EE 238

Power Engineering - II

Power Electronics

Lecture 2

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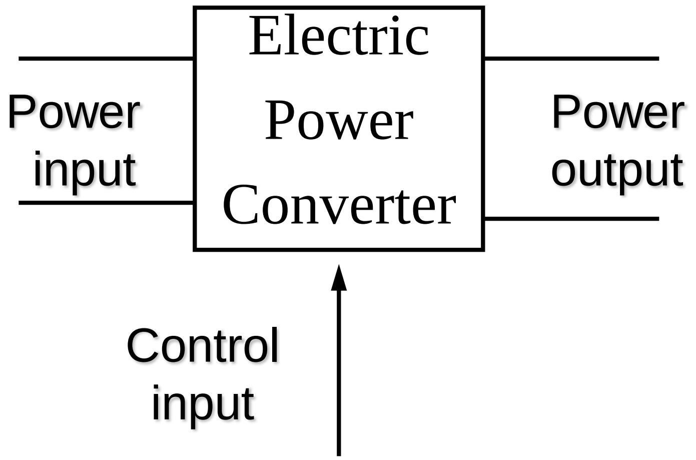
Conversion of electric power



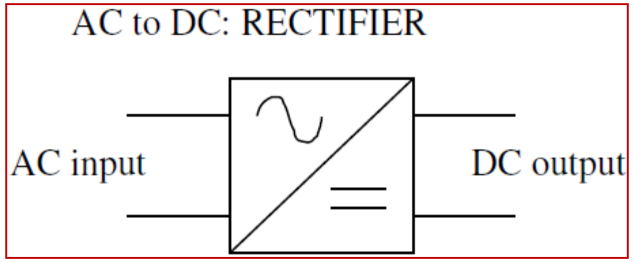
Other names for electric power converter:

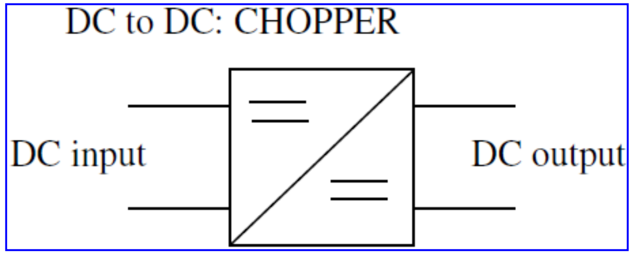
- Power converter
- Converter
- Switching converter
- Power electronic circuit
- Power electronic converter

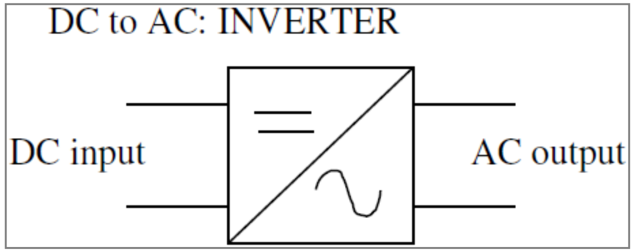
Two types of electric power	Changeable properties in conversion
DC(Direct Current)	Magnitude
AC (Alternating Current)	Frequency, magnitude, number of phases

Classification of power converters

Power input \ Power output	DC	AC
AC	AC to DC converter (Rectifier)	AC to AC converter (Fixed frequency : AC controller Variable frequency: Cycloconverter or frequency converter)
DC	DC to DC converter (Chopper)	DC to AC converter (Inverter)





