Automated Test Solution for UAV MEMS Pressure Sensor ICs

Pressure, Temperature and Dynamic Tests for Barometric Altitude and Differential Airspeed Sensing

Complete DAQ Solutions from DOEWE

DOEWE Application Notes-UAV-PRESSURE-V1.0

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1. Solution Overview

This solution targets pressure sensor ICs and packaged devices based on MEMS (micro-electro-mechanical systems) technology. UAVs use barometric sensors to measure absolute atmospheric pressure for height estimation and vertical-motion control. Fixed-wing aircraft and other platforms that require airspeed measurement can also use a pitot tube and differential-pressure sensor to obtain pressure differences related to airflow speed. These devices require different pressure ranges, references and pneumatic connections. Output error, noise, temperature behavior and update rate affect subsequent altitude or airspeed calculations, making pressure-performance records important for device selection.



Figure 1. Barometric altitude and airspeed sensing

Ambient pressure and temperature change during flight. Flight-controller warm-up, airflow disturbances and venting structures can also influence readings. IC tests first

evaluate error, noise and drift under controlled pressure, temperature and supply conditions, then examine small pressure changes, step response and update timing as required. Vent holes, protective materials, tubing and mounting location can be evaluated separately at board or assembly level, with the comparison linked to the chip-level results.

DOEWE combines pneumatic pressure control, independent reference measurement, temperature conditioning, sealed fixtures, power and acquisition, and software in an automated UAV pressure-sensor IC test system. Absolute-pressure tasks use control and reference channels that cover the target atmospheric range. Differential tasks use appropriately ranged low-differential-pressure control and reference channels. Software executes pressure and temperature sequences and retains measured inputs, device outputs and configurations. Multiple positions can share verified uniform test conditions.

Test objects include vented absolute-pressure ICs on test boards and packaged differential sensors with high and low pressure ports. Absolute sensors receive input through a small pressure chamber or package-specific sealed fixture, with electrical connections brought out through sealed feedthroughs. Differential devices connect through both ports. Tests cover pressure loading and unloading, temperature characteristics, constant-pressure noise and drift, power and interfaces, with small-change and dynamic-response extensions as needed.

The system uses clean gas compatible with the device. A vacuum branch establishes absolute-pressure points below ambient, while differential circuits are selected for both the differential and common-mode pressures. Ranges, temperatures, change rates, filtering and limits follow the device specification and application needs. Altitude or airspeed calculations retain the conversion model and reference conditions. Application scenes, equipment appearances and interface data are illustrative.



Figure 2. Automated test system for UAV MEMS pressure sensor ICs

2. Overall Test Workflow

The operator first selects an absolute-pressure altitude sensor or differential-pressure airspeed sensor and enters sample ID, range, interface and fixture position. The software loads the absolute range or differential and common-mode settings, then configures temperatures, sampling windows, output data rate, oversampling and filtering. The pressure circuit and reference standard are checked against the selected 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.

Reference data, sample records and frame completeness are checked before calculation. Environmental and communication exceptions retain reason flags, and valid data enter the performance calculations. Retests are stored separately and linked to the first result. Absolute-pressure tasks return gradually to ambient. Differential tasks first reduce the port-to-port difference to an allowed level, then restore pressure as required by the fixture. Samples are removed only after the permitted removal condition is reached, with the recovery sequence recorded.

