

# USB-Datenerfassung

## NI USB-6008

nidaq.tex KB 20081007



Für die Verwendung an der USB-Schnittstelle wurden in den letzten Jahren von verschiedenen Herstellern relativ preisgünstige Messsysteme entwickelt, die für viele einfache Messaufgaben durchaus ausreichend sind. Sie werden in der Regel über den USB auch mit Betriebsspannung versorgt, so dass keine weitere Stromversorgung erforderlich ist. Im Praktikum verwenden wir das NI USB-6008 der Firma National Instruments, einem der Marktführer auf diesem Gebiet. Das Messsystem bietet 8 analoge Eingänge (4 bei differenziellem Betrieb) und 2 analoge Ausgänge mit jeweils 12 Bit Auflösung, daneben 12 digitale Ein/Ausgänge und einen Zähler- bzw. Triggereingang. National Instruments bietet einen umfangreichen Software-Fundus zum Betrieb, in dem auch verschiedene einfache Beispielprogramme enthalten sind. Für die Einbindung in MATLAB oder Scilab sind dazu nur noch geringfügige Anpassungen zu machen.

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## 1 Hardware, Treiber und Hardwaretest

Zur einfacheren Handhabung im Praktikum ist das Messsystem mit einer Anschlussbox zusammenschaltet, durch die alle Anschlüsse über 2-mm-Buchsen zugänglich sind (Abbildung 1). Analoge und digitale Anschlüsse sind jeweils in getrennten Bereichen zusammengefasst, die Bezeichnungen entsprechen den im Handbuch und in der National-Instruments-Software verwendeten.

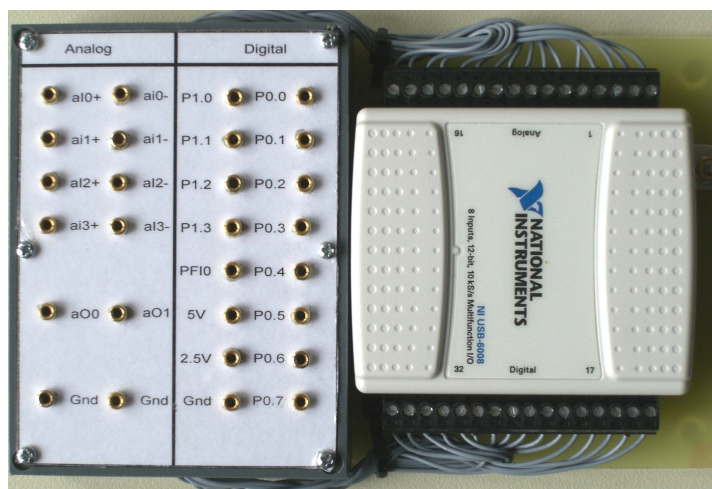


Abbildung 1: Datenerfassungssystem NI USB-6008 mit Anschlussbox.

Die Treibersoftware NI-DAQmx kann von der Web-Site von National Instruments bezogen werden, Hyperlink

<http://www.ni.com/dataacquisition/nidaqmx.htm>.

Sie muss auf dem Rechner installiert sein<sup>1</sup>, um das Messsystem betreiben zu können<sup>2</sup>. Neben den Gerätetreibern und Beispielprogrammen wird der *Measurement & Automation Explorer (MAX)* installiert, ein Verwaltungs- und Konfigurationsprogramm für die Hardware von National Instruments. Erste Tests führt man sinnvollerweise damit durch.

Nach dem ersten Anschließen des NI USB-6008 erfolgt der übliche *Plug-and-Play*-Ablauf, danach sollte das System als betriebsbereit gemeldet werden.

Zum Testen startet man MAX, der sollte das Messsystem finden und als NI-DAQmx-Gerät anzeigen (Abbildung 2).

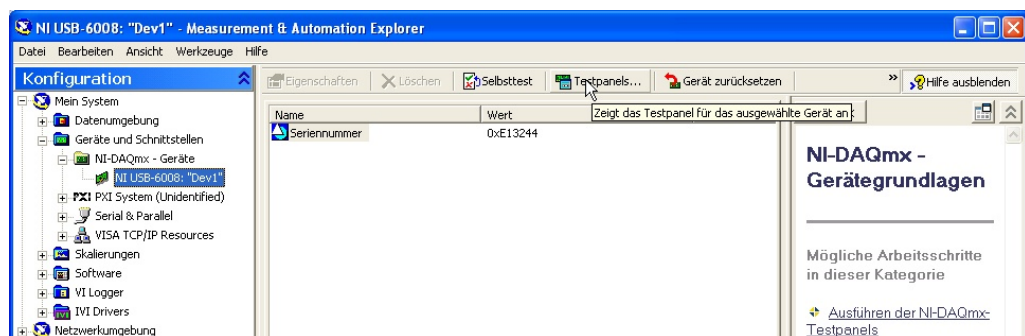


Abbildung 2: Der Measurement & Automation Explorer MAX.

Einfache Tests lassen sich mit den Testpanels durchführen. Dazu verbindet man einen der Ausgänge des Messsystems (ao0 und Masse) mit einem der differenziellen Eingänge (ai0+ und ai0-). Anschließend gibt man einen Spannungswert am Panel *Analoge Ausgabe* vor und misst den Wert am Panel *Analoge Erfassung* (Abbildung 3).

## 2 Betrieb unter MATLAB, MEX-Funktionen

Aus den von National Instruments mitgelieferten Beispielprogrammen in Ansi-C wurden zwei MEX-Funktionen in C++ entwickelt, `ni6008ao` für die analoge Ausgabe und `ni6008ai` für die analoge Erfassung. Die Listings finden Sie im Anhang<sup>3</sup>.

Zur Kompilierung der MEX-Funktionen muss unter MATLAB zunächst mit

<sup>1</sup> Falls LabView<sup>®</sup> verwendet wird, sollte es vorher installiert werden.

<sup>2</sup> Die Software sollte installiert werden, bevor das Messsystem angeschlossen wird.

<sup>3</sup> In den MEX-Funktionen ist als Gerätenamen "Dev1" eingestellt. Dieser Name wird vom National-Instruments-Treiber für das erste Gerät vergeben, das er kennt. Bei weiteren Geräten – leider aber auch beim Gerätewechsel – wird hochgezählt. In solchen Fällen muss das Gerät mit MAX wieder in "Dev1" umbenannt werden oder die MEX-Funktionen müssen angepasst werden.

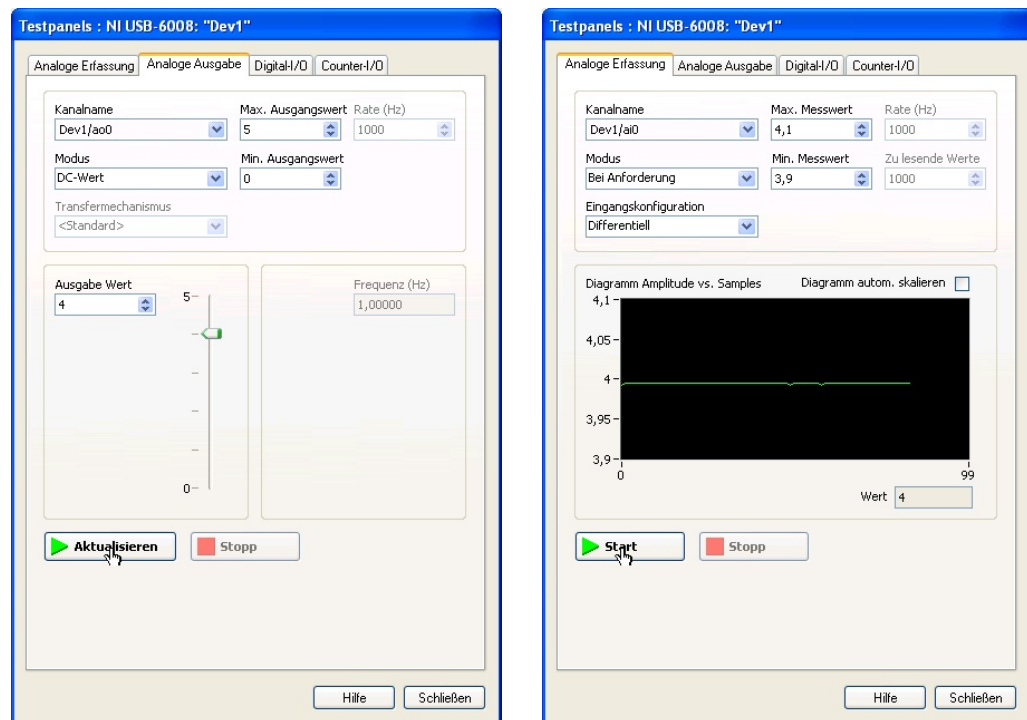


Abbildung 3: Testpanels für analoge Ausgabe und analoge Erfassung in MAX.

```
mex -setup
```

der benötigte Compiler eingerichtet werden (Microsoft Visual Studio), dann kann mit der Anweisung

```
mex -I'C:\Programme\National Instruments\NI-DAQ\DAQmx ANSI C Dev\include'...
-L'C:\Programme\National Instruments\NI-DAQ\DAQmx ANSI C Dev\lib\msvc'...
-lnidaqmx ni6008ao.cpp
```

kompiliert werden. Gegebenenfalls ist der Pfad zur National-Instruments-Software anzupassen.

Aufruf der MEX-Funktion für die **analoge Ausgabe** unter MATLAB mit

```
ni6008ao(outchannel,voltage);
```

darin outchannel=0,1, voltage=0..5.

Aufruf der MEX-Funktion für die **analoge Erfassung** durch

```
x=ni6008ai(inchannel);
```

mit inchannel=0..3; x ist dann ein Feld mit 500 Messwerten (Spannungswerte in V). Da die Messrate auf 5000 Hz eingestellt ist, erreicht man durch Mittelwertbildung über das Messwertfeld eine effektive Integrationszeitkonstante von 0.1 s. Alternativ kann durch einen zweiten Parameter eine andere Anzahl von Messwerten vorgegeben werden.

### 3 Einfache Messungen mit MATLAB: Kennlinien

Um Kennlinien – beispielsweise von Dioden – in dem vom Analogausgang des NI USB-6008 bereitgestellten Spannungsbereich von 0 bis 5 V zu messen, kann die in Abbildung 4 skizzierte Schaltung aufgebaut werden. Machen Sie sich das Messprinzip an einem vereinfachten Schaltplan klar. Den fertigen Aufbau zeigt Abbildung 5.

