EE-463 STATIC POWER CONVERSION-I

Basic Concepts

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Let's start with a simple DC-DC Converter

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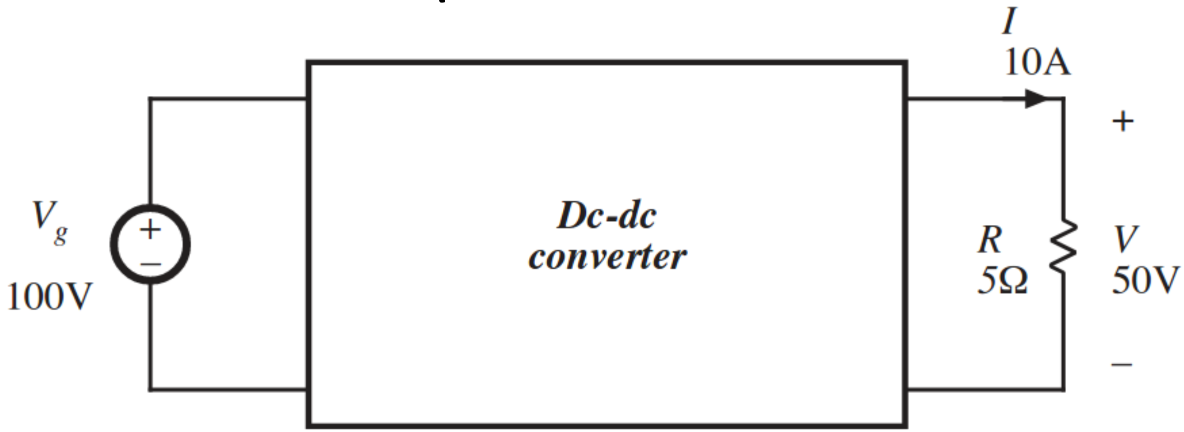
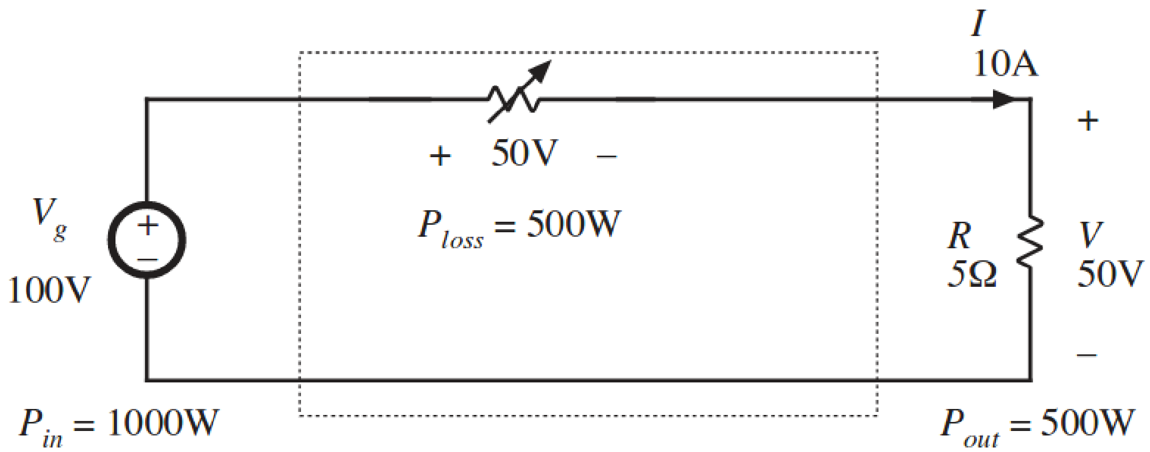
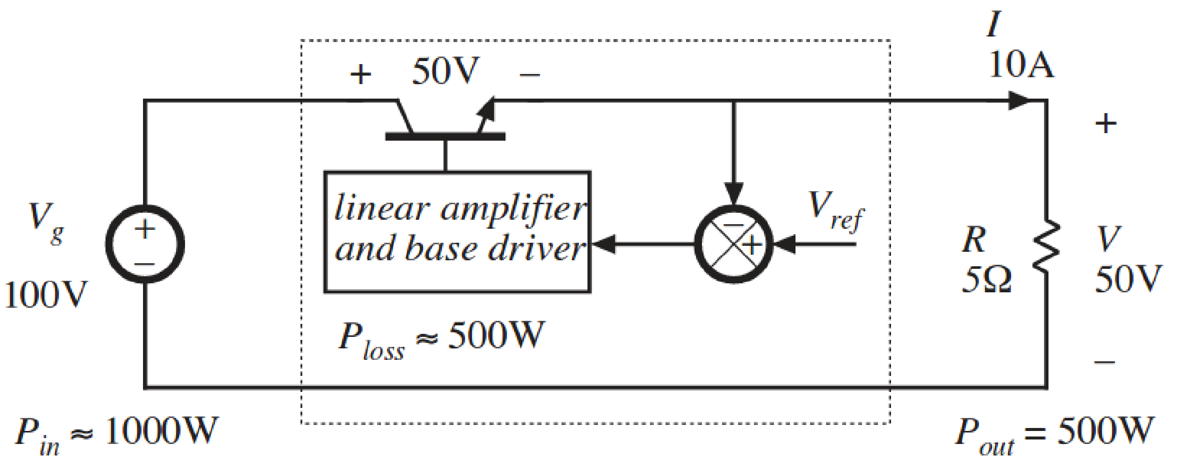


