Magnetic precision has a name

Fast Digital Integrator FDI2056

User's Manual

Version 1.1

(Revision 1.2)

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		Correct section numbering in Chapter 4
		Correct formatting of specifications table
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GETTING STARTED
1-Introduction

The Fast Digital Integrator FDI2056 is a high precision, high-speed voltage integrator, developed at the European Organization for Nuclear Research (CERN). Combined with an appropriate flux coil, the FDI2056 makes an extraordinarily flexible, fast, and sensitive magnetometer.

The CERN's original objective was to perform high-precision multi-pole measurements of dynamic field effects, in conjunction with a fast rotating-coil system. The FDI2056 is, however, a general-purpose instrument, capable of measuring low-level and rapid flux changes in all imaginable coil configurations: rotating coil, moving-coil, flip-coil, moving wire, static coil in an AC field, … For an overview of the instrument's capabilities, please see Chapter 5-Technical .

The FDI2056 is a 6U Eurocard module conforming to the PXI standard (PCI eXtensions for Instrumentation). Metrolab offers an appropriate crate, but it can plug into any PXI crate. In addition, since the FDI2056 currently does not use any PXI extensions such as backplane triggers, it can also plug into a CompactPCI (cPCI) crate. The PXI/cPCI crate can of course also contain other instrumentation. Daisy-chaining PXI/cPCI crates allows you to build systems with a large number of integrator channels.

The computer interface is a PXI-to-PCI bridge system that connects the PCI bus in the PXI crate directly to the PCI bus in the computer. This system is physically compatible with practically all modern computers – including laptop computers – and is capable of high transfer rates. Metrolab offers appropriate bridge systems, but again, these are standardized products and there are a number of compatible alternatives on the market.

The software interface to the instrument is provided via the NI-VISA library. VISA (Virtual Instrument Software Architecture) is an industry standard, with NI-VISA being an implementation from National Instruments. VISA is supported by all major instrumentation manufacturers, and NI-VISA provides excellent cross-platform compatibility (Windows, Macintosh, Linux, …).

The PXI-to-PCI bridge does not require any special drivers. The PCI enumeration performed by the low-level computer firmware (e.g. by the BIOS at Windows system start-up) should automatically detect the crate and the FDI2056 cards. However, some configuration files need to be installed on your computer to allow NI-VISA to access the instrument. Please take the time to carefully work through Chapter 2-Installation Guide. Pay particular attention to the cautionary notes.

The FDI2056 includes a simple utility program to allow you to quickly start acquiring data. This software contains on-line documentation that is also reproduced in Chapter 3-User Interface.

It is easy to develop custom software for the FDI2056, especially in LabVIEW, using Metrolab's FDI2056 Application Programming Interface (API). Please see Chapter 4-Application Programming Interface. We also supply a C-language API developed at the CERN; this software is provided as-is, with separate documentation.

Finally, keep your FDI2056 accurate and up to date by having it recalibrated at regular intervals. The recommended calibration interval is 12 months. At this time, Metrolab will also install the latest available firmware.

You can also download the latest software and manual, free of charge. We post all updates on our website. The easiest way to be notified of updates is to sign up for our electronic newsletter, published twice a year; please see the Newsletter Subscription page of the News section of Metrolab's website, www.metrolab.com.

We hope the FDI2056 will help you perform your magnetic field measurements easily and accurately. If you have problems and your reseller cannot help you further, the Metrolab team is ready to help. Even if you don't have problems, we are always interested in knowing more about how our instruments are used. Feel free to contact us at any time at contacts@metrolab.com.

GETTING STARTED
2-Installation Guide

This chapter is a step-by-step description of how to install the FDI2056. The FDI2056 takes some time to set up and will be intimately linked to your computer system, so please take your time and follow the outlined procedures carefully.

2-1 INSTALLING THE PXI BRIDGE CARD

The following instructions are specific to the Metrolab-supplied crate and bridge cards; for other systems, please see the manufacturer's instructions. The PXI bridge card usually comes pre-installed in the crate, so you can probably skip this section.

CAUTION

⇒ Ensure that the crate is powered down before installing the PXI bridge card.

⇒ The PXI bridge card is a 3U Eurocard module that plugs into the bottom half of the 6U crate. In the Metrolab crate, there is no top rail guide to hold the top half of the card. This is not a problem in operation; but the card insertion and removal must be done delicately to avoid bending the backplane pins.

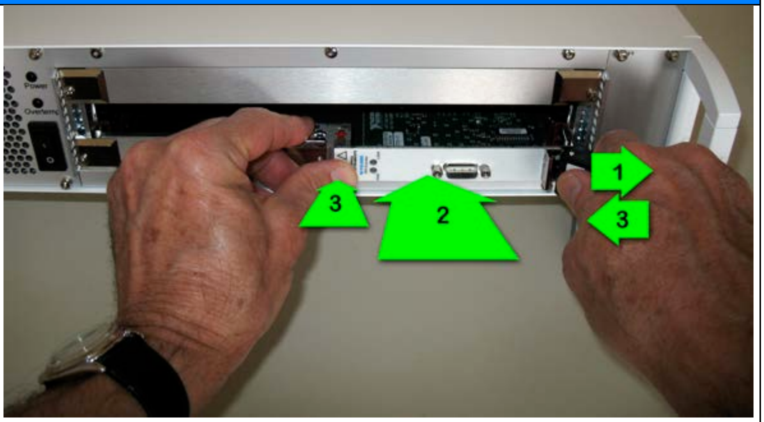
NOTICE

⇒ The PXI bridge card must be installed in the crate controller slot, indicated by the red card guide. The top (left) half of this slot should be covered by a blank faceplate.

⇒ It is easiest to install the PXI bridge card before the FDI2056 card, so you can use the adjacent empty slot to see the connectors.

NOTICE

⇒ To install the card:



1. Push the extractor lever outward; 2. Align the card on the bottom (right) card guide rail and slide it in until the backplane connector aligns with and just touches the backplane; and 3. Gently seat the card by simultaneously pressing the extractor lever inward and the top edge of the card forward.

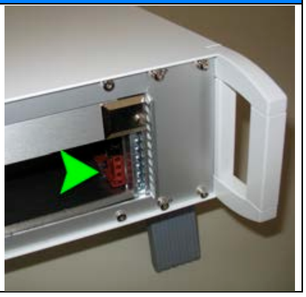
⇒ Tighten the screw at the top (left) edge of the card.

2-2 INSTALLING THE FDI2056 CARD

The FDI2056 module usually comes pre-installed in a crate. In this case, you can skip this section. To install an FDI2056 card in a PXI/cPCI crate, please follow the following instructions carefully.

NOTICE

⇒ One slot of the PXI/cPCI crate is reserved for the crate controller. This slot should be marked in some way; on the Metrolab crate, the card guides are red. Do not place an FDI2056 card in this slot.



CAUTION

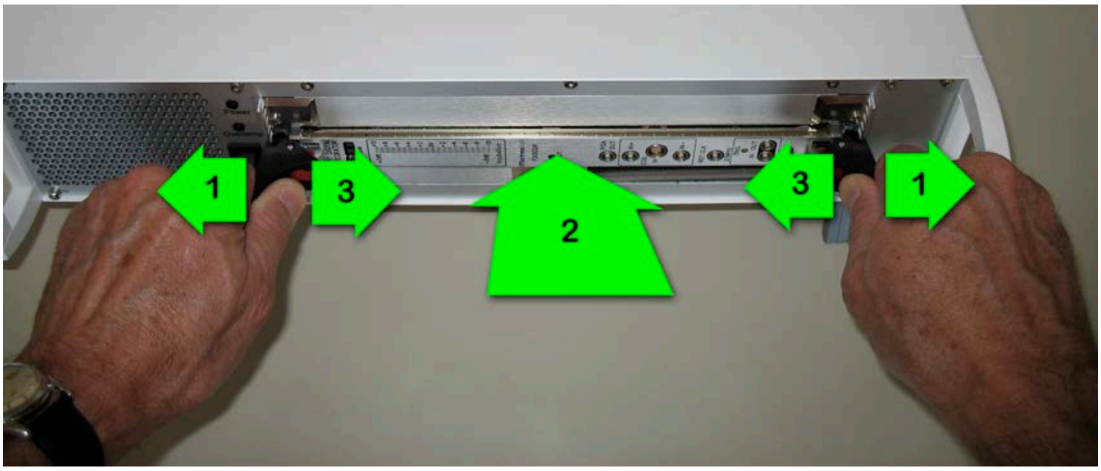
⇒ The FDI2056 electronics supports hot-swapping, but the firmware will not start up correctly. We recommend powering down the crate.

⇒ Handle the FDI2056 card with caution to avoid damage due to electrostatic discharge. Ground yourself before handling the card; the best is to use a grounded wrist-strap during installation.

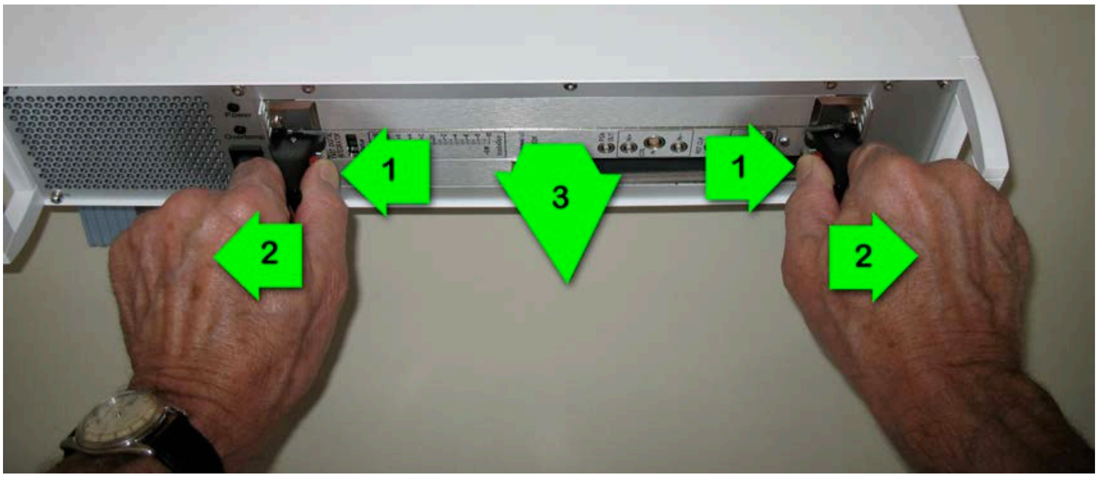
⇒ The FDI2056 card has components on the underside that just barely clear the faceplate of adjacent cards. Exercise extreme caution in order not to damage the card when you slide it into the crate. Slide it in slowly, and lift it slightly to keep the components from snagging.

NOTICE

⇒ PXI cards use a locking card extractor. When inserting the card: 1. Push the levers outward; 2. Push the card in until the black plastic extractor levers touch the crate; and 3. Push the levers inward until you hear both locks click.



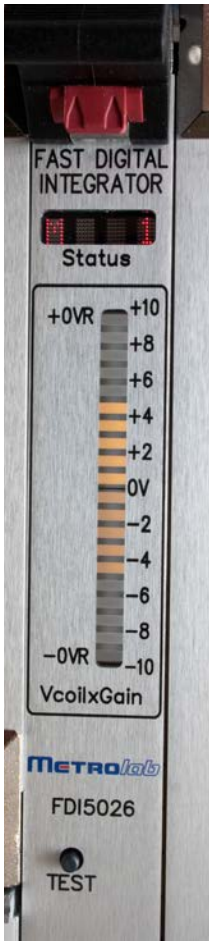
⇒ When removing a card: 1. Press the red lock levers with your thumbs; 2. Push the black extractor levers outward to extract the card; and 3. Gently pull the card out of the slot. See Caution note above.



⇒ To provide additional assurance that the card does not vibrate loose, for example when shipping, you can tighten the screws behind the extractor lever.

2-3 FDI2056 FRONT PANEL AND CONNECTIONS

CAUTION
⇒ The FDI2056 front-panel connectors are NOT protected against over-voltages or electrostatic discharge. Please be very attentive, and verify your signal levels on an oscilloscope, when making your connections.



1. The four-character "Status" display indicates the FDI2056's current state:
   - INIT = Reset
   - Gxxx = Idle, with selected gain
   - Mxxx = Measuring, with selected gain
   - Cxxx = Calibrating, with selected gain
2. The amplified signal amplitude can be monitored on the "Vcoil x gain" LED bar. The effect of changing the gain will be immediately visible. If the +OVR or –OVR lights come on ("+ Over-Range" and "- Over-Range", respectively), the signal risks being clipped.
3. The TEST button is only used during firmware development.

4. The "PGA OUT" output ("PGA" = "Programmable Gain Amplifier") can be used to monitor the coil signal, after input filtering and amplification, just before analog-to-digital conversion.
5. The coil can be connected to the FDI2056 either via the two LEMO 00 connectors, "IN+" and "IN-", or the single LEMO 0B connector. The FDI2056 is supplied with a 10 m cable with a LEMO 0B connector. The FDI2056 coil input characteristics can be adapted for your application – see Section 0 for details.
6. The "REF. CLK 20MHz" allows the FDI2056 time base to be checked with a precision counter.

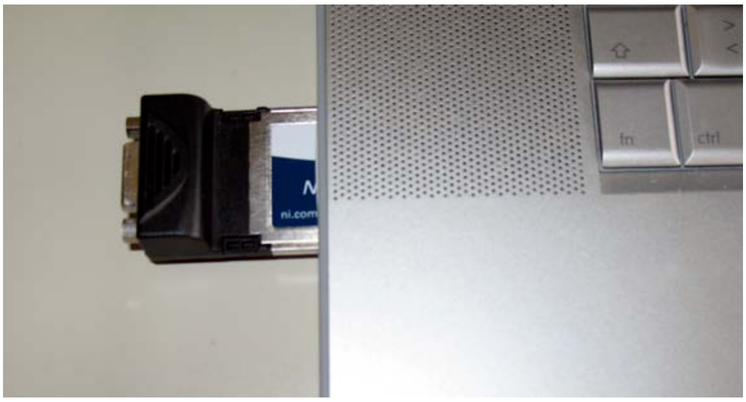
7. "TRIG. IN" is a 3.3V, 5V-tolerant TTL input. The negative-going edge of the "TRIG. IN" signal determines when partial integrals are computed. Each trigger pulse ends the previous partial integral (if there was one) and starts a new one. Thus, a sequence of N partial integrals requires N+1 trigger pulses. The rise times should be as fast as possible to minimize timing jitter.
8. The "TRIG. OUT" signal allows multiple FDI2056 channels to be daisy-chained, with a single trigger. This output can also be used to monitor the quality of the trigger signal, since it reproduces the trigger after discrimination.
9. The bright blue, unlabelled LED at the bottom of the front panel goes out when the FDI2056 is ready to communicate with the computer.

