Lecture-33

EE5325 Power Management Integrated Circuits

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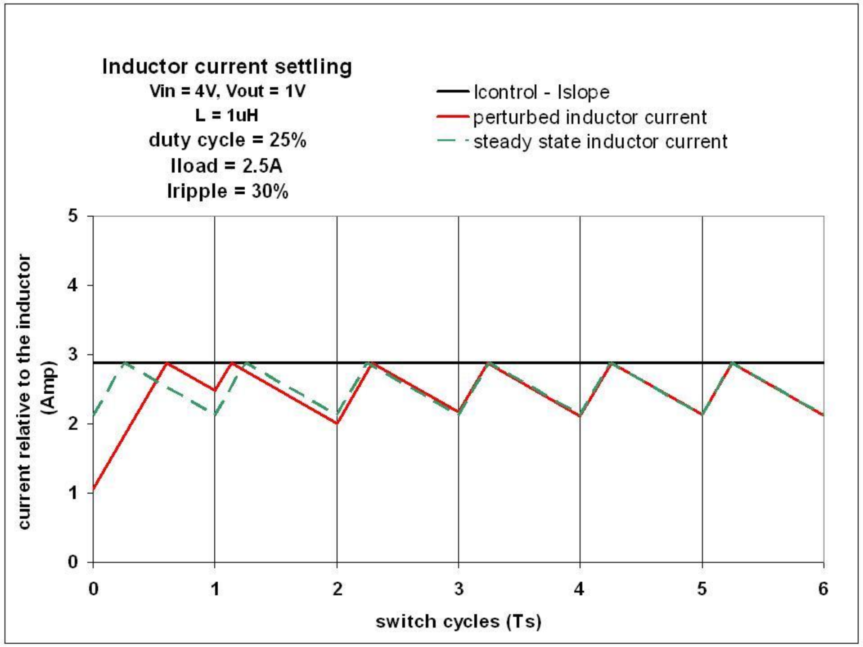
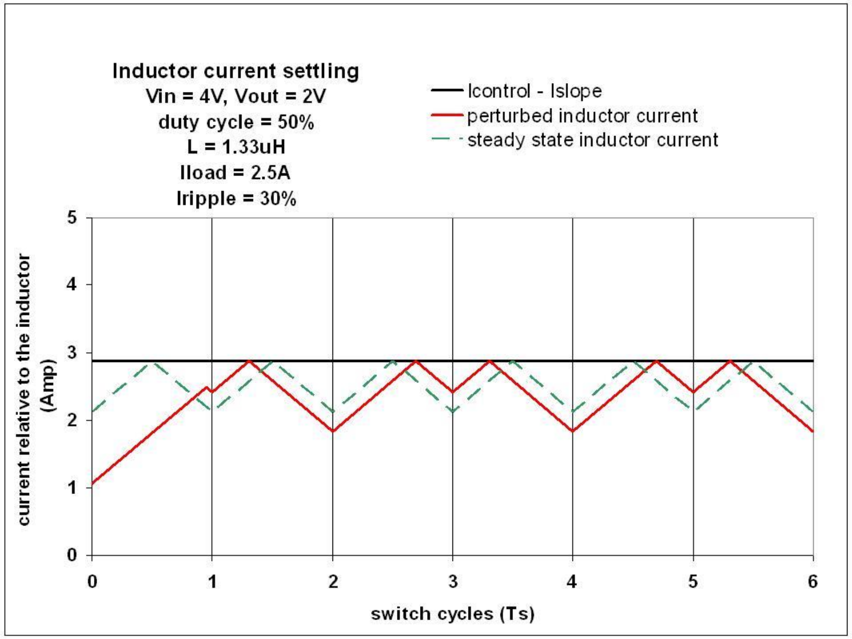
Sub-harmonic Oscillations

