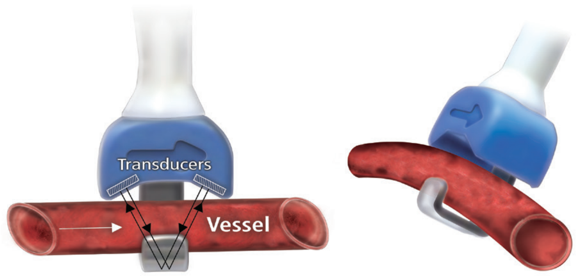
Theory of Operation

Transit-Time Ultrasound Technology

A Transonic® Perivascular Flowprobe consists of a probe body which houses ultrasonic transducers and a fixed acoustic reflector. The transducers are positioned on one side of the vessel under study and the reflector is positioned at a fixed position between the two transducers on the opposite side. Electronic ultrasonic circuitry directs a Flowprobe through the following cycles:



Schematic views of a Transonic® Perivascular Flowprobe. Using wide beam illumination, two transducers pass ultrasonic signals back and forth, alternately intersecting the flowing liquid in upstream and downstream directions. The Flowmeter derives an accurate measure of the "transit time" it takes for the wave of ultrasound to travel from one transducer to the other. The difference between the upstream and downstream integrated transit times is a measure of volume flow rather than velocity.

UPSTREAM TRANSIT-TIME MEASUREMENT CYCLE

An electrical excitation causes the downstream transducer to emit a plane wave of ultrasound. This ultrasonic wave intersects the vessel under study in the upstream direction, then bounces off the fixed "acoustic reflector." It again intersects the vessel and is received by the upstream transducer where it is converted into electrical signals. From these signals, the Flowmeter derives an accurate measure of the "transit time" it takes for the wave of ultrasound to travel from one transducer to the other.

DOWNSTREAM TRANSIT-TIME MEASUREMENT CYCLE

The same transmit-receive sequence is repeated, but with the transmitting and receiving functions of the transducers reversed so that the flow under study is bisected by an ultrasonic wave in the downstream direction. The Flowmeter again derives and records from this transmit-receive sequence an accurate measure of the transit time it takes for the wave of ultrasound to travel from one transducer to the other.

Just as the speed of a swimmer depends, in part, on water currents, the transit time of ultrasound passing through a conduit is affected by the motion of liquid flowing through that vessel. During the upstream cycle, the sound wave travels against flow and total transit time is increased by a flow-dependent amount. During the downstream cycle, the sound wave travels with the flow and total transit time is decreased by the same flow-dependent amount. Using wide beam ultrasonic illumination, the Flowmeter subtracts the downstream transit times from the upstream transit times. This difference in the integrated transit times is a measure of true volume flow.

Drost, C.J., "Vessel Diameter-Independent Volume Flow Measurements Using Ultrasound", Proceedings San Diego Biomedical Symposium, 17, p. 299-302, 1978.
U.S. PATENT 4,227,407, 1980.

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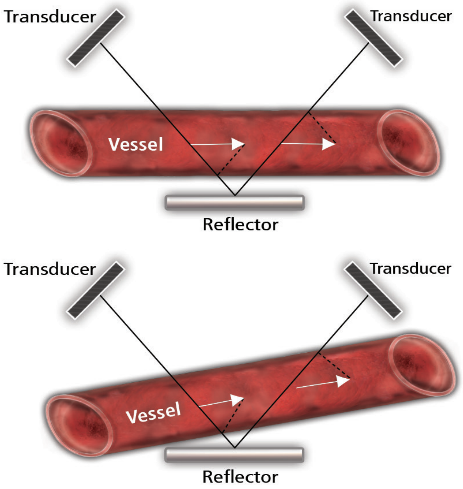
THE MEASURE OF BETTER RESULTS.

