








Getting Started
Series 100 Cobra Probe

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WARNINGS

Although the Cobra Probe is relatively robust compared to other flow measurement instrumentation, care must still be taken with its handling.

-  Avoid dropping the Probe, bending the stem or damaging the head.
-  Avoid applying excessive pressure to the pressure transducers.
-  There are no user serviceable parts in the Cobra Probe. Any significant damage will require the Probe to be returned to TFI for maintenance and recalibration.
-  The warranty will be void if a user dismantles the Probe without specific instructions from TFI.
-  The Probe should be kept in its wooden case when not in use.

TFI CONTACT DETAILS

Turbulent Flow Instrumentation – Victoria, Australia

- Main website: www.turbulentflow.com.au
- Email support: support@turbulentflow.com.au
- Support website: support.turbulentflow.com.au
- Phone support: +61 (2) 6020 9250

INTRODUCTION

This document outlines the basic procedure for using the Series 100 Cobra Probe. All users are encouraged to read this guide in its entirety as it provides all the information necessary to start using your instrumentation.

What is the Cobra Probe?

The Cobra Probe is a multi-hole pressure probe that provides dynamic, 3-component velocity and local static pressure measurements in real-time. The Probe is capable of a linear frequency-response from 0 Hz to more than 2 kHz and is available in various ranges for use between 2 m/s and 100 m/s. It can measure flow angles in a $\pm 45^\circ$ cone, all six Reynolds stresses and allows calculation of other higher order terms. Probes are supplied fully calibrated and ready to use. Figure 1 shows a diagram of the Series 100 Cobra Probe indicating its main features.

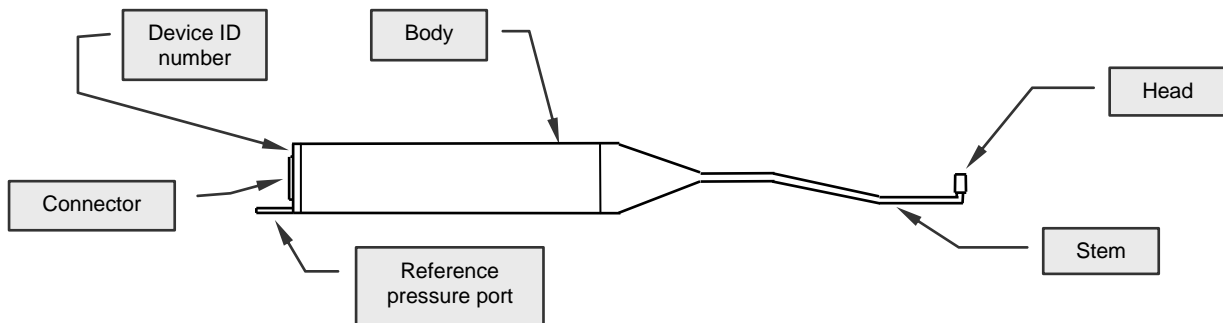


Figure 1: Series 100 Cobra Probe main features

The Cobra Probe outputs raw voltage data that are proportional to the pressures on the head. The voltage/pressure data are then converted to three-component velocity data by the *TFI Device Control* software, using pre-determined calibration surfaces and other signal processing. The *Device Control* software is used to operate the Cobra Probe and is provided when a Probe is purchased. The software provides access to all functions of the Probe, and can be used to configure measurements, obtain and view data, and save data to disk. The *Device Control* software can also be used with other devices.

Package contents

Your Series 100 Probe should have been supplied with the following items. If any items appear to be missing or damaged, contact TFI as soon as possible.

- Cobra Probe in storage case
- Interface unit
- Probe and interface unit cables
- Software installation CD – *TFI Device Control*
- This guide
- Any additional items that were ordered

System requirements

The requirements for running the *Device Control* software are listed below. These requirements allow real-time viewing of data from the Cobra Probe: Table 1 shows the minimum required to run the software. The use of a slower processor than that given in Table 1 may limit real-time display capability, while the use of a faster processor may be required to operate multiple Cobra Probes simultaneously.

Table 1: Minimum required computer system for running the *Device Control* software

Operating system	Microsoft® Windows 2000, XP, Vista or 7
Processor	Pentium 500 MHz or equivalent
RAM	256 MB
Display	1024x768, 65536 colours (16-bit)
Storage (program)	15 MB
Storage (data)#	Approx. 5 MB/minute (if saving all data)
A/D card	See below

This only applies if saving all time-varying data. Summary files of each run are less than 1 KB in size

Data Acquisition


TFI supplies various interface units with integrated data acquisition. Alternatively, you can use an external data acquisition system. The *Device Control* software supports the following analogue-to-digital (A/D) cards:

- National Instruments E-, M-, PXI and CompactDAQ series (for desktop and laptop computers)
- Data Translations cards (for desktop and laptop computers)
- Quatech DAQP series (for laptop computers)
- IOtech DaqBoard/2000 series (for desktop computers)

The chosen A/D card should meet the following minimum requirements:

- 4 analogue input channels per Cobra Probe
- $\pm 10 V_{DC}$ input range
- 5 kHz/channel sampling rate
- 16-bit resolution (preferred)

TFI can also customise the software to support other suitable A/D cards or data acquisition systems – contact us for further information.



 Please follow the A/D card manufacturer's instructions for installation of the A/D card before attempting to install and run the *Device Control* software.

GETTING STARTED

The following pages introduce the Probe set-up and operation. The hardware and software for the Cobra Probe have been designed to be very easy to use and by following the instructions on the following pages you will be able to install, configure and use your Cobra Probe very quickly.

Software installation

Before installing the Probe software, *TFI Device Control*, ensure that your data acquisition drivers are installed and operating correctly.

-  If using an interface unit with an integrated National Instruments data acquisition card, you should first install the data acquisition drivers from the supplied CD.
-  You will require administrator rights to successfully install the *Device Control* software.

