Operating Instructions

for the
PLUGSYS®-Module

Transit Time Flowmeter TTFM-2 Type 714

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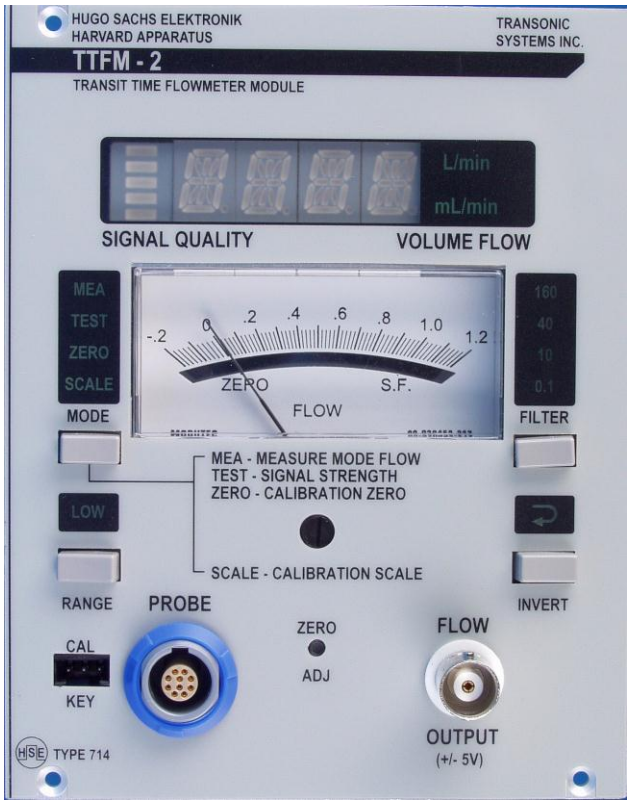

Contents

1. Introduction, manufacturer's details

These Operating Instructions describe the operation and use of the **TTFM-2** Module Type 714. It is part of the equipment and should be kept close to it.

All the information in these Instructions has been drawn up after careful examination but does not represent a warranty of product properties. Alterations in line with technical progress are reserved.

This PLUGSYS module is manufactured by:

Hugo Sachs Elektronik- HARVARD APPARATUS GmbH Gruenstrasse 1 D-79232 March-Hugstetten Germany	and	Transonic System Inc. 34 Dutch Mill Road, Ithaca NY 14850, USA
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1.1 Copyright

1.2 Trademark

PLUGSYS is a registered trademark of Hugo Sachs Elektronik-Harvard Apparatus GmbH, March/Hugstetten, Germany, a Harvard Bioscience company

2. Safety note

Important: This equipment is not suitable for operation in hazardous areas and/or in a flammable atmosphere.

NOT FOR HUMAN USE !!!
The equipment is not approved for measurement on humans!

The ultrasound transit time flow module works with high-frequency impulse voltage. The module, designed with all necessary shielding and high quality connectors guarantees a minimum of high frequency radiation. However conditioned by the principle of the transit time measurement some radiation in the area around the flowprobe is unavoidable.

3. General description, applications

The HSE-TRANSONIC Transit Time Flowmeter (TTFM-2) is an ultrasonic flowmeter for animal research.
It is a co-production of Hugo Sachs Elektronik-HARVARD APPARATUS GmbH and Transonic System Inc. USA and incorporates a complete one channel TRANSONIC ultrasonic transit time flow meter. It can be used with all flow probes compatible to the TS420 Transonic flow meter.

An extensive selection of probes for vessel diameters from 0.25 to 20mm are available for chronic and acute studies. The extra-corporal inline-probes, ideal for isolated organ preparations are available in sizes from 1.0mm to 22.2 mm.
The module features a build in digital display for direct reading of mean flow and an analog instrument to show flow, signal quality and scale factors.
The TTFM-2 has one output for mean and pulsatile recordings. The output frequency depends on filter settings.

For using the TTFM-2 module it has to be installed in a PLUGSYS housing Series 600.

