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MAGNETIZING SIGNAL GENERATOR FOR COMPENSATION FERROMETERS

Ivan Zemánek* — Petr Zemánek — Aleš Havránek***

A precise microprocessor controlled programmable generator of periodic magnetizing signals for compensation ferrometers was designed and realized. Generator digitally synthesizes and generates AC random waveform signals with amplitudes 0 – 10 V and frequencies 10 Hz – 120 kHz at sampling rates up to 20 MSPS and maximum 2048 samples per period. Generator exactly and reliably fulfils the most important functions of the compensation method magnetizing process – autonomous uninterrupted signal generation and simultaneous adaptive signal waveform correction. Results of measurement on realized generator are presented.

Keywords: magnetizing signal generation, microprocessor control, signal samples modification, dual-port SRAM

1 INTRODUCTION

Compensation ferrometers are single sheet testers (SSTs) for the measurement of magnetic properties of open specimen soft magnetic materials at AC magnetization based on the original Czech compensation method [1-3]. The block diagram of the compensation ferrometer is in Fig. 1.

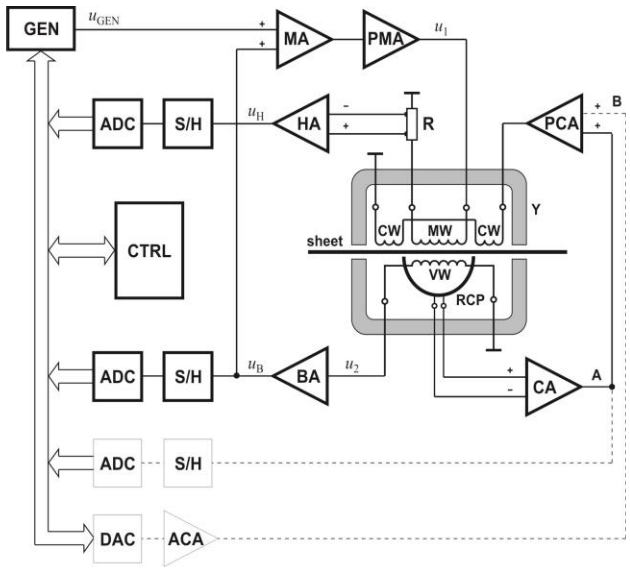

Fig. 1. Block diagram of compensation ferrometer

Magnetizing equipment (consisting of magnetizing yoke Y, magnetizing winding MW, voltage winding VW, compensation winding CW and Rogowski–Chattock potentiometer RCP) is excited by magnetizing voltage u_1 generated in the exciting system (signal generator GEN, magnetizing amplifier MA, power magnetizing amplifier PMA). The measuring system (Ayrton current shunt R, measuring amplifiers BA, HA, sample–holds S/H, analogue–digital converters ADC) digitally measures the magnetic flux density B and magnetic field strength H in the measured specimen (sheet) of a magnetic material (voltages u_B, u_H). Using digital signal processing of the voltages u_B and u_H in the control unit CTRL required magnetic parameters of measured material are computed. Correct magnetic field strength H measurement conditions are maintained by the analogue MMF compensation feedback loop (Rogowski–Chattock potentiometer RCP, compensation amplifier CA, power compensation amplifier PCA, compensation winding CW). The efficiency of the MMF compensation can be prospectively increased by additional digital feedback branch A–B (CA output A, sample–hold S/H, analogue–digital converter ADC, control unit CTRL, digital–analogue converter DAC, additional compensation amplifier ACA, PCA input B).

The programmable μP–controlled signal generator GEN is a topic of this paper.

2 SIGNAL GENERATOR FUNCTIONS

The requirements on signal generator functions [4-5] flow from three sources – the International standards (IEC) for soft magnetic materials AC measurements, the compensation method principle applied in compensation ferrometers, and requirements of research laboratory and industrial measurements of modern magnetic materials at standard and non–standard magnetizing conditions. The main required signal generator functions are:

- AC voltage signal.
- Three basic predefined waveforms:
  - sinusoidal
  - triangular
  - rectangular
- Programmable amplitude 0 – 10 V.
- Programmable frequency 10 Hz – 100 kHz.
- Autonomous uninterrupted signal generation, and simultaneous signal waveform correction (sample by sample modification).
- 12–bit precision, up to 2048 samples per period.

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3 SIGNAL GENERATOR

The structure of the designed and realized microprocessor controlled signal generator is in Fig. 2.

