IMPLEMENTATION OF PERIODIC WAVE GENERATORS BY USING FPAA

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The paper discuses generation of periodic functions by using Field Programmable Analog Array (FPAA) of Anadigm®. To this aim, the internal structure of the switched-capacitor Periodic Wave Building Block of AN221E04 analog array is described. An approach for automatic generation of the data in built-in Look-Up Table (LUT) is developed. The proposed methodology can use standard spreadsheet programs that simplify and accelerate design process. Different periodic functions are programmed and verified practically by using AN220D04 FPAA Evaluation Board of Anadigm®. Analysis and estimation of accuracy of the realization are carried out.

1. INTRODUCTION

Periodic wave generators are basic functional blocks for contemporary electronic systems. In the practice are usually used square wave, triangular wave and sinusoidal wave generators, but for testing of different electronic modules, construct medical devices, or building communication systems, the generators with more complex form of signal should be applied.

The most widely used approach to generate periodic signals with custom-determined form is based on the Look-Up Table (LUT) principle. The method is flexible and precise and can be implemented by simple standard electronic circuits. Therefore, the modification of this method is applied to generate periodic wave signals in Field Programmable Analog Arrays (FPAAs) of Anadigm®.

Field Programmable Analog Arrays are an analog equivalent to the Field Programmable Gate Arrays. They bring together the three most powerful design trends from the digital world (design automation, field-programmable integrated circuits and real-time updating) into a new platform for the analog design. With the latest generation FPAAs, the designers can construct, in simple manner, complex analog functions by using specially developed drag-and-drop EDA tools as well as to automatically adjust the functionality. By using the dynamically reconfigurable FPAAs, different analog functions can be controlled, updated and manipulated by the system processor in real time [1].

The paper examines the methodology for periodic wave generation by using Field Programmable Analog Array of Anadigm®. To this aim, the internal structure of the switched-capacitor Periodic Wave Generator Building Block of AN221E04 analog array is analyzed and a methodology for automatic computation of Look-Up Table data, by using standard spreadsheet, is developed. Different transfer functions are programmed and practically verified by using AN220D04 FPAA Evaluation Board.

2. PERIODIC WAVE GENERATION BY USING LOOK-UP-TABLE

One of the most effective methods to produce an analog waveform is the method of periodic wave generation by using Look-Up Table. To this aim, a time-varying signal in digital form is generated firstly and after that a digital-to-analog conversion is performed. Due to the fact these operations are primarily digital, the method offers fast switching between output frequencies, fine frequency resolution, and operation over a broad spectrum of frequencies [2].

In its simplest form, a described method can be implemented by a precision reference clock, an address counter, a programmable read only memory (PROM), and a D/A converter (Fig.1).

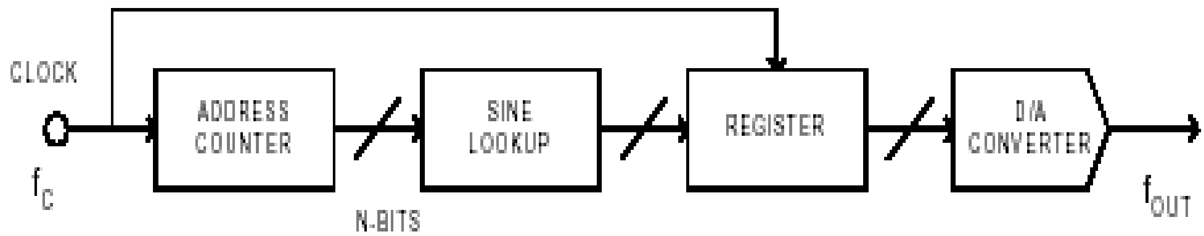

Fig. 1. Simple implementation of sine-wave generator by using LUT approach.

The digital amplitude information that corresponds to the complete period of the sine wave is stored in the PROM. Therefore the PROM functions as a sine Look-Up Table. The address counter steps through and accesses each of the PROM's memory locations and after that, their contents (the equivalent sine amplitude words) transfer to a high-speed D/A converter. The D/A converter generates an analog sine wave in response to the digital input words from the PROM.

