Indirect Lightning Testing to DO 160 Section 22 And MIL STD 461G Section CS117

Presented By Louis A Feudi

Ametek CTS

For IEEE EMC Society

All Graphics taken from DO-160 and MIL STD 461G

Why Indirect Lightning Testing

- Previous planes were manufactured using all metal construction which created a Faraday Cage to prevent coupling of lightning on the internal wiring in the plane.
- All coupling was done via apertures in the plane hull, such as Radomes, windows, and other openings in the planes
- With the use of Carbon Fiber Composite Materials in the construction of the plane, the plane became a giant resistor

Why Indirect Lightning Testing

- Although many of the components on the plane are critical to the flight operation of the plane, many airframe manufacturers are concerned about the operation of non mission critical components on the plane
- Operations such as entertainment systems, WIFI, galley functions are especially critical when on long flights of 6 hours or more

RTCA

- RTCA is the Radio Technical Commission for Aeronautics
- Publishes DO-160
- Has industry and regulators attending

SAE

- SAE serves the Aerospace, Automobile, Commercial Vehicle and Motorsport industries as a source of standardization of oil grades, transportation standards writing, and consulting services
- AE2 is the committee for Section 22 “Indirect Lightning Test requirements” technical requirements
- Attended by Industry Leaders such as test labs, FAA, Airframe Manufacturers and other standards Authorities
-

EUROCAE

- EUROCAE is the European Organization for Civil Aviation Equipment
- Publishes ED84: Aircraft Lightning Environment and Related Test Waveforms
- Sits in on AE2
- Practically the same requirements as DO 160

MIL STD 461

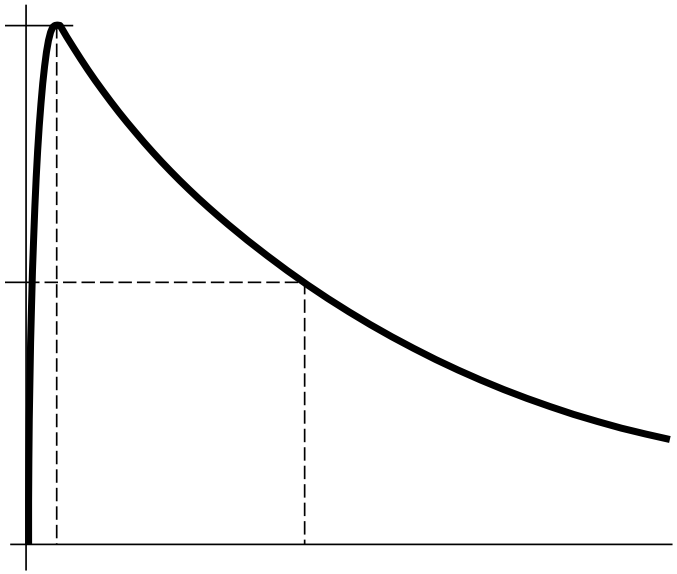
- MIL STD 461 is a Department of Defense Interface Standard
- Requirements for the control of Electromagnetic Interference Characteristics of Subsystems and Equipment

Waveform Requirements

- There are 7 waveforms called out by DO-160
- Waveform 1 – 6.4 us x 69 us (Current)
- Waveform 2 - 100 ns x 6.4 us (Voltage)
- Waveform 3 – 1 and 10 MHz (Ring Wave)
- Waveform 4 - 6.4 us x 69 us (Voltage)
- Waveform 5A - 40 us X 120 us (Current)
- Waveform 5B - 50 us X 500 us (Current)
- Waveform 6 - 250 ns X 4 us (Current)

Waveform Requirements

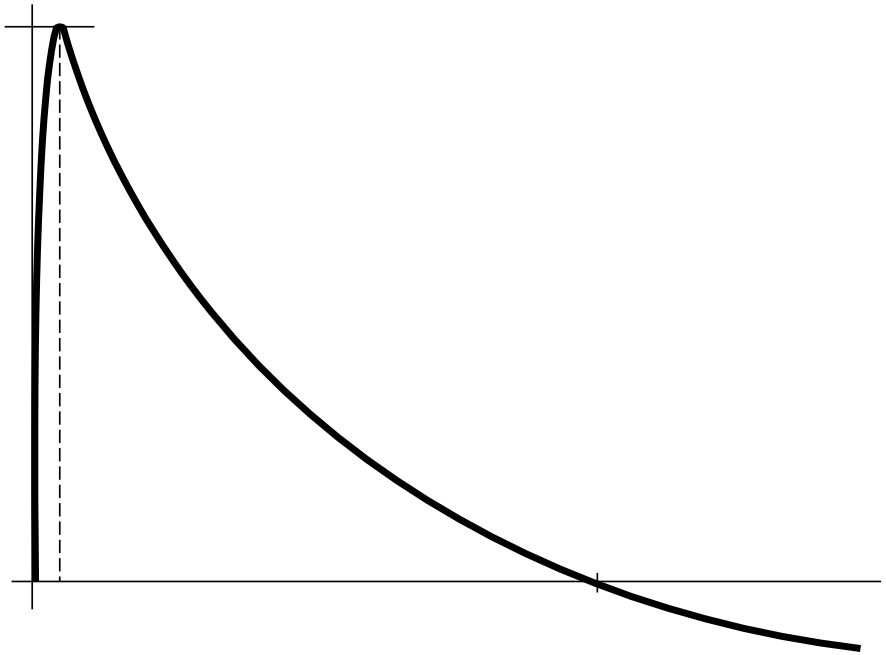
- Waveform 1 – 6.4 us x 69 us
- Current Waveform



