ABSTRACT

The DP83822 was designed to meet the needs of rugged and high performance applications while still maintaining strict adherence to the IEEE 802.3u standard. This application note will discuss how to configure the DP83822 for various Ethernet compliance tests, identify common system level mistakes and present solutions to those mistakes to ensure compliance.

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1 Introduction

The DP83822 10/100 Mbps Industrial Ethernet PHY is IEEE 802.3u compliant to:

- 100BASE-TX
- 100BASE-FX
- 10BASE-Te

This application note will only discuss 100BASE-TX and 10BASE-Te compliance. For additional support, visit our Texas Instruments E2E Community at www.e2e.ti.com.

Table 1. Terminology

<table>
<thead>
<tr>
<th>ACRONYM</th>
<th>DEFINITION</th>
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<tbody>
<tr>
<td>DUT</td>
<td>Device Under Test</td>
</tr>
<tr>
<td>LP</td>
<td>Link Partner</td>
</tr>
<tr>
<td>PHY</td>
<td>Physical Layer Transceiver</td>
</tr>
<tr>
<td>SMI</td>
<td>Serial Management Interface</td>
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<tr>
<td>IPG</td>
<td>Inter-Packet Gap</td>
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<tr>
<td>FLP</td>
<td>Fast Link Pulse</td>
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<tr>
<td>NLP</td>
<td>Normal Link Pulse</td>
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<tr>
<td>TX</td>
<td>Transmit – Digital Pins</td>
</tr>
<tr>
<td>RX</td>
<td>Receive – Digital Pins</td>
</tr>
<tr>
<td>TD</td>
<td>Transmit – Analog Pins</td>
</tr>
<tr>
<td>RD</td>
<td>Receive – Analog Pins</td>
</tr>
<tr>
<td>AVD</td>
<td>Analog Supply</td>
</tr>
<tr>
<td>CT</td>
<td>Magnetic Center Tap</td>
</tr>
<tr>
<td>VDDIO</td>
<td>Digital Supply</td>
</tr>
<tr>
<td>BIST</td>
<td>Built-In Self-Test</td>
</tr>
<tr>
<td>TPM</td>
<td>Twisted Pair Model</td>
</tr>
<tr>
<td>AOI</td>
<td>Active Output Interface</td>
</tr>
<tr>
<td>AFE</td>
<td>Analog Front-End</td>
</tr>
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</table>
2 Standards and System Requirements

2.1 Standards
The following standards serve as references for the tests described in this document.

- IEEE802.3-2005 Sub Clause 14.3.1
- IEEE802.3-2005 Sub Clause 25.4
- ANSI X3.263-1995

2.2 Test Equipment Suppliers
The following test equipment suppliers are known to offer IEEE 802.3 compliance test equipment.

- Tektronix
- Spirent
- Agilent (Keysight)

2.3 Test Equipment Requirements
For this application note, the following hardware and software was used.

- Oscilloscope and Physical Layer Compliance Software (Tektronix TDSET3)
- Differential Probe
- Ethernet Compliance Test Fixture
- TI USB-2-MDIO tool With PC (Not Required For All Tests)
- MSP430 LaunchPad MSP-EXP430F5529LP
- USB Cable
- DC Power Supply
3 Ethernet Physical Layer Compliance Testing

3.1 Standard Test Setup and Procedures

For Ethernet physical layer compliance testing, the PHY is managed through SMI to enable various test modes. Test results are determined and recorded by the oscilloscope’s Ethernet compliance software (for example, Tektronix’s TDSET3).

Variation between Ethernet physical layer compliance tests is primarily the test mode of the PHY (configured by setting the internal PHY registers via SMI) and the connection on the test fixture.

1. Connect 5-V DC supply to the EVM through the micro-USB connector. For other power supply options, see the DP83822 EVM User’s Guide (SNLU179).

2. Connect the EVM to the test fixture according to setup outlined in the test fixture/software manual (see Figure 1). Identify if a link partner and/or packet generator is needed for the test, and connect accordingly.

