EE 238

Power Engineering - II

Power Electronics

Lecture 3

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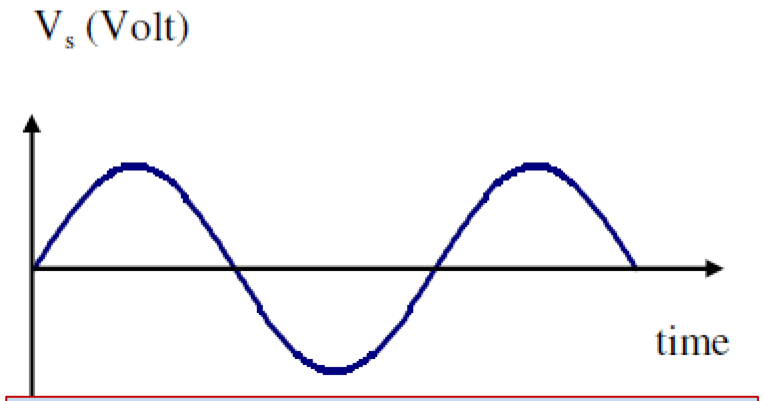
Power Conversion concept: example #1



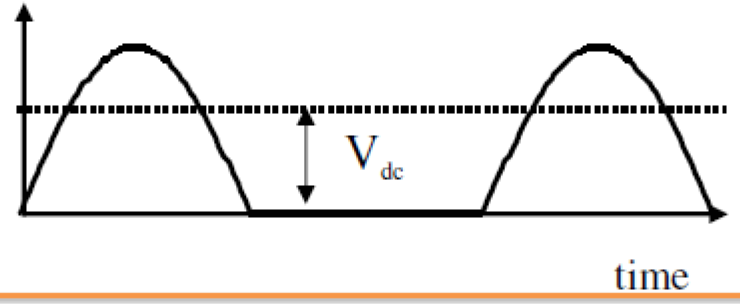
- The sine-wave supply gives zero DC component!

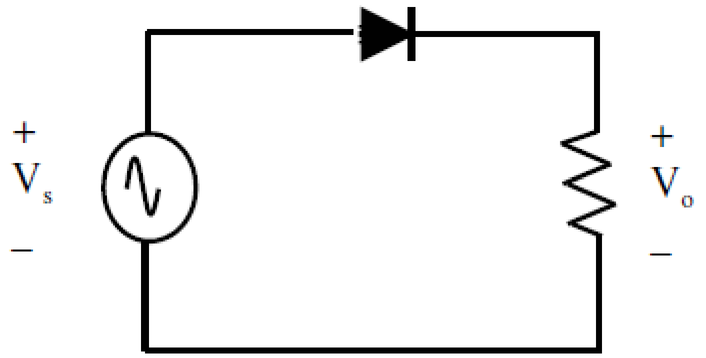
- Supply: 50Hz, 240V RMS (340V peak).

Customer needs DC voltage for welding purpose, say.

V_o

Average output voltage : $V_o = \frac{V_m}{\pi}$





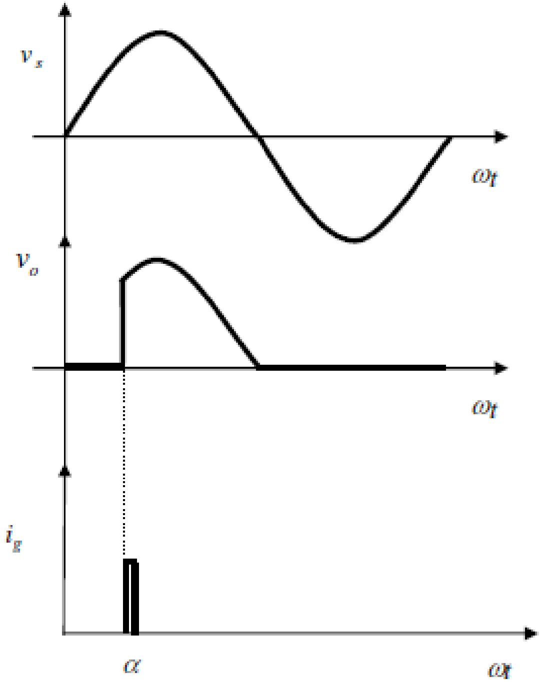
- We can use simple half-wave rectifier. A fixed DC voltage is now obtained. This is a simple PE system.

