Teaching of Switch-Mode Power Electronics Using A Building-Block Approach, Assisted by PSpice™ Modeling [1, 2]

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Please click on the Audio button, making sure that speakers are turned on.

Audio

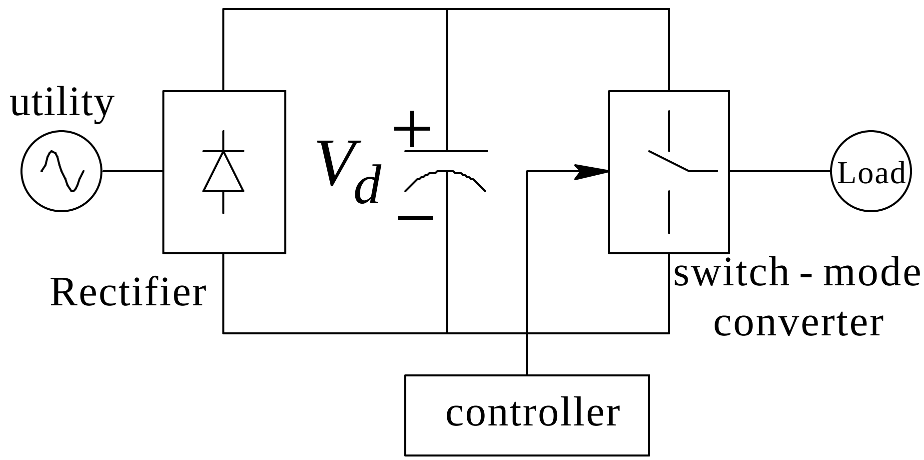
References

1. NSF-Sponsored Faculty Workshop on *Teaching of Power Electronics and Electric Drives*, University of Minnesota, to be held in Tempe, Arizona January 3-6, 2002. For details, contact mohan@ece.umn.edu.

2. NSF-Sponsored Faculty Workshops on *Teaching of Power Electronics and Electric Drives*, held at the University of Minnesota, 1991, 1994, 1997 and 1998.

Power Processing Unit (PPU) [3]

- ❑ Efficient conversion of power from line frequency AC to appropriate form required by the load



- ❑ Rectifier: Line frequency AC to DC
- ❑ Switch-Mode Converter: DC to form required by the Load

Benefits of Building-Block Approach [4, 5]

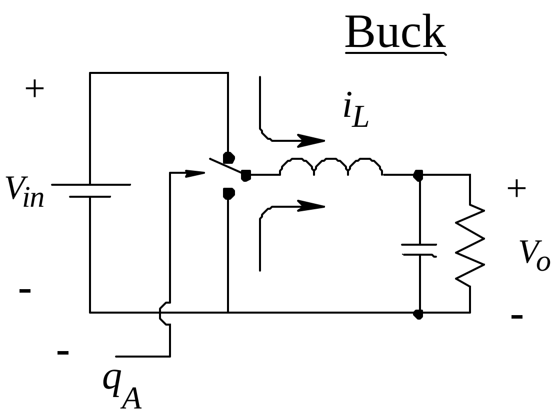
- For Practicing Engineers
  - Review material very quickly
  - Learn new topics in a very short time
- For a First Course in Power Electronics
  - Consistent Systematic Analysis of all converter topologies
  - Clearly shows Switch-Mode Synthesis using PWM
  - Extremely Simple Average Model Speeds up Simulations of Large Disturbances by a factor of 100 or more
  - Same Average Model Allows Small-Signal Response (Bode Plots) to be obtained using PSpice™ in CCM and DCM Modes for Feedback Controller Designs
  - Allows practical topics to be covered in a single-semester course

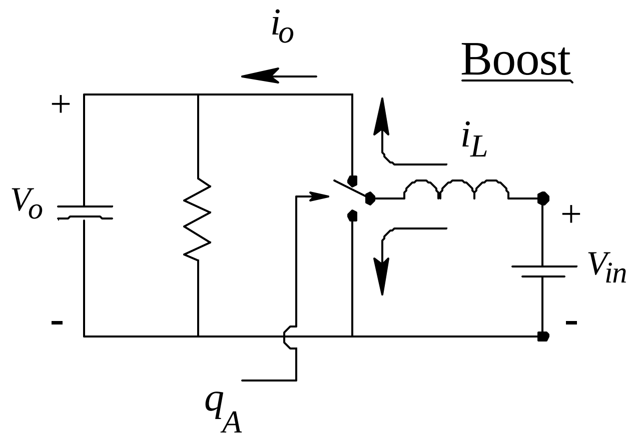
References

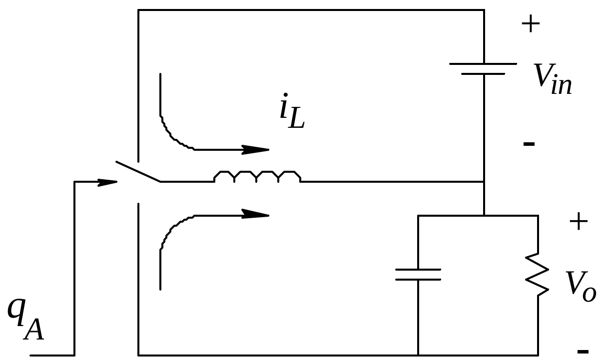
4. N. Mohan, Tutorials on *A Building-Block Approach to Switch-Mode Power Electronics* at IEEE-APEC, IEEE-PESC and PCIM conferences.

5. N. Mohan, *Learn a True Building-Block Approach to Power Electronics and Using this Unifying Analysis (Assisted by PSpice™ Modeling) to Design Feedback Controllers in Switch-Mode dc Power Supplies, Power-Factor-Correction Circuits and Motor Drives*, 4-1/2 hour video course, http://www.mnpere.com.

