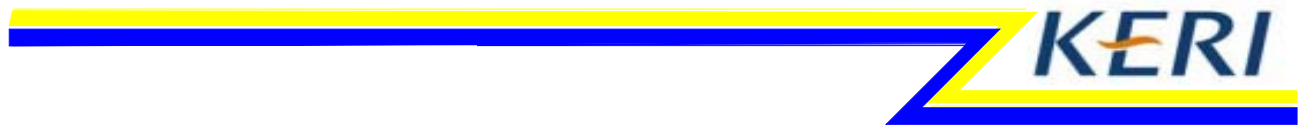


# ***TEST CERTIFICATE***



**한국전기연구원**  
**KOREA ELECTROTECHNOLOGY**  
**RESEARCH INSTITUTE**

## INFORMATION SHEET

KERI(Korea Electrotechnology Research Institute) issues a Type Test Certificate and a Test Report as below.

### 1. Type Test Certificate

A Certificate contains a record of a series of type tests carried out strictly in accordance with IEC, and/or regional standard and national standard that are identical to IEC standard. The equipment tested has fulfilled the requirements of this standard and the relevant ratings assigned by the manufacturer are endorsed by KERI. The Certificate is applicable only to the equipment tested. KERI is responsible for the validity and the contents of the Certificate. The responsibility for conformity of any apparatus having the same designation as the one tested rests with the manufacturer. The certificate contains the essential drawings and a description of the equipment tested. Detailed rules are given in KERI's Type Test Certification Procedure.

### 2. Test Report

#### 2.1 Type Test Report

A Type Test Report contains a record of a series of type tests carried out strictly in accordance with a standard recognized by KERI. The equipment tested has fulfilled the requirements of this standard and the relevant ratings assigned by the manufacturer are endorsed by KERI. The Type Test Report is applicable only to the equipment tested. KERI is responsible for the validity and the contents of the Type Test Report. The responsibility for conformity of any apparatus having the same designation as the one tested rests with the manufacturer. The Type Test Report contains the essential drawings and a description of the equipment tested. Detailed rules are given in KERI's Test Procedure.

#### 2.2 Performance Test Report

A Performance Test Report contains a record of one or more tests which have been carried out according to the client's instructions. These tests are not necessarily in accordance with a recognized standard. The test results do not verify ratings of the test object. Detailed rules are given in KERI's Test Procedure.

KERI issues three types of Performance Test Report.

2.2.1 The tests have been carried out strictly in accordance with a recognized standard. The apparatus has complied with the relevant requirements.

This sentence will appear on the front page of Performance Test Report if the tests have been performed in accordance with a recognized standard, but the series of tests does not completely fulfil the requirements for a Certificate of Compliance (for example, if the number of test series is not a complete series of type tests). The Report contains verified drawings and a description of the equipment tested. The condition of the test object after the tests is assessed and recorded in the Report.

2.2.2 The tests have been carried out in accordance with the client's instructions. Test procedure and test parameters were based on a recognized standard.

This sentence will appear on the front page of Performance Test Report if the number of test duties, the test procedure and the test parameters are based on a recognized standard and related to the ratings assigned by the manufacturer. Verification of the drawings (if submitted) and assessment of the condition after the tests is only done on the client's request.

2.2.3 The tests have been carried out according to the client's instructions.

This sentence will appear on the front page of Performance Test Report if the test shots, test procedure and/or test parameters are not in accordance with a recognized standard.

3 KERI is a member of STL(Short-circuit Testing Liaison) and the accredited testing laboratory under Clause 2 of Article 2 in "Guidelines on certified testing criteria and methods for electrical equipment" (Public Notice No. 2008-120, Ministry of Knowledge Economy, Korea).

## TYPE TEST CERTIFICATE OF SHORT-CIRCUIT PERFORMANCE

APPARATUS SF6 Gas Circuit Breaker with live tank and common operating mechanism

DESIGNATION 120-SFM-32B (Common operating mechanism)  
145 kV 3 150 A 40 kA 50 Hz

RECEIPT No. TRD11C00219 (March 21, 2011 )

MANUFACTURER Crompton Greaves Ltd.  
A-3 MIDC, Ambad, Nasik 422 010 Maharashtra, India

TESTED FOR Crompton Greaves Ltd.  
A-3 MIDC, Ambad, Nasik 422 010 Maharashtra, India

DATE OF TESTS April 13, 2011 ~ April 27, 2011

TESTED BY KERI, 12, bulmosan-ro 10beon-gil, Seongsan\_gu, Changwon-si,  
Gyeongsangnam-do, 642-120, Korea

The apparatus, constructed in accordance with the description, drawings and photographs incorporated in this certificate has been subjected to the series of proving tests in accordance with

IEC 62271-100:2008, subclauses 6.6(STC), 6.106(BSC), 6.108(DEF), 6.109(SLF) and 6.110(Out-of-phase)

This Type Test Certificate has been issued by KERI following exclusively the STL Guides.

The results are shown in the record of Proving Tests and the oscillograms attached hereto. The values obtained and the general performances are considered to comply with the above Standard and to justify the ratings assigned by manufacturer as listed on page No. 4.

The Certificate applies only to the apparatus tested. The responsibility for conformity of any apparatus having the same designations with that tested rests with the Manufacturer.

This Certificate comprises 197 sheets in total.

Only integral reproduction of this Certificate are permitted without written permission from KERI. Electronic copies in PDF-format or scanned version of this Certificate may be available and have the status "for information only". The sealed version of the Certificate is only the valid version.



*Park, Byung Rak*

Park, Byung-Rak  
Vice President  
for Testing & Certification  
Services

April 26, 2012

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**Tested by :**

|                 |      |
|-----------------|------|
| Park, Seung-Jae | KERI |
| Park, Yong-Hwan | KERI |
| Ryu, Jung-Hyeon | KERI |
| Park, Sang-Hun  | KERI |

**Witnessed by :**

|              |                       |
|--------------|-----------------------|
| S. S. Shete  | Crompton Greaves Ltd. |
| S. N. Rao    | Crompton Greaves Ltd. |
| S. R. Kulthe | Crompton Greaves Ltd. |

**Photographs :**

- Photo. HP01 : After basic short circuit tests(T100)
- Photo. HP02 : After short-line fault tests
- Photo. HP03 : After double-earth fault test(DEF)
- Photo. HP04 : After verification tests for single phase breaking of common operating mechanism
- Photo. HP05 : Contact after basic short circuit test(T100a)
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- Photo. HP07 : Contact after short line fault (L90)
- Photo. HP08 : Contact after short line fault (L75)
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- Photo. HP10 : Contact after basic short-circuit tests(T60) and double-earth fault test(DEF)

### Circuit diagrams and parameters :

Fig. HP01 : Circuit for short-time and peak withstand current tests

Fig. HP02 : Circuit for basic short-circuit tests(T100a, T100s(b), T60) and double-earth fault tests (DEF)

Fig. HP03 : Circuit for basic short-circuit tests(T100s(a))

Fig. HP04 : Circuit for short-line fault tests

Fig. HP05 : Circuit for voltage tests as a condition check

Fig. HP06 : Circuit for basic short-circuit tests (T30, T10) and out of phase making and breaking tests (OP2, Breaking)

Fig. HP07 : Circuit for out of phase making and breaking tests(OP2, Making)

Fig. HP08 : Circuit for verification tests for single phase breaking of common operating mechanism

### Drawings :

The manufacturer guarantees that the test object submitted is manufactured in accordance with the followings drawings. KERI verified that these drawings adequately represent the test object.

The following drawing is included in this type test certificate

| Reference No. | Drawing No. | Revision No. | Date       |
|---------------|-------------|--------------|------------|
| 001           | 3949627     | 0            | 2011.03.28 |

The following drawing have been returned to the manufacturer and listed for reference.

| Reference No. | Drawing No. | Revision No. | Date        |
|---------------|-------------|--------------|-------------|
| 002           | 3949634     | 0            | 2011.04.04  |
| 003           | 4949635     | 0            | 2011.04.04  |
| 004           | 4949628     | 1            | 2011.04.13  |
| 005           | 3943042     | 1            | 2011.04.06  |
| 006           | 2940037     | 3            | 2011.04.06  |
| 007           | 3940631     | 1            | 2009.11.16  |
| 008           | 3941858     | 1            | 2011.04.05  |
| 009           | 4944176     | 3            | 2011.04.06  |
| 010           | 3949227     | 8            | 2011.04.06  |
| 011           | 3949357     | 1            | 2010.10.02  |
| 012           | 3949646     | 0            | 2011.04.02  |
| 013           | 4941863     | 3            | 2006.09.11  |
| 014           | 4944045     | 2            | 2010.11.12  |
| 015           | 4944005     | 10           | 2010.11.13. |

### Attachments

Attachment HP01 : Inherent Line side TRV for L90

Attachment HP02 : Inherent Line side TRV for L75

**SF<sub>6</sub> Gas Circuit Breaker with Live Tank and Common Operating Mechanism**

|               |                                            |
|---------------|--------------------------------------------|
| Manufacturer  | Crompton Greaves Ltd.                      |
| Type          | 120-SFM-32B (Separate operating mechanism) |
| Serial number | 34342C                                     |

**Ratings of the test object assigned by manufacturer and proved by tests**

|                                                                 |         |
|-----------------------------------------------------------------|---------|
| Short-time and peak withstand current                           |         |
| r.m.s.                                                          | 40 kA   |
| Peak                                                            | 100 kA  |
| Duration                                                        | 3 s     |
| Short-circuit breaking current                                  | 40 kA   |
| Short-circuit making current                                    | 104 kA  |
| Out-of-phase breaking current                                   | 10 kA   |
| Short-line surge impedance                                      | 450 Ω   |
| Transient Recovery Voltage                                      |         |
| u <sub>1</sub>                                                  | 133 kV  |
| u <sub>c</sub>                                                  | 249 kV  |
| t <sub>1</sub>                                                  | 67 μs   |
| t <sub>2</sub>                                                  | 268 μs  |
| RRRV                                                            | 2 kV/μs |
| First-pole-to-clear factor                                      | 1.5     |
| Circuit Breaker suitable for systems other than earthed neutral |         |

**Ratings of the test object assigned by manufacturer but not proved by tests**

|                                     |                                     |
|-------------------------------------|-------------------------------------|
| Number of poles                     | 3 Phase                             |
| The number of interrupters per pole | 1                                   |
| Voltage                             | 145 kV                              |
| Normal current                      | 3 150 A                             |
| Frequency                           | 50 Hz                               |
| Method of operation                 | Three-phase common operating device |
| Closing                             | Spring, charged by motor            |
| Opening                             | Spring, charged at closing          |
| Supply voltage                      |                                     |
| Motor                               | AC / DC 230 V                       |
| Closing device                      | DC 110 V                            |
| Opening device                      | DC 110 V                            |
| Operating sequence                  | O - 0.3 s - CO - 3 min - CO         |
| Enclosure                           | Live tank type                      |
| SF <sub>6</sub> gas pressure(gauge) |                                     |
| Rated                               | 0.7 MPa                             |
| Minimum                             | 0.6 MPa                             |

## List of the tests

| Test items                                                                                    | Standard and clause                   | Test date             | Sheet No. |
|-----------------------------------------------------------------------------------------------|---------------------------------------|-----------------------|-----------|
| 1 Short-time and peak withstand current tests                                                 | IEC 62271-100:2008-04 6.6             | April 13, 2011        | 6/197     |
| 2 No-load operation checks                                                                    | –                                     | April 21, 2011        | 7/197     |
| 3 Basic short circuit tests (T100a)                                                           | IEC 62271-100:2008-04 6.106           | April 21, 2011        | 8/197     |
| 4 No-load operation checks                                                                    | –                                     | April 21 to 22, 2011  | 9/197     |
| 5 Basic short-circuit tests (T100s(a))                                                        | IEC 62271-100:2008-04 6.106           | April 22, 2011        | 10/197    |
| 6 Basic short-circuit tests (T100s(b))                                                        | IEC 62271-100:2008-04 6.106           | April 22, 2011        | 11/197    |
| 7 No-load operation checks                                                                    | –                                     | April 22, 2011        | 12/197    |
| 8 Short-line fault tests (L90)                                                                | IEC 62271-100:2008-04 6.109           | April 22, 2011        | 13/197    |
| 9 No-load operation checks                                                                    | –                                     | April 22 and 25, 2011 | 14/197    |
| 10 Short-line fault tests (L75)                                                               | IEC 62271-100:2008-04 6.109           | April 25, 2011        | 15/197    |
| 11 No-load operation checks                                                                   | –                                     | April 25, 2011        | 16/197    |
| 12 Voltage tests as a condition check                                                         | IEC 62271-100:2008-04 6.2.11          | April 25 to 26, 2011  | 17/197    |
| 13 No-load operation checks                                                                   | –                                     | April 26, 2011        | 18/197    |
| 14 Basic short-circuit tests (T10)                                                            | IEC 62271-100:2008-04 6.106           | April 26, 2011        | 19/197    |
| 15 Out of phase making and breaking tests (OP2, Making)                                       | IEC 62271-100:2008-04 6.110           | April 26, 2011        | 20/197    |
| 16 Basic short-circuit tests (T30) and out of phase making and breaking tests (OP2, Breaking) | IEC 62271-100:2008-04 6.106 and 6.110 | April 26, 2011        | 21/197    |
| 17 Basic short-circuit tests (T60)                                                            | IEC 62271-100:2008-04 6.106           | April 26, 2011        | 22/197    |
| 18 No-load operation checks                                                                   | –                                     | April 26, 2011        | 23/197    |
| 19 Double-earth fault tests (DEF)                                                             | IEC 62271-100:2008-04 6.108           | April 27, 2011        | 24/197    |
| 20 No-load operation checks                                                                   | –                                     | April 27, 2011        | 25/197    |
| 21 Verification tests for single phase breaking of common operating mechanism                 | IEC 62271-100:2008-04 6.2.11          | April 27, 2011        | 26/197    |
| 22 No-load operation checks                                                                   | –                                     | April 27, 2011        | 27/197    |
| 23 Description of tests                                                                       | –                                     | –                     | 28/197    |

## Measurement uncertainty

The measurement uncertainties listed below are the expanded uncertainties at the confidence level of approximately 95 % (coverage factor  $k=2$ ) guaranteed by KERI:

High power test

Current  $\pm 5 \%$

Voltage  $\pm 5 \%$

# 1 Short-time and peak withstand current tests

## 1.1 Resistance measurement of main circuit

| Test results     |                                   |                                              |                        |         |
|------------------|-----------------------------------|----------------------------------------------|------------------------|---------|
| Status           | Resistance<br>$\mu\Omega$         | Ambient<br>temperature<br>$^{\circ}\text{C}$ | Relative humidity<br>% | Remarks |
| Before STC test  | 33.9<br>32.2<br>32.6              | 18                                           | 20                     |         |
| After STC test   | 32.6<br>30.7<br>30.3              | 18                                           | 20                     |         |
| Measuring method | Voltage drop method with DC 100 A |                                              |                        |         |

## 1.2 Short-time and peak withstand current tests

| Test requirements |                               |
|-------------------|-------------------------------|
| Test current      | r.m.s. : 40 kA, Peak : 100 kA |
| Test frequency    | 50 Hz                         |
| Duration          | 3.0 s                         |

| Test results                     |                                                                                                    |                      |               |                             |
|----------------------------------|----------------------------------------------------------------------------------------------------|----------------------|---------------|-----------------------------|
| Condition before tests           | New and clean                                                                                      |                      |               | Test circuit :<br>Fig. HP01 |
| Test number                      | Test current                                                                                       |                      | Duration<br>s | Remarks                     |
|                                  | Peak<br>kA                                                                                         | r.m.s.<br>kA         |               |                             |
| HPC 1104-009                     | –<br>–<br>108                                                                                      | 40.9<br>41.0<br>40.7 | 3.03          |                             |
| Condition during and after tests | No visible damages externally.<br>After the test, the test object was opened at the first attempt. |                      |               |                             |

## 1.3 No-load operation checks

| Test results                    |                                    |                     |           |                       |                       |         |
|---------------------------------|------------------------------------|---------------------|-----------|-----------------------|-----------------------|---------|
| Test number                     | Operating<br>duty                  | Supply voltage (DC) |           | Closing<br>time<br>ms | Opening<br>time<br>ms | Remarks |
|                                 |                                    | Close<br>V          | Open<br>V |                       |                       |         |
| HPC 1104-010                    | O                                  | –                   | 110       | –                     | 26.8<br>25.7<br>26.5  |         |
| Condition during and after test | The test object operated normally. |                     |           |                       |                       |         |

## 2 No-load operation checks

| Test results                    |                                    |                     |           |                      |                      |              |
|---------------------------------|------------------------------------|---------------------|-----------|----------------------|----------------------|--------------|
| Test number                     | Operating duty                     | Supply voltage (DC) |           | Closing time<br>ms   | Opening time<br>ms   | Remarks      |
|                                 |                                    | Close<br>V          | Open<br>V |                      |                      |              |
| HPC 1104-037                    | O                                  | –                   | 110       | –                    | 26.0<br>25.3<br>25.2 | Before T100a |
|                                 | 0.3 s<br>CO                        | 110                 | 110       | 79.8<br>80.4<br>80.7 | 25.4<br>25.1<br>25.1 |              |
| HPC 1104-038                    | CO                                 | 110                 | 110       | 81.2<br>81.8<br>82.4 | 25.2<br>24.7<br>25.3 |              |
| HPC 1104-039                    | O                                  | –                   | 121       | –                    | 25.2<br>24.6<br>24.6 |              |
|                                 | 0.3 s<br>CO                        | 121                 | 121       | 78.6<br>79.2<br>79.4 | 24.9<br>24.5<br>24.6 |              |
| HPC 1104-040                    | CO                                 | 121                 | 121       | 79.4<br>80.0<br>80.7 | 24.8<br>24.3<br>24.8 |              |
|                                 |                                    |                     |           |                      |                      |              |
| Condition during and after test | The test object operated normally. |                     |           |                      |                      |              |

### 3 Basic short circuit tests (T100a)

| Test requirements            |                                                                                                                                                                       |
|------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| TRV                          | $u_1 = 133 \text{ kV}$ , $t_1 = 67 \mu\text{s}$ , $u_c = 249 \text{ kV}$ , $t_2 = 268 \mu\text{s}$ , $t_d = 2 \mu\text{s}$ , $\text{RRRV} = 2 \text{ kV}/\mu\text{s}$ |
| Test current                 | Breaking = 40 kA<br>Major loop : Peak = 68.4 kA, Duration = 11.5 ms<br>Minor loop : Peak = 41.9 kA, Duration = 8.5 ms                                                 |
| Test frequency               | 50 Hz                                                                                                                                                                 |
| SF <sub>6</sub> gas pressure | 0.6 MPa (gauge)                                                                                                                                                       |
| Control voltage              | DC 121 V                                                                                                                                                              |
| Operating sequence           | O - 3 times                                                                                                                                                           |

| Test results                    |                                                                                                                 |              |          |         |            |           |          |     |             |               |                                   |
|---------------------------------|-----------------------------------------------------------------------------------------------------------------|--------------|----------|---------|------------|-----------|----------|-----|-------------|---------------|-----------------------------------|
| Condition before test           | After maintenance<br>Supply side : Fixed contact<br>Test phase : A                                              |              |          |         |            |           |          |     |             |               | Test circuit :<br>Fig. HP02       |
| Test No.                        | Operating duty                                                                                                  | Test current |          |         |            |           |          | TRV | Arcing time | Breaking time | Remarks                           |
|                                 |                                                                                                                 | Making       | Breaking | di/dt   | th         | Last loop |          |     |             |               |                                   |
|                                 |                                                                                                                 |              |          |         |            | Peak      | Duration |     |             |               |                                   |
|                                 |                                                                                                                 | kA           | kA       | $\mu s$ | A/ $\mu s$ | kA        | ms       | kV  | ms          | ms            |                                   |
| HPC 1104-041                    | Injection current = 3.63 kA, Frequency = 527 Hz, di/dt = 17.0 A/ $\mu s$                                        |              |          |         |            |           |          |     |             |               | Injection current check (95 %)    |
| HPC 1104-042                    | $u_1 = 134$ kV, $u_c = 248$ kV, $t_1 = 69 \mu s$ , $t_2 = 262 \mu s$ , $t_d = 1.5 \mu s$ , RRRV = 2 kV/ $\mu s$ |              |          |         |            |           |          |     |             |               | TRV check (95 %)                  |
| HPC 1104-045                    | O <sub>s</sub>                                                                                                  | –            | 40.1     | 17.0    | 341        | 41.4      | 8.6      | 250 | 13.8        | 39.0          |                                   |
| HPC 1104-046                    | O <sub>s</sub>                                                                                                  | –            | 40.4     | 17.0    | 349        | 39.3      | 8.4      | 250 | 13.0        | 38.2          |                                   |
| HPC 1104-047                    | O <sub>s</sub>                                                                                                  | –            | 40.4     | 17.0    | 341        | 42.0      | 8.7      | 250 | 11.6        | 36.8          | Minimum arcing time               |
| HPC 1104-048                    | O <sub>s</sub>                                                                                                  | –            | 40.5     | 17.0    | 344        | 40.1      | 8.5      | –   | (10.3)*     | –             | Test to prove minimum arcing time |
| HPC 1104-049                    | O <sub>s</sub>                                                                                                  | –            | 40.6     | 17.8    | 301        | 68.6      | 11.6     | 256 | 20.6        | 45.8          |                                   |
| HPC 1104-050                    | O <sub>s</sub>                                                                                                  | –            | 40.4     | 17.8    | 314        | 68.6      | 11.6     | 256 | 16.2        | 41.4          |                                   |
| Condition during and after test | The test object was operated normally.<br>No visible damages externally.                                        |              |          |         |            |           |          |     |             |               |                                   |

Note The figures of parenthesis ( )\* means arcing time set for tests.

## 4 No-load operation checks

| Test results                    |                                    |                     |           |                      |                      |                 |
|---------------------------------|------------------------------------|---------------------|-----------|----------------------|----------------------|-----------------|
| Test number                     | Operating duty                     | Supply voltage (DC) |           | Closing time<br>ms   | Opening time<br>ms   | Remarks         |
|                                 |                                    | Close<br>V          | Open<br>V |                      |                      |                 |
| HPC 1104-051                    | O                                  | –                   | 110       | –                    | 25.4<br>25.6<br>25.5 | After T100a     |
|                                 | 0.3 s<br>CO                        | 110                 | 110       | 82.4<br>81.5<br>82.2 | 24.5<br>25.1<br>25.2 |                 |
|                                 | CO                                 | 110                 | 110       | 83.9<br>82.7<br>83.5 | 24.5<br>25.0<br>25.6 |                 |
| HPC 1104-052                    | CO                                 | 110                 | 110       | 83.9<br>82.7<br>83.5 | 24.5<br>25.0<br>25.6 | Before T100s(a) |
| HPC 1104-053                    | O                                  | –                   | 110       | –                    | 25.5<br>25.3<br>25.2 |                 |
|                                 | 0.3 s<br>CO                        | 110                 | 110       | 80.4<br>80.6<br>81.0 | 25.2<br>25.1<br>25.2 |                 |
|                                 | CO                                 | 110                 | 110       | 81.6<br>81.8<br>82.4 | 25.1<br>24.9<br>25.4 |                 |
| HPC 1104-055                    | O                                  | –                   | 77        | –                    | 29.2<br>29.0<br>28.9 |                 |
|                                 | 0.3 s<br>CO                        | 93.5                | 77        | 82.3<br>82.5<br>82.8 | 29.2<br>29.2<br>29.2 |                 |
|                                 | CO                                 | 93.5                | 77        | 83.4<br>83.6<br>84.1 | 29.1<br>29.0<br>29.3 |                 |
| HPC 1104-056                    | CO                                 | 93.5                | 77        | 83.4<br>83.6<br>84.1 | 29.1<br>29.0<br>29.3 |                 |
| HPC 1104-068                    | O                                  | –                   | 110       | –                    | 25.6<br>25.6<br>25.4 | After T100s(a)  |
| Condition during and after test | The test object operated normally. |                     |           |                      |                      |                 |

## 5 Basic short-circuit tests (T100s(a))

| Test requirements                |                 |
|----------------------------------|-----------------|
| Test voltage<br>(Phase to earth) | 84 kV           |
| Test current                     | 40 kA           |
| Test frequency                   | 50 Hz           |
| SF <sub>6</sub> gas pressure     | 0.6 MPa (gauge) |
| Control voltage                  | DC 93.5 V       |
| Operating sequence               | C <sub>s</sub>  |

| Test results                       |                                                                          |                         |                      |                 |                      |                                        |                           |                             |         |
|------------------------------------|--------------------------------------------------------------------------|-------------------------|----------------------|-----------------|----------------------|----------------------------------------|---------------------------|-----------------------------|---------|
| Condition<br>before test           | After Basic short-circuit tests (T100a)<br>Test supply : Fixed contact   |                         |                      |                 |                      |                                        |                           | Test circuit :<br>Fig. HP03 |         |
| Test No.                           | Operating<br>duty                                                        | Test voltage            |                      | Test<br>current |                      | making<br>delay<br>time<br><br>$\mu$ s | Pre-arc<br>time<br><br>ms | Making<br>time<br><br>ms    | Remarks |
|                                    |                                                                          | arc<br>initiation<br>kV | r.m.s.<br>kV         | peak<br>kA      | r.m.s.<br>kA         |                                        |                           |                             |         |
| HPC 1104-067                       | C <sub>s</sub>                                                           | 111.7<br>128.2<br>127.5 | 85.5<br>94.4<br>94.1 | 107.2<br>–<br>– | 40.2<br>40.5<br>40.1 | 89                                     | 0.8<br>1.0<br>1.5         | 82.6<br>82.6<br>82.6        |         |
| Condition during<br>and after test | The test object was operated normally.<br>No visible damages externally. |                         |                      |                 |                      |                                        |                           |                             |         |

## 6 Basic short-circuit tests (T100s(b))

| Test requirements            |                                                                                                                                                                                                  |
|------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| TRV                          | $u_1 = 133 \text{ kV}$ , $t_1 = 67 \text{ } \mu\text{s}$ , $u_c = 249 \text{ kV}$ , $t_2 = 268 \text{ } \mu\text{s}$ , $t_d = 2 \text{ } \mu\text{s}$ , $\text{RRRV} = 2 \text{ kV}/\mu\text{s}$ |
| Test current                 | Breaking = 40 kA, Making = 100 kA                                                                                                                                                                |
| Test frequency               | 50 Hz                                                                                                                                                                                            |
| Control voltage              | Close : DC 93.5 V Open : DC 77 V                                                                                                                                                                 |
| SF <sub>6</sub> gas pressure | 0.6 MPa (gauge)                                                                                                                                                                                  |
| Operating sequence           | O <sub>s</sub> , O <sub>d</sub> - 0.3 s - C <sub>0</sub> O <sub>s</sub> , C <sup>*</sup> O <sub>s</sub>                                                                                          |

| Test results                    |                                                                                                                                                                    |              |          |            |                |           |          |          |             |               |                                   |
|---------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|----------|------------|----------------|-----------|----------|----------|-------------|---------------|-----------------------------------|
| Condition before test           | After basic short-circuit tests (T100s(a))<br>Test supply : Moving contact<br>Test phase : C                                                                       |              |          |            |                |           |          |          |             |               | Test circuit :<br>Fig. HP02       |
| Test No.                        | Operating duty                                                                                                                                                     | Test current |          |            |                |           |          | TRV peak | Arcing time | Breaking time | Remarks                           |
|                                 |                                                                                                                                                                    | Making       | Breaking | di/dt      | t <sub>h</sub> | Last loop |          |          |             |               |                                   |
|                                 |                                                                                                                                                                    |              |          |            |                | Peak      | Duration |          |             |               |                                   |
|                                 |                                                                                                                                                                    | kA           | kA       | A/ $\mu$ s | $\mu$ s        | kA        | ms       | kV       | ms          | ms            |                                   |
| HPC 1104-071                    | Injection current = 3.63 kA, Frequency = 527 Hz, di/dt = 17.0 A/ $\mu$ s                                                                                           |              |          |            |                |           |          |          |             |               | Injection current check<br>(95 %) |
| HPC 1104-072                    | u <sub>1</sub> = 134 kV, u <sub>c</sub> = 250 kV, t <sub>1</sub> = 69 $\mu$ s, t <sub>2</sub> = 262 $\mu$ s, t <sub>d</sub> = 1.5 $\mu$ s,<br>RRRV = 2 kV/ $\mu$ s |              |          |            |                |           |          |          |             |               | TRV check<br>(95 %)               |
| HPC 1104-075                    | O <sub>s</sub>                                                                                                                                                     | –            | 40.7     | 17.9       | 329            | 57.2      | 10.3     | –        | (11.3)*     | 40.2          | Test to prove minimum arcing time |
| HPC 1104-076                    | O <sub>s</sub>                                                                                                                                                     | –            | 40.7     | 17.9       | 345            | 56.9      | 10.3     | –        | (12.0)*     | 40.9          | Test to prove minimum arcing time |
| HPC 1104-077                    | O <sub>s</sub>                                                                                                                                                     | –            | 40.7     | 17.8       | 355            | 57.6      | 10.4     | 253      | 13.1        | 42.0          | Minimum arcing time               |
| HPC 1104-081                    | O <sub>d</sub>                                                                                                                                                     | –            | 40.8     | –          | –              | –         | –        | –        | 13.3        | 42.2          |                                   |
|                                 | 0.3 s<br>C <sub>d</sub> O <sub>s</sub>                                                                                                                             | 108.7        | 40.6     | 17.8       | 346            | 61.5      | 10.8     | 254      | 20.7        | 49.6          |                                   |
| HPC 1104-082                    | C*O <sub>s</sub>                                                                                                                                                   | –            | 40.5     | 17.8       | 354            | 60.0      | 10.6     | 253      | 17.1        | 46.0          |                                   |
| Condition during and after test | The test object was operated normally.<br>No visible damages externally.                                                                                           |              |          |            |                |           |          |          |             |               |                                   |

Note The figures of ( ) \* means arcing time set for tests.

## 7 No-load operation checks

| Test results                    |                                    |                     |           |                      |                      |                |
|---------------------------------|------------------------------------|---------------------|-----------|----------------------|----------------------|----------------|
| Test number                     | Operating duty                     | Supply voltage (DC) |           | Closing time<br>ms   | Opening time<br>ms   | Remarks        |
|                                 |                                    | Close<br>V          | Open<br>V |                      |                      |                |
| HPC 1104-083                    | O                                  | –                   | 110       | –                    | 25.6<br>25.4<br>24.1 | After T100s(b) |
|                                 | 0.3 s<br>CO                        | 110                 | 110       | 81.5<br>81.2<br>83.5 | 25.4<br>25.6<br>24.1 |                |
| HPC 1104-084                    | CO                                 | 110                 | 110       | 82.9<br>82.7<br>85.0 | 25.1<br>24.8<br>24.1 |                |
| HPC 1104-085                    | O                                  | –                   | 110       | –                    | 25.5<br>25.3<br>25.4 | Before L90     |
|                                 | 0.3 s<br>CO                        | 110                 | 110       | 80.5<br>80.5<br>80.8 | 25.2<br>25.2<br>25.3 |                |
| HPC 1104-086                    | CO                                 | 110                 | 110       | 82.1<br>82.3<br>82.7 | 25.0<br>24.8<br>25.4 |                |
| HPC 1104-087                    | O                                  | –                   | 77        | –                    | 29.1<br>28.9<br>29.0 |                |
|                                 | 0.3 s<br>CO                        | 93.5                | 77        | 83.1<br>83.1<br>83.4 | 28.6<br>28.8<br>28.7 |                |
| HPC 1104-088                    | CO                                 | 93.5                | 77        | 84.7<br>84.8<br>85.2 | 29.1<br>29.1<br>29.4 |                |
| Condition during and after test | The test object operated normally. |                     |           |                      |                      |                |

## 8 Short-line fault tests (L90)

| Test requirements            |                                                                                                                                                                                                                                                                                                                                             |
|------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Test voltage                 | Source TRV : $u_C = 166 \text{ kV}$ , $t_3 = 83 \text{ } \mu\text{s}$ , $t_d = 2 \text{ } \mu\text{s}$ , $\text{RRRV} = 2.0 \text{ kV}/\mu\text{s}$<br>Line TRV : $u_L^* = 18.9 \text{ kV}$ , $\text{RRRV factor} = 0.2 \text{ (kV}\mu\text{s)}/\text{kA}$ , $Z_{\text{surge}} = 450 \text{ } \Omega$ , $t_{dL} < 0.1 \text{ } \mu\text{s}$ |
| Test current                 | 36 kA                                                                                                                                                                                                                                                                                                                                       |
| Test frequency               | 50 Hz                                                                                                                                                                                                                                                                                                                                       |
| SF <sub>6</sub> gas pressure | 0.6 MPa (gauge)                                                                                                                                                                                                                                                                                                                             |
| Control voltage              | Close : DC 93.5 V, Open : DC 77 V                                                                                                                                                                                                                                                                                                           |
| Operating sequence           | O <sub>s</sub> , O <sub>d</sub> - 0.3 s - C <sub>d</sub> O <sub>s</sub> , C*O <sub>s</sub>                                                                                                                                                                                                                                                  |

| Test results                    |                                                                                                                              |              |          |            |         |           |          |     |             |               |                                   |
|---------------------------------|------------------------------------------------------------------------------------------------------------------------------|--------------|----------|------------|---------|-----------|----------|-----|-------------|---------------|-----------------------------------|
| Condition before test           | After maintenance<br>Supply side : fixed contact<br>Test phase : A                                                           |              |          |            |         |           |          |     |             |               | Test circuit :<br>Fig. HP04       |
| Test No.                        | Operating duty                                                                                                               | Test current |          |            |         |           |          | TRV | Arcing time | Breaking time | Remarks                           |
|                                 |                                                                                                                              | Making       | Breaking | di/dt      | th      | Last loop |          |     |             |               |                                   |
|                                 |                                                                                                                              |              |          |            |         | Peak      | Duration |     |             |               |                                   |
|                                 |                                                                                                                              | kA           | kA       | A/ $\mu$ s | $\mu$ s | kA        | ms       | kV  | ms          | ms            |                                   |
| HPC 1104-091                    | Injection current = 2.1 kA, Frequency = 689 Hz, di/dt = 12.8 A/ $\mu$ s                                                      |              |          |            |         |           |          |     |             |               | Injection current (80.0%)         |
| HPC 1104-098                    | u <sub>c</sub> = 131 kV, t <sub>3</sub> = 82 $\mu$ s, t <sub>d</sub> = 1 $\mu$ s, RRRV = 1.60 kV/ $\mu$ s                    |              |          |            |         |           |          |     |             |               | Supply side TRV (80.0%)           |
| –                               | Peak factor = 16.8 kV, RRRV factor = 0.201 (kV $\mu$ s)/kA, t <sub>dL</sub> < 0.1 $\mu$ s<br>(refer to the attachments HP01) |              |          |            |         |           |          |     |             |               | Line TRV check                    |
| HPC 1104-102                    | O <sub>s</sub>                                                                                                               | –            | 36.4     | 16.0       | 317     | 50.0      | 10.0     | 162 | 15.3        | 44.4          |                                   |
| HPC 1104-103                    | O <sub>s</sub>                                                                                                               | –            | 36.4     | 16.2       | 317     | 49.6      | 10.0     | 167 | 14.3        | 43.4          | Minimum arcing time               |
| HPC 1104-104                    | O <sub>s</sub>                                                                                                               | –            | 36.4     | 16.2       | 346     | 49.6      | 10.0     | –   | (13.0)*     | 42.1          | Test to prove minimum arcing time |
| HPC 1104-107                    | O <sub>d</sub>                                                                                                               | –            | 37.5     | –          | –       | –         | –        | –   | 14.5        | 43.6          |                                   |
|                                 | 0.3 s<br>C <sub>d</sub> O <sub>s</sub>                                                                                       | –            | 36.3     | 16.2       | 334     | 51.7      | 10.3     | 166 | 22.9        | 52.0          |                                   |
| HPC 1104-109                    | C*O <sub>s</sub>                                                                                                             | –            | 35.9     | 16.2       | 342     | 49.9      | 10.2     | 166 | 18.9        | 48.0          |                                   |
| Condition during and after test | The test object was operated normally.<br>No visible damages externally.                                                     |              |          |            |         |           |          |     |             |               |                                   |

Note C\* : No-load closing operation.

The figures of parenthesis ( ) \* means arcing time set for tests.

## 9 No-load operation checks

| Test results                    |                                    |                     |           |                      |                      |            |
|---------------------------------|------------------------------------|---------------------|-----------|----------------------|----------------------|------------|
| Test number                     | Operating duty                     | Supply voltage (DC) |           | Closing time<br>ms   | Opening time<br>ms   | Remarks    |
|                                 |                                    | Close<br>V          | Open<br>V |                      |                      |            |
| HPC 1104-110                    | O                                  | –                   | 110       | –                    | 24.1<br>25.4<br>25.5 | After L90  |
|                                 | 0.3 s<br>CO                        | 110                 | 110       | 85.6<br>82.5<br>83.1 | 24.0<br>25.5<br>25.7 |            |
| HPC 1104-111                    | CO                                 | 110                 | 110       | 87.4<br>84.6<br>85.2 | 24.0<br>25.5<br>25.5 |            |
| HPC 1104-112                    | O                                  | –                   | 110       | –                    | 25.8<br>25.5<br>25.5 | Before L75 |
|                                 | 0.3 s<br>CO                        | 110                 | 110       | 80.0<br>80.3<br>80.4 | 25.4<br>25.3<br>25.3 |            |
| HPC 1104-113                    | CO                                 | 110                 | 110       | 81.9<br>82.3<br>82.9 | 25.1<br>25.1<br>25.6 |            |
| HPC 1104-114                    | O                                  | –                   | 77        | –                    | 29.4<br>29.2<br>29.2 |            |
|                                 | 0.3 s<br>CO                        | 93.5                | 77        | 82.2<br>82.5<br>82.7 | 29.3<br>29.2<br>29.2 |            |
| HPC 1104-115                    | CO                                 | 93.5                | 77        | 83.5<br>84.0<br>84.5 | 29.5<br>29.4<br>29.9 |            |
|                                 |                                    |                     |           |                      |                      |            |
|                                 |                                    |                     |           |                      |                      |            |
| Condition during and after test | The test object operated normally. |                     |           |                      |                      |            |

## 10 Short-line fault tests (L75)

| Test requirements            |                                                                                                                                                                                                                                                                                                |
|------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Test voltage                 | Source TRV : $u_c = 166 \text{ kV}$ , $t_3 = 83 \text{ } \mu\text{s}$ , $t_d = 2 \text{ } \mu\text{s}$ , $\text{RRRV} = 2.0 \text{ kV}/\mu\text{s}$<br>Line TRV : $u_L^* = 47.4 \text{ kV}$ , $\text{RRRV factor} = 0.2 \text{ (kV}\mu\text{s)/kA}$ , $Z_{\text{surge}} = 450 \text{ } \Omega$ |
| Test current                 | 30 kA                                                                                                                                                                                                                                                                                          |
| Test frequency               | 50 Hz                                                                                                                                                                                                                                                                                          |
| SF <sub>6</sub> gas pressure | 0.6 MPa (gauge)                                                                                                                                                                                                                                                                                |
| Control voltage              | Close : DC 93.5 V, Open : DC 77 V                                                                                                                                                                                                                                                              |
| Operating sequence           | O <sub>s</sub> , O <sub>d</sub> - 0.3 s - C <sub>d</sub> O <sub>s</sub> , C'O <sub>s</sub>                                                                                                                                                                                                     |

| Test results                    |                                                                                                                          |              |          |            |         |           |          |     |             |               |                                   |
|---------------------------------|--------------------------------------------------------------------------------------------------------------------------|--------------|----------|------------|---------|-----------|----------|-----|-------------|---------------|-----------------------------------|
| Condition before test           | After short-line fault tests (L90)<br>Supply side : fixed contact<br>Test phase : B                                      |              |          |            |         |           |          |     |             |               | Test circuit :<br>Fig. HP04       |
| Test No.                        | Operating duty                                                                                                           | Test current |          |            |         |           |          | TRV | Arcing time | Breaking time | Remarks                           |
|                                 |                                                                                                                          | Making       | Breaking | di/dt      | th      | Last loop |          |     |             |               |                                   |
|                                 |                                                                                                                          |              |          |            |         | Peak      | Duration |     |             |               |                                   |
|                                 |                                                                                                                          | kA           | kA       | A/ $\mu$ s | $\mu$ s | kA        | ms       | kV  | ms          | ms            |                                   |
| HPC 1104-116                    | Injection current = 1.3 kA, Frequency = 608 Hz, di/dt = 7.0 A/ $\mu$ s                                                   |              |          |            |         |           |          |     |             |               | Injection current (51.9%)         |
| HPC 1104-119                    | u <sub>c</sub> = 86.0 kV, t <sub>3</sub> = 82 $\mu$ s, t <sub>d</sub> = 1 $\mu$ s, RRRV = 1.05 kV/ $\mu$ s               |              |          |            |         |           |          |     |             |               | Supply side TRV (51.9%)           |
| -                               | Peak factor = 16.6, RRRV factor = 0.20 (kV $\mu$ s)/kA, t <sub>dL</sub> < 0.1 $\mu$ s<br>(refer to the attachments HP02) |              |          |            |         |           |          |     |             |               | Line TRV check                    |
| HPC 1104-124                    | O <sub>s</sub>                                                                                                           | -            | 30.8     | 13.5       | 339     | 44.4      | 10.2     | -   | (11.9)*     | -             | Test to prove minimum arcing time |
| HPC 1104-125                    | O <sub>s</sub>                                                                                                           | -            | 30.6     | 13.5       | 316     | 43.2      | 10.0     | -   | (13.1)*     | -             | Test to prove minimum arcing time |
| HPC 1104-126                    | O <sub>s</sub>                                                                                                           | -            | 30.6     | 13.5       | 313     | 41.5      | 9.8      | 160 | 14.3        | 43.5          | Minimum arcing time               |
| HPC 1104-130                    | O <sub>d</sub>                                                                                                           | -            | 30.1     | -          | -       | -         | -        | -   | 14.5        | 43.7          |                                   |
|                                 | 0.3 s<br>C <sub>d</sub> O <sub>s</sub>                                                                                   | -            | 31.0     | 13.5       | 327     | 42.8      | 10.1     | 160 | 23.4        | 52.6          |                                   |
| HPC 1104-131                    | C <sup>*</sup> O <sub>s</sub>                                                                                            | -            | 30.6     | 13.5       | 325     | 40.3      | 9.8      | 161 | 18.8        | 48.0          |                                   |
| Condition during and after test | The test object was operated normally.<br>No visible damages externally.                                                 |              |          |            |         |           |          |     |             |               |                                   |

Note C' : No-load closing operation.  
The figures ( ) \* means arcing time set for tests.

