



# KISTLER

measure. analyze. innovate.

## Indicating Power To Go!

**KiBox® To Go  
for In-Vehicle  
Combustion Analysis**



reddot design award  
winner 2009

# Advances in Combustion Analysis Systems ...

Economic and environmental concerns are of vital importance during vehicle research and development. The exact requirements are the result of new emission laws, rising energy prices and the subsequent demand for environmentally friendly and economical drive systems. Against this backdrop, automotive manufacturers attach greater importance to cylinder pressure analysis, particularly as it is no longer possible to develop advanced engine technologies without measuring and evaluating the complex and highly dynamic sequence of events in the combustion chamber.

derives and calculates more results from one raw signal than any other measurement technology in this area of application. The quality of the measurement results is determined by an intelligent system of sensors and amplifiers, by the versatility and compatibility of the data acquisition system and the downstream analysis software. Most importantly, the ideal combustion analysis system will supply data of a consistently high quality and should be easy to operate.

## Method

Piezoelectric sensors record the pressure in the combustion chamber as a direct measurand. The combustion analysis system relates the crankshaft position

– and thus the combustion chamber volume associated with the individual pressure value – to this pressure. Combustion chamber pressure indication





# ... Compact, Compatible, Mobile

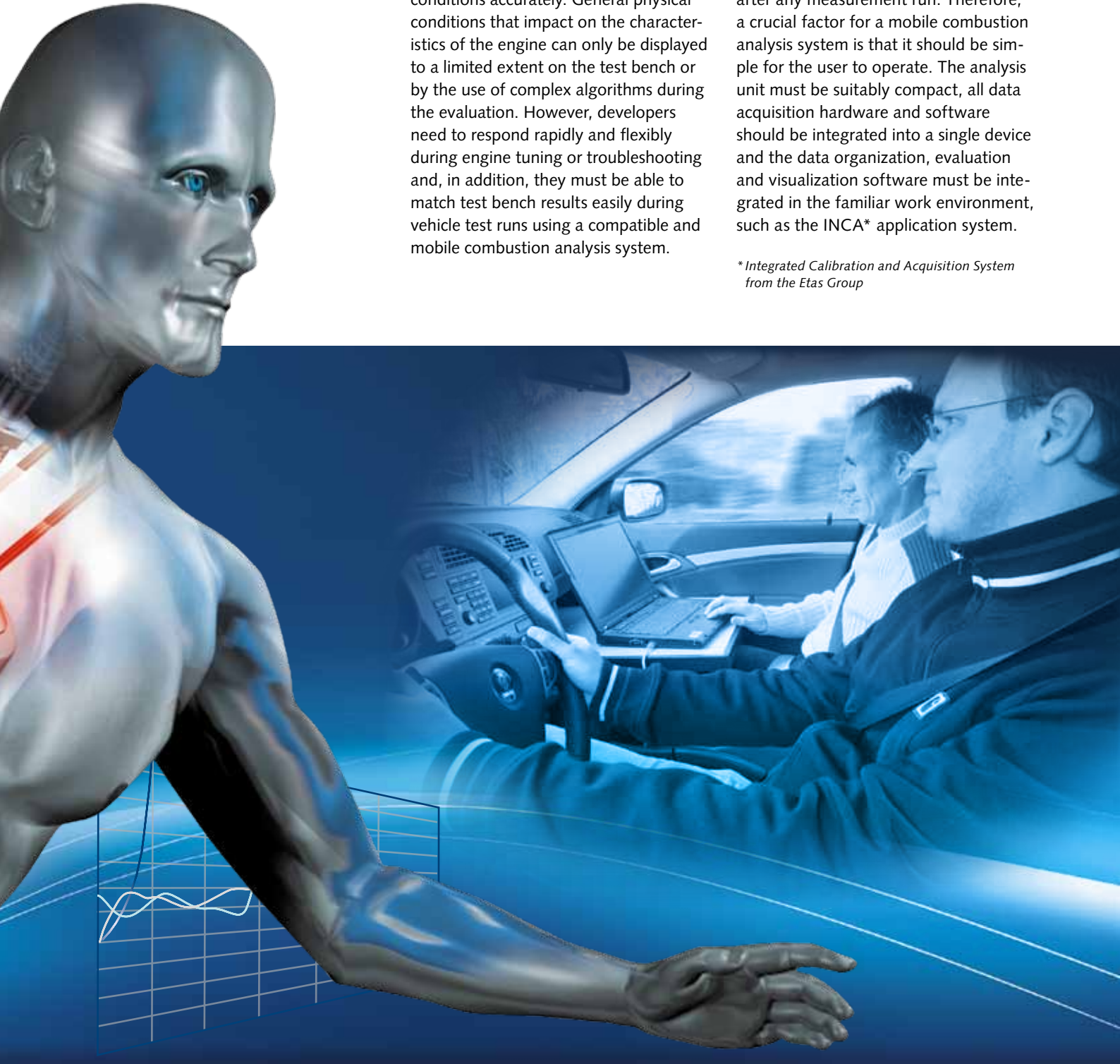
## Requirement

To help optimize the sequences of events inside engines, it is becoming ever more important to depict real driving conditions accurately. General physical conditions that impact on the characteristics of the engine can only be displayed to a limited extent on the test bench or by the use of complex algorithms during the evaluation. However, developers need to respond rapidly and flexibly during engine tuning or troubleshooting and, in addition, they must be able to match test bench results easily during vehicle test runs using a compatible and mobile combustion analysis system.

## Best Case Scenario

The application engineer wants a comprehensive and powerful tool he can use in the vehicle before, during and after any measurement run. Therefore, a crucial factor for a mobile combustion analysis system is that it should be simple for the user to operate. The analysis unit must be suitably compact, all data acquisition hardware and software should be integrated into a single device and the data organization, evaluation and visualization software must be integrated in the familiar work environment, such as the INCA\* application system.

*\* Integrated Calibration and Acquisition System  
from the Etas Group*



