

Mor M. Peretz, Switch-Mode Power Supplies [2-1]

DCM – rev.

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Synchronous rectifier

No DCM !



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Capacitors

- Capacitor types
- Output voltage ripple
- Real capacitor
 - Parallel connection
 - Load step

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Capacitor types

 Polarized (electrolytic)	 Non Polarized C < 10μF
Materials: Tantalum Aluminum	Paper Plastic Teflon Polypropylene Minerals Mica

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Output voltage ripple

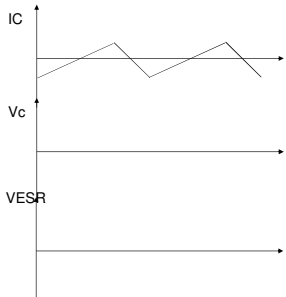
Buck

$$\Delta V_c = \frac{\Delta Q}{C}$$

$$\Delta Q = \frac{\Delta I_L T_s}{2} \cdot \frac{1}{2}$$

$$\Delta V_c = \frac{\Delta I_L}{8C f_s}$$

$$\Delta V_{ESR} = \Delta I_L R_{ESR}$$



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Output voltage ripple

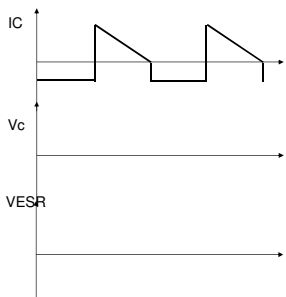
Boost

$$\Delta V_c = \frac{I_o}{C} T_{on} \text{ (on time)}$$

$$\left(\Delta Q = \frac{I_o T_{on}}{2} \right)$$

$$\Delta V_c = \frac{V_o}{2RC} D T_s$$

$$\Delta V_{ESR} = \Delta I D R_{ESR}$$



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Real capacitor

Series inductance
Capacitance
Equivalent series resistance (ESR)

$20\lg(|Z|)$
idea
-20db/dec
 $|Z| = \frac{1}{\omega C} = \frac{1}{2\pi f C}$

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Parallel connection

$20\lg(|Z|)$
 $\left(\frac{1}{2\pi f C_1}\right) \text{dB}$
 $\left(\frac{1}{2\pi f C_2}\right) \text{dB}$
 C_2
 C_1
 $\left(\frac{1}{2\pi f_2 C_1}\right) \text{dB}$
 $\left(\frac{1}{2\pi f_2 C_2}\right) \text{dB}$
 f
 f_1
 f_m
 f_2

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Load step

Ideal response
Practical response

V_o
 t
 t_s
 $\Delta V(\text{ESR})$
 t
 t_s

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Losses of SMPS

- Conduction losses
 - RMS current
 - Resistor
 - MOSFET
 - ESR
 - Average current
 - Diode
 - IGBT
- Switching losses
 - CV^2
- Heat conduction

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Conduction losses

$$P = \frac{1}{T} \int_0^T (V \cdot I) dt$$

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Conduction losses Resistor

Power losses are function of RMS current
Why???

$$P = \frac{1}{T} \int_0^T (V \cdot I) dt$$

Fourier series:

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Conduction losses RMS calculation of typical waveform

$$I_{rms} = I_{pk} \sqrt{D}$$

$$I_{rms} = \frac{I_{pk}}{\sqrt{3}}$$

$$I_{rms} = \sqrt{I_{av}^2 + \left(\frac{\Delta I}{2\sqrt{3}}\right)^2}$$

$$I_{rms} = \sqrt{D} \sqrt{I_{av}^2 + \left(\frac{\Delta I}{2\sqrt{3}}\right)^2}$$

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Conduction losses MOSFET

$$P_{RDS_ON} = D \left(I_{av}^2 + \left(\frac{\Delta I}{2\sqrt{3}}\right)^2 \right) R_{DS_ON}$$

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Conduction losses ESR

How to calculate ESR losses?
Topology dependent

$$P_{ESR} = \left(I_{av}^2 + \left(\frac{\Delta I}{2\sqrt{3}}\right)^2 \right) ESR$$