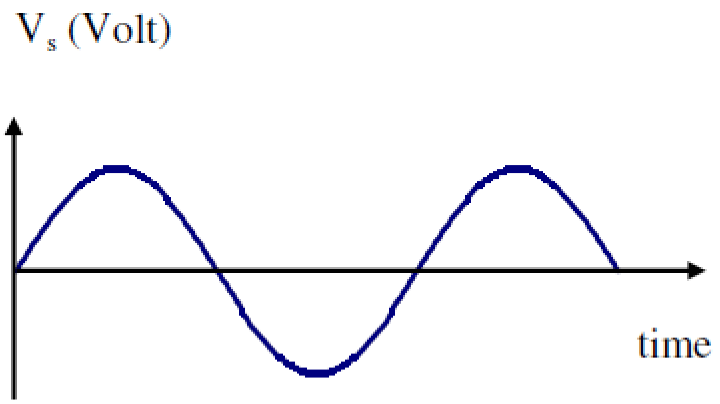


Power Conversion concept: example #1

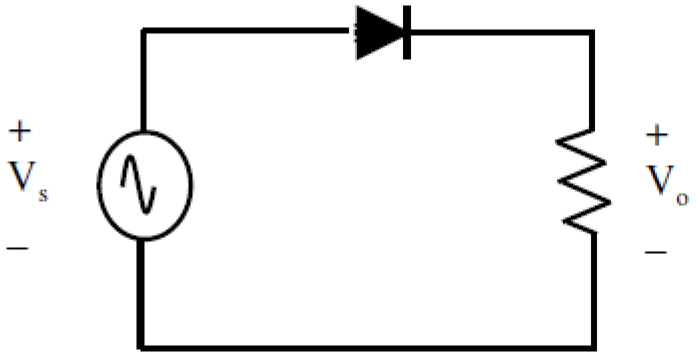
- Supply: 50Hz, 240V RMS (340V peak).

Customer needs DC voltage for welding purpose, say.

- The sine-wave supply gives zero DC component!

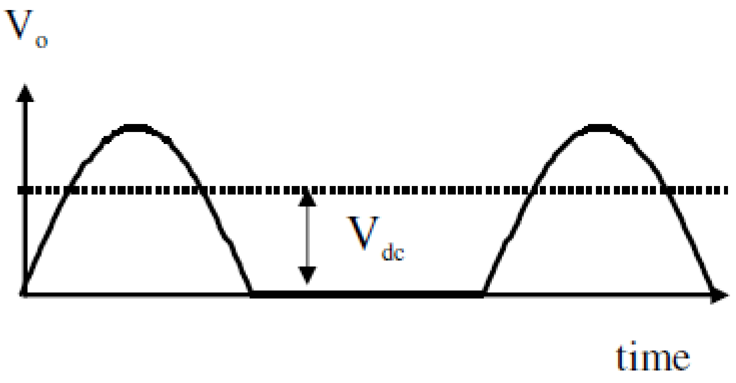


- We can use simple half-wave rectifier. A fixed DC voltage is now obtained. This is a simple PE system.



Average output voltage :

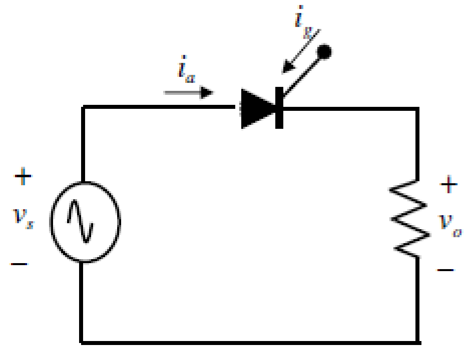
$$V_o = \frac{V_m}{\pi}$$



Conversion Concept

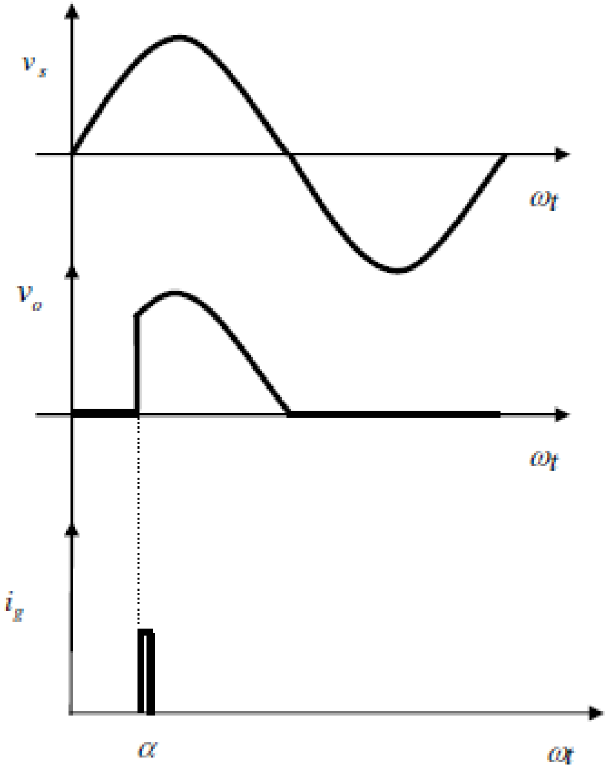
How if customer wants variable DC voltage?

