Session 6
Electrical and Functional Testing

Title
Elimination of Potential Electrical Stress During EMC (CS01) Testing

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Agenda

- Cassini Radar EMC test failure at JPL in 1995
- Oscillation observed
- Failure investigation
- Corrective action
- IRAC EMC test failure at GSFC in 1999
- MLS EMC test failure at JPL in 2000
- CS01 Test Fixture
- Existing concerns
- Recommendations
Cassini Radar EMC Test Failure at JPL

- On December 5, 1995 Cassini Radar instrument failed functional test in preparation for Electromagneticic Compatibility (EMC) conducted susceptibility (CS01) testing
  - The instrument power supply did not turn on as required
  - Failure occurred prior to injection of CS test stimulus
- CS01 testing terminated
- Problem documented using JPL Problem/Failure Reporting System
Oscillation Observed

- Oscillation on 30V input power line
  - 39 volts peak-to-peak
  - Approximately 1kHz frequency
Test Setup When Failure Occurred

Signal Generator (Off)

Amplifier (Off)

Device under test (DUT)

30Vdc Power Supply

1 mH winding inductance

Cassini Radar

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Testing Other Power Converters

- Six engineering and breadboard models of power converters previously EMC tested were tested using same test setup used during Cassini Radar test failure
- Oscillations resulted when testing two of these power converters
Laboratory Testing

- The Cassini Radar breadboard was tested in the radar laboratory
  - Secondary of actual EMC test transformer was connected between 30V supply and the 30V input of Cassini Radar
  - The primary of the EMC test transformer was left unconnected
- A 35V p-p oscillation was observed at the Cassini Radar 30V input
- No oscillation was observed when unit was tested without transformer (direct connection to 30V supply)
Failure Investigation

- PSPICE simulation of Cassini Radar 30V line using the EMC test setup was performed
- The result of the simulation was an oscillation on the 30V input of the power supply
- No oscillation when series inductance was significantly reduced
- No oscillation when a low resistance was connected across transformer primary
Failure Investigation (Cont.)

- It was determined that the Cassini Radar failed during EMC testing due to a trip-off of the power converter due to the detection of an over-voltage condition.
- It was also determined by a part stress analysis that several parts were potentially over-stressed.
- The potentially stressed parts were replaced.
Stability Criteria

- Stability exists if:
  \[
  \frac{P}{kE^2} < \frac{(R_s + R_c)C}{(L + CR_s R_c)}
  \]
  where:

  \( P \) = Converter output power
  \( k \) = Converter power efficiency
  \( E \) = Converter input voltage
  \( R_s \) = Series input resistance
  \( R_c \) = Capacitor series resistance
  \( C \) = Shunt input capacitance
  \( L \) = Series input inductance
  \( R_{in} \) = Switch-mode Converter input resistance

\[ \text{Diagram of DC power system with components:} \]

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EMC Test Corrective Actions

- The following changes were implemented for subsequent EMC testing at JPL:
  - A 50 ohm resistor connected across transformer primary. This results in a small resistive secondary impedance (50/4 = 12.5 ohms)
  - The signal generator and amplifier will be powered with the signal amplitude at minimum setting for UUT testing prior to injecting conducted susceptibility stimulus

- The conducted susceptibility testing of Cassini Radar flight hardware was successfully repeated with the corrective actions implemented
IRAC EMC Test Failure at GSFC

- On December 28, 1999 an oscillation occurred on the input power line of the SIRTF Infrared Array Camera (IRAC) while preparing to perform CS01 testing
- Resulted in damage to flight hardware
- Subsequent to failure, JPL provided GSFC history and corrective action from Cassini Radar CS01 test failure
- GSFC implemented the same corrective action as JPL, except that the value of the resistor connected across the isolation transformer primary winding is 2.5 ohms instead of 50 ohms
MLS EMC Test Failure at JPL

- On May 8, 2000 an oscillation occurred at JPL during EMC testing of the Microwave Limb Sounder (MLS)
- An investigation of this problem was performed by Vatche Vorperian. His investigation included performing a stability analysis of the test setup with tested assembly. Results of the analysis indicate that instability exists even with the 50 ohm damping resistor due to the low negative input impedance of MLS power converter
- As the result of this oscillation, Vatche Vorperian designed a test fixture that allows CS01 testing without the use of the series transformer
- Using this test fixture, the stability of the DC voltage at the tested hardware is ensured
MLS Oscillation Waveforms

Voltage

Current

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CS01 Test Fixture

CS01 Test Fixture (Conceptual Drawing)

External DC Power Supply
DC Voltage Control
AC Voltage Control
Controller Electronics
Voltage Feedback

Power Lines to Unit Under Test

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Existing Concerns

- Mil-Std-461 and Mil-Std-462 do not include warnings or safeguards to prevent oscillations from occurring.
- There may be many companies that are not aware of this problem.
- Electronics can be potentially fried at EMC test facilities if the consequences of switch mode power supply negative input impedance is not considered in EMC test design.
Recommendations

- Make EMC test community aware of the problem and potential solutions by presenting papers at major environmental test conferences
- Include warnings and safeguards in EMC test requirements and procedures
- Try to convince EMC test equipment suppliers to design a CS01 test fixture similar to fixture shown in the diagram
References

- Patrick K. Harris and Nathan F. Block, "Potential Damage to Flight Hardware from Mil-Std-462 Setup", IEEE EMC Symposium 2003