ORGANISATION EUROPEENNE POUR LA RECHERCHE NUCLEAIRE
EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Laboratoire Européen pour la Physique des Particules
European Laboratory for Particle Physics

Front-End Digital Optohybrid (DOH) Test Procedure

v.2.1

CERN

Document History			**Document ID**
Created	–	21 January by K. Gill	**CMS-TK-QP-0009**
Last Revision	–	22 July by K. Gill	
Approved	–	23 July by F. Vasey	

Table of Contents

REVISION HISTORY 2

1. QUALITY ASSURANCE PROGRAMME OUTLINE 3
   1.1. DOCUMENTATION 3
   1.2. DELIVERY SCHEDULE 3
   1.3. QUALITY ASSURANCE PROGRAMME OVERVIEW 3
2. PRE-PRODUCTION QUALIFICATION PROCEDURES 5
   2.1. PRE-PRODUCTION QUALIFICATION FLOW 5
3. LOT ACCEPTANCE PROCEDURES 7
   3.1. LOT ACCEPTANCE FLOW 7
4. TEST DESCRIPTIONS FOR PRE-PRODUCTION AND LOT-ACCEPTANCE 8
   4.1. VISUAL INSPECTION ① 8
   4.2. GEOMETRICAL MEASUREMENT ② 8
   4.3. OPTICAL/ELECTRICAL TESTS ③ 8
   4.4. ENVIRONMENTAL RELIABILITY TESTS 10
   4.5. MECHANICAL STRESS TESTS 12
5. MANUFACTURER PRODUCTION TEST PROCEDURES 13
   5.1. MANUFACTURER TESTS DURING ASSEMBLY (TBD) 14
   5.2. MANUFACTURER TESTS AFTER ASSEMBLY 14
   5.3. METHODS FOR MANUFACTURER ASSEMBLY AND POST-ASSEMBLY TESTS 14
6. REFERENCES 17

Revision History

Version	Date	Notes
1.0	21 Jan 2003	First draft
1.1	30 June 2003	Updated with new test-setups and procedures.
2.0	3 July 2003	Reviewed and corrected.
2.1	22 July 2003	Corrections to schedule. Burn-in and vibration test added.

1. Quality Assurance Programme outline

The aim of this document is to define all the test procedures involved in the manufacture of digital optohybrids (DOH). The resultant test-data can be consistently compared to the specifications leading to the acceptance or rejection of the batch under consideration.

The Quality Assurance Programme described in this document focuses mainly on the procedures to be carried out during pre-production qualification and lot-acceptance of digital optohybrids. Most of these tests will take place at CERN using a dedicated test-station. Other tests, particularly the environmental tests, will make use of facilities outside CERN, but using similar measurement equipment when in-situ monitoring is being performed.

In addition this document includes a description of the production test-system that will be provided by CERN to the manufacturer to allow the manufacturer to verify the basic functionality of the DOHs as they are produced. This system will share many components and procedures with the CERN test-system for pre-production and lot-acceptance.

1.1. Documentation

All test results will be documented in the form of a pre-production qualification report or a lot acceptance report depending upon the nature of the batch to which the results pertain. Copies of these reports will be sent to the manufacturer and will be copied into the CERN document archive (EDMS). Direct access to the documents in EDMS is restricted to members of CMS.

1.2. Delivery Schedule

The production of DOHs will proceed in Batches. The predicted numbers to be delivered are shown in Table 1.

Table 1: Delivery schedule.

Batch	Test Batch Description	Quantity	Delivery date forecast Delivery to CERN
D1	Pre-production qualification	40	October 31, 2003
D2	Series production	95	February 28, 2004
D3	Series production	100	March 31, 2004
D4	Series production	110	April 30, 2004
D5	Series production	185	May 31, 2004
D6	Series production	185	June 30, 2004
D7	Series production	185	July 31, 2004
D8	Series production	190	August 31, 2004
D9	Series production	185	September 30, 2004
D10	Series production	195	October 31, 2004
D11	Series production	195	November 30, 2004
D12	Series production	135	December 31, 2004
	Total	1800	

1.3. Quality Assurance programme overview

The quality assurance programme overview is shown in Table 2. The table shows the tests to be carried out during lot acceptance testing and pre-production qualification, together with the test target specifications from the technical specification for front-end digital optohybrids (CMS-TK-ES-0019[1]). The test procedures for pre-production qualification, lot acceptance and production testing are described in Sections 2, 3 and 5 respectively. Details of the methods are found in Sections 4 and 6. All tests are carried out at room temperature unless otherwise noted. All batches delivered from the manufacturer shall have a compliance certificate attached. The test procedures carried out by CERN will not cross-check all specifications.