# From Pioneer ...

## Measuring

Kistler PiezoStar® crystals provide the foundation for an optimized sensor design providing precision measurements from a miniature device. Combined with engine-specific adapters and the appropriate accessories these sensors produce readings that deliver the very best possible results. To analyze gas exchange, Kistler offers absolute pressure sensors based on the piezoresistive measuring principle.



## Amplifying

High-performance measurement amplifiers convert the raw pressure signal into a precision-scaled voltage which forms the interface between sensor signal and measuring system in the tried-and-tested Signal Conditioning Platform (SCP).



## Conditioning

The "PiezoSmart®" automatic sensor identification system is based on the TEDS (Transducer Electronic Data Sheet) protocol. This system automatically configures all cylinder and low pressure amplifiers and records the operating time, ensuring a high level of flexibility, data quality and process reliability.

## ... to Technology Leader

The development, production and practical application of piezoelectric sensors and amplifiers has been Kistler's core business since the 1950s. Even then our technology was being used in the research and development of internal combustion engines, both industrial and automotive. The ability to precisely measure and record

extremely dynamic pressure conditions in cylinders led to high levels of efficiency and lower emission values common in modern engines. For over ten years we have been growing piezoelectric crystals in-house, specifically for use in combustion pressure sensors. However, the precision of the results is determined

not only by the sensor properties alone but also by an application-specific measuring chain that includes connecting cables, amplifiers and an evaluation system. Our range of combustion analysis products is the result of decades of intensive collaboration with our customers.



### Analysis

Working in close collaboration with users, Kistler has taken a significant step in providing a development tool that will improve the quality of data and help to reduce the overall development time for new vehicles. Kistler realised that the only way to give combustion development and automotive calibration engineers the

information they need to perform their everyday tasks is to analyze the measured signals and the resultant parameters. By developing the KiBox, Kistler has now added to its product range a combustion analysis system designed specifically for in-vehicle use. Standardized interfaces, powerful PC technology and the option

to use the proven SCP amplifier modules ensure that the customer's investment is both well protected and well utilized. The same factors also mean that the user has a tool that is easy to use and can deliver extremely precise results after a very short set-up period.

