

# Test Report

|                  |   |          |   |                 |    |
|------------------|---|----------|---|-----------------|----|
| Document No.     | B7020147  | Copy No. | 1 | Number of pages | 96 |
| Apparatus        | Polymer-housed surge arrester section type PA-DM section ST with additional thermal insulation                    |          |   |                 |    |
| Designation      | ---   |          |   |                 |    |
| Serial Number    | ---   |          |   |                 |    |
| Manufacturer     | Joint-Stock Company " Polymer-Apparat"  |          |   |                 |    |
| Client           | Joint-Stock Company " Polymer-Apparat"<br>Ak. Kostantinova str., 1<br>195427 Saint-Petersburg - Russia Federation |          |   |                 |    |
| Tested for       | ---   |          |   |                 |    |
| Date(s) of tests | October 4 – December 4, 2017  |          |   |                 |    |
| Tested by        | CESI S.p.A.<br>Via Rubattino, 54<br>20134 Milano - Italy  |          |   |                 |    |
| Test performed   | Power-frequency voltage-versus-time   |          |   |                 |    |

PAD B7020147 (2448496) - CONFIDENTIAL USE

The apparatus, constructed in accordance with the description, drawings and photographs incorporated in this document has been subjected to the series of proving tests in accordance with: IEC 60099-4 – Edition 3.0 (2014-06)

The results are shown in the record of proving tests and the oscillograms attached hereto. The ratings assigned by the Manufacturer are listed on the ratings page.  
The document applies only to the apparatus tested. The responsibility for conformity of any apparatus having the same designations with that tested rests with the Manufacturer.

December 12, 2017

Date **Gregori Marco**  
B7020147 3059 AUT  
**Test Engineer in charge**

**The Manager - Arcidiaco Lorenzo**  
B7020147 821814 ASP  
**Approved By** Document Digitally Signed

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LAB N° 0030

The laboratory meets the requirements of the Standard EN ISO/IEC 17025: 2005 "General Requirements for the Competence of Testing and Calibration Laboratories". The in force status of the accreditation and the list of accredited tests may be checked in the WEB site: [www.accredia.it](http://www.accredia.it)



# CESI

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## Notes

### **STL-Member**

CESI Group members are founder members of the SHORT-CIRCUIT TESTING LIAISON (STL) which has been established in 1969. STL is a forum for voluntary international cooperation of testing organizations.

### **CESI Group Test Documents description**

#### **Type Test Certificate of .....**

Issued for type tests of high voltage products ( $> 1 \text{ kV}_{ac}$ ;  $> 1,5 \text{ kV}_{dc}$ ), which have successfully been carried out in full compliance with the relevant specifications or standards and STL Guides valid at the time of the test. The Type Test Certificate consists of documents unequivocally identifying the test object and describes all conditions under which the tests were conducted. It gives evidence of the unobjectionable behavior of the test object during the tests in line with the normative documents applied as well as of the results of successful testing.

#### **Test Certificate of (complete / selected) Type Tests**

Issued if type tests of low voltage products ( $< 1 \text{ kV}_{ac}$ ;  $< 1,5 \text{ kV}_{dc}$ ) requested by the relevant product standard were passed. For these tests the equipment under test must be clearly identified by technical description, drawings, and additional specifications.

#### **Certificate of Design Verification**

Issued for passed design verification tests according to IEC 61439. For these tests the equipment under test must be clearly identified by technical description, drawings, and additional specifications.

#### **Type Test Report**

Issued for high and low voltage products if parts of selected type tests have been passed; those shall be carried out in full compliance with the relevant standards but (for high voltage products) do not fulfill all STL requirements for issuing a Type Test Certificate. For these tests the equipment under test must be clearly identified by technical description, drawings, and additional specifications.

#### **Test Report**

Issued for all other tests on high and low voltage products which have been carried out according to specifications, standards and/or client instructions

#### **On-Site Test Record**

Issued as a record of results acquired during the on-site tests / measurements

#### **Test Award**

Can be additionally issued for all named types of test documents above if the tests to be referenced were passed

**Tests witnessed by:**

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**Identification of the object:** Effected

The Manufacturer guarantees that the tested object is manufactured according to the submitted drawings. CESI checked that these drawings adequately represent in shape and dimensions the essential details and the parts of the tested object.

These drawing, identified by CESI and numbered B7024364 No. 1 , is annexed to this document.

**Test evaluation**

With reference to the Standards/Specifications listed in the first page and the characteristics of the tested sample assigned by manufacturer, the carried out tests passed SUCCESSFULLY.

The data necessary to permit repetition of the tests are contained in the document marked: ----

*The reported expanded uncertainties are determined in accordance with the Publication JCGM 100 "Evaluation of measurement data - Guide to the expression of uncertainty in measurement" and are based on a standard uncertainty multiplied by a coverage factor  $k = 2$ , which for a normal distribution provides a level of confidence of approximately 95 %.*

|   |                |
|---|----------------|
| - Voltage a.c.                          | : $\pm 3,0\%$  |
| - Residual peak voltage (impulse tests) | : $\pm 3,0\%$  |
| - Current a.c.                          | : $\pm 3,0\%$  |
| - Peak current (impulse tests)          | : $\pm 3,0\%$  |
| - Time (impulse tests)                  | : $\pm 10,0\%$ |
| - Time (a.c. tests)                     | : $\pm 1,5\%$  |

**Laboratory information**

|                                   |                                 |
|-----------------------------------|---------------------------------|
| <b>Receipt date of the sample</b> | September 2017                  |
| <b>Test location</b>              | CESI – Via Rubattino 54 – Milan |
| <b>CESI testing team</b>          | Mr L. Podavitte                 |
| <b>Test laboratory</b>            | P177                            |
| <b>ODV SAP</b>                    | 70006781                        |

| content   | page     | test date          |
|---|----------|--------------------|
| Test object characteristics   | 5        |                    |
| Photograph of the test object   | 6        |                    |
| Reference standard  | 7        |                    |
| Test carried out  | 7        |                    |
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| Summary of test results   | 9        |                    |
| Initial test  | 10 to 11 | October 4-5, 2017  |
| Voltage correction factor and thermal energy calculations                               | 12       | October 5, 2017    |
| With prior duty test  | 13 to 16 | December 2-4, 2017 |
| Without prior duty test   | 17 to 18 | October 6, 2017    |
| Test evaluation   | 19 to 20 | December 4, 2017   |
| Technical data of the test circuit  | 21 to 25 |                    |
| <b>Pages annexed:</b>   |          |                    |
| Oscillograms - n. 68 pages  |          |                    |
| Client's drawing (Polymer-housed surge arrester section) – CESI no. B7024364 – n.1 page |          |                    |
| Client's drawing (MO resistor) – CESI no. B7020387 – n.1 page                           |          |                    |
| Technical document (TOV curve) CESI No.B7023131 – n.1 page                              |          |                    |

Test object characteristics (assigned by the client)

|   |                                       |
|---|---------------------------------------|
| Manufacturer's name                                 | Joint-Stock Company "Polymer-Apparat" |
| Polymer-housed surge arrester section type          | PA-DM section ST                      |
| Drawing code  | PA-DM.001.ST.02                       |
| MO-resistor supplier's                              | Joint-Stock Company "Polymer-Apparat" |
| Metal-oxide resistor type                           | B34/30                                |
| Arrester class                                      | Distribution                          |
| Designation   | DH                                    |
| Number of MO resistor fitted                        | 1                                     |
| Nominal discharge current - [kA]                    | 10                                    |
| Rated voltage - $U_r$ [kV]                          | $1,077 \times U_{ref.}$               |
| Continuous operating voltage - $U_c$ [kV]           | $0,861 \times U_{ref.}$               |
| Repetitive charge transfer rating - $Q_{rs}$ [C]    | 0,4                                   |
| Rated thermal charge transfer rating - $Q_{th}$ [C] | 1,1                                   |
| Flat surface area [cm <sup>2</sup> ]                | 10,52                                 |
| Reference current - $I_{ref.}$ [mA]                 | 1,0                                   |
| Rated frequency - [Hz]                              | 48÷62                                 |
| Year of manufacture                                 | 08/2017                               |

geometrical characteristics measured on the MO resistor

|                   |         |
|-------------------|---------|
| Total height [mm] | 31,1 mm |
| Diameter [mm]     | 36,6 mm |

Photographs of the test object



Photo no. 1

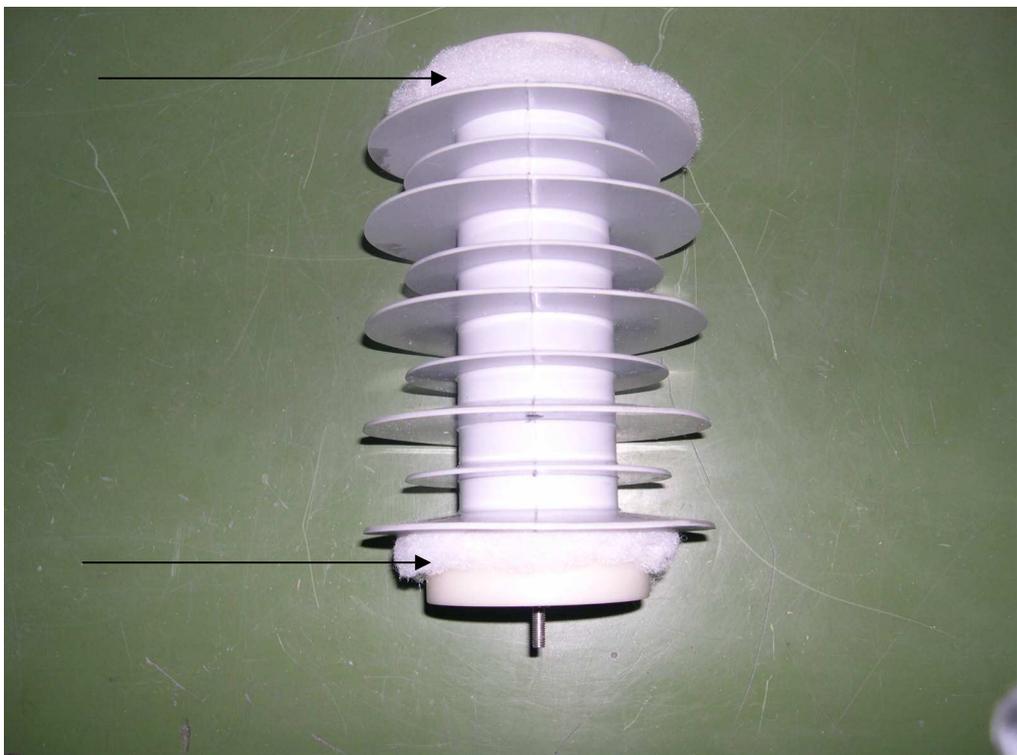


Photo no. 2

Polymer-housed surge arrester section type PA-DM section ST with additional thermal insulation

**Reference Standard**

IEC 60099-4 (2014/06) – Edition 3 - Clause 10.8.8.  
 “Metal-oxide surge arresters without gaps for a.c. system”

| Test carried out                         | Number of sample tested |
|--|-------------------------|
| Power-frequency voltage-versus-time test | 6                       |

Test object identification

| Test object name   | Identification of test sample (given by CESI) | Identification of test sample (given by JSC “Polymer Apparat) |
|--|---|---|
| Polymer-housed surge arrester section type PA-DH section ST with additional thermal insulation | TOV1  | 00102   |
|  | TOV2  | 00103   |
|  | TOV3  | 00104   |
|  | TOV4  | 00005   |
|  | TOV5  | 00009   |
|  | TOV6  | 00010   |

### Test procedure

The test procedure consisted of the following sequence:

#### **1. Test performed on Polymer-housed metal-oxide surge arrester section in open air**

##### Initial test

- a) Measurement of the lightning impulse residual voltage at the nominal discharge current
- b) Measurement of the power frequency reference voltage at the reference current

#### **2. Test performed on Polymer-housed metal-oxide surge arrester section assembled in thermal model**

##### Test with energy input (prior duty test)

- c) The surge arrester sections were kept in an oven at the temperature of 66 °C till thermal equilibrium (not more than twenty hours)
- d) Injection of two lightning current impulses 8/20 μs at the rated thermal charge transfer  $Q_{th}$ . A time shorter than 100 ms after the application of the second lightning current impulses 8/20 μs energization at  $U_{TOV}$  (declared by the manufacturer) for a time  $t_{TOV}$  (declared by the manufacturer) and then at  $U_c$  for 30 min. to verify the thermal stability.

Note:

- intervals between lightning duration current impulses: 60 seconds
- nominal test frequency : 50 Hz

Four samples were tested as specified below:

| Sample | $U_{TOV}$          | Duration | Note            |
|--------|--------------------|----------|-----------------|
| TOV1   | $1,080 \times U_r$ | 1 sec    | prior duty test |
| TOV2   | $1,040 \times U_r$ | 10 sec   |                 |
| TOV3   | $1,000 \times U_r$ | 100 sec  |                 |
| TOV4   | $0,960 \times U_r$ | 1000 sec |                 |

##### Test without energy input (no-prior duty test)

- e) The surge arrester sections were kept in an oven at the temperature of 66 °C till thermal equilibrium (not more than twenty hours)
- f) Application of the overvoltage  $U_{TOV}$  (declared by the manufacturer) for a time  $t_{TOV}$  (declared by the manufacturer) and then at  $U_c$  for 30 min. to verify the thermal stability.

Note:

- nominal test frequency : 50 Hz

Two samples were tested as specified below:

| Sample | $U_{TOV}$          | Duration | Note               |
|--------|--------------------|----------|--------------------|
| TOV5   | $1,130 \times U_r$ | 10 sec   | no-prior duty test |
| TOV6   | $1,040 \times U_r$ | 1000 sec |                    |

#### **3. Test performed on Polymer-housed metal-oxide surge arrester section in open air**

- g) Measurement of the lightning impulse residual voltage at nominal discharge current for comparison with initial value
- f) After that the sample has cooled to ambient temperature and two current impulses 8/20 at 0,5 kA/cm<sup>2</sup> have been applied to check the integrity of the internal parts. The interval between impulses was 50-60 seconds.

### Test result

The visual inspection of the sample after the test has revealed no sign of physical damage.

The variation of lightning impulse residual voltage before and after the test was less than 5% (maximum allowed variation according to reference standard is 5%). During the two last impulses the oscillograms not reveal any breakdown.

The thermal stability was achieved.

**The acceptance criteria are fulfilled. The test result is positive.**



Summary of test results

Variation of lightning impulse residual voltage at  $I_n$

| sample | before test       |                  | after test        |                  | Variation |
|--------|-------------------|------------------|-------------------|------------------|-----------|
|        | discharge current | residual voltage | discharge current | residual voltage |           |
|        | kA                | kV               | kA                | kV               | %         |
| TOV1   | 10,15             | 14,04            | 10,18             | 14,26            | +1,57     |
| TOV2   | 10,10             | 14,06            | 10,14             | 14,24            | +1,28     |
| TOV3   | 10,07             | 14,16            | 10,10             | 14,38            | +1,55     |
| TOV4   | 10,15             | 14,30            | 10,07             | 14,36            | +0,42     |
| TOV5   | 10,14             | 14,17            | 10,04             | 14,00            | +1,20     |
| TOV6   | 10,08             | 14,35            | 10,05             | 14,25            | -0,70     |

Power frequency voltage versus time test.

Lightning impulse residual voltage measurement before the test

Test circuit: A0120

Date: October 4, 2017

| Sample | Requested current | Charging voltage | Oscillogram | Current waveshape | Discharge current | Residual Voltage |
|--------|-------------------|------------------|-------------|-------------------|-------------------|------------------|
| No.    |                   | kV               | No.         | $\mu$ s           | kA                | kV               |
| TOV1   | I <sub>n</sub>    | 24,8             | 1           | 8,6/18,2          | 10,15             | 14,04            |
| TOV2   |                   | 24,8             | 2           |                   | 10,10             | 14,06            |
| TOV3   |                   | 24,8             | 3           |                   | 10,07             | 14,16            |
| TOV4   |                   | 24,8             | 4           |                   | 10,15             | 14,30            |
| TOV5   |                   | 24,6             | 5           |                   | 10,14             | 14,17            |
| TOV6   |                   | 24,6             | 6           |                   | 10,08             | 14,35            |

Notes:

**Power frequency voltage versus time test.**

**Reference voltage test.**

**Test circuit:** A0019

**Date:** October 5, 2017

| Sample No. TOV1 |         |                    |                    |                   |       |                        |
|-----------------|---------|--------------------|--------------------|-------------------|-------|------------------------|
| oscillogram     | voltage | current            | current            | current           | power | 3rd harmonic amplitude |
| No.             | kV      | + mA <sub>cr</sub> | - mA <sub>cr</sub> | mA <sub>rms</sub> | W     | μA                     |
| 7               | 5,47    | 0,884              | 1,000              | 0,562             | 1,41  | --                     |

| Sample No. TOV2 |         |                    |                    |                   |       |                        |
|-----------------|---------|--------------------|--------------------|-------------------|-------|------------------------|
| oscillogram     | voltage | current            | current            | current           | power | 3rd harmonic amplitude |
| No.             | kV      | + mA <sub>cr</sub> | - mA <sub>cr</sub> | mA <sub>rms</sub> | W     | μA                     |
| 8               | 5,37    | 0,939              | 1,000              | 0,570             | 1,46  | ---                    |

| Sample No. TOV3 |         |                    |                    |                   |       |                        |
|-----------------|---------|--------------------|--------------------|-------------------|-------|------------------------|
| oscillogram     | voltage | current            | current            | current           | power | 3rd harmonic amplitude |
| No.             | kV      | + mA <sub>cr</sub> | - mA <sub>cr</sub> | mA <sub>rms</sub> | W     | μA                     |
| 9               | 5,45    | 0,922              | 1,00               | 0,571             | 1,43  | ---                    |

| Sample No. TOV4 |         |                    |                    |                   |       |                        |
|-----------------|---------|--------------------|--------------------|-------------------|-------|------------------------|
| oscillogram     | voltage | current            | current            | current           | power | 3rd harmonic amplitude |
| No.             | kV      | + mA <sub>cr</sub> | - mA <sub>cr</sub> | mA <sub>rms</sub> | W     | μA                     |
| 10              | 5,39    | 0,887              | 1,000              | 0,564             | 1,42  | ---                    |

| Sample No. TOV5 |         |                    |                    |                   |       |                        |
|-----------------|---------|--------------------|--------------------|-------------------|-------|------------------------|
| oscillogram     | voltage | current            | current            | current           | power | 3rd harmonic amplitude |
| No.             | kV      | + mA <sub>cr</sub> | - mA <sub>cr</sub> | mA <sub>rms</sub> | W     | μA                     |
| 11              | 5,38    | 0,860              | 1,000              | 0,560             | 1,37  | ---                    |

| Sample No. TOV6 |         |                    |                    |                   |       |                        |
|-----------------|---------|--------------------|--------------------|-------------------|-------|------------------------|
| oscillogram     | voltage | current            | current            | current           | power | 3rd harmonic amplitude |
| No.             | kV      | + mA <sub>cr</sub> | - mA <sub>cr</sub> | mA <sub>rms</sub> | W     | μA                     |
| 12              | 5,40    | 0,884              | 1,000              | 0,563             | 1,39  | ---                    |

**Power frequency voltage versus time test.**

**Voltage correction factor and thermal energy calculations**

Date: October 5, 2017

| Sample | $U_{ref}$<br>[1] | $KU_r$<br>[2] | $KU_C$<br>[3] | $U_r'$<br>[4] | $U_c'$<br>[5] |
|--------|------------------|---------------|---------------|---------------|---------------|
| No.    | kV               |               |               | kV            | kV            |
| TOV1   | 5,47             | 1,077         | 0,861         | 5,891         | 4,710         |
| TOV2   | 5,37             |               |               | 5,783         | 4,624         |
| TOV3   | 5,45             |               |               | 5,870         | 4,692         |
| TOV4   | 5,39             |               |               | 5,805         | 4,641         |
| TOV5   | 5,38             |               |               | 5,794         | 4,632         |
| TOV6   | 5,40             |               |               | 5,816         | 4,694         |

- [1]  $U_{ref}$  : measured reference voltage
- [2]  $KU_r$  : maximum guaranteed factor for calculation of  $U_r' = U_r/U_{ref.min.}$
- [3]  $KU_C$  : maximum guaranteed factor for calculation of  $U_c' = U_c/U_{ref.min.}$
- [4]  $U_r'$  : corrected rated voltage [4] = [1] × [2]
- [5]  $U_c'$  : corrected continuous operating voltage [5] = [1] × [3]

| Sample | $U_r'$ | Requested thermal charge transfer, $Q_{th}$ | Requested $Q_{th}$ per impulse |
|--------|--------|---|--------------------------------|
| No.    | kV     | C   | C                              |
| TOV1   | 5,891  | 1,1   | 0,55 (±10%)                    |
| TOV2   | 5,783  |   | 0,55 (±10%)                    |
| TOV3   | 5,870  |   | 0,55 (±10%)                    |
| TOV4   | 5,805  |   | 0,55 (±10%)                    |

**Power frequency voltage versus time test.**

**Application of two lightning current impulses 8/20µs, corrected rated voltage  $U_r'$  and corrected continuous operating  $U_c'$  for evaluation of the thermal stability.**

Test circuit: A0124-A0020-A0130

Sample No.: TOV 1

Ambient temperature: 20 °C

Preheating temperature: 66 °C

Date: December 2, 2017

**Lightning current impulses 8/20 µs application**

| Oscillogram No. | Impulse No. | Charging voltage kV | Residual voltage kV | Discharge current kA | $Q_{th}$ C | Applicable range for $Q_{th}$ C |
|-----------------|-------------|---------------------|---------------------|----------------------|------------|---------------------------------|
| 13              | 1           | 65,0 x 2            | ---                 | 38,14                | 0,56       | 0,495÷0,605                     |
| 14              | 2           | 65,0 x 2            | ---                 | 38,07                | 0,55       | 0,495÷0,605                     |

|  |
|--|
| Current impulse waveshape<br>(µs)<br>8,8 /18,2 |
|--|

**Temporary overvoltage application**

Amplitude claimed by the manufacturer  $U_r' \times 1,080 = 5,891 \times 1,080 = 6,362 \text{ kV}$

Duration claimed by the manufacturer **1 sec.**

| Oscillogram No. | Time s | $U_r'$ kV | Current + mA <sub>cr</sub> | Current - mA <sub>cr</sub> |
|-----------------|--------|-----------|----------------------------|----------------------------|
| 15              | 0      | 6,362     | 145,0                      | 221,0                      |
| 16              | 1      |           | 132,0                      | 164,0                      |

**Corrected continuous operating voltage  $U_c'$  application to evaluate the thermal stability**

| Oscillogram No. | Time min | $U_c'$ kV | Current + mA <sub>cr</sub> | Current - mA <sub>cr</sub> | Power W | Temperature °C |
|-----------------|----------|-----------|----------------------------|----------------------------|---------|----------------|
| 17              | 0        | 4,710     | 0,98                       | 0,99                       | 1,10    | ---            |
|                 | 5        |           | 0,91                       | 0,94                       | 0,76    | ---            |
|                 | 10       |           | 0,90                       | 0,93                       | 0,64    | ---            |
| 18              | 15       |           | 0,88                       | 0,91                       | 0,59    | ---            |
|                 | 20       |           | 0,87                       | 0,90                       | 0,54    | ---            |
|                 | 25       |           | 0,86                       | 0,89                       | 0,50    | ---            |
| 19              | 30       |           | 0,85                       | 0,88                       | 0,48    | ---            |

**Note :** Before the injection of the energy, the temperature of the test sample has been checked with instrument type FLUKE 52II thermometer CESI no.30889

continued



Continued

Sample No.: TOV2

Ambient temperature: 20 °C

Preheating temperature: 66 °C

Date: December 2, 2017

**Lightning current impulses 8/20 μs application**

| Oscillogram No. | Impulse No. | Charging voltage kV | Residual voltage kV | Discharge current kA | Q <sub>th</sub> C | Applicable range for Q <sub>th</sub> C |
|-----------------|-------------|---------------------|---------------------|----------------------|-------------------|--|
| 20              | 1           | 65,0 x 2            | ---                 | 37,80                | 0,55              | 0,495÷0,605                            |
| 21              | 2           | 65,0 x 2            | ---                 | 37,80                | 0,55              | 0,495÷0,605                            |

|  |
|--|
| Current impulse waveshape<br>(μs)<br>8,8 /18,2 |
|--|

**Temporary overvoltage application**

Amplitude claimed by the manufacturer  $U_r' \times 1,040 = 5,783 \times 1,040 = 6,014$  kV

Duration claimed by the manufacturer 10 sec.

| Oscillogram No. | Time s | U <sub>r</sub> ' kV | Current + mA <sub>cr</sub> | Current - mA <sub>cr</sub> |
|-----------------|--------|---------------------|----------------------------|----------------------------|
| 22              | 0      | 6,014               | 80,0                       | 118,0                      |
| 23              | 10     |                     | 51,0                       | 67,0                       |

**Corrected continuous operating voltage U<sub>c</sub>' application to evaluate the thermal stability**

| Oscillogram No. | Time min | U <sub>c</sub> ' kV | Current + mA <sub>cr</sub> | Current - mA <sub>cr</sub> | Power W | Temperature °C |
|-----------------|----------|---------------------|----------------------------|----------------------------|---------|----------------|
| 24              | 0        | 4,624               | 0,98                       | 1,20                       | 1,70    | ---            |
|                 | 5        |                     | 0,90                       | 0,93                       | 0,76    | ---            |
|                 | 10       |                     | 0,89                       | 0,91                       | 0,65    | ---            |
| 25              | 15       |                     | 0,88                       | 0,90                       | 0,58    | ---            |
|                 | 20       |                     | 0,87                       | 0,88                       | 0,53    | ---            |
|                 | 25       |                     | 0,86                       | 0,87                       | 0,50    | ---            |
| 26              | 30       |                     | 0,85                       | 0,87                       | 0,48    | ---            |

**Note :** Before the injection of the energy, the temperature of the test sample has been checked with instrument type FLUKE 52II thermometer CESI no.30889

continued

Continued

Sample No.: TOV3

Ambient temperature: 20 °C

Preheating temperature: 66 °C

Date: December 2, 2017

**Lightning current impulses 8/20 μs application**

| Oscillogram No. | Impulse No. | Charging voltage kV | Residual voltage kV | Discharge current kA | Q <sub>th</sub> C | Applicable range for Q <sub>th</sub> C |
|-----------------|-------------|---------------------|---------------------|----------------------|-------------------|--|
| 27              | 1           | 65,0 x 2            | ---                 | 37,83                | 0,55              | 0,495÷0,605                            |
| 28              | 2           | 65,0 x 2            | ---                 | 37,90                | 0,55              | 0,495÷0,605                            |

|  |
|--|
| Current impulse waveshape<br>(μs)<br>8,8 /18,2 |
|--|

**Temporary overvoltage application**

Amplitude claimed by the manufacturer  $U_r' \times 1,000 = 5,870 \times 1,000 = 5,870 \text{ kV}$

Duration claimed by the manufacturer **100 sec.**

| Oscillogram No. | Time s | U <sub>r</sub> ' kV | Current + mA <sub>cr</sub> | Current - mA <sub>cr</sub> |
|-----------------|--------|---------------------|----------------------------|----------------------------|
| 29              | 0      | 5,870               | 43,0                       | 86,0                       |
| 30              | 100    |                     | 87,0                       | 17,0                       |

**Corrected continuous operating voltage U<sub>c</sub>' application to evaluate the thermal stability**

| Oscillogram No. | Time min | U <sub>c</sub> ' kV | Current + mA <sub>cr</sub> | Current - mA <sub>cr</sub> | Power W | Temperature °C |
|-----------------|----------|---------------------|----------------------------|----------------------------|---------|----------------|
| 31              | 0        | 4,692               | 0,92                       | 0,93                       | 0,70    | ---            |
|                 | 5        |                     | 0,89                       | 0,91                       | 0,57    | ---            |
|                 | 10       |                     | 0,88                       | 0,90                       | 0,52    | ---            |
| 32              | 15       |                     | 0,88                       | 0,89                       | 0,48    | ---            |
|                 | 20       |                     | 0,87                       | 0,88                       | 0,42    | ---            |
|                 | 25       |                     | 0,86                       | 0,87                       | 0,40    | ---            |
| 33              | 30       |                     | 0,85                       | 0,86                       | 0,37    | ---            |

**Note :** Before the injection of the energy, the temperature of the test sample has been checked with instrument type FLUKE 52II thermometer CESI no.30889

continued

Continued

Sample No.: TOV4

Ambient temperature: 20 °C

Preheating temperature: 66 °C

Date: December 4, 2017

**Lightning current impulses 8/20 µs application**

| Oscillogram No. | Impulse No. | Charging voltage kV | Residual voltage kV | Discharge current kA | Q <sub>th</sub> C | Applicable range for Q <sub>th</sub> C |
|-----------------|-------------|---------------------|---------------------|----------------------|-------------------|--|
| 34              | 1           | 65,0 x 2            | ---                 | 38,06                | 0,56              | 0,495÷0,605                            |
| 35              | 2           | 65,0 x 2            | ---                 | 37,90                | 0,55              | 0,495÷0,605                            |

|                                   |
|-----------------------------------|
| Current impulse waveshape<br>(µs) |
| 8,8 /18,2                         |

**Temporary overvoltage application**

Amplitude claimed by the manufacturer  $U_r' \times 0,960 = 5,805 \times 0,960 = 5,573 \text{ kV}$

Duration claimed by the manufacturer **1000 sec.**

| Oscillogram No. | Time s | U <sub>r</sub> ' kV | Current + mA <sub>cr</sub> | Current - mA <sub>cr</sub> |
|-----------------|--------|---------------------|----------------------------|----------------------------|
| 36              | 0      | 5,573               | 30,0                       | 55,0                       |
| 37              | 1000   |                     | 2,30                       | 3,60                       |

**Corrected continuous operating voltage U<sub>c</sub>' application to evaluate the thermal stability**

| Oscillogram No. | Time min | U <sub>c</sub> ' kV | Current + mA <sub>cr</sub> | Current - mA <sub>cr</sub> | Power W | Temperature °C |
|-----------------|----------|---------------------|----------------------------|----------------------------|---------|----------------|
| 38              | 0        | 4,641               | 0,87                       | 0,88                       | 0,60    | ---            |
|                 | 5        |                     | 0,86                       | 0,88                       | 0,56    | ---            |
|                 | 10       |                     | 0,85                       | 0,87                       | 0,52    | ---            |
| 39              | 15       |                     | 0,84                       | 0,86                       | 0,47    | ---            |
|                 | 20       |                     | 0,83                       | 0,85                       | 0,44    | ---            |
|                 | 25       |                     | 0,82                       | 0,84                       | 0,42    | ---            |
| 40              | 30       |                     | 0,81                       | 0,83                       | 0,40    | ---            |

**Note :** Before the injection of the energy, the temperature of the test sample has been checked with instrument type FLUKE 52II thermometer CESI no.30889

**Power frequency voltage versus time test.**

**Application of the temporary overvoltage  $U_{TOV}$  and evaluation of thermal stability  
( WITHOUT PRIOR DUTY TEST)**

Test circuit: A0123-A0130-A0020

Sample No.: TOV5

Preheating temperature: 66 °C

Date: October 6, 2017

**Temporary overvoltage application**

Amplitude claimed by the manufacturer  $U_r' \times 1,130 = 5,794 \times 1,130 = 6,547 \text{ kV}$

Duration claimed by the manufacturer **10 sec.**

| Oscillogram No. | Time s | Voltage kV | Current + mA <sub>cr</sub> | Current - mA <sub>cr</sub> | Power W |
|-----------------|--------|------------|----------------------------|----------------------------|---------|
| 41              | 0      | 6,547      | 193,0                      | 200,0                      | ---     |
| 42              | 10     |            | 167,0                      | 176,0                      |         |

**Corrected continuous operating voltage  $U_c'$  application to evaluate the thermal stability**

| Oscillogram No. | Time min | $U_c'$ kV | Current + mA <sub>cr</sub> | Current - mA <sub>cr</sub> | Power W | Temperature °C |
|-----------------|----------|-----------|----------------------------|----------------------------|---------|----------------|
| 43              | 0,5      | 4,632     | 0,74                       | 0,76                       | 0,47    | ---            |
|                 | 5        |           | 0,73                       | 0,75                       | 0,46    | ---            |
|                 | 10       |           | 0,72                       | 0,74                       | 0,43    | ---            |
| 44              | 15       |           | 0,71                       | 0,74                       | 0,40    | ---            |
|                 | 20       |           | 0,71                       | 0,73                       | 0,36    | ---            |
|                 | 25       |           | 0,70                       | 0,72                       | 0,35    | ---            |
| 45              | 31       |           | 0,69                       | 0,71                       | 0,33    | ---            |

**Note :** Before the injection of the energy, the temperature of the test sample has been checked with instrument type FLUKE 52II thermometer CESI no.30889

continued

Sample No.: TOV6

Preheating temperature: 66 °C

Date: October 6, 2017

**Temporary overvoltage application**

Amplitude claimed by the manufacturer  $U_r' \times 1,040 = 5,816 \times 1,040 = 6,049 \text{ kV}$

Duration claimed by the manufacturer **1000 sec.**

| Oscillogram No. | Time s | Voltage kV | Current +mA <sub>cr</sub> | Current - mA <sub>cr</sub> | Power W |
|-----------------|--------|------------|---------------------------|----------------------------|---------|
| 46              | 0      | 6,049      | 42,0                      | 56,0                       | ---     |
| 47              | 1000   |            | 33,0                      | 38,0                       |         |

**Corrected continuous operating voltage U<sub>c</sub>' application to evaluate the thermal stability**

| Oscillogram No. | Time min | U <sub>c</sub> ' kV | Current + mA <sub>cr</sub> | Current - mA <sub>cr</sub> | Power W | Temperature °C |
|-----------------|----------|---------------------|----------------------------|----------------------------|---------|----------------|
| 48              | 0        | 4,694               | 0,80                       | 0,84                       | 0,84    | ---            |
|                 | 5        |                     | 0,78                       | 0,81                       | 0,69    | ---            |
|                 | 10       |                     | 0,77                       | 0,79                       | 0,62    | ---            |
| 49              | 15       |                     | 0,75                       | 0,77                       | 0,55    | ---            |
|                 | 20       |                     | 0,74                       | 0,76                       | 0,50    | ---            |
|                 | 25       |                     | 0,73                       | 0,75                       | 0,47    | ---            |
| 50              | 30       |                     | 0,72                       | 0,75                       | 0,45    | ---            |

**Note :** Before the injection of the energy, the temperature of the test sample has been checked with instrument type FLUKE 52II thermometer CESI no.30889

continued

**Power frequency voltage versus time test.**

**Lightning impulse residual voltage measurement after the test**

Test circuit: A0120

Date: December 4, 2017

| Sample | Requested current | Charging voltage | Oscillogram | Current waveshape | Discharge current | Residual Voltage |
|--------|-------------------|------------------|-------------|-------------------|-------------------|------------------|
| No.    |                   | kV               | No.         | $\mu$ s           | kA                | kV               |
| TOV1   | I <sub>n</sub>    | 24,8             | 51          | 8,6/18,3          | 10,18             | 14,26            |
| TOV2   |                   | 24,8             | 52          |                   | 10,14             | 14,24            |
| TOV3   |                   | 24,8             | 53          |                   | 10,10             | 14,38            |
| TOV4   |                   | 24,8             | 54          |                   | 10,07             | 14,36            |
| TOV5   |                   | 24,6             | 55          |                   | 10,04             | 14,00            |
| TOV6   |                   | 24,7             | 56          |                   | 10,05             | 14,25            |

Notes:

**Power frequency voltage versus time test.**

**Additional two lightning impulses residual voltage measurement for check no damage occurred during the test**

**Test circuit:** A0120

Date: December 4, 2017

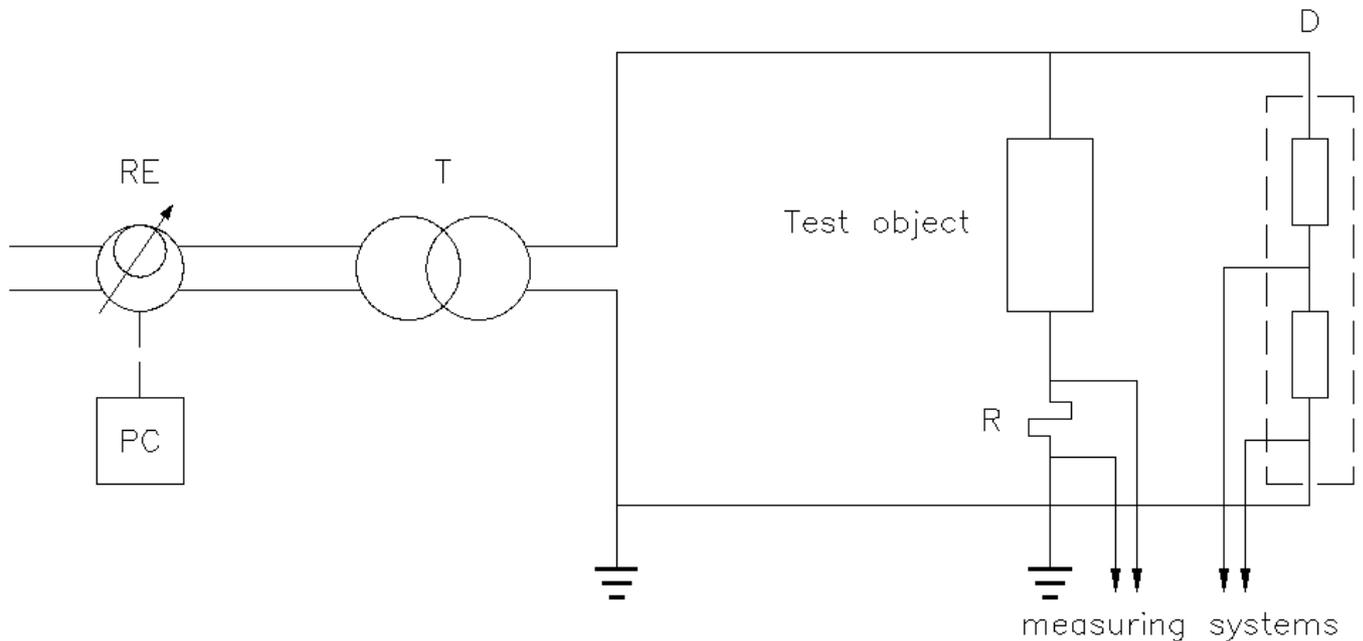
| Sample | Requested current | Charging voltage | Oscillogram | Current waveshape | Discharge current | Residual voltage |
|--------|-------------------|------------------|-------------|-------------------|-------------------|------------------|
| No.    |                   | kV               | No.         | μs                | kA                | kV               |
| TOV1   | 5,26(*)           | 19,4             | 57          | 7,8/20,0          | 5,44              | 13,22            |
|        |                   | 19,4             | 58          |                   | 5,36              | 13,26            |
| TOV2   |                   | 19,4             | 59          |                   | 5,46              | 13,21            |
|        |                   | 19,4             | 60          |                   | 5,42              | 13,24            |
| TOV3   |                   | 19,4             | 67          |                   | 5,33              | 13,33            |
|        |                   | 19,4             | 68          |                   | 5,28              | 13,30            |
| TOV4   |                   | 19,4             | 61          |                   | 5,27              | 13,31            |
|        |                   | 19,4             | 62          |                   | 5,27              | 13,34            |
| TOV5   |                   | 19,4             | 63          |                   | 5,48              | 13,12            |
|        |                   | 19,4             | 64          |                   | 5,45              | 13,10            |
| TOV6   |                   | 19,4             | 65          |                   | 5,31              | 13,36            |
|        |                   | 19,4             | 66          |                   | 5,28              | 13,29            |

Notes:

Requested current =  $0,5 \text{ kA/cm}^2 \times 10,52 \text{ cm}^2 = 5,26 \text{ kA}$

- -where  $0,5 \text{ kA/cm}^2$  is peak current density
- where  $10,52 \text{ cm}^2$  is surface area on the metal-oxide resistor used for this test declared by the manufacturer

## Circuit A0019



## Power frequency supply

- RE - programmable supply type PACIFIC A.C. Power Source 140 ASX.; CESI no. 0560408  
 PC - personal computer  
 T - voltage transformer type SPECIALTRASFO; power 30 kVA; voltage 200 V/15-30 kV

## Current measuring system

- R - Current shunt CESI No.31120;  $R=940,5\ \Omega$   
 - Electro optical system HBM CESI No. 57986(Rx) – 57987 (Tx)  
 OSC - Oscilloscope type NATIONAL INSTRUMENT NI PXI-1031/NI-PXI 8108/NI-PXI 5122;  
 - CESI No 056227- 0562226 (on channel No.1)

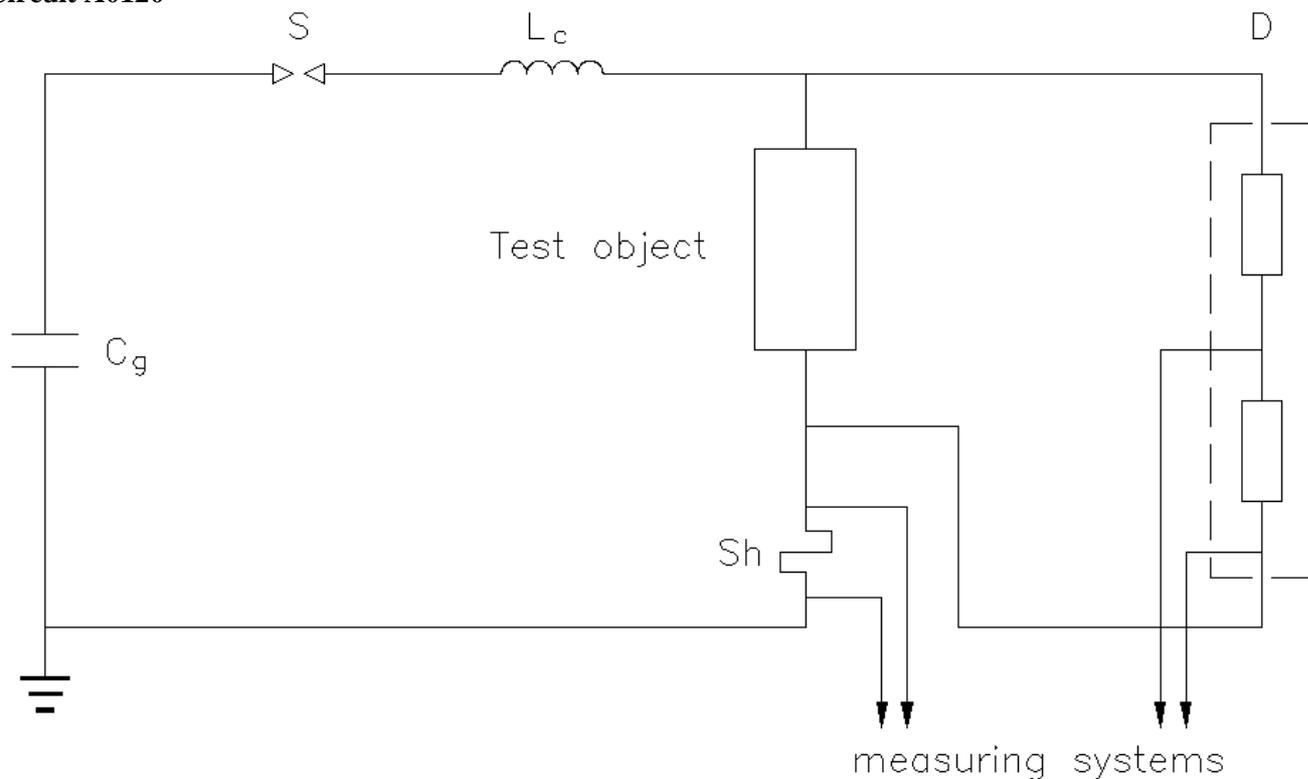
## Voltage measuring system

- D - Voltage divider SAGI; CESI No.11120  
 - Electro optical system type HBM CESI No. 57986(Rx) – 57991 (Tx)  
 OSC - Oscilloscope type NATIONAL INSTRUMENT NI PXI-1031/NI-PXI 8108/NI-PXI 5122;  
 - CESI No 056227- 0562226 (on channel No.2)

## SOFTWARE SYSTEM:

- SW - S.A.D. Surge arrester version 2.0

**Circuit A0120**



**Impulse generator**

- No. of stages    1
- Cg                6,64  $\mu$ F
- Lc                6  $\mu$ H
  
- S                 - Spark-gap

**Voltage measuring system.**

- D                 - Voltage divider SAGI; CESI No.11120
- Electro optical system type HBM CESI No. 57986(Rx) – 57991 (Tx)
- OSC             - Oscilloscope type NATIONAL INSTRUMENT NI PXI-1031/NI-PXI 8108/NI-PXI 5122
- CESI No 056227- 0562226 (on channel No.2)