More complex circuit using SCR is required.



Average output voltage :

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

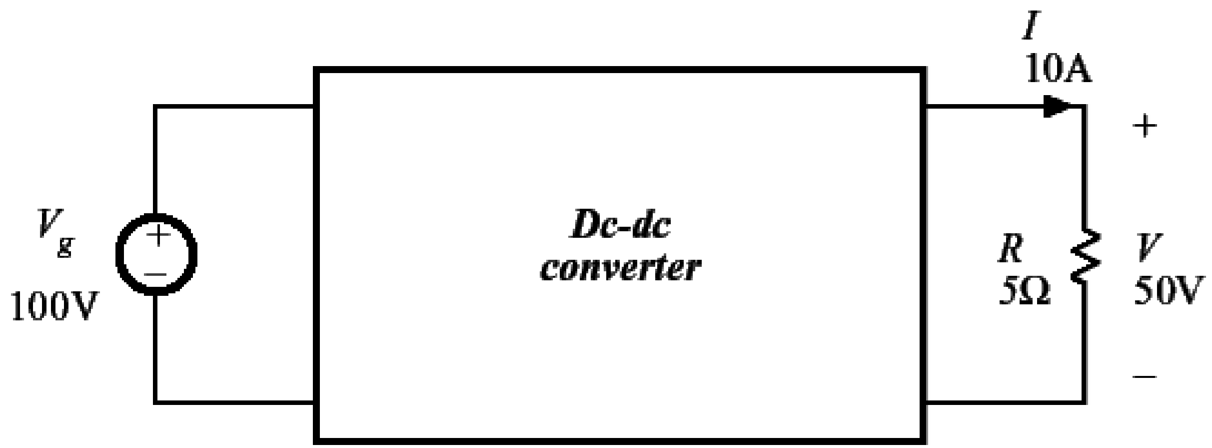


By controlling the firing angle, α, the output DC voltage (after conversion) can be varied.