2-4 CONNECTING THE FDI20256 SYSTEM TO THE COMPUTER

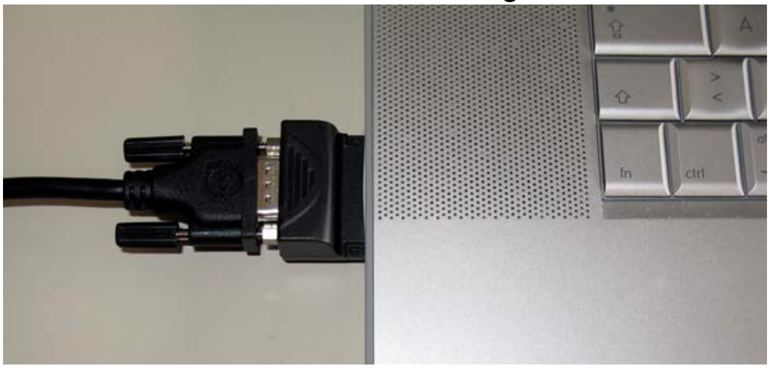
CAUTION

⇒ The following instructions are just a quick overview. Be sure to follow the detailed installation instructions for your bridge system. Even the recommended order of the steps may be different.

1. Install the bridge adaptor card in your computer. The photo shows an ExpressCard that simply plugs into a laptop computer; installing a PCI adaptor into a desktop computer requires the cover to be removed.



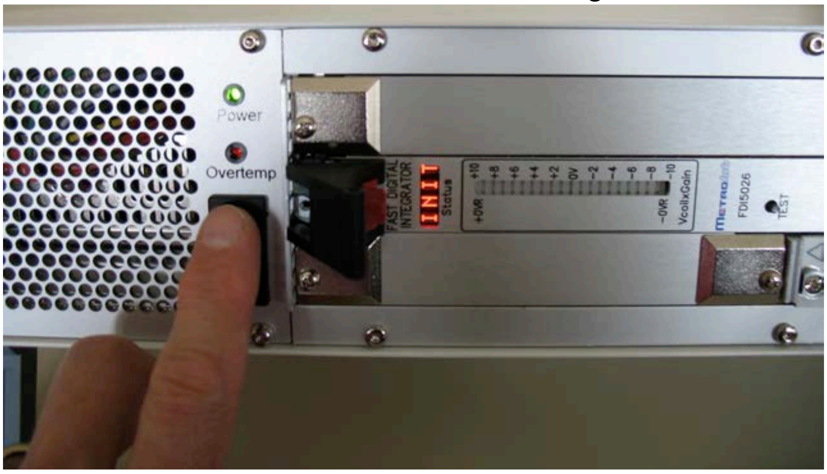
2. Connect the cable between the bridge cards in the computer and the crate.



2-5 INITIAL POWER-ON

NOTICE
⇒ Note that the Metrolab-supplied crate has two power switches: one on the back, and one on the front. Both must be set to "1" for the instrument to be powered on.

1. After the FDI2056 is powered on, the "Status" indicator briefly flashes "INIT". This indicates that the FDI2056 is resetting.



2. The "Status" indicator should then show "G0.1", which indicates that the default gain of 0.1 is selected. This is the minimum gain.

3. As long as the computer is not connected, the bright blue light at the bottom of the FDI2056 front panel stays lit. As soon as the computer interface is connected, this light should go out. On Metrolab-supplied PXI bridge cards, the "Link" light should light up at the same time.

2-6 SOFTWARE INSTALLATION – WINDOWS

- Insert the installation CD.
- Install the National Instruments LabVIEW Runtime Environment by double-clicking on \PC\LVRTExxxstd.exe, where "xxx" represents the version.

- Install the National Instruments VISA Runtime Library by double-clicking on \PC\visaxxxruntime.exe, where "xxx" represents the version.
- Install the FDI2056 software by double-clicking on \PC\FDI2056\setup.exe.
- Ensure that the PXI-to-PCI bridge is installed and the PXI crate is powered on, as described in the previous sections. Restart your computer.
- Start the software by selecting the short cut, Start Menu > All Programs > Metrolab > FDI2056 > FDI2056.
- If you have installed the development version of NI-VISA, you may identify what model PXI crate you are using. This allows NI-VISA to identify the slot location of each FDI2056 card; note that this makes absolutely no difference in the operation of the FDI2056 software.
  Also note that you may have to install an additional driver for your bridge card; for example, for the National Instruments bridge cards distributed by Metrolab, such a driver is installed from the CD "NI PXI Platform Services."
  To identify the PXI crate, start the National Instruments Measurement Automation Explorer (MAX), used to edit the VISA instrument database:
    - Select "Devices and Interfaces"
    - Open "PXI System (Unidentified)"
    - Open "PXI Bridge (NI PXI_8360)", or the equivalent for the bridge system you are using.
    - Right-click on "Chassis 1 (Unidentified)" and "Identify As > Metrolab FDI7056", or the equivalent for the PXI crate you are using.

2-7 SOFTWARE INSTALLATION – MACINTOSH

- Insert the installation CD.
- Copy the file /Source/Config/Metrolab_FDI2056.inf to /Library/Application Support/National Instruments/nipal/inf
  This directory is write-protected, and you will be asked to provide your Administrator password.
- Install the VISA Runtime Library by double-clicking on /Mac/NI-VISA-Runtime-x.x.x.dmg, where "x.x.x" is the version.

- Install the FDI2056 application by dragging /Mac/FDI2056 to your Applications folder.
- Ensure that the PXI-to-PCI bridge is installed and the PXI crate is powered on, as described in the previous sections. Restart your computer.
- Start the software by double-clicking on /Applications/FDI2056.

NOTICE
⇒ If needed – for example, if you install a new operating system on your computer – you can download and install more recent versions of the LabVIEW and VISA Runtime Libraries from the National Instruments website (http://www.ni.com).
⇒ You may already have these libraries installed, for example if you use LabVIEW.

2-8 SOFTWARE DEVELOPMENT

- Insert the installation CD.
- Copy the Source folder to your hard drive. The API subfolder contains the Application Programming Interface – see 4-Application Programming Interface. The UIF folder contains the source code of the FDI2056 measurement software.
- Modify the FDI2056 measurement software, or write a measurement system from scratch, using the LabVIEW development system.

USING THE FDI2056
3-User Interface

To use the FDI2056, you need to have installed both the hardware and the software, as described in the previous chapter. All data acquisition is performed by software – either the standard software that is delivered with the FDI2056, or custom software you have written yourself. Writing custom software is covered in later chapters; this chapter describes how to use the FDI2056 with the standard software application, which is simply called "FDI2056".

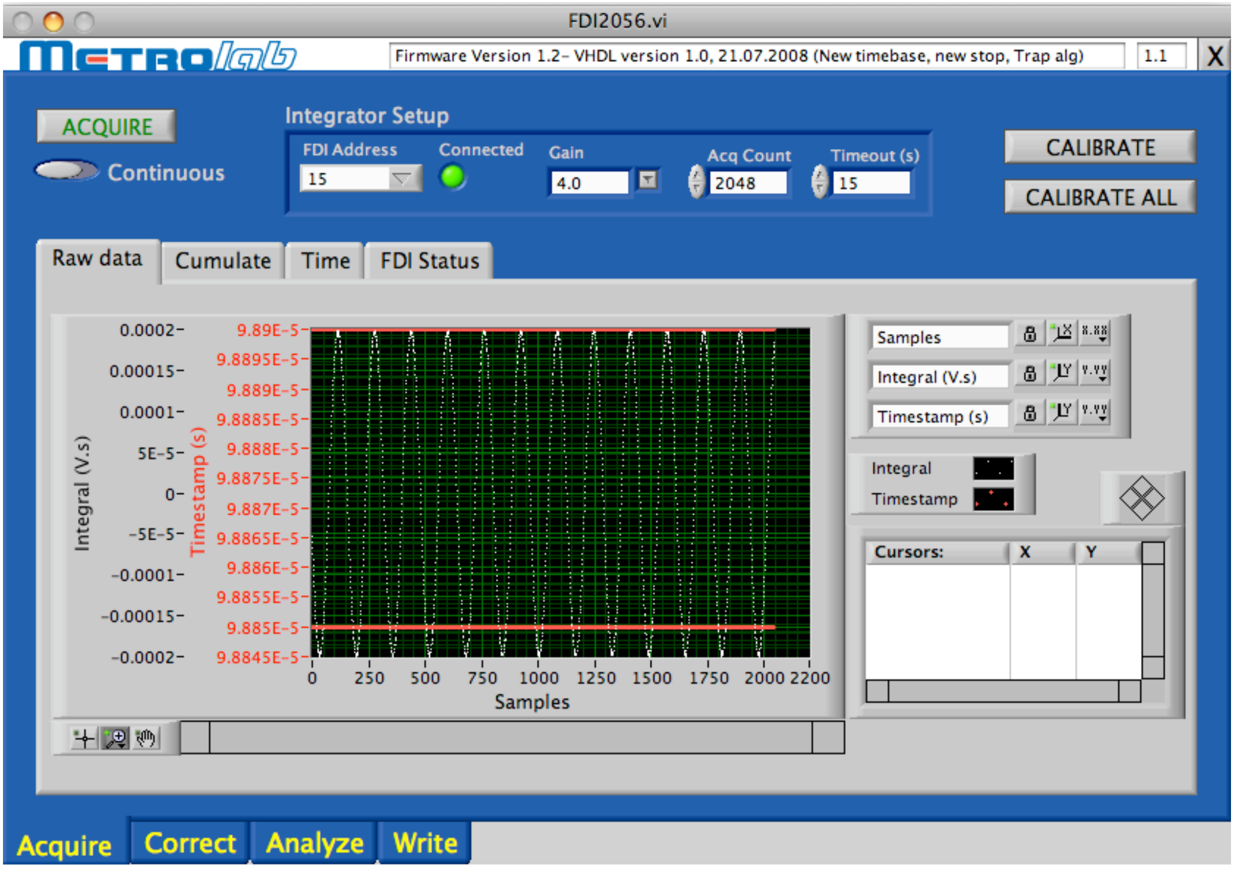
The FDI2056 application allows you to:

- Select the channel from which you want to acquire data;
- Select the gain and the number of points you want to acquire;
- Perform the internal calibration procedure on one or all channels;
- Launch the acquisition, either single-shot or continuously;
- Inspect the data, using three different views:
  - Raw: partial integrals and time intervals between triggers;
  - Cumulated: total integrals and time stamp at each trigger;
  - Time: X-Y plot of time stamp vs. total integral.
- Perform common data correction and analysis tasks, such as drift correction, time and amplitude measurements, data trimming, frequency or multi-pole analysis, and division by coil area to compute flux density.
- Record the data to a file;
- Read the data back from a file; and
- Monitor the FDI2056 status register.

The user interface and recording file format have been designed to allow additional measurement tasks to be integrated seamlessly, without forcing you to re-learn the software or throw away old data files.

The following sections describe the software functions in detail. The user interface organizes the major functions into different panels, selected by tabs at the bottom of the window. Each of these panels is described in a section below.

3-1 ACQUISITION



The acquisition panel, selected by the "Acquire" tab at the bottom of the window, controls all aspects of a single-channel acquisition:

- Acquire:
  This button initiates an acquisition, or a continuous acquisition if selected. The Acquire button stays lit as long as an acquisition is in progress. During this time the button is disabled; the only thing that will terminate an acquisition prematurely is a time-out.
- Continuous:
  Sliding this button to the right initiates an acquisition loop; sliding it to the left allows the current acquisition to terminate and then exits the loop.
- FDI Address:
  If you have multiple FDI2056 channels, this pull-down menu selects the channel you wish to use.

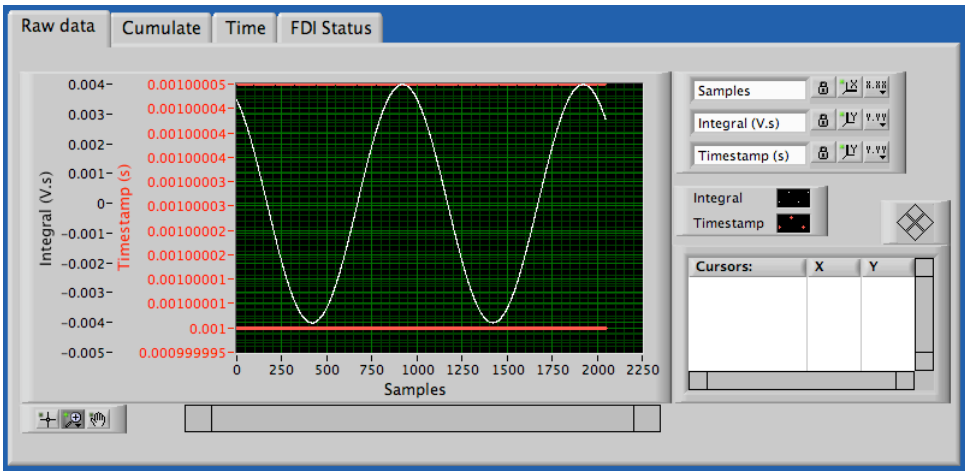
The menu is automatically populated with all the FDI2056 units detected by VISA; the full VISA resource name of the instrument is PXIx::yy::INSTR, where "x" is the bus number and "yy" is the address. Each address corresponds to a slot number in the PXI crate: Address 15 is the slot next to the bus controller, 14 is the slot next to that, and so forth.
If the menu is empty, your installation was unsuccessful; please review Chapter 2-Installation Guide carefully.