To install the *Device Control* software:

- Insert the installation CD (run *Setup.exe* from the CD if installation does not start automatically)
- Follow the on-screen instructions and upon reaching the **Choose Components** screen, refer to Figure 2

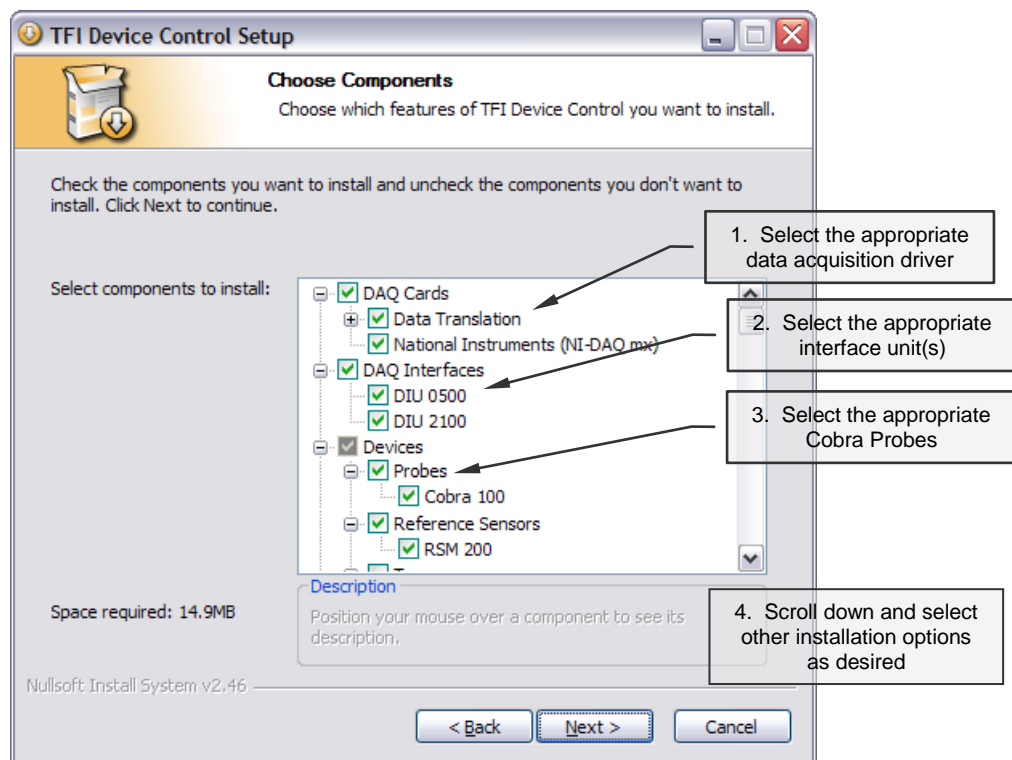



Figure 2: Software installation – Choosing which components are installed

-  All the devices that you have purchased should already be selected, but please ensure that the correct DAQ driver for the card that you are currently using is chosen.

After installation is complete, you can run the software – you should not need to restart your computer.

Hardware set up

After unpacking the Cobra Probe, you should not have any difficulty connecting it – connectors should only fit in suitable sockets. There are two types of interface unit for using the Cobra Probe:

- an Interface Unit with integrated data acquisition;
- an Interface Unit with external data acquisition.

These two types of systems are described in the following sections. Depending on which interface unit you have, refer to Figure 3 or Figure 4 for a diagram of the required connections. To connect up the system:

- Connect one end of the Probe cable to the Probe and the other end to the Interface Unit
- Depending on the type of interface unit you have, either connect the Interface Unit via a cable to a data acquisition unit, or use a USB cable to connect it to the computer

- i** Connections can be made in any order, even when the computer is already turned on.
- i** The labels above the sockets on the Interface Unit indicate the channel(s) that those sockets connect to (see the sections below).

Interface Unit with Integrated Data Acquisition (DIU)

This type of interface unit contains an internal data acquisition system and is known as a **Data-acquisition Interface Unit (DIU)**. Analogue signals from the Cobra Probe or other sensors are converted to digital signals before being sent to a computer via a USB cable. Power is supplied to the **DIU** and Cobra Probe via the USB cable (for most units), so it is not necessary to use an external power supply. See Figure 3 for an example of this type of interface unit and the typical connections required for operation.

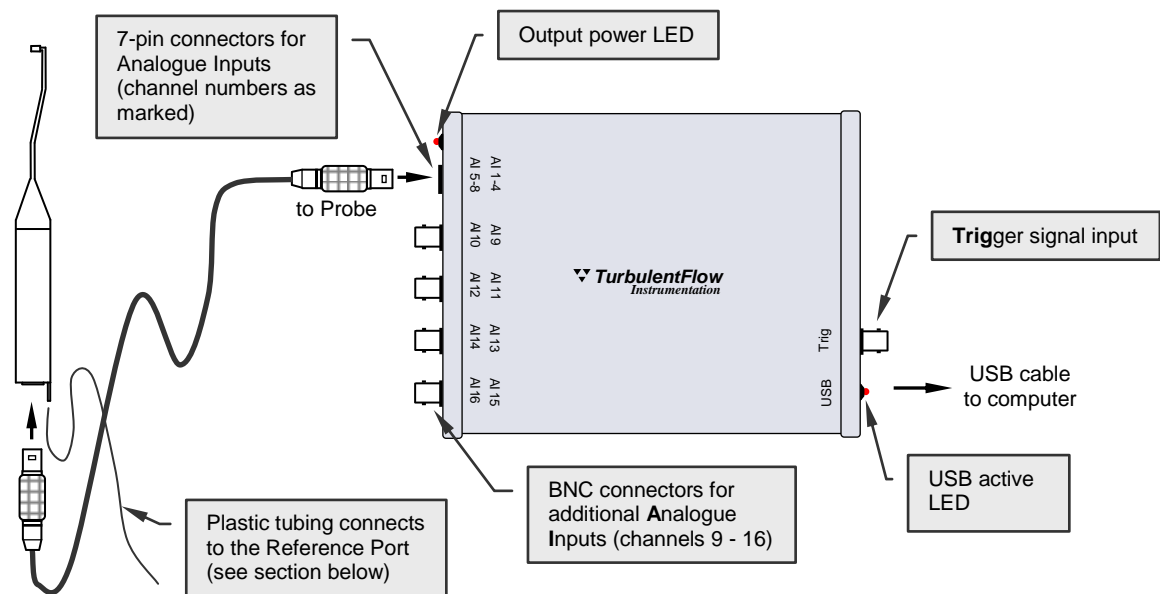


Figure 3: Schematic of an example Data-acquisition Interface Unit with integrated data acquisition.

