

# EE 238

## Power Engineering - II

### Power Electronics



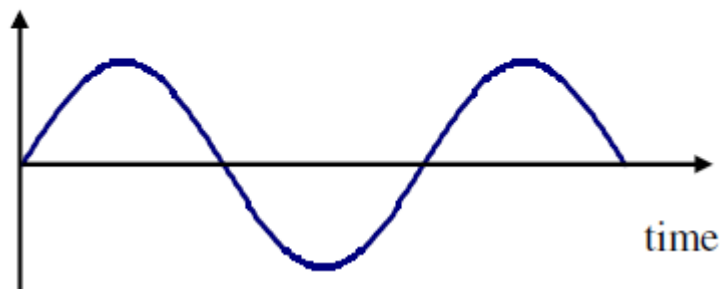
## Lecture 3

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## Power Conversion concept: example #1

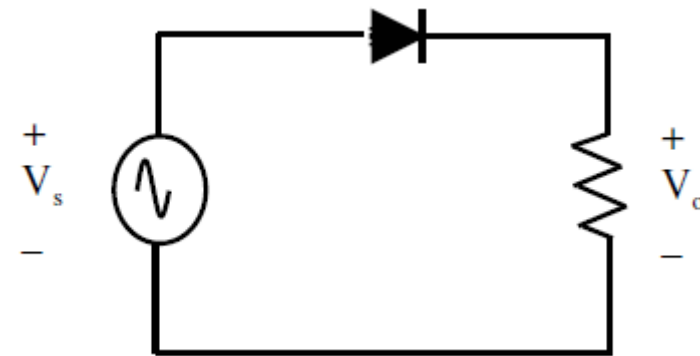
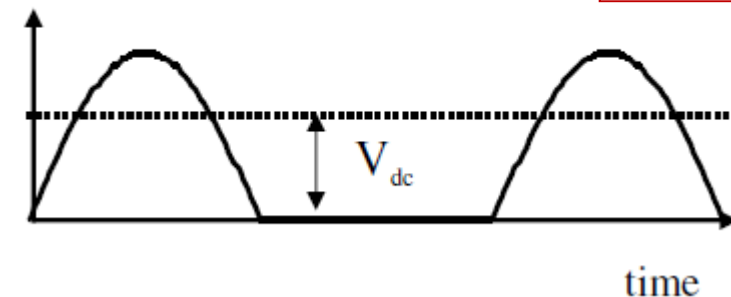
$V_s$  (Volt)



- The sine-wave supply gives zero DC component!

- Supply: 50Hz, 240V RMS (340V peak). Customer needs DC voltage for welding purpose, say.

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.

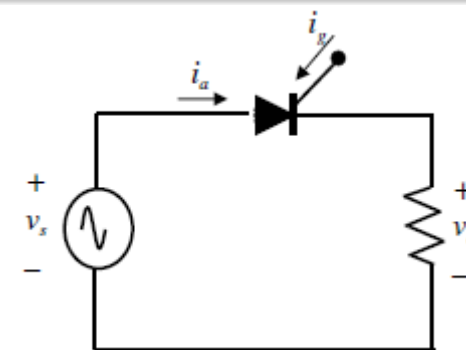
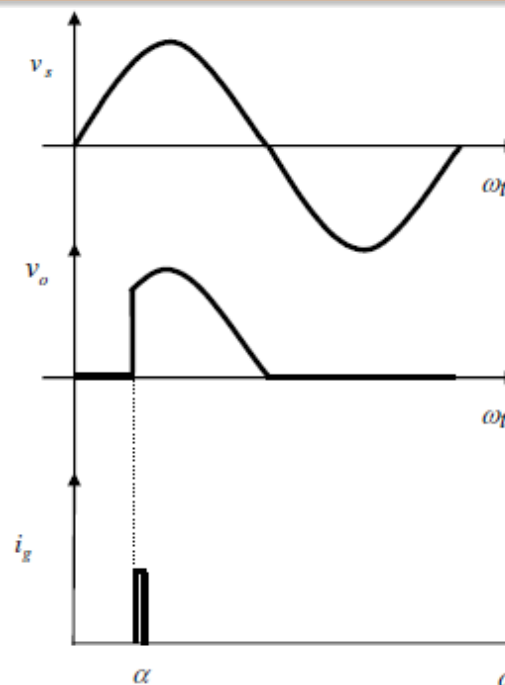
## How if customer wants variable DC voltage?