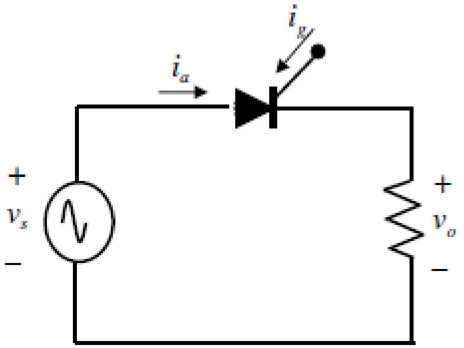
How if customer wants variable DC voltage?

Average output voltage : $$V_o = \frac{1}{2\pi}\int_{\alpha}^{\pi} V_m \sin(\omega t)\, d\omega t = \frac{V_m}{2\pi}\left[1+\cos\alpha\right]$$

By controlling the firing angle, α, the output DC voltage (after conversion) can be varied.

Obviously, this needs a complicated electronic system to set the firing current pulses for the SCR.





More complex circuit using SCR is required.

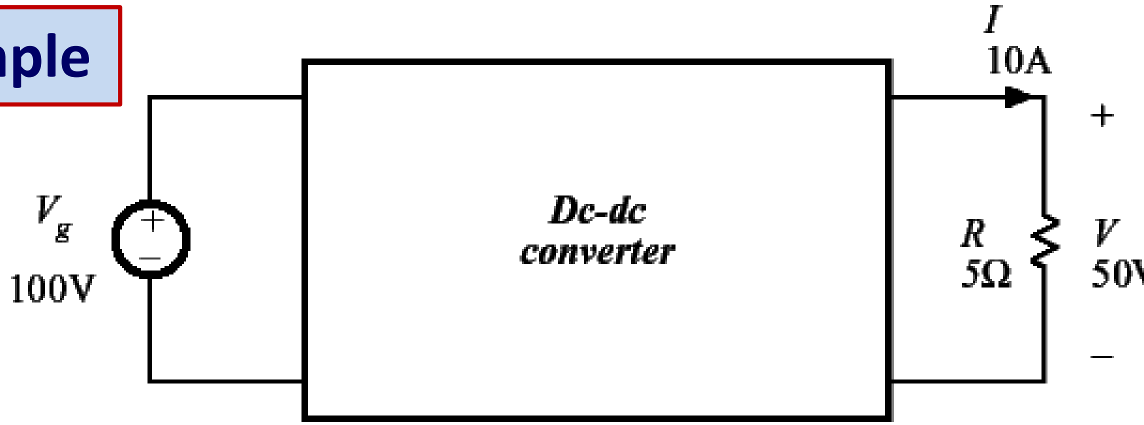
