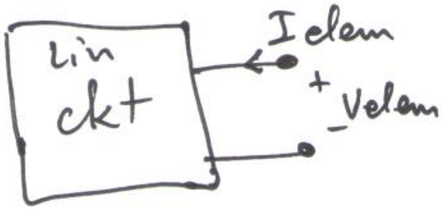
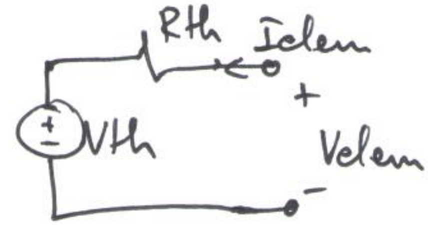
1

EE16A Touchscreen Module - Lecture 5

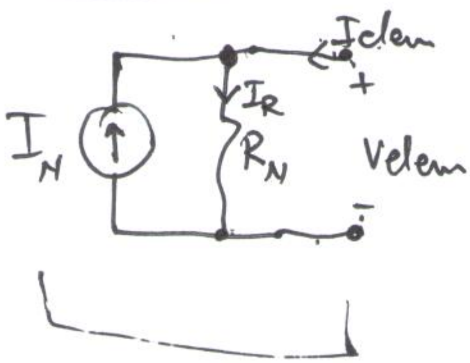
* Norton equivalent & examples
* Capacitive Touchscreen



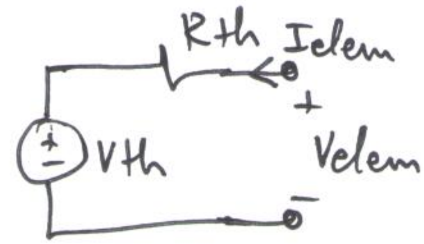
≡



<u>Norton:</u>



≡



step 1 (Vth): $\Rightarrow$ $\boxed{V_{th} = I_N \cdot R_N}$

Measure <u>open-circuit</u> voltage

$V_{o.c} = I_N \cdot R_N$

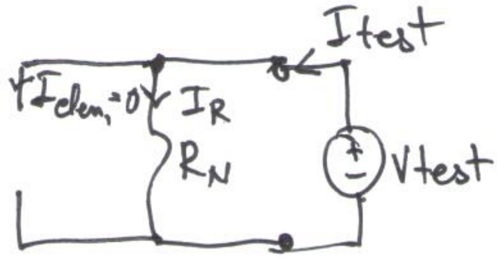
KCL: $I_N + \underbrace{\cancel{I_{element}}}_{0 \text{ b.c open-circuit}} = I_R$

$I_N = I_R$

$V_{element} = V_R = I_R \cdot R = \boxed{I_N \cdot R_N}$

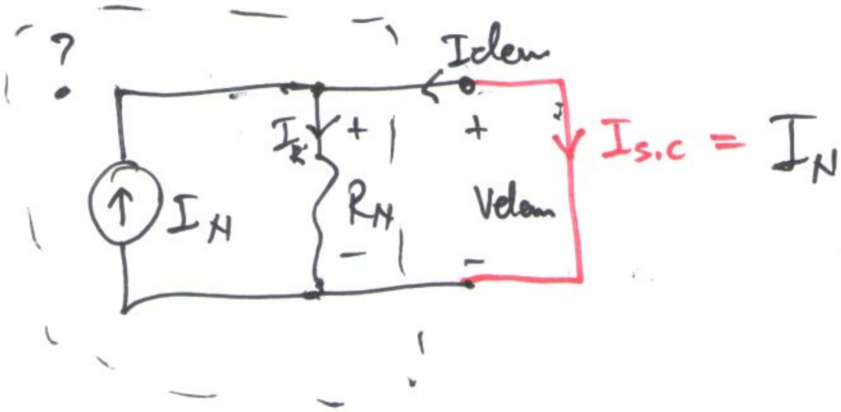
(2)

