

MultiGBASE-T1 EEE Test Suite

TC16 – Energy Efficient Ethernet Test Specification (1.0)

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164 Introduction

165 These tests are intended to examine interoperability and stability of PHYs in EEE mode. Devices tested with
166 this specification are expected to have already passed basic data mode testing, as specified in other OPEN
167 Alliance documents (e.g., those produced under TC15).

168 *Identification of patent holders, if any.*

169 Abbreviation/Symbols

170

*	AND
!	NOT
+	OR

BS	<i>Burst Size</i>
COM	<i>Communication ready (status bit)</i>
DUT	<i>Device Under Test</i>
EEE	<i>Energy Efficient Ethernet</i>
GMII	<i>Gigabit Media Independent Interface</i>
HDMI	<i>High-Definition Multimedia Interface</i>
IBG	<i>Inter-burst gap</i>
IEC	<i>International Electrotechnical Commission</i>
IPG	<i>INter-Packet Gap</i>
ISO	<i>International Organization for Standardization</i>
JTAG	<i>Joint Test Action Group</i>
LP	<i>Link Partner</i>
LPI	<i>Low Power Idle</i>
MDIO	<i>Management Data Input/Output</i>
MII	<i>Media Independent Interface</i>
MMD	<i>MDIO Manageable Device</i>
PHY	<i>Physical Layer Device</i>
PL	<i>Payload Length</i>
PSD	<i>Power Spectral Density</i>
RX	<i>Receiver</i>
Tx	<i>Transmitter</i>
VGA	<i>Video Graphics Array</i>

171

172 **ITEMS FOR FURTHER STUDY:**

- 173 1. *Test setup (Appendix B) specify loss requirements (maximum insertion loss, return loss) for line tap.*
- 174
- 175 2. *Environmental tests (e.g., EMC) are expected to be done in other TCs, referencing these profiles.*
- 176 *(possibly this is an ECU-level test)*

177 2 Scope (mandatory)

178 The scope of this document is the definition of test procedures to investigate interoperability and robustness
 179 of IEEE Std 802.3 2.5GBASE-T1, 5GBASE-T1, and 10GBASE-T1 PHYs when operating with Energy Efficient
 180 Ethernet enabled. These tests assume that interoperability and compliance with normal (i.e., non-EEE)
 181 operation has been sufficiently established. The test configurations in this document may be referenced by
 182 other test specifications (e.g., EMC or temperature testing) to exercise the EEE Low Power Idle quiet-refresh
 183 signalling under those conditions, but those performance tests are beyond the scope of this document.
 184 Additionally, testing auto negotiation, competitive analysis, power measurements, and latency measurements
 185 are out of scope of this test plan.

186 3 Normative references (mandatory)

187 The following documents are referred to in the text in such a way that some or all of their content constitutes
 188 requirements of this document. For dated references, only the edition cited applies. For undated references,
 189 the latest edition of the referenced document (including any amendments) applies.

190 IEEE Standard for Ethernet," in IEEE Std 802.3-2022 (Revision of IEEE Std 802.3-2018) , vol., no., pp.1-7025, 29
 191 July 2022, doi: 10.1109/IEEESTD.2022.9844436 - see especially clauses 149 (for 2.5GBASE-T1, 5GBASE-T1, and
 192 10GBASE-T1 PHYs), and relevant parts of clauses 45 (for MDIO registers), 46 (for XGMII codes), and 78 (for
 193 Energy Efficient Ethernet)

194 4 Terms and Definitions (mandatory)

195 For the purposes of this document, the following terms and definitions apply.

- 196 – ‘Assert LPI’ means that the PHY shall behave as if the ‘Assert LPI’ codeword is applied at the XGMII Tx. This
 197 may be achieved by directly applying signals at the XGMII Tx, or by other means.
- 198 – ‘Deassert LPI’ means that the PHY shall behave as if the ‘Assert LPI’ codeword is **not** applied at the XGMII
 199 Tx. This may be achieved by directly applying signals at the XGMII Tx, or by other means.

200

201 ISO and IEC maintain terminological databases for use in standardization at the following addresses:

202 — ISO Online browsing platform: available at <https://www.iso.org/obp>

203 — IEC Electropedia: available at <http://www.electropedia.org/>

204 Other terms, such as low power idle (LPI), and quiet-refresh are as defined in Clause 1.4 and used in Clause
 205 149 of IEEE Std 802.3-2022.

206 5 Organization of Tests

207 The tests are primarily designed to indicate EEE LPI interoperability (or operability) of the device.

208 These tests are defined based on the assumption that normal operation without Energy Efficient Ethernet
209 enabled has been previously established.

210 To Bring:

211 Equipment (each participant brings):

212 • EEE capable DUT and any converters necessary to interface to the traffic generators/analyzers (i.e., a
213 native 2.5G/5G/10G capable Ethernet interface), including any necessary scripts or configuration files.

