

Calibration of digital recorders to EN 601083-1
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1. INTRODUCTION

This paper describes a system set up to provide calibrations of the digital recorders used in high voltage measurements. A high voltage impulse can be up to several megavolts peak and a few microseconds long. A high voltage divider is used to reduce the voltage to a measurable level. The output of the divider is read by a digital recorder.

The calibrations are in accordance with the requirements of EN 601083-1 and cover

- Timebase
- Risetime
- Impulse scale factor
- Static and dynamic non-linearity
- Internal noise level
- Ripple tests
- Static scale factor

The measurements described were made on a Nicolet Power Pro 610 instrument but the principles are applicable to any instrument.

2. MEASUREMENTS

2.1 Timebase measurements

The standard specifies that the accuracy of the digitiser should be $< 0.1\%$ and that the integral non-linearity of the timebase shall be less than 2% of the time interval to be measured.

However, the specified uncertainty in typical instruments is much better than this and may be specified as, for example, $< 0.001\%$. It was decided to calibrate the instrument to the more restrictive requirement of its specification.

A stable sinusoidal wave of measured frequency (to within the uncertainties appropriate for the instrument being calibrated) is recorded on the digitiser. Measurements were carried out using the minimum time increment of 13 ns and 1000 points. A frequency of 0.301 MHz gave approximately 100 zero crossings. Software is used to analyse the applied waveform to determine accurately the zero crossing points, correcting for any non-linearities in the amplitude of the applied waveform. A linear least squares fit is made to determine the error in crossing-time versus the true crossing-time (as defined by the frequency source).

This method showed that the timebase was within $\pm 0.0008\%$ of nominal over a 130 μ s period.

An alternative method, looking over a much longer timescale of 1.3 s, and using the cursors on the instrument indicated that the timebase was within $\pm 0.00009\%$ of nominal.

2.2 Risetime Measurements

The risetime was measured using a step pulse with a transition duration of < 1 ns. The terms risetime and falltime are used interchangeably since the direction of the transition is not important.

The measurements were carried out using Reed Relay Pulse Generator (RRPG) developed at NPL. The circuit is shown in Figure 1. and the specification is shown below

Risetime/falltime into 1 M Ω : 0.628 ± 0.035 ns

Voltage range into 1 M Ω :

0.1 - 50 V

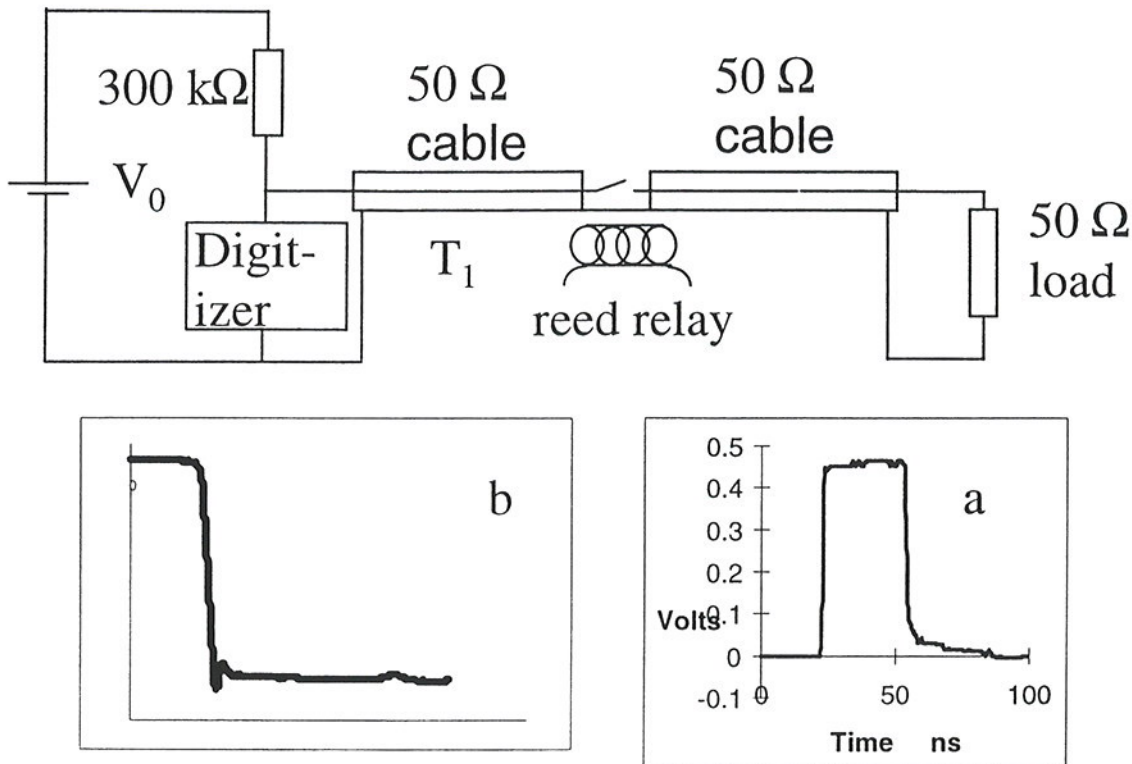


Figure 1. RRPG configured for use with a digitiser. A typical waveform at the 50 Ω load is shown at (a). The waveform at the digitiser is shown at (b).

