

PRACTICAL EXPERIMENTS FOR TRAINING IN INTERFACING SENSORS TO FIELD PROGRAMMABLE ANALOG ARRAY

Filip Todorov Koparanov, Mihail Hristov Tzanov, Hristo Milkov Pashov

Faculty of Electronic Engineering and Technologies, Technical University - Sofia
8 Kliment Ohridski blvd., 1000 Sofia, Bulgaria, phone: +359 2 965 3269, e-mail: fkop@abv.bg

The paper presents training experiments in interfacing sensors to Field Programmable Analog Array (FPAA). To this aim the internal structure and operation of AN221E04 chip of Anadigm Inc. is investigated. Different examples for application of FPAA in sensor circuits are discussed. The results are applied in the design and verification of circuit for modeling of transfer characteristic of DC thermistor bridge. The presented approach will find wide application in education and research in electronics.

Keywords: Sensor Interfacing, Field Programmable Analog Array, FPAA, Thermistor Bridge

I. INTRODUCTION

The Field Programmable Analog Arrays (FPAAs) are one of the most contemporary and perspective products for fast and flexible implementation of different circuits and devices. FPAAs are the analog equivalent of the well-known digital Field Programmable Gate Arrays (FPGA).

Field Programmable Analog Arrays, produced by Anadigm Inc., are modern integrated circuits, which afford opportunities for flexible programming of the functions, as well as for changing their configuration in the process of operation. They are widely used in measuring and control systems, medical devices, and communications. With regard to this, the problem of putting into practice the interfaces between the used sensors and FPAA is extremely important [1, 2].

The aim of this paper is to propose a number of practical experiments in interfacing sensors to FPAA. They will be used in aid of education in microelectronic circuitry.

II. INTERNAL STRUCTURE AND MODE OF OPERATION OF INPUT/OUTPUT CELLS OF FPAA

Analog input signals can be connected from the outside world via the four identical configurable Input/Output Cells. They have a special mixing feature, which allows the connection of up to 4 unique signal sources or loads. The internal structure of one of the Input/Output Cells is depicted on Fig. 1 [3]. Each Configurable Input / Output Cell contains a collection of resources which allow high fidelity connections to and from the outside world with no need for additional external components. They can pass a differential signal pair directly into the array or process either single-ended or differential input signals using combinations of: a unity gain buffer, a programmable gain amplifier, a programmable anti-alias filter and a special chopper stabilized amplifier. The chopper-stabilized amplifier is especially designed for use with signals requiring significant gain and hence ultra low input offset voltages.

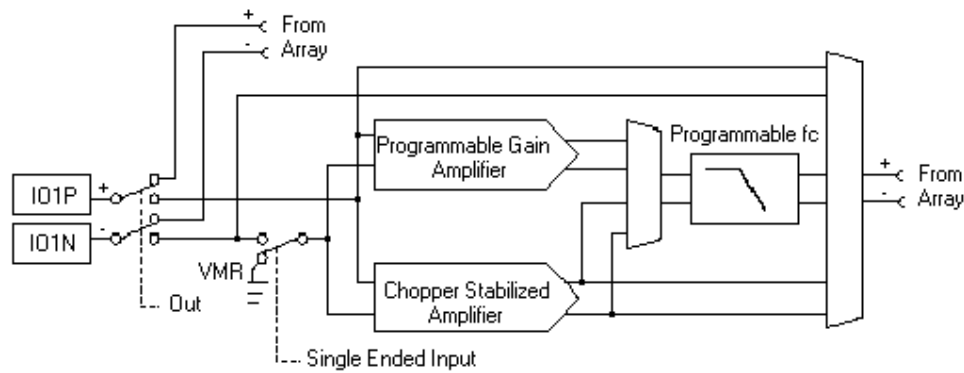


Fig.1. The internal structure of the Input/Output Cell

When the Input/Output Cell is used as an output, the connection is a direct, unbuffered connection of an internally sourced signal. There are no active circuit elements available in the Input/Output cell when it is configured as an output.