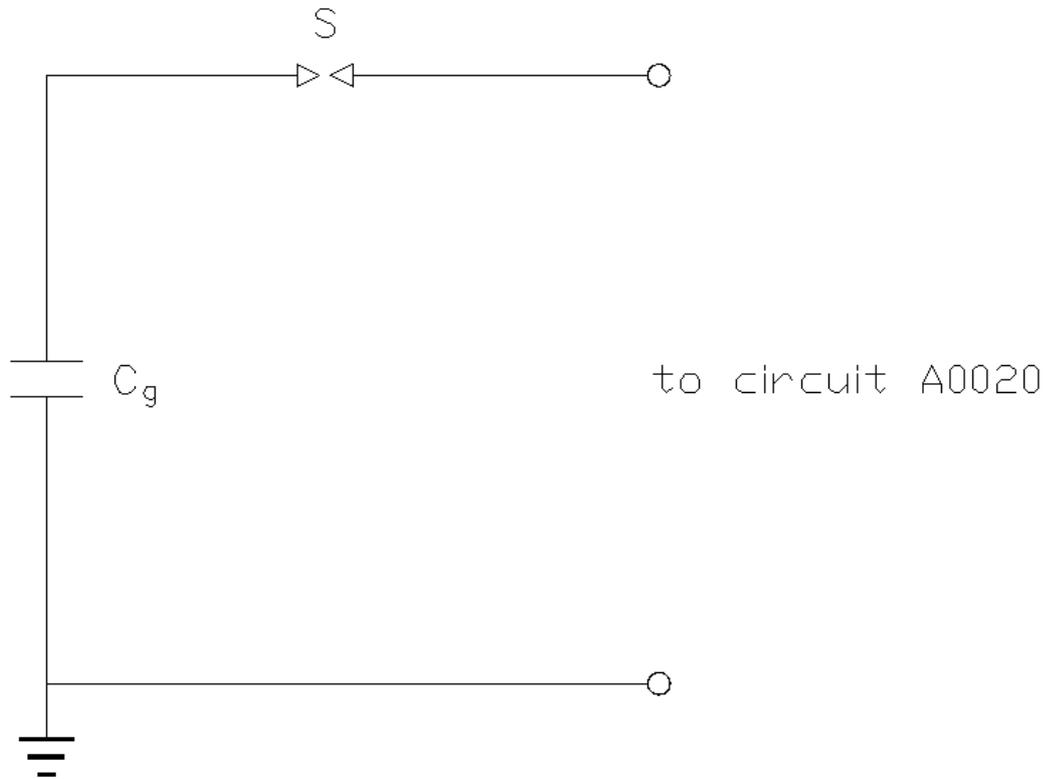
**Current measuring system**

- Sh                - Current shunt CESI No.6042; R= 2 m $\Omega$ ; peak current= 250 kA
- Electro optical system HBM CESI No. 57986(Rx) – 57987 (Tx)
- OSC             - Oscilloscope type NATIONAL INSTRUMENT NI PXI-1031/NI-PXI 8108/NI-PXI 5152;
- CESI No 056227- 0562226 (on channel No.1)

**SOFTWARE SYSTEM:**

- SW               - S.A.D. Surge arrester version 2.0

Circuit A0123



Impulse generator circuit for injection of  $Q_{th}$

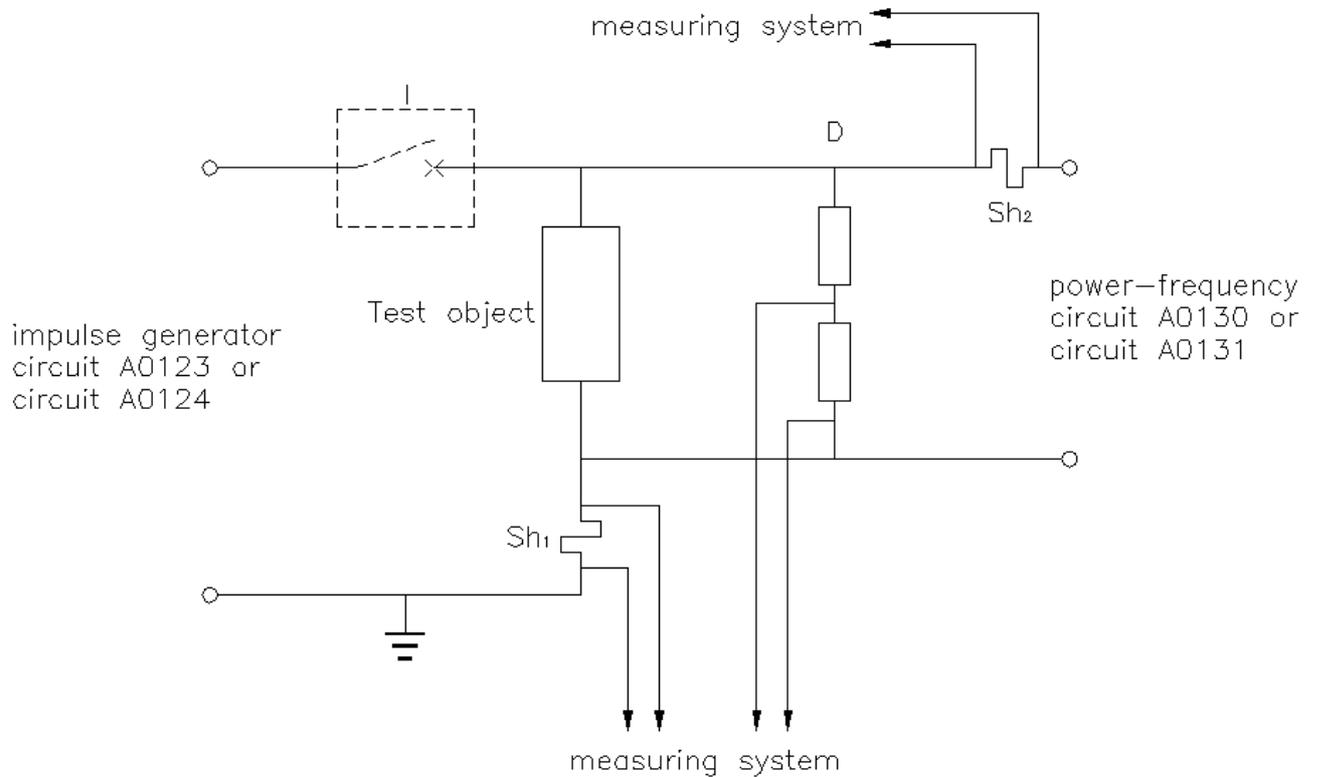
No. of stages 2

$C_g$  2,91  $\mu F$

$L_c$  12  $\mu H$

$S$  - spark-gap

**Circuit A0020**



**Impulse generator circuit A0123**

**Impulsive current measuring system**

- Sh<sub>1</sub> - Current shunt CESI No.6042; R= 2 m Ω
- Electro optical system HBM CESI No. 57986(Rx) – 57987 (Tx)
- OSC<sub>2,3</sub> - Oscilloscope type NATIONAL INSTRUMENT NI PXI-1031/NI-PXI 8108/NI-PXI 5122
- CESI No 056227- 0562226 (on channel No.2)
- I - Circuit-breaker

**Power frequency circuit A0131**

**Voltage measuring system.**

- D - Voltage divider SAGI; CESI No.11120
- Electro optical system HBM CESI No. 57986(Rx) – 57991 (Tx)
- OSC<sub>2,3</sub> - Oscilloscope type NATIONAL INSTRUMENT NI PXI-1031/NI-PXI 8108/NI-PXI 5122
- CESI No 056227- 0562226 (on channel No.2)

**Current measuring system**

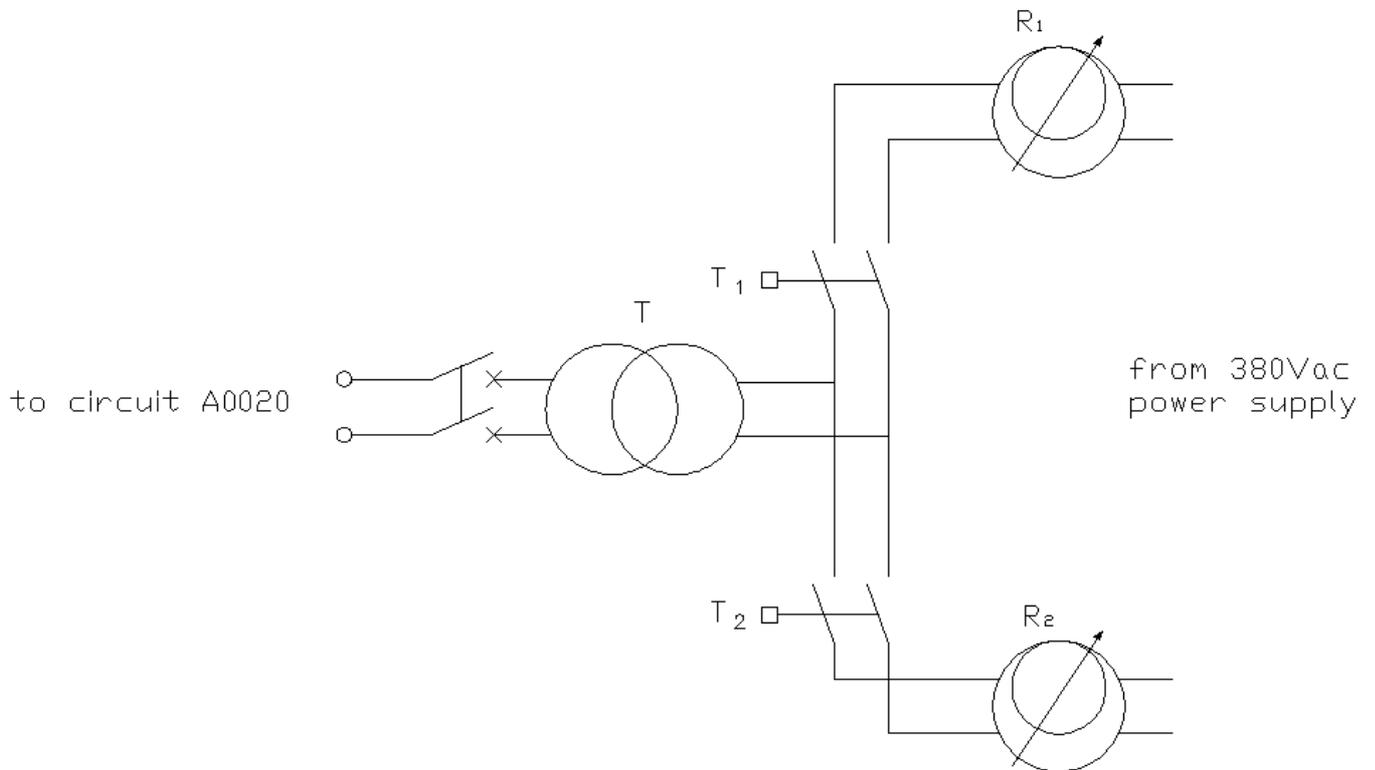
- Sh<sub>2</sub> (TOV - MCOV) - Current shunt CESI n. 058315 R= 500 Ω
- Electro optical system CESI No. 57986(Rx) – 58294 (Tx)
- OSC<sub>2,3</sub> - Oscilloscope type NATIONAL INSTRUMENT NI PXI-1031/NI-PXI 8108/NI-PXI 5122;
- CESI No 056227- 0562226 (on channel No.1)

**SOFTWARE SYSTEM:**

- SW - S.A.D. Surge arrester version 2.0



Circuit A0131

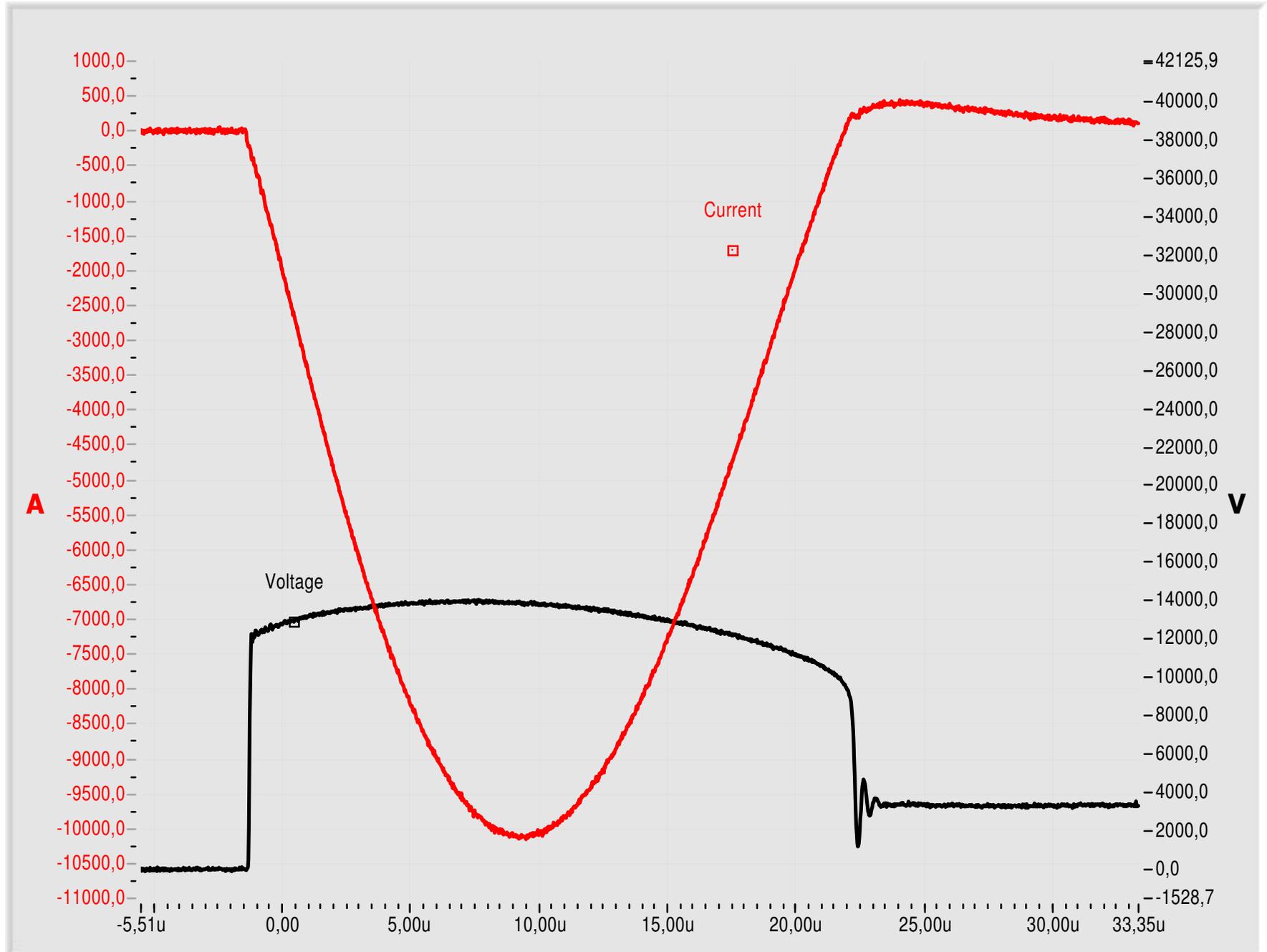


Power-frequency circuit

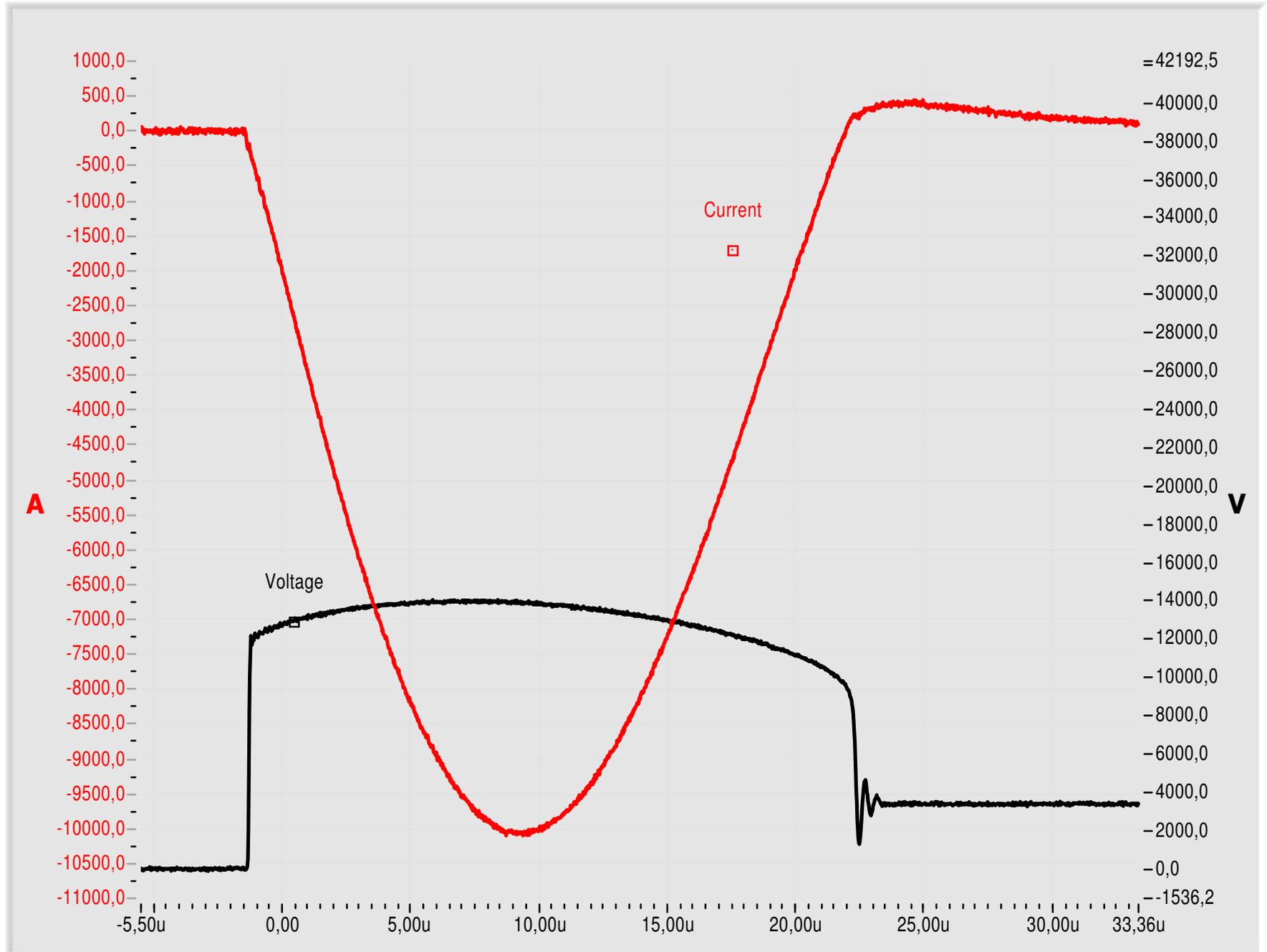
from 380Vac power supply

- R<sub>1</sub> single-phase voltage regulator CORMES; power 20 kVA; voltage 380/04220 Vac
- R<sub>2</sub> single-phase voltage regulator CORMES; power 10 kVA; voltage 380/04220 Vac
- T<sub>1</sub> voltage transformer type SPECIALTRASFO; power 30 kVA; voltage 200-400 V/15-30 kV

