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Sandia National Laboratories

HPM Testing of Modern Electronic Components

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

Outline

- Failure mechanisms associated with exposure to High Power Microwaves
  - Joule Heating
  - Voltage breakdown
- Direct injection Tests for characterizing the failure point of joule heating
  - Test Setup
  - Diagnostics and Data Acquisition
  - Indication of Failure from Reflected Pulse
  - Failure Analysis
- HPM Field Tests
  - Test plan
  - Test setup
  - HPM Failure Analysis
- Finale

Failure Mechanisms

There are two failure mechanisms associated with exposure to High Power Microwaves (HPMs). The first is Joule heating of the wire bonds, interconnections, or the bulk semiconductor, which is related to the amount of energy deposited into the device. The second is related to the exposure of the component to the high peak fields in a HPM pulse. The exposure to high peak fields can induce voltage breakdown in the semiconductor junctions within the device.

The DE Enterprise at SNL has created a direct injection system for effects testing on electronic components and a process for quantifying the energy threshold for failure.

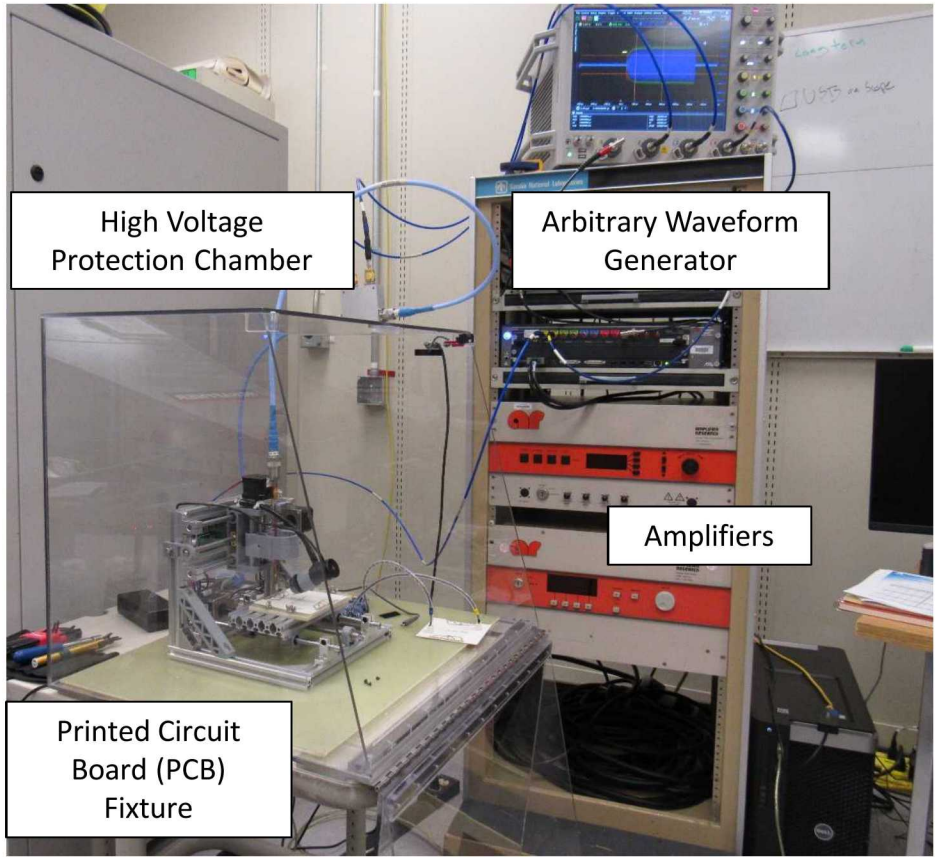
Direct Injection

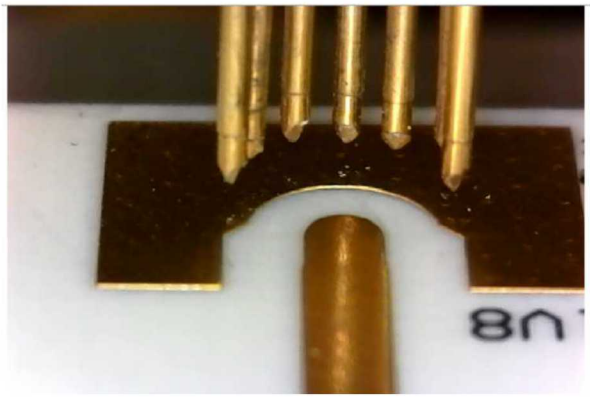
- Long pulse widths (µs)
- Relatively low peak powers
- Consistent well defined square pulse
  - Definite Frequency
  - Pulse width