[1] CMS Tracker Optical Control Link Specification, Part 2: Front-end Digital Optohybrid

Table 2: Test-program overview

#	Spec to be tested	min	typ	max	unit	CERN testing: Pre-production Qualification	CERN testing: Lot Acceptance	Manufacturer Production Testing
2.1	Bit Rate	2		100	Mb/s	③	③	(3+)
2.2	Bit error rate			10^{-12}		③	③ TBD	
2.3	Skew			1	ns	③		
2.4	Jitter			0.25	ns	③		
2.11	Number of Tx channels	2				①	①	①
2.12	Number of Rx channels	2				①	①	①
2.13	Size		25x35x5		mm	②	②	②
2.21	Differential input voltage	±300			mV	③	③	
2.22	Input impedance		120		Ω	③	③	
2.23	Differential output voltage	±250			mV	③	③	
2.24	Reset Output		Active low			③	③	(3+)
2.25	Power supply	2.25		2.7	V	③	③	
2.26	Power dissipation		350		mW	③	③	
2.27	I2C address		11100			③	③	(3+)
2.28	Default LLD laser I2C bias setting		$X_1X_2X_3$0000			③	③	(3+)
2.29	Default LLD gain setting		12.5		mS	③	③	(3+)
2.30	Electrical connector		26-way male NAIS			①	①	①
2.42	Tx average output power at power up	-8		-4	dBm	③	③	(3+)
2.43	Tx optical modulation amplitude	-11		-5	dBm	③	③	(3+)
2.44	Rx sensitivity			-18	dBm	③	③	(3+)
2.45	Rx saturation (d.c.)	-3			dBm	③	③	
2.47	Optical fibre type		single mode tight-buffered 9/125/250/900μm			①	①	①
2.48	Pigtail length		0.56 or 2.00		m	②	②	②
2.49	Optical connector		MU			①	①	①
2.50	Tensile strain	7.0			N	⑧⑨	⑧	
2.61	Magnetic field resistance	4				④		
2.62	Hadronic fluence			3e14		⑤		
2.63	Gamma dose			1.5e5		⑤		
2.64	Temperature	-20		70		⑥⑦		
2.167	Laser package bonding		MIL-STD-883			⑩		
2.172	DOH mechanical shock resistance		MIL-STD-883			⑪		

① Visual inspection ② Geometrical measurement ③(3+) Electrical /Optical test ④ Magnetic field test ⑤ Radiation hardness test ⑥⑦Temperature test ⑧⑨ Fibre pull tests ⑩ Bond pull test ⑪ Mechanical shock test

2. Pre-production Qualification Procedures

No failures related to the manufacturing process are allowed in the pre-production samples. Failure means that a device does not meet all the required specifications.

In the case of device failure, the cause of failure will be determined by CERN and/or the manufacturer. If required, a larger quantity of devices may be subjected to tests, or more detailed testing carried out, in order to satisfactorily diagnose the cause of failure.

In failures are found that are due to the manufacturing process, the manufacturer is expected to resolve any problems and to re-supply a batch of new DOH for qualification. If a satisfactory solution cannot be found, CERN reserves the right to disqualify the product.

If device failure occurs due to reasons not associated to the manufacturing process within the responsibility of the DOH manufacturer, CERN reserves the right to modify the DOH design, the component parts, or the specifications and to request a re-supply of a new pre-production batch of devices.

2.1. Pre-production Qualification Flow

The set of 40 samples from the pre-production batch 1 will be tested according to Table 3 and the flow diagram in Fig. 1. Details of each test are given in Section 4. If a device fails the tests will continue, if possible, so that the amount of maximum information can be passed back to the manufacturer for process evaluation and improvement. Where less than 100% testing is done, the samples are chosen at random.

Table 3: Sample sizes for use in pre-production qualification testing.

Test Number	Test Procedure	Sample Size
1	Visual Inspection	40 DOH: 100% of batch 1
2	Geometrical measurement	20 DOH: 50% of batch 1
3A	Optical/Electrical test	40 DOH: 100% of batch 1
4	Magnetic field test	2 DOH: 5% of batch 1
5	Irradiation test	6 DOH: 15% of batch 1
6	Thermal Storage	10 DOH: 25% of batch 1
3B	Optical/Electrical test	Re-test DOH used in Tests 4, 5 and 6
7	Thermal Cycles	10 DOH: 8 of batch 1 unirradiated plus 2 irradiated
3C	Optical/Electrical test	Re-test DOH used in Test 7
8	Non-destructive fibre pull test	5 DOH: 12% of batch 1
3D	Optical/Electrical test	Re-test DOH used in Test 8
9	Destructive fibre pull test	3 DOH (from those used in Test 8)
10	Bond Pull test[1]	5 DOH : 12% of batch 1 (different to those used in Test 9)
11	Mechanical Shock[2]	10 DOH: 25% of batch 1 (different to those used in Test 9 or Test 10)
3E	Optical/Electrical test	Re-test DOH used in Test 11

