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The Ornerly Theremin Synthesizer

The theremin synthesizer is certainly a unique musical instrument. In my experience and research, I have not come across another instrument that is played without contact between the player and the instrument (yes, I concede that an argument could be made for the jug whistle, but reliable playing technique would benefit from seating the chin on the lip of the jug, and only one note could be sounded without modification or use of multiple jugs). By using ones hands to modify the electric circuit of the device from afar, the player controls the pitch and volume of the electric output by moving his/her hands closer and further from the antennas. The mystical performance technique coupled with eerie futuristic tone made the theremin a natural choice for science fiction movie sound tracks and psychedelic rock shows, but it is perhaps in concert performance by such serious thereminists as Clara Rockmore and Leon Theremin himself that the beauty of the instrument has been most convincingly demonstrated.

(Very brief) Introduction

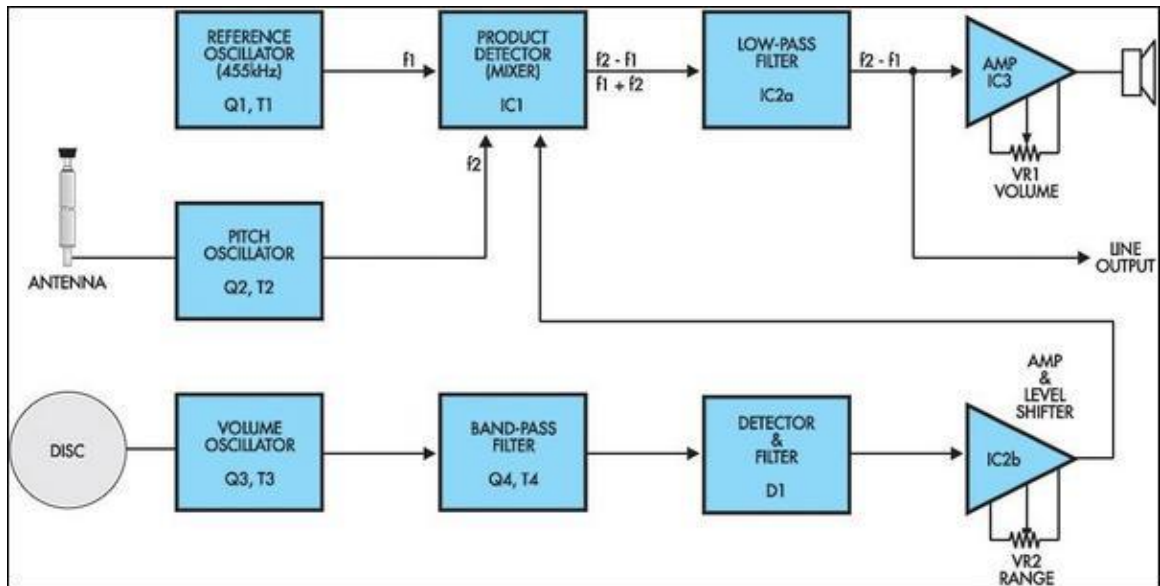
In the late 1910s, young physicist Lev Thermen, or Leon Theremin to us westerners, became intrigued with the possible use of the human body's natural capacitance to interfere with the capacity of an electrical circuit to change the circuit's parameters.¹ This intrigue was soon manifest as his "radio watchman," an invisible burglar alarm, in which a human body's having become close enough to the antenna on the device to adequately affect the capacity of the circuit and therefore the frequency of its high frequency oscillator causes a switch to close, producing an audible alarm.^{1,3} While experimenting with the use of high frequency oscillators to more accurately

measure fluctuations in the dielectric constants of various gases in response to temperature and pressure, Theremin made the frequency audible through earphones to monitor the capacity of the circuit by changes in its audible frequency, or pitch.¹ Being a cellist, Theremin soon realized the possibilities of this magical “etherphone.”