## 11 No-load operation checks

| Test results                    |                                    |                     |           |                      |                      |           |
|---------------------------------|------------------------------------|---------------------|-----------|----------------------|----------------------|-----------|
| Test number                     | Operating duty                     | Supply voltage (DC) |           | Closing time<br>ms   | Opening time<br>ms   | Remarks   |
|                                 |                                    | Close<br>V          | Open<br>V |                      |                      |           |
| HPC 1104-132                    | O                                  | –                   | 110       | –                    | 25.8<br>24.4<br>25.5 | After L75 |
|                                 | 0.3 s<br>CO                        | 110                 | 110       | 81.6<br>83.2<br>82.4 | 25.4<br>24.2<br>25.7 |           |
| HPC 1104-133                    | CO                                 | 110                 | 110       | 82.8<br>84.4<br>83.7 | 25.3<br>24.2<br>25.8 |           |
| Condition during and after test | The test object operated normally. |                     |           |                      |                      |           |

## 12 Voltage tests as a condition check

| Test requirements   |                                                                    |
|---------------------|--------------------------------------------------------------------|
| Wave shape          | $u_c = 390 \text{ kV}, t_3 = 39 \mu\text{s} \pm \frac{200}{10} \%$ |
| The number of tests | 5 times/each polarity                                              |

| Test results                    |                                                      |              |                        |                             |
|---------------------------------|------------------------------------------------------|--------------|------------------------|-----------------------------|
| Condition before test           | After short-line fault tests (L90)<br>Test phase : A |              |                        | Test circuit :<br>Fig. HP05 |
| Test number                     | Applied position                                     | Test voltage |                        | Remarks                     |
|                                 |                                                      | $u_c$<br>kV  | $t_3$<br>$\mu\text{s}$ |                             |
| HPC 1104-144                    | Fixed contact                                        | +391         | 99                     |                             |
| HPC 1104-145                    |                                                      | +399         | 99                     |                             |
| HPC 1104-146                    |                                                      | +401         | 99                     |                             |
| HPC 1104-147                    |                                                      | +403         | 99                     |                             |
| HPC 1104-148                    |                                                      | +405         | 99                     |                             |
| HPC 1104-149                    |                                                      | -397         | 99                     |                             |
| HPC 1104-150                    |                                                      | -398         | 99                     |                             |
| HPC 1104-151                    |                                                      | -399         | 99                     |                             |
| HPC 1104-152                    |                                                      | -399         | 99                     |                             |
| HPC 1104-153                    |                                                      | -399         | 99                     |                             |
| HPC 1104-154                    | Moving contact                                       | -391         | 99                     |                             |
| HPC 1104-155                    |                                                      | -401         | 99                     |                             |
| HPC 1104-156                    |                                                      | -403         | 99                     |                             |
| HPC 1104-157                    |                                                      | -404         | 99                     |                             |
| HPC 1104-158                    |                                                      | -403         | 99                     |                             |
| HPC 1104-159                    |                                                      | +401         | 99                     |                             |
| HPC 1104-160                    |                                                      | +405         | 99                     |                             |
| HPC 1104-161                    |                                                      | +407         | 99                     |                             |
| HPC 1104-162                    |                                                      | +400         | 99                     |                             |
| HPC 1104-163                    |                                                      | +401         | 99                     |                             |
| Condition during and after test | No visible damages externally.                       |              |                        |                             |

## 13 No-load operation checks

| Test results                    |                                    |                     |           |                      |                      |            |
|---------------------------------|------------------------------------|---------------------|-----------|----------------------|----------------------|------------|
| Test number                     | Operating duty                     | Supply voltage (DC) |           | Closing time<br>ms   | Opening time<br>ms   | Remarks    |
|                                 |                                    | Close<br>V          | Open<br>V |                      |                      |            |
| HPC 1104-164                    | O                                  | –                   | 110       | –                    | 25.7<br>25.7<br>25.5 | Before T10 |
|                                 | 0.3 s<br>CO                        | 110                 | 110       | 80.4<br>79.8<br>81.0 | 25.5<br>25.6<br>25.4 |            |
| HPC 1104-165                    | CO                                 | 110                 | 110       | 81.9<br>81.4<br>83.0 | 25.5<br>25.4<br>25.4 |            |
| HPC 1104-166                    | O                                  | –                   | 121       | –                    | 25.0<br>25.1<br>24.8 |            |
|                                 | 0.3 s<br>CO                        | 121                 | 121       | 79.4<br>78.8<br>80.0 | 25.0<br>25.0<br>24.9 |            |
| HPC 1104-167                    | CO                                 | 121                 | 121       | 80.9<br>80.3<br>81.9 | 24.9<br>24.7<br>24.7 |            |
| HPC 1104-168                    | O                                  | –                   | 77        | –                    | 29.7<br>29.7<br>29.4 |            |
|                                 | 0.3 s<br>CO                        | 93.5                | 77        | 82.5<br>81.9<br>83.1 | 30.2<br>30.1<br>30.9 |            |
| HPC 1104-169                    | CO                                 | 93.5                | 77        | 83.9<br>83.4<br>84.9 | 29.0<br>29.0<br>28.9 |            |
| Condition during and after test | The test object operated normally. |                     |           |                      |                      |            |

## 14 Basic short-circuit tests (T10)

| Test requirements            |                                                                                                                                        |
|------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|
| TRV                          | $u_c = 272 \text{ kV}$ , $t_3 = 39 \text{ } \mu\text{s}$ , $t_d = 6 \text{ } \mu\text{s}$ , $\text{RRRV} = 7.0 \text{ kV}/\mu\text{s}$ |
| Test current                 | 4 kA                                                                                                                                   |
| Test frequency               | 50 Hz                                                                                                                                  |
| SF <sub>6</sub> gas pressure | 0.6 MPa (gauge)                                                                                                                        |
| Control voltage              | Close : DC 93.5 V, Open : DC 77 V                                                                                                      |
| Operating sequence           | O <sub>s</sub> , O <sub>d</sub> - 0.3 s - C <sub>d</sub> O <sub>s</sub> , C <sub>d</sub> O <sub>s</sub>                                |

| Test results                    |                                                                                          |              |          |       |      |           |          |     |             |               |                                   |
|---------------------------------|------------------------------------------------------------------------------------------|--------------|----------|-------|------|-----------|----------|-----|-------------|---------------|-----------------------------------|
| Condition before test           | After short-line fault tests<br>Supply side : moving contact<br>Test phase : A           |              |          |       |      |           |          |     |             |               | Test circuit :<br>Fig. HP06       |
| Test No.                        | Operating duty                                                                           | Test current |          |       |      |           |          | TRV | Arcing time | Breaking time | Remarks                           |
|                                 |                                                                                          | Making       | Breaking | di/dt | th   | Last loop |          |     |             |               |                                   |
|                                 |                                                                                          |              |          |       |      | Peak      | Duration |     |             |               |                                   |
|                                 |                                                                                          | kA           | kA       | A/μs  | A/μs | kA        | ms       | kV  | ms          | ms            |                                   |
| HPC 1104-174                    | Injection current = 0.17 kA, Frequency = 479 Hz, di/dt = 0.72 A/μs                       |              |          |       |      |           |          |     |             |               | Injection current check (45 %)    |
| HPC 1104-180                    | u <sub>c</sub> = 278 kV, t <sub>2</sub> = 71 μs, t <sub>d</sub> = 2 μs, RRRV = 3.9 kV/μs |              |          |       |      |           |          |     |             |               | TRV check (100 %)                 |
| HPC 1104-179                    | O <sub>s</sub>                                                                           | –            | 4.0      | 1.6   | 430  | 5.7       | 10.4     | –   | (6.9)*      | –             | Test to prove minimum arcing time |
| HPC 1104-180                    | O <sub>s</sub>                                                                           | –            | 4.0      | 1.6   | 407  | 5.8       | 10.5     | 279 | 8.3         | 38.0          | Minimum arcing time               |
| HPC 1104-183                    | O <sub>d</sub>                                                                           | –            | 4.2      | –     | –    | –         | –        | –   | 8.1         | 37.8          |                                   |
|                                 | 0.3 s<br>C <sub>d</sub> O <sub>s</sub>                                                   | –            | 4.0      | 1.6   | 407  | 5.6       | 10.3     | 278 | 15.5        | 45.7          |                                   |
| HPC 1104-184                    | C <sub>d</sub> O <sub>s</sub>                                                            | –            | 4.1      | 1.6   | 389  | 5.9       | 10.7     | 281 | 12.2        | 41.2          |                                   |
| Condition during and after test | The test object was operated normally.<br>No visible damages externally.                 |              |          |       |      |           |          |     |             |               |                                   |

Note The figures of parenthesis ( ) \* means arcing time set for tests.

## 15 Out of phase making and breaking tests (OP2, Making)

| Test requirements            |                   |
|------------------------------|-------------------|
| Test voltage                 | 168 kV            |
| Test current                 | 1 kA              |
| Test frequency               | 50 Hz             |
| SF <sub>6</sub> gas pressure | 0.6 MPa (gauge)   |
| Control voltage              | Close : DC 93.5 V |
| Operating sequence           | C                 |

| Test results                    |                                                                                        |                |        |              |              |             |                             |
|---------------------------------|----------------------------------------------------------------------------------------|----------------|--------|--------------|--------------|-------------|-----------------------------|
| Condition before test           | After basic short-circuit tests(T10)<br>Supply side : moving contact<br>Test phase : A |                |        |              |              |             | Test circuit :<br>Fig. HP07 |
| Test No.                        | Operating duty                                                                         | Test voltage   |        | Test current | Pre-arc time | Making time | Remarks                     |
|                                 |                                                                                        | Arc initiation | r.m.s. |              |              |             |                             |
|                                 |                                                                                        | kV             | kV     | kA           | ms           | ms          |                             |
| HPC 1104-188                    | C                                                                                      | 240            | 173    | 1.3          | 3.6          | 80.4        |                             |
| Condition during and after test | The test object was operated normally.<br>No visible damages externally.               |                |        |              |              |             |                             |

## 16 Basic short-circuit tests (T30) and out of phase making and breaking tests (OP2, Breaking)

| Test requirements            |                                                                                                                                                                                                                                                                                                                                                                                |
|------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| TRV                          | T30 : $u_c = 273 \text{ kV}$ , $t_3 = 55 \text{ } \mu\text{s}$ , $t_d = 7 \text{ } \mu\text{s}$ , $\text{RRRV} = 5 \text{ kV}/\mu\text{s}$<br>OP2 : $u_1 = 222 \text{ kV}$ , $t_1 = 134 \text{ } \mu\text{s}$ , $u_c = 370 \text{ kV}$ , $t_2 = (268 \sim 536) \text{ } \mu\text{s}$ , $t_d = (2 \sim 12) \text{ } \mu\text{s}$<br>$\text{RRRV} = 1.67 \text{ kV}/\mu\text{s}$ |
| Test current                 | T30 : 12 kA (9.6 kA $\sim$ 14.4 kA)<br>OP2 : 10 kA (10 kA $\sim$ 11 kA)                                                                                                                                                                                                                                                                                                        |
| Test frequency               | 50 Hz                                                                                                                                                                                                                                                                                                                                                                          |
| SF <sub>6</sub> gas pressure | 0.6 MPa (gauge)                                                                                                                                                                                                                                                                                                                                                                |
| Control voltage              | Close : DC 93.5 V, Open : DC 77 V                                                                                                                                                                                                                                                                                                                                              |
| Operating sequence           | O <sub>s</sub> , O <sub>d</sub> - 0.3 s - C <sub>d</sub> O <sub>s</sub> , C*O <sub>s</sub>                                                                                                                                                                                                                                                                                     |

| Test results                    |                                                                                                             |              |               |            |            |           |              |     |                |                       |                                         |
|---------------------------------|-------------------------------------------------------------------------------------------------------------|--------------|---------------|------------|------------|-----------|--------------|-----|----------------|-----------------------|-----------------------------------------|
| Condition before test           | After out-of phase making and breaking tests(OP2, Making)<br>Supply side : moving contact<br>Test phase : A |              |               |            |            |           |              |     |                |                       | Test circuit :<br>Fig. HP06             |
| Test No.                        | Operati<br>ng duty                                                                                          | Test current |               |            |            |           |              | TRV | Arcing<br>time | Breaki-<br>ng<br>time | Remarks                                 |
|                                 |                                                                                                             | Making       | Breaki-<br>ng | di/dt      | th         | Last loop |              |     |                |                       |                                         |
|                                 |                                                                                                             |              |               |            |            | Peak      | Duratio<br>n |     |                |                       |                                         |
|                                 |                                                                                                             | kA           | kA            | A/ $\mu$ s | A/ $\mu$ s | kA        | ms           | kV  | ms             | ms                    |                                         |
| HPC 1104-190                    | Injection current = 0.86 kA, Frequency = 456 Hz, di/dt = 3.5 A/ $\mu$ s                                     |              |               |            |            |           |              |     |                |                       | Injection current<br>check<br>(65 %)    |
| HPC 1104-194                    | $u_c = 384$ kV, $t_2 = 75 \mu$ s, $t_d = 2 \mu$ s, RRRV = 5.1 kV/ $\mu$ s                                   |              |               |            |            |           |              |     |                |                       | TRV check<br>(100 %)                    |
| HPC 1104-195                    | O <sub>s</sub>                                                                                              | –            | 10.4          | 5.3        | 354        | 16.8      | 9.8          | 375 | 12.3           | 42.0                  |                                         |
| HPC 1104-196                    | O <sub>s</sub>                                                                                              | –            | 10.4          | 5.3        | 382        | 16.9      | 9.9          | –   | (11.0)*        | –                     | Test to prove<br>minimum arcing<br>time |
| HPC 1104-198                    | O <sub>d</sub>                                                                                              | –            | 10.7          | –          | –          | –         | –            | –   | 11.8           | 41.5                  |                                         |
|                                 | 0.3 s<br>C <sub>d</sub> O <sub>s</sub>                                                                      | –            | 10.3          | 5.3        | 400        | 16.4      | 10.0         | 375 | 19.8           | 51.2                  |                                         |
| HPC 1104-199                    | C'O <sub>s</sub>                                                                                            | –            | 10.4          | 5.3        | 389        | 17.1      | 10.3         | 376 | 16.4           | 45.4                  |                                         |
| Condition during and after test | The test object was operated normally.<br>No visible damages externally.                                    |              |               |            |            |           |              |     |                |                       |                                         |

Note The figures of parenthesis ( )\* means arcing time set for tests.  
C\* means no load closing operation

## 17 Basic short-circuit tests (T60)

| Test requirements            |                                                                                                                                                                                                              |
|------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| TRV                          | $u_1 = 133 \text{ kV}$ , $t_1 = 44 \text{ } \mu\text{s}$ , $u_c = 266 \text{ kV}$ , $t_2 = 264 \text{ } \mu\text{s}$ , $t_d = (2 \sim 20) \text{ } \mu\text{s}$ , $\text{RRRV} = 3.0 \text{ kV}/\mu\text{s}$ |
| Test current                 | 24 kA                                                                                                                                                                                                        |
| Test frequency               | 50 Hz                                                                                                                                                                                                        |
| SF <sub>6</sub> gas pressure | 0.6 MPa (gauge)                                                                                                                                                                                              |
| Control voltage              | Close : DC 93.5 V, Open : DC 77 V                                                                                                                                                                            |
| Operating sequence           | O <sub>s</sub> , O <sub>d</sub> - 0.3 s - C <sub>d</sub> O <sub>s</sub> , C'O <sub>s</sub>                                                                                                                   |

| Test results                    |                                                                                                                                                                 |              |          |            |            |           |          |     |             |               |                                     |
|---------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|----------|------------|------------|-----------|----------|-----|-------------|---------------|-------------------------------------|
| Condition before test           | After basic short-circuit tests(T30) and out of phase making and breaking tests (OP2, Breaking)<br>Supply side : moving contact<br>Test phase : C               |              |          |            |            |           |          |     |             |               | Test circuit :<br>Fig. HP02         |
| Test No.                        | Operating duty                                                                                                                                                  | Test current |          |            |            |           |          | TRV | Arcing time | Breaking time | Remarks                             |
|                                 |                                                                                                                                                                 | Making       | Breaking | di/dt      | th         | Last loop |          |     |             |               |                                     |
|                                 |                                                                                                                                                                 |              |          |            |            | Peak      | Duration |     |             |               |                                     |
|                                 |                                                                                                                                                                 | kA           | kA       | A/ $\mu$ s | A/ $\mu$ s | kA        | ms       | kV  | ms          | ms            |                                     |
| HPC 1104-200                    | Injection current = 1.61 kA, Frequency = 602 Hz, di/dt = 8.61 A/ $\mu$ s                                                                                        |              |          |            |            |           |          |     |             |               | Injection current check<br>(77.8 %) |
| HPC 1104-204                    | u <sub>1</sub> = 144 kV, t <sub>1</sub> = 46 $\mu$ s, u <sub>c</sub> = 268 kV, t <sub>2</sub> = 240 $\mu$ s, t <sub>d</sub> = 2 $\mu$ s, RRRV = 3.1 kV/ $\mu$ s |              |          |            |            |           |          |     |             |               | TRV check<br>(100 %)                |
| HPC 1104-204                    | O <sub>s</sub>                                                                                                                                                  | –            | 24.6     | 10.4       | 245        | 33.2      | 9.8      | 268 | 11.7        | 41.4          |                                     |
| HPC 1104-205                    | O <sub>s</sub>                                                                                                                                                  | –            | 24.4     | 10.4       | 225        | 36.9      | 10.5     | –   | (10.8)*     | –             | Test to prove minimum arcing time   |
| HPC 1104-207                    | O <sub>d</sub>                                                                                                                                                  | –            | 25.7     | –          | –          | –         | –        | –   | 11.5        | 41.2          |                                     |
|                                 | 0.3 s C <sub>d</sub> O <sub>s</sub>                                                                                                                             | –            | 24.8     | 10.4       | 344        | 32.6      | 9.8      | 273 | 19.3        | 49.5          |                                     |
| HPC 1104-208                    | C'O <sub>s</sub>                                                                                                                                                | –            | 24.5     | 10.4       | 314        | 34.1      | 10.2     | 276 | 16.0        | 45.0          |                                     |
| Condition during and after test | The test object was operated normally.<br>No visible damages externally.                                                                                        |              |          |            |            |           |          |     |             |               |                                     |

Note The figures of parenthesis ( )\* means arcing time set for tests.  
C\* means no load closing operation

## 18 No-load operation checks

| Test results                       |                                    |                     |           |                      |                      |         |
|------------------------------------|------------------------------------|---------------------|-----------|----------------------|----------------------|---------|
| Test number                        | Operating duty                     | Supply voltage (DC) |           | Closing time<br>ms   | Opening time<br>ms   | Remarks |
|                                    |                                    | Close<br>V          | Open<br>V |                      |                      |         |
| HPC 1104-209                       | O                                  | -                   | 110       | -                    | 26.1<br>26.0<br>25.8 |         |
|                                    | 0.3 s<br>CO                        | 110                 | 110       | 82.0<br>81.1<br>83.2 | 25.5<br>25.7<br>25.9 |         |
| HPC 1104-210                       | CO                                 | 110                 | 110       | 82.8<br>81.9<br>84.0 | 25.6<br>25.5<br>25.5 |         |
| HPC 1104-211                       | O                                  | -                   | 121       | -                    | 25.4<br>25.2<br>25.0 |         |
| Condition during<br>and after test | The test object operated normally. |                     |           |                      |                      |         |

## 19 Double-earth fault tests (DEF)

| Test requirements            |                                                                                                                                                                   |
|------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| TRV                          | $u_1 = 154 \text{ kV}$ , $t_1 = 77 \text{ } \mu\text{s}$ , $u_c = 288 \text{ kV}$ , $t_2 = 308 \text{ } \mu\text{s}$ , $\text{RRRV} = 2.0 \text{ kV}/\mu\text{s}$ |
| Test current                 | 34.8 kA                                                                                                                                                           |
| Test frequency               | 50 Hz                                                                                                                                                             |
| SF <sub>6</sub> gas pressure | 0.6 MPa(gauge)                                                                                                                                                    |
| Control voltage              | DC 121 V                                                                                                                                                          |
| Operating sequence           | O <sub>s</sub>                                                                                                                                                    |

| Test results                    |                                                                                                                                      |              |               |            |            |           |              |     |                |                       |                                        |
|---------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|--------------|---------------|------------|------------|-----------|--------------|-----|----------------|-----------------------|----------------------------------------|
| Condition before test           | After basic short-circuit tests (T60)<br>Supply side : fixed contact<br>Test phase : C                                               |              |               |            |            |           |              |     |                |                       | Test circuit :<br>Fig. HP02            |
| Test No.                        | Operati<br>ng duty                                                                                                                   | Test current |               |            |            |           |              | TRV | Arcing<br>time | Breaki-<br>ng<br>time | Remarks                                |
|                                 |                                                                                                                                      | Making       | Breaki-<br>ng | di/dt      | th         | Last loop |              |     |                |                       |                                        |
|                                 |                                                                                                                                      |              |               |            |            | Peak      | Duratio<br>n |     |                |                       |                                        |
|                                 |                                                                                                                                      | kA           | kA            | A/ $\mu$ s | A/ $\mu$ s | kA        | ms           | kV  | ms             | ms                    |                                        |
| HPC 1104-212                    | Injection current = 2.94 kA, Frequency = 449 Hz, di/dt = 11.7 A/ $\mu$ s                                                             |              |               |            |            |           |              |     |                |                       | Injection current<br>check<br>(75.5 %) |
| HPC 1104-213                    | u <sub>1</sub> = 122 kV, t <sub>1</sub> = 77 $\mu$ s, u <sub>c</sub> = 225 kV, t <sub>2</sub> = 308 $\mu$ s, RRRV = 1.58 kV/ $\mu$ s |              |               |            |            |           |              |     |                |                       | TRV check<br>(75.5 %)                  |
| HPC 1104-216                    | O <sub>s</sub>                                                                                                                       | –            | 34.9          | 15.6       | 346        | 48.1      | 10.2         | 298 | 20.9           | 45.9                  |                                        |
| Condition during and after test | The test object was operated normally.<br>No visible damages externally.                                                             |              |               |            |            |           |              |     |                |                       |                                        |

## 20 No-load operation checks

| Test results                       |                                    |                     |           |                      |                      |                                          |
|------------------------------------|------------------------------------|---------------------|-----------|----------------------|----------------------|------------------------------------------|
| Test number                        | Operating duty                     | Supply voltage (DC) |           | Closing time<br>ms   | Opening time<br>ms   | Remarks                                  |
|                                    |                                    | Close<br>V          | Open<br>V |                      |                      |                                          |
| HPC 1104-217                       | O                                  | –                   | 110       | –                    | 26.1<br>26.0<br>25.3 | After DEF                                |
|                                    | 0.3 s<br>CO                        | 110                 | 110       | 81.4<br>80.5<br>82.7 | 25.1<br>25.6<br>25.3 |                                          |
| HPC 1104-218                       | CO                                 | 110                 | 110       | 83.1<br>82.1<br>84.5 | 25.3<br>25.7<br>25.5 |                                          |
| HPC 1104-219                       | O                                  | –                   | 110       | –                    | 25.7<br>25.8<br>25.0 | Before verification test for<br>breaking |
|                                    | 0.3 s<br>CO                        | 110                 | 110       | 79.9<br>79.1<br>80.7 | 25.0<br>25.3<br>24.6 |                                          |
| HPC 1104-220                       | CO                                 | 110                 | 110       | 81.5<br>80.8<br>82.6 | 25.2<br>25.4<br>25.1 |                                          |
| HPC 1104-221                       | O                                  | –                   | 77        | –                    | 29.5<br>29.6<br>29.0 |                                          |
|                                    | 0.3 s<br>CO                        | 93.5                | 77        | 81.4<br>81.6<br>83.1 | 30.0<br>30.2<br>29.6 |                                          |
| HPC 1104-222                       | CO                                 | 93.5                | 77        | 83.5<br>82.8<br>84.6 | 30.0<br>30.1<br>29.8 |                                          |
| Condition during<br>and after test | The test object operated normally. |                     |           |                      |                      |                                          |

## 21 Verification tests for single phase breaking of common operating mechanism

| Test requirements  |             |
|--------------------|-------------|
| Breaking current   | 40 kA       |
| Test frequency     | 50 Hz       |
| Control voltage    | DC 110 V    |
| Operating sequence | O - 1 times |

| Test results                    |                                                                          |                    |                        |                      |                      |                             |
|---------------------------------|--------------------------------------------------------------------------|--------------------|------------------------|----------------------|----------------------|-----------------------------|
| Condition before test           | After maintenance<br>Supply side : Fixed contact                         |                    |                        |                      |                      | Test circuit :<br>Fig. HP08 |
| Test number                     | Operating duty                                                           | Test voltage<br>kV | Breaking current<br>kA | Arcing time<br>ms    | Breaking time<br>ms  | Remarks                     |
| HPC 1104-227                    | O                                                                        | 23.9               | 40.4<br>40.4<br>40.1   | 16.6<br>20.9<br>20.9 | 41.7<br>46.0<br>46.0 |                             |
| Condition during and after test | The test object was operated normally.<br>No visible damages externally. |                    |                        |                      |                      |                             |

## 22 No-load operation checks

| Test results                    |                                    |                     |           |                      |                      |                                                                                 |
|---------------------------------|------------------------------------|---------------------|-----------|----------------------|----------------------|---------------------------------------------------------------------------------|
| Test number                     | Operating duty                     | Supply voltage (DC) |           | Closing time<br>ms   | Opening time<br>ms   | Remarks                                                                         |
|                                 |                                    | Close<br>V          | Open<br>V |                      |                      |                                                                                 |
| HPC 1104-228                    | O                                  | —                   | 110       | —                    | 25.7<br>26.0<br>25.2 | After verification test for single phase breaking of common operating mechanism |
|                                 | 0.3 s<br>CO                        | 110                 | 110       | 82.0<br>81.3<br>83.3 | 25.5<br>26.0<br>25.6 |                                                                                 |
|                                 |                                    |                     |           | 82.9<br>82.2<br>84.1 | 25.2<br>25.6<br>25.4 |                                                                                 |
| HPC 1104-229                    | CO                                 | 110                 | 110       |                      |                      |                                                                                 |
| Condition during and after test | The test object operated normally. |                     |           |                      |                      |                                                                                 |

## 23 Description of tests

23.1 These tests were carried out with the sample supplied and confirmed by client.

## Photographs



Photo. HP01 : After basic short circuit tests(T100)

## Photographs



Photo. HP02 : After short-line fault tests

## Photographs

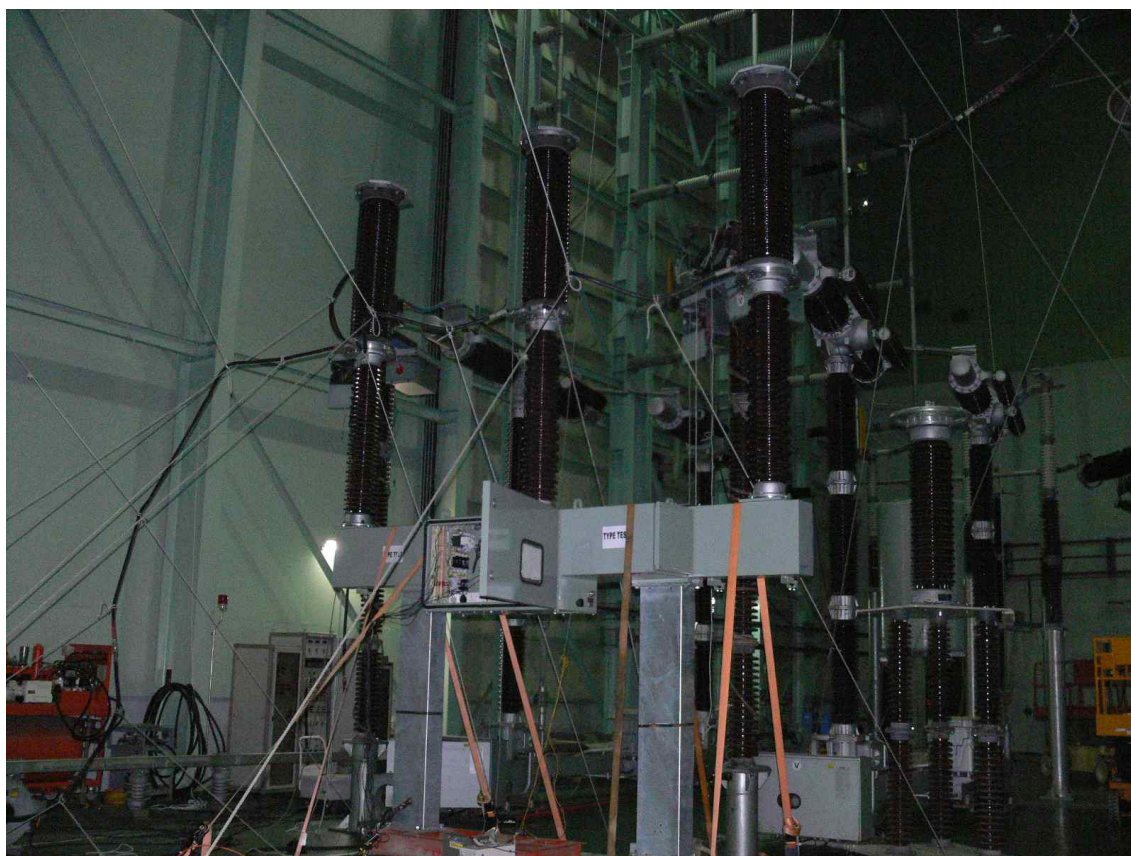


Photo. HP03 : After double-earth fault test(DEF)

## Photographs

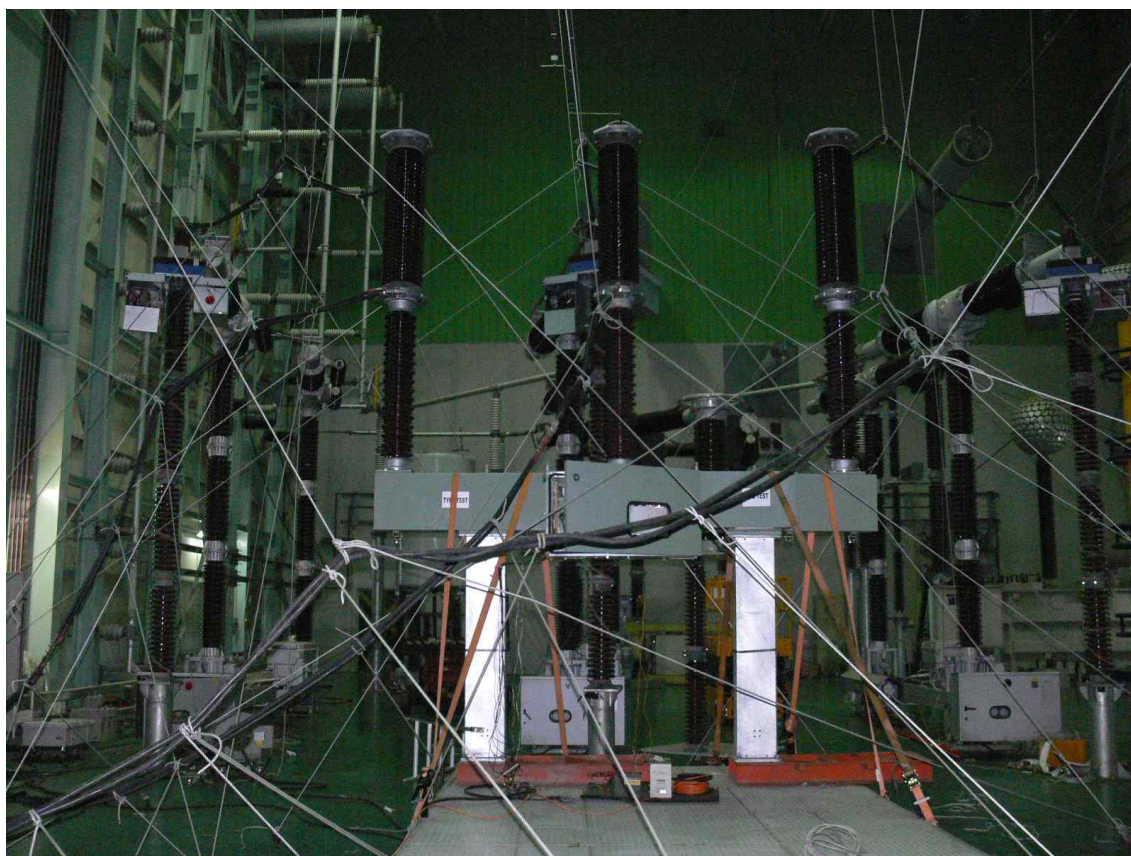


Photo. HP04 : After verification tests for single phase breaking of common operating mechanism

## Photographs



Photo. HP05 : Contact after basic short circuit test(T100a)

## Photographs



Photo. HP06 : Contact after basic short circuit test(T100s)

## Photographs



Photo. HP07 : Contact after short line fault (L90)

## Photographs



Photo. HP08 : Contact after short line fault (L75)

## Photographs



Photo. HP09 : Contact after basic short-circuit tests(T10, T30) and out of phase making and breaking(OP2)

## Photographs



Photo. HP10 : Contact after basic short-circuit tests(T60) and double-earth fault test(DEF)

## Circuit parameters

| Items                                                                                                                                                                   |                              | Fig. HP01  | Fig. HP02          | Fig. HP03       | Fig. HP04 |        | Fig. HP05          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------|------------|--------------------|-----------------|-----------|--------|--------------------|
|                                                                                                                                                                         |                              | STC        | T100a,<br>T100s(b) | T100s(a)        | L90       | L75    | Condition<br>check |
| Test cell                                                                                                                                                               |                              | TC-3       | TC-4               | TC-4            | TC-4      | TC-4   | TC-4               |
| Power frequency Hz                                                                                                                                                      |                              | 50         | 50                 | 50              | 50        | 50     | –                  |
| Number of phase                                                                                                                                                         |                              | 3          | 1                  | 3               | 1         | 1      | 1                  |
| Generator                                                                                                                                                               | connection                   | Y          | Y                  | Y               | Y         | Y      | –                  |
|                                                                                                                                                                         | neutral                      | E          | E                  | E               | E         | E      | –                  |
| TRV tuning capacitor $C_g$ $\mu F$                                                                                                                                      |                              | 3.6        | 3.6                | 3.6             | 3.6       | 3.6    | –                  |
| Current limiting reactor CLR $\Omega$                                                                                                                                   |                              | 0.000      | 0.000              | 0.000           | 0.000     | 0.000  | –                  |
|                                                                                                                                                                         |                              | 2.280      | 0.000              | 0.000           | 0.000     | 0.000  | –                  |
|                                                                                                                                                                         |                              | 2.105      | –                  | 0.000           | –         | –      | –                  |
| Transformer bank                                                                                                                                                        | connection                   | $\Delta/Y$ | P/P                | $\Delta/\Delta$ | P/P       | P/P    | –                  |
|                                                                                                                                                                         | ratio kV                     | 18/0.25    | 18/24              | 18/24           | 18/24     | 18/24  | –                  |
|                                                                                                                                                                         | neutral                      | –          | –                  | –               | –         | –      | –                  |
| Resistance in series $R_s$ $\Omega$                                                                                                                                     |                              | –          | –                  | –               | –         | –      | –                  |
| TRV tuning element                                                                                                                                                      | Resistance $R_e$ $\Omega$    | –          | –                  | –               | –         | –      | –                  |
|                                                                                                                                                                         | Capacitance $C_e$ $\mu F$    | –          | –                  | –               | –         | –      | –                  |
|                                                                                                                                                                         | Resistance $R_T$ $\Omega$    | –          | –                  | –               | –         | –      | –                  |
|                                                                                                                                                                         | Capacitance $C_T$ $\mu F$    | –          | –                  | –               | –         | –      | –                  |
| Load                                                                                                                                                                    | Resistance $R_L$ $\Omega$    | –          | –                  | –               | –         | –      | –                  |
|                                                                                                                                                                         | Reactance $L_L$ mH           | –          | –                  | –               | –         | –      | –                  |
|                                                                                                                                                                         | Capacitance $C_L$ $\mu F$    | –          | –                  | –               | –         | –      | –                  |
| Earthing                                                                                                                                                                | Resistance $R_N$ $\Omega$    | –          | –                  | –               | –         | –      | –                  |
|                                                                                                                                                                         | Capacitance $C_N$ $\mu F$    | –          | –                  | –               | –         | –      | –                  |
| Synthetic circuit                                                                                                                                                       | Inductance $L_{V1}$ mH       | –          | 7.05               | –               | 7.00      | 7.00   | 15.67              |
|                                                                                                                                                                         | Capacitance $C_{V1}$ $\mu F$ | –          | 12.70              | –               | 7.39      | 7.39   | 13.18              |
|                                                                                                                                                                         | Resistance $R_{T1}$ $\Omega$ | –          | 18.20              | –               | 102.00    | 102.00 | 137.50             |
|                                                                                                                                                                         | Capacitance $C_{T1}$ $\mu F$ | –          | 1.76               | –               | 0.34      | 0.34   | 0.133              |
|                                                                                                                                                                         | Inductance $L_{V2}$ mH       | –          | 3.52               | –               | –         | –      | –                  |
|                                                                                                                                                                         | Capacitance $C_{V2}$ $\mu F$ | –          | 25.40              | –               | –         | –      | –                  |
|                                                                                                                                                                         | Resistance $R_{T2}$ $\Omega$ | –          | 65.20              | –               | –         | –      | –                  |
|                                                                                                                                                                         | Capacitance $C_{T2}$ $\mu F$ | –          | 0.26               | –               | –         | –      | –                  |
| Power frequency inductance $L_{pf}$ H                                                                                                                                   |                              | –          | 1.2                | –               | 1.31      | 1.31   | –                  |
| Artificial line                                                                                                                                                         | Inductance $L_s$ $\mu H$     | –          | –                  | –               | 762       | 2282   | –                  |
|                                                                                                                                                                         | Inductance $L_R$ $\mu H$     | –          | –                  | –               | 381       | 1157   | –                  |
|                                                                                                                                                                         | Capacitance $C_1$ pF         | –          | –                  | –               | 465       | 465    | –                  |
|                                                                                                                                                                         | Resistance $R$ $\Omega$      | –          | –                  | –               | 1410      | 3860   | –                  |
| Short circuit point                                                                                                                                                     |                              | E          | E                  | E               | E         | E      | E                  |
| Note) E : Earthed, I : Isolated, P, S, $\Delta$ & Y : Transformer's parallel, series, delta and star connection<br>Transformer ratio voltage based on phase to neutral. |                              |            |                    |                 |           |        |                    |

## Circuit parameters

| Items                                                                                                                                                                   |                            | Fig. HP06 |                       | Fig. HP07       | Fig. HP02 | Fig. HP02 | Fig. HP08                      |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|-----------|-----------------------|-----------------|-----------|-----------|--------------------------------|
|                                                                                                                                                                         |                            | T10       | T30,<br>OP2(Breaking) | OP2<br>(Making) | T60       | DEF       | Verification<br>test(Breaking) |
| Test cell                                                                                                                                                               |                            | TC-4      | TC-4                  | TC-4            | TC-4      | TC-4      | TC-4                           |
| Power frequency Hz                                                                                                                                                      |                            | 50        | 50                    | 50              | 50        | 50        | 50                             |
| Number of phase                                                                                                                                                         |                            | 1         | 1                     | 1               | 1         | 1         | 3                              |
| Generator                                                                                                                                                               | connection                 | Y         | Y                     | Y               | Y         | Y         | Y                              |
|                                                                                                                                                                         | neutral                    | E         | E                     | E               | E         | E         | E                              |
| TRV tuning capacitor $C_g \mu F$                                                                                                                                        |                            | 3.6       | 3.6                   | 3.6             | 3.6       | 3.6       | 3.6                            |
| Current limiting reactor CLR $\Omega$                                                                                                                                   |                            | 0.000     | 0.000                 | 0.180           | 0.000     | 0.000     | 0.000                          |
|                                                                                                                                                                         |                            | 0.000     | 0.000                 | 0.180           | 0.000     | 0.000     | 0.000                          |
|                                                                                                                                                                         |                            | -         | -                     | -               | -         | -         | 0.000                          |
| Transformer bank                                                                                                                                                        | connection                 | P/P       | P/P                   | P/S             | P/P       | P/P       | $\Delta/\Delta$                |
|                                                                                                                                                                         | ratio kV                   | 18/24     | 18/24                 | 18/96           | 18/24     | 18/24     | 18/24                          |
|                                                                                                                                                                         | neutral                    | -         | -                     | -               | -         | -         | -                              |
| Resistance in series $R_s \Omega$                                                                                                                                       |                            | -         | -                     | -               | -         | -         | -                              |
| TRV tuning element                                                                                                                                                      | Resistance $R_e \Omega$    | -         | -                     | -               | -         | -         | -                              |
|                                                                                                                                                                         | Capacitance $C_e \mu F$    | -         | -                     | -               | -         | -         | -                              |
|                                                                                                                                                                         | Resistance $R_T \Omega$    | -         | -                     | -               | -         | -         | -                              |
|                                                                                                                                                                         | Capacitance $C_T \mu F$    | -         | -                     | -               | -         | -         | -                              |
| Load                                                                                                                                                                    | Resistance $R_L \Omega$    | -         | -                     | -               | -         | -         | -                              |
|                                                                                                                                                                         | Reactance $L_L mH$         | -         | -                     | -               | -         | -         | -                              |
|                                                                                                                                                                         | Capacitance $C_L \mu F$    | -         | -                     | -               | -         | -         | -                              |
| Earthing                                                                                                                                                                | Resistance $R_N \Omega$    | -         | -                     | -               | -         | -         | -                              |
|                                                                                                                                                                         | Capacitance $C_N \mu F$    | -         | -                     | -               | -         | -         | -                              |
| Synthetic circuit                                                                                                                                                       | Inductance $L_{V1} mH$     | 95.87     | 47.86                 | -               | 13.69     | 9.60      | -                              |
|                                                                                                                                                                         | Capacitance $C_{V1} \mu F$ | 1.14      | 2.52                  | -               | 5.01      | 13.00     | -                              |
|                                                                                                                                                                         | Resistance $R_{T1} \Omega$ | 1491.20   | 680.40                | -               | 50.3      | 22.50     | -                              |
|                                                                                                                                                                         | Capacitance $C_{T1} \mu F$ | 0.01      | 0.03                  | -               | 0.97      | 1.69      | -                              |
|                                                                                                                                                                         | Inductance $L_{V2} mH$     | -         | -                     | -               | 7.170     | 4.80      | -                              |
|                                                                                                                                                                         | Capacitance $C_{V2} \mu F$ | -         | -                     | -               | 9.57      | 26.00     | -                              |
|                                                                                                                                                                         | Resistance $R_{T2} \Omega$ | -         | -                     | -               | 211.5     | 79.70     | -                              |
|                                                                                                                                                                         | Capacitance $C_{T2} \mu F$ | -         | -                     | -               | 0.09      | 0.26      | -                              |
| Power frequency inductance $L_{pf} H$                                                                                                                                   |                            | -         | -                     | -               | 2.7       | 1.08      | -                              |
| Artificial line                                                                                                                                                         | Inductance $L_s \mu H$     | -         | -                     | -               | -         | -         | -                              |
|                                                                                                                                                                         | Inductance $L_R \mu H$     | -         | -                     | -               | -         | -         | -                              |
|                                                                                                                                                                         | Capacitance $C_1 pF$       | -         | -                     | -               | -         | -         | -                              |
|                                                                                                                                                                         | Resistance $R \Omega$      | -         | -                     | -               | -         | -         | -                              |
| Short circuit point                                                                                                                                                     |                            | E         | E                     | E               | E         | E         | E                              |
| Note) E : Earthed, I : Isolated, P, S, $\Delta$ & Y : Transformer's parallel, series, delta and star connection<br>Transformer ratio voltage based on phase to neutral. |                            |           |                       |                 |           |           |                                |

## Circuit diagrams

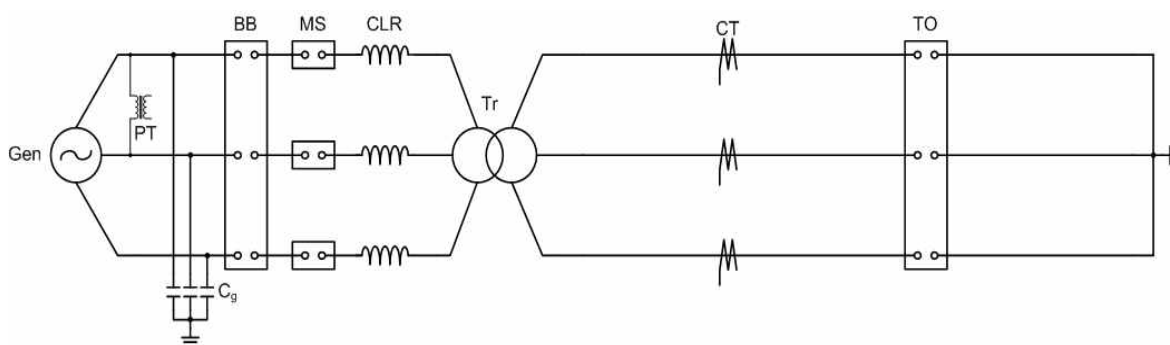


Fig. HP01 : Circuit for short-time and peak withstand current tests

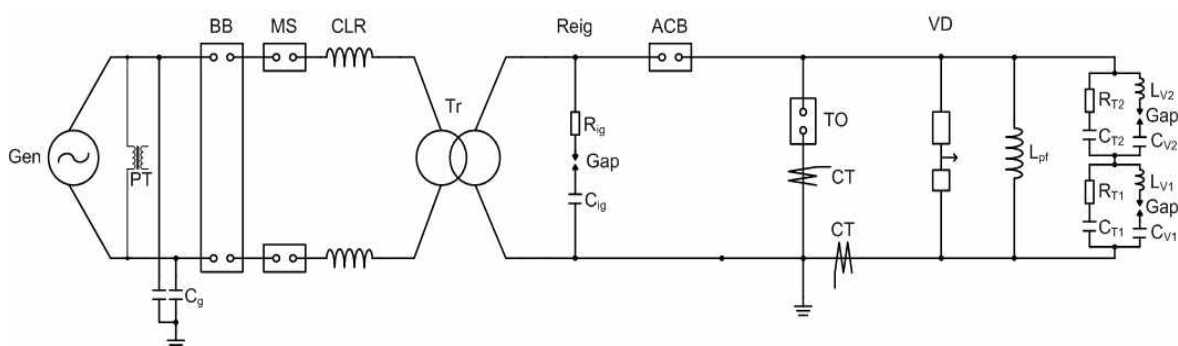


Fig. HP02 : Circuit for basic short-circuit tests(T100a, T100s(b), T60) and double-earth fault tests (DEF)

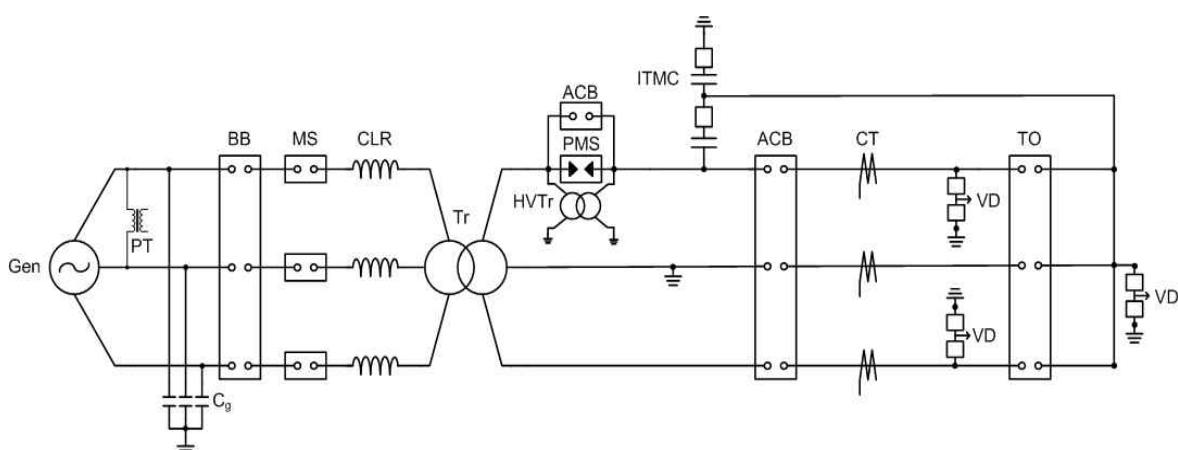


Fig. HP03 : Circuit for basic short-circuit tests(T100s(a))