3. Set the thermal stream or oven to desired temperature (if applicable).

4. Configure the PHY’s registers for the specific test. The SMI can be managed using TI’s USB-2-MDIO tool through a MSP430 Launchpad (see Appendix D). Register configurations are outlined in Appendix A. All test mode configuration scripts can be copied and used directly with the USB-2-MDIO tool.

5. Start and configure the oscilloscope’s Ethernet testing software (see software user’s manual).

6. Run the test and store the results (using the Ethernet compliance testing software).

7. Determine if the test has passed or failed according to IEEE standards.

8. Change test parameters or test channel and repeat.

Figure 1. DP83822 EVM Connected to a Testing Fixture
3.2 10BASE-Te Compliance Testing

Refer to Appendix A for 10BASE-Te test mode scripts. Sample test waveforms are included in Appendix C.

3.2.1 Link Pulse

Purpose: To ensure that the link pulse waveform is within the specified bounds.

Pass Condition: The link pulse must fit into the IEEE-defined template.

Specific Test Setup: Verify the test fixture connections. Set registers according to 10BASE-Te Link Pulse in Appendix A.

3.2.2 TP_IDL

Purpose: To ensure that the transmitter functions properly after transitioning to an idle state.

Pass Condition: The transmitter TP_IDL pulse must fit within the template for Load 1, 2, and 3 with and without the TPM.

Specific Test Setup: Verify the test fixture connections. Configure the PHY to be in analog loopback mode by setting registers according to 10BASE-Te Standard in Appendix A.

3.2.3 MAU, Internal

Purpose: To ensure that the transmitter output equalization is within the specified bounds.

Pass Condition: The transmitter waveform should fit within the IEEE-defined template for all data sequences when terminated with a 100-Ω resistor.

Specific Test Setup: Verify the test fixture. Configure the PHY to be in analog loopback mode by setting registers according to 10BASE-Te Standard in Appendix A.

3.2.4 Jitter With TPM

Purpose: To ensure that the jitter is within the specified bounds.

Pass Condition: The transmitter output jitter should be less than ±5.5 ns.

Note: Failure with TPM does not necessarily mean noncompliance.

Specific Test Setup: Verify the test fixture connections. Configure the PHY to be in analog loopback mode by setting registers according to 10BASE-Te Standard in Appendix A.

3.2.5 Jitter Without TPM

Purpose: To ensure that the jitter is within the specified bounds.

Pass Condition: The transmitter output jitter should be less than ±8.0 ns.

Specific Test Setup: Verify the test fixture. Configure the PHY to be in analog loopback mode by setting registers according to 10BASE-Te Standard in Appendix A.

3.2.6 Differential Voltage

Purpose: To ensure that the differential voltage is within the specified bounds.

Pass Condition: The peak differential voltage should be between 1.54-V and 1.96-V when terminated with 100-Ω resistor.

Specific Test Setup: Verify the test fixture. Configure the PHY to be in analog loopback mode by setting registers according to 10BASE-Te Standard in Appendix A.
3.2.7 Harmonic Content

**Purpose:** To ensure the harmonic content of the PHY is within the specified bounds.

**Pass Condition:** The Data Out circuit must drive all ones. All subsequent harmonics must be 27-dB below the fundamental.

**Specific Test Setup:** Verify the test fixture. Configure the PHY to be in analog loopback mode by setting registers according to 10BASE-Te Standard in Appendix A.

3.2.8 Common-Mode Voltage

**Purpose:** To ensure the common-mode voltage is within the specified bounds.

**Pass Condition:** The magnitude of the common-mode voltage should be less than 50-mV peak.

**Specific Test Setup:** Verify the test fixture connections. Configure the PHY to be in analog loopback mode by setting registers according to 10BASE-Te Standard in Appendix A.

