International Telecommunication Union

# ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

# Series K
## Supplement 27
(07/2022)

SERIES K: PROTECTION AGAINST INTERFERENCE

# The 100 kHz ring wave generator

ITU-T K-series Recommendations – Supplement 27

ITU-T

# Supplement 27 to ITU-T K-series Recommendations

## The 100 kHz ring wave generator


### Summary

Some regional standards offer the ring wave generator as an alternative test procedure. Surges in AC mains branch circuits have been found to show a damped ring wave. Supplement 27 to ITU-T K-series Recommendations looks at the history of ring waves, the ring wave generator, and its parameters.

For most purposes the 1.2/50-8/20 generator is sufficiently adequate for surge testing without using a 100 kHz ring wave generator.



### History

| Edition | Recommendation | Approval | Study Group | Unique ID* |
|---|---|---|---|---|
| 1.0 | ITU-T K Suppl. 27 | 2022-07-01 | 5 | 11.1002/1000/15081 |

### Keywords

100 kHz, AC mains branch circuits, ring wave, simulation.


* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

## FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

## NOTE

This is an informative ITU-T publication. Mandatory provisions, such as those found in ITU-T Recommendations, are outside the scope of this publication. This publication should only be referenced bibliographically in ITU-T Recommendations.

## INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this publication may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the publication development process.

As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents/software copyrights, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the appropriate ITU-T databases available via the ITU-T website at http://www.itu.int/ITU-T/ipr/.

## Table of Contents

# Supplement 27 to ITU-T K-series Recommendations

## The 100 kHz ring wave generator

### 1 Scope

This Supplement reviews the papers and standards that mention the AC branch circuit 100 kHz ring wave and its surge generator. To aid the simulation of such occurrences a generator simulation program with integrated circuit emphasis (SPICE) model is developed. In conclusion, the 100 kHz ring wave generator parameters are compared with those of the commonly used 1.2/50-8/20 surge generator.

### 2 References

None.

### 3 Definitions

None.

### 4 Ring wave parameters

Many people will have seen IEEE standards C62.41 and C62.45 where the ring generator is mentioned. C62.45 states the following 100 kHz ring generator parameters:

The open-circuit voltage waveform is defined as having:

– Rise time: 0.5 µs ± 0.15 µs, front edge time between 10% and 90% amplitude levels.

– Ringing frequency: 100 kHz ± 20 kHz, defined by time difference between first and third zero-crossings after the initial peak (10 µs ± 2 µs).

The ring wave voltage equation is given as:

$$V(t) = AV_p\left(1 - \exp\frac{-t}{\tau_1}\right)\exp\left(\frac{-t}{\tau_2}\right)\cos\left(2\pi ft\right)$$

where:

$\tau_1$ is 0.533 µs

$\tau_2$ is 9.788 µs

$2\pi f$ is $2\pi * 10^5\ s^{-1}$ (there is a mistake in the 2003 standard)

$A$ is 1.59

Plotting this equation with $V_p$ = 1000 V. Results shown in Figure 1:

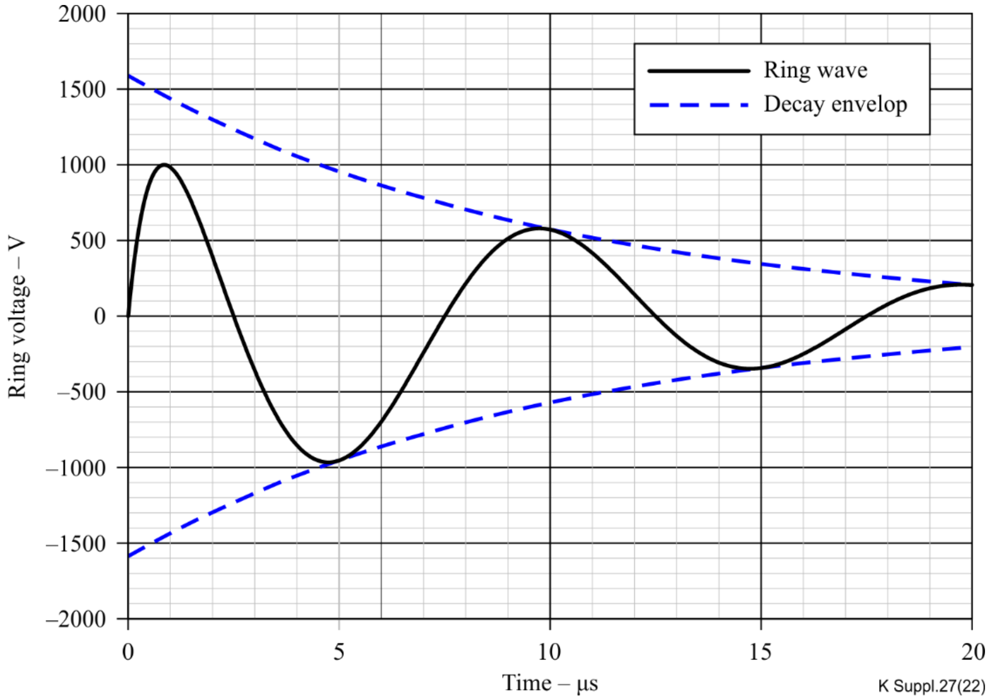


**Figure 1 – Equation ring wave and decay envelop**

The short-circuit current waveform is not specified for the 100 kHz ring wave generator, only the peak short-circuit current according to the location category (location Categories A and B) is specified. For a peak open-circuit voltage of 6 kV, the nominal peak short-circuit current will be 500 A for location Category B environments and 200 A for location Category A environments. This amounts to generator effective source impedances of 12 Ω ± 3 Ω for location Category B environments and 30 Ω ± 8 Ω for location Category A environments.

IEC 61000-4-12: Electromagnetic compatibility (EMC) – Part 4-12: Testing and measurement techniques – Ring wave immunity test has much the same material as C62.45 and includes a probably non-workable suggestion for a ring generator circuit, see Figure 2.

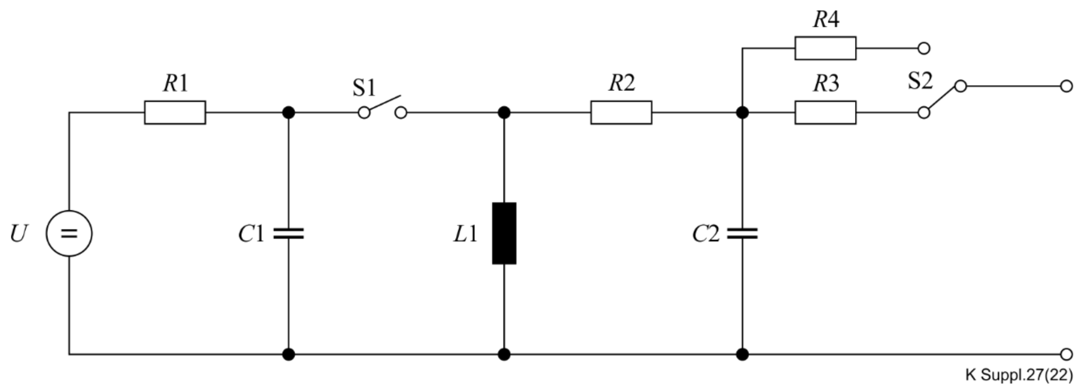


**Figure 2 – Suggested IEC 61000-4-12 ring generator circuit**

The paper "The Design of Simulation and the Creation of a Combination Wave and Ring Wave Generator are in accordance with the International Standard IEC 61000-4-5 and IEC 61000-4-12" was studied but not found to be very useful.

## 5 Basic circuit for a ring wave voltage generator

Figure 3 shows the main voltage waveform circuit elements. Here capacitor C5, of 1 µF charged to 5 kV is switch connected to a parallel inductor L1 of 2 µH and a discharge resistor R1. Several values of R1 are used to show its damping effects. An extra inductor L2 slows up the initial voltage waveform. The ratio of L2/R1 is maintained at 0.5 µs.

