Name Surname
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EEE 202-LAB #4

OBJECTIVE:

The aim of this experiment is to characterize a circuit which includes resistor, capacitor and inductor. After solving the circuit, we will calculate the time constant of the circuit and oscillation frequency if any. The voltage controlled switch will enable us to compare the time constant of the circuit with the frequency of the $v_{in}(t)$ (initially f=100 kHz).

1) In the preliminary work we omitted the diode D1 and solved the circuit according to that assumption. Due to an mistaken understanding we omitted the effect of the voltage controlled switch on the circuit. However we should have changed the initial values for every period of the switch. Using these assumptions we come up with the following differential equation:

$$\frac{d^2v_c}{dt^2}+\left(\frac{1}{R_{out}C_{eq}}+\frac{R_1}{L}\right)\frac{dv_c}{dt}+\left(\frac{R_1+R_{out}}{R_{out}LC_{eq}}\right)v_c=v_{in}.$$

Solving for $v_c = Ke^{st}$ gives a quadratic characteristic equation with solution:

$$s_{1,2}=-250050\mp j661418.93.$$

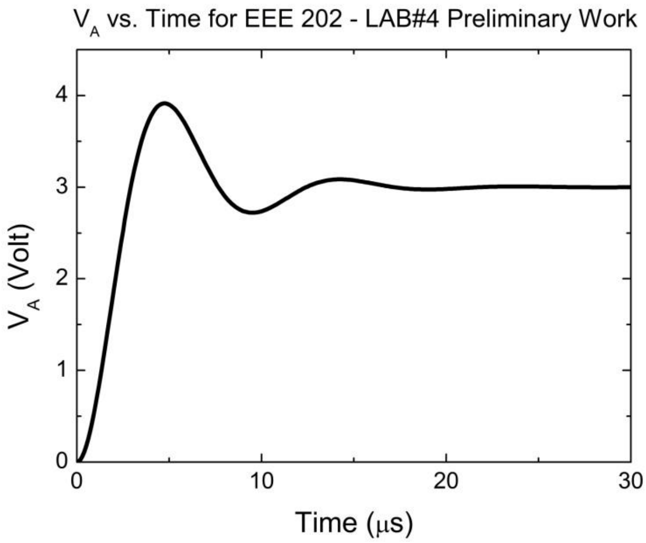
Then $v_c(t)$ is

$$v_c(t)=K_1\left(e^{s_1t}-\frac{s_1}{s_2}e^{s_2t}\right).$$

With the forced response solution our final answer will be:

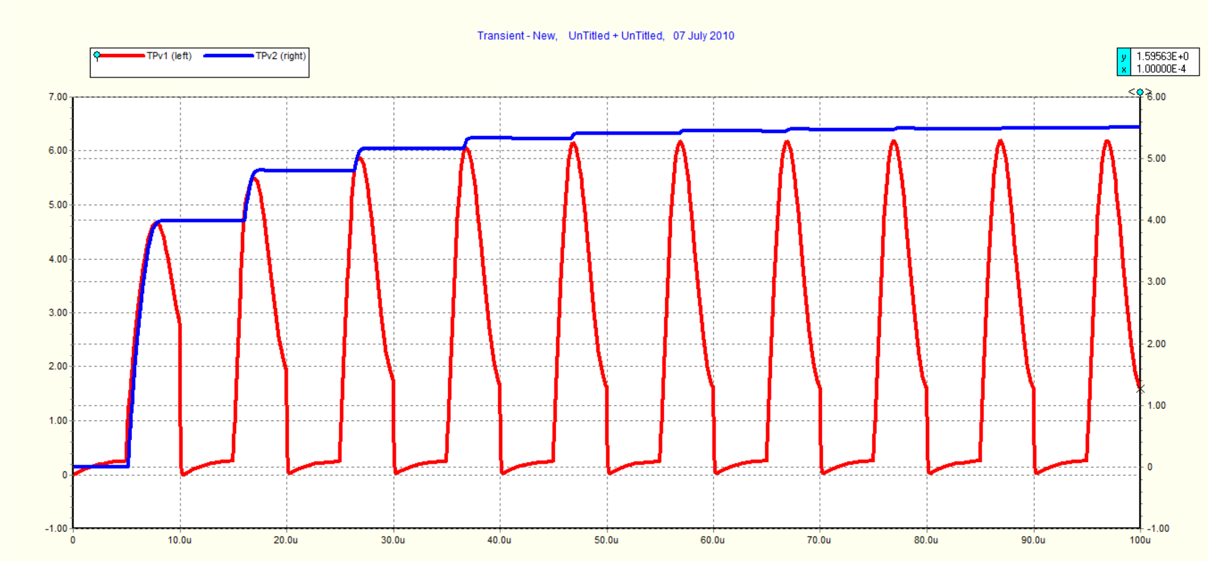
$$v_c(t)=\frac{v_{in}}{s_2-s_1}[s_{!}(e^{s_2t}-1)-s_2(e^{s_1t}-1)].$$

where $v_{in}=3u(t)V$. Plotting the $v_c(t)$ for three period duration of the switch gives the result in Plot 1. Calculation made by MATLAB and graph is plotted by using Origin8.