A simple example #2

A dc-dc converter example

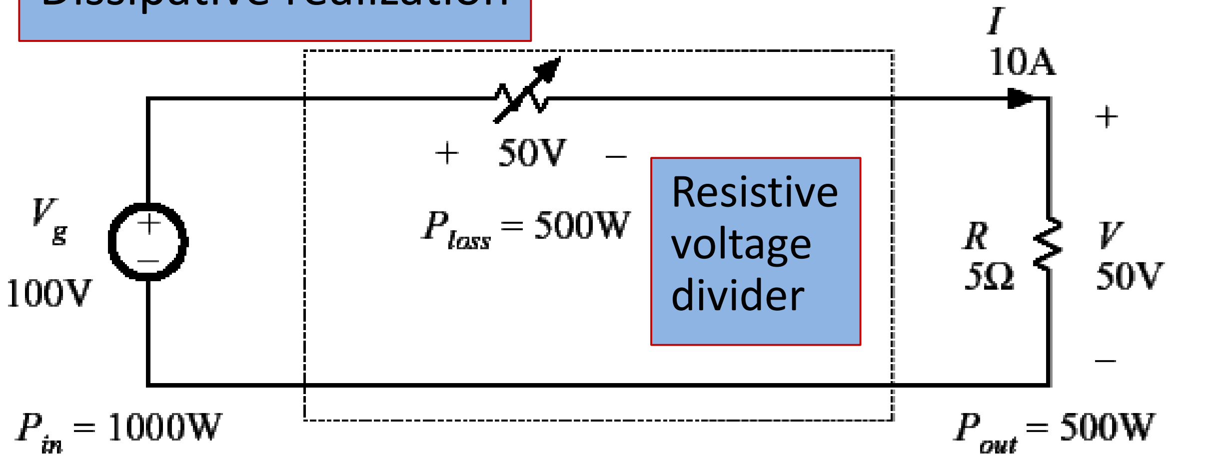
Input source: 100V

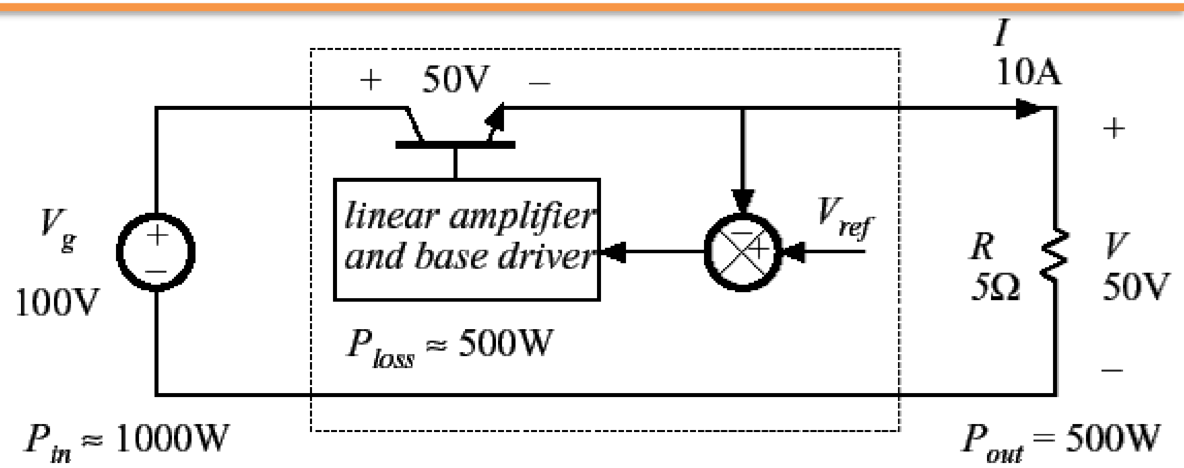
Output load: 50V, 10A, 500W

How can this converter be realized?

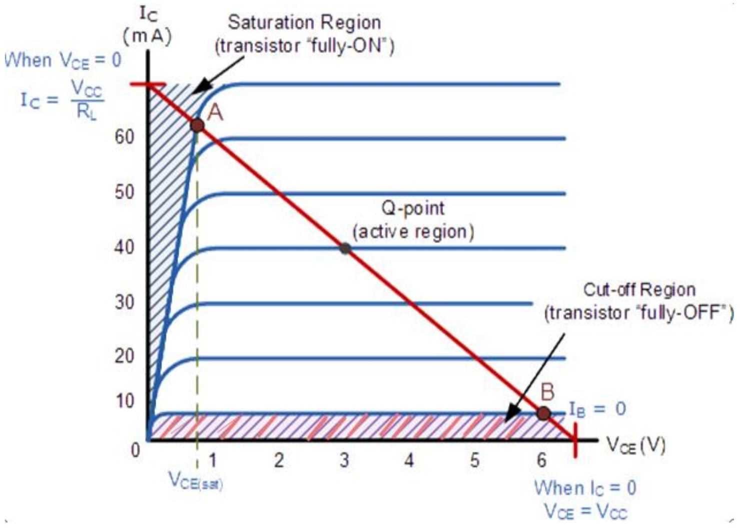


Dissipative realization





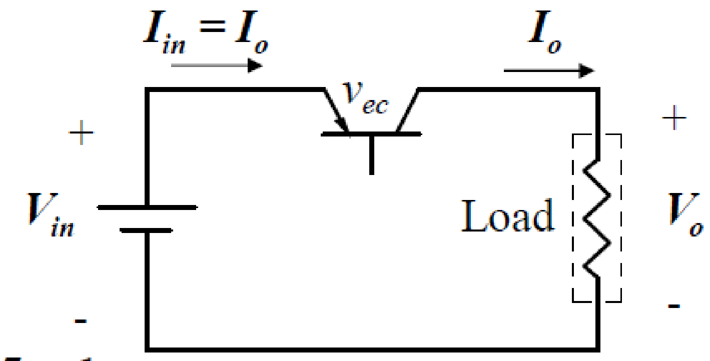
The transistor is controlled to absorb the voltage difference between Vg and V, thus providing a regulated output. The transistor operates in its active region as an adjustable output.



