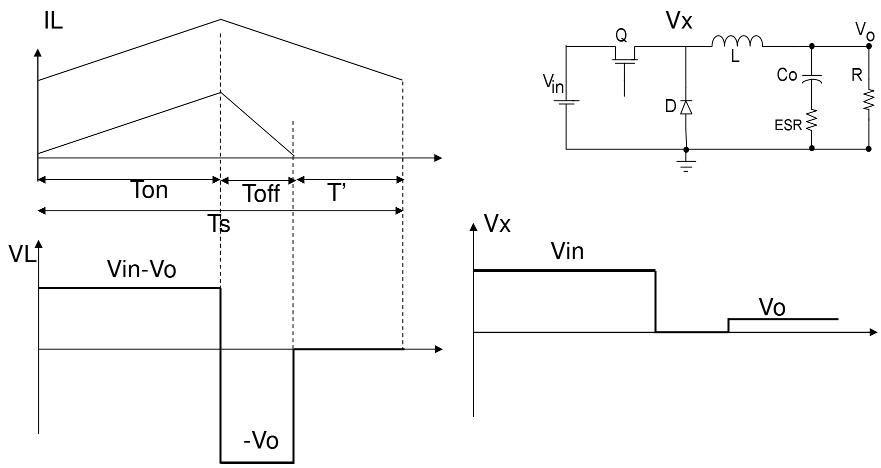
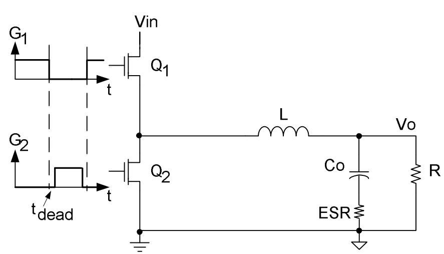
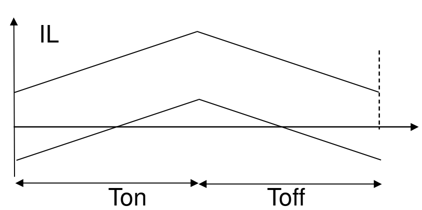
DCM – rev.



Synchronous rectifier



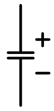
No DCM !



Capacitors

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

Capacitor types

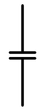


Polarized (electrolytic)

Materials:

