

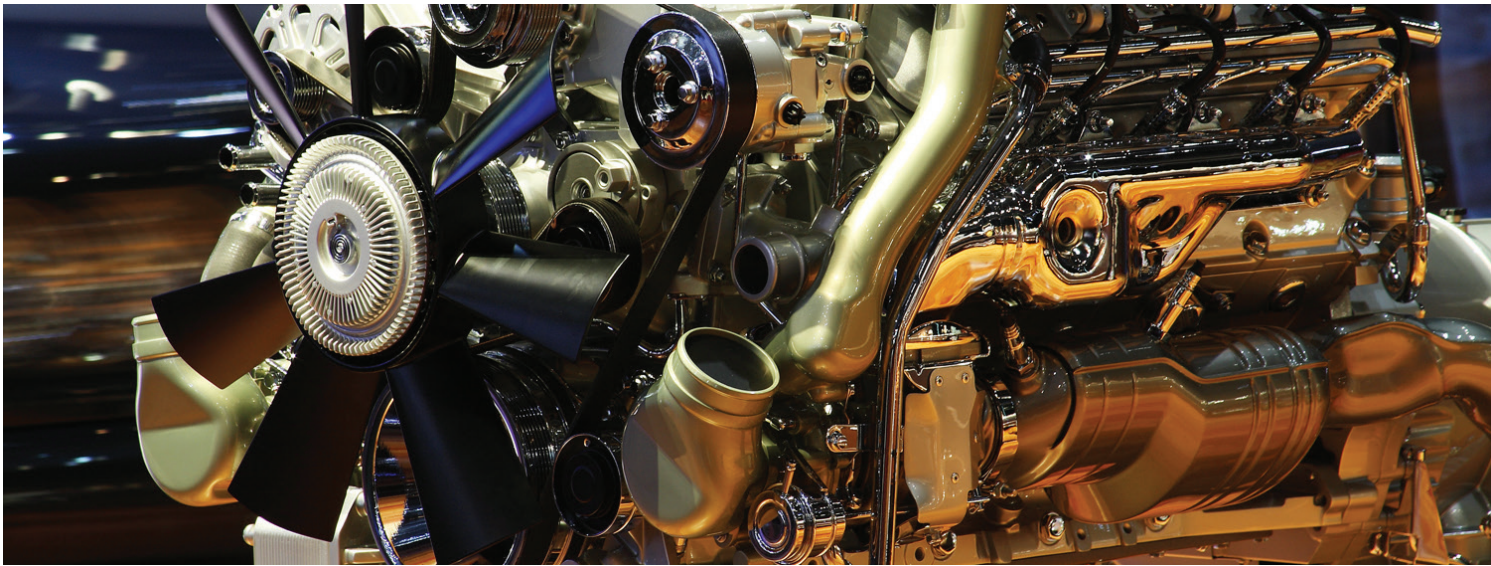


# VEHICLE & POWERTRAIN NVH SENSORS

 **PCB PIEZOTRONICS**  
AN AMPHENOL COMPANY

 **ENDEVCO**  
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## NVH - NOISE, VIBRATION & HARSHNESS

NVH stands for noise, vibration, and harshness and is an industry term associated with the treatment of vibration and audible sounds. Noise denotes unwanted sound; and hence the need to negate these sounds and vibrations. Vibrations above and below a specific range may not be detectable to the human ear, but may still require treatments for improved product performance and longevity. The frequency of the noise is paramount, as it dictates which method of treatment or what material will work best. Harshness usually refers to treatments of transient frequencies or shock.

NVH refinement has become an essential vehicle development attribute, as it is directly related to legal compliance, product quality, driving pleasure, brand image, and most importantly customer satisfaction.

Advanced NVH test methods and analytical simulation tools are prerequisites in today's fast paced automotive market to ensure front-end optimization of new designs for sound and vibration performance while still maintaining a balance with fuel efficiency, drivability, and component durability.

### CONCEPT DEVELOPMENT

The concept stage of the vehicle development process not only determines the most fundamental architecture of the automotive structure, but also offers an opportunity to reduce the amount of downstream development effort needed to achieve performance and attribute targets by optimizing core structures and system configurations and striking a balance between fuel economy, emissions, performance, ride, and NVH.

