Electrical principles

Electronics project

LED chaser circuit

By

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Plan
Throughout the duration of the planning period, I considered several circuit ideas, these being; a DC motor control circuit, a shadow detector alarm circuit, a light sensor circuit, a clap switch circuit, and finally, an LED chaser circuit. From all of these ideas, I decided the LED chaser circuit was the best choice, as it was simple to follow, easy to understand, and overall, it interested me the most.

The circuit itself is a sequential circuit in which, the LEDs light up one after the other, thus the depiction of it being a sequential circuit.

Purpose and working of the circuit
As mentioned before, the circuit will incorporate a mixture of discrete and integrated components, these of which will light up each LED, one after the other. All this is possible using the following circuit:

As you can see from the schematic above, the circuit will make use of: a 555 timer chip, a 4017 counter chip, and finally, an R-C network.

555 timer IC
The 555 timer chip, or integrated circuit, as it’s formally known is very commonly used in many electronic circuits as a basis up on which an engineer can build on. Not only is the 555 timer chip very versatile, but it is very cheap.

As you can see from the diagram below, the 555 timer chip has 8 pins, each of which provides a means of functionality. Throughout this section, I will label and describe how each pin works, and what it will be used for in this circuit.
**Pin 1, Ground:** As it states; the ground connects the 555 timer chip to the negative power rail, thus the voltage is 0.

**Pin 2, Trigger:** This essentially, as stated by the name is the “trigger” of the timing cycle. When the voltage across the pin is below $\frac{1}{3}$ of the rail voltage, basically the supply voltage, then the output from pin 3 will be high, which in terms of binary is on, or 1.

**Pin 3, Output:** As it states in the name, pin 3 is the output, this of which leads to the 4017 counter IC.

**Pin 4, Reset:** Pin 4 acts as a reset switch for the timing operation. If the reset pin is momentarily grounded, the timing operation is halted, and it will only return to its timing operation when the trigger activates it. This pin is connected to the supply voltage.

**Pin 5, Control Voltage:** As stated by the name of the pin, this particular pin controls the voltage in case there any fluctuations in the voltage. The controlling of fluctuations can be rectified by adding a capacitor in series between the control pin, and the ground. I won’t use this pin, as I will just add a capacitor across the power supply rails. The schematic above will outline the details of this.

**Pin 6, Threshold:** The purpose of this pin is essentially to monitor the voltage levels across pin 7, discharge. When the voltage across pin 7 reaches $\frac{2}{3}$ of the supply voltage, it will end the timing cycle, and the output from pin 3 will become low, 0.

**Pin 7, Discharge:** This pin works in terms of monitoring the discharge voltage from an external capacitor. Usually, the capacitor is connected to ground, and the resistor is connected to the supply voltage. The resistor and capacitor form an RC circuit, which acts as a timing interval.

**Pin 8, Vcc 3 to 15V:** Pin 8 connects the 555 timer chip to the supply voltage; this can range from as little as 3V, to the larger extent of 15V. The circuit that I am using will supply the 555 timer with 9V.
4017 Counter IC
The 4017 decade counter, as stated in its name is an IC with the capabilities of counting in sequence up to 10. Although, the pins on the 4017 counter start at 0, and end in 9.

The counting is made possible by the input of the 555 timer chip, as a pulse generator. When the input pin of 14 is high, it counts up 1, and then the corresponding output in line is lit up.

Output 5 1.
Output 1 2.
Output 0 3.
Output 2 4.
Output 6 5.
Output 7 6.
Output 3 7.
Vss 0V 8.
16. Vdd +3 to 15V
15. Reset Input
14. Clock Input
13. Enable Input
12. ÷ 10 Output
11. Output 9
10. Output 4
9. Output 8
Pin 1, Output 5: As it states; this is output 5 of the 10 outputs available.

Pin 2, Output 1: As it states; this is output 1 of the 10 outputs available.

Pin 3, Output 0: As it states; this is output 0 of the 10 outputs available.

Pin 4, Output 2: As it states; this is output 2 of the 10 outputs available.

Pin 5, Output 6: As it states; this is output 6 of the 10 outputs available.

Pin 6, Output 7: As it states; this is output 7 of the 10 outputs available.

Pin 7, Output 3: As it states; this is output 3 of the 10 outputs available.

Pin 8, Vss 0V: Although it states Vss; this pin isn’t the voltage source. It is actually the ground.

Pin 9, Output 8: As it states; this is output 8 of the 10 outputs available.

Pin 10, Output 4: As it states; this is output 4 of the 10 outputs available.

Pin 11, Output 9: As it states; this is output 9 of the 10 outputs available.

Pin 12, ÷10 Output: This pin is known as the cascade pin as, it allows for the use of more than one 4017 counter IC. Although you may be able to use more than one, it is advisable to limit yourself to 3, as it may result in errors if there were more than 3.

Pin 13, Enable Input: This pin is known as the disable pin. Although it is known as the enable pin, if connected to a high voltage, or logic high; then it will not advance the count respective of the clock input. For this reason, we will connect this pin to the ground voltage.

