Noise

- Randomly varying voltage or current
- Present at all frequencies
- Spectral density of noise is of interest
  ⇒ Measure of noise effect per Hz bandwidth

$$S_n = \frac{E_n^2}{B} \quad \left[\frac{V^2}{Hz}\right]$$

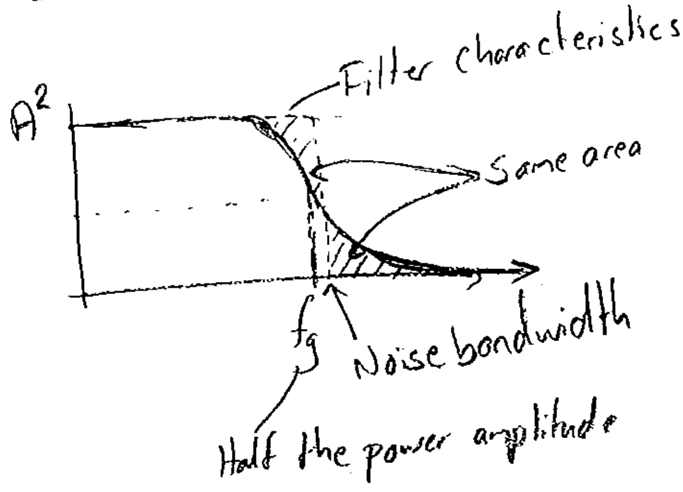
E_n ← Noise emk
B ← Bandwidth
S_n ← Spectral density

In datasheets often as $\left[\frac{V}{\sqrt{Hz}}\right]$ or $\left[\frac{\mu V}{\sqrt{Hz}}\right]$

Noise voltage

$$E_n = \sqrt{\int_{f_1}^{f_2} S_n \, df}$$

Noise bandwidth



Filter order		B/f_g
1	-20 dB/dec	1,57
2	-40 dB/dec	1,11
3	-60 dB/dec	1,05

Noise is random and therefore the power must be added from differend sources.

$$U_{n_{tot}}^2 = U_{n_1}^2 + U_{n_2}^2 \qquad \text{(Uncorrelated sources)}$$

$$U_{n_{tot}} = \sqrt{U_{n_1}^2 + U_{n_2}^2}$$

Signal to noise ratio, SNR

$$SNR = \frac{P_{signal}}{P_{noise}} = \frac{U^2_{signal}}{U^2_{noise}}$$

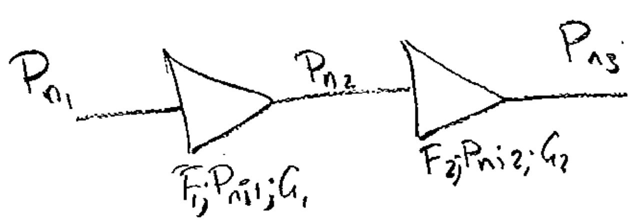
$$SNR_{dB} = 10 \log \frac{P_{signal}}{P_{noise}} = 20 \log \frac{U_{signal}}{U_{noise}}$$

Noise factor, F

Measure of how much the SNR is reduced when amplified

$$F = \frac{SNR_{in}}{SNR_{out}}$$

Cascaded amplifiers



$$P_{n2} = G_1 \cdot P_{n1} + P_{ni1}$$

$$P_{n3} = G_2 (G_1 P_{n1} + P_{ni1}) + P_{ni2}$$

$$P_{n3} = P_{n1} G_1 G_2 + P_{ni1} \cdot G_2 + P_{ni2}$$

$\Longrightarrow$

Relating all noise to the input

$$F_{tot} = \frac{P_{n3}}{P_{n1} \cdot G_1 \cdot G_2} = 1 + \frac{P_{ni1}}{P_{n1} \cdot G_2} + \frac{P_{ni2}}{P_{n1} \cdot G_1 \cdot G_2}$$

$$F_1 = 1 + \frac{P_{ni1}}{P_{n1} \cdot G_1}$$

$$F_2 = 1 + \frac{P_{ni2}}{P_{n2} \cdot G_2} \implies F_2 - 1 = \frac{P_{ni2}}{P_{n2} \cdot G_2}$$

$$F_{tot} = F_1 + \frac{F_2 - 1}{G_1} \left(+ \frac{F_3 - 1}{G_1 G_2} + \frac{F_4 - 1}{G_1 G_2 G_3} \right)$$

∴ Important with low noise factor and high gain in first stage.