The output frequency of this implementation depends on the frequency of the reference clock, and the sine wave step size that is programmed into the PROM. The output frequency can be changed by varying the frequency of the reference clock or by reprogramming the PROM.

Field Programmable Analog Array (FPAA) of Anadigm® provides an excellent opportunity for realization of this method.

3. PERIODIC WAVE GENERATOR BUILDING BLOK

Fig.2 shows the realization of the Arbitrary Periodic Waveform Generator circuit that is included in AN221E04 analog array of Anadigm® [3]. The device contains a single 256 byte Look-Up Table. The 8-bit address input of the LUT comes from a special 8-bit LUT counter. The counter continuously counts up and resetting itself back to zero each time when its programmable roll-over value is met. Each new count value is a new address for the LUT. The data, read from this address, are subsequently written into 1 or 2 target locations within Shadow SRAM. The used target location and the LUT contents are parts of the device's configuration data set.

The clock to the LUT counter sources from one of the 4 internal analog clocks (from one of the four clock dividers).

The subsequent transfer of these 1 or 2 bytes from Shadow SRAM into Configuration SRAM can occur as soon as the last configuration data byte is sent, or an internal zero crossing is detected, or a comparator trip point is met, or an external EXECUTE signal is detected.

With periodic clocking of the LUT counter, a LUT / CAB combination can form an arbitrary waveform generator or modulated signal.

The basic relations for this circuit are:

$$Vout = \frac{C_1 - C_2}{C_3} V_{REF}; \qquad C_2 = 128; \qquad C_4 = 255. \tag{1}$$

The requested Output Voltage Sequence is used to determine the value of C_3 and to load the Look-Up Table with C_1 values. During the operation, the counter drives the Look-Up Table to control the values of C_1. The requested function is described through N successive values within one period (N≤256). The amplitude of the output signal can reach the values of $\pm 4V$.

Formula (1) shows that the values of the output voltage are results from the capacitor ratios. These ratios can be implemented with high precision (0,1%), but the values of the capacitors are discrete, which causes a difference between calculated y_i and realized y_{iR} values of the generated voltage. For the error estimation, the next formula can be used:

$$\varepsilon = \sqrt{\frac{\Sigma (y_i - y_{iR})^2}{N}}. \tag{2}$$

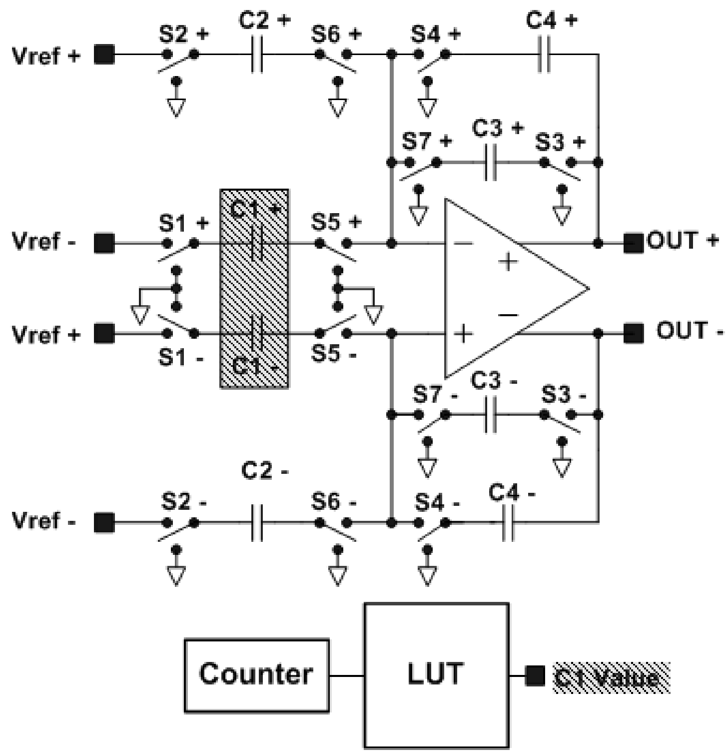

Fig. 2. Internal structure of Arbitrary Periodic Wave Generator Building Block.