Single-Quadrant Converters for Switch-Mode DC Power Supplies



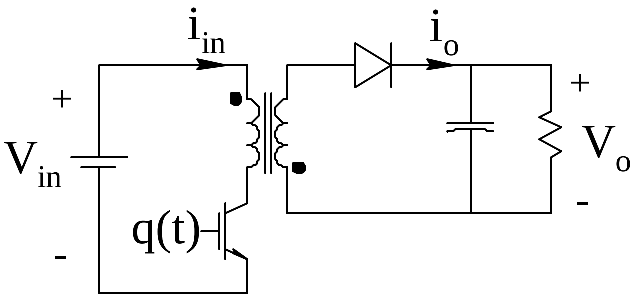




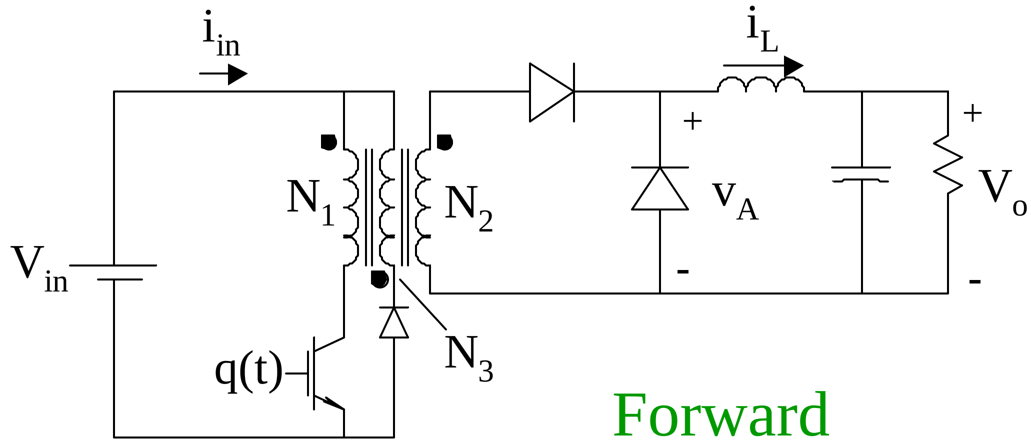
Buck/Boost

Click here for Transformer-Isolated Topologies

Single-Quadrant Transformer-Isolated DC-DC Topologies

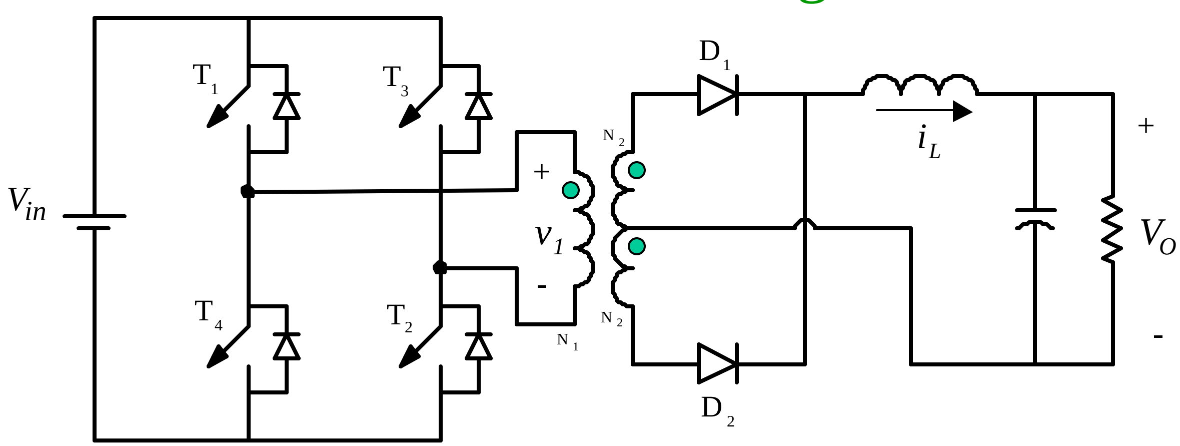


Flyback



Forward

Full-Bridge



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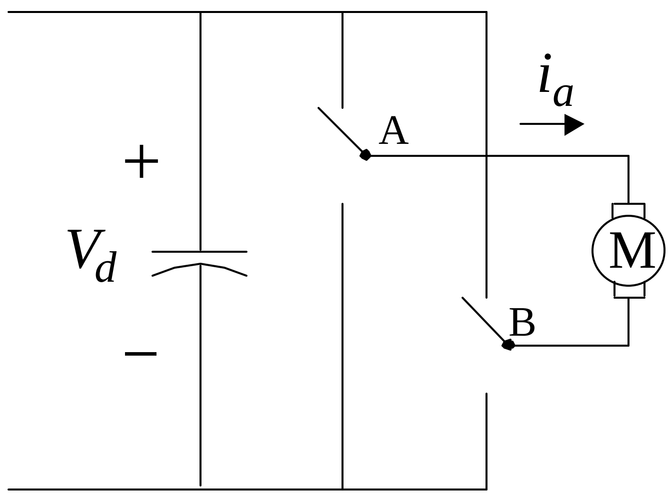
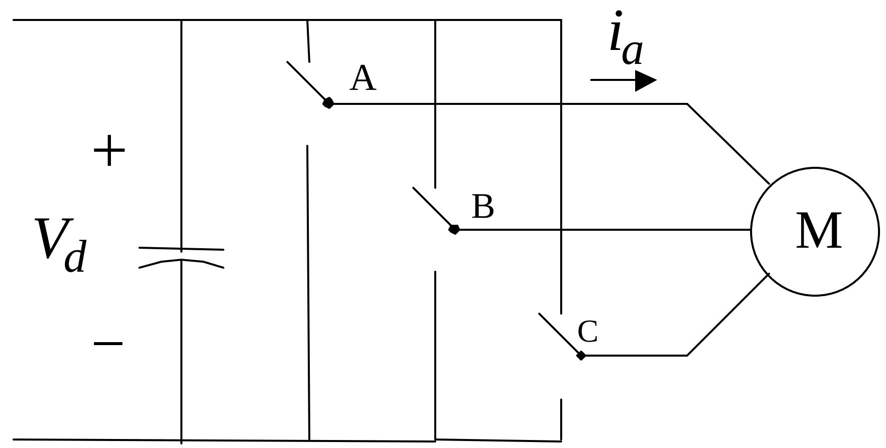
Four-Quadrant Converters for dc- and ac-motor drives [6]



