Automated Test Solution for Automotive Pressure Sensor ICs

Automated Multipoint Pressure and Temperature Characterization

Complete DAQ Solutions from DOEWE

DOEWE Application Notes-087-V0.3

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1. Solution Overview

Automotive pressure sensors are fundamental sensing devices in vehicle pressure measurement and control systems. They convert gas or liquid pressure into electrical signals that provide feedback to electronic control units. In engine intake and fuel systems, pressure data support load estimation and fuel delivery control. In braking and thermal management systems, they support pressure monitoring, actuator control and fault detection. Measurement accuracy and stability affect control precision, operating efficiency and fault assessment, making systematic performance testing essential before a device is used in a vehicle.

Operating pressure, ambient temperature and supply conditions change during vehicle operation. The sensing structure, package and compensation circuitry also influence the final output. Pressure sensor testing establishes the relationship between actual pressure and device output under these conditions, evaluating zero output, sensitivity, nonlinearity, hysteresis and temperature drift, together with startup behavior, operating current and communication status. Recording reference pressure, temperature near the device and electrical data together helps distinguish device characteristics from the effects of the test conditions.

DOEWE integrates pressure control, reference measurement, temperature conditioning, dedicated fixtures, power supply, data acquisition and test software into an automated test system. The pressure controller establishes each input point, the reference instrument measures the actual pressure, and the acquisition unit reads the device output. Software performs sampling, calculations and data archiving under the specified

conditions. Multiple test positions share the pressure and temperature conditions, while each channel retains the results for its corresponding device.

The system tests packaged devices with dedicated pressure ports, as well as packaged sensor ICs mounted on test boards and pressurized through sealed fixtures. The fixture applies gas or liquid pressure to the device's pressure-sensitive area while providing sealing, positioning and electrical connections. Tests include multipoint pressure loading and unloading, temperature characteristics, drift at constant pressure, and supply and interface checks. Response time, pressure cycling and overpressure recovery can be added according to the verification objectives. Bare-die or wafer-level testing can be supported with dedicated pressure chambers, probes or temporary electrical connections.

The system configuration follows the device's operating conditions. Gas-pressure testing uses a clean pneumatic circuit and pressure regulation unit; low absolute-pressure testing uses a vacuum branch, and higher-pressure testing uses a booster where required by the supply conditions. Liquid-pressure testing uses a compatible hydraulic circuit and sealing materials. Fixtures are designed around the device geometry and pressure ports, while acquisition modules are selected for voltage, current or digital outputs. Pressure ranges, temperature points and acceptance limits follow the device specifications and test objectives. Equipment appearances and interface data in this article illustrate the proposed solution.

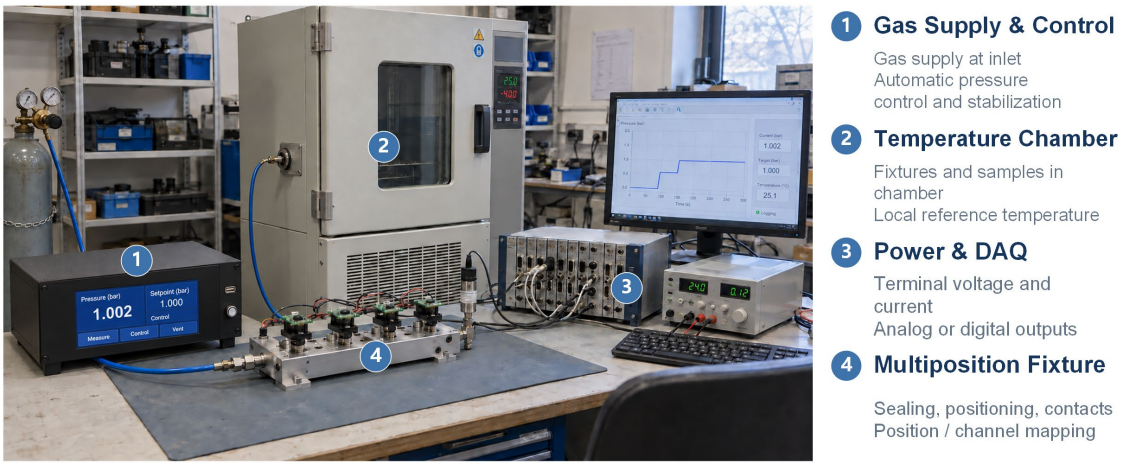

Figure 1. Automotive pressure sensor IC automated test system

2. Overall Test Workflow

When creating a task, the operator enters sample IDs, pressure type, range, interface and fixture positions, then selects the pressure points, temperature points and tests. The software loads the corresponding supply, sampling, stability and acceptance settings, and identifies the pressure branches, reference standards and acquisition channels required for the task.

