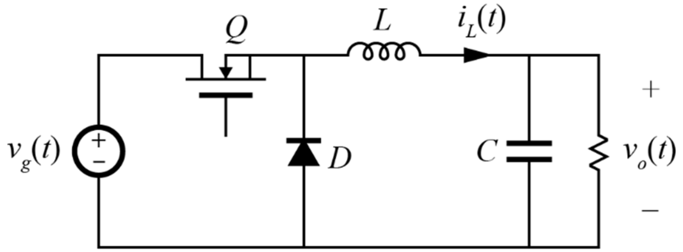
Current Programmed Modulation

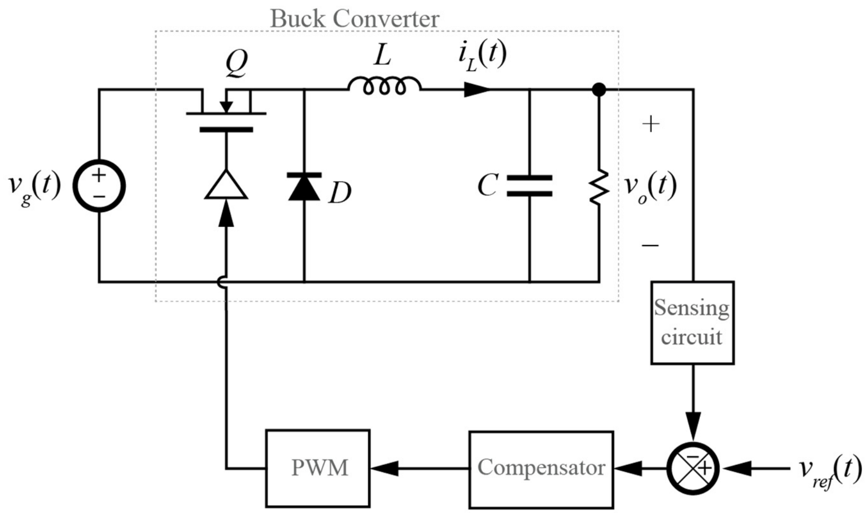
- Covered in *Fundamentals of Power Electronics*
  - Chapter 12, 2nd Edition
  - Chapter 18, 3rd Edition
- Replaces Pulse Width Modulation
- Transistor switching based on instantaneous current value, rather than duty cycle

