IEEE SW Test Workshop
Semiconductor Wafer Test Workshop

Real-World Avalanche Testing Of Single-Die, Wafers, Hybrid Modules, and Packaged Devices

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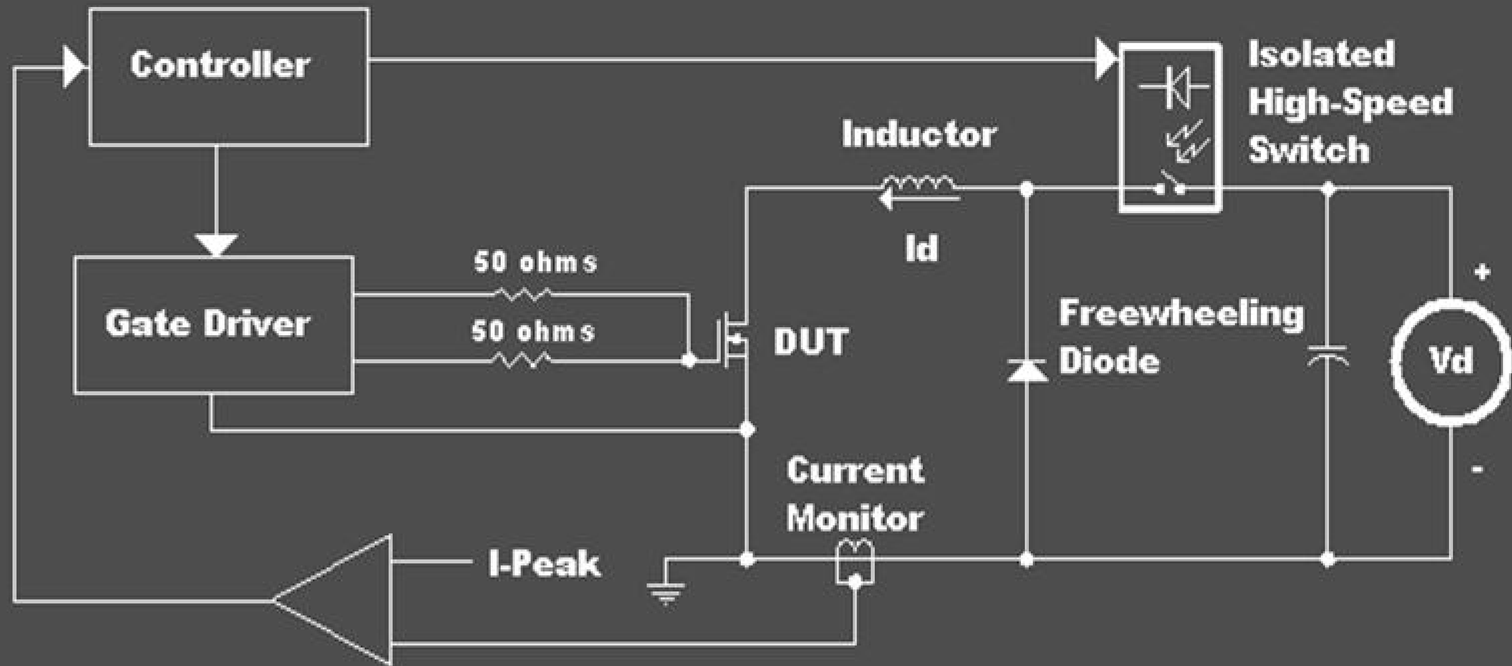
Avalanche Testing Background

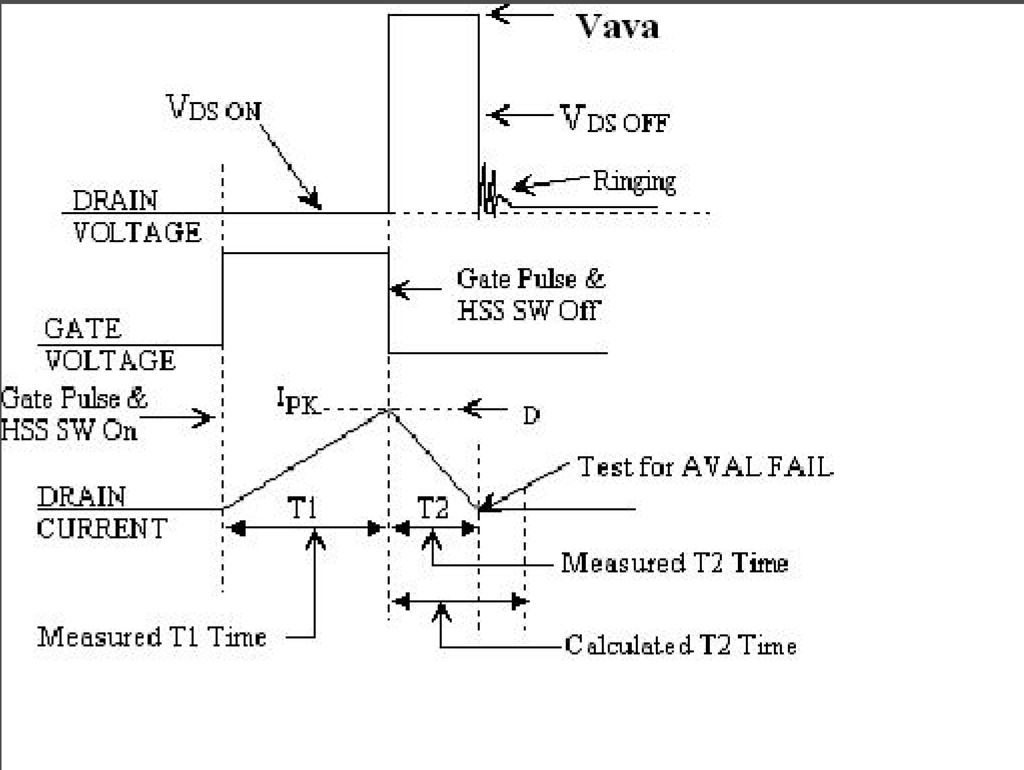
- MOSFET Avalanche Testing - 1985
- Manufactures Disagreed On Usefulness
- Major Manufactures Now Provide Energy Ratings
- What Is Avalanche Mode?
- What Is Ruggedness?
- Avalanche Test Methods
- Industrial Avalanche Test Standards
  - MIL-STD-750 METHOD 3470.2
  - JEDEC STANDARD JESD24-5

Ideal Avalanche Test Circuit



$$E_{AVA} = \frac{1}{2} L \times I^2_D$$

Good Avalanche Test Waveform

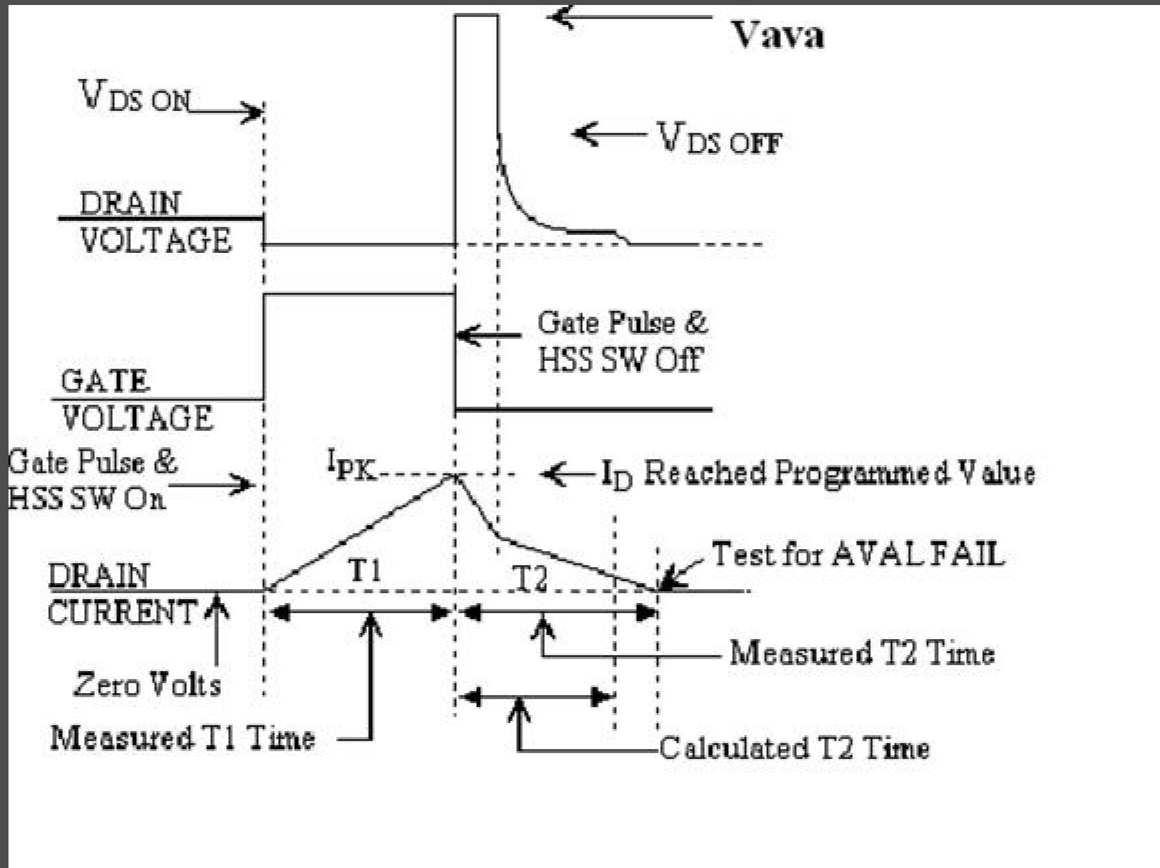


T1 and T2 Times Calculated From:

- Inductance Value
- I Peak
- Rated Drain Voltage

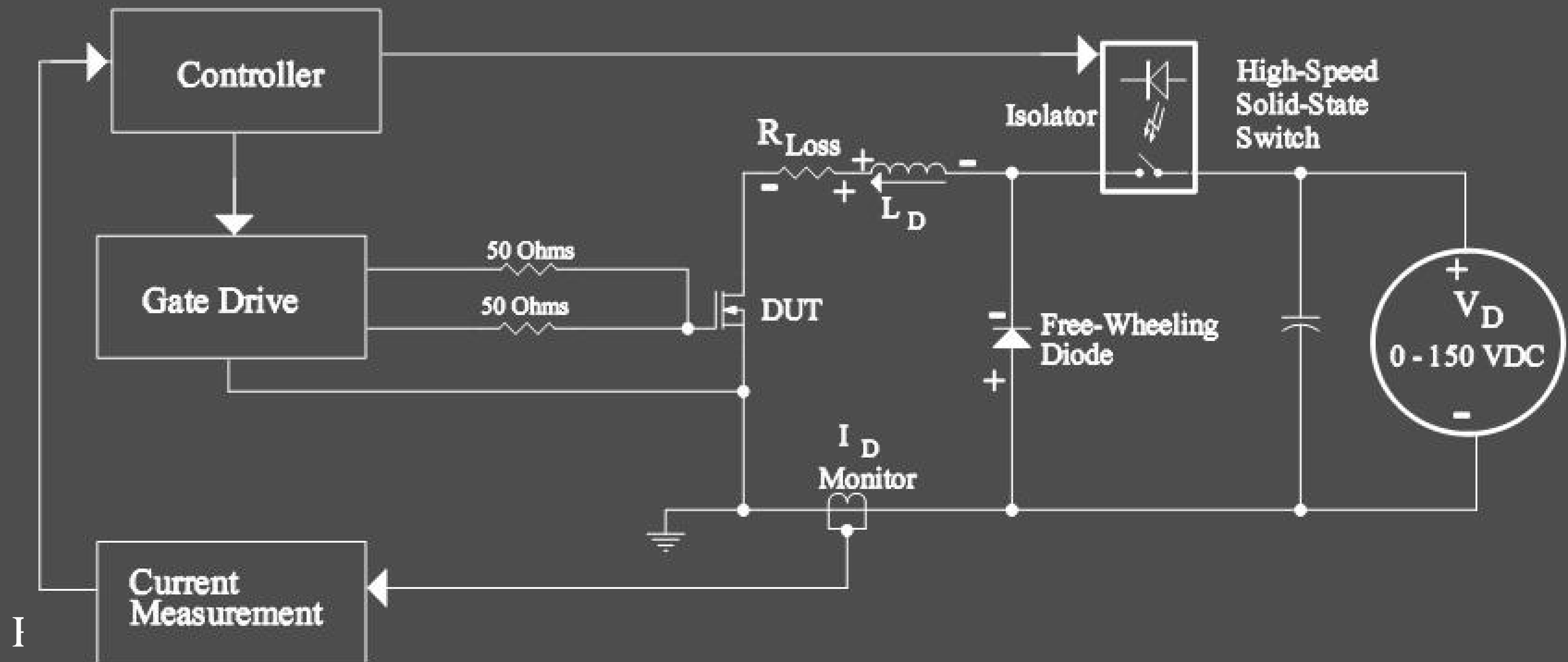
Shows DUT Passing Avalanche Based On Measured T2 Time

Failed Avalanche Test Waveform



Shows DUT Failing Avalanche Based On Measured T2 Time

Real-World Avalanche Circuit



$$T_1 = \frac{L}{R_{Loss}} LN\left(1 - \frac{R_{Loss} * I_P}{V_{ON}}\right)$$

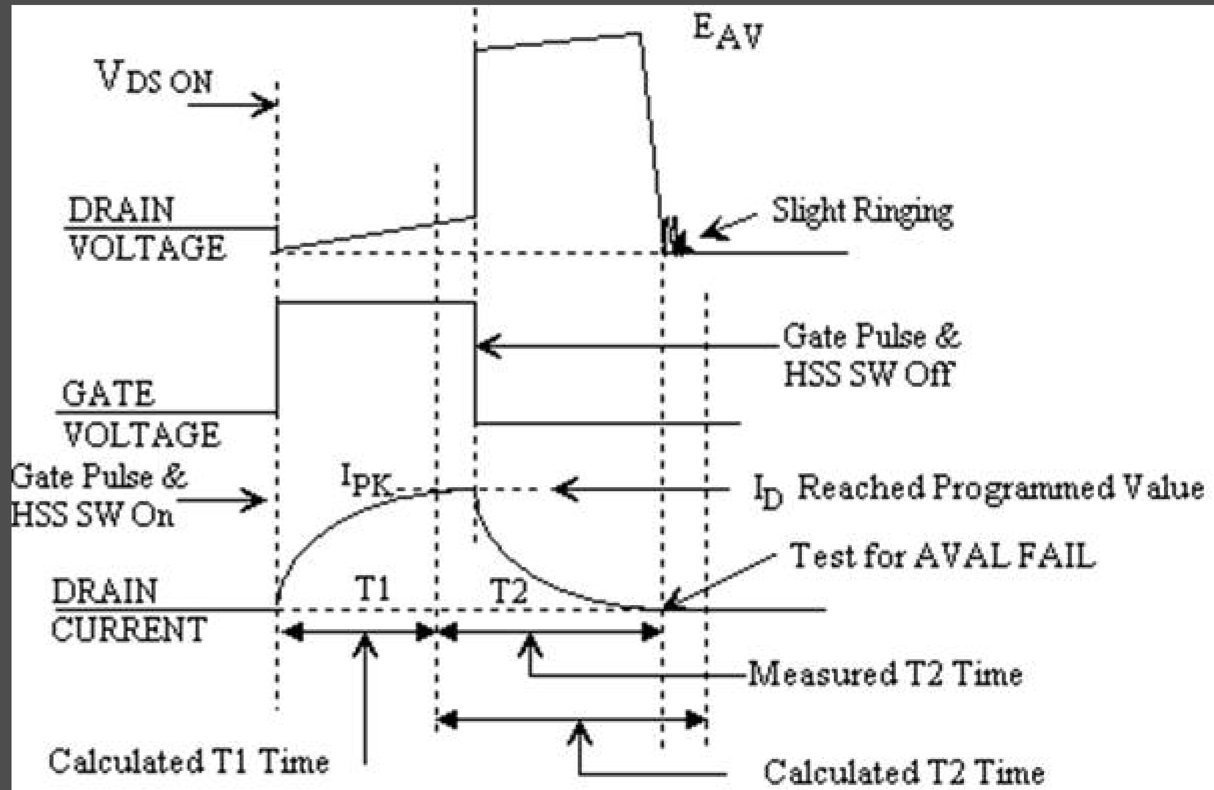
$$T_2 = \frac{L}{R_{Loss}} LN\left(1 - \frac{V_{ON}}{R_{Loss} * I_P + V_{ON}}\right)$$