After loading the samples, the operator verifies the mapping between pressure ports, position IDs and electrical channels. Sealing surfaces and fittings are kept clean, and clamping force follows the fixture design. When several positions share a manifold, each branch is checked for sealing integrity to confirm that all positions can be tested under the specified pressure conditions.

The startup sequence checks the pressure supply, valves, reference measurements, chamber and vent path, then performs a sealing check at the specified check pressure. Once these conditions are confirmed, the system powers the devices and records operating current, communication status and the first valid output. Formal testing begins after the prescribed warm-up period.

Static testing starts at the specified zero or lower-range point, increases pressure step by step to the upper limit, and then decreases pressure through the same points. At each point, the software evaluates pressure variation, trend and the prescribed waiting period using the reference pressure. Temperature tests also check the reference temperature near the device. Sampling begins when both pressure and temperature meet the stability

requirements. The equipment's in-position status is retained as an auxiliary record. If stabilization exceeds the configured time limit, the software records the reason and prompts a review of the affected point.

Temperature tests repeat the pressure-loading and unloading sequence at each target temperature. Drift tests continuously record data at a fixed pressure and temperature. Equipment setpoints, measured reference values, device outputs and operating status are saved with each test point. Static measurements are associated by point ID and sampling window; dynamic measurements are aligned using a common trigger or a validated time reference.

Before calculations, the software checks the completeness of the reference measurements, samples and communication frames. Data affected by environmental or communication anomalies retain a reason flag. Device outputs acquired under valid conditions are used for performance calculations and acceptance decisions. Retest data are saved separately and linked to the initial results, allowing comparison of intermittent anomalies and recurring deviations. At the end of the task, the system vents pressure and confirms that fixture pressure permits safe disassembly before the samples are removed.

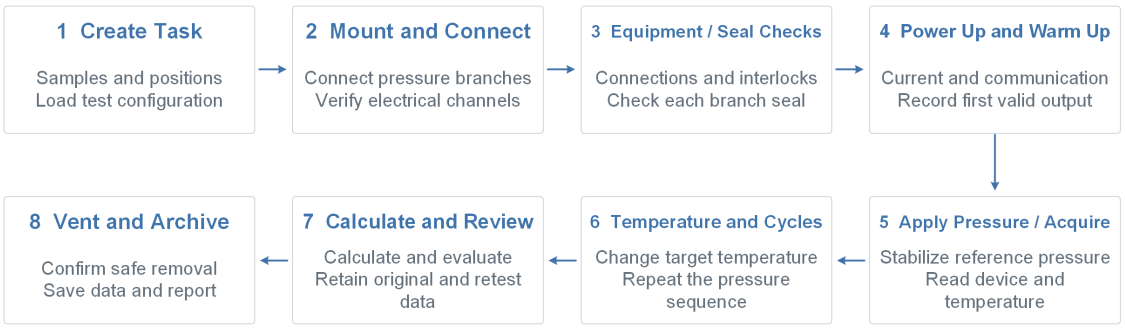

Figure 2. Automotive pressure sensor IC automated test workflow

Table 1 summarizes common tests. Pressure and temperature points, cycle counts, hold times and acceptance limits are configured according to the device documentation and test objectives. The measurement method is retained with the task.

