Loss free resistor

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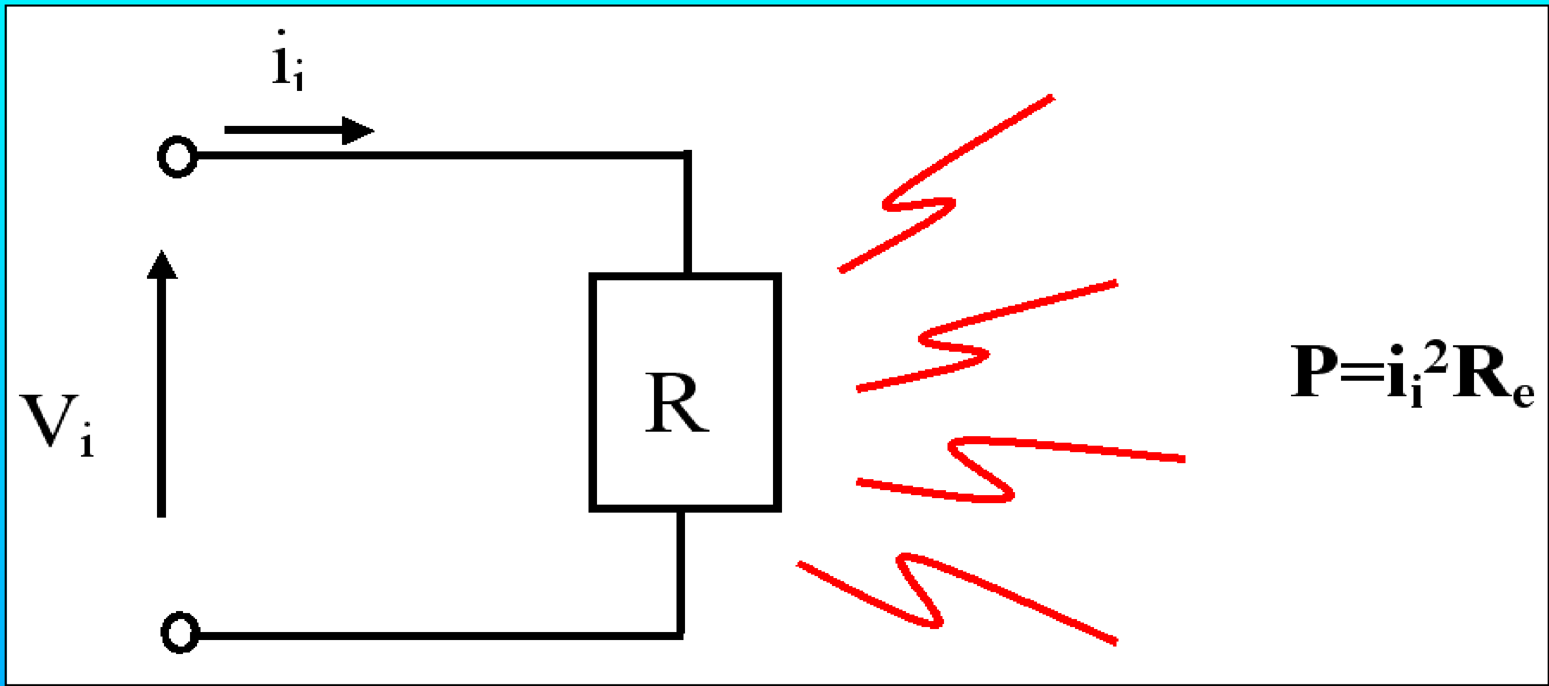
A conventional Resistor



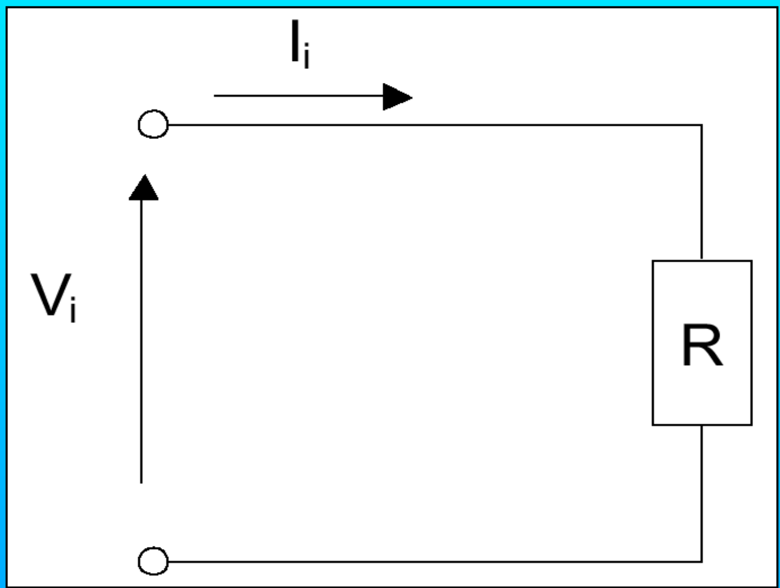
The power is wasted as heat

A system with a Resistor has two disadvantages when compared to the same system without the Resistor :

- Lower Efficiency
- Large bulk because of the heat sinks

However there are cases were the system requires the use of a resistor.

- Can we create a resistor that is loss- free?

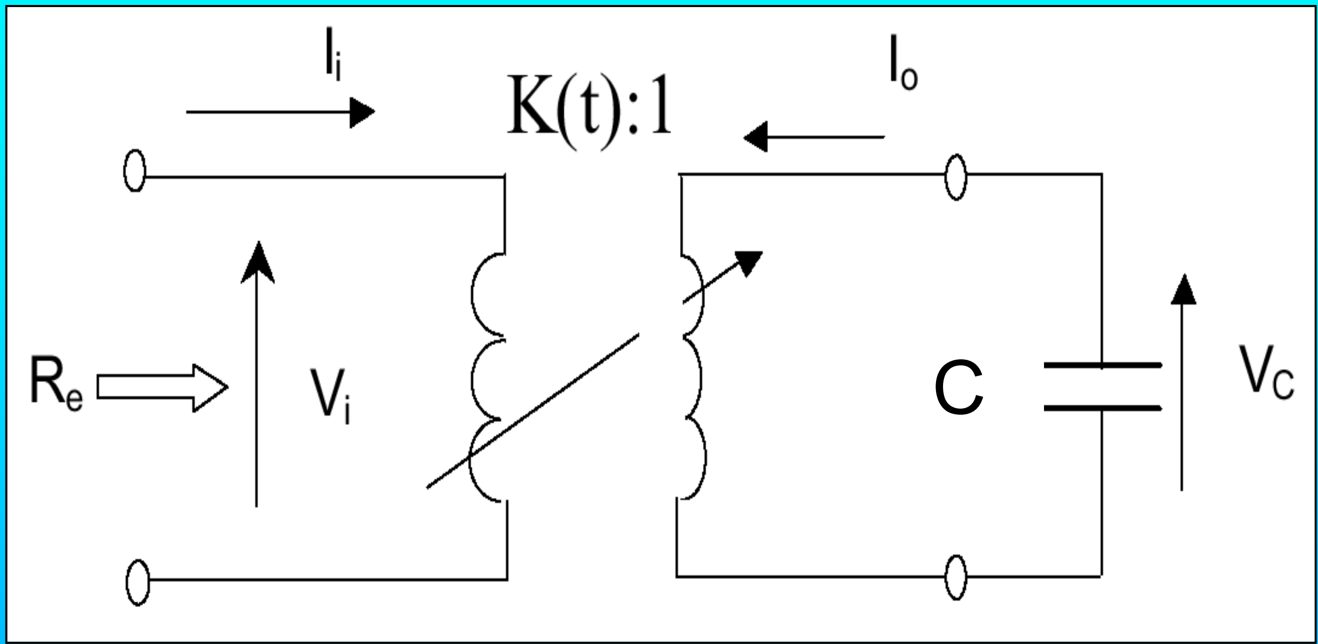


$V_i = i_i R$

$P = I_i^2 \cdot R$ → ?

Were will the power go?

