Application Note

Short-to-Ground Testing on TI High Side Switches

Alan Whitehead

ABSTRACT

High-side switches, commonly used in automotive and industrial applications, must demonstrate robust fault tolerance to maintain safety and reliability under abnormal operating conditions. A short-to-ground (STG) fault, where the load side of the switch is pulled to ground while the device is active, can induce high current stress and thermal shutdown. This application note outlines the test setup considerations, waveforms, pass/fail criteria, and results to better understand the dynamics of STG behavior. Identifying this performance allows for device robustness to be evaluated as well as the improvement of system reliability.

Table of Contents

List of Figures

List of Tables

Trademarks

All trademarks are the property of their respective owners.

1 Understanding Short-to-Ground Events

In a system there are two primary types of short scenarios, enable into short, and a hot short. An enable into short happens when the device is shorted while unpowered and is enabled into a short triggering the current limit protection. A hot short however is when the device is actively applying power to a load and is shorted triggering the current limit protection. The hot short scenario is understood to be the most severe because the device is heated due to the active FET before the short happens. The results in this document come from testing TI high side switches in a hot short.

2 Device-Level Protection in TI High Side Switches (HSS)

The devices tested are the TPS1HC100, TPS1HC30, and TPS2HC08, which have internal protection features during a STG event that can alert users of the fault while preventing damage. The adjustable current limit allows the device to clamp the inrush current under start up and short circuit events. The current limit holds the current to a set value and pulls up the SNS pin to VSNSFH. After the fault is asserted, the device turns off after the device reaches relative or absolute thermal shutdown.

3 Test Setup

To test device behavior under this condition, each short had to be a controlled variable in the test. This was established by wrapping wire around a PVC pipe to mimic the resistive and inductive properties of a short in an automotive system. This can be seen as a damaged wire harness, connection or pin failure, improper assembly, and a faulty load. Each situation can present a different level of stress to the high side switch. In addition, each high side switch was tested across a range of input voltages to see how the units reacted under higher power dissipation and thermal rise. Furthermore, each unit was shorted 50 times at each level to verify a device failure was not present. Table 3-1 displays the test procedure established when evaluating each device.

Table 3-1. Test Procedure

Short Cable		Iterations	12V	15V	18V	ABS MAX
10.1uH	180mΩ	50	PASS/FAIL	PASS/FAIL	PASS/FAIL	PASS/FAIL
4.7uH	102mΩ	50	PASS/FAIL	PASS/FAIL	PASS/FAIL	PASS/FAIL
0.7uH	63mΩ	50	PASS/FAIL	PASS/FAIL	PASS/FAIL	PASS/FAIL
0.2uH	43mΩ	50	PASS/FAIL	PASS/FAIL	PASS/FAIL	PASS/FAIL

As previously described, this document highlights how the devices behave in a hot short condition. To confirm each unit was getting as hot as possible before the short, the maximum nominal current displayed in each data sheet was used during this evaluation. This was in parallel to the short configuration. Figure 3-1 displays the hardware set up to test each high side switch.

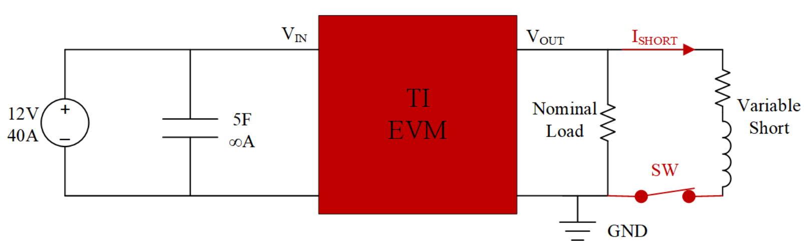

Figure 3-1. Short to Ground Hardware Schematic

A 5-farad capacitor was placed in parallel between the supply and the HSS. This was to establish the maximum amount of current was applied during the STG test essentially preventing the supply from limiting the inrush current. Furthermore, a 330uF capacitor was connected across the input of each EVM to maintain proper load regulation when in a STG condition. Load regulation refers to how the power supply's output voltage changes in response to variations in the load current. So, as the short was applied the input voltage can collapse if there was no capacitor to mitigate this load current change.

Moreover, to create the short the same way each time a STG board was used in this application. This is a test board intentionally designed to simulate STG faults in a system. To trigger each fault 5V was applied to the board acting as a switch between the live STG coil and the EVM ground plane.

3.1 Validation and Results

Table 3-2 outlines the results of each test. A passed test is determined by the device successfully providing power to the maximum nominal load after the short is applied. Each device was able to pass every short condition with no failures.

Table 3-2. TPS1HC100, TPS1HC30, and TPS2HC08 Test Results

Short Cable		Iterations	12V	15V	18V	ABS MAX
10.1uH	180mΩ	50	**PASS**	**PASS**	**PASS**	**PASS**
4.7uH	102mΩ	50	**PASS**	**PASS**	**PASS**	**PASS**
0.7uH	63mΩ	50	**PASS**	**PASS**	**PASS**	**PASS**
0.2uH	43mΩ	50	**PASS**	**PASS**	**PASS**	**PASS**

As each device passed, the waveforms varied across each short. The key here is the on state resistance (RDS(ON)) of each high side switch. Lower RDS(ON) is typically better for normal operation this means there is lower power dissipation, but allows more current in a short which stress the device. Figure 3-2 through Figure 3-4 display the 18V waveform for each device shorted with the lowest resistance and inductance. This is the highest input voltage specified in the recommended operating conditions of each high side switch.

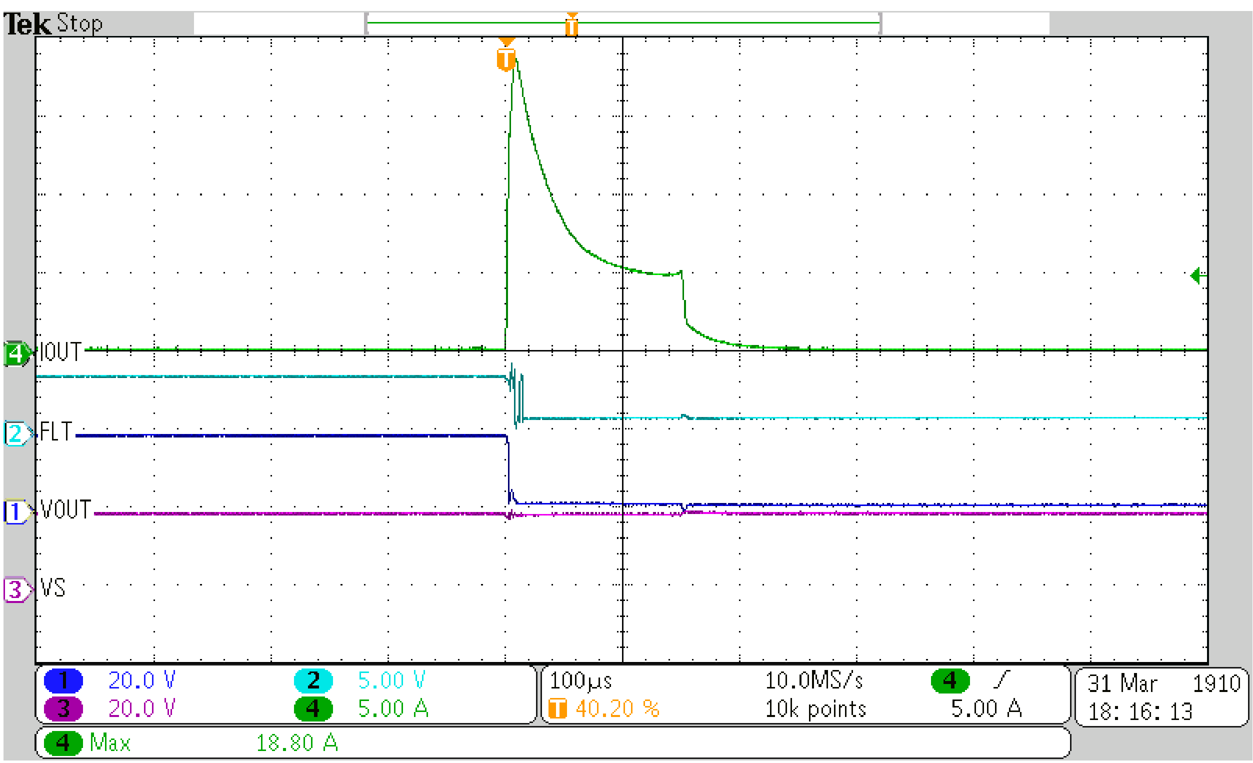

Figure 3-2. TPS1HC100 at 18V-0.2uH-43mΩ

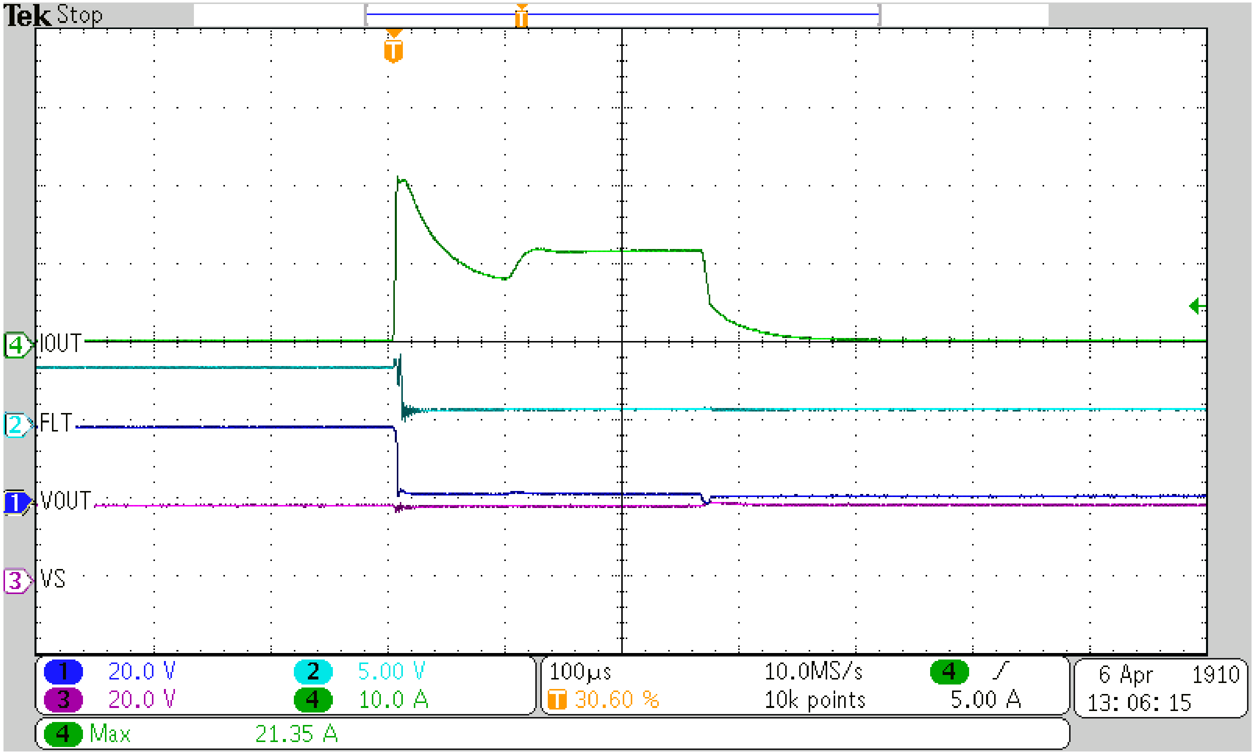

Figure 3-3. TPS1HC30 at 18V-0.2uH-43mΩ

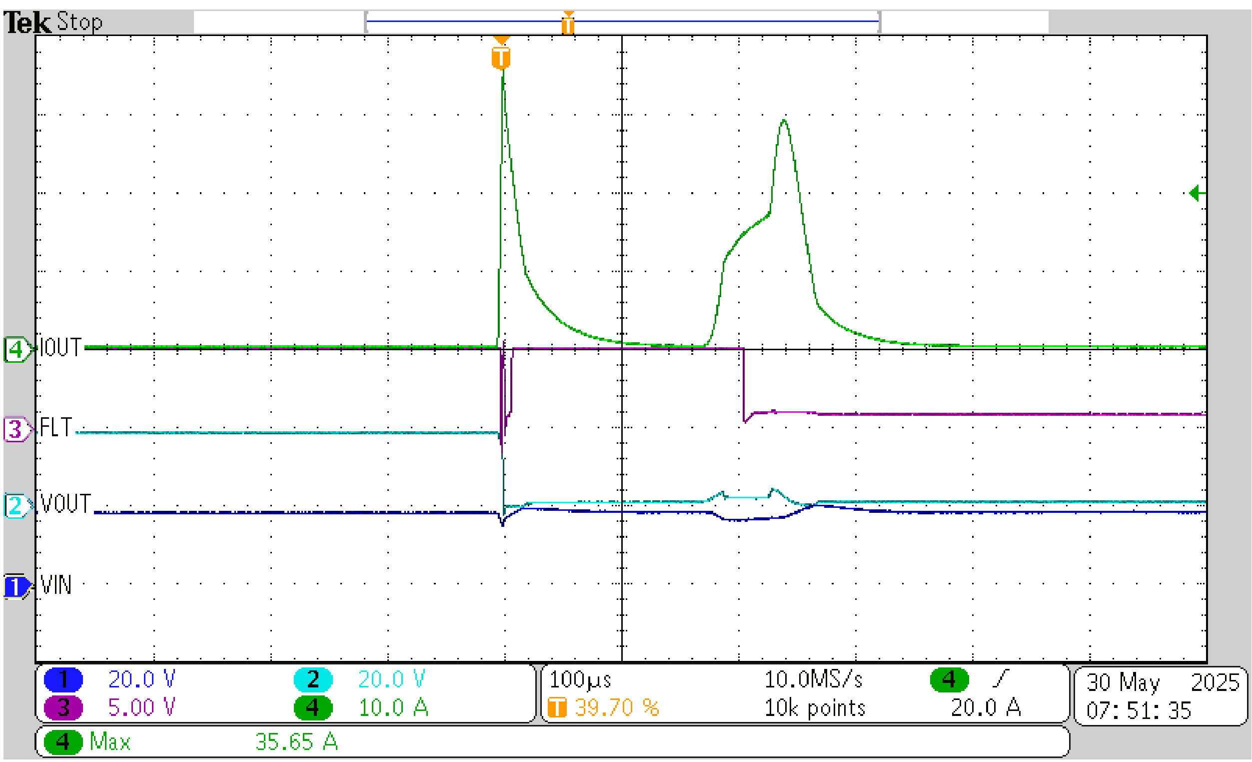

Figure 3-4. TPS2HC08 at 18V-0.2uH-43mΩ

As previously stated, each waveform reveals the short circuit current rising s the RDS(ON) of the high side switch decreases. With the TPS2HC08 seeing approximately 36A as soon as the short is applied. Furthermore, as seen in each waveform, the FLT is pulled low when the short is detected alerting the controller of a failure in the system.

4 Additional Information

Figure 4-1 and Figure 4-36 are the waveforms captured for each device. The data shown is for the 12V-18V short to ground scenarios that are within the recommended operating conditions of each device.

