Achieving High Quality Software

in the Renesas Synergy™ Platform SSP

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Contents

Introduction

A major thorn in embedded software developers' sides has been that the microcontroller manufacturer traditionally provides functional example code on how to use the microcontroller that is thrown together and is very low quality. Teams all around the world are forced either to base their products on low quality software that was never intended for a production environment or to write their own code from scratch that then increases their development times and budgets.

Renesas is taking a unique approach to assist product developers by providing fully warranted driver and framework code that has gone through a mature software development life cycle (SDLC) and software quality assurance (SQA) process that uses verifiable metrics to ensure that the drivers and framework code that are in the SSP are high-quality and usable in a certifiable embedded system. Most software claims to be high quality but does not really provide any data to back up such claims. If a development team needs to prove that the software is high quality, claims without any data won't help and great effort will need to be undertaken to acquire the data.

Software quality must be built into the software from the very beginning. Quality cannot be added near production through rigorous testing but must be on the development teams' minds throughout the entire development process. Quality software requires:

- Verifiable metrics
- A disciplined development team
- A well thought out design and architecture
- Testing built in at every stage
- Requirements traceability
- Code and design reviews
- Following industry recommendations and best practices

The Renesas Synergy SSP has been developed under these conditions in order create a first-class software solution for embedded systems developers. This white paper will examine a few key concepts on how Renesas achieves a high-quality SSP.

Customer and Business Benefits from Quality Software

Nearly everyone has had an experience with a product that either required the device to be periodically restarted or just plain did not function correctly. When customers are presented with a fine-tuned system that is based on stellar quality, they receive not only a superior end-product that results in greater satisfaction but the business brand becomes stronger and the perceived and actual value from the product dramatically increases. Quantifiable quality isn't just important to the end user but also to businesses that need to use the software to build their own certified devices.

Businesses often overlook software quality benefits because most development teams are not using verifiable metrics that allow them to quantitatively observe the benefits that their organization is gaining. There are many benefits that an organization receives through developing and using high-quality software. First, businesses and products become more flexible, portable and reliable which results in shortened product development times and on-budget deliveries. Low quality software often vexes developers because they are constantly debugging, fixing and reworking the software which adds delays to the project and results in budget overruns. Utilizing high quality software, especially drivers and framework code can provide a foundational platform for product development that allows developers to focus on their key differentiators along with providing predictable resource and schedule planning for the development cycle.

The Software Development Life Cycle (SDLC)

The software development life cycle manages the software product from requirements through its end-of-life. This includes design, implementation, verification, release management and software maintenance. Just following a SDLC though doesn't mean that the software is guaranteed to be quality. There are several key aspects that Renesas includes in their SDLC for the Synergy SSP that set it apart from any other microcontroller manufacturer.

First, the SSP was developed using a complete SDLC that is governed by the ISO/IEC/IEEE 12207 specifications for a SDLC. This is the same process specification that is used as a baseline for safety critical SDLC's such as industrial controls IEC 61508. Reputable software developers such as NASA and the U.S. Department of Defense also use this same specification.

Second, Renesas has integrated a robust verification system into their SLDC that includes code reviews and unit test development. Code reviews are the most efficient way to discover bugs within software. Creating and managing test development helps to ensure that the continuous integration server is checking and validating the software daily. Any non-conformance to the SSP specifications becomes immediately known and can be resolved before being released to the Synergy Platform users.

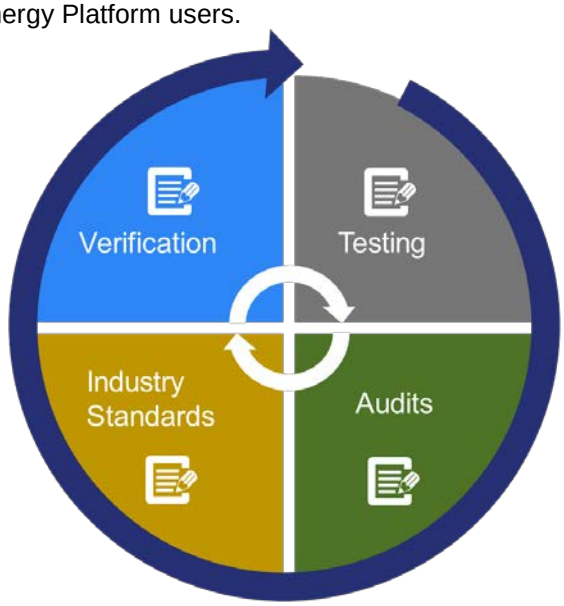

Figure 1 – SLDC is a continuous process

Finally, the SSP is maintained just like any software product that requires high reliability. The SLDC undergoes audits with the development process being continually improved. The SSP undergoes release management and management and the entire process repeats as the SSP adds new features and adapts to changing market conditions.

