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Performance evaluation methodology

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Abstract

A methodology for analysing the analogue performance of the optical link for the CMS tracker is described. The method is demonstrated on two different sets of links.

1 Tested link configurations

Two groups of links have been tested as shown in Table 1. Two sets of links with the same type of 4-way emitters and differing receiver modules have been tested. The measurement setup and method is described in appendix A.

Table 1: Tested Links

Link	Transmitter	Receiver	Connector type/#	# optical channels
"Type1"	Discrete, 4-way	Discrete, 4-way	MPO/2	52
"Type2"	Discrete, 4-way	Module, 12-way	FCPC/2, MPO/1, SMC/1	72

The link configuration for the tested links is shown in Fig. 1 and Fig. 2 respectively.

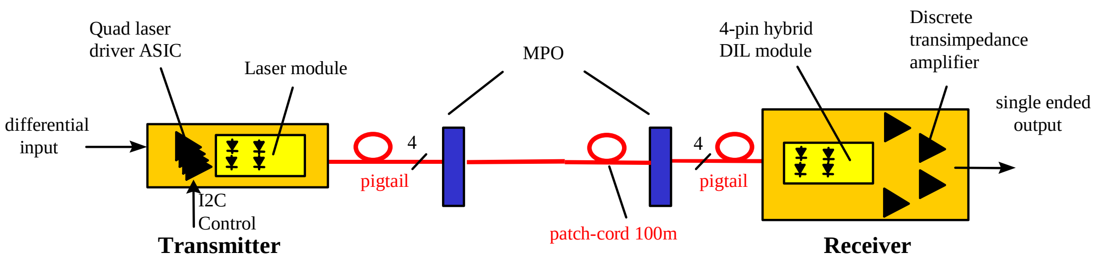

Fig.1: Link configuration for Type1 link

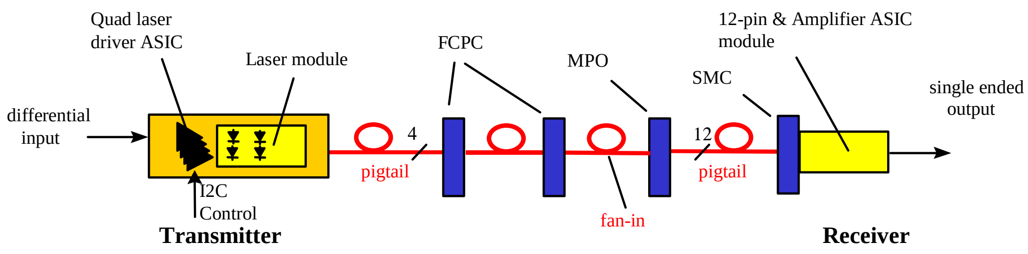

Fig.2: Link configuration for Type2 link. Note that for the Type2 link the transmitter module was kept the same for all 72 channels.

2 Performance evaluation - methodology

The evaluation of the optical links is based on the measurement of the system static transfer characteristic and is described in the following section.

2.1 Analogue performance measures

The measured parameters include system input, *X*, output voltage, *Y(X)*, and RMS-noise *dY(X)*. These parameters are processed to give information on linearity and input range. The average, *Y(X)*, and standard deviation, *dY(X)*, of the link output voltage is measured. The full input range, *X*, is 0.0-0.6V, with the working point set to be at 0V.

2.1.1 Static transfer characteristic

The link gains, *G*, are estimated from a linear regression fit over a range extending from the working point *X*=0V up to *X*=0.6V. The operating range considered is as stated in the previous paragraph between 0.0V and 0.6V. The laser thresholds have all been aligned off-line to -0.2V input voltage to ease comparison between links. In Fig. 3 and 4 the transfer characteristic of the Type1 and Type2 links are shown respectively. The corresponding gain distributions are shown in Fig. 5 and 6.

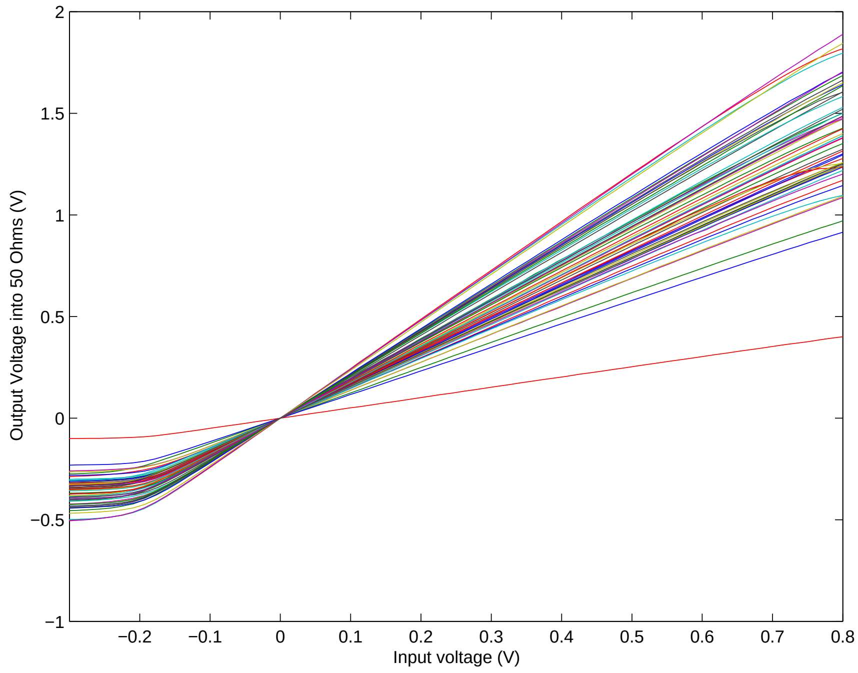

Fig. 3: Measured transfer characteristics for Type1 link (52channels).