Average output voltage :

$$V_o = \frac{1}{2\pi} \int_{\alpha}^{\pi} V_m \sin(\omega t) d\omega t = \frac{V_m}{2\pi} [1 + \cos \alpha]$$

By controlling the firing angle,  $\alpha$ , 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.

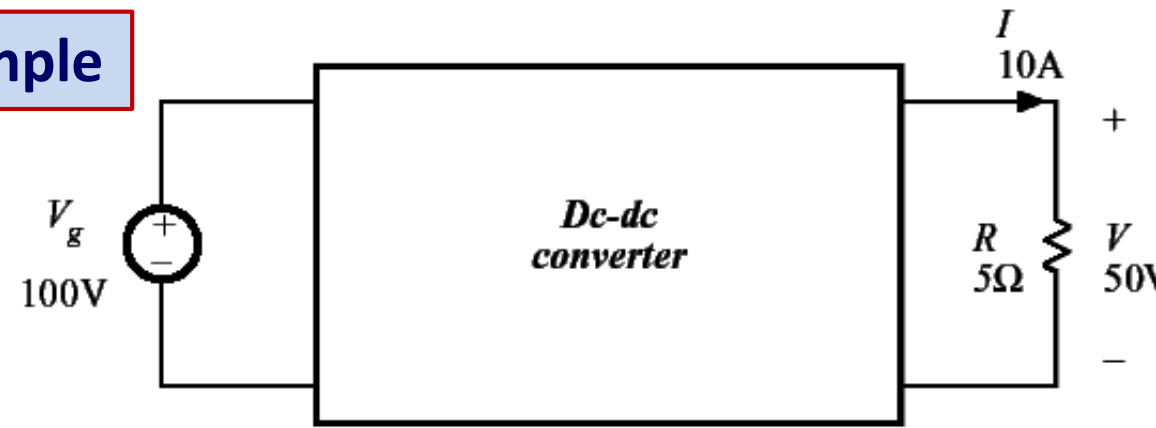
## A simple example #2

## A dc-dc converter example

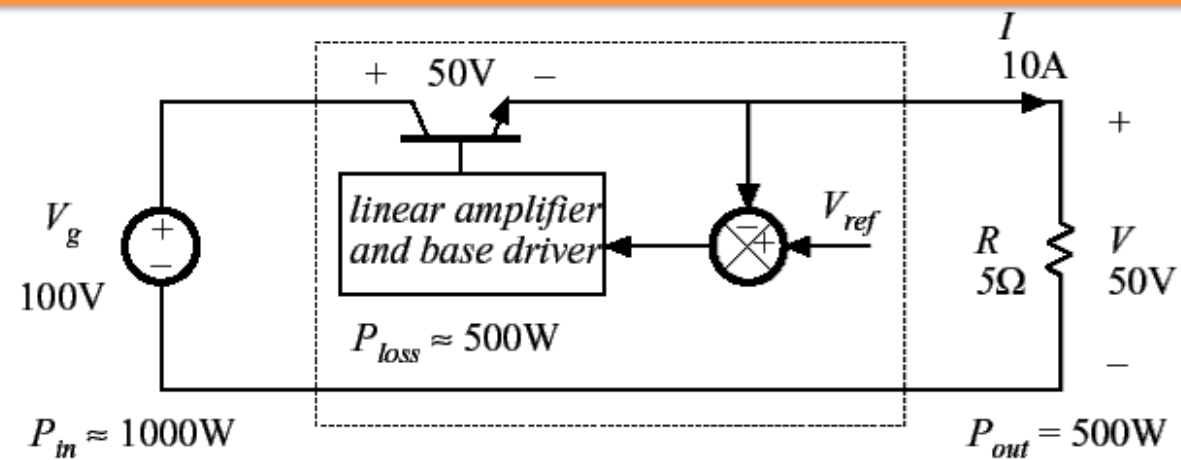
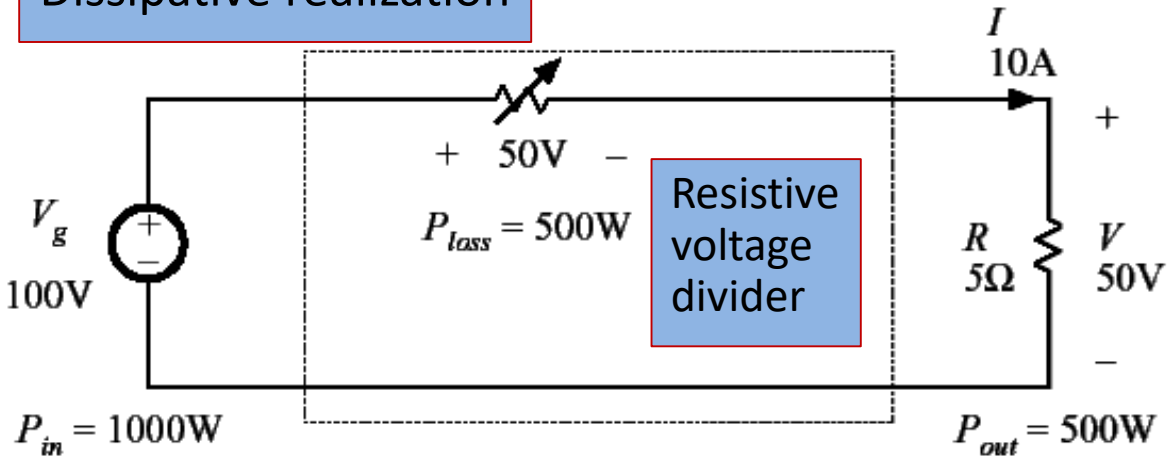
Input source: 100V

