Ground or Not to Ground Ethernet Protection (Part 2)

Nisar Chaudhry P.E. Tii Network Technologies, Inc

Presented at Protection Engineers Group 2013



Ground or Not to Ground Ethernet Protection

This presentation builds on the material presented last year at this forum. Some attendees during question period had suggested we do some additional testing on the Ethernet protection and present here in the PEG conference 2013

So the question still stands "Ground or Not Ground the Ethernet Surge Protection". Data presented in the last year's presentation even though not comprehensive, did point to necessity of grounding Ethernet protection circuits.

During the past year we have conducted a number of surge tests with additional Network Interface Cards as well as Surge protection circuits.

A brief review of last year presentation will not be out of place to start this presentation for the sake of continuity of the topic.

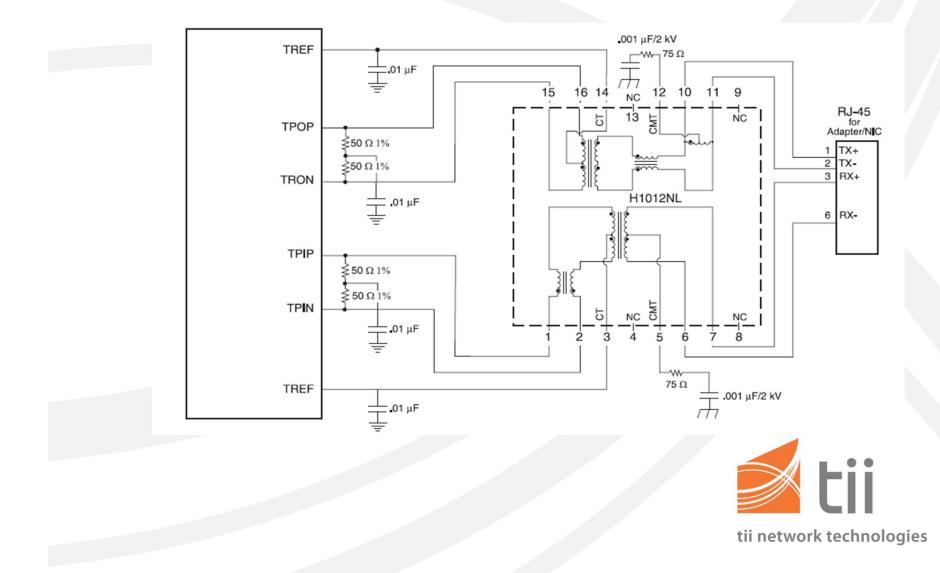


Typical NIC Card Ethernet Port – Network Side





NIC Card Front End Interface with RJ 45



Ethernet Port – Magnetics Dissected





Essentials for Surge Protection Evaluation

Following were considered necessary for Lab Evaluation of Ethernet Surge Protection

- 1. Computer Network to Verify operation of NIC cards
- 2. Means of inducing balanced Surges
- 3. Surge Generator with high enough Surge Energy and Voltage capability
- 4. Surge application fixture for NIC card
- 5. Means of measuring and recording surge events



Computer Network to Verify Operation of NIC Cards



Transferring data files from one computer to another computer. Monitoring the file transfer with windows task manager. Computer # 2 opened up for NIC card insert / remove capability.

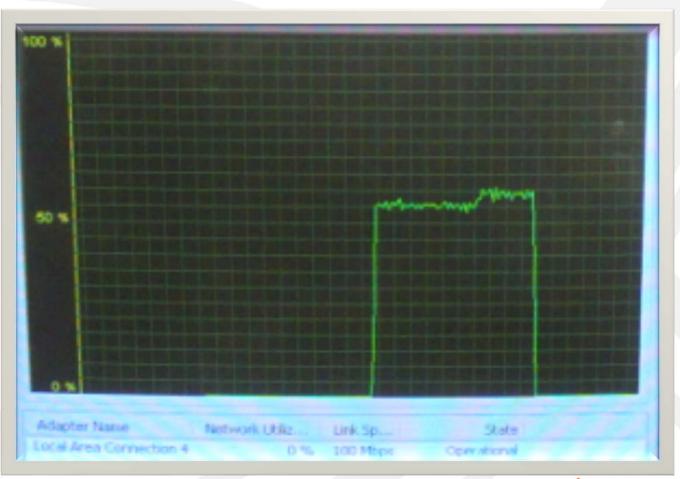


NIC Card Installed in Computer # 2



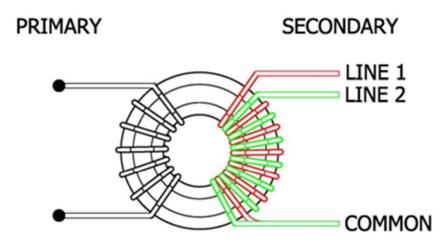


Windows Task Manager on Computer # 2





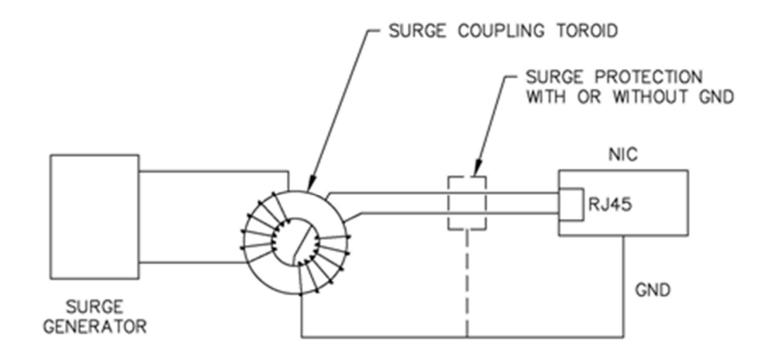
Means of Inducing Balanced Surges



TOROID



Surge Test Set-up



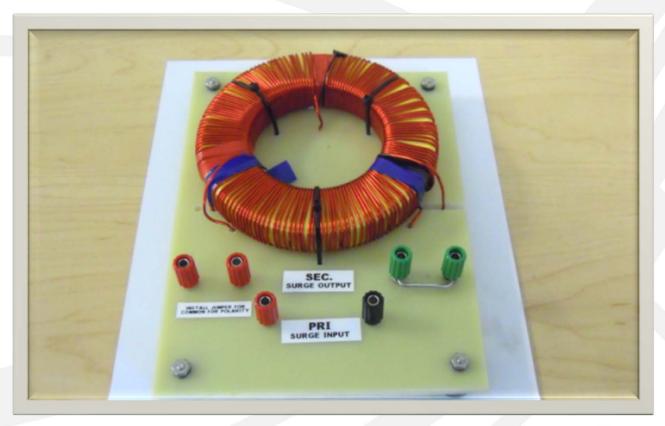


6kV 8/20 uS Surge Generator KeyTek 711



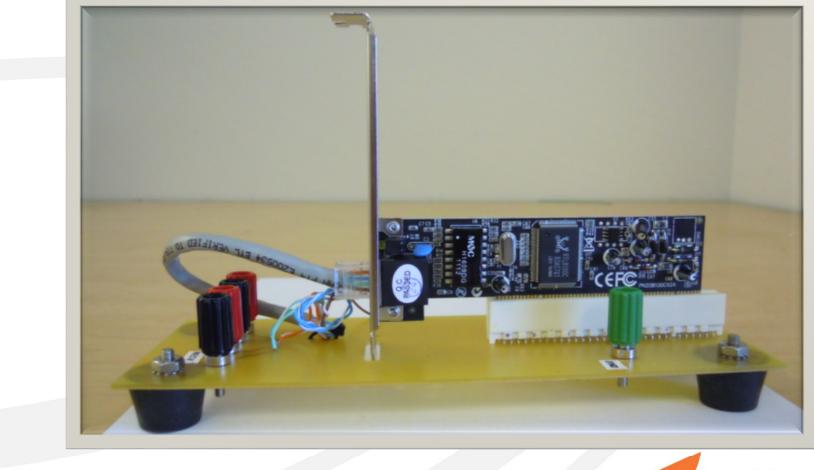


Means of Inducing Balanced Surges a Toriodal Transformer





Adapter Board for NIC Card Surge Application





Current Loop for Measuring Surge Current



Complete Surge Testing Setup





Surge Voltage Values vs Damage to NIC

Surge Voltages from 700 to 6000 volts were applied to the NIC cards and monitored with a scope.

Voltages in excess of 3500 volts were able to cause damage to the NIC cards

Voltages in excess of 5000 Volts caused enough damage that the NIC card stopped to connect to the network



Conclusions to Part 1

NIC card have pretty good Isolation levels, surges up to 3500 volts did not show any damage.

Protection Circuits without ground provided partial protection, some boards continued to function even with some damage on the boards.

Protection Circuit with ground provided complete protection to the maximum level of surges available during this evaluation.

If you need good protection, the answer to question: Ground or Not to Ground Ethernet protection is

Ground Ethernet Protection



Ethernet Protection (Part 2)



Objectives for Ethernet Protection Part 2

- 1. Investigate surge survival of NIC cards from various manufacturers.
- 2. Test additional Ethernet surge protection circuits taking into consideration of Power over Ethernet.
- 3. Analyze and compare transmission characteristics of the Ethernet surge protection circuits.
- 4. Conclusions













Surge Testing Results of Various NIC Cards

Board (1) LINKSYS No protection

Surged from 3.5KV to 6KV, Board showed damage at 3.5KV but operated fully to 5.5KV. At 6KV the board although operating, Data transmission was compromised and data transfer speed was decreased.

Board (2) INTEL No protection

Board showed damage at 3.5KV components damaged. Board stopped operating at 5KV.

Board (3)TRENDNET No protection surged 3.5KV to 4KV Board showed physical damage at 4KV and stopped operating at 4KV.

Board (4) D-LINK No protection surged from 3KV to 6KV Board showed no damage and operated fully.



Surge Protection Circuits Used

Circuit 1:

Consisted of two three electrode GDT protection. The GDTs selected had nominal breakdown voltage of 500 volts.

Circuit 2:

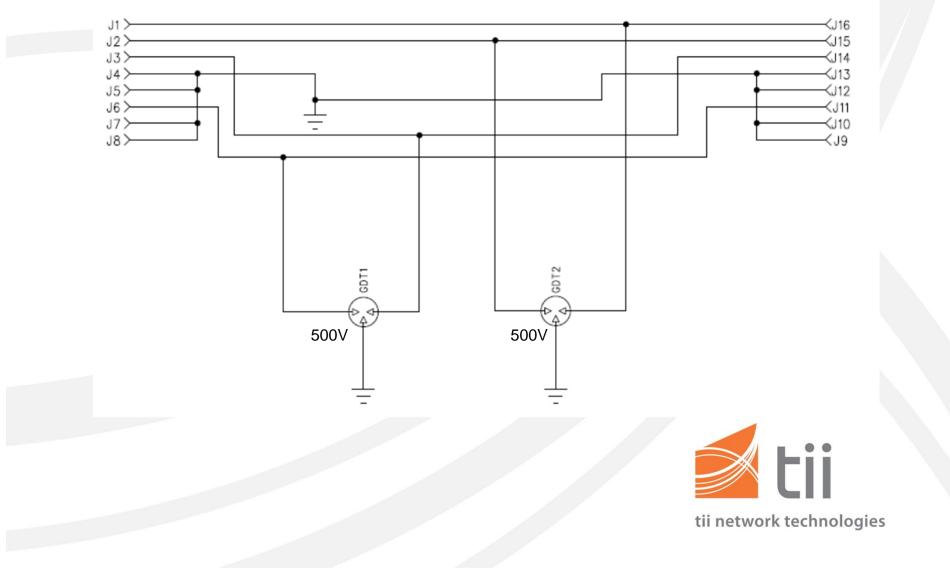
Consisted of two steering diode bridges with 12 volt bidirectional avalanche diodes, two 90 volts GDTs from pair 1 to pair 2 of the Ethernet circuit and two three electrode GDTs for surges referenced to Ground.

Circuit 3:

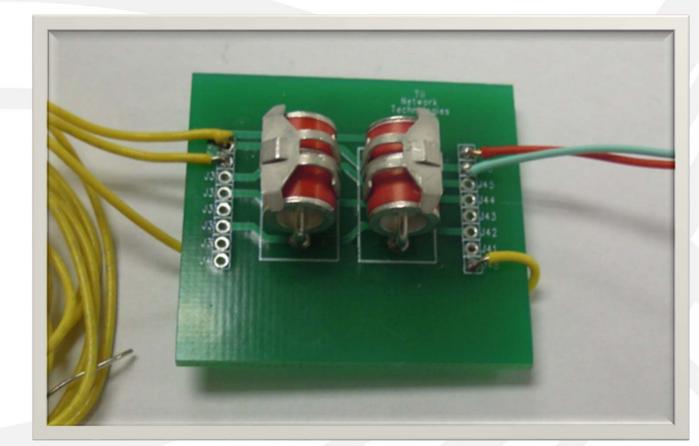
Comprised of steering diode bridges with two 24 volt bipolar avalanche diodes and one 3 electrode GDT of 500 volts nominal breakdown, with center electrode connected to ground.



