"The Next Step" for Failure Analysis of Vishay Siliconix Power MOSFET

By Kandarp Pandya

These guidelines chronologically cover most pertinent aspects and information for a proficient and valuable failure analysis of a suspect power MOSFET in electronic control applications.

Any failure in mass production environment raises the priority flags. Invariably, all the possible resources are pulled in to propel the best possible concurrent engineering efforts. The aim is to identify the root cause of failure and implement the containment action plan at the earliest possible opportunity. These guidelines help to maintain smooth and adequate information exchange in timely manner during the rush mode - due to raised priorities - of failure analysis.

One of the immediate and initial steps in most cases is to send the suspect power MOSFET back to the manufacturer and get the manufacturing expertise engaged on the failure analysis as soon as possible.

Well established protocol starting with Product Analysis Request form - Appendix A, steers the failure analysis process to a final 8D report concluding the root cause and recommended action plan, if any.

However, we do encounter scenarios where it is not possible to establish root cause of the MOSFET failure. That brings us to "The Next Step" for Failure Analysis. The attempt here is to start with a fresh look at everything i.e., work done so far and examine additional aspects that can help establish the root cause of failure. The focus here is extended to include application and examine each and every aspect looking for a possible cause that could lead to the failure of the MOSFET in question.

Appendix B Collects the Information with Focus on the Followings:

- Statistical data:
  a. Number of failures
  b. Total usage number in the application
  c. The period of usage in the particular application and platform
  d. Total usage number in identical application but on different platform
  e. Total usage number in same application but different assembly location/facility
  f. Failure point:
     1. ICT - In-Circuit Tester - Quantity
        - Electrical schematic diagram of test setup
        - Test program
     2. Functional Test - Quantity
        - Electrical schematic diagram of test setup
        - Test program
     3. Field Returns - Quantity
        - Length of operating life before field failure
  g. Changes if any at any stage of PC board assembly and testing
     1. Any other component level change in the associated circuit
     2. Test program changes
     3. Assembly or hardware changes at product level
     4. Assembly or hardware changes at end use
- Actual application, function of the MOSFET in the circuit.
- Examination of operating parameters and conditions under normal operation.
- Examination of operating parameters and conditions worst case analysis.
- Analysis of waveforms for electrical parameters see Appendix C and D:
  a. V_{GS} - Gate-Source Voltage
  b. V_{DS} - Drain-Source Voltage
  c. I_D - Drain Current
  d. P_D - Power Dissipation in MOSFET
- The waveform analysis for both normal and worst case conditions includes
  a. one complete On/Off cycle
  b. Zoomed view of turn-on event
  c. Zoomed view of turn-off event
- The *.csv files of waveforms listed in "Appendix C and D" above help define power profiles useful for thermal simulations if necessary. Refer to Appendix E for an example.

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The recommended protocol in “The Next Step” analysis is to send the complete PC board assembly with the suspect MOSFET - un-disturbed.

However, in case, the Entire PC board assembly is not practical to send, at least very carefully removed, 25 mm x 25 mm (1" x 1") cut-out PCB around the suspect MOSFET is the second preferred option.

In most of the first time failures, the user tend to test the suspect MOSFET on PC Board assembly using commonly used hand held multimeter to confirm the failure. De-solder the part using standard soldering stations and send the same to the manufacturer. However, the suspect MOSFET could have walked through a pit-fall losing significant failure signature/s. The testing and handling of the suspect MOSFET is quite critical for detecting and retaining the failure signatures in its original conditions. This is imperative as the subsequent failure analysis is equally complex as the original manufacturing process of the MOSFET die. Please refer to the application note AN839, “Guidelines for Handling Failed Power MOSFETs on PCB Assembly”.