[1] Manufacturer to make this test
[2] Manufacturer to make this test

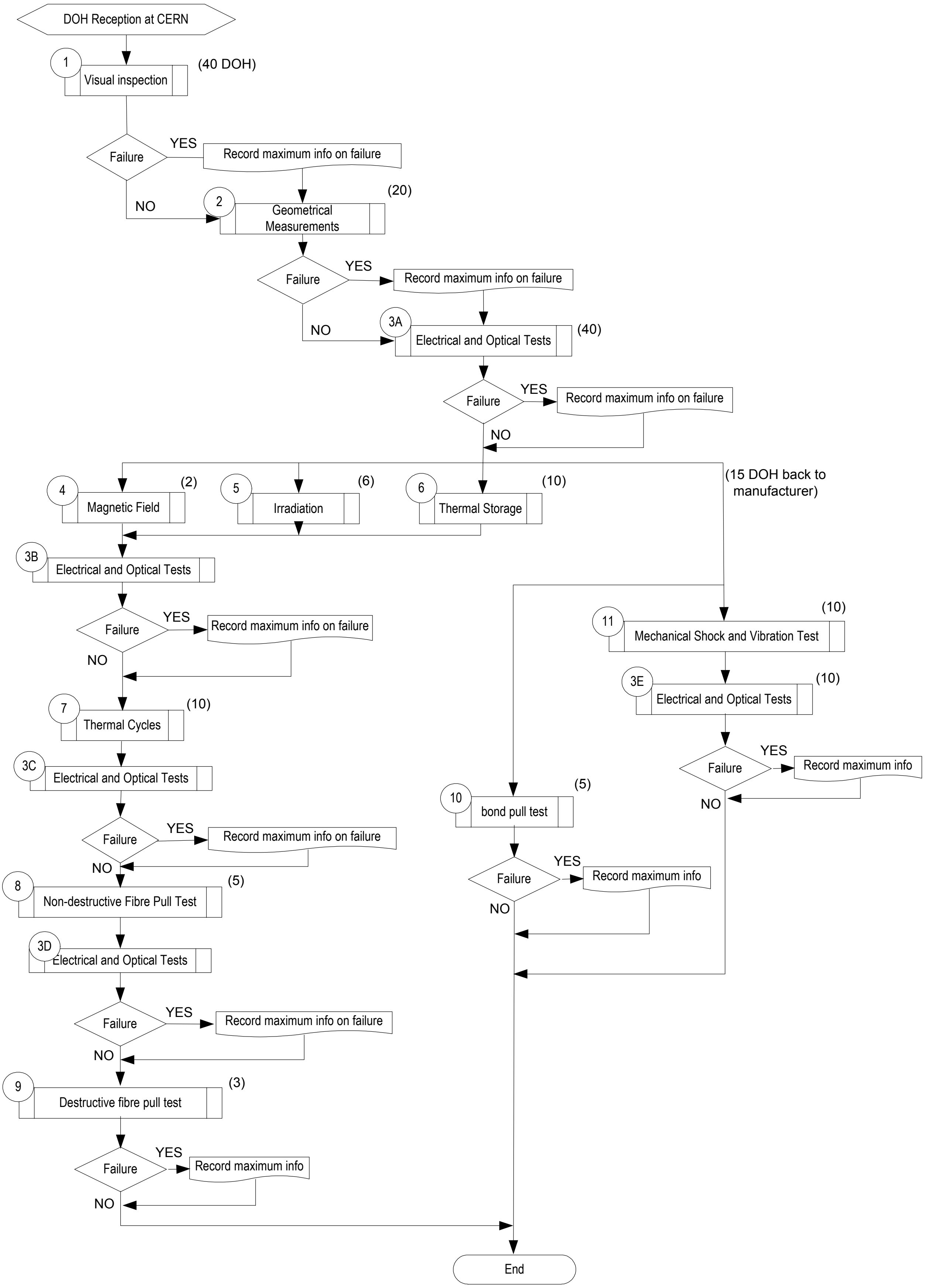

Fig. 1: Flow-chart of pre-production qualification procedure

3. Lot Acceptance Procedures

This section describes the lot acceptance procedure. Details of the specific tests are given in Section 4.

3.1. Lot Acceptance Flow

Sample size for lot acceptance is at least 5% of DOHs for each month of production, with a minimum of 5 samples.

No failures at the lot acceptance level are allowed. Furthermore the samples used for lot acceptance will pass sequentially through all of the procedures in the order they appear in Fig. 2. After use in the final test, the test samples used for lot acceptance will be archived at CERN for future reference, although some may be integrated into the final system.

In the event of failure of an early test, the full test program will be carried out if it remains possible. This will allow the maximum amount of feedback information to be given in the lot acceptance report.

100% of DOHs will be subjected to burn-in, with power-on, at 50°C for 72 hours, before integration into CMS. The burn-in will be carried out in parallel with the lot acceptance tests.

Failures during burn-in will not necessarily lead to the rejection of the lot. However, if failure during burn-in is related to a manufacturing process, the manufacturer is expected to repair or replace the failed device.