- Connected:
  This indicator lights up when the application has successfully initialized the FDI2056.
- Gain:
  This pull-down menu displays the currently selected gain. Changes should be immediately reflected in the "Status" display of the FDI2056 front panel.
- Acq Count:
  Enter the number of partial integrals you want to acquire in this field. Remember that N partial integrals require N+1 Trigger pulses.
  Also note that the data transfer rate from the FDI2056 to the computer is greatly degraded if you do not use a power of two. Please see Section 4-32, Programming Hints, for a full explanation.
- Timeout (s):
  This is a timeout period for the acquisition, in seconds. Choose this value carefully: if it is too short, your acquisition will be interrupted before it completes; if it is too long, you will be forced to wait unnecessarily long if there is some problem with your Trigger signal.
- Calibrate:
  Press this button to perform an internal gain/offset calibration of the currently selected gain setting. While the calibration is in progress, the button stays on and is disabled.
- Calibrate All:
  Press this button to perform an internal gain/offset calibration of all gain settings. While the calibration is in progress, the button stays on and is disabled.

- Raw data / Cumulate / Time / FDI Status:

  This tab control selects the different views of your data and the instrument:

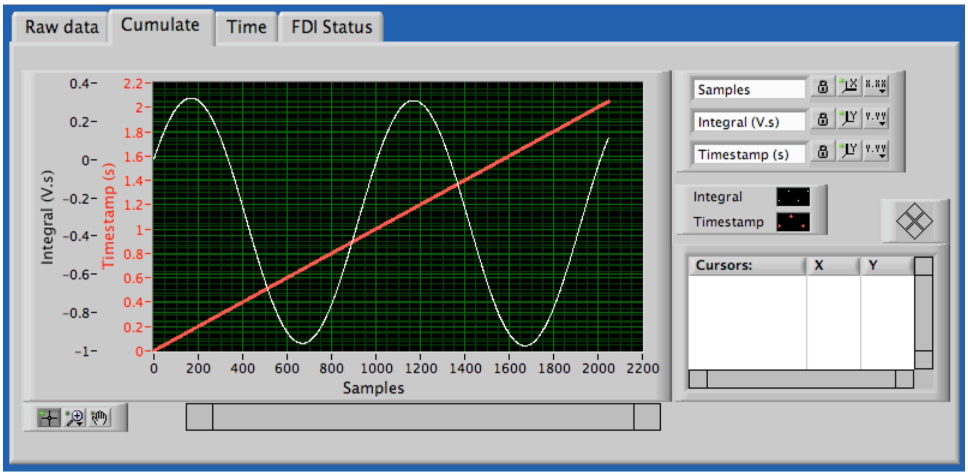
  - Raw data:



    - White points: partial integral between triggers, in Volts x seconds.

    - Red crosses: time interval between triggers, in seconds. In this example, there are two rows of red crosses, one at exactly 1 ms and one at (1 ms + 50 ns), in other words just 1 clock tick later. The trigger pulses were generated at 1 kHz, but the clock in the Trigger generator does not exactly match that in the FDI2056. This sort of pattern is usual for periodically sampled data.

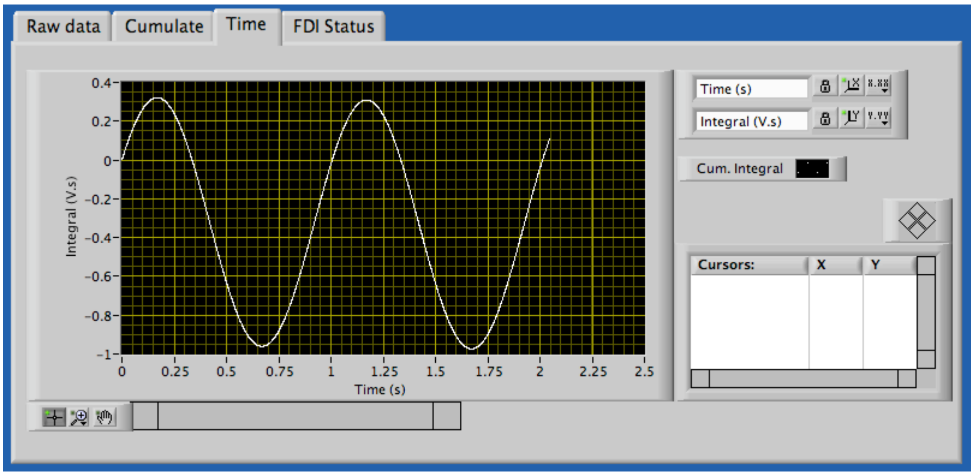
  - Cumulated:



    - White points: total integral from the beginning of the acquisition, in Volts x seconds.

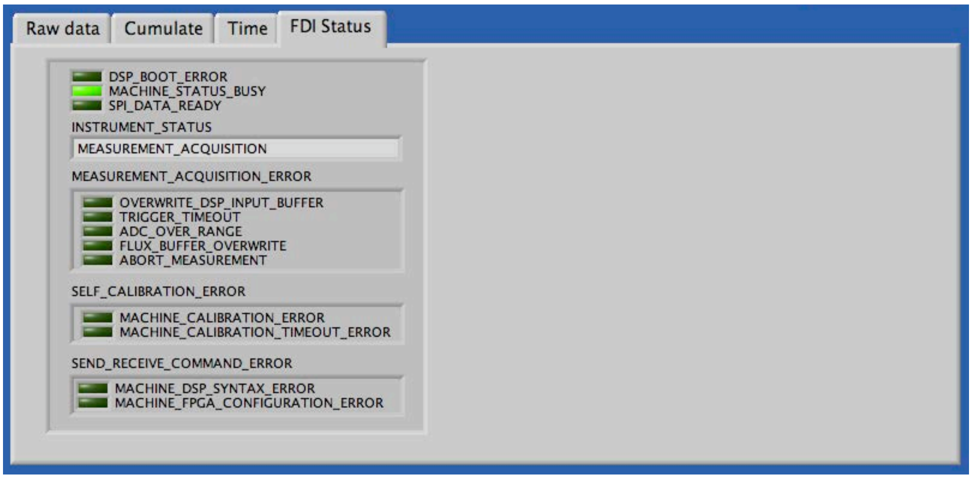
- Red crosses: time stamp at each trigger, in seconds.

- Time:



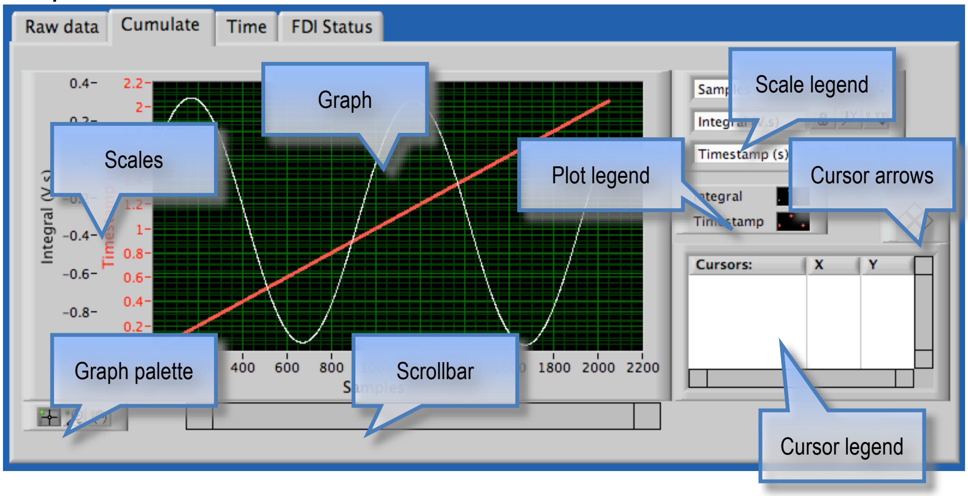
X-Y plot of time stamp vs. total integral.

- FDI Status:



A decoded display of the FDI2056 status word. This display is updated continuously during an acquisition or calibration. When idle, the status is updated once per second.

- Graph controls:



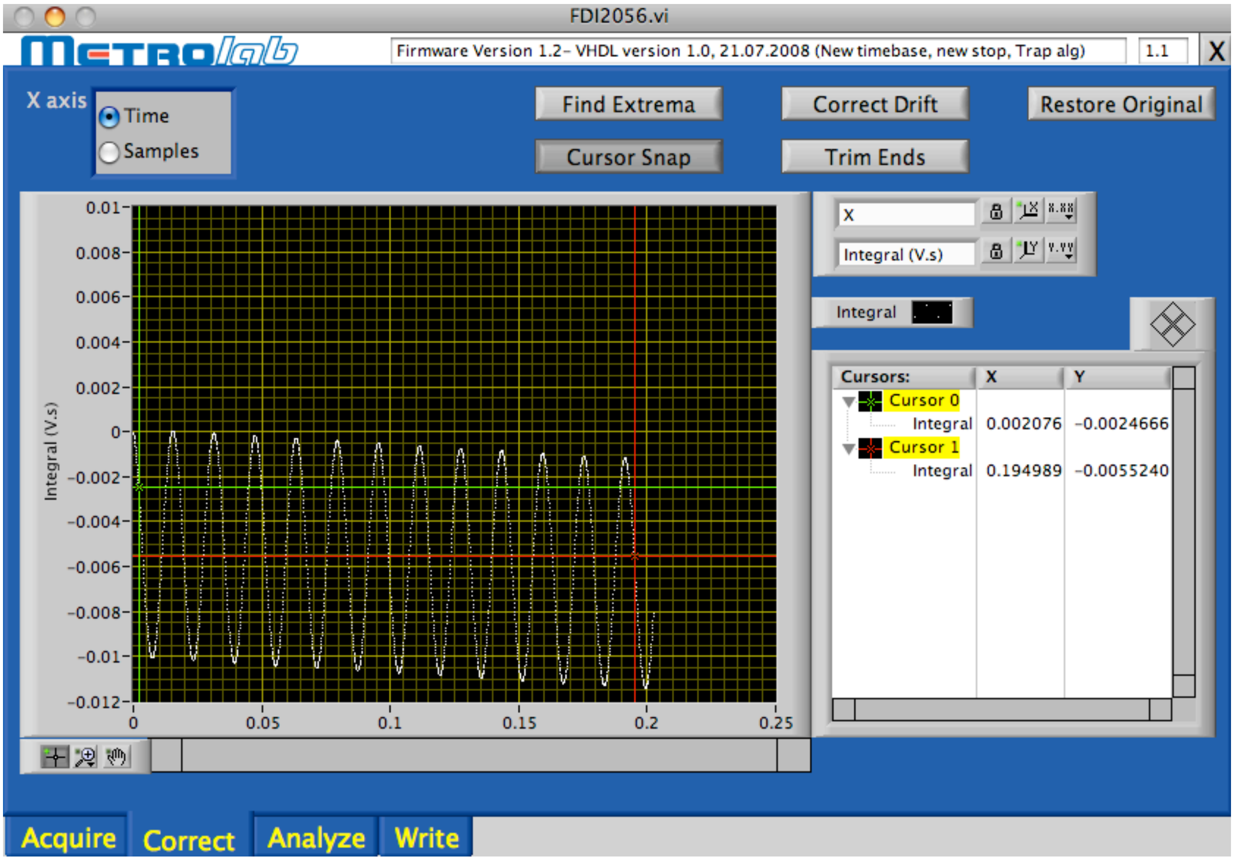
The standard LabVIEW graph controls provide you with a rich set of tools to explore your data. Right-clicking on the various objects will show you pop-up menus that allow you to customize your plot in myriads of ways. Nonetheless, because of the limited quality of the exported images, this is not an appropriate tool for making publication-quality graphs.
Here is a short summary of the most useful options:

- Graph:
  Right-click to clear, annotate or export the graph.
- Scales:
  Right-click to auto-scale (or not) or change marker spacing; select and change upper and lower limits.
- Graph palette:
  - Left button: select and move cursors;
  - Middle button: pull-down menu for zooming and un-zooming in various ways;
  - Right button: grab the graph and scroll it.
- Scrollbar:
  When zoomed, scroll left or right.
- Cursor legend:
  Right-click to create or delete a cursor. Cursors can be free or tied to the data. Right-click on an existing cursor to change its appearance,

to bring it to the center of the graph, or to scroll the graph to the cursor position.

- Cursor arrows:
  Move the currently active cursor left or right; shift-click moves faster. Move the cursor up or down to the other trace.
- Plot legend:
  Right-click to change the appearance of the data points.
- Scale legend:
  Unlock the scale by clicking on the lock button and change the scale label. Click on the right-hand button to change the appearance of the scale and the grid.