Circuit # 1

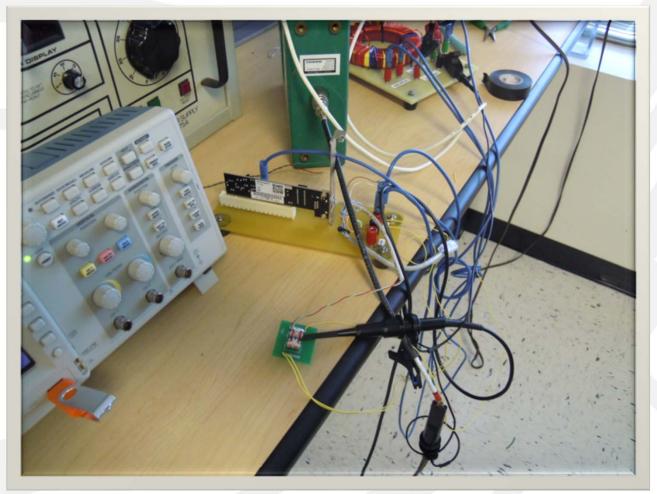


Circuit # 1Test Board



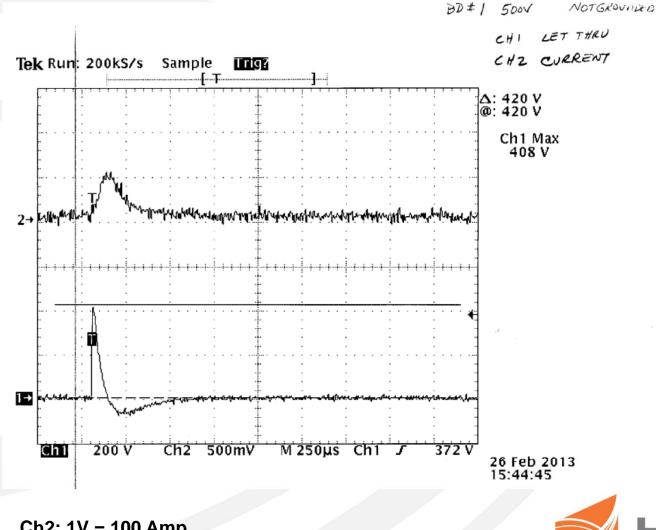


Circuit # 1Test Configuration



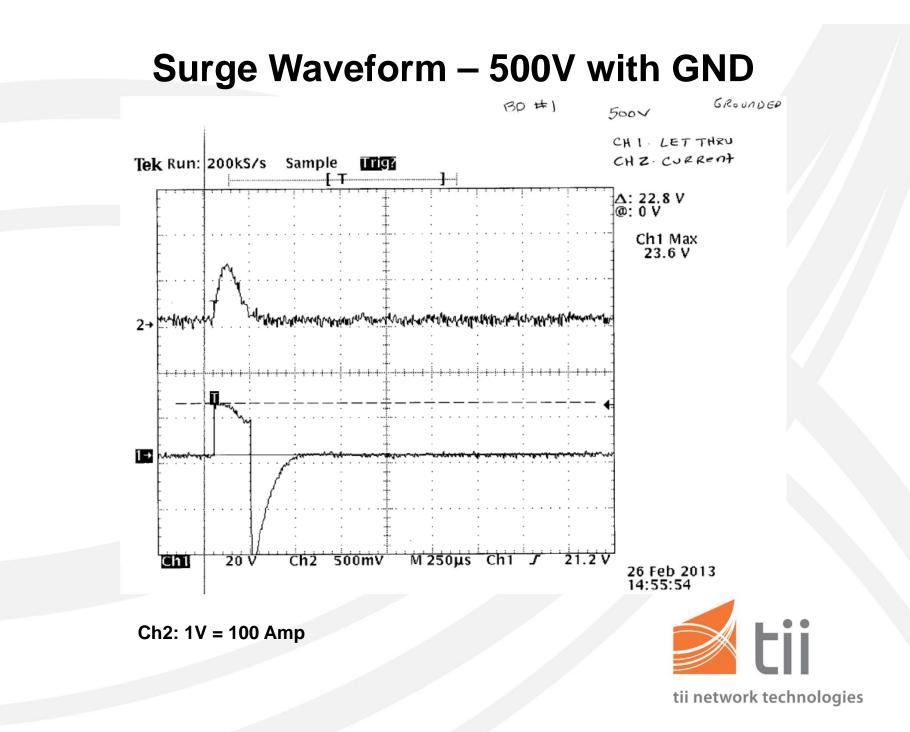


Surge Waveform – 500V without GND

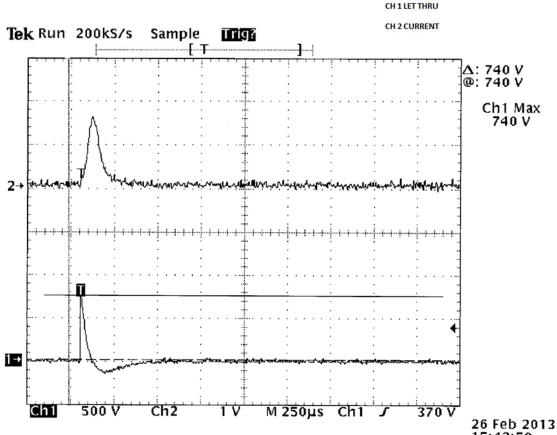


Ch2: 1V = 100 Amp





Surge Waveform – 1kV without GND



15:43:50

8X20uS 1KV BOARD #1 NOT GROUNDED

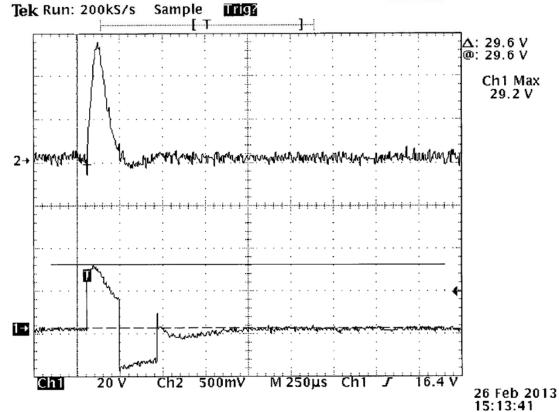


Surge Waveform – 1kV with GND

8X20uS 1.0KV BOARD #1 GROUNDED

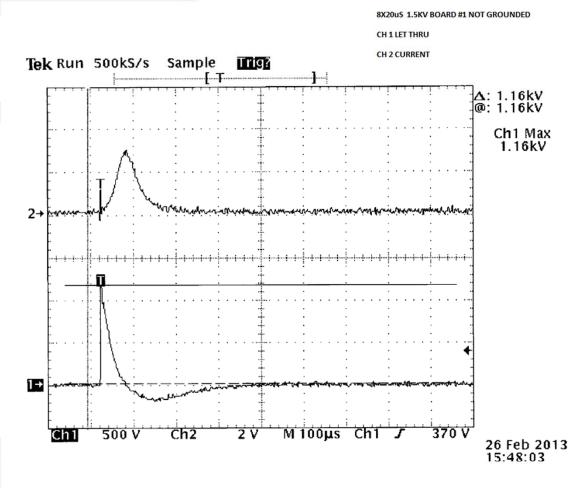
CH 1 LET THRU

CH 2 CURRENT





Surge Waveform – 1.5kV without GND



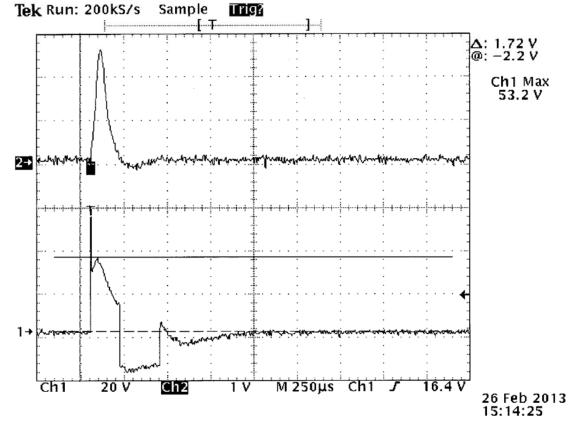


Surge Waveform – 1.5kV with GND

8X20uS 1.5KV BOARD #1 GROUNDED

CH 1 LET THRU

CH 2 CURRENT



Ch2: 1V = 100 Amp



Surge Waveform – 2kV without GND

8X20uS 2KV BOARD #1 NOT GROUNDED

CH 1 LET THRU CH 2 CURRENT Tek Run 200kS/s Sample Trig? F F ∆: 420 V @: 420 V Ch1 Max 408 V map water a super and a super and a super a super a super super super super a super 2→ Mh 1→ 200 V Ch2 500mV M 250µs Ch1 372 V Ch1 5 26 Feb 2013 15:44:45



Surge Waveform – 2kV with GND

8X20uS 2.0KV BOARD #1 GROUNDED

CH 1 LET THRU CH 2 CURRENT Tek Run: 200kS/s Sample Trig? F ∆: 3.44 V @: −4.4 V Ch1 Max 38.8 V 2→ 1→ ~~~ 16.4 V 2 V M 250µs Ch1 J 20 V Ch2 Ch1 26 Feb 2013 15:17:49

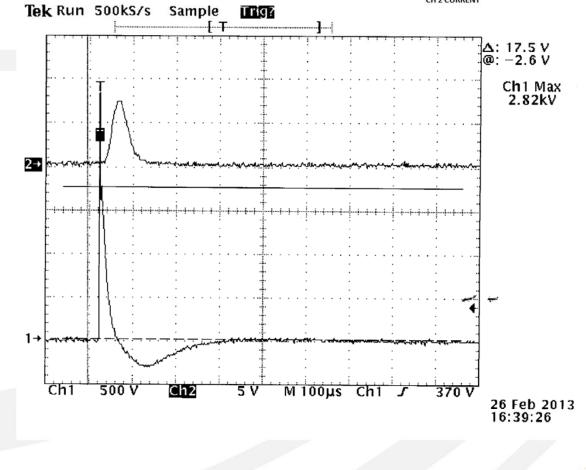


Surge Waveform – 2.5kV without GND

8X20uS 2.5KV BOARD #1 NOT GROUNDED

CH 1 LET THRU

CH 2 CURRENT



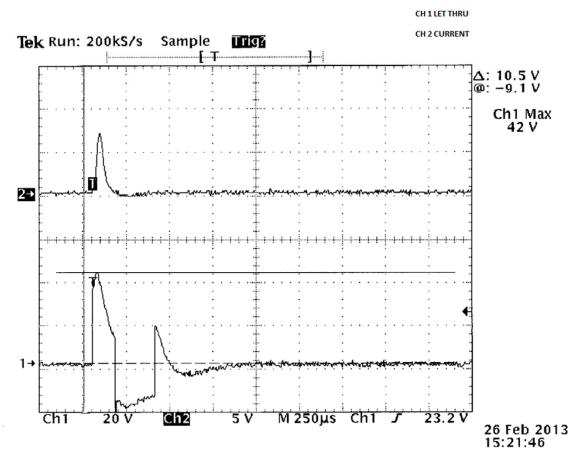
Ch2: 1V = 100 Amp



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Surge Waveform – 2.5kV with GND

8X20uS 2.5KV BOARD #1 GROUNDED



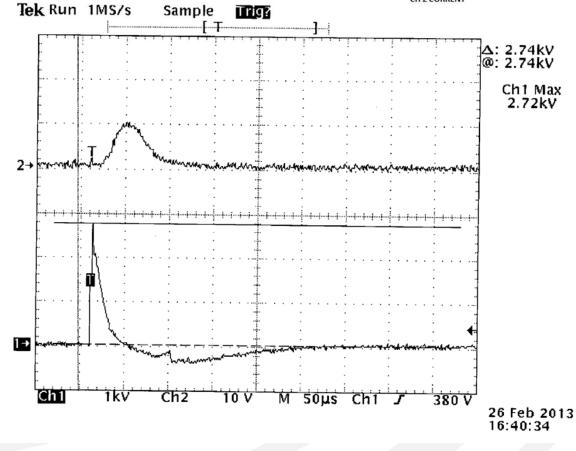


Surge Waveform – 3kV without GND

8X20uS 3.0KV BOARD #1 NOT GROUNDED

CH 1 LET THRU

CH 2 CURRENT



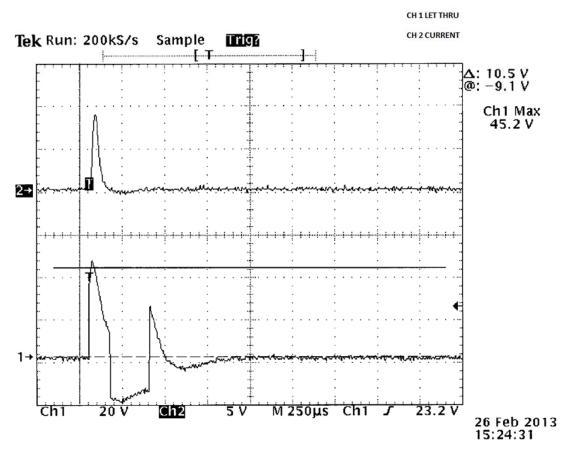
Ch2: 1V = 100 Amp



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Surge Waveform – 3kV with GND

8X20uS 3.0KV BOARD #1 GROUNDED





Surge Waveform – 3.5kV without GND

CH 2 CURRENT Tek Run: 1MS/s Sample Trig? FT ∆: 3.08kV @: 3.08kV Ch1 Max 3.08kV 2→ 1→ 50µs Ch1 800 V Chi 1kV Ch2 10 V M J 26 Feb 2013 16:42:51

Ch2: 1V = 100 Amp

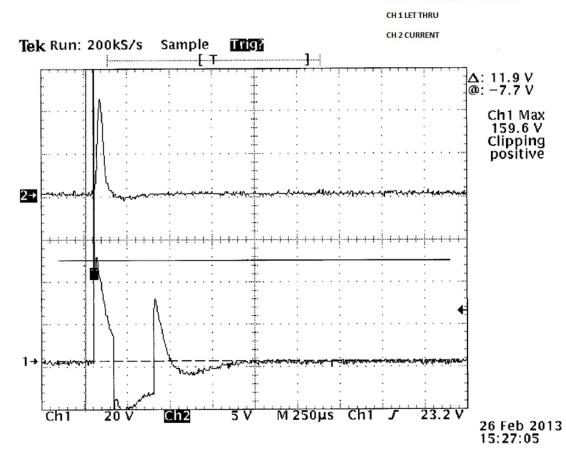


CH 1 LET THRU

8X20uS 3.5KV BOARD #1 NOT GROUNDED

Surge Waveform – 3.5kV with GND

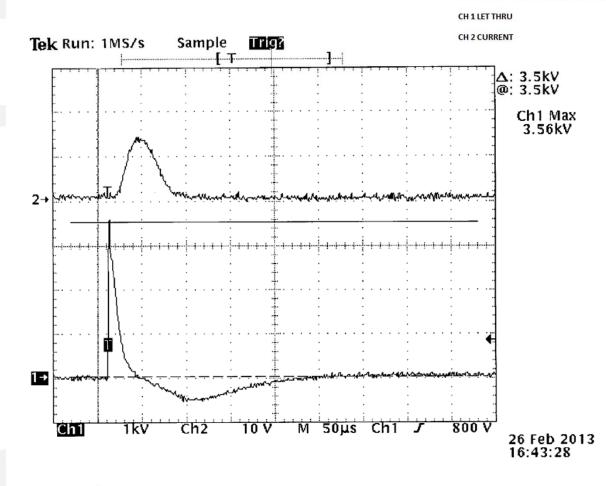
8X20uS 3.5KV BOARD #1 GROUNDED





Surge Waveform – 4kV without GND

8X20uS 4.0KV BOARD #1 NOT GROUNDED

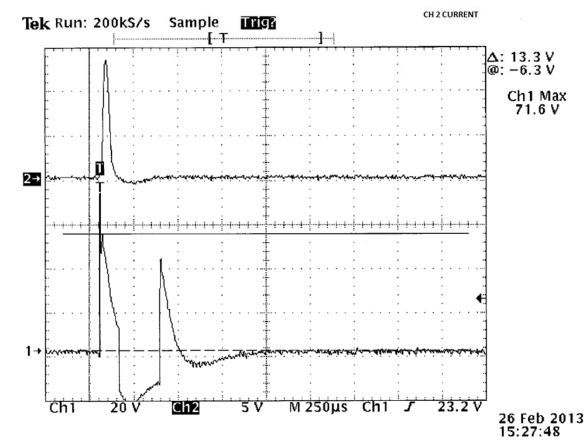




Surge Waveform – 4kV with GND

8X20uS 4.0KV BOARD #1 GROUNDED

CH 1 LET THRU





Surge Waveform – 4.5kV without GND

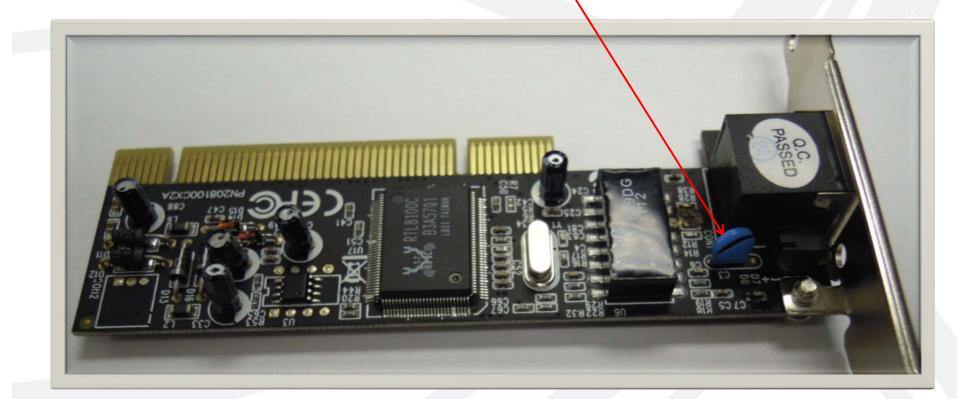
CH 1 LET THRU

CH 2 CURRENT Tek Run: 1MS/s Sample Trig? DAMAGE TO CAPACITOR WORKING -- F-- F---]--| ∆: 2.27kV @: 2.27kV Ch1 Max 4.43kV 4 the contract of the contract of the contraction o 2 + MM M 1∔ 800 V Ch1 M 50µs Ch1 J 500 V 10 V Ch2 26 Feb 2013 16:48:32