By 1922 Lev Theremin had developed his “etherphone,” and had gained the attention of Bolshevik leader Vladimir Lenin. In a private demonstration for the Soviet revolutionary, Theremin left a great impression and, as a result, received the support of the government that led to European and American tours and sharing his invention with the world.^{1,3}

(Brief) Physical explanation

I constructed a theremin from a kit designed by Silicon Chip and distributed by Jaycar Electronics. The simplified circuit is rather straightforward, and all technical information is adapted from the manual cited as source 2.



Pitch

For my theremin kit, the reference oscillator operates at about 455kHz. The pitch oscillator operates at a frequency greater than that of the reference and changes in frequency depending upon the amount of capacitance (to the earth) introduced by a hand or other human or animal part. By decreasing the distance between the plates (hand and antenna), the capacitance of the system increases ($C = (\epsilon_0 \text{Area})/\text{distance}$), which drops the frequency of the pitch oscillator. In his original design, Theremin took advantage of a new concept, the “heterodyne” principle,¹ in which frequencies could be combined to make a new frequency, often the difference between the two. This is precisely what occurs in the product detector: the frequency of the reference oscillator is compared with that of the variable oscillator, producing sum and difference frequencies. The sum frequency is removed in the low-pass filter, so only the difference frequency is applied to the power amp to drive the speaker. This means that, for example, if the capacitance presented by the hand (or face etc.) reduces the pitch oscillator to a frequency of 469kHz, then the difference (469kHz-455kHz) would be 14kHz, which would be heard through the speaker. The assembled kit differs from Theremin’s original design in that his pitch oscillator was higher in frequency than the reference oscillator, so that as he brought his hand nearer to the pitch antenna the pitch became higher.¹

Volume

The volume control operates similarly to the pitch control. The bandpass filter in the volume loop has a center frequency higher than the volume oscillator plate. As the oscillator frequency increases as the hand is brought away from the volume plate, the difference between the center frequency and oscillator frequencies increase so that the

difference between the two increases. This difference becomes the output signal, which is filtered in the detector/filter to produce a DC voltage, which is then amplified and modified by a level shifter so that it can control the product detector output level.

(Long, taxing) Construction Process

I bought a kit. Assembly was straightforward and I even learned to solder. After completing the device, it worked properly but had a limited pitch range of about one and one-half octave. I could even play “Somewhere Over the Rainbow” through my double envelope filter with distortion.

I then attempted to tune the device to increase the range. I absent-mindedly misidentified “VR2” (the range pot for the level shifter) for “T2” (the tuning transformer for the reference oscillator). I didn’t know that transformers could be overturned, so I did that. Because my reference oscillator was broken, I was not getting a nice sound out of the theremin. Unsupervised, I began exploring with a multimeter in hopes of locating the problem. In this process, I shorted a couple ICs, fried at least two transistors, and caused perhaps other damages. I took the device into the electronics shop, where Mr. Penhallegon and I explored the circuit for things I had broken. He told me about overturning transformers, and we tried to repair the damaged T2. We replaced transistors, I went to radio shack and bought replacement ICs, I ordered replacement transistors and ICs from Allied Electronics, and we made a thorough diagnosis test with his multimeter and oscilloscope. I learned how to test various components with his aptly named multiple components tester and his L/C meter. The final missing part, unless we’ll need to order replacement transformers from the Australia company because his replacement won’t tune quite to 455kHz, arrived this afternoon.

(Brief, optimistic) Conclusion

It's been a little frustrating, but I've learned lots about components, being careful with electronics, and how a theremin operates. I've definitely learned to appreciate electronics design and work. Dick works really hard and is very helpful.

When the theremin is fully operational it will likely make appearances on my friends' experimental albums and in my pseudo-psychedelic pop band's live show. They say they're excited... anything sounds good to them with enough digital delay and digital reverb.

Cited:

1. Glinsky, Albert (2000). *Theremin: Ether Music and Espionage*. Urbana, Illinois: University of Illinois Press.
2. Theremin Synthesiser (August 2000). *Silicon Chip Magazine*. 16-24.
3. "Theremin." *Wikipedia, The Free Encyclopedia*. 11 Dec 2009, 11:25 UTC. 19
<http://en.wikipedia.org/wiki/Theremin>