Table 1. Common tests for automotive pressure sensor ICs

Test	Method	Main Results
Supply and startup	Power up at the specified voltages and modes; record current and the first valid output.	Operating current; startup and recovery times

Test	Method	Main Results
Multipoint pressure loading	Increase and decrease pressure point by point; acquire together after stabilization.	Zero or lower-range output; sensitivity; nonlinearity
Hysteresis and repeatability	Compare corresponding points on the forward and return runs and across complete cycles.	Hysteresis; cycle-to-cycle variation
Temperature characteristics	Repeat the specified pressure sequence at each temperature.	Zero and sensitivity temperature drift; error over temperature
Drift at constant pressure	Record the reference and output continuously at fixed pressure and temperature.	Change relative to the reference
Sealing check	Isolate the branch at the specified check pressure; observe pressure and temperature.	Branch pressure decay; mounting or seal anomalies
Response time	Apply a fast pressure input; acquire reference and device waveforms together.	Delay; rise and fall times
Overpressure recovery and cycling	Apply loading per the specification; retest reference points after recovery.	Changes in zero, sensitivity and sealing
Output and interfaces	Check loads, frames and abnormal-condition recovery for the actual interface.	Output range; update interval; diagnostic status

3. Test System Components

Pressure and temperature equipment establish the test conditions, while the test board and acquisition unit provide device connections and electrical measurements. The host software coordinates their operation. Figure 3 distinguishes the pressure path, electrical measurement paths and equipment control connections. Test-point IDs and sampling times associate actual reference pressure, device output and environmental records for subsequent characterization and result review.

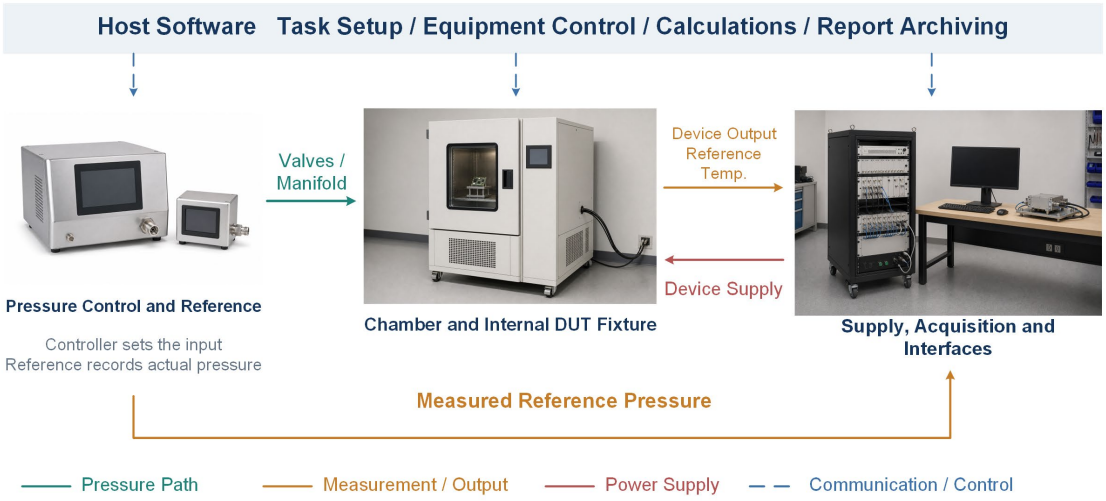

Figure 3. Pressure paths, electrical acquisition and equipment control

3.1 Pressure Generation, Control and Reference Measurement

The pressure source supplies inlet pressure to the controller, which uses a valve assembly or piston mechanism to increase, decrease and stabilize pressure. Vacuum and booster units are configured for the target pressure range. Drying and filtration control moisture, oil and particles in pneumatic circuits. Hydraulic circuits use media and seals selected for compatibility with wetted device materials, together with provisions for purging, cleaning and fluid collection.

This solution uses an independent pressure reference to record the actual device input. The reference instrument and the device under test connect to a section of pipe verified to be at uniform pressure, allowing their readings to be directly associated. The reference instrument's calibration range and measurement uncertainty are assessed against the device range and target error. When the controller's internal measurement channel is used as the reference, its measurement accuracy is evaluated separately from its calibration results and uncertainty. Control stability is used to evaluate the pressure regulation process.

Valves and manifolds distribute pressure, isolate branches and provide venting. For static tests at multiple positions, sealing checks and stabilization settings establish consistent pressure across branches. Dynamic tests use shorter connections and smaller internal volumes in pipes, fittings and fixtures to improve pressure transmission. In hydraulic circuits, the height difference between the reference and device ports is corrected for hydrostatic pressure using the fluid density. Pressure transmission,

reference measurement locations and stabilization time are reassessed after a fixture or pipe change.

