POLITECNICO
MILANO 1863





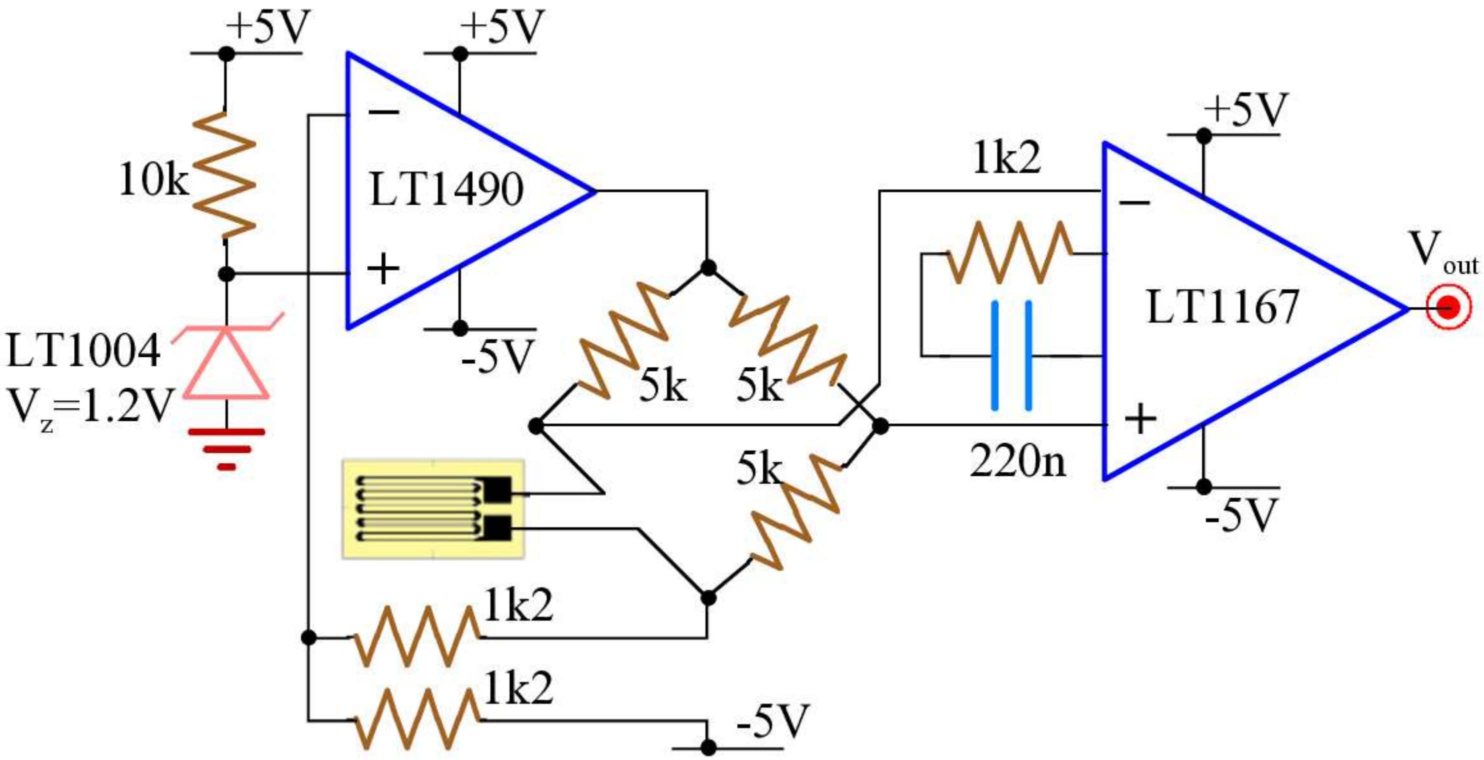
TUTORING on ELECTRONICS

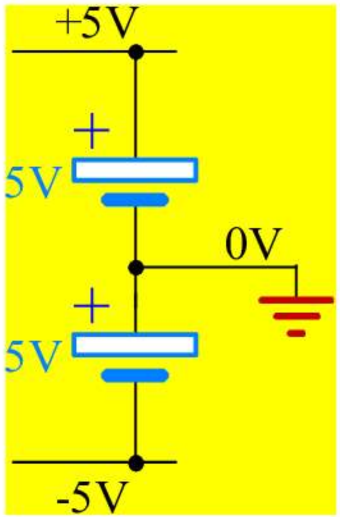
2021-22 academic year

Iris CUSINI and Fabio SEVERINI

Power supply

Typology: single- or dual- power supply





GROUND: local 0V reference

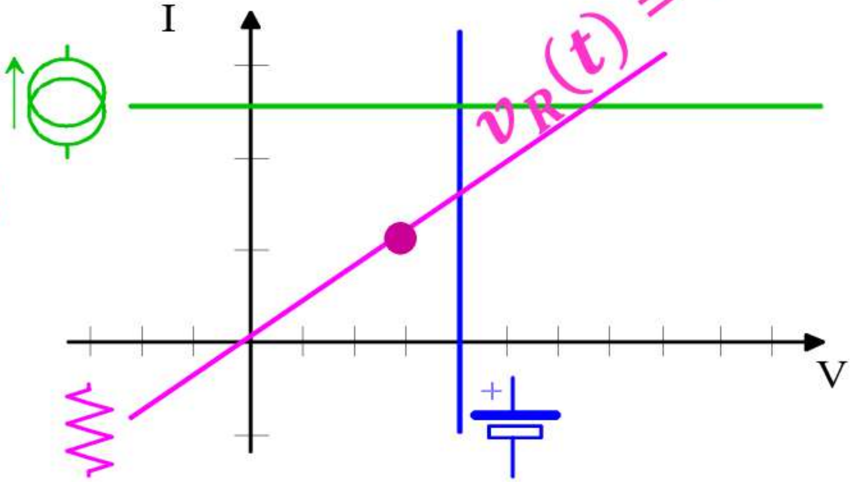
usually it is the copper plate of the printedCircuitboard

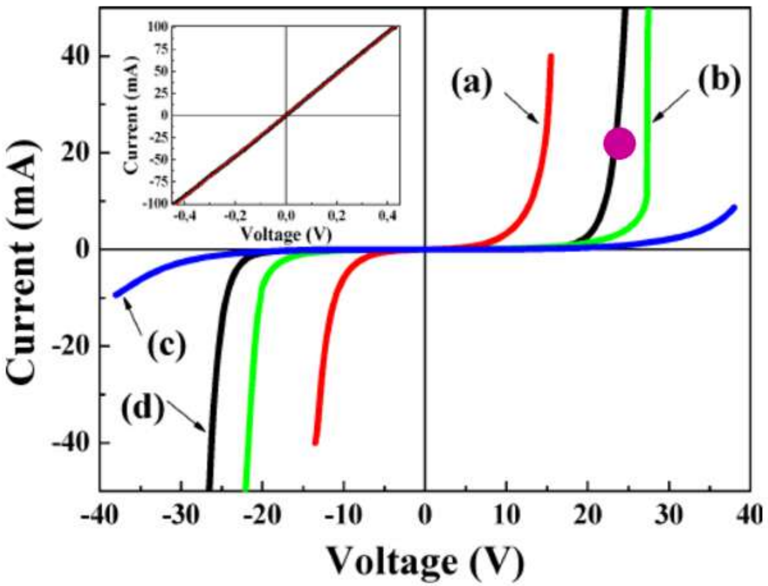
it can also be the chassis connection and possibly **EARTH**

Ohm's law applies only to R

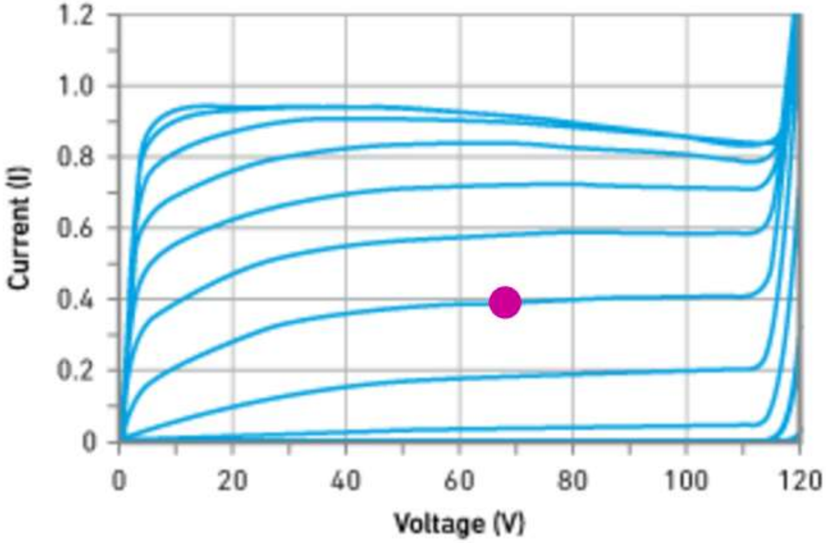
$$v_R(t) = R \cdot i_R(t)$$

I applied 3V, then I measured 1mA, so R=3kΩ





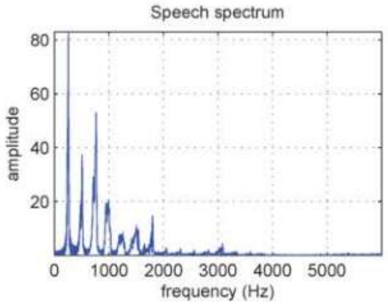
NO !
Most components exhibit
NON-LINEAR IV response!

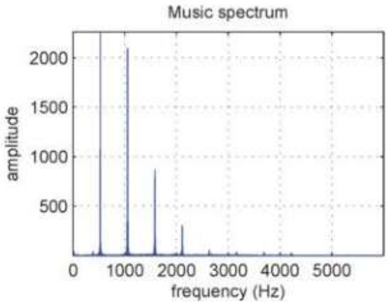


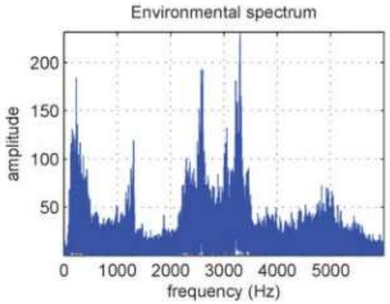
Frequency response is of utmost importance

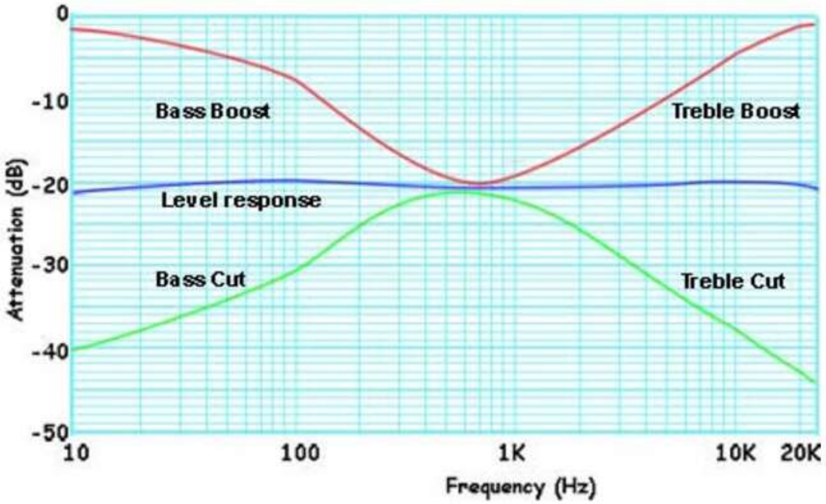
Not just to Low-Pass, Band-Pass, High-Pass, Notch, but also for Integrators, Derivators…

