Characterizing Touch Panel Sensor ESD Failure with IV-Curve TLP (System Level ESD)

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Presentation Outline

• Touch panel ESD damage scenarios

• Current methods to test and analysis ESD robustness
  • ESD simulator methods
    • Manual ESD test and failure detection
    • Robotic ESD test and failure detection (Amber Precision Instrument)

• IV-TLP probing methods (NEW)
  • Single-end ESD injection and IV measurement on one trace
    (High current melt a test trace)
  • Single-end ESD injection and IV measurement with neighbor traces
    (High current density melt a spot on a trace during spark)
  • Differential ESD injection and IV measurement with crossing traces
    (High current density melt a spot on a trace during spark)

• Some touch panel ESD test results and analysis

• Some ESD design weakness observed and suggestions

• Conclusion & Future works
ESD damages on Touch Panel

• Electrostatic Discharge (ESD) to capacitive touch panel can cause damage not only to the touch panel controller ICs, but also to the touch panel sensor traces (the perimeter silver (Ag) paste traces, and the Indium-Tin-Oxide (ITO) traces in the touch panel sense area)

• ESD occurs when the screen is touched. These are usually **air discharge from human**, and discharge voltages can be **12+ kV**.

• Such ESD events can **couple by capacitance through glass or break down the air gap around the display touch panel**

• ESD current running on touch panel traces can **fuse trace material** (**high current density heats, melts and evaporates the Ag or ITO material**) and disables the sensing area of the broken trace
Some ESD damage scenarios on Touch Panel

1. **ESD on Edge, Air Gap Breakdown**
   - Touch panel face down, strong capacitive coupling

2. **ESD on Screen, Capacitive Coupling**
   - ESD on screen, capacitive coupling

3. **ESD on Screen, Spark on Surface, Then Air Breakdown**
   - ESD on screen, spark on surface, then air break down

4. **Bottom**

5. **Top**

6. **Bottom**

7. **Top**

8. **GND**
- Metallic cell phone body
- ESD test table
- Earth ground, surrounding

ESD to the edge capacitive coupling

Glass
Touch
Glass
LCD
Glass
Backlight

GND
Glass Touch Glass LCD Glass Backlight

Metallic cell phone body

ESD test table

Earth ground, surrounding

ESD on screen, spark on surface, then air break down
Touch panel face down, strong capacitive coupling

Metallic cell phone body

ESD test table

Earth ground, surrounding
How to repeat and analysis the ESD damage?

1) ESD simulator discharge to complete touch panel system
   a) This method repeats the human contact and air discharge events with the overall touch panel system
   b) The overall ESD current can be measured with a current clamp, but it is hard to measure the trace current density (which is the critical factor of the ESD damage)
   c) It is hard to control and monitor the ESD current path! ESD at same injection point could lead to different damage locations
   d) ESD failure detection is difficult to automate

2) IV-TLP ESD probing methods for local ESD robustness characterization
   a) Both voltage and current time domain waveforms of the ESD injection event can be monitored
   b) ESD current path is well controlled for each test, the test result is much more repeatable
   c) ESD test and failure detection can easily be automated
   d) But ... probes need to be landed
Capacitive Touch Panel Display (reference page)

- The capacitive touch sense method uses an X and Y grid to determine where touch occurs. A finger or stylus touch at a grid point will change the capacitance, thereby yielding a means for sensing the coordinates.

- Generic touch panel trace layout
  - Wide ground trace around perimeter
  - Thinner, signal traces inside
    (Structures for buttons and interconnects not shown)

References
http://www.hantronix.com/page/index/resources/capacitive_touch_panel
http://atmelcorporation.wordpress.com/2012/12/13/integrating-capacitive-touchscreens-into-automotive-dashboards
Discharge touch panel edge discharge, spark can break though any small air gap and reach traces on the edge, usually the outer ring is the GND.

ESD current could return through all possible paths, including secondary break down paths if trace resistance is relatively high.
ESD damages on touch panel (ESD gun & TLP)

Note, there are also ITO layer trace damage, but due to material transparency, it is difficult to obtain an image.
ESD events that causes trace damages

• High ESD current on single trace – then fuse
  The **high current** will flow on the trace and depending on trace width changes, trace turning, and inconsistent material thickness, heating spots may occur at those locations and damage the trace material.

• Internal trace to trace breakdown – then fuse
  The Ag trace to trace distance is very close (e.g. 30 um), and break down can happen with 100’s of volts. When break down occurs the **high current density at the sparking points** causes damage.

