

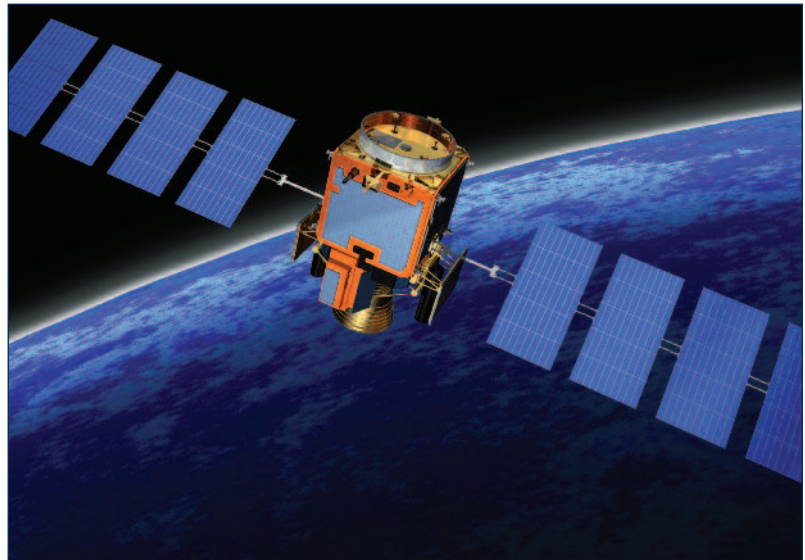


# Force Limited Vibration Testing System

For Easy and Accurate Measurement of the Input Force

## Highlights

- Minimizes Over-testing
- Reduces Risk of Damage to Critical Structures
- Measures Summed Forces
- Measures Force Differences (Moments)
- Simplifies and Expedites the Test Process
- Convenient and Easy to Implement



Due to the high cost, long development times, and uniqueness of sophisticated aerospace and other high-tech equipment, it has become imperative to implement techniques that ensure the safety of such items during vibration qualification testing.

Conventional control using acceleration has been shown to cause significant over-testing that may result in damage to the unit under test (UUT). In force limited vibration testing, the total input force to the UUT is measured and controlled, thereby limiting the "quasi-static" acceleration of the center-of-gravity and ensuring the integrity of the equipment.



260 & 261 Series



## Force Limited Vibration Testing System

The PCB® Force Limited Vibration Testing System meets most requirements for limiting the reaction force between the shaker and unit under test in random vibration testing. The use of piezoelectric, 3-component force sensors facilitates easy and accurate measurement of the input force. This force relates directly, using Newton's Second Law,  $F=ma$ , to the "quasi-static" acceleration of the structure's center-of-gravity. Since design loads for aerospace equipment are often given in terms of the "quasi-static" acceleration, the use of force sensors represents an ideal measurement approach for this application.

With force limited vibration testing, the force measurement signal is used in the vibration shaker's feedback control loop. This signal is compared to established force limits in the controller. At frequencies where the measured force exceeds the limit (at high Q resonances), the controller's output signal (i.e., the input signal to the shaker) is "notched". By reducing the input to the shaker at these frequencies, the reaction force between the test fixture and structure is maintained within specified limits.

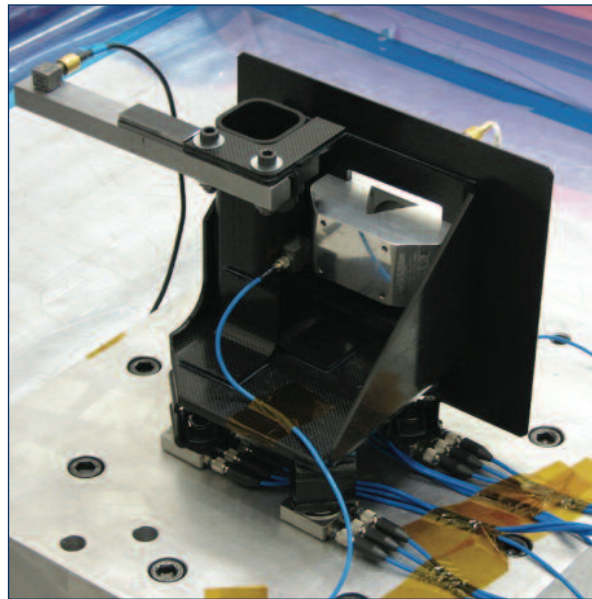
Accelerometers, typically mounted on the test fixture, are also used in the control loop. They serve to limit the shaker's excitation with respect to acceleration at frequencies other than resonances for which force limiting prevails. In order to accomplish this, the shaker control system must have "extremal control" capability. Extremal control is the ability to establish feedback control with

respect to the greater of several inputs, either force or acceleration, as a function of frequency. It is also desirable to have "dual control". Dual control is the ability to control both acceleration and force reference spectra.