Absolute, gauge and differential pressure devices use their respective pressure references. Absolute pressure is referenced to vacuum; gauge pressure is referenced to atmospheric pressure, with the device and reference instrument operating under the same atmospheric reference conditions. Differential pressure devices connect to high- and low-pressure ports, and a differential reference instrument measures the pressure difference. Venting one port to atmosphere represents the corresponding differential-pressure operating condition. To evaluate performance when both ports are subject to a higher common pressure, the two port pressures are controlled separately and the differential is adjusted at the specified common-mode pressure.

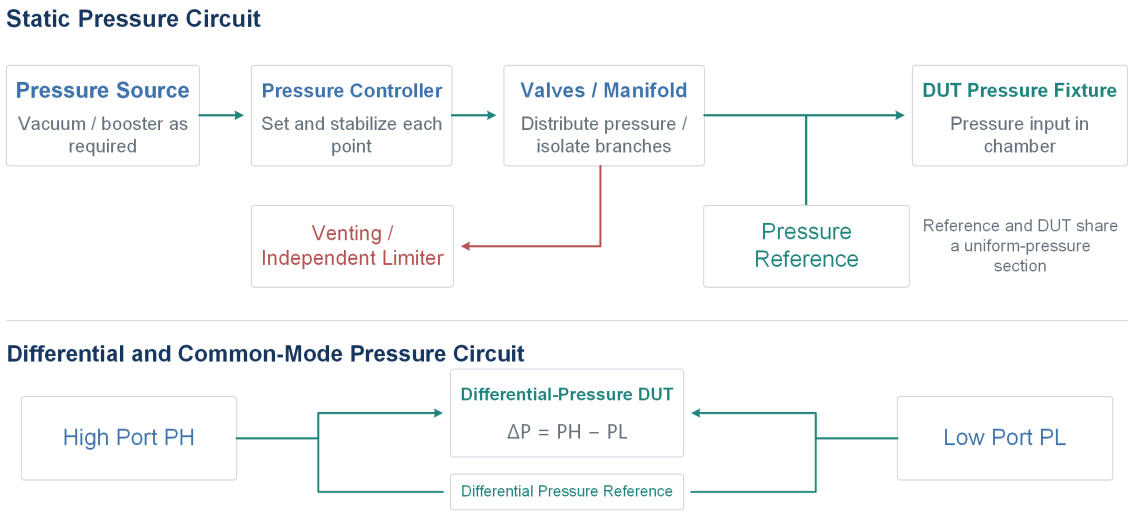

Figure 4. Static pressure circuit and differential-pressure extension

3.2 Test Boards, Package Fixtures and Pressure Connections

The test board routes the device pins to the supply and acquisition interfaces and provides decoupling, protection, loads and any necessary signal conditioning. Power and signal test points are retained. Changing the package primarily requires changes to the socket, test board and pressure adapter block. The carrier connection, electrical channel numbering and software task framework can continue to be used.

Each fixture position combines sealing, positioning and electrical contact. Seals and clamping structures are selected for the pressure, temperature and medium. Mechanical datums and clamping stops keep mounting conditions consistent between repeated installations. Each position has a unique ID, with pressure branches, test boards and

acquisition channels mapped in the software. Sealing checks identify anomalies through pressure decay in a specified volume. Leak-rate calculations account for volume, temperature and pressure changes originating in the test system itself.

During temperature tests, fixtures, cables and pressure lines enter the chamber with the devices, while the controller and reference instruments normally remain outside. A reference temperature sensor near the devices records their local ambient temperature. Gauge and differential pressure configurations are checked for reference-pressure differences between the inside and outside of the chamber. Long pipe runs and hydraulic connections are checked for pressure transmission and elevation corrections at the device. Sampling begins after both reference temperature and pressure meet the stability requirements.

