Ethan McAuliffe <mcaulife@mcmaster.ca>

Capacitor circuit question

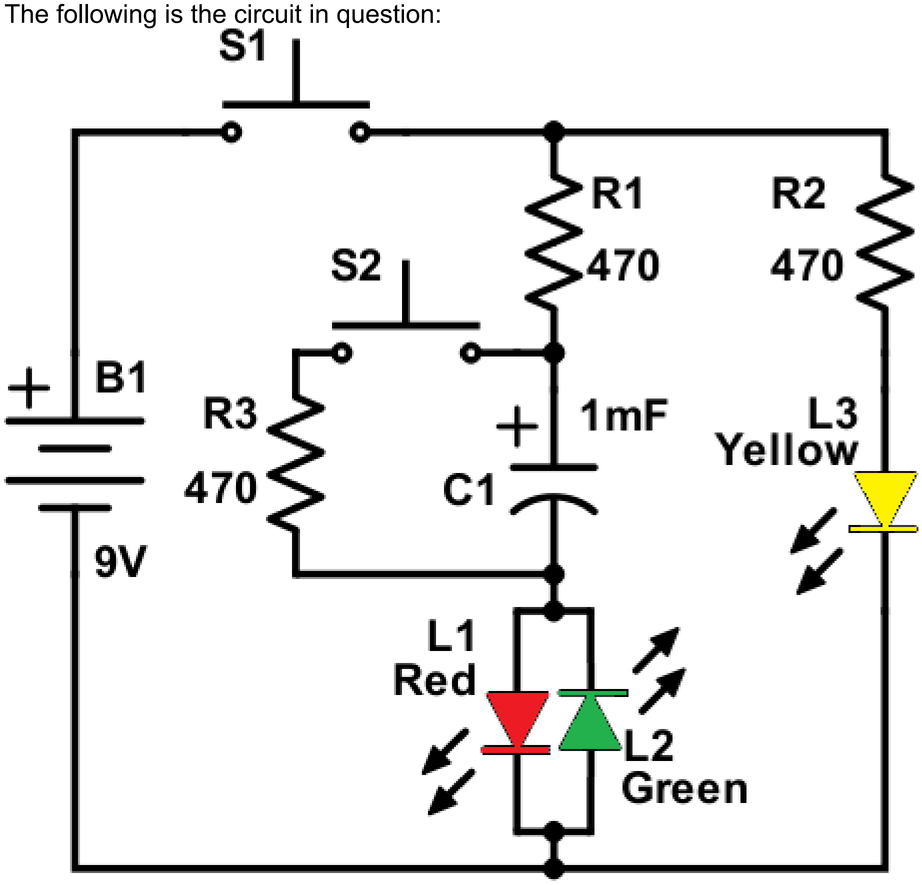
2 messages

Ethan McAuliffe <mcaulife@mcmaster.ca> Tue, May 7, 2019 at 8:00 AM
To: venus@physics.mcmaster.ca

Hi sir,

I was a student in your 1E03 class this winter semester. I was wondering if you could help answer a question I have regarding a capacitor charge/discharge circuit developed by my former high school teacher.

The following is the circuit in question:



When S1 is closed, the circuit charges up C1 and illuminates the yellow LED. When the cap is sufficiently charged, S1 is opened and the user then closes S2. When in this configuration, both the green and yellow LEDs light up (and then dim as the capacitor voltage decreases). If the cap is fully charged and both switches are left open, the cap will gradually discharge through the green and yellow LEDs.

This all makes sense to me. The issue is that the red LED lights up when only S1 is closed and I'm not sure why. It is my understanding that charge should not flow through the capacitor so a complete circuit is not created and the red LED should not light up. The dielectric in the capacitor is an insulator so there shouldn't be any charges moving between the positive and negative plates. And yet despite all this the red LED still turns on. Furthermore, the red LED dims as the capacitor charges. I assume this is because the voltage drop over the LED is eliminated when the capacitor is full. I'm just not sure where this voltage drop is coming from in the first place.

An aluminum electrolytic capacitor is used in this circuit. Not sure if this has anything to do with the behaviour of this circuit but I thought I'd include it in the event that it does.

Here's a video I took of the circuit in action: https://drive.google.com/file/d/1EOXTme5AaQ3pGzWYysTDYFYc4_mMCfhb/view?usp=sharing

Hopefully you can help me answer this question but if there's someone else I should ask let me know.

Thanks,

Ethan McAuliffe
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David Venus <venus@mbx.rhpcs.mcmaster.ca> Tue, May 7, 2019 at 1:19 PM
Reply-To: venus@physics.mcmaster.ca
To: Ethan McAuliffe <mcaulife@mcmaster.ca>

Hello Ethan:

Let's concentrate on S1 for the moment and leave S2 open. I am assuming you know that LEDs allow current to flow in only one direction (arrow).

After S1 is open for a long time, C1 has no charge. When S1 is closed, then B1 maintains 9V around two circuit loops, once containing the yellow LED and one containing C1. So the yellow LED is continuously lit and the capacitor starts to charge. This means it accumulates +Q on the top and -Q on the bottom. In order to accumulate -Q on the bottom, positive current has to leave the bottom of the capacitor, making a continuous circuit loop to the battery. This current will pass through the red LED. As the charge on C1 accumulates, less and less current flows and when C1 is completely charged the red LED will go off. The charging time scale is tau=R1C1 (prove it).

Now S1 is opened again and C1 discharges through the only closed circuit loop -- through the yellow and green LEDs. This will continue until it is discharged, and both LEDs go off. The discharging time scale is
tau=2R1C1 (prove it).

Now the whole process can be analysed with S2 closed. S1 is open for a long time, so C1 is discharged, and then S1 is closed. C1 charges, but notice that current can now flow through R3. Since C1 is connected across the terminals of R3, C1 will not charge to 9V but only the portion of the battery potential across R3. Since R1=R3, this will be 4.5 V. Also, even when C1 is charged, a current will continue to flow around it through R3, and the red LED will continue to glow. (As before the yellow LED is always glowing.) Also, the time constant for charging will change to tau=1/2 C1R1 (prove it).

Now S1 is opened again, and C1 discharges through two loops, those containing R3 and the yellow LED. During this process, the yellow and and green LED glow until they fade and turn off. For this discharging, the time constant is tau=2/3 C1R1 (prove it).

Hope this helps.

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