400-Series A/D Interface

Data Acquisition for 400-Series Flowmeters

Recording Flow Data: Manual, Analog or Digital?

Manual Data Recording

Transonic 400-Series flowmeter modules display average flow on the LED digital display which can be read and manually recorded. This provides quick, but limited information in an experiment.

Analog Data Output Signals

Flowmeter modules provide analog voltage output signals which can be recorded by a strip chart recorder or converted to digital signals for more automated recording by a computer. Modules provide a flow signal on their front BNC connector. This signal tracks the low-pass output filter selected on the meter module (0.1, 10, 40, 160 Hz). A broader range of output signals is available on the rear panel of T402 and T403 consoles via screw terminal connections (see below and in the flow module manual). Terminal output connections may be made with general purpose hookup wire (stranded wire preferred, UL 1007 or equivalent, 24-14 gauge, stripped end: 6mm minimum length).

Digital Data Collection

A computer record of a study typically combines signals from multiple instruments such as flow, pressure, temperature and other physiological data. This requires a separate Analog-to-Digital (A/D) converter and computer software. Both the software and A/D interface must be matched to the user's study requirements. These computer interface components are not included in the Transonic T400 flowmeter system, but are available from companies specializing in data collection software. The following notes provide guidance to select software to meet the requirements of Transonic T400 flowmeter modules.

Mouse Recording: multiple channels of simultaneous recorded data including pressure, temperature, superior mesenteric blood flow, probe received signal and phase. Data was recorded to computer using A/D converter and Dataq's Windaq software.

Analog Signals Available on Transonic Flow Modules

Transonic flowmeter modules provide the following analog signals on the rear panel of the T400 console.

• Volume Flow

Both average (0.1 Hz) and pulsatile (filtered at 10 Hz, 40 Hz, or 160Hz) flow signals are provided. For some chronic studies, average flow values may be adequate, but in many cases researchers will want to collect the full pulsatile flow signal for beat-to-beat calculations such as stroke volume, vascular resistance etc. This signal has a voltage range of -5V to +5 V, scaled to match a flow probe's flow range. To calibrate or scale the voltage output properly in the data acquisition recording, see Transonic Technical Note # 10 for specific details. See below for guidelines to selecting the optimal frequency filter and sample rate.

• Received Signal Amplitude

These signals represent the strength of the ultrasonic beam passing through the flowprobe and are useful in testing the quality or functionality of a probe. Low signal strength may indicate an ultrasonic obstruction (such as an air bubble) or a failing probe and may affect the measurement quality with increases in noise or zero offset. For quality tracking, a very low sampling rate should be adequate. A minimum of 2kHz sampling rate is recommended for bubble detection. There are 2 signal outputs: 1 per transducer pair for 4 transducer probes. These two signals are identical to each other for 2-transducer probes. These signals are "normalized" or standardized for the applied probe use under its factory calibration conditions (see probe data sheet). The signal ranges from 0V to +5V, 2V = 100% factory-calibration signal strength.

• Phase Signals (= Ultrasound Indicator Dilution)

These signals represent changes in the acoustic velocity of the fluid and are used for ultrasound indicator dilution studies. Transonic Hemodialysis Monitors use a 16 Hz per channel sampling rate for human indicator dilution measurements (1 Hz beat frequency). For smaller animal models, the sampling rate may be scaled up proportionally to the higher heart beat rate. There are 4 signal outputs; 2 per transducer pair (1 offset for reference) for 4 transducer probes. Two-transducer probes provide 2 identical signal output pairs.

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Guidelines for Selecting Flow Signal Frequency Filter & Data Acquisition Sampling Rates

The frequency spectrum of a flow signal with a strong pulsatile component consists of a base "beat" frequency and up to 9 higher harmonics. For instance, a human heart rate of 60 beats/minute has a base frequency of 1 Hertz (= 1 beat/second). A 10 Hertz frequency band contains this base frequency and the 9 higher harmonics and should be used to characterize the pulsatile flow components of a human heart beat.

A frequency band of X Hertz must be sampled digitally at a rate higher than 2X. A safe minimum sampling rate is 3X. This leads to the following sampling rate table for flow signals collected from the flow modules.

Flow Cutoff Frequency/ Flowmeter Filter Setting	Heart Rates up to	Recommended Minimum Sampling Rates
0.1 Hz	Average	0.3 Hz
10 Hz	60 beats/min	30 Hz
40 Hz	240 beats/min	120 Hz
160 Hz	1000 beats/min	500 Hz

Data acquisition packages combine hardware and software solutions for data recording. The sampling rate for digital recording is a factor in determining the accuracy of the reproduced data and the resolution of the measurement. Some software packages allow the user to select different sampling rates for the individual measurement channels. Maximum sampling rate per channel is dependent on A/D converter hardware and the number of instrument channels.

A further specification of A/D converters is its "bit conversion factor." A 12-bit converter maps a flow signal onto a number scale of 2^{12} = 4,096 "bits." This determines the resolution of the digital signal. For instance, a probe with a flow scale of -200 ml/min to +200 ml/min would be mapped into a 4,096 bit digital scale going from -2,048 bits to + 2,048 "flow bits" to give the digital flow signal a resolution of 0.1 ml/min. This may be adequate for most applications. New 16-bit A/D converters with a theoretical resolution of 2^{16} = 65,536 bits are becoming very common. These are more than adequate for all flowmetering applications.

Analog-to-Digital (A/D) Converter and Computer Software Selection

The operation of an A/D converter is configured by the same computer software that records and analyzes the physiological data delivered by the A/D converter. It is therefore recommended to purchase A/D converter and software from the same vendor to ensure compatibility.

Transonic Systems does not supply data acquisition hardware or software for the 400-series flowmeters but maintains a list of companies offering A/D interfacing and data acquisition solutions that are commonly used by researchers to process flow data. See Technical Note # 91 listing "Equipment Sources" on Transonic's web site: www.transonic.com

The Data Acquisition and Analysis software packages offered by these companies fall into three categories. Researchers should select a package with features that best meet their requirements.

GLP Compliant Systems

More demanding data collection for applications such as preclinical drug trials are commonly performed with software that meets GLP ("Good Lab Practices") standards defined for research and products regulated by the FDA. These sophisticated systems have extensive security, validated record keeping and data integrity, and automated analyzers for common research parameters. Companies offering such high-end software solutions are: EMKA Technologies (www.emka.fr), Notocord (www.notocord.com), Gould PONEMAH (www.gouldmedical.com).

Mid-level Life Science Solutions

These mid range cost systems include companies that specialize in software used in academic institutions with analysis for the common research applications. These include AD Instruments (www.adinstruments.com), BIOPAC Systems, Inc. (www.biopac.com) and Micro-Med, Inc. (www.digi-med.cc).

Engineering-Style Packages

These are less costly solutions without specialized life science analyzers. Transonic Systems has a long history of collaboration with Dataq Instruments (www.dataq.com) who offer a number of basic A/D converters and software including "WinDaq Lite," "WinDaq Waveform Browser" and "WinDaq/Pro." (See TN#96, Windaq Data Acquisition Systems.)

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