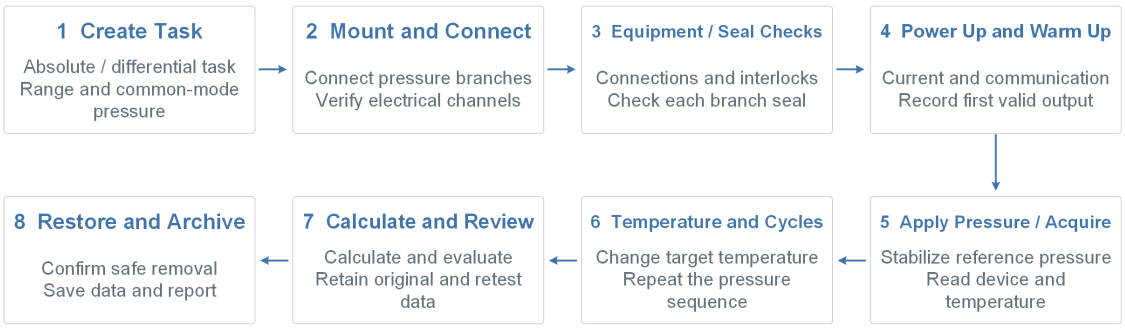


Figure 3. UAV MEMS pressure sensor IC automated test workflow

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 UAV MEMS 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
Pressure loading/unloading	Apply absolute or differential points; add points near the operating region.	Lower-limit error, 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 defined pressure sequence at each temperature.	Operating-point error, zero-differential offset, sensitivity changes
Constant-pressure noise and drift	Record reference and output at fixed pressure and temperature.	Short-term noise, drift relative to 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 4 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.

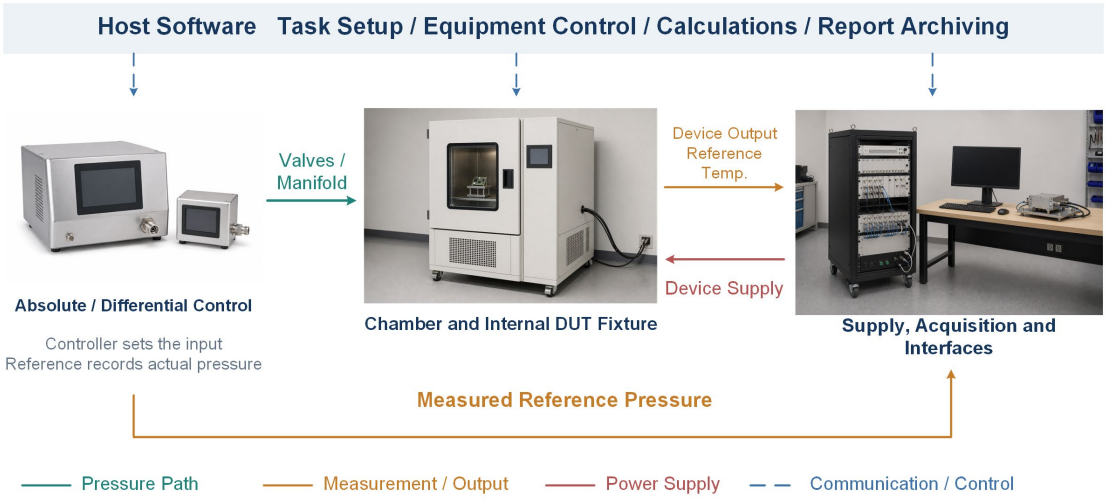


Figure 4. Pressure paths, electrical acquisition and equipment control

3.1 Pressure Generation, Control and Reference Measurement

The absolute-pressure circuit uses clean gas and a vacuum branch to cover the target range, with controlled loading, unloading and stabilization. Filtration, drying and contamination isolation are matched to the device, and the controller and valves are selected for minimum absolute pressure, stability and volume. Small differential-pressure tests use a dedicated control unit with verified resolution, zero stability and allowable pressure at both ports, giving the required capability for small-difference evaluation.

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, isolate and restore pressure. Multiposition static tests verify branch sealing and equalization time before sampling under common stability criteria. Small-change and dynamic tests control tubing, fitting and chamber volume, with the reference close to the device. Length, volume and response differences between the two differential branches are recorded. Fixtures, vents or tubing changes are followed by renewed pressure-transfer checks.

Absolute sensors are tested against an absolute-pressure reference at points within their specified operating range; the lower range limit need not be vacuum zero. Differential input is determined by both ports, ΔP = PH − PL. Airspeed applications can be tested by applying the specified difference at the target ambient absolute pressure. Port polarity, permitted negative differential pressure and common-mode limits are checked, and both port conditions and the differential reference are retained.