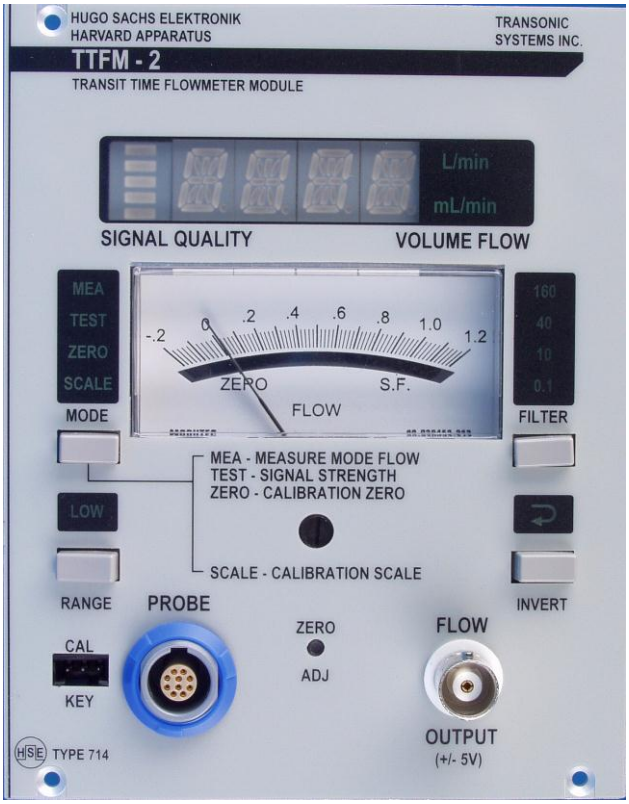


Fig. 1: TTFM-2 TRANSIT TIME FLOWMETER

The line-powered flowmeter module automatically identifies the scaling factor and individual calibration factor of the flowprobe connected to it. The flowprobes technical data (range, flow calibration etc.) are stored in a microchip in the flowprobes connector.

4. Description of the controls

(1) The digital display shows:

- mean VOLUME FLOW (in measure mode, **MEA, here -1.7ml/min**). The digital display presents absolute average (0.1 Hz low-pass filtered) volume flow in ml/min or L/min.
- Diagnostic Data (in TEST mode)
- Probe scale data (in ZERO and SCALE factor Calibration modes)
- The digital display shows **Ac.Er** (acoustic error) when no flowprobe is connected, or when the ultrasonic signals pathway in the flowprobes sensing window is blocked by air or fat; the reflector is misaligned; the probe or extension cable is malfunctioning, etc.
- signal quality on a 5 digit bargraph display

(2) MODE display
MEA Measure Mode
TEST Shows signal strength
ZERO Simulates zero flow at the output and display
SCALE Simulates maximal flow on the output and display, depends on probe size !

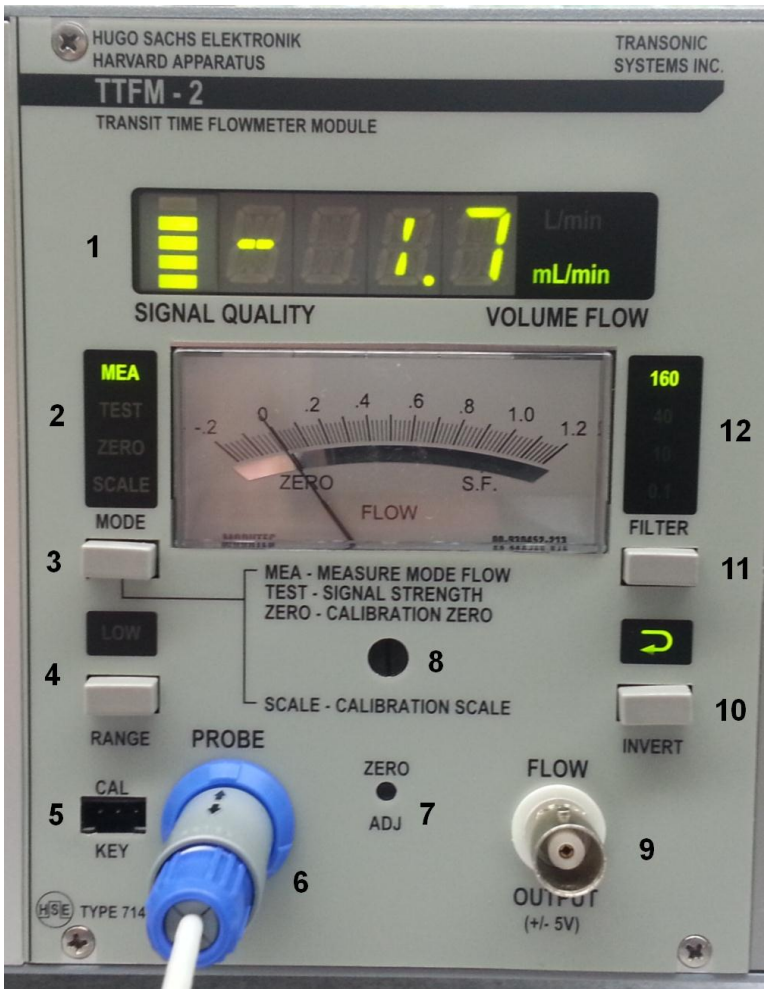


Fig. 2: Controls on the front panel

(3) MODE toggle switch
This switch controls the mode of operation: it selects between Measure **MEA, TEST, ZERO** and **SCALE** .
The **MEA** mode is the mode during the experiment where you measure.

In **TEST** mode the digital display presents a diagnostic message that identifies the probe size in mm and an assessment of the level of the received signal:

”Gd” = sufficiently strong received signal;
”Lo” = marginally adequate received signal;
”No” = insufficient or no received signal.