- **T1 = 6.4 microseconds ± 20% T2 = 69 microseconds ± 20%**
-

Waveform Requirements

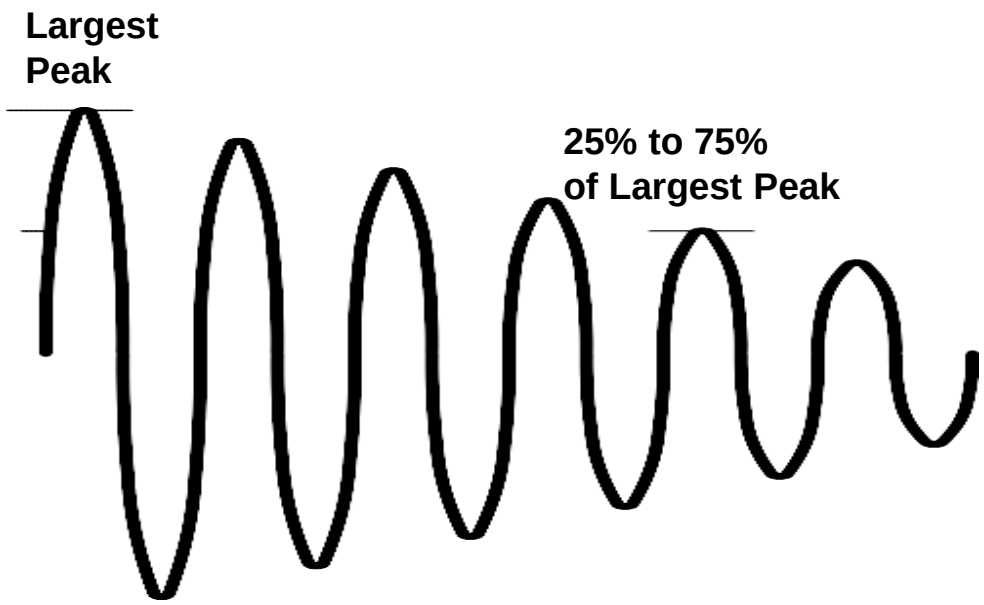
- Waveform 2-
- Voltage Waveform



- **T1 = 100 nanoseconds maximum T2 = 6.4 microseconds ± 20%**
-

Waveform Requirements

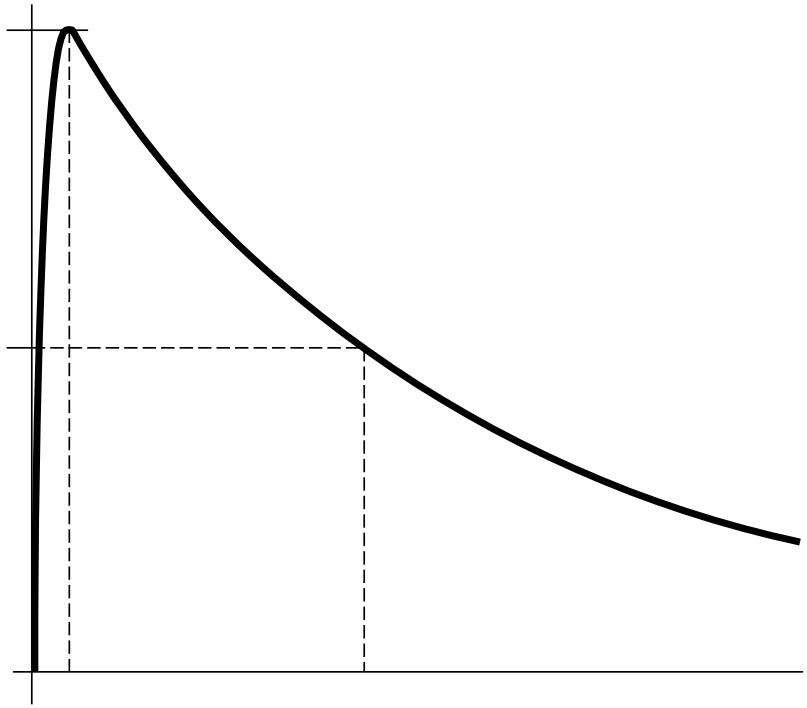
- Waveform 3 1 and 10 MHz
- Current Waveform



- NOTE:The waveshape may have either a damped sine or cosine waveshape.

