Innovative Sensor Technology

physical. chemical. biological.

Application Note
Silicon Flow Sensor
SFS01

Application Note
Silicon Flow Sensor
SFS01

Application Note
Silicon Flow Sensor
SFS01

1. SFS01 - Classification in the Product Portfolio

Innovative Sensor Technology IST AG develops thermal mass flow sensors and offers solutions for a wide range of flow applications. Complete modules with integrated flow channels and passive or active outputs are often offered on the market. These systems are suitable for many general applications, but they are usually not suitable for price-sensitive or space-limited applications. As a sensor element only, the flow sensors from IST AG form the basis for many customer-specific applications and enable application-specific and individually tailored integration.

The Silicon Flow Sensor (SFS) is IST AG's first flow sensor based on silicon technology. With the SFS01 flow can be determined not only quantitatively, but also qualitatively (flow direction). This is possible due to the calorimetric measuring principle with which the SFS is generally operated. The calorimetric measuring principle (see section 2.4 for details) is based on a heater and two nearby temperature sensors. The heater generates a heat cloud in the flow medium. The expansion and orientation of the thermal cloud are defined by the strength and direction of the flow and the composition of the gas. The orientation of the thermal cloud results in a temperature difference between the two temperature sensors. By measuring this temperature difference, the flow strength and flow direction are determined.

The symmetrical design of the SFS01 allows easy interpretation and evaluation of the measurement signal. The sensor can be used for different gases. Furthermore, the SFS is characterized by a large measuring range, high sensitivity and a very fast response time. A good design of the channel geometry allows the performance of the sensor to be optimally matched to the desired application. The SFS flow sensor is ideally suited for space-limited applications, but can also be easily upgraded to complete ready-to-use systems. IST AG offers a wide range of customer support services and cooperation, including system integration, pre-assembled, customer-specific partial solutions and complete solutions tailored to the customer's application.

2. Applications & Structure

2.1 Characteristics

- Measuring range up to 3.5 m/s (gases)
- Detection of flow direction
- Very fast response time <5 ms
- Very low energy consumption
- Simple system integration

2.2 Application Areas

- Automation technology
- Process and regulation technology
- Medicinal and biological technology
- Air conditioning
- Battery-operated applications in portable devices

2.3 Sensor Design

In the following, the different layers of the SFS flow sensor and their production are explained.

Substrate

The substrate of the SFS sensor and thus also the raw material for its production is a silicon wafer. First an oxide layer and then a silicon nitride layer are applied to the silicon. The silicon nitride layer later forms the sensor membrane of the SFS.

The high thermal conductivity of the silicon favours a homogeneous temperature distribution on the substrate as well as a constant reference temperature. This in turn enables measurements of very small temperature differences.

Sensitive Structure

The heater and the temperature sensors (thermopiles) are produced in a multi-stage lithographic process. First, silicon doped with phosphorus is applied. Out of this, the two heating elements and the first half of the thermopiles are structured by means of lithography. Aluminium is then applied, from which the second half of the thermopiles, the electrical conductors and the bond pads are structured.

Passivation

To protect the active surface (heater and temperature sensor) from aggressive media, a stack of silicon oxide and silicon nitride layers is applied. This layer forms the passivation of the sensor, which contributes not only to the protection but also to the stabilization of the SFS.

Etching of cavity

Etching creates a cavity in the silicon wafer below the active surface. The etching process stops at the silicon nitride layer so that it remains as a thin sensor membrane.

Finishing

In the last step, the wafers are diced and the sensors are separated with a fully automatic dicing machine.

