1. Slide 1

   Hi everyone!

   This video is a tutorial on how to construct an Atari Punk Console and a demo of the finished product. For brevity, I'll sometimes refer to the Atari Punk Console as the APC. I adapted the circuit made famous by Forrest Mims. I'll be showing you that circuit later in this video.

   The APC is a great intermediate level electronics project. Whether you're taking a deeper dive into electronics for the sake of it or in order to build a solid foundation for robotics, the APC project is a great place to start.

   In order to make this demo more interesting, I'm really demoing four things:
   a. # 1, the APC
   b. #2, my Line 6 amplifier, which requires input from a producer of sound; so, the APC is going to be that input
   c. #3, Camtasia Studio 8, which I used to put the video together; so, in a sense, this video is also a demo for Camtasia Studio 8
   d. #4, the Skype earphone/microphone combo, which is the only mic I could get working on my ThinkPad's combo audio jack

   I hope you enjoy this video! Do watch till the end, since I've saved the best for last.

2. Slide 2

   Here's an introductory demo, just to whet your appetite.

   After this we'll step back and look at how we build this.

   <Introductory demo clip>

3. Slide 3

   What I want to show you in this video is how a relatively simple circuit can produce such a rich and amazing set of sounds. And when you feed those sounds into an awesome amplifier like the Line 6 I'm using, the awesomeness is further magnified.

   So, let me show you how to build an APC.

4. Slide 4

   As I mentioned earlier, the APC was made popular by a circuit published by the legendary electronics enthusiast and author Forrest Mims. If you've never heard of him, I highly recommend that you look him up. Mims originally called this circuit a Stepped Tone Generator.

The circuit is also referred to as a noise maker or sound synthesizer.

Rather than diving straight into the APC circuit and possibly getting lost, I'm first going to cover some of the concepts that are required in order to understand the APC circuit.

The APC circuit is primarily the work of two 555 integrated circuit chips. The 555 is widely considered to be the world's most successful chip. It was created in 1971 by Hans Camenzind of Signetics. In demoing this APC project, I also aim to get you interested in electronics, that is if you're not already an electronics buff. And there's perhaps no better introduction to electronics than the 555 chip.

The 555 is often referred to as a timer chip. But it's not really a timer. There's no clock inside the chip. What this chip does is that it reacts to the time it takes a capacitor to charge up to a certain voltage (called the threshold voltage) and discharge down to a certain voltage (called the trigger voltage).

5. Slide 5

   Let's continue delving into what makes this circuit work, starting with a bit more detail on the 555 chip. This is the hardest part. Stay with me. We'll take a break after this and do another demo.

6. Slide 6

   As you can see on this slide, the 555 chip has eight pins or legs. The power supply, in this case a 9V battery, hooks up to pins 1 and 8 as shown. The negative connects to pin 1 and the positive connects to pin 8.

   The next set of pins to consider are 2, 3, 6 and 7. These pins are at the heart of what makes the APC work.

   Typically, you'll see a capacitor connected to pins 2 (which monitors the trigger voltage) and 6 (which monitors the threshold voltage). Fundamentally, the 555 is what's known as a flip-flop circuit. When the capacitor discharges (via pin 7) and its charge falls to 3 volts, the circuit flips - pin 2 gets triggered and the output on pin 3 turns on. In this state, the capacitor starts charging again. Once the capacitor charges to 6 volts, pin 6 (which monitors the threshold voltage) detects this and the circuit flops back to its earlier state – the output on pin 3 turns off and the capacitor starts discharging. As long as the circuit is powered, this cycle will repeat forever. In a nutshell, this is what makes the APC work. We will revisit this in more detail in the context of the APC circuit.

   In our circuit, pins 4 and 5 aren't used. So, pin 4 is connected to the positive rail. Making pin 4 negative will reset the circuit, but we don't need that function in our APC circuit. And pin 5 is left unconnected.

So, that's enough about the 555 for now. We will revisit these concepts after we've looked at the APC circuit.

7. Slide 7

   Now that we've covered some of the key concepts required to understand the APC circuit, let's take a look at how I built my Atari Punk Console. Let me start by describing the physical manifestation of my APC. I want to show you not only how to understand and build the circuit, but also how to put it all together in a solid manner so that it lasts a lifetime and is easily usable and portable.

8. Slide 8

   Here's the front of my APC. Think of it as the user interface or UI.

   I used an Altoids tin as my casing. I used a drill to make holes for the two potentiometers, the on/off switch and the audio jack.

   As you can see in the demos, this setup allows me to use the APC with great ease.

   The on/off switch turns the power supply on and off. Without the power supply the circuit will not operate.

   The audio jack is used to connect the APC output to an external device, such as the Line 6 amplifier that I've used in some of the demos.