The conditions under which the Synergy SSP were developed makes it such that developers using the platform can easily speed up their system certification using the documentation that the Renesas Synergy team has put together on how they manage the SSP software life cycle. This can dramatically decrease certification times when working with government bodies and save budget from having to develop the documentation internally.

The Five Key Software Quality Metrics

Nearly any developer or team that someone might speak to will tell you that they create quality software. The problem with these statements is that that don't have any verifiable metrics that are established and compared against to ensure that the software is indeed achieving the desired quality level. Renesas has established five key software quality metrics that the Synergy SSP is continuously monitored against in order to ensure the highest quality levels. These metrics include:

- Meeting coding standards
- Maintaining low complexity levels
- Establishing traceable requirements
- Clean builds
- Achieving full test coverage

Let's examine each software quality metric in greater detail.

Meeting Coding Standards

A coding standard is a documented agreement containing technical specifications or other precise criteria to be used consistently as rules or guidelines to ensure that materials, products, processes and services fulfill their purpose. The embedded software industry has several different coding standards that are often used in order to ensure that not only software quality is high but that common issues and potential bugs are avoided. These standards include MISRA-C and Cert C along with Renesas specific standards and style guides.

MISRA-C was developed by the Motor Industry Software Reliability Association (MISRA) which provides a set of guidelines for programming high reliability systems. MISRA-C provides mandatory and advisory rules which are designed to:

- Avoid bugs due to differences in compiler implementations
- Circumvent code constructs that are prone to failure or commonly misunderstood
- Produce maintainable code that can be debugged
- Provide industry best practices
- Limit the code complexity in order to reduce development and maintenance related issues.

Cert C on the other hand is a coding standard that contains rules and recommendations that if followed will prevent exploitable security vulnerabilities in the software. In general, violating the standards recommendations can create conditions in which the software can be attacked and exploited. Devices that are going to be connected to the internet especially need to make sure that they follow this standard.

Many development teams that are writing their own drivers or worse, using the microcontroller manufacturers source code don't follow a standard and even if they do, lack the internal processes to verify that they are meeting the standard. In order to ensure the highest quality level possible, the Synergy SSP is checked against both MISRA-C and CERT C standards through code reviews and static analysis to ensure that the SSP code meets these industry best practices which results in a higher reliability level but also a higher quality level as well.

Maintaining Low Complexity

The human mind can only keep track, on average, between 7 – 10 pieces of information at any given time. The more complex a software function becomes, the greater the chances that the code will be not just be difficult to follow but will also contain software bugs. Renesas uses a well-known complexity measurement, the Cyclomatic Complexity measurement, to ensure that SSP functions are within an acceptable complexity level in order to reduce complexity, bugs and improve readability.

Cyclomatic complexity quantitatively measures the number of linearly independent paths through a software function. It turns out that the Cyclomatic complexity measurement also provides a lower bound for the minimum number of test cases that must be ran on the function in order to fully test it. The software industry has shown that the higher the code complexity, the greater the debugging effort required and also the less reliable the software

can be. Table 1 demonstrates the correlation between different complexity measurements and the risk to the software's reliability. The Renesas SSP target is for all functions to have a complexity measurement at or below ten.

Complexity	Reliability Risk
1 – 10	A simple function, little risk
11 – 20	More complex moderate risk
21 – 50	Complex, high risk
51+	Untestable, very high risk

Table 1 – Complexity versus Reliability Risk

Complexity doesn't just impact the quality from a reliability stand-point but also from a maintenance stand-point. The higher the complexity, the greater the risk is of injecting a bug when changes are made to the software. Table 2 shows the correlation between the complexity measurement and the risk for injecting a bug into the software when a change is made. Once again, the Renesas SSP target is set at ten or below in order to minimize the risk that there are software bugs in the function to begin with and to ensure that the chances are minimized that they will be added during maintenance.

Complexity	Risk of injecting a bug when making a change
1 – 10	5%
11 – 20	20%
21 – 50	40%
51+	60%

Table 2 – Complexity versus Maintenance Risks

The Cyclomatic Complexity metric is quantitative and verifiable which allows the Renesas Synergy team to ensure that a high software quality level is not just achieved but also maintained through-out the entire software life cycle.

Traceable Requirements

An important aspect of quality that is often overlooked is the need to be able to trace the software requirements throughout the entire software development life cycle. Requirements tracing is not a singular step that occurs when the product is tested right before it goes into production. Requirements tracing begins the moment a requirement for the software is created.