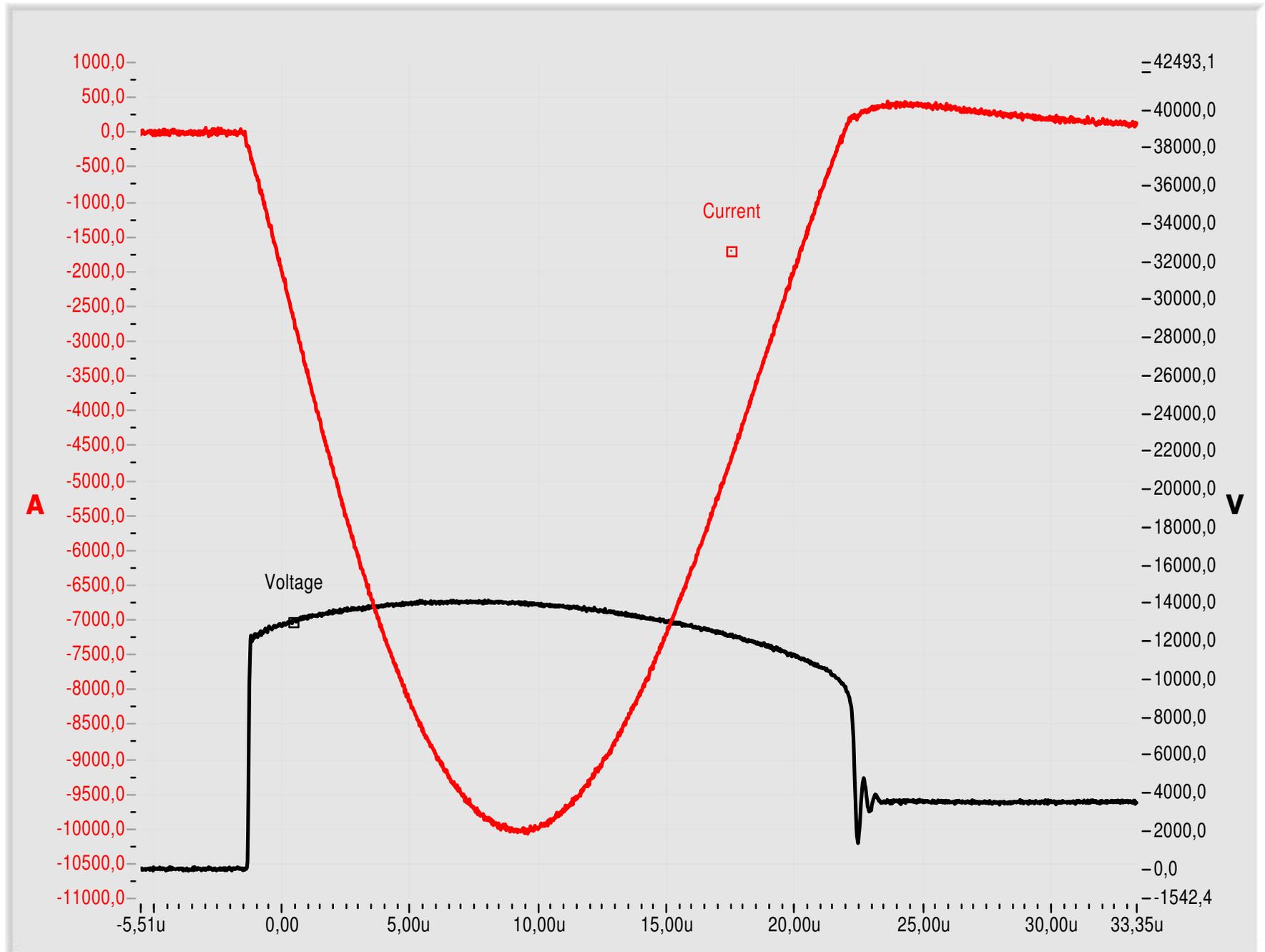
CESI B7020147 Oscillogram n. 1



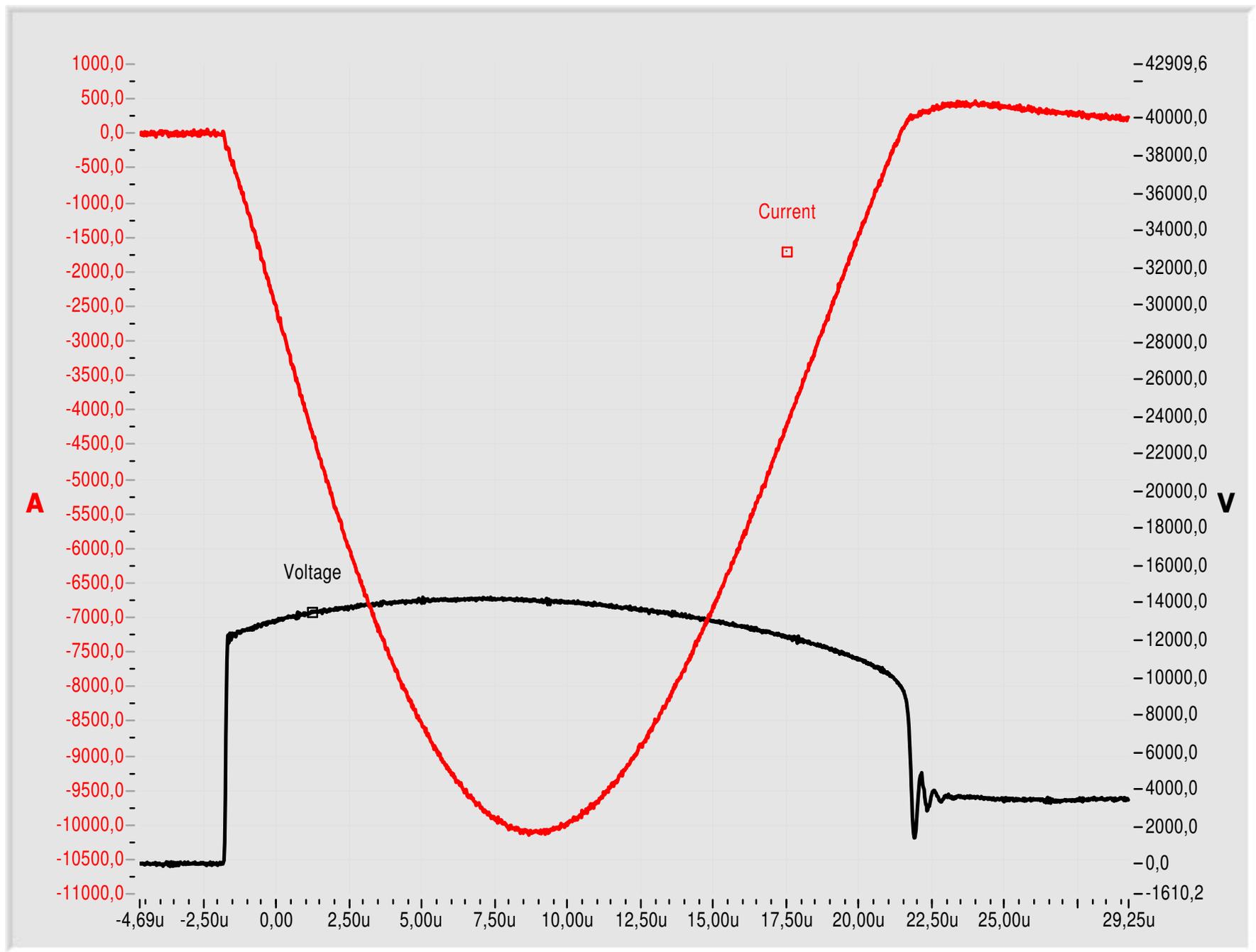
CESI B7020147 Oscillogram n. 2



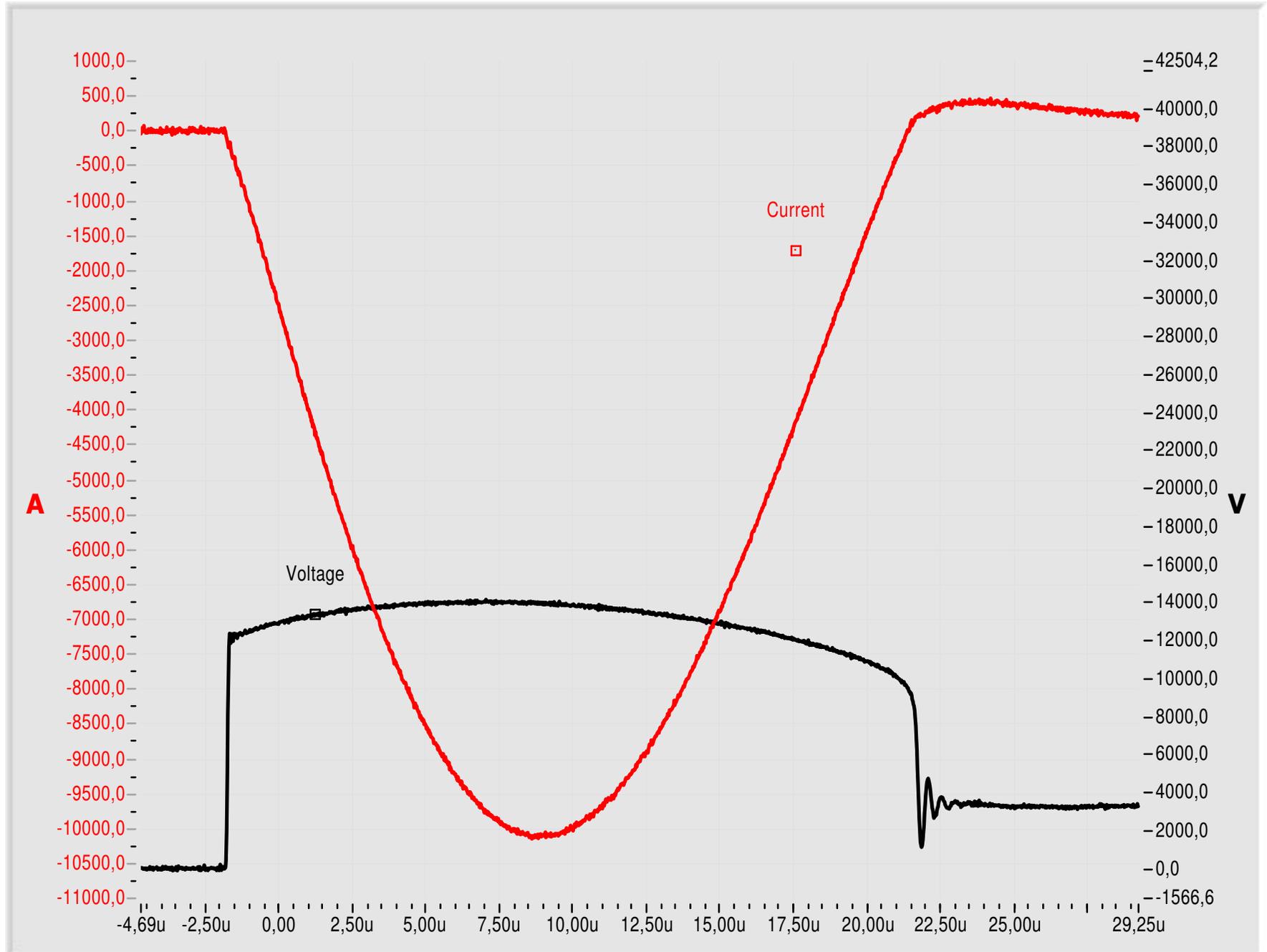
CESI B7020147 Oscillogram n. 3



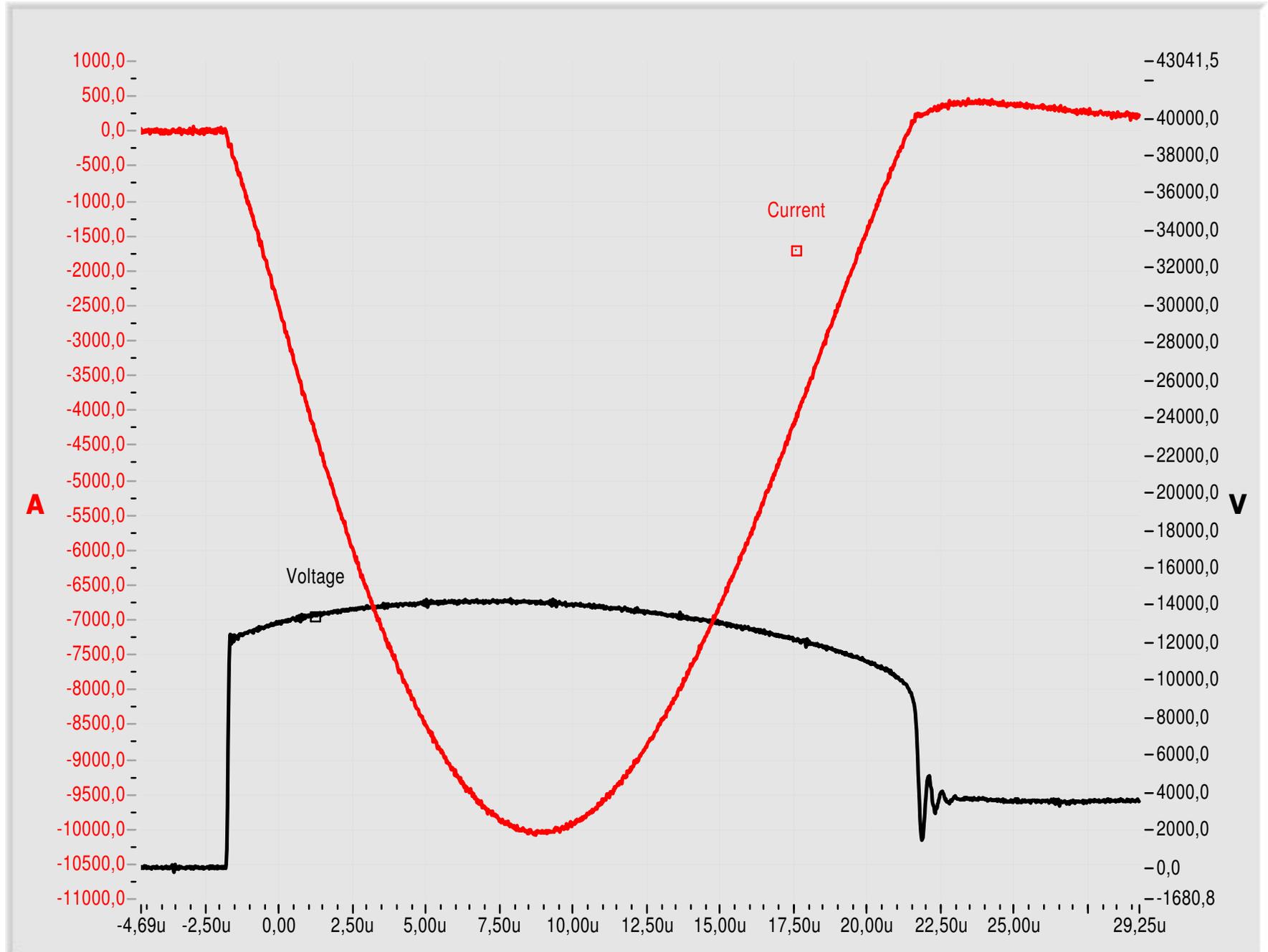
CESI B7020147 Oscillogram n. 4



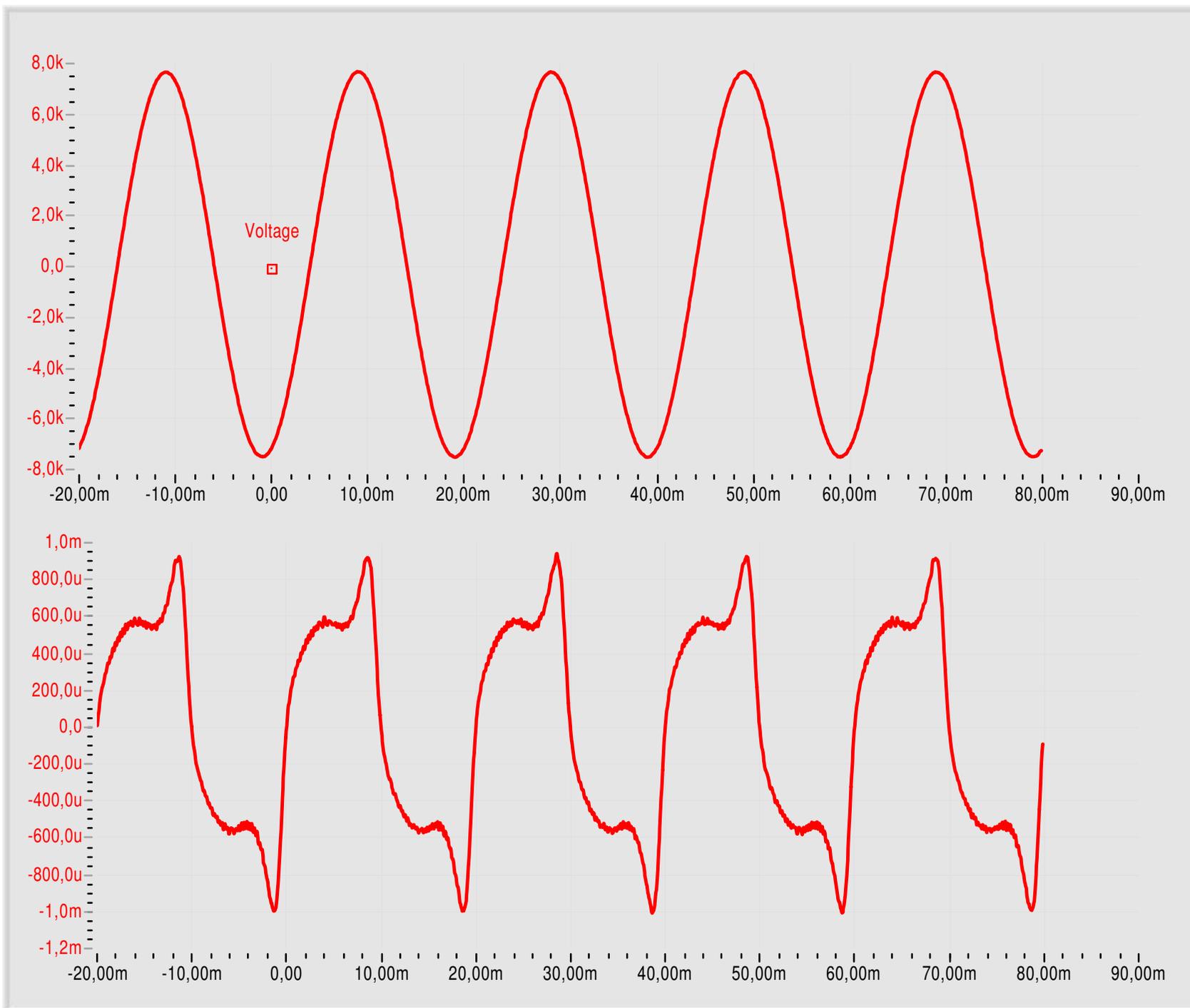
CESI B7020147 Oscillogram n. 5



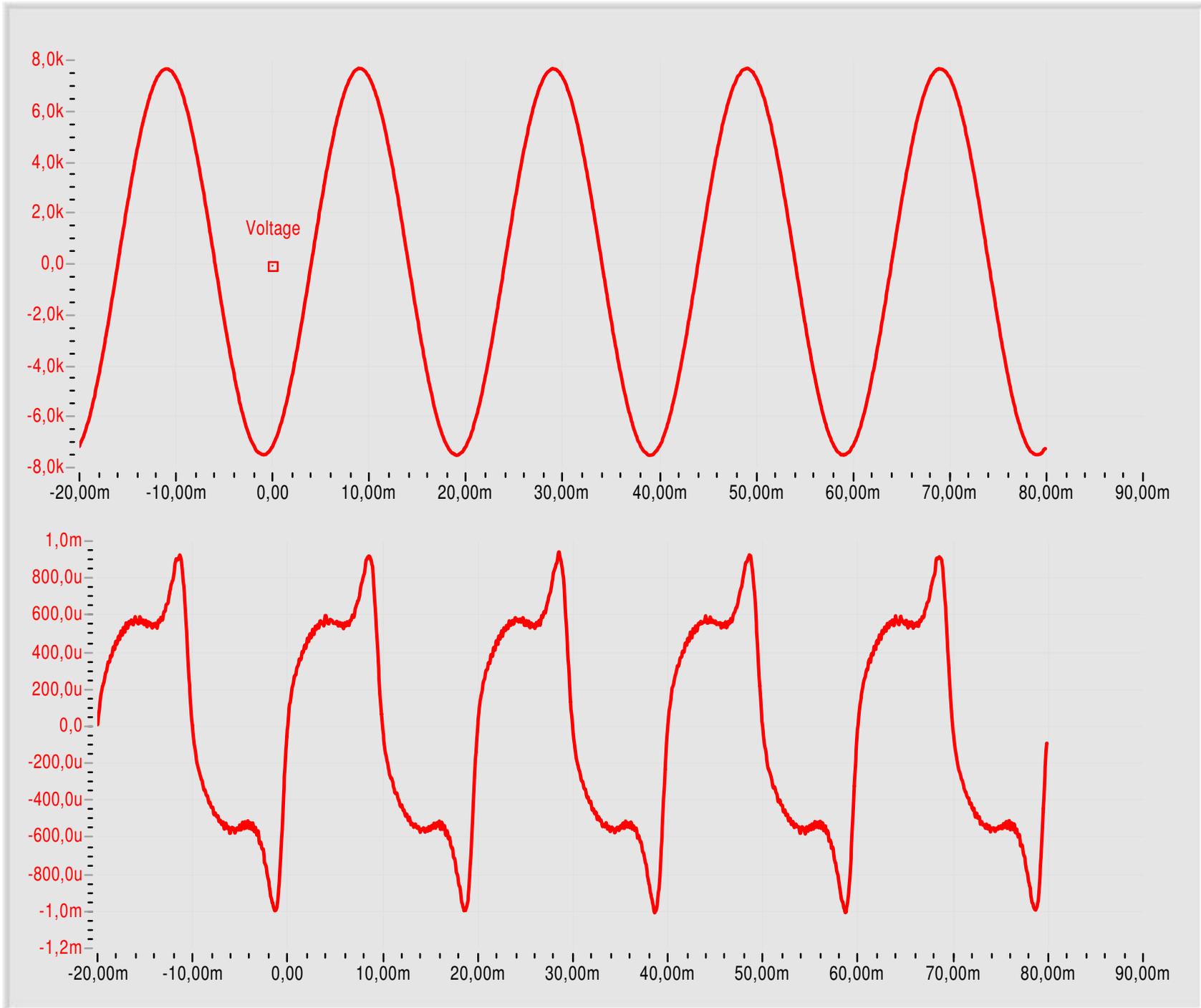
CESI B7020147 Oscillogram n. 6



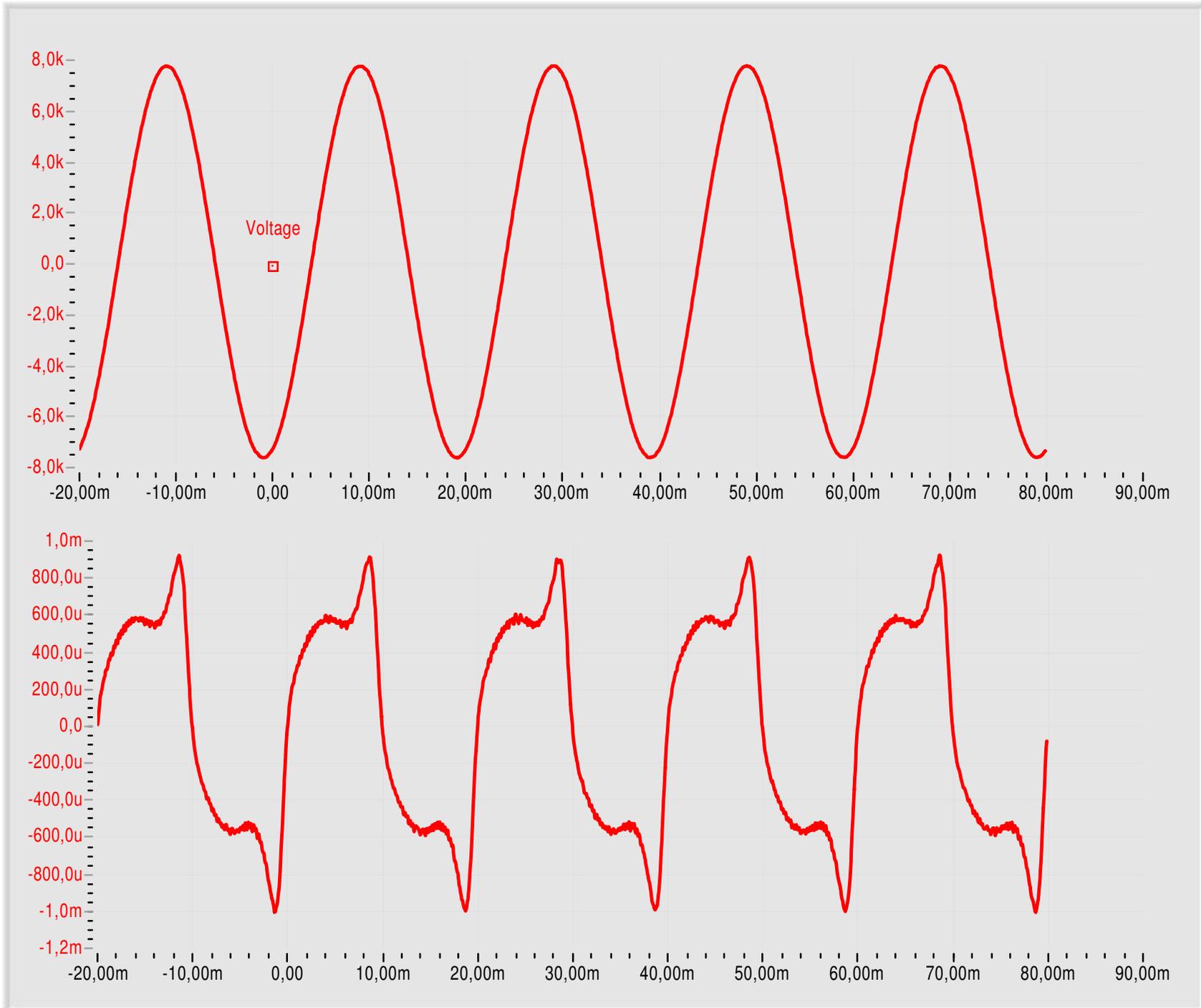
CESI B7020147 Oscillogram n. 7



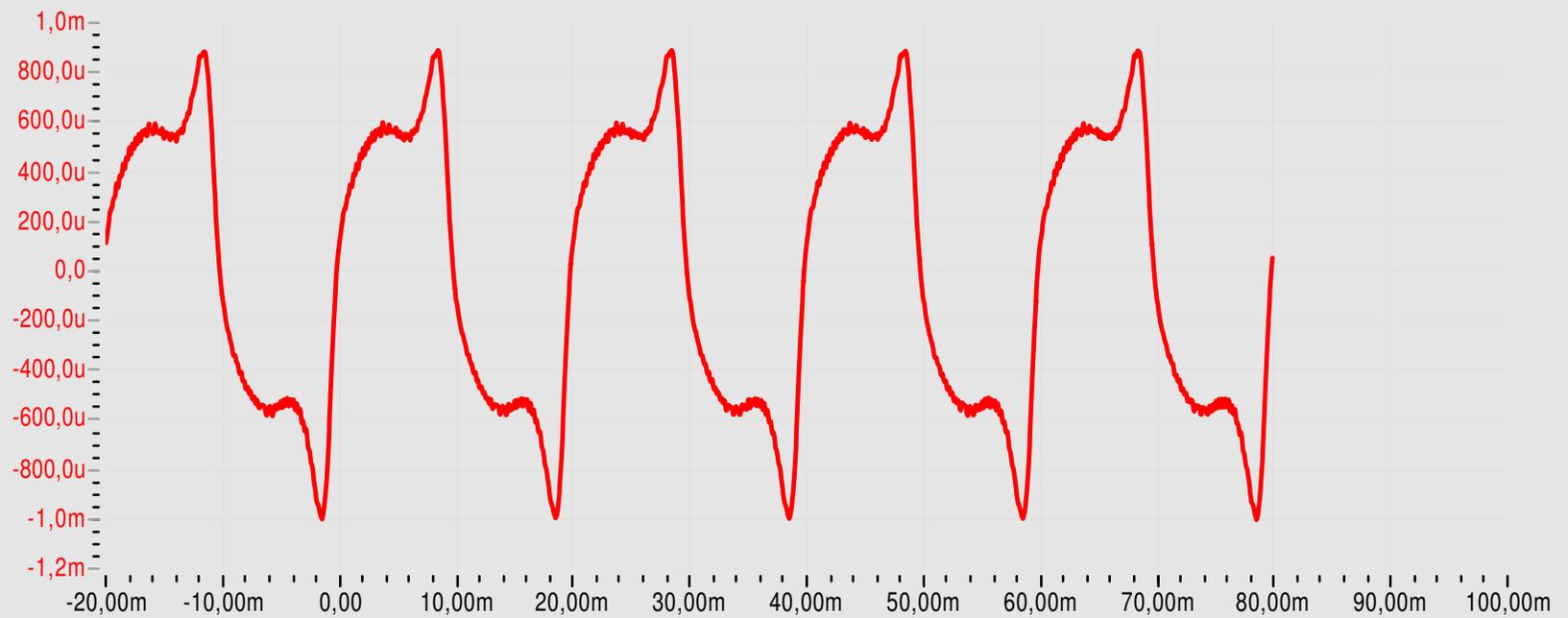
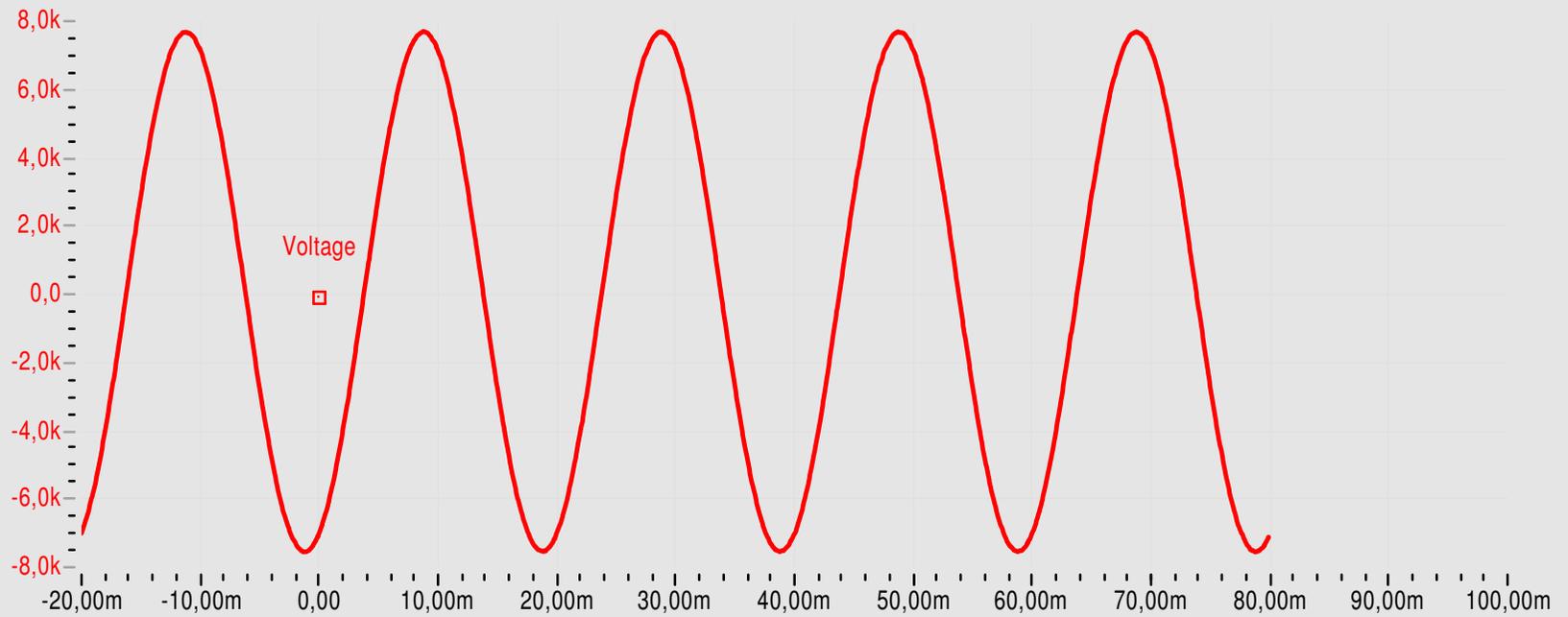
CESI B7020147 Oscillogram n. 8



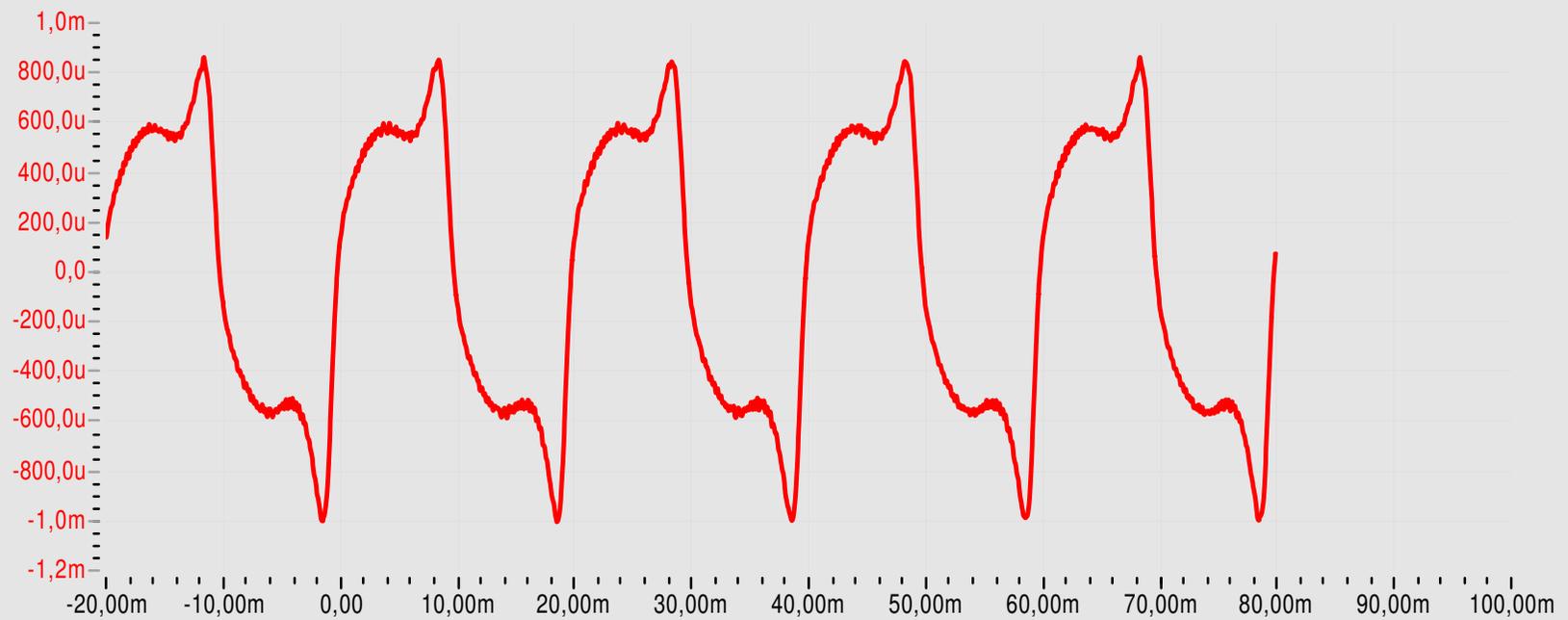
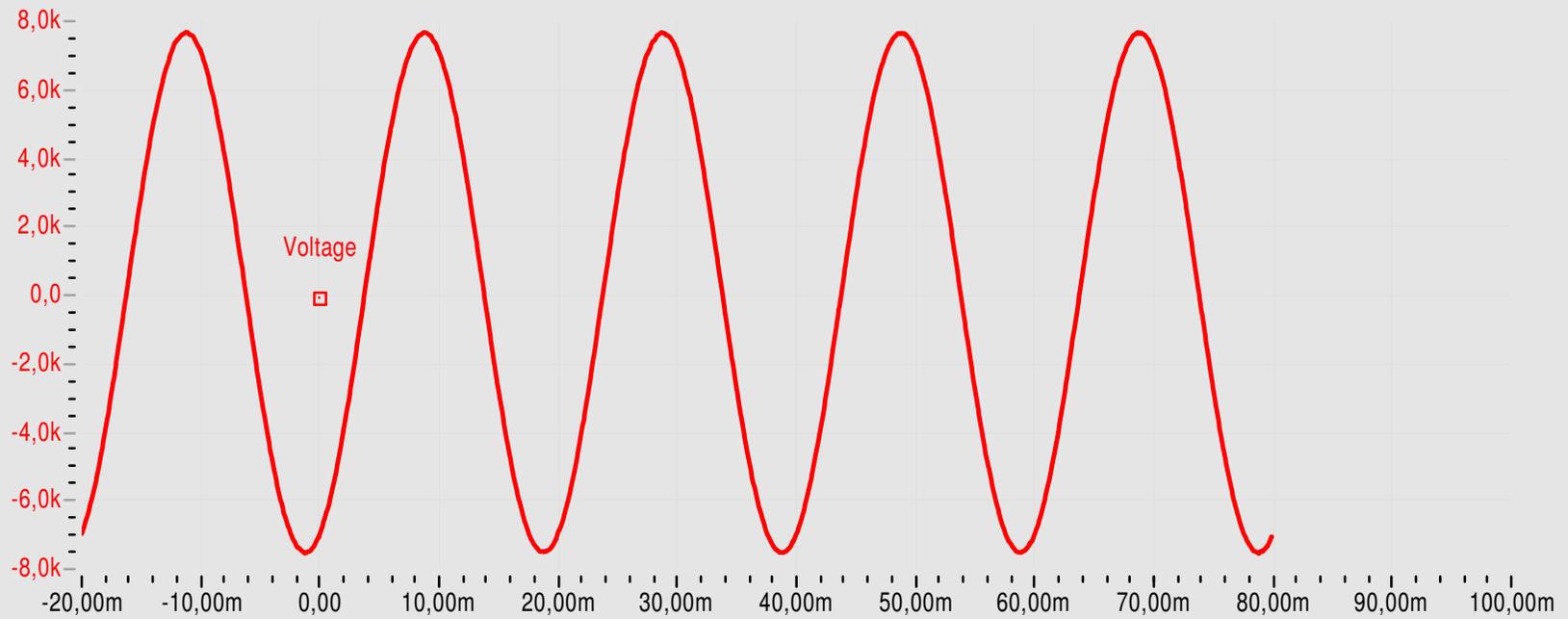
CESI B7020147 Oscillogram n. 9



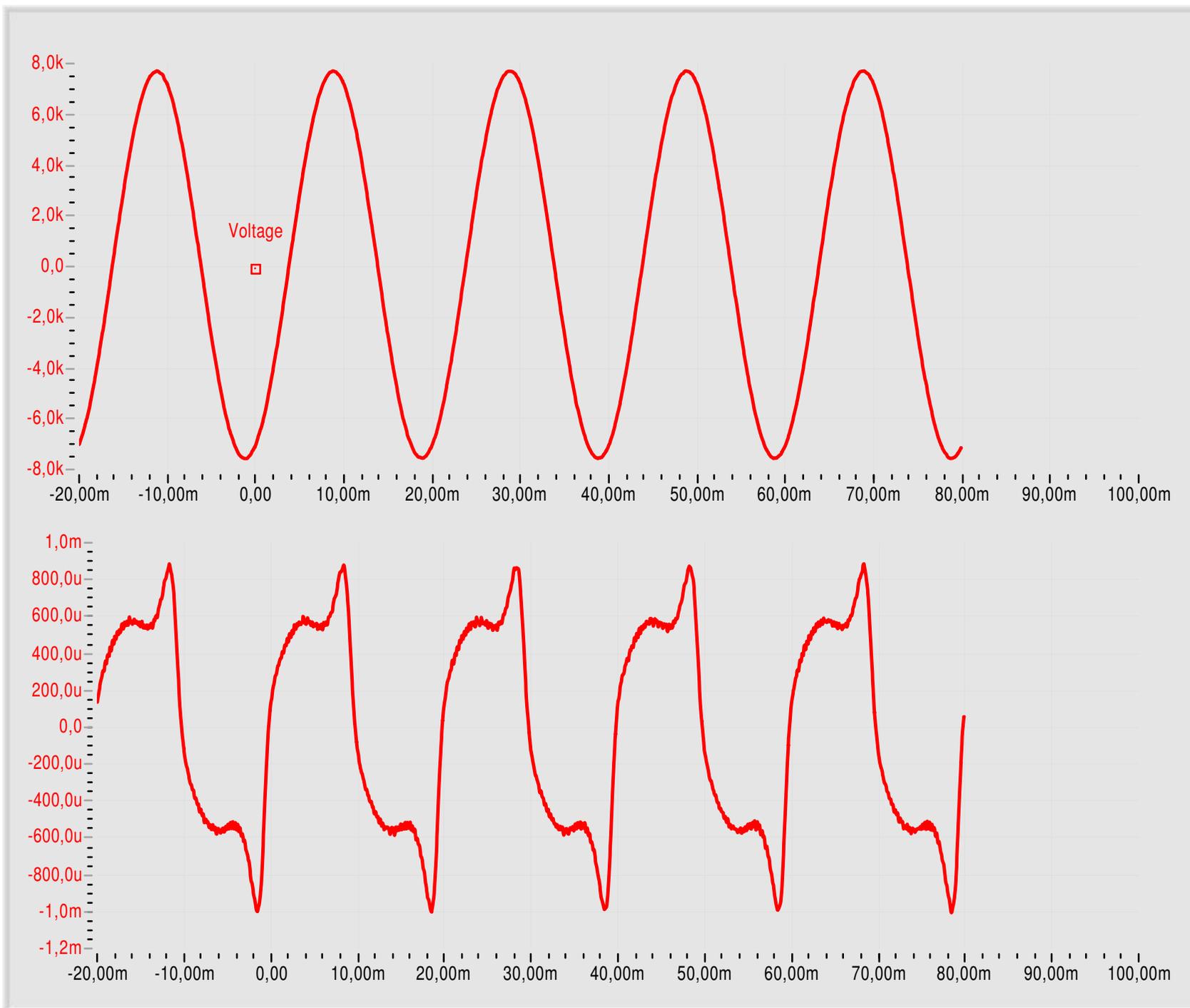
CESI B7020147 Oscillogram n. 10



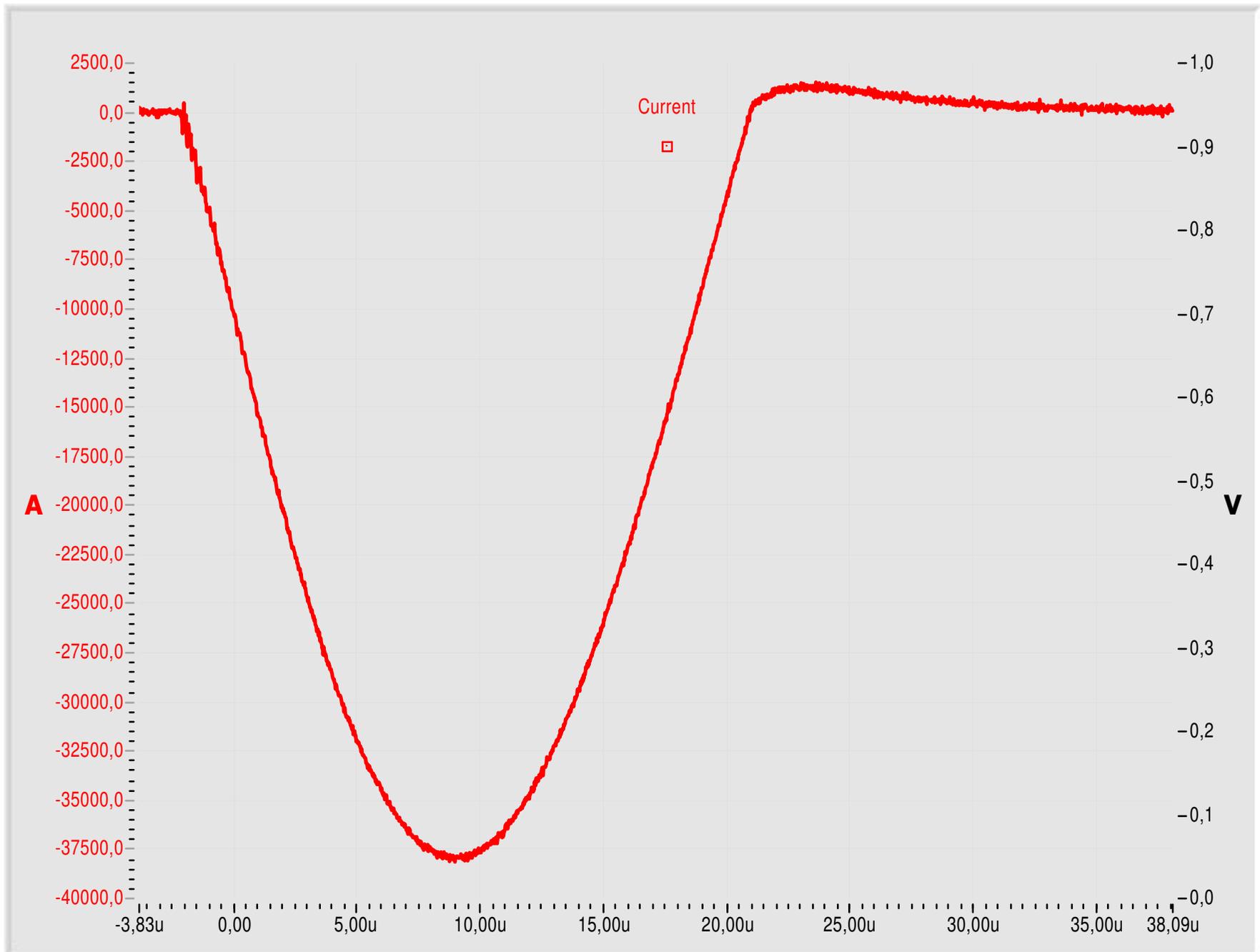
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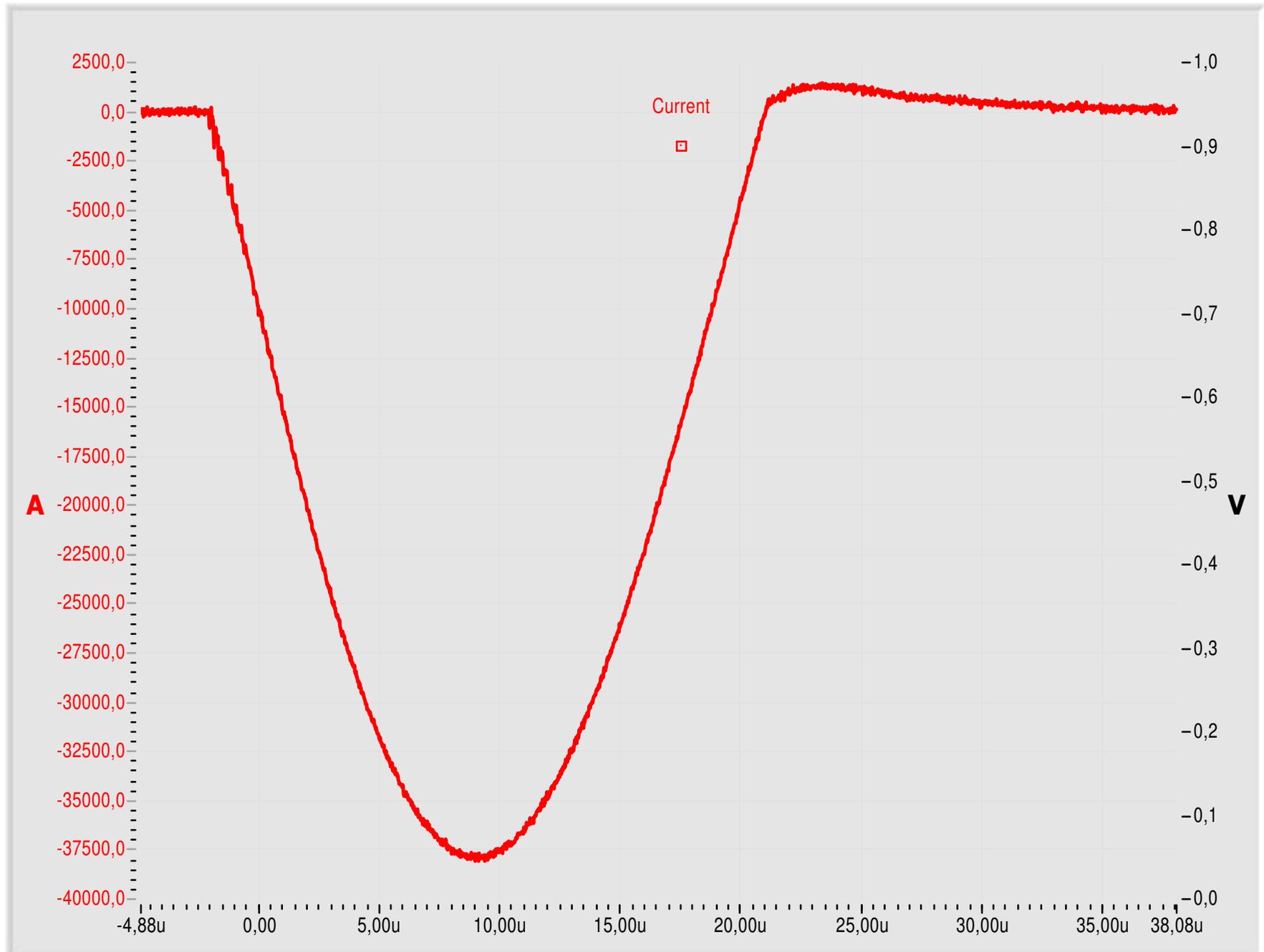
CESI B7020147 Oscillogram n. 12



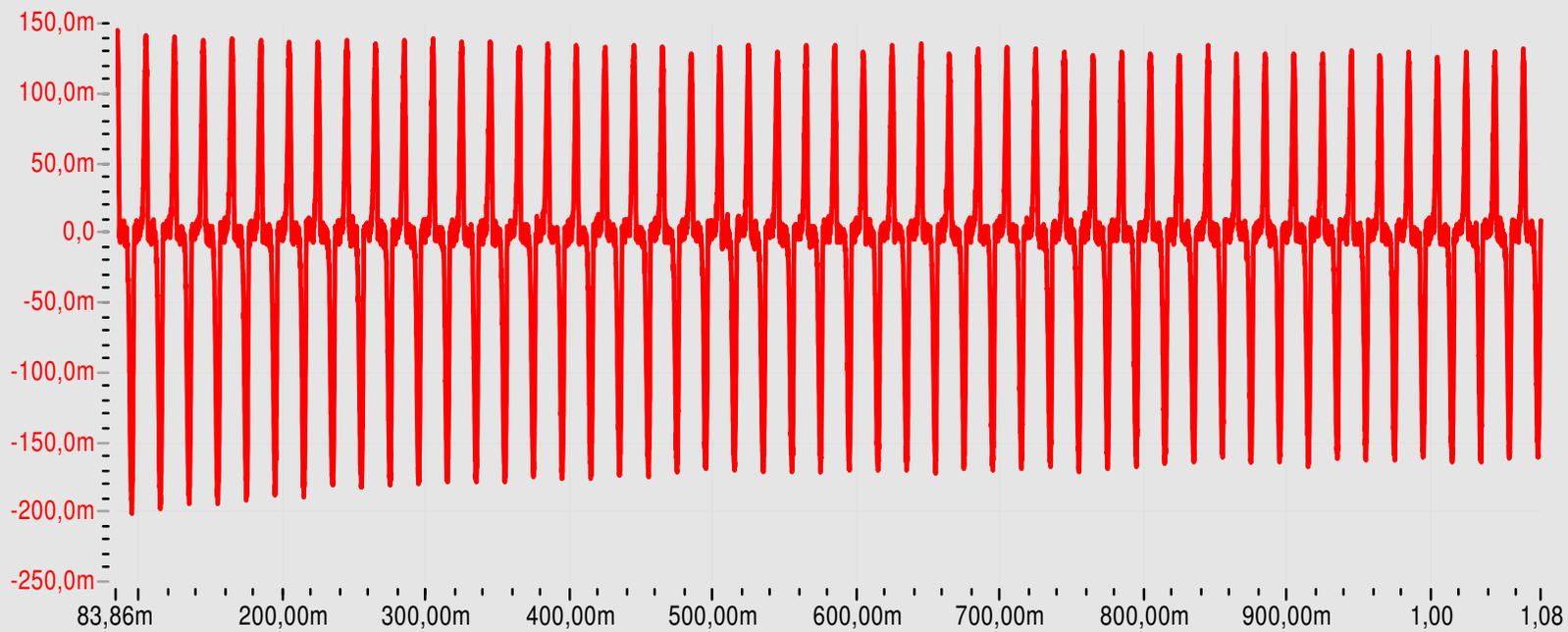
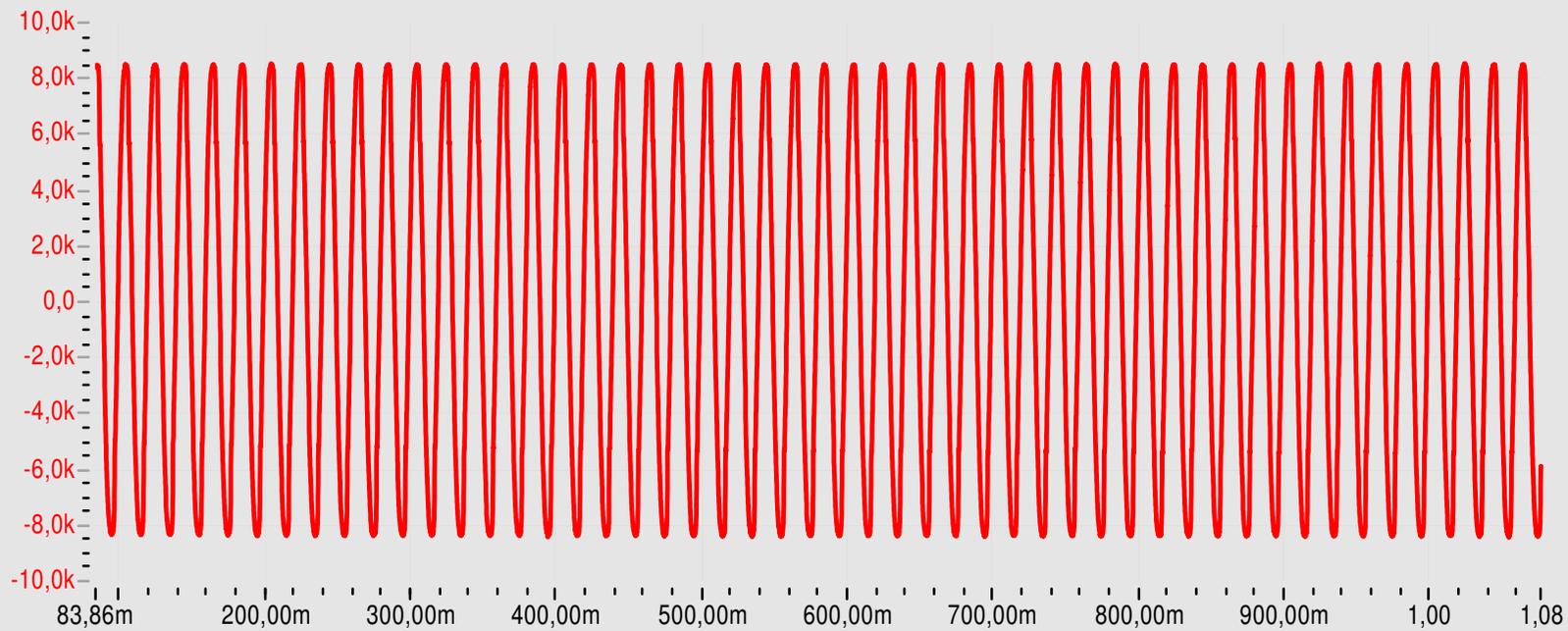
CESI B7020147 Oscillogram n. 13



