Experimental Results for a Fast, Self-stabilizing, Hysteretic Boost DC-DC Converter

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Motivation

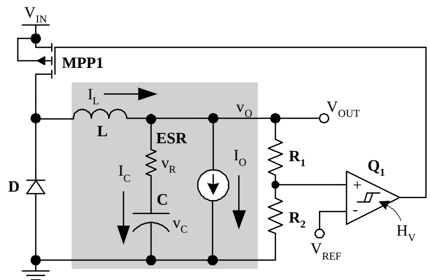
- Significant dependence of converter frequency response on passive components
- Tolerances in capacitor ESR, ESL values
- Variations in inductor, capacitor values per design

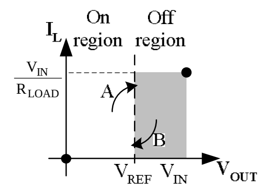
- IC solution for frequency compensation required because
  - Reduction in design time
  - Reduction in part count
  - Reduction in board size, cost
  - Ease of design

- Need to have IC solution that will give frequency compensation independent of external components

➢ **Hysteretic control provides a way !**

Hysteretic Buck Converter





- Hysteretic control regulates output voltage ripple $\mathbf{v_O}$
- With switch MPP1 held on: $V_{OUT} = V_{IN}$
- With switch MPP1 held off: $V_{OUT} = 0$
- V_{REF} is between "ON" and "OFF" regions, forming "switching surface"
- System state moves towards switching surface from either side

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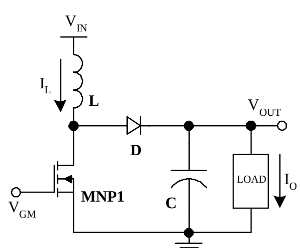
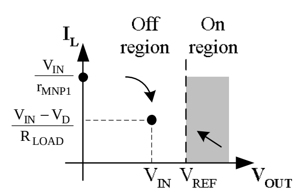
Issues with Hysteretic Control in Boost Converters





- With switch MNP1 held on: $V_{OUT} = 0$
- With switch MPP1 held off: $V_{OUT} = V_{IN}$
- V_{REF} is **not** between "ON" and "OFF" regions
- System state does not move towards V_{REF} from either side

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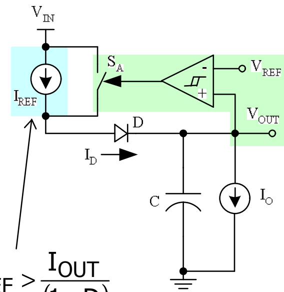
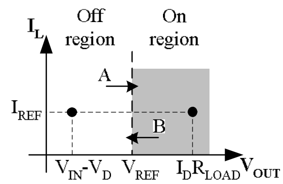
Proposed Hysteretic Control



$$I_{REF} > \frac{I_{OUT}}{(1-D)}$$



- With switch S_A held on: $V_{OUT} = 0$
- With switch S_A held off: $V_{OUT} = I_D R_{LOAD} > V_{REF}$
- V_{REF} is between "ON" and "OFF" regions
- System state moves towards V_{REF} from either side

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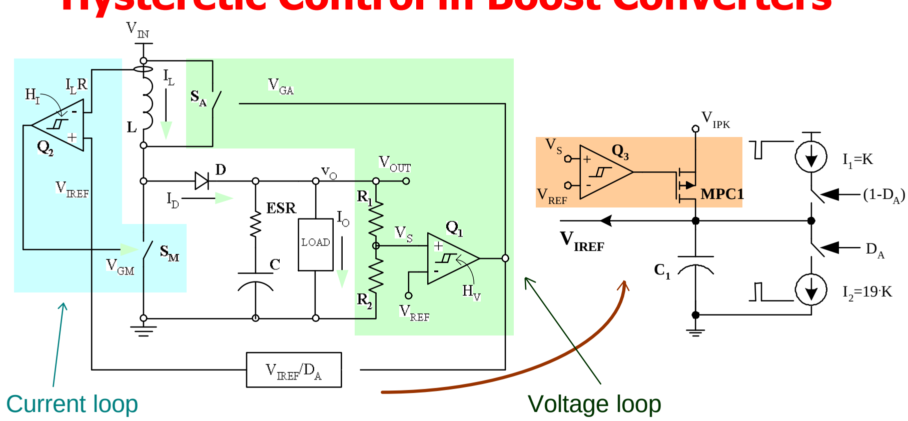
Hysteretic Control in Boost Converters



- ➢ If V_{IREF} too large, then power loss rises, efficiency decreases
- ➢ Hence, I_L kept only 5 % above I_{LMIN} duty-cycle-to-voltage demodulator
- ➢ $I_2 = 19 \cdot I_1$, therefore V_{IREF} steady-state when $D_A = \frac{I_1}{I_1 + I_2} = \frac{I_1}{20 \cdot I_1} = 5\%$

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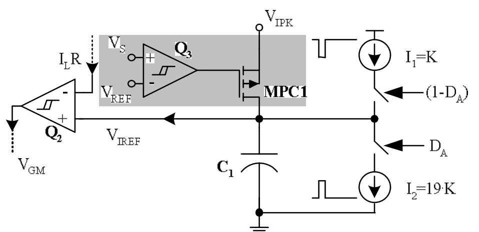
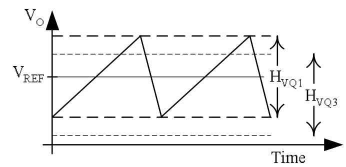
Hysteretic Control in Boost Converters: Transient Response