Example: if display shows **2-Gd** (may be interpreted as **2-6d**) this means a 2mm probe with good received signal is connected.

Analog meter indicates received signal amplitude of the flowprobe between 0 and 1.0
BNC connectors provides flow signals as in MEAS mode.

In **ZERO** mode the output of the display and the analog outputs show zero and deliver 0V on the BNC output. This is used to calibrate external recording devices or data acquisition systems and to check the probe.
In **SCALE** mode the digital display shows the recognized maximal flow value of the connected probe. The analog display shows the scale factor S.F. This means the needle of the analog instrument shows 1.0. The analog output should show 1V, which corresponds to the maximum flow value of the probe displayed on the digital display.

(4) Switch **RANGE Normal/LOW**. This switch is used to switch from the normal range to the LOW flow range. The Low Flow Range expands the displayed flow sensitivity by a factor of four, associated with that flow range is devided by 4. Example: e.g. in Normal range a flowprobe can work up to 100ml/min. If you set the Mode to LOW Flow the range it can work is only up to 25ml/min but with 4 times more accuracy. You always must recalibrate your DAQ system when you change from Normal to LOW !!! The little display above lights up with LOW when you pushed the RANGE button.

In CAL SCALE mode: digital display in LOW will read 25% of its former scale factor flow level.
In MEAS mode: digital display will continue to present absolute volume flow directly in ml/min or L/min at the analog meter and on the OUTPUT BNC connector, the same flow will be represented by a four times stronger electrical signal. To reset function to normal scale, switch to NORMAL. Please be informed that switching from NORMAL to LOW does not change the output voltage. If a recorder or a data acquisition system is connected you have to recalibrate these systems on the flow channel.

(5) **CAL key**, this port takes the key if implantable flowprobes are used

(6) **Input connector** for flow probe or extension cable. 10 pin Transonic probe input connector.

(7) **ZERO ADJ** push button. This button is used to zero a probe which gives not exactly zero value at zero flow. Offset Adjustment, dial for Zero flow reading during occlusion or when no flow is passing through flow sensor.
All flow probes are factory calibrated. For low flow applications the zero of the probes can be re-calibrated by pressing this button with a pen. The new zero value is stored in the module and in the probe. After pressing this push button for five seconds a new zero value is stored in the module. For this procedure the volume flow through the probe must be really zero! Occlude vessel, tube or stop pump.

(8) **Analog Instrument.** The analog instrument shows the flow signal in the MEAS mode, the signal quality (received signal amplitude) in TEST mode, ZERO in ZERO calibration mode and the scale factor of the probe (nominal flow value) in SCALE mode.
In **TEST** mode the analog instrument shows the signals strength. A good bubble free and well filled probes should show 1.0 on the analog instrument. Values between 0.5 and 1.0 are still sufficient. If the signal strength is below 0.4 the values are no longer relieable and the module shows Error.

(9) **FLOW Output**, BNC Flow Monitor Output, supply flow information to accessory instrumentation (recording software, chart recorder, oscilloscope, signal monitoring etc.)
Output frequency range depends on filter setting (11 & 12)
Shows pulsatile flow at filter positions 100Hz, 30Hz
Shows average volume flow, at 0.1Hz. All filters are low-pass filters.
Zero calibration = 0 Volts out, Scale factor flow = 1V ± 2%, Output resistance = 500 Ohm
Full range for flows = ± 5V (bi-directional flows, ± 4 times scale factor)

(10) INVERT Polarity switch
Polarity of displayed flow: inverts polarity of analog flow outputs and flow display if the flowprobe was installed in the opposit direction.

(11) Filter switch
Output filtering: 0,1, 10, 30 and 100 Hz low pass filtering applied to analog output (9)
Analog flow outputs represent pulsatile volume flow within the instruments accuracy specifications if the filter cut-off frequency (in Hz) is at least ten times the animal models pulse repetition rate in beats per second. Filter type: third order (3 pole) Butterworth in the 100 Hz setting; second order (2 pole) Butterworth in the 10, and 30 Hz settings.
BNC output socket shows pulsatile flow at filter positions 100Hz, 30Hz
Shows average flow, at 0.1Hz. All filters are low-pass filters.

(12) Filter setting display, shows lowpass filter setting in [Hz]

The TTFM-2 automatically adjusts itself as soon you connect the flow probe

Automatic adjustments:

- Probe size and corresponding flow output ranges (see flowprobe tables)
- Volume flow calibration of the applied probe

Probe Extension Cables

The TTFM-2 module comes with a blue 1m extension cable 73-4706 with grey connectors on both ends.

Other available extension cables are:

73-4706	EXTENSION CABLE FOR TTFM-2;CRA10-S-CRA10	supplied with each TTFM-2
73-4707	EXTENSION CABLE FOR TTFM-2;CRA10-M2-CRA10	2m length
73-4708	EXTENSION CABLE FOR TTFM-2;CRA10-M3-CRA10	3m length

5. Starting up

After the probe has been connected to the input socket measurement can begin. Check first for air bubbles and switch the TTFM-2 into the TEST mode to check signal strength.

