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Road vehicles — Electrical disturbances from conduction and coupling — Part 5: Enhanced definitions and verification methods for harmonization of pulse generators harmonization of pulse generators according to ISO 7637

Véhicules routiers — Perturbations électriques par conduction et par couplage — Partie 5: Amélioration des définitions et des méthodes de vérification pour l'harmonisation des générateurs d'impulsions selon la norme ISO 7637

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

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ISO/TR 7637-5 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 32,

— *Electrical and electronic components and general system aspects.*

Introduction

Pulses in vehicles are generated by different switching events of electrical loads connected to the supply system and coupled via the wiring harness to other components or wires. For test purpose these pulse phenomena are simulated by pulse generators and coupled via coupling structures to the wiring of a device under test. The test pulses are not real pulses but representatives for the wide range of pulse shapes, amplitudes, source resistances and pulse energy observed in vehicles. The definition of the test pulses and the coupling structures are described in ISO 7637 part 1, 2 and 3. Based on the standard definition test equipment has been developed and is commercially available.

The experience with existing test equipment shows some difficulties in terms of result reproducibility for the same DUT dependent on the used generator, which is caused by different realization of test generators coupling and decoupling networks. The intention of this paper is to describe the background for these variances and to define methods for harmonization of different generator behaviour.

Enhanced definitions and verification methods for harmonization of pulse generators according to ISO 7637

1 Scope

This technical report (TR) proposes extended definitions for pulse generators and verification methods necessary for harmonization of different generators used for pulse testing in accordance to ISO 7637-2 to ensure the comparability and reproducibility of test results independent on generator types. It presents generator verification results, based on current definitions of ISO 7637-2 Ed. 3, which show significant differences depending on the used generator type and explains the technical background of the variances.

This technical report is based on ISO 7637 part 1, 2 and 3.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this technical report. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this technical report are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 7637-1: 2002 Road vehicles - Electrical disturbances from conduction and coupling - Part 1: Definitions and general considerations

ISO 7637-2: 2011, Road vehicles - Electrical disturbances from conduction and coupling - Part 2: Electrical transient conduction along supply lines only

ISO 7637-3: 2007, Road vehicles - Electrical disturbances from conduction and coupling - Part 3: Vehicles with nominal 12 V, 24 V or 42 V supply voltage - Electrical transient transmission by capacitive and inductive coupling via lines other than supply lines

3 Terms and definitions

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

3.1 device under test (DUT)

DUT is defined as one single component or a combination of components as defined to be tested

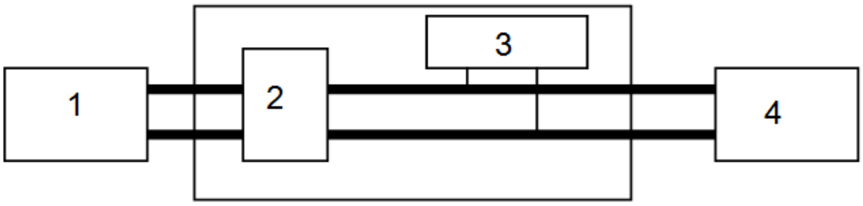
3.2 ground plane (GP)

a flat conductive surface whose potential is used as a common reference. Where applicable, the test voltage should also be referenced to the ground plane

4 Test pulse generator description

4.1 Existing generator description

The main parts of pulse generators are the pulse shaping and coupling networks, (important for generating and applying the test pulses to the DUT) and the decoupling network (important for protecting the connected power supply and effecting the pulse coupling to DUT). A block diagram is shown in



Key:

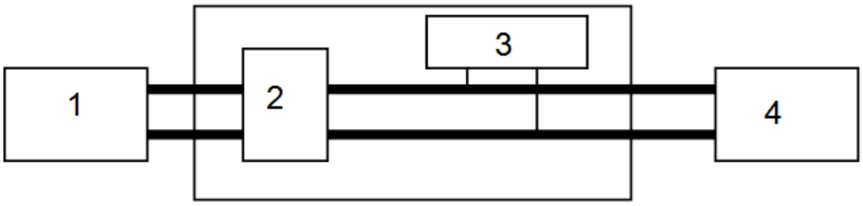
1 power supply

2 decoupling network

3 pulse shaping and coupling network

4 DUT (or verification load)

Figure 1 —.



Key:

1 power supply

2 decoupling network

3 pulse shaping and coupling network

4 DUT (or verification load)

Figure 1 — Pulse generator principle

The generator description in the current edition of ISO7637-2 defines only: “The test pulse generator shall be capable of producing the open circuit test pulses described in 5.6.1 to 5.6.4 at the maximum value of $|U_s|$. U_s shall be adjustable within the limits given in tables 2 to 6. The timing (t) tolerances and internal resistance (R_i) tolerance shall be ±20% unless otherwise specified.”

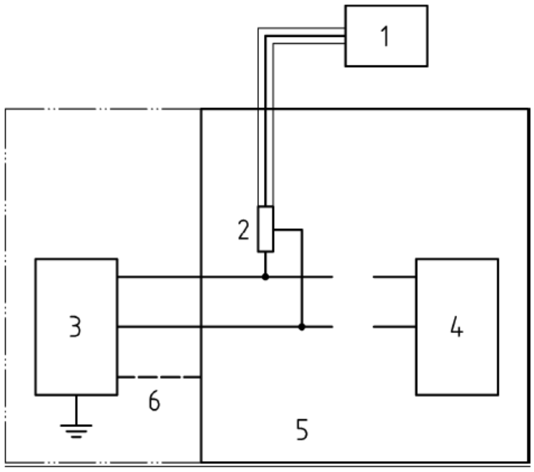
Beyond that, only timing diagrams of the open circuit voltage and the internal resistor are defined.

4.2 Test setups for generator verification

The test setup for generator verification is intended to represent typical load conditions applied to the test generator out of the infinite range of test applications. For the different setups the test generator shall show a linear behavior without resonance effects, under- or over swing effects. The setup shall be defined to evaluate relevant data of the test generator with minimal effect to the tolerance scheme of the complete test environment.

4.2.1 Existing verification setups

The actual test setup and generator verification procedure are described in Annex C of ISO 7637-2 Ed. 3 and limits the verification to open and matched termination with resistive load (load resistor equal to generator internal pulse source impedance) as shown in



Key:

1 oscilloscope or equivalent
2 voltage probe
3 test pulse generator with internal resistance R_i
4 DUT disconnected
5 ground plane
6 ground connection; maximum length for test pulse 3 is 100 mm

Figure 2 and Figure 2.

The verification defines and requires:

- U_a = 0 V,
- open load condition with
  - 10% magnitude tolerance for pulses 1, 2a, 3a, 3b,
  - 20% of duration for pulses 1, 2a and 30% duration for pulses 3a, 3b,
- matched load condition with
  - 20% tolerance of magnitude for pulses 1, 2a, 3a, 3b,
  - 20% of duration for pulses 1, 2a and 30% duration for pulses 3a, 3b,
  - matching load resistor with 1% tolerance.

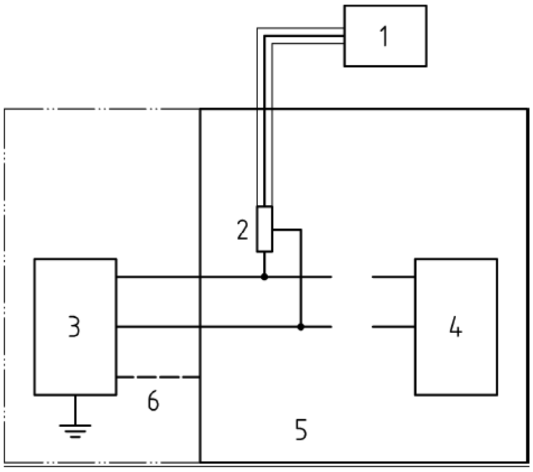
Table 2 — Test pulse 1 parameters

Test pulse 1 (Nominal 12 V system)

Test pulse 1	V_s	t_r	t_d
No load	- 100 V ± 10 V	$\left(1\ _{-0,5}^{\ 0}\right)$ µs	2 000 µs ± 400 µs
10 Ω load	- 50 V ± 10 V	-	1 500 µs ± 300 µs

Test pulse 1 (Nominal 24 V system)

Test pulse 1	V_s	t_r	t_d
No load	- 600 V ± 60 V	$\left(3\,^{0}_{-1,5}\right)$ µs	1 000 µs ± 200 µs
50 Ω load	- 300 V ± 60 V	-	1 000 µs ± 200 µs



Key:

1 oscilloscope or equivalent
2 voltage probe
3 test pulse generator with internal resistance R_i
4 DUT disconnected
5 ground plane
6 ground connection; maximum length for test pulse 3 is 100 mm

Figure 2 Generator verification setup

In addition, Annex D provides equations for voltage, current and energy calculation of a simple RC discharging network, consisting of a storage capacitor, internal and external resistor.

With these setup and tolerance definitions all existing pulse generators can be verified successfully. But the limited definitions and wide tolerances lead to different test results with different test generators and especially under load conditions as described in 4.3.2 and Annex A.

Resonances and nonlinear behavior of test generators, occurring when a real DUT is connected and powered via the pulse generator, cannot be detected with the existing verification method. Hence, a more detailed definition of pulse shaping, coupling-, decoupling network and enhanced verification definition is necessary.

4.2.2 Extended verification setups

Extended verification setups shall represent a wider range of application load impedances. These may be expected in real applications and enable to determine the available power. Based on the existing verification setup an extended set of termination impedances is defined and the pulses are described with closer tolerances.

The following set of verification impedances is defined in Table 2:

- open load conditions,
- matched resistor to generator source impedance,
- low resistive load to simulate applications with high current consumption ,

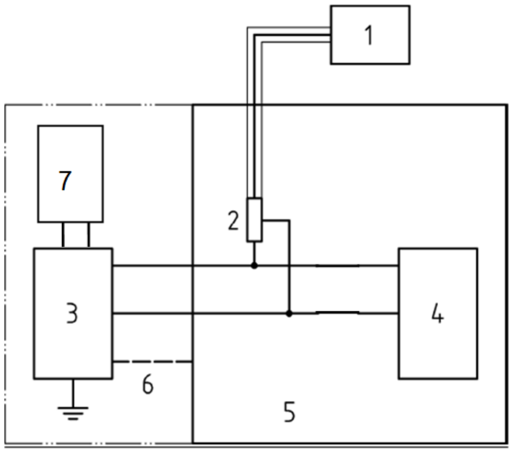
- resistive-capacitive load, to simulate low power loads (e.g. sensors).

This set of termination networks shall be defined with all values relevant for the frequency spectra of the pulses.

Table 1 Generator verification condition and load definition

Supply	Load	1	2a	3a	3b
unsupplied $U_a = 0$ V	open load	defined	defined	defined	defined
	matched load	defined	defined	defined	defined
supplied $U_a = U_N$,	open load	- -	new	tbd	tbd
	matched load	- -	new	tbd	tbd
	1 Ω	new	new	- -	- -
	100 nF||1 kΩ	new	new	- -	- -

An enhanced generator verification setup is described in Figure 3.



Key:

1 oscilloscope or equivalent
2 voltage probe
3 test pulse generator with internal resistance R_i
4 verification load
5 ground plane
6 ground connection; max. length for test pulse 3 is 100mm
7 battery or power supply

Figure 3 Enhanced generator verification setup

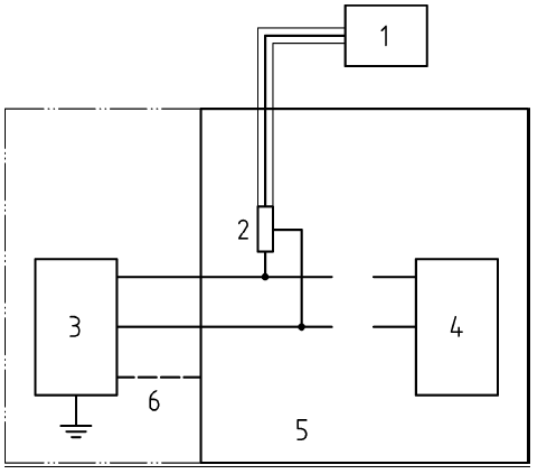
4.3 Generator verification

The performance of 16 pulse generators, specified for pulse immunity test according to ISO 7637, have been verified in order to check the compliance to the standard and the behaviour under real test conditions with supply and typical loads.

In a first step the test setups for generator verification defined in ISO 7637 were used and the compliance with the specification was checked. In a second step the generator input was connected to a power supply and the pulse generator output was loaded with different load impedances as given by real devices under test (DUT). In both setups the pulse waveform and the specified pulse parameters were monitored.

4.3.1 Verification results with existing setup definitions

For verification of the compliance with the standardized values the maximal pulse voltage and the pulse width at three different test levels for pulse 1 were measured and the deviation to the standardized value was evaluated.



Key:

1 oscilloscope or equivalent
2 voltage probe
3 test pulse generator with internal resistance R_i
4 DUT disconnected
5 ground plane
6 ground connection; maximum length for test pulse 3 is 100 mm

Figure 2 shows the verification results.