- ✓ **Excellent regulation, control**
- ✓ **Low noise, ripple at the output**

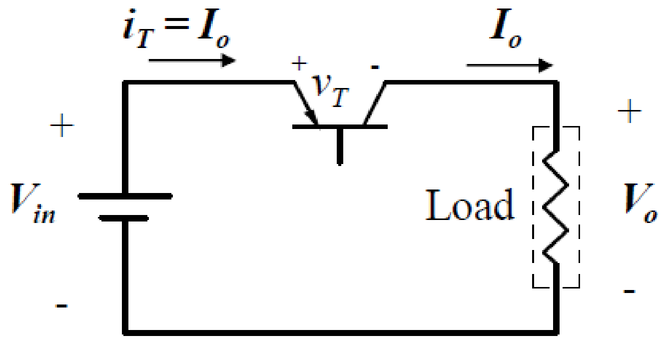
Problems with linear electronics approach

Input voltage : 10V to 14V DC
Output voltage : 5V DC +/- 0.1%
Output current : 1A max.



$$\text{Efficiency} = \frac{P_o}{P_{in}} = \frac{V_o I_o}{V_{in} I_{in}} = \frac{5 \times 1}{14 \times 1}$$

$$\boxed{= 35.7\%}$$

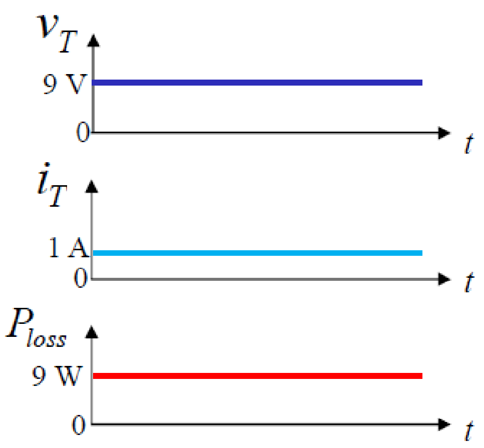


$$\text{Power lost in transistor} = v_T\, I_o$$

$$= (14 - 5) \times 1 \quad \boxed{= 9W}$$

↓ Need for large heatsinks / thermal management

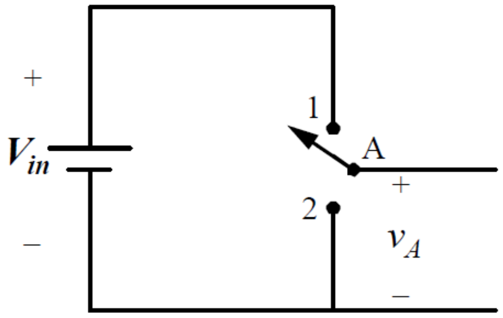
