Astemes LUnit

Astemes - Anton Sundqvist

Anton Sundqvist

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1. LUnit Basics

This document walks through the basic workflow using LUnit to test LabVIEW code. If you prefer to watch a video, there is an introduction available on this link.

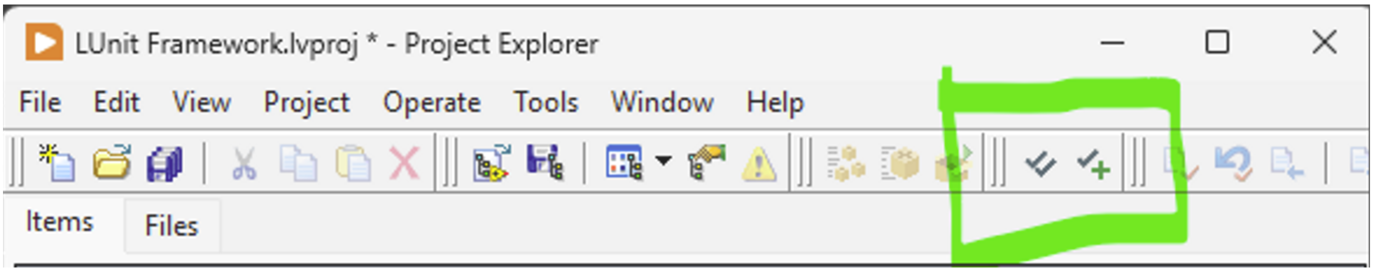
1.1 Prerequisites

To follow along with the instructions on this page you will need to have LabVIEW version 2020 or later installed as well as the LUnit unit testing framework.

1.2 Creating a Test Case

All tests you write will belong to a test case. The test case is implemented as a LabVIEW class, but in order to use it you will not need to know anything about object oriented programming.

To get started, create an empty project and add a test case to it by clicking the New Test Case button in the toolbar of the LabVIEW project.



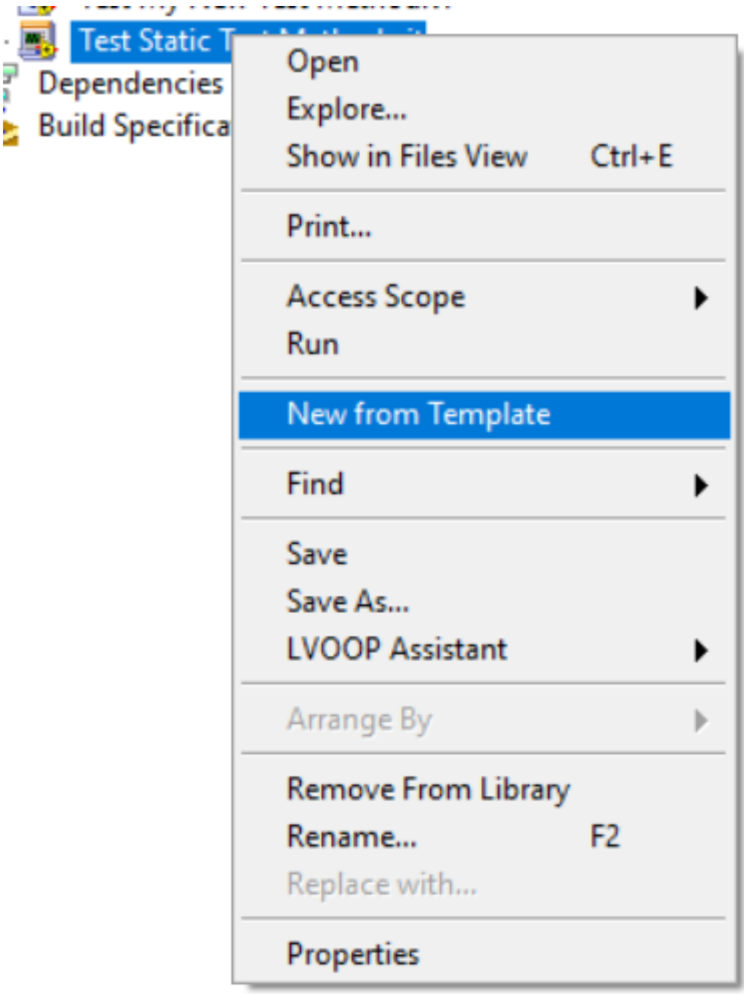
You can also do the same from the `Tools > LUnit > New Test Case...` menu option.

Save the test case in a convenient location. Some like to keep the tests next to the code they are testing, and other keep them in a separate folder called `Tests` or similar. I personally find the later option with a separate top level directory the most convenient.

1.3 Adding a Test Method

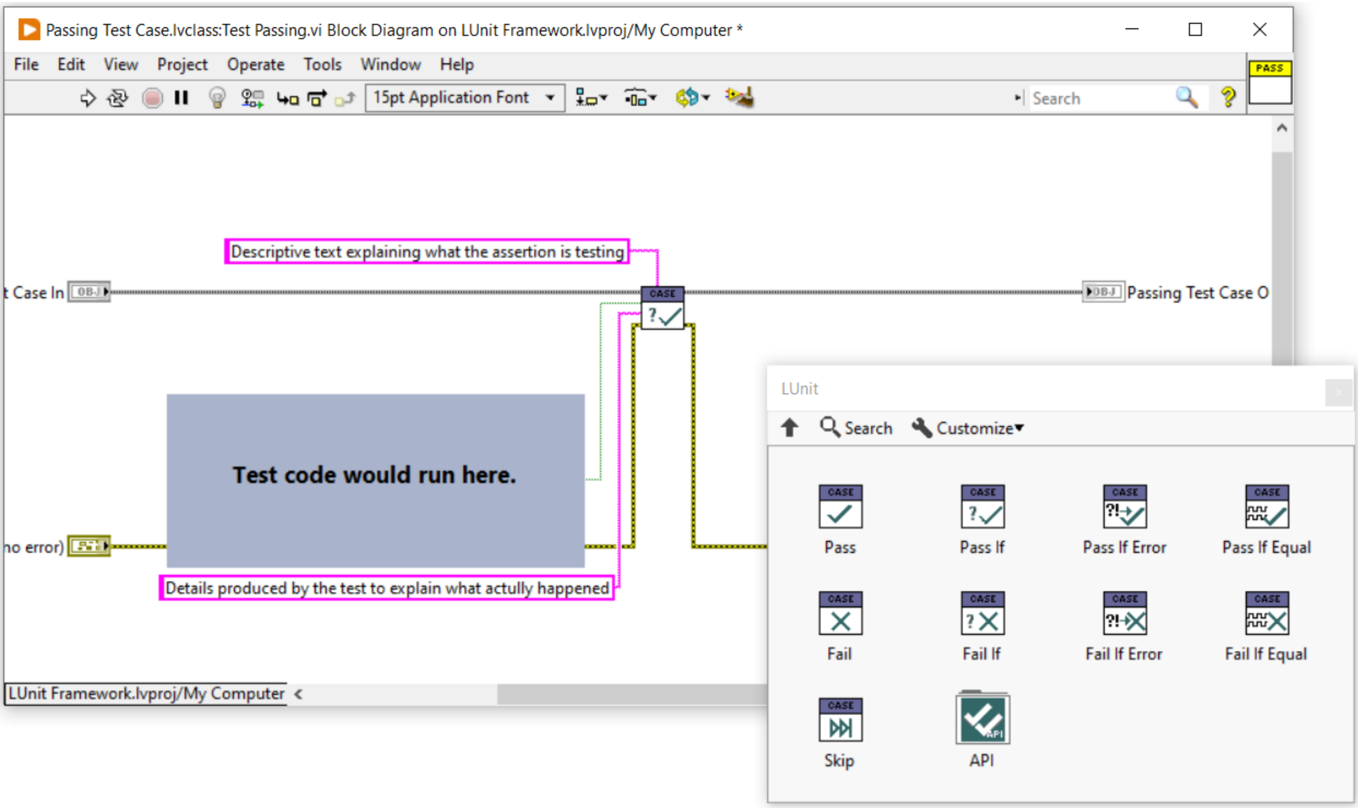
Now you have a test case and may add some test methods to the test case. A test method is a vi belonging to the test case class and will get executed by the framework.

