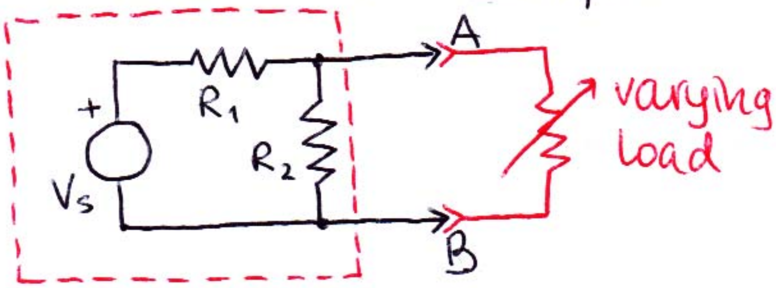
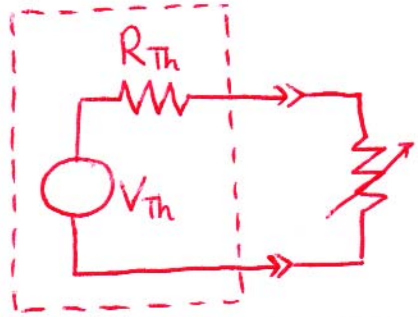
Lecture 3

Thevenin th. - example



voltage divider

⇒



Thevenin equivalent

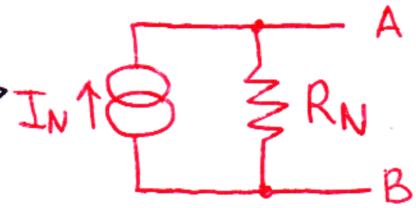
$$V_{Th} = V_{o.c.} = V_s \frac{R_2}{R_1+R_2} \; ; \; I_{s.c.} = \frac{V_s}{R_1} \, , \Rightarrow$$

$$R_{Th} = \frac{V_{Th}}{I_{s.c.}} = \frac{V_s R_2}{R_1+R_2} \, \frac{R_1}{V_s} = \frac{R_1 R_2}{R_1+R_2} = R_1 \| R_2$$

Useful trick: to find R_{Th}, short all volt. sources and open all curr. sources. R_{Th} is resistance by looking inside the two terminals.

Norton equivalent

same as Thevenin but ⇒



$I_N = I_{s.c.}$, $R_N = \dfrac{V_{o.c.}}{I_N}$

Q: R_N vs R_{Th}? same

Q: which one to use, N or Th?

if $R_N = R_{Th} \ll R_L$

⇒ use Th

if $R_N = R_{Th} \gg R_L$

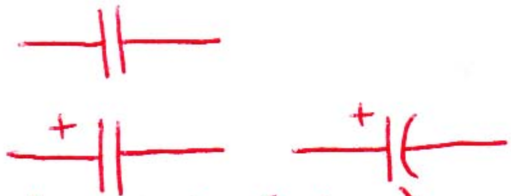
⇒ use N

Linear time-dep. elements

Linear if KVL & KCL contain terms $\propto I, V, \frac{dI}{dt}, \frac{d^2V}{dt^2}$, etc.
but never $I^2, IV, \left(\frac{dV}{dt}\right)^2$, etc.

4 Capacitor

stores en. in elect. field



electrolytic (>1μF)

2 parallel plates separated by insulator

$Q = CV$, $C = \frac{Q}{V} = \frac{\text{coul.}}{\text{volt.}}$

$[C]$ = farads

$$C_{Total} = \left(\sum \frac{1}{C_k}\right)^{-1} \quad \text{series}$$
$$= \sum C_k \quad \text{parallel}$$

} opposite to R

$V = \frac{Q}{C}$, $\Rightarrow \frac{dV}{dt} = \frac{1}{C}\underbrace{\frac{dQ}{dt}}_{\text{curr.}} = \frac{I}{C}$ $\quad \boxed{\frac{dV}{dt} = \frac{I}{C}}$