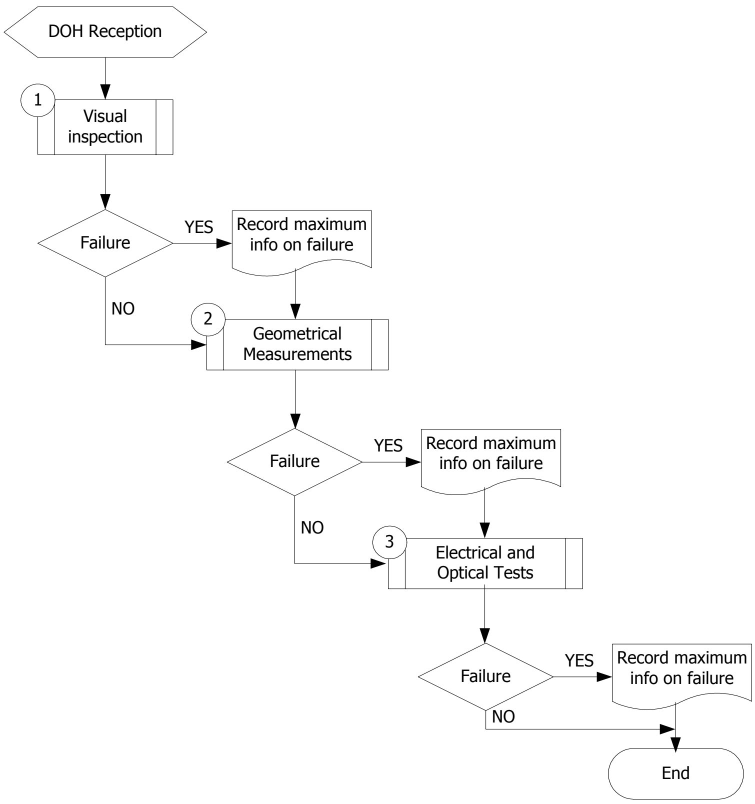

Fig. 2: Flow-chart of lot acceptance procedure

4. Test Descriptions for pre-production and lot-acceptance

4.1. Visual inspection ①

The DOH, including the fibre pigtails and MU-connectors shall be checked for visible defects, using a microscope if necessary.

DOHs with defects that are considered to be important enough to degrade the performance and/or lifetime of the component in the final system will be rejected.

4.2. Geometrical measurement ②

The dimensions of the DOH, including positioning of components and other layout features such as the mounting point, and the fibre lengths (including connector) will be measured with appropriate instruments.

The dimensions of the DOH should not differ from those specified by more than the agreed tolerance of the process.

The lengths of the fibre should not differ from the requested lengths for the given DOH.

4.3. Optical/electrical tests ③

The optohybrid under test is connected to the setup shown in Fig. 3, and Fig. 4 illustrates the flow of the subsequent optical and electrical measurements.

