Virtual Testing Framework for Industrial I/O modules

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Motivation

The development of I/O modules is a complex process that we can typically divide into hardware and firmware development. The efficiency of this process significantly impacts the profitability of the projects and, therefore, of the Company for which the product of this thesis was created.

Efficiency in development is closely tied to the quality and frequency of testing the modules under development. In fact, inefficiencies in the testing process are the most common reasons for project delays and budget overruns. Furthermore, time and hardware limitations often prevent comprehensive testing of various edge cases, potentially causing issues in production and undermining customer trust.

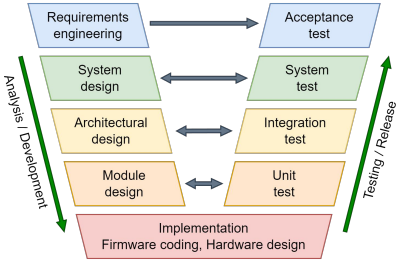
To deliver high-quality products, a rigorous and time-consuming testing process comprising four phases must be completed. Industry standards dictate that if a bug is discovered, the testing process must restart from the beginning, consuming substantial resources and often causing significant delays.

This thesis examines the testing process and its inefficiencies, proposing a virtual testing framework designed to mitigate these issues by enhancing the quality, frequency, and accessibility of testing.

Testing process of the I/O modules

Test phases

The testing process consists of four main phases, each with its specifics and goals. To understand the process as a whole and identify its inefficiencies, it is necessary to understand the following facts about each individual phase.



The CI/CD pipeline is the first phase of the testing process and does not require any physical hardware. However, it offers very limited options to test the functionality as it can only test one individual component at a time.

Integration testing is performed by a specialized team of testers using a physical module's HW. The goal is to test the interoperability of the individual components of the module.

System testing is required to be performed by an independent organization without any knowledge provided by the developers. This phase is crucial for ensuring the proper functionality of the final product.

Acceptance testing is the final phase prior to putting the product on the market. The goal is to verify the electrical safety of the product and receive the required certifications.

Virtual Testing Framework

Requirements for the VT framework

The final set of requirements for the VT framework was derived from the requirements of the developers, testers, and the Company's management. After a thorough discussion and analysis, the following requirements were created for the VT framework project:

Easily applicable: The VT framework should be applicable in the early stages of the project in 2-3 weeks and allow the developers to start with the firmware development even before the hardware is available.

Integration with the CI/CD pipeline: Virtual testing should become part of the automated testing process to maximize the frequency of testing.

Improved quality of testing: The VT framework should allow developers and testers to control the module extremely precisely and verify its behaviour in edge cases and under different conditions that are impossible to achieve with the physical hardware.

Lower the necessary resources for testing: The goal of the VT framework is to lower the necessary resources for testing by improving its quality and efficiency.

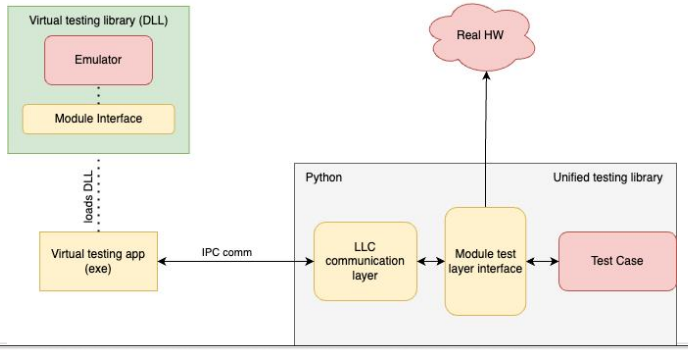
Software architecture of the VT framework

To fulfill all the requirements for the VT framework, the architecture is based on a client-server model, where the server is responsible for managing the virtual testing environment and the client for running the test cases.

The architecture of the VT framework is composed of three main components:

- **Virtual testing library(DLL):** A layer responsible for wrapping the technology part of the module and allowing the code to be compilable and executable on the Windows platform while allowing access to the technology code of the module.
- **Virtual testing app (Server):** An exe application that can load the DLL and manage the communication between the emulator and the testing client.
- **Testing client:** Any testing client used within the Company and implements the pre-defined interface for the VT framework.

This concept allows us to run the same test cases as on the physical hardware without any changes and perform integration testing with no physical hardware.

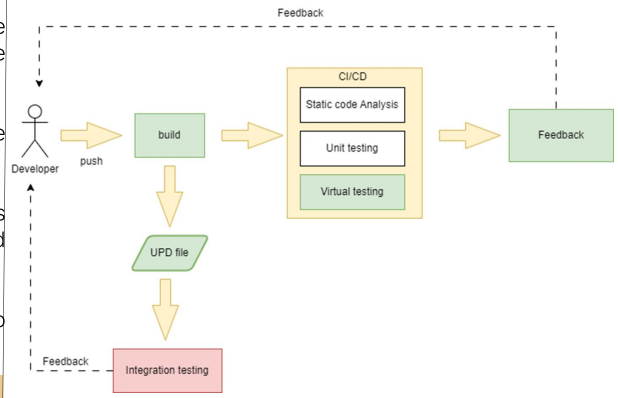


Results & Usage

Usage

The primary advantage of the VT framework is that it provides developers with frequent and detailed feedback comparable to the results obtained from integration testing performed by specialized testing teams.

This frequent testing is achieved by integrating the VT framework into the CI/CD pipeline, where virtual testing has been added as an additional step alongside existing steps such as static code analysis and unit testing.



Result

The implementation of the VT framework across multiple projects has demonstrated a positive impact on the development of the IO module. The results of this experiment indicate that the VT framework effectively enables developers to test newly implemented code within the same scope as integration testers, even without physical hardware. Early detection of bugs during testing leads to significantly increased efficiency and improved code quality, which results in lowering necessary resources and avoiding project delays.

Conclusion

The implemented solution effectively mitigates inefficiencies in the testing process, improving code quality while reducing the resources needed for testing. That is accomplished through a complex architecture composed of three individual components, which enables us to run the same test sets used for the integration testing on physical hardware.

The trial usage of the VT framework also shows a significant decrease in the number of bugs discovered in the later phases of the testing process.

Consequently, the risk of project delays and budget overruns is substantially reduced, providing considerable business value for the company.