- Begin by reviewing traditional PWM Buck

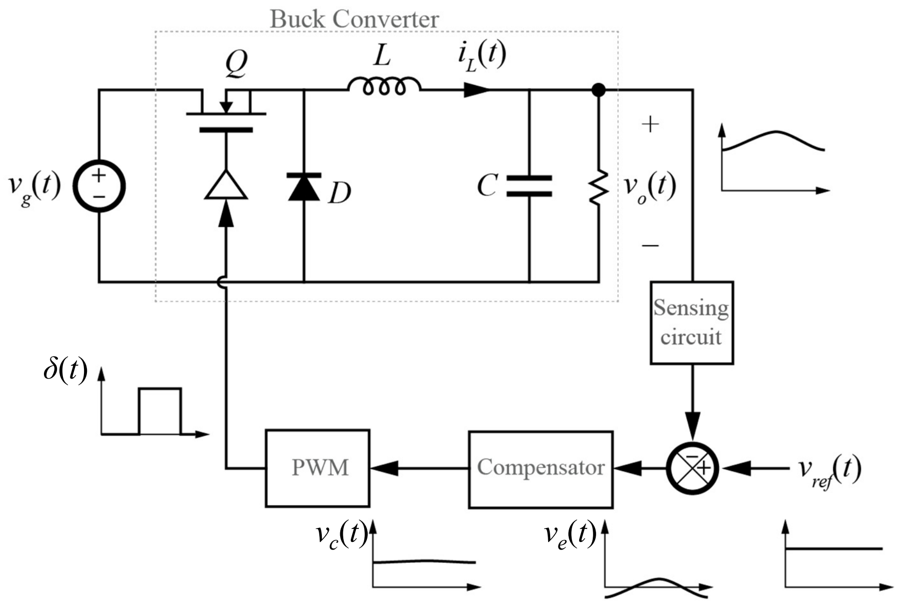
Buck Power Stage



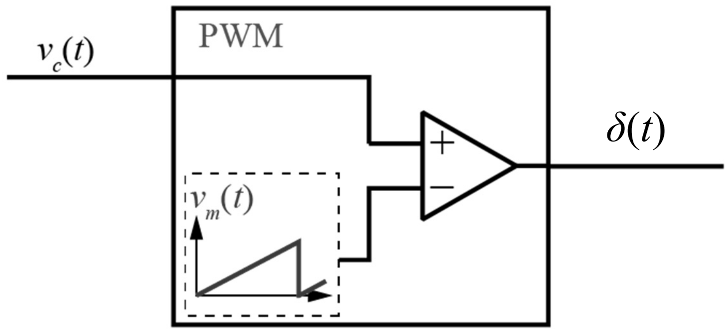
Traditional Output Voltage Control

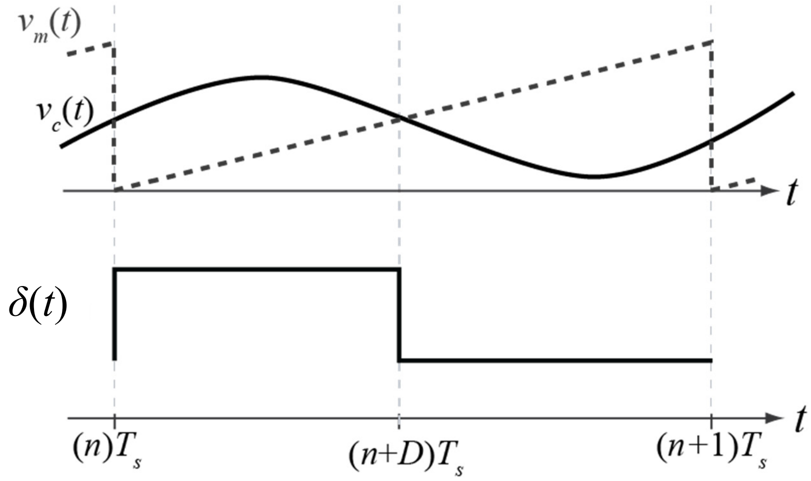


Time-Domain Waveforms

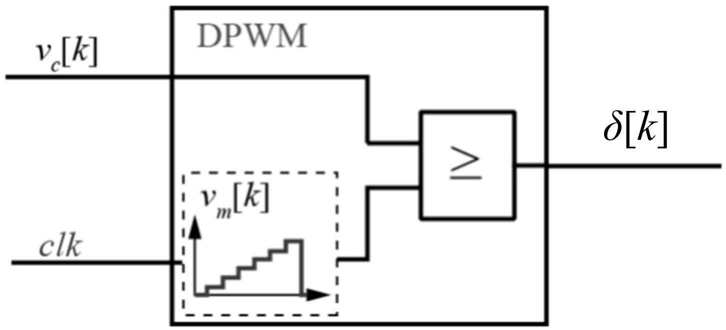


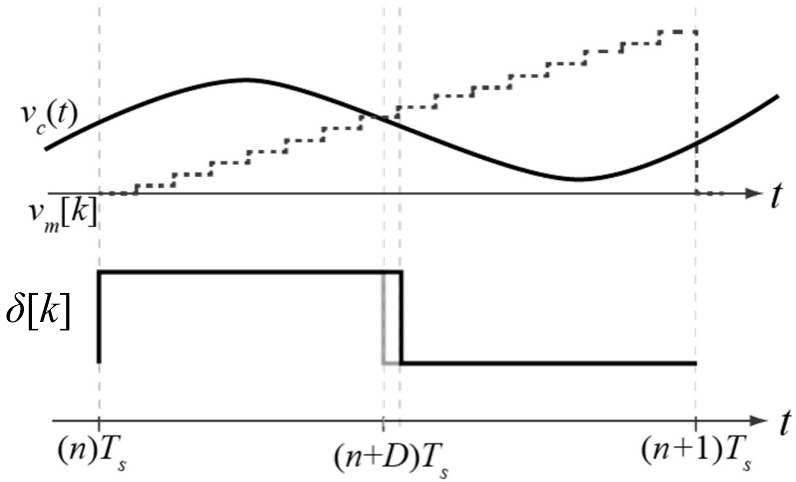
