Modulo di Compatibilità Elettromagnetica

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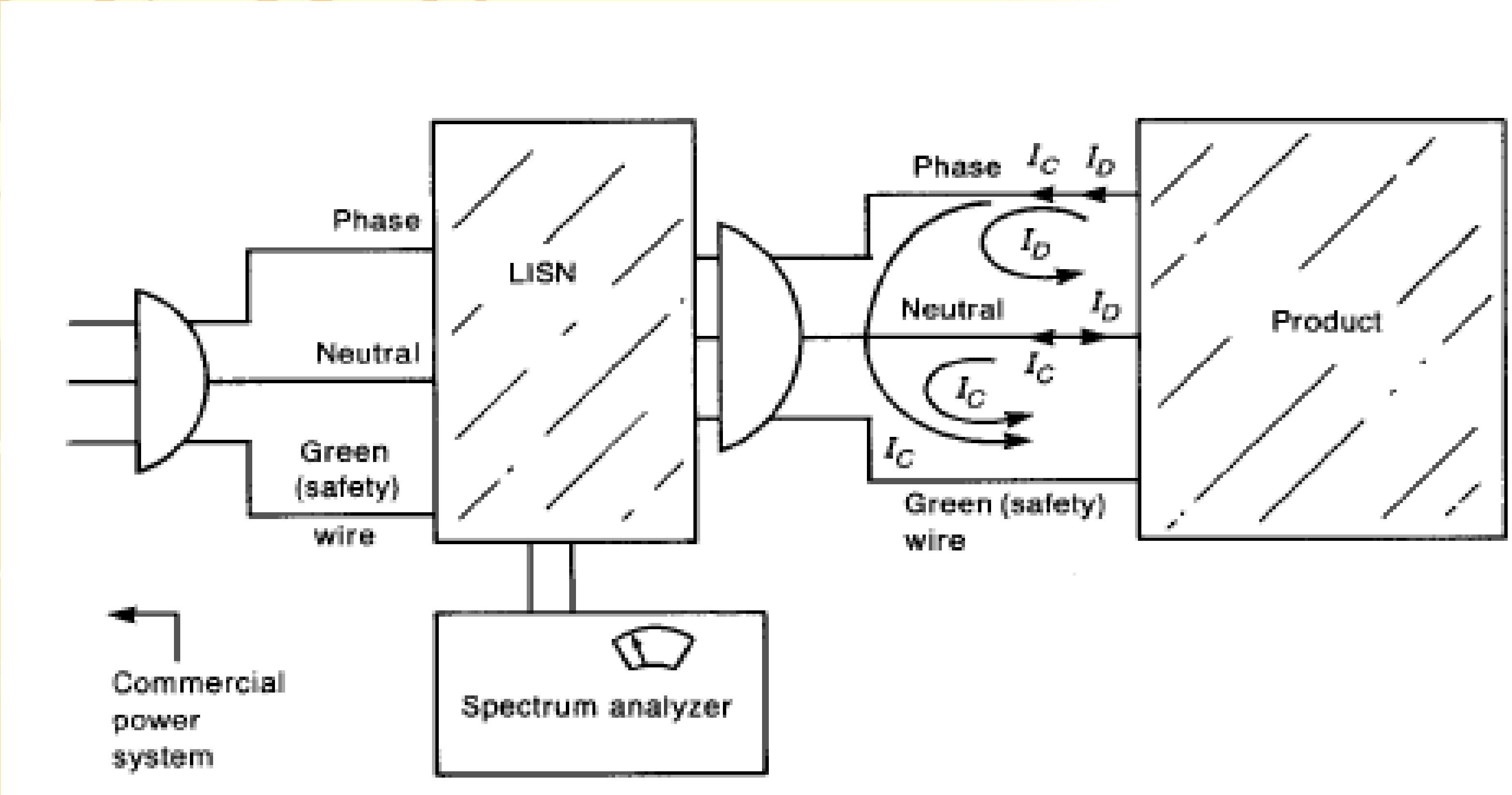
Note sul problema delle emissioni condotte

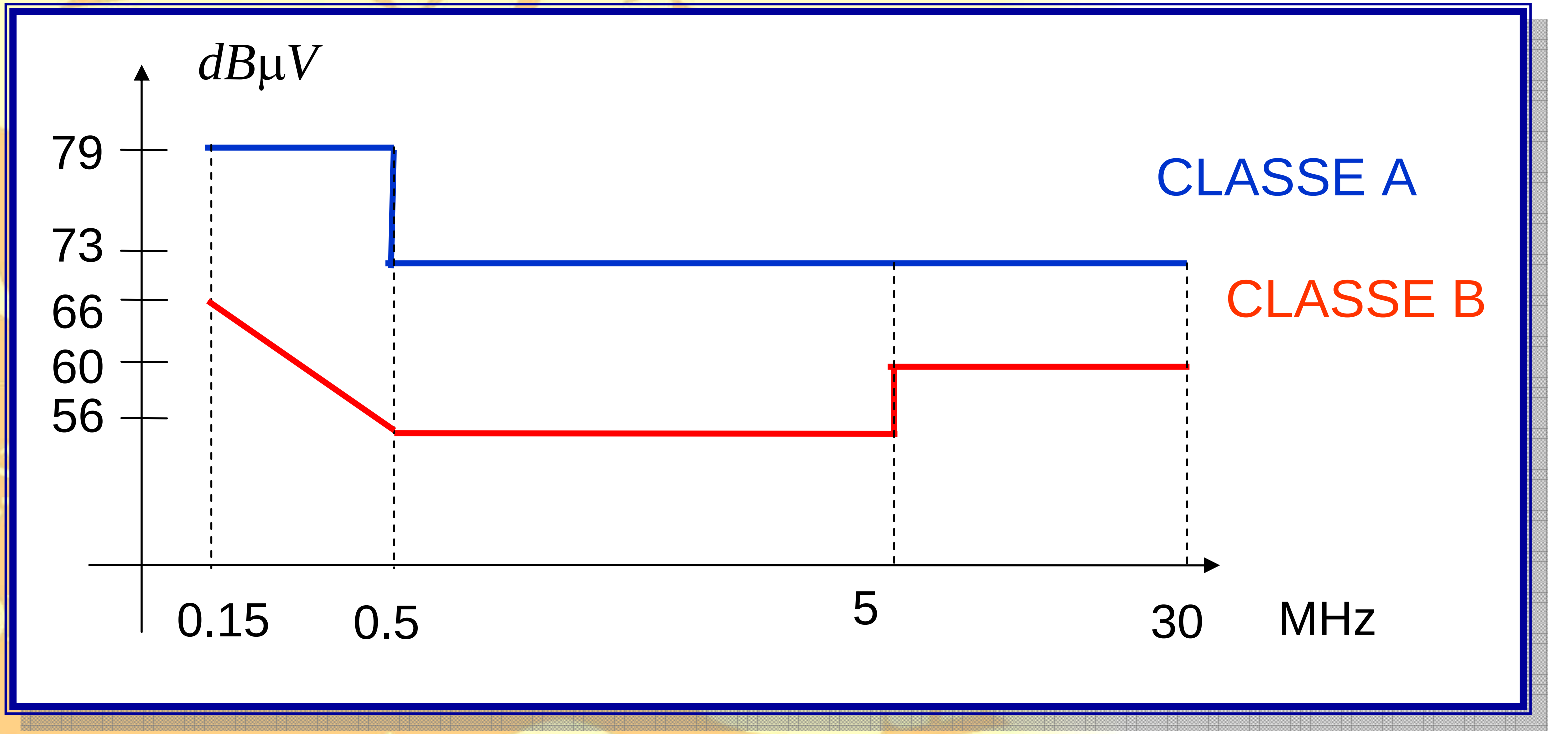
Emissioni condotte: tutti i disturbi che si propagano lungo i cavi di alimentazione e trasmissione

Range previsto dalla normativa: 150 kHz- 30 MHz

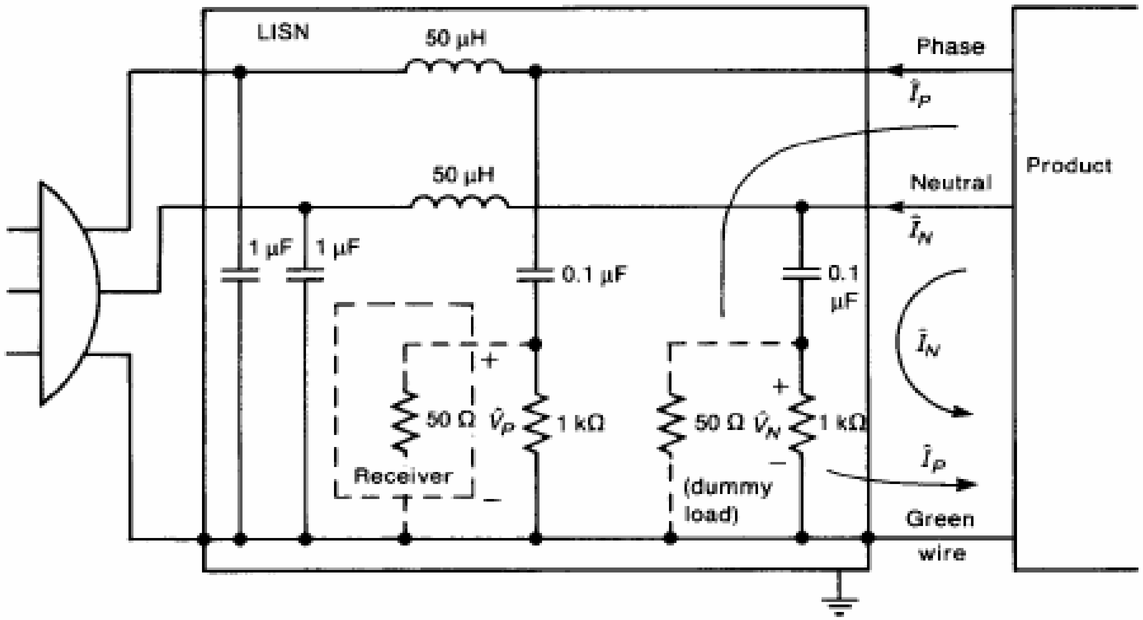
Schema tipo per l’analisi delle emissioni condotte



Maschera-tipo per le emissioni



LISN

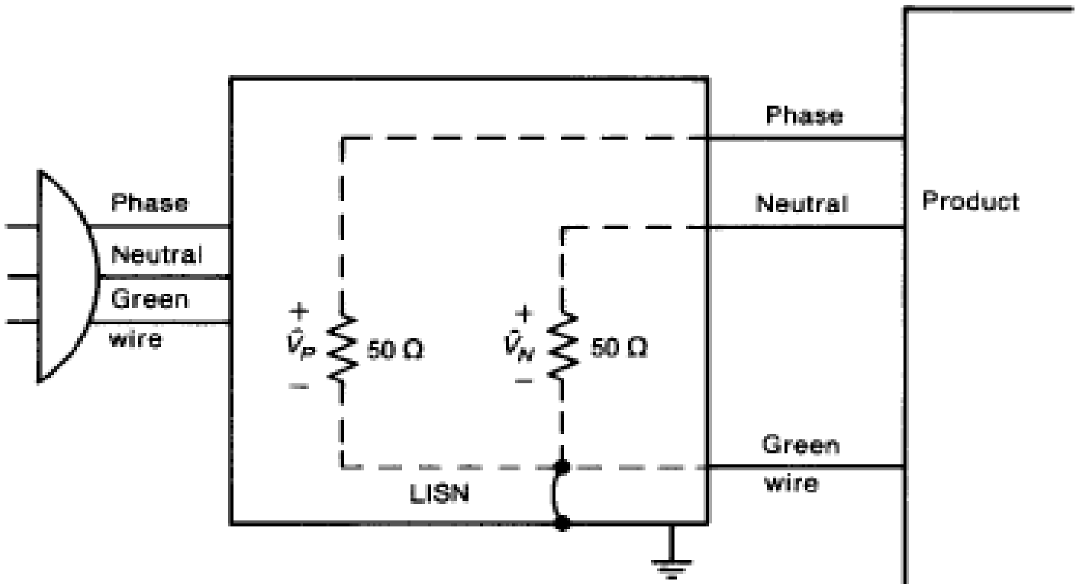


$$\hat{V}_P = 50\hat{I}_P$$

$$\hat{V}_N = 50\hat{I}_N$$

Element	$Z_{150\,\mathrm{kHz}}$	$Z_{30\,\mathrm{MHz}}$
50 µH	47.1 Ω	9424.8 Ω
0.1 µF	10.61 Ω	0.053 Ω
1 µF	1.06 Ω	0.0053 Ω

