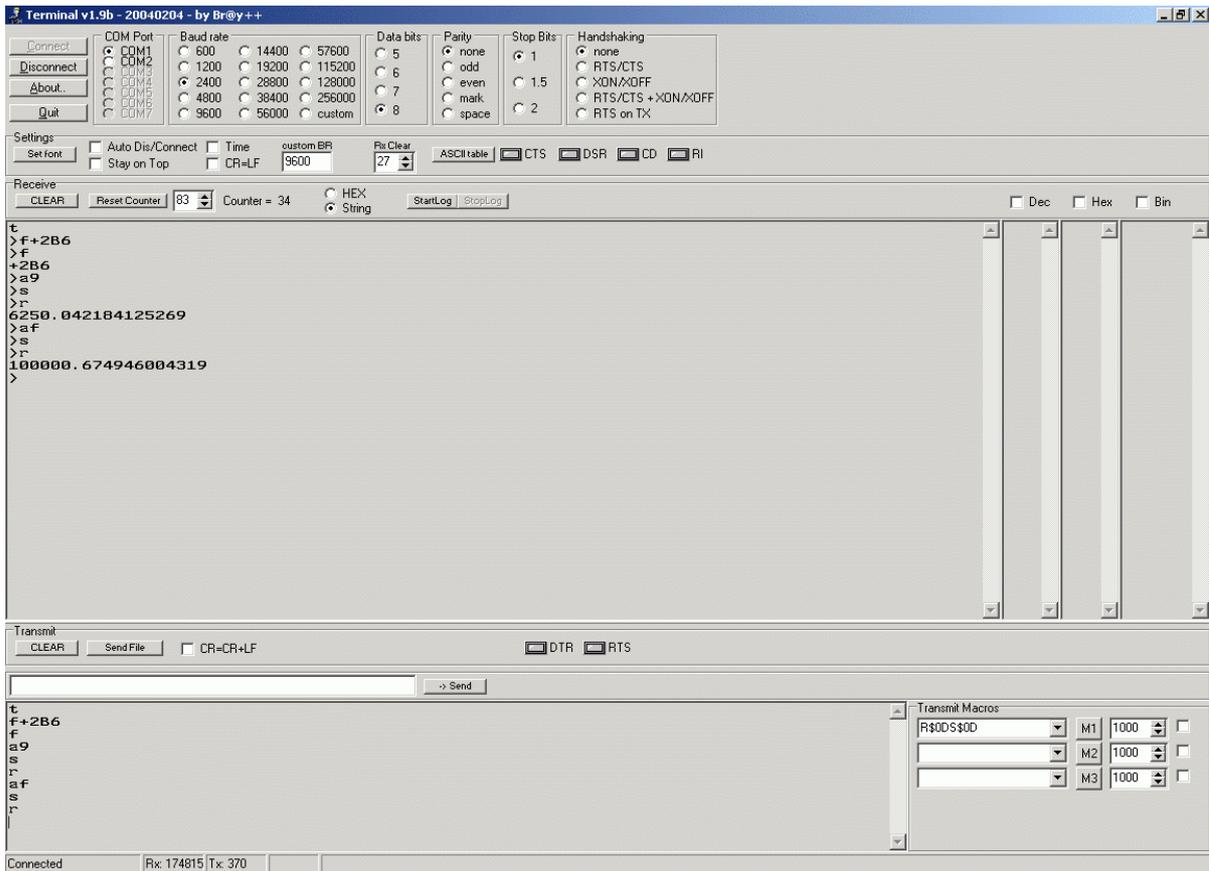


Fig. 5. Terminal V1.9b Window.

The virtual tachometer is shown in Figure 6. Its software was written in Visual Basic 6.0 with Component Works 2.0 (ActiveX control).