Plot 1: $v_A = v_c(t)$ vs. t plot for 3 periods.

We did not included the plot for v_{out} because the effect of the diode will not enable to voltage decrease and the voltage value will be stay at the maximum value of the $v_A(t)$ for every each interval. Due to these mistakes we have a different graph for the circuit. (Plot 2)



Plot 2: $v_A(t)$ (red curve) and $v_{out}(t)$ (blue curve) versus time for 100µs (three period) duration. v_A changes from 0 V to 6 V and v_{out} is equals to 5.5 V after 50 µs.

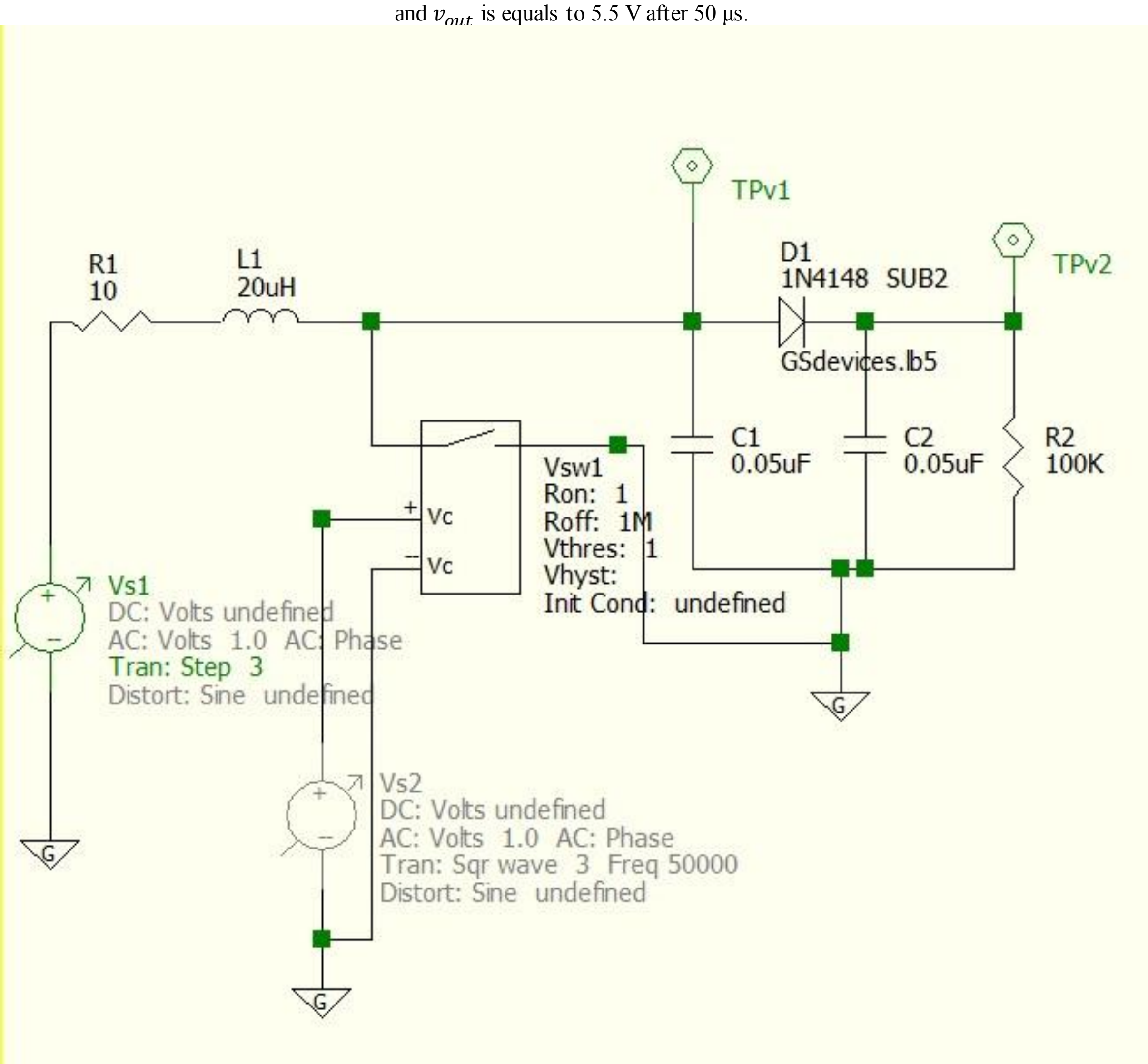
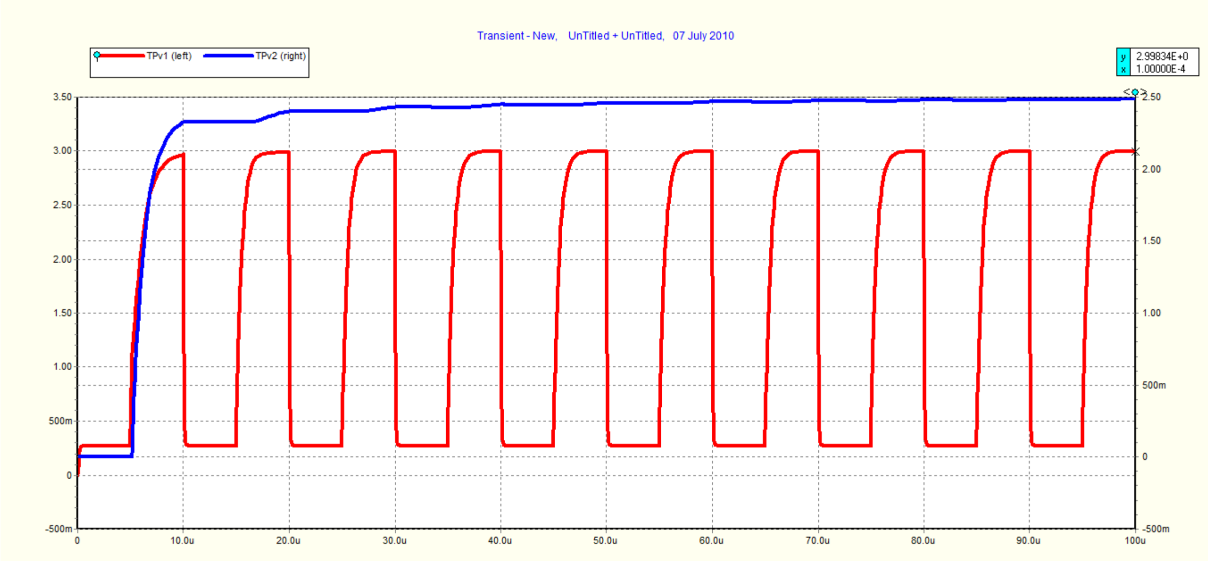
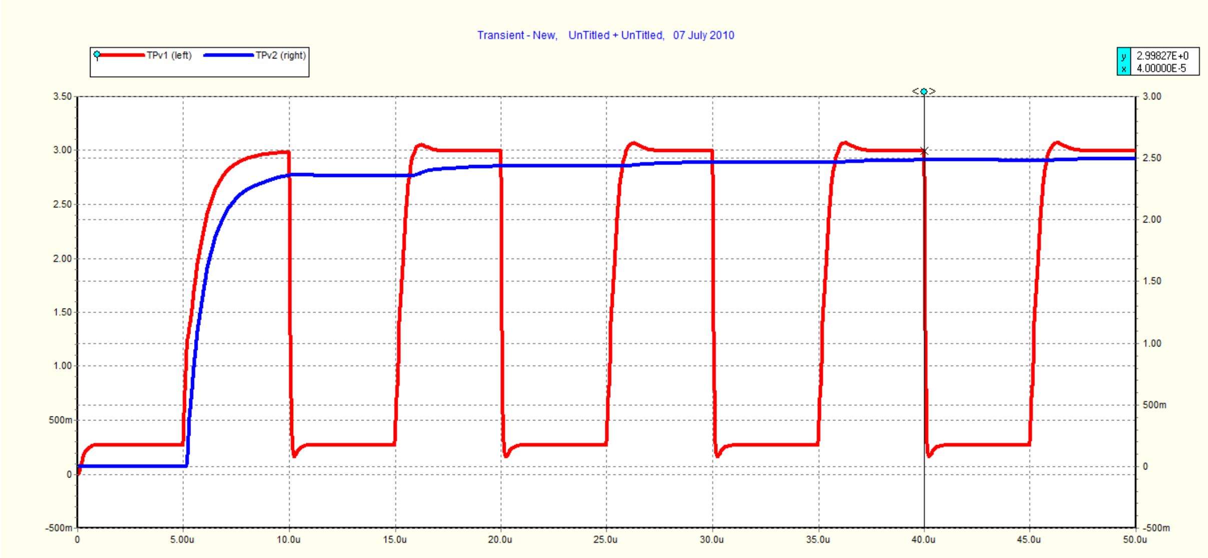


Figure 1: Circuit diagram for the given problem. The result of the circuit is in Plot 2.