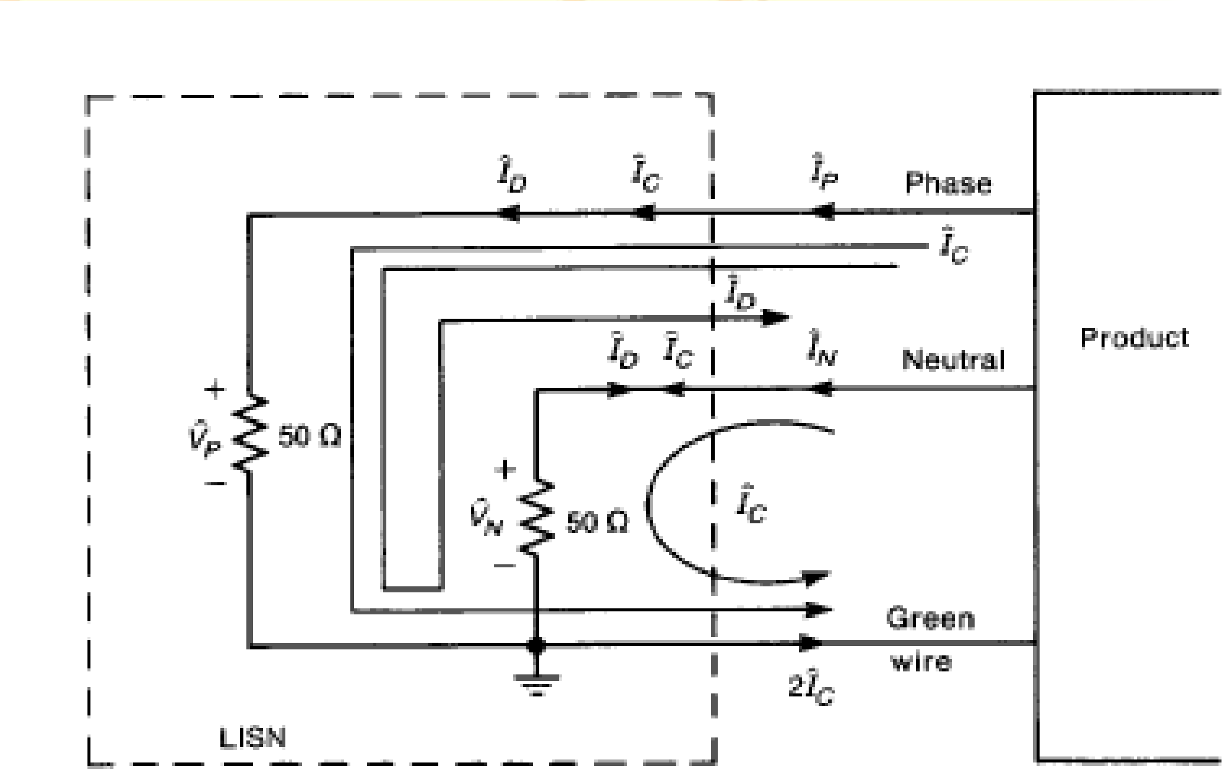
LISN: schema equivalente [150 KHz – 30 MHz]



$$\hat{V}_P = 50\hat{I}_P$$

$$\hat{V}_N = 50\hat{I}_N$$

Emissione condotta: modo comune e differenziale



$$\hat{I}_P = \hat{I}_C + \hat{I}_D$$

$$\hat{I}_N = \hat{I}_C - \hat{I}_D$$

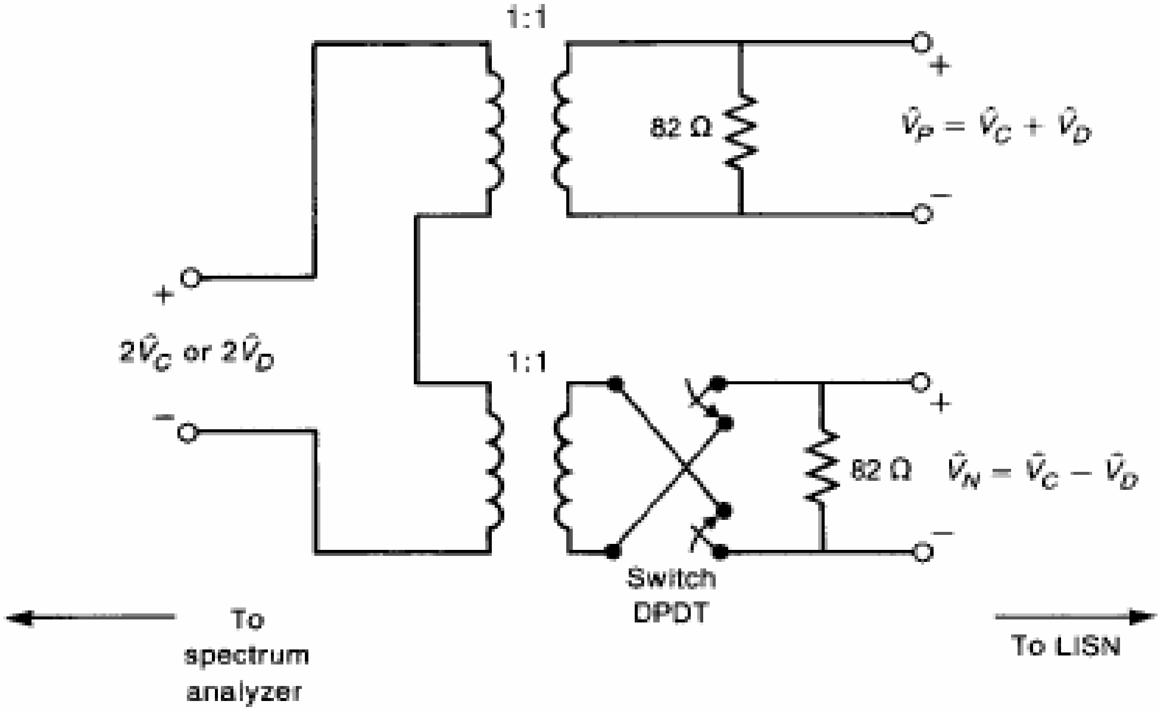
$$\hat{I}_D = \tfrac{1}{2}(\hat{I}_P - \hat{I}_N)$$

$$\hat{I}_C = \tfrac{1}{2}(\hat{I}_P + \hat{I}_N)$$

$$\hat{V}_P = 50(\hat{I}_C + \hat{I}_D)$$

$$\hat{V}_N = 50(\hat{I}_C - \hat{I}_D)$$

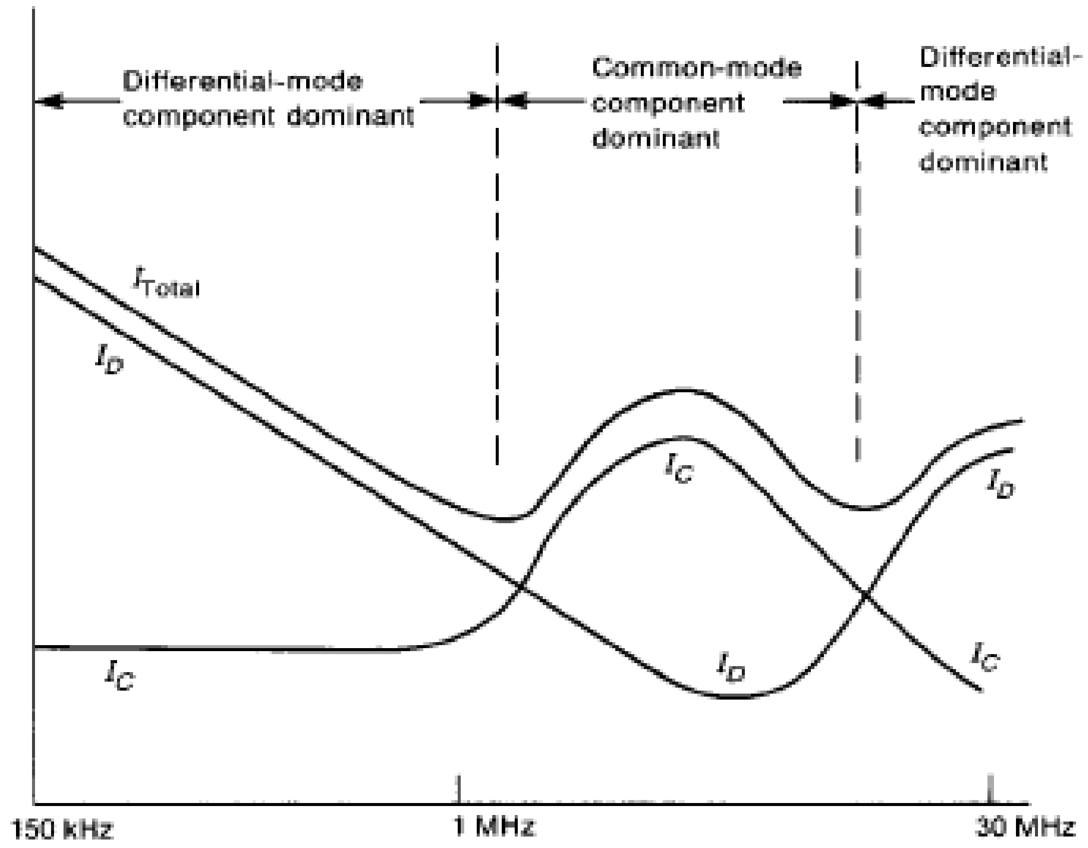
Analisi delle emissioni per CM e DM



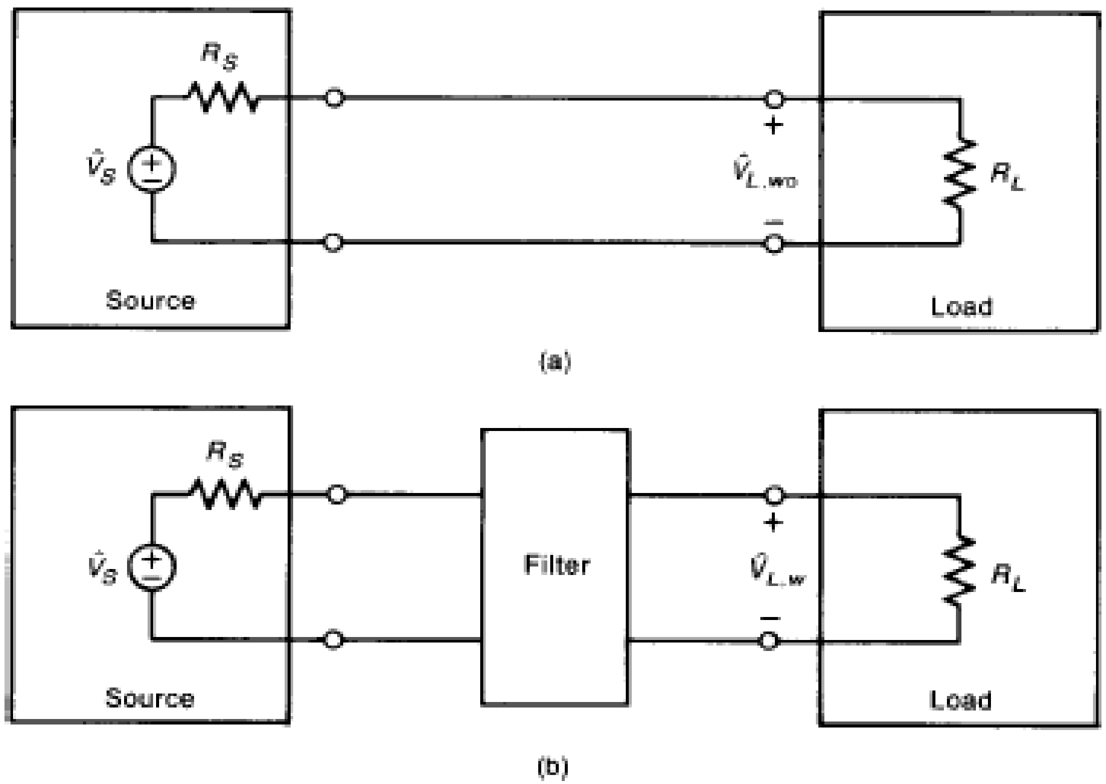
$$\hat{V}_P + \hat{V}_N = 2\hat{V}_C$$

$$\hat{V}_P - \hat{V}_N = 2\hat{V}_D$$

Esempio di analisi delle emissioni per CM e DM



Riduzione delle emissioni condotte: i filtri di alimentazione

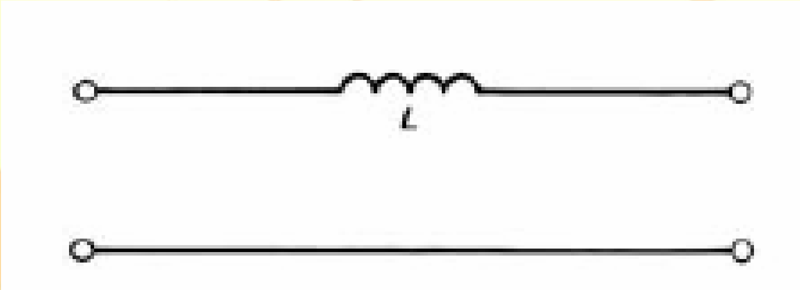


Insertion loss

$$
\begin{aligned}
\mathrm{IL}_{\mathrm{dB}} &= 10\ \log_{10}\left(\frac{P_{L,wo}}{P_{L,w}}\right) \\
&= 10\ \log_{10}\left(\frac{V_{L,wo}^2/R_L}{V_{L,w}^2/R_L}\right) \\
&= 20\ \log_{10}\left(\frac{V_{L,wo}}{V_{L,w}}\right)
\end{aligned}
$$