$\boxed{\text{step 2:}}$ **Find R_{th}:**



$$V_{test} = I_{test} \cdot R_N$$

$$R_{th} = \frac{V_{test}}{I_{test}} = R_N$$

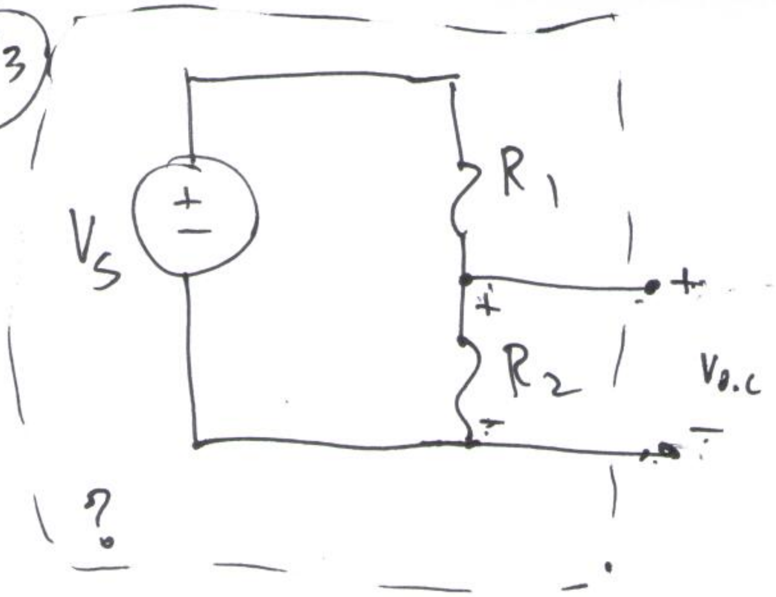


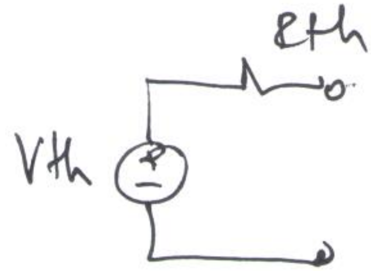
$$V_R = I_R \cdot R_N$$

$$V_R = V_{wire} = 0 \Rightarrow I_R = 0$$

KCL: $\underline{\underline{I_N}} = \cancel{I_R}^{\,0} + \underline{\underline{I_{s.c}}}$

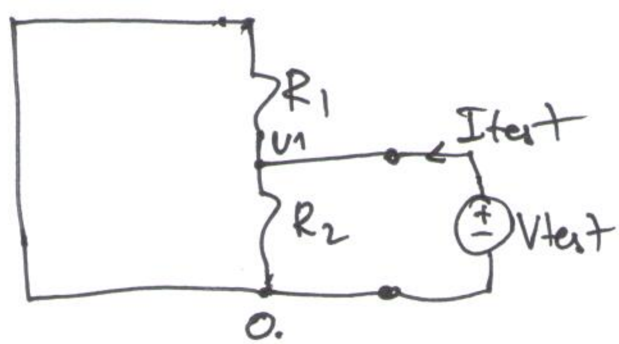
l3

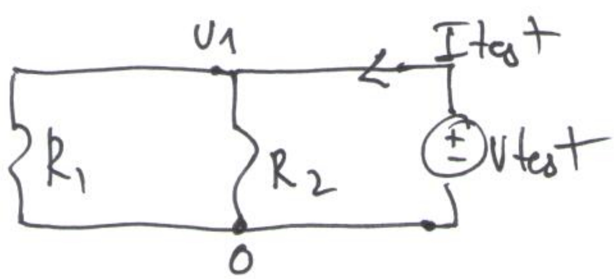




step 1: $V_{o.c} = \frac{R_2}{R_1 + R_2} \cdot V_s = V_{th}$

step 2: R_{th} (zero-out V_s)

