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MaxLinear

DMI920
G.hn Wave-2 Industrial EVK

User Guide

Revision History

Document No.	Release Date	Change Description
083UGR00	April 22, 2021	Initial release.

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Introduction

The scope of this document is to provide a guide to evaluate MaxLinear's G.hn Wave-2 industrial design EVK solution for powerline communications running Spirit GRID software.

Note: The features described and performance data within this document are for guidance only, and they cannot be construed as any form of specification, guarantee, or contract between MaxLinear and the evaluator.

This document helps you to evaluate the powerline communications (PLC) smart grid and industrial solution feature set at technical level using hardware and software tools provided in evaluation package. It also helps to learn the technology at the same time as checking its real-world performance.

Warning! The electrical safety of this evaluation kit (EVK) has not been fully evaluated against the requirements of the *IEC 62368-1/EN 62368-1/UL 62368-1 (Audio/video, information and communication technology equipment – Part 1: Safety requirements)* standard and this EVK cannot fulfill with all the relevant electrical safety requirements stated in such standard.

Before continuing, read carefully the "Appendix C: Safety Recommendations" on page 32.

Wave-2 G.hn Spirit GRID

MaxLinear's Spirit GRID software is intended for smart grid and industrial applications using the G.hn 88LX5153A/88LX2741 and 88LX5152/88LX2720 chipsets for PLC.

The Spirit GRID software introduces new features to extend coverage such as MIMO Robust profiles and MAC relaying (repeating) functionality which also enables increasing number of nodes supported in the same G.hn domain up to some hundreds. Tree network topology is automatically built by the software based on one fixed head end (HE) node and rest are end point (EP) nodes which can also act as repeaters. Data communication is only allowed between the EPs and HE. For further information about the Spirit GRID, refer to the *Spirit GRID Software User Guide (082UG)* and the latest released Spirit firmware release notes.

Related Documentation

■ *Spirit GRID Software User Guide (*082UG)

■ *G.hn Industrial EVK Design Guide* (036DG)

■ *88LX5152 and 88LX5153 Data Sheet* (072-5253DS)

■ *88LX2720, 88LX2730, 88LX2740, and 88LX2741 Wave-2 G.hn AFE Data Sheet* (081DS)

■ *TR-208 Test Plan for Powerline Communication (PLC) Systems.* For more information, go to the *Broadband Forum (BBF)* webpage. For more information, go to https://www.broadband-forum.org/download/TR-208_Issue-2.pdf.

DMI920 Industrial Evaluation Kit

MaxLinear G.hn offering introduces a new G.hn industrial multi-medium multi-interface EVK (DMI920) running the Spirit GRID software that allows you to evaluate new industrial PLC applications. This new EVK provides new external interfaces such as USB and RS485/RS232, SPI, as well as 1Gbps Ethernet RJ45 port. The industrial EVK running the Spirit GRID software can only support powerline profiles. However, you can load a Spirit home networking software and use coaxial and phone G.hn interfaces which are also available in this new multi-medium EVK.

The following figure shows the DMI920 block diagram with the main devices highlighted.
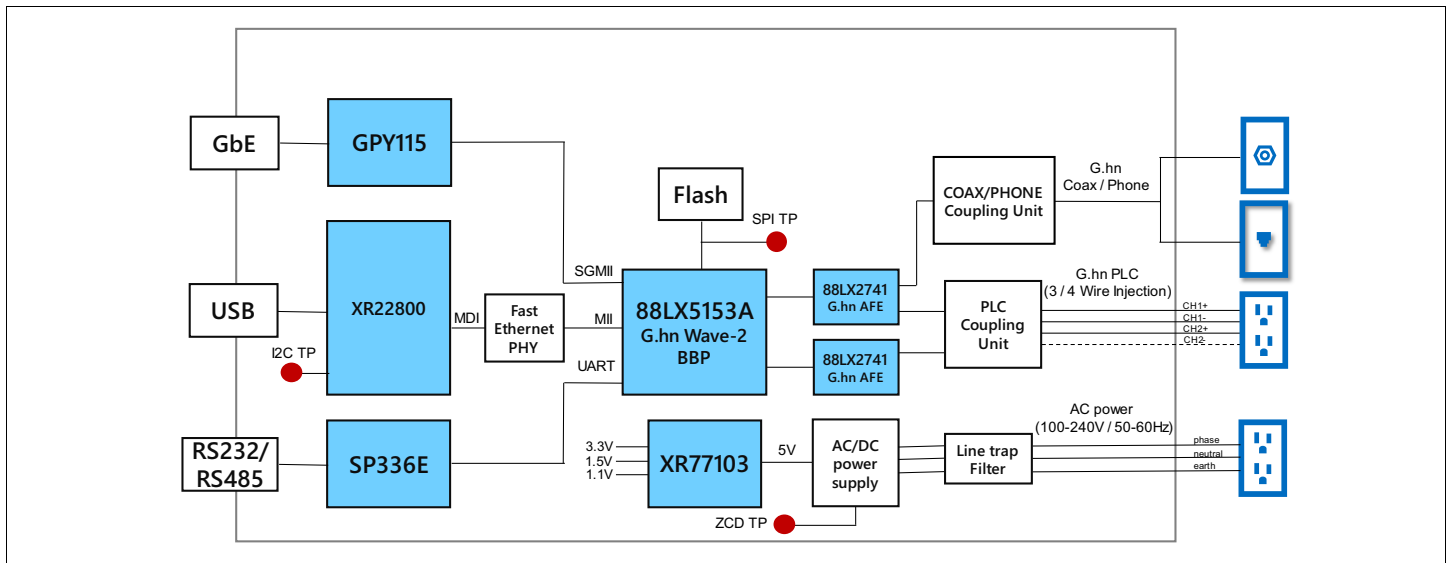
Figure 1: DMI920 Block Diagram

The DMI920 Industrial EVK provides the external interfaces shown in the following figure.
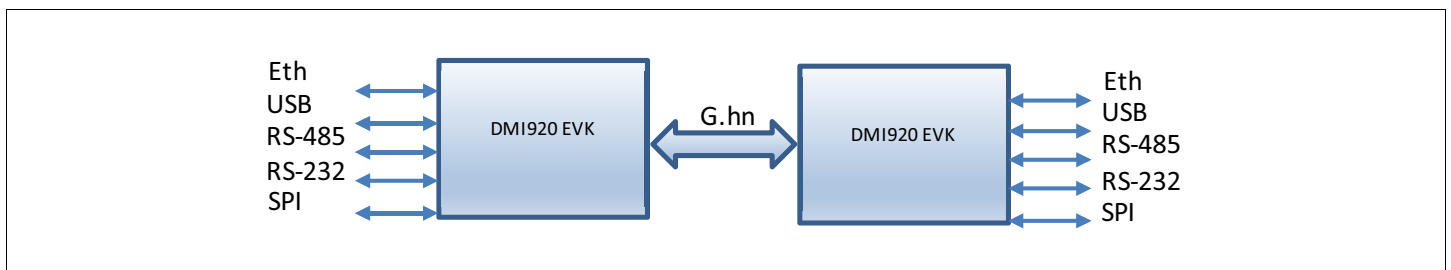
Figure 2: EVK External Interfaces

Ethernet Interface

The Gigabit Ethernet port is provided by MaxLinear GPY115 Itemp device connected to the 88LX5153A's SGMII interface.

USB Interface

The USB interface is provided by MaxLinear XR22800 device. The XR22800 is a hi-speed USB 2.0 device with an embedded hub and the following four downstream USB functions:

- 10/100 Ethernet MAC and PHY.

- UART.

- Multi- master capable I^2C controller.

- Enhanced dedicated GPIO entity (EDGE) controller.

Only the Ethernet interface of the XR22800 is used to connect to the 88LX5153A's device through the MII interface. An IP address is configured for the USB interface, so this interface is transparent from the G.hn firmware.

SPI Interface

An API to read and write on the SPI interface is already provided in the G.hn SDK to manage this interface.

RS232/RS485 Interface

Both RS-232 and RS-485 interfaces are provided by the SP336E device. The SP336E is a MaxLinear serial multi-transceiver device that contains both RS-232 and RS-485/RS-422 line drivers and receivers.

The SP336E is connected to the G.hn 88LX5153A through UART interface. The SP336E provides multiples modes but only native configurations for RS-232, RS-485 half and full duplex modes are enabled by the Spirit software using its serial tunneling component. It is in charge of packetize incoming bytes into packets, send them through G.hn, and do the opposite in the receiver part.

For further information about new industrial EVK, refer to the following documents:

- *G.hn Industrial EVK Design Guide* (036DG).

- *88LX2720, 88LX2730, 88LX2740, and 88LX2741 Wave-2 G.hn AFE Data Sheet.*

- *88LX2741 Wave-2 G.hn Industrial AFE Data Sheet (073-2741DS).*

- *DMI920 EVK design files.*

This is a typical scenario where the industrial multi-medium multi-interface can replace the RS-485 devices to reduce wiring and increase the connection distance.
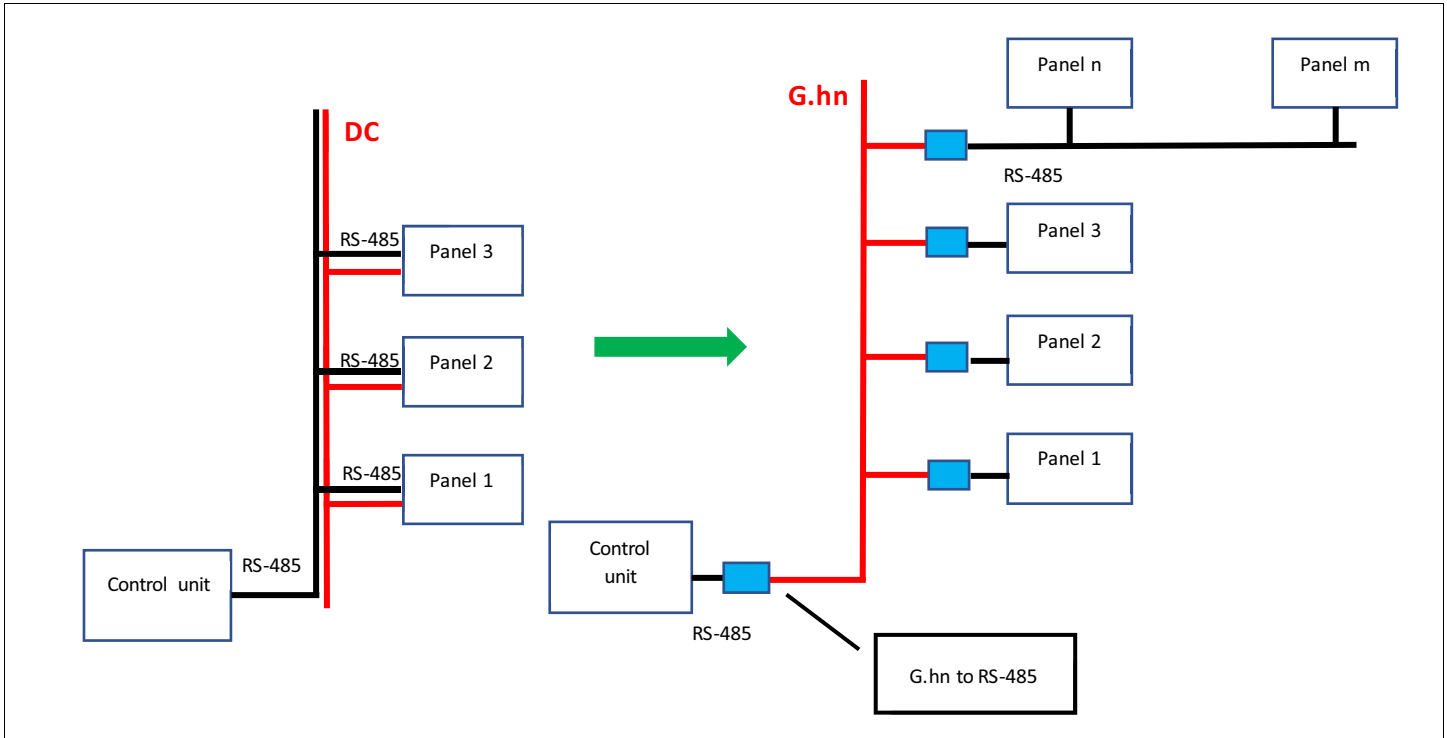
Figure 3: **Industrial Multi-Medium Multi-Platform scenario**

PLC coupling part

The DMI920 hardware user interface integrates a five-pole connector to connect power wires to couple PLC signal into electrical network. Two wires for SISO and three or four wires for MIMO can be connected. For combination details, see the following table.

