

Modularity in pressure calibration systems

Application Note

A popular buzz word in pressure calibration today is “modularity.” But what does this really mean, and why is it such an important consideration in the design and construction of pressure calibration equipment? When done correctly, modularity provides benefits over a traditional monolithic design. It can also present challenges in understanding the system’s overall measurement uncertainty and path of traceability. In this document we will review those benefits and challenges.



Overview of the concept of modularity

From a high level view, all pressure calibration systems fulfill a specific set of tasks:

1. Generate/control a pressure.
2. Measure the pressure.
3. Observe/record the output of the device under test.

In a traditional monolithic system, one device performs more than one of these functions. This can be very efficient and simplifies the overall design of the system. Conversely, in a modular system, each function is separated into its own module. Each module must fully encapsulate that task and all steps necessary to perform it, or the modules become dependent upon each other and the modularity is lost. Thus, a truly modular system isn’t as simple as it may seem.

As an example, the Fluke Calibration 6270A Modular Pressure Controller/Calibrator is a truly modular system. The primary functions of pressure control and measurement are separated into their own modules, with each module fully encapsulating its given task. The Pressure Measurement Module includes all of the items necessary to measure the pressure, and the Pressure Control Module includes the valves, pressure sensors, electronics, and firmware necessary to control the pressure.

Benefits of modularity

Why have modular calibration systems? A truly modular design provides some key benefits:

- **Rangeability**—Pressure measurement devices come in a variety of pressure ranges. The most useful calibration system is the one that can calibrate as many pressure ranges as possible. The term “rangeability” refers to an instrument’s ability to cover multiple ranges. With a modular system, multiple measurement modules can potentially be included, allowing for a wider range to be covered. To provide this benefit, the design of a modular system must:
 1. Accommodate multiple modules simultaneously. More modules mean more system rangeability.
 2. Accommodate measurement modules with adequate measurement performance. The measurement uncertainty and range coverage of each module contribute to how well the calibrator can cover a wide workload with the appropriate level of accuracy.
- **Expandability**—Your workload changes over time. This year, you may need to only go up to 7 MPa (1000 psi). What happens if next

year you need to go to 20 MPa (3000 psi)? With a traditional non-modular system, it's not always easy to expand to cover a wider pressure range. You may even need to purchase an entirely new system. A properly designed modular system can be expanded easily by simply adding more modules at a later date. The design needs to consider these factors:

- Adding higher or lower range pressure models later must not require purchasing a new instrument or a rebuild by the manufacturer.
- Adding pressure modules must be fast and easy to do.

The 6270A provides such a platform in which all modules are changed from the front of the instrument quickly by a user without special tools and even without powering down or disconnecting test supply pressure lines.

- **Reduced downtime**—A calibration system inherently has some downtime. At some point, it needs to be calibrated and while that is happening, it can't be used. With a robust modular measurement scheme there are multiple options to reduce or eliminate downtime during calibration and other maintenance. If all measurement modules are truly independent, calibrations can be sequenced so that the instrument maintains most of its range coverage even during maintenance and calibration. For example, if the system includes multiple measurement modules, you can send one out for calibration while the other modules are still being used. Or, in applications where continuous uptime is extremely valuable, you can purchase a spare set of modules and place them on a staggered calibration schedule. Thus, you always have calibrated modules available. Downtime is also eliminated by having a fully modular approach to the control function. A control module that does not require configuration with other components of the system provides for easier troubleshooting and repair of the pressure controller/calibrator.

To fulfill the promise of reduced downtime, certain considerations must be made in the design of the modular system.

- First, the modules must be easy and quick to swap out. The time it takes for a module to be removed and then reinstalled is downtime. This includes the time taken venting supply pressure, physically getting to the modules with the proper tools, disconnecting and reconnecting pressure lines, and testing the system to insure that no leaks were introduced and that the system is operating properly. Installation of the module must be such that leaks or similar problems aren't

generated. Troubleshooting and repair of the leak or other damage could result in substantially greater downtime.

- Second, the cost of the overall system must be split across the modules. If the module represents 80 percent to 90 percent of the system's cost, then it becomes uneconomical to have spare modules to maintain uptime. Third, the calibration must be on the modular level. The other components in the system cannot impact the calibration, thus allowing for the module to provide the same output when it is removed from the chassis and installed in a different chassis or calibration sled.

