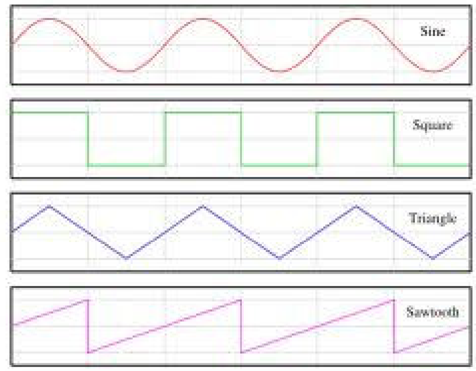
A brief explanation of:

A Brief Explanation of Photosynthesis

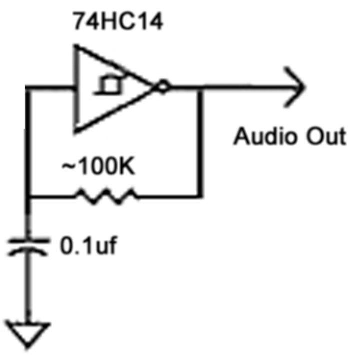
(Which is, in retrospect, a moderately wordy explanation of audio synthesizers)

Build your own optical Theremin for fun & profit!

The optical Theremin circuit at work in this house plant is a good introductory project for artists and hobbyists interested in analogue electronics. Its design is simple to follow, has wide tolerances for part substitutions, and provides several useful design solutions.

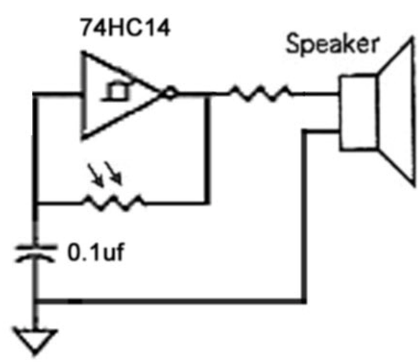


In electronics lingo, a Theremin is a kind of **oscillator**, which is to say that the circuit makes a signal that goes back and forth between two values (on and off, high and low, positive and negative, etc). The time it takes to switch from one state to the other is called the **period** or **frequency** of the oscillator and the pattern of that change is the **waveform**. A signal that changes states gradually would form a **sine** wave, while a signal that jumps from one to the other would be a **square** wave. Many other waveforms are possible. Oscillators are very common, an oscillator in your alarm clock cycles at about 1 **Hertz** (once every second) to advance the time while a faster one ,switching 200 times per second, can play a musical note (in the neighborhood of G).

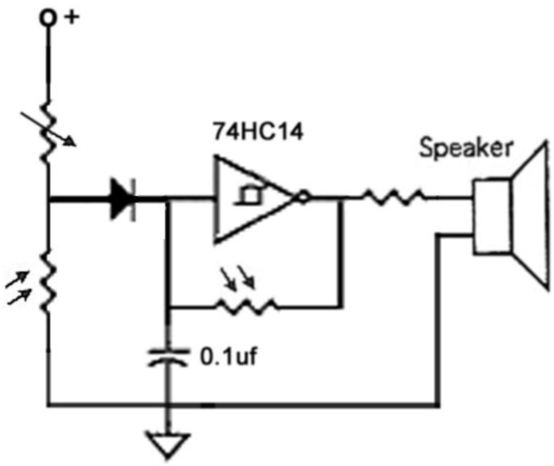


The schematic to the left shows a very simple audio oscillator that will be the starting point for our Theremin circuit. It produces a constant tone with a pitch determined by the resistor and capacitor. Larger values for either component will lower the pitch and smaller values will raise it.
Important: Remember to connect the chip to the power supply
+ to pin 14 and – to pin 7 (see datasheet)

How it works: The 74XX14 is a "hex inverter", a digital logic chip that reverses (or inverts) the input. If the input (the lead to the left of the triangle, pin 1) is High then the output (to the right, pin 2) will be Low and vice versa. In logic terms this is a NOT function. The chip includes 6 independent inverters, hence the hex. For this project I have chosen the "HC" series, which is an efficient, low voltage version of the chip. At the start of the cycle the input is Low, which means that the output will be High (in our circuit about 5V). The voltage across the resistor, from the output, charges the capacitor. As the capacitor approaches the rail voltage, the inverter recognizes it as a High input and switches states. The energy stored in the capacitor will then discharge through the resistor to the output (which is now Low) and the cycle repeats itself. A larger value capacitor, will take longer to charge, thus lowering the frequency. Similarly, a higher resistor will slow the charging of the capacitor, again reducing the frequency. Imagine that you are trying to fill a bucket with water and that you are under a Sisyphean curse that causes the bucket to empty itself whenever it is half full. The capacitor, in this analogy, would determine the size of the bucket, the resistor would be a kink in the hose (slowing the flow of water), and the rhythm of the bucket crashing futilely to the pavement would be the frequency of our oscillator.



If we had set out to make a fire alarm then we could stop here, but if this "instrument" is going to be playable we will need some way of interacting with the noise. An optical Theremin uses light to control the pitch of the oscillator; it does this by substituting the resistor from our first circuit with a photoresistor (also called an LDR or light dependent resistor). As the name suggests, the resistance of the LDR is affected by light, the brighter the light the lower the resistance. As in the previous circuit, that lower resistance will result in a higher pitch. A second resistor between the audio output and the speaker controls the volume.



The project seems to be going well, but soon enough we discover a problem. The LDR lets us play the instrument... but how do we stop it? While shading the LDR can drop the pitch, the drone remains bold and unrelenting. We have created a monster. Ideally, we would want the circuit to only turn on when the light is above a certain intensity, a **Threshold Level**. To do this we will **Gate** the oscillator using a diode, a second LDR, and a variable resistor (VR). A diode allows current to pass in only one direction. While the resistance of the second LDR is less than the VR (while light shines on the circuit) the diode will have no effect on the oscillator. When the resistance of the LDR rises above the VR (in the dark), however, the diode will hold the input of the inverter High and prevent the oscillator from cycling. Adjusting the variable resistor allows us to set the light level at which the Theremin is active.

Things are looking up, we have a working Theremin, we learned how to adjust the volume, our neighbors have stopped swearing, and we have calibrated it to the ambient light of the room. Suddenly, inspiration strikes: there are 5 more Theremins on this chip! The 74HC14 has 6 independent inverters and each of them can be used to make another oscillator. Check the datasheet to make sure that you identify the inputs and outputs correctly. When mixing audio signals, it is a good idea to add a resistor in series with each source. A headphone jack allows us to play the Theremin through more substantial audio equipment.