Data monitoring client for data acquistion servers

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Publisher’s version / Version de l'éditeur:
https://doi.org/10.4224/8895510
Student Report (National Research Council of Canada. Institute for Ocean Technology); no. SR-2008-03, 2008

National Research Council Canada
Institute for Ocean Technology

Conseil national de recherches Canada
Institut des technologies océaniques

Student Report SR-2008-03

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April 2008

DOCUMENTATION PAGE

REPORT NUMBER SR-2008-03	**NRC REPORT NUMBER**	**DATE** April 2008		
REPORT SECURITY CLASSIFICATION Unclassified		**DISTRIBUTION** Unlimited		
TITLE **DATA MONITORING CLIENT FOR DATA ACQUISITION SERVERS**				
AUTHOR(S) Chris Squibb				
CORPORATE AUTHOR(S)/PERFORMING AGENCY(S) IOT/NRC				
PUBLICATION N/A				
SPONSORING AGENCY(S) N/A				
IOT PROJECT NUMBER		**NRC FILE NUMBER**		
KEY WORDS Sweet, GDAP, data acquisition, GEDAP, metering, statistics		**PAGES** 42	**FIGS.** 19	**TABLES**

SUMMARY

During this past work term, most of my time was spent developing Digital Meter. Digital Meter is a Graphical User Interface (GUI) based application, which primarily allows users to monitor Data Acquisition Server (DAS) channel values. In a general sense, channels are usually data producing sensors such as pitch encoders, load cells, temperature and light sensors, etc. Digital Meter provides the user with an abundance of tools and features to aid in channel monitoring, ultimately allowing projects that make use of DAS technology to be run more effectively.

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Data Monitoring Client for Data Acquisition Servers

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April 17, 2008

1 Summary

During this past work term, most of my time was spent developing Digital Meter. Digital Meter is a Graphical User Interface (GUI) based application which primarily allows users to monitor Data Acquisition Server (DAS) channel values. In a general sense, channels are usually data producing sensors such as pitch encoders, load cells, temperature and light sensors, etc. Digital Meter provides the user with an abundance of tools and features to aid in channel monitoring, ultimately allowing projects that make use of DAS technology to be run more effectively.

The following report has been broken up into two distinct sections, one to act as a user's guide and another as a brief design document.

The user's guide walks through most of the prominent features within Digital Meter, explaining how to use them as well as expected results along the way. Diagrams and Digital Meter screen captures have been provided where applicable to provide feedback to the reader ensuring them that Digital Meter is being used properly. Notes have been appended to the relevant sections in an attempt to reason any behaviour that may seem a little strange or unexpected. It is recommended that anyone required to use Digital Meter read the user's guide section of this report.

The design documentation provides a brief overview of the primary classes within Digital Meter, as well as their interactions. This section of the report details specific software design principles and as such, carries an applicable scope of content. It is intended that this section of the report not be read by end users, rather, it is to be used by future developers of Digital Meter as an introduction to how Digital Meter operates.

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2 Introduction

2.1 Overview of Digital Meter

Digital Meter is a Graphical User Interface (GUI) based application developed to monitor channel values on one or more Data Acquisition Servers (DASs). Built from the ground-up as a multi-page application, Digital Meter provides the end user with many abilities and configuration options aiding in channel monitoring. While being feature-rich, Digital Meter maintained the ability to be used quickly and easily. Of the features found in Digital Meter, some of the more prominent include:

- Multi-page support, with the capability to select data sampling rate and averaging time on a page-by-page basis.
- Ability to display a channel's mean, min, max, standard deviation, and slope in 'real-time' once the specified averaging time has elapsed.
- Virtual channels can be created as a mathematical combination of one or more channels that are currently being monitored. These channels can be either from a DAS, or another virtual channel.
- Configuration saving/opening. Once a configuration has been designed (page layout, sampling rate, averaging time, font styles and colours, etc.) it can be saved for later usage, or to share amongst colleagues.
- Indicators for clock sync errors between the DASs and Digital Meter, user specified channel alarms, and channel staleness alert the end user of possible problems while monitoring.

Once installed[1], Digital Meter can be opened by double-clicking on its icon, assuming you have the required libraries installed. Digital Meter was developed using the Python scripting language and depends on the following libraries:

- **Python** {*public*}
  Python is a very powerful object oriented programming language that can be used for a wide variety of applications, such as Web Development, Database Access, Desktop GUI Applications, and Scientific Computing.

[1]Seek installation help from Keith Mews of the Software Engineering Group.

- **NumPy** {*public*}
  Since Python is an interpreted language, mathematical calculations on large sets of data run a measurable amount slower than they would in a compiled language such as C^{++}. NumPy addresses this problem by providing fast access multi-dimensional arrays packaged with functions and operators that can be performed on these arrays. Thus any algorithm that can be expressed primarily as operations on arrays will run almost as fast as the equivalent compiled code [1]. Digital Meter makes use of NumPy in order to calculate such things as the mean, standard deviation, and slope values for each channel.

- **wxPython** {*public*}
  wxPython is an extension module for Python which allows programmers to create a robust and highly functional GUI. It is essentially a wrapper of the popular wxWidgets cross platform GUI library, which is implemented in C^{++} and provides access to all of the common window components.

- **SWEET Framework** {*NRC internal*}
  From the SWEET Wiki[2]:

  > Sweet (SoftWare Environment for Experimental Technologies) is an environment used to manage the information technology needs of scientific and engineering research organizations. It was developed as a collaboration between the Institute for Information Technology (IIT) and the Institute for Ocean Technology (IOT) of the National Research Council of Canada. It is currently being adapted for use within the Institute for Aerospace Research.

3 User Guide

The following section is intended as a usage guide to the end users of Digital Meter. Explaining everything from the most basic use cases to the more advanced usage of virtual channels. It is recommended that anyone required to use (or interested in using) Digital Meter read the relevant sections of this guide.

3.1 Start-up Screen Overview

Upon launching Digital Meter you will be presented with a generic application window as shown in *Figure 1.* This window contains three main components; the main menu, the status bar, and the work area.

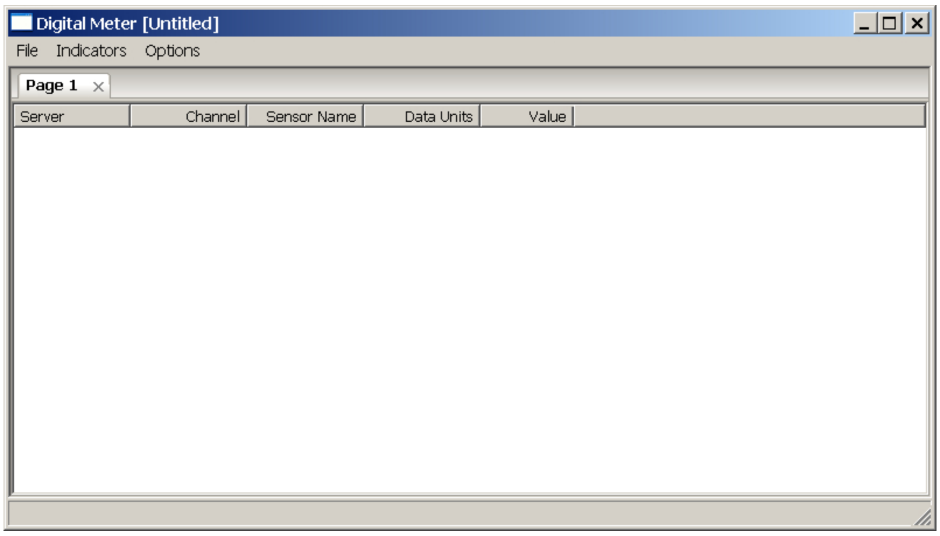


Figure 1: Digital Meter start-up screen

The main menu provides the user with options to manage their configurations, enable/disable status indicators and to set properties on them, as well as provide the ability to change global options of Digital Meter such as the time between screen updates.

The status bar is used as a means to quickly display the clock error between the client (computer running Digital Meter) and each server (DAS) that is currently being monitored. Ideally this would be as close to 0 as possible, though this is not always the case. If you are constantly seeing clock errors in excess of 75 ms in either signed direction it is suggested to make sure that the Network Time Protocol (NPT)[3] software is running correctly on your computer, as well as the computer hosting the DAS software.

The work area is where channel monitoring occurs. Within the work area there can be multiple pages, with different channels on each page. Also accessible from this work area is the context menu. To invoke the context menu, right-click anywhere within a page. The page that is used to invoke the context menu will be the page that receives all events which propagate from actions the user performs from within the context menu. The context menu provides access to most of the functionality available within Digital Meter, with the primary exception of Status Indicators, see *Section 3.4*. Throughout the rest of this document whenever a reference is made to the context menu, it is referring to this menu unless otherwise specified.

3.2 DAS Connections

3.2.1 Connecting to a DAS

In order to monitor channels from a DAS a connection must first be established. This process begins by selecting the *New Server* entry in the context menu. Once clicked, a dialog box will be displayed, prompting you to enter the address of the DAS you wish to connect to, as shown in *Figure 2*. This address is typically in one of two formats:

1. Local Network Name - If the DAS exists within the same local network as the client computer and the network name of the DAS is known (*eg.* DASPC35) then it can be entered into the address field.
2. IP Address - If the IP address (in the form of ###.###.###.###) of the DAS is known then it can be entered into the address field.

Once the address is supplied, click on the *Ok* button to attempt to establish a connection to the DAS. If the connection cannot be established, a dialog box will be displayed warning you of the connection issues. Attempts to connect will continue until the *Cancel* button is clicked. If the connection can not be established, ensure that the address specified is correct and that the DAS software is running on the address specified.

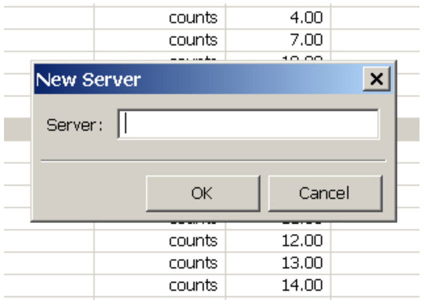


Figure 2: Creating a new connection.