Audio example

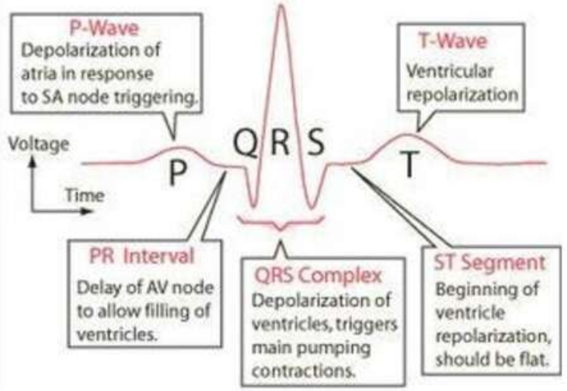


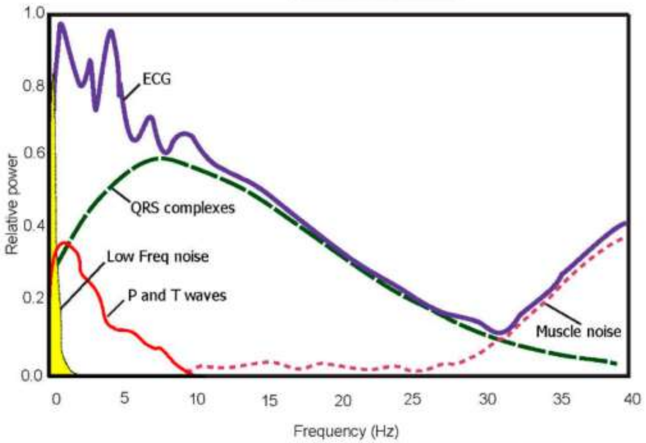


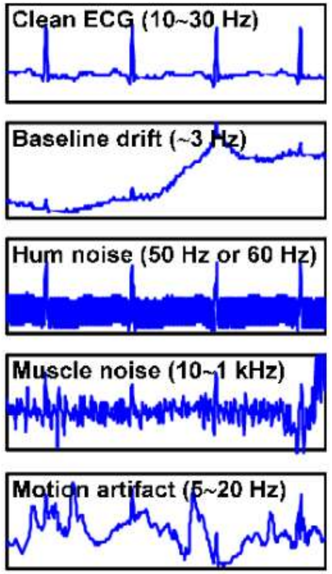




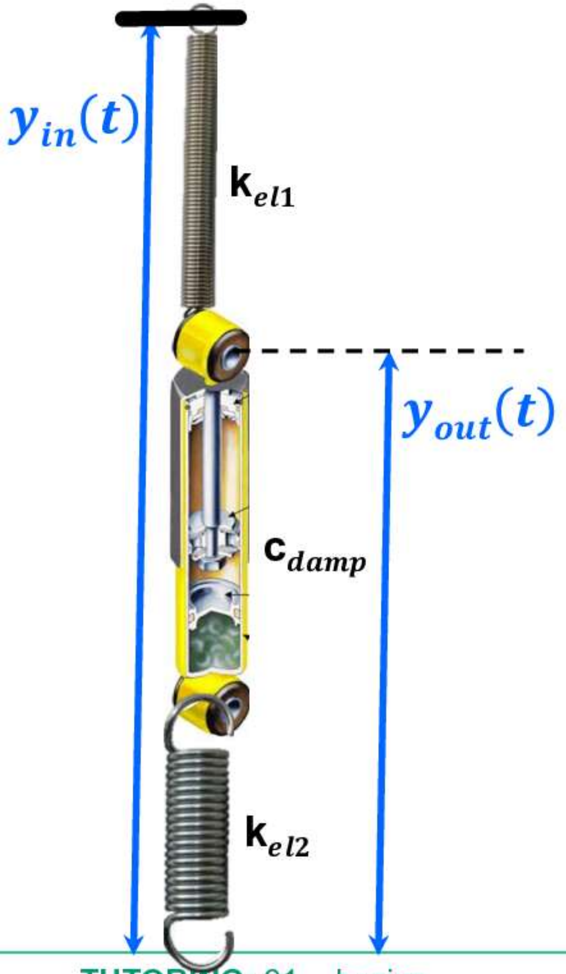
ECG example



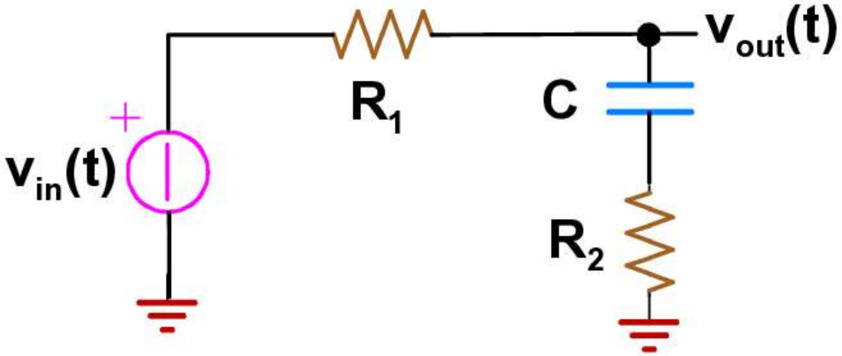




"Smart" frequency analysis:

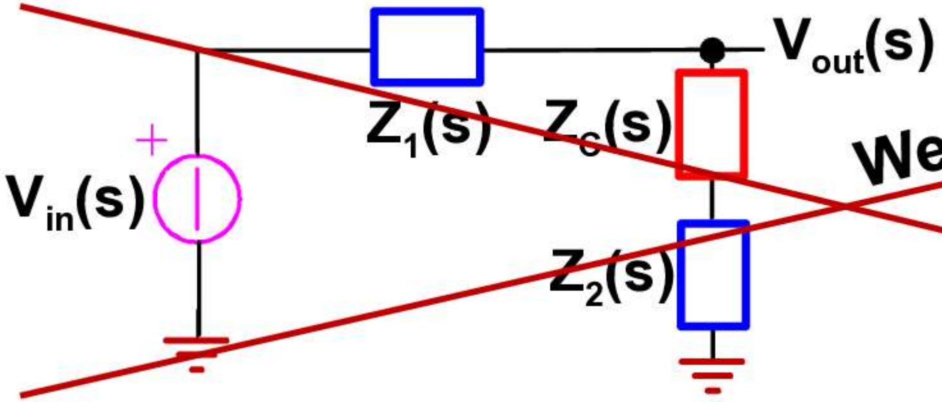


Given a circuit and sinusoidal signal sources…



… complex impedances must be considered

… and Laplace Transform should be employed

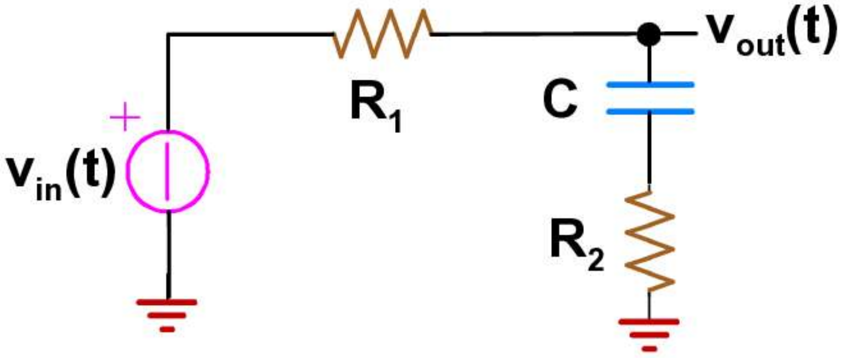


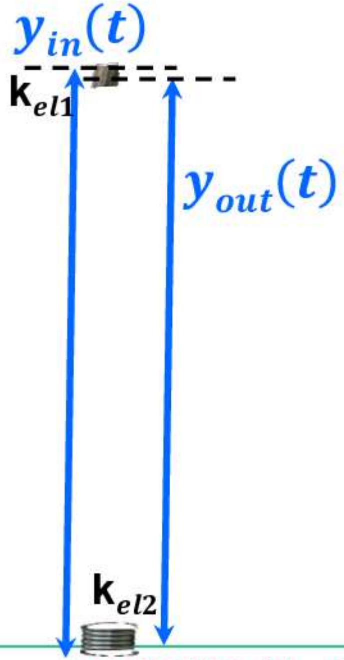
We don't need it, though !!!

$$H(s) = \frac{V_{out}(s)}{V_{in}(s)} = \frac{1 + sCR_2}{1 + sC(R_1 + R_2)}$$

… “asymptotic analysis”

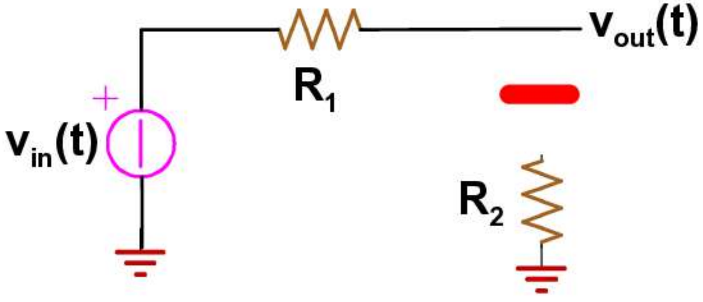
1- We simply evaluate the circuit response at **0Hz** and **∞Hz**





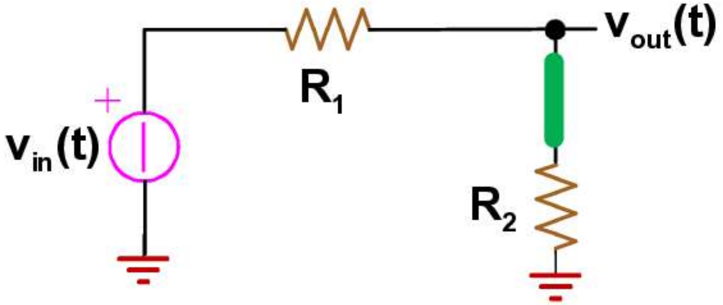
at DC:

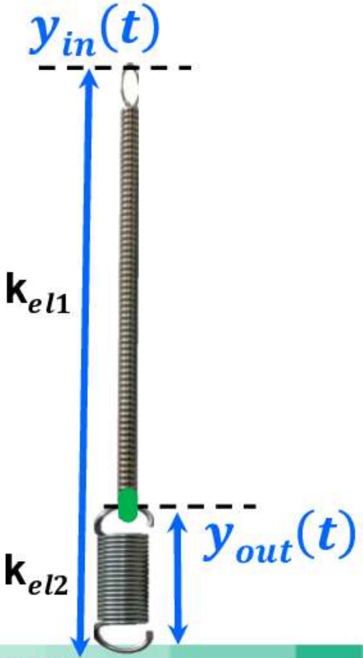
$$A_V(0) = \frac{v_{out}(0)}{v_{in}(0)} = 1$$



at ∞Hz:

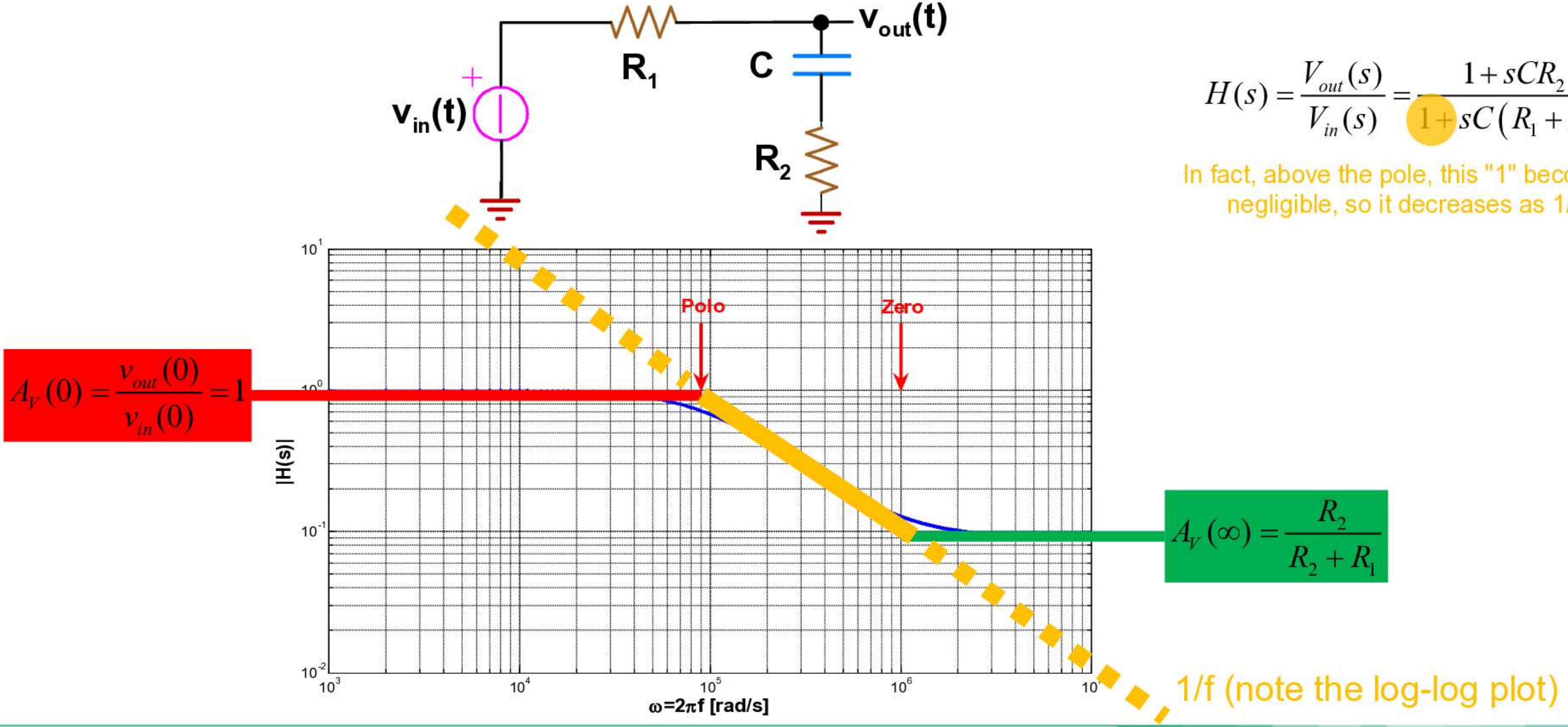
$$A_V(\infty) = \frac{v_{out}(\infty)}{v_{in}(\infty)} = \frac{R_2}{R_2 + R_1}$$





"Heartily" proposed analysis

2- Then, we join the **0Hz** and **∞Hz** asynptotic trends through a **line** in log-log plot



$$H(s)=\frac{V_{out}(s)}{V_{in}(s)}=\frac{1+sCR_2}{1+sC(R_1+R_2)}$$

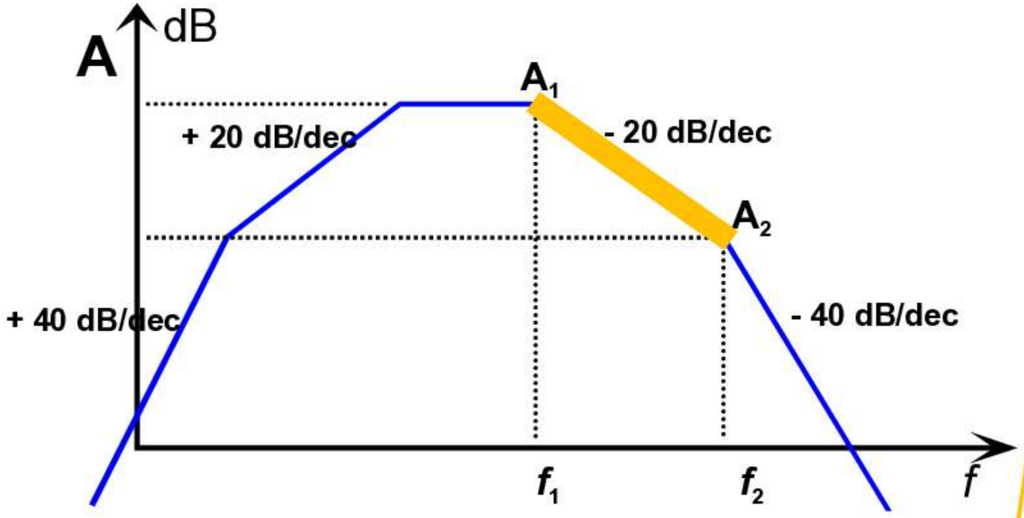
In fact, above the pole, this "1" becomes negligible, so it decreases as 1/f

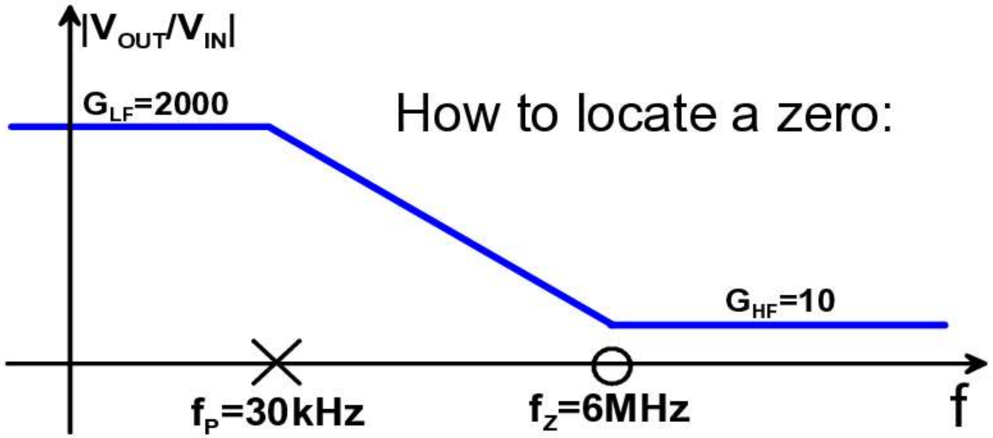
Bode diagrams

-20dB/dec: $A_1 \cdot f_1 = A_2 \cdot f_2$ the so called constant **Gain-Bandwidth Product GBWP**

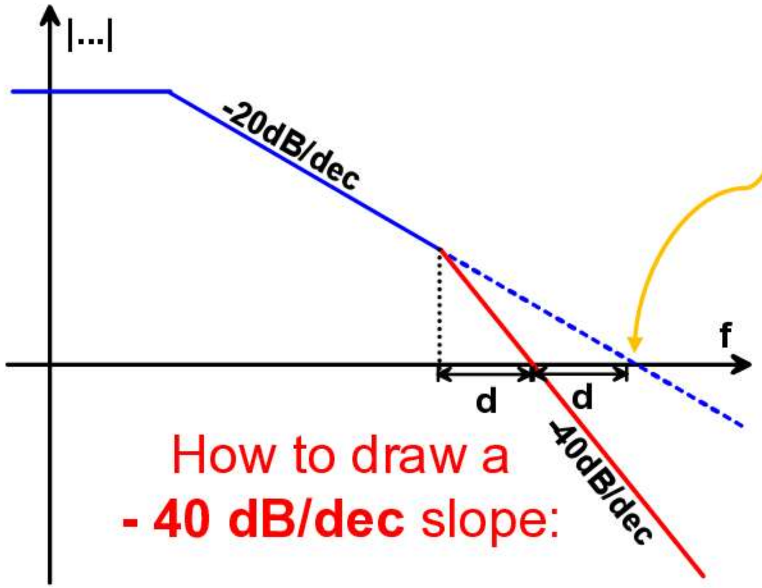
+20dB/dec: $\dfrac{f_1}{A_1} = \dfrac{f_2}{A_2}$

-40dB/dec: $\sqrt{A_1} \cdot f_1 = \sqrt{A_2} \cdot f_2$





How to locate a zero:



How to draw a **- 40 dB/dec** slope:

How to compute poles

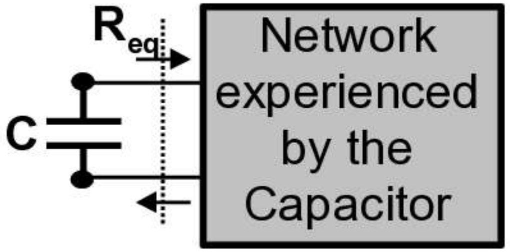
Switch off all generators (V=0 is a short-circuit, while I=0 is an open-circuit)

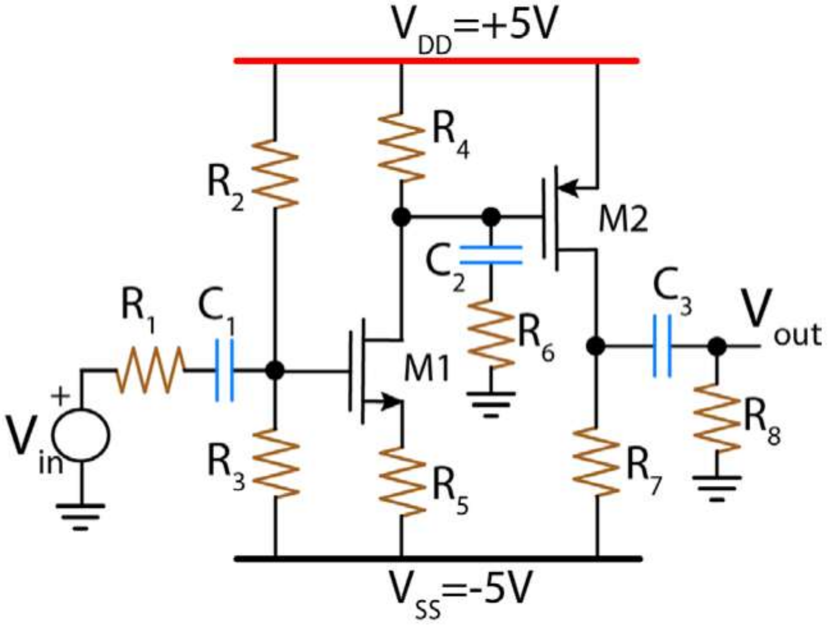
Don't care where inputs and outputs are!

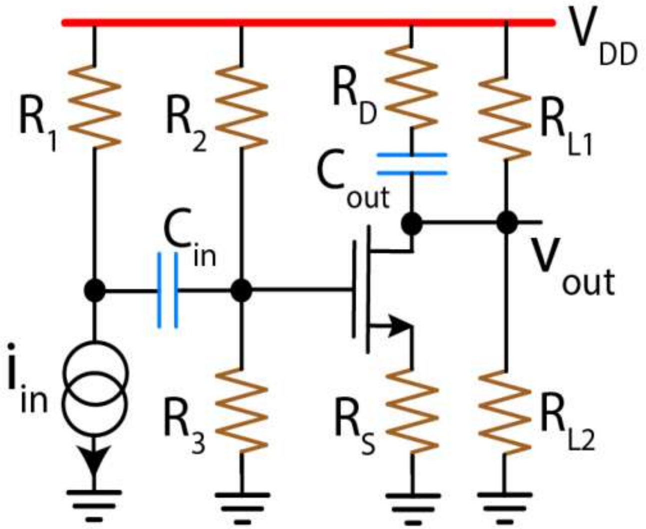
Compute the overall Resistance "seen" by the Capacitor!