214 • Any special Programming cables (JTAG etc) needed for the DUT

215 • Power Supplies

216 • Clock Sources

217

218 Equipment needed at the Lab (common equipment):

219 • Computer Monitors (VGA interface, HDMI or DisplayPort may require adapters)

220 • Power Strips

221 • Keyboards and Mice

222 • A limited selection of Power Supplies

223 • High Speed Oscilloscopes / line probing equipment

224 • Traffic generators/monitor

225

226 • Cabling for connecting PHYs and connecting monitor computers to the DUT

227 (Note – While precision measurements are not made except in 8.3 timing, channels and line probes (if used)
228 require measurement to understand the setup for repeatability. For these, calibration data is needed.)

229 • Test channels compliant with channels C1 and C2 specified in (TC15 and) Appendix B.

230 • Line tap specified in Appendix B (optional).

231

232 Test Outline:

233 • Mandatory tests: EEE LPI interoperability/operability tests

234 • Assert/Deassert LPI on control (Group 1)

- 235 • LPI based on traffic (Group 2)
- 236 ▪ Traffic Profile A: Low-utilization = Master
- 237 ▪ Traffic Profile B: Low-utilization = Slave
- 238 ▪ Optional tests:
 - 239 • “Autonomous” LPI mode (optional) (Group 3)
 - 240 • Fully loaded traffic/Stress Test (Group 4)

241 The first set of tests (Group 1) attempt a simple transition, asserting and deasserting LPI functionality on
 242 control. This test requires the ability to control the codeword asserted at the XGMII interface (or equivalent)
 243 in both the DUT and the LP, and to assess whether the RX LPI indication and RX LPI received bits are set in the
 244 MDIO registers. The assessment criteria is that the bits indicate the transition to and from LPI mode and that
 245 the link remains up.

246 The second set of tests (Group 2) assert the traffic pattern at the DUT and the link partner and monitor for
 247 dropped frames (i.e., that the frame count in = the frame count out). This is repeated in each direction, and
 248 repeated reversing which PHY is the master and which is the slave, for a total of 4 combinations.

249 With the traffic profiles listed, interoperability will be observed for the following testing matrix, testing vendor
 250 to vendor, where the column indicates the vendor device sourcing the timing (master), and the row indicates
 251 the vendor recovering timing (slave).

252 Each matrix will be repeated for each traffic profile and speed supported.

253 For each test configuration, read and record any negotiated link parameters (e.g., interleaver and precoder
 254 settings).

255 (2.5G, 5G, or 10G)BASE-T1 EEE (speed as appropriate)

	V1	V2	V3	V4	V5
V1					
V2					
V3					
V4					
V5					

256

257 6 DUT / LP Configuration Permutation Definitions

258 The test groups shall be executed in multiple DUT/LP configurations, unless the test groups states otherwise.
 259 The intention is to guarantee that a test is executed in all relevant permutations. The table below shows the
 260 basic configurations executed for each test group. Support of slow wake is optional in the standard. The test
 261 plan shall note the speeds supported by the DUT, and whether the DUT supports slow wake. Speeds not
 262 supported shall be omitted from the test. If slow wake is not supported, tests x-B and x-D shall be omitted for
 263 all speeds.

264 Example: For a device which supports three speeds (2.5G, 5G and 10G) there are a total of 6 mandatory
 265 configurations (2.5G-A & C to 10G-A & C).

266 **Table 1: DUT/LP Configurations Baseline. X denotes the speed grade (2.5G, 5G or 10G)**

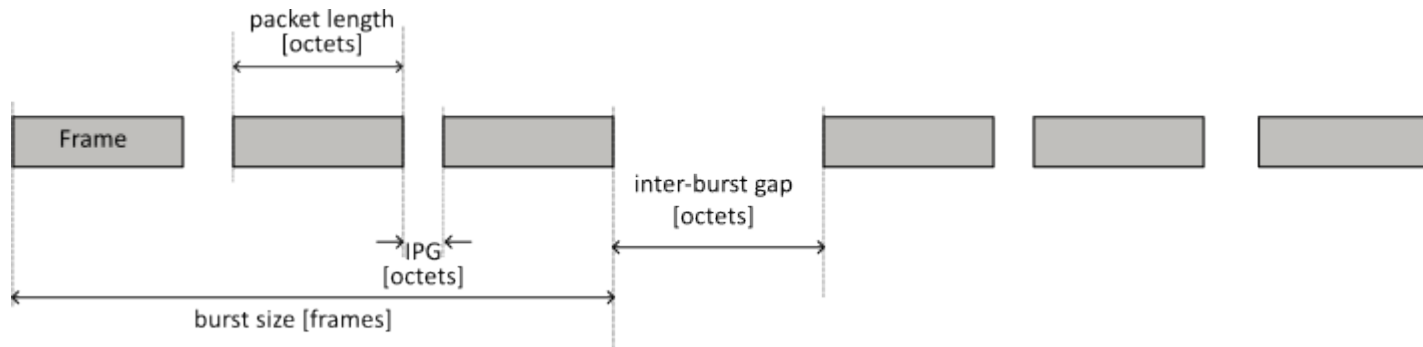
Configuration	DUT	LP	Optional?
x-A	LinkSync, SLAVE, Normal EEE	LinkSync, MASTER, Normal EEE	No
x-B	LinkSync, SLAVE, Slow Wake EEE	LinkSync, MASTER, Slow Wake EEE	Yes (Slow Wake)
x-C	LinkSync, MASTER, Normal EEE	LinkSync, SLAVE, Normal EEE	No
x-D	LinkSync, MASTER, Slow Wake EEE	LinkSync, SLAVE, Slow Wake EEE	Yes (Slow Wake)

