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# **Front-End Digital Optohybrid (DOH) Test Procedure**

**v.2.2**

**CERN**

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### 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.
2.2	12 November 2003	Schedule updated. Minor corrections to number of DOH to be tested for irradiation, thermal storage and thermal cycles. Additional details added for manufacturer tests before mounting of optoelectronic parts. Burn-in now during assembly.

## 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, or the individual DOH under test.

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 (TBD)

The production of DOHs will proceed in monthly batches divided according to the pigtail lengths.

The delivered schedule is shown in Table 1. The quantities to be delivered refer to working devices, therefore the actual quantity required to be produced may be larger, depending upon the assembly yield.

*Table 1: Delivery schedule – broken down into delivery of DOH with short (56cm) and long (200cm) pigtails*

Description	Pigtail length 56cm		Pigtail length 200cm		Delivery date to CERN
	Batch number	Quantity	Batch number	Quantity	
Pre-production	ShD1	40	-	0	January 31, 2004
Series production	ShD2	60	LoD1	60	April 30, 2004
Series production	ShD3	140	LoD2	60	May 31, 2004
Series production	ShD4	140	LoD3	60	June 30, 2004
Series production	ShD5	140	LoD4	60	July 31, 2004
Series production	ShD6	200	-	0	August 31, 2004
Series production	ShD7	200	-	0	September 30, 2004
Series production	ShD8	80	LoD5	130	October 31, 2004
Series production	ShD9	190	-	0	November 30, 2004
Series production	ShD10	110	-	0	December 31, 2004
Series production	ShD11	130	-	0	January 31, 2005
Total quantity	1430		370		

### **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).

The test procedures for pre-production qualification, lot acceptance and production testing are described in the following Sections.

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.

**Table 2: Test-program overview**

#	Spec to be tested	min	typ	max	unit	CERN testing		Manufacturer Production Testing
						Pre-production Qualification	Lot Acceptance	
2.1	Bit Rate	2		100	Mb/s	③	③	③
2.2	Bit error rate			10 <sup>-12</sup>		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	0110000				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	⑦⑧	⑦	
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		⑥		
2.167	Laser package bonding	MIL-STD-883				⑨		
2.172	DOH mechanical shock resistance	MIL-STD-883				⑩		

① Visual inspection ② Geometrical measurement ③③ Electrical /Optical test ④ Magnetic field test ⑤ Radiation hardness test ⑥ Temperature test ⑦⑧ Fibre pull tests ⑨ Bond pull test ⑩ 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%
2	Geometrical measurement	10 DOH: 25%
3A	Optical/Electrical test	40 DOH: 100%
4	Magnetic field test	2 DOH: 5%
5	Irradiation test	6 DOH: 15%
6	Thermal Tests	6 DOH: 15% (4 unirradiated plus 2 irradiated)
7	Non-destructive fibre pull test	5 DOH: 12%
3B	Optical/Electrical test	Re-test DOH used in Test 7
8	Destructive fibre pull test	3 DOH (from those used in Test 7)
9	Bond Pull test <sup>1</sup>	5 DOH : 12% (different to those used in Test 8)
10	Mechanical Shock <sup>1</sup>	10 DOH: 25% (different to those used in Test 8 or Test 9)
3C	Optical/Electrical test <sup>1</sup>	Re-test DOH used in Test 10