CAPACITÀ NON INTERAGENTI CALCOLO LA RESISTENZA VISTA AI CAPI DEL CONDENSATORE E TROVO I POLI

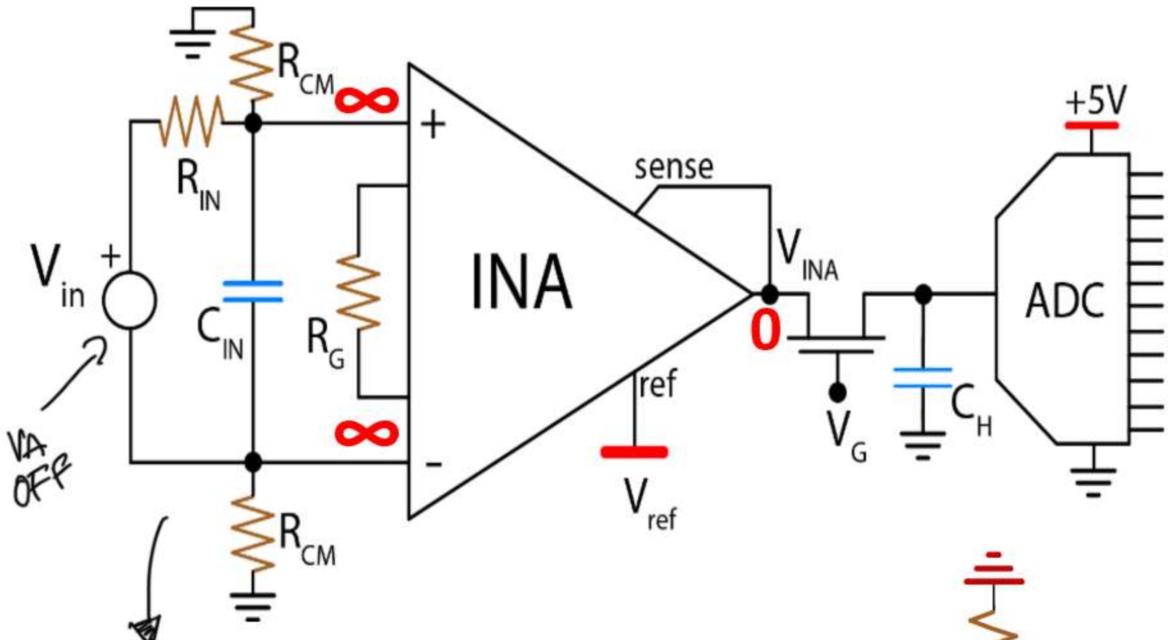
$$polo_{Hz} = \frac{1}{2\pi \cdot \mathrm{R}_{eq} \cdot C}$$

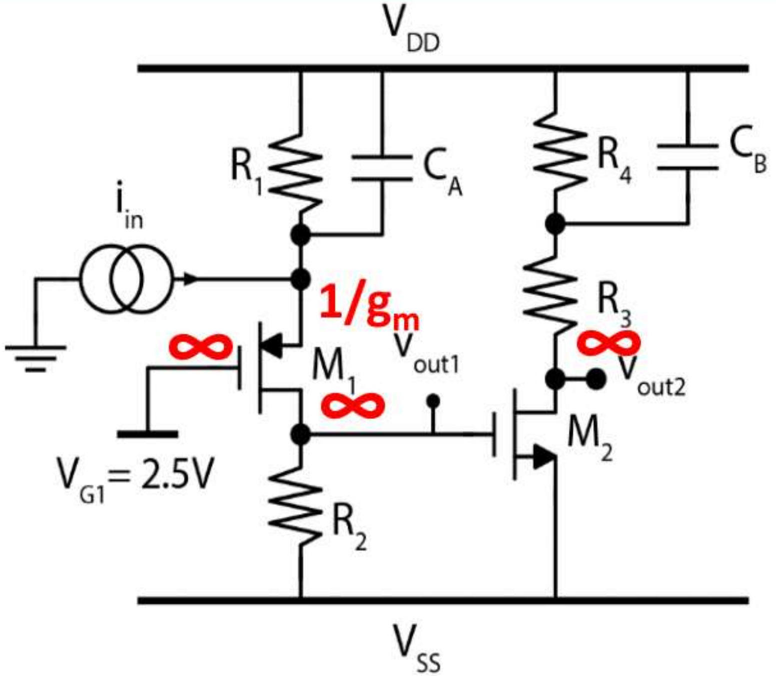


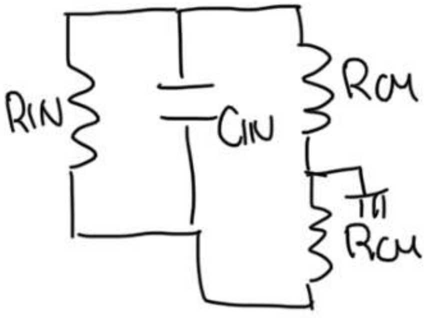




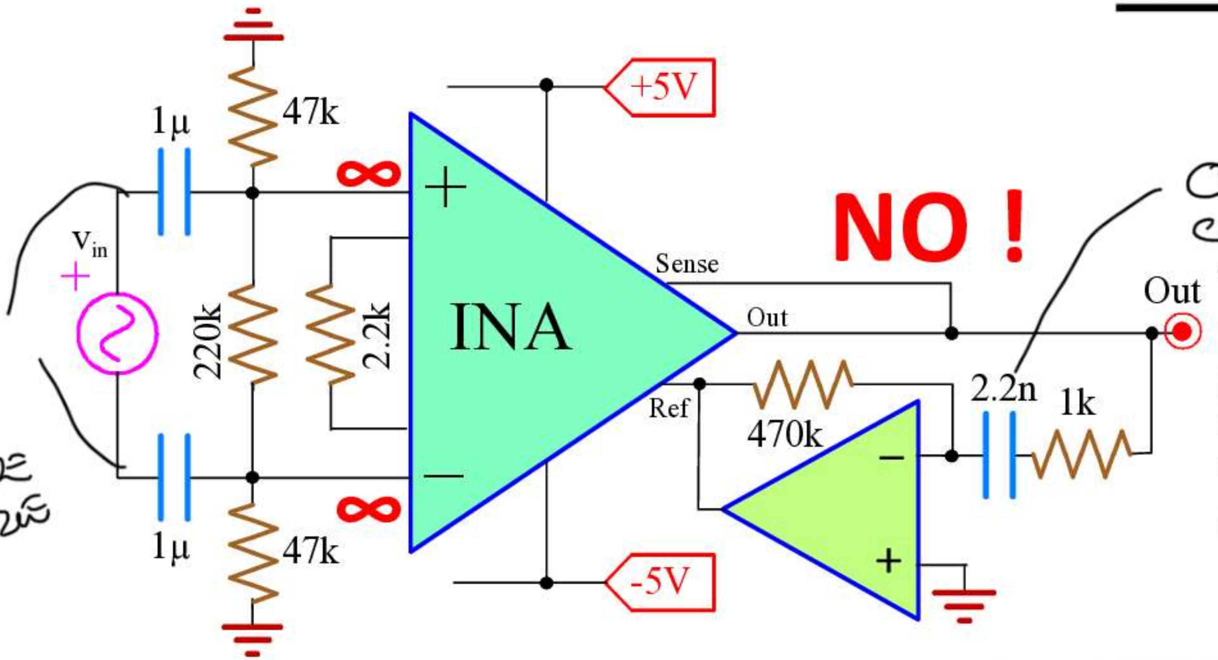
How to compute **poles**





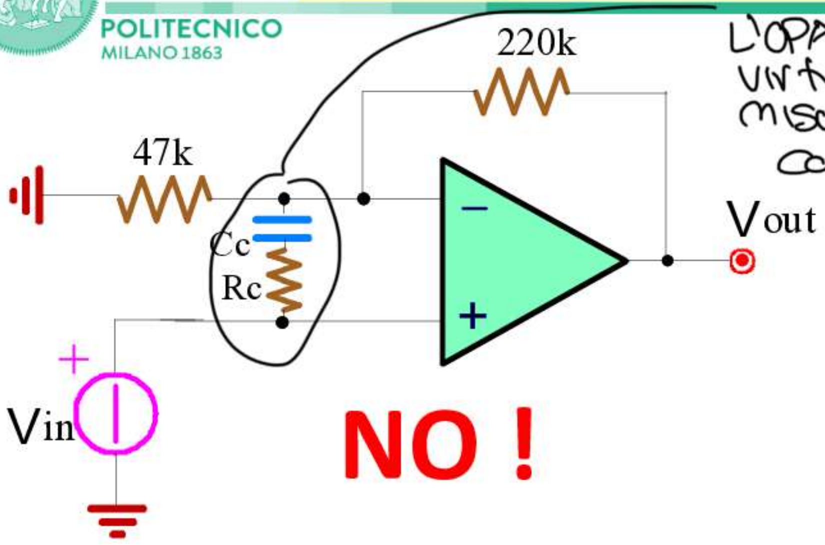


CONSIDERO COME UN SINGOLO CONDENSATORE (CONTO LA SERIE DEI 2)



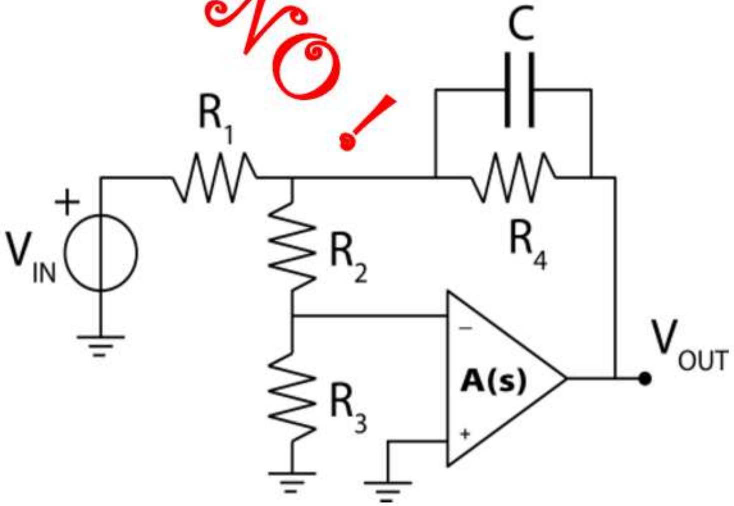
OGNI VOLTA CHE UN CONDENSATORE TOCCA UN NODO DI FEEDBACK ALLORA NON POSSIAMO CALCOLARE IL POLO IN MODO EASY

BEWARE OF FEEDBACK !

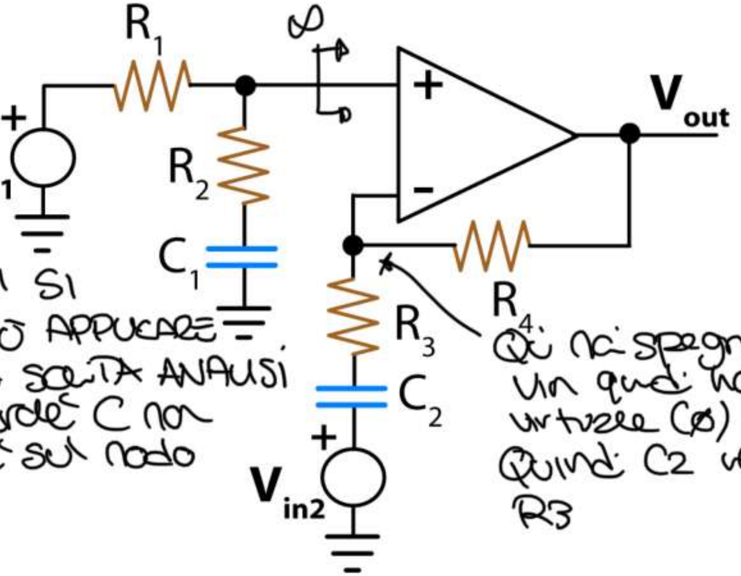


NO !