- H_{VQ3} sets the hysteresis window for transient response
- If V_{OUT} falls outside H_{VQ3}, switch MPC1 turned on
- V_{IREF} raised in single step to V_{IPK} ⊳ I_L to support max designed I_{OUT}
- Then, V_{OUT} rises in single cycle of switch S_A

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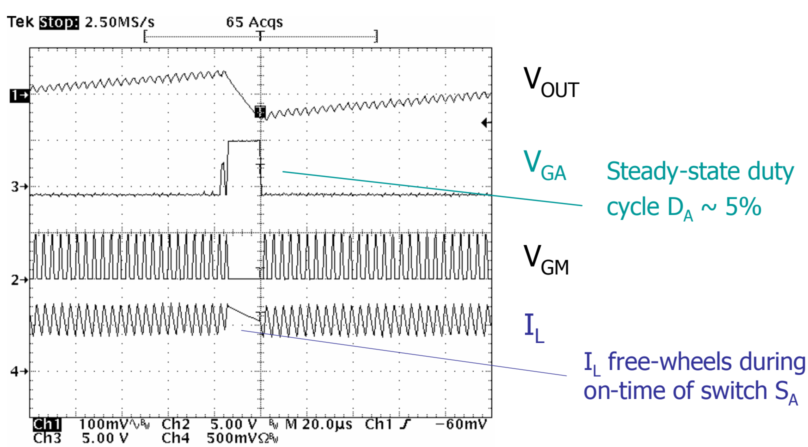
Experimental Results: Steady-state



V_{OUT} = 5 V, I_{OUT} = 0.3 A, V_{IN} = 3.5 V, L = 6.8 µH, C = 76 µF

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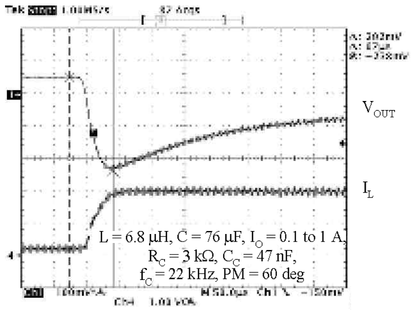
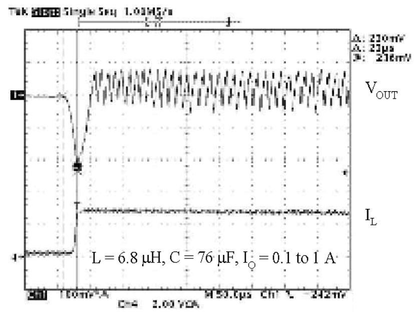
Experimental Results: Load Transient Response



Leading current-mode-control boost



Proposed hysteretic boost

- ΔV_{OUT} = 292 mV, Δt = 400 μs
- ΔV_{OUT} = 230 mV, Δt = 50 μs
    - 0.1 A to 1 A load step
    - Fast, single cycle response for hysteretic boost converter

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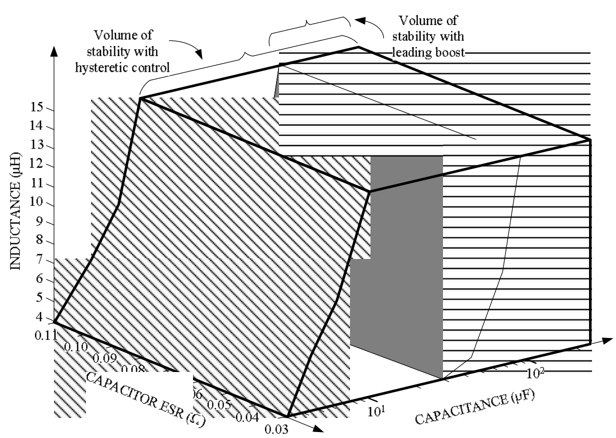
Experimental Results: LC Variation Limits



- C_{MIN} for proposed converter 9 times lower than that for leading conventional boost converter

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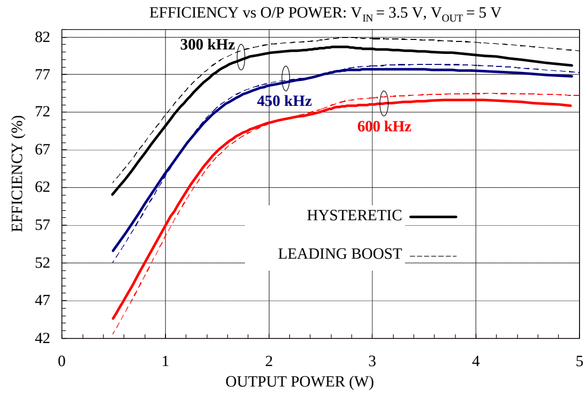
Experimental Results: Power Efficiency



- Proposed solution has slightly lower high-load efficiency (by 2 % @ 5 W) compared to leading boost converter

✓ At medium and light loads (less that 2.5 W), proposed solution superior (2 % improvement at 0.5 W)

Summary

- Need integrated DC-DC converter stable with wide variations in L, C
- Hysteretic control in buck converters fastest, simple and w/o compensation
- Novel dual-loop technique presented to implement hysteretic control in boost converters
- Proposed method has superior performance over leading boost converter
  - Lower C_{MIN} required for stable operation (9 times lower)
  - Fast transient response (20 % lower ΔV_{OUT})

without using any compensation circuit

- Efficiency degraded up to 2 % @ 5 W, but improved by 2 % at 0.5 W
- Solution can be used towards an increased degree of integration in DC-DC converters – without an external frequency compensation circuit