When requirement is added to the Renesas SSP, test cases are immediately created that will be used to verify that the requirement for the software is met. These test cases trace back to the requirement for which they are designed. Each test case will then require at least one test script that will run on a continuous integration server to ensure that the test cases are satisfied that verify the requirement.

The Renesas SSP isn't developed over night but is created through a process that takes considerable time. Each night, the SSP is tested and verified on a continuous integration server that runs the test scripts along with a suite of metric analysis. Each time the test scripts are executed, a new test execution instance is assigned to them which also output any defects that are found. Each morning the development team is able to review the previous night's results and determine if any changes from the previous day broke anything or if any new features didn't' quite meet the requirements for the software.

This entire process allows the requirement to be fully traceable through-out the development cycle. A single defect can be traced back to the test execution instance, the test script that ran and was verifying a test case that was generated to verify an initial requirement. This history can also then be used to track defects and examine the development process that can then be used to fine-tune it further which results in ever higher quality software.

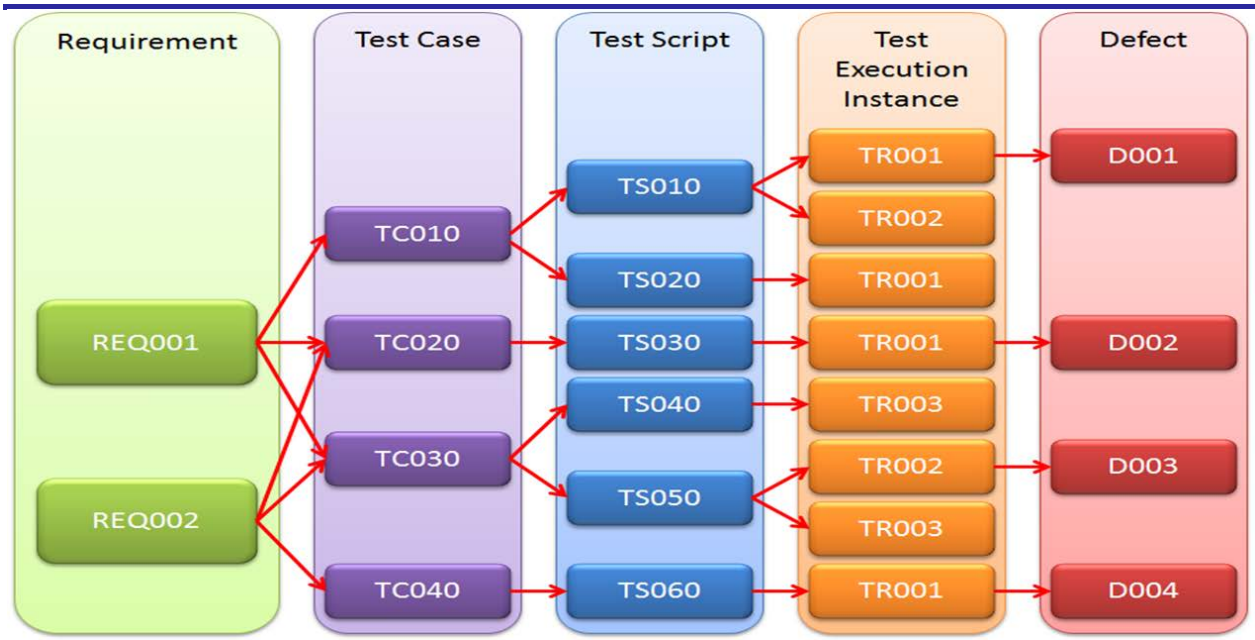

Figure 2 – Requirements Traceability

Following this process during the development of the Renesas SSP helps to ensure that Renesas is able to ensure no defects exist in the platform and that all requirements are met through-out the entire development life cycle.

Clean Software Builds

One problem that often plagues low and medium quality software is that the software does not build cleanly. The software will build without errors but there can be dozens, or sometimes even a hundred or more compiler warnings that are generated. The C compiler is generally loose when it comes to what it accepts so if the compiler is providing a warning, it means that there is something that should be further investigated by the developer. A clean build is a software compilation where there are no errors and no warnings. A clean build improves the software quality from the stand-point that the compiler is happy with the program that is generated. The Renesas Synergy SSP must build without any warnings in order to pass the clean software build.