Typical NVH activities could include:

- Structural computer aided engineering (CAE) and modal analyses
- Dynamic system simulations
- Powertrain mounting strategies
- Body mounting concepts
- Suspension configurations
- Vehicle simulations
- Competitor benchmarking



### LIGHTWEIGHT ICP® ACCELEROMETER

MODEL 352C22

Sensitivity: 10 mV/g  
Measurement Range:  $\pm 500$  g pk  
  
Frequency Range:  
1-10000 Hz ( $\pm 10$  %)  
  
Weight: 0.017 oz (0.5 gm)  
  
Ground isolated



### MINIATURE ICP® ACCELEROMETER

MODELS 352C65 & 352C68

Sensitivity: 100 mV/g  
Measurement Range:  $\pm 50$  g pk  
  
Frequency Range:  
0.3-12000 Hz ( $\pm 10$  %)  
  
Weight: 0.07 oz (2 gm)  
  
Integral mounting stud  
  
Ground isolation models available



### GENERAL PURPOSE ICP® ACCELEROMETER

MODELS 352C03 & 352C04

Sensitivity: 10 mV/g  
Measurement Range:  $\pm 50$  g pk  
  
Frequency Range:  
0.3-15000 Hz ( $\pm 10$  %)  
  
Weight: 0.2 oz (5.8 gm)  
  
Ground isolation, water resistant  
and TEDS models available



### MINIATURE TRIAXIAL ICP® ACCELEROMETER

MODELS 356A01 & 356A03

Sensitivity: 5 / 10 mV/g  
Measurement Range:  
 $\pm 1000$  /  $\pm 500$  g pk  
  
Frequency Range:  
2 to 8000 Hz ( $\pm 1$  dB)  
  
Small 0.25 (6.4 mm)  
adhesive mount cube  
  
Ground isolated, high temperature,  
and TEDS models available



### TRIAXIAL ICP® ACCELEROMETER

MODEL 356A33

Sensitivity: 10 mV/g  
Measurement Range:  $\pm 500$  g pk  
  
Frequency Range:  
2 to 10000 Hz ( $\pm 5$  %)  
  
Small 0.4 (10.2 mm)  
stud mountable cube  
  
High temperature model available



### HIGH FREQUENCY ICP® TRIAXIAL ACCELEROMETER

MODEL 356A19

Sensitivity: 10 mV/g  
Measurement Range:  $\pm 5$  g pk  
  
Frequency Range:  
1 to 13000 Hz ( $\pm 5$  %)  
  
Electrical Connector: 1/4-28 4-Pin  
  
Small 0.4 (10.2 mm)  
adhesive mountable cube  
  
TEDS IEEE 1451.4 enabled



### HIGH SENSITIVITY ICP® TRIAXIAL ACCELEROMETER

MODEL 356A15

Sensitivity: 100 mV/g  
Measurement Range:  $\pm 50$  g pk  
  
Frequency Range:  
1.4 to 6000 Hz ( $\pm 10$  %)  
  
