DO-160 Display Qualification

Mechanical and Special Environments

CHAPTER 4

In this chapter

Shock and vibration levels from DO-160G

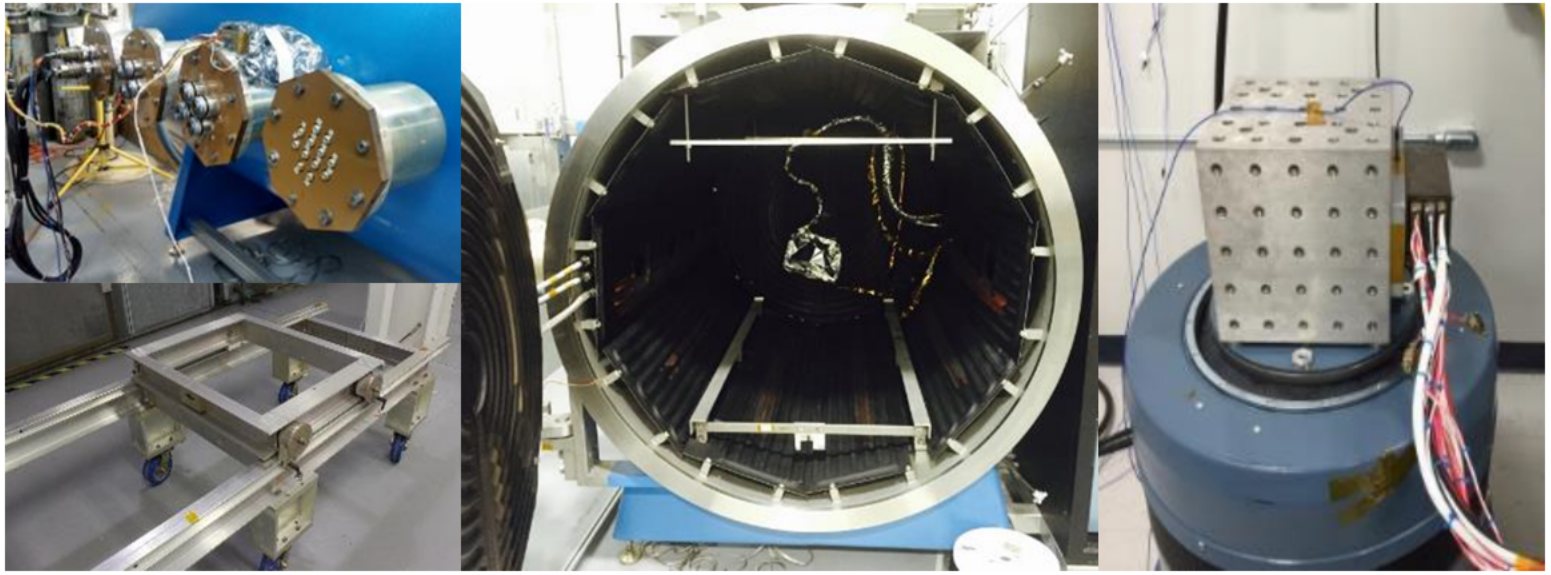
Resonance, damping and rotor harmonics

Display monitoring and special environments



Diggy Breiling
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ASQ · American Society for Quality
Current: CMDA
Previously held: CSSBB, CMQ/OE
ASCM / APICS: CPIM, CSCP
Association for Supply Chain Management

Shock, vibration and the load path



Fixture, fasteners and harness support matter

Operational function and crash retention differ

Dynamic imagery reveals intermittent faults

NASA Goddard Space Flight Center / Engineering and Technology Directorate; NASA imagery; generally not subject to US copyright

Fixed-wing and helicopter vibration



Terry Whalebone; CC BY 2.0

Aircraft type, zone and method define coverage

Rotor frequencies require an identified basis

A larger overall g value does not prove equivalence

Vibration and shock quantities

Exposure	Frequency or time	Severity quantity
Sine vibration	Frequency in Hz	g peak or displacement
Random vibration	Frequency band in Hz	PSD g^2/Hz and g RMS
Mechanical shock	Pulse duration in ms	Peak g and pulse shape

Acceleration PSD describes mean-square acceleration per hertz

Source and scope in narration and reading. Selected DO-160G data / FPD.DEV teaching examples.

