ECE 404-TD / 504-TD

ST: T&D APPLICATIONS OF VOLTAGE SOURCE CONVERTERS

SESSION no.  2
IDEAL SWITCH

OPEN \( \{ \begin{align*}
V = \text{ANYTHING} \\
i = 0
\end{align*} \)

CLOSED \( \{ \begin{align*}
V = 0 \\
i = \text{ANYTHING}
\end{align*} \)

\[ V_{\text{DC}} \]
\[ V_{\text{sw}} \]
\[ V_B \]
\[ V_D \]
Power lost on

the switch

\[ P = V_i \]

Open \[ P = (0)(0) = 0 \]

Closed \[ P = (0)(i) = 0 \]
Five Basic Concepts of Power Electronics

1. Current through an inductor is continuous.
2. Voltage across a capacitor is continuous.
3. Voltage across an inductor integrates to zero over a complete cycle.
4. Current through a capacitor integrates to zero over a complete cycle.
5. Energy is ALWAYS conserved.
\[ i_2 = \frac{1}{2} \int v_2 \, dt \]

\[ v_c = \frac{1}{C} \int i_c \, dt \]
EXAMPLE

$L_2 = 0$, $t = 0$

$10V$

$5V$

IDEAL

$L = 1\text{ mH}$

$closed$

$5A$

$1\mu s$

$2\mu s$
\[ c_L = \frac{1}{2} \int_{v_1} \left[ \left( \frac{1}{\text{L}H} \right) \left( v_2 - v_1 \right) \right] \, dv \]

\[ c_L = \frac{1}{2} \int_{0}^{\text{L}} \left( \frac{1}{\text{L}H} \right) \left( (1000 - 5v) \right) \, dv \]

\[ c_L = \frac{1}{2} \left( \frac{1}{\text{L}H} \right) \left[ 5v \right]_{0}^{\text{L}} \]

\[ c_L = \frac{5}{2} \]

\[ c_L = 5 \]
\[ i_C = \frac{1}{L} \int_{1ms}^{2ms} 5i \, dt + 5A \]

\[ i_C = \frac{1}{1\mu H} \int_{1ms}^{2ms} (0V - 5V) \, dt + 5A \]

\[ i_C = \frac{(-5V) (2ms - 1ms)}{1\mu H} + 5A \]

\[ i_C = 0 \]
\[ g_A = \begin{cases} 
1 & \text{up position} \\
0 & \text{down position} 
\end{cases} \]
The average voltage $\bar{U}_A$ is given by:

$$\bar{U}_A = \frac{1}{T_s} \int_0^{T_s} u_A \, dt$$
\[ \bar{U}_A = \frac{1}{T_s} \left[ \int_0^{T_{up}} V_{in} \, dt + \int_{T_{up}}^{T_s} 0 \, dt \right] \]

\[ U_A = \frac{V_{in} \cdot T_{up}}{T_s} + 6 \]

\[ V_A = \frac{T_{up} \cdot V_{in}}{T_s} \]

\[ dA = \frac{T_{up}}{T_s} \]
Example

\[ V = 9V \]

\[ L = 1mH \quad i_c' \]

\[ C = \frac{1}{200k\Omega} \quad \frac{v_c'}{v_o} \]

\[ d_A = 0.40 \quad f_s = 200kHz \quad R = 0.25\Omega \]

Find \( v_o \), \( i_c(t) \), \( P_{out} \)

\[ T_s = \frac{1}{f_s} = \frac{1}{200kHz} \]

\[ T_S = 5\mu \text{sec} \]

\[ \Delta T_{up} = d_A T_s = 2\mu \text{sec} \]
\[ V_0 = \text{dn} \ V_{\text{in}} \quad V_0 = 0.6V \quad V_0 = 3.6V \quad V_0 = (3.6V)^2 \]

\[ \frac{V_0}{R} = \frac{(3.6V)^2}{0.25\Omega} = \frac{3.6V}{0.25\Omega} = 14.4\text{mA} \]

\[ I_o = (14.4\text{mA})(0.25\Omega) = 5.184\mu A \]

\[ P_{out} = I_o^2 R \]

\[ P_{out} = (5.184\mu A)^2 \times 10^{-6} \]
ECE 404 / 504

T & D Applications of Voltage Sourced Converters

Lesson 2

Freewheeling Diode

Flyback Diode

Power pole building block

Vin is constant for a switching cycle; iA is continuous
A voltage stiff source switches into a current stiff load.

An idea here is that we control the average output voltage with a switching pattern or selection of switch instants.