ST60A3H1 based customer product qualification, factory testing and field debug

Introduction

The X-NUCLEO-60K1A1 is a kit composed of two expansion boards: an X-NUCLEO-60L1A1 expansion board and an X-NUCLEO-60R1A1 expansion board. These boards work as a pair and can be plugged onto most STM32 Nucleo boards equipped with the Arduino® UNO R3 connectors. It provides a complete evaluation kit that allows customers to learn, evaluate, and develop applications based on the ST60A3H1 transceiver for contactless connectivity up to 480 Mbit/s.

The ST60A3H1 is a full RF transceiver with a dual-linear-polarization integrated antenna, operating in half-duplex mode. It provides an optimized solution for a high-speed, low-power, short-range point-to-point 60 GHz RF link.

The aim of this document is to present some options that can be implemented by customers using the ST60A3H1 in their application for the purpose of:

- Qualifying the customer product

- Testing the product in their factory

- Debugging issues in the field and in the lab

The indications described in this document are not exhaustive or mandatory. Customers can follow them either fully, partly, or do completely otherwise.

1 Customer product qualification

Customers using the ST60A3H1 must first validate their solution functionally and perform the necessary tests to confirm their system is fully compliant with their specification. Once this is completed, they need to qualify their product that hosts the ST60A3H1.

The objective of this qualification phase is twofold:

- Guarantee that the product will work properly in the field within its operating conditions and over its targeted lifetime.
- Gather data to help define the factory test procedures and pass/fail limits.

This section only deals with aspects related to the ST60A3H1. It is assumed that the customer has already defined the qualification plan for the other components and functionalities of the product.

1.1 Qualification suggested tests

Below is a list of tests that could be done during the qualification:

- Statistics on power consumption measurements in the various functional modes of the product
- Statistics on RSSI (Received Signal Strength Indicator) estimation by both the Local and Remote ST60A3H1
- Statistics on power-up to entry into TUNNELING success rate and time. This must be done for all the targeted tunneling protocols. In the case of eUSB2 tunneling, the statistics should be evaluated from power-up up to entry into L0 state
- Statistics on RF link loss cycles and total link recovery tests. Additionally, in the case of eUSB2 tunneling, USB2 link loss cycles should be evaluated
- Data transfer integrity tests by checking BER (or an equivalent metric) of the data transferred through the ST60A3H1 link

The above tests do not require costly 60 GHz test equipment. They should be launched on as many product samples as possible to gather enough statistics. They should be done while modifying certain parameters such as the operating conditions (such as operating temperature within the specified range), product manufacturing tolerances, RF channel variations, etc., to check their impact on the product behavior.

2 Customer product factory testing

This section deals with factory testing and assumes that the product has been fully qualified. Similarly to the qualification phase, the factory testing does not require any 60 GHz equipment. This means that a full link must be established during the test.

2.1 Factory testing suggested tests

It is possible to create two different tests. One functional, simple and short, that is applied to all DUT (Device Under Test) samples and another one, more thorough, which would be applied to randomly selected DUTs (number or percentage to be decided by the customer).

2.1.1 The functional test

The functional test procedure and conditions (such as RF channel, power supply voltage, test temperature, test duration, configuration I^2C speed, tunneling protocol, etc.) must be defined by the customer following the qualification phase results. These conditions must be selected so that, provided the qualification phase results, a DUT passing this simple functional test means that it will work correctly in the field.

It may be useful to record the following during this test:

- Read Local (I^2C) and Remote (RRA once in LOW_POWER state)register with a known value (ID_1 for example). This is not necessary as proven OK by the following tests.
- Local and Remote ST60A3H1 RSSI (register values) and temperature.
- TUNNELING/L0 (if eUSB2 tunneling) stable entry success/failure.
- Active transfer of data in both directions (if HD/FD tunneling) and check that all transmitted data over the test duration is received without error (BER = 0).
- Peak and average current/power consumption during data transmission.

The test pass/fail criteria must be defined by the customer for each recorded parameter. These limits may be chosen as an outcome of the product qualification phase so that a DUT passing this simple functional test means that it will work correctly in the field.

2.1.2 The thorough test

The customer may want to test some randomly selected DUTs more thoroughly. This test should stress the DUTs more and confirm their robustness. A such test could include:

- Power/boot up to TUNNELING/L0 (if eUSB2 tunneling) cycles
- RF link loss cycles
- USB2 link loss cycles if eUSB2 tunneling
- Increase test duration for active data transfer tests
- Test at various operating conditions within the product specifications

2.2 Factory testing setup

As explained above, the testing facility must test the product in pairs of ST60A3H1s and enable the full link.

2.2.1 The DUT

The product or DUT could include the ST60A3H1 pair, in which case the test facility would only need to provide the test interface and control of the product. Another option would be to have one end of the link as the DUT (so testing a single ST60A3H1) and the testing facility would provide the other end as a test fixture. Depending on the application, it is also possible to daisy chain several product samples and test them simultaneously. Customers need to analyze the pros and cons of each of these options and select the one that is best for them.

2.2.2 The test fixture

The test fixture is a hardware/firmware ensemble that is part of or plugged to the factory tester and which provides all the means to test the DUT. The test fixture's content depends on the DUT definition among the options described in the previous paragraph.