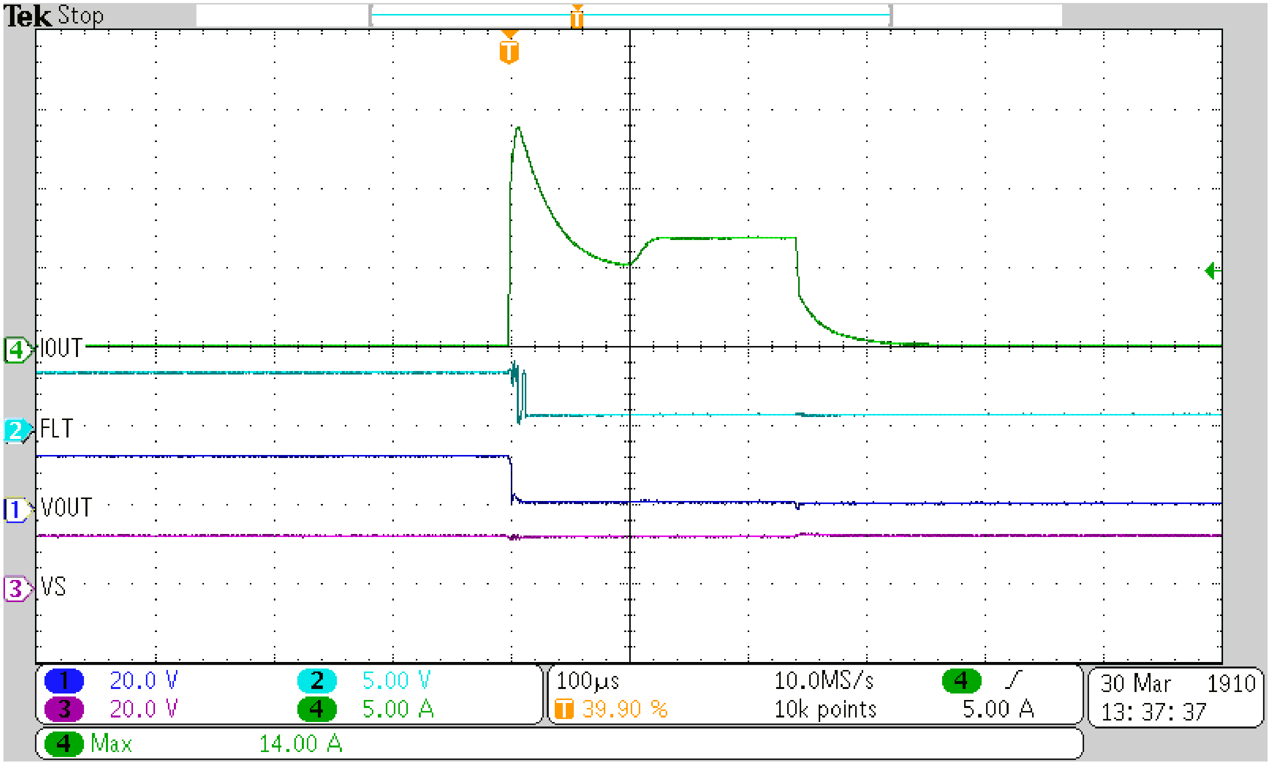

Figure 4-1. TPS1HC100-0.2uH-12V

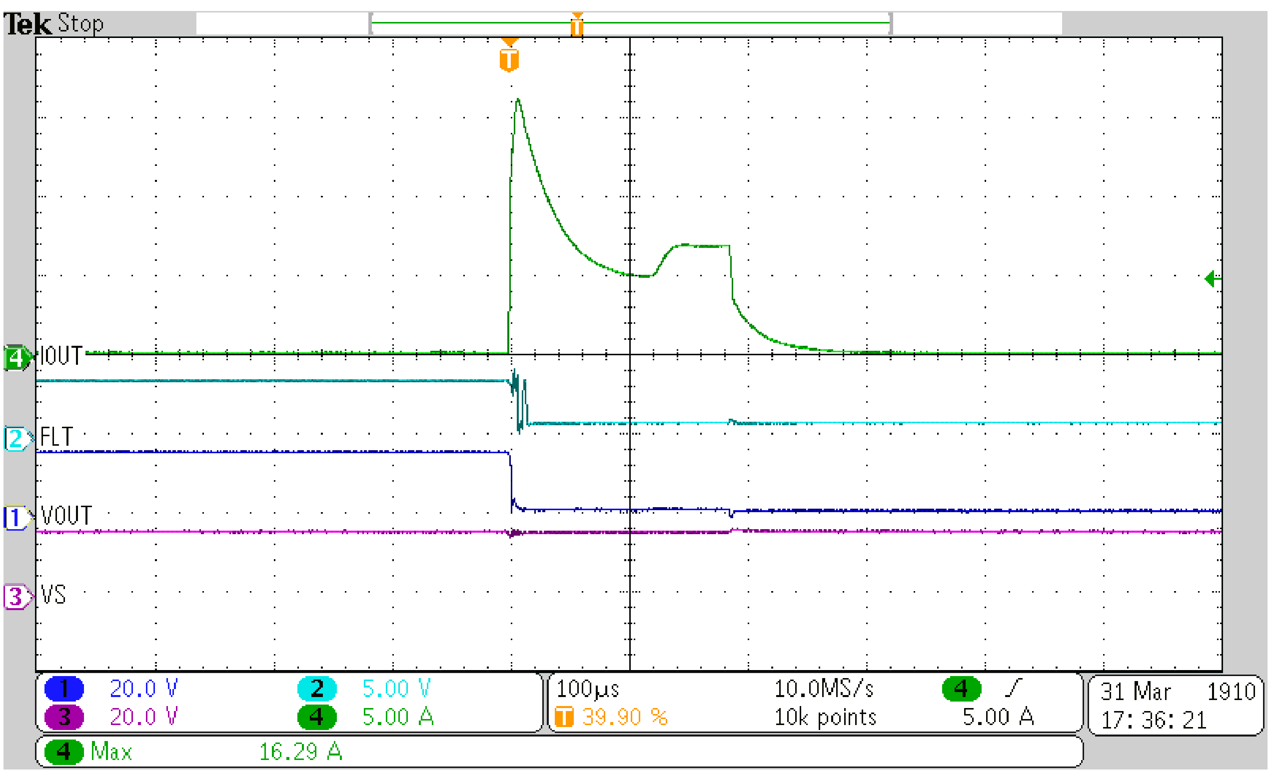

Figure 4-2. TPS1HC100-0.2uH-15V

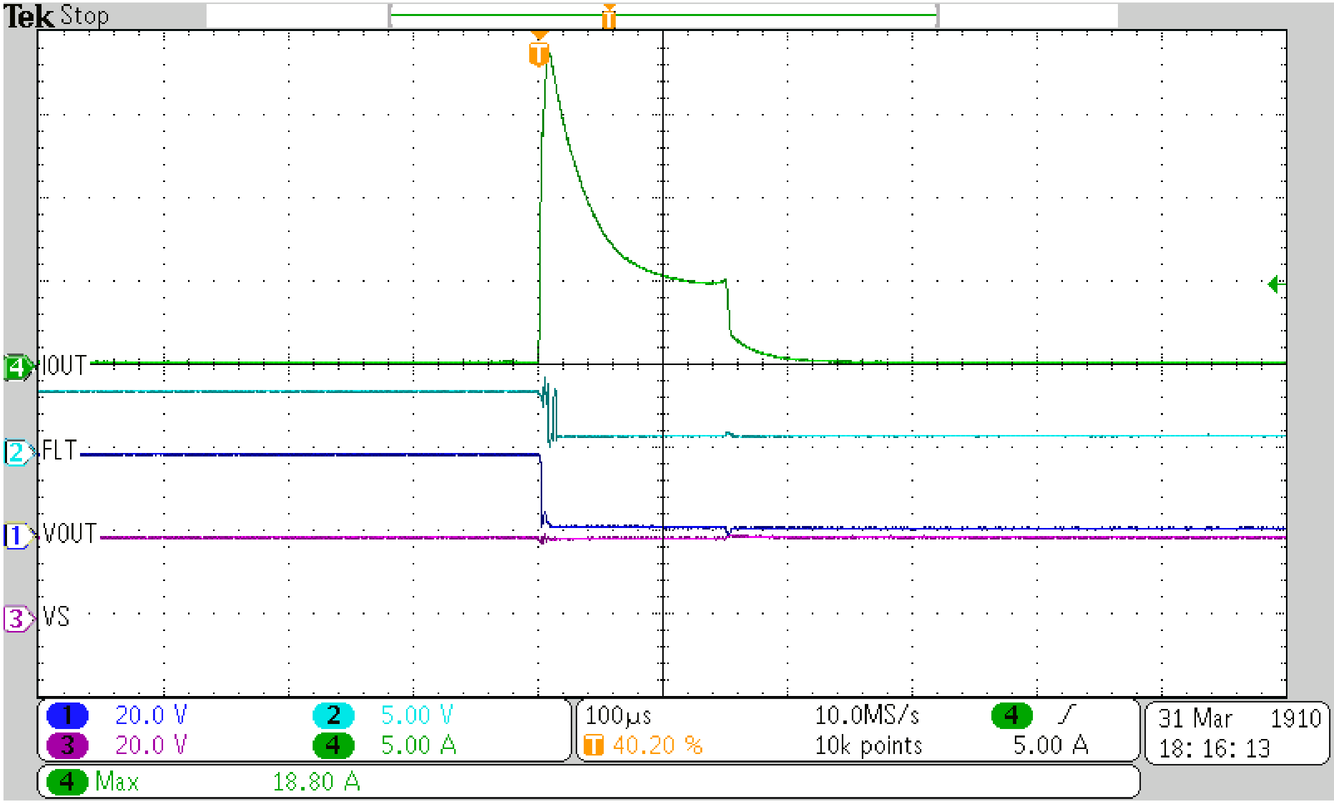

Figure 4-3. TPS1HC100-0.2uH-18V

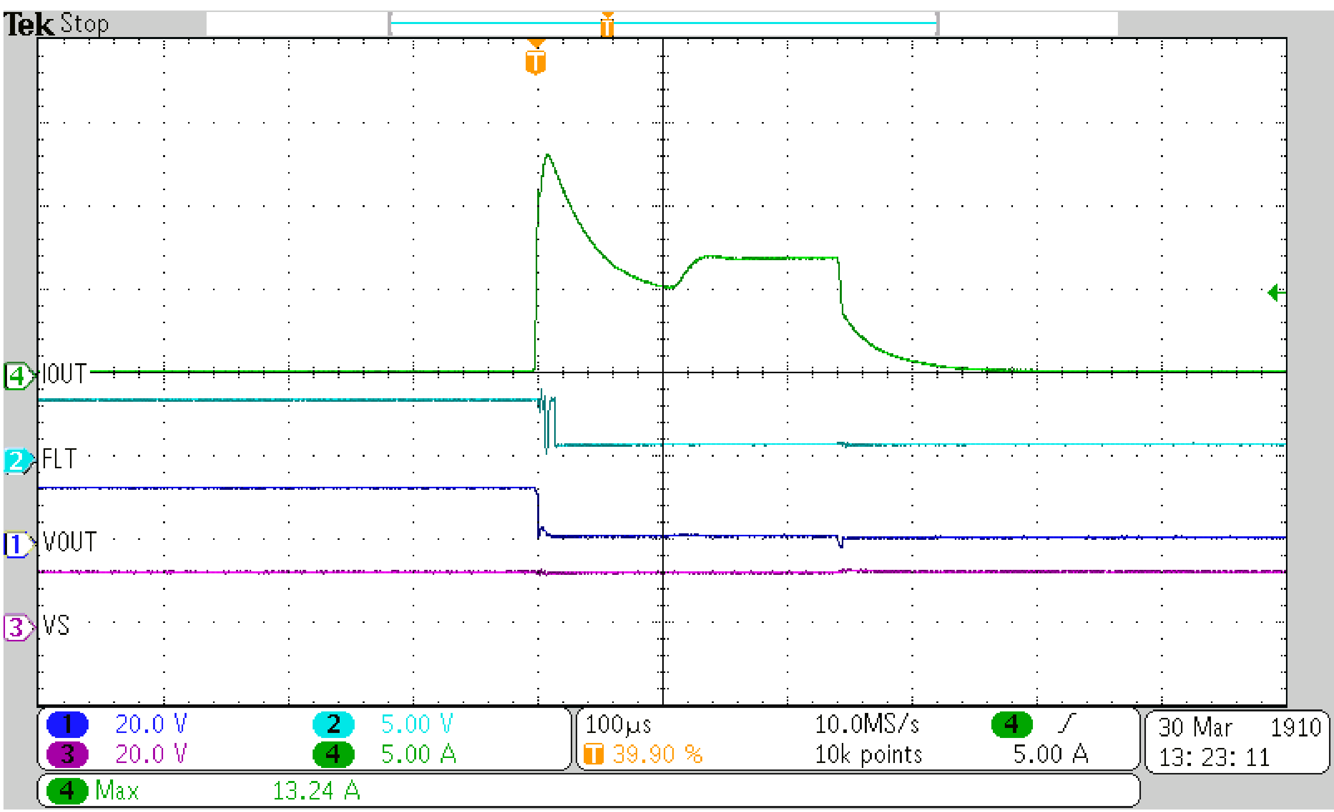

Figure 4-4. TPS1HC100-0.5uH-12V

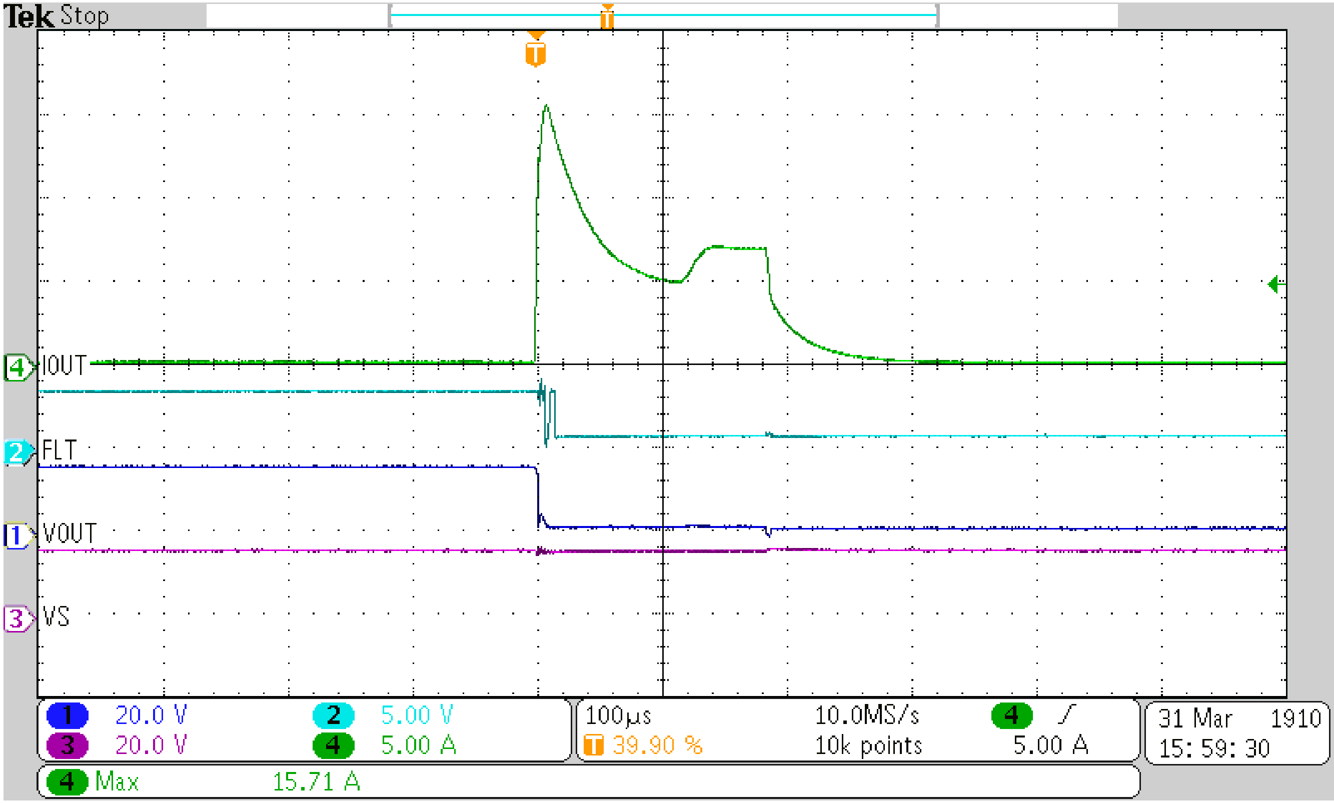

Figure 4-5. TPS1HC100-0.5uH-15V

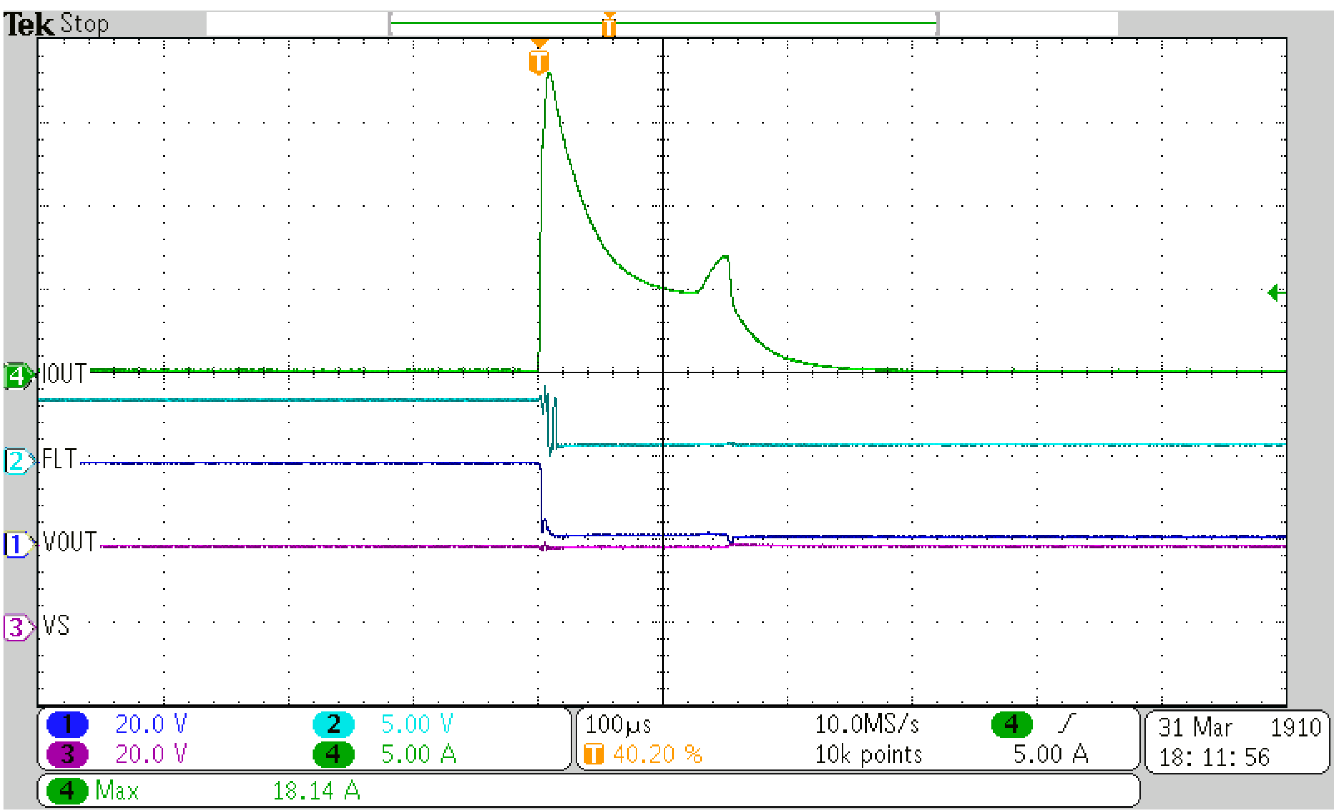

Figure 4-6. TPS1HC100-0.5uH-18V

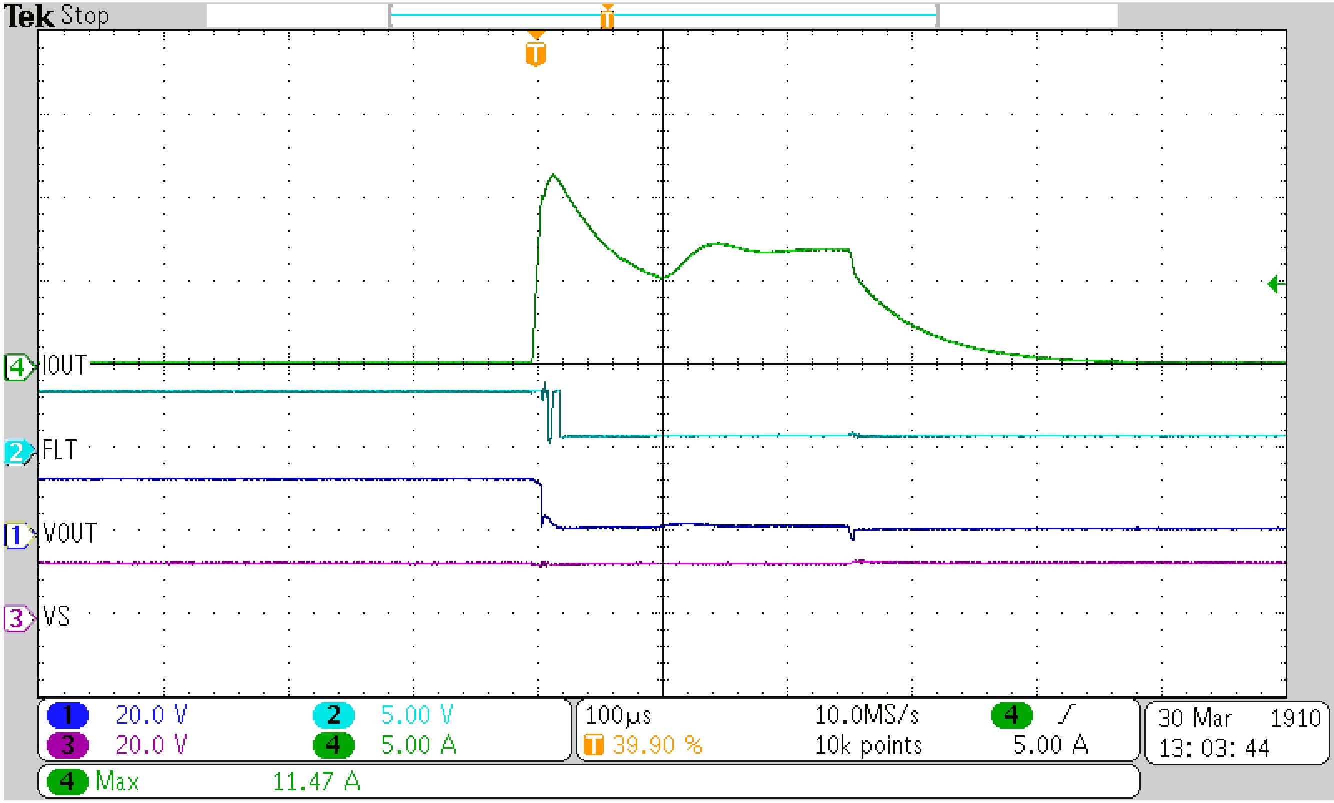

Figure 4-7. TPS1HC100-5uH-12V

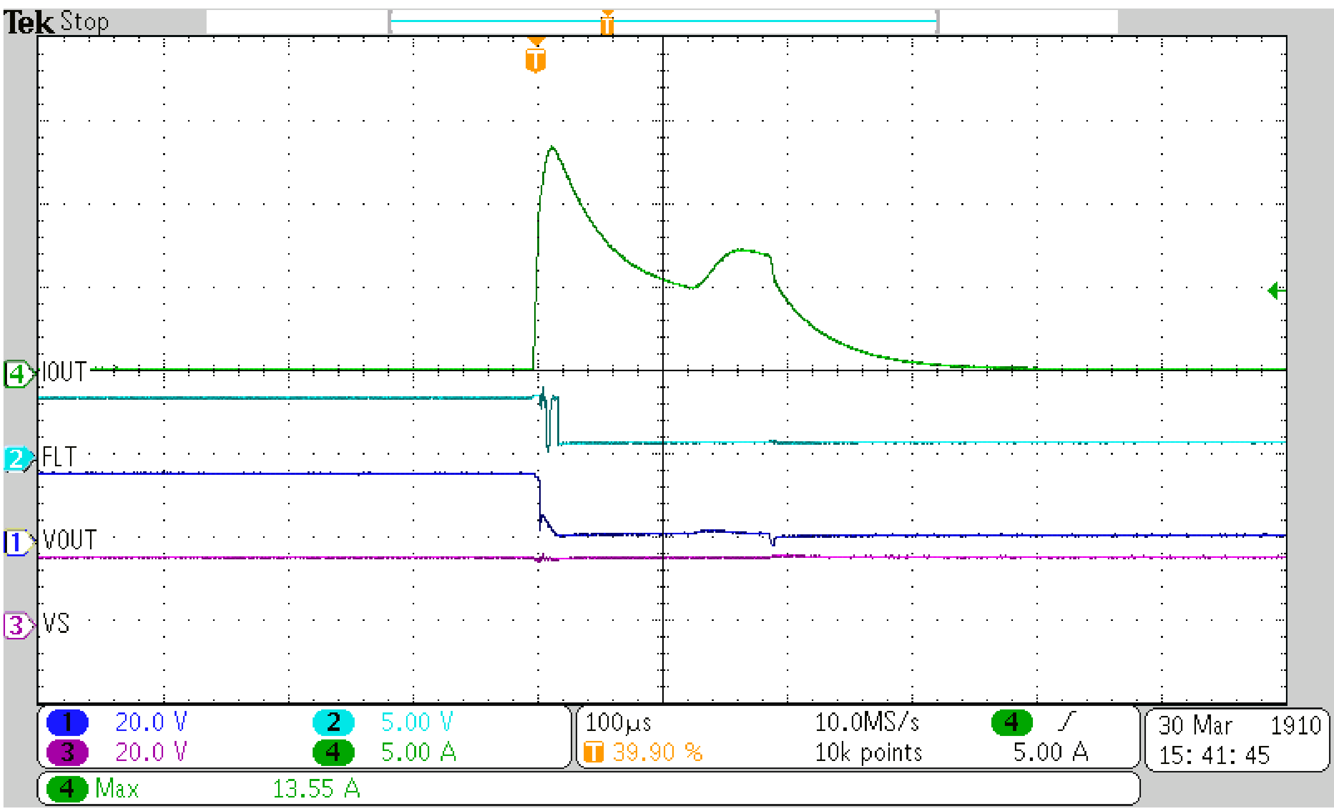