If a connection is successfully established with the DAS then a new dialog is displayed, which lists all the channels that were discovered on the DAS, as shown in *Figure 3*. From this dialog you must select which channels you wish to monitor, by checking the associated check box next to each entry. If you wish to monitor all of the listed channels, you can use the *Check All* button to select all of the entries. It is important to note that the selections made at this stage are not final, and any of the channels can be imported into (or removed from) Digital Meter very easily at a later time. It is however, required that you select at least one channel to monitor, as a DAS with no channels currently being monitored is considered invalid and the connection to the DAS will be automatically terminated. Once you have selected the desired channels, click *Ok* to append the selected channels to the page which was used to invoke the connection.

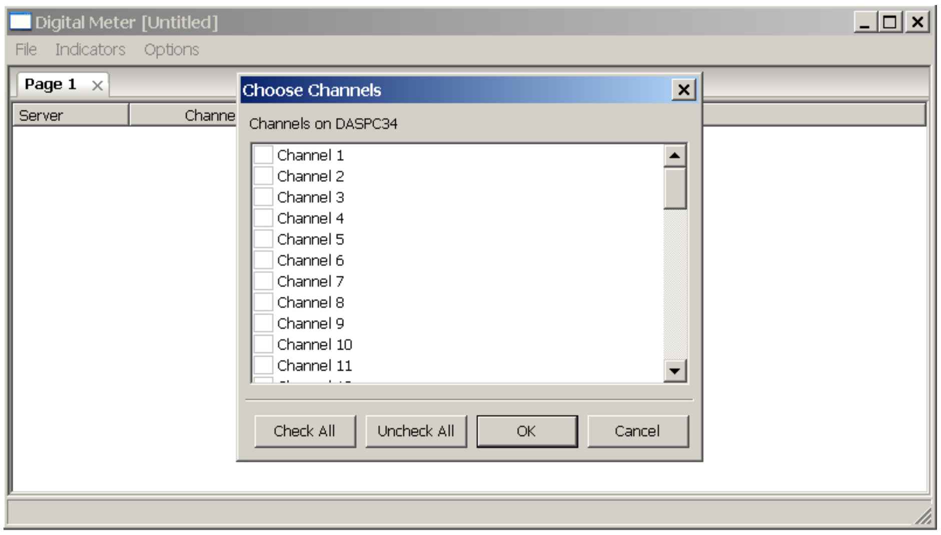


Figure 3: A list of channels discovered from a DAS.

3.2.2 Adding/Removing DAS channels

As previously mentioned, during the process of connecting to a DAS you must select some channels on that DAS to monitor. If you wish to change which channels from a particular DAS are currently displayed on the page, invoke the context menu and choose the menu item corresponding to the DAS server name (near the bottom of the menu). Clicking on a DAS server name in the context menu presents you with the same list dialog presented during the connection process. From this list, check/uncheck the boxes as required and click *Ok* when finished. This will add/remove the appropriate channels to/from the page.

3.2.3 Disconnecting from a DAS

Disconnections are handled in a somewhat automatic way, in that there is no actual disconnect option. Instead, to disconnect a DAS you remove all channels (from all pages) for that DAS, following the same procedure as discussed in *Section 3.2.2*.

3.2.4 Displayed Units

The units of each channel being monitored on a particular page can be one of:

- Raw
- Uncalibrated
- Calibrated[2]

To switch between these displayed units, invoke the context menu and at the top you will find a menu entry corresponding to each unit type. Selecting the desired unit type will issue a command to change the displayed units of all channels on the selected page. While different pages can have different display units, all of the channels on a single page are required to have the same.

[2]To see the correct calibrated units, you must have previously metered or acquired data from the channel using GDAC, to cause calibration information to be uploaded to the DAS.

3.3 Pages

Digital Meter is a multi-page application. In essence, this provides the user with the capability to monitor the same channel in a different fashion on each page, such as average each channel over a different averaging time. It also provides a means for the end user to separate groups of channels in a logical fashion.

3.3.1 Creating New Pages

To create a new page simply invoke the context menu and select the *New Page* option. This will create a new page in the work area, using a default name of *Page #*, where # is based on the number of previously created pages. This default page name can be changed from within the Page Properties dialog, as discussed in *Section 3.3.2*.

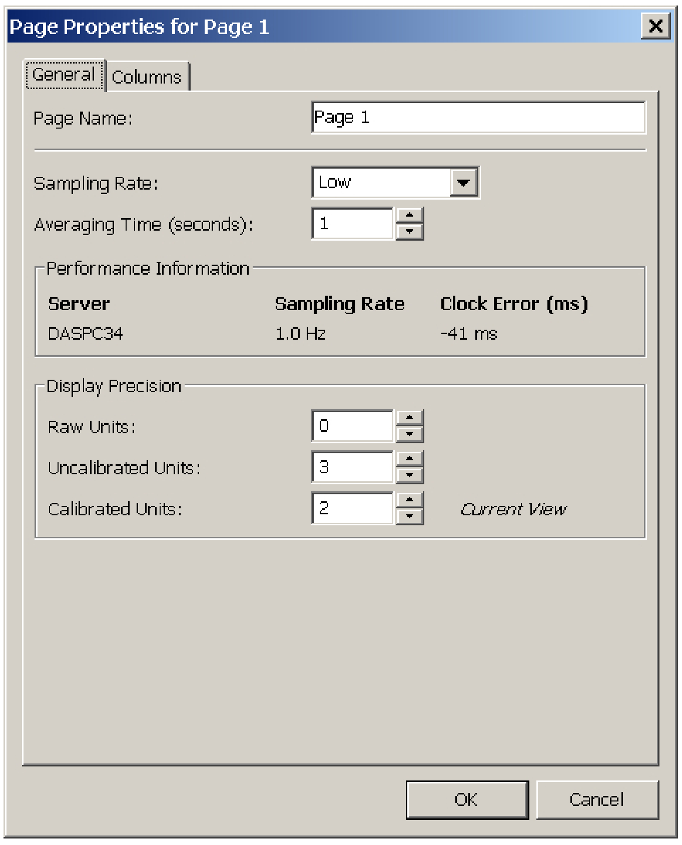
3.3.2 Page Properties

To access the page properties, invoke the context menu and select *Page Properties*. This will present a standard styled properties dialog, as shown in *Figure 4*. There are two tabs available within the page properties dialog:

- General - This is the main tab in which you can perform a variety of page configuration options. The page name can be changed by entering in a value in the *Page Name* field. The sampling rate and averaging time for the selected page can also be set.
  - Sampling Rate - This option controls how fast Digital Meter will acquire data from the DAS with respect to the selected page. In the case of a multi-paged configuration, the actual rate of which new data is retrieved from the DAS is determined by the page with the highest sampling rate, however, pages with a lower sampling rate will behave as if the sampling rate is as set.
  - Averaging Time - This is the time (measured in seconds) that the selected page will consider when determining such things as the mean, slope, min, max, and standard deviation of a channel.

  The next section of the page properties dialog provides a quick status overview of each DAS that owns one or more channels on the selected page. Providing such information as clock sync error and the actual obtained sampling rate allows the user to ensure that things are working correctly. Finally, the last section provides a way to change the significant digits to be displayed when viewing the page in each of raw, uncalibrated, and calibrated units. These values can also be changed through the context menu.

- Columns - This tab allows you to change which columns are to be displayed and hidden on the selected page. Columns with their associated check box checked are considered to be displayed. For an explanation of each of the columns please refer to *Section 3.3.4*



Page Name: Page 1

Sampling Rate: Low

Averaging Time (seconds): 1

Performance Information

Server	Sampling Rate	Clock Error (ms)
DASPC34	1.0 Hz	-41 ms

Display Precision

Raw Units: 0

Uncalibrated Units: 3

Calibrated Units: 2 *Current View*

Figure 4: The Page Properties dialog

Once changes have been made to the page properties, the *Ok* button must be clicked in order for them to take effect. Note, setting these options (specifically the sampling rate and averaging time) should not be done without caution. If you are monitoring many channels from multiple servers within a multi-page environment and set these options too high, then system performance can be adversely affected.

3.3.3 Drag-and-drop Support

Drag-and-drop a is feature inherent within most applications, usually providing the ability for the end user to move or copy data from one item to another. In terms of Digital Meter, drag-and-drop allows you to change the ordering of channels within a page, as well as change the location of pages themselves.

To perform drag-and-drop on pages, click the page tab (where the page name is displayed) and move the mouse to the location that you wish to drop the page. Valid page locations will be identified by a semi-transparent blue rectangle as you move the mouse around the screen. Once the blue rectangle appears in the desired area, let go of the mouse to set the pages new location.

There are essentially three combinations of drag-and-drop possible in regards to channel re-ordering:

1. Move within a page
2. Move between pages
3. Copy between pages

To perform either of these drag-and-drop options you select[3] the desired channels. Once the desired channels have been selected, click on any selected channel and drag (while holding the mouse button down) the group of channels to the desired drop location. Once at the drop location, release the mouse button and the channels will be moved. To copy channels from one page to another, repeat the above steps, except hold down the *Ctrl* key[4] before dropping the channels.

3.3.4 Column Meanings

As previously mentioned, on each page within the Digital Meter there are a number of possible columns that can be displayed. By default, the first page

[3]A channel is identifiable as selected when it turns navy blue in colour.

[4]The mouse pointer should change to indicate that the *Ctrl* key was pressed, usually indicated by a small + sign next to the cursor.

that is created when Digital Meter is launched contains five columns:

- Server - Address specified to make the connection to the DAS.
- Channel -Channel number of the associated channel from the DAS.
- Sensor Name - Sensor name of the associated channel, which will be blank if calibration information has not been uploaded to the DAS.
- Units - Units that the channel is currently being viewed in. If this is not specified then the assumption is that the units are raw counts.
- Value - Most recent value obtained from the DAS for the specific channel.

Digital Meter can be configured (on a page-by-page basis) to include the following optional columns:

- Mean - Displays the calculated mean value of the data collected from the channel over the specified averaging period.
- Min - Displays the minimum value of the data collected from the channel over the specified averaging period.
- Max - Displays the maximum value of the data collected from the channel over the specified averaging period.
- Standard Deviation - Displays the standard deviation of the data collected from the channel over the specified averaging period.
- Slope - Displays the calculated slope value of the data collected from the channel over the specified averaging period. The slope is calculated using a line of best fit through all data points in the data set.
- Alarm Name - Displays the optional alarm name associated with the channel. For more information regarding alarms please refer to *Section 3.4.1*

As one would expect, some of these columns have no meaning unless an averaging time has been specified. If this is the case, a $--$ value will be displayed in the appropriate cell. This value will also be displayed if there has not been enough data collected to satisfy the averaging time requested.

