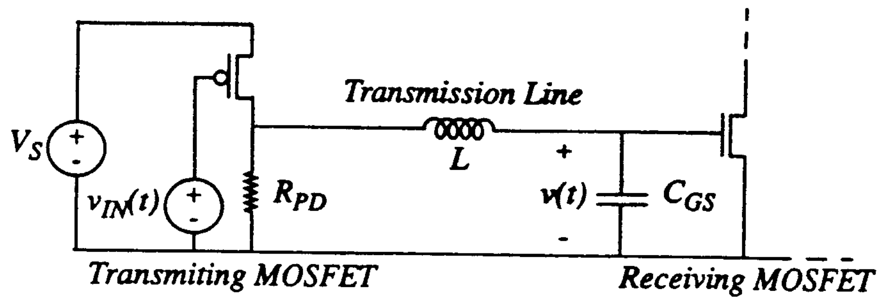
Problem 3 – 20%

In this problem a MOSFET and pull-down resistor having resistance R_{PD} are used to transmit digital data down a transmission line having inductance L as shown below. At the end of the transmission line is a receiving MOSFET having gate-to-source capacitance C_{GS}. Model the transmitting MOSFET with a switch-resistor model having on-state resistance R_{ON}.



(3A) Assume that v_{IN} turns the transmitting MOSFET off at $t = 0$ after it was on for a very long time. In this case, derive *but do not solve* the differential equation that describes the evolution of $v(t)$, the gate-to-source voltage of the receiving MOSFET. Also provide the corresponding initial conditions in terms of $v(t)$ and its derivatives at $t = 0$.

Eqn:

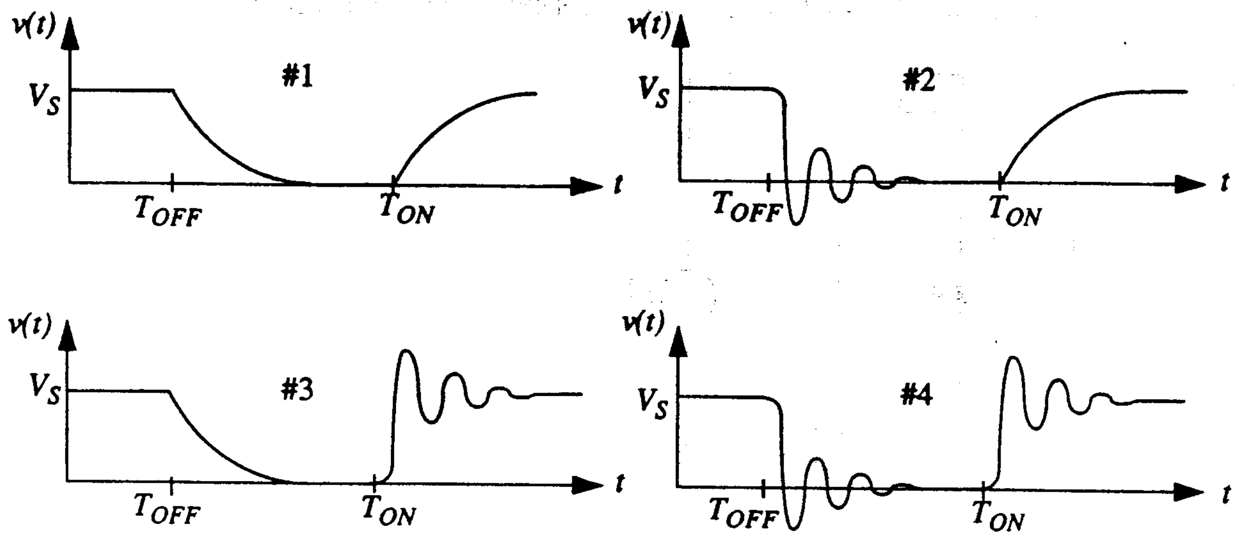
IC:

(3B) Assume that v_{IN} turns the transmitting MOSFET on at $t = 0$ after it was off for a very long time. In this case, derive ***but do not solve*** the differential equation that describes the evolution of $v(t)$, the gate-to-source voltage of the receiving MOSFET. Also provide the corresponding initial conditions in terms of $v(t)$ and its derivatives at $t = 0$.