   Finally, notice that I've attached knobs to the two potentiometers in order to make them easier to turn. The left knob controls the a-stable circuit, i.e. the pulse frequency, and the right knob controls the mono-stable circuit, i.e. the pulse width. I will say more about this later in this video.

9. Slide 9

   Now let's take a peek under the hood, so to speak.

   The key thing to note is my use of a small breadboard to connect the circuit. That's the black rectangle that all the wires are connecting into. I prefer this approach to an etched circuit board, mostly because it's easier and facilitates reuse of components.

   It's really important to use the right hookup wire so that the wires go into the breadboard just right and have a snug fit. The hookup wires are the white colored wires you see all over the breadboard. After a bit of research, I settled on solid 22 gauge hookup wire, which worked out perfectly. In hindsight, it all looks fairly simple, but it took me weeks to get each part of this project just right. Also, note my use of female to male solder-less Dupont jumper cables or wires to connect the potentiometers to the breadboard. Wherever possible, I prefer a solution that is solid but doesn't require soldering. Elsewhere, there's no choice but to use soldering to achieve a solid and lasting connection, for example on the on/off switch and the audio jack.

Once you've put it all together and have the Atari Punk Console working as desired, it should last forever. The only thing you should ever have to mess with is replacing the battery. Notice that I've used a clip to connect the battery so that it can easily be removed and replaced. I've already had to replace the batter once in the year or so that I've had this APC. If the APC starts functioning erratically, turning on and off randomly, almost as if there's a lose connection somewhere, by all means check your connections, but note that it might point to a weak battery. So, try replacing the battery to see if the erratic behavior goes away.

10. Slide 10

    What you see here is my APC circuit diagramed using the awesome Fritzing tool. It's an exact replica of my physical circuit on the breadboard and the Altoids tin. If I ever drop the APC or somehow need to rewire or recreate it, this is my reference for rebuilding what I had.

    Note that I've got the components labeled so that the circuit can be reproduced accurately.

11. Slide 11

    Okay, we've covered a lot of ground and there's been plenty to digest. So, let's take a break with another demo and then we'll come back to exploring the APC circuit further to understand exactly how it works.

    <Second demo clip>

12. Slide 12

    I hope you're still with me, because this is where the rubber hits the road. Whereas the Fritzing circuit diagram you saw previously is useful for rebuilding the physical device, the diagram you see here is better for understanding how the circuit operates.

    As I mentioned earlier, the APC is built using two 555 chips. In the diagram, you can see that the chip on the left is part of an a-stable oscillator circuit whereas the chip on the right is part of a mono-stable oscillator circuit. Let's discuss each of these two circuits briefly.

    First, let's review the a-stable circuit. Note that pins 2 and 6 are shorted. When we say shorted, we mean a direct connection, without an intervening resistor or some other component. Also, note the .01 micro Farad capacitor. As we will review in more detail later, this capacitor is at the heart of what causes this circuit to flip-flop as this capacitor charges and discharges, thereby producing a continuous stream of square pulses. The frequency of these pulses can be varied by turning the knob on the potentiometer. The pulse frequency is the number of on/off cycles per second, measured in Hertz. Note that the frequency is inversely proportional to the resistance. So, as the resistance decreases, the frequency increases. Finally, note that pin 3 is feeding the mono-stable circuit.

Next, let's review the mono-stable circuit. Here, pin 2 takes its input from the a-stable circuit and pins 6 and 7 are shorted. The output from this circuit goes to the speaker or the external device connected via the audio jack. The width of the output pulse can be varied by turning the knob on the potentiometer. Note that pulse width is the duration for which the pulse is positive, measured in microseconds. In this case, the pulse width is directly proportional to the resistance. So, as the resistance decreases, the pulse width also decreases.

The collaboration between the two circuits, a-stable and mono-stable, with the a-stable feeding the mono-stable, is what gives us the great variance of sounds we can produce by turning the two knobs.

There are many good books, web sites and videos explaining these concepts in more detail. As far as books go, I highly recommend "Make: Electronics" by Charles Platt.

13. Slide 13

    Let's recap the distinctions between the a-stable and mono-stable oscillator circuits. Pin connections. The a-stable circuit has pins 2 and 6 shorted. The mono-stable circuit has pins 6 and 7 shorted. Trigger. The a-stable circuit is triggered internally, every time the .01 micro Farad capacitor discharges down to 3v, as it goes through its perpetual charge/discharge cycle in collaboration with the 555's flip-flop capability. And lastly, the pulse. The a-stable circuit produces a stream of square pulses of programmable frequency. The mono-stable circuit produces a single square pulse of programmable width per trigger.

14. Slide 14

    Before we move on to the grand finale of demos (sort of like the July 4 fireworks), let's cover the wave forms for an a-stable circuit in a bit more detail.

