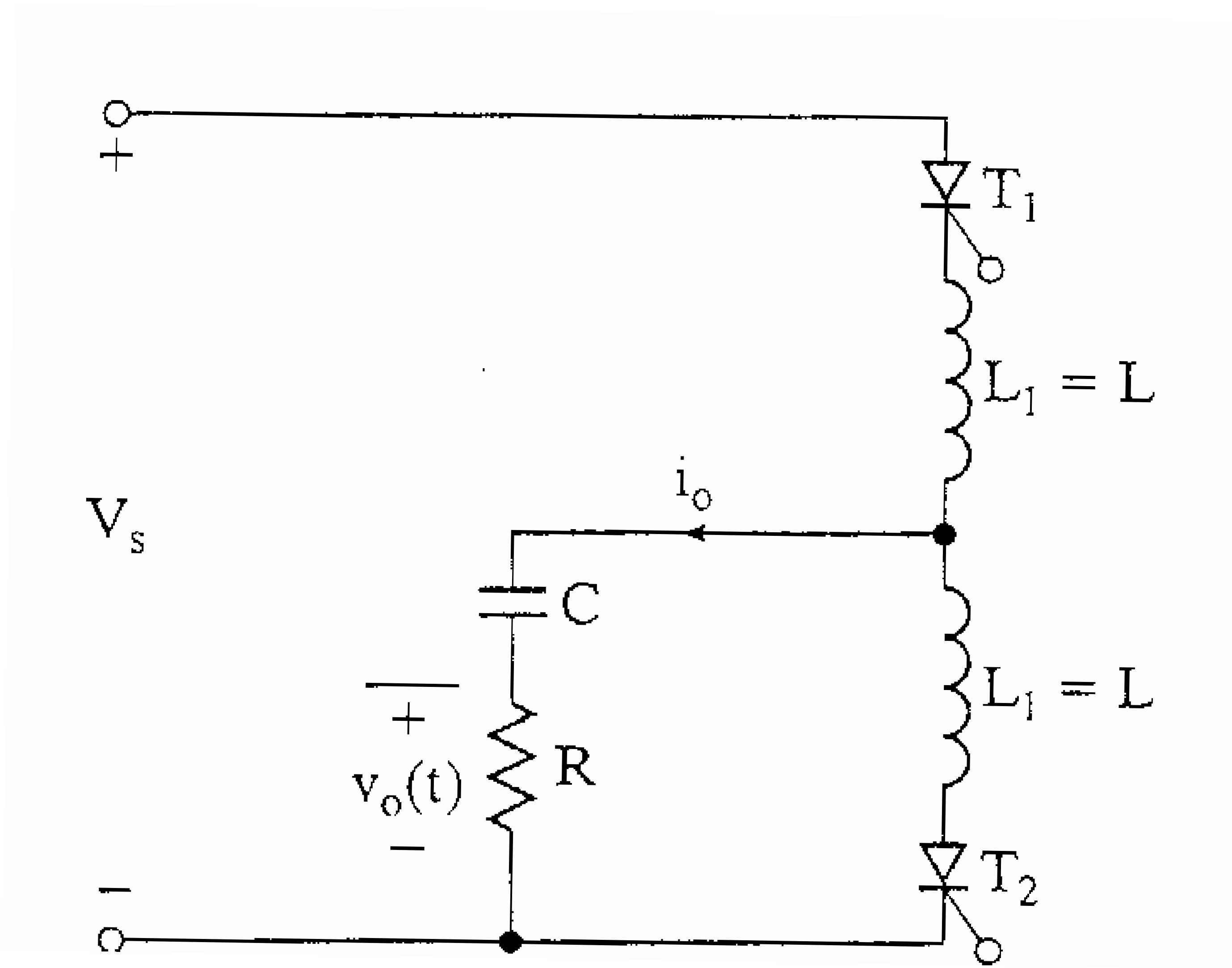
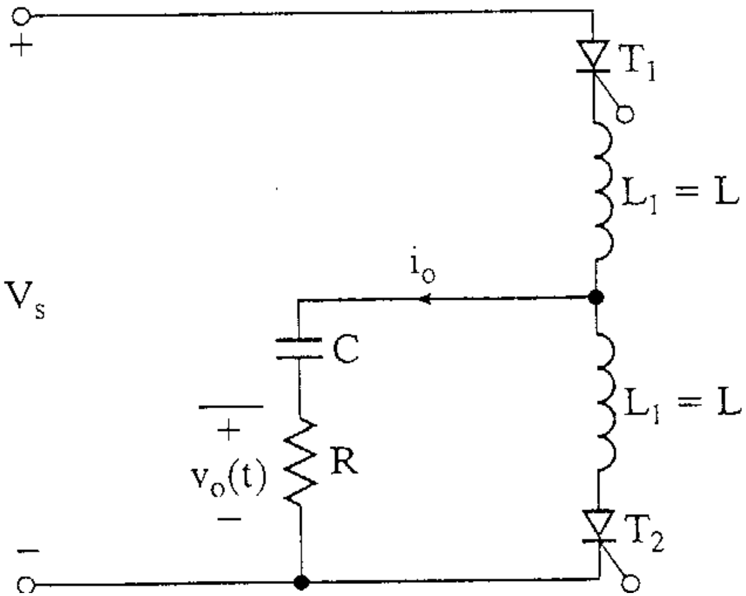
Series-Resonant Inverter