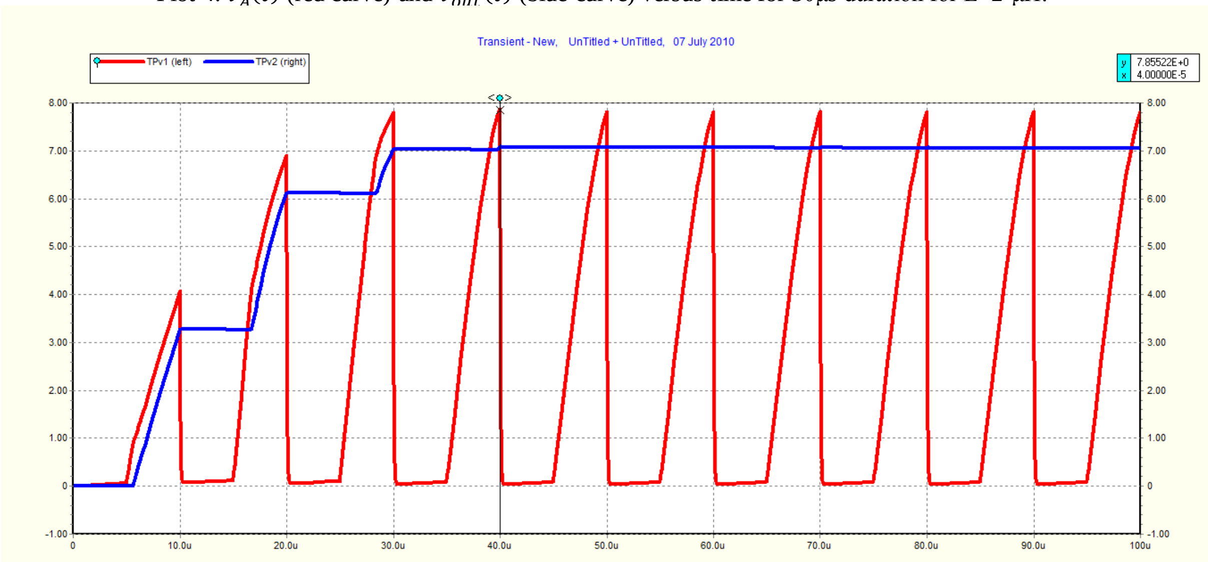
2) a. f=100kHz case is the initial case in Plot 2.



Plot 3: $v_A(t)$ (red curve) and $v_{out}(t)$ (blue curve) versus time for 100μs duration for L=2 nH.

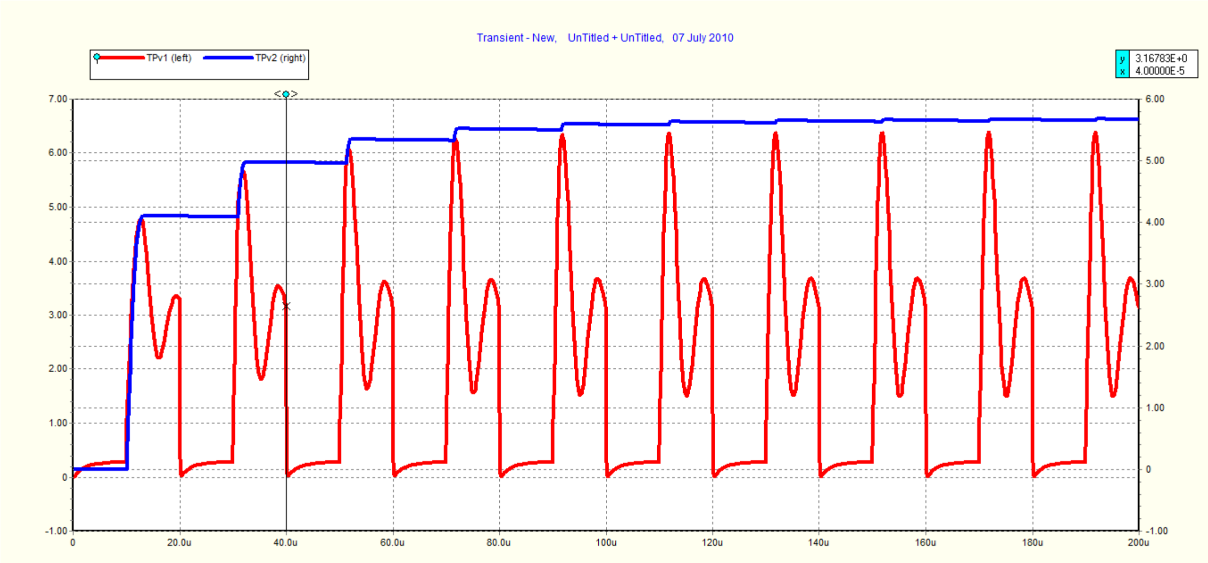


Plot 4: $v_A(t)$ (red curve) and $v_{out}(t)$ (blue curve) versus time for 50μs duration for L=2 μH.

