Thunder® FAQs

1. What is the frequency range over which THUNDER devices can operate?

THUNDER Actuators & Sensors can be designed and manufactured to operate effectively from DC up into the kilohertz range.

At low frequencies, i.e., below resonant frequency, THUNDER devices are capable of providing exceptionally high displacements and forces. Operation at resonance is not recommended unless there is significant damping in the system, because the device vibrates so powerfully that it could be damaged. At frequencies higher than resonance, performance may not be as good as that below resonance, but significant displacement as well as power output can be achieved.

At ultrasonic frequencies, i.e., above 20 kilohertz, THUNDER devices can be very effective, operating in either the CW or pulsed mode. Compared to conventional devices, significantly higher power output is possible without damage to the piezoceramic wafer, thanks to our novel manufacturing process. The device is also very effective as an ultrasonic receiver.

It should also be noted that the metal coatings on THUNDER devices help prevent cavitation damage to the wave-generating surfaces.

2. What is required to power THUNDER devices?

Because of the exceptional capabilities of THUNDER devices, a high voltage power supply is required to achieve peak performance.

Face International now offers two special THUNDER drivers, the TD-1and TD-2, which integrates the best features of such a high voltage power supply and a variable waveform generator. These compact and economical units enable various devices to be vigorously exercised.

Several commercial laboratory power supplies can also be used to power Face International THUNDER devices. We’re happy to offer technical assistance in designing dedicated-purpose power sources for your particular application.

3. Is it necessary to operate THUNDER devices at high voltages?

No. Any THUNDER device can be operated, and will provide performance advantages, at any voltage up to the specified limit. However, to achieve peak performance levels, high voltage operation is required.

THUNDER is designed and constructed to be capable of generating very large displacements repeatedly and safely. Conventional piezoelectric bending elements cannot achieve this high degree of motion because they would break when subjected to voltages that might make them move so much. The fact that THUNDER devices operate at voltages higher than other typical actuators is a measure of the benefits this technology can offer, not a difficulty to be overcome.

At any selected voltage, THUNDER shows significantly improved performance. Typical comparisons with comparable devices show a 250% improved displacement and a 550% greater maximum developed force.

4. How does a THUNDER device respond to a DC voltage?

A THUNDER device will become flatter if a positive DC voltage is applied to the top surface and will become more curved with a negative voltage.

Displacement is proportional to the amount of voltage. The position achieved by an applied voltage will be maintained as long as there is current flow. If current flow is stopped, the device will return to its neutral or "rest" position.

Under all circumstances, care must be taken to avoid exceeding maximum allowable voltage levels at any time in the cycle. The maximum voltage specification refers to any instantaneous level.

5. What happens when you exceed the maximum allowable input voltage?

Driving a THUNDER device above the maximum allowable input voltage can result in depoling or destruction of the device.

If an excessively high positive voltage (with respect to the top surface of the device) is applied, the device can arc and may be destroyed by shorting and/or burning out. If the voltage is excessively negative, the device will lose strength and amplitude because of depoling. Even greater negative voltages will result in arcing.

If the device is depoled, repoling can be accomplished by applying a high positive voltage. This procedure, however, must be performed by a trained, experienced operator. In most cases, it would be advisable to replace a device that has been depoled.

6. Can displacement be precisely controlled?

Yes. Given the current state of THUNDER technology, repeatable positioning can be achieved by using some type of feedback control. You can compensate for changes in load, applied voltage or temperature with any of a number of available position and proximity sensors.

There are several aspects of repeatability and precision that need to be considered. A single THUNDER device used for extended periods may show an early change in the relationship among displacement, applied voltage and force. However, after several hours of operation, the device will stabilize, and performance should remain stable for extended periods of use, continuous or intermittent. If the device is depoled by applying a voltage beyond the specified limit, or if it is operated at temperatures above 200° C (392° F), performance will be degraded and displacement will change.

At a constant set of conditions (voltage, frequency, load, temperature, etc.), there will be variations in performance among same-model THUNDER devices. Our current target for uniformity among same-model devices is ±10%, but the majority performs more uniformly than this. We continue to work on refining this parameter.

7. Is displacement unidirectional or bi-directional?

When a bipolar input voltage is applied to a THUNDER device, the mechanical motion is bi-directional, meaning the device moves to both sides of the rest position. Input biasing can adjust the motion from being symmetric around the rest position to being significantly offset from the rest position at all points in the cycle.

For example, if the input voltage range is 70%-90% of maximum allowable voltage, the device position will be correspondingly offset and will oscillate between positions close to the point of maximum displacement. With a symmetric input signal, there is a degree of hysteresis in the output -- typically 10%-15% at high voltages and decreases with decreasing input signal strength.

8. Is a THUNDER device as fragile and easily broken as a conventional piezoceramic element?

No. During the manufacturing process, metallic layers are intimately bonded to the top and bottom of the thin piezoceramic element at the heart of a THUNDER device.

This high-temperature fabrication process induces a compressive pre-stress condition in the composite structure that substantially strengthens and protects the device. With its virtual "suit of armor", the device is ruggedized and hardened against breaking, cracking or chipping due to dropping, hitting or being stepped on.

However, a THUNDER device can be damaged by excessive twisting, bending at a sharp radius or bending a device back through its neutral axis.

9. Can THUNDER devices operate in harsh chemical environments?

Yes. Common organic solvents will not damage THUNDER devices.