Operation



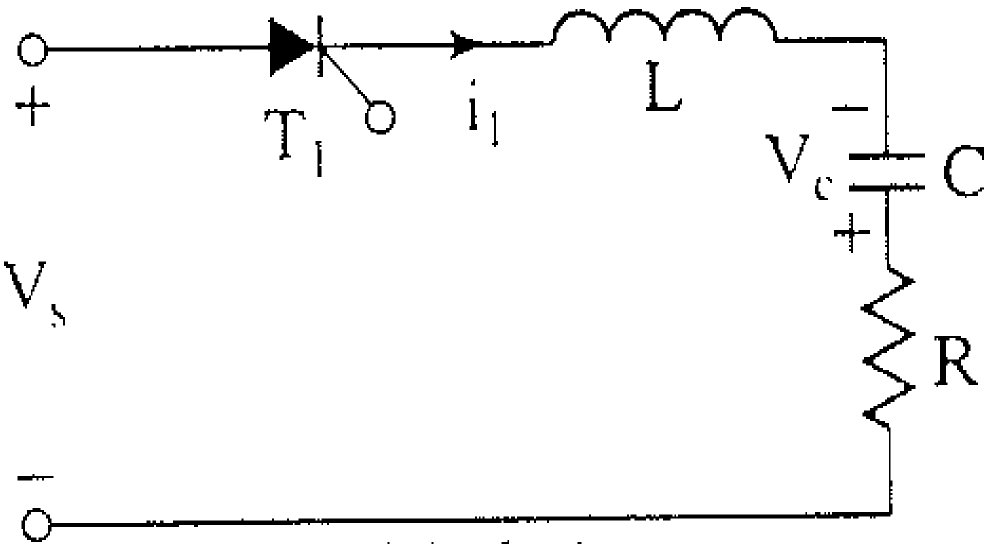
T_1 fired, resonant pulse of current flows through the load. The current falls to zero at $t = t_{1m}$ and T_1 is "self – commutated".

T_2 fired, reverse resonant current flows through the load and T_2 is also "self-commutated".

The series resonant circuit must be underdamped,

$R^2 < (4L/C)$

Operation in Mode 1 – Fire T_1



$$L\frac{di_1}{dt} + Ri_1 + \frac{1}{C}\int i_1 dt + v_C(0) = V_S$$

$$i_1(0) = 0$$

$$v_C(0) = -V_C$$

$$i_1(t) = A_1 e^{-\frac{R}{2L}t} \sin \omega_r t$$

$$\omega_r = \left(\frac{1}{LC} - \frac{R^2}{4L^2} \right)^{\frac{1}{2}}$$

$$\left. \frac{di_1}{dt} \right|_{t=0} = \frac{V_s + V_c}{\omega_r L} = A_1$$

$$\boxed{i_1(t) = \frac{V_s + V_c}{\omega_r L} e^{-\alpha t} \sin \omega_r t}$$

$$\alpha = \frac{R}{2L}$$

To find the time when the current is maximum, set the first derivative = 0

$$\frac{di_1}{dt} = 0$$

$$\left(\frac{V_s + V_c}{\omega_r L}\right)\left(-\alpha e^{-\alpha t} \sin \omega_r t + \omega_r e^{-\alpha t} \cos \omega_r t\right) = 0$$

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$$\frac{\omega_r}{\alpha} = \tan \omega_r t_m$$