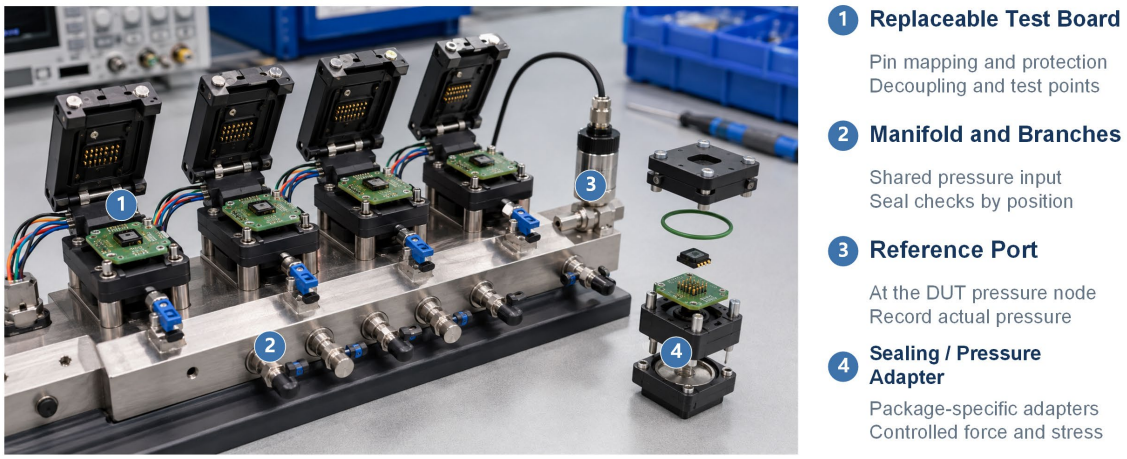

Figure 5. Multiposition pressure fixture and device connections

3.3 Power Supply, Data Acquisition and Digital Interfaces

A programmable power supply powers the devices while the acquisition unit measures voltage at the device terminals, current and output. Ratiometric voltage outputs are evaluated using the output-to-excitation ratio specified for the device. Millivolt-level bridges use low-noise excitation and differential measurements. Current outputs use suitable sensing resistors or current measurement channels. Devices at multiple positions can be powered in groups, with isolation of shorted branches or branches drawing abnormal current.

The acquisition method follows the test being performed. Steady-state tests calculate mean values and dispersion over a defined window, while response tests retain complete waveforms. Reference pressure, temperature and device output sequences are stored

separately with their time information. Sampling rates, ranges and filter settings are retained with the task. Interface units receive digital outputs close to the devices and associate them with the external reference data.

SENT interfaces are decoded from captured edges or pulse widths. PSI5 interfaces use sensor power and current-modulation receiver circuits. I²C interfaces use suitable logic levels and pull-ups, while SPI interfaces configure the clock, chip select and logic levels. The interface unit provides the electrical connections required by the device, and the software parses data fields, status information and pressure conversion relationships according to the relevant protocol.

3.4 Automated Test and Analysis Software

The software provides manual setup and automatic operation modes. During setup, the operator can control pressure, valves, the chamber and power supply individually and inspect raw outputs. Automatic mode executes equipment checks, warm-up, pressure and temperature changes, stability checks and acquisition in task order. The interface displays setpoints, measured reference values, the test sequence and device results together. The run log records equipment responses and anomalies so that an issue can be traced to a particular point and channel.

Each result is associated with the sample ID, position, test-board revision, device configuration, reference instrument and calibration information. Calculation methods and limits have separately controlled versions. Out-of-limit results can be reviewed against raw waveforms and run logs. Abnormal pressure, temperature or current stops the current sequence and invokes the configured isolation, venting or power-off strategy. Mechanical pressure limiting and hardware interlocks remain independent of the software. Reports are exported using project templates, with barcode, database or manufacturing execution system integration available as required.