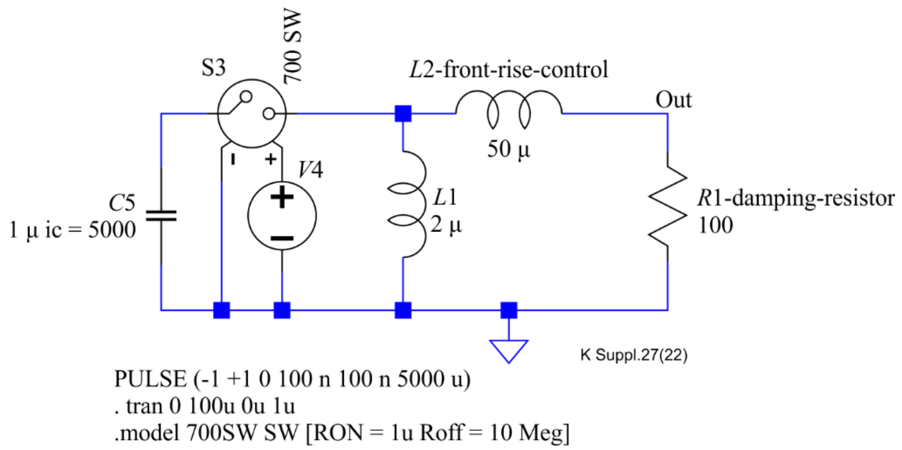


**Figure 3 – Basic ring waveform generator elements**

Figure 4 shows the resultant voltage out waveforms for R1 values of 100 Ω, 10 Ω and 1 Ω. It shows the decay shape required corresponds to an R1 value of 10 Ω.

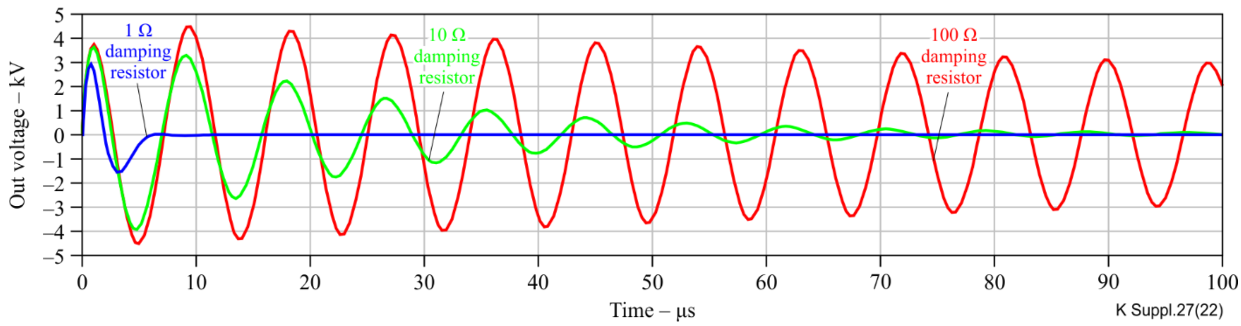


**Figure 4 – Generator out voltage for various values of damping resistor**

For the components chosen, the basic oscillation period will be 2 × π × (C5 (1 µF) × L1 (2 µH))$^{0.5}$ = 8.8 µs. The time constant for front edge shaping is L2/R1 = 0.5 µs. With R1 = 10 Ω, Figure 5 shows the voltage out waveform for the first 20 µs. The time between the second and third zero crossing is 8.77 µs, meaning the inductance of LI must be increased to reach 10 µs.

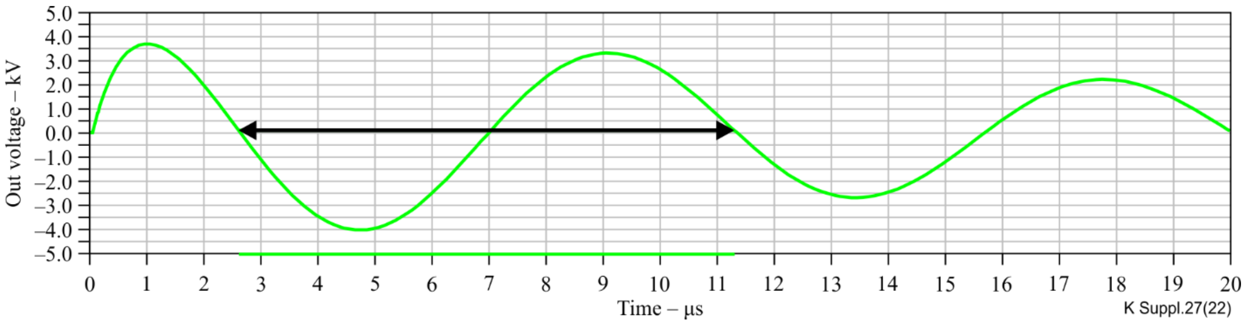


**Figure 5 – First 20 µs of the voltage out waveform for the circuit in Figure 3**

Figure 6 shows the voltage out waveform for the first 1.2 µs. The 10% to 90% rise time is 0.599 µs, meaning that inductor L2 needs to be reduced.