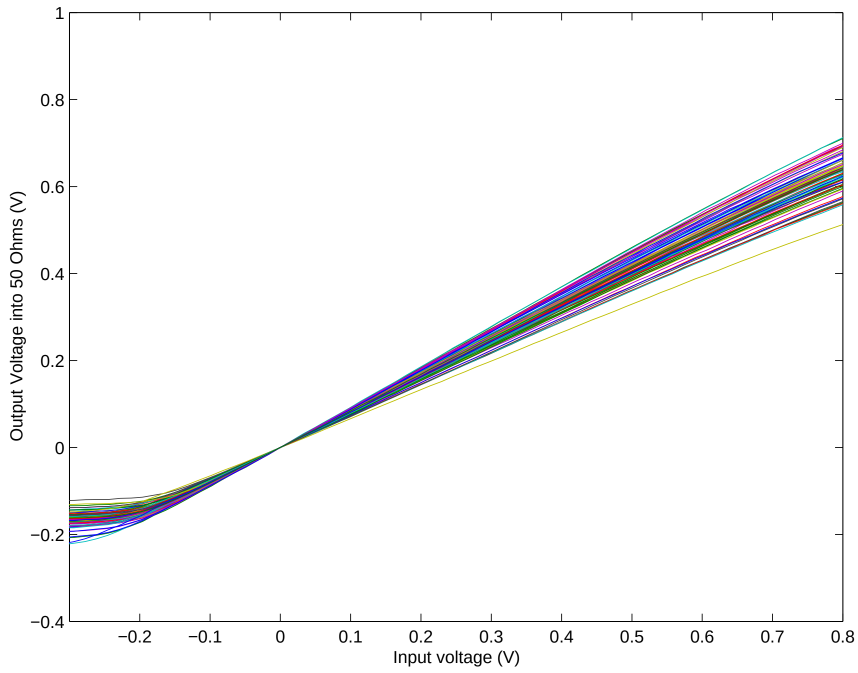

Fig. 4: Measured transfer characteristics for Type2 link (72channels).

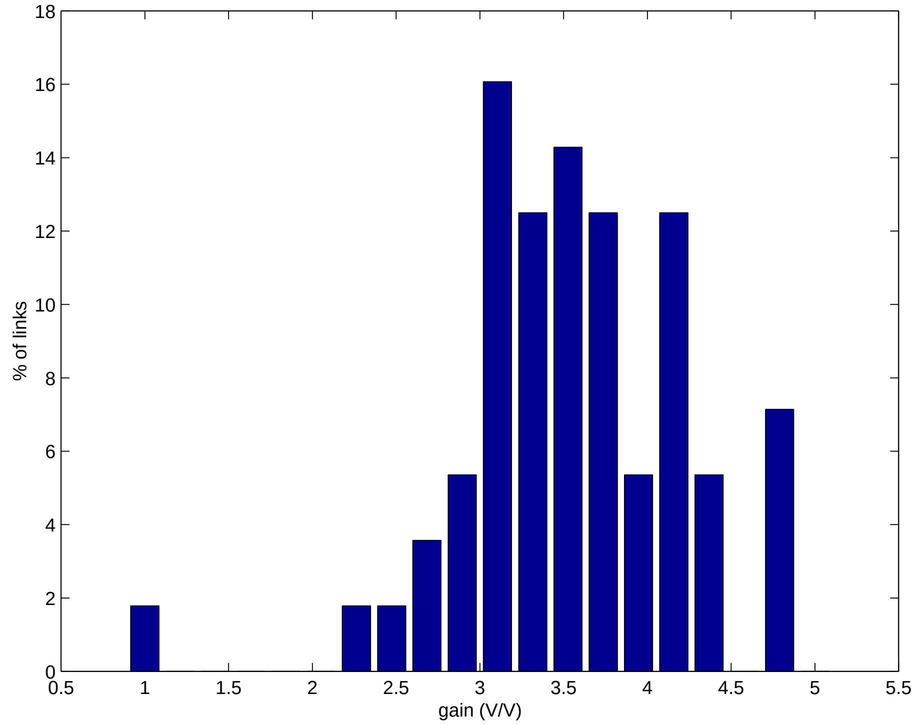

Fig. 5: Measured gain distribution for Type1 link (52channels).

