DC-DC Converters

- Applications
- Classifications
- Applications in AC Synthesis
- Basic Concepts in DC Steady State

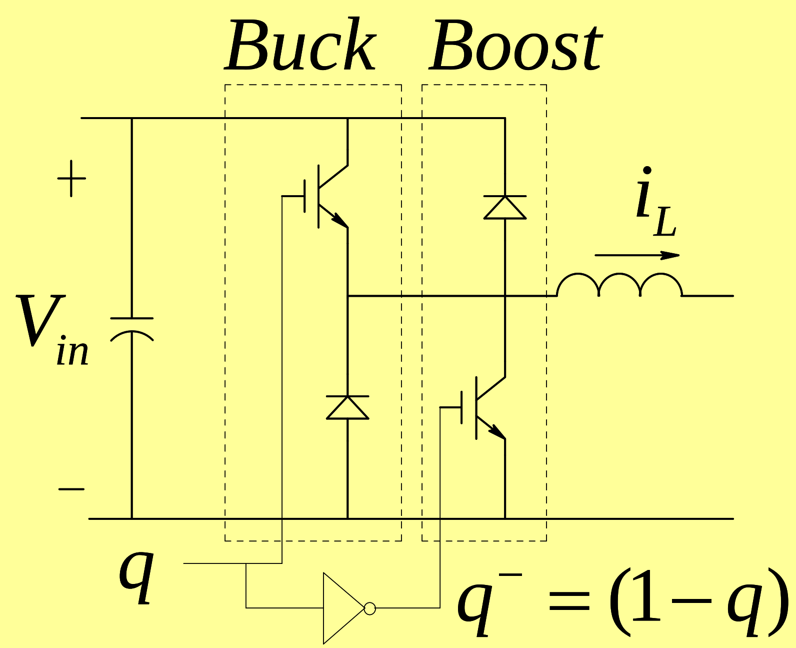
Applications of DC-DC Converters

- In PV Systems
- Switch-mode Regulated DC Power Supplies

Classification of DC-DC Converters

- Non-isolated dc-dc converters
  - Buck (Step-down)
  - Boost (step-up)
  - Buck-Boost (Step-down/up)
- Isolated dc-dc converters
  - Flyback
  - Forward
  - Half- and Full-Bridge