## Circuit diagrams

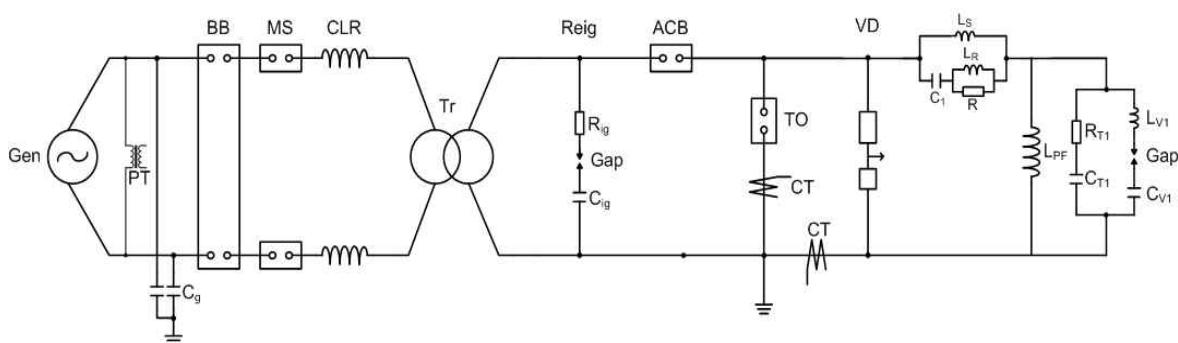


Fig. HP04 : Circuit for short-line fault tests

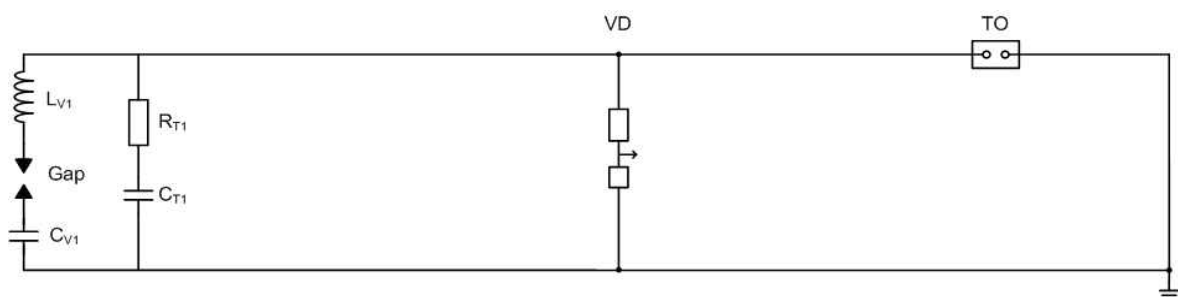


Fig. HP05 : Circuit for voltage tests as a condition check

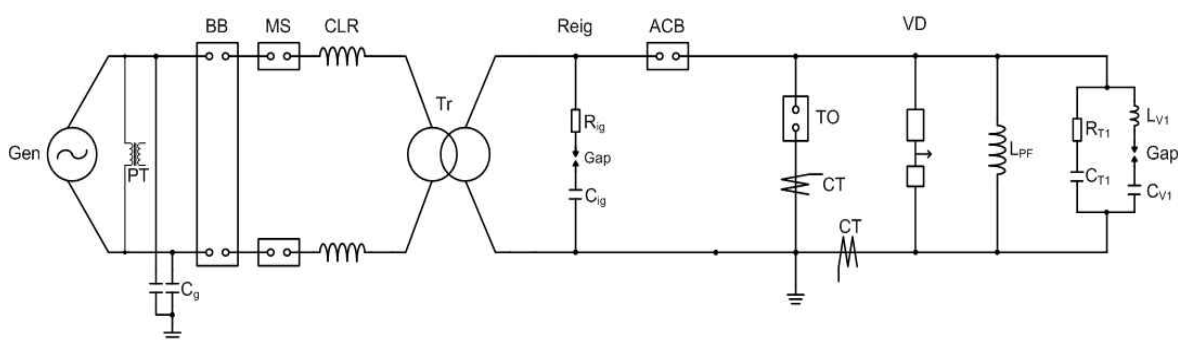


Fig. HP06 : Circuit for basic short-circuit tests (T30, T10) and out of phase making and breaking tests (OP2, Breaking)

## Circuit diagrams

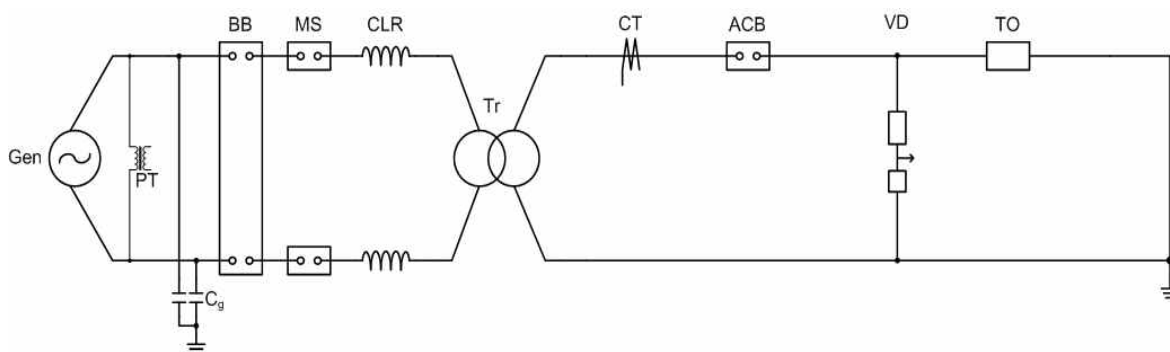


Fig. HP07 : Circuit for out of phase making and breaking tests(OP2, Making)

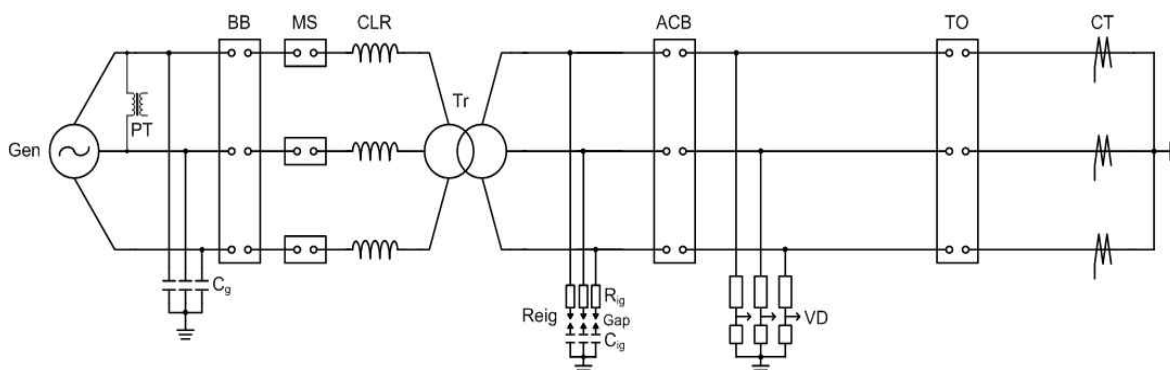
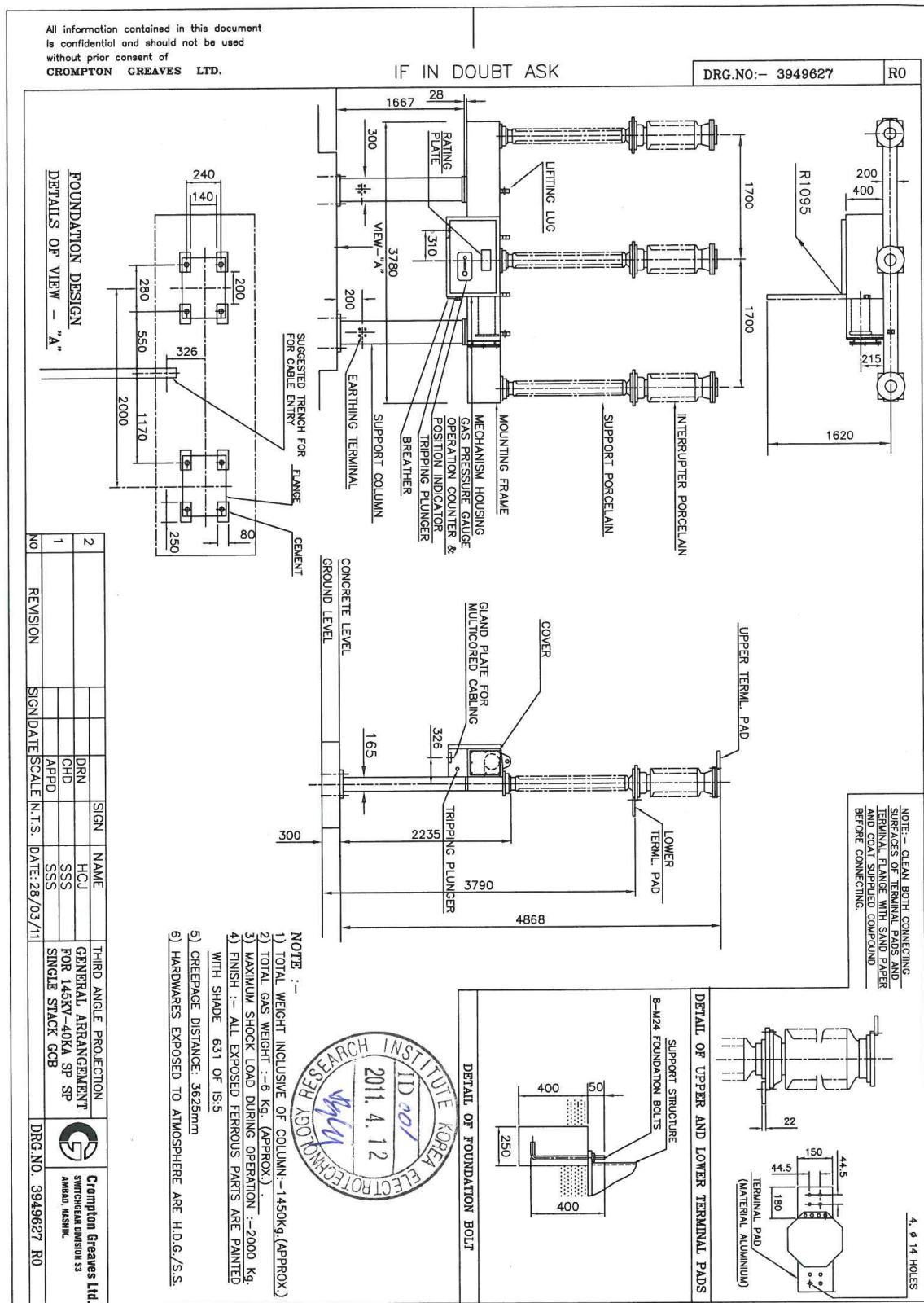


Fig. HP08 : Circuit for verification tests for single phase breaking of common operating mechanism

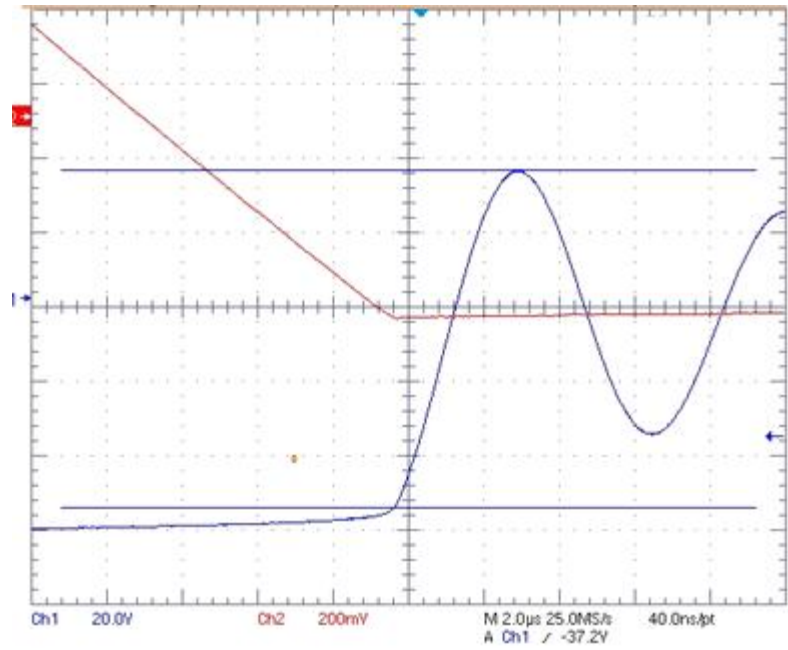
|          |       |                                          |
|----------|-------|------------------------------------------|
| Gen      | ----- | Generator                                |
| PT       | ----- | Potential transformer                    |
| Cg       | ----- | Capacitor for generator                  |
| BB       | ----- | Back-up circuit breaker                  |
| MS       | ----- | Making switch                            |
| CLR      | ----- | Current limiting reactor                 |
| Tr       | ----- | Transformer bank                         |
| CT       | ----- | Current transformer                      |
| TO       | ----- | Test object                              |
| ACB      | ----- | Auxiliary circuit breaker                |
| VD       | ----- | Voltage divider                          |
| Re       | ----- | TRV tuning resistor                      |
| Ce       | ----- | TRV tuning capacitor                     |
| Rs       | ----- | Resistance in series                     |
| Cv1, Cv2 | ----- | Main capacitor                           |
| Lv1, Lv1 | ----- | TRV tuning reactor                       |
| CT1, CT2 | ----- | TRV tuning capacitor                     |
| RT1, RT2 | ----- | TRV tuning resistor                      |
| Lpf      | ----- | Reactor for power frequency oscillation  |
| LS       | ----- | Reactor coil of artificial line          |
| C1       | ----- | TRV tuning capacitor of artificial line  |
| LR       | ----- | TRV tuning reactor of artificial line    |
| R        | ----- | TRV tuning resistor of artificial line   |
| Reig     | ----- | Reignition circuit                       |
| PMS      | ----- | Plasma Making Switch                     |
| HVTr     | ----- | High voltage transformer                 |
| ITMC     | ----- | Initial transient making current circuit |

## Drawings



Attachments

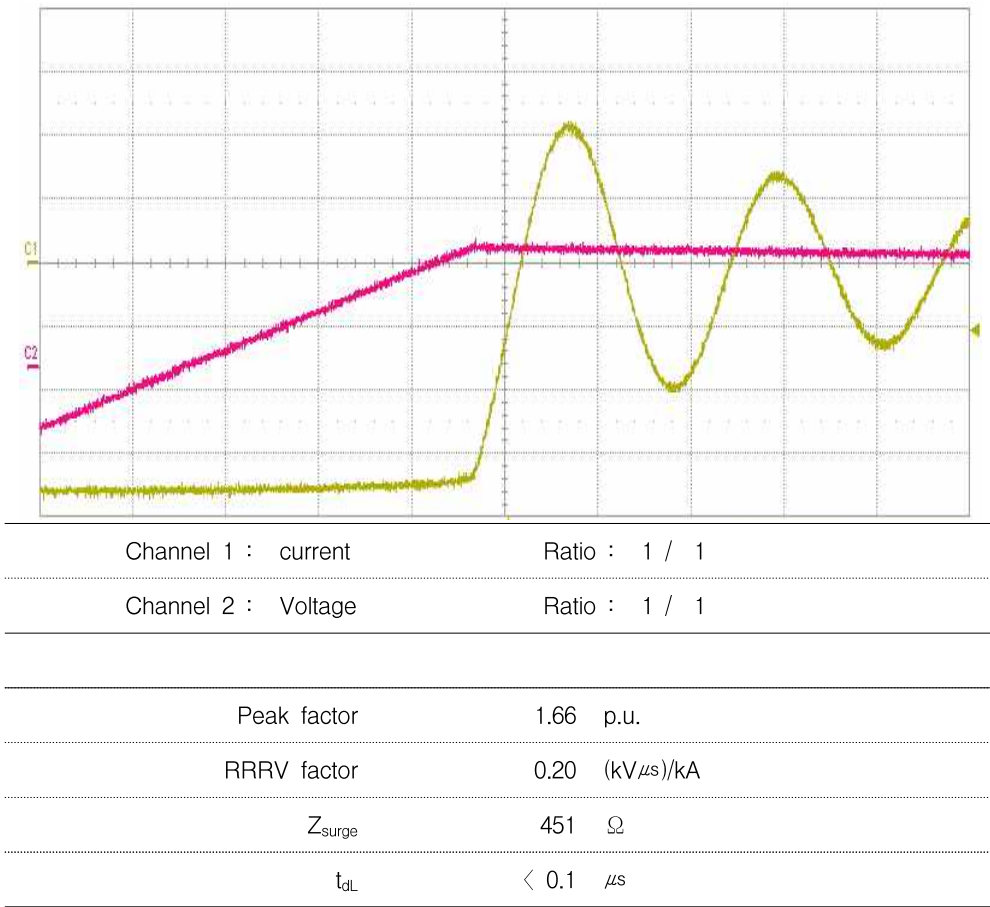
Attachment HP01 : Inherent Line side TRV for L90



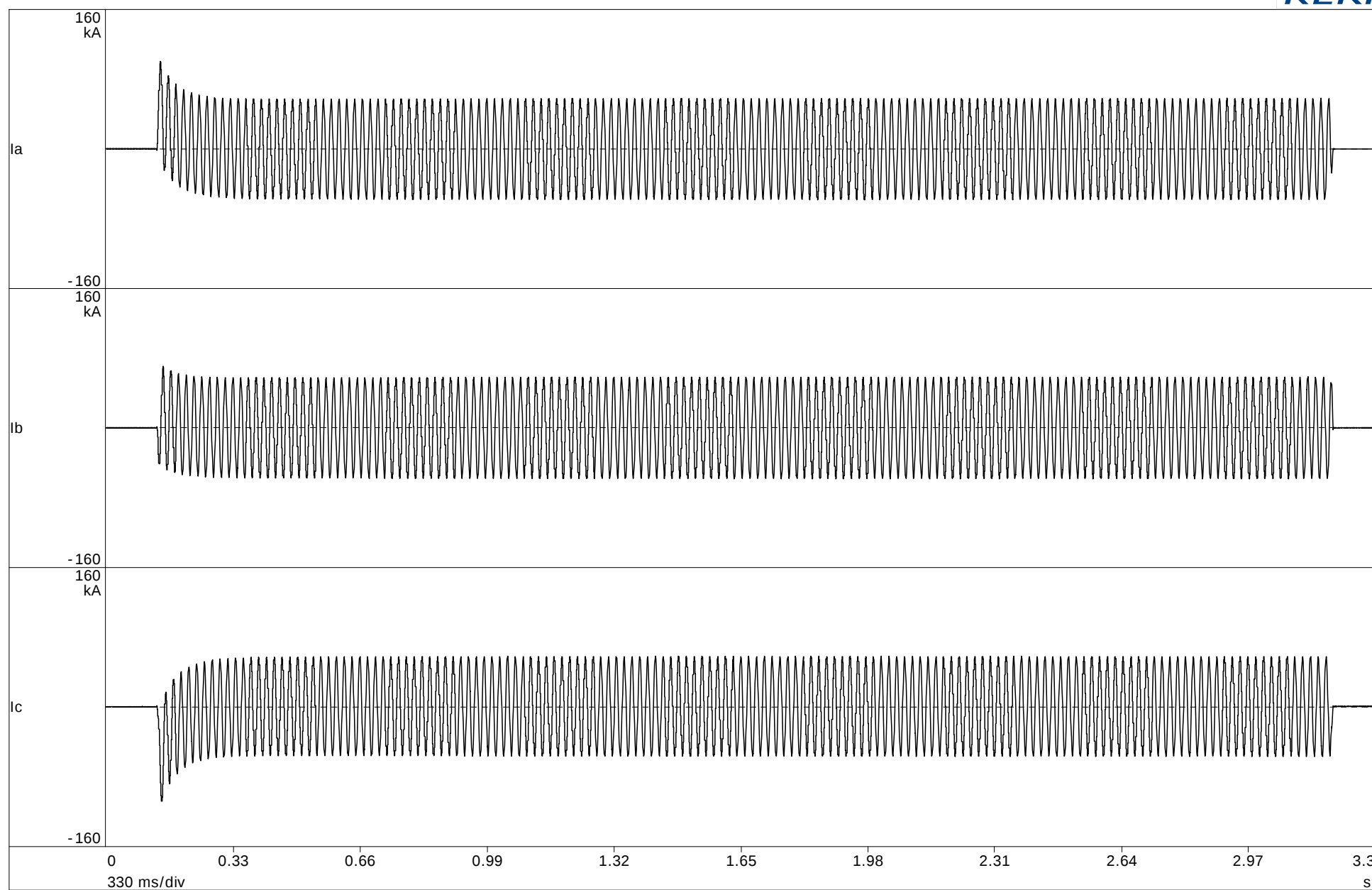
|                     |                 |
|---------------------|-----------------|
| Channel 1 : current | Ratio : 1 / 1   |
| Channel 2 : Voltage | Ratio : 1 / 1   |
| Peak factor         | 1.68 p.u.       |
| RRRV factor         | 0.201 (kVμs)/kA |
| Z <sub>surge</sub>  | 451 Ω           |
| t <sub>dL</sub>     | < 0.1 μs        |

Attachments

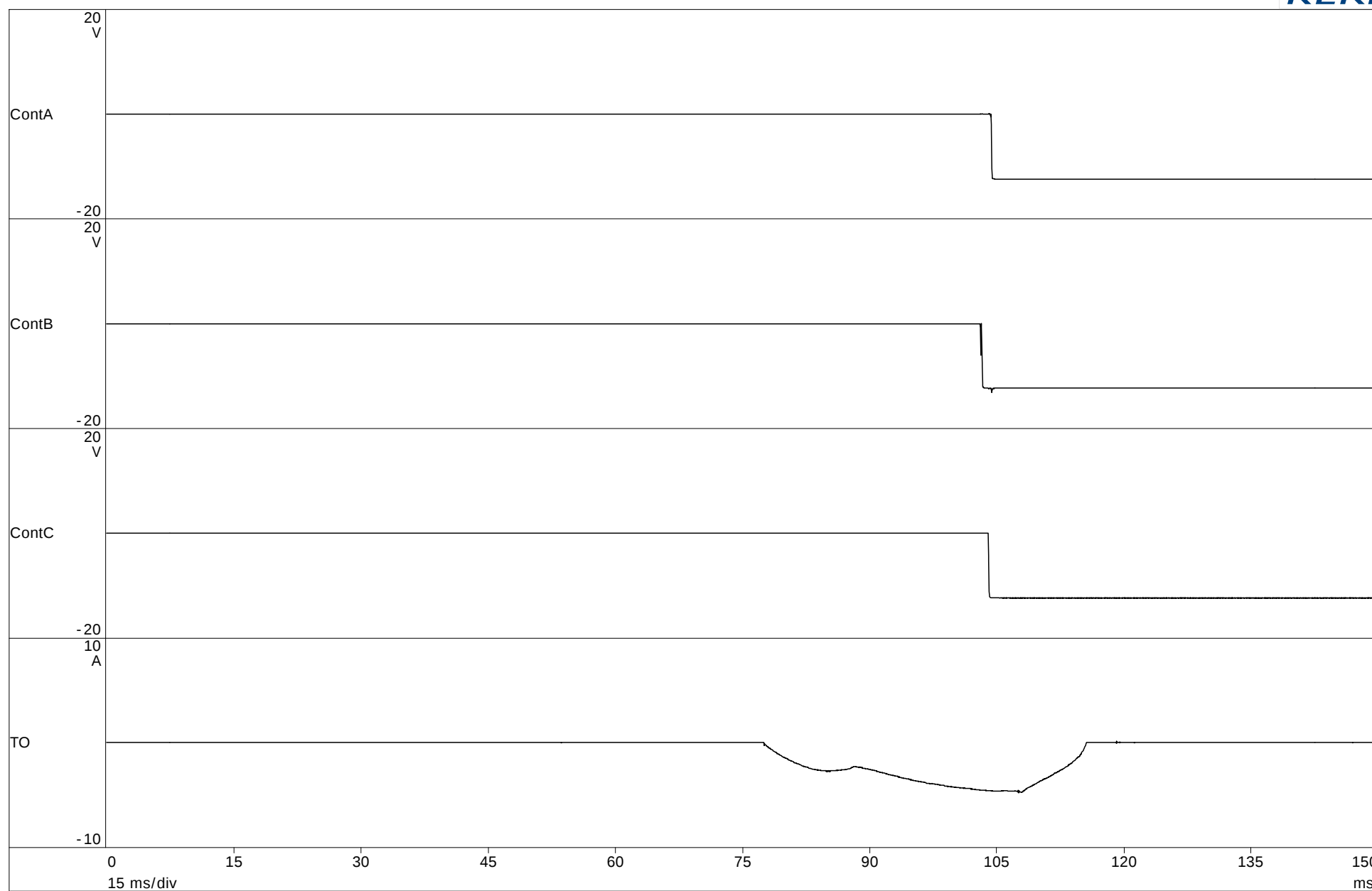
Attachment HP02 : Inherent Line side TRV for L75



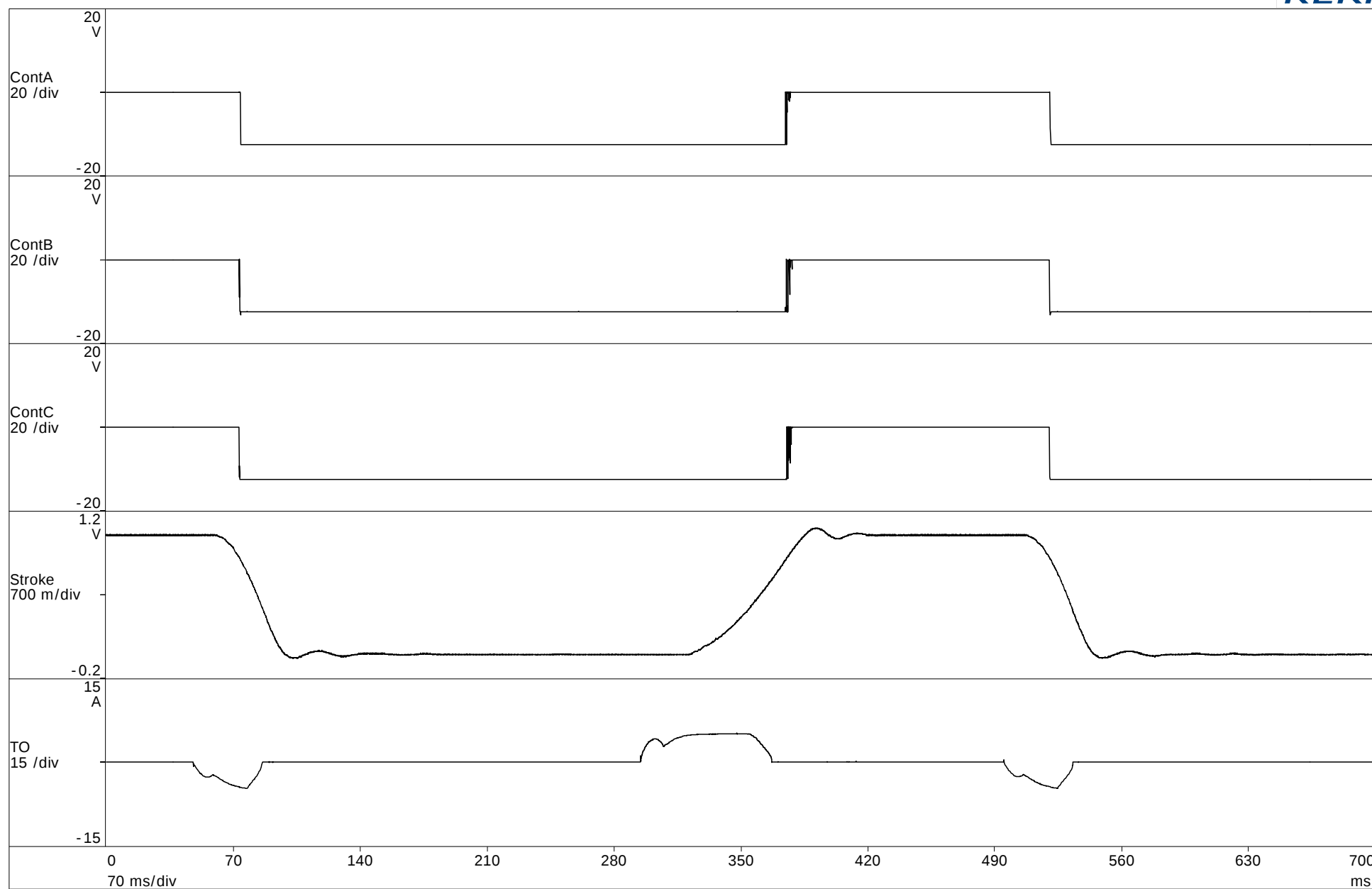
HPC 1104 - 009



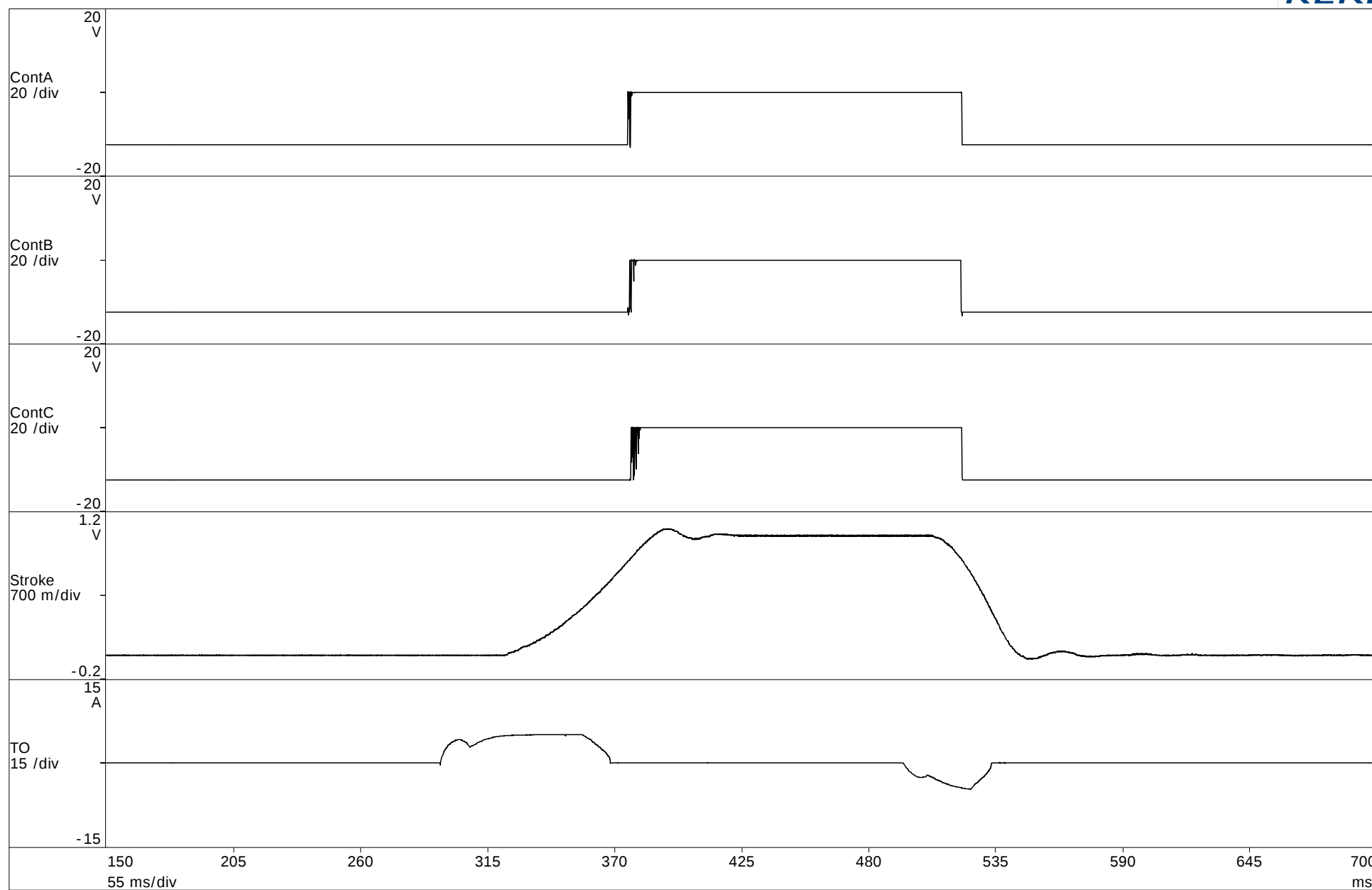
HPC 1104 - 010



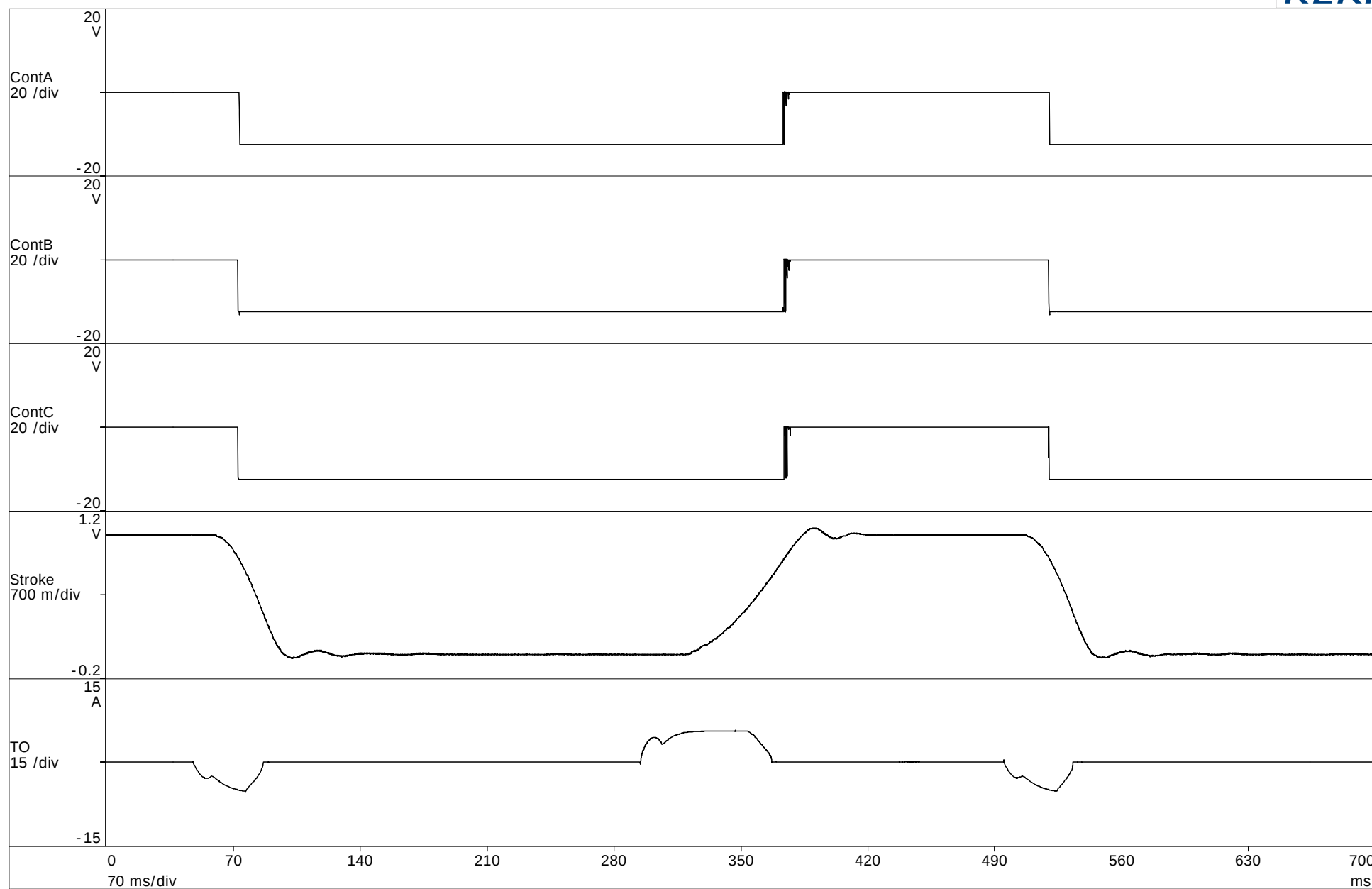
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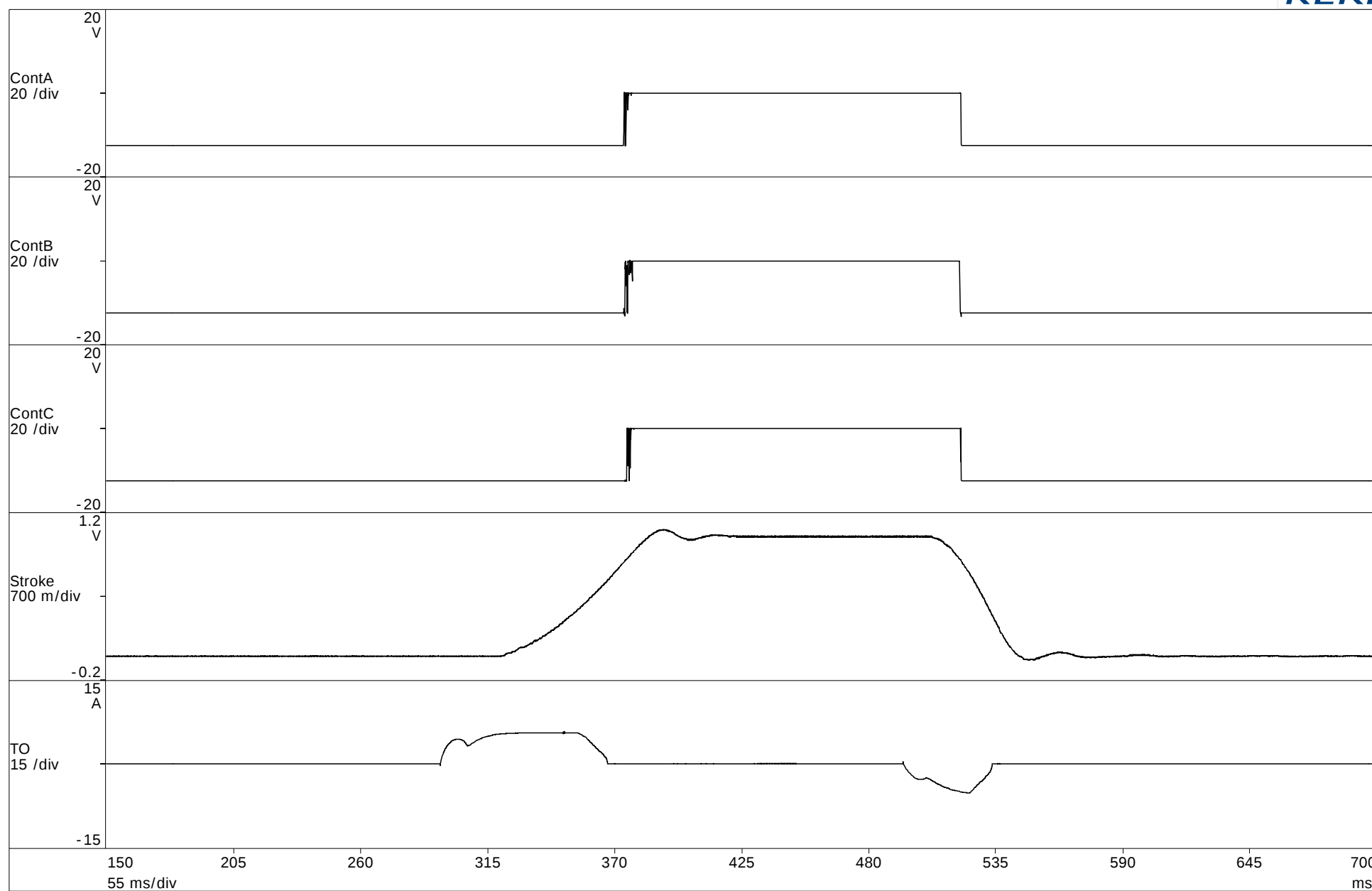
HPC 1104 - 038