L'OPAMP cerca di fare tutto per tenere la terra virtuale perciò se tolgo il condensatore per misurare la resistenza vedo che tutta la caduta di tensione cade su Rc, Allora $V_c = R_c i_c \rightarrow R_{eq} = R_c$

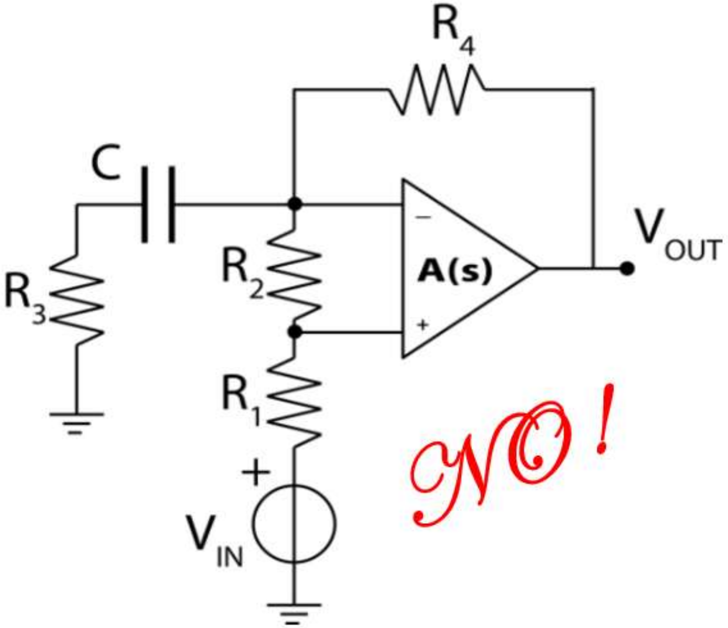


NO !

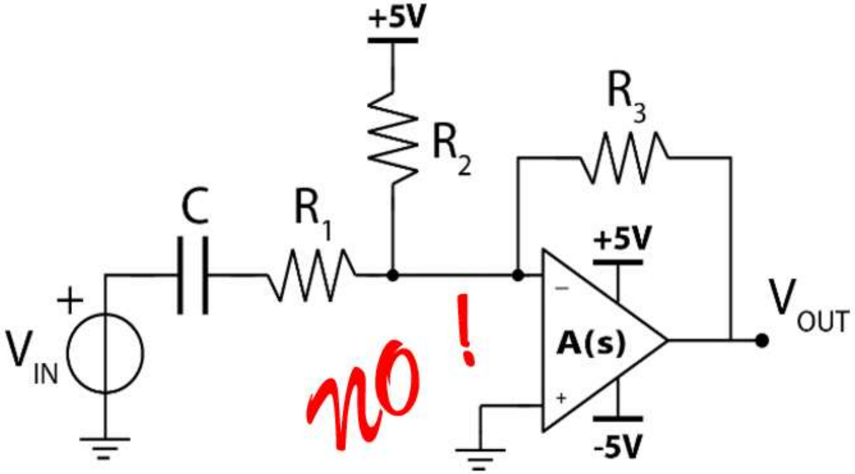


QUI SI PUO' APPLICARE LA SOLITA ANALISI PERCHE' C NON C'E SUL NODO

Qui ci spegniamo Vin quindi ho terra virtuale (∅) Quindi C2 vede solo R3



NO !



NO !

How to compute zeros – direct way

Switch off all generators (**V=0 is a short-circuit**, while **I=0 is an open-circuit**) **apart from the Input**

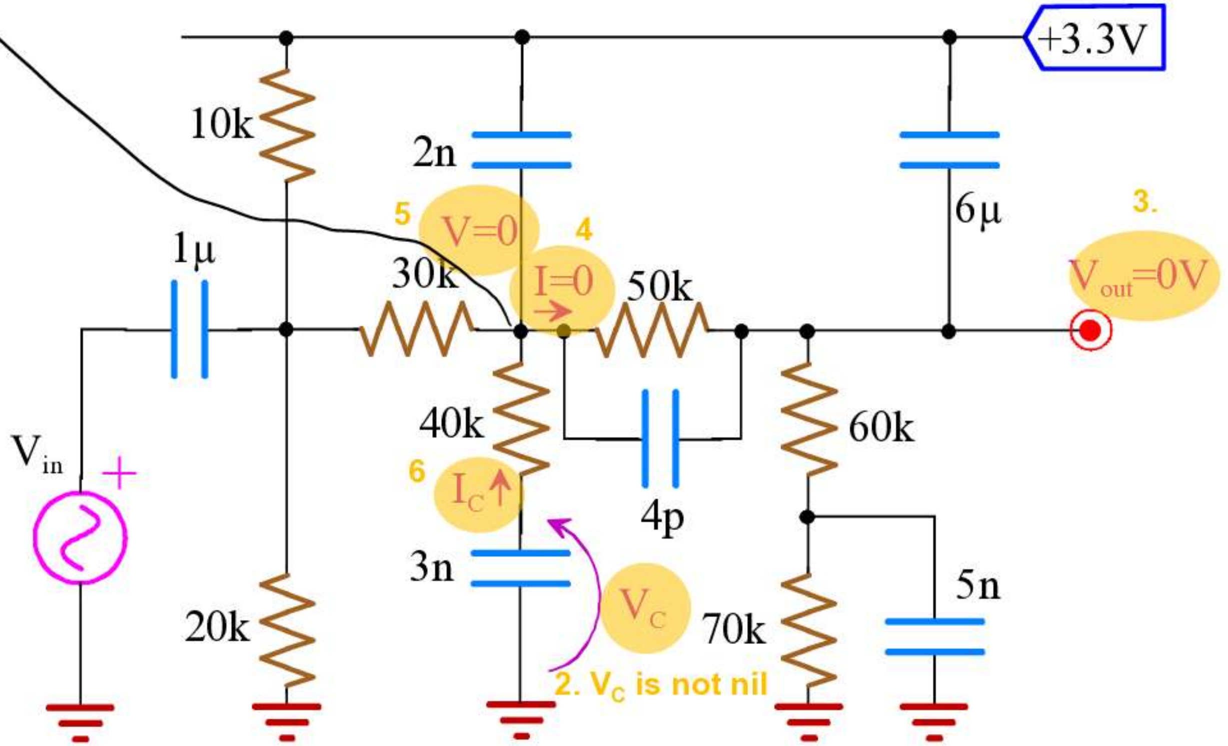
1. Apply a generic (NOT NIL) signal to the actual Input

2. Pretend to have a generic signal $V_C(t)$ and $I_C(t)$ on the C under test

3. Check if the Output can indeed be NIL anyhow

Questo nodo è a terra visto che Vout è a terra allora la caduta su Vc deve cadere interamente su R40k

Noi supponiamo Vout = ∅, quindi corrente a ∅ nel nodo
Poi supponiamo una tensione sul condensatore e vediamo che giro di cadute di tensione deve fare la corrente per avere Vout=∅



7

$$I_C = -\frac{V_C(s)}{1/sC} = \frac{V_R(s)}{R} = \frac{V_C(s)}{R}$$

8

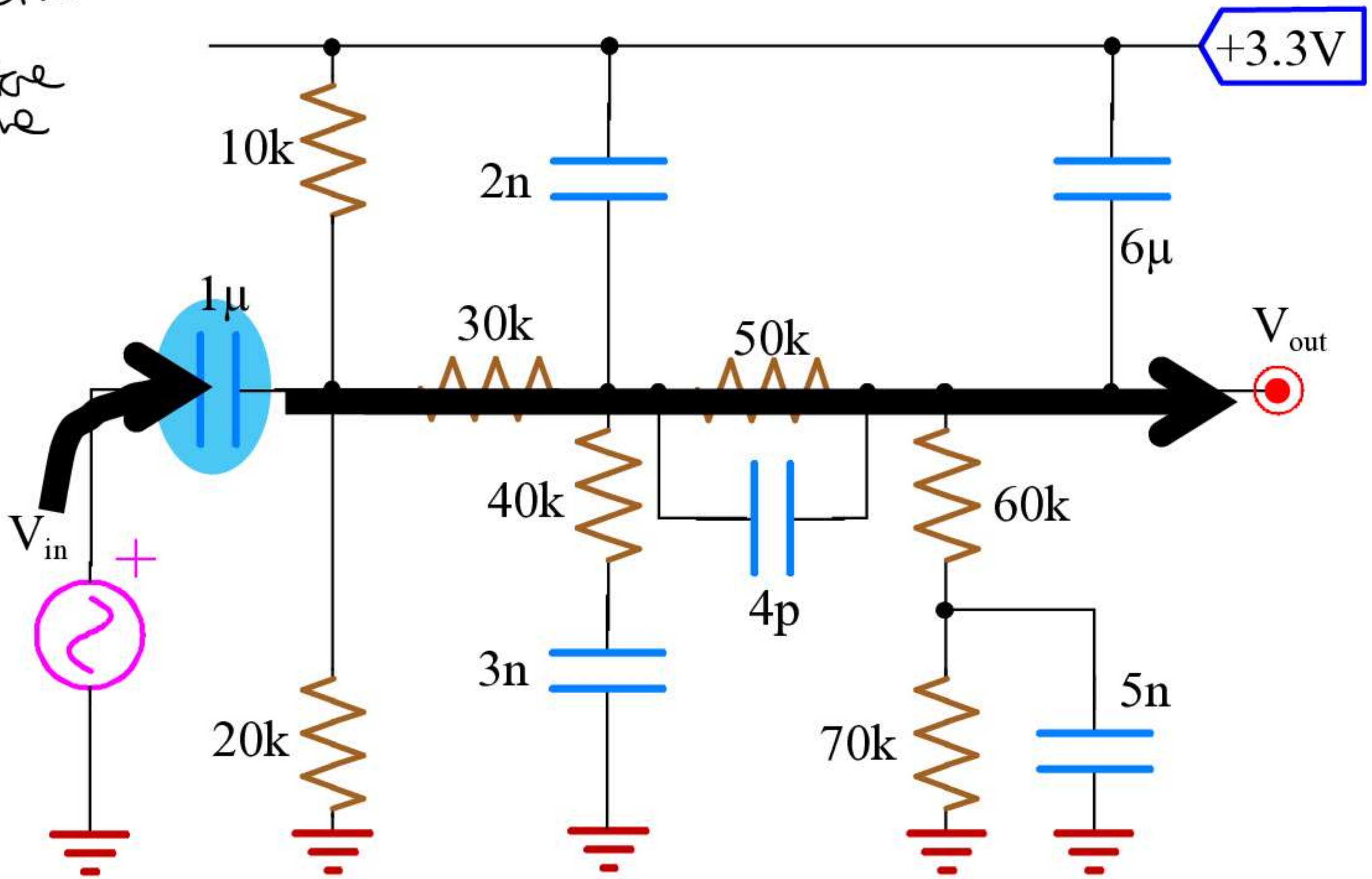
$$s = \text{zero} = -\frac{1}{R \cdot C}$$