To create a new test method, right-click on the Test Static Test Method.vit and select `New from Template`. **Important:** You need to save the test method using a name starting with the upper or lower case letters `test`.



You can create test methods any way you like and you are free to delete the template methods if you choose to. It is important however that the connector pane uses the same pattern of terminals as the template and that the name of the vi starts with the word `test`.

You should now make your test method test something useful by implementing the block diagram of the vi. To perform tests you will use the assertions available in the provided palette, or using quick drop.



1.4 Using Assertions

The result of each test is determined using assertions. There is a set of assertions to choose from, as shown in the figure above, and the names should be self explanatory. One test method may contain multiple assertions and the result from each assertion will show up in the result view.

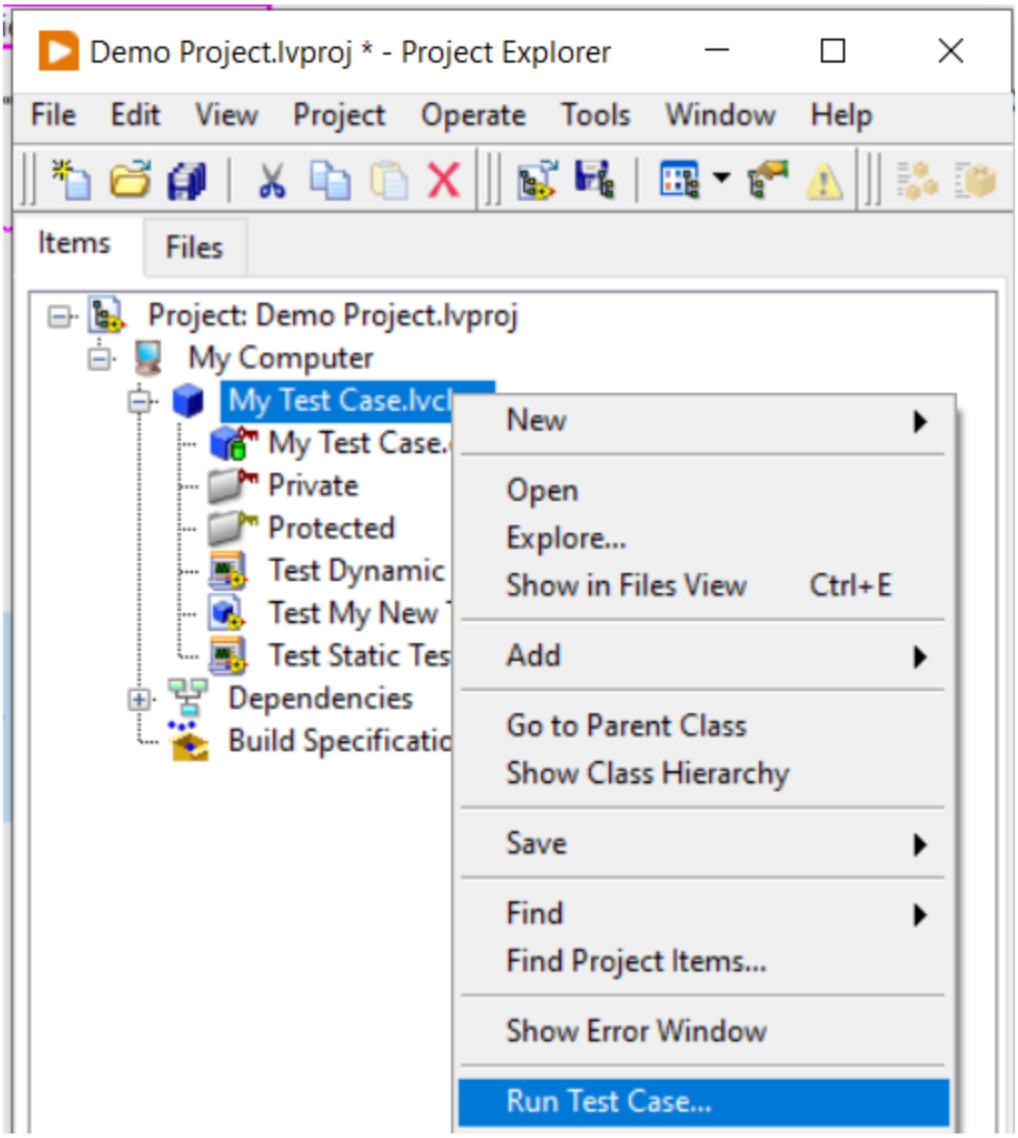
One pro-tip is that the `Pass if Equal.vi` assertion also works well for array data types. The result of comparing arrays will show up in the result view as shown below.

Please note that the `Pass if Equal.vi` assertion will fail if either the type or the value does not match.

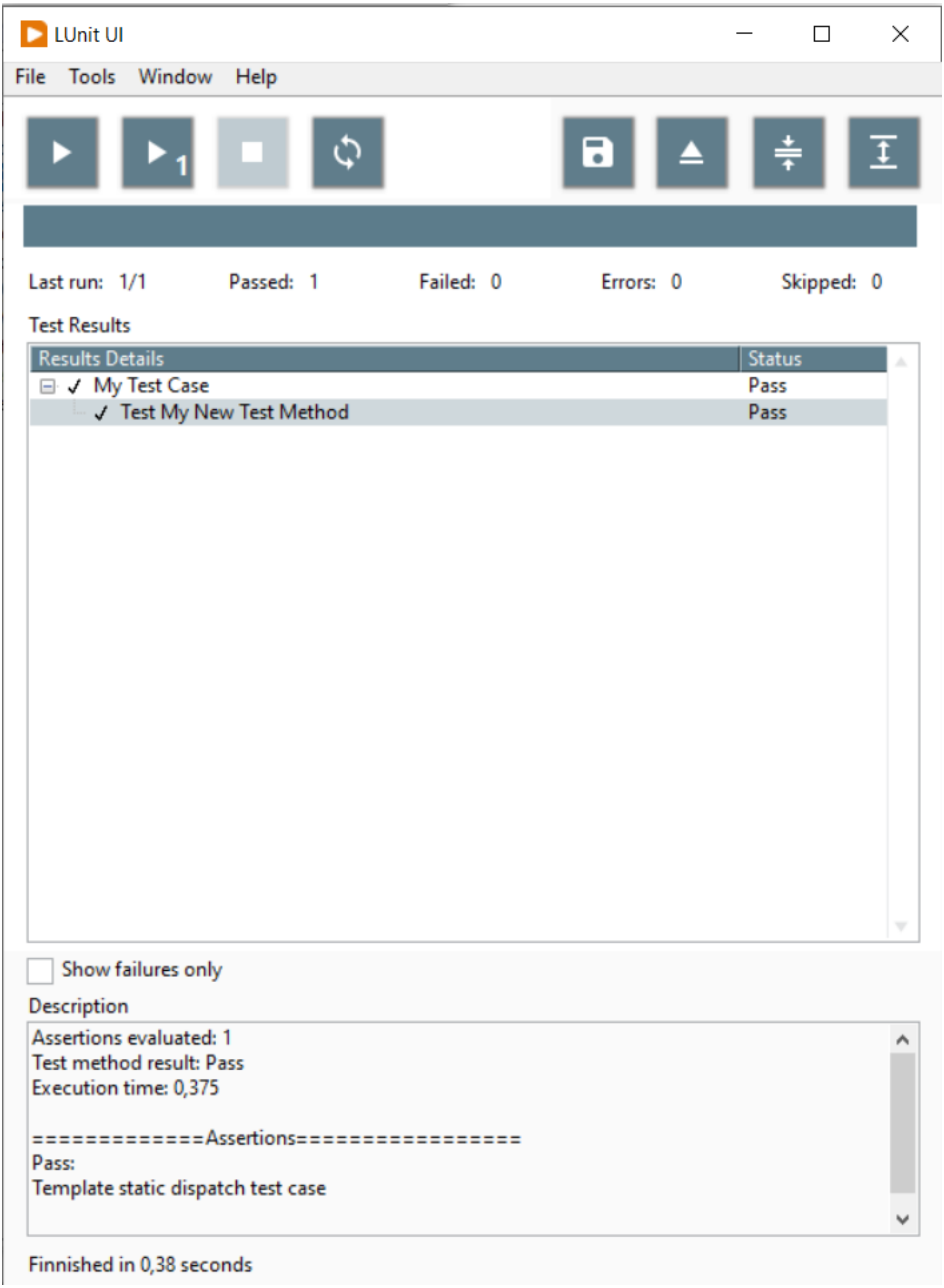
1.5 Running the Test Case

You can run a single test vi (using the Run Arrow) and it will run and show the user interface with the results of the test.