A simple “loss – free” resistor



$$V_i = k(t) \cdot V_C$$

$$I_O = C \cdot \frac{dV_C}{dt}$$

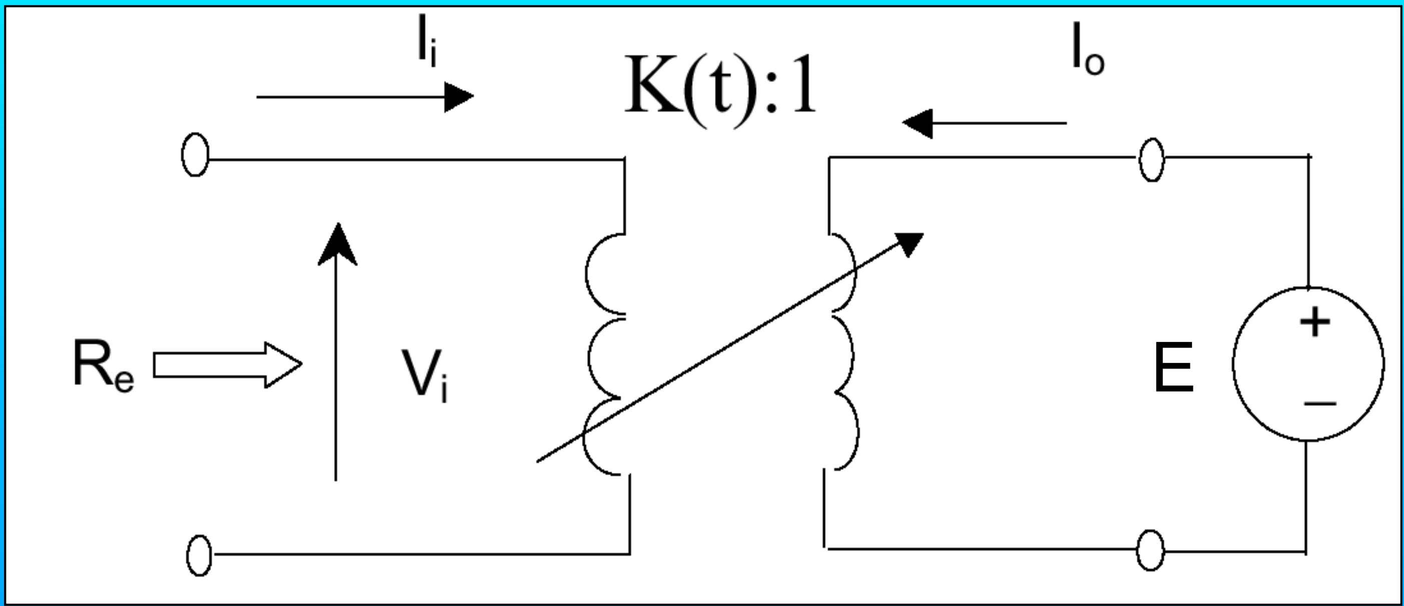
$$V_i = \mathrm{R_e} \cdot I_i$$

$$\Downarrow$$

$$k(t) = \mathrm{R_e} \cdot \left(\frac{c}{v_i}\right)\left(\frac{dv_c}{dt}\right)$$

The capacitor stores the energy instead of generating heat.

If we replace the capacitor by a battery, which would absorb the power delivered to the input terminals of the transformer, the energy would be stored.