$$f_{zero} = \frac{1}{2\pi \cdot R \cdot C}$$

A Capacitor **along the signal path**: a zero at the origin

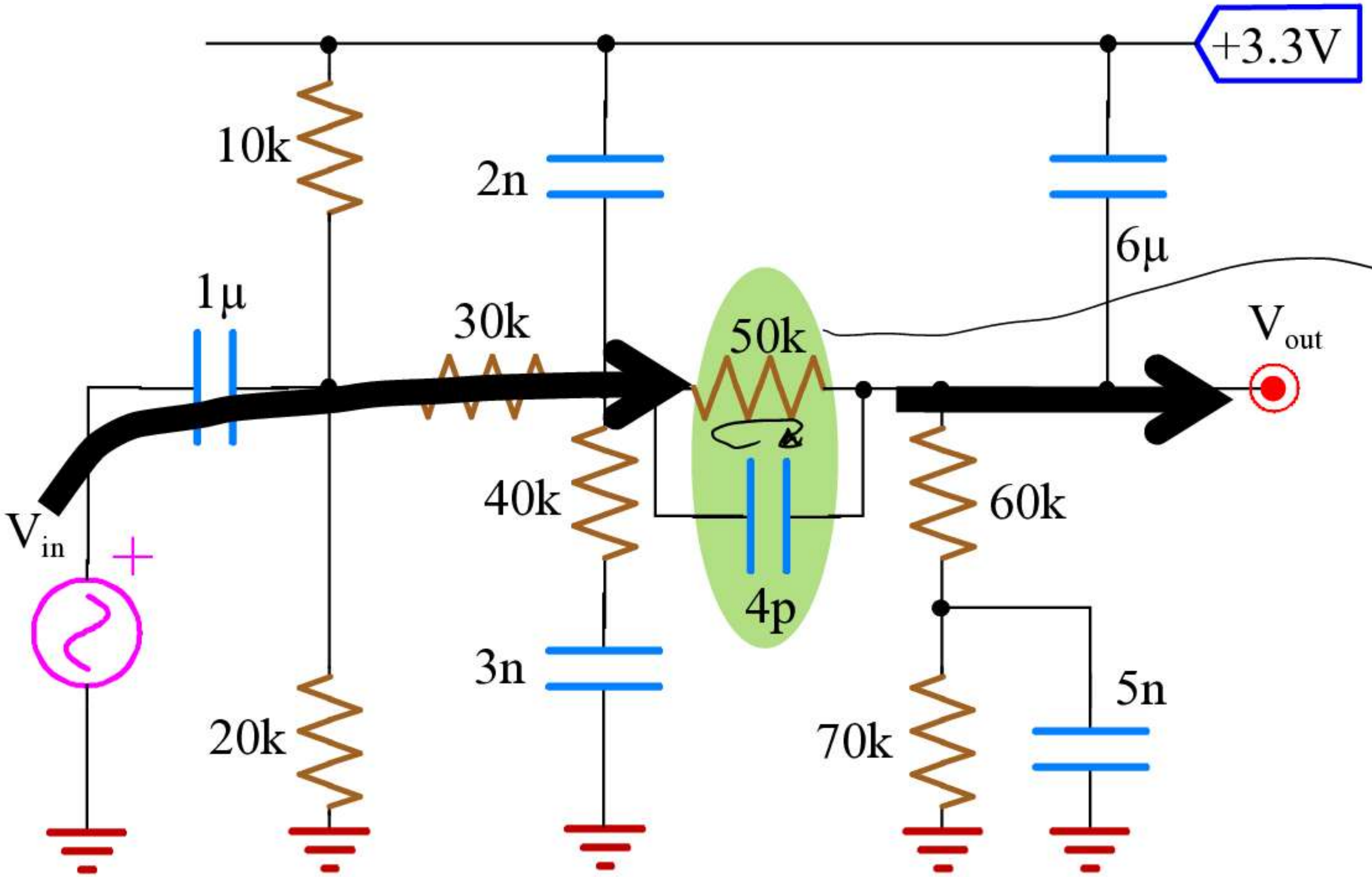
Quando abbiamo dei condensatori nel path principale, allora, se ho 1 solo condensatore ho uno zero nell'origine

$$f_{zero} = 0$$



How to compute zeros – most common cases

An **RC-shunt along the signal path**: a zero at finite frequency

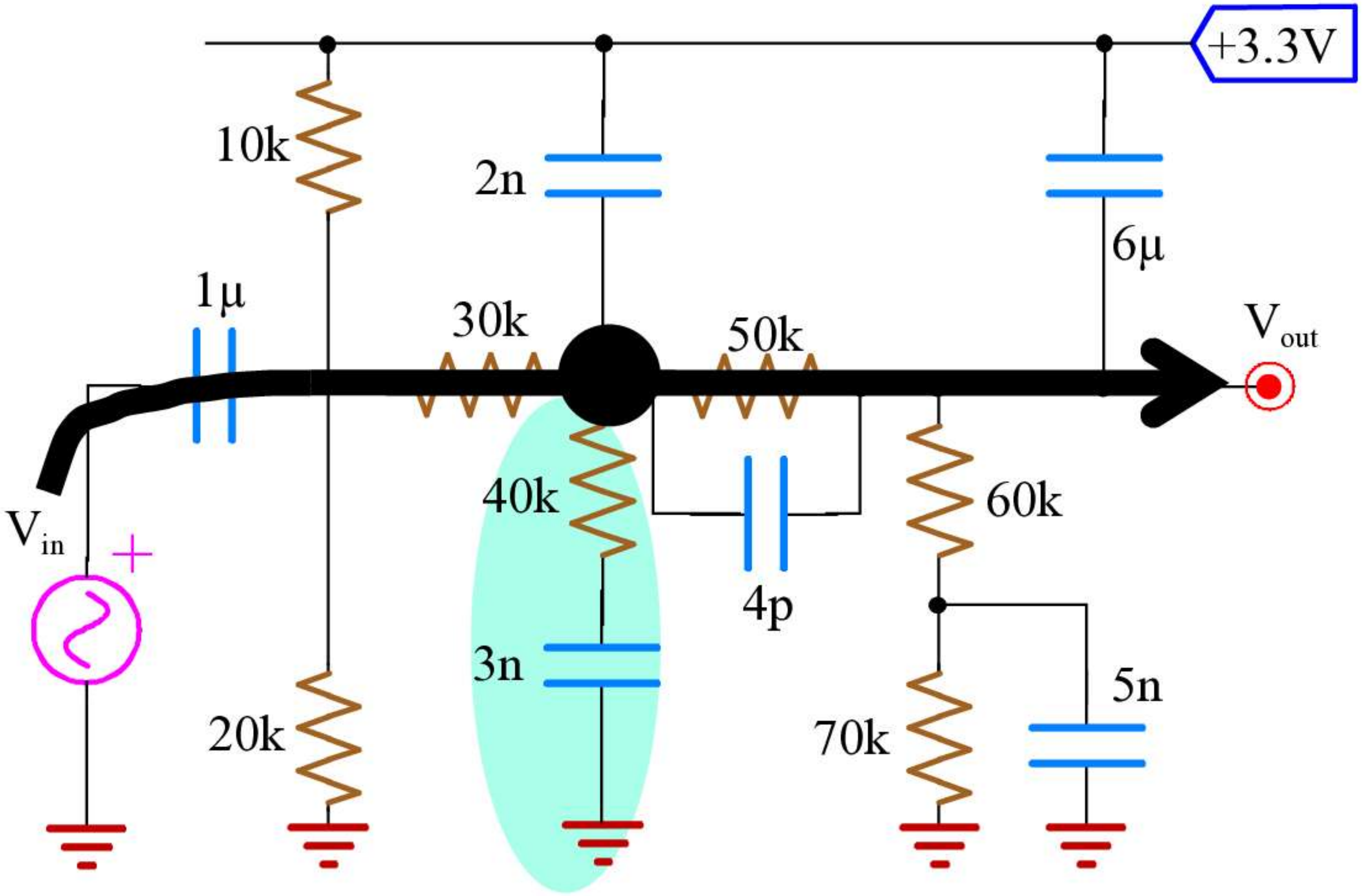


In questo caso
so che è
questo

$$f_{zero} = \frac{1}{2\pi \cdot R \cdot C}$$

How to compute zeros – most common cases

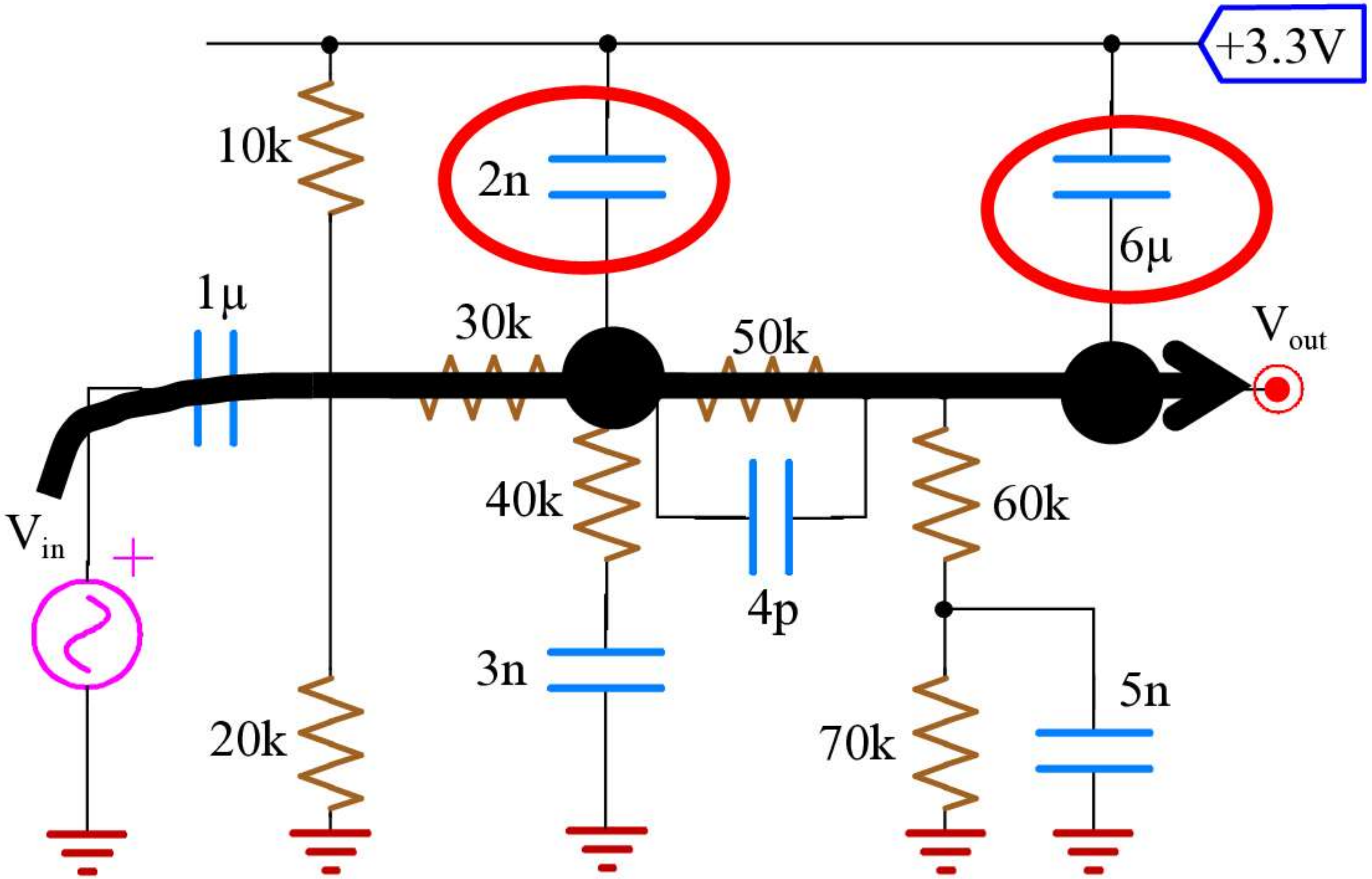
An **RC-series hanging at a node** along the signal path: a finite zero



