IMPLEMENTATION OF USER-DEFINED VOLTAGE TRANSFER FUNCTIONS IN FPAA

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Keywords: Field Programmable Analog Array, FPAA, Look-Up-Table, LUT, Transfer function

The paper investigates implementation of modules with linear and nonlinear transfer characteristics by using FPAA programmable blocks. To this aim, the internal structure of AN221E04 analog array from Anadigm$^®$ is analyzed and a methodology for automatic computation of look-up-table data, by using Microsoft Excel spreadsheet, is developed. Different transfer functions are programmed and verified by using AN220D04 FPAA Evaluation Board and their basic parameters are estimated. The presented solutions have good predictability, stability, flexibility and possibility for simple software control of the transfer characteristic. They are very appropriate to be used as a part of more complex analog and mixed-mode systems.

1. INTRODUCTION

The Field Programmable Analog Arrays (FPAAs) 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 an attractive way of reducing cost, size and complexity of electronic circuits.

One of the most popular FPAA architecture consists of configurable analog building blocks that are implemented by using switched-capacitor technique. Each block includes some bytes of 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, filters, etc. are available as IP modules. Many complex analog modules can be implemented by specifying the desired functions and wiring appropriate blocks from the library.

The circuits with different transfer characteristics are widely used as functional modules for sensor signal conditioning as well as for realization of different mathematical operations. In classic analog technique these circuits are implemented by operational amplifiers, resistors, diodes, transistors and voltage references. However, this approach possesses some disadvantages as low precision, complex implementation and instability. Switched-capacitor circuitry gives a simple and very precise facility to realize different transfer functions by using look-up-table approach.

The paper discusses implementation of modules with linear and nonlinear transfer characteristics by using switched-capacitor AN221E04 analog array from Anadigm$^®$.

To this aim, the internal structure of the Transfer Function Building Block of this array is investigated and a methodology for automatic computation of look-up-table data, by using Microsoft Excel spreadsheet, is presented. Different transfer functions are programmed and verified by using AN220D04 FPAA Evaluation Board and their basic parameters are estimated.

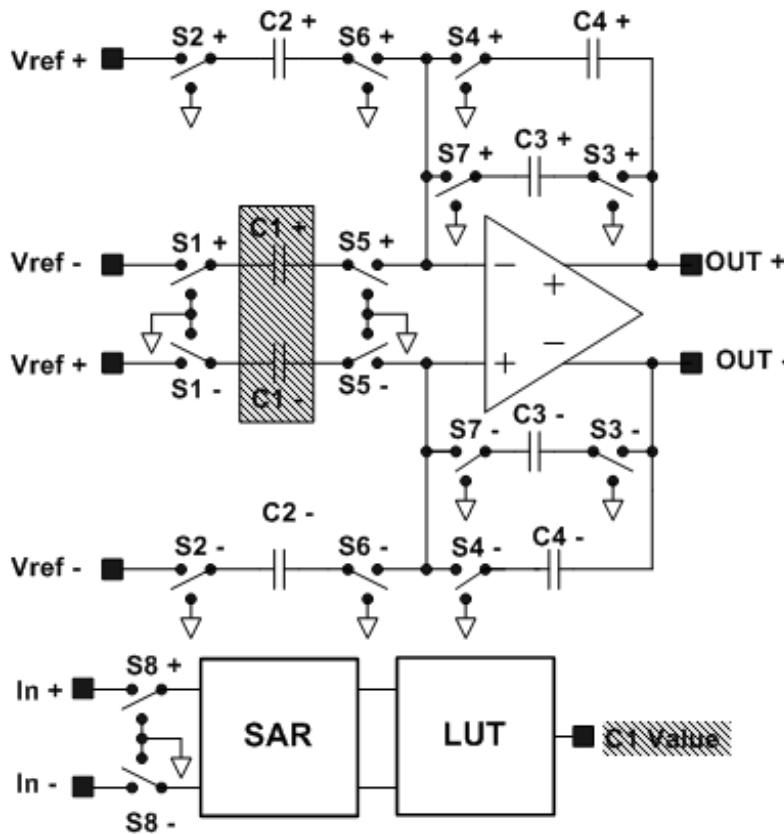## 2. INTERNAL STRUCTURE OF TRANSFER FUNCTION BLOCK

Fig. 1. Internal structure of Transfer Function block.

Fig.1 shows the circuit realization of the User-Defined Voltage Transfer Function block, included in the switched-capacitor AN221E04 analog array of Anadigm® [1]. It implements a user specified voltage transfer function with 256 quantization steps and produces a specified output voltage in response to the value of the sampled input voltage. The device contains a single 256 byte Look-Up Table (LUT), which controls the capacitor array C_1. The 8-bit address input to the LUT comes from the SAR-ADC 8-bit output. The transfer function for described block is:

(1) $$Vout = \frac{C_1 - C_2}{C_3} V_{REF},$$

where $C_2 = 128$, $C_4 = 255$.
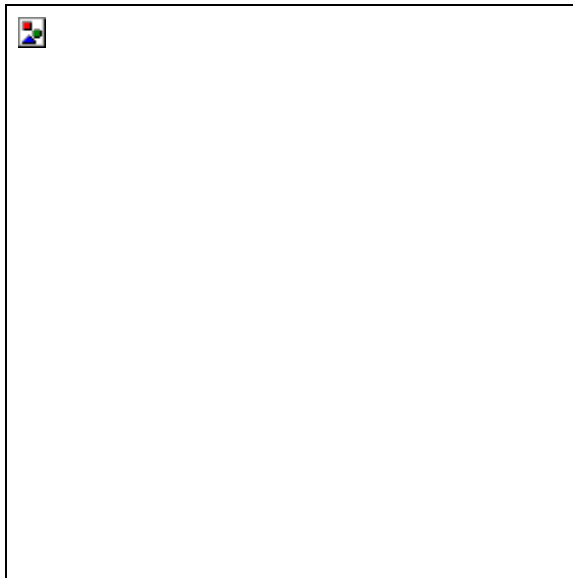
Thus, the requested Voltage Transfer Function determines the value of C3 and loads the Look-Up Table with C_1 values. During the operation, the SAR drives the Look-Up Table that controls the value of the capacitor C_1, according to the input voltage.

3. DESIGN PROCEDURE

Specific EDA tool, which simplifies the programming of desired transfer functions is developed by Anadigm Inc.

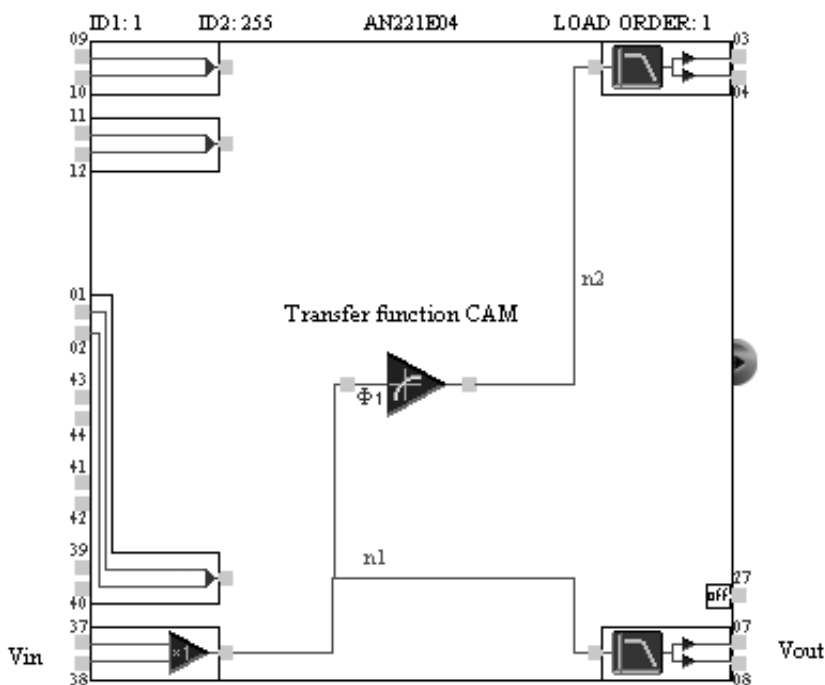Fig.2 demonstrates the screen with the basic structure for implementation of transfer functions.

Fig. 2. The basic structure for implementation of transfer functions.

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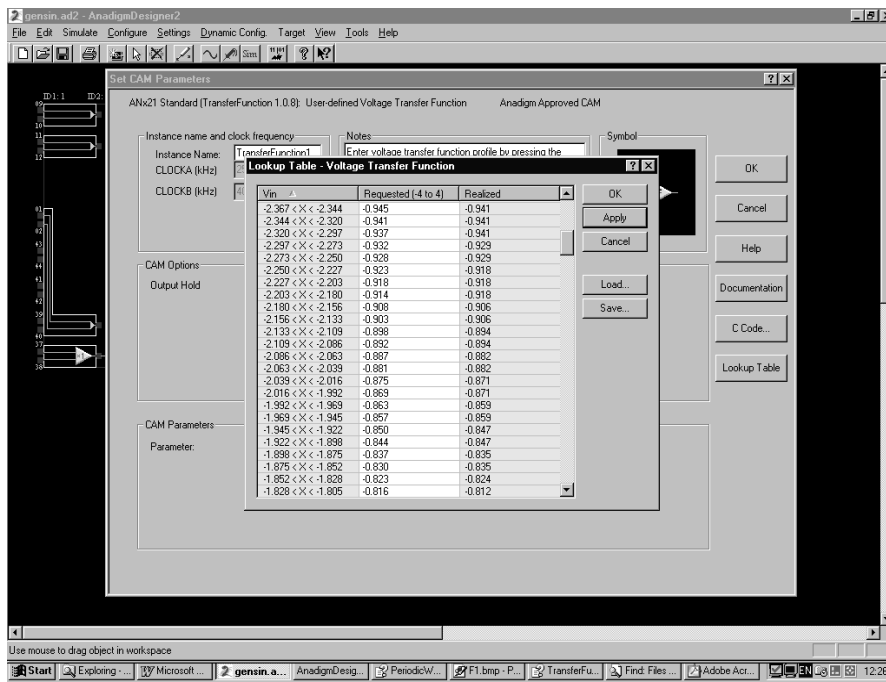
Fig.3. The screen of Anadigm Designer2 EDA tool for LUT data loading.