$$V_{ON} = V_{Loss} + V_{DUT\ ON}$$

$$V_{OFF} = V_{Loss} + V_{DUT\ OFF}$$

$$V_{DUT\ OFF} = V_{Avalanche}$$

Real-World With Losses Waveform

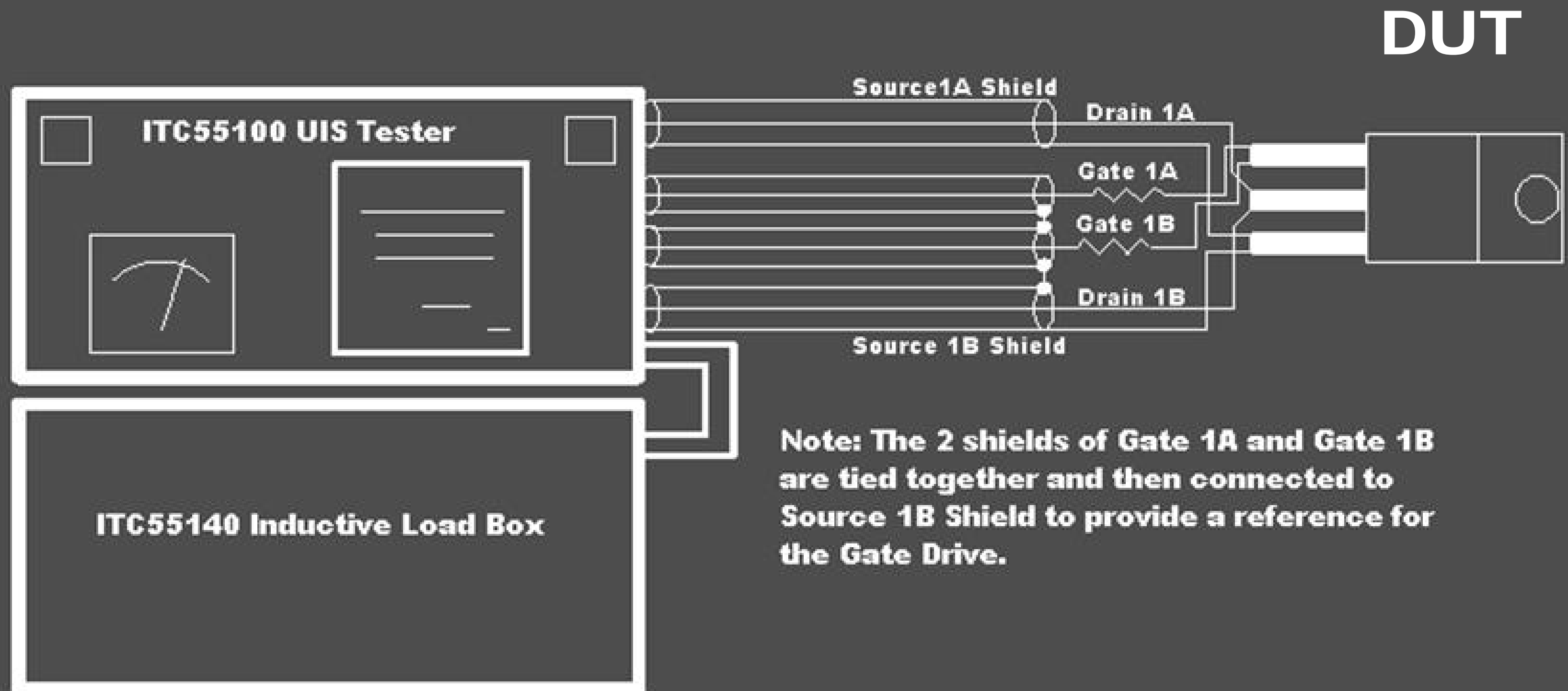


Note the "Rounded Current" Waveshape

Losses Increase T1 Time

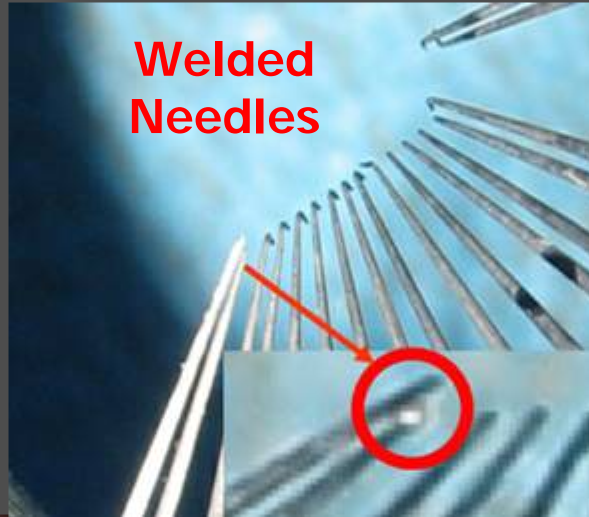
Losses Decrease T2 Time

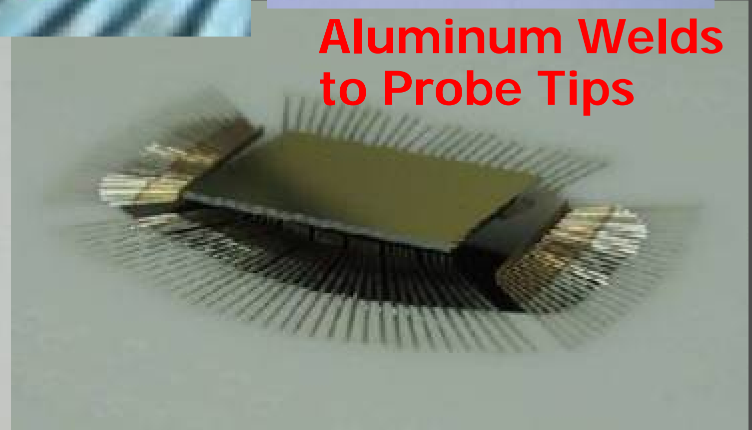
Package Level Avalanche Testing



… now to extend this same testing to Wafer and Die

High Power Testing on Probe Cards





Wafer and Die High Power Avalanche Testing

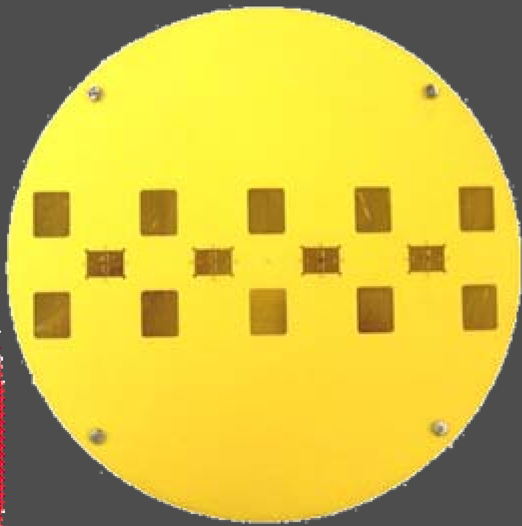
Realities:

- Probe Cards
- Probe Tips
- Testing Environment

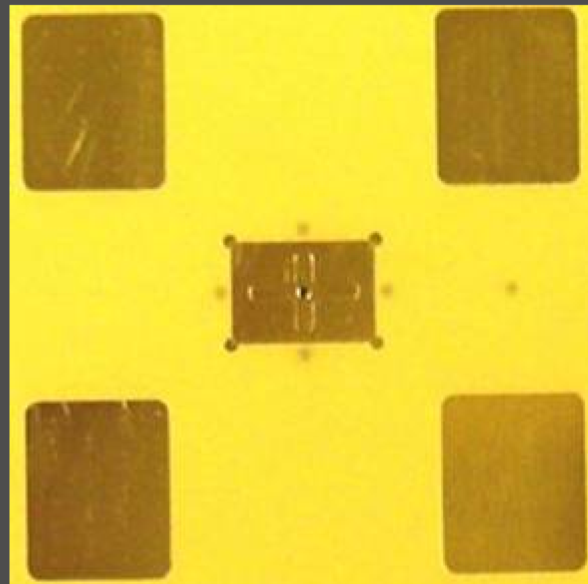
Benefits:

- Lower Cost Failures
- Faster Process Analysis
- Higher Net Yield
- Comparison with Packaged Parts