$$\tan^{-1} \frac{\omega_r t_m}{\alpha} = \omega_r t_m$$

$$t_m = \frac{1}{\omega_r} \tan^{-1} \frac{\omega_r}{2}$$

To find the capacitor voltage, integrate the current

$$v_{C_1}(t) = \frac{1}{C}\int_0^t i_1(t)dt - V_c$$

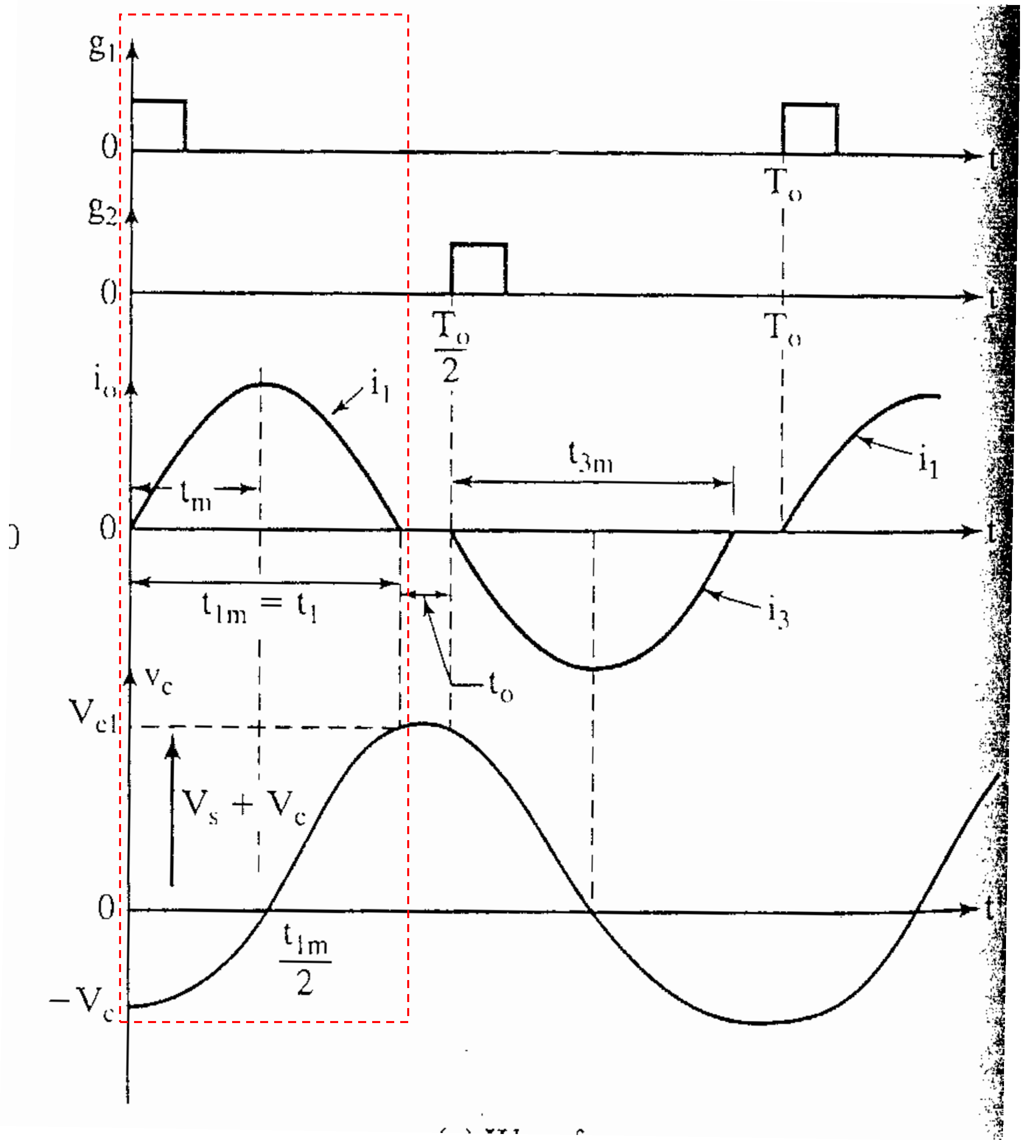
$$v_{C_1}(t) = \frac{1}{C}\int_0^t \left(\frac{V_s + V_c}{\omega_r L}\right)\left(e^{-\alpha t}\sin\omega_r t\right)dt - V_C$$

…

$$v_{C_1}(t) = -(V_s + V_C)e^{-\alpha t}(\alpha\sin\omega_r t + \omega_r\cos\omega_r t)/\omega_r + V_s$$

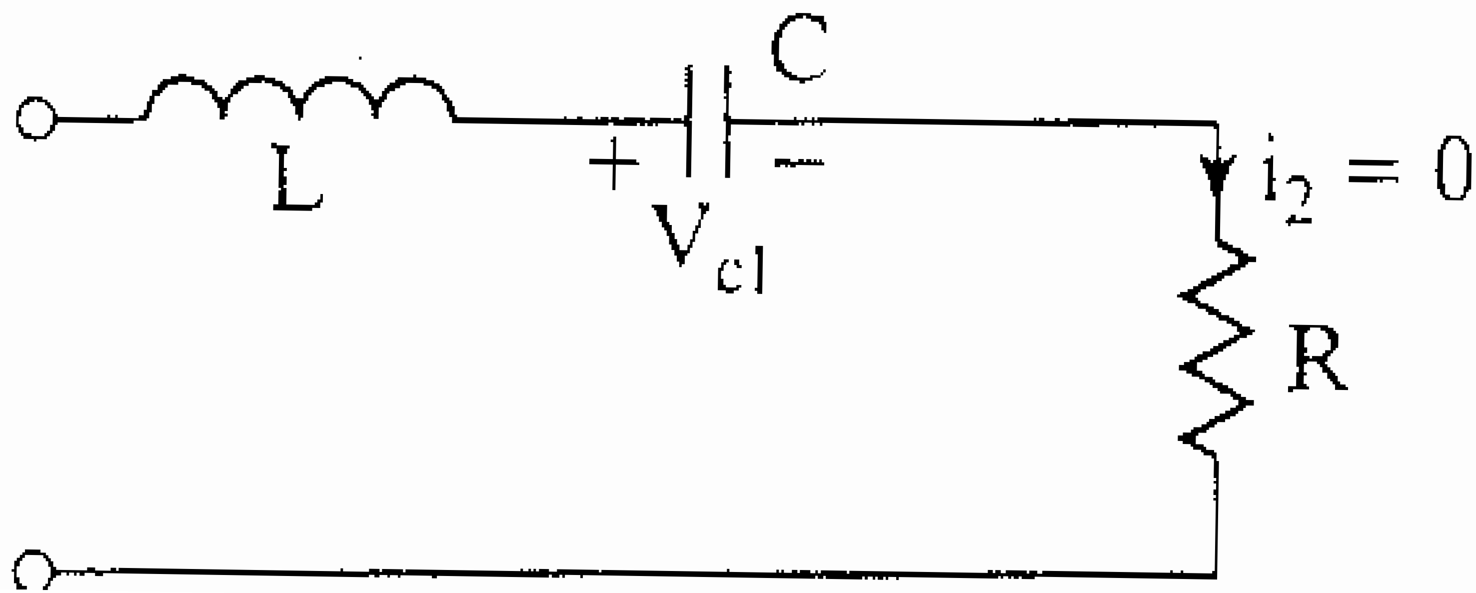
$$0 \le t \le t_{1m}\left(\frac{\pi}{\omega_r}\right) \longleftarrow$$ The current i_1 becomes = 0 @ $t=t_{1m}$

