Technical Article

TurboTrans™ Technology: One Resistor Dramatically Improves Transient Performance and Reduces Solution Size

Ever-evolving technology demands smaller, modular, performance-driven solutions. Power modules contribute to small solution sizes and board-space requirements, but can reduce design flexibility. While power modules reduce solution sizes, there's been an additional push to improve transient response. Many newer DC/DC regulators and power modules internalize loop compensation or feature operating architectures that do not require loop compensation, making them very easy to use. But in some cases, that could reduce your ability to fine-tune design performance.

Solving the Problem of Fast Transient Response with Accuracy

As process technology advances, processors require tighter voltage accuracy and lower core voltages. Table 1 is a chart from a field-programmable gate array (FPGA) datasheet stating that the recommended operating conditions for the V_{CCINT} rail are 1V, plus and minus 30mV. It is recommend to stay within this 3% range because the processor could behave unexpectedly outside this voltage window. Thus, you may have to increase the capacitance at the output of DC/DC converters to meet the 3% range during load changes.

Table 1. Recommended Operating Conditions for a Field-programmable Gate Array (FPGA)

Symbol	Min	Typ	Max	Units
FPGA logic				
V_{CCINT}	0.97	1.00	1.03	V
	0.87	0.90	0.93	V
V_{CCBRAM}	0.97	1.00	1.03	V
	0.87	0.90	0.93	V

While small capacitance increments are allowable, larger amounts could negatively affect the module's load transient response. To optimize transient response, designers typically add a feedforward capacitor (C_{FF}) in parallel with the upper feedback resistor, as shown in Figure 1. In the frequency domain the addition of C_{FF} creates a zero, which increases bandwidth and improves the transient response time.

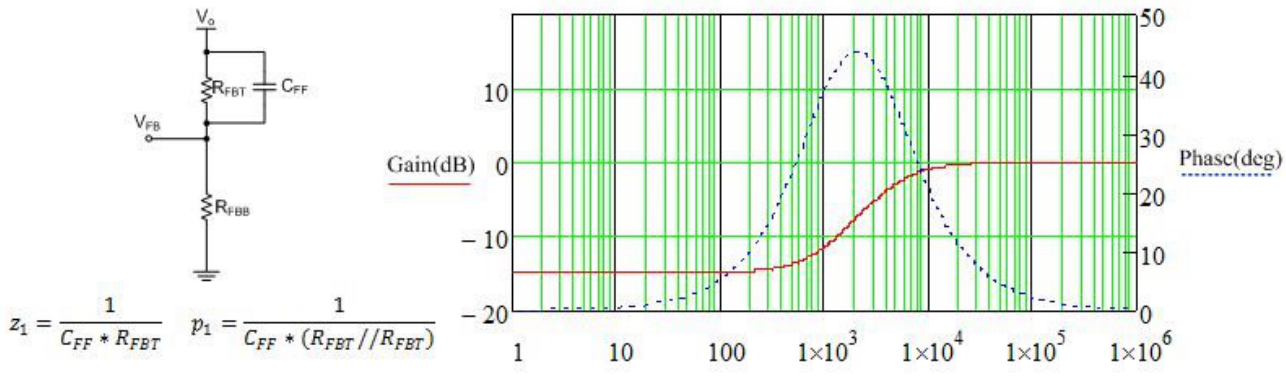

Figure 1. Feedback Divider with Feedforward Capacitor C_{FF}

Unfortunately, this solution isn't perfect either; while C_{FF} creates a zero to help increase bandwidth, it also creates a subsequent pole as a product of C_{FF} and the parallel combination of feedback resistors. This pole can negate the benefits brought about by the zero of the C_{FF}. Since C_{FF} adds a zero and a pole, which may not be too far apart in frequency, the choice and calculation of C_{FF} becomes tricky. The right C_{FF} value will help the situation, while a wrong C_{FF} value will bring no improvement and will just be a useless addition to the bill of materials (BOM).

How One Resistor Can Improve Performance

TurboTrans™ technology, shown in Figure 2, improves the loop response by adding just one resistor (R_{TT}). Adding an R_{TT} resistor enables you to optimize the feedback loop easily using a resistor outside of the module. By adjusting the TurboTrans resistor, you can optimize the zero and midband gain (A_{VM}) of the compensation stage as required. There are no side effects like that of a consequent C_{FF} pole with the use of a R_{TT} resistor.