5.1. Calibrating the TTFM-2 together with a data acquisition system

Calibration of data acquisition systems always requires two calibration points. To perform an easy calibration procedure the TTFM-2 has automatic detection of the connected flowprobe and the toggle switch **MEAS/TEST/ZERO/SCALE**. In position **ZERO** the display and the analog output shows Zero (0V). In Position **SCALE** the output of the display shows the probes nominal flow (scale) value and the analog output shows 1V for this scale value.

Follow the procedure indicated below:

- connect the TTFM-2 BNC output to your DAQ channel
- fill the probe with saline solution or hold it into a beaker with saline solution
- start your data acquisition software and go to menu item calibration and the flow channel
- set toggle switch **MEAS/TEST/ZERO/SCALE** to position **ZERO**
- now the digital and the analog display show zero, the output is on 0V
- read in the Low Cal (zero flow) value into your software.
- switch TTFM-2 to **SCALE**
  now the digital display shows the scale factor (nominal maximum flow) of the connected probe. The output voltage (1V) correspond to this scale factor. Is e.g. the scale factor 20.0 so the 1V on the output corresponds to 20ml/min.
- read in the High Cal flow value into your DAQ software
- save you calibration data

6. Experiment

After the TTFM-2 has been calibrated the measurement can be started. Place probe on the vessel where flow should be measured or place inline probe into the tube where flow should be measured. Set mode switch to **MEA**. If you get **Ac.Er.** (Acustic Error) on the display check if probe is bubble free or if the acustic path of the probe is interrupted. On using perivascular flow probes some saline solution at the probes surface or some ultrasound gel will help to get good readings. When using the inline (N) probes try to remove all bubbles from the probe. Best is that the flow through the probe goes from bottom to top this means the flow probe should be mounted vertically. In this case the flow takes all small air bubbles out of the probe.
The ”Ac.Er” message on the digital display will be replaced by the flow readings as soon acoustic conduction is established within the probe. A dry probe may have to be immersed in water for several minutes before this occurs; sloshing helps to speed up the process; the probes received signal stabilizes when probe body surfaces are entirely wet.

7. Installing the module in a housing

If the module has been supplied already installed you can omit Section 8 and continue with Section 9. If you have received the module as a separate unit you should continue here.)

Before you can use the **TTFM-2** module it has to be installed in a suitable HSE PLUGSYS housing Series 600 (601 to 603). If the module is supplied as part of a completely installed PLUGSYS measuring system the work described below has already been carried out and the selected signal paths have been entered in the bus diagram.

Before the module is installed in a housing the connections of the module to the bus lines have to be determined by plugging in links as described in the next section (Section 8.1).

Furthermore for installing this module you have to remove some of the black rails in the housing.

Do not forget to enter the selected connections in the bus diagram (in the white Operating Manual folder under Section 1).

Brief procedure (for full details see the Operating Manual of the housing):

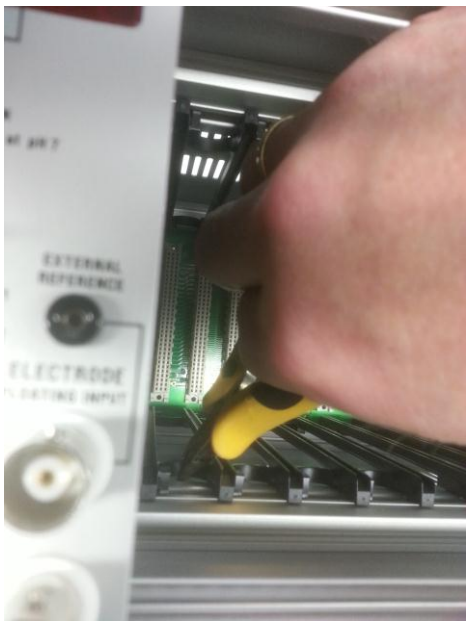
- Pull out the mains plug on the housing
- Remove the blank panel at the housing slot position intended for the **TTFM-2** module
- Remove 4 rails right of the rail where you intend to insert the module
- Prepare module according to Section 8.2 (set lines and links)
- Insert the **TTFM-2** module, note the guide rail on the left side
- Push the module firmly into the bus connector
- Screw on the front panel
- Connect the flow probe
- Reconnect the mains plug to the housing
- Switch on the power

7.1 Removing of the rails in a PLUGSYS housing

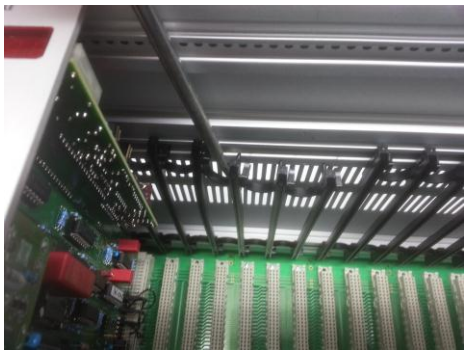
In the housing you see the black rails for the modules. As the TTFM-2 has a shielding case around its electronic 4 rails must be removed. The first rail right of the last module has to stay in place.