To run all tests contained in a test case, you can right click it in the project window and select the `Run Test Case...` menu option.

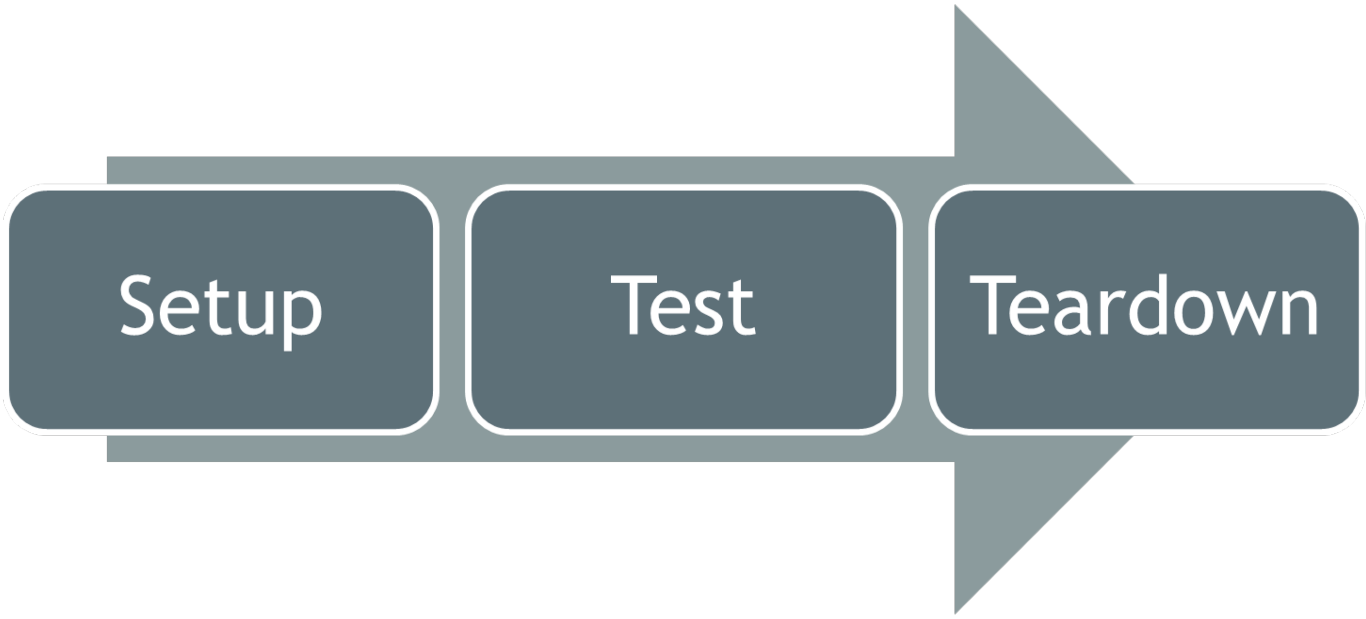


This will open the test execution user interface and run the test case. Alternatively you can also launch the user interface from the tools menu through the `Tools > LUnit > LUnit UI...` menu option. This will open the user interface and show all tests in the current project. As the test is run, the results are also shown as visual icons overlays in the project explorer.


LUnit UI
File
Tools
Window
Help
Last run: 1/1
Passed: 1
Failed: 0
Errors: 0
Skipped: 0
Test Results
Results Details
Status
My Test Case
Pass
Test My New Test Method
Pass
Show failures only
Description
Assertions evaluated: 1
Test method result: Pass
Execution time: 0,375
=============Assertions=================
Pass:
Template static dispatch test case
Finnished in 0,38 seconds

1.6 Using the Setup and Teardown methods

You can add a Setup and a Teardown method to the test case by overriding the corresponding dynamic dispatch vi:s. The Setup vi will run once before each test method in the test case and the Teardown will run once after the test method is completed. This is useful in some cases, but should not be overused as it makes the test methods less verbose. If you need to pass data from the Setup vi to the test method vi or Teardown vi, you can bundle the data into the test case class wire.

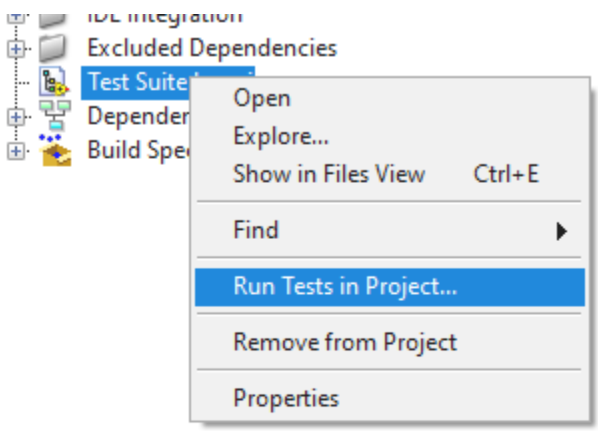


1.7 Organizing Tests

It does make sense to organize tests in some manner, especially as the number of tests increase. There are many common practices around where to keep tests and how to organize the folder structure on disk. In general it is useful to keep tests separated from the source, as there should be no dependency from the source on the test code.