Waveform Requirements

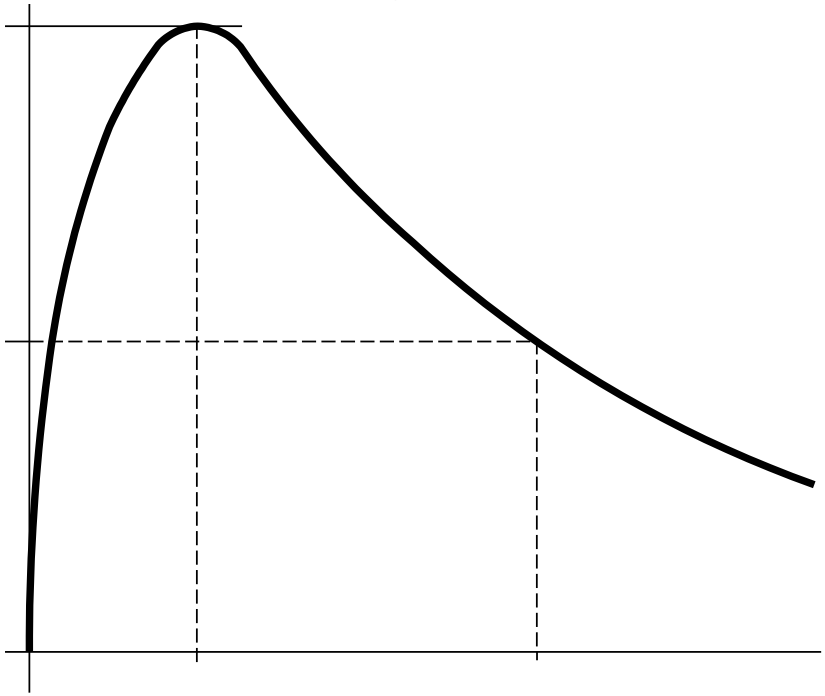
- Waveform 4
- Voltage Waveform



- **T1 = 6.4 microseconds ± 20% T2 = 69 microseconds ± 20%**

Waveform Requirements

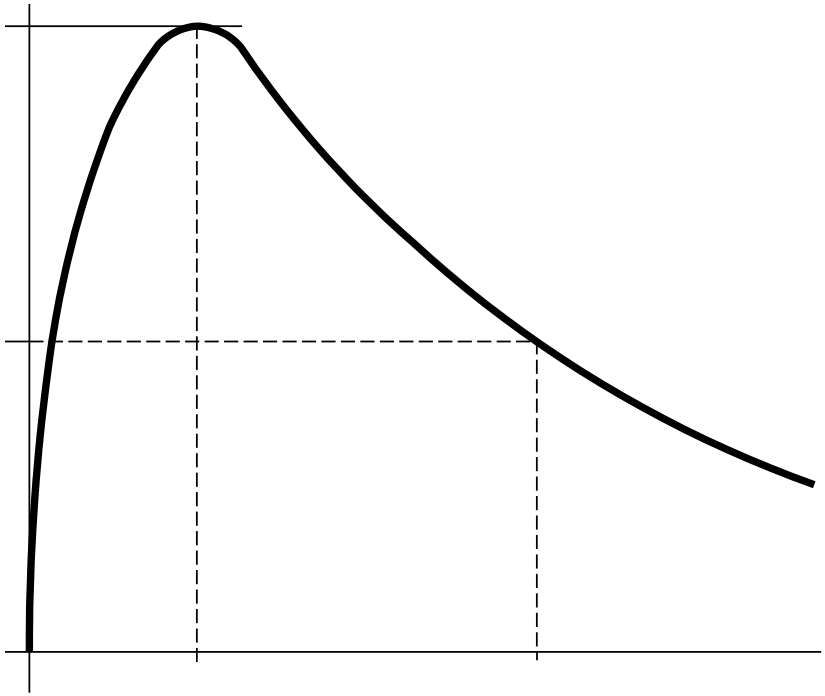
- Waveform 5A
- Current Waveform (Voltage for a select test)



- **T1 = 40 microseconds ± 20% T2 = 120 microseconds ± 20%**

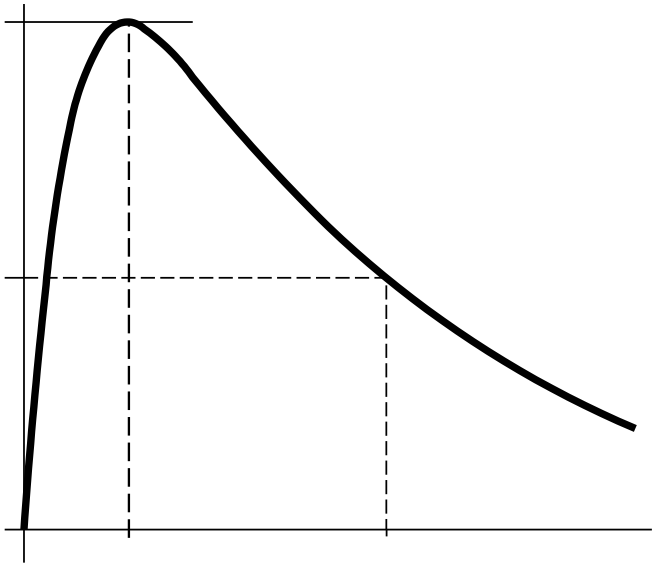
Waveform Requirements

- Waveform 5B
- Current Waveform



- **T1 = 50 microseconds ± 20% T2 = 500 microseconds ± 20%**

- Waveform 6
- Current Waveform



- **T1 = 250 nanoseconds ± 20% T2 = 4 microseconds ± 20%**

Power level applications

- Power levels range from Level 1 for well protected equipment to Level 5 for element exposed equipment or Mission Critical Equipment

