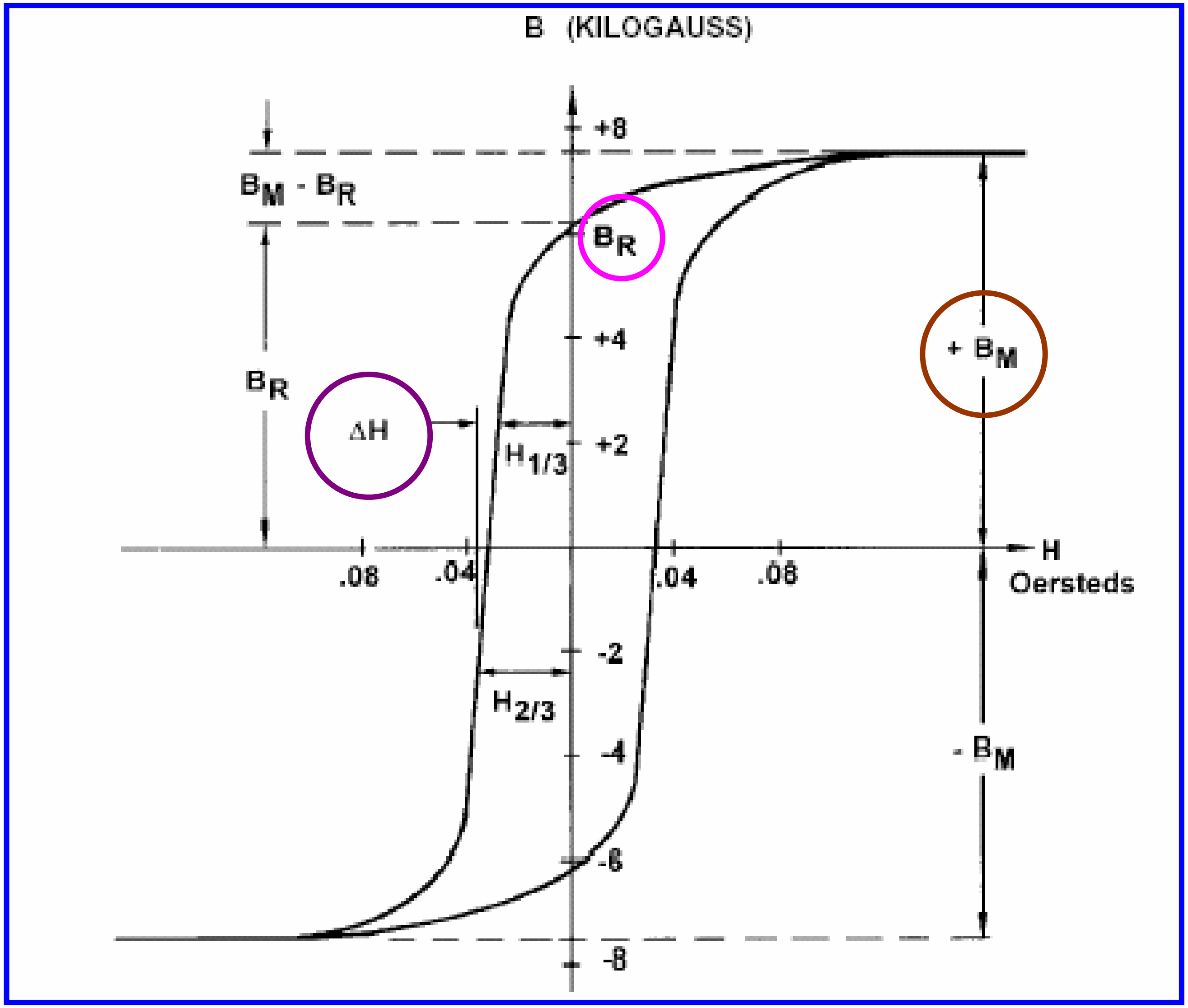
Technical Training

Adlsong

Basic Theory



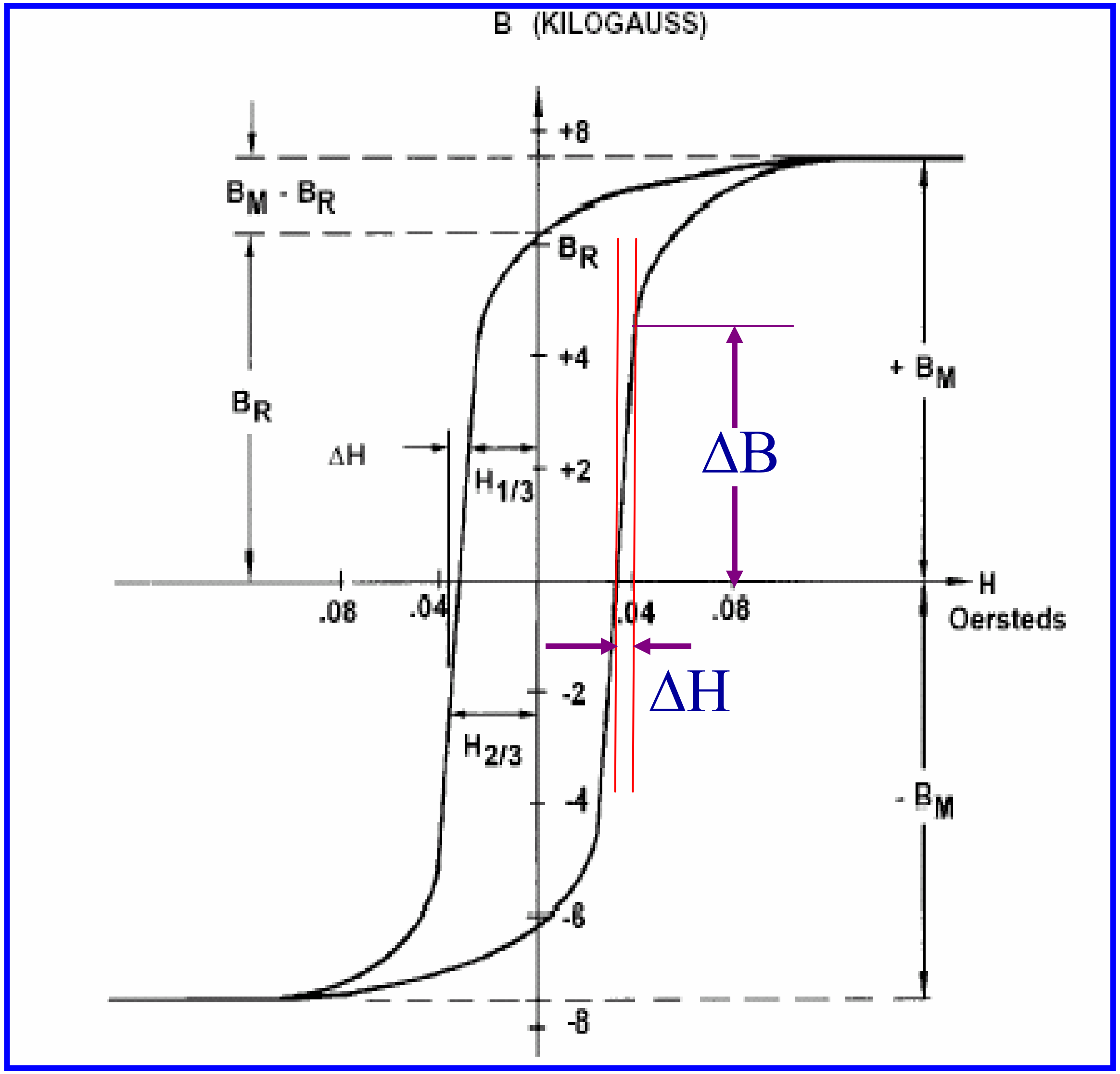