Pulse Width Modulator Model



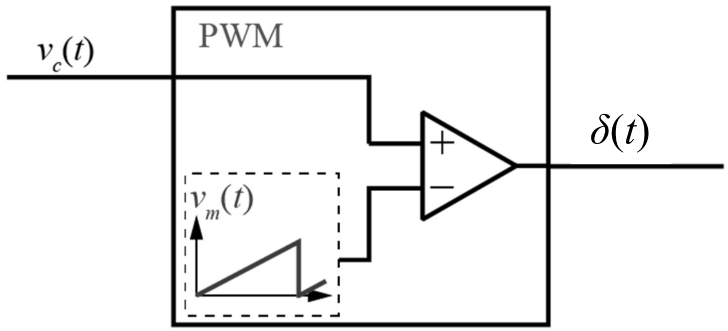


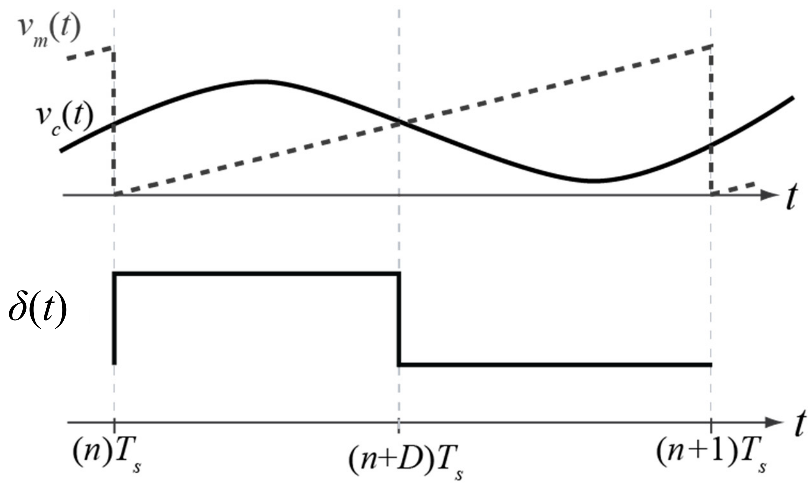
Digital PWM

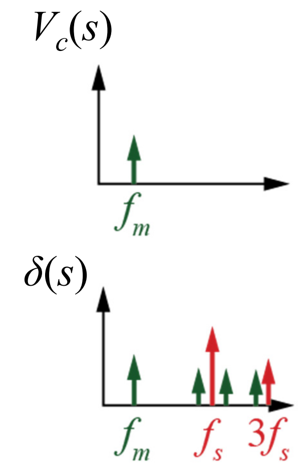




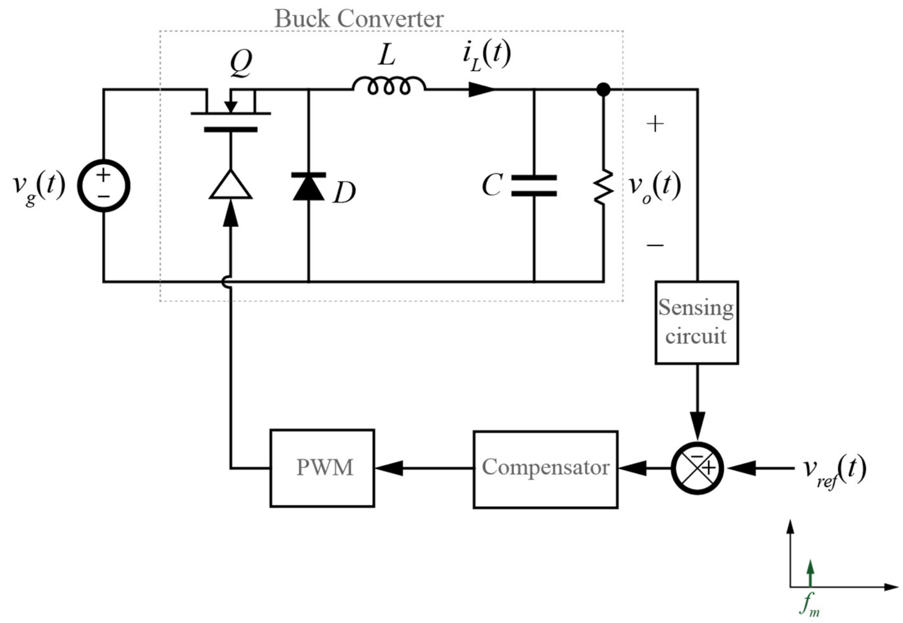
PWM Dynamics



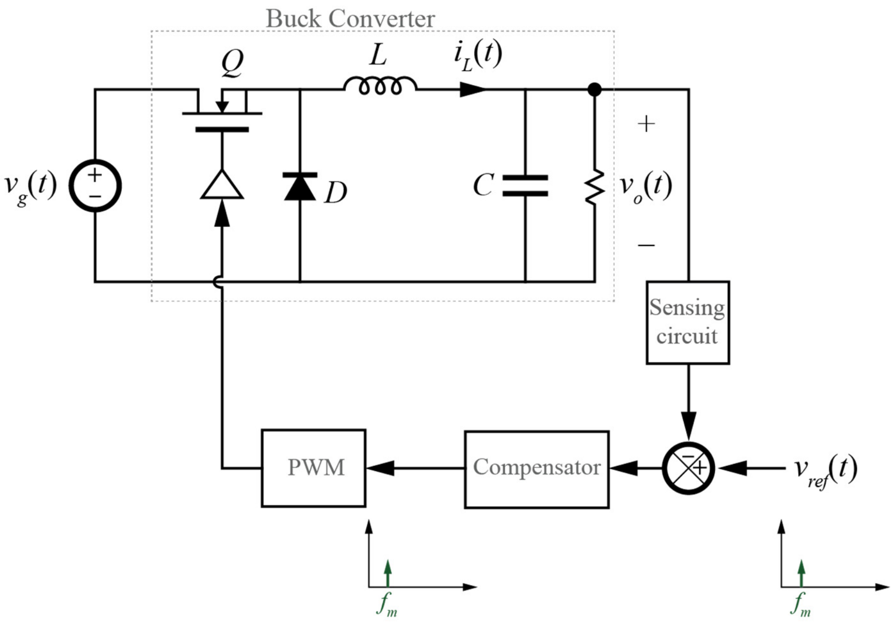




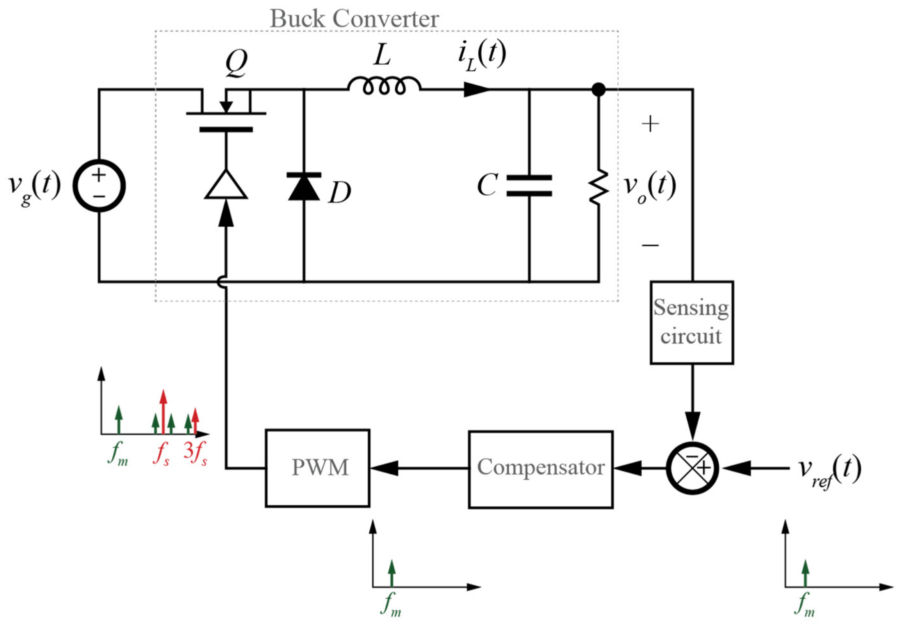