TestTypes

- Pin Injection – Direct discharge into the circuit under test
  - Achieved using:
  - inductive coupling onto the cable connected to the circuit
  - Direct connection of the generator to the pins
  - Ground injection using the cable ground shield to couple on the wires

TestTypes

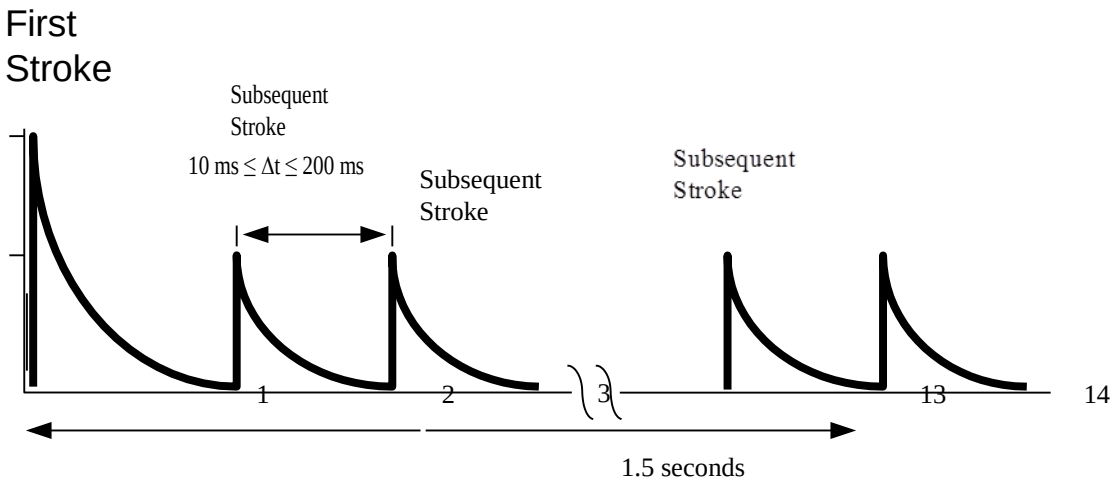
- Cable Bundle – Inductive coupling of the waveform onto the plane's cable bundles
- Three kinds of cable bundle waveform applications:
  - Single Stroke (Double Exponential)
  - Multi Stroke
  - Multi Burst

Example of Cable Bundle Manufacturers Code Designations

Waveform Set	Test Type	Test Waveform
C (unshielded, aperture coupling)	Single Stroke	2,3
D (unshielded, aperture and resistance coupling)	Single Stroke	2,3,4
E (shielded aperture coupling)	Single Stroke	1,3
F (shielded, aperture and resistance coupling)	Single Stroke	3,5A
G (unshielded, aperture coupling)	Single Stroke	2,3
	Multiple Stroke	2, 3
H (unshielded, aperture and resistance coupling)	Single Stroke	2, 3, 4
	Multiple Stroke	2, 3, 4
J (shielded, aperture coupling)	Single Stroke	1, 3
	Multiple Stroke	1, 3
K (shielded, aperture and resistance coupling)	Single Stroke	3, 5A
	Multiple Stroke	3, 5A
L	Multiple Burst	3
M	Multiple Burst	6

Multi Stroke

Simulates forked lightning strike

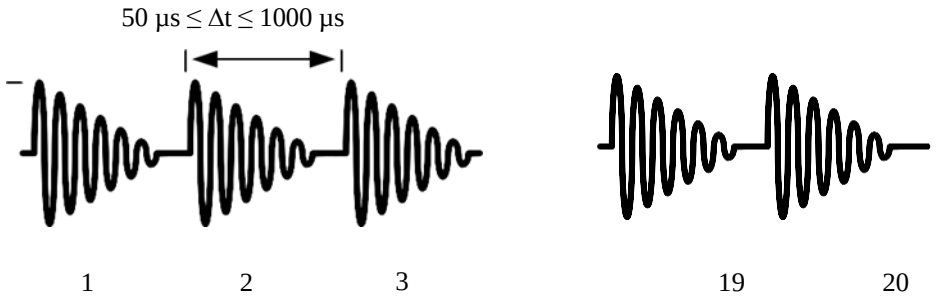


14 pulses total

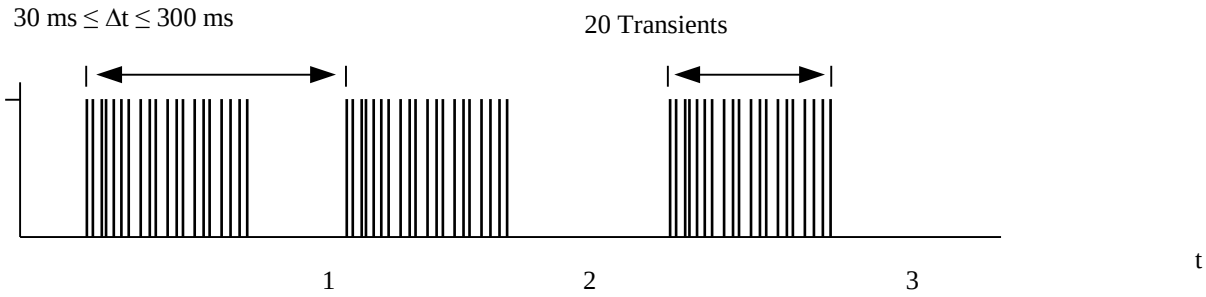
Subsequent strokes are ½ the peak amplitude of the first stroke