Riduzione delle emissioni condotte: i filtri di alimentazione

Filtro passa-basso



$$\hat{V}_{L,wo} = \frac{R_L}{R_S + R_L}\hat{V}_S$$

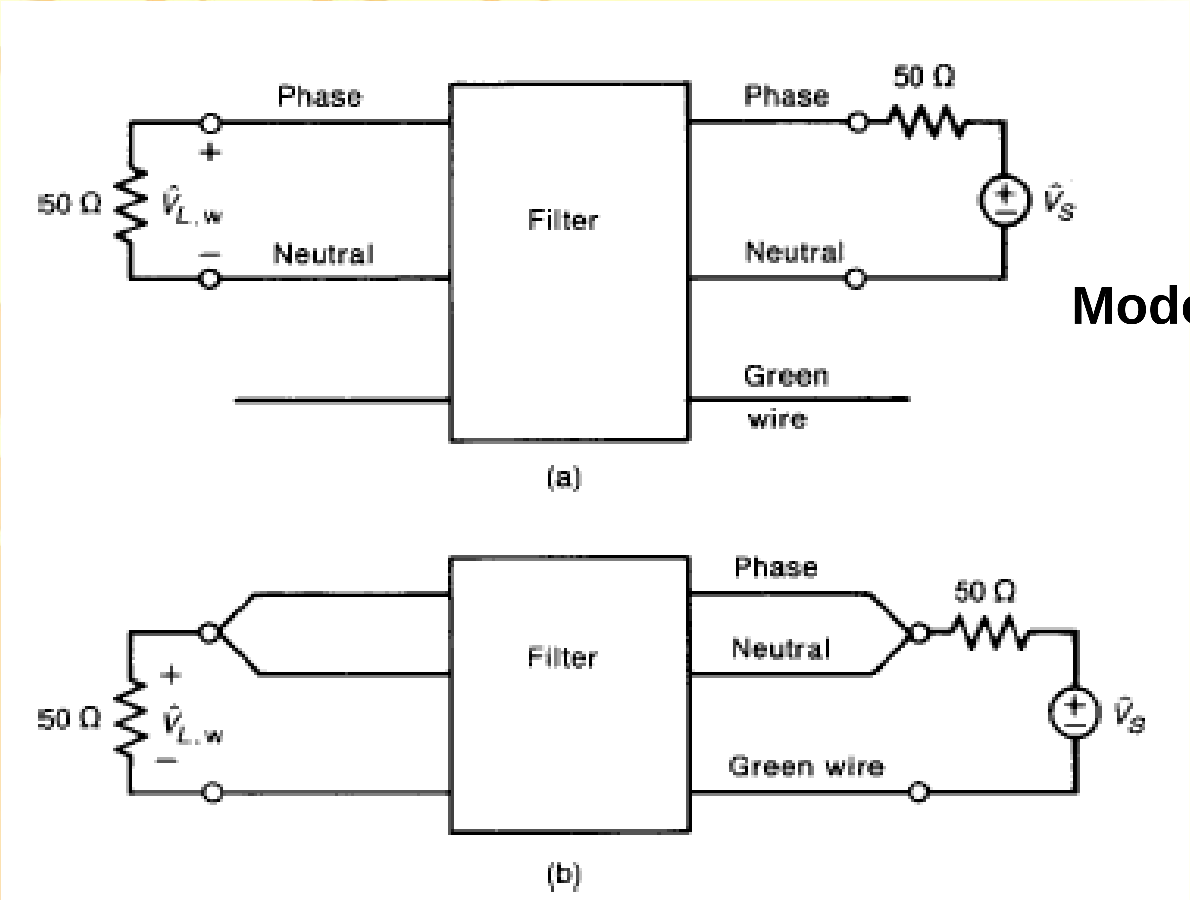
$$\hat{V}_{L,w} = \frac{R_L}{R_S + j\omega L + R_L}\hat{V}_S$$

Insertion loss

$$\begin{aligned}\mathrm{IL} &= 20\log_{10}\left|1 + \frac{j\omega L}{R_S + R_L}\right| \\ &= 20\log_{10}\left[\sqrt{1 + (\omega\tau)^2}\right] \\ &= 10\log_{10}[1 + (\omega\tau)^2]\end{aligned}$$

$$\tau = \frac{L}{R_S + R_L}$$

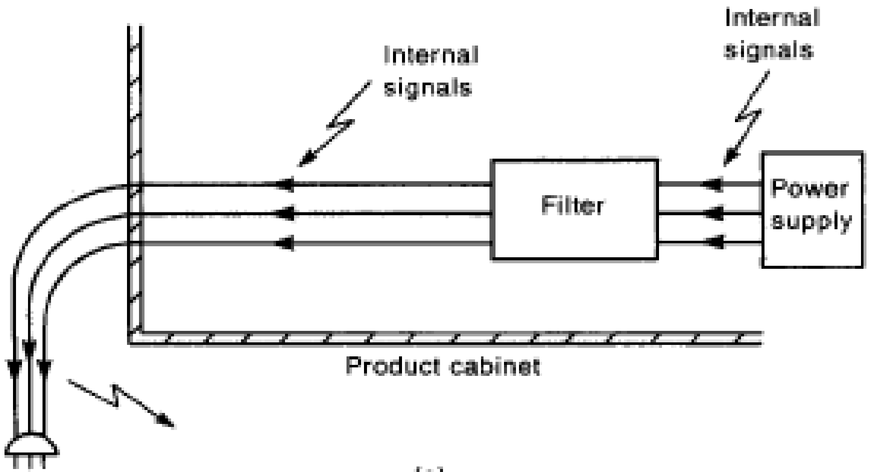
IL-test per modo comune e differenziale



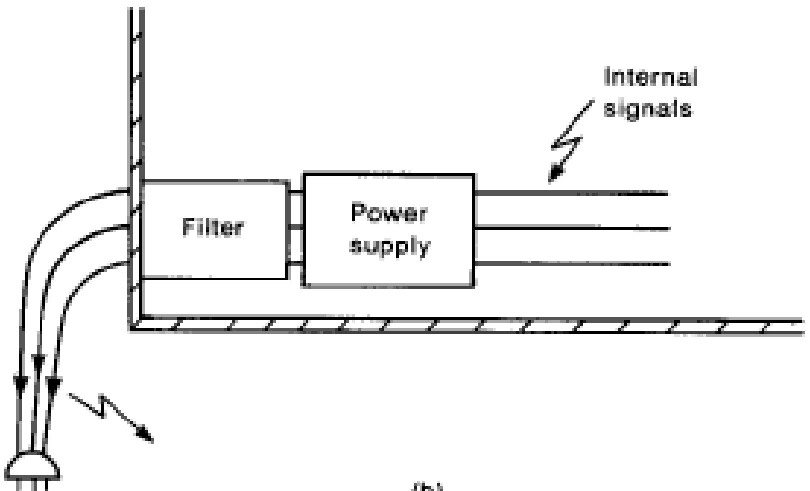
Modo differenziale

Modo comune

Inserimento del filtro di alimentazione

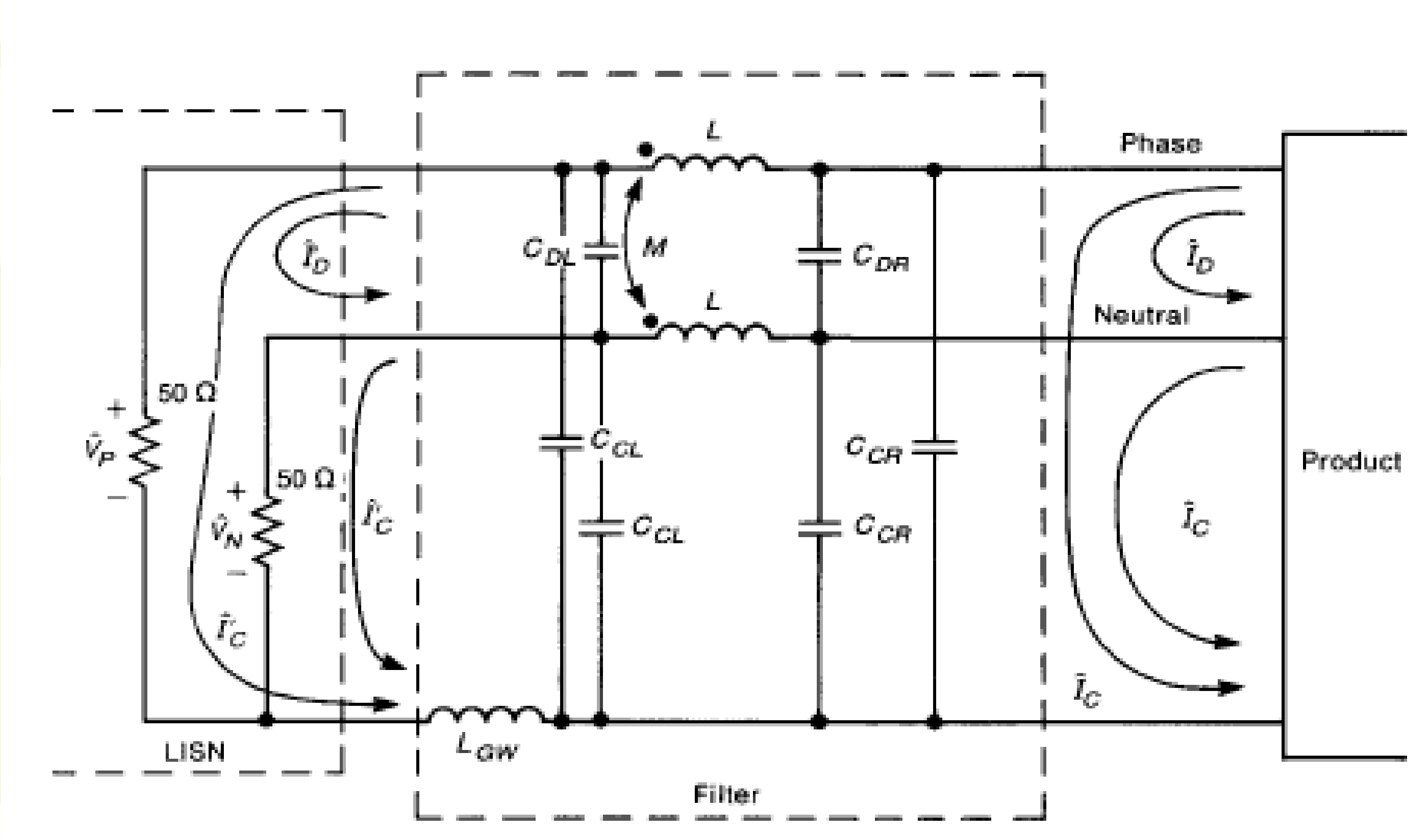


(a)