Power supplies

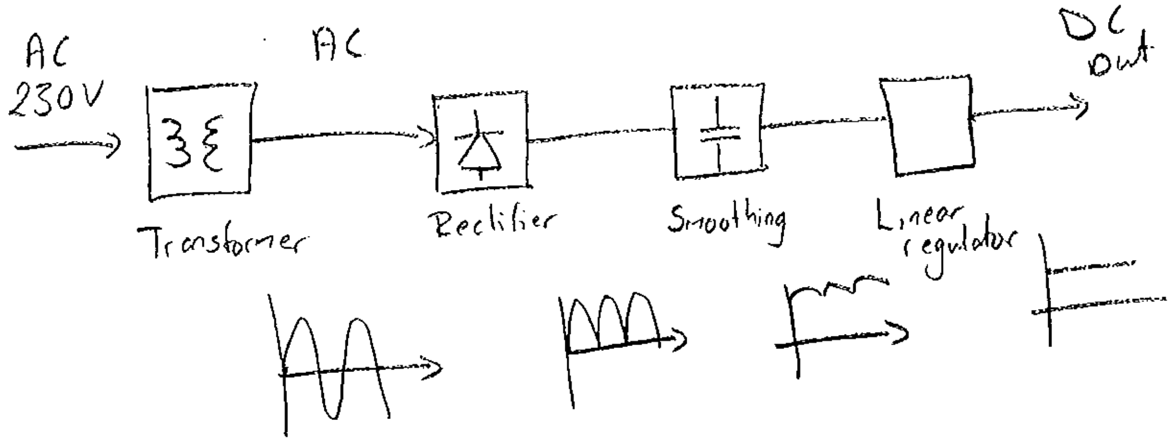
Linear supplies

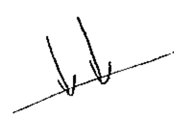
- \+ Simple
- \- Low efficiency

Switched supplies

- \+ High efficiency
- \+ High frequency switching
  - ⟹ Smaller transformer and passive elements
- \+ Variable input can be achieved

