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Technical Review Paper: Analog Computation in Music Synthesizer

Introduction

Analog computation is a type of computation that is performed on an analog circuitry and in the analog domain instead of the usual digital domain. Analog audio synthesizer is a form of an analog computer since its oscillators, filters, and many of its effects are controlled in the analog domain such as voltage. This paper is going to go over the analog computational modules that can be utilized in our project to create a music synthesizer with an FPAA.

Analog Computation for Audio Synthesizer

With the advancement of transistor technology, VLSI, and algorithmic approach to computation, in recent years, computation has been though as mostly digital operation. However, since the world of audio is analog domain and audio enthusiasts' penchant for the "warmth" of analog systems, the analog synthesizer market has been popular for musicians and audio engineers.

Basic operations of an analog computer are arithmetic operations such as addition, subtraction, multiplication, and division. The fundamental component for performing these operations is the operational amplifier. An operational amplifier takes in a voltage and applies gain. With the amplification property, it can perform addition and multiplication [1]. For multiplication, the gain scaling of the op-amp can be controlled with the ratio of resistances to the op-amp. Also, an op-amp can be configured to a summing circuit. An integrator can also be configured with an op-amp, resistor, and capacitor.

For analog music synthesizers, many function block designs utilize analog computation. Differential equations are common applications for analog computers and since filter responses can be characterized with differential equations, filter designs can be implemented with functional blocks of analog computers [2]. Also, many functional modules of an analog audio synthesizer such as VCO (voltage-controlled oscillator) and VCA (voltage-controlled amplifier) can be characterized by analog computation. In VCA designs, op-amps are used as summer to sum different multiple VCO outputs [3]. In VCO designs, op-amps can be used as an integrator to oscillate the voltage signal [4].

Commercial Applications/Availability of Analog Components

Currently, many commercial analog audio synthesizers use custom inhouse circuit designs and keep their component usage hidden due to the design contributing to the uniqueness of sound characteristics. However, for hobbyists in the modular synthesizer community, the most popular VCO IC is V3340 VCO by CoolAudio. V3340 is a modern clone of the famous CEM3040 VCO, which was used by many famous old school synthesizers. V3340 VCO is priced at $15.36. It can generate four different waveforms such as sawtooth, square, triangle, and pulse with voltage controllable pulse width. Also, it has temperature compensation, which prevents the frequency from drifting when there is temperature fluctuation [5].

For building custom functional blocks, many different op-amps can be used. One example of an op-amp used mainly for audio application is Texas Instruments LM13700. It is priced at $0.48 and features to op-amp in one IC. It also features linearizing diodes at the inputs to decrease distortions and allow high input levels, and it has high impedance buffers at the outputs to complement the dynamic range of the amplifier [6].

Implementation

For the purpose of our project, functional blocks of a synthesizer will be built on the FPAA's CAB (computation analogue block). A CAB within the fabric of the FPAA already contains an op-amp, switches, transistors, and capacitors which can be reconfigured to build any of the functional blocks for an audio synthesizer [7]. Dr. Hasler's previous research on implementing Moog's ladder VCF (voltage-controlled filter) design on an FPAA is detailed in this paper [8]. They implement the VCF by mapping the original BJT design to MOSFETs operating in the subthreshold region. Implementing various synthesizer functional modules will require good understanding of behavior of different microelectronics and research into different VCO, VCF, and VCA designs.

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