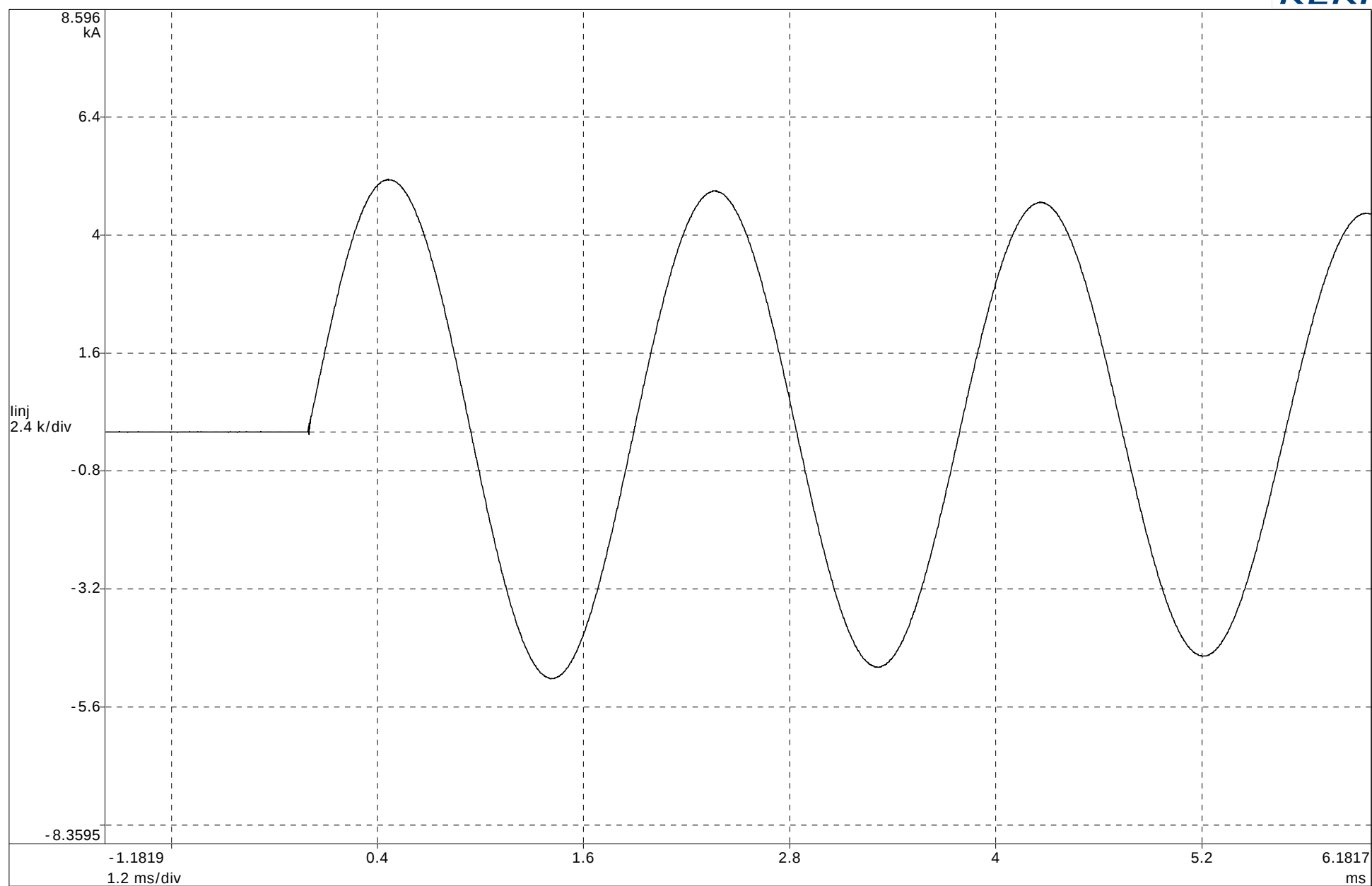
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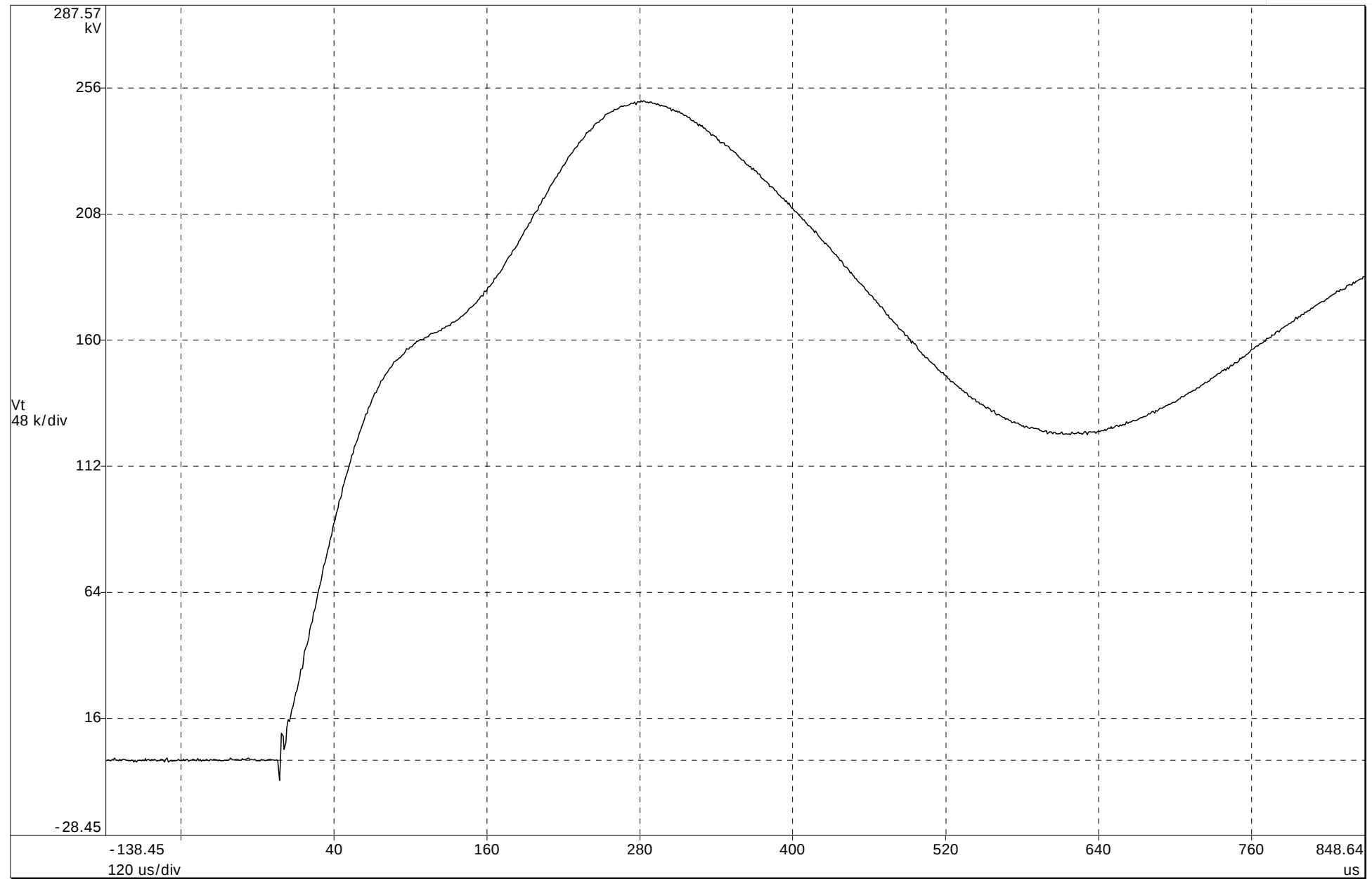
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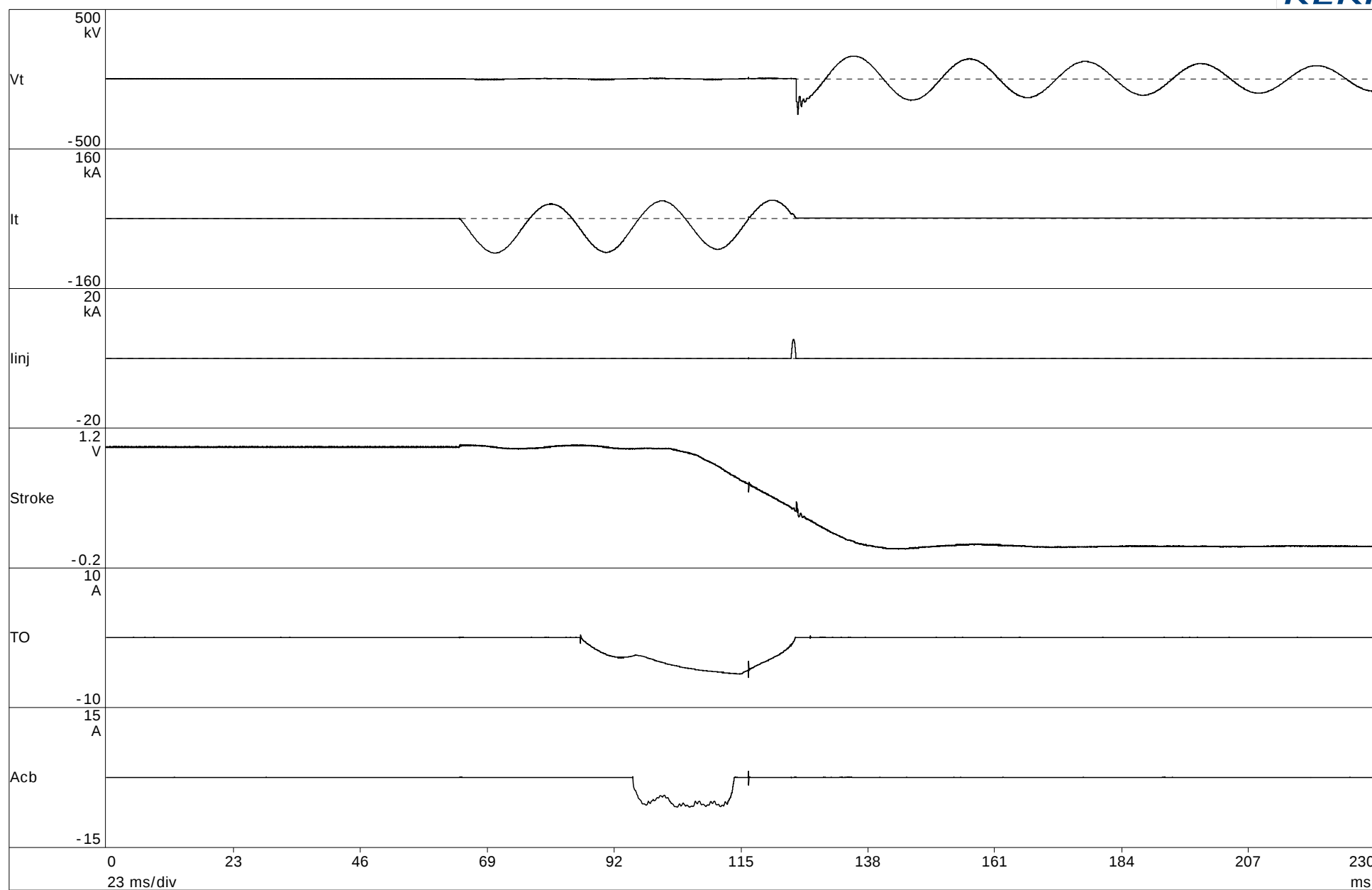
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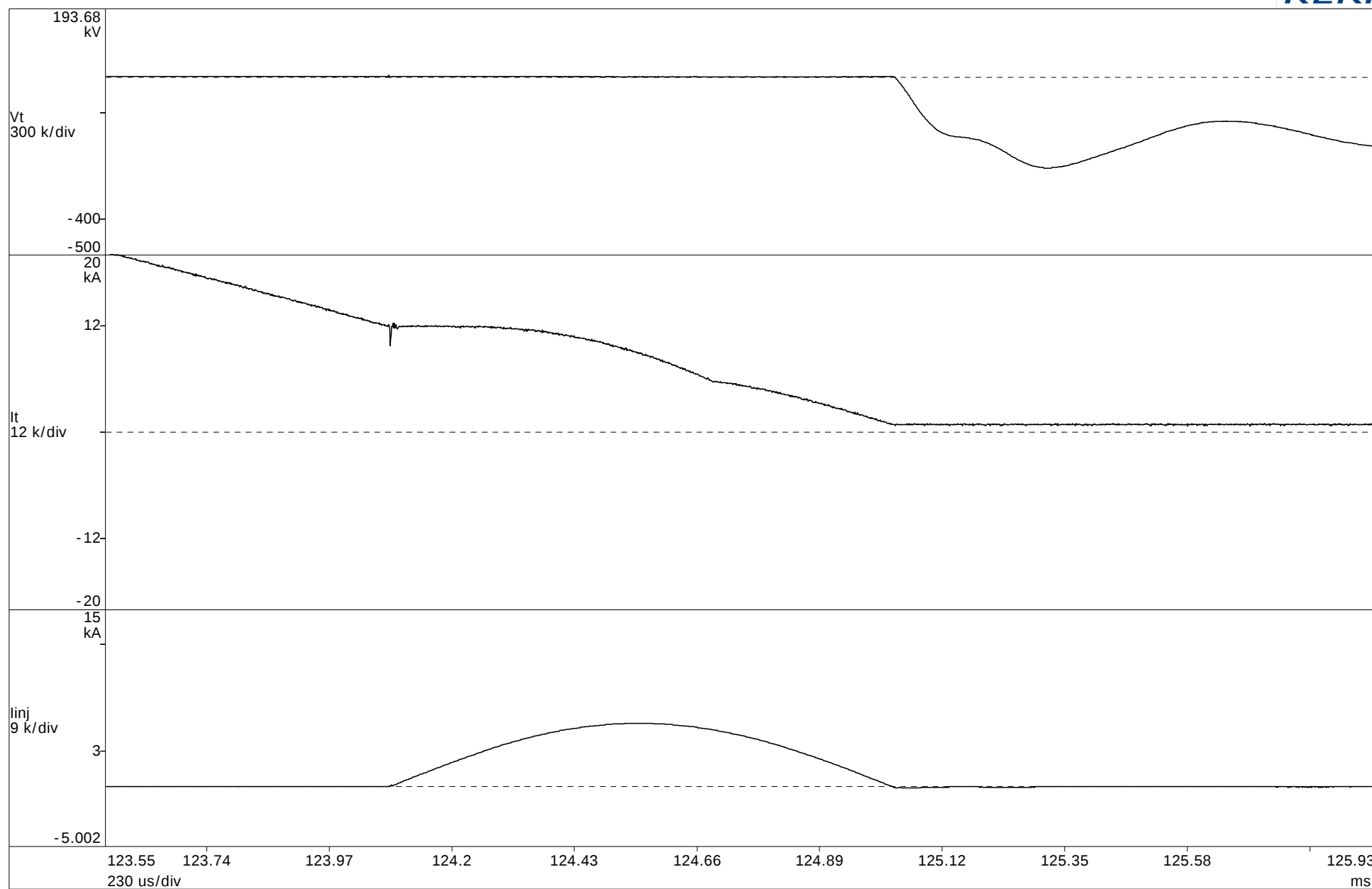
HPC 1104 - 042



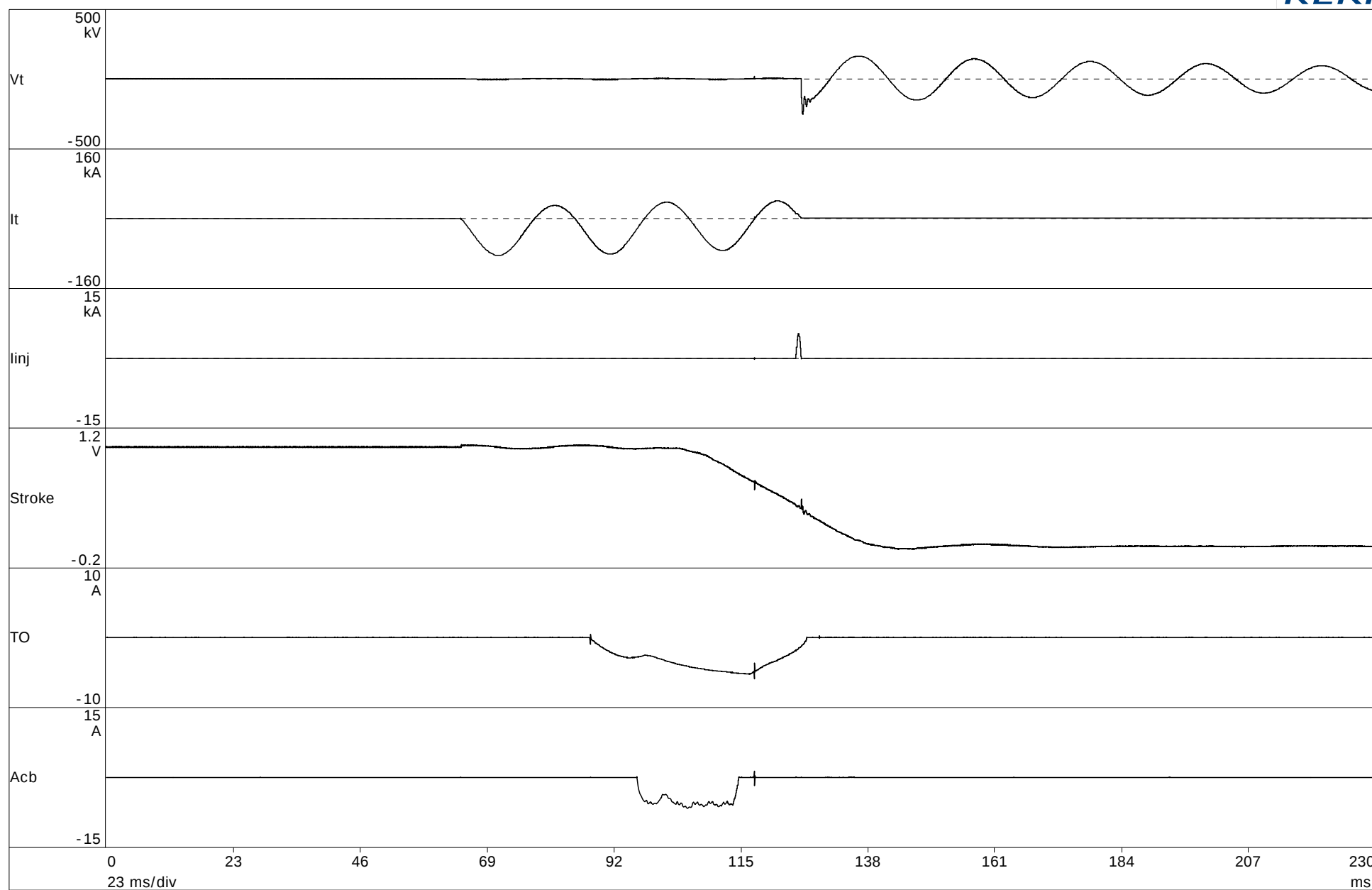
HPC 1104 - 045



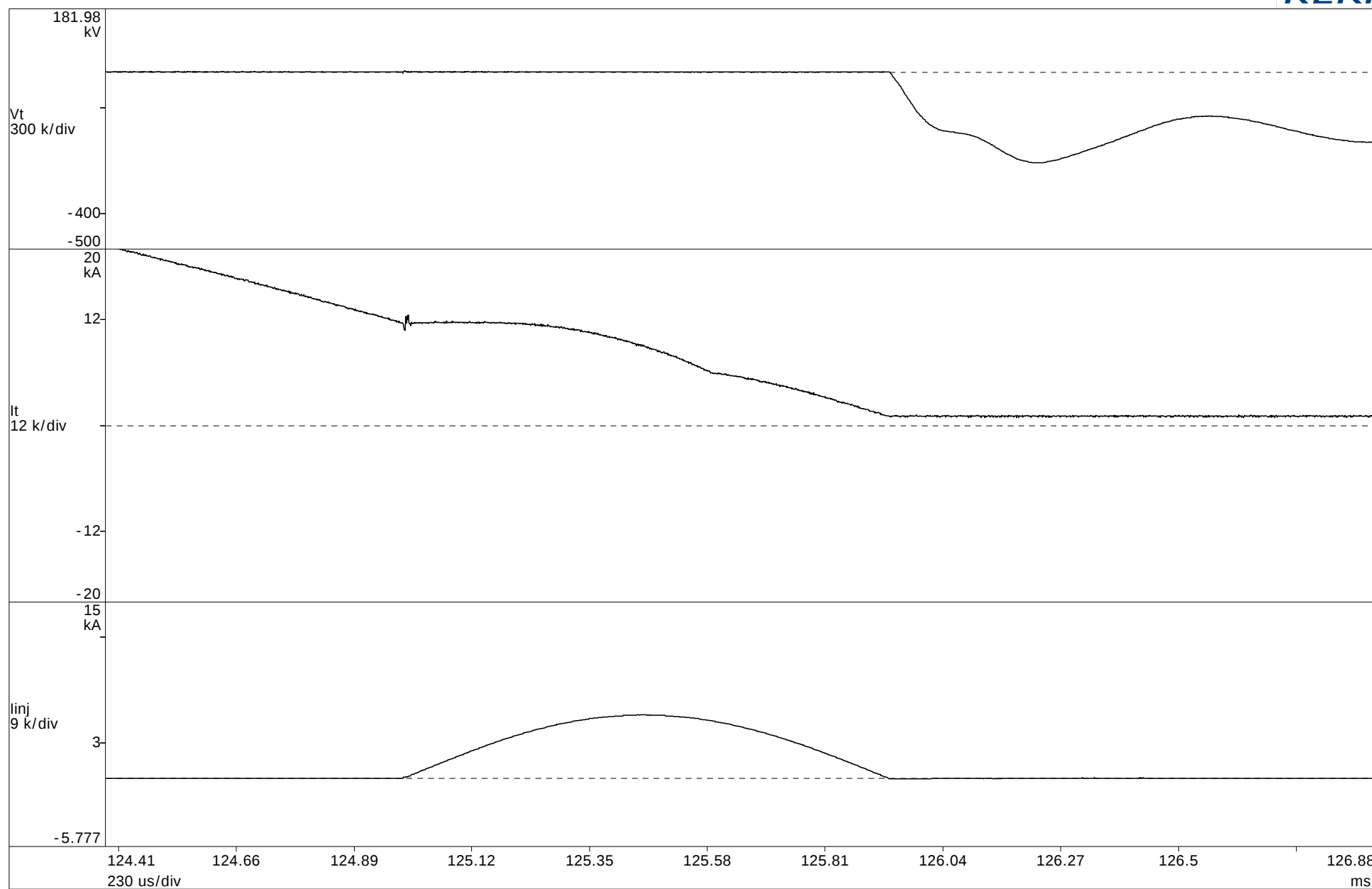
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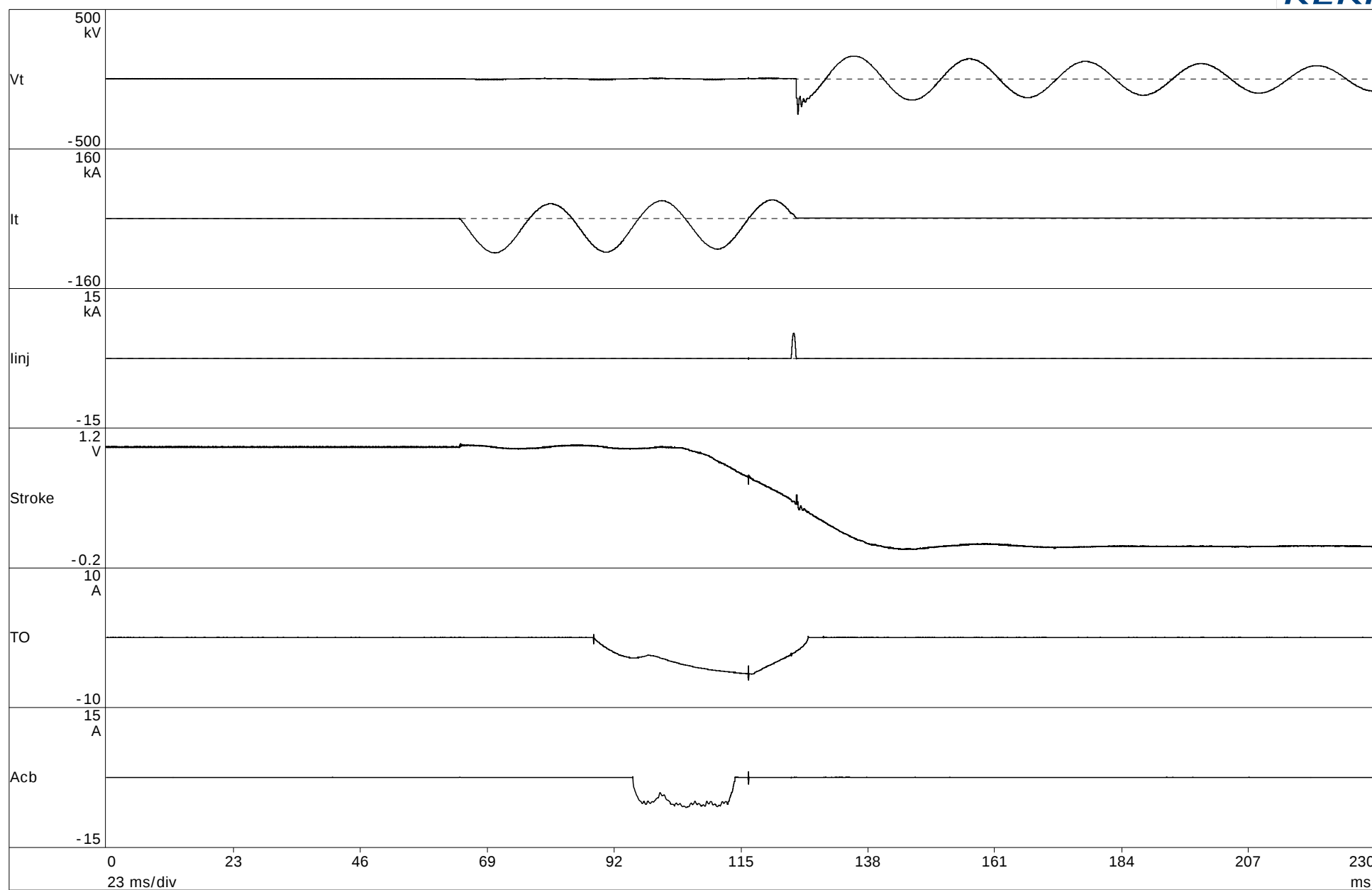
HPC 1104 - 046



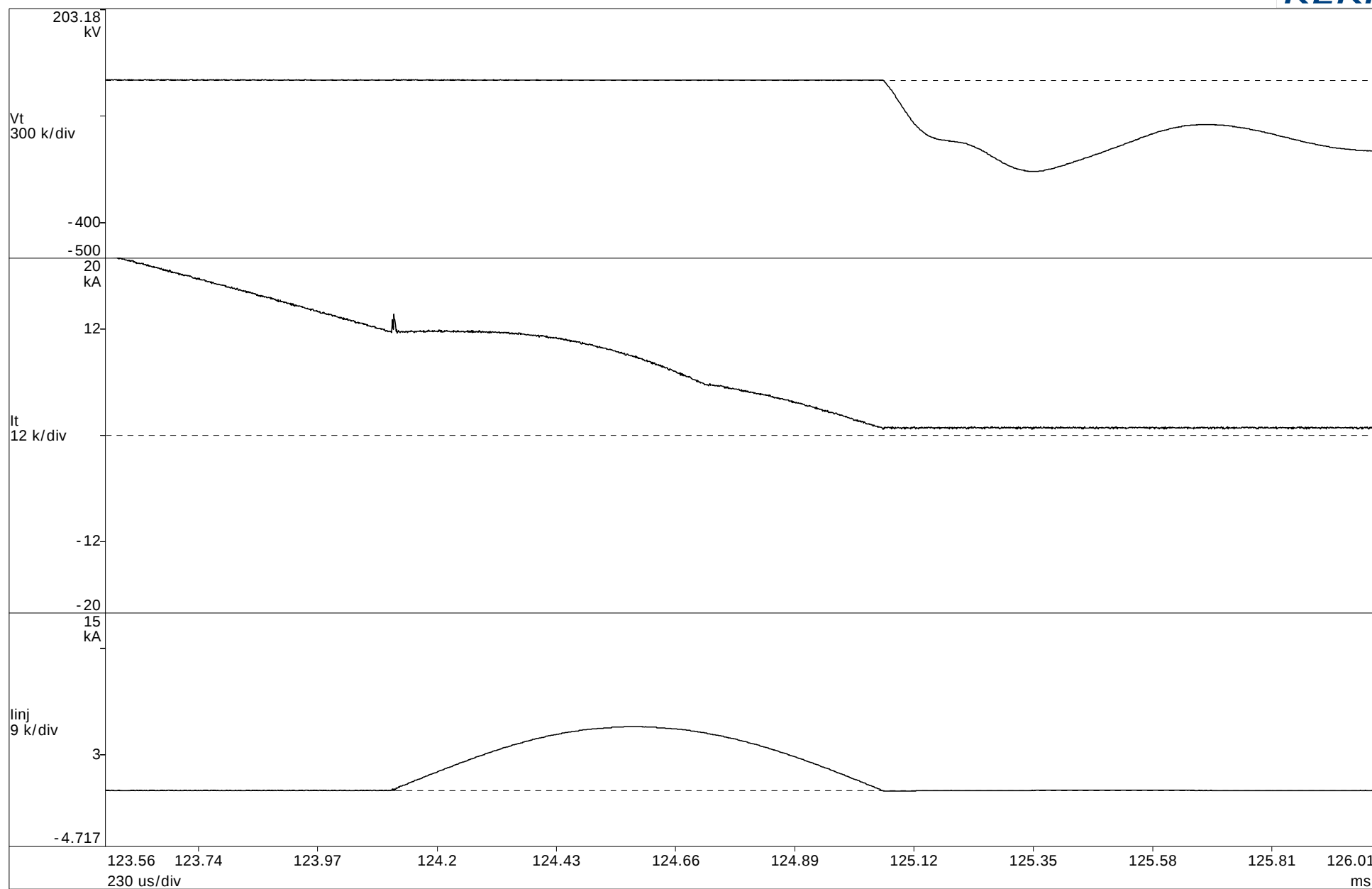
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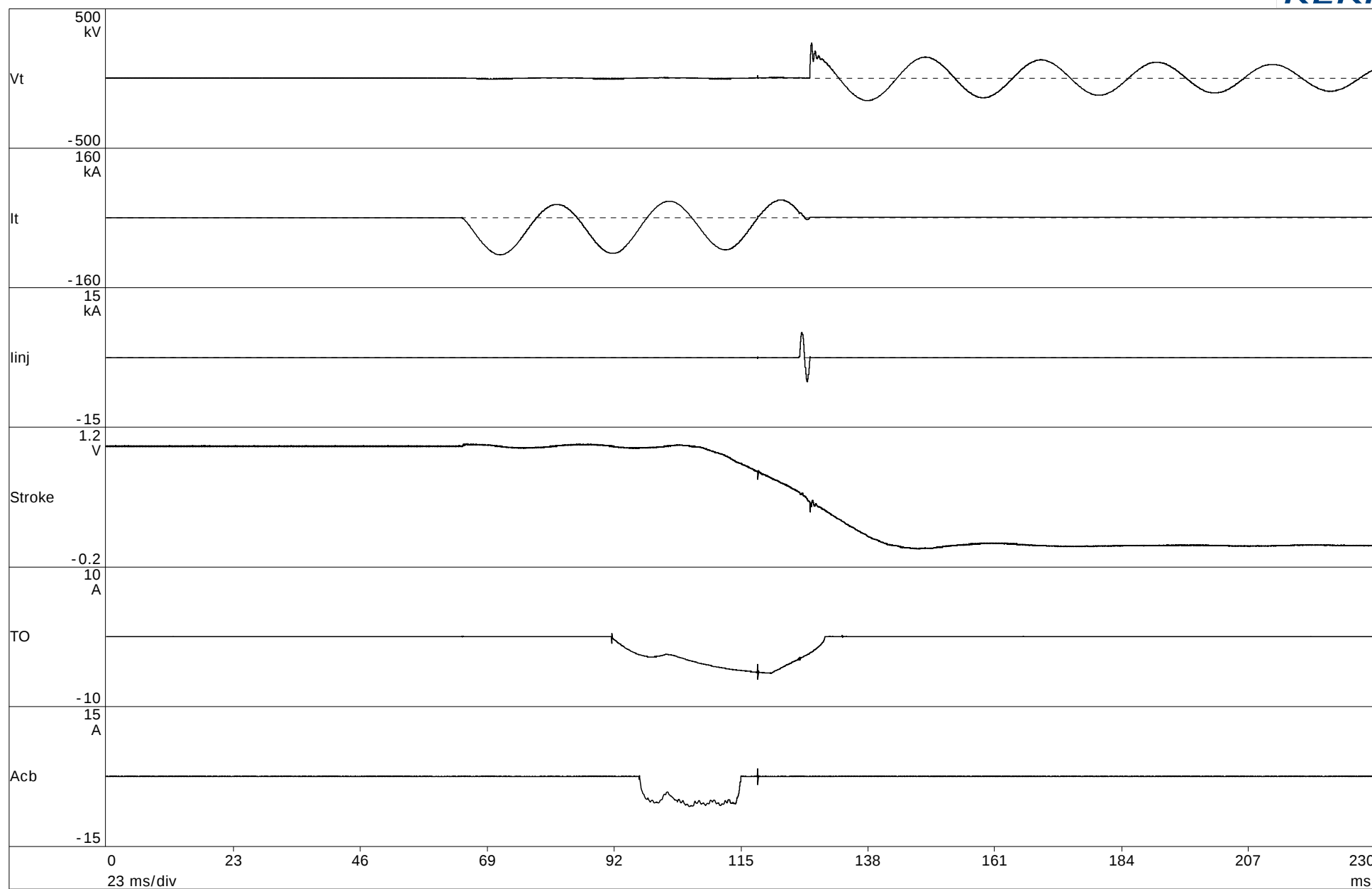
HPC 1104 - 047



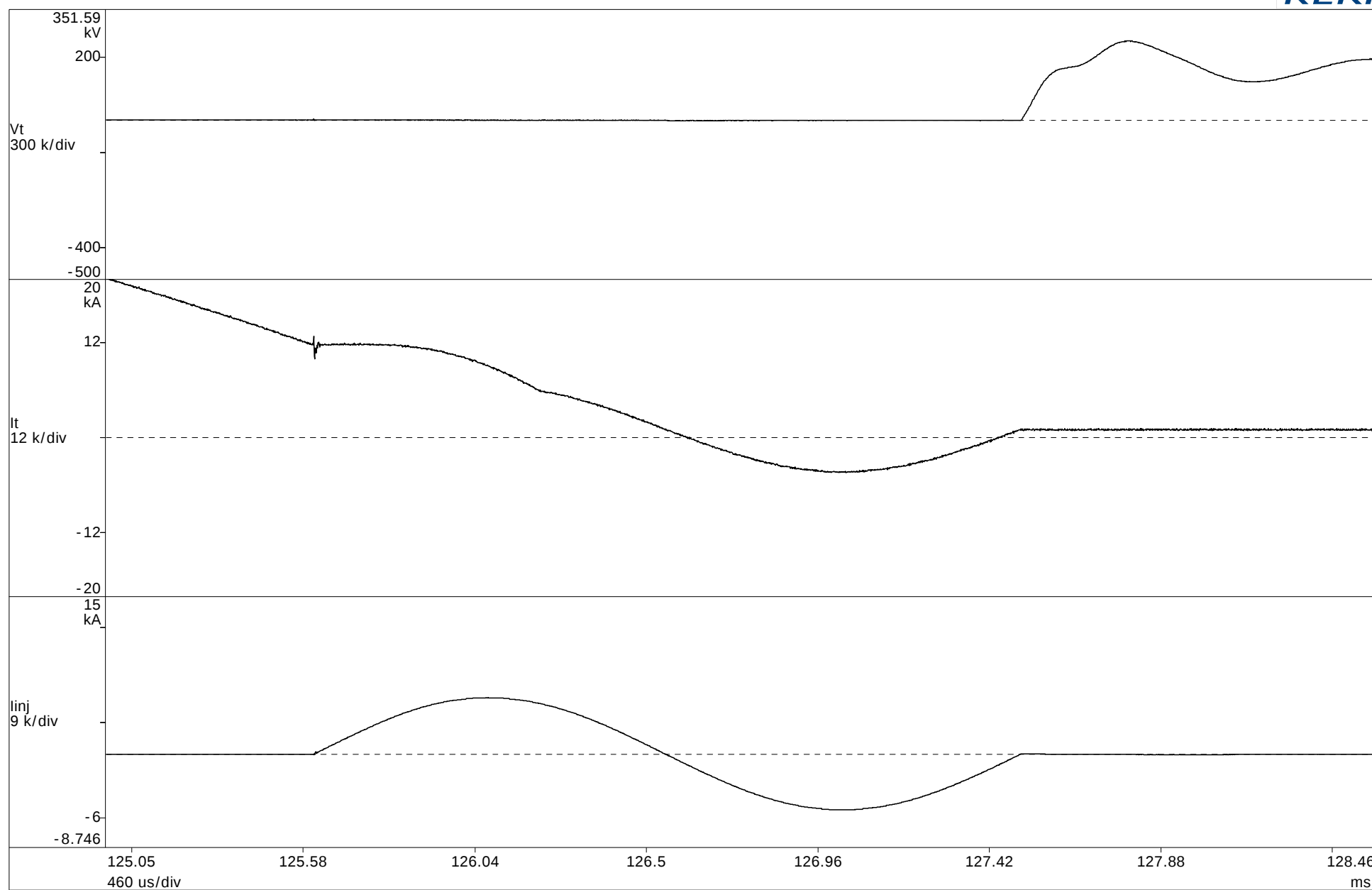
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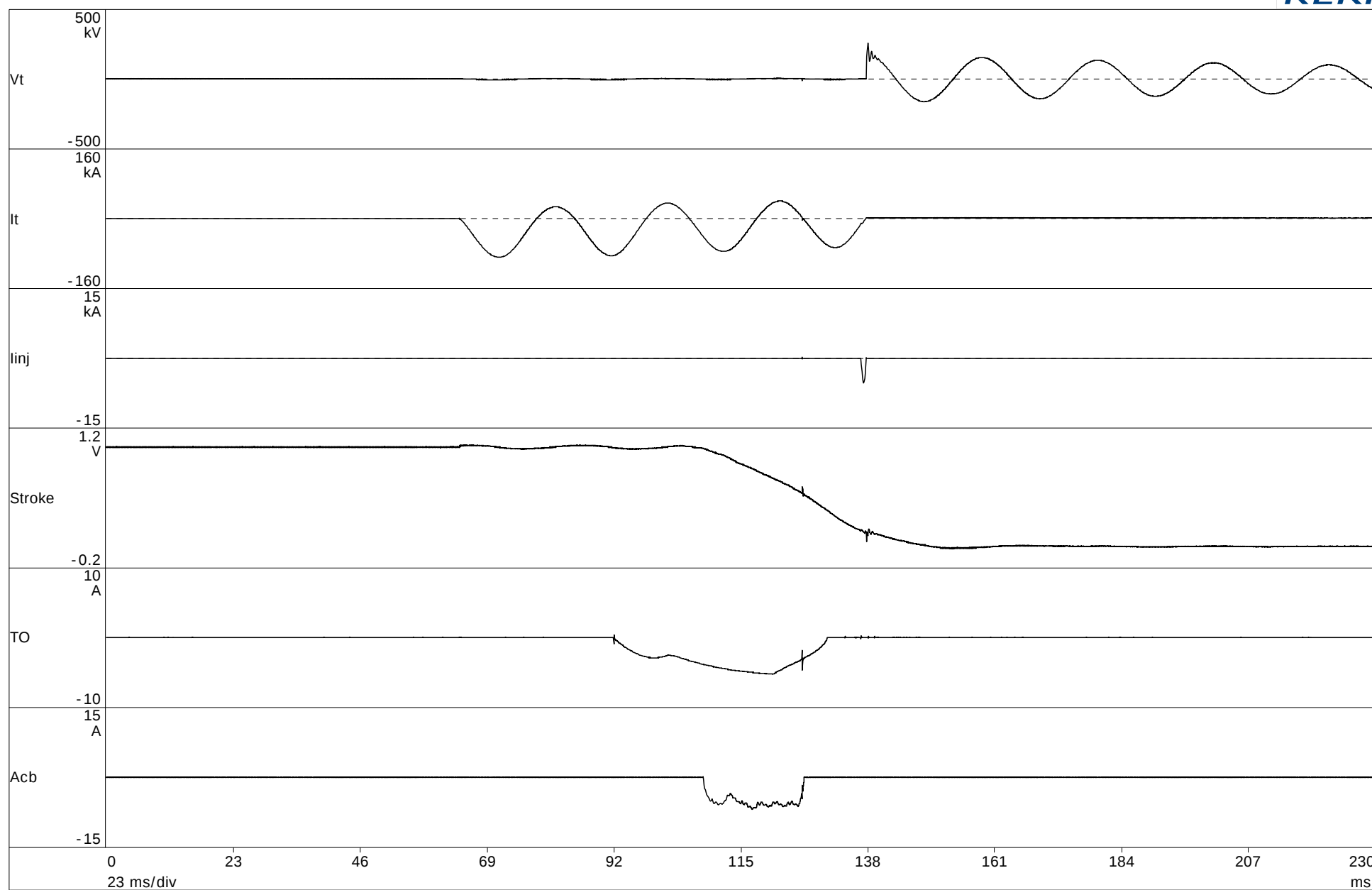
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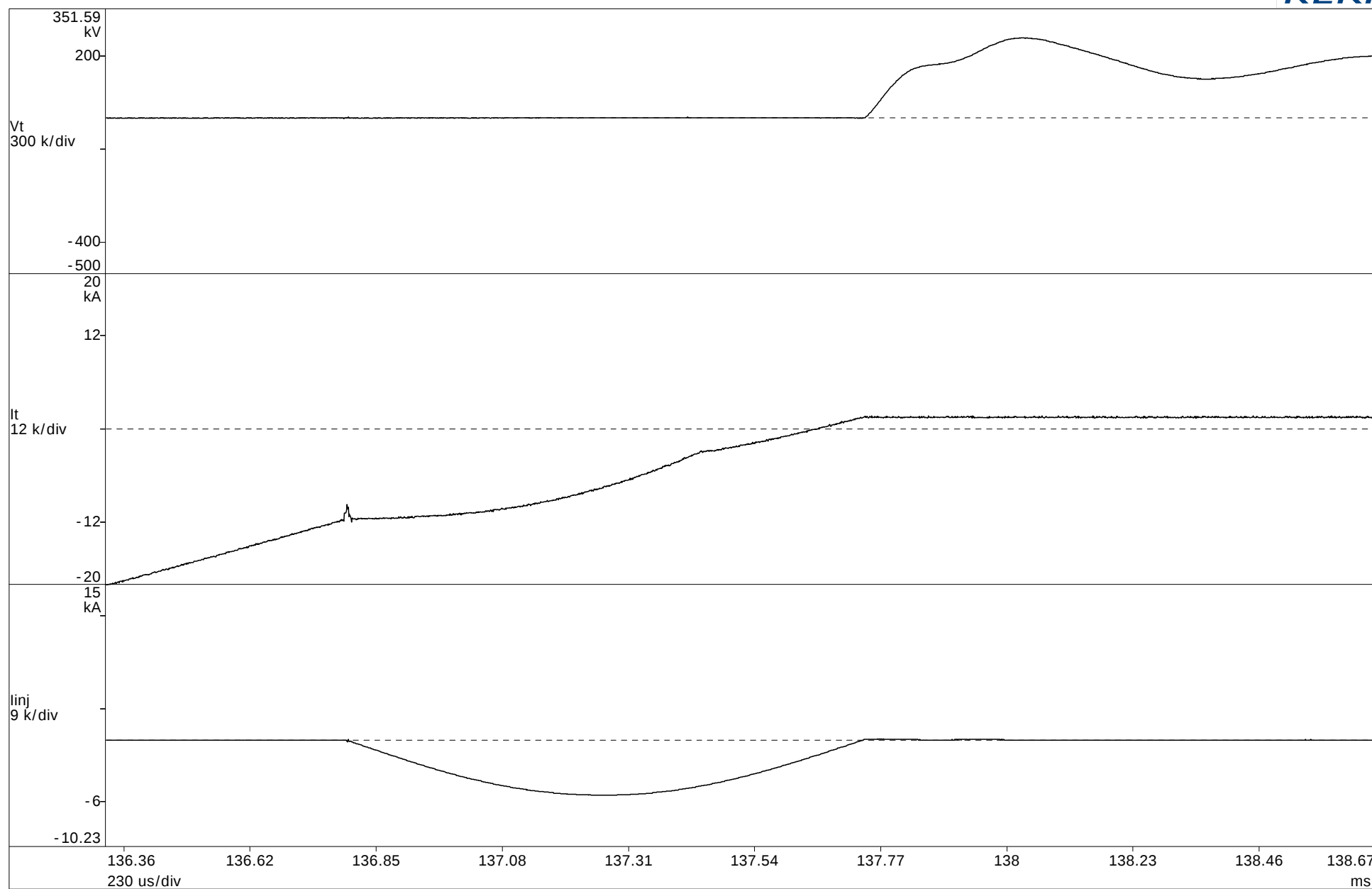
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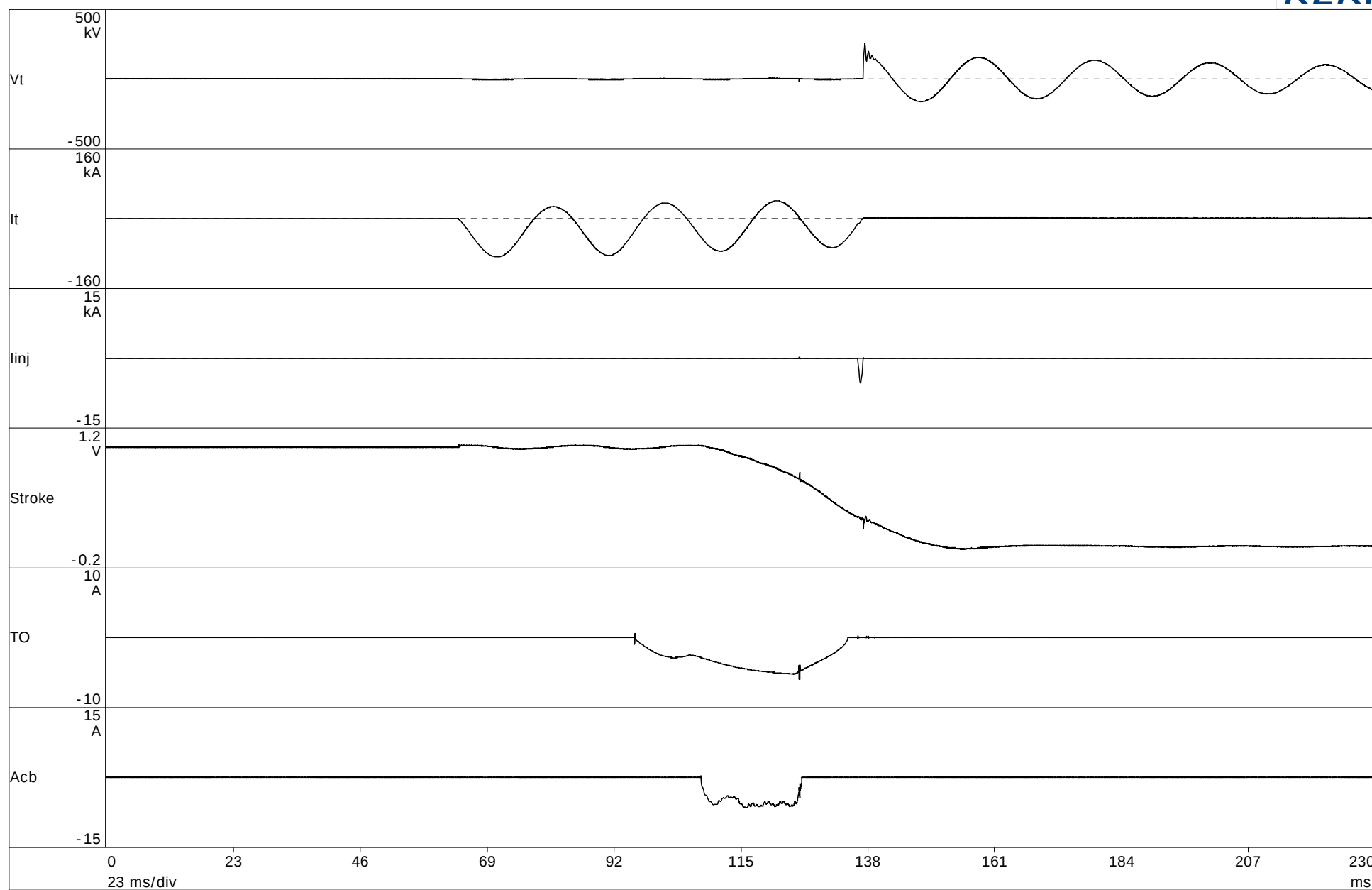
HPC 1104 - 049