Eqn:

IC:

(3C) Assume that $R_{ON} \ll \sqrt{L/C_{GS}} \ll R_{PD}$. In this case, which of the following sketches best describes the evolution of $v(t)$ given that the transmitting MOSFET turns on at T_{ON} and off at T_{OFF}? Why?



Sketch:

Why?

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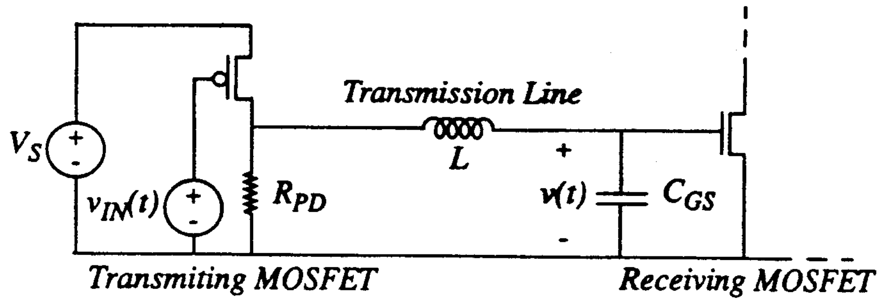
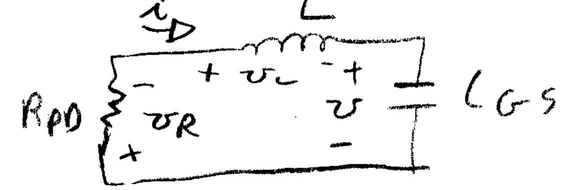


(3A) Assume that v_{IN} turns the transmitting MOSFET off at $t = 0$ after it was on for a very long time. In this case, derive *but do not solve* the differential equation that describes the evolution of $v(t)$, the gate-to-source voltage of the receiving MOSFET. Also provide the corresponding initial conditions in terms of $v(t)$ and its derivatives at $t = 0$.

mosfet off:



$$v + v_L + v_R = 0$$

$$\frac{1}{C}\int i\,dt + L\frac{di}{dt} + Ri = 0$$

$$i = C\frac{dv}{dt}$$

$$\Rightarrow v + LC\frac{d^2v}{dt^2} + RC\frac{dv}{dt} = 0$$

init, L = short, C = open, DC steady state

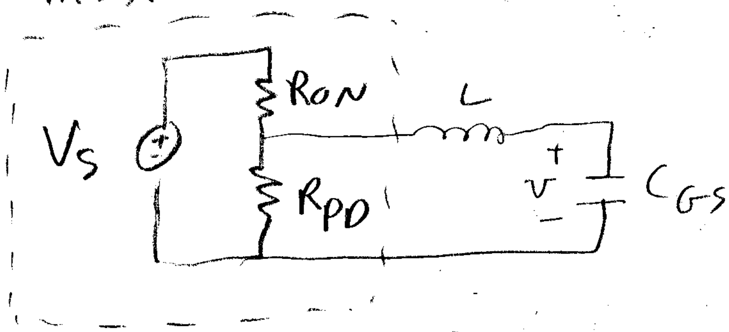
$$v(0) = \frac{V_S R_{PD}}{R_{PD} + R_{ON}} \qquad \frac{dv}{dt}(0) = 0$$

Eqn: $$\frac{d^2v}{dt^2} + \frac{R_{PD}}{L}\frac{dv}{dt} + \frac{v}{LC} = 0$$

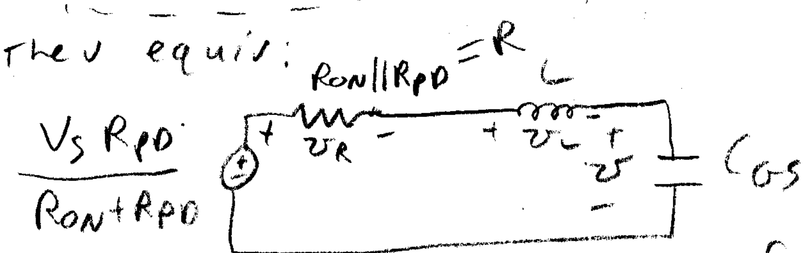
IC: $$v(0) = V_S\frac{R_{PD}}{R_{PD} + R_{ON}} \qquad \frac{dv}{dt}(0) = 0$$