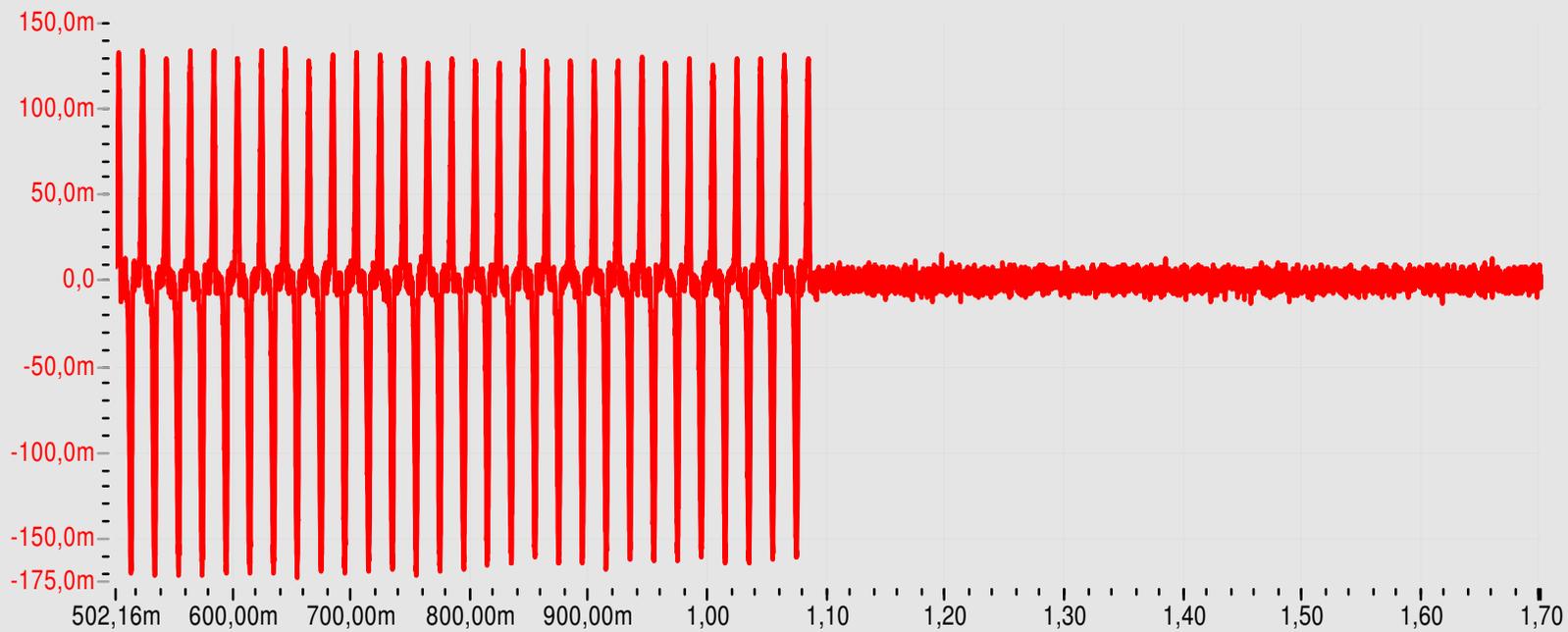
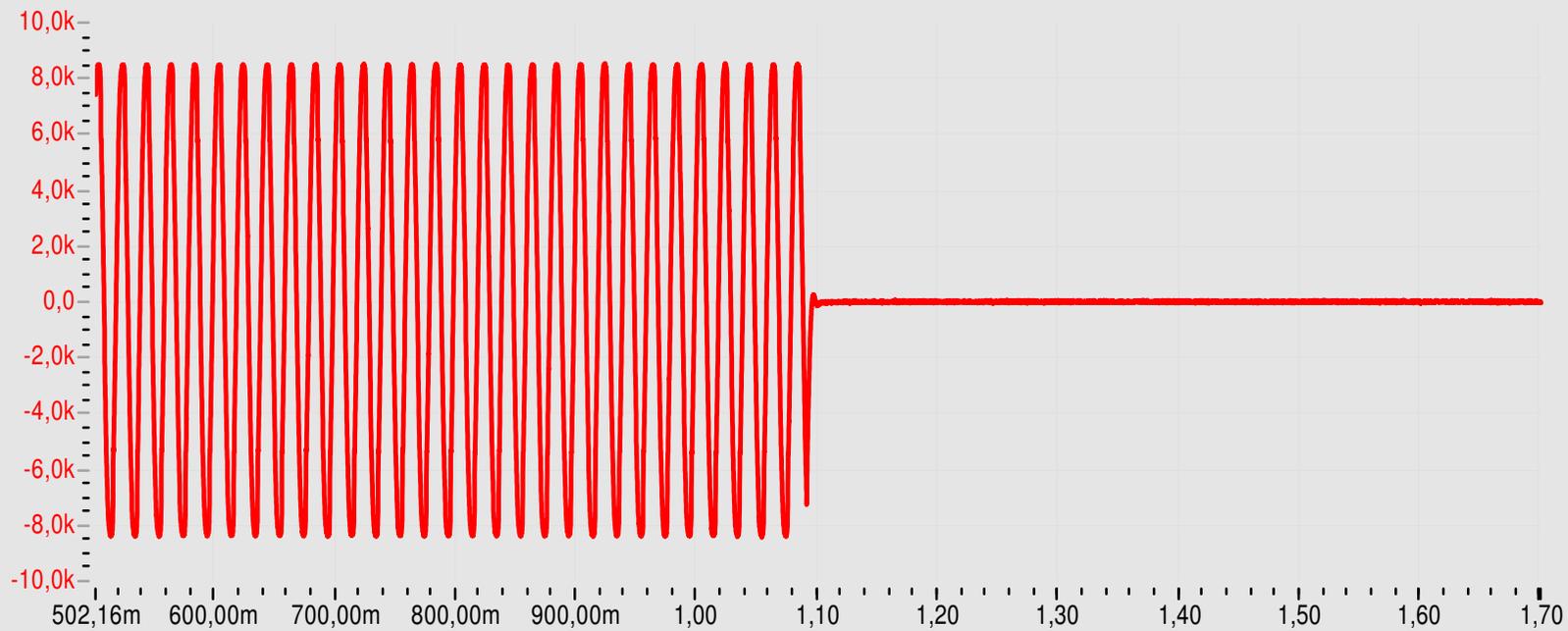
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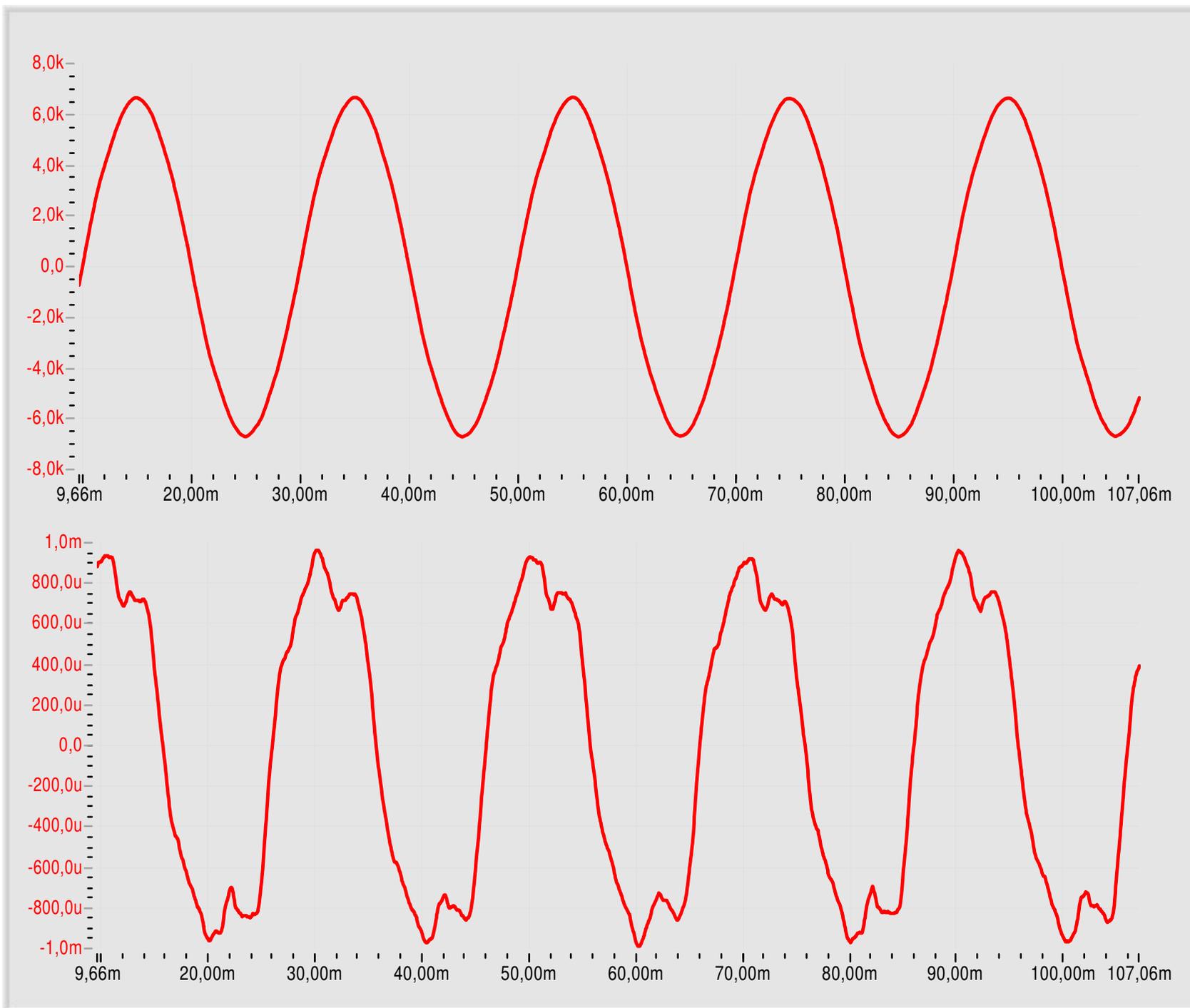
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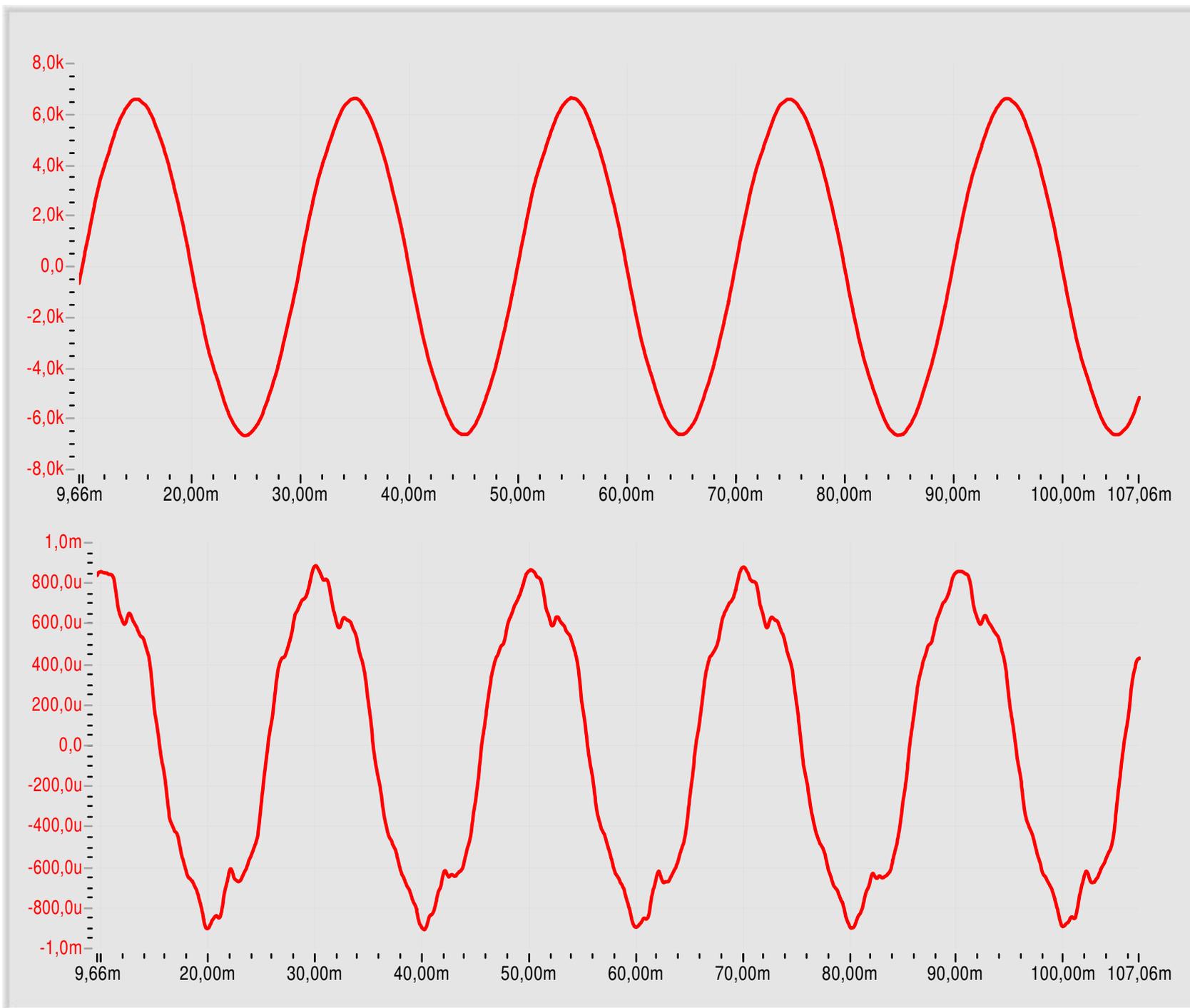
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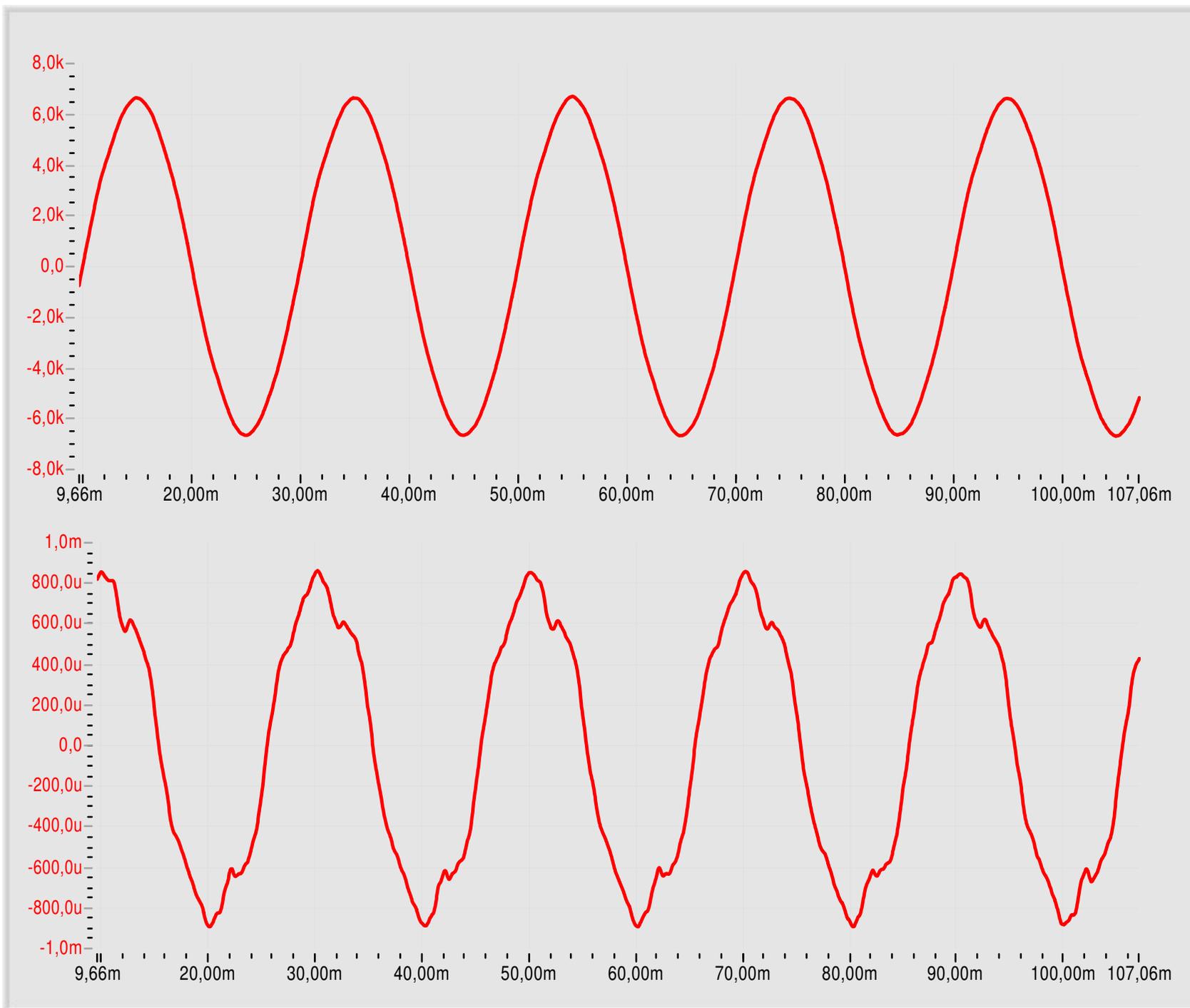
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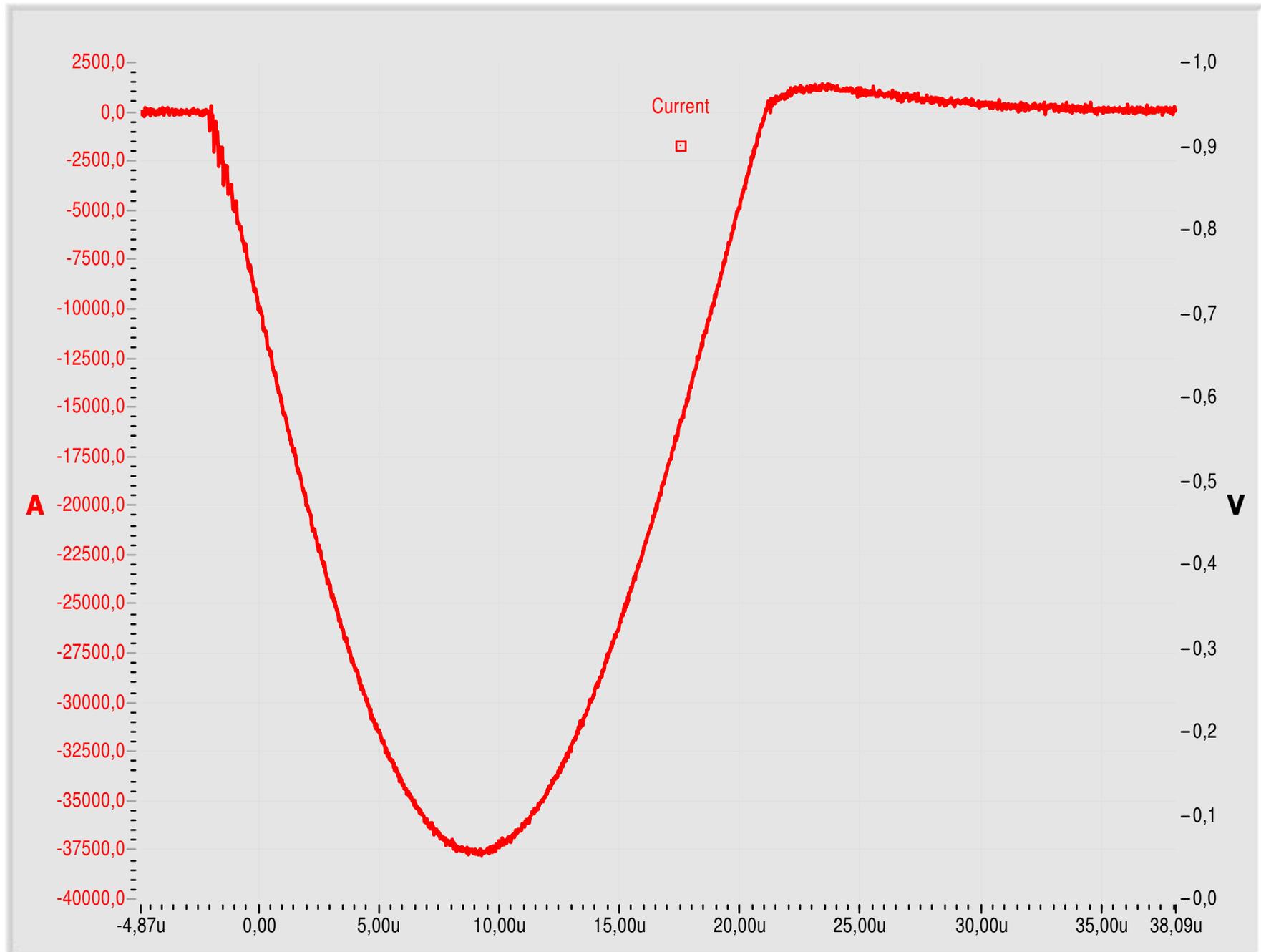
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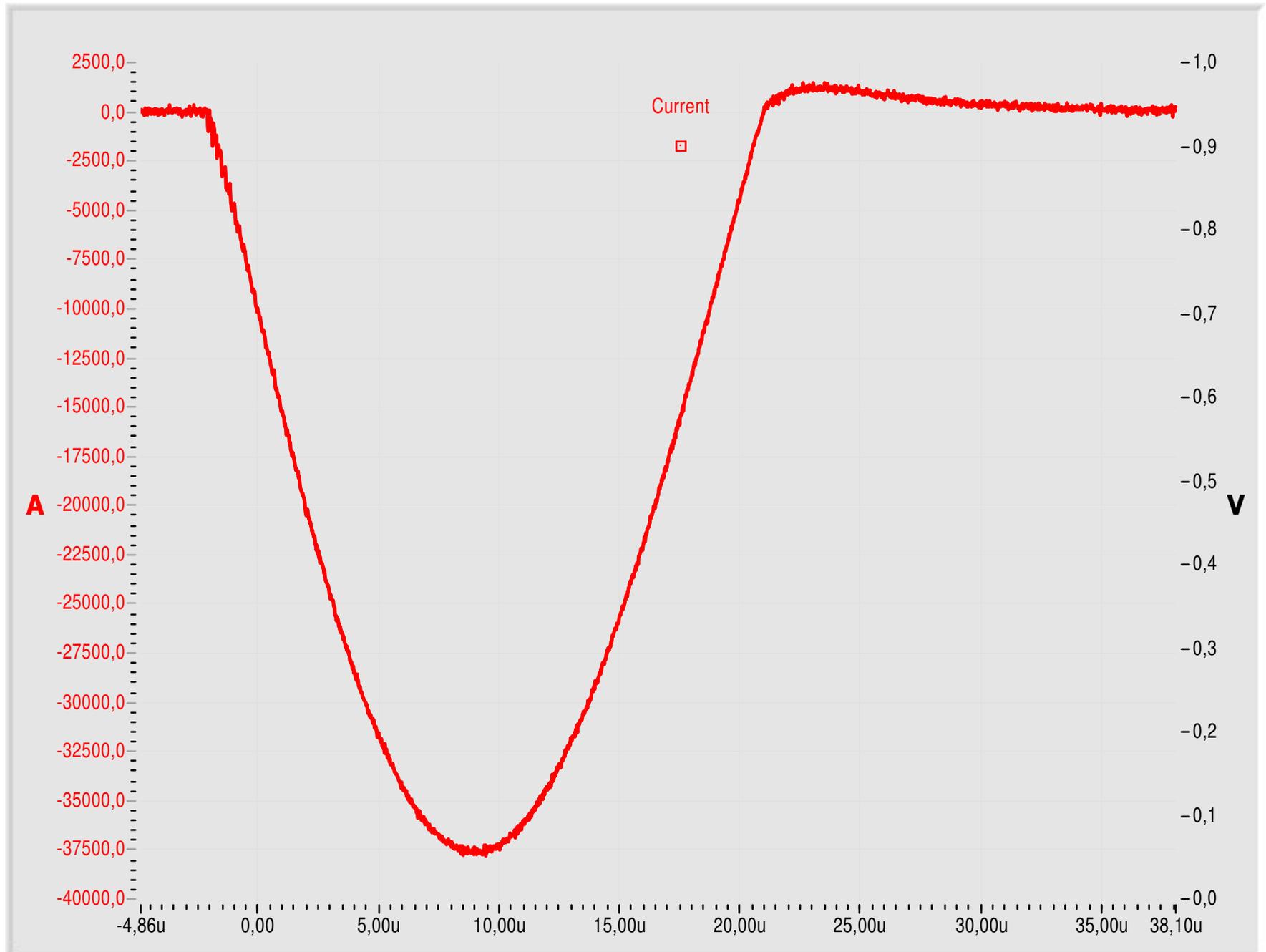
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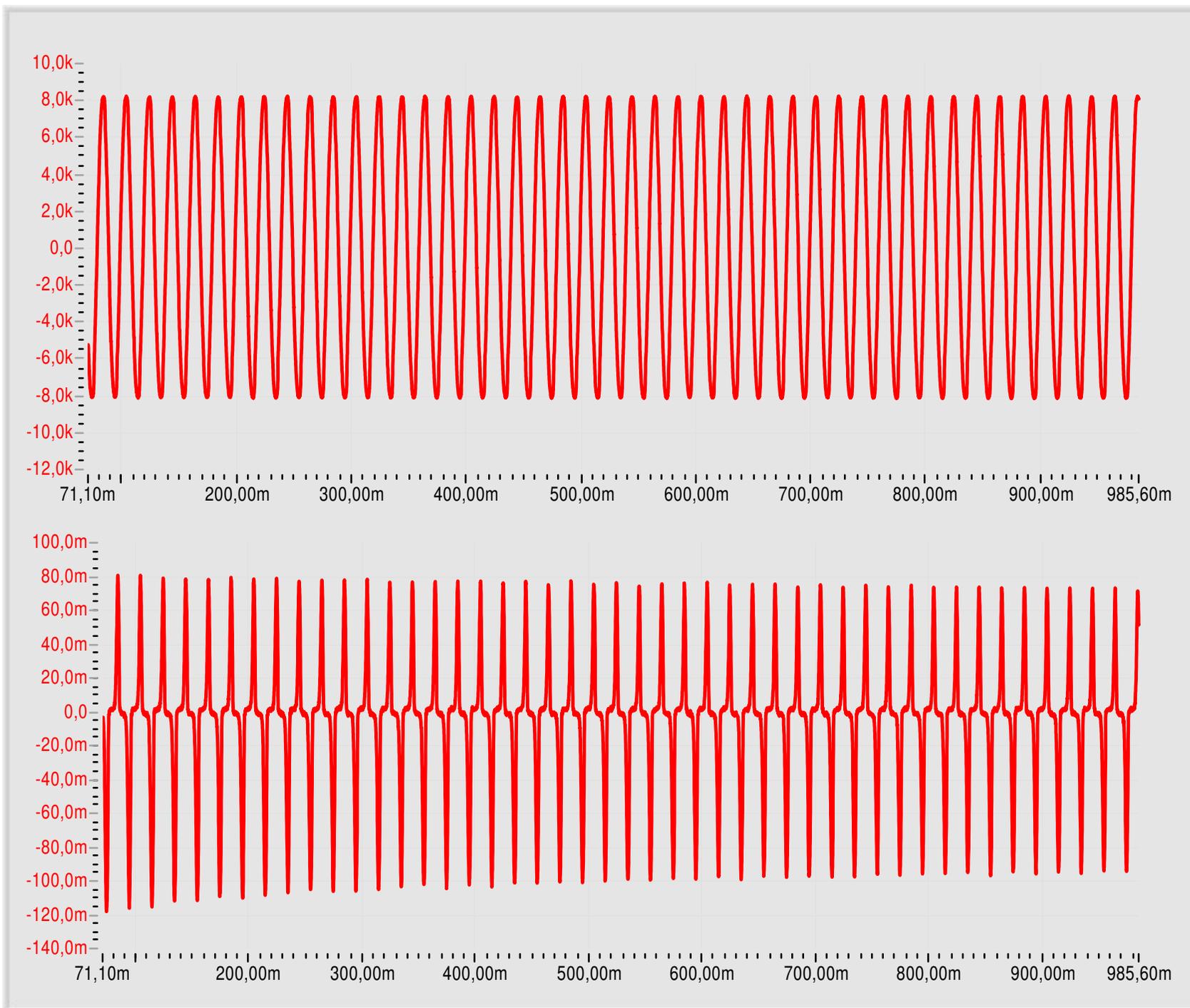
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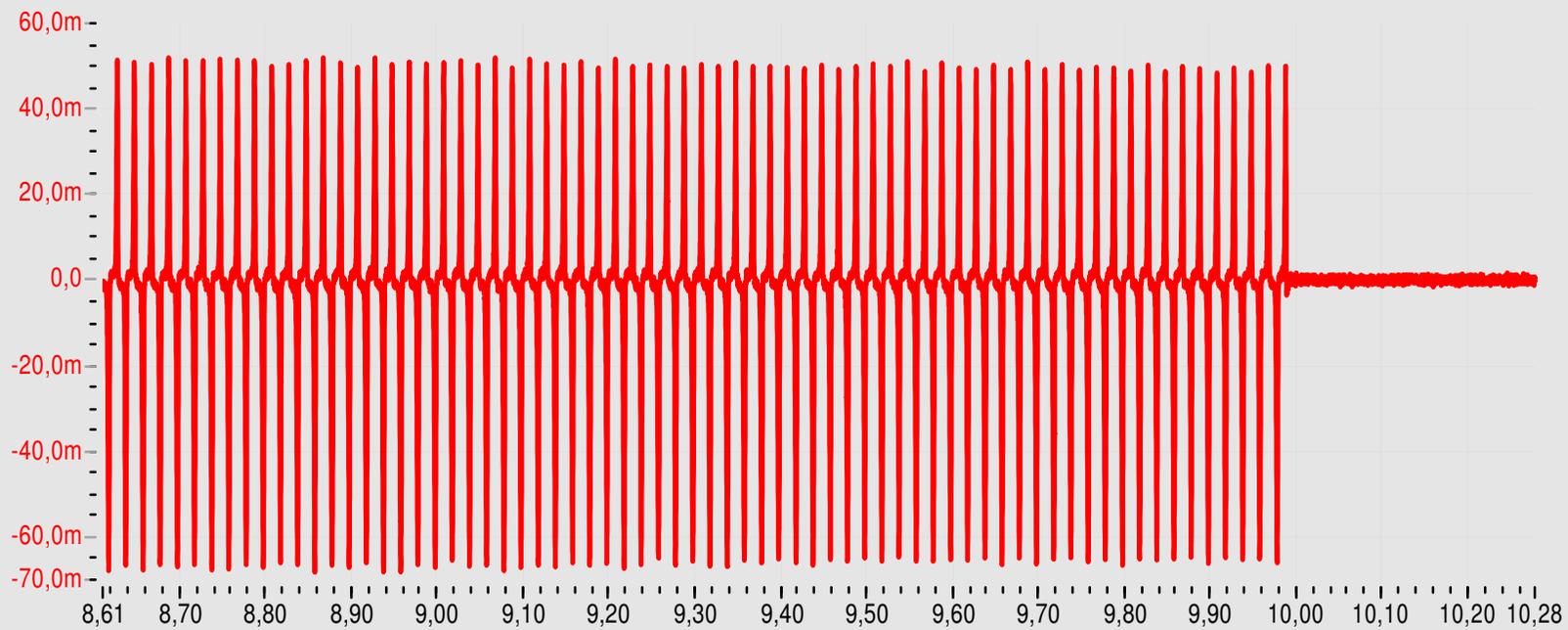
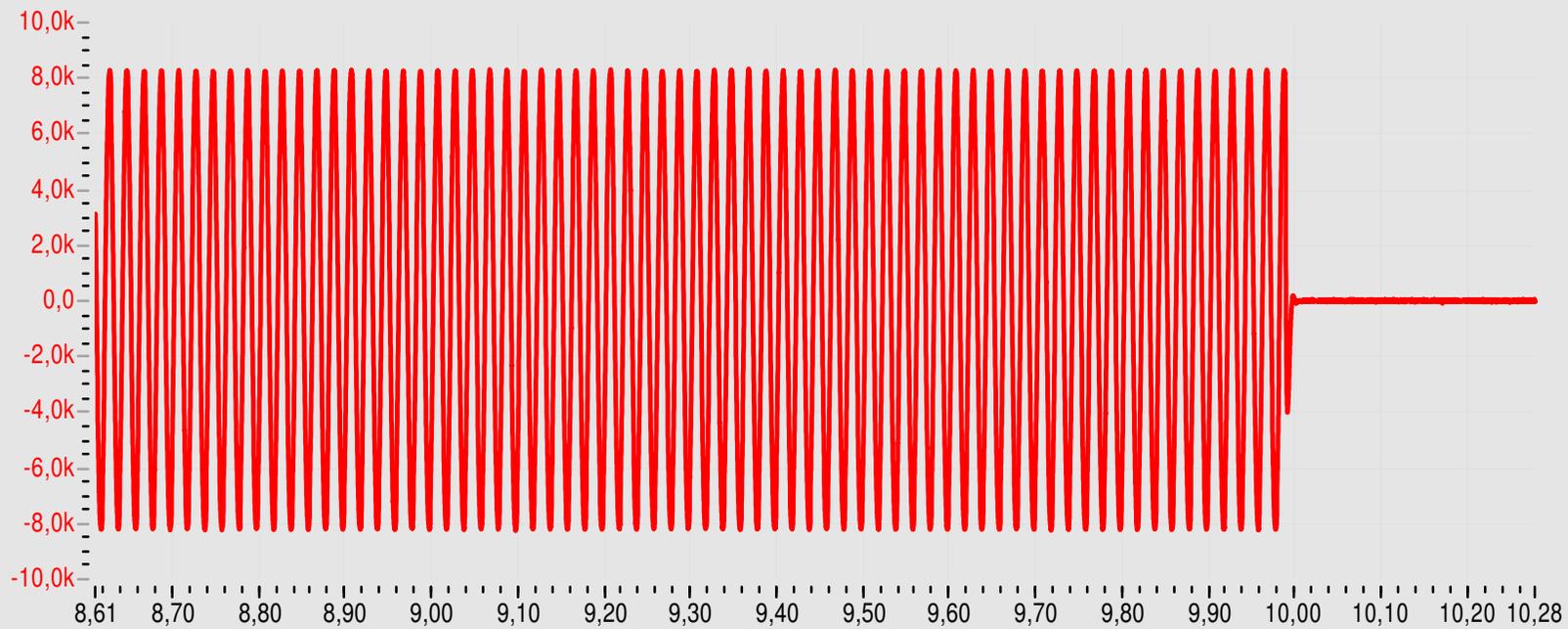
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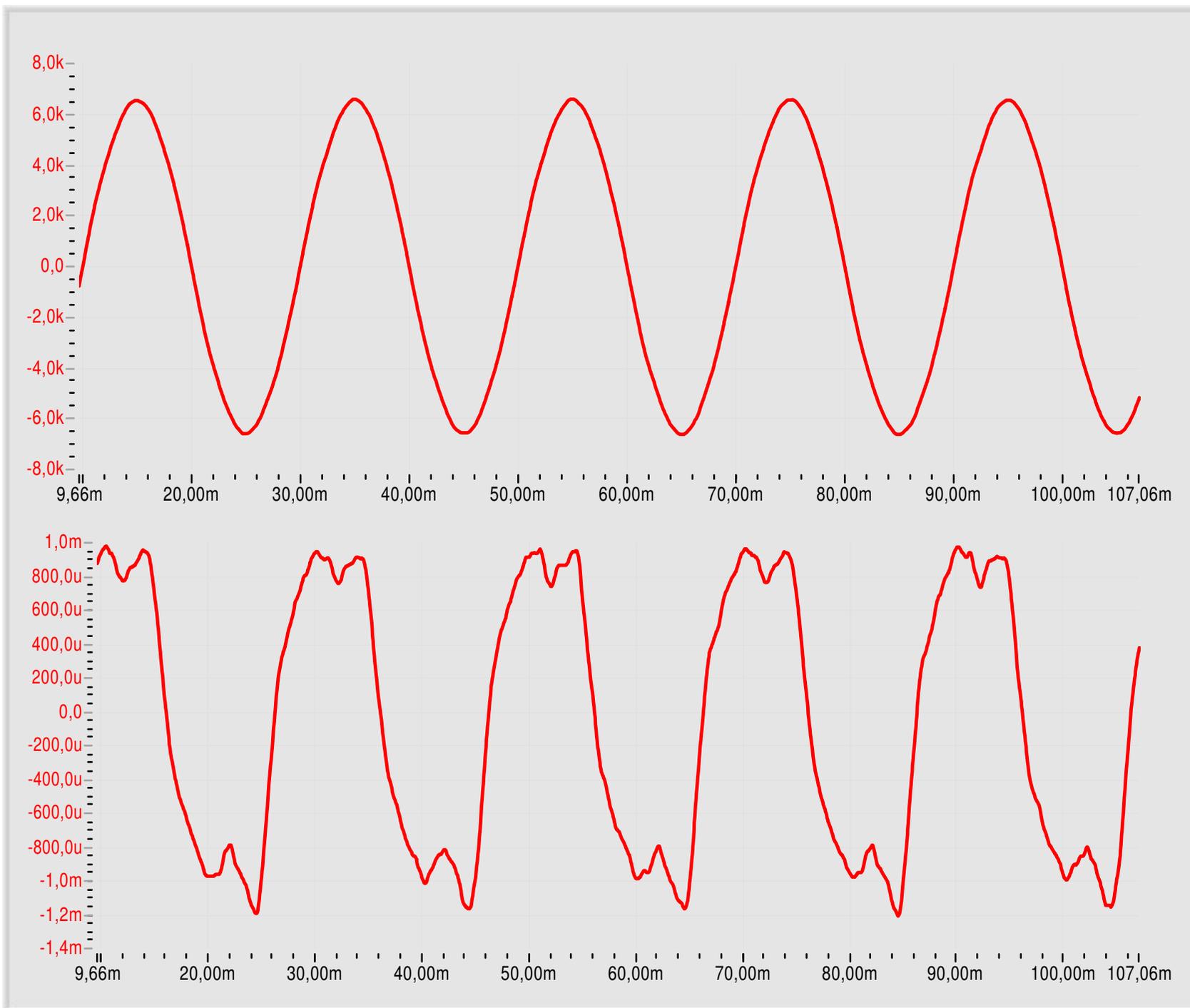
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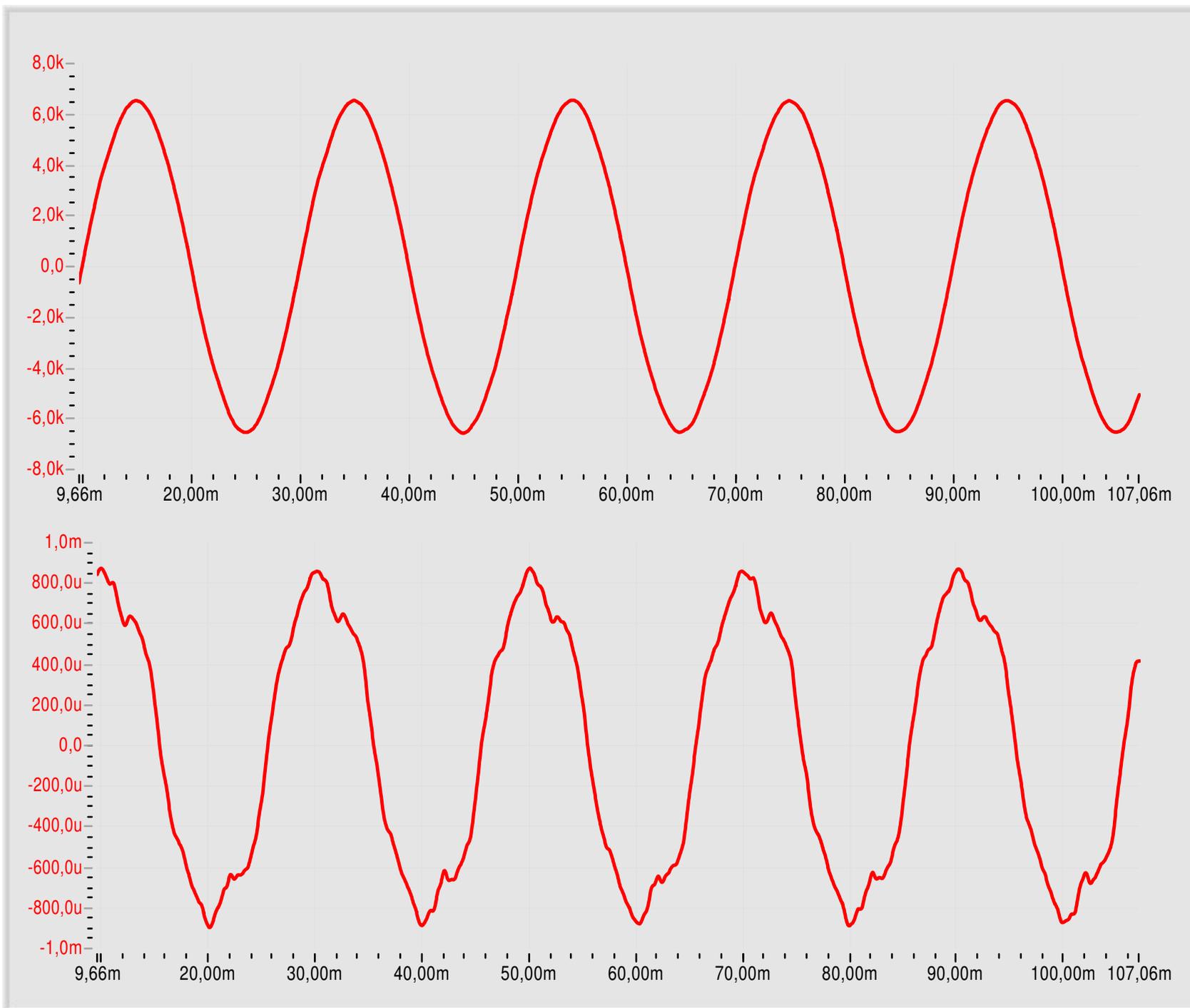
CESI B7020147 Oscillogram n. 23



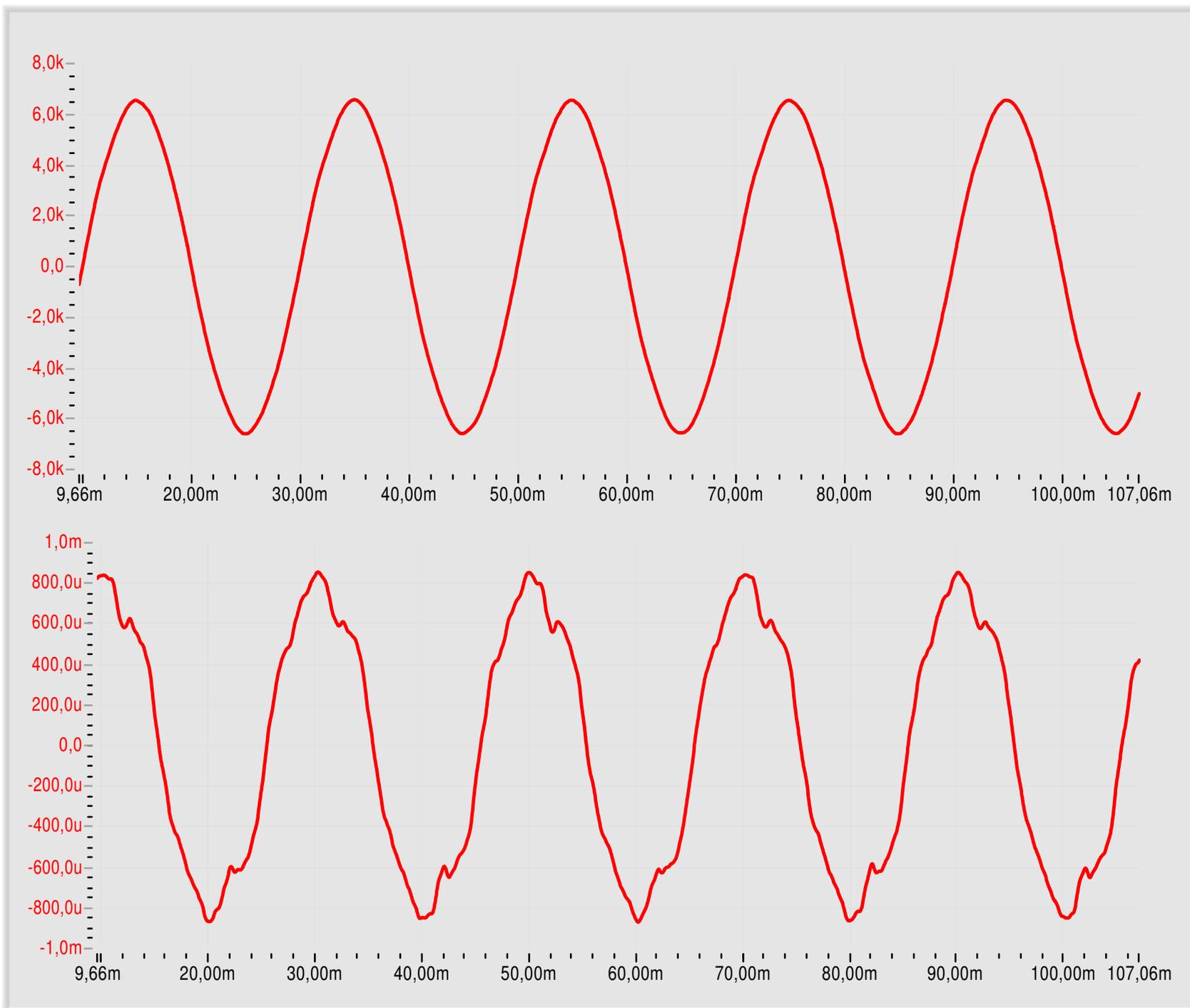
CESI B7020147 Oscillogram n. 24



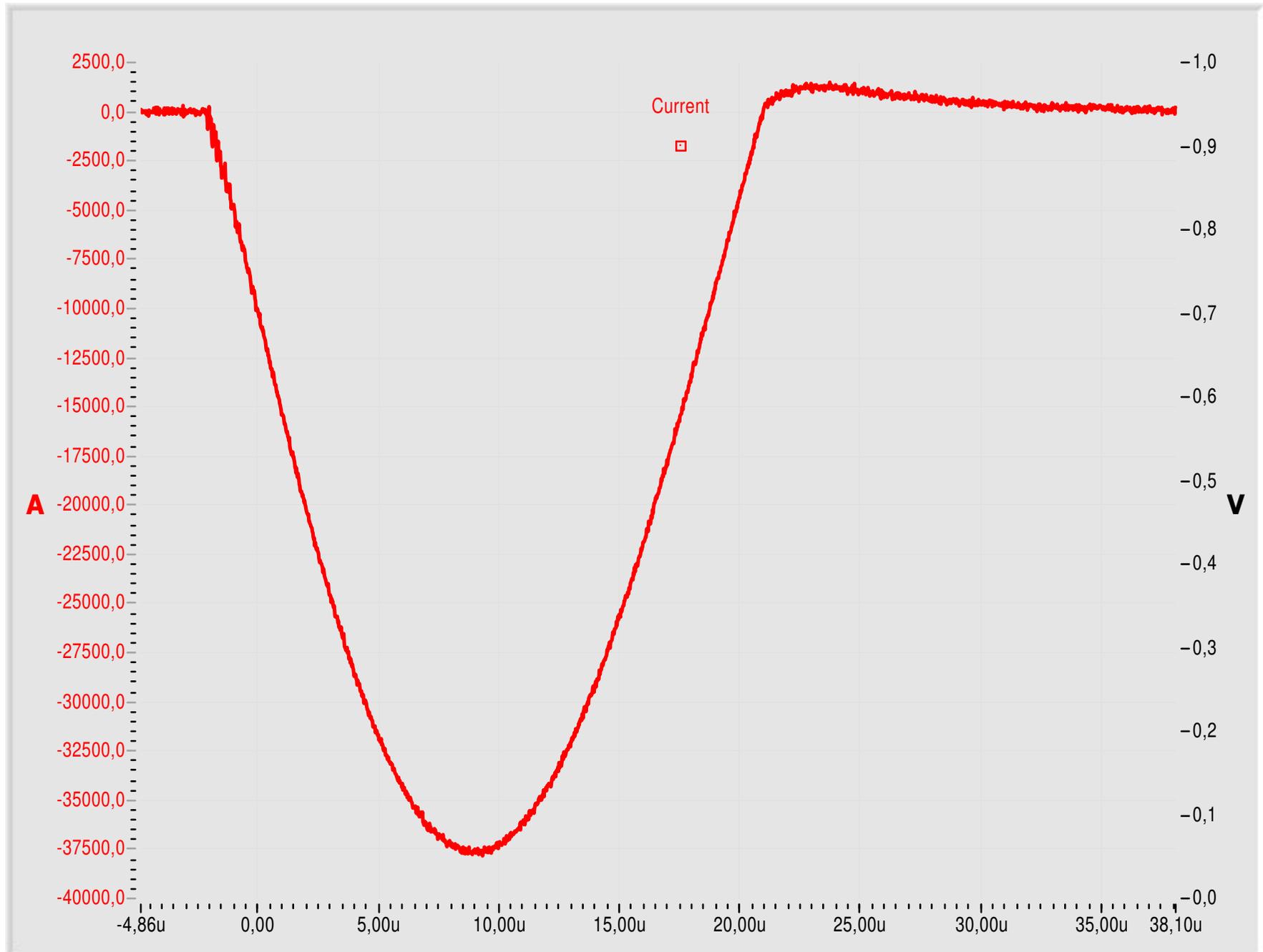
CESI B7020147 Oscillogram n. 25



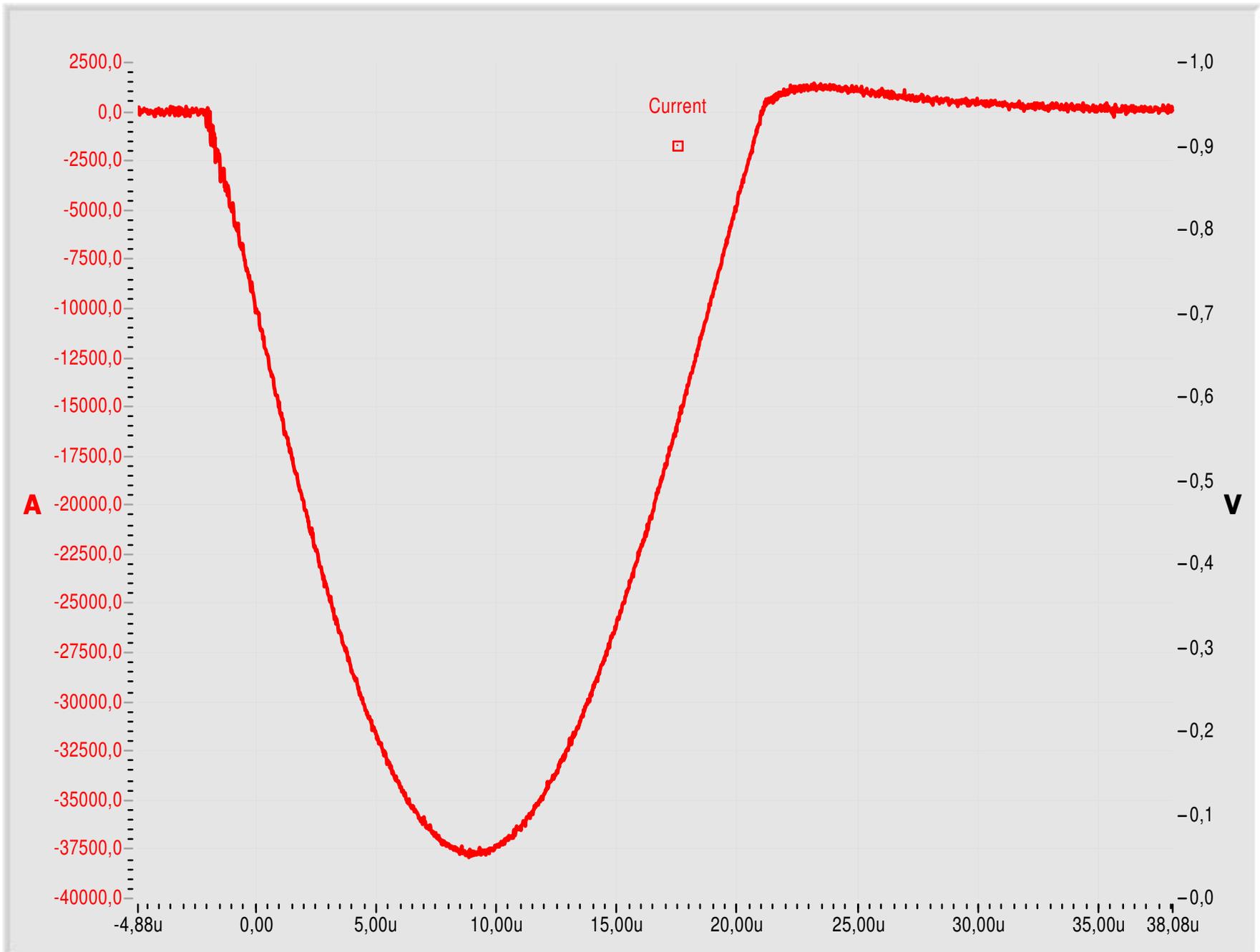
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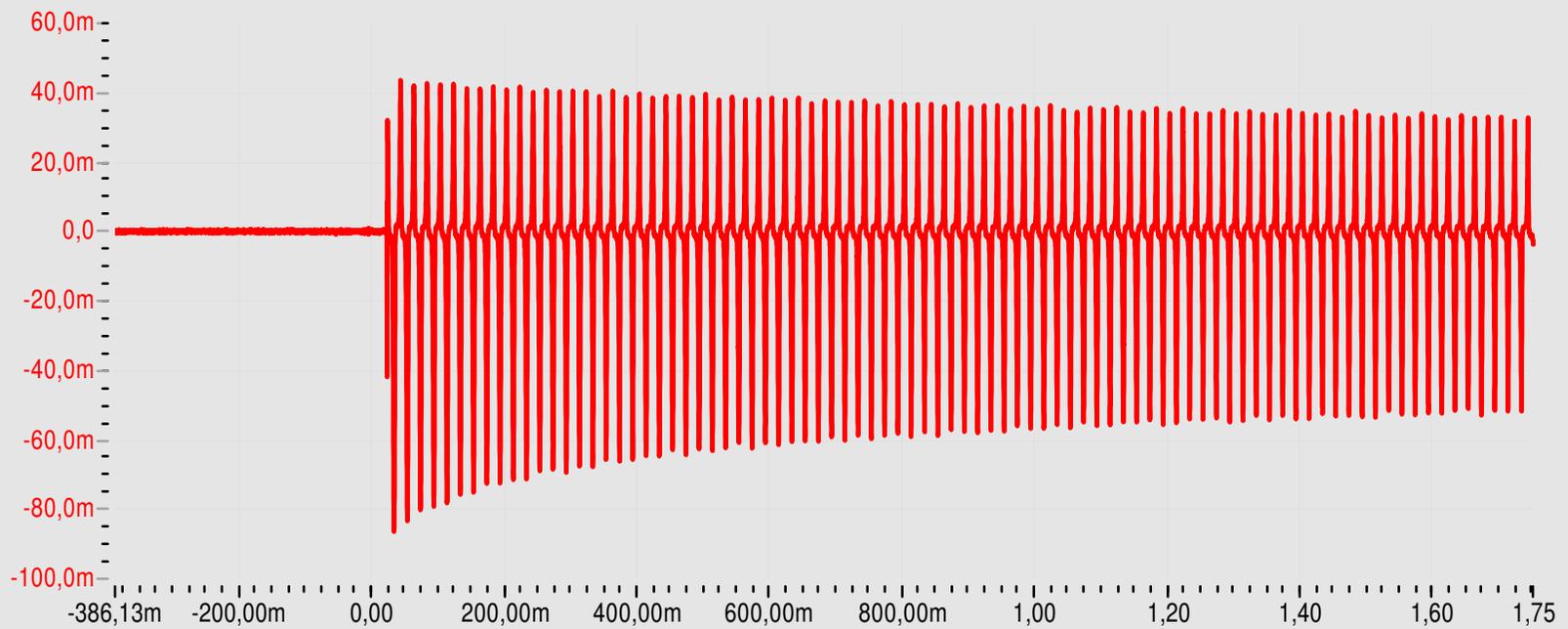
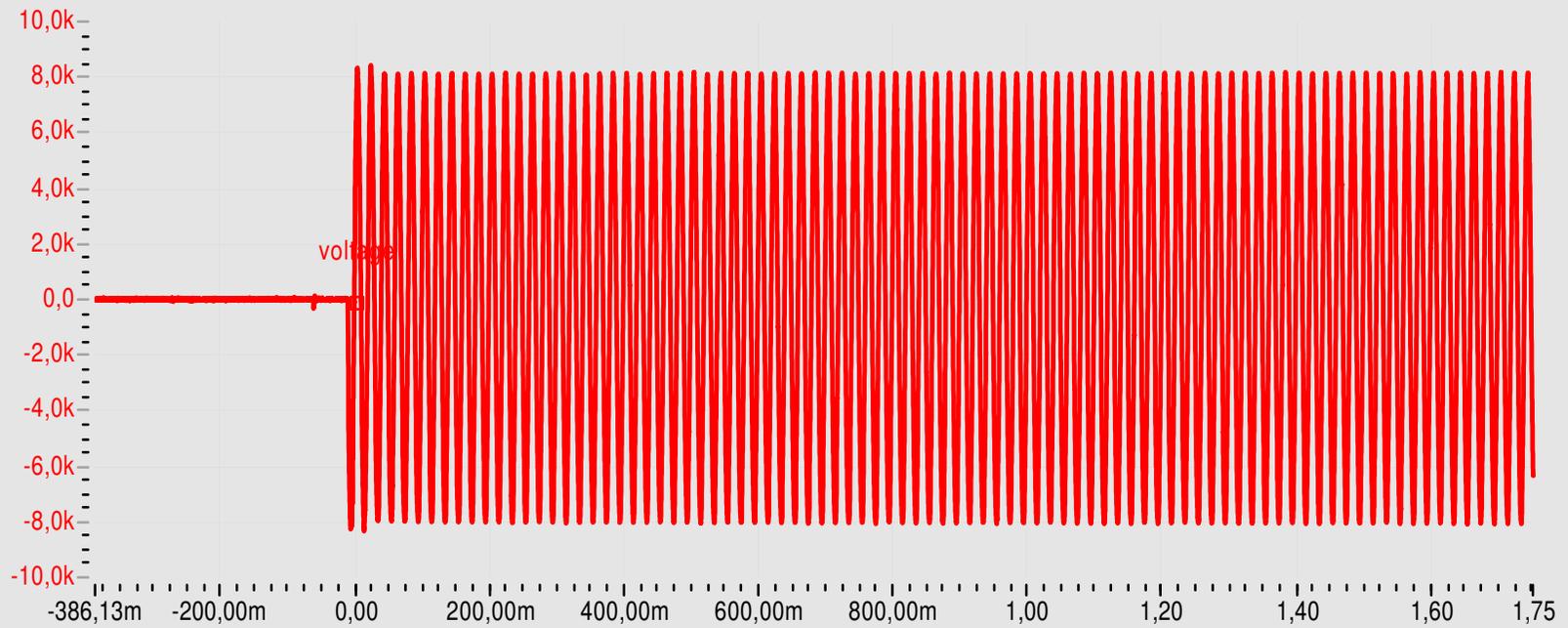
CESI B7020147 Oscillogram n. 27



