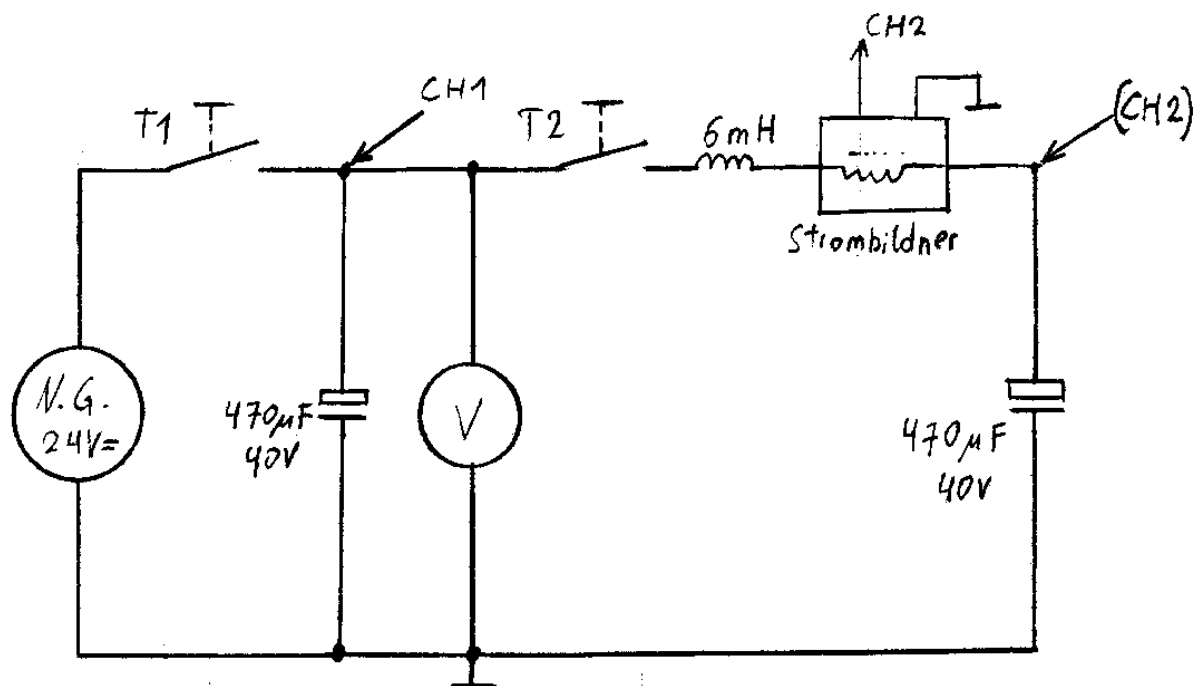


## "The Condenser Problem"

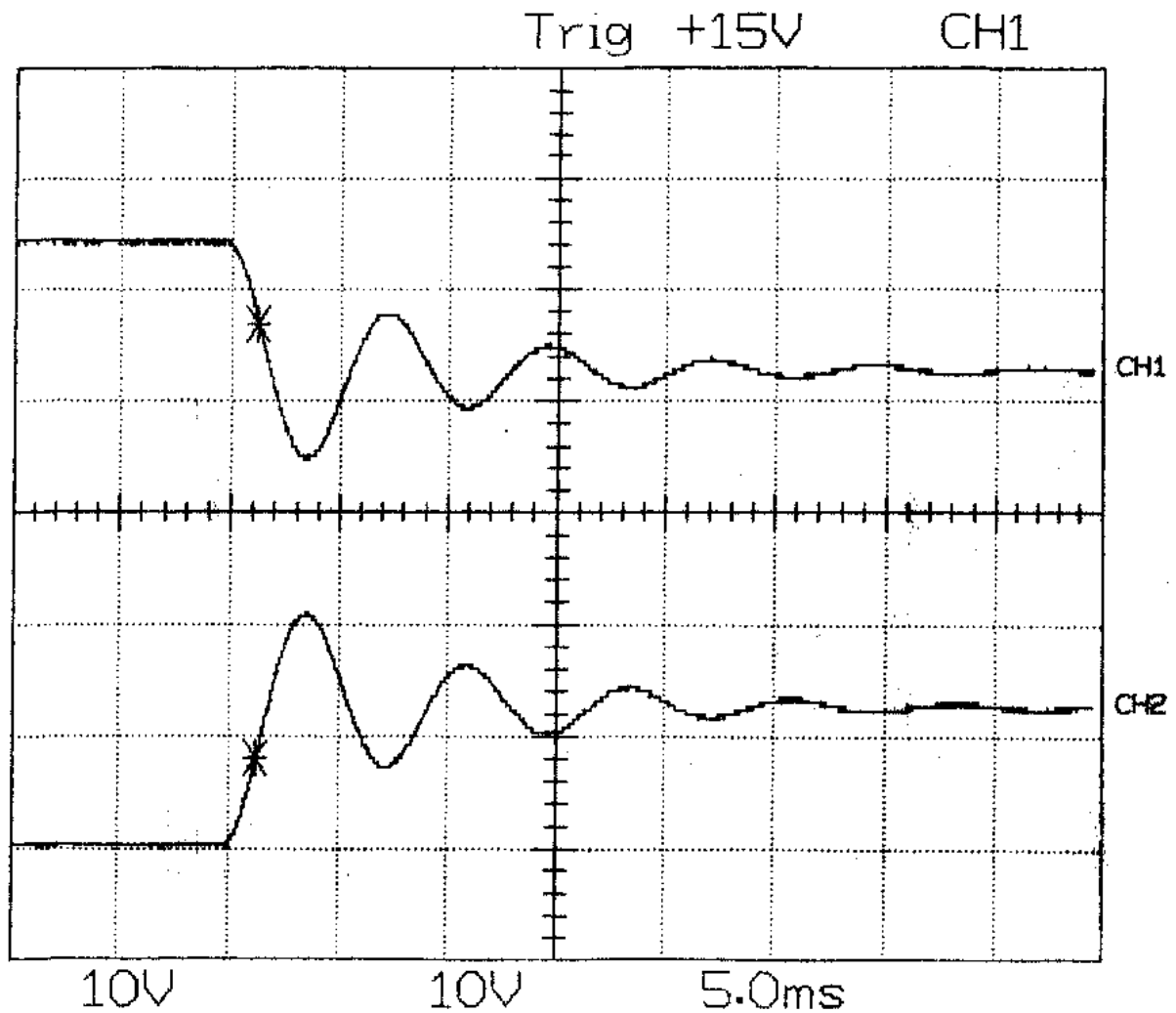
Capacitors are so common by, that nobody seeks for contradictions in them anymore. But that there are indeed still some mystique in them, the Electrogravitation-experiments of T.T. Brown for example or Naudin's LIFTER show just that.

But a much different and way more trivial problem occurs, once you want to charge up a capacitor by another capacitor. If you do that, in a "mysterious way", HALF THE ENERGY IS LOST.



Picture 1, Experimental setup.