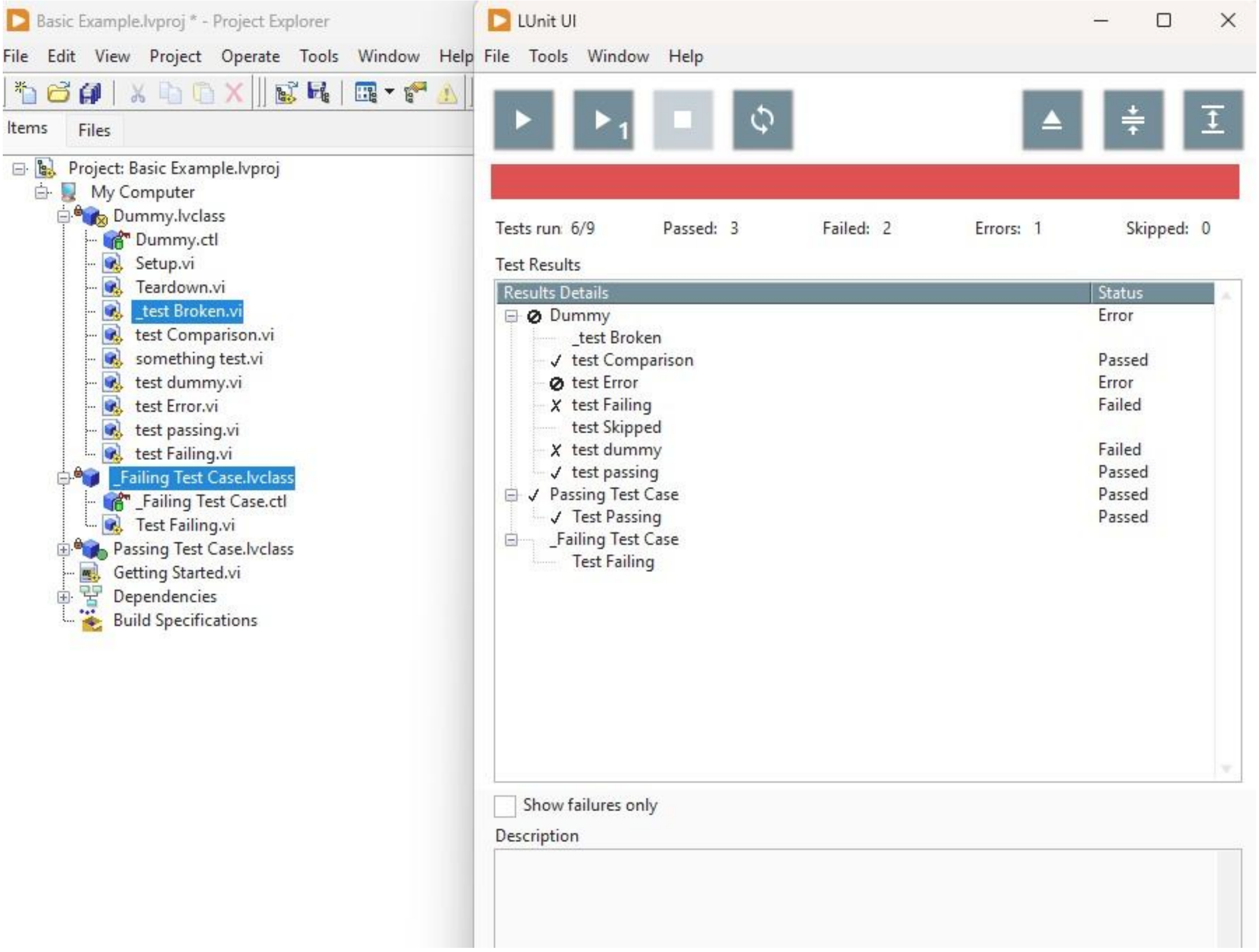
While developing, it is convenient to keep the tests within the active LabVIEW project, as they may then be run quickly through the project integration and you can run all the tests in the project through the tools menu option. As test suites grow, it becomes less convenient as the test time accumulates with larger test suites and some of the tests might not be relevant to the feature under development. While it is important to run the whole suite to catch regression issues, this does not have to be done as frequently as tests covering the new feature.

A good workflow is to keep a separate LabVIEW project file as a test suite where all tests are collected. Tests may be moved from the active project into this test suite and the test suite may then be added to the active LabVIEW project as a project item. All tests within the test suite project may then be executed using the right clikc menu option, but will not be executed when running all tests in current project from the tools menu option and will not need to be loaded with the project.



When executing tests in a Continuous Integration environment, this test suite LabVIEW project file is a good entry point for running tests.

In LUnit version 1.3.1, an additional feature was introduced to help speeding up test execution by skipping slow or unrelated tests. A test method (`vi`) or entire test case class (`lvclass`) may be marked with an underscore `_` character as the first character, making it into a `dashed` test class or test case. `Dashed` tests may be skipped when running through the user interface by using the menu option `Ignore Dashed Tests` as shown below.



Notice that the test "_test Broken.vi" and the entire "_test Failing Test Case.lvclass" were not executed during the test run in the previous image. By toggling the `Ignore Dashed Tests` menu option, it is straight forward to optimize test execution for either execution speed or test coverage. In a typical test driven development workflow, test execution speed must be very fast as the tests are executed repeatedly on time scale of minutes. It is however important to catch regressions by regularly running the full test suite, including the dashed tests. When running LUnit using the API, as would be the case on a Continuous Integration server, dashed tests are never skipped.

2. Framework Architecture

The LUnit unit testing framework is derived from the xUnit architecture. This page briefly introduces the main concepts. The core was rewritten as of version 1.2 and the discussion below is accurate only for versions more recent than 1.2.

2.1 General Architecture

The framework defines a Runnable interface, which, as the name, implies defines a class as runnable. The base Test Case class implements the runnable interface and an xecution of a test is done by instantiating an object of a Test Case class and running it. To run more than one test, multiple instances of the Test Case class are instantiated.

Multiple tests may be aggregated into a Test Suite object, which also implements the Runnable interface, and may be executed by calling the Run VI on the Test Suite. While a Test Case will always be done after one call to the Run VI, a Test Suite may require multiple calls before beeing done. Test Suites may form composites (suites of suites), but this is not visible through the Runnable interface.

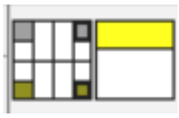
Test Suites are typically generated through test discovery using factory VIs located in the Test Suite class. These VI:s can generate test suites containing all tests in a specific class, library or project.

2.2 Test Case

A Test Case is the base class containing all test methods which are included in the test case. The Test Case class defines two dynamic dispatch test methods called Setup.vi and Teardown.vi. These methods are executed before and after each test method in the test case.

2.3 Test Methods

A test method is a VI belonging to a class inheriting from the Test Case class. The test method name must start with the letters `test` in either upper or lower case. The conector pane of the test case must use the 4-2-2-4 pattern and have the standard connectors for static or dynamic dispatch methods.



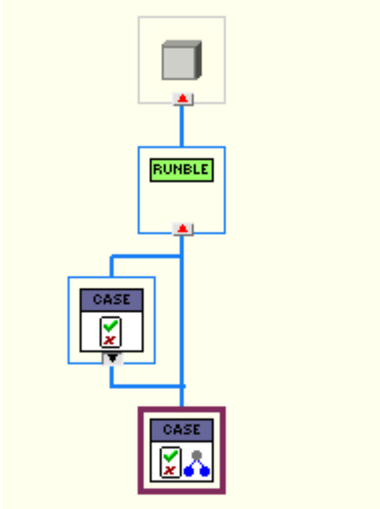
2.4 Static and Dynamic Test Methods

A Test Method may be implemented as either a dynamic or static dispatch vi, just like for any LabVIEW class. The concept is slightly overloaded by the LUnit framework to allow for minimal code duplication when testing class hierarchies.

A static test method will only be executed for the test case in which it has been defined.

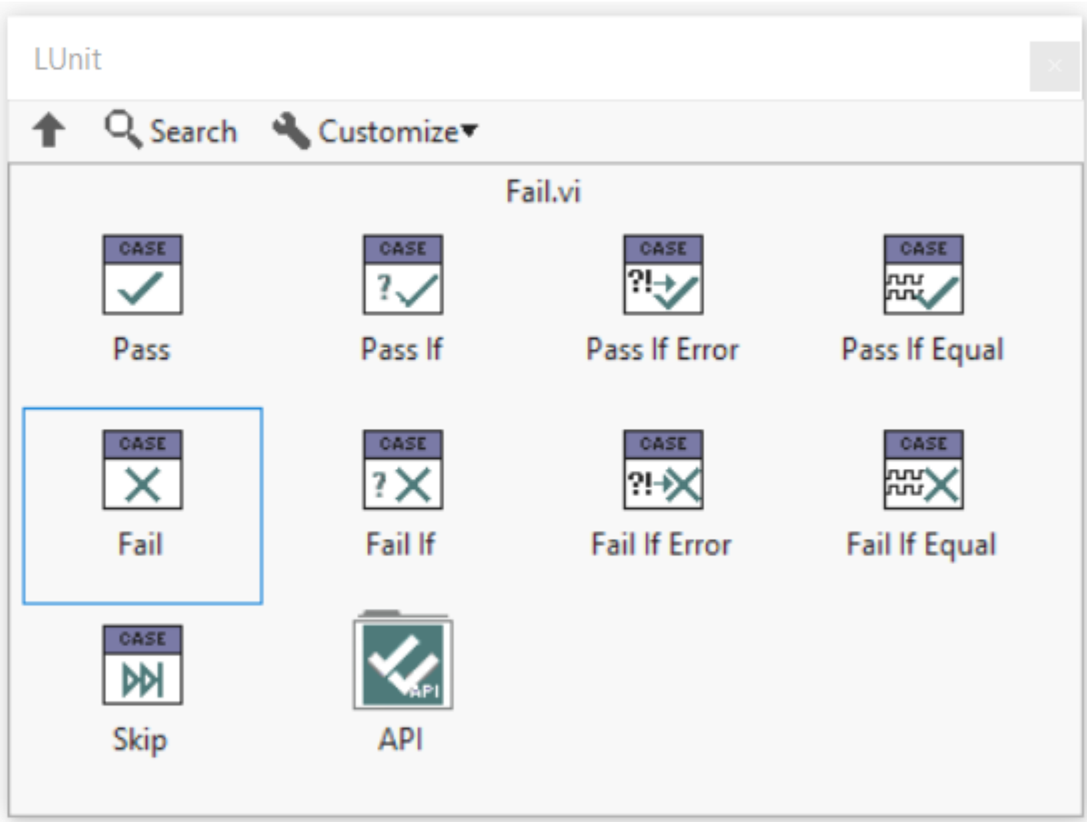
A dynamic test method will be executed for the test case where it is defined and for any test case inheriting from the test case defining it. For this to make sense, a dynamic dispatch test method will need some kind of mechanism for knowing the context which it runs within, *i.e.* what to test. A pattern used for this is illustrated in the example called `Test Inheritance`. In this pattern the class under test is configured by setting the class under test in the Setup.vi method