Tantalum

Aluminum



Non Polarized
C < 10μF

Paper

Plastic

Teflon

Polypropylene

Minerals

Mica

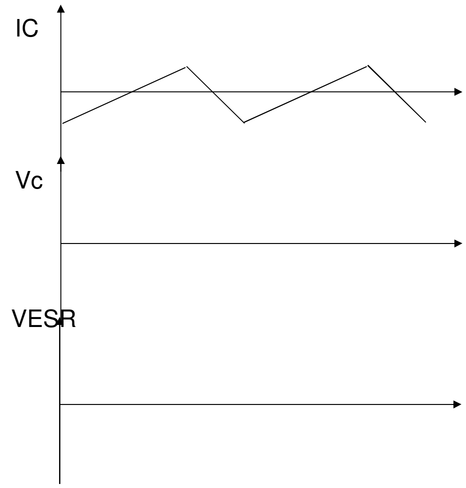
Output voltage ripple
Buck

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

$$\Delta Q = \frac{\Delta IL}{2}\frac{Ts}{2}\frac{1}{2}$$

$$\boxed{\Delta Vc = \frac{\Delta IL}{8C\,fs}}$$

$$\boxed{\Delta V_{ESR} = \Delta IL\, R_{ESR}}$$



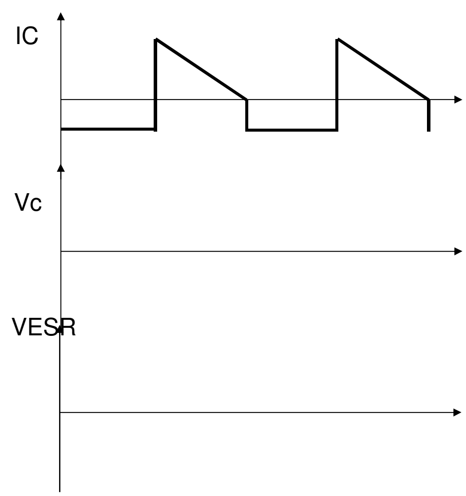
Output voltage ripple
Boost

$$\Delta Vc = \frac{Io}{C}Ton \quad (\text{on time})$$

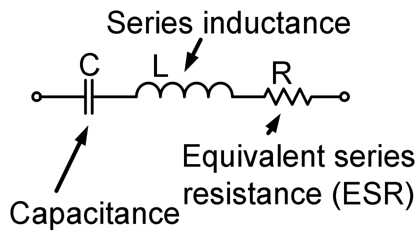
$$\left(\Delta Q = \frac{IoTon}{2}\right)$$

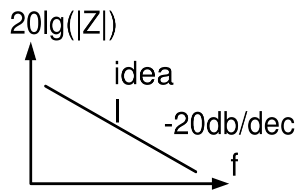
$$\boxed{\Delta Vc = \frac{Vo}{2RC}DTs}$$

$$\boxed{\Delta V_{ESR} = \Delta ID\, R_{ESR}}$$



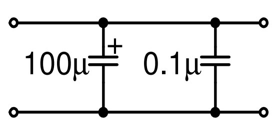
Real capacitor

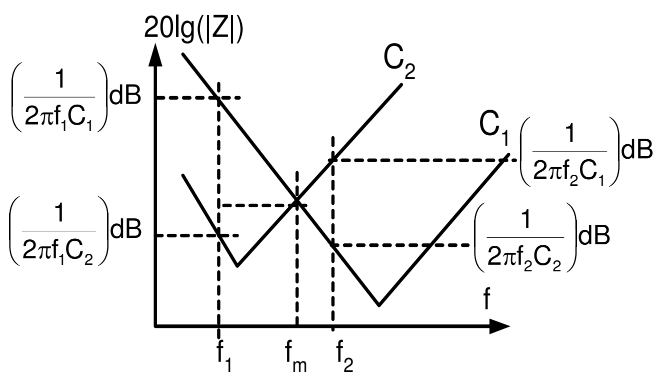




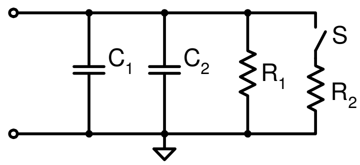
$$|Z| = \frac{1}{\omega C} = \frac{1}{2\pi f C}$$