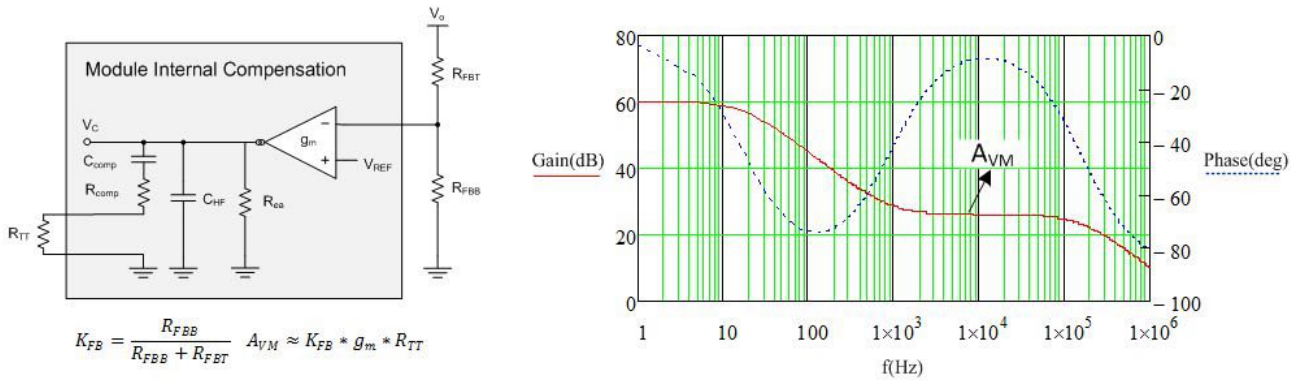

Figure 2. Power Module with TurboTrans Technology

The R_{TT} resistor is nothing but an additional series resistor in the Type II compensation scheme. This additional R_{TT} resistor doesn't require in-depth knowledge of loop compensation techniques because, like for any other power module, the data sheet will provide an equation to calculate the right value. Your calculation will simply depend on the amount of total output capacitance. The R_{TT} will compensate for any additional capacitance at the output, and the load transient response will remain spectacular.

TurboTrans in Action

Let's use TI's TPSM84824 to show how TurboTrans technology helps achieve a fast transient response. In order to meet the 3% range (recalling Table 1), the only thing you can do in the absence of TurboTrans technology is increase the output capacitance. As you can see in Figure 4 and Table 2, capacitance increments have little effect on the voltage droop. That's because with increasing output capacitance, the overall bandwidth of the regulator reduces considerably (as shown in Figure 3). This makes the loop slow and increases the time required to react to a load transient. Consequently, even with a large value of output capacitance, the power module still cannot maintain less than 30mV of voltage droop.