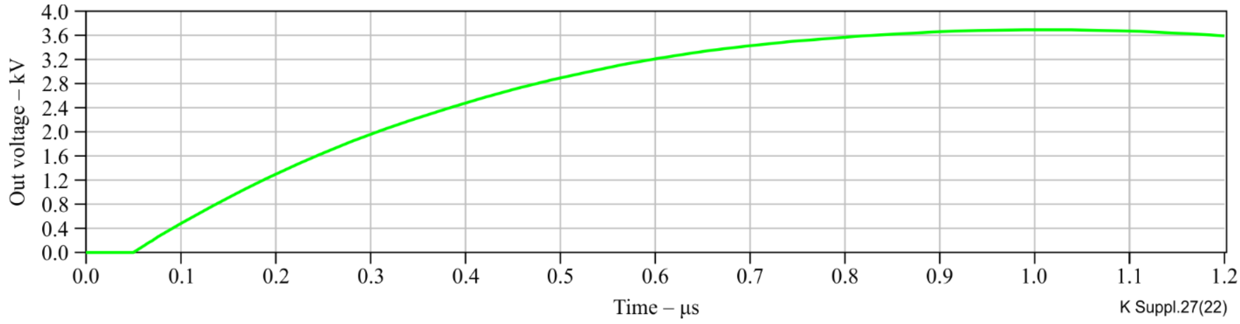


**Figure 6 – First 1.2 µs of the voltage out waveform for the circuit in Figure 3**

Figure 7 is the out voltage for the modified circuit with the peak voltage increased to give a 6 kV peak voltage.

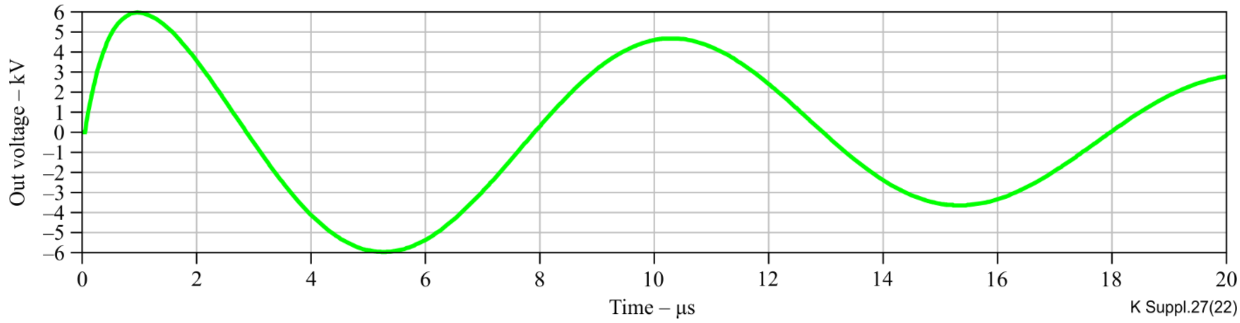


**Figure 7 – First 20 µs of the voltage out waveform for the modified circuit in Figure 3**

This waveform satisfies the ring wave output requirements.

## 6 Short-circuit current

Adding a series resistor to the output will define the short-circuit conditions. With a 9.4 Ω series output resistor added the 500 A Category B environment current level was obtained, see Figure 8.