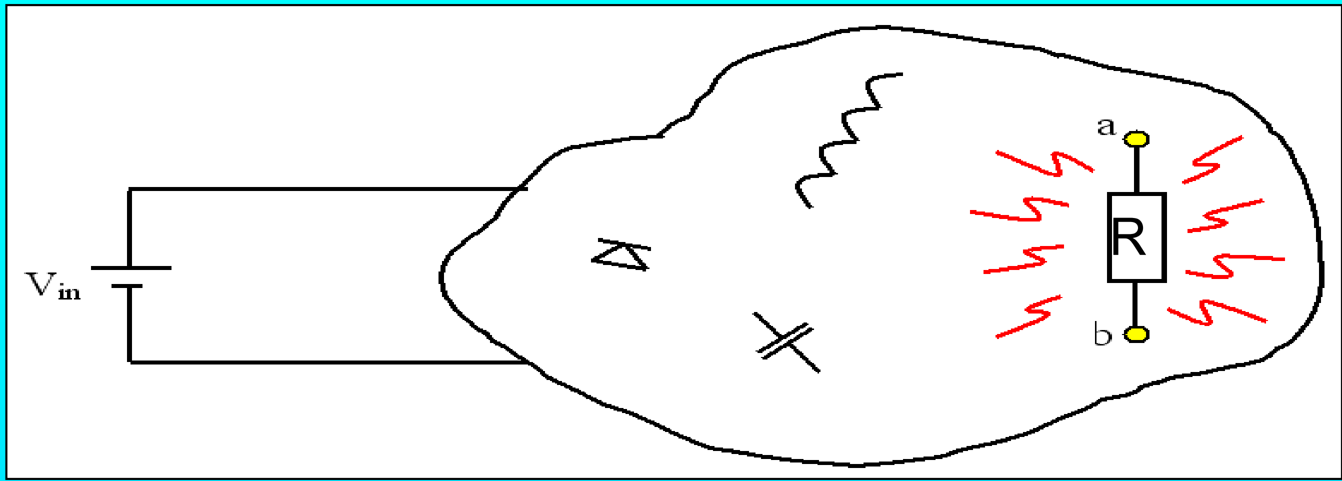


$$V_i = K(t) \cdot E$$

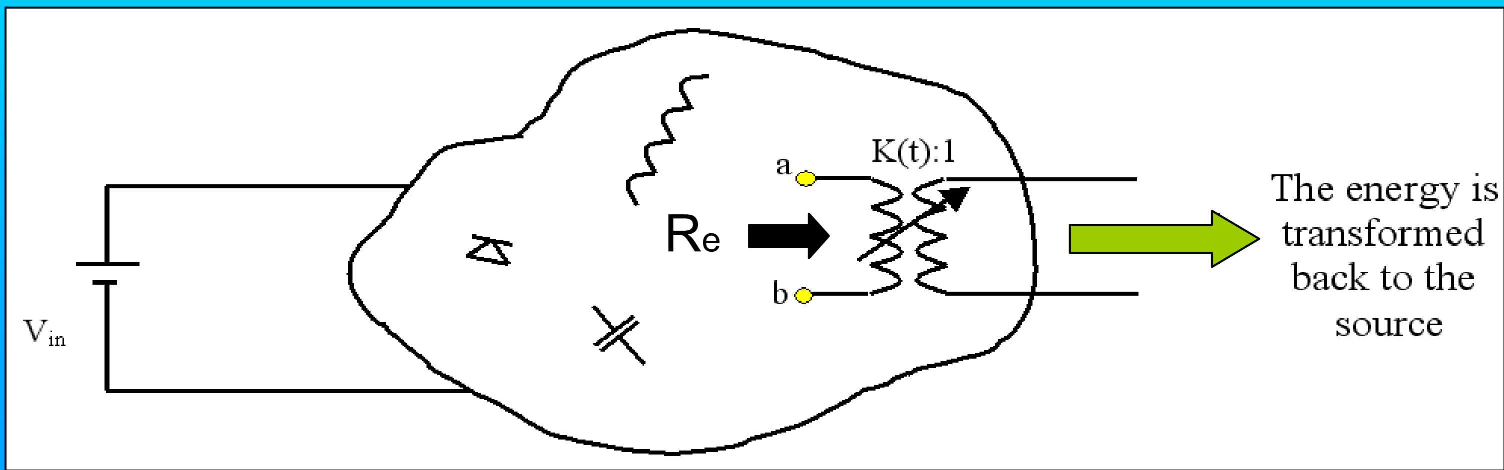
$$V_i = I_i \cdot \mathrm{R}_e$$

$$\Downarrow$$

$$K(t) = \frac{I_i}{E} \cdot \mathrm{R}_e$$

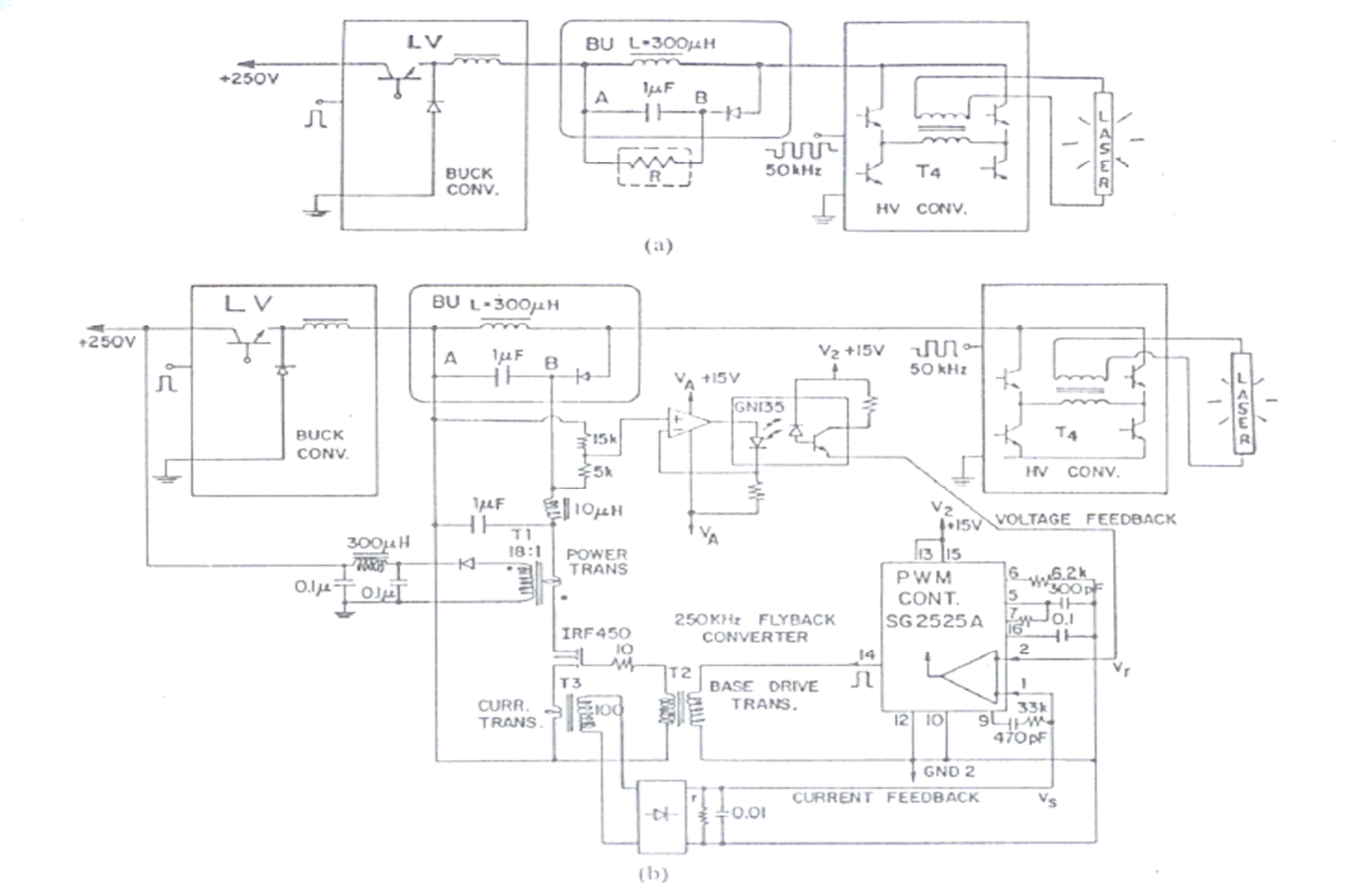


Now we can replace the battery by the source which powers the total system.

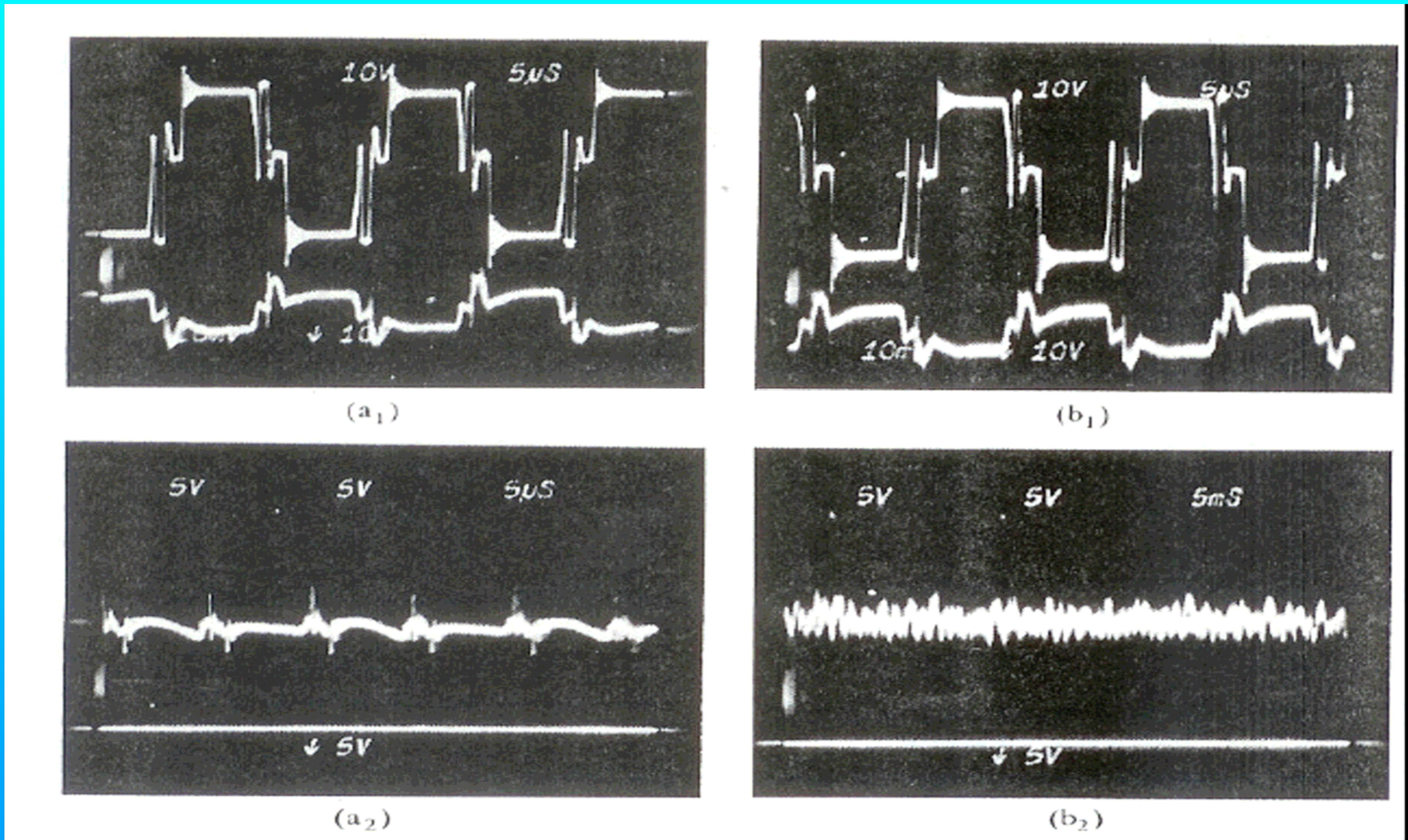


Thus we can replace a real resistor in the system with a time variable transformer.