267

268 7 EEE Profile Definition

269 The following sections define the traffic profiles which are used throughout different test groups. A traffic
 270 profile is the traffic that is sent by a single traffic generator into either DUT or LP as described further in the
 271 test group procedures.

272 The following figure illustrates the parameters in the defined traffic profiles.



273
 274 **Figure 1 Traffic Profile Parametrization**

275

276 7.1 General Definitions – EEE Timing at xMII

277 Depending on the test procedure, the traffic generator sends LPI code words during longer IDLE times (IBG or
 278 similar), or the DUT has the ability to generate LPI internally. The timing of the LPI code words shall obey the
 279 IEEE Std 802.3-2022 requirements. That specifically means, that while the link is in LPI and the traffic
 280 generator is about to generate traffic, the first frame after LPI must always be preceded by a wake-up period.
 281 The wake-up is a period of Idles after the LPI assertion period has completed and before the first frame of the
 282 burst is transmitted. The wake-up period is referred to as $T_{w_sys_tx}$ in IEEE Std 802.3-2022, Clause 78. The
 283 duration must exceed the minimum values in Table 78-4 for the speed (and wake mode) selected (case 3 for
 284 slow wake and case 1 for no slow wake). For definitions of the Case-1 and Case-3 in Table 2, see IEEE Std
 285 802.3-2022 at subclause 78.5.

286

287 **Table 2: Wake period (from IEEE Std 802.3-2022, Table 78-4)**

PHY type	Case	$T_{w_sys_tx}$ (min) (μ s)
2.5GBASE-T1	Case-1	35.84
	Case-3	148.48
5GBASE-T1	Case-1	17.92
	Case-3	74.24
10GBASE-T1	Case-1	8.96
	Case-3	34.56

288

289 **7.2 Profile A-1**

290 Profile A-1 and A-2 mimic a camera scenario. Traffic comes in a high-utilization stream (A-1) from one
 291 direction and a low-utilization, but bursty, stream (A-2) in the other direction. High utilization may be either
 292 the master or slave, as specified in the test scenario. Average data rates are over a 1 second interval.

293 Throughout this document the utilization (U in equations) is defined as all non-control (or IDLE) octets that are
 294 transmitted by the MAC divided by all octets in a sufficiently large observation time window.

295 **Table 3: Traffic Parameters Profile A-1**

Description	Continuous 90% L1 utilization in downstream direction. Specifically, the "non-control (or IDLE)" octets do not include control codes such as LPI.
L1 data rate	9.0 Gbps (10GBASE-T1) 4.5 Gbps (5GBASE-T1) 2.25 Gbps (2.5GBASE-T1)
Inter-packet gap ¹	Value implicitly given by $IPG = PL \cdot \left(\frac{1}{U} - 1\right)$, where PL is the payload length and U is the average L1 link utilization (i.e. 0.9).
Inter-burst gap	-
Burst-size	-
Packet length	1518 octets

296 **7.3 Profile A-2**

297 Profile A-2 is the low data rate, control flow for in a typical video scenario, see Profile A-1 for details.

298 **Table 4: Traffic Parameters Profile A-2**

Description	Bursty control traffic in upstream direction. Depending on the test, the packet generator sends LPI code words on the xMII interface with the intention to bring the link into LPI.
L1 data rate	Average 0.01 Gbps (same for 2.5/5/10GBASE-T1)
Inter-packet gap	12 octets
Inter-burst gap ²	Value implicit given by: $IBG = BS \cdot PL \left(\frac{1}{U} - 1\right) - BS \cdot IPG$, where IBG denotes the inter-burst gap in octets, U is the average L1 link utilization (here 0.1 % for 10G, 0.2 % for 5G, 0.4 % for 2.5G and 1 % for 1G), BS denotes the burst-size in frames, PL denotes the packet length in octets and IPG denotes the inter-packet gap during a burst in octets.

¹ The equations for IPG and IBG yield non-integer values. In practice, the actual IPG/IBG shall be close to the integer octet value and only vary by +/-1 octet. For example, deficit idle count (DIC) or other methods can be used to meet this requirement.

² See comment for IPG.