<sup>1</sup> Manufacturer to make this test

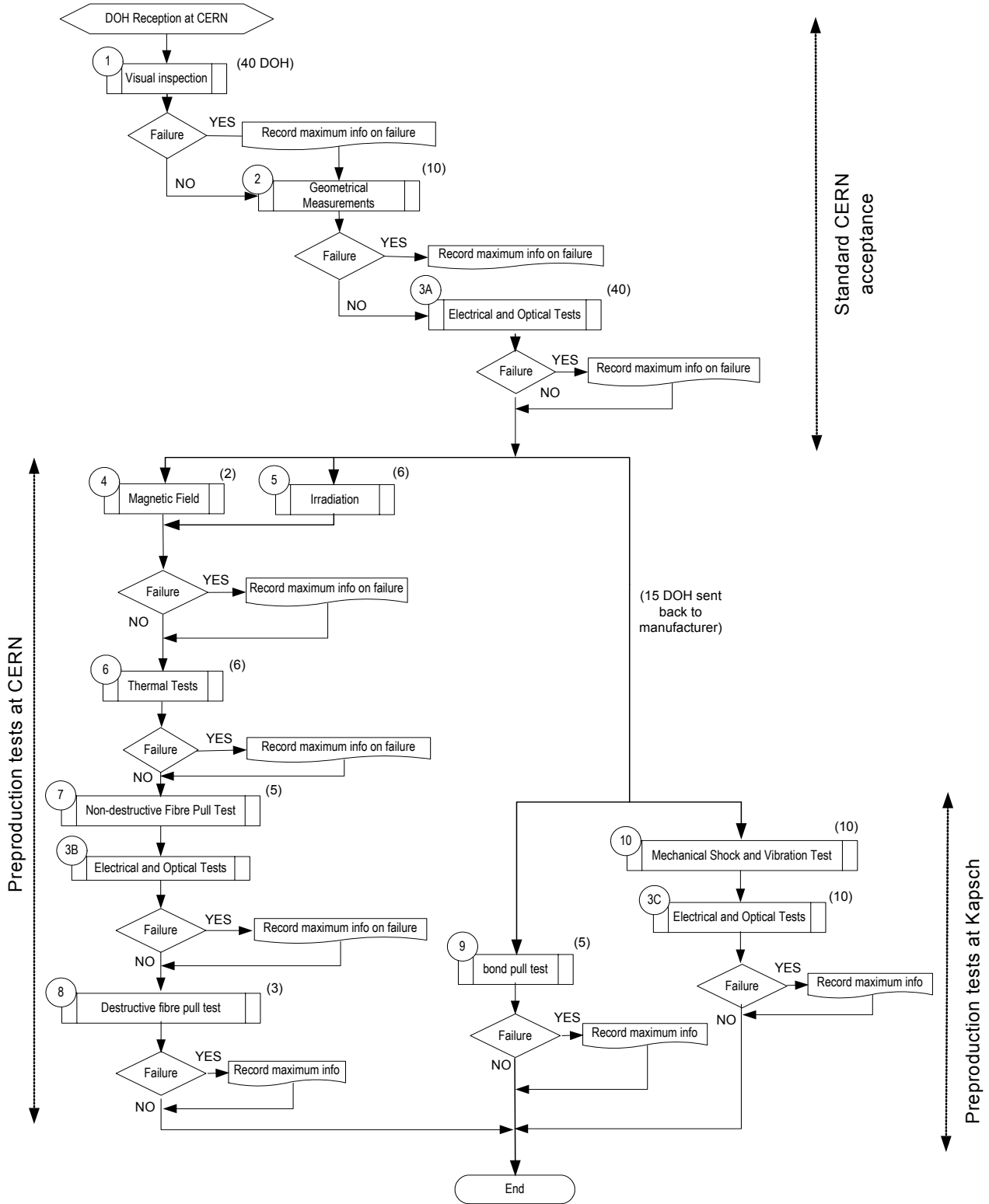


Fig. 1: Flow-chart of pre-production qualification procedure

### 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

100% of DOHs in the early production batches will be tested at CERN. The sample size for subsequent lots remains TBD. The samples used for lot acceptance will pass sequentially through all of the procedures in the order they appear in Fig. 2.

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.

Failures during acceptance will not necessarily lead to the rejection of the entire lot, unless a significant number of DOHs are considered to be at risk.

Failed devices shall be repaired or replaced by the manufacturer if the failure was related to the manufacturing process.