Frequency-Domain Signals



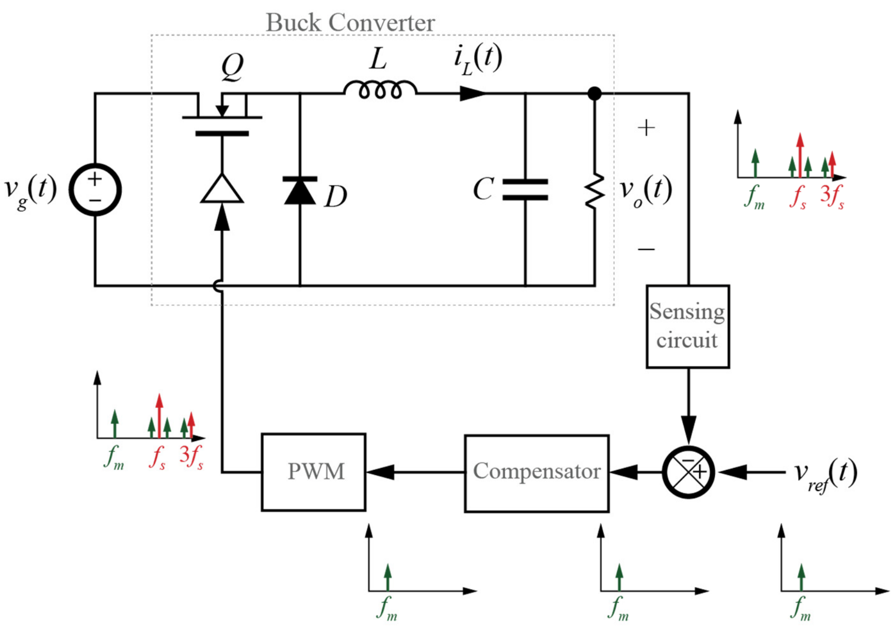
Frequency-Domain Signals



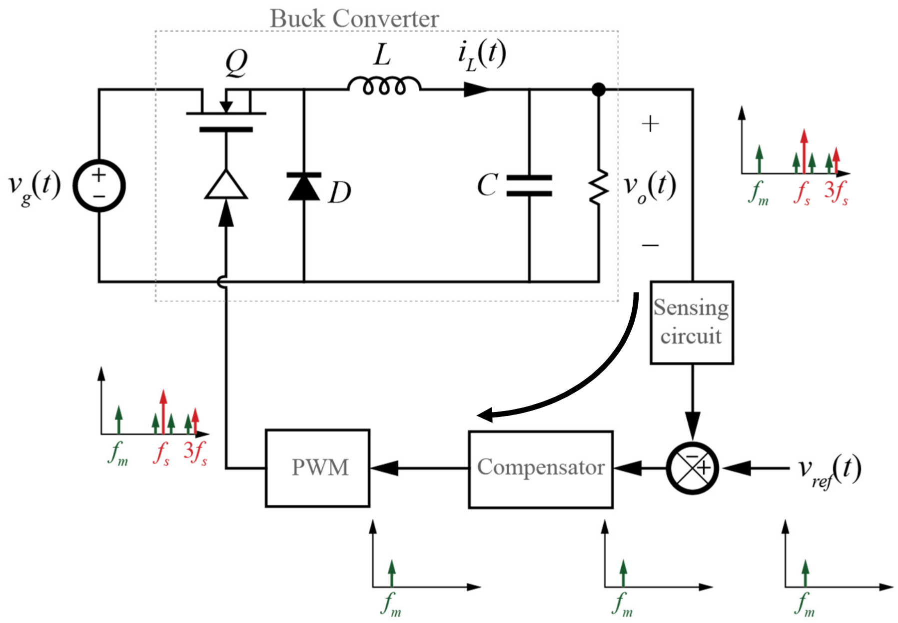
Frequency-Domain Signals



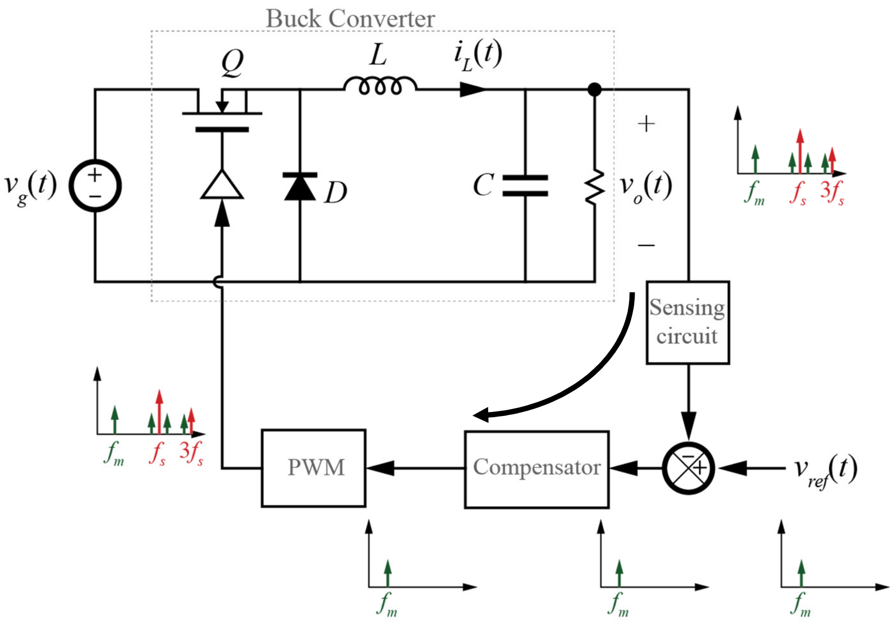
Frequency-Domain Signals



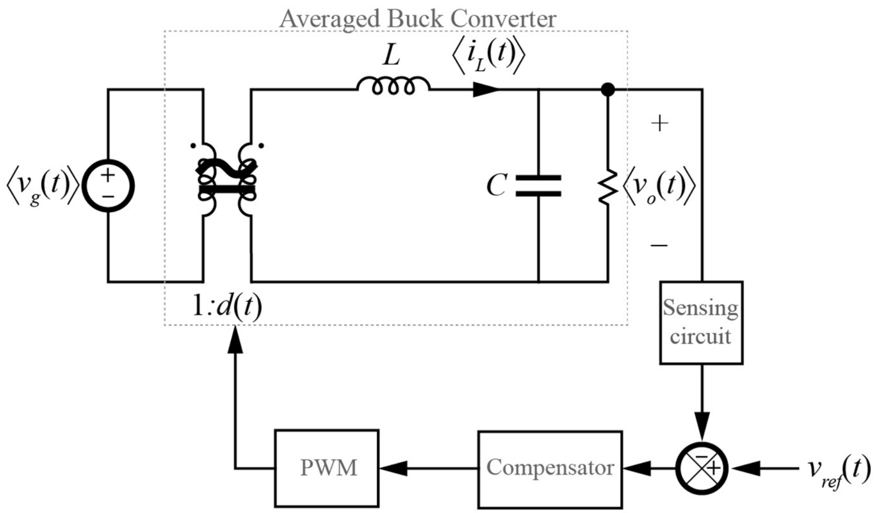
Frequency-Domain Signals