Table 1: **DMI920 PLC 5-Pole Connector**

Coupling Mode	Pole	Comment
SISO 2 wires (P and N)	1 and 2	P to pin 1 and N to pin 2.
MIMO 4 wires	1 and 2 for CH1 3 and 4 for CH2	-
MIMO 3 wires	1, 2, and 3 Bridge 4 and 5	For example, Phase to pin 1, Neutral to pin 2 and Protective Earth to pin 3.

Warning! You do not need to supply power in the PLC 5-pole connector to avoid any electrical discharge and injury. This is only intended for PLC signal.
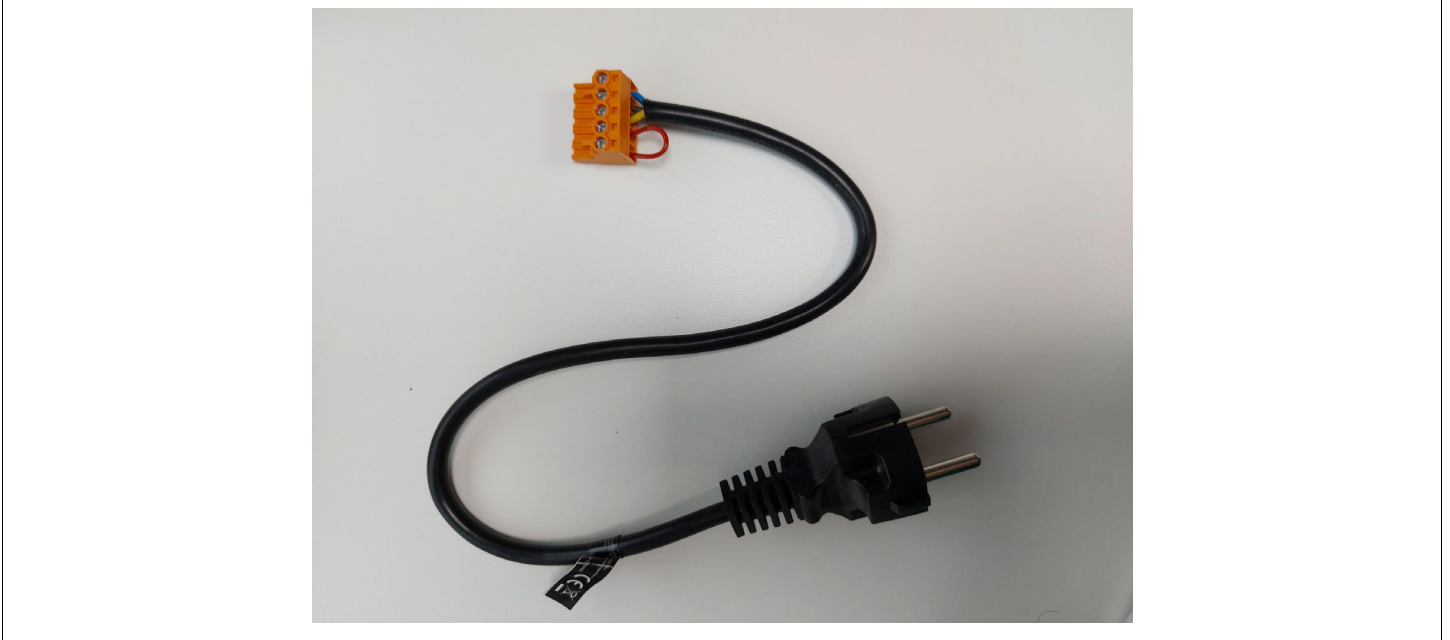
Figure 4: 5-Pole Connector for MIMO 3-Wires

Ordering Information

To evaluate and configure the adapters during the test, you can use the following elements:

■ MaxLinear's DMI920 Wave-2 G.hn industrial evaluation board with the Spirit GRID 7.12 SR1 firmware loaded. Be aware that two or more units are needed to execute the suggested test cases described in this document.

■ This document, DMI920 G.hn Wave-2 Industrial EVK Evaluation User Guide (083UG).

■ The Spirit Configuration Tool (SCT) 4.1.14 o178 (or higher) software application.

The following figure also shows the DMI920 Wave-2 front side.
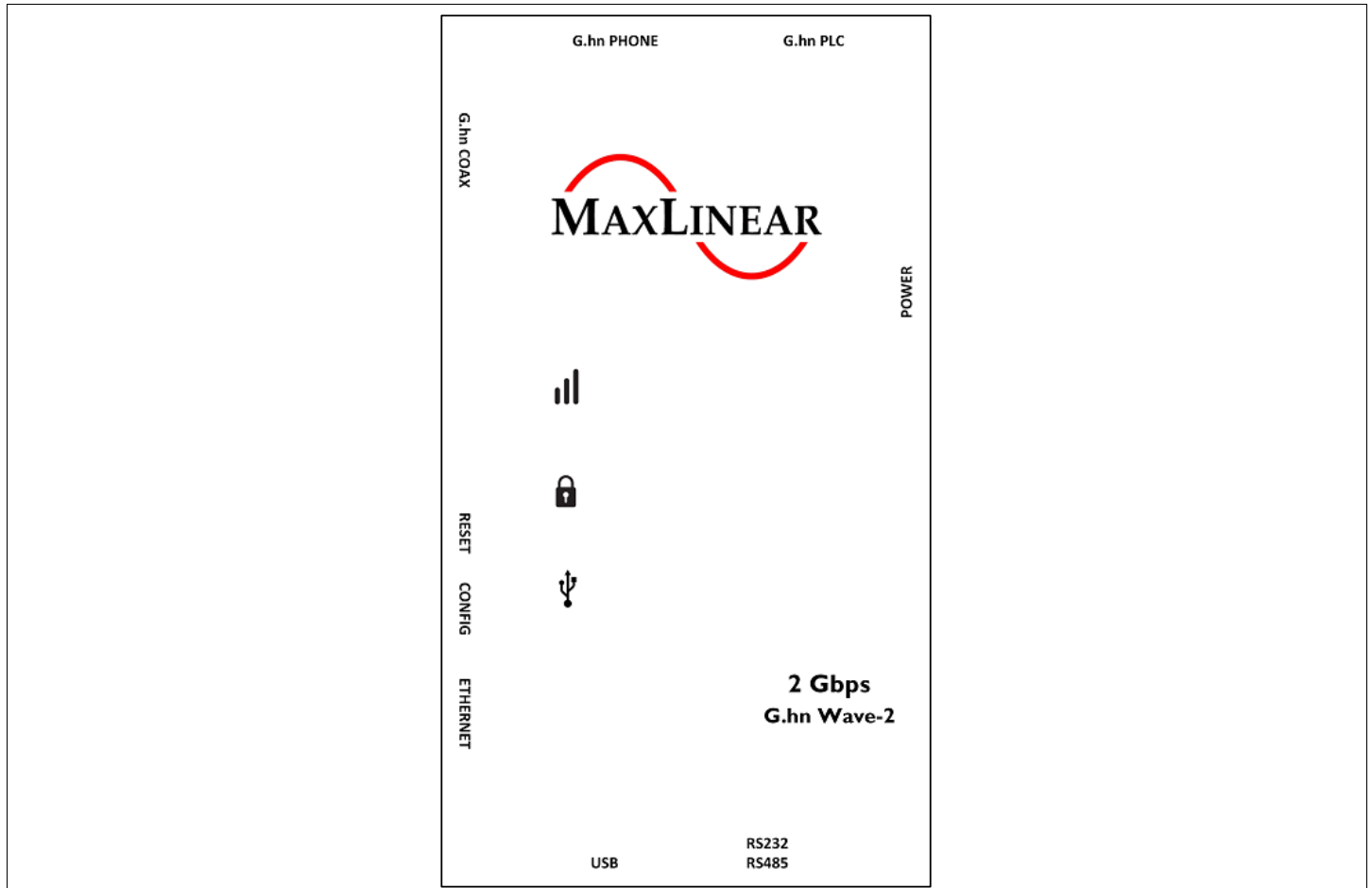
Figure 5: DMI920 Wave-2 Front Side

Table 2: G.hn Wave-2 Industrial EVK Contents

Part Number	Package Content	Description
RD-GRID-2DMI920KIT-01	2 × DMI920 Wave-2 G.hn industrial EVK	G.hn Industrial IoT multi-medium (AC/DC PLC, coaxial, phoneline), multi-Interface (1G Ethernet, RS485/232, USB, SPI) evaluation kit with two G.hn adaptors (88LX5153A+88LX2741).
	PLC 5-pole connector	-
	DMI920 to the RS-485/RS-232 connector accessory. (RS485ACC)	Accessory to interconnect DMI920's 10-pin connector with the RS485 or RS232.
	2 × RS485 10pin ribbon cable	Ribbon cable, IDC receptacle to IDC receptacle, 10 ways.
	2 × USB cable	USB Cable, type A plug to mini type B plug.
	2 × IEC Mickey mouse electrical cable	Mains cordset EU. Europlug IEC320 C5.
	2 × Ethernet cable	-

MaxLinear highly recommends t that you get at least two universal PLC splitter (3-port mains-PLC signal splitter for SISO and vendor-independent MIMO following the *TR-208 Test Plan for Powerline Communication (PLC) Systems* in addition to the DMI920 EVK. They are used to perform the proposed laboratory tests and help to control the attenuation between the powerline boards. See Figure 6.

To purchase of this universal PLC (UPLC) kit, you can go to Telebyte Broadband (https://www.telebyteplc.com). The following table lists the corresponding ordering information.

Table 3: Ordering Information for Telebyte's PLC Evaluation Accessories

Part Number	Package Content	Number of Devices
GHN-SP-UPLC	Universal PLC splitter	1
GHN-AT-PROG-UPLC-3-Slope	Channel-slope programmable attenuator	1
GHN-SP-SPLCOMB-UPLC-3	3-Channel Splitter/Combiners	1

To perform the test cases described in the following sections, BNC Male-BNC Male 50Ω cables and several 20dB and 10dB 50Ω BNC attenuators can be also required. They are not included in the UPLC kit. However, you can purchase them in most hardware and electronics stores. Other recommendable accessory from Telebyte Broadband is a 3-channel-slope programmable attenuator (GHN-AT-PROG-UPLC-3-Slope), as well as 3-channel splitter/combiners (GHN-SP-SPLCOMB-UPLC-3) for some multi-mode test cases.

The following figure shows the universal PLC signal splitter.

Figure 6: Universal PLC Signal Splitter

DMI920 User Interface

The main features provided by the DMI920 hardware user interface are:

■ Pairing (one button security setup, OBUS – **ONLY Spirit Home Networking**): Automatic generation of a random domain name and encryption password. It is used to guarantee network security and exchange these parameters between the adapters by using a single button push as defined by *HomeGrid Forum f*or compliance and interoperability purposes.

■ Unpairing (**ONLY Spirit HN**): Returns to the default security settings.

■ Manual factory reset.

■ Link quality indicator with a three-color LED. The three different levels of the link quality is shown in the receiver adapter.

■ Reset: Manual reset of the board.