3.3.5 Column Sorting

Column sorting is available in ascending and descending order for the following columns:

- Server
- Channel
- Sensor Name
- Units

Column sorting is smart. If sorting by a particular column makes no difference to the order then a secondary[5] column would be chosen on which to sort. For example, if there is only one DAS connection, then sorting by *Server* would yield no change. In this case the *Channel* column would be chosen as the secondary sort column.

3.3.6 Other Page Customizations

Along with the general page properties discussed in *Section 3.3.2* there are a number of other customizations that can be made to a page:

- Fonts - The font style and colour of the entire page can be changed (*eg.* Font size can be greatly increased so that Digital Meter can be read from a distance.). To change the font of a page invoke the context menu and select *Font*. This will present you the standard Windows font selection dialog as shown in *Figure 5*. From it you can change things such as the font face, style, colour, size, etc.
- Channel Background Color - To aid in channel monitoring the ability to highlight channels, by changing their background colour, has been designed into Digital Meter. To change the background colour of a channel right-click on the desired channel(s) and select *Change Background Colour*. This will present you with a colour chooser dialog box, from which you select the colour you want to associate with that channel. This change applies only to the current page. If a modified

[5]and then tertiary, quaternary, ... as needed

channel exists on another page, it will not be affected. Note also that background colour is preserved through the drag-and-drop operations described in *Section 3.3.3*.

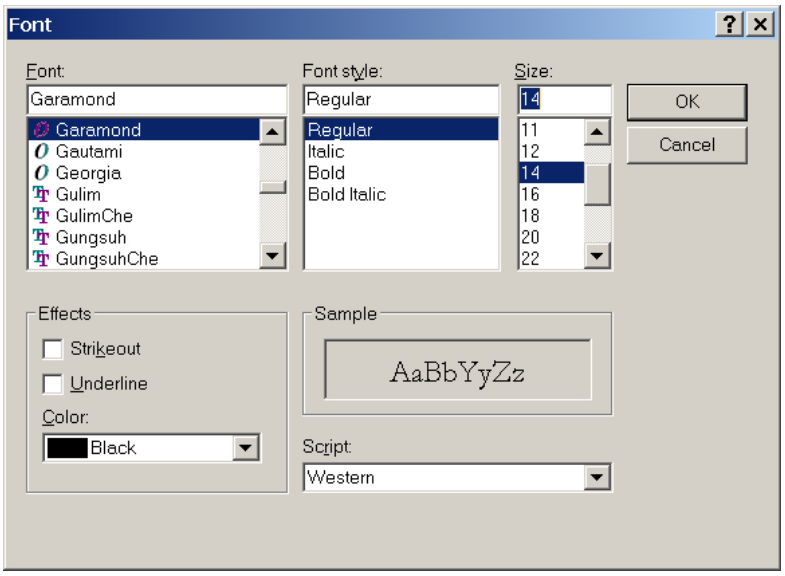


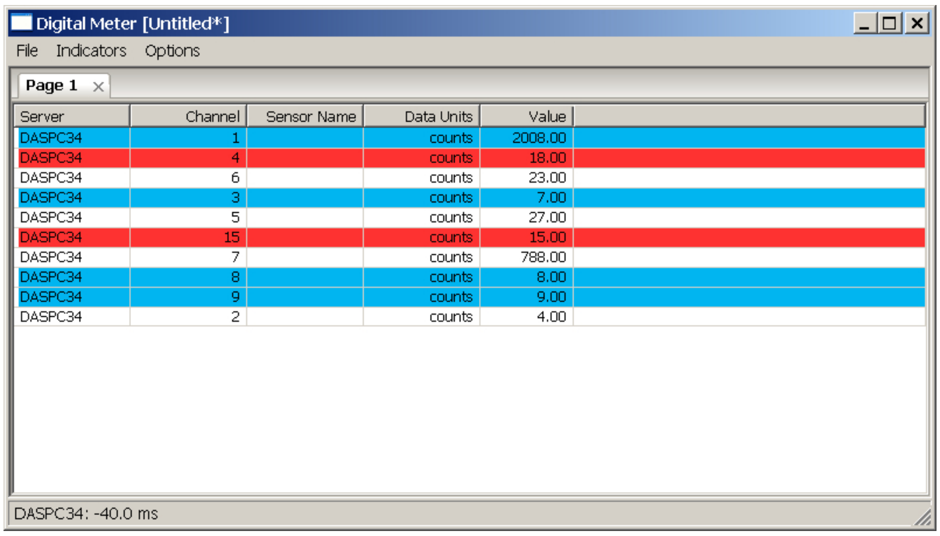
Figure 5: The page-based font selection dialog.

3.4 Status Indicators

Status indicators are a way of providing the user with some feedback on the status of specific channels of a DAS, or the DAS as a whole. For most of these indicators, what is considered safe and unsafe is determined by input from the user. The user also has the option to disable and enable each of the indicators globally, or based on a specific DAS channel in some cases. The following three sections outline the details surrounding each of the three major indicators, Alarms, Clock Sync Error, and Channel Staleness. Refer to *Figure 6* to see a sample configuration of Digital Meter in which multiple indicators have been triggered.

3.4.1 Alarms

Alarms are used to indicate when the value of a channel falls outside of a user specified range. When this happens the alarm is triggered and all instances of the channel will show up with a red background (by default).



Server	Channel	Sensor Name	Data Units	Value
DASPC34	1		counts	2008.00
DASPC34	4		counts	18.00
DASPC34	6		counts	23.00
DASPC34	3		counts	7.00
DASPC34	5		counts	27.00
DASPC34	15		counts	15.00
DASPC34	7		counts	788.00
DASPC34	8		counts	8.00
DASPC34	9		counts	9.00
DASPC34	2		counts	4.00

DASPC34: -40.0 ms

Figure 6: Digital Meter monitoring a DAS with triggered alarms(red) and stale channels(blue).

A list of alarms and their properties can be viewed by one of two methods:

1. Page-by-page - If you wish to view only those alarms for channels on the selected page, invoke the context menu and select *Edit Alarms*.
2. All alarms - If you wish to view a list of all alarms, from the main menu click *Indicators* → *Edit Alarms*.

3.4.2 Alarm Properties

The Alarm Properties dialog is accessible two ways. The easiest way to access the Alarm Properties dialog is to right-click on a single channel on any page, and from the context menu select *Alarm Properties*. Another way is to bring up a list of alarms as discussed in *Section 3.4.1* and double-click on the desired alarm.

Alarms have three properties that are associated uniquely to each channel, independent of page. All of which are modified through the Alarm Properties dialog. These properties are:

- Alarm Name - Alarms can be given a, which will be displayed in the Alarm Name column on any page that contains the channel (assuming the column is enabled). Alarm Names are intended to allow the user enhance the existing channel description information to make identifying the channel easier. They are especially useful when multiple channels are similar (such as core body temperature of group of people, where the alarm name could be the persons name).

- Alarm Limits - As previously mentioned, alarms must have their limits defined by the user. Limits can be defined in a multiple ways. It is possible to change the limits on a single channel, as well as batch modification of multiple channels.
  - Single channel - From the Alarm Properties dialog, enter the min and max values to define the limits. These values can be either entered manually, or by use of the *% of Range* feature to set the min and max values based on a percentatage of the measurement range.
  - Multiple channels - From the list of alarms, select the channels you wish to modify and then right-click on any of the selected channels. From the displayed menu, choose, *Set Limits*, or *Set Limits as % of Range.* Fill in the information in the presented dialog box and click *Ok.*
- Alarm Status - Alarms can be disabled and enabled on an individual basis. As expected, when an alarm is disabled, it will not be triggered when the value of the associated channel falls outside the limits. Note that, if alarms are disabled globally (via the *Indicators* main menu item) then the individual alarm enabled/disabled status will have no effect until alarms are globally enabled again.

3.4.3 Clock Sync Error

Clock Sync indicators are used to indicate when the absolute value[6] of clock difference between a server (DAS) and the client (Digital Meter) is greater than 75ms. This value is not configurable by the user. When a clock sync error indicator is triggered the background colour of all channels, on all pages, belonging to that DAS will turn yellow (by default)[7].

[6]While absolute value is taken when considering the status indicator, signed results are available in the status bar and within the Page Properties dialog.

[7]Unless an alarm is already triggered, as they have a higher precedence. See *Section 3.4.6*.

Unlike alarms, clock sync errors can not be disabled/enabled on a DAS-by-DAS basis, they can only be enabled/disabled globally from the *Indicators* main menu item. Clock sync errors for all DASs currently being monitored are always displayed in the status bar. A positive clock sync error represents that client time is ahead of server time, negative indicates the opposite.

3.4.4 Channel Staleness

Channel Staleness is defined as the absence of value change. If a channel is stale for more than 30 seconds then the associated indicator will be triggered, setting the background color of the channel to blue (by default)[8]. The aforementioned 30 seconds can be modified through the indicator properties, discussed in *Section 3.4.5*.

Channel staleness indicators can not be enabled/disabled on a channel-by-channel basis. They can only be enabled/disabled globally, via the *Indicators* main menu item.

3.4.5 Indicator Properties

Indicator properties control global options related to all of the indicators discussed above. To bring up the Indicator Properties dialog click *Indicators* → *Properties* from the main menu[9]. This will present a standard styled properties dialog to you, containing three tabs:

- Alarms - The *Alarms* tab allows you to enable/disable the global status of alarms, as well as change the colours used to indicate that an alarm is triggered. To change either of these colours simply click the *Change Background* or *Change Foreground*[10] button as appropriate. This will present a color chooser dialog from which you can select the desired colour. To restore the colours back to their original schema click the *Restore Defaults* button.
- Clock Sync - The *Clock sync* tab is similar to the *Alarms* tab and should be used as such.

[8]Unless an alarm or Clock Sync Indicator is already triggered, as they have a higher precedence. See *Section 3.4.6*.