$$f_{zero} = \frac{1}{2\pi \cdot R \cdot C}$$

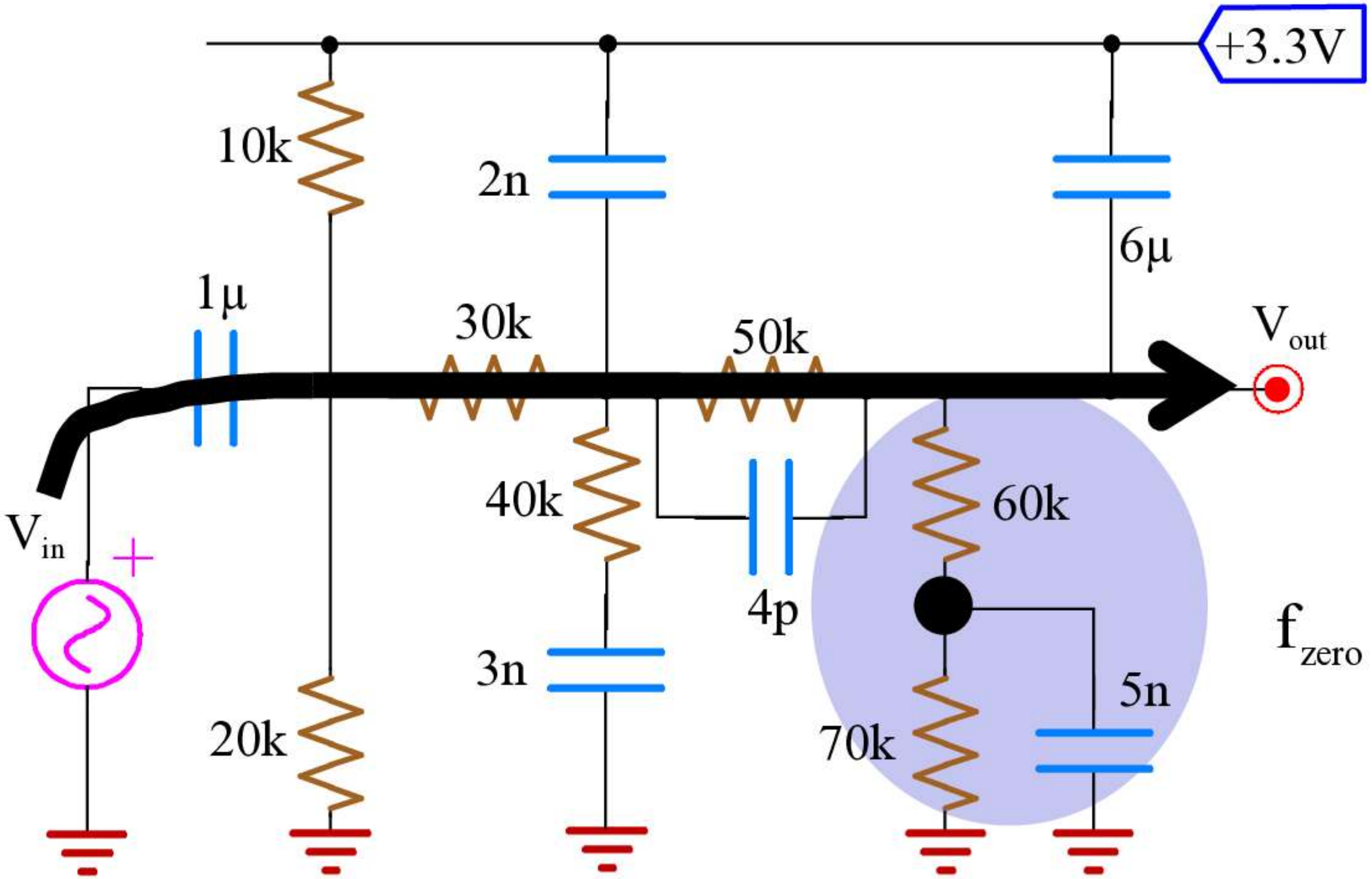
How to compute zeros – most common cases

A Capacitor hanging at a node along the signal path: NO ZERO



How to compute zeros – most common cases

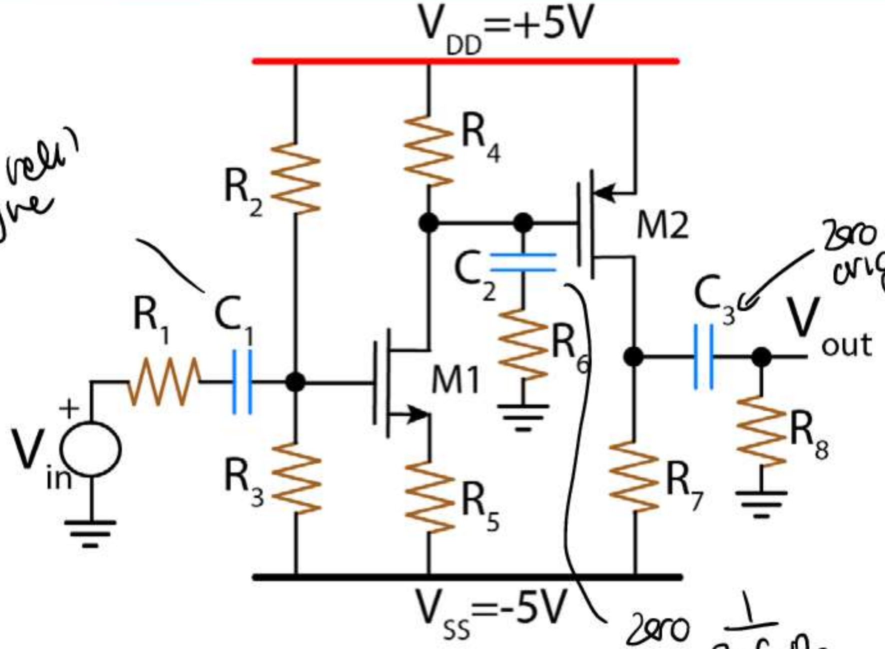
A **Capacitor hanging at a node off the signal path**: a finite zero