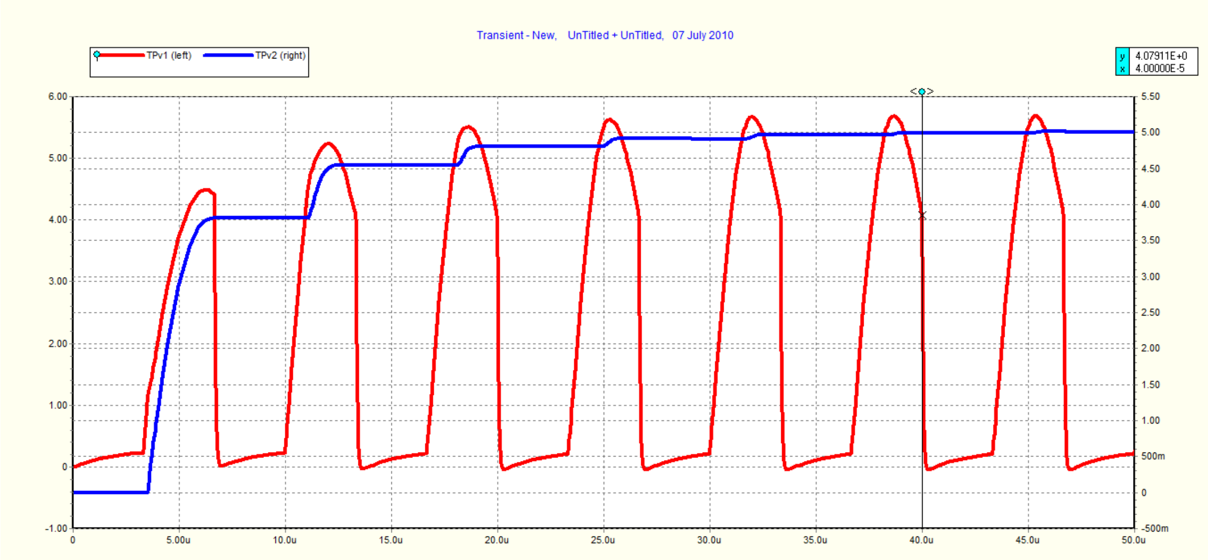


Plot 5: $v_A(t)$ (red curve) and $v_{out}(t)$ (blue curve) versus time for 100μs duration for L=200 μH.

b.

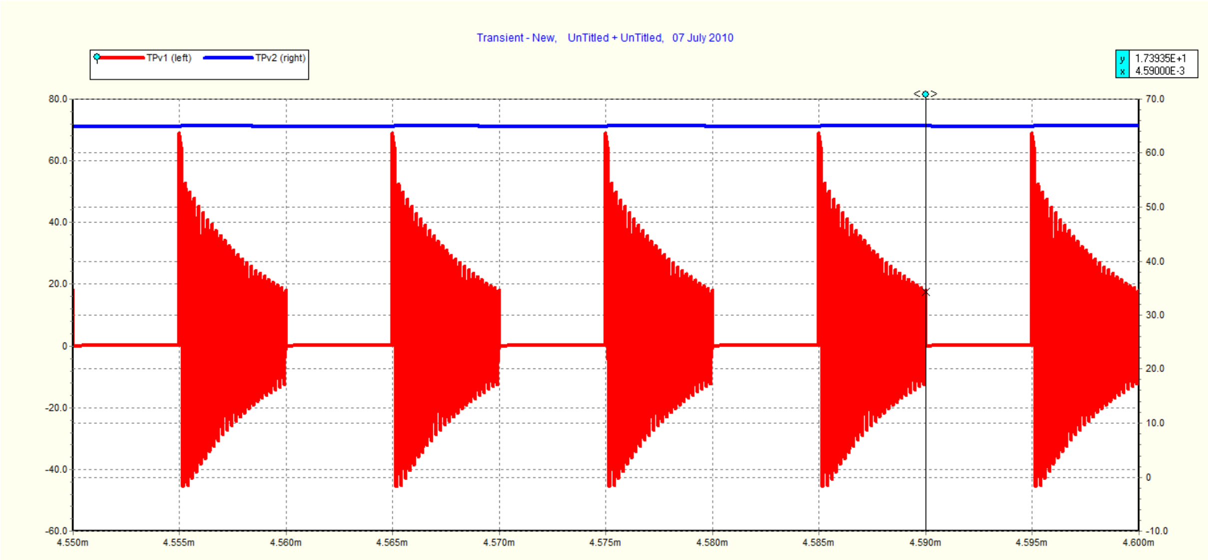


Plot 6: $v_A(t)$ (red curve) and $v_{out}(t)$ (blue curve) versus time for 200µs duration for f=50 kHz.