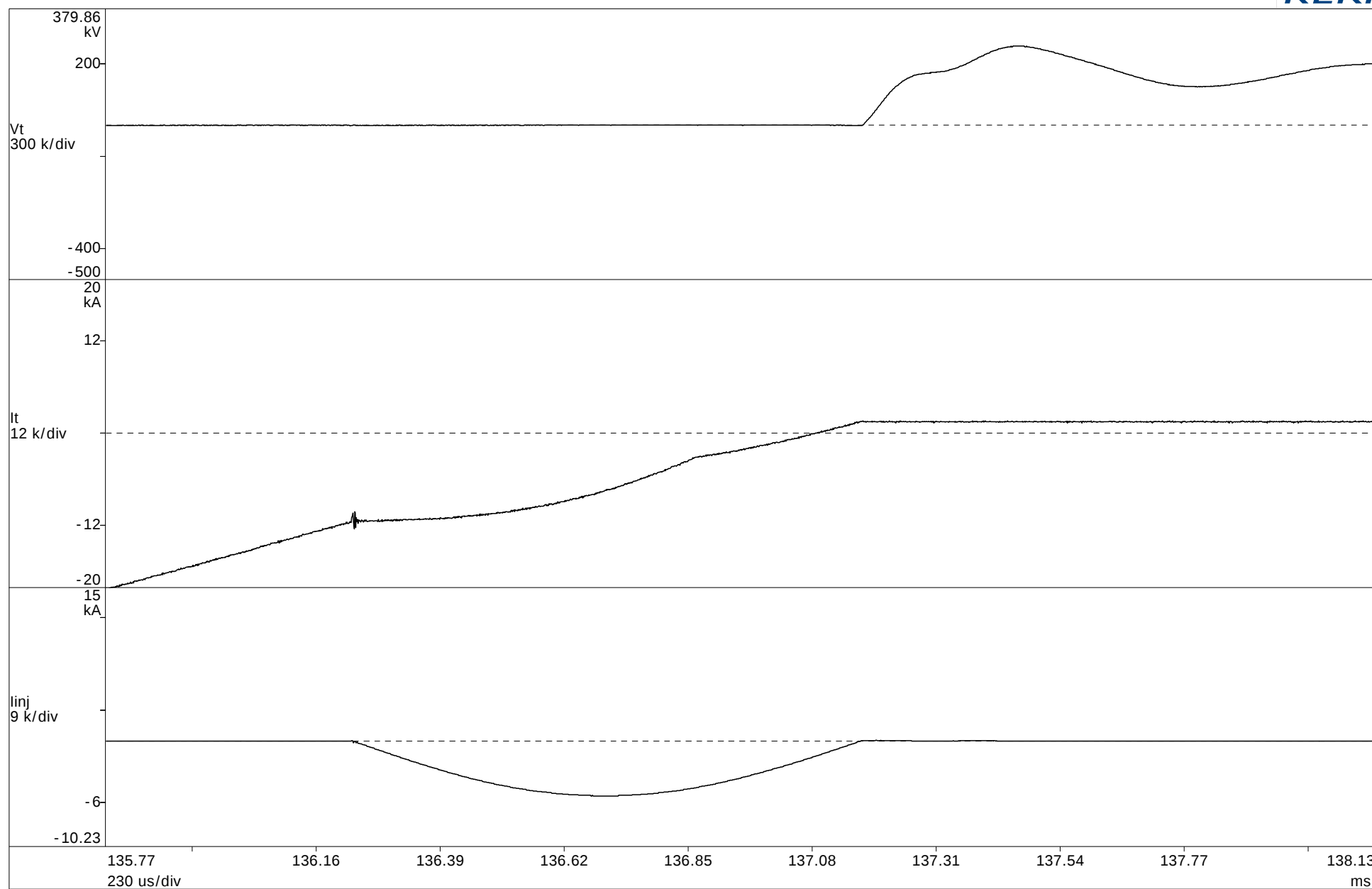
HPC 1104 - 049



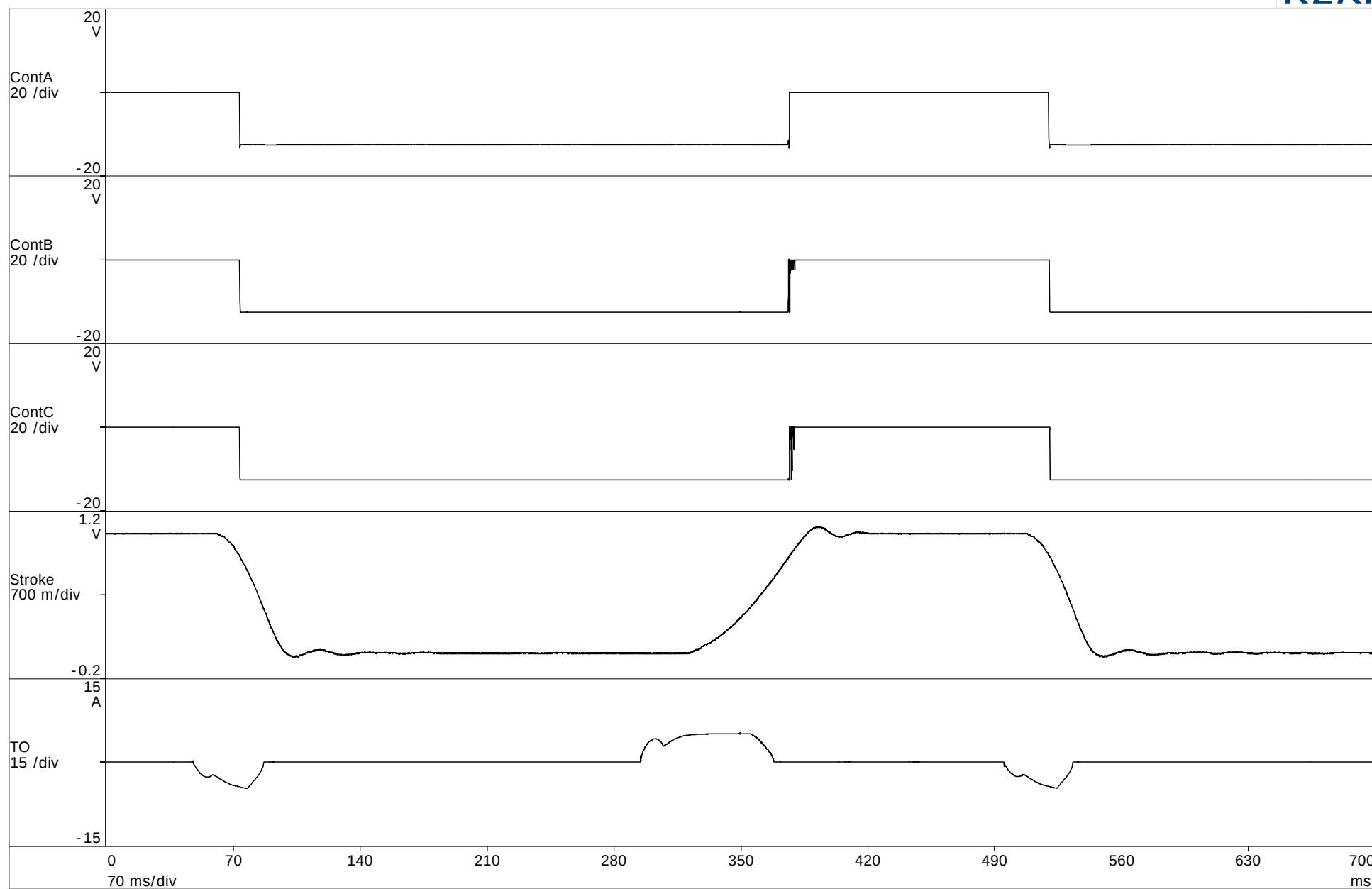
HPC 1104 - 050



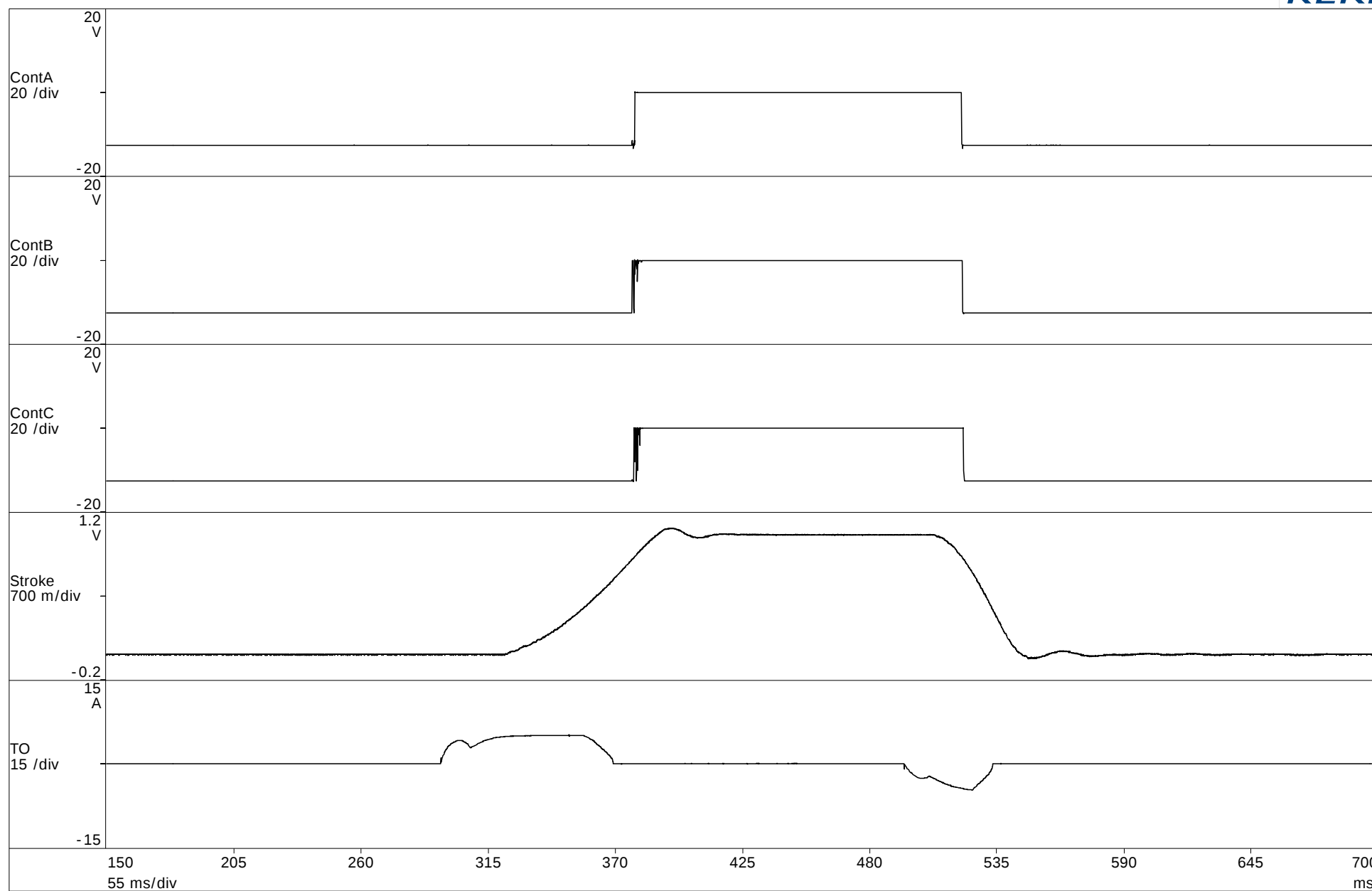
HPC 1104 - 050



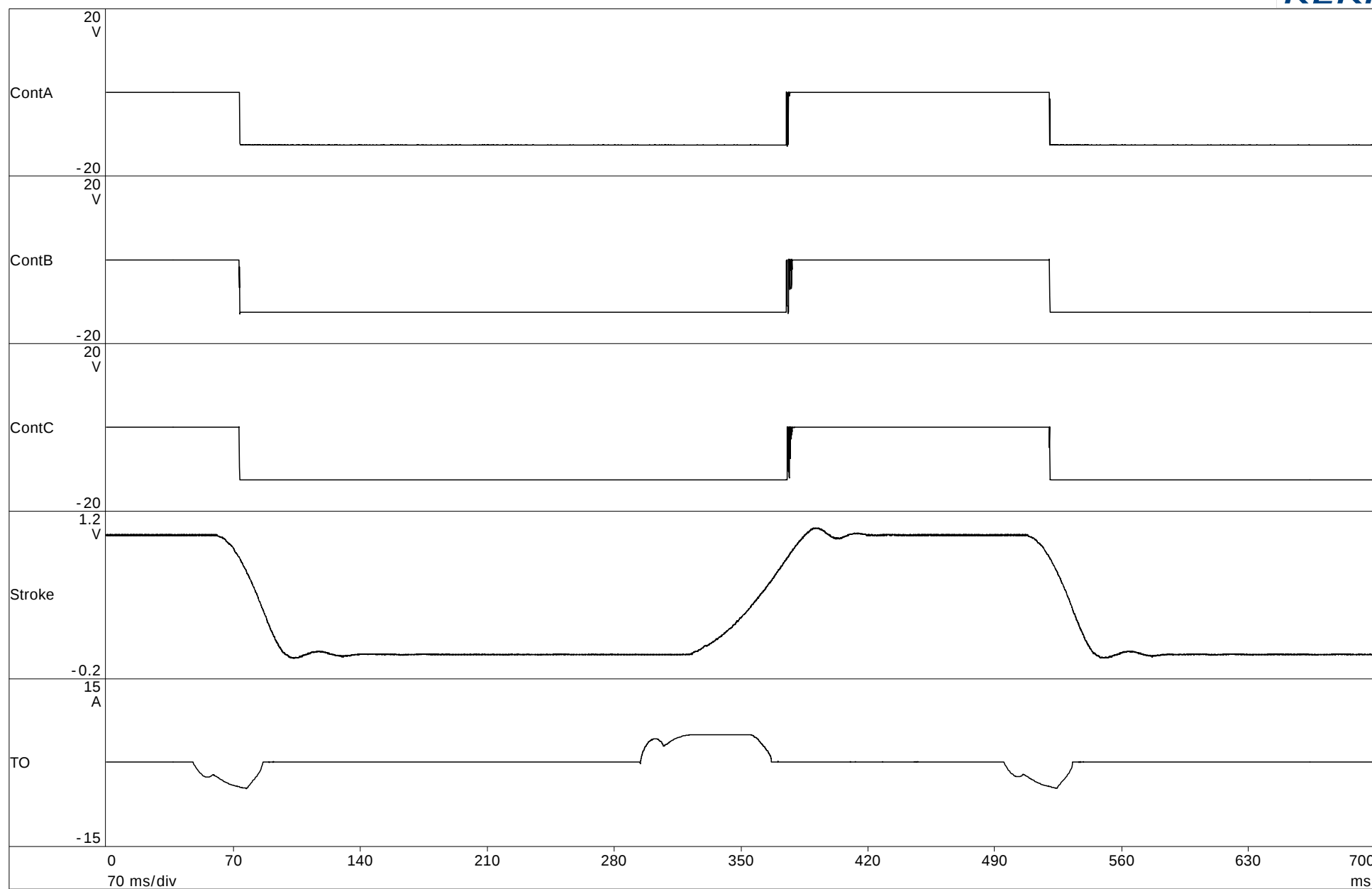
HPC 1104 - 051



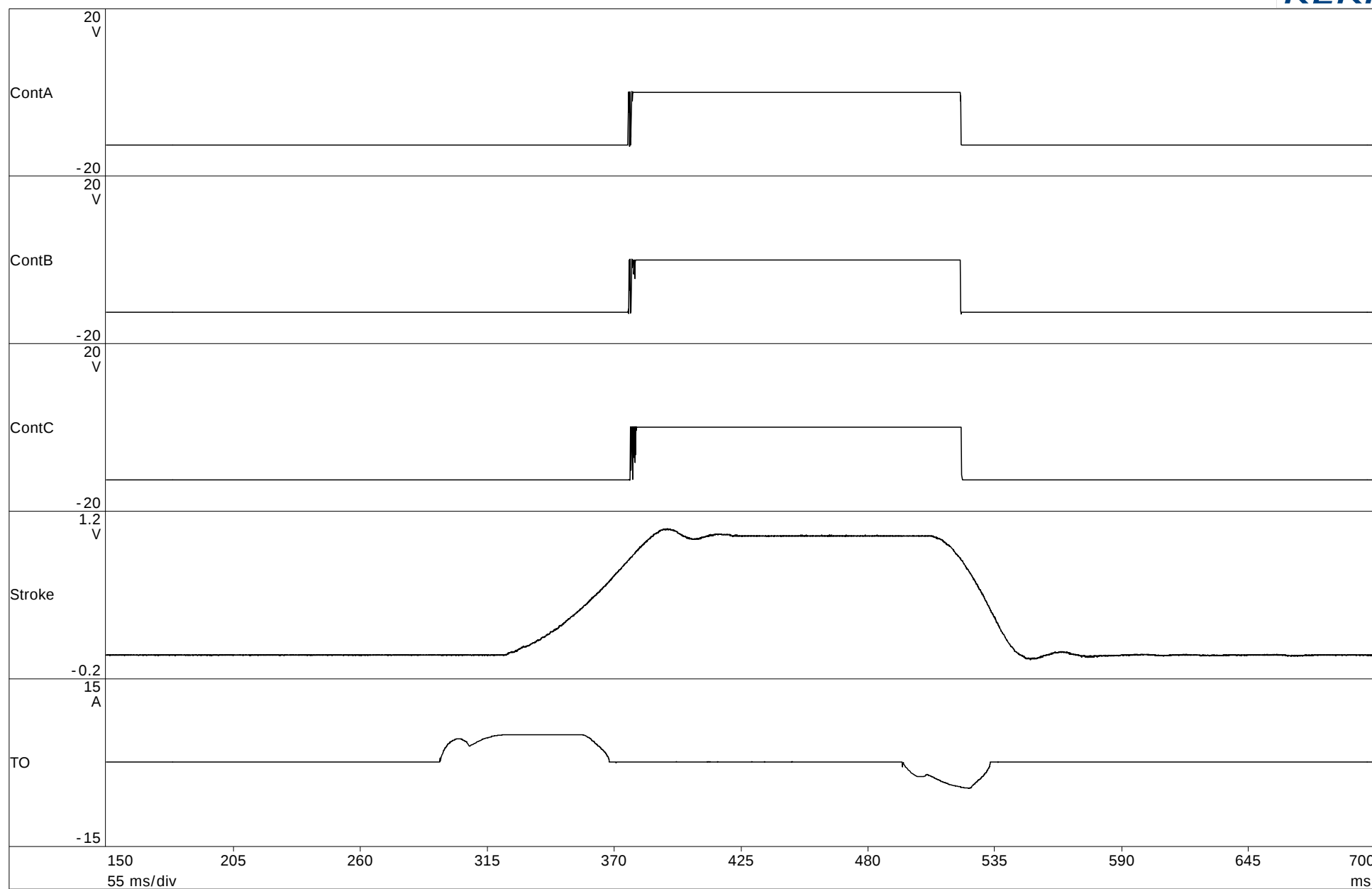
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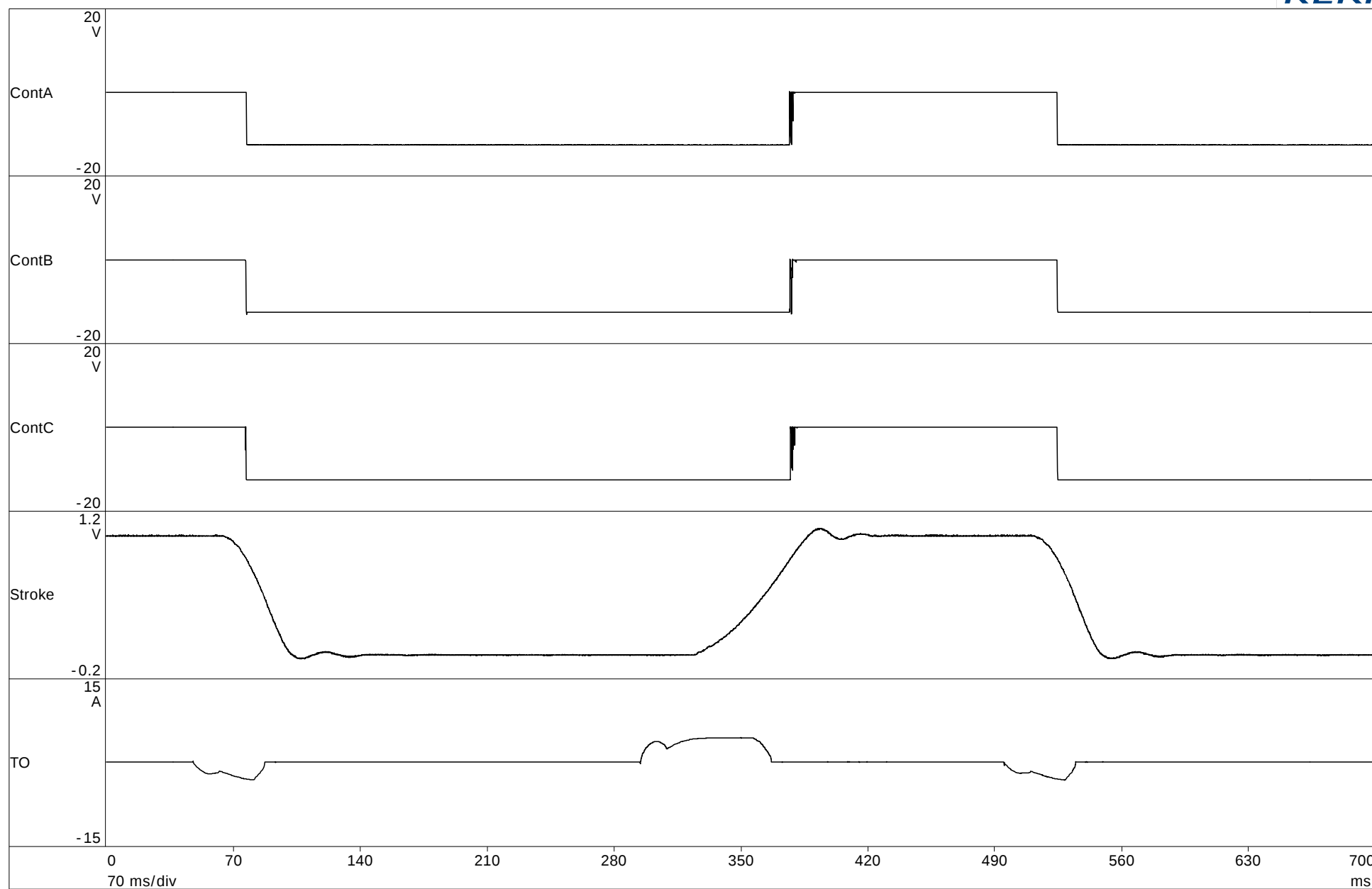
HPC 1104 - 053