Electrical Connector: 1/4-28 4-Pin



### HIGH SENSITIVITY ICP® TRIAXIAL ACCELEROMETER

MODEL 356B18

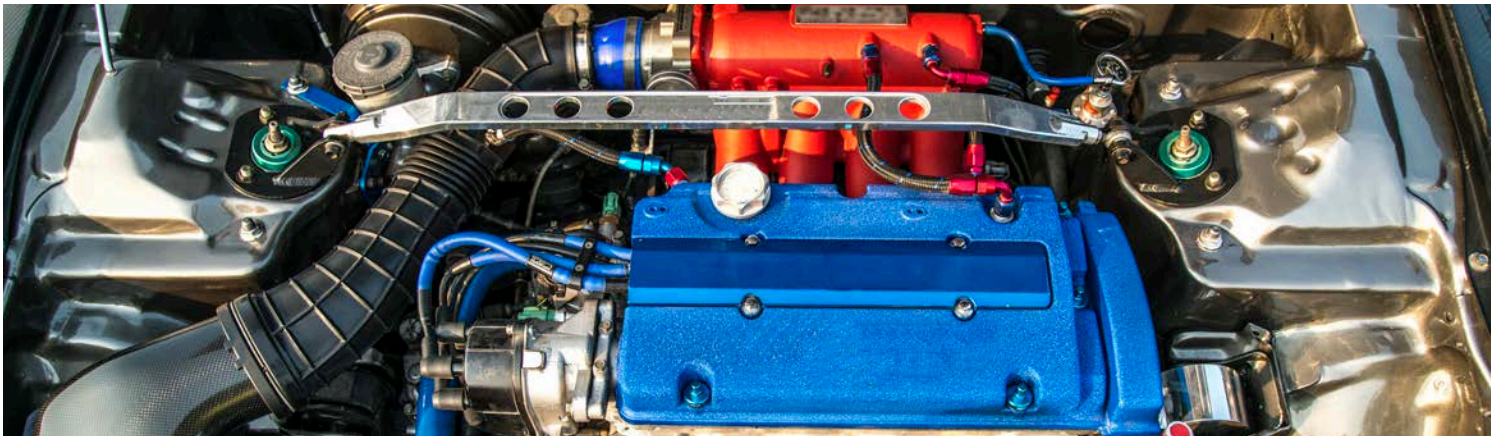
Sensitivity: 1000 mV/g  
Measurement Range:  $\pm 5$  g pk  
  
Frequency Range:  
0.3 to 5000 Hz ( $\pm 10$  %)  
  
Electrical Connector: 1/4-28 4



### GROUND ISOLATED TRIAXIAL HIGH SENSITIVITY ICP® ACCELEROMETER

MODEL 354C03

Ground isolated  
Frequency Range:  
0.5 to 4000 Hz ( $\pm 10$  %)  
Sensitivity: 100 mV/g  
Thru-hole mounting



## VEHICLE & POWERTRAIN DEVELOPMENT

### FILTERED, HIGH TEMPERATURE & THERMALLY STABLE SENSORS

Measuring NVH in powertrain and driveline applications presents a unique set of challenges. Whether internal combustion or electric drive systems, the influence of wide temperature ranges and signal saturation caused by metal-to-metal impacts on the quality of measurement can be significant. The ability to mitigate the influence of these external environmental conditions while accurately capturing the desired data requires a thoughtful application of both transducer technologies and engineering foresight.

#### ELECTRICALLY FILTERED SENSORS

Environments with mechanical shock or significant high frequency vibration content necessitate specialized accelerometers designed with these demanding test conditions in mind. Mechanical shock events can excite the high frequency resonance of the piezoelectric crystal (PCB or others), saturating the signal and leading to clipping in the ICP<sup>®</sup> signal conditioned output. To combat the effects of the crystal resonance, PCB employs carefully selected low-pass filtering in select accelerometers. This integrated pre-filtering minimizes the opportunity for erroneous frequency content to be generated and accepted as valid data, by suppressing the effects of the crystal resonance before it can influence the output signal. An additional purpose for filtering is to extend the usable high frequency range of the sensor by minimizing crystal resonance influence, resulting in an extended flat frequency response.

#### HIGH TEMPERATURE & THERMALLY STABLE SENSORS

Thermal influence on the performance of accelerometers is another aspect that needs to be considered when designing NVH testing plans. Both quartz and ceramic piezoelectric sensing elements have a measurable amount of thermally induced output, even at static condition. If ignored, this can potentially induce unaccounted for inaccuracies into the data being collected. To combat this, PCB has developed a specialized family of accelerometers that utilize UHT-12™ crystal technology which offers extremely stable sensitivity over a wide temperature range, far superior to quartz or ceramic. In addition to improved accuracy over temperature, this family of accelerometers exhibit low noise, low base strain sensitivity and a wide operating frequency range. PCB's family of low temperature coefficient (LTC) sensors offers the capability to cover a wide variety of demanding applications. With filtering, temperature coefficients down to 0.005% / °F (0.009% / °C), and operating temperatures to 356 °F (180 °C), this family of hermetically sealed titanium accelerometers are ideal for evolving NVH testing challenges well into the future.