Can you design this converter?

Resistive Voltage Divider

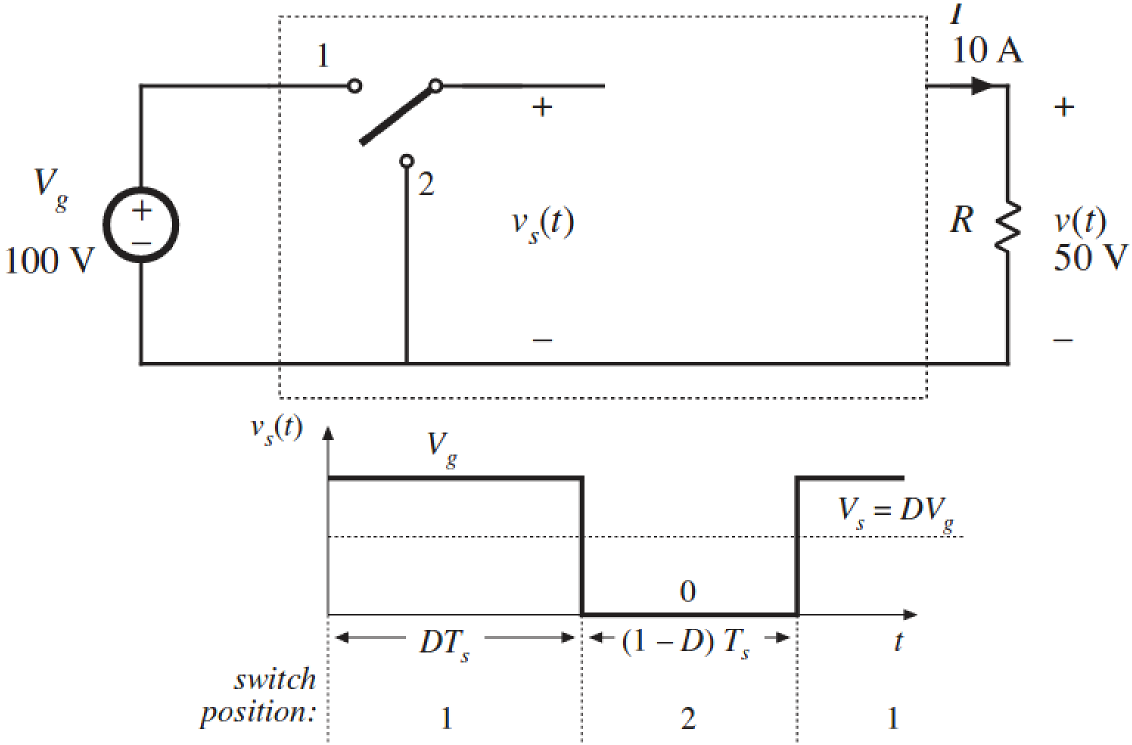


Series Regulator (Transistor in linear mode)

