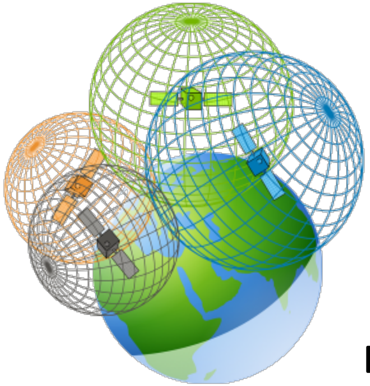
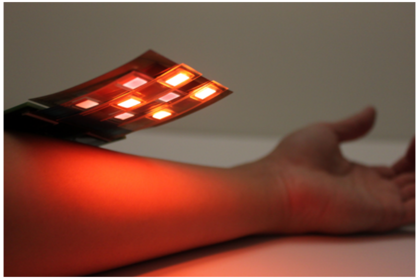




Welcome to EECS 16A!

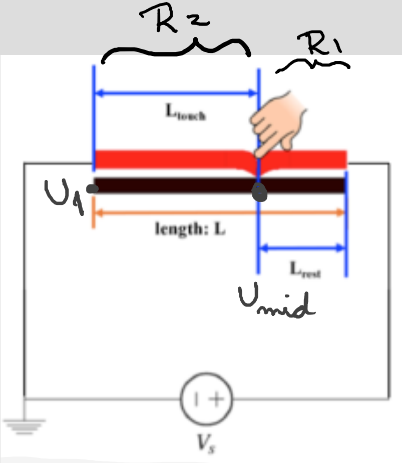
Designing Information Devices and Systems I

Ana Claudia Arias and Miki Lustig

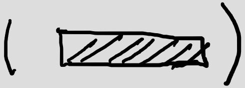
Fall 2021

Module 2
Lecture 4
2D Touchscreen
(Note 14)

Resistive Touch Screen – More realistic model



$\Rightarrow$ Model 1



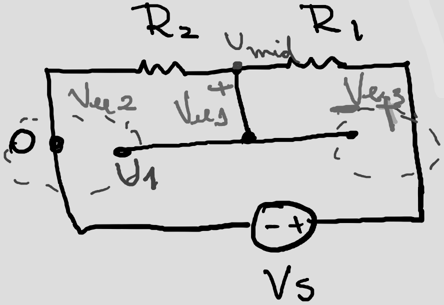
Ideal Wire

↳ Added:

el₁ : wire

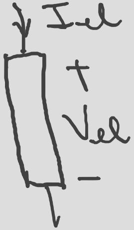
el₂ : open-circuit (V_{el2})

el₃ : open-circuit (V_{el3})



$$R_2 = \rho \frac{L_{touch}}{A}$$

$$R_1 = \rho \frac{L_{rest}}{A}$$



Model Ø

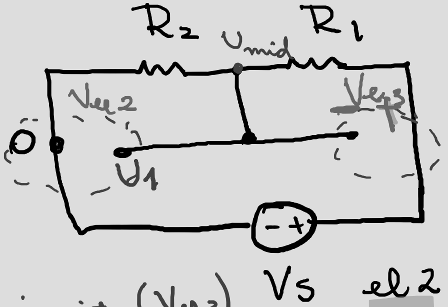
$$U_{mid} = \frac{R_2}{R_1 + R_2} \cdot V_S$$

(Voltage Divider)

Resistive Touch Screen – More realistic model

⇒ Model 1

(▨)
Ideal Wire
↳ Added:
el$_1$: wire
el$_2$: open-circuit (V_{el2})
el$_3$: open-circuit (V_{el3})



Model ∅

$$U_{mid} = \frac{R_2}{R_1+R_2} \cdot V_s$$

(Voltage Divider)

$$R_2 = \rho \frac{L_{touch}}{A}$$

$$R_1 = \rho \frac{L_{rest}}{A}$$

el 2:

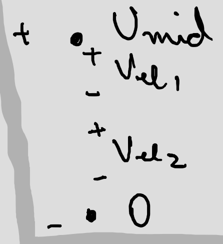
$$V_{el2} = U_1 - 0 \quad \text{(definition of elem. V)}$$

el 1:

$$V_{el1} = U_{mid} - U_1$$

KVL:

$$U_{mid} - 0 = V_{el2} + V_{el1}$$



Resistive Touch Screen – More realistic model

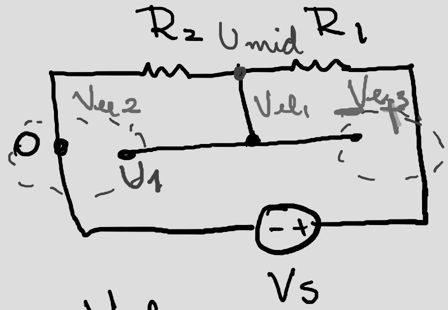
⇒ Model 1

(▨)
Ideal Wire
↳ Added:
el$_1$: wire
el$_2$: open-circuit (V_{el2})
el$_3$: open - circuit (V_{el3})

el 2:
$V_{el2} = U_1 - 0$ (definition of elem. V)

el 1:
$V_{el1} = U_{mid} - U_1$

KVL:
$U_{mid} - 0 = V_{el2} + V_{el1}$



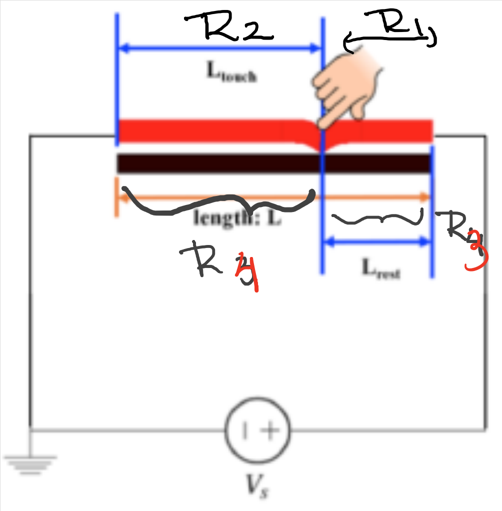
$$\left.\begin{aligned} U_1 &= V_{el2} \\ U_{mid} - U_1 &= V_{el1} \end{aligned}\right\} + \quad \begin{aligned} U_{mid} - \cancel{U_1} + \cancel{U_1} &= V_{el1} + V_{el2} \\ U_{mid} &= V_{el1} + V_{el2} \end{aligned}$$

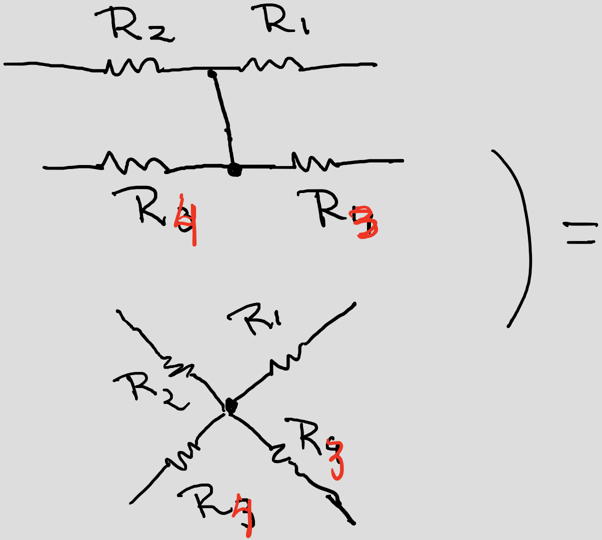
el 1 is a wire ∴ $V_{el1} = 0$

$$\underline{U_{mid}} = 0 + V_{el2} = V_{el2} = \underline{U_1}$$

* By measuring V_{el2} we get U_{mid} for any ↳ touch.