Frequency-Domain Signals



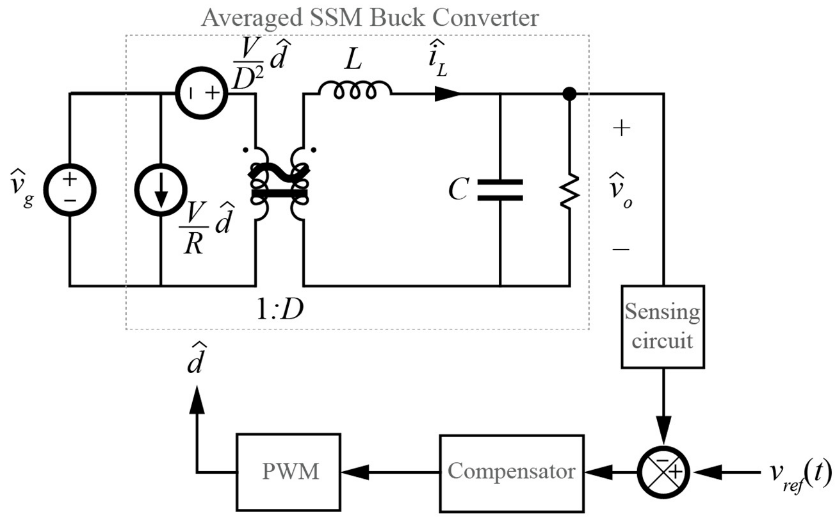
Averaged, Nonlinear Equivalent Circuit



$$L\frac{\langle i_L(t)\rangle}{dt} = d(t)\langle v_g(t)\rangle - \langle v_o(t)\rangle$$

$$C\frac{\langle v_o(t)\rangle}{dt} = \langle i_L(t)\rangle - \frac{\langle v_o(t)\rangle}{\mathrm{R}}$$