Recommended Procedure and Steps:

- Prepare and pack for shipping the PCB assembly containing the suspect MOSFET or the suspect MOSFET for failure analysis. Typically, the package contains:
  a. The suspect MOSFET on PCB assembly or cut-out as discussed above.
  b. The Vishay Siliconix Failure Analysis Request form, Appendix B; duly completed to the possible extent. The missing information can follow later to expedite and facilitate proficient failure analysis.
- Here are the shipping instructions:
  Shipping label should read
  Leilani L. Taa
  Manager, Document Control & Customer Returns
  Quality Engineering & Systems
  Vishay Siliconix
  2201 Laurelwood Road, Santa Clara, CA. 95054-1595, USA
  Phone: +1 (408) 970-5481 | Fax: +1 (408) 567-8991
  e-mail: Leilani.Taa@Vishay.com
- Vishay Siliconix will further investigate the failure mode. The failure analysis continues with communications exchanges on findings and mutually agreed action plans.
- Final response from Vishay Siliconix - an updated “8D” summarizes finding of failure analysis and mutually agreed containment action plan - required if any.

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APPENDIX A

VISHAY®

Customer Analysis Request

CS Group **Ref:** *CS Group* **-xxxxx**

Customer Information

Customer : ____________
Contact Person : ____________
Tel No. : ____________
Email Address : ____________
Cust. Ref. No. : ____________
Cust. Location : ____________

Vishay Information

Vishay Originator : ____________
Date Vishay 1st Rec'd : ____________
Date Sent to Mfg Site : ____________
Sent to : ____________
Sales/CS Contact : ____________
AWB # : ____________

Device Information

Vishay PN : ____________
Customer PN : ____________
Quantity : ____________
Potential Return : ____________
Datecode : ____________
Plant Code : ____________
Lot/Serial # : ____________
DN/Invoice # : ____________

Defect Information

Type of Complaint
[ ] Electrical [ ] Mechanical [ ] Visual
[ ] Packing [ ] Label [ ] Mixed Part
[ ] Other:

Comments: ____________

~For soldering complaint, pls attach customer's profile and solder composition~

Point of Defect
[ ] Qualification [ ] Incoming [ ] Assembly
[ ] Field/Warranty Defect *(How long has the product been in use?):* ____________
[ ] Reliability: [ ] Line / 0km (for automotive)

Comments: ____________

~Please note any important test, process, or usage conditions~

Defect Rate : ____________

Application : ____________

Remarks/Other Data : ____________

Notes:

1. Please attach a copy of the reel label.
2. Please take precaution against ESD and mechanical damage when forwarding samples.

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APPENDIX B

VISHAY SILICONIX FAILURE ANALYSIS REQUEST FORM	
COMPANY INFORMATION	
Company Name:	
Contact Person:	
Request Reference # and Date:	
Adress:	
DEVICE INFORMATION	
Quantity Purchased:	
Quantity Returned:	
Failure Rate:	
Part Number:	
Geometry:	
Lot#:	
Assembly Location:	
APPLICATION INFORMATION	
Application:	
Time on Field:	
Failure Events:	
Number of Parts Failed:	
Total Usage in the Same Application:	
Failure Detection Mechanism/Code:	
Purpose of this Transistor in Application:	
Is the Application Working after Replacement of the Suspect Transistor with Another fresh Transistor?	
Application Details - (Electrical Schematic and Operation Parameters):	
Application Waveforms for Failing Parts - (V_{GS}, V_{DS}, I_D, P_D, One Complete On-Off Cycle, Zoomed at Turn-on, at Turn-off:	

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VISHAY SILICONIX FAILURE ANALYSIS REQUEST FORM	
APPLICATION INFORMATION	
Application Waveforms for Good Parts:	
Worst Case Operating Conditions:	
Operating Ambient (Temperature):	
Board and Assembly Level Testing:	
Does the Customer want the Board Back after Complete Failure Analysis?	
Customer Comment/Suggest FA:	
Attached Documents (Electrical Schematics, Application Details, etc)	