Table 4: **DMI920 User Interface Buttons and LEDs**

Definition	Icon	Function
CONFIG button	CONFIG	Used to implement the following tasks: ■ One button security setup (Pairing). ■ Return to default security settings (Unpairing). ■ Factory reset. ■ Force recovery mode (Power on device with CONFIG button pressed).
RESET button	RESET	Manual reset of the board.
Link Quality indicator		Three-color code LED that indicates if the adapter has G.hn link. It also shows the application throughput level available in the link (*throughput indicator*) and also indicates if the adapter enters in power saving mode.
Secure" indicator		LED that indicates whether the device is *secure* or not, that is, whether the device has received/generated the network keys (so it belongs to a unique secure domain) or not. Spirit home networking ONLY.
USB indicator		LED that indicates the link and traffic through USB port.

The meanings of the various LEDs and buttons are given in the following tables.

Table 5: Link Quality Indicator Description

Color	Adapter Status	Meaning
OFF	ON	No G.hn link.
RED	ON	G.hn link is present and the estimated application throughput < 20Mbps (configurable)
ORANGE	ON	G.hn link is present and 20Mbps (configurable) < estimated application throughput < 40Mbps (configurable)
GREEN	ON	G.hn link is present and estimated application throughput > 40Mbps (configurable)
BLINKING in RED, ORANGE, or GREEN	ON	Tx/Rx activity in the G.hn port.
BLINKING in RED every 5s	POWER SAVING	When the adapter enters in power saving, this LED blinks once every 5s.

Table 6: Secure Indicator Description

Secure LED State	Meaning
OFF	The device is not secure. It has neither received nor generated network keys (domain name and encryption password).
ON	The device is secure. It has either received or generated network keys).
SLOW BLINKING	The device is in configuration mode (and can exchange network keys).
QUICK BLINKING	The device is in *return* to default security settings mode" (unpairing).
Three FLASHES	The device has received key from another secure device and has finished its configuration.

Table 7: CONFIG Button

Button	Meaning
CONFIG	■ Press more than 2s (*Secure* indicator starts slow blinking) and release = The pairing procedure is started and the configuration period is open. ■ Press more than 5s (*Secure* indicator starts quick blinking) and release = The security settings are set to default values. ■ Press more than 10s (*Secure* indicator switches off) and release = A factory reset is performed.

Note: Some of the user interface buttons and LEDs only apply for Spirit home networking, for instance pairing functionality.

Laboratory Evaluation and Tests

Evaluation Software Tool

The SCT is a Java software tool to help you during the G.hn adapters testing.

The SCT enables reading and writing main configuration settings of the MaxLinear G.hn adapters belonging to same logical network and it is used for most of the evaluation tests introduced in this section.

For more information about installation and use of SCT, refer to the *Spirit Configuration Tool User Guide* (052UG).

Network Performance Test

Test 1: Dynamic Range Measurement in Flat Channel

This test concentrates on two nodes network performance. You can measure the variation of the following variables as a function of attenuation:

- Physical throughput.
- TCP throughput.
- UDP throughput

Test Equipment

- 2 × MaxLinear DMI920 EVK (one node with *dmi920_v1_x-HE-GRID_flash-SPIRIT.v7_12_r820+5_cvs* loaded and one node with *dmi920_v1_x-EP-GRID_flash-SPIRIT.v7_12_r820+5_cvs* image loaded).
- A dedicated HW network performance analysis system such as Ixia or Spirent's Smartbits.
- Alternatively, use two PCs with one of the following software options:
  - Chariot SW from Ixia.
  - Iperf software (a public domain application that you can download for free), but the specific hardware and operating system can place a limitation on the results. For instance, Windows PC usually limits iperf UDP performance as client, so use of Linux is advised for UDP performance tests when possible.
- Spirit Configuration Tool (SCT).
- 2 x GHN-SP-UPLC.
- Combined fixed attenuators.
- BNC coaxial cables.

The following figure shows a test setup diagram that uses this test equipment.
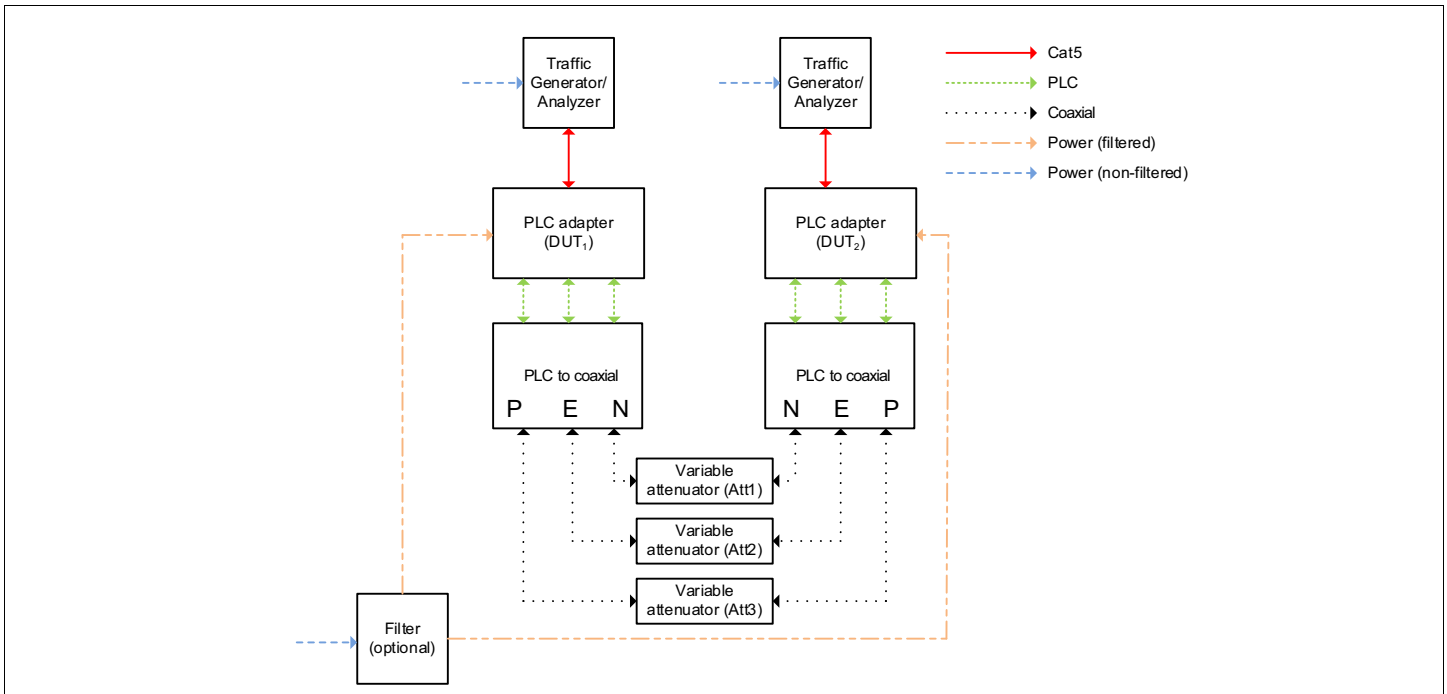
Figure 7: **Test Setup for Two Nodes Based on TR208**

Warning! Yo do not need to supply power in PLC 5-pole connector to avoid any electrical discharge and injury. This is only intended for PLC signal. For instance, you do not need to power the universal PLC splitter to run evaluation test cases.

Test Methodology

To perform this test:

1. Select the G.hn PLC profile to be tested (Spirit GRID supports `PHYMNG.GENERAL.RUNNING_PHYMODE_ID=15` or 16, default is 16 for DMI920) and configure it into the PLC adapters by using SCT.

2. Set an attenuation of 10dB between the adapters.

3. Check with the SCT the G.hn connections and note the PHY rates.
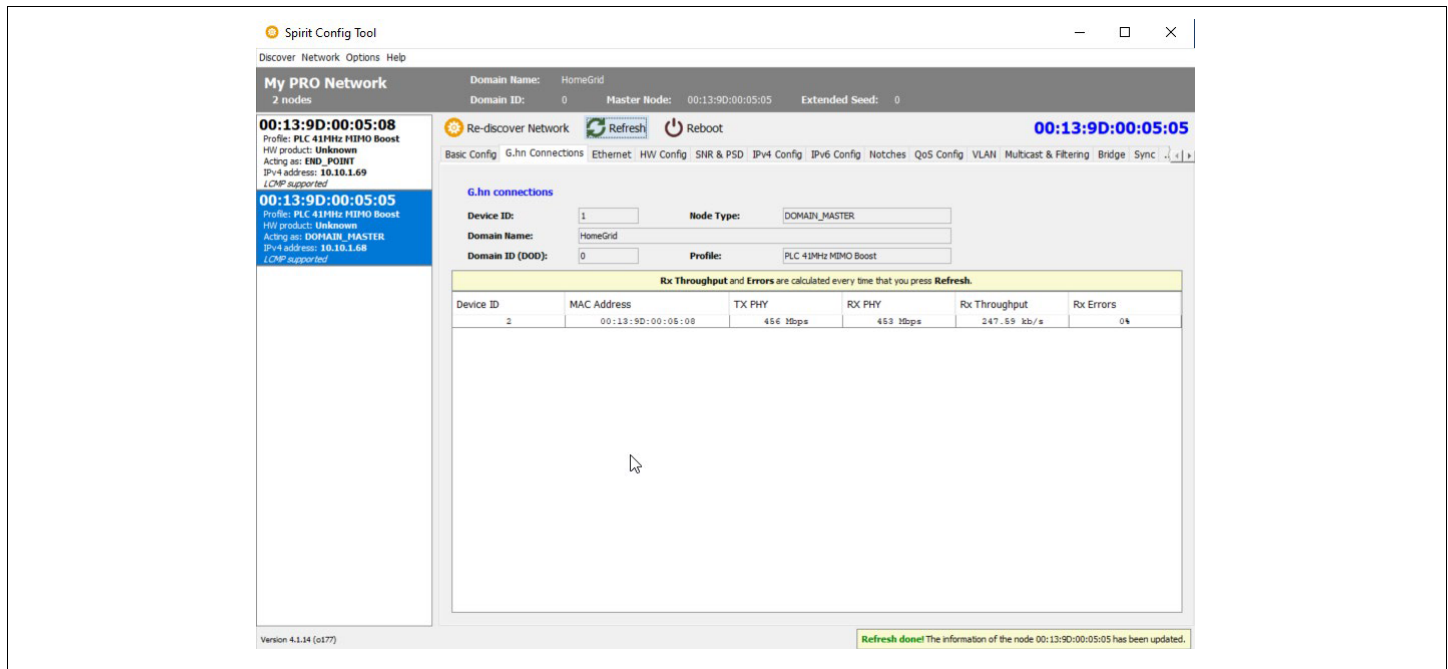
Figure 8: G.hn connections in SCT

4. Run the corresponding Ixia tests that measure TCP throughput, UDP throughput, latency, frame lost, and jitter.

5. Alternatively, run iperf as follows:

   a. Perform a TCP throughput test typing the following commands in a console window:

     ▪ Server side (PC1): `iperf -s -w 32K`

     ▪ Client side (PC2): `iperf -c [Server IP] -w 32K -i 1 -t 60 -P 16`

   b. Test the UDP throughput by typing he following:

     ▪ Server side (PC1): `iperf -s -i 1 -u -w 512K`

     ▪ Client side (PC2): `iperf -c [Server IP] -i 1 -u -w 512K -t 60 -b X`

   where X is the injected bandwidth (in bps) for the application. Select an X value around 350M.

6. Write down the transmission and reception physical throughput obtained using SCT.

7. Once done, repeat these steps increasing the attenuation value by 10dB or 20dB until achieved throughput is near to 0 (evaluator can trigger a channel adaptation with `FLOWMONITOR.GENERAL.DID_ESTIMATE=<remote node DID>` when changing the attenuation to speed up test).

8. Note the results in a table. See Table 8 on page 13 and Table 9 on page 13 as examples.

Table 8: **DMI920 UDP Unidirectional Measurements (Mbps)**

Attenuation	Profile 15	Profile 16
10dB	335	351
20dB	335	351
30dB	280	314
40dB	247	280
50dB	212	206
60dB	113	124
70dB	79	96
75dB	52	62
80dB	39	43
85dB	30	34
90dB	21	27
95dB	16	22
100dB	0	0

Note: Results bu using the Spirit GRID 7.12 SR1 version loaded.

