

Lezione 35

Codici numerici

$$G = \begin{bmatrix} G_1 & 0 & 0 & \dots \\ 0 & G_2 & 0 & \dots \\ 0 & 0 & G_3 & \dots \\ \dots & \dots & \dots & \dots \end{bmatrix}; E_0 = \begin{bmatrix} E_{01} \\ E_{02} \\ E_{03} \\ \dots \end{bmatrix}; I_0 = \begin{bmatrix} I_{01} \\ I_{02} \\ I_{03} \\ \dots \end{bmatrix}.$$

$$AI = -AI_0 + AGA^T E - AGE_0 = 0.$$

$$Y = AGA^T.$$

$$YE = AI_0 - AGE_0 = J_0.$$

Condensatore ed induttore



$$i = C \frac{dv}{dt}$$

$$v(t) = v(t - \Delta t) + \frac{i(t)}{C} \Delta t$$

$$v(t) = k_0 + k_1 i(t)$$



$$v = L \frac{di}{dt}$$

$$i(t) = i(t - \Delta t) + \frac{v(t)}{L} \Delta t$$

$$i(t) = k_0 + k_1 v(t)$$

Codici numerici

$$YE = AI_0 - AGE_0 = J_0.$$

$$Y = AGA^T.$$

Codici numerici

- **Codici numerici per l'analisi dei circuiti;**
- **Reti lineari di grandi dimensioni;**
- **Componenti non lineari;**
- **Grafi complessi con componenti non lineari.**

Codici numerici

- **SPICE ;**
- **Simulation Program with Integrated Circuit Emphasis;**
- **Università della California Berkeley (1975);**
- **Versioni anche per PC (1984).**

Codici numerici

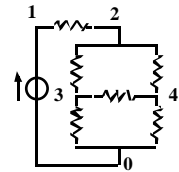
- Pspice, Hspice, Spectre, Eldo....
- Microsim Corporation;
- Orcad, Cadence.....;
- La fortuna di SPICE;

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SPICE (d.c. 1)

PONTE 1
*CIRCUITO RESISTIVO IN CONTINUA

```
R1 2 3 10
R2 2 4 2
R3 3 4 5
R4 3 0 5
R5 4 0 1
R6 1 2 2
V0 1 0 2
.END
```



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SPICE (d.c. 2)

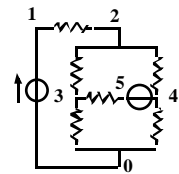
F	femto	1E-15
P	pico	1E-12
N	nano	1E-9
U	micro	1E-6
M	milli	1E-3
K	kilo	1E+3
MEG	mega	1E+6
G	giga	1E+9
T	tera	1E+12

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SPICE (d.c. 3)

PONTE 2
*CIRCUITO RESISTIVO IN CONTINUA

```
R1 2 3 10
R2 2 4 2
R3 3 5 5
VA 5 4 0
R4 3 0 5
R5 4 0 1
R6 1 2 2
V0 1 0 2
.END
```

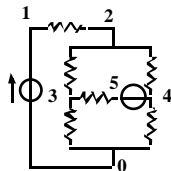


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SPICE (d.c. 4)

PONTE 3
*CIRCUITO RESISTIVO IN CONTINUA

```
R1 2 3 10
R2 2 4 2
R3 3 5 5
VA 5 4 0
R4 3 0 5
R5 4 0 1
R6 1 2 2
V0 1 0 2
.DC V0 2 2 1
.PRINT DC V(2,3) V(3,4) I(R2)
.END
```

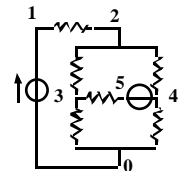


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SPICE (d.c. 5)

PONTE 4
*CIRCUITO RESISTIVO IN CONTINUA

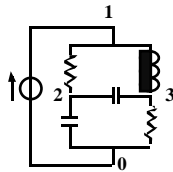
```
R1 2 3 10
R2 2 4 2
R4 3 0 5
R5 4 0 1
R6 1 2 2
V0 1 0 2
.TF V(3,4) V0
.END
```