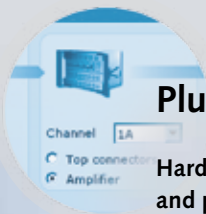


# Open ...

"measure. analyze. innovate" – first and foremost, the Kistler philosophy stands for user-friendly solutions. Therefore, our intelligent measuring chains must be open and flexible when interacting with external systems. All interfaces and protocols in the mobile KiBox® are

transparent so that measuring data can be post-processed as efficiently as possible. After all, the key issues for users are "what values are measured and how?" and perhaps most importantly, "what happens to the data within the system?".

In any downstream application, this openness and transparency is essential for the accurate and reliable post-processing of data and bringing algorithms in line with other measuring results.



## Plug & Go

**Hardware and software optimized for convenience and portability**

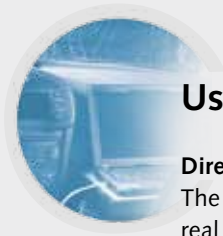
Key features of the KiBox are its compact size, modular vehicle accessories and the fact that all sensor connections are located on the front panel. The measuring parameters can be configured using a graphical user interface featuring a simple and intuitive layout.



## Integrated and Simple to use

**Optimum functionality with PiezoSmart® and INCA integration**

The sensor signals are configured automatically by means of the electronic data sheet (TEDS) and the running time is acquired and saved for sensor management purposes. Designed with application engineers in mind, the data can be processed and displayed in the familiar INCA environment. The "KiBox Cockpit" graphical interface also provides a fully independent data display.



## User-Friendly and Quick

**Direct interface to the application system PC**

The system offers high-performance, integrated computing with key parameters in real time. Setup is performed directly on the application system's laptop, which is also used for any custom visualization required. Practical modular accessories, such as the un-interruptible power supply and the brackets for securing the KiBox in the vehicle, are available and can be added to the system.



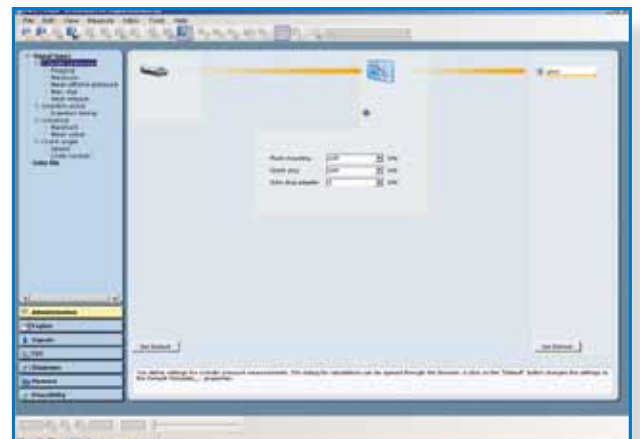
## Synchronized Measuring Chain

A functional in-vehicle combustion analysis system should not influence the running of the engine while providing highly accurate measurement results. With these objectives in mind, all components of the measuring chain – mounting studs, sensors, cables, amplifiers and data acquisition units – must be optimized both individually and as a complete system. With the KiBox Kistler can now provide the right products for every link in this chain.

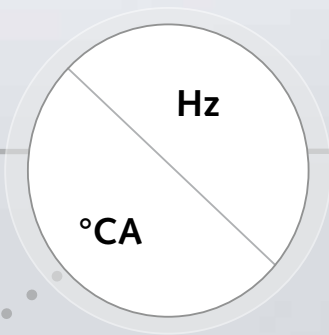
One example is the PiezoSmart® automatic sensor identification function. It makes handling easier, enables measuring chain parameters to be set automatically and ensures that measuring points are assigned correctly. This is achieved by means of a three-way exchange of data between sensors, amplifiers and the KiBox. Calibration data is read using the TEDS protocol and to enable the calibration cycles to be monitored more effectively, the operating time of each sensor is determined and stored on its individual TEDS chip.

## The "KiBox® Cockpit"

The "KiBox Cockpit" is implemented as an easy to use Windows application and as a result, menu guidance is transparent and user-friendly. Its operation reflects the logical approach a user would adopt and follows the process chain from the sensor via signal conditioning to the evaluation. Routine operations are made easier by intuitive icons and a context-sensitive help system.