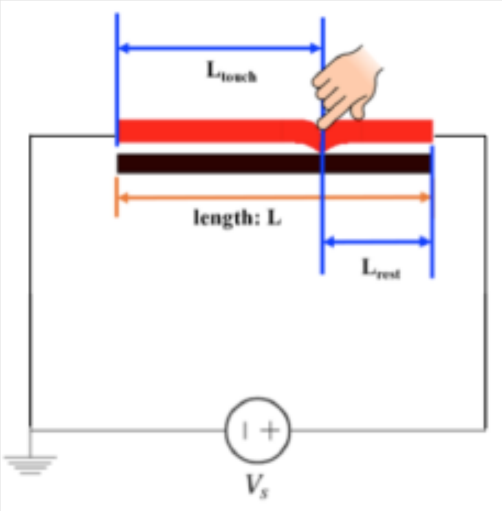
Resistive Touch Screen – More realistic model

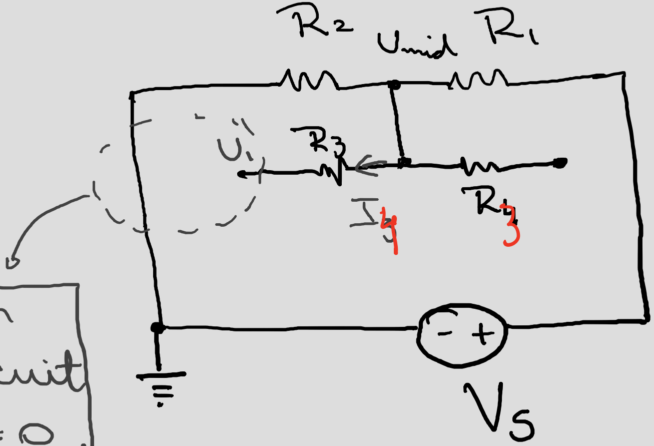




R_1, R_2, R_3 and R_4 are unknown.

Resistive Touch Screen – More realistic model





Open circuit

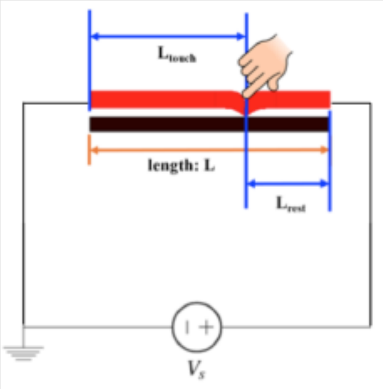
$I = 0$

$I_4 = 0$

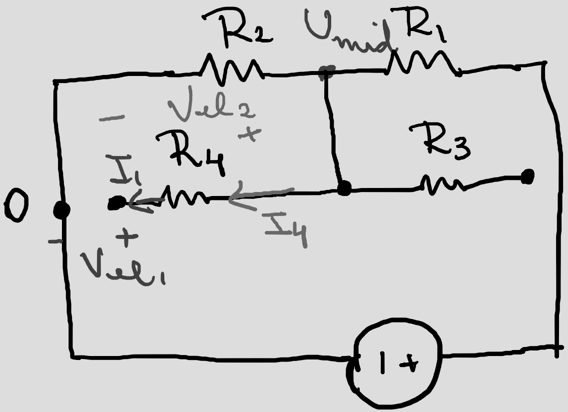
$U_1 = 0$

Read out is Voltage!

Resistive Touch Screen – More realistic model



Model 2 – imperfect conductor (resistor)



Added

el_1 : open-circuit $\Rightarrow$

el_2 : resistor (R_4)

$V_{el_2} = R_4 \cdot I_4$ (Ohm's Law)

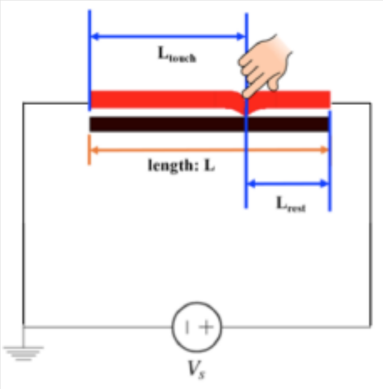
KCL : $I_1 = I_4$

$I_1 = 0 \quad \therefore \quad I_4 = 0$

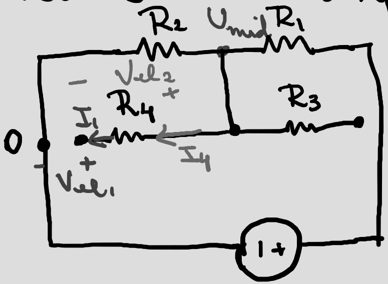
$U_{mid} = V_{el_1} + V_{el_2} = V_{el_1} + \cancel{R_4 \cdot I_4}^{\to 0}$