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SPICE (a.c. 1)

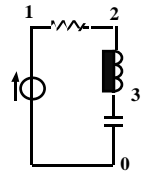
```
AC 1
*PONTE IN C.A.
V0 1 0 AC 141.42
R1 1 2 5
L2 1 3 0.1
R3 3 0 10
C4 2 0 2E-3
.AC LIN 1 15.91 15.91
.PRINT AC Vm(2) Vp(2) Vr(2) Vi(2)
.PRINT AC Vm(3) Vp(3) Vr(3) Vi(3)
.END
```



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SPICE (a.c. 2)

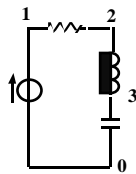
```
AC 2
*CIRCUITO RLC, ANALISI ARMONICA
V0 1 0 AC 1.41
R1 1 2 5
L2 2 3 0.01
C3 3 0 1E-6
.AC LIN 51 1K 2K
.PLOT AC I(V0)
.PROBE
.END
```



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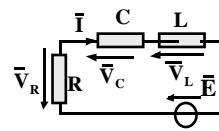
SPICE (a.c. 3)

```
AC 3
*CIRCUITO RLC, ANALISI ARMONICA
V0 1 0 AC 1.41
R1 1 2 5
L2 2 3 0.01
C3 3 0 1E-6
.AC LIN 301 1K 2K
.PLOT AC I(V0)
.PROBE
.END
```



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Il circuito risonante



$$\bar{E} = R\bar{I} + j\omega L\bar{I} - j\frac{1}{\omega C}\bar{I}$$

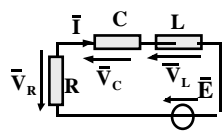
$$\bar{I} = \frac{\bar{E}}{R + j\omega L - j\frac{1}{\omega C}}$$

Al variare dei parametri L, R e C

$$\omega L - \frac{1}{\omega C} \quad \omega = \frac{1}{\sqrt{LC}}$$

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Il circuito risonante



$$\bar{E} = R\bar{I} + j\omega L\bar{I} - j\frac{1}{\omega C}\bar{I}$$

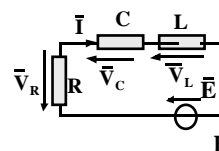
$$\bar{I} = \frac{\bar{E}}{R + j\omega L - j\frac{1}{\omega C}}$$

Al variare della frequenza del generatore

$$f(\omega/\omega_0) = \frac{RI(\omega)}{E}$$

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La curva di risonanza



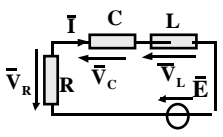
$$\bar{E} = R\bar{I} + j\omega L\bar{I} - j\frac{1}{\omega C}\bar{I}$$

$$\bar{I} = \frac{\bar{E}}{R + j\omega L - j\frac{1}{\omega C}}$$

$$I = \frac{E}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}}$$

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Il circuito risonante



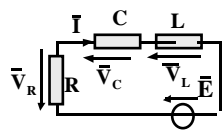
$$\bar{E} = \bar{I} + j\omega L\bar{I} - j\frac{1}{\omega C}\bar{I}$$

$$\bar{I} = \frac{\bar{E}}{R + j\omega L - j\frac{1}{\omega C}}$$

$$f(\omega) = \frac{R}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}}$$

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Il circuito risonante



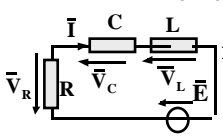
$$f(\omega) = \frac{R}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}}$$

$$Q = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 RC}, \quad \omega_0 = \frac{1}{\sqrt{LC}}$$

$$f\left(\frac{\omega}{\omega_0}\right) = \frac{1}{\sqrt{1 + Q^2 \left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)^2}}$$