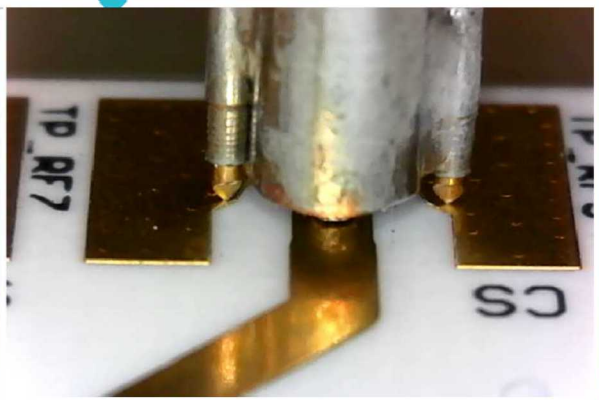
HPM

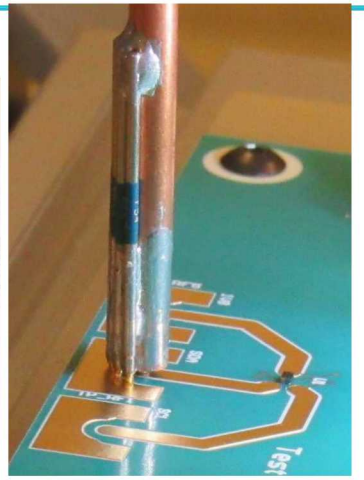
- Short pulses (ns)
- High peak powers
- Varying HPM pulse characteristics from shot to shot
  - Frequency
  - Pulse width