↓ Impact on power density



Use of an SPDT switch

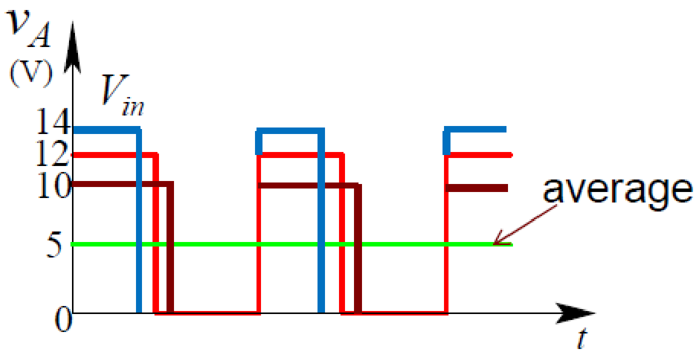
Switch mode approach

Uses a **bi-positional** switch

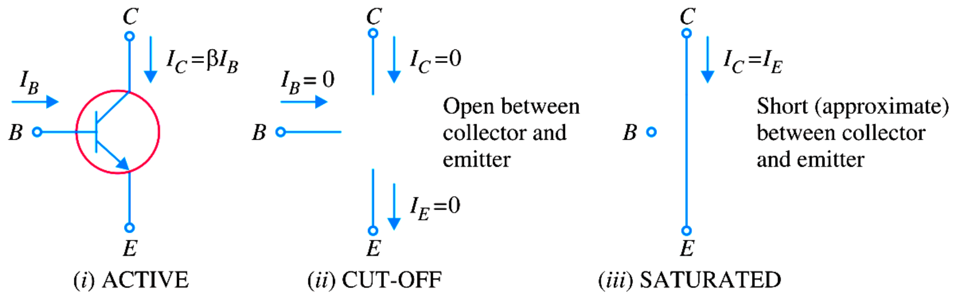


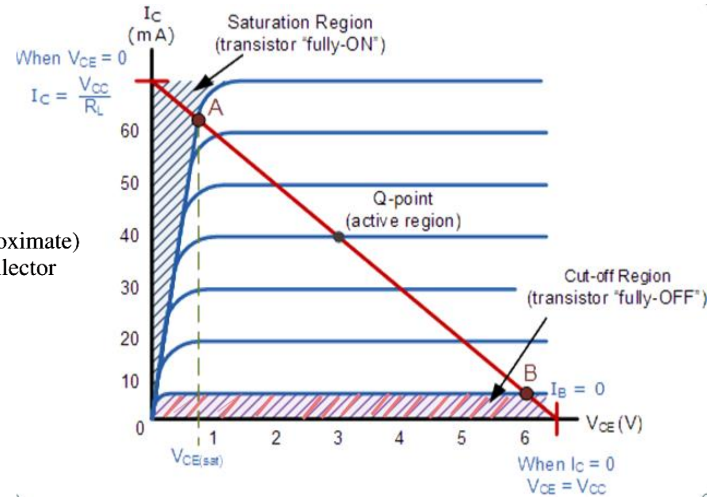
Switch in position 1 ➡ $v_A = V_{in}$

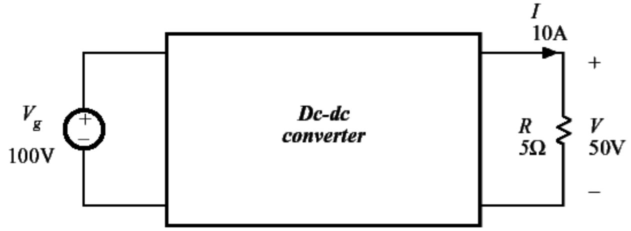
Switch in position 2 ➡ $v_A = 0$

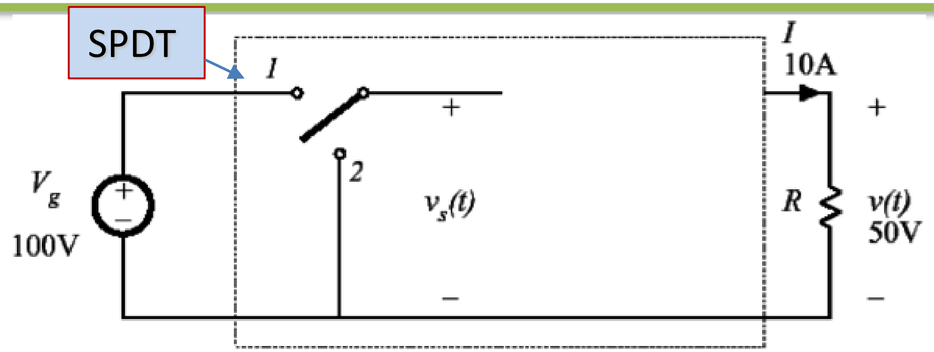


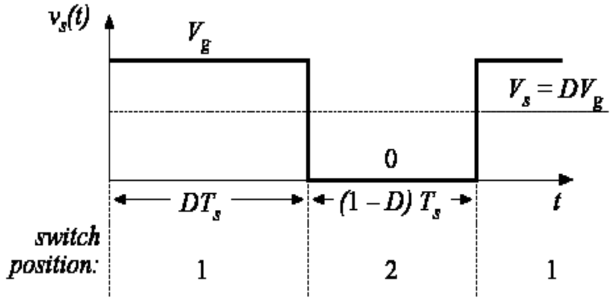
- ✓ **By controlling the duration of ON interval (time when switch is in Position 1), the *average* output can be continuously controlled.**











