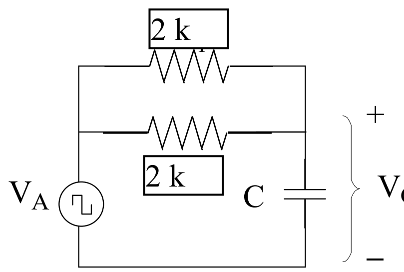
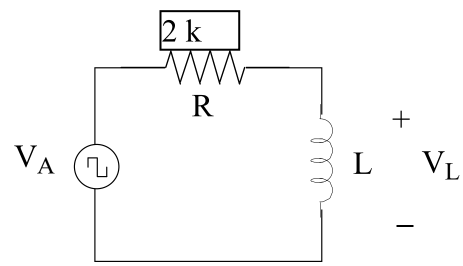
LAB 8 - RC & RL STEP RESPONSE (2h)



RC circuit



RL circuit

Step response is obtained by the sudden application - or removal - of a DC voltage. We will achieve this STEP INPUT by applying a square wave from the function generator. RC and RL circuits have a characteristic response to this input, and in this lab we will investigate this response.

8.1 EQUIPMENT LIST

1. Trainer
2. Oscilloscope (+ scope probes)
3. Function Generator (+ BNC cable, break-out cable, BNC-T splitter)
4. Resistors - 2 kΩ (x2)
5. Capacitor, 0.1 μF
6. Inductor L (unknown value)
7. Potentiometer (~ 100 kΩ, to vary τ continuously)
8. STUDENTS BRING A USB FLASH DRIVE
9. (***) Measure component values with DMM
10. Note - if the scope trace seems to "jiggle", reset the scope (Save/Recall > Default Setup)

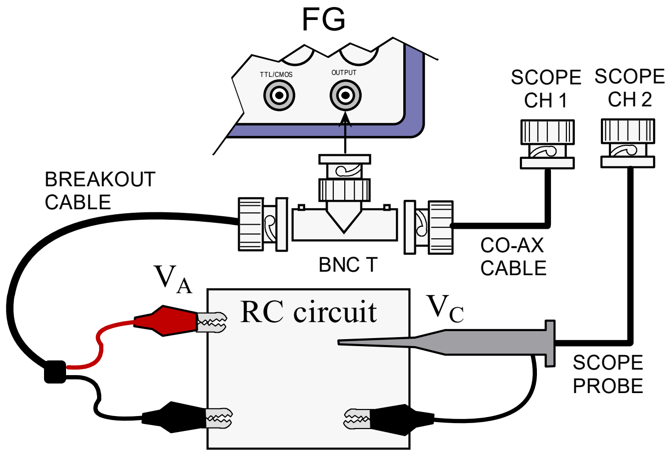
8.2 RC STEP RESPONSE

We will analyze the step response of an RC circuit. Theory tells us that an RC circuit will respond to a step as an exponential decay curve. The speed of the decay is quantified in a single value - the time constant. We will check the theoretical time constant against a measured one.

8.2.1 Obtain a nice Display

STEPS

1. Construct the RC circuit shown in figure above (power off). R = 2 k, C = 0.1 uF (C closest to GND).
2. Note V_A means "applied voltage". Vc = V across C (capacitor).
3. Set V_A from FG (SQUARE wave, 3 Vpp, ~ 560 Hz, 0 DC offset). (**check FG param's**)
4. Verify probe attenuation is correct (1x for co-ax cable, 10x for scope probe).
5. After completing the circuit, turn trainer ON.



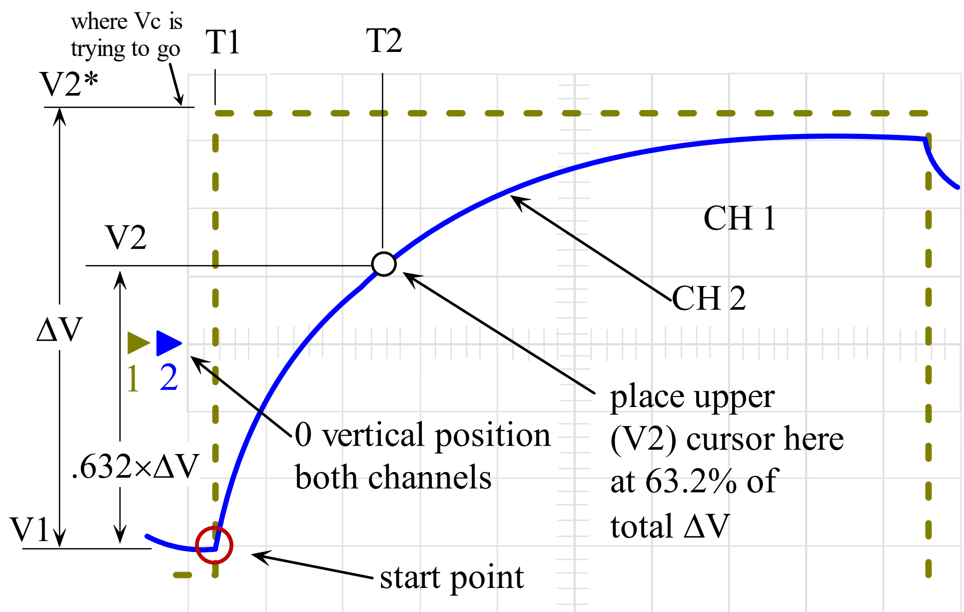
Get both Vin (input) and Vc (output) to appear nicely on the scope.
Display both CH 1 & CH 2. Set both channels to DC coupling.
Overlay the traces using vertical positioning knobs. Set vertical position to 0 for BOTH channels.
Do NOT use Autoset which will offset them.
Adjust the voltage scale so the height of a full square wave can be seen
Adjust the time scale to get half of a period to show. Then adjust the horizontal (time) position so the trace wave looks something like the figure shown. Voltage scale should be same for both traces.

