MASSACHUSETTS INSTITUTE OF TECHNOLOGY

DEPARTMENT OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

6.622 Power Electronics Assessment #4

Due: Thursday March 23, 2023 at 11:00 pm (Cambridge time)

YOUR NAME Solutions

YOUR KERBEROS ID

General Instructions:

1. You must complete this assessment on your own with no consultation or discussion with any other person, excepting 6.622 staff, of whom you may ask clarifying questions. Do not discuss your solutions with anyone until the solutions have been released.

2. You may use a calculator and review the course lectures, notes and textbook (Principles of Power Electronics) when completing this assessment. Please do not use other computational tools or reference materials.

3. Please do all of your work in the space provided. In particular, try to do your work for each question within the boundaries of the question, or on the additional pages at the end of the uploaded document, clearly marking those pages to indicate what problem they relate to. Place the answer to each question within the appropriate answer box.

4. The assessment must be completed and uploaded by the indicated date/time to receive credit.

5. Please make sure to show all of your work. This is important both for you to receive credit for a correct answer and to receive partial credit when an answer is wrong or incomplete.

 Name:_______________________

Problem 1

Figure 1 shows a type of "tapped-inductor" power converter having an unusual transfer characteristic. The tapped inductor in the circuit can be viewed as a two-winding (N_1:N_2) transformer, in which the two windings are connected together.

a. Sketch an equivalent circuit model for the circuit, with the tapped inductor modeled with a magnetizing inductance (referred to the primary N_1 winding) and an ideal transformer.

b. Determine an analytical expression for the conversion ratio V_2/V_1 as a function of switch duty ratio D and turns N_1 and N_2. You may assume that all components are lossless, and that the converter operates in continuous conduction mode.

c. What are the allowed (steady-state) polarities of voltage V_1 and V_2 in this circuit with the indicated switch implementations? (e.g., $V_1 \leq 0$, $V_1 \geq 0$, or either polarity? $V_2 \leq 0$, $V_2 \geq 0$, or either polarity?) Please justify your answer.

d. What duty ratios are permissible in this circuit for periodic steady-state operation when $N_1 = N_2$? Please justify your answer. (*Hint: You may want to consider the voltage polarities indicated for different duty ratios and the requirements imposed by the switch implementations in making your determination.*)

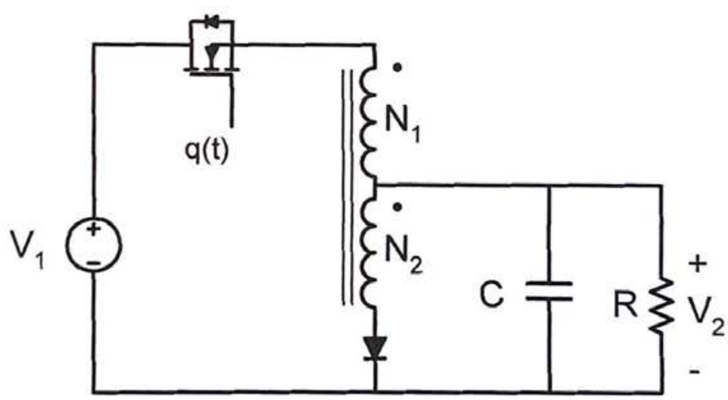


Figure 1 A tapped-inductor power converter.

 Name:

The converter is sometimes called the "Inverse Watkins-Johnson" converter. It is a topological variant of the "Watkins-Johnson" converter, named after the Watkins-Johnson company.

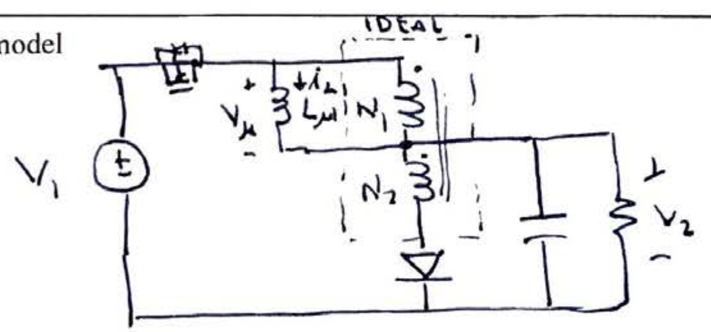
Volt-seconds balance on L_μ

$$D(V_1 - V_2) + (1-D)\cdot\frac{N_1}{N_2}\cdot V_2 = 0$$

$$V_2 \cdot \left[\frac{N_1}{N_2}(1-D) - D\right] = -DV_1$$

$$\frac{V_2}{V_1} = \frac{D}{D - (1-D)\cdot\frac{N_1}{N_2}} = \frac{D}{\left(1+\frac{N_1}{N_2}\right)D - \frac{N_1}{N_2}}$$

(a) Circuit model



(b) $V_2/V_1 = \dfrac{D}{\left(1+\frac{N_1}{N_2}\right)D - \frac{N_1}{N_2}}$

$V_2 < 0$ otherwise there would be a positive average voltage applied across the diode.

$V_1 > 0$ we require $i_L > 0$ based on diode polarity and thus $V_1 > 0$ to draw energy from V_1 during the switch on-state duration

@ $N_1 = N_2$ $\frac{V_2}{V_1} = \frac{D}{2D-1}$

for $V_1 > 0$, $V_2 < 0$ we thus require $D < 0.5$

(c) allowed polarity(ies) of V_1: $V_1 > 0$ {To deliver power L→R with allowed $i_L > 0$ }

allowed polarity(ies) of V_2: $V_2 < 0$ {or diode condit. violated}

(d) Permissible duty ratio range for $N_1=N_2$: $0 < D < 0.5$

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