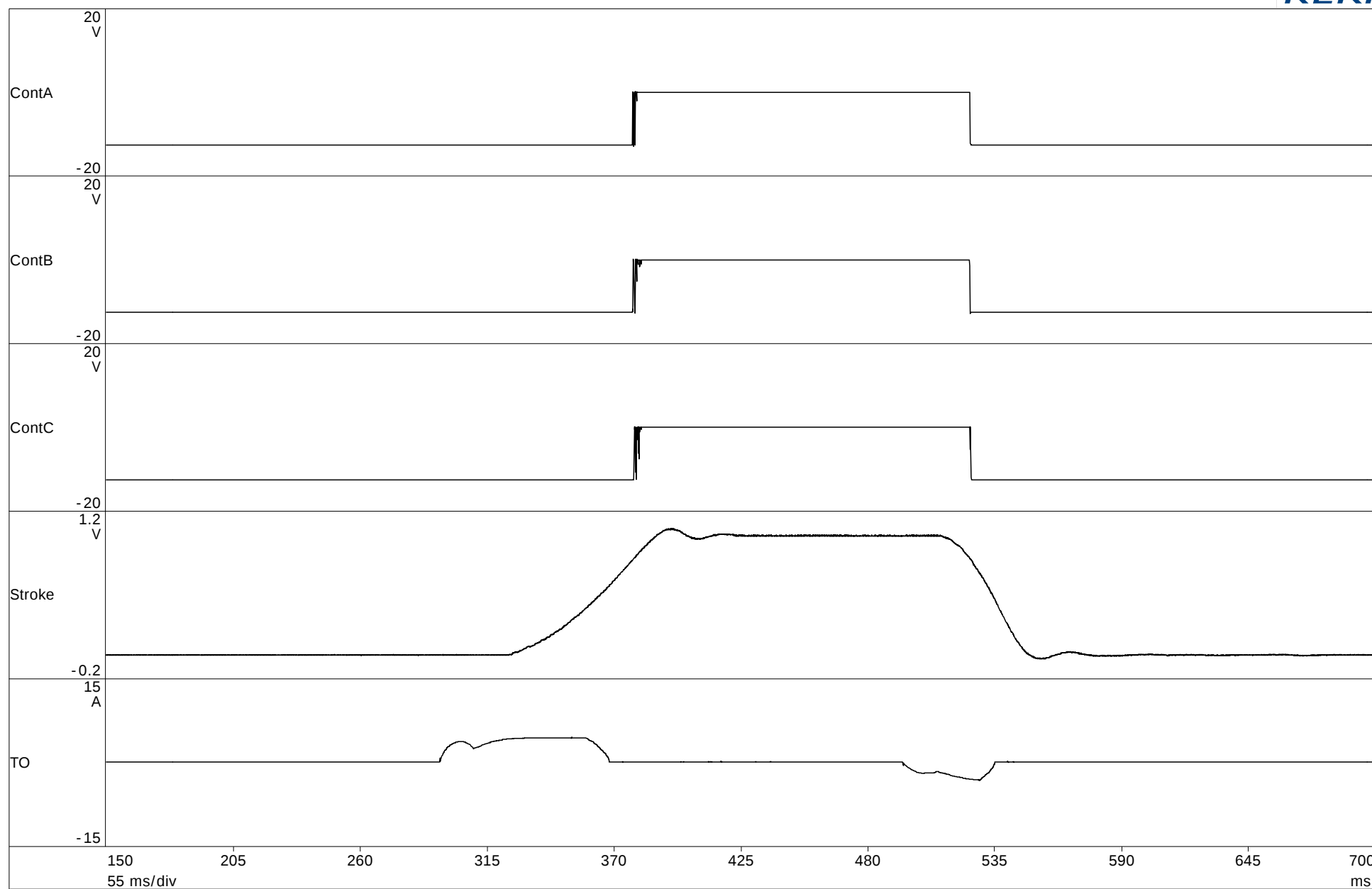
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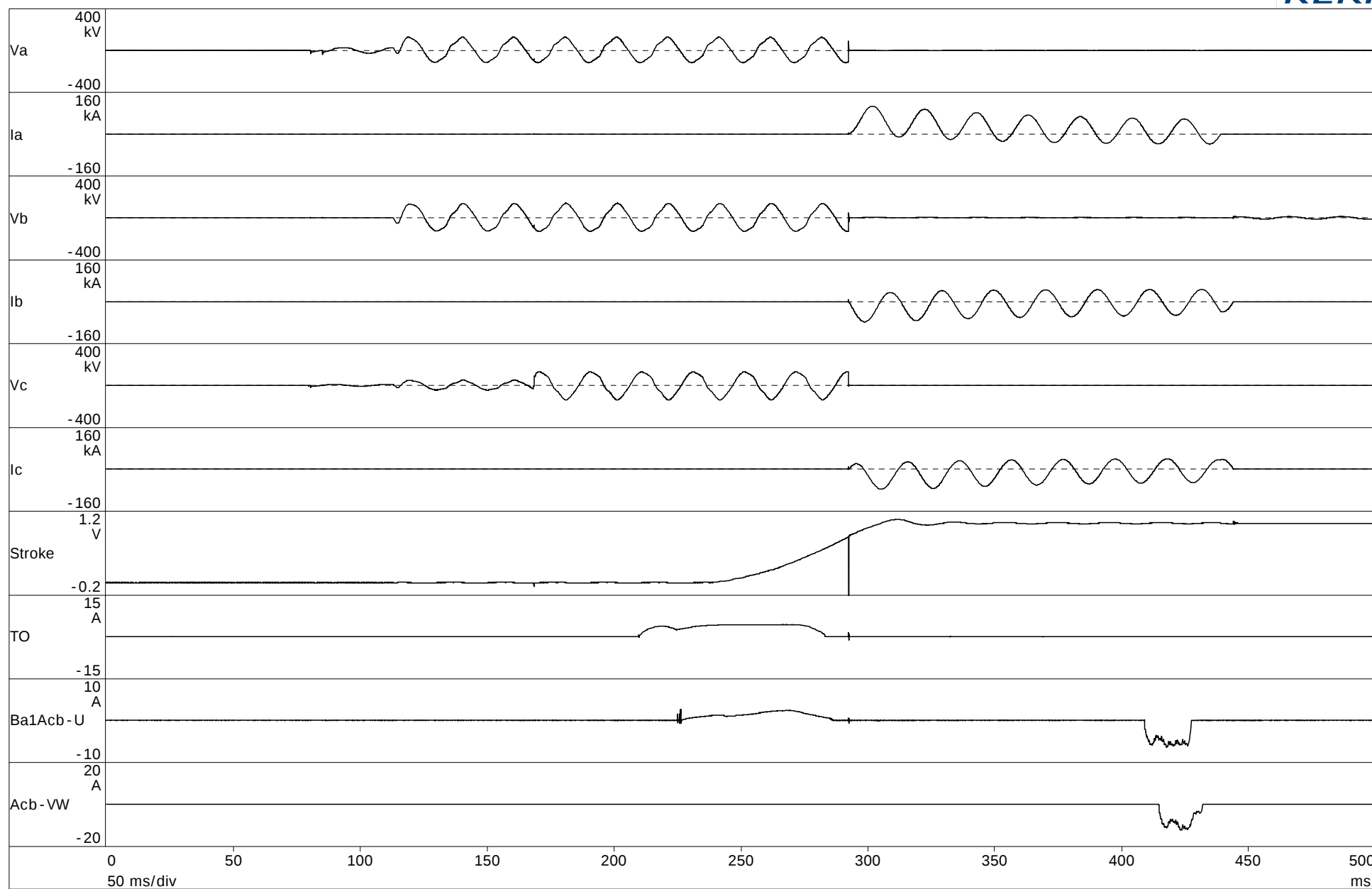
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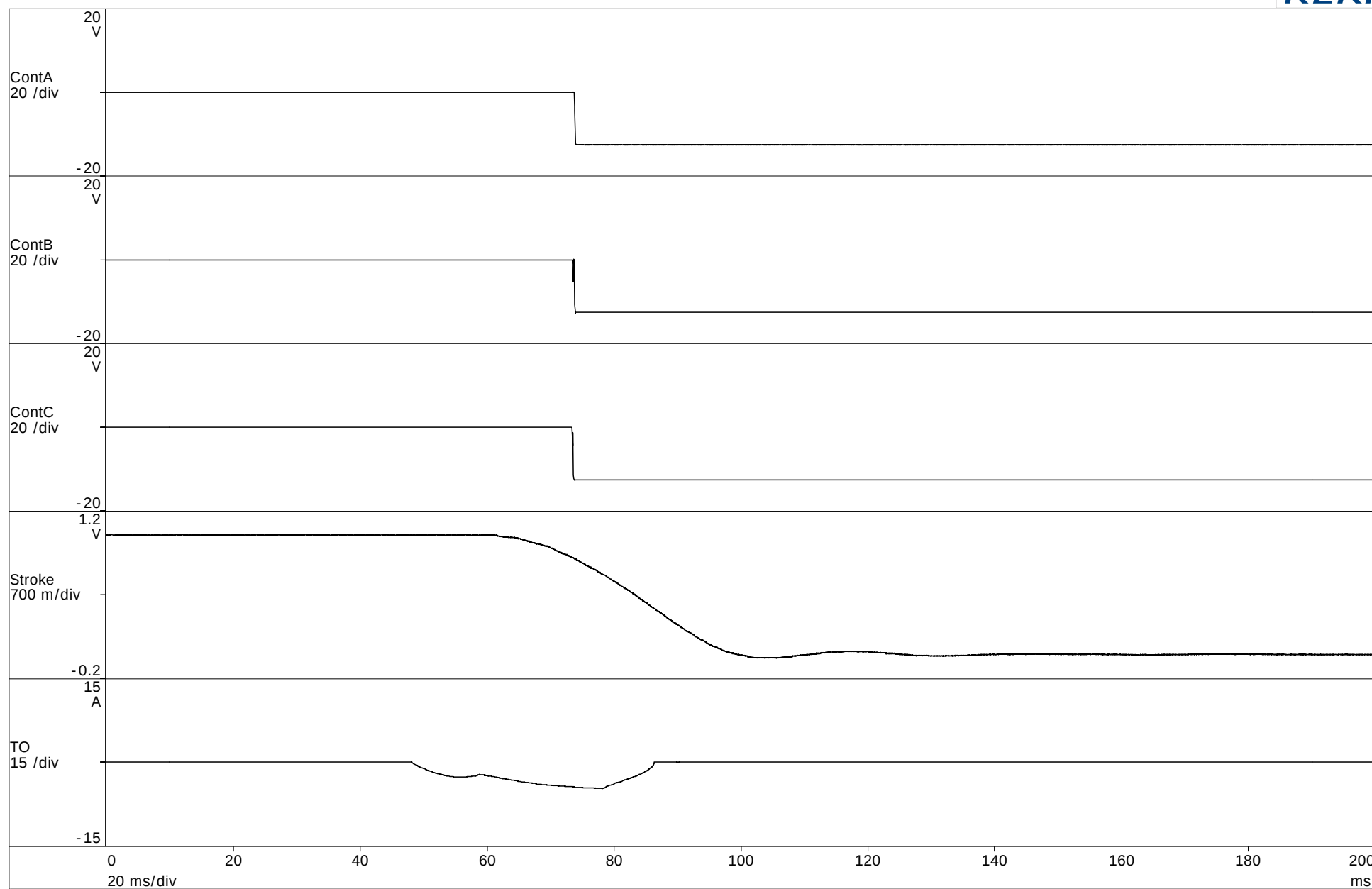
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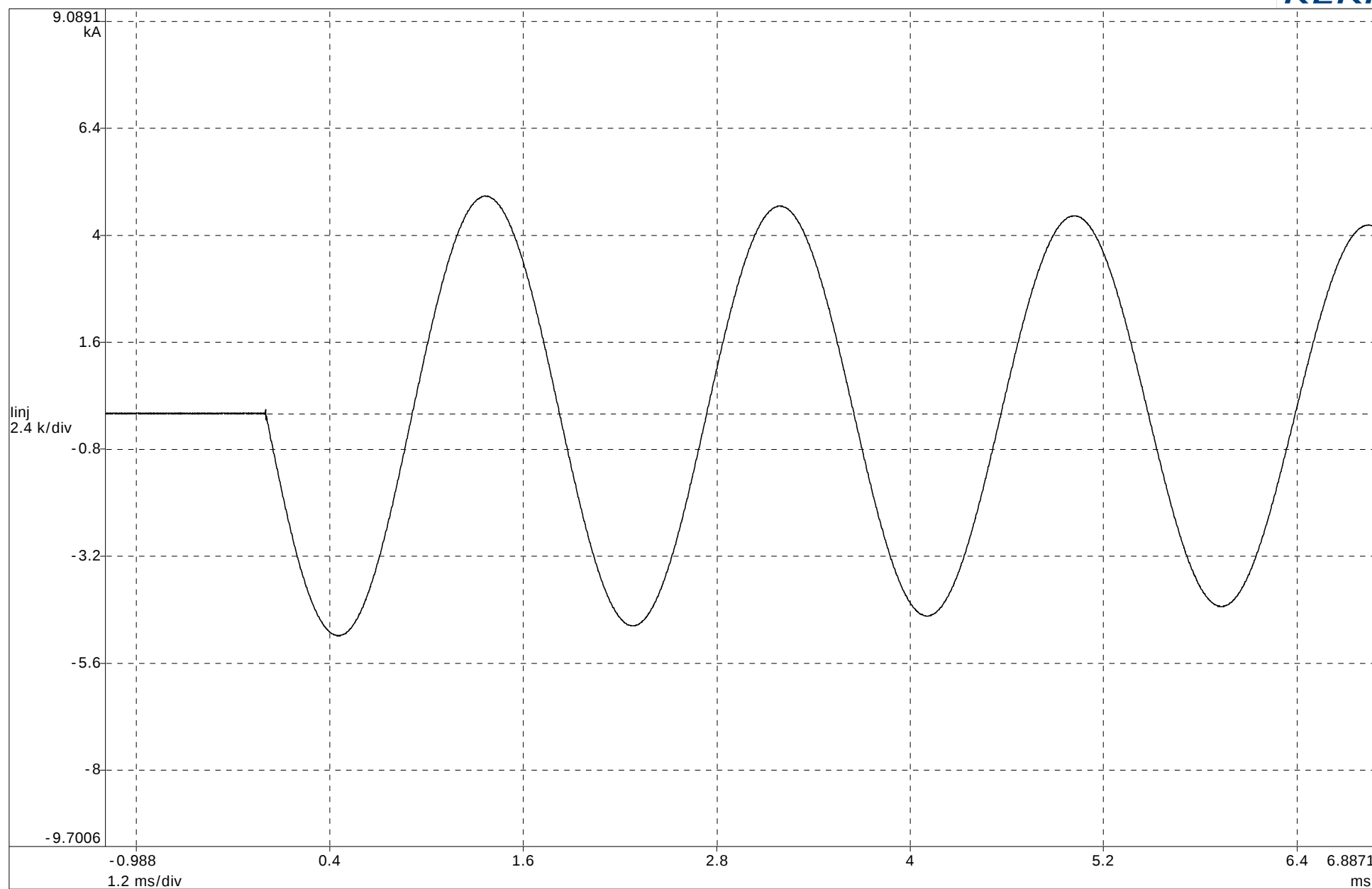
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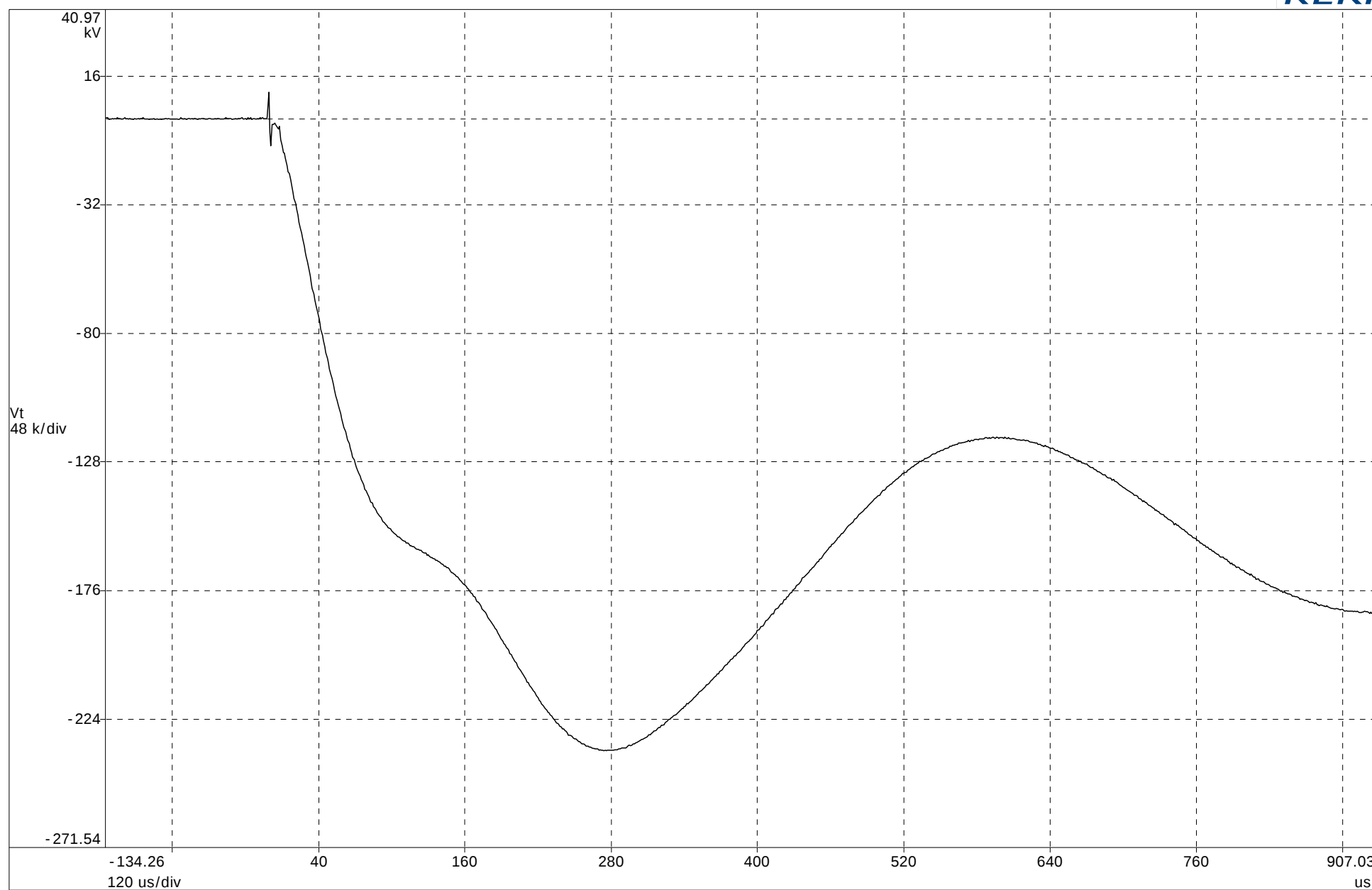
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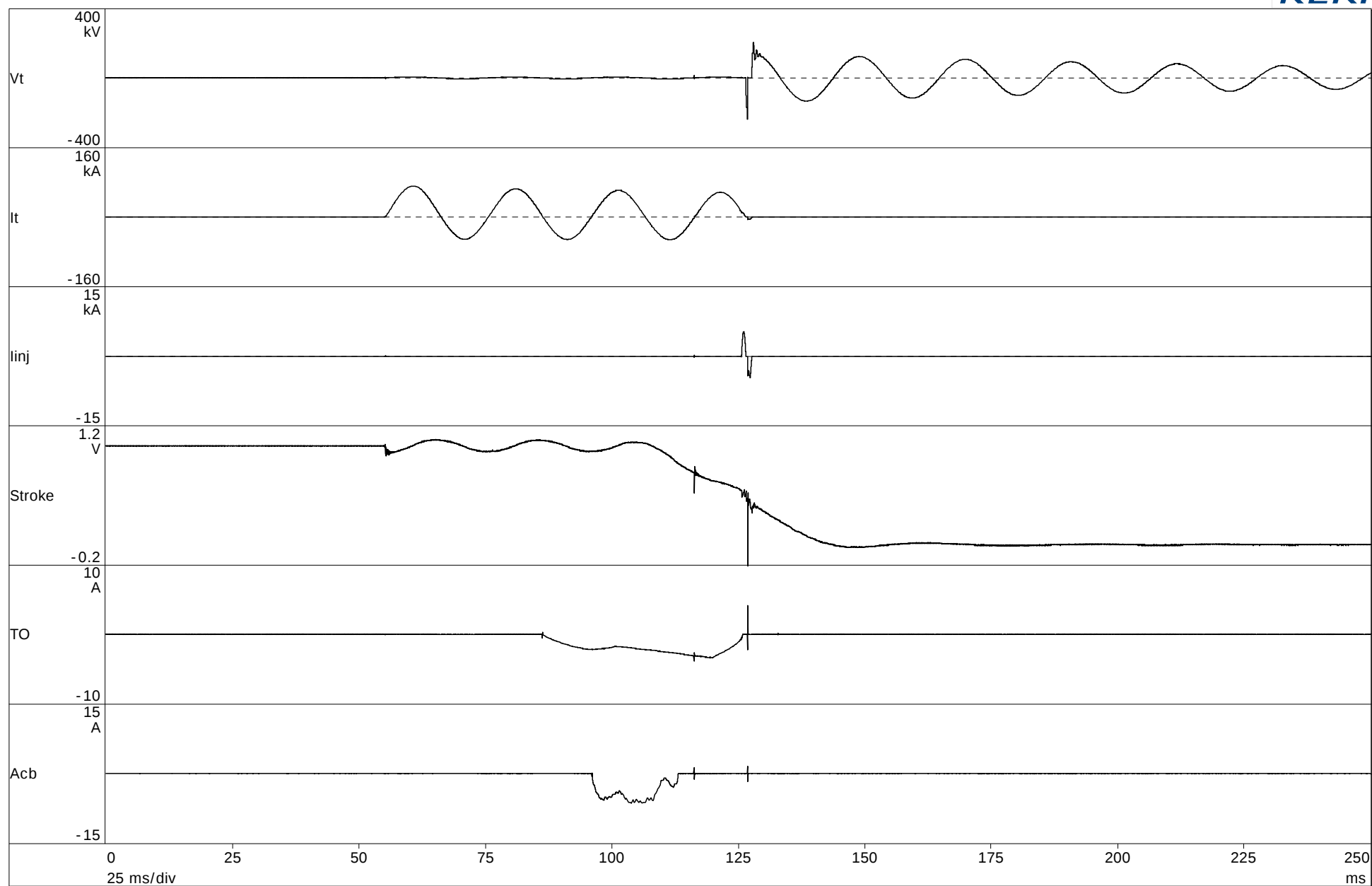
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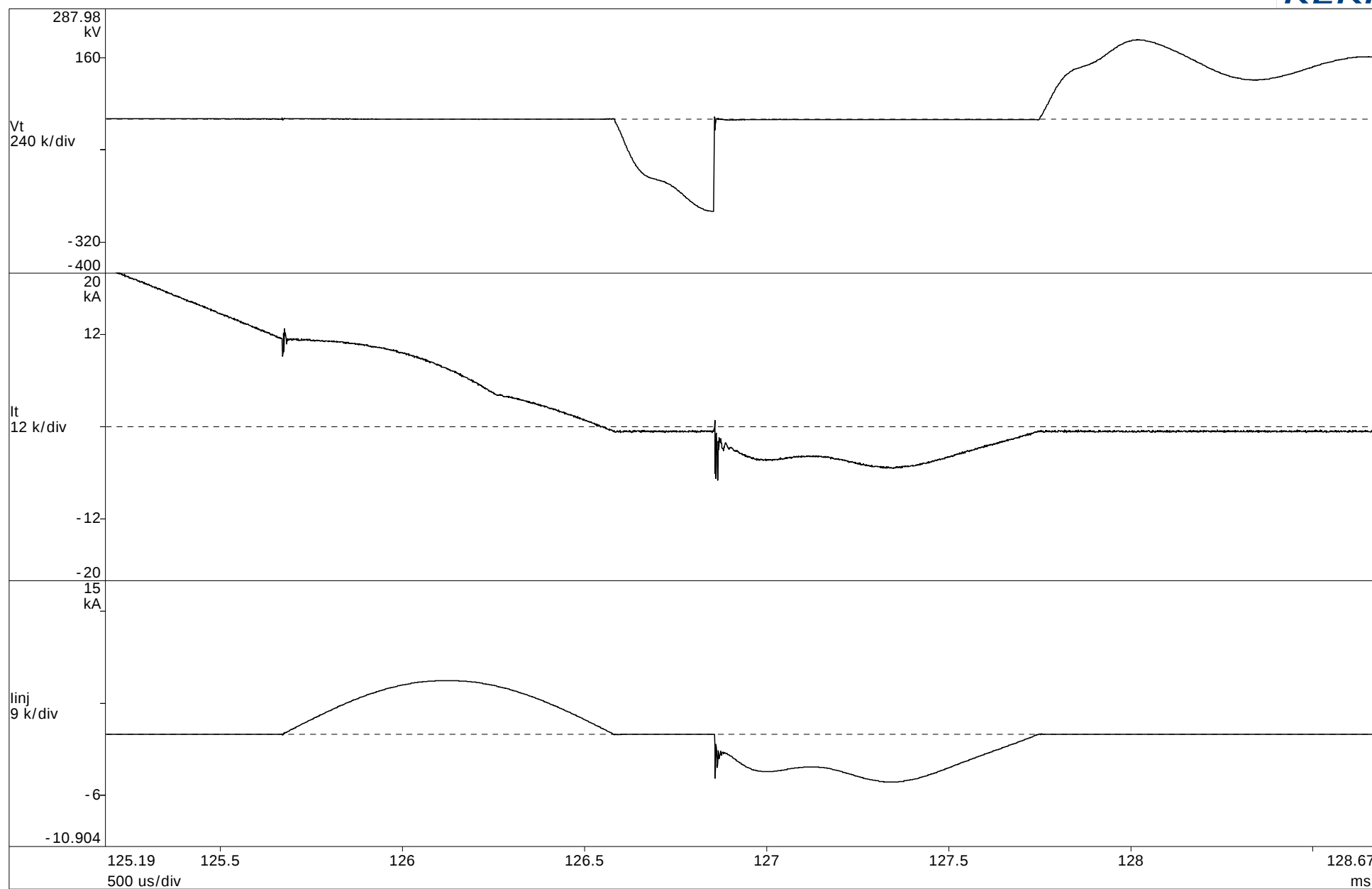
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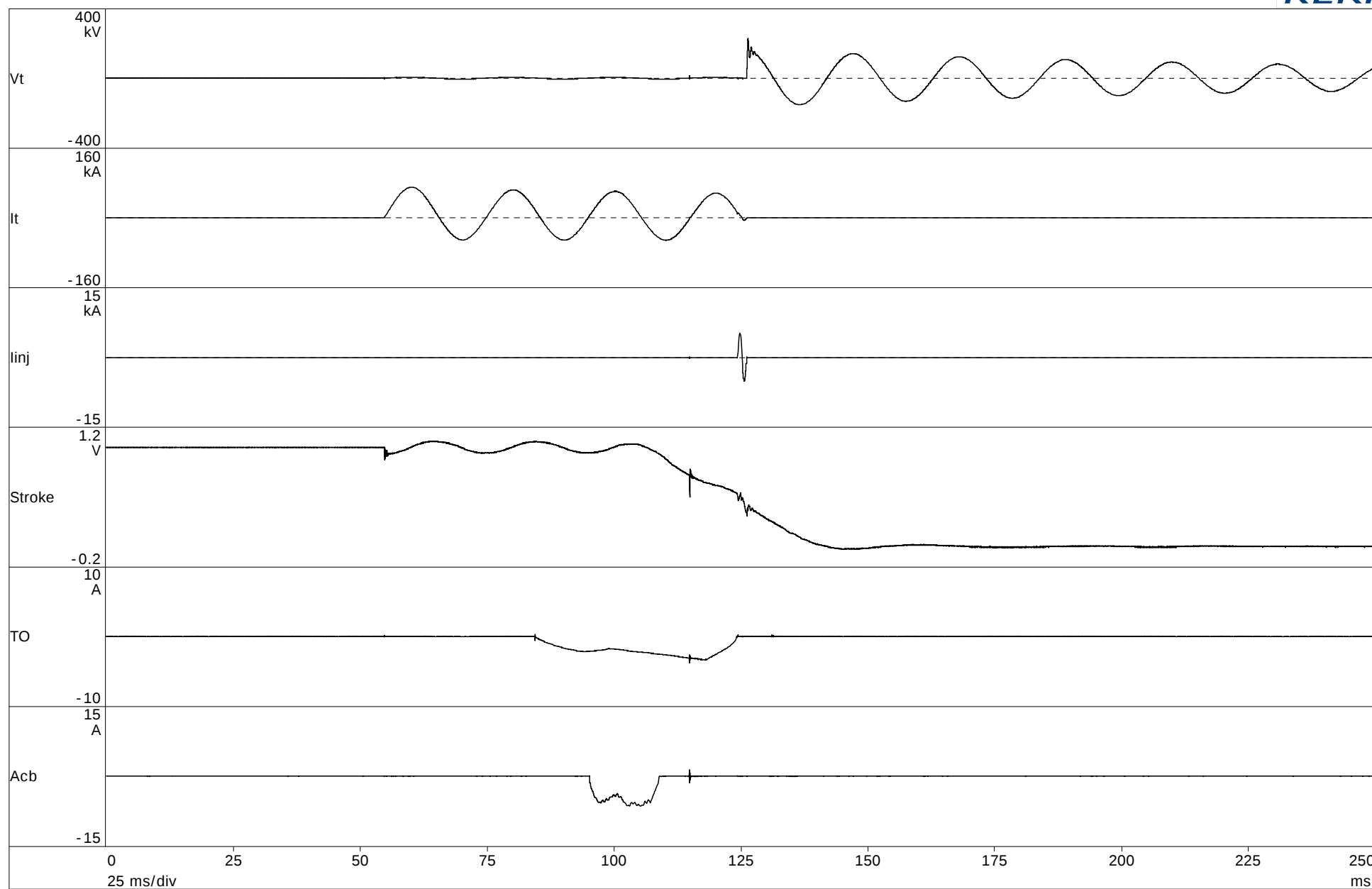
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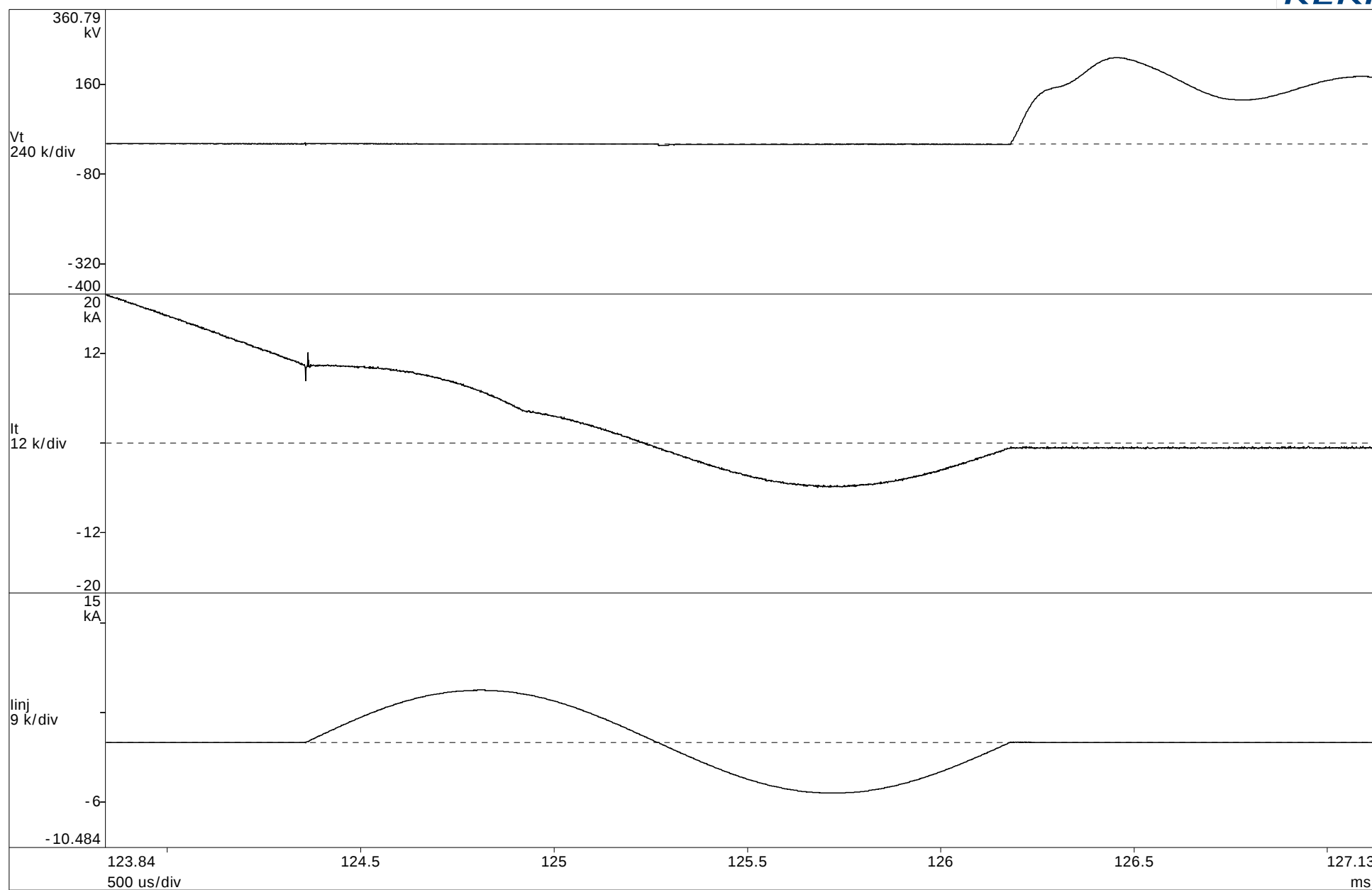
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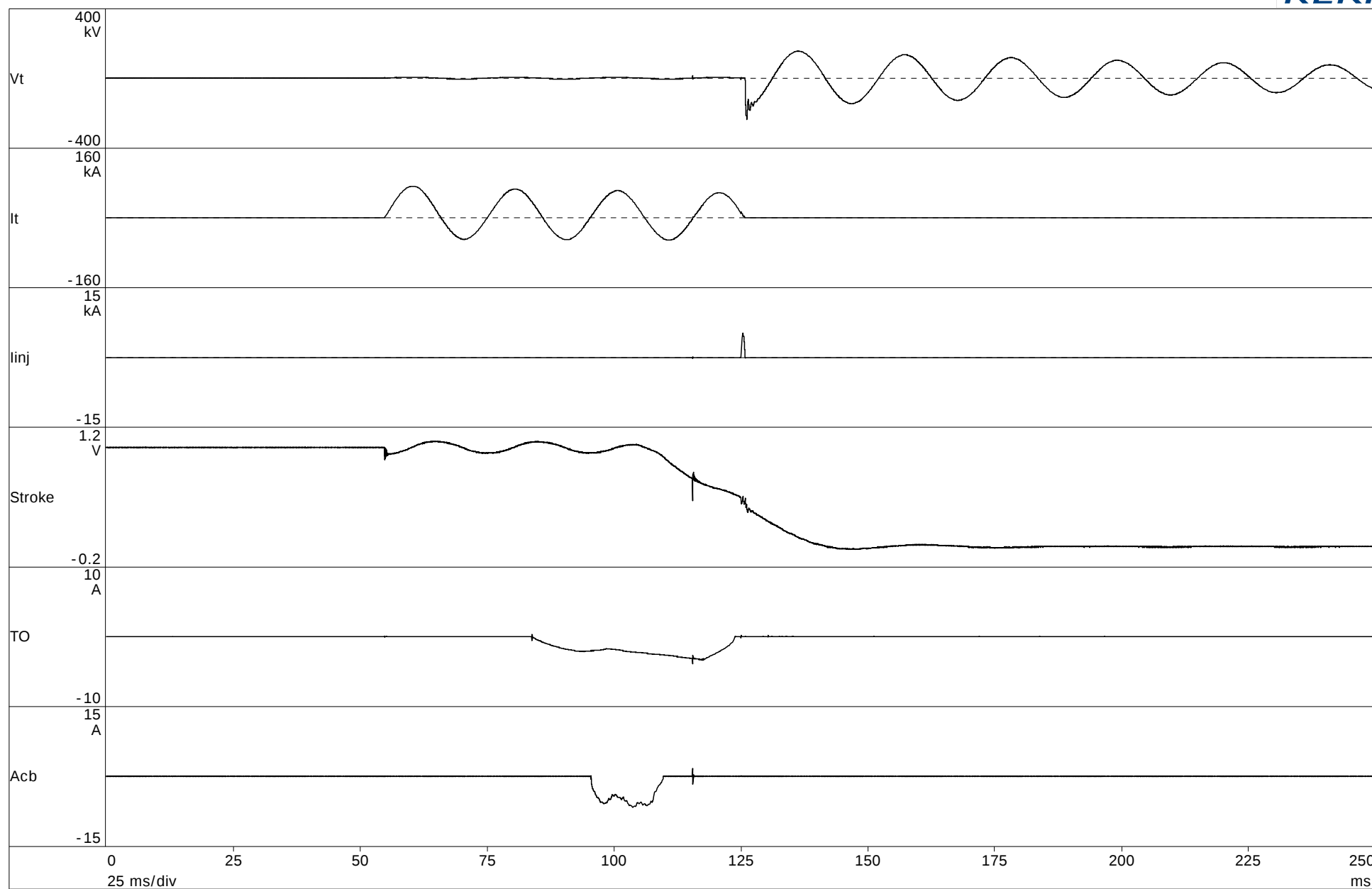
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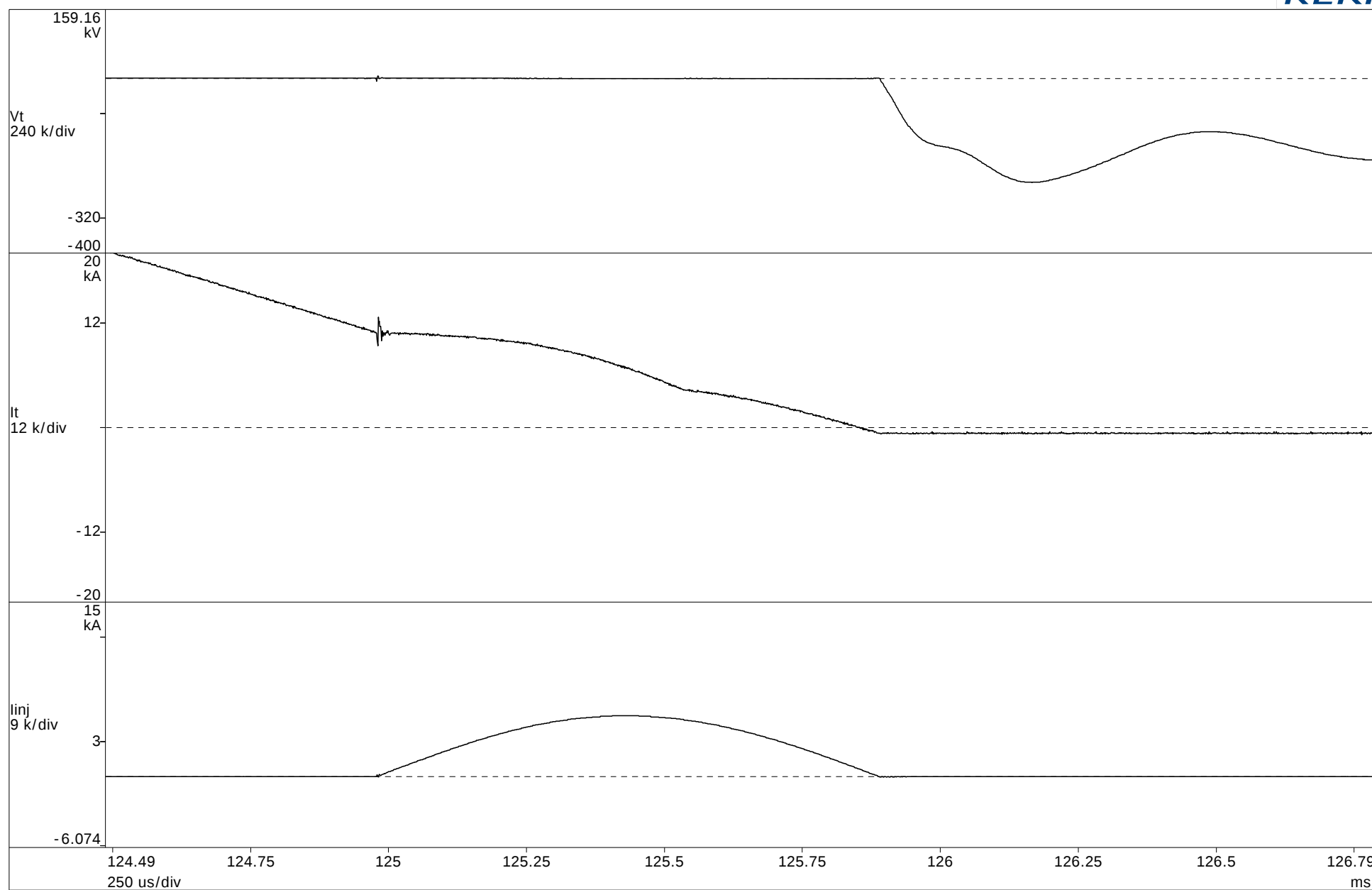
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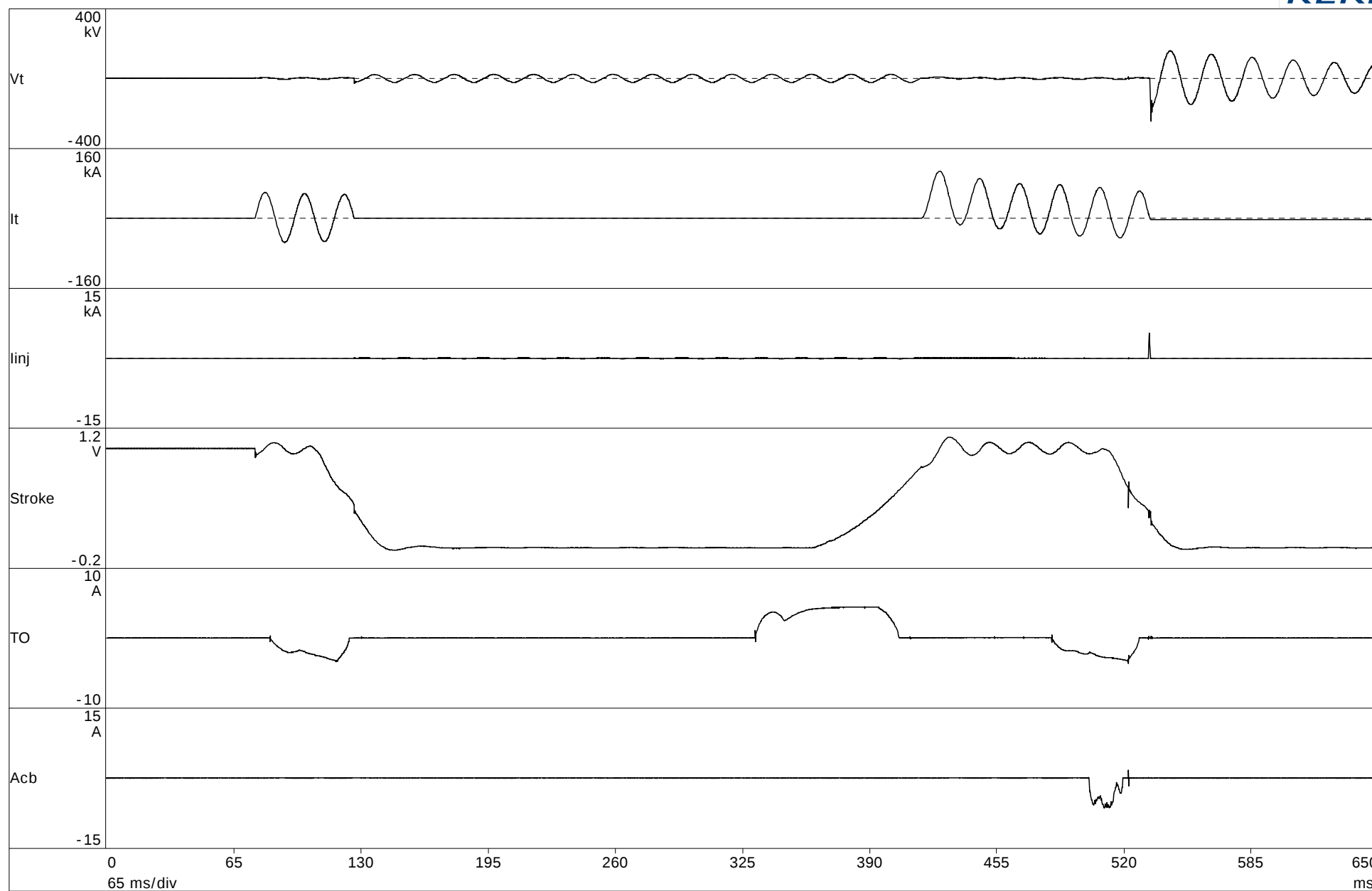
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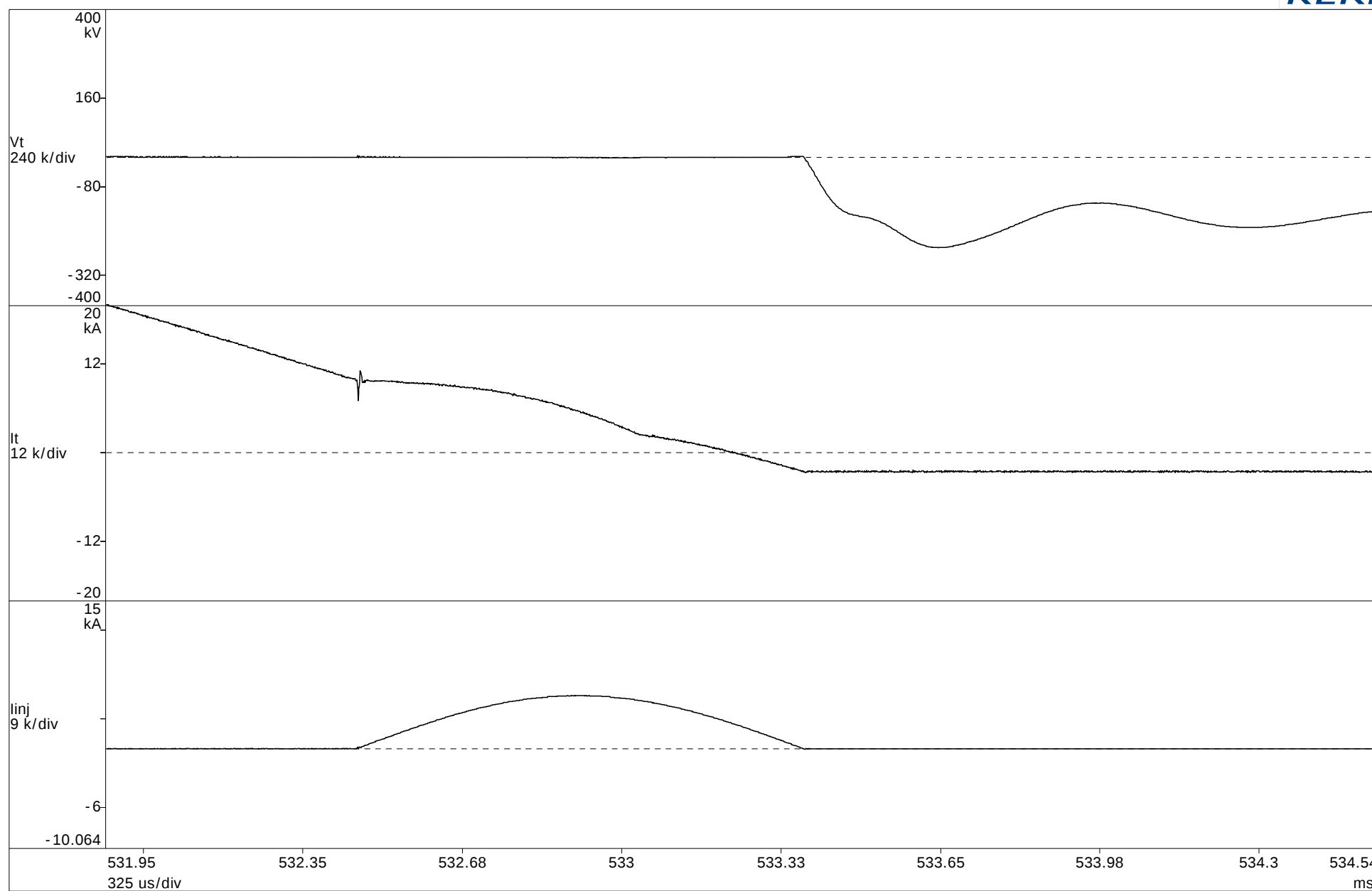
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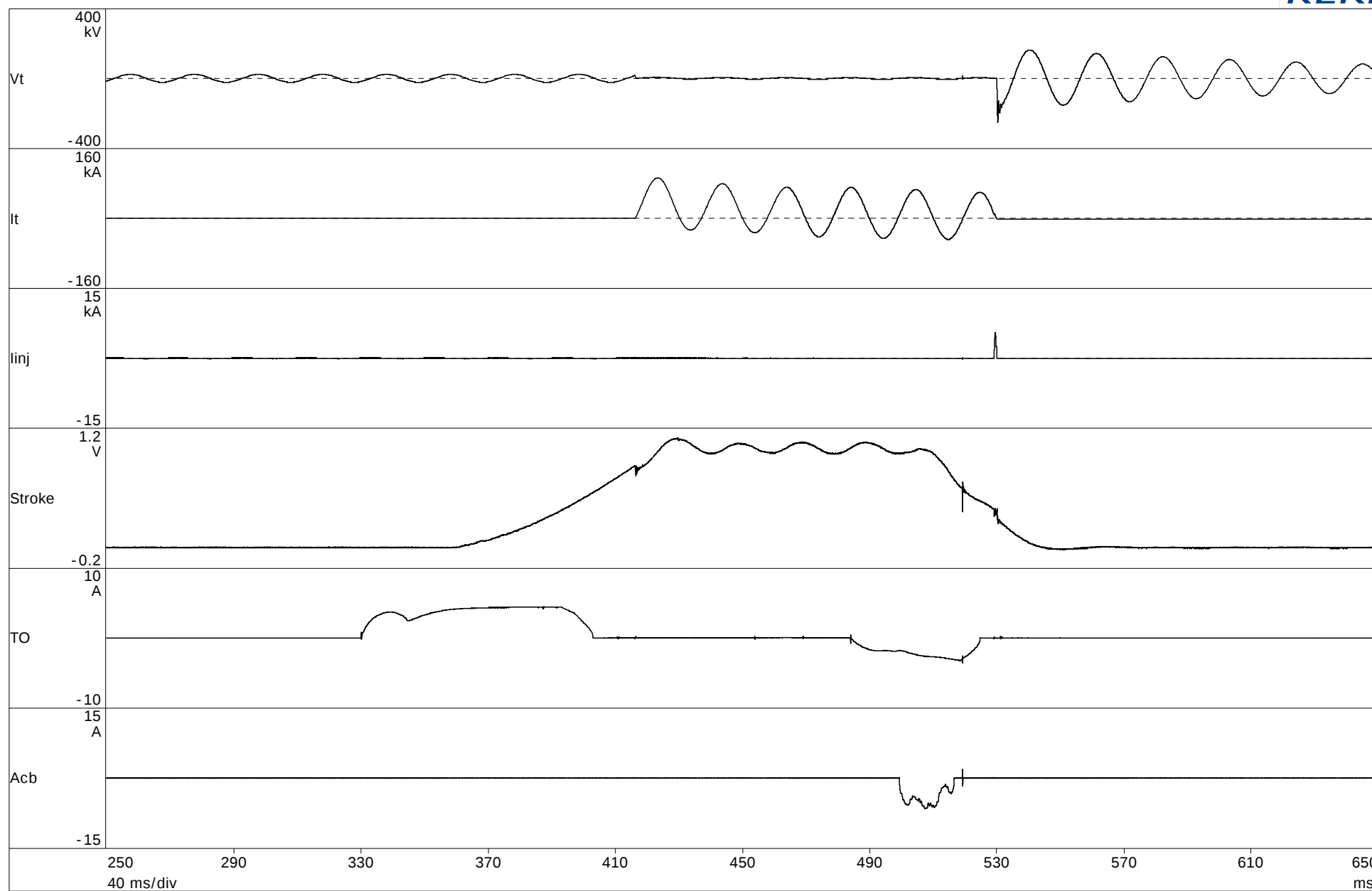
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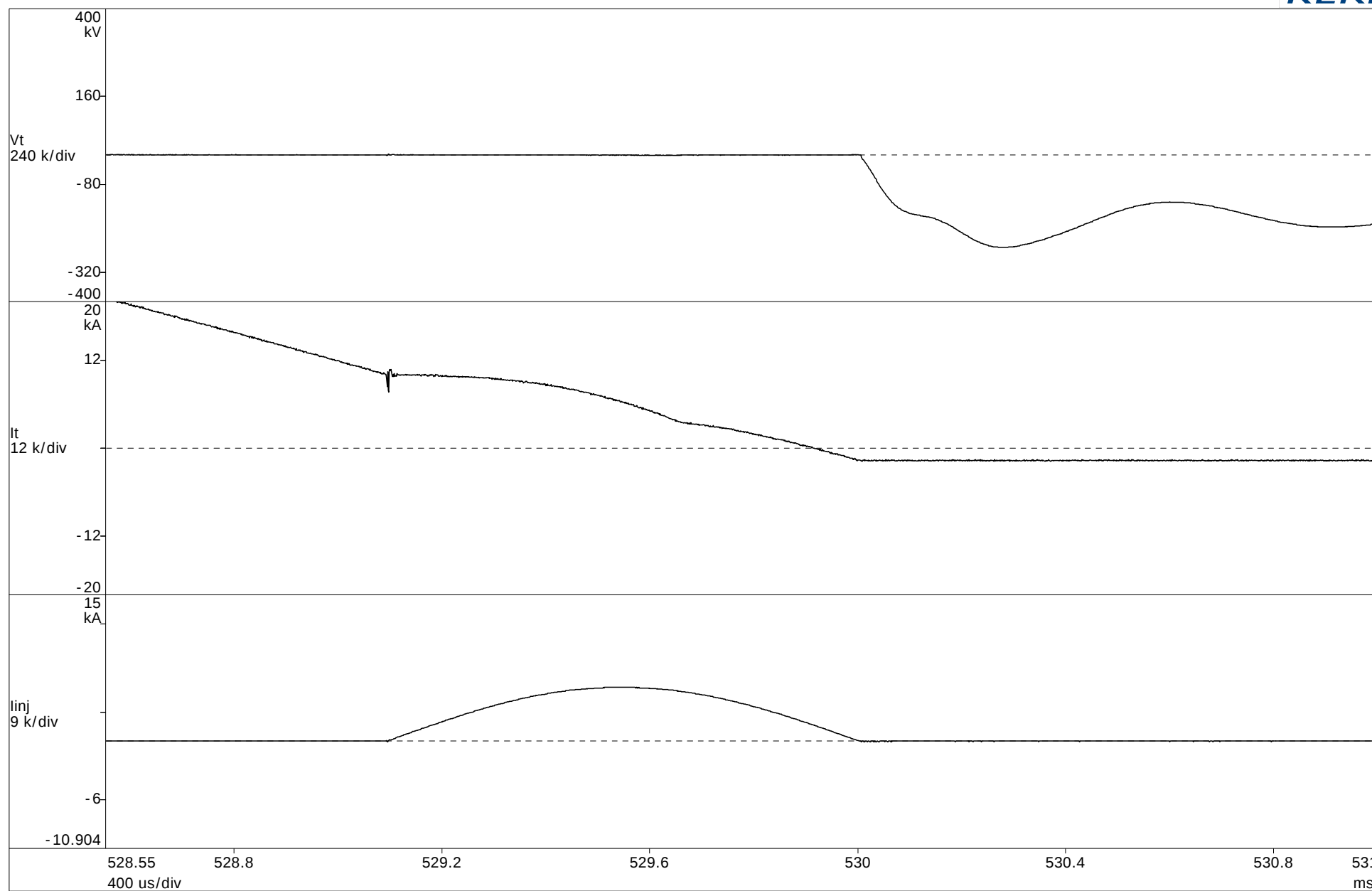
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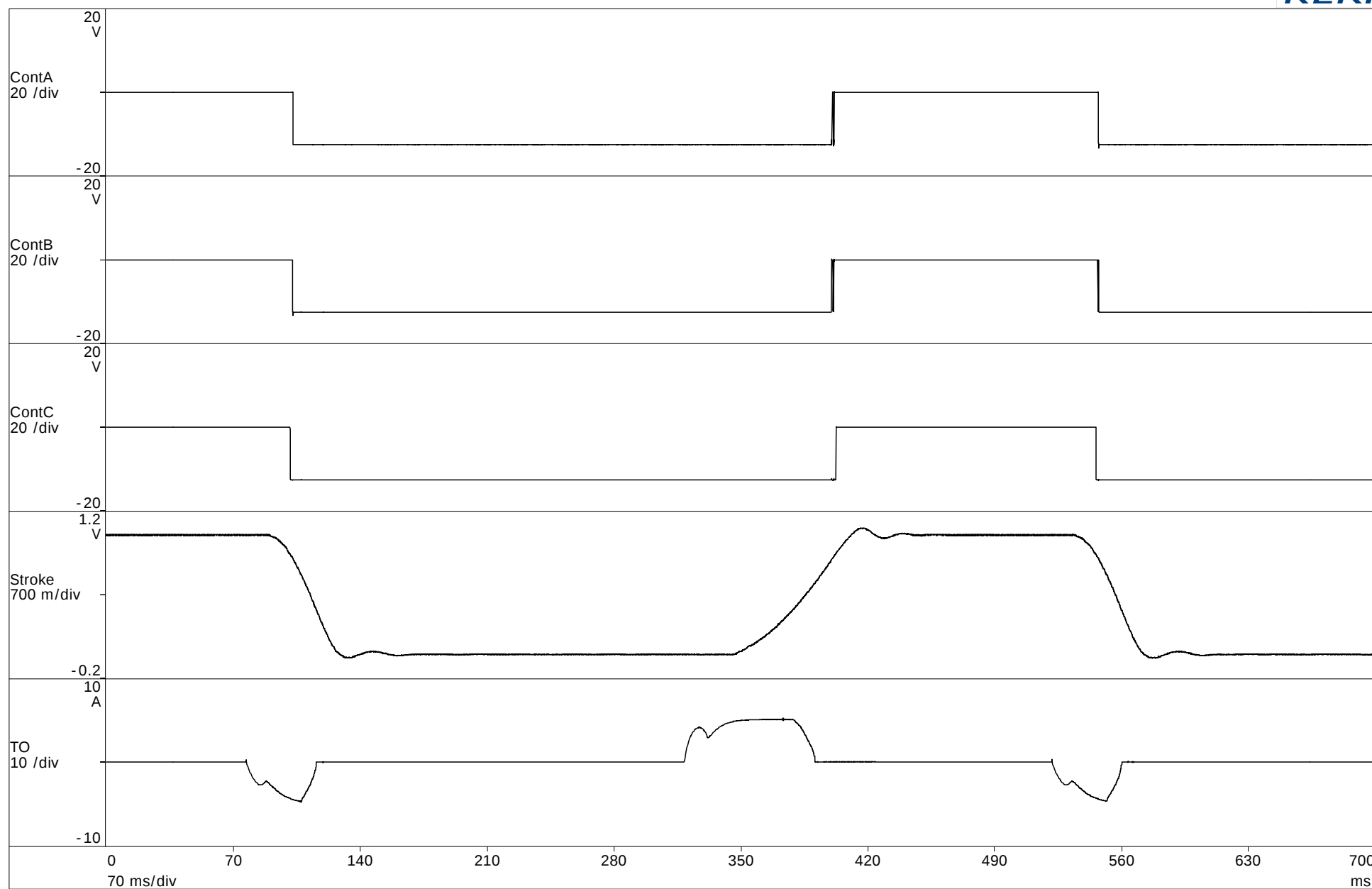
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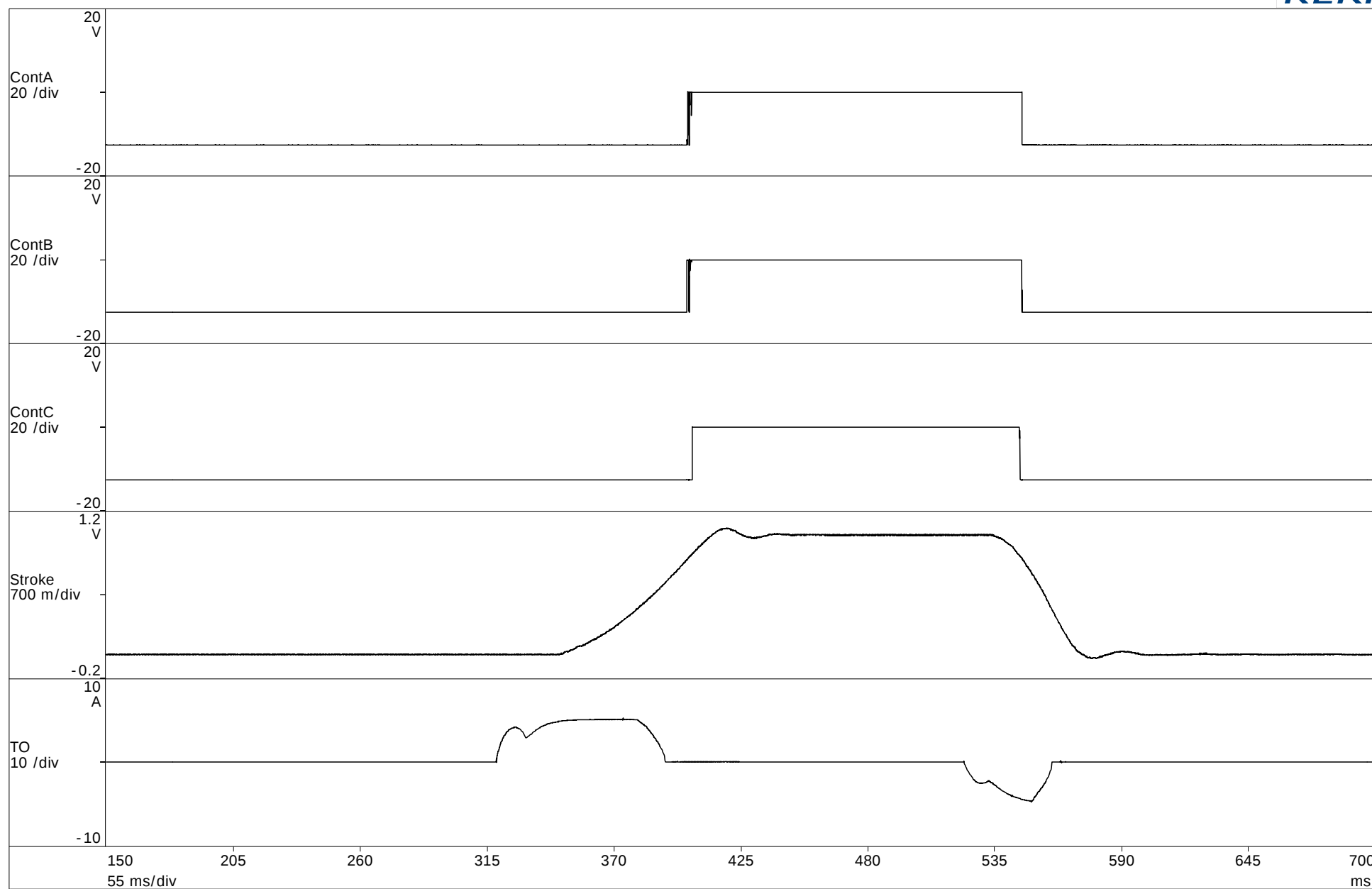
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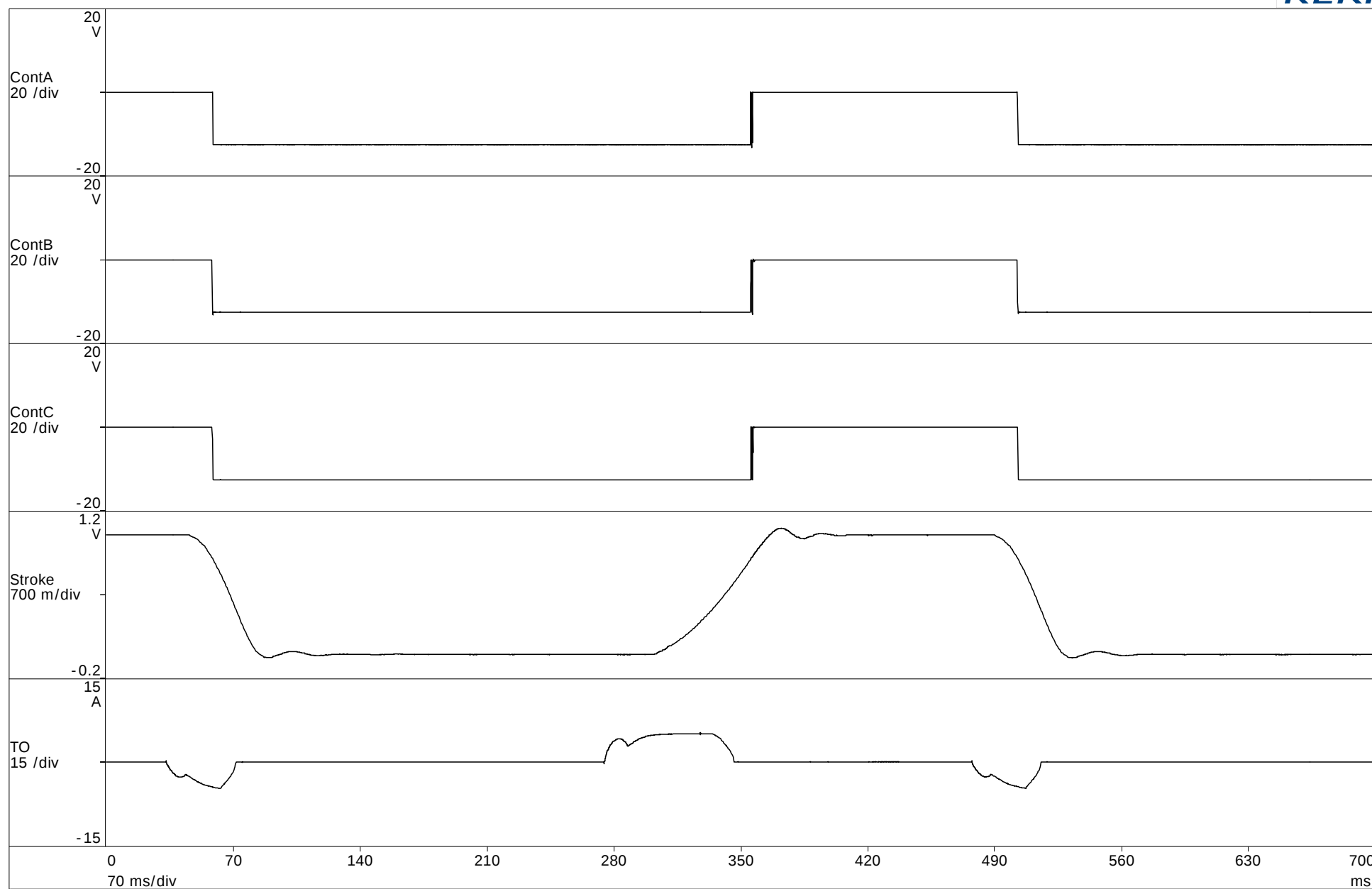
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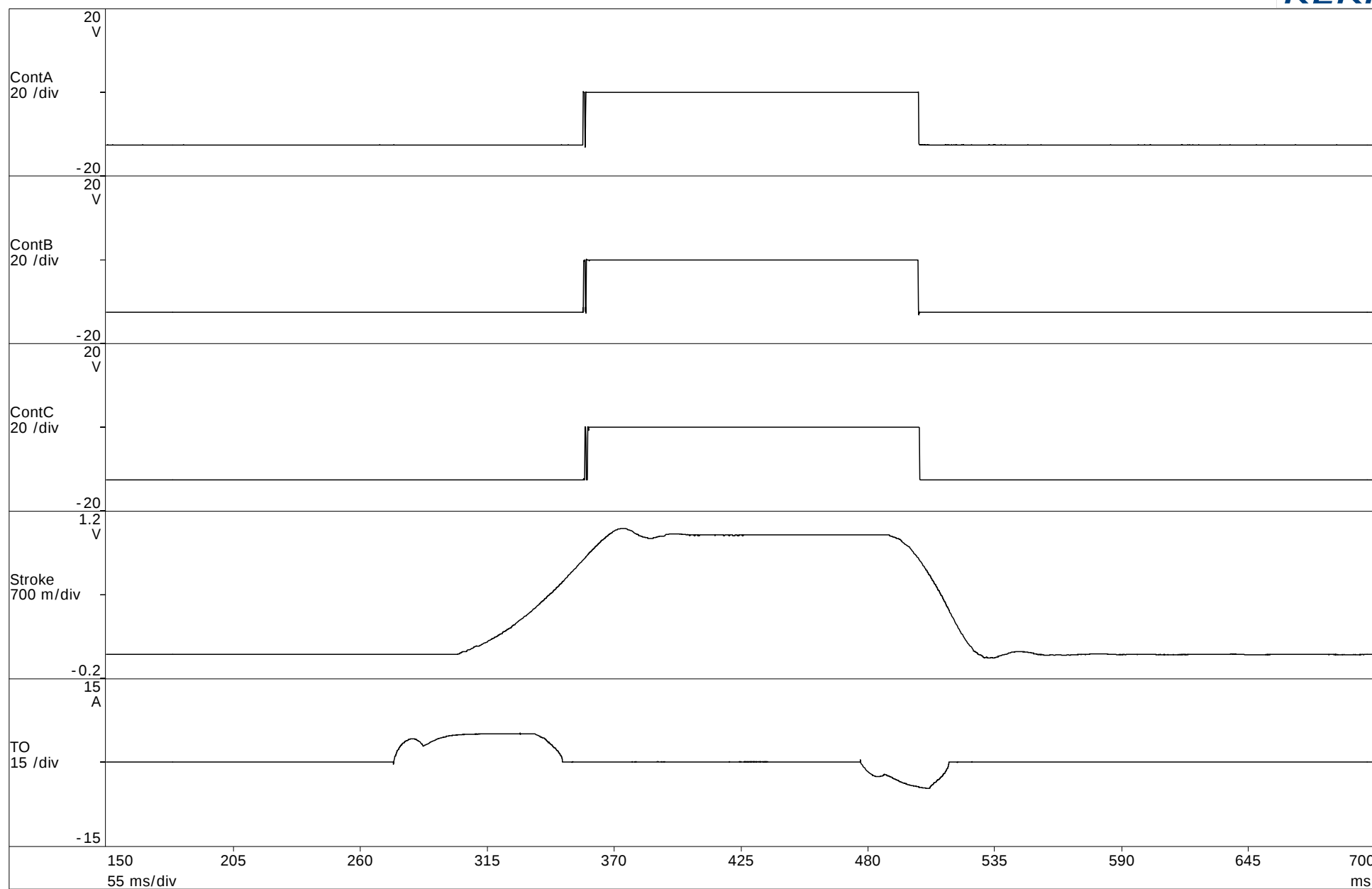
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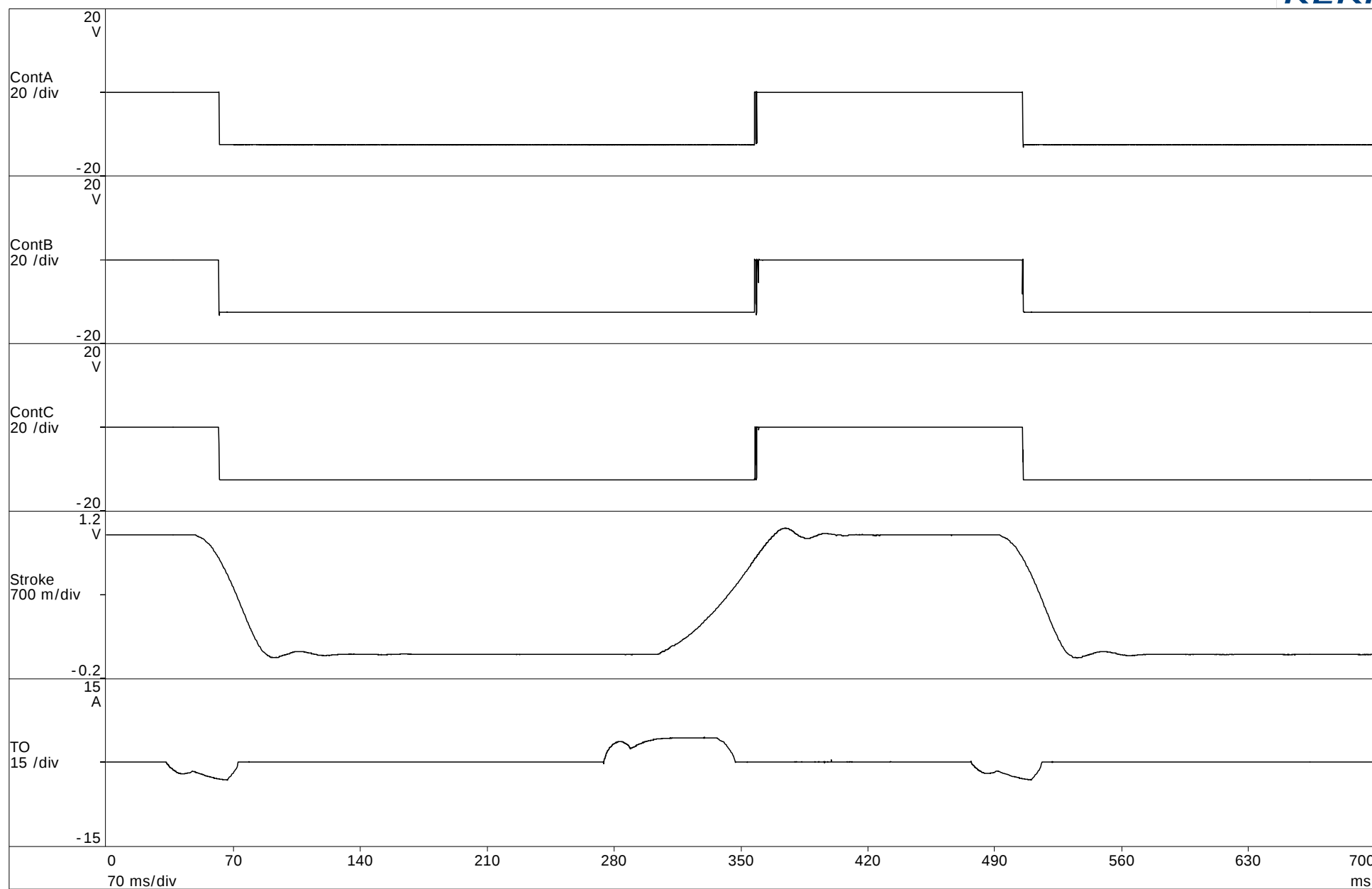
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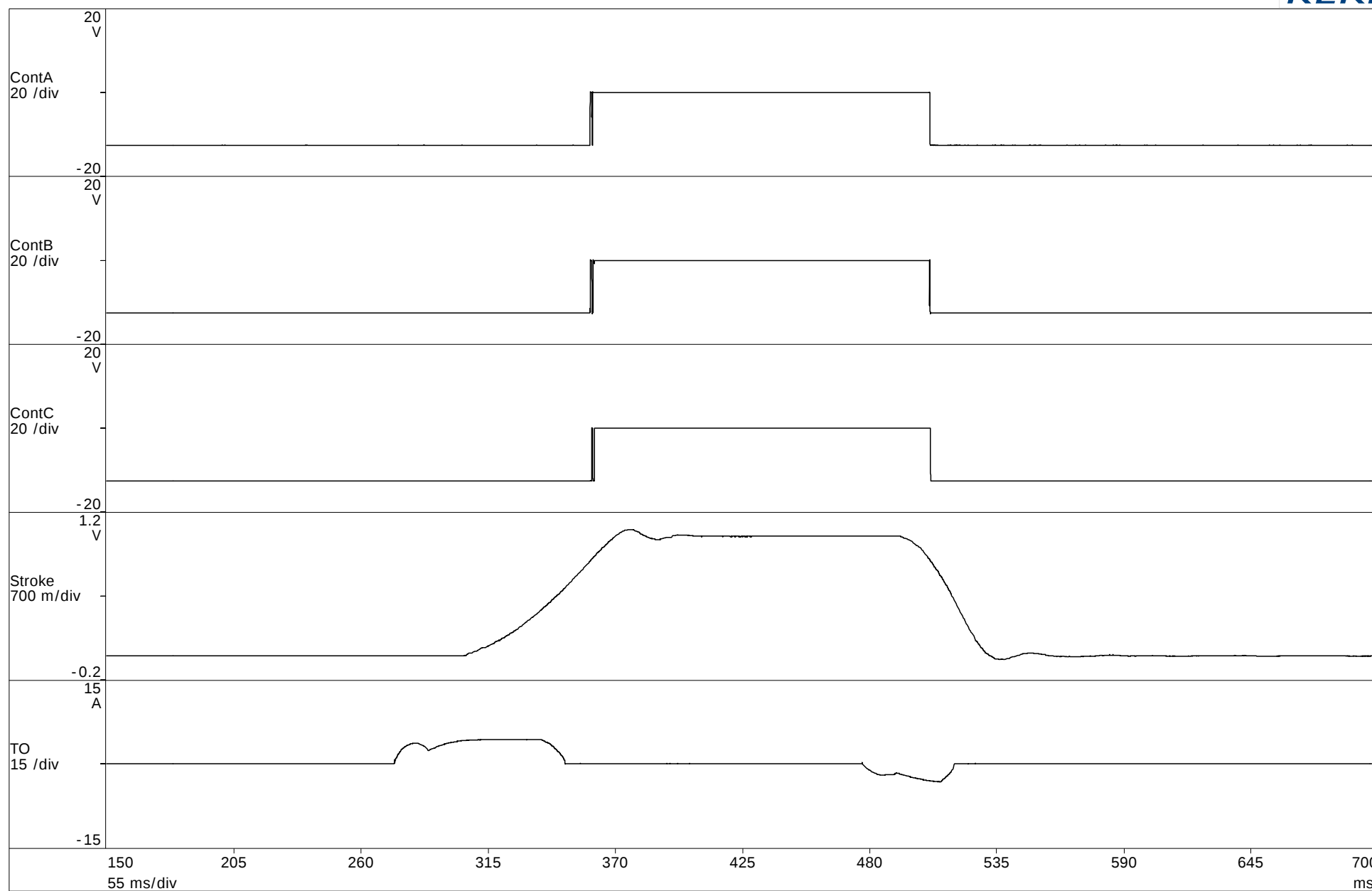
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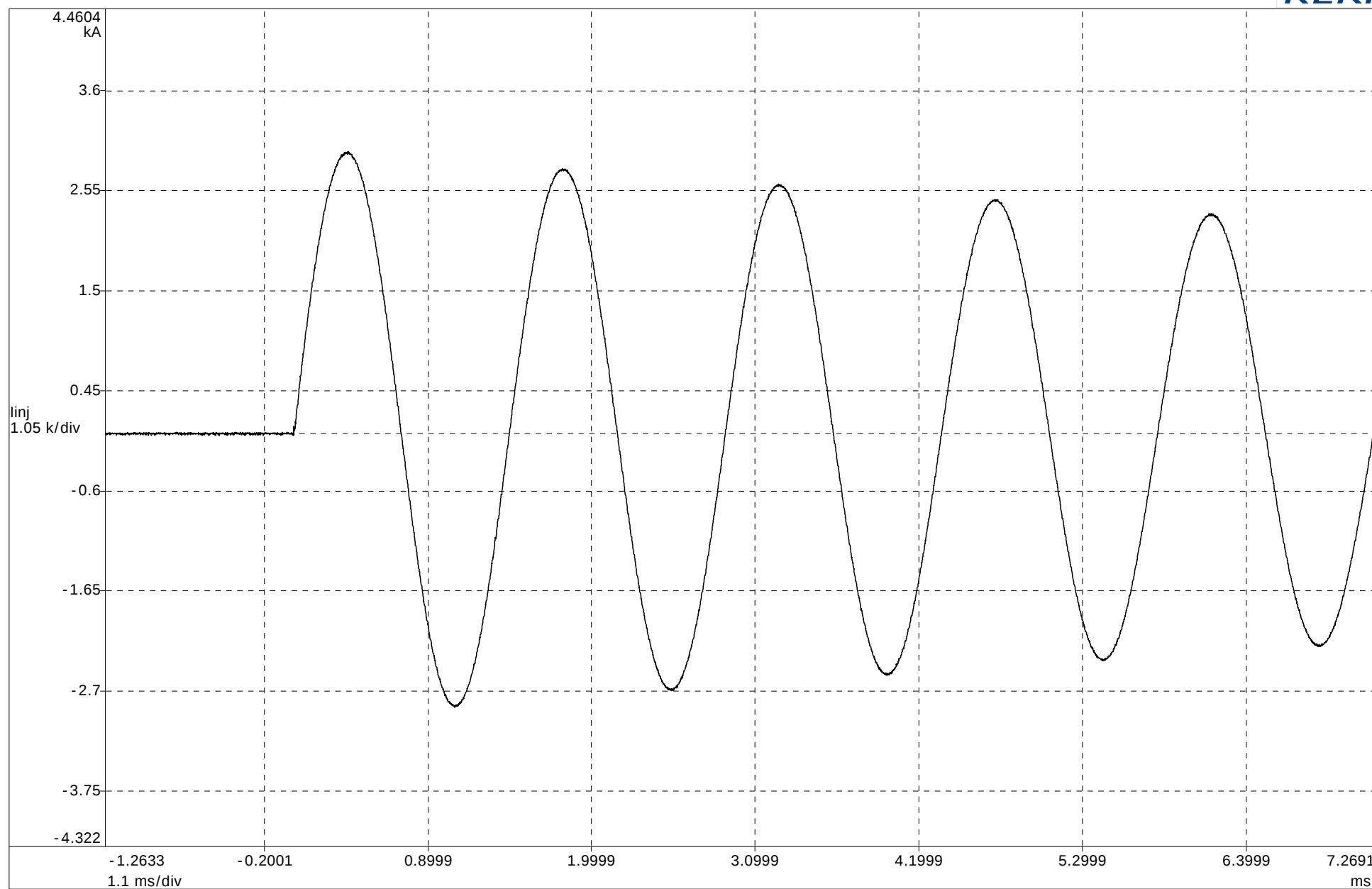
HPC 1104 - 087