D = switch duty cycle

$0 \le D \le 1$

T_s = switching period

f_s = switching frequency $= 1 / T_s$

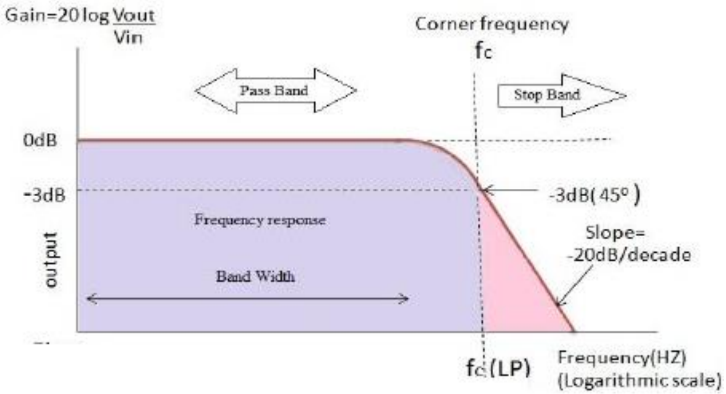
DC component of $v_s(t)$ = average value:

$$V_s = \frac{1}{T_s}\int_0^{T_s} v_s(t)\,dt = DV_g$$

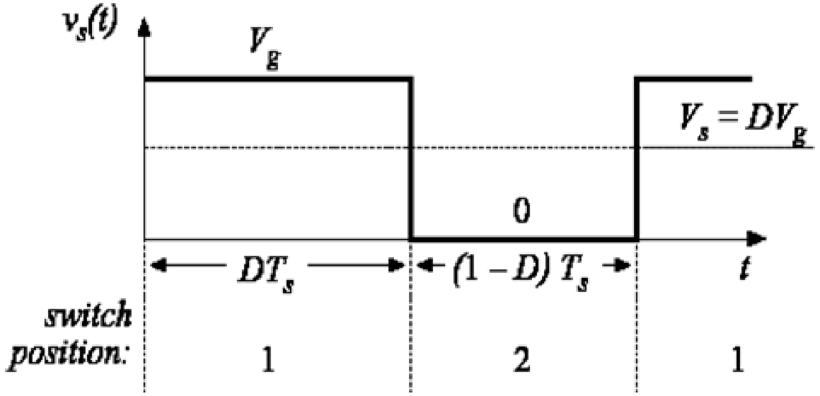
The switch changes the dc voltage level

Simple step-down converter

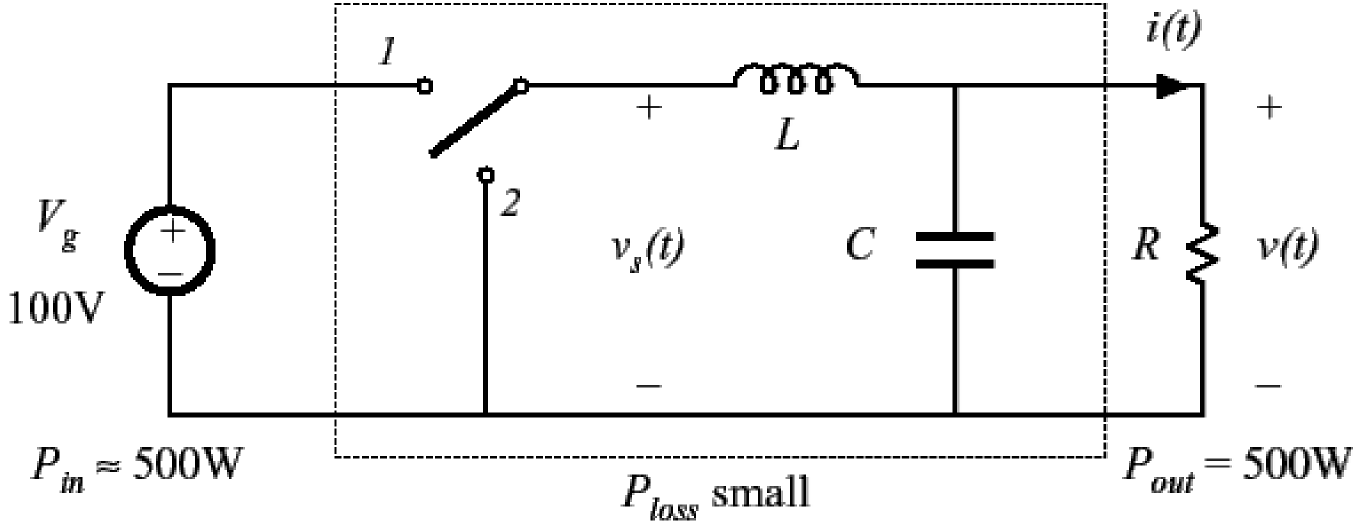