[9]Only available if one or more DASs have been connected

[10]Foreground colour represents the text color.

- Staleness - The *Staleness* tab is similar to the *Alarms* tab, with an extra field. The *Elapsed Time* field is used to determine how long a channel must remain at the same value before it is considered stale.

3.4.6 Indicator Precedence

In the event of multiple indicators being triggered for a specific channel the indicator precedence is as follows:

$$\text{Alarms} \rightarrow \text{Clock sync error} \rightarrow \text{Channel staleness}$$

Meaning that if an alarm is triggered for a channel, it will be displayed no matter what other indicators are also triggered.

3.5 Virtual Channels

Virtual channels are channels that are not associated with a DAS, but are defined and created by the end user. These channels are typically mathematical combinations of one or more channels[11]. Uses of virtual channels can range from unit conversions (*eg.* Celsius to Fahrenheit) to resolution of forces and moments. Virtual channels can also be a constant used in other virtual channels.

3.5.1 Creating New Virtual Channels

To create a new virtual channel, right-click on a page and choose *Create a Virtual Channel.* This will display the main virtual channel dialog box from which you can create the virtual channel, shown in *Figure 7.* Detailed steps of the creation process are as follows:

- Step 1 - Enter appropriate values into the *Channel Name* and *Channel Units* fields. While only the channel name is required, it is highly recommended to fill in the units as well, if applicable.

[11]These channels can be either DAS based channels, or other virtual channels.

- Step 2 - If the virtual channel requires other DAS or virtual channels as variables, click the *Variable Selection* button. This will display a new dialog which lists all of the channels currently available. These are categorized based on DAS. For each channel to be reference as a variable, check the associated box next to the channel. Once the desired channels have been selected, click *Ok*.

- Step 3 - Now that the desired channels have been selected, they must be assigned a variable name (*eg.* x, y, or something more meaningful). Upon closing the previous dialog, the *Current Variable Mapping* list is populated with the channels you had chosen. To assign a variable to each of these channels, double-click the associated cell in the *Equation Variable* column. This should present a yellow highlighted box in which you can type a variable name (no spaces or numbers allowed).

- Step 4 - Finally, the equation can be developed using the variables created above, constants, and any normal mathematical operation[12]. For example, if you assigned a channel to be a variable x, then entering $x+3$ in the equation field will result in a virtual channel that is equivalent to the channel plus 3, while $x**2$ would be the channel to the power of two. If you wish to use the math functions provided then select the text you wish to become the operand of the function and then click the desired function button, *eg. sin()*.

Note, the value of virtual channels, by nature, will be slightly delayed to that of real channels. Whether or not this is noticeable depends on a lot of variables, and it usually not noticeable. The reason behind this phenomena is based on the fact that virtual channels depend on the value of real channels. This dependency means that in order for virtual channels to update, the real channels must first be updated, else the virtual channel will get the old value.

3.5.2 Modifying Virtual Channels

Modification of a virtual channel is very similar to the creation of one, except that during the modification process all previous values that were entered in to the applicable fields will be populated with the virtual channels information. To select new variables for the virtual channel you follow the same process as described above in Step 2, except that the dialog which opens

[12]Currently supported operations are: Addition (+), Subtraction (-), Multiplication (*), Division (/), and Exponentiation (**).

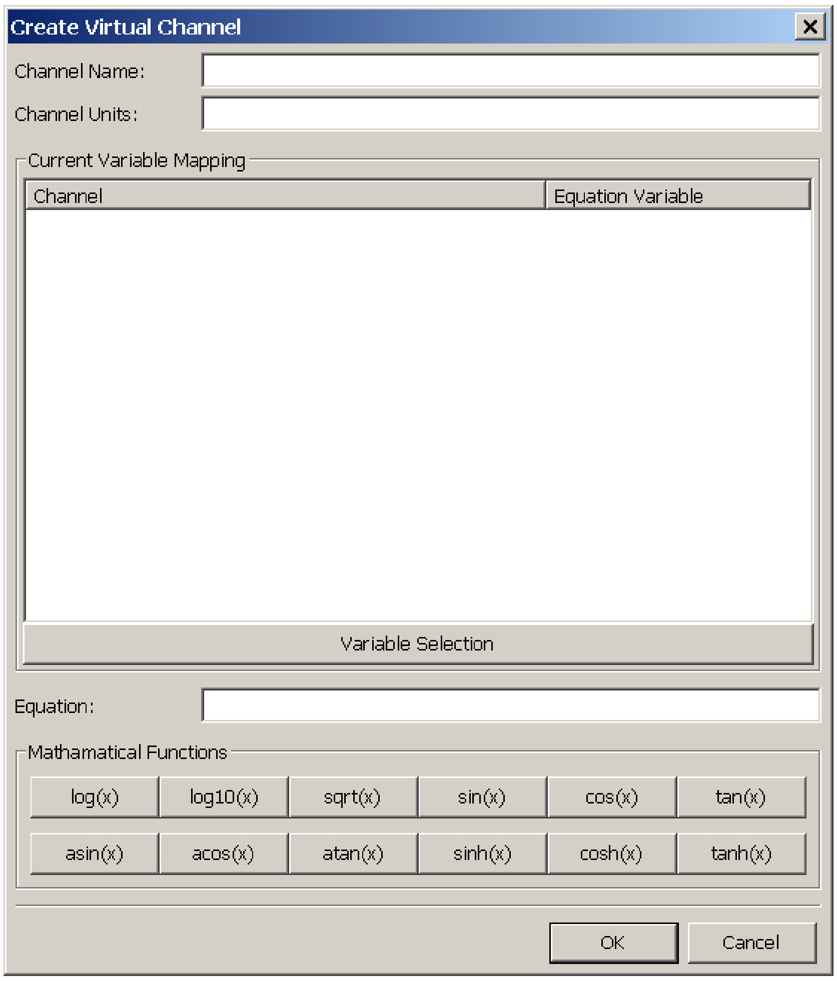


Figure 7: Virtual channel creation/modification dialog.

up after clicking the *Variable Selection* button will already have check boxes next to the channels currently contained within the virtual channel. If either of these boxes are unchecked then the associated channel is no longer considered to be a variable of that virtual channel, implying that you will have to also change the virtual channel equation. Any new variables introduced at this time will have to be given new variable names, as done in the creation of the virtual channel.

3.5.3 Virtual Channel Behaviour w.r.t Offline Channels

Creating a dependency between virtual channels and DAS channels presents an issue that must be considered. What should happen to the virtual channel if one of its variables depends on a DAS channel that is no longer available (*eg.* the DAS has gone offline)? There are essentially three cases to consider, outlined below followed by the expected behaviour.

- Case 1: Virtual channel depends on one DAS, and the DAS goes offline
  - The virtual channel will not be removed from Digital Meter.
  - The virtual channel will remain stale at the last value that it calculated, using the last value from the DAS channel.
  - If the DAS comes back online, then the virtual channel will automatically pick up on the new values coming in from the DAS.
- Case 2: Virtual channel depends on more than one DAS, and not all of them go offline
  - The virtual channel will not be removed from Digital Meter.
  - The virtual channel will use the new values from all available DASs and use the stale values for DASs that have gone offline.
  - If the DAS comes back online, then the virtual channel will automatically pick up on the new values coming in from the DAS.
- Case 3: Loading a configuration that has a virtual channel that depends on at least one DAS, which is offline at the time of loading
  - The virtual channel will still be added to Digital Meter.
  - A value of $--$ will be displayed, since there is no old stale value available from the offline DAS(s).
  - If the DAS(s) come back online, then the virtual channel will automatically pick up on the new values coming in from the DAS(s).

In either case, trying to edit a virtual channel that contains a variable consisting of a channel from an offline DAS, then a dialog box is displayed indicating that variables associated with channels on the offline DAS(s) can not be loaded. Then the modification proceeds as in *Section 3.5.2*

3.6 Configurations

While much effort has been put into streamlining the GUI configuration of Digital Meter, some complex configurations may still take some time to create. Once these configurations have been created it would be useful to save them, either for personal use later, or to share with colleagues. Digital Meter provides this functionality through the common Load/Save options found in the *File* menu. The operating mechanics behind these mimic that of most GUI based applications, down to the keyboard short-cuts.

These save files are of the file type *.dmc, a home-grown file type which stands for Digital Meter Configuration. These files store all[13] of the information required for a user to load them later (in the same version of Digital Meter) and restore the GUI to the previous functional state, with all DASs and channels preserved, assuming that connections can be established.

[13]Page locations are not stored, due to lack of support in wxPython.

4 Design Methodologies

4.1 Introduction

This section of the report will provide a brief overview of some of the major design elements behind Digital Meter, as well as an overview of the algorithms used. It will not go into great detail regarding the implementation of some of these algorithms as it is out of the intended scope of this document. The primary motivation behind this discussion is to aid future developers who may modify the Digital Meter code in any way, either to fix bugs or to add new features.

While Digital Meter consists of nearly 50 classes, only a relatively small subset of these are to be considered primary classes[14]. The others are usually dialogs, specific extensions of window components to fill these dialogs, or windows component data entry validation classes. To start things off, an introduction to each primary class is given, allowing me to assume the reader has knowledge of these classes when writing about their interactions later.

4.2 Primary Classes Overview

- **Frame** - Usually involved during any command that is invoked through the GUI from the user. In terms of the common Model/View/Controller[4] design pattern, the *Frame* would be considered the controller, in a weak sense as it is coupled slightly with the view, though most of the view operations have been delegated to other classes, specifically the *Notebook*.

- **Notebook** - This is the primary controller of the GUI. As the name would imply, it is the foundation behind the multi-page capability of Digital Meter. It is through this class that new pages are created, old ones destroyed, and their information updated.

- **ListCtrl** - The component which makes up a *Notebook* page. *ListCtrl* is where the actual channel listings are displayed. It implements (or delegates to other classes) all of the features related to how the channels are displayed. This includes such things as ordering, background colour, font styles, triggered indicators, etc.

[14]All class names within normal text have been marked in italics to aid in identification.

- **GenericAcqThread** - A generic acquisition thread provides Digital Meter with data. There are two derived classes from this base class, *Meter* (for acquiring data from a DAS) and *VirtualChannel* (calculates its own data based on its associated equation as opposed to actually acquiring it, though it still provides a value for other classes to retrieve so bundling it under the *GenericAcqThread* base class makes sense as it requires the same interface).