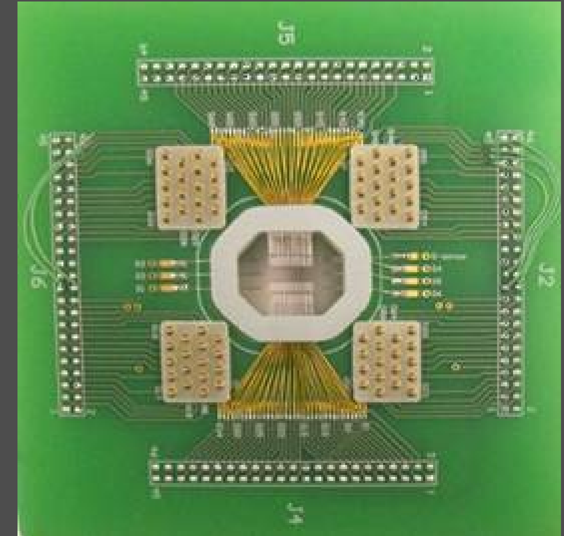
Typical Die/Chip Carrier & Probe Card



Chip Carrier



Enlarged Carrier View

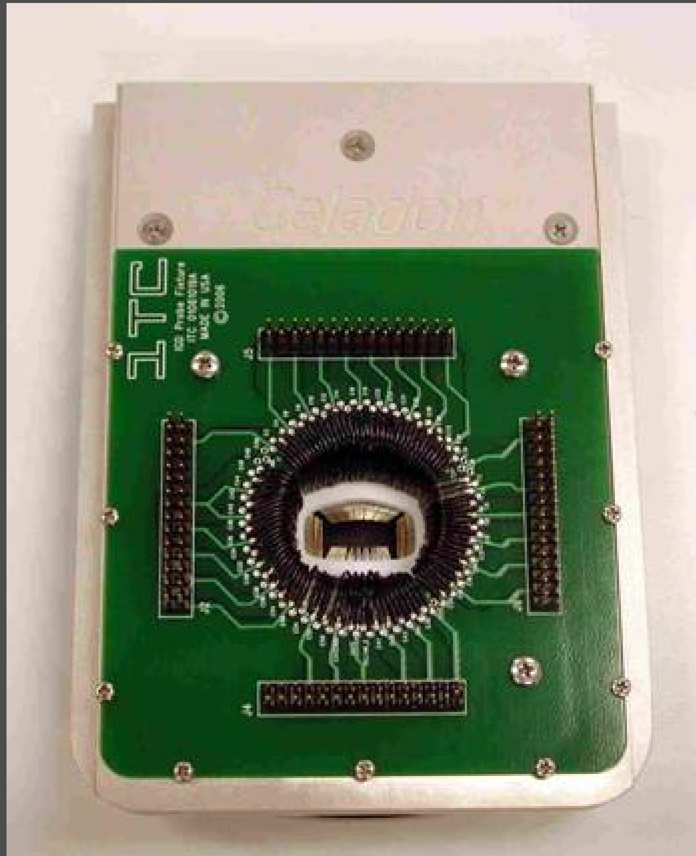


Probe Card with

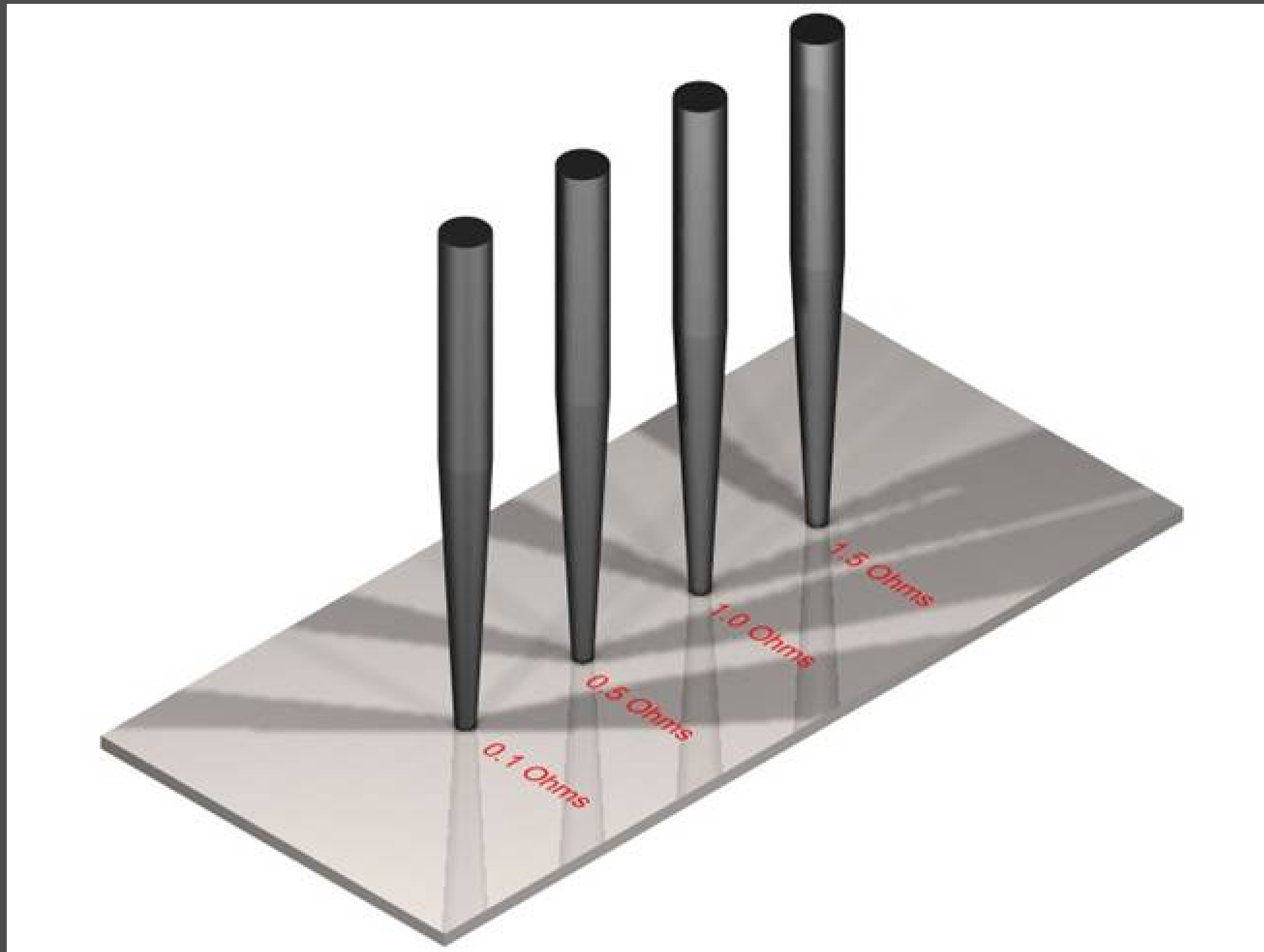
5 mil tip dia probes

and Pogo Pins

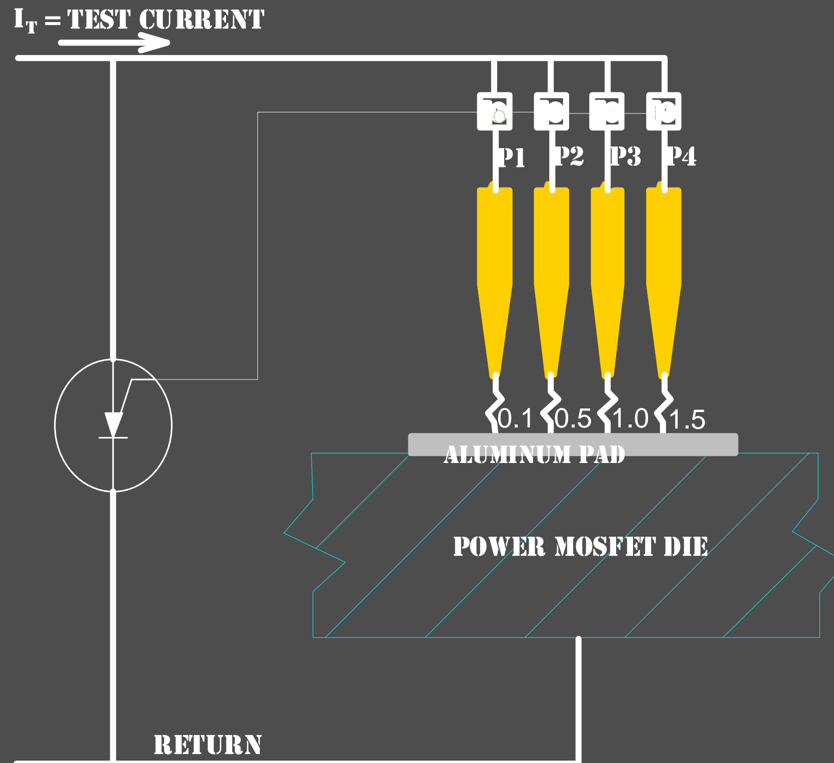
200 Amp, 1000V Probe Card



