L.E.D. Oscilloscope, Part 1
Basic Electronics
Learn **E**lectronics by **D**oing
- Theory is pretty thin stuff until it's mixed with experience.-

Chapter 11
Section "D" - Capacitor Timing Experiment

In this next section we will add a large Electrolytic Capacitor to your skills and see how the voltage and currents change as it charges.

Assembly of Section "D"

You will need the usual tools:

- Safe work space/place (See the ***Safety*** section)
- Safety Glasses
- Schematic Sheet #1- Sig-Gen-1c
- Parts Layout Sheet #1- Sig-Gen-1c
- Parts Set #1
- Sig-Gen-1c PC board
- Power Supply and Wall-Mount power module
- Tweezers, Pliers, Wire Cutters
- Soldering station (or Soldering Iron & Stand)
- 63/37 Solder

(60/40 is ok, but the 63/37 flows best, and remember, *Do Not Use Plumbing solder.)*

- Digital Multi Meter (DMM)

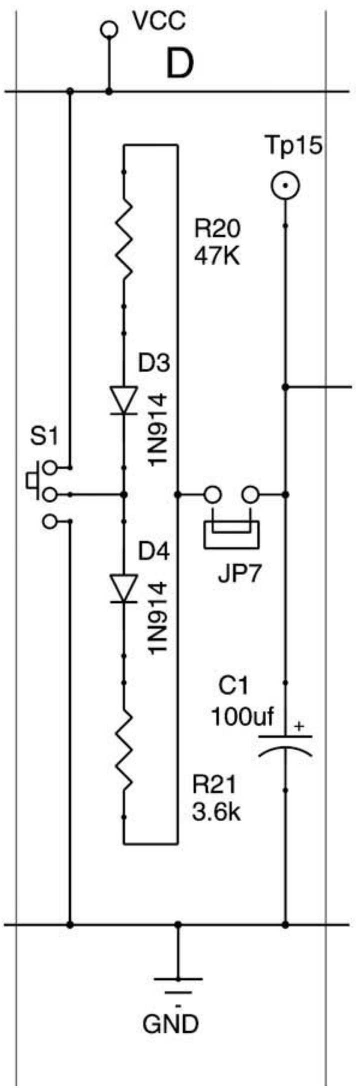
Setup your soldering station or iron as before, and let the iron come up to operating temperature. From Parts Set #1, find and lay out these parts:

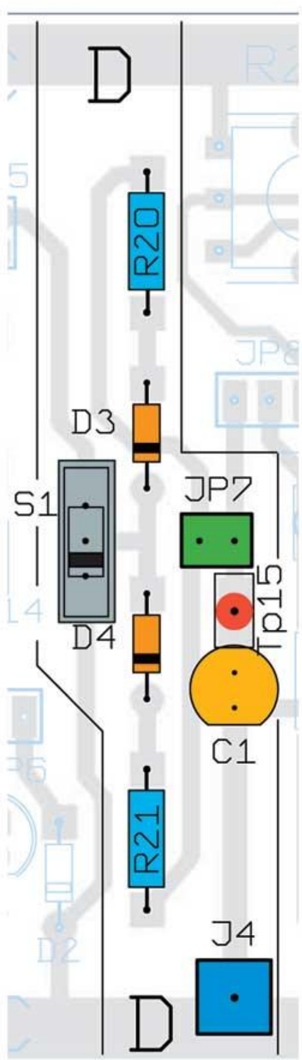
1 -	2-pin header		JP7
1 -	Shorting Block		
1 -	47K Resistor (Yellow-Violet-Orange)		R20
1 -	3.6K Resistor (Orange-Blue-Red)		R21
2 -	Signal Diodes	1N914	D3, D4
1 -	100uf Electrolytic Capacitor		C1
1 -	SPDT Switch (Single Pole, Double Throw)		S1

Assembly

Check the box *after* you have completed each step. Refer often to the schematic and try to reference the part to its place in the schematic. Do not just use the parts placement guide to get them soldered in place. Trace through the paths the currents must flow. Repeating this for each step will help develop your ability to read schematics. And, yes, I am repeating myself because I do not want you to ignore this process.

☐ 1) As you have done before, verify the resistor values with your multimeter. If your multimeter can test diodes, select that function, and test them next. Note the polarity cathode/negative band and the direction of charge flow.





☐ 2) Insert and install the jumper block JP7 first, then the SPDT switch, S1. Solder these components in place. Move the slide-switch lever towards the bottom, "ground" edge of the PC board.