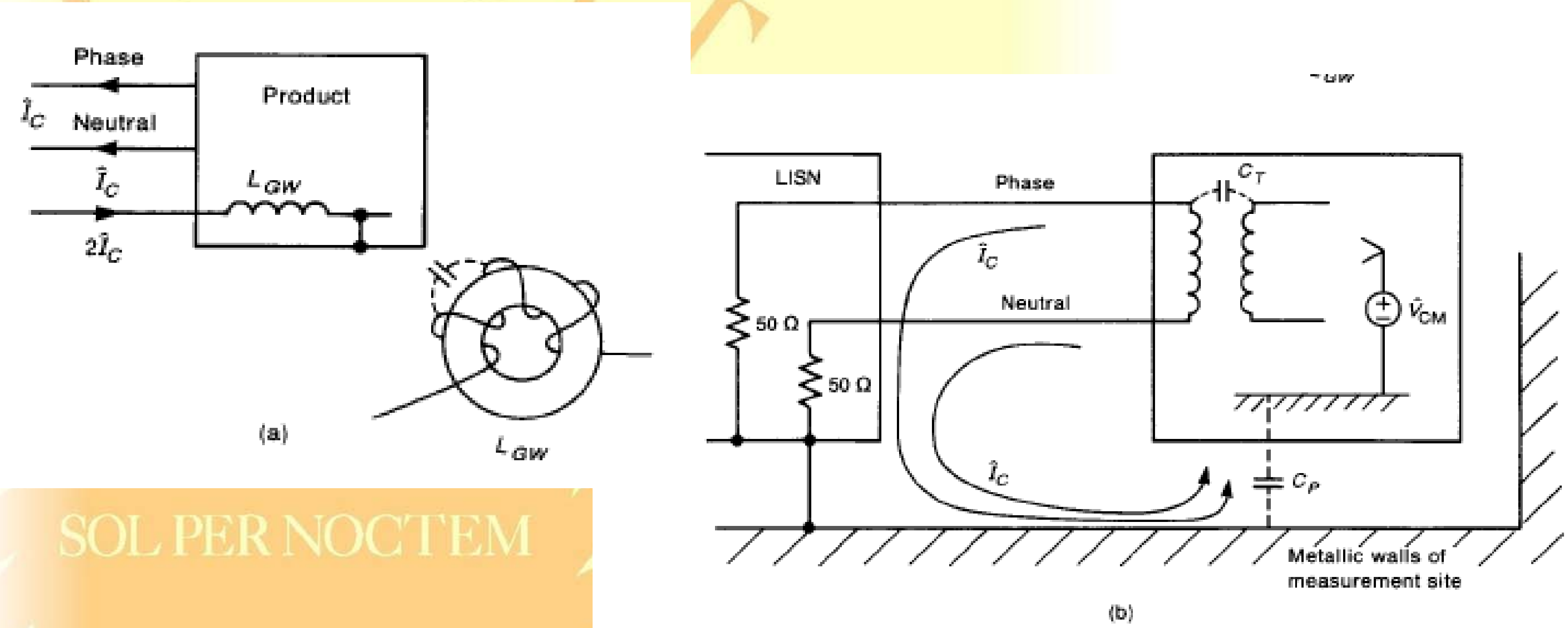


(b)

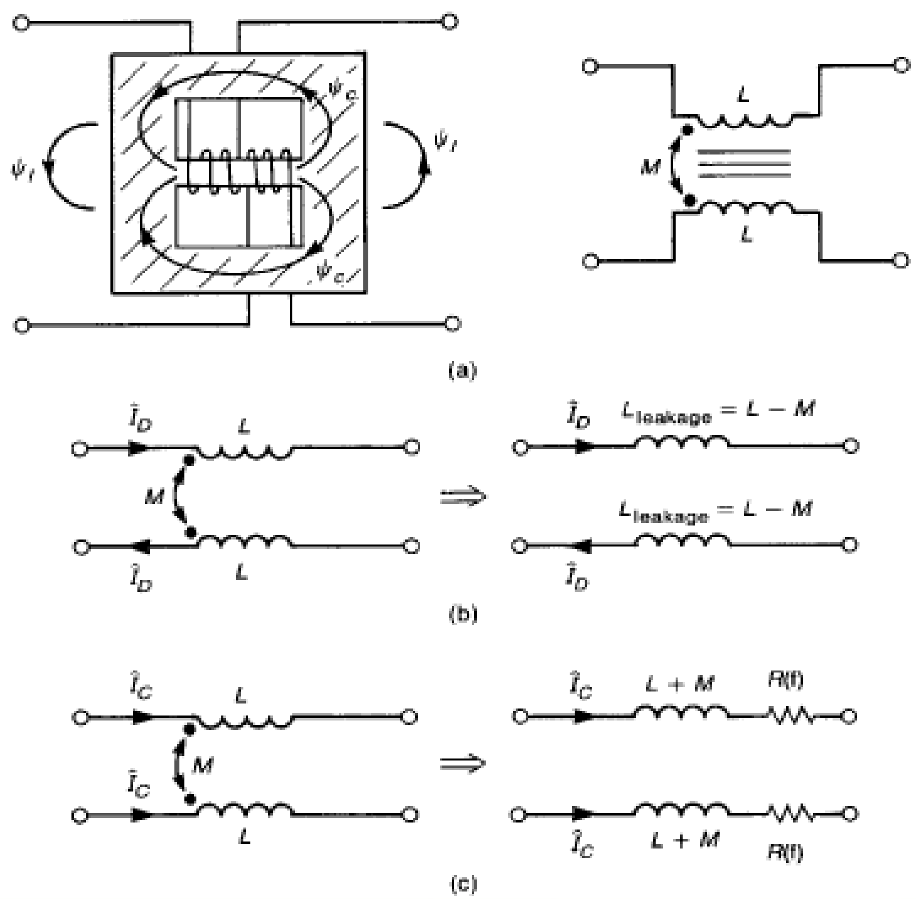
Topologia generica per i filtri di alimentazione



Emissione condotta: blocco del modo comune



Induttore accoppiato (choke)



$$k = \frac{M}{\sqrt{L_1 L_2}} \cong \frac{M}{L} \cong 1$$

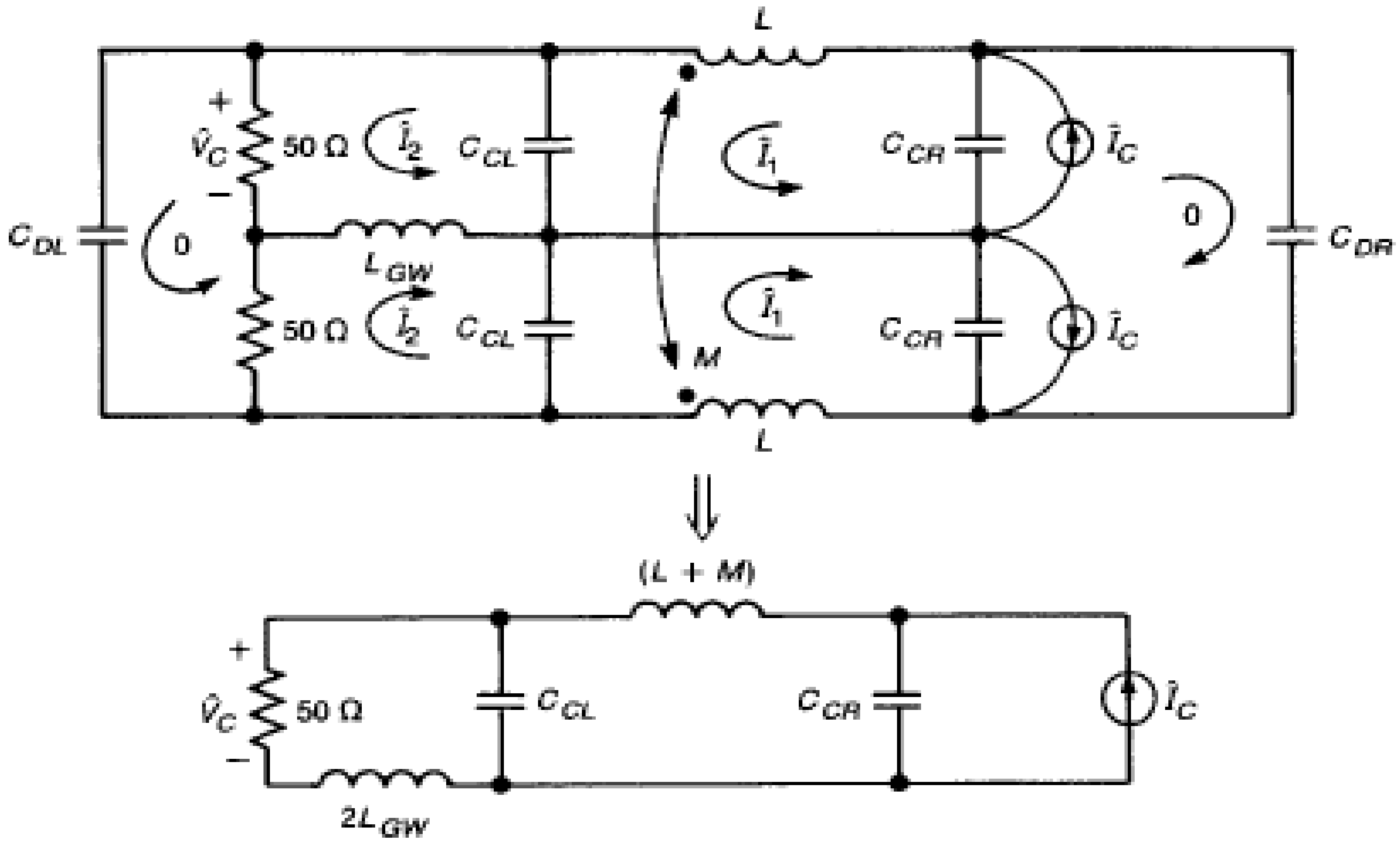
Modo differenziale

$$\hat{V} = j\omega L\hat{I}_D - j\omega M\hat{I}_D$$
$$= j\omega(L - M)\hat{I}_D$$

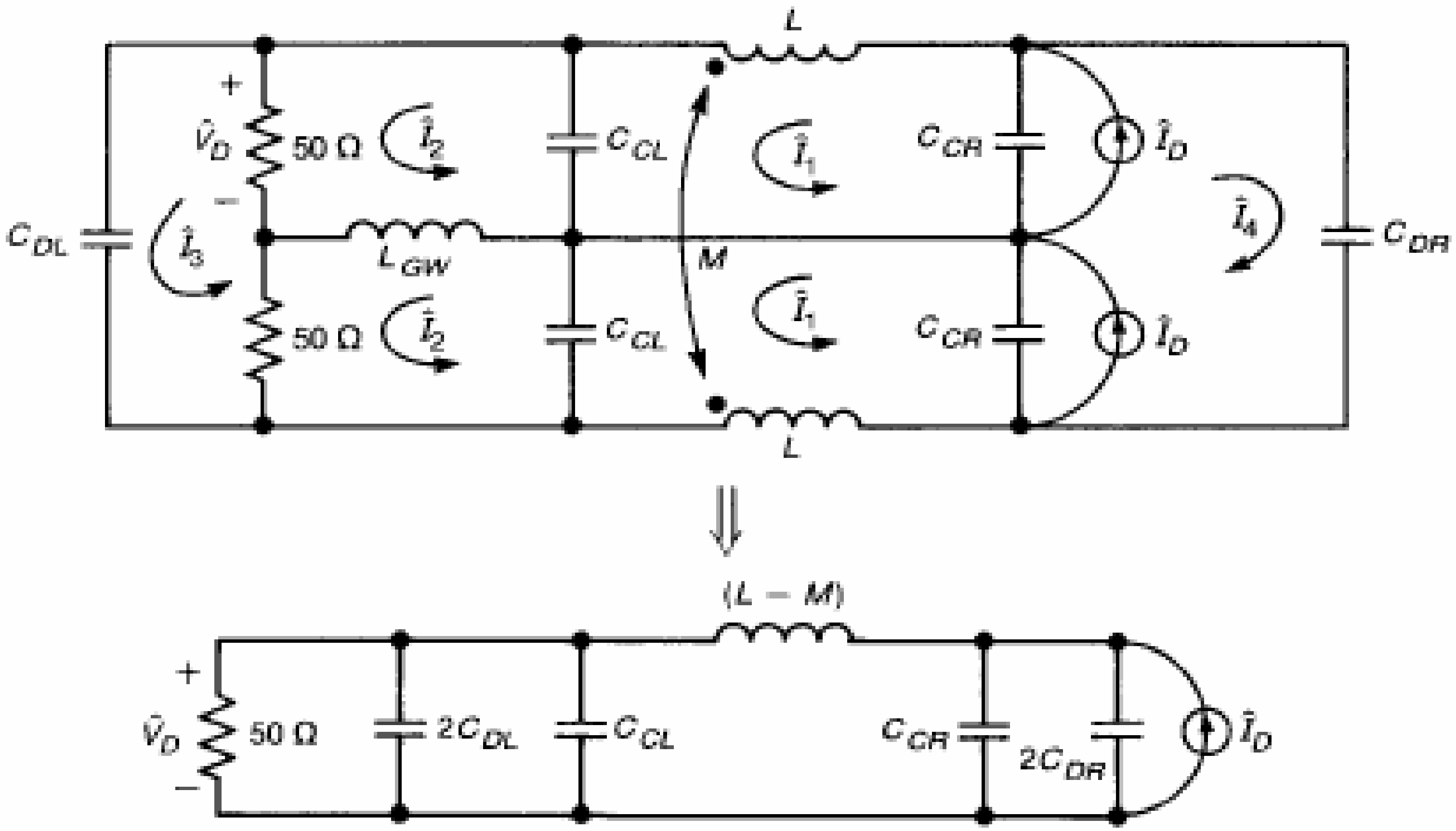
Modo comune

$$\hat{V} = j\omega L\hat{I}_C + j\omega M\hat{I}_C$$
$$= j\omega(L + M)\hat{I}_C$$