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Il circuito risonante



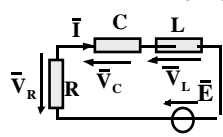
$$f(\omega) = \frac{R}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}}$$

$$Q = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 RC}, \quad x = \frac{\omega}{\omega_0}$$

$$f(x) = \frac{1}{\sqrt{1 + Q^2 \left(x - \frac{1}{x}\right)^2}}$$

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Il circuito risonante

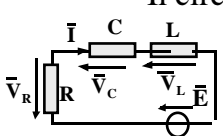


$$f(x) = \frac{1}{\sqrt{1 + Q^2 \left(x - \frac{1}{x}\right)^2}}$$

$$Q = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 RC}, \quad f(x) = \frac{1}{\sqrt{2}} \longrightarrow \frac{1}{1 + Q^2 \left(x - \frac{1}{x}\right)^2} = \frac{1}{2}$$

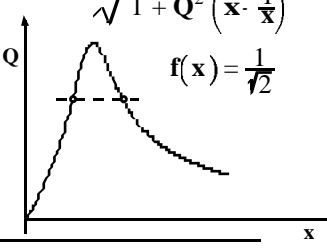
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Il circuito risonante



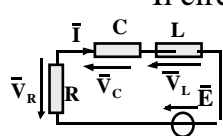
$$f(x) = \frac{1}{\sqrt{1 + Q^2 \left(x - \frac{1}{x}\right)^2}}$$

$$Q = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 RC}, \quad f(x) = \frac{1}{\sqrt{2}}$$

$$\frac{1}{1 + Q^2 \left(x - \frac{1}{x}\right)^2} = \frac{1}{2}$$


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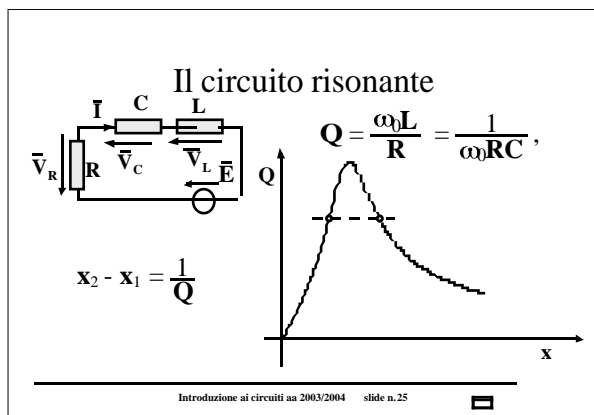
Il circuito risonante



$$Q = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 RC}, \quad Q^2 \left(x - \frac{1}{x}\right)^2 = 1 \quad \left(x - \frac{1}{x}\right) = \pm \frac{1}{Q} \quad x^2 \pm \frac{1}{Q}x - 1 = 0$$

$$x = \pm \frac{1}{2Q} \pm \sqrt{\frac{1}{4Q^2} + 1} \quad x_2 - x_1 = \frac{1}{Q}$$

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Riepilogo della Lezione 35

- Spice;
- Il circuito RLC al variare di ω ;
- La risonanza.

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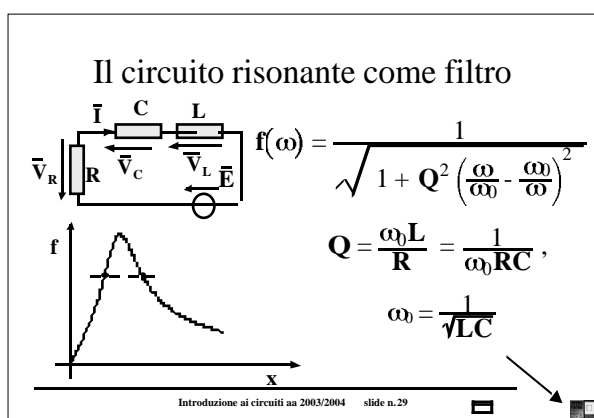
Fine della Lezione 35

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Luciano DeMenna:
1/12/2003

Lezione 36

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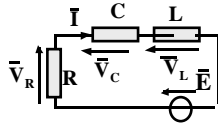


In Laboratorio

Determinare ω_0 e Q !