The PCB® Force Limited Vibration Testing System contains all of the signal conditioning required to process force signals from piezoelectric, charge-output, or ICP® 3-



**Model 260A03**  
3-Component Force Sensor  
(10k lb Range)



**Force sensors can be used with low outgassing accelerometers in thermal vacuum chambers.**

component force sensors for shaker control. The system outputs one resultant (summation of forces) x-axis force signal, one resultant y-axis force signal, and a sum of the differences of pairs of z-axis signals. The x- and y-axis force signals are summed using a summation module. This eliminates the need for multiple charge amplifiers, keeping the system cost down. Each summed output is then routed through a signal conditioner to provide a low impedance voltage signal that is proportional to the resultant forces. The z-axis force

signals are first conditioned and then opposing pairs of z-axis signals are then subtracted and the differences summed using a computational signal conditioner. The resultant is a low impedance voltage output signal that is proportional to the moment about a selected axis.

Since the system is modular, it can be customized to handle most configurations and any number of inputs. It can also be provided with or without force sensors and cabling.



**Model 260A11**  
3-Component Force Sensor  
(1000 lb Range)



## 3-Component Quartz Force Rings

### Applications & Highlights

- Force Limited Vibration Testing
- Cutting Tool Forces
- Force Dynamometer
- Engine Mount Analysis
- Biomechanics
- Modal analysis
- ICP® & Charge Output

### 3-Component Quartz Force Rings

Model Number	260A01	260A02	260A03	260A11	260A12	260A13
Measurement Range (z axis)	1000 lb 4.45 kN	1000 lb 4.45 kN	10k lb 44.48 kN	1000 lb 4.45 kN	1000 lb 4.45 kN	10k lb 44.48 kN
Measurement Range (x or y axis)	500 lb 2.22 kN	1000 lb 4.45 kN	4000 lb 17.79 kN	500 lb 2.22 kN	1000 lb 4.45 kN	4000 lb 17.7 kN
Sensitivity (z axis)	2.5 mV/lb 0.56 mV/N	2.5 mV/lb 0.56 mV/N	0.25 mV/lb 0.06 mV/N	15 pC/lb 3.37 pC/N	32 pC/lb 7.19 pC/N	15 pC/lb 3.37 pC/N
Sensitivity (x or y axis)	10 mV/lb 2.25 mV/N	5 mV/lb 1.12 mV/N	1.25 mV/lb 0.28 mV/N	32 pC/lb 7.19 pC/N	15 pC/lb 3.37 pC/N	32 pC/lb 7.19 pC/N
Maximum Force (z axis)	1320 lb 5.87 kN	1320 lb 5.87 kN	11 klb 48.93 kN	1320 lb 5.87 kN	1320 lb 5.87 kN	11 klb 48.93 kN
Maximum Force (x or y axis)	660 lb 2.94 kN	1000 lb 4.45 kN	4400 lb 19.57 kN	660 lb 2.94 kN	1000 lb 4.45 kN	4400 lb 19.57 kN
Maximum Moment (z axis)	14 ft-lb 18.98 N-m	40 ft-lb 54.23 N-m	240 ft-lb 325.4 N-m	14 ft-lb 18.98 N-m	40 ft-lb 54.23 N-m	240 ft-lb 325.4 N-m
Maximum Moment (x or y axis)	13 ft-lb 17.63 N-m	70 ft-lb 94.91 N-m	325 ft-lb 440.7 N-m	13 ft-lb 17.63 N-m	70 ft-lb 94.91 N-m	325 ft-lb 440.7 N-m
Broadband Resolution (z axis)	0.006 lb-rms 0.027 N-rms	0.006 lb-rms 0.027 N-rms	0.05 lb-rms 0.222 N-rms	[1]	[1]	[1]
Broadband Resolution (x or y axis)	0.002 lb-rms 0.0089 N-rms	0.006 lb-rms 0.027 N-rms	0.01 lb-rms 0.04 N-rms	[1]	[1]	[1]