In order to maximize signal fidelity, all signal routing and processing within the device is fully differential. Accordingly, each Input/Output Cell accepts or sources a differential signal. Differential signals can be represented in two ways, either by their positive and negative components or by their differential and common-mode components, as related through these two equations [3]:

$$V_{DIFFERENTIAL} = V_{POSITIVE} - V_{NEGATIVE}, \quad (1)$$

$$V_{CM} = \frac{V_{POSITIVE} + V_{NEGATIVE}}{2} \quad (2)$$

A single-ended signal can be used as an input to the cell. If a single-ended source is attached, an internal switch will connect the negative side of the internal differential signal pair to Voltage Main Reference (VMR is the reference point for all internal signal processing and is set at 2.0 V above AVSS). As with any sampled data system, it may sometimes be necessary to low pass filter the incoming signal to prevent aliasing artifacts. The input path of the cell contains a second order programmable anti-aliasing filter. The filter may be bypassed, or set to selected corner frequencies. When using the anti-aliasing filter, Anadigm recommends that the ratio of filter corner frequency to maximum signal frequency should be at least 30. These filters are a useful, integrated feature for low-frequency signals (signals with frequency up to 15 kHz) only; and if high-order anti-aliasing is required. Where input signal frequencies are higher, Anadigm does recommend the use of external anti-aliasing. A second unique input resource available within each Input/Output Cell is an amplifier with programmable gain and optional chopper stabilizing circuitry. The chopper-stabilized amplifier greatly reduces the input offset voltage normally associated with op-amps. This can be very useful for applications where the incoming signal is very weak and requires a high gain amplifier at the input. The programmable gain of the amplifier can be set to 2^n where $n = 4$ through 7. The output of the amplifier can be routed through the programmable anti-aliasing input filter, or directly into the interior of the array (into a Configurable Analog Block, CAB).

Single-ended input signals must use either the amplifier or the anti-alias filter in order to get the required single to differential conversion. The programmable gain amplifier, the chopper-stabilized amplifier and the programmable anti-aliasing filter are all resources available only on the input signal path.

It is not recommended to use an Input/Output Cell as a bypass mode input. Anadigm® recommends that to use at least the unity gain buffer in the Input/Output Cell when configured as an input.

III. TRAINING EXPERIMENTS FOR DEMONSTRATION OF BASIC OPERATION AND CHARACTERISTICS OF FPAA INPUT CELLS

The following training experiments with FPAA input cells are developed:

- Interfacing of simple voltage divider to single-ended input (Fig.2). The main attention is given to the +2V shifting of the internal analog ground. The students can examine and discuss different software controlled variants (with band-pass filter, with or without amplification, with low-offset chopper).

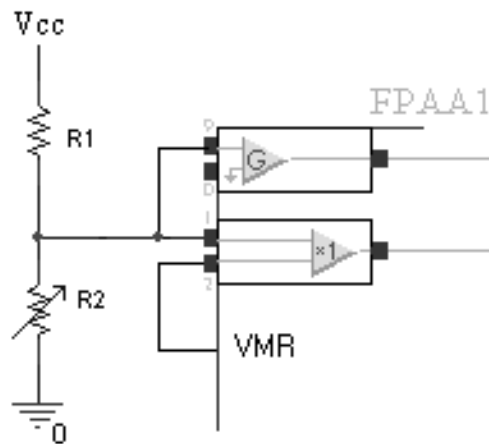


Fig. 2. Interfacing of simple voltage divider to single-ended input

- Interfacing of DC Bridge to differential input (Fig.3). Different modes of operation can be investigated and conclusions for their application in real measurement systems can be proposed from the students.

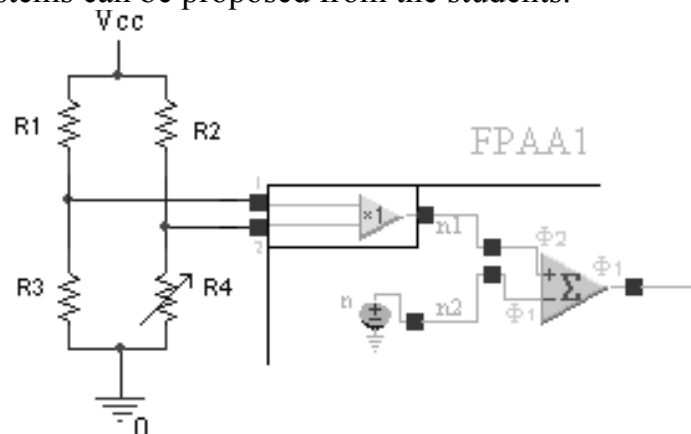


Fig. 3. Interfacing of DC Bridge to differential input

- Interfacing of photodiode to input transimpedance amplifier (Fig.4). This experiment illustrates the dependence of the output voltage vs. input light flow.

