Design and Investigation of Pulse Width Modulator Using FPAA

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***Abstract* – The paper presents the design of a pulse width modulator using field programmable analog array (FPAA). The presented circuit is designed and implemented as integrated analog IP core using the FPAAs of Anadigm®. The operation of the designed pulse width modulator has been simulated using AnadigmDesigner2 software. The simulation results have been validated using Anadigm® evaluation board.**

The presented results will be used in further design of more complex analog and mixed-mode systems using FPAA.

***Keywords* – Pulse width modulator (PWM), Field programmable analog array (FPAA), Switched capacitor circuit, Analog IP core**

I. INTRODUCTION

Pulse width modulators (PWM) convert analog voltage $u_i(t)$ to square waves $u_{PWM}(t)$ with a constant frequency and a variable width, which is accurately proportional to the analog quantity as it is shown on the time diagrams in Fig. 1. The magnitude of the pulses is equal to the supply voltage. PWMs are used in the industrial measurement and in the automation and control, especially for motion control. Pulse width modulators are basic stages in the switching power supplies and power amplifiers [1].

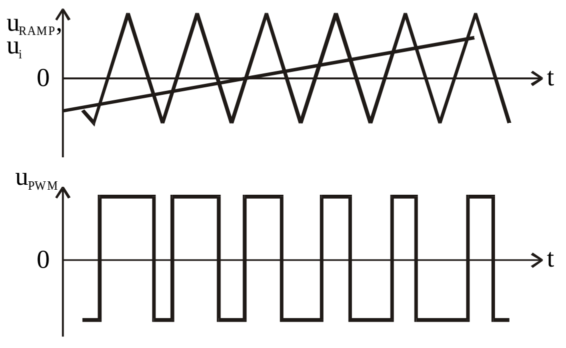

Fig. 1. Time diagrams of a pulse width modulator

The transfer function of the pulse width modulator is [4]:

$$U_{PWM} = \frac{U_{mid} - U_i}{U_{pk}} U_{CC}, \qquad (1)$$

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where U_{PWM} is the average value of the output voltage $u_{PWM}(t)$, U_i is the average value of the input voltage $u_i(t)$, U_{mid} is the middle point of the ramp voltage $u_{RAMP}(t)$, U_{pk} is the peak value of the ramp voltage $u_{RAMP}(t)$, U_{CC} is the supply voltage [2].

PWM circuits are taking the same general course of development traveled by operational amplifiers and many other electronic functions. Concepts were brought to life using discrete components and were followed by modules, hybrids and then monolithics. In order to obtain a high accuracy and linearity they require stable voltage references and precise passive components. If the settings must be changed the used components have to be replaced by another with different values or to be used components with variable values.

Most of the disadvantages can be avoided by using field programmable analog arrays (FPAA) [3]. They are integrated circuits that possess the possibility of programming and dynamic reconfiguration of different analog and mixed-mode functions in one chip. These contemporary and very advanced products offer reducing of cost, size and complexity of electronic circuits. As the physical platform the FPAA architecture is built on the natural precision, generic form, and switching fabric of a CMOS-based switched-capacitor (SC) network. The analog circuits based on this array can perform multiple functions, adjust to different environmental conditions, or compensate for equipment aging.

II. BASIC CIRCUIT

The functional PWM circuit which operation corresponds to the above time diagrams is shown in Fig. 2. It comprises a ramp voltage generator and a comparator.

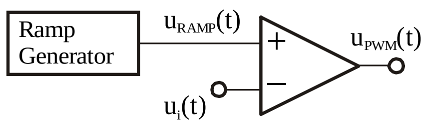

Fig. 2. Functional circuit of PWM

The accuracy depends on the offset of the comparator and the linearity of the ramp voltage. The peak value of the ramp voltage determines the range of the input voltage.

The circuit of the ramp voltage generator is based on the very popular self-oscillating functional generator [4], shown in Fig. 3 and consists of an integrator, a comparator (Schmitt trigger), an electronic switch and two voltage references. The output of the comparator makes the electronic switch to connect the input of the integrator either to the positive or to the negative reference voltage. R_1 and R_2 determine the thresholds (U_+ and U_-) which are the peak values of the ramp voltage $u_{RAMP}(t)$. If the values of the voltage references are equal the duty-cycle will be 50%. The operation of the circuit is shown on the time diagrams in Fig. 4.

