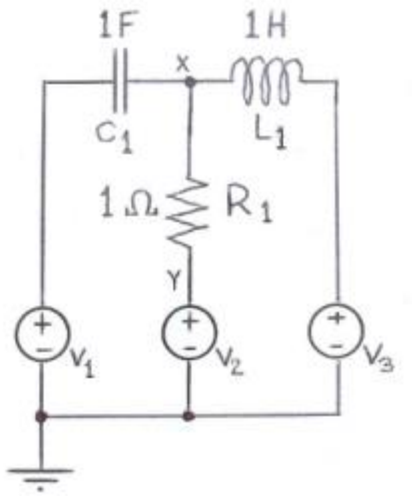
Circuit Challenge 11

Consider the circuit shown below.



Initial Conditions

All three voltage sources are at 0V, and have been at 0V for a long time.
The capacitor is completely discharged, and has been discharged for a long time.
There is no current flowing in any circuit element, nor is any current changing.

The Event

At t=0 voltage source V_1 ramps positive at 5V/s
At t=0 voltage source V_3 steps from 0V to 5V

The Challenge

Determine the behavior of voltage source V_2 so that Node X remains at 0V (i.e., becomes a virtual ground). You may compare your solution with what you find by scrolling down to the solution.

Analysis for Challenge 11

If Node X remains at 0V, V1 will be forcing current through the capacitor from left-to-right, such that

$i_{C1} = C_1 dV/dt$

$i_{C1} = 1F \bullet 5V/s$

$i_{C1} = 5A$

If Node X remains at 0V, V_3 will be forcing current through the inductor from right-to-left, so that

$v_{L1} = L_1 di/dt$

$5V = 1H(di/dt)$

$di/dt = 5A/s$

Then, if Node X is to remain at 0V, V_2 must necessarily force Node Y negative in such a way that i_{R1} is given by

$i_{R1} = u(t)[5A + (5A/s)t]$

Where u(t) is the unit step function, defined as

$u(t) = 0 \text{ for } t < 0$

$u(t) = 1 \text{ for } t \geq 0$

So, if R_1 is 1Ω, we can write, for v_Y

$v_Y = 0 - u(t)[5A + (5A/s)t] \bullet 1\Omega$

$v_Y = 0 - u(t)(1 + t)5V$

And this, then, is the voltage at Node Y that forces node X to be 0V (a virtual ground) for the duration of the event.

<u>Observation</u>

This is a nice theoretical exercise, but would be virtually impossible to re-create in an actual circuit. Why? First, because the timing would need to be virtually perfect. Secondly, even if the currents are scaled back to mA or uA levels, some kind of feedback from Node X would likely be required to manage Node Y for the duration of the event.