Linear supplies



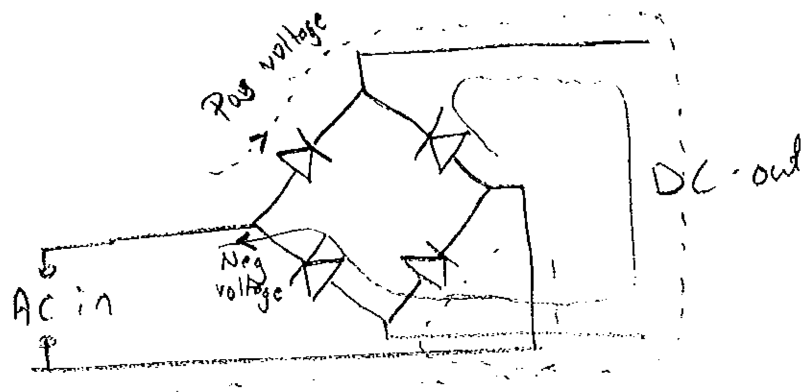


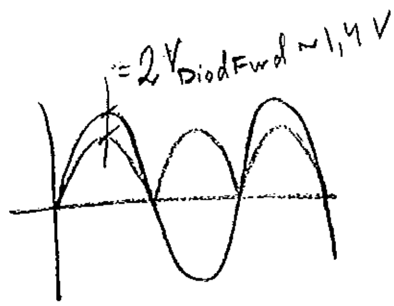
Transformer

$$\frac{U_2}{U_1} = \frac{N_2}{N_1}$$

- Converts Voltage
- Isolates from power network

Rectifier

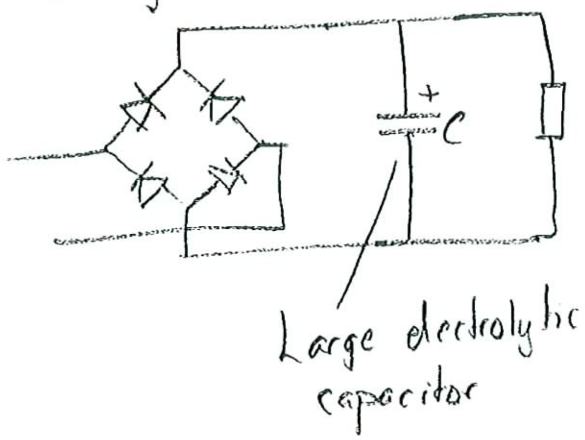


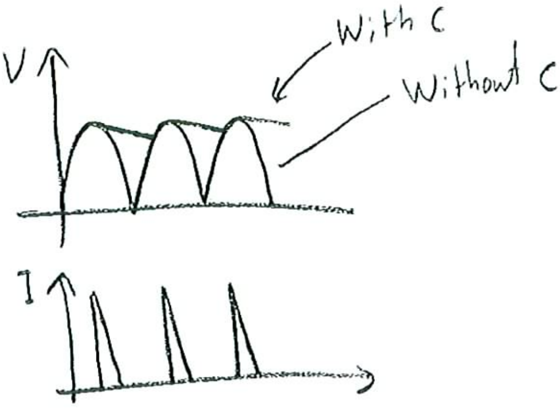


Power loss is unavoidable

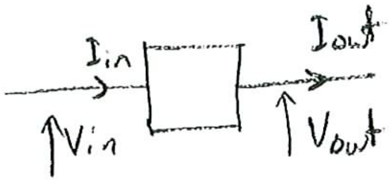
- More losses for low voltages.

Smoothing





Linear regulation



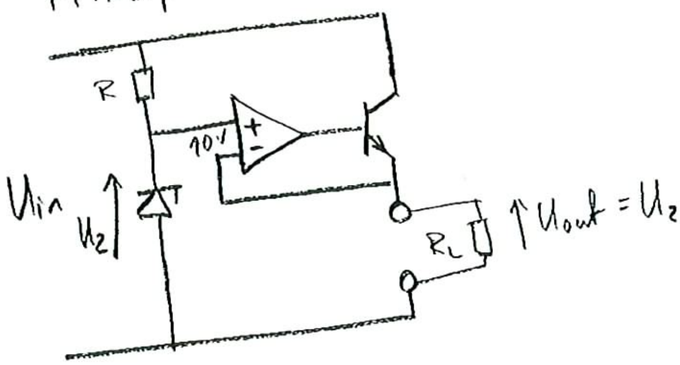
$V_{out} < V_{in}$

$I_{out} = I_{in}$

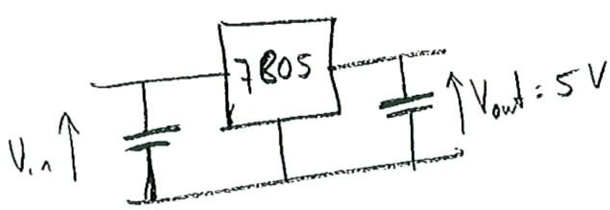
Efficiency $\eta = \frac{P_{out}}{P_{in}} = \frac{V_{out} \cdot I_{out}}{V_{in} \cdot I_{in}} = \frac{V_{out}}{V_{in}}$ ($I_{in} = I_{out}$)