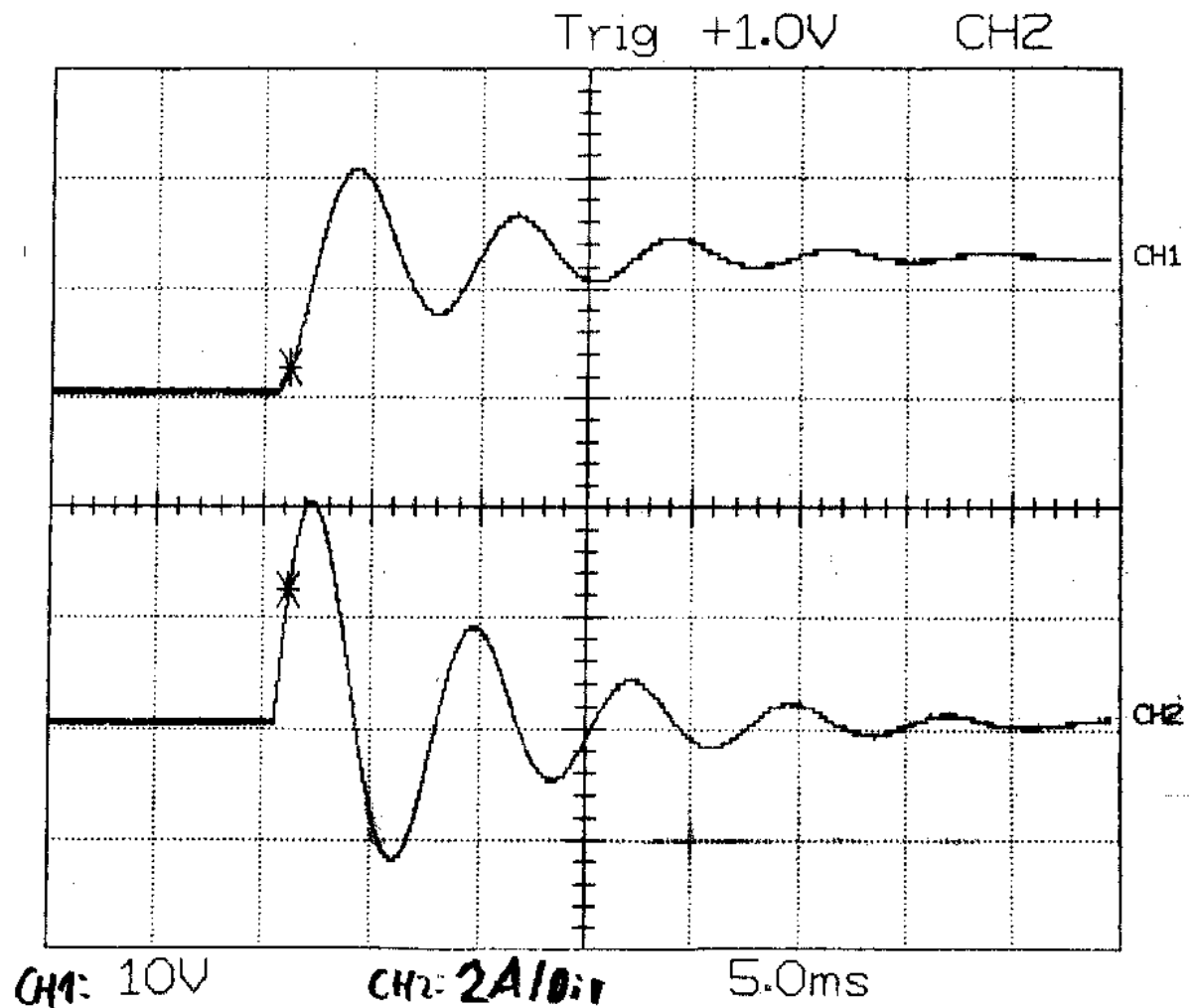
A simple experimental circuit is shown here to verify this effect by your self. After closing the switch T1, a 470uF capacitor is charged-up by a 24V PowerSupply-Unit. Once this capacitor is fully charged, the switch will be opened again. A meter now must show a steady 24V. Now T2 is closed and by this a sendcond, similar 470uF -uncharged/empty-capacitor will be connected in parallel. The inductors in this case are only there to limit/smooth the currentflow. The action of this can be seen in the second picture.



Picture 2, Oscillations in both capacitors.

This oscilloscope shows the oscillations of the Voltage on both capacitors. CH1 shows the fully charged Capacitor and CH2 the empty one. A frequency of around 130Hz is seen. This is exactly the frequency that calculatable from a 6mH inductor and a 235uF capacitor with the Resonance-Formula,  $f = \frac{1}{2} * \pi * \sqrt{LC}$ .