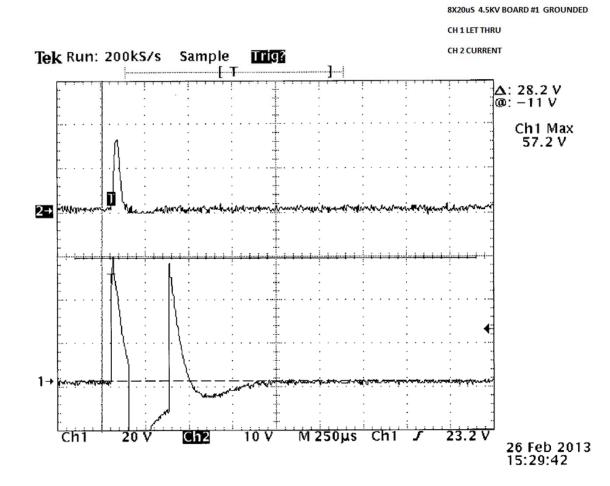
Surge Waveform – 4.5kV without GND

Damage to Capacitor C3



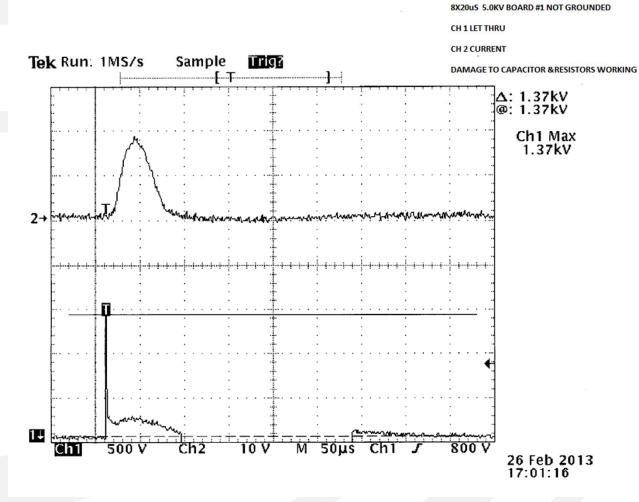


Surge Waveform – 4.5kV with GND





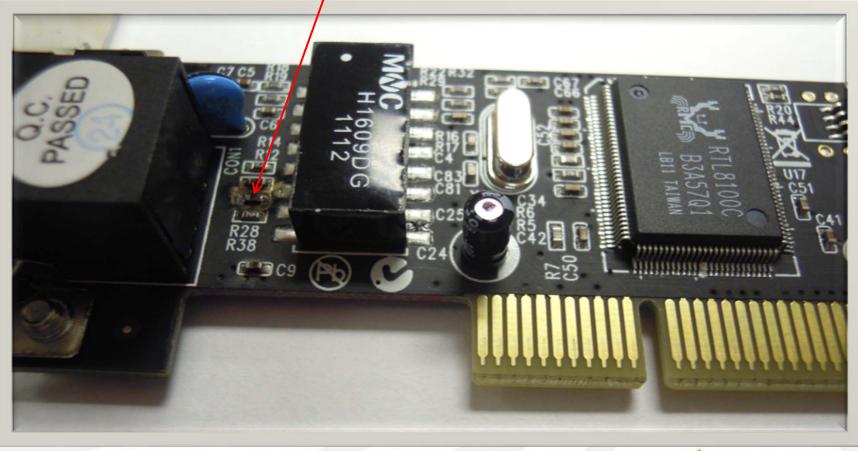
Surge Waveform – 5kV without GND



Ch2: 1V = 100 Amp



Surge Waveform – 5kV without GND / Damage to Resistor R28





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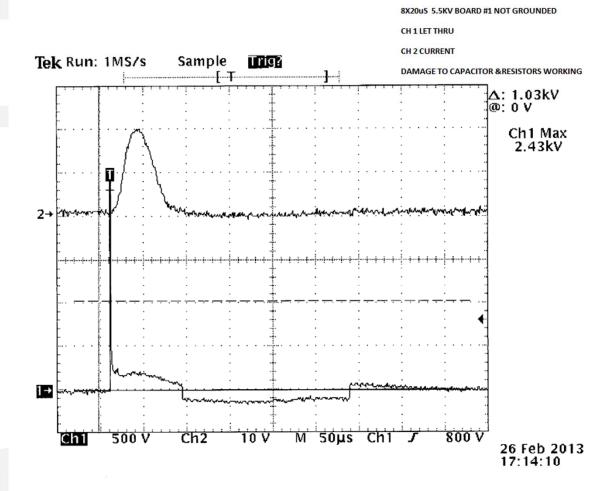
Surge Waveform – 5kV with GND

8X20uS 5.0KV BOARD #1 GROUNDED

CH 1 LET THRU CH 2 CURRENT Tek Run: 200kS/s Sample Trig? E-T--]---[∆: 29 V @: −10.2 V Ch1 Max 58.8 V 2→ Å Lough work 1 + inmary M 250µs Ch1 J 23.2 V Ch2 10 V Ch1 20 V 26 Feb 2013 15:30:19



Surge Waveform – 5.5kV without GND



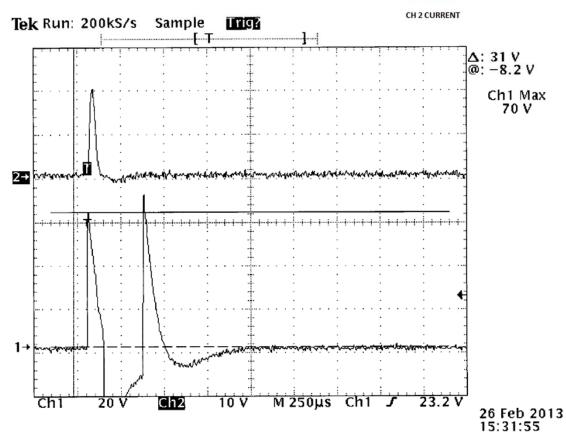
Ch2: 1V = 100 Amp



Surge Waveform – 5.5kV with GND

8X20uS 5.5KV BOARD #1 GROUNDED

CH 1 LET THRU



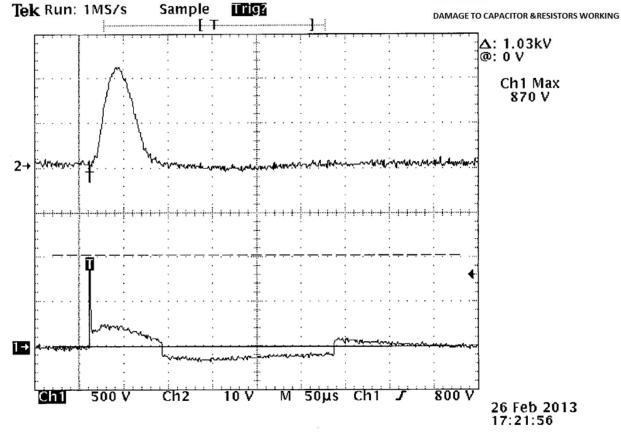


Surge Waveform – 6kV without GND

8X20uS 6.0KV BOARD #1 NOT GROUNDED

CH 1 LET THRU

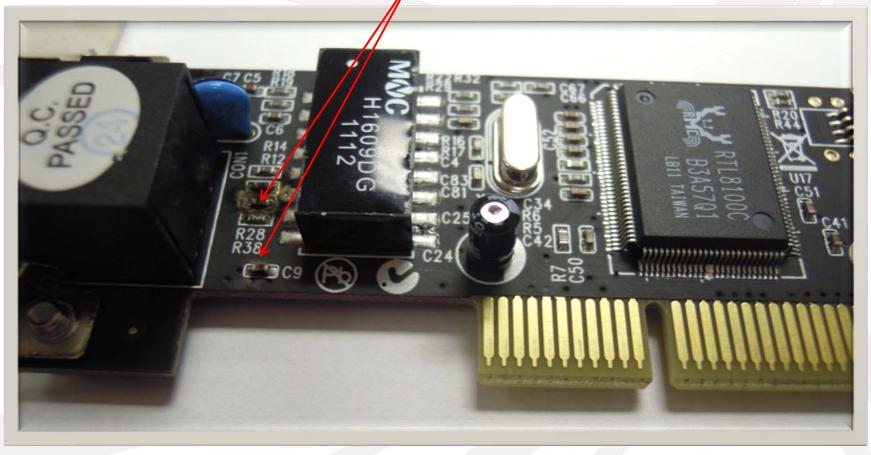
CH 2 CURRENT



Ch2: 1V = 100 Amp



Surge Waveform – 6kV without GND Damage to R28 and C9





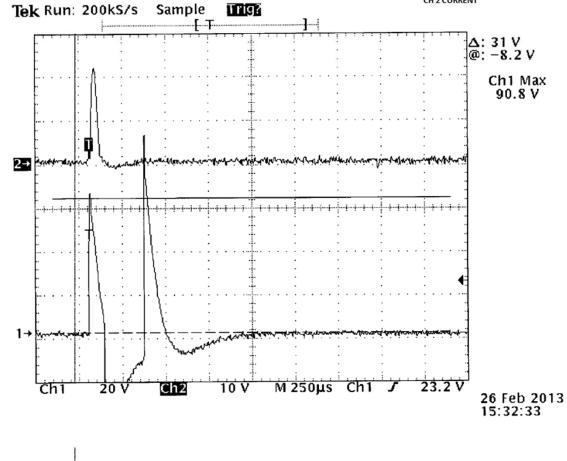
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Surge Waveform – 6kV with GND

8X20uS 6.0KV BOARD #1 GROUNDED

CH 1 LET THRU

CH 2 CURRENT





Protection Circuit 1 Test Results

No Ground Connection:

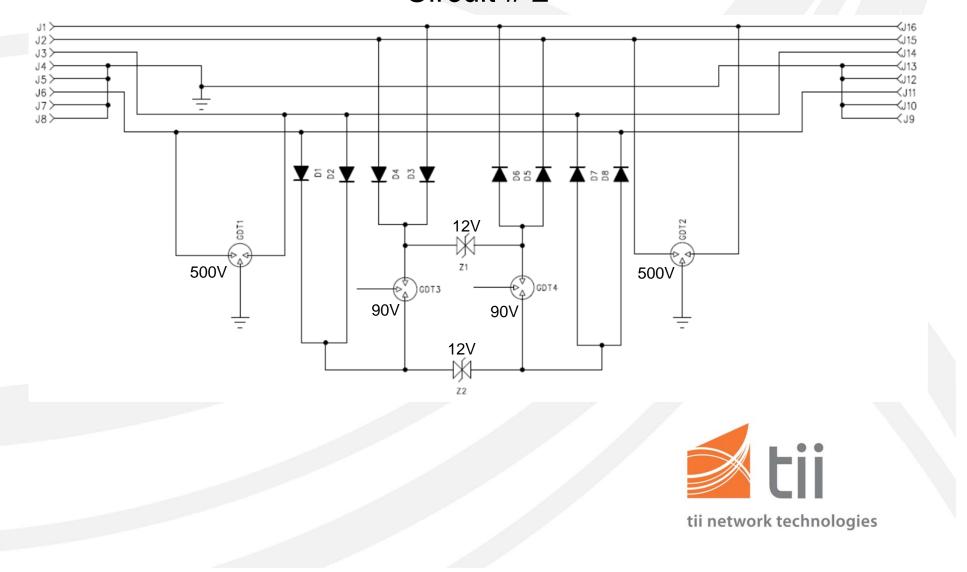
NIC cards started showing damage when surge voltage levels were increased beyond 4000 volts.

With Ground Connection:

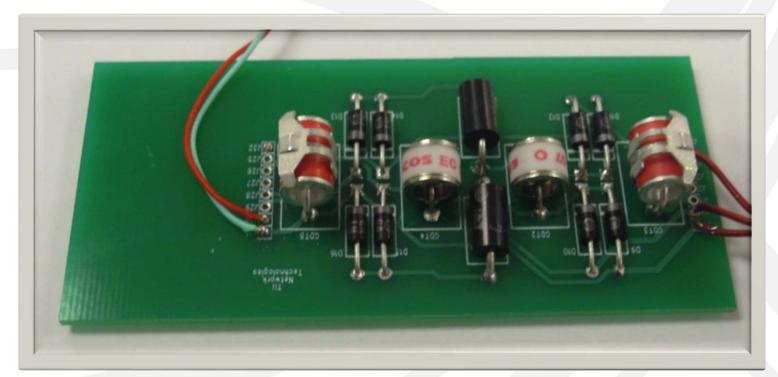
NIC cards showed no damage when ground connection was present and the GDT allowed surge energy to be diverted to ground.



