E151 Lecture 2 – Thevenin and 2 Port Hacks

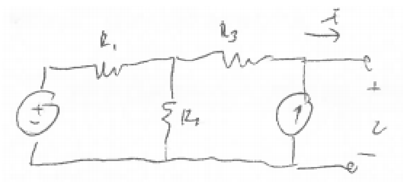
Matthew Spencer
Harvey Mudd College
ENGR151

Disclaimer

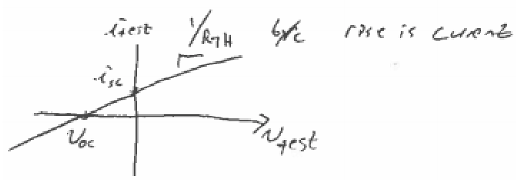
These are note for Prof. Spencer to give the lecture, they were not intended as a reference for students. Students asked for them anyway, so I'm putting them up as a courtesy. Remember that they are not intended as a substitute for lecture.

Thevenin

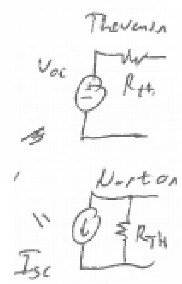
- Connect circuits to the world at ports, model w/ 1 line b/c linear
- Note that Norton is literally slope intercept form of line



what is i-v relation across port?
→ must be linear
~~model~~ may have DC value
— model w/ s/c + res



Norton is V-I curve instead of I-V



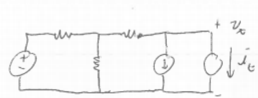
Example Find Thevenin Impedance 2 Ways

- Options: voc/isc (slope), simplify network (test source / derivative)
- Then I show 3rd way: test sources (derivative of circuit)

① $v_{oc} = v_3 = I(R_3 + R_1||R_2) + V\frac{R_2}{R_1+R_2}$ by super pos $i_{sc} = I + \frac{V}{R_3 + R_1||R_2}\cdot\frac{R_2}{R_1+R_2}$

② $R_{TH} = R_3 + R_1||R_2$ w/ shorted & opened sources

③



- can pick current or voltage test
- ask how much i or v out (find dv_t/di_t)
- ∫ easy here b/c || w/ I
- MUST use this technique w/ dept. src.

$v_t = V\frac{R_2}{R_1+R_2} + (I+i_t)(R_3+R_1||R_2)$

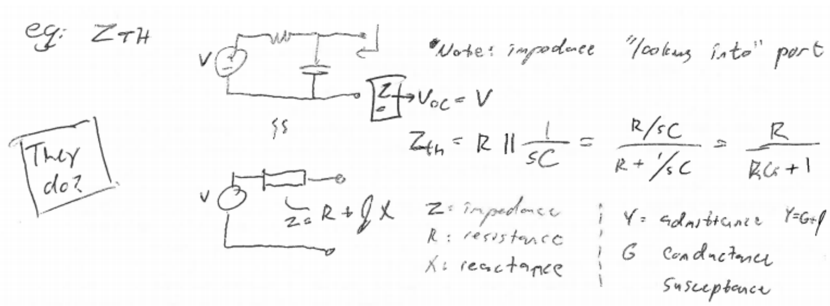
$\frac{dv_t}{di_t} = R_3 + R_1||R_3$ (eq to small signal model, setting v & i to 0)

[super handy for ignoring tricky circuit details!]

MUST SHUT OFF SOURCES for di/dv. (Small wiggles go to die)

Odds and Ends

- Non-resistive impedances?
  - Just fine, have a Zth (general case) rather than Rth (like homework)



- What if no sources? In quadrants 1&4, dissipative, called "passive"

Dynamics Review – Initial and Final Values

- What do we want to know dynamics responses to?
  - Sines → transfer functions work great
  - Steps → … time domain, need some trick
  - Ramps → integrated steps, next
  - Exponentials → basically ramps, next
- We can get time domain responses from xfer fn with IVT/FVT