For DC Drives

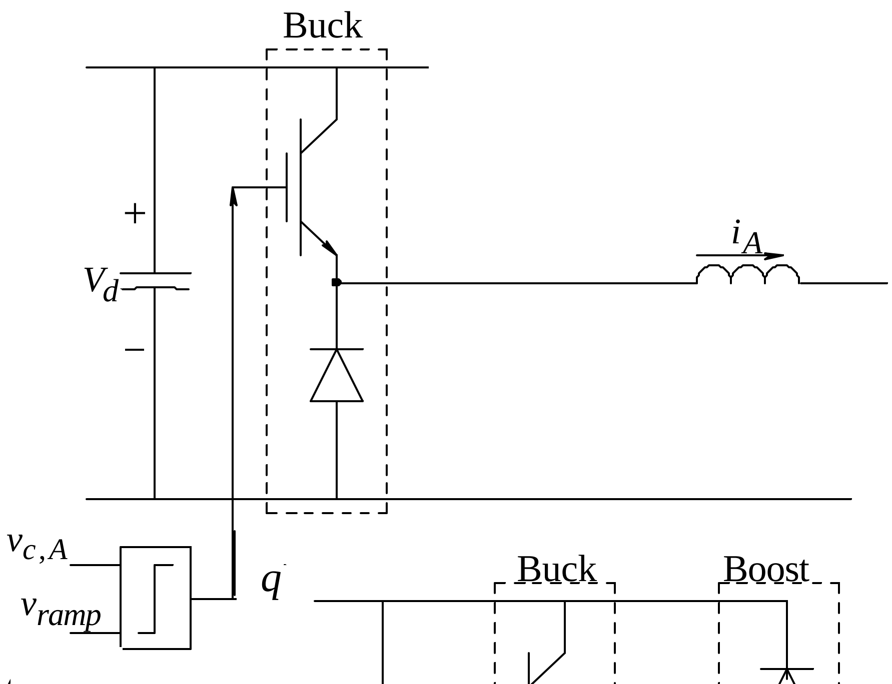


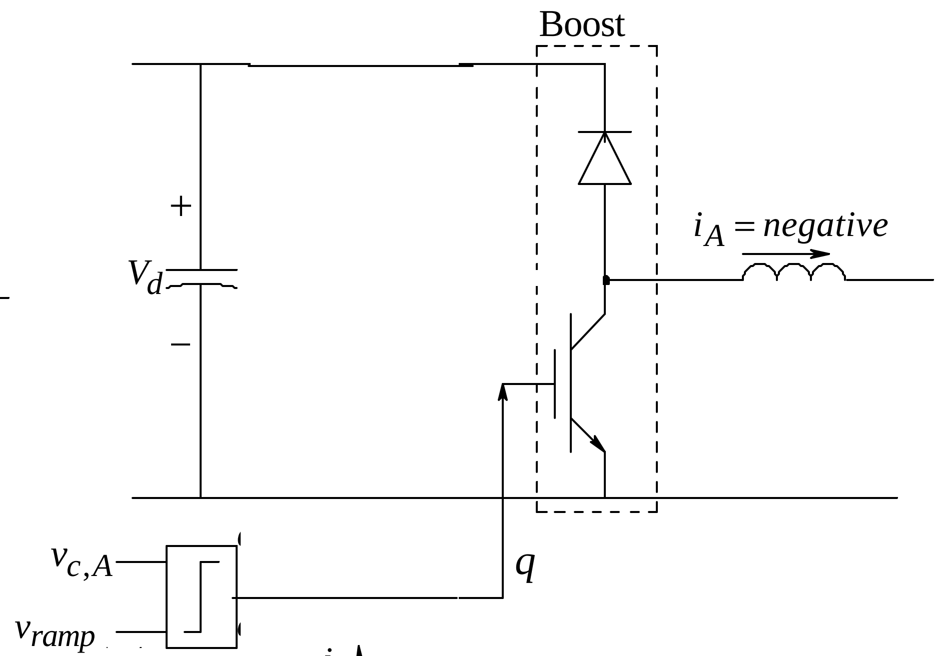
For AC Drives

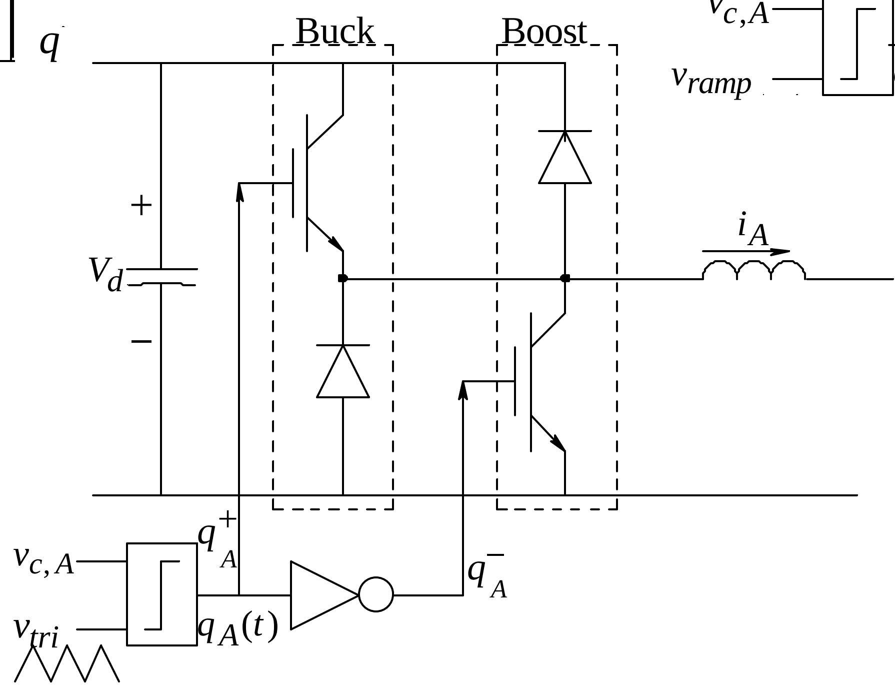
Reference

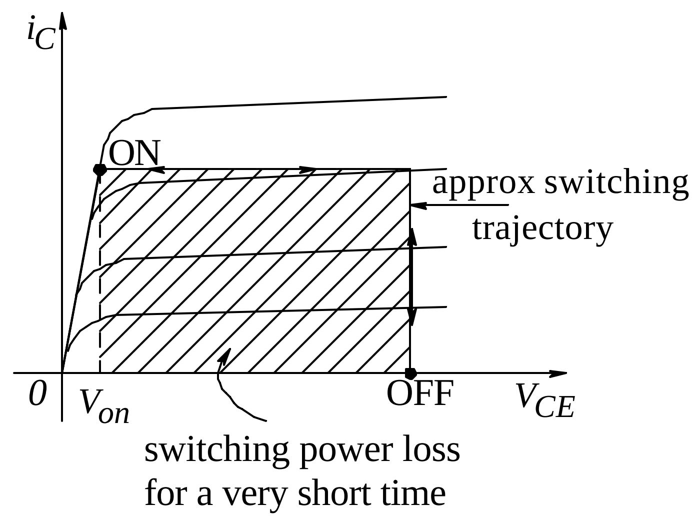
6. N. Mohan, Electric Drives: An Integrative Approach, year 2001 edition, http://www.mnpere.com. A review of this book appears in the IEEE Industrial Electronics Newsletter, Vol. 47, No. 3, September 2000, http://sant.bradley.edu/ienews/00_3/edrives.html.

Implementation of a Bi-Positional Switch









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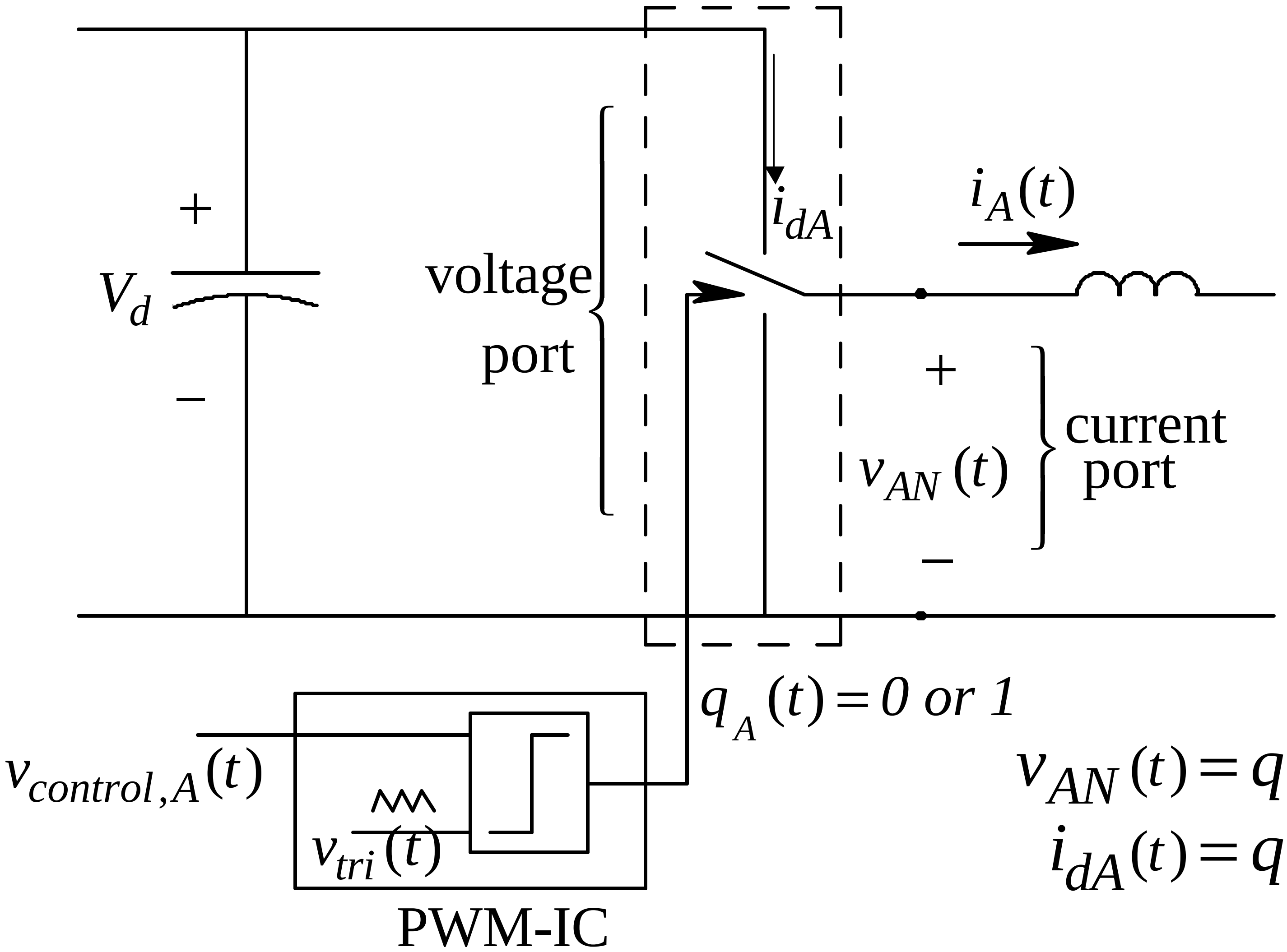
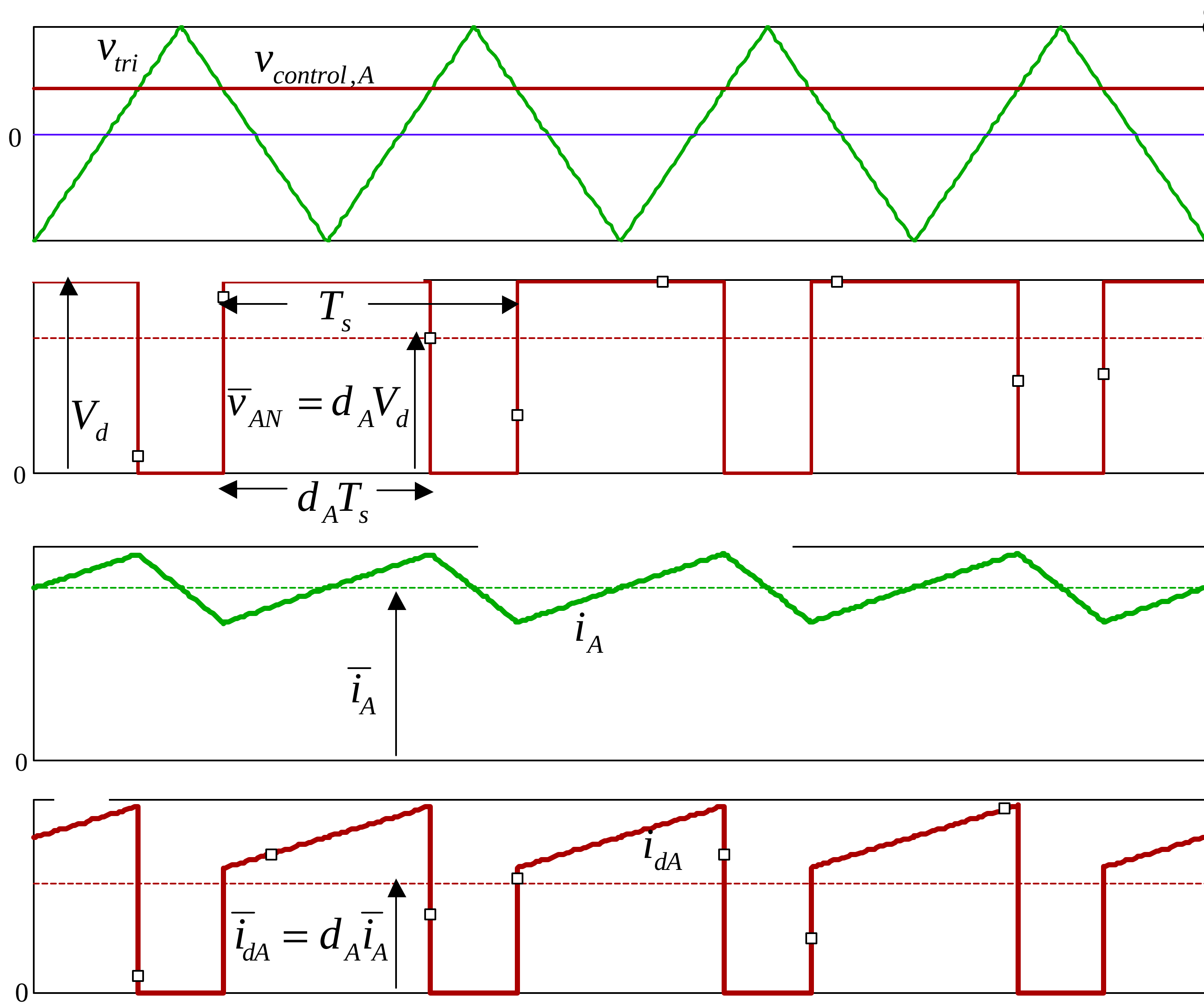
❑ Pole as a Building Block: Synthesis by PWM