### THERMALLY STABLE ICP® ACCELEROMETER

MODEL 320C52 & 320C53

Sensitivities: 10 / 1 mV/g  
Measurement Ranges:  
±500 / ±5000 g pk  
  
Frequency Range:  
0.6 to 10000 Hz (±10%)  
  
Temperature Range:  
-100 to +325 °F (-73 to 163 °C)  
  
Miniature (2 gm), ring-style



### UHT-12™ TRIAXIAL ICP® ACCELEROMETER

MODEL 339C31

Sensitivity: 10 mV/g  
Measurement Range: ±500 g pk  
  
Frequency Range:  
1.5 to 11000 Hz (±10%)  
  
Temperature Range:  
-65 to 250°F (-54 to 121°C)  
  
Integral low-pass electrical filter



### MINIATURE HIGH TEMPERATURE CHARGE ACCELEROMETER

MODEL 357A08

Sensitivity: 0.35 pC/g  
Measurement Range: ±1000 g pk  
  
Frequency Range: 1 to 20000 Hz  
(+10 %)  
  
Weight: 0.006 oz (0.16 gm)  
  
Temperature Range:  
-100 to 350°F (-73 to 177°C)



### THERMALLY STABLE ICP® ACCELEROMETER

MODEL 320C20

Sensitivity: 10 mV/g  
Measurement Range: ±500 g pk  
  
Frequency Range:  
1.5 to 10000 Hz (±10%)  
  
Temperature Range:  
-100 to +325 °F (-73 to 163 °C)  
  
Integral low-pass electrical filter



### FILTERED LTC TRIAXIAL ICP® ACCELEROMETER

MODELS TLD339A36 & TLD339A37

Sensitivities: 10 / 100 mV/g  
Measurement Ranges:  
±500 g pk / ±50 g pk  
  
Frequency Range: 1 to 8000 /  
0.2 to 7000 Hz (±10 %)  
  
Temperature Range:  
-65 to 325 / 356°F (-54 to 163 / 180°C)  
  
Integral low-pass electrical filter



### VERY HIGH TEMPERATURE, SINGLE-ENDED CHARGE ACCELEROMETER

MODEL 357A63

Sensitivity: 0.53 pC/g  
Measurement Range: ±5000 g pk  
  
Frequency Range: 1 to 10000 Hz  
(+10 %)  
  
Weight: 0.31 oz (8.7 gm)  
  
Temperature Range:  
-65 to +900 °F (-54 to 482 °C)



### HIGH FREQUENCY ICP® ACCELEROMETER

MODEL 352A60

Sensitivity: 10 mV/g  
Measurement Range: ±500 g pk  
  
Frequency Range:  
5 to 60000 Hz (±3dB)  
  
Weight: 0.21 oz (6.0 gm)



### HIGH FREQUENCY ICP® TRIAXIAL ACCELEROMETER

MODELS 356A24

Sensitivity: 10 mV/g  
Measurement Range: ±500 g pk  
  
Frequency Range:  
0.5 to 12000 Hz (±10%)  
  
Temperature Range:  
-65 to +250 °F (-54 to 121 °C)  
  
Weight: 0.11 oz (3.1 gm)



### MINIATURE CHARGE TRIAXIAL ACCELEROMETER

MODEL 356A71

Sensitivity: 10 pC/g  
Measurement Range: ±500 g pk  
  
Frequency Range: 1 to 7000 Hz  
(+10 %)  
  
Weight: 0.8 oz (22.7 gm)  
  
Temperature Range:  
-95 to +490 °F (-70 to 254 °C)



## NVH TESTING DC RESPONSE ACCELEROMETERS

PCB® series 3711F, 3713F, 3741F, and 3743F DC response sensors are used to measure low frequency motion down to zero hertz. These accelerometers are used in NVH applications with low frequency and amplitude requirements, as well as road load data acquisition (RLDA), drivability, ride and handling, and vehicle performance testing. Each series includes a full scale measurement range from  $\pm 2g$  to  $\pm 200g$  and features low spectral noise with high resolution. The units feature capacitive, silicon MEMS sensing elements for uniform, repeatable performance and offer high frequency overload protection.