Interface Unit with External Data Acquisition

This type of Interface Unit (IU) must connect to an external data acquisition system or **DAQ Device**, such as an A/D card in a computer or some other stand-alone data acquisition system. Power is supplied via the cable from the **DAQ Device** or external power supply and the IU passes the analogue data signals from Cobra Probes and other sensors to the **DAQ Device**, where they are converted to a digital format. See Figure 4 for an example of this type of interface unit and the typical connections required for operation.

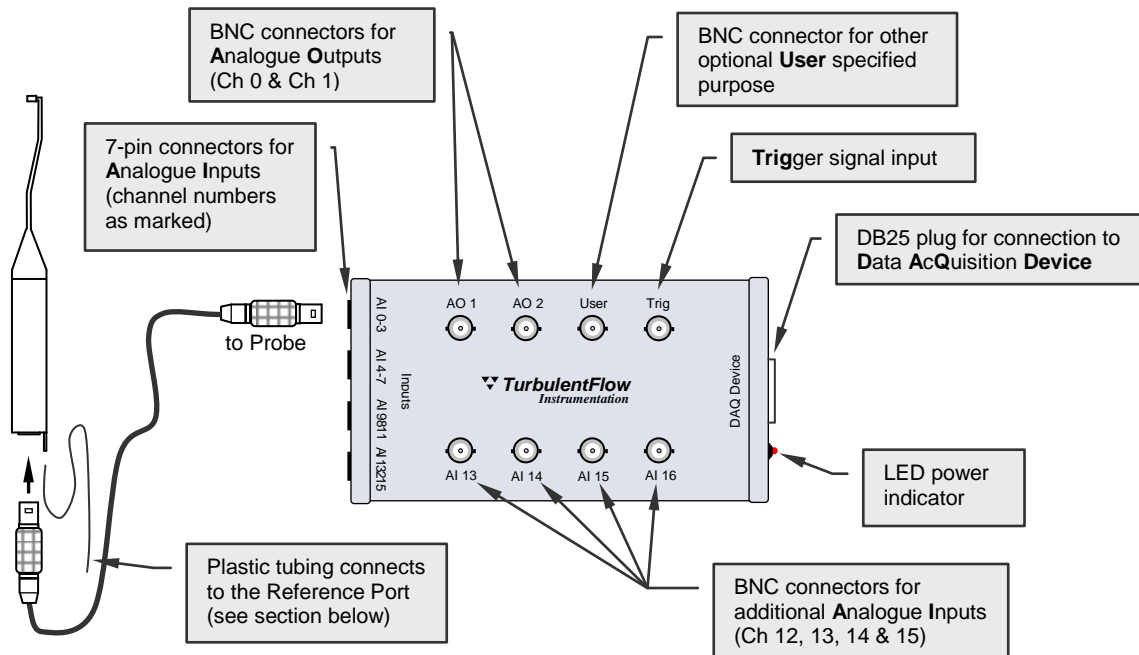


Figure 4: Schematic of an example Interface Unit with external data acquisition.

Interface Unit Common Features

The interface unit configuration will depend on your specified requirements, but interface units have common features (refer to Figure 4 and Figure 3):

- LED power indicator (illuminates when power is connected via the **DAQ Device** or **USB** socket)
- **Analogue Inputs**: one or more 7-pin connectors for multiple Cobra Probes or other devices, depending on customer requirements. Each 7-pin connector is connected to a group of four channels on the data acquisition system, as indicated by the labels, e.g. **AI 1-4** connects to input channels 1, 2, 3 and 4.
- **Additional Analogue Inputs** as per customer requirements: one or more BNC connectors for optional inputs (e.g. for a reference pressure sensor). Each BNC connector is connected to the data acquisition system channel as indicated by its label, e.g. **AI 15** connects to channel 15.

Synchronisation, Triggers and Other Connections:

- **Sync In and Sync Out**: Connections for synchronised operation of multiple interface units; this is optional but proves very accurate clock synchronisation of multiple interface units. **Sync** cables can be connected between interface units in any order - it is only possible to connect each plug to the corresponding correct socket. Software auto-detection determines the 'master' and 'slave' interface units for correct operation. Synchronisation must be enabled in **Advanced (DAQ)**.
- **Trigger signal input**: user-supplied trigger signal used to start sampling and synchronise measurements with other events. The trigger line is held high (5 V) via a 10 kΩ pull-up resistor

and will activate when pulled low (grounded). This can be accomplished by short circuiting the **Trig** centre pin to the outside of the BNC connector.

- **Analogue Outputs:** one or more BNC connectors for use with A/D cards that support such functions. Each BNC connector is connected to the data acquisition system channel as indicated by its label, e.g. **AO 1** connects to output channel 1.
- **Additional User input/output:** a BNC connector not normally connected but can be used for A/D cards that support other functions – contact TFI for wiring details.

Reference Port

The reference pressure port (see Figure 1) provides the common reference pressure for the transducers. Therefore, pressures measured by the Probe, including local static pressure, are relative to the pressure applied at the reference port.

- ⓘ When immersing the entire Probe in a flow, it is important to vent the reference port to a location out of the flow or to a reference static pressure probe. Plastic or silicon tubing is normally used; a length of small diameter tube and some tube size adaptors should have been provided with the Cobra Probe. Typically a short length (10-20 mm) of silicon tubing is attached to the reference port and then a tube size adaptor is used to connect to a larger diameter tube that runs to the venting location.