☐ 3) Bend the leads of resistors R20 and R21 to match the spacing of holes on the printed circuit board and insert them into their correct locations. Bend the leads back slightly to keep them from falling out, turn the board over, and solder these components in place.

☐ 4) C1 is an electrolytic capacitor and will have polarity markings. There will be a white stripe on the side nearest the negative terminal. Normally, a 100uf capacitor would be physically fairly large. In order to fit such a large electron storage capacity in such a small package, special construction methods are used, and that requires the inner surfaces of the capacitor's plates to be "polarized". This means that when a voltage is applied in the correct direction, the insulating layer will be strengthened. A reverse voltage will start breaking down this insulating layer and the capacitor would be damaged.

Another type of electrolytic capacitors is called bi-polar or non-polar, and will not have the white stripe. Internally it is actually two polarized capacitors connected back to back. If one's insulating layer is reduced, the other will be strengthened.

Install C1 with the polarity markings correctly aligned with those shown on the PC board (top of board). Bend the leads slightly outwards to hold it in place, and solder and trim the leads.

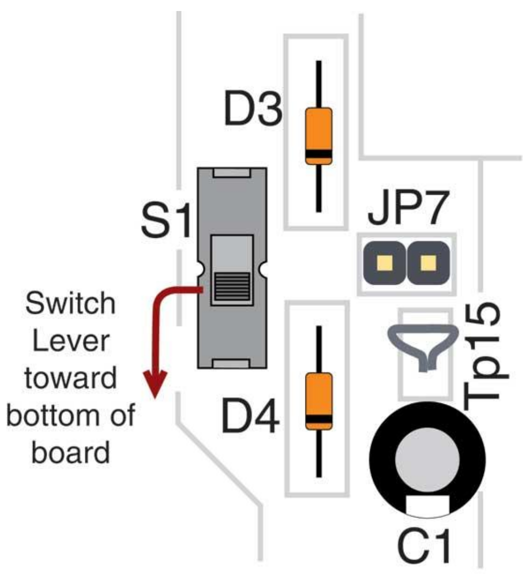
☐ 5) Bend the leads for the diodes to match their spacing on the PC board, align them with their polarity markings, and install them. Bend their leads slightly to keep them in place when you turn the board over. Both the diodes and the capacitor have a small chance of being damaged if over heated, so, as you did in the previous section, try to solder them quickly.

☐ 6) Go back and check each soldering joint. Inspect for too little solder; too much solder. Are the component lead and circuit pad fully wetted with solder? If so, remove small amounts of excessive solder by first cleaning the iron's tip, then quickly wiping it across the joint to remove a bit of solder. (Doing this slowly will melt all the solder and tends to cause it to stay put.) Re-heat the joint if the solder is not fully flowed to form a nice smooth and shiny joint.

Testing and Analysis

☐ 1) Do a little clean up first -- Clean and add solder to the tip of the iron and turn it off. Gather up the tools you have been using and set them aside. Make sure there is no conductive, or other, debris under your PC board.

Be sure the power module is turned off -- the switch lever will be away from the LED. Plug the AC power adapter into an outlet and plug the adapter's cable into your power supply module. The red LED should be off. Connect the power supply regulator to the Signal Generator Board -- the red lead to the pins labeled "**Vcc**"/"**+5**", and the black lead to the "GND" ground pins. Double check to be sure the polarity is correct. Turn on the power supply. Its indicator LED should be lit.