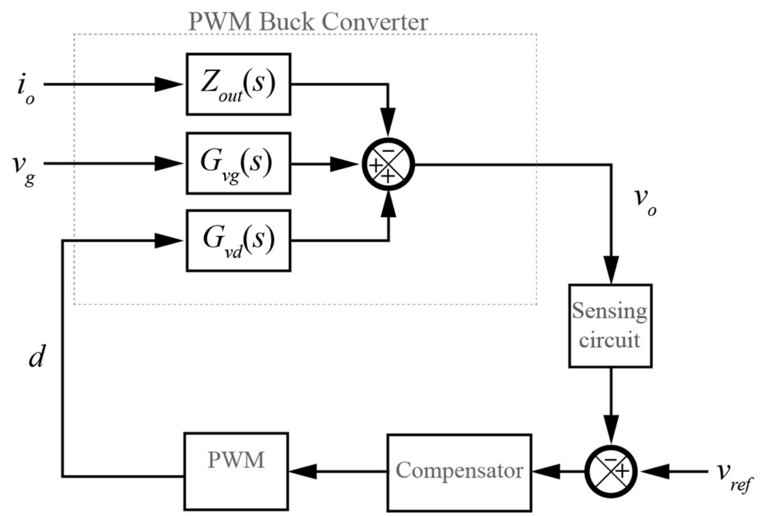
Average Small-Signal Equivalent Circuit



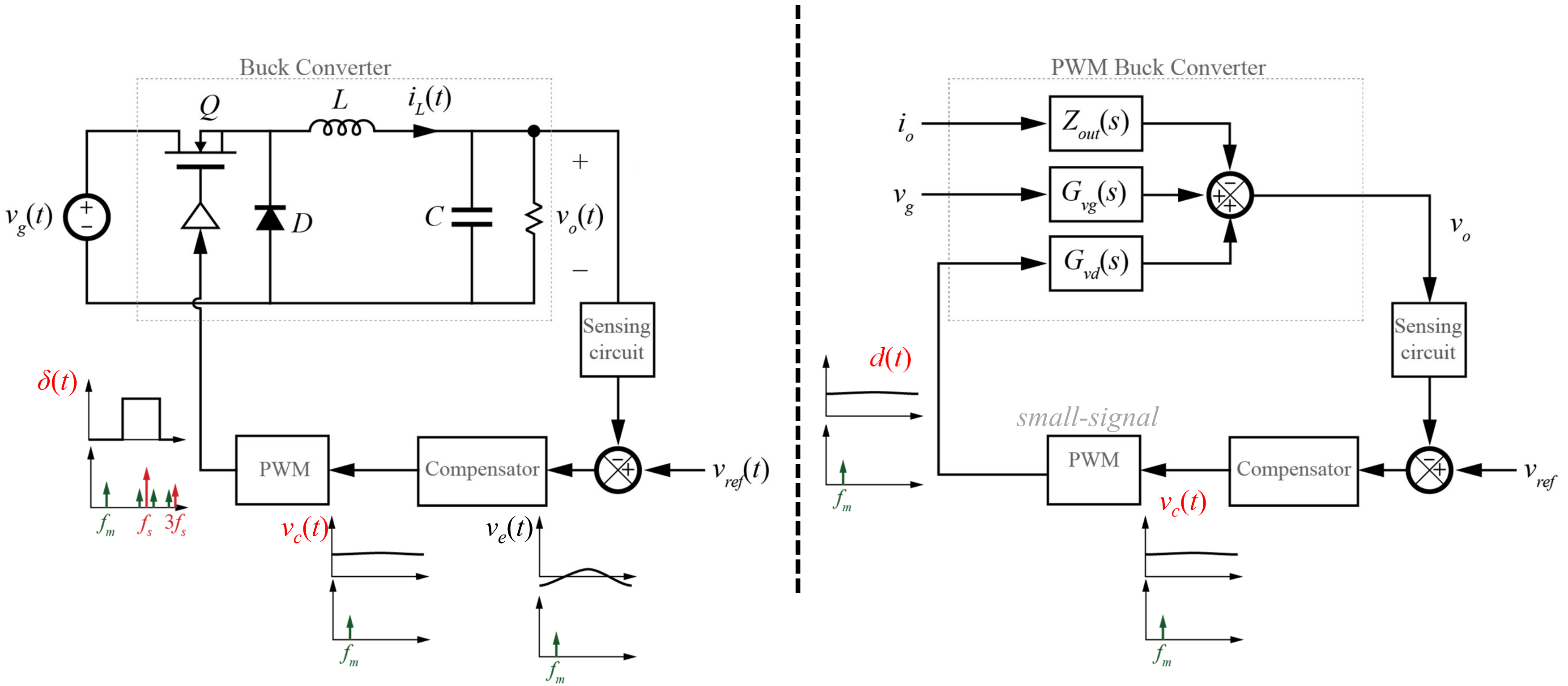
$$L\frac{\widehat{i_L}}{dt} = D\hat{v}_g + V_g\hat{d} - \hat{v}_o$$