The generator control unit CTRL is realized by the microprocessor STM32F100RB. Its ports PA, PB, and PC are programmed as the control, address and data buses, respectively. One bit of the PD port (PD_1) brings exact stable basic control frequency (clock frequency) f_{GEN} = 11.0592 MHz from the microprocessor internal crystal oscillator. This basic frequency is convenient for exact and easy generation of other required frequencies (by division)

$$f_{GEN} = 11.0952 \text{ MHz} = 2^{14}\, 3^{3}\, 5^{2} \text{ Hz} . \tag{1}$$

The main control (timing) frequency f_T is generated in frequency predivider D (division by 8) and programmable frequency divider PD (division by D_T).

$$f_T = \frac{f_{GEN}}{8 D_T} = N f . \tag{2}$$

For given number of samples per period N the control frequency f_T determines resulting frequency f of the generated voltage signal $u(t)$.

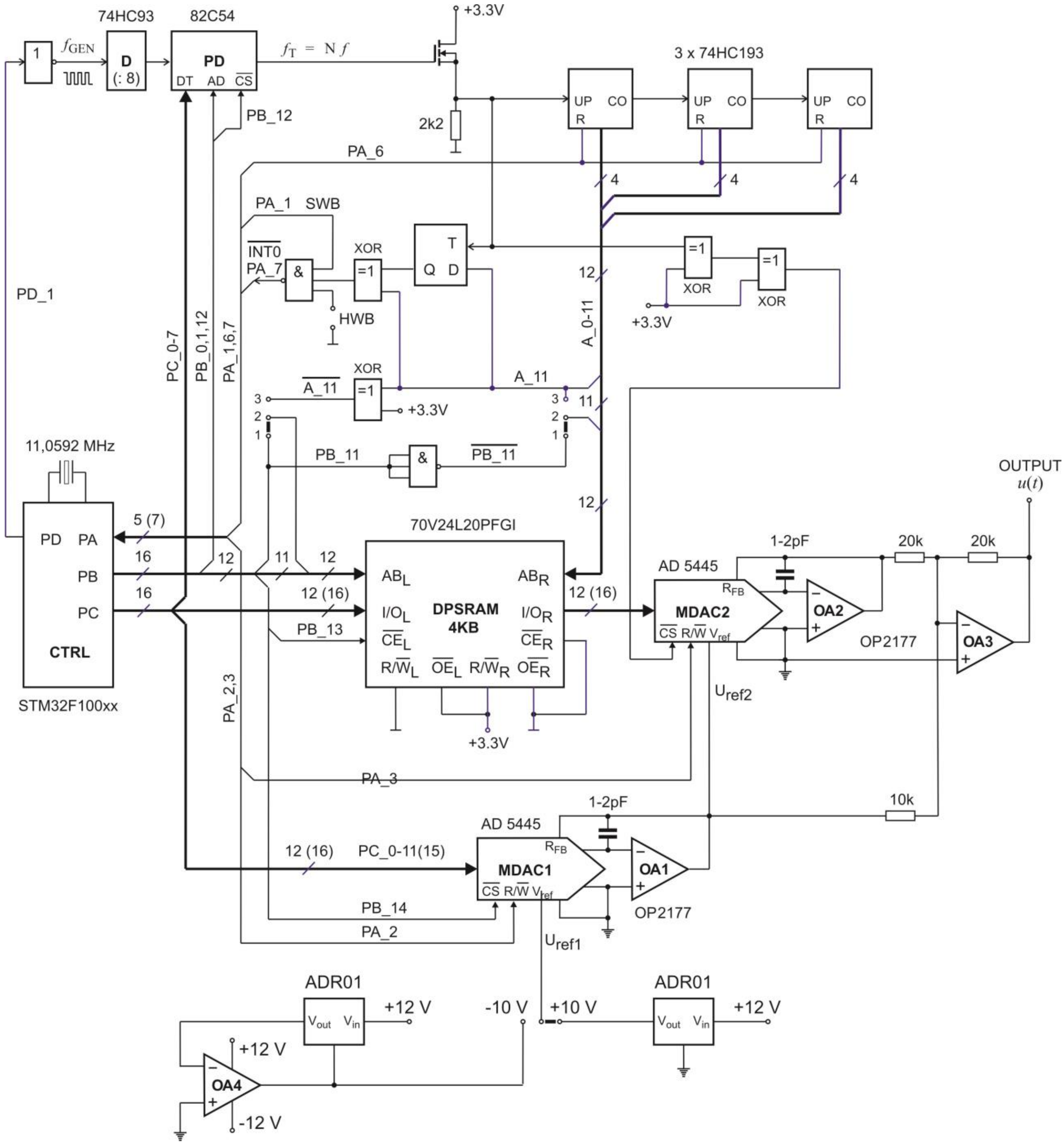

Fig. 2. Microprocessor controlled signal generator

The most significant component of the generator is the dual-port static memory DPSRAM (4K × 16). This type of memory gives possibility for both autonomous uninterrupted signal generation, and simultaneous memory contents modification – signal samples correction.