Table 9: **DMI920 TCP Unidirectional Measurements (Mbps)**

Attenuation	Profile 15	Profile 16
10dB	293	320
20dB	293	319
30dB	276	277
40dB	240	222
50dB	197	185
60dB	120	107
70dB	70	66
75dB	48	51
80dB	31	38
85dB	22	30
90dB	13	21
95dB	10	16
100dB	0	0

Note: Results bu using the Spirit GRID 7.12 SR1 version loaded.

Test 2: RFC 2544 Throughput and Latency Test

The RFC 2544 methodology, established by the Internet Engineering Task Force (IETF), is the de-facto methodology that outlines the tests required to measure and prove performance criteria for carrier Ethernet networks. The standard provides an out-of-service benchmarking methodology to evaluate the performance of network devices using throughput, frame loss, and latency tests.

The methodology defines the frame size, test duration, and number of the test iterations. Once completed, these tests provide performance metrics of the Ethernet network under test.

To ensure that an Ethernet network can support a variety of services (such as VoIP or video), the RFC 2544 test suite supports seven pre-defined frame sizes (74, 128, 256, 512, 1024, 1280, and 1518 bytes) to simulate various traffic conditions. Small frame sizes increase the number of frames transmitted, thereby stressing the network device as it must switch many frames.

The test starts by sending frames at the specified rate (usually the maximum theoretical rate of the port), while the frame loss is monitored. The frames are sent from and received at all of the ports on the device under test, and the Tx and Rx rates are recorded. A binary, step, or combo search algorithm is used to identify the maximum rate at which no frame loss is experienced.

The latency test determines the latency of the device under test. In the latency test, frames are transmitted for a fixed duration. The Rx ports compute the latency values for every frame in the test by comparing the Tx timestamp with the Rx timestamp. The difference between the two timestamps is the latency. This quick test provides the statistical results: Average latency, minimum latency, and maximum latency.

Test Equipment

- ■ 2 × MaxLinear DMI920 EVK (one node with *dmi920_v1_x-HE-GRID_flash-SPIRIT.v7_12_r820+5_cvs* loaded and one node with *dmi920_v1_x-EP-GRID_flash-SPIRIT.v7_12_r820+5_cvs* image loaded).
- ■ A dedicated HW network performance analysis system such as Ixia or Spirent's Smartbits.
- ■ Spirit Configuration Tool (SCT).
- ■ 2 × GHN-SP-UPLC.
- ■ Combined fixed attenuators.
- ■ BNC coaxial cables.

See Figure 7 on page 11 as a test setup diagram using this test equipment.

Test Methodology

To perform this test:

1. Set a fixed attenuation of 20dB between the G.hn modems.

2. Select the profile to be tested in the G.hn adapters using the SCT (either 15 or 16).

3. Ensure that ALB is disabled in all nodes (`QOSENGINE.ALB.ENABLED=NO`) to avoid moving from idle to active state affects RFC2544 measurement.

4. Run the RFC 2544 throughput/latency unidirectional test in Ixia IxNetwork (it takes several hours to be completed).

5. Run the RFC 2544 throughput/latency bidirectional test in Ixia IxNetwork (it takes several hours to be completed).

6. Note the results in a table. See Table 10 on page 15 and Table 11 on page 15 as examples.

Table 10: DMI920 RFC2544 Measurements (Mbps) – PLC MIMO 41 MHz (Profile 15)

Frame Size (bytes)	Unidirectional Passed Rate (Mbps)	Bidirectional Passed Rate (Mbps)
74	196.86	307.65
128	277.3	329.58
256	307.72	342.06
512	311.57	349.63
1024	319.59	352.7
1280	316.95	354.2
1512	318.5	354.35

Table 11: DMI920 RFC2544 Measurements (Mbps) – PLC MIMO 50MHz (Profile 16)

Frame Size (bytes)	Unidirectional Passed Rate (Mbps)	Bidirectional Passed Rate (Mbps)
74	299.2	338.95
128	320.99	357.76
256	332.71	370.23
512	339.23	379.25
1024	342.5	383.05
1280	343.07	383.26
1512	342.8	384.19

Test 3: Repeating Test

This test concentrates on network performance in point to multipoint scenarios with repeating. As such, the variation of the following variables is measured as a function of attenuation for networks with three (or more) G.hn DMI920 devices.

■ Physical throughput.

■ TCP throughput.

■ UDP throughput.

■ Frame Lost.

Test Equipment

■ 4 × MaxLinear DMI920 EVK (one node with *dmi920_v1_x-HE-GRID_flash-SPIRIT.v7_12_r820+5_cvs* loaded and three nodes with *dmi920_v1_x-EP-GRID_flash-SPIRIT.v7_12_r820+5_cvs* image loaded).

■ A dedicated network performance analysis system such as Ixia or Spirent's Smartbits. Alternatively, use four PCs with Chariot or iperf software.

■ Spirit Configuration Tool.

■ 4 × universal PLC splitters (GHN-SP-UPLC).

■ Combined fixed and variable attenuators.

■ 15 × BNC coaxial cables.

■ 2 × 3-Channel symmetrical splitters.

■ Auxiliary electrical cables.

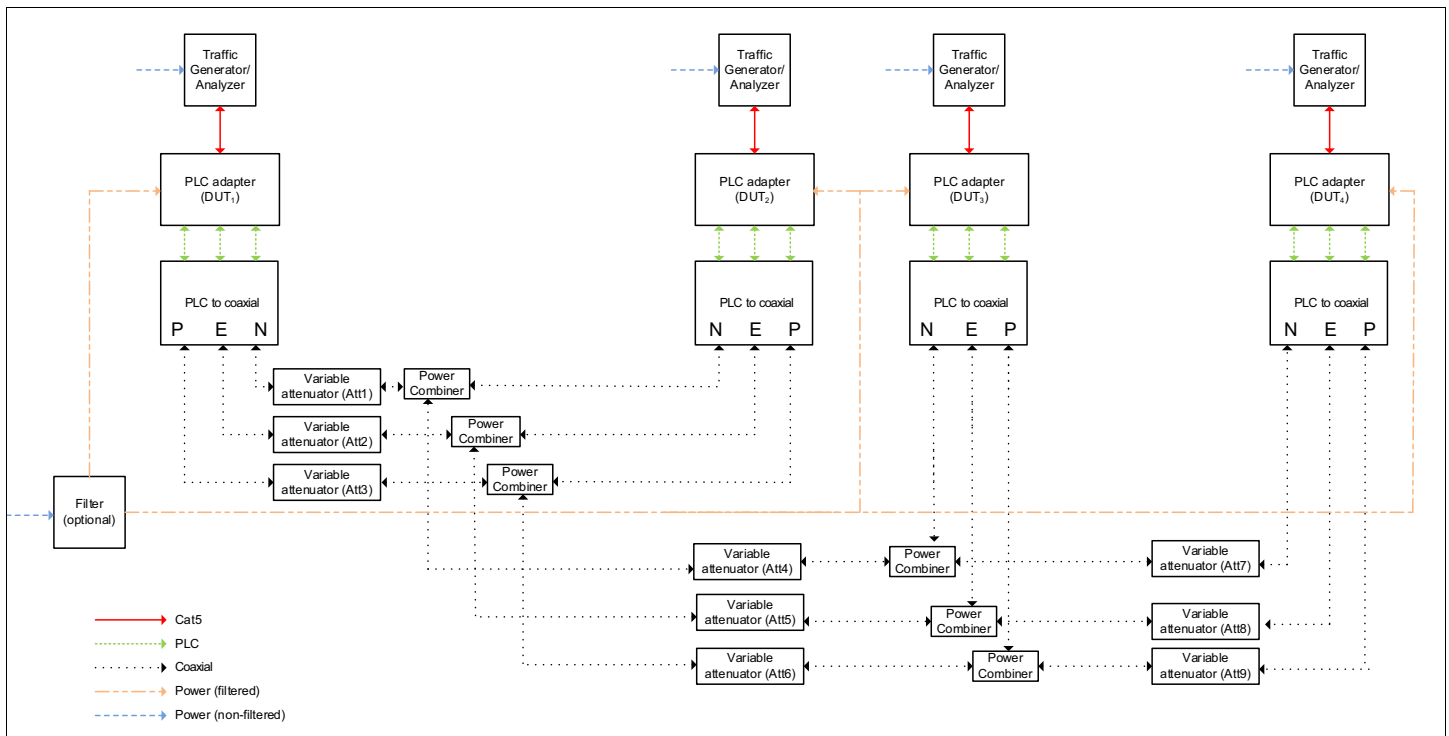The following figure shows a test setup diagram using mentioned test equipment.

Figure 9: **Test Diagrams for Repeating Point to Multi-point**

Test Methodology

1. Set an attenuation of 50dB between HE DMI920 and CPE1 DMI920 (Att1&Att2&Att3=50dB), 50dB attenuation from CPE1 to CPE2 (Att4&Att5&Att6=50dB) and another 50dB from CPE2 to CPE3 (Att7&Att8&Att9=60dB) to force a repeating scenario with three hops (power combiner adds 6dB more between BNC ports).

2. In the HE node, check the **Topology** tab with the SCT and confirm the repeating scenario as the following figure shows:
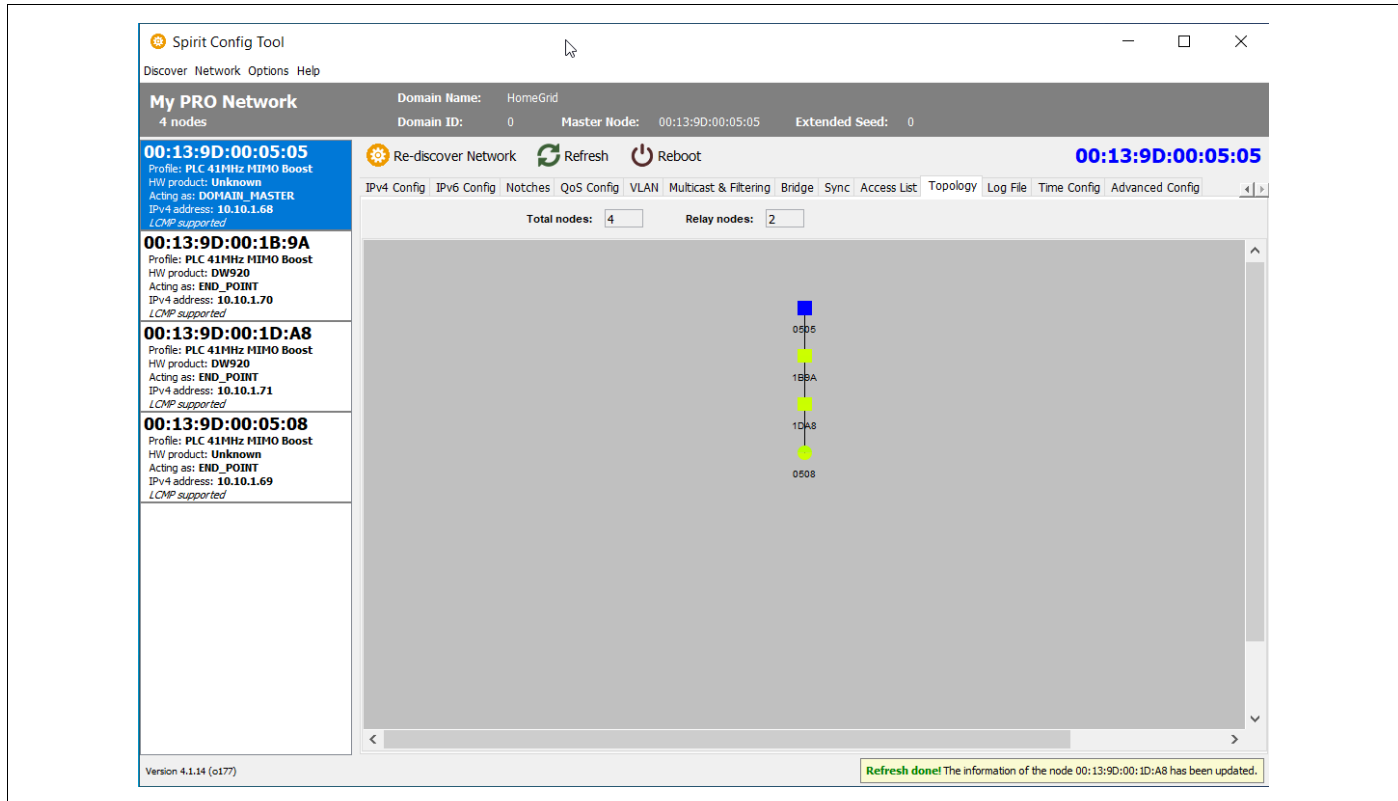
Figure 10: Topology in SCT

3. Ensure that the ALB is disabled in all nodes (`QOSENGINE.ALB.ENABLED=NO`) to avoid moving from idle to active state affects RFC2544 measurement.