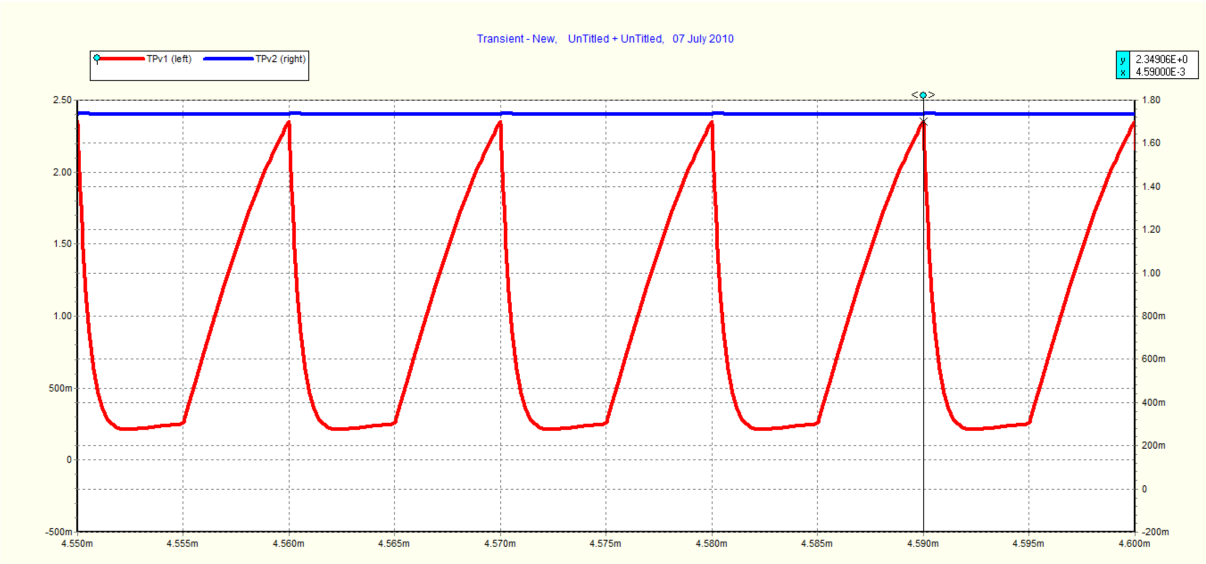


Plot 7: $v_A(t)$ (red curve) and $v_{out}(t)$ (blue curve) versus time for 1 ms duration for f=150kHz.

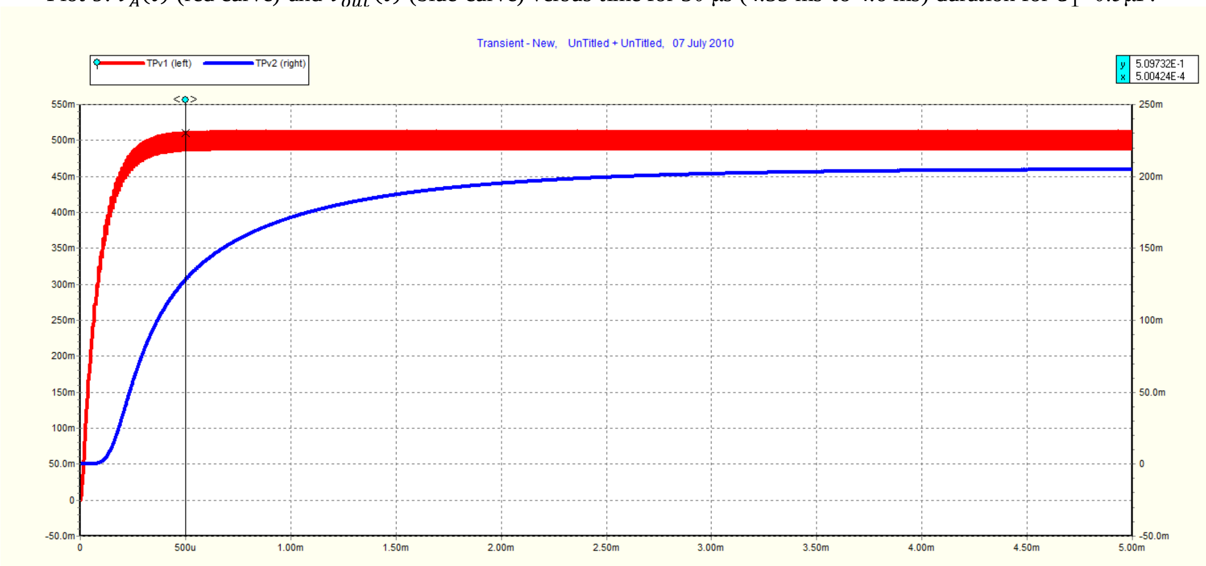
c.