Circuit # 2

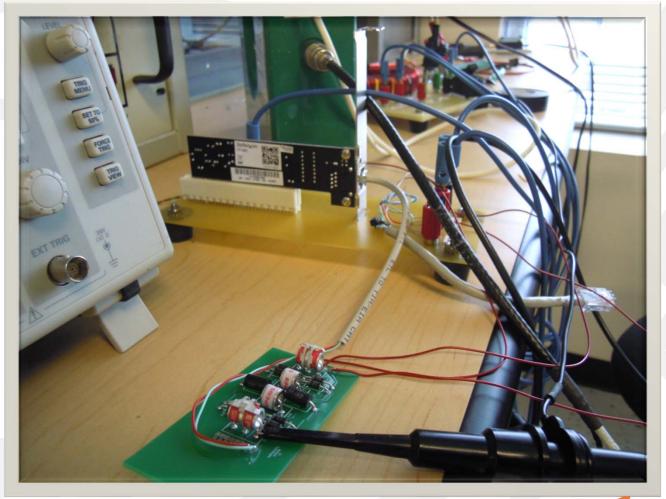


Circuit # 2Test Board





Circuit # 2Test Configuration





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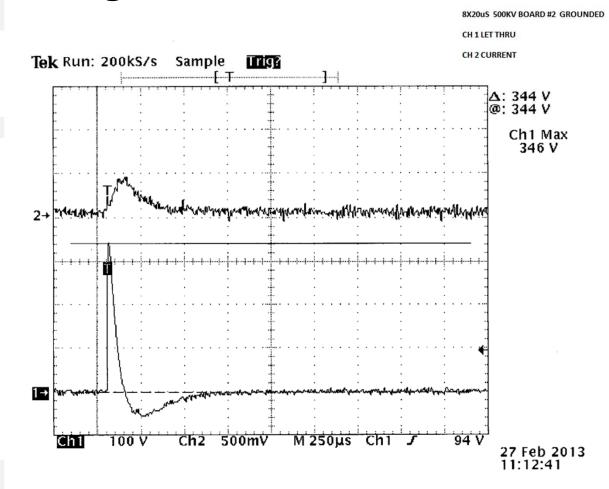
Surge Waveform – 500V without GND

8X20uS 500V BOARD #2 NOT GROUNDED

CH 1 LET THRU CH 2 CURRENT Tek Run: 5kS/s Sample Trig? -]--| F ∆: 392 V @: 392 V Ch1 Max 392 V un a that an ever allow of the half and a large of the section of the land a state of the 2 - Hypernal 1→ 128 V M 10ms Ch1 Ch2 500mV Ch1 200 V 27 Feb 2013 12:04:57

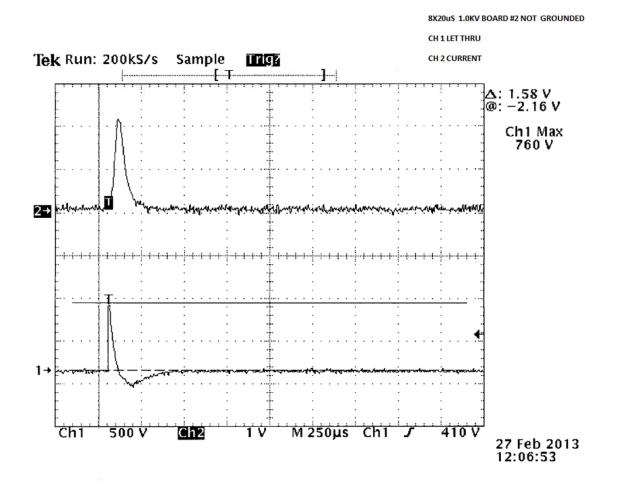


Surge Waveform – 500V with GND





Surge Waveform – 1kV without GND

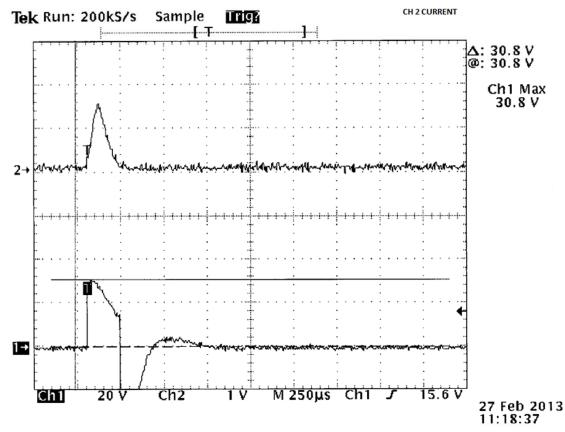




Surge Waveform – 1kV with GND

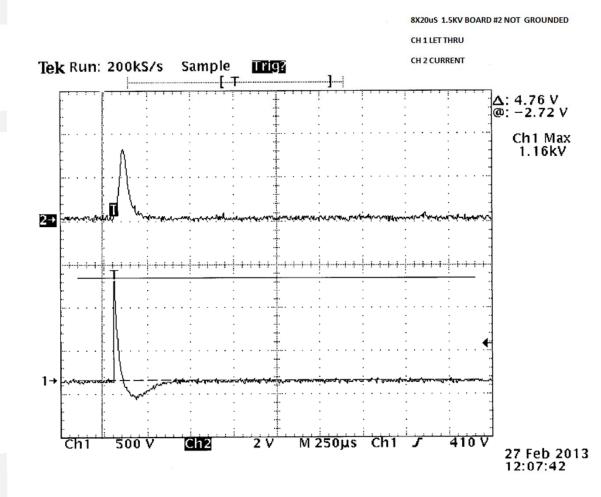
8X20uS 1.0KV BOARD #2 GROUNDED

CH 1 LET THRU





Surge Waveform – 1.5kV without GND



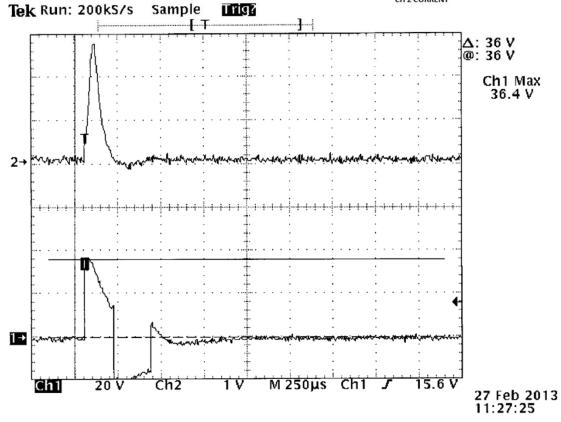


Surge Waveform – 1.5kV with GND

8X20uS 1.5KV BOARD #2 GROUNDED

CH 1 LET THRU

CH 2 CURRENT



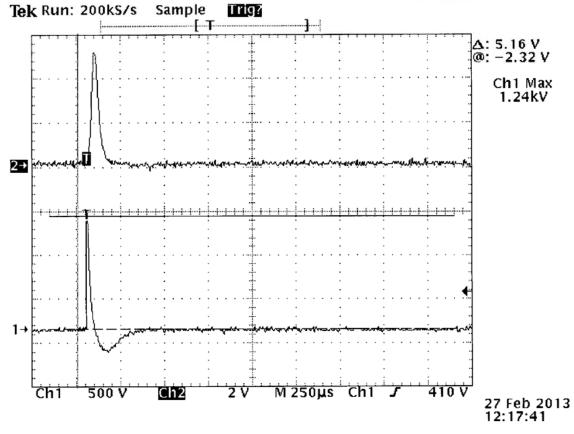


Surge Waveform – 2kV without GND

8X20uS 2.0KV BOARD #2 NOT GROUNDED

CH 1 LET THRU

CH 2 CURRENT



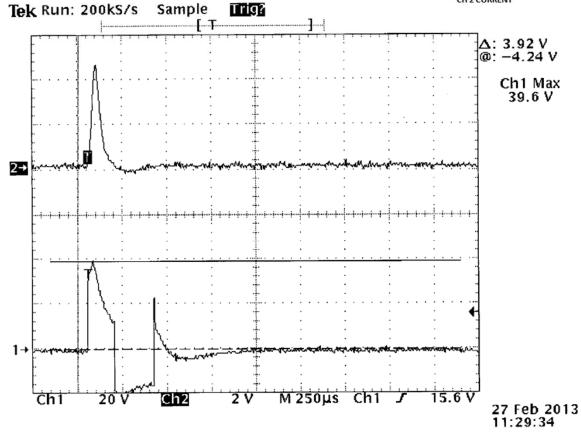


Surge Waveform – 2kV with GND

8X20uS 2.0KV BOARD #2 GROUNDED



CH 2 CURRENT



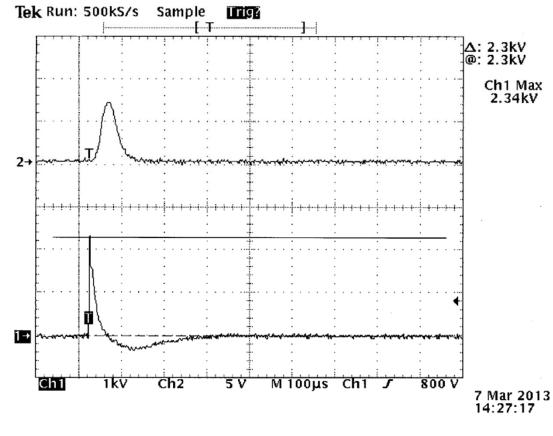


Surge Waveform – 2.5kV without GND

8X20Us 2.5KV BOARD #2 NOT GROUNDED



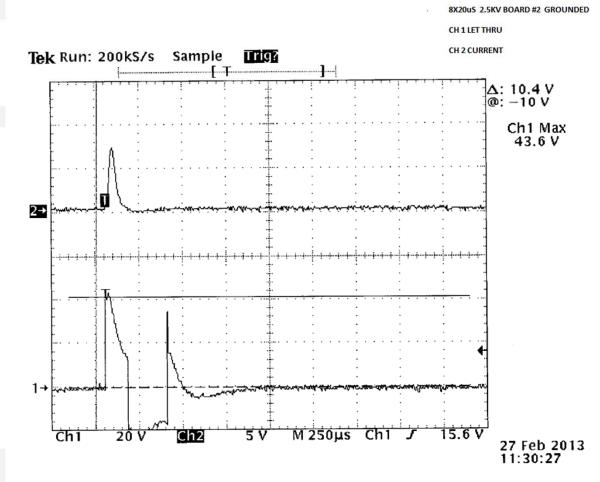
CH 2 CURRENT



Ch2: 1V = 100 Amp



Surge Waveform – 2.5kV with GND



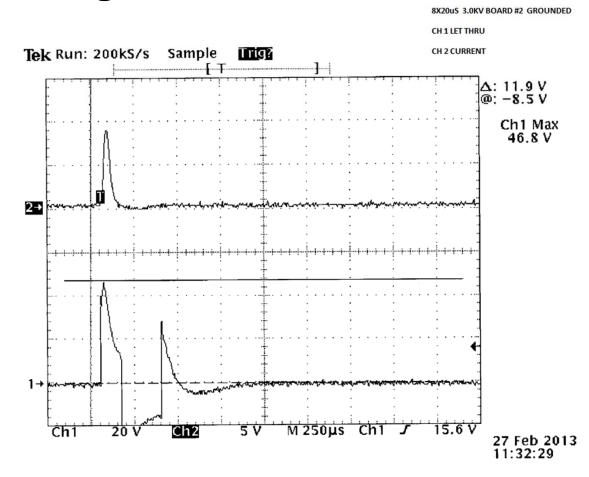


Surge Waveform – 3kV without GND

8X20uS 3.0KV BOARD #2 NOT GROUNDED CH 1 LET THRU CH 2 CURRENT Tek Run: 500kS/s Sample Trig?]--| ∆: 1.9kV @: 1.9kV Ch1 Max 1.88kV 2→ 1→ M 100µs Ch1 J 1kV 5 V 1kV Ch2 Ch1 27 Feb 2013 12:18:37



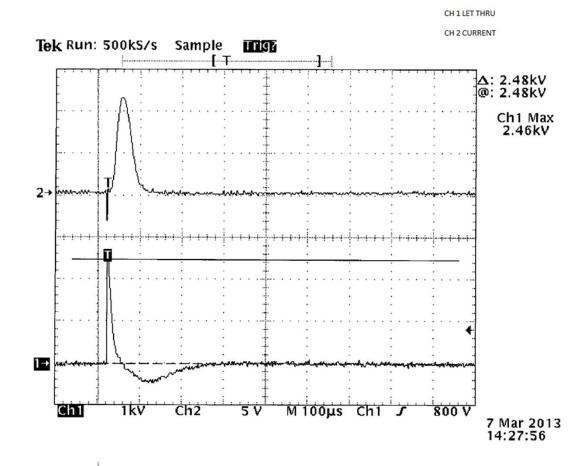
Surge Waveform – 3kV with GND





Surge Waveform – 3.5kV without GND

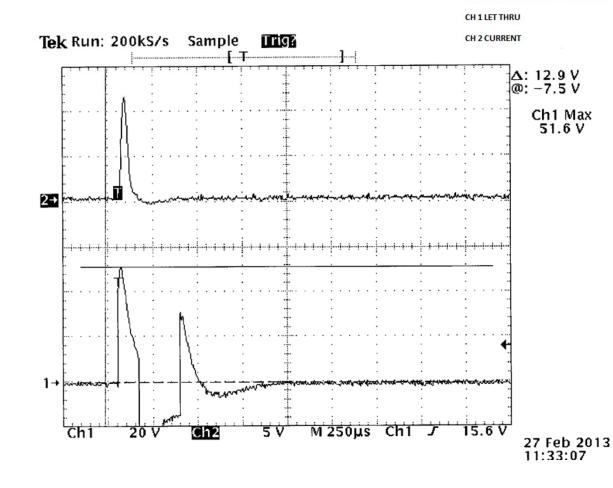
8X20Us 3.5KV BOARD #2 NOT GROUNDED





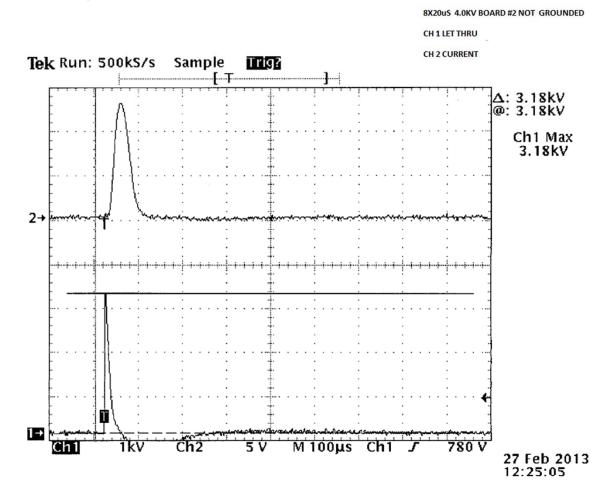
Surge Waveform – 3.5kV with GND

8X20uS 3.5KV BOARD #2 GROUNDED





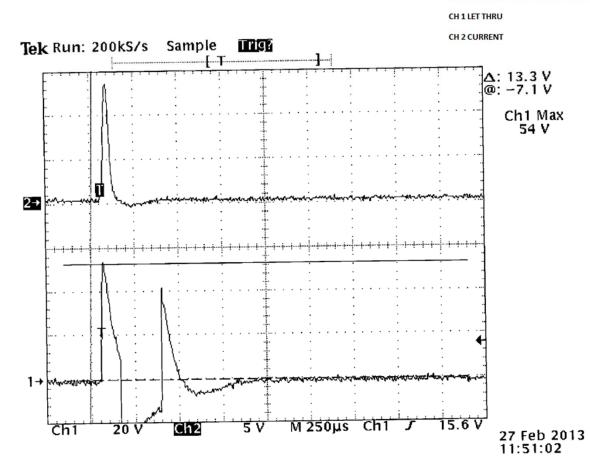
Surge Waveform – 4kV without GND





Surge Waveform – 4kV with GND

8X20uS 4.0KV BOARD #2 GROUNDED





Surge Waveform – 4.5kV without GND

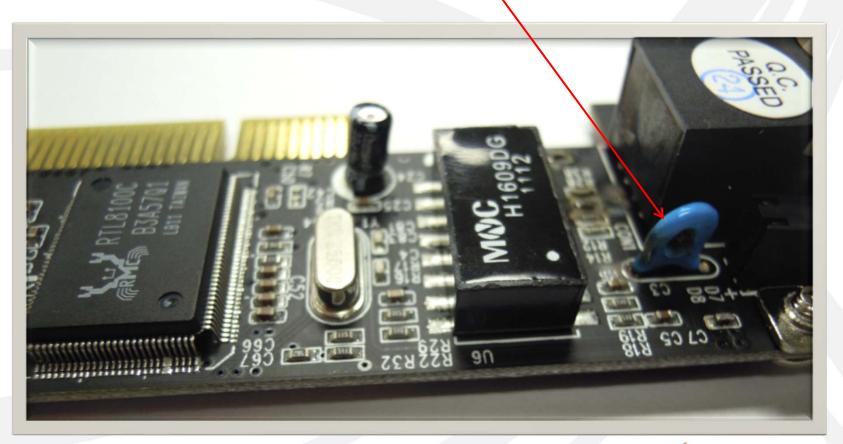
8X20uS 4.5KV BOARD #2 NOT GROUNDED

CH 1 LET THRU

CH 2 CURRENT Tek Run: 500kS/s Sample Trig? DAMAGE TO CAPACITOR WORKING F T ∆: 48.2 V @: −600mV Ch1 Max 4.86kV 2 - modelan where the second and the second and the second s 1→ Ch1 780 V 10 V M100µs Ch1 1kV Ch2 1 27 Feb 2013 12:26:00