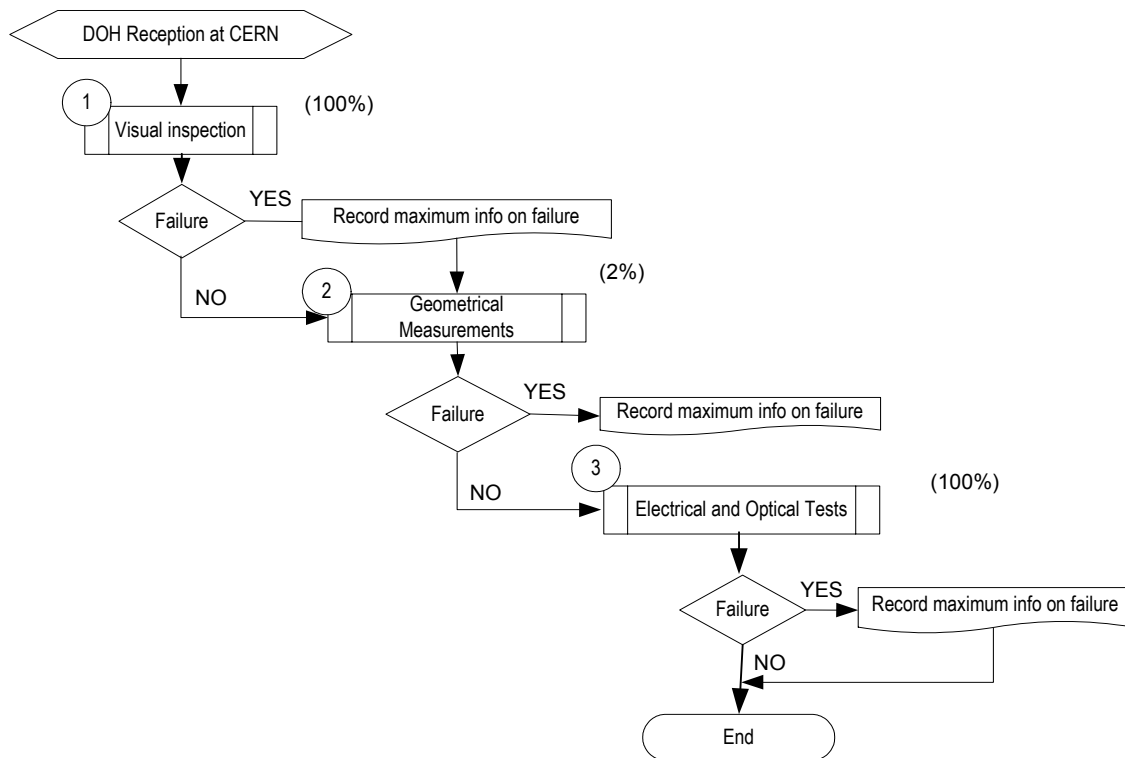


Fig. 2: Flow-chart of lot acceptance procedure



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

### 4.1. Visual inspection ①

The DOH, including the fibre pigtailed 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.

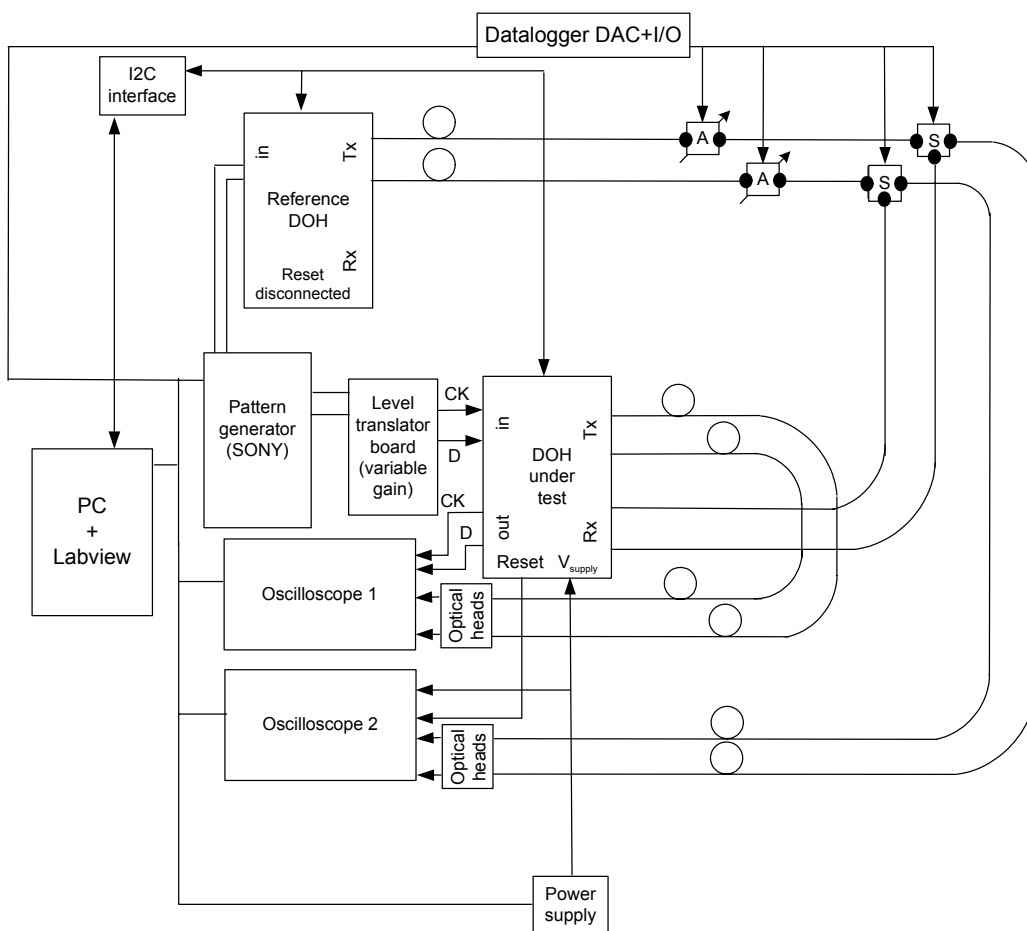
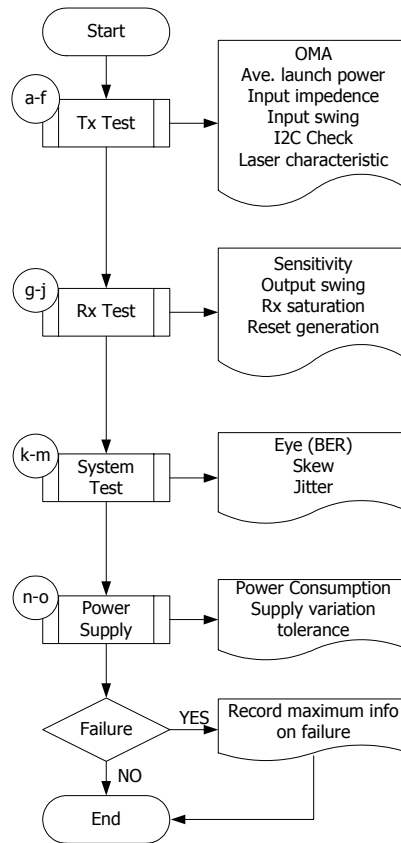