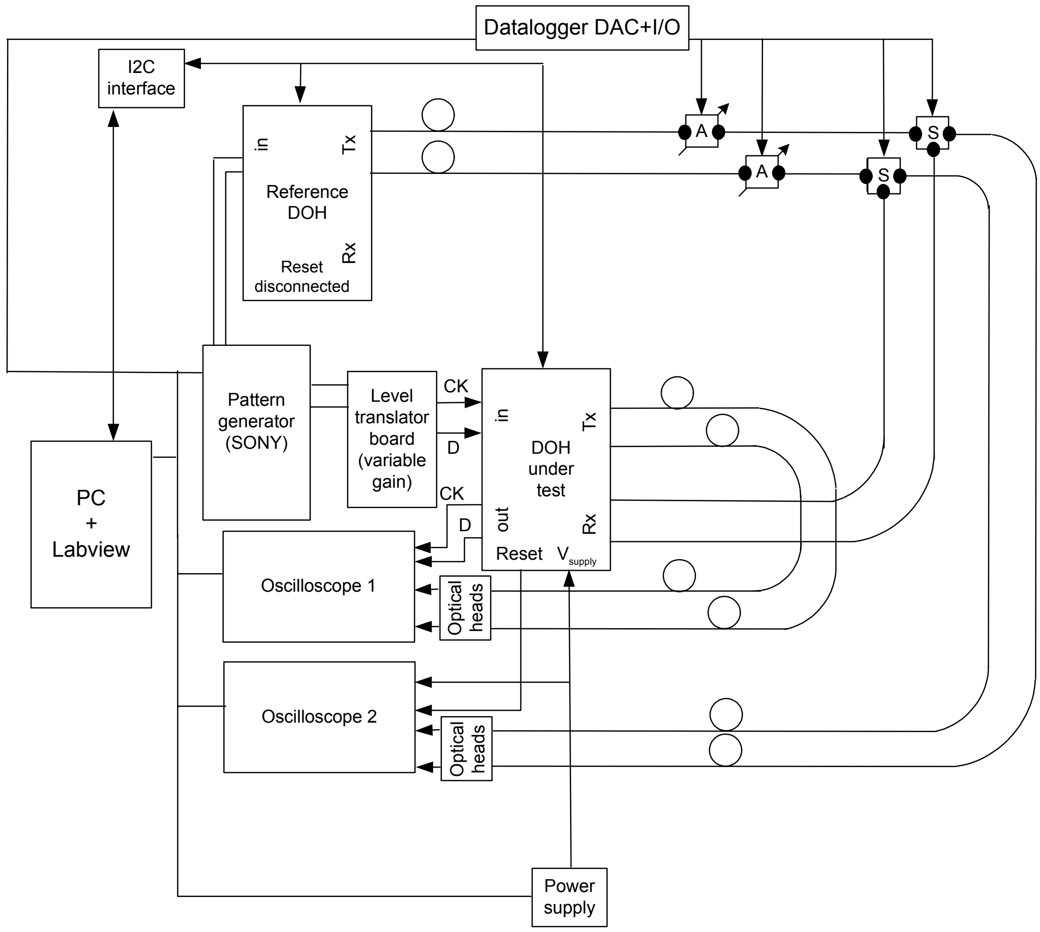

Fig. 3: Test setup for measuring DOH optical and electrical characteristics

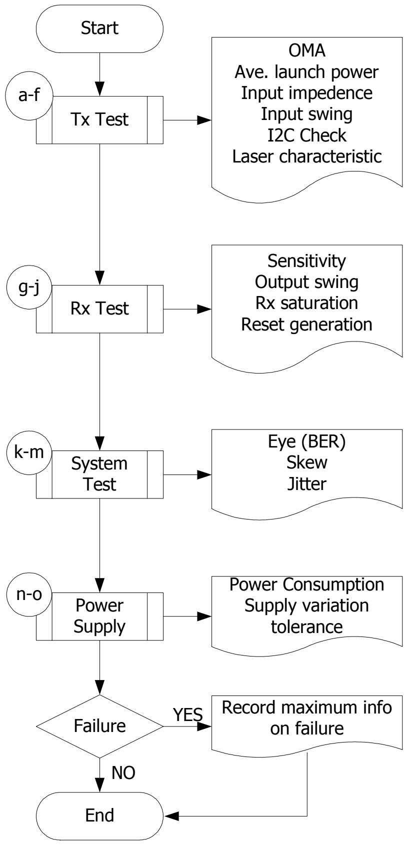

Fig. 4: DOH Optical/Electrical Test Sequence

4.3.1. Tx Test

On both CK and DA output optical channels the following measurements are made:

(a) Optical modulation amplitude (OMA) (spec 2.43)

With ±400mV input and default I2C settings the output OMA is measured using an optical head coupled to an oscilloscope.

(b) Average launch power (spec 2.42)

With default I2C settings, the average optical launched power is measured using an optical head coupled to an oscilloscope. The values should lie within the specified range.

(c) Input voltage swing (spec 2.21)

The input voltage swing is set to the minimum spec of ±300mV and the output optical levels are re-measured.

(d) Input impedence (spec 2.22)

The input impedence is not measured directly, but any gross variation of the resistor values, or defects in the mounting of the termination resistors, can be detected through unusual levels of output OMA.

(e) I2C check (specs 2.27 – 2.29)

The different communication modes of the LLD ASIC are checked before and during the L-I characteristic measurement.

(f) L-I characteristic(specs 2.28 – 2.29)

Whilst ramping the I2C values, as well as looping over the different gain settings, the dc optical output characteristics are measured. The default LLD I2C startup settings are checked.

4.3.2. Rx Test

On both clock CK and data DA channels the following measurements are made:

(g) Receiver sensitivity (spec 2.44)

The receiver output is monitored whilst increasing the variable attenuation such that the power decreases below 10μW.

(h) Output voltage swing (spec 2.23)

The output voltages from the DOH (with appropriate termination) are measured with a differential probe.

(i) Receiver saturation (spec 2.45)

The receiver output is monitored whilst increasing the I2C of the corresponding laser channel on the reference hybrid.

(j) Reset generation (spec 2.24)

The output of the reset pin is monitored whilst the number of missing '1's in the DA pattern is increased, measuring when the reset occurs, and its duration and voltage level.

4.3.3. System test

(k) Eye pattern (BER) (specs 2.1, 2.2)

The electrical output eye pattern (on the DA line) and clock signal (on CK line) are recorded, at a pre-set attenuation in the optical channels to check for bit-errors.

A separate bit-error test will also be made on at least 5 DOH samples using a dedicated BER Test machine. This will measure BER using optical signals of variable amplitude into both clock and data optical inputs on the DOH under test. These signals are generated by the BER tester and transmitted/received through a reference DOH.

(l) Skew(spec 2.3)

The skew between clock and data lines is measured at the electrical output of the DOH and the value corrected for cable delays to/from the DOH.

(m) Jitter(spec 2.4)

The jitter on CK and DA lines at the output of the DOH is measured with respect to the input electrical signals into the DOH.