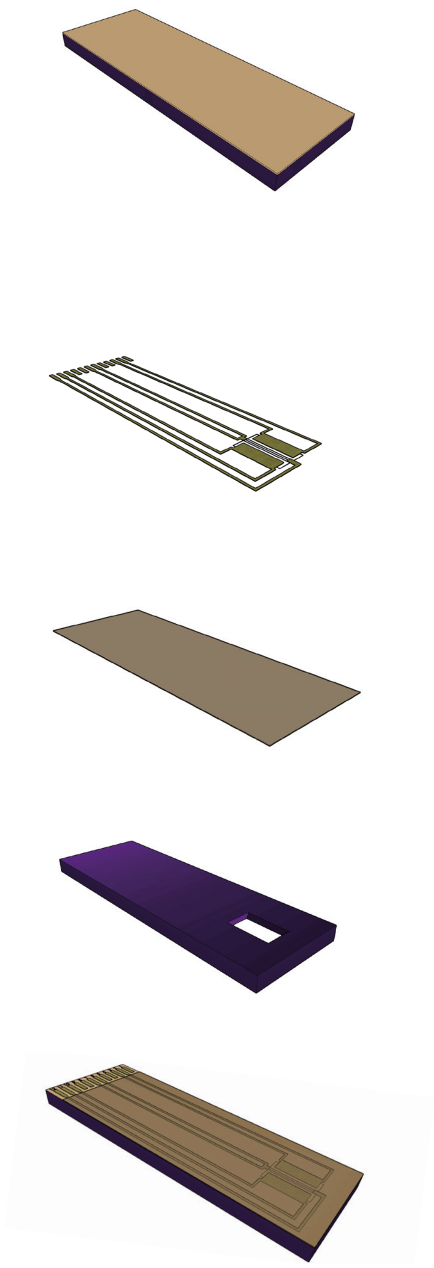


Fig. 1: Structure of the SFS01 sensor

2.4 Measuring Principle

IST AG offers thermal mass flow sensors using the calorimetric or anemometric measuring principle. The functionality of the SFS01 is based on the calorimetric measuring principle. The sensor element consists of a heater and two temperature sensors located next to the heater. The temperature difference between the two temperature sensors is flow-dependent and can therefore be used as a parameter for the flow.

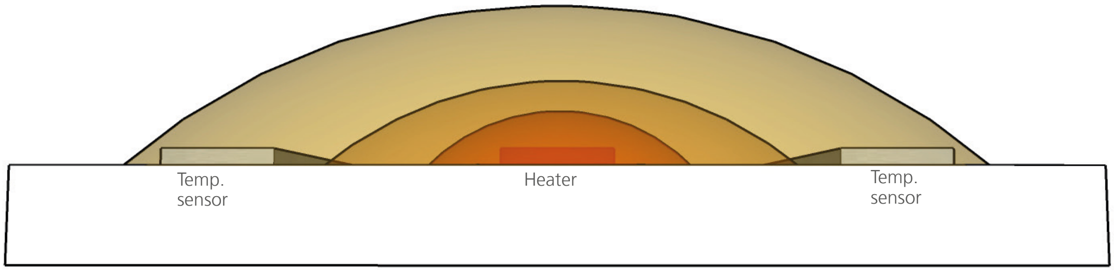


Fig. 2: Schematic representation of the thermal cloud in the calorimetric measuring principle, if no flow exists

If there is no flow, the thermal cloud is symmetrical (Fig. 2) around the heater, i.e. the temperature sensors have the same temperature. Thus the temperature difference is zero. The thermal cloud is generated by the heater with a defined thermal output (Joule Heating). The SFS is generally operated with a constant heat output, i.e. the output is a parameter.

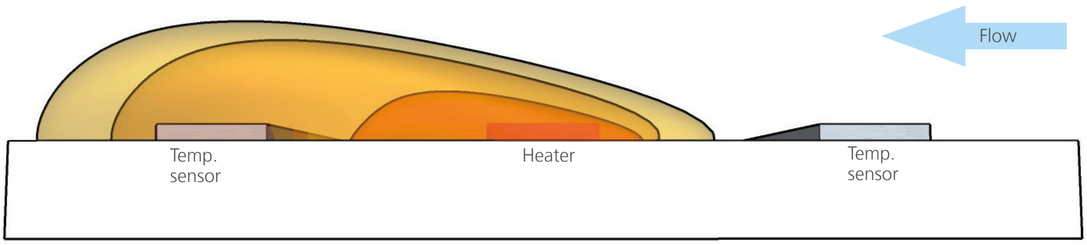


Fig. 3: Schematic representation of the thermal cloud in the calorimetric measuring principle with a finite flow

When a flow occurs, the thermal cloud shifts to one of the two temperature sensors according to the flow direction (Fig. 3), resulting in a temperature difference between the two sensors. Up to a certain point the temperature difference increases with increasing flow.

The temperature difference as a function of the flow strength is shown schematically in Fig. 4.