Surge Waveform – 4.5kV without GND Damage to Capacitor C3

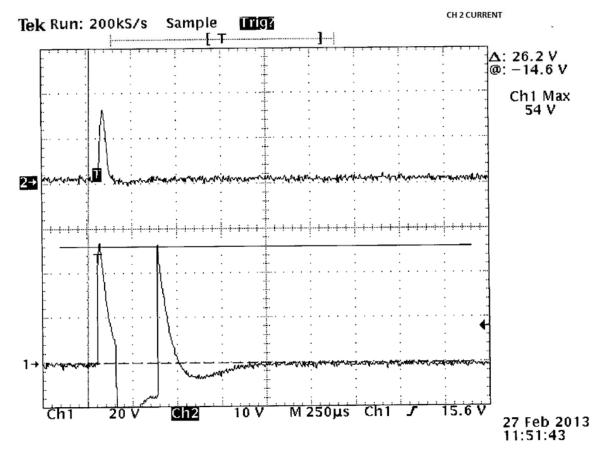




Surge Waveform – 4.5kV with GND

8X20uS 4.5KV BOARD #2 GROUNDED

CH 1 LET THRU





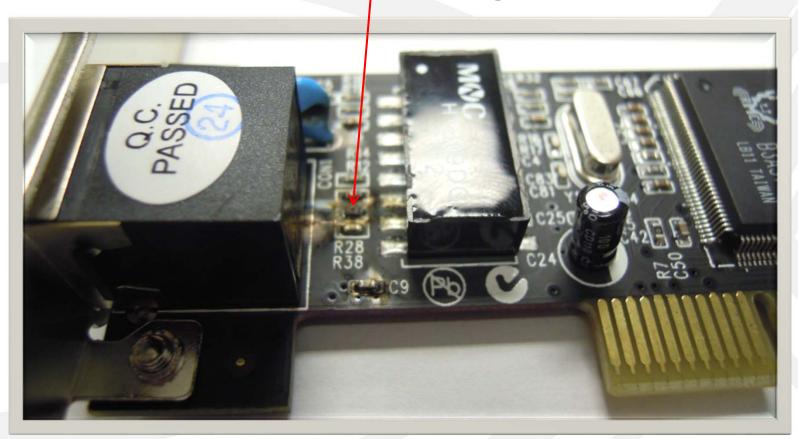
Surge Waveform – 5kV without GND

8X20uS 5.0KV BOARD #2 NOT GROUNDED

CH 1 LET THRU CH 2 CURRENT Tek Run: 500kS/s Sample Trig? DAMAGE TO CAPACITOR & RESISTORS WORKING FT -----∆:360 V @:−30 V Ch1 Max 470 V 2→ manufamentermenterment 1→ Ch2 10 V M 100µs Ch1 780 V 500 V Ch1 5 27 Feb 2013 12:37:14



Surge Waveform – 5kV without GND Damage to Resistor R28

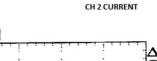


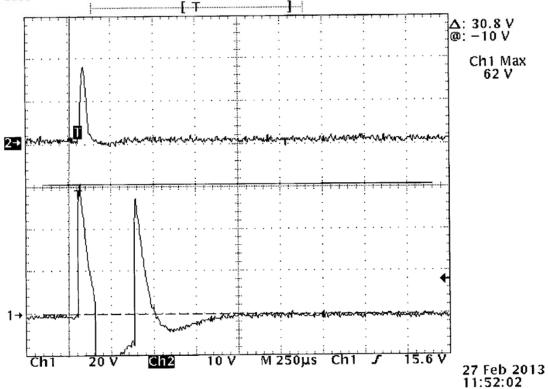


Surge Waveform – 5kV with GND

8X20uS 5.0KV BOARD #2 GROUNDED

CH 1 LET THRU





Ch2: 1V = 100 Amp

Tek Run: 200kS/s Sample

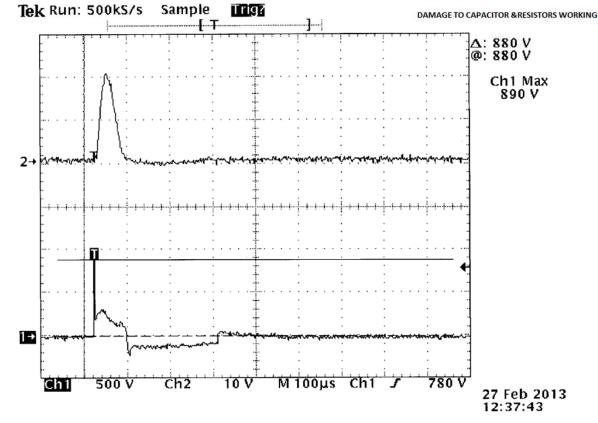


Surge Waveform – 5.5kV without GND

8X20uS 5.5KV BOARD #2 NOT GROUNDED

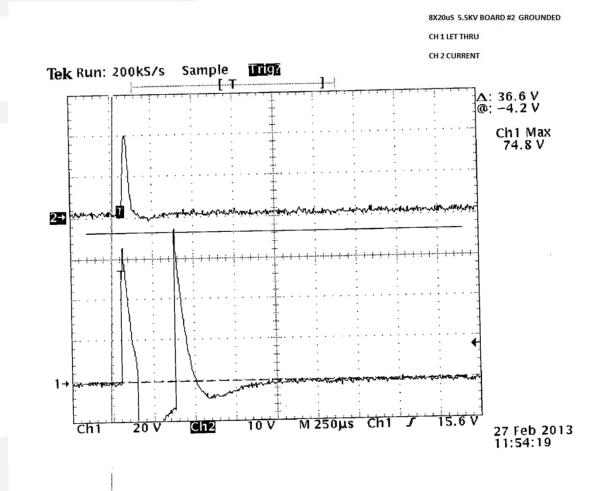
CH 1 LET THRU

CH 2 CURRENT



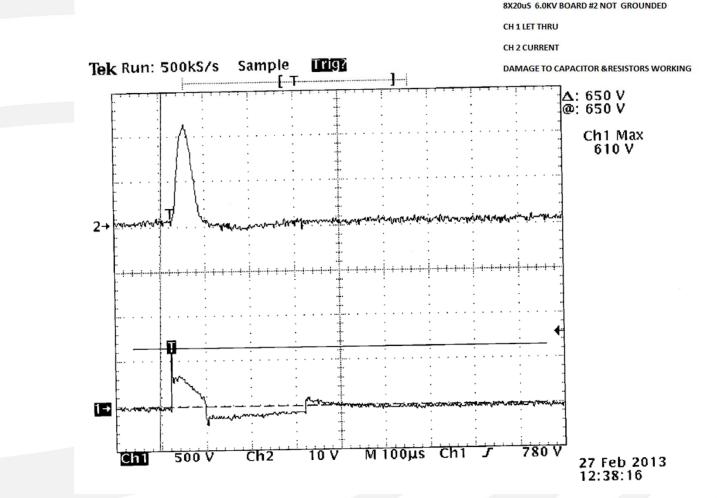


Surge Waveform – 5.5kV with GND





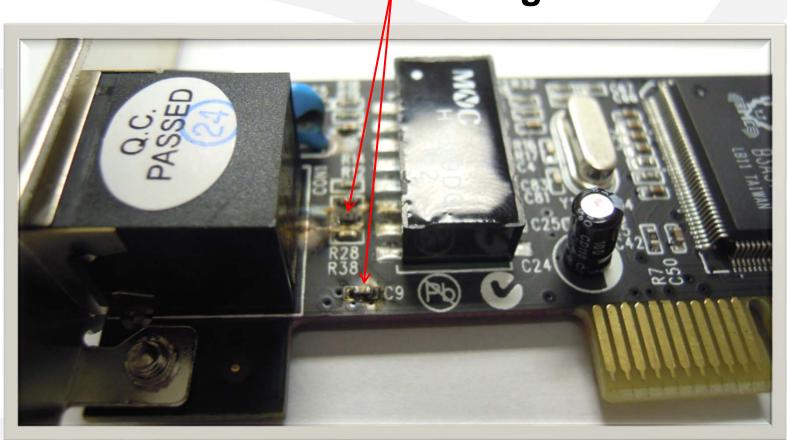
Surge Waveform – 6kV without GND



Ch2: 1V = 100 Amp

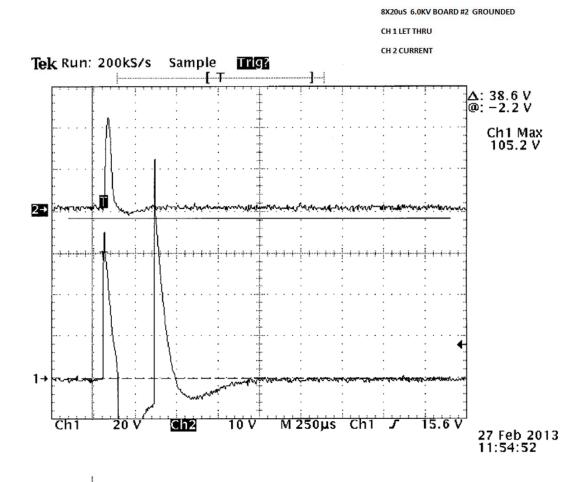


Surge Waveform – 6kV without GND Damage to R28 and C9





Surge Waveform – 6kV with GND





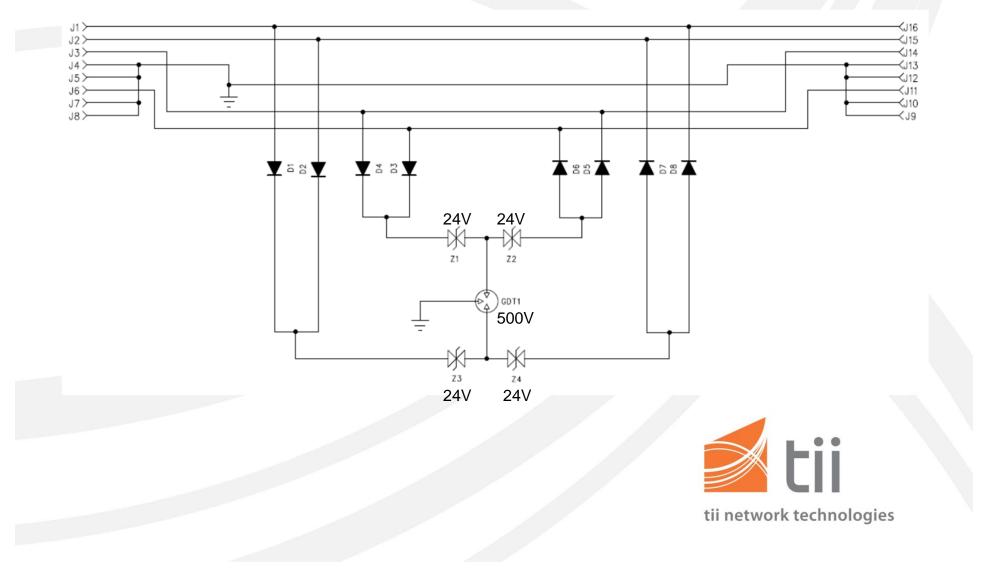
Protection Circuit 2 Test Results

No Ground Connection: NIC cards got damaged when surge voltages approached 4000 volts or higher.

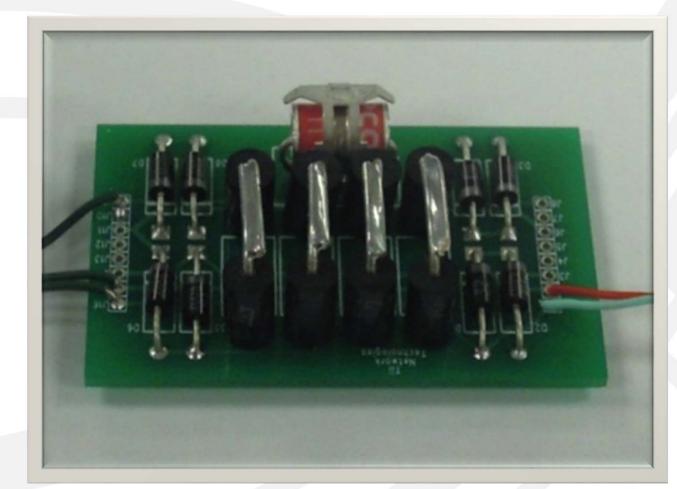
With Ground Connection: No damage suffered by the NIC cards when Ground connection was present.