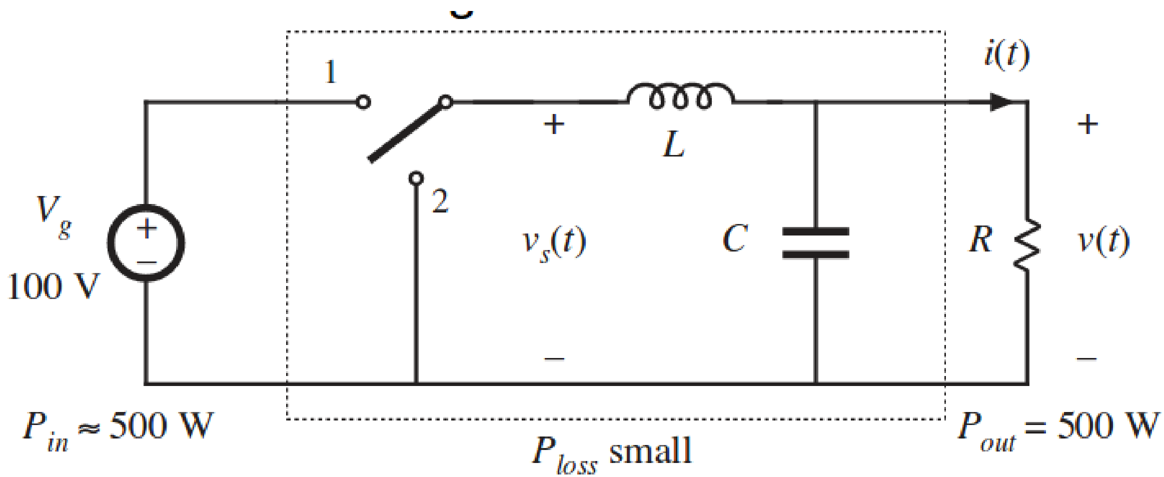


Efficiency= 50% !

