LECTURE 4

Introduction to Power Electronics Circuit Topologies: The Big Three

I. **POWER ELECTRONICS CIRCUIT TOPOLOGIES**
   A. **OVERVIEW**
   B. BUCK TOPOLOGY
   C. BOOST CIRCUIT
   D. BUCK - BOOST TOPOLOGY
   E. COMPARISION OF THE BIG THREE

II. **TOPOLOGY OF L-C OUTPUT FILTERS**
   A. C ALWAYS Located ACROSS V_{out}
   B. L LOCATED BETWEEN CRUDE UNFILTERED V_{dc} AND STABILIZED V_{out}
      1. BUCK
      2. BOOST
      3. BUCK-BOOST
      4. LOW RIPPLE APPROXIMATION FOR OUTPUT SIGNALS AT f_{sw}
         a) INDUCTOR RIPPLE:

$$\Delta i = \frac{V}{L} dt(switch)$$

         b) CAPACITOR RIPPLE:

$$\Delta V = \frac{I}{C} dt(switch)$$

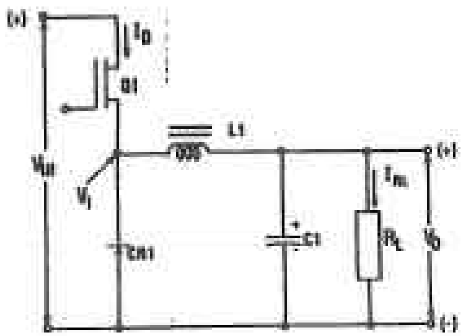
dt(switch)=(Duty cycle)*T_s(period of f_{sw})

L 2 Copy

(1)

TYPE OF CONVERTER: Buck (Step Down)

CIRCUIT CONFIGURATION



IDEAL TRANSFER FUNCTION

$$\frac{V_O}{V_{IN}} = \frac{t_{on}}{T_S} = D$$

PEAK DRAIN CURRENT •

$$I_{DMAX} = I_{RL} + \frac{\Delta I_{L1}}{2}$$

PEAK DRAIN VOLTAGE •

$$V_{DS} = V_{IN} + V_D$$

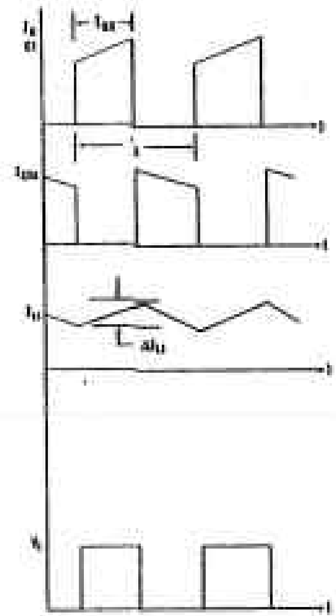
AVERAGE DIODE CURRENTS •

$$I_{CR1} = I_{RL}\,(1\text{-}D)$$

DIODE VOLTAGES (VRM) •

$$V_{RM} = V_{IN}$$

VOLTAGE AND CURRENT WAVEFORMS

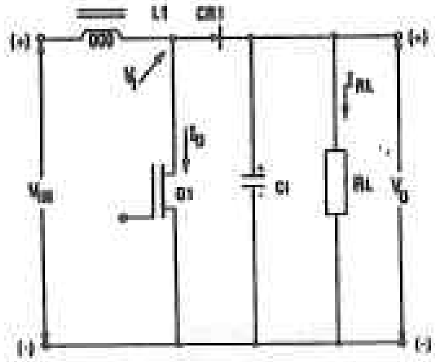
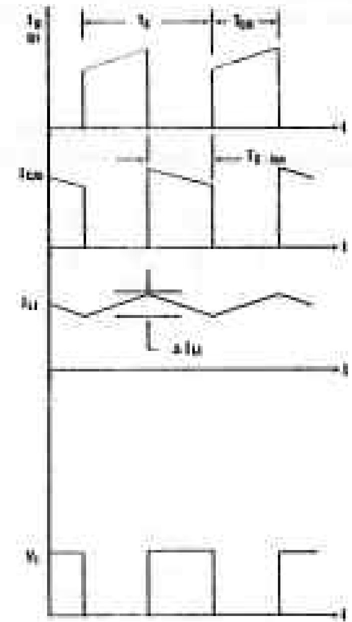


ADVANTAGES: High efficiency, simple, no transformer, low switch stress. Small outpd filter, low ripple.