Burst-size	100 frames (fixed)
Packet length	64 octets

299

300 7.4 Profile B

301 The traffic pattern in this profile is a simple stop-and-go scenario in which the generator sends a single frame
 302 followed by a long idle time. Depending on the test, the traffic generator sends LPI code words, resulting in a
 303 repetitive interleaved LPI/frame sequence.

304 **Table 5: Traffic Parameters Profile B**

Description	Single frame, followed by IDLE. Depending on the test, the traffic generator sends LPI code words, resulting in a repetitive interleaved LPI/frame sequence.
Inter-packet gap	12 octets
Inter-burst gap	1 ms
Burst-size	1 frames (fixed)
Packet length	1518 octets

305

306 7.5 Profile C

307 This is a high load scenario to stress a single direction with the maximum possible data rate.

308 **Table 6: Traffic Parameters Profile C**

Description	Continuous high utilization in one direction. Specifically, the "non-control (or IDLE)" octets do not include control codes such as LPI.
Inter-packet gap	12 octets
Packet length	1518 octets

309 8 Interoperability Test Cases

310 8.1 Group 1: Simple Interoperability

311 **Overview:** These tests are designed to identify problems that may exist between two EEE capable devices in
312 establishing a complete link, exchanging packets with each other, while entering and leaving the LPI state, using
313 slow wake or not, as specified for the configuration.

314 **Out of Scope:** Competitive performance evaluation of a vendor's product will not be performed. Extensive
315 protocol conformance testing will not be pursued unless warranted for troubleshooting purposes.

316 **Additional DUT capabilities needed:** Devices will be required to be able to be forced into a LPI mode via
317 management registers, physical switches, or equivalent. Devices should be capable of indicating if they and/or
318 the link partner is in a LPI mode through management registers, LEDs, or equivalent.

319 MDIO access to management registers will be required to access the following:

- 320 • Link status MMD 1.1.2 or 1.2310.0
- 321 • Rx LPI indication, MMD 3.1.8, or 3.2323.8
- 322 • Rx LPI received, MMD 3.1.10, or 3.2323.10

323 NOTE - these registers are latching high, with clear on read. They will need to be read prior to getting a valid
324 stable state result.

325 Ability to manually configure MASTER/SLAVE without AutoNeg.

326 NOTE – tests are designed and configured to test devices as both MASTER and SLAVE. Timing mode of the test
327 is noted, and will be separately reported (i.e., results of steps 1-5 below are reported separately from results
328 of steps 6 & 7). Future tests may consider whether single-mode devices are permitted.

329 **Test Setup:** Connect link pair together with channel C1 as specified in Appendix B, and with a traffic
330 generator/packet tester. Repeat test with channel C2.

331 If a traffic generator is unavailable, this test can be performed if the PHY can enter LPI quiet-refresh signalling
332 by a forced configuration (e.g., register bit or pin).

333 Refer to test suite appendix A.

334 **Configurations:** Configurations specified in Table 1. If the DUT does not support slow wake, omit cases x-B
335 and x.-D.

336 **General Procedures:**

- 337 1. Reset DUT and LP prior to test execution
- 338 2. Establish a link between the link pair (no autoneg)
- 339 3. Observe both Link Partners Entering and Exiting the LPI mode
- 340 4. Observe that traffic can be sent from the link partner while the local transmitter is in LPI mode

341

342 **Specific Procedures:**

343 1. Establish a link between the link pair, as per the selected configuration and confirm the configuration
344 by reading the configuration back from the DUT/LP.
345 Read negotiated interleaving and precoder settings from DUT and LP and document.

346
347 2. Assert LPI at DUT, and deassert LPI at LP.

348
349 Expect Rx LPI indication = 1 at LP, and Rx LPI indication = 0 at DUT.
350 Expect Rx LPI received = 1 at LP, and Rx LPI received = 0 at DUT.

351
352 Observe for **1** minute.
353 Continuously monitor link status on DUT and LP – fail if link does not remain stable.

354
355 NOTE – use of a line tap is not required, but if available:
356 Verify that DUT produces a quiet-refresh cycle with the line tap.
357 Fail if quiet-refresh cycle is observed from the LP.

358
359 3. Assert LPI at LP, and deassert LPI at DUT.
360 Expect Rx LPI indication = 1 at DUT, and Rx LPI indication = 0 at LP.
361 Expect Rx LPI received = 1 at DUT, and Rx LPI received = 0 at LP.

362 Observe for **1** minute.
363 Continuously monitor link status on DUT and LP – fail if link does not remain stable.

364 NOTE – use of a line tap is not required, but if available:
365 Verify that LP produces a quiet-refresh cycle with the line tap.
366 Fail if quiet-refresh cycle is observed from the DUT.

367
368
369 4. Assert LPI at DUT, and assert LPI at LP.
370 Expect Rx LPI indication = 1 at DUT, and Rx LPI indication = 1 at LP.
371 Expect Rx LPI received = 1 at DUT, and Rx LPI received = 1 at LP.