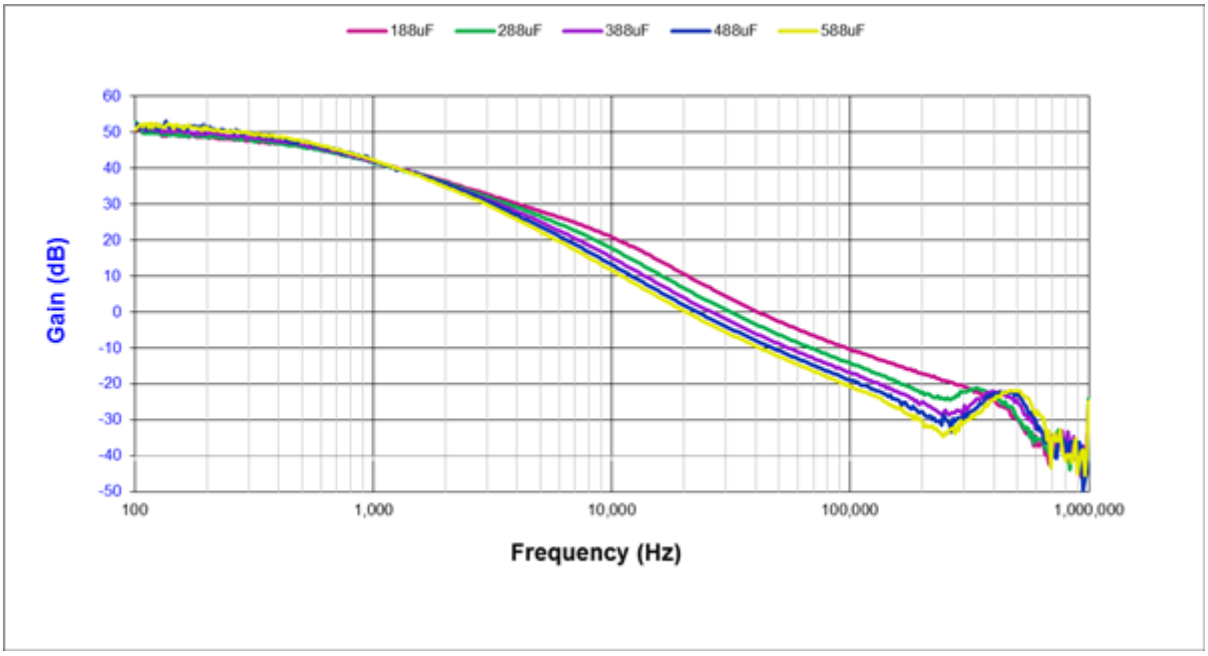

Figure 3. Gain Curve with Different Output Capacitance

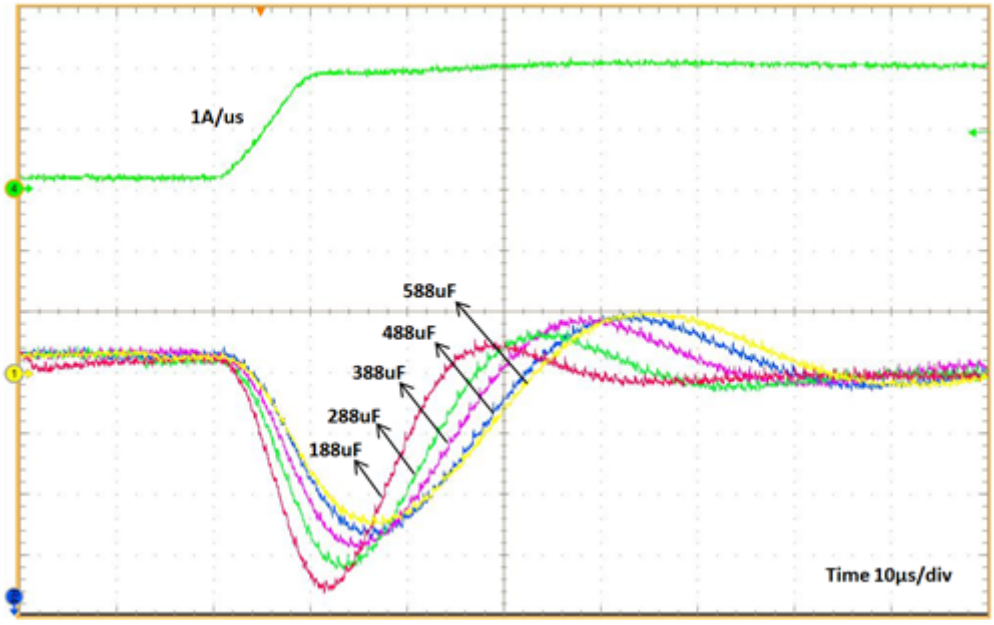

Figure 4. Transient Response with Different Output Capacitance

Table 2. Voltage Droop with Different Output Capacitance

Output capacitance (µF)	Crossover frequency (kHz)	Voltage droop (mV)
188	41.0	114.6
288	31.3	103.2
388	26.0	92.4
488	22.8	86.4
588	20.5	82.2

The situation improves if you use the TurboTrans feature. By adjusting the TurboTrans resistor, you can easily get 17.4mV of voltage droop, as shown in Figure 5.

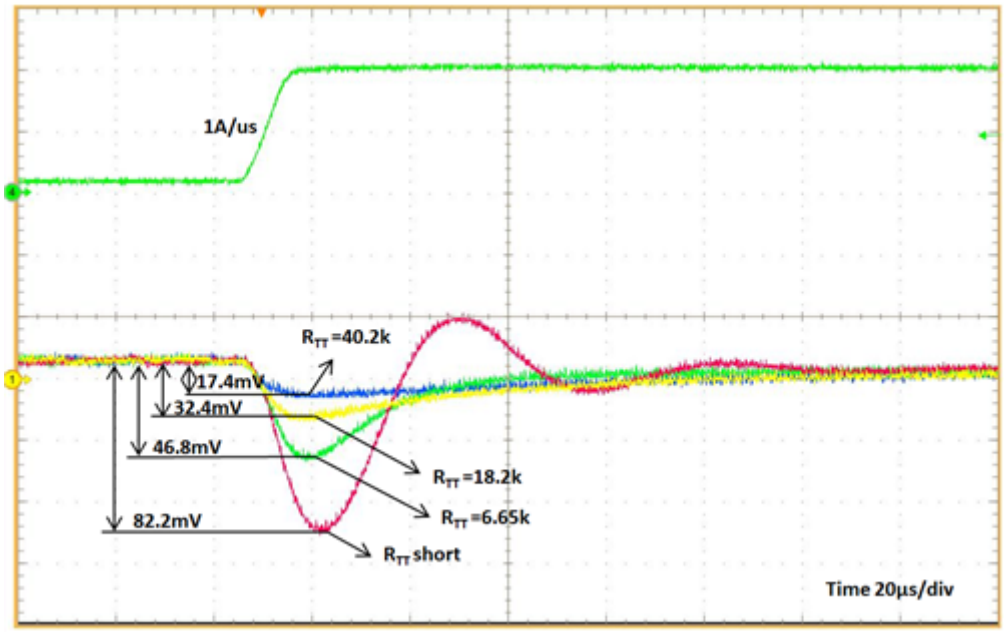

Figure 5. Transient Response with TurboTrans Technology

Conclusion

As the experimental results show, TurboTrans technology enables you to considerably improve the performance of your power module while potentially reducing the overall capacitance at the output. This not only boosts the performance of the applications, but also leads to reduced system cost and size.

Additional Resources

- Learn more about TI DC/DC power modules.
- Read the application report, "LMZ1050x/LMZ1050xEXT SIMPLE SWITCHER® Power Module – Quick Compensation Design."

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265