    This slide is a graphical representation of some of the details I've alluded to previously. My hope is that this graph will help to drive these concepts home.

    The bottom green line represents negative or ground, which connects to pin 1 of the 555 chip.

    The yellow line, which is the next line up, represents the trigger voltage, which is monitored by pin 2. When pin 2 detects that the capacitor charge has dropped to the trigger voltage setting, the 555 sets the output pin 3 to high. The trigger voltage is typically $1/3^{rd}$ of the supply voltage. So, in our case the trigger voltage is 3v.

    The brown line, which is the next line up, represents the threshold voltage, which is monitored by pin 6. When pin 6 detects that the capacitor charge has risen up to the threshold voltage setting, the 555 sets the output pin 3 to low. The threshold voltage is typically 2/3rd of the supply voltage. So, in our case the threshold voltage is 6v.

The top red line represents positive, which connects to pin 8 and in our case is 9v.

Next, take a look at the black square wave. This is the output wave form generated on pin 3.

Finally, take a look at the blue capacitor charge graph. As we've been discussing, in collaboration with the 555's flip-flop capability, the capacitor charge oscillates back and forth (up and down).

This perpetual charge/discharge cycle of the capacitor is at the heart of what allows the Atari Punk Console to produce a continuous stream of notes.

Now, let's look at the two yellow circles labeled A and B on the graph and try to pull together all of what we've discussed so far.

What's happening at point A is that the capacitor charge, which had been falling, has finally reached the trigger voltage of 3v. As you can see on the graph, this causes output pin 3 (represented by the black graph) to go high. In the binary world, high is usually 5v or 9v and low is 0v or ground. You can see that the output on pin 3 represented by the black square wave is at almost 9v. Pin 3 stays high while the capacitor starts charging (on its journey from point A to point B on the diagram). At the point labelled B on the graph the capacitor charge reaches the threshold voltage of 6v. This causes the output on pin 3 to go low and the discharge pin 7 to go low so that the capacitor starts discharging again. This cycle repeats forever as long as the circuit is powered. This cycle is the basis for the continuous tones we get from the APC.

Finally, note the two brackets around the square wave. The yellow bracket is the pulse width, which the amount of time that the pulse is high, measured in microseconds. The red bracket is the pulse duty cycle. Pulse frequency is the number of cycles per second, measured in Hertz.

That's it for the key concepts behind the workings of the APC. But we haven't covered every detail about the 555 chip or the APC circuit by a long shot. For example, what are the roles of the .1 micro farad and 10 micro farad capacitors in this circuit? I will leave these and other topics for you to discover on your own. For now, let's move on to the final set of demos.

15. Slide 15

First, let's operate the a-stable circuit by turning the left knob, which varies the resistance and therefore the voltage and current on pins 6 and 2. Listen for the pulse frequency going up as the resistance is lowered, since the pulse frequency is inversely proportional to the resistance. Note that the resistance is at the maximum of 470 kilo ohms when the knob is pointing north or at 12 o'clock. The resistance drops as I turn the knob clockwise, thereby increasing the pulse frequency.

<A-stable mode clip>

16. Slide 16

    Now, let's operate the mono-stable circuit by turning the right knob, which varies the resistance and therefore the voltage and current on pin 6. Listen for the pulse width going down as the resistance is lowered, since pulse width is directly proportional to resistance. Again, note that the resistance is at the maximum 470k ohms when the knob is pointing north or at 12 o'clock. The resistance drops as I turn the knob clockwise, thereby decreasing the pulse width.

    <Mono-stable mode clip>

17. Slide 17

    Now, this is where the fun starts! We'll see that by mixing and matching different pulse frequencies and widths using our two circuits (a-stable and mono-stable) we can create a variety of sounds, basically letting the APC act like a little sound synthesizer.

18. Slide 18

    Now, for the grand finale!

    We're ready to plug our handy dandy sound synthesizer into an amplifier.

    You can connect the APC's external audio jack to any sound system that accepts external input via a standard 3.5mm audio cable, e.g. a Bose Wave Music System.

    I chose the Line 6 amplifier because it adds another dimension to this demo.

    The Line 6 Spider IV is a solid state, 75 watt amplifier with a 12 inch Celestion custom speaker. This amplifier has more than 300 built in effects, some of which we're going to add on top of our APC during these demos.

    So, here we go. Fasten your seatbelts. Sit back. And relax.

19. Slide 19

    I hope you enjoyed it as much as I did! Thanks for watching! Don't forget to <u>like</u> this video and <u>subscribe</u> to my channel. Also, <u>post</u> comments or questions. I enjoy answering questions because it helps me learn and it might even help you move a tiny step forward in your own journey, whether its electronics, robotics, or something else! Until next time, goodbye and happy tinkering!