4. Run the corresponding Ixia IxNetworks test RFC 2544 that measures unidirectional or bidirectional UDP throughput, latency, frame loss, and jitter between the HE and the CPE1.

5. After that, run the same test between the HE and the CPE2.

6. Finally, run the same test between the HE and the CPE3.

7. Alternatively, run iperf between the HE and every CPEx as follows:

    a. Perform a TCP throughput test typing the following commands in a console window:

      - Server side (PC1): `iperf -s -w 32K`
      - Client side (PC2): `iperf -c [Server IP] -w 32K -i 1 -t 60 -P 16`

    b. Test the UDP throughput by typing the following:

      - Server side (PC1): `iperf -s -i 1 -u -w 512K`
      - Client side (PC2): `iperf -c [Server IP] -i 1 -u -w 512K -t 60 -b X`

    where X is the injected bandwidth (in bps) for the application. Select an X value around 350M.

8. You can add/remove more repetition levels with similar configuration and test different performance metrics. For more information, refer to the latest released Spirit firmware release notes.

9. Note the results in a table. See the following tables as examples.

Table 12: Results RFC 2544 between the HE and the CPEx Test PLR 0% Bidirectional—Profile 16

Frame Length	HE-CPE1	HE-CPE2	HE-CPE3
64	76.18	39.68	27.03
128	80.34	43.89	28.37
256	83.27	46.59	29.70
512	85.56	47.65	30.74
1024	86.58	48.67	31.58
1280	86.51	48.70	31.60
1518	87.50	48.66	31.70

Table 13: Results RFC 2544 between the HE and the CPEx Test PLR 0% Bidirectional—Profile 15

Frame Length	HE-CPE1	HE-CPE2	HE-CPE3
64	63.6	34.04	22.81
128	67.76	36.81	24.21
256	70.48	38.25	25.52
512	71.93	39.45	25.62
1024	73.71	39.54	26.57
1280	73.88	40.19	26.58
1518	73.86	40.44	26.07

Test 4: Adaptative Load Balancing and Latency Test

This test concentrates on network performance in point to multi-point scenarios with repeating with and without adaptative load balancing (ALB) feature. As such, the variation of the following variables is measured in networks with three (or more) G.hn DMI920 devices.

■ Latency with ALB on or off.

Test Equipment

■ 4 × MaxLinear DMI920 EVK (one node with *dmi920_v1_x-HE-GRID_flash-SPIRIT.v7_12_r820+5_cvs* loaded and three nodes with *dmi920_v1_x-EP-GRID_flash-SPIRIT.v7_12_r820+5_cvs* image loaded).

■ A dedicated network performance analysis system such as Ixia or Spirent's Smartbits. Alternatively, use four PCs with *Fping.exe* installed in one connected to the HE (https://github.com/dexit/fping-windows).

■ Spirit Configuration Tool.

■ 4 × universal PLC splitters (GHN-SP-UPLC).

■ Combined fixed and variable attenuators.

■ 15 × BNC coaxial cables.

■ 2 × 3-Channel symmetrical splitters.

■ Auxiliary electrical cables.

Test Methodology

1. Set an attenuation of 50dB between the HE DMI920 and the CPE1 DMI920 (Att1&Att2&Att3=50dB), 50dB attenuation from the CPE1 to the CPE2 (Att4&Att5&Att6=50dB) and another 50dB from the CPE2 to the CPE3 (Att7&Att8&Att9=50dB) to force a repeating scenario with three hops (power combiner adds 6dB more between BNC ports)

2. In HE node, check the **Topology** tab with SCT and confirm the repeating scenario as shown in Figure 10 on page 17.

3. Check the ALB configuration with the SCT and disable it with `QOSENGINE.ALB.ENABLED=NO` in the HE node.

4. Run the corresponding Ixia IxNetworks test RFC 2544 that measures bidirectional UDP throughput, latency, frame loss, and jitter between the HE and the CPE3.

5. Perform ping test between the PC connected to the HE to a PC connected to leaf CPEs using the Fping tool.

   a. Create a txt file with a list of the IP computers to ping (comma delimited), for example *hosts.txt*

   b. Fping.exe -n 100 -H hosts.txt

6. Repeat step 4# with the SCT the ALB configuration enabled with `QOSENGINE.ALB.ENABLED=YES` in the HE node.

7. Note the results in a table. See the following tables as examples.

Table 14: Results of Latency with ALB On and Off

ALB setting	HE to CPE3
ON	
OFF	

Table 15: Results RFC 2544 between the HE and the CPE3 Test PLR 0% Bidirectional—ALB off vs on

Frame Length	HE—CPE3 (ALB OFF)	HE—CPE3 (ALB ON)
64	27.03	29.85
128	28.37	34.19
256	29.70	36.55
512	30.74	37.71
1024	31.58	38.73
1280	31.60	38.76
1518	31.70	38.77

RS-232/RS-485 Evaluation

G.hn systems transparently transmit the information that is received through the UART, the serial tunneling feature packetizes the incoming bytes into packets, send them through G.hn, and do the opposite in the receiver part. The SP336 device included in DMI920 (G.hn industrial design) is a transceiver between the RS232/RS485/RS422 interface and G.hn's UART.

To test the RS-232 and RS-485 interfaces of the DMI920 device, you can follow the tests proposed in this section. Table 16 lists the main serial tunnel configuration parameters which should be configured in every node depending on their role in the RS232/RS485 network as well as the RS232/RS485 characteristics.

Table 16: **Serial Tunneling Config Layer Parameters**

CFL Parameter	Default	Range	Description
`SERIALTUNNELING.GENERAL.MODE`	NONE	NONE/RS232/RS485_HALF/RS485_FULL	Configure the serial interface to be used for tunneling.
`SERIALTUNNELING.GENERAL.BUFFER_SIZE`	256	1-1490	Size of the buffer to store the UART input data. Use to minimize the number of the G.hn messages sent through to the G.hn network. G.hn messages are only send when the buffer is full or the end of the UART data frame is detected.
`SERIALTUNNELING.GENERAL.ENDFRAME_TIMEOUT`	5	N/A	It detects the end of a UART input frame if several consecutive chars are not received during a frame reception. Used to minimize the number of the G.hn messages sent through the G.hn network. The G.hn messages are only sent when the buffer is full or the end of the UART data frame is detected.
`SERIALTUNNELING.RS485.NODES [250]`	00:00:00:00:00:00,00:00:00:00:00:00,…	N/A	List of the RS485 registered MAC addresses. Used to minimize the number of the G.hn messages sent by the domain master through G.hn network. The G.hn messages are only sent to the nodes that support the RS485 functionality.
`SERIALTUNNELING.RS232.DESTINATION`	00:00:00:00:00:00	N/A	MAC address of the RS232 destination node. This parameter should only be set in the domain master node. The RS232 end point node automatically sends the response to the domain master node.

Test 1: Basic RS-232 Test

The RS-232 support can be tested using a basic setup as shown in the following figure.
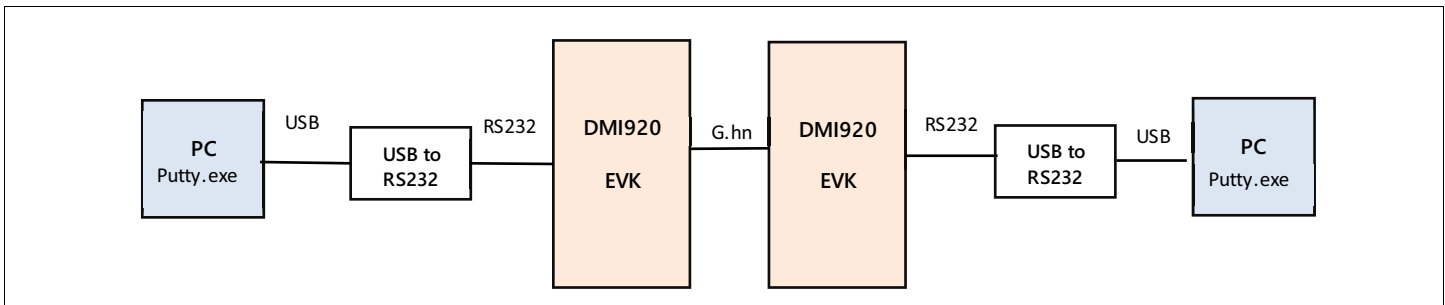

Figure 11: RS-232 Basic Use Case

There are commercial cables which allow you to convert the USB interface to the RS-232 interface. Both the USB to the RS232 cables and the DMI920 EVK can be used to transmit and receive bytes between two terminals using the *putty.exe* freeware.

Test Equipment

- 2 × MaxLinear DMI920 EVK (one node with *dmi920_v1_x-HE-GRID_flash-SPIRIT.v7_12_r820+5_cvs* loaded and one node with *dmi920_v1_x-EP-GRID_flash-SPIRIT.v7_12_r820+5_cvs* image loaded).

- 2 × USB to RS232 cable.

- 2 × DMI920 to RS-485/RS-232 connector accessory (RS485ACC).

    Note: For more info about RS485ACC accessory connections options, see "Appendix D: RS485ACC Accessory for Industrial EVK" on page 33.

- 2 computers with *putty.exe* installed.

- Spirit Configuration Tool (SCT).

- 2 × GHN-SP-UPLC.

- Combined fixed attenuators.

- BNC coaxial cables.

Test Methodology

To perform this test:

1. Configure the following CFL settings in the DMI920 nodes:

    a. `SERIALTUNNELING.INTERFACE=` `RS232` in both nodes

    b. Set the MAC address of the EP in the `SERIALTUNNELING.RS232.DESTINATION` parameter in the DM.

    c. Configure the same UART settings in the nodes and in their connected computers.

2. Run *putty.exe* in both computers using serial interface with the same settings than those configured in the UART config layer parameters.

3. Type some message and send them from one computer to the other and in the opposite direction to confirm that the bidirectional communication is working through the RS-232.

Test 2: Basic RS-485 Test

The RS-485 support can be tested using the basic setup shown in the following figure.
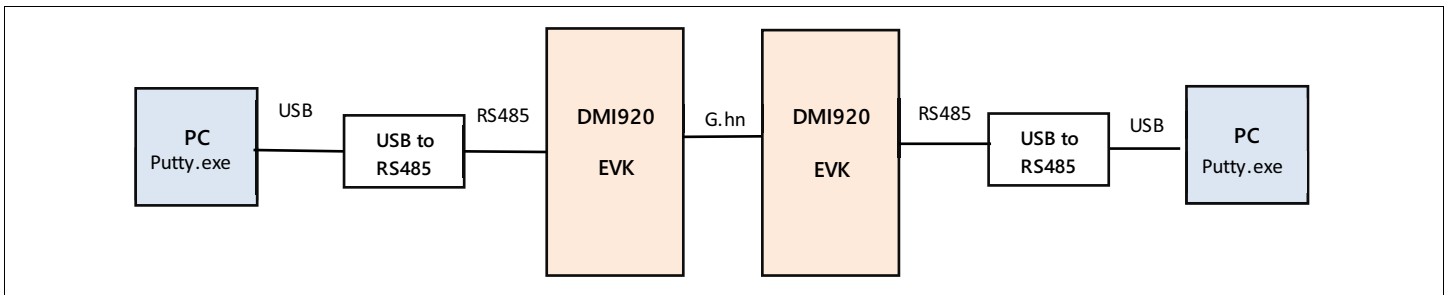

Figure 12: RS-485 Basic Use Case

There are some commercial cables which allow you to convert the USB interface to the RS-232 or RS-485 interface. Both the USB to the RS485 cables and theDMI920 EVK can be used to transmit and receive bytes between two terminals using the *putty.exe* freeware.