372 Observe for **1** minute.
373 Continuously monitor link status on DUT and LP – fail if link does not remain stable.

374
375 NOTE – use of a line tap is not required, but if available:
376 Verify that DUT produces a quiet-refresh cycle with the line tap.
377 Verify that LP produces a quiet-refresh cycle with the line tap.

378
379 5. Send traffic Profile B from the traffic generator into DUT's xMII.
380 Send traffic Profile B from the traffic generator into LP's xMII.
381 Continuously monitor link status on DUT and LP and expect that link remains stable.

382
383 Observe for 2 minutes (120 seconds).

384 Expect all frames transmitted by the DUT to be received by the LP, without any frame errors or
385 missing frames.

386 Expect all frames transmitted by the LP to be received by the DUT, without any frame errors or
387 missing frames.

388 Expect Rx LPI received = 1 at DUT, and Rx LPI received = 1 at LP.

389

390 **Other expected results:**

391 a) After the links have been established the link status of MMD 1.1.2 should always be reported as 1 and
392 should never be reported as 0. Recording a value of 0 indicates a link problem potentially caused by
393 an EEE interoperability problem.

394 b) The EEE wake error counter of MMD 3.22 should always record a value of 0. A value other than 0
395 indicates a problem in the LPI wake-up sequence.

396

397 **Notes:**

398 **NOTE – If one wishes to perform tests specified by TC15 while exercising EEE functionality, the Group 1 test**
399 **sequence can be used.**

400 **8.2 Group 2: Typical Application**

401 **Overview:** This test is designed to monitor packet-handling for asymmetric traffic with a pair of EEE capable
402 devices entering and exiting LPI operation. These tests can be used to identify whether problems exist causing
403 packet loss or link drop during entry to or exit from LPI operation..

404 **Out of Scope:** Competitive performance evaluation of a vendor’s product will not be performed. Extensive
405 protocol conformance testing will not be pursued unless warranted for troubleshooting purposes.

406 **Additional DUT capabilities needed:** Devices will be required to accept packets for transmit and deliver
407 packets on reception to a packet generator/monitor. Devices must be capable of indicating if they and/or the
408 link partner is in a LPI mode through management registers or equivalent functionality.

409 MDIO access to management registers will be required to access the following:

- 410 • Link status MMD 1.1.2 or 1.2310.0
- 411 • Rx LPI indication, MMD 3.1.8 or 3.2323.8
- 412 • Rx LPI received, MMD 3.1.10 or 3.2323.10
- 413 • NOTE - these registers are latching high, with clear on read. They will need to be read prior to getting
414 a valid stable state result.

415

416 Ability to manually configure MASTER/SLAVE without AutoNeg.

417 NOTE – tests are designed and configured to test devices as both MASTER and SLAVE. Timing mode of the test
418 is noted, and will be separately reported (i.e., results of steps 1-5 below are reported separately from results
419 of steps 6 & 7). Future tests may consider whether single-mode devices are permitted.

420

421 **Test Setup:** Connect link pair together with test channel C1 from Appendix B. Connect each end of the link
422 pair to the traffic generator in full duplex. Repeat test with channel C2.

423 **General Procedures:**

- 424 1. Reset DUT and LP prior to test execution
425 2. Establish a link between the link pair (no autoneg)
426 3. Monitor link status, transmit and received frame counts in both directions
427 4. Observe that link remains stable over at least 2 minutes (120 seconds) and transmit frame count =
428 receive frame count in each direction. (A large finite number of frames should be transmitted in both
429 directions, from DUT to LP and from LP to DUT.)
430

431 **Specific Procedures:**

- 432 1. Establish link between the link pair, as per the selected configuration and confirm the configuration by
433 reading the configuration back from the DUT/LP.
434 Read negotiated interleaving and precoder settings from DUT and LP and document.
435
436 2. Assert Profile A-1 at the DUT and Profile A-2 at the LP.
437 Confirm that the link has entered LPI in LP-to-DUT direction by reading:
438 Rx LPI indication, MMD 3.1.8, or 3.2323.8
439 Rx LPI received, MMD 3.1.10, or 3.2323.10
440

441 NOTE - these registers are latching high, with clear on read. They will need to be read prior to getting
442 a valid stable state result.

443
444 Observe for 2 minutes (120 seconds)..

445
446 Expect transmit frame count = received frame count in each direction after time elapsed.
447 Continuously monitor link status on DUT and LP and expect that link remains stable.
448

449 **Other expected results:**

- 450 c) After the links have been established the link status of MMD 1.1.2 (link status) should always be
451 reported as 1 and should never be reported as 0. Recording a value of 0 indicates a link problem
452 potentially caused by an EEE interoperability problem.
453 d) The EEE wake error counter of MMD 3.22 should always record a value of 0. A value other than 0
454 indicates a problem in the LPI wake-up sequence.
455

456 **8.3 Group 3: Typical Application – Autonomous LPI (Optional)**

457 **Scope:** This test is designed to monitor packet-handling for asymmetric traffic with a pair of EEE capable devices
458 entering and leaving a LPI state autonomously.