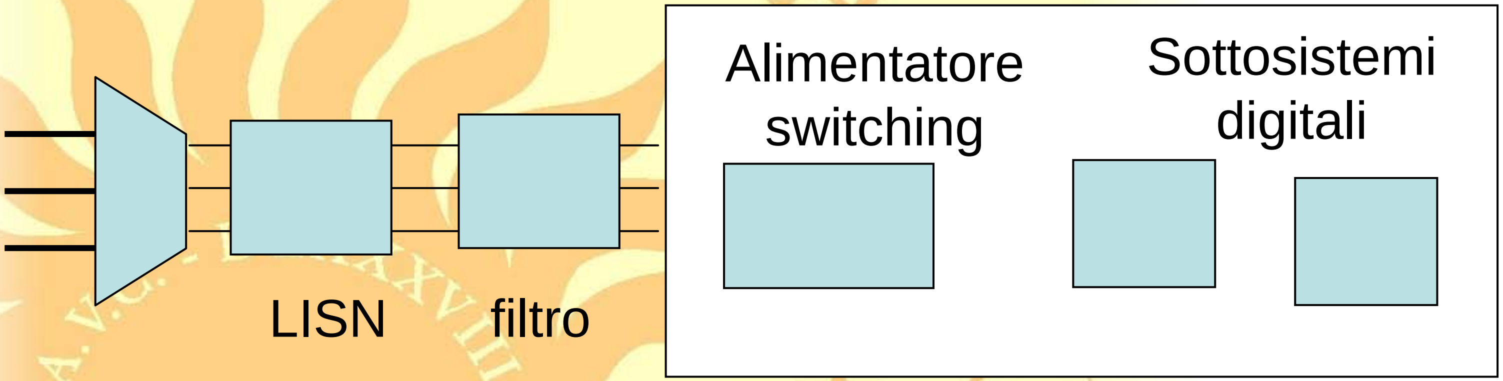
Schema equivalente per CM



Schema equivalente per DM

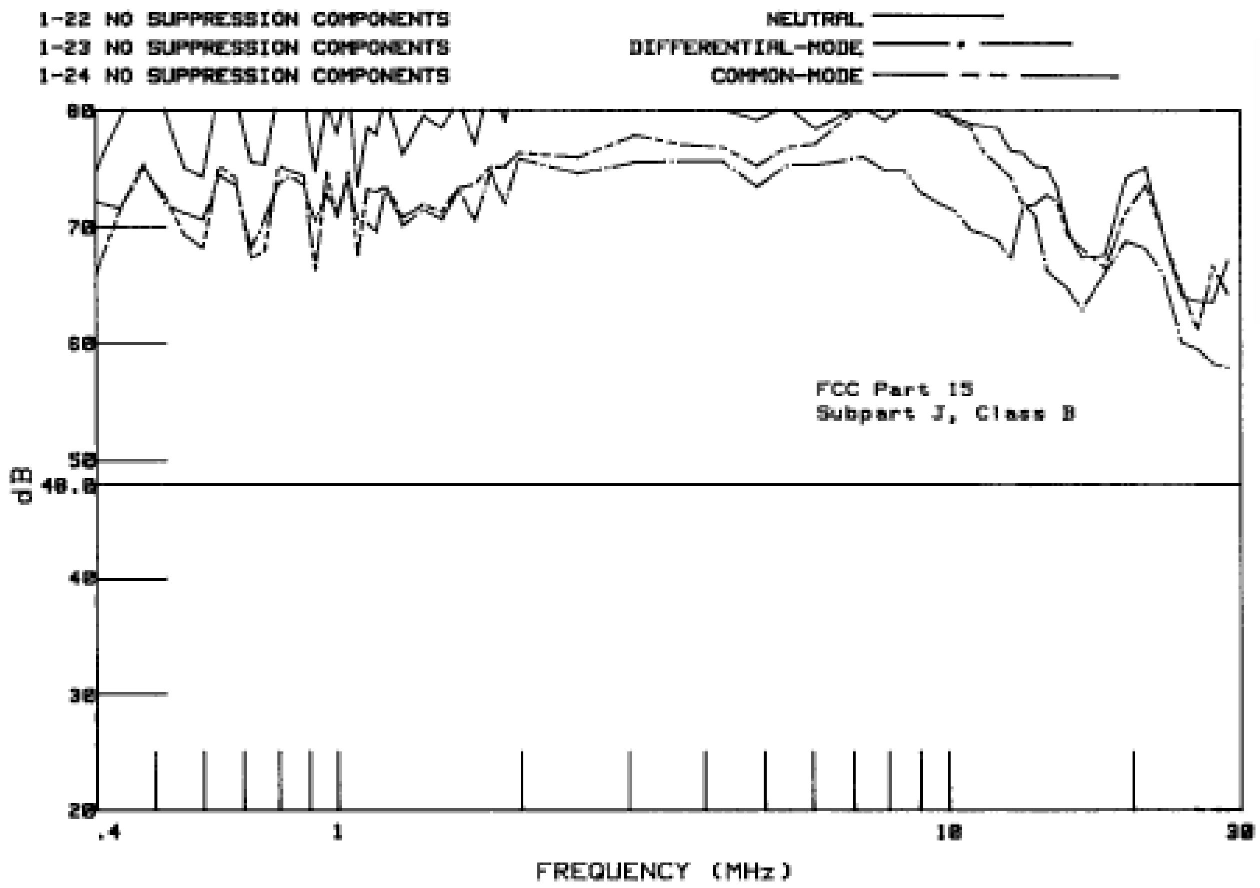


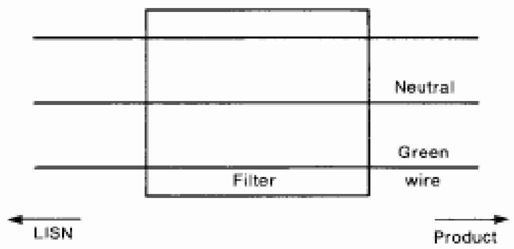
Analisi delle emissioni per CM e DM: esempio



EUT (equipment under test): digital device

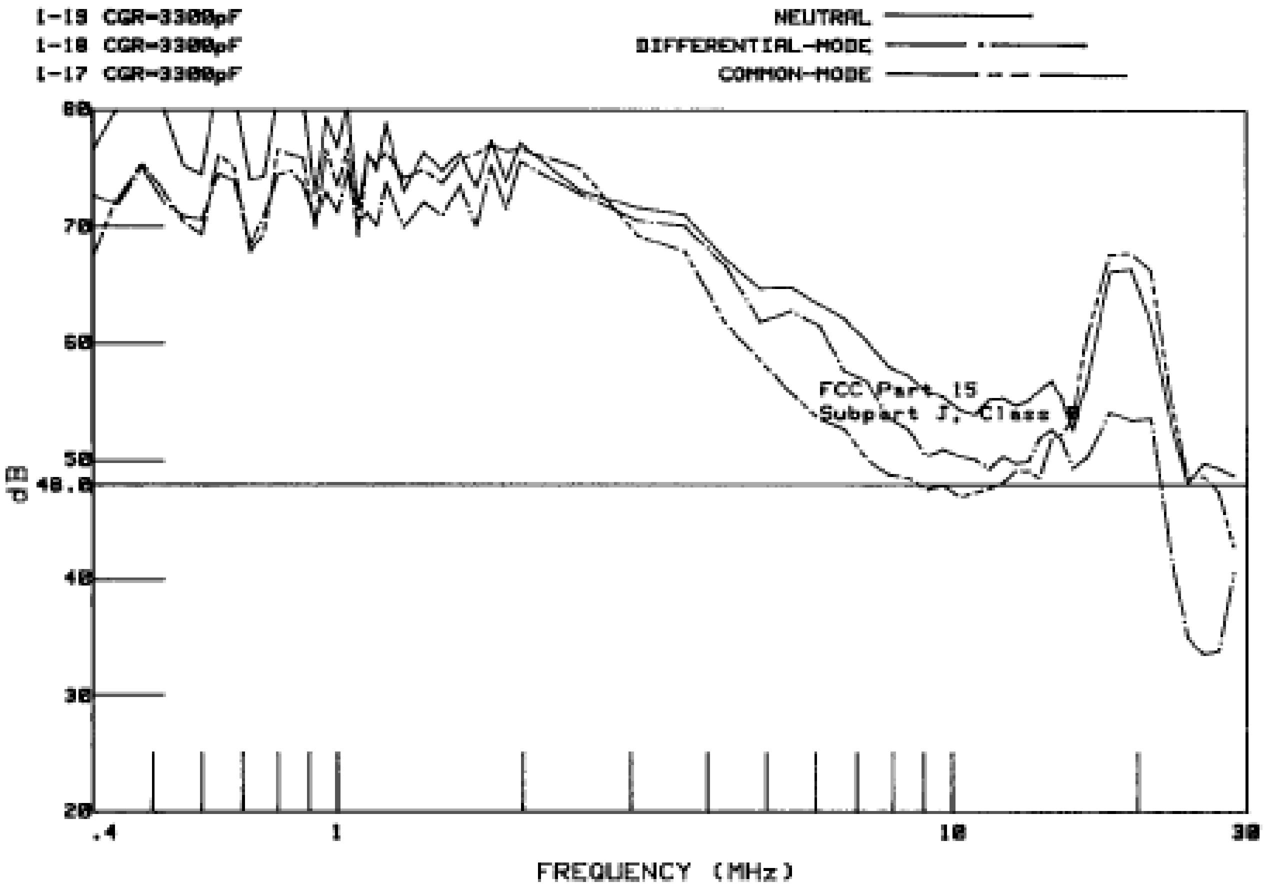
Analisi delle emissioni per CM e DM: esempio