Probe Calibration

The Probe is supplied fully calibrated and ready to use. The Cobra Probe has three types of calibration: static; frequency response; and head calibrations. The only calibration required by the user is a periodic ‘static calibration’ check. Static calibration determines the voltage-to-pressure scaling factors of the pressure transducers. Frequency response and head calibrations should not change unless the Probe is physically damaged or ports become blocked.

Static calibration requires you to apply a range of accurately known pressures to the reference pressure port on the tail end of your Cobra Probe. To do this, you must connect a device capable of supplying a stable pressure to both the Probe's reference pressure port and to a reference pressure transducer with a display of the applied pressure. A range of pressures is then applied to the reference pressure port of the Cobra Probe. At each pressure, you are required to enter the magnitude of the pressure being applied and have the software sample the voltage at that pressure. Using a number of pressure points and a least squares fit, the software will calculate the voltage-to-pressure scaling ratios. As much of the calibration procedure has been automated in the software, this process should be relatively quick and easy.

- ⓘ The static calibration procedure should be repeated every 6 months or when there has been a large change in air temperature.

Static Calibration Procedure

Using a ‘T-piece’ or other similar tubing adaptor, connect a reference pressure transducer, the Cobra Probe's reference pressure port and your pressure-applying device. Then:

1. Start the *Device Control* software if you have not already done so
2. From the **Settings** menu, choose **Devices**
3. Select the Cobra Probe you wish to calibrate
4. Click the **Calibration** button
5. Select the **Voltage Scaling** tab
6. Set the **Amplifier Gain** setting to the desired value (most Probes only have one setting available)
7. Click the **Calibrate...** button

8. Repeat the following steps when applying a range of different pressures
 - a. Apply and accurately hold a pressure
 - b. Enter the applied pressure in the **Reference Pressure** box (you can select the units of the reference pressure)
 - c. While maintaining the applied pressure, click the **Sample** button (sampling will take approximately 5 seconds, after which the display will be updated)
 - d. Click the **Reset** button to restart if you are not happy with one or more of the points
 9. When you have sufficient points (a regression (R^2) coefficient of at least 0.99990 should be attainable), click the **Apply Calibration** button to set the new values.
 10. Repeat the above process for any other gain settings if required.
- i** The static calibration procedure should be repeated every 6 months or when there has been a large change in air temperature.
 - i** Typically a minimum of 5 to 7 pressures over the full operating range of the probe are required to give an accurate calibration.
 - i** You must calibrate your probe at each gain setting that you wish to use (most Probes only have one gain setting available so this procedure need only be completed once).
 - i** If a negative voltage-to-pressure scaling factor is detected, you will be asked if you wish to make the scaling factor positive - if you are using the cabling and connections supplied with your Probe, you should choose to have the scaling factor made positive as this will be correct.

Axis System

Figure 5 shows the standard axis system of the Cobra Probe.

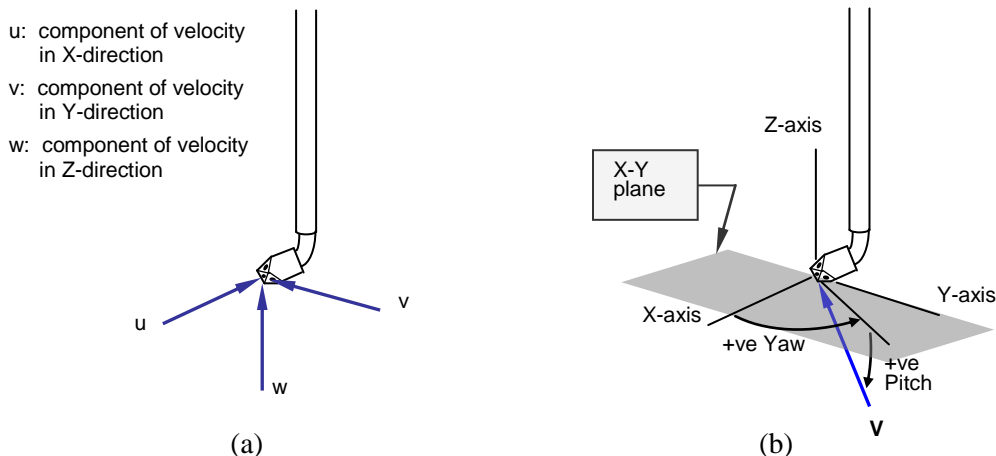


Figure 5: (a) Flow axis system with respect to the Probe head; (b) Positive flow pitch and yaw angles

- i** Note: Yaw angle is technically ‘azimuth’ (rotation angle about the z-axis); and Pitch is technically ‘elevation’ (the angle between the flow velocity vector \mathbf{V} and the X-Y plane).

Software configuration

Some basic settings need to be configured when the software is first run, or when the set-up is changed, in order to correctly use your instrumentation.

Prior to configuring your Cobra Probe (or any other device), ensure the data acquisition details are correct. When the *Device Control* software is run you can access information about the data acquisition devices available for use on the **Advanced (DAQ)** tab. Check this first to ensure that your data acquisition devices have been identified.