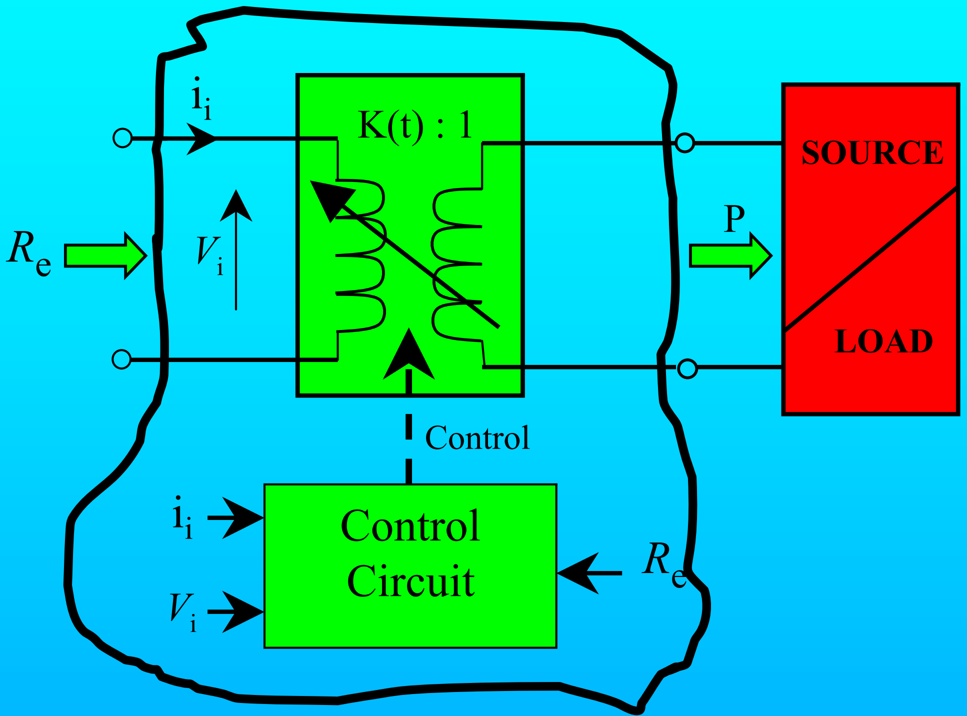
LFR Application in Laser System

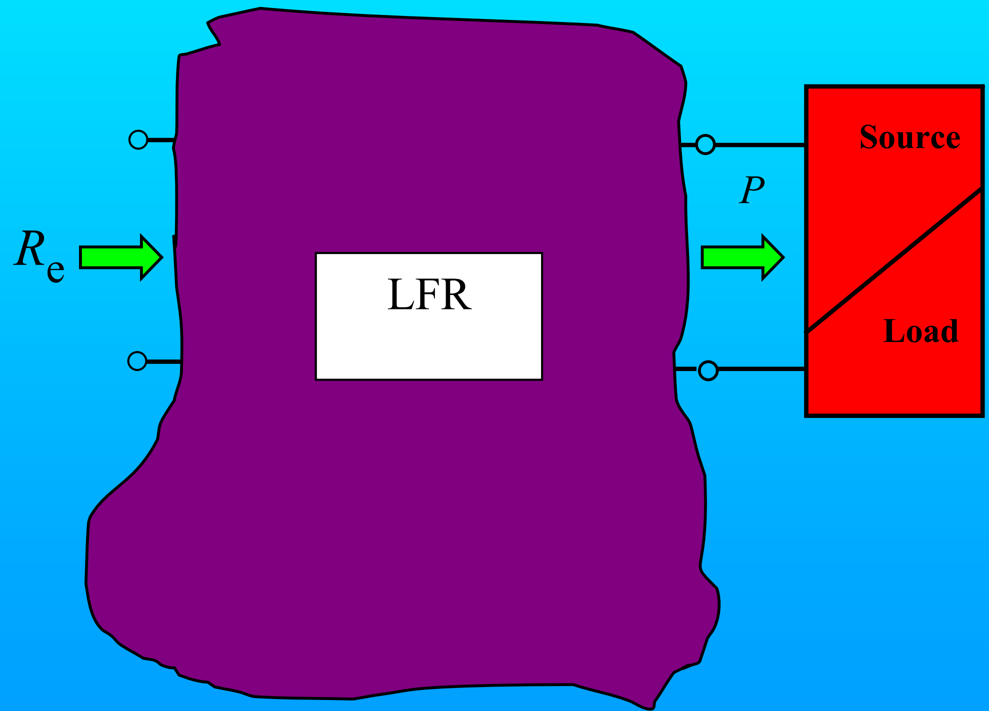


Wave Forms with conventional Resistor (a_1,a_2) and with LFR (b_1,b_2)

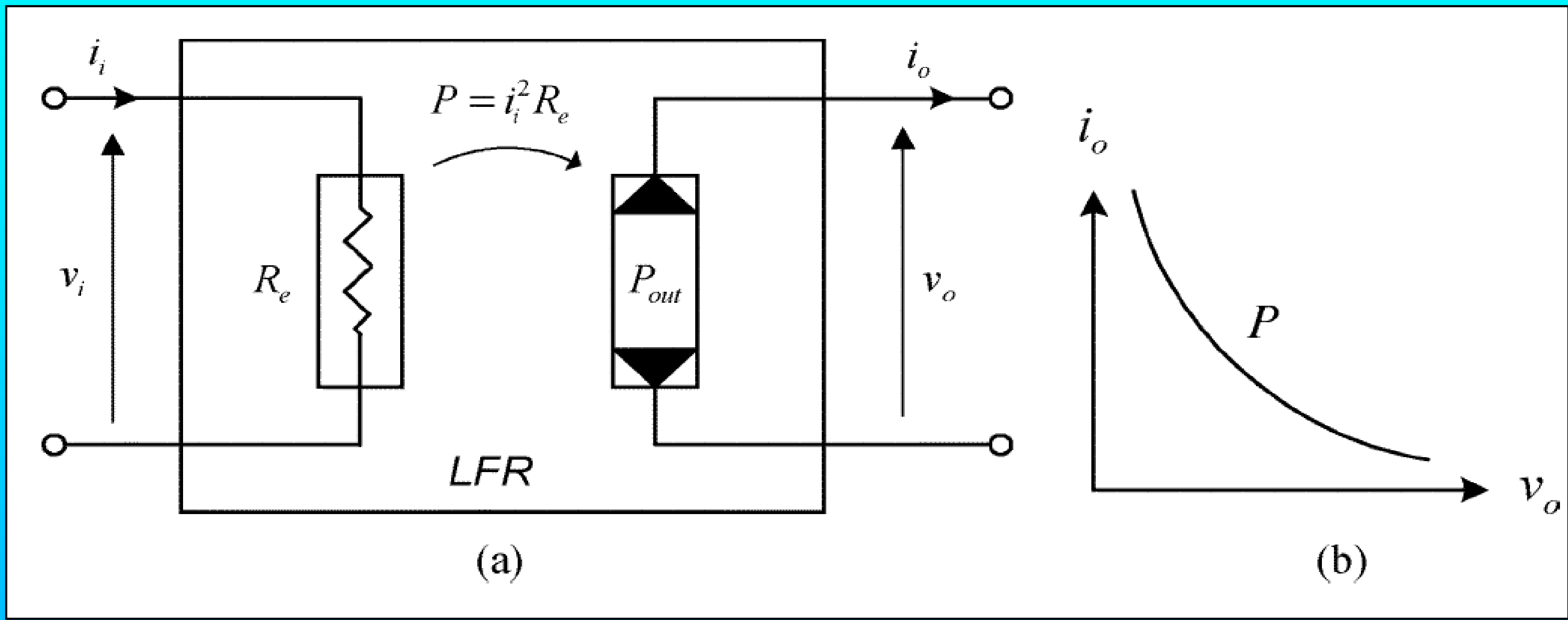


Transformer Based LFR-(Principle)