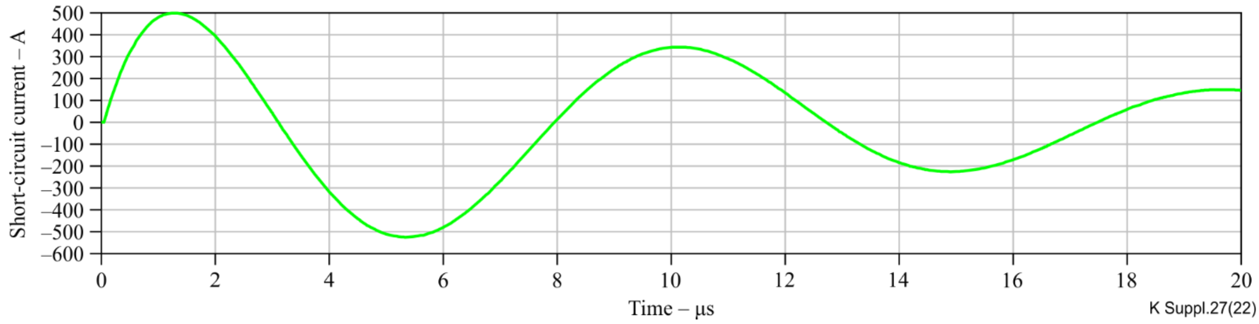


**Figure 8 – 500 A Category B environment current level with series 9.4 Ω resistor**

With a 27 Ω series output resistor added the 200 A Category A environment current level was obtained, see Figure 9.

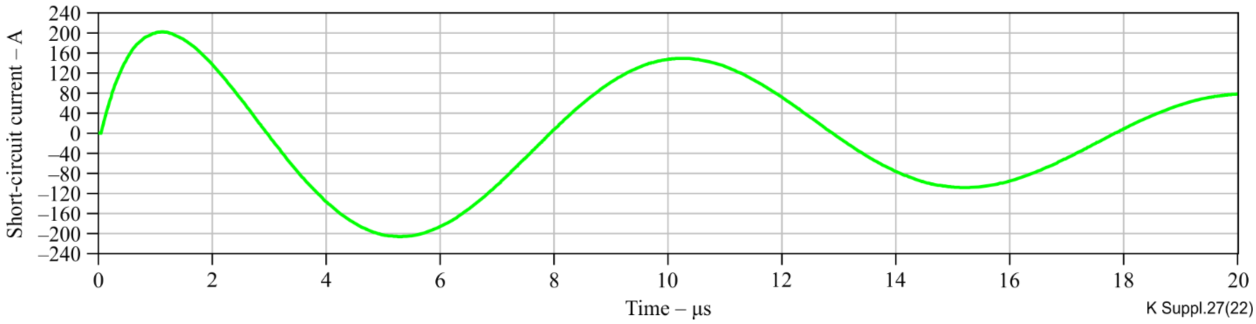


**Figure 9 – 200 A Category A environment current level with series 27 Ω resistor**

## 7 dv/dt

The front edge of the ring wave is about 1 µs. In the first 200 ns the average rate of voltage rise is 14 kV/µs. Figure 10 shows the voltage front edge and the incremental dv/dt resulting from the equation given earlier and shown by Figure 1.