$$v_{C_1}(t_{1m}) = V_{C1} = \left(V_s + V_C\right)e^{-\frac{\alpha\pi}{\omega_r}} + V_s$$



g_1
0
t
T_o
g_2
0
t
$\frac{T_o}{2}$
T_o
i_o
i_1
t_{3m}
i_1
t_m
0
t
$t_{1m} = t_1$
i_3
t_o
v_c
V_{c1}
$V_s + V_c$
0
t
$\frac{t_{1m}}{2}$
$-V_c$

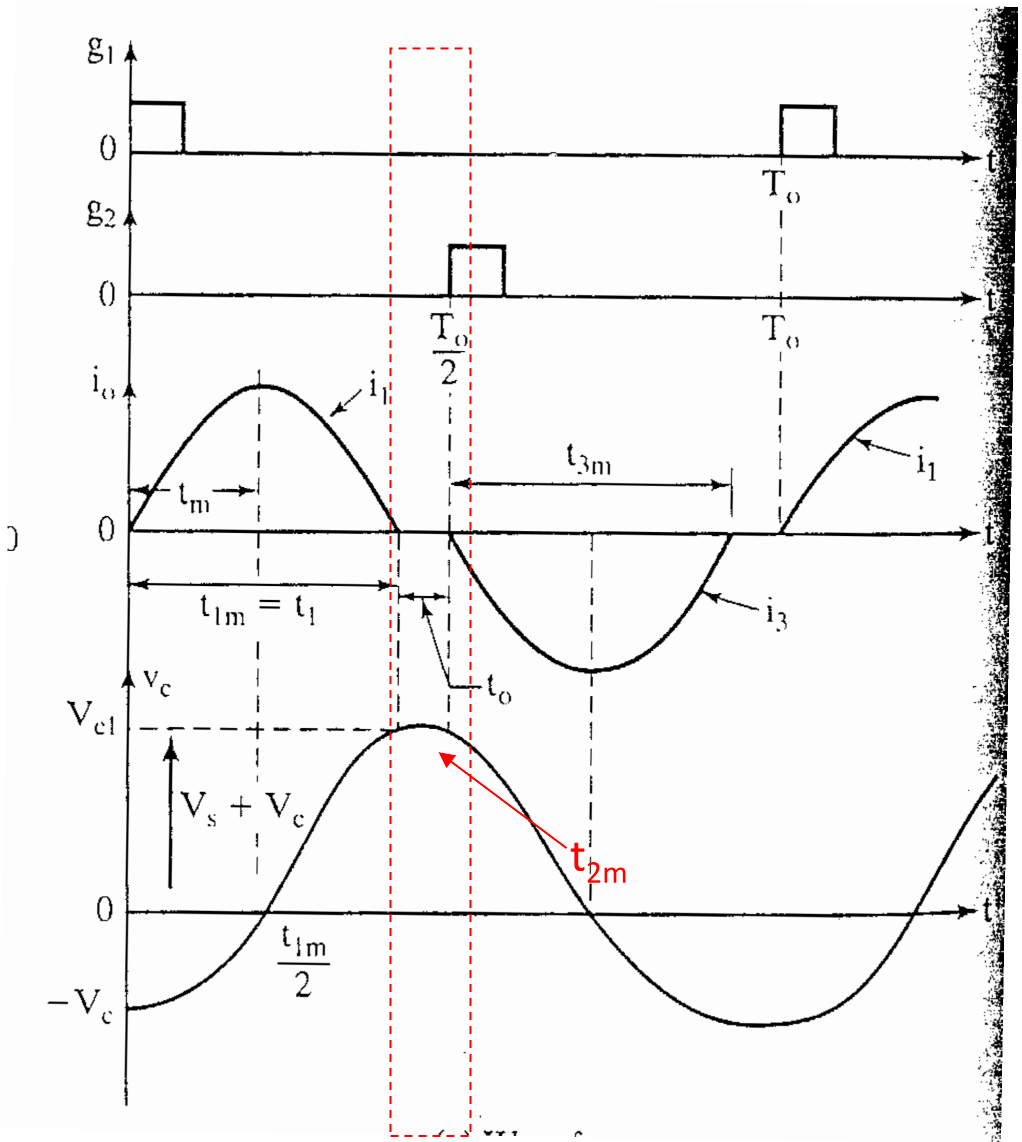
Operation in Mode 2 – T_1, T_2 Both OFF



$$i_2(t) = 0$$

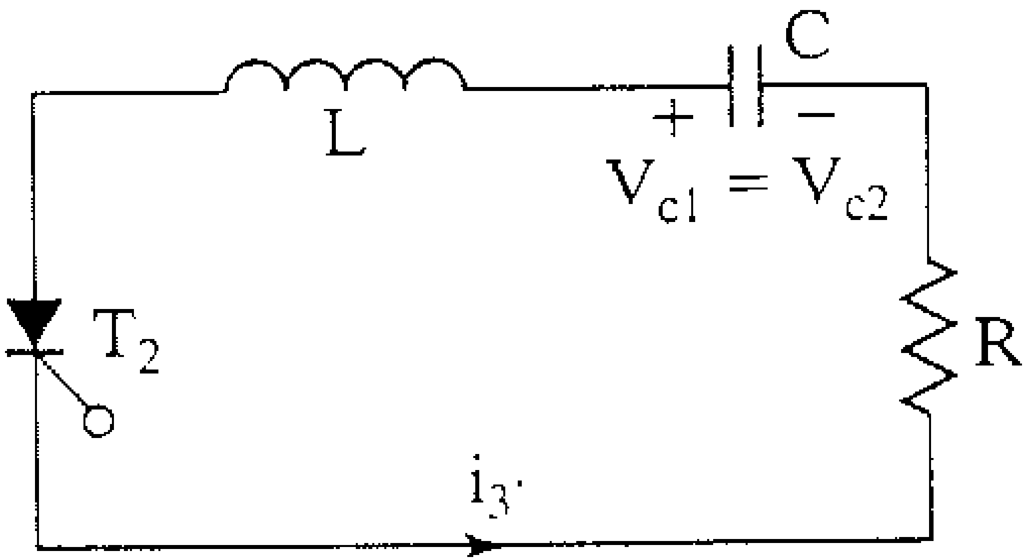
$$v_{C_2}(t) = V_{C_1}$$

$$v_{C_2}(t_{2_m}) = V_{C_2} = V_{C_1}$$



g1
0
t
To
g2
0
t
To/2
To
io
i1
t3m
i1
tm
0
t
t1m = t1
i3
to
vc
Vc1
Vs + Vc
t2m
0
t
t1m/2
−Vc

Operation in Mode 3 – Fire T_2



$$L\frac{di_3}{dt} + Ri_3 + \frac{1}{C}\int i_3 dt + v_{C_3}(0) = 0$$

$$i_3(0) = 0$$

$$v_{C_3}(0) = -V_{C_2} = -V_{C_1}$$

$$\boxed{i_3(t) = \frac{V_{C_1}}{\omega_r L} e^{-\alpha t} \sin \omega_r t}$$

$$v_{C_3}(t) = \frac{1}{C} \int_0^t i_3 dt - V_{C_1}$$

$$\boxed{v_{C_3}(t) = \frac{-V_{C_1} e^{-\alpha t} (\alpha \sin \omega_r t + \omega_r \cos \omega_r t)}{\omega_r}}$$

$$0 \leq t \leq t_{3_m} \left(\frac{\pi}{\omega_r}\right)$$

$$v_{C_3}(t_{3_m}) = V_{C_3} = V_C = V_{C_1} e^{-\alpha \frac{\pi}{\omega_r}}$$

$$v_{C_1}(t_{1_m}) = V_{C_1} = (V_S + V_C) e^{-\alpha \frac{\pi}{\omega_r}} + V_S$$

.