$\boxed{U_{mid} = V_{el_1}}$

Resistive Touch Screen – More realistic model



Model 2 – imperfect conductor (resistor)



$$KCL : I_1 = I_4$$

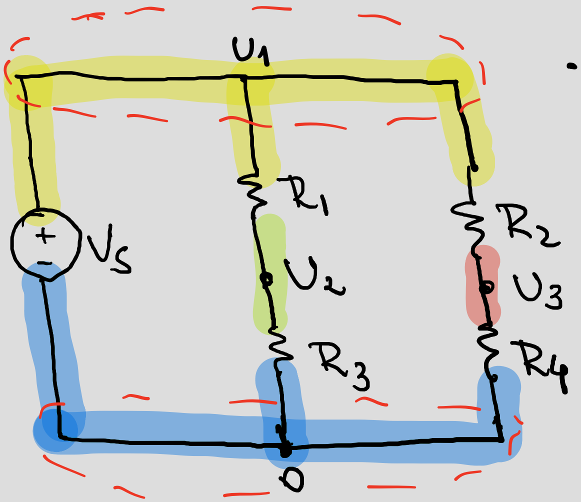
$$I_1 = 0 \;\therefore\; I_4 = 0$$

$$U_{mid} = V_{el_1} + V_{el_2} = V_{el_1} + \cancel{R_4 \cdot I_4}^{\to 0}$$

$$\boxed{U_{mid} = V_{el_1}}$$

We can: measure Umid at Vee1 regardless of backplane material and value of L touch

An interesting circuit



- What are U_2 and U_3?

$$U_2 = \frac{R_3}{R_1 + R_3} \cdot V_S$$

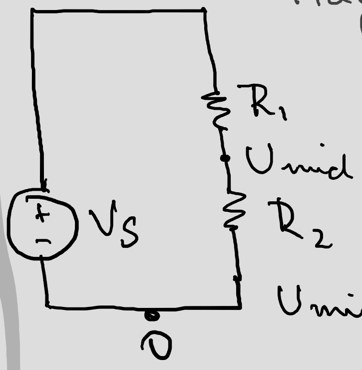
$$U_3 = \frac{R_4}{R_2 + R_4} \cdot V_S$$

$$V_S = U_1 - 0$$

$$U_2 - 0 = \frac{R_3}{R_1+R_3} \cdot (\overbrace{U_1 - 0}^{V_S})$$

$$U_3 - 0 = \frac{R_4}{R_2+R_4} \cdot (\overbrace{U_1 - 0}^{V_S})$$

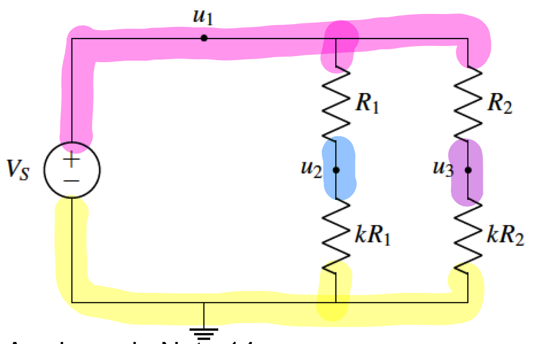
Voltage Divider



$$U_{mid} = \frac{R_2}{R_1+R_2} \cdot V_S$$

Operator!

An interesting circuit



As shown in Note 14

Power supply keeps V in wires equals to V_s regardless of how many branches we have.