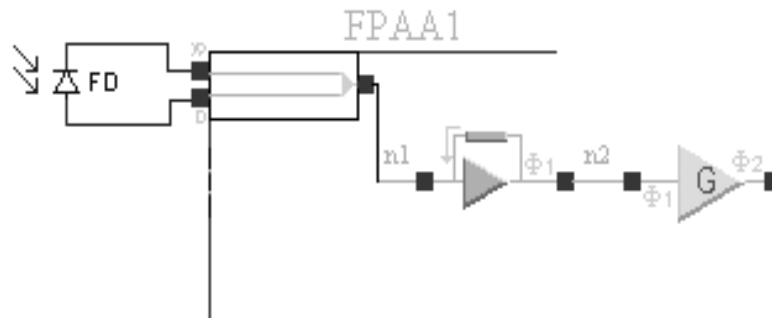


Fig.4. Interfacing of photodiode to input transimpedance amplifier

The presented experiments improve students' knowledge and their practical skills.

IV. EXAMPLE: CIRCUIT FOR MODELLING OF TRANSFER CHARACTERISTIC OF DC THERMISTOR BRIDGE

Very frequently in practice it is necessary to generate test signals that correspond to the voltage at the output of the DC thermistor bridge. Fig.5 shows the block circuit of a module, which emulates the same signals. The module has two outputs. Simple resistive divider with potentiometer drives the circuit. According to the position of the potentiometer, the circuit generates output voltage, proportional to the "temperature" and its corresponding voltage at the output of a resistive DC bridge with a thermistor.

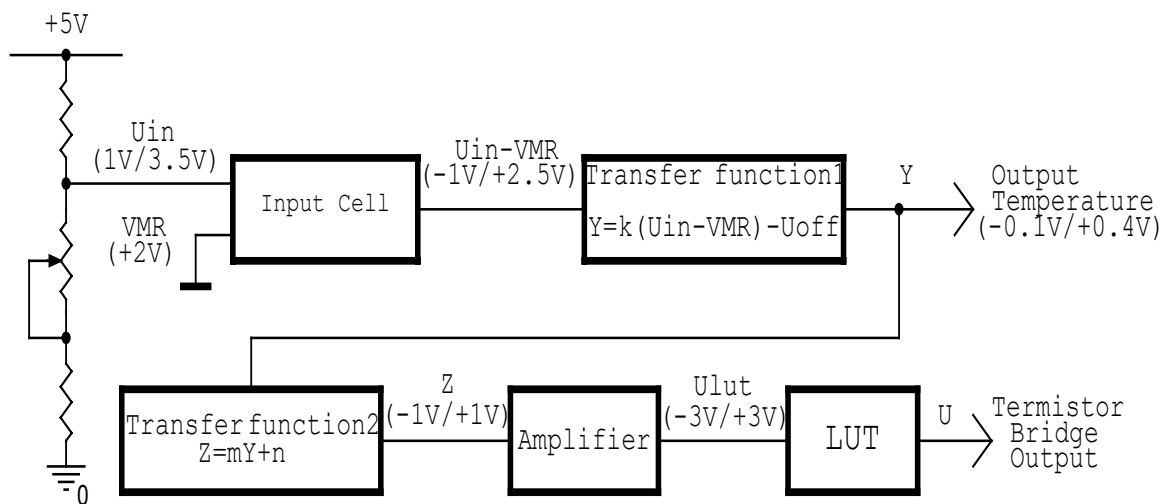


Fig.5. Block circuit of the module for modelling of transfer characteristic of DC thermistor bridge

Fig.6 shows practical FPAA implementation of the described module using AnadigmDesigner2 software. The input divider is connected to the positive input (pin 09) of the first input cell. This cell operates in differential mode. The negative input (10) is connected to the internal analog ground VMR (+2V) of the array. The upper output cell (pins 03-04) generates voltage between $-100\text{mV}/+400\text{mV}$ (i.e. "-

10°C/+40°C”). This voltage depends on the position of the potentiometer. The same voltage controls the look-up table (LUT). The table generates a signal with amplitude that corresponds to the voltage at the output of a resistive DC bridge with a thermistor. It appears to the bottom output (pins 07-08).