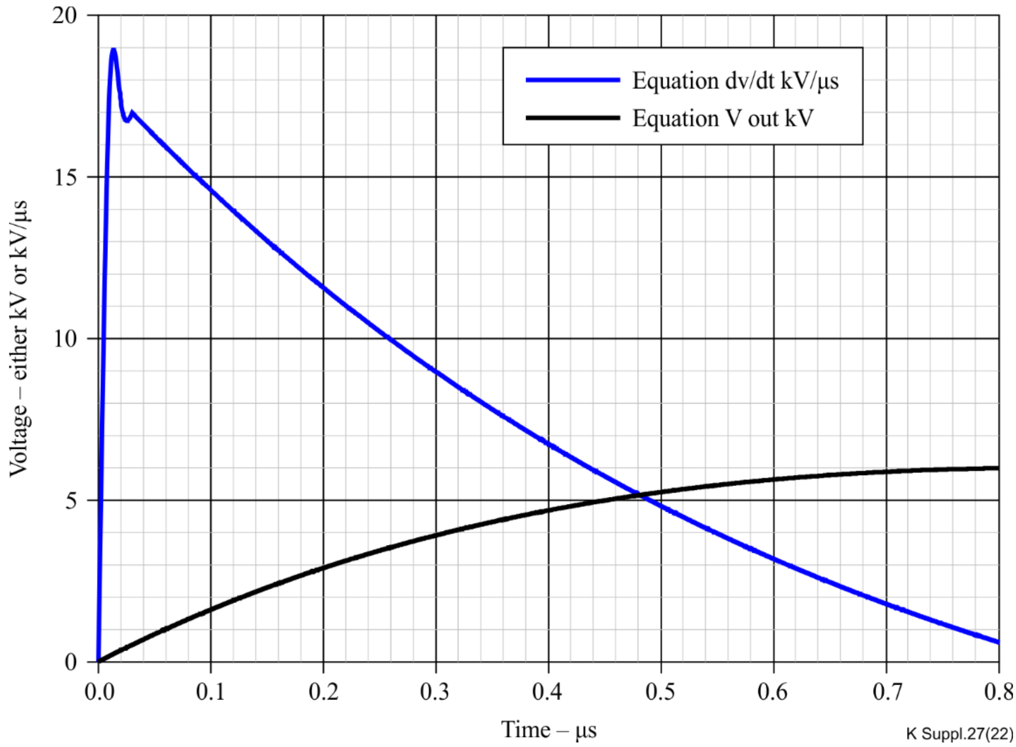


**Figure 10 – Ring wave equation plot of front voltage and incremental dv/dt**

Figure 11 shows the voltage front edge and the incremental dv/dt resulting from the simulation circuit.

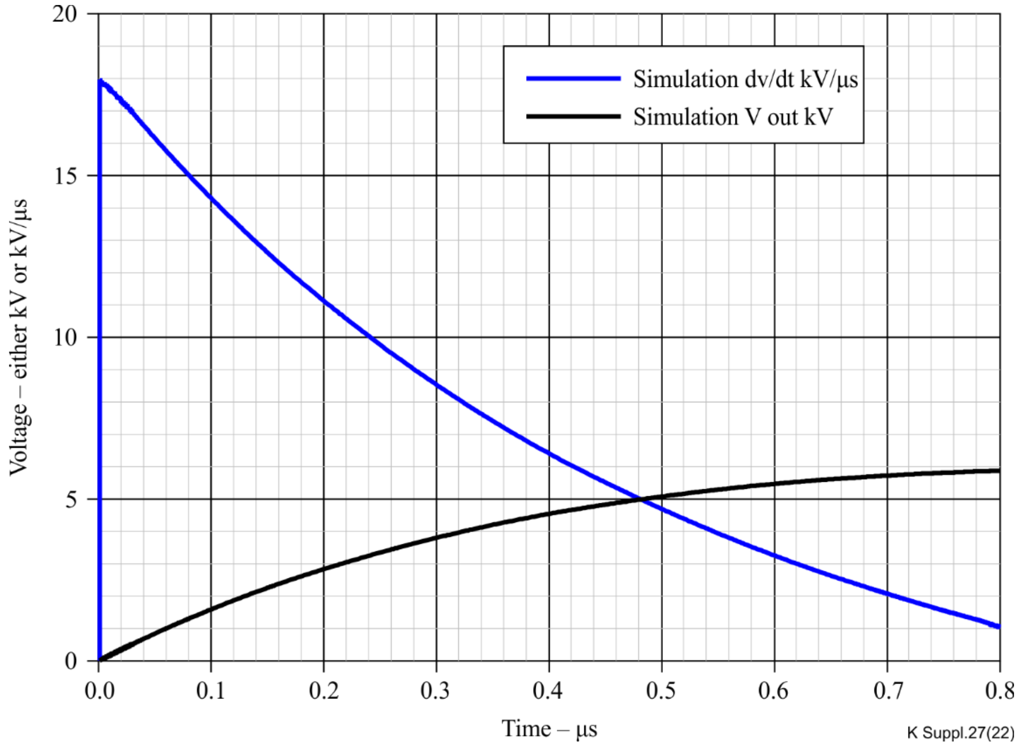


**Figure 11 – Ring wave generator simulation plot of front voltage and incremental dv/dt**

During the first 200 ns of the waveforms the average dv/dt is 14 kV/µs (Figure 10) and 13.9 kV/µs (Figure 11).

How does this compare with a 1.2/50-8/20 generator with a 6 kV peak output voltage? The "Surge generator values and simulations" 1.2/50-8/20 generator simulation was used for this analysis, see Figure 12.

