Overview
The NI 445x Series are dynamic signal acquisition devices for making high-accuracy frequency measurements with PCI computers. The NI 445x boards simultaneously digitize input signals over the entire bandwidth. The NI 4451 has two analog input channels and two analog output channels. The NI 4452 and NI 4454 have four analog input channels and no analog output. When combined with the Sound and Vibration Toolset (see page 107 for more information) or other analysis tools, you can obtain a variety of accurate frequency measurements for your application.

Hardware
Analog Inputs
The analog inputs of the NI 445x boards have 16-bit resolution ADCs that are simultaneously sampled at several software-programmable rates. The hardware can digitize standard digital audio frequencies such as 44.1 kS/s (the standard rate used in CD players), 32.0 kS/s, and 48.0 kS/s (the rates used in digital audio tape (DAT) recorders). This board is well suited for sound and vibration analysis applications.

The analog inputs have AC/DC coupling. A programmable gain amplifier stage on the inputs gives programmable gain select from -20 to +60 dB in 10 dB steps. Furthermore, to provide you with the quietest and highest quality analog measurements, the input stage has been designed to accept differential or single-ended signal connections with the NI 4451 and NI 4452.

The 90 dB dynamic range of the NI 445x boards contributes to low noise and distortion effects and makes possible high-accuracy measurements. The boards have excellent amplitude flatness of ±0.1 dB within the frequency range of DC to 95 kHz, and have a maximum THD specification of -90 dB at 1 kHz and a worst case THD of -80 dB at higher frequencies.

The low noise and low distortion of the NI 445x boards are achieved by using state-of-the-art, 128-times oversampling, delta-sigma modulating ADCs. Because these ADCs sample at 128 times the specified sampling rate with 1-bit resolution, they produce nearly perfect linearity. Extremely flat, linear-phase, lowpass digital filters then remove the quantization noise from the band of interest, divide the sample rate by 128, and increase the resolution to 16 bits. Using the delta-sigma modulating ADCs, the NI 445x boards are immune to the DNL distortion associated with conventional DAQ boards.

Antialiasing
The analog inputs have both analog and real-time digital filters...
implemented in hardware to prevent aliasing. Input signals are first passed through fixed analog filters to remove any signals with frequency components beyond the range of the ADCs. Then digital antialiasing filters automatically adjust their cutoff frequency to remove any frequency components above half the programmed sampling rate.

### Analog Outputs

The NI 4451 has two channels of 16-bit resolution, high-fidelity analog output. A common application of the analog output is to stimulate a system under test while measuring the frequency response with the analog inputs. The output conversions occur simultaneously at software-programmable rates from 1.25 to 51.2 kS/s in increments of 47.684 µS/s. The analog output circuitry uses 8-times oversampling interpolators with 64-times oversampling delta-sigma modulators to generate high-quality signals. Software-programmable attenuation of 0, -20, or -40 dB is available on the output channels. The NI 4451 has an excellent amplitude flatness of ±0.2 dB within DC to 23 kHz, and a THD of -90 dB at 1 kHz. The user may simultaneously acquire data on the input channels while updating the output channels.

### Anti-imaging

The NI 4451 output channels have both analog and digital anti-imaging filters. These filters remove the unwanted glitches and high-frequency signals generated when an analog signal is generated from digital data. The digital filters limit the bandwidth of the output signal to half the original conversion rate, thereby rejecting images caused by the 8-times oversampling process. The signals generated by the analog output circuitry are low-distortion, low-noise, flat-frequency analog signals.

### Multiboard Synchronization

For applications requiring more than four channels, two or more NI 445x boards can be synchronized in their operation. Using the RTSI bus, you can send and receive timing signals between NI 445x boards as well as between a NI 445x board and other DAQ boards. Synchronization is achieved by sharing a digital trigger and the clock from one board to another.

### Triggering

The NI 445x family has several trigger modes for acquiring signals. Pretrigger mode digitizes signals before and after a trigger condition occurs. Posttrigger mode digitizes signals after a trigger condition occurs. Delay trigger mode begins signal capture after a programmable delay from the trigger. The source of the trigger can come from any analog input channel, the external digital trigger input, the RTSI bus, or the software. The external digital trigger is 5 V/TTL-compatible and is activated by a choice of rising or falling edge. Triggering is needed in applications that acquire transient signals. When striking a metal beam with a hammer, for example, transient vibrations are measured with accelerometers whose acquisition is triggered by the hammer.