Table 2 Generator verification result summary pulse 1

Test-Pulse	Supply U_a	Load	Generator voltage U_s	Pulse voltage U_s min / max	U_s deviation % **standard** (min / max)	Pulse width t_d min / max	t_d deviation % **standard** (min / max)
ISO pulse 1 open-load definition *)	no	open	-100 V	-100 V ±10 V	**±10%**	2 ms ± 0,4 ms	**±20%**
result	no	open	-50 V	-56 V / -45 V	**5,0%** (-9,4% / +12,5%)	1,8 ms / 2,3 ms	**6,1%** (-10% / +15%)
result *)	no	open	-100 V	-109 V / -93 V	**3,5**% (-6,3% / +9,2%)	1,9 ms / 2,2 ms	**5,4%** (-5% / +10%)
result	no	open	-150 V	-142 V / -164 V	**3,5%** (-5,2% / +9,1%)	1,9 ms / 2,2 ms	**5,5%** (-5% / +10%)
ISO pulse 1 10Ω-load definition *)	no	10 Ω	-100 V	-50 V ±10 V	**±20%**	1,5 ms ±0,3 ms	**±20%**
result	no	10 Ω	-50 V	-25 V / -22 V	**3,3%** (-5,8% / +4,6%)	1,4 ms / 1,6 ms	**5%** (-6,7% / +6,7%)
result C	no	10 Ω	-100 V	-52 V / -46 V	**3,6%** (-6,8% / +5,5%)	1,3 ms / 1,5 ms	**4,1%** (-13,3% / 0%)
result	no	10 Ω	-150 V	-80 V / -70 V	**4,4%** (-6,9% / 7,5%)	1,3 ms / 1,5 ms	**3,9%** (-13,3% / 0%)
*) values to be verified according to ISO 7637-2 definition							

The standard deviation of the pulse voltage over all generators for pulse 1 for three levels -50 V, -100 V and -150 V varies between 3,5% and 5% for open load conditions. The maximal deviation increases up to 12,5% at -50 V. The standard deviation of the pulse width over all generators for pulse 1 for three levels -50 V, -100 V and -150 V varies between 5,4% and 6,1% for open load conditions. The maximal deviation increases up to 15% at -50 V. All generators are well within the standardized tolerances (required for -100 V).

The standard deviation of the pulse voltage over all generators for pulse 1 for three levels -50 V, -100 V and -150 V varies between 3,3% and 4,4% for 10 Ω conditions. The maximal deviation increases up to 7,5 % at -150 V. The standard deviation of the pulse width over all evaluated generators for pulse 1 for three levels -50 V, -100 V and -150 V varies between 3,9% and 5% for 10 Ω conditions. The maximal deviation increases up to -13,3 % at – 100 V. One generator failed the pulse width requirements with -46,7% and has been excluded from deviation assessment. All generators except one (excluded) are within the standardized tolerances (required for -100 V).

More information about the evaluated pulse parameters and monitored pulse wave forms are given in Annex A.

For compliance verification of pulse 2a the maximal pulse voltage and the pulse width at four different test levels were measured. Furthermore the deviation to the standardized values was evaluated. Table 3 shows the verification results.

Table 3 Generator verification result summary pulse 2a

Test-Pulse	Supply U_a	Load	Generator voltage U_s	Pulse voltage U_s min / max	Us deviation % **standard** (min / max)	Pulse width t_d min / max	t_d deviation % **standard** (min / max)
ISO 2a open-load definition *)	no	open	75 V	75 V ±7,5 V	**±10%**	50 µs ± 10 µs	±20%
result	no	open	50 V	48 V / 51 V	**3,0%** (-4,0% / +5,6%)	45 µs / 58 µs	**6,9%** (-10,0%/15,2%)
result *)	no	open	75 V	72 V / 78 V	**2,9**% (-3,5% / +3,9%)	45 µs / 55 µs	**6,6%** (-10,0% / 10%)
result	no	open	100 V	97 V / 101 V	**1,6%** (-2,9% / +1,8%)	45 µs / 55 µs	**7,1%** (-10,0% / 10%)
result	no	open	125 V	120 V / 126 V	**1,6%** (-3,6% / 1,4%)	44 µs / 56 µs	**8,3%** (-12% / 12%)
ISO 2a 2-Ω-load definition *)	no	2 Ω	75 V	37,5 V ±7,5 V	**±20%**	12 µs ± 2,4 µs	+/-20%
result	no	2 Ω	50 V	19 V / 26 V	**9,4%** (-24,8%/+4,0%)	11,8 µs / 15 µs	**10,6%** (-1,7% / 25%)
result *)	no	2 Ω	75 V	33 V / 41 V	**8,3%** (-13% / +9,2%)	11,8 µs / 14,4 µs	**8,6%** (-1,7% / 20%)
result	no	2 Ω	100 V	44 V / 53 V	**7,0%** (-11,3%/ +5,8%)	11,8 µs / 14 µs	**7,3%** (-1,7% / 16,7%)
result	no	2 Ω	125 V	56 V / 68 V	**7,7%** (-10,9% / +8%)	11,8 µs / 13,7 µs	**6,4%** (-1,7% / 14,2%)
*) values to be verified according to ISO 7637-2 definition							

The standard deviation of the pulse voltage over all generators for pulse 2a for four levels 50 V, 75 V, 100 V and 125 V varies between 1,6% and 3% for open load conditions. The maximal deviation increases up to 5,6% at 50 V. The standard deviation of the pulse width over all generators for pulse 2a for four levels 50 V, 75 V, 100 V and 125 V varies between 6,6% and 8,3% for open load conditions. The maximal deviation increases up to 15,2% at 50 V. All generators are well within the standardized tolerances (required for 75 V).

The standard deviation of the pulse voltage over all generators for pulse 2a for four levels 50 V, 75 V, 100 V and 125 V varies between 7% and 9,4% for 2 Ω load conditions. The maximal deviation increases significantly up to 24,8% at 50 V. The standard deviation of the pulse width over all evaluated generators for pulse 2a for four levels 50 V, 75 V, 100 V and 125 V varies between 6,4% and 10,6% for 2 Ω load conditions. The maximal deviation increases significantly up to 25% at 50 V. One generator failed the pulse width requirements with +38,3% and has been excluded from deviation assessment. All generators except one (excluded) are within the standardized tolerances (required for 75 V).

More information about the evaluated pulse parameters and monitored pulse wave forms are given in Annex A.

4.3.2 Verification results with extended setup definitions

For verification of the different generator performance for pulse 1 under test conditions with application load impedances the same tests have been performed. The maximal pulse voltage and the pulse width at 3 different test levels were measured and the deviations to the expected pulse voltage values were evaluated. Two different loads, low resistive load 1Ω and high impedance load 1kΩ//100nF, were used. Table 3 shows the verification results.

Table 4 Generator extended verification result summary for pulse 1

Test-pulse	Supply U_a	Load	Generator-voltage U_s	Pulse target voltage U_s min / max	Pulse voltage U_s min / max	U_s deviation % **standard** Min / max
ISO 1 open-load definition	no	open	-100 V	-100 V	-100 V ±10 V	**±10%**
ISO 1 10-Ω-load definition	no	10 Ω	-100 V	-50 V	-50 V ±10 V	**±20%**
result	no	1 Ω	-50 V	-4,6 V	-5,6 V / -4,2 V	**9,1%** (-7,7% /+24,4%)
result	no	1 Ω	-100 V	-9,1 V	-10,6 V / -8,3 V	**8,1**% (-8,6% / +16,8%)
result	no	1 Ω	-150 V	-13,6 V	-25 V / -12,4 V	**23,2%** (-9,0% / +83,1%)
result	no	1 kΩ‖100 nF	-50 V	-49,5 V	-61 V / -45 V	**7,5%** (-9,6% / +23,4%)
result	no	1 kΩ‖100 nF	-100 V	-99 V	-133 V / -92 V	**10,4%** (-6,8% / +34,8%)
result	no	1 kΩ‖100 nF	-150 V	-148 V	-204 V / -140 V	**12,1%** (-5,9% / 37,4%)

The standard deviation of the pulse voltage over all generators for pulse 1 for three levels -50 V, -100 V and -150 V varies between 8,1% and 23,2% for 1 Ω load conditions. But the maximal deviation increases significantly up to 83% at -150 V.

The standard deviation of the pulse voltage over all generators for pulse 1 for three levels -50 V, -100 V and -150 V varies between 7,5% and 12,1% for 1 kΩ‖100 nF load conditions. The maximum deviation is 37,4% at -150 V.

Although all generators are well within the standardized tolerances under test conditions with application load impedances the results are spread over a wide range up to 83% deviation which needs to be solved.

More information about the evaluated pulse parameters and monitored pulse wave forms are given in Annex A.

For verification of the different generator performance for pulse 2a under test conditions with power supply and connected application load impedances the same tests have been performed. The maximal pulse voltage and the pulse width at four different test levels were measured and the deviation to the expected pulse voltage values was evaluated. Four different loads were used (open, match, low resistive load 1 Ω and high impedance load 1 kΩ//100 nF). Table 5 shows the verification results.

Table 5 Generator extended verification result summary for pulse 2a

Test-Pulse	Supply U_a	Load	Generator voltage U_s	Pulse target voltage min / max	Pulse voltage U_s min / max	U_s deviation % **standard** (min / max)	Supply U_a under swing min / max	Pulse U_s overshoot min / max
ISO 2a open-load definition	No	open	75 V	75 V±7,5 V		±**10%**	-	-
ISO 2a 2-Ω-load definition	No	2 Ω	75 V	37,5V±7,5V		±**20%**	-	-
result	13,5 V	open	50 V	63,5 V	59 V / 67 V	**3,1%** (-7,8% / 5,2%)	-	-
result	13,5 V	open	75 V	88,5 V	84 V / 92 V	**3,4**% (-5,2% / 4,0%)	-	-
result	13,5 V	open	100 V	113,5 V	105 V / 133 V	**6,1%** (-7,3% / **17,0%)**	-	-
result	13,5 V	open	125 V	138,5 V	128 V / 142 V	**2,6%** (-7,3% / 2,2%)	-	-
result	13,5 V	2 Ω	50 V	31,75 V	25 V / 31 V	**8,0%** (-27,7% /-2,6%)	-0,1V **/-6,5 V**	-
result	13,5 V	2 Ω	75 V	44,25 V	30 V / 43 V	**8,3%** (-31,3% / -2,9%)	-0,2V /**-7,6V**	-
result	13,5 V	2 Ω	100 V	56,75 V	39 V / 56 V	**8,6%** (-31,6% / -5,1%)	-0,2V /**-8,3V**	-
result	13,5 V	2 Ω	125 V	69,25 V	48V / 67 V	**11,2%** (-44,0% / -4,4%)	-0,1V /**-8,6V**	-
result	13,5 V	1 Ω	50 V	21,17 V	15 V / 23 V	**13,1%** (-29,1%/+10,9%)	-0,1V /**-5V**	-
result	13,5 V	1 Ω	75 V	29,50 V	22 V / 30 V	**9,1%** (-25,9% / 1,5%)	-0,3V /**-7,8V**	-
result	13,5 V	1 Ω	100 V	37,83 V	28 V / 40 V	**9,3%** (-25,0% / 6,8%)	-0,4V /**-9,6V**	-
result	13,5 V	1 Ω	125 V	46,17 V	35 V / 47 V	**12,5%** (-45,3% / 2,2%)	-0,4V/**-10,3V**	-
result	13,5 V	1 kΩ// 100nF	50 V	63,40 V	60 V / 93 V	**13,3%** (-5,5% /+47%)	-	-5,5%/**47%**
result	13,5 V	1 kΩ// 100nF	75 V	88,35 V	101 V / 142 V	**12,4%** (14,8% /61%)	-	14,8% /**61%**
result	13,5 V	1 kΩ// 100nF	100 V	113,30 V	114 V / 201 V	**18,1%** (0,9% / 77%)	-	0,9% /**77%**
result	13,5 V	1 kΩ// 100nF	125 V	138,25 V	167 V / 260 V	**17,0%** (20,7% /+88%)	-	20,7%/**88%**

The results in the Table 5 show that as soon as the generators are connected to the battery supply (13,5 V) and loaded, a significant spread of the 2a pulse parameters can be observed depending on the generator type. For supplied and 2 Ω loaded generators the pulse voltage starts to deviate from the expected level in a range between -2,9% and -31,3% for e.g. 75 V pulse voltage.

The standard deviation of the pulse voltage over all generators for pulse 2a for four levels 50 V, 75 V, 100 V and 125 V varies between 9,1% and 13,1% for 1 Ω load conditions. But the maximal deviation increases significantly up to -45,3% at 125 V.

The standard deviation of the pulse voltage over all generators for pulse 2a for four levels 50 V, 75 V, 100 V and 125 V varies between 12,4% and 18,1% for 1 kΩ||100 nF load conditions. The maximum deviation is 88%.

Additionally, for 75 V generator level, an under swing in the supply voltage occurs depending on the generator type between -0,2 V and -7,6 V for 2 Ω load. Higher load currents of the DUT and higher pulse voltages lead to a deeper under swing e.g. -10,3 V for 125 V pulse at a 1 Ω load.