3.2.9 Return Loss

**Purpose:** To ensure that the return loss is above the specified attenuation.

**Pass Condition:** The reflection of any incident signal to the PHY must be attenuated: \( \geq 15 \, \text{dB} \) over the frequency range of 5 MHz to 10 MHz

**Specific Test Setup:** Two waveform inputs may be necessary depending on testing setup. Verify the test fixture connections. Configure the PHY to be in analog loopback mode by setting registers according to 10BASE-Te Standard in Appendix A.

3.2.10 Common-Mode Rejection

**Purpose:** Verify that the PHY’s common-mode rejection ratio is within the specified bounds.

**Pass Condition:** See IEEE 802.3 14.3.1.2.6

**Specific Test Setup:** Refer to the high voltage injection testing procedures (not included in this app note). Set registers according to 10BASE-Te Standard in Appendix A.
3.3 100BASE-TX Compliance Testing
Refer to Appendix A for 100BASE-TX register writes. The following tests are done with forced MDI using the PHY Control Register (PHYCR, address 0x0019). For MDIX operation set bits \([15:14] = 0b01\). Sample test waveforms are included in Appendix C.

3.3.1 Template (Active Output Interface)
**Purpose:** To ensure that the output fits the transmit template.
**Pass Condition:** MLT-3 eye fits into the specified ANSI AOI template.
**Specific Test Setup:** Verify the correct test fixture connections. Configure PHY to 100BASE-TX Standard in Appendix A.

3.3.2 Differential Output Voltage
**Purpose:** To ensure the differential output voltage is within the specified bounds.
**Pass Condition:** The differential output voltage should be within a positive +950-mV to +1050-mV and negative –950-mV to –1050-mV.
**Specific Test Setup:** Verify the correct test fixture connections. Configure PHY to 100BASE-TX Standard in Appendix A.

3.3.3 Signal Amplitude Symmetry
**Purpose:** To ensure the Signal Amplitude Symmetry is within the specified bounds.
**Pass Condition:** The ratio of the positive peak to negative peak amplitudes should be within 2% or \(0.98 \leq \frac{|+VOUT|}{|-VOUT|} \leq 1.02\)
**Specific Test Setup:** Verify the correct test fixture connections. Configure PHY to 100BASE-TX Standard in Appendix A.

3.3.4 Rise and Fall Time
**Purpose:** To ensure that the device rise and fall time are within the specified bounds.
**Pass Condition:** The rise and fall time (between 10% and 90% voltage levels for both positive and negative) should be between 3 ns and 5 ns. The maximum and minimum rise and fall times should be within 0.5 ns.
**Specific Test Setup:** Verify the correct test fixture connections. Configure PHY to 100BASE-TX Standard in Appendix A.

3.3.5 Rise and Fall Time Symmetry
**Purpose:** To ensure that the device rise and fall time symmetry are within the specified bounds.
**Pass Condition:** Rise and fall time symmetry should be less than 500 ps.
**Specific Test Setup:** Verify the correct test fixture connections. Configure PHY to 100BASE-TX Standard in Appendix A.

3.3.6 Waveform Overshoot
**Purpose:** To ensure that the waveform overshoot is below the specified bound.
**Pass Condition:** The overshoot (both positive and negative maximum voltage level on transition) should not exceed 5% over the steady-state voltage level (VOUT).
**Specific Test Setup:** Verify the correct test fixture connections. Configure PHY to 100BASE-TX Standard in Appendix A.
3.3.7 Jitter

**Purpose:** To ensure that the transmit output jitter is within the specified bounds.

**Pass Condition:** The transmit output jitter should be less than 1.4 ns.

**Specific Test Setup:** Verify the correct test fixture connections. Configure PHY to 100BASE-TX Standard in Appendix A.

3.3.8 Duty Cycle Distortion

**Purpose:** To ensure that the duty cycle distortion is below the specified bound.

**Pass Condition:** The duty cycle distortion (defined as above and below 50% of Vout) should not exceed ±0.25 ns.

**Specific Test Setup:** Verify the correct test fixture connections. Configure PHY to 100BASE-TX Standard in Appendix A.