Test Equipment

- 2 × MaxLinear DMI920 EVK (one ode with d*mi920_v1_x-HE-GRID_flash-SPIRIT.v7_12_r820+5_cvs* loaded and one node with *dmi920_v1_x-HE-GRID_flash-SPIRIT.v7_12_r820+5_cvs* image loaded)
- 2 × USB to the RS485 cable (for example, DSD TECH SH-U11L USB to RS485 RS422 cable with FTDI FT232 chip)
- 2 × DMI920 to the RS-485/RS-232 connector accessory (RS485ACC).
- 2 computers with *putty.exe* installed.
- Spirit Configuration Tool (SCT).
- 2 × GHN-SP-UPLC.
- Combined fixed attenuators.
- BNC coaxial cables.

Test Methodology

To perform this test:

1. Configure the following CFL settings in the DMI920 nodes:
   a. `SERIALTUNNELING.INTERFACE= RS485_HALF` in both nodes.
   b. Configure the same UART settings in the nodes and in their connected computers.
2. Check with SCT reading parameter `SERIALTUNNELING.RS485.NODES` that the SLAVES nodes are registered in the DM.
3. Run *putty.exe* in both computers using serial interface with the same settings than those configured in the UART config layer parameters.
4. Type some message and send them from one computer to the other and in the opposite direction to confirm that the bidirectional communication is working through RS-485.

Test 3: RS-485 Multi-Node Test

The proposal of this test is to use several RS-485 devices that support the Modbus protocol. Use it also to demonstrate that the DMI920 EVKs with the Spirit GRID 7.12 SR1 loaded can manage several RS-485 devices connected through the G.hn network.

Figure 13 shows a demo setup. The Modbus RTU protocol is running externally in displays, sensors, computer with CAS Modbus Scanner GUI that you can use to validate the RS485 interface included in the DMI920 device.
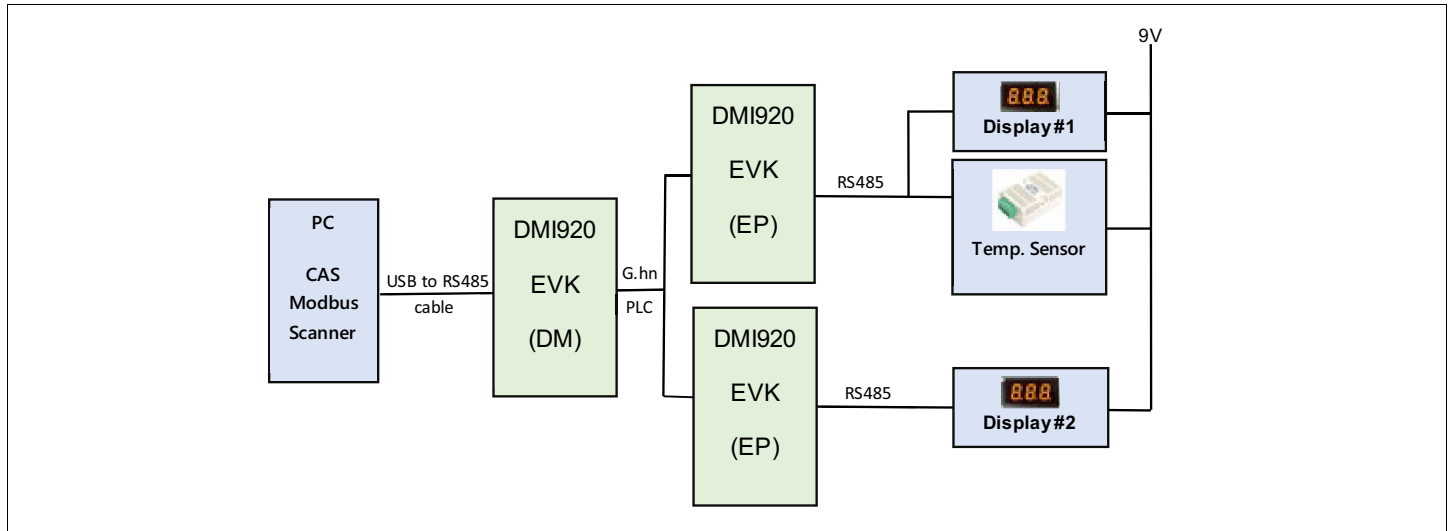

Figure 13: RS-485 Multi-node Modbus

Test Equipment

- ■ 3 × MaxLinear DMI920 adapters (one node with *dmi920_v1_x-HE-GRID_flash-SPIRIT.v7_12_r820+5_cvs* loaded and two nodes with *dmi920_v1_x-EP-GRID_flash-SPIRIT.v7_12_r820+5_cvs* image loaded)

- ■ 1 × USB to RS485 cable (for example, DSD TECH SH-U11L USB to RS485 RS422 cable with FTDI FT232 chip).

- ■ 3 × DMI920 to RS-485/RS-232 connector accessory (RS485ACC).

- ■ 2 × Display sensor (ModbusRTU protocol).

- ■ 1 × Temperature sensor (ModbusRTU protocol).

- ■ 1 Computer with *CAS Modbus Scanner* software installed (https://freemodbus.com/about/index.html).

- ■ Spirit Configuration Tool (SCT).

- ■ 3 x GHN-SP-UPLC.

- ■ 2 x Combined fixed attenuators.

- ■ BNC coaxial cables.

Figure 14: 10pin RS-485 Interface Connected to the USB to the RS485 Cable (Half Duplex)

Test Methodology

To perform this test:

1. Configure the following CFL settings in the DMI920 nodes:

   a. `SERIALTUNNELING.INTERFACE= RS485_HALF` in all nodes

   b. Configure the same UART settings in the HE node and its connected computer

2. Check with SCT reading parameter `SERIALTUNNELING.RS485.NODES` that SLAVES nodes are registered in the DM.

3. Connect the computer to the HE node and run the *CAS Modbus Scanner* software in the computer.

4. Right click on the left window and select **Add Connection.** Then add COM port assigned to the USB to the RS485 in the device manager

5. Set serial interface speed, data bits, stop bits, parity, and flow control

6. Right click on the new COM created and select **Add Device.** For example a *Display* with *Slave ID 2* as shown in Figure 14.

7. Right click on the new device and then select **Add Write Task**. Then select **06 Preset Single Register** with *Offset* equal to 1 and *Value* equal to 6666 as shown in the following figure.
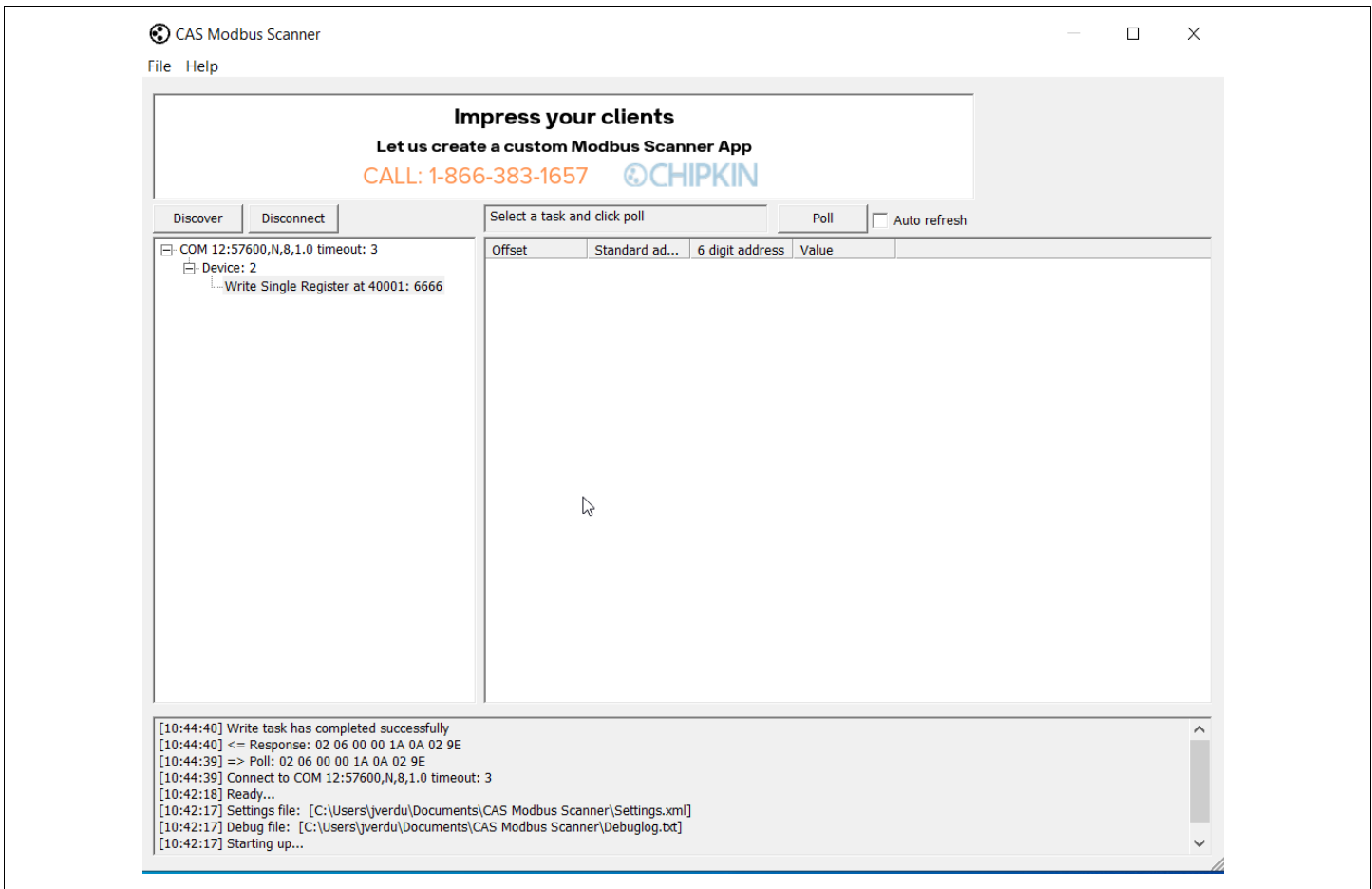

Figure 15: CAS Modbus Scanner GUICAS Modbus Scanner GUI

8. Right click on the new COM created and select **Add Device.** For example a Sensor with *Slave ID 3.*

9. Right click on the new device and select **Add Request Task.** Then select **04 Read Input Register** with *Offset* equal to 1. It should return the current temperature.

USB

Use the following test to evaluate the USB interface.

Test 1: Dynamic Range Measurement in a Flat Channel

This test concentrates on two nodes network performance that use the USB interface. You can measure the variation of the following variables as a function of attenuation:

- Physical throughput.
- TCP throughput.
- UDP throughput.