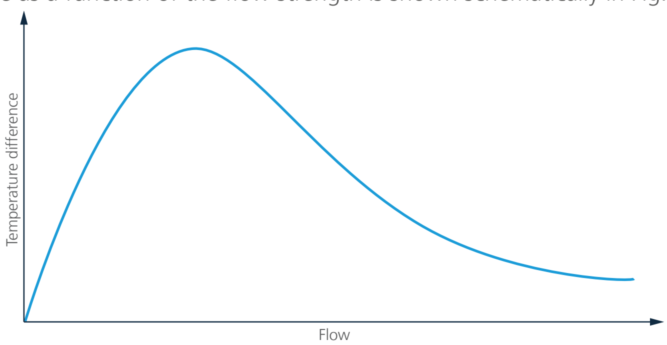


Fig. 4: Temperature difference as a function of flow

At a certain point or at a certain flow, as much heat is carried away by the flow as is generated by the heater and the temperature difference has reached its maximum. If the flow becomes even larger, the temperature difference decreases again. For a sensor operating on the calorimetric principle, the maximum flow range is defined by the maximum of the possible temperature difference, otherwise the uniqueness of the signal is lost.

The effective signal of the SFS is the two voltages of the thermopiles or the difference between the two voltages, which is proportional to the temperature difference between the two thermopiles.

2.5 Dimensions

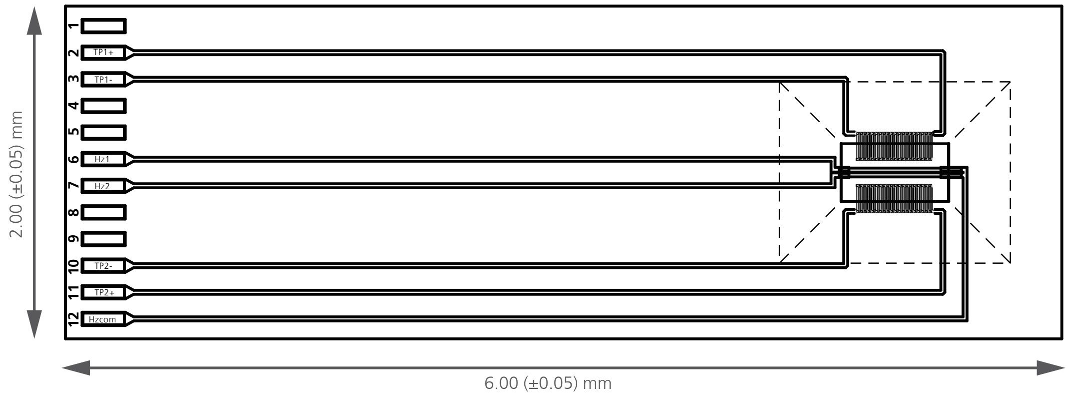


Fig. 5: Dimensions of the SFS sensor

The dimensions of the SFS01 sensor chip are 6.00±0.05 x 2.00±0.05 x 0.525±0.1 mm^3 (L x W x H) (see fig. 5). The silicon nitride membrane (indicated by a dotted line) is approx. 2µm thick.

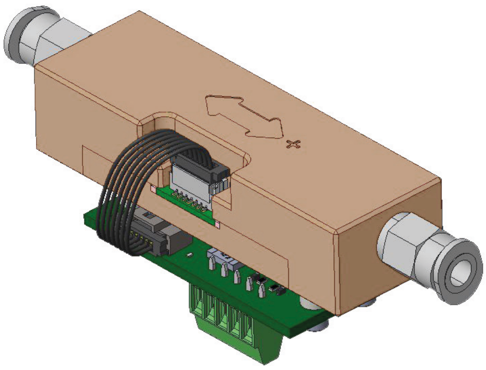
3. Assembly & Delivery

3.1 Assembly

The recommended bonding method for the SFS01 is Wedge-Wedge with aluminum wire.

The SFS01 can be mounted in a PCB cavity or directly in the flow channel. The connection between the sensor and the electronics is made using bond wires.

Customer-specific mounting of the SFS01 in an individual flow channel is also possible.