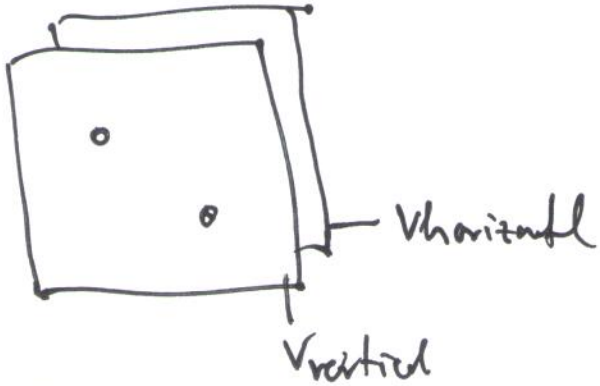




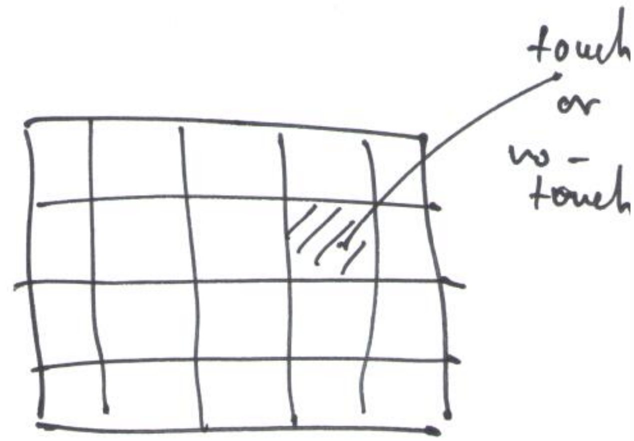
$$R_{th} = R_1 || R_2 = \frac{R_1 \cdot R_2}{R_1 + R_2}$$

(14)

An improved touchscreen



Resistive touch

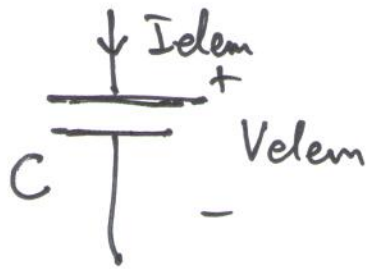


Capacitive touch

Circuit model:

"I - V"

Capacitor Symbol



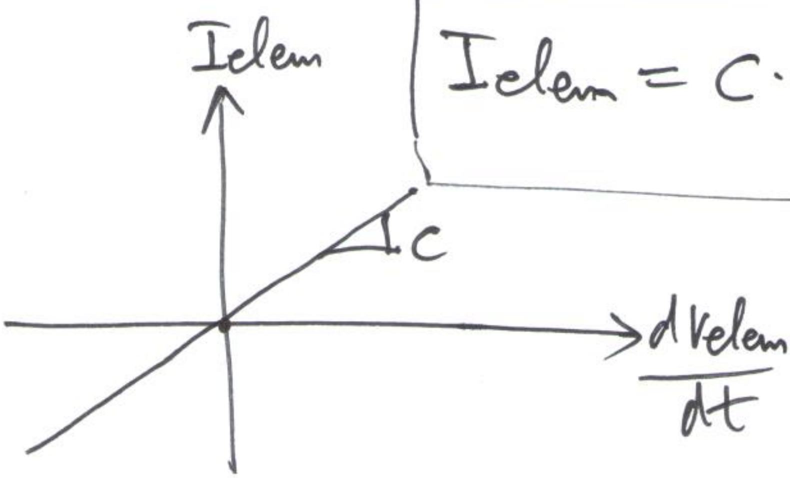
$$\boxed{Q_{elem} = C \cdot V_{elem}}$$

Q_{elem}: [C] $\quad$ C: [F] Farad $\quad$ V_{elem}: [V]