– IVT

$$\lim_{t \to 0} f(t) = \lim_{s \to \infty} sF(s)$$

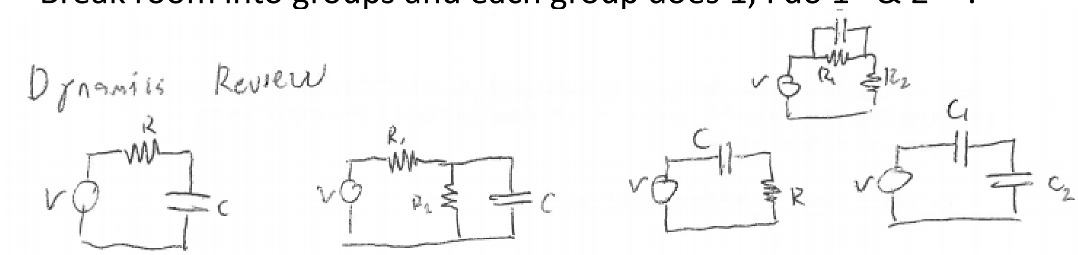
– FVT

$$\lim_{t \to \infty} f(t) = \lim_{s \to 0} F(s)$$

Don't forget that LT F(s) implicitly involves initial condition, so the IC is added to IVT/FVT value

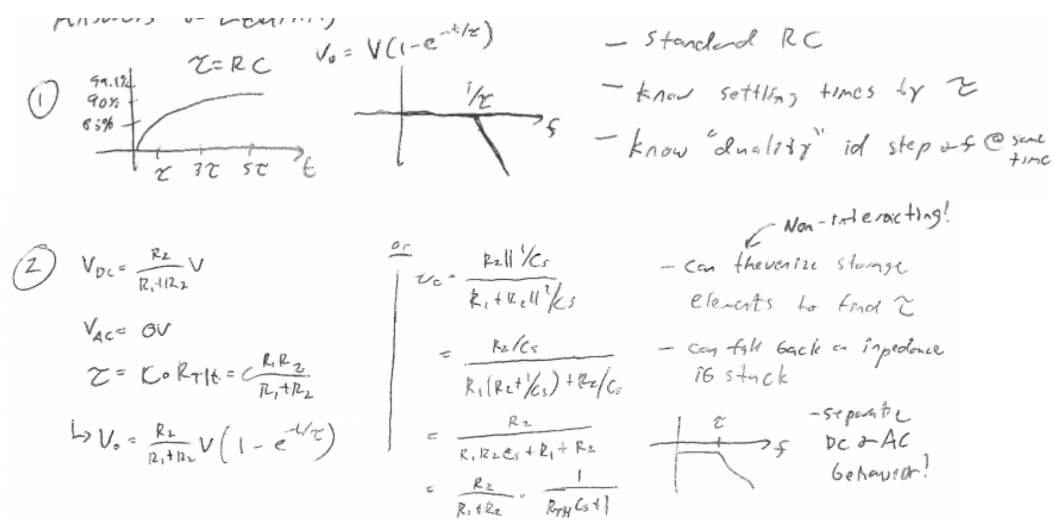
Exercise: sketch vo step for these circuits

- Break room into groups and each group does 1, I do 1st & 2nd ?



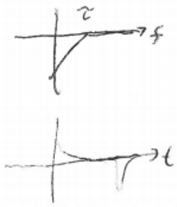
- Main points: IVT/FVT practice, tau is same in t and f, AC vs. DC ckt. To find Vi and Vf, Thevenize from cap to find tau (if only 1 cap)
- Original solutions on next few pages, often drop some details

Exercise answers



Exercise Answers

(3) $V_{DC} = 0V$
$V_{AC} = V$
$\tau = RC$
$V_o = Ve^{-t/RC}$



- Value on far side of cap already has an "average" value
- AC coupled signals are transient
  - ↳ Interesting behavior turning bursts on & off

(4) $V_{DC} = \frac{R_2}{R_1+R_2} V$

$V_{AC} = V$

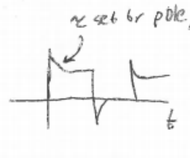
$\tau = R_1 \| R_2 \cdot C$

$V_o = V\left(\frac{R_1}{R_1+R_2} + \frac{R_2}{R_1+R_2} e^{-t/\tau}\right)$

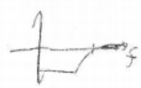
$\frac{R_2}{\frac{R_1}{R_1Cs+1} + R_2}$

$\frac{R_2}{R_1+R_2} \frac{1+R_1Cs}{1+\frac{R_1R_2}{R_1+R_2}Cs}$

τ set by pole, not zero



- capacitive feedthrough
- ac part is transient
- parallel forward paths means obligate zero
  - ↳ change from gain A to gain B



- Changing gain & change in f linked & still 1st order

(5) $V_o = \frac{1/j\omega C_2}{1/j\omega C_1 + 1/j\omega C_2} = \frac{C_1}{C_1+C_2}$

- capacitive divider
- output is DC floating but will stay b/c coupling or fixed (scope probe)
- frequency independent!