Test Setup



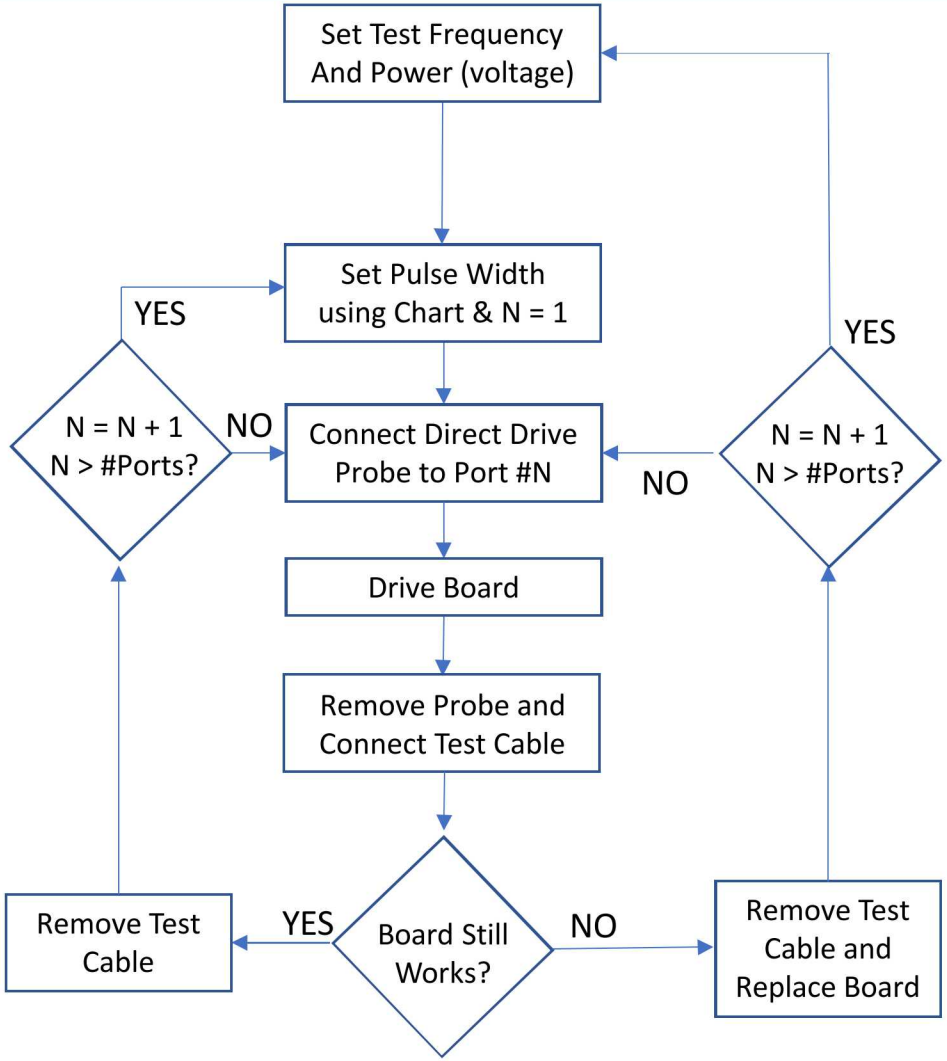


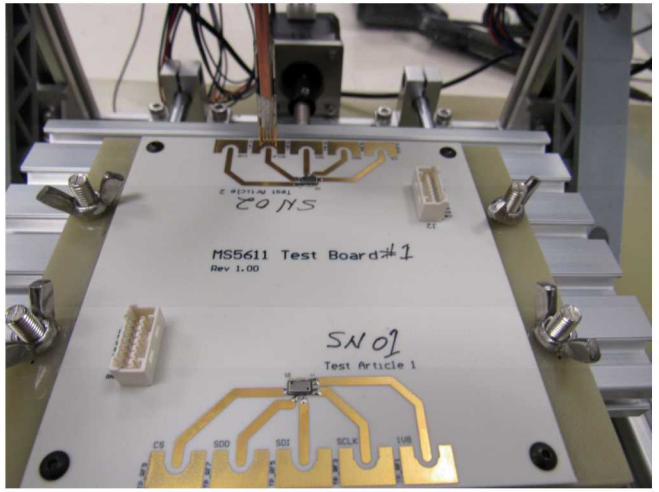


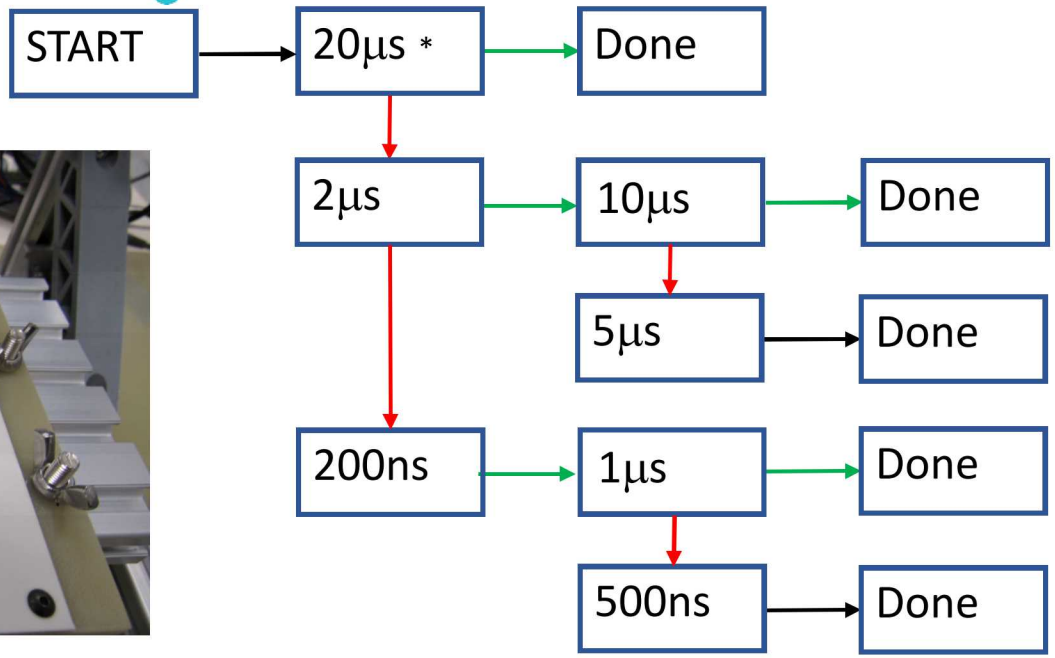


- Amplifiers – 1kW output from 10 kHz-4.2GHz, plans for 1kW capability up to 10GHz
- Arbitrary waveform generator – injected pulse definition
  - Capability to define a pulse to match
- Interlocked high-voltage protection chamber
- XYZ PCB table – remotely position the injection probe onto the test board
- HV Injection probe – pogo pin soldered onto outer conductor of RG402 (D=.141”) and the inner conductor extended forward