Plot 8: $v_A(t)$ (red curve) and $v_{out}(t)$ (blue curve) versus time for 50 µs duration (4.55 ms to 4.6 ms) for C_1=0.05 nF.

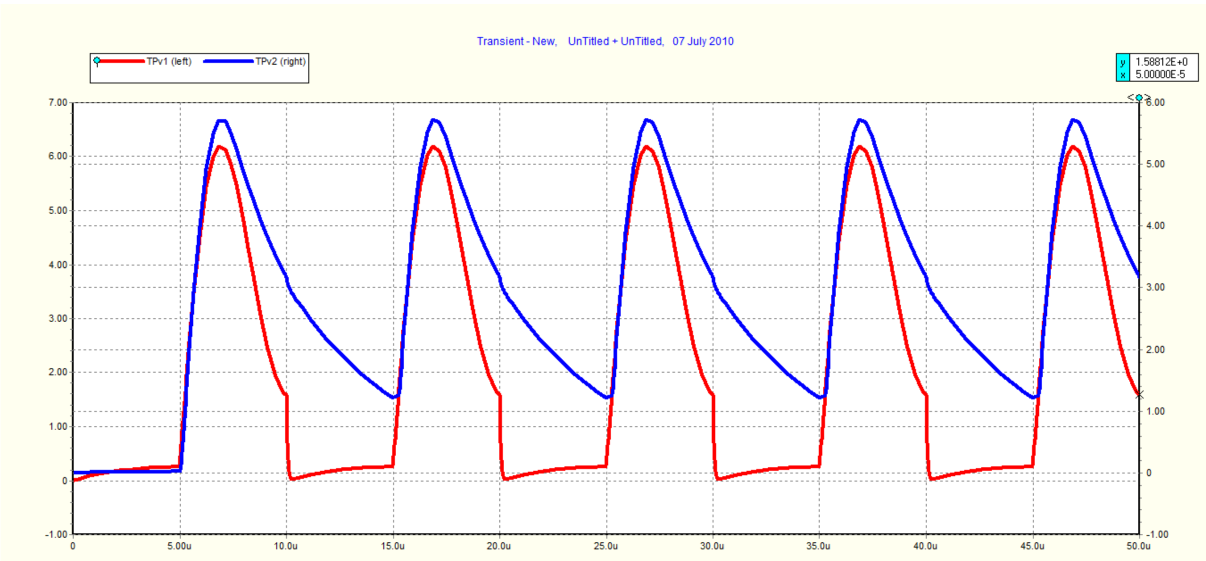


Plot 9: $v_A(t)$ (red curve) and $v_{out}(t)$ (blue curve) versus time for 50 µs (4.55 ms to 4.6 ms) duration for C_1=0.5µF.

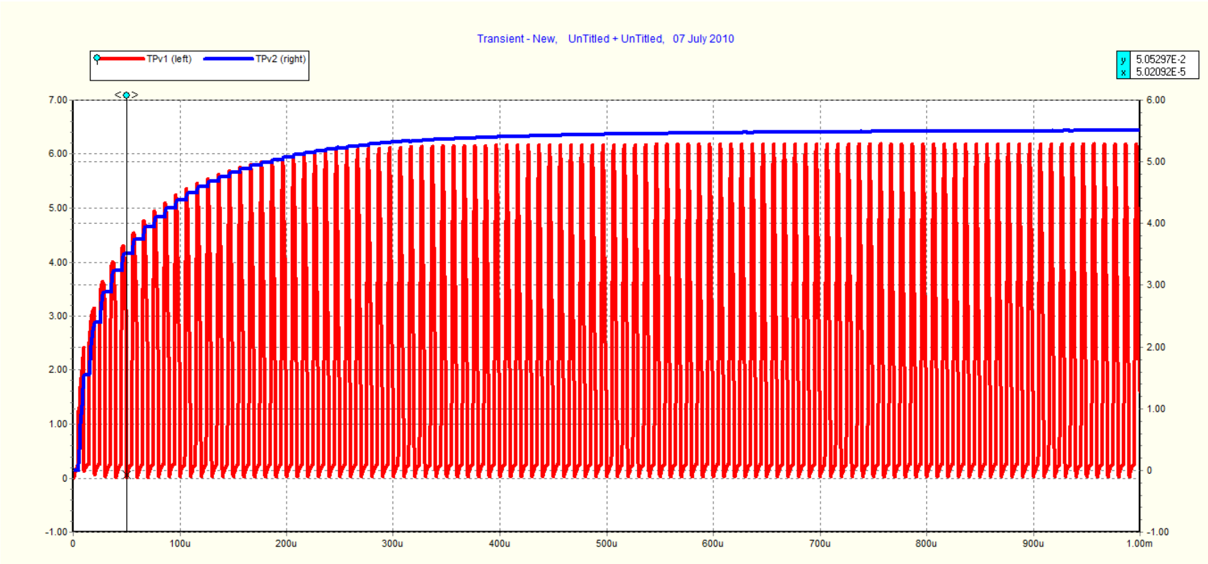


Plot 9: $v_A(t)$ (red curve) and $v_{out}(t)$ (blue curve) versus time for 5 ms duration for C_1=0.05 mF.