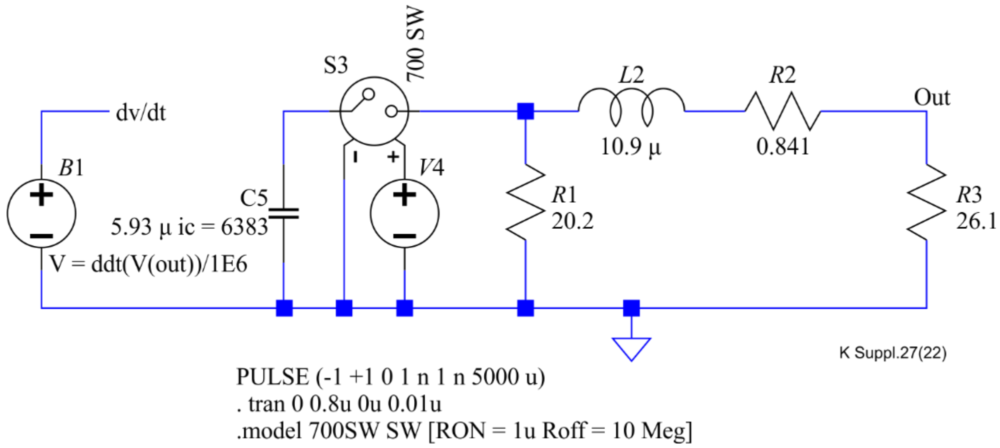


**Figure 12 – 1.2/50-8/20 combination generator simulation**

In Figure 13, during the first 200 ns the average dv/dt is 12 kV/µs and the peak incremental dv/dt is 15.6 kV/µs. This means that a protection circuit containing a series gas discharge tube (GDT) would give a slightly higher front protection voltage (14 kV/µs vs 12 kV/µs) when connected to a perfectly made ring wave generator than a 1.2/50-8/20 generator.

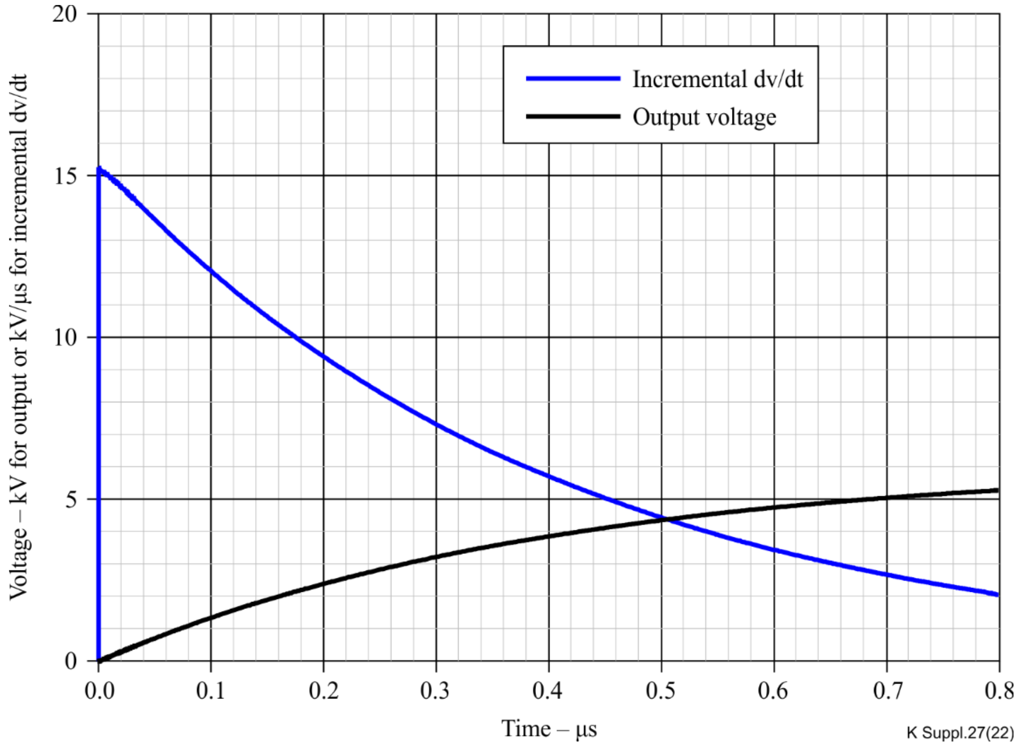


**Figure 13 – 1.2/50-8/20 generator simulation plot of front voltage and incremental dv/dt**

## 8 Summary

The 100 kHz ring generator lacks comprehensive technical support. It is hoped that the information given here helps the understanding of the electrical parameters. For those wanting more information on this topic refer to [b-NIST1], [b-NIST2], [b-NTHU] and [b-Standler].