4. DESIGN PROCEDURE

The configuration and programming of the Arbitrary Periodic Waveform Generator use a specific EDA tool named AnadigmDesigner2.

Fig.3 demonstrates the screen with basic structure for implementation of periodic wave generator.

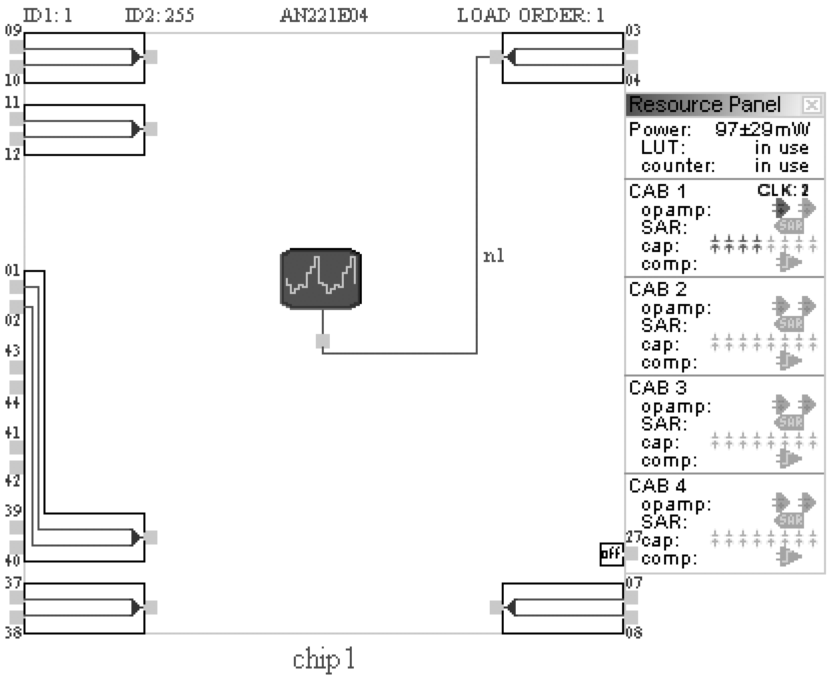

Fig. 3. The basic structure for implementation of periodic wave generator.

Fig.3. shows the screen of Anadigm Designer2 EDA tool for Look-Up-Table data loading.