Addition of low pass filter



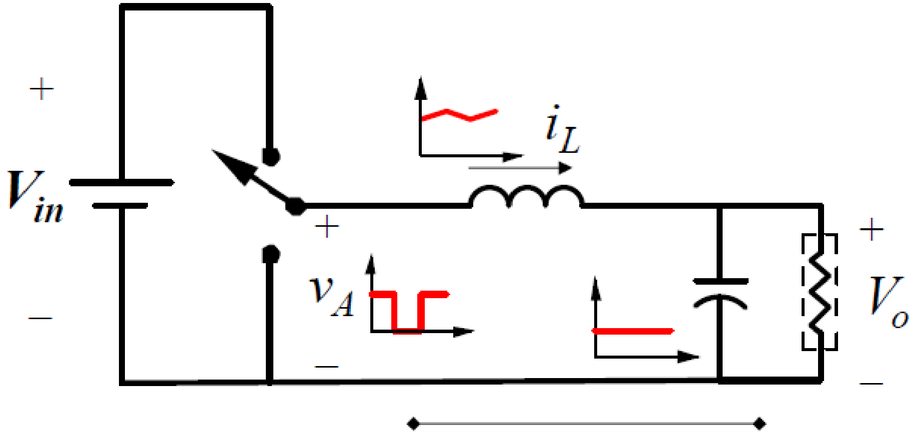
$$fc = \frac{1}{\pi\sqrt{L\,C}}\ Hz$$



Addition of (ideally lossless) L-C low-pass filter, for removal of switching harmonics:

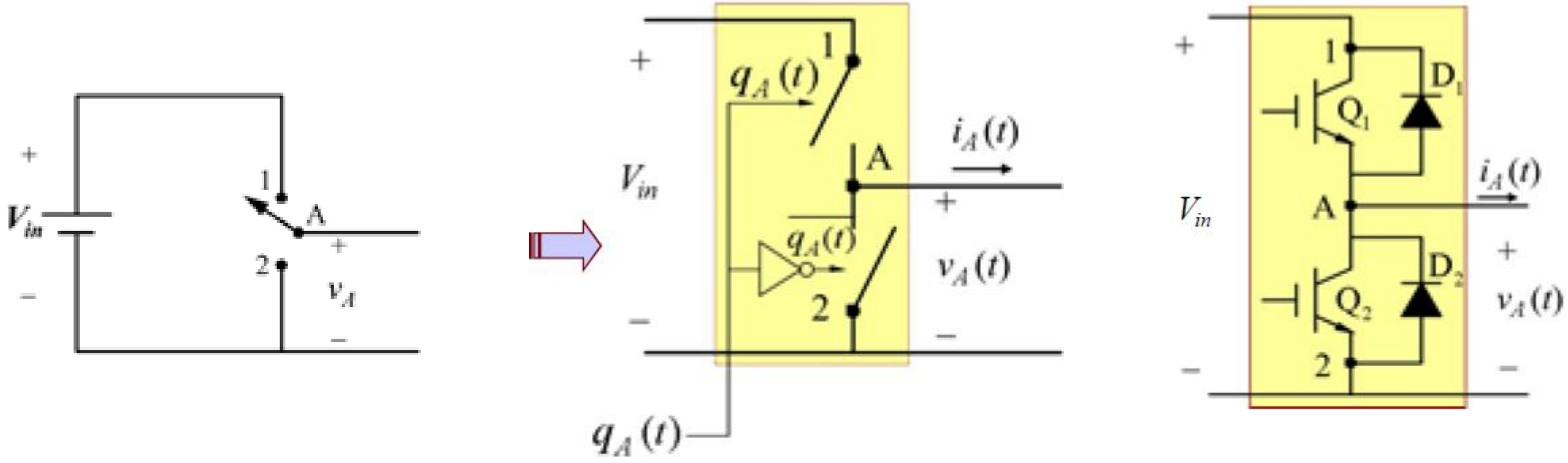


- Choose filter cutoff frequency fc much smaller than switching frequency fs
- This circuit is known as the "buck converter"