$$I_{elem} = \frac{dQ_{elem}}{dt} = C \cdot \frac{dV_{elem}}{dt}$$

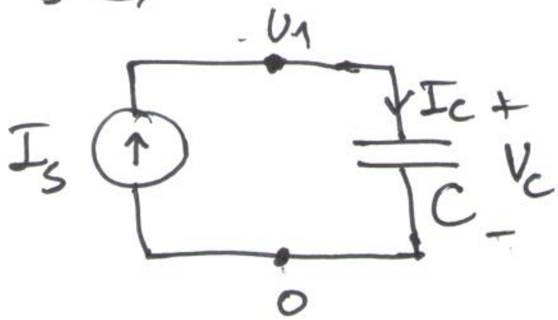
(assume C does not change in time)

$$\boxed{I_{elem} = C \cdot \frac{dV_{elem}}{dt}}$$



l5

single ckt #1:



KCL: $I_s = I_c$ ✓

elem. def for C: $I_c = C \cdot \dfrac{dV_c}{dt}$

KVL: $V_c = U_1$

$$\Downarrow$$

$$I_s = C \frac{dU_1}{dt} \Rightarrow U_1$$

$$\Rightarrow \frac{I_s}{C} = \frac{dU_1}{dt}$$

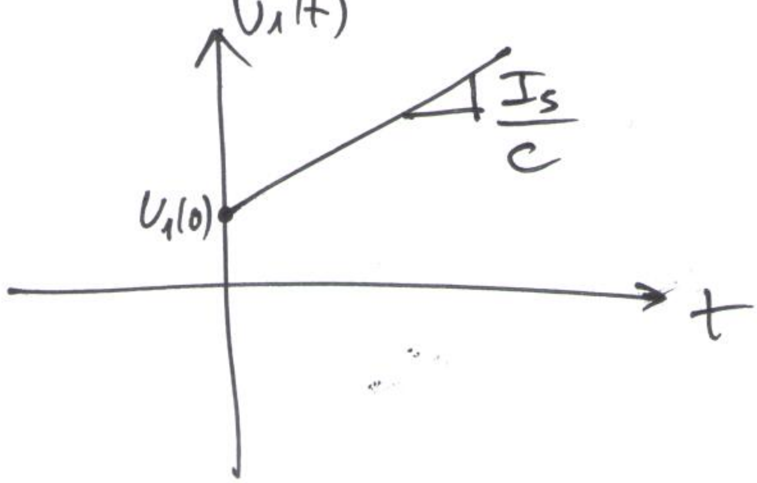
rate

$$\int_0^t I_s \cdot dt = \int_{U_1(0)}^{U_1(t)} C \, dU_1$$

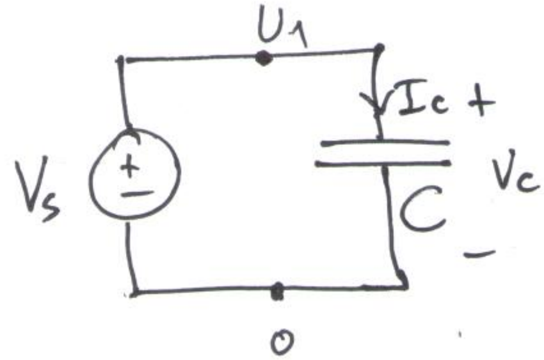
$$I_s \cdot (t-0) = C \cdot [U_1(t) - U_1(0)]$$

$$I_s \cdot t = C \cdot [U_1(t) - U_1(0)]$$

$$\underbrace{U_1(t) = \frac{I_s}{C} \cdot t + U_1(0)}$$



Simple ckt #2:

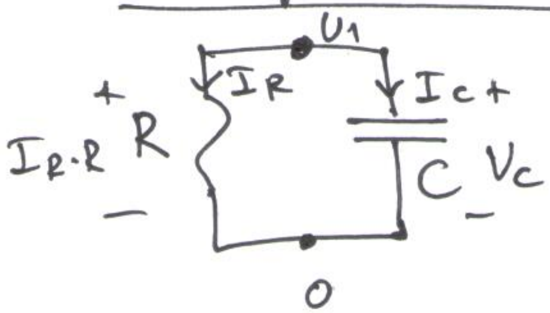


$U_1 = V_s$

$V_c = U_1 \Rightarrow V_c = V_s$

$$I_c = C\cdot\frac{dU_c}{dt} = C\cdot\underbrace{\cancel{\frac{dV_s}{dt}}}_{0} = 0$$