- **Caused due to instability in the current loop**

Peak CMC



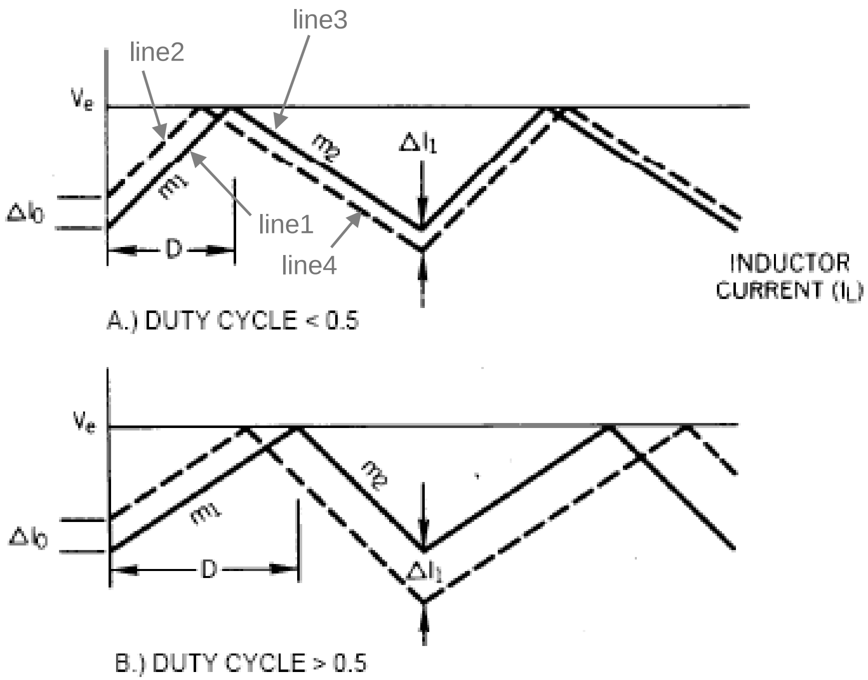
D < 0.5 (Stable)



D > 0.5 (Un-stable)

Current loop instability

- Current Loop suffers from sub-harmonic oscillations when D > 0.5 (for peak CMC) and D<0.5 (for valley CMC)
- This sub-harmonic oscillation is suppressed by adding a compensating ramp in the control signal



Using eq. of straight line

For line1, $I_1 = m_1(T_0) + I_0$

For line2, $I_1 = m_1(T_0\text{-}\Delta T_0) + I_0 + \Delta I_0$

Subtracting two eq.

$\Delta T_0 = \Delta I_0/m_1$

similarly line3 and line4 gives

$\Delta I_1 = -m_2\,\Delta T_0$

Substituting ΔT_0, we get

$$\Delta I_1 = -\Delta I_0 \left(\frac{m_2}{m_1}\right) \qquad (1)$$

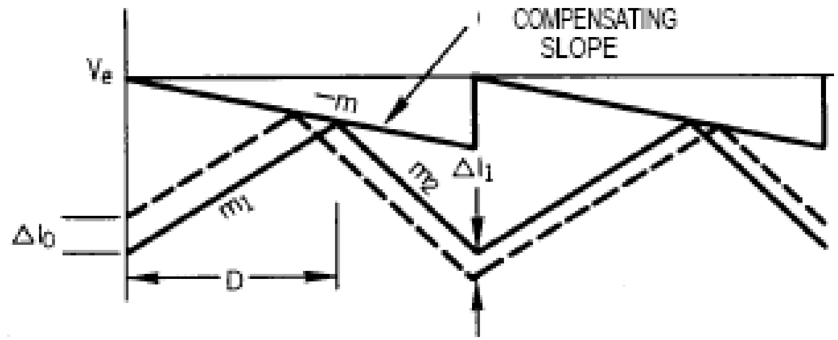
Case-1: D < 0.5 → $m_1 > m_2$ → $\Delta I_1 < \Delta I_0$; stable

Case-2: D = 0.5 → $m_1 = m_2$ → $\Delta I_1 = \Delta I_0$; critically stable

Case-3: D > 0.5 → $m_1 < m_2$ → $\Delta I_1 > \Delta I_0$; unstable

Ramp Compensation

- The current loop is stabilized by adding a small ramp in the current or subtracting the same from error signal



C.) DUTY CYCLE > 0.5 WITH SLOPE COMPENSATION

$$\Delta I_1 = -\Delta I_0 \left(\frac{m_2 - m}{m_1 + m}\right) \qquad (2)$$

Disturbance after *n* cycles:

$$\Delta i_n = \left(-\frac{m_2 - m}{m_1 + m}\right)^n \cdot \Delta i_0 \qquad (3)$$

Hence to ensure the stability of current loop Δi_n should die out → $(m2-m) < (m1+m)$

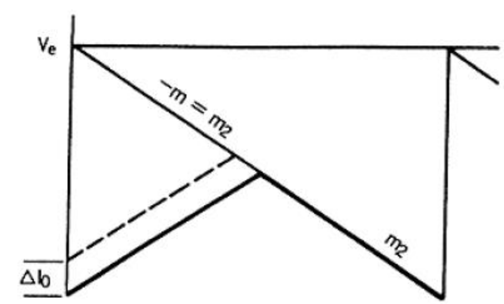
Stability Condition: $\Delta i_n / \Delta i_0 < 1$

