Design and Investigation of FPAA Square-wave Generator

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Abstract – **In this paper a FPAA (field programmable analog array) square-wave generator with programmable frequency and duty cycle is designed. The synthesized circuit is investigated by using AN220D04 Evaluation Board from Anadigm®.**

Keywords – **programmable analog IC, Field programmable analog array (FPAA), square-wave generator**

I. Introduction

The Field Programmable Analog Arrays (FPAAs) are one of the most contemporary and perspective products for fast and flexible implementation of different circuit and devices. Essentially, FPAAs are the analog equivalent of well-known digital Field Programmable Gate Arrays (FPGA). The most popular of them use switched-capacitor techniques, which ensure improved accuracy and consistency of time constants and give possibilities for dynamic programming of configuration and performance of the circuits [1].

Some of the most popular FPAAs are the chips of Anadigm Inc. [2]. They consist of switched-capacitor configurable analog blocks and SRAM. By changing the configuration data, stored in the memory, designer can control the functionality or parameters of the blocks. This programming procedure uses CAD tools that automate the process. Currently, different types of amplifiers, sample-and-hold circuits, integrators, differentiators, filters, etc. are available as library components (IP modules). Different complex analog systems can be implemented by using them. The simplicity and compactness of these solutions stimulate designers to synthesize and examine various circuits and systems by using FPAA.

The paper presents design and investigation of square-wave generator with programmable frequency and duty cycle by using FPAA from Anadigm®.

II. Classic square-wave oscillator

Fig. 1 shows the classic square-wave oscillator circuit [3]. The circuit uses two op amps: first of them (A), together with the resistors R1 and R2, build up a symmetric Schmitt trigger; the second (B), together with the resistor R and capacitor C, build up an Integrator.

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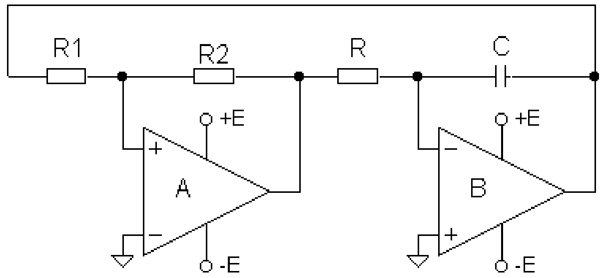

Fig. 1. Classic square-wave oscillator

The equations for pulse width T^+ and pause T^- are:

$$T^+ = \frac{H}{kU^+} \qquad (1)$$

$$T^- = \frac{H}{kU^-} \qquad (2)$$

where H is the hysteresis of Schmitt trigger, k is the constant of the integrator ($k=1/RC$), U^+ and U^- are the corresponding output values of positively and negatively saturated op amp A. Because of $U^+ \approx -U^-$, the duty cycle D is constant (about 50%).

In Fig. 2 is depicted the functional structure of improved square-wave oscillator [4]. To control duty cycle D and frequency of generation f, two independent voltage sources U^+ and U^- are added. Through analog multiplexer AMUX (controlled by Schmitt trigger output state), these voltage sources are switched alternatively to the input of the integrator. By changing their values, the duration of T^+ and T^- (and consequently the frequency f and duty cycle D) of the signal can be controlled.

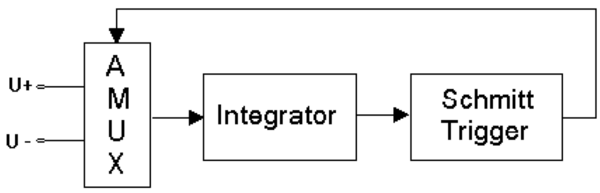

Fig. 2. Functional structure of square wave oscillator with independent control of frequency and duty cycle

III. FPAA square-wave oscillator circuit

Fig. 3 shows FPAA implementation of the oscillator from Fig. 2. The square waves appear between pins 3 and 4, and triangular waves - between pins 7 and 8. The circuit is designed by using specialized development software AnadigmDesigner2. The integrator *Int* is realized with standard IP module from the Anadigm® library. The Inverting

Schmitt trigger [5] uses Gain Stage with Switchable Inputs (*Comp1+PGA1*), Reference Voltage Source (*+3V*) and Inverting Gain Stage Amplifier (*IGS*). The analog multiplexer AMUX consists of second Gain Stage with Switchable Inputs (*Comp2+PGA2*) and two Reference Voltage Sources (*+3V* and *–3V*). The Gain Stage with Switchable Inputs is a standard library block of AnadigmDesign2 software [2]. It consists of comparator *Comp* and switchable input amplifier with low-pass filter *PGA*. The output of the comparator *Comp* controls the input switching of the amplifier. The gain of amplifier *PGA* can be programmed independently for each of the switchable signals.