Use an Ideal (Two Position) Switch

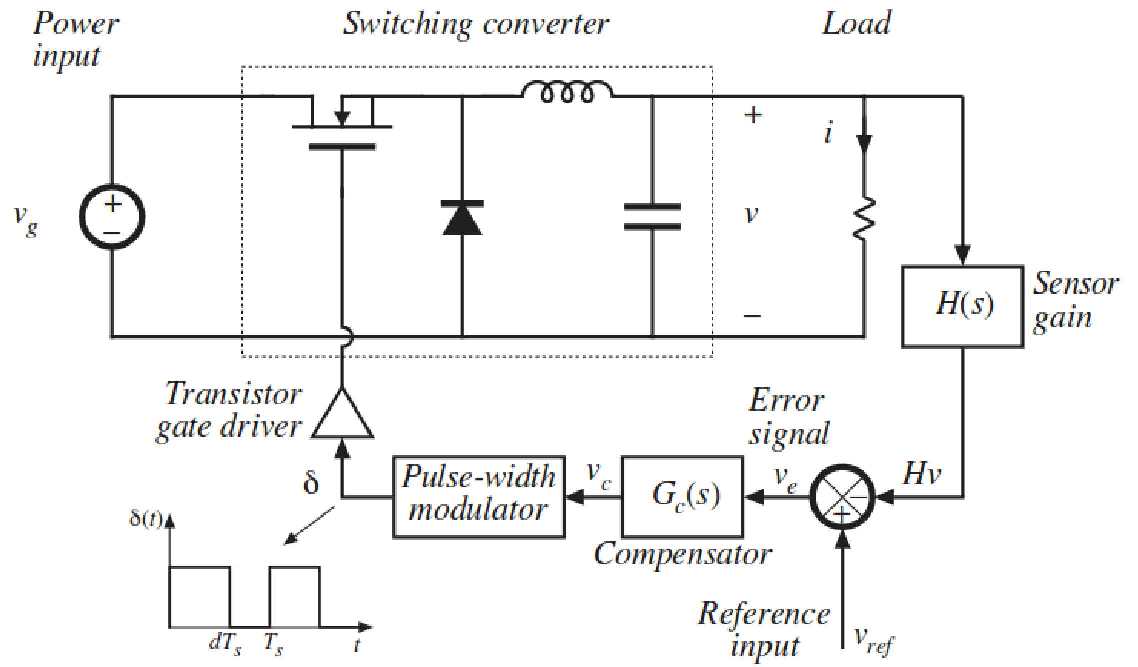


With L-C (Low-Pass) Filter

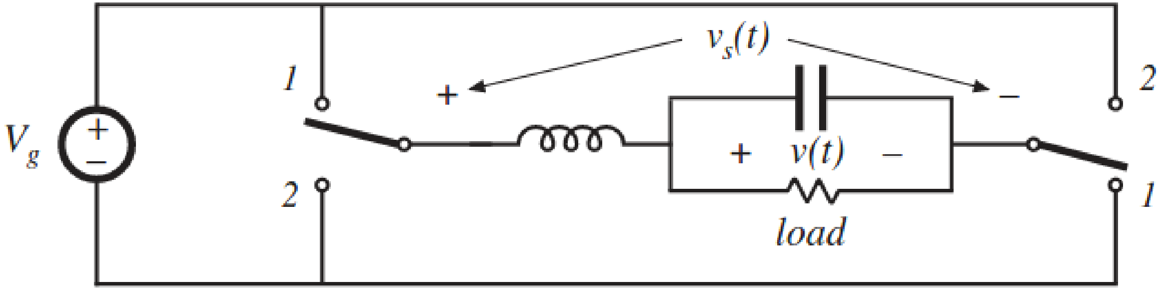


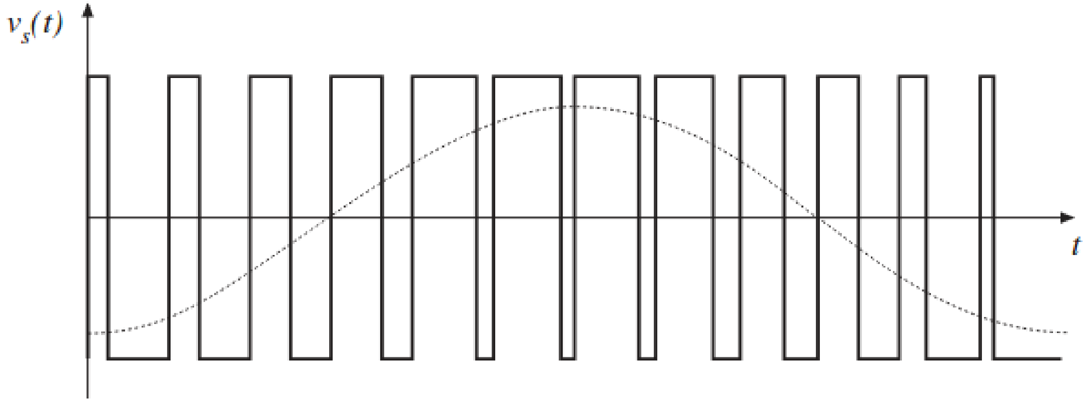
Notice high efficiency

A more realistic example (Buck converter)



