Transient Load Testing – How To Pick The Right Electronic Load

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Scope

As electronic system loads (integrated circuits, electromechanical devices, etc.) increase in current level and complexity, it places greater demands on incoming voltage sources to provide adequate current supply and voltage regulation. In turn, adequate testing of these regulators requires an equal increase in testing sophistication.

The scope of this paper is to discuss key factors regarding transient load testing for electronic voltage regulators. As most board-level power is locally regulated, we will focus on board-level loads and supplies.

Three areas will be discussed. These are:

- The nature of the loads themselves.
- How that nature affects voltage regulators.
- What load unit features are relevant to adequately simulate the required loads.

Load Review

In this paper, we will be discussing PCB-level DC electronic loads. Each of these contains the following elements:

- Minimum current value.
- Maximum current value.
- Thermal current value.
- Dynamic change over time, both during start-up and during normal operation.
- Specified supply voltage set point and tolerance for acceptable operation. Voltage requirements may vary under different operating conditions.

Voltage Regulators

Voltage regulators may be either linear or one of the various switching regulator types. They may be on board or off board. However, each provides a voltage defined according to several parameters:

- Initial output tolerance.
- Variation with temperature.
- Long term drift.
- Input line regulation.
- Output load regulation.
- Output ripple and noise.
- Dynamic response.
- Output impedance.

A Bit of (Hopefully) Useful History…

Those of us who have been around for a while have observed how dramatically computers and other electronic systems have changed over time. Computer enclosures went from buildings to cabinets to boxes to boards to ever-shrinking chips. Power systems have followed suit.

Somewhere in the Middle Ages of computing (late 1980s), power systems began a major shift. Starting as multiple boxes of low voltage outputs with hundreds to thousands of amperes of capacity, they gave way to a higher voltage central sources with board-level distributed regulation. This trend spread to smaller machines. By the early 2000s, desktop computers regulated high current outputs separately, relying more and more on the 12V output of their silver box supply rather than 5V or 3.3V.

Notebooks carried the concept even further, with a single output brick supply and all-local regulation. Recent notebook generations have further evolved, becoming much like power systems found in smart phones. Multiple board-level voltage regulators and load switches combine to save energy and reduce heat, allowing simultaneous increases in performance and battery life.

Processors and other large ICs follow suit, shutting down unnecessary portions and functions to save heat, allowing bursts of higher performance without overheating. They also do it in concert with the regulators powering them, optimizing voltage as performance and power savings dictate.

So why the history lesson? History is a flow, where the past explains the present and informs future direction. There are four takeaways from this regarding our topic:

1. Semiconductor improvements and increased demand management have significantly increased step current requirements over early computing, making greater demands of power sources.
2. Accordingly, verification of power sources increasingly requires emphasis on response to load transients.
3. Because both loads and power sources are now distributed on the same board, test loads must be similarly located. External load units with long connections are inadequate for transient testing.
4. The dual trends of decreasing size (increasing integration) and increased power management will continue. Power management techniques will expand in depth and complexity for large ICs and will propagate more to medium and smaller ICs.

Load Slammers

Devices made to assist in transient load testing have been called transient generators, transient load testers, voltage transient testers, or mini slammers. They are also called 'load slammers' because they change the voltage load rather emphatically. Many load slammers are custom made, but they can be purchased as well. Whether you solder it up yourself or not, what makes a good load slammer? Here are some areas for consideration:

- Fast step transition rate.
- Controllable transition rate.
- Controllable step frequency and duty cycle.
- Arbitrary load profile capable.

- Low impedance connection to circuit board.
- Adequate dissipation capability.
- Protection circuitry.
- Instrumentation output.
- Easy to use.
- Cost.

Let's take these one at a time.

Step transition rate needs to be significantly faster than the voltage regulator control loop to adequately exercise the converter. Since various converters have different loop bandwidths, how fast is fast enough? In terms of current slew rate, fast enough also depends on the size of the load step.