- Run the *Device Control* software
- Select **Advanced (DAQ)** from the **Settings** menu, then refer to Figure 6

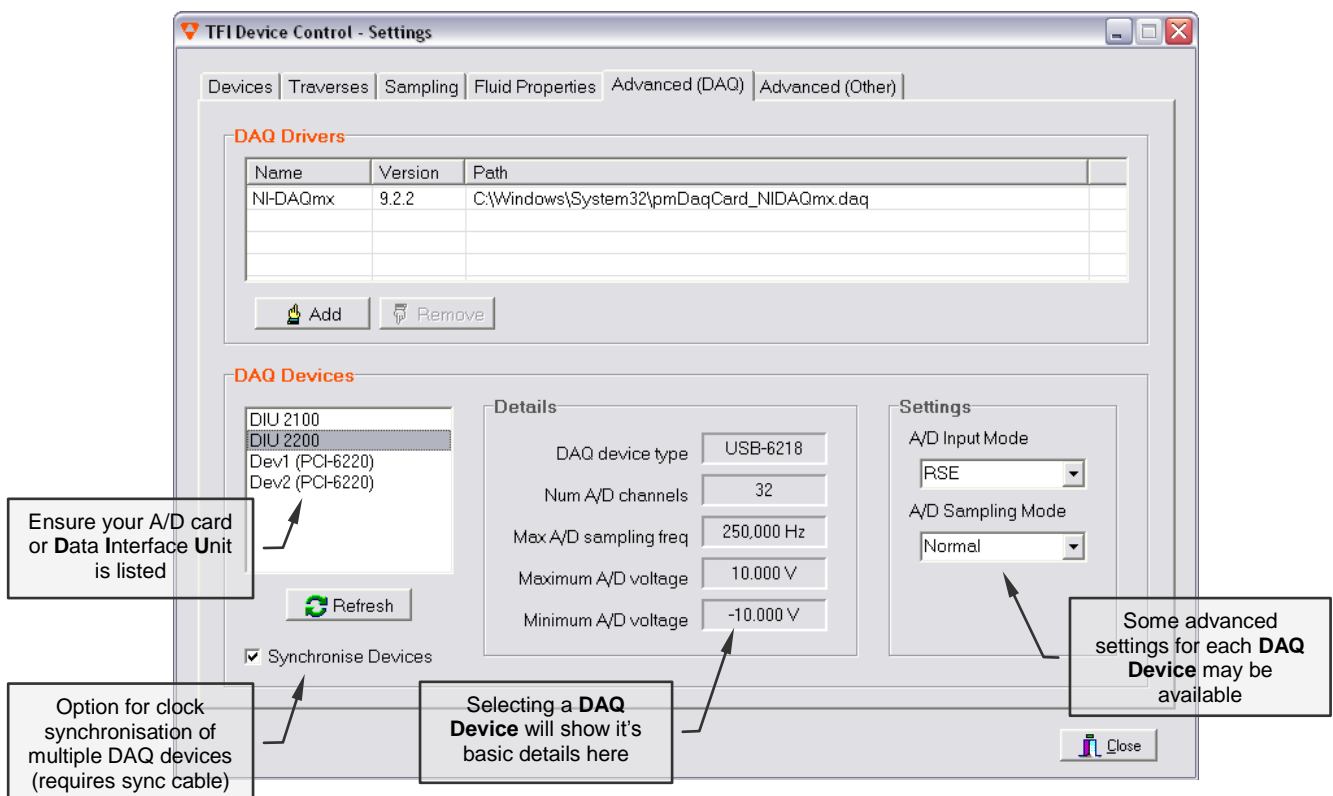


Figure 6: Software configuration – Checking the data acquisition details

- i** The **DAQ Devices** list should contain one item for each data acquisition device installed in, or connected to, your computer.
- i** For DAQ devices that use a common input voltage range for all channels (e.g. some Data Translations A/D cards) it will also be necessary to choose the appropriate input voltage range on the **Advanced DAQ** tab (this is not shown above in Figure 6 but will appear if such a DAQ device is selected).

- To choose and configure the devices that you wish to use, select the **Devices** tab (or choose **Devices** from the **Settings** menu) and refer to Figure 7.