Fig. 3: Test setup for measuring DOH optical and electrical characteristics



**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  $\pm 400\text{mV}$  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  $\pm 300\text{mV}$  and the output optical levels are re-measured.

(d) *Input impedance (spec 2.22)*

The input impedance 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  $10\mu\text{W}$ .

*(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 or the magnetic field 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.

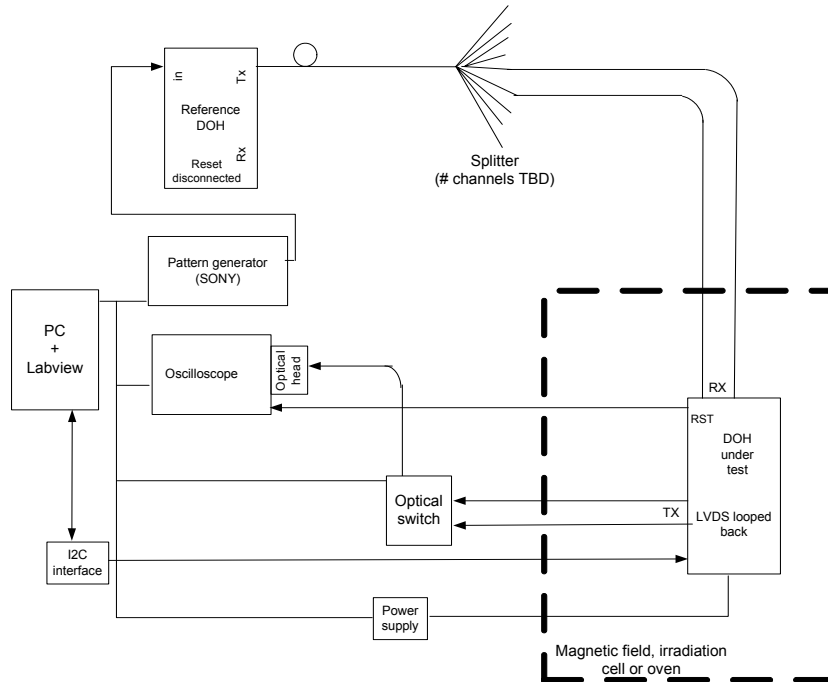


Figure 5: Test equipment for environmental tests. Several DOH boards will be tested in parallel.

##### 4.4.1. Magnetic field test ④

This test will be carried out by CERN.