To obtain the LUT data Microsoft Excel spreadsheet can be used (Fig.4). The content of the columns in the table is as follows:

- First column A contains 256 rows that are ranked from 0 to 255. Thus the transfer function is separated in 256 discrete values.

- Second column B contains the results from calculation of the values of the argument V_{in}. They vary between –3V and +3V with step ΔV_{in} that is equals to:

$$(2) \qquad \Delta V_{in} = \frac{6}{256} V .$$

- Third column C shows the values of the desired transfer function, which is calculated with high (10 decimal places) precision by using appropriate formula. The output values can vary between –4V and +4V.

- In fourth column D are the real values of the output voltage, which will be included in LUT of FPAA. These values are obtained by using the AnadigmDesigner2 program.

- The fifth column E presents the difference Δx_i between high-precise (column C) and real-written (column D) output values.

- In sixth column F the results in E are raised to the second power and the error is calculated. To this aim the next formula is used:

$$(4) \qquad \varepsilon = \sqrt{\frac{\Sigma (\Delta x_i)^2}{256}} .$$

Fig. 4. Excel Spreadsheet to compute the values of LUT data.

After filling the table, the values from columns C must be saved as spreadsheet file in comma delimited format (*.csv). This file is used to load the necessary values in FPAA Look-Up-Table.

4. PRACTICAL VERIFICATION

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

Fig.5 demonstrates the results from implementation and examination of $y = \frac{1}{3}x^2$ function. The input signal varies from -3V to +3V and the output signal - from 0 to 3V. The error is $\varepsilon \le 0.5\%$.
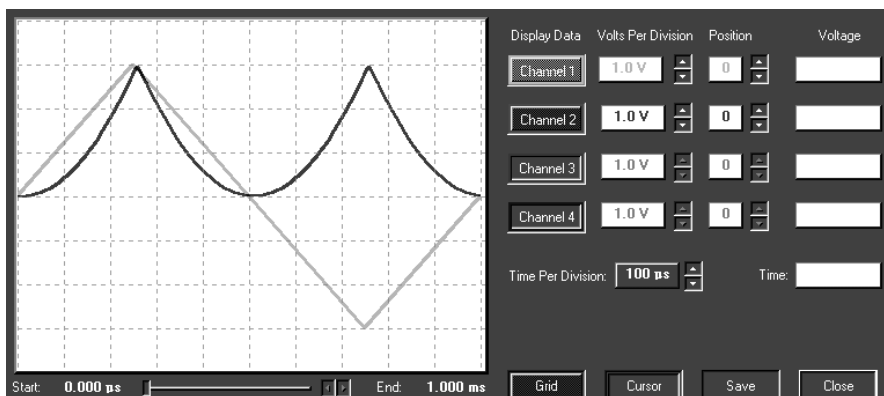

Fig. 5. Results from examination of quadratic function.

Fig.6 shows the results from conversion of the triangular input voltage to the sinusoidal output voltage. The error is $\varepsilon \le 0.35\%$.
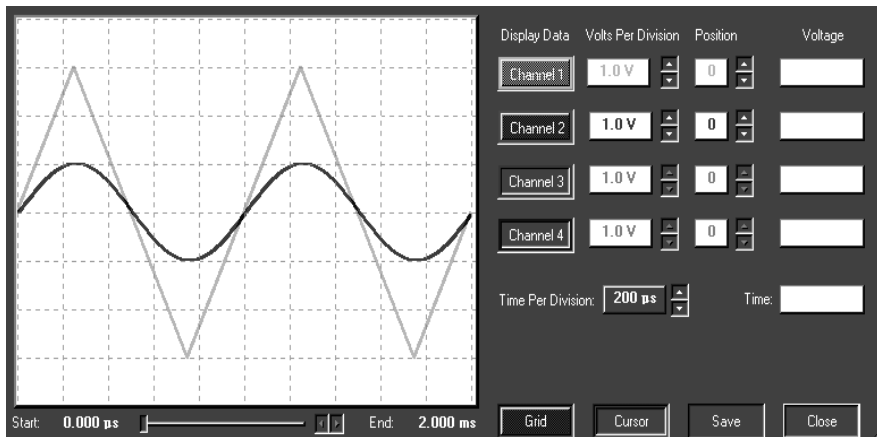
Fig. 6. Results from conversion of triangular input voltage to sinusoidal output voltage.

Many algebraic, trigonometric and special functions were investigated by using described approach. The obtained results confirmed its validity.

5. CONCLUSION

In this paper are presented the results from practical examination of different transfer functions by using switched-capacitor AN221E04 analog array from Anadigm®. To this aim the procedure for creation and loading of the transfer function data is developed and verified.

The examined solutions have good predictability, stability, flexibility and possibility for simple software control of transfer characteristics.

6. REFERENCES

[1] Anadigm Inc. Field Programmable Analog Arrays - User Manual. 2002.