Sine motion: frequency changes travel

At 1 g peak	Peak displacement	Peak-to-peak travel
10 Hz	2.484 mm	4.968 mm
100 Hz	0.02484 mm	0.04968 mm
Relationship	a peak = $(2\pi f)^2$ x peak	Sine RMS = peak / √2

Same 1 g peak input, very different displacement

Source and scope in narration and reading. Selected DO-160G data / FPD.DEV teaching examples.

Random vibration: PSD and g RMS

Illustrative input	Calculation	Result
PSD and bandwidth	0.010 × (500 − 20)	4.80 g^2
Overall acceleration	√4.80	2.19 g RMS
PSD doubled	√(2 × 4.80)	3.10 g RMS

g RMS = square root of the area under the acceleration PSD

Source and scope in narration and reading. Selected DO-160G data / FPD.DEV teaching examples.

DO-160G random curve B

Frequency (Hz)	Acceleration PSD (g^2/Hz)
10	0.012
40	0.012
100	0.002
500	0.002
2,000	0.00013

Selected Figure 8-1 data: 10–2,000 Hz, listed 1.48 g RMS

Source and scope in narration and reading. Selected DO-160G data / FPD.DEV teaching examples.

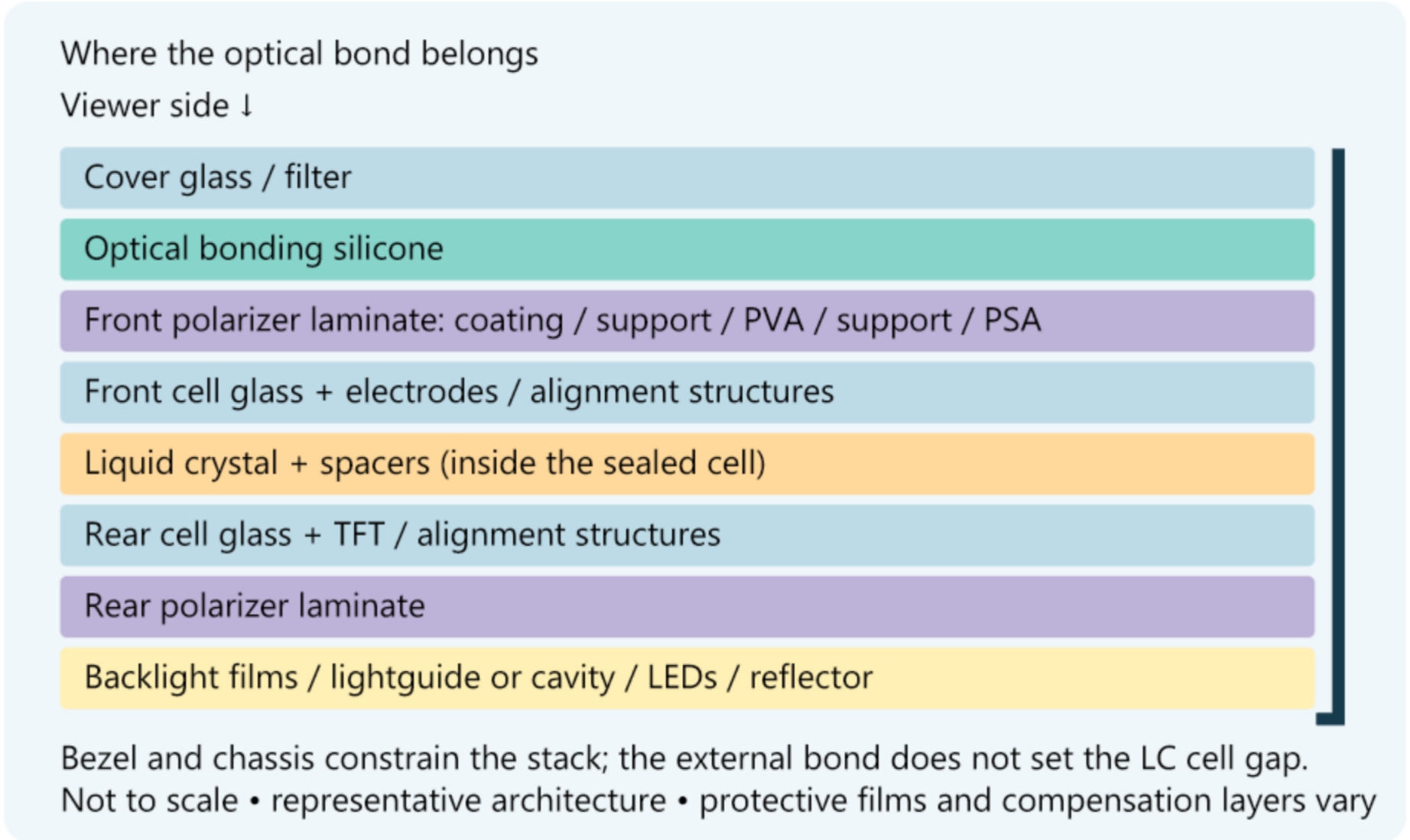
Resonance scans and random exposure

Step	Input and duration	Equipment state
Initial sine scan	0.5 g peak, 10–2,000 Hz	Not operating
Random performance	Selected PSD, ≥1 h per axis	Operating
Final sine scan	Repeat initial scan	Compare resonances
All three axes	Scan rate ≤1 octave/min	Record response