### Calibration

The offset voltage and gain accuracy of the analog input are calibrated by National Instruments. An onboard precision voltage reference ensures that the input gain is stable and accurate. The boards are shipped with NIST-traceable and ISO-9002-certified calibration certificates.

### PCI I/O Channel Interface

Each NI 445x is a full-size PCI board. The boards use the PCI MITE to deliver full DMA bus-master data transfer rates of 20 to 30 Mbytes/s and burst rates up to 128 Mbytes/s. A 512-sample, analog input FIFO and analog output FIFO prevent data loss if DMA or interrupt service latency is long.

### Software

The NI 445x boards use the NI-DAQ driver as the hardware and operating system interface. You can build automated test systems or integrate the NI 4451, NI 4452, and NI 4454 boards with other hardware, including the computer-based instruments and multifunction DAQ products, through NI-DAQ function calls for LabVIEW, Measurement Studio, C/C++, and Visual Basic.

The NI 445x boards are well suited for applications in audio, sound and vibration analysis. These applications are specifically addressed in the Sound and Vibration Toolset for LabVIEW. With this toolset in conjunction with the NI 445x board, you can obtain power spectrums, frequency response, fractional octave analysis, sound level measurements, transient analysis and sensor calibration. A typical setup for an environmental noise measurement application would be using the NI 4451 and accessories, LabVIEW, and the Sound and Vibration Toolset.

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**Ordering Information**

<table>
<thead>
<tr>
<th>Device</th>
<th>Accessory 1</th>
<th>Accessory 2</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>NI 4451</td>
<td>BNC-2140 (777597-01)</td>
<td>SCB-BB (77844-01)</td>
<td>Shipped with NI-DAQ for Windows 2000/NT/Me/9x and Mac OS unless otherwise noted.</td>
</tr>
<tr>
<td>NI 4452</td>
<td>BNC-2140 (777597-01)</td>
<td>SCB-BB (77844-01)</td>
<td>Shipped with NI-DAQ for Windows 2000/NT/Me/9x and Mac OS unless otherwise noted.</td>
</tr>
<tr>
<td>NI 4454*</td>
<td>BNC-2140 (777597-01)</td>
<td>SCB-BB (77844-01)</td>
<td>Shipped with NI-DAQ for Windows 2000/NT/Me/9x and Mac OS unless otherwise noted.</td>
</tr>
</tbody>
</table>

* Windows only

**Extended warranty and value added services**

See page 880 for detailed specifications.

**Example Configurations**

See page 304 for detailed specifications.

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**See page 301 for accessory and cable options.**
Dynamic Signal Acquisition and Analysis Specifications

**NI4551, NI 4552 (Continued)**

### Triggers

**Analog Trigger**
- **Source**
  - NI 4551: ACH<0..1>
  - NI 4552: ACH<0..3>
- **Level**: Full-scale
- **Slope**: Positive or negative (software selectable)
- **Resolution**: 16 bits
- **Hysteresis**: Programmable

**Digital Trigger** (NI-DAQ mode only)
- **Compatibility**: TTL
- **Response**: Rising or falling edge
- **Pulse width**: 10 ns min

**Bus Interface Type**
- PCI Master/Slave

### Power Requirement

- **Power (NI 4551)**
  - +5 V, 2.8 A idle, 3.8 A active typical
  - +5 V, 5 A momentary relay (not including relay switching)

#### NI 4552
- +5 V, 3.3 A idle, 4.3 A active typical
- +5 V, 5 A momentary relay (not including relay switching)

**Available power analog I/O connector**
- +4.65 to +5.25 VDC at 1.0 A

**Available power digital I/O connector**
- +4.65 to +5.25 VDC at 1.0 A

### Physical

- **Dimensions (not including connectors)**: 10.65 by 31.19 by 1.84 cm
  - (4.19 by 12.28 by 0.73 in.)
- **Digital I/O connector**: 50-pin VHICC female type
- **Analog I/O connector**: 68-pin VHICC female type