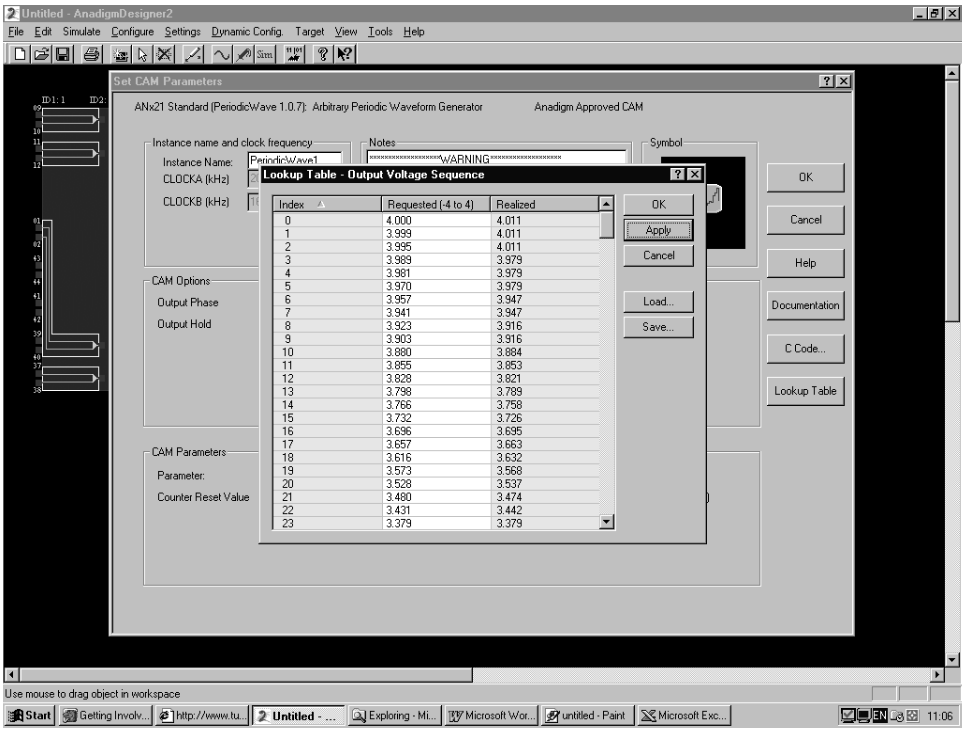

Fig.4. The screen of Anadigm Designer2 EDA tool for LUT data loading.

To obtain the LUT data follows steps have to be executed:

- Determining the number of points N (N_{max}=256), used to generate one period of the function.
- Calculation of step size Δx of the argument. For example, if the function is $y = \cos(x)$, $\Delta x = \frac{2\pi}{256}$.
- Determining the value of the argument for each point of the generated function ($x_i = i\Delta x$, where *i* is the serial number of the point).
- Calculation of function's value ($y_i = \cos(x_i)$).
- Determining the scaling constant $k = \frac{U_{out\max}}{y_{i\max}}$. $U_{out\max}$ is the specified maximum output voltage and $y_{i\max}$ is the maximum value of the calculated function.
- Computation of the values of the function for all the selected points ($\bar{y}_i = ky_i$).
- Saving the obtained data in comma delimited format (*.csv).
- Loading the file in look-up table by using AnadigmDesigner2.

The described sequence of steps can be programmed for automatic execution by using standard spreadsheet programs. This will give high flexibility of the programming process and will assure possibilities for additional proceeding of the data (for example automatic calculation of error from eq.(2)).

5. PRACTICAL VERIFICATION

To examine the described approach, different functions were programmed and verified by using AN220D04 Evaluation Board of Anadigm®.

Fig.5 demonstrates the results from implementation of cosine generator. The number of points is 256 (maximal possible). The frequency is 7,81 kHz output voltage varies between -4V and 4V, the error ε is smaller than 1%.

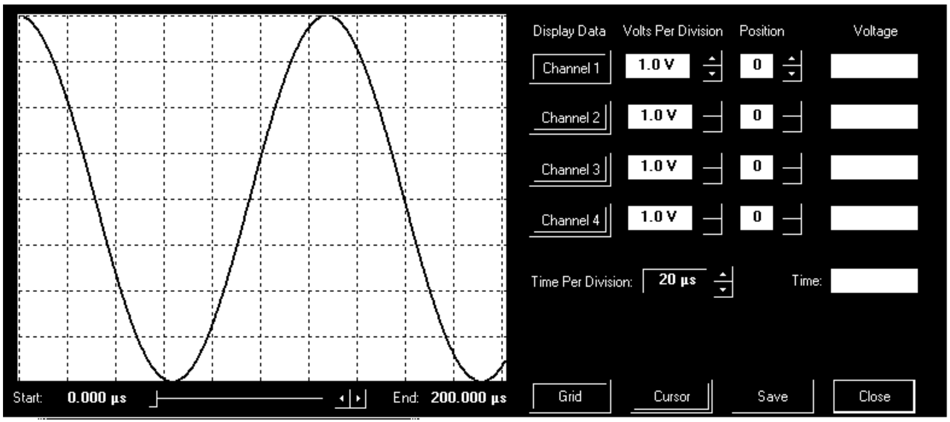

Fig. 5. Results from cosine generator implementation (N=256).

By using different values of clock frequency, the frequency of the generation can be controlled. In AN221E04 analog array, the maximal clock frequency for Periodic Wave Generator Block is 16 MHz. By means of embedded dividers, this value can be diminished to 32kHz. The drawback of this approach is the diminishing of all clock signals in the array.