Circuit # 3

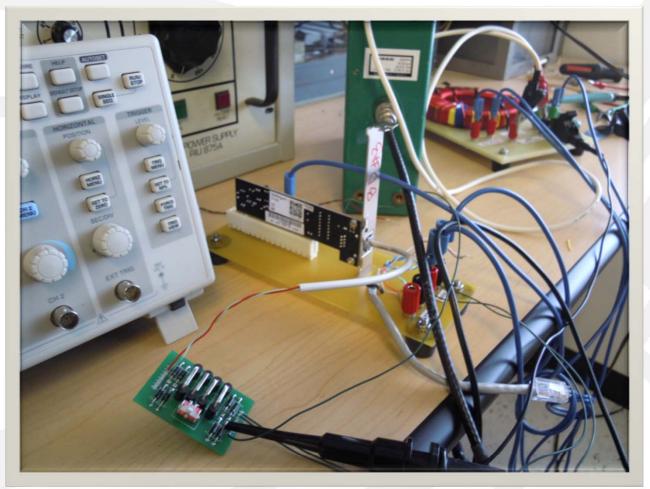


Circuit # 3Test Board



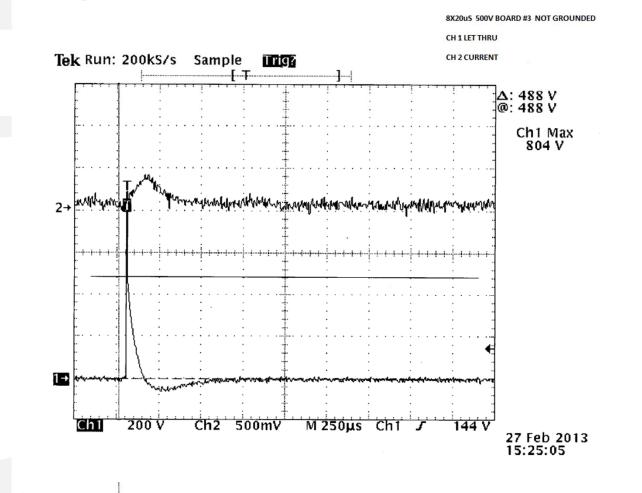


Circuit # 3Test Configuration





Surge Waveform – 500V without GND



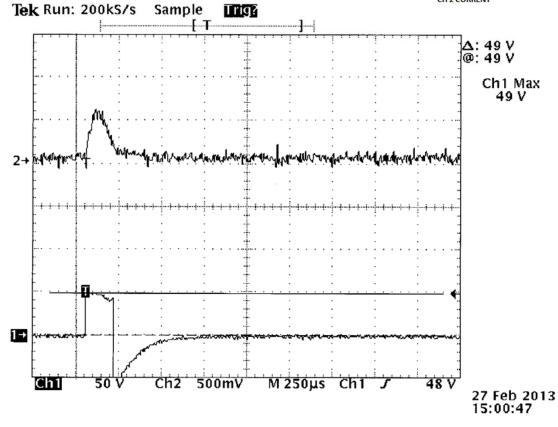


Surge Waveform – 500V with GND

8X20uS 500V BOARD #3 GROUNDED

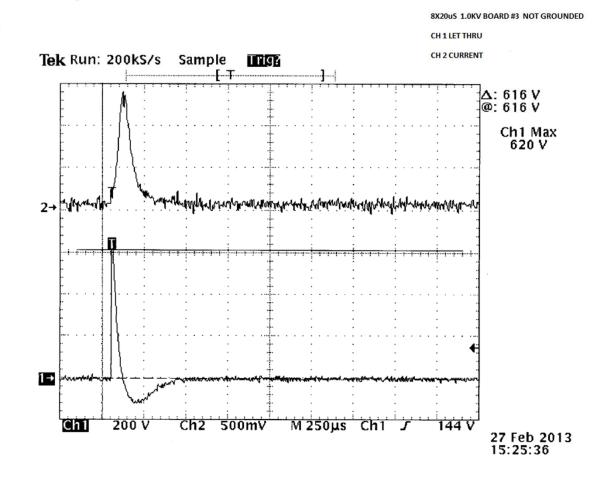
CH 1 LET THRU

CH 2 CURRENT





Surge Waveform – 1kV without GND



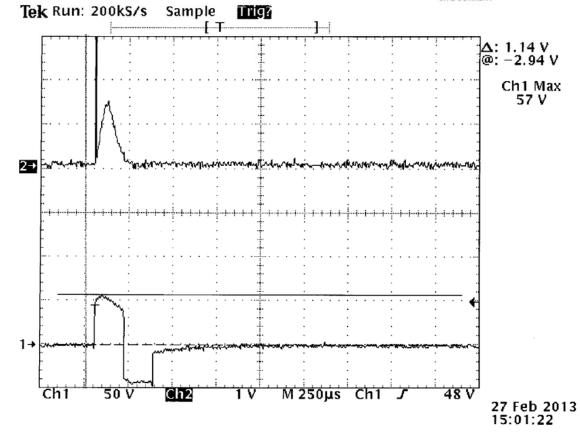


Surge Waveform – 1kV with GND

8X20uS 1.0KV BOARD #3 GROUNDED

CH 1 LET THRU

CH 2 CURRENT



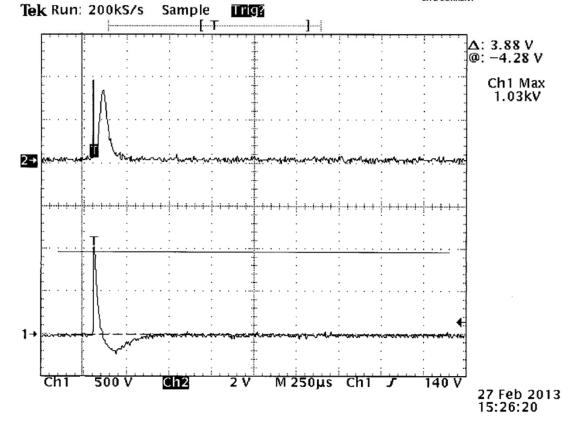


Surge Waveform – 1.5kV without GND

8X20uS 1.5KV BOARD #3 NOT GROUNDED

CH 1 LET THRU

CH 2 CURRENT



Ch2: 1V = 100 Amp

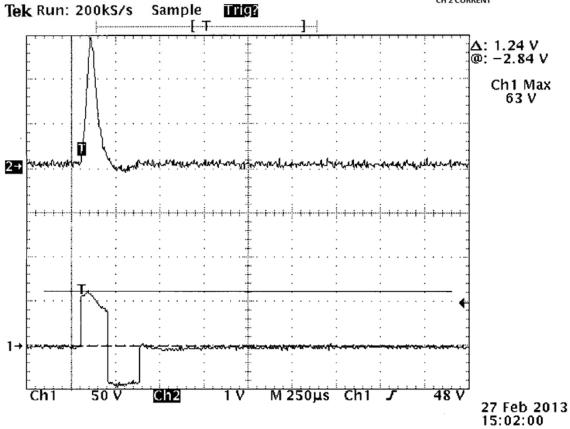


Surge Waveform – 1.5kV with GND

8X20uS 1.5KV BOARD #3 GROUNDED

CH 1 LET THRU

CH 2 CURRENT

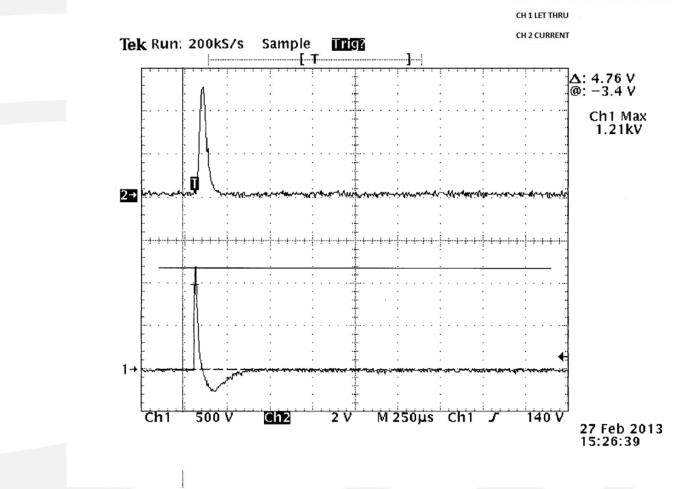


Ch2: 1V = 100 Amp



Surge Waveform – 2kV without GND

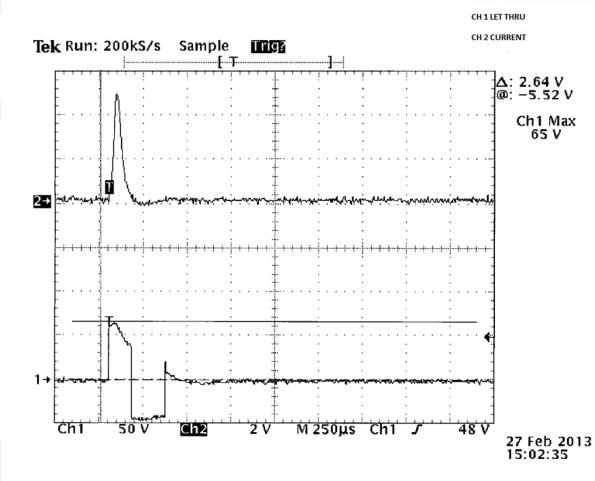
8X20uS 2.0KV BOARD #3 NOT GROUNDED





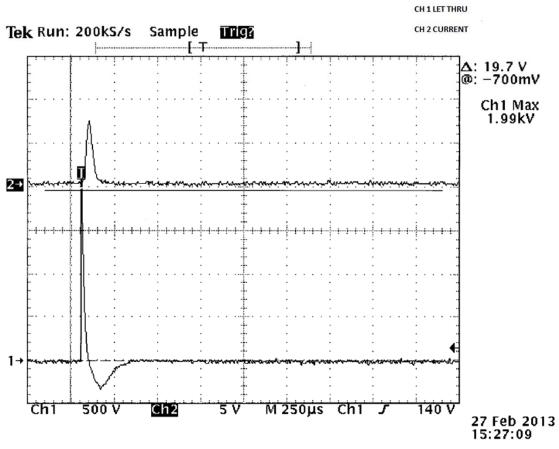
Surge Waveform – 2kV with GND

8X20uS 2.0KV BOARD #3 GROUNDED





Surge Waveform – 2.5kV without GND 8X20uS 2.5KV BOARD #3 NOT GROUNDED



Ch2: 1V = 100 Amp

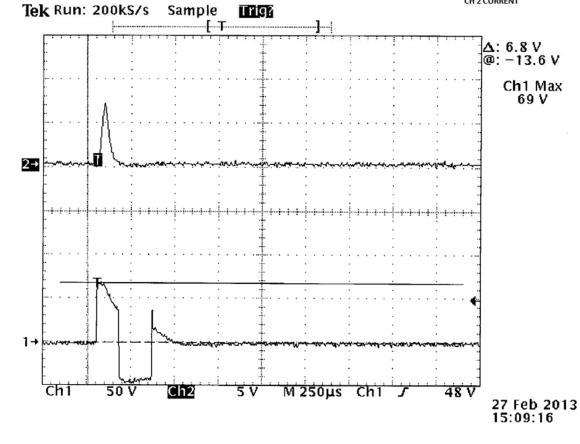


Surge Waveform – 2.5kV with GND

8X20uS 2.5KV BOARD #3 GROUNDED

CH 1 LET THRU

CH 2 CURRENT

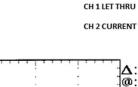


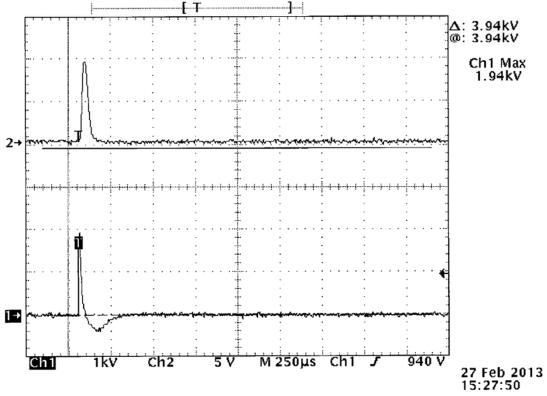


Surge Waveform – 3kV without GND

Trig?