Output load: 50V, 10A, 500W

How can this converter be realized?

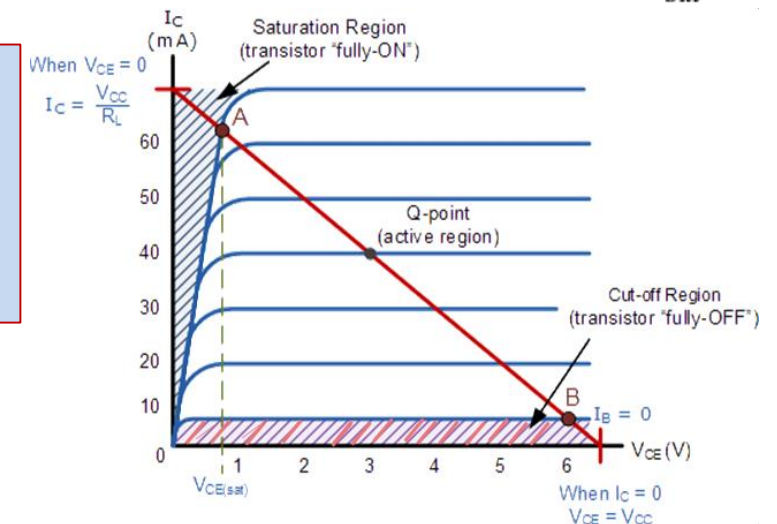


### Dissipative realization



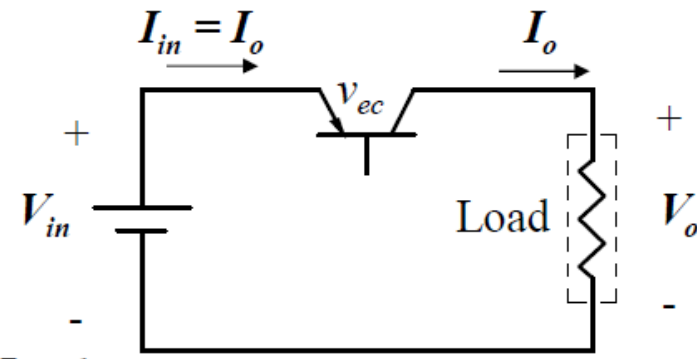
The transistor is controlled to absorb the voltage difference between  $V_g$  and  $V$ , thus providing a regulated output. The transistor operates in its active region as an adjustable output.

- ✓ 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.