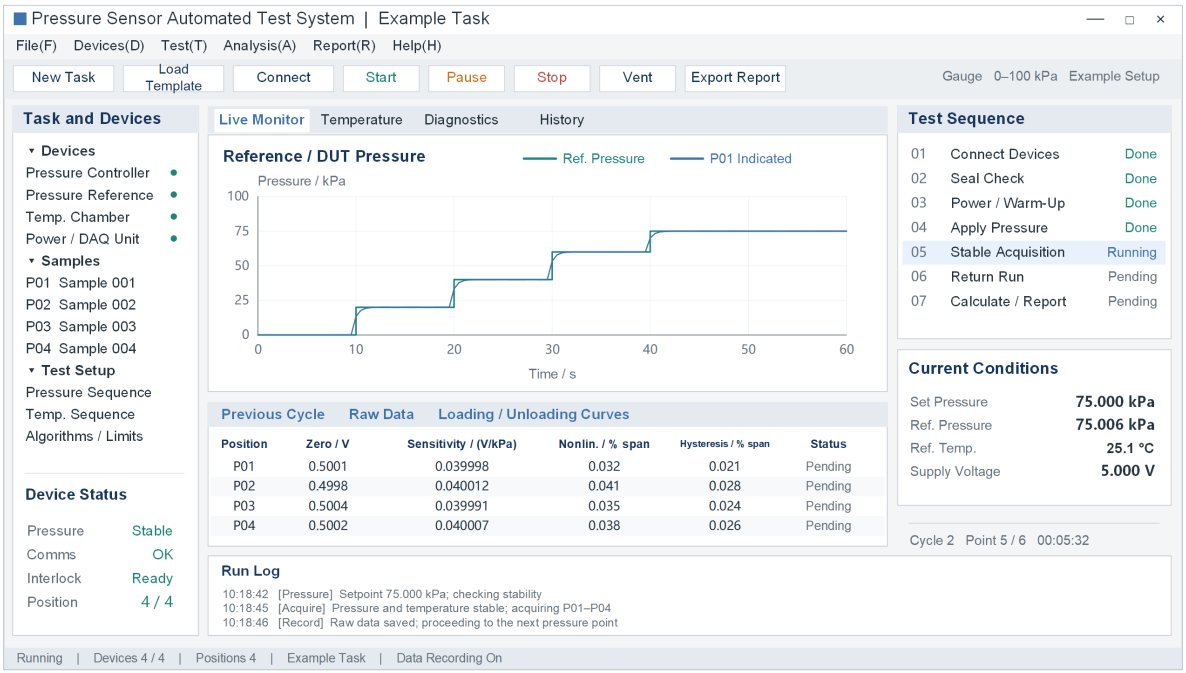

Figure 6. Illustrative pressure sensor automated test and analysis interface

4. Typical Test Methods

4.1 Multipoint Pressure Loading, Hysteresis and Repeatability

At the specified temperature and supply conditions, pressure is increased from the lower-range point to the upper-range point and then decreased through the same points. Once each point is stable, reference pressure and device output are acquired together, retaining the mean, standard deviation and sample count. Repeating the complete cycle the prescribed number of times produces a common dataset for analyzing the transfer characteristic, hysteresis and repeatability.

Sensitivity can be calculated from the output span divided by the reference-pressure span, or from the slope of a multipoint fit. For an approximately linear output, S = (YH − YL)/(PH − PL), where PH and PL are the high and low reference pressures for the same temperature, loading direction and cycle, and YH and YL are their corresponding outputs. Zero output is measured under the device's specified zero-pressure condition, while lower-range output is measured at the lower-range pressure point. The two results are recorded according to the device's pressure definition.

Nonlinearity is the maximum deviation from the selected reference line, with the endpoint, best-fit straight-line or device-specified method identified. Hysteresis

compares the outputs at the same actual pressure during increasing and decreasing pressure. Repeatability compares outputs from different cycles at the same direction and actual pressure. When measured pressures differ slightly between the forward and return runs, the software uses neighboring measured points within their common pressure interval to interpolate the two outputs to the same pressure before comparison. The interpolation method and the points used are saved with the results.

For outputs converted to pressure, the error at a point is $E_i = P_{DUT,i} - P_{ref,i}$. When normalized to pressure span, $\delta_i = E_i/(P_H - P_L) \times 100\%$. The report identifies the normalization basis and algorithm and retains the uncertainty assessment for the reference standard, temperature, acquisition and pressure branches. Nonlinearity, hysteresis and total error are reported separately, with acceptance assessed using the agreed decision rule.

4.2 Temperature Characteristics and Drift at Constant Pressure

The same pressure sequence is used at each temperature, with fixed supply conditions, sampling windows and mounting configuration. After the chamber reaches its setpoint, the reference temperature near the devices is monitored until both temperature and pressure are stable. Where thermal hysteresis is to be evaluated, the same points are tested during heating and cooling.