8X20uS 3.0KV BOARD #3 NOT GROUNDED





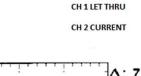
Ch2: 1V = 100 Amp

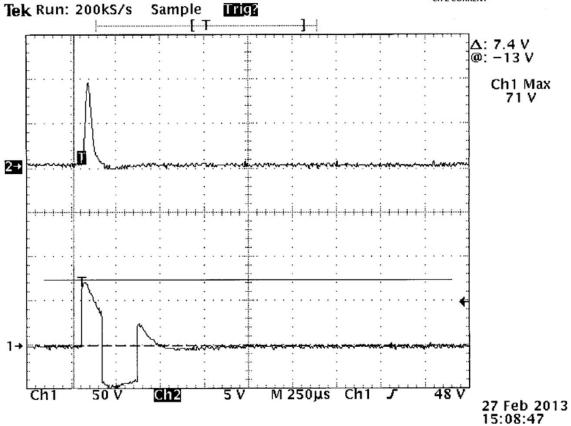
Tek Run: 200kS/s Sample



Surge Waveform – 3kV with GND

8X20uS 3.0KV BOARD #3 GROUNDED



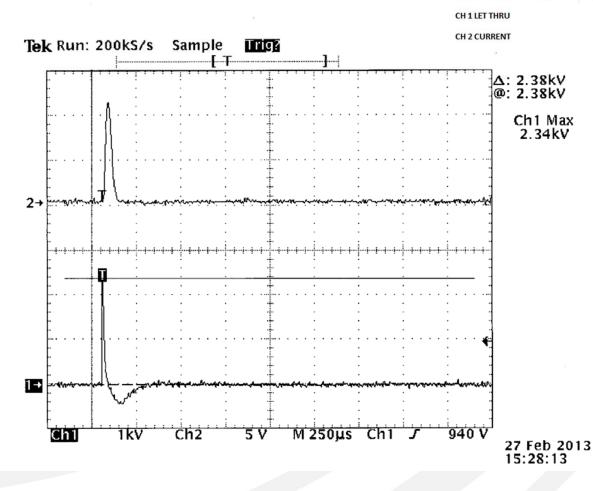


Ch2: 1V = 100 Amp



Surge Waveform – 3.5kV without GND

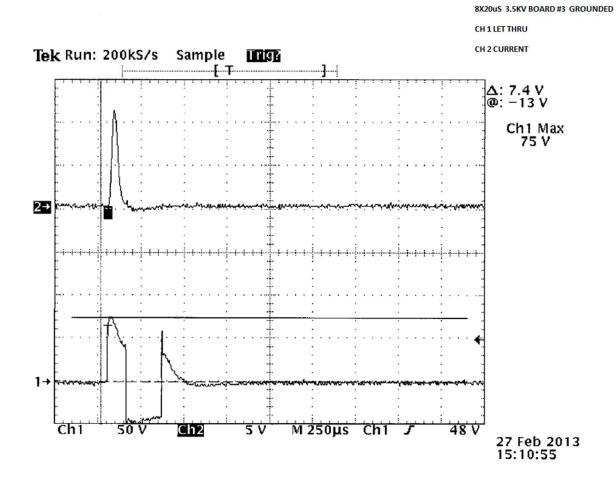
8X20uS 3.5KV BOARD #3 NOT GROUNDED



Ch2: 1V = 100 Amp



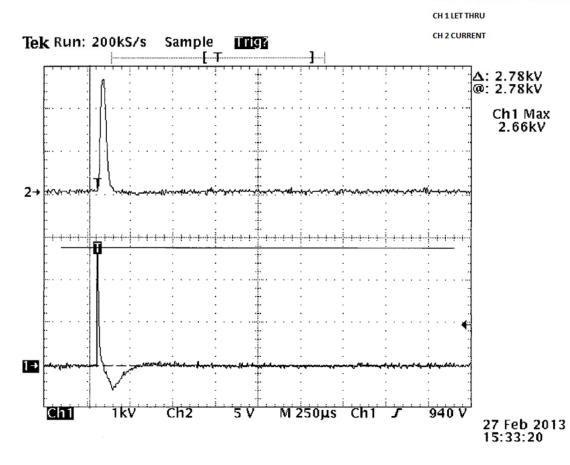
Surge Waveform – 3.5kV with GND





Surge Waveform – 4kV without GND

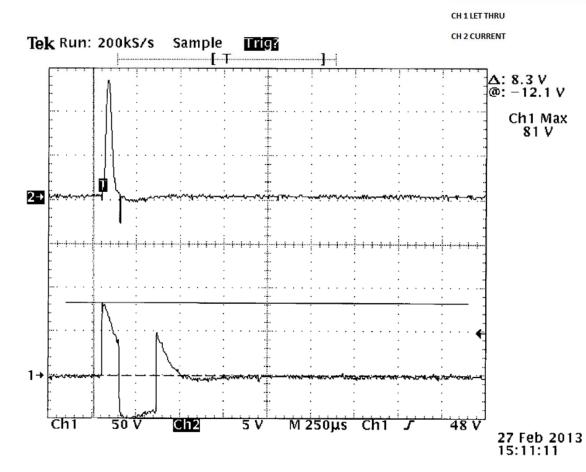
8X20uS 4.0KV BOARD #3 NOT GROUNDED





Surge Waveform – 4kV with GND

8X20uS 4.0KV BOARD #3 GROUNDED



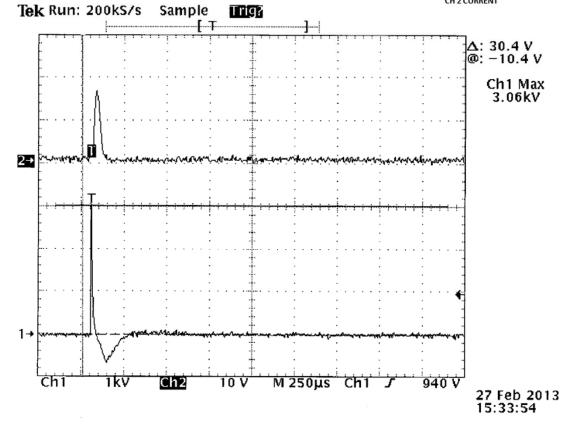


Surge Waveform – 4.5kV without GND

8X20uS 4.5KV BOARD #3 NOT GROUNDED

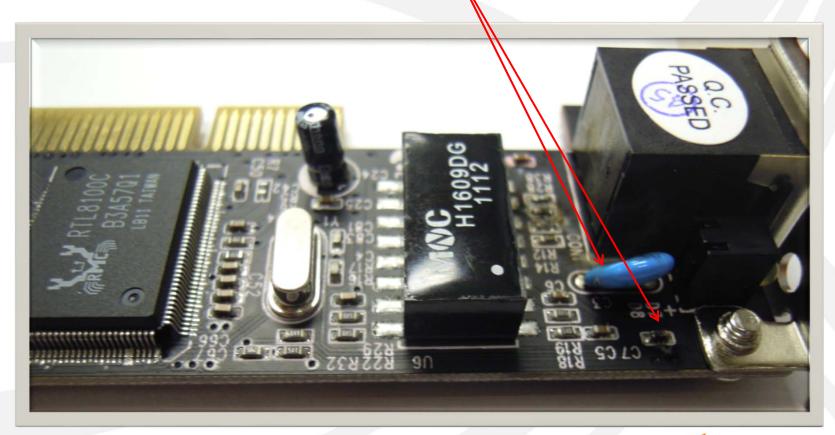
CH 1 LET THRU

CH 2 CURRENT



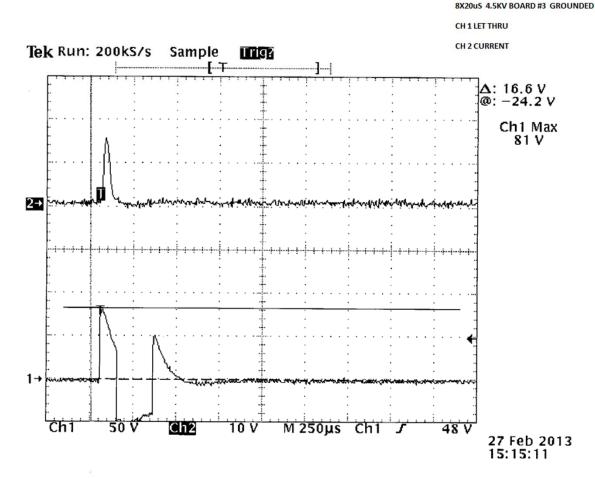


Surge Waveform – 4.5kV without GND Damage to C3 and C7





Surge Waveform – 4.5kV with GND



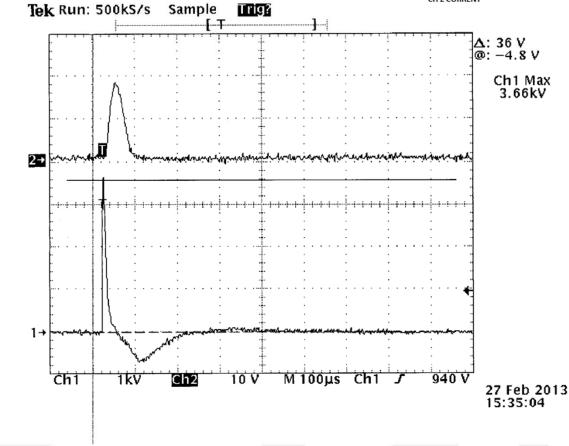


Surge Waveform – 5kV without GND

8X20uS 5.0KV BOARD #3 NOT GROUNDED

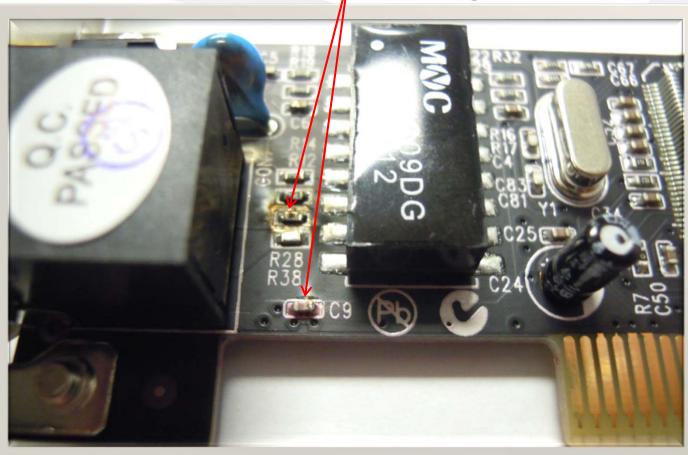


CH 2 CURRENT





Surge Waveform – 5kV without GND Damage to R28 and C9



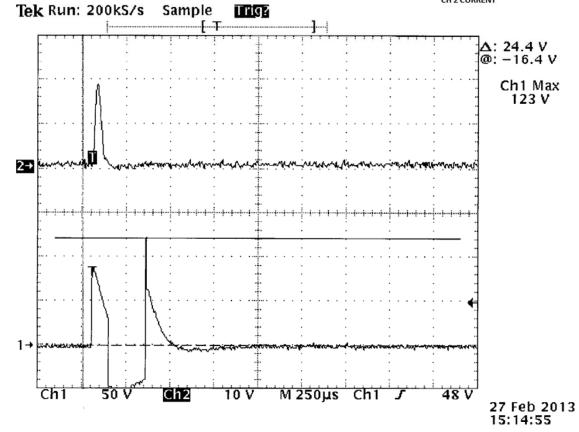


Surge Waveform – 5kV with GND

8X20uS 5.0KV BOARD #3 GROUNDED



CH 2 CURRENT



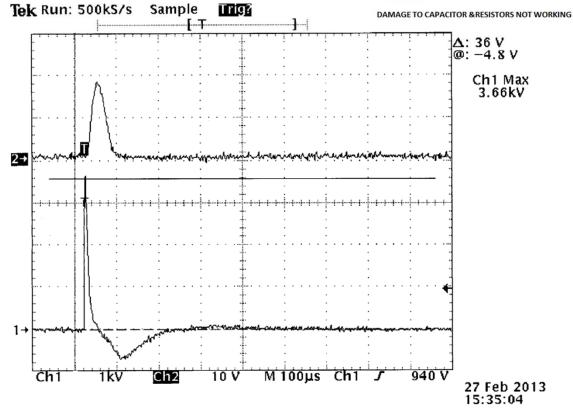


Surge Waveform – 5.5kV without GND

8X20uS 5.5KV BOARD #3 NOT GROUNDED

CH 1 LET THRU

CH 2 CURRENT





Surge Waveform – 5.5kV with GND

8X20uS 5.5KV BOARD #3 GROUNDED



CH 2 CURRENT Tek Run: 200kS/s Sample Trig? FT 1-1 ∆: 21.6 V @: −19.2 V Ch1 Max 107 V 2 - inumla 1→ M 250µs Ch1 J 10 V 48 V Chi 50 V Ch2 27 Feb 2013 15:22:31

Ch2: 1V = 100 Amp

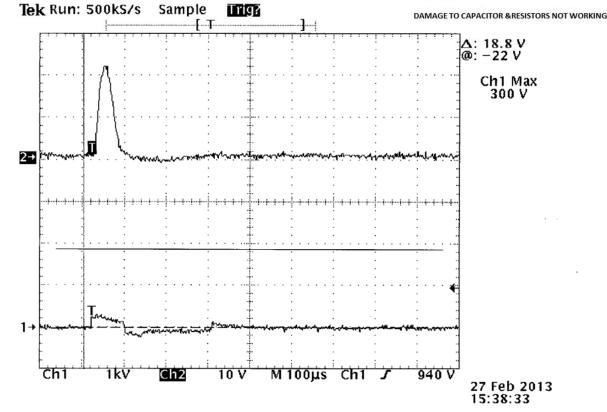


Surge Waveform – 6kV without GND

8X20uS 6.0KV BOARD #3 NOT GROUNDED

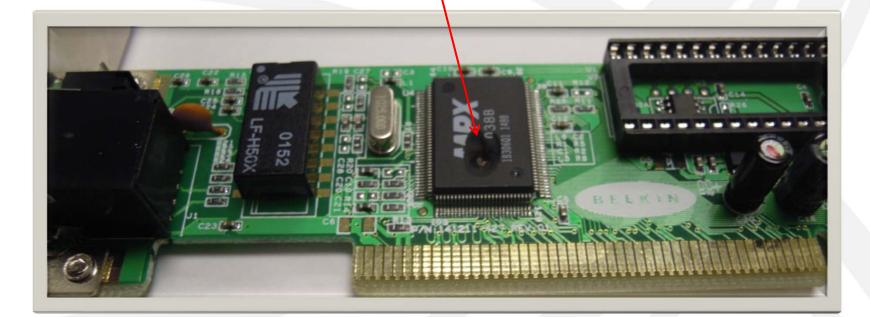


CH 2 CURRENT





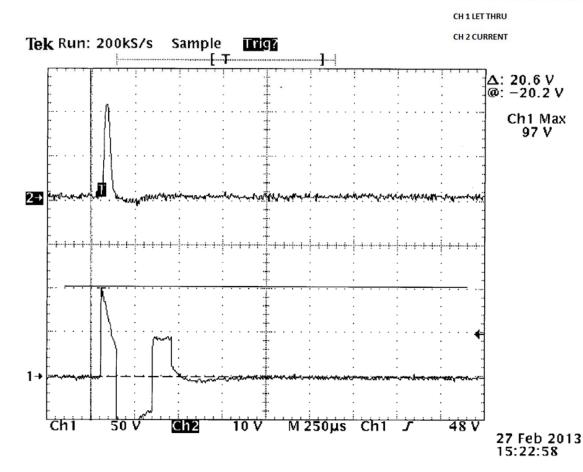
Surge Waveform – 6kV without GND Damage to Ethernet Controller





Surge Waveform – 6kV with GND

8X20uS 6.0KV BOARD #3 GROUNDED



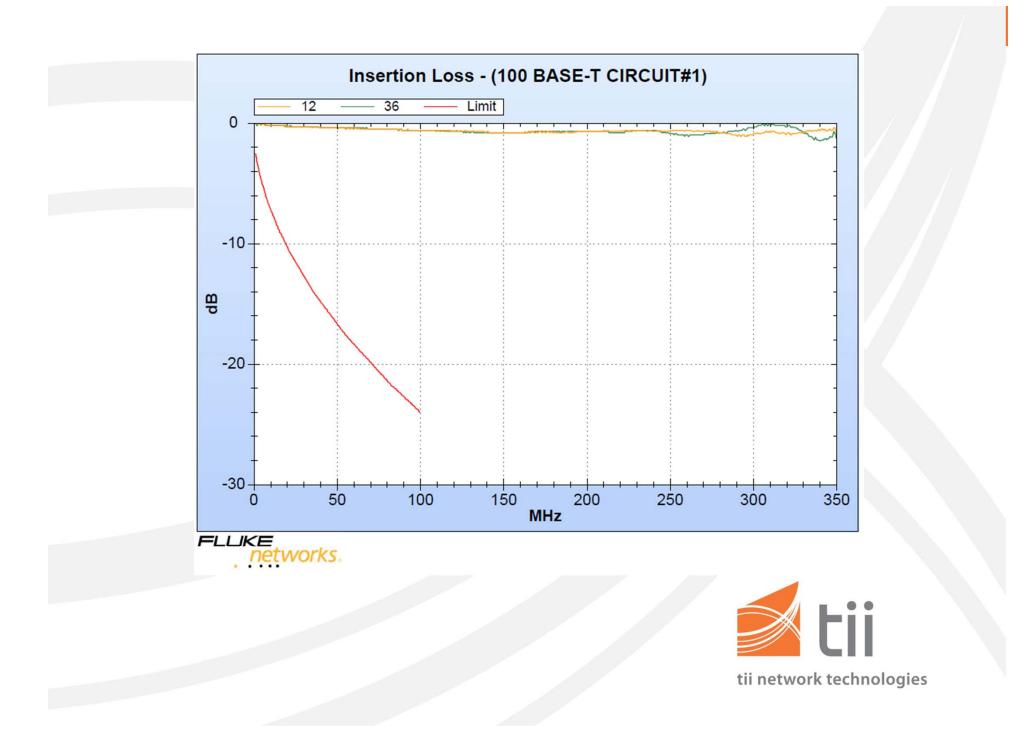


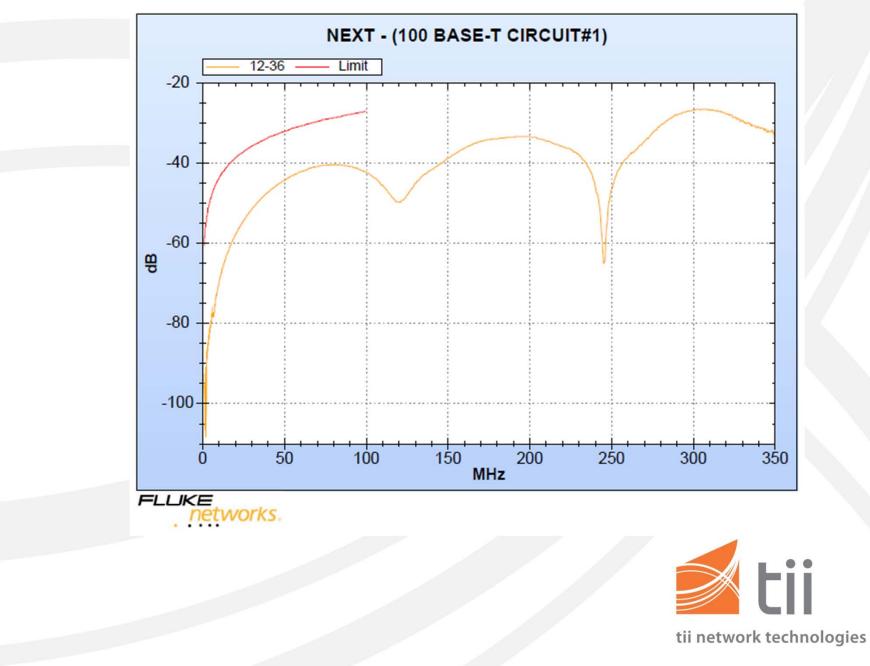
Protection Circuit 3 Test Results

No Ground Connection: Damage to NIC cards when surge voltage exceeded 4000 volts.