### Environment

- **Operating temperature**: 0 to +40 °C
- **Storage temperature range**: -25 to +85 °C
- **Relative humidity**: 10 to 95%, no condensation

**Calibration interval**
- 1 year

### Certifications and Compliances

**CE Mark Compliance**

**NI 4451, NI 4452, NI 4454**

### Analog Input

**Channel Characteristics**

<table>
<thead>
<tr>
<th>Product</th>
<th>Number of Channels</th>
<th>Input Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>NI 4451</td>
<td>2</td>
<td>Simultaneously sampled balanced differential</td>
</tr>
<tr>
<td>NI 4452</td>
<td>4</td>
<td>Simultaneously sampled single-ended</td>
</tr>
<tr>
<td>NI 4454</td>
<td>4</td>
<td>Ditto-sigma, 128-times oversampling</td>
</tr>
</tbody>
</table>

#### Sample rates

- **NI 4451**: 5 kS/s to 204.8 kS/s in increments of 190.735 µS/s
- **NI 4452**: 5 kS/s to 51.2 kS/s in increments of 47.684 µS/s
- **NI 4454**: 5 kS/s to 51.2 kS/s in increments of 47.884 µS/s

### Gain Full-Scale Range

<table>
<thead>
<tr>
<th>Product</th>
<th>Gain</th>
<th>Full-Scale Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>NI 4451</td>
<td>-20 dB</td>
<td>±4.24 V</td>
</tr>
<tr>
<td>NI 4452</td>
<td>-10 dB</td>
<td>±10 V</td>
</tr>
<tr>
<td>NI 4454</td>
<td>0 dB</td>
<td>±10 V</td>
</tr>
</tbody>
</table>

### Product Linear Log (Peak)

<table>
<thead>
<tr>
<th>Product</th>
<th>Gain</th>
<th>Full-Scale Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>NI 4451</td>
<td>-20 dB</td>
<td>±4.24 V</td>
</tr>
<tr>
<td>NI 4452</td>
<td>-10 dB</td>
<td>±10 V</td>
</tr>
<tr>
<td>NI 4454</td>
<td>0 dB</td>
<td>±10 V</td>
</tr>
</tbody>
</table>

### Product Gain Max Offset

<table>
<thead>
<tr>
<th>Product</th>
<th>Gain</th>
<th>Max Offset</th>
</tr>
</thead>
<tbody>
<tr>
<td>NI 4451</td>
<td>-20 dB</td>
<td>±40 mV</td>
</tr>
<tr>
<td>NI 4452</td>
<td>-10 dB</td>
<td>±10 mV</td>
</tr>
<tr>
<td>NI 4454</td>
<td>0 dB</td>
<td>±3 mV</td>
</tr>
</tbody>
</table>

### Product Gain Flatness

<table>
<thead>
<tr>
<th>Product</th>
<th>Gain</th>
<th>Flatness</th>
</tr>
</thead>
<tbody>
<tr>
<td>NI 4451</td>
<td>-20 dB</td>
<td>±0.1 dB</td>
</tr>
<tr>
<td>NI 4452</td>
<td>-10 dB</td>
<td>±0.1 dB</td>
</tr>
<tr>
<td>NI 4454</td>
<td>0 dB</td>
<td>±0.1 dB</td>
</tr>
</tbody>
</table>

### Product Input Impedance

<table>
<thead>
<tr>
<th>Product</th>
<th>Input Impedance</th>
</tr>
</thead>
<tbody>
<tr>
<td>NI 4451</td>
<td>1 MΩ in parallel with 50 pF (+ and – each to AIGND)</td>
</tr>
<tr>
<td>NI 4452</td>
<td>1 MΩ in parallel with 80 pF (+ to AIGND)</td>
</tr>
</tbody>
</table>

### Flatness (relative to 1 kHz)

<table>
<thead>
<tr>
<th>Product</th>
<th>Gain</th>
<th>Flatness</th>
</tr>
</thead>
<tbody>
<tr>
<td>NI 4451</td>
<td>-20 dB</td>
<td>±0.1 dB</td>
</tr>
<tr>
<td>NI 4452</td>
<td>-10 dB</td>
<td>±0.1 dB</td>
</tr>
<tr>
<td>NI 4454</td>
<td>0 dB</td>
<td>±0.1 dB</td>
</tr>
</tbody>
</table>