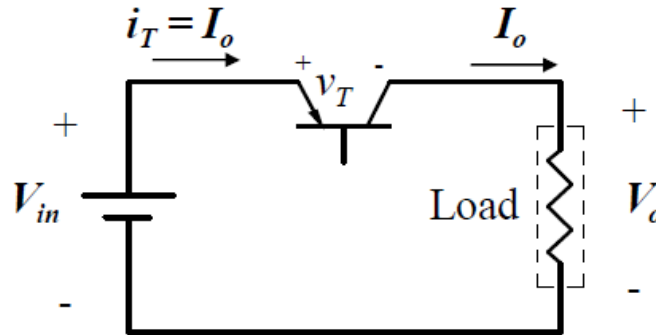


$$\text{Efficiency} = \frac{P_o}{P_{in}} = \frac{V_o I_o}{V_{in} I_{in}} = \frac{5 \times 1}{14 \times 1}$$

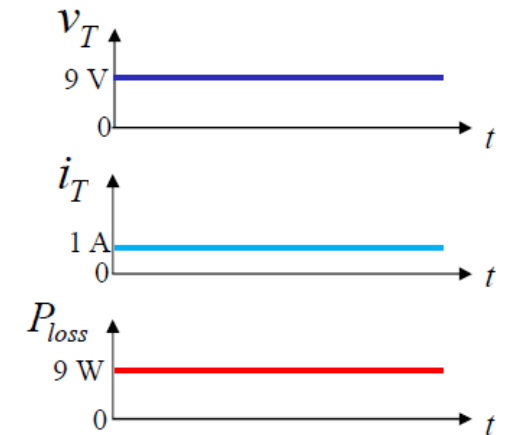
$$= 35.7\%$$

Power lost in transistor =  $v_T I_o$

$$= (14 - 5) \times 1 = 9W$$

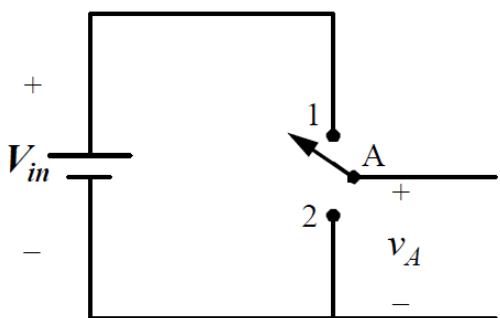