The first rail right of the last build-in module has to stay in place.

You need sharp pliers to cut out the rails.



Cut off the rails on top and bottom.



Use a screwdriver to remove the cutted rails

Housing with the removed 4 rails on top and bottom, ready to insert the new TTFM-2 module.

Slide the module in and close all 4 screws delivered with the module.

Don´t forget to set the internal analog bus lines before installing the module.

7.2 Internal instrument settings, analog links

Warning: The **TTFM-2** module must be protected against electrostatic discharges while it is outside the housing! The **TTFM-2** module contains highly sensitive components which can be damaged or destroyed by electrostatic discharges. If you dismantle the module or if you carry out any operations on the dismantled module you must ensure potential equilibration before touching any part of the printed circuit (by touching some grounded metal part, e.g. water tap, central heating radiator. grounded housing, PLUGSYS housing or similar).

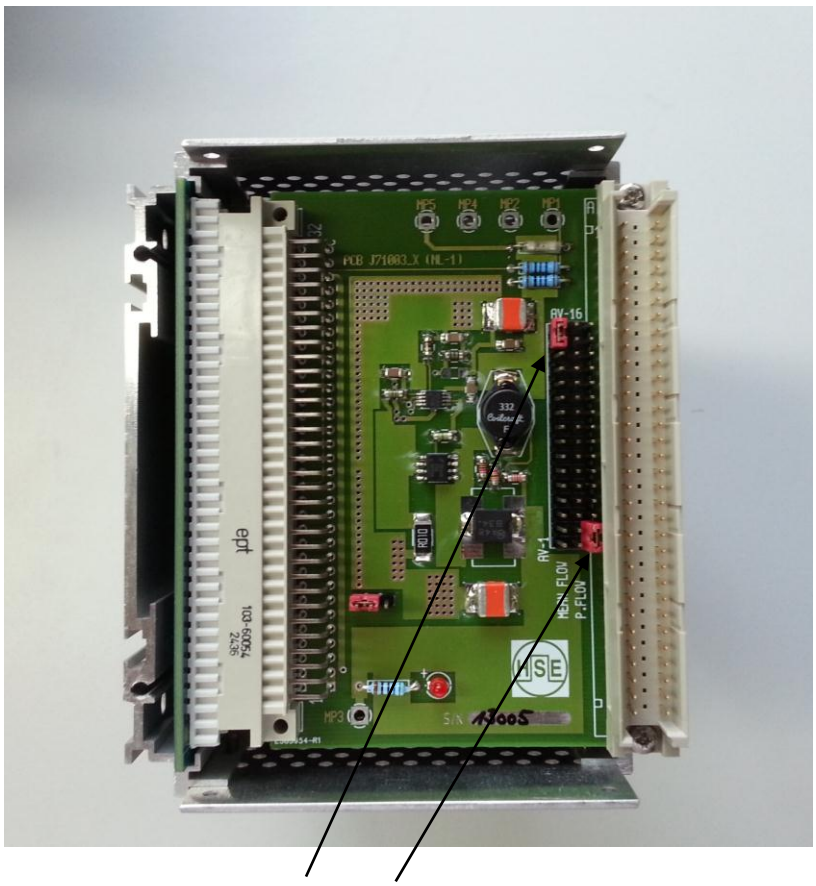
Before you install the **TTFM-2** module into the PLUGSYS housing it is necessary to set the links on the rear circuit board in order that the output signal is linked to the appropriate or required bus line. The module can only be used in conjunction with the complete system if the bus lines have been connected up correctly.

Do not forget to enter the selected signal assignment in the bus diagram for the PLUGSYS housing (the bus diagram is filed in the Operating Manual folder under Section 1).

If the module is supplied as part of a completely installed PLUGSYS measuring system, the operations described below have already been completed and the selected signal paths have been entered in the bus diagram.

The location of the links (jumpers) is shown in the illustration below. The following links can be set:

- mean signal output to transfer the **mean flow signal** to the PLUGSYS bus system
- pulsatile signal output to transfer the **pulsatile flow signal** to the PLUGSYS bus system