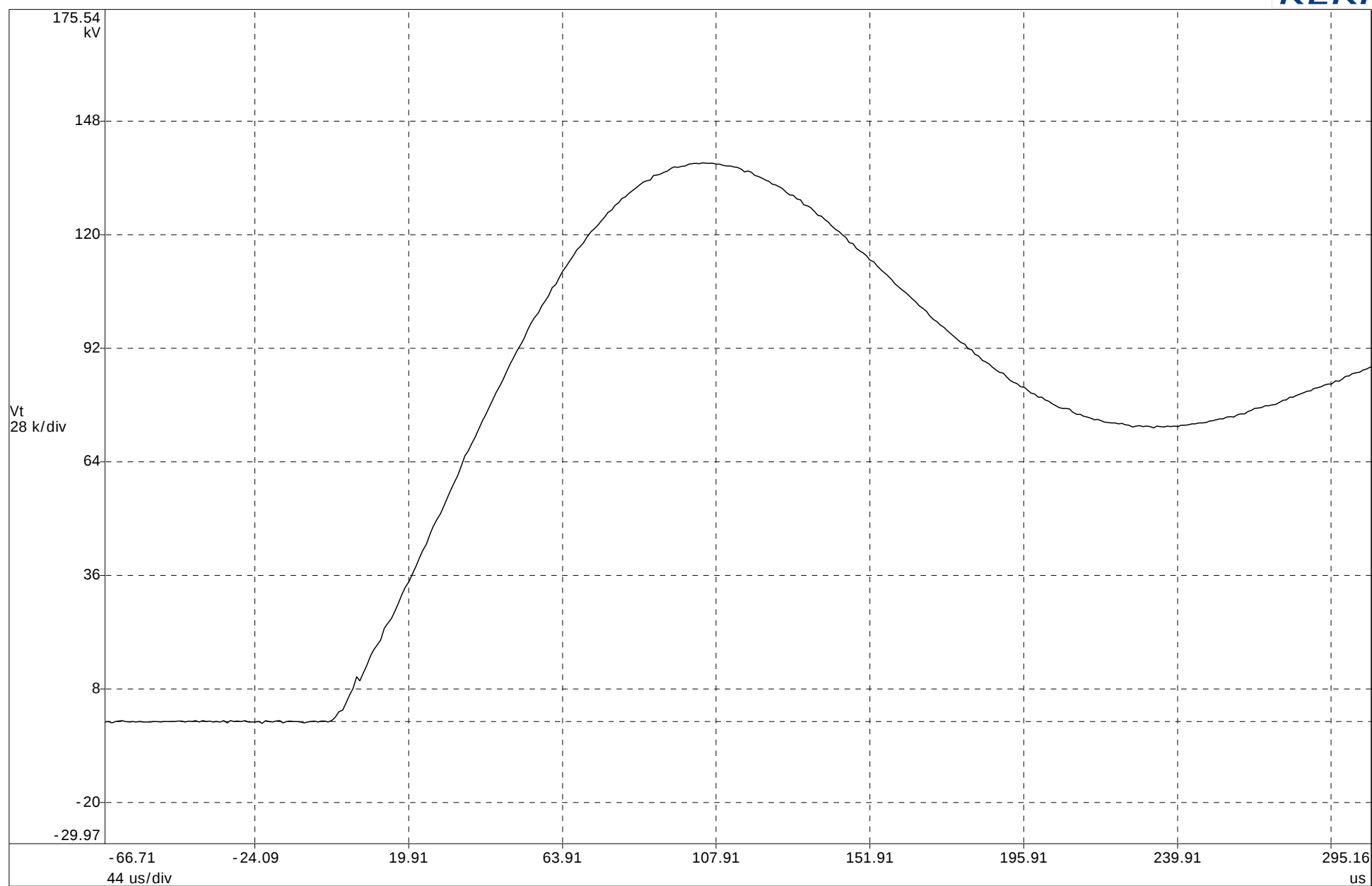
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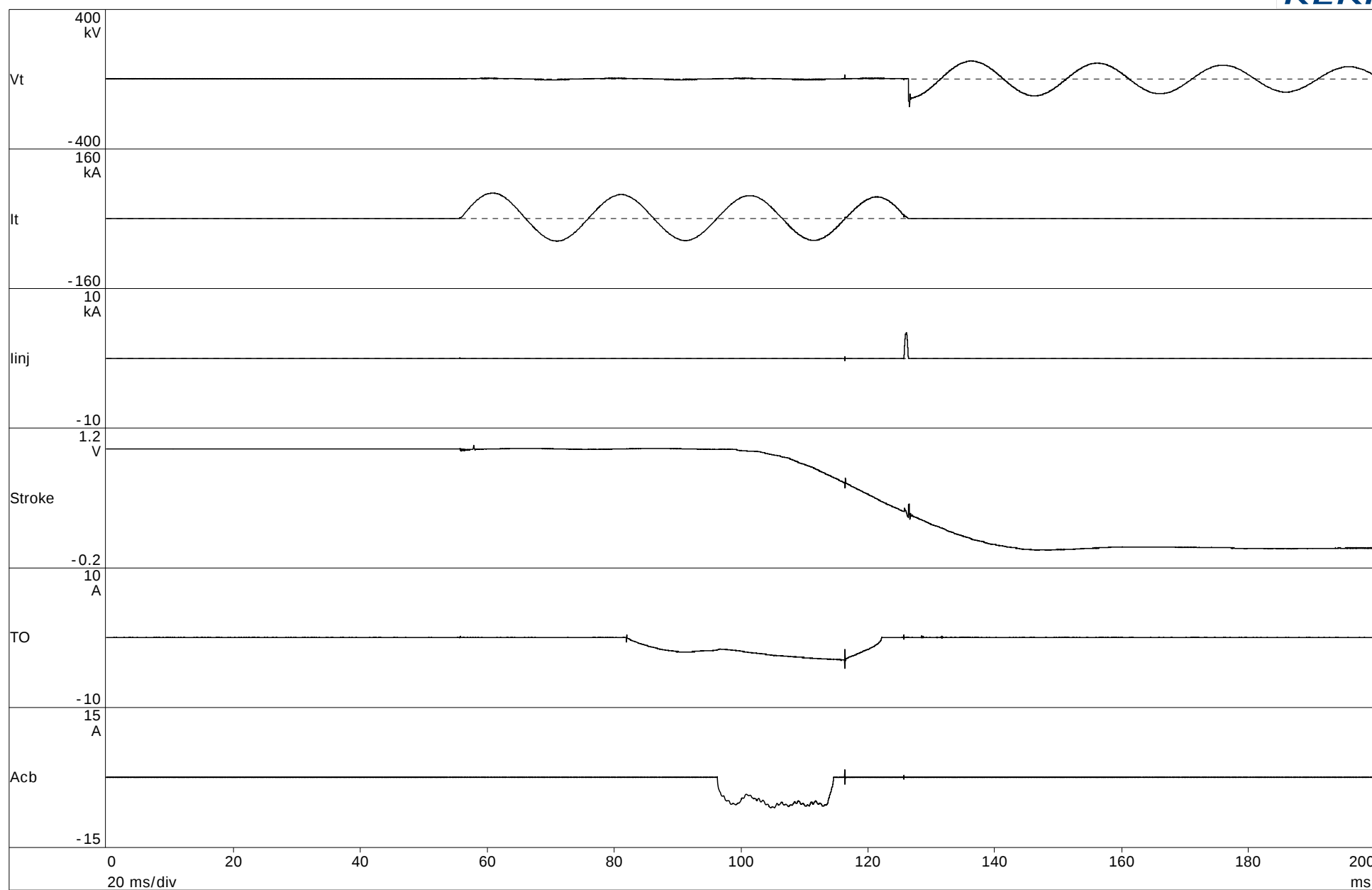
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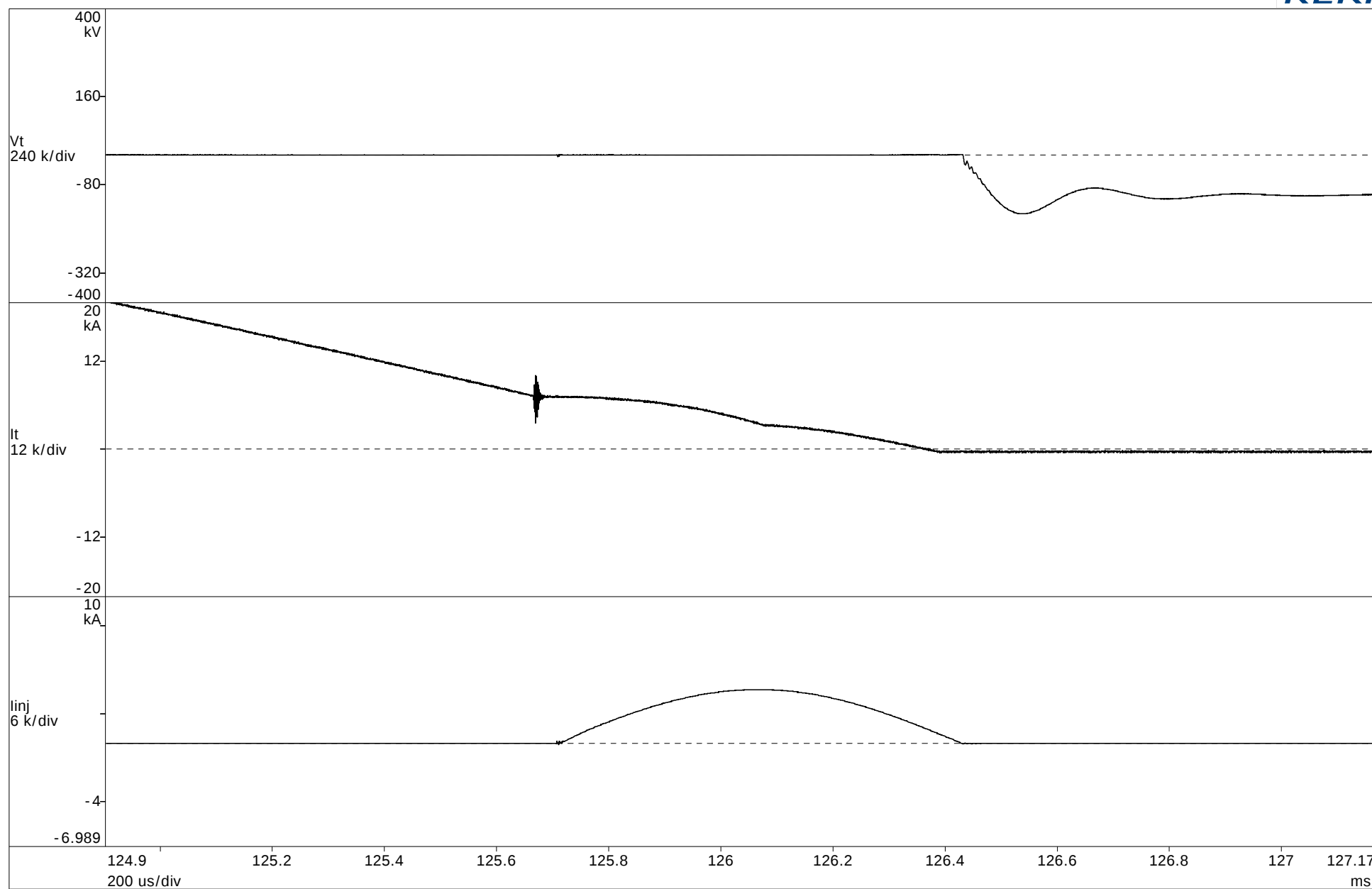
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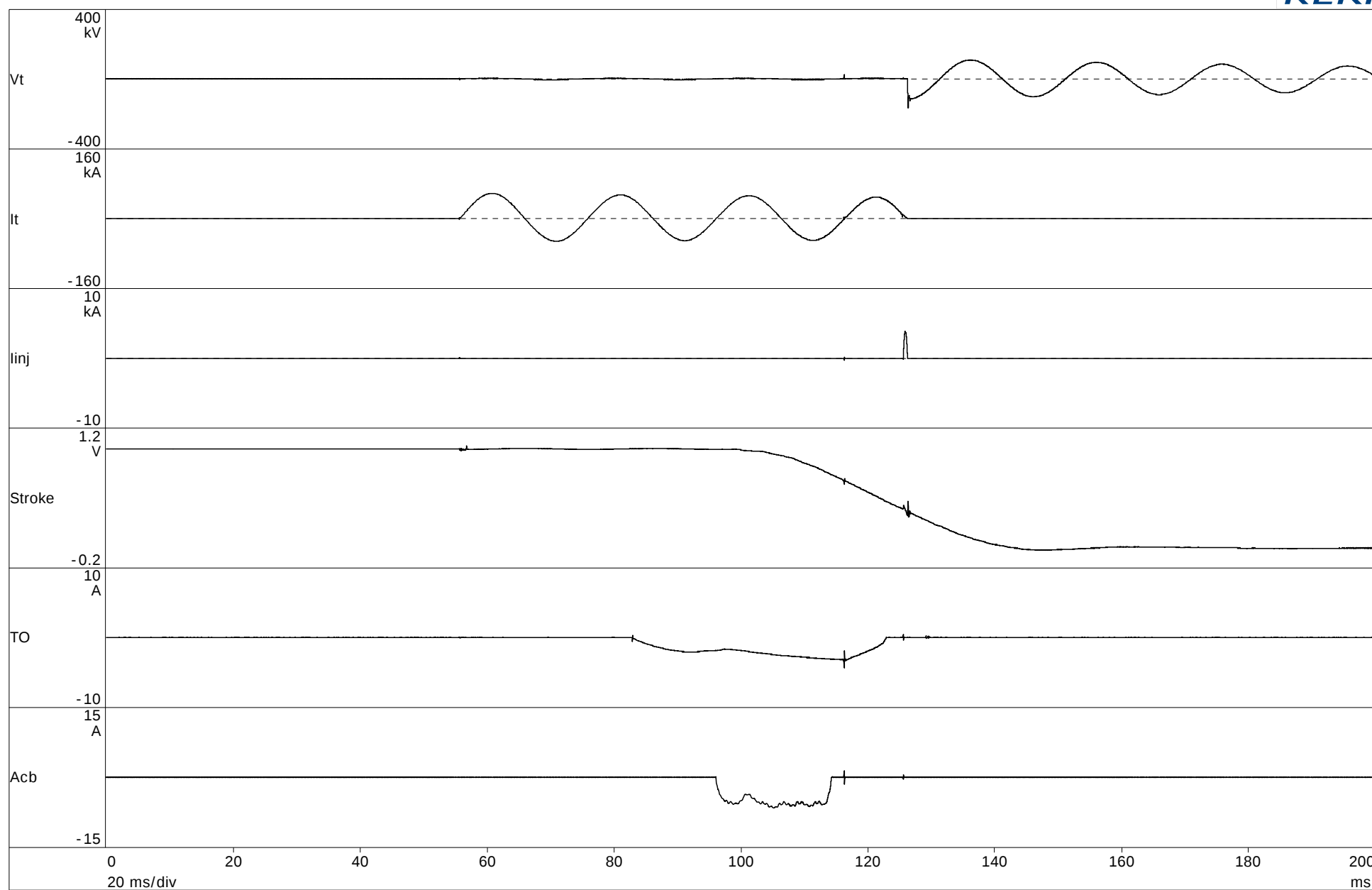
## HPC 1104 - 102



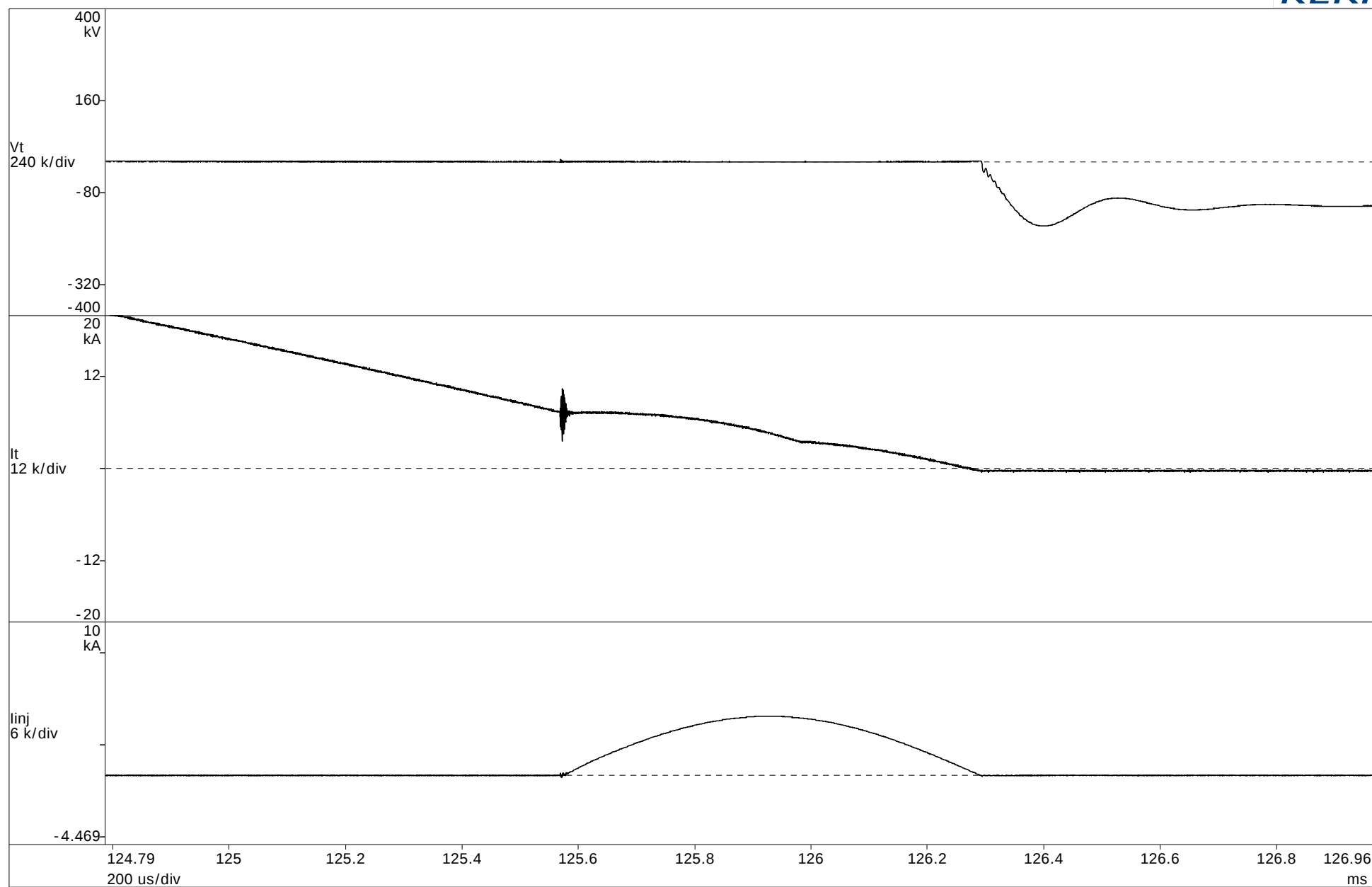
## HPC 1104 - 102



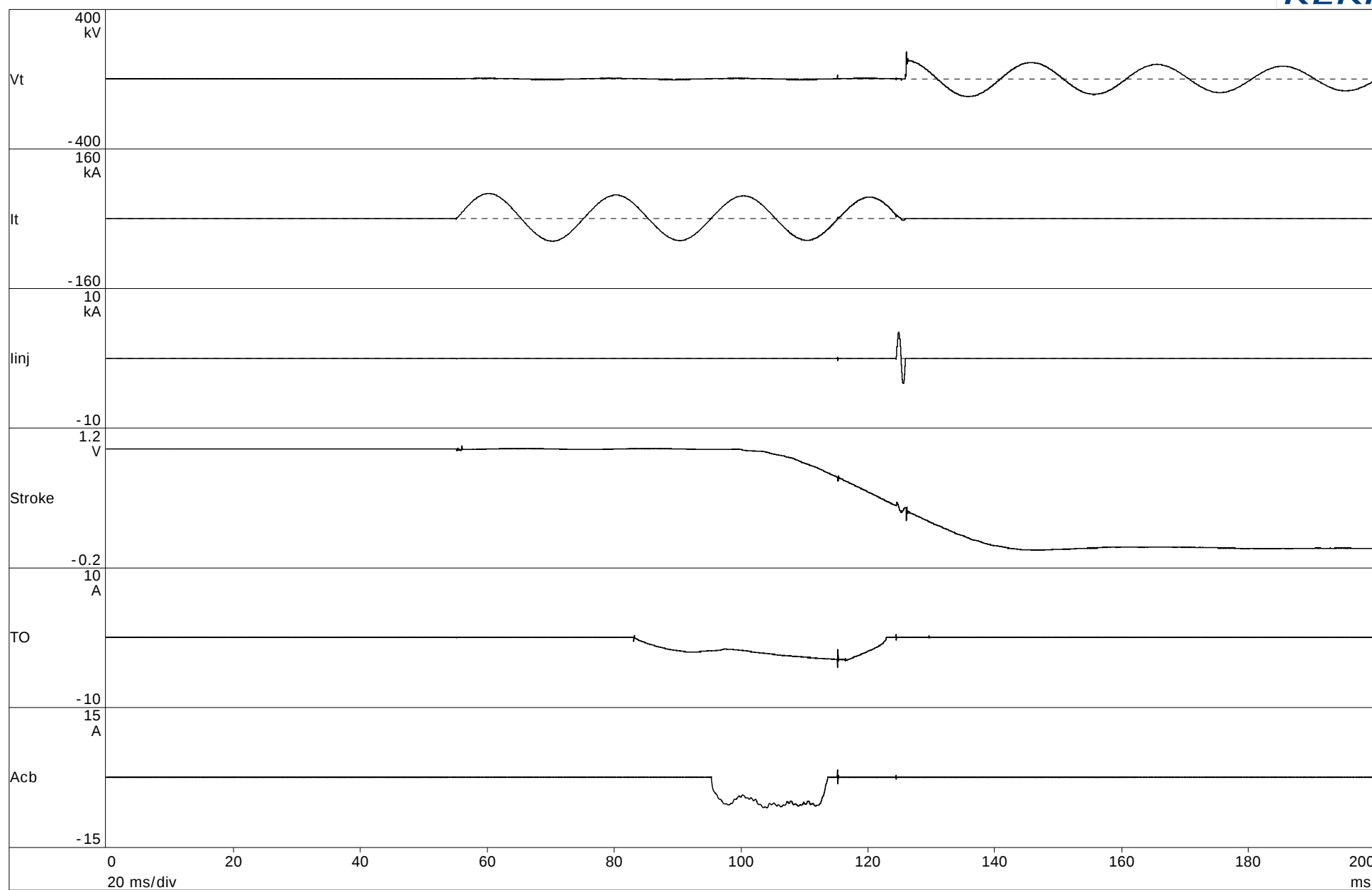
## HPC 1104 - 103



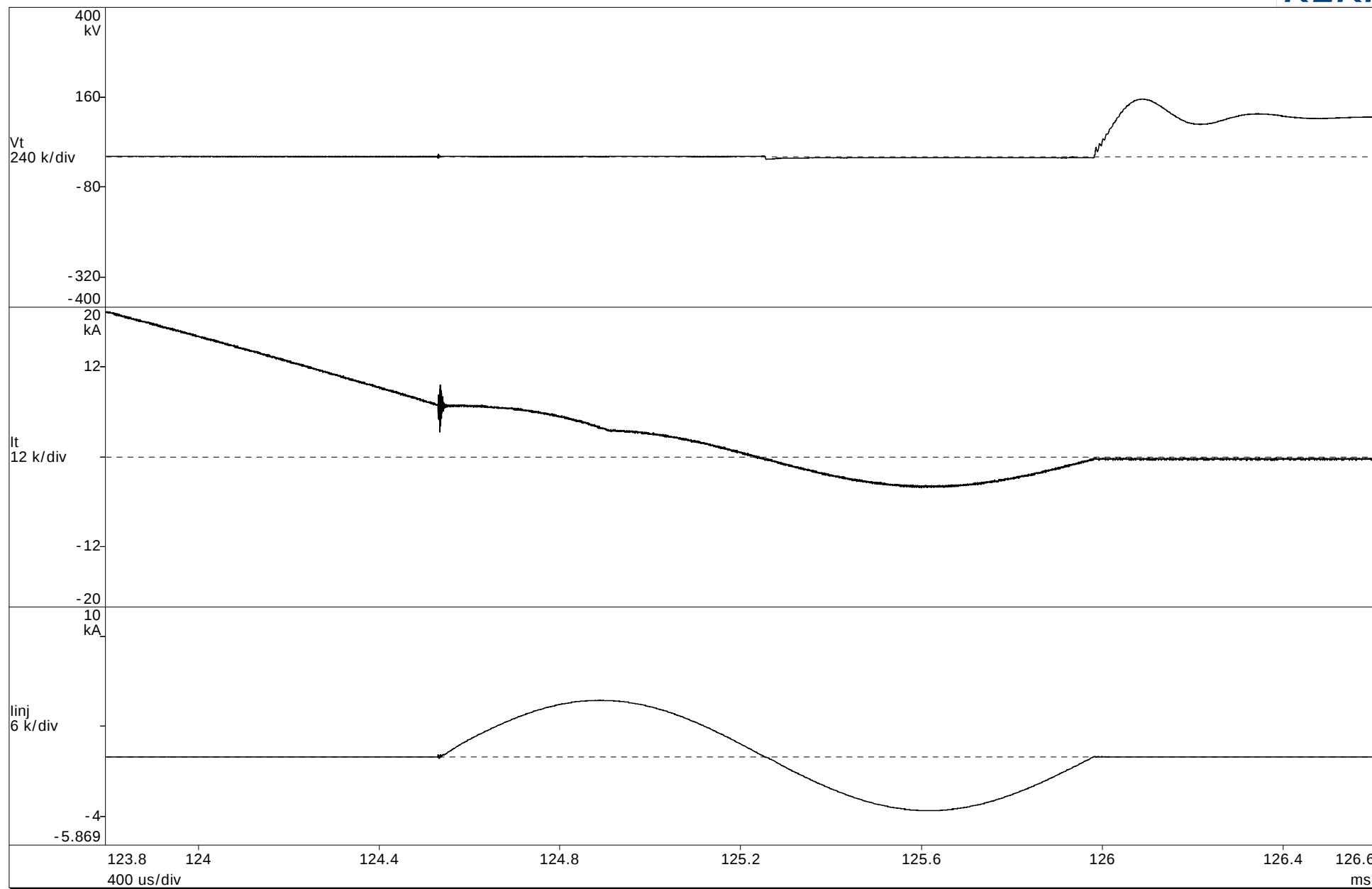
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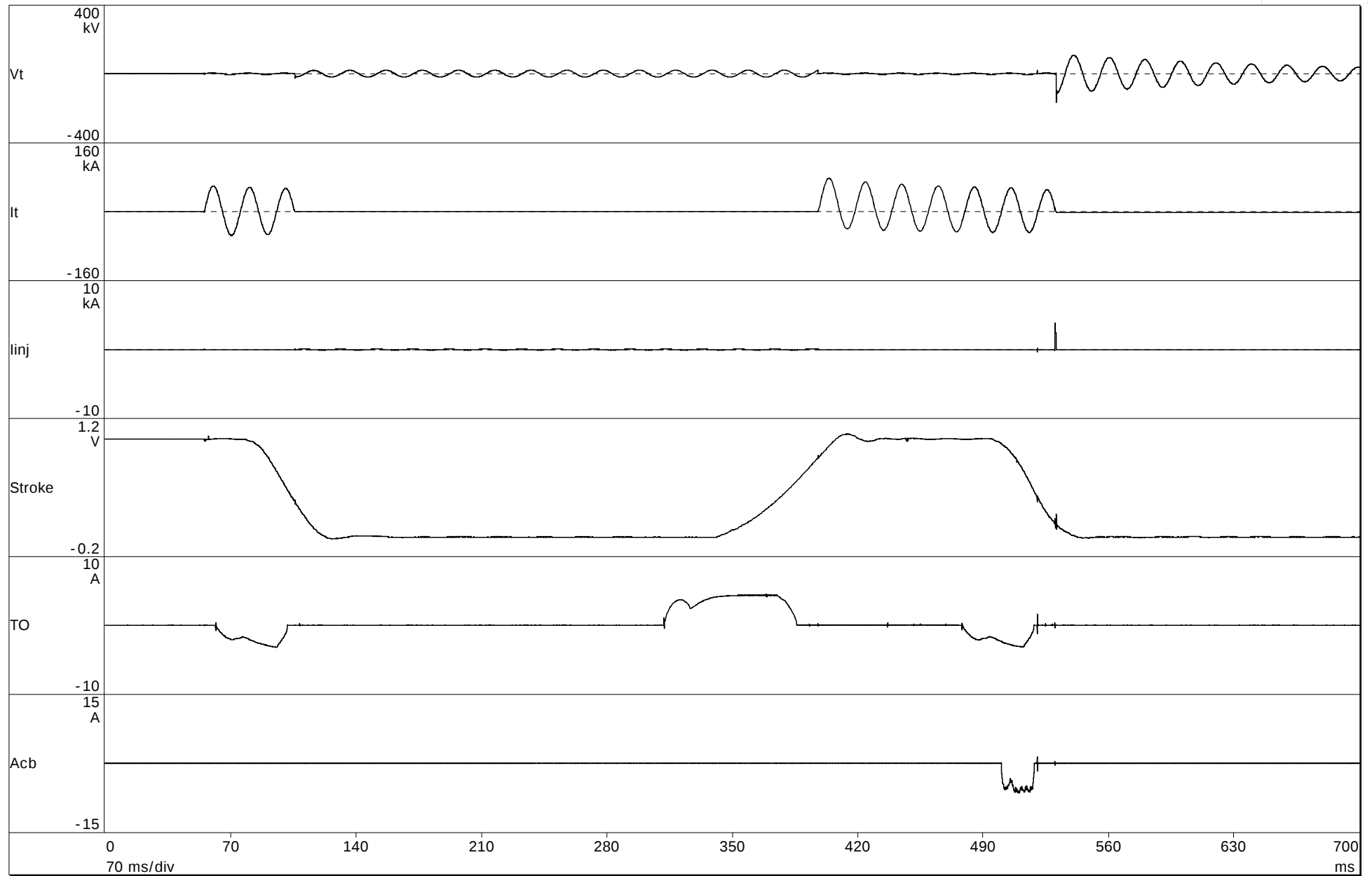
## HPC 1104 - 104