8.2.2 Measure RC Time Constant

Measure the time constant of the exponential curve using CURSORS function.

STEPS
1. Press "Cursor" key.
2. Set Source to CH 2 (press F1).
3. Press "Horizontal" or "Vertical" key to scroll through 4 choices for adjusting the cursors.
   Choices: no cursors (2 dotted lines)
   Adjust both cursors simultaneously (2 solid lines)
   Adjust cursor 1 only (1 line solid, 1 line dotted… the solid line is the one that adjusts).
   Adjust cursor 2 only (1 line dotted, the other line solid…. The solid line adjusts).
4. Then adjust cursors by turning the "variable" knob.
5. Set cursors to the "start point" (see figure).
   Set the bottom "vertical" (voltage) cursor to V1 level.
   The start point can be anywhere on the response curve, but it is best here.
   Note - vertical cursors appear as horizontal lines
6. Set the top "vertical" cursor to the V2* position
   (at the square wave… where the response curve is "trying" to go).
   This location is CRITICAL for accurate results.
7. Record the ΔV value.
8. Multiply ΔV by .632 and record.
9. Now move the top "vertical" cursor until you have the value you just recorded.
10. Turn on "Horizontal" cursors (button F2) to measure time values (T1 & T2).
    Note - horizontal cursors are vertical lines
11. Adjust the left cursor to align with where V1 crosses the response curve (this is T1 in figure).
12. Adjust the right cursor to coincide with "T2" (where V2 crosses the response trace).
13. (***) Record Δt ("Δ" in lower right of T1 & T2). This is τ (actual) (in ms).

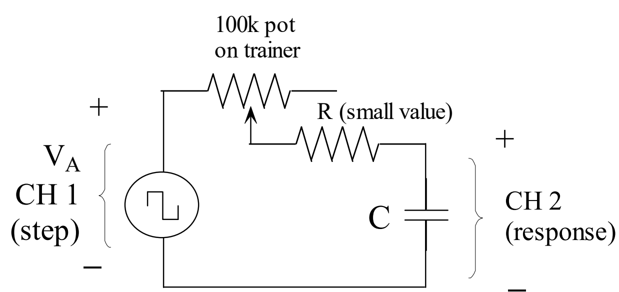
14. (***) Compute τ (theory) using measured values of R and C (in ms).
15. (***) Capture the trace (include voltage & cursors specifying tau.)



8.2.3 Alter Time Constant

Remove one of the resistors.
The response curve should change.
(***) Capture the trace (include voltage & cursors specifying tau.).

8.2.4 Continuous Change in Time Constant



Here we will use a variable resistance (a potentiometer). Now we can continuously change the response curve.

STEPS
1. Build the circuit shown. (R = 2 k)
2. Turn the dial on the pot and observe the changes to the exponential response curve.

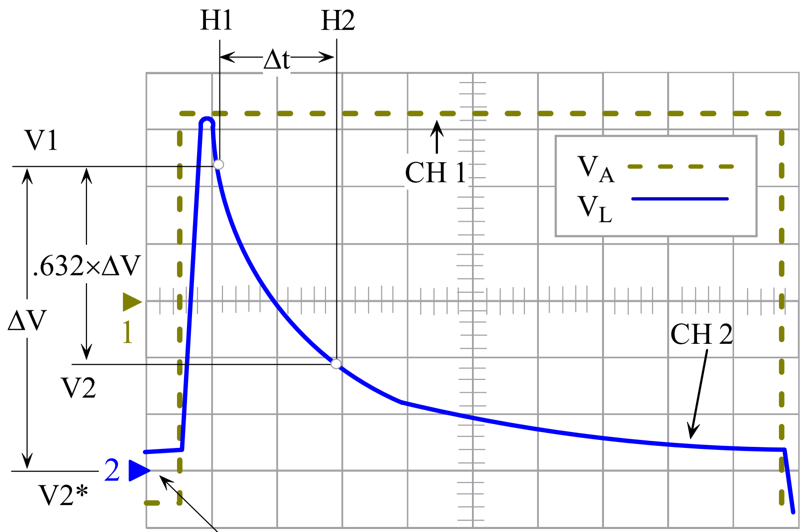
8.3 RL RESPONSE (TO COMPUTE L)

8.3.1 Measure RL Time Constant

Here we will measure the time constant of an RL circuit. The inductor L will have an unknown value, and we will use the time constant to estimate the value of L.