Applied using cable bundle test method

Multi Burst

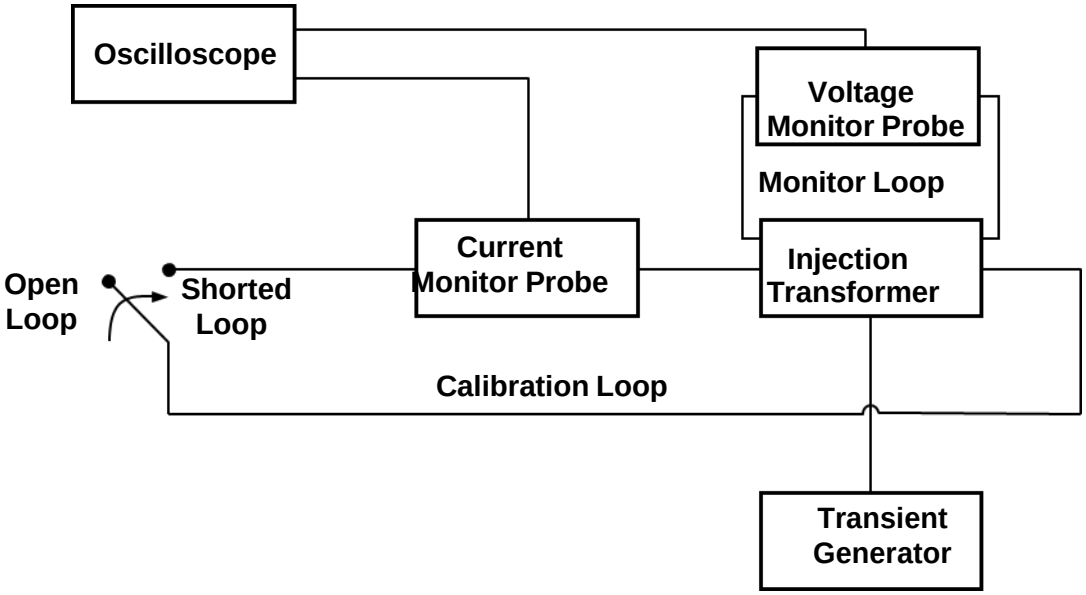


One burst is 20 transients spaced 50-1000 microseconds

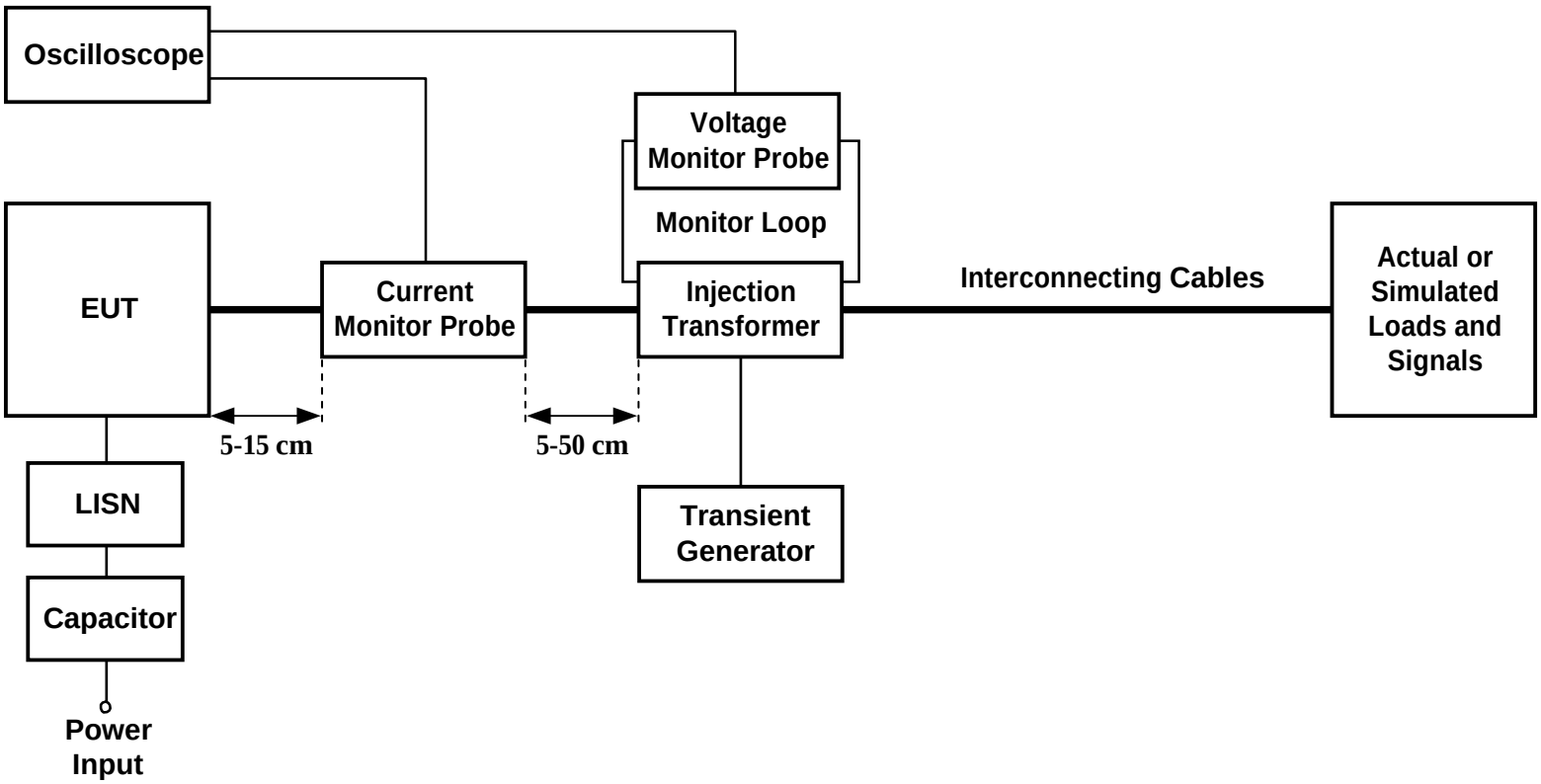


One burst application is 3 sets of bursts spaced 30-300 milliseconds

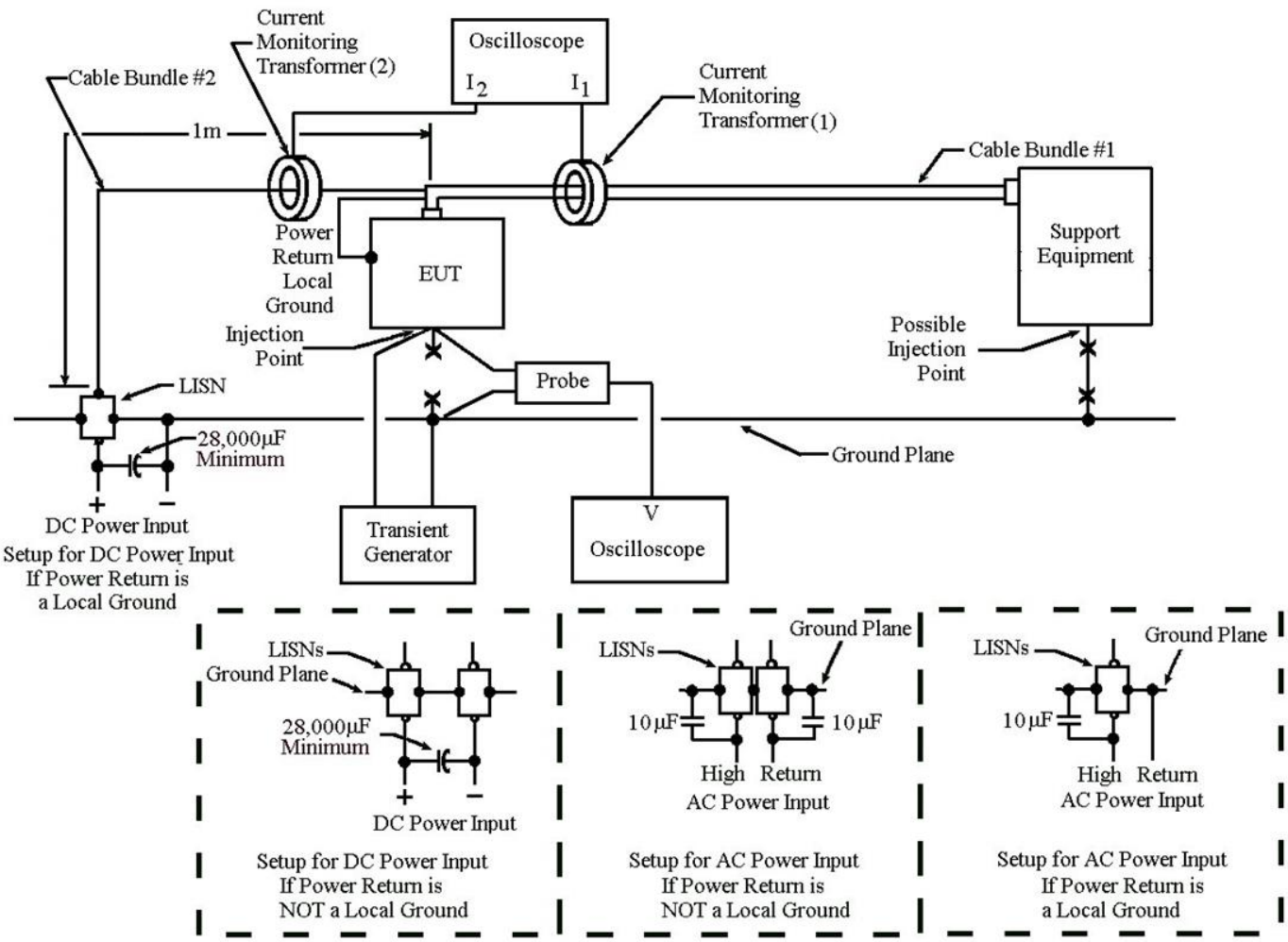
Cable Bundle Verification Setup



Bulk Cable Injection Test Setup



Ground Injection Test Setup



MIL STD 461 CS117

Applicable to:

- all aircraft safety-critical equipment interconnecting cables,including complete power cables, and individual high side power leads
- non-safety critical equipment with interconnecting cables/electrical interfaces that are part of or connected to equipment performing safety critical functions.
- May be applicable to aircraft equipment performing non-safety critical functions when specified by the procuring activity
- This requirement applies to surface ship equipment which is located above deck or has interconnecting cables which are routed above deck.