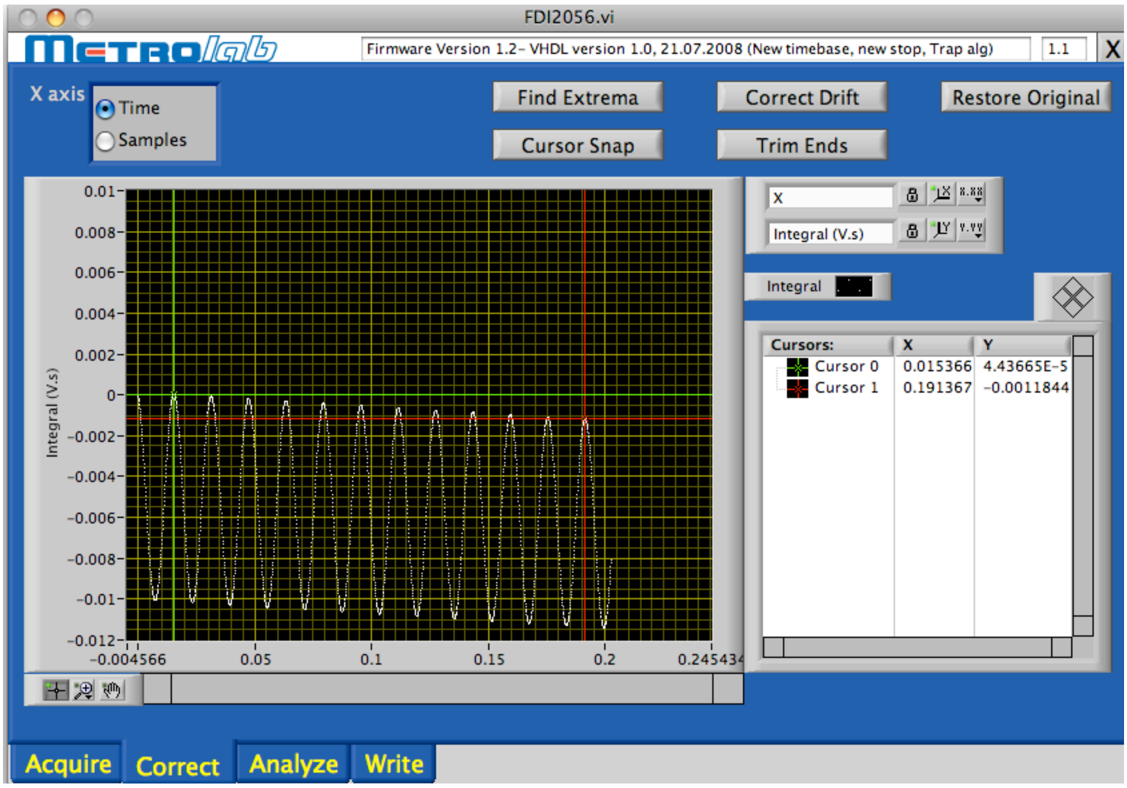
3-2 DATA CORRECTION

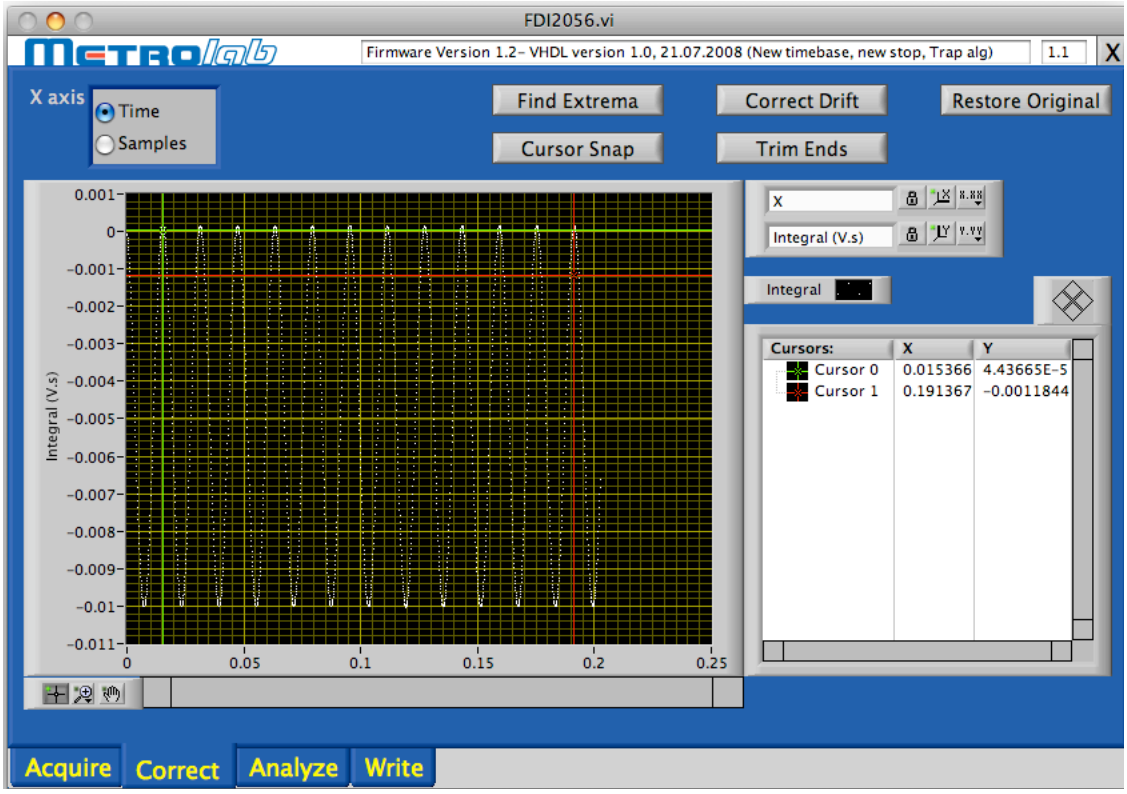


The Data Correction panel, selected by the "Correct" tab at the bottom of the window, allows the data to be manipulated in various ways:

- X axis: Select whether the X axis represents time (in seconds, as reconstructed from the timestamps) or sample numbers. The first option is more appropriate for timed triggers, for example a trigger every 10 µs to study a rapid field variation. The second option is more appropriate for spatial triggers, for example every 4th count of a rotational encoder on a rotating-coil system.

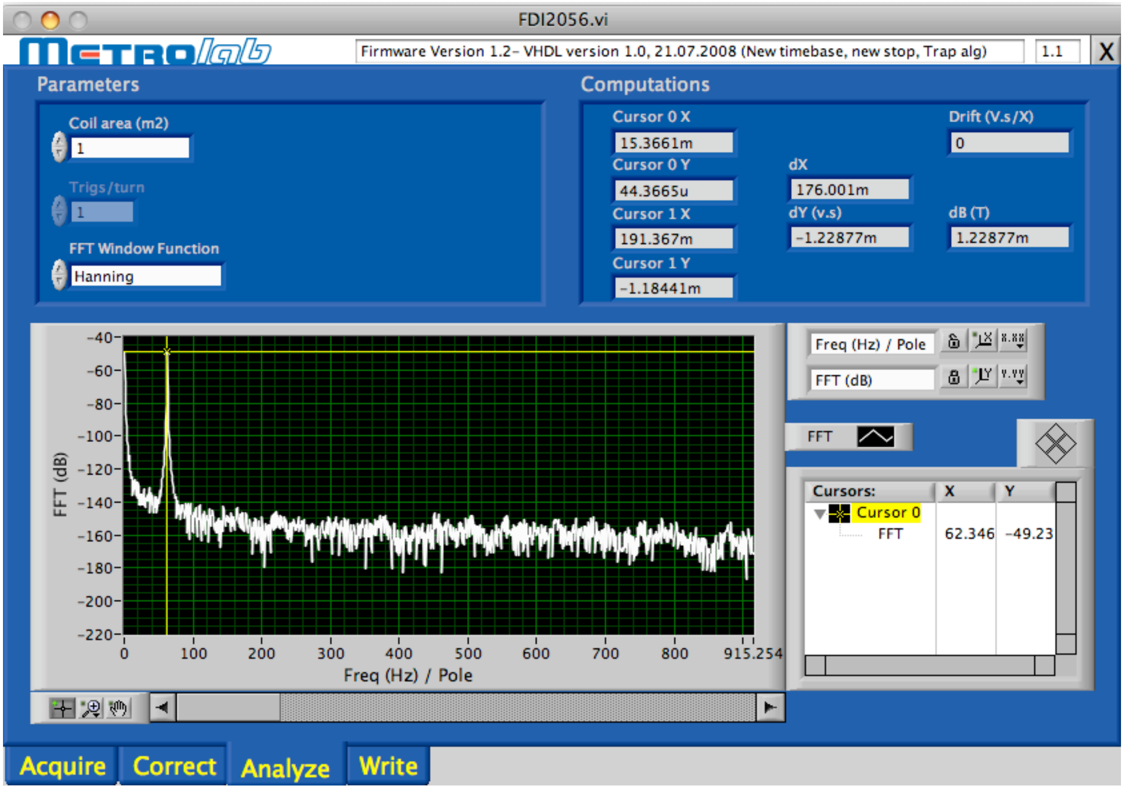
- Plot: Displays the cumulated integral, in V.s, plotted against the selected X axis units. This plot can be manipulated as described in Section 3-1. In particular, the cursors can be placed for various types of corrections and measurements.
- Find Extrema: Move Cursors 0 and 1 to the minimum or maximum nearest to their current position. Cursor Snap is automatically turned off, since the computed positions are based on a polynomial interpolation, and usually do not correspond to a single data point.
- Cursor Snap: Control whether Cursors 0 and 1 automatically snap to the nearest data point, or can be moved freely.
- Correct Drift: Use the current cursor positions to estimate the drift, and subtract this slope from the data points. It is generally easiest to correct the drift by placing the two cursors on a pair of equivalent minima or maxima, using the "Find Extrema" option, as shown in the following example:





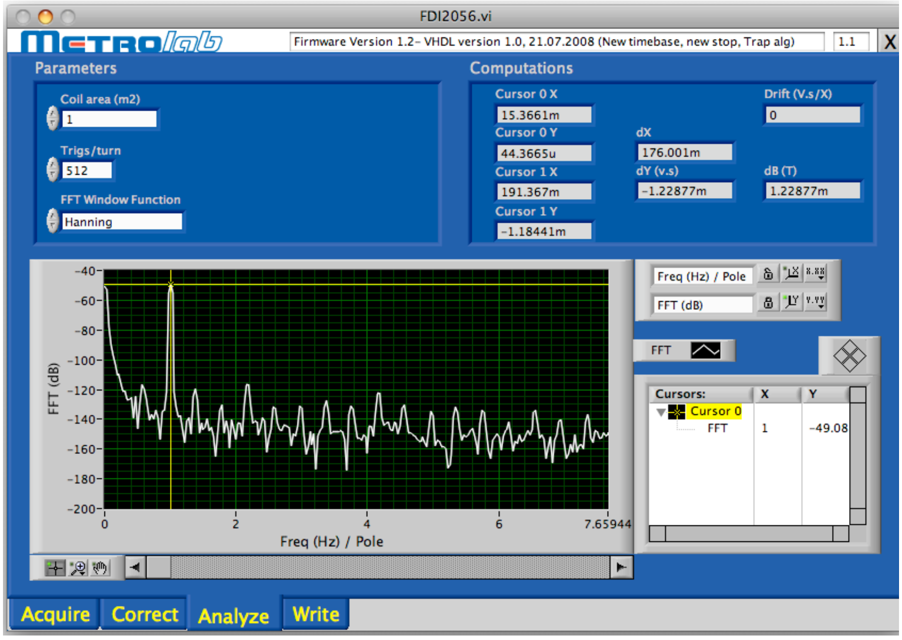
- Trim ends: Discard samples that lie outside the range indicated by Cursors 0 and 1.
- Restore Original: Discard all data corrections and restore the original data.

3-3 DATA ANALYSIS



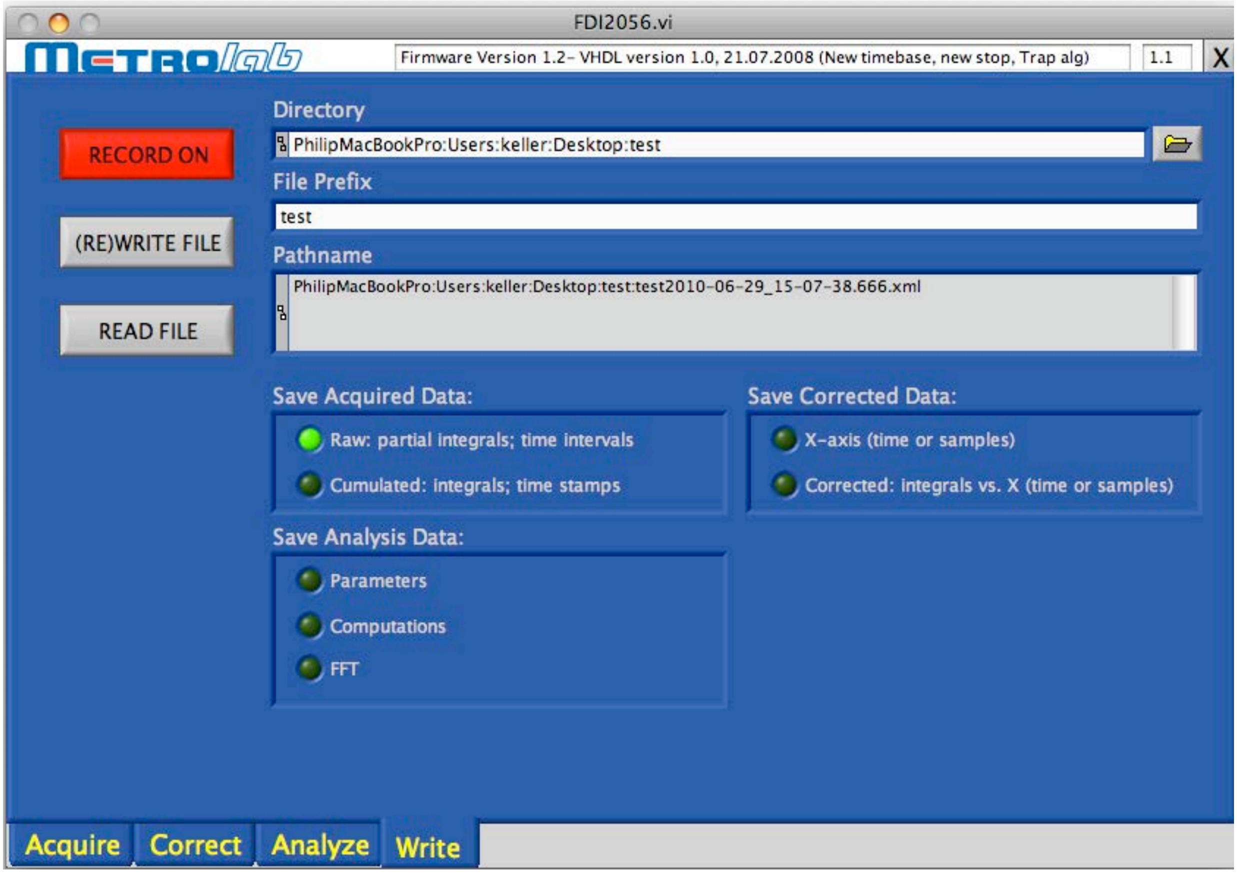
The Data Analysis panel, selected by the "Analyze" tab at the bottom of the window, displays the results of various commonly used data measurements:

- Coil area (m2): Enter the coil area, in m^2, to convert a flux change (dY) to a flux density change (dB).
- Trigs/turn: Triggers per turn, for rotational coils. This parameter is only enabled if the X axis units, as selected on the Data Correction panel, are samples. This converts the FFT plot into a multi-pole plot, where the spectral peaks correspond to the dipole, quadrupole, hexapole, … amplitudes. The following example shows a simulated perfect dipole (with an uncorrected DC term):



- FFT Window Function: Selects the window function to be applied to the corrected signal from the Data Correction panel, before computing the FFT.
- Cursor 0 X, Cursor 0 Y, Cursor 1 X, Cursor 1 Y: The position of Cursors 0 and 1 in the Data Correction plot.
- dX: The X distance between Cursors 0 and 1 in the Data Correction plot, in the selected X axis units.
- dY (V.s): The Y distance, or flux change, between Cursors 0 and 1 in the Data Correction plot, in V.s.
- dB (T): The flux density change, in Tesla, that corresponds to dY, assuming the given coil area.
- Drift (V.s/X): The drift computed in the Data Correction panel. The units are V.s divided by the selected X axis units.
- FFT: Plots the magnitude of the FFT of the corrected signal from the Data Correction panel. First applies the indicated window function. The units of the X axis are Hz if the X axis is time, and multi-pole number if the X axis is samples and Trigs/turn has been entered. The plot can be manipulated as described in Section 3-1; in particular, the cursor facilitates reading off the coordinates of peaks.

