ELECTRICALENGINEERING

Idea behind current mode control in DC-DC converter

Asked 1 year, 5 months ago Modified 1 year ago Viewed 2k times

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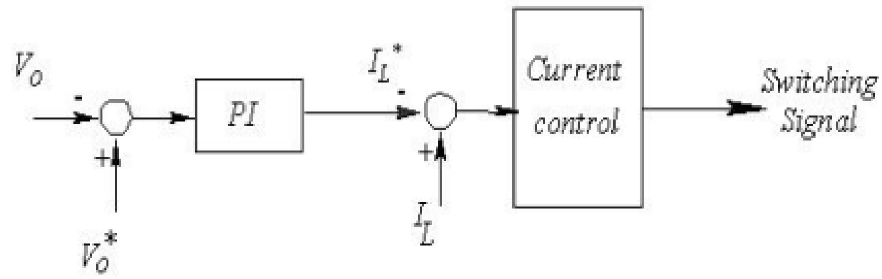
I am learning about control strategies for DC-DC converters.

While I find voltage mode control easy to understand, I struggle to understand current mode control.



Is the idea here to control the output voltage by controlling the inductor current?

If so, what is the relation between them?

dc-dc-converter buck boost buck-boost

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edited Mar 28, 2023 at 20:03
JRE
73.1k 10 110 194

asked Mar 28, 2023 at 19:34
hakam zoubi
67 5

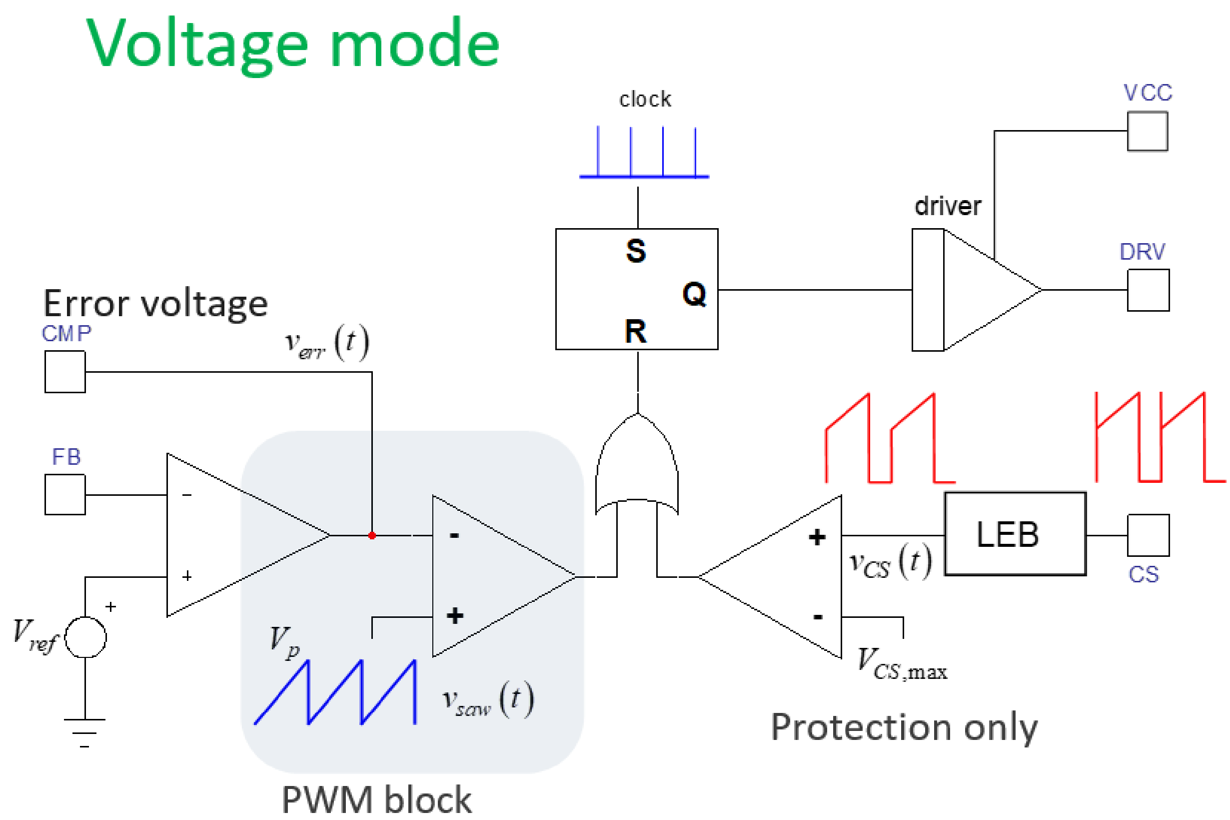
Your diagram is missing a few steps in relation to your text. Perhaps you should expand it to include inputs and outputs? – Tim Williams Mar 28, 2023 at 19:43

2 Answers

Sorted by: Highest score (default)