Probe Tips on Aluminum Pad



Probe Tip Protection Technique



It = 20 Amps

Imax = 5A/Probe, 5 mil dia

I_{P1} = 5A, V_{P1} = 0.5V

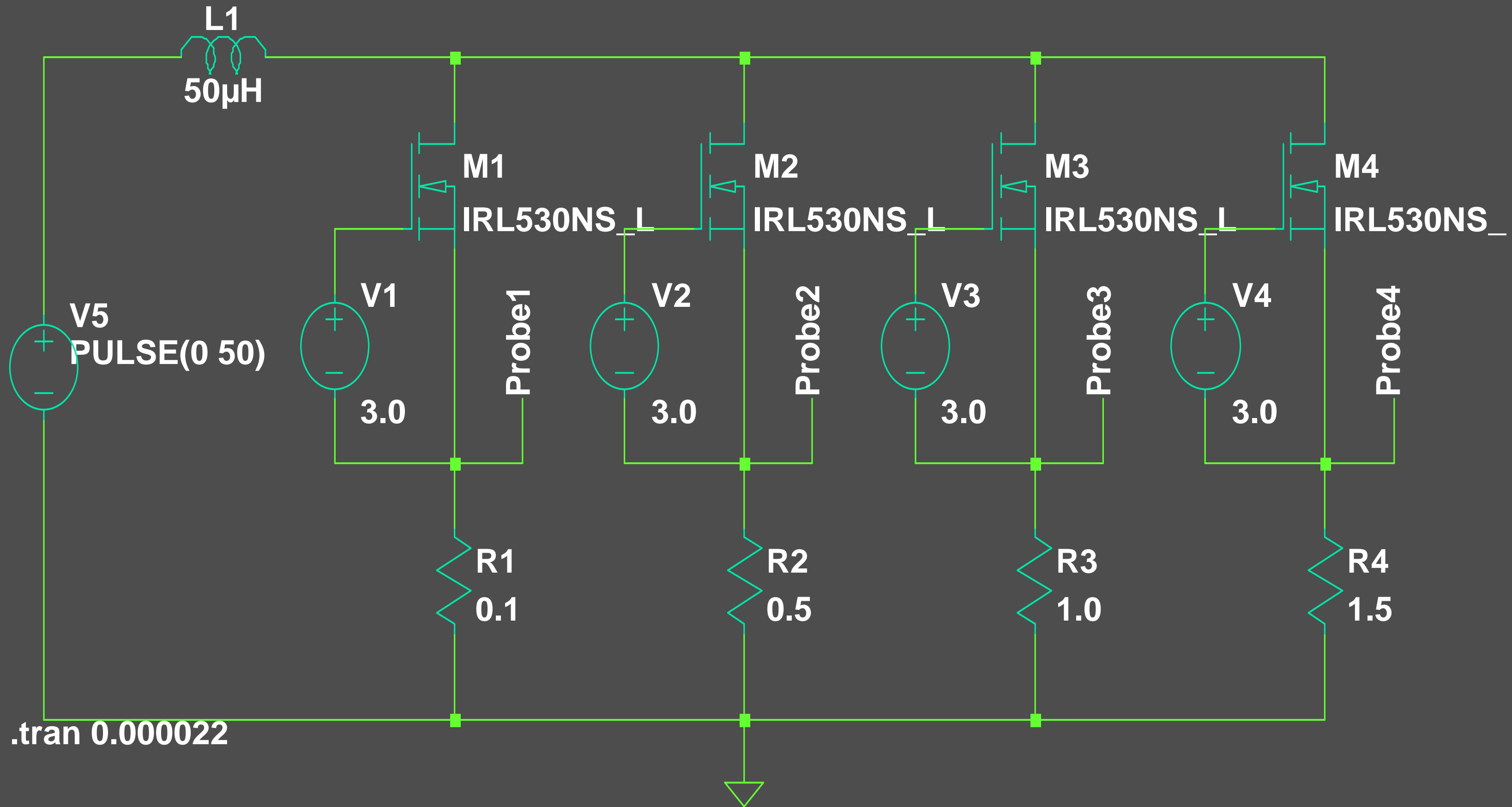
P_{P1} = 2.5W

Manage Probe Current & Voltage to keep POWER Dissipation from harming Probes

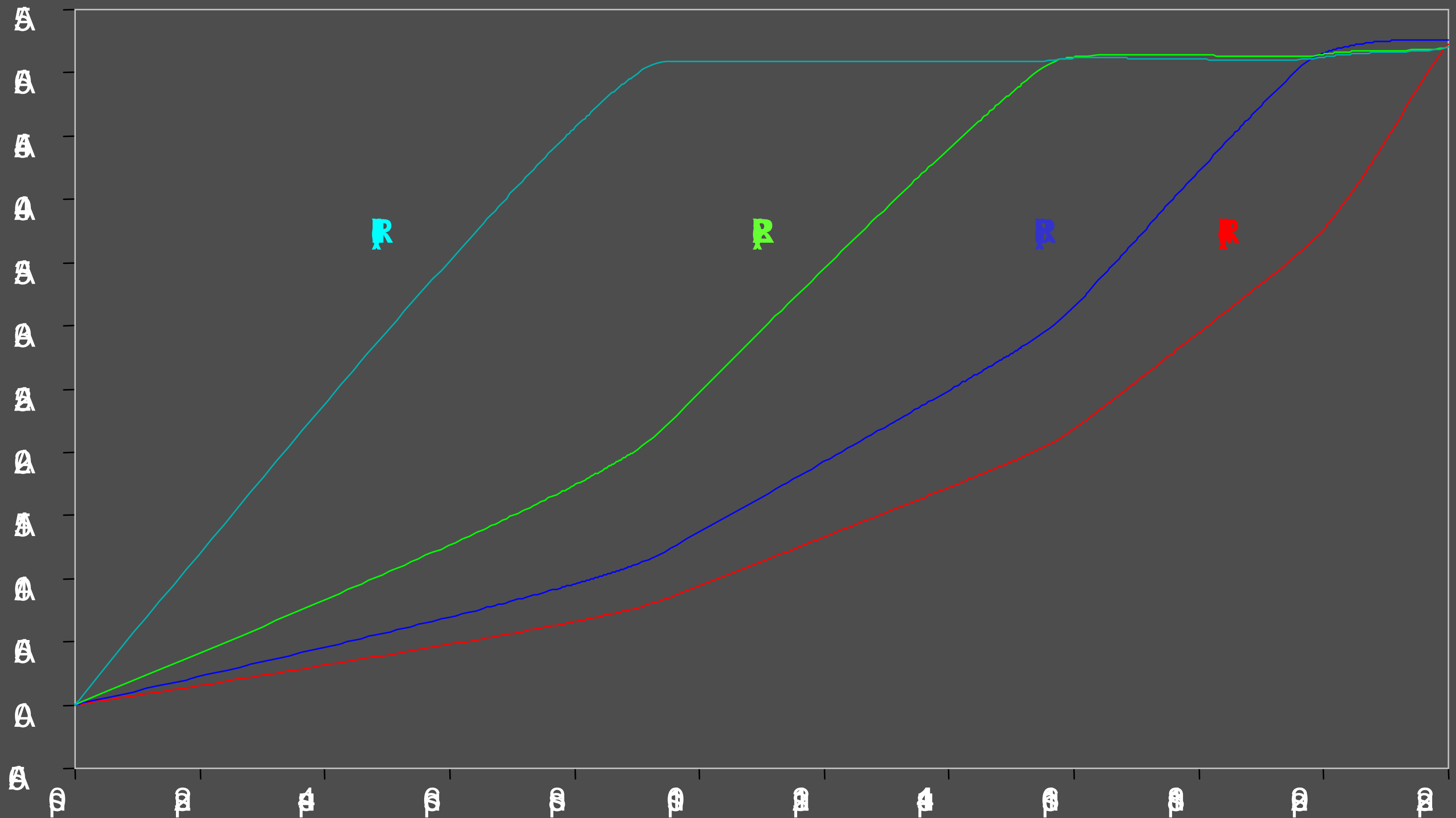
I_{P4} = 5A, V_{P4} = 7.5V