3-4 RECORDING



The Recording panel, selected by the "Write" tab at the bottom of the application window, controls all aspects of data recording:

- RECORD ON:
  Select "RECORD ON" to save each acquisition to disk, "RECORD OFF" to stop recording. Each acquisition creates one file; for continuous acquisition, a series of files is created, one for each acquisition. The pathname is constructed from Directory and File Prefix, as described below. If one of these is empty, a pathname prompt is displayed.
- (RE)WRITE FILE:
  Write, or re-write, the data to the file indicated in Pathname. If Pathname is empty, the pathname is constructed from Directory and File Prefix, as described below. If one of these is also empty, a pathname prompt is displayed.
- READ FILE:
  Read back a data file. While the file is being read, a watch cursor is displayed, and the data type lights are turned on as the corresponding data

type is read in. First the raw data is read and analyzed, and then the correction/analysis results are overwritten by the results stored in the file. Note that this process can lead to inconsistent information, depending on what was saved; use the "Restore Original" button on the Data Correction panel to eliminate such inconsistencies. Also note that this function is quite slow on a Macintosh, for reasons that are not clear.

- Directory:
  Click on the file-folder button on the right of the Directory field to select or create the directory where the recording files are to be saved.
- File Prefix:
  The name of the recording file will be the File Prefix followed by the date and time, followed by the ".xml" file extension; for example: "test2010-06-29_15-07-38.666.xml".
- Save Acquired Data:
  Select whether you want to save the cumulated data. The data files always contain the raw data, so the corresponding option cannot be deselected.
- Save Corrected Data:
  Select whether you want to save the X axis selection and/or the Corrected data.
- Save Analysis Data:
  Select whether you want to save the Analysis Parameters, Analysis Computations and/or FFT.

3-5 RECORDING FILE FORMAT

As the file name extension implies, the recording file is written in XML (Extensible Markup Language). In fact, we use a standard LabVIEW functionality to "flatten" the acquired data into an XML file. The contents of a recording file typically look like this:

```
<?xml version='1.0' standalone='yes' ?>
<LVData>
<Version>8.5.1</Version>
<String>
<Name>SW Version</Name>
<Val>1.1</Val>
</String>
```

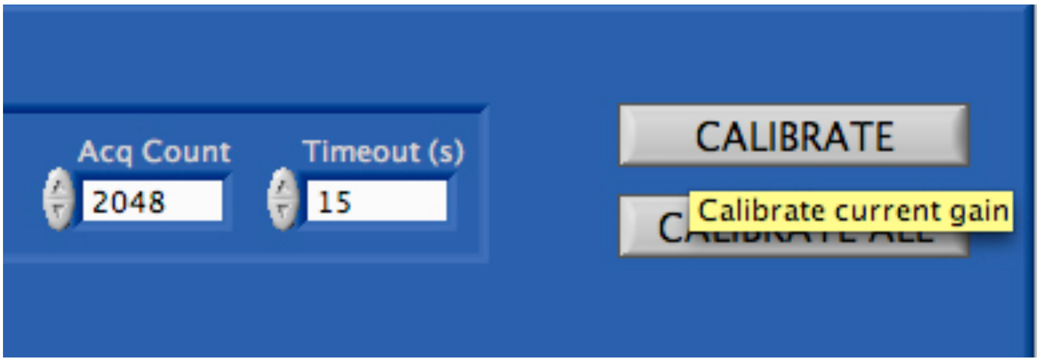
```
<Array>
<Name>Raw Data</Name>
<Dimsize>2</Dimsize>
<Dimsize>16384</Dimsize>
<DBL>
<Name></Name>
<Val>4.31788E-5</Val>
</DBL>
…
```


The benefits of XML include:

- It is widely used; for example, almost all web browsers can parse it;
- It is also human-readable (although not exactly human-friendly);
- It is platform- and manufacturer-independent, based on open standards;
- All data is tagged. In the example above, one can see that the file was written with LabVIEW version 8.5.1 and the FDI software version 1.1, and that it contains a 2x16384 array of double-precision floating-point numbers called "Raw Data".
- Because of the tags, the file can be easily extended to include new data types. Compatibility with old software is not broken, assuming existing tags are not changed and the software systematically ignores unknown tags.

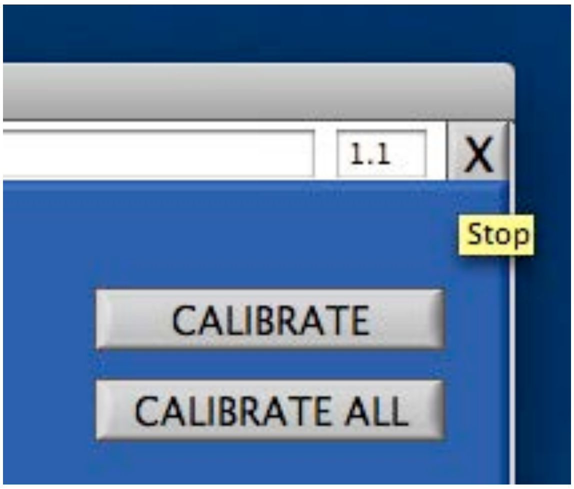
Reading such a file is very easy in LabVIEW; please use the FDI2056 User Interface code as an example. To read a FDI2056 recording file in a textual programming language, we suggest using an XML parser such as Expat (http://expat.sourceforge.net/). A copy of the LabVIEW schema file with which the data was written can be found on the FDI20256 CD, in the Source/XML directory.

3-6 ON-LINE HELP



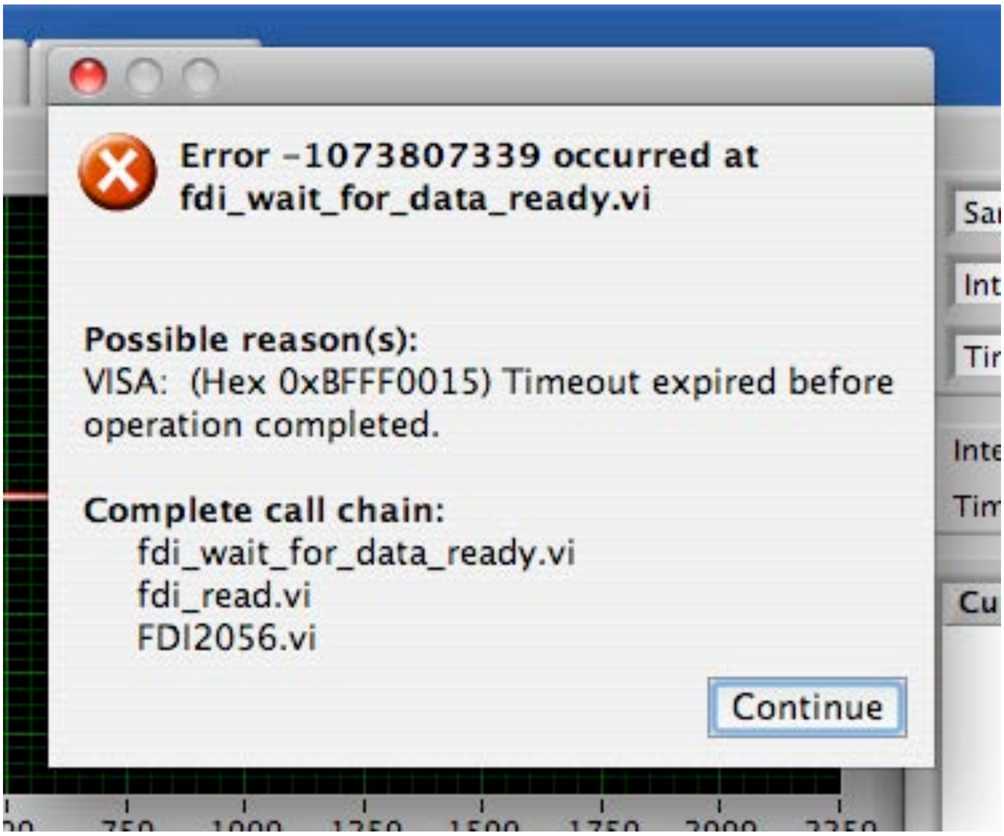
If you point at an object on the screen, a brief tip concerning its function will appear.

3-7 STOPPING THE APPLICATION



To stop the application, use the small "X" button in the top right corner of the window. This ensures that all connections are closed cleanly; if you stop the application in another way, the VISA library may be left in an unstable state, requiring the computer system to be restarted.

3-8 HANDLING ERRORS



Errors are reported in a dialog box. The example shown above, reporting a time-out error, is probably the one you will encounter the most often. In this case, it was caused intentionally, simply by unplugging the Trigger signal, causing the acquisition to time out.

The function trace-back at the bottom of the dialog shows where the error occurred. In this case, we can see that the application ("FDI2056") was trying to read back data ("fdi_read"), but that it timed out waiting for the data to become available ("fdi_wait_for_data_ready"). Chapter 4-Application Programming Interface explains what the various functions do. If you want to report an error to Metrolab, please note the error number, the reason, and the function trace-back.

3-9 VERSION NUMBERS

The firmware version of the selected FDI2056 instrument and the version of the running software are displayed between the Metrolab logo and the Stop button.

PROGRAMMING THE FDI2056
4-Application Programming Interface

The LabVIEW programming Application Programming Interface (API) for the FDI2056 allows users to easily write instrument control programs. Both the LabVIEW API and User Interface (UIF) are included in source code format on the CD that came with your FDI2056. If upgrades become available, you will be able to download them from the Metrolab website, download.metrolab.com.

4-1 GENERAL

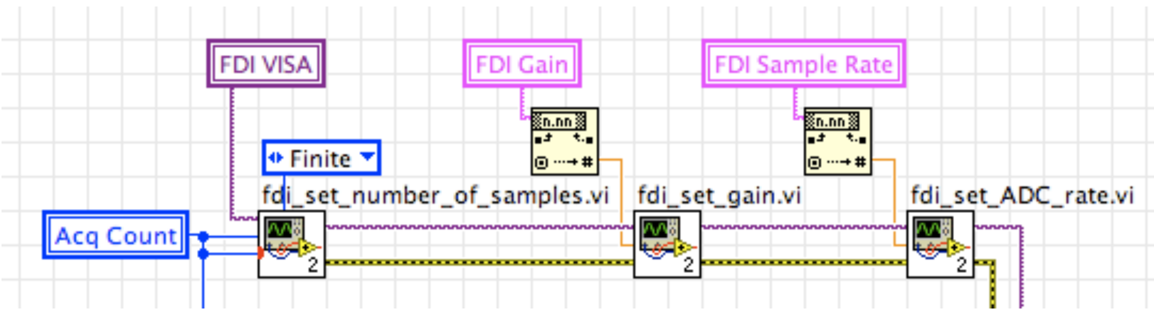
The VIs in the programming API have two standard inputs:

- VISA resource: VISA resource name that specifies the instrument with which we want to communicate;
- Error in: a standard error structure describing errors in previous VIs;

and two standard outputs:

- Dup VISA resource: a copy of VISA resource number;
- Error out: describes errors that occurred in this VI or in previous ones.

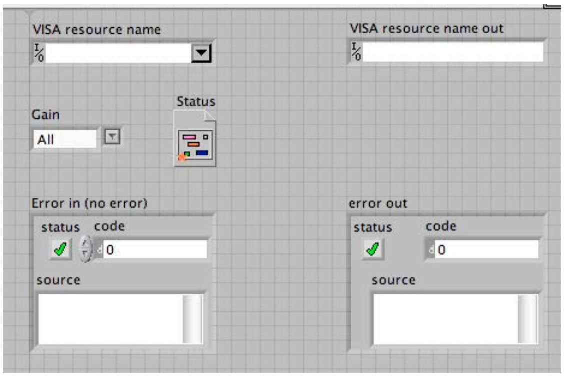
As is common practice in LabVIEW, the connectors for these standard inputs and outputs are located on the four corners of the VI's icon. In a sequence of VIs, the standard outputs of each VI are wired to the standard inputs of the succeeding VI, as shown in the example below:



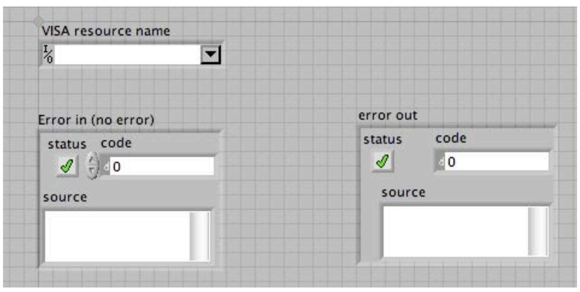
This chaining serves two purposes: it forces the VIs to be executed in the given order, and it stops the execution of the chain if an error occurs. In fact, each VI checks whether its "Error in" input indicates that an error has occurred in a previous VI; if so, instead of its normal function, it simply copies "Error in" to "Error out." In this fashion, the "Error out" at the end of the chain indicates the precise error that caused the rest of the chain not to execute.

The following sections describe each Virtual Instrument (VI) in the API, with its inputs and outputs. The four standard inputs and outputs, described above, are not documented for each VI. The VIs are listed in alphabetical order, which is obviously not the order of importance, nor the logical order in which to call the VIs. For completeness, documentation is also included for low-level routines that in principle should never be called by user programs. See Section 4-32, Programming Hints, for a quick summary of how all the pieces fit together.