459 **Overview:** These tests are designed to identify problems that may exist between two EEE capable devices
460 exercising entry and exit of LPI with asymmetric traffic. In this test, the DUT enters LPI autonomously based on
461 traffic heuristics. This is a mode which is commonly implemented, but exceeds the IEEE Std 802.3-2022
462 specification and is optional.

463 **Out of Scope:** Competitive performance evaluation of a vendor's product will not be performed. Extensive
464 protocol conformance testing will not be pursued unless warranted for troubleshooting purposes. The
465 performance of the LPI heuristics in terms of power savings is not performed.

466 **Additional DUT capabilities needed:** Devices will be required to accept packets for transmit and deliver
467 packets on reception to a packet generator/monitor. Devices should be capable of indicating if they and/or
468 the link partner is in a LPI mode through management registers, LEDs, or equivalent. The device shall be able
469 to autonomously enter LPI.

470 MDIO access to management registers will be required to access the following:

- 471 • Link status, MMD 1.1.2 or 1.2310.0
- 472 • Rx LPI indication, MMD 3.1.8 or 3.2323.8
- 473 • Rx LPI received, MMD 3.1.10 or 3.2323.10

474 NOTE - these registers are latching high, with clear on read. They will need to be read prior to getting a
475 valid stable state result.

476
477

478 Ability to manually configure MASTER/SLAVE without AutoNeg.

479 **Test Setup:** Connect link pair together with test channel C1 from Appendix B. Connect each end of the link
480 pair to the traffic generator in full duplex. Repeat test with channel C2.

481 **Configurations:** No deviations from baseline definition.

482 **General Procedures:**

- 483 1. Reset DUT and LP prior to test execution
- 484 2. Disable LPI generation for traffic generator connected to DUT.
- 485 3. Establish a link between the link pair (no autoneg)
- 486 4. Monitor link status, transmit and received frame counts in both directions
487 Observe that link remains stable over at least 2 Minutes (120 seconds) and transmit frame count =
488 receive frame count in each direction. (A large finite number of frames should be transmitted in both
489 directions, from DUT to LP and from LP to DUT.)

490
491
492

491 **Specific Procedures:**

- 493 1. Establish link between the link pair, as per the selected configuration and confirm the configuration by
494 reading the configuration back from the DUT/LP.
495 Read negotiated interleaving and precoder settings from DUT and LP and document.
496
- 497 3. Assert Profile A-1 at the DUT and Profile A-2 at the LP.

- 498 a. Traffic generator connected to LP shall send LPI at times of IDLE.
499 b. Traffic generator connected to DUT shall be configured to never send LPI.
500 c. Confirm that the link has entered LPI in LP-to-DUT direction by reading:
501 Rx LPI indication, MMD 3.1.8, or 3.2323.8
502 Rx LPI received, MMD 3.1.10, or 3.2323.10
503 NOTE - these registers are latching high, with clear on read. They will need to be read prior to
504 getting a valid stable state result.
505 Observe for 2 minutes (120 seconds).
506 Expect transmit frame count = received frame count in each direction after time elapsed.
507 Continuously monitor link status on DUT and LP and expect that link remains stable.
508
509 4. Assert Profile A-2 at the DUT and Profile A-1 at the LP.
510 a. Traffic generator connected to LP shall send LPI at times of IDLE.
511 b. Traffic generator connected to DUT shall be configured to never send LPI.
512 c. Confirm that the link has entered LPI in DUT-to-LPI direction by reading:
513 Rx LPI indication, MMD 3.1.8, or 3.2323.8
514 Rx LPI received, MMD 3.1.10, or 3.2323.10
515 NOTE - these registers are latching high, with clear on read. They will need to be read prior to
516 getting a valid stable state result.
517 Observe for 2 minutes (120 seconds).
518 Expect transmit frame count = received frame count in each direction after time elapsed.
519 Continuously monitor link status on DUT and LP and expect that link remains stable.
520

521 **Other expected results:**

- 522 e) After the links have been established the link status of MMD 1.1.2 (link status) should always be
523 reported as 1 and should never be reported as 0. Recording a value of 0 indicates a link problem
524 potentially caused by an EEE interoperability problem.
525 f) The EEE wake error counter of MMD 3.22 should always record a value of 0. A value other than 0
526 indicates a problem in the LPI wake-up sequence.
527

528 **8.4 Group 4: Stress Pattern**

529 **Scope:** This test is designed to stress the LPI quiet-refresh cycles

530 **Overview:** These tests are designed to identify problems that may exist between two EEE capable devices
531 exercising entry and exit of LPI under synthetical traffic conditions. The link will be mostly LPI in one direction,
532 sending frames sparsely. The other direction is utilized as per line rate, and should only have minimum IPG
533 spacing, hence should not go into LPI.