4.3.4. Power supply

(n) Power consumption (spec 2.26)

Using a calibrated power supply the consumption of the DOH is measured, at the default and maximum I2C settings.

(o) Power supply variation (spec 2.25)

The input voltage supply is varied within the specified bounds whilst monitoring the output DA and CK trace and comparing them with a predefined mask to check for significant degradation of the output bit patterns.

4.4. Environmental Reliability Tests

The effects of temperature, magnetic field and radiation damage will be measured using the equipment in Fig. 5. Failures or other problems found that are related to radiation damage are the responsibility of CERN.

CERN reserves the right to make any necessary subsequent modifications to the layout, specification, piece-parts and test-procedures in order to guarantee sufficient reliability of the optohybrid.

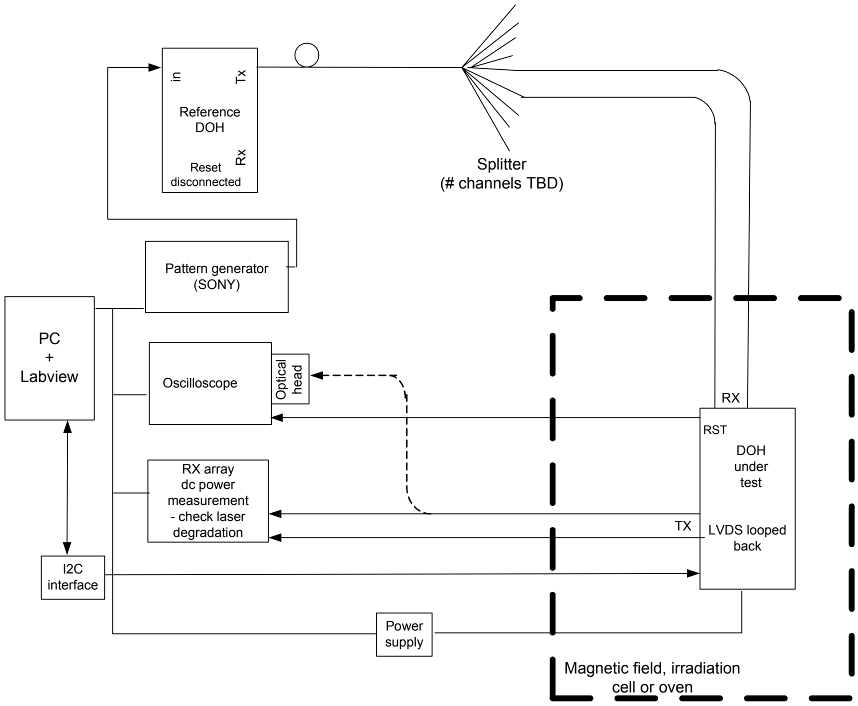

Figure 5: Test equipment for environmental tests.
Several DOH boards may be tested at the same time in parallel.

4.4.1. Magnetic Field test ④

Two DOH samples will be exposed to a strong (>1T) magnetic field.

The correct functionality of the DOH under test is checked during exposure to the field.

4.4.2. Irradiation test ⑤

Six DOH will be exposed to gamma ray doses and neutron fluences equivalent (in terms of damage to the lasers) to the worst-case expected during operation in the CMS Tracker, namely 150kGy dose and $3x10^{14}$ pions/cm^2 (200MeV).

The correct functionality of the DOHs under test will be checked periodically during exposure to the radiation. The I2C settings will be adjusted to compensate for the change in the laser threshold current with radiation damage.

This test will be carried out by CERN. The effects of radiation and their consequences are the responsibility of CERN.

4.4.3. Thermal storage ⑥

Ten optohybrids will be stored (unpowered) at 50°C for 100 hours.

The correct functionality of the DOHs under test will be checked before and after the storage test.

This test will be carried out by CERN (in parallel with the burn-in of other optohybrids).

4.4.4. Thermal cycles ⑦

Ten optohybrids (including at least 2 irradiated) will be tested, using the equipment in Fig. 5, during 50 thermal cycles between –20°C and 40°C over 50hours.

The correct functionality of the DOHs under test will be checked periodically during the cycles.

The I2C settings will be adjusted to compensate for the change in the laser threshold current with temperature.

This test will be carried out by CERN.

4.5. Mechanical Stress Tests

4.5.1. Non-destructive fibre pull-test ⑧

Each fibre pigtail on three DOH will be subjected to 7N tensile load applied at the MU connector.

This test will be carried out by CERN.

4.5.2. Destructive fibre pull-test ⑨

Each fibre pigtail on three DOH of those tested in Test ⑧ will be subjected to a tensile load at the MU connector that is sufficient to break the fibre or connector. The applied load at the break is recorded.

This test will be carried out by CERN.

4.5.3. Bond pull-test ⑩

The laser bonds on five DOH will be tested according to MIL STD 883[ref 1], Test Method 2011, Condition D.