DISADVANTAGES: No isolation betwen input and output. Potential over-voltage if Q1 sorts. Only one output possible. High-side switch dive required. High input ripple current.

TYPICAL APPLICATIONS: Small size, imbeddd systems.

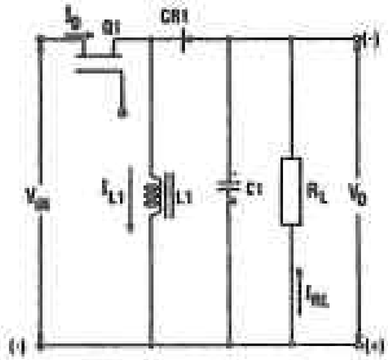
APPLICABLE HARRIS PRODUCTS: HIP5600 w/P-IGBT For off line CKTS.

TYPE OF CONVERTER	Boost (Step Up)
CIRCUIT CONFIGURATION	
IDEAL TRANSFER FUNCTION	$\frac{V_O}{V_{IN}} = \frac{T_S}{T_S - t_{on}} = \frac{1}{(1-D)}$
PEAK DRAIN CURRENT	$I_{DMAX} = I_{RL}\left(\frac{1}{1-D}\right) + \frac{\Delta I_{L1}}{2}$
PEAK DRAIN VOLTAGE	$V_{DS} = V_O + V_D$
AVERAGE DIODE CURRENTS	$I_{CR1} = I_{RL}$
DIODE VOLTAGES (VRM)	$V_{RM} = V_O$
VOLTAGE AND CURRENT WAVEFORMS	
ADVANTAGES	High efficiency, simple, no transformer. Low input ripple current.
DISADVANTAGES	No isolation between input and output. High peak collector current. Only one output is possible. Regulator loop hard to stabilize. High output ripple. Unable to control short-circuit current.
TYPICAL APPLICATIONS	Power-factor correction. Battery up-converters.
APPLICABLE HARRIS PRODUCTS	HIP5061, ICL7667, HV400

TYPE OF CONVERTER

Buck - Boost (Step Down/Up)

CIRCUIT CONFIGURATION



IDEAL TRANSFER FUNCTION

$$\frac{V_O}{V_{IN}} = -\left(\frac{t_{on}}{T_S - t_{on}}\right) = -\left(\frac{D}{1-D}\right)$$

PEAK DRAIN CURRENT

$$I_{DMAX} = I_{RL}\left(\frac{1}{1-D}\right) + \frac{\Delta I_{L1}}{2}$$

PEAK DRAIN VOLTAGE

$$V_{DS} = V_{IN} + V_O + V_D$$

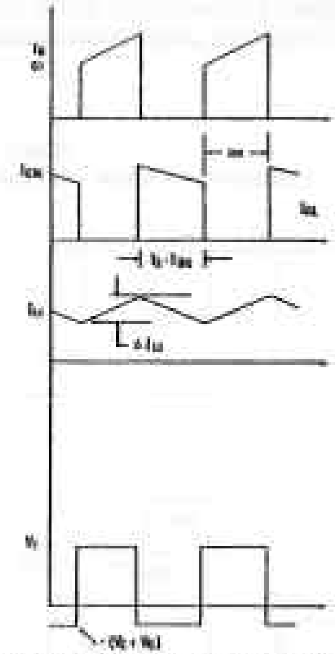
AVERAGE DIODE CURRENTS

$$I_{CR1} = I_{RL}$$

DIODE VOLTAGES (VRM)

$$V_{RM} = V_O + V_{IN}$$

VOLTAGE AND CURRENT WAVEFORMS



ADVANTAGES

Voltage inversion without using a transformer, simple, high frequency operation.