U_{out} is typ $0,5 - 0,7 \cdot U_{in} \Rightarrow \eta \sim 0,5 - 0,7$

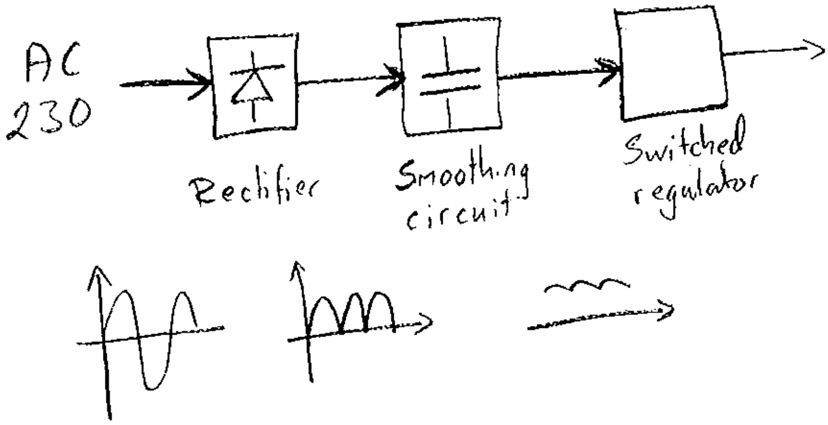
Principle



Integrated linear regulators exits

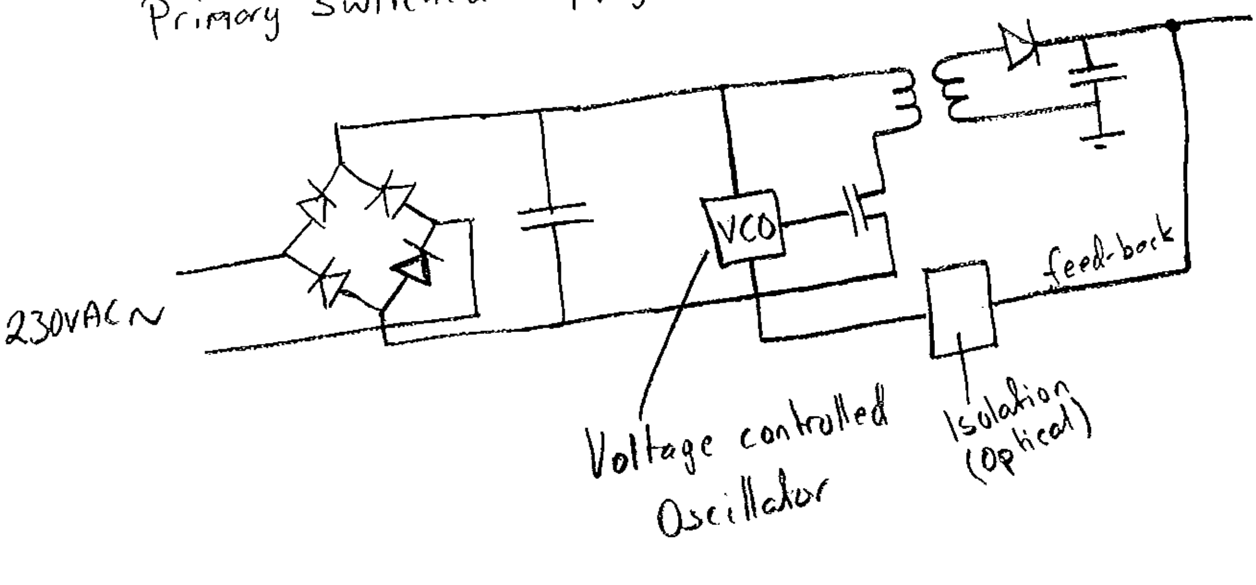


Switched supplies



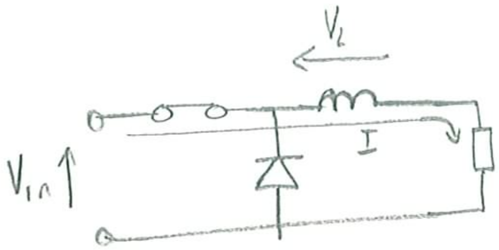
- Rectifiing and smoothig at high voltages (Primary switched)
  - → Low losses in retifier
  - → Smaller Smoothing capacitors required