$$f_{zero} = \frac{1}{2\pi \cdot (60k // 70k) \cdot C}$$

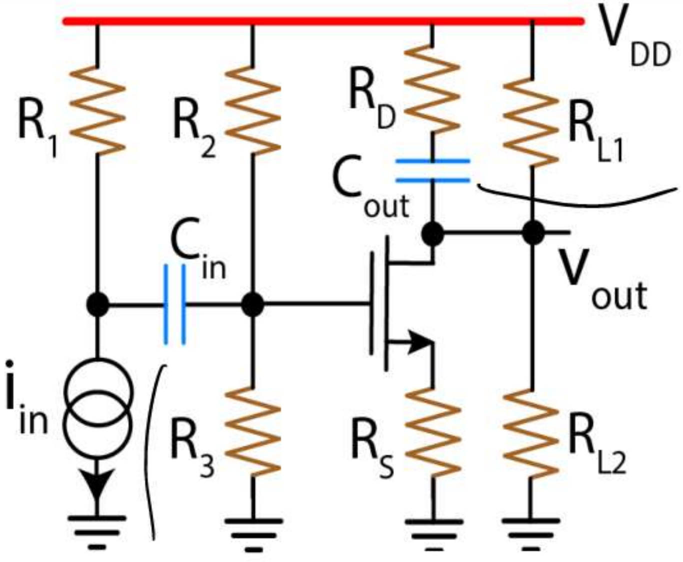
How to compute zeros

zero nell' origine



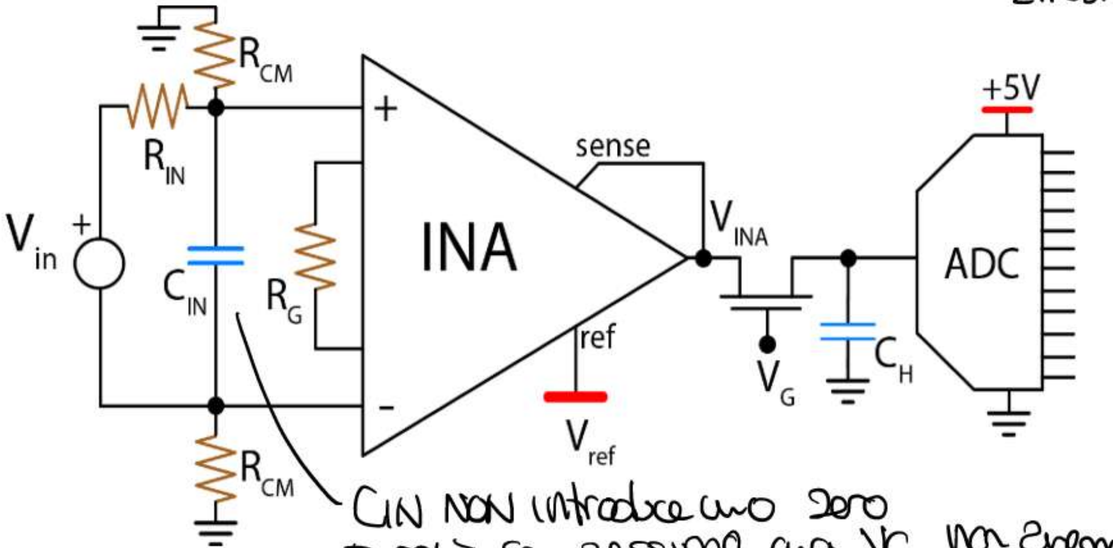
zero nell' origine

zero $\frac{1}{2\pi C_2 R_6}$

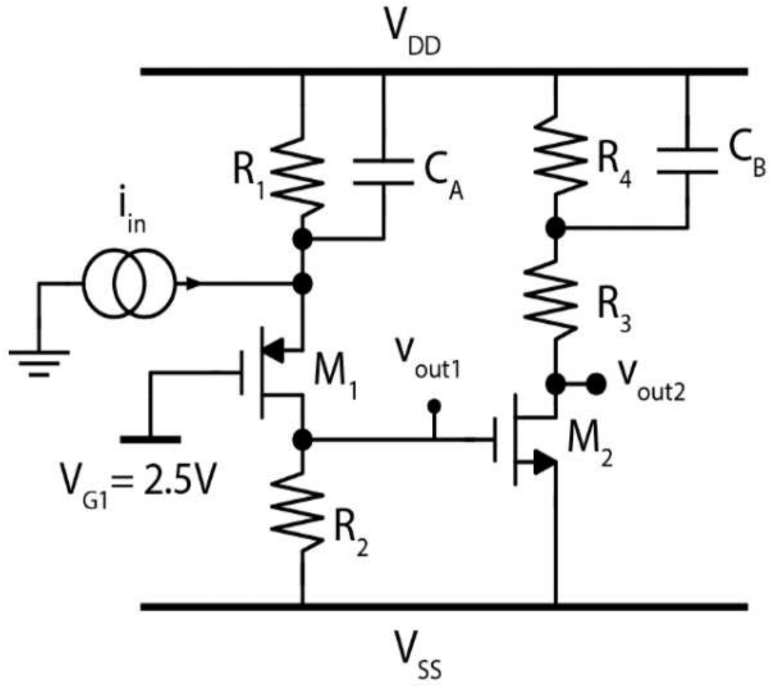


zero dato da Cout RD

zero origine



CIN NON introduce uno zero
perchè se aessimo ava VC non avremmo Vout Ø

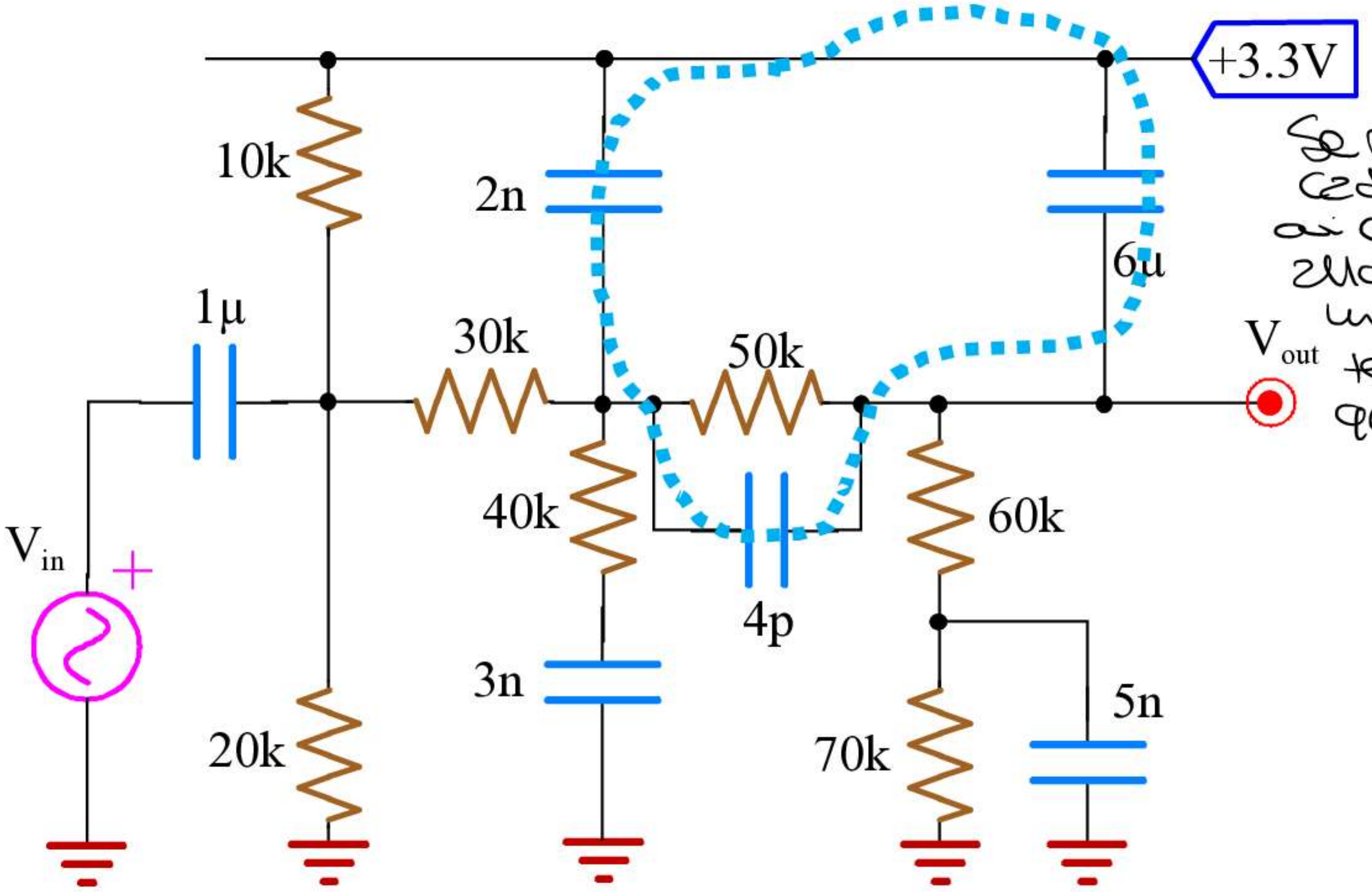


Total number of poles and zeros

CAPACITÀ INTERAGENTI

In conclusion, 4 zeros and 6 poles ?

Instead no… just 5 poles, because of close «*dependency*» of some !



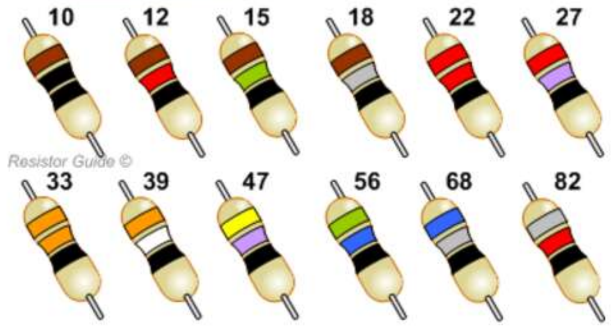
Se mettiamo una caduta di tensione ai capi di 2 condensatori allora questi impongono una ddp anche sul terzo e quindi sono interagenti

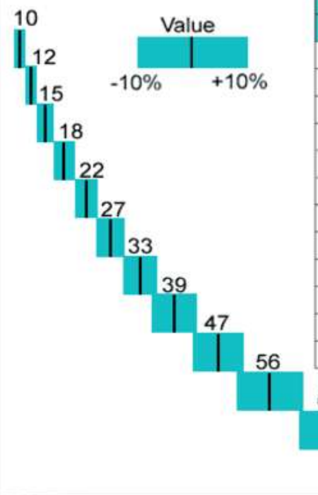
Resistors

Values: $0.1\Omega \div 4.7M\Omega$

Tolerances: 10% ÷ 1%

Power ratings: 1/8, ¼, ½, 1, 2, 5, 10W





E12 Series +/- 10%		
Min	Value	Max
9.0	10	11.0
10.8	12	13.2
13.5	15	16.5
16.2	18	19.8
19.8	22	24.2
24.3	27	29.7
29.7	33	36.3
35.1	39	42.9
42.3	47	51.7
50.4	56	61.6
61.2	68	74.8
73.8	82	90.2

	Colour coding									
anello										
1°	-	1	2	3	4	5	6	7	8	9
2°	0	1	2	3	4	5	6	7	8	9
3°	-	0	00	000	0000	00000	000000	0000000	00000000	000000000
4°										

Preferred values:

10%: 10 12 15 18 22 27 33 39 47 56 68 82

5% e 2%: 11 13 16 20 24 30 36 43 51 62 75 91

1%: 100 102 105 107 110 113 115 118 …

Resistors

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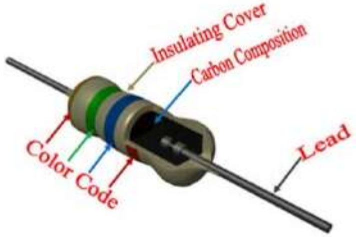
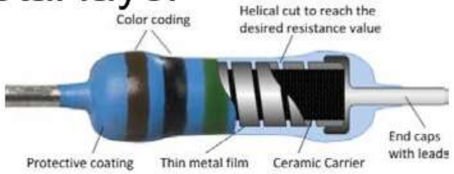
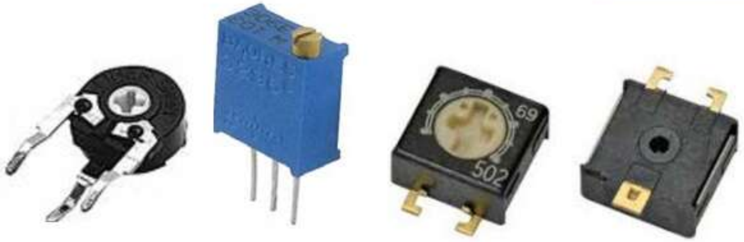
Technology: wire  mould 

metal layer 

Package: through-hole   SMD, Sourface Mounting Device 

Variable: potentiometer  trimmer 

Sensors: photoR  thermoR  …

Capacitors

Values: 1pF ÷ 1’000µF

Asian coding:	pF	“104”=100’000pF=100nF
American coding:	pF starts with figure; µF with “.”	“1.8”=1.8pF “0.0012”=1.2nF
European coding:	pF starts with “.”; nF with “n”; µF with “u”	“1p5”=1.5pF “n15”=0.15nF “u1”=0.1µF

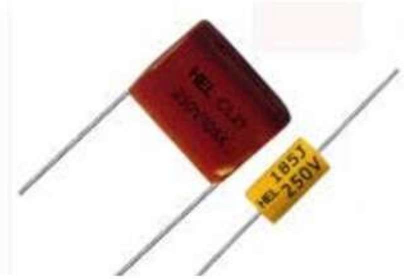
Tolerance: 20% ÷ 5% “M” 20% “K” 10% “J” 5%

Voltage ratings: 5V ÷ 400V “104M100” = 100nF 20% $100V_{max}$

Capacitors

Technology: ceramic 

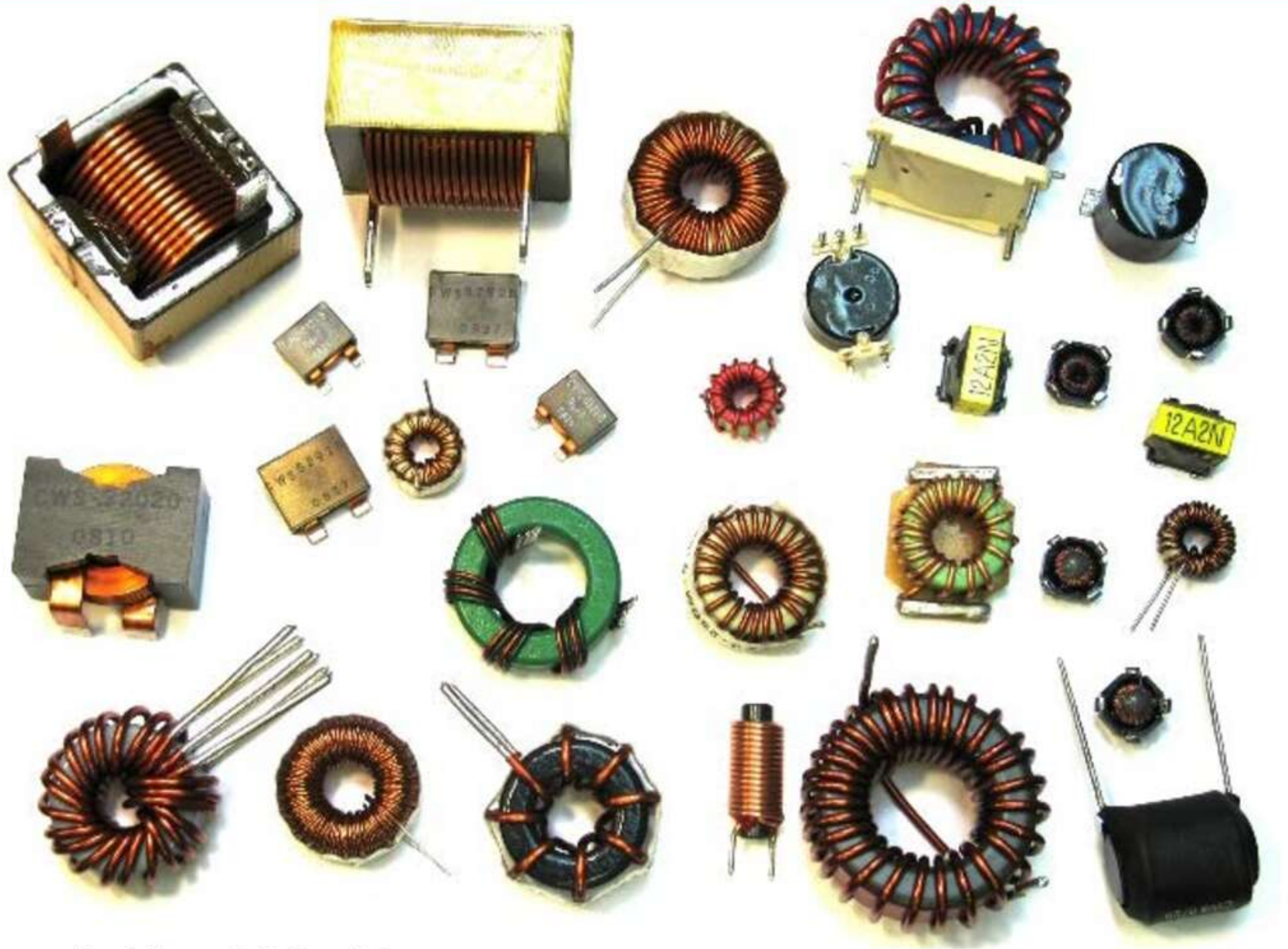
electrolithic 
tantalum 

Package: through-hole 
SMD 

Variable: open air 
mica 
SMD 
varicap 

Sensors: weight
humidity 
touch 
…

Inductors



Values: 1nH ÷ 100mH

Tolerances: 20% ÷ 5%

Current ratings: 1mA ÷ 1A

Inductors

Technology:

coil 

transformer 

Package:

through-hole 

SMD 

Variable:

Sensors:

proxi 

magnetic fields

…