(3B) Assume that v_{IN} turns the transmitting MOSFET on at $t = 0$ after it was off for a very long time. In this case, derive *but do not solve* the differential equation that describes the evolution of $v(t)$, the gate-to-source voltage of the receiving MOSFET. Also provide the corresponding initial conditions in terms of $v(t)$ and its derivatives at $t = 0$.

mosfet on:



Thev equiv:



$$v + v_L + v_R = \frac{V_s R_{PD}}{R_{ON} + R_{PD}}$$

from part A:

$$v + LC\frac{d^2v}{dt^2} + RC\frac{dv}{dt} = \frac{V_s R_{PD}}{R_{ON} + R_{PD}}$$

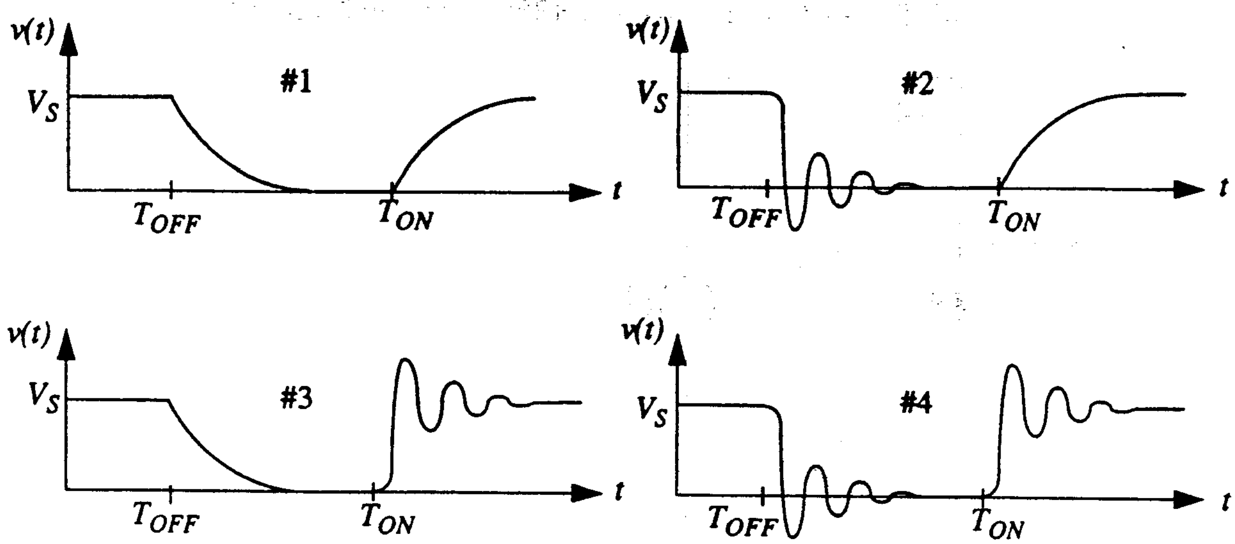
init, L = short, C = open, DC steady state

$$v(0) = 0, \quad \frac{dv}{dt}(0) = 0$$

Eqn: $$\frac{d^2v}{dt^2} + \frac{(R_{ON} \| R_{PD})}{L}\frac{dv}{dt} + \frac{v}{LC} = \frac{1}{LC}\frac{V_s R_{PD}}{R_{on} + R_{pd}}$$

IC: $$v(0) = 0, \quad \frac{dv}{dt}(0) = 0$$

(3C) Assume that $R_{ON} \ll \sqrt{L/C_{GS}} \ll R_{PD}$. In this case, which of the following sketches best describes the evolution of $v(t)$ given that the transmitting MOSFET turns on at T_{ON} and off at T_{OFF}? Why?



$$\frac{d^2 v}{dt^2} + 2\alpha \frac{dv}{dt} + \omega_0^2 v = V$$

oscillate if $\alpha < \omega_0$

don't if $\alpha \geq \omega_0$

Sketch: #3

Why?

Toff oscillates if $\frac{R_{PD}}{2L} < \sqrt{\frac{1}{LC}}$

or $\frac{R_{PD}}{2} < \sqrt{\frac{L}{C}}$, but $R_{PD} >> \sqrt{\frac{L}{C}}$

so no oscillation

Ton oscillates if $\frac{R_{ON} \| R_{PD}}{2} < \sqrt{\frac{L}{C}}$

and $R_{ON} << \sqrt{\frac{L}{C}}$, so oscillates.