$$v_{AN}(t) = q_A(t) \cdot V_d$$

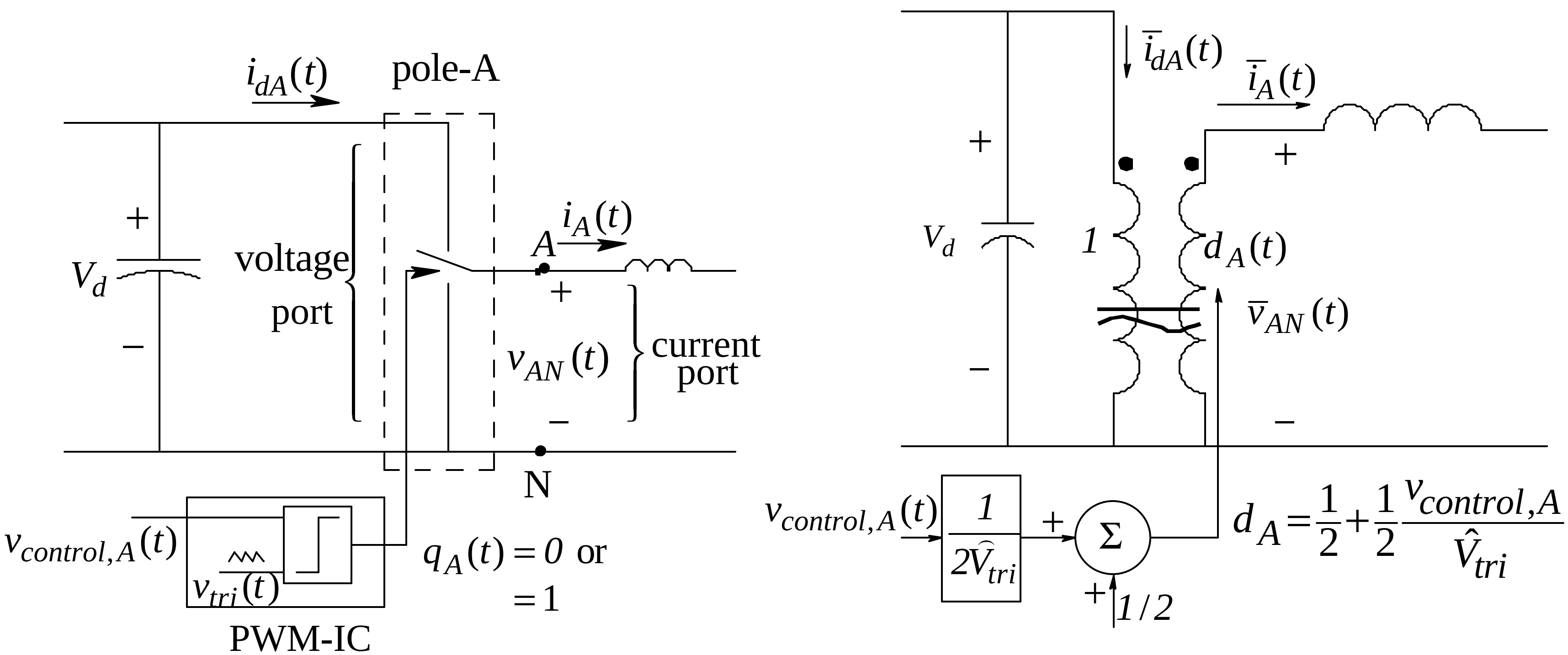
$$i_{dA}(t) = q_A(t) \cdot i_A(t)$$

Synthesis by PWM



$$d_A = \frac{1}{2} + \frac{1}{2}\frac{v_{control,A}}{\hat{V}_{tri}} \qquad \overline{v}_{AN}(t) = d_A(t) \cdot V_d \qquad \overline{i}_{dA}(t) = d_A(t) \cdot \overline{i}_A(t)$$