### SINGLE-ENDED MEMS ACCELEROMETERS

SERIES 3711F & 3713F

- Sensitivities:  
6.75 mV/g to 675mV/g ( $\pm 3\%$ )
- Measurement Ranges:  
 $\pm 2 g$  pk to  $\pm 200 g$  pk
- Frequency response  
from 0 Hz up to 2500 Hz ( $\pm 10\%$ )
- Case isolated, hermetically sealed titanium housing
- Available with integral cable or multi-pin, threaded electrical connector
- Available in single-axis or triaxial configurations



### DIFFERENTIAL OUPUT, SINGLE AXIS MEMS ACCELEROMETERS

SERIES 3741F

- Sensitivities:  
13.5 mV/g to 1350 mV/g ( $\pm 3\%$ )
- Measurement Ranges:  
 $\pm 2 g$  pk to  $\pm 200 g$  pk
- Frequency response  
from 0 Hz up to 2500 Hz ( $\pm 10\%$ )
- Ground isolated, hard-anodized aluminum housing
- Integral, 4-conductor shielded cable



### DIFFERENTIAL OUPUT, TRIAxIAL MEMS DC ACCELEROMETERS

SERIES 3743F

- Sensitivities:  
13.5 mV/g to 1350 mV/g ( $\pm 3\%$ )
- Measurement Ranges:  
 $\pm 2 g$  pk to  $\pm 200 g$  pk
- Frequency response  
from 0 Hz up to 2500 Hz ( $\pm 10\%$ )
- Case isolated, hermetically sealed titanium housing
- 9-Pin threaded electrical connector

# RIDE QUALITY ELECTRIC VEHICLE DEVELOPMENT

Hybrid and electric vehicles present unique NVH testing challenges due to vehicle complexity and potential for problems with electrical isolation. NVH issues related to the addition of new electrical devices, gear whine, and vehicle resonances increase the number of areas and components to be tested. PCB's broad line of accelerometers are engineered to meet these challenges with ground and case isolation. These accelerometers are ideal for use in strong electrical fields generated by electric and hybrid vehicle systems. Electrical isolation reduces noise in these fields and eliminates ground loops.



## GROUND ISOLATED TEDS TRIAxIAL ACCELEROMETER

MODELS J356A43, J356A44, J356A45

Available in sensitivities 10 mV/g, 50 mV/g, and 100 mV/g

Frequency Range:  
0.4 to 10000 Hz ( $\pm 10\%$ )

1/4 - 28 4-pin connector

Rugged titanium ground isolation

TEDS IEEE 1451.4 enabled



## MINIATURE TRIAXIAL ICP® ACCELEROMETER

MODEL J356A03

Sensitivity: 10 mV/g  
Measurement Range:  $\pm 500$  g pk

Frequency Range:  
2 to 8000 Hz ( $\pm 5\%$ )

Weight: 0.04 oz (1 gm)

Small 0.28 (7.1 mm)  
adhesive mount cube



## MINIATURE CERAMIC SHEAR ICP® ACCELEROMETER

MODEL 352A24

Sensitivity: 10 mV/g  
Measurement Range:  $\pm 50$  g pk

Frequency Range:  
1 to 10000 Hz ( $\pm 10\%$ )

Weight: 0.03 oz (0.8 gm)

Anodized Aluminum ground  
isolation



## HIGH SENSITIVITY ICP® ACCELEROMETER

MODEL J352C33

Sensitivity: 100 mV/g

Frequency Range:  
0.5 to 14000 Hz ( $\pm 10\%$ )

Integral ground isolation base

TEDS IEEE 1451.4 capable  
and waterproof models available



## CASE ISOLATED HIGH SENSITIVITY TRIAXIAL ICP® ACCELEROMETER

MODEL 354B04 & 354B05

Sensitivity: 10 and 100 mV/g

Frequency Range:  
0.6 to 10000 Hz ( $\pm 5\%$ )

Weight: 0.51 oz (14.5 gm)

Thru-hole mounting

Case isolated



## INTRINSICALLY SAFE ACCELEROMETER

MODEL EX639A91

Sensitivity: 100 mV/g  
Measurement Range:  $\pm 50$  g pk

Frequency Range:  
0.5 to 13000 Hz ( $\pm 3$  dB)

IP68-rated 4-Pin, M12 connector

Case isolated and Intrinsically safe  
for EV battery testing

# NVH TESTING ACOUSTICS

Noise source measurements during the vehicle design process can present unique challenges. As electric vehicle design efforts overtake that of conventional vehicles, the demands for better resolution, lower noise floor and broader frequency response become more important to achieving a successful measurement. PCB's line of acoustic measurement products includes condenser, prepolarized, externally polarized, array, probe, low-profile surface, water and dust resistant, high temperature and other special purpose microphones, designed to accommodate virtually any sound testing environment.