For high impedance loads (as e.g. sensor devices) represented by a 100 nF capacitor in parallel to a 1 kΩ resistor an generator dependent over shoot of the pulse voltage was observed.

For the 75 V pulse voltage the over shoot is in the range of 14,8% up to 61%. For higher pulse voltages the over shoot voltage and range increase. For e.g. 125 V pulse voltage an over shoot between 20,7% and 88% was observed which nearly doubles the pulse voltage.

Although all generators are well within in the standard specification, different generator types lead to a wide range of test results far-off the expected tolerances when loaded with more realistic test and load conditions.

4.4 Verification summary - missing generator definitions leading to different results

Existing pulse generators are defined by a verification procedure limited to source impedance and open load voltage. The evaluation with a loaded generator is used to determine the internal source impedance and to check the pulse energy capability of the generator. The tolerances are relatively wide which may also lead to generator dependent test results.

Beyond that, secondary effects caused by undefined and not verified generator parameters lead to test results with real DUTs which strongly depend on the generator type.

The pulse shaping network of the generator and the pulse coupling and decoupling network has an important impact on the results for different load conditions. Missing definitions of decoupling networks cause different under swing voltages for DUTs with medium and high load currents. The under swing is caused by the inductive decoupling network connecting to power supply line. When the pulse is decayed and the DUT returns to normal battery supply the occurring di/dt in the decoupling networks generates a voltage under swing. Due to the unpowered generator verification such effects are neither observed nor defined by the current standard. Another impact on the test result is given by the inductance of the pulse shaping and coupling network if a high impedance, capacitive DUT is connected. Depending on the generator type a resonant overshoot of the pulse voltage occurs.

The above mentioned details on measurement deviations could be reduced by defining extended generator internal parameters and enhanced verification setups.

5 Proposal of extended definitions for pulse generators and verification methods

The following options may be considered:

- extend the verification definition for pulse generators as proposed in section 4.2.2,
- define new tolerance levels for generator verification including extended verification setup to limit generator dependent test result variances,
- extend the generator definition including coupling and decoupling networks to improve the technical base and to achieve generator independent results by standard definition,
- define a procedure how to handle result variances caused by undefined generator behaviour.

5.1 Test procedure adaptation

As a first step, the following test procedure adaptation could be considered:

- To verify the applied test pulse at the DUT input during testing, use a high impedance probe of an oscilloscope connected to monitor the voltage signal applied to the DUT,
- In case of an overvoltage higher than the intended pulse voltage, the generator settings should be reduced until the targeted test voltage amplitude is reached at the DUT. It has to be noted that the applied test energy is reduced,
- If a failure (e.g. reset or under voltage detection) of the DUT occurs during the test caused by a voltage under swing, originated by the implemented decoupling network in the generator, this has not to be considered as a failure of the DUT. To avoid such a situation a decoupling network with diode as shown in Figure shall be used.

5.2 Tolerance definition for generator evaluation

- Power supply under swing for pulse 2a with the extended verification load of 1 Ω should be as low as possible but in any case less than 10% of the nominal power supply voltage,
- Pulse voltage overshoot for pulse 2a with extended verification load of 100 nF//1 kΩ should be as low as possible but in any case less than 10% of the open load pulse voltage.

5.3 Extended generator definition

5.3.1 Decoupling network

The power supply decoupling network for pulse 2a can be realized differently either by chokes see Figure or by a diode see Figure . While the inductive decoupling causes an under swing dependent on the inductivity of the used choke and the load current of the DUT, the decoupling by a diode is load current independent and does not have any unwanted under swing in the supply voltage. In this respect the diode decoupling without additional choke seems to be the better solution and could be used as default definition. A further option for pulse decoupling and discharging capacitors of the DUT after a defined time (e.g. 2 x t_d) could be a discharge transistor in parallel to the decoupling diode.

But in any case the decoupling network needs to be defined and verified to avoid generator dependent test results.

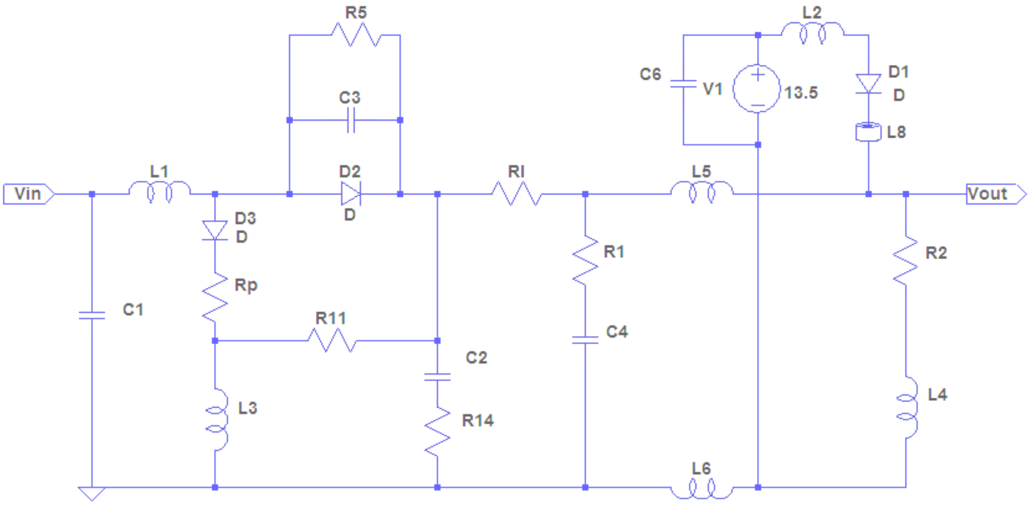


Figure 4 Decoupling network with chokes

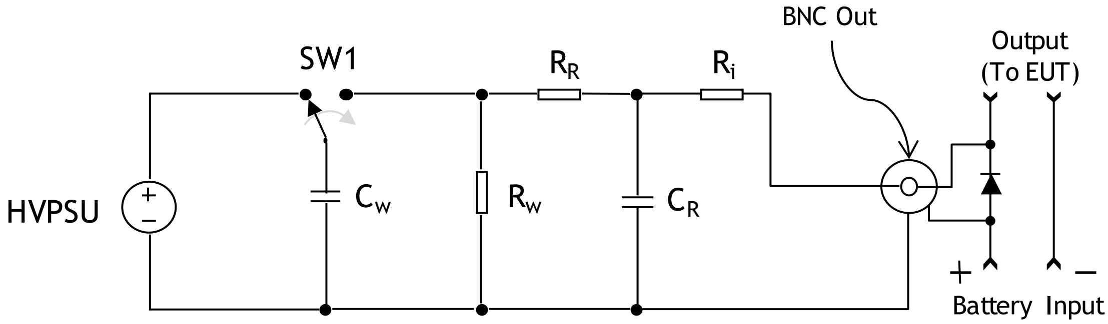


Figure 5 Decoupling network with diode

5.3.2 Coupling network

The pulse 2a shaping and coupling network of the generator as shown in Figure causes unwanted resonant overshoots at high impedance capacitive DUTs depending on the values of the stray inductance of the test set-up (shown in Figure 6 as L1 and L2). Dependent on the network assembly and layout they can be significantly reduced to eliminate these over shoots as shown in Figure 7. The stray inductance in this network should be limited to avoid undefined resonant over shoots caused by the test generator design. A current limitation for those networks is acceptable as over shoot effects are expected for high impedance loads only.

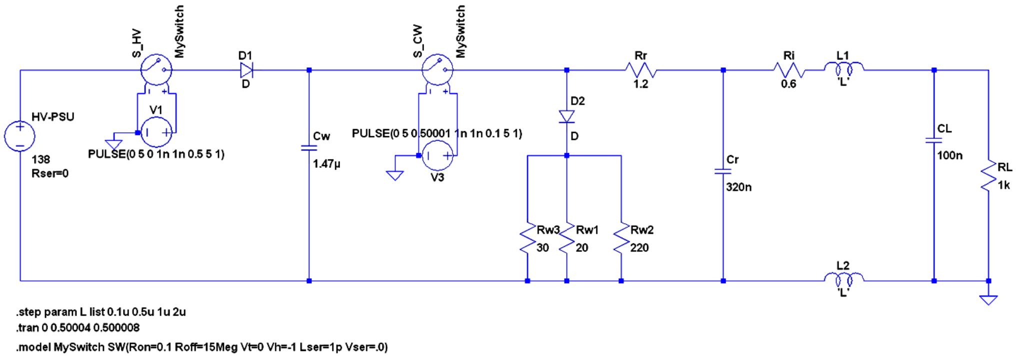


Figure 6 Coupling network example pulse 2a

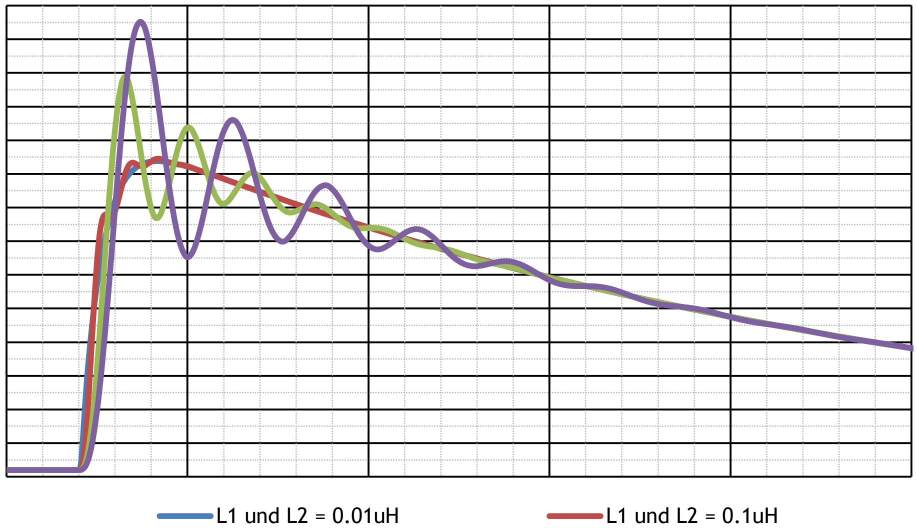


Figure 7 Pulse 2a over shoot dependency on network inductivity

5.4 Generator models for simulation

For development and pre-verification of DUT robustness or verification of generator behaviour under different loading conditions a simulation model of the generator may be used. To support this approach either an equivalent circuit of the generator or a simulation model for e.g. Spice, Saber, VHDL-AMS libraries should be provided by the test generator manufacturer.

Annex A
(informative)

Investigation summary of existing pulse generators

A.1 Generator data evaluation

The following tables A.1 to A.12 show the analysed parameters of the verified generators. For some generators only a limited number of tests were done and respective data available. So the total number of analysed results varies depending on the test case.