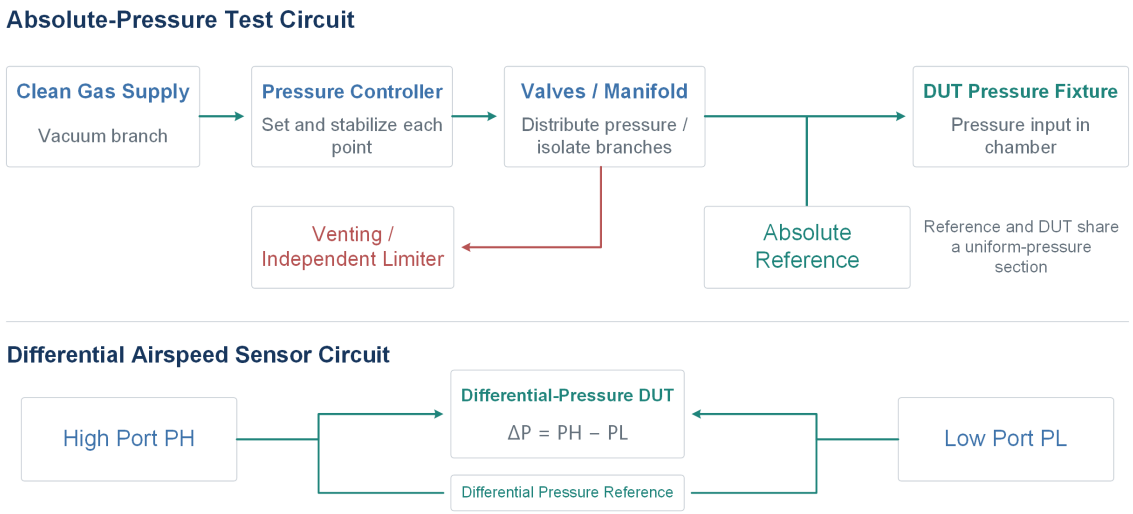


Figure 5. Test circuits for barometric altitude and differential airspeed sensors

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.

Fixtures provide pressure cavities and seal boundaries around the package vent while retaining the specified gas-entry path. Mechanical datums and stops control clamping. Position numbers map branches, boards and acquisition channels in software. Seal checks first assess pressure retention at the fixture and connections. Pressure transfer through a vent membrane or protective structure is tested separately in the relevant assembly state so that it is distinguished from external leakage.

Fixtures, boards, cables and pressure lines enter the chamber, while the controller and reference instruments normally remain outside. A reference sensor records temperature close to the IC after stabilization. Internal temperature codes and current are

also retained when examining power-on self-heating. Differential circuits are checked for pressure transfer and thermal differences between branches; sampling starts after temperature and reference pressure both meet the stability criteria.

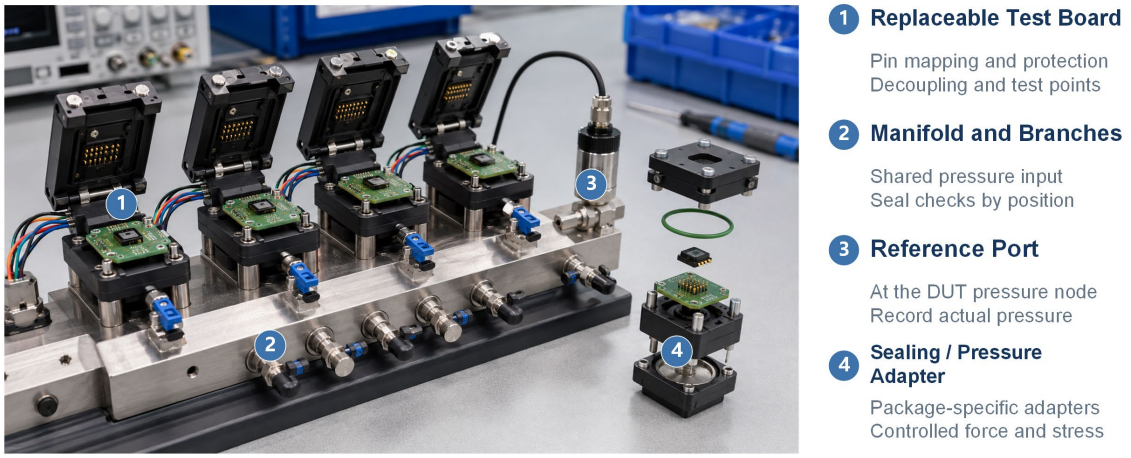


Figure 6. Multiposition pressure fixture and device connections

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.