Example scope: §8.5.2 standard random test, fixed-wing aircraft

Source and scope in narration and reading. Selected DO-160G data / FPD.DEV teaching examples.

LCD cell gap and transient contrast



FPD.DEV Optical Bonding course. Cell deformation can change contrast or cause flashes.

Mounting for viewability and survival

01 Support the module without twisting or point loading

02 Control gasket compression and cable forces

03 Allow thermal movement while retaining the assembly

Isolation depends on the complete assembly

01 Isolation can reduce harmful transmitted motion

02 Resonance can amplify the display response

03 Verify motion, image quality and retention together

Vibration fixture and installation

01 The fixture transmits the commanded input

02 Mount, fasteners and cable support affect response

03 Record control and response sensor positions

04 Justify any departure from the installed boundary

Resonance and isolator trade-offs

01 Excitation near a natural frequency can amplify motion

02 Isolation depends on frequency and damping

03 Soft mounts increase displacement and clearance needs

04 Temperature and ageing can change mount behaviour

Natural frequencies of a display

01 Simple model: $f_n = (1 / 2\pi) \sqrt{(k / m)}$

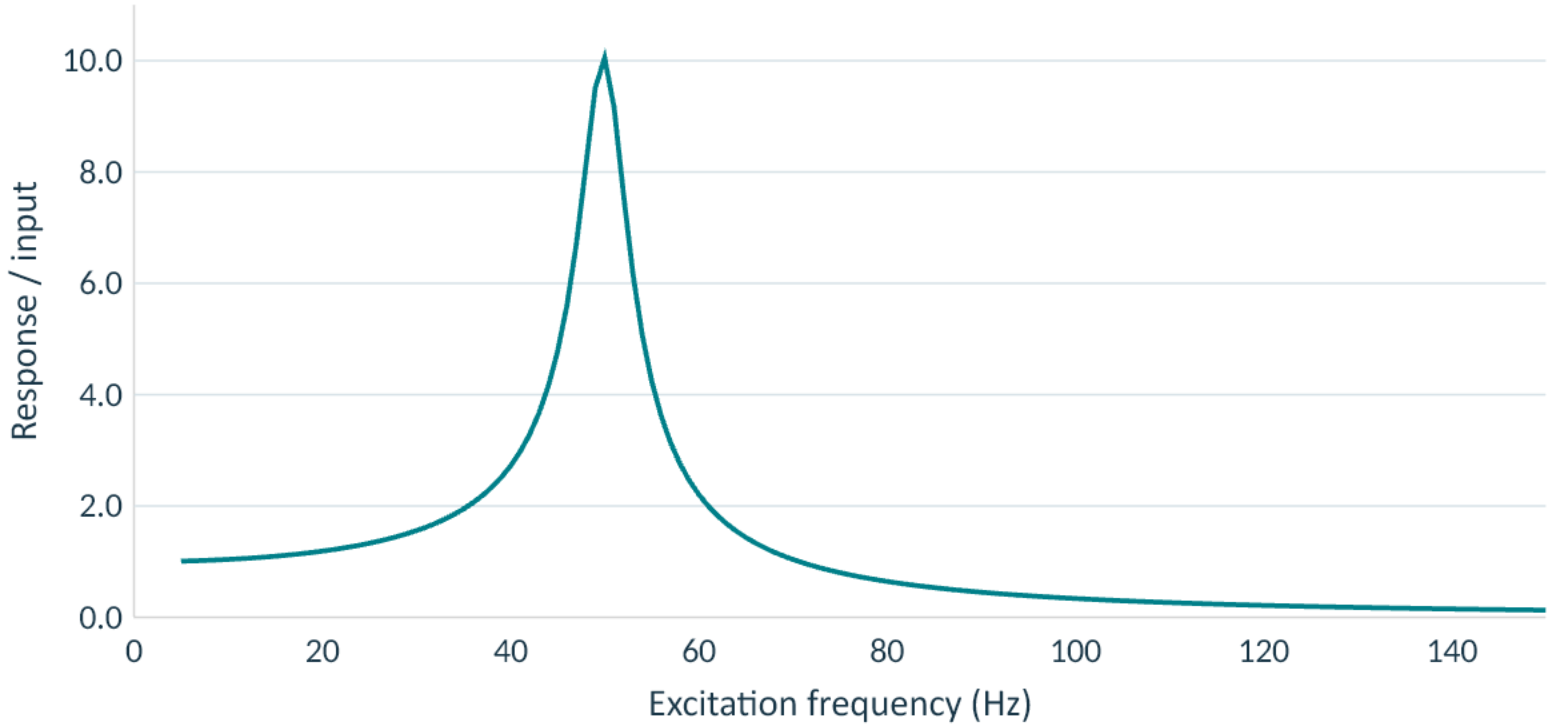
02 Higher stiffness raises the natural frequency