3.3.9 Return Loss

**Purpose:** To ensure that the return loss is above the specified attenuation.

**Pass Condition:** The reflection of any incident signal to the PHY must be attenuated:
- ≥16 dB over the frequency range of 2 MHz to 30 MHz
- ≥10 – 20log 10 (f /30) dB over the frequency range 30 MHz to 60 MHz (f in MHz)
- ≥10 dB over the frequency range 60 MHz to 80 MHz

**Specific Test Setup:** Verify the correct test fixture connections. Configure PHY to 100BASE-TX Standard in Appendix A.

**Note:** A spectrum analyzer may be needed depending on Ethernet Compliance Software.

3.3.10 Common-Mode Rejection

**Purpose:** Verify that the PHY’s common-mode rejection ratio is within the specified bounds.

**Pass Condition:** See ANSI X3-263-1995 9.2.3

**Specific Test Setup:** Refer to the high voltage injection testing procedures (not included in this app note). Verify the correct test fixture connections. Configure PHY to 100BASE-TX Standard in Appendix A.
4 Debug Test Methods

The DP83822 includes various debug tools within the device to identify issues with the connected system or improper implementation of the device itself. The following subsections are ordered in the way that debug should proceed if operation is not as expected.

4.1 Common System Issues

This list serves as a common check to ensure that the DP83822 is properly implemented.

- Are the AVD, CT, and VDDIO supply rails at expected levels?
- Is the Magnetic CT tied to AVD?
- Is RBIAS resistor 4.87 KΩ?
- Is the reference clock at the correct frequency?
- Does the MDIO have a 2.2-KΩ pullup resistor?
- Do the LED_0 and LED_1 pins have parallel pullup or pulldown resistors to the LED and current-limiting resistor?
- Are the RESET_N and INT/PWDN_N not pulled to a low state?
- Are the bootstraps latching to the expected state?
  - Read Strap Latch-in Register #1 (SOR1, address 0x0467)
  - Read Strap Latch-in Register #2 (SOR2, address 0x0468)
- Register settings are correctly executed?

4.2 Loopback Modes

There are six internal loopback paths within the DP83822. Each loopback serves a unique purpose in the debug process and system verification. The subsections below detail the most common loopback modes used and possible case scenarios for why they might be implemented.

![Figure 2. Loopback Test Modes](image)

4.2.1 MII Loopback

MII Loopback is the shallowest loopback within the DP83822. Data presented on the TX pins is internally routed back to the RX pins. This loopback mode is enabled by setting bit[14] in the Basic Mode Control Register (BMCR, address 0x0000).

**Purpose:** MII Loopback is typically used to identify issues along the digital transmit and receive paths. This shallow loopback can isolate and help identify issues with routing errors, cut traces and unconnected pins.

**Register Setting:** Refer to MII Loopback 100BASE-TX or 10BASE-Te script in Appendix B.
4.2.2 Analog Loopback

Analog Loopback is the deepest forward loopback within the DP83822. Data received on the TX pins from a connected MAC is passed through the entire transmit block. The data is then outputted on the TD pins by the AFE. An internal path within the DP83822 routes the TD data to the AFE receiver, where the data is then passed through the entire receive block and presented on the RX pins to the connected MAC. This loopback mode is enabled by setting bit[3] in the BIST Control Register (BISCR, address 0x0016).

Note: This mode requires 100-Ω termination as shown in Figure 3. This mode also requires the PHY to be operating in either forced 100BASE-TX or 10BASE-Te mode.

![Figure 3. Analog Loopback Terminations](image)

Purpose: Analog loopback is typically used to identify issues with improper MDI termination and reference clock violations. This loopback is often used when performing IEEE 802.3 compliance tests.

Register Setting: Refer to Analog Loopback 100BASE-TX or 10BASE-Te script in Appendix B.

4.2.3 External Loopback

External loopback is not a loopback within the DP83822; however, it is included in this discussion because it is a useful tool in the debug process. Data received on the TX pins from a connected MAC is passed through the entire transmit block. The data is then outputted on the TD pins by the AFE. Transmit data pins are directly wired back to the receive data pins using a loopback cable. The data is received by the DP83822 and is then passed through the entire receive block and presented on the RX pins to the connected MAC.