Q: can V_c change abruptly? no, b/c unphys. $I_c \to \infty$

5 Inductors

stores energy in magn. field

$$\boxed{V = L\frac{dI}{dt}}$$

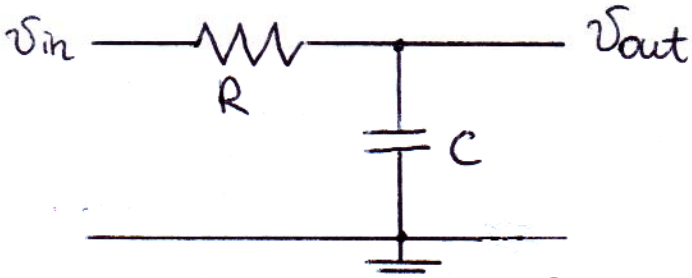
$[L] = \frac{V \cdot s}{A}$ = henries

$$L_{TOTAL} = \sum L_k \quad \text{series}$$
$$= \left(\sum L_k^{-1}\right)^{-1} \quad \text{parallel}$$

} like R

Bulky $\lesssim$ MHz, not routinely used (often can do the same with R & C)

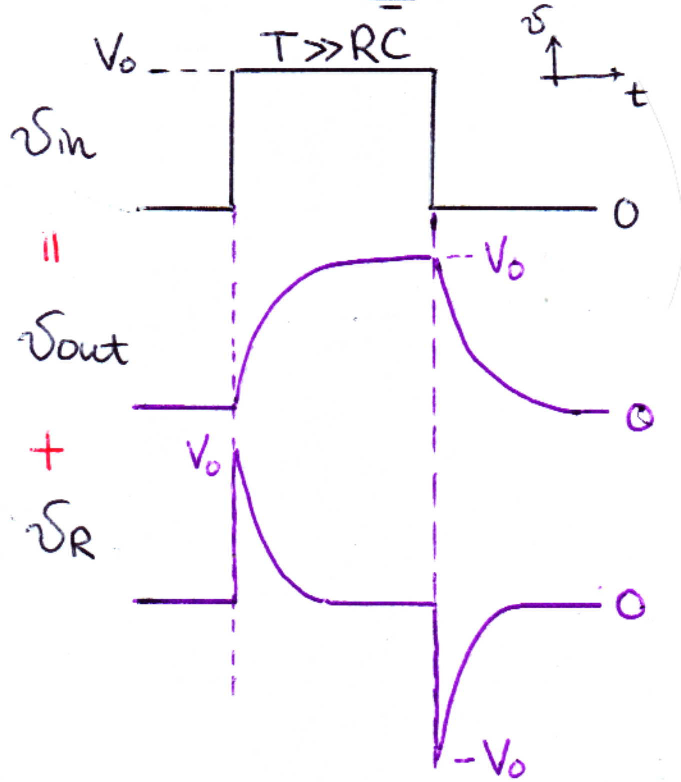
Low-Pass filter (pass low speed signal)



$v_{in} - v_{out} = v_R$, $v_C = v_{out}$

$i_R = i_C$. $v_R = i_R \cdot R$, $i_C = C\frac{dv_C}{dt}$.

$$\frac{v_{in} - v_{out}}{R} = C\frac{dv_{out}}{dt} \quad \text{. Diff. eqn.}$$



For voltage step (V_I to V_F at $t=0$), the soln.

$$v_{out} = V_F + (V_I - V_F)\, e^{-\frac{t}{\tau}}$$

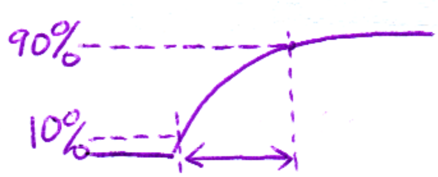
with $\tau = RC$

check that the formula works at $t=0$ and $t \to \infty$.