Generating AC: Single-Phase Inverter





Common Points

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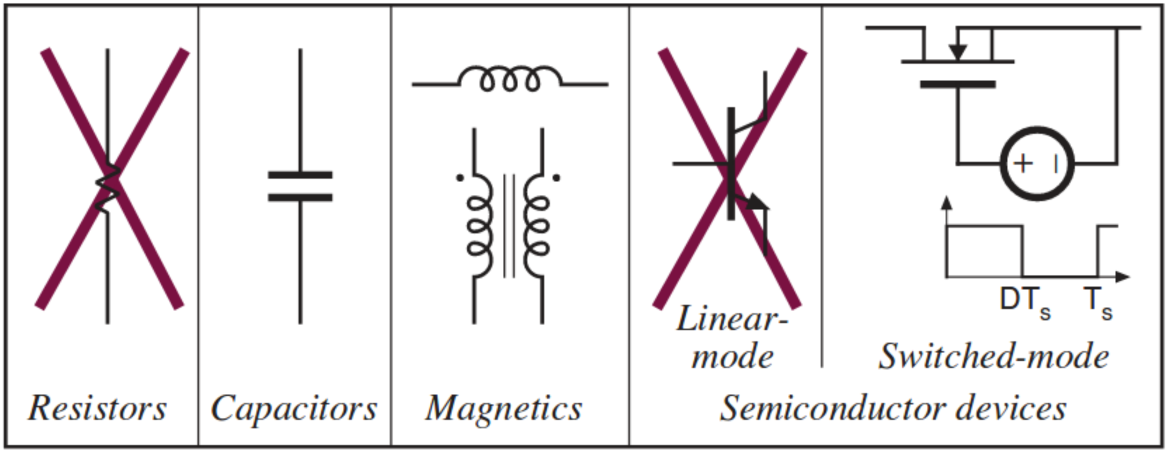
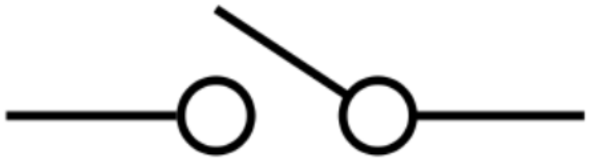
Avoid lossy elements!



Ideal Switch



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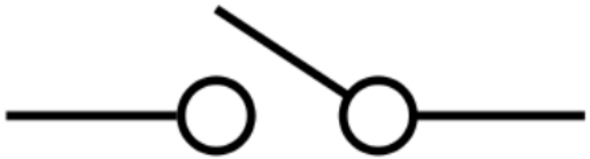

Which factors make a switch ideal?

Ideal Switch

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- No voltage drop in the on-state

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- Zero switching time

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Ideal Switch

- No voltage drop in the on-state
- Zero switching time
- No leakage current in the off-state
- Infinite breakdown voltage and current capacity

What happens if you turn off a inductive load?

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or

What happens if turn-on with a capacitive load?

Practical Switch

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- Conduction losses (voltage drop, leakage current)

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- Conduction losses (voltage drop, leakage current)
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- Limited current and voltage capacity
- Limited dv/dt and di/dt rating

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Inductors behave like current sources

Capacitors behave like voltage sources

Inductors in Steady-State Operation

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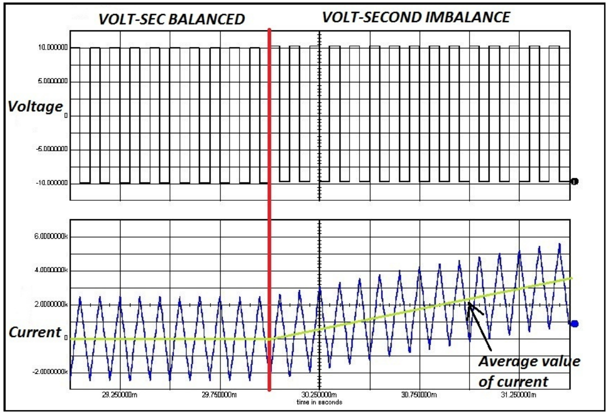
a.k.a. Inductor Volts-Seconds Balance

Average value of inductor voltage is zero in steady-state

(Positive and negative areas of inductor voltage cancel each other)



Capacitors in Steady-State Operation

a.k.a. Capacitor Charge (or Ampere-seconds) Balance

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(Positive and negative areas of capacitor current cancel each other)