P_{P4} = 37.5W!!!!
TOO HIGH

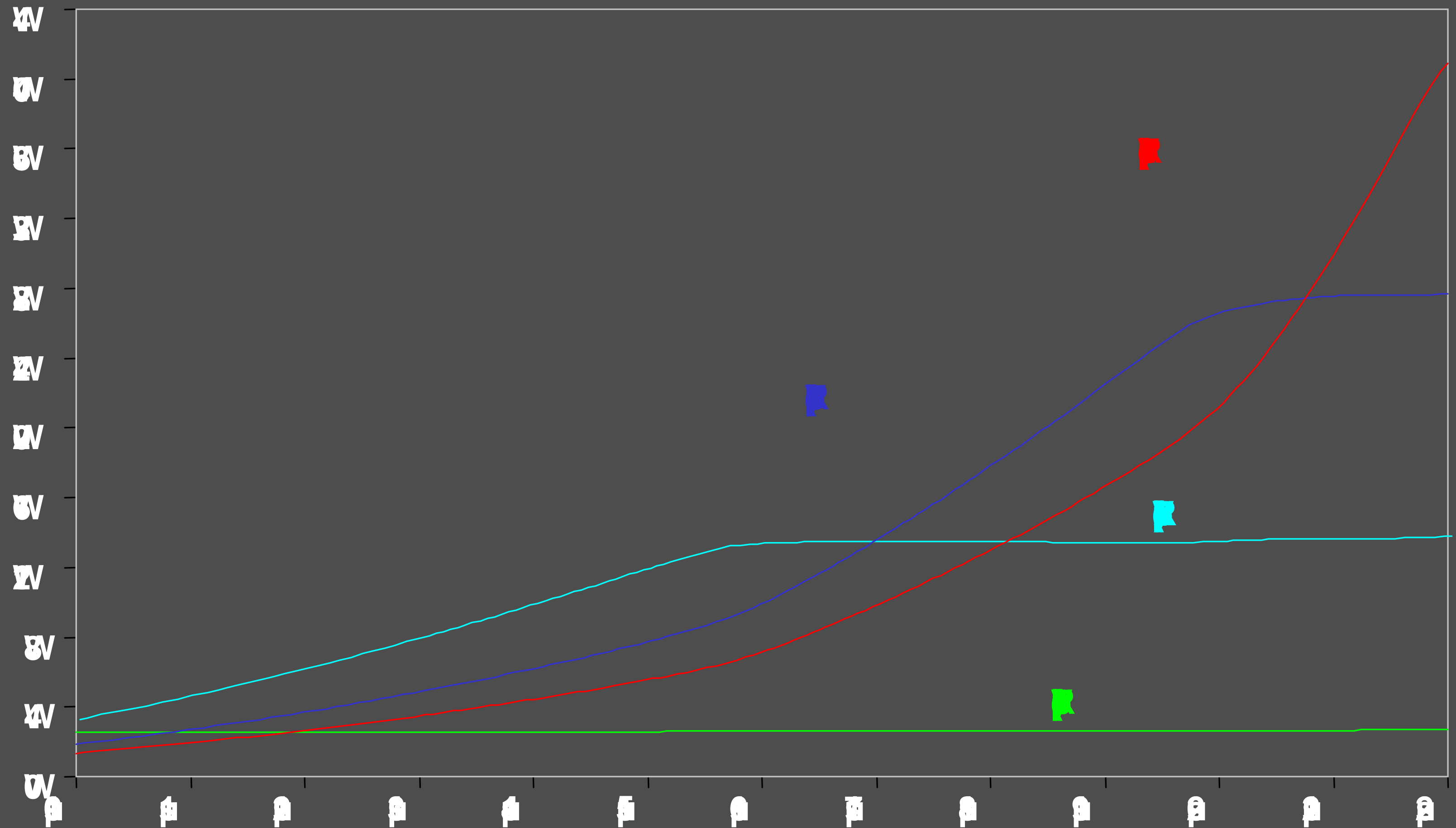
Probe Simulation Circuit



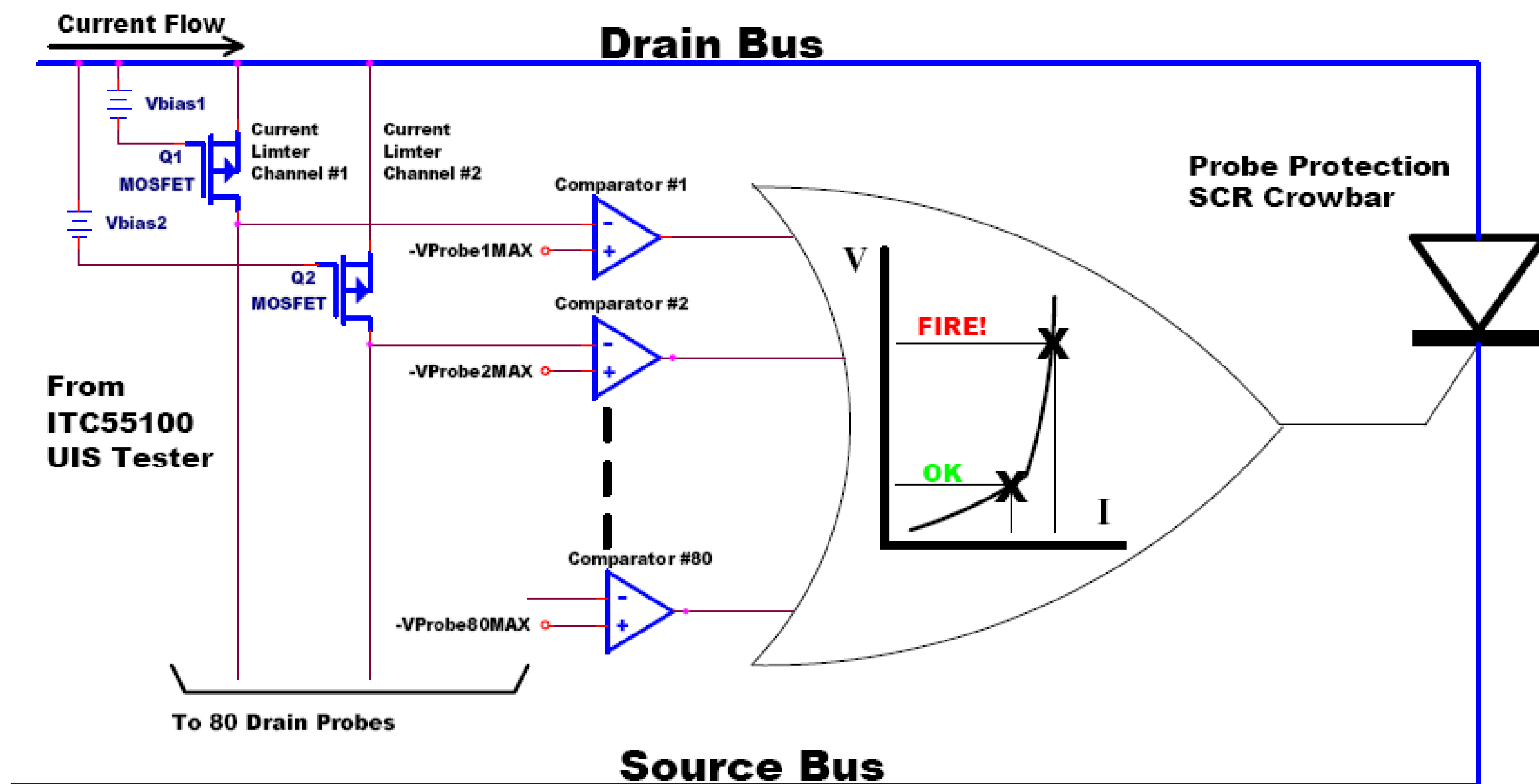
Probe Tip Currents



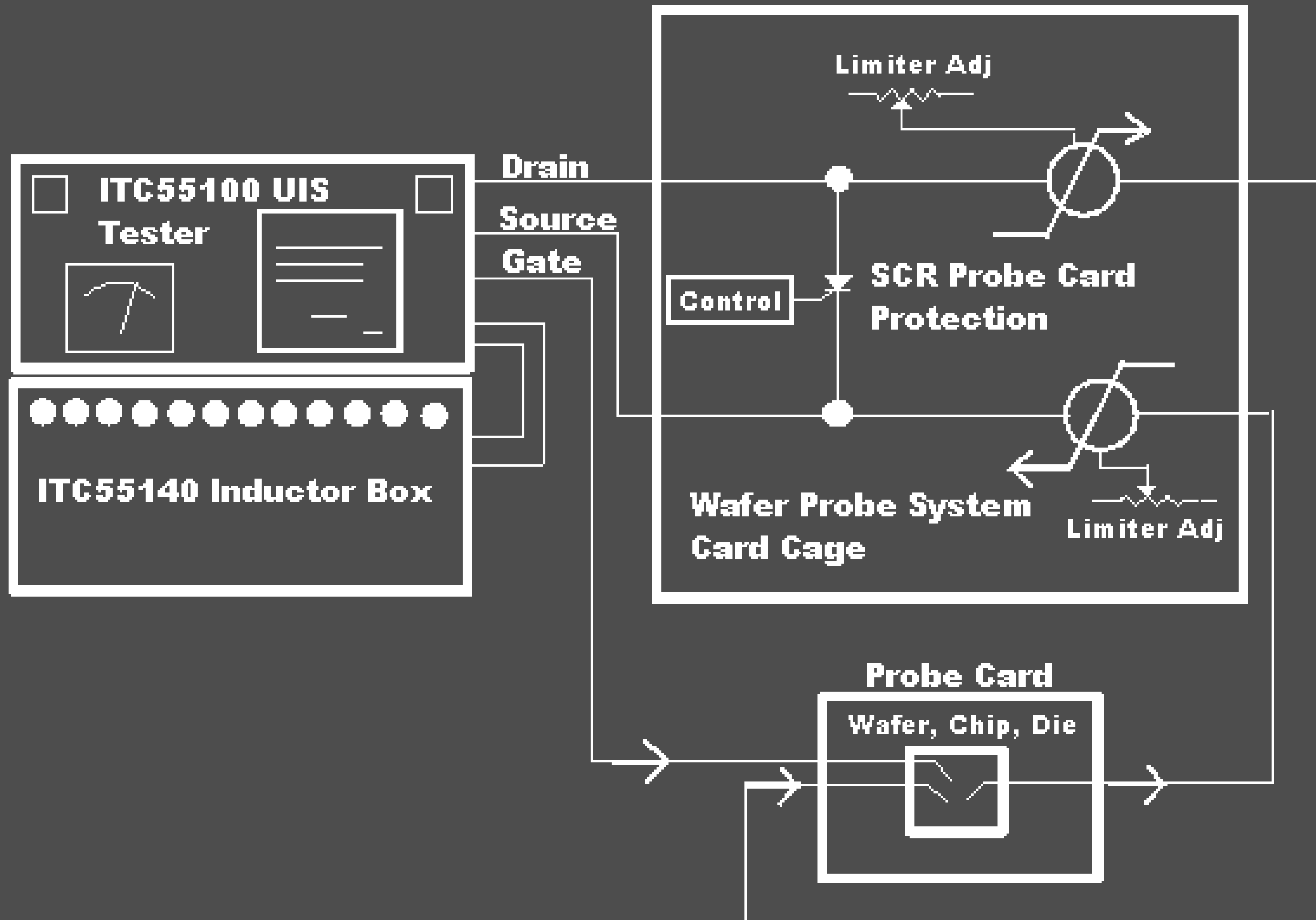
Probe Tip POWER



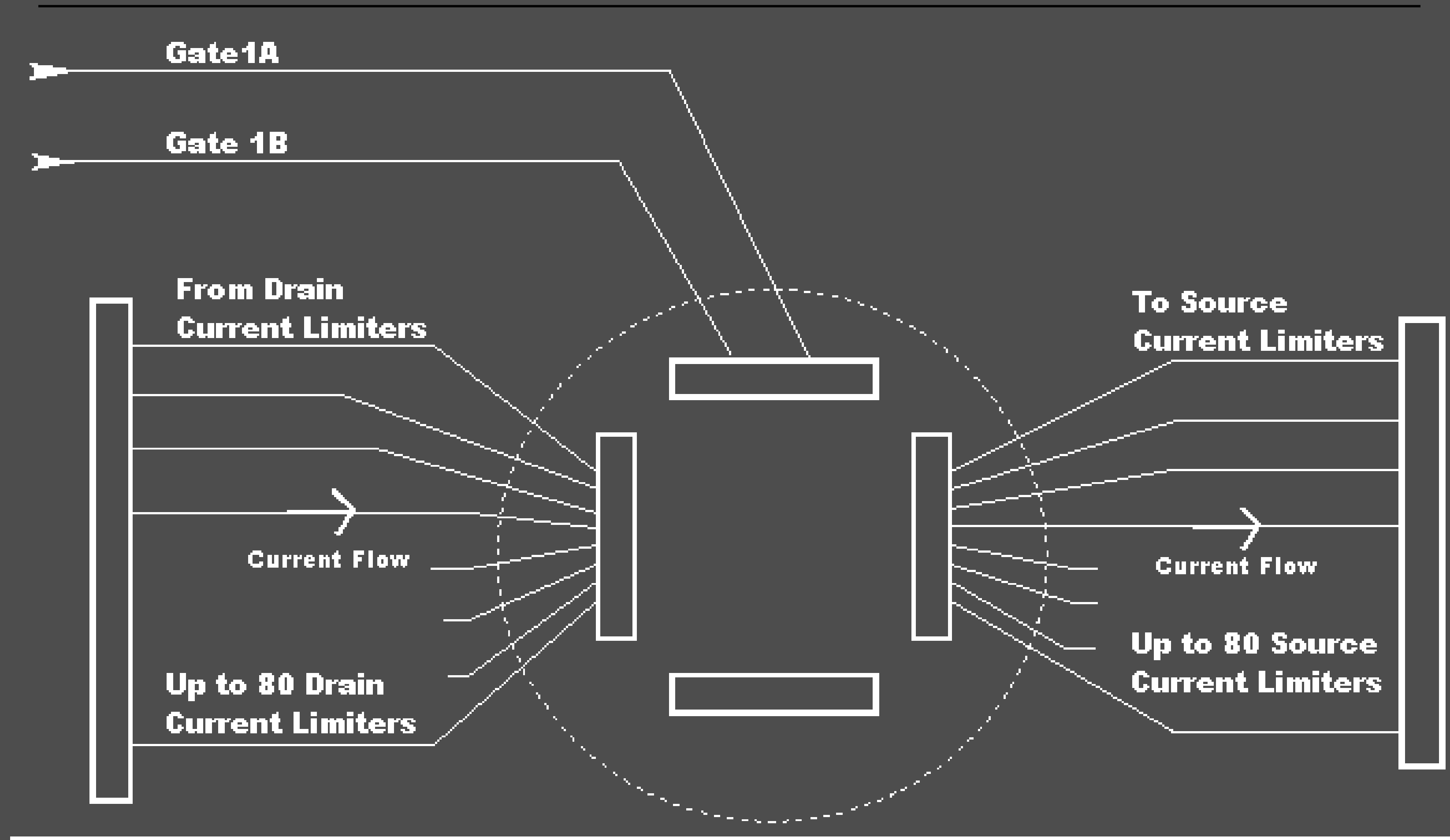
Power Limiter Showing Probe Tip Protection Concept