03 More supported mass lowers it

04 Real assemblies have several modes and shapes

Source and scope in narration and reading. Selected DO-160G data / FPD.DEV teaching examples.

Resonance: input and response



Illustrative fn = 50 Hz

5% damping: about 10× at fn

Play to compare input and response

Animated explanation in the course player. Analytical model with stated assumptions.

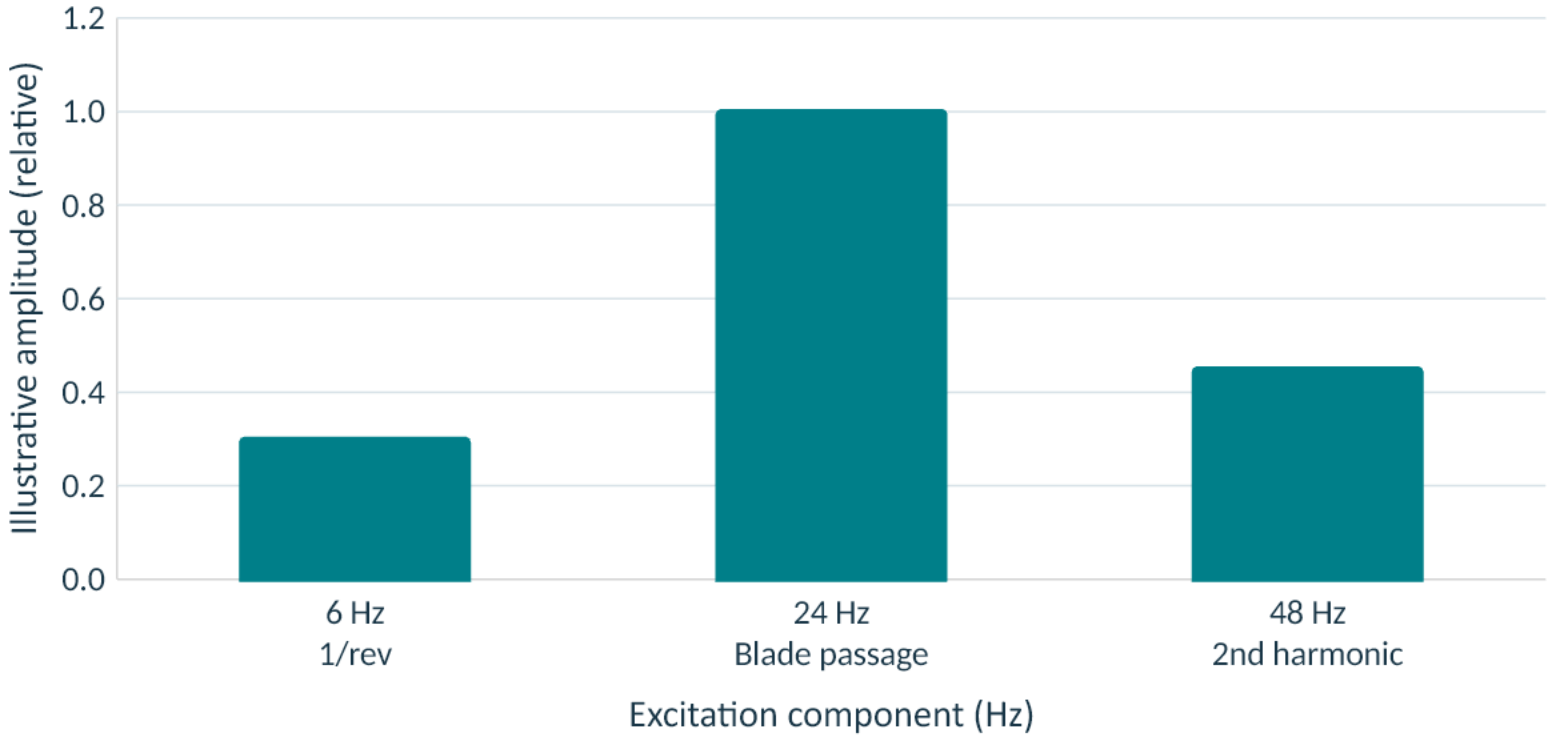
Damping limits resonance

Damping ratio	Response / input at fn	Response to 0.5 g peak
5%	10.05	5.02 g peak
10%	5.10	2.55 g peak
20%	2.69	1.35 g peak

Linear base-excitation model, at fn = 50 Hz

Source and scope in narration and reading. Selected DO-160G data / FPD.DEV teaching examples.

Harmonics and structural modes



360 rpm = 6 revolutions/s

Four blades: 24 Hz blade passage

Second blade-passage harmonic: 48 Hz

Animated explanation in the course player. Analytical model with stated assumptions.

Helicopter instrument-panel tones

Zone 2 / G tone	DO-160G relationship	360 rpm, 4 blades
f1	NM × FM	24 Hz
f2	2 × NM × FM	48 Hz
f3 and f4	No entries for Zone 2	Other zones differ

Table 8-2a excerpt: Zone 2, curve G

Source and scope in narration and reading. Selected DO-160G data / FPD.DEV teaching examples.

Helicopter curve G acceleration

Tone	Performance (g peak)	Endurance (g peak)
24 Hz	0.04 × 24 = 0.96	2.5
48 Hz	1.6	2.5
External-airflow case	Multiply sine levels by 1.5	When note 2 applies

Selected Table 8-2b values applied to the 24 Hz / 48 Hz example

Source and scope in narration and reading. Selected DO-160G data / FPD.DEV teaching examples.

Sine-on-random: two severity measures

Random background	Performance	Endurance
W0 (g^2/Hz)	0.010	0.020
Listed random g RMS	2.75	3.89
Add sine components	Use each peak² / 2	Then sum mean squares

Table 8-2b and Figure 8-6: background and discrete tones

Source and scope in narration and reading. Selected DO-160G data / FPD.DEV teaching examples.