Average Representation of a Pole as An Ideal Transformer



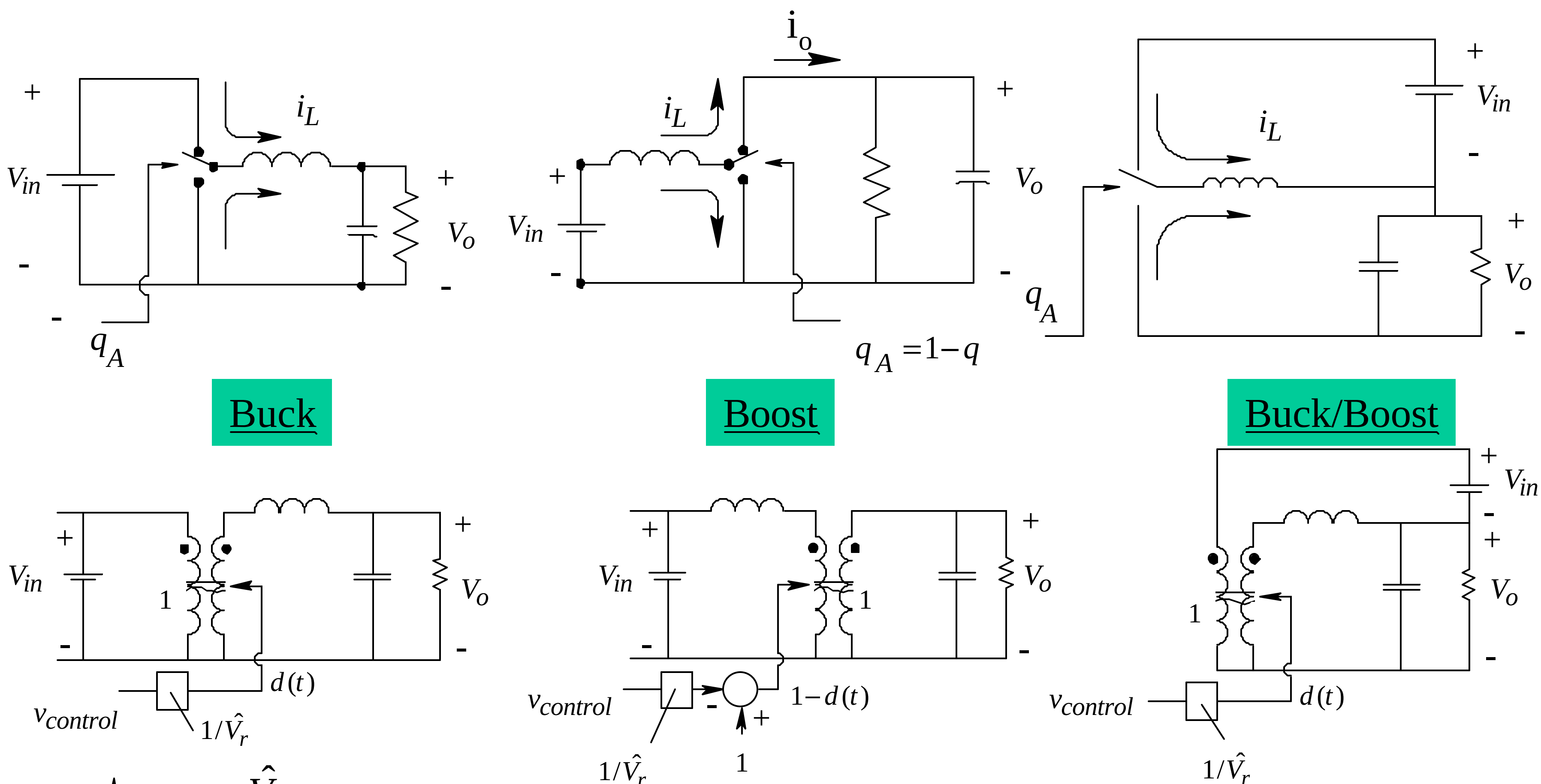
$$v_{AN}(t) = q_A(t) \cdot V_d$$

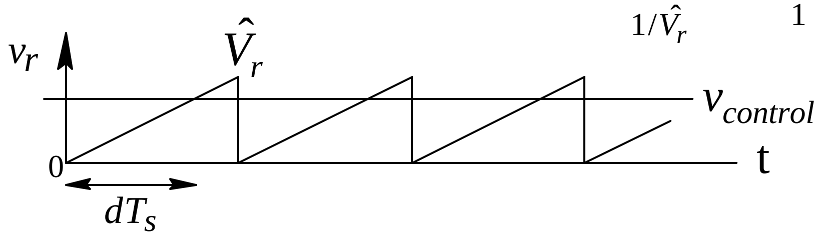
$$i_{dA}(t) = q_A(t) \cdot i_A(t)$$

$$\bar{v}_{AN}(t) = d_A(t) \cdot V_d$$

$$\bar{i}_{dA}(t) = d_A(t) \cdot \bar{i}_A(t)$$

Average Representation of 1-Quadrant Converters

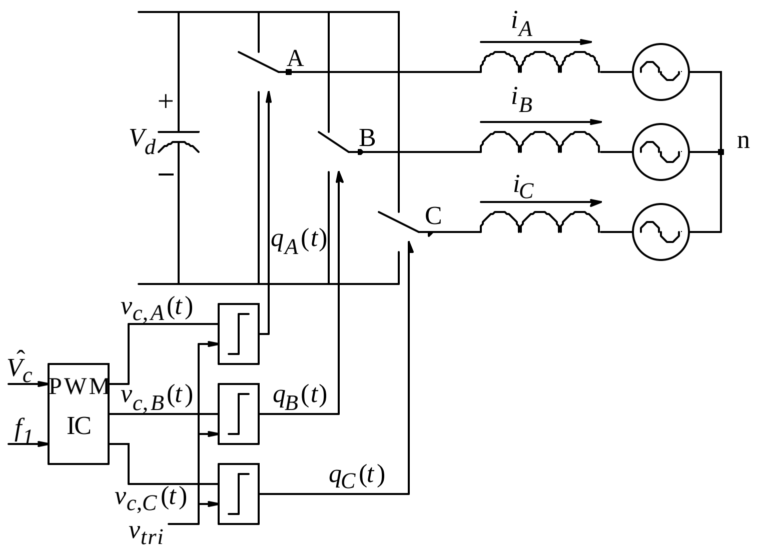




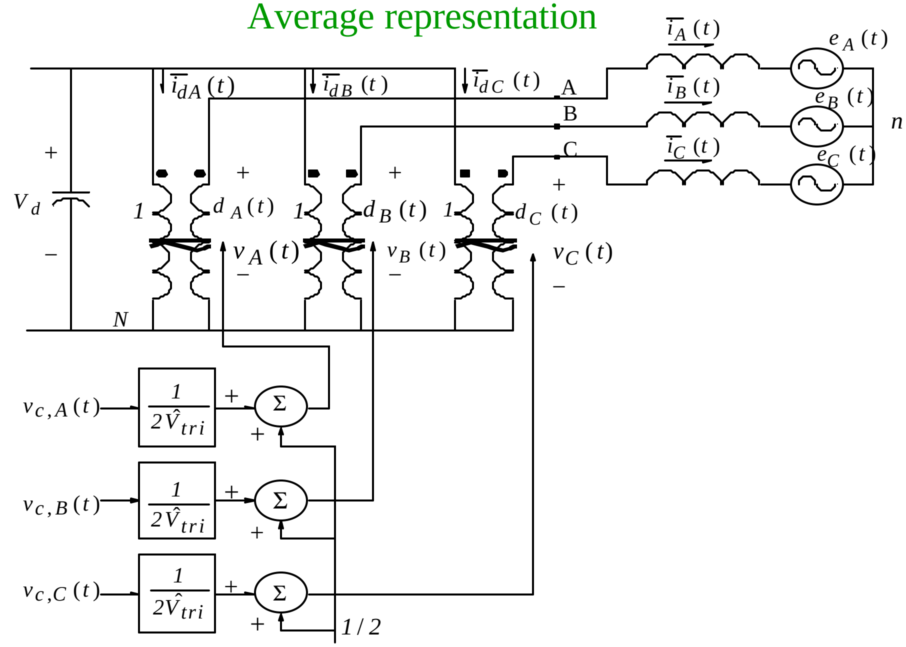
$$d(t) = \frac{v_{control}}{\hat{V}_r}$$