Test process





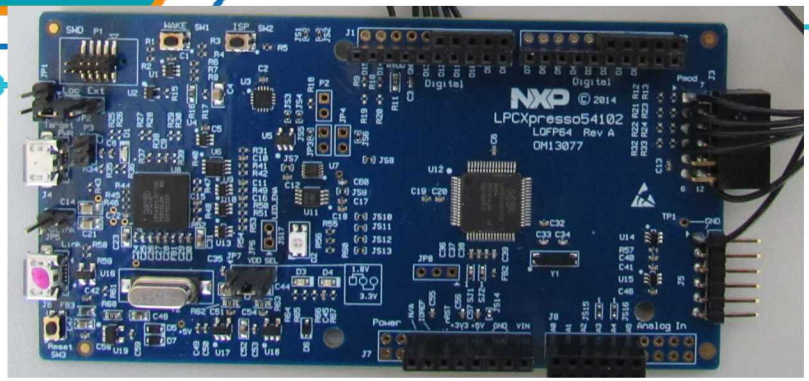


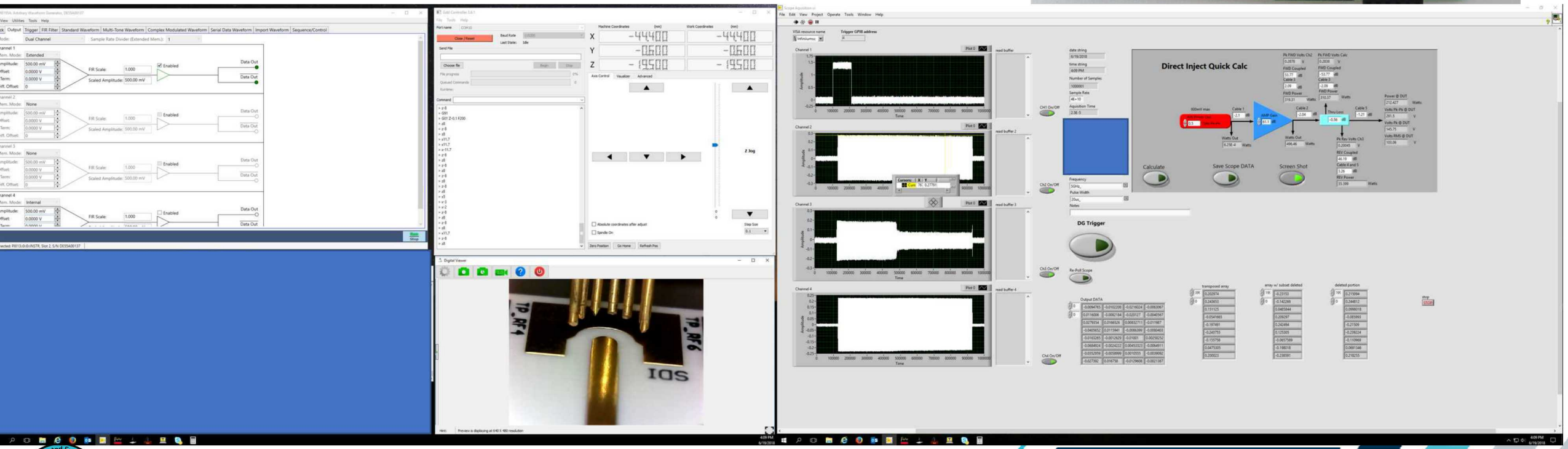
- The testing process is intended to define a failure point for a certain component pin at a certain frequency in terms of power and pulse width

Diagnostics

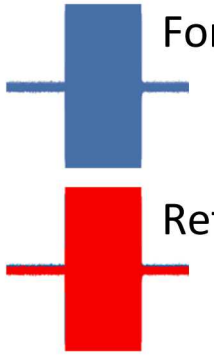
- Semi-automated data acquisition system
  - Probe placement
  - Pulse input characteristics
  - Captures raw data file
  - Preliminary analysis