Figure 4-8. TPS1HC100-5uH-15V

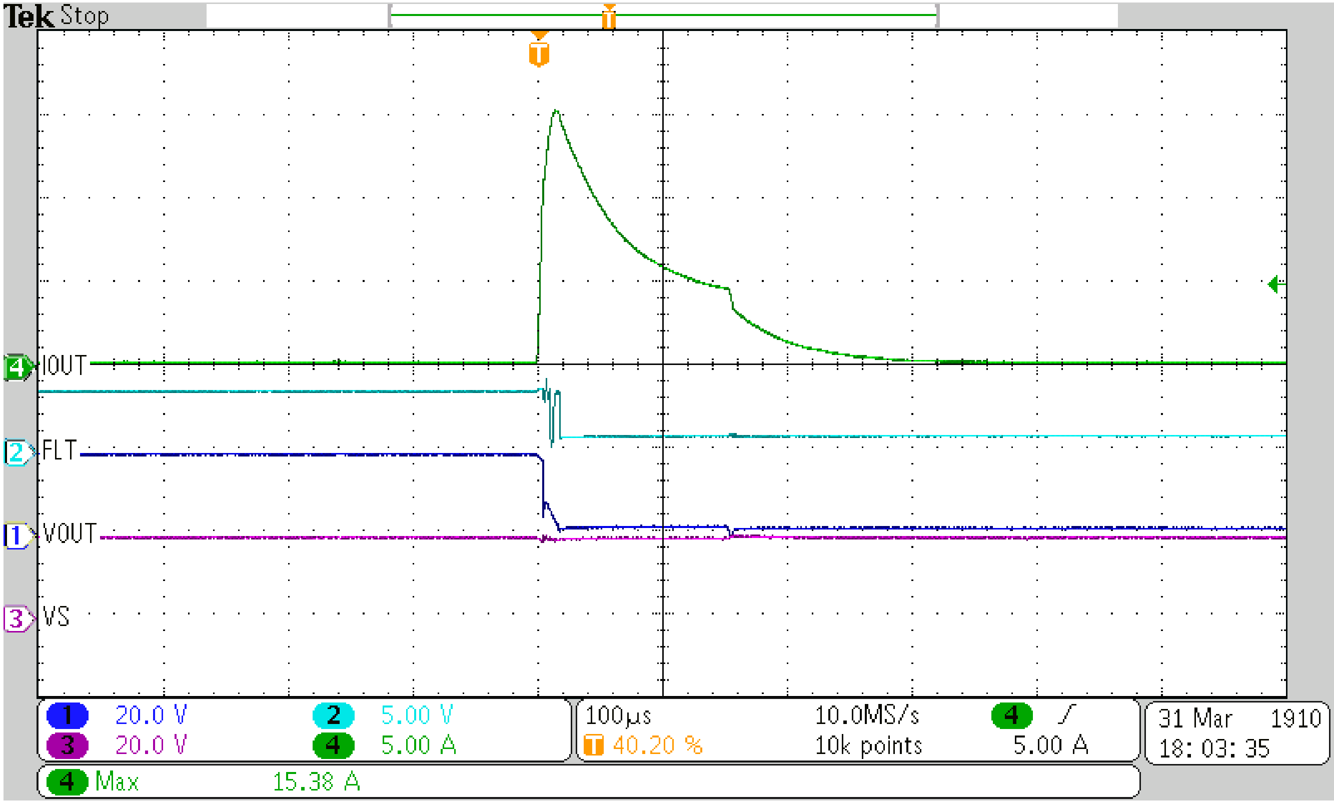

Figure 4-9. TPS1HC100-5uH-18V

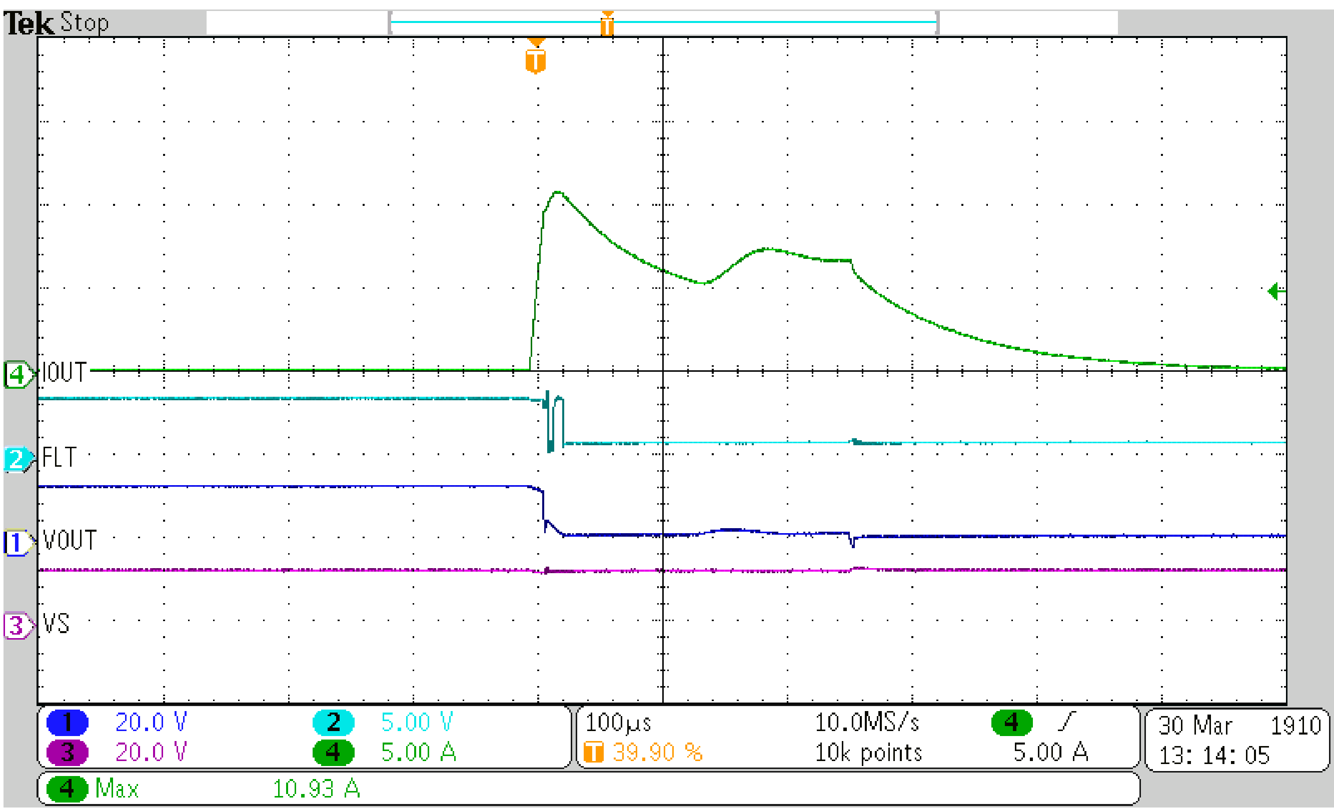

Figure 4-10. TPS1HC100-10uH-12V

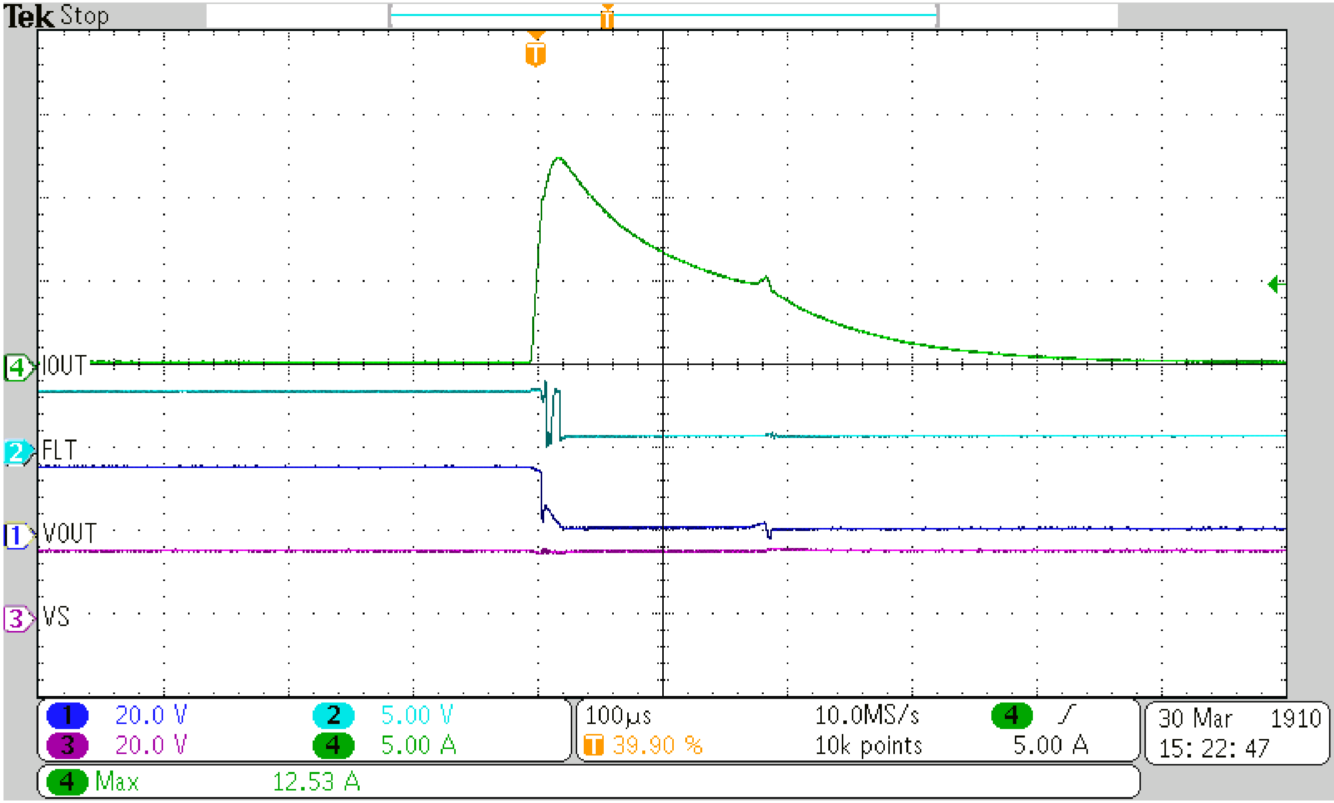

Figure 4-11. TPS1HC100-10uH-15V

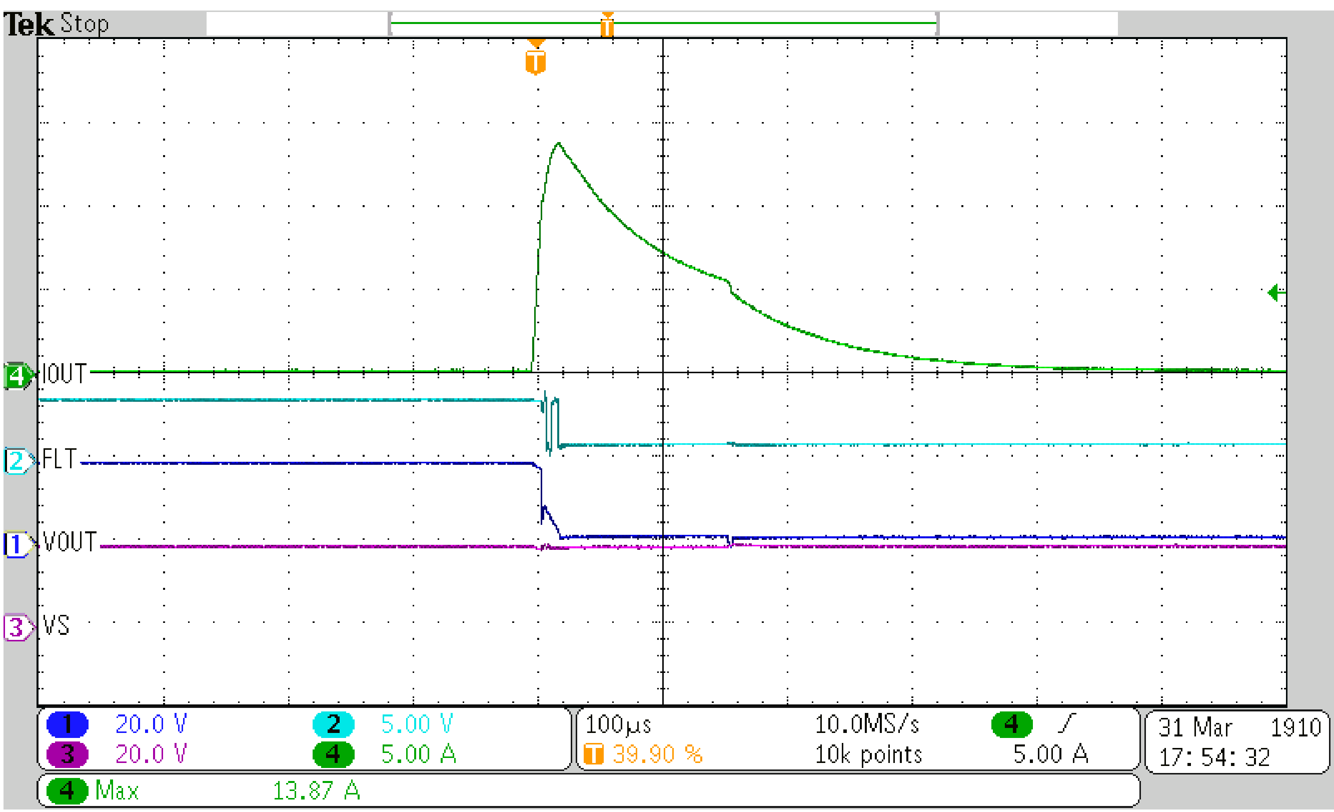

Figure 4-12. TPS1HC100-10uH-18V

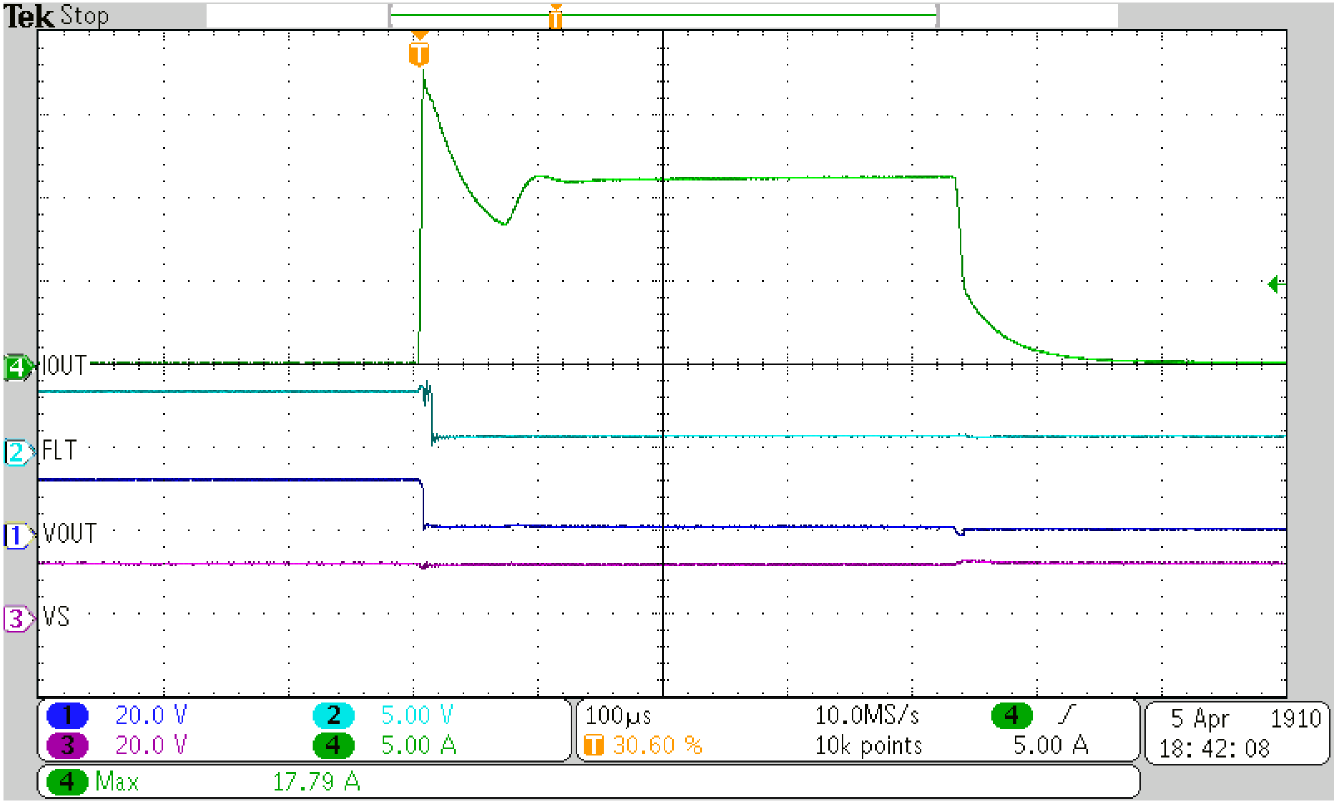

Figure 4-13. TPS1HC30-0.2uH-12V

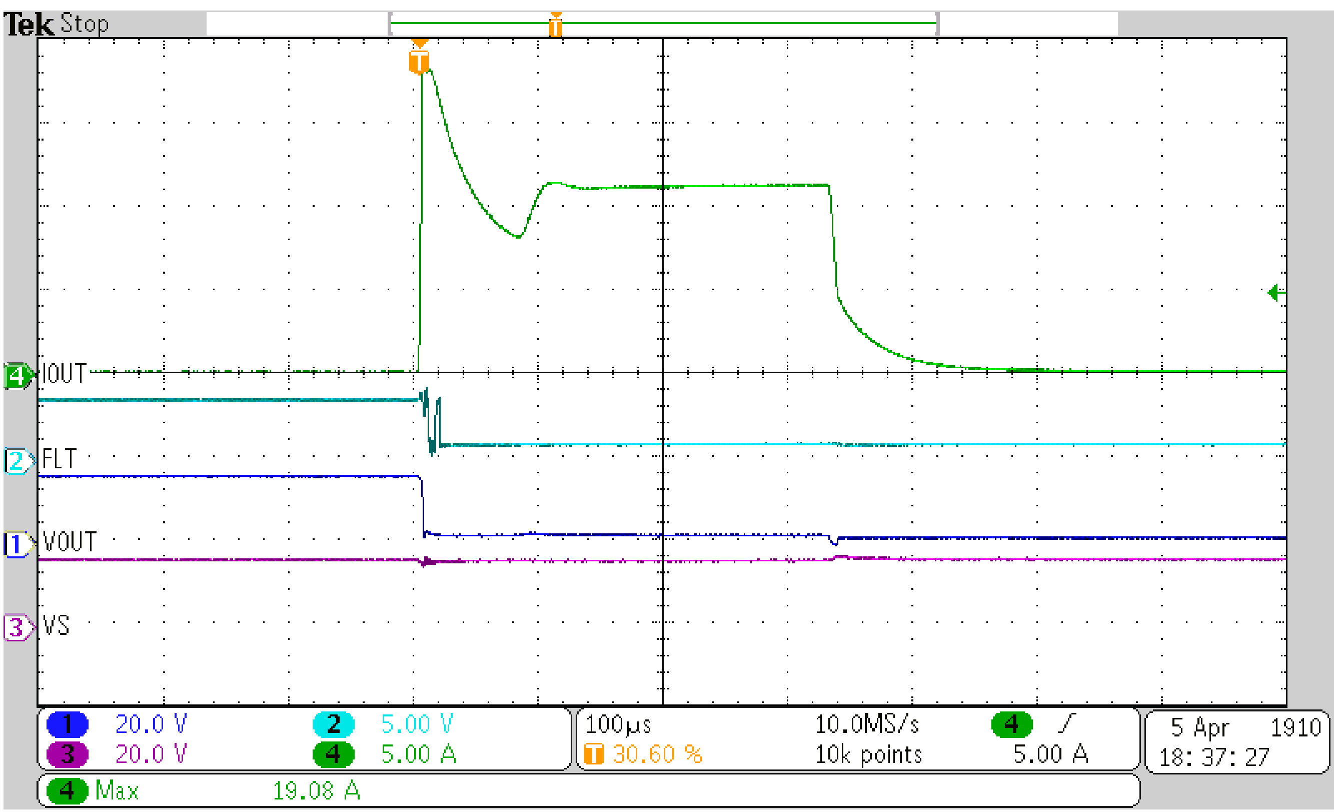

Figure 4-14. TPS1HC30-0.2uH-15V

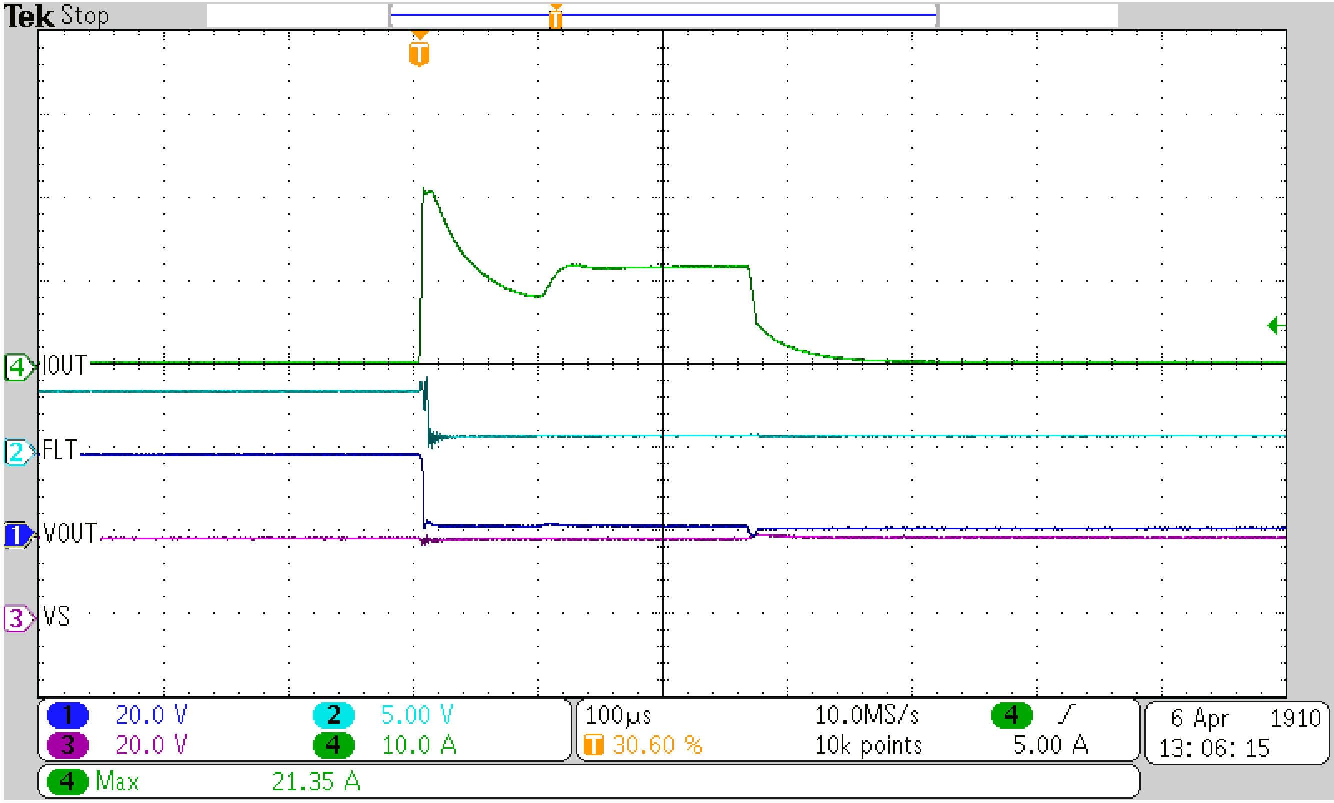

