

# FSI interrogator system

## High-speed optical system to measure temperature, strain and shape

Type 2549A...  
with cockpit software

This unique monitoring system is based on Fiber Segment Interferometry (FSI) and supports multiple fiber sensors for high-precision measurement of temperature, strain and shape (one fiber per dimension). Each FSI interrogator can address up to 88 sensor segments, distributed along the length of the sensors.

Features of the FSI interrogator system

- **Compact** – typical sensor diameters range from 150  $\mu\text{m}$  (strain) to 1.6 mm in diameter (temperature). Due to the small dimensions and mass, sensors can be applied to or inside a structure with little intrusion.
- **Robust** – the sensor fibers are passive without any electronic components and are non-conductive.
- **Scalable** – Number and geometry of the sensing segments, number of sensor fibers and interrogators operated in a network can be tailored to perfectly match the different requirements.
- **Immunity** – FSI sensing elements are intrinsically safe and are immune to interference from electrostatic, electromagnetic or radio frequency sources.
- **Multiplexing** – Many measurement segments can be inscribed into a single sensor fiber to minimize cable mass and volume.
- **Remote sensing** – the distance between interrogator and sensing elements can be several kilometers/miles without the risk of signal to noise degradation.
- **Ease of installation** – One connector and a single, flexible fiber for multiple test points reduces cost of installation and potential sources of errors. It also means less down time for test stands and prototypes.



Fig.1: 2549A FSI interrogator base unit



Fig.2: 2069A10 FSI temperature sensor

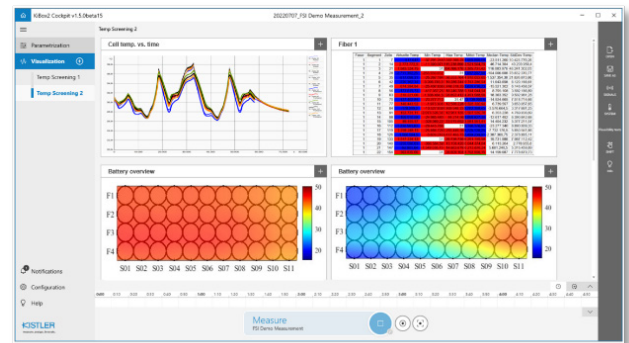


Fig.3: Software 2549A10 FSI temperature monitoring application

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## Technical data

Mechanical			
Dimensions	length	mm	295
	width	mm	275
	height	mm	92
Mass	Interrogator base unit	kg	3.5
	incl. accessories, case	kg	8

Ambient conditions			
Operating temperature	°C	0 ... +40	
	°F	+32 ... +104	
Storage temperature	°C	-20 ... +70	
	°F	-4 ... +158	
Humidity (non-condensing)	%	10 ... 95	
Power consumption	typ.	W	50
	max.	W	120
Mains supply voltage (using adapter)	VAC	110 ... 240	
Direct current input voltage	VDC	9 ... 30	
Pollution degree		2	
Overvoltage category		II	
Accreditation/conformity		CE	

Measuring and Processing			
Number of sensor inputs		4	
Compatible sensors		2069A...	
Optical sensor connector		FC/APC 2.5mm	
Max. number of measurement segments per FSI Interrogator		22	
Temperature sensor measurement range range	min.	°C	-35
		°F	-31
	max.	°C	+110
		°F	+230
Temperature accuracy	°C	<1.5	
Temperature resolution	°C	0.1	
Minimum segment length	mm	10	
Sensor diameter (strain)	mm	<0.25	
Resolution (strain) for 100 mm segment	nε	<20	
Sensor diameter (temperature) typ.	mm	1.6	
Max. distance between interrogator and 1st measurement segment	km	>1	
Sampling frequency range (limited to 25 kHz for large numbers of segments)	kHz	50	

\*Calibrated temperature range depends on customer requirement. Stated resolution is intended as 2 times the signal standard deviation. Stated accuracy is "as calibrated", assuming installation minimizes mechanical strain on sensor.

This information corresponds to the current state of knowledge. Kistler reserves the right to make technical changes. Liability for consequential damage resulting from the use of Kistler products is excluded.

