Theremin

Francis Flores

11/28/2011

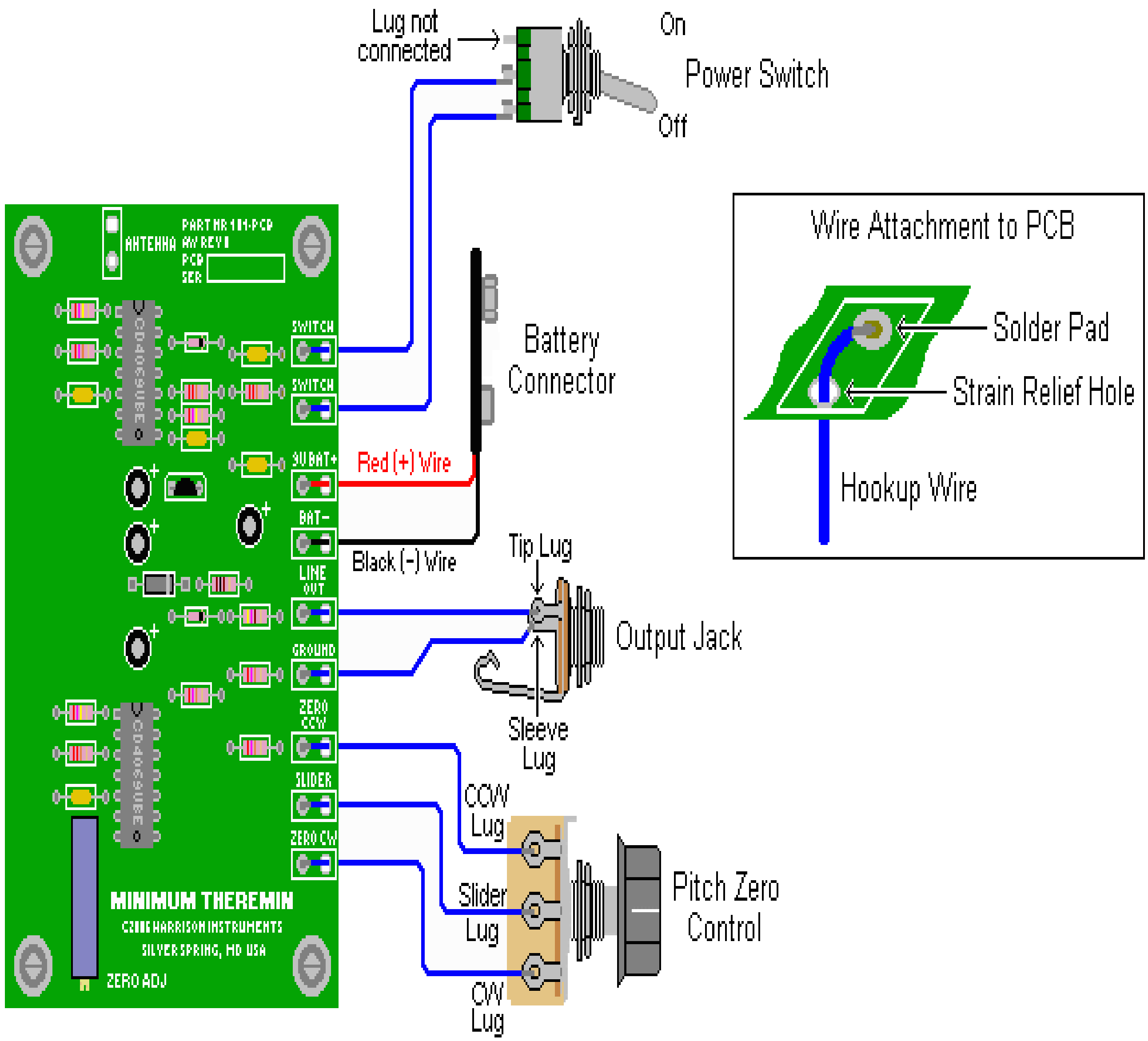
The Theremin is an electronic musical instrument that is controlled by the proximity of the player's hands to its two antennae. One antenna controls the pitch of the tone produced, while the other controls the volume. The Theremin does not require actual contact between the player and the instrument which gives the Theremin such a unique quality; an onlooker only sees a musician adjusting his or her hands slightly to produce a wailing electronic emission of a curious nature. One may assume that this strange instrument was a product of the late twentieth or early twenty-first century due to its electronic nature. This, however, misses the mark by more than seventy years! The original Theremin was created by the Russian born Leon Theremin circa 1920. His interest in high frequency electricity and efforts to produce a radio wave based alarm system led to the development of the Theremin. (Glettler,J, 2011) Although not very well known amongst the general population by name, most have heard it in one way or another. Some of the places that a Theremin can be heard are in a small portion of orchestras (Leon Theremin had intended it to be a mainstay in the orchestral arrangements of his day onward) and some rock/pop music of the twentieth century such as "Good Vibrations" by the Beach Boys or "Whole Lotta Love" by Led Zeppelin. But by far the most commonly heard Theremin tones come from the musical scores of 1950's Sci-Fi films.