Parallel connection

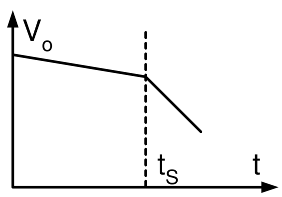




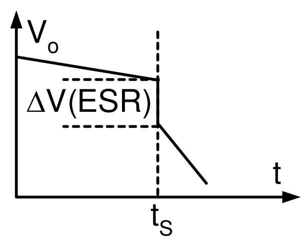
Load step



Ideal response



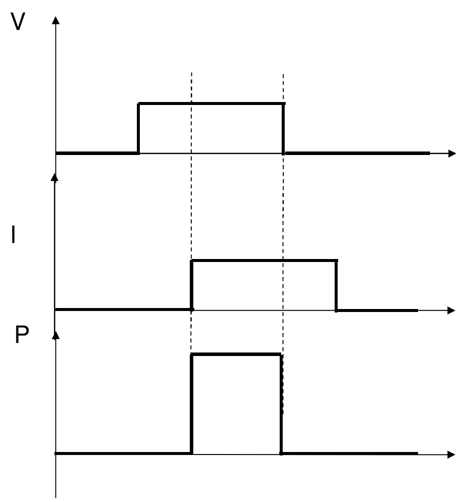
Practical response



Losses of SMPS

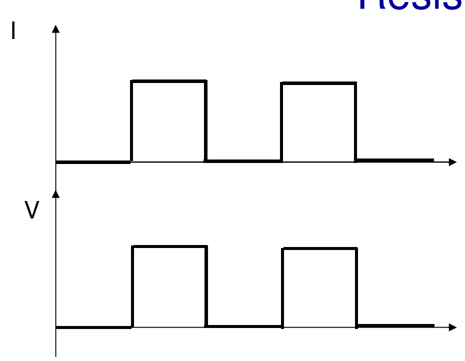
- Conduction losses
  - RMS current
    - Resistor
    - MOSFET
    - ESR
  - Average current
    - Diode
    - IGBT
- Switching losses
  - CV^2
- Heat conduction

Conduction losses



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

Conduction losses
Resistor

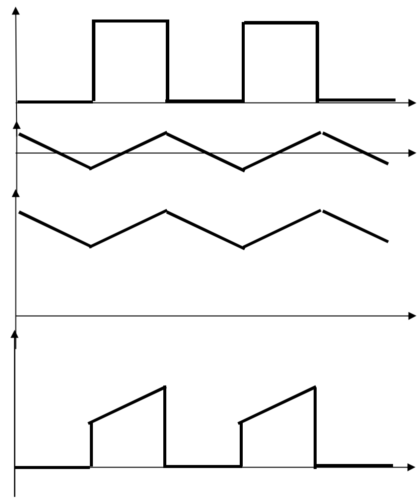


Power losses are function of RMS current
Why???

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

Fourier series:

Conduction losses
RMS calculation of typical waveform



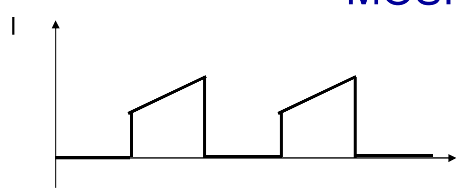
$$Irms = Ipk\sqrt{D}$$

$$Irms = \frac{Ipk}{\sqrt{3}}$$

$$Irms = \sqrt{Iav^2 + \left(\frac{\Delta I}{2\sqrt{3}}\right)^2}$$

$$Irms = \sqrt{D}\sqrt{Iav^2 + \left(\frac{\Delta I}{2\sqrt{3}}\right)^2}$$

Conduction losses
MOSFET



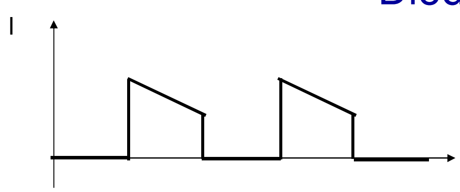
$$P_{RDS\_ON} = D\left(Iav^2 + \left(\frac{\Delta I}{2\sqrt{3}}\right)^2\right)R_{DS\_ON}$$

Conduction losses
ESR

How to calculate ESR losses?
Topology dependent

$$P_{ESR} = \underline{\qquad} \left(Iav^2 + \left(\frac{\Delta I}{2\sqrt{3}} \right)^2 \right) ESR$$

Conduction losses
Diode

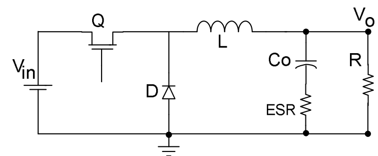


Conducting diode is a **voltage source**

Power dissipation is related to the average current

$$P_D = Iav\, V_D$$

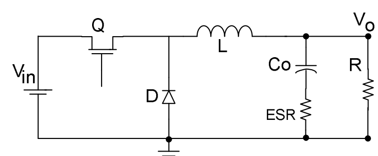
Conduction losses
Example



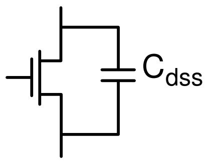
- Buck converter
- Vin = 10v ; Vout = 5V ; Iout = 5A ; fs=100kHz
- L = 100uF
- R_{DSon}=10mOhm ; VD=1V ; ESR=50mOhm