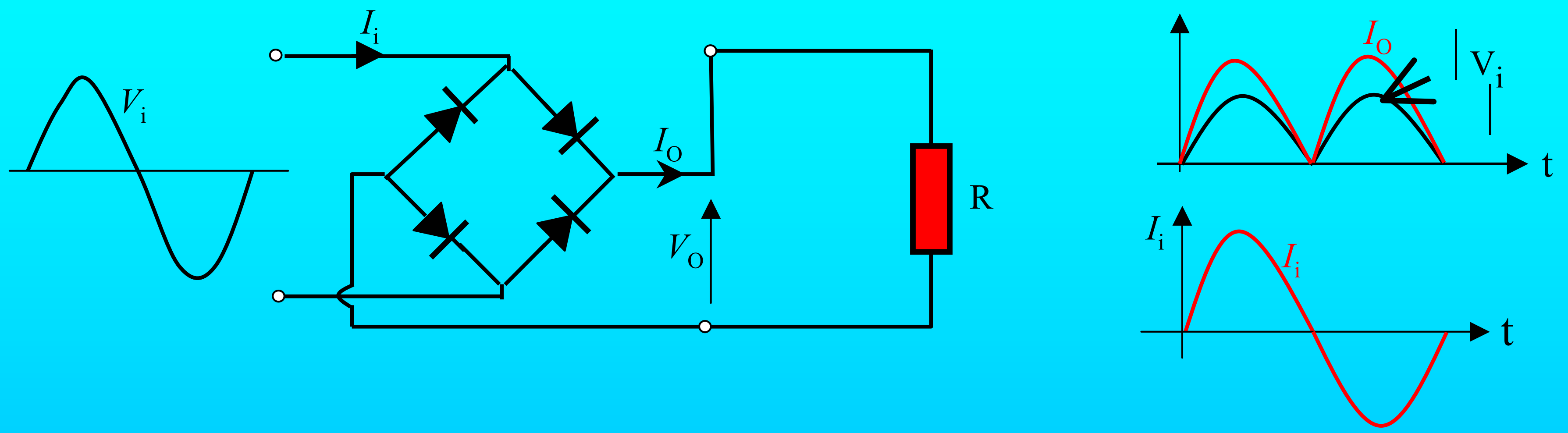


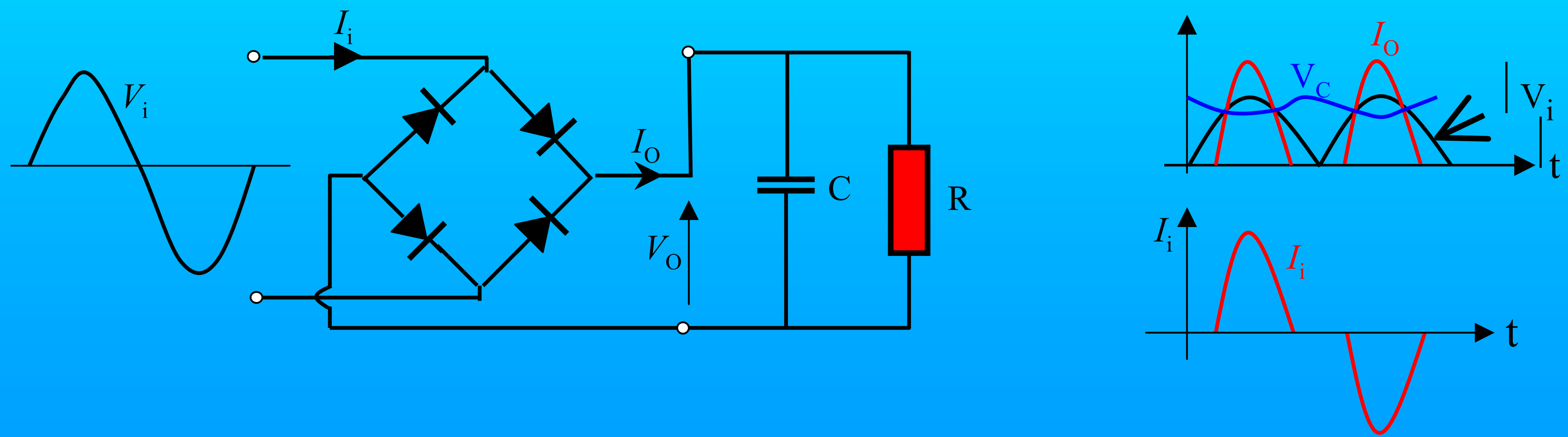
A model for the loss free resistor



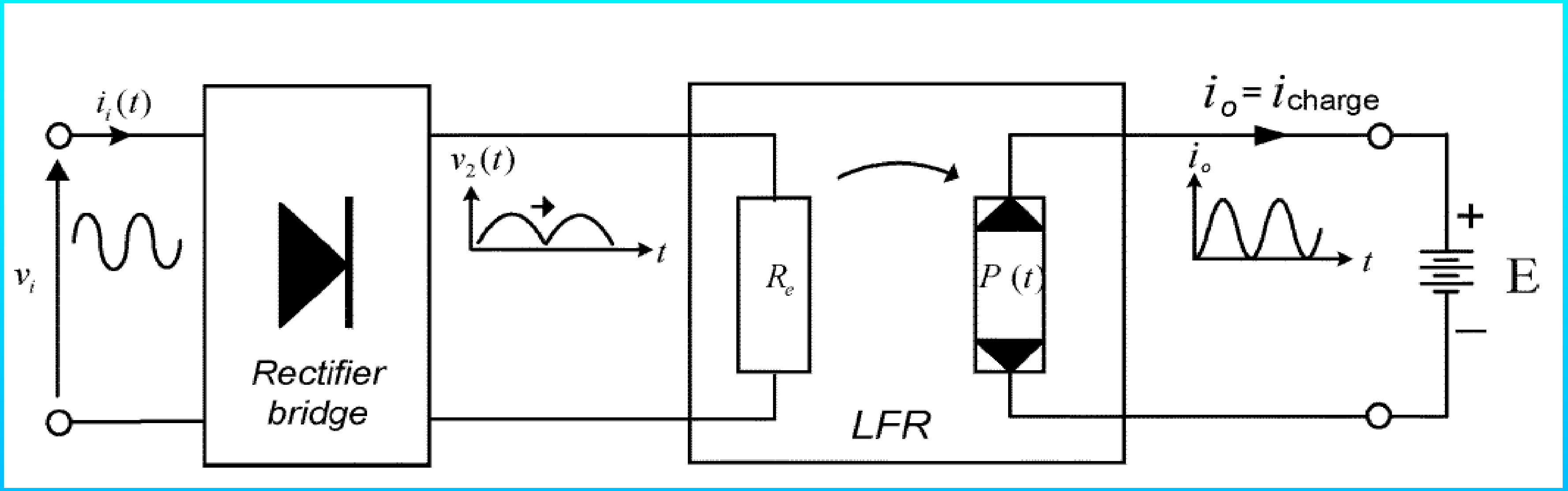
Were R_e is the equivalent resistance that the source "feels" and P is the power that is given to the loss-free resistor.

Conventional Rectification

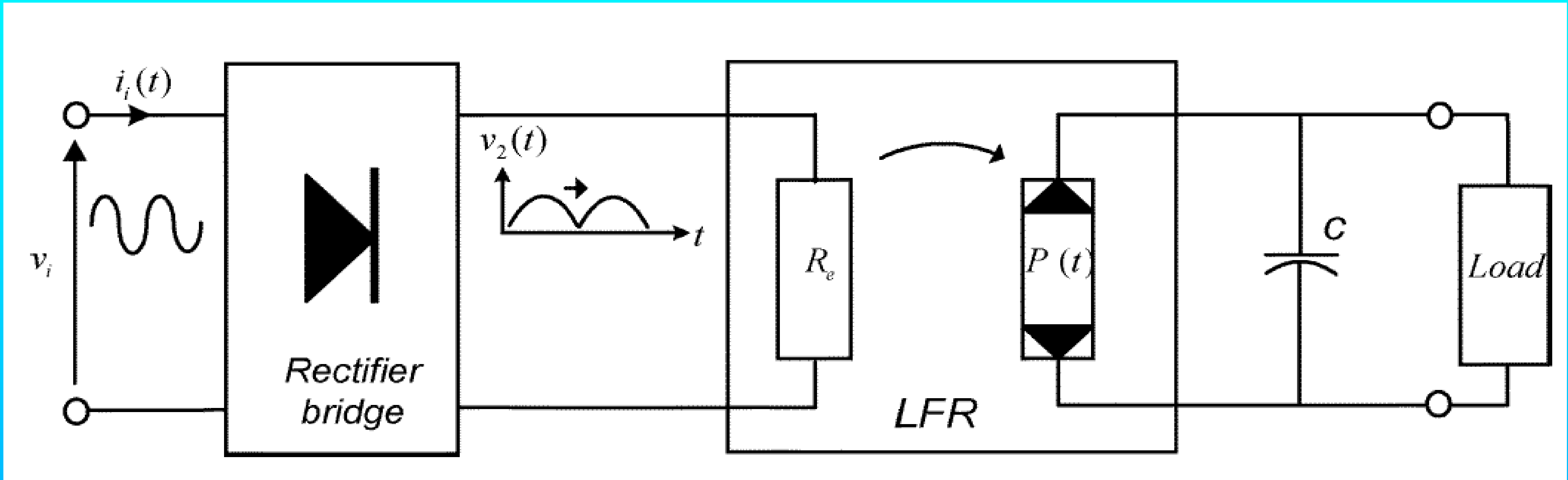




Application for the LFR may include harmonics-free battery charging



harmonics-free ac/dc conversion based on the LFR concept



$$C = \frac{p_{dc}}{V_{dc}^2 \omega \left| \frac{\Delta v_c}{V_{dc}} \right|_{pp}}$$

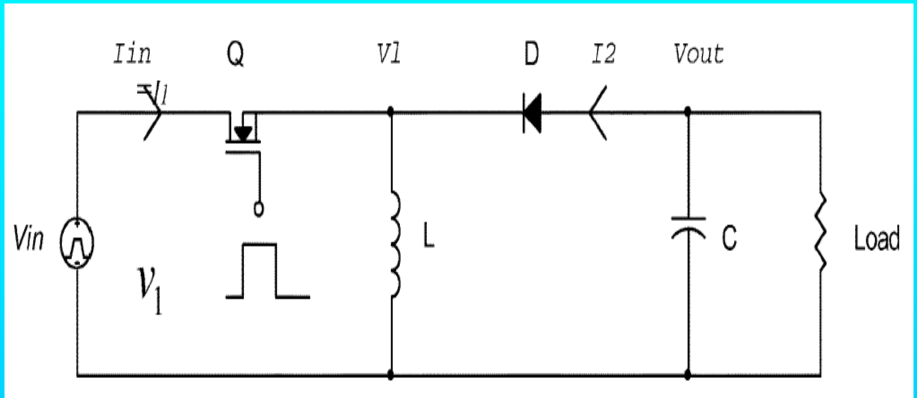
The capacitor needed for a desired ripple at the load.

So by using time variable transformer, a loss – free resistor can be created.