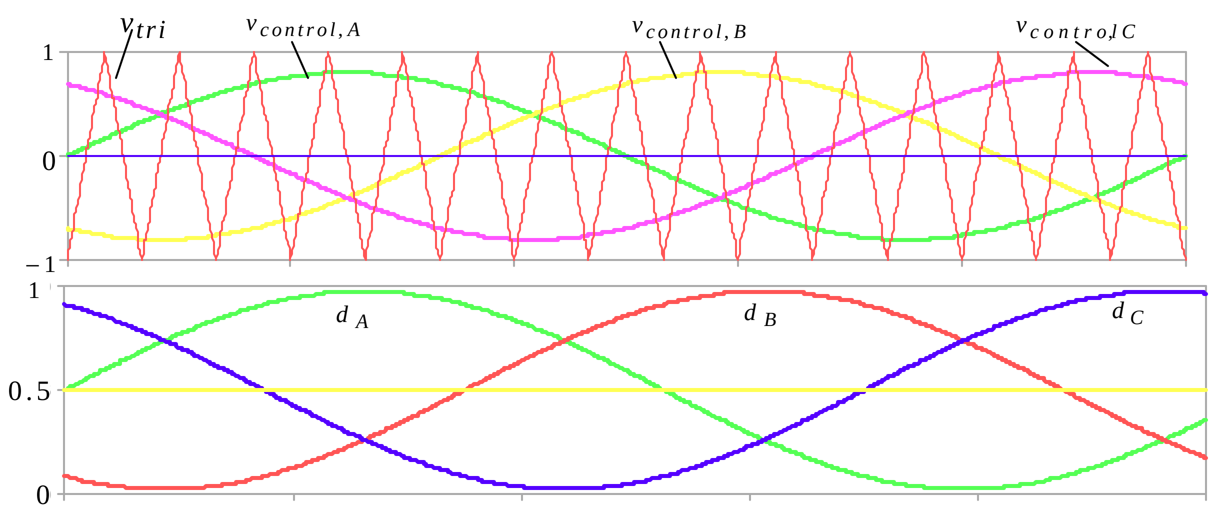
Application of Building Block – Three Phase Inverter [6]

Switching Converter



Average representation





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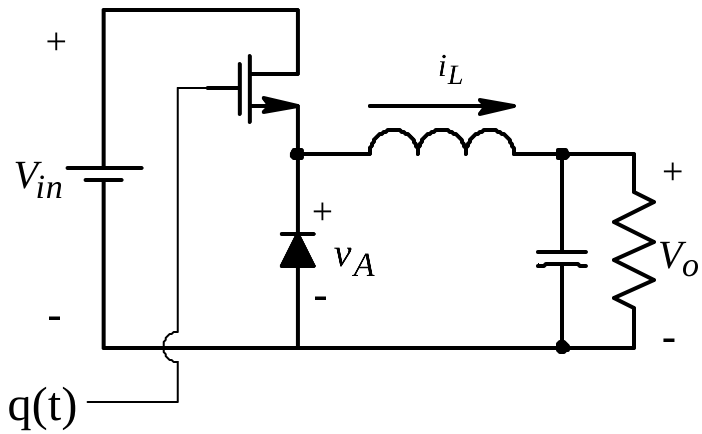
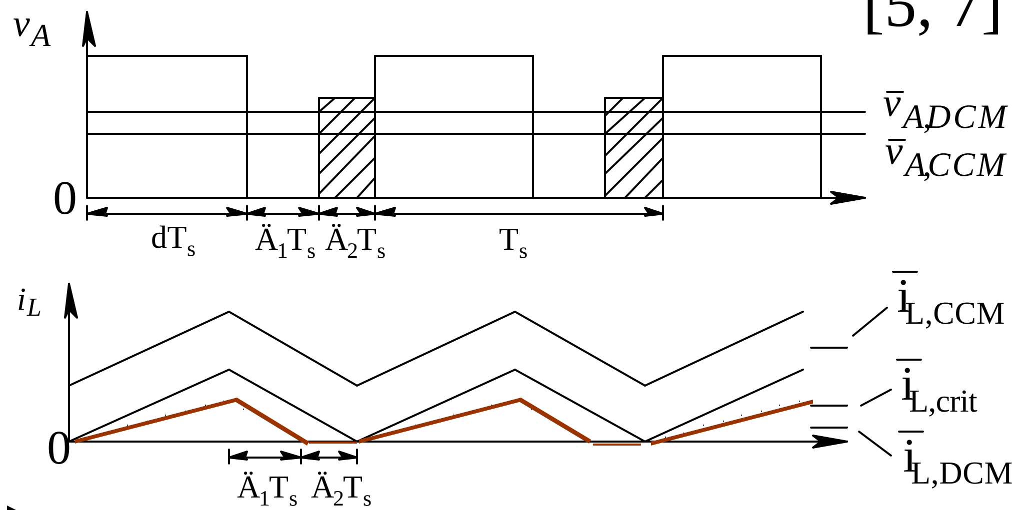
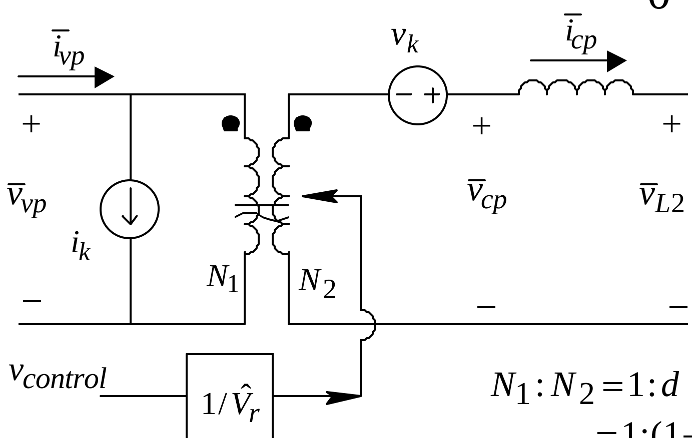
Discontinuous-Conduction Mode in DC-DC Converters

[5, 7]