- ↓ Need for large heatsinks / thermal management
- ↓ Impact on power density



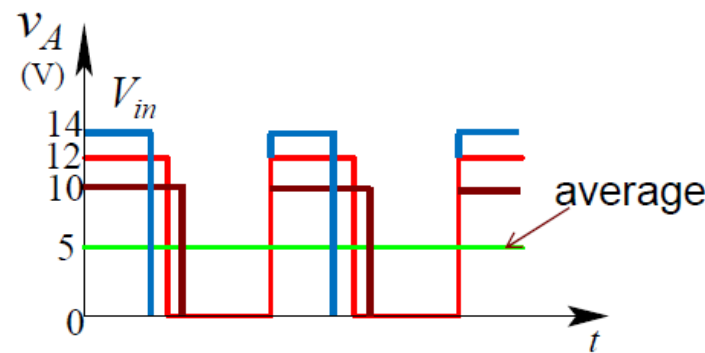
# Use of an SPDT switch

Switch mode approach  
Uses a bi-positional switch

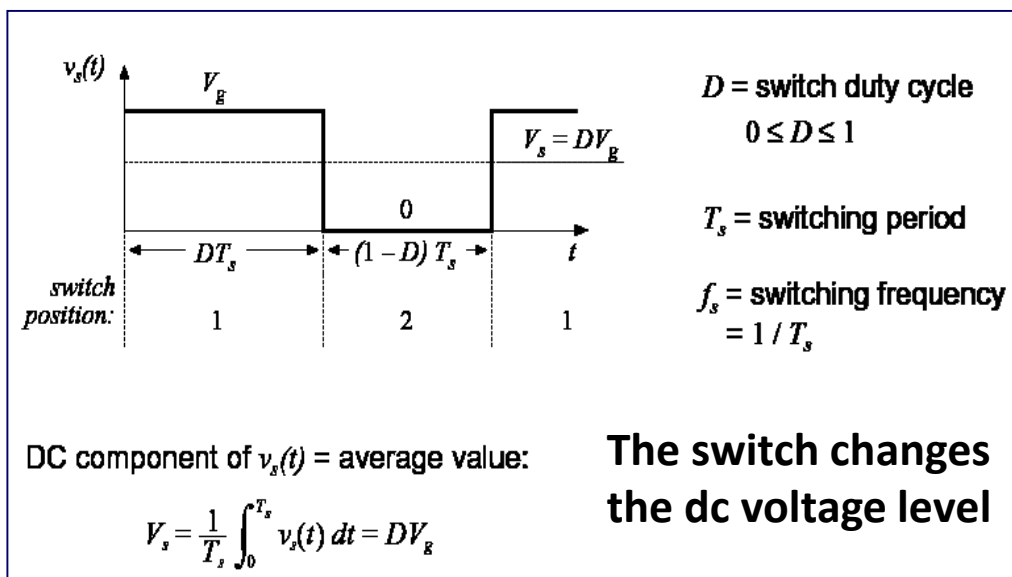
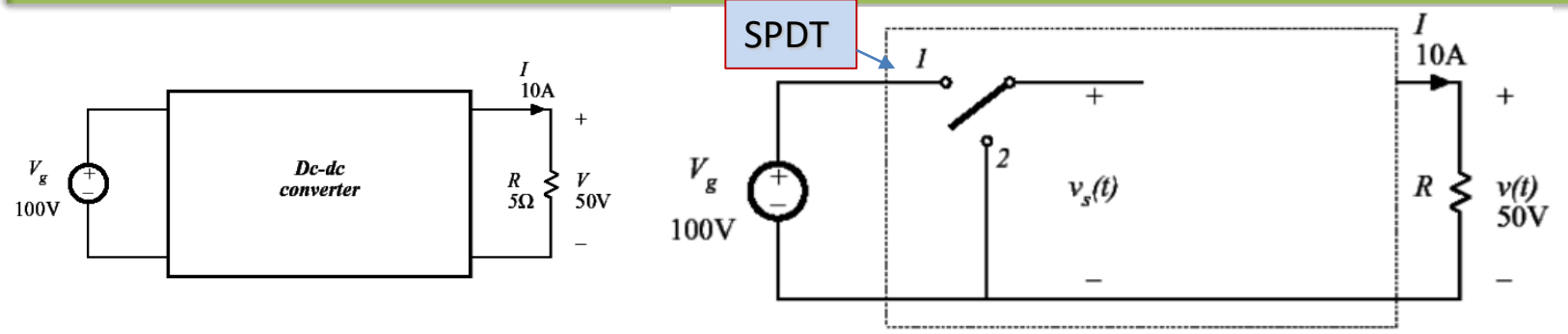
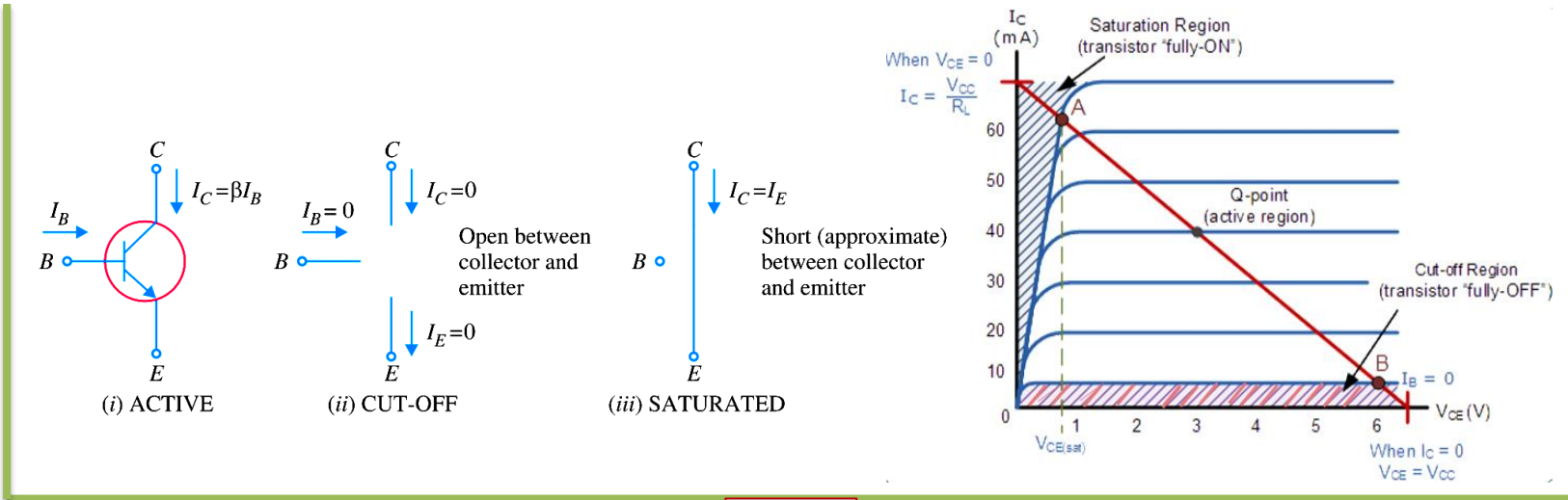