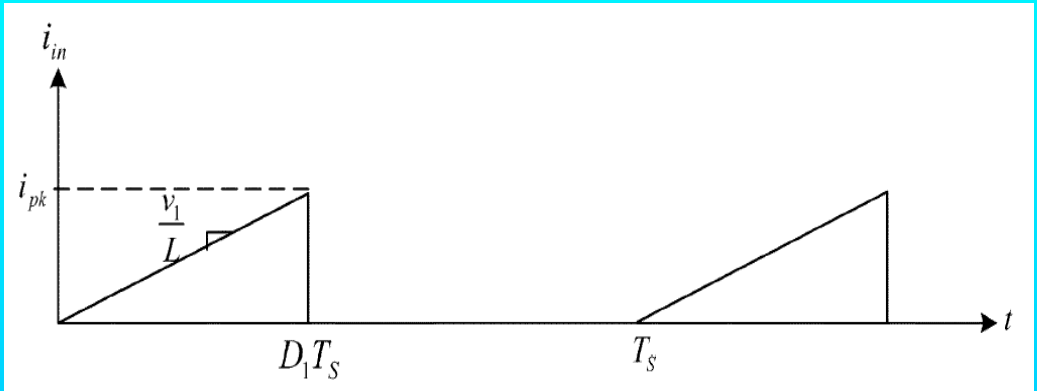
However this requires a control system.

Can a loss – free resistor be created without this control?

An example for a natural (without control) loss free resistor.



Buck-Boost converter working in DCM



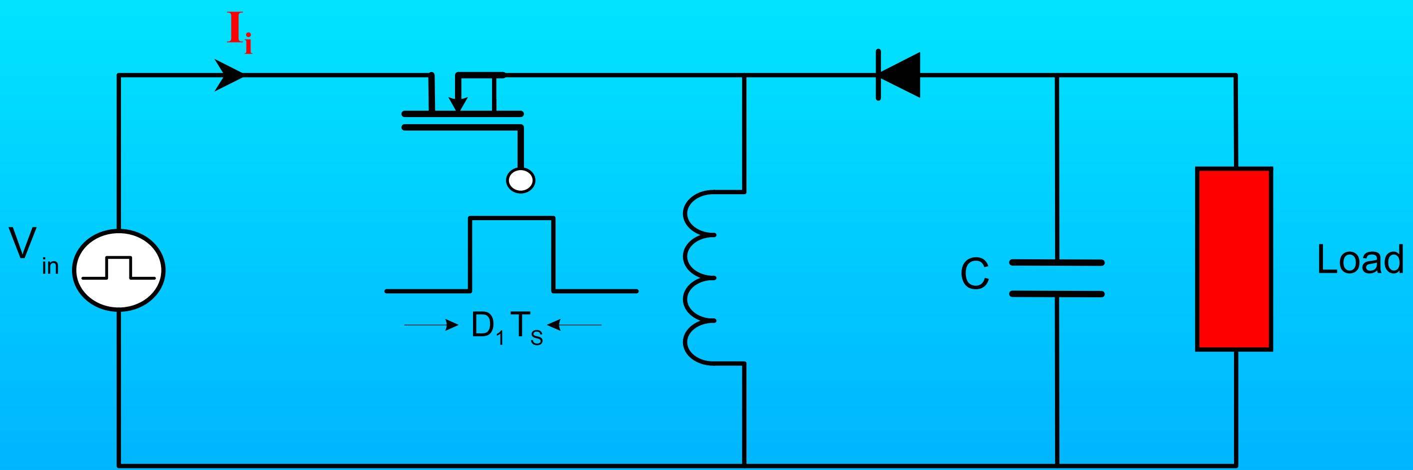
Input current of the converter

The equivalent resistance the source “feels” is:

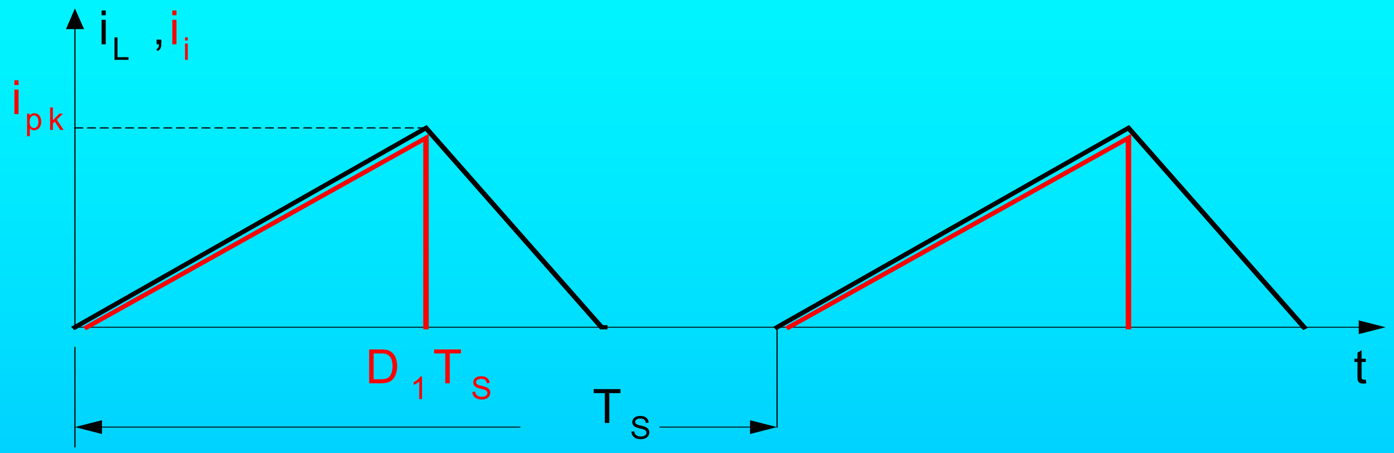
$$R_e = \frac{2L}{D_1^2 \cdot T_s}$$

“Clean” LFR Realization based on a “natural” LFR modules

Flyback at DCM mode



The flyback currents wave forms



$$F(t) \equiv \left\{ \begin{array}{ll} & < t < D \; T_S \\ & D \; T_S < t < T_S \end{array} \right\}$$

$$i_i = F(t) \cdot \frac{V_i}{L} t$$

$$i_i = V_i G_e(t)$$

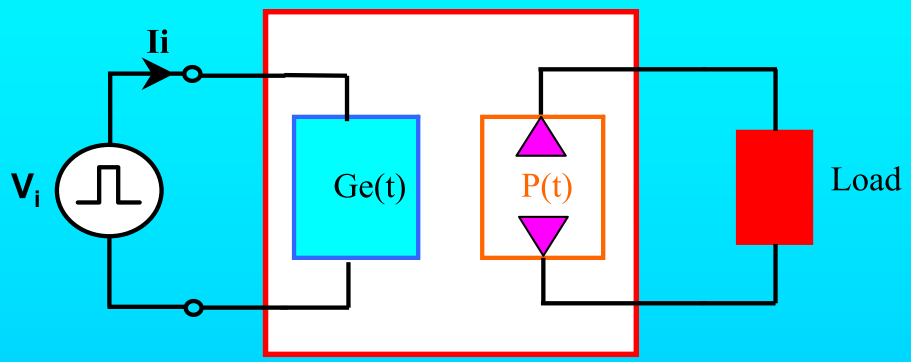
$$G_e(t) \equiv F(t) \cdot \frac{t}{L}$$