Primary switched supply



Switched mode power supplies

Buck converter



Inductor

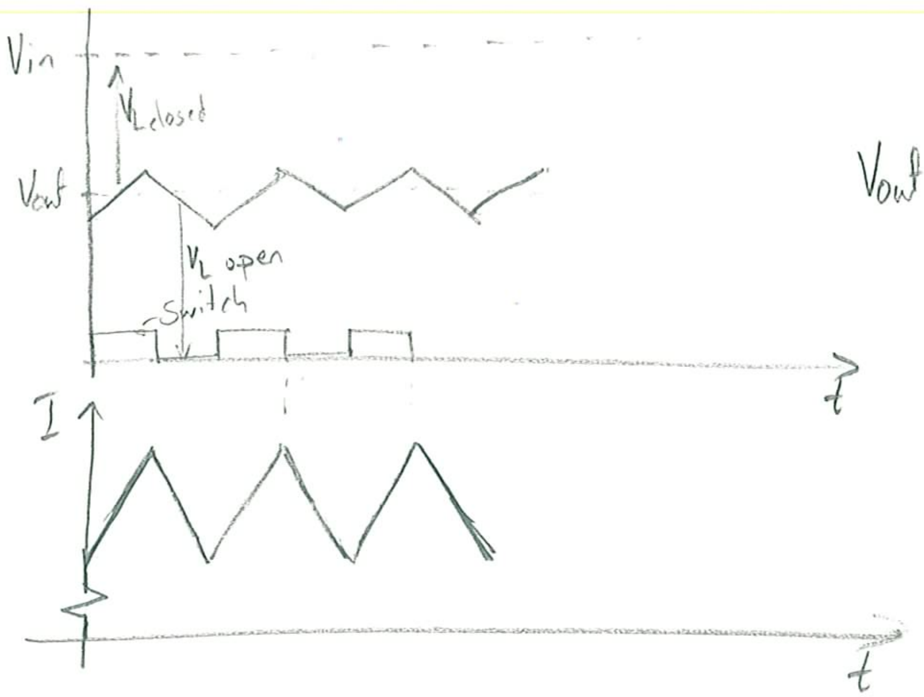
$$V = L\frac{di}{dt} \qquad \frac{di}{dt} = \frac{1}{L}V$$

$$I = \frac{1}{L}\int V\,dt = I(0) + \frac{1}{L}\int_0^T V(t)\,dt$$

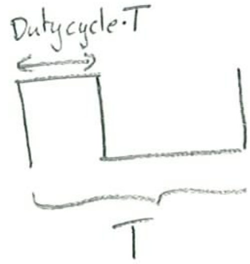
Switch closed
- Assume $V_L = V_{in} - V_{in}$ fairly constant

  I increases linearly $\rightarrow$ V_{out} increases

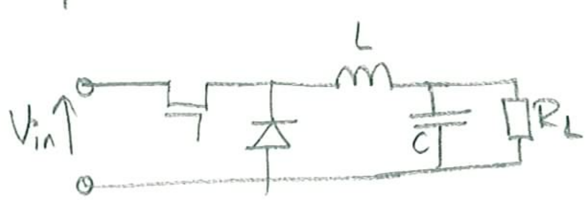
Switch open
  I decreases linearly



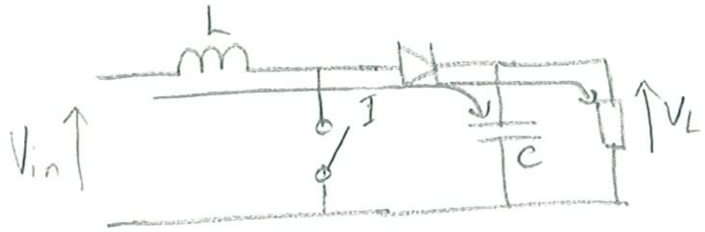
$$V_{out} = V_{in} \cdot \text{Duty cycle}$$