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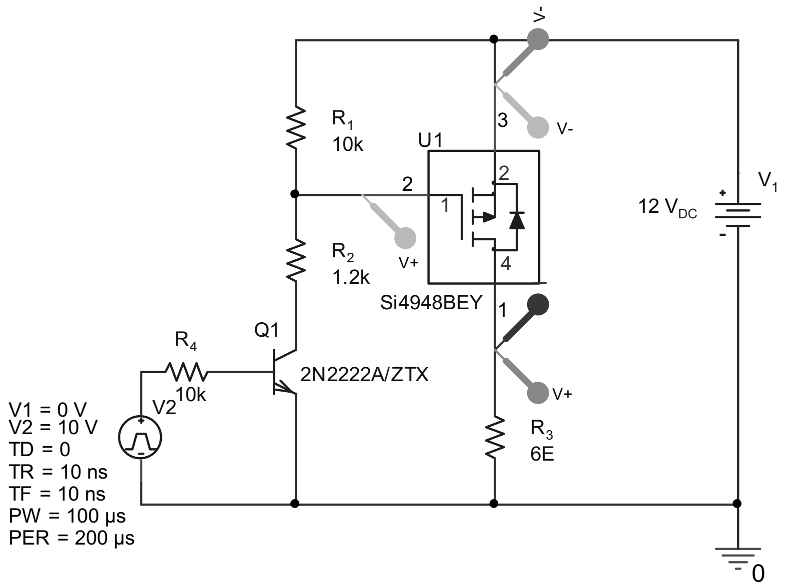
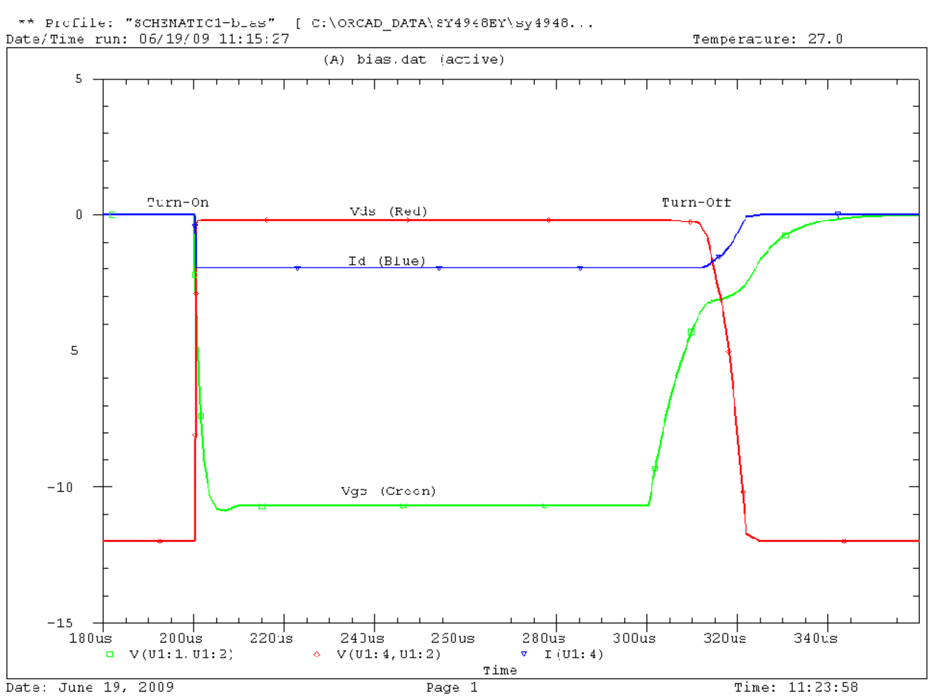
APPENDIX C