Image stability during vibration

01 Use moving and stationary reference patterns

02 Capture brief flashes, dropouts and connector events

03 Separate optical effects from camera artefacts

04 Correlate the image with mechanical measurements

Shock survival and retained function

01 Operating shock and crash safety have different aims

02 Record axes, mounting and specimen state

03 Inspect load paths and retained attachments

04 Apply the acceptance criteria for the selected test

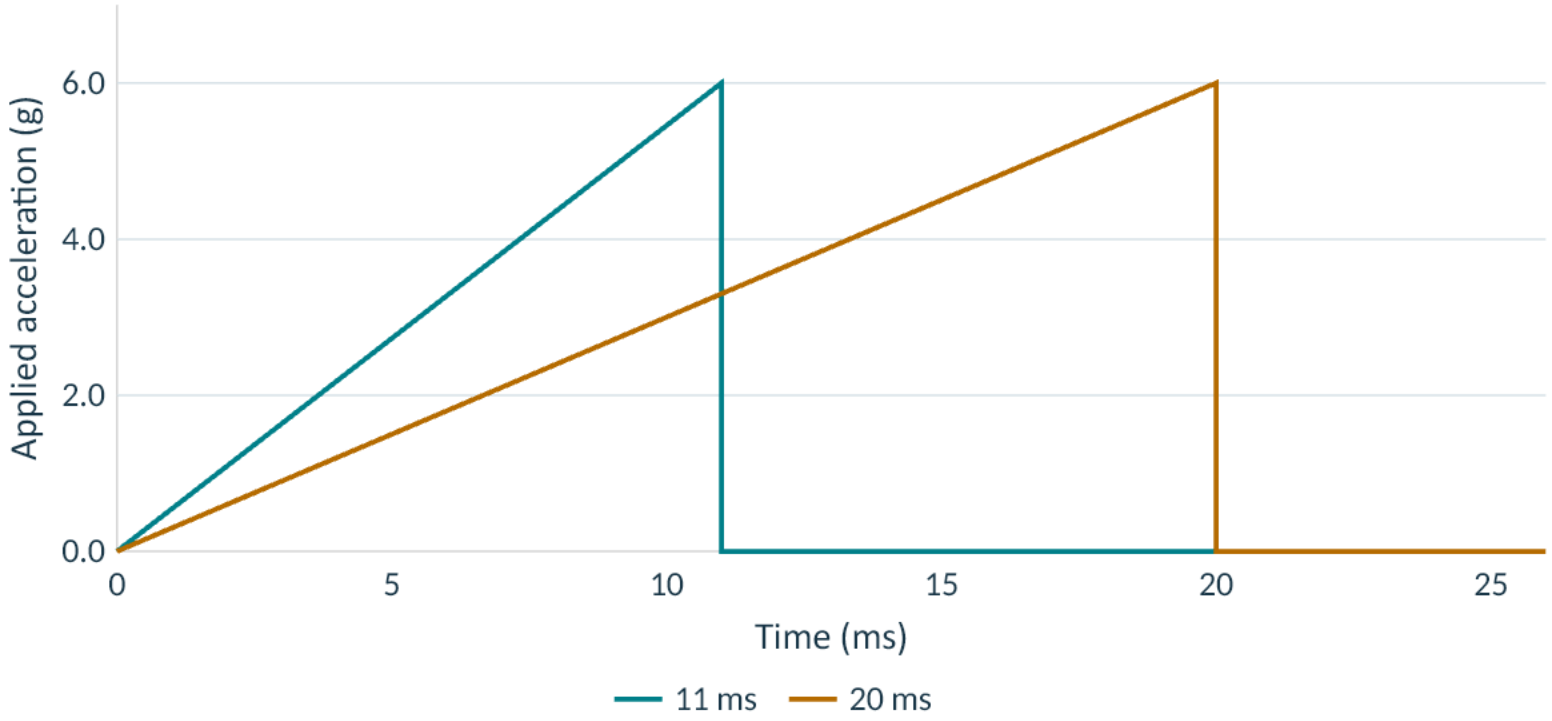
DO-160G shock pulse examples

Test example	Peak and nominal duration	Count / scope
Operational, standard	6 g, 11 ms	3 per orientation
Operational, low frequency	6 g, 20 ms	3 per orientation
Crash impulse	20 g, applicable 11 / 20 ms	1 per orientation
Crash sustained	Table 7-1 loads	≥3 s per load direction

Terminal sawtooth pulses; category and procedure determine applicability

Source and scope in narration and reading. Selected DO-160G data / FPD.DEV teaching examples.

Shock duration and ringing



A shock has a broad frequency spectrum

11 ms and 20 ms are durations

Play to compare ideal 6 g pulses

Animated explanation in the course player. Analytical model with stated assumptions.

Crash sustained loads: one table row

Aircraft load direction	Minimum sustained acceleration
Up	3 g
Down	6 g
Forward	9 g
Aft	1.5 g
Left and right	4 g each

Table 7-1 excerpt: fixed-wing transport, known fixed orientation (F)

Source and scope in narration and reading. Selected DO-160G data / FPD.DEV teaching examples.

Monitoring the display response

01 Measure fixture input and selected structural responses

02 Synchronize acceleration, image and interface logs

03 Check glass, bond edges, boards and connectors

04 Compare modes before and after the exposure

Source and scope in narration and reading. Selected DO-160G data / FPD.DEV teaching examples.

Special environments and material scope

01 Explosion proofness: ignition in a flammable atmosphere

02 Icing: allocated freezing-moisture exposure

03 Fire: applicable category and installation requirements

Make the applicability decision reviewable

01 Identify the installation exposure and requirement

02 Match material, thickness and assembly to evidence

03 Record the rationale, owner and unresolved inputs

Special environments: a scope record

Subject	Installation question	Record
Magnetic effect	Compass proximity?	Separation basis
Icing / explosion	Relevant exposure?	Applicability rationale
Fire / flammability	Which requirement?	Material / equipment scope

A reasoned applicability decision for each section

Enhancements create coupled trade-offs

01 Brighter backlights add power and heat

02 EMI layers can reduce optical transmission

03 Heaters affect power, optics and touch

04 Recheck the complete enhanced assembly



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The Future of Display and Systems Development

Next chapter

Power and Electrical Transients

I'm Diggy Breiling. Thank you for joining me.

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