lsynth: A Tempo Synchronized Rate Selectable Oscillator for LEDs

Matthew Aldrich
09.28.2007
www.visiphon.com
aldrich [at] runbox [dot] com

Abstract - The device addresses the inherent problems of sound/lighting synchronization in a novel and computationally efficient manner. The lsynth is a synthesizer that produces waveforms at frequencies below human perception. Drawing on influences from early synthesizers, the lsynth produces color shows by utilizing the concept of rate selectable low frequency oscillators (LFOs). Two challenges are solved: 1) there is no need for computationally intensive (and often ineffective) tempo estimation and 2) the lsynth can accompany a diverse range of musical styles making its integration in many environments possible.

I. Introduction

Many methods exist for synchronizing music with lighting. Some methods include passive filters, active filters, and signal processing. These techniques can run on a PC or some embedded device. Control options can be proprietary protocols, MIDI, Ethernet, or DMX. Traditionally, a light that responds to music is known as a color organ. These unsophisticated organs merely respond to amplitude changes in predetermined frequency bands of the music. These devices are typically very cheap and require little or no computational power. In most cases, the organ is comprised of passive components. Unfortunately, due to the lack of processing power, these organs prohibit user interaction and in most cases, respond very poorly to the actual tempo of the music. A color organ lacks the ability to produce any signal other than "on" or "off."

Another approach analyzes the frequency spectrum of the audio signal. By analyzing the incoming signal's spectral data, the tempo can be calculated, and specific frequency bands can be selected to trigger data to send to the lights. This technique is computationally expensive, and requires the use of either a sophisticated microcontroller, or a personal computer. Unlike the color organ, the tempo can be "estimated" from the incoming audio signal using comb filters and resonance. Thus a light show can, in theory, be synchronized to the music. However, most tempo estimation algorithms perform poorly over a wide range of musical styles, and are best suited for electronic music. Additionally, these programs do not allow the user to dynamically reconfigure the show, that is, the device and algorithms are not suitable for interactive performances.

The lsynth is not a color organ and it does not require complex mathematics. Instead, the lsynth incorporates features common in many analog synthesizers to achieve results in a computationally efficient manner. Additionally, the user can control and perform with the device making for an interactive experience.

II. lsynth Overview

A great challenge in audio/visual synchronization is the calculation and extraction of the tempo from live audio. Many algorithms inaccurately calculate the tempo when the music lacks repetitive rhythms and thus, the tempo is either wrong, or constantly fluctuating. A second challenge is the creation of stimulating effects and visuals that are synchronized to the music. Finally, many interfaces do not entice the user to modify, dial, and "tweak" parameters on the fly; they are not interactive.

The lsynth addresses these fundamental problems by localizing audio playback and visual control on a single PC, removing the difficulty of tempo calculation, and creating an interface that is intuitive and responsive to user input. The design is meant to compliment an artist's visual performance and blend into their setup easily.

The lsynth incorporates software and hardware and the core of the design written in Max/MSP. The lsynth block diagram is given in figure 1.

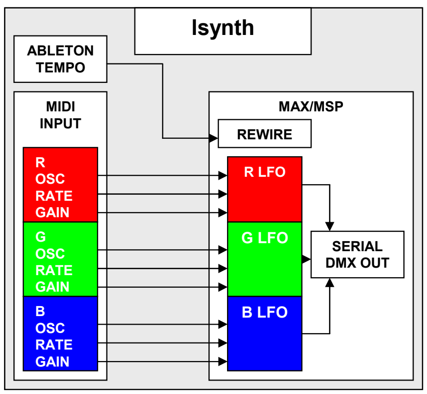

Figure 1 – lsynth Block Diagram

Ableton Live is a sophisticated audio and MIDI sequencer designed for live performance and interaction. Ableton allows audio playback at a user specified tempo and can also be an audio mixer/DJ console, and effects panel, or an audio and MIDI recorder. Ableton's widespread acceptance, its versatility, and its support for MIDI and the Rewire interface made it a suitable choice for integration into the design.

MIDI devices are commonly used in conjunction with Ableton Live and Max/MSP. MIDI controller data is supported in both Ableton and Max. Additionally, the controllers have an acceptable price point for most artists. Rather than create custom hardware to control the device, an M-Audio Trigger-Finger was selected due to its competitive price and abundance of knobs and sliders.

The synthesizer controls high power Luxeon 1 red, green, and blue LEDs from Lumileds. The lsynth patch packetizes the red, green, blue data and provides either a serial or DMX compatible output. Renaissance Lighting's 3 channel LED driver, microcontroller board, and RGB LED arrays were used in the device demo. The hardware used in the setup can be seen in figure 2.

Figure 2 – MCU, Driver, and LEDs

III. The lsynth Patch

As shown previously in figure 1, the user provides information for the red, green, and blue channels. MIDI knobs can be assigned and reassigned to each LFO function. The user can independently set the type of oscillator, the rate at which 1 oscillation occurs, and the gain, or intensity, of the waveform for each of the three channels. With a few knob turns, the user can create a complex color pattern with little or no understanding how the system works. This provokes the user to "knob twiddle" and, like a synthesizer, invites the user to constantly modify and play with the device.