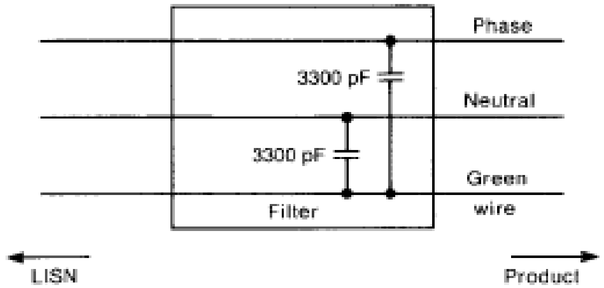




Assenza di filtro

Analisi delle emissioni per CM e DM: esempio

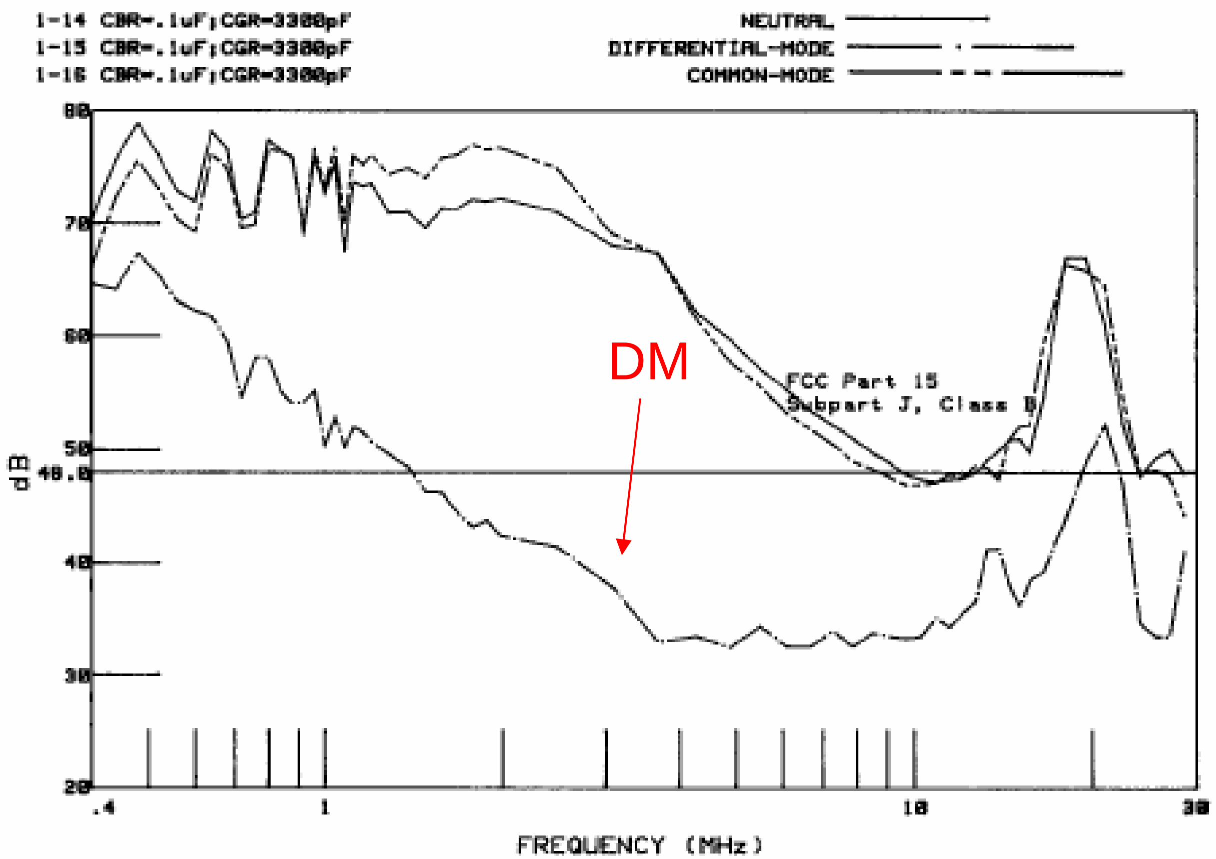


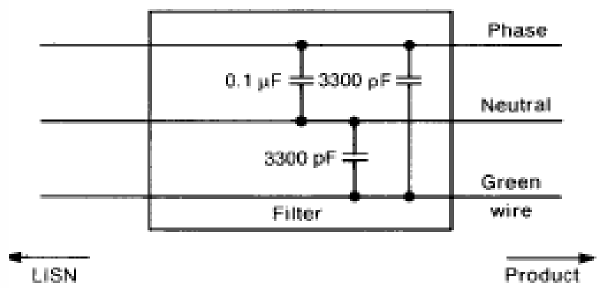


Inserzione dei condensatori line-ground

3300 pF = 50 Ω @ 1 MHz

Analisi delle emissioni per CM e DM: esempio

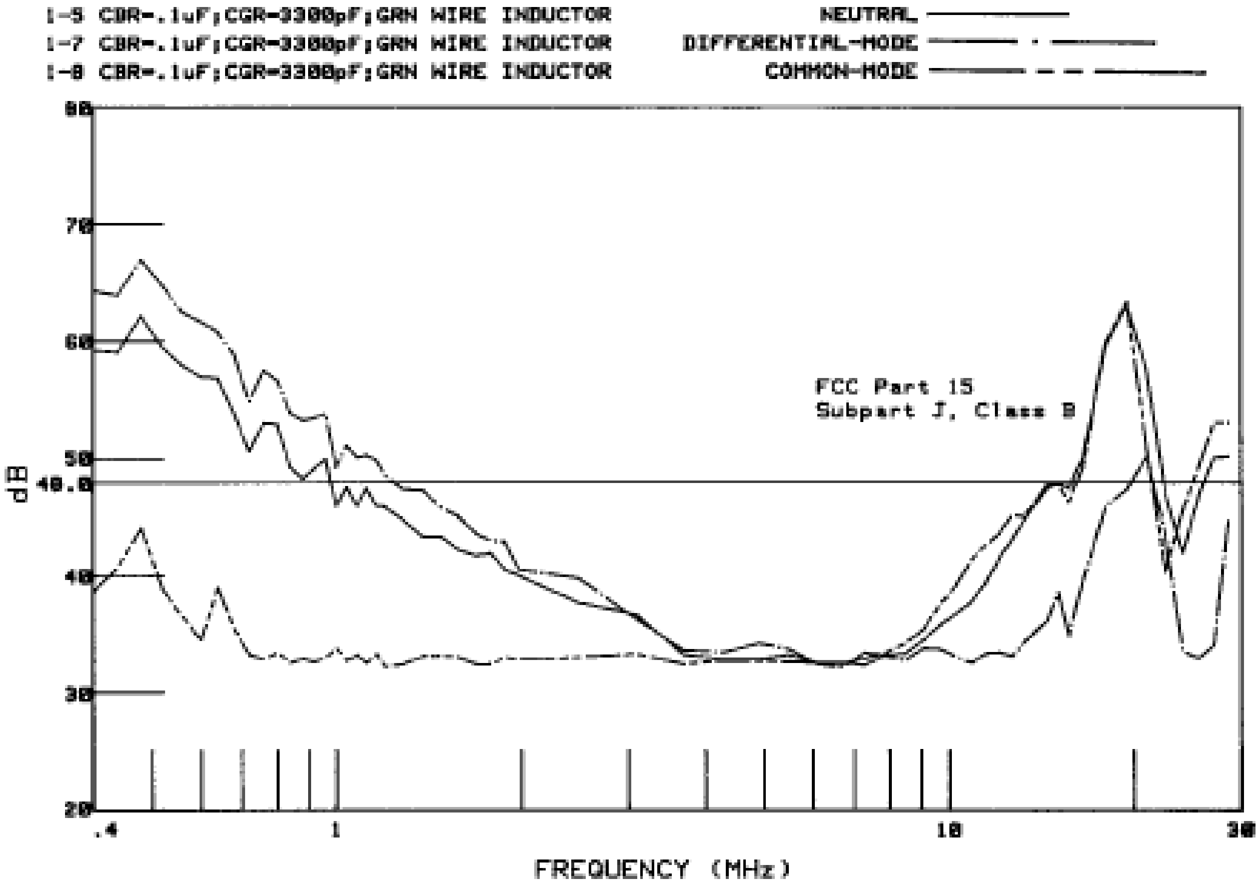


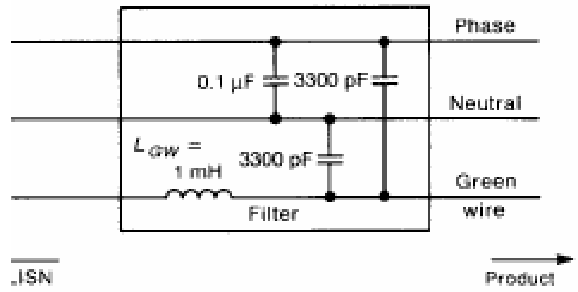


Inserzione dei condensatori line-line

Break frequency @ 15.7 kHz

Analisi delle emissioni per CM e DM: esempio

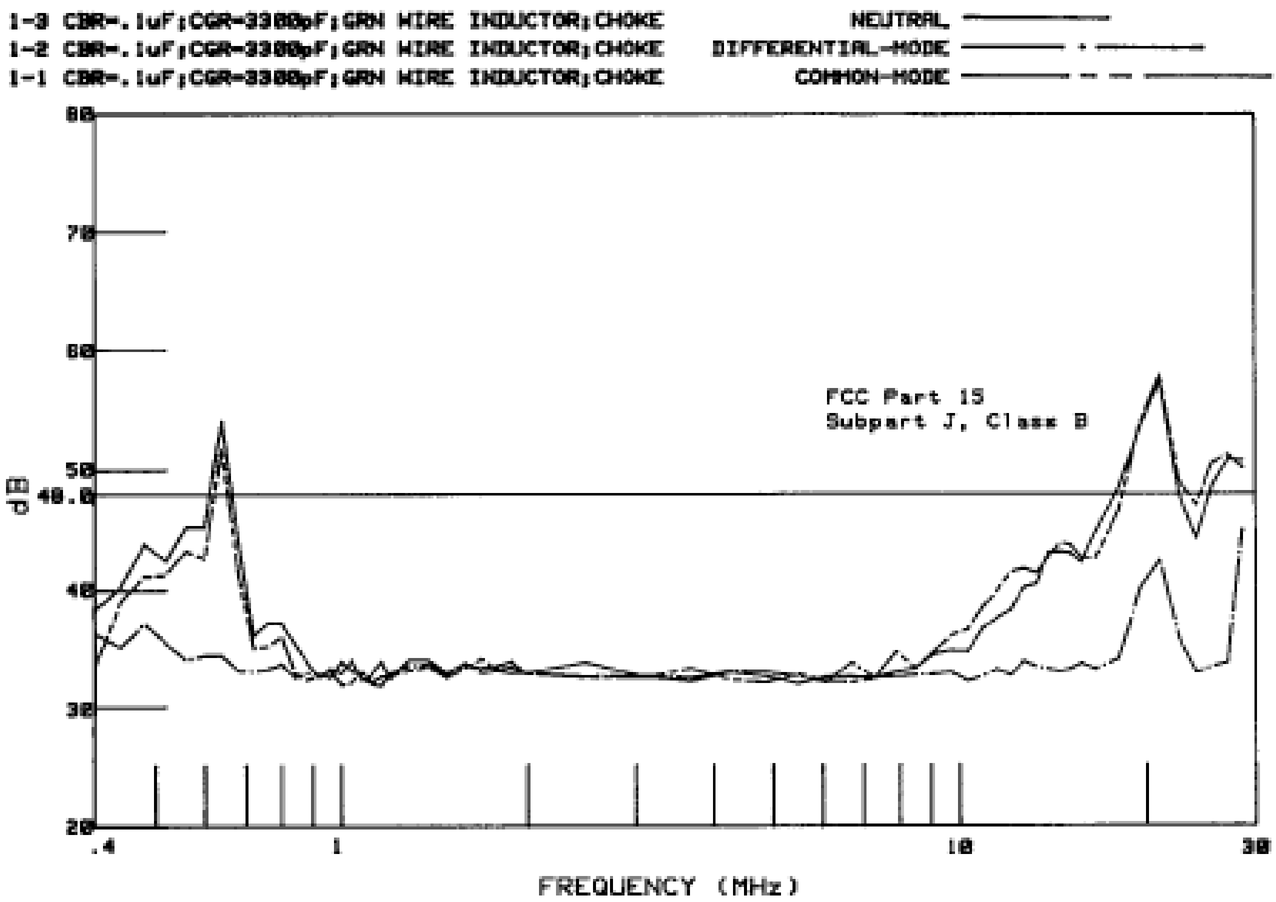


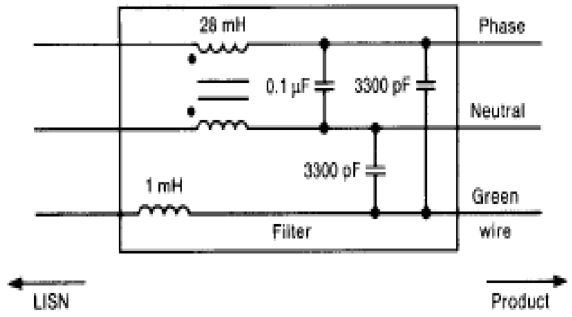


Inserzione dell'induttore su GND

Break frequency @ 4 kHz