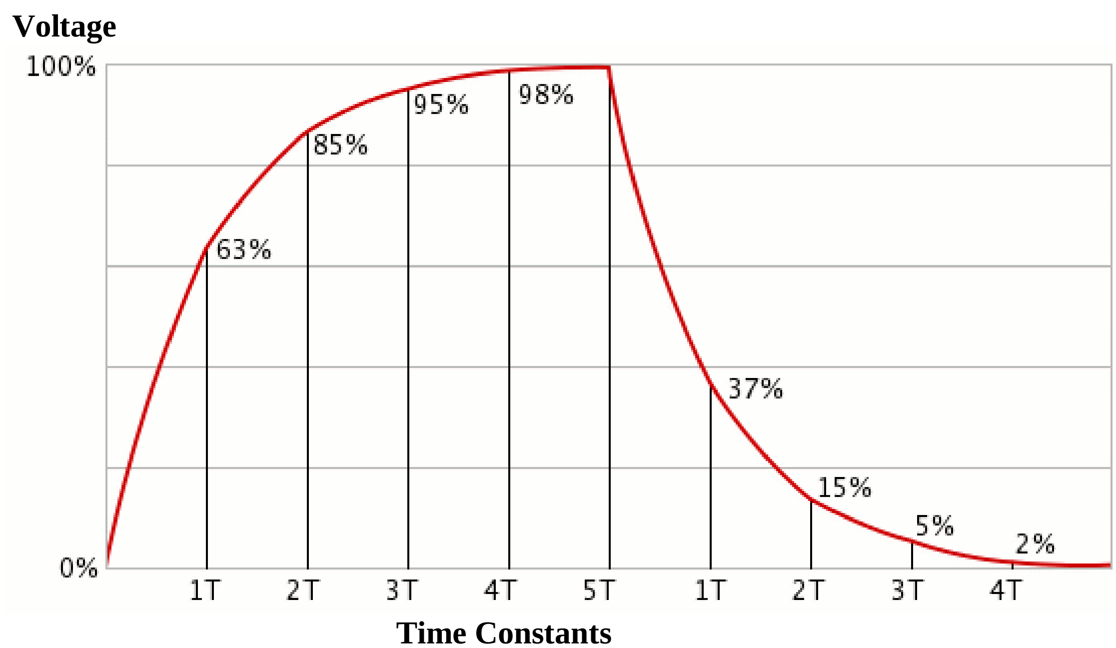


☐ 2) Install shorting blocks on JP5 and JP7. The shorting block on JP5 will cause LED D1 to light. This can now be a "Power-is-On" status indicator for the Signal Generator Board. The shorting block on JP7 connects the capacitor to the rest of the diode and switch circuit.

☐ 3) Connect the multimeter's negative (black) lead to ground, set the scale to the 20 volt range, and touch the positive (red) lead to the test point Tp15. It should read zero volts if the slide-switch lever is still towards the bottom of the board. (If it is towards the top edge, slide it back towards the bottom.)

Study the schematic and you will see that D3 and D4 are being used as “Steering Diodes” -- they steer the capacitor’s charging current through different resistors depending upon the S1 switch position. These allow us to create different time periods for charge and discharge part of a cycle.

Now watch the meter as you slide the switch towards the top. This will supply current through resistor R21 and diode D4 to start the capacitor charging. It will take about a second for the capacitor to fully charge. The voltage increases quickly at first, and then slows down as it reaches the full supply voltage, which should be about 5.0 volts. Next, watch the voltage on the capacitor when the switch is slid down. Notice that the voltage quickly drops at first, then the change slows down as it gets closer to zero. If you were to carefully time and measure the voltage changes and plot them on graph paper, you would find they create what is known as an “exponential curve”.



Exponential voltage curves of a Capacitor Charging and Discharging

Do the Math

Using a resistor to control how long it will take a capacitor to charge is used in timing circuits. The time it takes for the voltage reaches 70.71 % of the supply voltage is called the “RC time constant”. This time period will be the same for any supply voltage: It will take the same time with a 2 volt supply as with a 25 volt supply. That is why it is called a “time constant”. It is equal to the value of the resistance in ohms times the value of the capacitance in farads. Remember that a farad is a very large value and typically capacitors are rated in millionths of a farad, or microfarads, written as “µF”. Our 100µF capacitor is therefore .0001 F, and the time constant for the charge constant would be: 3600 ohms X .0001 F = .36 seconds. Looking at the time constant graph, in order to reach 95% of full voltage would take three time constants. This would take 3 x .36 seconds, or 1.08 seconds.

Note that it takes longer to discharge the capacitor than to charge it. This is because the charge and discharge paths are through different resistors. With the switch in the top position, D3 blocks the current and D4 allows it to flow through R21 to charge C1. When the switch is in the bottom position, D4 now blocks and D3 allows C1 to discharge through R20. The diodes can be called steering diodes because they steer the current through different section of the circuit.

Calculate what the time constant should be for the discharge path:

RC Discharge Time: ______________________________

Within 5% of Ground: ______________________________

The “Fine Print”

Remember that the voltage that the capacitor will charge up to for this RC time constant will be lowered by the forward voltage drop across the steering diode:

$$\mathbf{V_{TC} = .7071 \times (V_{suppply} - V_{DiodeForward})}$$

This is not critical for this experiment, but these are the details you will need to remember to look for when your calculated results don’t match your real measurements.

Summary

- Diodes can be used to steer currents to modify circuit functions.
- Large capacitance values are typically provided by Electrolytic capacitors.
- Electrolytic capacitors are usually polarized, but there are non-polarized versions.
- The RC time constant is equal to the resistance times the capacitance, and is the time it takes the capacitor to charge up to 2/3s the supply voltage.
- 5 RC time constants will reach 99% of supply voltage.

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