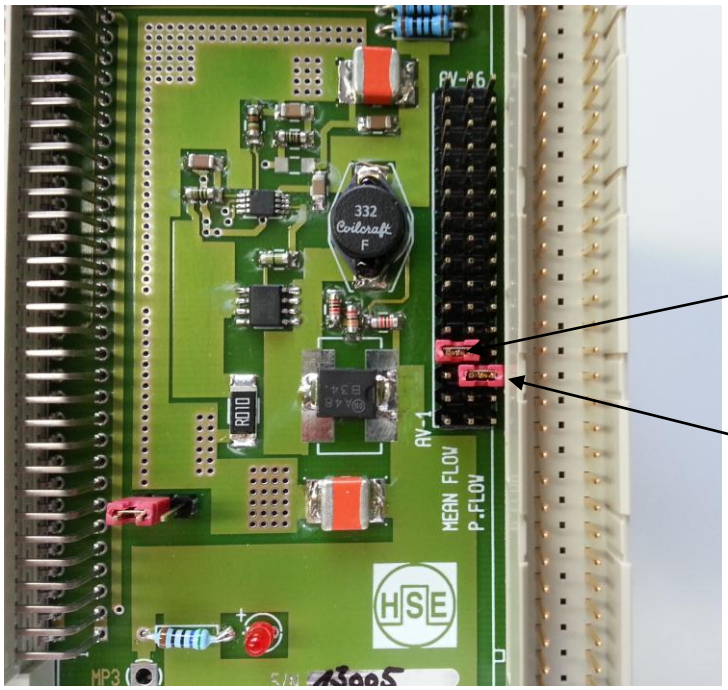
This photo shows the red jumpers in park position

7.2.1 Analog signal output to send the mean and the pulsatile flow values to the PLUGSYS bus

Plugging these links (jumpers) transfers the analogue signals corresponding to the mean flow or pulsatile flow to the PLUGSYS bus. The link must be plugged on to the appropriate channel (AV1 - AV16).

Note:

When selecting the bus line (AV1...16) be sure to use a free line and check this in the bus diagram. If there is no appropriate information in the bus diagram you can determine the bus line assignment only by removing all the modules and determining the signal paths selected on them using the corresponding operating instructions.



Jumper for mean Flow in position AV4

Jumper for pulsatile Flow in position AV3

Result of this setting:
The Pulsatile Flow (P.Flow) signal will be connected to Channel AV3 (Analog Voltage 3)
The mean Flow (MEAN Flow) signal (filtered with a 0.1Hz lowpass) will be connected to Channel AV4 (Analog Voltage 4).

If you use a HSE Data Acquisition system and software (e.g. ISOHEART, PULMODYN, BDAS, HAEMODYN, NEURODYN etc.) with the build in A/D board your channel AV1 to AV16 directly corresponds with your software channel numbers.

8. PROBE Input

The **TTFM-2** module carries a 10 pin input socket for all transonic flow probes.
Connect only Transonic flowprobes made for TS420 or TTFM-2 modules.
Connecting other probes may destroy the input circuit !

9. Faults, causes and remedies

Fault: Digital display shows "**Ac.Er.**" Acoustic Error

Cause: Air bubble in the probe (N-probes), acustic path interrupted (R and S-probes).
Remedy: On N-probes produce a flow through the probe and hold the probe vertical, so that the flow direction is from bottom to top. This method removes the air bubbles from the probe. Produce a big air bubble which takes the small bubbles out of the probe.
On R and S-probes use some saline solution or some ultrasound gel to get a good acustic coupling

Fault: Digital display shows "0"

Cause: toggle switch **MEA/TEST/ZERO/SCALE** not in position MEA.
Remedy: toggle switch **MEA/TEST/ZERO/SCALE** into position MEA

Fault: Signal is inverted, positive flow is displayed as negative flow

Cause: flow probe mounted in wrong direction
Remedy: press polarity switch **INVERT** to invert signal

10. Maintenance and cleaning

The PLUGSYS module does not really require any maintenance. The **TTFM-2** module is supplied fully calibrated. Any operation on or modification of the electronic circuit invalidates the warranty and the manufacturer's product liability.
The front panel can be cleaned if necessary with a lightly moistened (not a wet) cloth. Before cleaning always pull out the mains supply plug!
No moisture must find its way into the unit and especially not into the switches and keys, since this leads to corrosion at the switch contacts resulting in faulty operation. In general the PLUGSYS housing should be protected against splash water and salt solutions as this may damage individual components and may cause a short-circuit!

11.Transport and storage

In order to avoid transport damage when returning the unit to the factory, the PLUGSYS housing should be packed in a suitably large carton (the carton should allow a spacing of about 10 cm all round so that sufficient packing material such as polystyrene, hard foam panel or similar can be included to protect against impact damage). When shipping individual modules these should also be well packed, preferable enclosed in antistatic foil or envelope.

If you have in any case a problem with a single module it is not necessary to send the whole PLUGSYS housing with all the modules back to HSE.

12. CE Declaration of Conformity

CE

This product and accessories conform to the requirements of the Low-voltage Directive 73/23 EEC as well as the EMC Directive 89/336 EEC and are accordingly marked with the CE mark. For conformity to the standards during operation it is essential that the details in the instructions provided are observed.

