Understanding Ruggedness of an Electronic Product with Respect to Drop

Overview

During the lifetime of an electronic product, it is likely that at some point it will be dropped. The total cost of ownership for the end user of the product depends upon how the product endures that drop. This white paper examines the ruggedness, or resistance to damage, of electronic products when dropped.

Beyond that first drop, most products are dropped on multiple occasions. The intensity of the drop can vary from extreme—occurring less frequently—to the more commonly occurring lower-intensity drop, referred to as a “tumble.”

Since no established group of standards that electronic devices are tested to withstand exists today, it is important for companies to understand the standards that can be applied, and the major factors that determine the ruggedness of an electronic product.

Equating the methods used in specifying resistance to damage to a customer’s use cases is critical in evaluating if the rating or test method is a valid measurement or guide to how the product will survive with actual use.

When evaluating an electronic product’s ruggedness when dropped, it is important to understand:

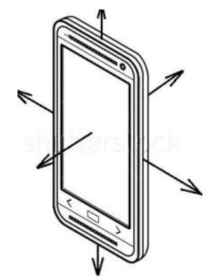
- The various standards of drop testing, along with their limitations.
- How the surface to which the product is dropped can greatly affect the cumulative damage a product may sustain.
- For the frequent low-level drops that a product may sustain, how the product may be tested to ensure a level of resistance to damage from tumbling.

What is Drop Testing?

Drop testing evaluates a product’s ability to withstand being dropped. Since accidental drops are likely to occur during a product’s lifetime, it is important that a product be designed to withstand a minimum defined number of these impacts. (Note that this does not mean that devices are designed to be dropped intentionally.)

Prior to testing, the number of drops, height of the drops, and surface to which the product is dropped must be specified.

- During the test, a product is dropped in a “free fall” manner a set number of times, from a fixed height, to a flat surface. (Objects are dropped from a stationary position and are not thrown or directed.)



- The test unit is placed in a specified orientation (for example, display down, display up, on its side, etc.) for each drop.
- After each drop, the unit is examined for damage. Units exhibiting a major loss in functionality, such as problems with powering on, capturing data, and allowing data entry, after drop testing do not pass the test.
- Several factors increase the severity level of testing, including increasing the required number of drops, height above the surface, the hardness of the drop surface, and decreasing the temperature of the unit during a drop (as product becomes more rigid with respect to impact).

What are the Limitations of Drop Testing?

While drop testing validates that a device design can withstand a limited number of impacts of a specific intensity, it cannot ensure that a device will survive all drop situations.

Several limitations to drop testing include:

- Drops or impacts that exceed product specification limits, which may cause the product to fail physically or functionally. For example:
  - Throwing or dropping the device from a higher height than indicated in the product specifications may result in higher impact forces and cause failures.
  - Dropping the device to a surface that is harder than the specified test surface generally increases the severity of the impact.
- With each successive drop, the unit becomes more susceptible to physical and/or functional failure, which is referred to as *cumulative damage*. In this situation, the product becomes more likely to experience physical and/or functional damage as a result of the next drop. Products that are repeatedly dropped will likely experience physical and/or functional damage faster than those that experience only occasional drops.
- Environmental factors, such as temperature and chemical exposure, can also degrade a product's ability to survive a drop.
- It is important to avoid usage beyond the product specifications to ensure that the device has a long working lifetime.

What are the Drop Standards?

Various drop standards or drop specification references are often used when testing devices. These include Zebra® internal drop standards, U.S. Military Standard (MIL-STD), and competitive drop standards/specification references.

ZEBRA INTERNAL DROP TESTING

Zebra's internal drop testing standards require that:

- A unit is dropped 36 times—6 times per side.
- The test is repeated on 3 different units across the device's operating temperature range (at high, low, and room temperature).
- Test units are operational (powered on) when dropped.
- Drop heights range from 4 to 8 feet.

If the device powers off or reboots and data is lost during testing, the device is deemed to have failed the drop test.

U.S. MILITARY STANDARD DROP TESTING

U.S. Military Standard, MIL-STD-810G, defines a process by which devices are dropped 26 times, on all faces (sides), corners, and edges.

- Distributed over 5 test units, the unit test includes 8 corner drops, 12 edge drops, and 6 face drops.
- Units are dropped at test method-defined temperatures.
- Units are non-operational (powered off) for the drop test.