Achieving Full Test Coverage

High quality software requires that the development team achieve full test coverage on their software. If every line of code isn't tested, then there is no way to know if there is a bug hiding in that code that wasn't executed during testing. Many companies when they test their software test it only at the highest, functional level and easily overlook the corner cases. Even worse, the testing process is manual by nature and time consuming. Subtle changes in the code may not be tested for weeks or even months after the code was changed.
There are several different methods that Renesas uses in order to ensure that the SSP has achieved full test coverage. Renesas has put into place a complete end to end test and verification solution that performs:

- Unit Testing
- Functional Testing
- Regression Testing
- Integration Testing
- Performance Testing

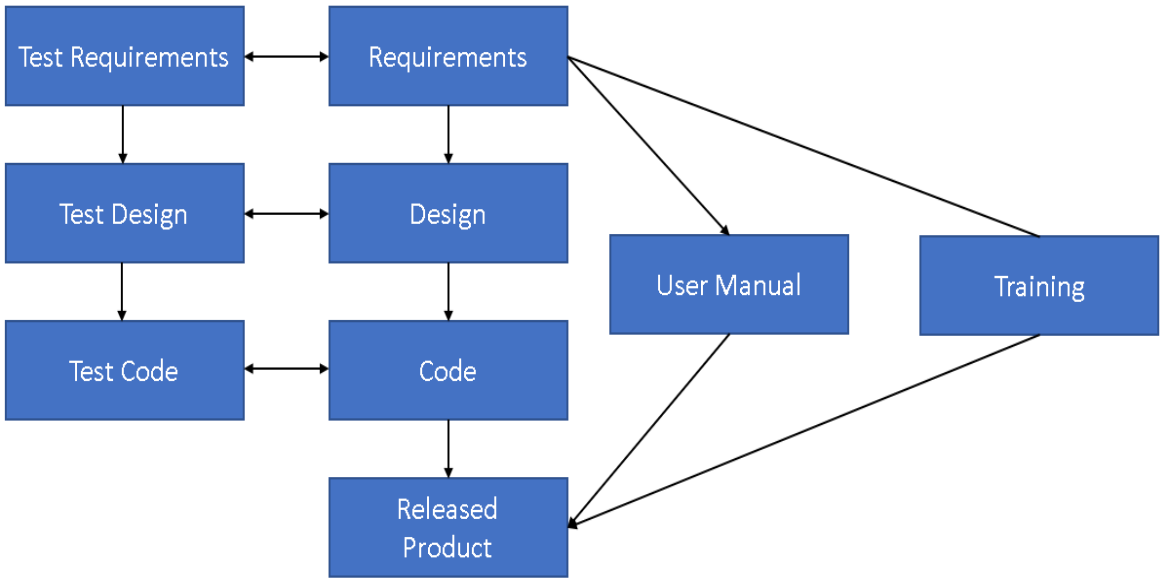

Figure 3 – Achieving Full Test Coverage on the Renesas SSP

When all these tests are integrated together they dramatically improve the SSP quality. For example, unit testing ensures that each software component is correct and complete. Functional testing ensures that the individual component has the correct behavior. Integration testing checks for correct behavior when multiple components must work together. Regression testing is able to immediately catch any new bugs or issues that crop up when need features are added or modified and ensure backwards compatibility. Finally, the performance testing is used to make sure the software performance meets market requirements
Renesas runs all these tests throughout-out the entire development on a nightly ran continuous integration server which then provides verifiable metrics that can be used to guarantee superior software.

Testing the SSP

Renesas tests the SSP using all the high-quality software techniques and verifiable metrics that have been discussed so far in this paper. Perhaps the most profound aspect on how they achieve high quality in the SSP is how all these methods and metrics are combined into a continuous integration server that executes every single night to ensure that not only everything is working as expected but also that all the metrics are being met or improved. An example setup that is used to test the SSP can be seen in Figure 4.