13. Technical data

Digital Display	shows average flow rate in ml/min or L/min
Analog Display factors	for monitoring analog flow, quality of the ultrasound signal and scale
	shows Flow signal in MEA mode shows signal quality in TEST mode
	shows zero and scale factors in ZERO and SCALE mode
NORMAL/LOFLOW	low flow scale selection for increased sensitivity (x4) on low flows
ZERO	performs an automatic zero adjustment
MEAS//TEST	switch to select the four modes MEASURE/TEST/ZERO/SCALE
ZERO/SCALE	allows to adjust the zero value and to read the scale factor of the connected probe
INVERT	Inverts the output flow signal in the case a flow probe was mounted in the wrong direction
FILTER	three filter positions 100/30/10/0.1 Hz for smoothing the PULSATILE OUTPUT. Filters directly act to the BNC output
BNC OUTPUT	pulsatile and mean analog flow signals can be recorded from the corresponding BNC socket on the front panel, depends on filter settings if you receive pulsatile or mean signal
INTERNAL OUTPUTS	pulsatile and mean analog flow signals are also available on the PLUGSYS system bus
Power supply	5V/1,8A, through connector from PLUGSYS bus system

MECHANICAL DATA

Dimensions	module for PLUGSYS system width 18E (90.9 mm) height 3U (128.7 mm) depth Europe size (220 mm)
Connector	DIN 41612, 96-pin VG
Weight	800 g
Accessories	operating instruction, probe adapter cable, BNC-output cable

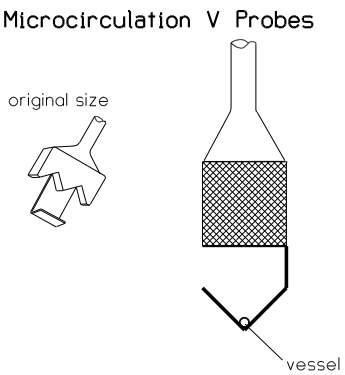
14. Appendix

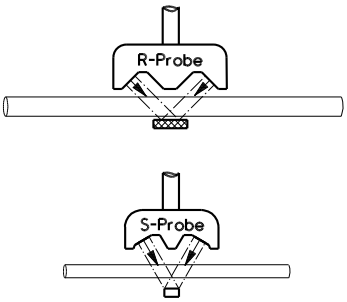
14.1 Flow Probes (sensors)

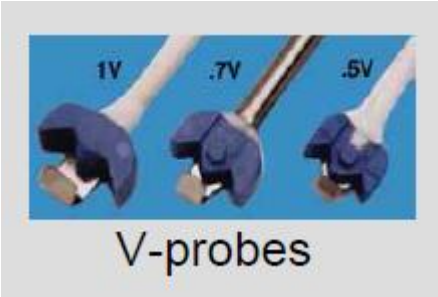
Transonic flow sensors are connected to the TTFM-2 module via a flexible cable. Two ultrasonic transducers within the flow sensor body transmit a minimum level of ultrasound through a rectangular sensing window and sense volume flow of all liquid passing through the window, irrespective of where the flow occurs within the window, and with low and stable zero flow offset and high resolution. Transonic flow sensors can measure flow in aqueous, non-aerated fluids and do not require particulate content or ionization of the monitored liquid.

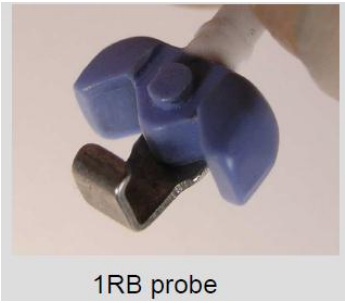
14.2 PERIVASCULAR FLOWPROBES

Transonic perivascular flowprobes (V-, R-, S- Series) for use in acute or chronic animal research studies measure instantaneous and average volume flow in arteries, veins and ducts 0.25 mm to 36 mm in diameter. When several vessels are led together through a perivascular probe, total directional volume flow passing through the sensor is measured.



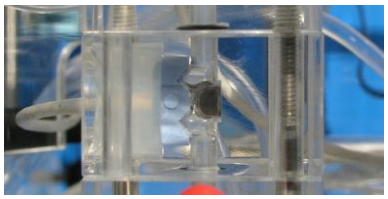





1RB probe

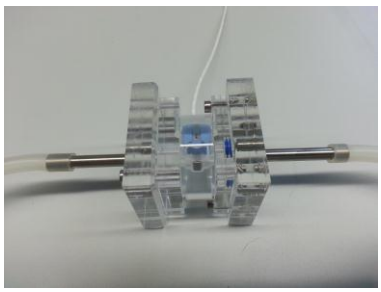
14.3 IN-LINE FLOWPROBES

Transonic N-Series flowprobes are spliced into laboratory tubing from .046 to 1.25 inch (1.2mm to 32.1mm) internal diameter (I.D.) to directly measure instantaneous and average volume flow. The probes are designed for general bench-top applications (isolated organ preparations, in-line monitoring of pumped flows, etc). HSE makes special flowprobe probe holders or modificated flow sensors eg. for measuring aortic flow on the isolated murine heart.