Although the tones the Theremin produces are very odd to hear, the underlying principles that the device is based on are relatively simple. The first component of the Theremin that is to be considered is the LC Tank, where the L stands for Inductor and the C for Capacitor. Its action closely resembles a mass on a spring that is set into motion which is based on the principle of Simple Harmonic Motion. (Glettler, J, 2011) Like a mass on a spring the LC Tank has a resonant frequency that depends on the properties of the inductor and the capacitor involved, mathematically represented as $f_r = \frac{1}{2\pi\sqrt{LC}}$ (Glettler, J, 2011) In any system some energy is lost to the environment. This case is no different; for the oscillation of the LC Tank to continue periodically without decaying there needs to be some constant input of energy. Theremin went about this through the use of vacuum tubes, but later designs used transistors. In Theremin designs there is often more than a single oscillating component involved. When two oscillators interact their signals are multiplied giving an output of $V_{out} = A_1 A_2 \sin w_1 t \sin w_2 t$ where w is the angular frequency. This can be rewritten as $V_{out} = \frac{A}{2}[\cos(w_1 - w_2)\, t - \cos(w_1 + w_2)\, t]$ (Skeldon, K, 1998). In a Theremin one of the capacitors involved is one that is created between the pitch antenna and the user's hand. Changing the distance your hand is from the antenna tunes the oscillator by changing the capacitance to a small extent. But a small change in capacitance (Pico Farad change) isn't going to lead to any noticeable change in the resonant frequency of the oscillator according to the resonant frequency equation. This is where the second V out equation comes into play. According to this equation the output signal has two frequency components. One is from the difference of the two oscillators frequencies and the other is from the sum. (Skeldon, K, 1998) The change in capacitance is seen in the sum of the two signals because the frequency is much larger and therefore a small percentage change in capacitance has a much greater results. The sum of frequencies is generally outside of the range of hearing and that is where the difference is important. The high frequency radio signal is being modulated by the low frequency audio signal. This process is called heterodyning and is common in radio technology. (Glettler, J, 2011) The signal is then passed through a rectifier of sorts to isolate the low audible signal.

Returning to a previous subject, the pitch antenna and the user's hand act together as a parallel plate capacitor where each object can be considered a plate. As with any parallel plate capacitors, when one moves the plates together the capacitance increases. This is the action that changes the pitch or the frequency of the Theremin.

One important phenomenon to consider is the lock-in effect. This occurs when multiple bodies share a similar frequency of oscillation and will tend to pull towards each other until they share the same frequency. This can be problematic for Theremin constructors when two of the oscillators in a Theremin operating at low frequencies lock in and cause the pitch produced to suddenly stop changing and stay at a specific frequency. To avoid this many constructors harness inductors in series with capacitors to avoid ground currents and to decouple the signals. (Skeldon, K, 1998)

The properties discussed above are all related to the analog Theremin design, but there are also modern Theremins not based on analog components. The Theremin that I constructed is of the latter. Although interesting, the way this kind works is different than the analog design and will not be discussed here. Below is the diagram of the Theremin from the manufacturer's website. This specific design is a simplified version that only has one antenna which controls pitch. There is not a volume antenna.


Lug not connected
On
Power Switch
Off
Wire Attachment to PCB
Solder Pad
Strain Relief Hole
Hookup Wire
ANTENNA
PART NR 101-PCB
AW REV 1
PCB SER
SWITCH
SWITCH
9V BAT+
BAT-
LINE OUT
GROUND
ZERO CCW
SLIDER
ZERO CW
MINIMUM THEREMIN
ZERO ADJ
Battery Connector
Red (+) Wire
Black (-) Wire
Tip Lug
Output Jack
Sleeve Lug
CCW Lug
Slider Lug
CW Lug
Pitch Zero Control

Sources:

- Glettler, James. M.I.T., “Theremaniac Bringing Leon Theremin and his instrument from the twenties to the twenty first century.” Last modified 2002. Accessed October 3, 2011 www.mit.edu/~glettler/resume/undergrad/phys489_**Theremaniac**.pdf

- No Name, First. Harrison Instruments, Incorporated, “Minimum Theremin Kit 101” Last modified 2011. Accessed October 3, 2011 http://harrisoninstruments.com/101/101_description.html

- Skeldon, K; Reid, L; McInally, V; Dougan, B; Fulton, C. “Physics of the Theremin” Last modified May 15, 1998, Accessed November 4, 2011 http://ajp.aapt.org/resource/1/ajpias/v66/i11/p945_s1