This test will be carried out by the manufacturer, who shall report the results to CERN within one month of the test date.

4.5.4. Mechanical Shock and Vibration Tests ⑪

CERN will return 10 DOH from the preproduction batch to the manufacturer for these tests.

The ten devices will exposed to mechanical shock according to MIL STD 883[ref 1], Method 2002.3, Condition B. This test will be performed by the manufacturer, who shall then check the functionality of the samples with the production test equipment provided by CERN.

The same DOH samples will then be exposed to vibration according to MIL STD 883[ref 1], Method 2007, Condition A. This test will also be performed by the manufacturer, who shall then check the functionality of the samples with the production test equipment provided by CERN.

These tests are as recommended in the Bellcore Standards[ref 2], but with fewer test-samples.

Following these tests the DOH will then be returned to CERN for full characterization.

The manufacturer shall provide a report of these tests within one month of the test date.

5. Manufacturer Production Test Procedures

This section describes the procedures for tests on DOH during production at the manufacturer (to be carried out in addition to the pre-production tests outlined in the previous Section).

These tests follow a sequence shown in Fig. 6, which will check the basic functionality of the hybrid after assembly. The required test equipment will be supplied by CERN and configured as in Fig. 7.

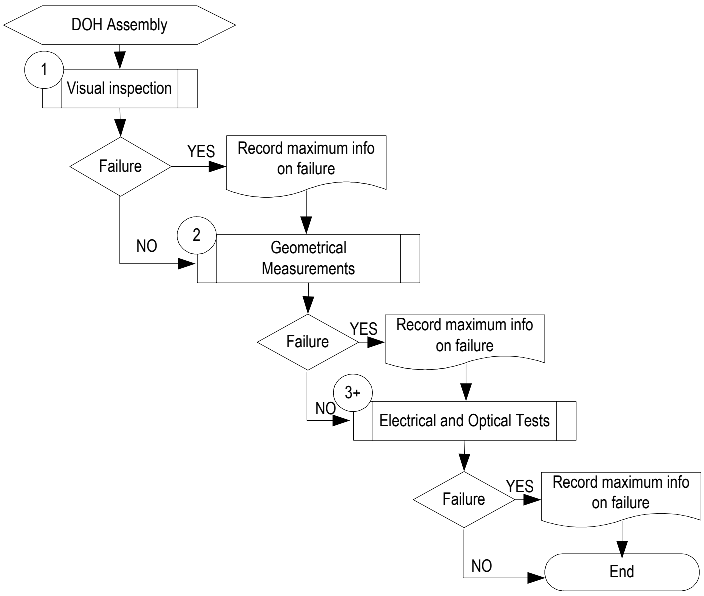

Fig. 6: Flow-chart of manufacturer production test procedure

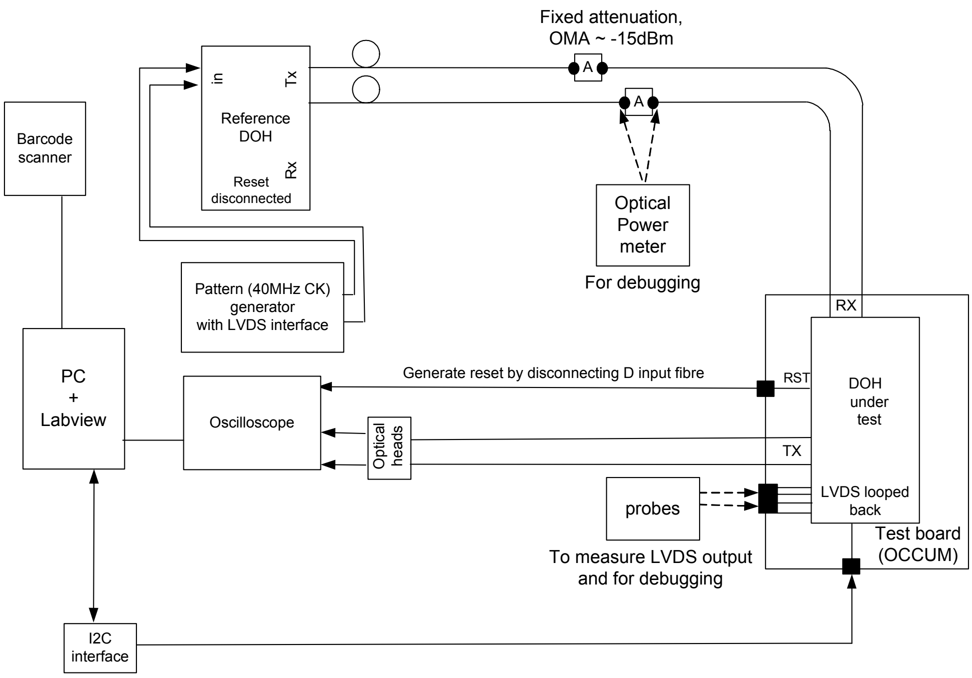

Fig. 7: Test-equipment provided by CERN to manufacturer for production tests.