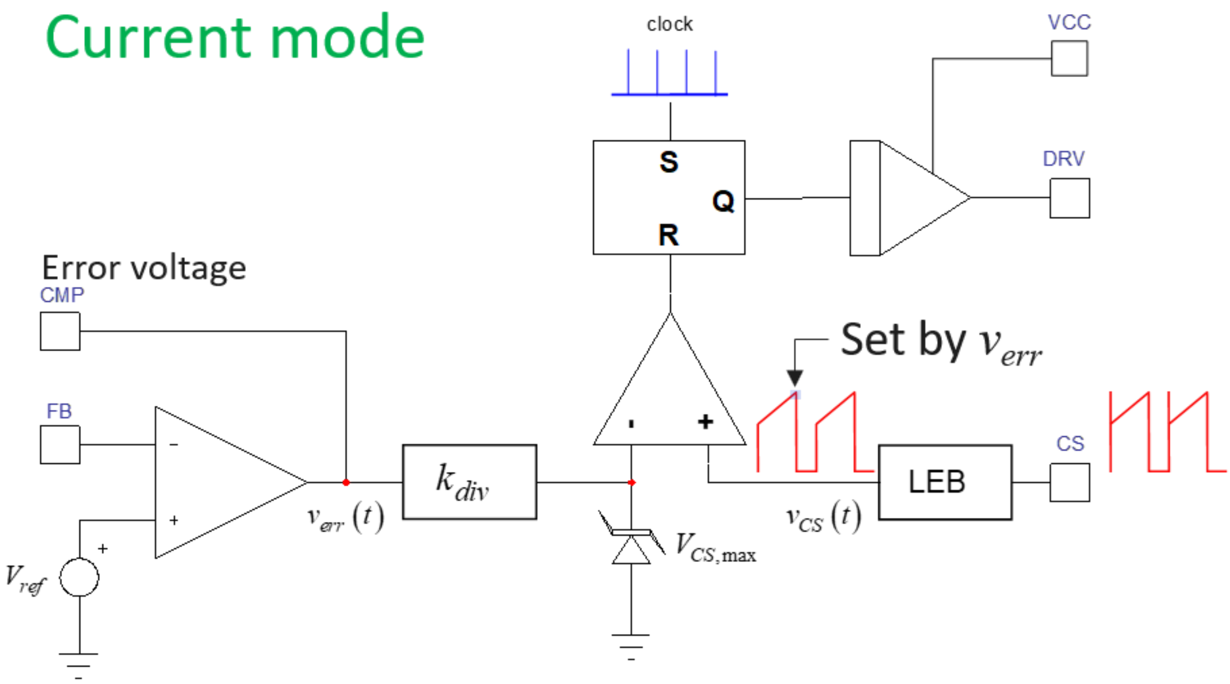
15

It is a vast subject to discuss but, basically, with voltage-mode control, the error voltage delivered by the compensator *directly* sets the duty ratio D. By doing so, you adjust the output power delivered by your converter, according to its dc transfer characteristic like $V_{out} = DV_{in}$ for a buck converter:



The duty ratio is elaborated via a pulse-width modulator (PWM) block made of a comparator and an artificial ramp pulsing from 0 to a peak value V_p. When the ramp intersects with the error voltage (a flat dc level in theory), then toggling occurs, turning the main transistor off. By changing the dc error voltage - the loop does that by monitoring the deviation of V_{out} from its target - you *directly* adjust the duty ratio and ensures regulation. In this mode, you don't need to consider the inductive current $i_L(t)$ to operate the converter. You actually implement a current limit but for safety reasons and not for regulation purposes.

In current-mode control, it is different. The sawtooth is replaced by the inductor current which is also a ramp. This current can be directly observed by a current transformer or via a resistive shunt which delivers a voltage image. The error voltage will now set the inductor peak current cycle-by-cycle and will adjust the value based on the operating point: a high peak for a large output power, a low value in light-load conditions:



In this mode, you control the inductor peak current and *indirectly* the duty ratio D. If you operate the buck converter in voltage- or current-mode control, D will be identical between the two converters for a similar operating point. It is only the way this duty ratio is elaborated that changes between the two. This time, you must monitor the inductor current cycle-by-cyle and it provides inherent protection to the converter.

Below is a quick summary between the two techniques and each bullet is a subject to expand in itself :) You can have a look at my last small seminar on the subject:

Voltage-mode control:

- Ease of implementation: no need to sense inductor current
- Can operate down to very low duty ratio
- Large-amplitude artificial voltage brings good noise immunity
- Inherently-low output impedance
- ❖ Poor input rejection: any perturbation must first propagate before correction
- ❖ Second-order response complicates compensation

Current-mode control:

- Natural input feedforward brings excellent input voltage rejection
- Inherent cycle-by-cycle overcurrent protection
- First-order response eases feedback loop design
- ❖ Inherently-high output impedance requires high loop gain
- ❖ Sub-harmonic instability in CCM needs slope compensation
- ❖ Difficult to operate at very low duty ratio

Share Cite Follow edited Aug 19, 2023 at 14:18 answered Mar 28, 2023 at 20:28


Verbal Kint
23k 1 19 56

2

As a simple qualitative explanation, if you put an inner control loop on the inductor current, you turn the inductor into a current source (within the BW of the loop, etc.). The voltage loop "programs" more current in the inductor as the load increases to keep the output voltage constant.

At a high simplistic level, this has the effect of removing the inductor from the LC filter, and making the control-output transfer function a single-pole system, the current source feeding the output capacitor (and load).

On a less simplistic level, you have to add slope compensation to deal with potential subharmonic oscillations, and you wind up with a pair of complex poles at half the switching frequency. The pole due to the inductor actually just moves out to a higher frequency.

But current mode is easier to compensate than voltage mode and has better line regulation and disturbance rejection, among other advantages.

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answered Mar 28, 2023 at 20:12

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24.2k 1 41 62