Can be achieve by two ways

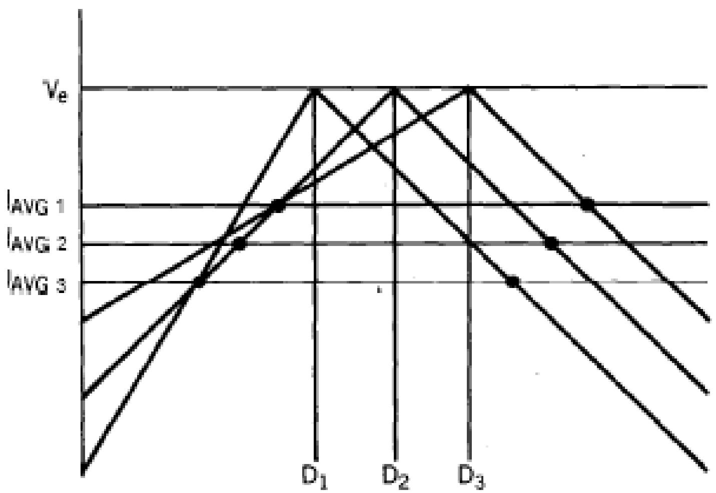
$$m > \frac{1}{2} m_2 \quad \text{or} \quad m > \frac{1}{2}(m_2 - m_1)$$

Substituting both the case in (3) results in $(m2-m) < (m1+m)$ hence satisfying the condition of stability

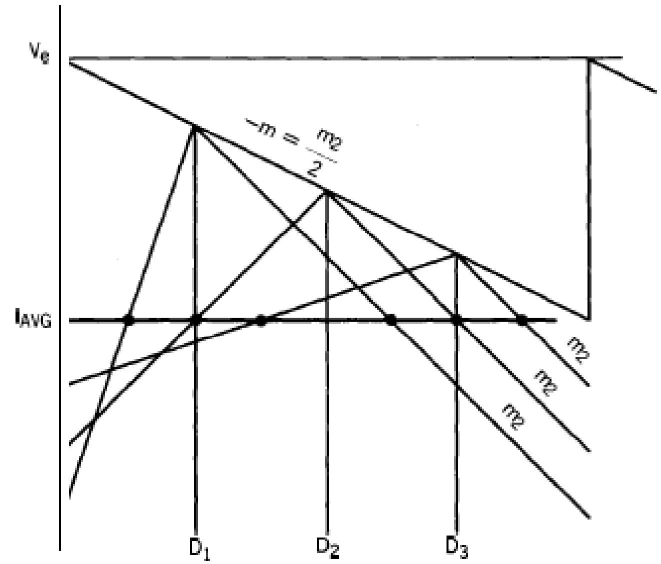
Ideal slope for compensating ramp, m = m2 causes the output to settle in one clock cycle



Ramp Compensation

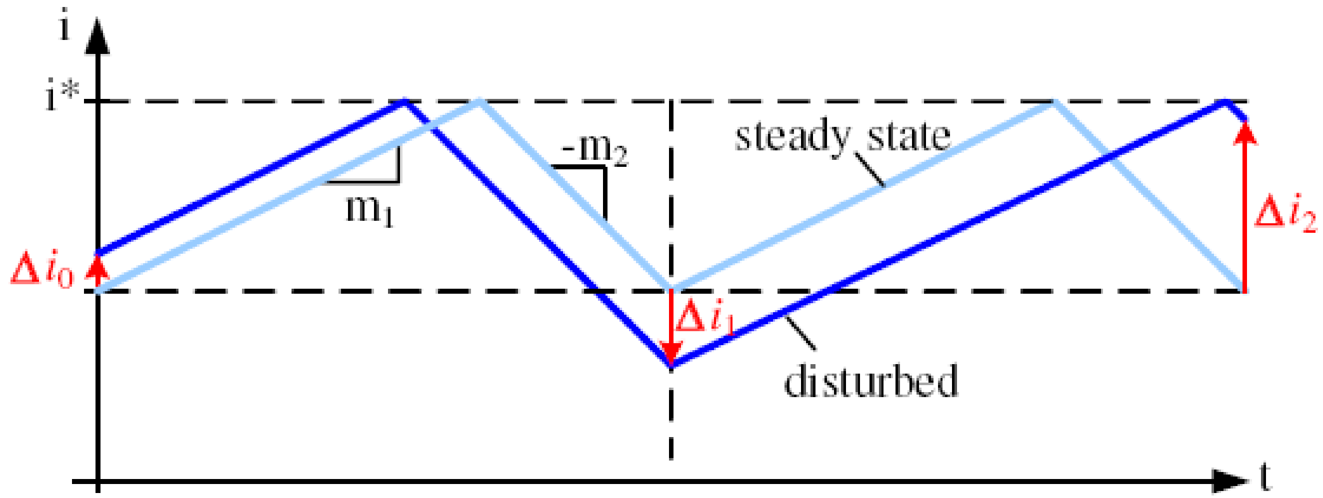


PEAK CURRENT SENSING WITHOUT SLOPE COMPENSATION ALLOWS AVERAGE INDUCTOR CURRENT TO VARY WITH DUTY CYCLE



- AVERAGE INDUCTOR CURRENT IS INDEPENDENT OF DUN CYCLE AND INPUT VOLTAGE VARIATION FOR A SLOPE COMPENSATION OF $m = -\frac{1}{2} m_2$.