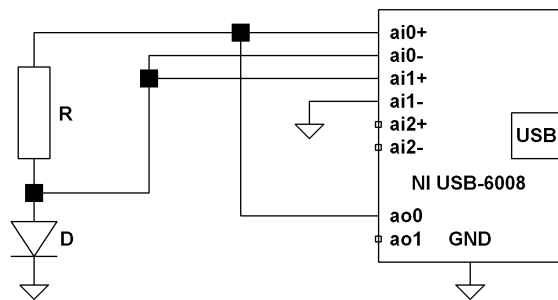


Abbildung 4: Schaltung zur Messung der Durchlasskennlinie von Dioden mit dem NI USB-6008.

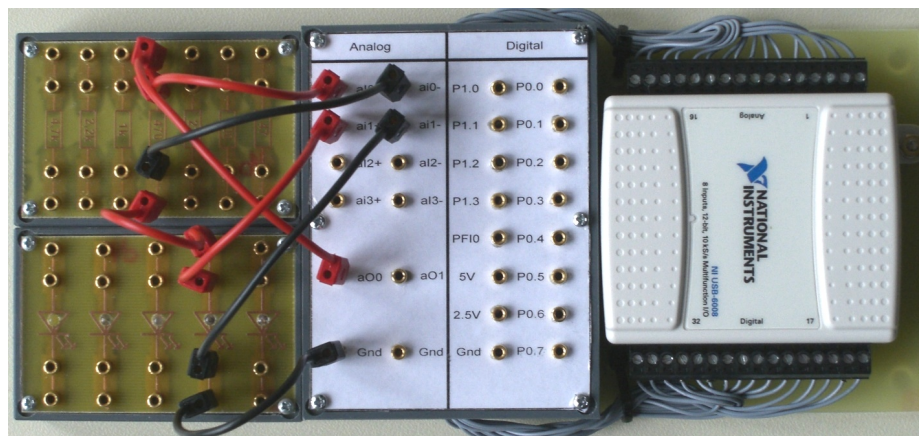


Abbildung 5: Messaufbau zur Schaltung der Abbildung 4.

Die Messung erledigt das nachstehende MATLAB-Skript. Durchlasskennlinien unterschiedlicher Lumineszenzdioden, die auf diese Weise gemessene wurden, sind in Abbildung 6 dargestellt.

```

1 function [u,c] = Diodenkennlinie(R)
2 if nargin==0, R = 470; end
3 Vzzero = 0; % 2.5 bei bipolarem Verstaerker
4 volts = linspace(0,5);
5 k = 1;
6 for v = volts,
7     ni6008ao(0,v);
8     c(k) = mean(ni6008ai(0))/R*1000; % mA
9     u(k) = mean(ni6008ai(1));
10    k = k+1;
11    hp = plot(u,c,'k');
12    set(gca,'XLim',[-10,6],'YLim',[-15,15]);
13    drawnow;
14 end
15 ni6008ao(0,Vzzero);

```

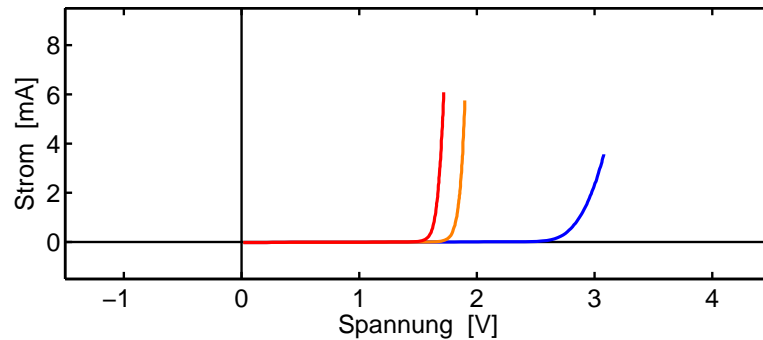


Abbildung 6: Durchlasskennlinien unterschiedlicher Lumineszenzdioden.

Aufgrund der begrenzten Ausgangsspannung kann immer nur eine Polarität gemessen werden. Benötigt man beide Polaritäten, kann man das durch zwei Messung erledigen, zwischen denen das Bauteil umgepolt wird. Ein Beispiel zeigt Abbildung 7, die nahezu symmetrische Kennlinie einer zweifarbigem Lumineszenzdiode. Überlegen Sie, wie die zweifarbigem Lumineszenzdiode intern aufgebaut ist, und begründen Sie die Kennlinienform.

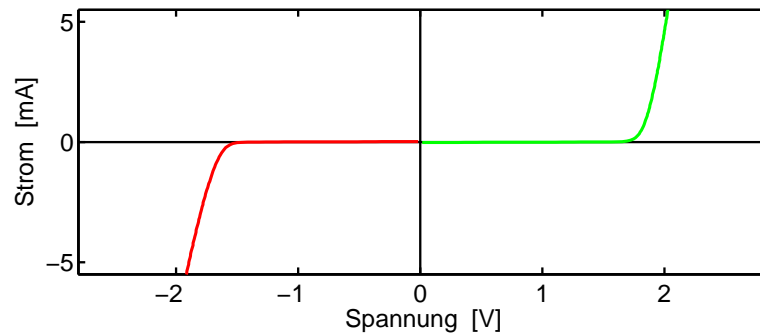


Abbildung 7: Kennlinie eine zweifarbigem Lumineszenzdiode; Zusammensetzung von zwei jeweils unipolar gemessenen Kennlinien.

#### 4 Differenziell – massebezogen – massefrei

Der NI USB-6008 verfügt über 8 Analogeingänge, die für unterschiedliche Betriebsarten konfiguriert werden können – einzeln als *massebezogene* oder jeweils paarweise als *differenzielle* Eingänge.

In der massebezogenen Betriebsart wird die Spannung gegen das gemeinsame Massepotenzial des Systems gemessen, in der differenziellen Betriebsart die Spannungsdifferenz zwischen den beiden beteiligten Eingängen. Die oben beschriebene MEX-Funktion zur analogen Erfassung stellt die differenzielle Betriebsart ein, darauf ist auch das Layout des Anschlusskästchens angepasst.

Differenzielle Betriebsart bedeutet jedoch nicht völlige Massefreiheit im Sinne einer kompletten Potenzialtrennung zwischen Eingängen und USB.

Das liegt daran, dass Verstärker und A/D-Wandler aus der üblichen 5-V-Betriebsspannung versorgt werden<sup>4</sup>. Die Spannungsfestigkeit der Eingänge gegenüber dem Massepotenzial liegt bei  $\pm 35$  V, dieser Wert darf unter keinen Umständen überschritten werden.

Bei vielen Messgeräten (z. B. einfachen Oszilloskopen) sind die Eingänge massebezogen. Das muss dann bei Messschaltungen berücksichtigt werden, damit nicht versehentlich Kurzschlüsse zum Massepotenzial auftreten. Beim NI USB-6008 können Sie die massebezogene Betriebsart dadurch simulieren, dass Sie die negativen Eingänge mit Masse verbinden. Wie müsste die Schaltung der Abbildung 4 und wie das Messprogramm modifiziert werden, um auch so Kennlinien messen zu können?

Aus naheliegenden Gründen sind die beiden Analogausgänge jeweils massebezogen: Die Spannungen werden aus der Betriebsspannung des USB generiert.

## 5 Ausgangsverstärker

Durch die Spannungsversorgung via USB sind die Ausgangsspannungen des NI USB-6008 auf den Bereich  $0 \dots 5$  V beschränkt. Benötigt man Spannungen außerhalb dieses Bereichs (um beispielsweise bei Dioden die Durchlass- und Sperrkennlinien ohne Umstecken zu messen), kann dieser Bereich durch geeignete lineare Verstärker erweitert werden. Im Praktikum steht ein Verstärkerbaustein zur Verfügung, der den Bereich auf  $0 \dots 10$  V ( $U_a = 2 \cdot U_e$ ) bzw. auf  $-10 \dots 10$  V ( $U_a = 4 \cdot U_e - 10$  V) erweitert (Abbildung 11).

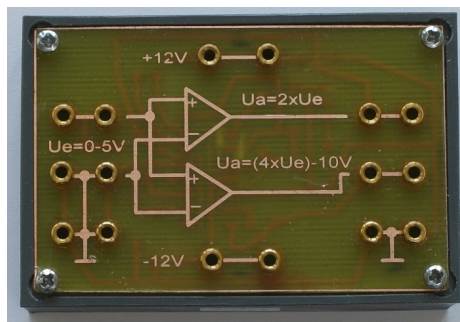


Abbildung 8: Verstärker für den Analogausgang des Messsystems NI USB-6008.

Zur Versorgung wird ein zusätzliches Netzteil benötigt ( $-12$  V,  $+12$  V), einen typischen Aufbau zeigt Abbildung 9.

Die Spannungen am Verstärker werden dort über drei differenzielle Analogeingänge des Ni USB-6008 gemessen. Auch hier lassen sich erste einfache Tests mit den Testpanels von MAX durchführen.

<sup>4</sup> Für eine echte Potenzialtrennung müsste man ein Teilsystem am Eingang mit potenzialgetrennter Stromversorgung oder mit Batterien betreiben und die digitalisierten Messdaten durch Optokoppler oder Lichtleiter übertragen.

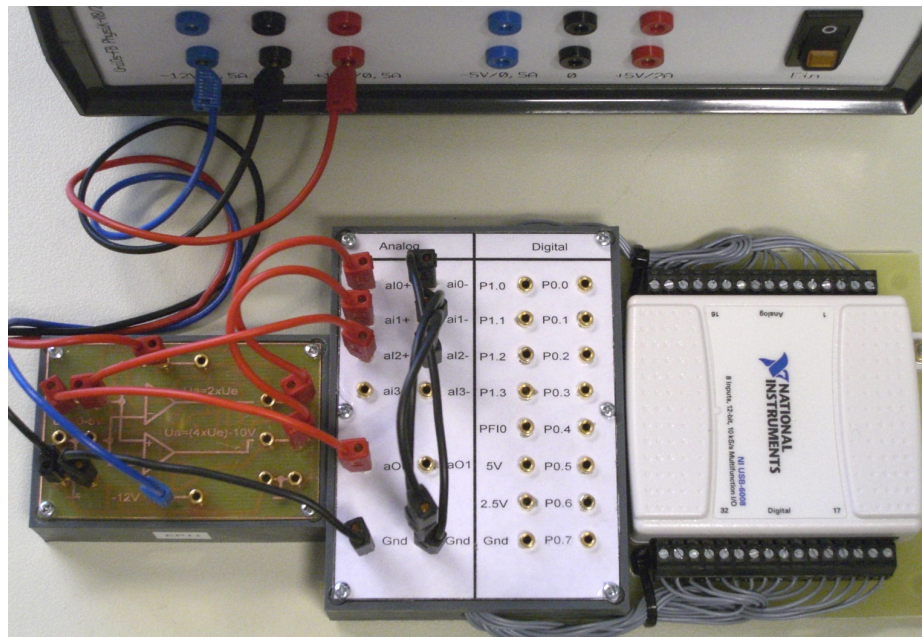


Abbildung 9: Messschaltung mit dem Spannungsverstärker.