Switch in position 1  $\Rightarrow v_A = V_{in}$

Switch in position 2  $\Rightarrow v_A = 0$

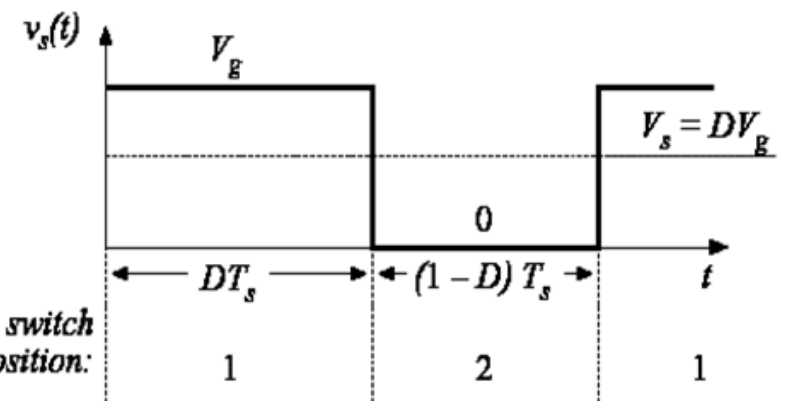


✓ By controlling the duration of ON interval (time when switch is in Position 1), the **average** output can be continuously controlled.