$$C\frac{\hat{v}_o}{dt} = \widehat{i_L} - \frac{\hat{v}_o}{\mathrm{R}}$$

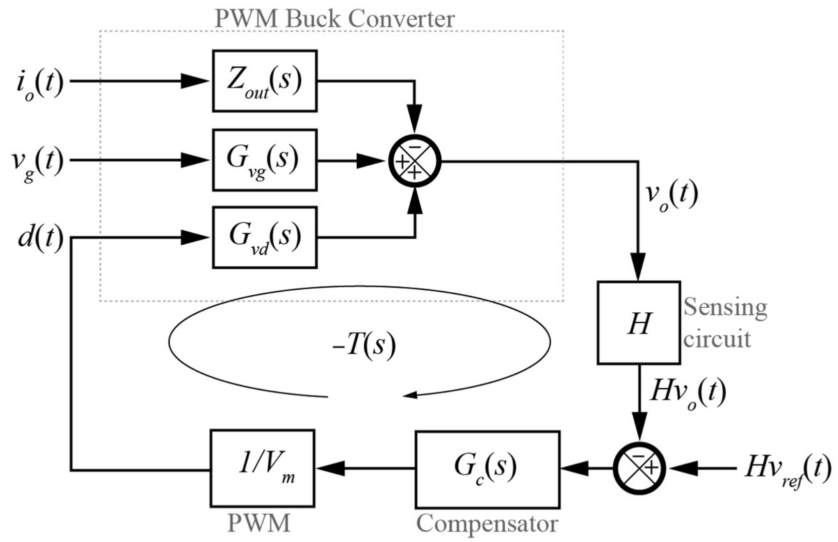
Averaged, Small-Signal Block Diagram



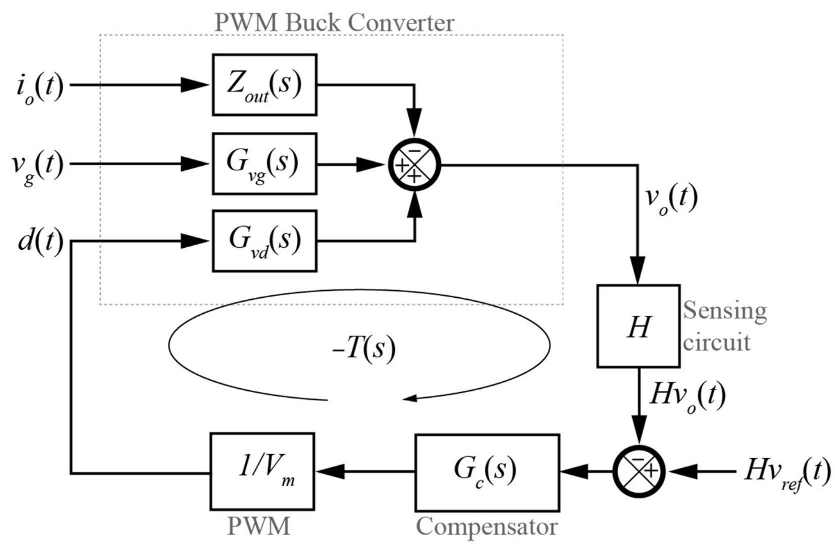
Averaged Modeling and PWM



Averaged, Small-Signal Control Model



Averaged, Small-Signal Control Model



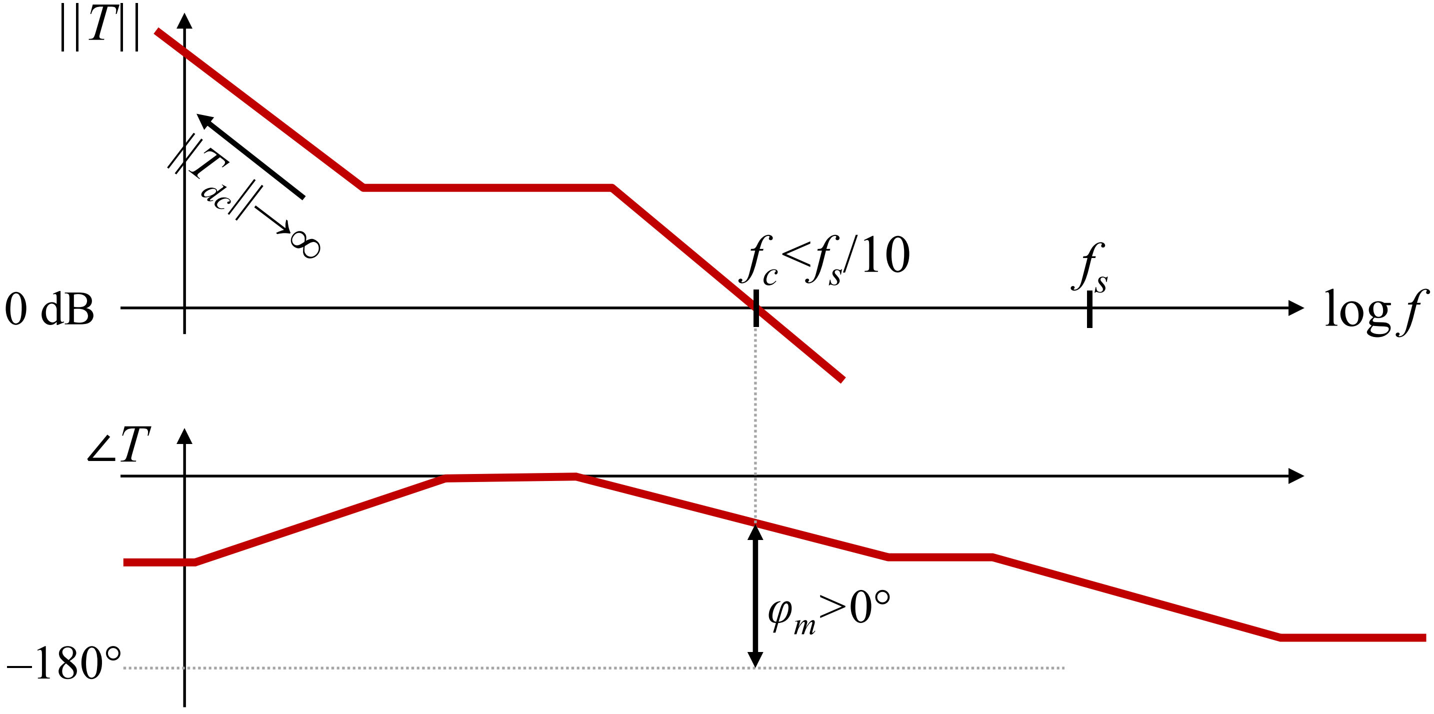
Shape $T(s)$ to have

- High DC gain
- High phase margin
- High bandwidth

Subject to limitations

- Bandwidth < $f_s/10$
