



## Signal Conditioning for the NASA Vibro-Acoustic Test Facility Plum Brook Station

### Introduction

As humans push farther into our solar system, they need spacecraft proven to withstand the extreme conditions encountered in space. The NASA Plum Brook Station Space Power Facility (SPF) in Sandusky, Ohio, is home to the world's largest and most powerful space environmental simulation test cells. At 100 feet in diameter and 122 feet high, the SPF's Space Simulation Vacuum Chamber is the world's largest space environment thermal vacuum chamber and an ideal site for testing space hardware. The SPF also houses the Reverberant Acoustic Testing Facility, a 101,500 cubic foot chamber that blasts test articles with acoustic sound pressure of up to 163 dB, making it the most powerful spacecraft acoustic test chamber in the world. The three-axis vibration system of the Mechanical Vibration Test Facility shakes test subjects of up to 75,000 pounds to simulate the vibration that occurs during launch and ascent. In addition, NASA has developed the capability to perform electromagnetic interference/compatibility (EMI/EMC) testing on full-scale spacecraft.



The Space Power Facility at NASA's Plum Brook Station

Courtesy NASA

Such rigorous, large-scale testing means accurate measurements are essential. To support the large number of sensor measurements taken at the SPF, NASA needed a new system to interface to spacecraft and facility sensors in order to condition, digitize, display, analyze, store, and archive the critically important test data.

### Solution

Support for a wide mix of sensors was required throughout the vibration, acoustic, and thermal-vacuum test chambers. These sensors include integrated electronic piezoelectric (IEPE) accelerometers, IEPE/charge microphones, 4-arm strain gages, load cells, thermocouples, and general purpose voltage monitoring inputs. The installation required a total of 1024 channels of sensor conditioning. Due to the wide range of test protocols and the tests' high cost and crucial importance, the data system had to be flexible, reliable, and traceable to NIST standards. Above all, test data had to be highly accurate and fully defensible. Together, the signal conditioning front-end and the data acquisition system comprise the Plum Brook Station Facility Data Acquisition System (FDAS).

NASA chose Precision Filters' 28000 signal conditioning system for the data system front-end to interface to the spacecraft and facility

sensors and to provide amplified filtered sensor signals to the downstream data acquisition system. The 28000, a mix-and-match transducer conditioning system, has over a dozen plug-in signal conditioning cards to meet almost any sensor conditioning requirements. To meet the vibration measurement requirements of the Plum Brook FDAS, the Precision 28316C 16-channel isolated IEPE conditioner card was selected. The high density of the 28316C card provides the required 768 channels. NASA chose the 28144 quad-channel wide-band transducer conditioner for the 184 full-bridge sensors, and the 28304 quad-channel charge/IEPE amplifier for the 40 channels of IEPE/charge sensors. Seven 6U 28000 chassis house the entire system.

The 28316C card supports programmable filtering, gain, and IEPE supply current from 1 to 8 mA. The proprietary balanced push-pull IEPE supply and isolated input of the 28316C break the ground loops that traditional IEPE conditioners cannot address. To monitor transducer health, sensor open, short, and bias level are checked and reported. The conditioners have 4-pole programmable low-pass Butterworth filters with cutoffs programmable from 300 Hz to 30 kHz and a wideband (filters bypassed) bandwidth of 190 kHz. Programmable high-pass filters provide cutoffs of 0.25 or 10 Hz. The 28316C card has dual buffered outputs per channel available to allow diagnostic monitoring or connection to auxiliary recording devices without corrupting the primary data path. To facilitate the logistics of system setup and gain scaling to the calibrated sensitivity of 768 sensors, the 28316C is compatible with Transducer Electronic Data Sheet (TEDS) equipped accelerometers. Sensor data, such as calibrated sensitivity, is read directly by the attached 28316C and made available to the host computer. While other TEDS readers on the market are limited to a maximum cable length of 400 feet, Precision Filters' proprietary Long Distance TEDS (LDTEDS) can operate with cable lengths of up to 1,500 feet.



ESA's European Service Module ready for testing in the Space Power Facility  
Courtesy NASA

For piezoelectric pressure and accelerometers, the 28304 plug-in card provides charge mode conditioning with full-scale charge range from 2.5 pC to 100,000 pC and input noise as low as 0.005 pC. For system, sensor, and cable health checks, the 28304 supports voltage substitution, shunt calibration, and T-insertion.