The final simulation circuit with a 6 kV peak output voltage is shown in Figure 14. For testing to Category, A and B locations the specified series resistance shall be added to the out terminal. For simulation purposes, a controlled source B1 is added to provide a direct monitor of the waveform dv/dt.

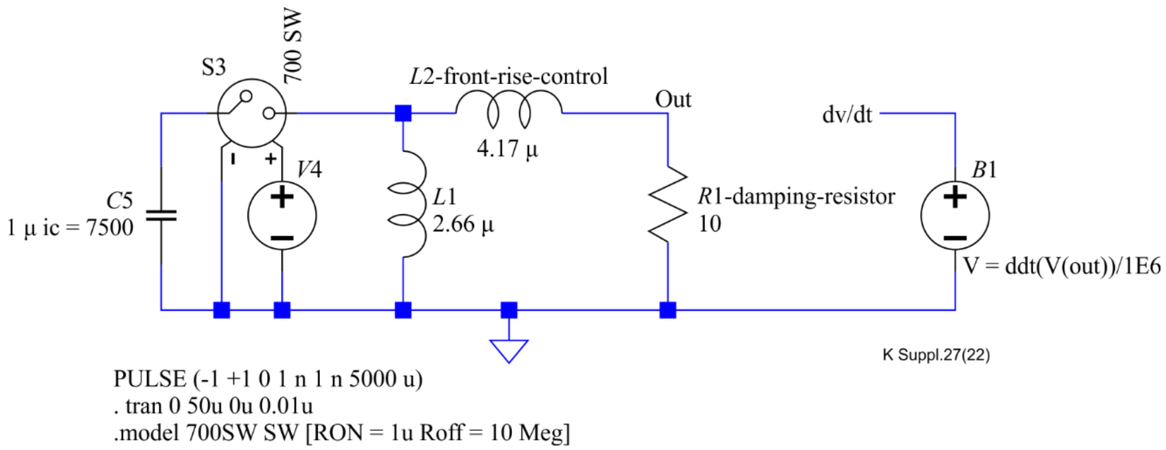


**Figure 14 – Final 100 kHz ring wave generator simulation**

For most purposes the 1.2/50-8/20 generator is sufficiently adequate for surge testing without using a 100 kHz ring wave generator.

# Bibliography


[b-NIST1] Martzloff, Pellegrini, *Real, Realistic Ring Waves for Surge Testing*
https://www.nist.gov/system/files/documents/pml/div684/Real_Waves.pdf

[b-NIST2] Martzloff , *The Trilogy update of IEEE C62.41*
https://dokument.pub/the-trilogy-update-of-ieee-c62-nist-physical-measurement-flipbook-pdf.html

[b-NTHU] Tsing Hua University, *Chapter 8, Natural and Step Responses of RLC Circuits*
https://www.ee.nthu.edu.tw/~sdyang/Courses/Circuits/Ch08_Std.pdf

[b-Standler] Ronald B. Standler, *Protection of Electronic Circuits from Overvoltages*, pp 91-92

## SERIES OF ITU-T RECOMMENDATIONS

| | |
|---|---|
| Series A | Organization of the work of ITU-T |
| Series D | Tariff and accounting principles and international telecommunication/ICT economic and policy issues |
| Series E | Overall network operation, telephone service, service operation and human factors |
| Series F | Non-telephone telecommunication services |
| Series G | Transmission systems and media, digital systems and networks |
| Series H | Audiovisual and multimedia systems |
| Series I | Integrated services digital network |
| Series J | Cable networks and transmission of television, sound programme and other multimedia signals |
| **Series K** | **Protection against interference** |
| Series L | Environment and ICTs, climate change, e-waste, energy efficiency; construction, installation and protection of cables and other elements of outside plant |
| Series M | Telecommunication management, including TMN and network maintenance |
| Series N | Maintenance: international sound programme and television transmission circuits |
| Series O | Specifications of measuring equipment |
| Series P | Telephone transmission quality, telephone installations, local line networks |
| Series Q | Switching and signalling, and associated measurements and tests |
| Series R | Telegraph transmission |
| Series S | Telegraph services terminal equipment |
| Series T | Terminals for telematic services |
| Series U | Telegraph switching |
| Series V | Data communication over the telephone network |
| Series X | Data networks, open system communications and security |
| Series Y | Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities |
| Series Z | Languages and general software aspects for telecommunication systems |

Printed in Switzerland
Geneva, 2022