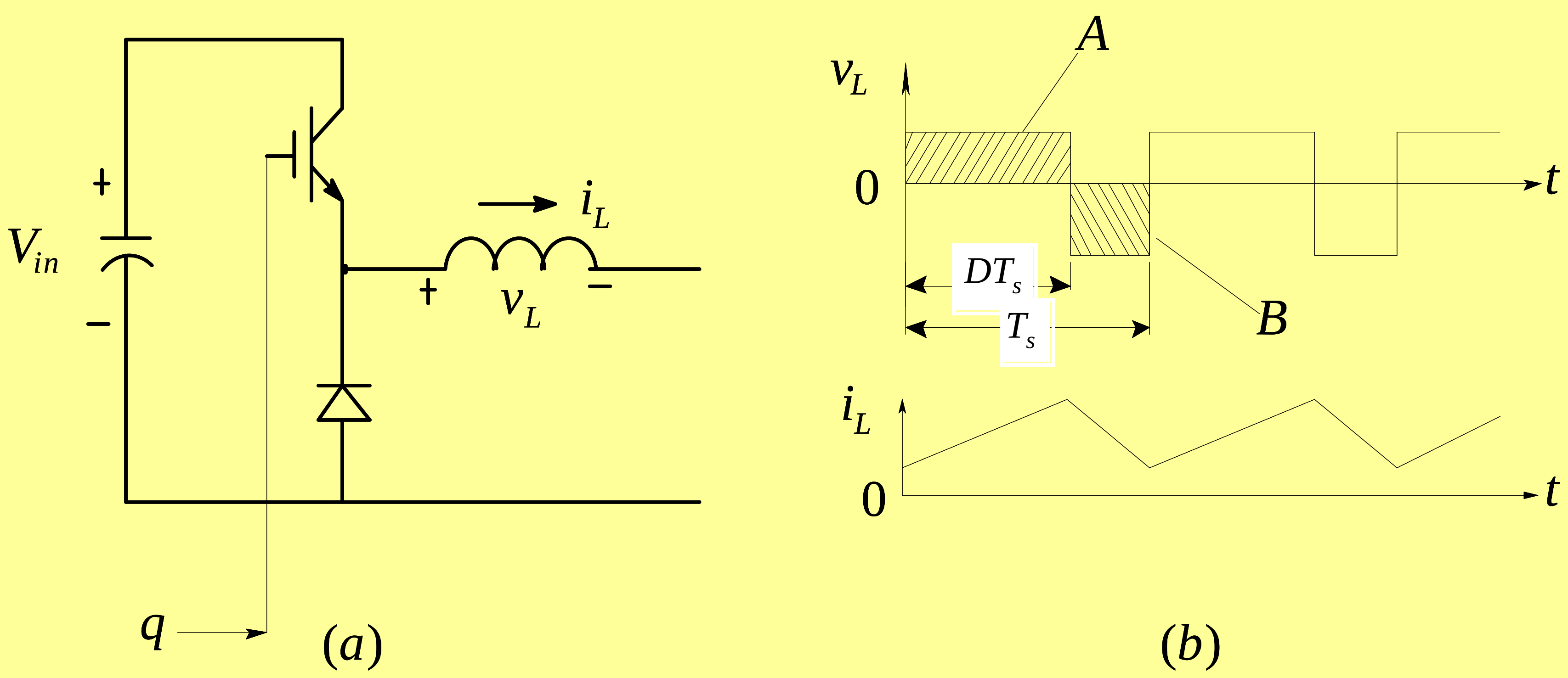
Applications in AC Voltage Synthesis



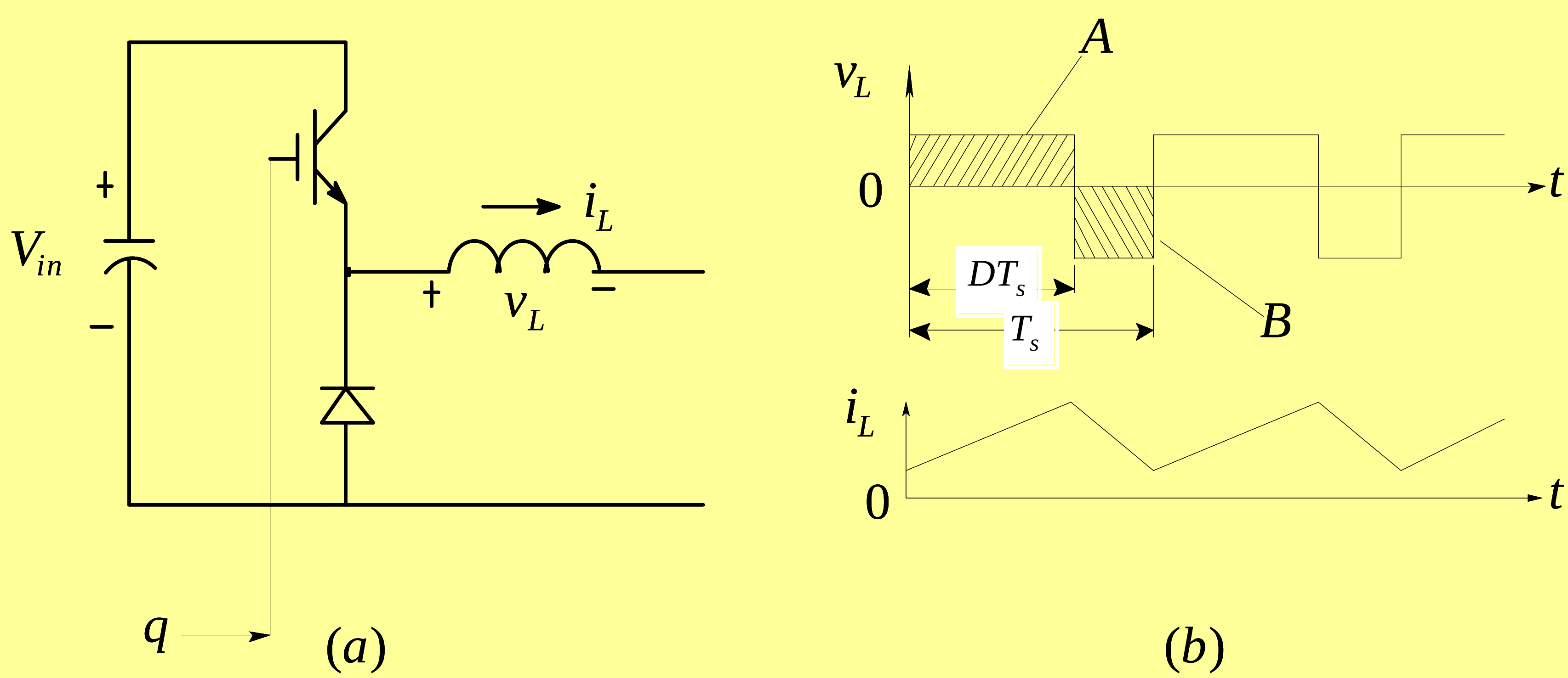
JUSTIFYING SWITCHES AND DIODES AS IDEAL

- Very High Converter Efficiencies are needed
  – Low on-state voltage drop across devices
  – Low switching losses