Component specific functionality tests





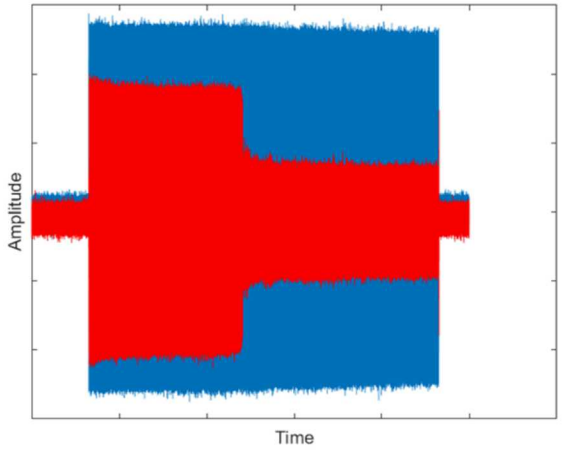
Indication of Failure from behavior of reflected wave

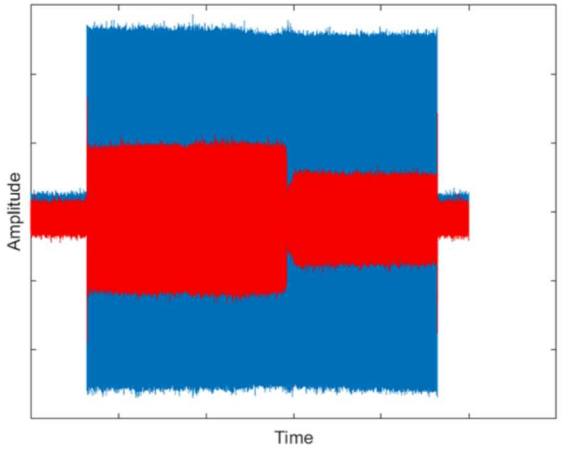


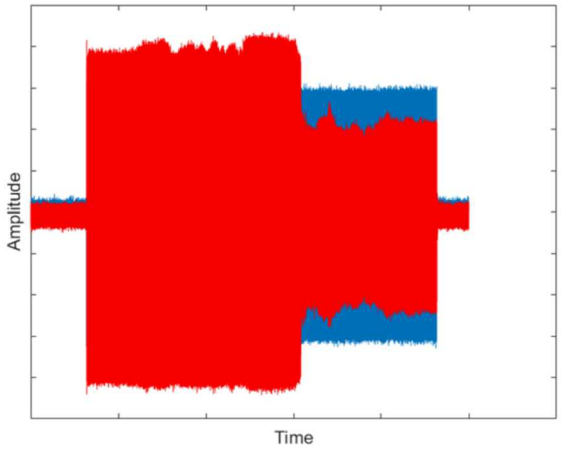
Forward Wave

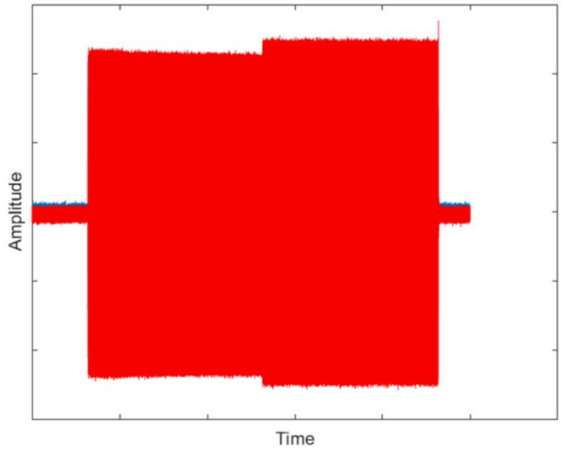
Reflected Wave

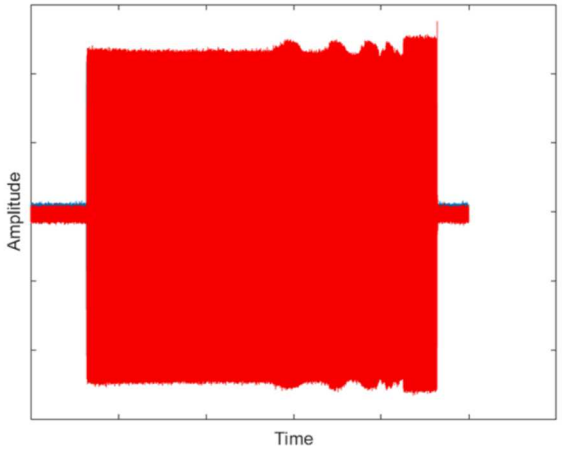
Prior to diagnosing the functionality of the component, the reflected wave that showed a change in impedance during the injected pulse, was a reliable indicator of failure.