534 **Out of Scope:** Competitive performance evaluation of a vendor's product will not be performed. Extensive
535 protocol conformance testing will not be pursued unless warranted for troubleshooting purposes.

536 **Additional DUT capabilities needed:** Devices will be required to accept packets for transmit and deliver
537 packets on reception to a packet generator/monitor. Devices should be capable of indicating if they and/or
538 the link partner is in a LPI mode through management registers, LEDs, or equivalent.

539 MDIO access to management registers will be required to access the following:

- 540 • Link status MMD 1.1.2 or 1.2310.0
- 541 • Rx LPI indication, MMD 3.1.8 or 3.2323.8
- 542 • Rx LPI received, MMD 3.1.10 or 3.2323.10

543 NOTE - these registers are latching high, with clear on read. They will need to be read prior to getting a
544 valid stable state result.

545

546 **Test Setup:** Connect link pair together with test channel C1 from Appendix B. Connect each end of the link
547 pair to the traffic generator in full duplex. Repeat test with channel C2.

548 **Configurations:** No deviations from baseline definition.

549 **General Procedures:**

- 550 1. Reset DUT and LP prior to test execution
 - 551 2. Establish a link between the link pair (no autoneg)
 - 552 3. Monitor link status, transmit and received frame counts in both directions
- 553 Observe that link remains stable over at least 2 Minutes (120 seconds) and transmit frame count =
554 receive frame count in each direction. (A large finite number of frames should be transmitted in both
555 directions, from DUT to LP and from LP to DUT.)

556

557 **Specific Procedures:**

558

- 559 2. Establish link between the link pair, as per the selected configuration and confirm the configuration by
560 reading the configuration back from the DUT/LP.

561 Read negotiated interleaving and precoder settings from DUT and LP and document.

562

563 Assert Profile B at the DUT and Profile C at the LP.

564 Confirm that the traffic generator is sending LPI code words for Profile B by reading:

565 Rx LPI indication, MMD 3.1.8, or 3.2323.8

566 Rx LPI received, MMD 3.1.10, or 3.2323.10

567 NOTE - these registers are latching high, with clear on read. They will need to be read prior to getting
568 a valid stable state result.

569 Observe for Observe for 2 minutes (120 seconds).

570 Expect transmit frame count = received frame count in each direction after time elapsed.

571 Continuously monitor link status on DUT and LP and expect that link remains stable.

572

- 573 5. Assert Profile C at the DUT and Profile A at the LP.

574 Confirm that the traffic generator is sending LPI code words for Profile A-2 by reading:

575 Rx LPI indication, MMD 3.1.8, or 3.2323.8

576 Rx LPI received, MMD 3.1.10, or 3.2323.10

577 NOTE - these registers are latching high, with clear on read. They will need to be read prior to getting
578 a valid stable state result.

579 Observe for Observe for 2 minutes (120 seconds).

580 Expect transmit frame count = received frame count in each direction after time elapsed.

581 Continuously monitor link status on DUT and LP and expect that link remains stable.
582

583 **Other expected results:**

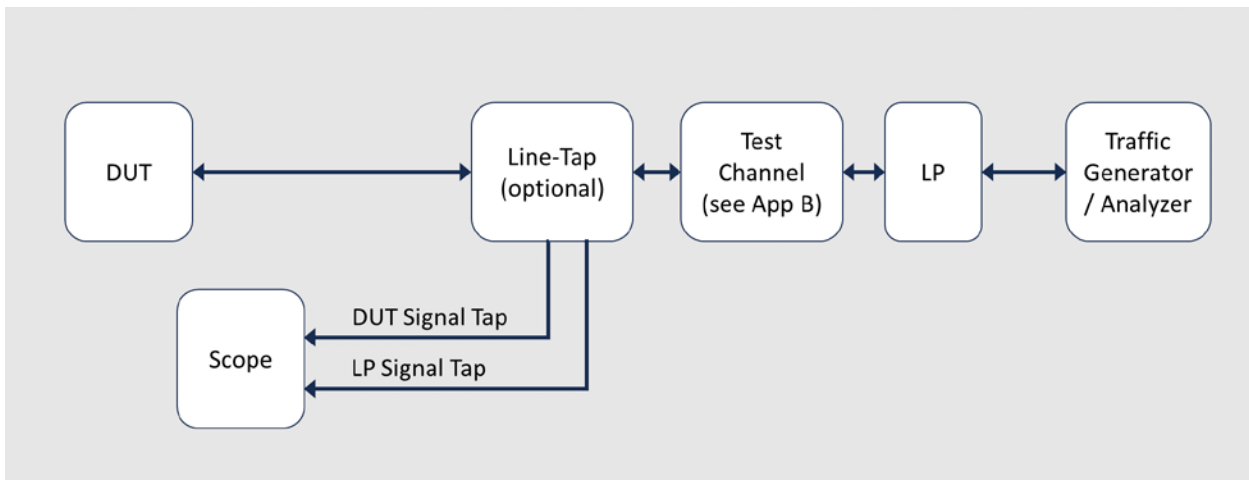
- 584 g) After the links have been established the link status of MMD 1.1.2 (link status) should always be
585 reported as 1 and should never be reported as 0. Recording a value of 0 indicates a link problem
586 potentially caused by an EEE interoperability problem.
- 587 h) The EEE wake error counter of MMD 3.22 should always record a value of 0. A value other than 0
588 indicates a problem in the LPI wake-up sequence.
589