Test Equipment

- 2 × MaxLinear DMI920 EVK (one node with *dmi920_v1_x-HE-GRID_flash-SPIRIT.v7_12_r820+5_cvs* loaded and one node with *dmi920_v1_x-HE-GRID_flash-SPIRIT.v7_12_r820+5_cvs* image loaded)
- Use two PCs with one of the following software options:
    - Chariot SW from Ixia.
    - Iperf software (a public domain application that you can download for free), but the specific hardware and operating system can place a limitation on the results. For instance, Windows PC usually limits iperf UDP performance as client, so use of Linux is advised for UDP performance tests when possible.
- Spirit Configuration Tool (SCT).
- 2 × GHN-SP-UPLC.
- Combined fixed attenuators.
- BNC coaxial cables.

The following figure shows a test setup diagram using the previous test equipment.
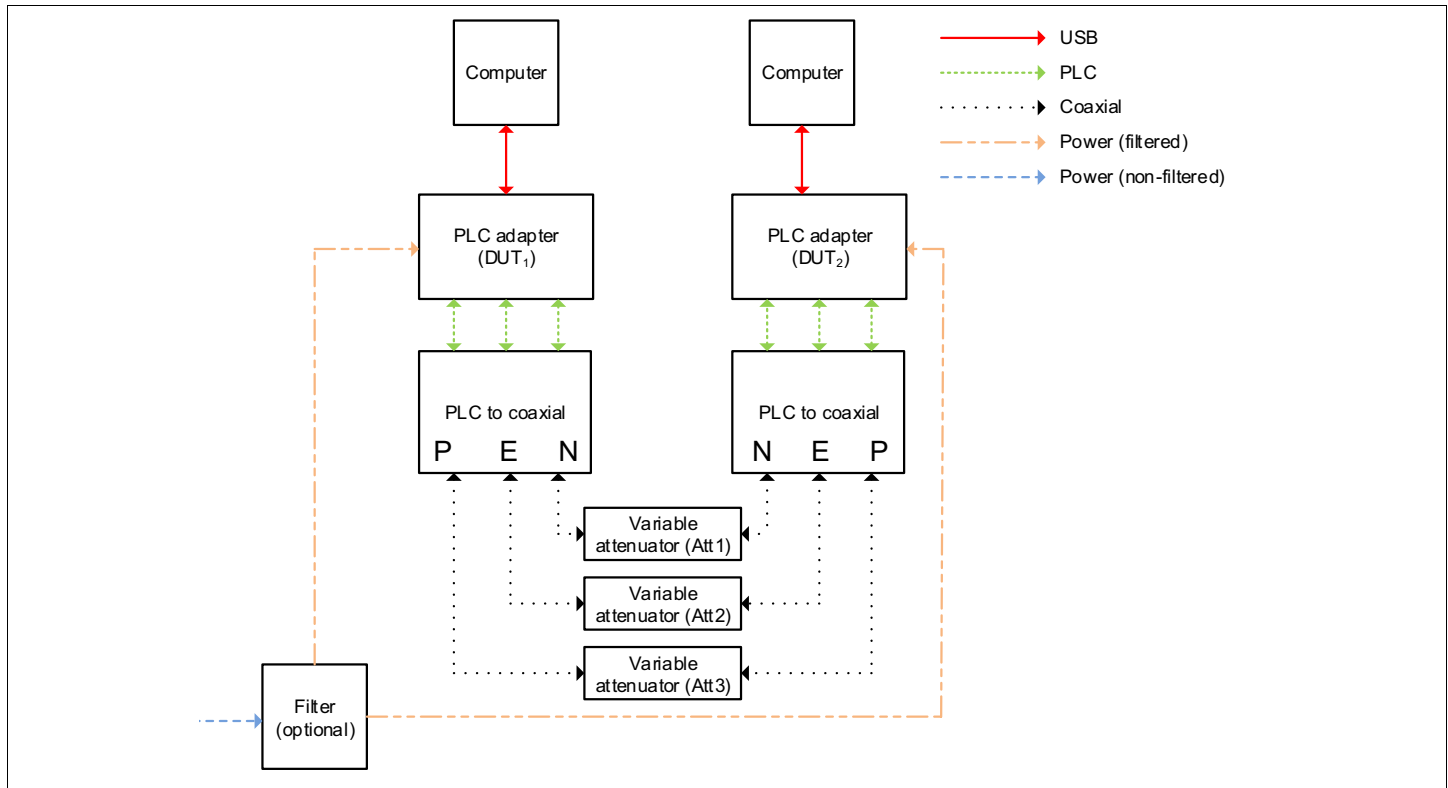
Figure 16: Test Setup for 2 DMI920 Nodes with USB Based on TR208

Warning! You do not need to supply power in the PLC 5-pole connector to avoid any electrical discharge and injury. This is only intended for PLC signal. For instance, you do not need to power universal PLC Splitter to run evaluation test cases.

Test Methodology

To perform this test:

1. Install USB Exar XR2280x driver in computers (https://www.maxlinear.com/support/design-tools/software-drivers).

2. Select the G.hn PLC profile to be tested (Spirit GRID support either 15 or 16. The default is 16 for the DMI920 device) and configure it into PLC adapters using SCT.

3. Set an attenuation of 10dB between the adapters.

4. Ensure that the ALB is disabled in all of the nodes (`QOSENGINE.ALB.ENABLED=NO`) to avoid moving from idle to active state affects measurement.

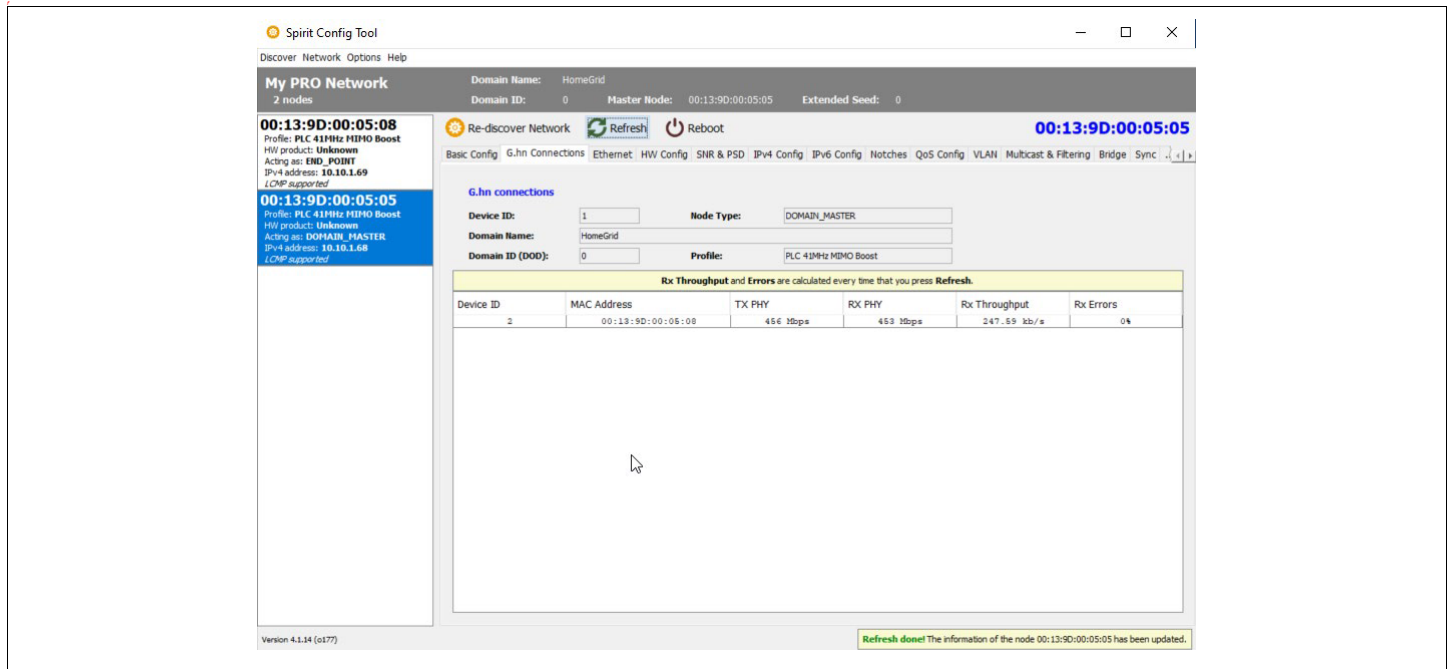**5.** Check the G.hn connections and note PHY rates with the SCT.

Figure 17: G.hn Connections Tab in SCT

6. Run iperf as follows:

Note: The maximum data rate is 100Mbps in USB.

a. Perform a TCP throughput test typing the following commands in a console window:

- Server side (PC1): `iperf -s -w 32K`
- Client side (PC2): `iperf -c [Server IP] -w 32K -i 1 -t 60 -P 16`

b. Test the UDP throughput typing the following:

- Server side (PC1): `iperf -s -i 1 -u -w 512K`
- Client side (PC2): `iperf -c [Server IP] -i 1 -u -w 512K -t 60 -b X`

where X is the injected bandwidth (in bps) for the application. Select an X value around 100M.

7. Write down the transmission and reception physical throughput obtained by using SCT.

8. Once done, repeat these steps increasing the attenuation value by 10dB or 20dB until achieved throughput is near to 0

Note: You can trigger a channel adaptation with `FLOWMONITOR.GENERAL.DID_ESTIMATE=<remote node DID>` when changing attenuation to speed up test.

9. Note the results in a table. See the following tables as examples.

Table 17: DMI920 UDP Unidirectional Measurements (Mbps) with USB Interface

Attenuation	Profile 16
10dB	92.6
20dB	92.6
30dB	92.6
40dB	92.6
50dB	92.6
60dB	92.6
70dB	68.4
80dB	45
90dB	27
100dB	0

Note: Results obtained by using the Spirit GRID 7.12 SR1 version loaded.

Table 18: DMI920 TCP Unidirectional Measurements (Mbps) with USB Interface

Attenuation	Profile 16
10dB	89.2
20dB	89.2
30dB	89.2
40dB	89.2
50dB	88.6
60dB	87.2
70dB	65.3
80dB	40.5
90dB	21
100dB	0

Note: Results obtained by using the Spirit GRID 7.12 SR1 version loaded.

Appendix A: Coaxial Profile Evaluation

To evaluate a coaxial profile, you should load a Spirit home networking *dmi920c* image for the DMI920 device instead of the Spirit GRID image.

> **Note:**
>
> - To get the Spirit home networking *dmi920c* image, contact MaxLinear Customer Technical Support.
> - To use coaxial physical interface in the DMI920 design, do not mount RT4, RT5, and RT6 in the PCB.

For further information about coaxial evaluation test plan, refer to the *Wave-2 Coaxial and Phoneline Home Networking Evaluation User Guide (057-W2CPLHN).*

Appendix B: Phone Profile Evaluation

To evaluate a coaxial profile, you should load a Spirit home networking *dmi920c* image for the DMI920 device instead of the Spirit GRID image.

> **Note:**
>
> - To get the Spirit home networking dmi920c image, contact MaxLinear Customer Technical Support.
> - To use phone physical interface in the DMI920 device, do not mount RT7 and RT8 in the PCB.

For further information about phone evaluation test plan, refer to the *Wave-2 Coaxial and Phoneline Home Networking Evaluation User Guide (057-W2CPLHNUG).*

MaxLinear Confidential

Appendix C: Safety Recommendations

To protect yourself from injuries and avoid damage of the device, always observe the following safety instructions when installing and working with the EVK.

The DMI920 (G.hn Industrial EVK) is an electrical/electronic product that can be connected to different dangerous energy sources capable of causing pain or injury.

The electrical safety of this EVK is not fully evaluated against the requirements of the *IEC 62368-1/EN 62368-1/UL 62368-1 (Audio/video, information and communication technology equipment – Part 1: Safety requirements)* standard and this EVK cannot fulfill with all the relevant electrical safety requirements stated in such standard.

Avoiding Injuries

Warning!

- This equipment must be used, connected and manipulated **ONLY BY SKILLED OR INSTRUCTED PERSONNEL** (as per the definitions in *IEC 62368-1* product safety standard).
- Electrical current!
- Electrical current from power and communications cables can be hazardous.
- Never touch any electrical elements with bare hands.