## 6 Beispielmessungen

Drei Beispiele – Spannungen am Verstärker, Diodenkennlinien, Transistorkennlinien – sollen das Arbeiten mit der USB-Datenerfassung und dem Spannungsverstärker unter MATLAB veranschaulichen.

### 6.1 Spannungen am Verstärker

Es wird der in Abbildung 9 dargestellte Aufbau verwendet. Die Schaltung ist in Abbildung 10 skizziert.

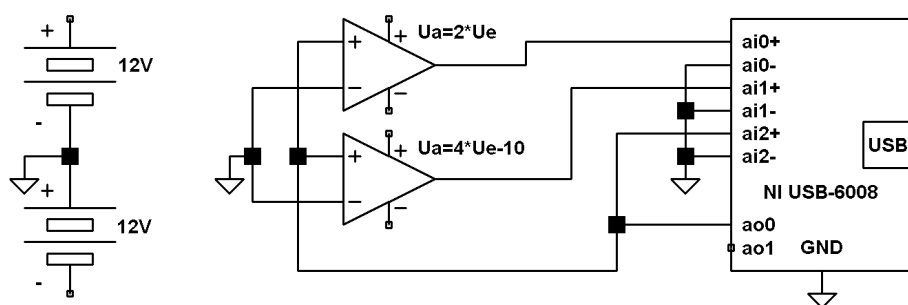


Abbildung 10: Schaltung zur Messung der Spannungen am Verstärker; die Verbindungen zur Spannungsversorgung (hier als Batterien symbolisiert) sind nicht mit eingezeichnet.

Die Messung der Spannungen am Verstärker als Funktion der Verstärkereingangsspannung (diese wird vom analogen Ausgang des Messsystems vorgegeben) kann durch das folgende MATLAB-Skript erledigt werden:



```

1 function [u0,u1,u2] = Verstaerker
2 volts = linspace(0,5);
3 k = 1;
4 for v = volts,
5     ni6008ao(0,v);
6     u(k) = v;
7     u0(k) = mean(ni6008ai(2));
8     u1(k) = mean(ni6008ai(1));
9     u2(k) = mean(ni6008ai(0));
10    k = k+1;
11    h0 = plot(u,u0,'k');
12    hold on;
13    h1 = plot(u,u1,'r');
14    h2 = plot(u,u2,'b');
15    hold off;
16    set(gca,'XLim',[0,5],'YLim',[-10.4,10.4]);
17    drawnow;
18 end
19 set([h0,h1,h2],'Linewidth',2);
20 set(gca,'Linewidth',1.5);
21 hx = xlabel('Vorgabespannung [V]');
22 hy = ylabel('Verstaerkererausgang [V]');
23 legend({'U_e','2*U_e','4*U_e-10'},'Location','SouthEast');
24 set([hx,hy,gca],'FontSize',16);

```

Der (wie erwartet lineare) Verlauf der Verstärkereingangs- und -ausgangsspannungen als Funktion der Vorgabespannung am Analogausgang des USB-Messsystems ist in Abbildung 11 dargestellt.

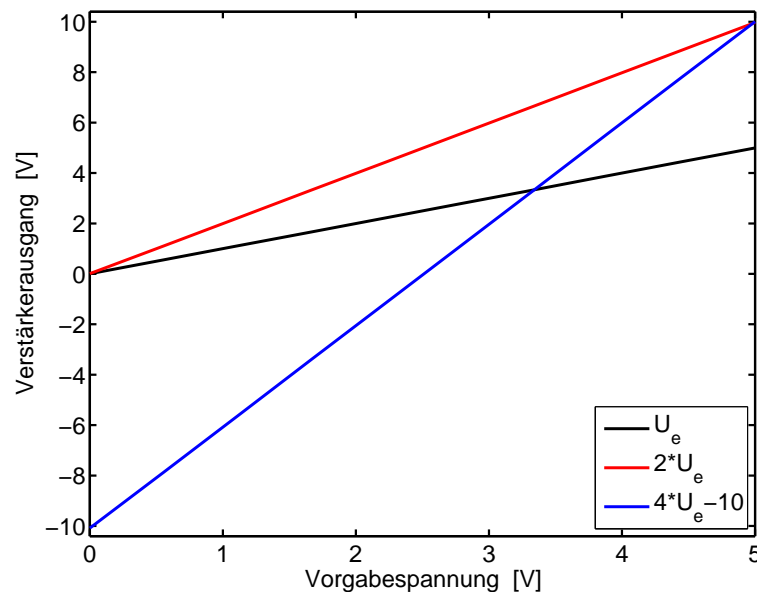


Abbildung 11: Gemessene Eingangs- und Ausgangsspannungen am Verstärker als Funktion der Vorgabespannung am Analogausgang des USB-Messsystems.

## 6.2 Diodenkennlinien

Zur Messung von Diodenkennlinien über einen weiteren Bereich (Durchlass- und Sperrkennlinie,  $-10 \dots 10$  V) verwendet man zweckmäßigerweise eine Schaltung wie in Abbildung 12, in der die Ausgangsspannung des D/A-Wandlers durch den linearen Verstärker auf den gewünschten Bereich umgesetzt wird. Diese Spannung wird an eine Reihenschaltung aus Widerstand und Diode angelegt. Aus den beiden am Vorwiderstand und an der Diode gemessenen Teilspannungen ergeben sich die Strom- und Spannungswerte der Kennlinie. Den Aufbau zeigt Abbildung 13.

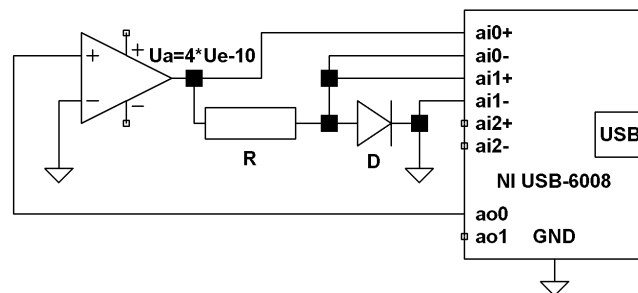


Abbildung 12: Schaltung zur Messung von Diodenkennlinien; die zusätzliche Spannungsversorgung für den Verstärker ist nicht mit eingezeichnet (vgl. Abbildung 10).

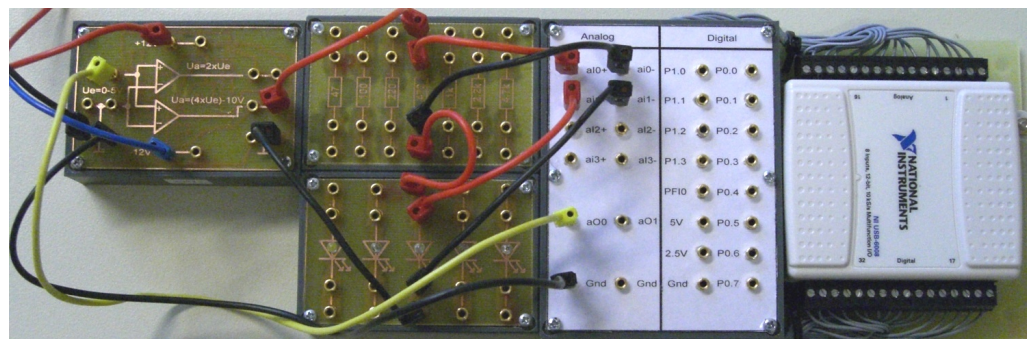


Abbildung 13: Aufbau zur Messung von Diodenkennlinien mit dem USB-Messsystem NI USB-6008.

Die Messung erledigt das aus Kapitel 3 bekannte MATLAB-Skript, auf diese Weise gemessene Kennlinien sind in Abbildung 14 dargestellt.

## 6.3 Transistorkennlinien

Als Beispiel für Transistorkennlinien messen wir die Ausgangskennlinie eines npn-Transistors. In der Schaltung (Abbildung 15) wird der zweite Analogausgang des Messsystems dazu verwendet, die Basisspannung bzw. mit einem geeigneten Vorwiderstand  $R_b$  (100 k) den Basisstrom vorzugeben. Die restliche Schaltung entspricht der für die Messung der Diodenkennlinien. Den Aufbau zeigt Abbildung 16.

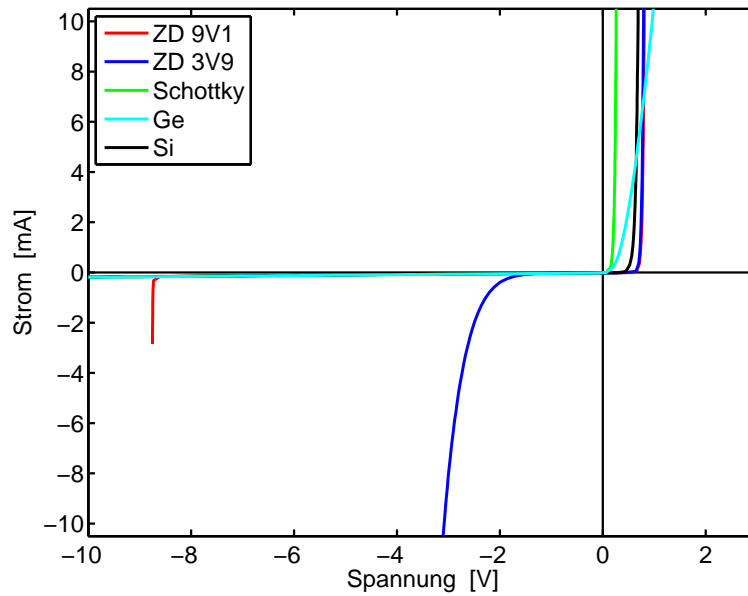


Abbildung 14: Diodenkennlinien: Zwei unterschiedliche Zenerdioden, eine Schottky-, eine Germanium- und eine Siliziumdiode.