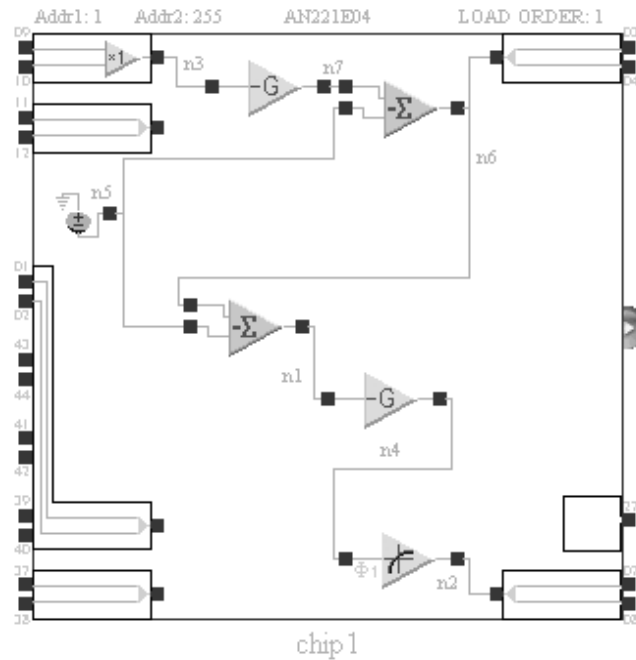


Fig. 6. FPAAs implementation of the module for modelling of transfer characteristic of DC thermistor bridge

Fig.7 shows the comparison between the theoretical and practically measured voltage at the bottom output.

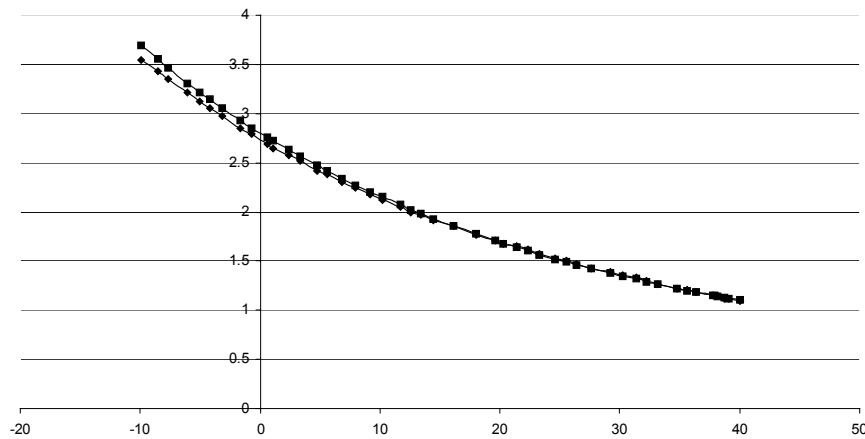


Fig.7. Comparison between theoretical and practically measured voltage at the bottom output

Fig.8 shows the relative error between theoretical and practically measured voltage at the second output.

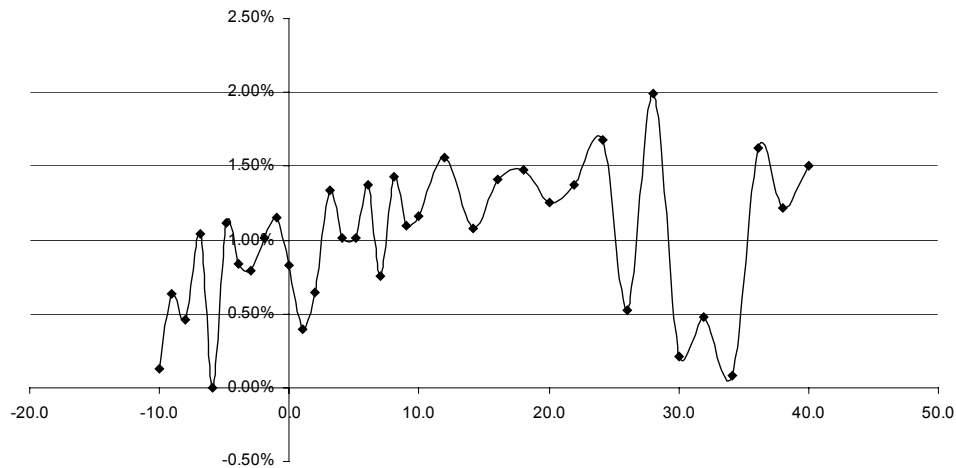


Fig.8. The relative error between theoretical and practically measured voltage at the second output

IV. CONCLUSION

The paper proposes a number of practical experiments in interfacing sensors to FPAA. The presented experiments are verified by using AN221E04 Evaluation board of Anadigm Inc. and demonstrate the perfect possibilities for application of FPAA in different test, measurement and control circuits.

The presented results will be applied in the educational and research work in electronics.

V. REFERENCES

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