- Low gain at frequencies ≥ f_s

Example Loop Gain



Shape $T(s)$ to have

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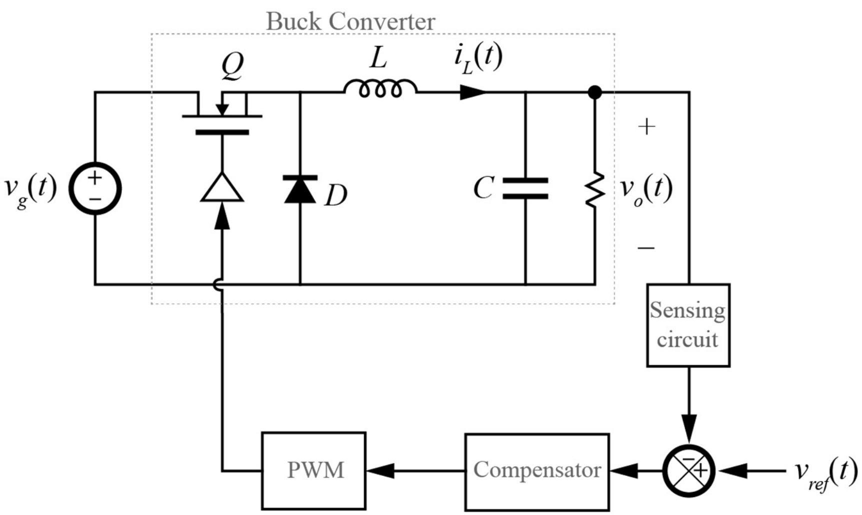
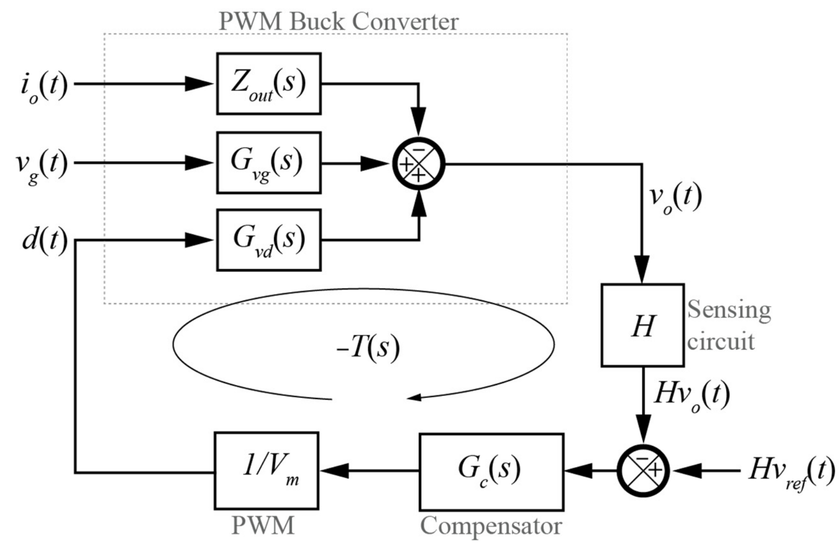
Averaging Approximation





- *Averaged*, small-signal power stage model for *PWM-controlled* Buck converter has
- Assuming $T(s)$ has LPF characteristics, switching ripple is attenuated and high frequency dynamics ignored
  - Therefore, averaged model is a good approximation