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Appendix A (informative)

Test Setups

594 A.1 Interoperability Test Setup



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596
597

Figure 2: Example Test Setup

598 Proposed test setup involves the use of an optional line tap for monitoring LPI signalling of both the DUT and
599 LP. This would also allow for some rough timer measurements. If a line tap is used, the channel (see Appendix
600 B) must be verified for compliance with IEEE 802.3 insertion loss and return loss specifications, and, if
601 necessary, the channel must be adjusted so that the resulting combination of cabling and line tap meets the
602 IEEE 802.3 specifications for these parameters.

603 Note that connector interfaces may be needed between the various blocks depending on the connectors used
604 on individual units (e.g., DUT to line-tap, line-tap to test channel, etc.)

605 The link partner will need to be able to interface with the traffic generator and convert the signalling to
606 MGBASE-T1. If there is no desire to monitor the LPI signalling directly on the line, the line tap can be removed
607 from the test setup.

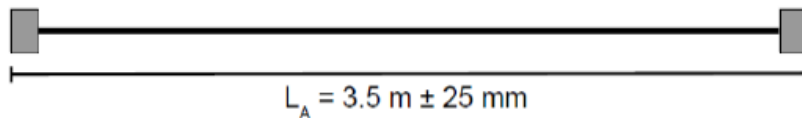
608 The lab test environment (external to specific DUT or cabling used in temperature tests) shall be at room
609 temperature, i.e., between 20C and 25C.

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611
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613

Appendix B (normative)

Test Channels

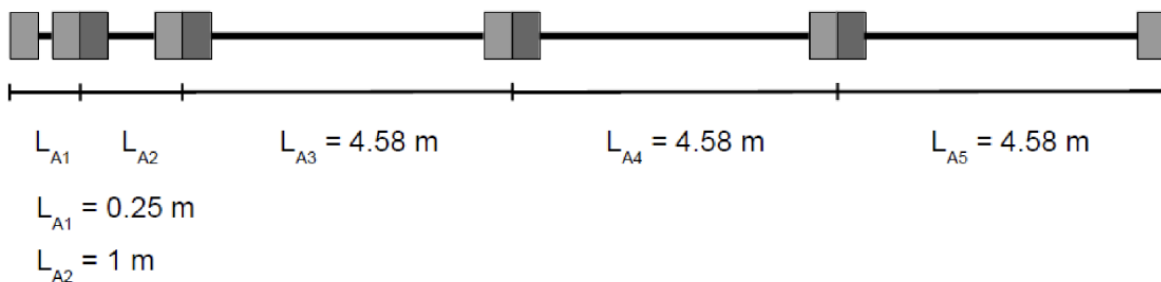
The channel type C1 has a total length of 3.5 m, with cable connectors on each end as shown in Figure 2.



614
615

Figure 3: Channel type C1 (see TC15 specification)

The channel type C2 has a total length of 15 m, consisting of five cable segments and four inline connectors as shown in Figure 1.



616
617
618

Figure 4: Channel type C2 (see TC15 specification)

619 NOTE - If a line tap is used, the channel must be adjusted so that the channel plus the line tap complies with
620 the insertion loss and return loss specifications. Recommended adjustment is to replace a segment (i.e., A1 or
621 A2) with the line tap, to take into account additional losses from the line tap. Channel insertion loss shall be
622 less than or equal to Equation 149-18 of IEEE Std 802.3-2022 at all frequencies from 1 MHz to 4 GHz, repeated
623 here for reference: $Insertion\ Loss(f) \leq 0.002f + 0.68f^{0.45}$. **Use of the line tap is optional, and insertion loss**
624 **specifications for the line tap are for further study.**

625 Channel return loss shall be greater than or equal to the return loss specified in 149.7.1.3 of IEEE Std 802.3-
626 2022 for the given speed of the DUT and insertion loss of the actual channel used. See standard for details.

627 Addition of alien crosstalk is outside the scope of these tests. Noise may be added for tests under other TCs,
628 as specified in those TCs, and those TCs may specify combining that with the Group 1 and Group 2 tests in this
629 plan.

630

Proposed Additions for Next Edition

631 The following items are proposed for a future edition of this test specification.

632 Contributions proposing specific text changes and additions are requested on these topics:

633 - Support for 1000BASE-T1 EEE Testing,