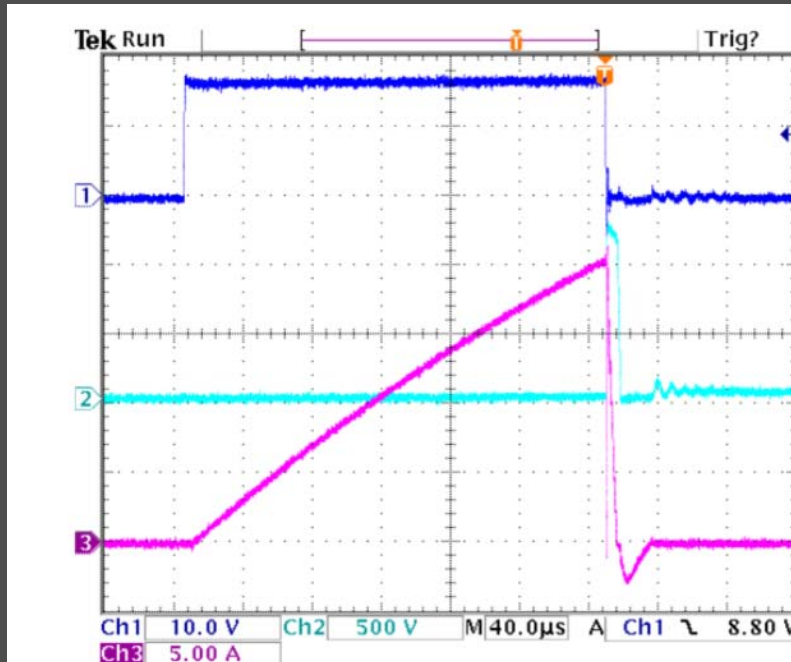
Production Avalanche WPS

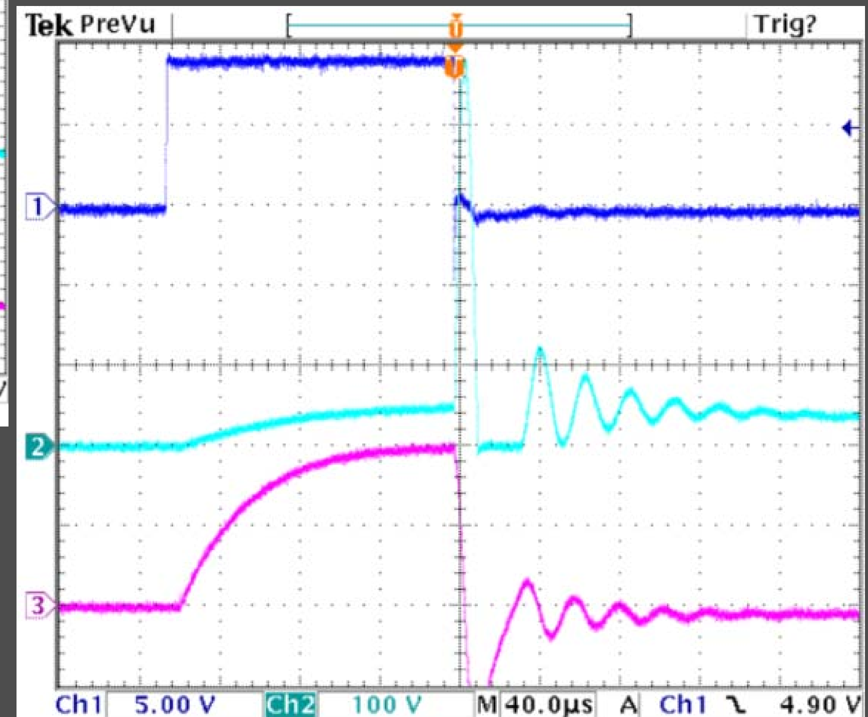


Simple Avalanche Connection Diagram

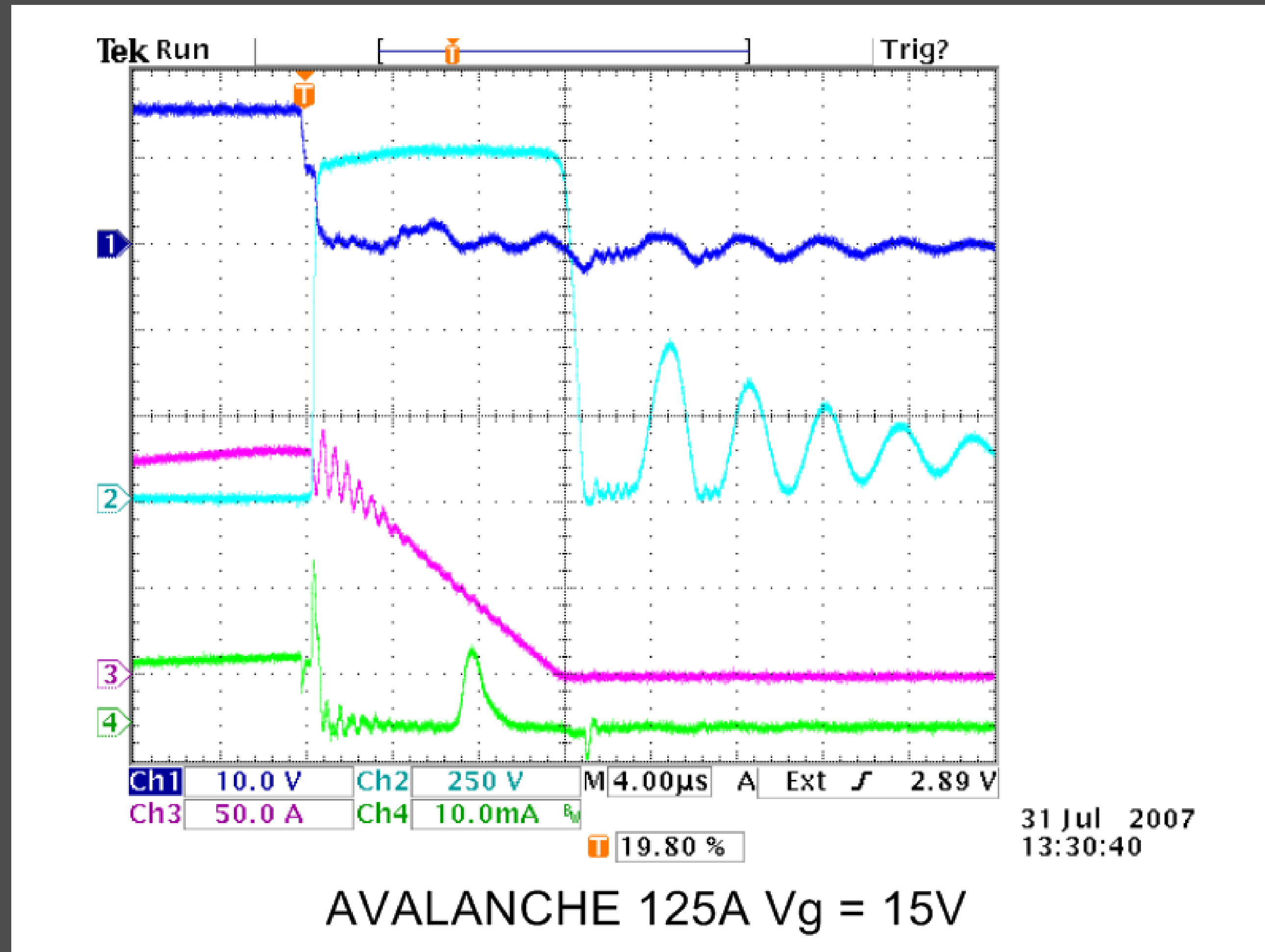


Realized Avalanche Waveforms





Avalanche Waveform – PASS



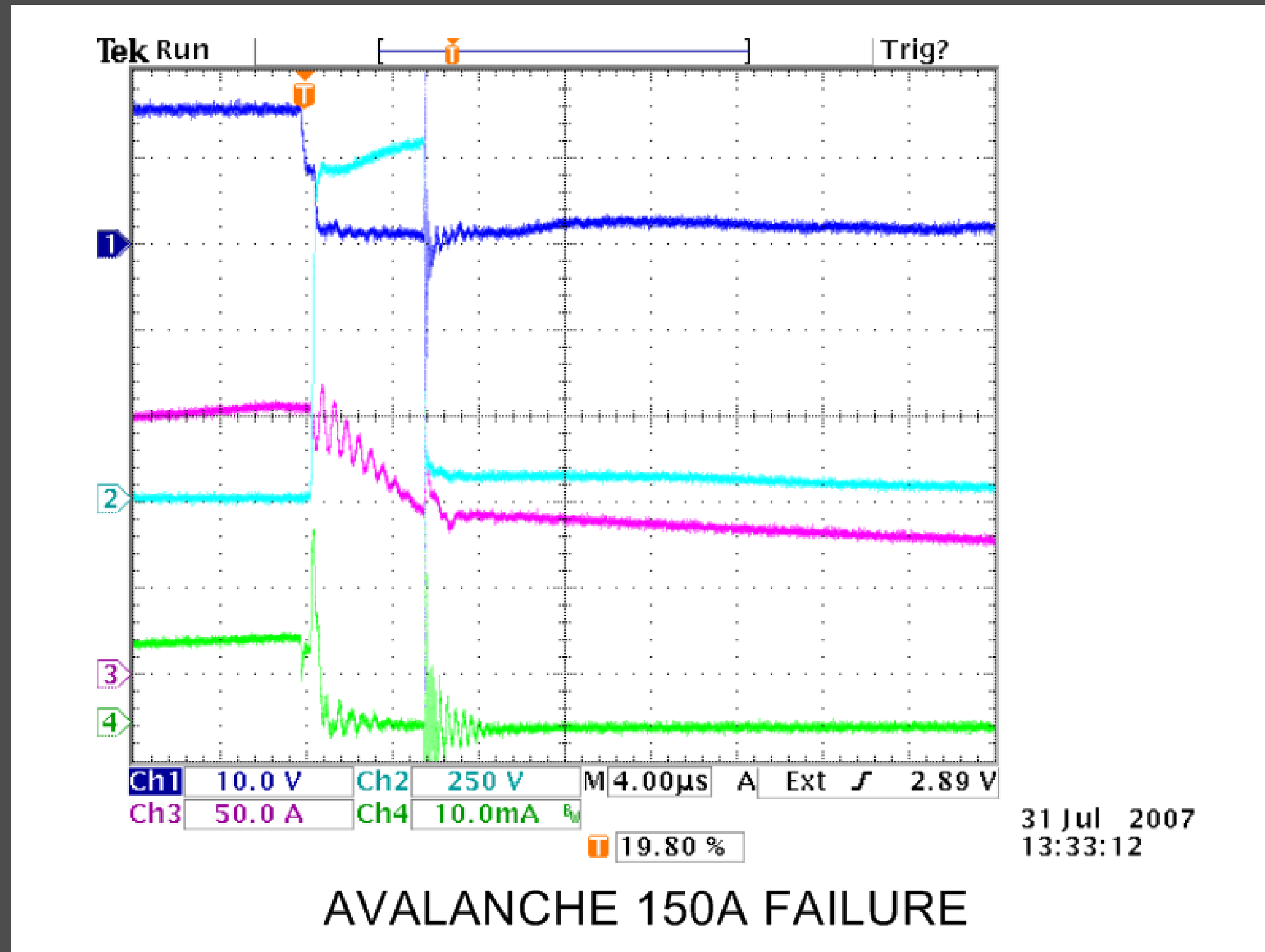
Collector Current

Collector Voltage

Gate Voltage

Sense Emitter

Avalanche Waveform – FAILURE



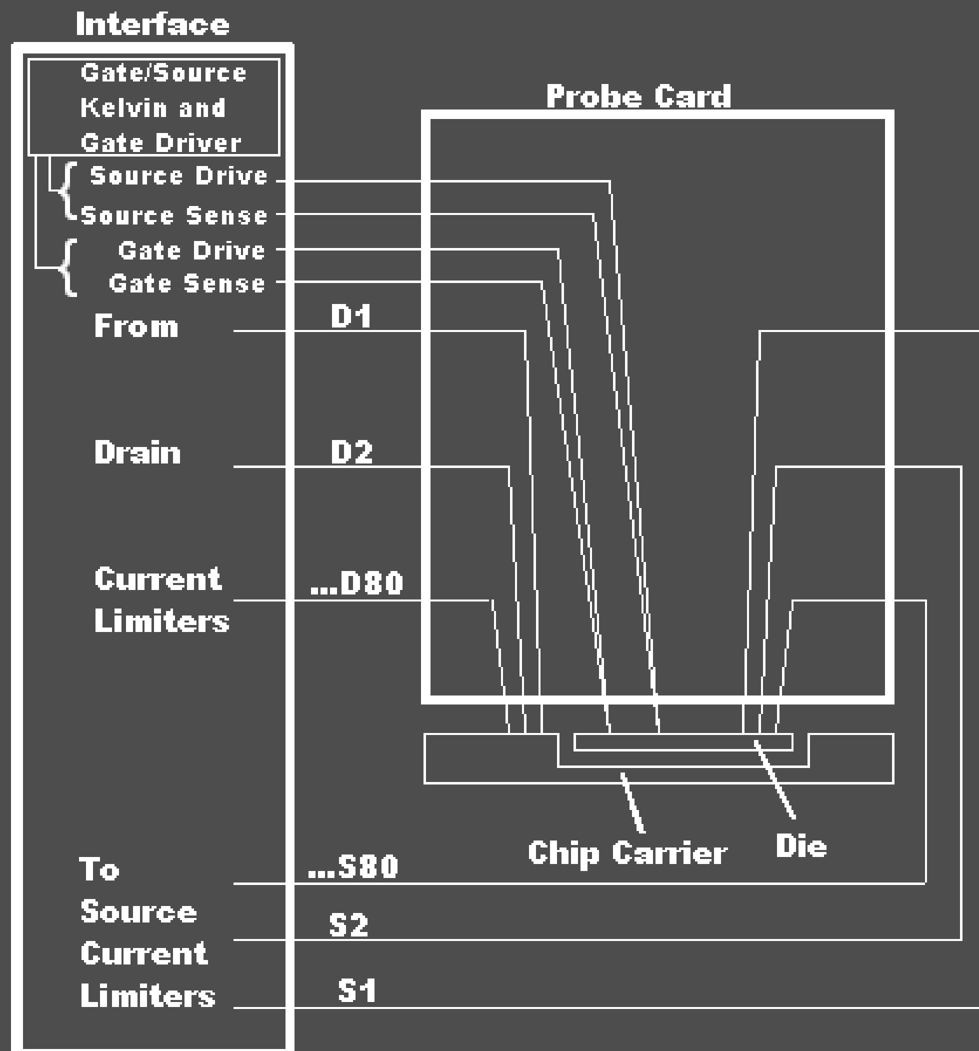
Collector Current

Collector Voltage

Gate Voltage

Sense Emitter

Advanced Chip or Die Level Avalanche Testing Connections



WPS Current Limiter Overview

- Patent-Pending Power Limiter Circuit
- Set for 5 Amps per Probe and uses Standard Probe Card Technology
- Limits Maximum Current In The BEST Probe
- Limits Maximum Power in the WORST Probe
- Voltage Across Contact Resistance Monitored for Complete Protection

Summary

- Allows for Standard Avalanche Test Methods to be used FULL Power
- Expandable to High Power and High Current Parts and Tests
- Power MOSFETs, IGBTs, Diodes, Transzorbs
- Avalanche, RB_{SOA}, V_{DSON}, R_{DSON}, V_{CEON}, V_{F-SD}(body diode)
- All performed with the SAME equipment at the SAME Probe Station
- Allows Correlation with Packaged Parts

References

Tim McDonald, Marco Soldano, Anthony Murry, Teodor Avram *"Power MOSFET Avalanche Design Guidelines"* IR Application Note AN-1006

Kenneth Dierberger "*Understanding The Difference Between Standard MOSFETs and Avalanche Energy Rated MOSFETs*" Advanced Power Technology Application Note

"*Power MOSFET Single-Shot And Repetitive Avalanche Ruggedness Rating*"
Philips Semiconductor Application Note AN10273-1

Warren Schultz "*Power Transistor Safe Operating Area*" ON Semiconductor Application Note AN875/D

Michael Bairanzade "*Understanding Power Transistors Breakdown Parameters*"
ON Semiconductor Application Note AN1628/D