Switching power-pole as the building block of dc-dc converters



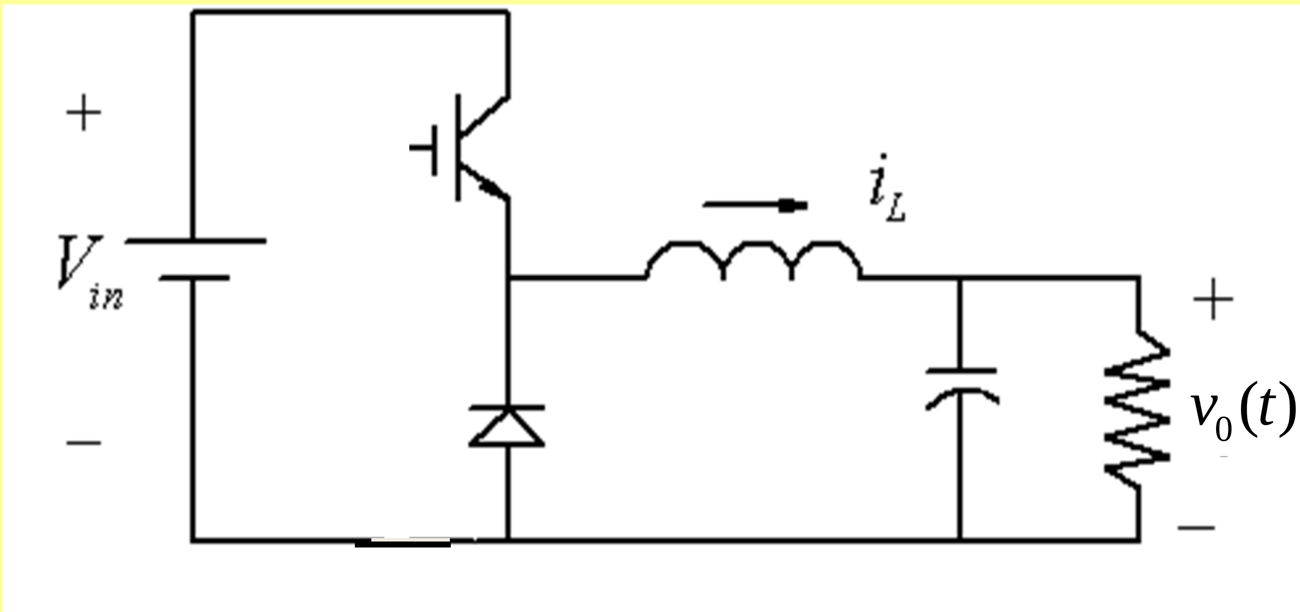
In DC Steady State:



Waveform repeats with the Time-Period T_s:

$$i_L(t) = i_L(t - T_s)$$

In Steady State:



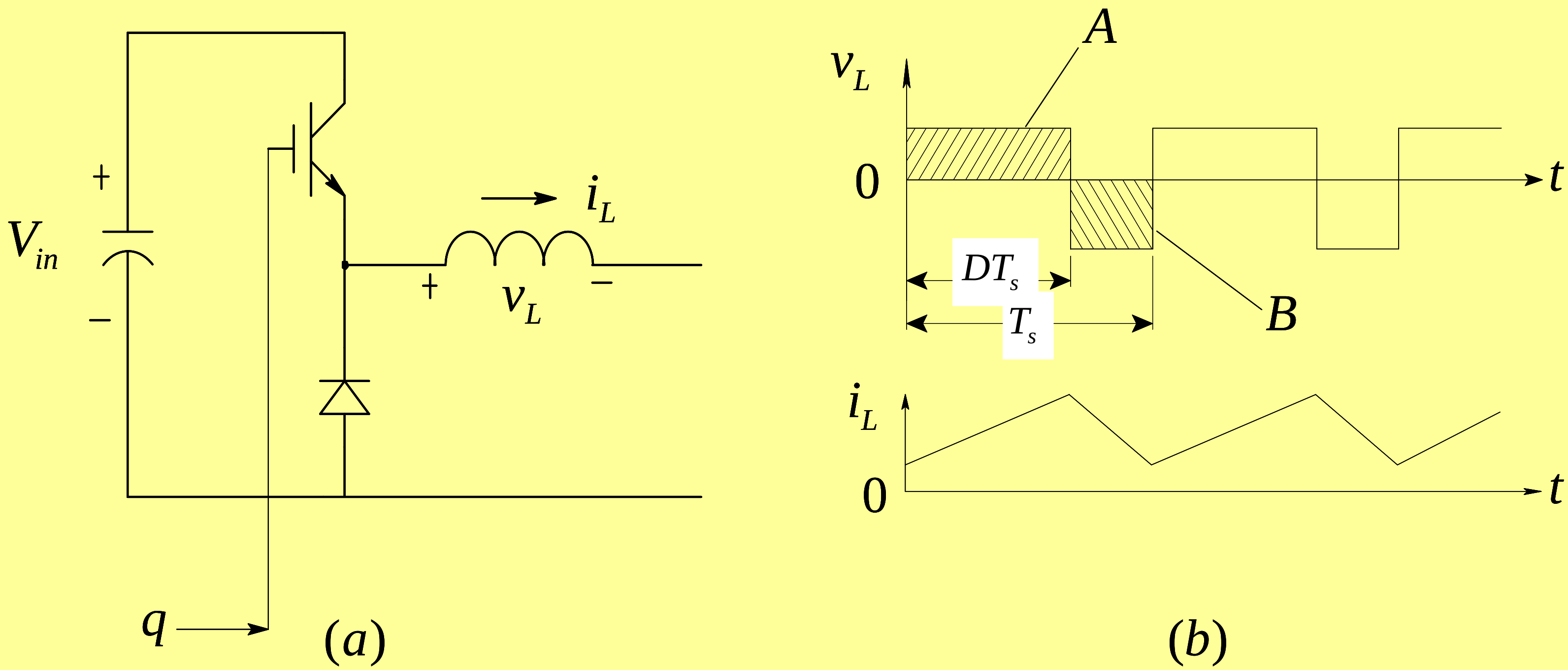
In Steady State, the average voltage across an inductor is zero:

$$v_L = L\frac{di_L}{dt}$$

$$\int_{i_L(0)}^{i_L(T_s)} di_L = i_L(T_s) - i_L(0) = 0$$

$$\frac{1}{L}\int_0^{T_s} v_L \cdot dt = 0$$

$$V_L = \frac{1}{T_s}\int_0^{T_s} v_L \cdot dt = 0$$



$$V_L = \frac{1}{T_s}\left(\underbrace{\int_0^{DT_s} v_L \cdot d\tau}_{\text{area } A} + \underbrace{\int_{DT_s}^{T_s} v_L \cdot d\tau}_{\text{area } B} \right) = 0$$

In Steady State, the average current through a capacitor is zero:

$$i_C = C\frac{dv_C}{dt}$$

$$\int_{v_C(0)}^{v_C(T_s)} dv_C = v_C(T_s) - v_C(0) = 0$$

$$\frac{1}{C}\int_0^{T_s} i_C \cdot dt = 0$$

$$I_C = \frac{1}{T_s}\int_0^{T_s} i_C \cdot dt = 0$$

In Steady State, KCL applies:

Instantaneous: $$\sum_k i_k = 0$$

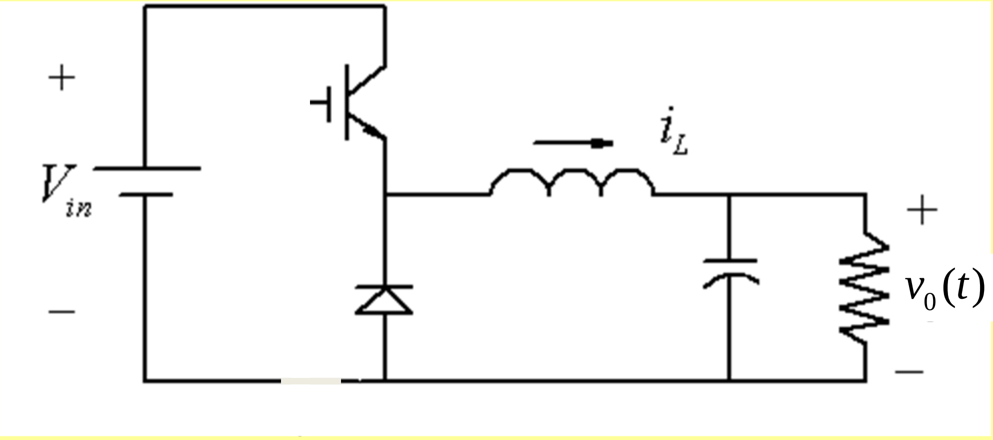
Average: $$\sum_k I_k = 0$$

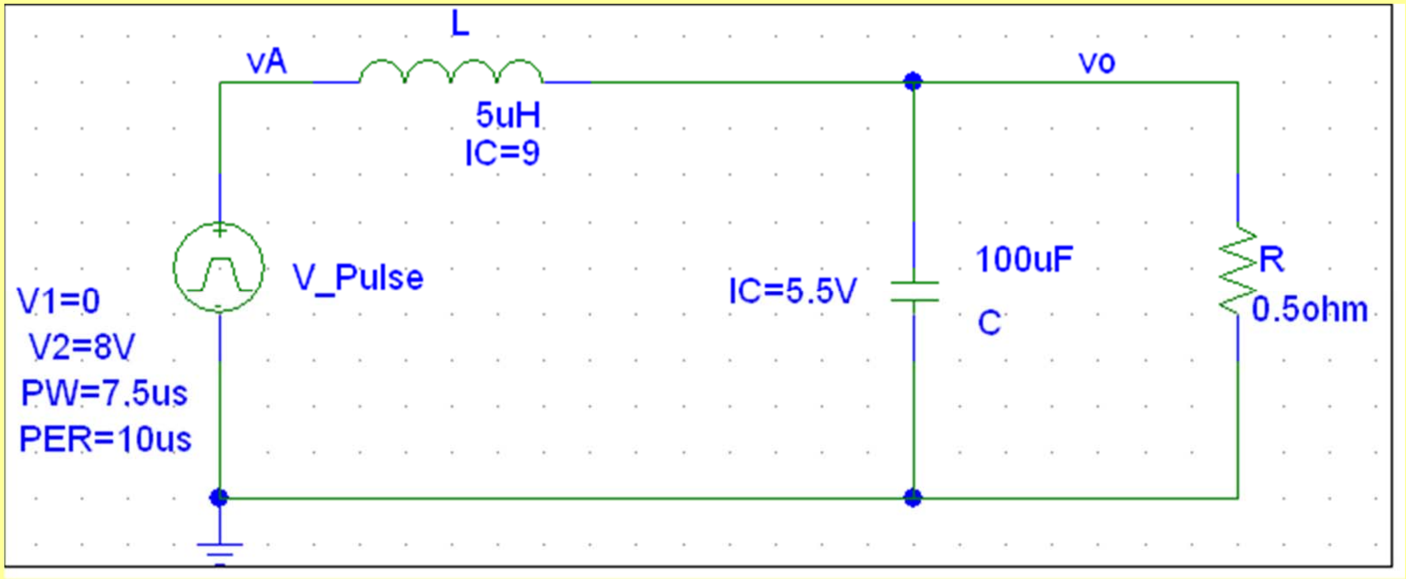
In Steady State, KVL applies:

Instantaneous: $$\sum_k v_k = 0$$

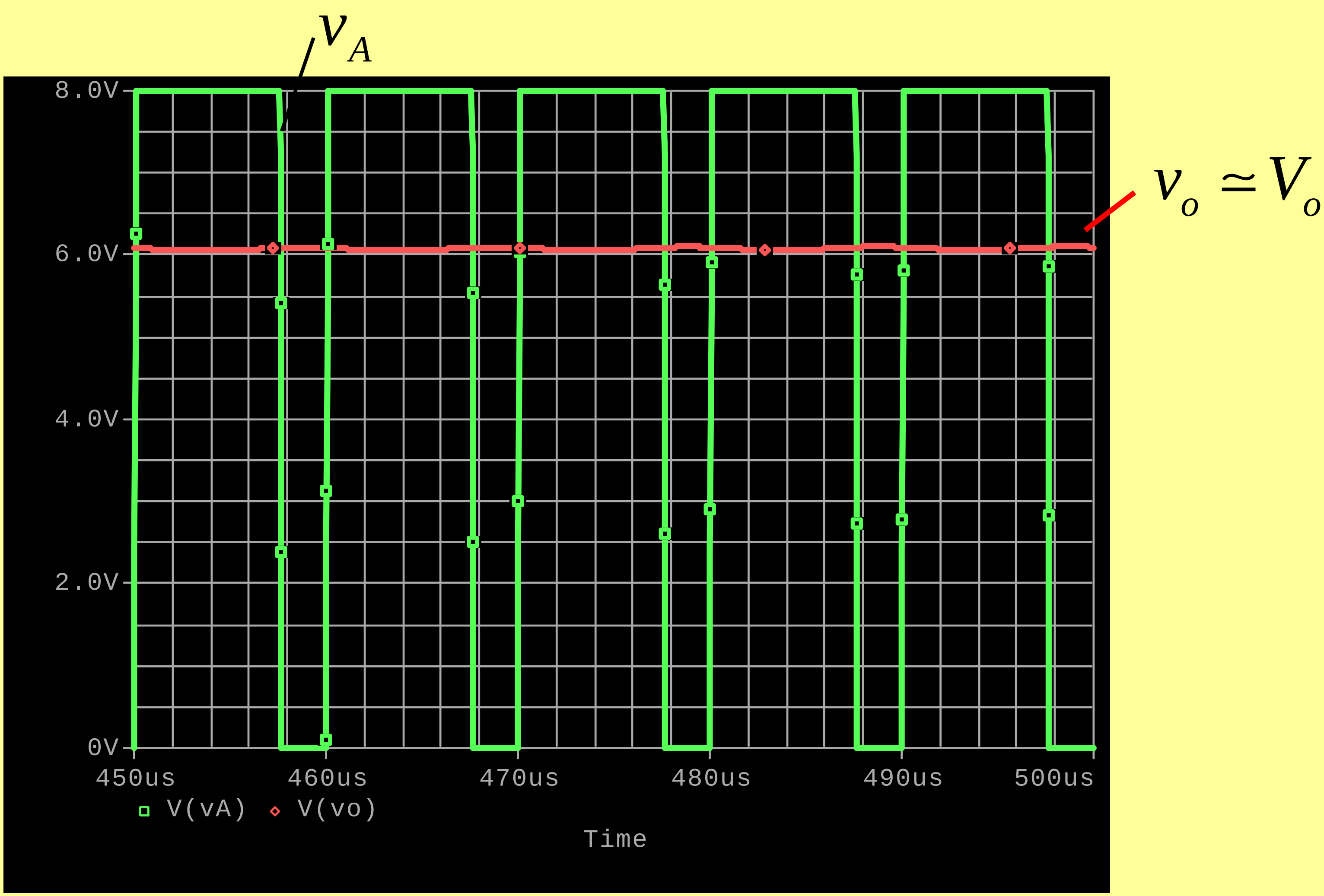
Average: $$\sum_k V_k = 0$$

Simulations using PSpice





Simulation Results



Fourier Analysis

FOURIER COMPONENTS OF TRANSIENT RESPONSE V(vA)

DC COMPONENT = 6.080000E+00

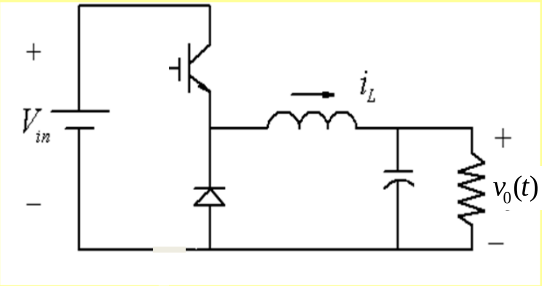
HARMONIC NO	FREQUENCY (HZ)	FOURIER COMPONENT	NORMALIZED COMPONENT	PHASE (DEG)	NORMALIZED PHASE (DEG)
1	1.000E+05	3.487E+00	1.000E+00	-4.860E+01	0.000E+00
2	2.000E+05	2.543E+00	7.293E-01	-7.200E+00	9.000E+01
3	3.000E+05	1.310E+00	3.757E-01	3.420E+01	1.800E+02
4	4.000E+05	1.600E-01	4.589E-02	7.560E+01	2.700E+02
5	5.000E+05	6.012E-01	1.724E-01	-6.300E+01	1.800E+02
6	6.000E+05	8.387E-01	2.405E-01	-2.160E+01	2.700E+02
7	7.000E+05	6.193E-01	1.776E-01	1.980E+01	3.600E+02
8	8.000E+05	1.600E-01	4.589E-02	6.120E+01	4.500E+02
9	9.000E+05	2.763E-01	7.923E-02	-7.740E+01	3.600E+02
10	1.000E+06	4.924E-01	1.412E-01	-3.600E+01	4.500E+02

FOURIER COMPONENTS OF TRANSIENT RESPONSE V(vo)