Hysteresis Loop

Bs: saturate magnetic flux density

Br: residual magnetic flux density

Hc: coercive force

Basic Theory



Hysteresis Loop

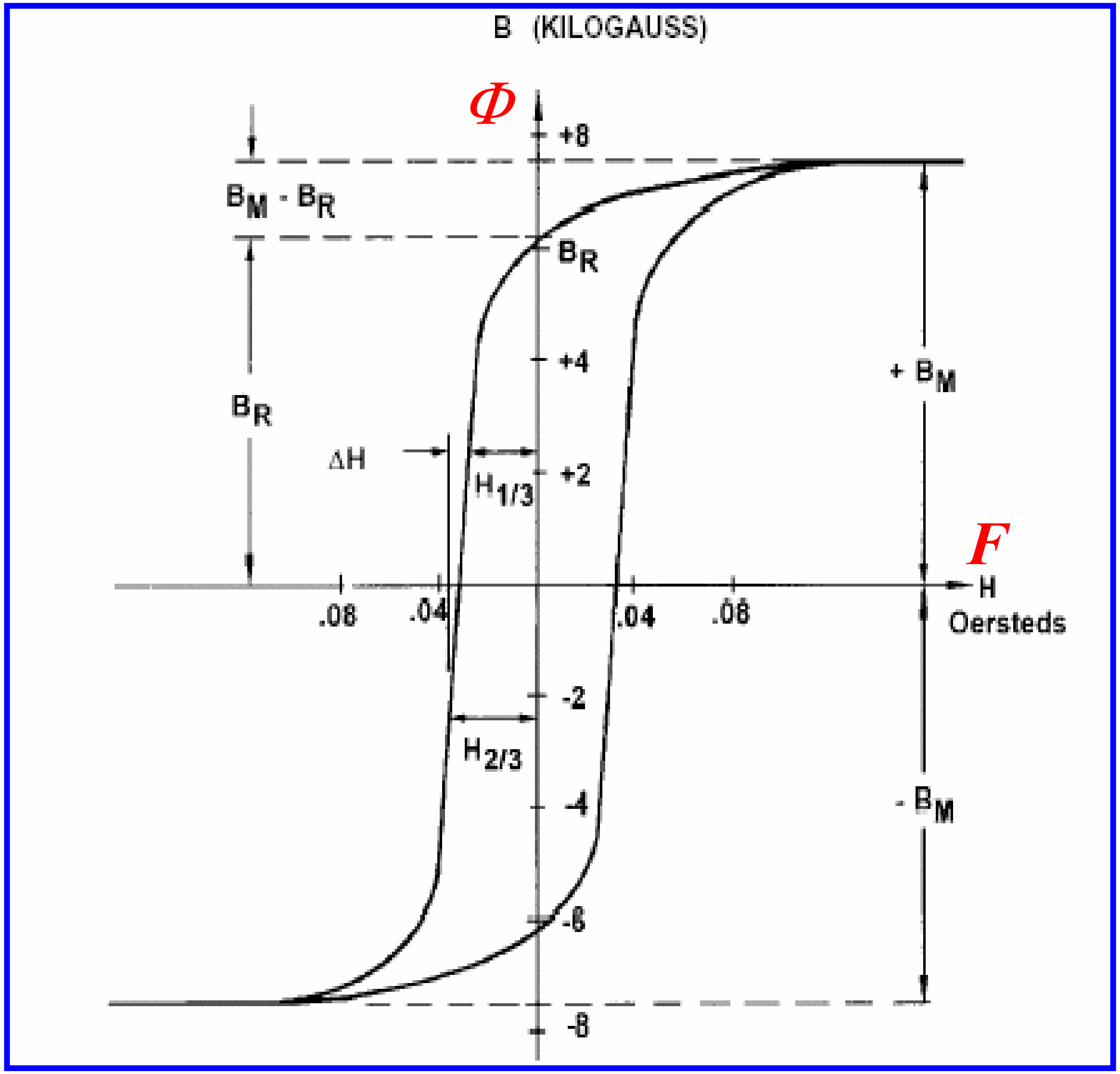
$$B = \mu \cdot H$$

B: flux density (tesla)

H: field intensity (A-T/m)