Interfaces			
CAN	Channels	1	
	Standard	CAN 2.0b	
	Max. Bitrate	MBit/s	1
Ethernet/LAN	Port	1	
	Standard	TCP/IP	
	Max. Bitrate	Gbit/s	1
Data/Time synchronization		NTP, PTP, IEEE1588	

File Formats	
Data file	.mdf4
Parameter file	.k2p
CAN database file	.dbc
Export file	.csv

## Connections / Indicators on the front panel



## Connections / Indicators on the back panel



Description	
1	Status LED – Power
2	Status LED – Ready
3	Status LED – Measuring
4	Status LED – Warning/Fault
5	Optical sensor connectors – FC/APC 2.5 mm
6	CAN – DSub, 9Pin, male
7	Power supply – LEMO B
8	Interface to cockpit, Ethernet – RJ45

## Components and type numbers for the FSI interrogator system Type 2549A

### Included accessories Type/Mat. No.

- FSI Interrogator base unit 2549A1
- Gigabit Ethernet cable, 1 m
- Power supply 100...240 VAC
- Country-specific power cable
- One-Click connector cleaner
- CLETOP-S connector cleaner
- Document folder incl. QuickStart guide, Safety instructions, Calibration certificates
- USB memory stick incl. Operating instructions and Cockpit SW
- Carrying case with foam inlay

### Sensing elements

- |                                    |              |
|------------------------------------|--------------|
| FSI temperature sensor, customized | 2069A10-Q... |
| FSI shape sensor, customized       | 2069A20-Q... |
| FSI strain sensor, customized      | 2069A30-Q... |

### Cockpit applications

- |  |                     |
|--|---------------------|
| FSI temperature monitoring application | Software<br>2549A10 |
| FSI shape monitoring application       |                     |
| FSI strain monitoring application      |                     |

### Optional accessories Type/Art. No.

- |                            |            |
|----------------------------|------------|
| Cascading set / PTP switch | 1200A247A1 |
| jBEAM Powertrain edition   | 2848A      |

### Services & training

(please contact Kistler for requests)

#### Services

- FSI interrogator calibration
- Planning, preparation and realization of on-site measurements by Kistler expert

#### Training

- FSI interrogator system user training

2549A\_003-654e-10.23

# FSI temperature monitoring system

## High-speed optical system to analyze the thermal behavior of powertrain components

Type 2549A...  
with cockpit software

This unique temperature monitoring system is based on Fiber Segment Interferometry (FSI) and supports multiple fiber sensors for precision measurement of temperatures on electric vehicle powertrain components such as battery packs, inverters or converters. Each 4-channel interrogator can address up to 88 individual measuring segments, precisely centered on the test regions of interest. The high number of temperature segments brings examination of thermal processes to the next level and visualization of the data in time-resolved heat maps allows an imaging-like view of the gathered data.

Features of the FSI temperature monitoring system

- **Compact** – the sensor is between 0.6 ... 1.6 mm in diameter depending on requirements. Due to the small dimensions and mass, sensors can be applied to or inside a structure with little intrusion.
- **Robust** – the sensor fibers are passive without any electronic components and are non-conductive. The sealed structure is perfectly suited for operation in harsh environments or applications including high-voltages, extended temperatures, and immersion cooling.
- **Scalable** – Number and geometry of the sensing segments, number of sensor fibers and interrogators operated in a network can be tailored to perfectly match the different requirements.
- **Immunity** – FSI sensing elements are intrinsically safe and are immune to interference from electrostatic, electromagnetic or radio frequency sources.
- **Multiplexing** – Many measurement segments can be inscribed into a single sensor fiber to minimize cable mass and volume.
- **Remote sensing** – the distance between interrogator and sensing elements can be several kilometers/miles without the risk of signal to noise degradation.
- **Ease of installation** – One connector and a single, flexible fiber for multiple test points reduces cost of installation and potential sources of errors. It also means less down time for test stands and prototypes.