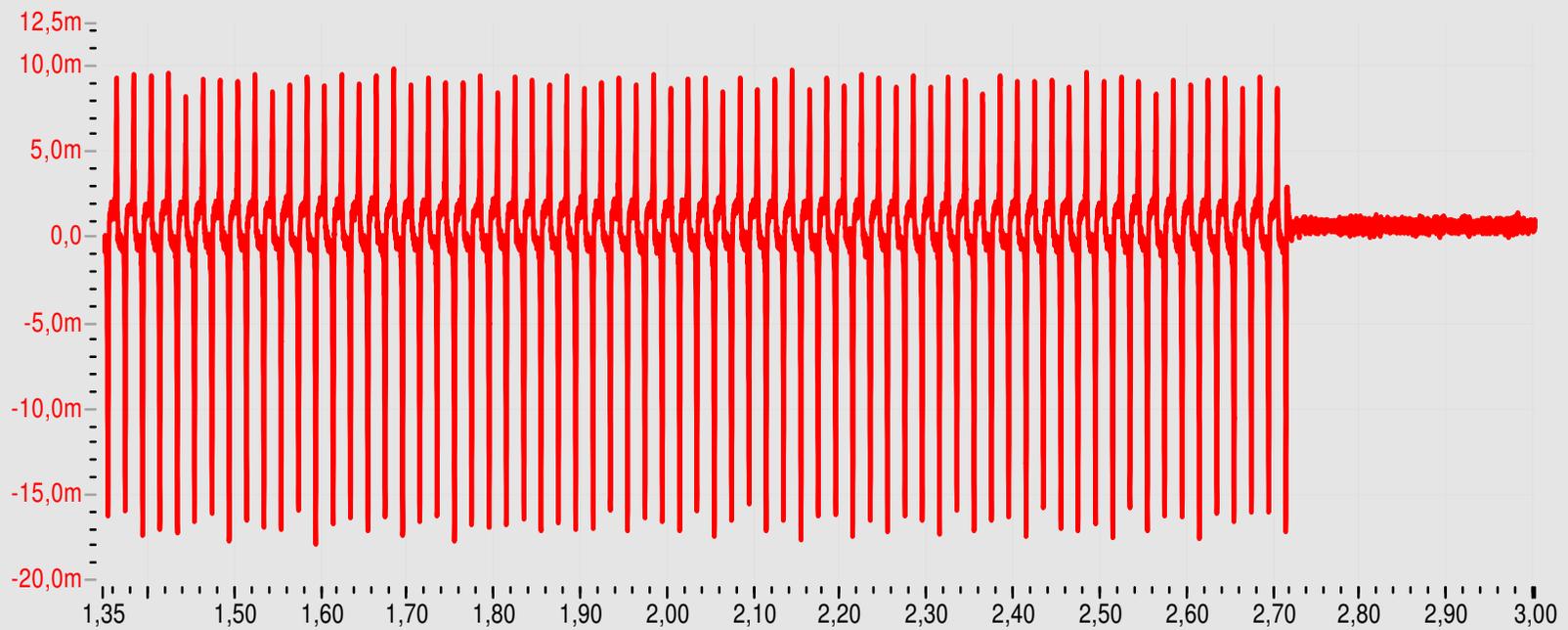
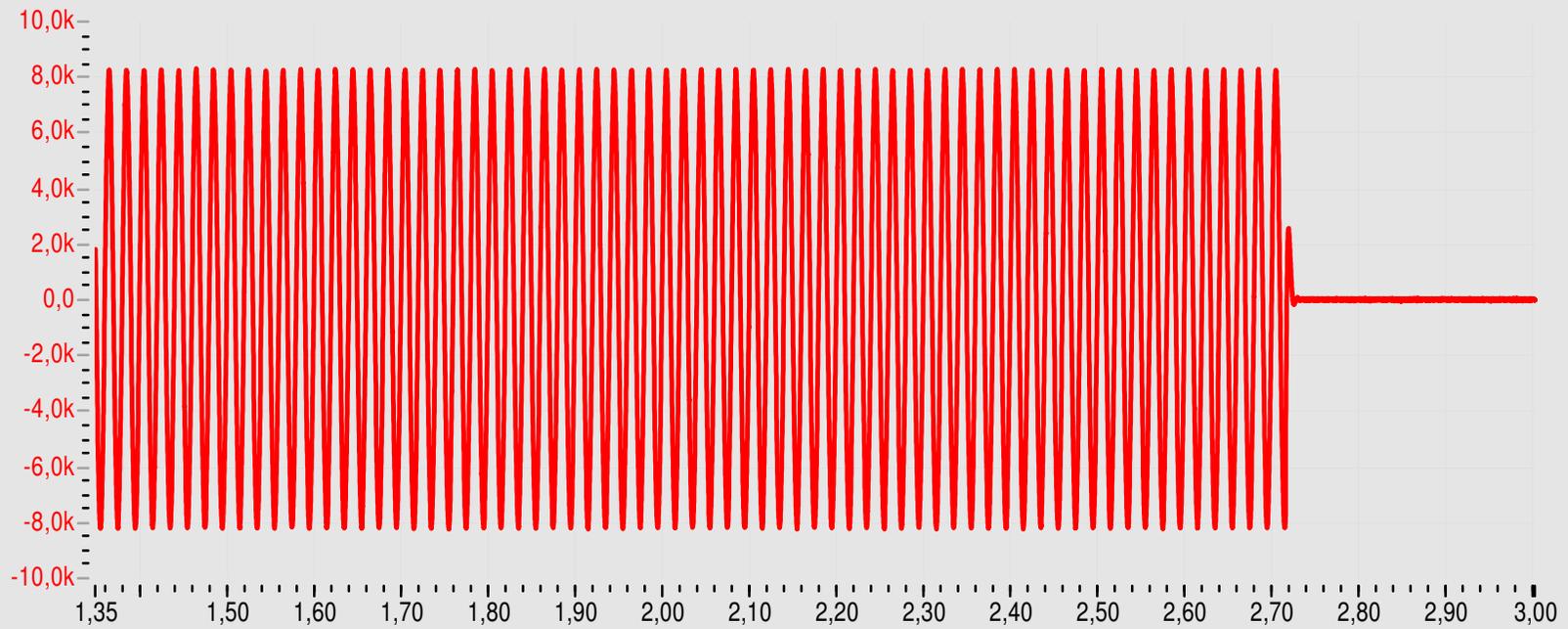
CESI B7020147 Oscillogram n. 28



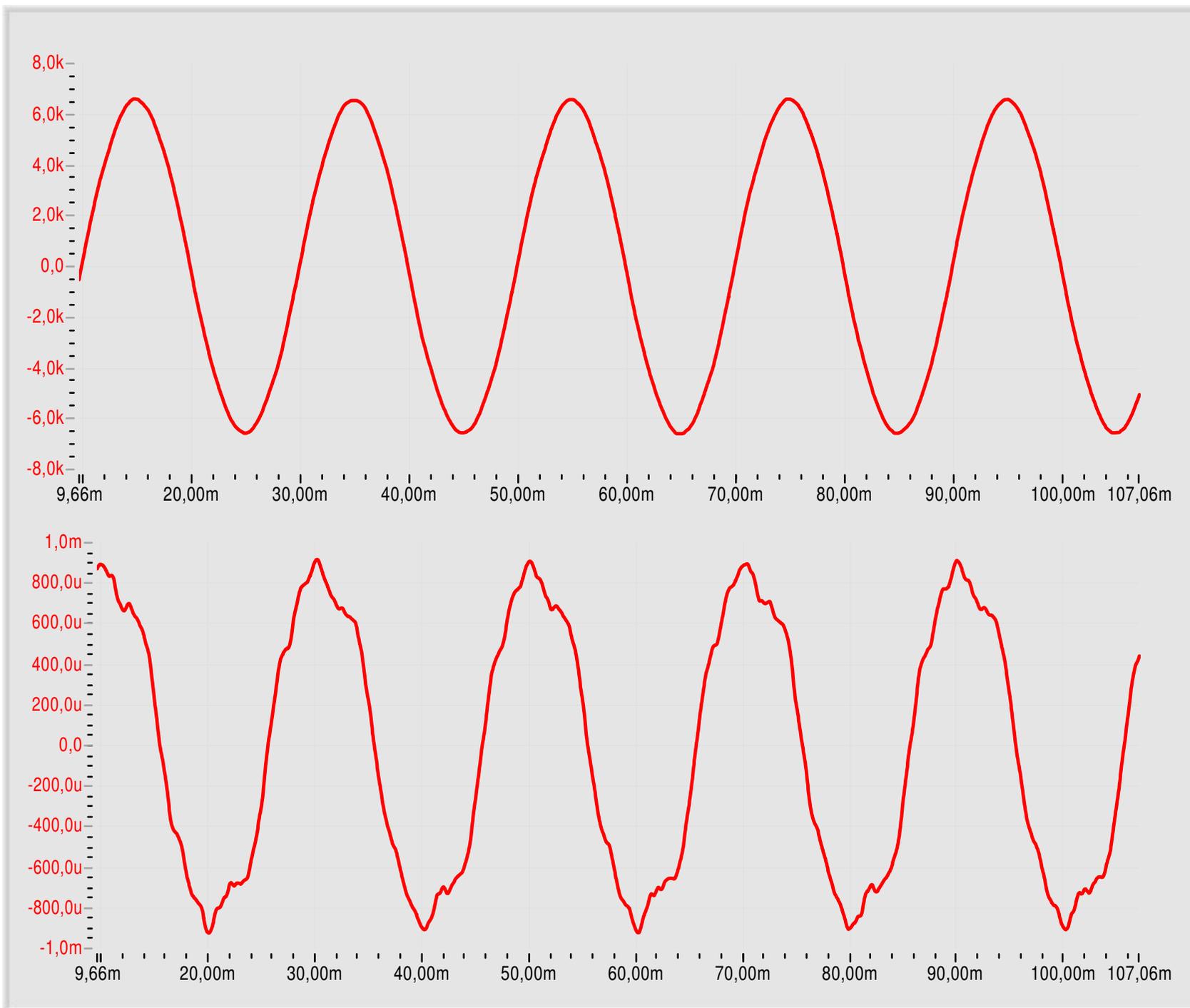
CESI B7020147 Oscillogram n. 29



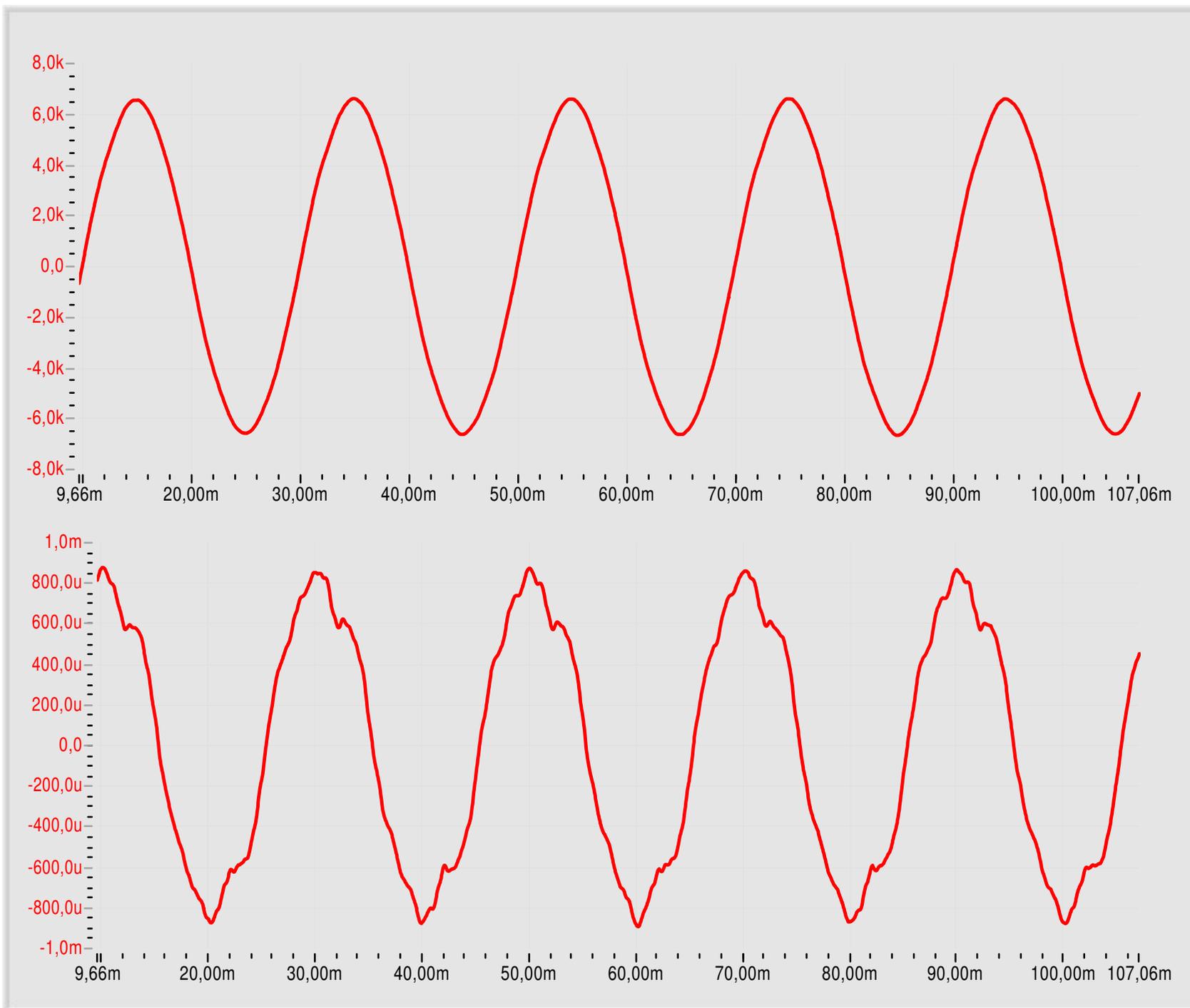
CESI B7020147 Oscillogram n. 30



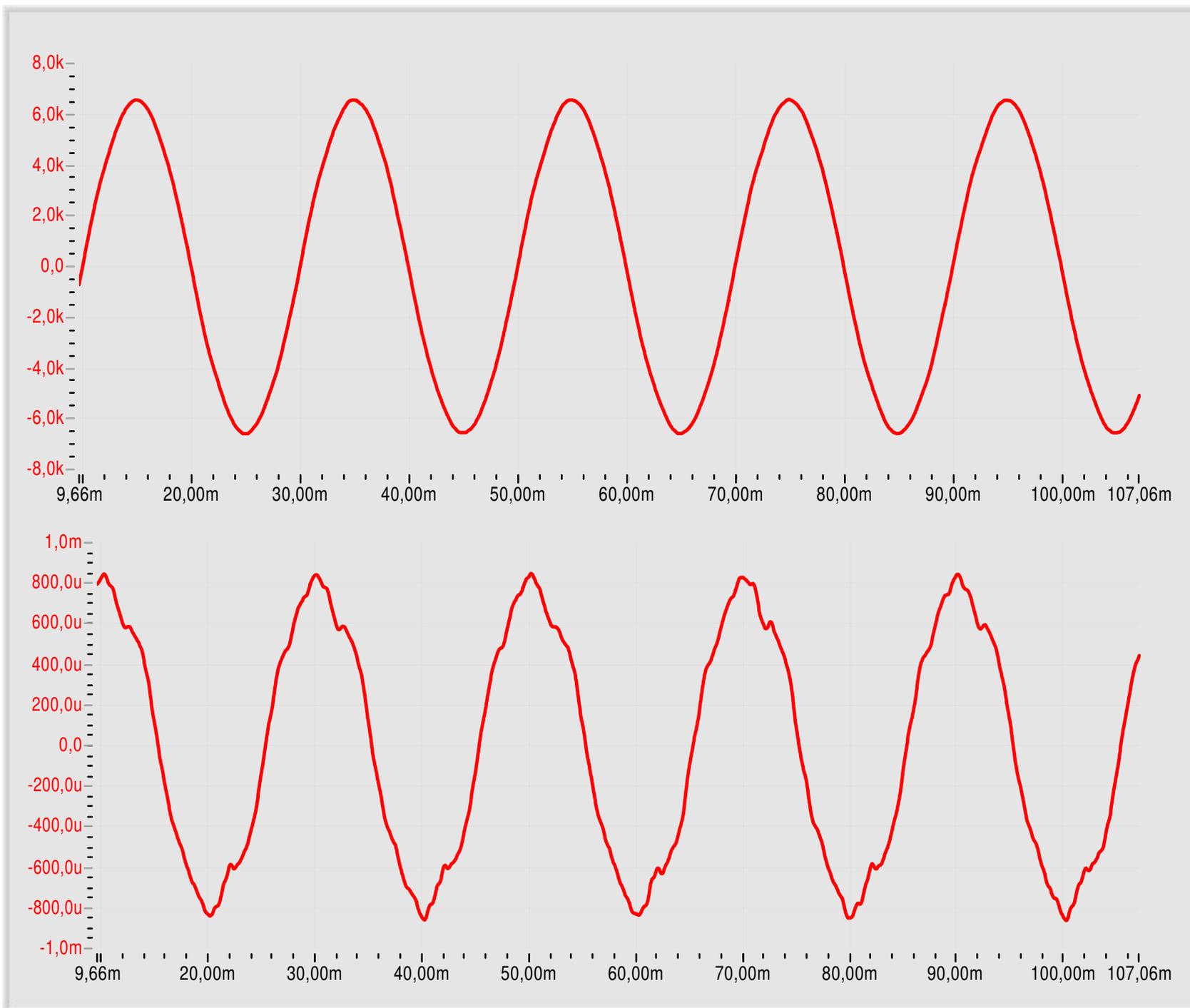
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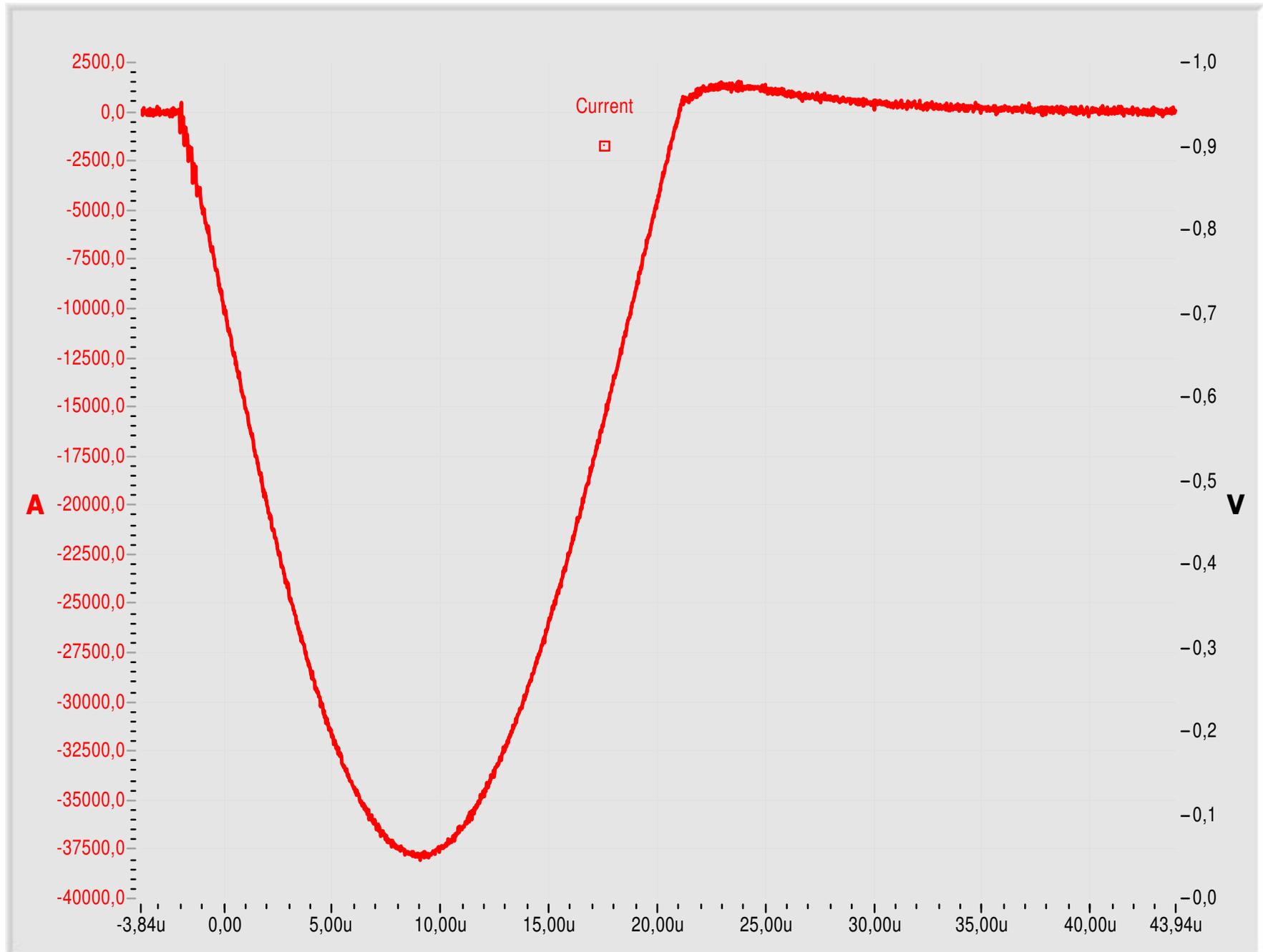
CESI B7020147 Oscillogram n. 32



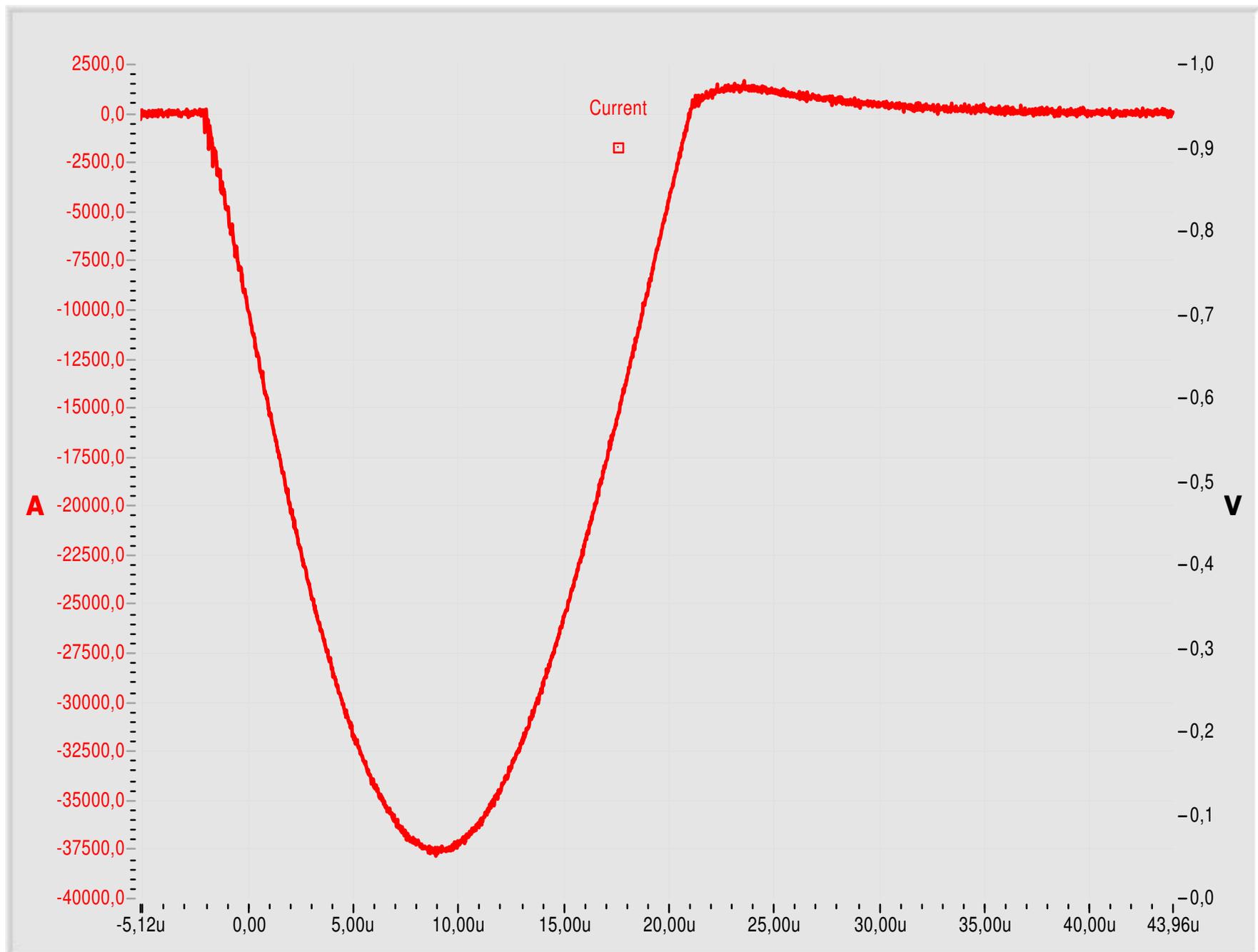
CESI B7020147 Oscillogram n. 33



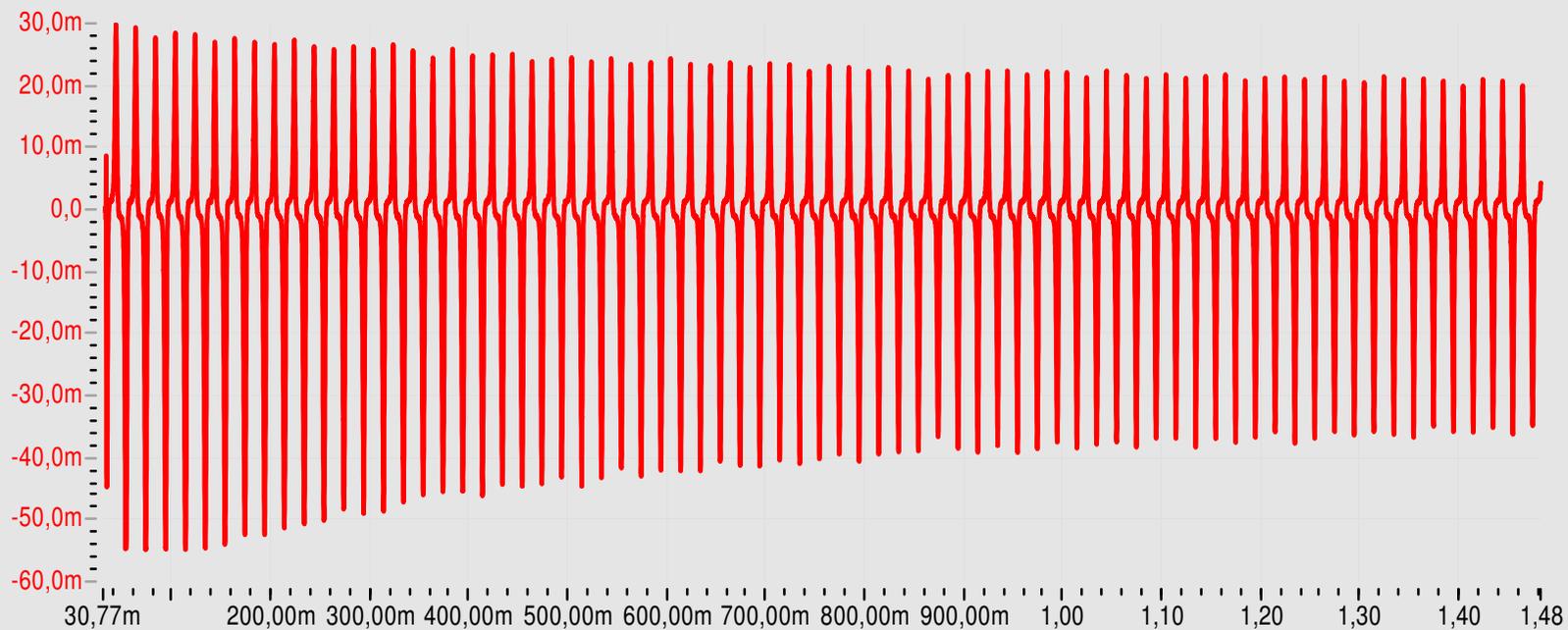
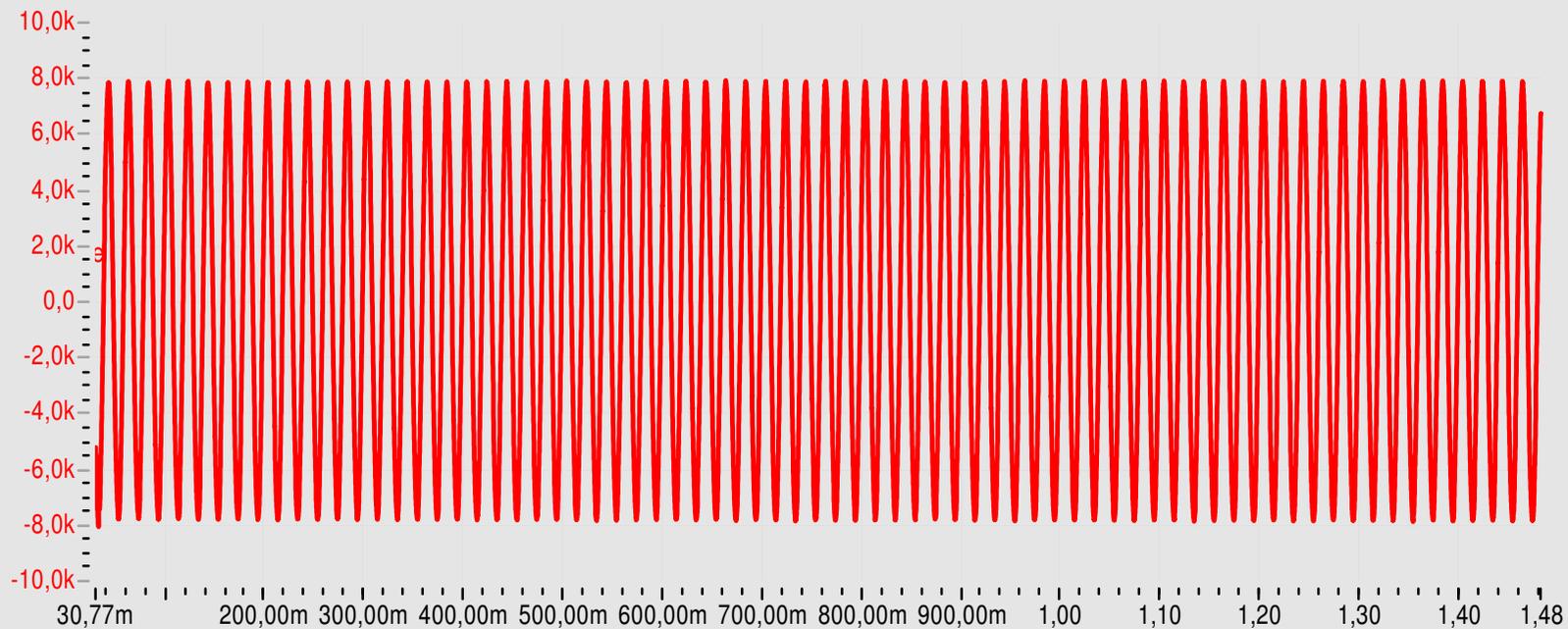
CESI B7020147 Oscillogram n. 34



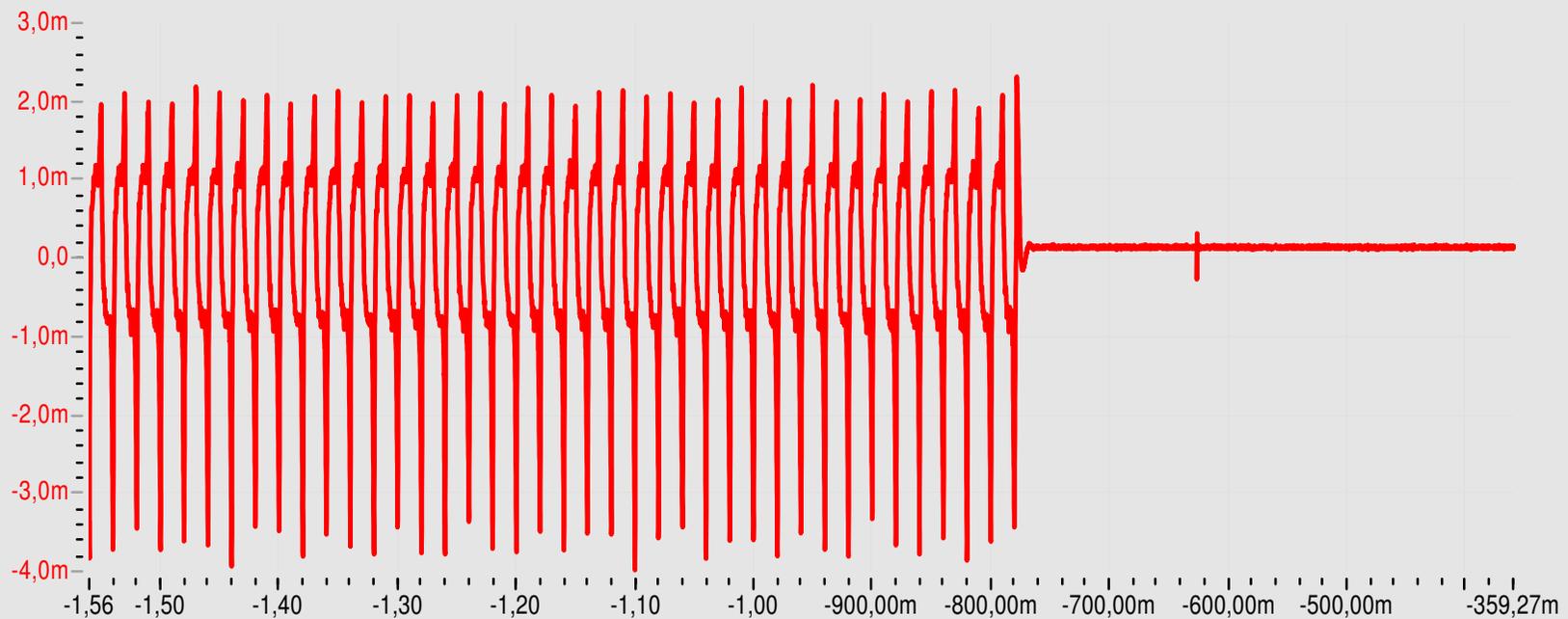
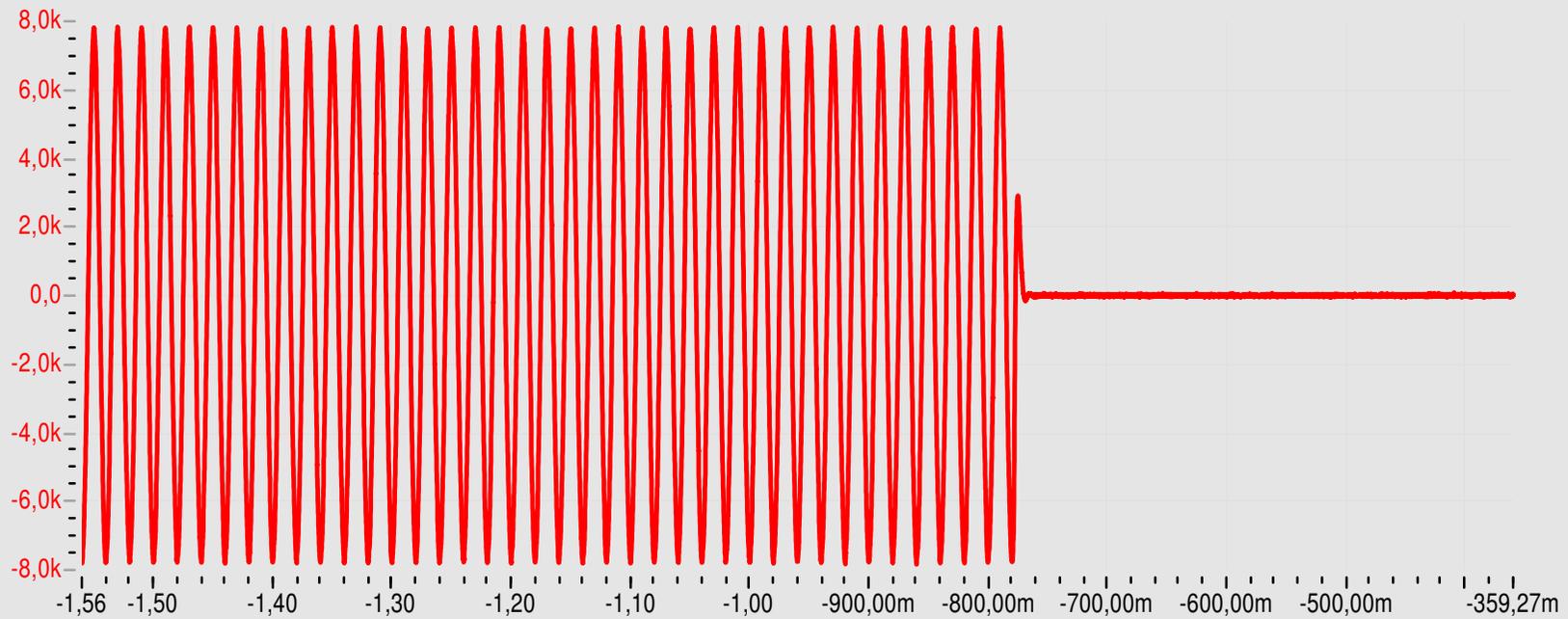
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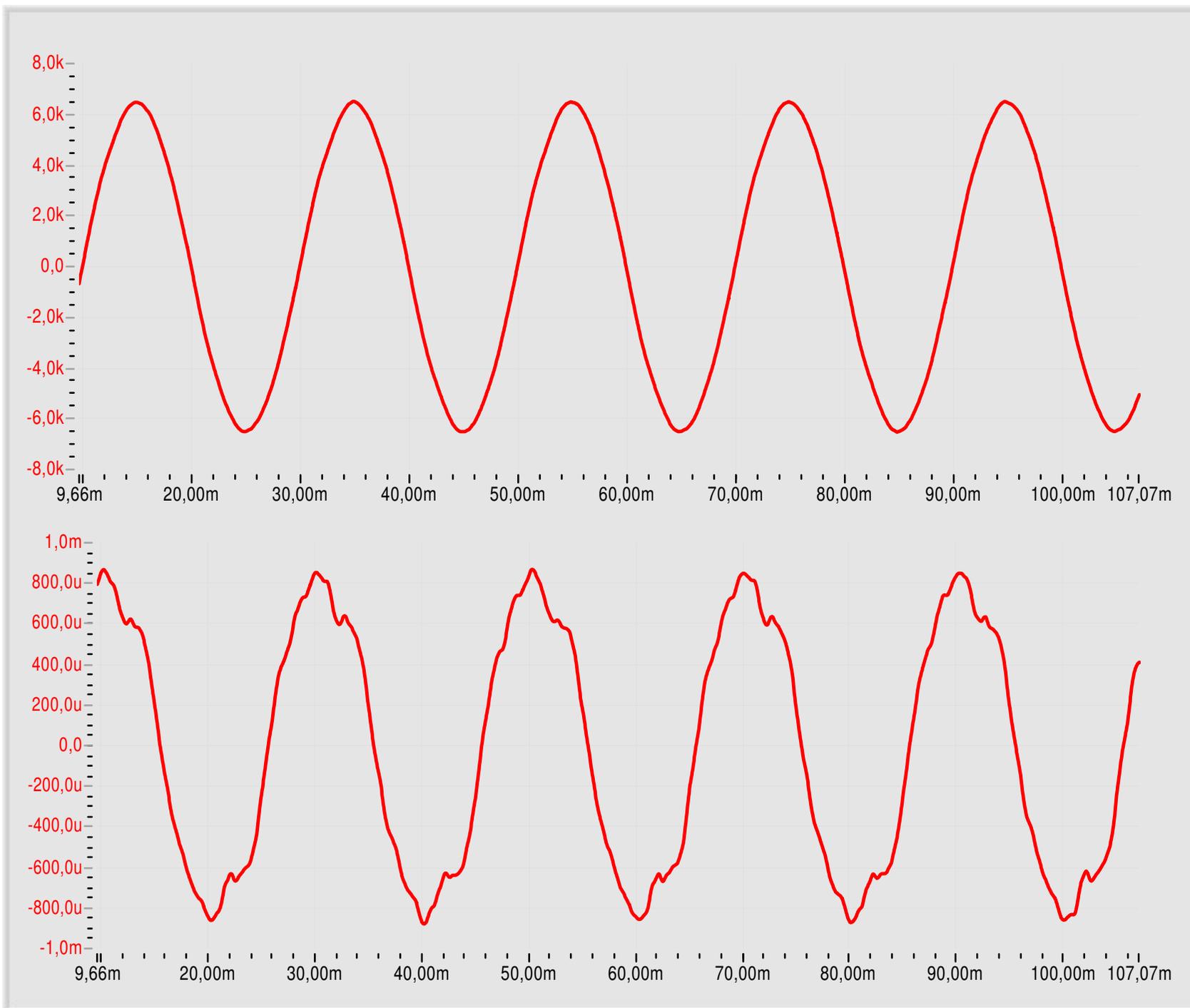
CESI B7020147 Oscillogram n. 36