μ: permeability

Basic Theory



Hysteresis Loop

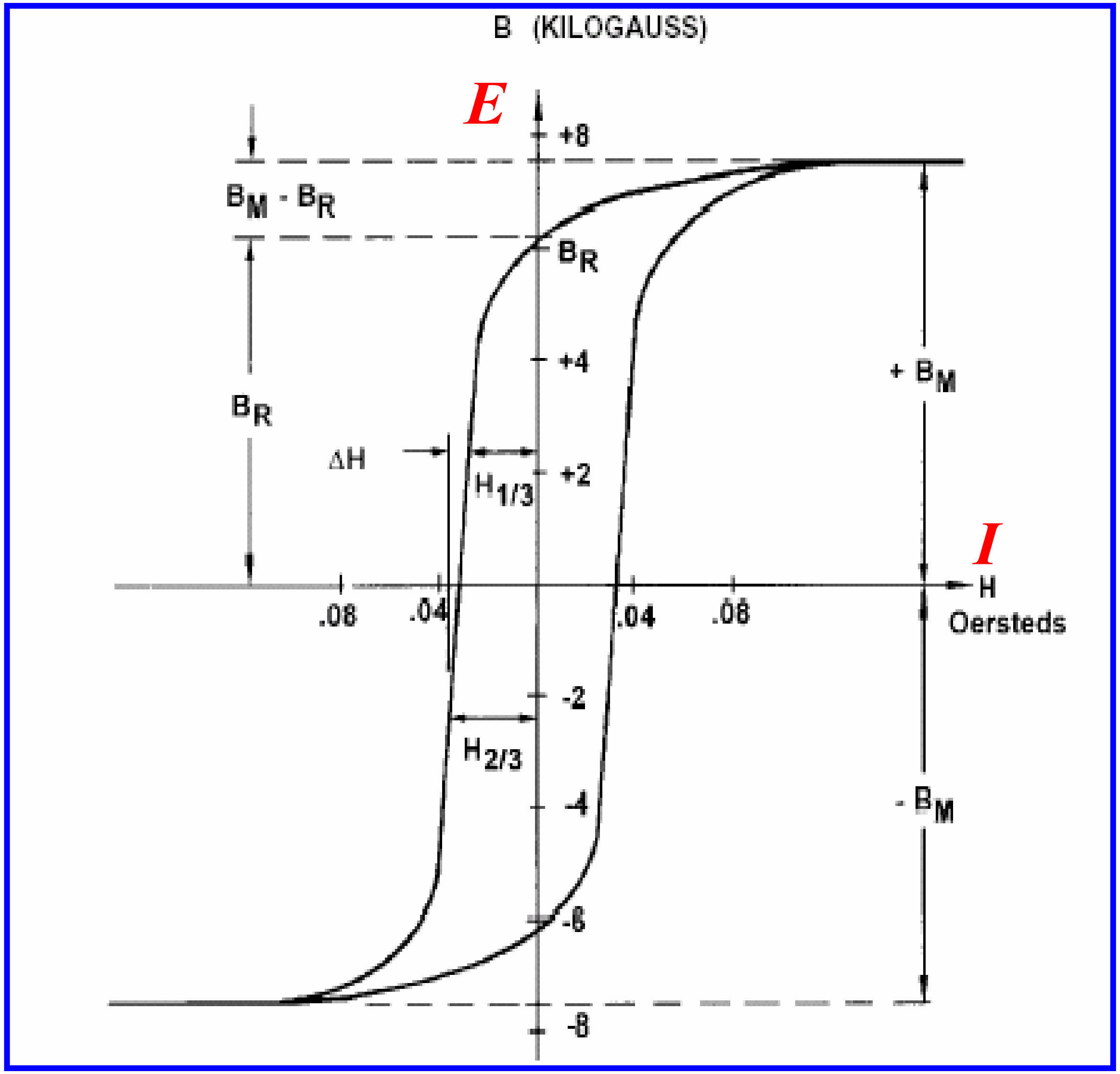
X	Y
H	B
F $(F = H \cdot l)$	Φ $(\Phi = B \cdot A)$

A: core effective area (m^2)
Φ: flux ($T{\cdot}m^2$ or webers)
F: magnetic force (ampere-turns)
l : path length (m)

B – H **:** defining a core material

Φ – F **:** defining a specific core with Ae and Le

Basic Theory



Hysteresis Loop

X	Y
H	B
I ($I=Hl/N$)	E ($E=Nd\Phi/dt$)

***E* – *I* :** defining a specific core wound with N turns

Basic Theory

Two Important Laws

① **Ampere's Law:** $F = \int H \cdot dl = \Sigma H \cdot l = N \cdot I$

I : loop current (ampere)

N : turns of windings

② **Faraday's Law:** $E = N\, d\Phi / dt$

E: induced voltage (volts)

Flux cannot change instantaneously:

The time is required to move along B(Φ) and a change in energy takes palce

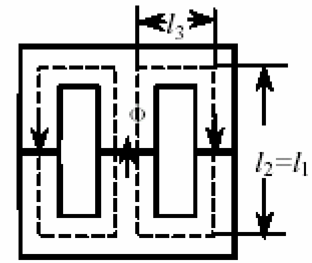
Basic Theory

Without air gap:

$W = \int Vol \cdot HdB = \int I \cdot Edt \quad (W/m^3 = 0.5 \cdot H \cdot B)$

$L = N \cdot \Phi / i = \mu_0 \cdot N^2 \cdot A / l = A_L \cdot N^2$

A_L: inductance factor

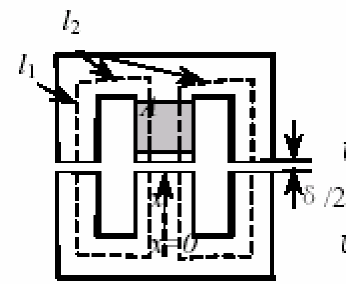


With air gap:

$W = \int Vol \cdot HdB = V \cdot B^2/2\mu + Vg \cdot B^2/2\mu_0$

$L = \mu_0 N^2 A / (l/\mu_r + g) \approx \mu_0 N^2 A / g = A_L \cdot N^2$

$B = \mu_0 NI/(g+l/\mu r)$



Note: Most of the energy is stored in the gap portion

$\mu >> \mu_0$, $l/\mu_r >> g$

g: air gap length

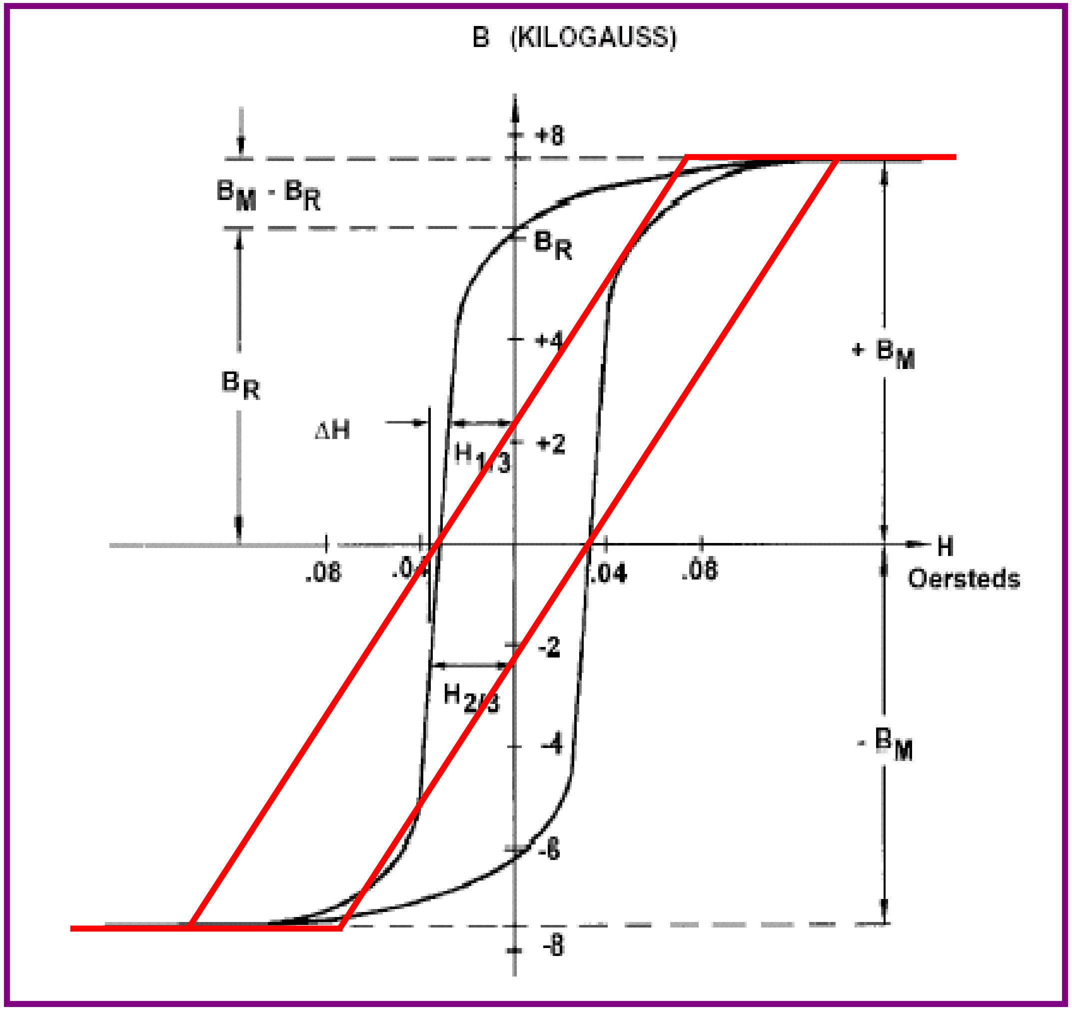
l: magnetic path length

μ: magnetic core permeability

μ0: space permeability

μr : relative permeability

Basic Theory



As for the same current:
Effective flux density of no air gap magnetic core is decreased compared with air gap magnetic core