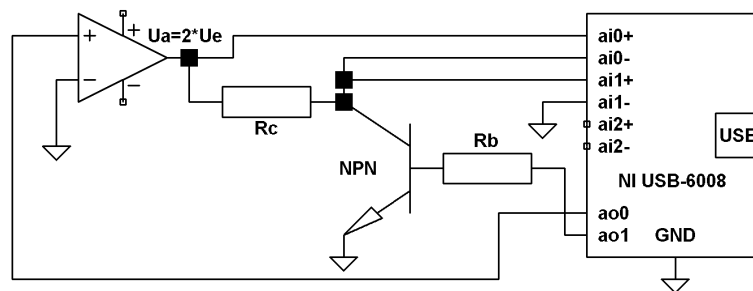


Abbildung 15: Schaltung zur Messung von Ausgangskennlinien an npn-Transistoren.

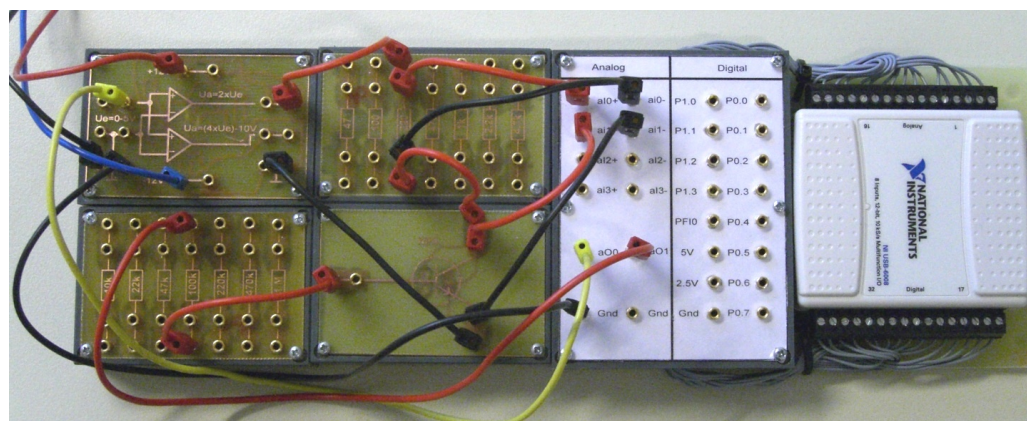


Abbildung 16: Aufbau zur Messung der Ausgangskennlinien von npn-Transistoren mit dem USB-Messsystem NI USB-6008.

Auch hier wieder das zuständige MATLAB-Skript und die damit gemessenen Ausgangskennlinien (Abbildung 17)

```
1 function [u,c] = Transistorkennlinie(Rc, Ub)
2 if nargin<2, Ub=4; end
3 if nargin<1, Rc=220; end
4 ni6008ao(1,Ub); % Basisspannung
5 volts = linspace(0,5);
6 k = 1;
7 for v = volts,
8     ni6008ao(0,v);
9     c(k) = mean(ni6008ai(0))/Rc*1000; % mA
10    u(k) = mean(ni6008ai(1));
11    k = k+1;
12    hp = plot(u,c,'k');
13    set(gca,'XLim',[0,10],'YLim',[0,15]);
14    drawnow;
15 end
16 ni6008ao(0,0);
17 ni6008ao(1,0);
```

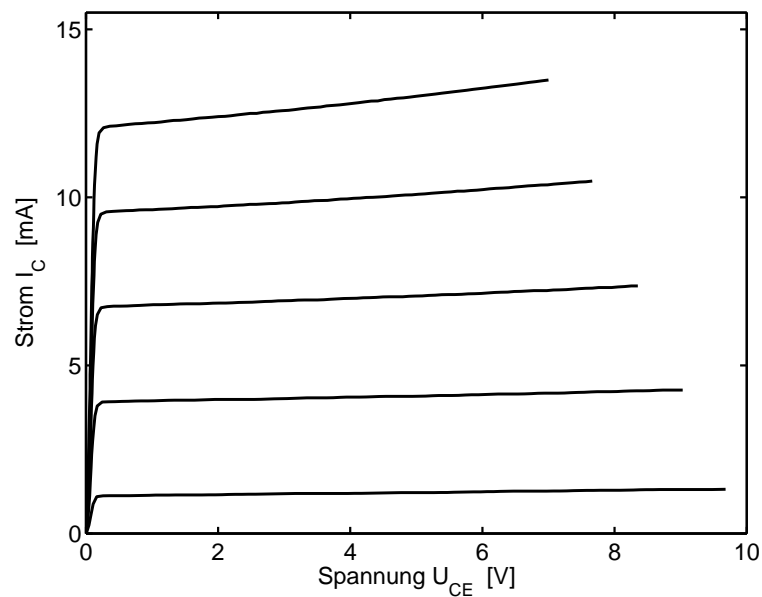


Abbildung 17: Ausgangskennlinien eines npn-Transistors.

**A Analoge Ausgabe: MEX-Programm ni6008ao**

```
1 // ni6008ao.cpp (c) KB 20070806
2
3 // analog output ni6008
4 // call from MATLAB thru "ni6008ao(channel,voltage)"
5 // with: channel=0,1; voltage=0..5
6
7 #include "mex.h"
8 #include "NIDAQmx.h"
9
10 void mexFunction( int nlhs, mxArray *plhs[],
11                 int nrhs, const mxArray *prhs[] )
12 {
13     if (nrhs==0)
14         return;
15     TaskHandle taskHandle = 0;
16
17     uInt32 channel = mxGetScalar(prhs[0]);
18     if (channel>1)
19         return;
20     double voltage = 0;
21     if (nrhs>1)
22         voltage = mxGetScalar(prhs[1]);
23
24     char chan[20];
25     sprintf(chan,"Dev1/ao%1d", channel);
26     float64 min = 0.0;
27     float64 max = 5.0;
28     float64 timeout = 10.0;
29
30     DAQmxCreateTask("",&taskHandle);
31     DAQmxCreateAOVoltageChan(taskHandle,chan,"",min,max,DAQmx_Val_Volts,NULL);
32     DAQmxStartTask(taskHandle);
33
34     DAQmxWriteAnalogScalarF64(taskHandle,TRUE,timeout,voltage,NULL);
35
36     if( taskHandle!=0 ) {
37         DAQmxStopTask(taskHandle);
38         DAQmxClearTask(taskHandle);
39     }
40 }
```

**B Analoge Erfassung: MEX-Programm ni6008ai**

```
1 // ni6008ai.cpp (c) KB 20050901
2
3 // analog differential input ni6008
4
5 // call from MATLAB using "x=ni6008ai(channel)"
6 // or "x=ni6008ai(channel,samples)"
7 // average by "voltage=mean(x)"
8
9 #include "mex.h"
10 #include "NIDAQmx.h"
11
12 void mexFunction( int nlhs, mxArray *plhs[],
```

```

13     int nrhs, const mxArray *prhs[] )
14 {
15     TaskHandle taskHandle = 0;
16
17     char        source[] = "OnboardClock";
18     uInt32      channel = 0;
19     if (nrhs>0)
20         channel = mxGetScalar(prhs[0]);
21     if (channel>7)
22         channel = 0;
23     uInt32      samplesPerChan = 500;
24     if (nrhs>1)
25         samplesPerChan = mxGetScalar(prhs[1]);
26     uInt32      bufferSize = samplesPerChan;
27     uInt32      pointsToRead = samplesPerChan;
28     float64     sampleRate = 5000.0;
29
30     char chan[20];
31     sprintf(chan,"Dev1/ai%1d", channel);
32     float64     min = -10;
33     float64     max = 10;
34
35     plhs[0] = mxCreateDoubleMatrix(samplesPerChan,1, mxREAL);
36     double * data = mxGetPr(plhs[0]);
37
38     int32       pointsRead;
39     float64     timeout = 10.0;
40
41     DAQmxCreateTask("",&taskHandle);
42     DAQmxCreateAIVoltageChan (taskHandle, chan, "", DAQmx_Val_Cfg_Default,
min, max, DAQmx_Val_Volts, NULL);
43     DAQmxCfgSampClkTiming (taskHandle, source, sampleRate, DAQmx_Val_Rising,
DAQmx_Val_FiniteSamps, samplesPerChan);
44     DAQmxStartTask(taskHandle);
45
46     DAQmxReadAnalogF64 (taskHandle, pointsToRead, timeout, 0, data, bufferSize,
&pointsRead, NULL);
47
48     if( taskHandle!=0 ) {
49         DAQmxStopTask(taskHandle);
50         DAQmxClearTask(taskHandle);
51     }
52 }

```

## C User Guide USB-6008/6009

Auf den folgenden Seiten finden Sie den *User Guide* mit der ausführlichen Hardware-Beschreibung des NI USB-6008.

# USER GUIDE

# USB-6008/6009

This user guide describes how to use the National Instruments USB-6008/6009 data acquisition (DAQ) devices.

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## Introduction

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The NI USB-6008/6009 provides connection to eight analog input (AI) channels, two analog output (AO) channels, 12 digital input/output (DIO) channels, and a 32-bit counter when using a full-speed USB interface.

**Table 1-1.** Differences Between the USB-6008 and USB-6009

Feature	USB-6008	USB-6009
AI Resolution	12 bits differential, 11 bits single-ended	14 bits differential, 13 bits single-ended
Maximum AI Sample Rate*	10 kS/s	48 kS/s
DIO Configuration	Open-drain	Open-drain or push-pull
* Might be system dependent		



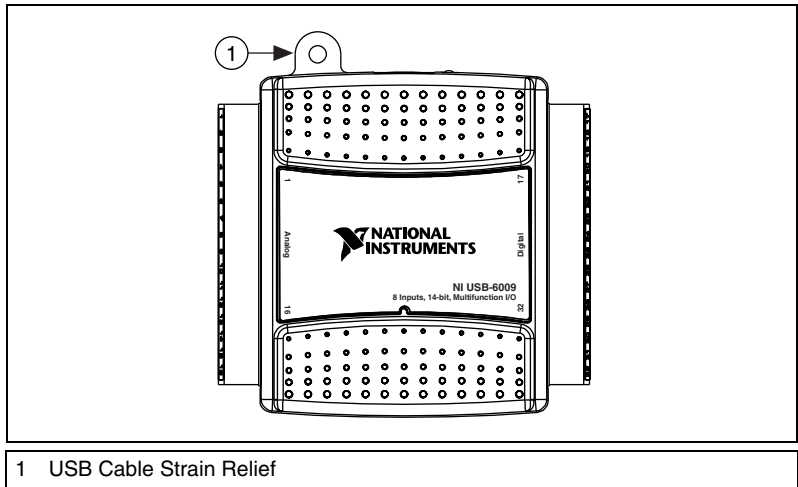


Figure 2. USB-6008/6009

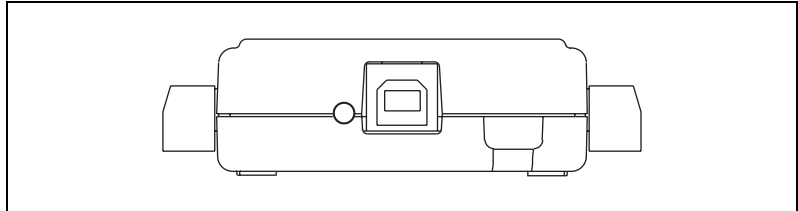


Figure 3. USB-6008/6009 Back View

## Safety Guidelines



**Caution** Operate the hardware only as described in these operating instructions.

The following section contains important safety information that you must follow when installing and using the USB-6008/6009.