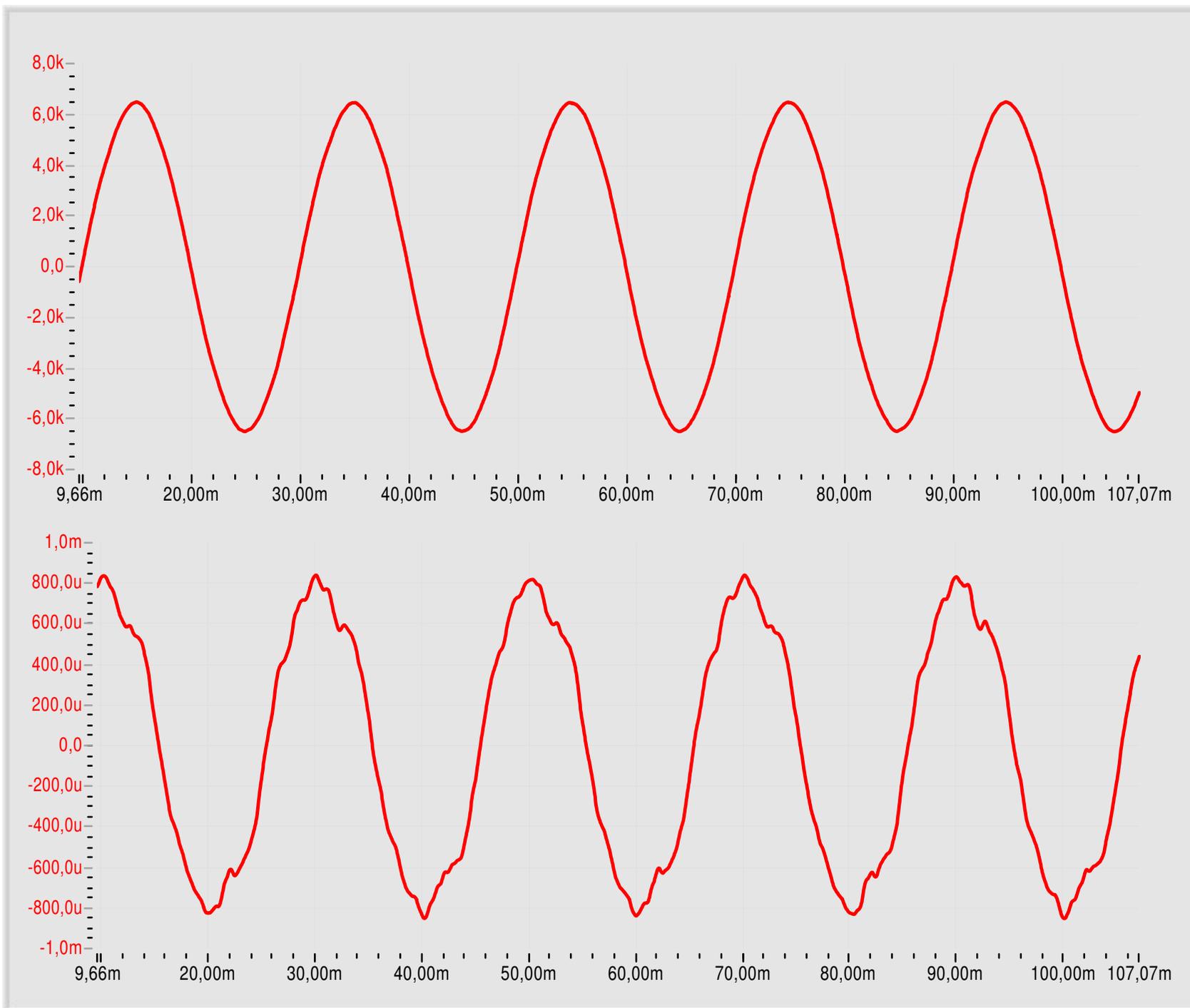
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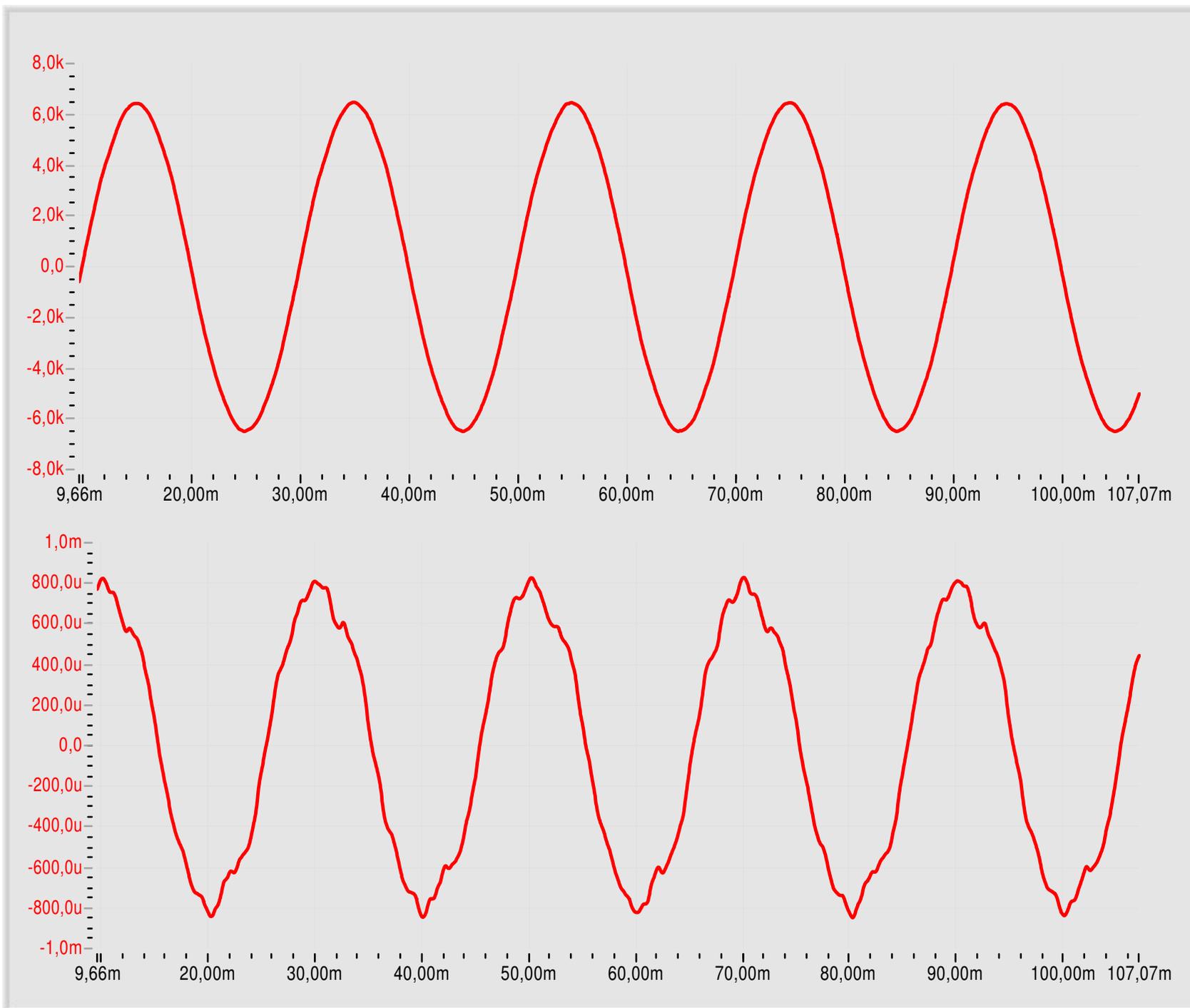
CESI B7020147 Oscillogram n. 38



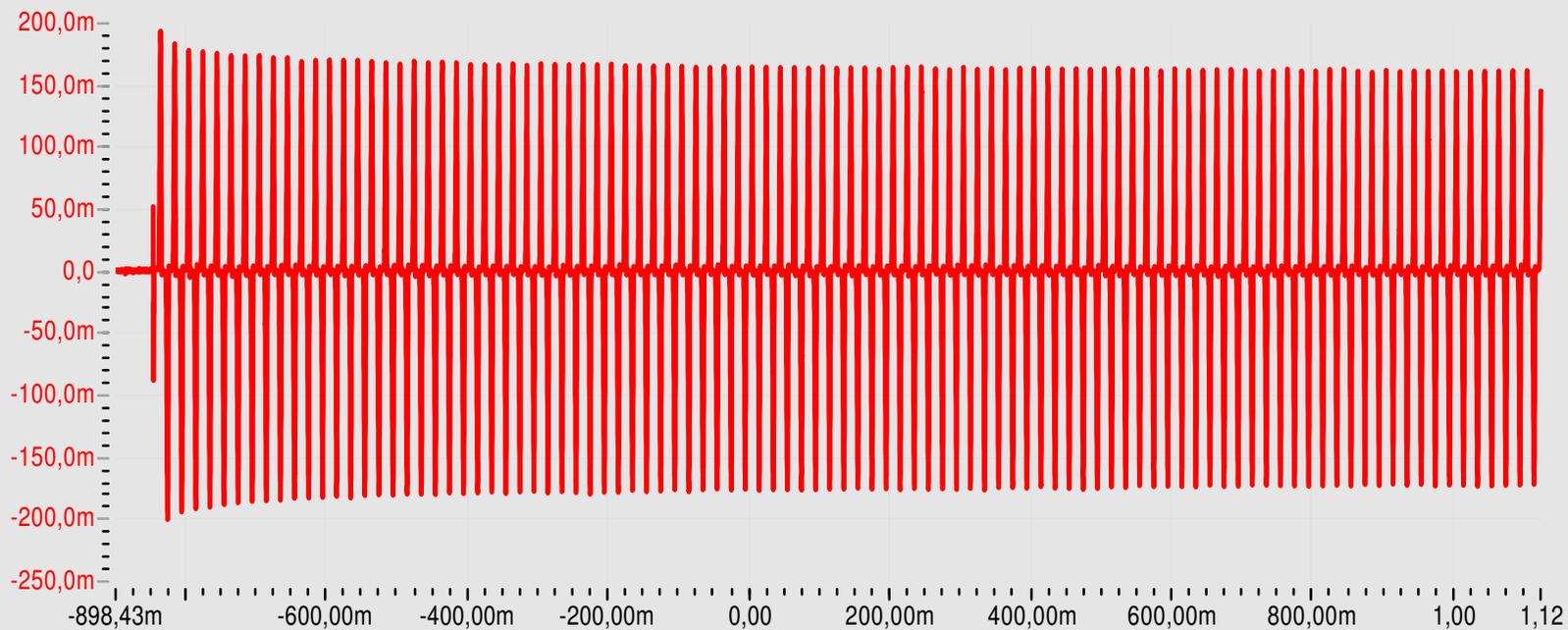
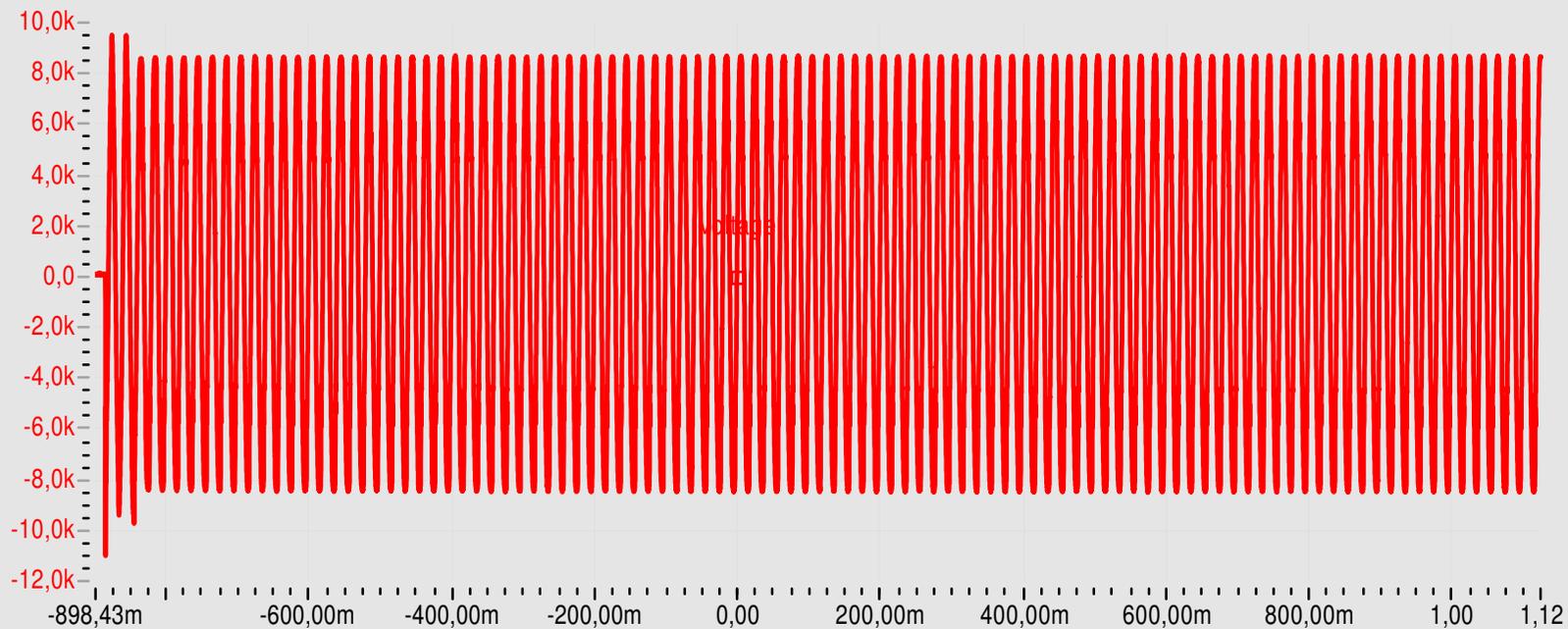
CESI B7020147 Oscillogram n. 39



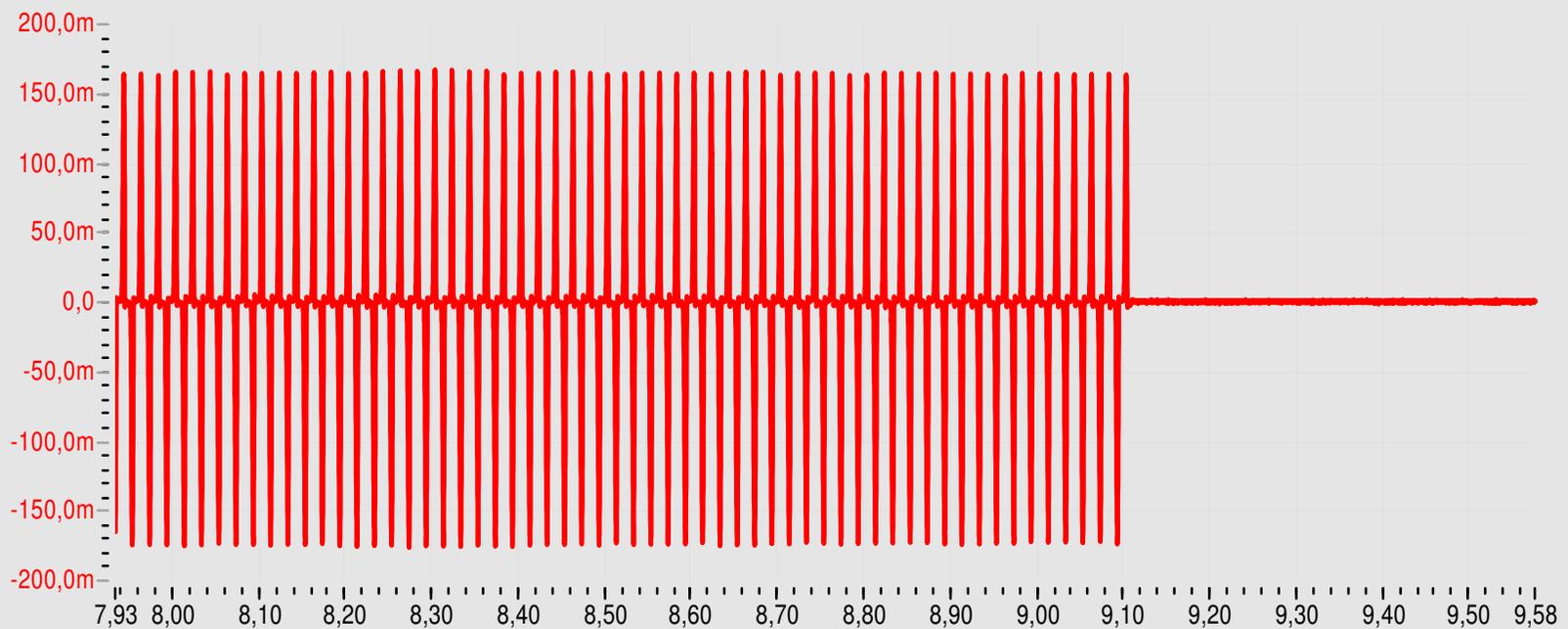
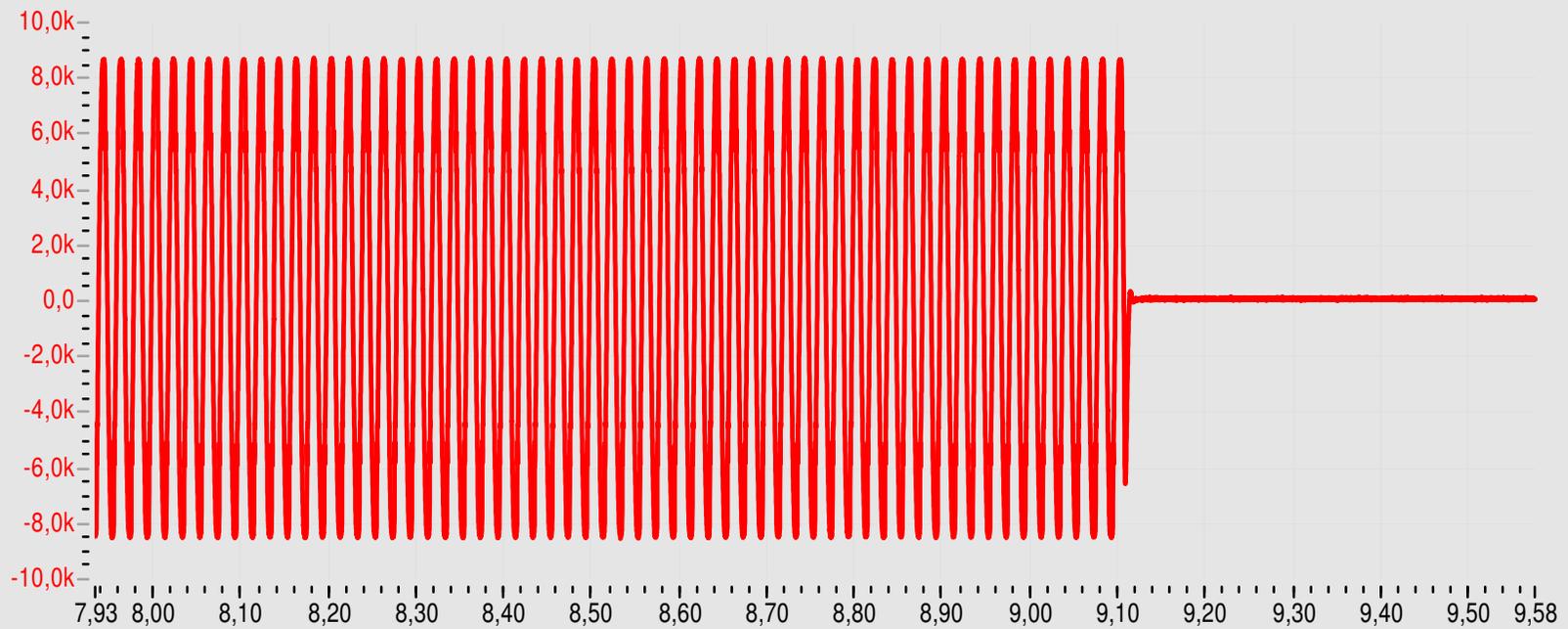
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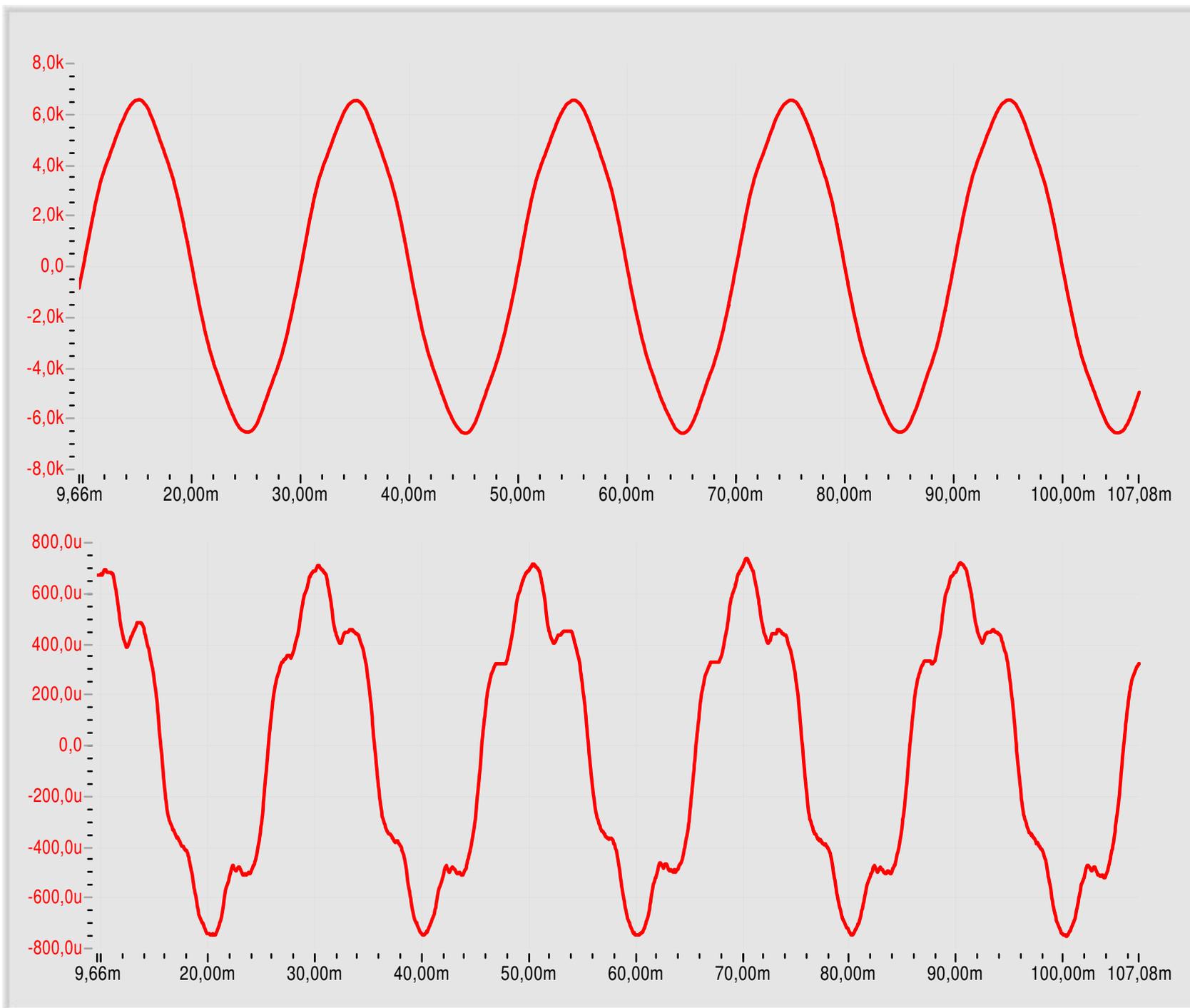
CESI B7020147 Oscillogram n. 41



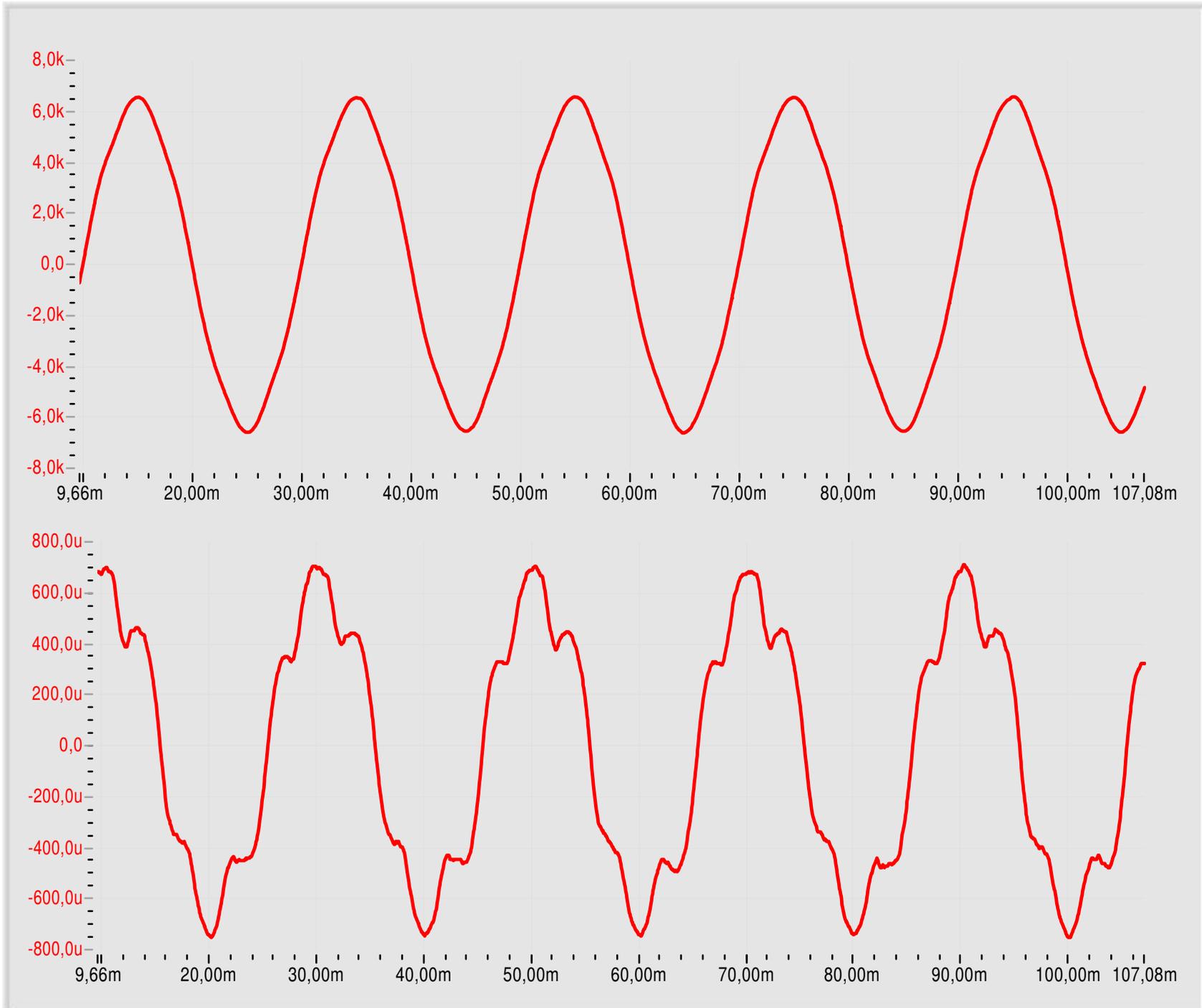
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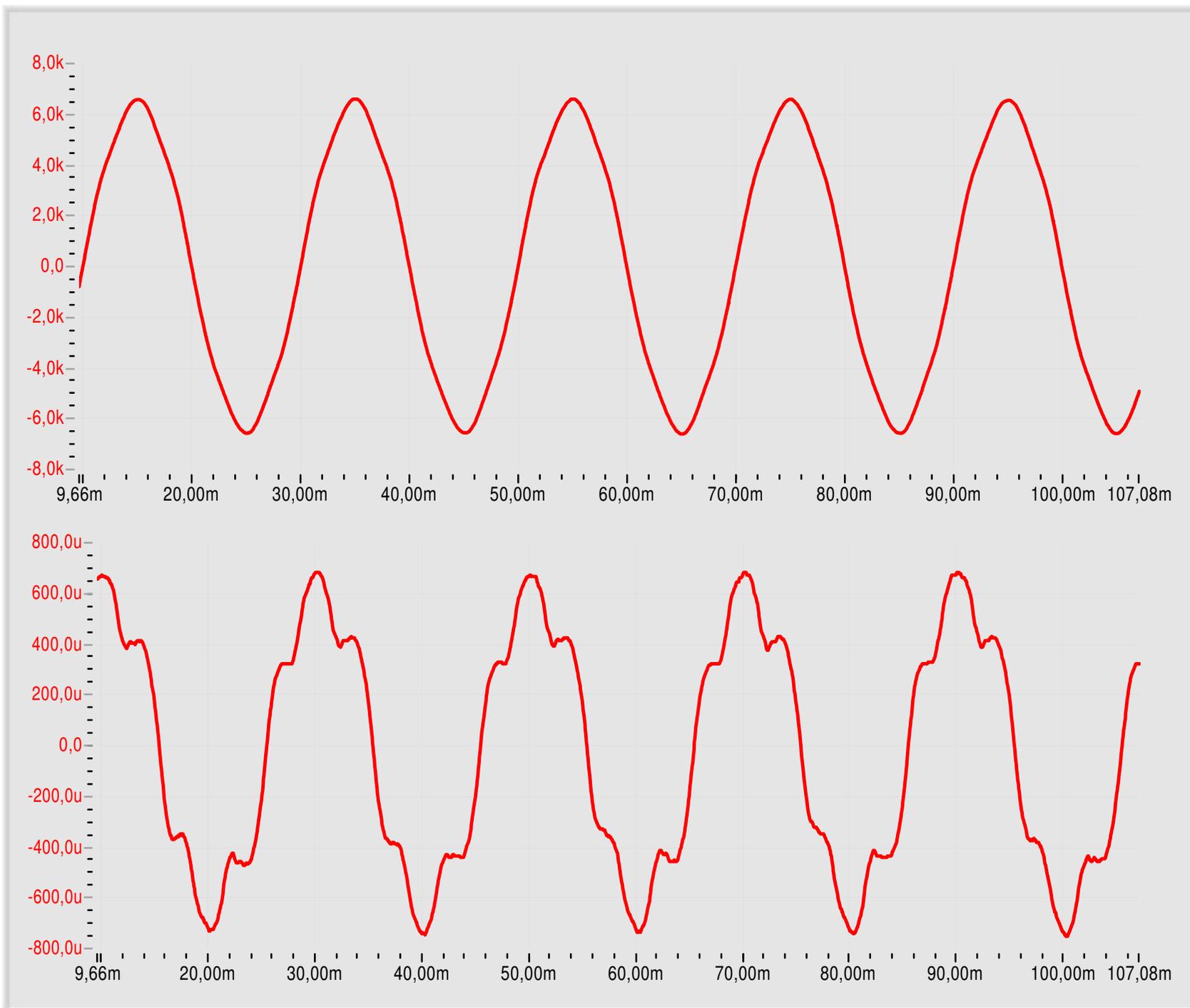
CESI B7020147 Oscillogram n. 43



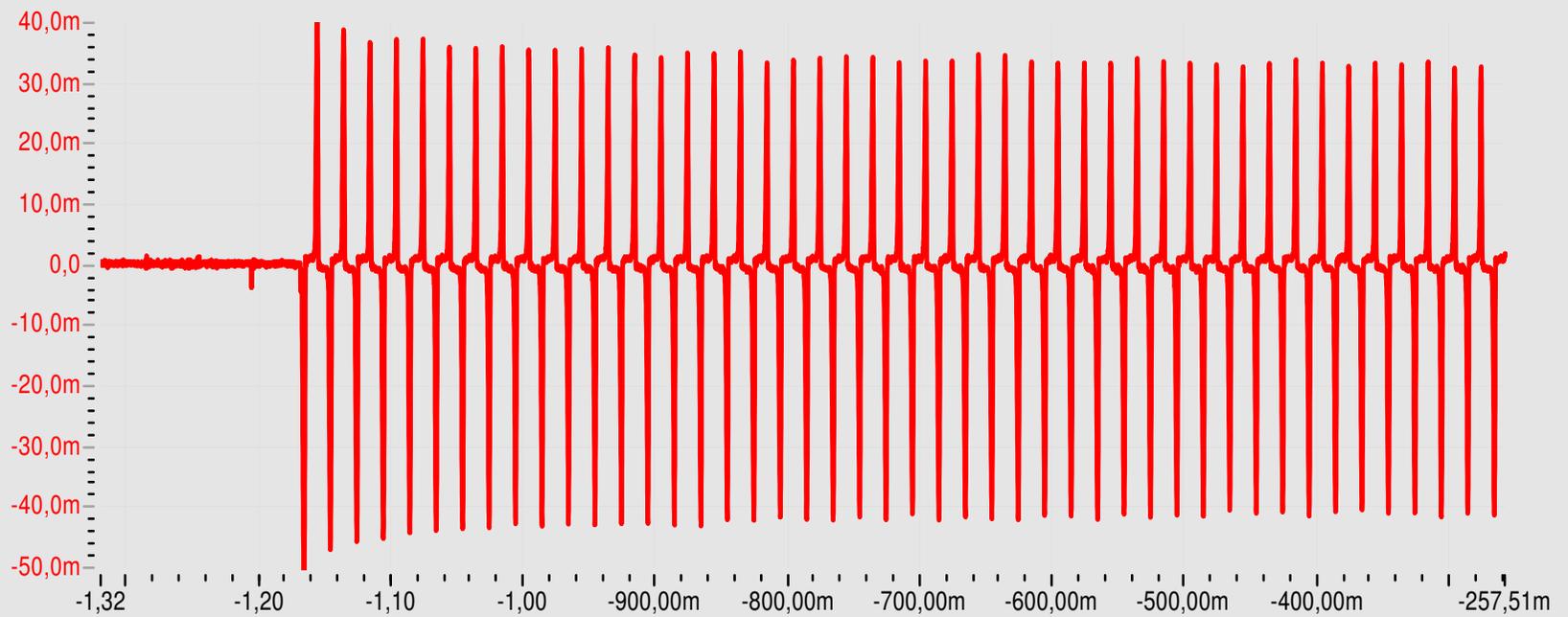
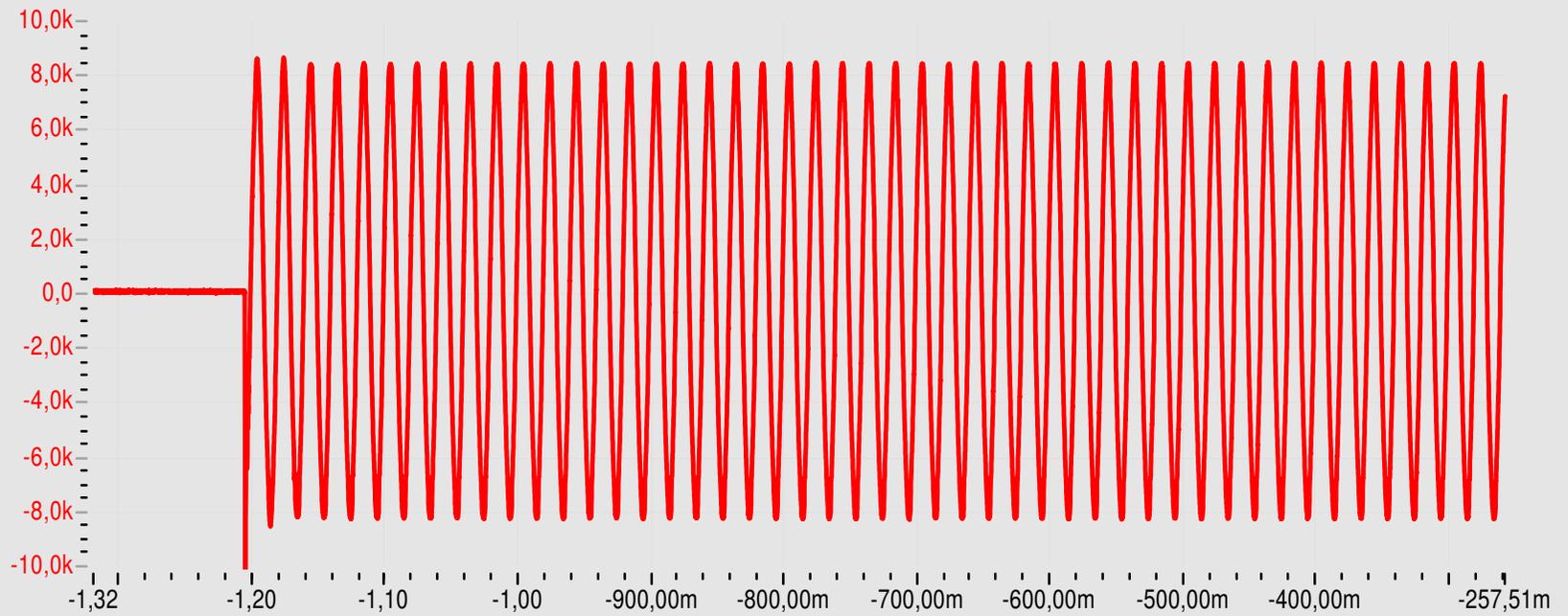
CESI B7020147 Oscillogram n. 44



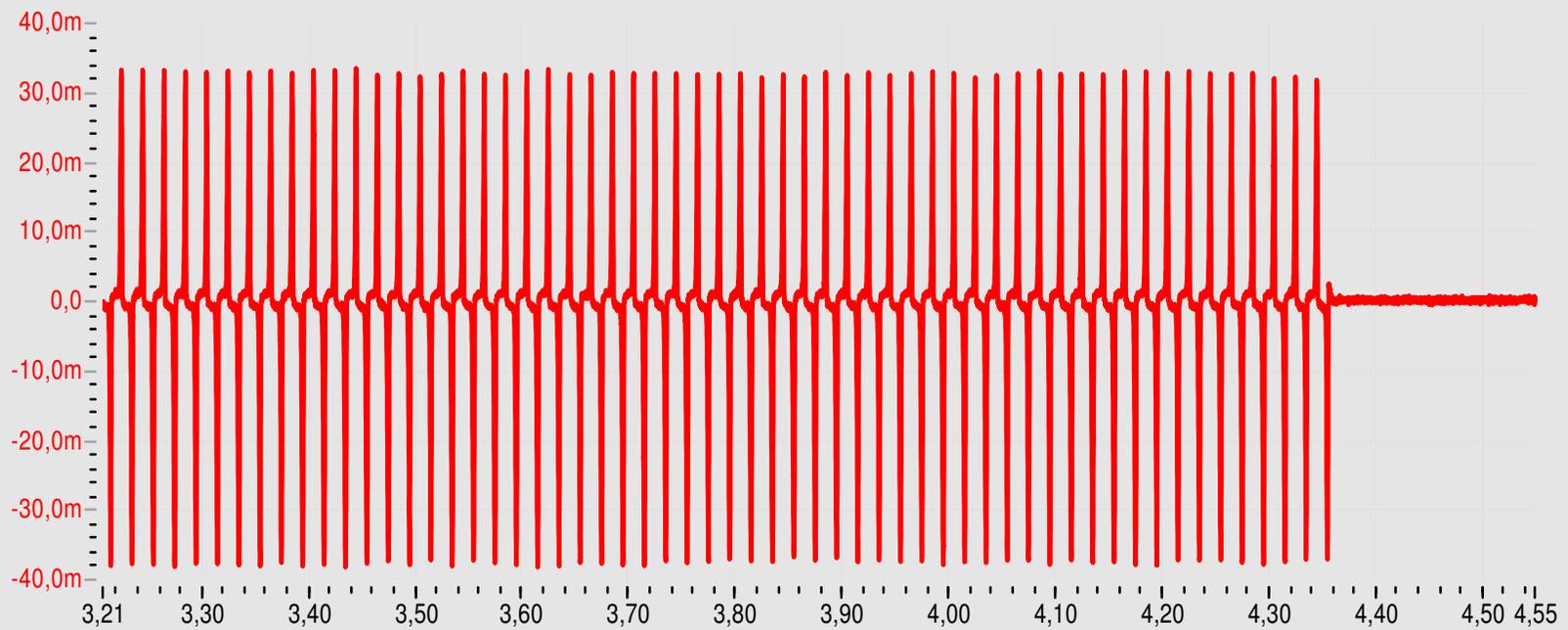
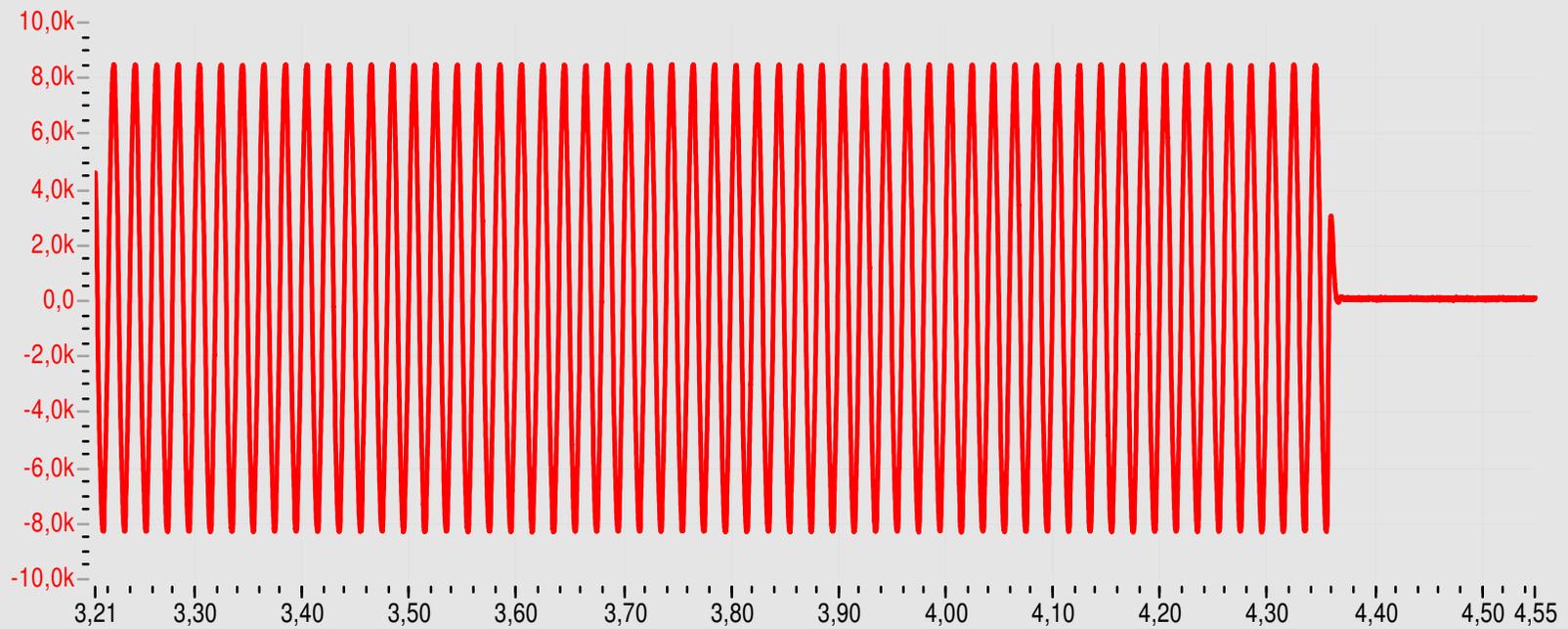
CESI B7020147 Oscillogram n. 45