Expert level pre-settings protected by administrator password



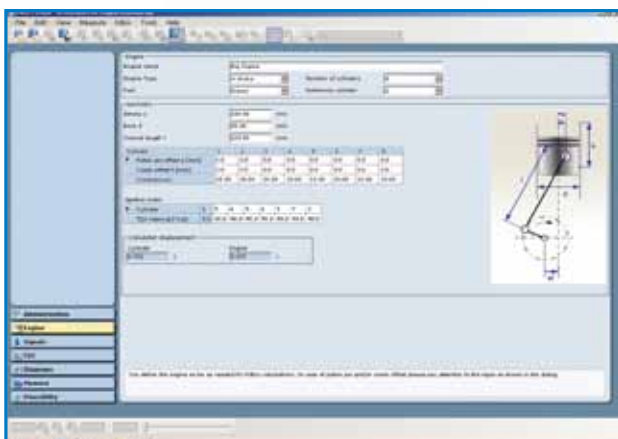
## CrankSmart® – Reliable Data Quality

In order to optimize the quality of measured data in an in-vehicle combustion analysis system in transient engine operation and where severe torsional vibrations are present, Kistler experts have been working alongside FKFS\*\* to develop the innovative and time-saving CrankSmart process.

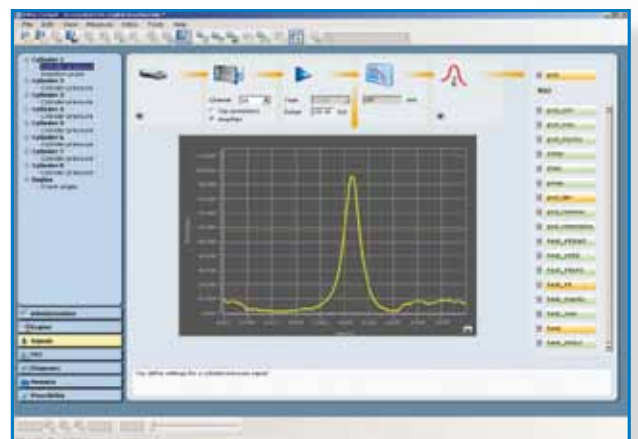
KiBox does not depend on a particular crank angle sensor, rather it generates the reference to the crank angle and TDC by using the standard engine speed sensor rotor and performs high-resolution interpolation to 0.1 degree. The specific characteristics of the sensor rotor are taken into account and compensated for during data conditioning. All signals (cylinder pressure, low pressure, ignition, injection pressure, and crank angle marks) are thus measured simultaneously on time base and immediately linked logically with the associated crankshaft position.

KiBox reduces the amount of expensive equipment required for each test vehicle and the results from an in-vehicle combustion analysis system are comparable with those taken from a test bench measurement, despite the different way the crank angle is recorded.

*\*\* Research Institute of Automotive Engineering and Vehicle Engines Stuttgart*



Engine definitions required for combustion analysis.  
Graphics and help functions make user inputs easy



Cylinder pressure shown with oscilloscope function. When using a PiezoSmart® (TEDS) sensor combustion results are only one click away