The HALF capacity is used because for the tuned/resonant circuit both capacitors are in SERIES and thus the overall-capacity decreases because it is like you would simply increase the gap between the plates of a single capacitor.



Picture 3, Current and voltage in the capacitors.

Here the current is shown of the above process on CH2. CH1 shows voltage on empty capacitor. The characteristic  $90^\circ$  phase-angle is very nicely shown.

After the equilibrizing a meter and also the scope shows exactly 12V. Didn't you expect a different result because it was stated that there is half the energy lost?

It sounds logic but it actually isn't when you look at the formula for the stored energy in a capacitor:

$$W = \frac{C \cdot U^2}{2}$$

$$Q = C \cdot U$$

$$\frac{W}{2} = \frac{C \cdot U^2}{4} = \frac{C \cdot \left(\frac{U}{\sqrt{2}}\right)^2}{2}$$

$$\frac{Q}{2} = \frac{C \cdot U}{2} = C \cdot \frac{U}{2}$$

Picture 4, Stored energy formula.

According to Charge-formula (the one on the right hand side) everything is fine. When you halve the charge, then the voltage is only half, too. But the Energy-formula (the one on the left hand side) says that the

ENERGY RISES QUADRATICALLY (example: with 3 times the voltage you get 9 times the energy). So if you assume that no energy is lost during the process and that you divided this same energy equal to both capacitors, then the voltage must only sink by a factor of  $\sqrt{2}$  and NOT by half!

$$W_1 = \frac{C \cdot U_1^2}{2} = \frac{470 \cdot 10^{-6} F \cdot (24V)^2}{2} = 135,36 mWs$$

$$W_2 = 2 \cdot \frac{C \cdot U_2^2}{2} = 2 \cdot \frac{470 \cdot 10^{-6} F \cdot (12V)^2}{2} = 67,68 mWs$$

Picture 5, Calculated energy.

When you calculate the energy for 24V stored in the capacitor, you result with 135.36mWs (milli-watt-seconds). In two capacitors with half the voltage (12V) there is, when added, only 67.68mWs stored. Exactly one half of the initial energy is lost. But where is it gone? At a closer look to this problem many questions will arise on which we will now try to find the answer.

Question: Is the energy lost directly in the capacitors?

To eliminate this / prove this as a false theory you can try with different condensers. So this experiment was done with a 3300uF electrolytic 60V and a unpolarized MP-Capacitor with 16uF and 500V. The use of electrolytic capacitors is by the way allowed because you can see on the oscillograph that the voltage never reaches a negative value (only at negative value / wrong polarity the cap will take damage / loose energy by itself). But in all experiments the voltages ever ended up on exactly half the initial value of the first cap. But different capacitors must shows different losses IF this theory was correct.

Question: Is the energy lost in form of electromagnetic radiations?

This is because of the used/observed frequency no possible. For effectively radiating at 130Hz you would need a antenna with over 1000km of length. Even in wire-wound electrolytic capacitors such a length is never reached. So if this theory was correct, then at higher frequencies (by use of smaller inductance/choke) this effect must much stronger but this never happened.

Question: Is the energy lost/dissipated in the inductor/choke?

Here a aircoils with 0.8mm wire was used. The resistivity is that small (only a very few mWs) that it is negligible. Also there are no magnetic losses because of the air-core.

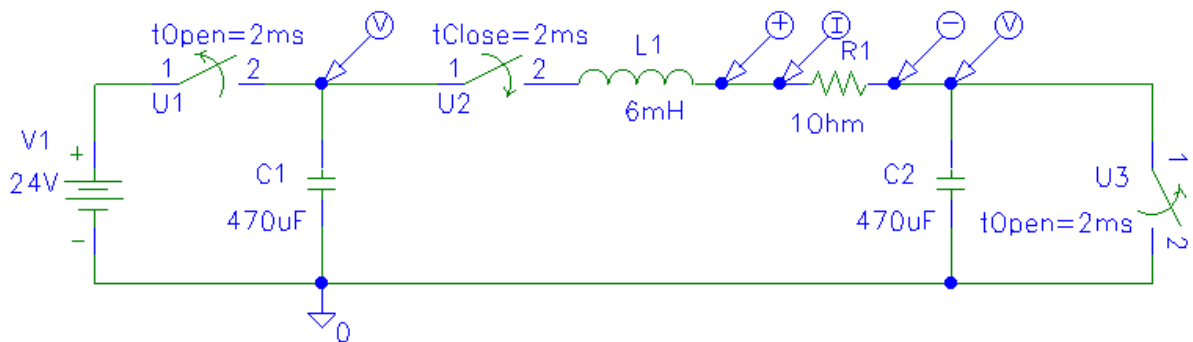
Question: Why is it of no importance of which resistance you use in the circuit?