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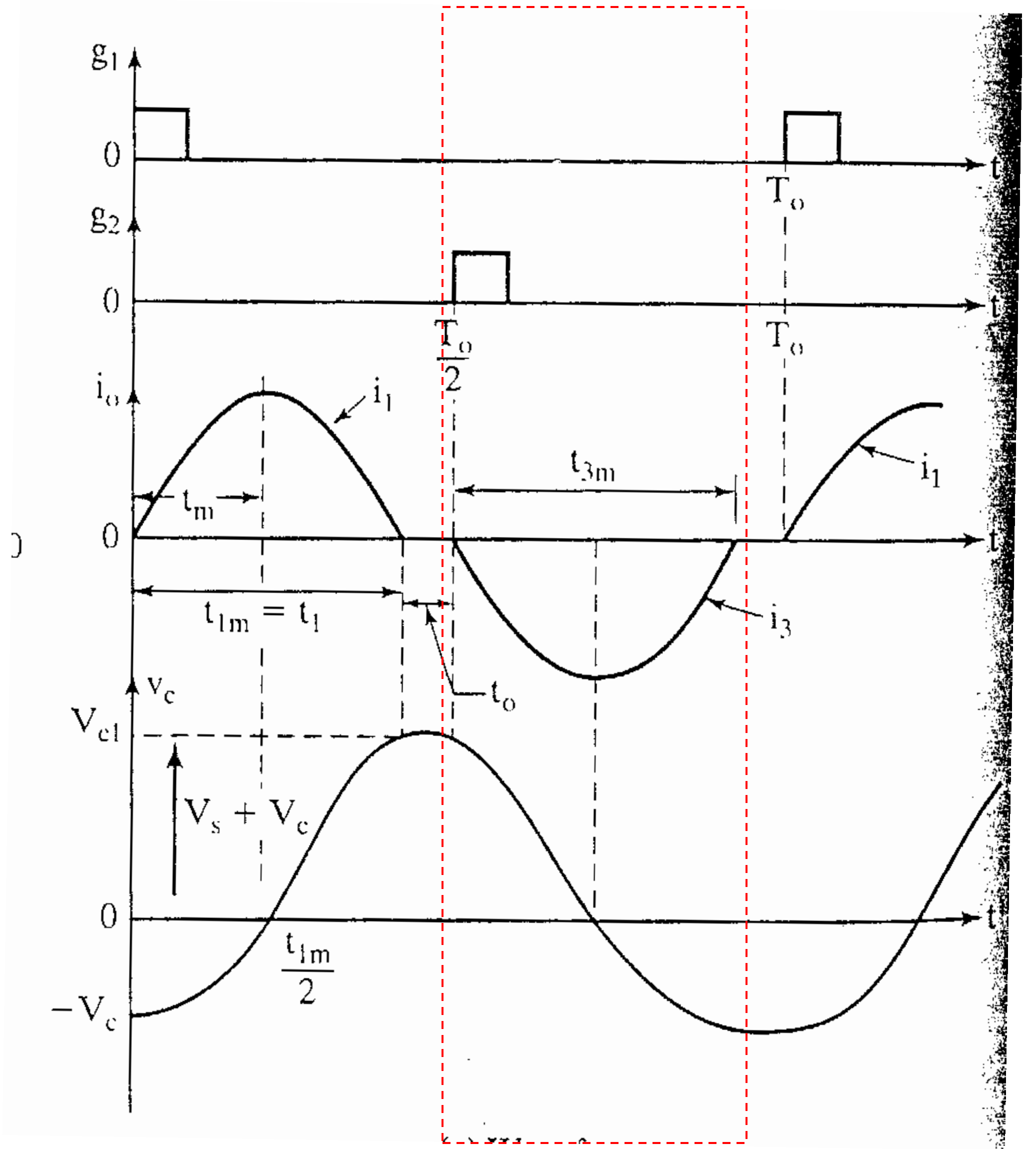
$$V_C = V_S \frac{1}{e^z - 1}$$