Fig.1: 2549A FSI interrogator base unit

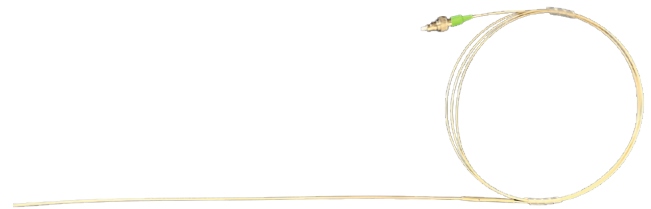


Fig.2: 2069A10 FSI temperature sensor, straight, up to 22 measuring points

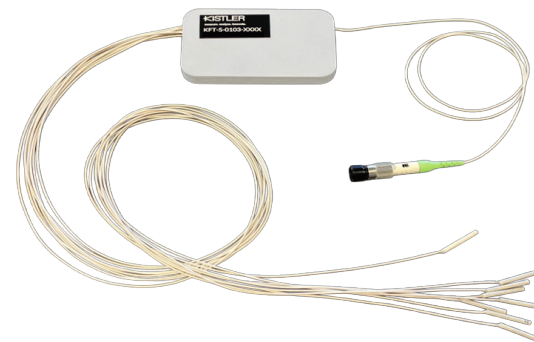


Fig.3: 2069A11 FSI temperature sensor, flexible, up to 12 measuring points

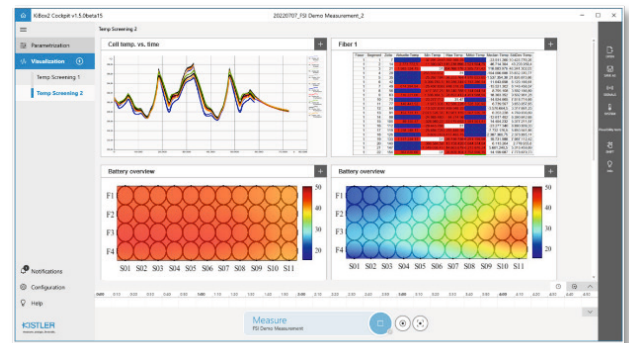


Fig.4: Cockpit software 2549A10 FSI temperature application

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**Description**

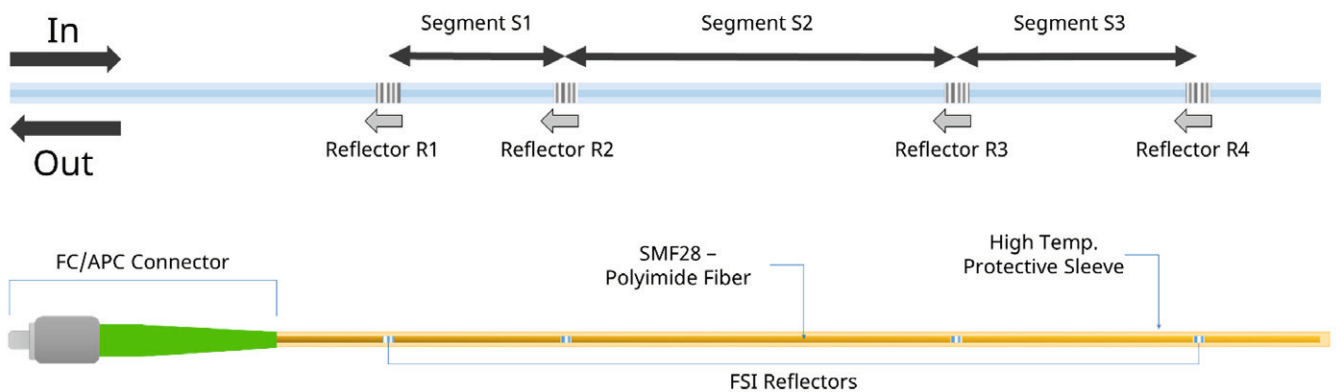


Fig.5: Schematic view FSI measurement principle and corresponding temperature sensor

**Measuring principle**

FSI sensing elements are inscribed in the core of the optical fiber. Laser light from the FSI interrogator resonates between these reflectors and the resulting interference patterns in the returning light are measured and analyzed. From these interferograms, the length of each segment can be measured rapidly, and with nanometric precision. These length changes are calibrated against the measurement of interest like temperature.

FSI temperature sensors consist of a micro-structured optical fiber enclosed within a protective outer sleeve or tube. This sleeve is bonded to the device under test, ensuring the fiber sensor is free to expand independently of mechanical strain effects.

**Application**

- Reduced wiring (replace up to 88 thermocouples with FSI temperature sensors)
- Immune to electromagnetic interference
- More cell temperatures lead to improved simulation models
- Reduced battery costs due to reduction of thermo elements
- Better thermal management:
  - Battery usage closer to thermal limits
  - Longer battery lifetime
  - Better fast charging – avoid lithium plating
- Thermal runaway testing
  - Testing beyond functional condition >500°C
  - Capture fast events <200 ms