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

A simple example #2

A dc-dc converter example



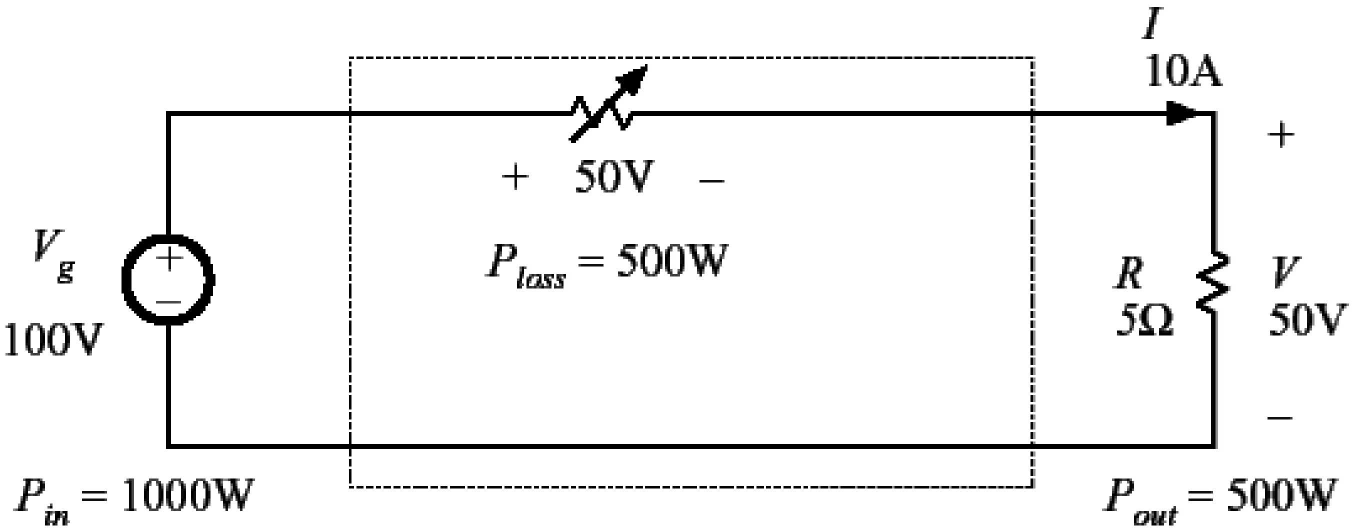
Input source: 100V

Output load: 50V, 10A, 500W

How can this converter be realized?