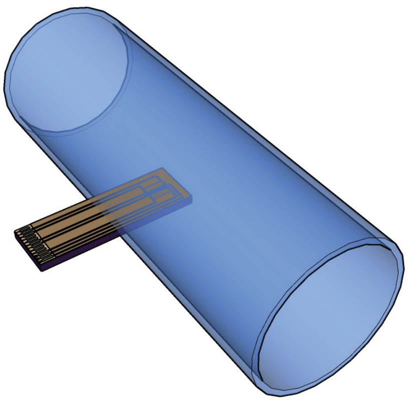


Fig. 6: Possible mountings: Bonded to a PCB and inserted into a flow channel according to customer specifications or bonded directly into a flow channel

3.2 Delivery & Contents

Small quantities can be delivered within one week, large quantities on request. The SFS01 is delivered without channel and electronics. A test module for the SFS01 can be purchased separately.

3.3 Handling

The sensors are sent in a chip tray. Fig. 7 shows how the sensors are placed in an open chip tray.

Fig. 7: SFS sensors in chip tray

The sensors may only be touched with plastic or vacuum tweezers. When removing the sensors from the chip tray, make sure that they are not touched in the area of the membrane. The membrane is very thin and can easily be damaged.

Fig. 8 shows in which areas the SFS01 chip may be touched with tweezers (green area) and which areas should not be touched (red areas).

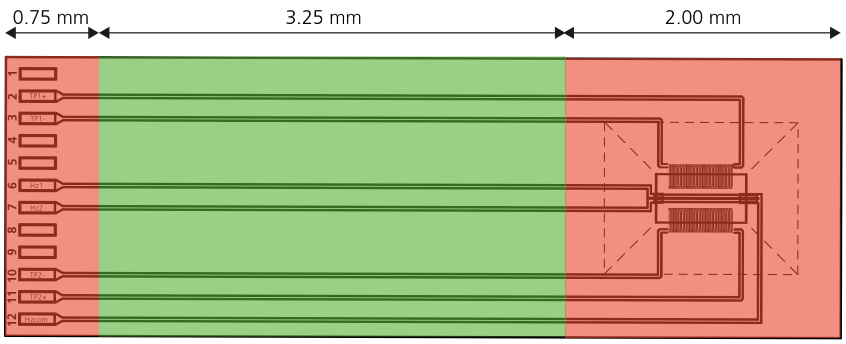


Fig. 8: „Touch zone" of the SFS01 (green) resp. „protective zones" (red) which must not be touched

4. Performance & Linearization

4.1 Performance

The following graph (fig. 9) shows the typical characteristic curve of the SFS flow sensor under laboratory conditions (nitrogen, 25 °C, channel cross-section: 1 x 1 mm²). Application-dependent deviations are possible and must be verified in each case.

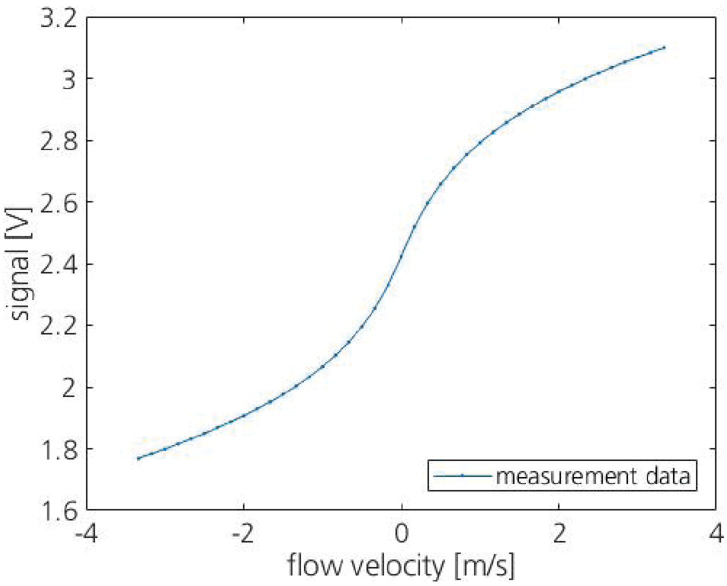


Fig. 9: Typical characteristic curve of the SFS flow sensor

This output signal was generated with an electronics that amplifies the difference of the thermopile voltage by a factor of 50. The flow medium was nitrogen. The heating power was adjusted in a way that the range of the output voltage covers the whole flow range. Here the output voltage without flow was 2.4 Volt. As a direct consequence of the symmetrical sensor construction, the signal is point symmetrical to this zero point.

4.2 Influences

The following points show examples of possible influences on the output signal. These influences are strongly dependent on the application. If you have any questions about a specific application and possible influences, please do not hesitate to contact us.