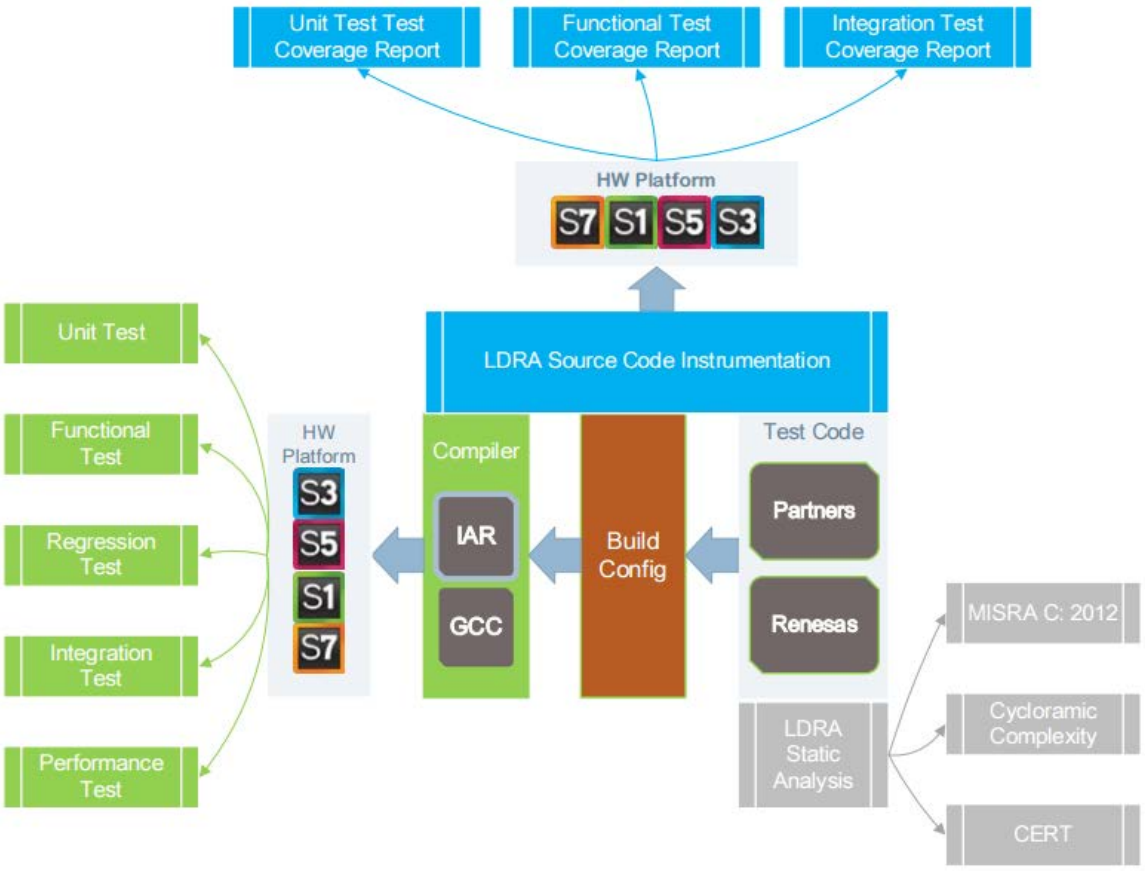

Figure 4 – Continuous Integration Testing of the SSP

At the heart of the continuous integration testing is the LDRA toolchain. LDRA provides several key aspects to generating the verifiable metrics. These include:

- Performing static analysis on the SSP to verify that industry coding standards are being met and also that function cyclomatic complexity measurements are within acceptable limits
- Performing dynamic code analysis on the SSP to compare overall control and data flow against the model behavior.

These tests are not only performed on the software but also on test harnesses that run the software and gather data on whether the SSP run-time is meeting requirements.
In addition to the code analysis that is performed with the LDRA toolchain, a separate test harness runs the Renesas Synergy hardware along with all the test scripts that are required to execute and achieve full test coverage.
The final output from all this testing is then compiled into a test report that compares the results to the key software metrics Renesas identified to ensure the highest level of code quality.

Conclusions

The Renesas Synergy SSP is an embedded software framework for microcontrollers that has been developed under the strictest processes and industry best practices in order to ensure that developers can focus on their own product features immediately out-of-the-box rather than having to start at the bit and byte level within the microcontroller. The software quality level isn't just something that through a hand waving conversation is talked about, instead there are verifiable metrics to back-up how well the software has been developed along with what developers can expect to get from the platform.

Achieving high-quality software is critical when so many devices are being connected to the internet and being used in systems that will directly interact with human beings. Using the Renesas Synergy Platform provides embedded system developers with a solid foundation from which they build their products and focus on their clients' needs and their businesses value.

Going Further

If you are interested in learning more about the Renesas Synergy SSP software quality process, there are several sources that you may want to investigate next. These include:

- The Renesas SQA Handbook
- The Renesas Synergy Quality Summary Report for SSP 1.2.0

In addition to these publicly available resources, there is additional documentation that can be used to certify the SSP and further explore the quality process under NDA.

References

1. McCabe, Thomas Jr. Software Quality Metrics to Identify Risk. Presentation to the Department of Homeland Security Software Assurance Working Group, 2008. (http://www.mccabe.com/ppt/SoftwareQualityMetricsToIdentifyRisk.ppt#36) and Laird, Linda and Brennan, M. Carol. Software Measurement and Estimation: A Practical Approach. Los Alamitos, CA: IEEE Computer Society, 2006.

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Revision History

		Description	
Rev.	**Date**	**Page**	**Summary**
1.00	Oct 19, 2017	—	Initial release

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