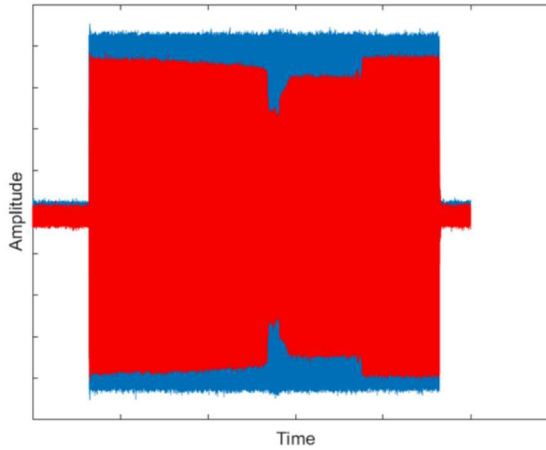




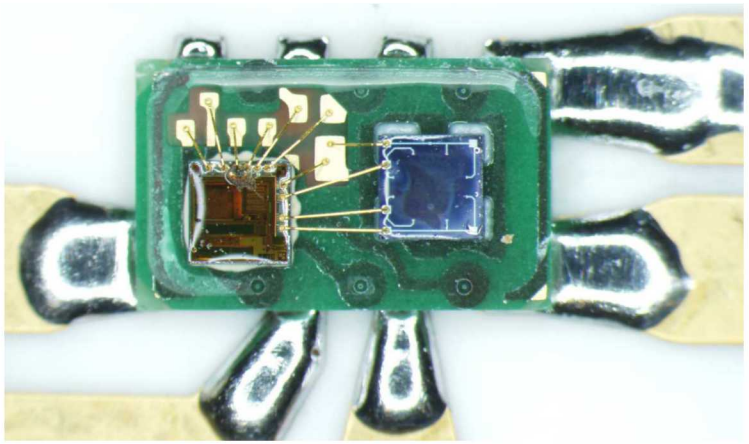




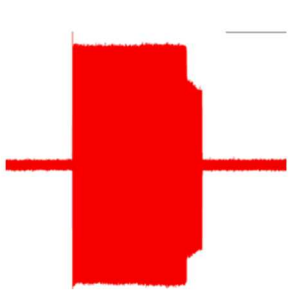


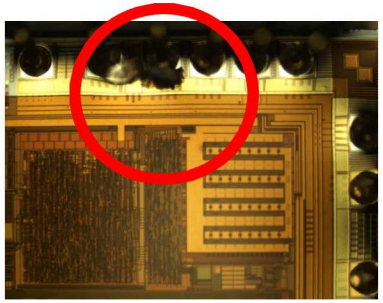


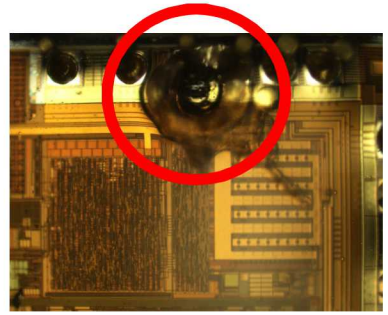
Failure analysis of direct injection components

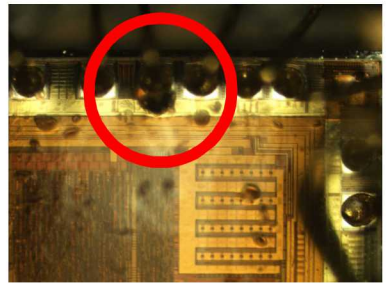


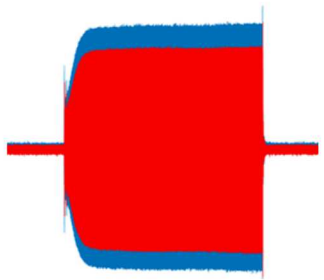
Some of the failed components from direct injection test were visible obvious, while some failed components required more advance FA techniques.