As of LUnit version 1.4, test cases using inheritance must descend from the `Inheriting Test Case.lvclass` located at *\<vi.lib>/Astemes/LUnit*. As the use of dynamic test methods is much less common than static methods, the complexity of handling test inheritance has been factored out into this class.



2.5 Assertions

Tests are evaluated by one or more assertions called in the test method. The assertions are available from the LUnit palette and the quick drop menu. Assertions are evaluated when the test case executes and the result of the assertions are reported by the framework. Multiple assertions may be used in a single test method and results from all assertions will be available in the test report. A test case will fail if one or more of the assertions fail. Likewise a test case will produce an error result if one or more of the assertions receives an error on the `Error In` terminal.



2.6 Test Runner

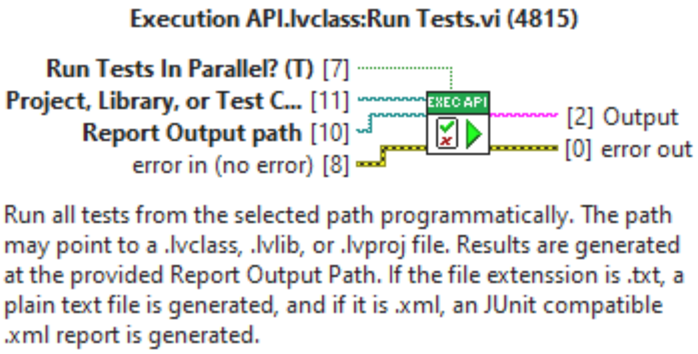
A test runner is a process executing a Test Suite and collecting the results. LUnit supports spawning multiple parallell test runners, which can significantly reduce the test time for large test suites. Test runners may run in separate threads and can leverage a multithreaded processor to run tests concurrently. When the Parallell Test Runner is enabled, tests are grouped into one suite for each Test Case class and all these are then executed in separate threads.

2.7 Test Finder

When launching the LUnit UI, the test finder searches for classes inheriting from the base Test Class within the current application instance. The result is saved into an index file and retrieved on subsequent runs to only search through classes which have changed since last time. To force the test finder to recreate the index, use the refresh test index button in the LUnit UI.

2.8 LabVIEW API

An API is provided for executing tests programatically from LabVIEW. The use of the API is illustrated in the `LUnit API Demo` example.



The API was simplified in version 1.2.6 and now only consists of one VI for running tests from a path. The reason for this change is that the low level API, provided earlier, had some sensitivity to internal changes and made updates more difficult.

The low level API is still used by the high level API method and the low level VIs may be used to alter the behavior of the test execution. Because of the low level nature, this API is more volatile and may break in later releases, while the high level method is very likely to remain stable.

2.9 Low Level API

Before going on, see the warning in the previous section. Now continue on yout own risk.

The low level API may be use to run tests in various ways. Tests are executed using the provided methods and results are returned using User Events, which may be registered for using the provided API method. To use the API methods, an API reference must first be obtained using the `LUnit Open API Reference.vi`. The configuration VI:s `LUnit Configure Reporting.vi` and `LUnit Configure Test Runner.vi` should be used before executing a test.

A test case is executed by calling one of the Run Test API VI:s. To observe the results of the test execution, the `LUnit Register for Events.vi` must be called before starting test execution. Results are returned using a data object through the user event registration.

When the execution has completed a result with type `Test Run` is generated. To abort a running test, use the `LUnit Abort.vi`. When done, use the `LUnit Close API Reference.vi` and unregister for any event obtained from `LUnit Register for Events.vi`.

2.10 Command Line Interface

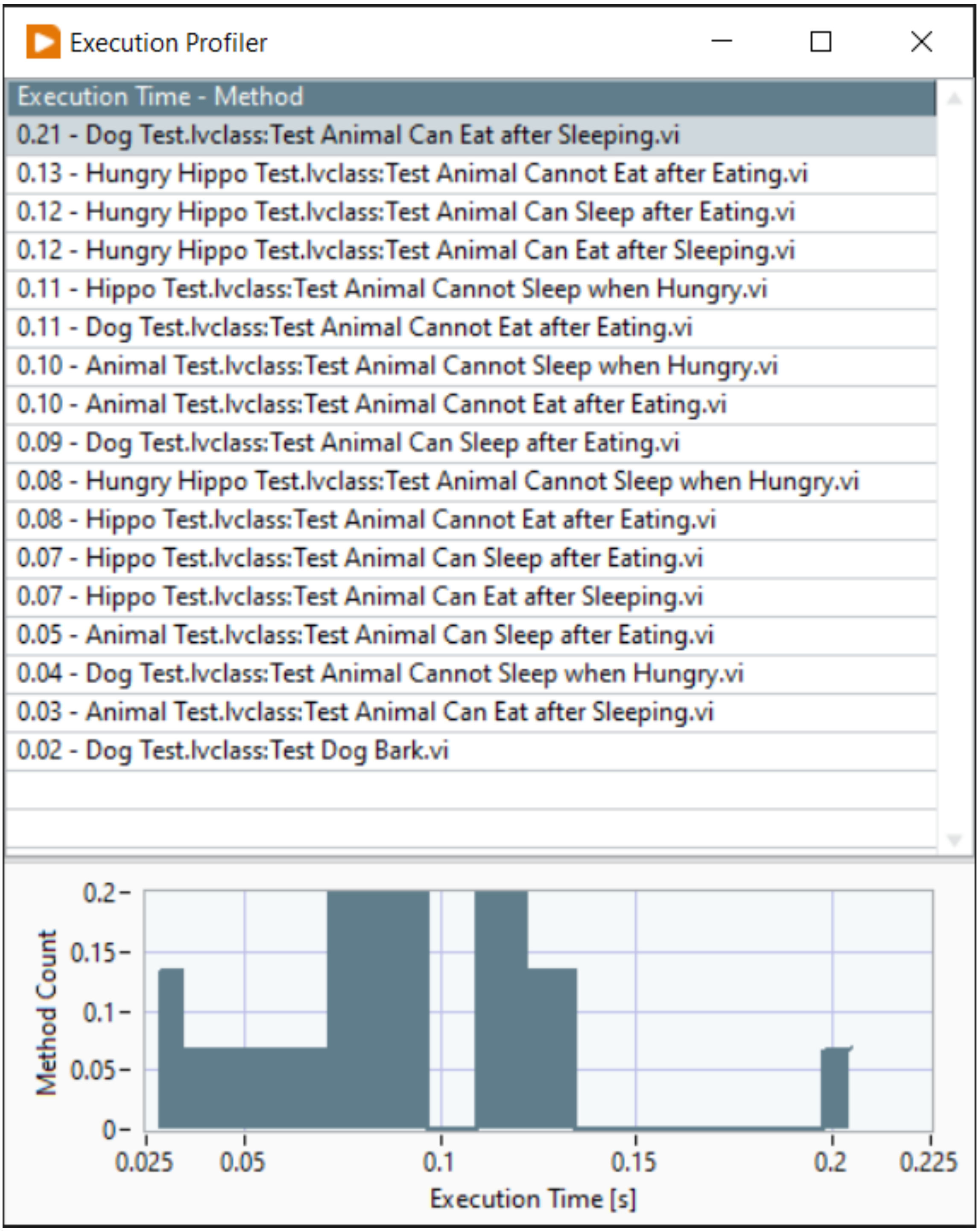
LUnit exposes a command line interface (CLI) to enable execution from continuous integration tools. LUnit adds an operation to the LabVIEWCLI when installed. Please note that LUnit must be installed for the version of LabVIEW called from the CLI.