Pin 14, Clock Input: This pin receives the clock impulse generated by the 555 timer IC.

Pin 15, Reset Input: As it states in the name, this pin can be used to reset the IC. You can reset the IC by attaching this input to a high voltage source, or logic high, 1. In normal operation, we will attach it to ground so it doesn’t cause complications in the circuit.

Pin 16, Vdd +3 to 15V: This pin receives the input voltage from the power supply. The input voltage for this circuit is 9V.

Timing of the 555 timer
The timing aspect of the 555 timer chip will be controlled by an external capacitor and corresponding resistor; this is known as an RC network. From this network, we can work out the timing of the pulses through something called a time constant, \( \tau \). The time constant can be worked out through the product of the resistor value, and the capacitor value, as so: \( \tau = RC \).

In this case, the resistor value will be 47kΩ, and the capacitor value will be 2.2µF. From this information, we can work out the time constant of this RC network, as so:
\[ \tau = (47 \times 10^3) \times (2.2 \times 10^{-6}) = 0.1034 s \text{ or } 0.1 s \text{ (to 1sf)} \]

From this, we can say that the timer generates a pulse every 0.1 seconds. If we wanted to increase the frequency of which this circuit operated, we could replace the capacitor with a capacitor of smaller capacitance.

How the circuit actually works?
From the information given on the two integrated circuits we are using in this circuit, we will not piece together the entire circuit and explain how it all works.

As we can see, the circuit is powered by a 9V battery supply. From this 9V battery supply, it will give power to the two integrated circuits through the relevant pins (as mentioned previously). The timing aspect of the circuit for the 555 timer chip will be made possible through the two resistors and the capacitor.

When the voltage across pin 2 on the 555 timer chip is below that of \( \frac{1}{3} \) the rail voltage, then the output will be high. When the output is high, it will activate the count on the 4017 decade counter in which it will produce an output on the corresponding output pin. The first output to turn on will be output 0. As the count continues, it will continue in sequence through each output until it resets. The output in this circuit will be in the form of an LED lighting up.

As there is a constant fluctuation of voltage, and therefore current in the ICs. We will need to stabilize any voltage spikes through the means of a low value capacitor across the voltage supply. The capacitor will be of capacitance, 0.1\( \mu F \).

Comparing my chosen design with other designs of the same function
Throughout my research on the different variations of my circuit, I was confounded to find anything of dissimilar design. The majority of circuits that were made to create a chasing LED effect consisted of a 555 timer IC to generate the pulses, and a 4017 decade counter as a means of counting. There was one circuit that I was able to find, but it consisted of only 3 LEDs and 3 transistors. Here is a schematic of the alternative, albeit dissimilar design.
As you can see, the circuit consists of three subsystems, each one consisting of; one LED, one capacitor, one transistor, one zener diode, and two resistors.

From this circuit, we can see that it's limited to 3 LEDs, although, this may be extended to have additional LEDs through the use of many more subsystems. Through the use of more subsystems, we can see that this will require a greater amount of space than if you were to use integrated circuits to carry out the same function.

Final design
I have decided to go with the design consisting of the 555 timer and the 4017 decade counter, as not only does it provide me with a simpler circuit, which in turn requires less components, but it is an easier concept to understand.

Risk assessment
As I am only using a DC source of 9V, there won’t be a need for precaution when working on or around my circuit. If on the other hand, it was of a higher voltage, then I would need to ensure that the relevant precautions were taken to prevent injury.

When the circuit is to be built or tested, I will need to ensure that:
- The area is well lit and clear of debris.
- There isn’t any volatile or flammable substances within the vicinity.
- The battery is kept away from a heat source, as this will result in severe injury.
- Liquids are to be kept away from the work area, as this will also result in injury.

Choosing components
As I’ve already chosen a circuit design, I will need to find the relevant components, and any corresponding data sheets to aid with the construction of the circuit. Although, as I was searching for the data sheets on any components in my circuit, I could only find the data sheets for the 555 timer IC, and the 4017 decade counter IC. I have attached the data sheets as appendix A and B. Appendix A being the 555 timer, and appendix B being the 4017 decade counter.

Here I will write down three relevant numerical parameters from each data sheet, and explain what they mean:

555 timer IC

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Voltage</td>
<td>Vcc</td>
<td>4.5</td>
<td>16</td>
<td>V</td>
</tr>
<tr>
<td>Threshold Voltage</td>
<td>VTH</td>
<td>9.2</td>
<td>10.8</td>
<td>V</td>
</tr>
<tr>
<td>Trigger Voltage</td>
<td>VTR</td>
<td>4.5</td>
<td>5.6</td>
<td>V</td>
</tr>
</tbody>
</table>

As you can see, all three values pertain to the voltage across the 555 timer chip. Here I will explain the meanings of the three values.

Vcc is the amount of voltage supplied to the 555 timer chip. This will essentially power the 555 timer. For this circuit, it will be 9V.
\( V_{th} \) is the threshold voltage, and as explained earlier, it monitors the amount of voltage discharged by the capacitor. If the voltage exceeds that of \( \frac{2}{3} \) the supply voltage, then the output will be low.