Zero temperature drift compares zero output at the specified zero condition across temperatures. Sensitivity temperature drift compares the corresponding slopes. Temperature-compensated devices are evaluated using their final compensated outputs, with on-chip temperature codes retained as supplementary data. Where compensation coefficients are calculated and written to the device, separate coefficient-calculation points and independent validation points are defined. The validation points check output after programming, while coefficient versions, point assignments and before-and-after data are retained.

Drift tests acquire continuously at a fixed pressure and temperature. The software converts output to pressure using the device transfer function and plots the difference between device-indicated pressure and reference pressure against time, while recording reference temperature. This dataset shows drift relative to the reference and supports analysis of slow pressure-source changes and temperature fluctuations. Observation

duration, sampling settings and reference measurement uncertainty are saved with the test.

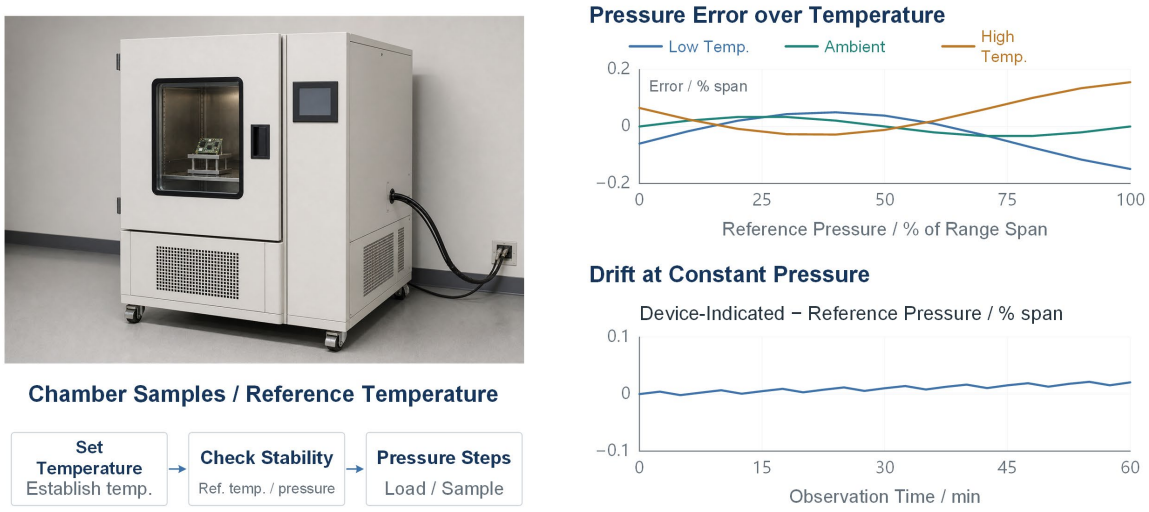

Figure 7. Temperature test arrangement and illustrative result analysis

4.3 Response Time, Overpressure and Burst-Test Extensions

Response-time tests use fast valves or a dedicated dynamic pressure generator to create a pressure change in a low-volume circuit. A high-bandwidth reference sensor is installed close to the device, and both waveforms are acquired using a common trigger or a validated time reference. Valve selection, line volume and reference-channel bandwidth follow the expected device response so that the pressure input and reference channel respond substantially faster than the device under test. The actual pressure step is recorded to verify excitation speed and assess the contribution of the measurement chain.

Analysis first checks the actual pressure waveform, then calculates delay, rise time and fall time using the specified thresholds. Figure 8 illustrates rise time between 10% and 90%; the applicable definition follows the device specification. Overpressure recovery tests apply the prescribed pressure for the specified hold time, then recheck zero output, sensitivity and sealing after venting and recovery. Pressure cycling evaluates performance changes after repeated loading, with loading rate and cycle count set by the verification requirements.

Overpressure and pressure-cycling branches are checked for rated capacity at the maximum test pressure and fitted with pressure-limiting and venting devices. Burst testing uses separate protective equipment, remote operation and a dedicated pressure

circuit, with test media and debris collected and handled within that circuit. These extensions can be configured separately for development verification, performance calibration or endurance testing.