Dissipative realization

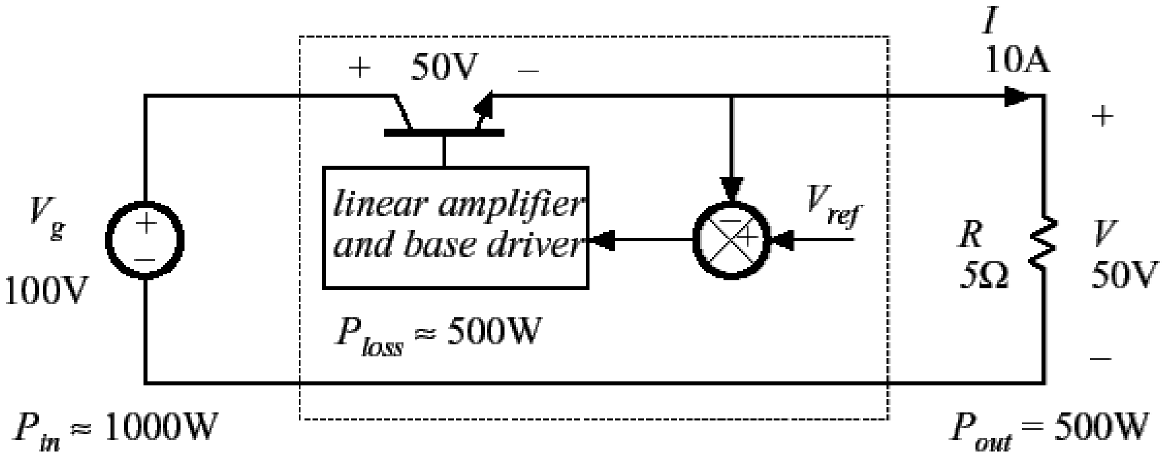
- **Resistive voltage divider**

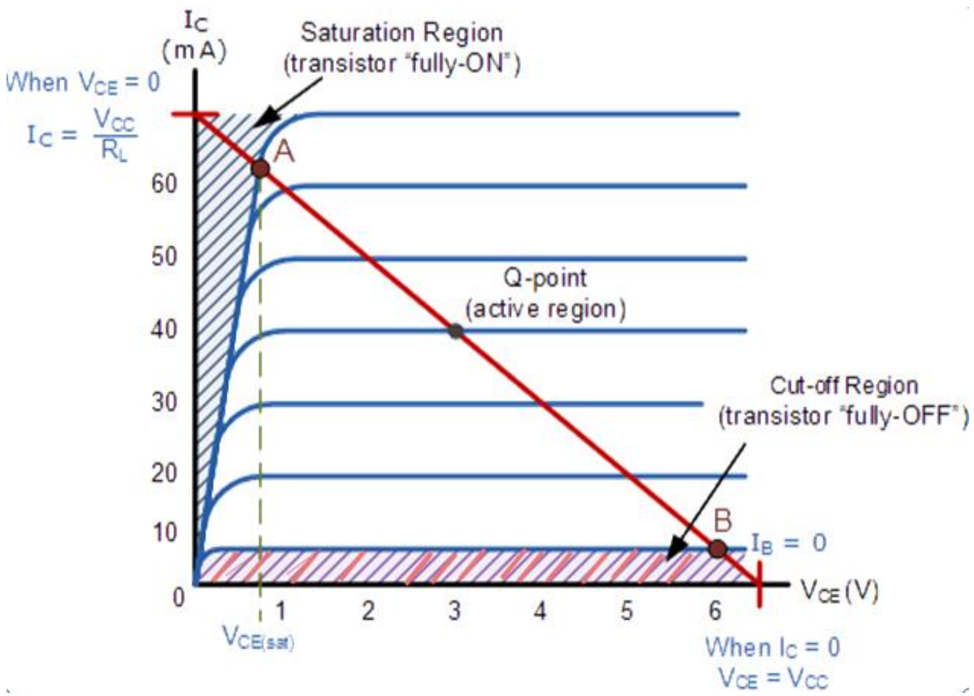


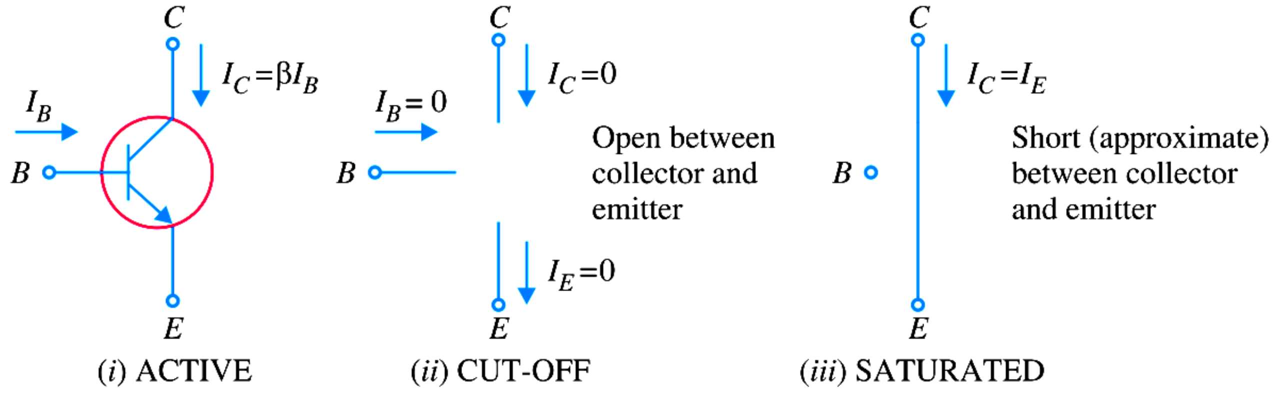
Dissipative realization

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.