Example of Signals Useful for Analysis of MOSFET Behavior





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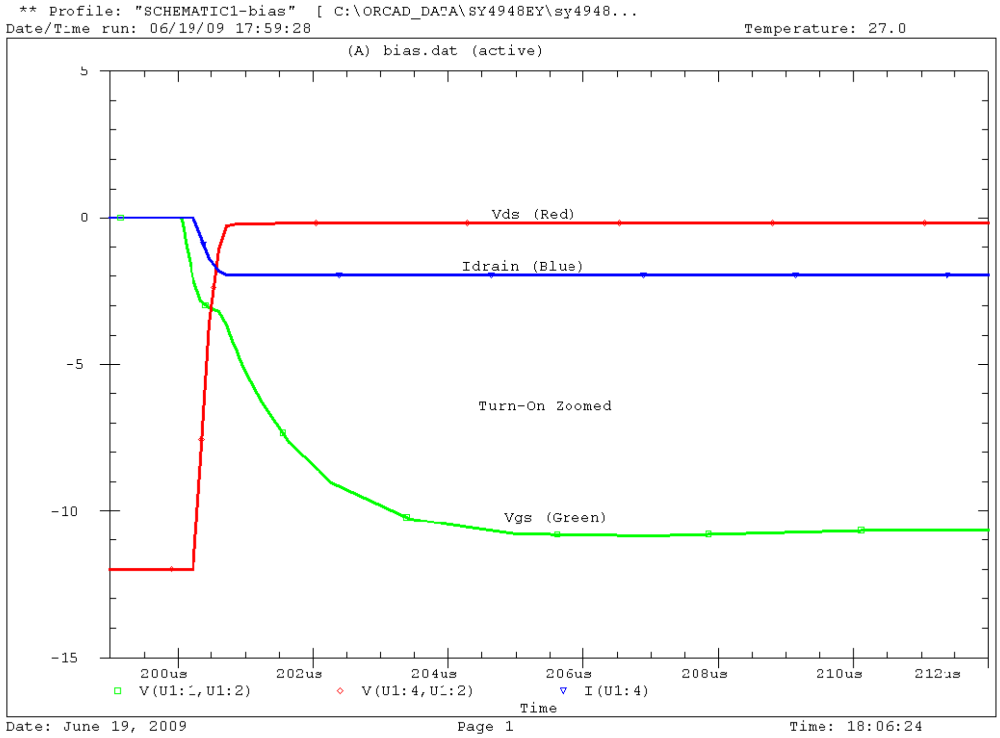
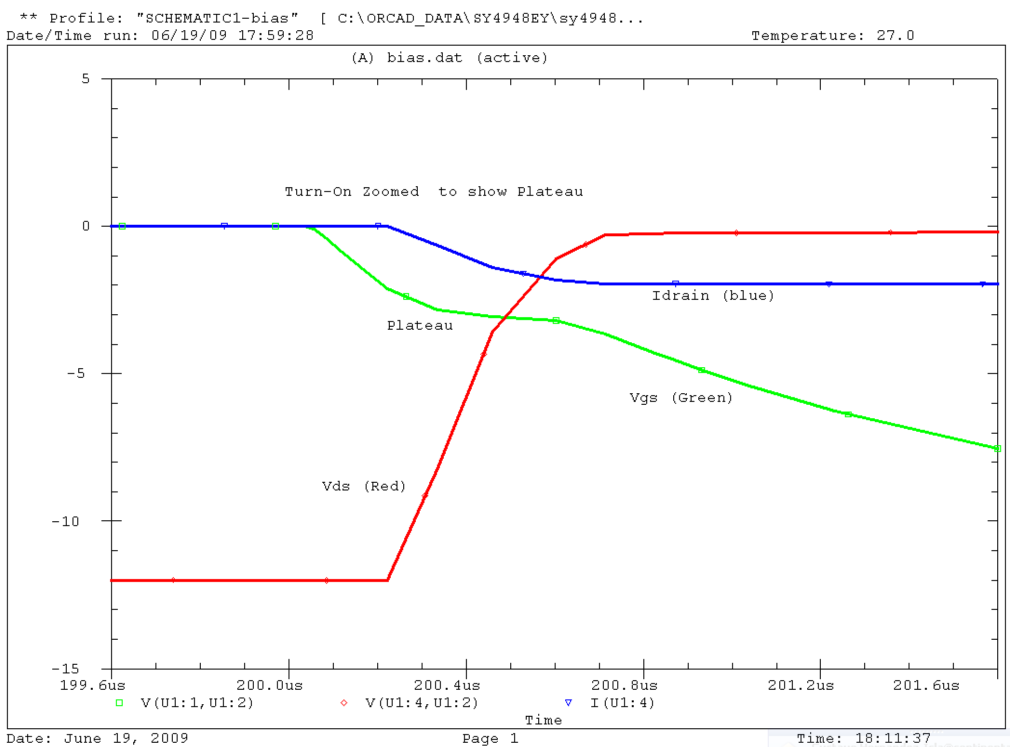
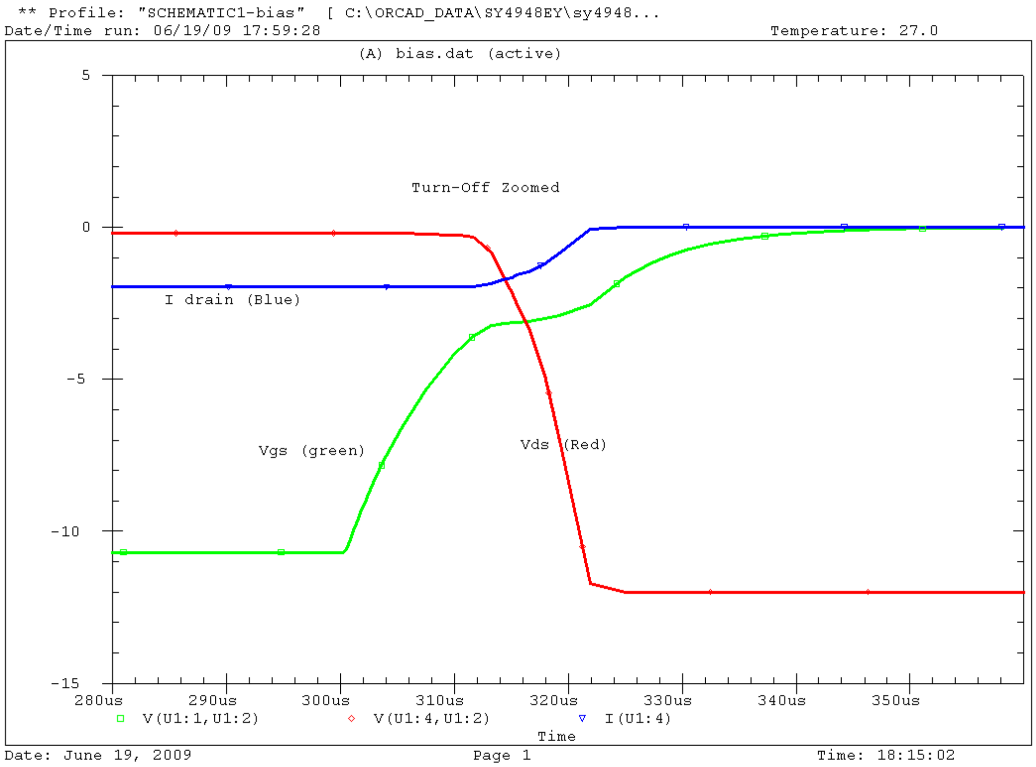