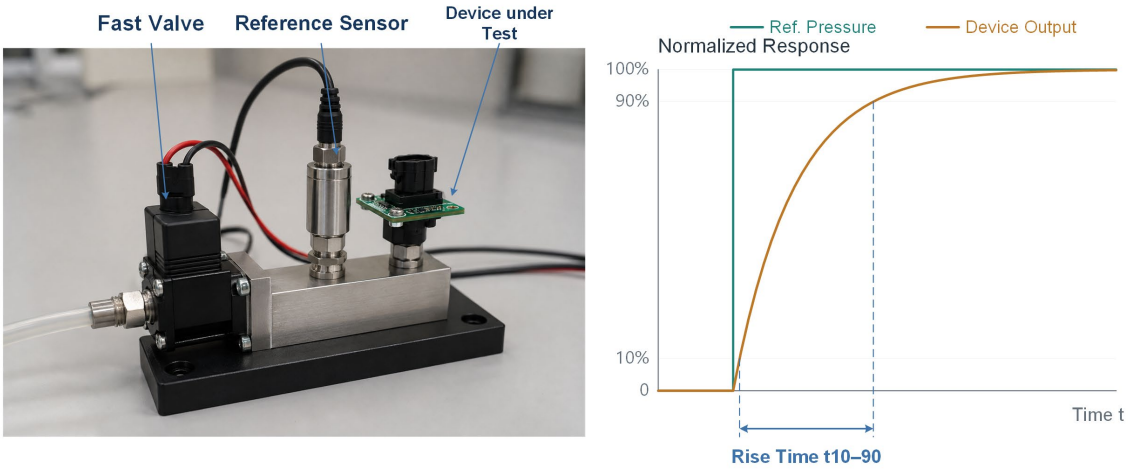

Figure 8. Dynamic pressure test arrangement and response-time definition

4.4 Power Supply, Analog Output and Digital Interface Tests

Supply tests operate the device at its specified voltages and modes, recording terminal voltage, operating current and the first valid output. Current and output transients are retained separately for startup, sleep wake-up and mode changes. Analog outputs are checked for range, ratiometric behavior and saturation under specified loads. Recovery conditions following abnormal supply states are also defined by the device documentation.

Digital interface tests check pressure data, update intervals, checksums and status information, retaining raw frames or edge records. Interfaces that share power and communication wiring are also monitored for bus voltage and current. Configuration and debug interfaces are checked for register access and parameter programming. Normal operating interfaces are checked for pressure-data updates, diagnostic status and recovery from abnormal conditions. Each check has its own result.

5. Core Advantages

DOEWE integrates pressure equipment, temperature conditioning, electrical acquisition and test software into a continuous device-verification workflow. The main advantages are as follows:

- Corresponding measurements of pressure input and device output. Each test point retains actual reference pressure and electrical output. Temperature and supply records support error-source analysis and provide a complete basis for characterization.
- Automated pressure and temperature test sequences. Software schedules pressure loading and unloading, temperature changes, stability checks and acquisition. This reduces manual setpoint entry and transcription and makes the same test conditions easier to repeat.
- Shared equipment with results managed by channel. The manifold and chamber provide common conditions for multiple devices. Position IDs are mapped to acquisition channels for batch comparison and retesting of individual positions.
- Fixtures and interfaces that support device changes. Test boards, sockets and pressure adapters are adapted to the package and output format. Pressure equipment, the chamber, acquisition platform and software framework can be reused within their applicable ranges.
- Traceable results that can be reviewed. Raw data, reference-instrument calibration information, and algorithm and limit versions are archived with the task. Initial and retest records are saved separately, supporting point-by-point review of waveforms, frames and run logs.
- Tests that expand with the verification stage. The base system covers static and temperature characteristics. Dynamic pressure, pressure cycling, overpressure recovery and separate burst-test equipment can be added for product development and reliability verification.

6. Conclusion

Automotive pressure sensor verification establishes the relationship between input and output under defined pressure, temperature and supply conditions. Pressure control and reference measurement establish the input basis. Dedicated fixtures and electrical acquisition provide device connections and data records. Automated software executes the tests consistently and preserves the calculation process, allowing the results to support device evaluation, sample comparison and subsequent review.

DOEWE can provide pressure equipment, dedicated fixtures, test boards, acquisition units and automated test software to suit the device package, pressure type, medium, range and interface. For automotive pressure sensor development verification, calibration or automated test-system projects, contact DOEWE to discuss a suitable configuration and implementation approach.