### Amplifier Characteristics

### Input Impedance

<table>
<thead>
<tr>
<th>Product</th>
<th>Gain</th>
<th>Flatness</th>
</tr>
</thead>
<tbody>
<tr>
<td>NI 4451</td>
<td>-20 dB</td>
<td>±0.1 dB</td>
</tr>
<tr>
<td>NI 4452</td>
<td>-10 dB</td>
<td>±0.1 dB</td>
</tr>
<tr>
<td>NI 4454</td>
<td>0 dB</td>
<td>±0.1 dB</td>
</tr>
</tbody>
</table>

### Common mode range

<table>
<thead>
<tr>
<th>Product</th>
<th>Gain</th>
<th>Flatness</th>
</tr>
</thead>
<tbody>
<tr>
<td>NI 4451</td>
<td>≥0 dB</td>
<td>±0.1 dB</td>
</tr>
<tr>
<td>NI 4452</td>
<td>≤0 dB</td>
<td>±0.1 dB</td>
</tr>
</tbody>
</table>

### Common mode range

<table>
<thead>
<tr>
<th>Product</th>
<th>Gain</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>NI 4451</td>
<td>≥0 dB</td>
<td>Both + and – should remain within ±12 V of AIGND</td>
</tr>
<tr>
<td>NI 4452</td>
<td>≤0 dB</td>
<td>Both + and – should remain within ±12 V of AIGND</td>
</tr>
</tbody>
</table>

### Overvoltage protection

<table>
<thead>
<tr>
<th>Product</th>
<th>Gain</th>
<th>Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>NI 4451</td>
<td>≥0 dB</td>
<td>ACH0, ACH1, ACH2, ACH3</td>
</tr>
<tr>
<td>NI 4452</td>
<td>≤0 dB</td>
<td>ACH0, ACH1, ACH2, ACH3</td>
</tr>
</tbody>
</table>
Dynamic Signal Acquisition and Analysis Specifications

**NI 4451, NI 4452, NI 4454 (Continued)**

### Common-Mode Rejection Ratio $f_{sys} < 1 \text{ kHz}$

<table>
<thead>
<tr>
<th>Product</th>
<th>Gain</th>
<th>CMRR</th>
</tr>
</thead>
<tbody>
<tr>
<td>NI 4451</td>
<td>≥20 dB</td>
<td>90 dB</td>
</tr>
<tr>
<td>NI 4452</td>
<td>≥20 dB</td>
<td>60 dB</td>
</tr>
<tr>
<td>NI 4454</td>
<td>0 dB</td>
<td>90 dB</td>
</tr>
</tbody>
</table>

Input noise spectral density: 8 nV/√Hz (achievable only at Gain = +50 dB)

Idle channel noise: -90 dB (+60 dB for NI 4451/4452)

### Dynamic Characteristics

- **Bias-free bandwidth**
  - NI 4451/4452: DC to 0.464 f_s, for sample rates > 30 kS/s
  - NI 4454: DC to 0.464 f_s, for sample rates > 10 kS/s
- **Alias rejection**
  - ≥80 dB, 0.536 f_s < f_s < 4.364 f_s
- **Spurious-free dynamic range**
  - ≥90 dB
- **THD**
  - ≤80 dB, ≤0 dB for f_s < 20 kHz
- **IMD**
  - ≤-100 dB (CCIF 1 kHz + 1 kHz)
- **Crosstalk**
  - ≤-100 dB, DC to 10 kHz measurement bandwidth

### Phase Linearity and Interchannel Phase

<table>
<thead>
<tr>
<th>Product</th>
<th>Gain</th>
<th>Phase Linearity</th>
</tr>
</thead>
<tbody>
<tr>
<td>NI 4451</td>
<td>≥20 dB</td>
<td>±1 deg</td>
</tr>
<tr>
<td>NI 4452</td>
<td>&lt;20 dB</td>
<td>±2 deg</td>
</tr>
<tr>
<td>NI 4454</td>
<td>±0 dB</td>
<td>±1 deg</td>
</tr>
</tbody>
</table>