- Calculate efficiency

Buck converter
Example - solution



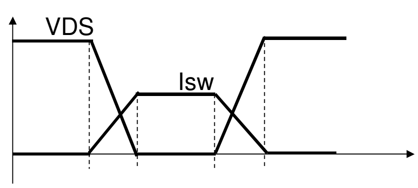
Switching losses



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

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

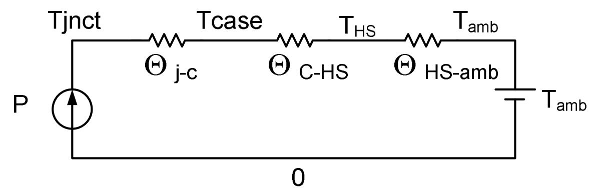
Switching losses



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

$$P_{SW} = \frac{E_{on} + E_{off}}{2} fs = \frac{Isw V_{DS}}{3} tr\, fs$$

Thermal considerations

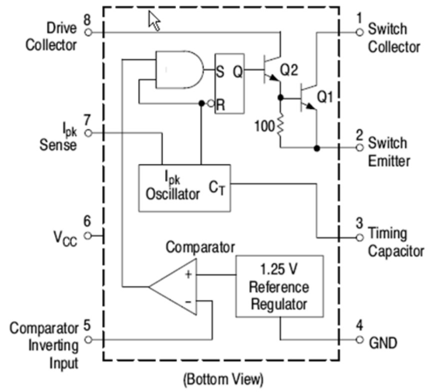


- Power coded to source
- Temperature coded to voltage
- Thermal coefficient - resistance

Thermal considerations
Example

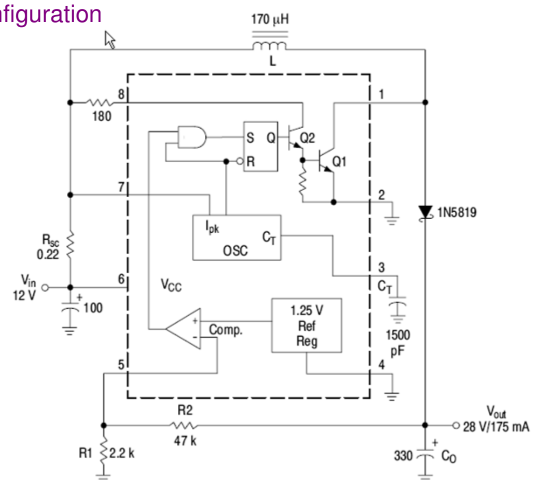
- Power to dissipate: 20W
- Θj-c = 1 °C/W ; Θc-HS = 1 °C/W
- Tjnct = 100 °C ; Tabm = 40 °C
- Calculate ΘHS-amb (determine the heatsink)

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



Improving efficiency
Example – MC34063 (onsemi)

Step-up (Boost) configuration



Improving efficiency
Example – MC34063 (onsemi)

External BJT switch

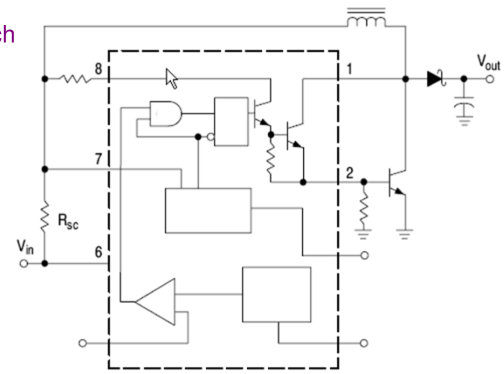


Figure 9. External Current Boost Con

9a. External NPN Switch