Table A.1 Generator data evaluation – Pulse voltage evaluation generator 1- 4

Test-pulse	Supplied /Unsupplied	Load	Generator-Voltage	Target-Voltage	Deviation		Generator 1		Generator 2		Generator 3		Generator 4	
					High	Low	Voltage	Deviation	Voltage	Deviation	Voltage	Deviation	Voltage	Deviation
1	Unsupplied	open	-50	-50,00	12.5%	-9.4%	-48,61	-2,8%	-50,56	1,1%	-51,29	2,6%	-49,53	-0,9%
	Unsupplied	open	-100	-100,00	9.2%	-6.3%	-97,43	-2,6%	-99,99	0,0%	-102,70	2,7%	-97,44	-2,6%
	Unsupplied	open	-150	-150,00	9.1%	5.2%	-145,73	-2,8%	-147,59	-1,6%	-150,85	0,6%	-145,1	-3,3%
1	Unsupplied	10Ω	-50	-25,00	1.8%	-12.0%	-26,14	4,6%	-23,82	-4,7%	-24,60	-1,6%	-23,57	-5,7%
	Unsupplied	10Ω	-100	-50,00	4.8%	-6.8%	-52,75	5,5%	-48,06	-3,9%	-49,44	-1,1%	-46,59	-6,8%
	Unsupplied	10Ω	-150	-75,00	7.5%	-6.9%	-79,60	6,1%	-71,70	-4,4%	-73,81	-1,6%	-69,81	-6,9%
1	Unsupplied	1Ω	-50	-4,55	24.4%	-7.7%	-5,14	13,0%	-4,59	0,9%	-4,39	-3,5%	-4,2	-7,7%
	Unsupplied	1Ω	-100	-9,09	16.8%	-8.6%	-10,39	14,3%	-8,79	-3,3%	-8,82	-3,0%	-8,31	-8,6%
	Unsupplied	1Ω	-150	-13,64	83.1%	-9.0%	-15,70	15,1%	-12,93	-5,2%	-13,25	-2,9%	-12,41	-9,0%
1	Unsupplied	1kΩ||100nF	-50	-49,51	23.4%	-9.7%	-48,03	-3,0%	-49,95	0,9%	-50,85	2,7%	-48,73	-1,6%
	Unsupplied	1kΩ||100nF	-100	-99,01	34.8%	-6.8%	-96,41	-2,6%	-99,41	0,4%	-102,28	3,3%	-95,85	-3,2%
	Unsupplied	1kΩ||100nF	-150	-148,51	37.4%	-5.9%	-144,21	-2,9%	-146,92	-1,1%	-150,68	1,5%	-144,3	-2,8%
2a	Unsupplied	open	50	50,00	1.4%	-4.0%	49,41	-1,2%	49,82	-0,4%	51,30	2,6%	48,35	-3,3%
	Unsupplied	open	75	75,00	3.9%	-3.5%	74,09	-1,2%	73,81	-1,6%	75,43	0,6%	72,39	-3,5%
	Unsupplied	open	100	100,00	1.2%	-2.9%	98,05	-2,0%	99,06	-0,9%	101,77	1,8%	97,08	-2,9%
	Unsupplied	open	125	125,00	1.1%	-3.6%	122,77	-1,8%	123,45	-1,2%	126,80	1,4%	120,47	-3,6%
2a	Unsupplied	2Ω	50	25,00	4.0%	-24.8%	21,87	-12,5%	21,25	-15,0%	26,00	4,0%	24,91	-0,4%
	Unsupplied	2Ω	75	37,50	3.2%	-13.0%	33,89	-9,6%	32,61	-13,0%	39,04	4,1%	38,14	1,7%
	Unsupplied	2Ω	100	50,00	5.8%	-11.3%	45,72	-8,6%	44,34	-11,3%	52,90	5,8%	51,13	2,3%
	Unsupplied	2Ω	125	62,50	8.0%	-10.9%	57,93	-7,3%	55,67	-10,9%	38,47	-38,4%	64,04	2,5%
2a	Supplied	open	50	63,50	5.2%	-7.8%	61,22	-3,6%	62,01	-2,3%	63,40	-0,2%	61,7	-2,8%
	Supplied	open	75	88,50	4.0%	-5.2%	86,11	-2,7%	85,87	-3,0%	88,18	-0,4%	85,81	-3,0%
	Supplied	open	100	113,50	17.0%	-7.3%	109,97	-3,1%	111,53	-1,7%	113,91	0,4%	110,69	-2,5%
	Supplied	open	125	138,50	2.2%	-7.3%	134,77	-2,7%	136,33	-1,6%	139,19	0,5%	134,16	-3,1%
2a	Supplied	2Ω	50	38,50	19.6%	-35.9%	24,69	-35,9%	25,25	-34,4%	28,84	-25,1%	29,25	-24,0%
	Supplied	2Ω	75	51,00	15.5%	-40.4%	35,00	-31,4%	35,15	-31,1%	40,30	-21,0%	39,09	-23,4%
	Supplied	2Ω	100	63,50	12.3%	-38.9%	46,31	-27,1%	45,45	-28,4%	52,53	-17,3%	50,76	-20,1%
	Supplied	2Ω	125	76,00	11.5%	-36.8%	57,79	-24,0%	55,44	-27,1%	38,77	-49,0%	62,86	-17,3%
2a	Supplied	1Ω	50	30,17	-22.2%	-50.3%	17,60	-41,7%	19,28	-36,1%	21,50	-28,7%	22,45	-25,6%
	Supplied	1Ω	75	38,50	-22.2%	-43.2%	22,47	-41,6%	23,39	-39,2%	26,99	-29,9%	28,31	-26,5%
	Supplied	1Ω	100	46,83	-13.7%	-39.4%	29,82	-36,3%	28,55	-39,0%	35,47	-24,3%	34,62	-26,1%
	Supplied	1Ω	125	55,17	-14.4%	-37.2%	37,37	-32,3%	35,63	-35,4%	25,24	-54,3%	42,17	-23,6%
2a	Supplied	1kΩ||100nF	50	63,40	46.7%	-5.5%	93,03	46,7%	78,67	24,1%	81,19	28,1%	77,16	21,7%
	Supplied	1kΩ||100nF	75	88,35	60.5%	14.8%	141,80	60,5%	119,00	34,7%	120,90	36,8%	114,83	30,0%
	Supplied	1kΩ||100nF	100	113,30	77.4%	0.9%	201,05	77,4%	153,30	35,3%	153,50	35,5%	151,6	33,8%
	Supplied	1kΩ||100nF	125	138,25	88.1%	20.7%	260,00	88,1%	208,41	50,7%	192,68	39,4%	191,13	38,2%

Table A.2 Generator data evaluation – Pulse voltage evaluation generator 5 - 8

Test-pulse	Supplied /Unsupplied	Load	Generator-Voltage	Target-Voltage	Deviation		Generator 5		Generator 6		Generator 7		Generator 8	
					High	Low	Voltage	Deviation	Voltage	Deviation	Voltage	Deviation	Voltage	Deviation
1	Unsupplied	open	-50	-50,00	12.5%	-9.4%	-52,91	5,8%	-47,58	-4,8%	-56,24	12,5%	-50,04	0,1%
	Unsupplied	open	-100	-100,00	9.2%	-6.3%	-98,90	-1,1%	-98,10	-1,9%	-109,15	9,2%	-99,85	-0,2%
	Unsupplied	open	-150	-150,00	9.1%	5.2%	-149,80	-0,1%	-149,90	-0,1%	-163,61	9,1%	-156,64	4,4%
1	Unsupplied	10Ω	-50	-25,00	1.8%	-12.0%	-25,45	1,8%	-23,54	-5,8%	-24,63	-1,5%	-24,30	-2,8%
	Unsupplied	10Ω	-100	-50,00	4.8%	-6.8%	-47,56	-4,9%	-48,77	-2,5%	-51,63	3,3%	-48,60	-2,8%
	Unsupplied	10Ω	-150	-75,00	7.5%	-6.9%	-72,29	-3,6%	-75,03	0,0%	-80,59	7,5%	-73,95	-1,4%
1	Unsupplied	1Ω	-50	-4,55	24.4%	-7.7%	-4,80	5,5%	-5,66	24,4%	-4,54	-0,2%	-4,27	-6,2%
	Unsupplied	1Ω	-100	-9,09	16.8%	-8.6%	-8,80	-3,2%	-10,62	16,8%	-9,45	4,0%	-8,52	-6,3%
	Unsupplied	1Ω	-150	-13,64	83.1%	-9.0%	-13,58	-0,4%	-24,98	83,1%	-14,67	7,6%	-13,24	-2,9%
1	Unsupplied	1kΩ‖100nF	-50	-49,51	23.4%	-9.7%	-51,70	4,4%	-61,09	23,4%	-50,59	2,2%	-49,26	-0,5%
	Unsupplied	1kΩ‖100nF	-100	-99,01	34.8%	-6.8%	-97,28	-1,7%	-133,48	34,8%	-113,14	14,3%	-99,19	0,2%
	Unsupplied	1kΩ‖100nF	-150	-148,51	37.4%	-5.9%	-146,19	-1,6%	-204,03	37,4%	-186,53	25,6%	-156,64	5,5%
2a	Unsupplied	open	50	50,00	1.4%	-4.0%	51,52	3,0%	-	-	50,70	1,4%	50,20	0,4%
	Unsupplied	open	75	75,00	3.9%	-3.5%	72,39	-3,5%	74,59	-0,5%	77,93	3,9%	77,93	3,9%
	Unsupplied	open	100	100,00	1.2%	-2.9%	101,21	1,2%	98,43	-1,6%	100,52	0,5%	99,85	-0,2%
	Unsupplied	open	125	125,00	1.1%	-3.6%	124,60	-0,3%	122,76	-1,8%	126,42	1,1%	126,42	1,1%
2a	Unsupplied	2Ω	50	25,00	4.0%	-24.8%	-	-	-	-	21,97	-12,1%	25,46	1,8%
	Unsupplied	2Ω	75	37,50	3.2%	-13.0%	-	-	-	-	35,31	-5,8%	40,38	7,7%
	Unsupplied	2Ω	100	50,00	5.8%	-11.3%	-	-	-	-	46,27	-7,5%	51,34	2,7%
	Unsupplied	2Ω	125	62,50	8.0%	-10.9%	-	-	-	-	58,56	-6,3%	66,20	5,9%
2a	Supplied	open	50	63,50	5.2%	-7.8%	62,69	-1,3%	-	-	58,56	-7,8%	62,88	-1,0%
	Supplied	open	75	88,50	4.0%	-5.2%	83,97	-5,1%	-	-	83,91	-5,2%	91,22	3,1%
	Supplied	open	100	113,50	17.0%	-7.3%	112,44	-0,9%	-	-	105,17	-7,3%	111,14	-2,1%
	Supplied	open	125	138,50	2.2%	-7.3%	135,56	-2,1%	-	-	128,41	-7,3%	139,04	0,4%
2a	Supplied	2Ω	50	38,50	19.6%	-35.9%	29,76	-22,7%	22,96	-40,4%	-	-	30,28	-21,4%
	Supplied	2Ω	75	51,00	15.5%	-40.4%	40,40	-20,8%	32,78	-35,7%	34,65	-32,1%	41,96	-17,7%
	Supplied	2Ω	100	63,50	12.3%	-38.9%	53,83	-15,2%	44,48	-30,0%	45,94	-27,7%	52,25	-17,7%
	Supplied	2Ω	125	76,00	11.5%	-36.8%	65,54	-13,8%	54,31	-28,5%	58,23	-23,4%	65,53	-13,8%
2a	Supplied	1Ω	50	30,17	-22.2%	-50.3%	22,31	-26,1%	17,43	-42,2%	18,65	-38,2%	22,97	-23,9%
	Supplied	1Ω	75	38,50	-22.2%	-43.2%	27,42	-28,8%	21,85	-43,2%	24,80	-35,6%	29,28	-23,9%
	Supplied	1Ω	100	46,83	-13.7%	-39.4%	35,14	-25,0%	28,36	-39,4%	30,44	-35,0%	34,59	-26,1%
	Supplied	1Ω	125	55,17	-14.4%	-37.2%	43,65	-20,9%	34,67	-37,2%	37,97	-31,2%	44,28	-19,7%
2a	Supplied	1kΩ‖100nF	50	63,40	46.7%	-5.5%	74,41	17,4%	76,90	21,3%	59,89	-5,5%	77,93	22,9%
	Supplied	1kΩ‖100nF	75	88,35	60.5%	14.8%	101,40	14,8%	113,90	28,9%	108,49	22,8%	117,12	32,6%
	Supplied	1kΩ‖100nF	100	113,30	77.4%	0.9%	137,75	21,6%	144,40	27,4%	155,00	36,8%	153,32	35,3%
	Supplied	1kΩ‖100nF	125	138,25	88.1%	20.7%	166,88	20,7%	180,10	30,3%	209,78	51,7%	199,81	44,5%