If the capacitors are big enough (they must not self-discharge them in the time of experiment) so the used resistors only affect the duration of the

equilizing-process. THE CHOKE CAN ALSO BE REMOVED WITHOUT AFFECTING THE RESULTS!

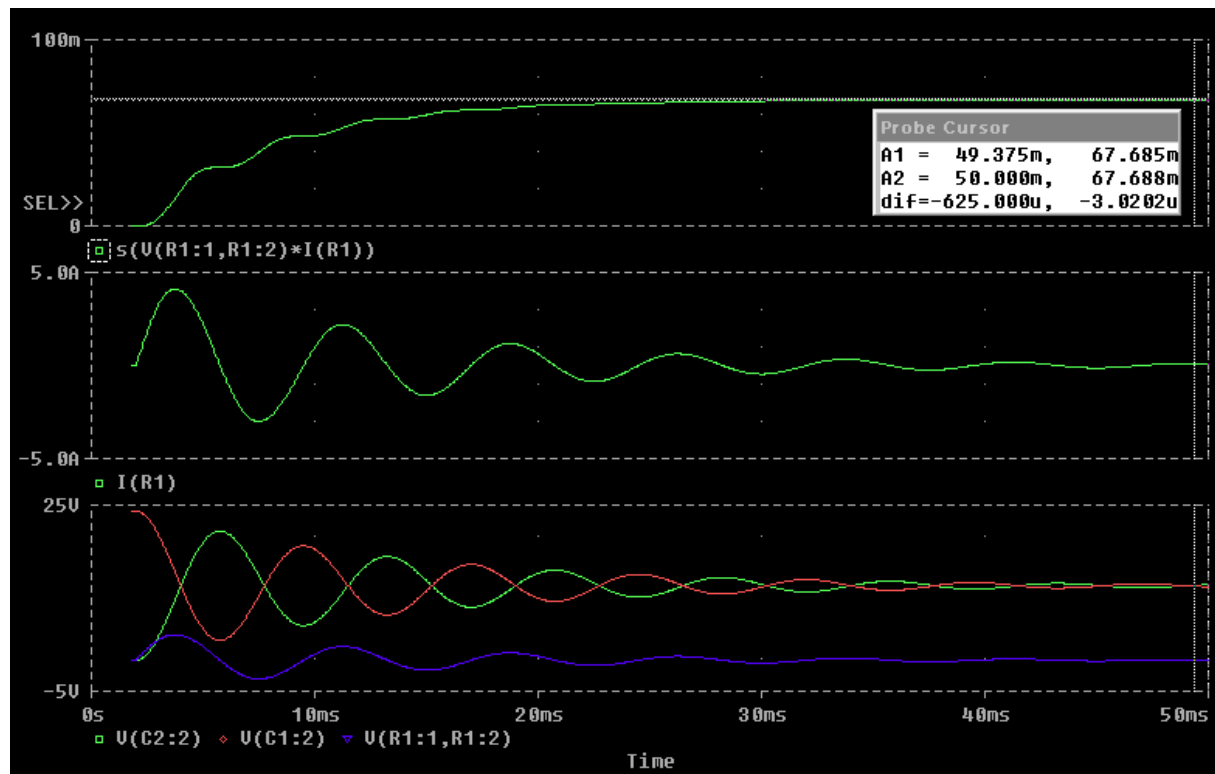
Also it is no problem to use several kilo-ohms of resistance. This increases the time-period of the equilizing-process to some minutes but still doesnt affect the results. But this brings us a step closer to the solution of this problem:

Every resitor through which there flows a current it must also dissipate a part of this energy ( $P=I^2 \cdot R$ ). To understand this better now a simulation of the circuit follows:



Picture 6, Simulation - Explanation

To understand the circuit better now a new circuit with PSpice was made. But it is the same setup as above. R1 represents the ohmic losses of the circuit, a total of 10hm in this case. The resistivity of the switch was set to 1u0hm and is negligible. New is the switch U3. It discharges the capacitor safely and prevents a charge-up through the insulating-resistors of the switch (which cannot be set to infinit in the simulation unfortunately).

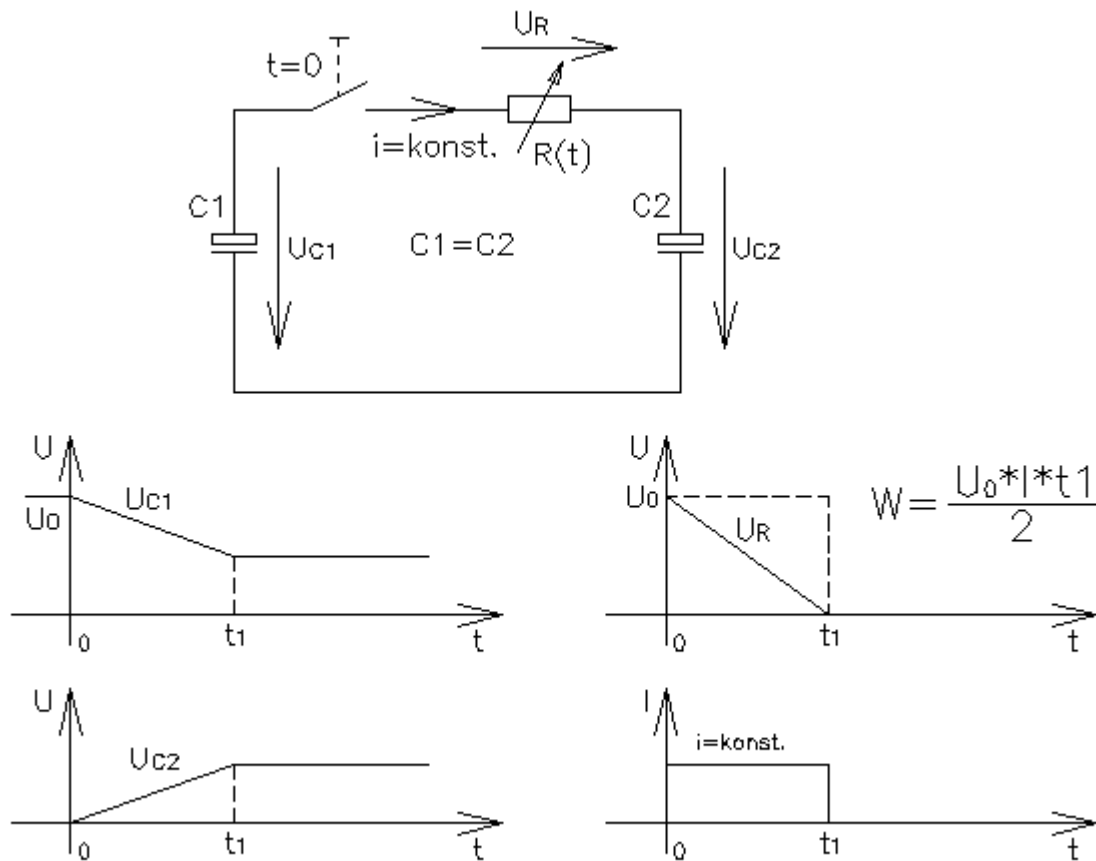


Picture 7, Simulation result.