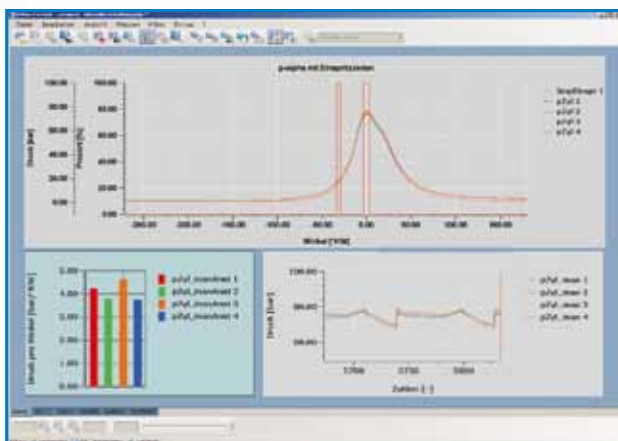


## Characteristics Straight out of the KiBox®

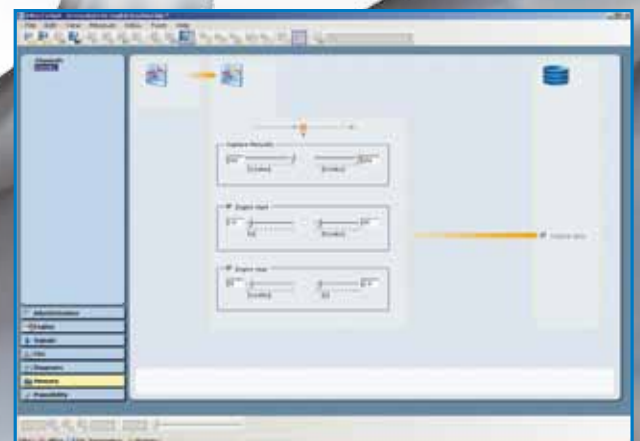
- Peak pressure (mechanical load) and its angular position
- Maximum pressure rise and its angular position
- Indicated/net mean effective pressure (work, misfires, gas exchange losses)
- Statistics, e.g. running smoothness from indicated mean pressures
- Angular position of the energy transfer (efficiency, ignition delay, duration of combustion)
- Point of ignition
- Knocking
- Injection timing
- Mean rotational speed for each working cycle

## Choosing the Primary KiBox® Functions

- Filtering of signal noise
- Conditioning of sensor signals, e.g. 60-2
- Precise TDC assignment of measurement signals
- Data acquisition when engine starts and stops
- Heat release rate according to selectable algorithms
- Frequency analysis (combustion noise)
- Interface for customer-specific functions
- Transfer of results via CAN and software interfaces, e.g. to INCA
- Automated data storage
- Data export in a variety of formats



Continuous data visualization on the ride. Example: Cylinder pressure trace and injection timing, bar chart for maximum pressure rise, peak cylinder pressure developing over time



Settings for automatic saving of data prior and after engine stop and engine start

Notebook

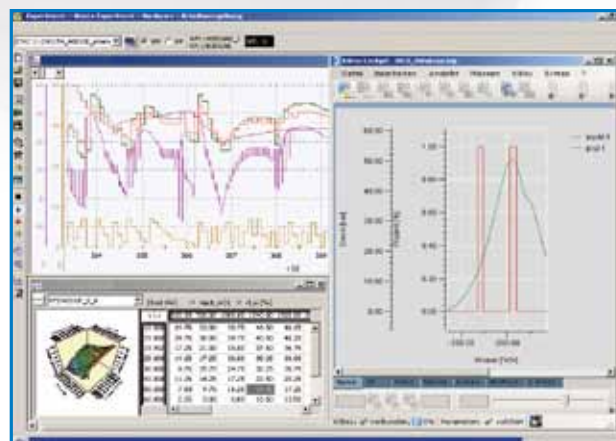
INCA ...



## Interfaces – Greater Flexibility and Compatibility

The KiBox concept includes total compatibility with common application environments. The user can, for instance, operate the KiBox through the widely-available INCA user interface. Important controls such as "Load parameters", "Select results", "Start measurement" and "Save data" are controlled by the application engineer from within the familiar INCA environment.

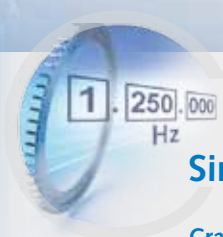
Application engineers can also find characteristic combustion analysis values in the same user interface, and these are displayed perfectly synchronized with other values. Appropriate tests have confirmed that the calculated results are correct and comparable with classic test cell combustion analysis systems. This interface compatibility, which extends to other systems as well as INCA, means KiBox is a highly productive in-vehicle solution for day-to-day work.



Synchronous plot of INCA data incorporating combustion results and / or separate visualization in a KiBox® window

... and Transparent

KiBOX



### Simple and Innovative

#### **CrankSmart® for enhanced measurement quality**

CrankSmart is a brand new method for measuring indication signals precisely without an optical crank angle encoder. The existing engine speed sensor is used for the crank angle and the TDC reference. Time-based measurement means that aliasing effects can at last be prevented and pipe oscillations eliminated.



### Dynamic and Precise

#### **Reliable combustion analysis in all operating conditions**

With no additional effort required for any engine operating condition – starting, accelerating, stopping – measurements are acquired dynamically and delivered with precision, even before the crankshaft begins to rotate.