$$U_2 = \frac{R_3}{R_1 + R_3} \cdot V_s$$

$U_2 = ?$

$U_3 = ?$

$R_3 = k R_1 \qquad R_4 = k R_2$

$$U_2 = \frac{k \cancel{R_1}}{\cancel{R_1} + k\cancel{R_1}} \cdot V_s$$

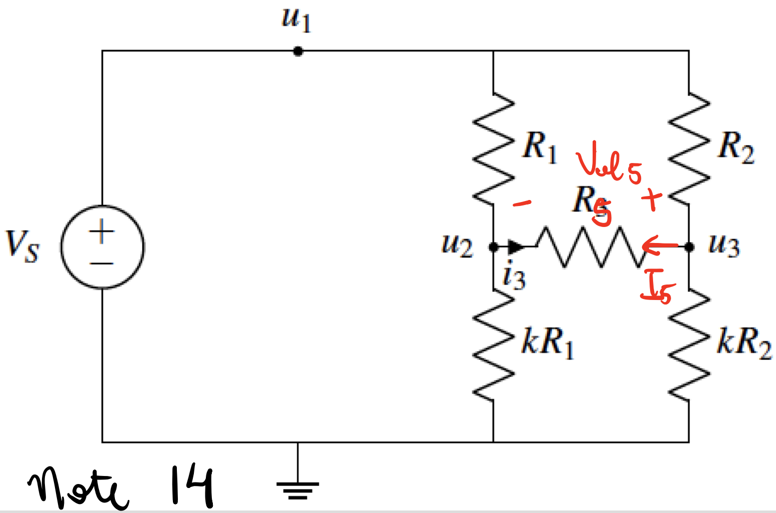
$$\boxed{U_2 = \frac{k}{1+k} \cdot V_s}$$

$$U_3 = \frac{k \cancel{R_2}}{\cancel{R_2} + k\cancel{R_2}} \cdot V_s$$

$$\boxed{U_3 = \frac{k}{1+k} \cdot V_s}$$

$U_2 = U_3$

Let's add on more resistor



Note 14

$E_{elem\,5}$ = resistor
R_5

$V_{el\,5} = U_3 - U_2$ (Voltage Definition)

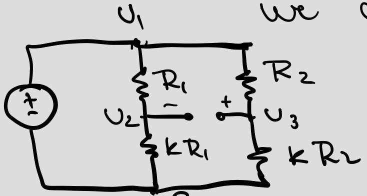
$V_{el\,5} = I_{el\,5} \cdot R_5$ (Element Def.)

Bold Assumption

$V_{el\,5} = 0$

if $V_{el\,5} = 0 \Rightarrow I_{el\,5} = \dfrac{\cancel{V_{el\,5}}^{\,0}}{R_5} = 0$

if $I_{el\,5} = 0 \Rightarrow$ the circuit is the same as the one we already analysed without R_5.



$I_{el\,5} = 0$

$U_2 = \dfrac{k}{1+k} V_S$

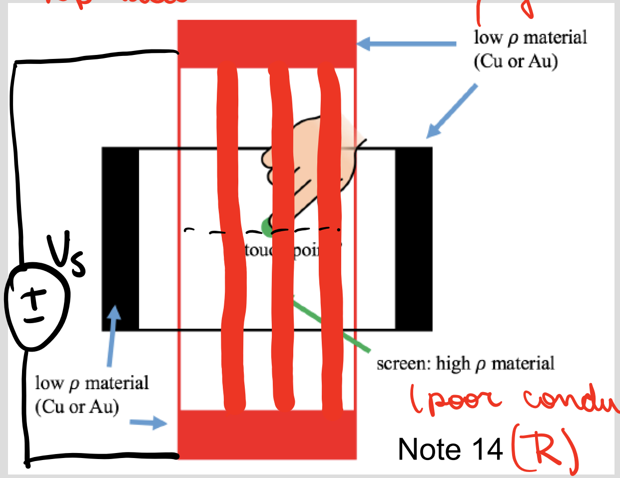
$U_3 = U_2 \Rightarrow V_{el\,5} = U_3 - U_2 = 0$

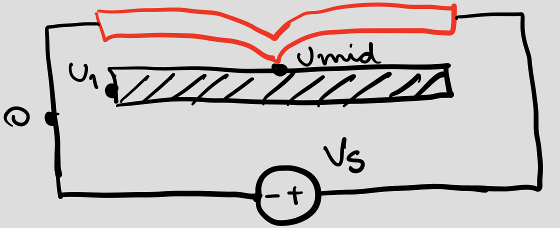
More on equivalence later!