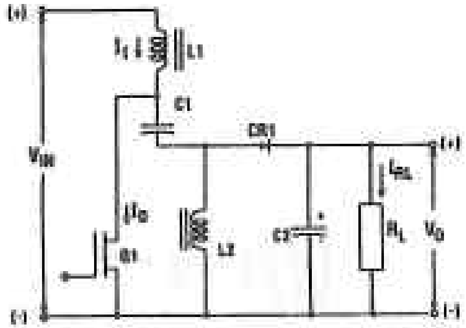
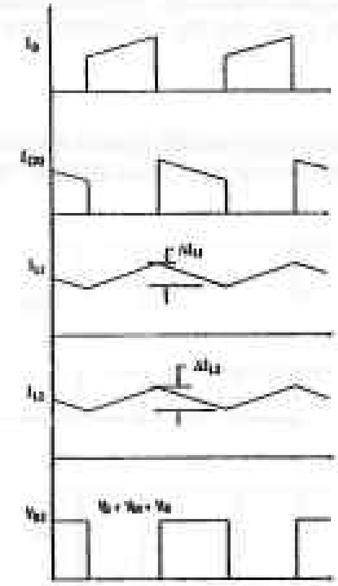
DISADVANTAGES

No isolation between input and output. Only one output is possible. Regulator loop hard to stabilize. High-side switch drive required. High output ripple. High input ripple current.

TYPICAL APPLICATIONS

Inverse output voltages.

APPLICABLE HARRIS PRODUCTS

TYPE OF CONVERTER	SEPIC (Step Down/Up)
CIRCUIT CONFIGURATION	
IDEAL TRANSFER FUNCTION	$\frac{V_O}{V_I} = \frac{D}{1-D}$
PEAK DRAIN CURRENT	$I_{DMAX} = I_1 + I_{RL} + \frac{\Delta I_{L1} + \Delta I_{L2}}{2}$
PEAK DRAIN VOLTAGE	$V_{DS} = V_O + V_{IN} + V_D$
AVERAGE DIODE CURRENTS	$I_{CR1} = I_{RL}$
DIODE VOLTAGES (VRM)	$V_{RM} = V_O + V_{IN}$
VOLTAGE AND CURRENT WAVEFORMS	
ADVANTAGES	Low ripple input current, step-up or step-down with no inversion, no transformer. Capacitive isolation protects against switch failure (unlike Buck).
DISADVANTAGES	No isolation between input and output. Switch has high peak and rms currents which limit output power, C1 and C2 have high ripple current requirements (low ESR), continuous current mode makes loop stabilization difficult, potential instabilities with circuit-mode control. High output ripple.
TYPICAL APPLICATIONS	Power-factor correction. High reliability. Wide input voltage range.
APPLICABLE HARRIS PRODUCTS	HIP5060, HIP5061, HIP5062, HIP5063

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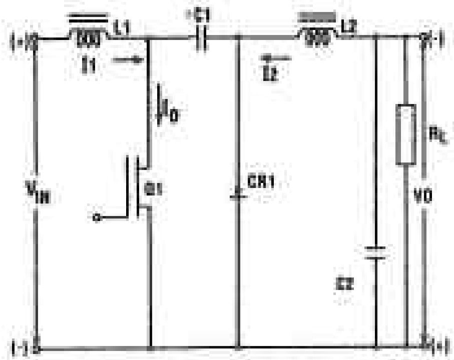
TYPE OF CONVERTER

CUK (Step Up/Down)

CIRCUIT CONFIGURATION



IDEAL TRANSFER FUNCTION

$$\frac{V_O}{V_{IN}} = -\left(\frac{t_{on}}{T_S - t_{on}}\right) = -\left(\frac{D}{1-D}\right)$$

PEAK DRAIN CURRENT

$$I_{DMAX} = I_1 + I_2 = I_1\left(\frac{1}{D}\right)$$

PEAK DRAIN VOLTAGE

$$V_{DS} = 2\ V_{IN}$$

AVERAGE DIODE CURRENTS

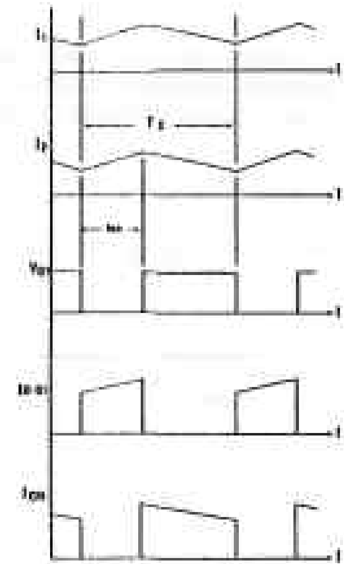
$$I_{CR1} = I_1 + I_2$$

$$I_1 + I_2 = I_1\left(\frac{1}{D}\right)$$

DIODE VOLTAGES (VRM)