Table A.3 Generator data evaluation – Pulse voltage evaluation generator 9 - 12

Test-pulse	Supplied /Unsupplied	Load	Generator-Voltage	Target-Voltage	Deviation		Generator 9		Generator 10		Generator 11		Generator 12	
					High	Low	Voltage	Deviation	Voltage	Deviation	Voltage	Deviation	Voltage	Deviation
1	Unsupplied	open	-50	-50,00	12.5%	-9.4%	-49,37	-1,3%	-51,20	2,4%	-48,80	-2,4%	-48,80	-2,4%
	Unsupplied	open	-100	-100,00	9.2%	-6.3%	-99,19	-0,8%	-99,20	-0,8%	-96,80	-3,2%	-100,80	0,8%
	Unsupplied	open	-150	-150,00	9.1%	5.2%	-148,34	-1,1%	-150,00	0,0%	-150,00	0,0%	-154,00	2,7%
1	Unsupplied	10Ω	-50	-25,00	1.8%	-12.0%	-24,13	-3,5%	-25,00	0,0%	-23,80	-4,8%	-25,20	0,8%
	Unsupplied	10Ω	-100	-50,00	4.8%	-6.8%	-48,60	-2,8%	-49,60	-0,8%	-48,40	-3,2%	-52,40	4,8%
	Unsupplied	10Ω	-150	-75,00	7.5%	-6.9%	-71,29	-4,9%	-75,20	0,3%	-72,80	-2,9%	-80,00	6,7%
1	Unsupplied	1Ω	-50	-4,55	24.4%	-7.7%	-4,27	-6,2%	-4,80	5,5%	-4,40	-3,3%	-4,80	5,5%
	Unsupplied	1Ω	-100	-9,09	16.8%	-8.6%	-8,52	-6,3%	-9,20	1,2%	-8,80	-3,2%	-10,00	10,0%
	Unsupplied	1Ω	-150	-13,64	83.1%	-9.0%	-12,71	-6,8%	-13,60	-0,3%	-12,80	-6,2%	-14,00	2,6%
1	Unsupplied	1kΩ||100nF	-50	-49,51	23.4%	-9.7%	-48,59	-1,9%	-47,60	-3,9%	-46,80	-5,5%	-48,40	-2,2%
	Unsupplied	1kΩ||100nF	-100	-99,01	34.8%	-6.8%	-99,19	0,2%	-96,80	-2,2%	-96,00	-3,0%	-100,00	1,0%
	Unsupplied	1kΩ||100nF	-150	-148,51	37.4%	-5.9%	-148,34	-0,1%	-148,00	-0,3%	-146,00	-1,7%	-154,00	3,7%
2a	Unsupplied	open	50	50,00	1.4%	-4.0%	50,70	1,4%	52,80	5,6%	48,00	-4,0%	52,80	5,6%
	Unsupplied	open	75	75,00	3.9%	-3.5%	77,27	3,0%	-	-	-	-	-	-
	Unsupplied	open	100	100,00	1.2%	-2.9%	97,19	-2,8%	-	-	-	-	-	-
	Unsupplied	open	125	125,00	1.1%	-3.6%	125,09	0,1%	-	-	-	-	-	-
2a	Unsupplied	2Ω	50	25,00	4.0%	-24.8%	25,63	2,5%	21,60	-13,6%	18,80	-24,8%	25,40	1,6%
	Unsupplied	2Ω	75	37,50	3.2%	-13.0%	40,96	9,2%	-	-	-	-	-	-
	Unsupplied	2Ω	100	50,00	5.8%	-11.3%	52,25	4,5%	-	-	-	-	-	-
	Unsupplied	2Ω	125	62,50	8.0%	-10.9%	67,53	8,0%	-	-	-	-	-	-
2a	Supplied	open	50	63,50	5.2%	-7.8%	62,21	-2,0%	63,20	-0,5%	60,80	-4,3%	66,80	5,2%
	Supplied	open	75	88,50	4.0%	-5.2%	89,89	1,6%	89,60	1,2%	84,80	-4,2%	92,00	4,0%
	Supplied	open	100	113,50	17.0%	-7.3%	110,48	-2,7%	116,80	2,9%	107,20	-5,6%	132,80	17,0%
	Supplied	open	125	138,50	2.2%	-7.3%	137,71	-0,6%	140,80	1,7%	-	-	141,60	2,2%
2a	Supplied	2Ω	50	38,50	19.6%	-35.9%	30,94	-19,6%	26,80	-30,4%	-	-	26,40	-31,4%
	Supplied	2Ω	75	51,00	15.5%	-40.4%	42,95	-15,8%	38,00	-25,5%	30,40	-40,4%	37,20	-27,1%
	Supplied	2Ω	100	63,50	12.3%	-38.9%	52,58	-17,2%	49,20	-22,5%	38,80	-38,9%	50,40	-20,6%
	Supplied	2Ω	125	76,00	11.5%	-36.8%	66,20	-12,9%	59,60	-21,6%	48,00	-36,8%	63,20	-16,8%
2a	Supplied	1Ω	50	30,17	-22.2%	-50.3%	23,47	-22,2%	18,60	-38,3%	15,00	-50,3%	23,20	-23,1%
	Supplied	1Ω	75	38,50	-22.2%	-43.2%	29,94	-22,2%	26,40	-31,4%	23,60	-38,7%	28,60	-25,7%
	Supplied	1Ω	100	46,83	-13.7%	-39.4%	35,98	-23,2%	33,20	-29,1%	30,40	-35,1%	40,40	-13,7%
	Supplied	1Ω	125	55,17	-14.4%	-37.2%	45,28	-17,9%	40,00	-27,5%	36,00	-34,7%	47,20	-14,4%
2a	Supplied	1kΩ||100nF	50	63,40	46.7%	-5.5%	77,27	21,9%	85,60	35,0%	-	-	89,60	41,3%
	Supplied	1kΩ||100nF	75	88,35	60.5%	14.8%	120,44	36,3%	126,40	43,1%	125,60	42,2%	128,00	44,9%
	Supplied	1kΩ||100nF	100	113,30	77.4%	0.9%	158,30	39,7%	166,00	46,5%	166,00	46,5%	168,00	48,3%
	Supplied	1kΩ||100nF	125	138,25	88.1%	20.7%	209,78	51,7%	202,00	46,1%	212,00	53,3%	212,00	53,3%

Table A.4 Generator data evaluation – Pulse voltage evaluation generator 13 - 16

Test-pulse	Supplied /Unsupplied	Load	Generator-Voltage	Target-Voltage	Deviation		Generator 13		Generator 14		Generator 15		Generator 16	
					High	Low	Voltage	Deviation	Voltage	Deviation	Voltage	Deviation	Voltage	Deviation
1	Unsupplied	open	-50	-50,00	12.5%	-9.4%	-50,51	1,0%	-	-	-	-	-45,30	-9,4%
	Unsupplied	open	-100	-100,00	9.2%	-6.3%	-100,28	0,3%	-	-	-	-	-93,73	-6,3%
	Unsupplied	open	-150	-150,00	9.1%	5.2%	-150,08	0,1%	-	-	-	-	-142,23	-5,2%
1	Unsupplied	10Ω	-50	-25,00	1.8%	-12.0%	-25,27	1,1%	-22,00	-12,0%	-	-	-23,59	-5,6%
	Unsupplied	10Ω	-100	-50,00	4.8%	-6.8%	-49,95	-0,1%	-47,60	-4,8%	-	-	-48,39	-3,2%
	Unsupplied	10Ω	-150	-75,00	7.5%	-6.9%	-74,92	-0,1%	-74,08	-1,2%	-	-	-73,37	-2,2%
1	Unsupplied	1Ω	-50	-4,55	24.4%	-7.7%	-5,14	13,0%	-4,22	-7,3%	-	-	-4,49	-1,3%
	Unsupplied	1Ω	-100	-9,09	16.8%	-8.6%	-9,99	9,9%	-8,94	-1,7%	-	-	-9,23	1,5%
	Unsupplied	1Ω	-150	-13,64	83.1%	-9.0%	-14,90	9,2%	-14,36	5,3%	-	-	-13,92	2,1%
1	Unsupplied	1kΩ||100nF	-50	-49,51	23.4%	-9.7%	-50,37	1,7%	-44,72	-9,7%	-	-	-44,78	-9,6%
	Unsupplied	1kΩ||100nF	-100	-99,01	34.8%	-6.8%	-100,44	1,4%	-92,64	-6,4%	-	-	-92,23	-6,8%
	Unsupplied	1kΩ||100nF	-150	-148,51	37.4%	-5.9%	-148,66	0,1%	-145,40	-2,1%	-	-	-139,73	-5,9%
2a	Unsupplied	open	50	50,00	1.4%	-4.0%	-	-	-	-	-	-	50,32	0,6%
	Unsupplied	open	75	75,00	3.9%	-3.5%	-	-	-	-	-	-	77,03	2,7%
	Unsupplied	open	100	100,00	1.2%	-2.9%	-	-	-	-	-	-	100,06	0,1%
	Unsupplied	open	125	125,00	1.1%	-3.6%	-	-	-	-	-	-	123,27	-1,4%
2a	Unsupplied	2Ω	50	25,00	4.0%	-24.8%	-	-	-	-	-	-	22,84	-8,6%
	Unsupplied	2Ω	75	37,50	3.2%	-13.0%	-	-	-	-	-	-	34,97	-6,7%
	Unsupplied	2Ω	100	50,00	5.8%	-11.3%	-	-	-	-	-	-	45,85	-8,3%
	Unsupplied	2Ω	125	62,50	8.0%	-10.9%	-	-	-	-	-	-	56,83	-9,1%
2a	Supplied	open	50	63,50	5.2%	-7.8%	-	-	-	-	-	-	64,31	1,3%
	Supplied	open	75	88,50	4.0%	-5.2%	-	-	-	-	-	-	91,17	3,0%
	Supplied	open	100	113,50	17.0%	-7.3%	-	-	-	-	-	-	114,29	0,7%
	Supplied	open	125	138,50	2.2%	-7.3%	-	-	-	-	-	-	138,17	-0,2%
2a	Supplied	2Ω	50	38,50	19.6%	-35.9%	-	-	-	-	30,69	-20,3%	27,03	-29,8%
	Supplied	2Ω	75	51,00	15.5%	-40.4%	-	-	-	-	43,08	-15,5%	38,35	-24,8%
	Supplied	2Ω	100	63,50	12.3%	-38.9%	38,57	-39,3%	-	-	55,71	-12,3%	48,40	-23,8%
	Supplied	2Ω	125	76,00	11.5%	-36.8%	-	-	-	-	67,26	-11,5%	58,74	-22,7%
2a	Supplied	1Ω	50	30,17	-22.2%	-50.3%	-	-	-	-	-	-	17,37	-42,4%
	Supplied	1Ω	75	38,50	-22.2%	-43.2%	-	-	-	-	-	-	24,35	-36,8%
	Supplied	1Ω	100	46,83	-13.7%	-39.4%	-	-	-	-	-	-	30,65	-34,6%
	Supplied	1Ω	125	55,17	-14.4%	-37.2%	-	-	-	-	-	-	37,27	-32,4%
2a	Supplied	1kΩ||100nF	50	63,40	46.7%	-5.5%	-	-	-	-	-	-	85,36	34,6%
	Supplied	1kΩ||100nF	75	88,35	60.5%	14.8%	-	-	-	-	-	-	137,21	55,3%
	Supplied	1kΩ||100nF	100	113,30	77.4%	0.9%	114,27	0,9%	113,60	0,3%	117,64	3,8%	185,86	64,0%
	Supplied	1kΩ||100nF	125	138,25	88.1%	20.7%	-	-	-	-	-	-	236,97	71,4%

Table A.5 Generator data evaluation – Pulse width evaluation generator 1- 4

Test-pulse	Supplied /Unsupplied	Load	Generator-Voltage	Target-td (ms)	td Deviation %		Generator 1			Generator 2			Generator 3			Generator 4		
					max	min	td(ms)	%	tr (µs)	td(ms)	%	tr (µs)	td(ms)	%	tr (µs)	td(ms)	%	tr (µs)
1	Unsupplied	open	-50	2,0	15,0%	10,0%	2,2	10,0%	-	2,3	15,0%	-	2	0,0%	-	2	0,0%	-
	Unsupplied	open	-100	2,0	10,0%	-5,0%	2,2	10,0%	-	2,2	10,0%	-	2	0,0%	-	1,9	-5,0%	-
	Unsupplied	open	-150	2,0	10,0%	-5,0%	2,2	10,0%	-	2,2	10,0%	-	2	0,0%	-	1,9	-5,0%	-
1	Unsupplied	10Ω	-50	1,5	6,7%	-6,7%	1,4	-6,7%	-	1,6	6,7%	-	1,4	-6,7%	-	1,4	-6,7%	-
	Unsupplied	10Ω	-100	1,5	0,0%	-13,3%	1,4	-6,7%	-	1,5	0,0%	-	1,4	-6,7%	-	1,3	-13,3%	-
	Unsupplied	10Ω	-150	1,5	0,0%	-13,3%	1,4	-6,7%	-	1,5	0,0%	-	1,4	-6,7%	-	1,3	-13,3%	-
1	Unsupplied	1Ω	-50				1		-	1,5		-	1,1		-	1,1		-
	Unsupplied	1Ω	-100				1		-	1,3		-	1,1		-	1		-
	Unsupplied	1Ω	-150				1		-	1,3		-	1,1		-	1		-
1	Unsupplied	1kΩ‖100nF	-50				2,2		-	2,2		-	2		-	1,9		-
	Unsupplied	1kΩ‖100nF	-100				2,2		-	2,1		-	1,9		-	1,8		-
	Unsupplied	1kΩ‖100nF	-150				2,2		-	2,1		-	1,9		-	1,8		-
							td (µs)	%	tr (µs)	td (µs)	%	tr (µs)	td (µs)	%	tr (µs)	td (µs)	%	tr (µs)
2a	Unsupplied	open	50	50,0	15,2%	-10,0%	54	8,0%	0,8	53	6,0%	0,8	51	2,0%	1	50	0,0%	1
	Unsupplied	open	75	50,0	10,0%	-10,0%	54	8,0%	0,8	55	10,0%	0,8	52	4,0%	0,8	50	0,0%	1
	Unsupplied	open	100	50,0	10,0%	-10,0%	53	6,0%	0,8	55	10,0%	0,8	53	6,0%	0,8	50	0,0%	0,9
	Unsupplied	open	125	50,0	12,0%	-12,0%	54	8,0%	0,8	56	12,0%	0,7	-	-	-	51	2,0%	0,9
2a	Unsupplied	2Ω	50	12,0	25,0%	-1,7%	14,8	23,3%	2,6	17	41,7%	1,4	14,4	20,0%	1,6	13,5	12,5%	1,7
	Unsupplied	2Ω	75	12,0	20,0%	-1,7%	14,2	18,3%	2,5	16,6	38,3%	1,4	14,4	20,0%	1,6	13,4	11,7%	1,6
	Unsupplied	2Ω	100	12,0	16,7%	-1,7%	13,8	15,0%	2,4	16,4	36,7%	1,3	14	16,7%	1,5	13,2	10,0%	1,6
	Unsupplied	2Ω	125	12,0	14,2%	-1,7%	13,5	12,5%	2,3	16,3	35,8%	1,3	21,2	76,7%	1,3	13,1	9,2%	1,5
2a	Supplied	open	50				50		0,8	49		0,8	46		1	44		1
	Supplied	open	75				50		0,8	49		0,8	45		0,8	44		0,9
	Supplied	open	100				49		0,8	48		0,8	45		0,8	44		1
	Supplied	open	125				49		0,8	48		0,8	45		0,8	43		0,9
2a	Supplied	2Ω	50				8,1		2,3	6,6		1,1	7		1,4	6,8		1,3
	Supplied	2Ω	75				9,4		2,2	7,8		1,3	8,3		1,4	8		1,3
	Supplied	2Ω	100				10		2,2	9,1		1,3	9,2		1,4	8,9		1,4
	Supplied	2Ω	125				10,2		2,2	9,8		1,2	10,6		1,3	9,3		1,4
2a	Supplied	1Ω	50				7,4		1,8	5,5		1,2	6		1,3	6,4		1,4
	Supplied	1Ω	75				8,3		2,4	6,2		1,2	6,7		1,3	6,6		1,3
	Supplied	1Ω	100				9		2,6	7		1,2	7,4		1,8	7,1		1,4
	Supplied	1Ω	125				9,3		2,6	7,6		1,5	7,3		1,1	7,5		1,5
2a	Supplied	1kΩ‖100nF	50				36,6		1,7	37,7		1,1	37,1		1,1	36,6		1
	Supplied	1kΩ‖100nF	75				34,9		1,3	37,8		1,1	35,8		0,9	35,4		0,9
	Supplied	1kΩ‖100nF	100				34,1		1,1	37,8		0,8	36,2		0,7	34,1		0,7
	Supplied	1kΩ‖100nF	125				32,5		0,9	36,9		0,6	35,9		0,8	34,2		1

