MORE on Capacitors charging.

Finding the voltage to which a capacitor will charge in an RC circuit irrespective of the time in seconds.

(instead of just a time constant period).

This mini tutorial is placed here because many have asked how to work out the what the voltage across a capacitor is after any amount of time following the closing of the switch. (see circuit below). We learnt in the course how to find the voltage across the capacitor for any time constant from 1 to 5. But what if the time we want is **not** a multiple of the time constant.

Note: this is extra information only and **not** a requirement for amateur radio exams.

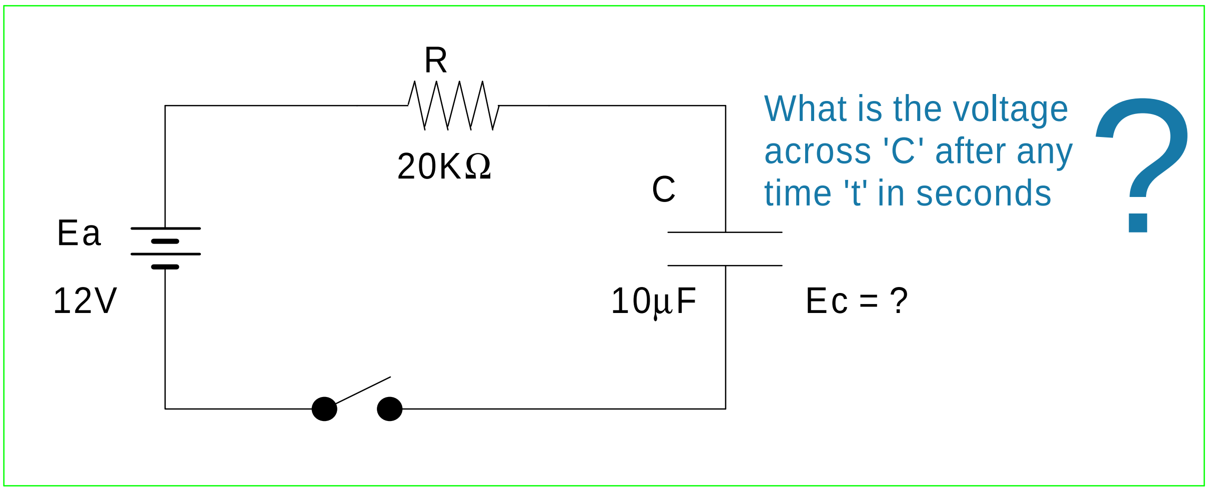
We know that a time constant T=RC - For the circuit below the value of T is 20KΩ x 10µF = 0.2 seconds. This means that if the switch is closed the capacitor will charge to 63.2% of the applied voltage (Ea) in 0.2S. In the next time constant the voltage on the capacitor will rise a further 63.2% of the **remaining** voltage go. We consider the capacitor charged after 5 time constants. That is after 5 time constants or 5 x 0.2S = 1 second the capacitor will charge to Ea (12 volts).

See the section on RC time constants in downloads and the notes for a refresher if you need it.

Using the simple but a little bit clumsy method we can work out the voltage across the capacitor are a number of 'fixed' time constant periods from 1 to 5.

But what if we want to know the what the voltage across the capacitor after say 0.5 seconds is?

Here is the circuit and how it is done...



$$Ec = Ea(1-\varepsilon^{-t/RC})$$

Where:

Ec - the voltage across the capacitor after time ‘t’
Ea – the applied voltage

ε - Greek letter Epsilon – the base of the natural logarithm and equal to 2.718281828
t = time is seconds since the voltage was applied
R - resistance in Ohms
C – capacitance in Farads

We want to know what the voltage on the capacitor will be after 0.5 seconds (just as an example). We know that the capacitor will charge to 63.2% of the applied voltage after 1 time constant. So after 0.2 seconds the voltage on the capacitor will be 63.2% of 12 = 7.584 volts. The capacitor has another (12-7.584) 4.416 volts to charge before it reaches Ea (12) – in the next time constant period the capacitor will charge a further 63.2% of this remaining voltage or an additional (63.2% of 4.416) 2.790912 volts – which means the total voltage of the capacitor after 2 time constants is 7.584 + 2.790912 = 10.374912 volts.

After 2 time constants or 0.4 seconds this capacitor will have 10.374912 volts across it.

You quickly see that this method is cumbersome and it does not allow us to find the voltage at 0.5 seconds. Using the above formula we can find the voltage across the capacitor after any time ‘t’ is second. Let’s use the formula firstly to find the voltage across the capacitor after 0.4 seconds and see how this method compares to the first method.

Calculating voltage on C (Ec) after 0.4 seconds (t).

Ea = 12V; t=0.4, RC = 0.2.
Use the ε^x on your calculator and don’t forget the minus sign.

$$Ec = Ea(1-\varepsilon^{-t/RC})$$
$$Ec= Ea ((1-\varepsilon^{-0.4/0.2})$$
$$Ec = 10.3759766 \text{ volts}$$

There you go much easier and more accurate.
So what is the voltage across C after 0.5 seconds? Use the formula again for 0.5:

$$Ec = Ea(1-\varepsilon^{-t/RC})$$
$$Ec= Ea ((1-\varepsilon^{-0.5/0.2})$$
$$\underline{Ec = 11.01498002 \text{ volts}}$$

A much easier method.

In radio and electronics a capacitor charging is often used for timing. For example a relay or transistor can be set to operate when and only when the voltage across a capacitor reaches X volts. The time taken for the capacitor to reach X volts during charge can be easily changed by changing the R in the circuit above.

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Since writing this a couple of students have asked me for my calculator keystrokes for the above calculation – okay here they are with the explanation of what I am doing. You need a basic scientific calculator to do this…

Press AC – all clear
Press 0.5
Press +/- (we have now entered –0.5)
Press / (divided)
Press 0.2
Press = (the display shows –2.5)
Press ε^X You usually have to press 2nd or INV to access this function
The display now shows 0.082084998
Press – (minus)
Press 1
Press X⇔Y This swaps X (0.082084998) and Y (1)
Press = The display now shows 0.917915001
Press X (multiply)
Press 12
Press = 11.01498002 volts The answer.

If you have trouble doing this and you really want to do it drop me a line at the above email address or ronber@one.net.au

73 de VK2DQ

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Idea – write a computer program to output the voltage across the capacitor from switch on for increasing time ‘t’ in set increments until charged. Send it to me and we can share it.

End of document.