Introduction

The advent of electronics has had a profound effect on music production and reproduction. Electronic synthesizers may be designed to emulate existing musical instruments or to create an entirely unique sound. In recent decades, the popularity of music generated entirely by electronic means has increased, spurred on partially by the ubiquity of the personal computer. However, all-electronic music production is not a solely modern notion. One of the earliest all-electronic instruments was invented by Russian scientist Léon Theremin in 1919. This instrument sparked an early twentieth-century interest in electronic music production and remains popular due to its unique tonality and novel control method [1]. The design, operation, and application of Theremin's namesake instrument are the subjects of the present discussion.

Operation

The performer plays a Theremin by moving their hands in relation to two antennae, one for pitch and another for volume. Though several variations exist, traditionally the instrument volume decreases as the left hand is moved closer to a looped antenna and the pitch decreases as the right hand is moved away from a straight antenna [2]. Sound is generated by the principle of heterodyning, that is, two signals of slightly different radio frequencies mixed together to create a audible “beat” frequency. The position of the performer's hands change the capacitance of the antennae and thereby modify the resonant frequency of tuned oscillator circuits in the instrument. Since the electrical interaction with the Theremin is capacitive in nature rather than radiative, the sensitivity of the instrument is closely related to the antenna surface area. The varying frequency produced by the tone oscillator in response to the performer's hand is mixed with a fixed-frequency signal to create audible tones [3]. Figures of merit which are typically applied to various Theremin implementations include sensitivity to hand motion, pitch range and volume dynamic range. The instrument often includes additional controls which allow the performer to tweak these parameters.

Implementation

The original Theremin design described in [3] and later licensed to RCA is an entirely analog implementation constructed mostly with thermionic vacuum tubes and passive components (resistors, condensers, chokes, transformers). Most modern Theremin designs are also analog in nature and use similar circuitry to the original, typically substituting transistors for vacuum tubes as active devices. However, there is also interest in building devices which are interacted with in a similar manner, but operate on very different principles. For example, infrared optical sensors and full-frame motion
capture technologies borrowing from the Theremin control scheme have been developed and integrated into modern electronic music production systems [4] [5].

Most Theremin-like designs may be implemented with common, easily-obtainable components. Analog designs require passive components similar to those in the original as well as active devices such as amplifier integrated circuits, transistors, or even vacuum tubes [6]. Digital implementations may be readily envisioned using FPGAs or software packages which support DSP functionality. If a capacitive electrical interaction method similar to the first Theremin is desired, antennae designed to maximize capacitive coupling are required. Optical methods may utilize simple motion detectors such as LEDs and photodiodes or more complicated systems like camera and motion detection software [4] [5]. In cases where simplicity is preferred, the volume control portion of the Theremin may be left out entirely, limiting performer interaction to pitch control.

**Availability**

Several types of Theremin are available for purchase or construction. The earliest commercially available example was the RCA Theremin, an instrument licensed from Léon Theremin's original design which possessed a pitch range of about three octaves [7]. One well-known modern design is the Moog Etherwave, an analog IC and transistor-based device with about five octaves of pitch range. The current model Etherwave retails for about US$400 and may be purchased in kit form for about US$320. Additionally, there are numerous Theremin numerous designs freely available on the Internet such as those found in [6].

**References**