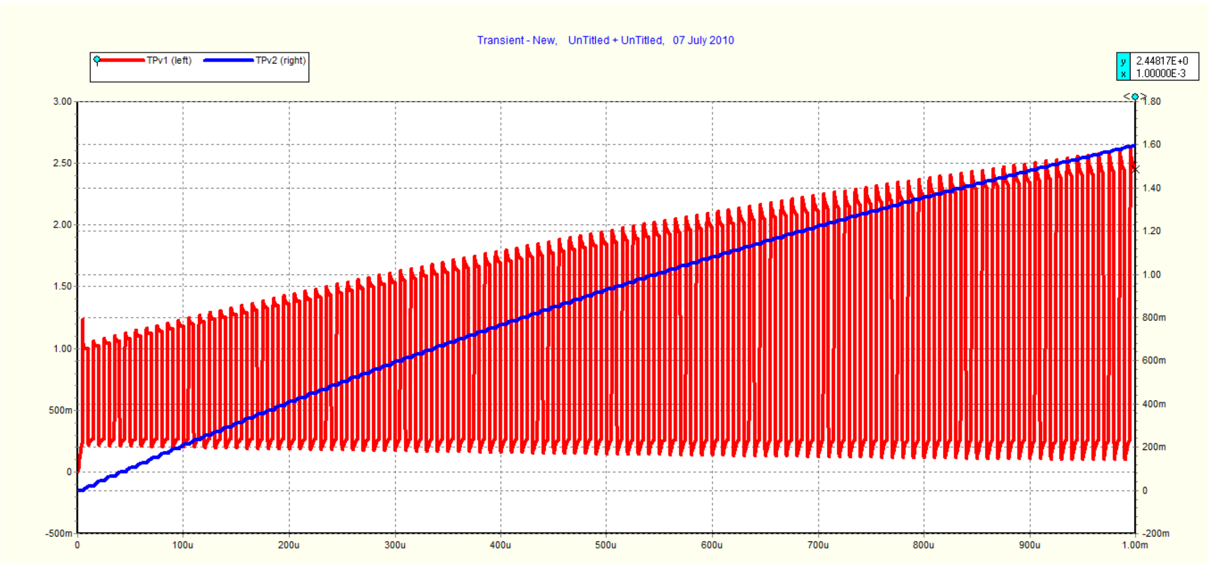
d.



Plot 10: $v_A(t)$ (red curve) and $v_{out}(t)$ (blue curve) versus time for 50 µs duration for C_{out}=0.05 nF.



Plot 10: $v_A(t)$ (red curve) and $v_{out}(t)$ (blue curve) versus time for 1 ms duration for C_{out}=0.5 µF.



Plot 11: $v_A(t)$ (red curve) and $v_{out}(t)$ (blue curve) versus time for 1 ms duration for C_{out}=0.05 mF.

3) Since we have to reduce the ripple voltage, solving the differential equation with the given resistance and input values gives us a relation between capacitance and the inductance:

$$L^2 - (4 \times 10^{10} + 2 \times 10^6) L C_{eq} + 10^{12} C_{eq} \cong 0.$$

Here $C_{eq} = C_1 + C_{out}$. Then for $C_1 = 1$ nF, $C_{out} = 11$ nF and $L = 2$ H we obtain the below graph.

Plot : $v_{out}(t)$ vs. t for 20ms to 20.05ms duration. We waited till 20ms to reach stead state. $v_{out,max} = 75.655\,V$ and Ripple Voltage (Peak-to-peak) equals to $75.654 - 75.578 = 76$ mV.

CONCLUSION:

For question 1 verification could not be done because preliminary calculation was wrong.

For 2.a we saw the time constant increases with increasing the value of the inductor L. As we increased the inductor value capacitor charge-discharge time increases and at L=200µH the 10µs period of the switch is not enough. Also increasing the inductor up to reasonable value increases the pump effect and the output voltage.

For 2.b increasing frequency decreases the effect of the pump. However low frequencies allow circuit to respond for long durations and ripple voltage increases.

For 2.c decreasing C_1 increases the output voltage and pump effect. Also increasing the capacitance value increases the ripple voltage value so it beneficial to keep C_1 as small as possible.

For 2.d increasing the C_{out} value increases the time required to reach the steady state and decreases the output voltage value especially in short term.

Also high inductance values decreases the time the required for simulation end.