$i_R = \frac{v_R}{R}$ → current flows only during switching

(efficient battery-driven devices don't like high f)

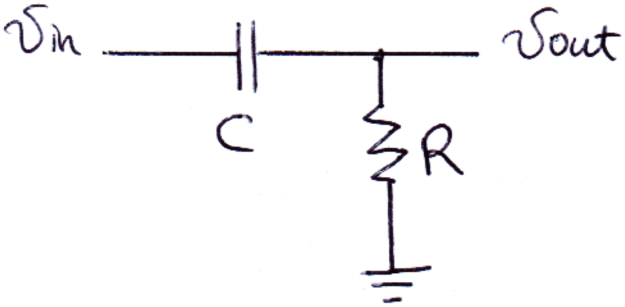
Piece of trivia: v_C vs t after step in voltage

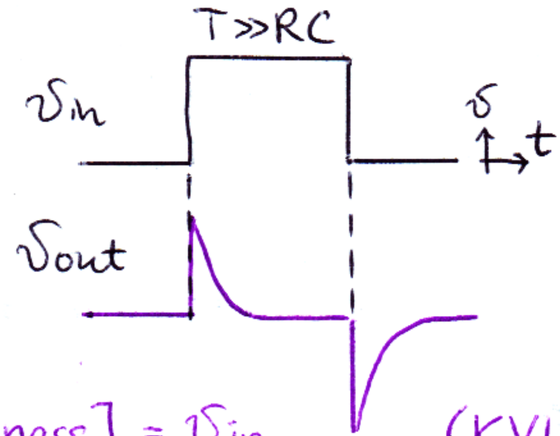


$T_{rise} = 2.2RC$

how scope finds T_{rise}

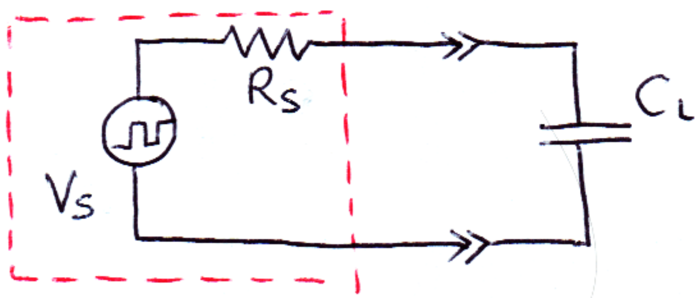
High-pass filter (swap R&C positions)





[v_{out} hi pass] + [v_{out} lo pass] = v_{in} (KVL)

Exp I-10



Function generator produces  drives capacitive load C_L
e.g. piezzo, MOSFETs

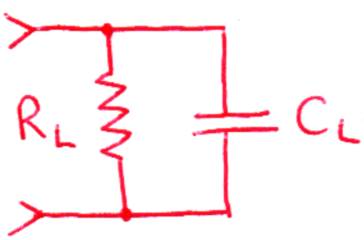
input 

if $T \ll R_S C_L \Rightarrow$ output 
not what you intended

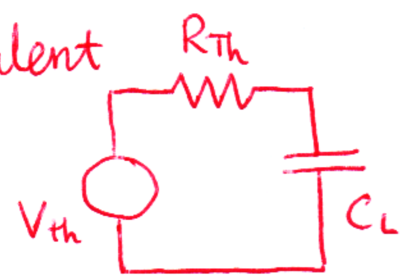
'Fake' large R_i by adding large R to f-generator.

Need to transmit shape. How?

Soln.



Thev. equivalent



New $\tau = R_{Th} C_L$ can be made $\tau \ll T$.

$$R_{Th} = \frac{R_S R_L}{R_S + R_L}, \quad V_{Th} = V_S \frac{R_L}{R_S + R_L}$$

Shape transmitted! (But now V_{Th} can be $V_{Th} \ll V_S$)