Digital interfaces follow the IC's actual protocol, such as I²C or SPI. I²C checks cover logic levels, pull-ups and timing; SPI checks cover clock, chip select and sampling edge. Data-ready events or internal timing identify sample updates. Software applies the device-specified pressure and temperature compensation and retains raw codes,

coefficient revisions and configuration. Analog differential sensors use suitable voltage or bridge acquisition channels.

3.4 Automated Test and Analysis Software

Software supports individual-point setup and automatic operation. The interface distinguishes absolute and differential tasks and displays pressure definition, measured reference, temperature and update status. Automated sequences perform seal checks, warm-up, pressure and temperature changes, stabilization and acquisition. Small-change, noise and dynamic tests retain continuous raw sequences. Logs associate equipment responses and exceptions with positions, test points and device configurations.

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.

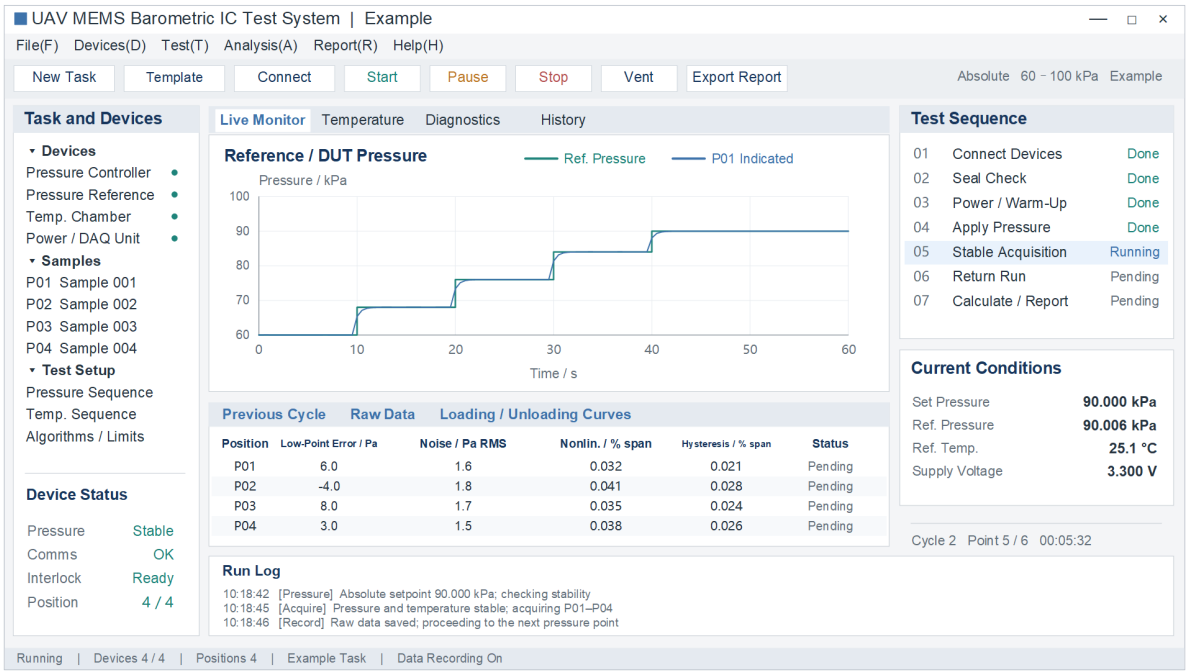


Figure 7. Illustrative MEMS pressure sensor automated test and analysis interface

4. Typical Test Methods

4.1 Multipoint Pressure Loading, Hysteresis and Repeatability

At the specified temperature and supply, pressure is increased from the permitted lower limit and then decreased through the same points. Barometric sensors can include closely spaced points around the intended operating pressure; differential sensors can include small positive and, where allowed, negative differences around zero. Each point records reference and output together, retaining mean, standard deviation and sample count. Complete cycles support hysteresis and repeatability comparisons.