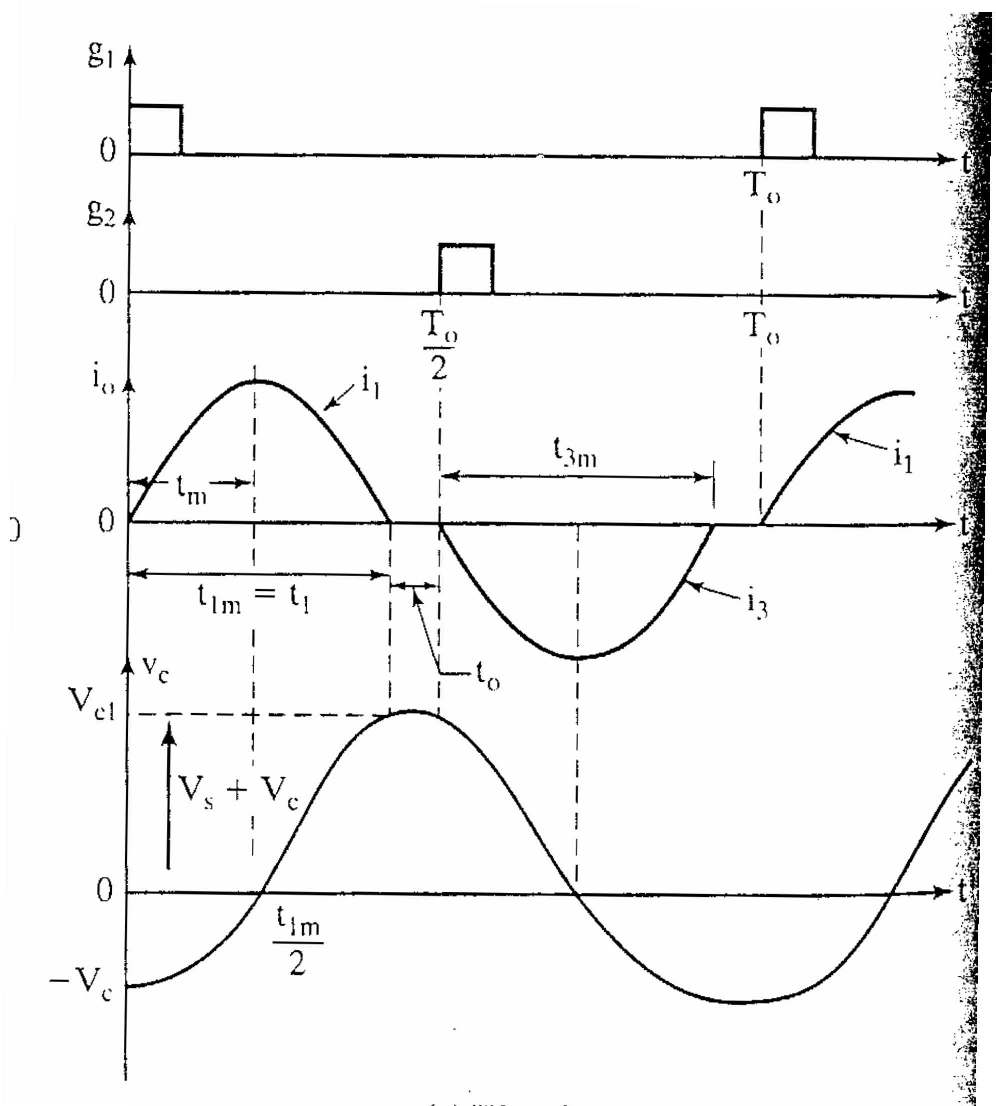
$$V_{C_1} = V_S \frac{e^z}{e^z - 1}$$

$$V_C + V_S = V_{C_1}$$

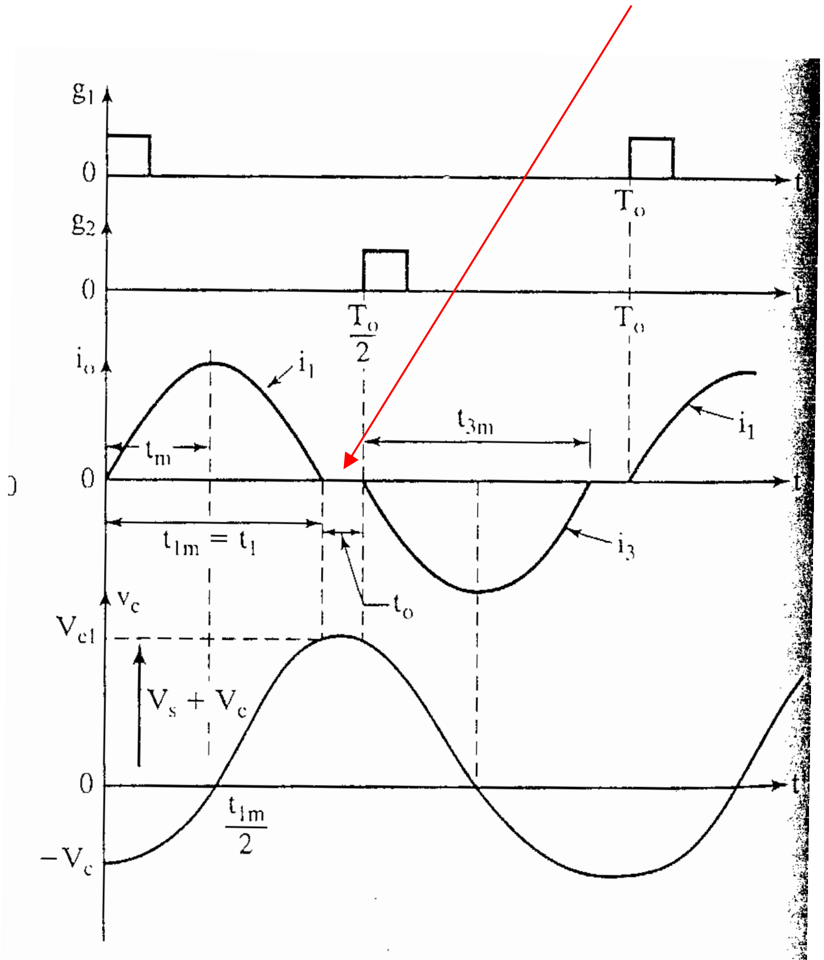


g1
0
t
To
g2
0
t
To/2
To
io
i1
t3m
i1
tm
0
t
t1m = t1
i3
to
vc
Vc1
Vs + Vc
0
t
t1m/2
−Vc

Summary -- Series Resonant Inverter



To avoid a short-circuit across the main dc supply, T_1 must be turned OFF before T_2 is turned ON, resulting in a "dead zone".