Figure 4-15. TPS1HC30-0.2uH-18V

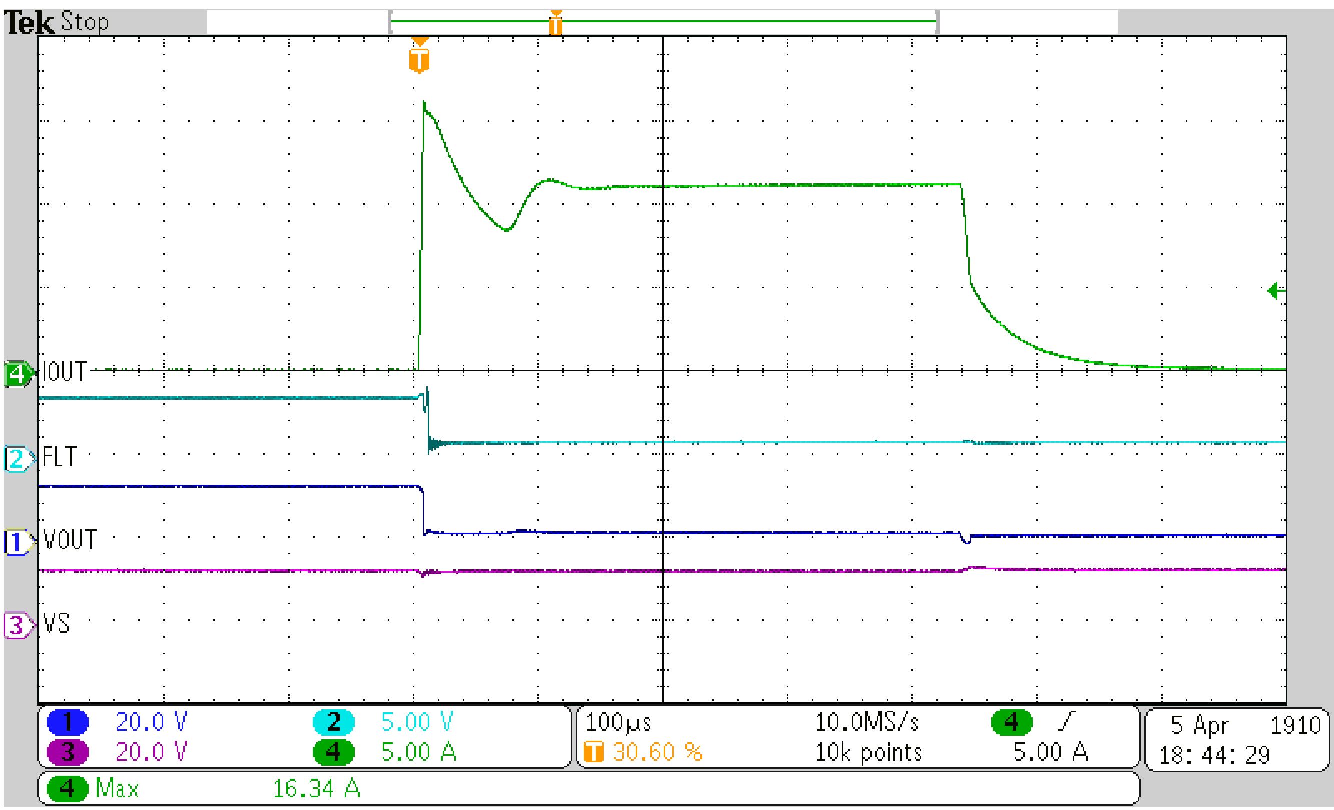

Figure 4-16. TPS1HC30-0.5uH-12V

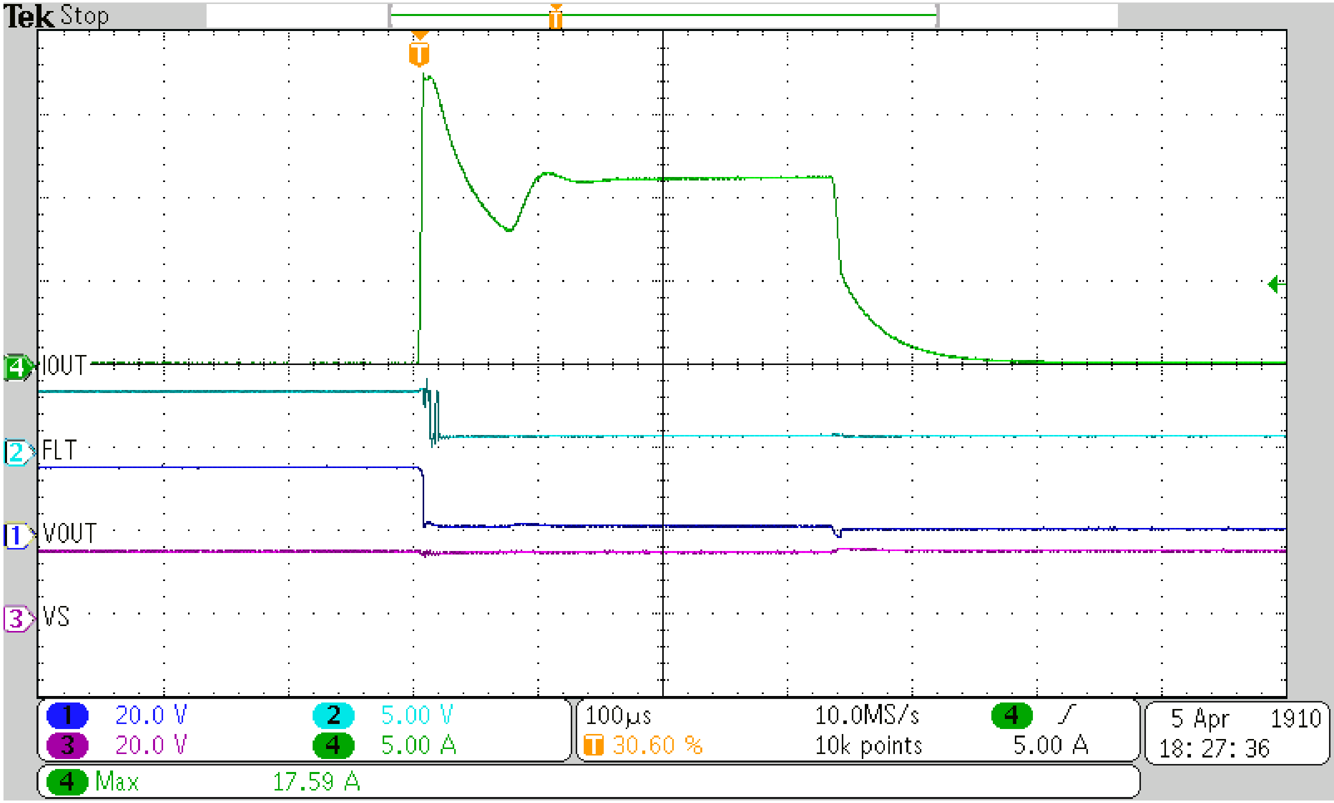

Figure 4-17. TPS1HC30-0.5uH-15V

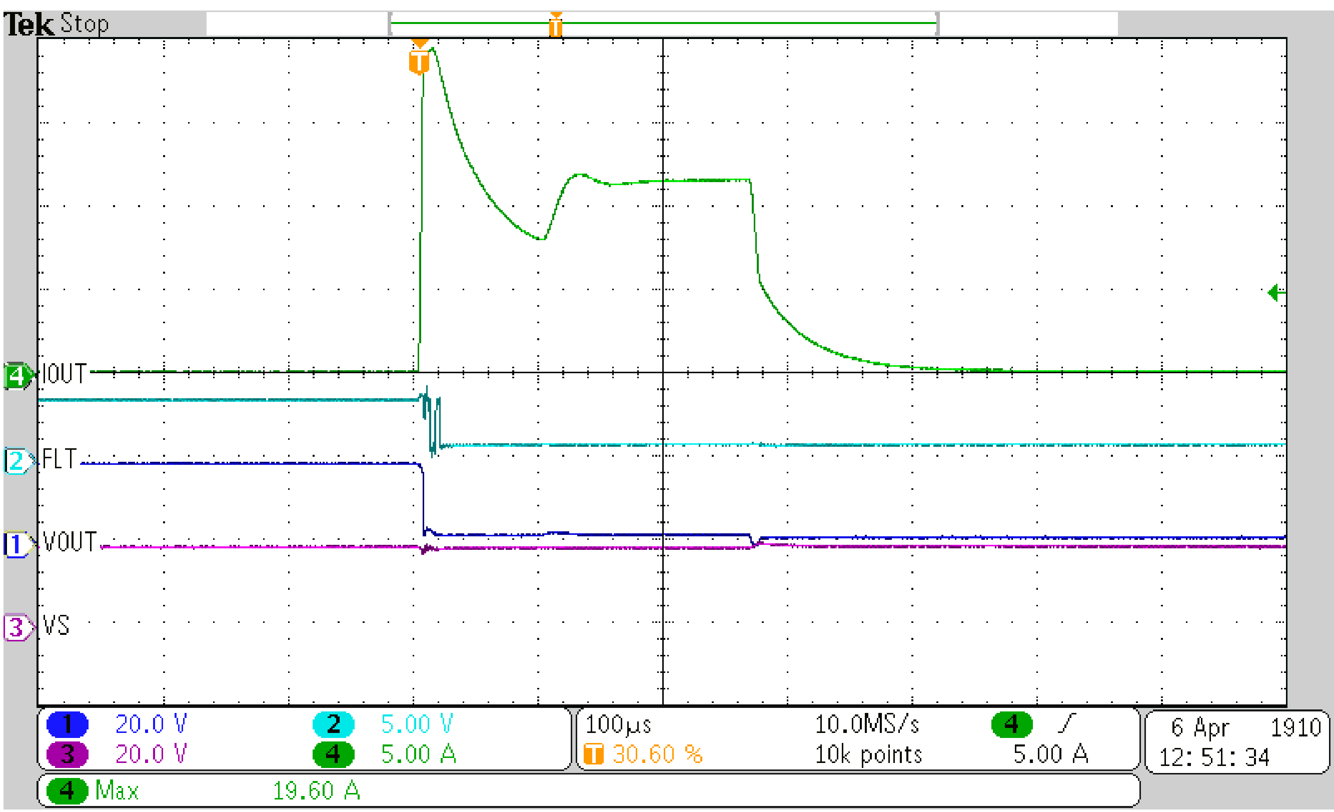

Figure 4-18. TPS1HC30-0.5uH-18V

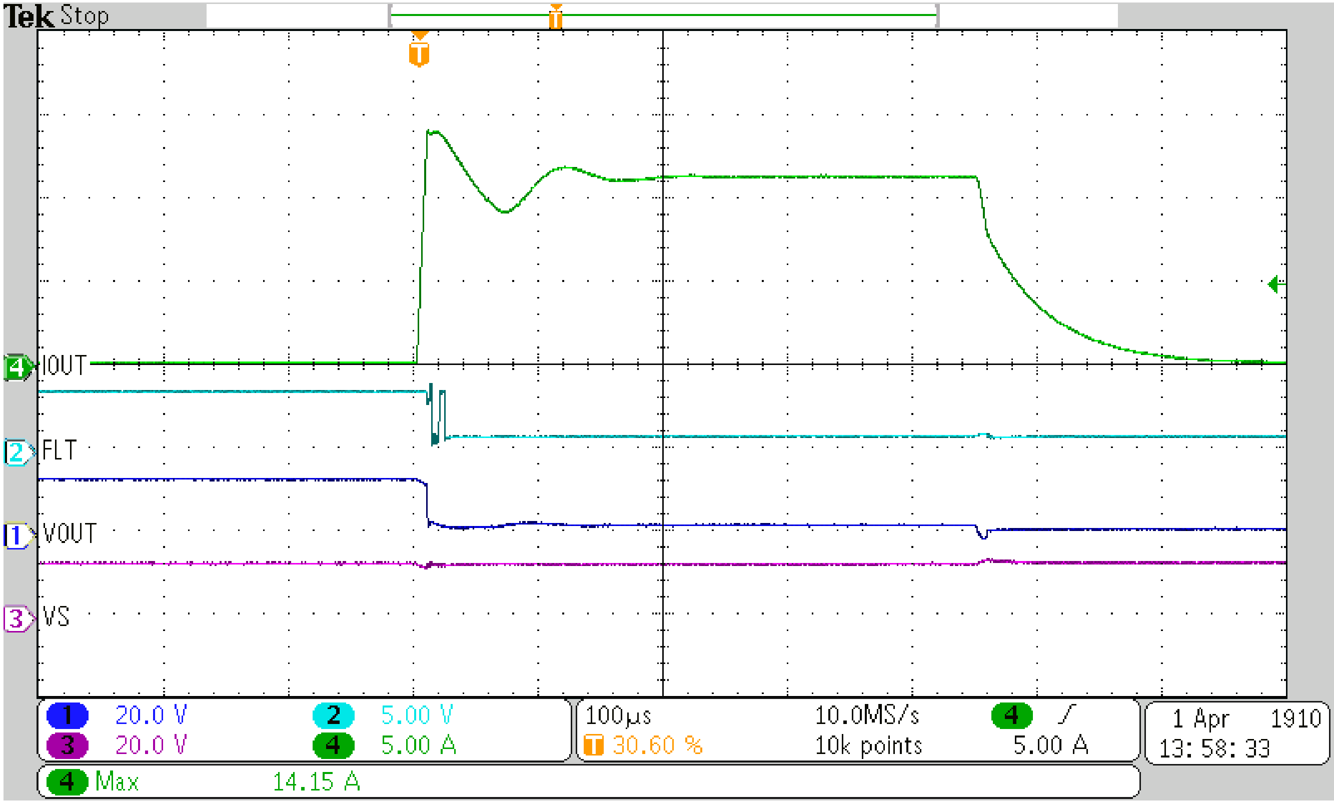

Figure 4-19. TPS1HC30-5uH-12V

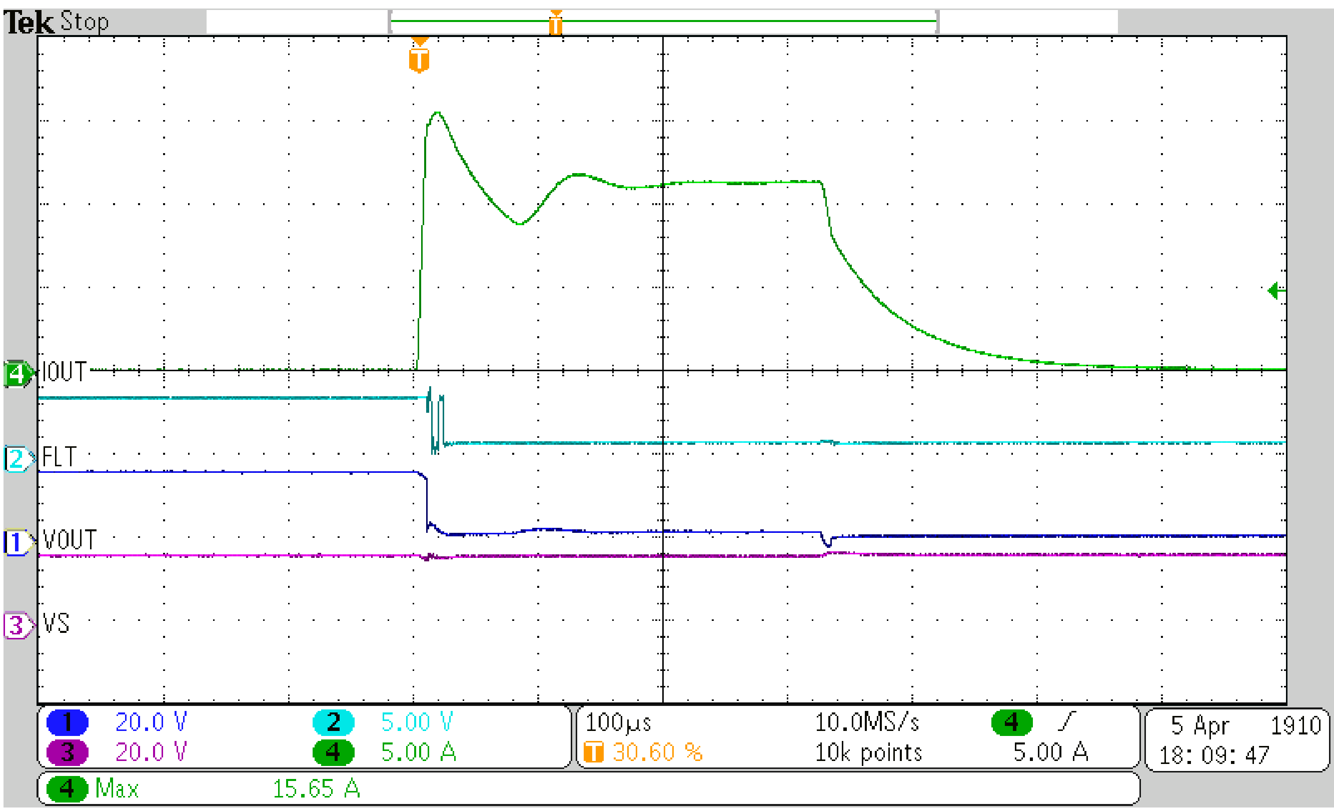

Figure 4-20. TPS1HC30-5uH-15V

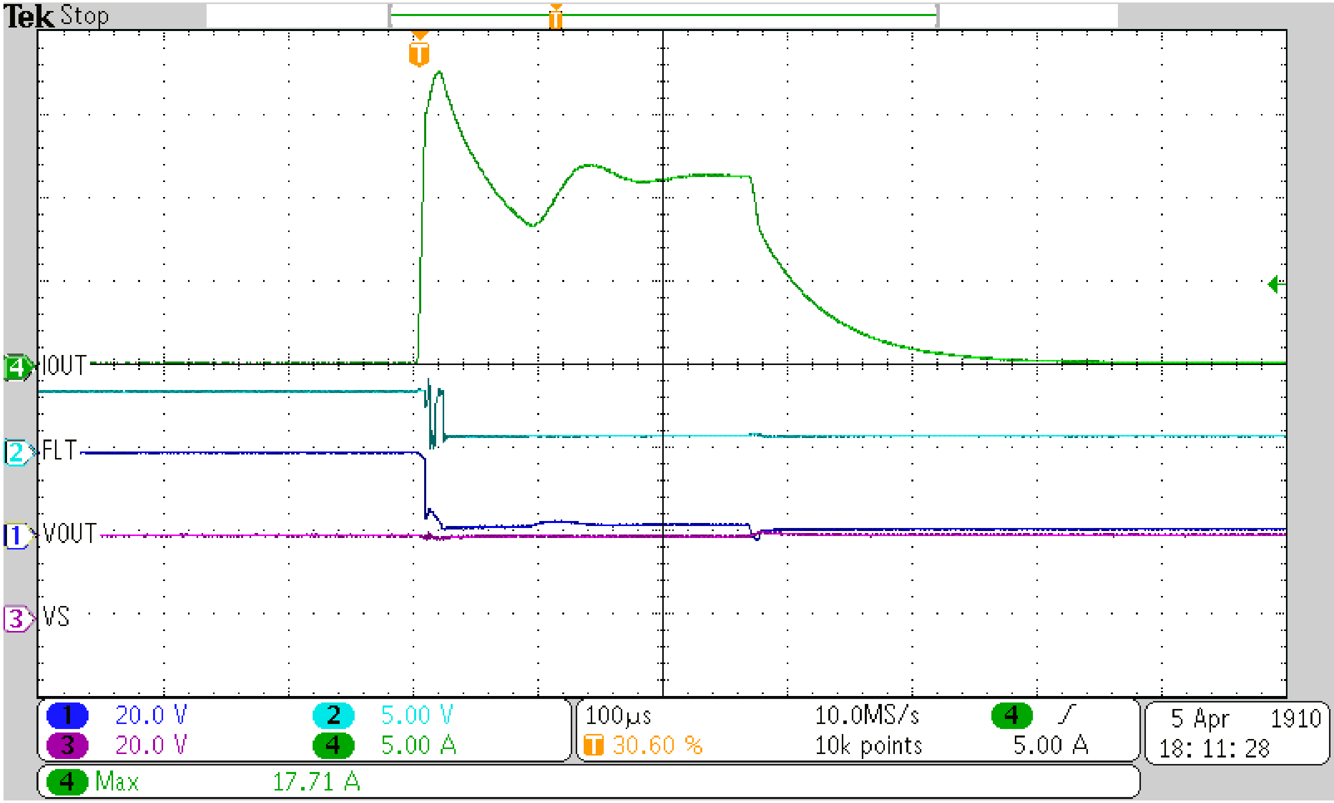

Figure 4-21. TPS1HC30-5uH-18V

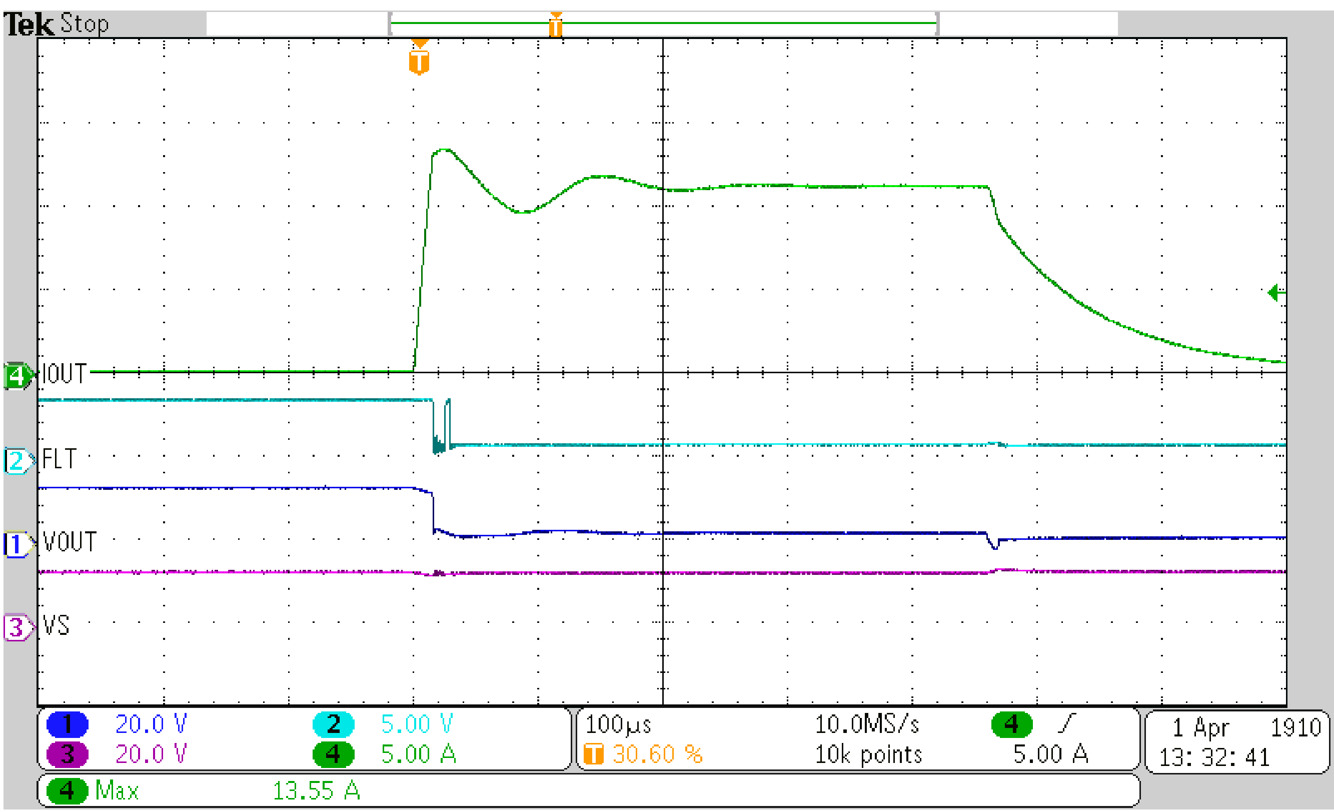

Figure 4-22. TPS1HC30-10uH-12V

