Buck Regulator Architectures

4.5 Current/Emulated Current Mode Buck Regulators
CURRENT MODE
Current-Mode Buck Regulator

Modulator

Output Filter

Error Amplifier

VIN
RC
CC
COUT
Slope
Comp
RESR
RLOAD
L
RFB2
RFB1
VOUT
VFB
VBG

+
+
VC
+
-
+
-
Current-Mode Buck-Regulator Architecture

- **Modulator and Power Stage**
  - Corrective Ramp
  - PWM Comparator
  - Current Sense Amplifier
  - Feedback, Error Amplifier, and Compensation

- **Integrated or External**
  - Reference
  - V_{OUT}
  - V_{IN}
  - R_S
  - L
  - C
  - R_C (ESR)
  - R_L
Advantages and Disadvantages

• Advantages
  – Power plant gain offers a single-pole roll-off
  – Line rejection
  – Cycle-by-cycle current limiting protection
  – Current sharing

• Disadvantages
  – Noise
  – Minimum ON-time
  – Sense resistor
CMC Sub-Harmonic Oscillation

- Current mode controlled power converters operating at duty cycles >50% are prone to sub-harmonic oscillation.

- Disturbances in peak rising current ($\Delta I$) increase at the end of the cycle.
Slope Compensation

\[ m_c = \text{Internal Slope Comp} \]

Stability criteria

\[ 1 > \frac{m_2 - m_c}{m_1 + m_c} \]
The current sense element is usually a resistor or the $R_{DS-ON}$ of the FET.
Output Filter

\[ V_{SW} \quad \text{C}_{OUT} \quad R_{ESR} \quad R_{LOAD} \quad V_{OUT} \]

\[ \omega_{z1} = \frac{1}{C_{OUT} R_{ESR}} \]

\[ \omega_{p1} = \frac{1}{C_{OUT} R_{LOAD}} + \frac{1}{f_s L C_{OUT}} (m_c D' - 0.5) \]
Control-Loop Considerations
Rules of Thumb

• Crossover frequency at 1/5th the switching frequency with a phase margin of 45°
• Higher crossover frequency relates to faster transient response and an increased likelihood of instability
• Lower crossover frequency relates to slower transient response and an increased likelihood of stability
Current Mode Line Transients
Performance Trade-offs

• Sudden changes in the line voltage are alleviated by use of a large input cap
• Inherently better response in current mode because of implicit line feed-forward
• Use of several caps in parallel reduces the ESR also improving performance
• High crossover frequency allows control loop to quickly accommodate perturbations in the system
Current Mode Control Example: LM284x

Internal Block Diagram

Typical Application Circuit
EMULATED CURRENT MODE (ECM) BUCK REGULATORS
Why Emulated Current Mode?

Leading edge spike, conventional current mode control.
15W Supply With Emulated Current Mode Regulator

- 6-42V input
- 5V, 3A output
- 300 kHz Switching Frequency
Thank you!