- **AcqThreadContainer** - Acts as a container for *GenericAcqThread* objects, where each class derived from *GenericAcqThread* should have an associated container. *Meter* objects are contained within the *Meters* container, while *VirtualChannel* objects are contained within the *VChannels* container.

- **Server** - Contains and controls a DAS connection. A *Server* object should only exist within a *Meter* object, in a one-to-one relationship.

- **RingBuffer** - A specialized implementation of the ring buffer data structure. It is used to store data (as well as the time of retrieval) obtained by *GenericAcqThread* objects.

- **HealthNotification** - Provides indicators on channels and DASs, alerting the end user in a visual manner of possible problems. There are three derived classes, *Alarm*, *ClockSyncIndicator*, and *StalenessIndicator* which implement the behaviour as described in *Sections 3.4.1, 3.4.3 and 3.4.4* respectively.

4.3 Algorithms

4.3.1 Application Start-up

When Digital Meter is launched you are presented with a standard windows styled application. Most of this, as would be expected by anyone familiar with GUI programming, is handled by the Frame class. Some of the main components that the Frame class is responsible for upon instantiation are:

- Creation of the *Meters* and *VChannels* container classes.

- Creation of the *Notebook* class

Once the application has started, it idles until receiving a command from the user[15].

4.3.2 Connecting to a DAS

Lets consider the most probable first command that Digital Meter will receive, a requested DAS connection. After getting the required input from the user (DAS address) a new *Meter* object is created. During instantiation, a *Server* object is also created. The *Meter* object then invokes the `connect()` method of the *Server* object in an attempt to establish a connection with the DAS. Assuming the connection is successful, and the user selects one or more channels to monitor, then the *Meter* thread is told to start, by calling its `run()` method, which will continually loop until told to pause or stop. A stop would disconnect the DAS while a pause would simply stop it from acquiring data.

Each iteration through the main `run()` loop invokes the `get_scan()` method of the *Server* object, which returns a list of the latest data acquired from each channel on the DAS. These values are then stored in the *Meter*'s *RingBuffer* object.

The size of the *RingBuffer* is determined by a multiplication of the maximum averaging time (60 seconds), the maximum sampling rate (20Hz), and an overflow allowance of 25%, for a total size of 1500 acquisitions. The *RingBuffer* consists of two lists, one represents data values while the other represents the time of data acquisition. It is assumed that all channels acquire their data at the same time[16], meaning that the data list will be longer than the time list by a factor of how many channels are located on the DAS.

The *Meter* thread will continuously run until the *Server* object it is coupled with is disconnected. Rather than letting the thread run as fast as possible and hogging CPU time and other resources, it is slept during each iteration of its main loop within `run()`. The sleep time is determined by the page that has the fastest sampling rate[17].

[15]In the case of loading a configuration the commands are automatically generated.
[16]While this is not actually true, it is close enough for our purposes.
[17]Pages without channels belonging to the DAS in question are obviously not considered.

4.3.3 GUI Updating

Within the main *Frame* object there is a timer, by default this timer is set to expire once a second, though this can be changed by the user within Digital Meter. When this timer executes it calls the *Notebook*'s `update()` method, which in turn iterates through each page, calling each *ListCtrl*'s `update()` method.

During a *ListCtrl* update, all items displayed within that *ListCtrl* are iterated over, converting them from a text and/or integer entry into the object that it represents. Once this conversion occurs the *ListCtrl* will ask the associated *Meter* or *VirtualChannel* object for the required values, which include all or some of {Value, Mean, Standard Deviation, Slope, Min, Max} via the methods `get_value()`, `get_mean()`, `get_sd()`, `get_slope()`, `get_min()`, and `get_max()` respectively.

During development it was noticed that the application flickered, especially when a large number of channels were within the *ListCtrl*. This was caused by trying to update a large number of cells at the same time. While no solution was found to totally eliminate[18] the flicker, it was able to be alleviated a fair amount by simply comparing the 'new' values to the previous values contained within the cell, if they were the same then the cell would not be updated.

4.3.4 Indicators

All three indicators are checked during the aforementioned *ListCtrl*'s `update()` method. As indicators are not specific to any single page, the *ListCtrl* asks it's parent (the *Notebook* object, which in turn asks its parent (the *Frame* object)) to perform the indicator checking. If any of the indicators trip then a status variable is flagged in the appropriate *Alarm*, *ClockSyncIndicator*, or *StalenessIndicator* object.

Within the *ListCtrl*'s `update()` method we then check this status variable for each channel in an if/elif/else fashion and set the items background/foreground colour accordingly. This inherently provides us with the idea of indicator precedence without the actual *HealthNotification* derived classes knowing

[18]Usually done with double-buffering, though it did not help in this case as the numbers contained within the cells usually change a fair amount between updates so the buffered image would be much different than the 'next-to-be' displayed image.

their own level of precedence. The precedence, in order from highest to lowest is as follows:

Alarm → *ClockSyncIndicator* → *StalenessIndicator* → *User Defined Colours* → *Default Colour*

4.4 Shortcomings and Wish-list Changes

4.4.1 Saving and Loading

Partially due to the lack of experience in the implementation of GUI saving and load capability, a mistake, (or design flaw) is admitted. Currently the save/load functionality is contained within the *Frame* class, and in fact it is a large chunk of the Frame class. This save/load functionality should be removed from the *Frame* class and put into its own; I will fictitiously call them *GUIStateSave* and *GUIStateLoad*. I then imagine that other objects that contain information that would require saving/loading (*eg. ListCtrl*) would extend these *GUIState*{*Save*|*Load*} classes and implement their own `save()` and `load()` methods. Then when a new configuration is loaded, each of these `save()` and `load()` methods would be iterated over and perform the appropriate action. Of course, there would have to be some form of known priority as some load events depend on other load events having already occurred (*eg.* you can't load a Meter object without first loading the ListCtrl).

4.4.2 Saving of Page Locations

Without getting into much detail about wx, due to a limitation in wx-Python the `LoadPerspective()` and `SavePerspective()` methods of the AUI Notebook class have not been implemented, thus not allowing access to the page locations. Until this does get implemented in wxPython, there are two workarounds possible:

1. Implement the methods yourself, as wxPython is open source. Once done you could even submit the patch for review!
2. Create similar methods in python within Digital Meter by recording mouse movements and clicks. There are events being sent from the AUI Notebook that would tell us when a page is being dragged, so we

would be able to use these to know when to poll information from the mouse. This is of course a less-than-ideal way to do it.

5 Conclusions

There are a large number of features built into Digital Meter. These features ultimately make Digital Meter more powerful and useful than previously available tools. Providing users with the ability to recognize errors early during the data acquisition stage of a test rather than the data analysis stage can greatly increase efficiently if a failure of a sensor did occur.

The GUI to Digital Meter has also been developed with users in mind, as it is useless to create a tool which is hard to use. Changing the way the GUI interacted with the user was an on-going process during development, always trying to achieve the maximum amount of usability for each feature. In doing so, Digital Meter has encompassed a large feature set that can be accessed very easily and with a minimal learning curve.

From an internal view-point, Digital Meter has made use of common software engineering design principles and patterns where appropriate, making it a very extensible application.

6 Recommendations

While Digital Meter was designed to follow common software engineering practices, there are some areas in which good design is lacking. If further development were to occur then some of the pre-existing areas that should be considered to re-design include:

- Saving and Loading of GUI Configurations - This is currently encapsulated within the *Frame* class, it should be delegated to it's own set of classes allowing other objects to extend `save()` and `load()` methods.
- Screen Flickering - During a heavy load, Digital Meter displays some flickering during the `update()` method of each *ListCtrl* object. This has been alleviated, but still exists.

Aside from this, already there are some features requests from users that should be candidates for implementation:

- Ability to tare channels - Each channel has a tare value associated with it, which defaults to 0, and which is added to the Value column and displayed in a Tared column. The user has the ability to enter the tared value for each channel. Also, the user has the option of capturing a snapshot of the mean, and using it as the tare value, instead of entering it.

References

[1] *Performance Python*. Retrieved April 2 2008, from `http://scipy.org/PerformancePython`

[2] *SWEET Wiki*. Retrieved April 16 2008, from `http://sweet.iit.nrc.ca/sweet/`

[3] *Network Time Protocol*. Retrieved April 2 2008, from `http://www.ntp.org/`

[4] Dean Helman (1998) *Model-View-Controller*. Retrieved April 3 2008, from `http://ootips.org/mvc-pattern.html`

A List of Acronyms

DAS - Data Acquisition Server
DMC - Digital Meter Configuration
GUI - Graphical User Interface
MVC - Model/View/Controller
NTP - Network Time Protocol
SWEET - SoftWare Environment for Experimental Technologies

B UML: Primary Classes

The following is a class level UML diagram of the primary classes within Digital Meter. Functions and attributes have only been shown if they are important to understanding the logics behind the design.