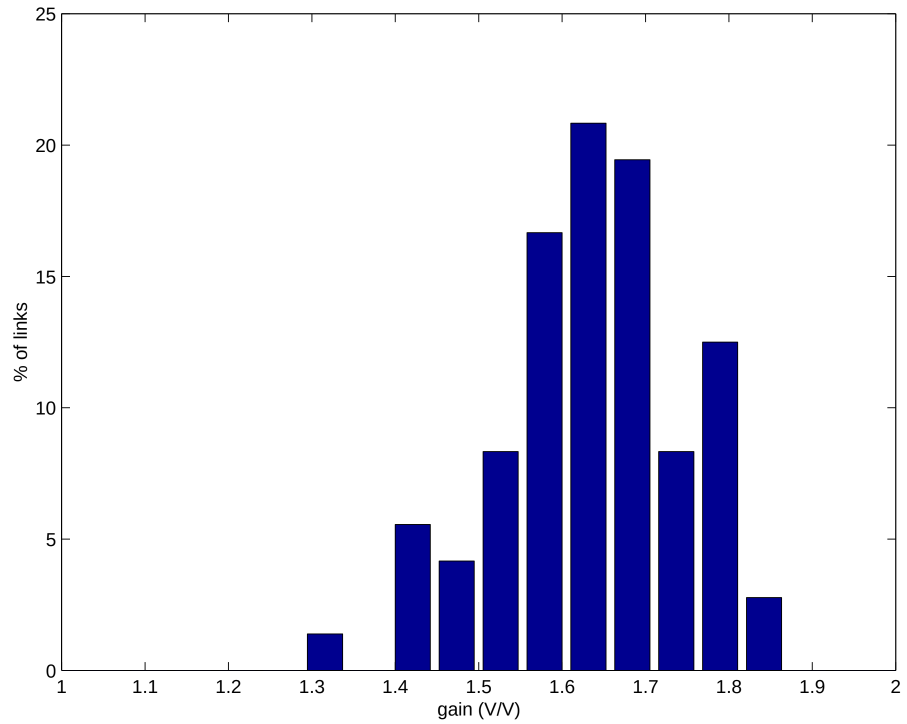

Fig. 6: Measured gain distribution for Type2 link (72channels).

2.1.2 Equivalent input noise

The measured RMS-noise, *dY(X)*, is normalised with the estimated gain, *G*, and the resulting Equivalent Input Noise, *EIN(X)*, is defined by:

$$EIN(X) = \frac{dY(X)}{G}$$

The Signal-to-Noise Ratio, *SNR*, is related to the *EIN* by:

$$SNR = \frac{Y(X)}{dY(X)} \cong \frac{G \times X}{dY(X)} = \frac{X}{EIN(X)}$$

The specification limit on the signal to noise ratio is:

$$20 Log(SNR(X)) \geq 48dB$$

For the present work 3 limits on the *EIN* (*SNR*) is considered as shown in Table 2:

Table 2: Noise limits used

SNR-limit (dB)	48 (spec)	50	52
SNR-limit (V/V)	252	316	398
EIN-limit, X=0.6V (mV)	2.4	1.9	1.4

The measured *EIN* is shown in Fig. 7 and 8 for the two measured link types.

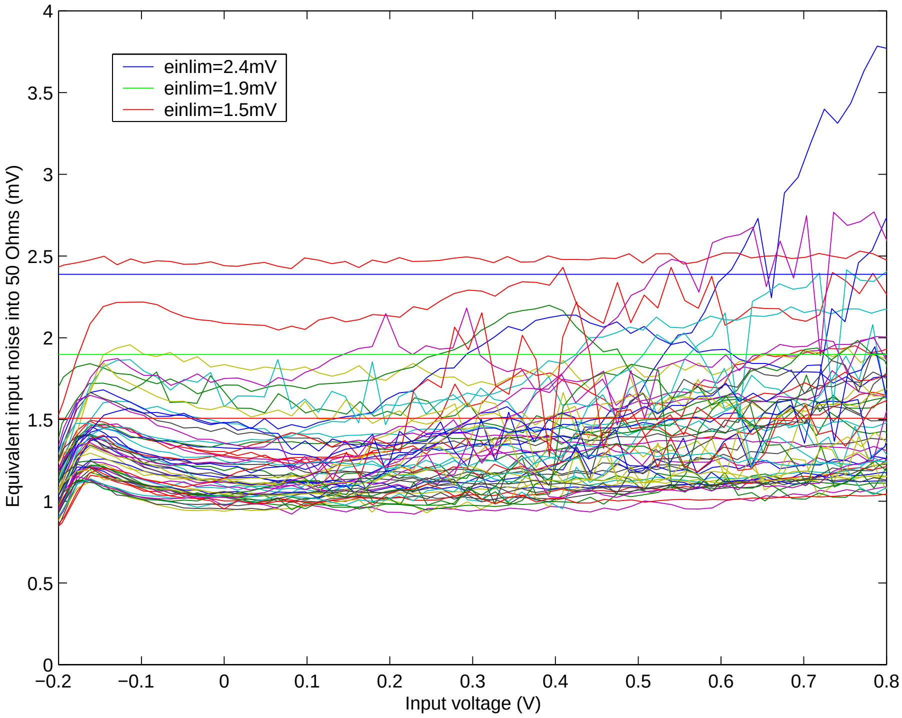

Fig. 7: *EIN* for the 52 Type1 links.

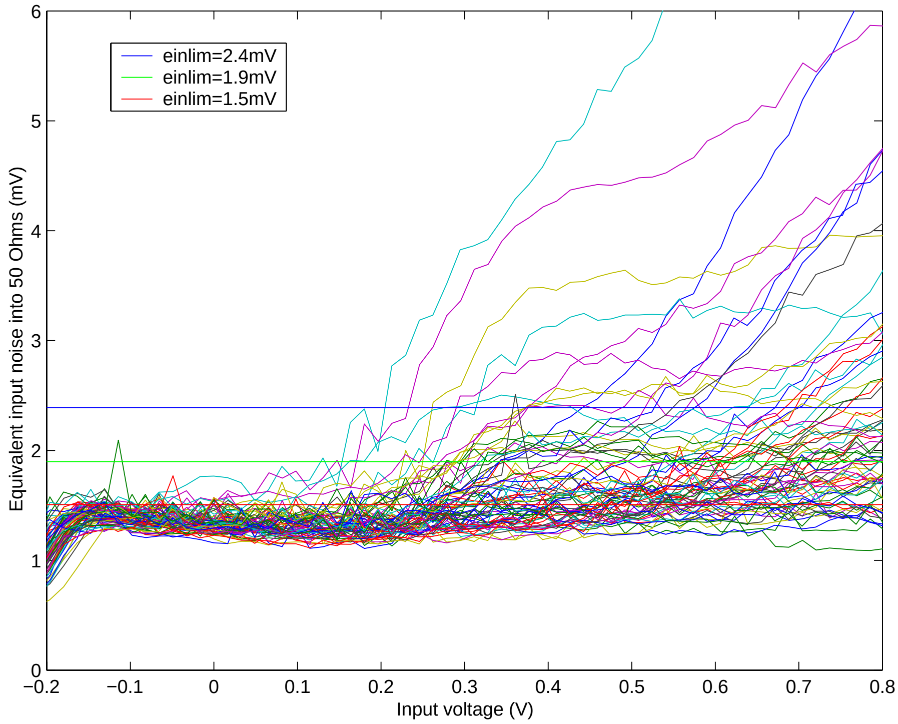

Fig. 8: *EIN* for the 72 Type2 links.