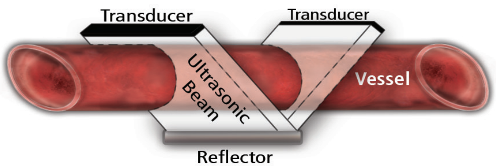
Transit-Time Ultrasound Theory of Operation Continued

WIDE BEAM ILLUMINATION

One ray of the ultrasonic beam undergoes a phase shift in transit time proportional to the average velocity of the liquid times the path length over which this velocity is encountered. With wide-beam ultrasonic illumination, the receiving transducer integrates these velocity-chord products over the vessel's full width and yields volume flow: average velocity times the vessel's cross sectional area. Since the transit time is sampled at all points across the vessel diameter, volume flow measurement is independent of the flow velocity profile. Ultrasonic beams which cross the acoustic window without intersecting the vessel do not contribute to the volume flow integral. Volume flow is therefore sensed by Perivascular Flowprobes even when the vessel is smaller than the acoustic window.



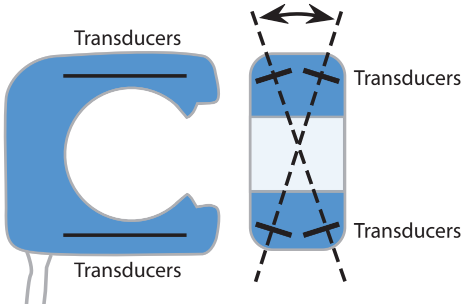
The ultrasonic beam intersects the vessel twice on its reflective path. With each intersection, the transit time through the vessel is modified by a vector component of flow. The full transit time of the ultrasonic beam senses the sum of these two vector components. With misalignment (bottom), one vector component of flow increases as the other decreases, with little consequence to their sum.



The vessel is placed within a beam that fully and evenly illuminates the blood vessel. The transit time of the wide beam then becomes a function of the volume flow intersecting the beam, independent of vessel dimensions.

X-BEAM ILLUMINATION

PAU-Series COnfidence Flowprobes® and XL Tubing Flowsensors use four transducers in X-beam illumination to accomplish the same volume flow measurements as the standard Perivascular Flowprobes. Ultrasound waves are transmitted in both the upstream and downstream directions by each pair of transducers. This provides two upstream and two downstream transit times which the Flowmeter combines into a single true volume flow measurement. The X-beam pattern of ultrasonic illumination provides the same advantages as wide beam illumination: measurement independence from velocity profile and vessel orientation.



COnfidence Flowprobes® use four transducers to create an X-beam ultrasonic illumination pattern to achieve a full vessel volume flow measurement.

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Transonic Systems Inc. is a global manufacturer of innovative biomedical measurement equipment. Founded in 1983, Transonic sells "gold standard" transit-time ultrasound flowmeters and monitors for surgical, hemodialysis, pediatric critical care, perfusion, interventional radiology and research applications. In addition, Transonic provides pressure and pressure volume systems, laser Doppler flowmeters and telemetry systems.

AMERICAS
Transonic Systems Inc.
34 Dutch Mill Rd
Ithaca, NY 14850
U.S.A.
Tel: +1 607-257-5300
Fax: +1 607-257-7256
support@transonic.com

EUROPE
Transonic Europe B.V.
Business Park Stein 205
6181 MB Elsloo
The Netherlands
Tel: +31 43-407-7200
Fax: +31 43-407-7201
europe@transonic.com

ASIA/PACIFIC
Transonic Asia Inc.
6F-3 No 5 Hangsiang Rd
Dayuan, Taoyuan County
33747 Taiwan, R.O.C.
Tel: +886 3399-5806
Fax: +886 3399-5805
support@transonicasia.com

JAPAN
Transonic Japan Inc.
KS Bldg 201, 735-4 Kita-Akitsu
Tokorozawa Saitama
359-0038 Japan
Tel: +81 04-2946-8541
Fax: +81 04-2946-8542
info@transonic.jp