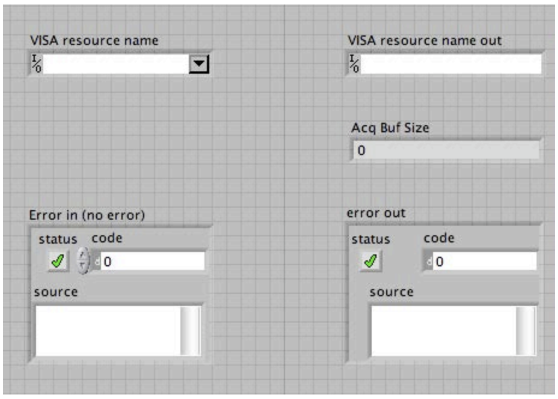
4-2 FDI_CALIBRATE

	Perform calibration of the given gain range. Note that this is an in-place calibration, using reference voltages generated in the instrument itself and designed to control short-term drift. This does not replace a full calibration, based on external reference and measurement equipment, traceable to national and international standards. Gain [In]: The range to calibrate. "All" causes all gain ranges to be calibrated. Status [In]: Reference to a FDI2056 status indicator, for monitoring the status during the wait.

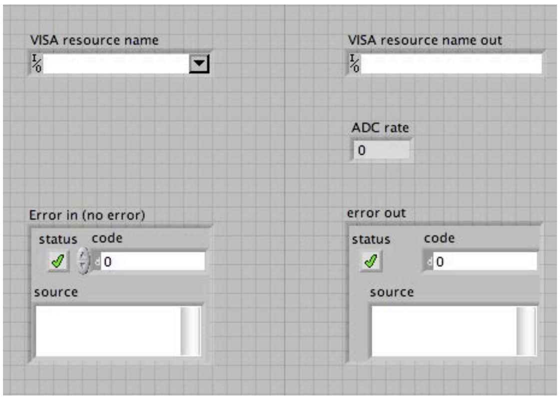
4-3 FDI_CLOSE

	Closes the current session.

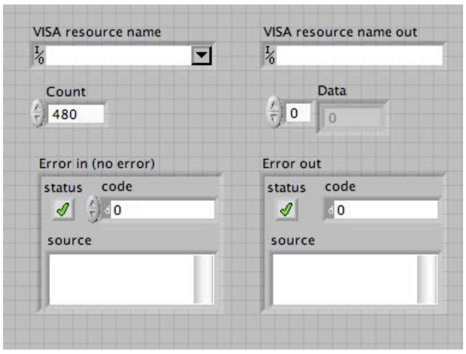
4-4 FDI_GET_ACQ_BUFFER_SIZE

	Get the current acquisition buffer size. Acq Buf Size [Out]: Current acquisition buffer size, in 32-bit words.

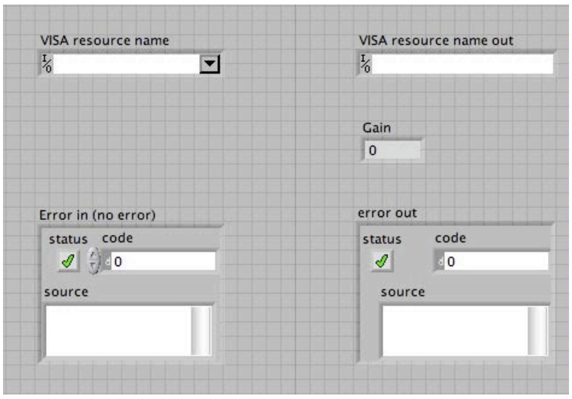
4-5 FDI_GET_ADC_RATE

	Get the ADC sampling rate. Acq Buf Size [Out]: Current ADC sampling rate, in Hz.

4-6 FDI_GET_BUF_8

	Low-level routine to read back byte data from register address 0x8000. Count [In]: Number of bytes to read. Data [Out]: Returned data.

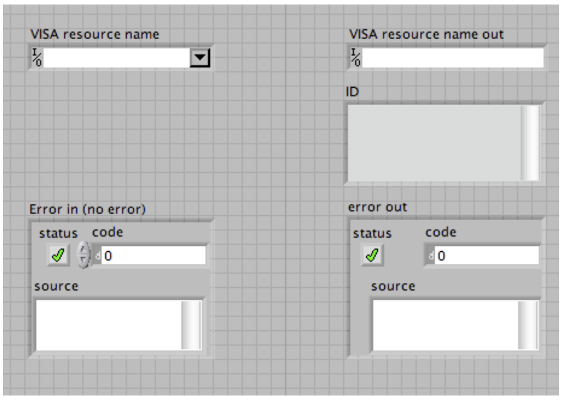
4-7 FDI_GET_GAIN



Return currently selected gain.

Gain [Out]: Currently selected gain.

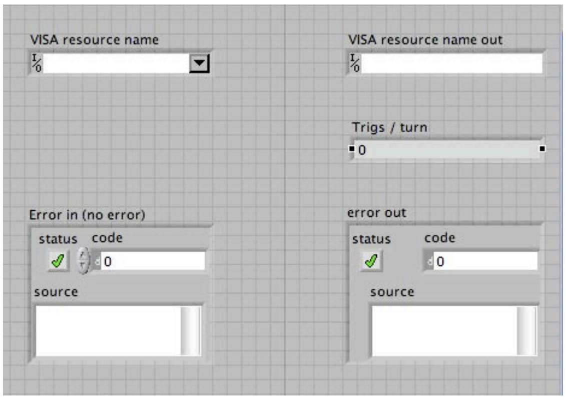
4-8 FDI_GET_ID



Return instrument identification.

ID [Out]: Text identifying the firmware version of the instrument.

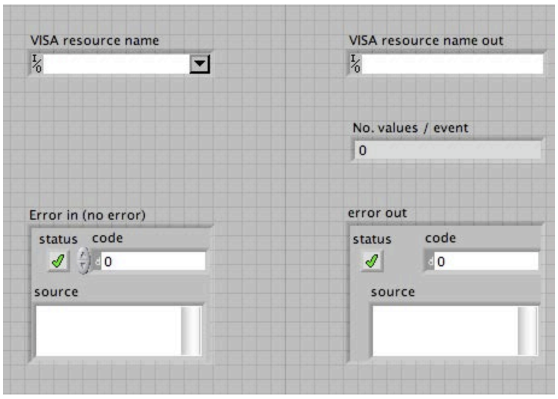
4-9 FDI_GET_NUM_OF_TRIG_PER_TURN



Return currently requested number of triggers per turn.

Trigs / turn [Out]: Currently requested number of triggers per turn.

4-10 FDI_GET_READ_NUM_PER_EVENT

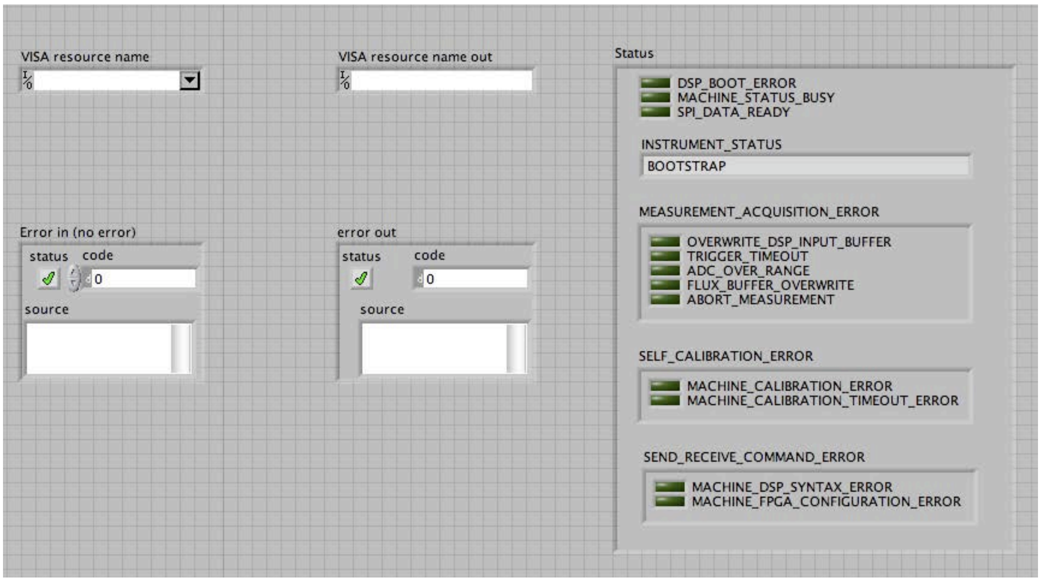


Return the amount of data stored for each trigger.

No. values / event [Out]: amount of data stored per trigger. The default is two, for (Flux, Timestamp) pairs.

Note: Currently the instrument only supports 2 values/event.

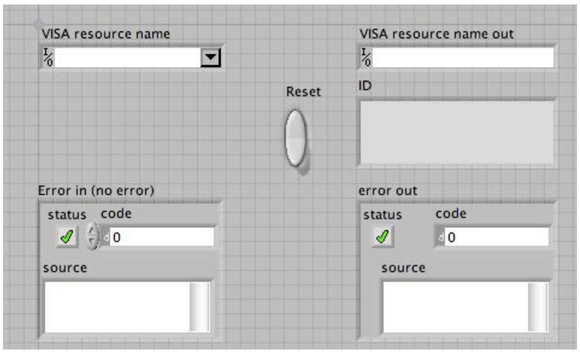
4-11 FDI_GET_STATUS_REG



Fetch and decode instrument status register.

Status [Out]: Decoded instrument status.

4-12 FDI_INITIALIZE

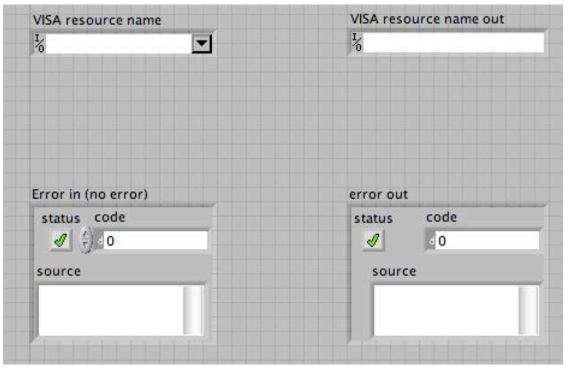


Initialize the instrument. Opens a VISA session and optionally resets the instrument.

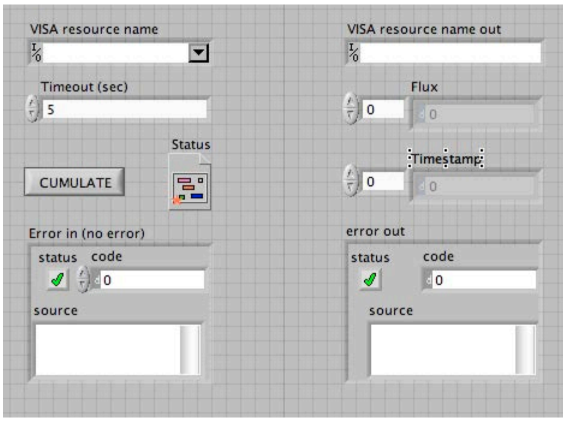
Reset [In]: Whether or not to reset the instrument.

ID [Out]: Text identifying the firmware version of the instrument.

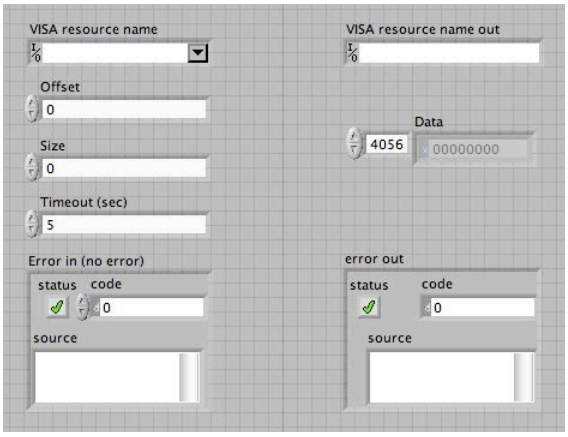
4-13 FDI_MOVE_TO_READY

	Low-level routine to prepare the instrument for a new acquisition.

4-14 FDI_READ

	Read acquired data in accordance with parameters set by fdi_setup_acquisition. Timeout (sec) [In]: Time-out value for data acquisition. CUMULATE [In]: Whether or not to cumulate the partial integrals. Status [In]: Reference to a FDI2056 status indicator, for monitoring the status during the read. Flux [Out]: Partial integrals, in V.sec. If CUMULATE is set, the instrument returns partial integrals starting at zero; otherwise, the partial integral between triggers. Timestamp [Out]: Timestamps corresponding to the flux values, in sec. If CUMULATE is set, the instrument returns a timestamp for each Flux value; otherwise, the time between triggers.

4-15 FDI_READ_BLOCK



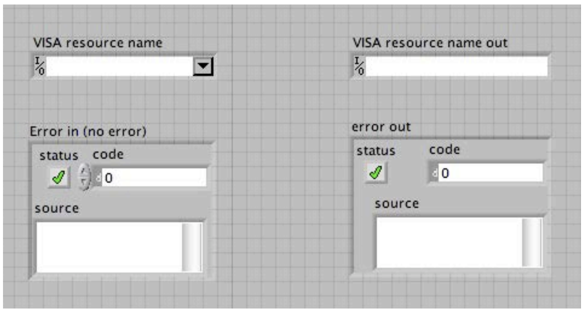
Low-level routine to read a block of acquired data.

Offset [In]: Offset (in 32-bit words) of start of data block to be read.

Size [In]: Size (in 32-bit words) of data block to be read.

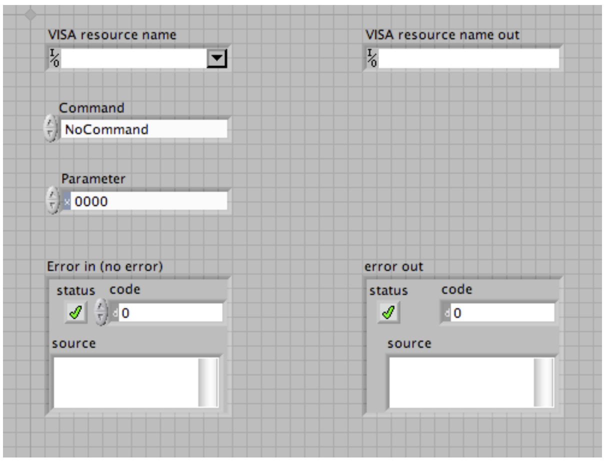
Data [Out]: Returned data block, as an array of 32-bit words. The data consists of (Flux, Timestamp) pairs. Flux is the partial integral of the voltage between two trigger pulses; it is represented as a 32-bit floating-point number, and has units of Volt*second. The Timestamp is an unsigned 32-bit integer, representing a 20 MHz (50 ns) tick count.