The result shows a very similar behaviour in frequency and dampening of the oscillation. In the lower plot the voltages of the capacitors and R1 is displayed. The middle plot shows the current through R1. With the courses of voltage and current there was calculated the dissipated power by integration. This power is read out with the cursor in the upper plot. It shows a dissipated power of 67.68mWs on R1. This is exactly our lost energy, horay!!!

So the preliminary result of this simulation is that you can indeed dissipate all the lost engery on the tiny 10hm circuit-resistance. 10hm is easily reached when you replicate the setup.

Now it also becomes clear why it also works without a choke or resistor. Half the energy is always lost onto the resistances, regardless of how small it is. The reason why it works with different value resitors is because a big-value (say 1 Mega-Ohm) resistor only lets a small current flow for a long time while a small-valie (say 10hm) resistor let the current flow big and only short time. The integration of voltage and current of time ever results in the same, half energy is lost.



Picture 8, Visualize the effect.

This effect is easily visualized when you use a variable resistor instead of a fixed value one. Imagine, you ever adjust the vari-resistor so that a equal amount of current flows. This means at start the resistor is set to a biggest value and you decrease over time until you end with smallest value. In the last moment of the equilizing the resistance is zero and after that there cannot flow any more current because both caps now show the same voltage.

The capacitor  $C_1$  is charged to a voltage  $U_{C1}=U_0$ . At time  $t=0$  the switch is closed and current is allowed to flow to the empty capacitor  $C_2$ . Now the variable resistor  $R(t)$  is adjusted continously, so that always a equal amount of current flows. The Voltage on  $C_2$ ,  $U_{C2}$  will raise lineary as the voltage  $U_{C1}$  sinks. This process is finished as soon as both voltages reach  $U_0/2$ . The voltage  $U_R$  has been in the whole range of  $U_0$  to zero. At the beginning  $C_2$  represents a SHORT CIRCUIT and because of this the full voltage  $C_1$  is applied to to the resistor. The energy which is dissipated by this resistor in this time is calculated by:  $W=U_0*I*t_1/2$  and is equal to the energy which was transferred to  $C_2$  and also the energy which was withdrawn from  $C_1$ . This means in short that one QUARTER (1/4) of the initial energy is now in each capacitor and the rest is lost onto the resistor.

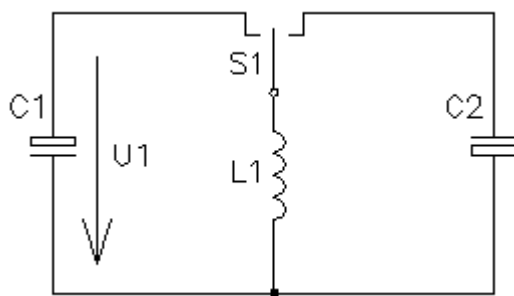
Charge itself is NOT energy. Only the transfer from on capacitor to the other produces the energy!

A charge transfer is always related with a dissipation of energy or output of energy. The reason for this is the principle of "influence" which is known from the "Kelvin's Generator", too, where it wants to prevent the waterdrops from falling down.

A different theory leads us into the electrostatics. You could try to use a plate-capacitor and charge it at first with only half-overlapping plates. After charging you move the plates fully together and thus have the double capacity. The voltage must decrease because of this, too. According to the formula  $U=Q/C$  the voltage must drop to one half. And you see, the same problem of lost energy occurs. Now the energy is lost because the opposite charges try to best place them in covering fully together and thus moved, too. This also shows that a capacitor bears its second name "condenser" to rightness: It "condenses" charge/potential energy so that you cannot use it anymore directly. (Don't get confused here, it reverses is also, see below.)