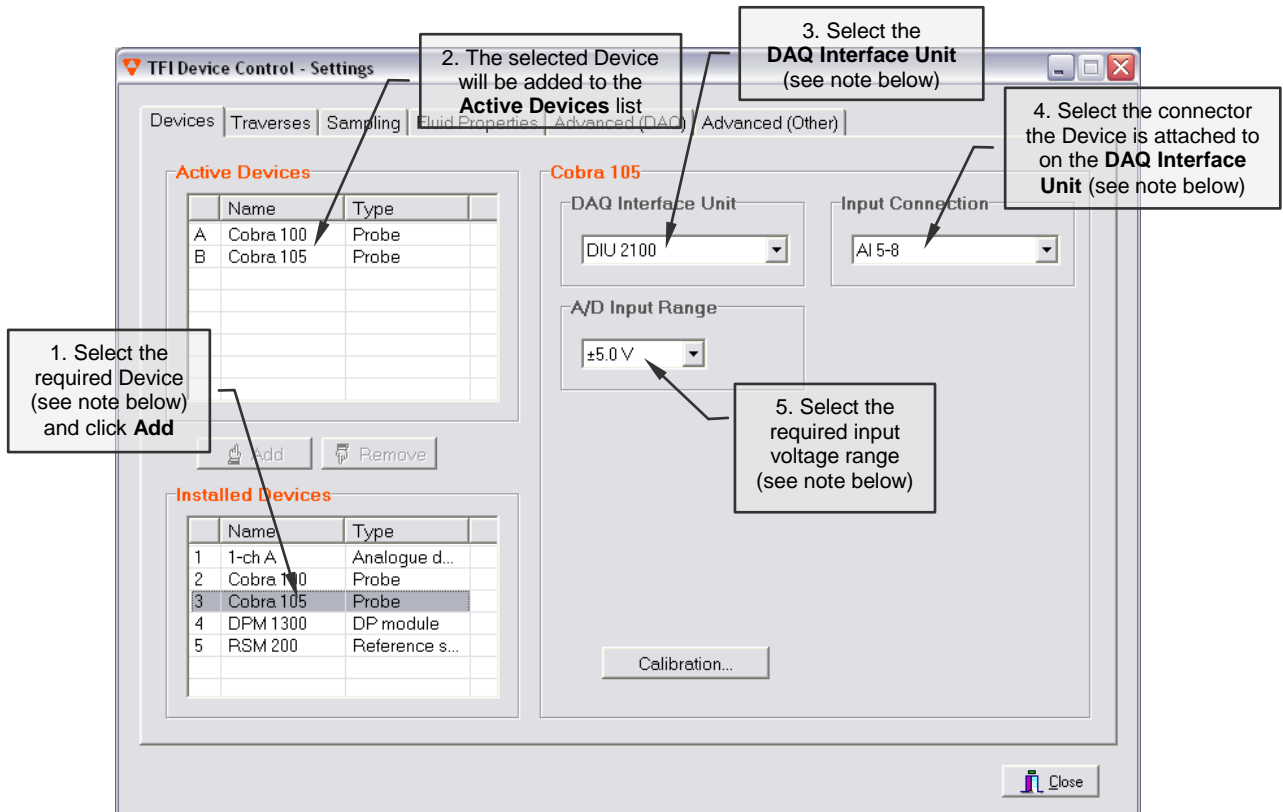


Figure 7: Software configuration – Adding and configuring devices

- Repeat the steps shown in Figure 7 for each additional Probe or other device.
- i** The Device ID number is engraved on the Probe body (see Figure 1).
 - i** New ‘devices’ can be created if other inputs are required, e.g. to use the TFI software to sample data from other instrumentation. (See the section on Sampling Data from Other Sources for details.)
 - i** If your DAQ Interface Unit is not listed, go back and check the **Advanced (DAQ)** tab.
 - i** Selecting a connector in the **Input Connection** list will automatically configure the channel list (see the Hardware Set Up section for details about Interface Units and connections).
 - i** If not using an Interface Unit, select **None** as the **DAQ Interface Unit**, a new box will appear, select a **DAQ Device** and manually configure the channel list (see the Hardware section below for channel number details).
 - i** If using a water Probe, select ‘Water’ as the **Fluid Type** on the **Fluid Properties** settings page.
 - i** For cards that use a common input voltage range for all channels, a note will pop up that the **A/D Input Range** is set on the **Advanced (DAQ)** tab (see Figure 6).

Operation

The basic operation of a Probe is outlined in Figure 8, which shows the main screen that appears when the *Device Control* software is run.

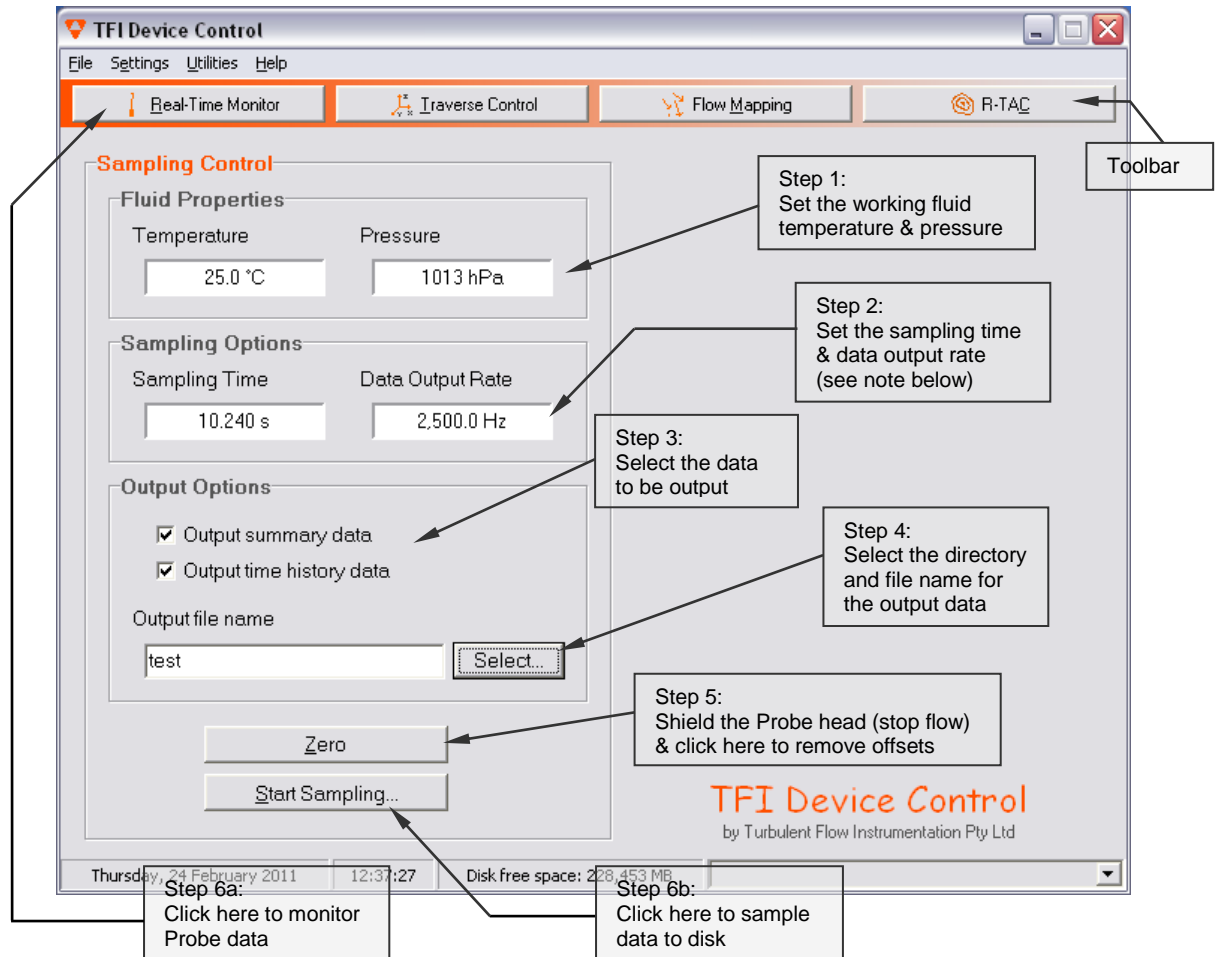


Figure 8: The Main screen of the *TFI Device Control* software & how to obtain data

- i** The **Data Output Rate** is that required for the data that is written to a file or displayed on the screen and is different to the **Acquisition Scan Rate** (see the Sampling and Data Rates section below).
- i** The Probe should be ‘zeroed’ regularly to remove offset voltages from the pressure transducers. Offsets change with variations in temperature and rotation of the Probe. While zeroing, the flow should be stopped, or the Probe completely shielded from the flow (i.e. no pressure input).