Low value section of hysteresis loop is
Very linearized

Basic Theory

2.1 Three types of devices

Resistor: $u/i = R$

u, i can change instantaneously

Inductor: $L \cdot di_L/dt = u_L$

i cannot change instantaneously

Capacitor: $C \cdot du_C/dt = i_C$

u cannot change instantaneously

Basic Theory

2.2 ZCT

$L \cdot di_L/dt = u_C$

$i_L = -i_C = -C \cdot du_C/dt$

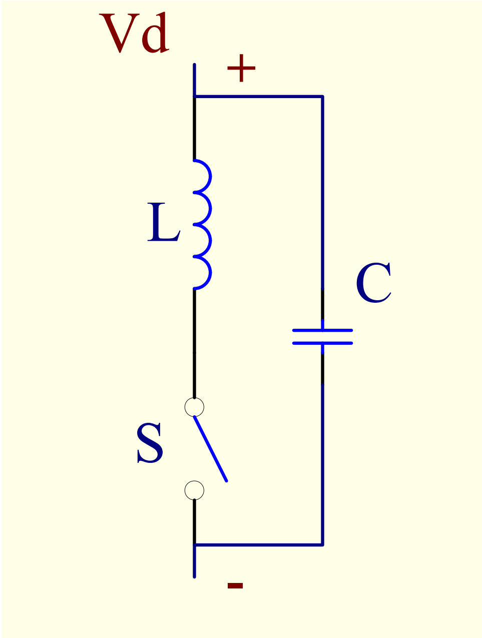
$i_{C(0)} = 0,\ i_{L(0)} = 0,\ U_{C(0)} = Ud$

So: $u_C = Ud \cdot \cos w_0 t$

$i_L = Ud \cdot \sin w_0 t / Zc$

$w_0 = (1/LC)^{1/2}$

$Zc = (L/C)^{1/2}$



Basic Theory

(1) Resonant tanks: LC, L and S in series, S is off at the beginning. The resonant process is starting when S is switched on.

(2) $w_0 t = k\pi$, $i_L = 0$, ZCT when $i_L = 0$.

(3) half wave : the current cannot be reverse after $w_0 t = k\pi$ because S is off

(4) Full wave when a diode is in parallel with S –current: forward and reverse direction).

Basic Theory

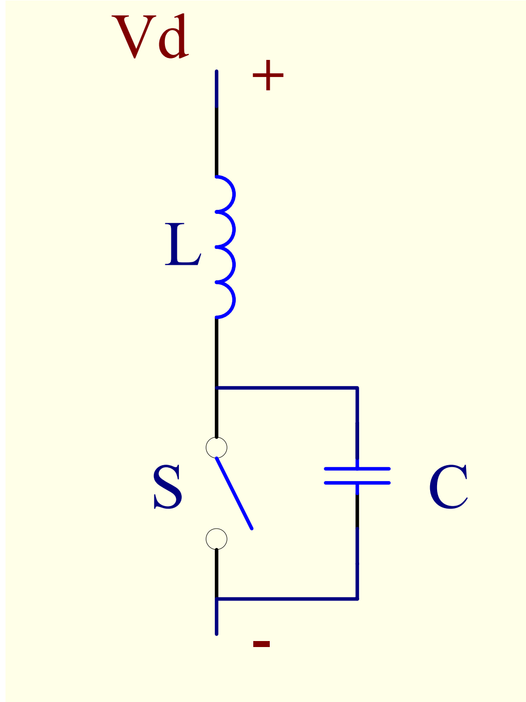
2.3 ZVT

$L \cdot di_L/dt + u_C = U_d$

$i_L = i_C = C \cdot du_C/dt$

$i_{C(0)} = 0$, $u_{C(0)} = 0$, $U_{C(0)} = U_d$

$C \cdot du_C/dt = I_{L0}$



So:

$$u_C = Ud \cdot (1+(1+(Z_0 I_{L0}/Ud)^2)^{1/2})\sin(w_0 t - a)$$

$$i_L = Ud \cdot \sin w_0 t / Zc$$

$$w_0 = (1/LC)^{1/2}$$

$$Z_0 = (L/C)^{1/2}$$

$$a = \mathrm{arctg}\ Ud/Z_0 I_{L0}$$

(1) Resonant tanks: LC, C and S in parallel, S is on at the beginning. The resonant process is starting when S is switched off.

(2) $w_0t - a = 0$, $u_C > 0$; $w_0t - a = 3/2\pi$, $u_L < 0$. ZVT when $u_C = 0$.

(3) full wave : the voltage can be reverse after $u_C = 0$ (4) half wave when a diode is in parallel with S

--the voltage is clamped by the diode.