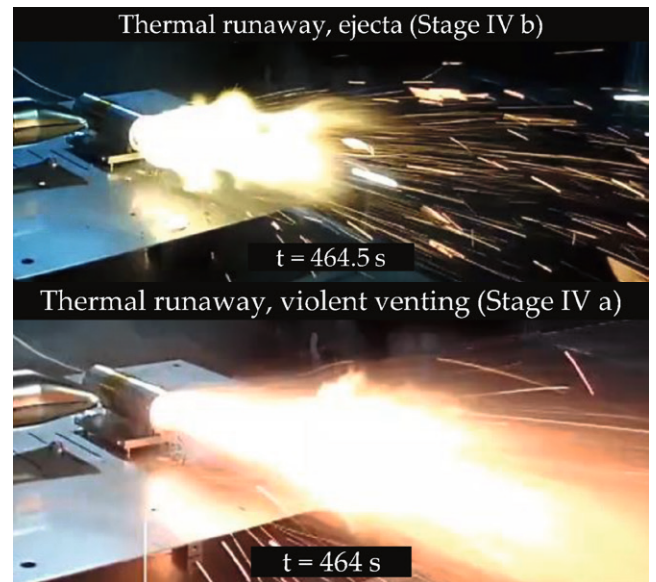


Fig.6: Thermal runaway, experiments with safety valve

2549A\_003-635e-11.25

**Technical data**

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	width	mm	275
	height	mm	92
Mass	Interrogator base unit	kg	3.5
	incl. accessories, case	kg	8

Ambient conditions			
Operating temperature	°C	0 ... +40	
	°F	+32 ... +104	
Storage temperature	°C	-20 ... +70	
	°F	-4 ... +158	
Humidity (non-condensing)	%	10 ... 95	
Power consumption	typ.	W	50
	max.	W	120
Mains supply voltage (using adapter)	VAC	110 ... 240	
Direct current input voltage	VDC	9 ... 30	
Pollution degree (EN 60664)	2		
Overvoltage category	CAT II		
Accreditation/conformity	CE		

Measuring and Processing			
Number of sensor inputs	4		
Optical sensor connector	FC/APC 2.5mm		
Sampling frequency range	Hz	1.5 ... 25k	
Distance interrogator to sensor	km	<1	

Interfaces			
CAN	Channels	1	
	Standard	CAN 2.0b	
	Max. Bitrate	MBit/s	1
Ethernet/LAN	Port	1	
	Standard	TCP/IP	
	Max. Bitrate	GBit/s	1
Data/Time synchronization	NTP, PTP, IEEE1588		

File Formats	
Data file	.mdf4
Parameter file	.k2p
CAN database file	.dbc
Export file	.csv

FSI temperature sensor, straight		2069A10-Q...	
Max. number of measurement segments sensor / interrogator	22/88		
Standard sensor operating range	°C	-40 ... +120	
	°F	-40 ... +248	
High temperature sensor operating range	°C	-40 ... +500	
	°F	-40 ... +932	
Accuracy	°C	<0.5	
Resolution	°C	<0.05	
Response time (sleeve dependent) T60 / T90	s	<0.8 / <1.2	
Measurement segment length	mm	10 ... 100	
Sensor diameter	mm	0.6 ... 1.6	
Absolute temperature	no		
Submergible	yes		
Flexible / bending radius	mm	no / -	

FSI temperature sensor, flexible		2069A11-Q...	
Max. number of measurement segments sensor / interrogator	4 or 8 / 16 or 32		
Sensor operating range	°C	-40 ... +140	
	°F	-40 ... +248	
Accuracy	°C	<0.25	
Resolution	°C	<0.05	
Response time (sleeve dependent) T60 / T90	s	<0.2 / <0.25	
Sensor / measurement segment length	mm	22 / 3	
Sensor diameter	mm	2.2	
Cable diameter	mm	<1	
Absolute temperature	no		
Submergible	no		
Flexible bending radius	mm	yes / 10	

In case of applications specific sensor requirements contact your local Kistler sales representative.

2549A\_003-635e-11.25

**Connections / Indicators on the front panel**



**Connections / Indicators on the back panel**



Description	
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- Gigabit Ethernet cable, 1 m
- Power supply 100...240 VAC
- Country-specific power cable
- One-Click connector cleaner
- CLETOP-S connector cleaner
- Document folder incl. QuickStart guide, Safety instructions, Calibration certificates
- USB memory stick incl. Operating instructions and Cockpit SW
- Carrying case with foam inlay

**Sensors**

**Type/Art. No.**

- FSI temperature sensor, customized 2069A10-Q....
- FSI temperature sensor, 4 elements, 2 m 2069A11-Q002

**Software applications**

- FSI temperature monitoring application 2549A10

**Optional accessories**

- Cascading set / PTP switch 1200A247A1
- jBEAM Powertrain Professional 2848A  
(Advanced post-processing SW)

**Services**

- FSI interrogator calibration
- Planning, preparation and realization of on-site measurements by Kistler expert

**Training**

- FSI temperature monitoring system user training

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