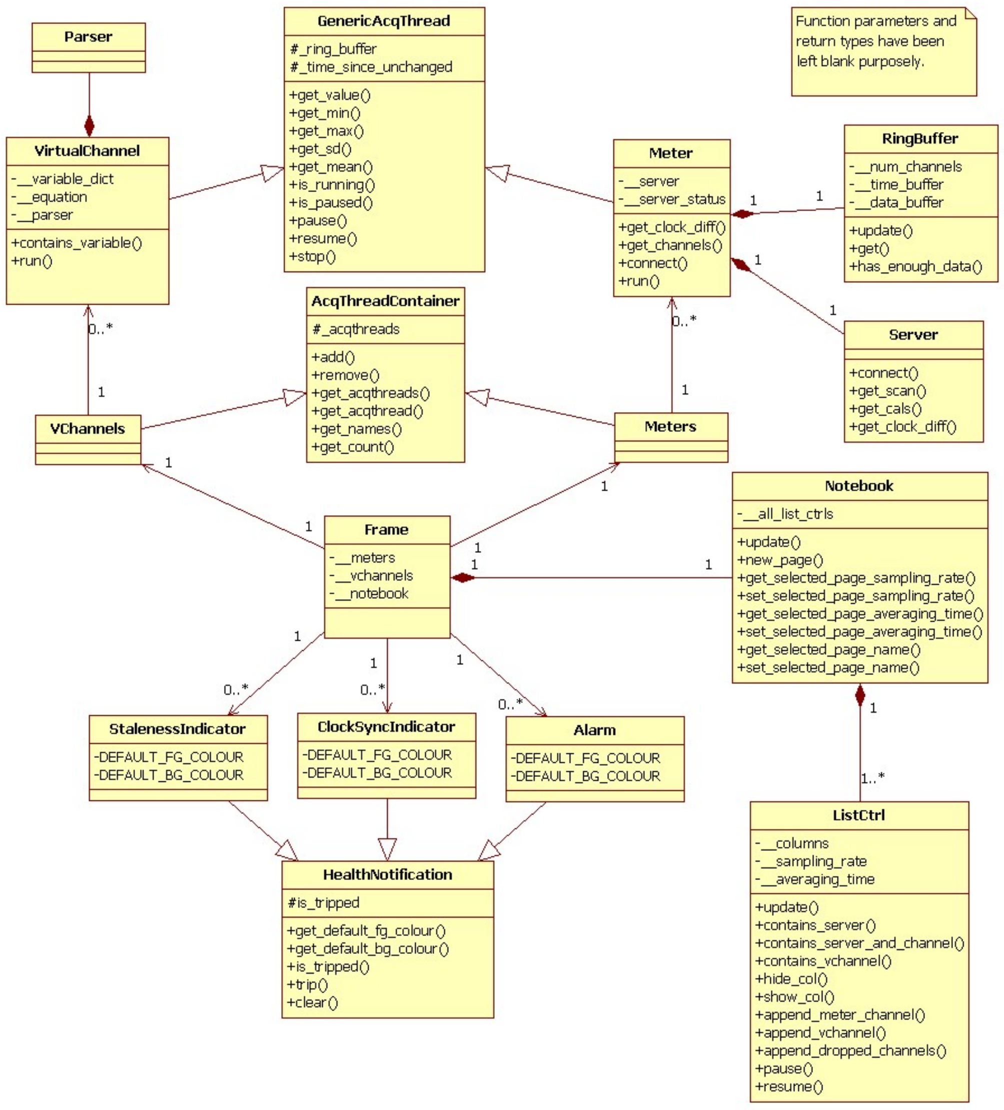
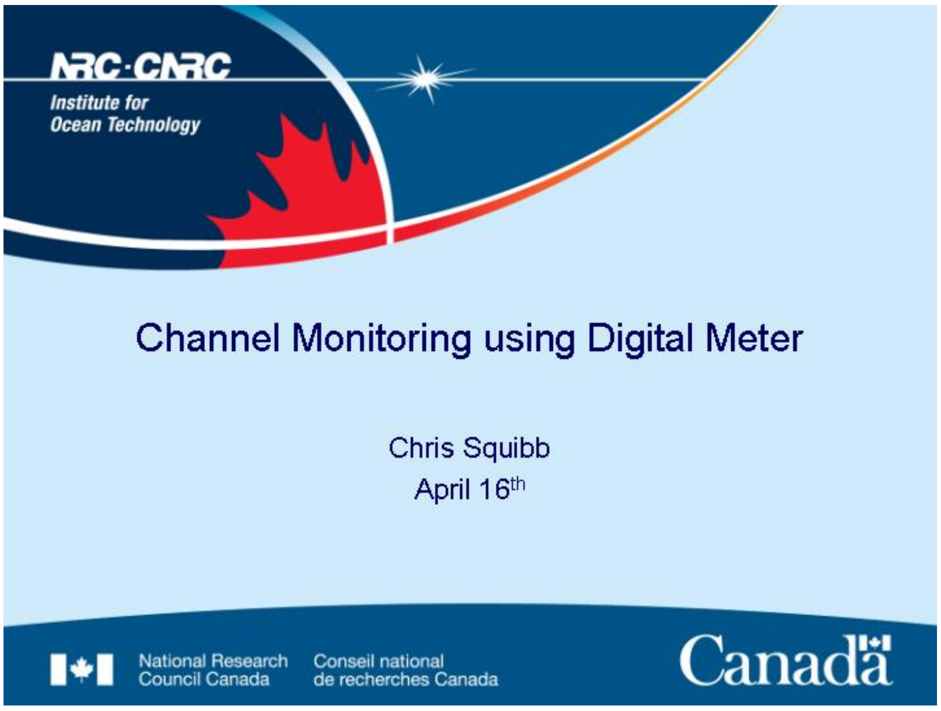


Figure 8: Primary class UML diagram, with function parameter and return types removed.

C Presentation

The following images are exported copies of the slides from the presentation that I gave regarding Digital Meter on April 16th 2008.



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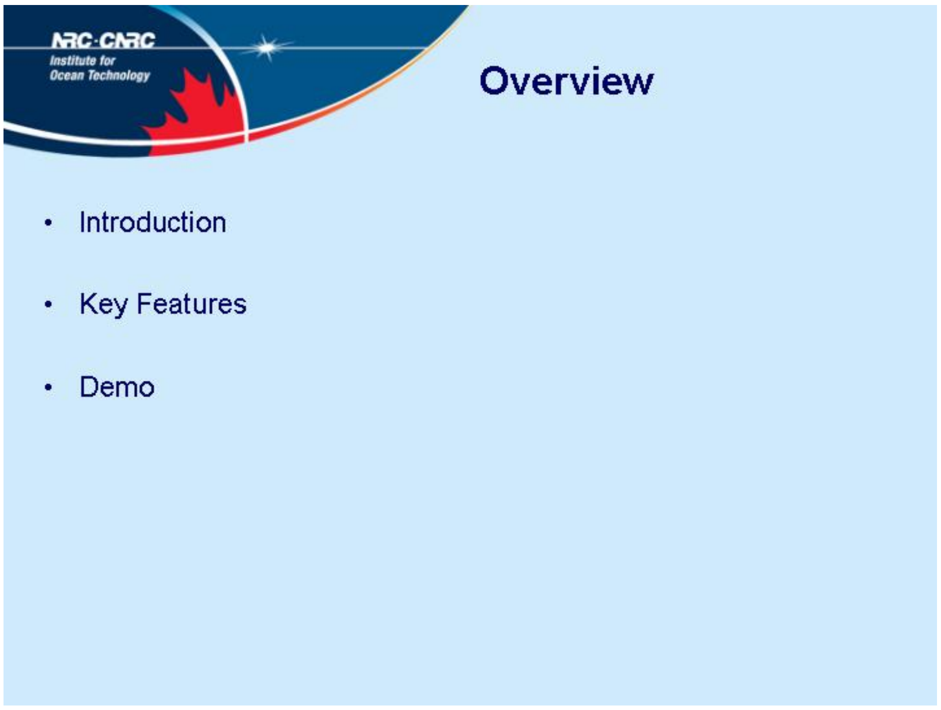
Channel Monitoring using Digital Meter

Chris Squibb
April 16th

National Research Council Canada
Conseil national de recherches Canada

Canada

Figure 9: Slide 1 of 11



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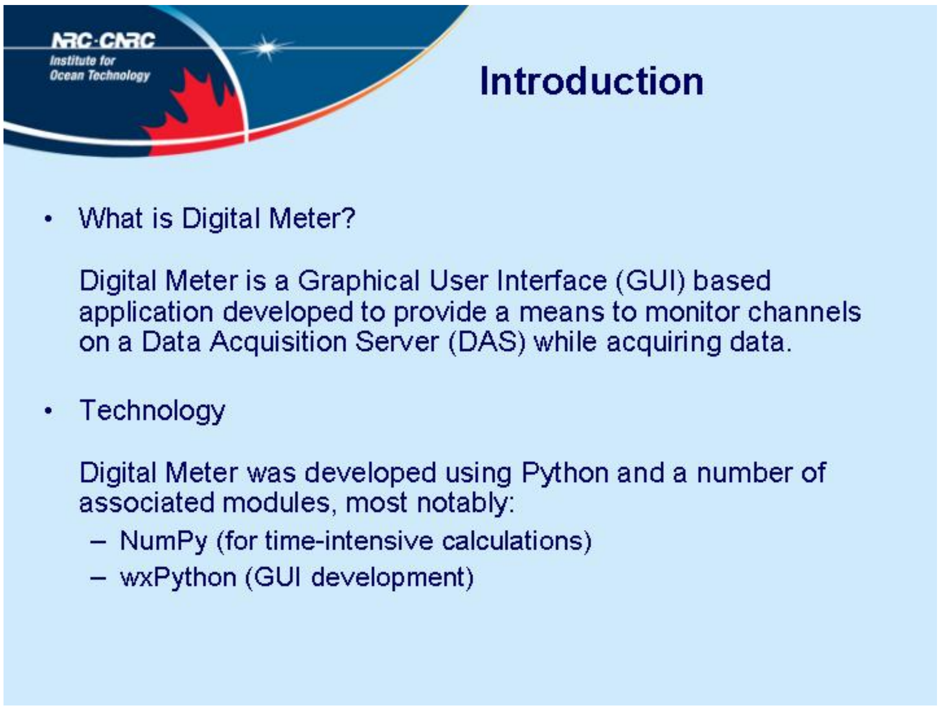
Overview

- Introduction
- Key Features
- Demo

Figure 10: Slide 2 of 11



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Introduction

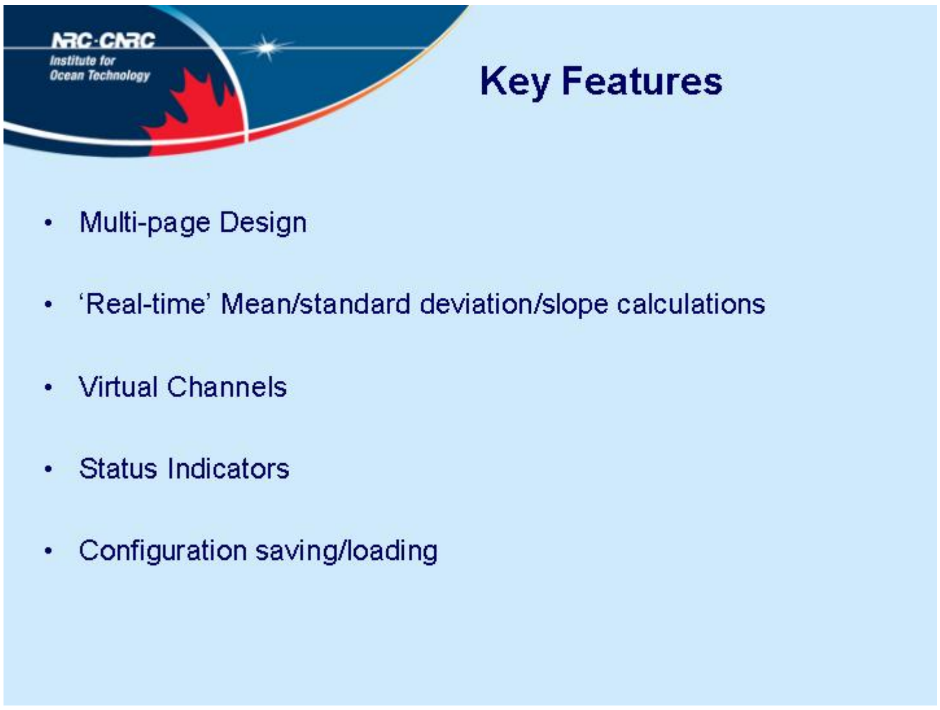
- What is Digital Meter?