Note: External loopback requires the use of a loopback cable as shown in Figure 4.

![Figure 4. Loopback Cable](image)

Purpose: External loopback is used to check the entire system, including external passive components (that is, termination resistors, magnetics and connectors).

Register Setting: No register configuration is necessary for external loopback.
4.3 Built-In Self-Test

The DP83822 has an internal BIST that allows for on-board testing without the need for a connected MAC. BIST can be used for customized testing and debugging scenarios. The DP83822 BIST is controlled using the BIST Control Register (BISR, address 0x0016), BIST Control and Status Register #1 (BICSR1, address 0x001B) and the BIST Control and Status Register #2 (BICSR2, address 0x001C).

BIST packet length (address 0x001C) and IPG (address 0x001B) can be controlled in the DP83822 allowing for customizable test scenarios. Bits[7:0] in BICSR1(address 0x001B) defines the IPG in bytes. Bits[10:0] in BICSR2(address 0x001C) defines the packet length in bytes.

Standard Setup for BIST:
1. Connect 5-V DC supply to the EVM through the micro-USB connector. For other external power supply options see the DP83822 EVM User’s Guide (SNLU179).
2. Configure the PHY for the specific loopback test by setting the corresponding SMI registers as outlined in Appendix B.
3. Perform the test by writing the SMI registers as outlined in Appendix B. Read the BIST Control Register (BISR, address 0x0016) for PRBS status, and BIST Control and Status Register #1 (BICSR1, address 0x001B) for BIST error count. Note that to read BIST error count, bit[15] in BICSR1(address 0x001B) must be set to 1. This will lock the current value of the BIST errors for reading. Note that setting bit[15] also clears the BIST Error Counter.

4.4 Cable Diagnostics

The DP83822 offers Time Domain Reflectometry (TDR). TDR can be used to determine opens, shorts, cable impedance mismatch, cable length, and other discontinuities along the cable.
IEEE802.3u Compliance Testing Scripts for the DP83822

A.1 100BASE-TX Standard Test Script

begin
  001F 8000  // software reset (clears register)
  0000 2100  // programs DUT to 100BASE-TX mode
  0019 0021  // programs DUT to Forced MDI mode, set to 4021 for MDIX mode
  001F 4000  // digital reset (doesn't clear register)
end

A.2 10BASE-Te Link Pulse Test Script

begin
  001F 8000  // software reset (clears register)
  0000 0100  // programs DUT to 10BASE-Te mode
  0019 0021  // programs DUT to Forced MDI mode, set to 4021 for MDIX mode
  001F 4000  // digital reset (doesn't clear register)
end

A.3 10BASE-Te Standard Test Script

begin
  001F 8000  // software reset (clears register)
  0000 0100  // programs DUT to 10BASE-Te mode
  0019 0021  // programs DUT to Forced MDI mode, set to 4021 for MDIX mode
  0016 7108  // programs DUT to generate data and enables analog loopback mode
  001F 4000  // digital reset (doesn't clear register)
end
Loopback and BIST Mode Scripts for the DP83822

B.1 MII Loopback 100BASE-TX Script

begin
  001F 8000 //software reset (clears register)
  0000 6100 //programs DUT to 100BASE-TX mode and enables MII Loopback
  001F 4000 //digital reset (doesn’t clear register)
end

B.2 MII Loopback 10BASE-Te Script

begin
  001F 8000 //software reset (clears register)
  0000 4100 //programs DUT to 10BASE-Te mode and enables MII Loopback
  001F 4000 //digital reset (doesn’t clear register)
end

B.3 Analog Loopback 100BASE-TX Script

begin
  001F 8000 //software reset (clears register)
  0000 2100 //programs DUT to 100BASE-TX mode
  0019 0021 //programs DUT to Forced MDI mode, set to 4021 for MDIX mode
  0016 0108 //enables analog loopback mode
  001F 4000 //digital reset (doesn’t clear register)
end