2D Touch Screen

Top View

(wire) good conductor



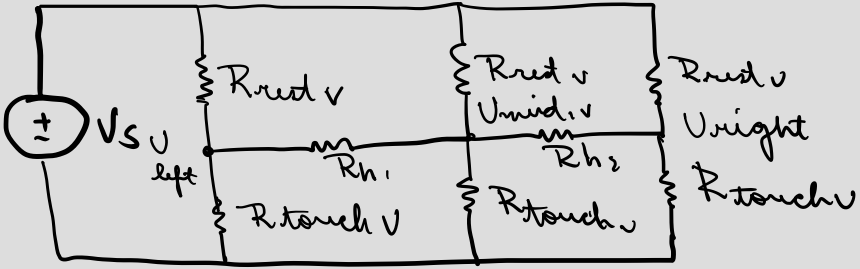


This is our interesting circuit.

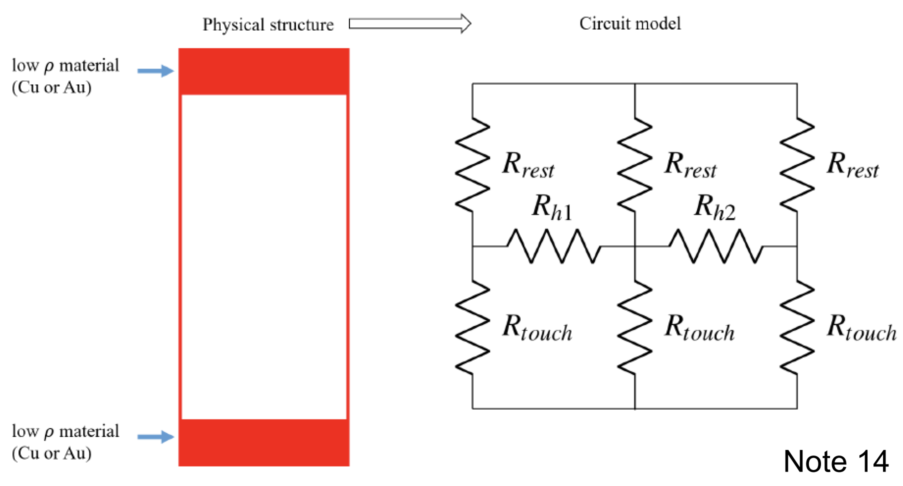
$$V_{mid,V} = V_{left} = V_{right}$$

$$V_{mid,V} = \frac{R_{touch}}{R_{rest} + R_{touch}} \cdot V_s$$

$$V_{mid,V} = \frac{\cancel{\rho}\,\frac{L_{touch,V}}{\cancel{A}}}{\cancel{\rho}\,\frac{L_{rest,V}}{\cancel{A}} + \cancel{\rho}\,\frac{L_{touch}}{\cancel{A}}} \cdot V_s$$



Top Plate Model

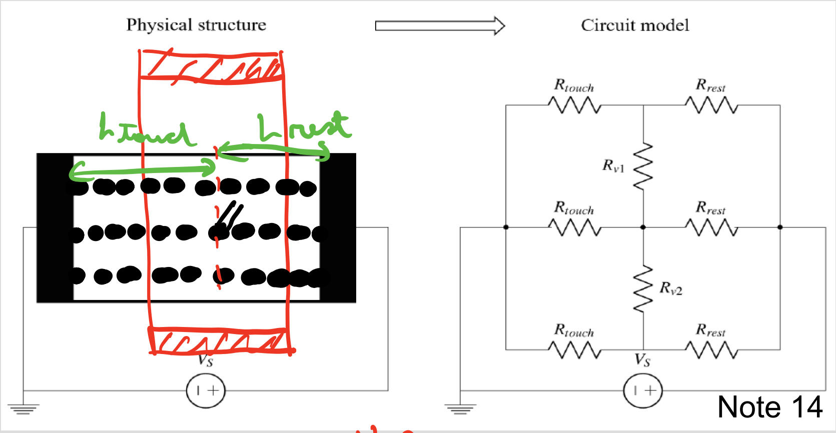


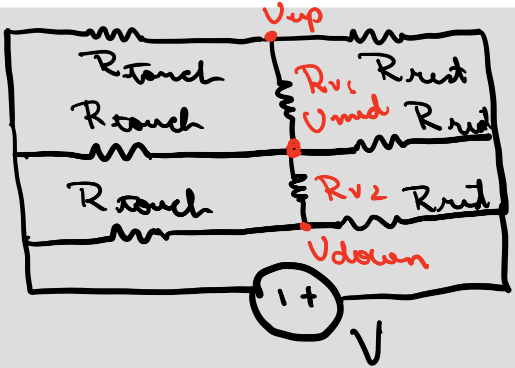
$$U_{mid,v} = \frac{L_{touch}}{L_{rest}} \cdot V_s$$

↳ Vertical position in the screen.