A block diagram of a generic LFO is given in figure 3. The master tempo is passed from Ableton Live to the lsynth patch via Rewire. Four generic oscillators are available in each LFO. The user is able to select a sine, saw, ramp, or square type of oscillation. The user can also turn a channel off. In order to synchronize the rate of the oscillations to specific patterns in audio and add complexity to the pattern, the user can select from 12 rate multipliers that correspond to note duration. Oscillator frequencies are guaranteed to be synchronized to the music because the master tempo is passed from Ableton Live into the Max/MSP patch via Rewire.

The quarter note tempo from Ableton Live drives a "phasor" in the lsynth patch whose output linearly increments from 0 to 1 over each quarter note. Thus, by multiplying the rate at which the phasor cycles, a new phasor representing the 12 musical notes can be generated. This modified phasor controls the output of the selected oscillator.

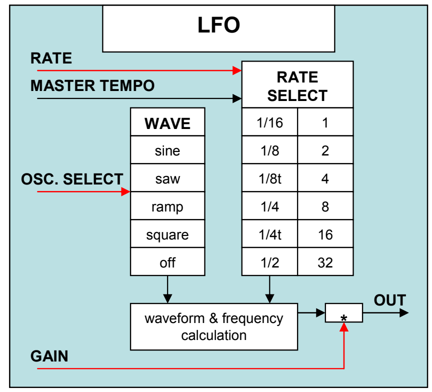

Figure 3 – LFO Block Diagram

To ensure that the waveforms remain synchronized with the music, changes in either the oscillator or rate are quantized to 1 bar. Changes in intensity are instantaneous. The red green and blue data are each normalized to 10b and packetized for transmission. Figure 4 shows a LFO in Max/MSP.

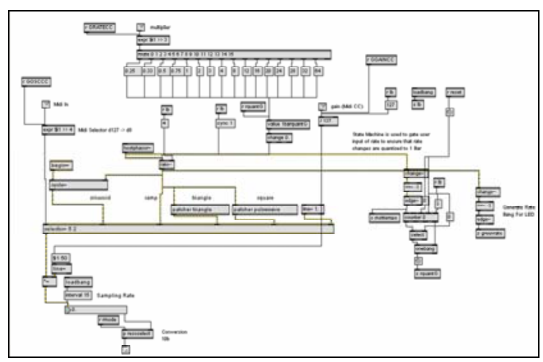

Figure 4 – LFO Block Diagram in Max/MSP

IV. Applications and Performance

The lsynth yields smooth transitions at 10b of resolution. If DMX transmission is required, the maximum resolution for any color is 8b. This still yields satisfactory results. Programs such as Ableton Live allow to the user to assign MIDI controllable effects to the audio. By assigning effects and lsynth control to the same knobs, audio and visual effects can be controlled at the same time increasing the effect on the audience. Traditionally, control of lighting and effects are not the responsibility of the performing artist, however the device allows a musician or DJ to control the lighting as well the music. However, the applications are not limited to electronic music, or electronic artists. The tempo is always settable and dynamic visual feedback is possible with many genres of music and any type of installation.

V. Future Work

The Isynth's core merely touches the surface of sound and light synchronization. For example, with additional control knobs, the Max/MSP patch can be easily rewritten to allow for additive and subtractive synthesis providing the user with more options for visual effects. AM and FM modulation, ADSR envelopes, multiple LFOs, and additional wavetables can be easily integrated at the cost of processing speed and device complexity.

Max/MSP was used to quickly "sketch" the concept and explore the possibilities of controlling light with LFOs. The core concepts of a user settable tempo and stored wavetables makes this Max patch an excellent candidate for a hand held, battery powered device.

Little memory or processing power is needed to store and lookup the wave tables used in this patch. Additionally, the wavetables do not need to be stored as floating point numbers. Specifying device operation as integer only arithmetic is simple in this case. The user interface consists of several knobs and sliders, which are low cost and easy to integrate. Lastly, the user will need to "tap" in the tempo for the device to reflect what the user is listening to. This removes the PC from the setup, and opens up the possibilities of integrating light and sound control where no PC is present or available.

V. Conclusions

This paper presents the motivations, design, and control of a device that allows easy synchronization of sound and light. It discusses the challenges of traditional methods and presents a new design to address the problems inherent in previous and current designs. Finally, several ideas are discussed that can improve the design and expand its capabilities. Matt wishes to thank Renaissance Lighting for allowing the use of the hardware.

About

Matt Aldrich is an EE at Renaissance Lighting, a small start up specializing in solid state lighting. He received his B.S. in electrical engineering from Yale University in 2004. He enjoys sound synthesis, and novel ways of incorporating his passion of music with modern computing.