Do not operate the USB-6008/6009 in a manner not specified in this document. Misuse of the device can result in a hazard. You can compromise the safety protection built into the device if the device is damaged in any way. If the device is damaged, contact National Instruments for repair.

Do not substitute parts or modify the device except as described in this document. Use the device only with the chassis, modules, accessories, and cables specified in the installation instructions. You must have all covers and filler panels installed during operation of the device.

Do not operate the device in an explosive atmosphere or where there may be flammable gases or fumes. If you must operate the device in such an environment, it must be in a suitably rated enclosure.

If you need to clean the device, use a dry cloth. Make sure that the device is completely dry and free from contaminants before returning it to service.

Operate the device only at or below Pollution Degree 2. Pollution is foreign matter in a solid, liquid, or gaseous state that can reduce dielectric strength or surface resistivity. The following is a description of pollution degrees:

- Pollution Degree 1 means no pollution or only dry, nonconductive pollution occurs. The pollution has no influence.
- Pollution Degree 2 means that only nonconductive pollution occurs in most cases. Occasionally, however, a temporary conductivity caused by condensation must be expected.
- Pollution Degree 3 means that conductive pollution occurs, or dry, nonconductive pollution occurs that becomes conductive due to condensation.

You must insulate signal connections for the maximum voltage for which the device is rated. Do not exceed the maximum ratings for the device. Do not install wiring while the device is live with electrical signals. Do not remove or add connector blocks when power is connected to the system. Avoid contact between your body and the connector block signal when hot swapping modules. Remove power from signal lines before connecting them to or disconnecting them from the device.

Operate the device at or below the Measurement Category I<sup>1</sup>. Measurement circuits are subjected to working voltages<sup>2</sup> and transient stresses (overvoltage) from the circuit to which they are connected during measurement or test. Measurement categories establish standard impulse withstand voltage levels that commonly occur in electrical distribution systems. The following is a description of measurement categories:

- Measurement Category I is for measurements performed on circuits not directly connected to the electrical distribution system referred to as MAINS<sup>3</sup> voltage. This category is for measurements of voltages from specially protected secondary circuits. Such voltage measurements include signal levels, special equipment, limited-energy parts of equipment, circuits powered by regulated low-voltage sources, and electronics.

---

<sup>1</sup> Measurement Category as defined in electrical safety standard IEC 61010-1. Measurement Category is also referred to as Installation Category.

<sup>2</sup> Working Voltage is the highest rms value of an AC or DC voltage that can occur across any particular insulation.

<sup>3</sup> MAINS is defined as a hazardous live electrical supply system that powers equipment. Suitably rated measuring circuits may be connected to the MAINS for measuring purposes.

- Measurement Category II is for measurements performed on circuits directly connected to the electrical distribution system. This category refers to local-level electrical distribution, such as that provided by a standard wall outlet (for example, 115 V for U.S. or 230 V for Europe). Examples of Measurement Category II are measurements performed on household appliances, portable tools, and similar E Series devices.
- Measurement Category III is for measurements performed in the building installation at the distribution level. This category refers to measurements on hard-wired equipment such as equipment in fixed installations, distribution boards, and circuit breakers. Other examples are wiring, including cables, bus-bars, junction boxes, switches, socket-outlets in the fixed installation, and stationary motors with permanent connections to fixed installations.
- Measurement Category IV is for measurements performed at the primary electrical supply installation (<1,000 V). Examples include electricity meters and measurements on primary overcurrent protection devices and on ripple control units.

## Software

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Software support for the USB-6008/6009 is provided by NI-DAQmx Base, which is a subset of the NI-DAQmx API.

The NI-DAQmx Base CD contains example programs that you can use to get started programming with the USB-6008/6009. Refer to the *NI-DAQmx Base 1.x Getting Started Guide* for more information.

## Logging Application

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NI-DAQmx Base includes ready-to-run datalogging software that allows you to take data measurements without programming first. The application is available at **Start»All Programs»National Instruments»NI-DAQmx Base»Datalogging Software**.

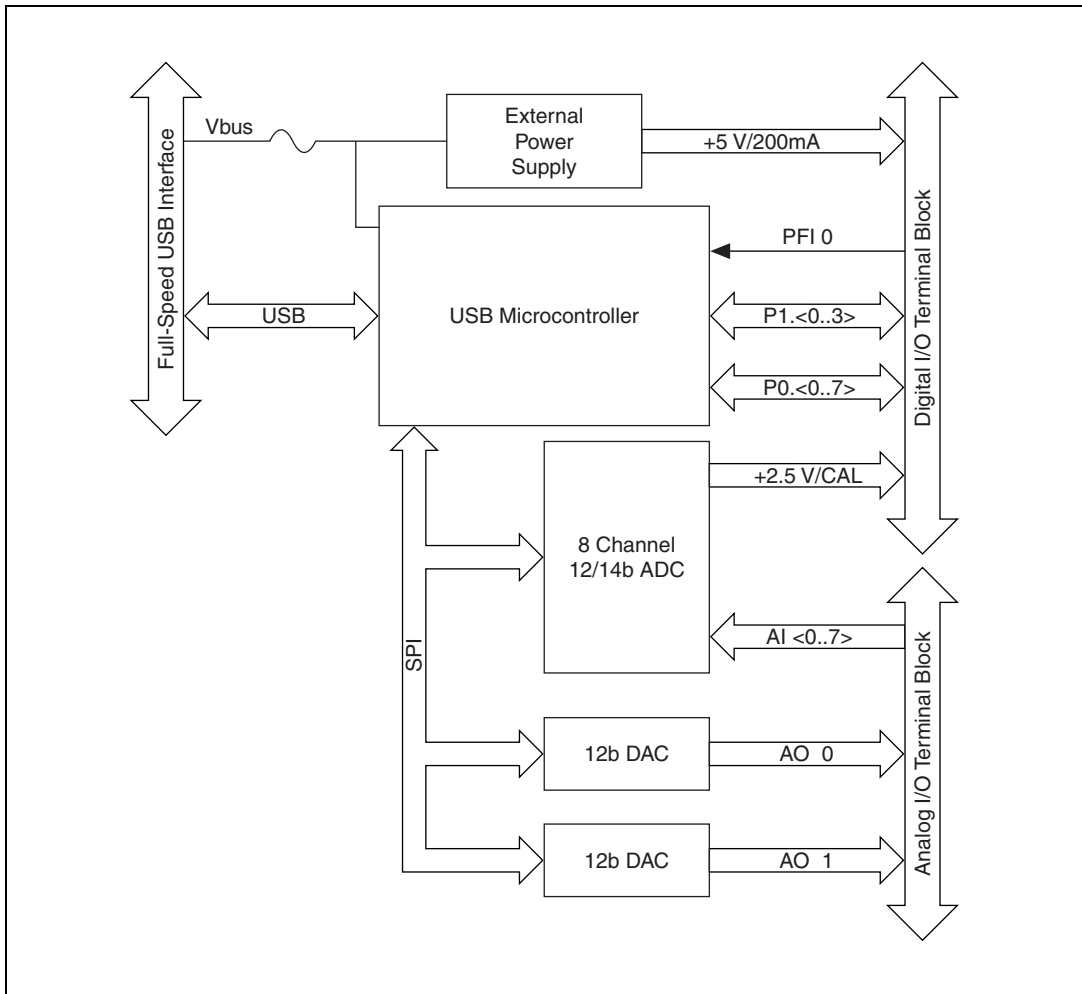
## Self Test

---

NI-DAQmx Base includes an interactive control panel example that can be used to verify the operation of the USB-6008/6009. The application is located in **Start»All Programs»National Instruments»NI-DAQmx Base»Examples**.

# Hardware

The following block diagram shows key functional components of the USB-6008/6009.



**Figure 4.** Device Block Diagram

# Setting Up Hardware

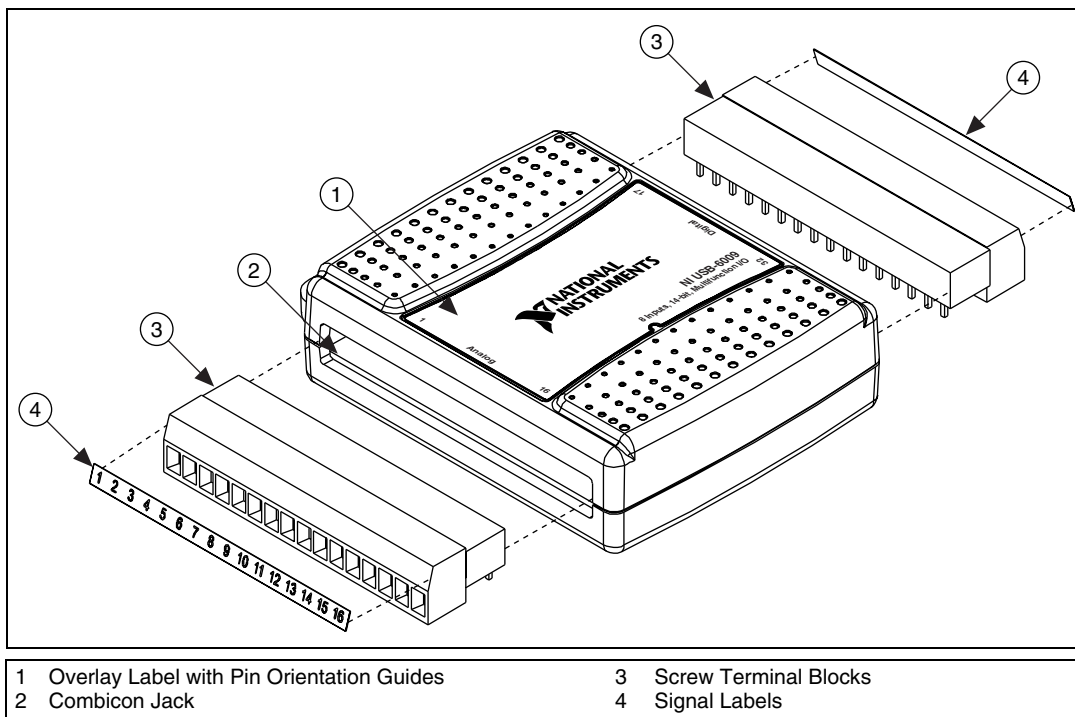
Complete the following steps to set up the hardware:

1. Install combicon screw terminal blocks by inserting them into the combicon jacks.



**Note** The USB-6008/6009 kit ships with signal labels. You can apply the signal labels to the screw terminal blocks for easy signal identification.