- **Transistor operates in active region**



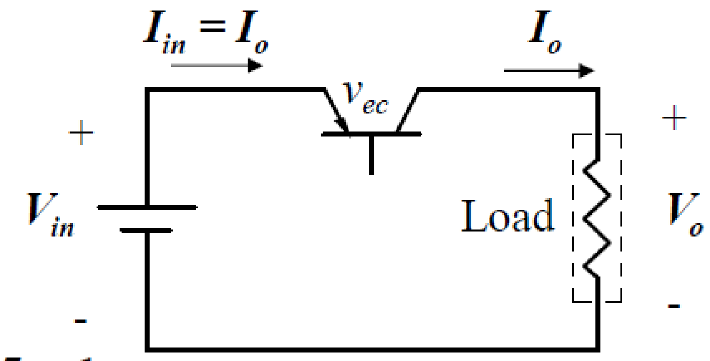




- ✓ **Excellent regulation, control**
- ✓ **Low noise, ripple at the output**

Problems with linear electronics approach

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

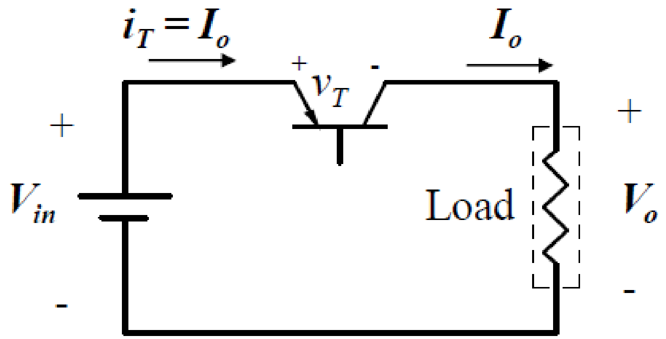


$$\text{Efficiency} = \frac{P_o}{P_{in}} = \frac{V_o I_o}{V_{in} I_{in}} = \frac{5 \times 1}{14 \times 1}$$

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

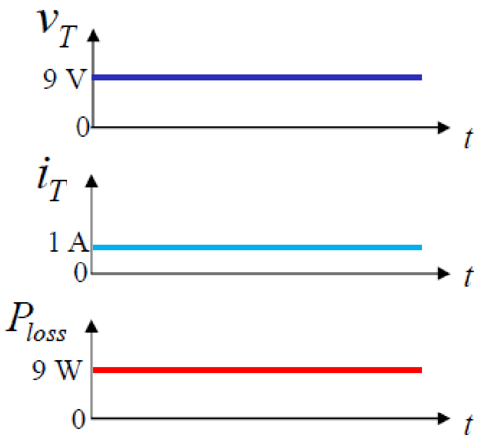
$$\text{Power lost in transistor} = v_T\, I_o$$