2.5RB probe integrated into perspex block in an isolated heart system for small rodents IH-SR

2.5RB probe integrated into perspex block in an isolated heart system for rabbits IH-5



4RB probe integrated into perspex block with tube adapters on both sides

14.4 Available Flowprobes and ordering numbers

73-4617	TTFM-2 TRANSIT TIME;FLOWMETER MODULE TYPE 714
73-4636	MA0.5PSL FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4637	MA0.5PSB FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4638	MA0.5PSS FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4639	MA0.7PSB FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4640	MA0.5VB FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4641	MA0.7VB FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4643	MA1.5PSL FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4644	MA2PSB FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4646	MA2PSSFLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4647	MA2.5PSB FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4648	MA2.5PSSFLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4649	MA2.5PSL FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4650	MA3PSB FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4651	MA3PSS FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4652	MA4PSB FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4653	MA4PSS FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4654	MA6PSB FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4655	MA6PSS FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4656	MA8PSB FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4657	MA8PSS FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4658	MA10PSB FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4659	MA10PSS FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4660	MA12PSB FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4661	MA12PSS FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4662	MA14PSB FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4663	MA14PSS FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4664	MA16PSB FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4665	MA16PSS FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4666	MA20PSB FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4667	MA20PSS FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4668	MA1PRB FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4669	MA1PRS FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4670	MA1.5PRB FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4671	MA2PMP FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4672	MA3PMP FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4673	MA4PMP FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4674	MA6PMP FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4675	MA8PMP FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4676	MA10PMP FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4677	MA12PMP FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4678	MA14PMP FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4679	MA8PAU FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4680	MA10PAU FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4681	MA12PAU FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4682	MA14PAU FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4683	MA16PAU FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE

73-4684	MA20PAU FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4685	MA24PAU FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4686	MA28PAU FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4687	MC8PAU FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4688	MC10PAU FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4689	MC12PAU FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4690	MC14PAU FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4691	MC16PAU FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4692	MC20PAU FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4693	MC24PAU FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4694	MC28PAU FLOW PROBE FOR HSE;TTFM-2 OR TS420 MODULE
73-4706	EXTENSION CABLE FOR TTFM-2;CRA10-S-CRA10
73-4707	EXTENSION CABLE FOR TTFM-2;CRA10-M2-CRA10
73-4708	EXTENSION CABLE FOR TTFM-2;CRA10-M3-CRA10

15. Theory of Operation (R-, S-, C-, N- Series Flowprobes)

A Transonic R-, S-, N-, & C- Series flowprobe consists of a probe body which houses two ultrasonic transducers and a fixed acoustic reflector. The transducers are positioned on one side of the vessel or tube under study and the reflector is positioned midway between the two transducers on the opposite side of the vessel or tube. The flowmeter´s electronic ultrasonic circuitry directs a flowprobe through the following cycles:

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 or tubing under study in the upstream direction, then bounces off the "acoustic reflector", again intersects the vessel and is received by the upstream transducer where it is converted into electrical signals. From these signals, the flowmeter then derives an accurate measure of the "transit time" it took for the wave of ultrasound to travel from one transducer to the other.

Downstream Transit-Time Measurement Cycle
The same transmit-receive sequence of the upstream cycle is repeated, but with the transmitting and receiving functions of the transducers reversed so that the liquid flow under study is bisected by an ultrasonic wave in the downstream direction. Again, the flowmeter derives and records from this transmit-receive sequence an accurate measure of transit time.

Just as the speed of a swimmer depends, in part, on water currents, the transit time of ultrasound passing through a vessel / 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 flow and total transit time is decreased by the same flow-dependent amount. The Transonic flowmeter subtracts the downstream transit time from the upstream transit time utilizing wide-beam ultrasonic illumination. This difference of integrated transit times is a measure of volume flow rather than velocity.

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 sums (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 beam rays which cross the acoustic window without intersecting the vessel do not contribute to the volume flow integral. Volume flow is therefore sensed by perivascular probes even when the vessel is smaller than the acoustic window.

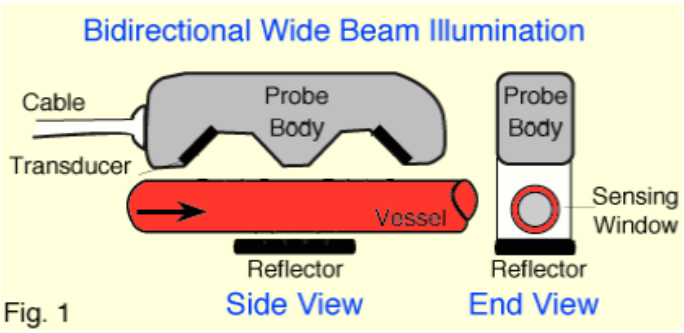


Fig. 1

Source:
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.