4-16 FDI_RESET



Reset the instrument and wait for Ready status.

4-17 FDI_SEND_CMD

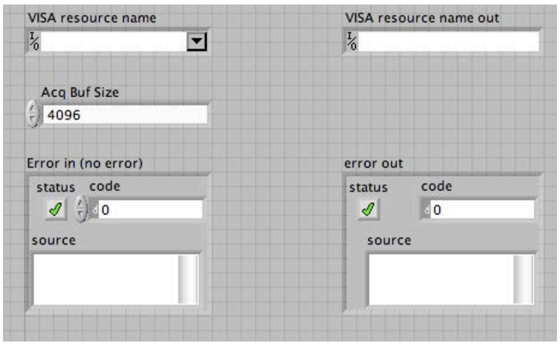


Low-level routine to send a command and its associated parameter to the instrument.

Command [In]: Command to send.

Parameter [In]: Command parameter.

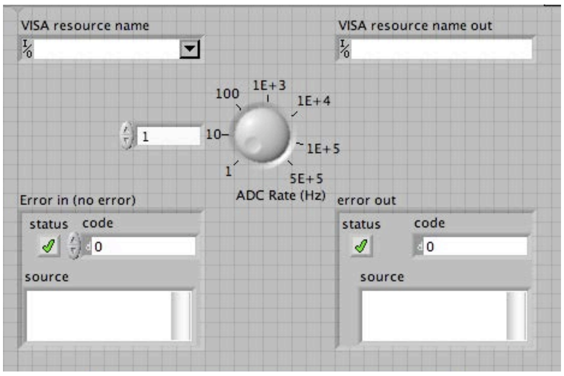
4-18 FDI_SET_ACQ_BUFFER_SIZE



Low-level routine to set the number of (Flux, Timestamp) samples in the acquisition buffer size.

Acq Buf Size [In]: Desired size of acquisition buffer, in 32-bit words. The minimum size is 1 and the maximum size is 4096.

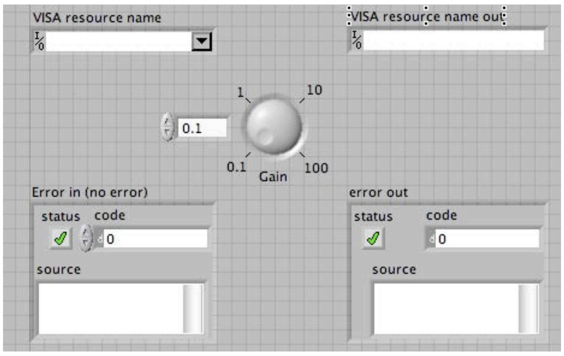
4-19 FDI_SET_ADC_RATE



Set ADC sample rate.

Acq Rate (Hz) [In]: Desired ADC sample rate.

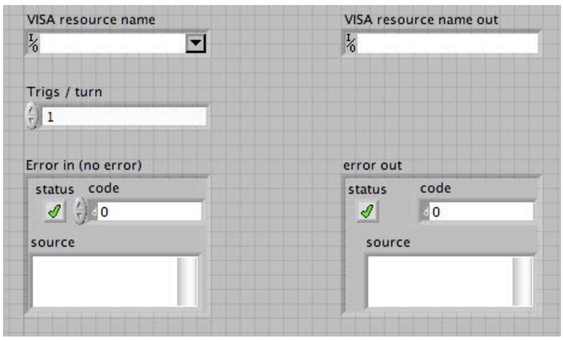
4-20 FDI_SET_GAIN



Set the input gain.

Gain [In]: Desired input gain.

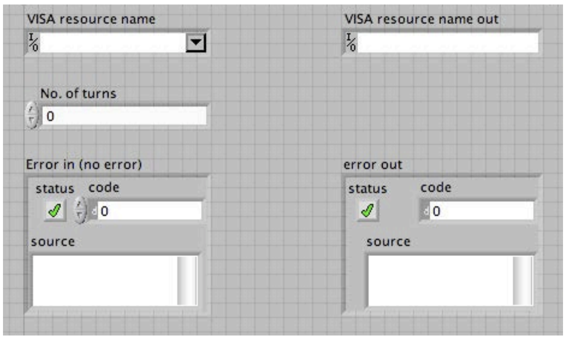
4-21 FDI_SET_NUM_OF_TRIG_PER_TURN



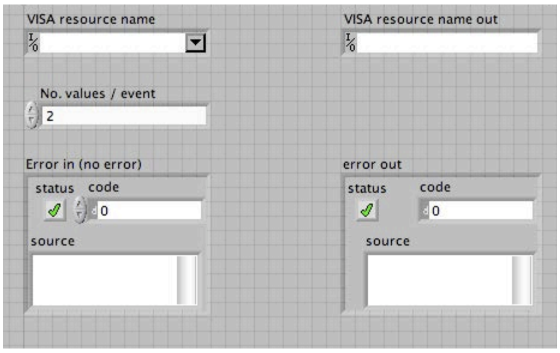
Low-level routine to set the number of triggers per turn.

Trigs / turn [In]: Number of triggers per turn of the rotating coil. Should be a power of two less than 8192.

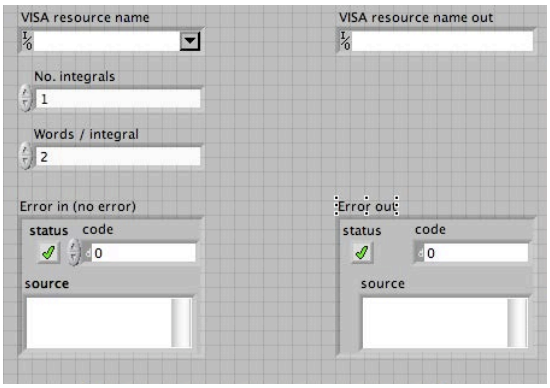
4-22 FDI_SET_NUM_OF_TURNS

	Low-level routine to set the number of turns to acquire. No. of turns [In]: Number of turns of data to acquire. Should be a power of two less than 2^{31}.

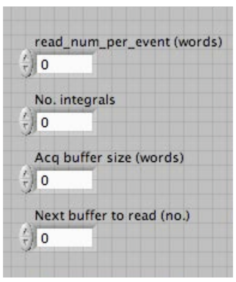
4-23 FDI_SET_READ_NUM_PER_EVENT

	Low-level routine to set the amount of data to store for each trigger. No. values / event: desired amount of data per trigger. The default is two, for (Flux, Timestamp) pairs. Note: Currently the instrument only supports 2 values/event.

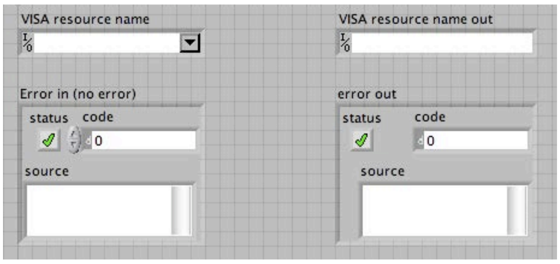
4-24 FDI_SETUP_ACQUISITION

	Set the number of partial integrals to acquire in a subsequent call to fdi_read. Set up the acquisition buffer size, number of words / event, number of triggers / turn, and number of turns accordingly. No. integrals [In]: The number of integrals to read back at a time. Note that powers of two are more efficient. Words / integral [In]: Amount of data stored per trigger. The default is two, for (Flux, Timestamp) pairs. Note: Currently the instrument only supports the default value.

4-25 FDI_SETUP_ACQUISITION_GLOBAL

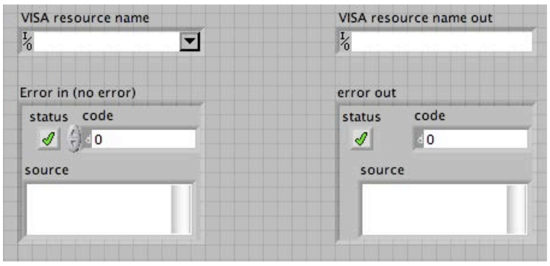
	Low-level global to retain the setup information.

4-26 FDI_START_MEASURE



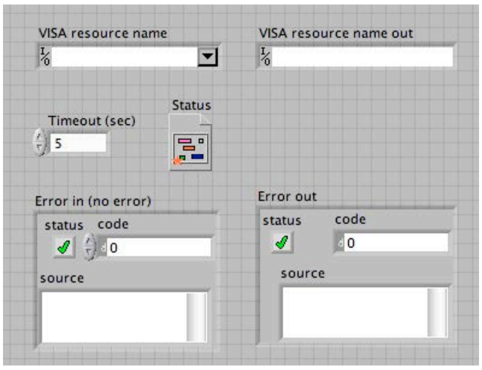
Start an acquisition sequence.

4-27 FDI_STOP_MEASURE



Stop an acquisition sequence.

4-28 FDI_WAIT_FOR_ABORT_MEAS

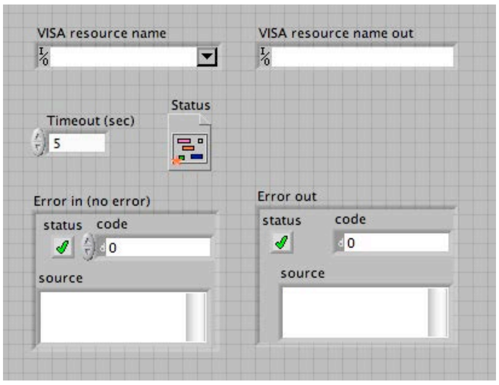


Low-level routine to wait for an acquisition sequence to be aborted.

Timeout (sec) [In]: Maximal time to wait.

Status [In]: Reference to a FDI2056 status indicator, for monitoring the status during the wait.

4-29 FDI_WAIT_FOR_DATA_READY

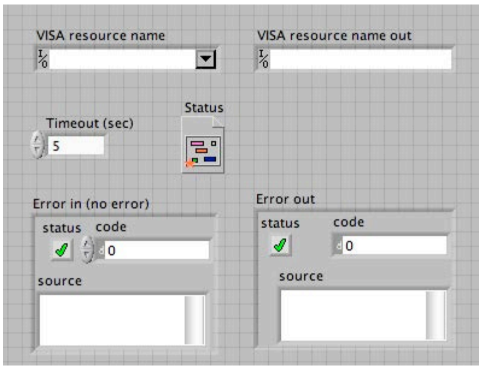


Low-level routine to wait for data to be ready to be read.

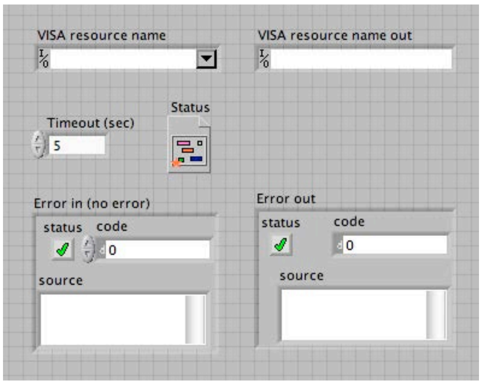
Timeout (sec) [In]: Maximal time to wait.

Status [In]: Reference to a FDI2056 status indicator, for monitoring the status during the wait.

4-30 FDI_WAIT_FOR_MEAS_STATUS

	Low-level routine to wait for an acquisition sequence to be started. Timeout (sec) [In]: Maximal time to wait. Status [In]: Reference to a FDI2056 status indicator, for monitoring the status during the wait.

4-31 FDI_WAIT_FOR_READY_STATUS

	Low-level routine to wait for the instrument to be ready. Timeout (sec) [In]: Maximal time to wait. Status [In]: Reference to a FDI2056 status indicator, for monitoring the status during the wait.

4-32 PROGRAMMING HINTS

A typical program will contain the following steps:

- fdi_initialize to open a VISA session and optionally reset the instrument.
- Optionally, fdi_calibrate to perform an internal gain calibration. This minimizes short-term drift errors and incoherencies between gain settings.
- fdi_set_gain to select the gain setting appropriate for the expected input signal.
- fdi_setup_acquisition to set the number of partial integrals to acquire.
- Optionally, fdi_set_ADC_rate to select the ADC sampling rate. By default, the maximum rate of 500 kS/s is selected, and there is very little reason to select a lower value. In fact, increasing the oversampling ratio generally improves the signal-to-noise ratio.
- fdi_start_measure to start the acquisition.
- fdi_read to acquire the measured flux values. This may be repeated.

- fdi_stop_measure to stop the acquisition.
- fdi_close to close the VISA session.

The source code for the FDI2056 User Interface program (UIF) provides a good example of all these steps.

The number of integrals you wish to read, specified via fdi_setup_acquisition, has a critical impact on the system performance. The acquisition buffer size – which must be a power of two – is chosen to be an integral divisor of this number. For example, if the number of integrals is 1024, the acquisition buffer size is set to 1024, and the entire acquisition requires only a single read operation. If, however, the number of integrals is 1023, the acquisition buffer size is set to 1, and the acquisition requires 1023 separate read operations. Another example: for 8192 integrals, the buffer size is chosen to be 2048 (the maximum), and the acquisition completes in four read operations. However, for 8188 integrals, the buffer size is 4, and 2047 read operations are required. This may slow the acquisition down so much to cause buffer overrun errors. A better approach may be to acquire some additional data and throw it away.