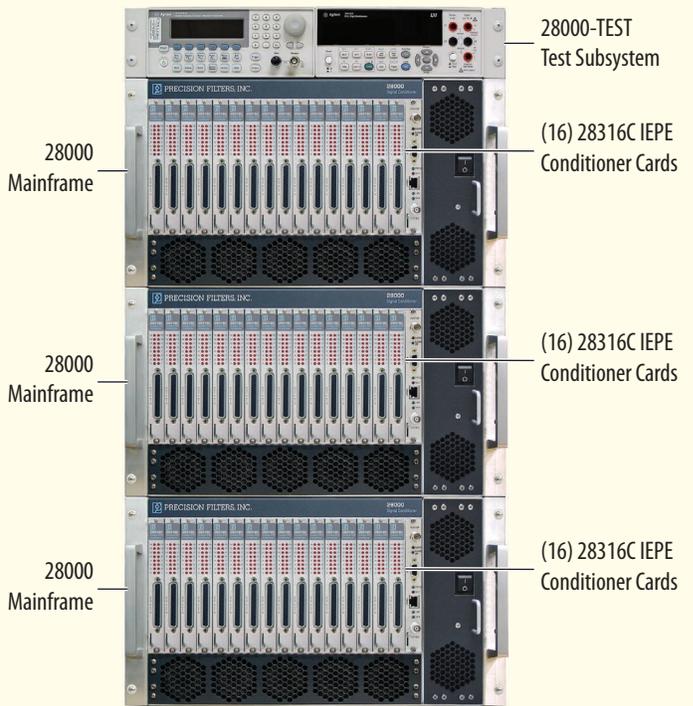
When the test regimen requires Wheatstone bridge conditioning, the 28144 plug-in card is compatible with 1/4, 1/2, or full bridges for static measurements using constant voltage excitation and dynamic measurements using PFI's proprietary balanced constant current excitation. The card is capable of bridge autobalance and 5000-step bipolar shunt calibration. The voltage excitation supply utilizes balanced voltage excitation to improve rejection of high frequency common-mode signals. The 28144 includes a 4-pole programmable filter with selectable flat amplitude response characteristics with sharp roll off for spectral analysis, or pulse Bessel type characteristics for time domain uses including transient (shock) and waveform analysis.

Whether the sensor type is voltage, IEPE, bridge, or charge, each channel of the 28000 is fully programmable to provide sensor scaled, amplified, and filtered data acquisition ready signals to the FDAS's downstream A/D converters.

### NIST-Traceable Calibration

All test and measurement systems require periodic calibration. Typically, this means that test systems are dismantled and cards are uninstalled and shipped either to an in-house cal lab or back to the manufacturer—requiring an average of 30 days of downtime. NASA needed automated in-situ calibration, as the expected test schedule does not tolerate a month of downtime each year for equipment calibrations. Precision Filters' built-in test hardware and software lets Plum Brook engineers perform NIST traceable calibration tests on site, without removing the system from the equipment rack.

### Precision Filters 28000 Signal Conditioning System



- The FDAS IEPE sensor conditioning subsystem consists of seven 6U high 28016 mainframes, each equipped with a low-noise power supply, integrated cooling, and a 28000-BIF-FT controller card.
- Thirty-four 28316C 16-channel conditioner cards provide 544 isolated IEPE sensor channels (shown above).
- Forty-six 28144 quad-channel conditioner cards provide 184 bridge sensor channels.
- Ten 28304 quad-channel conditioner cards provide 40 charge sensor channels.
- One 28000-TEST test subsystem performs validation and in-situ NIST-traceable calibrations.

## 28000 Plug-in Cards

### 28316C Isolated IEPE Accelerometer Conditioner with LDTEDS™

- 16 channels per card, 256 channels per chassis
- IEPE conditioner or AC filter/amplifier with balanced differential input
- Isolated channel input allows conditioning of grounded IEPE accelerometers without introducing ground loops
- Precision Filters LDTEDS (Long-Distance Transducer Electronic Datasheet) compliant
- Gain x0.5 to x512 with 0.05% resolution
- Autogain setup for best analog-to-digital converter (ADC) dynamic range



### 28144 Quad-Channel Wideband Bridge Conditioner

- 4 channels per card, 64 channels per chassis
- Balanced programmable constant voltage source with remote sense
- Balanced constant current source for dynamic strain and RTDs
- Programmable bridge configuration, autobalance, and shunt cal
- Up to 200 kHz filtered or 700 kHz wideband bandwidth
- 2- to 10-wire plus shield input interface



### 28304 Quad Charge/IEPE Conditioner with Long Distance TEDS™

- 4 channels per card, 64 channels per chassis
- Dual mode: piezoelectric or IEPE
- Ground sense input mode conditions grounded sensors
- Up to 100 kHz filtered bandwidth or 370 kHz wideband bandwidth
- T-insertion for health test of inaccessible accelerometers
- Programmable IEPE current to 0, 4, 8, 12 mA
- Two charge conversion ranges for 10,000 or 100,000 pC FS inputs
- Programmable amplifier: x0.25 to x8192 with 0.05/vernier



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