With a broad product offering, measurements such as buzz, squeak and rattle (BSR), noise path analysis/transfer path analysis (NPA/TPA), and pass-by noise are common applications where the rugged design and exceptional performance of PCB microphones can be regularly found. Challenging measurement environments such as under-hood

and in wheel-well can easily be addressed with microphones specially designed for use in extreme temperatures, high humidity and dirty environments.

Prepolarized microphones have many advantages over externally polarized models. They use low power circuitry and do not require an external polarization voltage, making them especially useful in applications that require battery powered equipment. Adding to their ease of use, prepolarized microphone systems use common coaxial cables with BNC connectors and can be shared with other ICP® compatible products, including accelerometers, force sensors, and pressure sensors. Portability and interchangeability with other sensors minimize test set-up time and reduce the cost per-channel. All PCB microphones come standard with transducer electronic data sheets (TEDS) for microphone identification.



## 1/2" PREPOLARIZED LOW NOISE MICROPHONE SYSTEM

MODEL 378A04

Sensitivity: 450 mV/Pa

Frequency: 5 to 16000 Hz ( $\pm 2$  dB)

Noise Floor: 5.5 dB(A)

Dynamic Range: (3% Distortion Limit) >80 dB re 20  $\mu$ Pa



## 1/2" PREPOLARIZED FREE-FIELD CONDENSER MICROPHONE

MODEL 378B02

Sensitivity: 50 mV/Pa ( $\pm 1.5$  dB)

Frequency: 3.75 Hz – 20 kHz ( $\pm 2$  dB)

Available in high temperature, intrinsically safe, and rugged configurations



## 1/2" PREPOLARIZED RANDOM INCIDENCE CONDENSER MICROPHONE

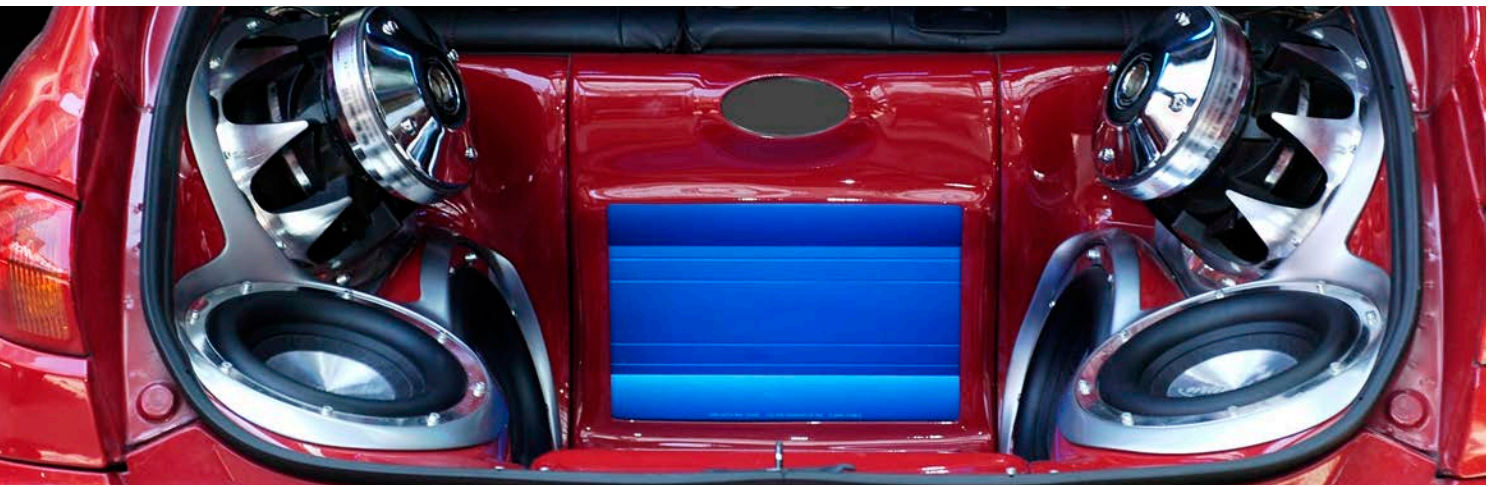
MODEL 378C20

Sensitivity: 50 mV/Pa ( $\pm 1.5$  dB)