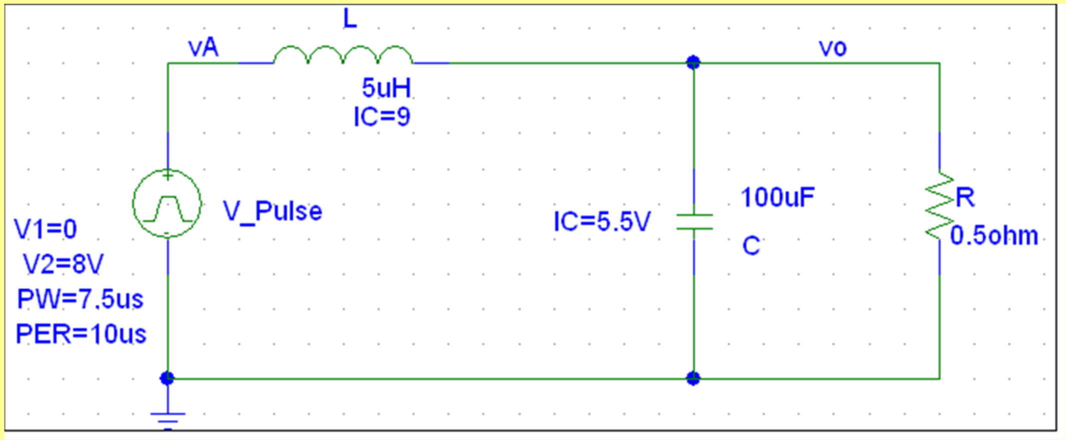
DC COMPONENT = 6.083044E+00

HARMONIC NO	FREQUENCY (HZ)	FOURIER COMPONENT	NORMALIZED COMPONENT	PHASE (DEG)	NORMALIZED PHASE (DEG)
1	1.000E+05	1.795E-02	1.000E+00	1.343E+02	0.000E+00
2	2.000E+05	3.400E-03	1.894E-01	1.746E+02	-9.403E+01
3	3.000E+05	8.465E-04	4.715E-02	-1.489E+02	-5.518E+02
4	4.000E+05	1.226E-04	6.826E-03	-1.492E+02	-6.865E+02
5	5.000E+05	1.602E-04	8.922E-03	1.447E+02	-5.269E+02
6	6.000E+05	1.718E-04	9.570E-03	1.707E+02	-6.352E+02
7	7.000E+05	1.158E-04	6.448E-03	-1.626E+02	-1.103E+03
8	8.000E+05	5.644E-05	3.143E-03	-1.560E+02	-1.231E+03
9	9.000E+05	4.483E-05	2.497E-03	1.751E+02	-1.034E+03
10	1.000E+06	5.570E-05	3.102E-03	1.789E+02	-1.164E+03