Performance Parameters for Waveforms

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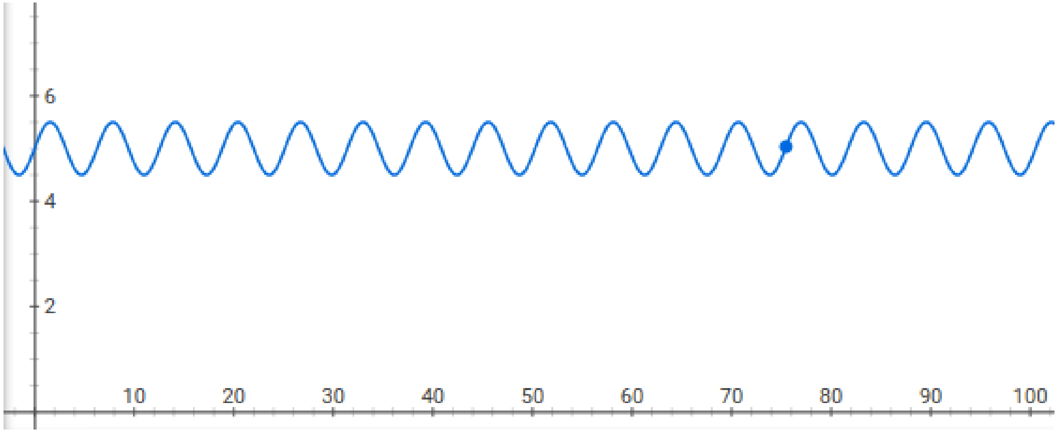
i.e. How do you decide an output is better than another?

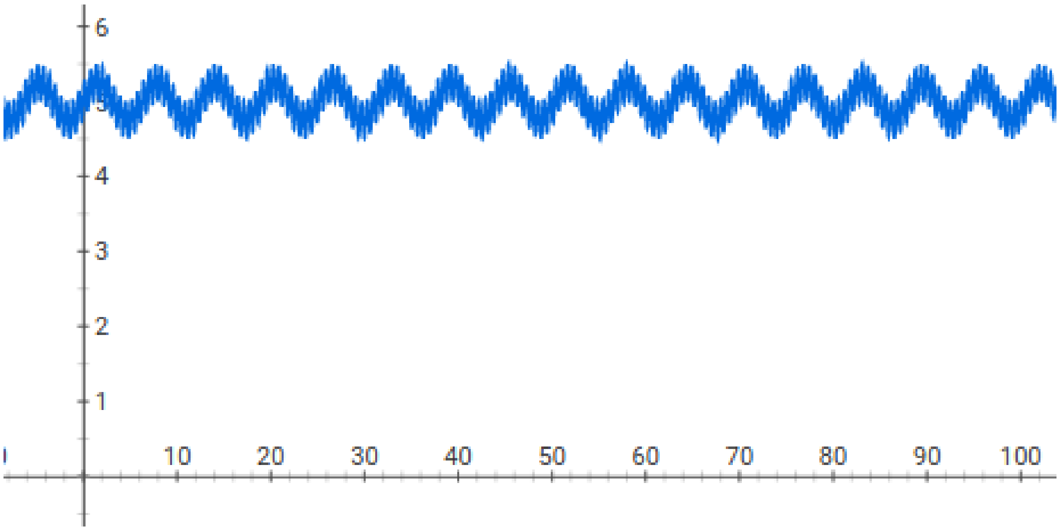
For example, can you tell which one of the DC supply voltage is better?

- 5 + 0.5sin(x)



or

- 5+0.25*sin(x)+0.25*sin(10*x)