The signal samples generation, their periodical modification, recalculation, correction and writing back into the DPSRAM is controlled by the microprocessor (control unit CTRL) connected with the write-only DPSRAM left port. The control routine is periodically called by the interrupt signal \INT0 generated in the control logic.

The generated periodic signal is digitally synthesized from 12-bit (16-bit) samples stored before in the DPSRAM. The memory contents reading is controlled independently on the microprocessor control unit (CTRL) by the 12-bit address counter AC modulo M = 4096 (three 4-bits binary counters cascade) clocked by the control (timing) frequency f_T. The address counter AC addresses the DPSRAM through the read-only DPSRAM right port. The read-out signal samples are continually converted in the multiplying digital-analogue converter MDAC2 with the reference voltage U_{ref2} controlled by the microprocessor control unit CTRL and digital-analogue converter MDAC1. The current outputs of both digital-analogue converters must be completed by the operational amplifiers (OA1 and OA2, OA3, respectively) those serve as the current-voltage converters (in the case of the MDAC2 the OA2, OA3 generate bipolar AC waveform). The resulting magnetizing voltage $u(t)$ of the required waveform, amplitude and frequency is generated.

One of the most important functions of the control logic is the suppression of unwanted data write-in and read-out collision. For that it is sufficient to guarantee the MSBs of the DPSRAM writing and reading addresses to be different (binary complements) at any time. There are two possible ways of the collision suppression. Both of them are in Fig. 3.

The first possibility is realized if both jumpers are in positions 1-2. The DPSRAM writing addresses are formed from bits PB_0-11 only generated by the control unit CTRL. The DPSRAM reading addresses are combined from the inverted MSB PB_11 (binary complement \PB_11) and from bits A_0-10 generated by the address counter AC. The MSB PB_11 and its complement \PB_11 divide the 4K DPSRAM into two 2K blocks – write-in and read-out ones. Unwanted data write-in and read-out collision is suppressed by this way. The MSB A_11 is ignored in this case. The MSB A_11 is used for the interrupt signal \INT0 generation only. This way of the collision suppression is advantageous due to the fact – the signal samples modification and their writing to the DPSRAM have no time limit. After the writing process the write-in and read-out functions of both 2K DPSRAM blocks are changed by the MSB PB_11 software inversion.

The second possibility of the collision suppression is realized if the jumpers are in positions 2-3. The DPSRAM writing addresses are formed from the LSBs PB_0-10 (generated by the CTRL) completed by the binary complement \A_11 of the MSB A_11 (generated by the address counter AC) The DPSRAM reading addresses are formed from the AC bits A_0-11 only. The MSB A_11 and its complement \A_11 divide the 4K DPSRAM into two 2K blocks – write-in and read-out ones. The MSB A_11 is used for both read-out addressing and for the interrupt signal \INT0 generation, too. This way of the collision suppression is much simple (in comparison with previous one). However, the signal samples modification and their writing to the DPSRAM have time limit – they must be finished during half period of the AC counting period (*ie* before the MSB A_11 change). This fact brings troubles in high frequency applications.

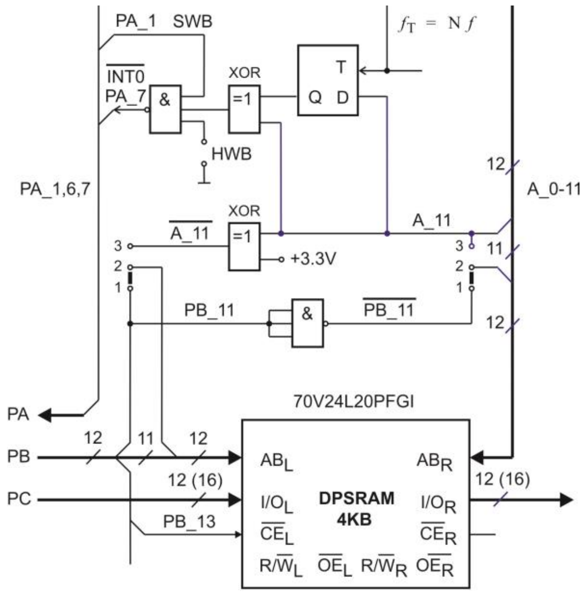

Fig. 3. DPSRAM and control logic

The signal samples modification and their writing to the DPSRAM are controlled by the control unit CTRL and realized in special interrupt routine called by the interrupt signal \INT0 generated by the control logic (Fig. 3).