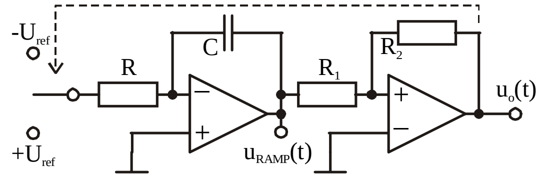

Fig. 3. The classic circuit of a functional generator

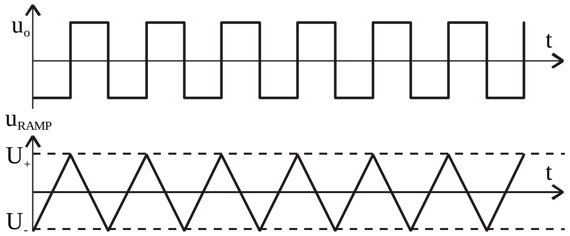

Fig. 4. Time-diagrams of the generator from Fig.3

So, the parameters of the ramp voltage depend on the values of R_1, R_2, the time-constant of the integrator and the voltage references. At the same time these components are error sources. The accuracy could be increased by introducing new technologies and integrated circuits like the FPAA.

III. Circuit design using FPAA

Anadigm® brings platform-based design to the analog world with prequalified software and hardware components that allow complex analog circuits to be implemented in an analog equivalent to the FPGA [2].

Configurable Analog Modules (CAMs) are the functional building blocks for AnadigmDesigner®2-based designs.

The circuit implementation is shown in Fig. 5.

The input voltage is applied at node 6 (*n6*) of the circuit, which is the inverting input of the comparator. The ramp voltage is connected to the non-inverting input *n5* of it. The ramp voltage generator is designed according to the circuit in Fig. 3. There are used a positive voltage reference, two gain inverting stages (-*G*), an integrator and a CAM, which combines a gain stage with switchable inputs and a comparator. The comparator output controls which of the input signals will be switched on. The output signal *n2* of the gain stage with switchable inputs drives the inputs of the integrator and the first (–*G*). Changing the gain of the corresponding input with small steps adjusts every of the thresholds of the Schmitt trigger, consequently the peak value and the frequency of the ramp voltage in the integrator's output *n5*. In addition both thresholds could be adjusted by changing the gain of the first (-*G*). The frequency could be tuned changing the time constant of the integrator. The second (-*G*) is used to obtain negative voltage reference. Its value could be adjusted changing the gain of this stage. The output PWM signal is obtained from the output of the comparator *n7*. Thus the control of the all parameters mentioned above is available and high precision can be achieved.

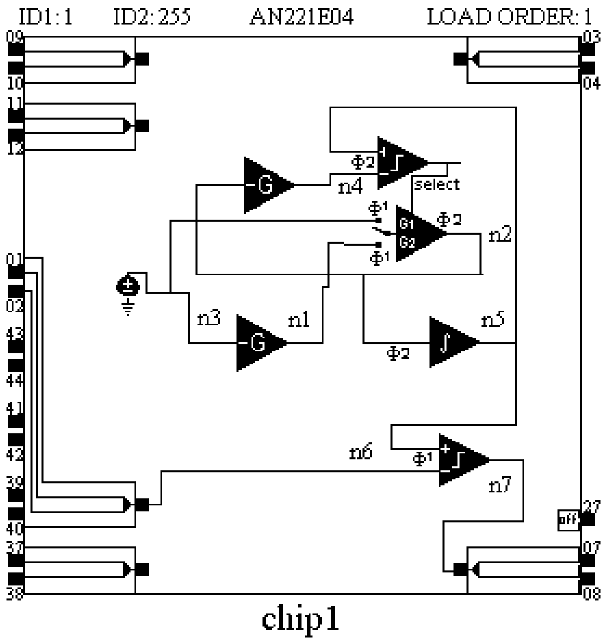

Fig. 5. FPAA implementation of the pulse width modulator

The operation of the designed circuit has been simulated using AnadigmDesigner2 software.

The simulation results have been validated using Anadigm® evaluation board. The obtained results confirm emphatically the above propositions.

IV. Conclusions

User-programmable and re-programmable attributes of FPAAs under software control assure flexibility in design and adjustment of analog circuits with different applications.

FPAAs are suitable for design of PWM circuits because of the independence on the components aging and tolerances.

Acknowledgements

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References

[1] Malvino, A.P., Electronic Principles. McGraw-Hill Book Company. 1998.
[2] Pulse Width Modulation Amplifier, Application Note 30, Apex Microtechnology, Feb. 2001
[3] Anadigm Inc. Documentation. www.anadigm.com.
[4] Tietze, U., Ch. Schenk. Halbleiter-schaltungstechnik. Springer-Verlag. 1980.