What should be our next step?

Bottom Plate Model





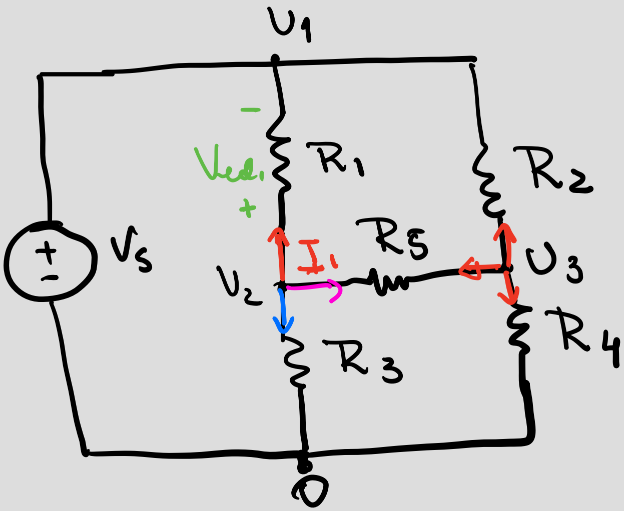
$$U_{up} = U_{mid} = U_{down}$$

$$U_{mid\,H} = \frac{R_{touch\,H}}{R_{rest\,H} + R_{touch}} \cdot V_S$$

$$U_{mid} = \frac{h_{touch\,H}}{h_H} \cdot V_S$$

Horizontal information

Faster Circuit Analysis



Step 1 : Label nodes and choose a ref. node

Step 2 : write equations for nodes that have voltage sources between them

$V_1 - 0 = V_s \Rightarrow V_1 = V_s$

Step 3 : KCL + IR combo including current sources.

$V_{el_1} = I_1 R_1$

$I_1 = \frac{V_2 - V_1}{R_1} \rightarrow V_{el_1} = V_2 - V_1$

Magic : Apply KCL to nodes !

$$U_2: \quad \frac{U_2 - \cancel{U_1}^{\,V_S}}{R_1} + \frac{U_2 - 0}{R_3} + \frac{U_2 - U_3}{R_5} = 0$$

$U_2 = ?$

$U_3 = ?$

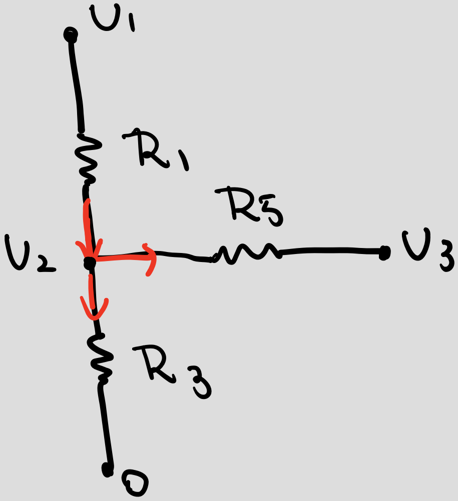
Apply to U_3

$$\frac{U_3 - \cancel{U_1}^{\,V_S}}{R_2} + \frac{U_3 - U_2}{R_5} + \frac{U_3 - 0}{R_4} = 0$$

$$U_2\left(\frac{1}{R_1} + \frac{1}{R_3} + \frac{1}{R_5}\right) - \frac{1}{R_5} U_3 = \frac{V_S}{R_1}$$

$$U_3\left(\frac{1}{R_2}+\frac{1}{R_5}+\frac{1}{R_4}\right)-\frac{1}{R_5}U_2=\frac{U_s}{R_2}$$

Example



negative

$$\frac{U_1-U_2}{R_1}=\frac{U_2-0}{R_3}+\frac{U_2-U_3}{R_5}$$