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

This test will be carried out by CERN.

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  $3 \times 10^{14}$  pions/cm<sup>2</sup> (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 tests ⑥

This test will be carried out by CERN.

Six optohybrids (including at least 2 irradiated) will be tested, using the equipment in Fig. 5, during 25 thermal cycles between  $-20^{\circ}\text{C}$  and  $40^{\circ}\text{C}$  over 125 hours. Each cycle consists of 1 hour ramp from  $-20^{\circ}\text{C}$  to  $40^{\circ}\text{C}$ , 1.5 hours dwell at  $40^{\circ}\text{C}$ , 1 hour ramp from  $40^{\circ}\text{C}$  to  $-20^{\circ}\text{C}$ , then 1.5 hours dwell at  $-20^{\circ}\text{C}$ .

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.

## **4.5. Mechanical Stress Tests**

### **4.5.1. Non-destructive fibre pull-test ⑦**

This test will be carried out by CERN.

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

### **4.5.2. Destructive fibre pull-test ⑧**

This test will be carried out by CERN.

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.

### **4.5.3. Bond pull-test ⑨**

This test will be carried out by the manufacturer. See Section 5.4.

### **4.5.4. Mechanical Shock and Vibration Tests ⑩**

This test will be carried out by the manufacturer. See Section 5.4.