"Natural" LFR realization by DCM Flyback

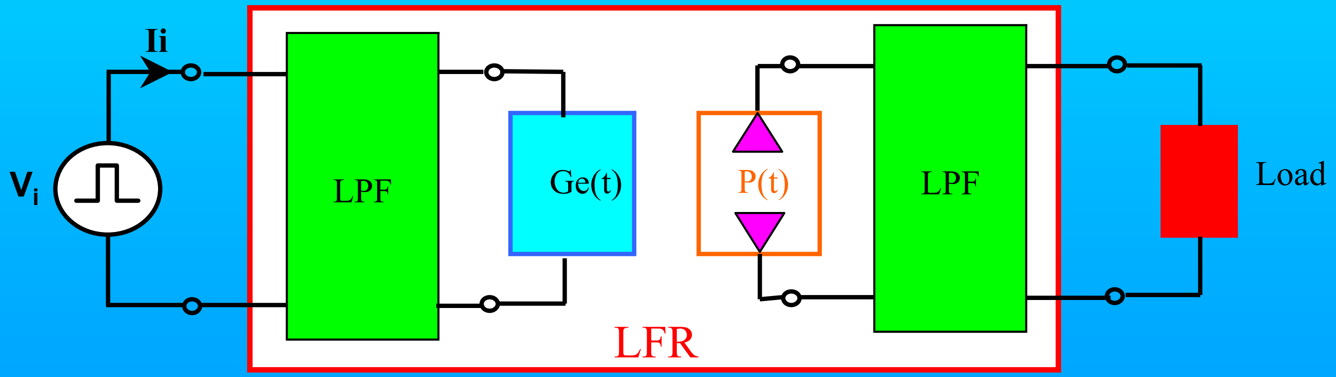
a) The equivalent flyback mode

b) LFR realization

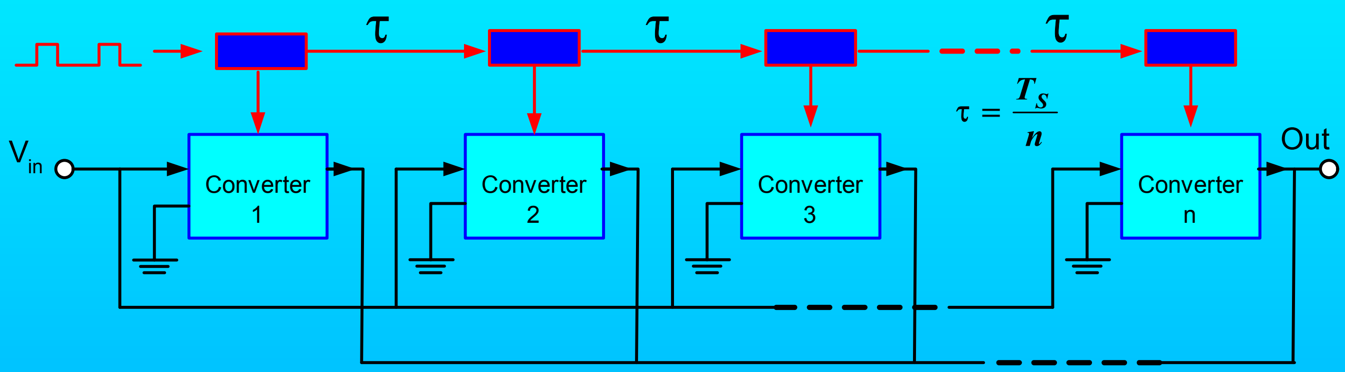
(a)



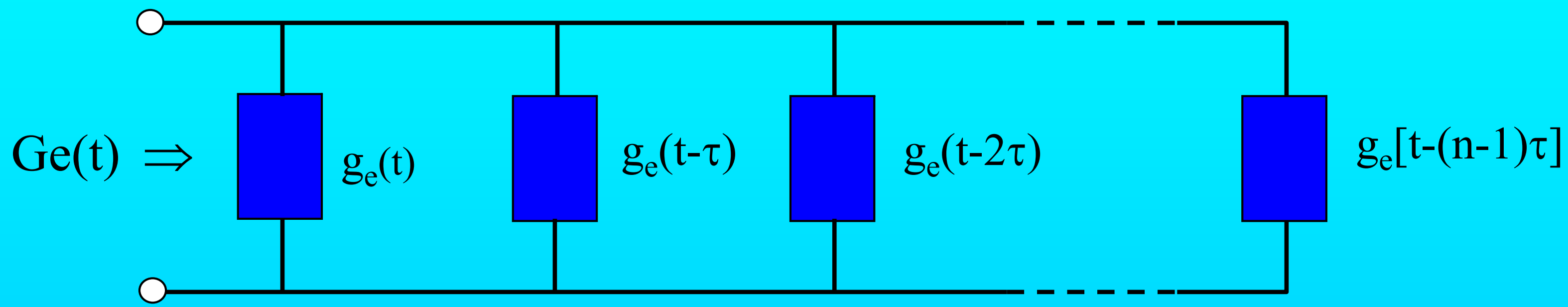
(b)



A group of n interleaved modular converters



Equivalent conductance of n modular interleaved converters



$$\langle G_e(t)\rangle_{T_S} = \frac{1}{T_S}\cdot\int_0^{T_S} G_e(t)dt = \frac{D^2\cdot T_S}{2L} \equiv G_e \quad ; \quad L = \frac{l}{n}$$

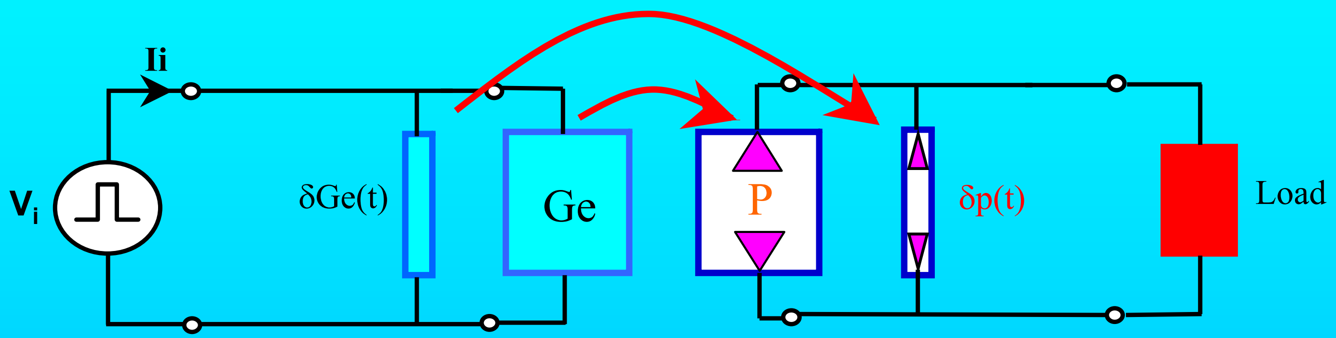
$$G(t) = Ge + \delta G(t)$$

$$\frac{|\delta G(t)|_{\max}}{G_e} = \frac{1}{D\cdot n}$$

l : Inductance of each of the modular converter

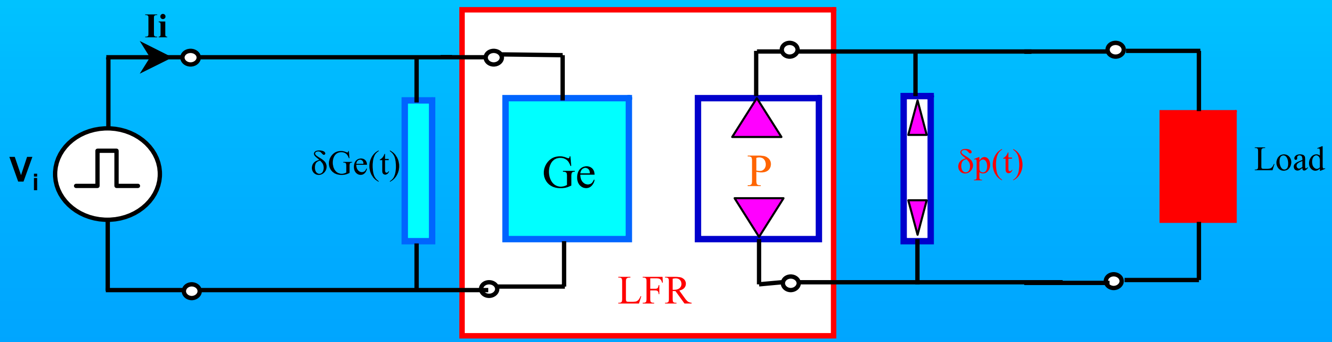
$\delta G(t)$: Has a saw tooth waveform with frequency n times higher than the switching frequency