$N_1 : N_2 = 1 : d$ Buck, Buck/Boost

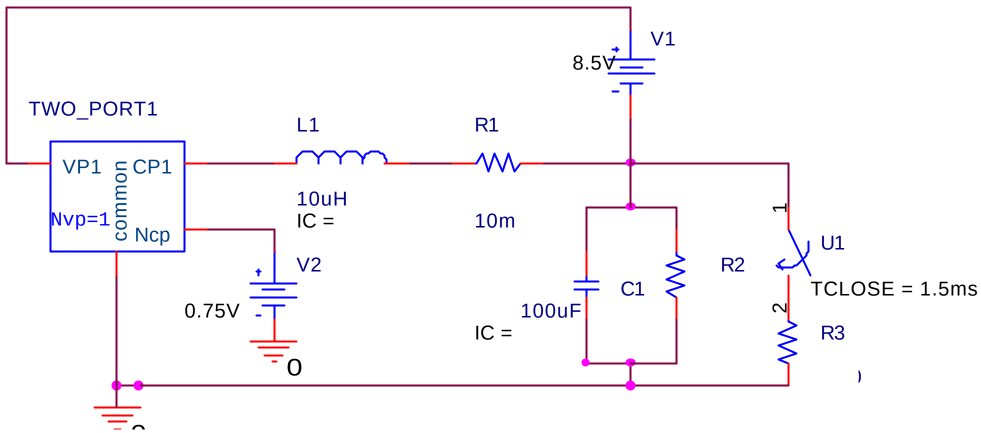
$= 1 : (1-d)$ Boost

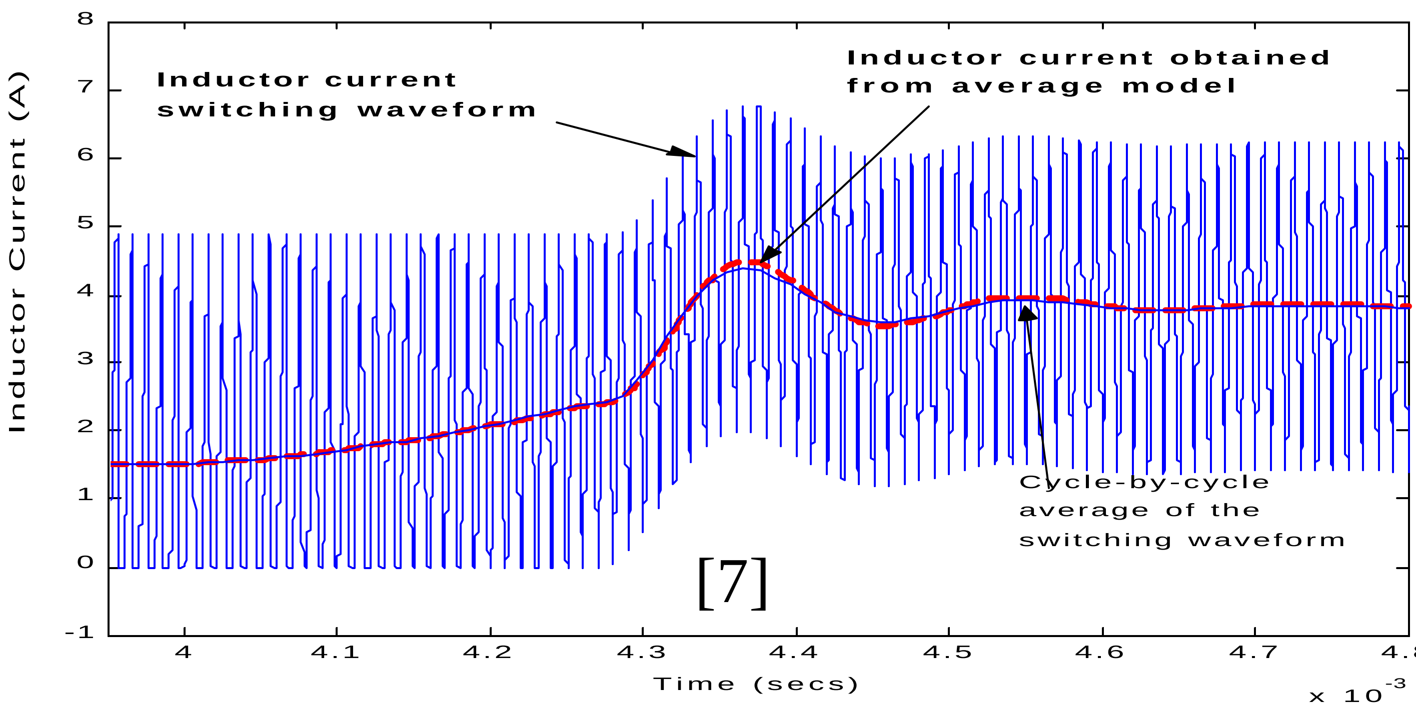
$$d(t) = \frac{v_{control}}{\hat{V}_r}$$

v_k and i_k are both zero in CCM.

Simulation of Large Disturbances Using the Average Model

[5, 7, 8]





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References

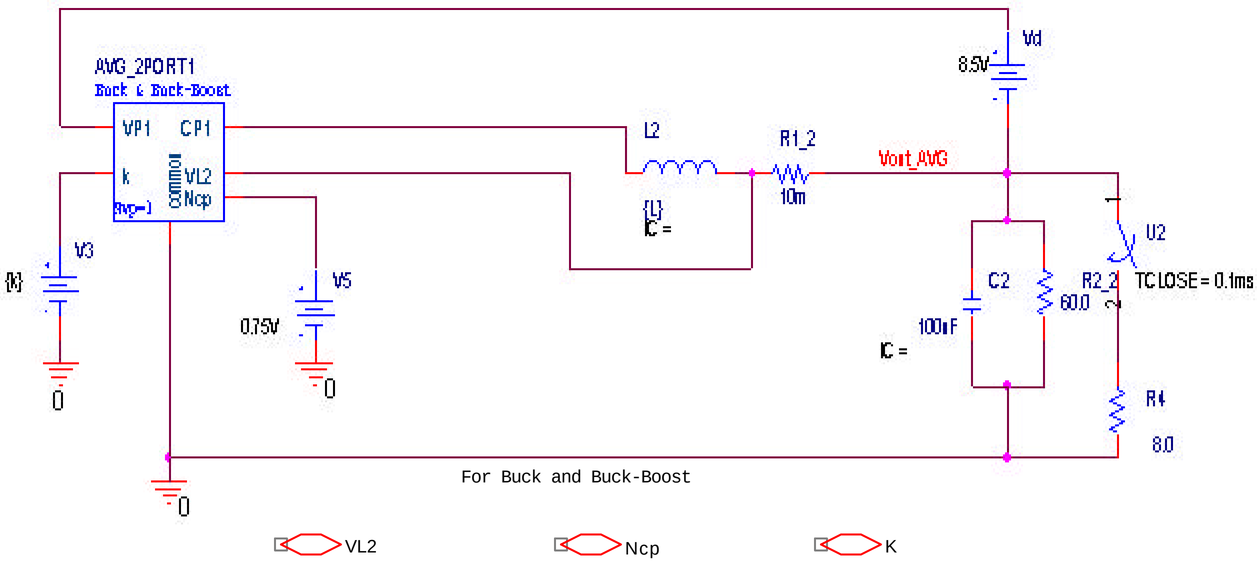
5. N. Mohan, *Learn a True Building-Block Approach to Power Electronics and Using this Unifying Analysis (Assisted by PSpice™ Modeling) to Design Feedback Controllers in Switch-Mode dc Power Supplies, Power-Factor-Correction Circuits and Motor Drives*, 4-1/2 hour video course, http://www.mnpere.com.

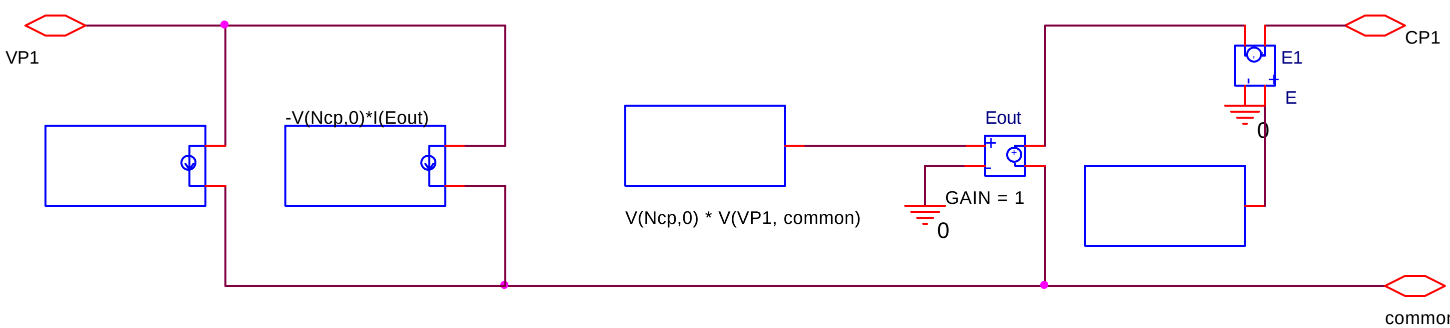
7. G. Nirgude, R. Tirumala and N. Mohan, "A New, Large-Signal Average Model for Single-Switch DC-DC Converters operating in both CCM and DCM," IEEE-PESC, Vancouver, Canada, June 2001.