Next we consider the input range between 0V (working point) and the point where the noise crosses the upper limits as given in Table 2. A frequency plot of the result is shown in Fig. 9 (Type1) and Fig. 10 (Type2).

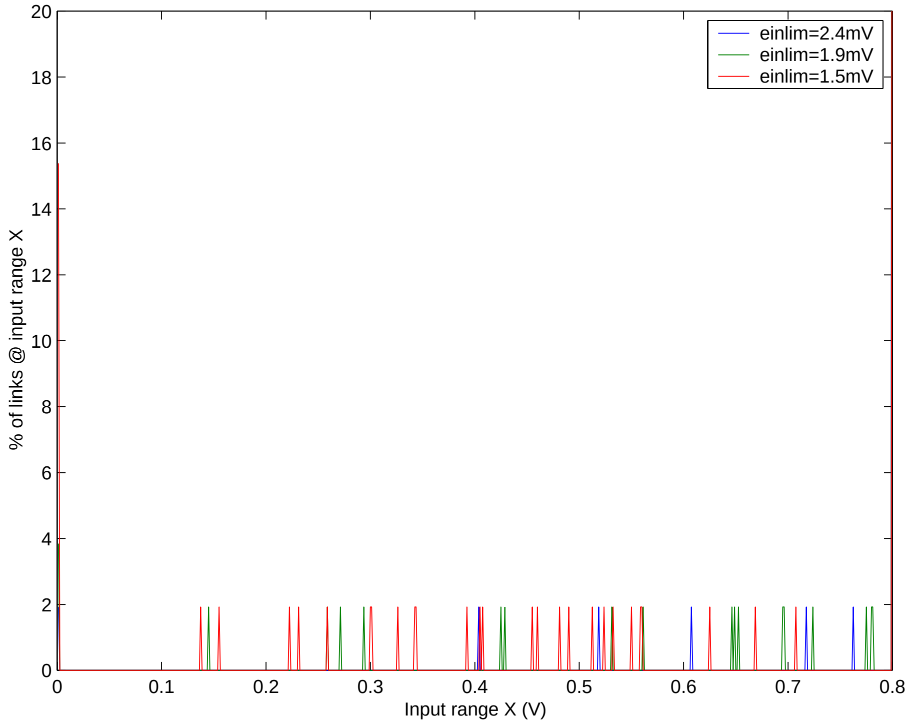

Fig. 9: Frequency plot of *EIN*-limited, maximum input ranges for the 52 measured Type1 links. The majority of the links have an input range above 0.6V. The reason for the large peak at 0.8V is that links with input ranges above this limit have been binned at 0.8V.

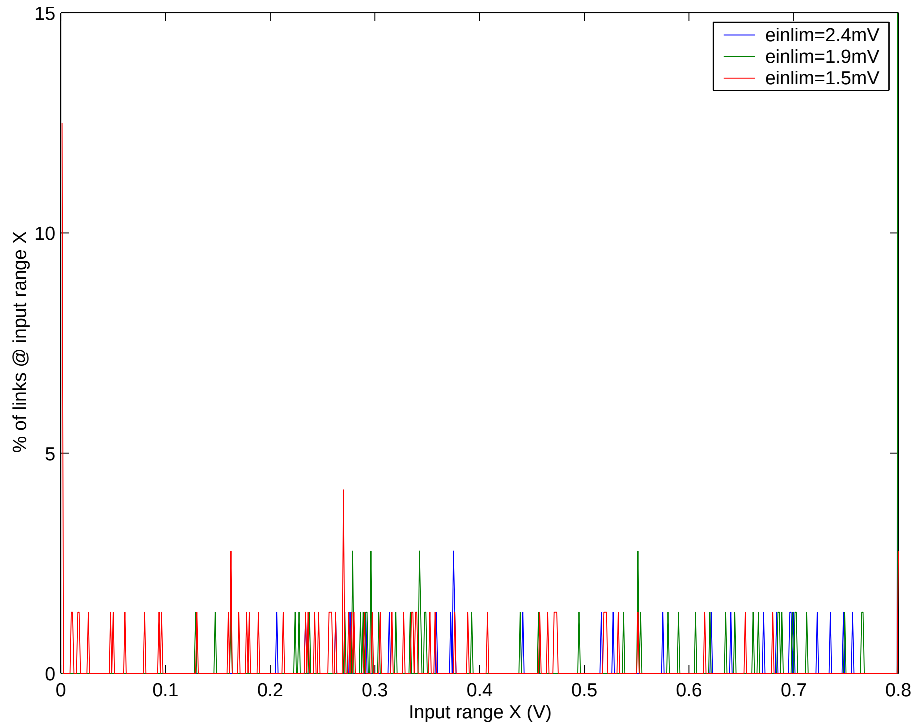

Fig. 10: Frequency plot of *EIN*-limited, maximum input ranges for the 72 measured Type2 links. The majority of the links have an input range above 0.6V. The reason for the large peak at 0.8V is that links with input ranges above this limit have been binned at 0.8V.