!!!!This you could try to reverse, so that you charge-up the capacitor with fully overlapping plates at first and then move the plates to half-position. The capacity decreases to one half and the voltages increase to the double of the initial value. This effect is also used by the Whimshurst-Machine (Influence-Machine) to produce the high voltages. BUT THE ENERGY INCREASES QUADRATICALLY WITH THE VOLTAGE AND SO YOU END UP WITH DOUBLE THE ENERGY STORED IN THE CAPACITOR AS THE INITIAL VALUE BY THIS. This is also a possible explanation for the theory of how the "Therstatica" works because the parallel-movement of the plates in this case uses/wastes LESS energy than you GAIN by this!

The reverse of the effect - finally a gain!



Picture 9, The circuit.

So we have learned why a conservation of charge in a system results in a loss of energy. But what happens if we succeed in splitting/dividing the energy LOSSLESS to both capacitors?

This is not as hard as it might sound at first! We only need one active part! In this case this is a toggle-switch S1. Now we assume again that C1 is charged to a voltage U1; that S1 is in middle-position and that C2 is total empty. The switch S1 is now brought into the left position. By this

the current through the coil L1 increases "slowly", so the coil takes/stores energy from the capacitor C1. Now when exactly HALF THE ENERGY is in the coil (you will know because it is when voltage decreased by a factor of SQRT(2) (that is by a factor of 1.414213562373095)) the switch S1 is brought to the right position. This must happen in a very short amount of time or you will end up with a voltage-spike only.

In practica this is solved by the use of a freewheel DIODE! The coil now tries to drive the current further (it's one of the most significant behaviours of an inductor, to keep current / counter-act on changes! In the same direction than like it entered L1 to the capacitor C2. This means it charges this capacitor C2 in reverse polarity, so you must place it in reverse polarity (the right one also, with plus on bottom). This discharge-process is kept until the current in L1 is zero. Then the switch S1 is brought back into the middle position (end of cycle, dump C2 to load, refill C1 with little energy, repeat. Now the FULL energy of L1 is stored in C2!

In summa summarum this means that the initial energy which was introduced to C1 is now splitted into two equal parts onto C1 and C2. The in the prior case (without that inductor-switching) inevitable loss of energy DID NOT TAKE PLACE this time because we introduced also a resonant-/tuned-circuit to the system by the addition of L1. And we know from standard-science that a resonant-/tuned-circuit can work lossless indeed. So by the correct control of the switch S1 we succeed in losslessly spitting the energy to both capacitors.

Now for the calculation we assume: C1=C2, U1=U2, U2=0 and after the equilizing U1=U2=U. Now see this formula:

#### Before the balance

$$W = \frac{C * U^2}{2}$$

$$Q = C * U$$

#### After the balance

$$W = 2 * \frac{C * \left(\frac{U}{\sqrt{2}}\right)^2}{2} = \frac{C * U^2}{2}$$

$$\underline{\underline{Q = 2 * C * \frac{U}{\sqrt{2}} = \underline{\underline{\sqrt{2} * C * U}}}}$$

Now if we calculate the results, so we see that on the left hand side formula everything fits in. The SQRT(2) lowered voltage results in both capacitors together to the initial value again. But with the charge-volume (Formula on right side.) there is now a difference!!!

Because the voltage did NOT decrease to exactly one half (like the chargeformula wants that) we end up after the equilizing with a EXCESS IN CHARGE! The total-charge in both capacitors together is now GREATER by a factor of SQRT(2) than the initial value!!!

Most of us have ever thought that charges are those tinny electrons that fly around here there and everywhere and then finally settle on the plates of the capacitor. So if there are more charges after the equilizing than before, so where did those come from and where are those now beeing absent???

In this context it is interessting that in old schoolbooks regarding electrostatic there you can read that a capacitor "condenses" charge, like its 2nd name "condenser" implies, too. This you can imagine like charges become solid once they are pumped in a capacitor by a high pressure (=high voltage). So they are not availabe for direct use anymore. Once you release the pressure (voltage), the charges become liquid and appear back again. So by spitting the energy to two capacitors one might think that with less pressure also more charges are available, because less are condensed/solid, too. This is a bit esoteric way of explaining but one of best.

Sourche: <http://www.hcrs.at/KOND.HTM>