For output not yet converted to pressure, sensitivity can be calculated from the endpoint output difference divided by the reference-pressure difference, or by the prescribed multipoint fit. For an approximately linear output, S = (YH − YL)/(PH − PL), using values from the same temperature, direction and cycle. Digital devices that already report pressure are evaluated directly for pressure error. Absolute sensors record lower-limit output, while differential sensors also record zero-differential output, with labels matching the 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.

Point error is $E_i = P_{DUT,i} - P_{ref,i}$ and can be normalized to the specified span, retaining uncertainty contributions from the reference, temperature and acquisition path. Altitude applications emphasize small changes and noise near the operating pressure. Conversion to altitude error states the reference pressure, temperature assumptions and atmospheric model. Differential-pressure conversion to airspeed records the pitot relationship and air-density conditions, allowing pressure performance and application calculations to be reviewed separately.

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.

Absolute sensors are compared for lower-limit and operating-point error over temperature; differential sensors also track zero-differential offset and sensitivity. Temperature-compensated devices are evaluated using final pressure output, with internal temperature codes retained as supporting data. When coefficients are calculated and written, calculation and independent verification points are kept separate. Coefficient revisions, point groups and before/after records are saved, and verification points confirm output over temperature.

Constant-pressure tests acquire continuously at fixed pressure, temperature and device settings. Short windows quantify output variation, while longer records track change relative to the reference. Oversampling, output-rate or filter comparisons keep other conditions constant and compare noise, update time and dynamic response. Record

duration, reference temperature, acquisition settings and reference uncertainty are saved to analyze slow pressure changes, self-heating and device drift.

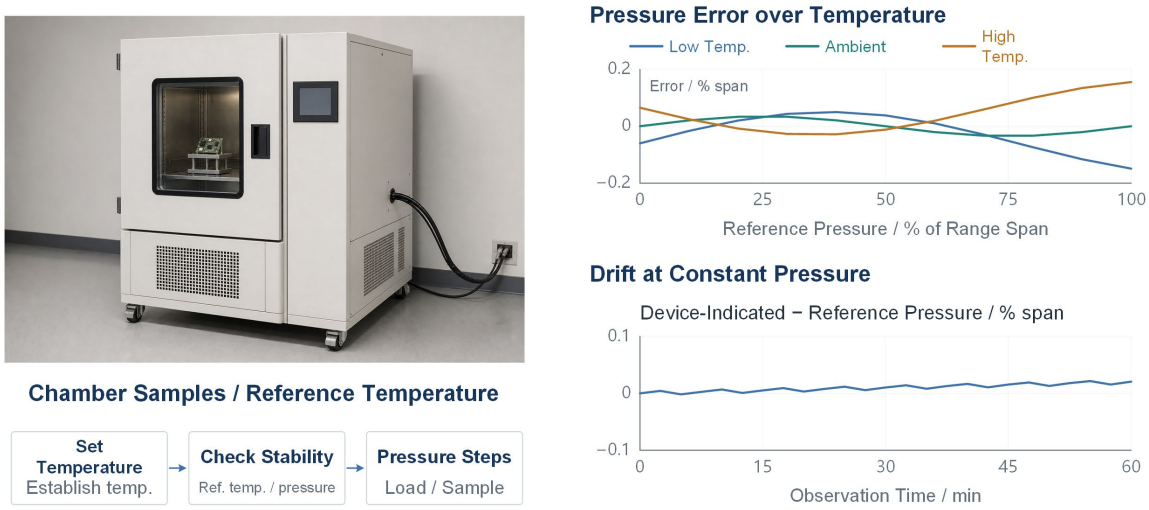


Figure 8. Temperature test arrangement and illustrative result analysis

4.3 Small Pressure Changes, Dynamic Response and Pressure Cycling

Dynamic tests use a fast valve or dedicated pressure generator selected for the expected response, with a nearby reference sensor and common triggering or a validated time base. Circuit volume, excitation speed and reference bandwidth are checked together so that the input and reference path can resolve the response. Absolute sensors can include slow ramps and small steps around an operating point. Differential sensors receive pressure changes at a specified common-mode pressure, with actual reference waveforms retained.