  Digital Meter is a Graphical User Interface (GUI) based application developed to provide a means to monitor channels on a Data Acquisition Server (DAS) while acquiring data.

- Technology

  Digital Meter was developed using Python and a number of associated modules, most notably:
  - NumPy (for time-intensive calculations)
  - wxPython (GUI development)

Figure 11: Slide 3 of 11



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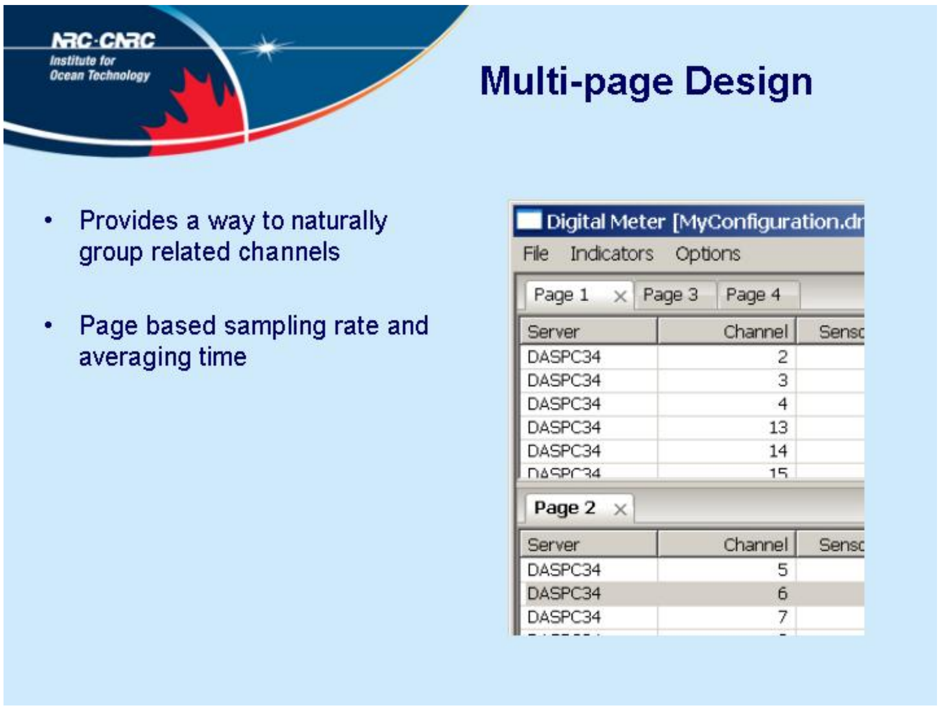
Key Features

- Multi-page Design
- 'Real-time' Mean/standard deviation/slope calculations
- Virtual Channels
- Status Indicators
- Configuration saving/loading

Figure 12: Slide 4 of 11



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Multi-page Design

- Provides a way to naturally group related channels
- Page based sampling rate and averaging time

Digital Meter [MyConfiguration.dr

File Indicators Options

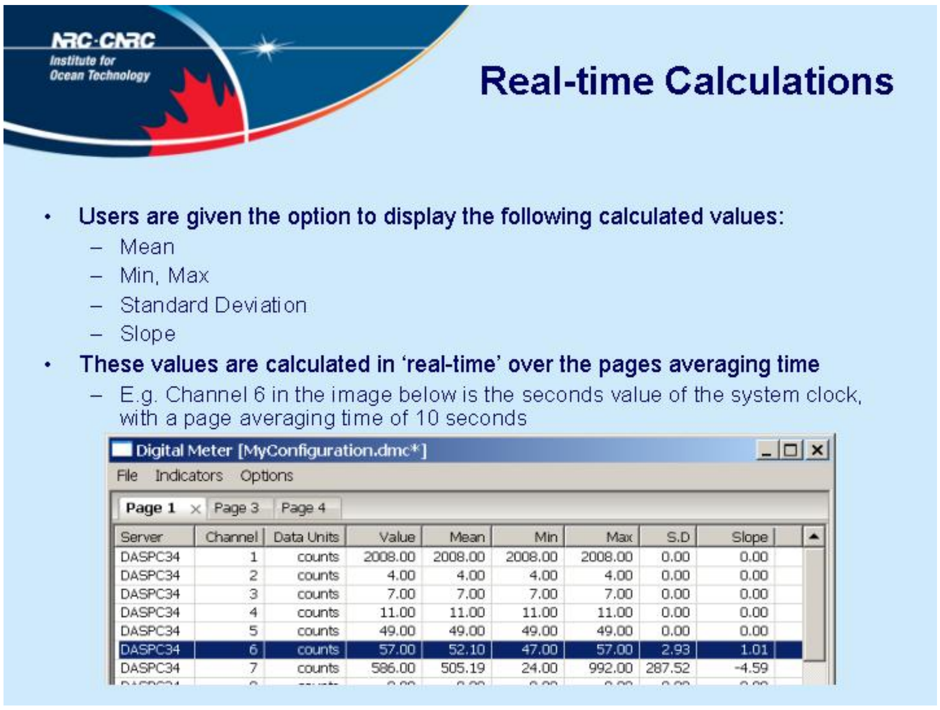
Page 1 | Page 3 | Page 4

Server	Channel	Senso
DASPC34	2	
DASPC34	3	
DASPC34	4	
DASPC34	13	
DASPC34	14	
DASPC34	15	

Page 2

Server	Channel	Senso
DASPC34	5	
DASPC34	6	
DASPC34	7	

Figure 13: Slide 5 of 11



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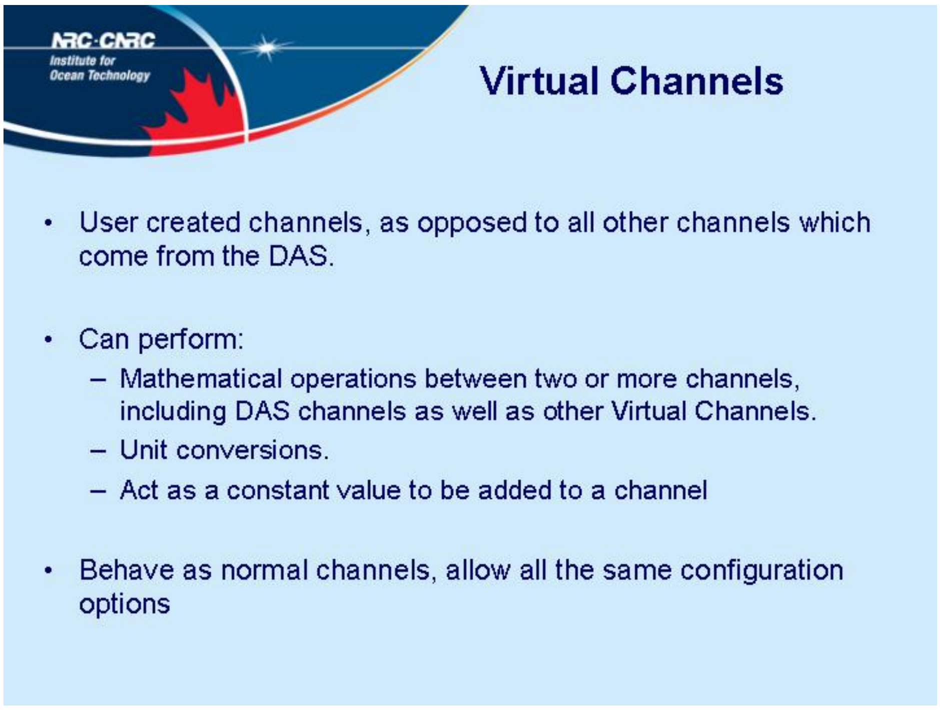
Real-time Calculations

- **Users are given the option to display the following calculated values:**
  - Mean
  - Min, Max
  - Standard Deviation
  - Slope
- **These values are calculated in ‘real-time’ over the pages averaging time**
  - E.g. Channel 6 in the image below is the seconds value of the system clock, with a page averaging time of 10 seconds

Digital Meter [MyConfiguration.dmc*]
File
Indicators
Options
Page 1
Page 3
Page 4

Server	Channel	Data Units	Value	Mean	Min	Max	S.D	Slope
DASPC34	1	counts	2008.00	2008.00	2008.00	2008.00	0.00	0.00
DASPC34	2	counts	4.00	4.00	4.00	4.00	0.00	0.00
DASPC34	3	counts	7.00	7.00	7.00	7.00	0.00	0.00
DASPC34	4	counts	11.00	11.00	11.00	11.00	0.00	0.00
DASPC34	5	counts	49.00	49.00	49.00	49.00	0.00	0.00
DASPC34	6	counts	57.00	52.10	47.00	57.00	2.93	1.01
DASPC34	7	counts	586.00	505.19	24.00	992.00	287.52	-4.59