REFERENCE
5-Technical Details

5-1 DIGITIZER PERFORMANCE

Parameter	Conditions	Min	Typ	Max	Unit
ADC RESOLUTION				18	bit
ANALOG INPUT					
Differential voltage range (full-scale FS)	±5 V on each input leg		±10		V
	±10 V on each input leg		±20		V
External trigger source f_t	$f_{ADC} \geq 2 \cdot f_t$	1		250000	Hz
ADC sampling rate f_{ADC}	8 programmable values	1		500000	S/s
Gain	13 programmable values	0.1		100	
DC	FS = ± 10 V, ± 2 σ				
Digitizer Differential Nonlinearity			1.5		LSB
Integrator Integral Nonlinearity	30 min, 27°C – 36°C		± 7		ppm
Integrator stability	24 h, 30°C		± 3		ppm
Integrator repeatability	30 min, 30°C		± 1		ppm
Gain error	30 min, 27°C – 36°C		0.2		%
	24 h, 30°C		0.2		%
Offset error	30 min, 27°C – 36°C		17		ppm
	24 h, 30°C		7		ppm
AC	f_{ADC} = 500 kS/s, OSR = 100, fin = 10 Hz				
Digitizer Signal-to-Noise and Distortion			97		dB
Digitizer Signal Non Harmonic Ratio			103		dB
Digitizer Total Harmonic Distortion			-99		dB
Integrator Signal-to-Noise and Distortion			108		dB
Integrator Signal Non Harmonic Ratio			118		dB
Integrator Total Harmonic Distortion			-109		dB
TIMER RESOLUTION			50		ns
THROUGHPUT RATE	cPCI/PXI bus			1	MB/s

5-2 SYSTEM CONFIGURATION

Connectors	COIL IN+, IN-: 2 x LEMO 00 or LEMO 0B ±100 mV to ± 100 V full-scale, depending on gain TRIG IN, OUT: 2 x LEMO 00 3.3 V, 5 V tolerant TTL, triggered on negative slope REF CLK: LEMO 00 3.3 V TTL PGA OUT: LEMO 00 ± 20 V max full-scale
Indicators	Status: LED 4-character display Vcoil x Gain: LED bar with range of ±10 Test, Hot-Swap: LED (unused)
System bus	Compact Peripheral Component Interconnect (cPCI) or PCI eXtensions for Instrumentation (PXI)
Card size	6U
System bus	Compact Peripheral Component Interconnect (cPCI) or PCI extensions for Instrumentation (PXI)
Standard crate configurations	19", 3-slot cPCI (one slot required for controller), 200 W max
Standard crate controller	PCI Bridge to host computer: cPCI/PXI to PCI, PCI Express, ExpressCard or CardBus/PCMCIA
Software support	LabVIEW User Interface (UIF) and Application Programming Interface (API) on host computer, using NI-VISA
Software functionality	▪ Open, close, reset and auto-calibrate ▪ Set/get parameters: data acquisition type, ADC rate, gain, number of samples, acquisition buffer size ▪ Read data ▪ Get ID and status register
Supported operating systems	Windows, Mac OS X (Linux not tested)

5-3 INSTRUMENT STATUS REGISTER

The instrument status register can be read at any time, and is located at address 0x8418 of the BAR2 address space. Its bits are defined as follows:

DSP BOOT ERROR	0	
BUSY	1	
SPI DATA READY	2	
MACHINE STATUS	3	See table below
	4	
	5	
SELF CALIBRATION ERROR	6	See table below
	7	
MEASUREMENT_ACQUISITION ERROR	6	Overwrite buffer
	7	Trigger timeout
	8	ADC Over range
	9	Measurement error (Overrun)
	10	Abort measurement
SEND_RECEIVE_CMDS ERROR	6	See table below
	7	

MACHINE STATUS				**Value**
5	4	3		
0	0	0	BOOTSTRAP	0x0000
0	0	1	READY	0x0008
0	1	0	SELF_CALIBRATION	0x0010
0	1	1	SEND_RECEIVE_CMDS	0x0018
1	0	0	MEASUREMENT_ACQUISITION	0x0020
1	0	1	RECOVERY	0x0041

MEASUREMENT_ACQUISITION_ERROR						**Value**
10	9	8	7	6		
0	0	0	0	1	OVERWRITE DSP INPUT BUFFER	0x0040
0	0	0	1	0	TRIGGER TIMEOUT	0x0080
0	0	1	0	0	ADC OVER RANGE	0x0100
0	1	0	0	0	FLUX BUFFER OVERWRITE	0x0200
1	0	0	0	0	ABORT MEASUREMENT	0x0400

SELF CALIBRATION ERROR			**Value**
7	6		
0	1	MACHINE_CALIBRATION_ERROR	0x0040
1	0	MACHINE_CALIBRATION_TIMEOUT_ERROR	0x0080

SEND RECEIVE CMDS ERROR			Value
7	6		
0	1	MACHINE_DSP_SYNTAX_ERROR	0x0040
1	0	MACHINE_FPGA_CONFIGURATION_ERROR	0x0080

5-4 INSTRUMENT COMMAND SUMMARY

The reset register is at 0x8420 of the BAR2 address space. Writing 1 to this register resets the instrument.

The command register is at address 0x8414 of the BAR2 address space. Each command consists of an eight-bit command code and eight bits of data, as shown in the table below.

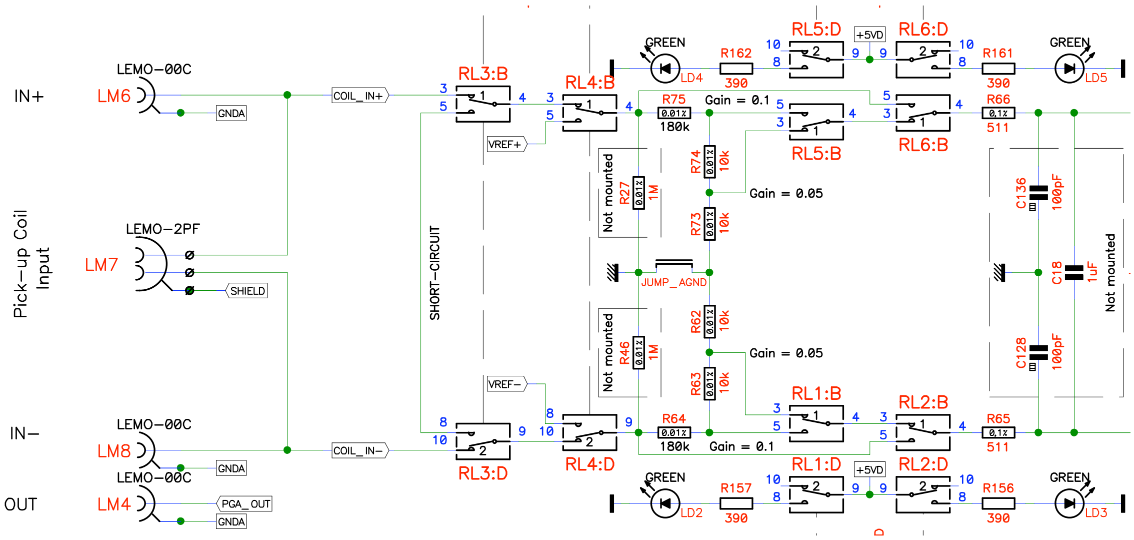
Command	**Code**	**Parameter**
Calibrate	0x1	None
Calibrate_All	0x2	None
Start_Measure	0x3	None
Move_To_Ready	0x4	None
ID	0x5	None
Set_Algorithm	0x6	Algorithm number; 4 bits (8-11); command currently not used.
Set_Size_Flux_Buffer	0x7	Size of acquisition buffer, in words; 4 bits (8-11); power of two; maximum value is 12, since 2^12 = 4096 = half of flux memory.
Set_Gain	0x8	Gain level; 4 bits (8-11).
Set_F_Adc	0x9	ADC sampling rate; 3 bits (8-10): 0 0 0 500 kHz 0 0 1 250 kHz 0 1 0 125 kHz 0 1 1 62.5 kHz 1 0 0 31.25 kHz 1 0 1 15.625 kHz 1 1 0 7.8125 kHz 1 1 1 1 Hz
Read_Gain	0xA	None
Read_F_Adc	0xB	None
Number_Of_Trigger	0xC	Number of triggers per turn; 4 bits (8-11); power of two.
Set_Turn_Number	0xD	Number of turns; 5 bits (8-12); power of two.
DAC_Calibration	0xE	Command not used.
Read Size Flux Buffer	0xF	None
Read Number_of_Trigger	0x10	None
Read Turn_Number	0x11	None
Set_Number_Read	0x12	Number of data words per trigger; currently be 2.
Read_Number_read	0x13	None
Abort_Measurement	0xFF	0xFF

The read commands return their result as an ASCII string at address 0x8000 of the BAR2 address space.

The acquisition buffer is located at address 0x0000 of the BAR2 address space. It is organized as an N-buffer, where N = 8192 / Acq buffer size, given by the Set_Size_Flux_Buffer command. When starting an acquisition, the instrument first fills buffer 0, issues data ready, then starts filling buffer 1, and so forth until it wraps back around to buffer 0. Each partial integral occupies two words; thus the memory can hold at most 8192 / 2 = 4096 partial integrals.

5-5 INPUT ADAPTATION

The "IN+" and "IN-" coil inputs can be optimized for your coil signals. The schematic below shows an excerpt of the FDI2056 input circuitry.



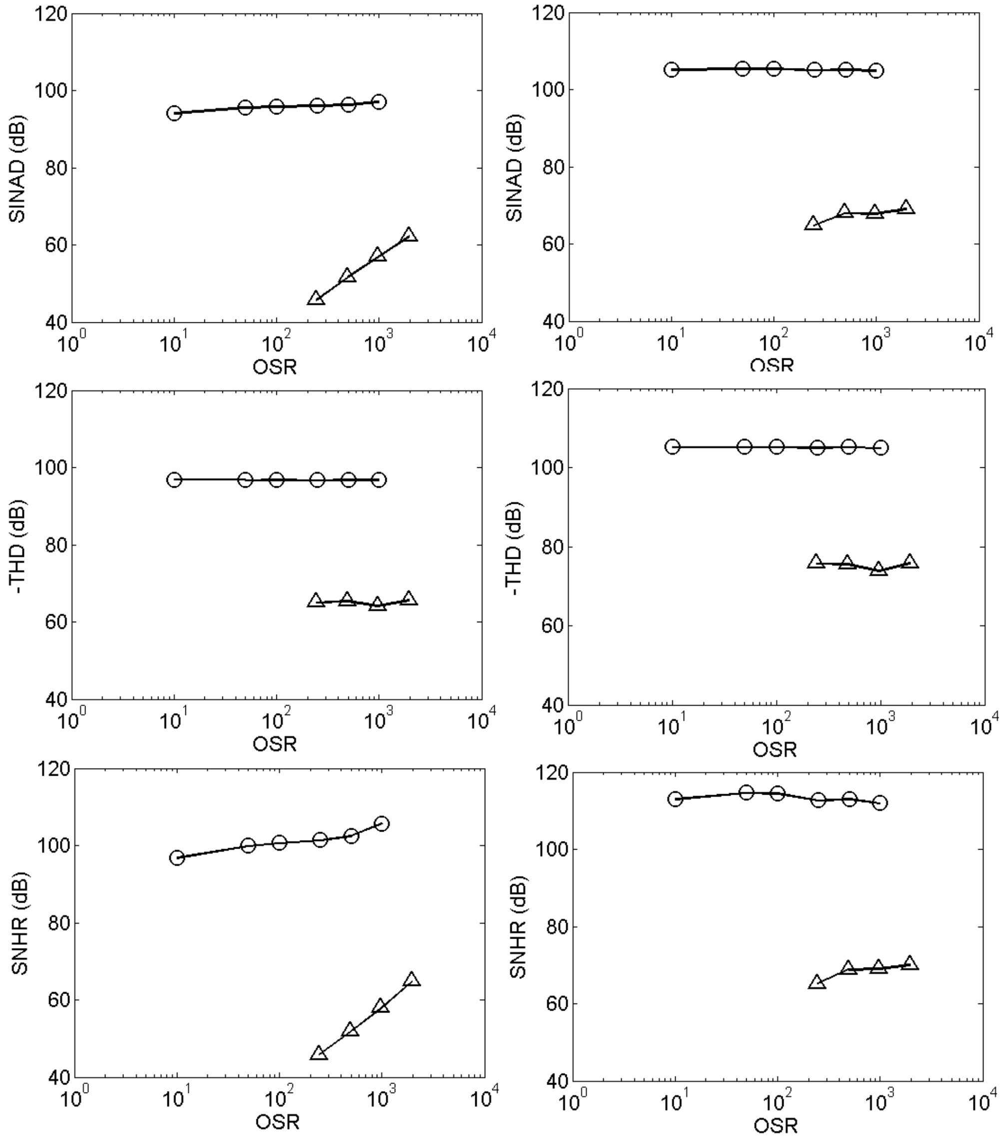
- R27 and R46 can be mounted to tie IN+ and IN-, respectively, to ground. By default, these are not mounted, so that both are floating inputs.
- C18 can be used to filter common-mode HF noise. By default, this is used as an anti-aliasing filter for the ADC, with a cut-off around 250 kHz.
- C136 and C128 can be used to filter HF noise on IN+ and IN-, respectively, relative to ground. By default, these are not mounted.

CAUTION

⇒ These modifications are to be performed only by professional electronics technicians. Unprofessional workmanship may destroy your card and will void your warranty. Metrolab will happily perform any necessary modifications for a nominal service fee, and free of charge if you state your requirements at the time of ordering.

5-6 COMPARISON WITH PRECISION DIGITAL INTEGRATOR

The following graphs show the results of tests comparing the dynamic performance of the FDI2056 (○) with that of the previous-generation Precision Digital Integrator architecture used in the Metrolab PDI5025 (△), when used as a digitizer (left) and as an integrator (right). Shown are the Signal-to-Noise and Distortion (SINAD), Total Harmonic Distortion (THD) and Signal Non Harmonic Ratio (SNHR) as a function of Oversampling Ratio (OSR). The ADC sampling rate used was 500 kS/s, so an OSR of 10 corresponds to a trigger rate of 50 kHz. The lowest OSRs, corresponding to the fastest sampling rates, cannot be attained by the PDI.[1]

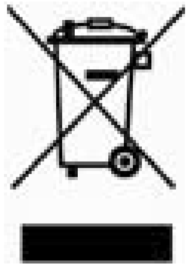


[1] *These results, as well as the performance specifications in Section 5-1, are taken from the Ph.D. Thesis of Giovanni Spezia, University of Sannio, 2008.*

5-7 WARRANTY, CALIBRATION, CERTIFICATION AND MAINTENANCE

Warranty	2 years
Recommended calibration interval:	12 months
Maintenance	None

NOTICE

⇒ 

This product conforms to the WEEE Directive of the European Union (2002/96/EC) and belongs to Category 9 (Monitoring and Control Instruments). For proper environment friendly disposal, you can return the instrument free of charge to us or our local distributor.