5.1. Manufacturer tests during assembly (TBD)

The level of testing during assembly is TBD.

Visual inspection and geometrical measurements should be made.

Electrical and optical measurements will be difficult unless the photodiodes have been mounted since there must be a modulated signal current into the RX40 chip in order to avoid that it continuously generates a reset condition.

5.2. Manufacturer tests after assembly

100% of DOHs will be tested using the test-equipment in Fig. 7 provided by CERN.

Details of the specific test methods are given in Section 6. These tests should be performed after all components have been integrated.

Failures at this level are allowed but should be noted and diagnosed. The faulty DOH should be repaired if possible, in order to still meet all required specifications, otherwise it should be labeled as faulty and archived.

5.3. Methods for manufacturer assembly and post-assembly tests

5.3.1. Visual inspection ①

(Same as in Section 4.1)

The DOH, including the fibre pigtails and MU-connectors shall be checked for visible defects, using a microscope if necessary.

DOHs with defects that are considered to be important enough to degrade the performance and/or lifetime of the component in the final system shall be rejected if they cannot be repaired.

5.3.2. Geometrical measurement ②

(Same as in Section 4.2)

The dimensions of the DOH, including positioning of components and other layout features such as the mounting point, and the fibre lengths (including connector) will be measured with appropriate instruments.

The dimensions of the DOH should not differ from those specified by more than the agreed tolerance of the process.

The lengths of the fibre should not differ from the requested lengths for the given DOH.

5.3.3. Optical/electrical tests 3+

The optohybrid under test is connected to the setup shown in Fig. 7, and Fig. 8 illustrates the flow of the subsequent optical and electrical measurements.

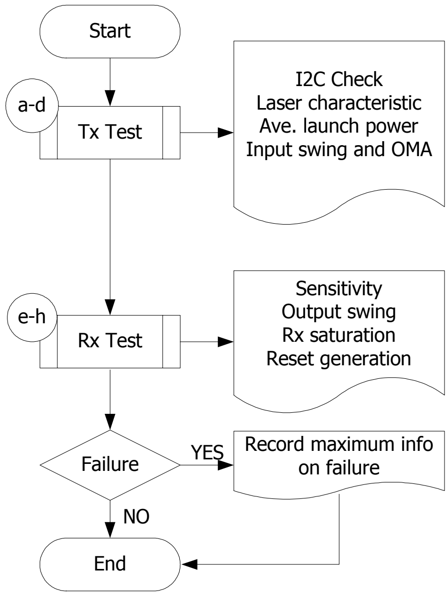

Fig. 8: DOH Optical/Electrical Production Test Sequence.

5.3.3.1. Tx Test

(i) For DOH tested **during assembly** before the lasers are mounted.

Electrical and optical measurements will be difficult unless the photodiodes have been mounted since there must be a modulated signal current into the RX40 chip in order to avoid that it continuously generates a reset condition.

(a) I2C check

If the RX40 can be provided an input signal, the different communication modes of the LLD ASIC are checked before and during the L-I characteristic measurement.

(ii) For DOH **after complete assembly**.

On both CK and DA output optical channels the following measurements are made:

(a) I2C check (specs 2.27-2.29)

The different communication modes of the LLD ASIC are checked before and during the L-I characteristic measurement.

(b) L-I characteristic (specs 2.28-2.29)

Whilst ramping the I2C values, as well as looping over the different gain settings, the dc optical output characteristics are measured. The default LLD I2C startup settings are checked.

(c) Average launch power (spec 2.42)

With default I2C settings, the average optical launched power is measured using an optical head coupled to an oscilloscope.

(d) Input voltage swing and optical modulation amplitude (OMA) (spec 2.43)

With ±300mV input and default I2C settings the output OMA is measured using an optical head coupled to an oscilloscope.

5.3.3.2. Rx Test

On DOH both during assembly (after mounting the photodiodes) and after complete assembly, the following measurements are made on both clock CK and data DA channels:

(e) Receiver sensitivity (spec 2.44)

The receiver output is monitored whilst having the fixed attenuation of ~5dB in place. The precise value of the attenuation depends upon the type of lasers on the reference optohybrid.

(f) Output voltage swing (spec 2.23)

The output voltages from the DOH (with appropriate termination) can be measured using probes for debugging purposes.

(g) Receiver saturation (spec 2.45)

The receiver output is monitored whilst increasing the I2C of the corresponding laser channel on the reference hybrid.

(h) Reset generation (spec 2.24)

The output of the reset pin of the DOH under test is monitored whilst the modulated signal to the data input on the reference optohybrid is removed.

6. References

[1] MIL STD 883. Available online:
http://www.dscc.dla.mil/Downloads/MilSpec/Docs/MIL-STD-883/std883.pdf

[2] General Reliability Assurance Requirements for Optoelectronic Devices Used in Telecommunications Equipment. Bellcore, GR-468-CORE, Issue 1, Dec. 1998.