Hot Hand™ Motion Controlled Effects

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Introduction

The SA10x products are a line of motion controlled guitar effects units which use micro-machined accelerometer sensors to sense motion of a player. The signals produced by the sensor are digitized and processed into a useful set of control signals that can be combined with various audio signals in the digital domain. This system of accelerometer-based effects control is a patent-pending technology designed and conceived by Source Audio.

Background

In the world of guitar effects there are a limited number of options available to a user for controlling those effects. The most common of these is the expression pedal. Instead of having an effect which is controlled automatically by an envelope detector (i.e. envelope filter, auto-wah) or a low frequency oscillator (LFO, i.e. phaser, flanger, chorus), an expression pedal provides a user with the ability to dynamically control an effect by means of actuating with a foot pedal. The downside of an expression pedal is that it's limited in speed and that it's rooted to the floor. In order to use it, a user must be fixed to a particular spot on a stage or floor.

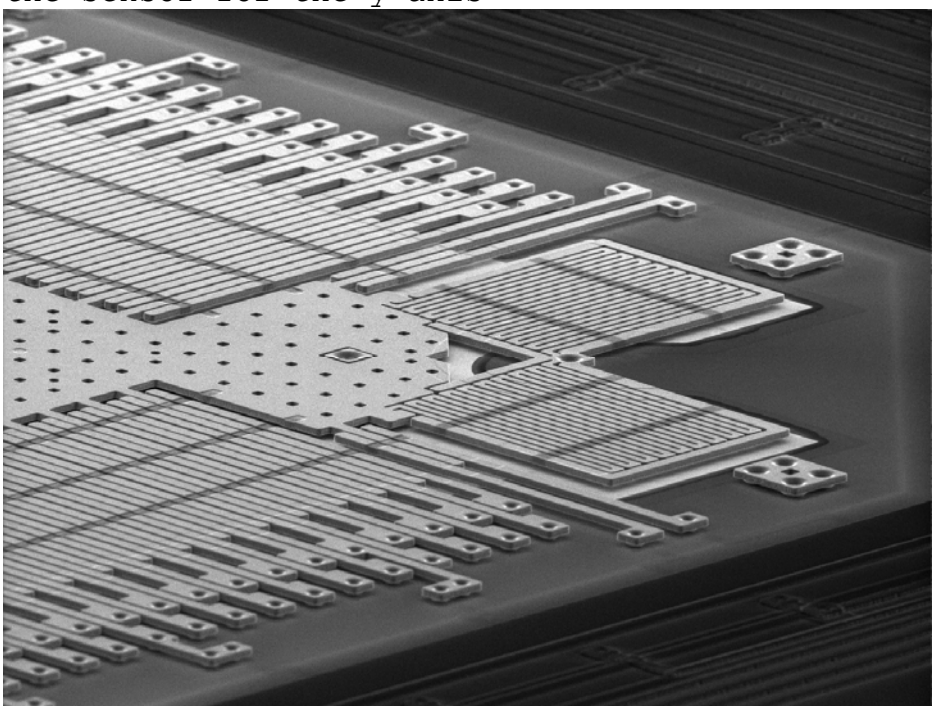
The concept of Hot Hand™ is to give users a new expressive means of effect control. The system provides the basic control of an expression pedal in addition to new and unique manipulations that are not feasible with a traditional pedal. The Hot Hand™ sensor can be mounted in a ring, on a headband, or foot. Since it is attached to the body users are free to move about and make the control of effects part of their performance.

Technology

The core of the Hot Hand™ motion sensing system is a very small package dual-axis accelerometer. The size of the device is well suited to producing a wearable package which is small, lightweight, and can be mounted in various positions on the body. An accelerometer, as its name implies, senses acceleration. The device is a fully integrated circuit on a micro-machined piece of silicon.

The micro-machining actually cuts out small moving squares of metal that are suspended over the wafer on polysilicon springs, making it sensitive to movement and tilt. The variations in the position of the metal are detected by capacitive sensors along the sides. The signals are converted into a pair of analog outputs for both the x and y-axis.

It is important to note that the sensor detects acceleration and not velocity or position. This means that it is not only capable of detecting movement but also acceleration due to gravity. By using simple trigonometric functions, it's simple to deduce the position of the sensor relative to the surface of the earth. When the sensor is mounted in a ring on a user's strumming hand the output of the sensor for the y-axis



(Enlarged view of a micro-machined accelerometer)

will be zero when the forearm and hand are parallel to the ground. From that position, the angle between the ground and the user's forearm while pivoting at the elbow can be easily computed. The acceleration due to gravity on the Earth's surface is 9.81 m/s^2. The angle in degrees, when the voltage output is scaled to range from +1g to -1g, is given by:

Θ = Arc sin (Acceleration Y / 9.81)

In addition to sensing the angle or "tilt", the accelerometer is also useful for measuring greater accelerations associated with quick hand or arm movements. The accelerometer has a maximum measurement range of +/- 5g which is five times the normal acceleration of gravity. This range is beyond what is normally generated by a hand in motion; however accelerations measured at the hand can commonly exceed 3g.

Implementation

Finding the right location for the sensor is a critical issue in making motion controlled effects a reality. We experimented with various locations on both the guitar and body. Some were more appropriate than others. We finally settled on the back of the hand or a ring mount because that position gives the best combination of a range of motion and intuitive feel. Other positions, such as mounting on a headband or a shoe, have intriguing possibilities but were not the focus of the first Hot Hand product. With the sensor location set we then had to make refinements to the system.

The signals from the accelerometer are analog and need to be digitized to be of any use in the digital audio processor. Since the signals are control signals and are limited in frequency, a low bit resolution/ high sample-rate converter is suitable for this purpose. Once the raw data is available the to digital signal processor (DSP) it needs to be filtered to cut out unwanted frequencies. Without any filtering, the combination of the accelerometer signals and the audio will sound too jittery and unstable especially if the user has an unsteady hand. A lowpass filter is used to eliminate the unwanted high frequencies.

In most cases, it's necessary to alter the cutoff frequency of the filter to match a playing style or to achieve a particular sound. The Hot Hand unit has a "Motion" knob to serve that purpose. The cutoff of the filter ranges from 20 Hz in the "Pick" to 2 Hz in the "Flail" setting.

After processing the accelerometer signals are ready to control various effects. In our first generation Hot Hand product, Hot Hand Wah Filters, the signals are used to control the frequency of various resonant filter types. This process of dynamically sweeping a filter is commonly referred to as "wah-wah" or simply "wah". In the nominal hand position (hand centered over the strings) the accelerometer output is zero and the filter is in the

center of its range. As the player picks, strums, or makes large gestures the frequency of the filter is swept up or down depending on the direction of motion or the angle relative to ground.

The accelerometer, because it is mechanical in nature, will have some intrinsic error from one device to the next. Large alignment errors are screened out in the testing process; however, small variations of +/- 1 degree are typical and must be accounted for in the system. The Hot Hand unit contains a calibration procedure to account for these errors and for adjusting the sensor to different playing styles. The user holds his/her hand in their nominal playing position (the natural resting position) and initiates the calibration sequence. The calibration sets this position as the center of filter range and when the frequency of the filter moves in response to motion it will be relative to that point.

Summary

Motion control offers a new means of controlling standard audio effects. In recent years, many effects unit manufacturers have moved away from manual effect controls to systems where effects are controlled automatically without much input from the user. While some interesting sounds can be created in the manner, the user can feel somewhat removed and out of control. The Hot Hand system represents an effort to give control of effects back to the user and offers a new means of artistic expression. After all, artistic expression is what music is all about.