Simple ckt #3:



I am looking for U_1 value when $U_1 = \text{const}$ (i.e in steady-state)

$\Downarrow$

$I_c = 0$

$U_1 = 0$

steady-state means when voltages settle

KCL: $I_R + \overset{0}{\cancel{I_c}} = 0$

Ohm's law: $\underset{0}{\cancel{I_R}} \cdot R = 0$

$U_1 = \underset{0}{\cancel{I_R}} \cdot R = 0$

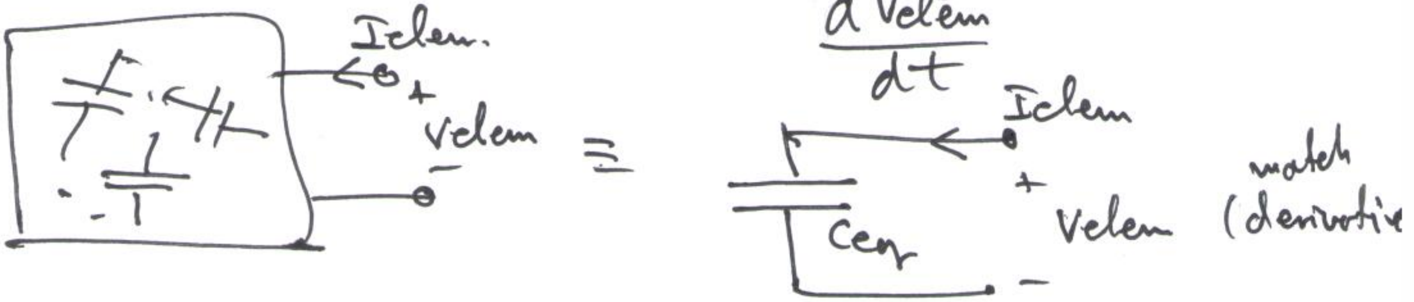
17

Equivalent ckts with capacitors:

* Capacitor-only ckts

~~step 1: find Vth or I_N~~ $\Longrightarrow$ No source

step 2: $$C_{eq} = \frac{I_{elem}}{\frac{dV_{elem}}{dt}}$$

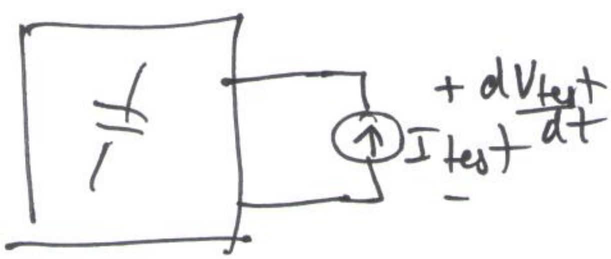


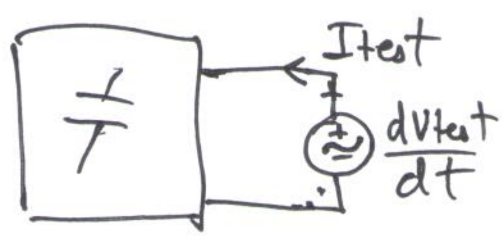
a) Apply I_{test} and measure $\frac{dV_{test}}{dt}$