8. N. Mohan, Power Electronics Modeling Simplified using PSpice™ (Release 9), http://www.mnpere.com.

Frequency Response for Feedback Controller Design

[5, 8]



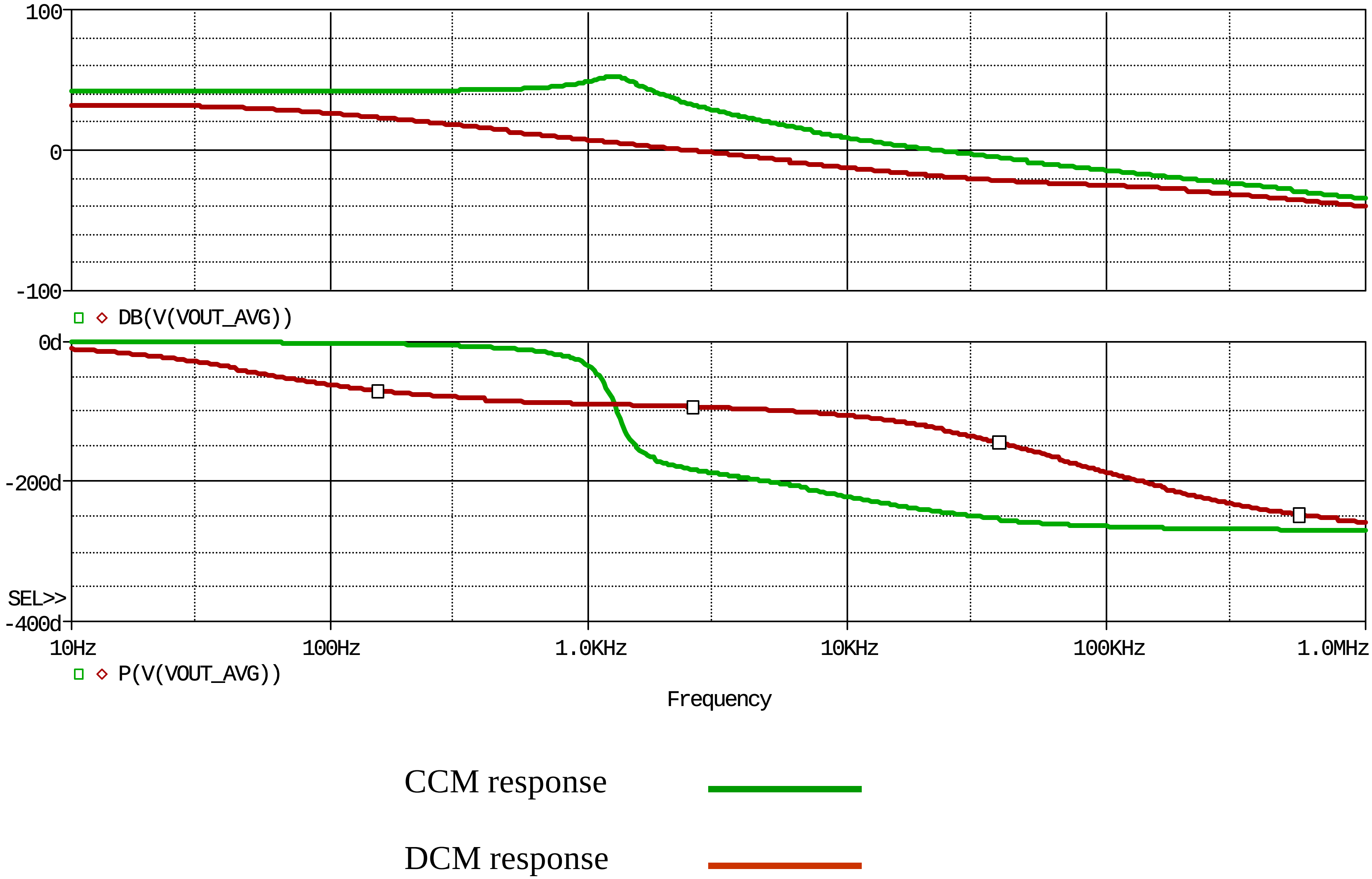


IF((((V(K,0)*(-I(Eout)))/(V(VP1,VL2)*V(Ncp,0)))<1) , ((1-((V(K,0)*(-I(Eout)))/(V(VP1,VL2)*V(Ncp,0))))*V(VL2,common)) , 0)

IF((((V(K,0)*(-I(Eout)))/(V(VP1,VL2)*V(Ncp,0)))<1) , ((V(Ncp,0)*V(Ncp,0)*V(VP1,VL2)/V(K,0)) - (V(Ncp,0)*(-I(Eout)))) , 0)

Frequency Response for Feedback Controller Design – cont.

[5, 8]



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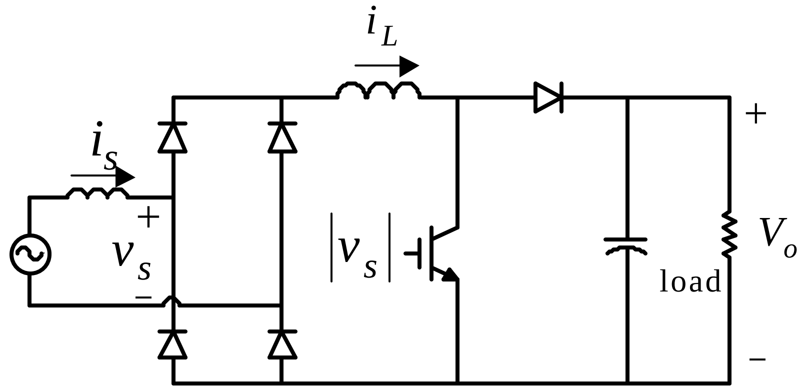
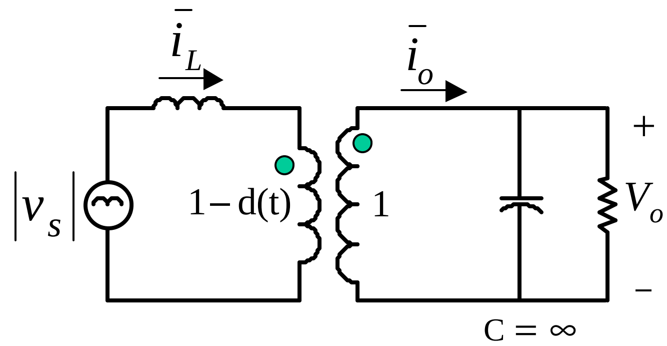
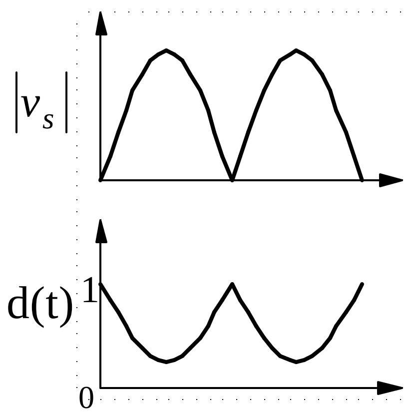
Power-Factor-Correction (PFC) Circuit [5]

- Use a boost dc-dc converter to shape the rectified current





Average model



$$\frac{V_o}{|v_s|} = \frac{1}{1-d(t)}$$

$$\therefore \; d(t) = 1 - \frac{\hat{V}_s |\sin(\omega t)|}{V_o}$$

Inner Current Loop: $\frac{\tilde{i}_L}{\tilde{d}}(s) = \frac{V_o}{sL}$

Outer Voltage Loop:

$$\bar{i}_o(t) = \frac{1}{2}\frac{\hat{V}_s}{V_o}\hat{I}_L - \frac{1}{2}\frac{\hat{V}_s}{V_o}\hat{I}_L\cos(2\omega t)$$

$$\frac{\bar{i}_{o\sim}}{\hat{I}_{L\sim}}(s) = \frac{1}{2}\frac{\hat{V}_s}{V_o}$$

SUMMARY

1. Consistent Systematic Analysis of switch-mode topologies
2. Clearly shows Switch-Mode Synthesis using PWM
3. Extremely Simple Average Model Speeds up Simulations of Large Disturbances by a factor of 100 or more
4. Same Average Model Allows Small-Signal Response (Bode Plots) to be obtained using PSpice™ in CCM and DCM Modes for Feedback Controller Designs
5. Allows practical topics to be covered in a single-semester course

Ideal For:

- Practicing Engineers
- For a First Course in Power Electronics

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3. Mohan, Undeland and Robbins, *Power Electronics: Converters, Applications and Design*, 2nd Edition 1995, http://www.wiley.com.

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Continued……

References (contd.)

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