Different Options within MIL-STD Drop Testing and Their Effects on Products

MIL-STD provides options for passing the drop test. When a product is specified to meet MIL-STD-810G drop standards, it is important to compare the product specifications directly to the many options of the military standard to see the exact details of the drop tests, and therefore better understand the severity of the testing; and consequently, the true ruggedness of the device.

Various options within MIL-STD drop testing affect the severity of a test, including:

- Height of Drop—devices can be dropped from varying heights within MIL-STD specifications. Higher drops produce greater impacts.

- Surface Material—surface material to which units are dropped, such as plywood over concrete, vinyl tile over concrete, concrete, or steel. Harder and rougher surfaces produce higher impacts during drop tests. See "Drop Surface" sections for details.
- Temperature—drop tests can be performed at temperatures above the operating temperature of the device or just at room temperature, depending on the military specification option picked. Drop tests occurring over a wider temperature range are more difficult to pass because components are more prone to physical failures at temperature extremes (such as cracking at cold temperatures and swelling at hot temperatures).

COMPETITIVE DROP STANDARDS OR SPECIFICATION REFERENCES

- May specify more than just the drop height:
  - The drop surface, number of drops, and temperature range may be included or excluded from the specifications.
  - The temperature range of drop tests can also be omitted.
- Factors typically not defined include:
  - Number of units dropped to pass the test.
  - Definition of the unit's power state (on/off).

Drop Standards Summary

- Not all drop specifications are the same.
- When assessing drop performance, one should look at these factors:
  - What drop standards (for example, Zebra internal or MIL-STD810G) or specification references are used
  - Drop height
  - Drop surface
  - Drops over a range of temperatures
  - Number of drops, if listed
  - Whether a tumble specification is also defined

What Factors Affect the Severity of the Drop Testing?

Product specifications identify the drop testing severity levels required for the product to pass the drop testing. These specifications include drop surface hardness and roughness.

DROP SURFACE HARDNESS

The drop surface material hardness influences the severity of drop testing.

- Harder Surfaces—generally increase the severity of the test because they absorb less energy than softer surfaces during an impact. Some of a product's kinetic energy (energy from its motion) is transferred from the product to the surface it impacts.
- Softer Surfaces—generally decrease the severity of the test because they absorb more energy than harder surfaces by increasing the impact time. Since the change in momentum to bring a falling object to a stop is fixed, impact force must decrease as impact time increases. Therefore, softer surface materials have lower impact forces than harder surface materials.

For example, several different drop surfaces, in order of increasing hardness, include:

- Plywood
- Vinyl tile placed over concrete
- Concrete
- Steel

A drop test to vinyl tile is less likely to see failures than a drop test to concrete since vinyl tile is a softer material than concrete.

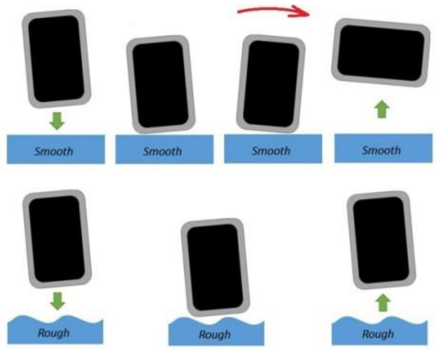
In contrast, while concrete is not as hard as steel, its rough surface leads to several localized high impacts, and thus a more severe drop. See the "Drop Surface Roughness" section for details.

Note: All surfaces are thick enough to resist any bending during impacts. MIL-STD requires a surface thickness of 2 inches.

DROP SURFACE ROUGHNESS

The roughness of a surface also influences the severity of drop testing.

- Smoother Surfaces—have fewer bumps (localized impacts) on them and are less likely to cause damage to the test unit.
- Rougher Surfaces—cause higher impacts during drop testing because:
  - The bumps on the surface act like point contacts and concentrate loads on the test unit during drops
  - The rough surface tends to grip into the test subject's housing, thus preventing sliding of the unit that would otherwise release impact energy through rotational motion.



For example, drops to concrete are generally more severe than drops to steel for a given height because concrete is much rougher than steel. As a result, drops to concrete are more likely to produce failures, such as broken displays and product scarring, than are drops to steel.

However, specification sheets can specify a polished concrete drop surface, which is less likely to grip the product, generally leaving less scarring and resulting in more energy being transferred to rotational motion rather than having to be absorbed by the product.

Accelerometer Testing

The following table presents an example of test data for a specific case, which changes only the drop surface and height.