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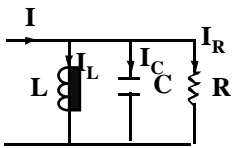
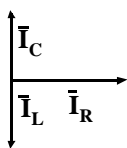
In Laboratorio



Determinare ω_0 e Q!

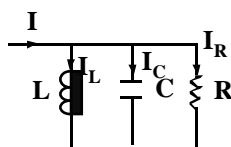
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Risonanza parallelo

Introduzione ai circuiti aa 2003/2004 slide n.32

Risonanza parallelo

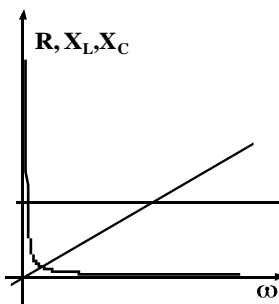


$$Y = \frac{1}{R} - j \frac{1}{\omega L} + j \omega C$$

$$f(\frac{\omega}{\omega_0}) = \frac{I_R}{I}$$

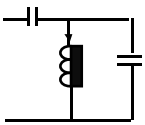
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I bipoli fondamentali in funzione di ω

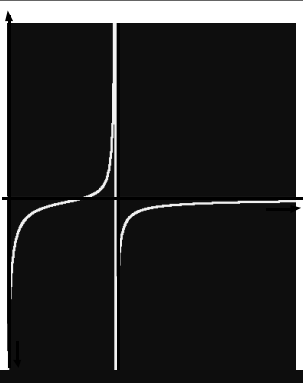


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Risonanza



Teorema di Foster



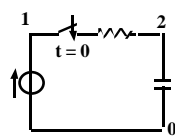
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SPICE (t.1)

```

Tran 1
*CIRCUITO RC, CARICA DI C
V0 1 0 DC 10
R1 1 2 50
C3 2 0 1E-3 IC=0
.TRAN 0.001 0.5 UIC
.PLOT TRAN V(2)
.PROBE
.END

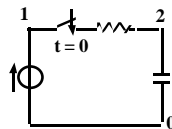
```



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SPICE (t.2)

```
Tran 2
*CIRCUITO RC, CARICA DI C
V0 1 0 DC 10
R1 1 2 50
C3 2 0 1E-3 IC=20
.TRAN 0.001 0.5 UIC
.PROBE
.END
```

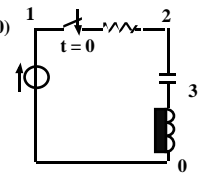


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SPICE (t.3)

```
Tran 3
*CIRCUITO RLC, OSCILLAZIONI
V0 1 0 PWL(0 0 1e-6 10 1000e-6 10)
R1 1 2 20
L2 2 3 10M
C3 3 0 1E-6
.TRAN 1e-3 2e-3
.PROBE
.END

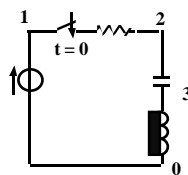
V0 1 0 PWL (T1 V1 <T2 V2 T3 V3.....>)
```



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SPICE (t.4)

```
Tran 3.1
*CIRCUITO RLC, OSCILLAZIONI
V0 1 0 SIN(0 1 3k)
R1 1 2 20
L2 2 3 10M
C3 3 0 1E-6
.TRAN 1e-3 2e-3
.PROBE
.END
```

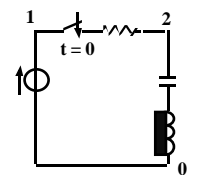


```
V0 1 0 SIN (V0 VA FREQ TD θ PHASE )
```

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SPICE (t.5)

```
Tran 3.2
*CIRCUITO RLC, OSCILLAZIONI
V0 1 0 SIN(0 1 3k)
R1 1 2 20
L2 2 3 10M
C3 3 0 1E-6
.TRAN 1e-3 2e-3 0 1e-5
.PROBE
.END
```



```
.TRAN TSTEP TSTOP <TSTART<TMAX>> <UIC>
```

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Riepilogo della Lezione 36

- Il circuito RLC come filtro;
- RLC parallelo;
- La risonanza in generale;
- Ancora su SPICE;
- Esercizi.

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Fine della Lezione 36

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