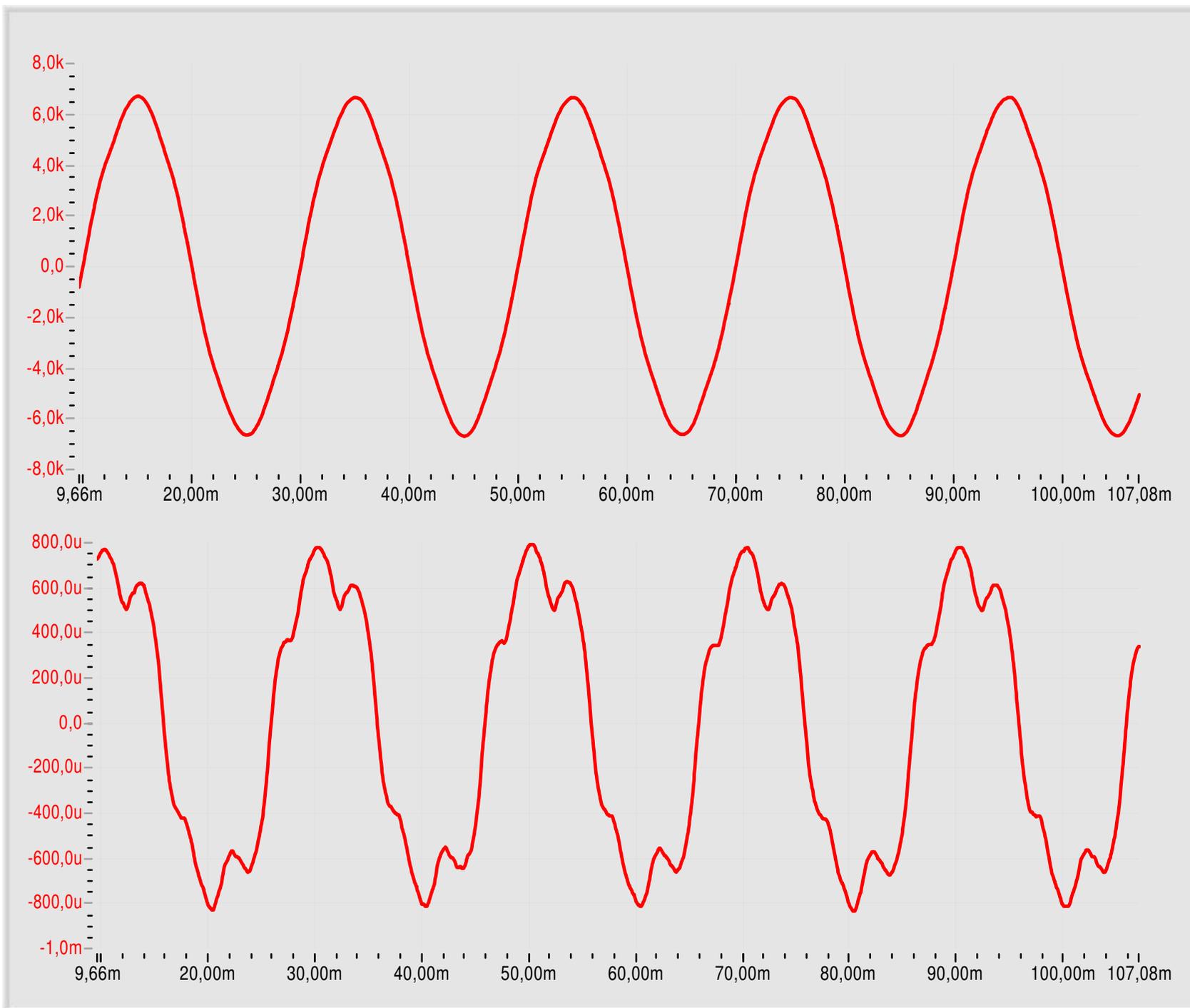
CESI B7020147 Oscillogram n. 46



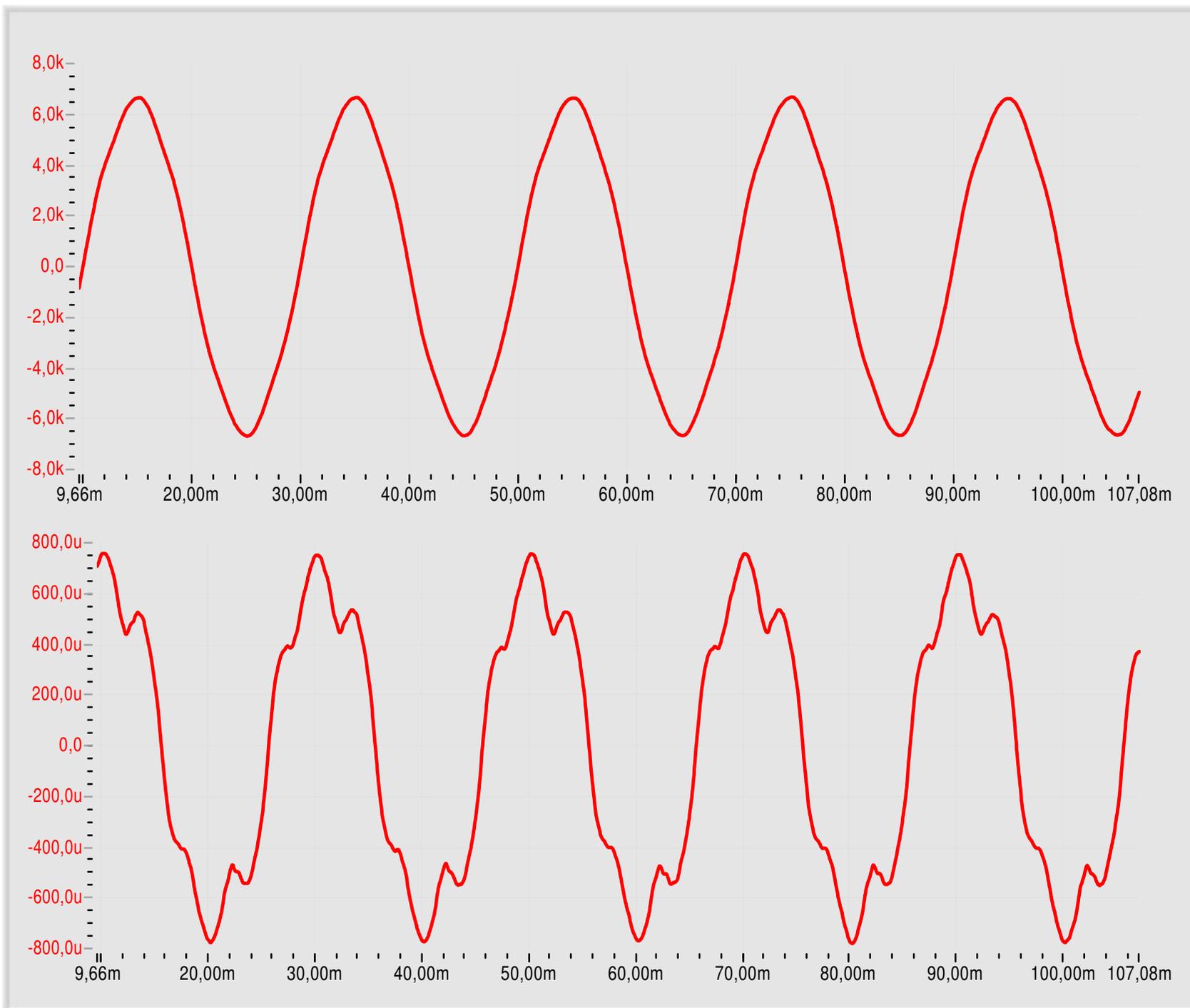
CESI B7020147 Oscillogram n. 47



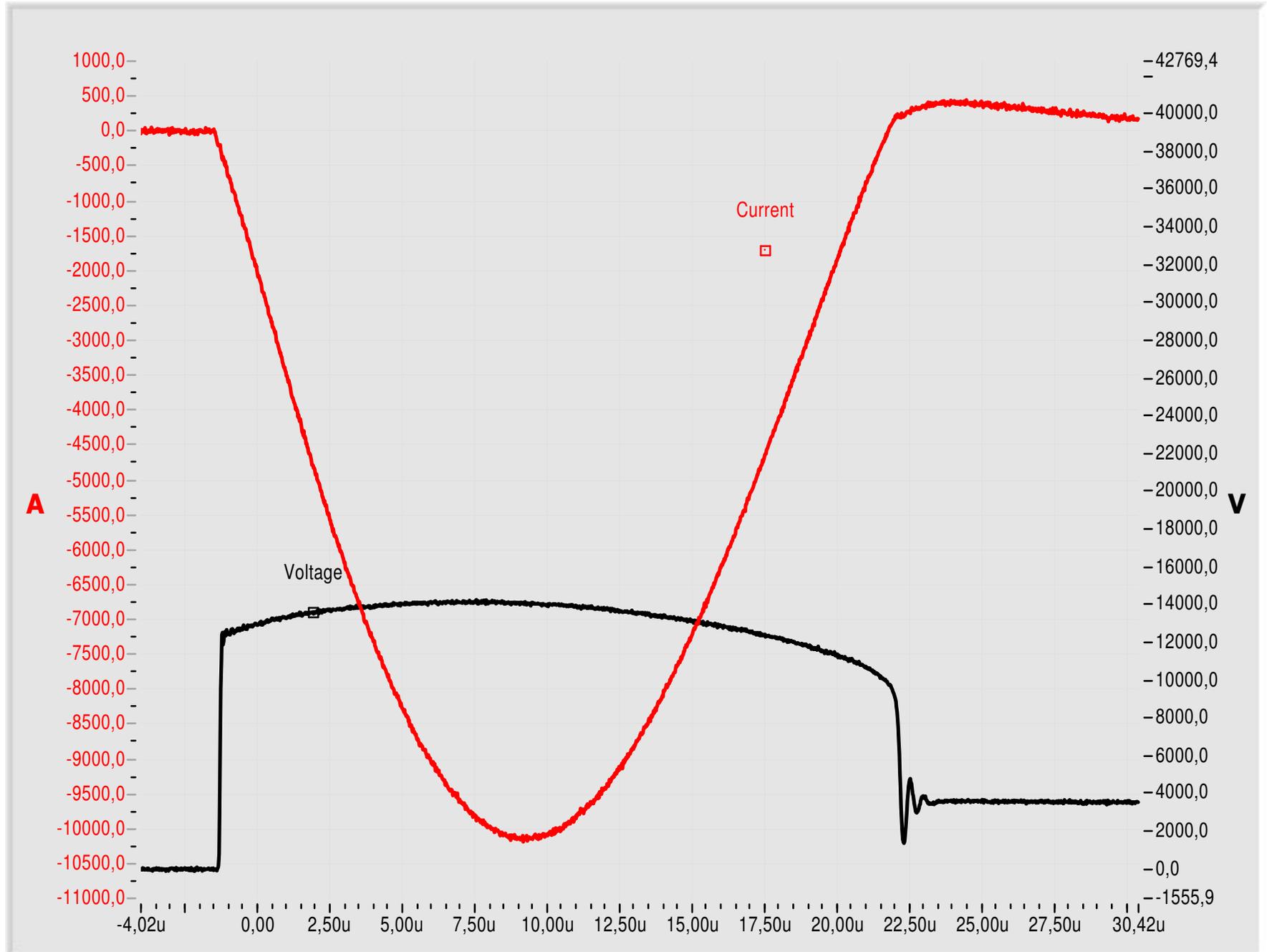
CESI B7020147 Oscillogram n. 48



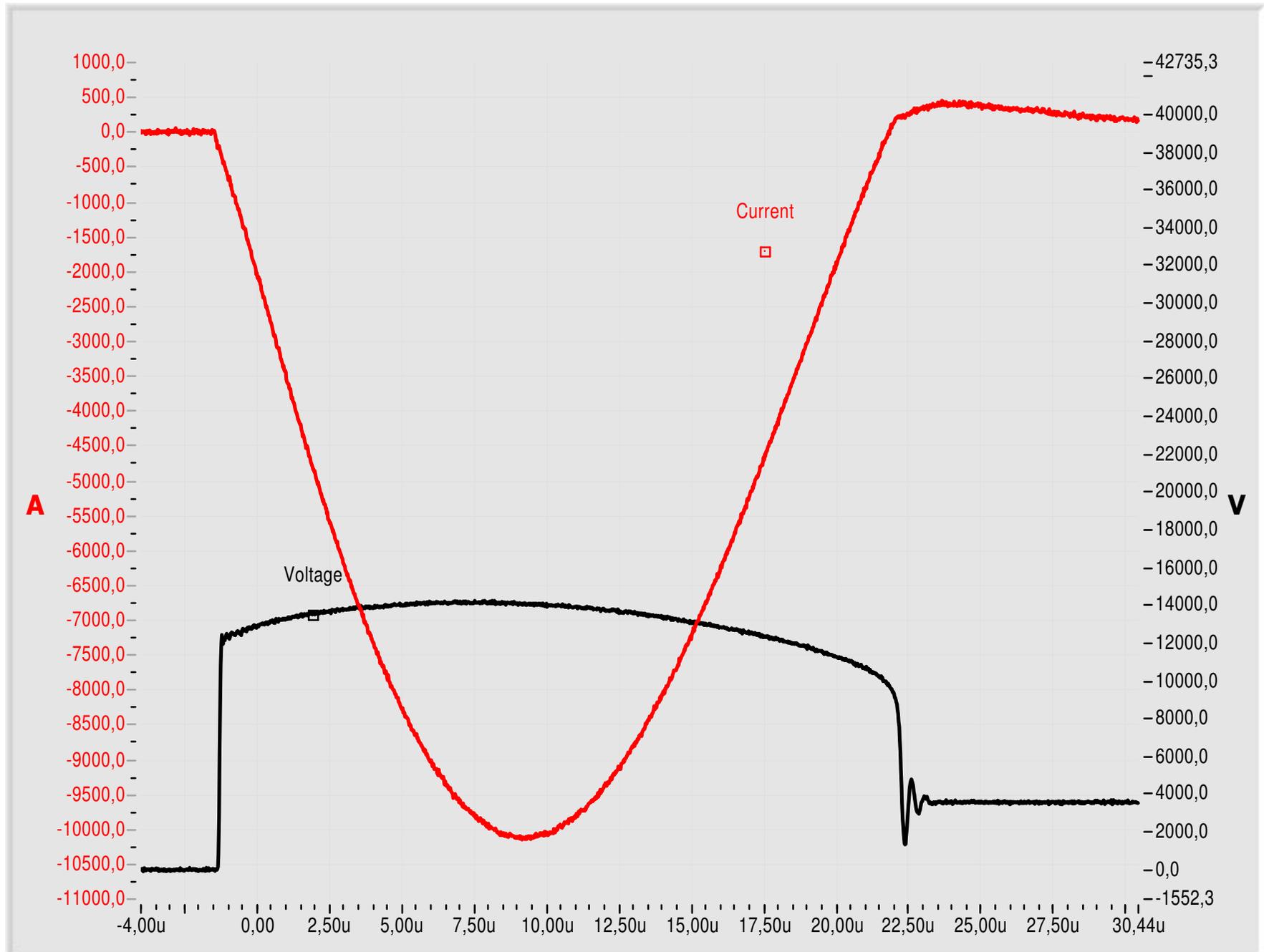
CESI B7020147 Oscillogram n. 49



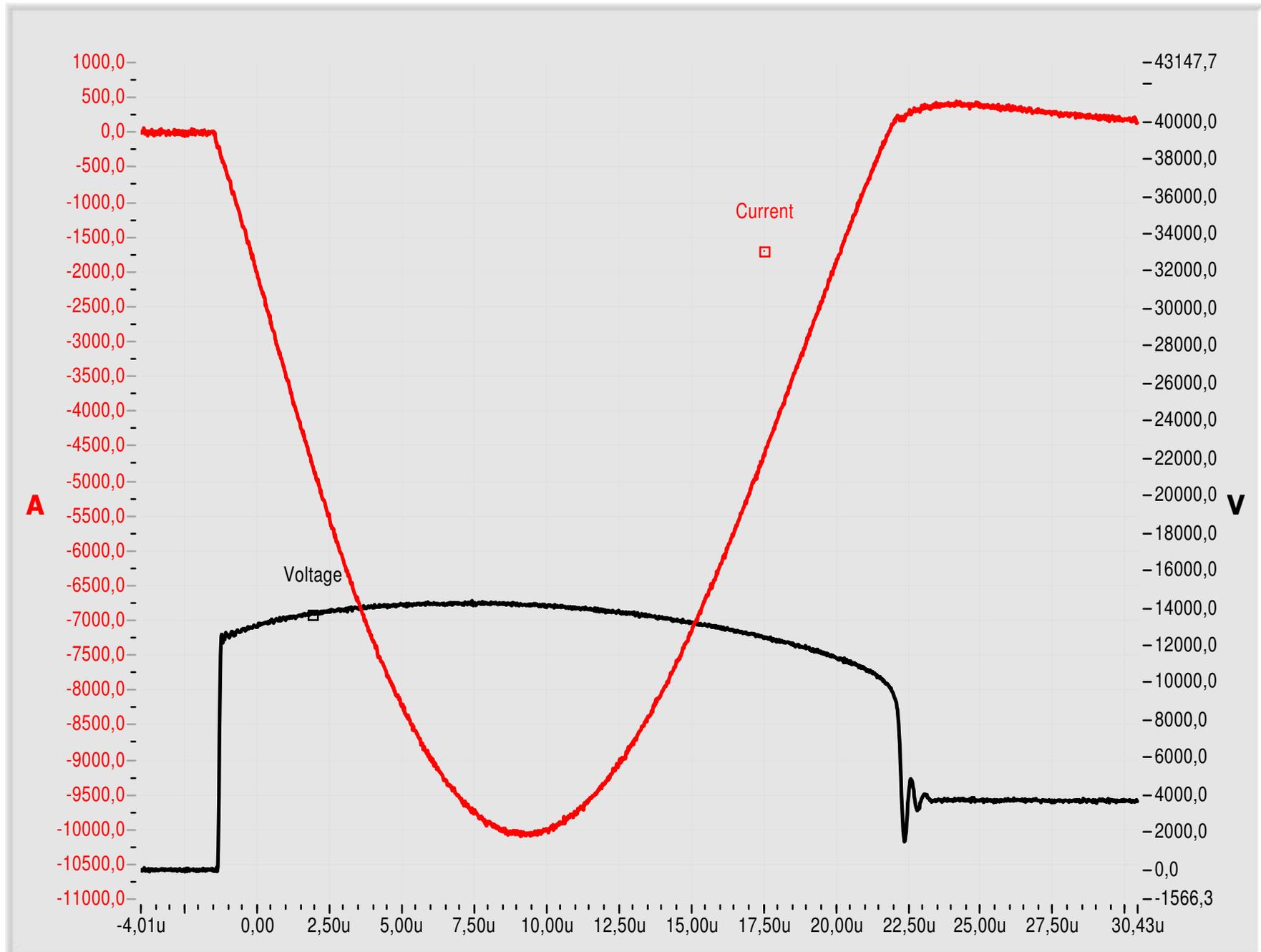
CESI B7020147 Oscillogram n. 51



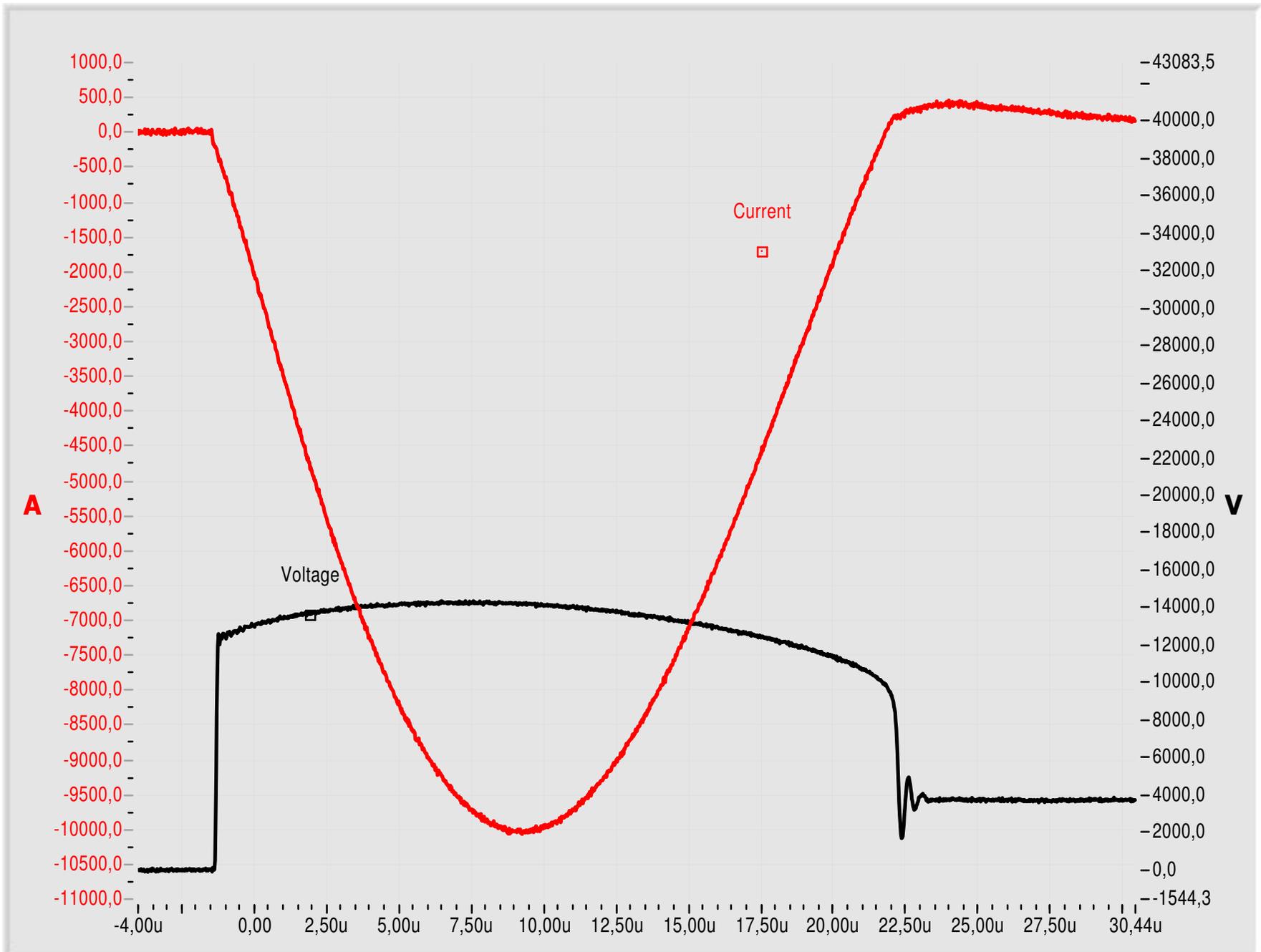
CESI B7020147 Oscillogram n. 52



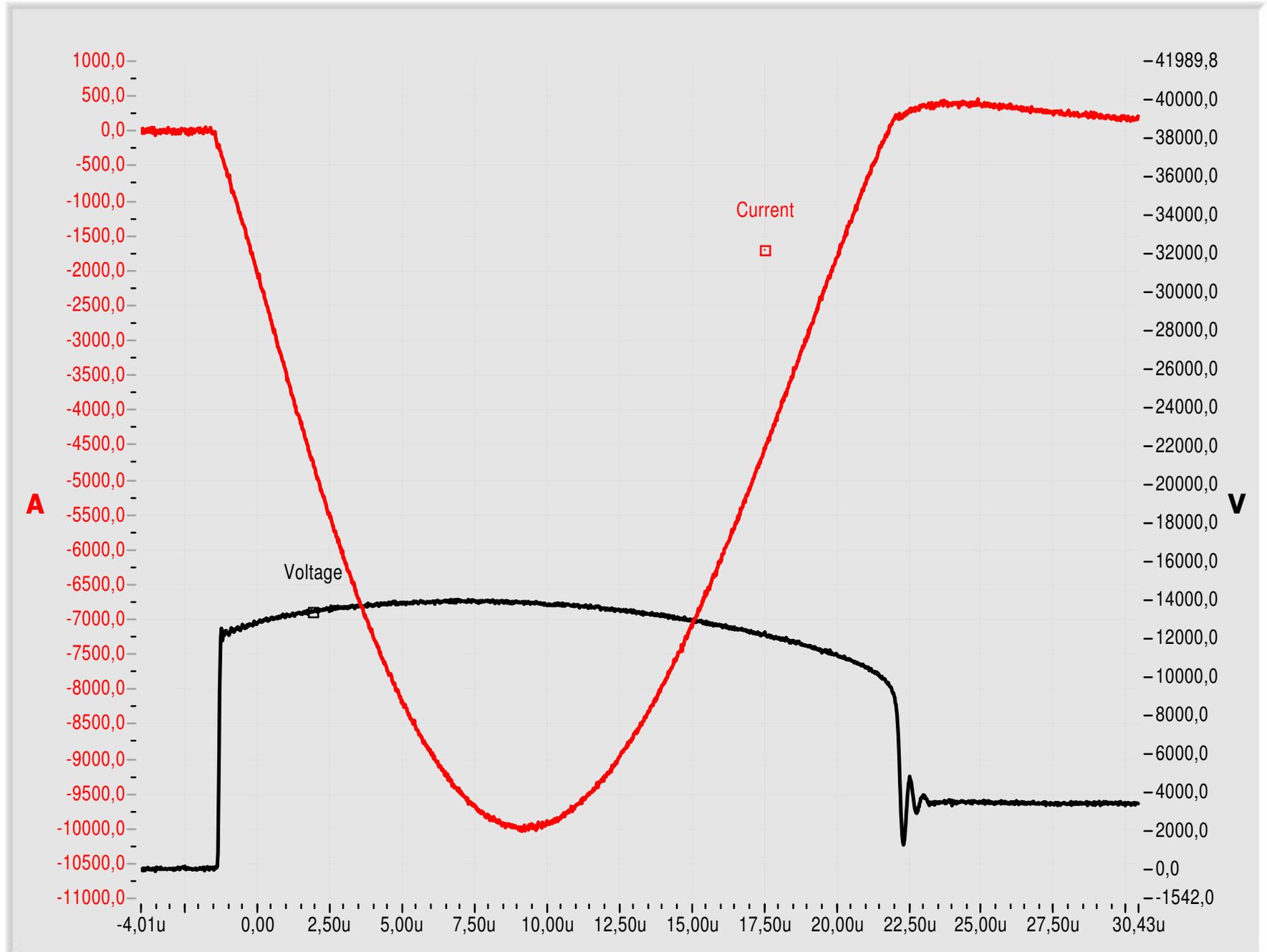
CESI B7020147 Oscillogram n. 53



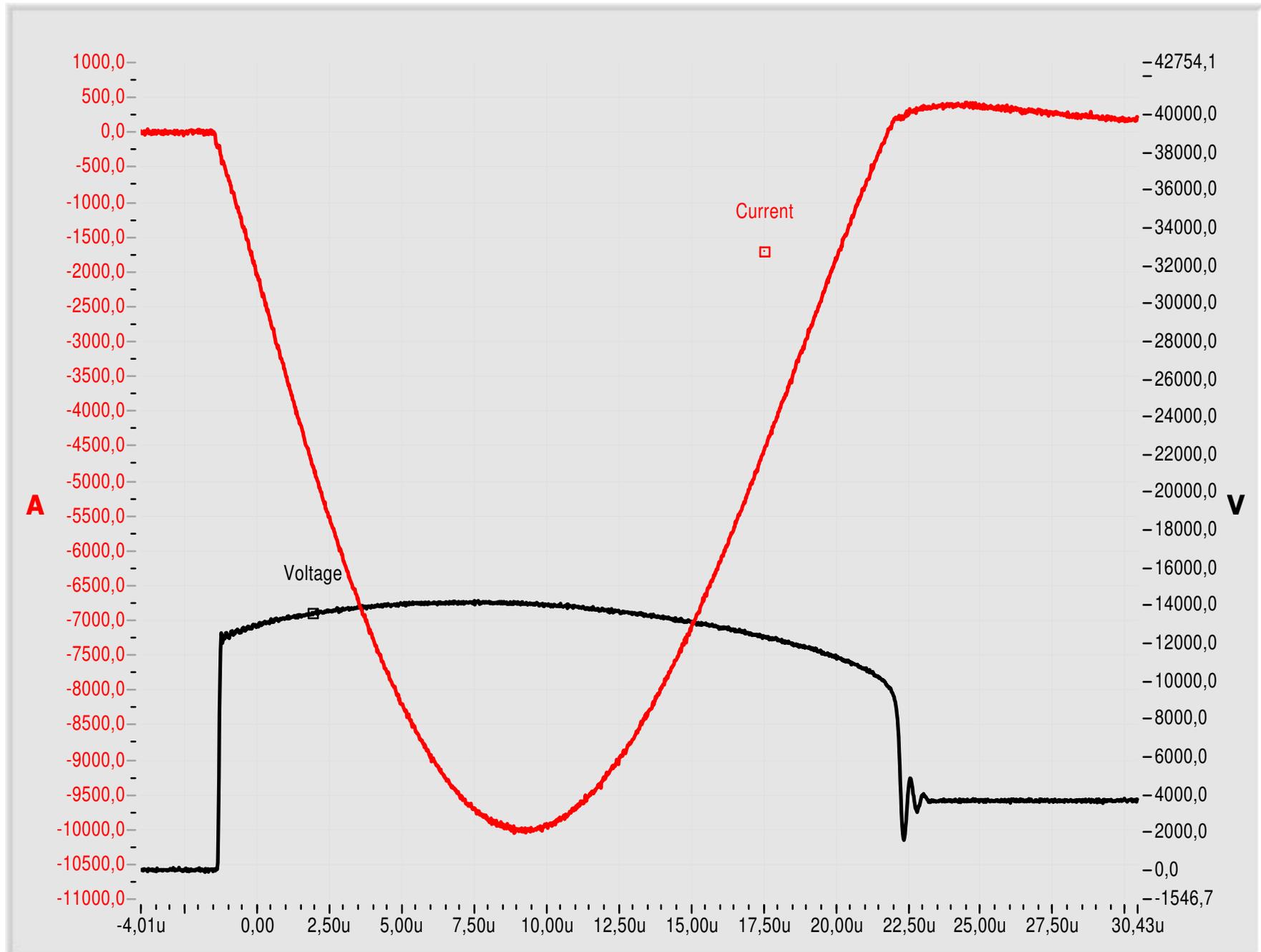
CESI B7020147 Oscillogram n. 54



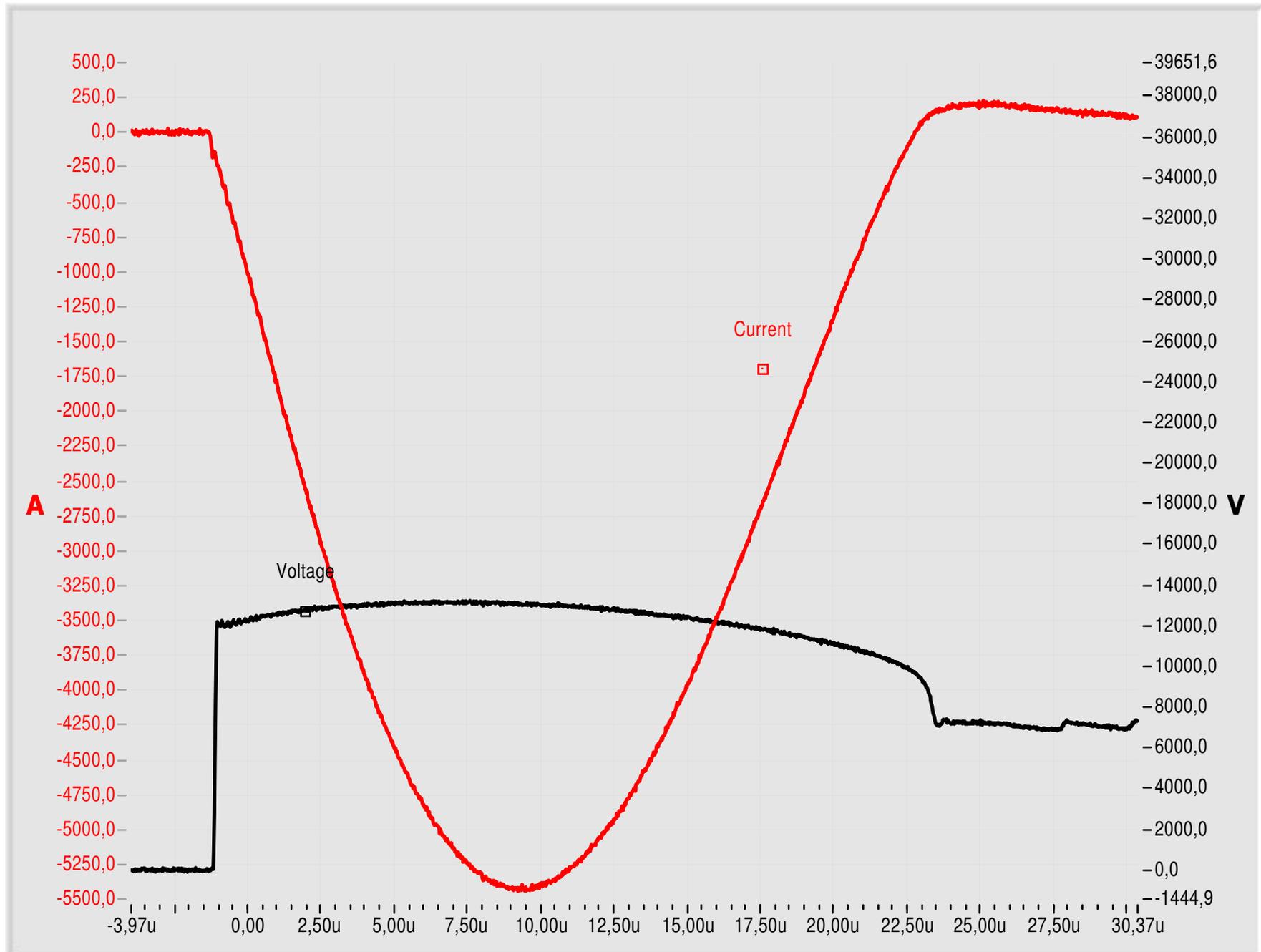
CESI B7020147 Oscillogram n. 55



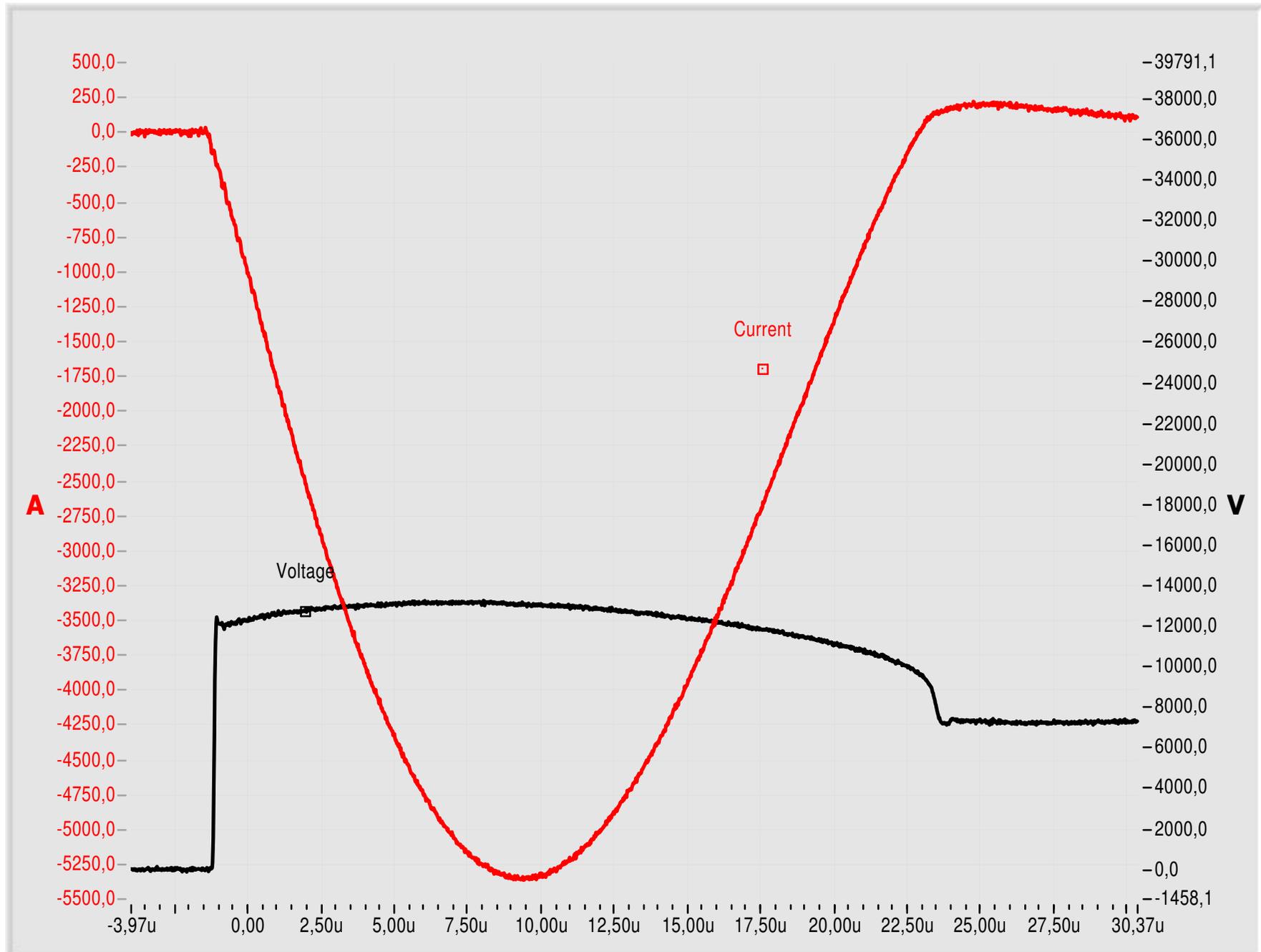
CESI B7020147 Oscillogram n. 56



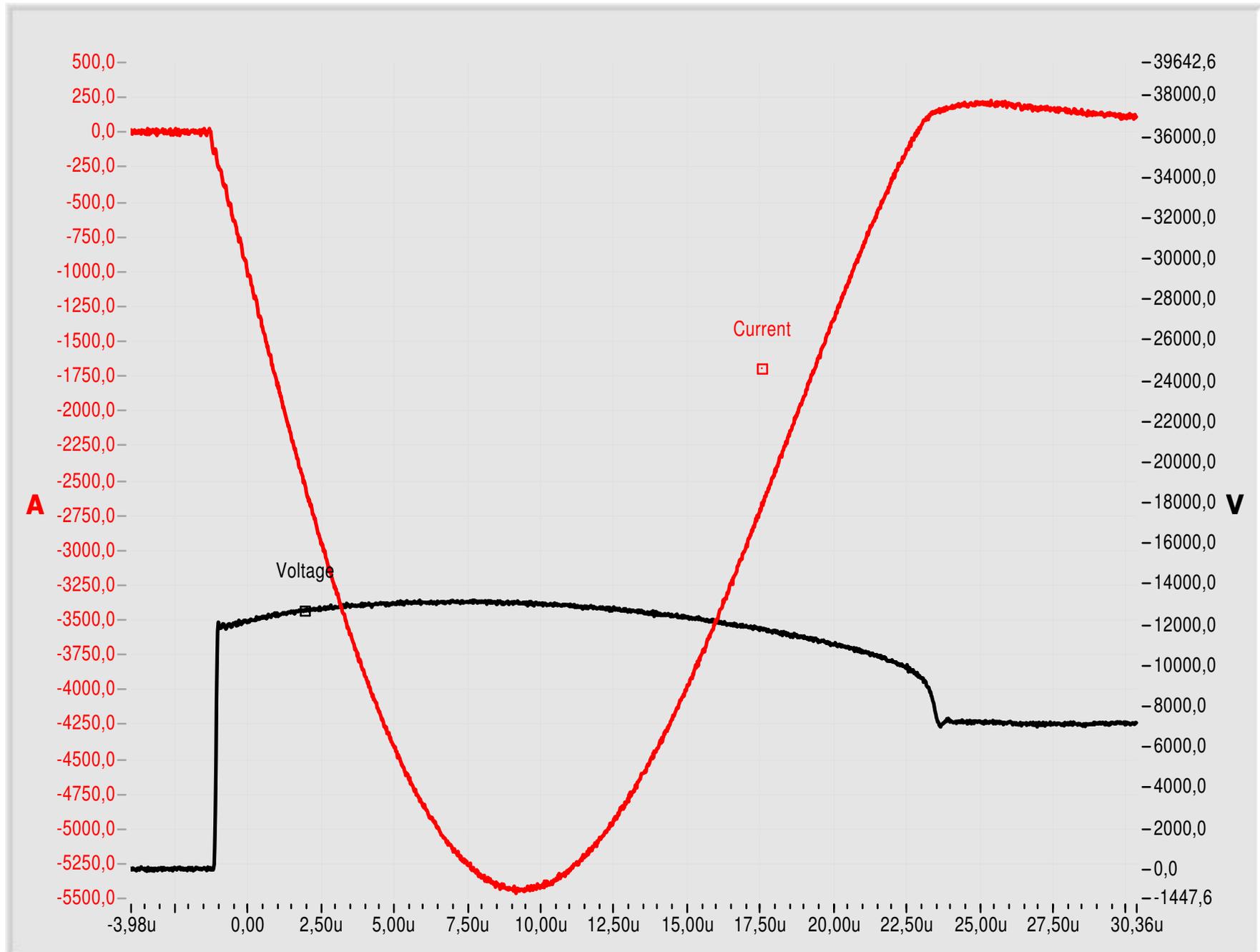
CESI B7020147 Oscillogram n. 57



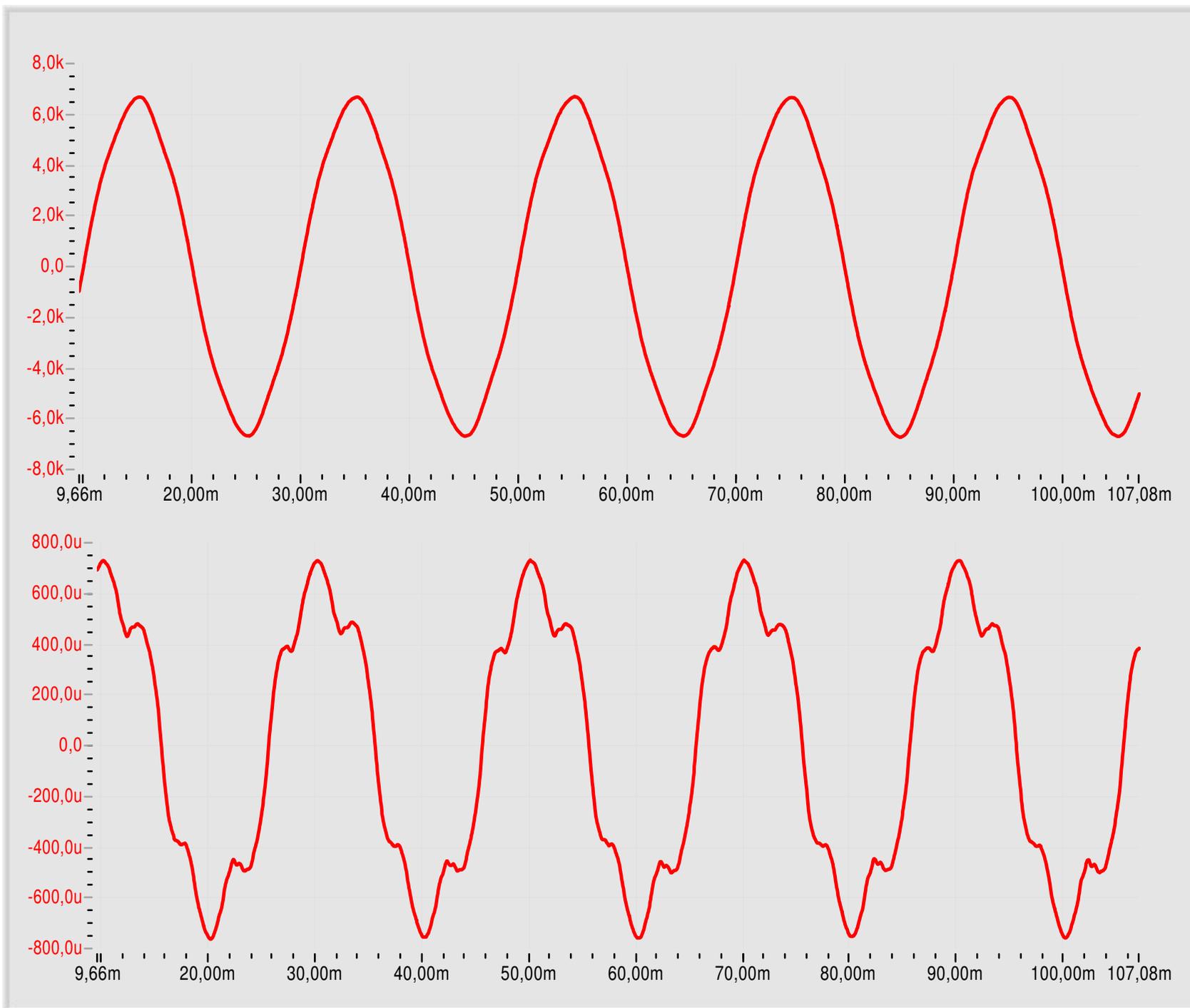
CESI B7020147 Oscillogram n. 58



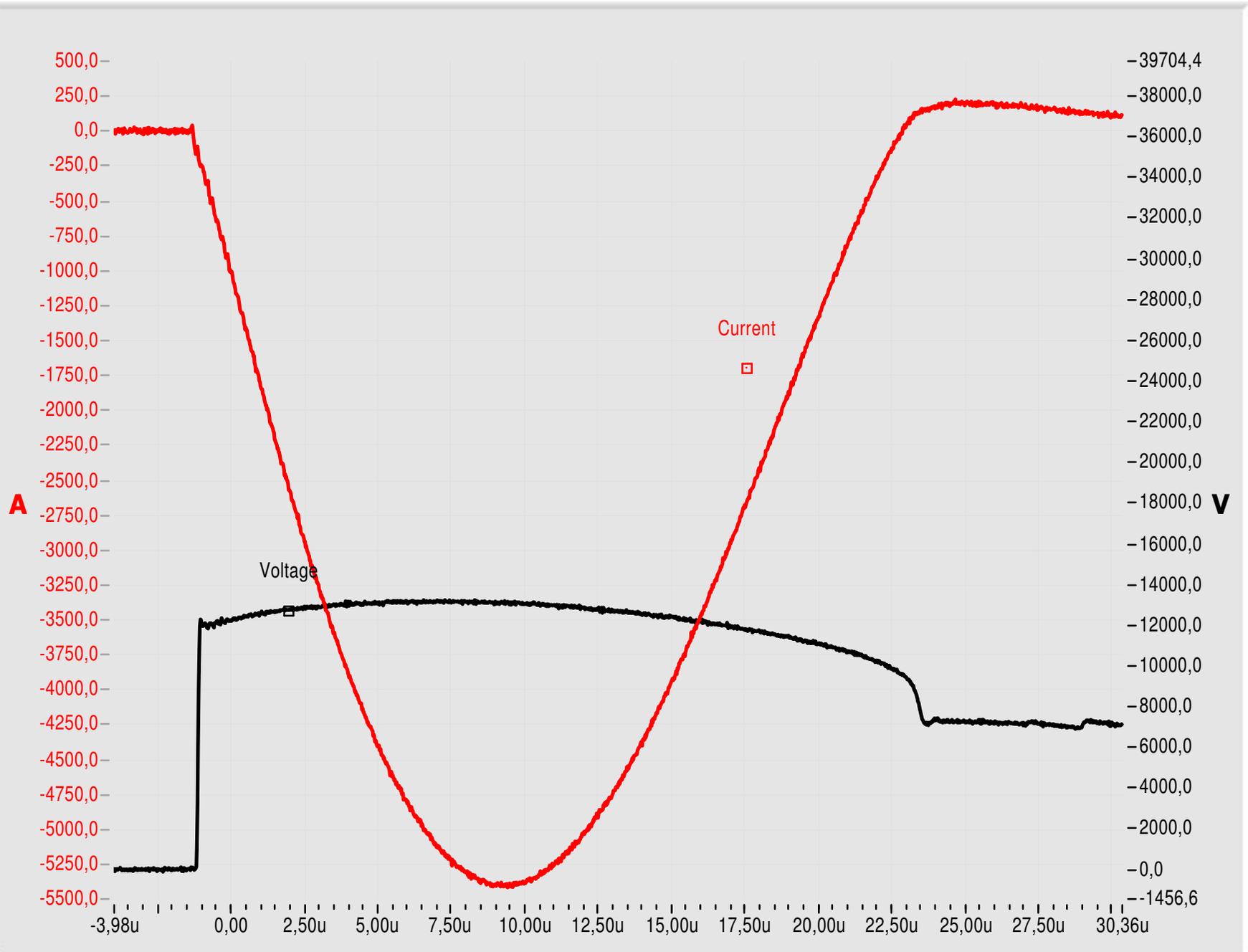
CESI B7020147 Oscillogram n. 59



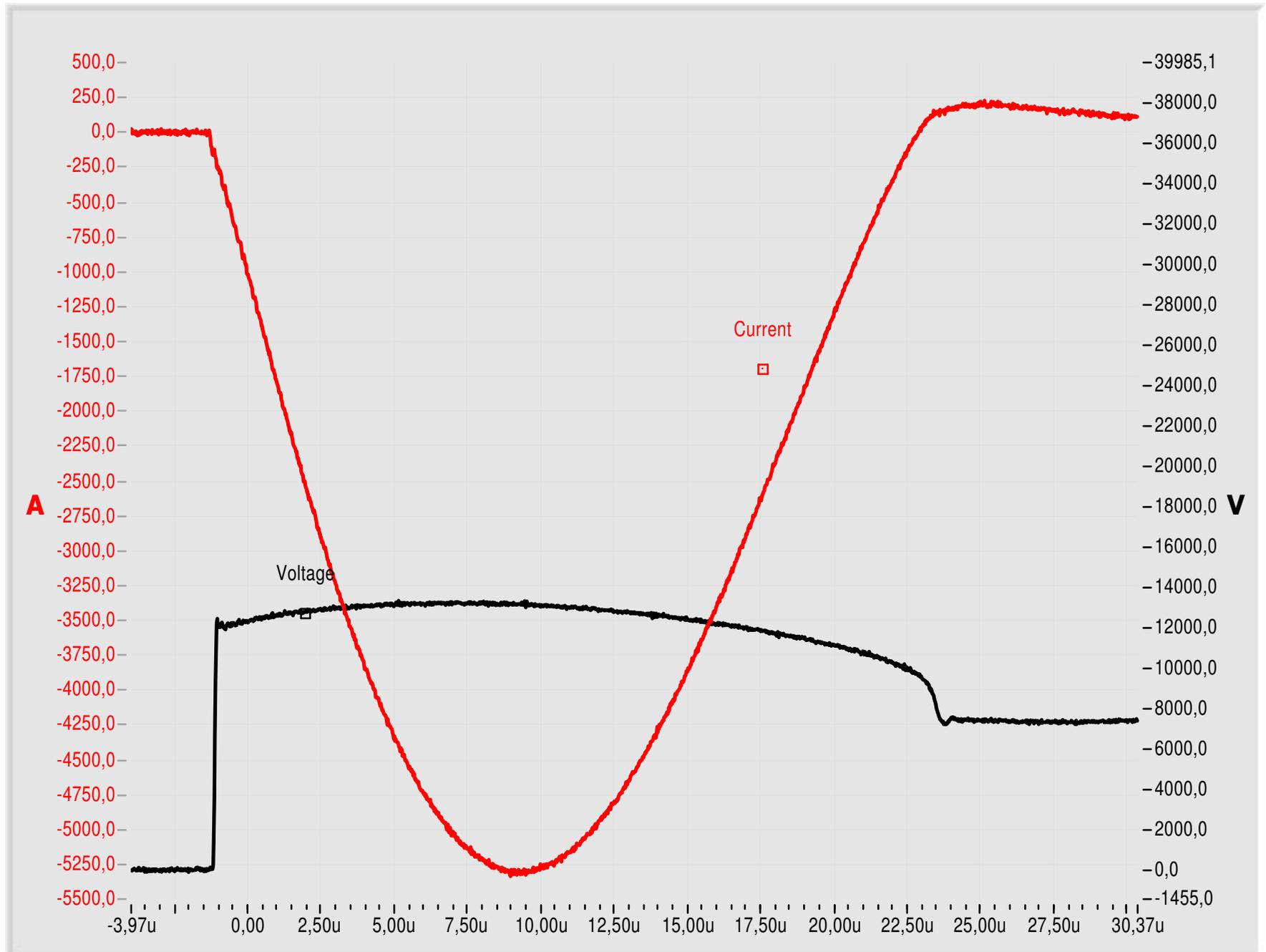
CESI B7020147 Oscillogram n. 50



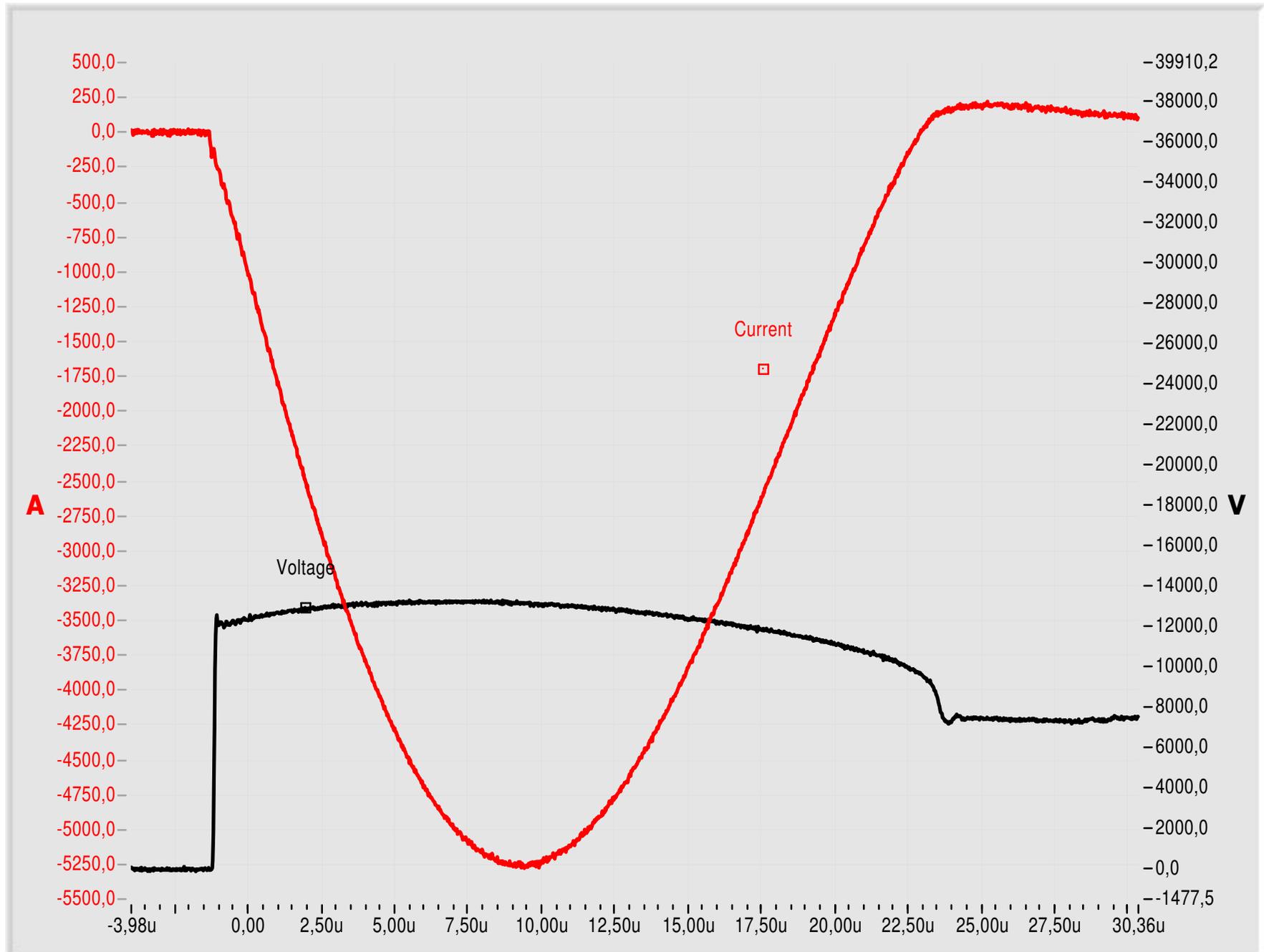
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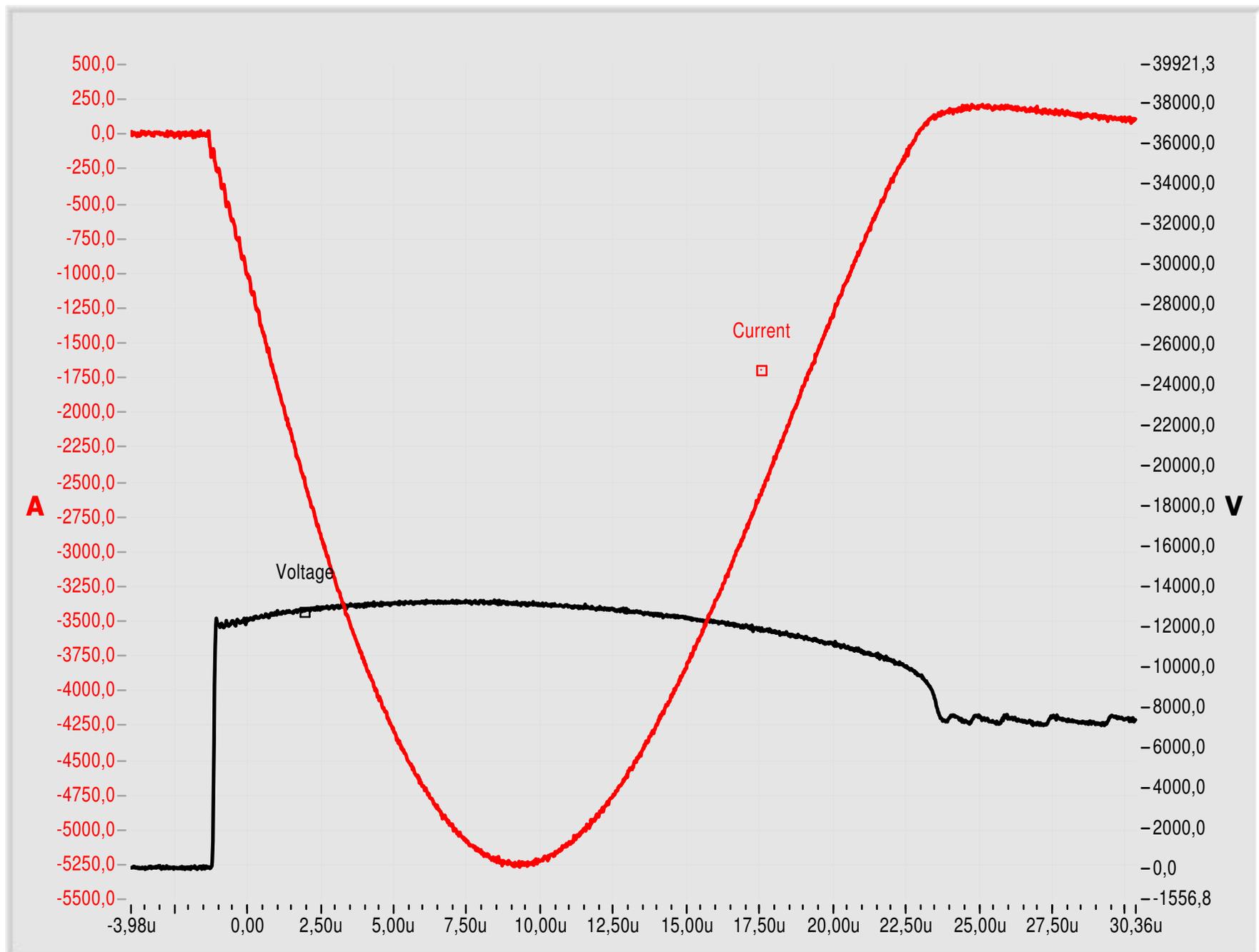
CESI B7020147 Oscillogram n. 61



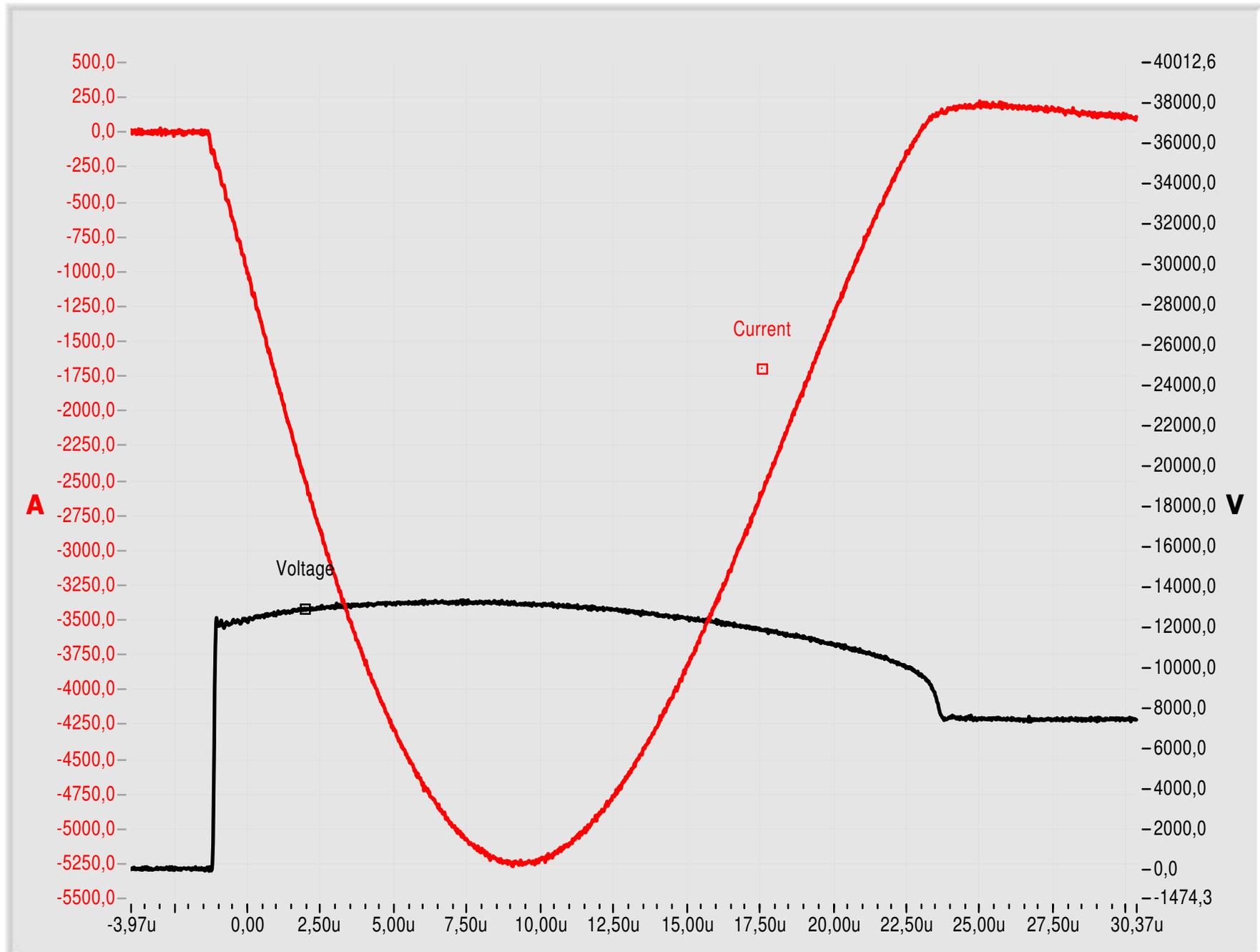
CESI B7020147 Oscillogram n. 62



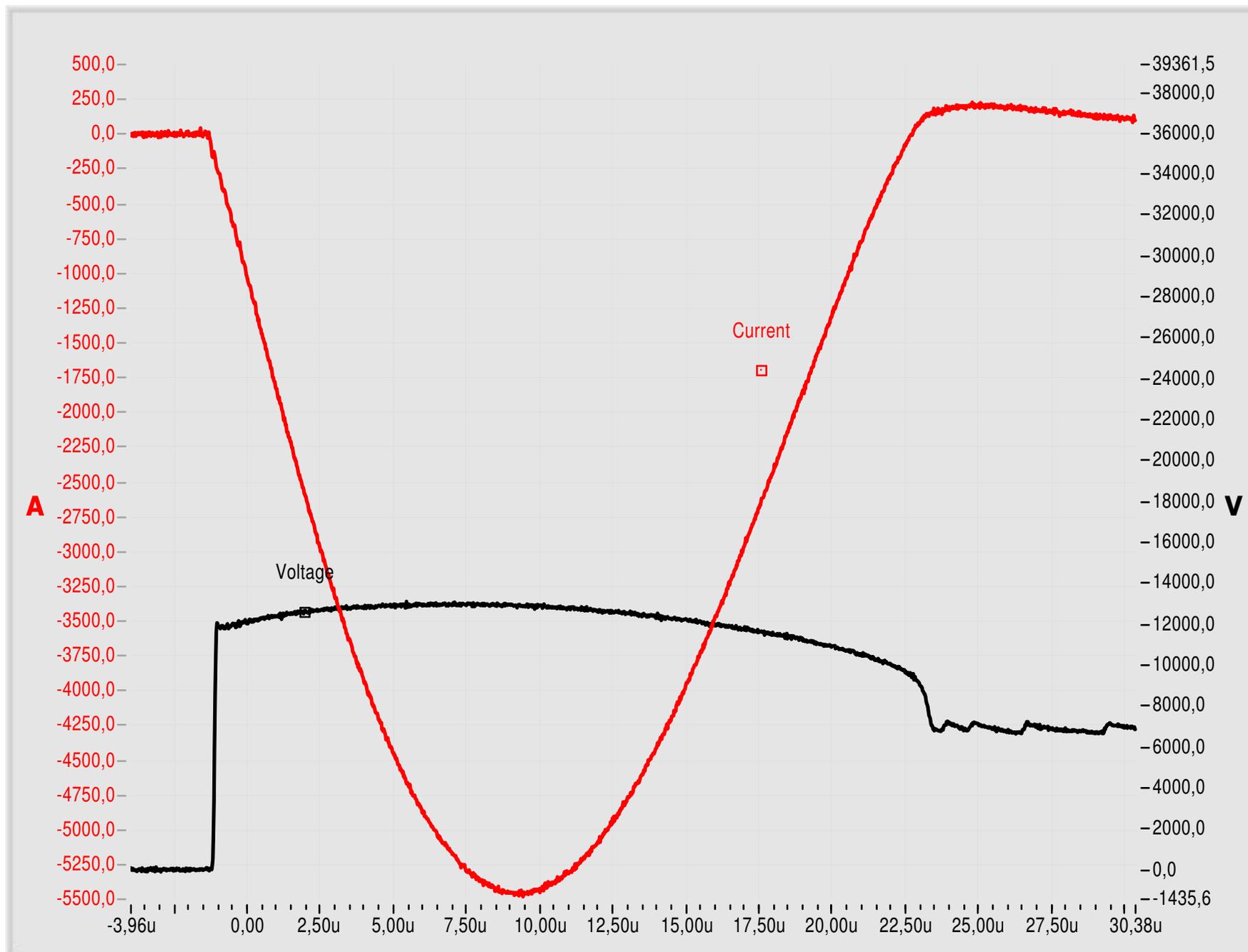
CESI B7020147 Oscillogram n. 63



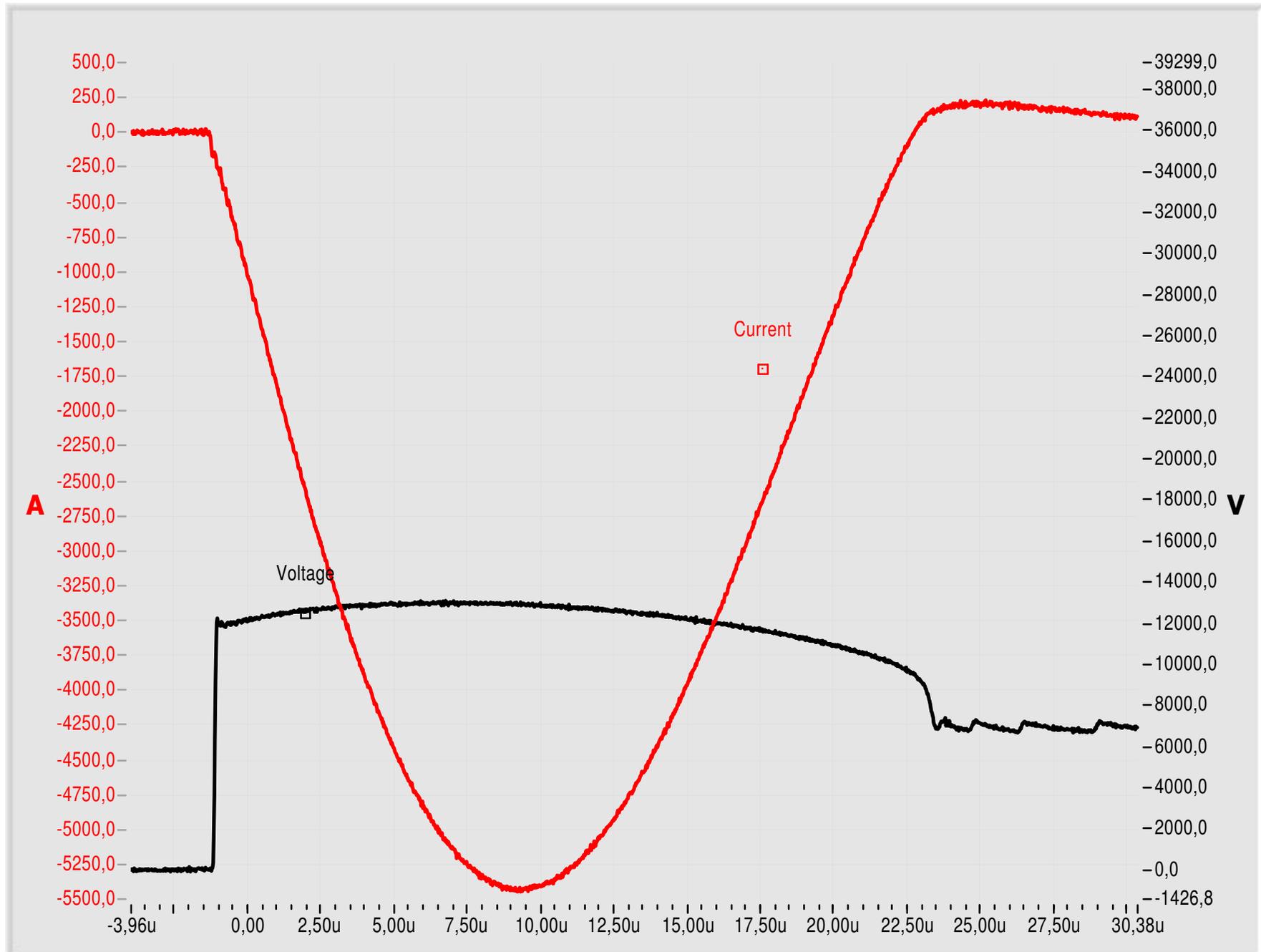
CESI B7020147 Oscillogram n. 64



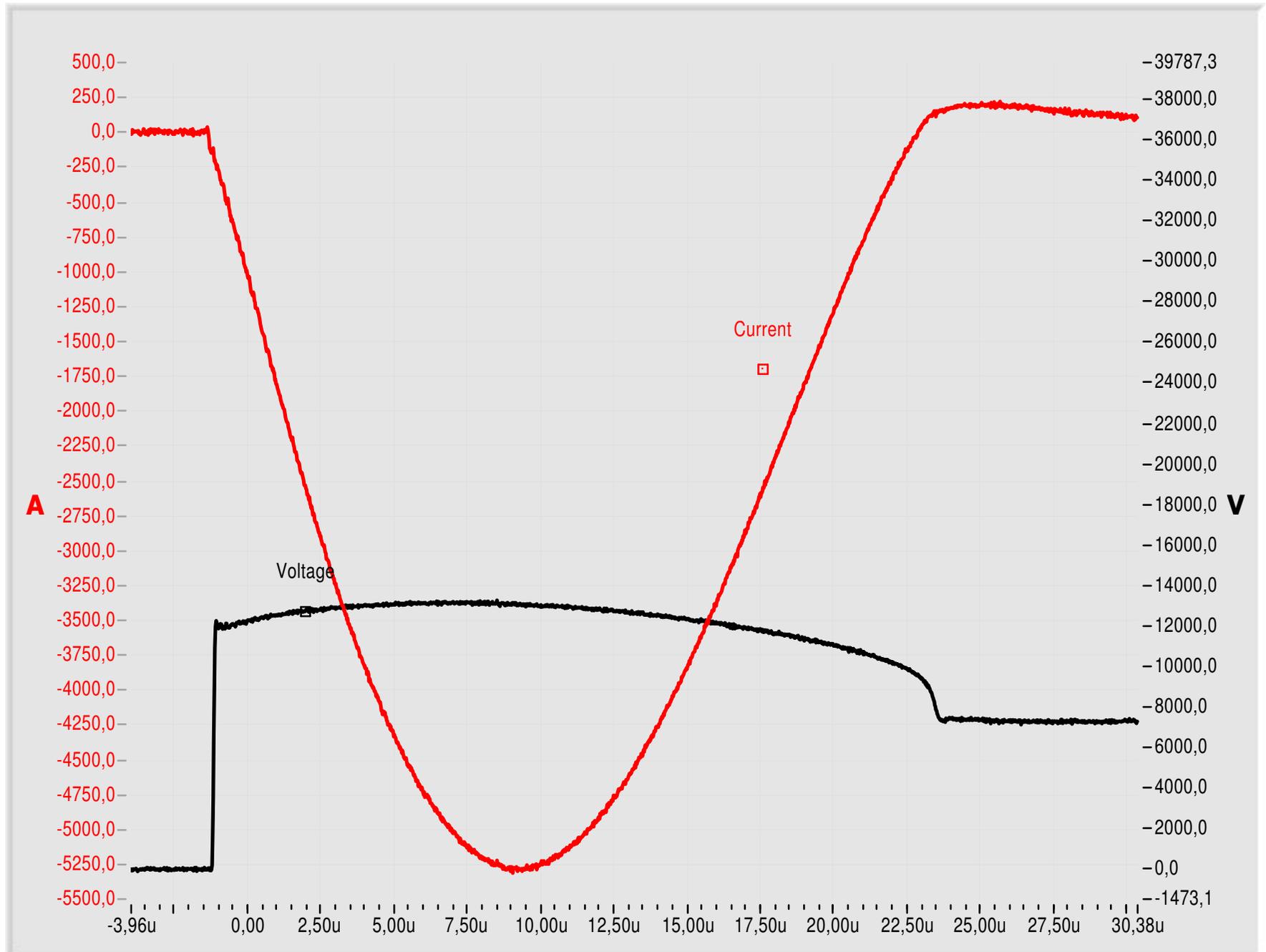
CESI B7020147 Oscillogram n. 65



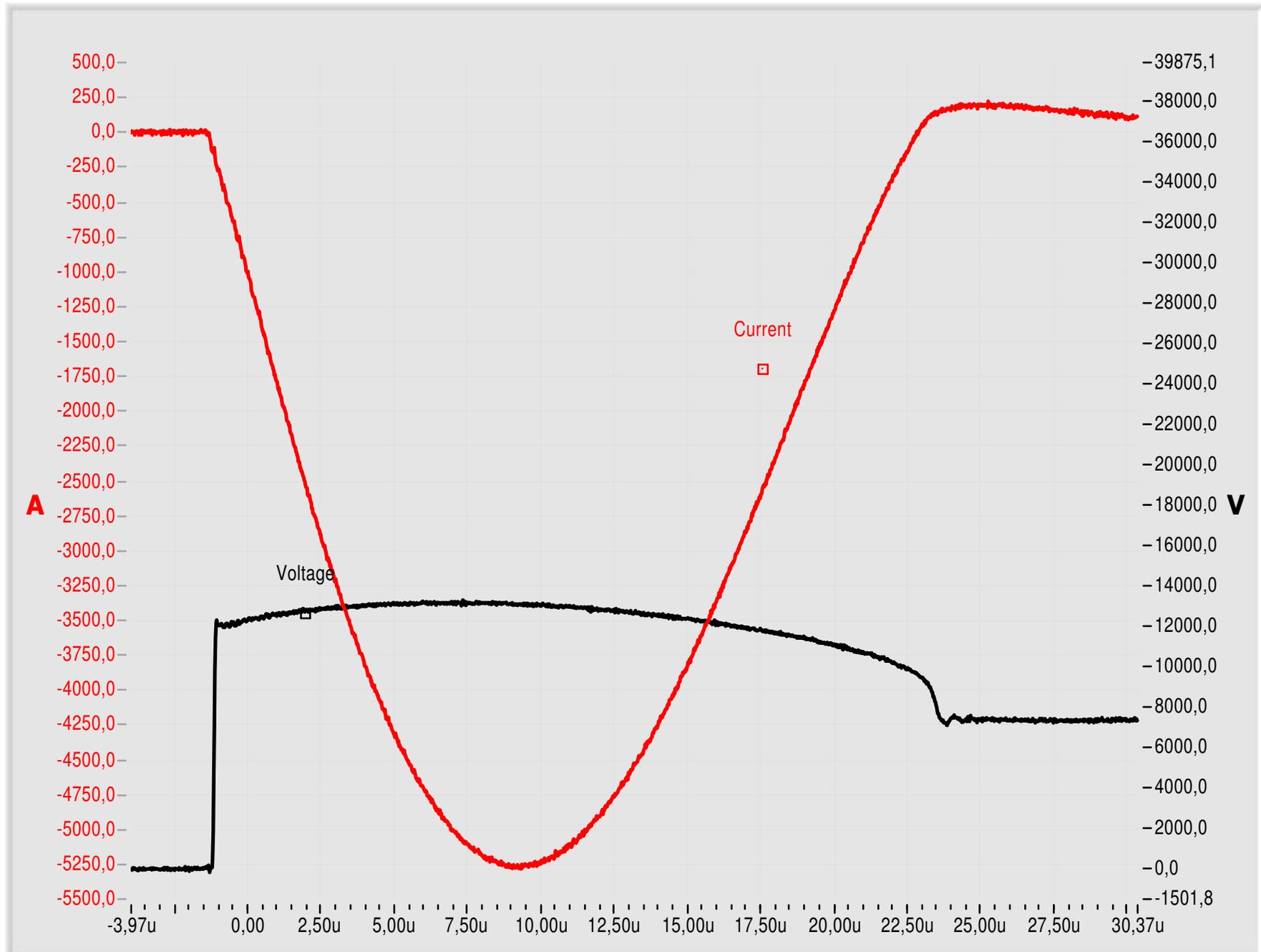
CESI B7020147 Oscillogram n. 66



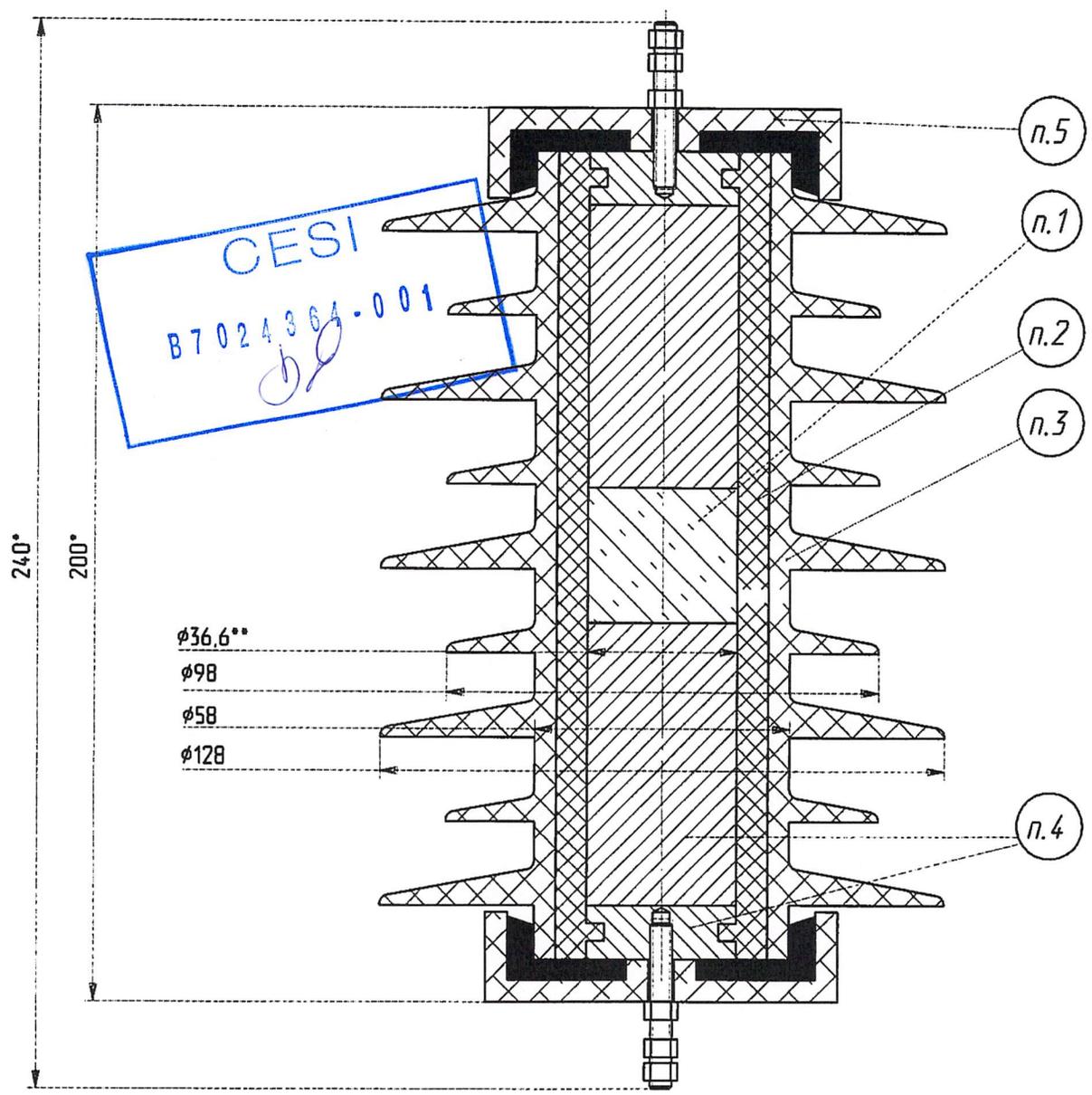
CESI B7020147 Oscillogram n. 67



CESI B7020147 Oscillogram n. 68



PA-DM.001.ST.02



Перв. применение  
Справ. №

Подп. и дата  
Инд. № дробл.  
Инд. № Инд. №  
Взак. инд. №  
Подп. и дата  
Инд. № подл.

| № п.п. | name                          | note |
|--------|-------------------------------|------|
| n.1    | varistor B34/30               | 000  |
| n.2    | Housing                       | 000  |
| n.3    | External insulation           | 000  |
| n.4    | Metal flanges and spacers     | 000  |
| n.5    | Additional thermal insulation | 000  |

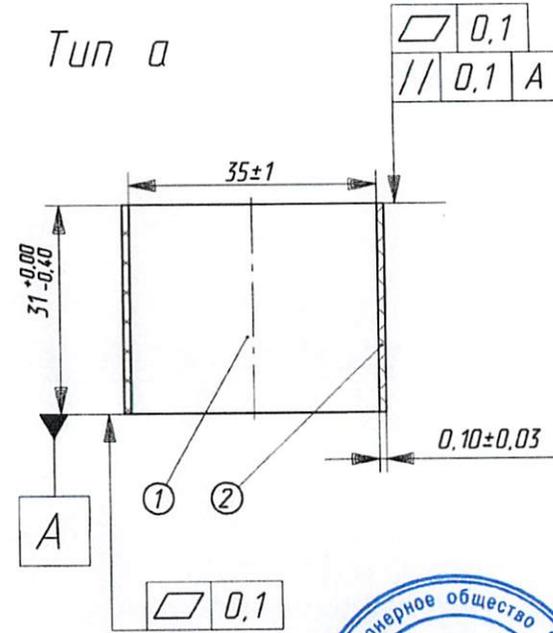
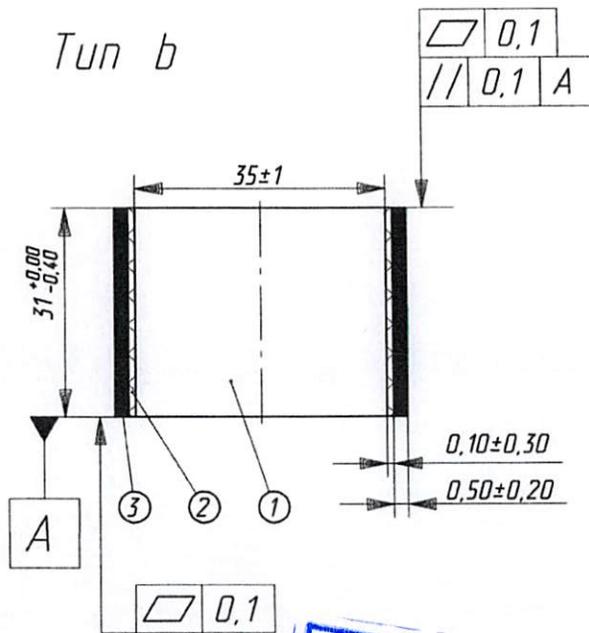
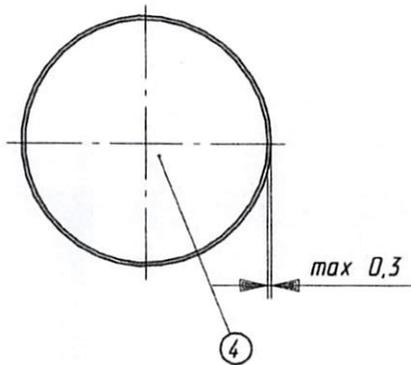
1. \* - Dimensions for reference  
2. \*\* - Typical diameter B34 / 30

|          |              |          |       |      |   |          |     |
|----------|--------------|----------|-------|------|---|----------|-----|
|          |              |          |       |      | <b>PA-DM.001.ST.02</b>                            |          |     |
| Изм.     | Лист         | № докум. | Подп. | Дата | section in thermal model.<br>Surge Arrester PA-DM |          |     |