Interchannel gain mismatch: ±0.1 dB, for any gain (same configuration for all input channels)

Signal delay: ≥42 sample periods, any sample rate (time from when signal enters analog input to when digital data is available)

### Analog Output (NI 4451 only)

- **Channel Characteristics**
  - Number of channels: 2 simultaneously updated
  - Output configuration (4451): Balanced differential
  - Resolution: 16 bits
  - Type of DAC: Delta-sigma, 64-times oversampling
  - Sample rates: 1.25 to 51.2 kS/s in increments of 4.7684 kS/s
  - Frequency accuracy: ±25 ppm

### Output Signal Ranges (software selectable)

<table>
<thead>
<tr>
<th>Product</th>
<th>Gain</th>
<th>Full-Scale Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>NI 4451</td>
<td>1</td>
<td>±10.0 V</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>±1.00 V</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>±0.100 V</td>
</tr>
</tbody>
</table>

- **FIFO buffer size**: 512 samples
- **Data transfers**: DMA, programmed I/O, interrupt

### Transfer Characteristics

- Offset (residual DC): ±5 mV max, any gain
- Gain (amplitude accuracy): ±0.1 dB, f_s = 1 kHz

### Voltage Output Characteristics

- Output impedance: 22 kΩ between + and - of DACxOUT
- Open circuit: 4.55 V to 5VAD
- Flatness (relative to 1 kHz): ±0.2 dB, 0 to 23 kHz, 51.2 kS/s
- -3 dB bandwidth: ±492 kHz
- Output coupling: DC
- Short-circuit protection: Yes (+ and - may be shorted together indefinitely)
- Outputs protected: ±DACxOUT, ±DAC0UT
- Idle channel noise: ±9.1 dB, DC to 23 kHz measurement bandwidth

### Dynamic Characteristics

- **Image-free bandwidth**: DC to 0.450 f_s
- **Image rejection**: 90 dB, 0.550 f_s < f_s < 63.450 f_s
- **Spurious-free dynamic range**: 90 dB, DC to 100 kHz measurement bandwidth

**Input noise spectral density**: 8 nV/√Hz (achievable only at Gain = +50 dB)

Idle channel noise: -90 dB (+60 dB for NI 4451/4452)

### Digital I/O (NI 4451/4452 only)

- **Number of channels**: 8 input/output
- **Compatibility**: 5 V/TTL/CMOS
- **Digital logic levels**: Power-on state: Input (High-Z)
- **Data transfers**: Programmed I/O

### Timing I/O (NI 4451/4452 only)

- **Number of channels**: 2 up/down counter/timers, 1 frequency scaler

### Triggers

- **Analog Trigger**
  - Source: NI 4451: ACH<0..1>
  - NI 4452/4454: ACH<0..3>
  - Level: ± full-scale, ±10 V for NI 4454
- **Compatibility**: Positive or negative (software selectable)

### Power Requirement

- **NI 4451**: +5 V, 1.7 A idle, 2.0 A active
  - +12 V, 100 mA typical (not including momentary relay switching)
- **NI 4452**: +5 V, 2.2 A idle, 2.5 A active
  - +12 V, 150 mA typical (not including momentary relay switching)
  - +12 V, unused, +3.3 V, unused
- **NI 4454**: +5 V, 1.35 A idle, 1.5 A active
  - +12 V, 150 mA typical (not including momentary relay switching)
  - +12 V, unused, +3.3 V, unused

Available power (analog I/O connector): +4.65 to +5.25 VDC at 1.0 A

Available power (digital I/O connector): +4.65 to +5.25 VDC at 1.0 A

### Physical

- **Dimensions (not including connectors)**: 10.65 by 3.19 by 1.84 cm
  - 4.19 by 12.28 by 0.73 in.
- **Analog I/O connector (NI 4451/4452)**: 68-pin VHDCI female type
- **Digital I/O connector**: 50-pin VHDCI female type

### Environment

- **Operating temperature**: 0 to +40 °C
- **Storage temperature range**: -25 to +85 °C
- **Relative humidity**: 10 to 95%, no condensation

### Calibration

- **Calibration interval**: 1 year