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Conduction losses Diode

Conducting diode is a voltage source

Power dissipation is related to the average current

$$P_D = I_{av} V_D$$

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Conduction losses Example

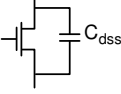
- Buck converter
- $V_{in} = 10\text{v}$; $V_{out} = 5\text{V}$; $I_{out} = 5\text{A}$; $f_s = 100\text{kHz}$
- $L = 100\mu\text{F}$
- $R_{Dson} = 10\text{m}\Omega$; $V_D = 1\text{V}$; $ESR = 50\text{m}\Omega$
- Calculate efficiency

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Buck converter Example - solution

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Switching losses

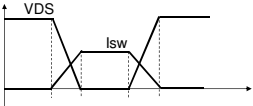


$$E_{sw} = \frac{C_{DS} V_{max}^2}{2}$$

$$P_{sw} = \left(\frac{C_{DS} V_{max}^2}{2} \right) f_s$$

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Switching losses

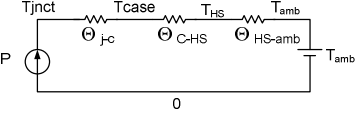


$$E_{on} = E_{off} = \int_0^{tr} \left(\frac{I_{sw}}{tr} t \right) \left(V_{DS} - \frac{V_{DS}}{tr} t \right) dt = \frac{I_{sw} V_{DS}}{6} tr$$

$$P_{sw} = \frac{E_{on} + E_{off}}{2} f_s = \frac{I_{sw} V_{DS}}{3} tr f_s$$

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Thermal considerations



- Power coded to source
- Temperature coded to voltage
- Thermal coefficient - resistance

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Thermal considerations Example

- Power to dissipate: 20W
- $\Theta_{j-c} = 1 \text{ }^\circ\text{C/W}$; $\Theta_{c-HS} = 1 \text{ }^\circ\text{C/W}$
- $T_{jnt} = 100 \text{ }^\circ\text{C}$; $T_{amb} = 40 \text{ }^\circ\text{C}$
- Calculate Θ_{HS-amb} (determine the heatsink)

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Improving efficiency Example – MC34063 (onsemi) step up/down converter

(Bottom View)

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Improving efficiency Example – MC34063 (onsemi) Step-up (Boost) configuration

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Improving efficiency Example – MC34063 (onsemi)

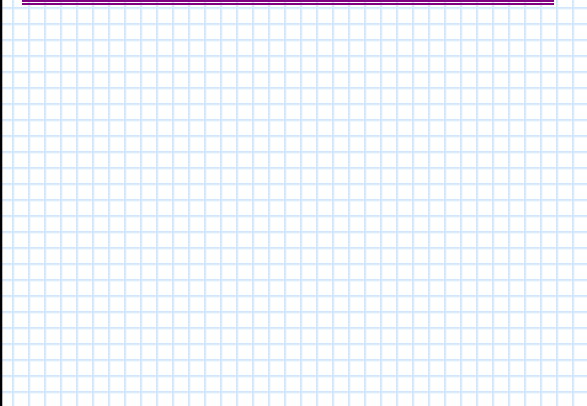
External BJT switch


Figure 9. External Current Boost Con
9a. External NPN Switch

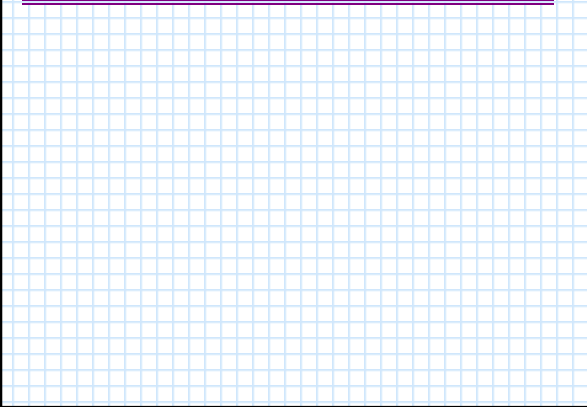
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