STEPS

1. Construct the RL circuit shown in figure above. R = 2 k, L = unknown. (L closer to GND).
2. Set V_A to be from FG (SQUARE wave, 1 Vpp, ~ 60-70 kHz, 0 DC offset). (**check FG params**)
3. Adjust the voltage and time scales to fill the display with the full square wave & HALF a period.
4. Overlay the 2 traces (0 V vertical offset for both). Do NOT use Autoset.
5. Display both V_A (CH 1) and V_L(CH 2) on the scope.
6. Ensure probe attenuation is correct (1x for co-ax cable, 10x for scope probe).
7. Adjust scope to fill screen with signals overlapped as shown below.
8. Adjust horizontal position so a full half period is shown.
9. Adjust the vertical position of both channels to 0.0V (initially). Do not use Autoset.
10. Then alter the CH2 vertical position downward so its ‘zero position’ is aligns with a grid line. This will be the voltage level that the response curve is "trying to go to" (V2*). This point may not align with the kink in the trace!
11. Use CURSORS to measure the time constant on the response curve as before.
12. (***) Record time constant



Set vertical position of CH 2 on a grid line.
This marks V2* (where curve is TRYING to go)

16. Compute L
    a. (***) Write the equation for τ for RL circuits.
    b. (***) Re-arrange equation to solve for L.
    b. (***) Compute value of L using measured values of τ and R (in mH)

LAB 8 - ANSWER SHEET

RC & RL STEP RESPONSE

Team Number: ___________

Name 1: ______________________________ Name 2: ______________________________

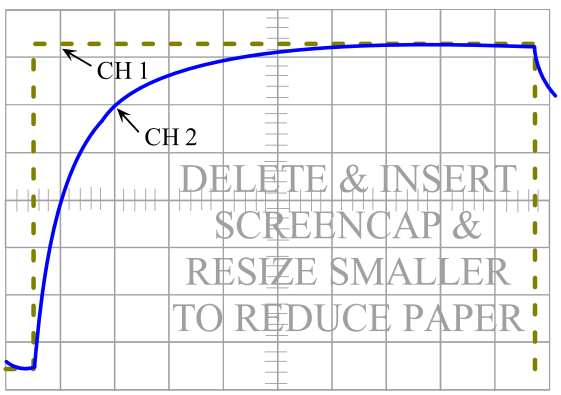
8.1 Component Values

R (2 kΩ) __________ __________ C (0.1 uF) ________

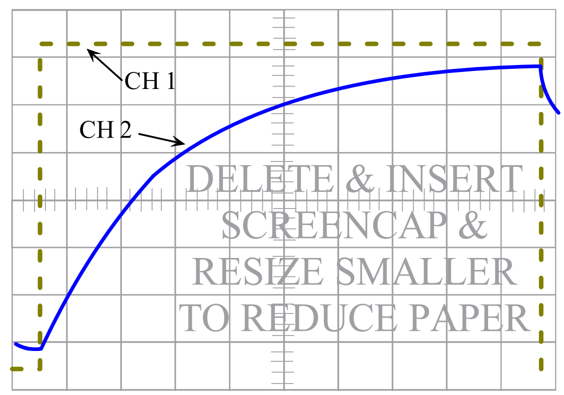
8.2 RC Step Response

τ (theory, ms) : ________________________. τ (theory, ms): ________________________.

τ (measured, ms): ____________. τ (measured, ms): ____________.



RC STEP RESPONSE



RC STEP RESPONSE with altered R

8.3 RL Step Response

______________. τ (measured, μs)

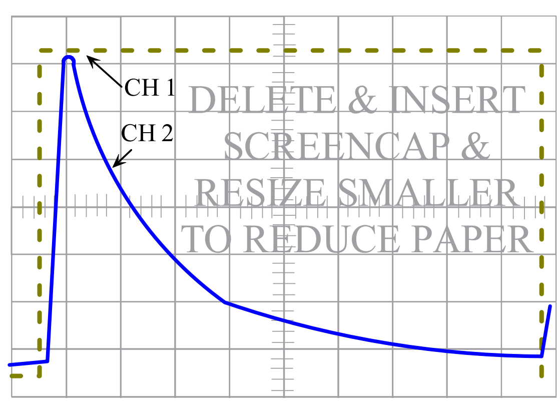
________________. τ equation for RL circuits

_______________. Re-arrange equation to solve L

_______________. Computed L value (in mH)

Show work below:

___________________________________.



RL STEP RESPONSE