Flow medium:	Due to the different specific thermal parameters (thermal conductivity, heat capacity, density, viscosity and others), the composition of the flow medium has an influence on the formation of the thermal cloud and thus the detection by the temperature sensors.
Contamination:	Dust and impurities can influence the signal and in the worst case even damage the sensor.
Implementation:	The determination of the flow over the complete flow profile must be carried out by extrapolation of the selectively recorded output signal of the SFS. Accordingly, the geometry of the channel and the associated flow profile are - indirectly - included in the calibration. The positioning of the sensor element relative to the flow profile also has an influence. The sensor element must be placed „sufficiently well" in the flow channel so that the desired dynamic range is covered and the required measurement accuracy is achieved. The following factors can have an influence on the flow profile: - channel diameter - inlet length - position of the sensor

Temperature:	The output signal is temperature-dependent, as the thermal parameters of the medium are temperature-dependent, among other things.

We will be happy to support you in finding the best possible solution for your application.

4.3 Electrical circuit

Fig. 10 below shows a schematic and simplified circuit diagram in which the two heating resistors are connected in parallel. It is also possible to connect the two heating resistors (Hz_1, Hz_2) in series. Due to the thermo-electric effect, a voltage is generated at the two thermopiles (TP_1, TP_2), whereby the difference of the two thermopiles voltages is amplified and then measured.

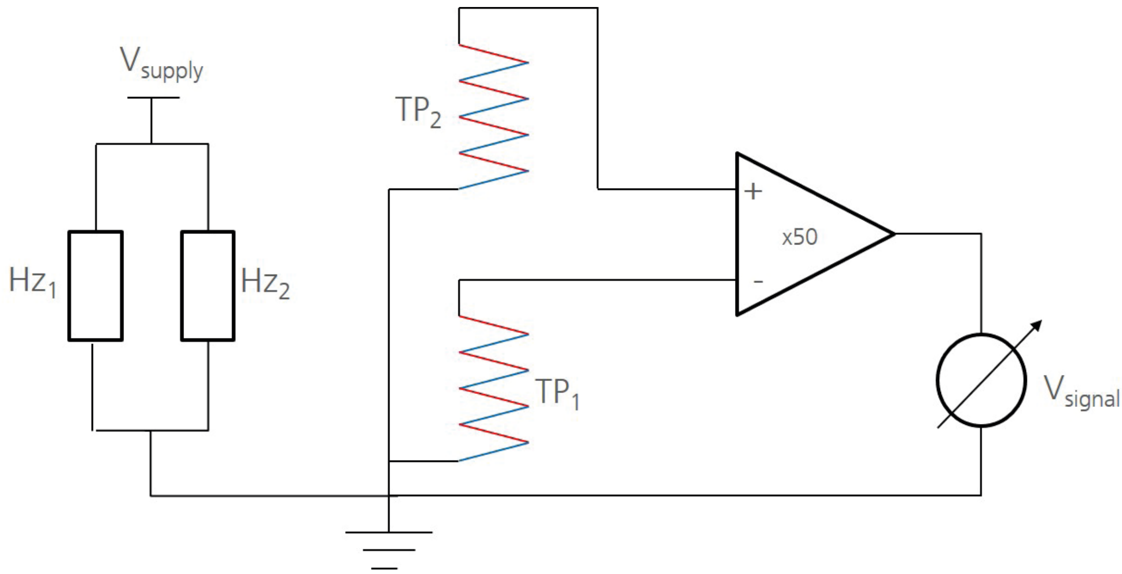


Fig. 10: Schematic and simplified circuit diagram of the SFS01

4.4 Calibration & Linearization

4.4.1 Calibration

The following function was empirically determined for the SFS. It maps the output signal against the flow velocity and represents the basis of the calibration:

$$V_{signal}(v) = a + b \cdot sgn(v)e^{c|v|^d}$$

Where v is the signed flow velocity and V signal(v) is the output signal. The function sgn() indicates the flow direction via the sign. The parameters a (offset), b (amplitude), c and d (damping factors) are the calibration parameters and must be determined for each application and geometry by a regression analysis. Depending on the application, the function can also be displayed in a different or simplified way.