The line operates as follows:

- 50 Ω line T_1 is initially charged to some potential $V_c \approx 0.77 V_0$ for a digitiser with 1 M Ω input impedance;
- when the relay is closed a pulse of amplitude $V/2$ propagates in both directions;
- the pulse travelling to the left takes time T_1 to reach the high impedance load of the digitiser and the 300 k Ω charging resistor. (The latter resistor is used to ensure a high impedance or open circuit relative to the 50 Ω line);
- the pulse is reflected by the "open circuit", producing a transition from V_c to zero volts, resulting in a pulse of length $2T_1$ travelling to the right into the 50 Ω load;
- the pulse travelling to the right is terminated in the 50 Ω load giving a voltage of $V_c/2$.

The risetime of the RRPG pulse, travelling to the right into the 50 Ω load is determined by the quality of the switch, cable and load and therefore places an upper limit on the risetime of the pulse at the switch.

The falltime of the pulse, travelling left through the cable T_1 into the high impedance load or near open circuit load is determined by the former, together with the reflection at the open circuit, the length of cable T_1 , the quality of the switch and the quality of the open circuit.

The falltime was measured for a range of voltages (positive and negative) from 1 V to 39 V; no significant dependence on polarity or voltage was observed.

The risetime of the digitiser was measured as (20 ± 6) ns. This translates to a bandwidth of 17.5 MHz (assuming a risetime.bandwidth product of .35) slightly lower than the 25 MHz specified by the manufacturer, but within the requirements of the standard.

2.3 Impulse Scale Factor

This measures the response of the digitiser to a voltage step of known height. The same experimental arrangement as used in the previous section was used to determine the impulse scale factor. A fast voltage step from 40 V to 0 V is applied to the recorder. At some point after the transition the voltage recorded by the digitiser must be zero. We have interpreted the standard to mean that we must show that the voltage switches to a value close to zero within the time specified by the standard, that is the settling time to some level. We have taken the time for measuring the zero value to be the mean in the region 0.6 μ s to 4 μ s after the transition. The standard requires the settling errors to be less than 1% of the amplitude.

The applied dc and zero voltages were measured using a dc calibration of the digitiser. The same voltage was applied to the RRPg using the set-up of Figure 1. The standard was interpreted to state that the mean voltage should be measured before the switching and in a period 0.6 μ s to 4 μ s after the transition. A number of measurements were made with a range of voltages up to ± 20 V, in excess of the 40% f.s.d required by the standard.

The main uncertainties in this measurement are in the knowledge of the test pulse. The contributions of the dc calibration and timebase (negligible) were also taken into account.

The impulse scale factor is 1.0 ± 0.005 , within the specification required by the standard.

2.4 Direct voltage measurements

The detailed definitions of the attributes to be measured are given in EN 601083-1.

In these tests a set of voltage levels is applied to the instrument and the output is examined to determine the static scale factor, the static integral non-linearity and the differential non-linearity under d.c. conditions.

Measurements were made on the 40 V range (± 20 V) at voltages up to 20 V.

The data is obtained automatically from the instrument and analysed using an EXCEL spreadsheet.

The static scale factor is 0.0400 V. This is defined as $(p(x) - p(y))/(x - y)$ where $p(x)$ is the average of the two code transition thresholds which delineate level x and similarly for level y .

The standard EN 601083-1 states that static integral non linearity should be within ± 0.5 % of the full scale deflection ie 0.02 V for the voltage applied. The observed values lie between - 0.001 V and +0.003 V.

EN 601083-1 requires that the differential non-linearity shall be within ± 0.8 per unit of the average code bin width, i.e. the results over the range of applied voltage should be within ± 0.8 . The results fall within ± 0.1 .

2.5 Differential non-linearity under dynamic conditions

The standard requires that a triangular wave of slope $> f.s.d/0.4 T_x$ be applied to the digitiser and a histogram of the occurrence of every digital level calculated.

The average amplitude of the histogram is 121 with a standard deviation of 20. The standard requires that the dynamic differential non linearity should be within ± 0.8 per unit of the average code bin width. This means that the code bin width can be taken as 121 and therefore the points on the histogram should be between 24 and 218. All the points on the histogram satisfy this condition.

2.6 Internal noise level

Measurements were made on three ranges. The average voltage and standard deviation of 1000 points are given in the Table below

Range	Average voltage	Standard deviation	Tolerance
40 V	9.0007	0.005 V	0.16 V
16 V	4.0015	0.006 V	0.06 V
8 V	2.0012	0.005 V	0.03 V

The tolerance required by the standard is also given. The instrument is within the prescribed tolerances.

2.7 Ripple

A voltage of 8 V was applied to the instrument on the 40 V range for a scale length of 20 ms. For the recorder tested there was no evidence of any effect due to ripple.

3.CONCLUSIONS

A system has been assembled which is capable of calibrating the type of digitiser used in high voltage impulse work to the requirements of EN601083-1. The calibration is, of course, general in the sense that the properties examined are used for applications other than high voltage work.

4. ACKNOWLEDGEMENTS

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