THUNDER devices are not affected by common solvents such as acetone, xylene, chlorinated solvents or alcohols. There are a few relatively exotic solvents than can destroy the device. Strong inorganic acids and bases can damage the metallic components of a THUNDER device, but special materials can be used when necessary to adapt the device to such hostile environments. We will gladly offer advice on such materials.

10. Can THUNDER devices operate at extreme temperatures?

Yes. However, performance can vary somewhat over the operating temperature range of -40° C to +200° C.

THUNDER devices can be temperature-compensated to minimize the potential effects of extreme temperatures.

11. How do you mount THUNDER devices?

When evaluating mounting techniques, the most important consideration is to allow a THUNDER device to move freely, except where the load is applied. Rectangular devices used in a cantilevered mode should generally be clamped on a metal tab as close to the laminated (ceramic) area as possible. Circular devices can be supported on the outer dia-meter, concave toward the support; or they can be used "upside-down", with the apex stationary and the load supported by the outer skirt.

The proper mounting of a THUNDER device is very important in order to achieve peak performance. Certain considerations need always be kept in mind. For instance, if the load is supported on the apex of a rectangular device, do not constrain both of the support ends simultaneously. In other words, do not prevent the ends from moving relative to each other by holding both in a rigid position. As the device flexes, the bases of the arch need to move alternately closer together and farther apart. Sliding friction should be as low as possible. Similarly, the base ends need to change the angle as the apex moves up and down. If either end is held at a fixed angle while the device tries to bend, reduced displacement will result.

For circular THUNDER devices, bending and friction restrictions are the same as described above. If the load is applied to the apex of a circular device, contact with the apex should be planar; use a flat plate to bear on the apex, not a linear or point load. The plane contact should extend outward so that the device does not form a reverse curvature (a central depressed region) outside the contact area. Using this method, significantly increased loads can be supported.

12. Can the tabs or skirts of a THUNDER device be safely cut or trimmed?

No. Cutting, trimming, abrading, bending or otherwise modifying tabs or skirts can easily damage or destroy the device.

Any rectangular THUNDER device can be supplied with single, dual or no metallic tabs. Similarly, any circular device can have a skirt of varying sizes.

13. What are key variables that affect THUNDER performance?

A device made with a thicker piezoceramic element will…

- generate more force
- generate less displacement
- perform at higher frequencies
- require more voltage to drive it
- use less current

Piezoceramics of similar thickness but different lengths and widths will…

- generate displacement that is nearly linear with length
- generate force that is directly proportional to width

Increasing the input voltage (as an actuator)…

- at relatively low voltages, will generate greater displacement and force, the increase being approximately linear with voltage

Input power…

- the power required to move a THUNDER device is proportional to the work being done by the device (work is force times displacement)

Input frequency…

- below the resonant frequency of the device, displacement and force are relatively constant with changes in frequency
- as drive frequency approaches resonance, force and displacement increase significantly
- as drive frequency increases above resonance, force and displacement decrease

Input displacement (sensor)…

- at relatively low displacement (h/ho or fractional displacement <0.6), increasing displacement results in an approximately linear increase in voltage and power

If multiple THUNDER devices are arranged together…

- in stacks like bowls, force is directly proportional to the number of elements in the stack; displacement does not change
- in a clamshell configuration, and clamshells are then stacked, displacement is directly proportional to the total number of THUNDER devices in the stack; force does not change.

14. How are electrical leads best attached to a THUNDER device?

Leads may be attached in various ways, such as by aluminum-based solder or conductive tape.

Because THUNDER devices can achieve extraordinarily large displacements, lead attachment can be something of a challenge. It can be accomplished by soldering leads to the top and bottom metallic surfaces, but attempting such attachment can be risky due to the fact that the heat required can compromise the integrity and performance of the composite device.

Should the soldering option be chosen, it may be helpful first to use pristine steel wool or other clean abrasive material to roughen the area where lead attachment is desired. Applying a drop of flux lets the soldering proceed quicker and easier. Be sure to hold the soldering iron on the connection only long enough to melt the solder; otherwise the high temperature could damage the aluminum superstrate as well as the piezoceramic. Because THUNDER devices move far more than typical piezo actuators, it's recommended that a drop of epoxy, glue, rubber or other flexible material be placed on the solder joint for strain relief.

Copper conductive tape may be used by applying it anywhere to the appropriate surfaces, but this technique is suitable only for initial testing and experimentation. One piece of this tape should be placed on the stainless steel substrate (bottom layer) and another piece on the aluminum superstrate (top layer). Be careful to strip away only enough of the paper backing to connect the tape securely to the THUNDER device. If too much of the backing is peeled away -- allowing the conductive portion of the tape to extend over the ceramic and stainless layers of the device -- a short could result.

15. How should a THUNDER device be attached or bonded to a surface such as a steel beam or similar structure?

Thanks to the extraordinary flexibility and adaptability of THUNDER devices, attachment to various rigid structures can be accomplished in many ways.

THUNDER's metallic bottom layer, which in standard device designs is stainless steel, allows the use of epoxy, "super glue", welding or soldering, among various approaches. Whichever attachment method is chosen, be sure not to heat the piezoceramic above 200° C at any time.

If you have a specific attachment or bonding question, feel free to contact Face International Corporation, and we will gladly work with you to find an answer.