Corresponding cumulative plots of the maximum input ranges as shown in Fig. 11 and Fig. 12 for the Type1 and Type2 links respectively.

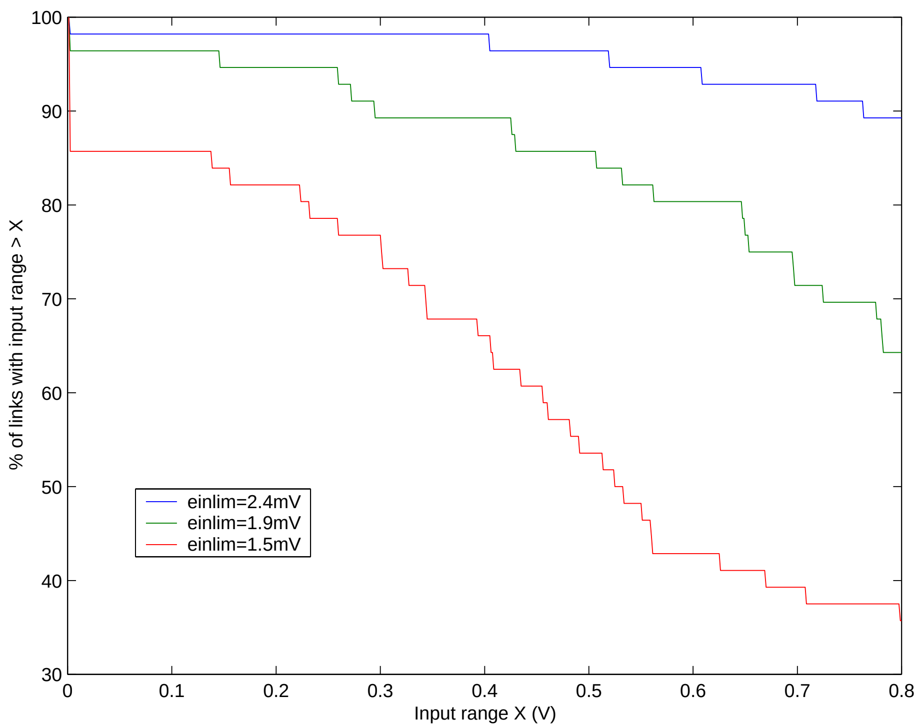

Fig. 11: Cumulative frequency plot of *EIN*-limited, maximum input ranges for the 52 measured Type1 links.

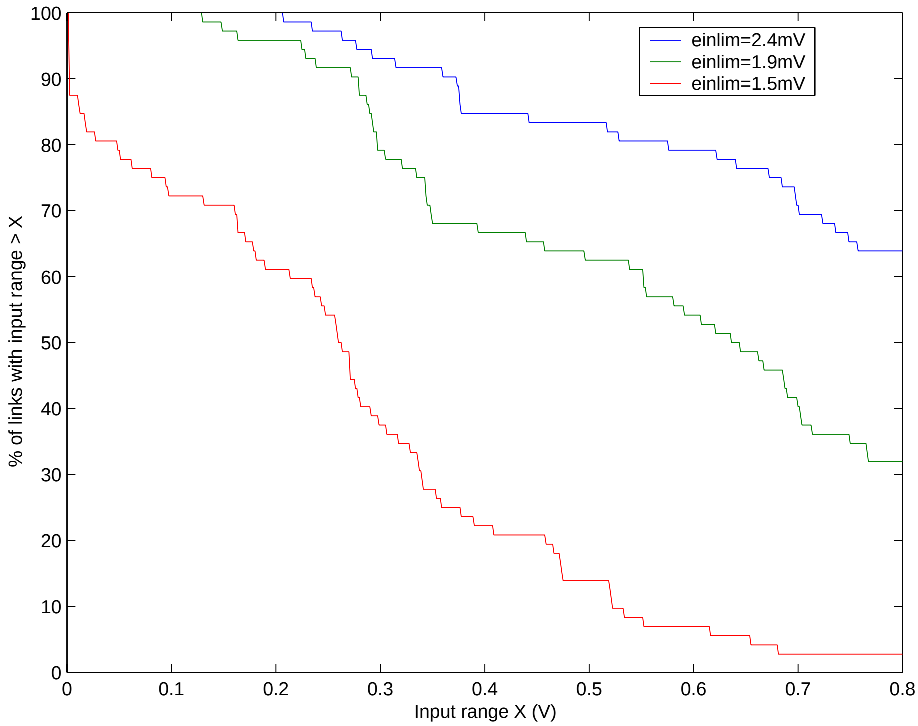

Fig. 12: Cumulative frequency plot of *EIN*-limited, maximum input ranges for the 72 measured Type2 links.

2.1.3 Equivalent input nonlinearity

The measure used to quantify deviation from linearity is Equivalent Input Nonlinearity, *EINL(X)*, defined in percent as:

$$EINL(X) = \frac{|Y(X) - GX|}{G}$$

It should be kept in mind that the position in *X* and width of the range chosen for the regression line fit (to extract the gain, *G*) influences the final calculated nonlinearity to some extent. A fitting range of 0.0-0.6V has been found to be a reasonable compromise that results in good linearity for both small and larger input signals.

The specification limit on nonlinearity is given in units of integral nonlinearity as:

$$INL(X) = \frac{|Y(X) - GX|}{G\Delta X} \times 100 \leq 2\%$$

Here the normalisation factor is ΔX=0.6V. An upper bound on *INL* can be transformed into an upper bound on EINL using:

$$EINL(X) = \frac{INL(X) \times \Delta X}{100}$$

Resulting in Table 3 for the 3 limits used on in this work. The measured *EINL* is shown in Fig 13 and Fig. 14.