Figure 14: Slide 6 of 11



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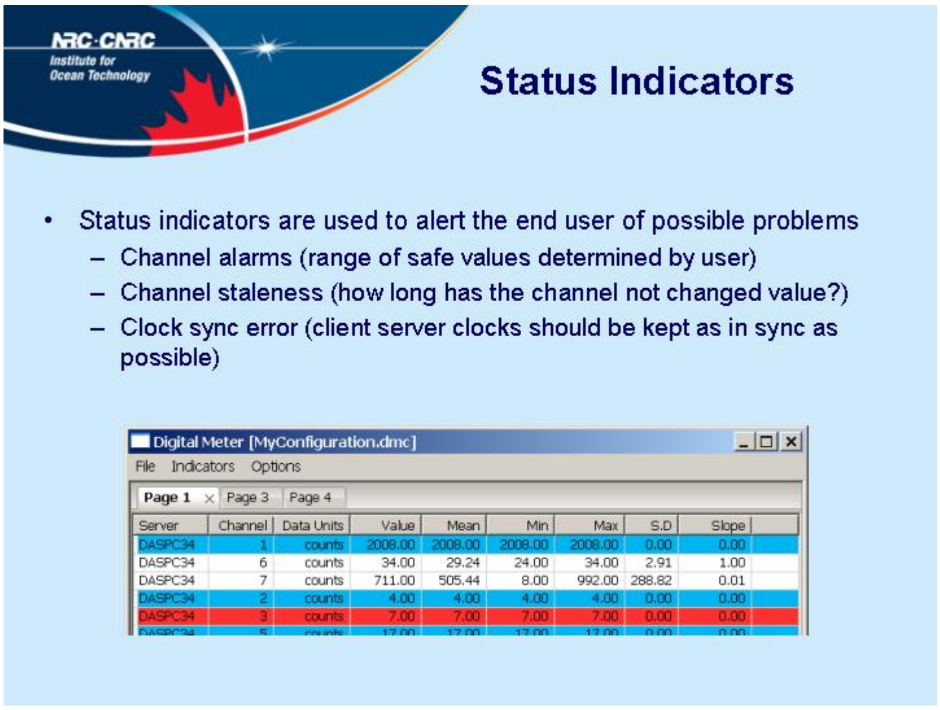
Virtual Channels

- User created channels, as opposed to all other channels which come from the DAS.
- Can perform:
  - Mathematical operations between two or more channels, including DAS channels as well as other Virtual Channels.
  - Unit conversions.
  - Act as a constant value to be added to a channel
- Behave as normal channels, allow all the same configuration options

Figure 15: Slide 7 of 11

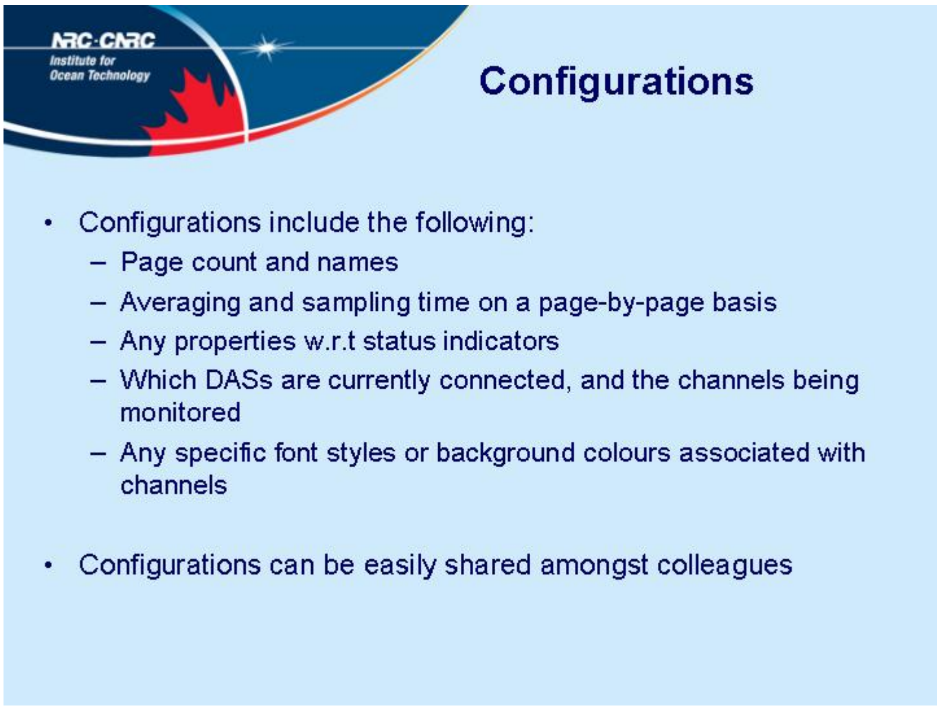


Status Indicators

- Status indicators are used to alert the end user of possible problems
  - Channel alarms (range of safe values determined by user)
  - Channel staleness (how long has the channel not changed value?)
  - Clock sync error (client server clocks should be kept as in sync as possible)

Server	Channel	Data Units	Value	Mean	Min	Max	S.D	Slope
DASPC34	1	counts	2008.00	2008.00	2008.00	2008.00	0.00	0.00
DASPC34	6	counts	34.00	29.24	24.00	34.00	2.91	1.00
DASPC34	7	counts	711.00	505.44	8.00	992.00	288.82	0.01
DASPC34	2	counts	4.00	4.00	4.00	4.00	0.00	0.00
DASPC34	3	counts	7.00	7.00	7.00	7.00	0.00	0.00
DASPC34	5	counts	17.00	17.00	17.00	17.00	0.00	0.00

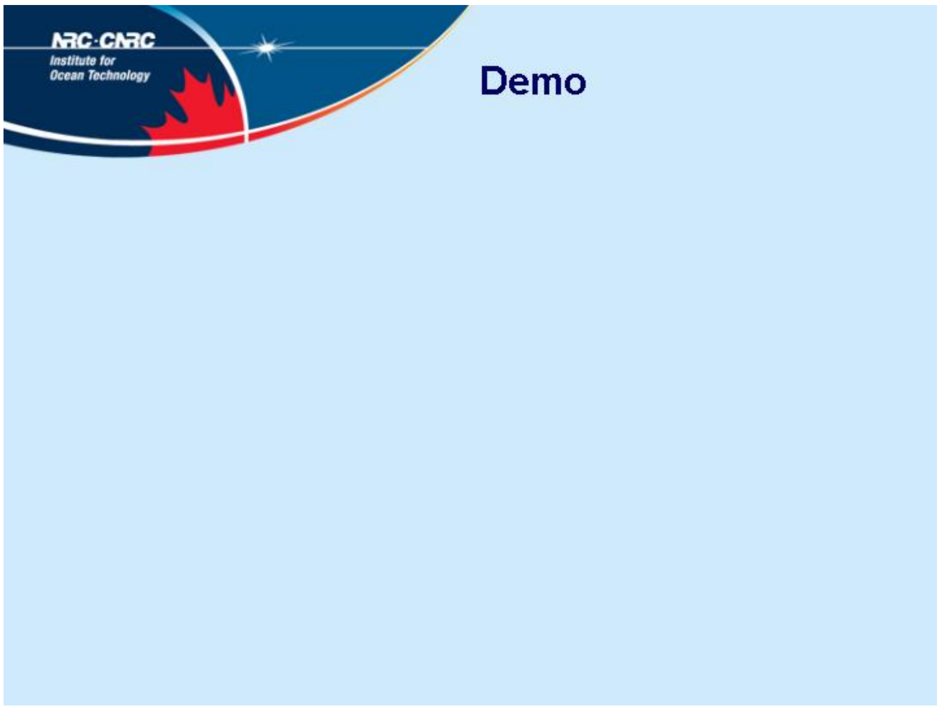
Figure 16: Slide 8 of 11



Configurations

- Configurations include the following:
  - Page count and names
  - Averaging and sampling time on a page-by-page basis
  - Any properties w.r.t status indicators
  - Which DASs are currently connected, and the channels being monitored
  - Any specific font styles or background colours associated with channels
- Configurations can be easily shared amongst colleagues

Figure 17: Slide 9 of 11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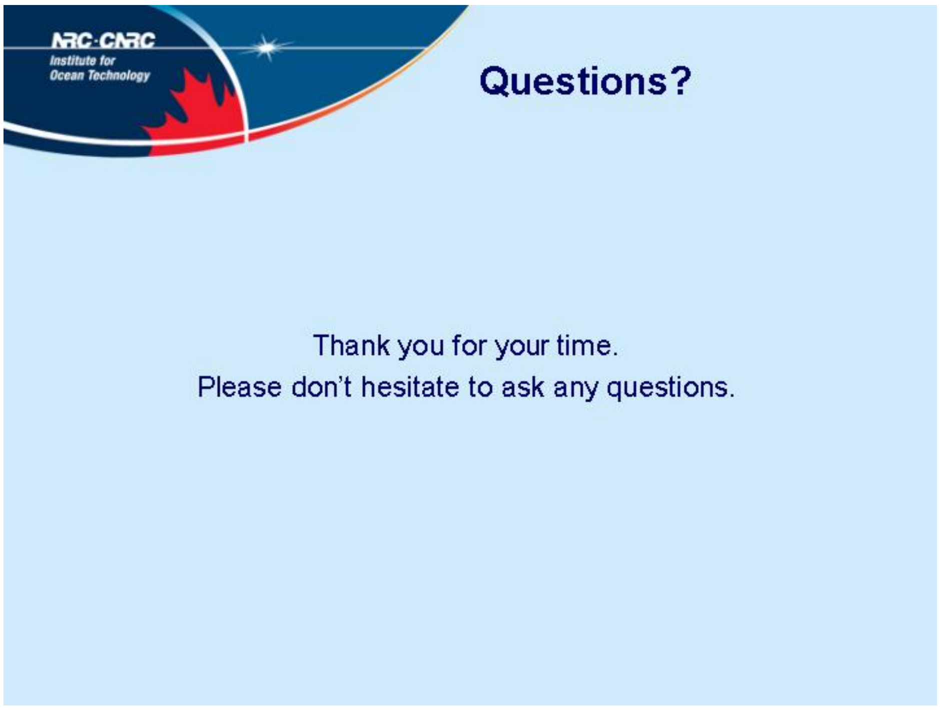
Demo

Figure 18: Slide 10 of 11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Questions?

Thank you for your time.
Please don't hesitate to ask any questions.

Figure 19: Slide 11 of 11