• ITO layer breakdown – then fuse
  ITO layer X & Y traces are very thin and close to each other. Break down can occur between the XY crossing points, especially for the design without enough insulation between them. When break down occurs the **high current density at the spark points** causes damage.
How IV-TLP probing injection and IV measurement method can test the ESD robustness?

High ESD current on single trace – then fuse
  • At what current level and pulse length will traces fuse?
    A normal single-end IV-TLP test applied on the 2 ends of a single trace can characterize the robustness

Internal neighbor trace to trace breakdown – then fuse
  • At what voltage level and pulse length will voltage breakdown occur between two neighbor traces? i.e. between ground trace and a signal trace
    A single-end IV-TLP test setup applied on the 2 ends of 2 traces with leakage bridge connection between them (to check for trace failure) can characterize the robustness

ITO layer breakdown – then fuse
  • At what voltage level and pulse length will voltage breakdown occur at one of these intersections?
    A differential IV-TLP test setup applied on the 2 ends of 2 traces with leakage bridge connection between can characterize the robustness
**Single-end ESD injection and IV measurement**

- Communication, TLP (ES621), ESD injection and IV probe (ES651), Computer, and Data Capture (SMU Keithley 2400)
- Leakage Control Module (switch between TLP Pulsing & Leakage measurement)
  - Leakage Control Module used for ensuring good connections and checking for device failure
- Direct Voltage (resistive voltage divider) and Current (CT1/2) measurement probe
LEAKAGE PROBES

1. Help to test for good connection to traces
2. Provide check for trace damage
Single-end ESD injection and IV measurement for 2 traces (for testing trace fusing)

- TLP disconnected
- SMU connected thru ES 651 Pulsing Pin to Touch Panel Ag paste trace
- ES 651 Voltage measurement disconnected
- Current Probe in ES 651 is open circuit at DC (current transformer)
- Leakage Probes complete the circuit between traces to ground
Differential ESD injection and IV measurement

- Use two ES651 probes in addition to a splitter/Inverter
Why Differential ESD injection?

- **Single-End**
  - TLP Voltage: 1000V
  - Internal Attenuator: 2dB (0.794 decimal)
  - Applied Voltage (into open): 794V

- **Differential**
  - TLP Voltage: 1000V
  - No Internal Attenuator: 0dB
  - Splitter/Inverter Attenuation: 10dB (0.316)
  - Applied Voltage (into open): 632V

The single-ended ESD injection will apply more voltage between pulsed pin and return, but it does this relative to several traces, and it is not certain where breakdown may occur.

The differential ESD injection pulse will apply 2x the voltage across the desired trace combination versus any other trace combination, helping to ensure where breakdown will occur.
Some IV-TLP measurement setup and test results

For results presented herein the following TLP parameters were used:

- 100ns Pulse Width
- Single Ended Applied Voltage (open) – 1588V
- Pulse Window used for measurement scaling of oscilloscope display
  - 70 to 90% measurement window
  - For example: for a 100ns pulse the range from 70ns to 90ns was averaged and used to adjust the oscilloscope display range to optimize waveform measurement resolution and avoid clipping
- This range is also used to form the Dynamic IV curve
Single trace ESD injection & fusing result

- Use leakage measurement to determine when a trace has fused because it will lead to an open circuit.

Ag paste trace looks like a non-linear resistance until fusing.

Partial damage occurred, resistance changed.

After fuse, looks like an open circuit.
Single trace ESD injection & fusing result

- Time waveforms corresponding to previous Dynamic IV curve.

  Just before fusing  
  (peak point on Dynamic IV).

  After fusing  
  (last point on Dynamic IV).
Trace to Trace Breakdown Result

• From measurement experience, Trace to Trace breakdown resulted in the opening of one or both of the traces, the leakage current (loop measurement) changes from milli-amps to pico-amps.

Sparking between traces destroys traces
Trace to Trace Breakdown Cont’d

- VI curve measurement did not capture the trace being opened, but leakage loop sees and open circuit

Small signal current with shorted back end

Damage

Why is there like 1k? From probing?
ITO Layer Breakdown Measurement Results

Current flows during spark.

ITO intersection looks like an open circuit.

Voltage drops as breakdown occurs.

Current increases as breakdown between traces occurs.
Current conclusion:
1. It is possible to characterize some failure mechanisms of Touch Panel displays using TLP measurement techniques.

2. It was shown that damage can be reproduced using single ended and differential direct injection and probing methods.