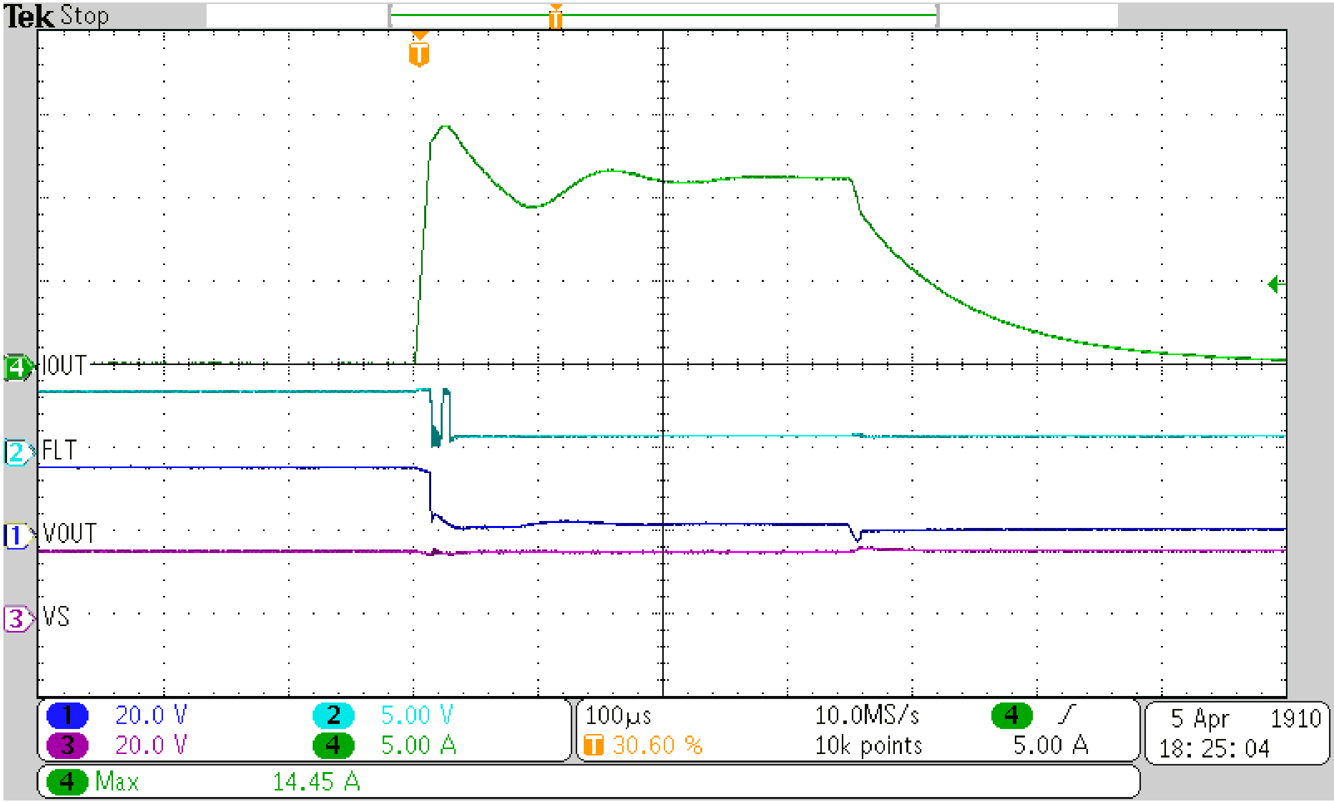

Figure 4-23. TPS1HC30-10uH-15V

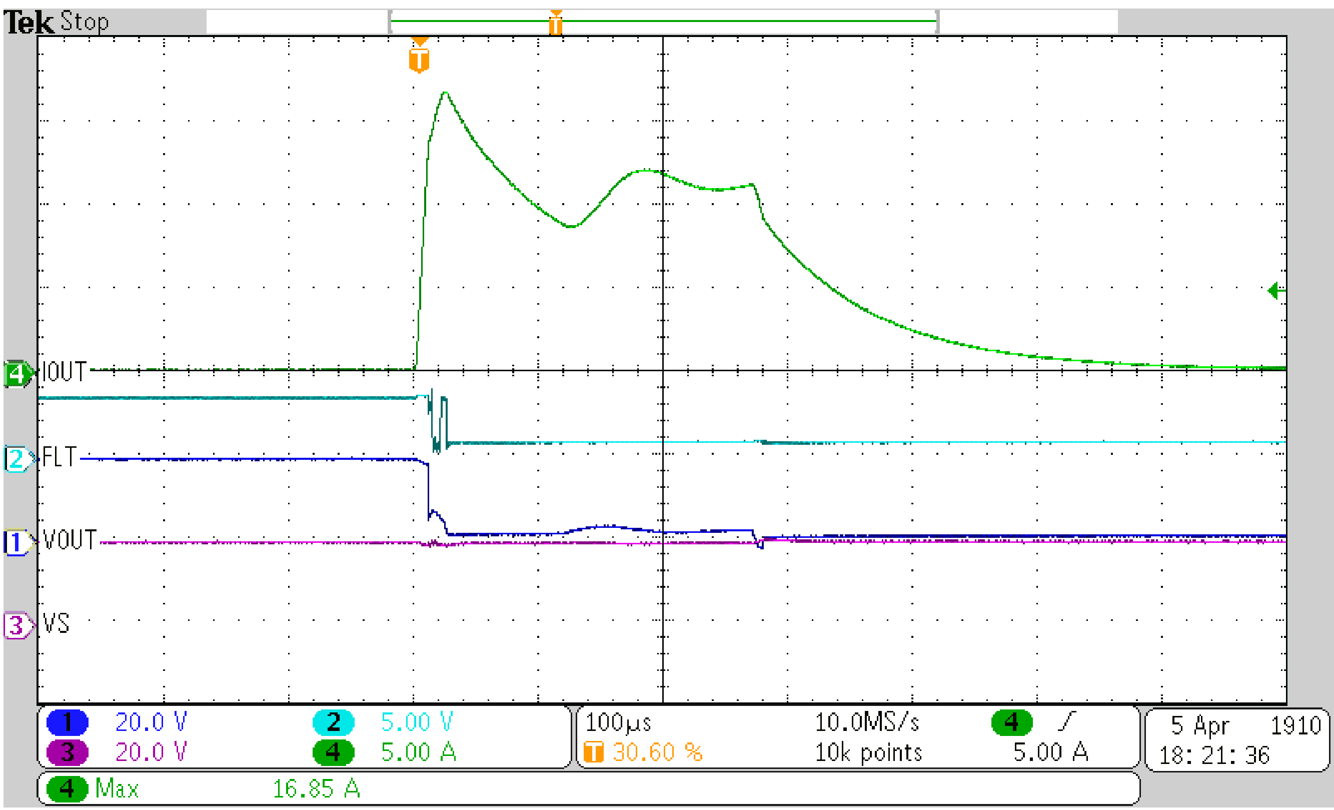

Figure 4-24. TPS1HC30-10uH-18V

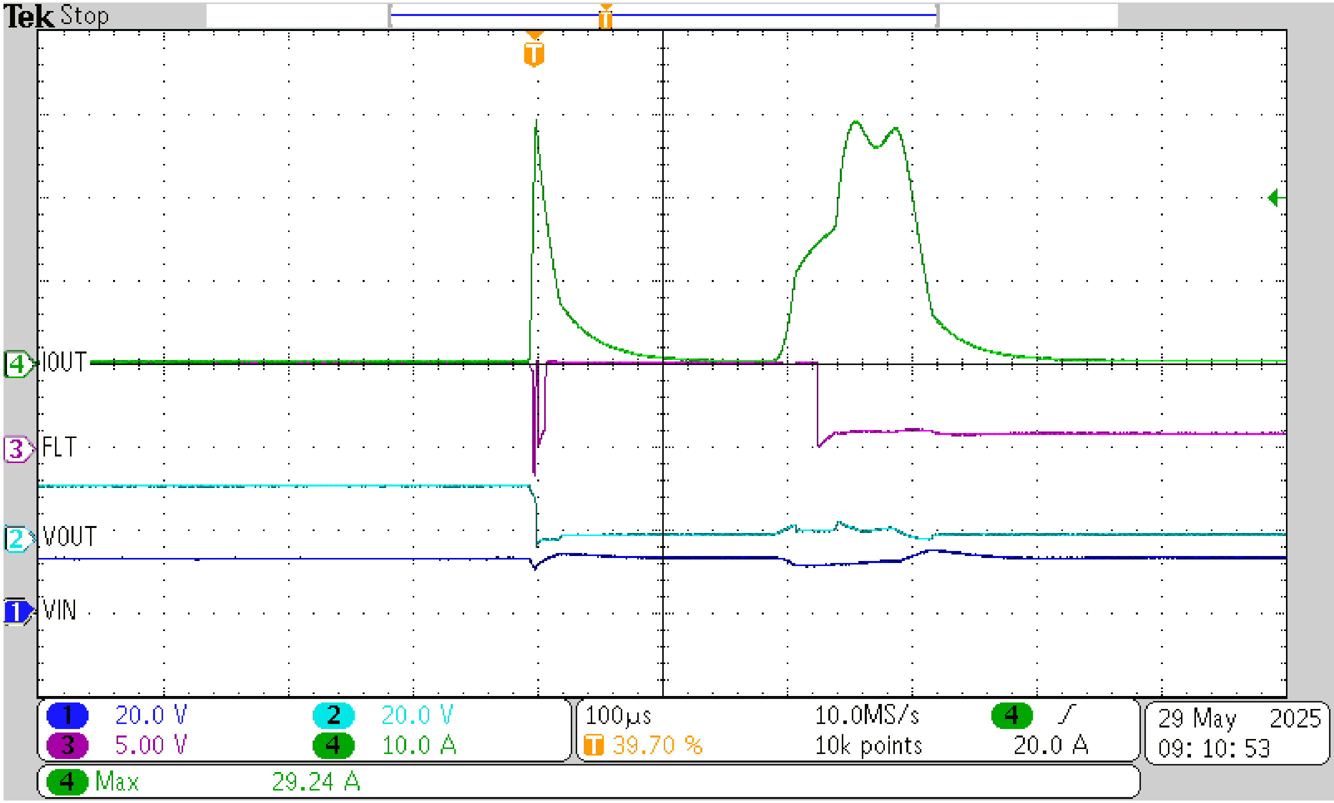

Figure 4-25. TPS2HC08-0.2uH-12V

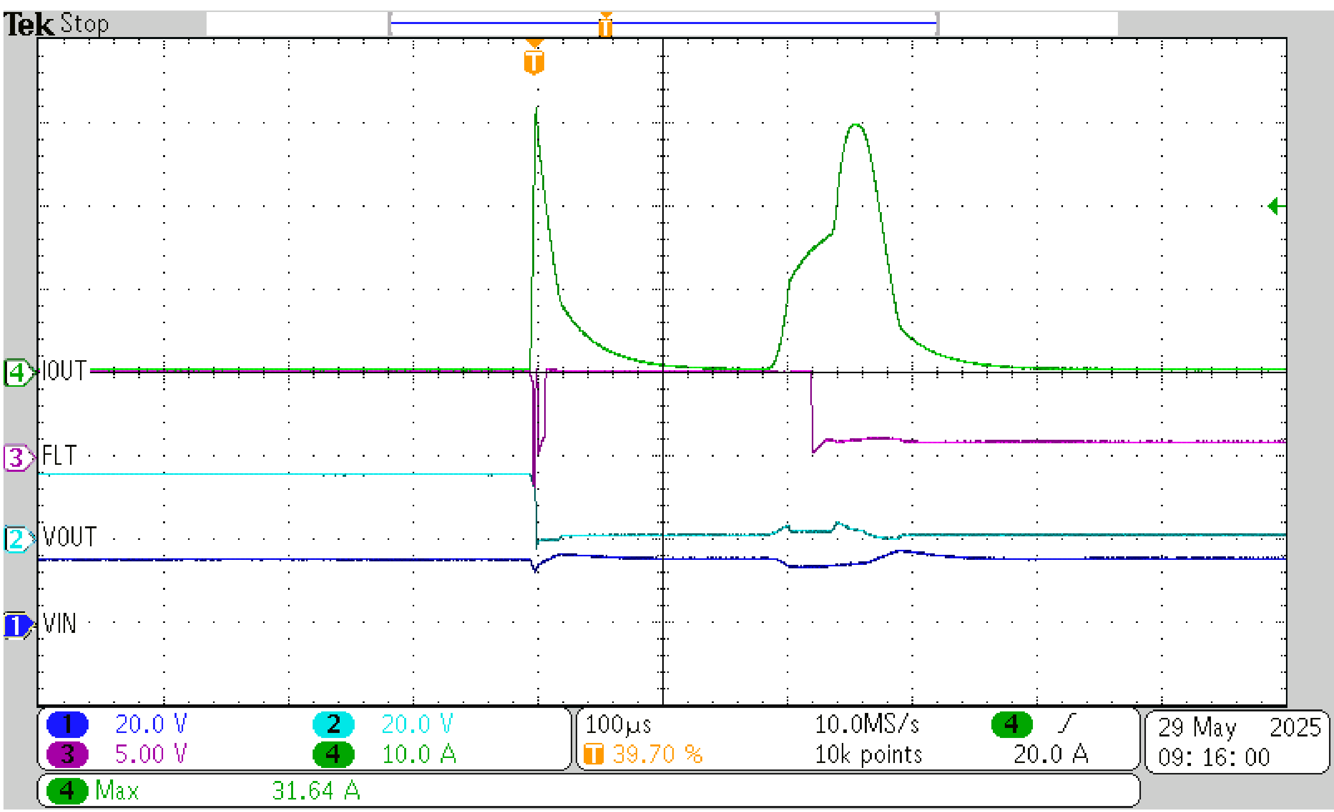

Figure 4-26. TPS2HC08-0.2uH-15V

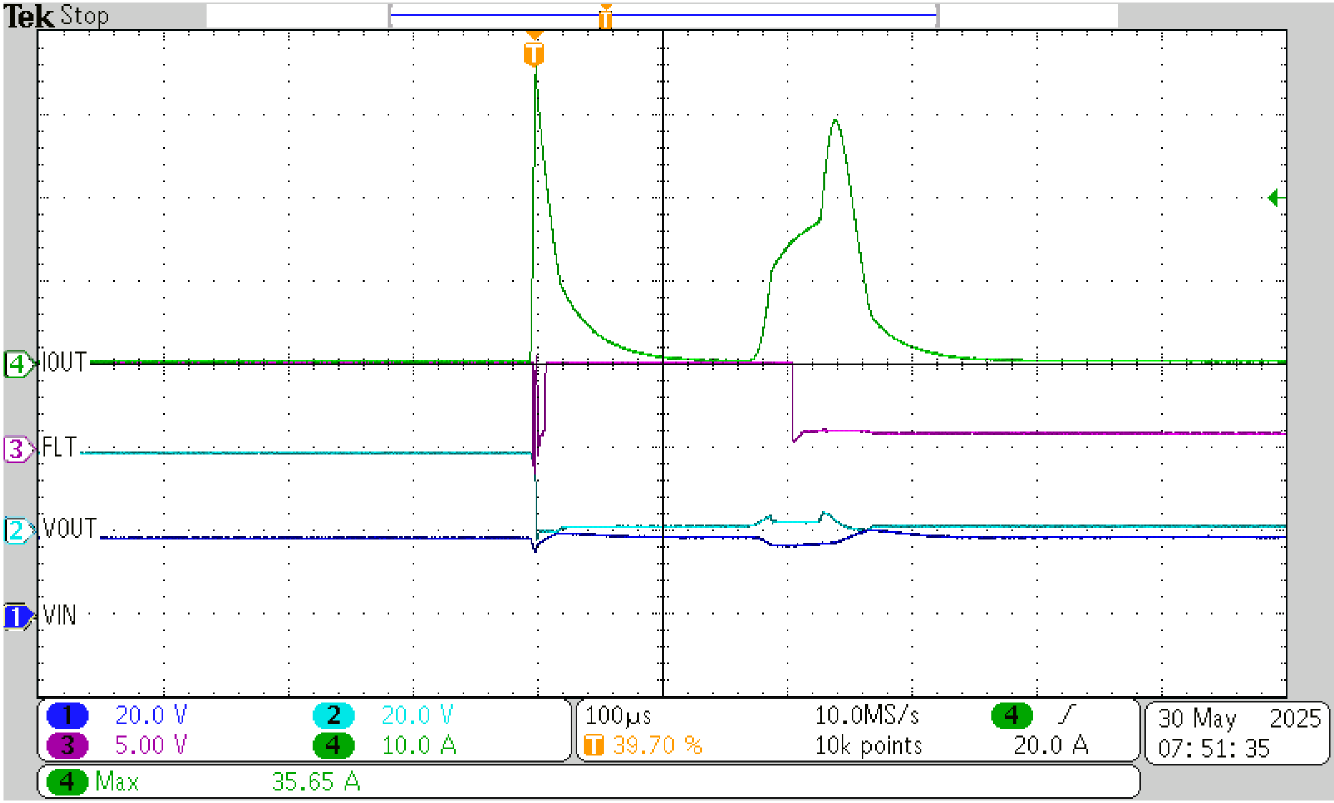

Figure 4-27. TPS2HC08-0.2uH-18V

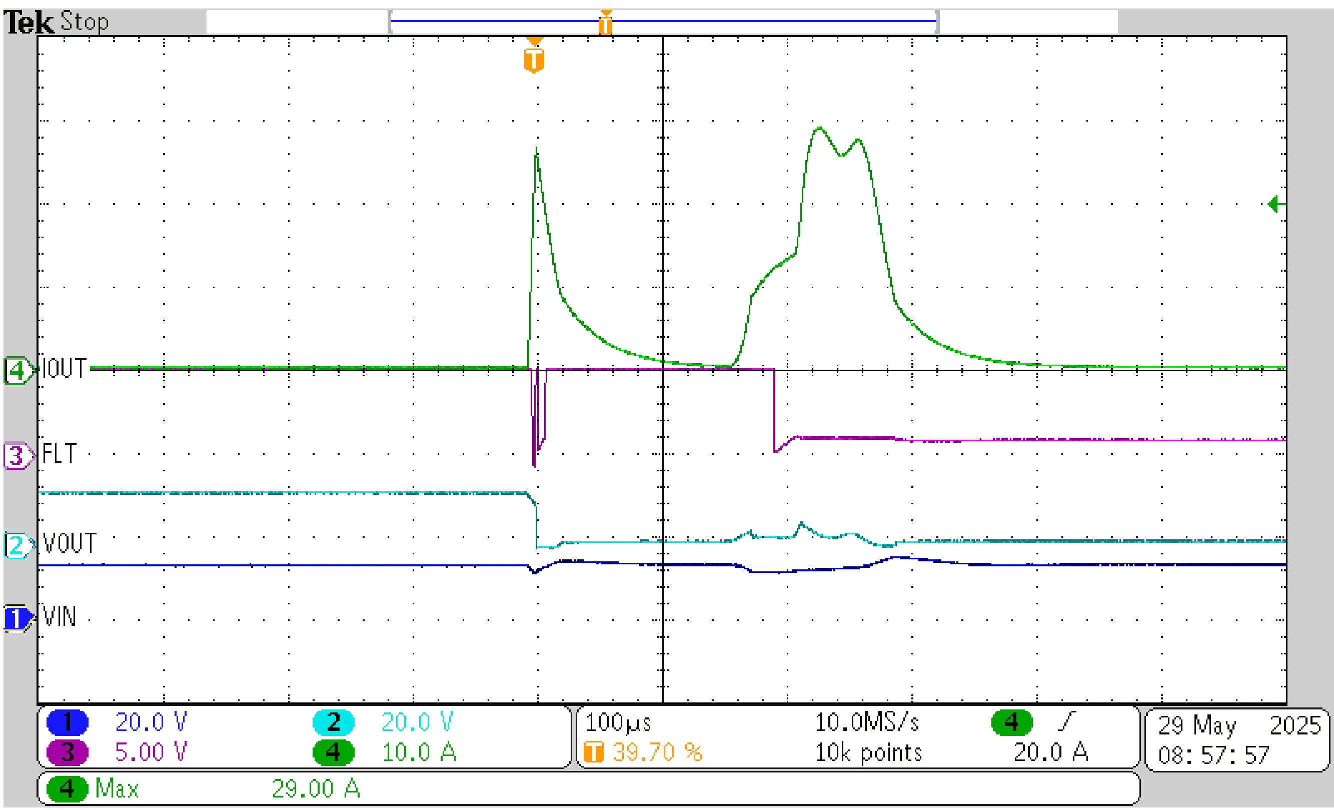

Figure 4-28. TPS2HC08-0.5uH-12V

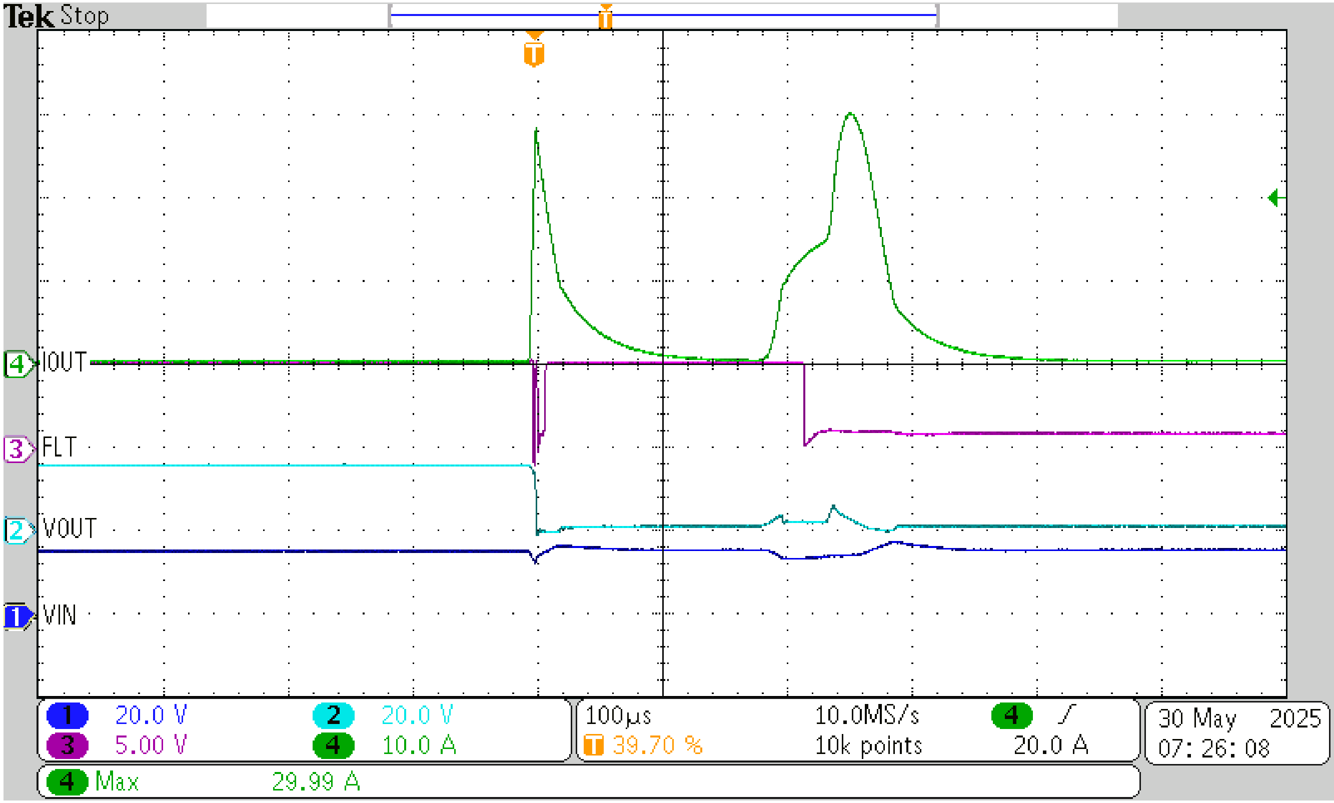

Figure 4-29. TPS2HC08-0.5uH-15V

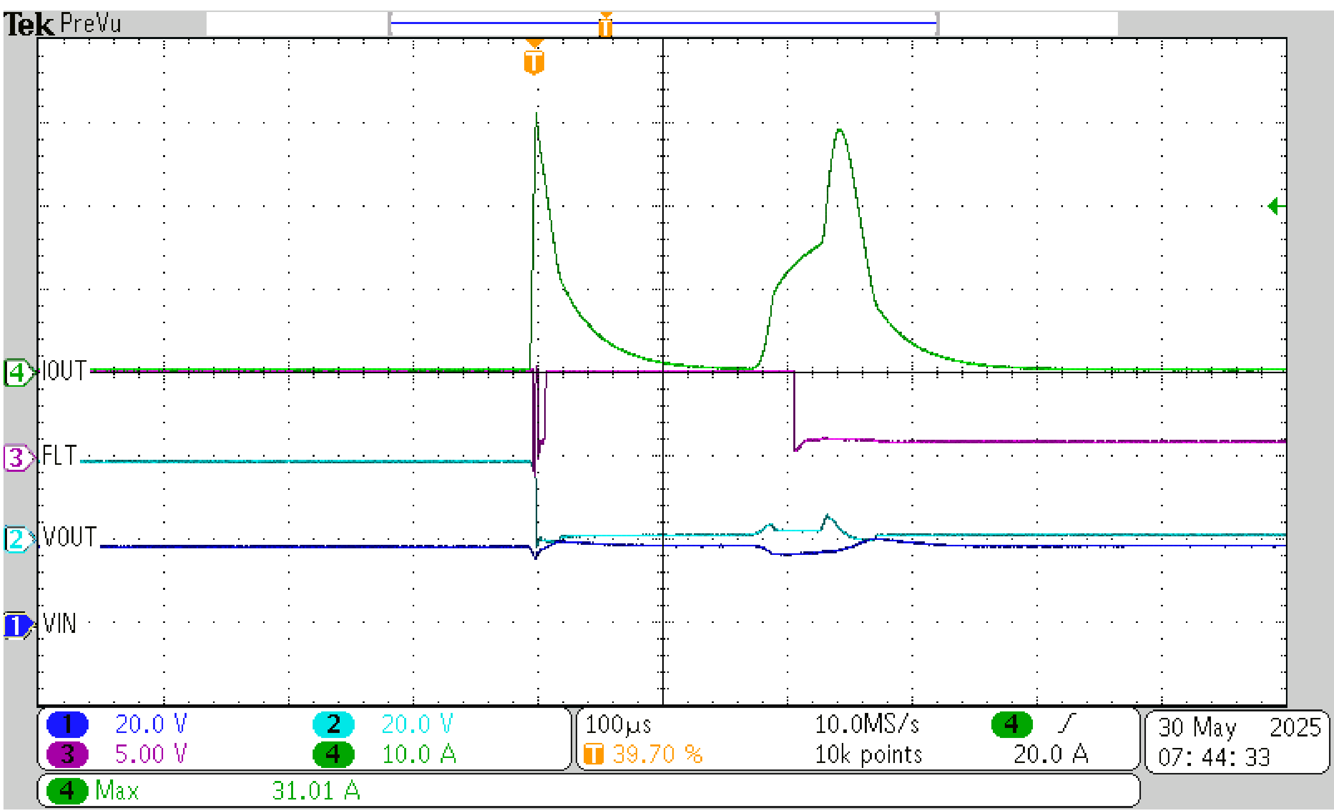