### Modular System, Secure Investment

#### **Standard PC processors and plug-in amplifiers**

To protect your investment, the KiBox is based on standard PC processors combined with specific data acquisition hardware, ensuring that the system remains cost-effective. The amplifier modules come from the established Kistler SCP series, making the KiBox the perfect tool for combustion analysis in test vehicles.



# Efficiency ...

With the KiBox, Kistler has transferred its own technological expertise into an integrated portable combustion analysis solution. This new development has focused on finding innovative answers to key questions with the aim of

improving the entire measuring chain. Sensors and engine preparation, data acquisition and evaluation – all these essential processes are significantly improved thanks to our intensive and detailed development work.

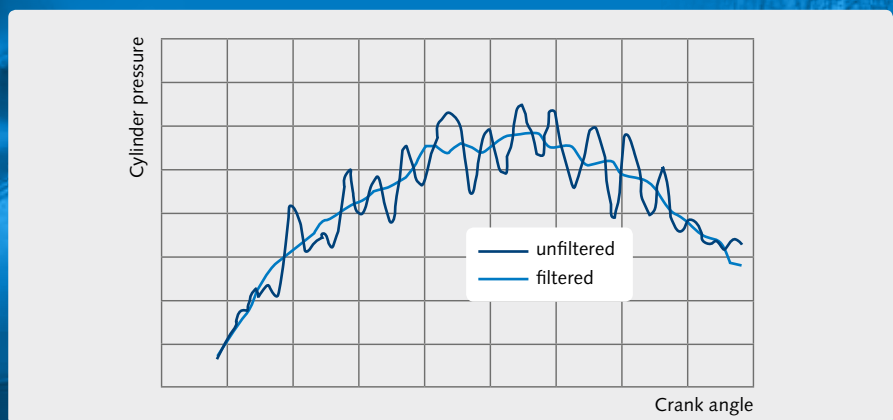


Figure 1: Pipe oscillations

## Determining TDC While Driving

Significant combustion parameters include the indicated mean effective pressure, a measure of the work performed, and the angular position at the center of combustion which is a measure of the efficiency of energy conversion. In order to calculate these parameters reliably, the allocation of the measuring signals to TDC is extremely important. In a test vehicle, TDC is evaluated from the cylinder pressure signal and saved in the KiBox before the actual process of measuring and optimization commences. A function for determining TDC specifically for the requirements on a test drive is provided in the KiBox Cockpit.

## Multi-Cylinder Measuring Channels

Another central innovation of the KiBox is its ability to split the signal from a single measuring channel to several virtual signals. For instance, the KiBox can generate four timing signals from the output of one current clamp installed around four ignition cables. For this reason, two current clamp inputs are specifically built into the KiBox.

## Highest Data Quality

The signals pass through a low-pass filter (anti-aliasing filter) to avoid aliasing effects as they are being digitized. Following this, any interference effects in the measuring signal, e.g. pipe oscillations (see Fig. 1) are selectively eliminated using digital algorithms. In parallel, the crank angle marks undergo high-resolution interpolation. This innovative signal processing means the quality of KiBox data satisfies the strict criteria for mobile combustion analysis of transient engine operation in the test vehicle.

# ... in Every Detail

## Measuring Without Information Loss

The data resolution and angular reference requirements are extremely varied depending on the evaluation required (see Fig. 2). Whereas time-based sampling is ideal for determining maximum pressure, knocking analysis and combustion noise, the relevant crank

angle is required for determining mean effective pressure and for carrying out thermodynamic analyses. The signal patterns (pressure curves, angle marks, etc.) are brought together exactly on a common time base following their digitization. Kistler has combined all

this under the name CrankSmart® in order to provide an extremely precise angular reference for all measurement data, even when using a standard sensor rotor, e. g. 60-2 teeth.