MIL STD 461 CS117

- No Pin Injection Testing
- Cable Bundle Testing only
- Multi-Stroke considered representative of Single Stroke Test

MIL STD 461 CS117
Table CS117-1

Test Number	Test Description/Applicability	Internal Equipment Limits [1/]	External Equipment limits [1/]
1	Multiple Stroke –Waveforms 1 and 2. Applicable to all aircraft.	Initial Stroke V_L = 300 volts (WF #2) I_T = 600 amps (WF #1) I_L = 60 amps [2/] Subsequent Strokes V_L = 150 volts (WF #2) I_T = 150 amps (WF #1) I_L = 30 amps [2/]	Initial Stroke V_L = 750 volts (WF #2) I_T = 1500 amps (WF #1) I_L = 150 amps [2/] Subsequent Strokes V_L = 375 volts (WF #2) I_T = 375 amps (WF #1) I_L = 75 amps [2/]
2	Multiple Stroke – Waveform 3, (apply at both 1 and 10 MHz) Applicable to all aircraft.	Initial Stroke V_T = 600 volts (WF #3) I_L = 120 amps (WF #3) I_T = 12 amps [2/] Subsequent Strokes V_T = 300 volts (WF #3) I_L = 60 amps (WF #3) I_T = 12 amps [2/]	Initial Stroke V_T = 1500 volts (WF #3) I_L = 300 amps (WF #3) I_T = 60 amps [2/] Subsequent Strokes V_T = 750 volts (WF #3) I_L = 150 amps (WF #3) I_T = 30 amps [2/]
3	Multiple Stroke – Waveform 4 and 5. Applicable to aircraft with composite skin/structure. Not applicable to an all-metal skin/structure aircraft.	Initial Stroke V_L = 300 volts (WF #4) I_T = 1000 amps (WF #5) I_L = 300 amps [2/] Subsequent Strokes V_L = 75 volts (WF #2) I_T = 200 amps (WF #1) I_L = 150 amps [2/]	Initial Stroke V_L = 750 volts (WF #4) I_T = 2000 amps (WF #5) I_L = 750 amps [2/] Subsequent Strokes V_L = 187.5 volts (WF #2) I_T = 400 amps (WF #1) I_L = 375 amps [2/]
4	Multiple Burst –Waveform 3, (apply at both 1 and 10 MHz). Applicable to all aircraft.	V_T = 360 volts (WF #3) I_L = 6 amps (WF #3) F = 1 MHz, 10 MHz	V_T = 900 volts (WF #3) I_L = 15 amps (WF #3) F = 1 MHz, 10 MHz
5	Multiple Burst –Waveform 6. Applicable to low impedance bundles only.	V_T = 600 volts (WF #6) I_L = 30 amps (WF #6)	V_T = 1500 volts (WF #6) I_L = 75 amps (WF #6)

NOTES:
1/ Amplitude Tolerance is +20%,-0% for the all waveforms, except the tolerance is relaxed to +50%,-0% for the Subsequent Strokes. V_T represents the test voltage level in Volts and I_T represents the test current level in Amperes. V_L (Volts) and I_L (Amperes) represent limits intended to prevent over-stressing the EUT beyond the requirements.
2/ Levels intended for individual power leads or low count wire bundles. When multiple leads are tested together, this current shall be increased to the full bundle level or to the number of leads

MIL STD 461 CS117

- The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual equipment or subsystem specification, when subjected to the levels and lightning transients specified in Table CS117-1 and supplemented by the waveform and timing definitions shown on Figures CS117-1 through CS117-8.
- In the event that there is platform lightning transient data available, this data may be used to tailor the requirements with different selected levels or waveforms, pending approval by the procuring activity.