Table A.6 Generator data evaluation – Pulse width evaluation generator 5 - 8

Test-pulse	Supplied /Unsupplied	Load	Generator-Voltage	Target-td (ms)	td Deviation % max	min	Generator 5 td(ms)	%	tr (µs)	Generator 6 td(ms)	%	tr (µs)	Generator 7 td(ms)	%	tr (µs)	Generator 8 td(ms)	%	tr (µs)
1	Unsupplied	open	-50	2,0	15,0%	10,0%	2	0,0%	-	2	0,0%	-	1,8	-10,0%	-	2	0,0%	-
	Unsupplied	open	-100	2,0	10,0%	-5,0%	1,9	-5,0%	-	2	0,0%	-	1,9	-5,0%	-	1,9	-5,0%	-
	Unsupplied	open	-150	2,0	10,0%	-5,0%	1,9	-5,0%	-	2,1	5,0%	-	2	0,0%	-	1,9	-5,0%	-
1	Unsupplied	10Ω	-50	1,5	6,7%	-6,7%	1,4	-6,7%	-	1,4	-6,7%	-	1,4	-6,7%	-	1,4	-6,7%	-
	Unsupplied	10Ω	-100	1,5	0,0%	-13,3%	1,4	-6,7%	-	1,4	-6,7%	-	1,3	-13,3%	-	1,4	-6,7%	-
	Unsupplied	10Ω	-150	1,5	0,0%	-13,3%	1,4	-6,7%	-	1,4	-6,7%	-	1,3	-13,3%	-	1,4	-6,7%	-
1	Unsupplied	1Ω	-50				1,5		-	1		-	1,1		-	1,1		-
	Unsupplied	1Ω	-100				1,2		-	1		-	1		-	1,1		-
	Unsupplied	1Ω	-150				1,2		-	1		-	1,1		-	1,1		-
1	Unsupplied	1kΩ‖100nF	-50				2		-	2		-	1,9		-	2		-
	Unsupplied	1kΩ‖100nF	-100				1,9		-	2		-	1,8		-	1,9		-
	Unsupplied	1kΩ‖100nF	-150				1,9		-	2		-	1,8		-	1,9		-
							td (µs)	%	tr (µs)	td (µs)	%	tr (µs)	td (µs)	%	tr (µs)	td (µs)	%	tr (µs)
2a	Unsupplied	open	50	50,0	15,2%	-10,0%	45	-10,0%	1	-		-	47	-6,0%	0,9	47	-6,0%	1
	Unsupplied	open	75	50,0	10,0%	-10,0%	45	-10,0%	0,9	49	-2,0%	0,9	46	-8,0%	0,8	47	-6,0%	0,9
	Unsupplied	open	100	50,0	10,0%	-10,0%	45	-10,0%	0,8	45	-10,0%	0,8	47	-6,0%	0,7	46	-8,0%	0,8
	Unsupplied	open	125	50,0	12,0%	-12,0%	45	-10,0%	0,8	44	-12,0%	0,8	46	-8,0%	0,7	47	-6,0%	0,8
2a	Unsupplied	2Ω	50	12,0	25,0%	-1,7%	-		-	-		-	12,4	3,3%	2,1	13,1	9,2%	1,5
	Unsupplied	2Ω	75	12,0	20,0%	-1,7%	-		-	-		-	12,2	1,7%	2,1	12,8	6,7%	1,5
	Unsupplied	2Ω	100	12,0	16,7%	-1,7%	-		-	-		-	12,2	1,7%	2,1	13,3	10,8%	1,5
	Unsupplied	2Ω	125	12,0	14,2%	-1,7%	-		-	-		-	12,1	0,8%	2,1	12,5	4,2%	1,4
2a	Supplied	open	50				40		1	-		-	48		1,3	40		1
	Supplied	open	75				40		0,9	-		-	47		1,2	40		0,9
	Supplied	open	100				39		0,8	-		-	46		0,9	39		0,8
	Supplied	open	125				39		0,8	-		-	47		0,8	40		0,8
2a	Supplied	2Ω	50				7,1		1,2	6,5		1,8	-		-	6,1		1,3
	Supplied	2Ω	75				7,7		1,4	8,3		1,6	8,8		2,3	7,3		1,4
	Supplied	2Ω	100				8,7		1,3	9,1		1,7	9,2		2,4	8,1		1,3
	Supplied	2Ω	125				9,1		1,3	9,5		1,7	9,7		2,2	8,8		1,3
2a	Supplied	1Ω	50				6,5		1,3	7,1		1,7	8,6		2,5	5,5		1,4
	Supplied	1Ω	75				6,6		1,3	7,2		1,7	8,4		2,3	6,3		1,4
	Supplied	1Ω	100				7		1,3	7,6		1,8	8,4		2,3	6,6		1,3
	Supplied	1Ω	125				7,2		1,6	8,2		1,8	8,8		2,5	7		1,7
2a	Supplied	1kΩ‖100nF	50				34,4		1,1	36,5		0,9	-		1,6	35,3		1,1
	Supplied	1kΩ‖100nF	75				34,9		1,1	-		0,7	-		1,4	31,6		1
	Supplied	1kΩ‖100nF	100				34,1		1,1	38,1		0,6	-		1,3	31,1		0,9
	Supplied	1kΩ‖100nF	125				34,4		1,1	40		0,6	-		1,1	29,4		0,8

Table A.7 Generator data evaluation – Pulse width evaluation generator 9 - 12

Test-pulse	Supplied /Unsupplied	Load	Generator-Voltage	Target-td (ms)	td Deviation %		Generator 9			Generator 10			Generator 11			Generator 12		
					max	min	td(ms)	%	tr (µs)	td(ms)	%	tr (µs)	td(ms)	%	tr (µs)	td(ms)	%	tr (µs)
1	Unsupplied	open	-50	2,0	15,0%	10,0%	1,9	-5,0%	-	2,1	5,0%	-	2,1	5,0%	-	2,1	5,0%	-
	Unsupplied	open	-100	2,0	10,0%	-5,0%	1,9	-5,0%	-	2,1	5,0%	-	2	0,0%	-	1,9	-5,0%	-
	Unsupplied	open	-150	2,0	10,0%	-5,0%	1,9	-5,0%	-	2,1	5,0%	-	2	0,0%	-	1,9	-5,0%	-
1	Unsupplied	10Ω	-50	1,5	6,7%	-6,7%	1,4	-6,7%	-	1,4	-6,7%	-	1,4	-6,7%	-	1,5	0,0%	-
	Unsupplied	10Ω	-100	1,5	0,0%	-13,3%	1,4	-6,7%	-	1,3	-13,3%	-	1,3	-13,3%	-	1,4	-6,7%	-
	Unsupplied	10Ω	-150	1,5	0,0%	-13,3%	1,3	-13,3%	-	1,4	-6,7%	-	1,3	-13,3%	-	1,4	-6,7%	-
1	Unsupplied	1Ω	-50				1,1		-	1		-	1		-	1,1		-
	Unsupplied	1Ω	-100				1,1		-	1		-	0,9		-	1		-
	Unsupplied	1Ω	-150				1,1		-	1		-	1		-	0,9		-
1	Unsupplied	1kΩ‖100nF	-50				1,9		-	1,9		-	1,9		-	2		-
	Unsupplied	1kΩ‖100nF	-100				1,9		-	2		-	1,9		-	2		-
	Unsupplied	1kΩ‖100nF	-150				1,9		-	2		-	2		-	1,9		-
							td (µs)	%	tr (µs)	td (µs)	%	tr (µs)	td (µs)	%	tr (µs)	td (µs)	%	tr (µs)
2a	Unsupplied	open	50	50,0	15,2%	-10,0%	49	-2,0%	0,9	57,6	15,2%	1	51,4	2,8%	0,8	52,6	5,2%	1
	Unsupplied	open	75	50,0	10,0%	-10,0%	51	2,0%	0,8	-		-	-		-	-		-
	Unsupplied	open	100	50,0	10,0%	-10,0%	50	0,0%	0,7	-		-	-		-	-		-
	Unsupplied	open	125	50,0	12,0%	-12,0%	50	0,0%	0,7	-		-	-		-	-		-
2a	Unsupplied	2Ω	50	12,0	25,0%	-1,7%	14,4	20,0%	1,4	15	25,0%	1,9	14,6	21,7%	1,7	12	0,0%	0,9
	Unsupplied	2Ω	75	12,0	20,0%	-1,7%	14,1	17,5%	1,4	-		-	-		-	-		-
	Unsupplied	2Ω	100	12,0	16,7%	-1,7%	14	16,7%	1,4	-		-	-		-	-		-
	Unsupplied	2Ω	125	12,0	14,2%	-1,7%	13,7	14,2%	1,3	-		-	-		-	-		-
2a	Supplied	open	50				45		0,9	54,4		1	45		1	56,6		0,8
	Supplied	open	75				43		0,8	54,4		1	47,4		0,8	55		1
	Supplied	open	100				42		0,7	53,8		1	47,3		0,9	48		0,8
	Supplied	open	125				43		0,7	52,1		0,9	-		-	52,3		0,8
2a	Supplied	2Ω	50				6,5		1,2	8,9		2,1	-		-	8,4		1
	Supplied	2Ω	75				7,6		1,3	10,2		1,9	8,5		1	8,9		0,8
	Supplied	2Ω	100				8,7		1,2	10,6		1,9	9,1		1,3	9,7		0,9
	Supplied	2Ω	125				9,3		1,2	10,8		1,8	9,8		1,2	10		0,8
2a	Supplied	1Ω	50				5,6		1,3	7,7		2,9	5,2		0,9	4,4		0,9
	Supplied	1Ω	75				6,3		1,2	8,3		2,4	6,1		1,8	7		0,6
	Supplied	1Ω	100				6,6		1,2	6,6		1,2	6,9		1,3	7,2		0,5
	Supplied	1Ω	125				7,2		1,8	9,3		1,5	7,6		1,1	7,5		0,7
2a	Supplied	1kΩ‖100nF	50				37		1,1	44		1,2	-		-	49,8		1
	Supplied	1kΩ‖100nF	75				34,1		1	43,4		1,1	36,3		1	44,4		0,9
	Supplied	1kΩ‖100nF	100				33,8		0,9	45		0,9	36,2		0,9	41		0,7
	Supplied	1kΩ‖100nF	125				31,1		0,8	42,3		0,8	35,4		0,7	40,9		0,6