Table 3: *EINL*-limits used

INL-limit (%)	2 (spec)	1.5	1
EINL-limit, X=0.6V (mV)	12	9	6

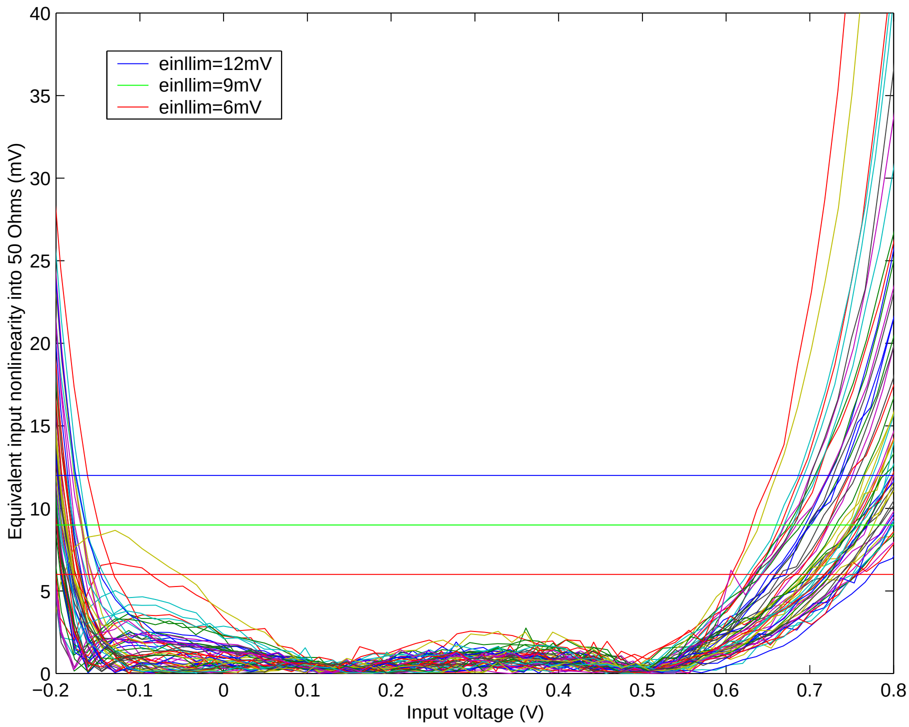

Fig 13: Equivalent input nonlinearity for 52 Type1 links.

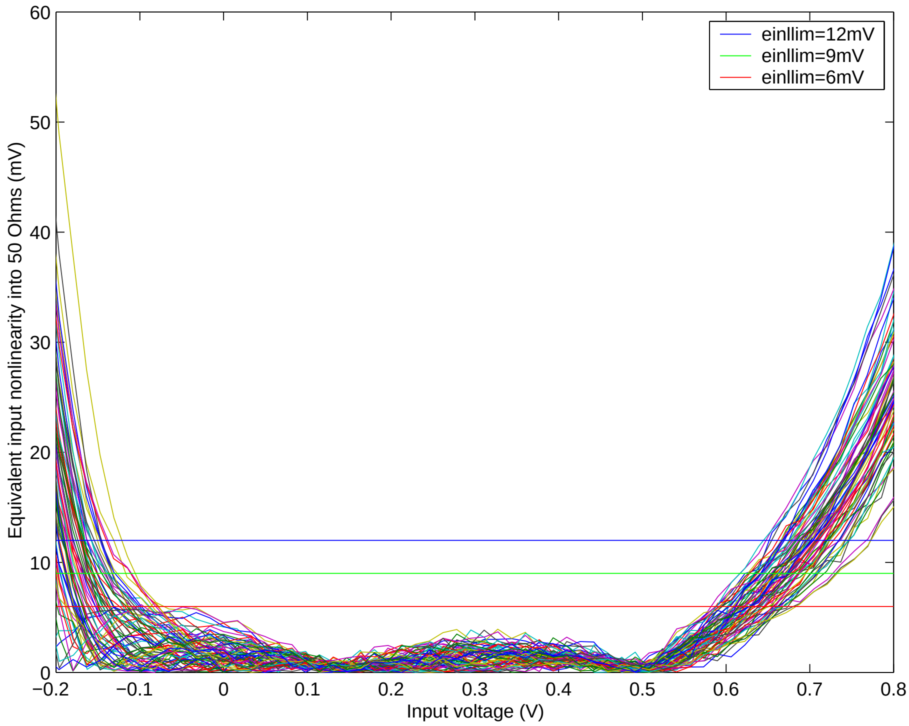

Fig 14: Equivalent input nonlinearity for 72 Type2 links.

In the same way as for the *EIN* it is now possible to produce frequency and cumulative frequency plots of the maximum input range as given by the equivalent input nonlinearity, *EINL*, as shown in Fig. 15 to Fig. 18.