\( V_t \) is the trigger voltage, and as explained earlier, it essentially starts the timing cycle of the 555 timer chip. If the voltage across pin 2 lies under \( \frac{1}{3} \) of the supply voltage, then the output will be high.

### 4017 decade counter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Voltage</td>
<td>Vdd</td>
<td>3</td>
<td>18</td>
<td>V</td>
</tr>
<tr>
<td>Clock input frequency</td>
<td>( f_{cl} ) if Vdd = 15V</td>
<td>-</td>
<td>5.5</td>
<td>MHz</td>
</tr>
<tr>
<td>Clock pulse width</td>
<td>( t_W ) if Vdd = 15V</td>
<td>60</td>
<td>-</td>
<td>ns</td>
</tr>
</tbody>
</table>

Vdd is known as the supply voltage for the 4017 counter. It is essentially the power source that allows the IC to operate.

\( f_{cl} \) is the clock input frequency. As the 555 timer chip alternates from a high voltage output to a low voltage output, it is generating a clock frequency. Basically, this is an alternating square wave, in which the peak of the square wave is high, and the bottom is low. It is this clock signal that is measured in Hertz, or in this case, Megahertz.

\( t_W \) is the clock pulse width; this is the minimum amount of time that the clock pulse should be left in a logic state of 1, which is a high voltage.

### Comparison and choice of components

Throughout my research on my chosen circuit, I looked at any similar components out there that I could compare with the ones that I had selected. The components that I had chosen to compare were the 555 timer, and the 4017 counter. Unfortunately, as I kept looking through all the components, they were all very similar in their design, function, and layout. It occurred to me, as the 555 timer, and the 4017 counter provided a functionality unique to their design, it was important for the manufacturers to provide a product with similar properties. From this, it was clear to me, regardless of the manufacturer, I would receive a product of the same properties; this is why I opted for the cheapest priced one on the internet.

### Finished circuit on breadboard

Annex A shows pictures of my final design on a breadboard (‘Figure 1’ and ‘Figure 2’). In these pictures, I will show the circuit constructed, and I will show the circuit working.

### Testing

Here I will test the characteristics of the LEDs I am using in my circuit. Unfortunately, there wasn’t any data sheets included with the LED, although, I was able to find a list of characteristics on the product page, as follows:

- Forward voltage: 2.0 – 2.2V
- Maximum continuous forward current: 20mA

Through the use of a multimeter, and the LED set up on a breadboard with a power source, I was able to carry out a test to verify that these characteristics meet the ones found on the LED:
### Forward voltage

<table>
<thead>
<tr>
<th>Test</th>
<th>Voltage, V</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.99V</td>
</tr>
<tr>
<td>2</td>
<td>1.97V</td>
</tr>
<tr>
<td>3</td>
<td>1.96V</td>
</tr>
<tr>
<td>Average</td>
<td>1.97V (to 3sf)</td>
</tr>
</tbody>
</table>

### Maximum continuous forward current

<table>
<thead>
<tr>
<th>Test</th>
<th>Current, mA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16.66mA</td>
</tr>
<tr>
<td>2</td>
<td>16.62mA</td>
</tr>
<tr>
<td>3</td>
<td>16.83mA</td>
</tr>
<tr>
<td>Average</td>
<td>16.70mA (to 3sf)</td>
</tr>
</tbody>
</table>

As you can see, the forward voltage stays at a voltage of around 2V, as stated by the characteristic sheet. The current on the other hand stays below its maximum of 20mA.

Here is a link to the characteristics of the LEDs I have used:
http://www.amazon.co.uk/gp/product/B0087ZT24A/ref=oh_details_o02_s00_i00?ie=UTF8&psc=1/

### Further development

As the timing of the circuit was solely due to the RC network that I had setup. It meant that my circuit was limited to the value of capacitor I had used for the timing. If I was to make any changes or improvements, I could have replaced the capacitor with a capacitor of different capacitance. I demonstrated this by replacing the 2.2µF with a 0.1µF capacitor instead. After I had replaced the capacitor with the 0.1µF capacitor, I instantly saw a result. Instead of the LEDs lighting up at a labored pace, it was a lot faster. We can demonstrate this by looking at the time constant of the RC network, as demonstrated:

\[
\tau = (47 \times 10^3) \times (0.1 \times 10^{-6}) = 4.7 \times 10^{-3} s \text{ or } 4.7 \text{ ms}
\]

As you can see, the time it takes to generate a pulse is distinctly quicker compared to the previous value of 0.1s.

Another method of changing the timing of the RC network could be carried out by using a variable resistor. The variable resistor would allow the user to change the value of the resistance, thus you would be able to change the timing without removing any components.

### Annex A
Figure 2: Series of photos illustrating LED lighting in sequence

References


Doctronics. *555 Timer*, [online], Available: http://www.doctronics.co.uk/555.htm/ - 05/05/2014

Doctronics. *Aasters*, [online], Available: http://www.doctronics.co.uk/DDE/DDE_03.html/ - 05/05/2014