To avoid potential shock hazards:

- Do not remove the enclosure with the adapter plugged to mains.
- Remove all the cables connected to the EVK before to remove the enclosure.
- Do not manipulate the circuits and/or components with enclosure removed and adapter powered.
- Do not touch any component from the boards when it is plugged into the mains.
- Do not carry out any installation, maintenance, or (re)configuration work during a thunderstorm.
- Do not connect or disconnect any power cables during a thunderstorm.
- For installation in a hot-plug system, observe the safety instructions specific to this system.

Read the relevant documentation.

Appendix D: RS485ACC Accessory for Industrial EVK

General description

Use the RS485ACC accessory for industrial EVK. It supports the following interfaces:

- RS485 Half duplex
- RS485 Full duplex
- RS232

To connect the accessory to the EVK, use the socket J1.

By default, both switches SW1 and SW2 should have their four levers at OFF position. These switches provide the device a redundant fail-safe status for the communications lines (positions 1 and 4) and a termination resistor (positions 2 and 3) when the length of the lines requires them for avoiding undesired reflections. You can also get this information on the PCB as shown in the following figure.
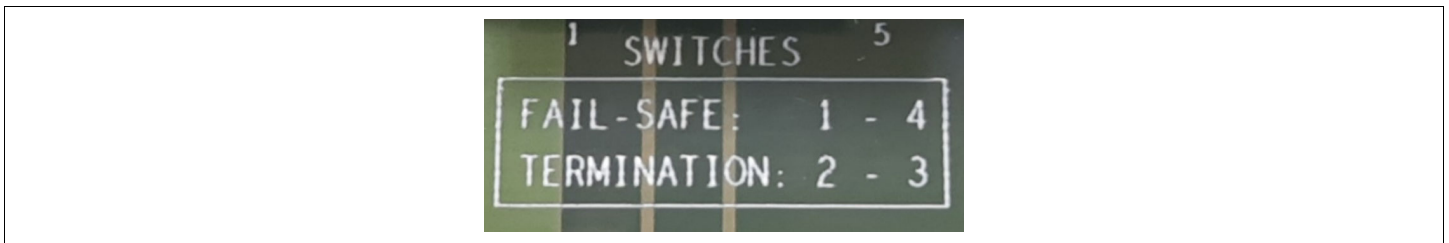
Figure 18: Fail-safe Status and Termination Resistor on PCB

MaxLinear's transceiver SP336E has implemented an internal fail-safe to prevent from undesired input states. For more information, refer to the *SP336E 3.3v/5v Programmable RS-232/RS-485/RS-422 Serial Transceiver* document.

The resistors are marked as follows:

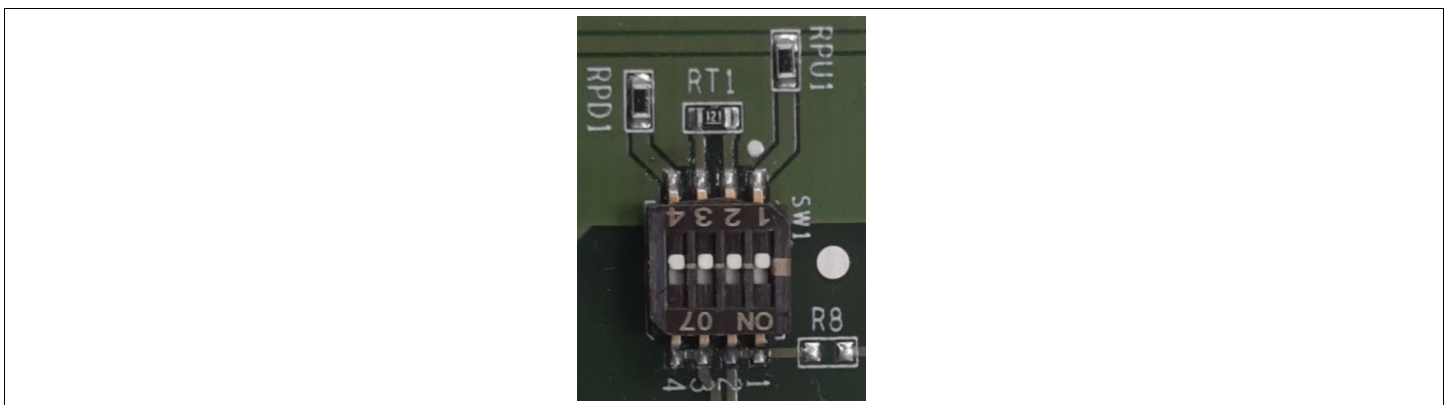- R Pull-up: RPU
- R Pull-down: RPD
- R Termination: RT

Figure 19: RPU, RPD, and RT Resistors

RS485 Half Duplex

The B, A, and GND wires of the communications bus should be connected to the socket J2 in the positions that are marked on the top of the PCB as shown in the following figure.
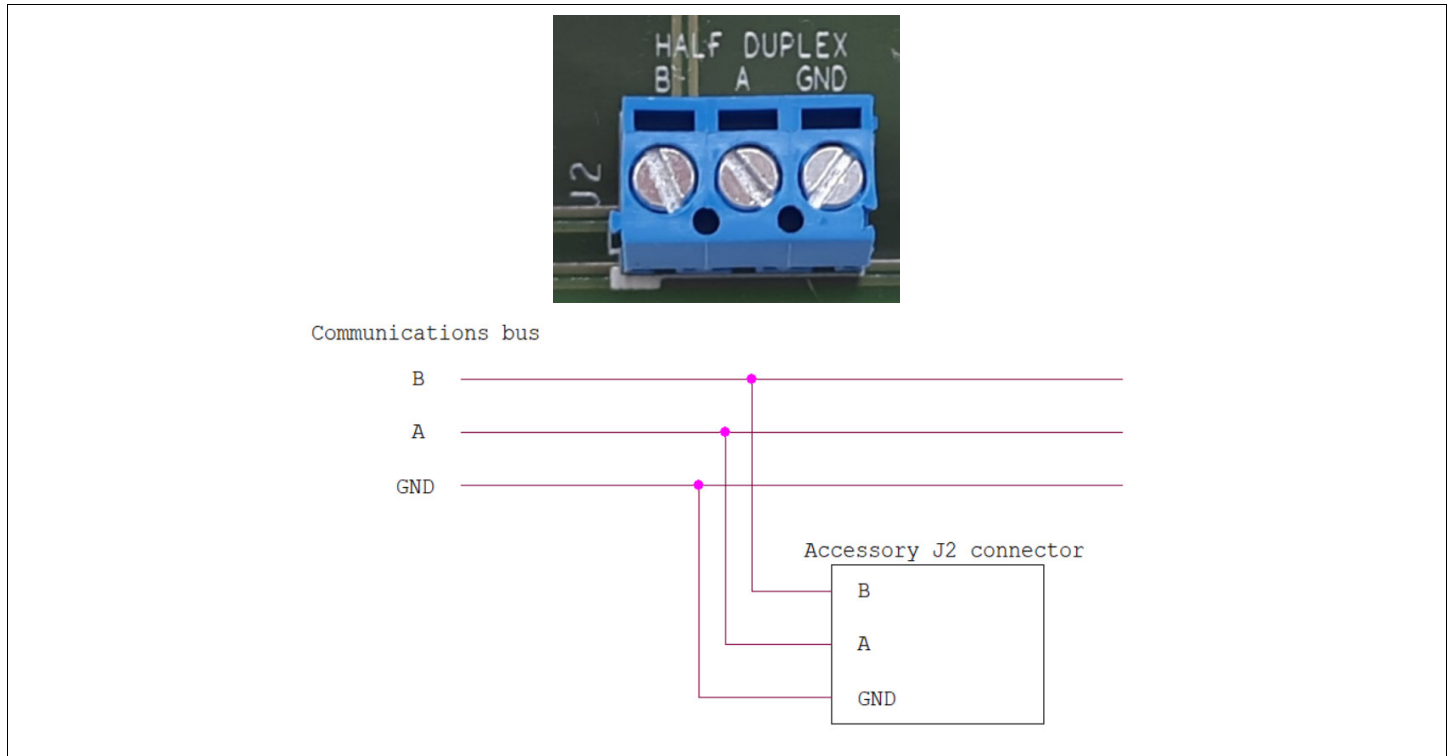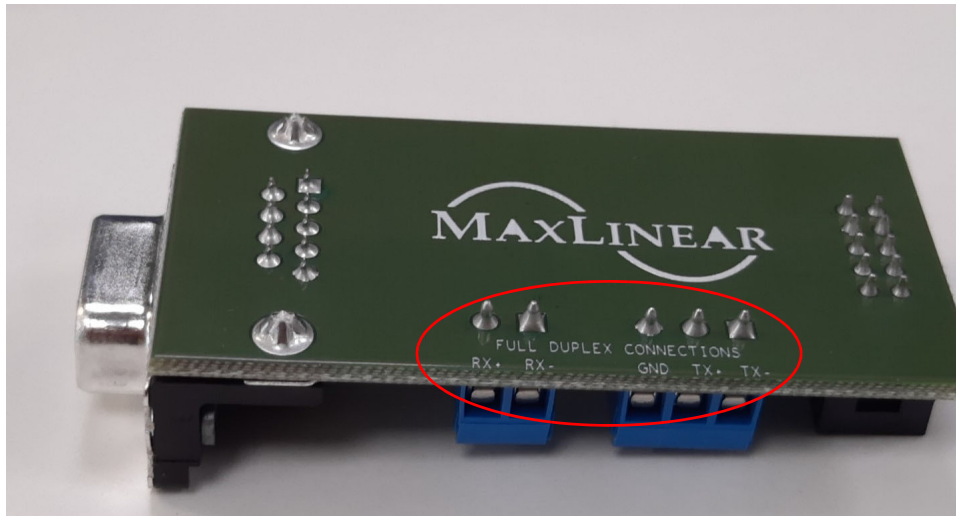

Figure 20: RS485 Half Duplex

RS485 Full Duplex

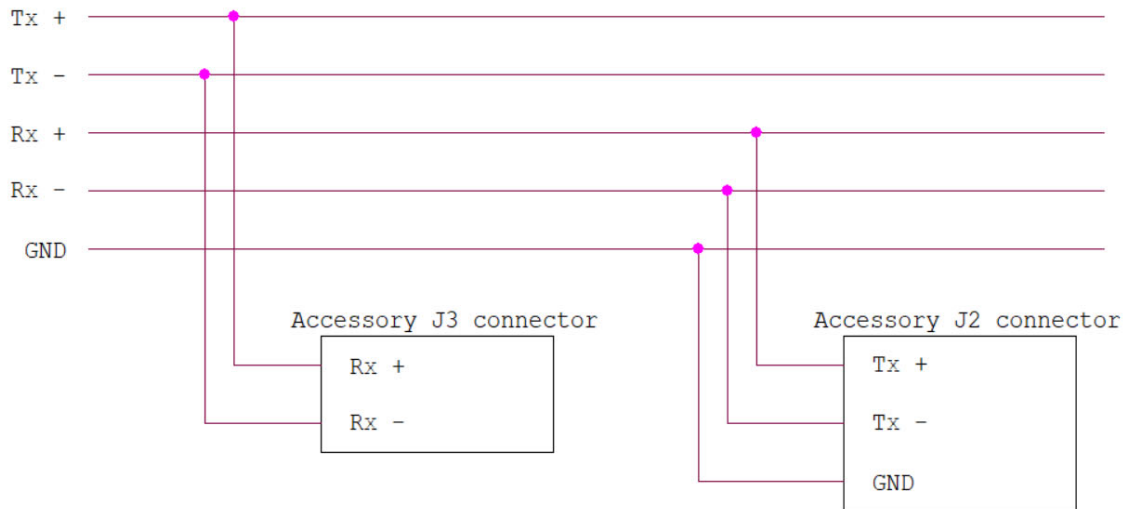The position of the connections is provided on the back of the PCB. For this mode, you must use the sockets J2 and J3.

Figure 21: RS485 Full Duplex