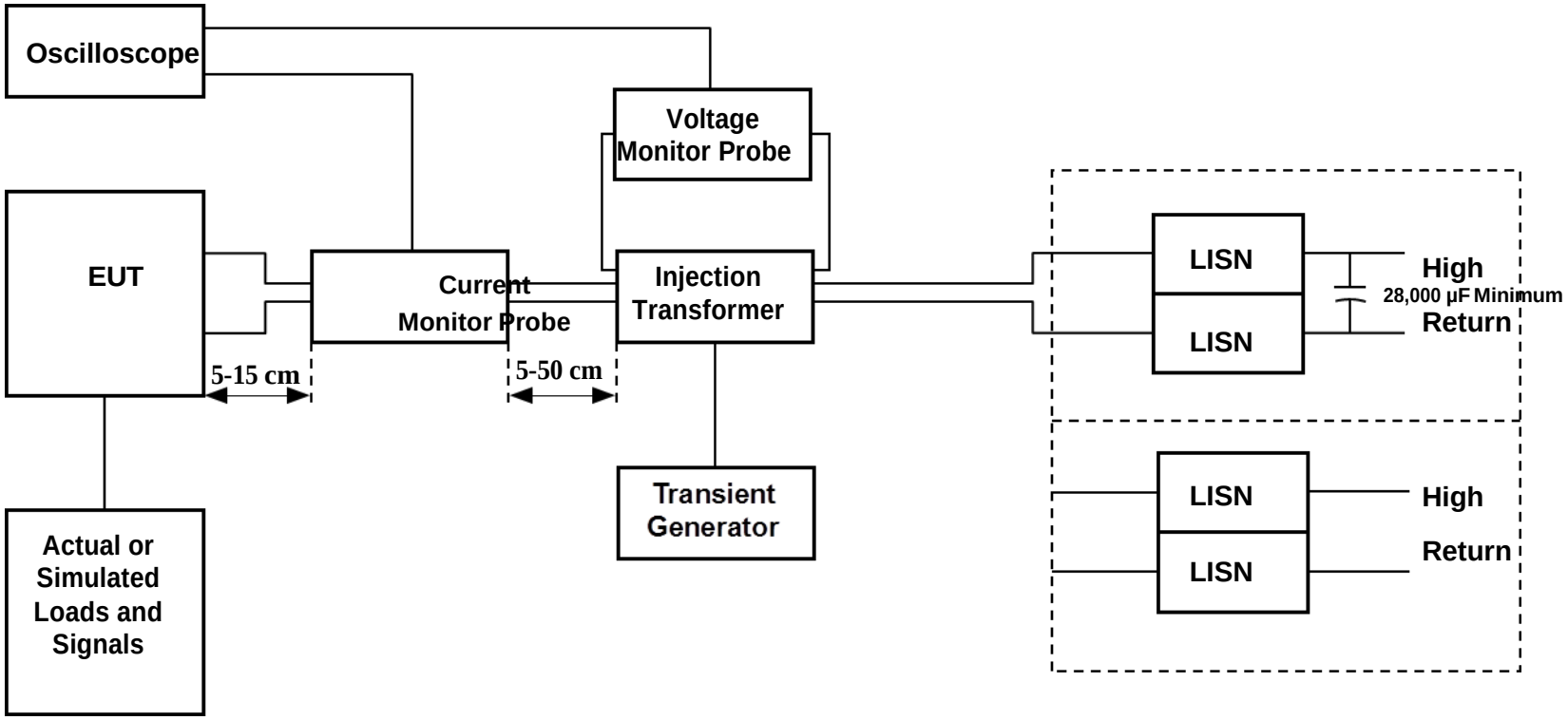
MIL STD 461 CS117

- Single stroke same as DO-160
- For the Multiple Stroke test, at the generator setting established in 5.15.3.4c(2), apply a minimum of ten multiple stroke applications while monitoring the operation of the EUT. The maximum time between application of each Multiple Stroke transient shall be no greater than 5 minutes.
- (4) For the Multiple Burst test, at the generator setting established in 5.15.3.4c(2), apply a multiple burst application every 3 seconds (3 seconds between the start of each set of three bursts) continuously for at least 5 minutes.
- Reverse the transient generator polarity and repeat

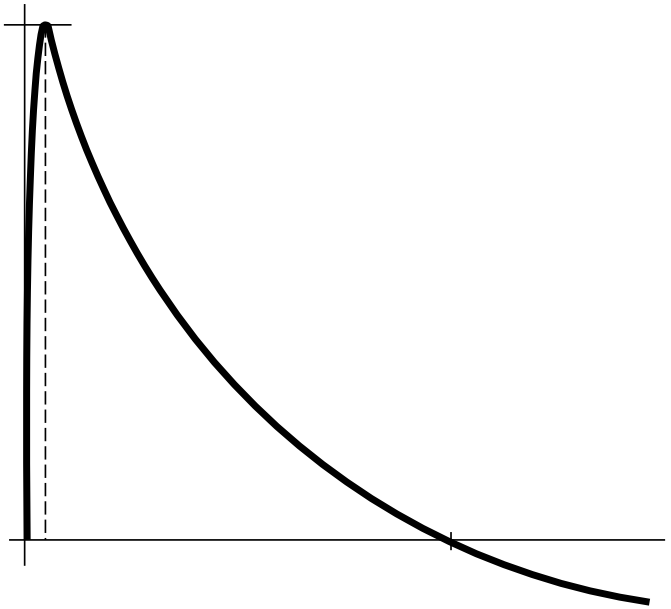
MIL STD 461 CS117

- Repeat on each cable bundle interfacing with each electrical connector on the EUT.
- For power cables, perform on complete power cables (high sides and returns) and on the power cables with the power returns and chassis grounds (green wires) excluded from the cable bundle.
- For connectors which include both interconnecting leads and power, perform
  - on the entire bundle
  - on the power leads (including returns and grounds) grouped separately
  - and on the power leads grouped with the returns and grounds removed

MIL STD 461 Cable Bundle Test for bundles with Power leads and return removed



MIL STD 461 CS117
Modified Waveform 2



Peak

T1 = 340 nanoseconds maximum
T2 = 6.4 microseconds ± 20%

0 **t**
T1 **T2**

FIGURE CS117-2. Voltage Waveform 2.

MIL STD 461 CS117

- No Waveform 5B!
- Waveforms 1, 3, 4, 5A and 6 the same

Q & A

Questions