2. Refer to Table 1 and Figure 5 for label orientation and affix the provided signal labels to the screw terminal blocks. Until the signal labels are applied, you can insert the screw terminal blocks into either of the combicon jacks. Refer to Figure 5 for more information about signal label orientation.



**Figure 5.** Signal Label Application Diagram



**Note** Once you label the screw terminal blocks, you must only insert them into the matching combicon jack, as indicated by the overlay label on the USB-6008/6009 device.

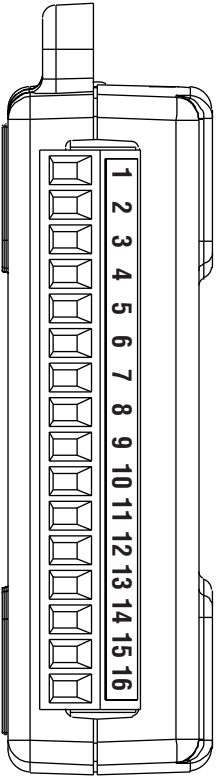
3. Connect the wiring to the appropriate screw terminals.

# I/O Connector

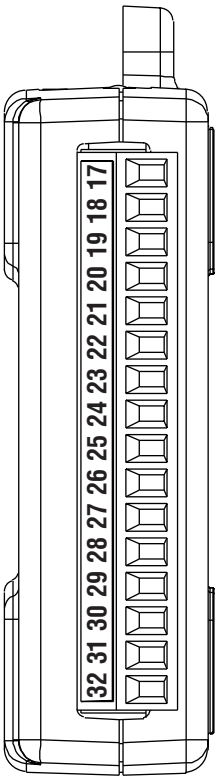
The USB-6008/6009 ships with one detachable screw terminal block for analog signals and one detachable screw terminal block for digital signals. These terminal blocks provide 16 connections that use 16 AWG to 28 AWG wire.

Table 1 lists the analog terminal assignments, and Table 2 lists the digital terminal assignments.

**Table 1.** Analog Terminal Assignments

Module	Terminal	Signal, Single-Ended Mode	Signal, Differential Mode
	1	GND	GND
	2	AI 0	AI 0+
	3	AI 4	AI 0-
	4	GND	GND
	5	AI 1	AI 1+
	6	AI 5	AI 1-
	7	GND	GND
	8	AI 2	AI 2+
	9	AI 6	AI 2-
	10	GND	GND
	11	AI 3	AI 3+
	12	AI 7	AI 3-
	13	GND	GND
	14	AO 0	AO 0
	15	AO 1	AO 1
	16	GND	GND

**Table 2.** Digital Terminal Assignments

Module	Terminal	Signal
 <p>A detailed line drawing of a 32-pin terminal block. The pins are arranged in two rows of 16. The top row is numbered 17 through 32, and the bottom row is numbered 1 through 16. The drawing shows the physical shape of the terminal block, including mounting tabs and a central channel.</p>	17	P0.0
	18	P0.1
	19	P0.2
	20	P0.3
	21	P0.4
	22	P0.5
	23	P0.6
	24	P0.7
	25	P1.0
	26	P1.1
	27	P1.2
	28	P1.3
	29	PFI 0
	30	+2.5 V
	31	+5 V
	32	GND

# Signal Descriptions

Table 3 describes the signals available on the I/O connectors.

**Table 3.** Signal Descriptions

Signal Name	Reference	Direction	Description
GND	—	—	<b>Ground</b> —The reference point for the single-ended AI measurements, bias current return point for differential mode measurements, AO voltages, digital signals at the I/O connector, +5 VDC supply, and the +2.5 VDC reference.
AI <0..7>	Varies	Input	<b>Analog Input Channels 0 to 7</b> —For single-ended measurements, each signal is an analog input voltage channel. For differential measurements, AI 0 and AI 4 are the positive and negative inputs of differential analog input channel 0. The following signal pairs also form differential input channels: <AI 1, AI 5>, <AI 2, AI 6>, and <AI 3, AI 7>.
AO 0	GND	Output	<b>Analog Channel 0 Output</b> —Supplies the voltage output of AO channel 0.
AO 1	GND	Output	<b>Analog Channel 1 Output</b> —Supplies the voltage output of AO channel 1.
P1.<0..3> P0.<0..7>	GND	Input or Output	<b>Digital I/O Signals</b> —You can individually configure each signal as an input or output.
+2.5 V	GND	Output	<b>+2.5 V External Reference</b> —Provides a reference for wrap-back testing.
+5 V	GND	Output	<b>+5 V Power Source</b> —Provides +5 V power up to 200 mA.
PFI 0	GND	Input	<b>PFI 0</b> —This pin is configurable as either a digital trigger or an event counter input.

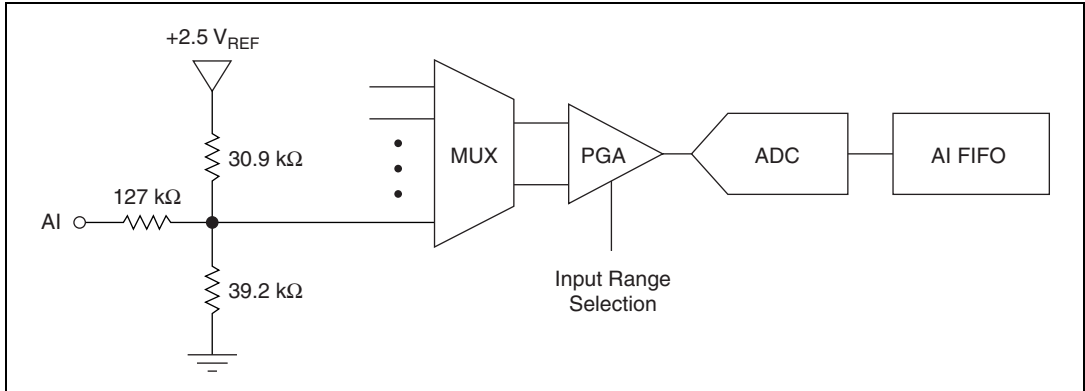


# Analog Input

You can connect analog input signals to the USB-6008/6009 through the I/O connector. Refer to Table 3 for more information about connecting analog input signals.

## Analog Input Circuitry

Figure 6 illustrates the analog input circuitry of the USB-6008/6009.



**Figure 6.** Analog Input Circuitry

### MUX

The USB 6008/6009 has one analog-to-digital converter (ADC). The multiplexer (MUX) routes one AI channel at a time to the PGA.

### PGA

The programmable-gain amplifier provides input gains of 1, 2, 4, 5, 8, 10, 16, or 20 when configured for differential measurements and gain of 1 when configured for single-ended measurements. The PGA gain is automatically calculated based on the voltage range selected in the measurement application.

### A/D Converter

The analog-to-digital converter (ADC) digitizes the AI signal by converting the analog voltage into a digital code.

## AI FIFO

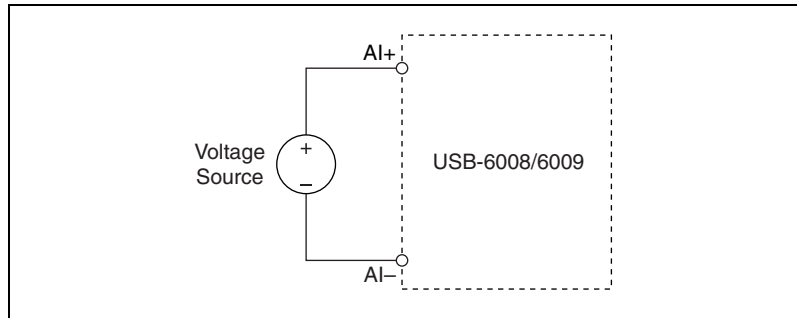
The USB-6008/6009 can perform both single and multiple A/D conversions of a fixed or infinite number of samples. A first-in-first-out (FIFO) buffer holds data during AI acquisitions to ensure that no data is lost.

## Analog Input Modes

You can configure the AI channels on the USB-6008/6009 to take single-ended or differential measurements. Refer to Table 3 for more information about I/O connections for single-ended or differential measurements.

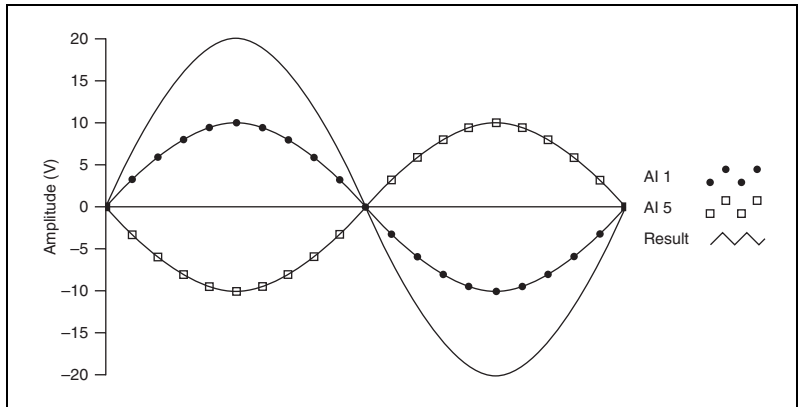
### Connecting Differential Voltage Signals

For differential signals, connect the positive lead of the signal to the AI+ terminal, and the negative lead to the AI- terminal.