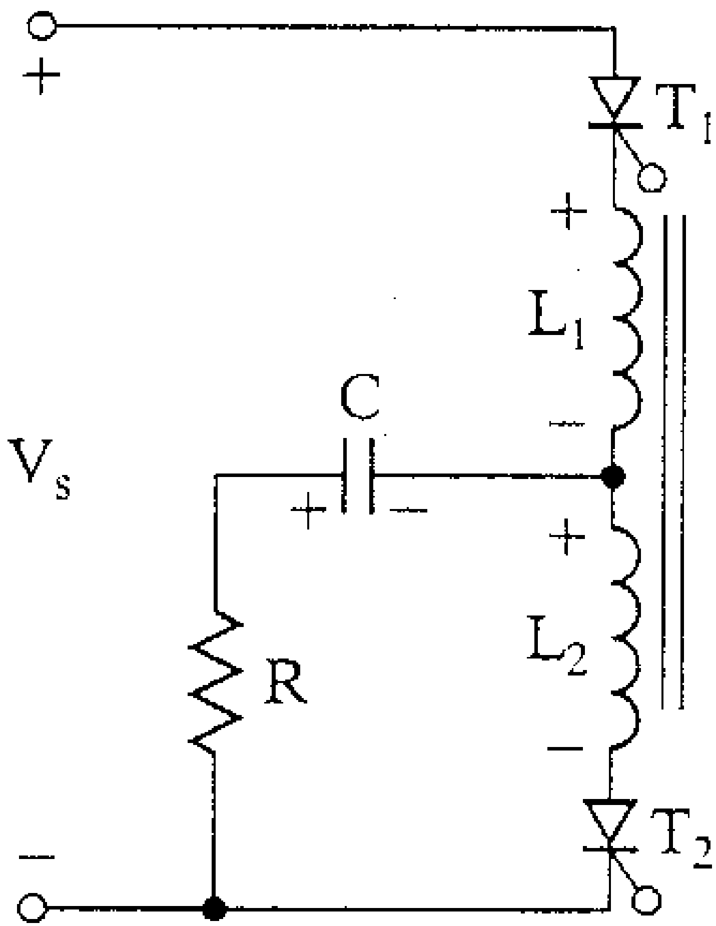
This "off-time" must be longer than the turn-off time of the thyristors, t_q.

$$\frac{\pi}{\omega_0} - \frac{\pi}{\omega_r} = t_{off} > t_q$$

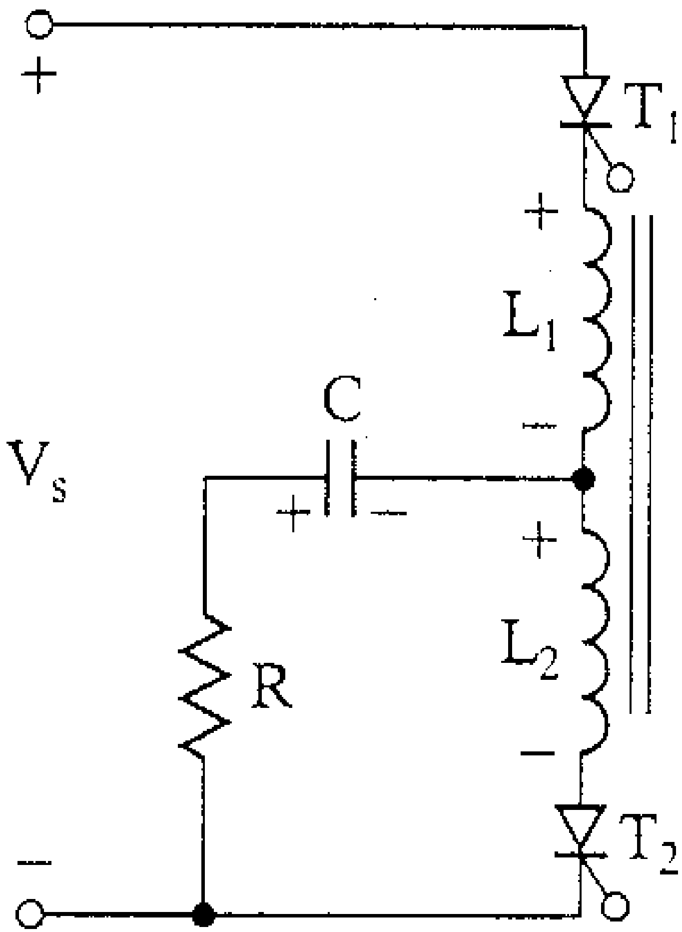
The maximum possible output frequency is

$$\boxed{f_0 \le f_{max} = \frac{1}{2\pi\left(t_q + \frac{\pi}{\omega_r}\right)}}$$

Series Resonant Inverter
Coupled Inductors



Improvement in performance



- When T_1 turned ON, voltage @ L_1 is as shown, voltage @ L_2 in same direction, adding to the voltage @ C
- This turns T_2 OFF before the load current falls to 0.