MIDDLE EAST TECHNICAL UNIVERSITY

ELECTRICAL & ELECTRONICS ENGINEERING

EE464 - STATIC POWER CONVERSION II
PROJECT II

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1 Analytical Calculations

1.1 a)

To obtain the transfer function of the push-pull converter, we should be properly understand its operation first. The schematic in Figure 1.1.1 is to be used while investigating the topology.

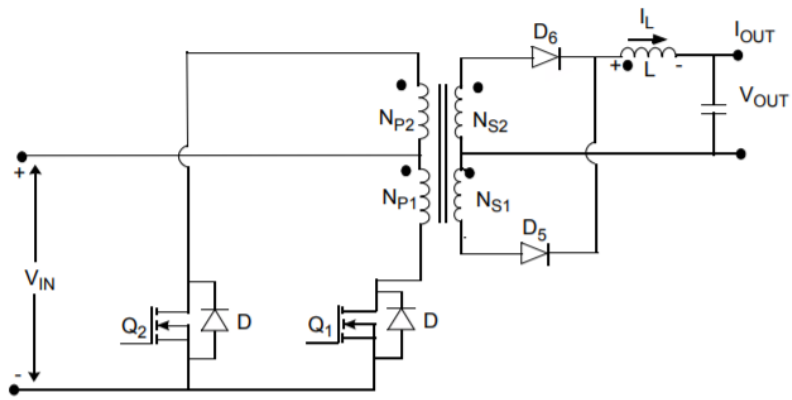

Figure 1.1.1: Push Pull Converter Topology

Switches Q_1 and Q_2 are turned in half cycles of the overall switching time, T_s. That is to say that they will be in ON state for DT_s period and they will turn on with $T_s/2$ time difference. It should be noted that D should strictly be smaller than **0.5**. A wise decision would be to keep a margin for the magnetizing current to flow through the body diodes as well during the OFF states of switches.

In the first DT_s period, Q_1 is ON. First primary winding sees input voltage on it. N_{S2} winding forward biases the D_6 diode and inductor charges up. Inductor current during this period is obtained to be

$$V_L = nV_s - V_O$$

where n is the turns ratio, $\frac{N_S}{N_P}$

After that time, for a -ideally- $T_s/2 - DT_s$ period, both of the switches stay OFF. Inductor current splits to two in the secondary side. Assuming the turn numbers are equal in secondary side windings, secondary side voltage on transformer becomes 0. During this period,

$$V_L = -V_O$$

Same chain of events happen in the remaining half cycle, only the switches are changed. If the voltage-seconds rule for the inductor is applied, the transfer function of the converter can be derived.

$$2(nV_S - V_O)DT_s - V_O(1-2D) = 0$$
$$2nV_S D - 2V_O D - V_O + 2V_O D = 0$$

Transfer function can now be obtained as

$$\frac{V_O}{V_S} = 2nD$$

1.2 b)

The output capacitor never feeds the load by itself during operation. Therefore we should use the inductor current ripple to find the voltage ripple on the capacitor.

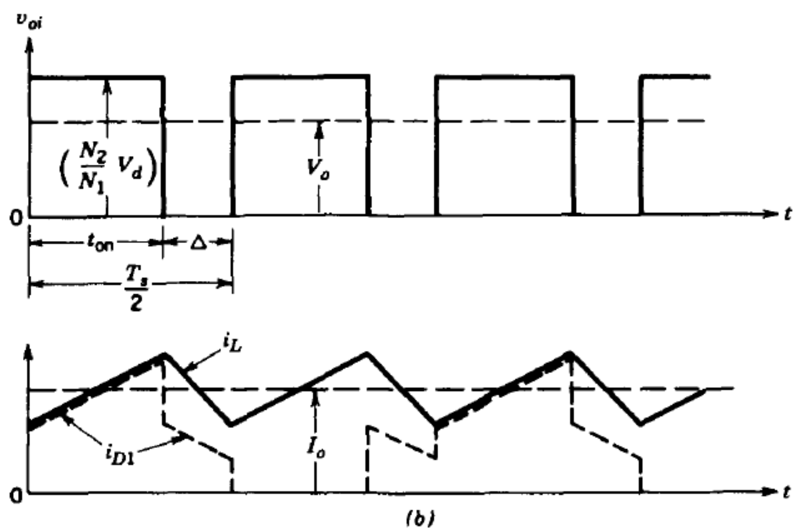

Figure 1.2.1: Inductor Current in Push Pull COnverter

During OFF times of the switches, inductor voltage equals $-V_{out}$ and inductor current drops. Let us start with this period. We know

$$\Delta i_L = \frac{V_L \Delta t}{L}$$

Therefore,

$$\Delta i_L = \frac{-V_O(0.5-D)T_s}{L}$$

.

Assuming inductor current changes linearly, half of this peak-to-peak ripple charges the capacitor for $0.25T_s$. We are talking about the small triangle on top of average line in Figure 1.2.1. We also know that

$$\Delta Q = \Delta VC = \frac{\Delta i_L}{2} 0.25T_s$$

Insert what is found so far for the ripple equation now to obtain the output voltage ripple as follows.

$$\Delta V_O = \frac{V_O(0.5 - D)T_s^2}{8LC}$$

2 Circuit Parameters

2.1 a)

We will use the output voltage equation found in Part 1.1. $V_S = 48V$ and $V_O = 12V$ in our design. $D = 0.25$ is chosen. Insert all in the following formula to find turns ratio, n.

$$\frac{V_O}{V_S} = 2nD \implies n = \frac{V_O}{2DV_S} = \frac{12V}{48V * 2 * 0.25} = 0.5$$

We will need a center-tapped, step-down transformer with turns ratio **0.5**.

2.2 b)

Inductor ripple current expression was found theoretically in Part 1.2 as follows.

$$\Delta i_L = \frac{V_O(0.5 - D)T_s}{L}$$

We aim for a converter that can supply $96W$ under $V_O = 12V$. This means an average output current value of $8A$. It can easily be seen that average inductor current is also equal to that value. We can then deduce

$$\Delta i_L = 0.8A$$

To find L_{min}, we can alter the ripple formula. We also know that $D = 0.25$ and $T_s = 1/40kHz = 25\mu s$. Then insert all in the formula.

$$L_{min} = \frac{12V * 0.25 * 25\mu s}{0.8A} = 93.75\mu H$$

Filter inductor should be **at least** $93.75\mu H$ to guarantee 10% inductor current ripple.

2.3 c)

It is aimed for 1% output voltage ripple. This corresponds to $\Delta V_O = 0.12V$. The ripple formula found in Part 1.2 is to be used as follows.

$$C_{min} = \frac{V_O(0.5 - D)T_s^2}{8\Delta V_O L} = \frac{12V * 0.25 * 625ps}{8 * 0.12V * 93.75\mu H} = 20.8\mu F$$

Output capacitor should be **at least** $20.8\mu F$ to guarantee 1% output voltage ripple.