The frequency of generation can be increased by using number of points for one period, which is smaller than 256. Fig.6 demonstrates the results from the examination of the cosine generator with 16 points for period. In the form of output signal can be observed 16 steps. The frequency is 125 kHz. In this case the error ε is about 1%, but the distortions grow up exceptionally.

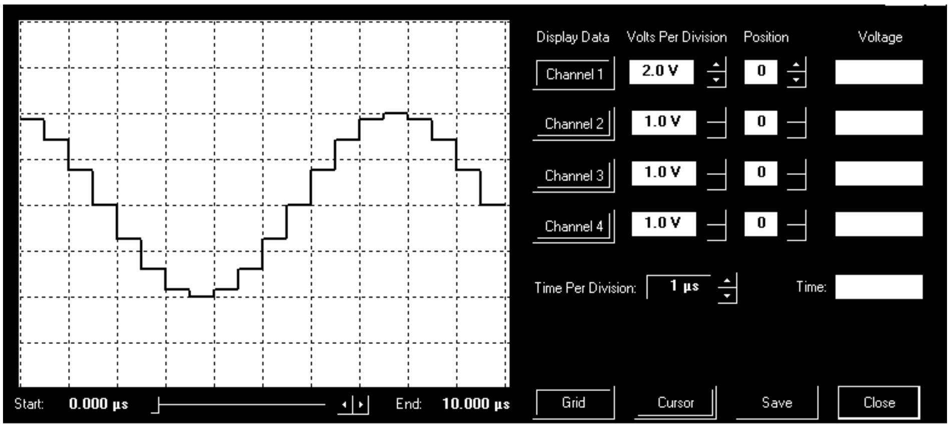

Fig. 6. Results from cosine generator implementation (N=16).

Fig.7 shows the results from investigation of generator that produces more specific form of signal. The error is $\varepsilon \le 0.5\%$.

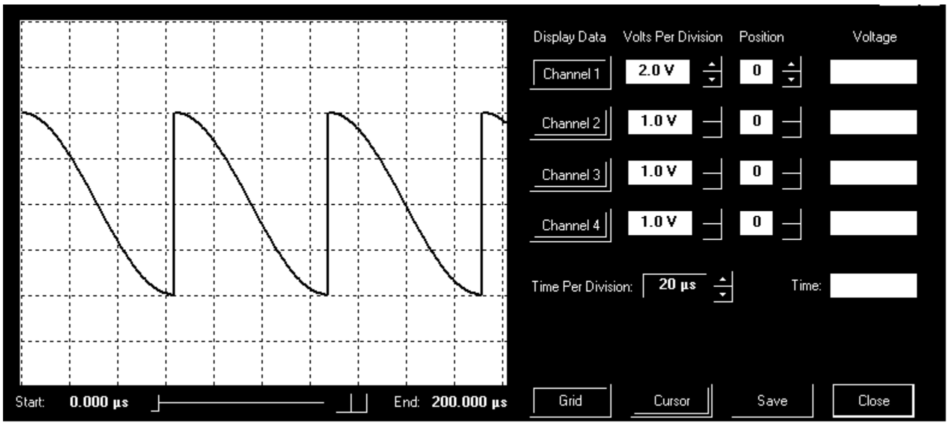

Fig. 7. Results from examination of generator with more complex form of signals.

By using the described approach, many algebraic, trigonometric and special functions were generated. The obtained results confirm its validity.

6. CONCLUSION

In this paper are presented the results from practical examination of different programmable wave generators by using switched-capacitor AN221E04 analog array from Anadigm®. To this aim, the procedure for automatic generation and storage of the data in built-in Look-Up Table is developed. It can use spreadsheet programs that simplify and standardize design process.

The presented results will find a wide application in the research and education in the field of analog circuit design.

6. REFERENCES

[1] Anadigm Inc. Field Programmable Analog Arrays - User Manual. 2002.
[2] Analog Devices, Inc. A Technical Tutorial on Digital Signal Synthesis. 1999.
[3] Anadigm Inc. Documentation. www.anadigm.com.