The interrupt routine can be called at the beginning of any half period of the address counter AC only. This moment is indicated as the MSB A_11 change by the simple logic consisting of D flip-flop and Exclusive OR gate (XOR) where the signal A_11 and the delayed one are compared (D flip-flop output Q controlled by the timing frequency f_T). The interrupt signal \INT0 (PA_7) can be blocked by software blocking signal SWB (PA_1) in the 3-input NAND gate.

4 EXPERIMENTS

The microprocessor controlled signal generator was designed and realized. The STM-Discovery design kit with microprocessor STM32F100 was used as a control unit CTRL for experiments and control software design. The achieved experimental results are:

- Generator generates periodic random waveform voltages with zero average value (AC signals).

- Sinusoidal, triangular and rectangular waveforms are predefined.
- Programmable amplitude U_m = 0 – 10.2 V.
- Programmable frequency f = 10 Hz – 120 kHz.
- The autonomous uninterrupted signal generation, and simultaneous signal waveform modification (sample by sample modification).
- 12–bit precision, up to 2048 samples per period.
- Generated signals form factor (3) and distortion (4) at U_m = 10 V and f = 450 Hz are in Table 1.

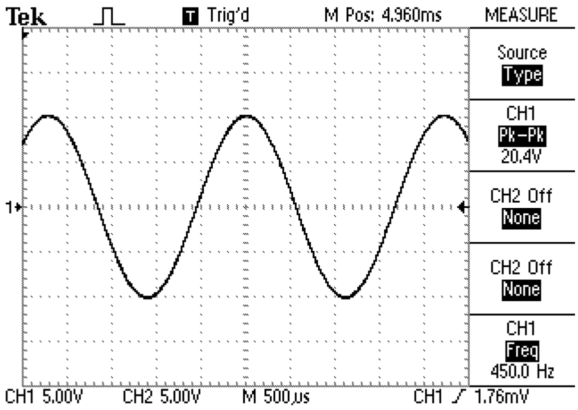

Fig. 4. Generated sinusoidal signal (U_m=10 V, f =450 Hz)

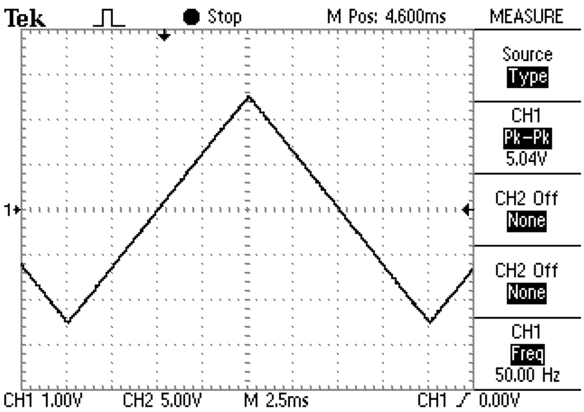

Fig. 5. Generated triangular signal (U_m=2.5 V, f =50 Hz)

$$k = \frac{U_{\mathrm{RMS}}}{U_{\mathrm{mean}}}, \tag{3}$$

$$d = \frac{\sqrt{U_{\mathrm{RMS}}^2 - U_{\mathrm{RMS},1}^2}}{U_{\mathrm{RMS}}}, \tag{4}$$

Table 1. Generated signals (U_m=10 V, f =450 Hz)

Signal	k_{id}	k	d
sinusoidal	1.1107	1.1101	0.0083
triangular	1.1547	1.1536	–
rectangular	1.0000	1.0048	–

5 CONCLUSION

The microprocessor controlled AC signal generator for compensation ferrometers was designed and realized. The classic structure with discrete components was used for generator functions verification.

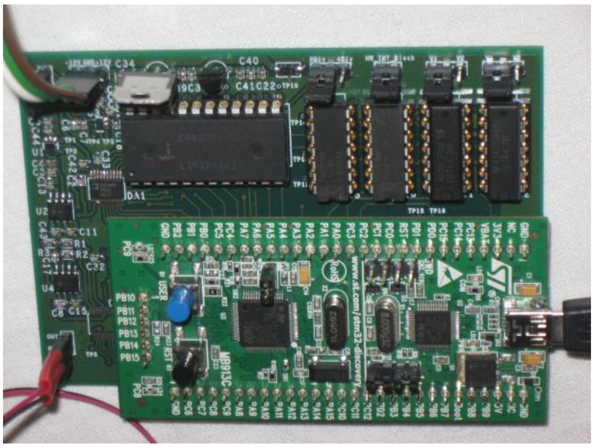

Fig. 6. Generator with STM–Discovery design kit

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