The following figures illustrate the acceleration data above when the device is dropped to concrete only (single surface).

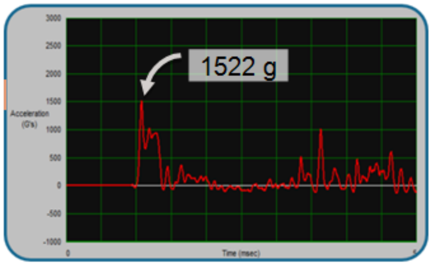


Figure 1: 4 ft. Drop to Concrete

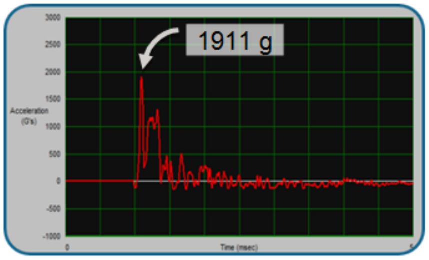


Figure 2: 5 ft. Drop to Concrete

Data from dropping the same device to various surfaces and heights reflects the expected trends in acceleration.

For a single surface material, acceleration upon impact increases with increasing drop height because an object dropped at a higher height has more time to gain speed before hitting the ground. As a result, it takes a greater impact acceleration to slow down and stop the object's motion.

Drop Surface	Max. Acceleration at 4 ft. when Dropped	Max. Acceleration at 5 ft. when Dropped
Concrete	1522 g	1911 g
Steel	1346 g	1619 g

Drop Surfaces Summary

- Not all drop surfaces have the same effect on products
- Determine the drop standards (such as Zebra Internal or MIL-STD810G) or specification references that can be used
- When assessing drop performance, one should look at different drop surfaces. For example:
  - Concrete
  - Polished concrete
  - Steel
  - 2 inches plywood over concrete
  - Vinyl tile over concrete

Understanding Tumble Testing

Tumble testing is intended to simulate the rough handling typical of enterprise mobile and other handheld mobile computing or scanning devices.

- The device is placed inside the tumbler "barrel" and the barrel is set to rotate automatically at a predetermined rate. While rotating, the device "tumbles" from one end to the other, simulating a fall from a lower height during use (intentional or unintentional).
- There is also an additional element of abrasion as the product scrapes against the different surfaces in the tumbler. Typical real-world scenarios would be devices tossed into bins, pushed across a desk, or knocked off a box onto the bed of a truck.
- The tumbler would be set to turn off after a number of cycles determined to approximate the service life, with a safety factor added.

TEST EQUIPMENT

The tumble tester is constructed of steel, plastic, and wood to a shape in accordance with international testing standards. The shape of the "barrel" is designed to reproduce a random fall from a set height (see Figure 3).

The toe-shaped ends keep the product from sliding slowly until the barrel is nearly upright. Without them, the product would begin to slip as the barrel rotates just past horizontal, which would only gently propel the product to the opposite end, with little impact.

On its way down, the product will slide and roll over steel, plastic, and rubber in a random fashion, finally landing on steel backed with wood. Repeating this several hundred or thousand times ensures virtually every surface, corner, and protrusion on the device is impacted and scraped against with a variety of materials.

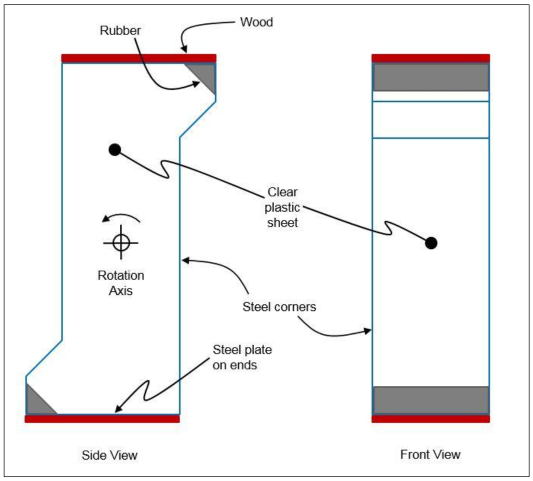


Figure 3: Tumble Tester

TUMBLE VS. DROP TESTING

Tumble testing is designed not to replace, but to complement drop testing. While drop tests subject the product to maximum loads expected when devices are accidentally dropped during use, tumble testing applies many repeated bumps of a lesser force to continually stress many aspects of the design, such as screws, seals, flexible rubber parts, and electrical connections, among others.