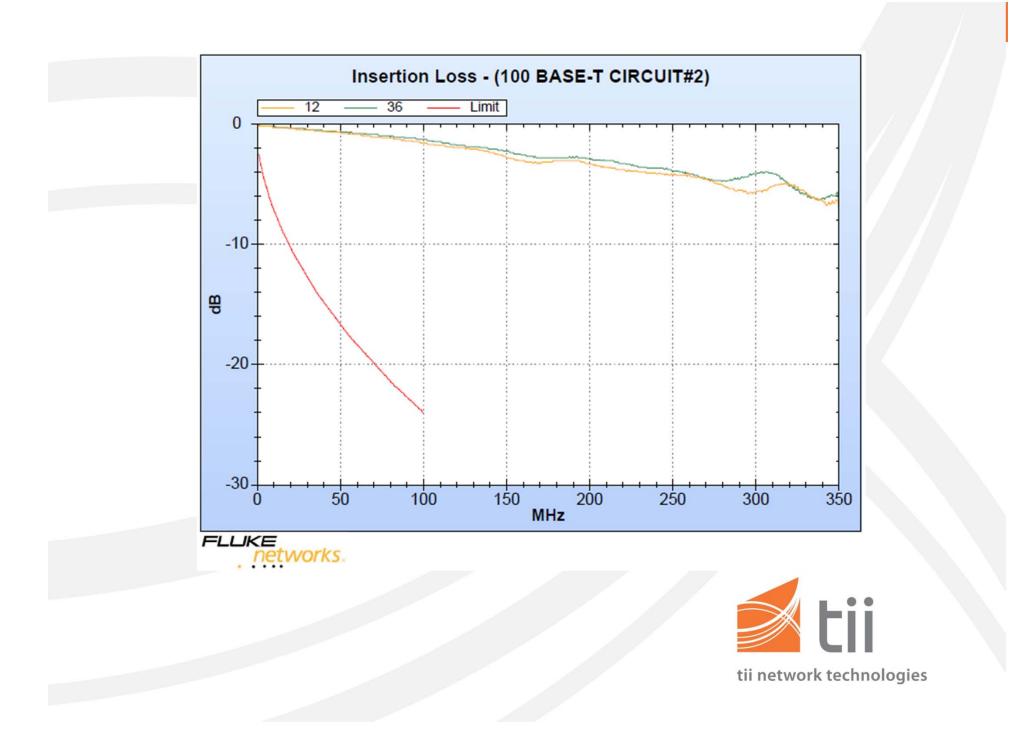
With Ground Connection: No Damage to the NIC cards when tested up to 6000 volts of peak surge voltage.

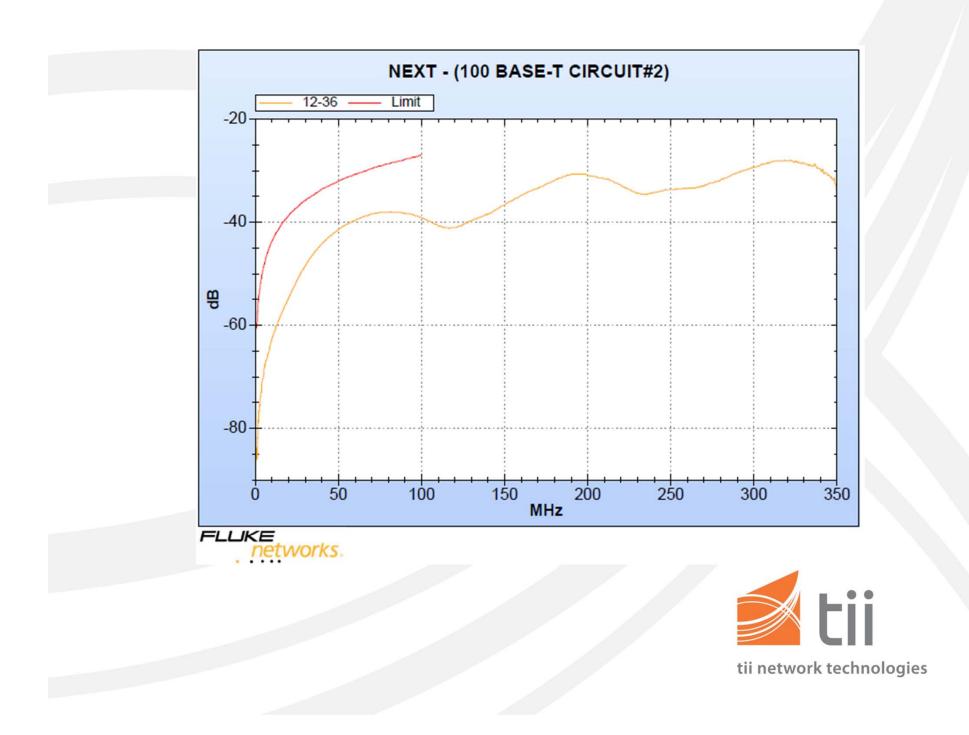


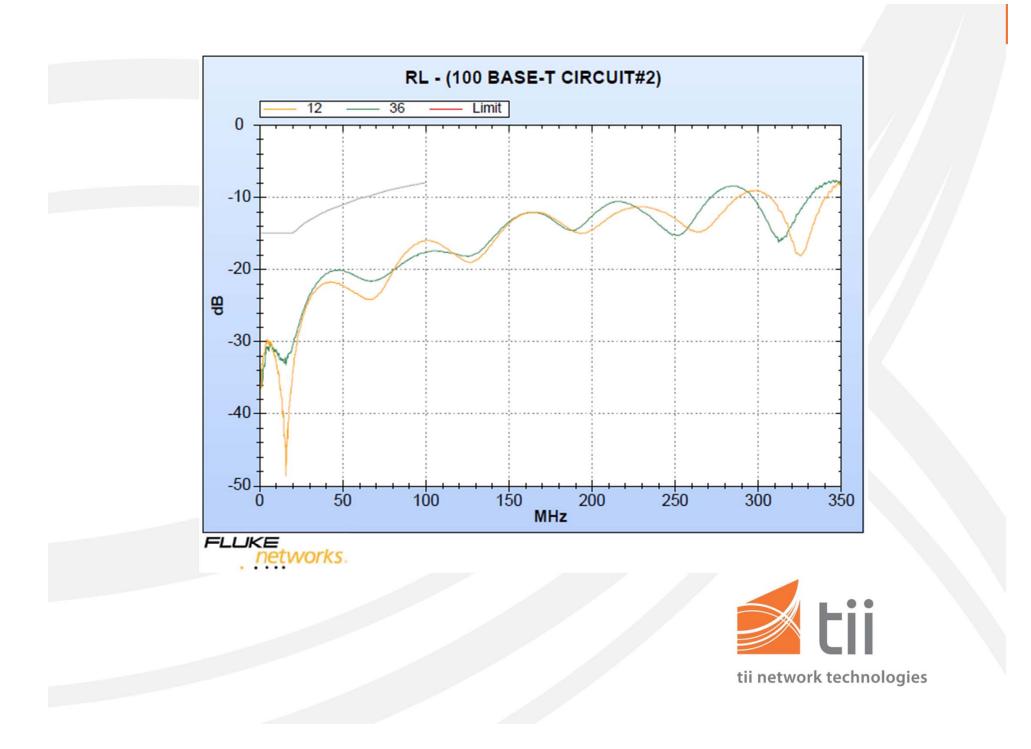


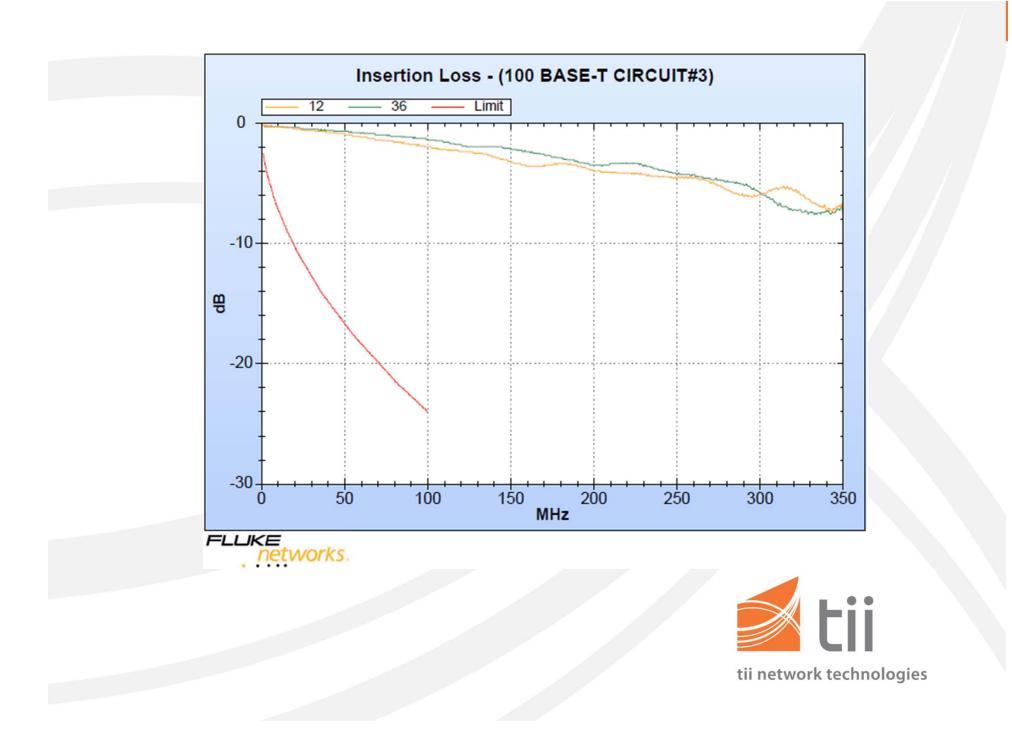


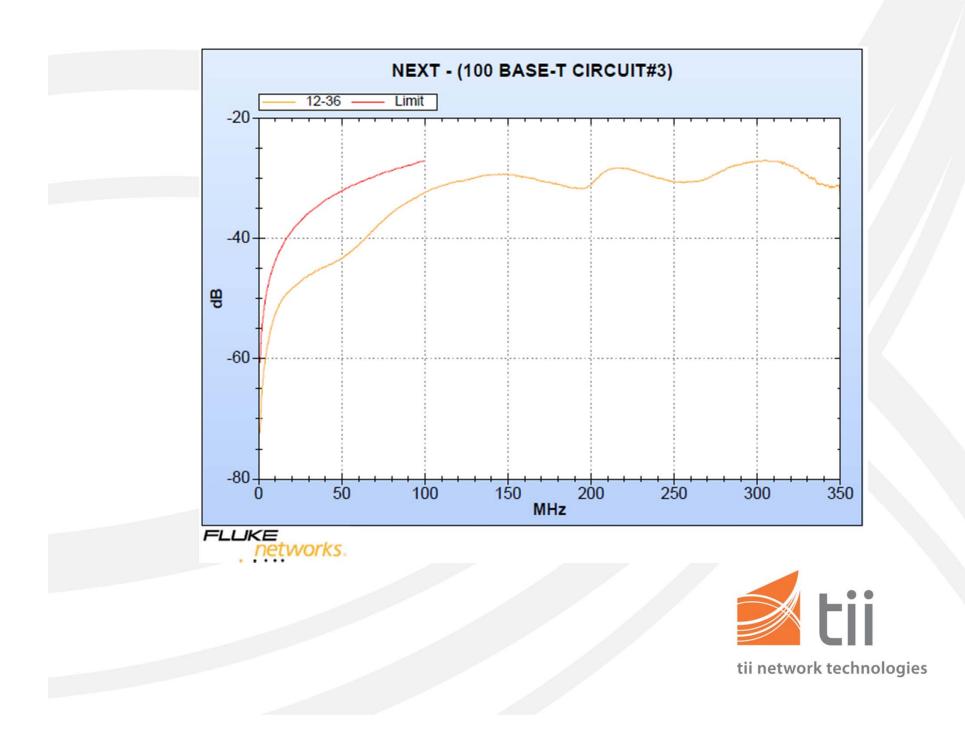


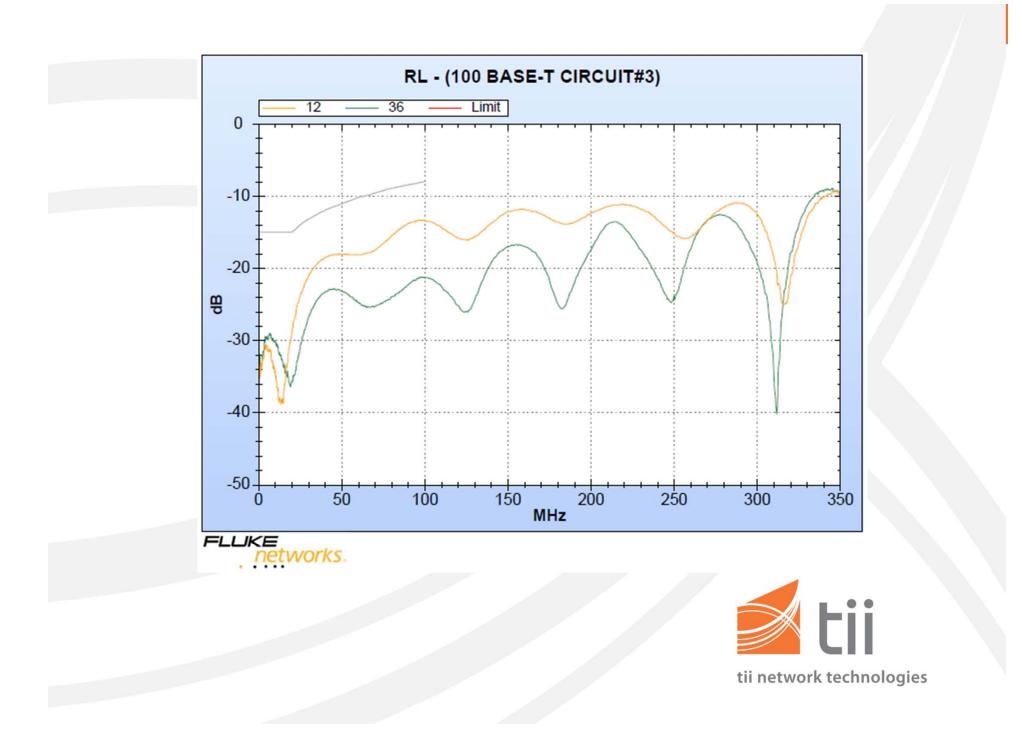












Conclusions

Surge Protection Circuits with ground provide complete protection to the maximum level of surges tested.

Some NIC cards made with higher breakdown voltage caps and higher isolation voltage levels can survive without any surge protection.

Improved surge protection circuits could affect data transmission rate. Surge protection device design must meet transmission requirements of the Ethernet circuit.



Any Questions