While obtaining data from the Probe, the **Data Display** form will be shown. A sample screenshot is given in Figure 9.

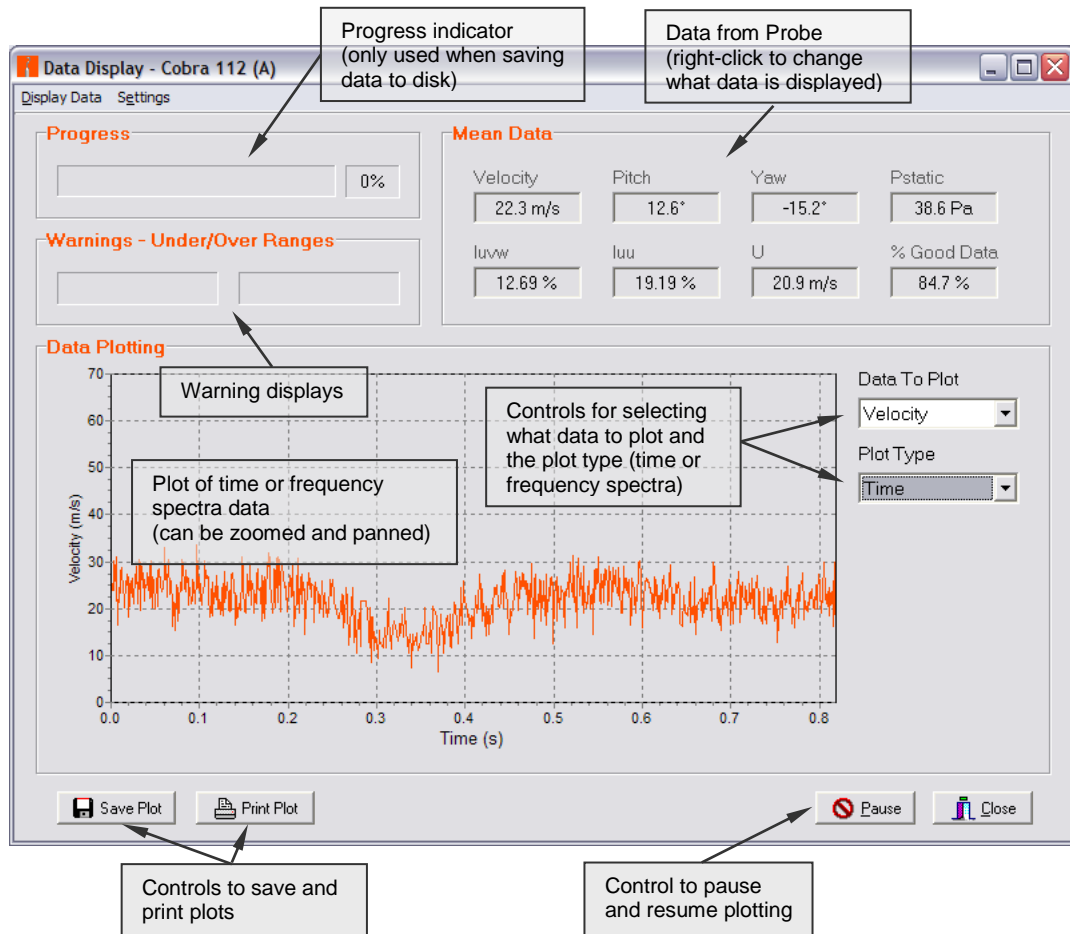


Figure 9: The Data Display screen of the TFI Device Control software

Sampling and Data Rates

Two terms are used to configure the sampling and data rates: Acquisition Scan Rate and Data Output Rate. The Acquisition Scan Rate is the frequency that the analogue data are sampled at, and is the sampling rate *per channel*. It must be set high enough to avoid aliasing; typically at least 5 kHz/channel is required for a Cobra Probe and 8-10 kHz/channel is preferred. The Acquisition Scan Rate multiplied by the number of channels being sampled must also be lower than the A/D card maximum sampling rate. Ideally the Acquisition Scan Rate should be below 80% of the A/D card maximum sampling rate divided by the number of channels being sampled to maximise accuracy.

$$5\text{kHz} \leq \text{Acquisition ScanRate} \leq 0.80 \times \frac{\text{A/D card maximum sampling rate}}{\text{number of sampled channels}}$$

The Acquisition Scan Rate setting is found by selecting **Advanced** from the **Settings** menu and clicking on **Show Advanced Settings**.

The Data Output Rate is the frequency at which data are output to screen and file. This rate must be equal to or less than the Acquisition Scan Rate. The Data Output Rate is achieved by decimating (low-pass filtering and down sampling) data from the Acquisition Scan Rate down to the required Data

Output Rate. This allows data to be sampled at a sufficiently high frequency to prevent aliasing while outputting data at a lower rate if only low frequency components are required. A higher Acquisition Scan Rate also helps to reduce measurement noise.

The Data Output Rate setting is found by selecting **Sampling** from the **Settings** menu.

Data Output Files

There are two common data output files: plain text summary files and binary time-history (TH) files. The summary files contain an overall summary of the measured data. The TH files contain u , v , w and static pressure data for each measured sample, at the specified **Data Output Rate** (see Step 2, Figure 8). The TH files can be viewed within the Device Control software or directly loaded into MATLAB[®]. For use with other applications, such as spreadsheet applications, the binary TH files can be converted to plain text files.

Viewing Saved Data

Recorded time-history data can be replayed by selecting **View Time History File** from the **Utilities** menu.