"The Next Step" for Failure Analysis of Vishay Siliconix Power MOSFET



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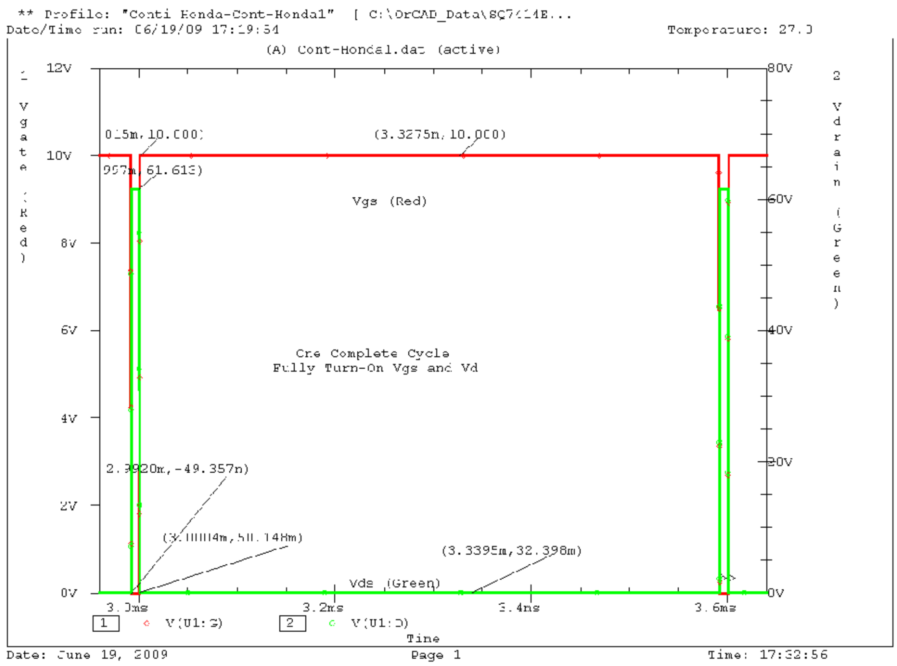
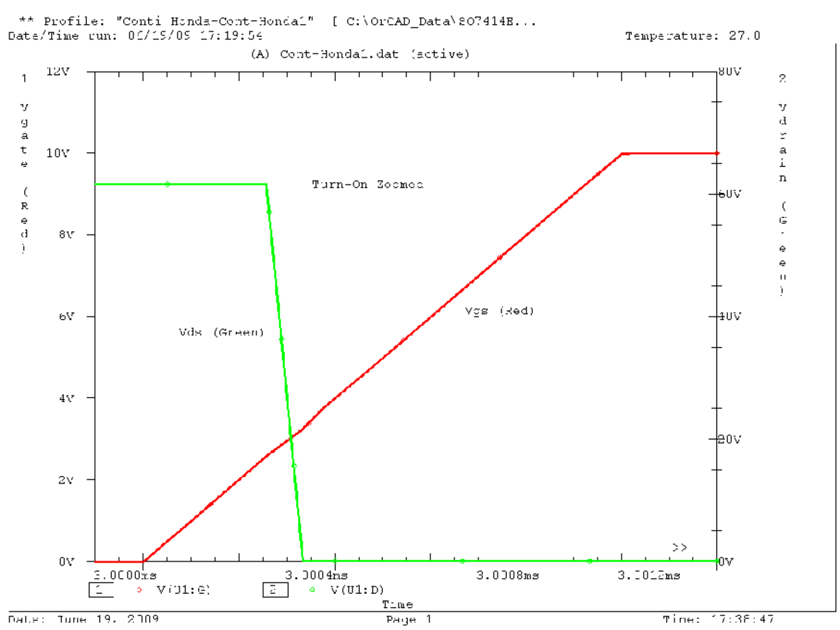
APPENDIX D

Please Ignore the Voltage Values as these are for Different Circuit and Different MOSFET:
Example of Fully On V_{GS} and V_{DS}