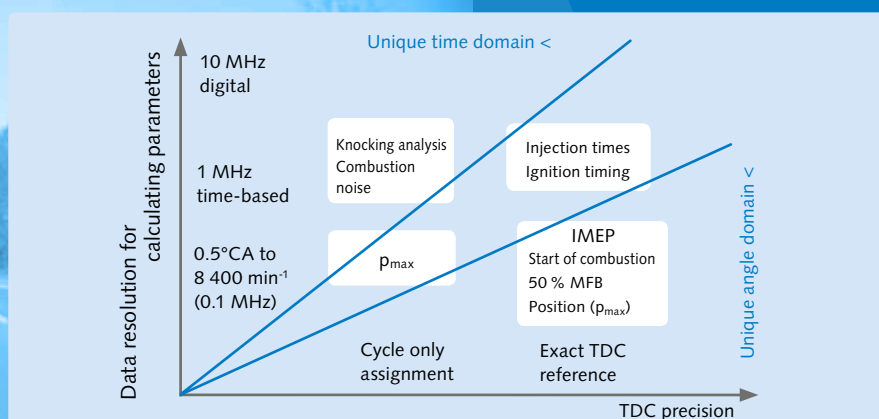


Figure 2: Quality of measured data required for combustion analysis

## Single Cycle Evaluation of the Combustion Location

The efficiency of the energy conversion in the individual cylinders is optimized based on the characteristics of the rate of cylinder pressure change. In actual vehicle operation, cylinder pressure changes significantly from one combustion cycle to the next therefore, the analysis results cannot be acquired from mean (smoothed) rates; instead they can only be acquired for each combustion cycle. The KiBox's high-quality filter functions eliminate interference to the signal patterns of individual cycles and cylinders. This results in dependable combustion parameters – even from the actual, but not necessarily ideal, quality of sensor signals in vehicle operation.

## Combustion Noise Analysis

Two methods enable the cylinder pressure curve to be used to evaluate the combustion noise that is audible to humans:

1. Maximum increase in the cylinder pressure signal after start of combustion:  
The results are shown as pressure rise per degree of crank angle, or preferably on a time basis [bar/ms]. The maximum rise is a reference value that is easy to calculate for a positive or negative change in the combustion noise, e. g. when the injection timing is changed.

2. Noise level derived from a frequency analysis:

The frequency range is evaluated to reflect the noise attenuation due to the engine structure and sensitivity characteristics of human hearing (A-evaluation). As the attenuation characteristics of the engine structure can be imported as a file, KiBox will be compatible with future engine designs.

# Our Service ...

Our customers associate Kistler with first-class service. At Kistler, this image is a living tradition and philosophy. Our service is all-inclusive – quick, competent, and with no red tape. Our sales engineers, application specialists and service personnel receive intensive, hands-on training on the KiBox in our own application centers. Needless to say, our service package is valid all over the world and addresses all concerns our customers may have.

## Expertise

The motivation and qualifications of our staff are well above average. KiBox customers benefit from access to our expert and highly efficient technical staff.

## Presence

Customers anywhere in the world have access to the know-how on all aspects of the KiBox via our Sales and Engineering support centers. Our specialists are at your service every day.