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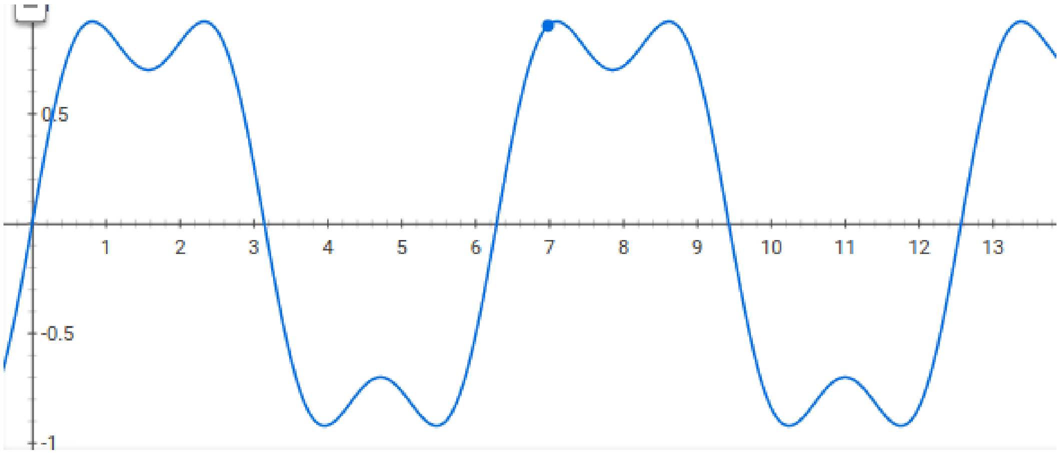
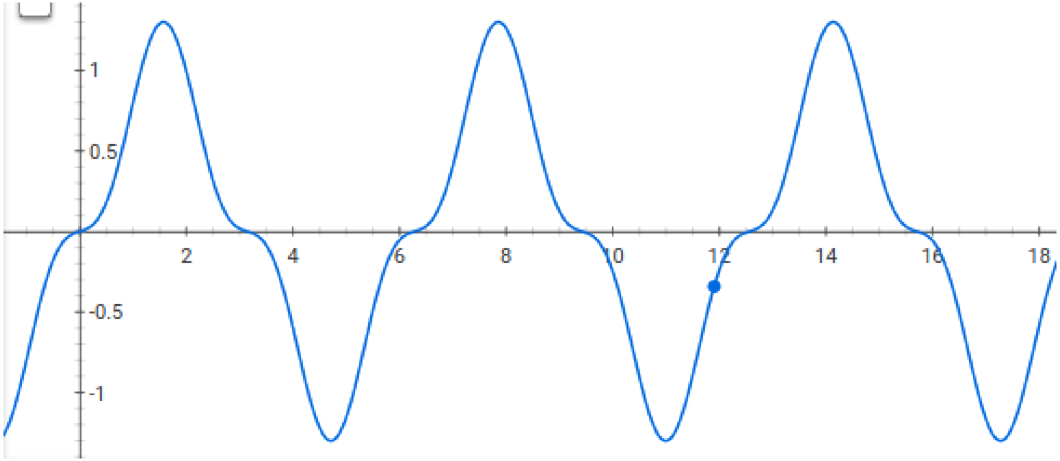


or

- [sin(x) - 0.3sin(3x)]

or

- [sin(x) - 0.3sin(3x)]



RMS

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$$I_{RMS} = \sqrt{\frac{1}{T}\int_0^T i^2(t)dt}$$

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Average power dissipated if connected to $1\ \Omega$ resistor

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What is the RMS of a signal with harmonics?

$$I = I_1 + I_2 + I_3 \ldots$$

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$$I_{RMS} = \sqrt{I_{1_{RMS}}^2 + I_{2_{RMS}}^2 + I_{3_{RMS}}^2 \ldots}$$

Distortion Factor

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Ratio of Fundamental RMS to Total RMS

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$$DF = \frac{I_{1_{RMS}}}{I_{s_{RMS}}}$$

Quick Question: What is the DF for a square wave?

Displacement Power Factor

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Power factor for the fundamental component

i.e. DPF=$cos(\phi)$, where ϕ is the phase difference between the FUNDAMENTAL components of V and I.

drawing

(True) Power Factor

(True) Power Factor

Ratio of Real Power (P) to Apparent Power (S)

$$PF = \frac{P}{S}$$

True Power Factor includes all harmonics, whereas DPF includes only the fundamental component.