Figure 4-30. TPS2HC08-0.5uH-18V

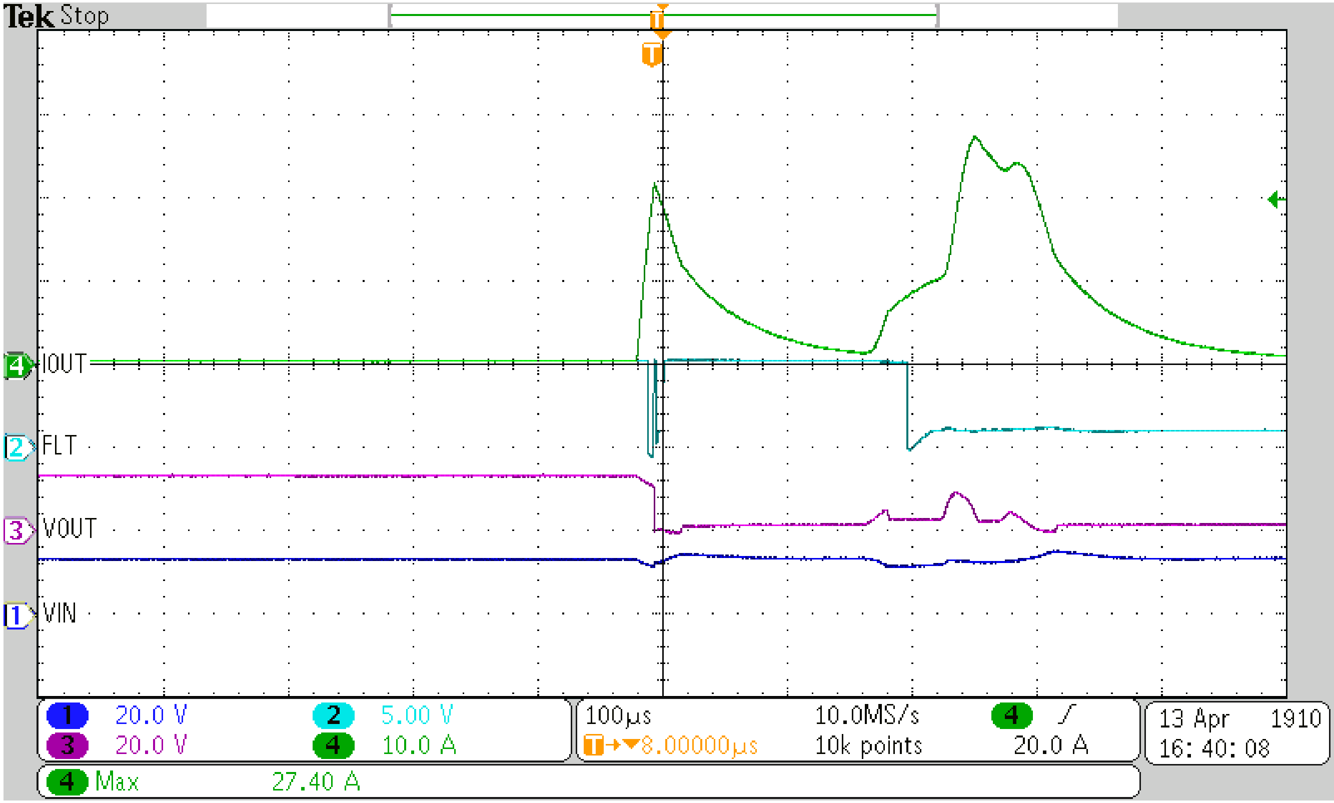

Figure 4-31. TPS2HC08-5uH-12V

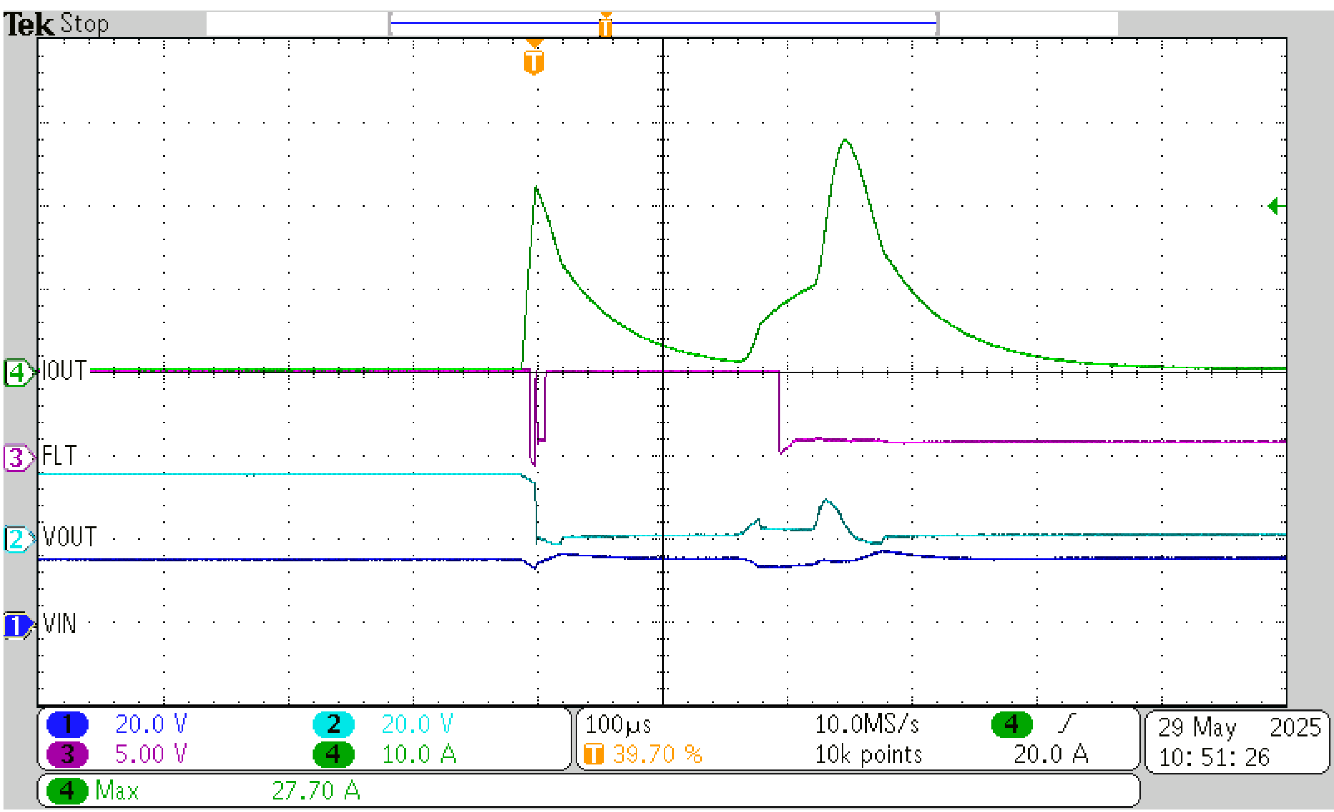

Figure 4-32. TPS2HC08-5uH-15V

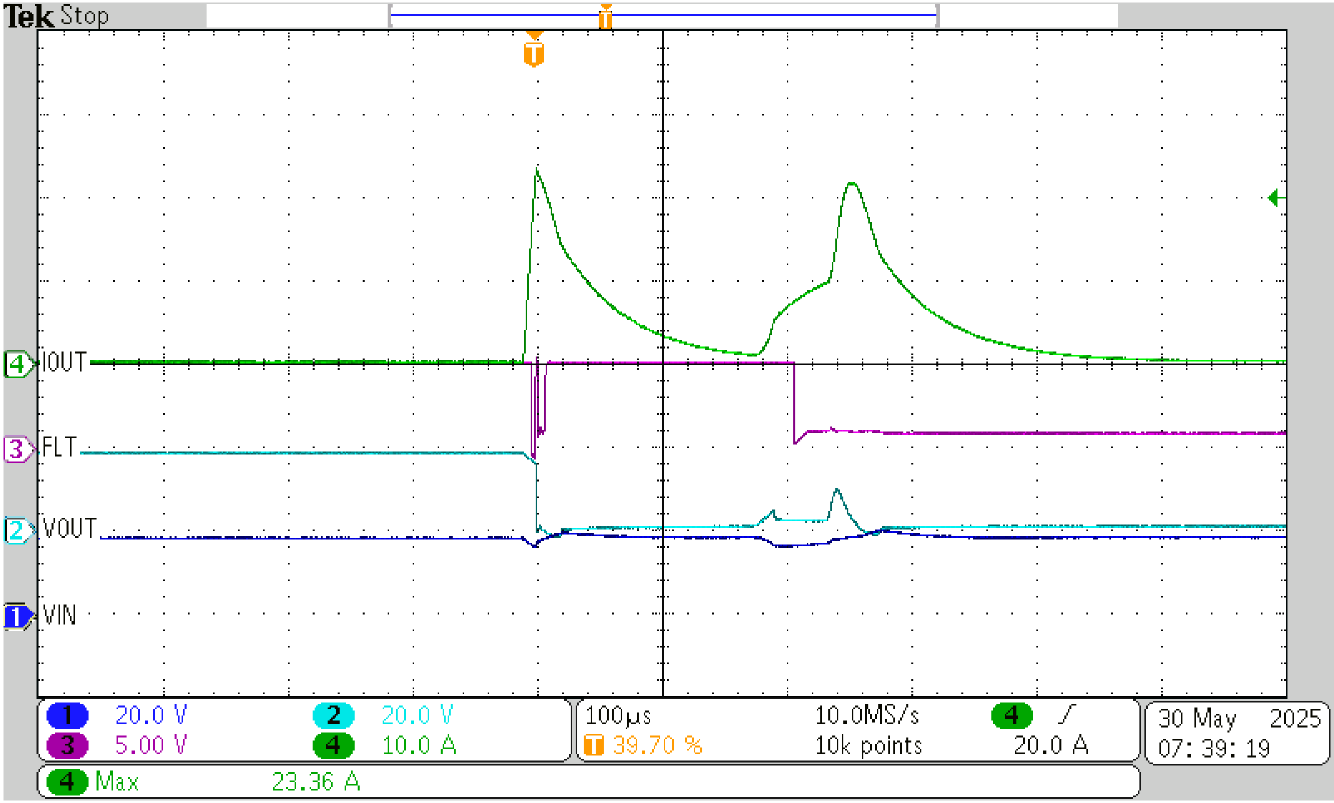

Figure 4-33. TPS2HC08-5uH-18V

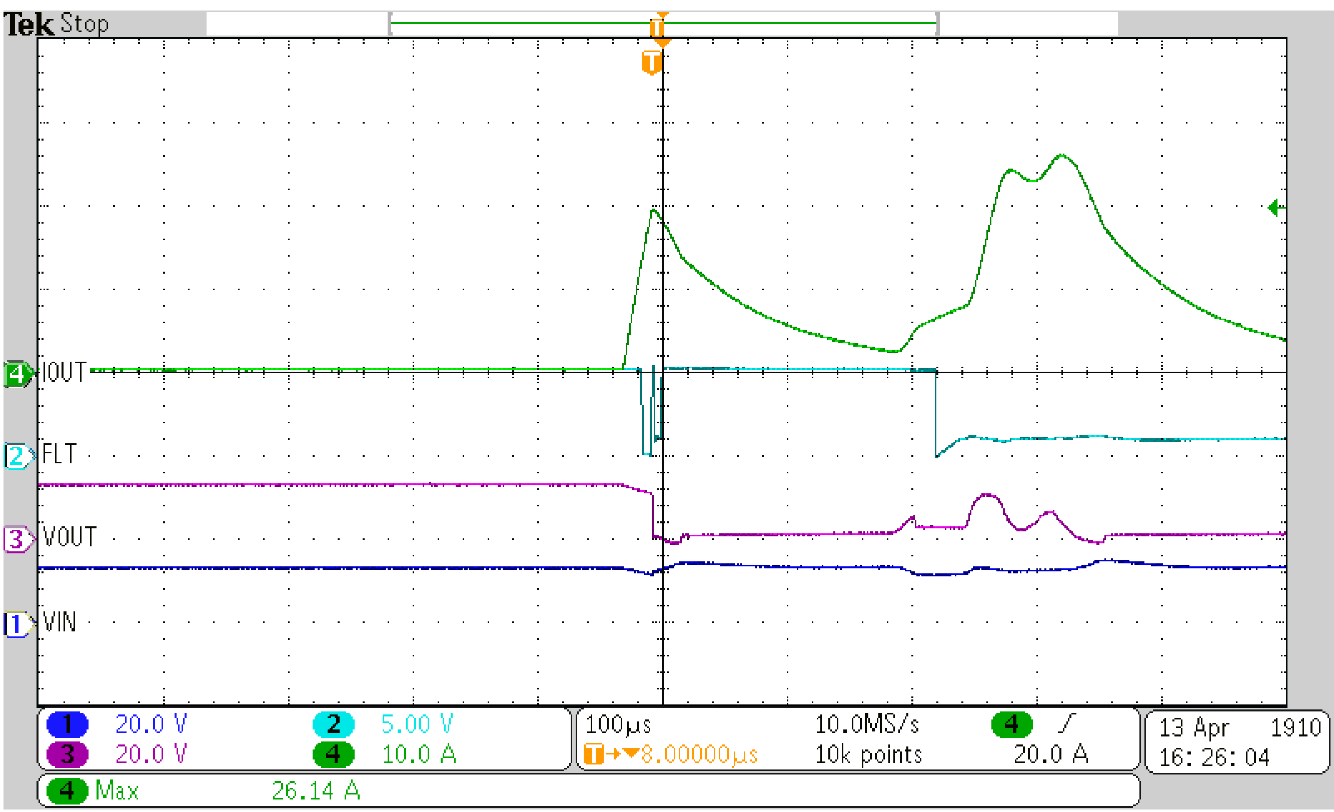

Figure 4-34. TPS2HC08-10uH-12V

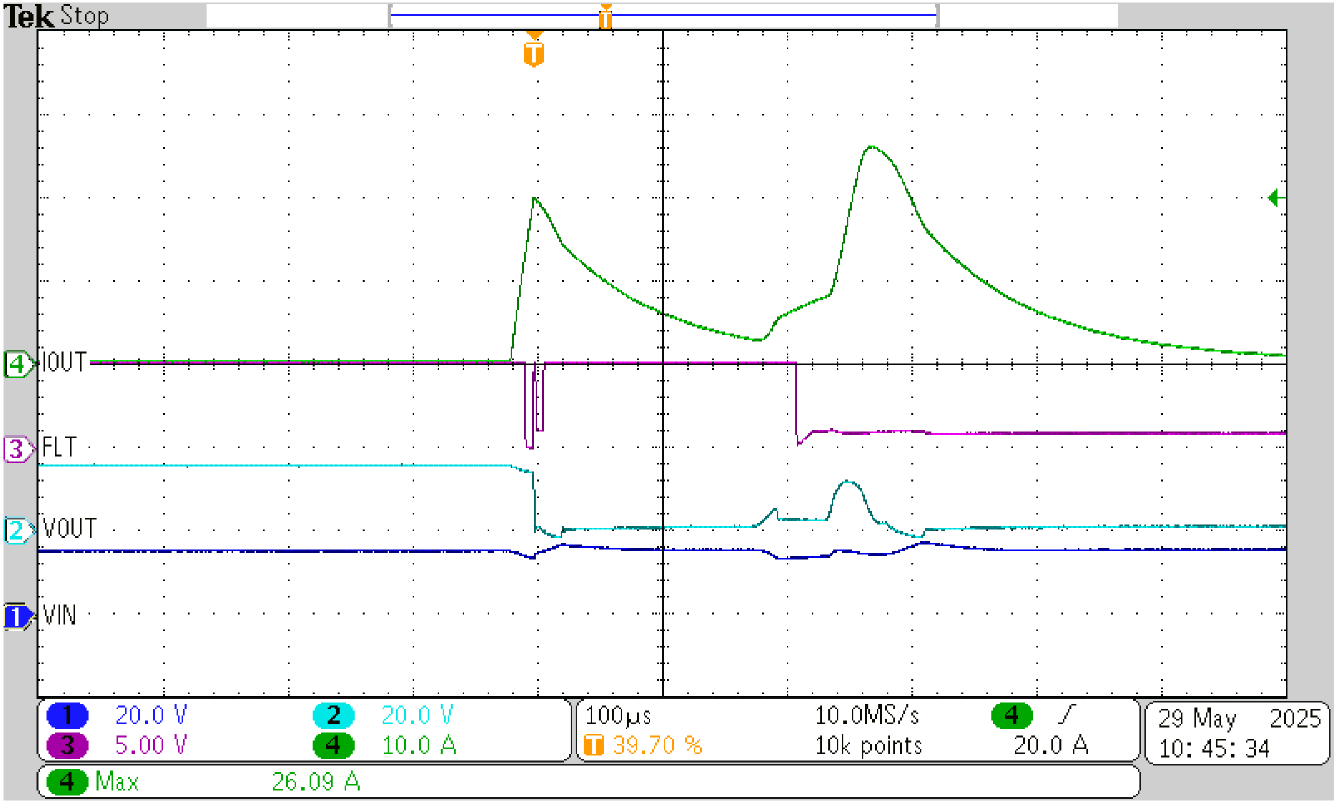

Figure 4-35. TPS2HC08-10uH-15V

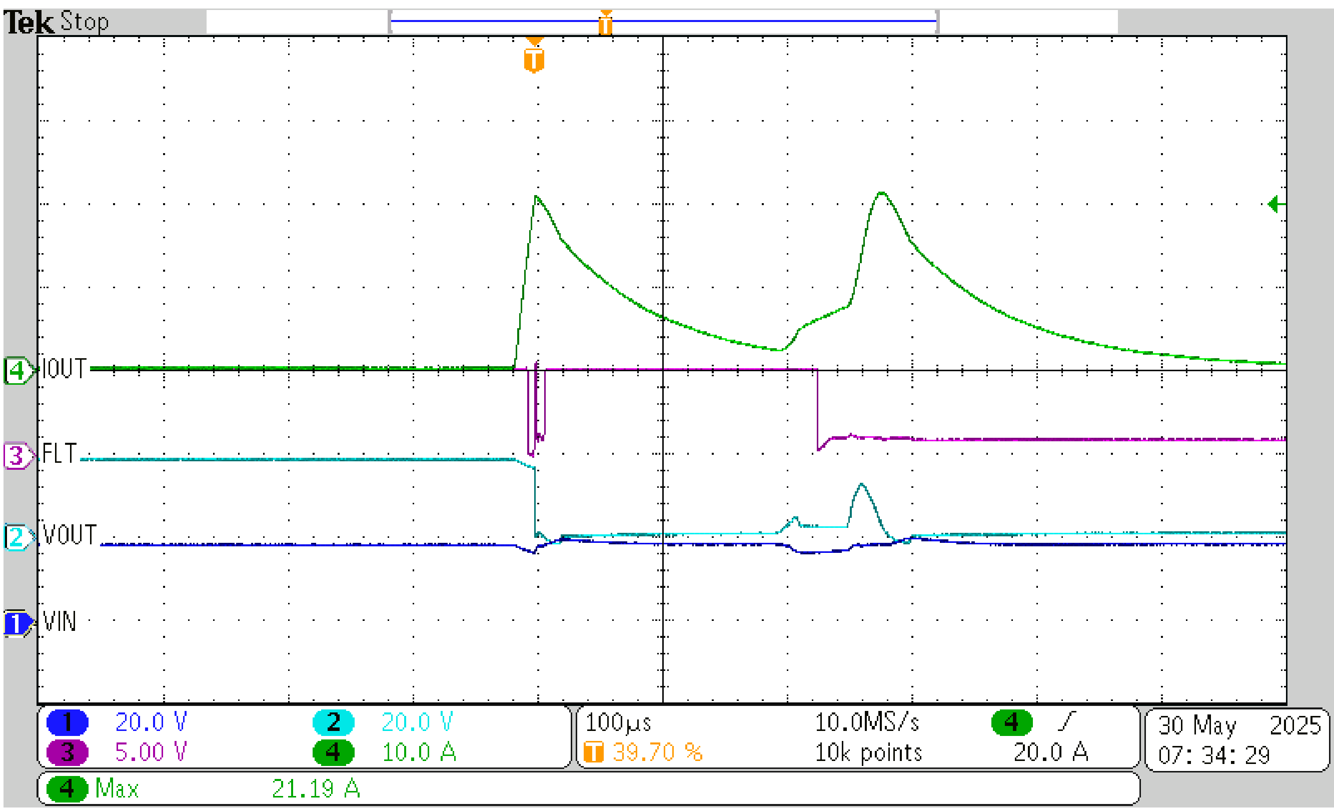

Figure 4-36. TPS2HC08-10uH-18V

5 Summary

STG testing is a critical step in validation the robustness and reliability of high side switches in various applications. This document outlined the methodology for creating realistic STG conditions, monitoring key parameters such as output current, and fault signaling, and evaluating the devices ability to handle fault events within the electrical specifications. The results of the testing confirm that the HSS evaluated can withstand typical short-to-ground scenarios when operated within the recommended conditions. By simulating worst-case fault conditions in a controlled environment, designers can make sure the selected HSS protects downstream loads and upstream power sources.

6 References

- Texas Instruments, TPS1HC30-Q1, 30mΩ, 5A, Single-Channel Automotive Smart High Side Switch, data sheet
- Texas Instruments, TPS1HC100-Q1 100mΩ, 2.5A Single-Channel Automotive Smart High-Side Switch, data sheet
- Texas Instruments, TPS1HC30-Q1 Evaluation Module, user's guide
- Texas Instruments, TPS1HC100 Evaluation Module, user's guide
- Texas Instruments, TPSxHCxx-Q1 Evaluation Module, user's guide

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