### 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.

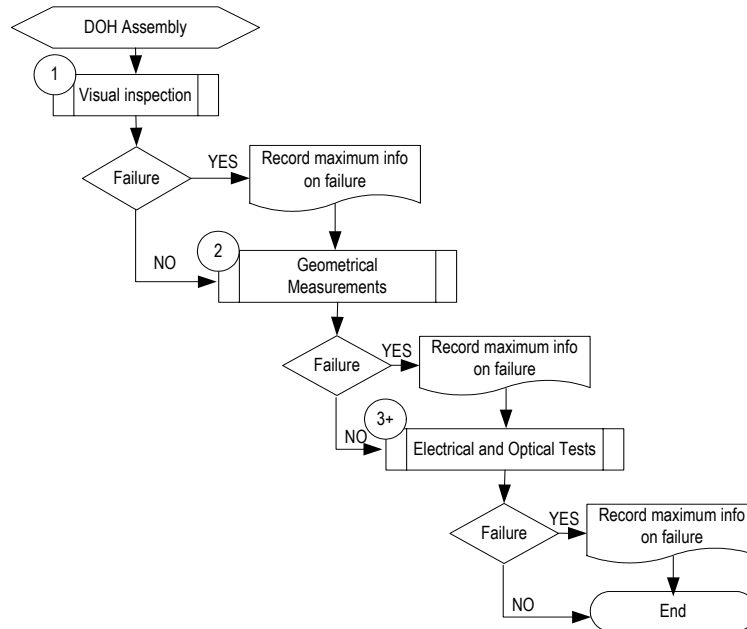


Fig. 6: Flow-chart of manufacturer production test procedure

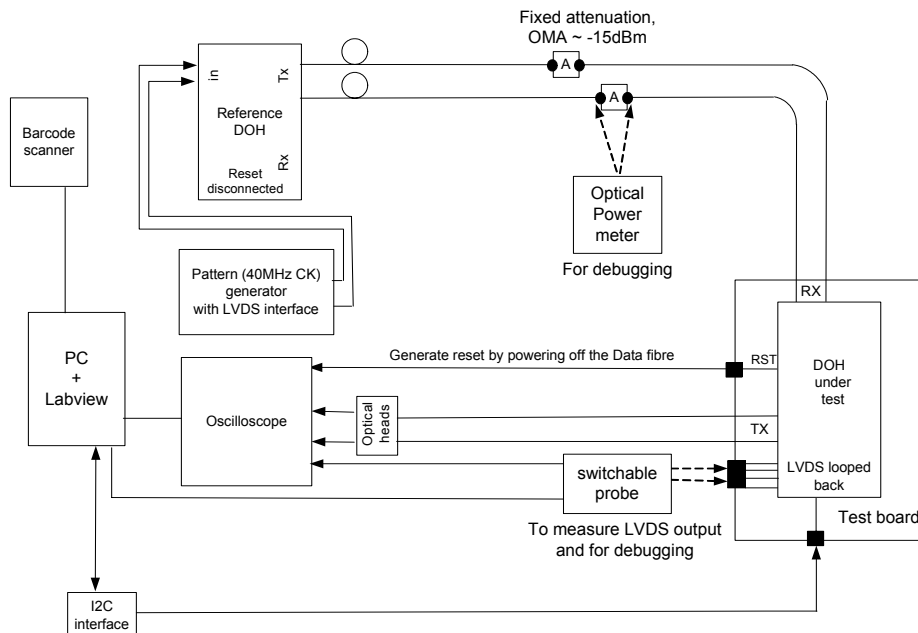


Fig. 7: Test-equipment provided by CERN to manufacturer for production tests. A modified DOH Test Board will also be provided (without only electrical inputs/outputs) to test DOHs before integration of the lasers and photodiodes.

### 5.1. Visual inspection ①

(Same as 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.

### 5.2. Geometrical measurement ②

(Same as 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. Optical/electrical tests

The optohybrid under test is connected to the setup provided by CERN shown in Fig. 7. There will be two different DOH carriers provided by CERN, one for testing DOH that have been fully assembled and one that has been modified to test DOH without optoelectronic components. The modified carrier uses probes to inject a modulated signal current into the RX40 chip.

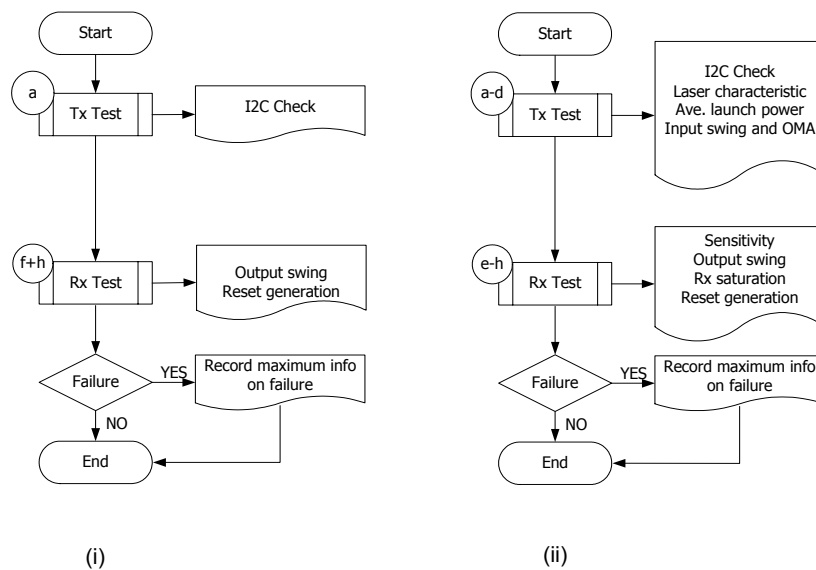
100% of DOHs will be tested before integration of the optoelectronic parts.

Then the lasers and photodiodes will be mounted and the DOHs burned-in for 72 hours at 50°C, in parallel with the curing step of the epoxy.

100% of fully assembled DOHs will then be re-tested.

Details of the specific test methods are given below.

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.



**Fig. 8: DOH Optical/Electrical Production Test Sequence: (i) before and (ii) mounting of the lasers and photodiodes**

### 5.3.1. Tx Test

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

(a) *I2C check (specs 2.27-2.29)* **(before and after mounting optical parts)**

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)* **(after mounting optical parts)**

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)* **(before and after mounting optical parts)**

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

(d) *Input voltage swing & optical modulation amplitude (OMA) (spec 2.43)* **(after mounting optical parts)**

With  $\pm 300\text{mV}$  input and default I2C settings the output OMA is measured using an optical head coupled to an oscilloscope.

### 5.3.2. 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)* **(after mounting optical parts)**

The receiver output is monitored whilst having the fixed attenuation of  $\sim 5\text{dB}$  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)* **(before and after mounting optical parts - TBD)**

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

(g) *Receiver saturation (spec 2.45)* **(after mounting optical parts)**

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

(h) *Reset generation (spec 2.24)* **(before and after mounting optical parts)**

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.

## 5.4. Mechanical Tests to be performed by the manufacturer.

During pre-production 15 DOH will be sent back to the manufacturer after being tested at CERN. These devices will be tested as follows:

### 5.4.1. Bond pull-test ☉

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.

### 5.4.2. Mechanical Shock and Vibration Tests ☉

Ten DOH will be 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 archiving.

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

## **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.