**Notes**  
[1] Resolution is dependent upon cable length and charge amplifier characteristics

## 3-Component Quartz Force Links

### Applications & Highlights

- Force Limited Vibration Testing
- Impact Testing
- Biomechanics
- Force Plates
- Vehicle Dynamics
- Cutting Tool Force Monitoring
- ICP® & Charge Output
- Easy Flange Mounting
- Fixed Preloaded Assembly
- English & Metric Mounting

### 3-Component Quartz Force Links

Model Number	261A01	261A02	261A03	261A11	261A12	261A13
Measurement Range (z axis)	1000 lb 4.45 kN	1000 lb 4.45 kN	10k lb 44.48 kN	1000 lb 4.45 kN	1000 lb 4.45 kN	10k lb 44.48 kN
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Sensitivity (z axis)	2.5 mV/lb 0.56 mV/N	2.5 mV/lb 0.56 mV/N	0.25 mV/lb 0.06 mV/N	15 pC/lb 3.37 pC/N	32 pC/lb 7.19 pC/N	15 pC/lb 3.37 pC/N
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**Notes**  
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## Signal Conditioning System Component Specifications

### Model 443B102 Dual-Mode Amplifier Module

Channels	1
Display (Menu Driven)	Backlit 2 x 16 character LCD
Voltage Gain (ICP® Sensor Mode)	x0.1 to x1000 (4-digit resolution)
Charge Gain (Charge Mode)	0.1 to 10 000 mV/pC (4-digit resolution)
Discharge Time Constant	0.18, 1.8, 10, 100, 1000, > 100k sec
Drift [1]	< 0.03 pC/sec
Broadband Noise (ICP® Sensor Mode) [2] (2 Hz to 22.4 kHz)	< 3 µV (< -110.5 dB)
Broadband Noise (Charge Mode) [3] (2 Hz to 22.4 kHz)	< 5 fC (< 0.005 pC)
Low Frequency Response (-10%)	2, 0.2, 0.03, 0.003, 0.0003 -0 Hz
High Frequency Response (-10%)	0.1, 1, 3, 10, 100, >200 kHz

### Model 070A15 Summing Block

Input	4-Channels of Charge Input
Output	1-Channel of Summed Charge Output

### Model 070M70 Charge Summation Node Module

Input	8-Channels of charge mode sensor signals
Summed Output (Charge Mode)	1-Channel (A + B + C + D + E + F + G + H)

### Model 070M69 Computational Signal Conditioner

Input	8-Channels of ICP® sensor or voltage signals
Computational Function	[(A-B) + (C-D) + (E-F) + (G-H)] x Gain
Excitation Voltage (for ICP® Sensors)	24 VDC
Excitation Current (Selectable)	0, 2, 4, 8, 12, 20 mA
Differenced Output	4-Channels: (A-B), (C-D), (E-F), (G-H)
Function Output	1-Channel
Gain	x0.1, x1, x10

### Model 070M90 12-Channel Summing Amplifier

Input	12-Channels of ICP® signals
Excitation Voltage (for ICP® Sensors)	24 VDC
Excitation Current	2 to 20 mA adjustable
Output	1-Channel
Gain	x0.1, x1, x10

### Notes:

- [1] Long discharge time constant mode. [2] Measured at gain of 1000 (60 dB), input referred.  
[3] Measured at gain of 10 V/pC (80 dB) with a 1 nF source capacitance, input referred.



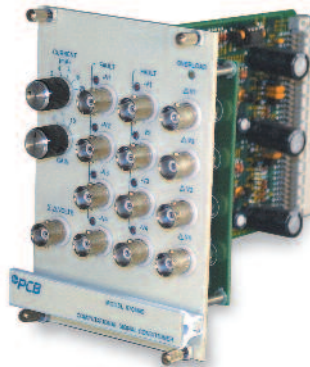
**Model 443B102**  
Dual-Mode Amplifier Module



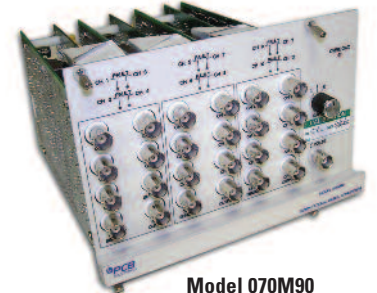
**Model 070A15**  
Summing Block for Charge Mode Sensors



**Model 070M70**  
Charge Summation Node Module



**Model 070M69**  
Computational Signal Conditioner



**Model 070M90**  
Summing Amplifier  
for ICP® Sensors

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