Table A.8 Generator data evaluation – Pulse width evaluation generator 12 – 16

Test-pulse	Supplied /Unsupplied	Load	Generator-Voltage	Target-td (ms)	td Deviation % max	min	Generator 13 td(ms)	%	tr (µs)	Generator 14 td(ms)	%	tr (µs)	Generator 15 td(ms)	%	tr (µs)	Generator 16 td(ms)	%	tr (µs)
1	Unsupplied	open	-50	2,0	15,0%	10,0%	2	0,0%	-	-		-	-		-	2	0,0%	-
	Unsupplied	open	-100	2,0	10,0%	-5,0%	2	0,0%	-	-		-	-		-	2	0,0%	-
	Unsupplied	open	-150	2,0	10,0%	-5,0%	2	0,0%	-	-		-	-		-	1,9	-5,0%	-
1	Unsupplied	10Ω	-50	1,5	6,7%	-6,7%	0,8	-46,7%	-	1,4	-6,7%	-	-		-	1,6	6,7%	-
	Unsupplied	10Ω	-100	1,5	0,0%	-13,3%	0,8	-46,7%	-	1,3	-13,3%	-	-		-	1,4	-6,7%	-
	Unsupplied	10Ω	-150	1,5	0,0%	-13,3%	0,8	-46,7%	-	1,4	-6,7%	-	-		-	1,4	-6,7%	-
1	Unsupplied	1Ω	-50				0,6		-	1,1		-	-		-	1,2		-
	Unsupplied	1Ω	-100				0,6		-	1		-	-		-	1,1		-
	Unsupplied	1Ω	-150				0,6		-	1		-	-		-	1,1		-
1	Unsupplied	1kΩ||100nF	-50				1,9		-	2,2		-	-		-	2,1		-
	Unsupplied	1kΩ||100nF	-100				1,9		-	2,1		-	-		-	2		-
	Unsupplied	1kΩ||100nF	-150				2		-	2,1		-	-		-	1,9		-
							td (µs)	%	tr (µs)	td (µs)	%	tr (µs)	td (µs)	%	tr (µs)	td (µs)	%	tr (µs)
2a	Unsupplied	open	50	50,0	15,2%	-10,0%	-		-	-		-	-		-	51	2,0%	0,8
	Unsupplied	open	75	50,0	10,0%	-10,0%	-		-	-		-	-		-	49	-2,0%	0,8
	Unsupplied	open	100	50,0	10,0%	-10,0%	-		-	-		-	-		-	49	-2,0%	0,8
	Unsupplied	open	125	50,0	12,0%	-12,0%	-		-	-		-	-		-	49	-2,0%	0,8
2a	Unsupplied	2Ω	50	12,0	25,0%	-1,7%	-		-	-		-	-		-	11,8	-1,7%	1
	Unsupplied	2Ω	75	12,0	20,0%	-1,7%	-		-	-		-	-		-	11,8	-1,7%	1
	Unsupplied	2Ω	100	12,0	16,7%	-1,7%	-		-	-		-	-		-	11,8	-1,7%	1
	Unsupplied	2Ω	125	12,0	14,2%	-1,7%	-		-	-		-	-		-	11,8	-1,7%	1
2a	Supplied	open	50				-		-	-		-	-		-	53		0,8
	Supplied	open	75				-		-	-		-	-		-	50		0,8
	Supplied	open	100				-		-	-		-	-		-	50		0,8
	Supplied	open	125				-		-	-		-	-		-	49		0,8
2a	Supplied	2Ω	50				-		-	-		-	6,6		0,2	6,8		0,7
	Supplied	2Ω	75				-		-	-		-	7,3		0,6	7,9		0,9
	Supplied	2Ω	100				17		1,3	-		-	7,9		0,6	8,5		0,8
	Supplied	2Ω	125				-		-	-		-	8,5		0,6	8,9		0,9
2a	Supplied	1Ω	50				-		-	-		-	-		-	5,5		0,6
	Supplied	1Ω	75				-		-	-		-	-		-	6,6		0,7
	Supplied	1Ω	100				-		-	-		-	-		-	7,3		0,8
	Supplied	1Ω	125				-		-	-		-	-		-	7,6		0,8
2a	Supplied	1kΩ||100nF	50				-		-	-		-	-		-	40		0,9
	Supplied	1kΩ||100nF	75				-		-	-		-	-		-	40		0,8
	Supplied	1kΩ||100nF	100				-		1,4	47		1,2	49,4		0,7	37,1		0,7
	Supplied	1kΩ||100nF	125				-		-	-		-	-		-	36		0,6

Table A.9 Generator data evaluation – Pulse overshoot and supply under swing generator 1- 4

Test-pulse	Supplied /Unsupplied	Load	Generator-voltage	Target-Voltage	Generator 1 Over-shout (V)	Under swing (V)	Generator 2 Over-shout (V)	Under swing (V)	Generator 3 Over-shout (V)	Under swing (V)	Generator 4 Over-shout (V)	Under swing (V)
2a	Supplied	2Ω	50	31,8	24,7	-4,5	25,3	-4,3	28,8	-4,5	29,3	-6,3
	Supplied	2Ω	75	44,3	35,0	-5,4	35,2	-4,6	40,3	-4,4	39,1	-6,4
	Supplied	2Ω	100	56,8	46,3	-6,0	45,5	-4,6	52,5	-4,4	50,8	-6,7
	Supplied	2Ω	125	69,3	57,8	-6,3	55,4	-4,7	38,8	-2,6	62,9	-6,4
2a	Supplied	1Ω	50	21,2	17,6	-3,8	19,3	-2,7	21,5	-4,5	22,5	-4,4
	Supplied	1Ω	75	29,5	22,5	-6,0	23,4	-4,6	27,0	-6,2	28,3	-7,2
	Supplied	1Ω	100	37,8	29,8	-6,8	28,6	-5,4	35,5	-6,4	34,6	-8,8
	Supplied	1Ω	125	46,2	37,4	-7,0	35,6	-5,6	25,2	-3,3	42,2	-8,9
2a	Supplied	1kΩ||100nF	50	63,4	93,0	-	78,7	-	81,2	-	77,2	-
	Supplied	1kΩ||100nF	75	88,4	141,8	-	119,0	-	120,9	-	114,8	-
	Supplied	1kΩ||100nF	100	113,3	201,1	-	153,3	-	153,5	-	151,6	-
	Supplied	1kΩ||100nF	125	138,3	260,0	-	208,4	-	192,7	-	191,1	-

Table A.10 Generator data evaluation – Pulse overshoot and supply under swing generator 5 - 8

Test-pulse	Supplied /Unsupplied	Load	Generator-voltage	Target-Voltage	Generator 5		Generator 6		Generator 7		Generator 8	
					Over-shout (V)	Under swing (V)	Over-shout (V)	Under swing (V)	Over-shout (V)	Under swing (V)	Over-shout (V)	Under swing (V)
2a	Supplied	2Ω	50	31,8	29,8	-5,9	23,0	-4,4	-	-	30,3	-6,5
	Supplied	2Ω	75	44,3	40,4	-6,2	32,8	-3,5	34,7	-7,6	42,0	-7,6
	Supplied	2Ω	100	56,8	53,8	-6,3	44,5	-3,1	45,9	-8,3	52,3	-7,6
	Supplied	2Ω	125	69,3	65,5	-6,4	54,3	-3,5	58,2	-8,6	65,5	-7,6
2a	Supplied	1Ω	50	21,2	22,3	-4,7	17,4	-4,0	18,7	-2,7	23,0	-5,0
	Supplied	1Ω	75	29,5	27,4	-6,9	21,9	-5,3	24,8	-5,1	29,3	-7,8
	Supplied	1Ω	100	37,8	35,1	-8,6	28,4	-5,7	30,4	-7,3	34,6	-9,6
	Supplied	1Ω	125	46,2	43,7	-8,7	34,7	-5,1	38,0	-8,6	44,3	-10,3
2a	Supplied	1kΩ||100nF	50	63,4	74,4	-	76,9	-	59,9	-	77,9	-
	Supplied	1kΩ||100nF	75	88,4	101,4	-	113,9	-	108,5	-	117,1	-
	Supplied	1kΩ||100nF	100	113,3	137,8	-	144,4	-	155,0	-	153,3	-
	Supplied	1kΩ||100nF	125	138,3	166,9	-	180,1	-	209,8	-	199,8	-

Table A.11 Generator data evaluation – Pulse overshoot and supply under swing generator 9 - 12

Test-pulse	Supplied /Unsupplied	Load	Generator-voltage	Target-Voltage	Generator 9		Generator 10		Generator 11		Generator 12	
					Over-shout (V)	Under swing (V)	Over-shout (V)	Under swing (V)	Over-shout (V)	Under swing (V)	Over-shout (V)	Under swing (V)
2a	Supplied	2Ω	50	31,8	30,9	-6,3	26,8	-1,0	-		26,4	-0,2
	Supplied	2Ω	75	44,3	43,0	-7,0	38,0	-0,8	30,4	-0,8	37,2	-1,2
	Supplied	2Ω	100	56,8	52,6	-7,0	49,2	-1,2	38,8	-1,2	50,4	-0,8
	Supplied	2Ω	125	69,3	66,2	-7,0	59,6	-2,4	48,0	-2,4	63,2	-0,4
2a	Supplied	1Ω	50	21,2	23,5	-4,5	18,6	-1,4	15,0	-1,2	23,2	-0,2
	Supplied	1Ω	75	29,5	29,9	-7,1	26,4	-2,0	23,6	-2,0	28,6	-0,4
	Supplied	1Ω	100	37,8	36,0	-9,0	33,2	-1,8	30,4	-2,4	40,4	-0,4
	Supplied	1Ω	125	46,2	45,3	-9,0	40,0	-2,0	36,0	-1,6	47,2	-0,8
2a	Supplied	1kΩ||100nF	50	63,4	77,3	-	85,6	-	-	-	89,6	-
	Supplied	1kΩ||100nF	75	88,4	120,4	-	126,4	-	125,6	-	128,0	-
	Supplied	1kΩ||100nF	100	113,3	158,3	-	166,0	-	166,0	-	168,0	-
	Supplied	1kΩ||100nF	125	138,3	209,8	-	202,0	-	212,0	-	212,0	-

Table A.12 Generator data evaluation – Pulse overshoot and supply under swing generator 13 - 16

Test-pulse	Supplied /Unsupplied	Load	Generator-voltage	Target-Voltage	Generator 13		Generator 14		Generator 15		Generator 16	
					Over-shout (V)	Under swing (V)	Over-shout (V)	Under swing (V)	Over-shout (V)	Under swing (V)	Over-shout (V)	Under swing (V)
2a	Supplied	2Ω	50	31,8	-	-	-	-	30,7	-0,1	27,0	-0,3
	Supplied	2Ω	75	44,3	-	-	-	-	43,1	-0,2	38,4	-0,4
	Supplied	2Ω	100	56,8	38,6	-0,7	-	-	55,7	-0,2	48,4	-0,4
	Supplied	2Ω	125	69,3	-	-	-	-	67,3	-0,1	58,7	-0,6
2a	Supplied	1Ω	50	21,2	-	-	-	-	-	-	17,4	-0,1
	Supplied	1Ω	75	29,5	-	-	-	-	-	-	24,4	-0,3
	Supplied	1Ω	100	37,8	-	-	-	-	-	-	30,7	-0,4
	Supplied	1Ω	125	46,2	-	-	-	-	-	-	37,3	-0,4
2a	Supplied	1kΩ||100nF	50	63,4	-	-	-	-	-	-	85,4	-
	Supplied	1kΩ||100nF	75	88,4	-	-	-	-	-	-	137,2	-
	Supplied	1kΩ||100nF	100	113,3	114,3	-	113,6	-	117,6	-	185,9	-
	Supplied	1kΩ||100nF	125	138,3	-	-	-	-	-	-	237,0	-