Analysis first checks the actual pressure waveform, then calculates delay, rise time and fall time using the specified thresholds. Figure 9 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.

Board-level verification can compare an exposed vent with the intended protective structure under the same input to assess response time and pressure lag. Pressure cycling and overpressure recovery follow device ratings and project requirements, with error,

noise and communication rechecked afterward. If destructive tests are required, they use separately protected equipment and a dedicated circuit, preserving the clean branch used for routine barometric characterization.

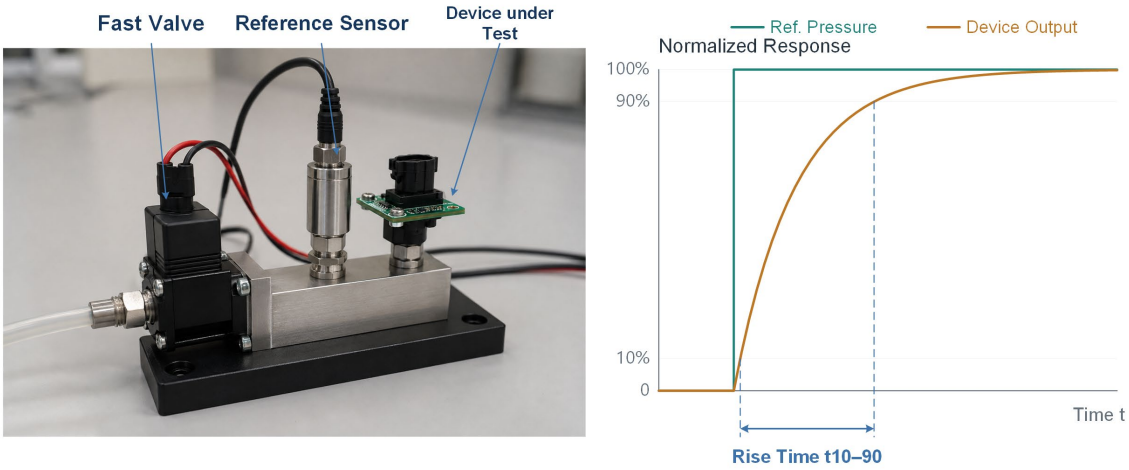


Figure 9. Dynamic pressure test arrangement and response-time definition

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 tests check raw pressure and temperature codes, compensated output, update intervals and status flags, together with integrity checks and recovery functions actually provided by the device. Data-ready, interface-read and host-receive times are recorded separately. FIFO or block-read samples use device timing to reconstruct sample times. Output rate and the first valid sample are rechecked after oversampling, filter or low-power changes so that repeated reads are distinguished from new data.

5. Core Advantages

DOEWE integrates absolute and differential pressure control, temperature conditioning, acquisition and software to support device evaluation for UAV barometric altitude and differential airspeed sensing. The main benefits 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 extend around application needs. Pressure and temperature characterization can include small changes near the operating point, constant-pressure noise, filter and update-time comparisons, and assembly-level evaluation of vents and pressure tubing.

6. Conclusion

UAV pressure-sensor verification starts by distinguishing barometric altitude sensing from differential airspeed sensing and selecting the appropriate control and reference circuits. Multipoint pressure and temperature tests establish error; steady records and small changes reveal noise and resolution behavior; dynamic and interface tests characterize pressure transfer and updates. Linking chip results to assembly conditions, conversion models and references supports flight-controller component selection and subsequent system development.

DOEWE can provide pressure equipment, sealed fixtures, test boards, acquisition and automated software for the package, range, interface and objectives of UAV barometric or differential-pressure ICs. Contact DOEWE to discuss altitude-sensor or airspeed-sensor verification and automated test-system configuration.