B.4 Analog Loopback 10BASE-Te Script

begin
  001F 8000 //software reset (clears register)
  0000 0100 //programs DUT to 10BASE-Te mode
  0019 0021 //programs DUT to Forced MDI mode, set to 4021 for MDIX mode
  0016 0108 //enables analog loopback mode
  001F 4000 //digital reset (doesn’t clear register)
end
B.5 Reverse Loopback 100BASE-TX Script

begin
001F 8000 //software reset (clears register)
0000 2100 //programs DUT to 100BASE-TX mode
0016 0110 //enables reverse loopback mode
001F 4000 //digital reset (doesn't clear register)
end

B.6 Reverse Loopback 10BASE-Te Script

begin
001F 8000 //software reset (clears register)
0000 0100 //programs DUT to 10BASE-Te mode
0016 0110 //enables reverse loopback mode
001F 4000 //digital reset (doesn't clear register)
end

B.7 BIST 100BASE-TX Script

begin
001F 8000 //software reset (clears register)
0000 2100 //programs DUT to 100BASE-TX mode
001B 007D //bits[7:0] determine IPG, default 0x7D is equal to 125 bytes
001C 05EE //bits[10:0] determine packet length, default 0x05EE is equal to 1518 bytes
0016 7100 //enable continuous error check BIST mode
001F 4000 //digital reset (doesn't clear register)
end

B.8 BIST 100BASE-TX with Analog Loopback Script

begin
001F 8000 //software reset (clears register)
0000 2100 //programs DUT to 100BASE-TX mode
0019 0021 //programs DUT to Forced MDI mode
001B 007D //bits[7:0] determine IPG, default 0x7D is equal to 125 bytes
001C 05EE //bits[10:0] determine packet length, default 0x05EE is equal to 1518 bytes
0016 7108 //enable continuous error check BIST mode with analog loopback mode
001F 4000 //digital reset (doesn't clear register)
end
B.9  BIST Status and Error Count Script

begin
0016 //reads address 0x0016, bits[11:9] show packet generator and checker status
001B //reads address 0x001B, bits[15:8] show BIST Error Count
end
PHY Test Mode Waveforms

Figure 5. 100BASE-TX Template

Figure 6. 100BASE-TX Differential Output Voltage (Negative)
Figure 7. 100BASE-TX Fall Time

Figure 8. 100BASE-TX Rise Time
Figure 9. 100BASE-TX Duty Cycle Distortion

Figure 10. 100BASE-TX Jitter
Figure 11. 100BASE-TX Waveform Overshoot

Figure 12. 10BASE-Te Link Pulse
The SMI can be managed using TI's USB-2-MDIO tool via a MSP430 Launchpad (either MSP430G2 or MSP430F5).

Setup for SMI access with TI's USB-2-MDIO Tool:
1. Download and follow the setup instructions for TI's USB-2-MDIO Tool (see the USB-2-MDIO User’s Guide (SNLU197)). Verify that the MSP430 LaunchPad drivers are installed.
2. Connect Host PC to DP83822 EVM via MSP430 Launchpad. Connect a USB cable to the LaunchPad, and then break out MDIO, MDC, and GND. When using the MSP430G2, pin 1.5 connects to MDIO pin on the DP83822 EVM and pin 1.4 connects to MDC pin on the DP83822 EVM. When using the MSP430F5, pin 4.1 connects to MDIO pin on the DP83822 EVM and pin 4.2 connects to MDC pin on the DP83822 EVM. A common ground needs to be connected between the DP83822 EVM and MSP430.

3. Start the USB-2-MDIO Tool, select the correct PHYID and com port (PHY must be powered). Open the port and write and/or read desired registers. Scripts can be run by navigating to the File tab located on the top left corner of the tool. For additional information regarding scripting and saving, refer to the USB-2-MDIO User’s Guide (SNLU197).
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