For example, consider a load step of 2 A with a slew rate of 2 A/usec. Total transition time is 1 usec, which we will equate to rise time (10% to 90%). Rise time is approximately 2.2 times the circuit time constant τ, which equals 1/(2*π*f). F calculates to 350 kHz, which is significantly faster than most loops so can provide useful step loading and information.

However, if the load step is 120 A with the same slew rate, then transition time is 60 usec, which correlates to a frequency of 5.8 kHz. That is dismally slow for exercising a high-performance voltage regulator! Rather, we would want a slew rate of at least 120 A/usec, or even 1000 A/usec or faster for the fastest multiphase regulators.

With small local load slammers, maximum slew rate will be limited by board and connector parasitics, so as they say, your mileage may vary. But it will still be orders of magnitude better than an external load unit.

Beyond that, there is the issue of accurately measuring a current transition that fast. Current probe loops introduce far too much inductance to allow fast transients, and even chip resistors for current sensing must be compensated for their internal inductance. We will leave that topic as outside of the scope of this paper.

Controllable transition rate is necessary as discussed above for different load step magnitudes to achieve a desired overall transition speed. It can be employed to match varying di/dt requirements of the actual load. If fast enough, it can help debug the system decoupling solution.

Controllable step frequency and duty cycle help tailor the test to a particular converter. For example, a very fast loop may recover quickly enough that a slow repetition rate yields little information other than a very brief recovery time. On the other hand, a slow loop simply won't respond to fast step frequencies. It yields information about the output decoupling, but little about the converter loop.

Arbitrary load profile capability allows a load to vary in a nonlinear manner over time. It can be used to imitate start up and state change currents, or specific functions (read/write, processor operations, electromechanical loads).

For best performance, a load slammer should have a **low impedance connection to the circuit board**. Since there is typically not room for mounting the slammer on the board, a multi-pin, low inductance connector should be placed appropriately to allow it to plug in directly. Once system operation is verified, subsequent board builds may remove the connector footprint or simply not install it.

For DC testing, as well as thermal testing, it is desirable for the load slammer to have **adequate dissipation capability**. This is a challenge for small load slammer units due to their size. Some are better than others, but it may be necessary to use a larger external load unit or resistor bank for this testing.

Protection circuitry is a second area where slammers bow to larger external load units. They typically are less robust in terms of overvoltage shutdown, reverse voltage protection, overtemperature, and the like. But do they at least have some protection such as fusing or temperature sensing? Or are they priced low enough that they can be considered disposable?

What **instrumentation output** is available from the load slammer? Does it read DC current and voltage? Transient response voltage? How fast does it update? How accurate is it? Most slammers are not calibrated. Do you need that, or are you okay with an uncalibrated device? Or, does the unit simply have a coaxial connector or other test points for plugging in a scope probe?

Next, to get the most out of a load slammer, it must be **easy to use**. This speaks mainly to the GUI used to set up and operate the load. Does the software install easily and work properly? Is it buggy? Is it easy to initialize and operate? Can it be integrated into a larger automated system?

In the final analysis, users will balance the features that they need versus those that they would like to have, which brings us to cost.

Cost is always a factor, and not just for limited budgets. If you need the best, you can always buy the best. However, if a less expensive load slammer does what you need for a specific application, it can minimize your investment, freeing more money for other things. You may be able to simply expense it and be up and running, rather than wading through the capital equipment process. That saves time as well as money. It may also allow purchasing of dedicated units for each lab bench or for each production test fixture.

Conclusion

As electronic systems evolve, board level loads create greater challenges for the voltage regulators that power them. Accordingly, verifying operation of these regulators requires a different approach and different form factors for test equipment. Small, locally mounted load slammers can provide significant transient load advantages over traditional, more expensive, external load units.

Our next paper will discuss how load slammers can be used to exercise, debug, and verify voltage regulators.