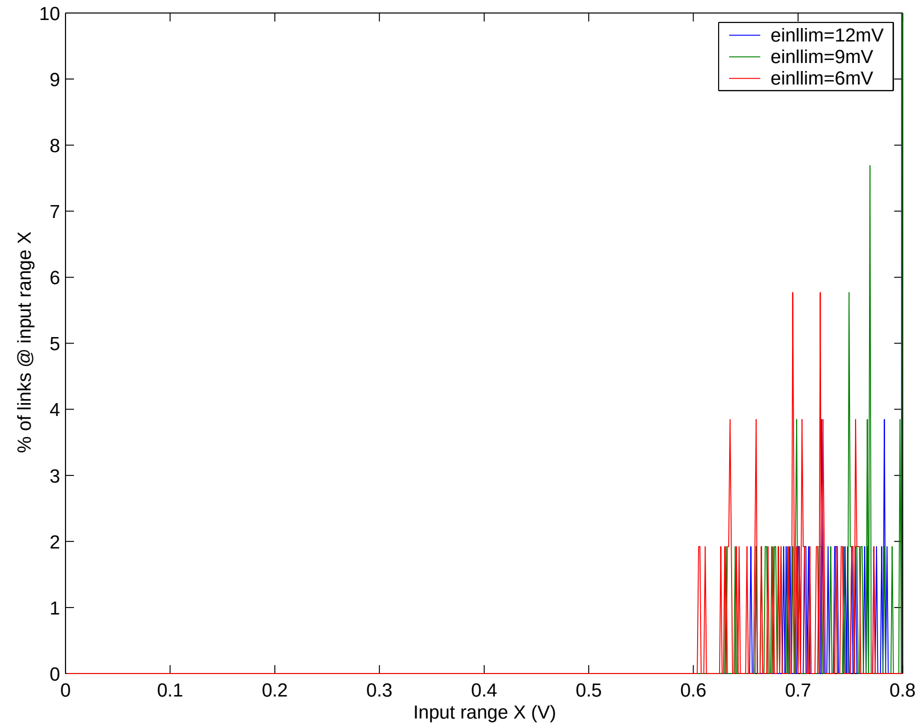

Fig. 15: Frequency plot of *EINL*-limited, maximum input ranges for the 52 measured Type1 links. The majority of the links have an input range above 0.6V. The reason for the large peak at 0.8V is that links with input ranges above this limit have been binned at 0.8V.

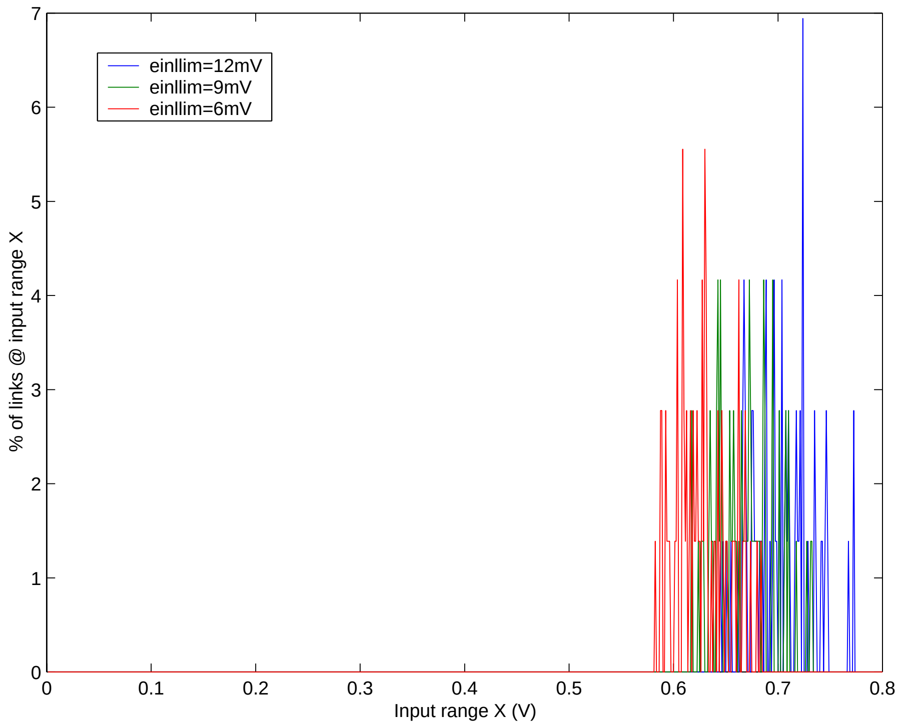

Fig. 16: Frequency plot of *EINL*-limited, maximum input ranges for the 72 measured Type2 links. The majority of the links have an input range above 0.6V.

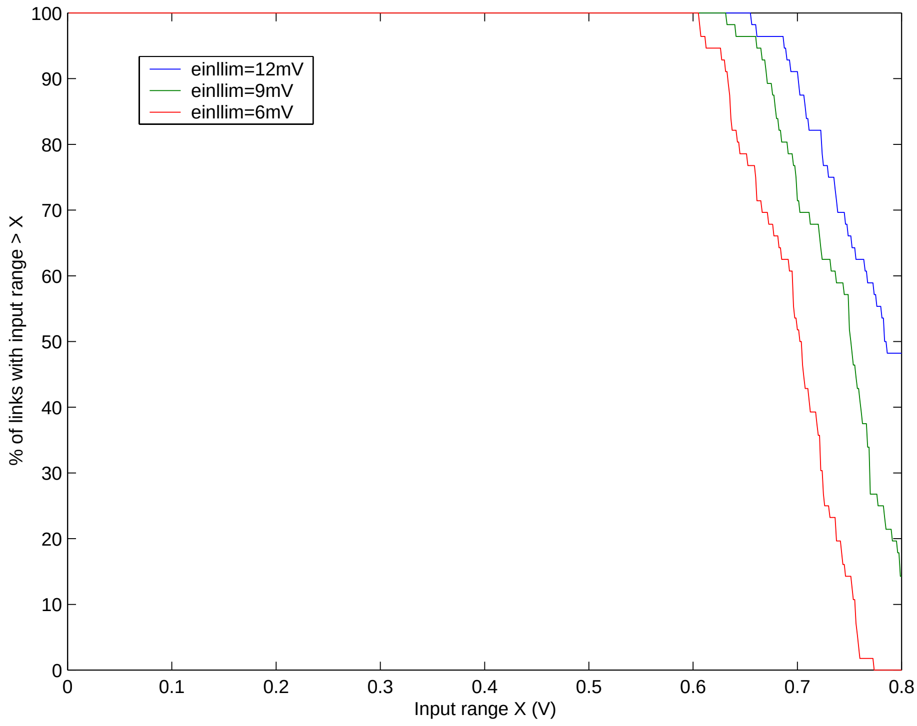

Fig. 17: Cumulative frequency plot of *EINL*-limited, maximum input ranges for the 52 measured Type1 links.