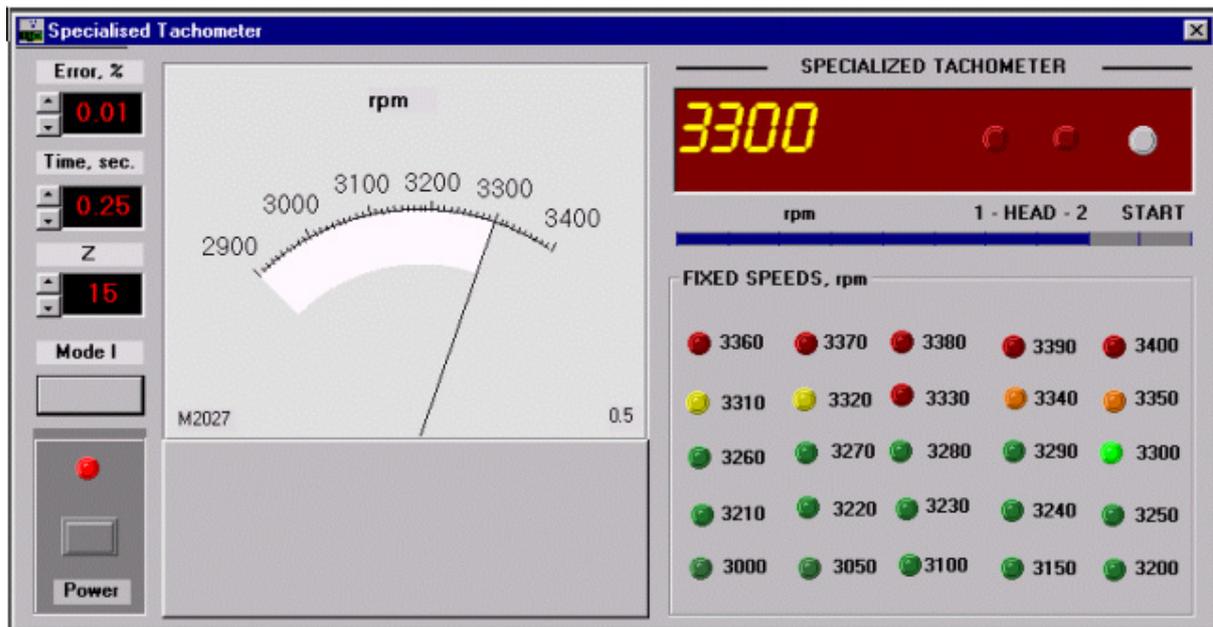


Fig. 6. Virtual Tachometer.

5. Conclusions

The described approach for a high precision, wide speed rotation sensing is based on the Universal Frequency-to-Digital Converter UFDC-1. It lets significantly simplify the design process, reduce time-to-market and production price and produce tachometers and tachometric systems with high metrological performances and digital self-adaptive smart rotation speed sensors.

In comparison with the direct microcontroller interfacing the proposed approach also lets to eliminate many design problems connected with the use of advanced methods for rotation speed measurement and SoC creation.

References

- [1]. Sensors Web Portal (http://www.sensorsportal.com/HTML/SENSORS/RotationSens_Manuf.htm).
- [2]. Kirianaki N.V., Yurish S.Y., Shpak N.O., Deynega V.P., Data Acquisition and Signal Processing for Smart Sensors, *John Wiley & Sons*, 2002.
- [3]. Smart Sensors and MEMS, ed. by Sergey Y. Yurish and Maria Teresa S.R. Gomes, *Kluwer Academic Publishers*, 2004.
- [4]. Kirianaki N.V., Gayduchok R.M., Digital Measurements of Frequency-Time Parameters of Signals, *Vyshcha Shkola*, Lviv, 1978 (in Russian).
- [5]. Universal Frequency-to-Digital Converter (UFDC-1), Specification and Application Note, 2004 (http://www.sensorsportal.com/HTML/E-SHOP/PRODUCTS_4/UFDC_1.htm).
- [6]. Digital Inductive Position Sensor 1200, Product Description, CEMS, Switzerland, 2000.
- [7]. Digital Inductive Position Sensor PO1210, PO1210-DS-V2B, *Posic SA*, Switzerland, (<http://www.posic.com>).
- [8]. Mechanical and electrical interfacing of PO1210. Application note, *Posic SA*, Switzerland, 2002.