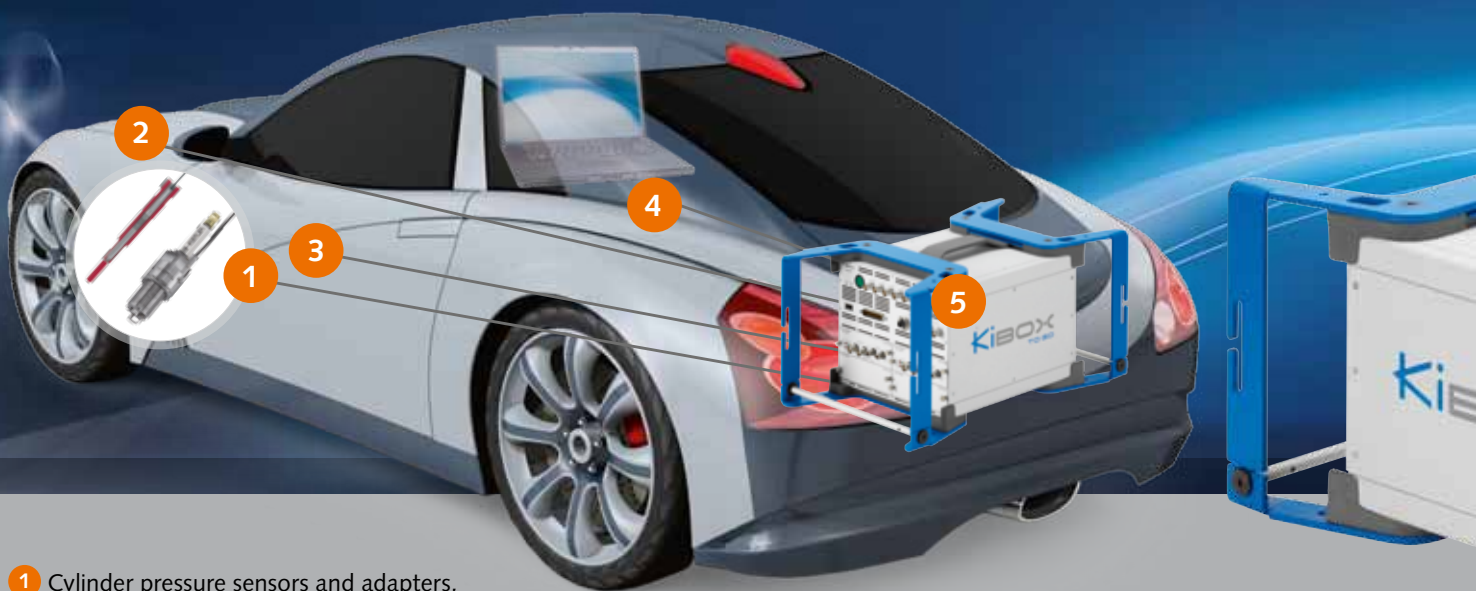
## Quality

The full KiBox scope of delivery (hardware and software) undergoes a thorough system quality inspection.

## Support

KiBox support is individually tailored and provided by technical experts. If required, it can also include commissioning and on-site user training. The local Kistler sales engineer is always the customer's permanent contact for

## Layout of System Components



- 1 Cylinder pressure sensors and adapters, e. g. glow plug adapters
- 2 Current clamp for injection and/or ignition timing
- 3 Crank angle adapter for connecting to the vehicle's speed sensor
- 4 GB Ethernet connection to laptop with INCA (or similar)
- 5 "KiBox To Go" with plug-in amplifiers



## ... Your Success

advice and service. The KiBox comes with access to a dedicated telephone helpdesk for initial troubleshooting calls.

### Software maintenance

The "KiBox To Go" excels both in terms of functionality and compatibility. The system software is continuously developed and free updates are available to download at [www.kistler.com](http://www.kistler.com).

### Interaction

We regard intensive dialog with our customers as a crucial factor in improving our products and stimulating innovative solutions. This communication results in ongoing enhancements to our range of services and products.



*The "KiBox® To Go" is an in-vehicle combustion analysis solution that complements our extensive range of sensors and amplifiers. Our range of services also includes all the elements of the combustion analysis measuring chain, including training, calibration and other services. These can also be provided on site.*

### "KiBox® To Go" at a glance

#### Measuring channels

- 8 analog inputs via integrated amplifiers or universal for any voltage signals
- Modular architecture for additional analog inputs
- 2 current clamp inputs
- 1 angle input for original vehicle sensor (60-2 etc.)
- Angle and trigger inputs for optical crank angle sensor
- 8 digital channels for measurement and control functions

#### Preparing to measure

- PiezoSmart® sensor identification (TEDS)
- Protected administrator area for critical settings
- Determining TDC exactly on a test drive
- Time-saving management of engine and measuring parameters

#### Measuring modes

- Continuous measurement and real-time calculation
- Measurements on engine start or stop
- Controlling the KiBox using the INCA user interface
- Many different ways of triggering data storage

#### Real-time calculation and output of results

- Cylinder pressure analysis
- Injection timing
- Ignition timing
- Transfer of parameters to INCA
- Parameter output via DAC (optional)
- Data storage and export, choice of data formats

#### Data display

- Parameters selected and displayed in INCA
- On-line/off-line data displays in "KiBox Cockpit"

#### Main accessories

- Crank angle adapter
- Current clamps

*Other more detailed specifications can be found in the data sheet.*

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