Frequency: 3.75 Hz – 16 kHz ( $\pm 2$  dB)

Available in high temperature, intrinsically safe, and rugged configurations





**HIGH TEMPERATURE  
PROBE MICROPHONE**

MODEL 377B26

Sensitivity: 2.15 mV/Pa

Frequency Range: 2 to 20000 Hz  
(+2.2/-4.9dB)

Temperature Range:  
-40 to +1472° F (-40 to +800°C)

Dynamic Range: 165 dB re 20 µPa



**ICP® ARRAY  
MICROPHONE**

MODELS 130F20, 130F21, 130F22

Sensitivity: 45 mV/Pa

Frequency Range:  
10 to 16000 Hz (±2dB)

Inherent Noise:  
29 dB re 20 µPa (Linear)

Dynamic Range: 122 dB re 20 µPa



**ICP® LOW PROFILE  
PRESSURE MICROPHONE**

MODEL 130B40

Sensitivity: 8.5 mV/Pa

Frequency Range:  
20 to 10000 Hz (±3dB)

Inherent Noise:  
<32 dB(A) re 20 µPa

Dynamic Range: 150 dB re 20 µPa



**ICP® WATER RESISTANT  
ARRAY MICROPHONE**

MODEL 130A24

Sensitivity: 10 mV/Pa

Frequency Range:  
20 to 16000 Hz (±3dB)

Inherent Noise: <30 dB(A) re 20 µPa

Dynamic range: 143 dB re 20 µPa



**1/4" LOW NOISE ICP®  
PREPOLARIZED MICROPHONE  
SYSTEM**

MODEL 378A08

Sensitivity: 50 mV/Pa

Frequency Range: 12 to 20k Hz

Noise Floor: 25 dBA  
(22 dBA typical)

Multiple sound field usage capability



**1/4" PREPOLARIZED  
PRESSURE  
MICROPHONE**

MODEL 378C10

Sensitivity: 1 mV/Pa

Frequency Range:  
5 to 70000 Hz (±2dB)

Dynamic Range: 173 dB re 20 µPa

Inherent Noise: 50 dB(A) re 20 µPa

# RECOMMENDED TESTING SOLUTIONS

## SHAKER KITS FOR VIBRATION TESTING

The Modal Shop's exciter family provides solutions for applications ranging from experimental modal analysis to general vibration testing of small components and sub-assemblies. The broad range of shakers includes small-sized 2 lbf (10 N) up to 500 lbf (2,224 N). Available designs include the revolutionary SmartShaker™ with integrated power amplifier providing a high degree of flexibility when testing and Modal Shakers designed with a through-hole armature to simplify a common testing challenge: stinger setup and alignment. The mini inertial shaker is well-suited for structural testing in small, confined locations and dual purpose platform shakers are ideal for component testing.



### IMPEDANCE HEAD

MODEL TLD288D01

- ICP® impedance head (force/acceleration) for driving point measurements
- Force: 100 mV/lbf, ± 50 lbf
- Accel: 100 mV/g, ± 50 g
- Available with TEDS functionality



### AIRRIDE® MOUNT

MODEL 8032S

- Provides extremely low mounting frequencies for large rigid body test structures
- Eliminates multiple mounting frequencies, as AirRide® natural frequency does not shift significantly with changes in load



### LATERAL EXCITATION STAND

MODEL 2050A

- Combining lateral and vertical excitation distributes input energy and helps excite uncoupled lateral modes
- Provides versatility to adapt a modal shaker for horizontal input
- Ensures proper alignment with coarse and fine vertical adjustment