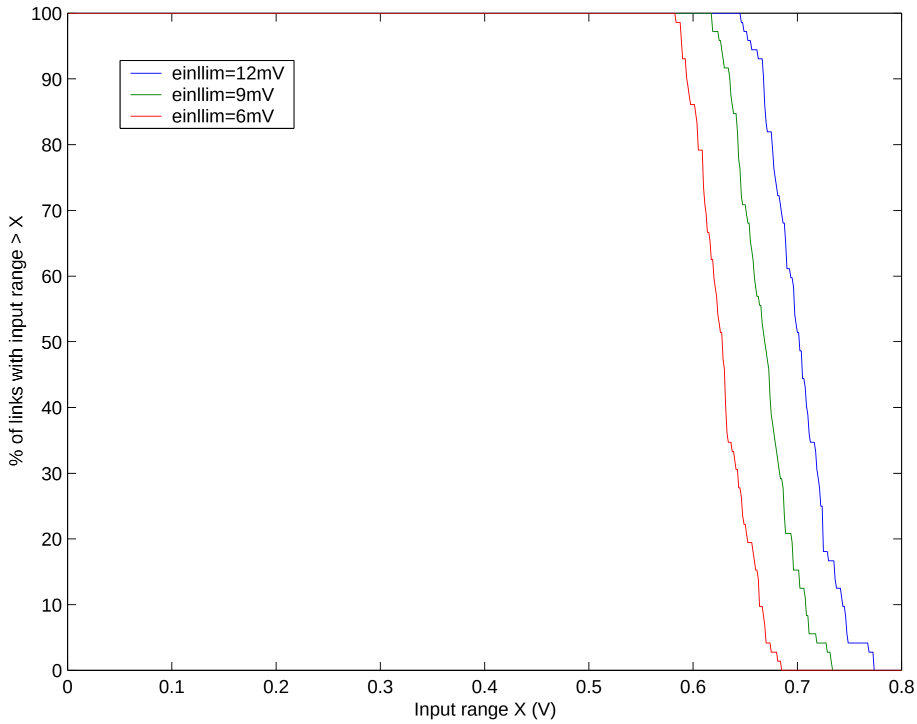

Fig. 18: Cumulative frequency plot of *EINL*-limited, maximum input ranges for the 72 measured Type2 links.

3 Conclusions

A methodology has been developed for analysing the analogue performance of optical links for the CMS tracker read-out system. The method allows typical system behaviour to be extracted and analogue performance to be quantified. Test-data for links of two different types were analysed as an example of how the performance evaluation method can be applied.

Related literature

[1] F. Jensen et al., "Evaluation and selection of analogue optical links for the CMS tracker - methodology and application", CMS-note 074, 1999. Submitted for publication to Journal of Physics G.

[2] G. Cervelli et al., "A Method for the Static Characterisation of the CMS Tracker Analogue Links". CMS Note 043, 1999.

[3] CMS Tracker Optical Readout Link Specification, Part 2: System, Version 3.2, September 1999.

Appendix A: Experimental method

The test arrangement is shown in Fig. 19. The evaluation of the different links is based on the measurement of the system static transfer characteristic. An arbitrary waveform generator (AWG) generates about 100 static voltage levels, *X*, that are fed sequentially to the laser driver input as a ramp. Synchronization signals for the measuring instruments are also produced by the AWG. For each static measurement point the average, *Y(X)*, and standard deviation, *dY(X)*, of the link output voltage are measured. A high-resolution (12bit) analog to digital converter (ADC), is used to evaluate the static transfer characteristic and a wide bandwidth (300MHz) oscilloscope is utilized to measure the noise into the system bandwidth. In order to cover the expected system input swing of ±400mV, corresponding to an input range of 800mV, an input swing of at least ±500mV is used in all cases. All system outputs are terminated with 50Ω.

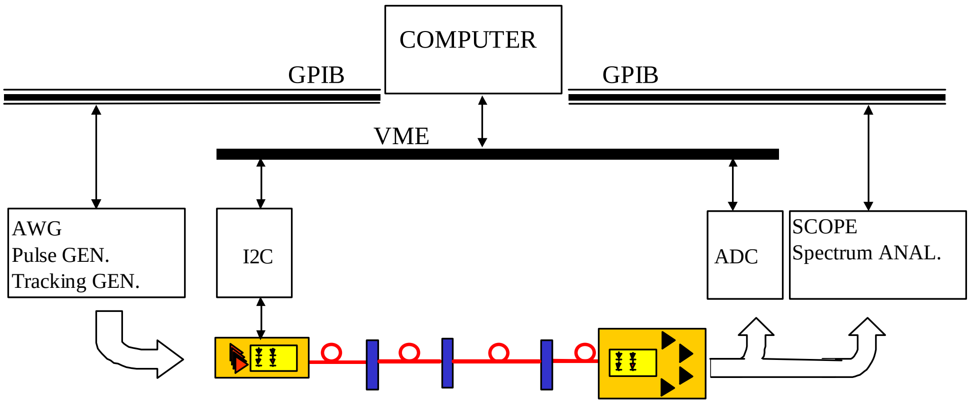

Fig. 19: Test setup for static and noise evaluation.