2.2.2.1 Test fixtures with the ST60A3H1

In the case of a DUT comprising one end of the full link, the test fixture should include the other end of the link and therefore host an ST60A3H1. While based on an ST60A3H1 part, the test fixture will be used as measurement equipment to test and retain or reject the DUT. As such, the test result must not depend on the test fixture or, in other words, the test fixture should not be a limiting factor leading to false fails. It is therefore important to ensure that these test fixtures have typical to best RF performances. Such test fixtures are called golden fixtures below.

The test fixture can be the same hardware as the DUT or a different board developed by the customer for this specific usage. Customers could also use the X-NUCLEO-60L1A1 board for this purpose.

Within the chosen test fixture hardware configuration, the customer can select the golden ones to be used in the test factory. This can be done following the procedure below:

1. Gather N test fixture candidate boards.
2. Select one board (let us name it Local board) among them and pair it with each of the N-1 remaining boards (named Remote boards). Record the RSSI estimated by the Local board and the Remote board for each pair.
3. RSSI estimated by the Local board gives information about the Remote board's TX stage gain. Use this value to rank the N-1 Remote boards based on their TX stage gain (highest Local RSSI means the corresponding Remote board has the highest TX stage gain).
4. RSSI estimated by the Remote board gives information about the Remote board's RX stage gain (since Local board's TX stage gain remains the same) use this value to rank the N-1 Remote boards based on their RX stage gain (highest Remote RSSI means the corresponding Remote board has the highest RX stage gain).
5. Select the boards with high ranking in both RX stage gain and TX stage gain contest and use them as golden fixtures.

3 Customer product field and lab debug

Several functional or performance failures may be faced in the field during production stage. It is important to quickly find the root cause and isolate the IC or circuit portion that is failing.

For products hosting the ST60A3H1, it is necessary to determine whether the ST60A3H1 pair functions properly or not. This section describes the items to check to confirm that the ST60A3H1 pair is not faulty or, if it is deemed faulty, debug the issue.

In this section it is assumed that

- The customer product is fully qualified (expected to work in the field conditions).
- The faulty product has been tested OK in the factory.
- All the ICs in the product (including the ST60A3H1 parts) are production parts which have been fully qualified and tested by the various silicon vendors.
- The fault occurs while the operating conditions are within the product specification.

The analysis and debug tools and methods presented here may be used depending on the issue that is observed and on the debug location/capabilities (field, customer lab, access to lab equipment, etc.)

3.1 Issue identification

The customer must be able to describe the issue as precisely as possible. Saying “it doesn’t work” is not enough. The questions below are examples of what needs to be answered:

- Can the issue be reproduced in a reliable manner? If so, describe the procedure to reproduce it.
- How many product samples present the issue? Many samples must be tested.
- Is it the Local or Remote ST60A3H1 side that is faulty? Application sink or source? Swapping boards or roles helps answer this question. It may also help to replace the customer board with a board from the X-NUCLEO-60K1A1 kit.
- Did the product sample work before showing the issue or does it show the issue from the beginning?
- Does the issue happen in some specific conditions or after some application or environmental event? Record all conditions such as temperature, etc.
- Is it a functional or a performance issue? Functional issue example: IC does not boot. Performance issue example: too many errors received.
- Are there identified conditions or changes to apply which make the issue disappear or never appear at all?

3.2 How to confirm that the ST60A3H1 pair works properly

When the ST60A3H1 pair works properly, it reaches the desired tunneling mode and stays there. This is ascertained by checking or monitoring over time some parameters listed below:

- Local and Remote ST60A3H1 register access, directly through I^2C or through RRA (to be done in LOW_POWER state only).
- Local and Remote ST60A3H1 FSM over time. In case it is eUSB2 tunneling, the ST60A3H1 eUSB2 state machine should be monitored as well.
- Local and Remote LINK_STATUS signal using an oscilloscope.
- Local and Remote ST60A3H1 power consumption.
- Local and Remote ST60A3H1 received signal levels (RSSI).

Note that it is possible that the ST60A3H1 pair works correctly but leaves the TUNNELING state (high-level watchdog) because of a problem that is unrelated to the ST60A3H1.

3.3 Debug tools and methods

Some of the usual debug methods are listed below:

- Visual (or using a tool) inspection of the boards.
- Measure current consumption in various states and compare with reference numbers in the same conditions.
- Instrument the driver code and log the traces. If the product does not have provision for debug traces, notepad register fields could be used to trace the functions that have been called.
- Add code in the driver to dump Local and Remote registers when requested.

- Check I^2C access to the Local ST60A3H1 and RRA access to the Remote ST60A3H1 (if LOW_POWER state is reached).
- Check the power-up sequence by monitoring power supplies and all control signals.
- Play with ST60A3H1 timers (mainly SLEEP_TIMER and WATCHDOG_TIMER).
- Record Local and Remote TSSI (Transmitted Signal Strength Indicator), RSSI, and temperature and compare them to reference numbers.
- Monitor MODE_INT interrupt signal with selected source events.
- If in eUSB2 tunneling and an issue related to the USB2 link is encountered:
  - Monitor eUSB2 state machine as well as TUNNELING_STATUS1 register for more eUSB2 IP internal signals.
  - Insert USB2 analyzer and check traces.
  - Connect oscilloscope probes on USB2 and/or eUSB2 signals and check the signals.
- If any doubts on the RF signal, it is possible to configure the Local ST60A3H1 to output a CW or a modulated signal without the need for the Remote ST60A3H1. The signal could then be observed on a 60 GHz spectrum analyzer.

Revision history

Table 1. **Document revision history**

Date	Revision	Changes
07-Mar-2025	1	Initial release.

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