or

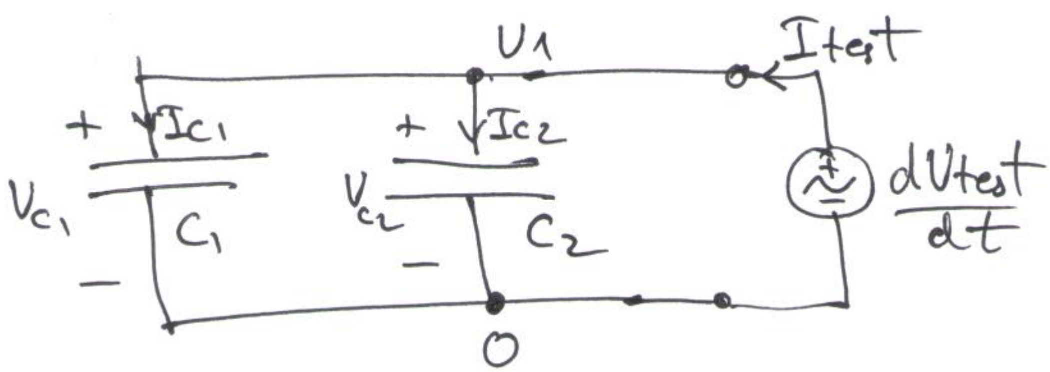
b) Apply $\frac{dV_{test}}{dt}$ and measure I_{test}

$$\Rightarrow C_{eq} = \frac{I_{test}}{\frac{dV_{test}}{dt}}$$





18



$$V_{c_1} = U_1 \ , \ V_{c_2} = U_1 \quad \text{and} \quad U_1 = V_{test}$$

$$\frac{dU_1}{dt} = \frac{dV_{test}}{dt}$$

$$I_{c1} = C_1 \frac{dV_{c1}}{dt} = C_1 \frac{dV_{test}}{dt}$$

$$I_{c2} = C_2 \cdot \frac{dV_{c2}}{dt} = C_2 \cdot \frac{dV_{test}}{dt}$$

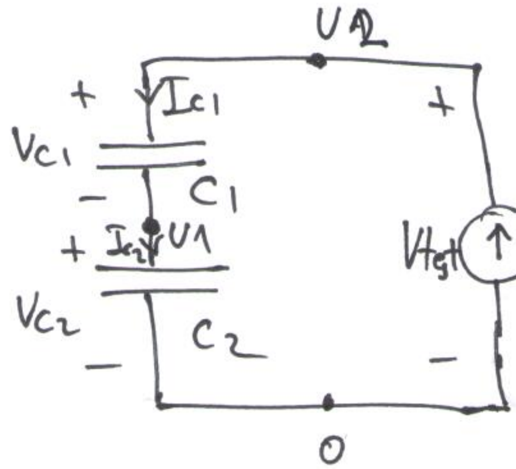
KCL: $$I_{test} = I_{c1} + I_{c2} = C_1 \frac{dV_{test}}{dt} + C_2 \frac{dV_{test}}{dt}$$

$$I_{test} = (C_1 + C_2) \frac{dV_{test}}{dt}$$

$$C_{eq} = \frac{I_{test}}{\frac{dV_{test}}{dt}} = C_1 + C_2$$

$$\doteq \quad R_{eq} = R_1 + R_2$$

(19)



KCL: $I_{C1} = I_{C2} = \underline{I_{test}}$

element: $I_{C2} = C_2 \dfrac{dV_{C2}}{dt}$.

$$I_{C1} = C_1 \cdot \frac{dV_{C1}}{dt}$$

KVL: $V_{C2} = U_1$

$V_{C1} = U_2 - U_1$

$U_2 = V_{test}$

$$\frac{dU_1}{dt} = \frac{I_{test}}{C_2}$$

$$\frac{dU_2}{dt} - \frac{dU_1}{dt} = \frac{I_{test}}{C_1} \Rightarrow \frac{dU_2}{dt} = \frac{dU_1}{dt} + \frac{I_{test}}{C_1}$$

$$\frac{dV_{test}}{dt} = I_{test} \cdot \left(\frac{1}{C_1} + \frac{1}{C_2}\right)$$

$$C_{eq} = \frac{I_{test}}{\frac{dV_{test}}{dt}} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2}} = \frac{C_1 C_2}{C_1 + C_2} = C_1 || C_2$$

$$\boxed{C_{eq} = C_1 || C_2}$$

operator (mathematical)