3. Profiling Tools

LUnit has built in tools to help profile test suites. These tools are meant to be used to identify issues and locate parts needing improvement, but should probably not be used as hard benchmarking tools. The tools are enabled from the `Tools` menu of the LUnit User Interface and the results are displayed after test have been executed.

3.1 Execution Profiler

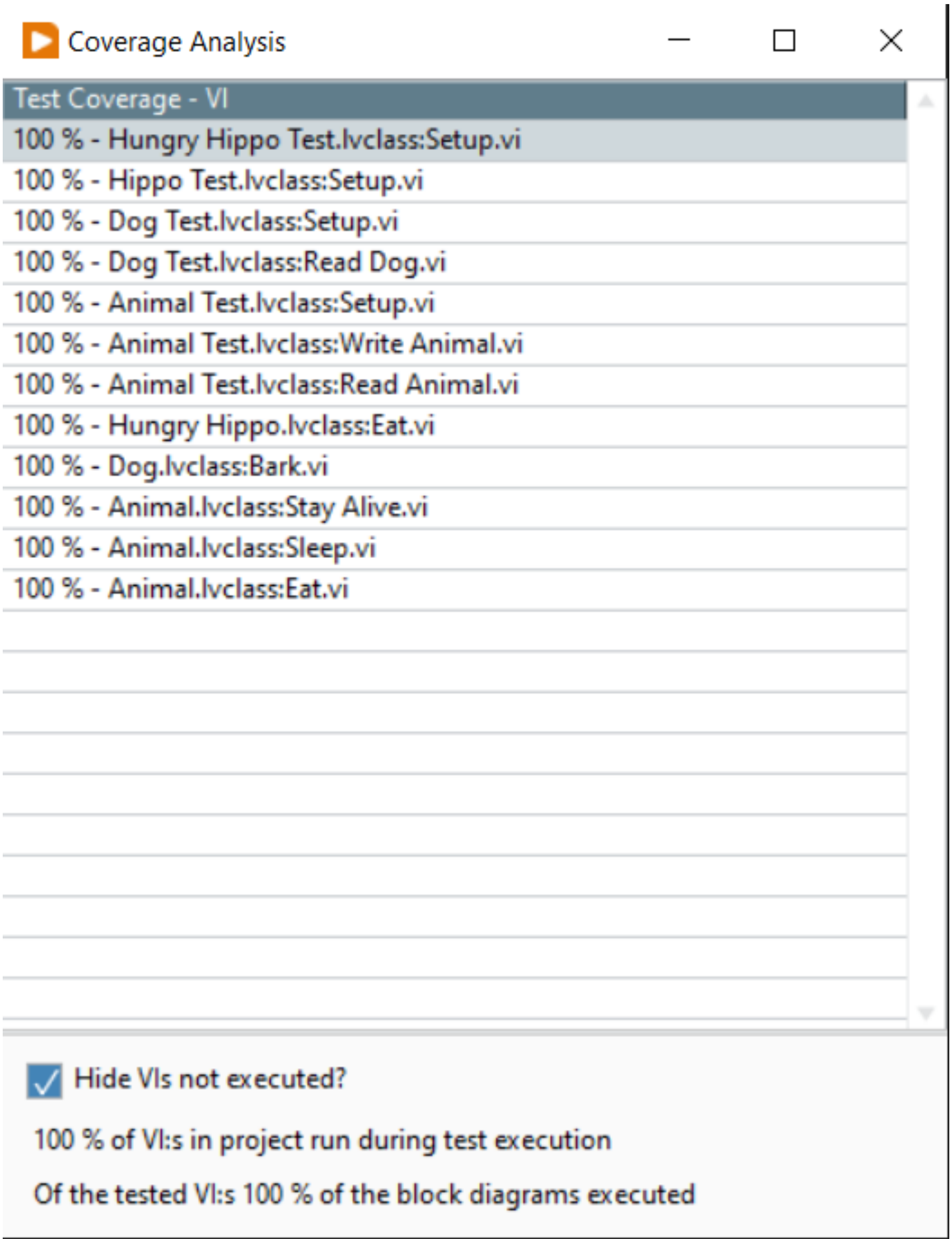
The execution profiler is used to profile the time each test method takes to execute. It is useful for identifying bottlenecks and improve the performance of a test suite. Once activated, the following window is shown after each test execution.



In the table, the execution time for the test and the test name are shown, ordered by test time. The histogram is useful to identify outliers and it is often these tests which have the biggest impact on the test execution time.

3.2 Code Coverage Analyzer

Analysis of code coverage was added as a feature in LUnit version 1.0.6. The code coverage analyzer is useful for identifying parts of the code which has low test coverage. The coverate is reported for each VI as a percentage indicating how much of the block diagram is exercised during test execution.



There are a few caveats to be aware of when using the coverage tool.

- The tool measures how many of the diagrams are executed in a VI as a percentage
- The reported coverage is zero for VIs which do not have debugging activated
- VIs in vi.lib are ignored
- Any VI with a name starting with `test` is ignored

Further, it is important to understand that the number obtained does not tell anything about the quality of the tests. It only reveals how much of the code is exercised by the tests. For a deeper discussion of the usefulness of the metric, please see this blog post.

4. CI Integration

LUnit was designed to easily and natively integrate into continuous integration (CI) pipelines. To achieve this, a way of executing tests from the command line is needed and the results need to be available in a format which may be digested by the CI system.

4.1 Executing Tests from the Command Line

LUnit installs a command line operation using the LabVIEW native LabVIEWCLI by NI. This operation is named LUnit and may be called using LabVIEWCLI -OperationName LUnit. An example ilustrating the useage of the CLI i provided at `...\LabVIEW 20XX\examples\Astemes\LUnit\LUnit CLI Demo.vi`. A path to load tests from is provided using the -ProjectPath argument and the report directory is specified using the -ReportPath argument.

When executing tests from the command line, the test case index is cleared and re-created by default each time. This ensures that all inherited test methods are detected*, at the expense of some overhead for test discovery. The `-ClearIndex` flag may be used to override this behaviour and re-use the index to improve the execution time.

Argument	Description
`-ProjectPath`	The project containing the tests to be executed. The interface also accepts libraries or test case classes of types .lvlib or .lvclass.
`-TestRunners`	Specifies the number of parallell test runners to spawn. Default value is 1.
`-ReportPath`	The output path for the report file generated. The execution generates either a .txt-file or an .xml-file, based on the path specified.
`-ClearIndex`	Clear the index and force LUnit to rediscover all tests. Default is `True`. The index must be cleared to find new tests inherited for a Test Case.

The LabVIEW CLI uses VI Server and by default it is configured to work on port 3363. You will need to make sure that the connection is not blocked by firewalls.

4.2 Capturing the Test Results

Test results are saved in a text based format at the location specified when executing the command line operation.