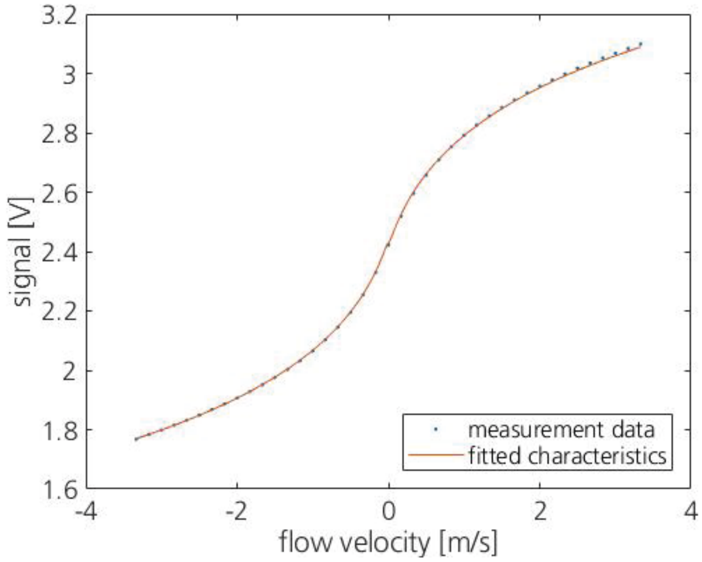


Fig. 11: Measured measuring points and fitted characteristic curve

To be able to calculate these four variables, at least four measurement points must be recorded. However, it is recommended to record significantly more measurement points. In addition, the measuring points should be selected in such a way that the entire dynamic range is covered in the later application. The best result can be achieved if the framework conditions during the calibration correspond to those of the end application. A check of the symmetry around the zero point (v=0) allows conclusions to be drawn about possible optimization potential with regard to the positioning of the sensor element.

The calculated parameters for the measurement shown above (fig. 11) are:

a = 2.43

b = 3.36

c = 2.23

d = -0.26

In general, the calibration parameters of the SFS under laboratory conditions (nitrogen, +25 °C, channel cross-section: 1 x 1 mm²) are in the range of the exemplary values mentioned above. Depending on the application and sensor installation, however, these values differ.

4.4.2 Linearization

Once the parameters a, b, c, d have been determined, the calibration is complete. The inverse function of $V_{signal(v)}$ provides the signed flow velocity for a measured output signal.

$$v(V_{signal}) = sgn(V_{signal} - a)\left(\frac{-\log\left(\frac{|V_{signal}-a|}{b}\right)}{c}\right)^{1/d}$$

The linearized signal is shown in fig. 12.

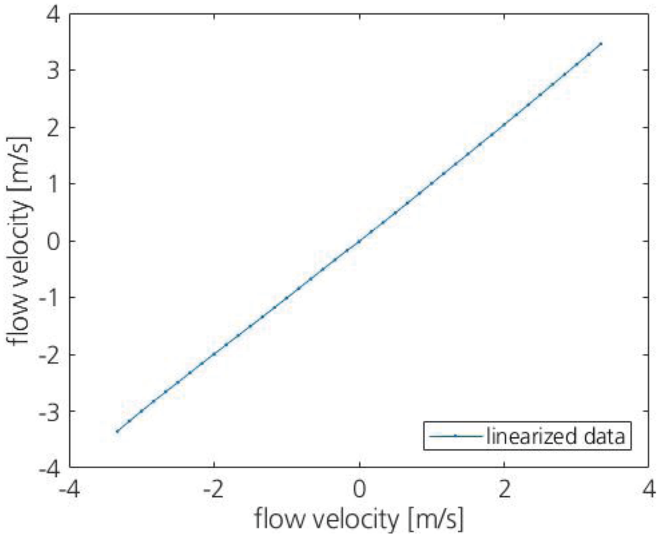


Fig. 12: Linearized signal of the SFS01

5. Order information

Sensor element:	SFS01
Order code	105050
Former order code:	*350.00312*

6. Additional Electronics

EvaKit:	SFS01 EvaKit
Order code	105059
Former order code:	*350.00330*

7. Additional Documents

Data Sheets:	DFSFS01_E
	DFSFS01_EvaKit_E

Innovative Sensor Technology IST AG, Stegrütistrasse 14, 9642 Ebnat-Kappel, Switzerland
Phone: +41 71 992 01 00 | Fax: +41 71 992 01 99 | Email: info@ist-ag.com | www.ist-ag.com