(True) Power Factor

For perfect sine wave

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For perfect sine wave

DF = 1 and DPF = PF

(True) Power Factor

For perfect sine wave

DF = 1 and DPF = PF

For distorted waves

(True) Power Factor

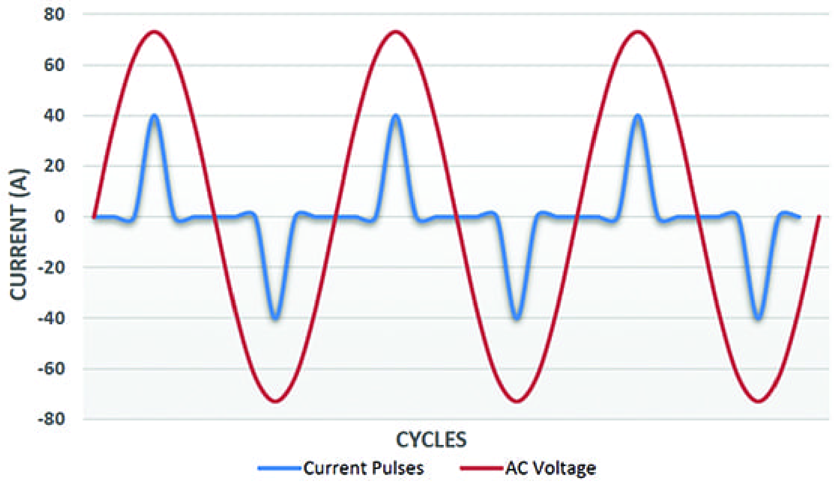
For perfect sine wave

DF = 1 and DPF = PF

For distorted waves

DF<1 and PF<DPF

For this waveform:



displacement power factor (DPF) = 1

but true power factor is < 1

THD

THD (Total Harmonic Distortion)

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Ratio of the RMS of the harmonics (excluding the fundamental) to RMS of the fundamental component

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Ratio of the RMS of the harmonics (excluding the fundamental) to RMS of the fundamental component

$$THD = \frac{\sqrt{\sum_{h=2}^{\infty} I_h^2}}{I_1}$$

i.e. ratio of power in harmonics to power in the fundamental component

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In 2014, it was increased to 8%. Why?

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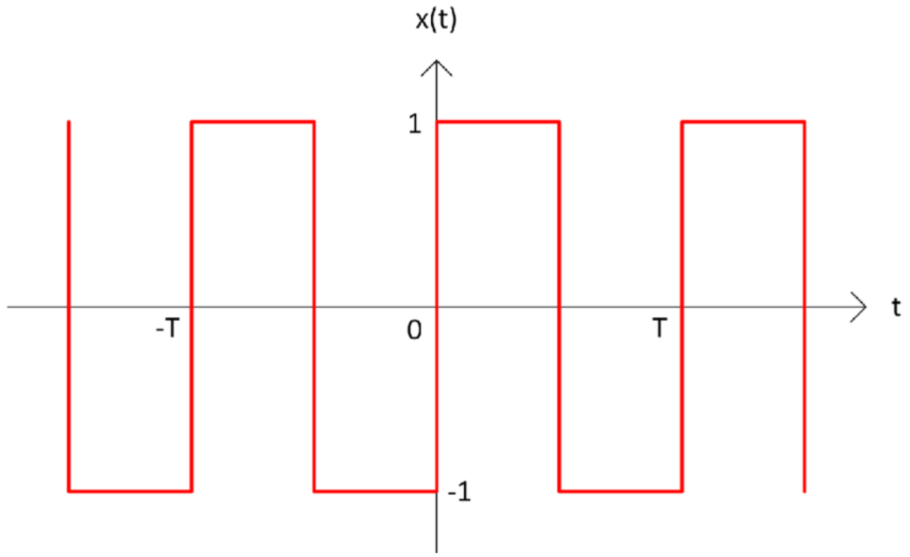
Distortion factor can be expressed in terms of THD

$$DF = \frac{1}{\sqrt{1 + THD^2}}$$

Quick Question: Derive the THD of a square waveform



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