A.2 Generator verification waveforms

A.2.1 Generator verification waveforms of standardized setup for pulse 1

Examples of pulse 1 waveform for standardized setup are given in Figure A.1

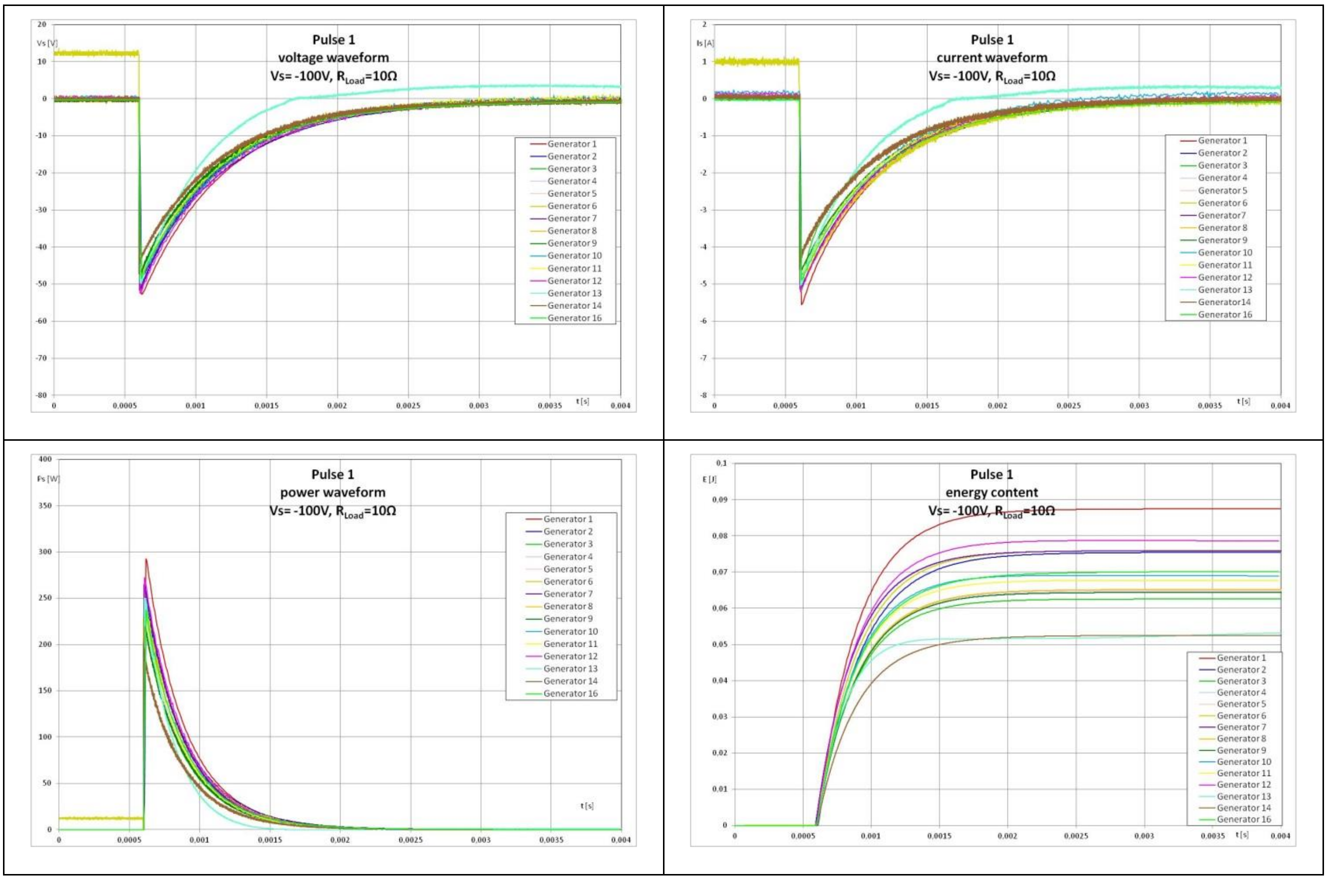


Figure A.1 Pulse 1 waveform examples of standardized setup

A.2.2 Generator verification waveforms of extended setup for pulse 1

Examples of pulse 1 waveform for extended setup are given in Figure A.2

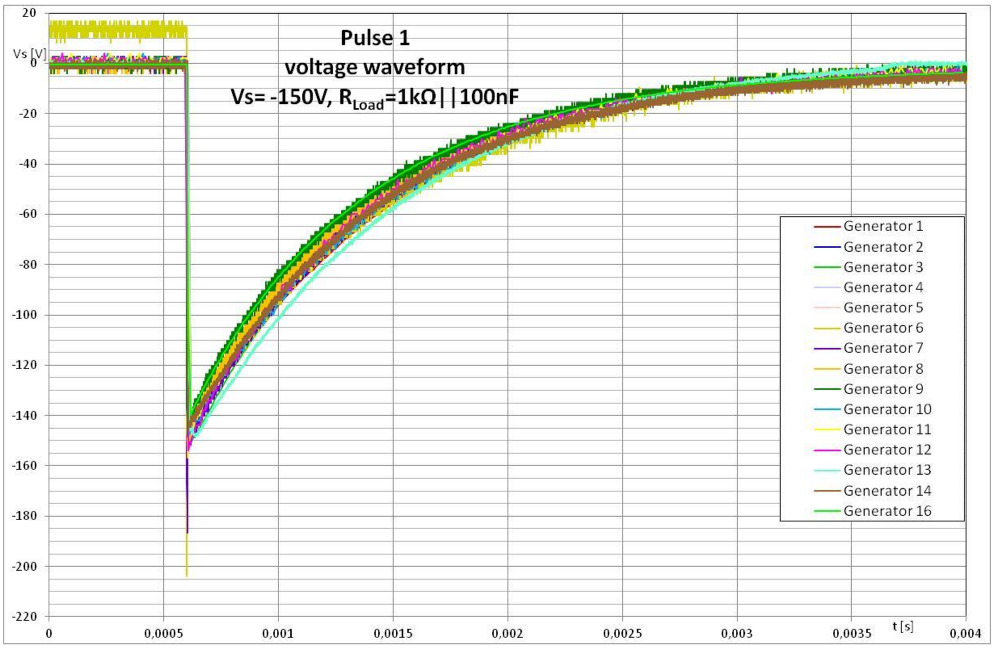


Figure A.2 Pulse 1 waveform examples of extended setup

A.2.3 Generator verification waveforms of standardized setup for pulse 2a

Examples of pulse 2a waveform for standardized setup are given in Figure A.3

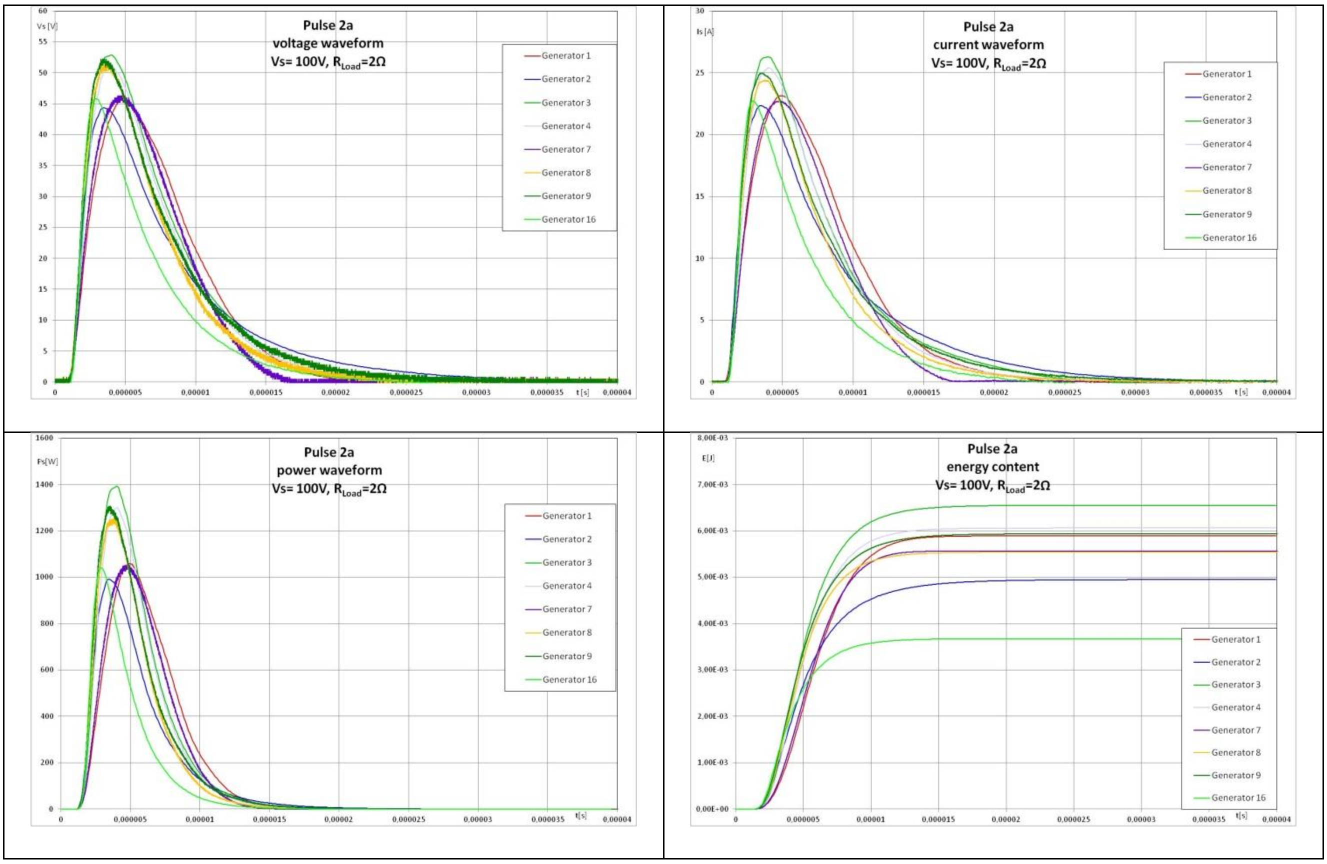


Figure A.3 Pulse 2a waveform examples of standardized setup

A.2.4 Generator verification waveforms of extended setup for pulse 2a

Examples of pulse 2a waveform are given in Figure A.4 for extended setup low impedance and in Figure A.5 for extended setup high impedance

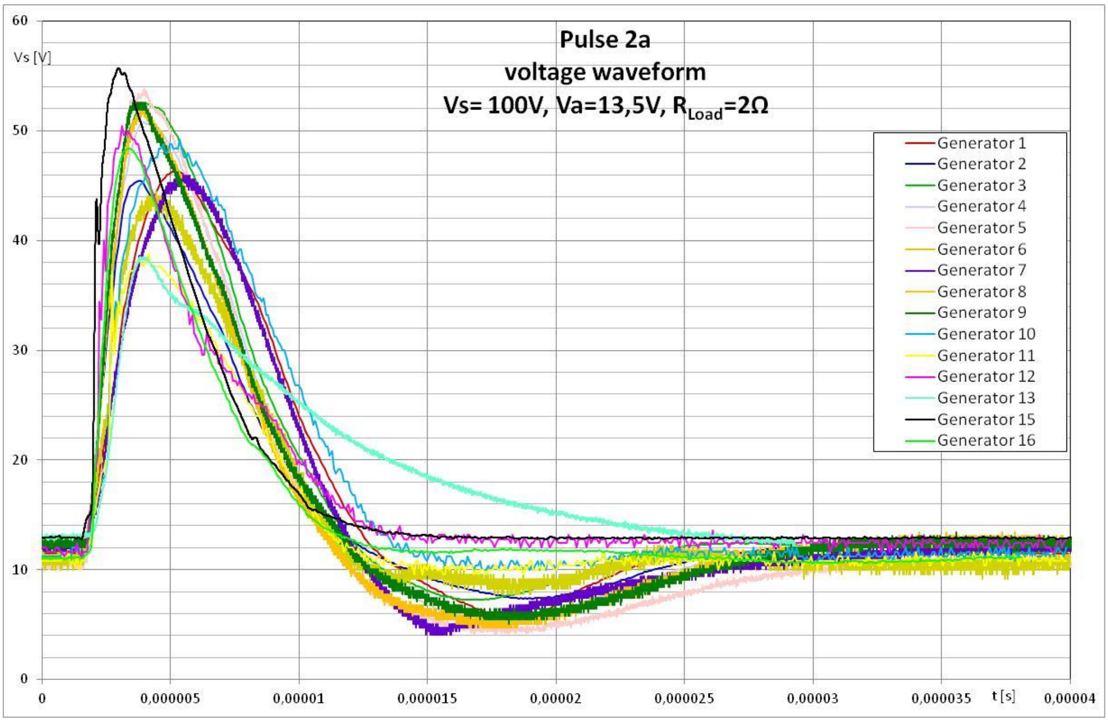


Figure A.4 Pulse 2a waveform examples of extended setup low impedance

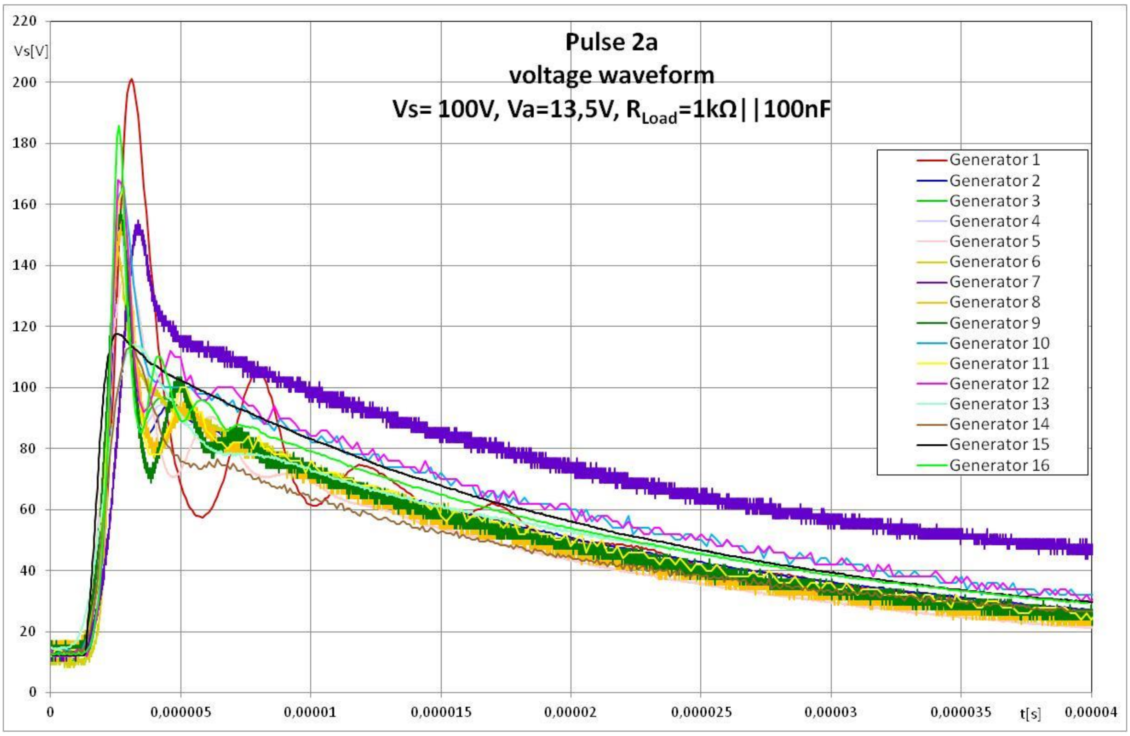


Figure A.5 Pulse 2a waveform examples of standardized setup high impedance