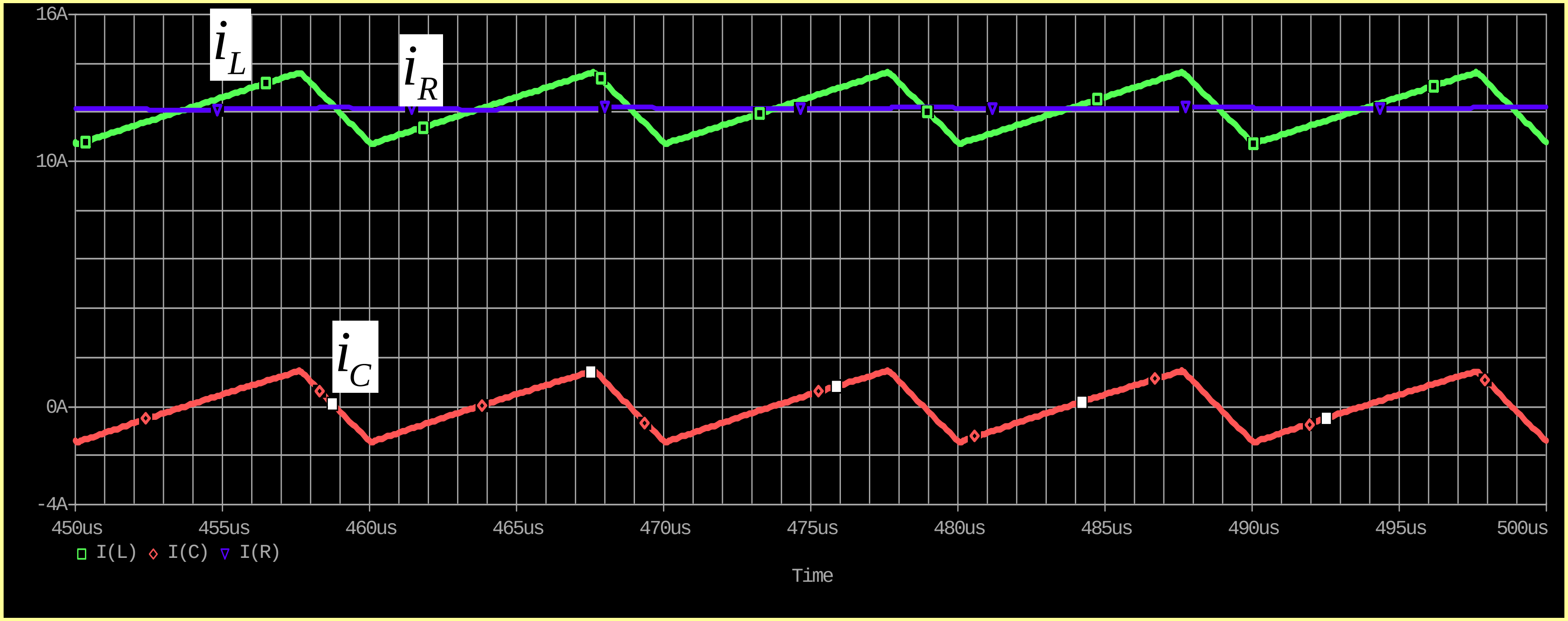
Currents



V_{in}
i_L
$v_0(t)$

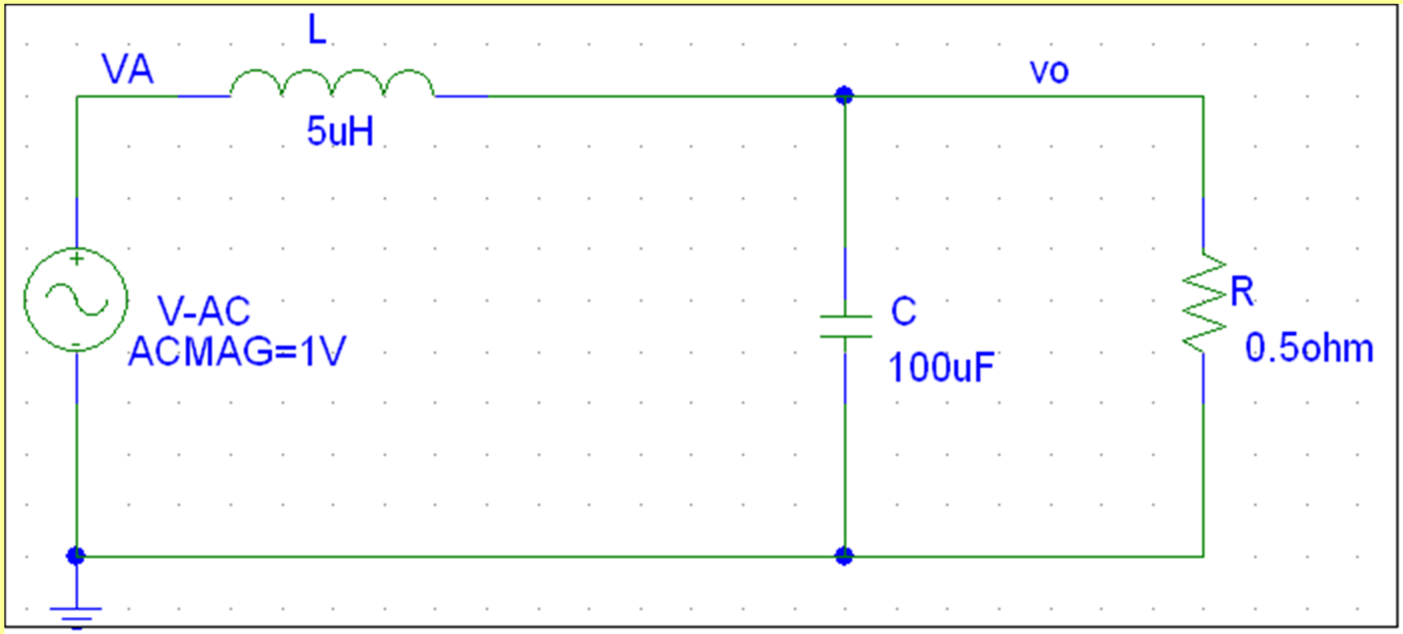


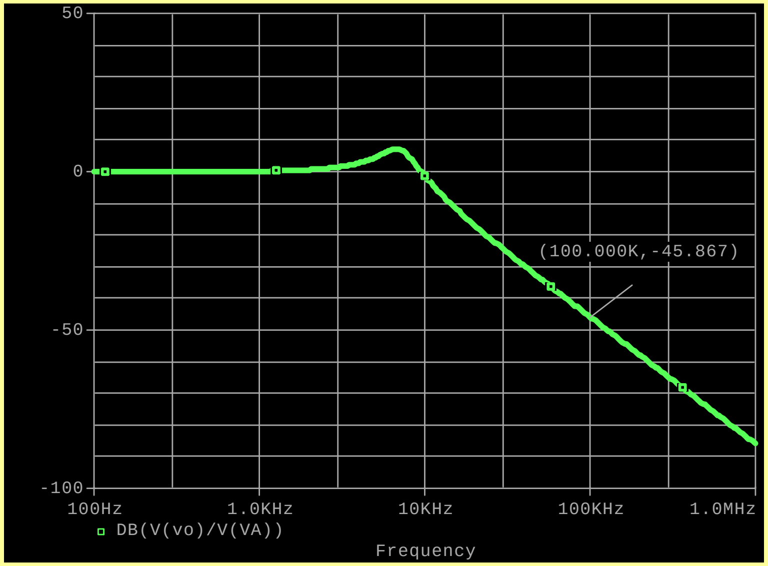
L
vA
5uH
IC=9
vo
V_Pulse
V1=0
V2=8V
PW=7.5us
PER=10us
IC=5.5V
100uF
C
R
0.5ohm



16A
10A
0A
-4A
i_L
i_R
i_C
450us
455us
460us
465us
470us
475us
480us
485us
490us
495us
500us
I(L) I(C) I(R)
Time

Frequency Analysis





Summary

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  - Basic Concepts in DC Steady State