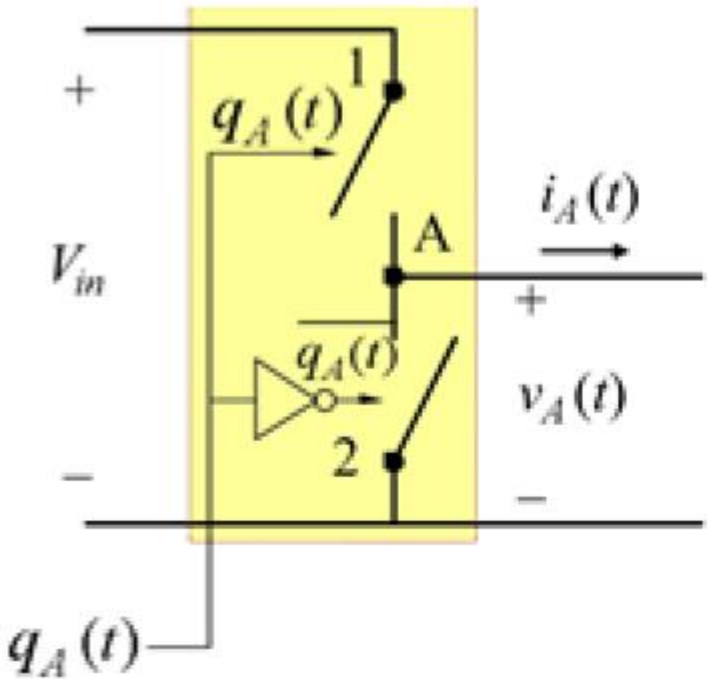
- High frequency content in *vA* filtered using LC filter
- Filter size and cost very small with high frequency

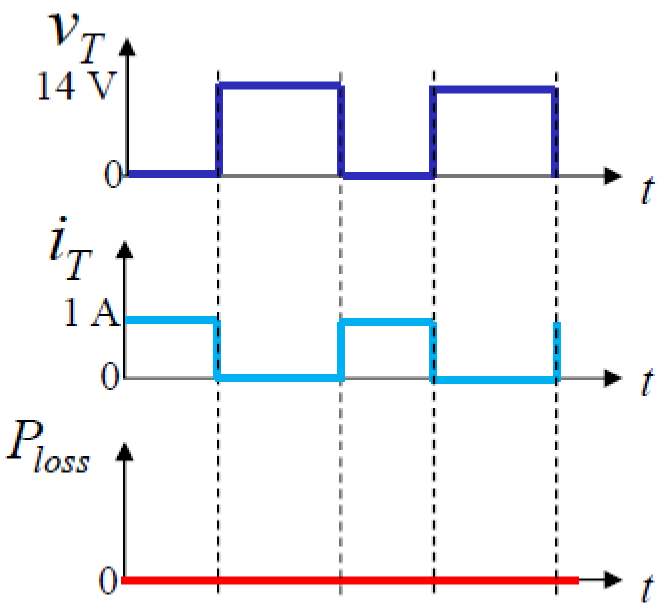
Bi-positional switch: electronic implementation



- ✓ **SPDT switch realized with two SPST switches**
- ✓ **SPST implemented with MOSFETs and IGBTs or other power semiconductor devices**
- ✓ **Bi-positional switch is a main building-block of power converters**

Switch mode approach: efficiency





- **Efficiency, theoretically 100% (with ideal components)**
  - **Zero voltage when switch is ON**
  - **Zero current when switch is OFF**

- **Practical efficiency > 95% in many applications**

Power supply problem example #3

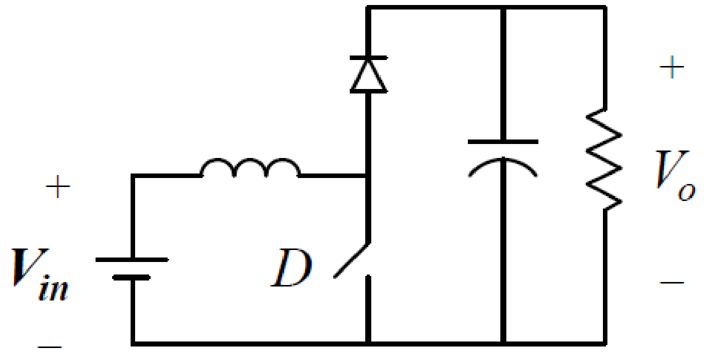
Input voltage : 1.5V to 2V DC
Output voltage : 5V DC +/- 0.1%
Output current : 0.1A max.

Linear Approach

??

Switch-Mode Approach

Boost Converter



$$V_o = \frac{1}{1-D} V_{in}$$