Analisi delle emissioni per CM e DM: esempio





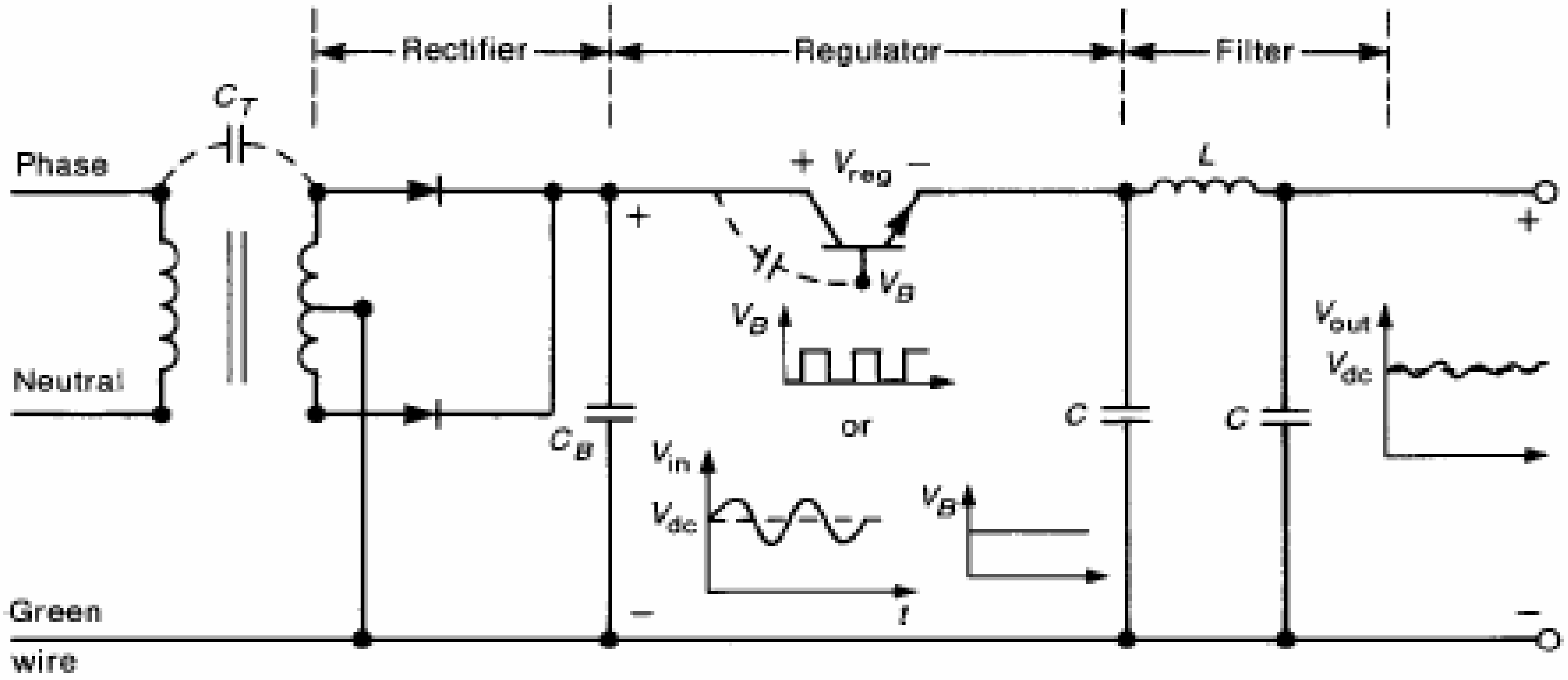
Inserzione del
CM choke

CM pressoché
inalterato
DM migliorato (choke
non ideale)

Sorgenti delle emissioni condotte: gli alimentatori

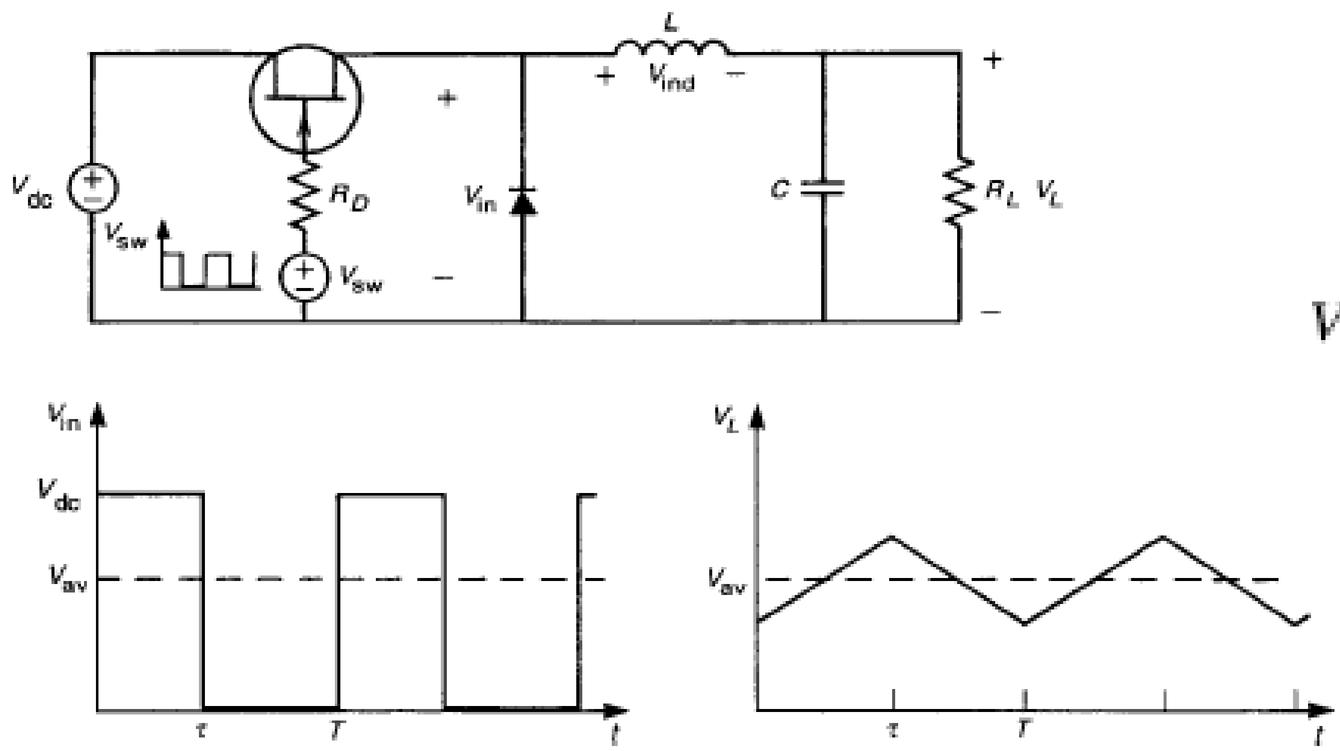
Alimentatori lineari

$$V_{out} = V_{in} - V_{reg}$$



Poco efficienti ma pochi problemi EMC

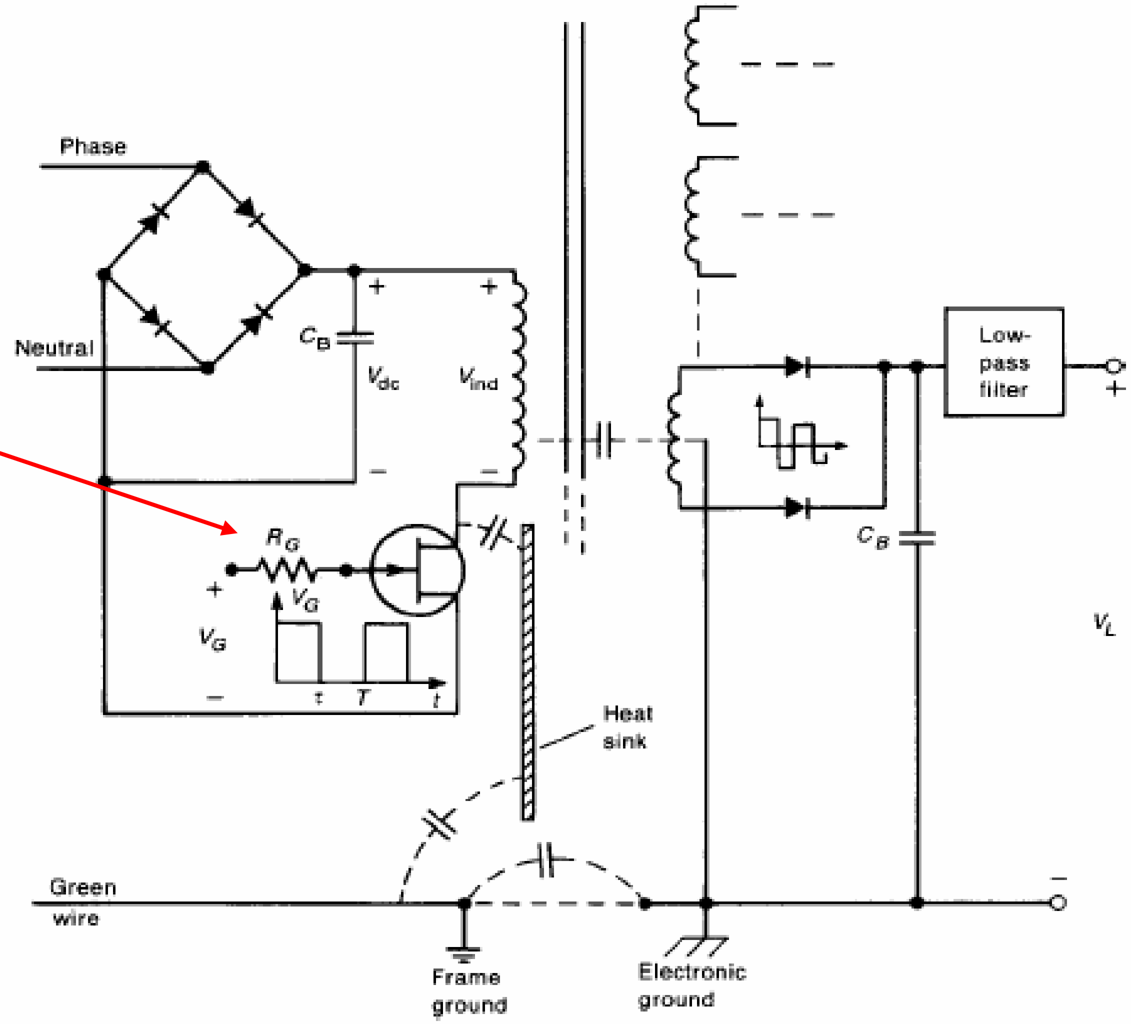
Alimentatori switching: basic bulk regulator



$$V_{av} = \frac{\tau}{T} V_{dc}$$

Molto efficienti, notevoli problemi EMC

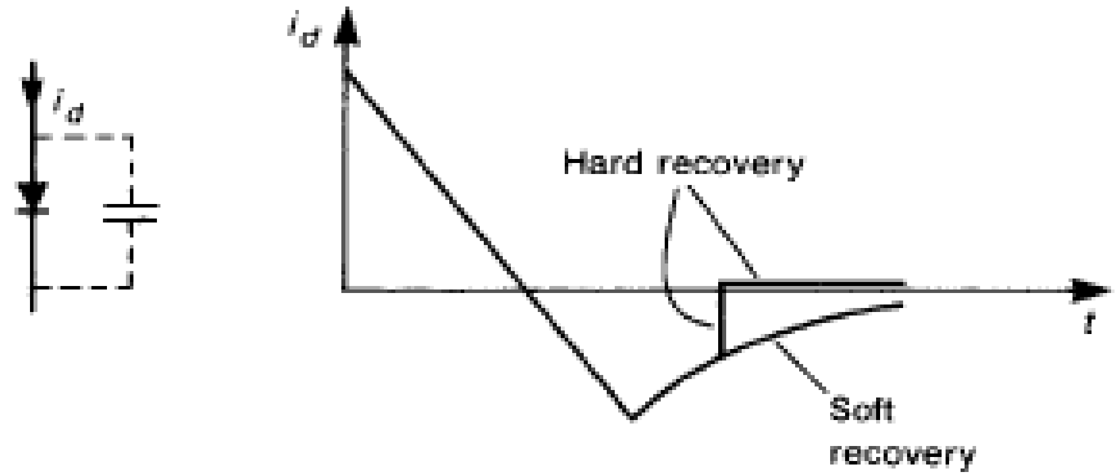
Convertitore flyback

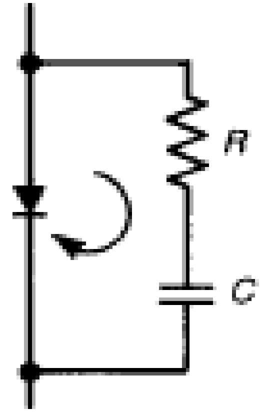


Trade-off tra efficienza ed EMI nel ruolo di RG:

Aumento di RG: aumento del rise-time e della potenza dissipata

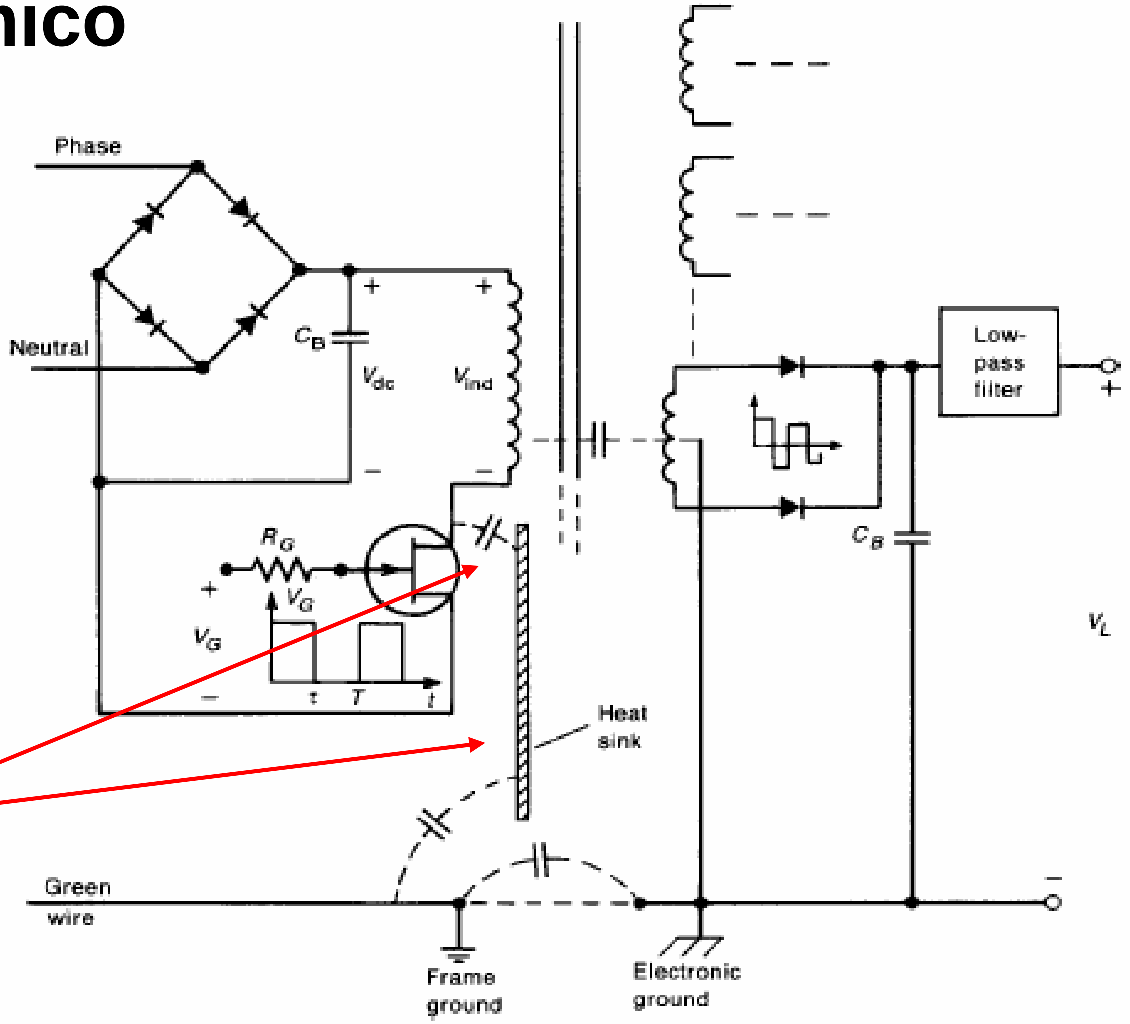
Effetto dei componenti degli alimentatori: diodi





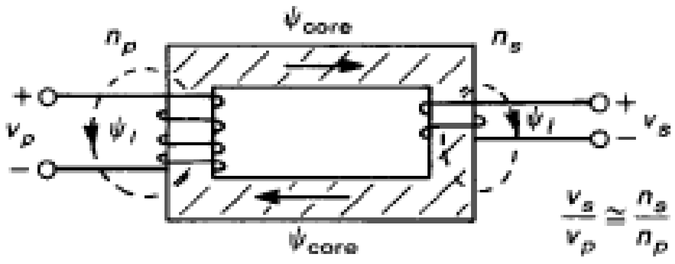
circuito snubber

Effetto dei componenti degli alimentatori: dissipatore termico

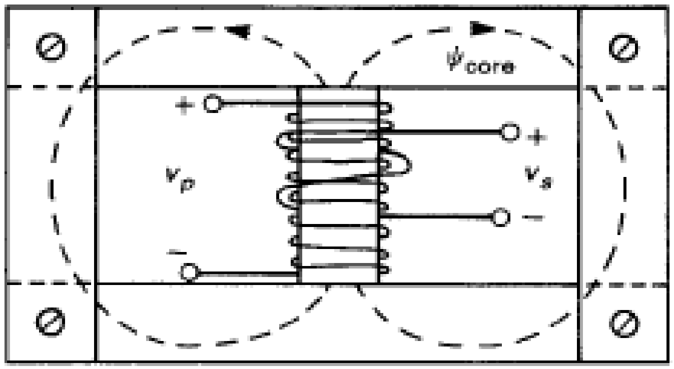


Coupling col dissipatore

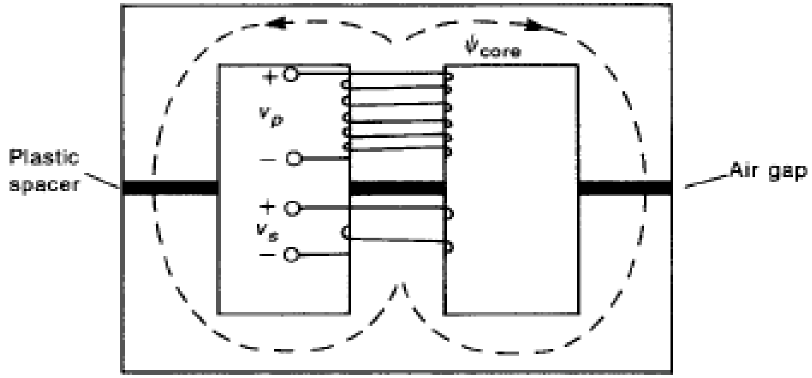
Effetto dei componenti degli alimentatori: trasformatori



(a)

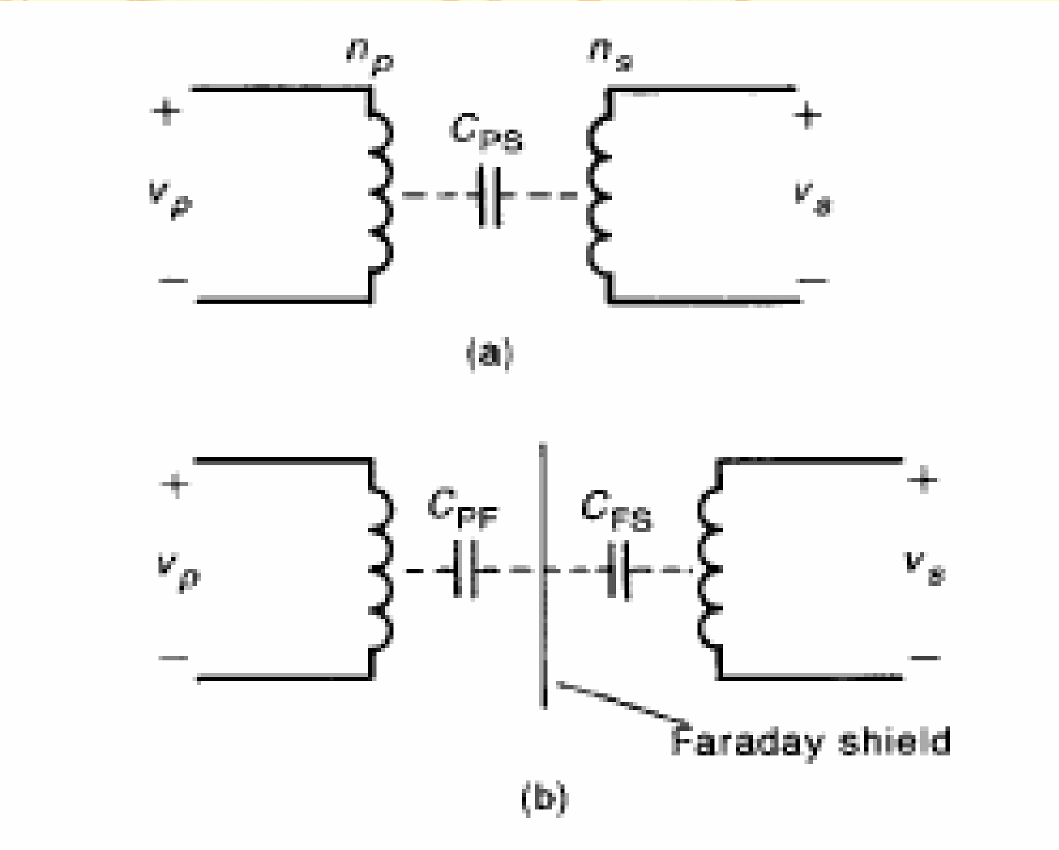


(b)



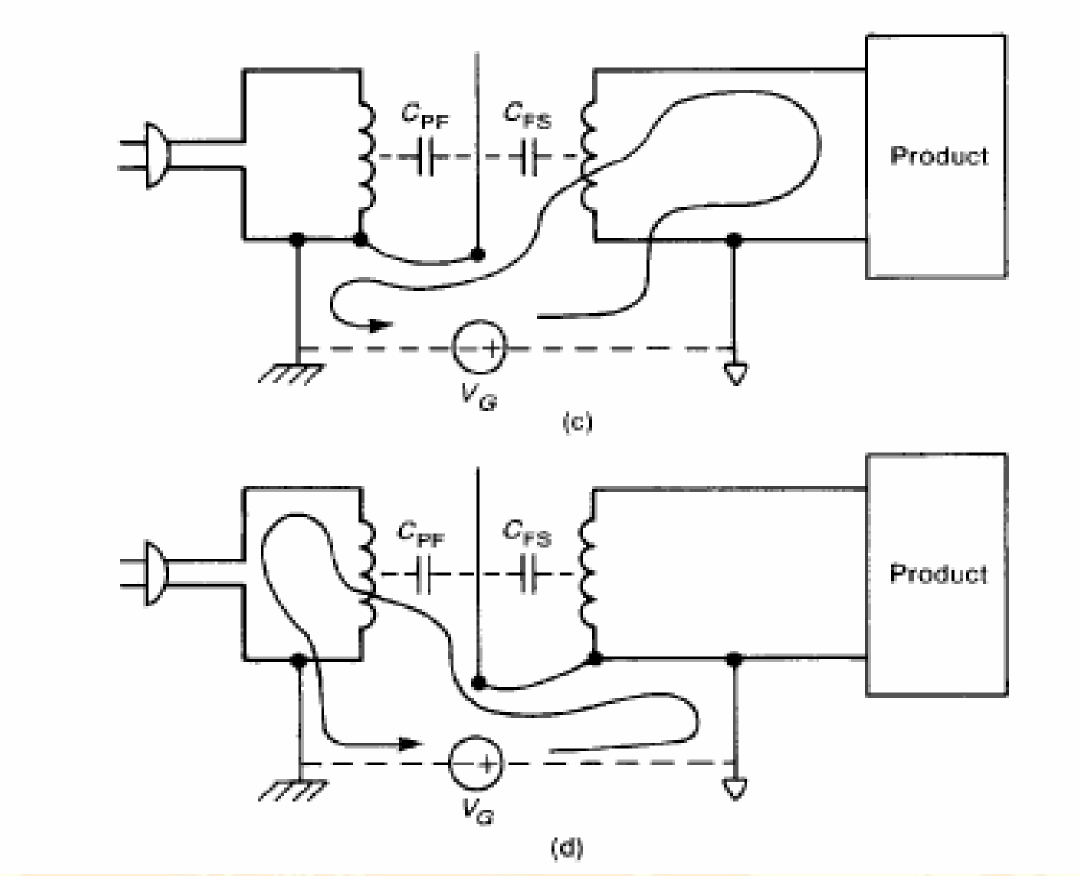
(c)

Trasformatori: coupling capacitivo tra primario e secondario



Schermo di faraday

Trasformatori: coupling capacitivo tra primario e secondario



Schermo di Faraday: collegamento