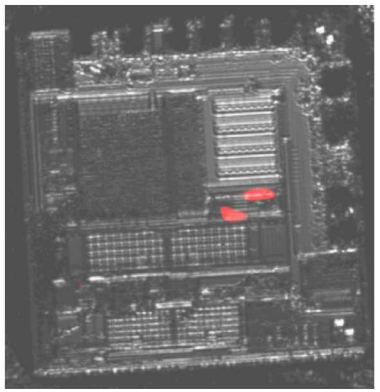


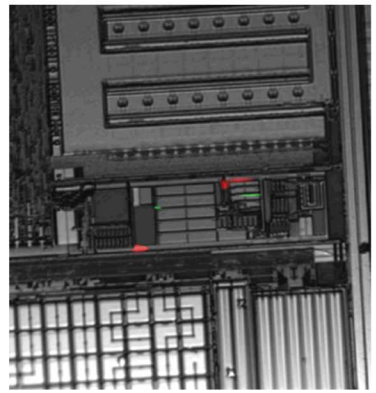


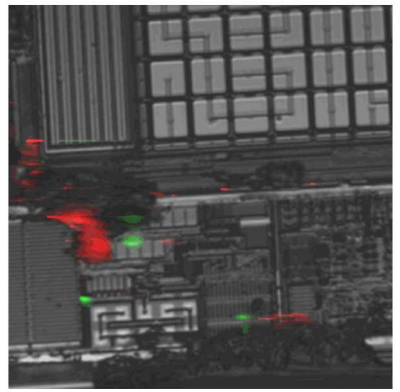




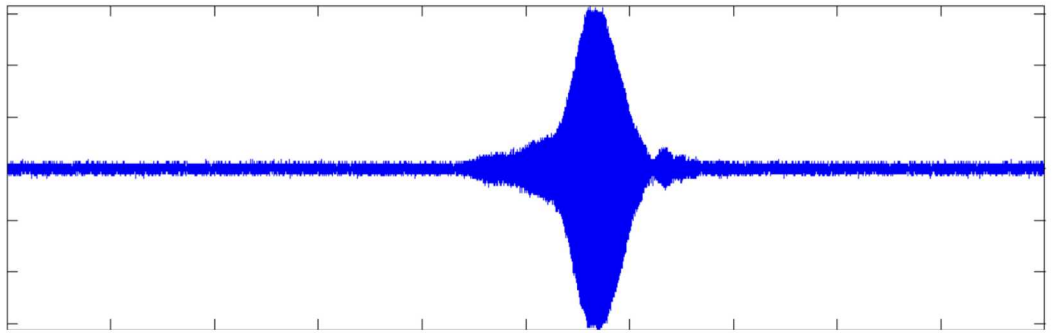


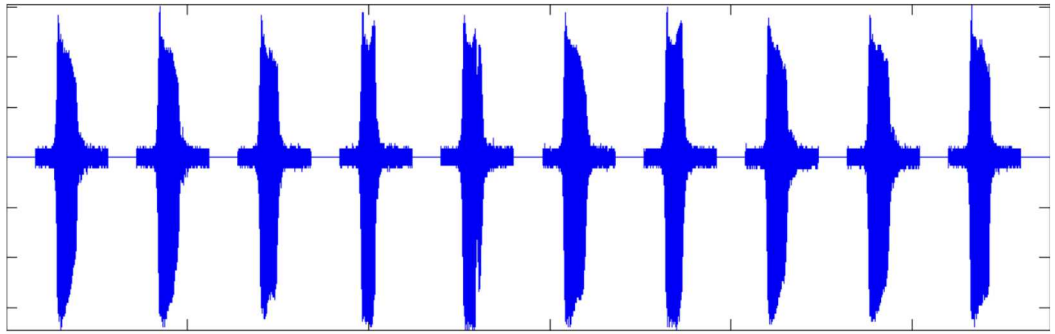






HPM Tests





$$A_e = \frac{G\lambda^2}{4\pi} \qquad P = A_e * S_{mean}$$

- Surface mounted SMA connectors were soldered onto the pads of the PCB boards.
- Surface mounted SMAs connected to receiving antennas in multiple configurations depending on the HPM source
- Energy per pulse can be calculate and compared to direct injection tests
- HPM tests with several different sources with varying frequencies, PW, peak powers, etc…

Recap, results, future work…

Capability

- Direct injection system for individual electronic components and possibly boards
- Process for approximating the energy threshold for damage
- Soon to have amplifier range up to 1kW, up to 10 GHz

Testing

- Failure analysis of damage HPM components is currently underway
- HPM pulses with orders of magnitude lower energy per pulse (narrow pulse width) are still able to damage devices
  - This can be attributed to the second failure mechanism, voltage breakdown within the semi-conductor junctions
- Consistency with direct injection testing varies depending on the device

Questions?