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



↓ Need for large heatsinks / thermal management

↓ Impact on power density

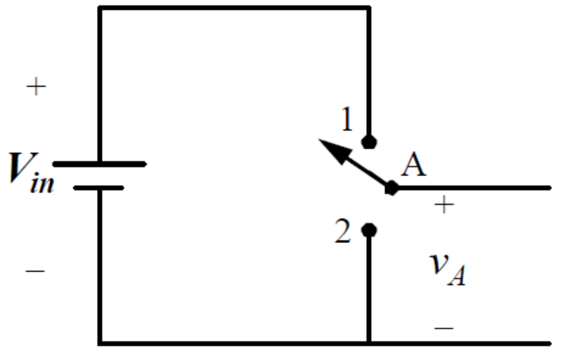


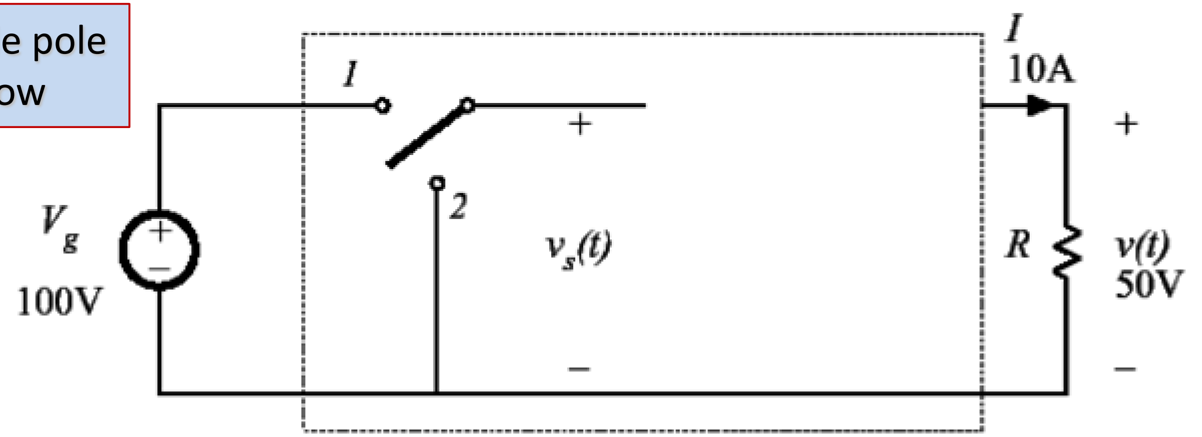
Use of a SPDT switch

SPDT: Single pole double throw

Switch mode approach

Uses a **bi-positional** switch

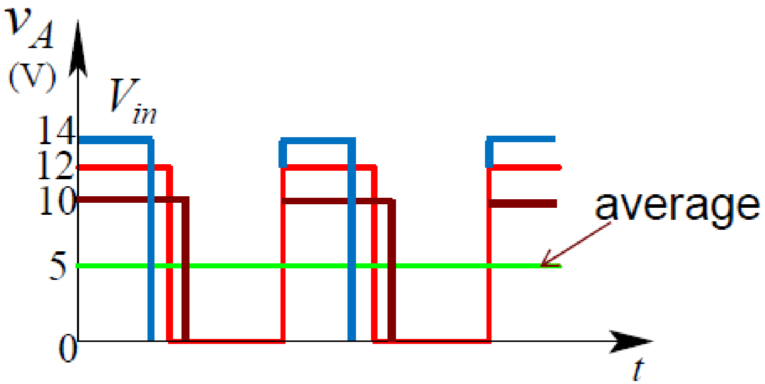


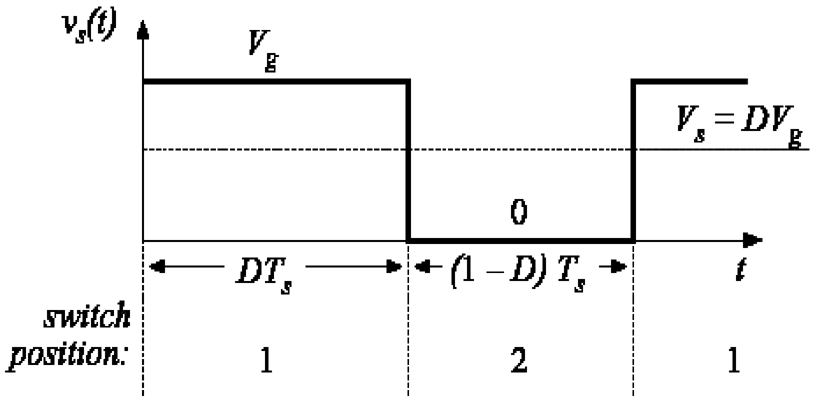


✓ **By controlling the duration of ON interval (time when switch is in Position 1), the *average* output can be continuously controlled.**

Switch in position 1 ➡ $v_A = V_{in}$

Switch in position 2 ➡ $v_A = 0$





D = switch duty cycle

$0 \le D \le 1$

T_s = switching period

f_s = switching frequency $= 1 / T_s$

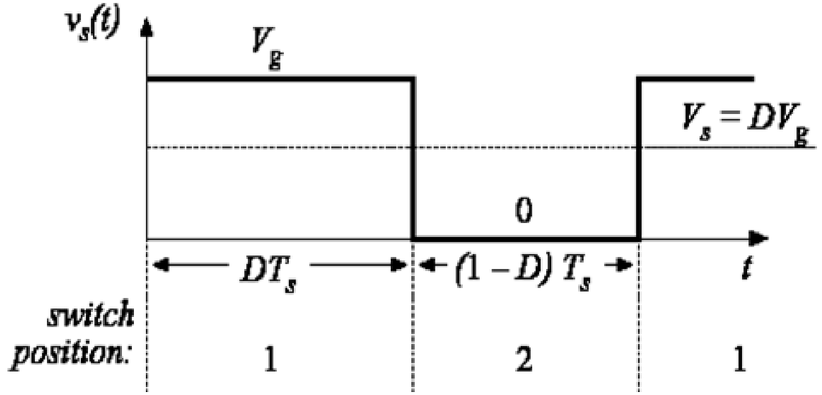
DC component of $v_s(t)$ = average value:

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

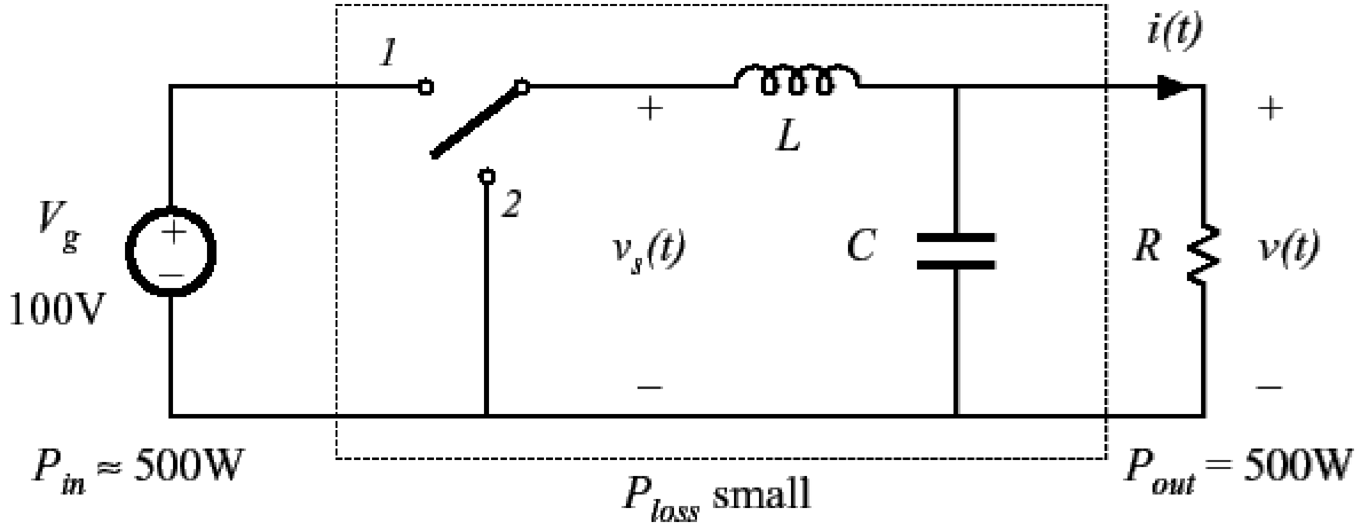
The switch changes the dc voltage level

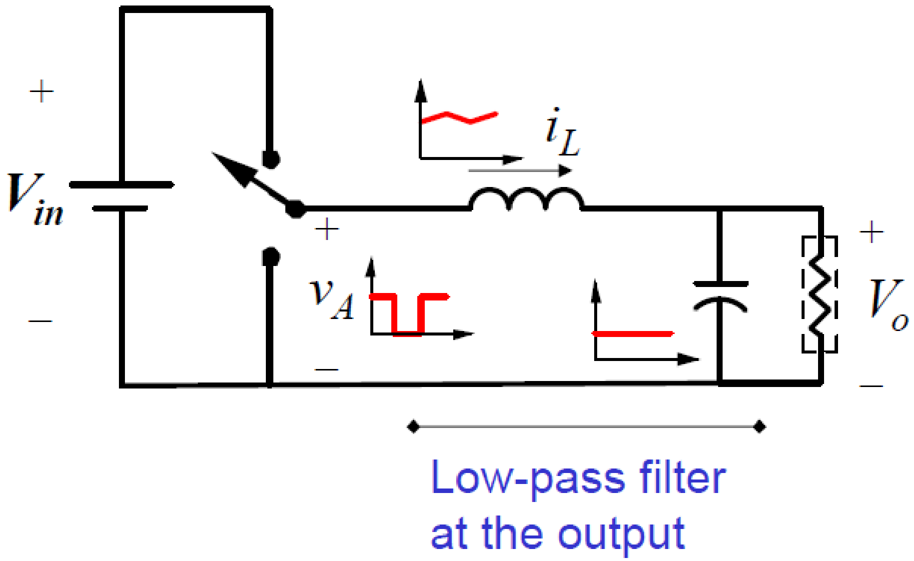
Simple step-down converter

Addition of low pass filter



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





- Choose filter cutoff frequency f0 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