Exporting Data - MATLAB[®]

Functions for loading time-history data into MATLAB[®] are installed by default with the *Device Control* software. To use the supplied functions the directory containing the m-files must be added to the MATLAB[®] path. By default the m-files are located in:

C:\Program Files\Common Files\TFI\Matlab m-files

To load a TH file, enter the following command in MATLAB[®]:

```
[u, v, w, ps, s] = ReadTHFile;
```

MATLAB[®] is not case sensitive for commands and either 'readthfile' or 'ReadTHFile' will work.

Data for the three orthogonal velocity components u , v and w (see Figure 5), and the static pressure ps are loaded into the variables as column vectors, while details including data rate, channel names and units will be loaded into s (note that s is an optional output argument). There are several options for using the readTHfile function; for more details enter:

```
help ReadTHFile
```

Exporting Data – Other Applications

For other applications, the binary TH data files can be converted to plain text files by using the **Time History File Conversion** utility under the **Utilities** menu. Many applications such as spreadsheets can then load this data. The file format used by the binary TH files is available for users who wish to write code for importing data directly into other applications.

Sampling Data from Other Sources

To sample data from other sources, such as 3rd-party instrumentation, a 'device' must be created. After creating a device, you can acquire data from it as easily as with the Cobra Probe. To create a new device, use the TFI Hardware Manager.

1. Open the TFI Hardware Manager (can be opened from the **Utilities** menu on Main form)
2. On the **Analogue Devices** tab, click **New Device**
3. Enter a name for the device

4. Configure the device as required
 - a. Set the number of channels
 - b. Enter the 'name' of the first channel (usually 0 or 1)
 - c. Select if the device requires zeroing (i.e. offset voltage removal)
5. Click **OK** to save the device and close the **Hardware Manager**


You can now select, activate and configure the new device using the same procedure as for the Cobra Probe. By default, the volts-to-engineering units ratio is set to 1.0, which is equivalent to saving raw voltage data. The volts-to-engineering units ratio can be changed in the **Calibration** form (select **Devices** from the **Settings** menu and click on **Calibration**).

FURTHER INFORMATION

The hardware and software described here have been designed to be as easy as possible to use. All details required for general operation are described in this guide. However, if you have specific questions or require further information on the set-up and operation of the Cobra Probe and *Device Control* software, send an email to support@turbulentflow.com.au.

Help Hints

Placing the mouse cursor over a control in the *Device Control* software will display a brief hint describing its function.

 To enable the Help Hints function, ensure that **Show Help Hints** is selected in the **Help** menu.

Context Sensitive Help

Help about specific controls in the software can be accessed by selecting a control in the software and pressing the **F1** key.

APPENDIX: DEFINITION OF TERMS

Nomenclature

$\mathbf{V}, \bar{\mathbf{V}}, \mathbf{V}'$	Instantaneous, time-averaged & time-varying 'local' velocity vector
u, v, w	Instantaneous velocity components
$\bar{u}, \bar{v}, \bar{w}$	Time-averaged (mean) velocity components
u', v', w'	Time-varying (non-mean) velocity components
θ, ψ	Pitch and yaw angles
I_{uu}, I_{vv}, I_{ww}	Turbulence intensity components
I_{uvw}	Overall turbulence intensity
R_{uu}, R_{vv}, R_{ww}	Reynolds normal stresses
R_{uv}, R_{vw}, R_{uw}	Reynolds shear stresses
N	Number of samples

⚠ The velocity vector \mathbf{V} is the Cobra Probe local velocity, not free-stream velocity.

Components

$$|\mathbf{V}| = \sqrt{u^2 + v^2 + w^2}$$

$$u = \bar{u} + u' = |\mathbf{V}| \cdot \cos(\theta) \cdot \cos(\psi)$$

$$v = \bar{v} + v' = |\mathbf{V}| \cdot \cos(\theta) \cdot \sin(\psi)$$

$$w = \bar{w} + w' = |\mathbf{V}| \cdot \sin(\theta)$$

Angles

$$\theta = \sin^{-1}\left(\frac{w}{|\mathbf{V}|}\right)$$

$$\psi = \tan^{-1}\left(\frac{v}{u}\right)$$

Turbulence Intensity

$$I_{uu} = \frac{\sqrt{\overline{u'^2}}}{|\bar{\mathbf{V}}|} = \frac{\sigma_u}{|\bar{\mathbf{V}}|} = \frac{\text{stddev}(u)}{|\bar{\mathbf{V}}|}$$

$$I_{vv} = \frac{\sqrt{\overline{v'^2}}}{|\bar{\mathbf{V}}|} = \frac{\sigma_v}{|\bar{\mathbf{V}}|} = \frac{\text{stddev}(v)}{|\bar{\mathbf{V}}|}$$

$$I_{ww} = \frac{\sqrt{\overline{w'^2}}}{|\bar{\mathbf{V}}|} = \frac{\sigma_w}{|\bar{\mathbf{V}}|} = \frac{\text{stddev}(w)}{|\bar{\mathbf{V}}|}$$

$$I_{uvw} = \frac{\sqrt{\frac{1}{3}(\overline{u'^2} + \overline{v'^2} + \overline{w'^2})}}{|\bar{\mathbf{V}}|}$$

Reynolds Stress

$$R = -\rho \begin{bmatrix} \overline{u'^2} & \overline{u'v'} & \overline{u'w'} \\ \overline{v'u'} & \overline{v'^2} & \overline{v'w'} \\ \overline{w'u'} & \overline{w'v'} & \overline{w'^2} \end{bmatrix}$$

$$R_{uu} = -\rho \overline{u'^2} = -\rho \sigma_u^2 = -\rho \cdot \text{var}(u)$$

$$R_{vv} = -\rho \overline{v'^2} = -\rho \sigma_v^2 = -\rho \cdot \text{var}(v)$$

$$R_{ww} = -\rho \overline{w'^2} = -\rho \sigma_w^2 = -\rho \cdot \text{var}(w)$$

$$R_{uv} = -\rho \overline{u'v'}$$

$$R_{uw} = -\rho \overline{u'w'}$$

$$R_{vw} = -\rho \overline{v'w'}$$