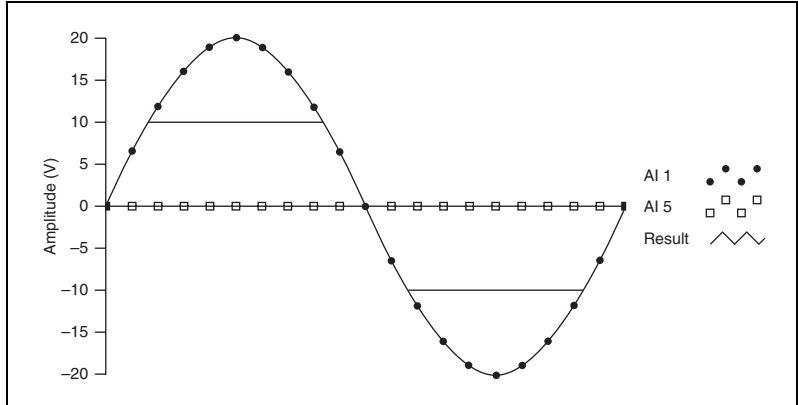
**Figure 7.** Connecting a Differential Voltage Signal

The differential input mode can measure  $\pm 20$  V signals in the  $\pm 20$  V range. However, the maximum voltage on any one pin is  $\pm 10$  V with respect to GND. For example, if AI 1 is +10 V and AI 5 is -10 V, then the measurement returned from the device is +20 V.



**Figure 8.** Example of a Differential 20 V Measurement

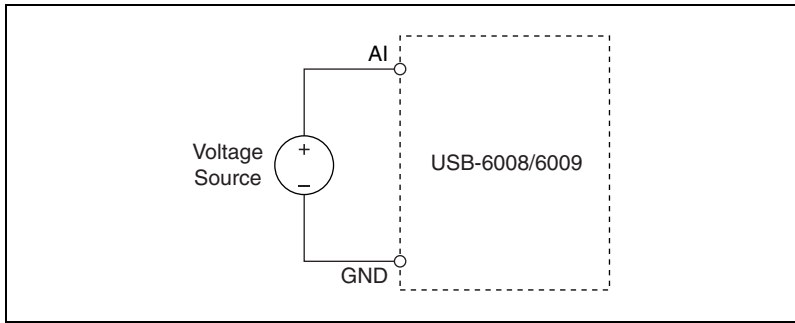
Connecting a signal greater than  $\pm 10$  V on either pin results in a clipped output.



**Figure 9.** Exceeding +10 V on AI Returns Clipped Output

## Connecting Reference Single-Ended Voltage Signals

To connect reference single-ended voltage signals (RSE) to the USB-6008/6009, connect the positive voltage signal to the desired AI terminal, and the ground signal to a GND terminal.



**Figure 10.** Connecting a Differential Voltage Signal

## Digital Trigger

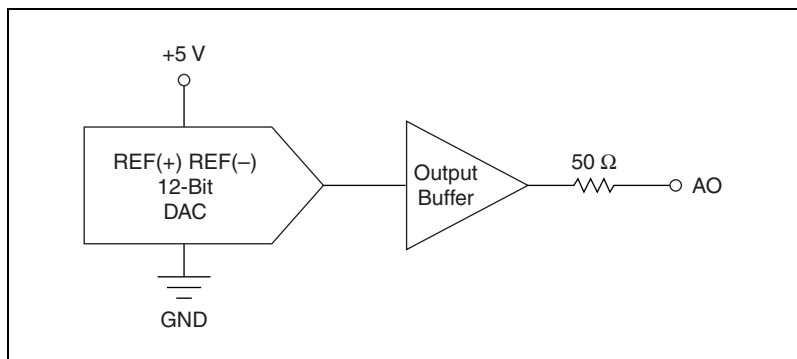
When an AI task is defined, you can configure PFI 0 as a digital trigger input. When the digital trigger is enabled, the AI task waits for a rising edge on PFI 0 before starting the acquisition. To use ai/Start Trigger with a digital source, specify PFI 0 as the source and select rising edge.

## Analog Output

The USB-6008/6009 has two independent AO channels that can generate outputs from 0–5 V. All updates of AO lines are software-timed.

## Analog Output Circuitry

Figure 11 illustrates the analog output circuitry for the USB-6008/6009.



**Figure 11.** Analog Output Circuitry

## DACs

Digital-to-analog converters (DACs) convert digital codes to analog voltages.

## Connecting Analog Output Loads

To connect loads to the USB-6008/6009, connect the positive lead of the load to the AO terminal, and connect the ground of the load to a GND terminal.

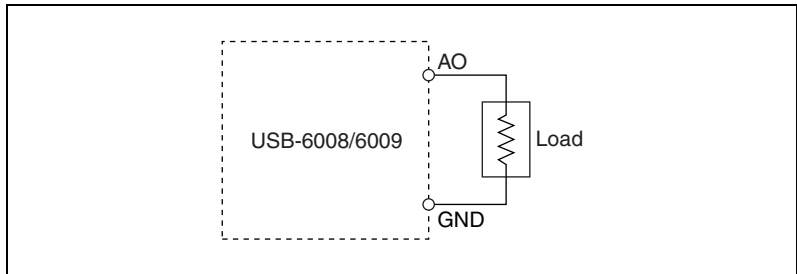


Figure 12. Connecting a Load

## Minimizing Glitches on the Output Signal

When you use a DAC to generate a waveform, you may observe glitches in the output signal. These glitches are normal; when a DAQ switches from one voltage to another, it produces glitches due to released charges. The largest glitches occur when the most significant bit of the DAC code changes. You can build a low-pass deglitching filter to remove some of these glitches, depending on the frequency and nature of the output signal. Refer to [ni.com/support](http://ni.com/support) for more information about minimizing glitches.

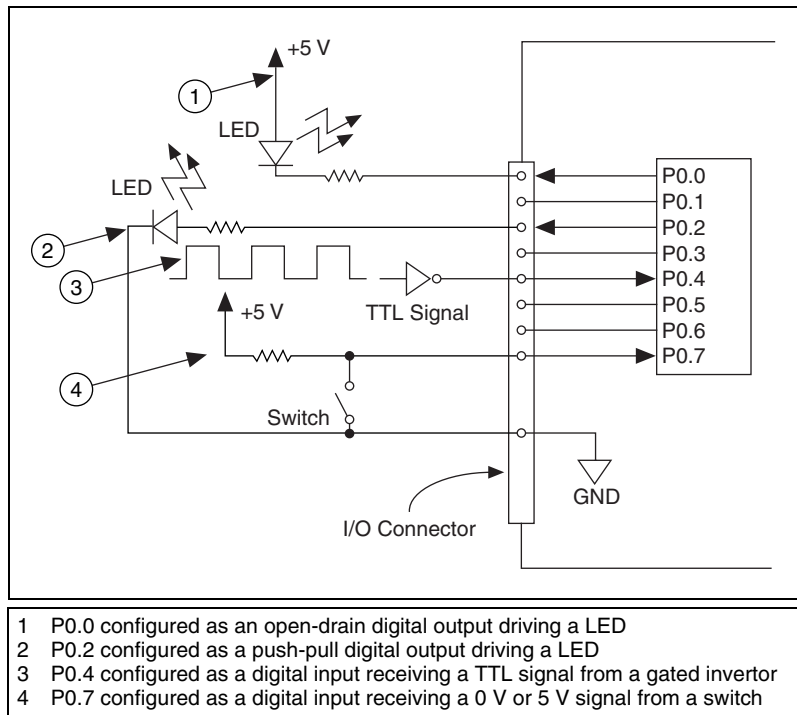
## Digital I/O

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The USB-6008/6009 has 12 digital lines, P0.<0..7> and P1.<0..3>, which comprise the DIO port. GND is the ground-reference signal for the DIO port. You can individually program all lines as inputs or outputs.

### Digital I/O Circuitry

Figure 13 shows P0.<0..7> connected to example signals configured as digital inputs and digital outputs. You can configure P1.<0..3> similarly.



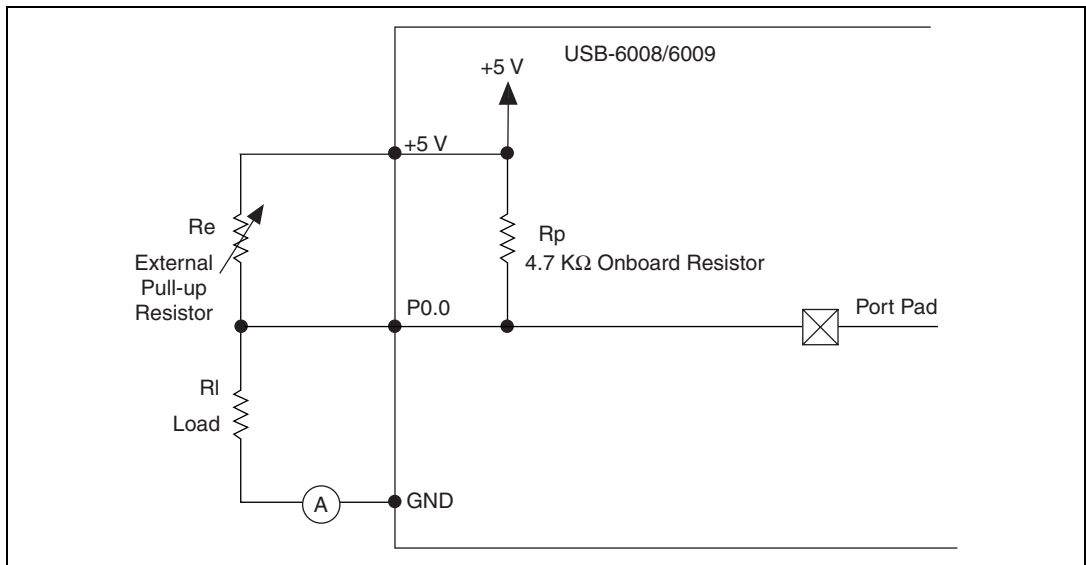
**Figure 13.** Example of Connecting a Load



**Caution** Exceeding the maximum input voltage ratings or maximum output ratings, which are listed in the specifications, can damage the DAQ device and the computer. National Instruments is not liable for any damage resulting from such signal connections.

## Source/Sink Information

The default configuration of the USB-6008/6009 DIO ports is open-drain, allowing 5 V operation, with an onboard 4.7 k $\Omega$  pull-up resistor. An external, user-provided, pull-up resistor can be added to increase the source current drive up to a 8.5 mA limit per line as shown in Figure 14.



**Figure 14.** Example of Connecting External User-Provided Resistor

Complete the following steps to determine the value of the user-provided pull-up resistor:

1. Place an ammeter in series with the load.
2. Place a variable resistor between the digital output line and the +5 V.
3. Adjust the variable resistor until the ammeter current reads as the intended current. The intended current must be less than 8.5 mA.
4. Remove the ammeter and variable resistor from your circuit.
5. Measure the resistance of the variable resistor. The measured resistance is the ideal value of the pull-up resistor.
6. Select a static resistor value for your pull-up resistor that is greater than or equal to the ideal resistance.
7. Re-connect the load circuit and the pull-up resistor.