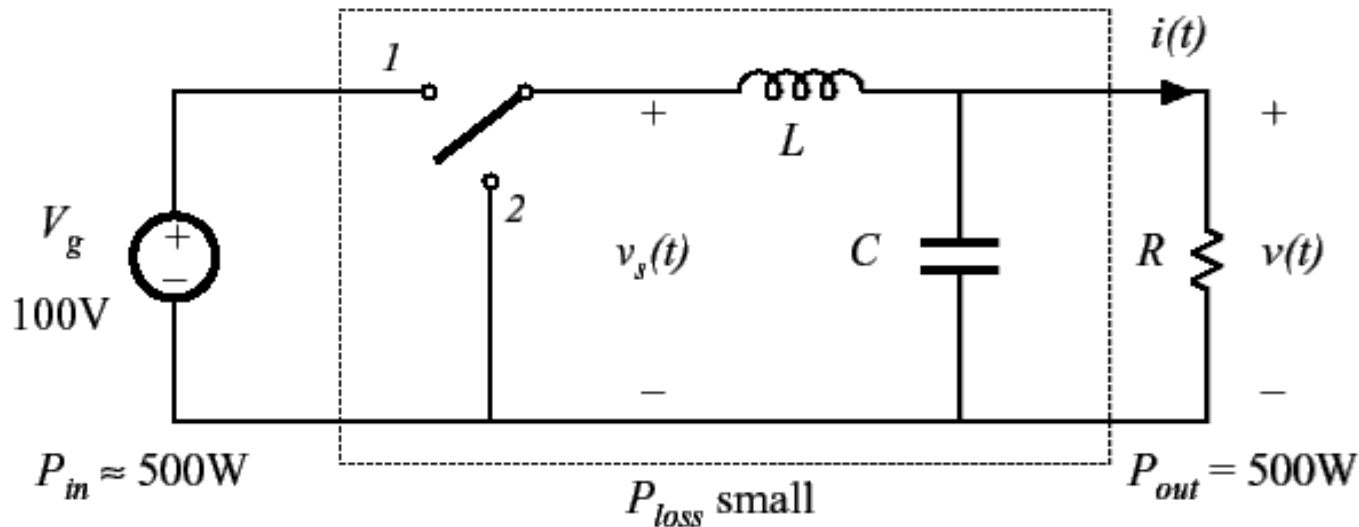
## Simple step-down converter

## Addition of low pass filter



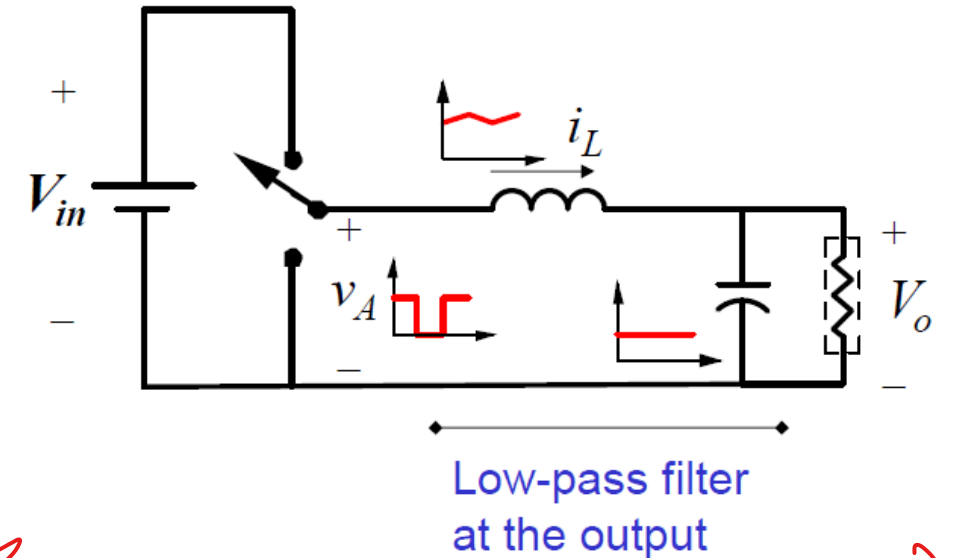
$$f_c = \frac{1}{\pi\sqrt{LC}} \text{ Hz}$$

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



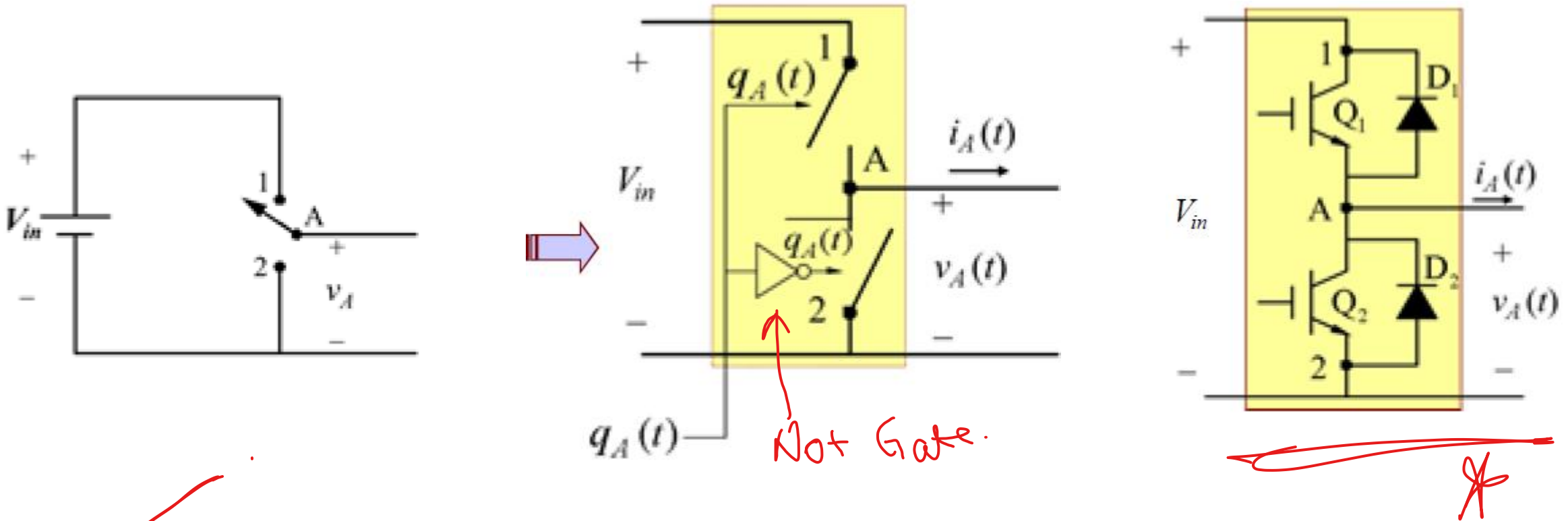
Choose filter cutoff frequency  $f_c$  much smaller than switching frequency  $f_s$