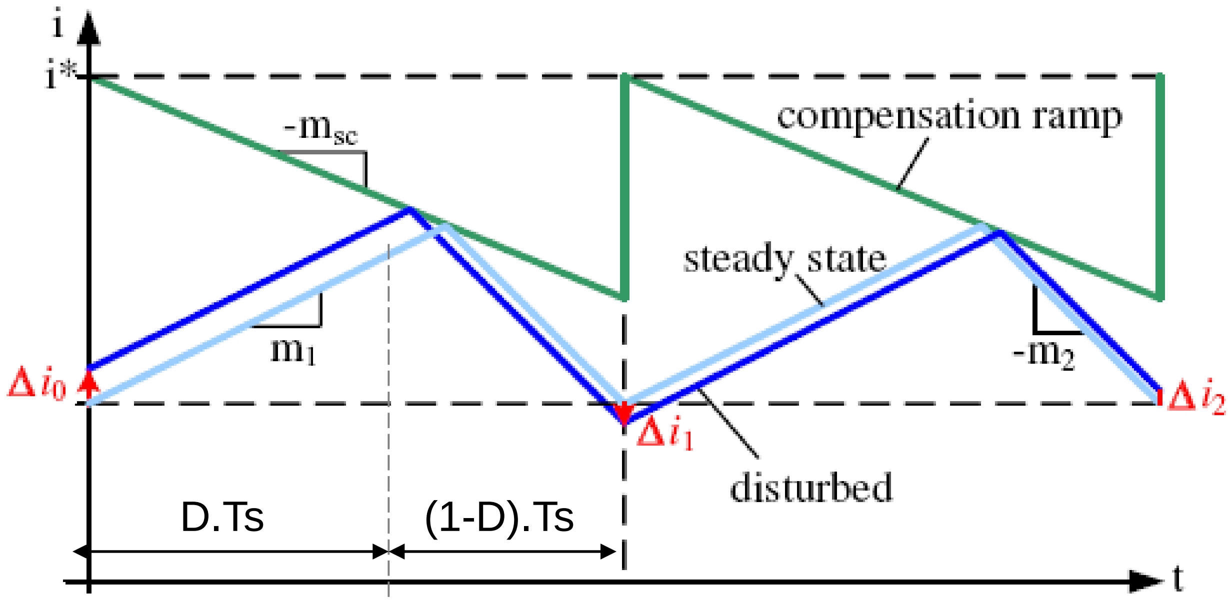
Slope Compensation



Disturbance after *n* cycles: $$\Delta i_n = \left(-\frac{m_2}{m_1}\right)^n \cdot \Delta i_0$$

Condition for stable operation: $$m_1 > m_2 \qquad (D < 0.5)$$

Slope Compensation



$$\frac{m_2}{m_1} = \frac{D}{1-D}$$

Disturbance after *n* cycles:

$$\Delta i_n = \left(-\frac{m_2 - m_{sc}}{m_1 + m_{sc}} \right)^n \cdot \Delta i_0$$

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Required compensation:

$$m_{sc} > \frac{1}{2}(m_2 - m_1)$$

Adaptive Slope Compensation

$$m_{sc} > \frac{1}{2}(m_2 - m_1) \rightarrow \frac{1}{2} m_1 (\frac{m_2}{m_1} - 1) \qquad (1)$$

$$\frac{m_2}{m_1} = \frac{D}{1-D} = \frac{V_{out}}{V_{in} - V_{out}} \qquad (2)$$

For buck: *D = Vout/Vin*

$$substituting\ (2)\ in\ (1)$$

$$\Rightarrow m_{sc} > \frac{1}{2} m_1 \frac{V_{in}}{V_{in} - V_{out}} \quad or \quad \frac{m_{sc}}{m_1} > \frac{1}{2} \frac{V_{in}}{V_{in} - V_{out}}$$

$$also\, m_1 = \frac{V_{in} - V_{out}}{L} \Rightarrow m_{sc} > \frac{V_{in}}{2L}$$

The optimum slope compensation can be calculated by knowing one of the followings:

- m_1, V_{in} and V_{out}
- V_{in} and L