LUnit has a built in xml-format for test reports which is using the same structure as the one used by JUnit testing framework and specified here. To use the JUnit xml format, you must provide a file path with the `.xml` extenssion. Once the tests have finished, the result file is available at the specified path. File may now be digested by most CI tools. For Jenkins this is done using the JUnit plugin.

4.3 Jenkins Example

Jenkins is a popular open source automation server used for continuous integration and delivery pipelines. A pipeline in Jenkins may be configured using a declarative Jenkinsfile which may be saved directly in the repository. Below is an example showing a basic configuration.

```
pipeline {
    agent any
    environment{
        LV_PROJECT_PATH = "Path to Your LabVIEW Project.lvproj"
        NUM_TEST_RUNNERS = "1"
        LV_PORT = "3363"
    }
    stages {
        stage('Unit Tests') {
            steps {
                bat "LabVIEWCLI -OperationName LUnit -ProjectPath \"${WORKSPACE}\\${LV_PROJECT_PATH}\" -TestRunners ${NUM_TEST_RUNNERS} -ReportPath \"$
{WORKSPACE}\\lunit_reports\\lunit.xml\" -ClearIndex TRUE -PortNumber ${LV_PORT} -LogFilePath \"${WORKSPACE}\\LabVIEWCLI_LUnit.txt\" -LogToConsole true -
Verbosity Default"

                junit "lunit_reports\\*.xml"
            }
        }
    }
}
```

The pipeline above declares three environment variables used to configure the call to LUnit using the LabVIEW CLI. The first is the path to the project file relative to the workspace, *i.e.* the path relative to the root of the repository where the Jenkinsfile is located. The second is the number of parallell test runners to spawn, here configured to one. The third parameter is the port configured for VI server in LabVIEW under Tools->Options->VI Server.

The report is saved in the path `lunit_reports` using the file name `lunit.xml` with incrementing index. After the execution of tests using the bat command the junit plugin is called to digest the report files generated. This requires that the Jenkins JUnit plugin is installed, which it is by using the recommended default settings when installing Jenkins.

Note that this is a minimal example meant to demonstrate the concept. It could be improved significantly to reduce the details in the Jenkinsfile using shared libraries. As an example, the build system used to build LUnit uses a simpler command `runLUnit "${LV_PROJECT_PATH}"` in the Jenkinsfile in stead of the rather detailed `bat` command.

4.3.1 * Footnote on Test Finder indexing

The test finder keeps an index of all test methods for all test classes in the project. When the test finder is started, it loads the index and compares all classes to the index. If the classes has changed since the index was created, the class will be re-indexed. As of version 1.0, the test indexer will however not re-index a class when a parent class has added a dynamic test method. To detect new inherited dynamic method the test index must be re-created, which happens when the `-ClearIndex` flag is left at default value `True`.

5. Real-Time Systems

A good rule of thumb is to only write tests for the code which you want to work. Thus, code running on a real time system does in general qualify for testing. And it is particularly useful to test the code outside production as debugging and troubleshooting a real-time target can be very painful.

5.1 Testing with hardware

Any kind of input/output (IO) is problematic when writing test code. In LabVIEW we typically have IO in the form of user interfaces, hardware drivers, and possibly some databases and files. When running tests on code coupled to IO of some sort, it is in general worth separating the code at the boundaries to test the IO communication separtely from the rest of the application. There are many reasons for this including:

- Testing with hardware requires you to have the hardware setup in order to run the tests. This might not be convenient or even feasible in many cases.
- Including hardware, and the configuration of it, adds a large chunk of complexity as there are more things that can fail.
- Hardware communication adds significant overhead to the test time.
- If the hardware is hidden behind an abstraction, it may easily be replaced.
- Replacing hardware IO with a test double ensures determinism when running the tests.
- Testing that the driver works does not add much value in an automated test environment.

How to use test doubles to avoid testing with real world IO is an interesting topic, but beyond the scope of this document.

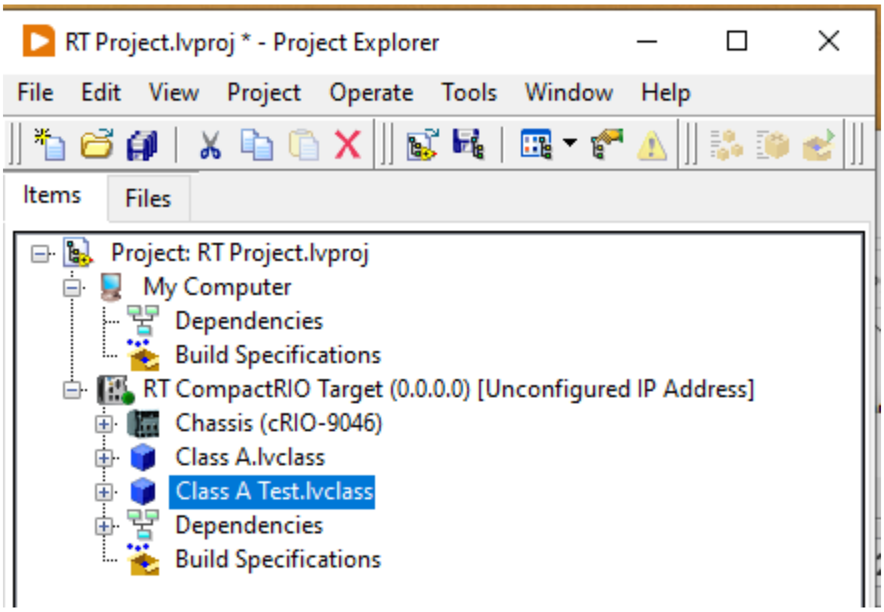
5.2 About running tests on a Real-Time target

While it is very important to test the code on actual hardware, it does not make sense in most cases to run unit tests on a real-time target. To do so would slow down test execution and requires access to the target during development. There are some differences and peculiarities to keep in mind when executing code in an RT environemnt, *e.g.* file paths and unsupported features, but apart from that the code should work the same as under Windows. This means that a failing test under Windows should fail on the RT system as well. Even if the reverse is not allways true, it is often best to assume it is and fall back on debugging when it is not. If running tests on the RT system is necessary, please see this section

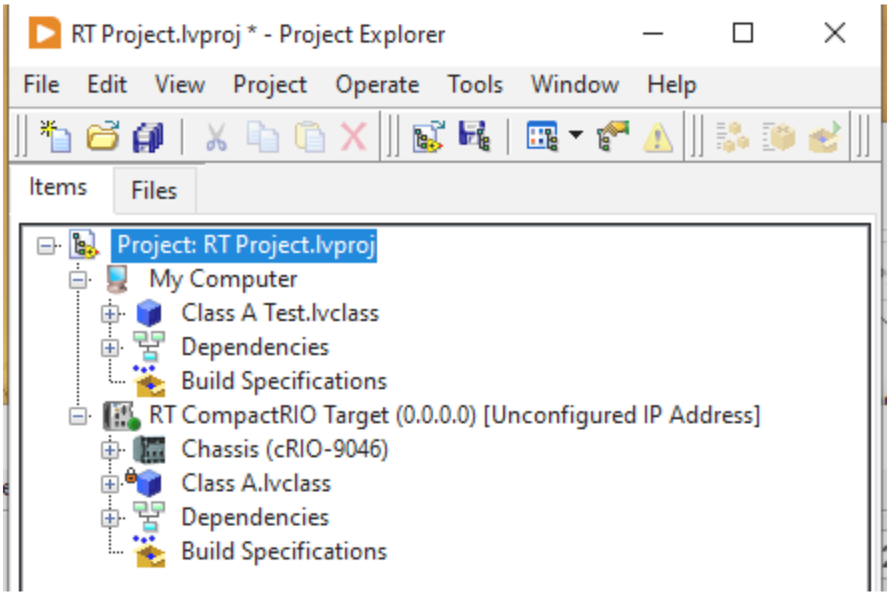
5.3 Working with tests in LabVIEW Real-Time

It is somewhat more tedious to work with tests for code on a LabVIEW Real-Time target compared to vanilla LabVIEW. One reason for this is that libraries gets locked when opened in multiple application instances, and this would happen frequently when developing code on an RT target and testing under Windows. Additionally the code needs to be recompiled for the different targets.