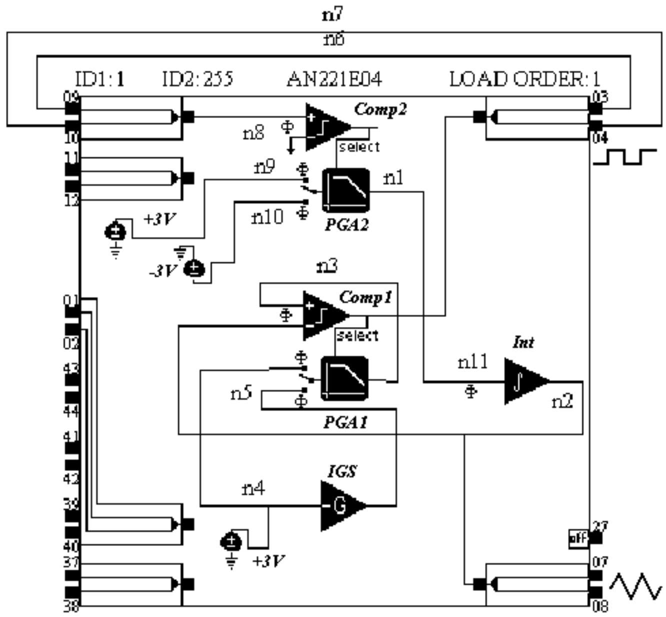

Fig. 3. Implementation of FPAA square wave generator with independent control of frequency and duty cycle

From (1) and (2), for the frequency *f* and duty cycle *D* of oscillations is obtained the following:

$$f = \frac{k}{H\left(\frac{1}{U^{+}} + \frac{1}{U^{-}}\right)} \qquad (3)$$

$$D = \frac{U^{-}}{U^{-} + U^{+}}. \qquad (4)$$

In the above formulas U^{+} and U^{-} are the corresponding values of voltage at node n11 (the input of the Integrator) during the pulses and pauses of the signal. Their values are:

$$U^{+} = +3G_1 \qquad (5)$$

$$U^{-} = -3G_2 \qquad (6)$$

where G_1 and G_2 are the gain for each of the channels of *PGA2*.

The value of hysteresis *H* depends on the gain parameters of the amplifier with low-pass filter *PGA1*, which is included in the Schmitt trigger [5].

Hence, the full scale values of the frequency and duty cycle could be adjusted by changing *k*, *H*, U^{+} and U^{-}.

The discussed oscillator is examined by using AN220D04 FPAA Evaluation Board from Anadigm®. This board allows programming of FPAA integrated circuit AN220D04 via the serial port of the personal computer.

The synthesized circuit is examined for different combinations of values of *k* (between 0,04μS^{-1} and 4,05μS^{-1}), *H* (between 0.3*V* and 6*V*), U^{+} (between 0.15*V* and 3*V*) and U^{-} (between 0.15*V* and 3*V*). As results, time intervals from 2μS to 400μS were obtained. The summarized results for four corner combinations of U^{+} and U^{-} are shown in Table 1. To ensure better linearity of integration and higher accuracy of generated waveforms in discussed experiment, the values of *k* and *H* are chosen as follows: *k*=0.1μS^{-1} and *H*=6*V*.

TABLE 1
SUMMARIZED RESULTS FROM CIRCUIT EXAMINATION

U^{+}, V	U^{-}, V	*Frequency, Hz*		*Duty cycle*	
		Calculated	*Measured*	*Calculated*	*Measured*
0.3	0.3	2500	2500	0.5	0.4875
0.3	3	4545.5	4525	0.909	0.905
3	0.3	4545.5	4444	0.0909	0.0889
3	3	25000	23810	0.5	0.488

The analysis of results shows good predictability of the generated frequency and its duty cycle. Specific feature of the amplifiers, used in the circuit, is the possibility to regulate their gain with very small step (down to 0.01). Hence, the desired waveform parameters can be tuned more precisely by using simple interactive procedures based on the successive and purposefully changing of U^{+} and U^{-} up to the achievement of the desired results.

IV. CONCLUSION

The paper proposes an implementation of square-wave oscillator with programmable frequency and duty cycle by using FPAA. To this aim, an analogy with classic oscillators is used to determine the functional structure of oscillator with external control of parameters. On this base, FPAA circuit, which uses specific functional blocks from the library of the FPAA device, is synthesized. The proposed circuit is practically implemented and examined with AN220D04 FPAA Evaluation Board from Anadigm®. It is characterized with good predictability, simple tuning and high precision in setting of the frequency and duty cycle of the generated waveforms.

The presented results will be used as a part of more complex analog and mixed-mode FPAA systems.

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