| Разраб.  | Потапов В.В. |          |       |      |   |          |     |
| Прод.    | Потапов А.В. |          |       |      | Лист 1  | Листов 1 | 1:1 |
| Т.контр. |              |          |       |      | ЗАО<br>"Полимер-Аппарат"                          |          |     |
| И.контр. |              |          |       |      |   |          |     |
| Утв.     | Шевицов И.В. |          |       |      |   |          |     |

Копировал

Формат А3

PA.VAR.0400.30



1. Металлооксидный варистор (MOV disk)
2. Изоляционное покрытие стекло (Glass insulating collar)
3. Изоляционное покрытие полиуретан (PU insulating collar)
4. Алюминиевый электрод (Al - electrode)



|              |              |
|--------------|--------------|
| Инв. № дубл. | Подп. и дата |
| Взам. инв. № | Подп. и дата |
| Инв. № подл. | Подп. и дата |

|          |      |              |           |       |
|----------|------|--------------|-----------|-------|
| Изм.     | Лист | № докум.     | Подп.     | Дата  |
|          |      |              |           |       |
| Разраб.  |      | Поталов А.В. | Игорь     | 09.17 |
| Проб.    |      | Петухов А.П. | Александр | 09.17 |
| Т.контр. |      |              |           |       |
| Н.контр. |      |              |           |       |
| Утв.     |      | Шевцов И.В.  | Игорь     | 09.17 |

PA.VAR.0400.30

Varistor B34/30

Оксид цинка

|                          |          |        |
|--------------------------|----------|--------|
| Лит.                     | Масса    | Масшт. |
|                          | 0.177    | 1:1    |
| Лист 1                   | Листов 1 |        |
| ЗАО<br>"Полимер-Аппарат" |          |        |

### The TOV characteristics of PA-DM surge arresters.

The TOV characteristics (in p.u.  $U_r$ ) of PA-DM surge arresters "with prior duty" and "without prior duty" as per IEC 60099-4 Ed. 3.0 are presented in the Fig.2 below.

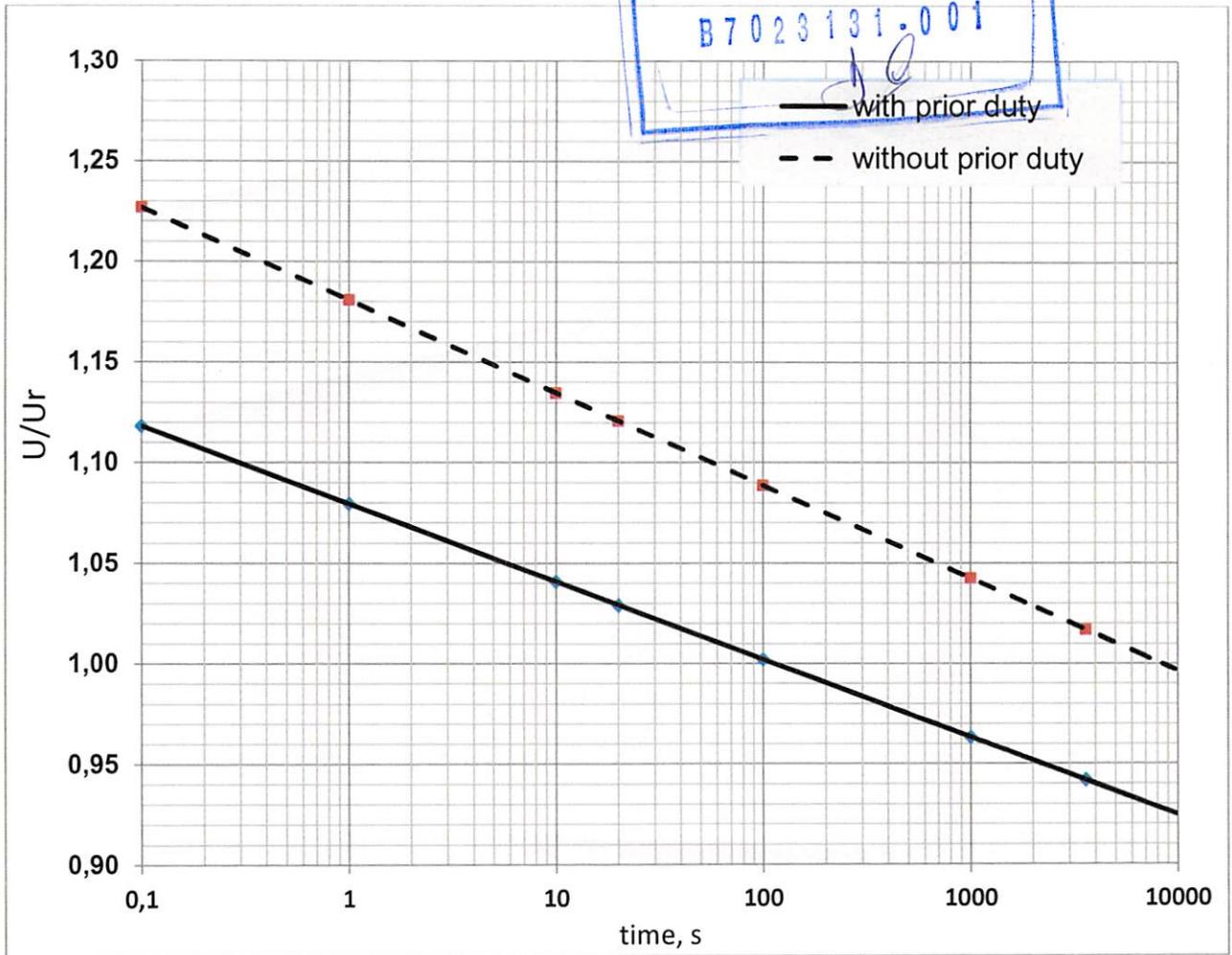


Figure 2. The TOV characteristics of PA-DM surge arresters.

The TOV values in per unit of  $U_r$  for times 0,1 s, 1 s, 10 s, 100 s, 1000 s and 3600 s are presented in the table 4.

Table 4.

| Time, s | The TOV values in p.u. $U_r$ |                      |
|---------|------------------------------|----------------------|
|         | "with prior duty"            | "without prior duty" |
| 0,1     | 1,120                        | 1,230                |
| 1       | 1,080                        | 1,180                |
| 10      | 1,040                        | 1,130                |
| 100     | 1,000                        | 1,090                |
| 1000    | 0,960                        | 1,040                |
| 3600    | 0,940                        | 1,020                |