## I/O Protection

To protect the USB-6008/6009 against overvoltage, undervoltage, and overcurrent conditions, as well as ESD events, you should avoid these fault conditions by using the following guidelines:

- If you configure a DIO line as an output, do not connect it to any external signal source, ground signal, or power supply.
- If you configure a DIO line as an output, understand the current requirements of the load connected to these signals. Do not exceed the specified current output limits of the DAQ device.

National Instruments has several signal conditioning solutions for digital applications requiring high current drive.

- If you configure a DIO line as an input, do not drive the line with voltages outside of its normal operating range. The DIO lines have a smaller operating range than the AI signals.
- Treat the DAQ device as you would treat any static sensitive device. Always properly ground yourself and the equipment when handling the DAQ device or connecting to it.

## Power-On States

At system startup and reset, the hardware sets all DIO lines to high-impedance inputs. The DAQ device does not drive the signal high or low. Each line has a weak pull-up resistor connected to it.

## Static DIO

Each of the USB-6008/6009 DIO lines can be used as a static DI or DO line. You can use static DIO lines to monitor or control digital signals. All samples of static DI lines and updates of DO lines are software-timed.

## Event Counter

---

You can configure PFI 0 as a source for a gated inverter counter input edge count task. In this mode, falling-edge events are counted using a 32-bit counter. For more information about event timing requirements, refer to the [Specifications](#) section.

## Reference and Power Sources

---

The USB-6008/6009 creates an external reference and supplies a power source.

### +2.5 External References

The USB-6008/6009 creates a high-purity reference voltage supply for the ADC using a multi-state regulator, amplifier, and filter circuit. The resulting +2.5 V reference voltage can be used as a signal for self test. Refer to the [Self Test](#) section, for more information.



## +5 V Power Source

The USB-6008/6009 supplies a 5 V, 200 mA output. This source can be used to power external components.



**Note** While the device is in USB suspend, the output is disabled.

## Specifications

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The following specifications are typical at 25 °C, unless otherwise noted.

### Analog Input

Converter type.....	Successive approximation
Analog inputs .....	8 single-ended/4 differential, software selectable
Input resolution	
USB-6008 .....	12 bits differential, 11 bits single-ended
USB-6009 .....	14 bits differential, 13 bits single-ended
Max sampling rate <sup>1</sup>	
USB-6008 .....	48 kS/s
USB-6009 .....	10 kS/s
AI FIFO.....	512 bytes
Timing resolution.....	41.67 ns (24 MHz timebase)
Timing accuracy.....	100 ppm of actual sample rate
Input range	
Single-ended .....	±10 V
Differential.....	±20 V, ±10 V, ±5 V, ±4 V, ±2.5 V, ±2 V, ±1.25 V, ±1 V
Working voltage.....	±10 V
Input impedance.....	144 kΩ
Overvoltage protection.....	±35

---

<sup>1</sup> Might be system dependent

Trigger source .....Software or external digital trigger

System noise .....0.3 LSBrms ( $\pm 10$  V range)

Absolute accuracy at full scale, single ended

Range	Typical at 25 °C (mV)	Maximum over Temperature (mV)
$\pm 10$	14.7	138

Absolute accuracy at full scale, differential<sup>1</sup>

Range	Typical at 25 °C (mV)	Maximum over Temperature (mV)
$\pm 20$	14.7	138
$\pm 10$	7.73	84.8
$\pm 5$	4.28	58.4
$\pm 4$	3.59	53.1
$\pm 2.5$	2.56	45.1
$\pm 2$	2.21	42.5
$\pm 1.25$	1.70	38.9
$\pm 1$	1.53	37.5

<sup>1</sup> Input voltages may not exceed the working voltage range.

## Analog Output

Converter type .....Successive approximation

Analog outputs .....2

Output resolution .....12 bits

Maximum update rate .....150 Hz, software-timed

Output range .....0 to +5 V

Output impedance .....50  $\Omega$

Output current drive .....5 mA

Power-on state .....0 V

Slew rate..... 1 V/ $\mu$ s  
 Short circuit current ..... 50 mA  
 Absolute accuracy (no load) ..... 7 mV typical, 36.4 mV maximum  
 at Full Scale

## Digital I/O

### Digital I/O

P0.<0..7>..... 8 lines  
 PI.<0..3> ..... 4 lines

Direction control ..... Each channel individually  
 programmable as input or output

### Output driver type

USB-6008 ..... Open-drain  
 USB-6009 ..... Each channel individually  
 programmable as push-pull or  
 open-drain

Compatibility ..... TTL, LVTTTL, CMOS

Absolute maximum voltage range ..... -0.5 to 5.8 V with respect to GND

Pull-up resistor ..... 4.7 k $\Omega$  to 5 V

Power-on state..... Input (high impedance)

### Digital logic levels

Level	Min	Max	Units
Input low voltage	-0.3	0.8	V
Input high voltage	2.0	5.8	V
Input leakage current	—	50	$\mu$ A
Output low voltage (I = 8.5 mA)	—	0.8	V
Output high voltage			
Push-pull, I = -8.5mA	2.0	3.5	V
Open-drain, I = -0.6mA, nominal	2.0	5.0	V
Open-drain, I = -8.5mA, with external pull-up resistor	2.0	—	V

## External Voltage

+5 V output (200 mA maximum) ..... +5 V typical, +4.85 V minimum

+2.5 V output (1 mA maximum) ..... +2.5 V typical

+2.5 V accuracy .....	0.25% max
Reference temperature drift .....	50 ppm/°C max

## Counter

Number of counters .....	1
Resolution .....	32 bits
Counter measurements .....	Edge counting (falling-edge)
Pull-up resistor .....	4.7 kΩ to 5 V
Maximum input frequency .....	5 MHz
Minimum high pulse width .....	100 ns
Minimum low pulse width .....	100 ns
Input high voltage .....	2.0 V
Input low voltage .....	0.8 V

## Bus Interface

USB specification .....	USB 2.0 full-speed
USB bus speed .....	12 Mb/s

## Power Requirements

USB	
4.10 to 5.25 VDC .....	80 mA typical, 500 mA max
USB suspend .....	300 μA typical, 500 μA max

## Physical Characteristics

If you need to clean the module, wipe it with a dry towel.

### Dimensions

Without connectors .....	6.35 cm × 8.51 cm × 2.31 cm (2.50 in. × 3.35 in. × 0.91 in.)
With connectors .....	8.18 cm × 8.51 cm × 2.31 cm (3.22 in. × 3.35 in. × 0.91 in.)

I/O connectors ..... USB series B receptacle,  
(2) 16 position terminal block  
plug headers

#### Weight

With connectors ..... 84 g (3 oz)

Without connectors ..... 54 g (21 oz)

Screw-terminal wiring ..... 16 to 28 AWG

Torque for screw terminals ..... 0.22 to 0.25 N · m  
(2.0 to 2.2 lb · in.)

## Safety

### Standards

The USB-6008/6009 is designed to meet the requirements of the following standards of safety for electrical equipment for measurement, control, and laboratory use:

- IEC 61010-1, EN 61010-1
- UL 61010-1
- CAN/CSA-C22.2 No. 61010-1



**Note** For UL and other safety certifications, refer to the product label, or visit [ni.com/certification](http://ni.com/certification), search by model number or product line, and click the appropriate link in the Certification column.

### Voltages

Connect only voltages that are within these limits.

Channel-to-GND .....  $\pm 30$  V max,  
Measurement Category I

Measurement Category I is for measurements performed on circuits not directly connected to the electrical distribution system referred to as *MAINS* voltage. *MAINS* is a hazardous live electrical supply system that powers equipment. This category is for measurements of voltages from specially protected secondary circuits. Such voltage measurements include signal levels, special equipment, limited-energy parts of equipment, circuits powered by regulated low-voltage sources, and electronics.



**Caution** Do not use this module for connection to signals or for measurements within Measurement Categories II, III, or IV.

## Hazardous Locations

The USB-6008/6009 are not certified for use in hazardous locations.

## Environmental

The USB-6008/6009 device is intended for indoor use only.

Operating temperature

(IEC 60068-2-1 and IEC 60068-2-2).....0 to 55 °C

Operating humidity

(IEC 60068-2-56) .....10 to 90% RH, noncondensing

Maximum altitude.....2,000 m (at 25°C ambient temperature)

Storage temperature

(IEC 60068-2-1 and IEC 60068-2-2).....-40 to 85 °C

Storage humidity

(IEC 60068-2-56) .....5 to 90% RH, noncondensing

Pollution Degree (IEC 60664).....2

## Electromagnetic Compatibility

Emissions .....EN 55011 Class A at 10 m  
FCC Part 15A above 1 GHz

Immunity .....Industrial levels per  
EN 61326:1997 + A2:2001,  
Table 1

EMC/EMI .....CE, C-Tick, and FCC Part 15  
(Class A) Compliant



**Note** The USB-6008/6009 may experience temporary variations in analog input readings when exposed to radiated and conducted RF noise. The device returns to normal operation after RF exposure is removed.

## CE Compliance

This product meets the essential requirements of applicable European Directives, as amended for CE marking, as follows:

Low-Voltage Directive (safety) ..... 73/23/EEC

Electromagnetic Compatibility  
Directive (EMC) ..... 89/336/EEC



**Note** Refer to the Declaration of Conformity (DoC) for this product for any additional regulatory compliance information. To obtain the DoC for this product, visit [ni.com/certification](http://ni.com/certification), search by model number or product line, and click the appropriate link in the Certification column.

# Where to Go for Support

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The National Instruments Web site is your complete resource for technical support. At [ni.com/support](http://ni.com/support) you have access to everything from troubleshooting and application development self-help resources to email and phone assistance from NI Application Engineers.

A Declaration of Conformity (DoC) is our claim of compliance with the Council of the European Communities using the manufacturer's declaration of conformity. This system affords the user protection for electronic compatibility (EMC) and product safety. You can obtain the DoC for your product by visiting [ni.com/certification](http://ni.com/certification). If your product supports calibration, you can obtain the calibration certificate for your product at [ni.com/calibration](http://ni.com/calibration).

National Instruments corporate headquarters is located at 11500 North Mopac Expressway, Austin, Texas, 78759-3504. National Instruments also has offices located around the world to help address your support needs. For telephone support in the United States, create your service request at [ni.com/support](http://ni.com/support) and follow the calling instructions or dial 512 795 8248. For telephone support outside the United States, contact your local branch office:

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