Example of Turn-On Zoomed: Notice Shorter Time Scale



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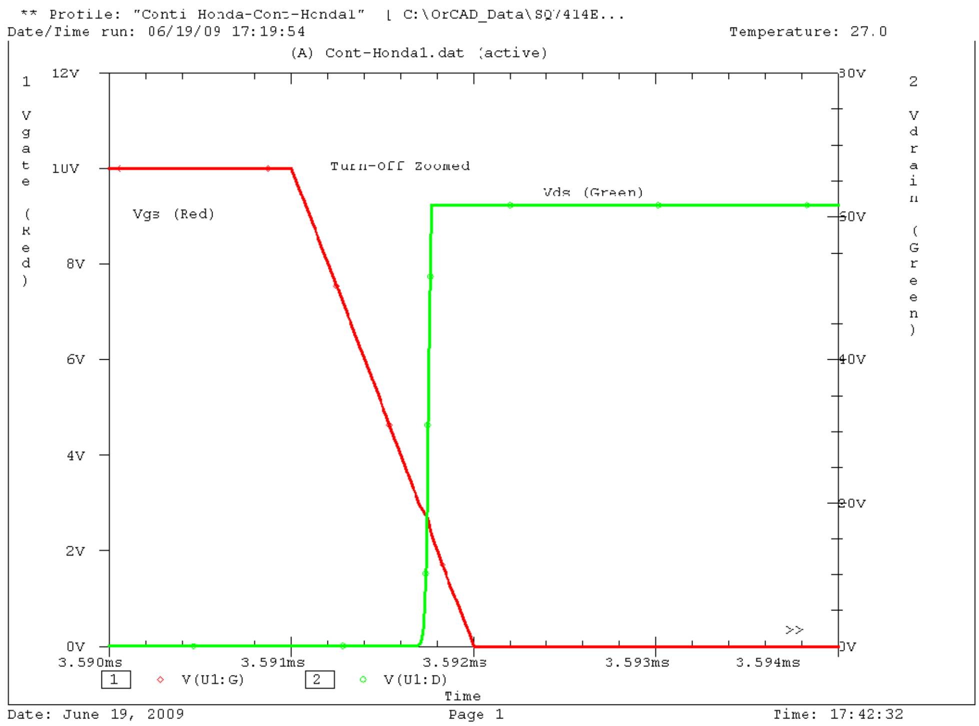
Example of Turn-Off Zoomed. Notice Shorter Time Scale.



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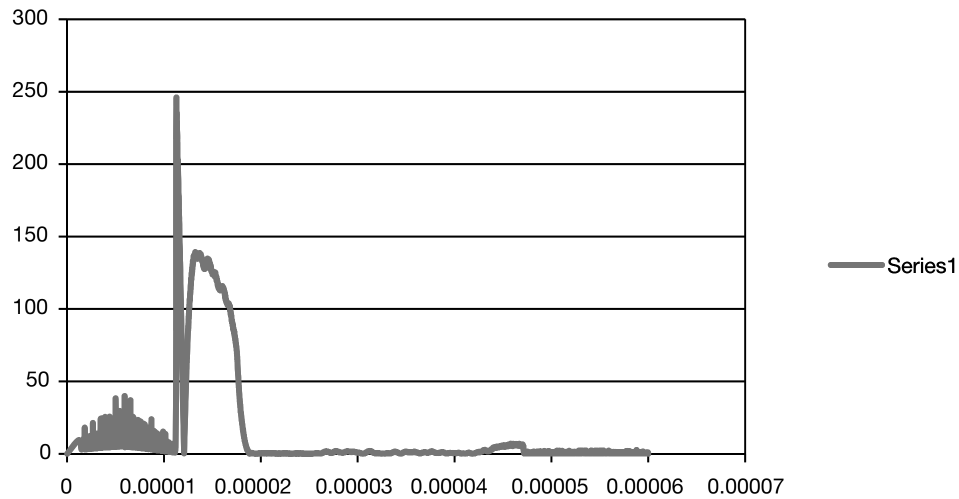
APPENDIX E

Example of *.CSV file (Partial Data) of the Series 1 Waveform on Right.

0	0
1.2E-06	9.482123
1.5E-06	2.914048
1.74E-06	10.84139
1.75E-06	3.895316
1.79E-06	10.95363
1.8E-06	3.935556
1.82E-06	18.09269
1.83E-06	3.124866
1.85E-06	11.08923
1.88E-06	3.156623
1.91E-06	4.024415
1.92E-06	3.182206
1.93E-06	10.41826
1.95E-06	3.202057
1.96E-06	4.065218
1.97E-06	3.214845
2E-06	11.43216
2.01E-06	3.241309
2.03E-06	11.50232
2.05E-06	4.140664
2.06E-06	11.57245
2.09E-06	3.294675
2.11E-06	4.192073
2.13E-06	10.85343
2.14E-06	4.217782
2.15E-06	11.78912
2.18E-06	3.355981
2.2E-06	4.269763
2.21E-06	3.376714



APPLICATION NOTE