Multiphase 101 FAQs

Carmen Parisi, November 20, 2017

When should I look to make the switch from a single phase converter to a multiphase one?

It varies based on the exact design parameters but in general switching to a multiphase design makes sense when thermal design currents are around 25-30A. A multiphase converter will offer better thermal performance, higher efficiency, lower DC ripple, and lower output voltage swings on transients over their single phase counterparts.

What are the drawbacks of using a multiphase switching regulator?

While there are many benefits of multiphase converters they come at the potential expense of PCB area, BOM cost, and circuit complexity. PCB area can grow as phases are added which requires adding FETs, inductors, and a few passive components. BOM cost will likely increase as the phase count grows but could also drop if the cost of using more, lower current rated components is less than using fewer higher current rated components.

Circuit complexity will always increase as phase increases due to the issue of phase management. All multiphase switchers need some form of current feedback to the controller in order to properly balance current between all phases. Without this feedback stability issues appear and DC regulation suffers. In a worst case scenario FETs, inductors, or possibly the load device could be damaged if the phase management circuitry cannot maintain control of the regulator.

What if I only need two or three phases of a four phase controller? Are TI's parts easy to configure?

TI's controllers are extremely easy to adapt to lower phase count designs. Typically all that is required is tying the current sense lines of unused phases to the controllers +3.3V supply and leaving unused PWM pins open. Be sure to check the datasheet for any additional requirements.

One of the benefits of multiphase converters is fewer input and output capacitors for a given set of design conditions. How many caps can I really save?

When it comes to output capacitors the short answer is a lot. The easiest way to verify this claim though is to run the numbers. Let's look at some generic specs for a high powered FPGA core rail:

VIN	12	**V**
VOUT	1.0	**V**
D	0.083	
IMAX	120	**A**
fsw	600	**kHz**
ΔVOUT	0.05	**V±**
ΔVIN	1.2	**Vpp**
L	0.22	**µH**
ΔIOUT	60	**A**

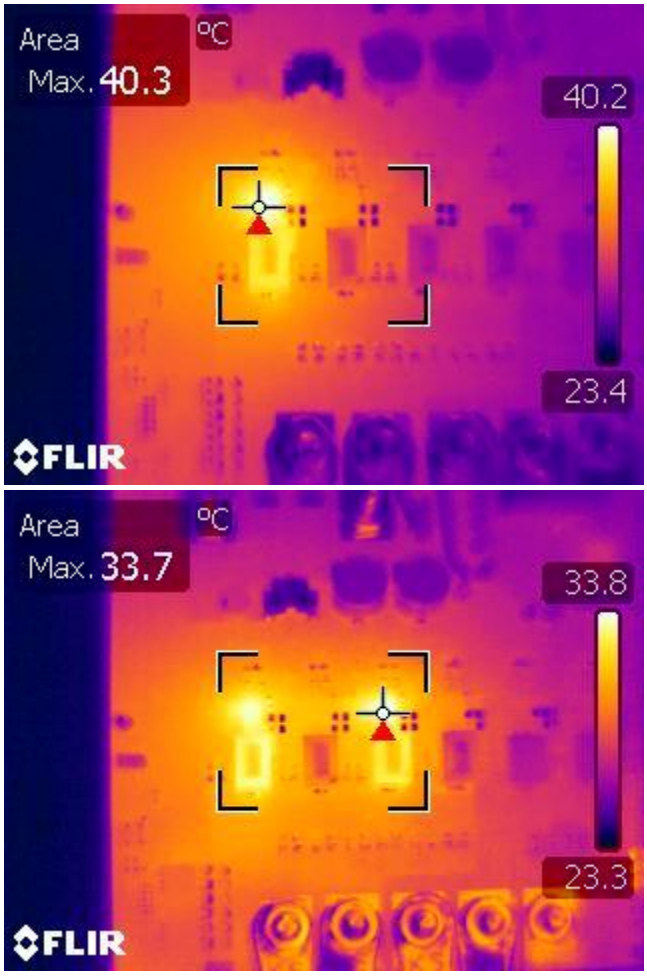
Using these specs we can figure out how many capacitors we would need to meet the DC input ripple, RMS input current, and output over/undershoot specs for single and multiphase options. The chart below shows those results and highlights the number of caps need for CIN and COUT in green for each case.

Design Parameter	Number of Phases			
	1	2	4	6
RMS Input Current (Arms)	33.17	22.36	14.14	10.00
# of Input Caps - RMS Current	4	3	2	2
CIN (µF) - Vin Ripple	41.67	20.83	10.42	6.94
# of Input Caps - Ripple Spec	5	3	2	1
Undershoot COUT (µF)	780	420	240	180
# of Output Caps - Undershoot	8	5	3	2
Overshoot COUT (µF)	7980	4020	2040	1380
# of Output Caps - Overshoot	80	41	21	14
Assumes 10µF, 1206 Input Caps rated to 8.66Arm and 100µF Output Caps				

Switching to a multiphase design can cut down the number of input ceramic capacitors by half but the real savings are found when looking at the output capacitance. Simply going from one phase to two cuts the COUT requirements in half! Jumping to four phases requires only a quarter of the output capacitance that a single phase design would need thanks a lower equivalent inductance. From these results we can also see that adding more than four phases wouldn't results in saving too many more capacitors and the cost of additional FETs, inductors, and PCB area would probably outweigh the savings. Always be sure to find your ideal phase count before committing to a design.

How much does adding phases to a design affect thermal performance?

Once again, let's let the test results speak for themselves. The following thermal images were captured for the following conditions:
12VIN, 1VOUT, 600kHz, 25A Load
20°C Ambient, 5 minute soak at load, no airflow
Single and Dual Phase Configurations



The single phase solution is running almost 7°C hotter than the dual phase configuration for the same conditions! Multiphase thermal performance will only improve as the load current increases to 30A and beyond. Sticking with single phase for such high currents quickly leads to a complicated thermal design as heftier heatsinks and more airflow is required to keep the FETs at a safe operating temperature.

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