A capacitor is used to smoothen the voltage



Boost converter

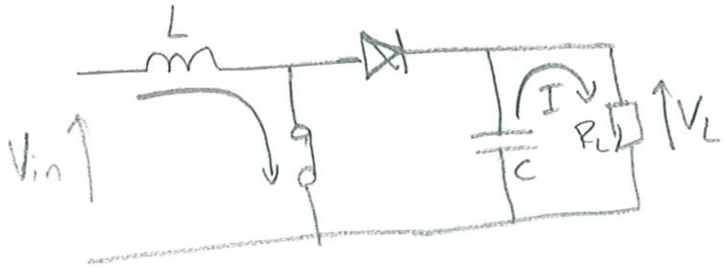


Switch open

$V_{out} \to V_{in}$

Switch closes

I_L increases, V_L is held by C

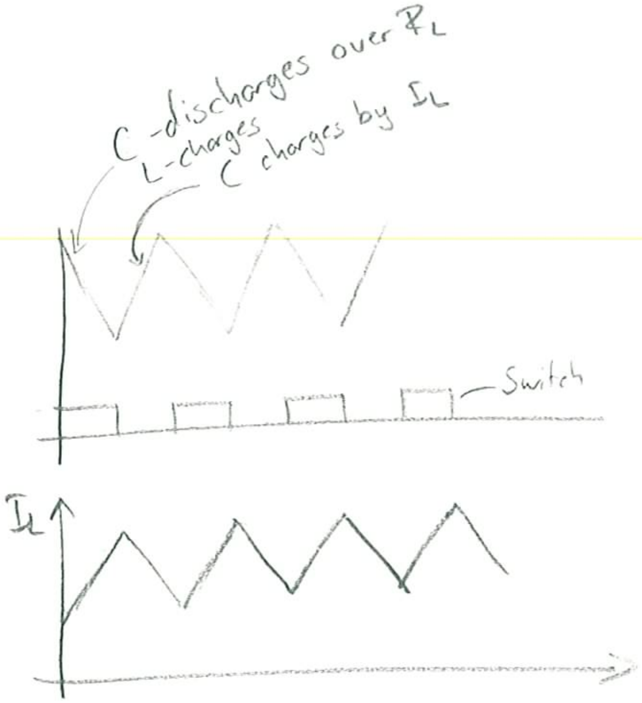


Switch opens

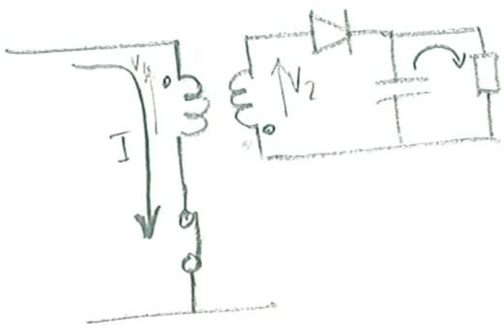
I_L is redirected through the diode charging the capacitor

$\to V_L > V_L$

$$V_{out} = \frac{V_{in}}{1 - \text{Duty Cycle}}$$

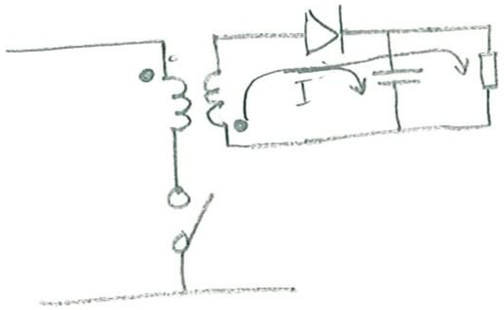


Flyback - converter



Switch closed

- I_L increases and energy stored in magnetic field
- V_2 is negative so the diode isolates



Switch opens

- Energy stored