Determining traceability with a modular system

Behind the scenes, there are multiple steps that take place to measure a pressure. Each of those steps potentially impacts the overall uncertainty of the measurement. In a modular system, not all of those steps are going to be performed in the same module.

Generally, the steps associated with making a measurement include:

1. Pressure is introduced to the system.
2. The pressure exerts a force upon the sensing element.
3. The force causes a change in the output of the pressure sensor. Depending upon the design of the pressure sensor, this could be a frequency or millivolt signal (or similar).
4. The pressure sensor output is measured by the electronics and converted to a digital value.
5. Coefficients are applied to the digital value.
6. The value is reported to the user by either being displayed on the front panel or sent over the remote interface.

The behavior of certain steps will vary or drift with time, and thus calibration is required. The relationship of the force to the output signal in step 3 and the measurement by the electronics in step 4 will potentially change with time. Therefore, the calibration needs to encompass steps 3 through 5. In other words, the module must take as input the physical pressure and the output must be a digital value that requires no further conditioning or correction.

There are other considerations in the module's design to ensure that the module reads the same, regardless of the chassis it is installed in:

- **Electronic stimulus**—Depending on the pressure sensor's design, its output can be a function of, not only the applied pressure, but also the supply voltage or other electronic

stimulus. In a modular setup, it's not possible to guarantee that two chassis will provide the same exact supply voltage to the module. Thus, the module must be designed so that it can operate with a range of supply signal without significant influence on the final measurement.

- **Temperature**—Pressure sensors are also impacted by temperature. If a module is designed to operate both inside of a chassis and in a calibration sled, then the temperature compensation must be comprehensive and effectively accommodate widely varied thermal environments, such as those inside and outside of a calibrator chassis.
- **Electromagnetic interference**—A pressure sensor and the accompanying electronics may be impacted by EMI. In a traditional instrument, the overall instrument is designed to eliminate the impact through shielding and electrical design. With a modular system, the module must be immune to EMI, even when not installed in the chassis. It must also be immune to any EMI generated inside the chassis, as that EMI won't be there when the module is calibrated outside the chassis.

The 6270A and its accompanying Pressure Measurement Modules fulfill the above requirements, allowing for calibration to be performed at the modular level. The design is such that the raw pressure is applied to the module, resulting in the module outputting a digital value that requires no additional conditioning. The module design takes into account all outside influences, including supply voltage, temperature, and EMI.

When using a modular calibration system like the 6270A to calibrate other pressure measurement devices, what item do you list on the calibration report as the standard used? The measurement modules, control module, chassis, or some combination of all three? The path of traceability is through the measurement modules. These are the only items that require calibration. Therefore, any measurement module used in the calibration needs to be listed. The control module and chassis do not need to be listed on the calibration report.

Choosing the right pressure measurement modules

Choosing the right pressure measurement modules is a simple and straight forward process.

1. Evaluate the workload

If there is a defined workload, then create a list of pressures and the required uncertainty at those pressures. In most cases, the workload will have a percent full scale specification.

Thus, the pressures of interest will correspond with the full scales of the devices under test.

For operations that support a varied and unpredictable workload, such as a third party calibration laboratory, the workload may not be as well defined. In these cases, it may be necessary to instead look at the highest pressure and lowest pressure that need to be covered.

2. Choose modules

Start at the highest pressure required and then work down to the lowest pressure required. There may be multiple modules that will provide sufficient uncertainty at a given pressure. In some cases, it's better to go with one that is "overkill" at one pressure but can be used at multiple pressures. In other scenarios, it is more cost effective to go with a larger quantity of lower accuracy modules.

3. Remember expandability

A modular system allows for future expandability. Your pressure calibration workload is almost sure to change over time. If some of the workload is not well defined or there is potential for future growth, consider how capabilities can be added at a later date.



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Fluke Calibration
PO Box 9090,
Everett, WA 98206 U.S.A.

Fluke Europe B.V.
PO Box 1186, 5602 BD
Eindhoven, The Netherlands

For more information call:
In the U.S.A. (877) 385-3225 or Fax (425) 446-5116
In Europe/M-East/Africa +31 (0) 40 2675 200 or Fax +31 (0) 40 2675 222
In Canada (800)-36-Fluke or Fax (905) 890-6866
From other countries +1 (425) 446-5500 or Fax +1 (425) 446-5116
Web access: <http://www.flukecal.com>

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