The model of the interleaved DCM flyback group



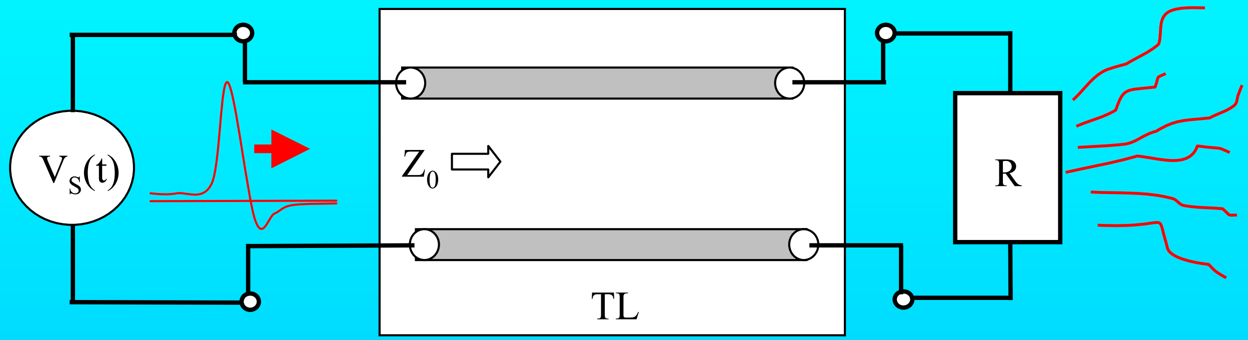
$P = G_e \cdot V_i^2$

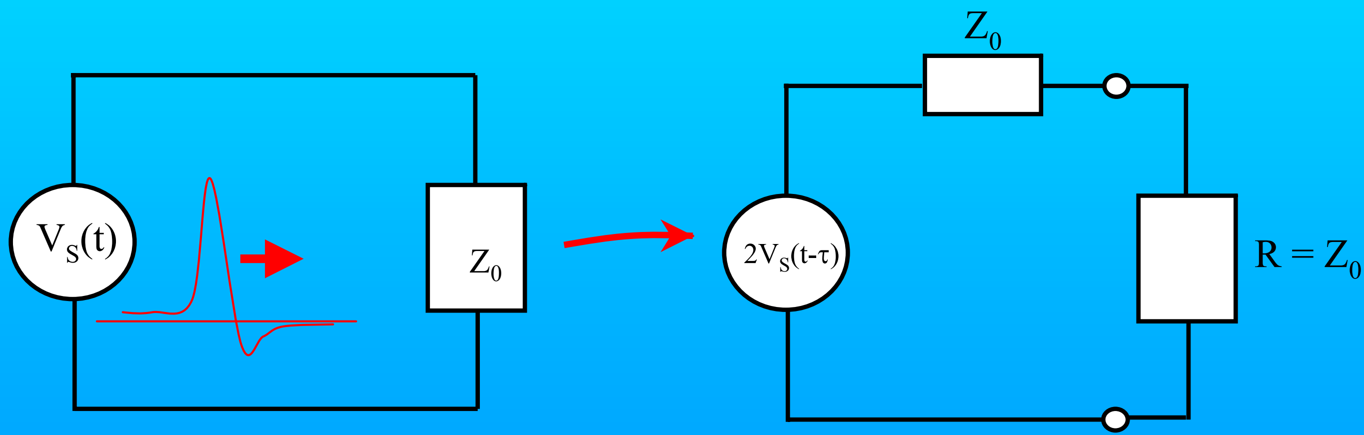
$\delta p(t) = \delta G_e(t) \cdot V_i^2$



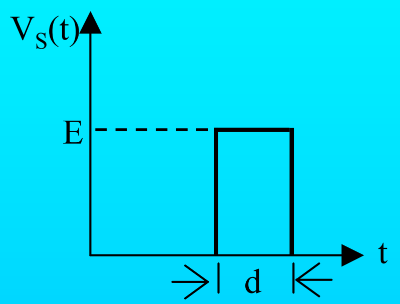
Transmission line Based LFR

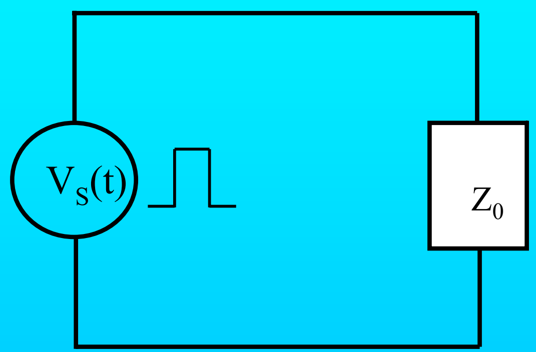
Pulse absorption in Transmission line

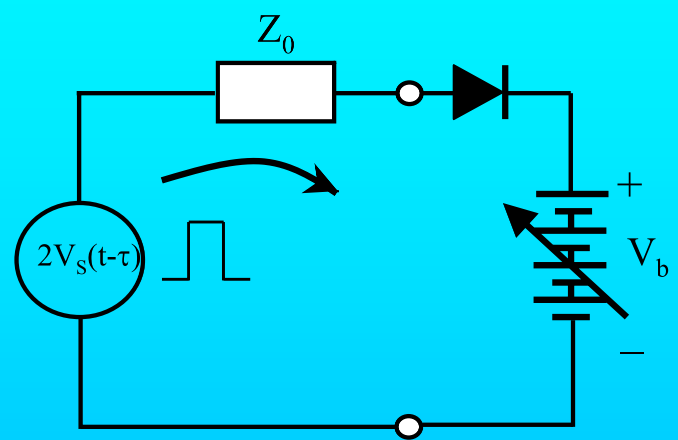




Recycling of rectangular pulse by voltage source







$$W_S = \frac{E^2 \cdot d}{Z_0}$$

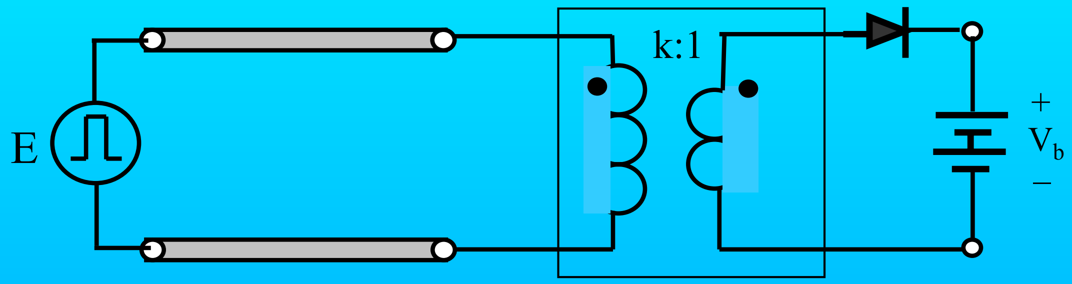
At first pulse absorption

$$p_a = V_b \cdot i_b = \frac{V_b(2E - V_b)}{Z_0}$$

$$Wa = \int_{t=\tau}^{t=\tau+d} p_a(t)dt = \frac{V_b(2E - V_b)}{Z_0} \cdot d$$

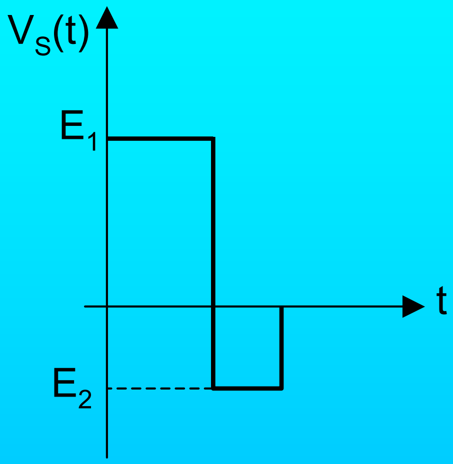
$$\frac{\partial W}{\partial V_b} = 0 \;\Rightarrow\; V_b = E$$ for maximum Energy recycling

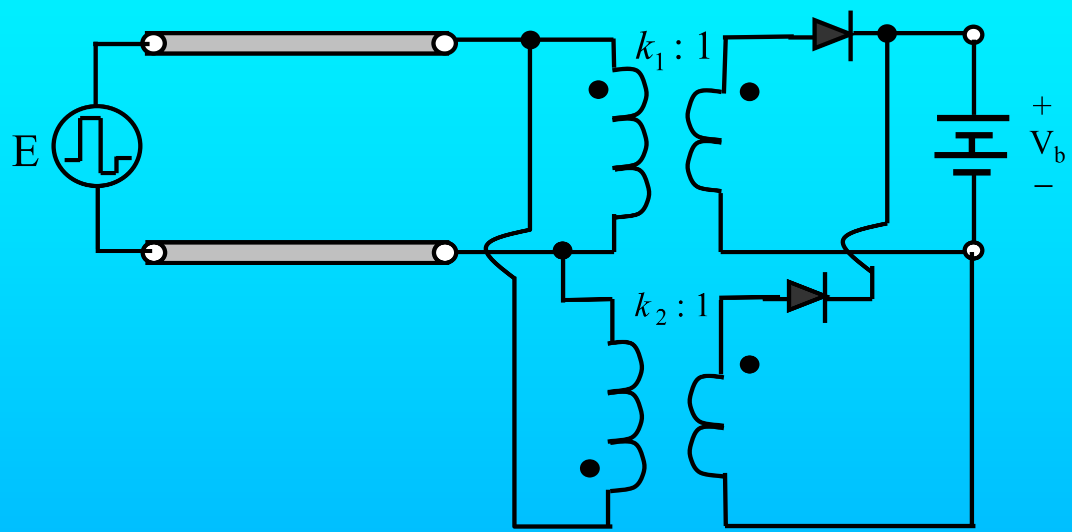
Application of pulse transformer if $V_b \neq E$



$$k = \frac{E}{V_b}$$

Absorption of positive and negative parts of pulse





$$k_1 = \frac{E_1}{V_b}$$

$$k_2 = \frac{E_2}{V_b}$$