A direct approach would be to keep the test case under the target and run it as normal using the UI.

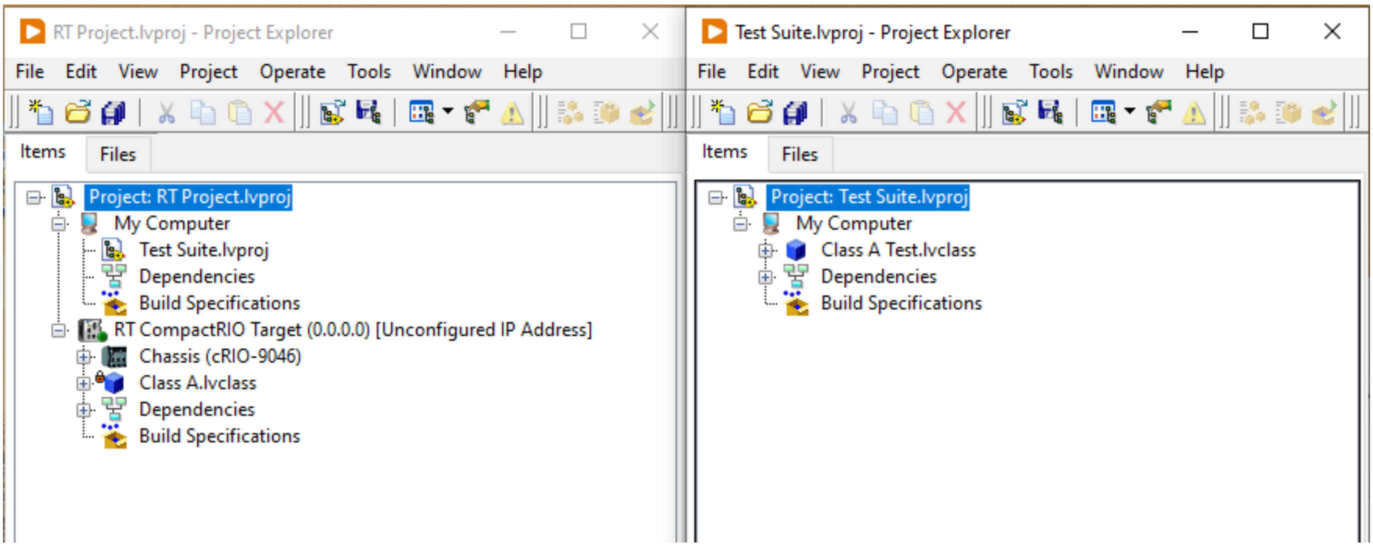


This works in principle, but LabVIEW will recompile the code for each test execution and is for this reason rather slow. This recompilation can be avoided by moving the test case to the My Computer target.

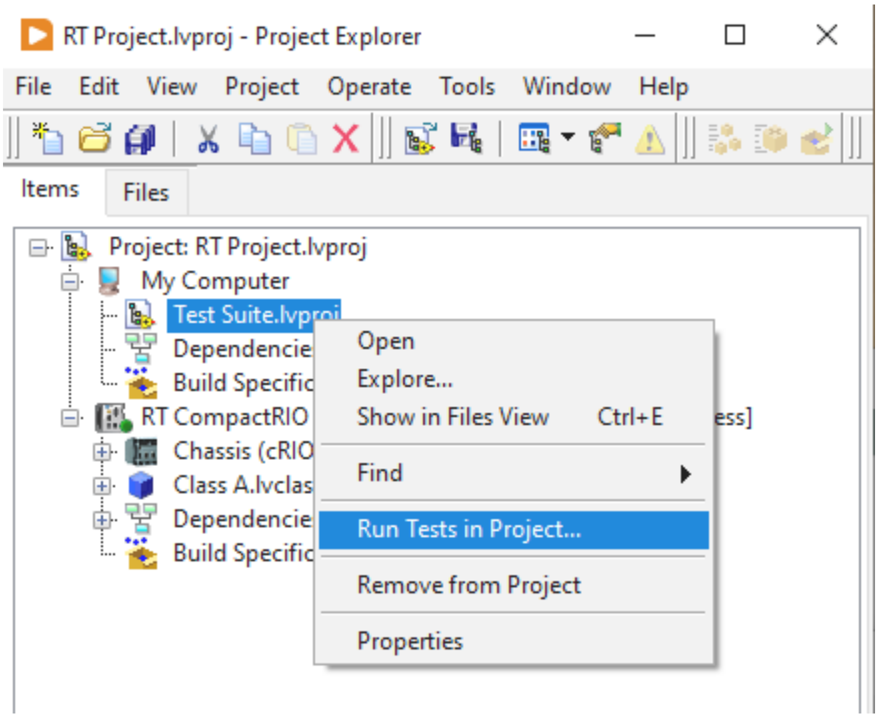


This speeds up the loading of the test as compilation is avoided, but it comes at the cost of locking the class under test. The lock occurs because the test case depends on the class under test, which is then loaded into two separate application instances.

To solve this we can create a new project file to contain the tests and add this to our main project as a project item.



As the project file is treated as a text file by LabVIEW, it will not load anything into memory when added to the project. This implies that the class under test will not be locked unless the test suite is also in memory. The test suite may then be run from the right click menu and tests will not need to be recompiled on subsequent test executions. There will however be a smaller overhead from loading the project into memory when running the tests. Please note that this feature requires LUnit version 1.0.5 or higher.



5.4 Running LUnit on a Real-Time target

There is nothing preventing LUnit from running in a Real-Time environment. However, the Test Execution UI will not be able to run on the target as it uses front panel events not available under LabVIEW Real-Time. Instead the LUnit LabVIEW API should be used to execute tests and collect results when the tests must run on the Real-Time target.

6. Creating Report Plugins

LUnit was designed to be extendable through plugins and a lot of the features of LUnit are implemented as plugins behind the scenes. If you'd like to create your own reporting plugin, this can be done following the guide below. The only requirements for a reporting plugin is that it implements two specific interfaces and is placed in a specific folder within vi.lib.

6.1 Getting started

To create a custom reporting plugin, you will need to create a class inheriting from `LUnit Report.lvclass`. This parent class implements the `LUnit Report Interface.lvclass` and `LUnit Plugin.lvclass` and these will therefore be inherited. The later plugin is a legacy dependency and the plugin methods does not need to be implemented. The dependency on `LUnit Plugin.lvclass` will be deprecated in a future release, but this will not break integration of classes implementing it. The easiest way to get started is to copy one of the existing plugins, which are located at `C:\Program Files (x86)\National Instruments\LabVIEW 202X\vi.lib\Astemes\LUnit\plugins`. It is recommended to use LabVIEW 2020 to ensure backward compatibility.

6.2 Implementing the Report Interface

The report interface is very simple and is called into by the report generator. The `LUnit Open Report File.vi` is called when a new test execution is started, `LUnit Handle Result.vi` is called on the fly for each result generated, and `LUnit Close Report File.vi` is called when the execution is done.

It is important to understand the different types of results which are sent to the `LUnit Handle Result.vi`. Please refer to the Framework Architecture document and the unit tests in the LUnit project fot the native report formats.

6.3 Deploying your plugin

To deploy the plugin, it should be placed in the plugin directory at `C:\Program Files (x86)\National Instruments\LabVIEW 202X\vi.lib\Astemes\LUnit\plugins`. The plugin name should begin with the `LUnit` prefix. The `.lvclass` file should be directly in the `plugins` directory, but the member VI:s of the class will need to be placed in a sub directory to avoid naming conflicts.

After doing this, the plugin should appear in the drop-down menu in the reporting configuration dialog. To automate this, making a VIPM package is recommended and sharing it with the community through VIPM is encouraged.

7. License

7.1 Astemes LUnit

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