### DIGITAL ICP® SIGNAL CONDITIONER

MODEL 485B39

- Powers ICP® sensors while digitizing signals
- Pocket-sized, dual channel with standard USB digital output
- Plug & Play signal conditioning offers quick setup and simple usability with no driver installation needed



### DIGIDUCER® USB DIGITAL ACCELEROMETER

MODEL 333D01

- Piezoelectric ruggedness and dynamic range
- Eliminates need for data acquisition
- Flat response up to 8 kHz
- Plug & Play – record vibration data via laptop or tablet



### ICP® LASER TACHOMETERS

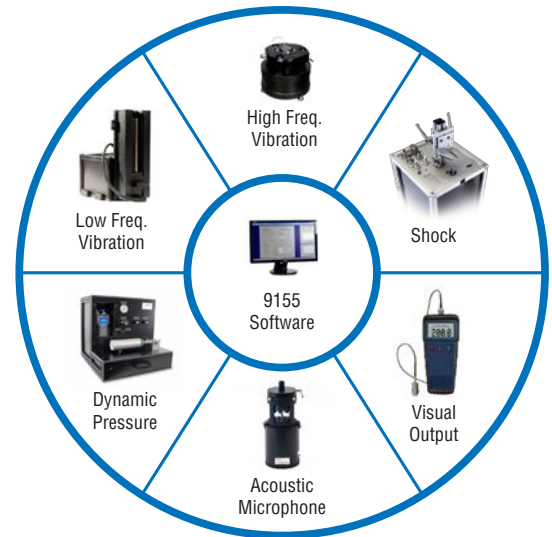
MODEL LT2

- Operates with standard ICP® signal conditioning; simplifies cabling
- One pulse/rev eliminates need to oversample all channels for a high frequency tach
- Offers continuous laser for jitter-free operation

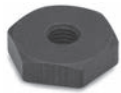
## PRECISION SENSOR CALIBRATION WORKSTATION

The Precision Sensor Calibration Workstation Model 9155 is a turnkey solution that provides all the necessary components out of the box. Principal components include a Windows® PC controller, software, printer, and 24-bit data acquisition card with software. System options allow custom configuration of the modular system with a variety of calibration-grade exciter systems and signal conditioning. The Model 9155 can calibrate a wide range of accelerometers (including ICP®, charge, MEMS, and piezoresistive), microphones (including array, phantom power, externally polarized, and prepolarized), and dynamic pressure sensors.

To learn more about how a 9155 system can meet your specific needs, visit [www.modalshop.com/configure](http://www.modalshop.com/configure) for a custom calibration configuration guide or contact The Modal Shop's Calibration Team.



## RECOMMENDED SENSOR ACCESSORIES



**ADHESIVE MOUNTING BASE**  
MODEL 080A



**TRIAXIAL MOUNTING ADAPTER**  
MODEL 080B16



**ADHESIVE**  
MODEL 080A90



**MOUNTING CLIP**  
MODEL 080A237



**PETRO WAX**  
MODEL 080A109



**REMOVAL TOOL**  
MODEL 039A08



**4-CONDUCTOR, SHIELDED, FEP CABLE**  
MODEL 034WXX

Used with triaxial ICP® accelerometers

4 conductor, shielded, FEP jacket

IP68 Rated 1/4-28, 4-socket plug to 3 BNC plugs



**4-CONDUCTOR, SHIELDED, POLYURETHANE CABLE**  
MODEL 078WXX

Used with triaxial ICP® accelerometers

4 conductor, shielded, flexible polyurethane jacket

IP68 Rated 1/4-28, 4-socket plug to 3 BNC plugs



**NF CABLE**  
4-CONDUCTOR TERMINATION

Connector Style: Triple Splice

Connector Style: BNC

Connection Type: Plug (male pin)

Temperature Range:  
-40 to +176 °F (-40 to +80 °C)

Grounded shield

## RECOMMENDED ACOUSTIC ACCESSORIES



**ADAPTOR**  
MODEL ADP043



**NOSE CONE**  
MODEL 079B21



**WINDSCREEN**  
MODEL 079A06  
MODEL 079A07



**PREAMPLIFIER HOLDER**  
MODEL 079A11



**SWIVEL HEAD ADAPTOR**  
MODEL 079B23



**MICROPHONE STAND**  
MODEL 079A15



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