$$V_{RM} = V_O + V_{IN}$$

VOLTAGE AND CURRENT WAVEFORMS



ADVANTAGES

Simple, low ripple input and output current, capacitive isolation protects against switch failure.

DISADVANTAGES

High drain current. C1 has high ripple current requirement (low ESR). High voltage required for Q1. Voltage inversion.

TYPICAL APPLICATIONS

Low noise, inverse output voltages.

APPLICABLE HARRIS PRODUCTS

HIP5060, HIP5061, HIP5062, HIP5063

EE 581

Francisco Ostojic

IBM
ultrastar 15K

Extra Credit Question.

WHAT IS THE RPM OF HARD DRIVES.

SeaGate	10,000RPM
Quantum	10,000RPM
HP	9,0000 RPM
	7840 RPM –

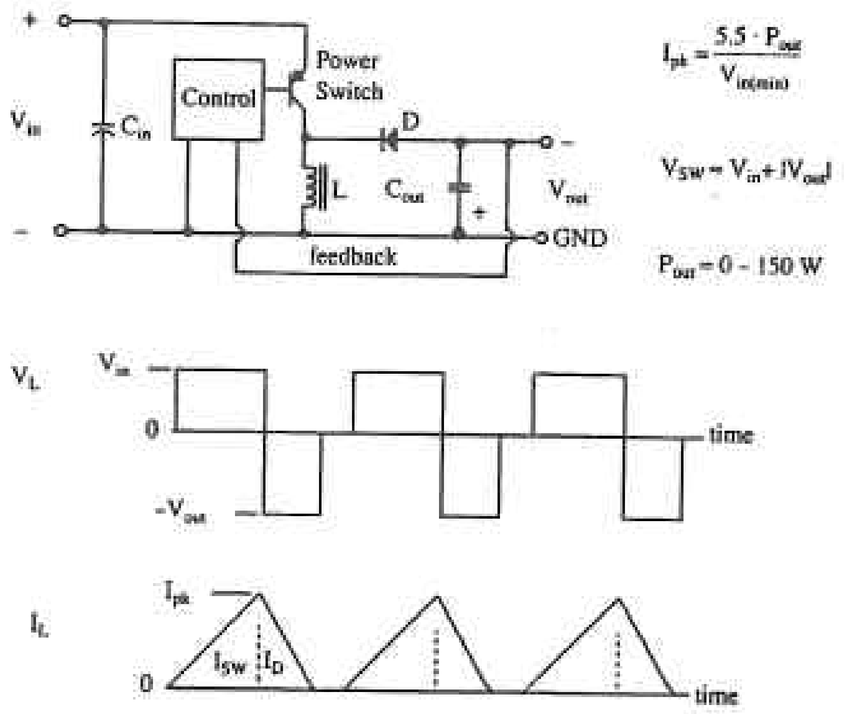
7500

The problems that Hard drive designers have to deal with are:

Current loss due to motor that induces the spinning
Windage losses.
Back emf coming from the motor.
Very difficult to design a circuit and a motor that can produce 10,000RPM with a 5V power supply.

6K OK

10K Nov



The buck/boost regulator topology.

In preparation for your midterm exam, look at the attached schematic on pg. 8 of a flyback converter slowly - don't panic. try to find only the essential power electronics portions.

(1) identify the crude dc generation in the upper left driven by 120 ac mains. this CRUDE DC IS DRIVEN BY THE SWITCH #1 INTO THE TRANSFORMER PRIMARY.

(2) On the right side of the schematic notice the three secondaries of the transformers with the three dc outputs: 5, 12, and 30 v.

(3) Find the cmos transistor Q1 (middle) which is the switching transistor. From the gate of this cmos switch the gate control circuitry may also be found.

We will spend the rest of the semester detailing how such circuits work.