This circuit is known as the "buck converter"



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

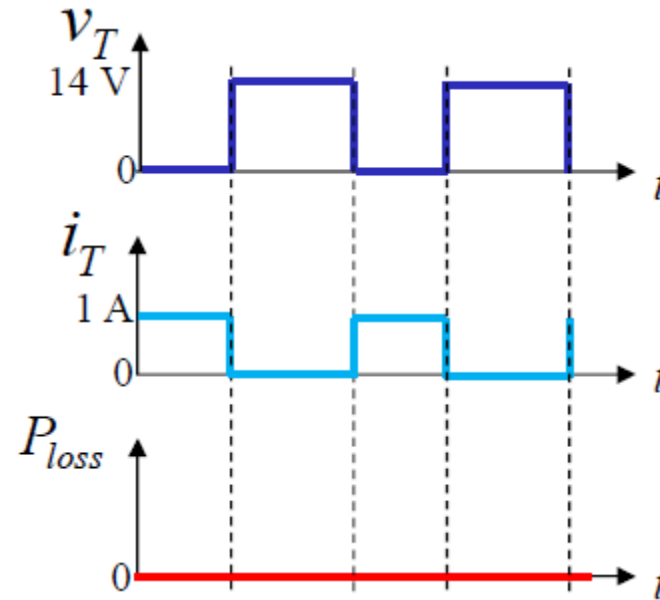
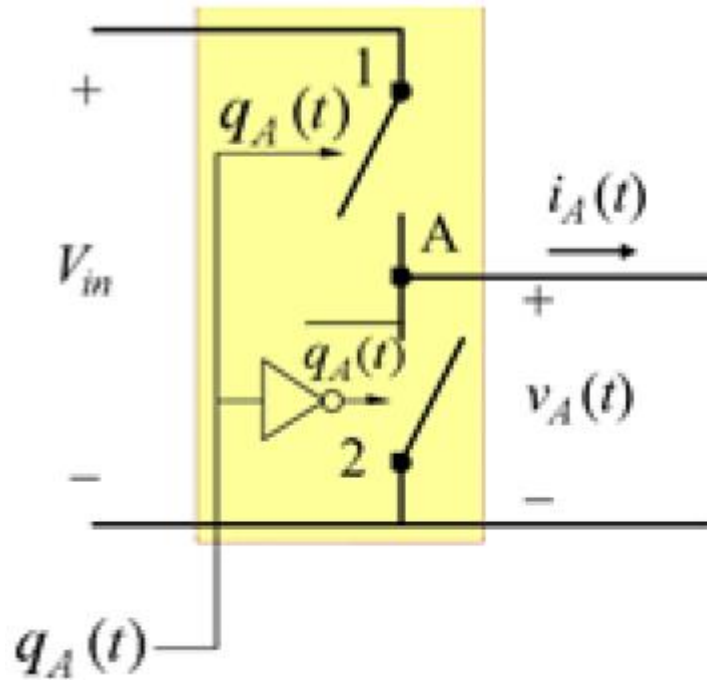
## Bi-positional switch: electronic implementation



- ✓ 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

Modified BJT (BJT + MOSFET)  
Ron ↓ & speed ↑

## 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

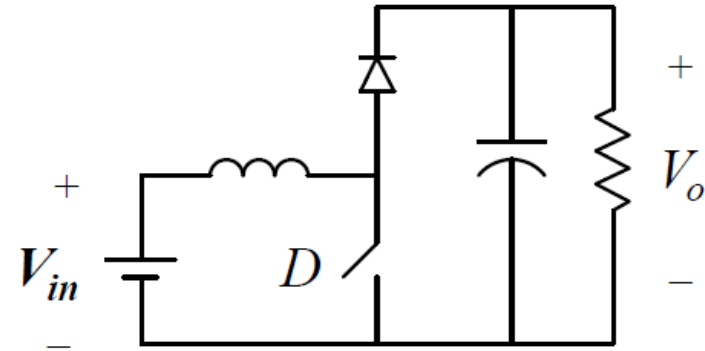
Input voltage : 1.5V to 2V DC  
Output voltage : 5V DC +/- 0.1%  
Output current : 0.1A max.

Linear Approach

??

Switch-Mode Approach

Boost Converter



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