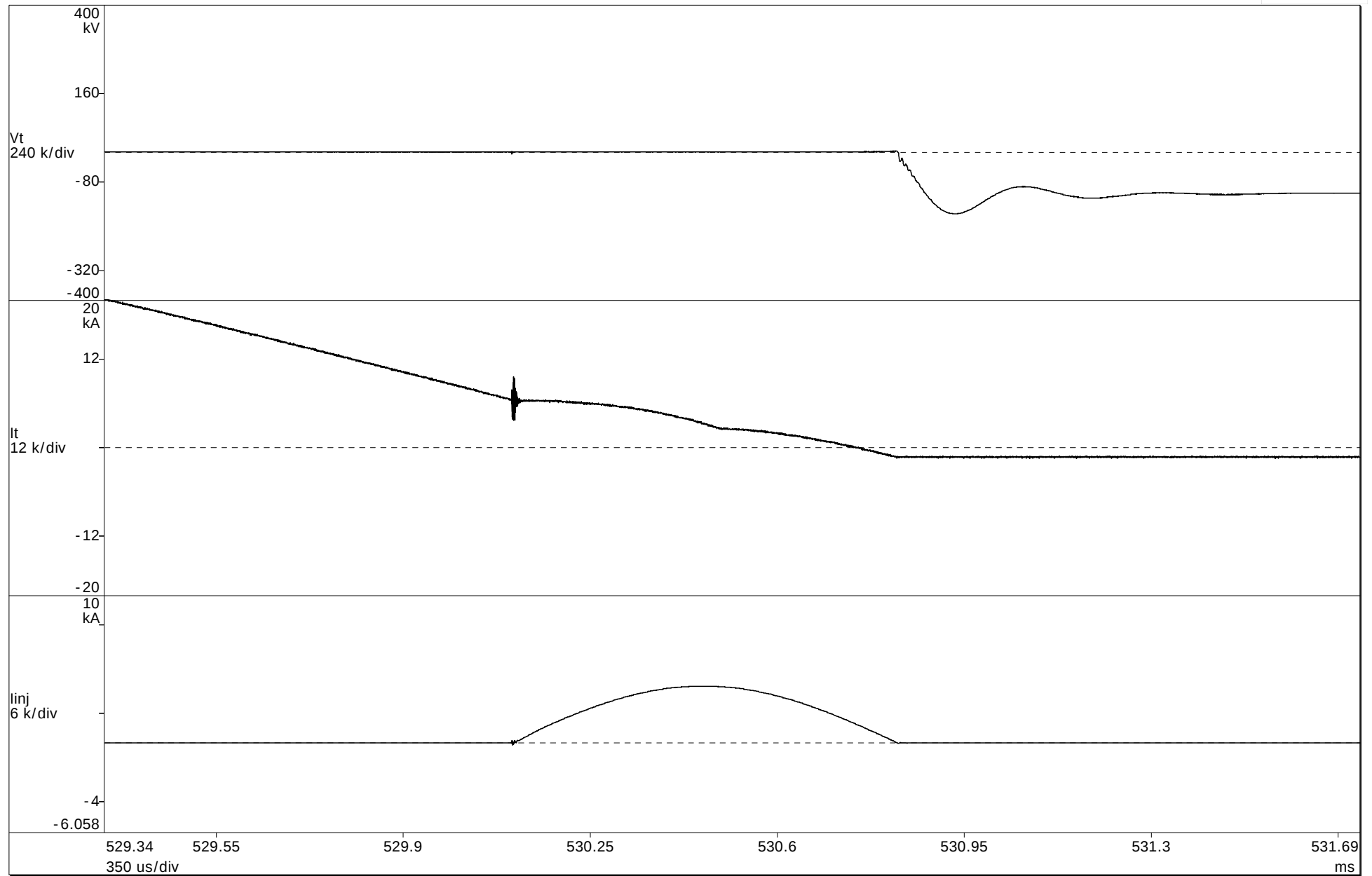
## HPC 1104 - 104



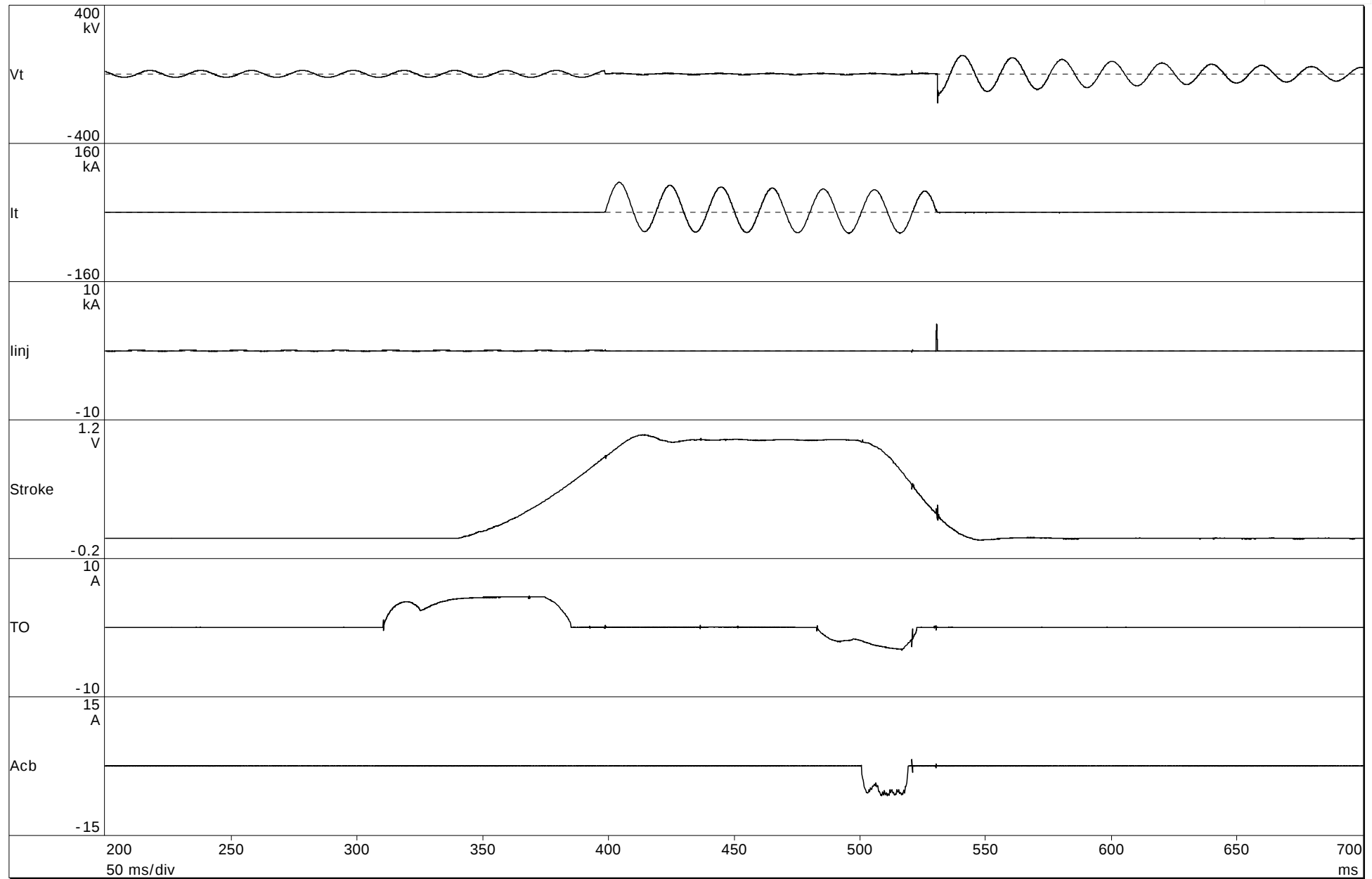
## HPC 1104 - 107



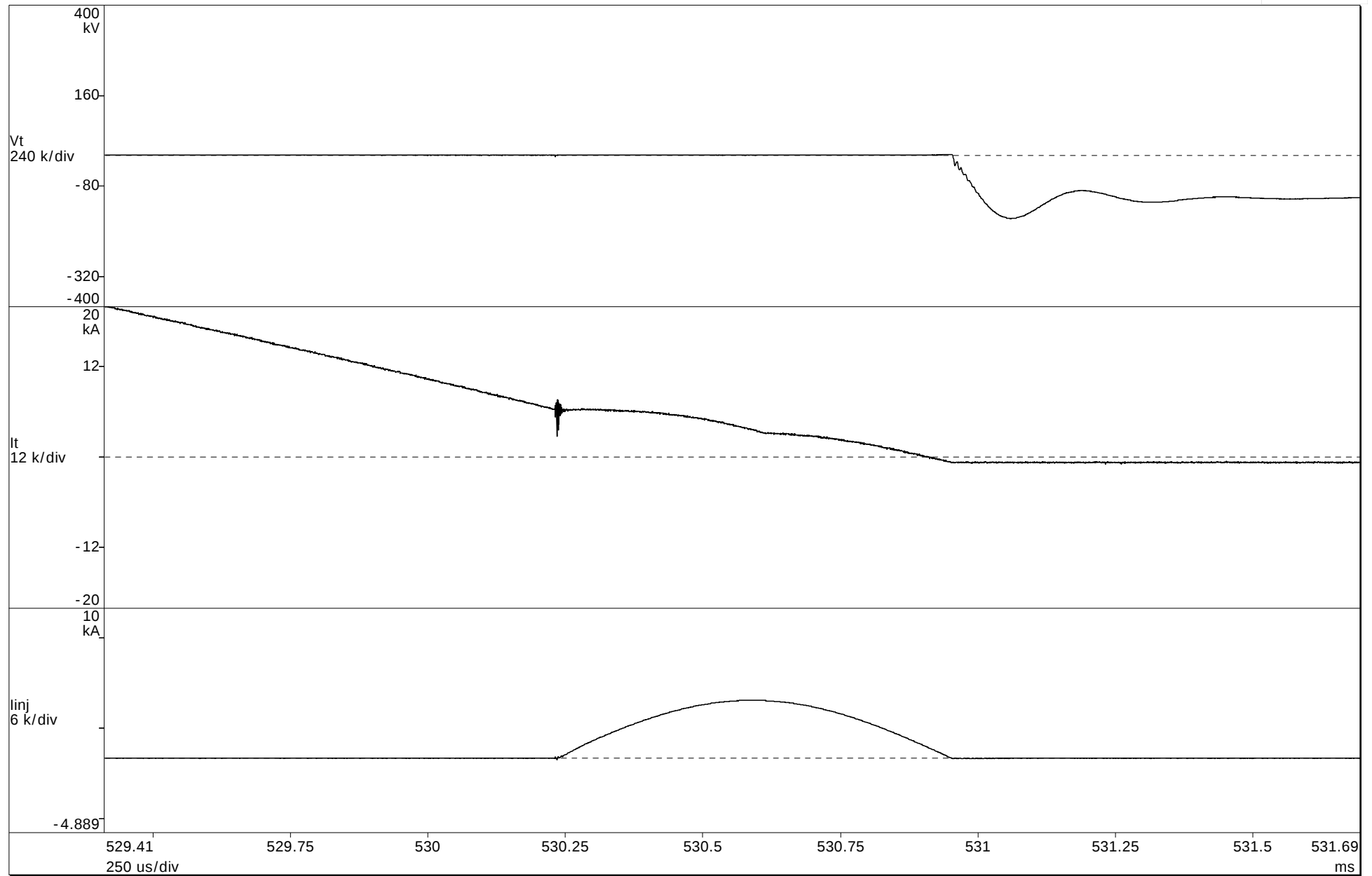
## HPC 1104 - 107



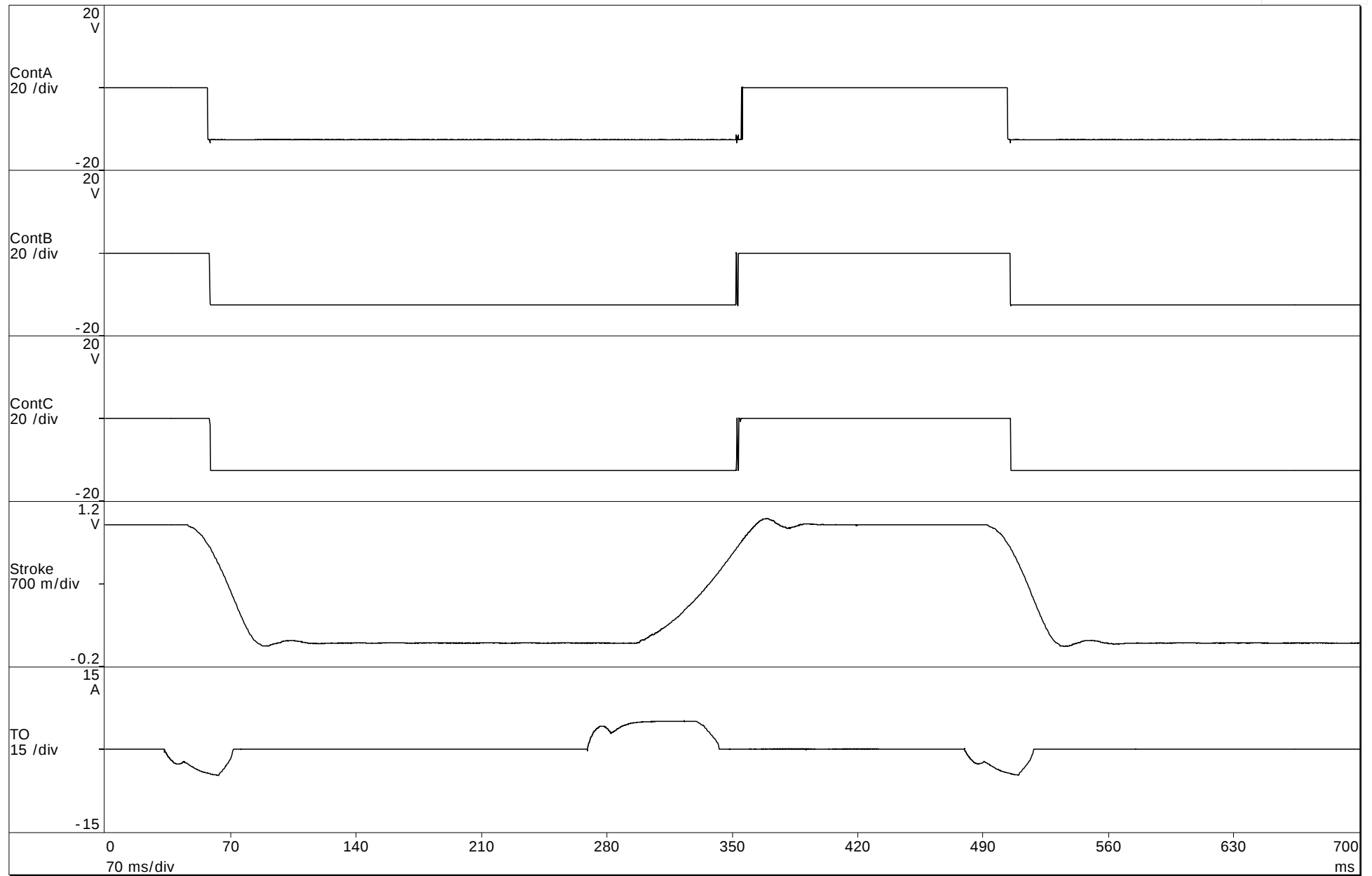
## HPC 1104 - 109



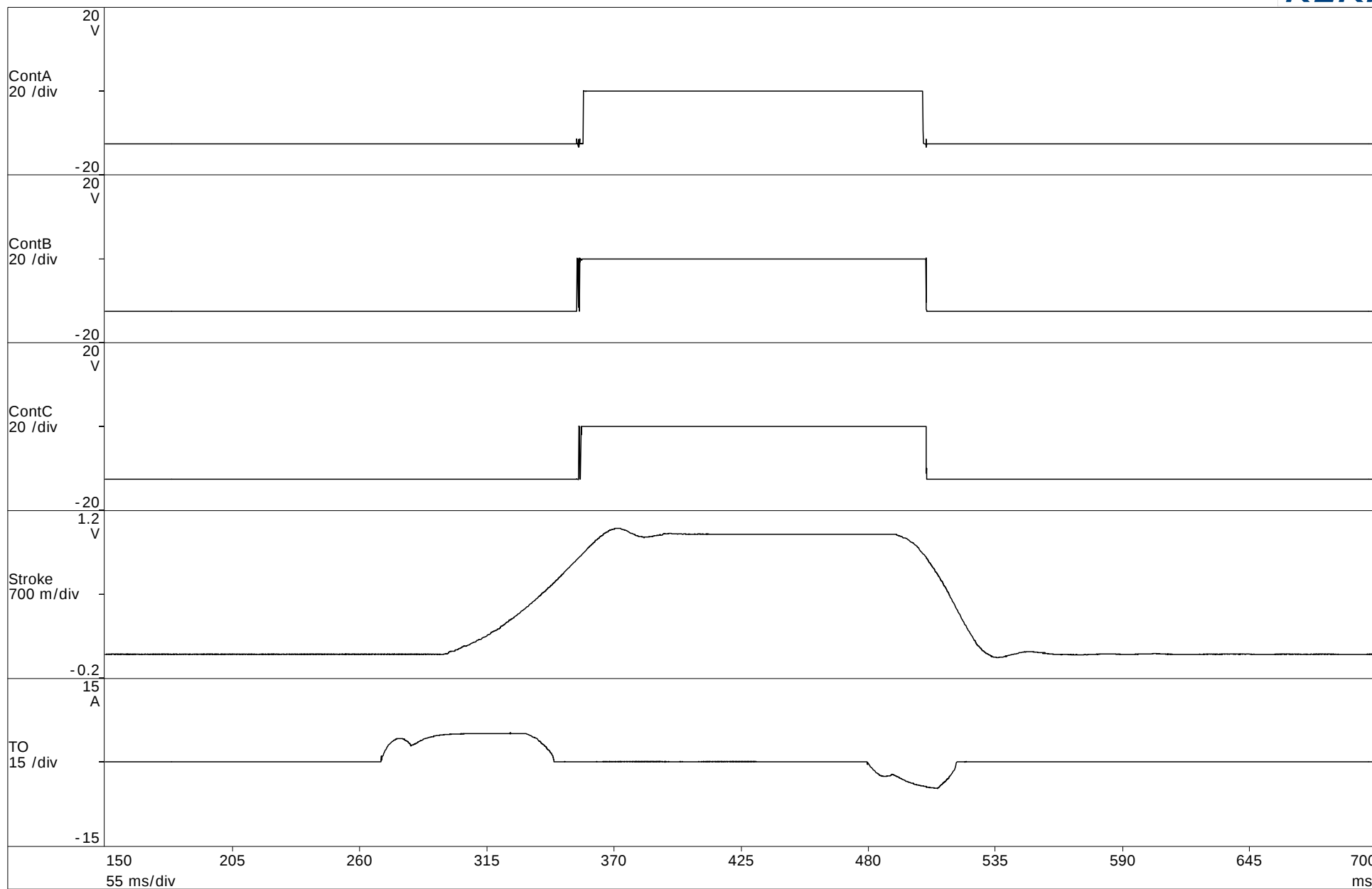
## HPC 1104 - 109



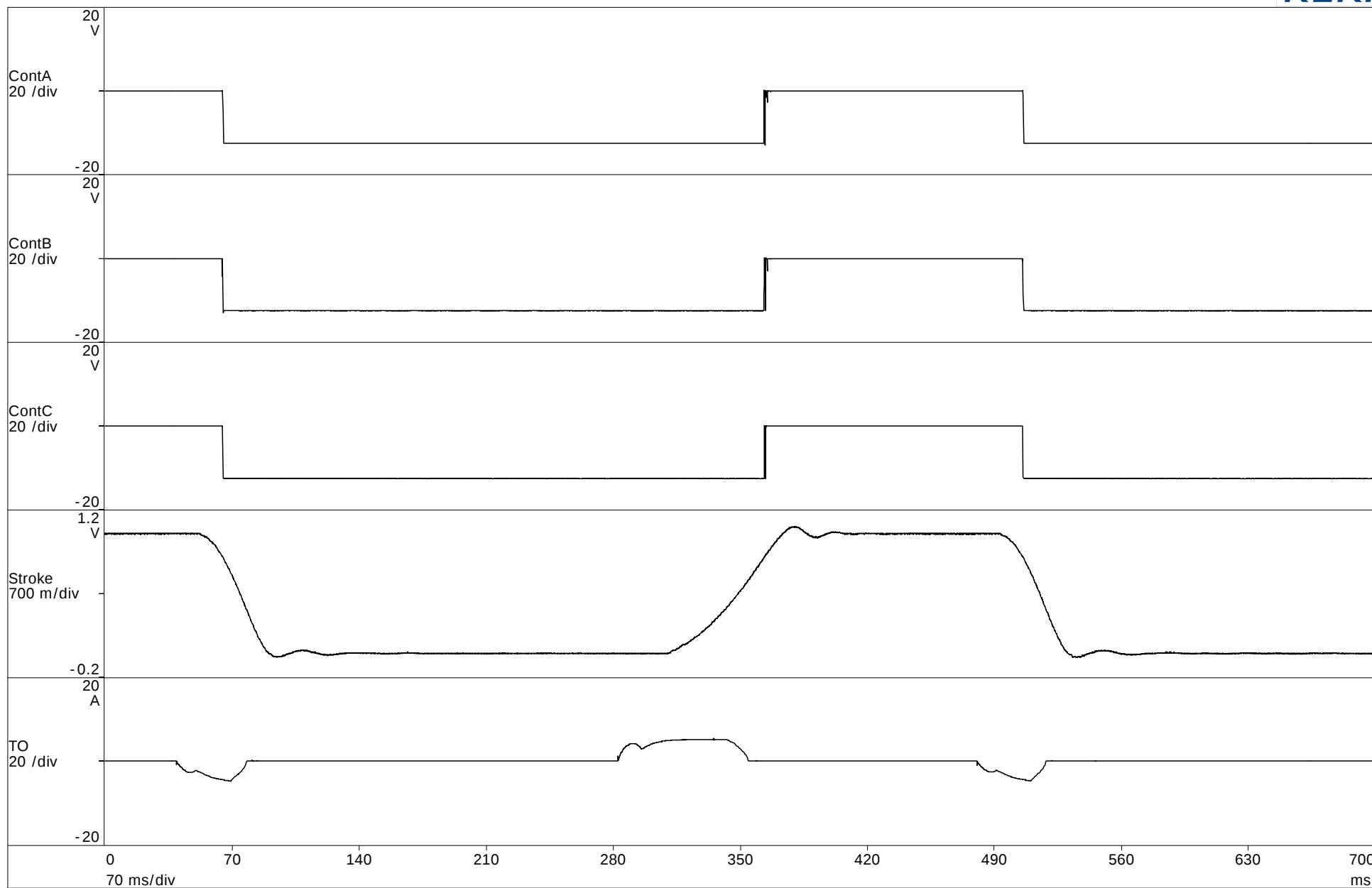
## HPC 1104 - 110



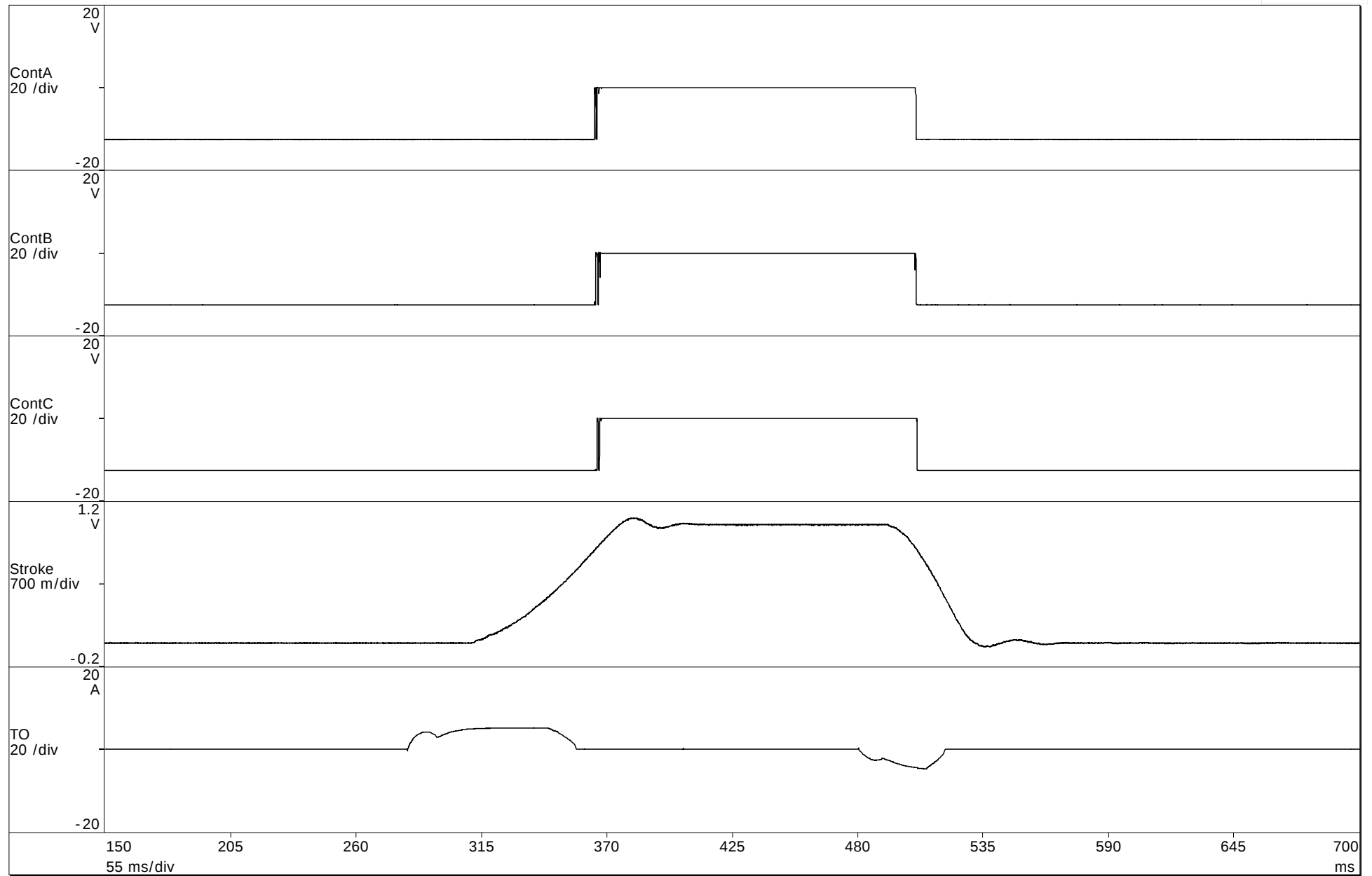
## HPC 1104 - 111



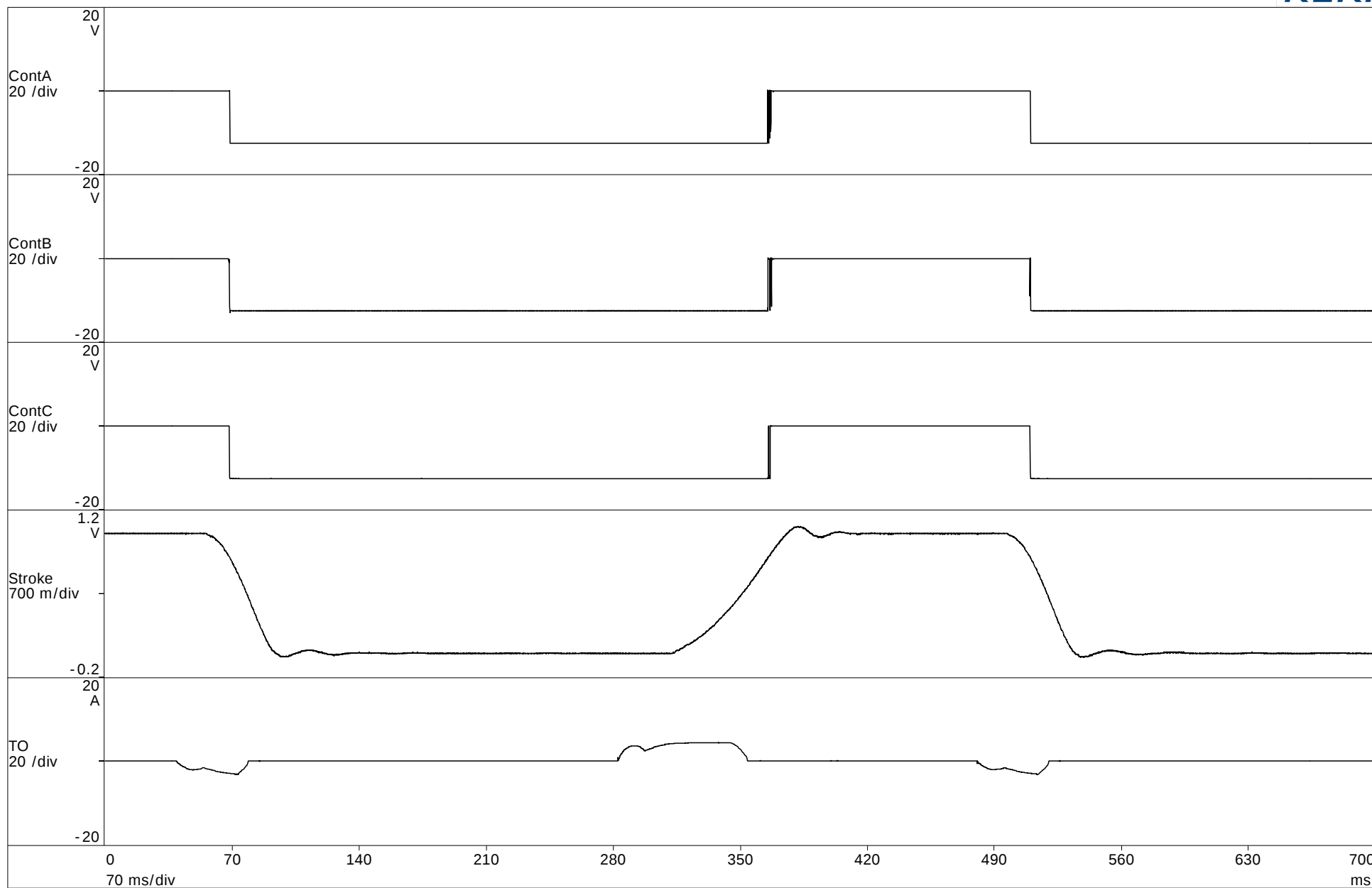
## HPC 1104 - 112



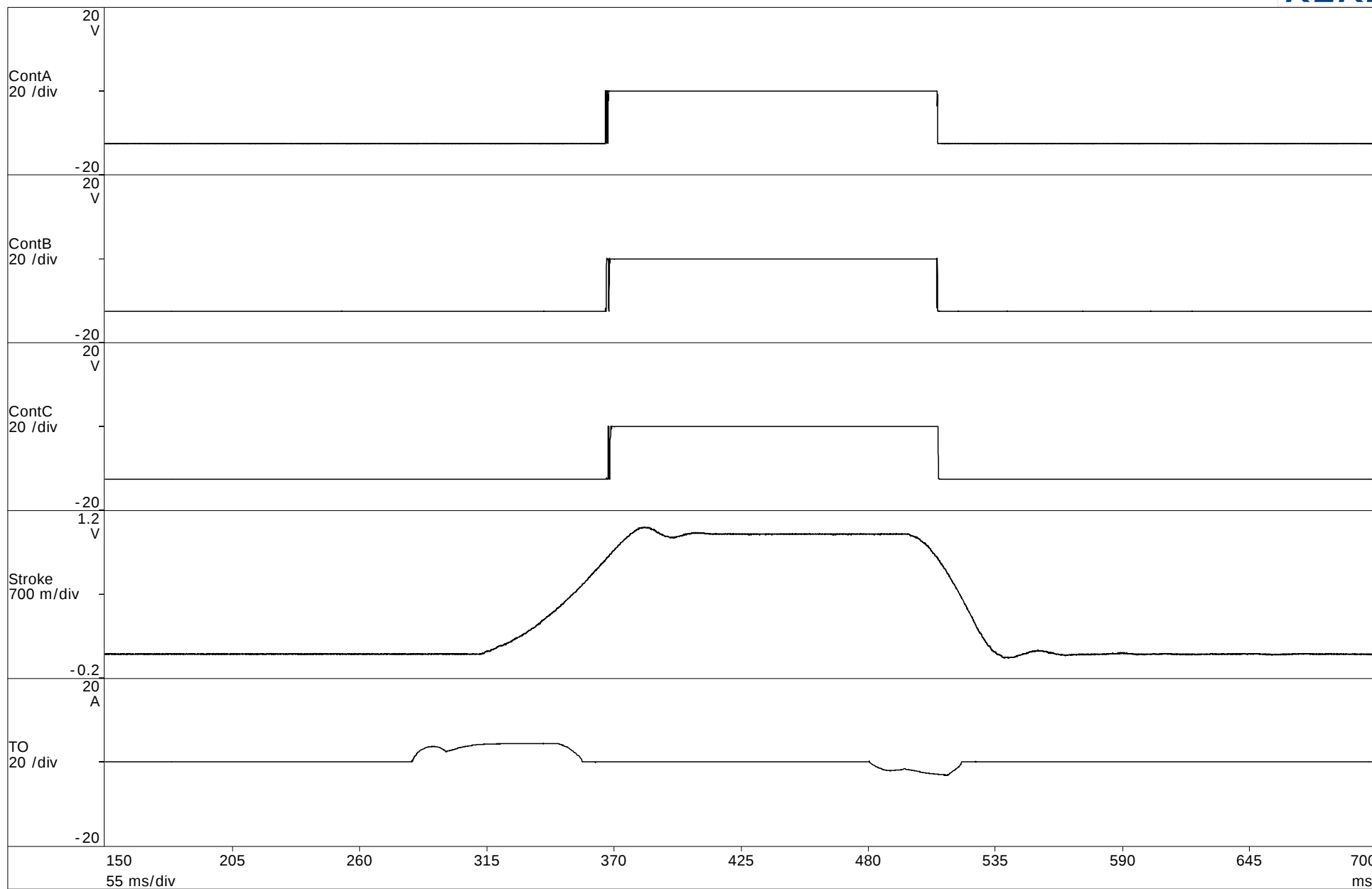
## HPC 1104 - 113



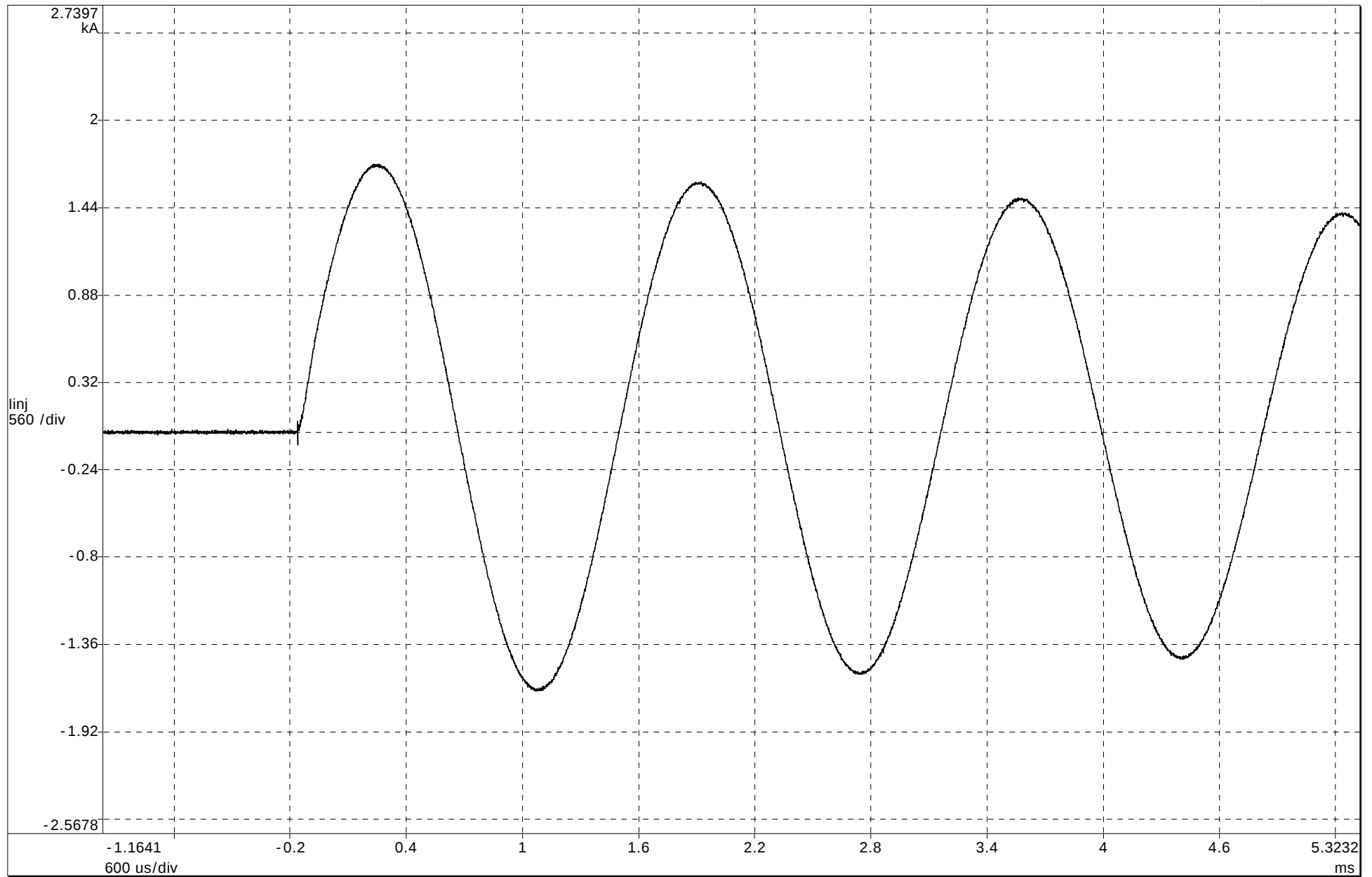
## HPC 1104 - 114



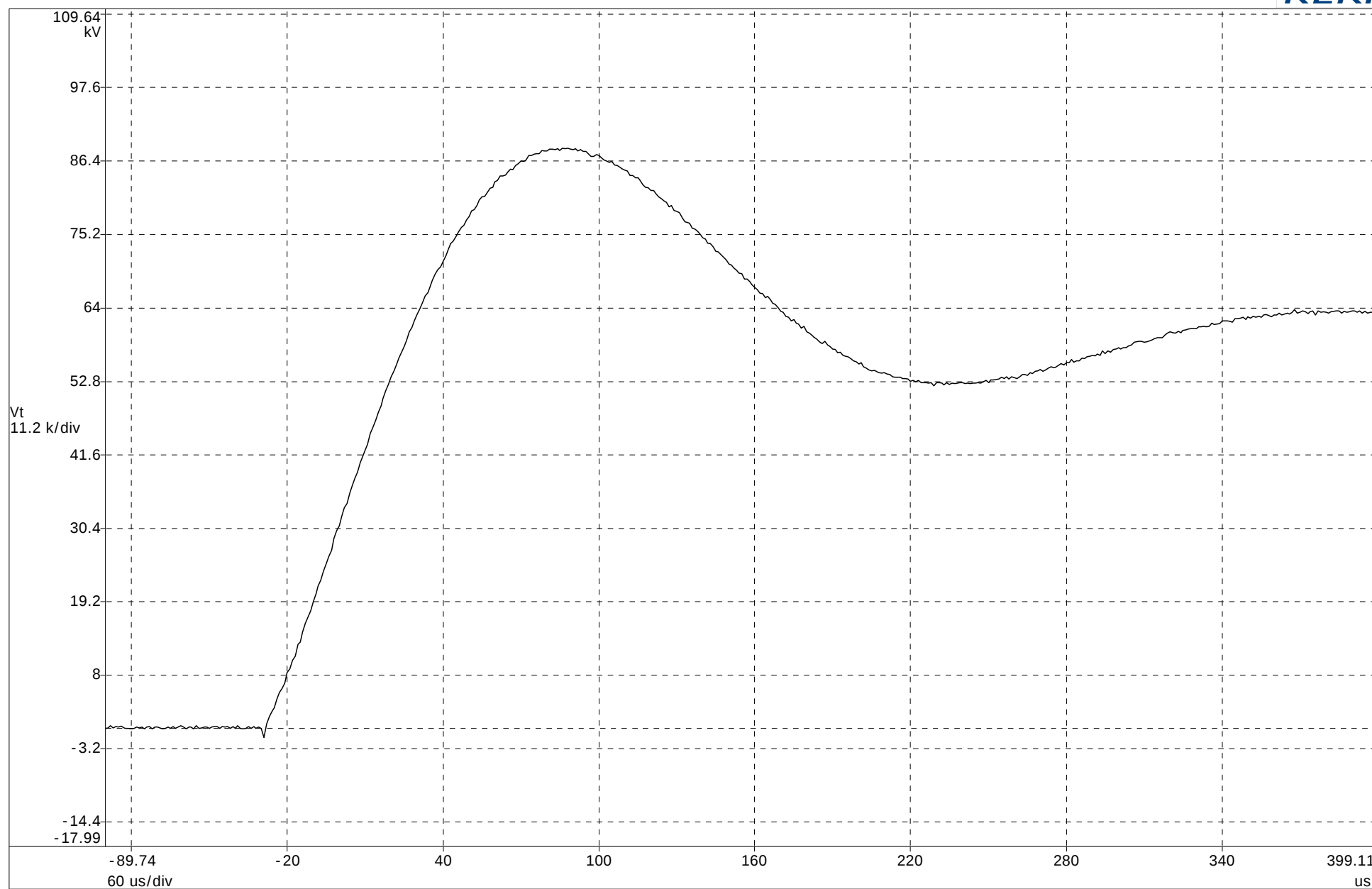
## HPC 1104 - 115



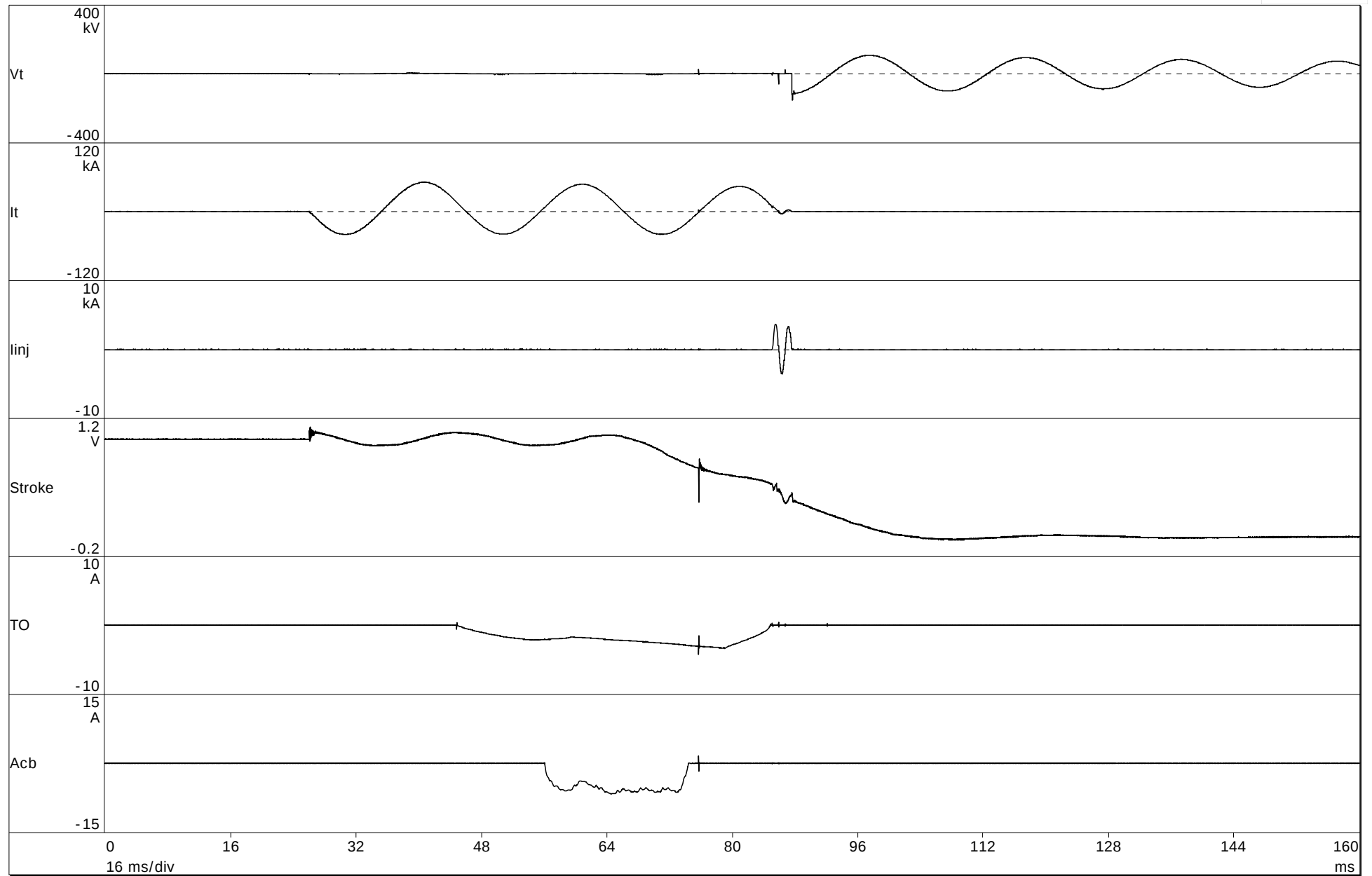
HPC 1104 - 116



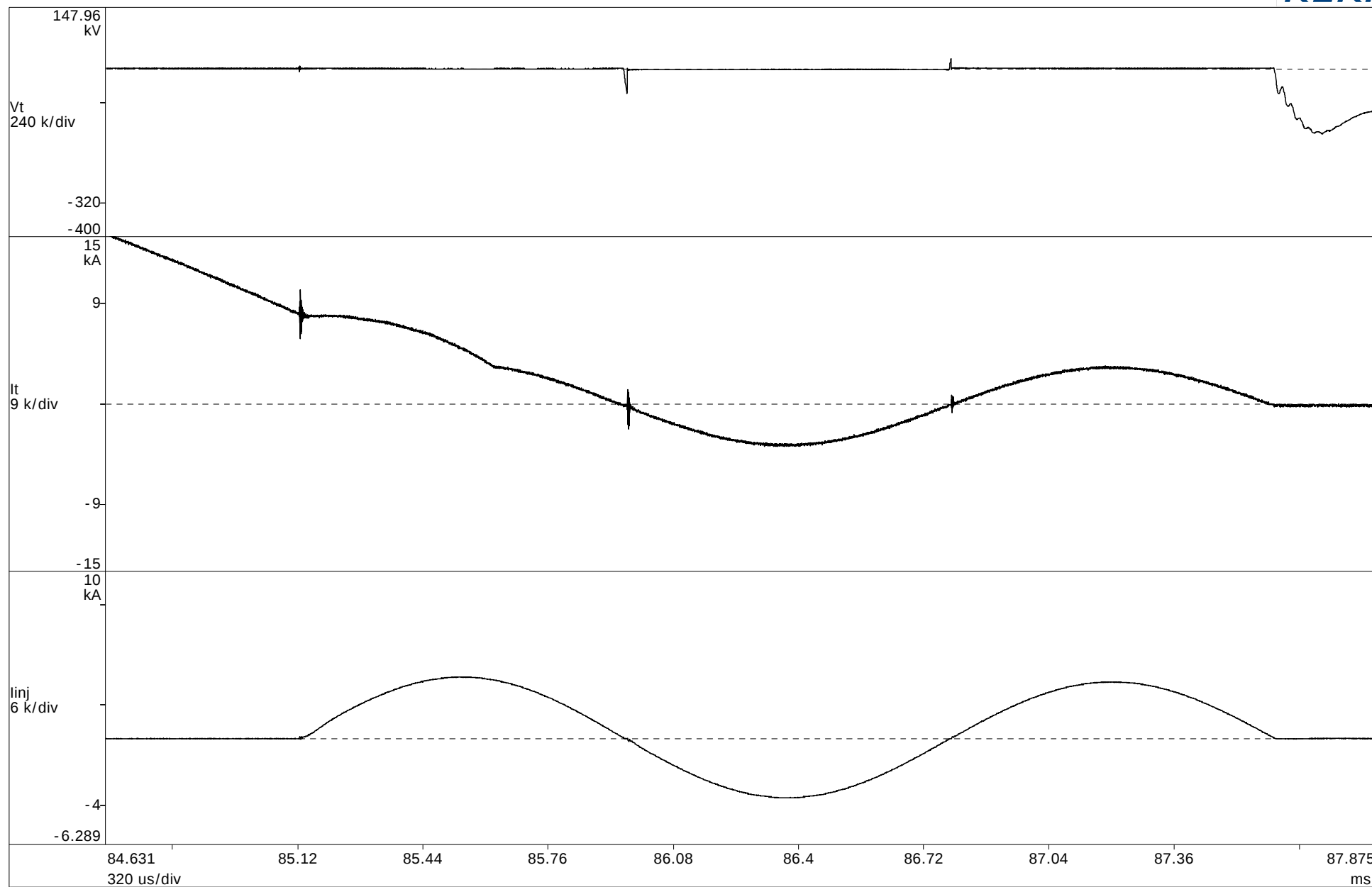
HPC 1104 - 119



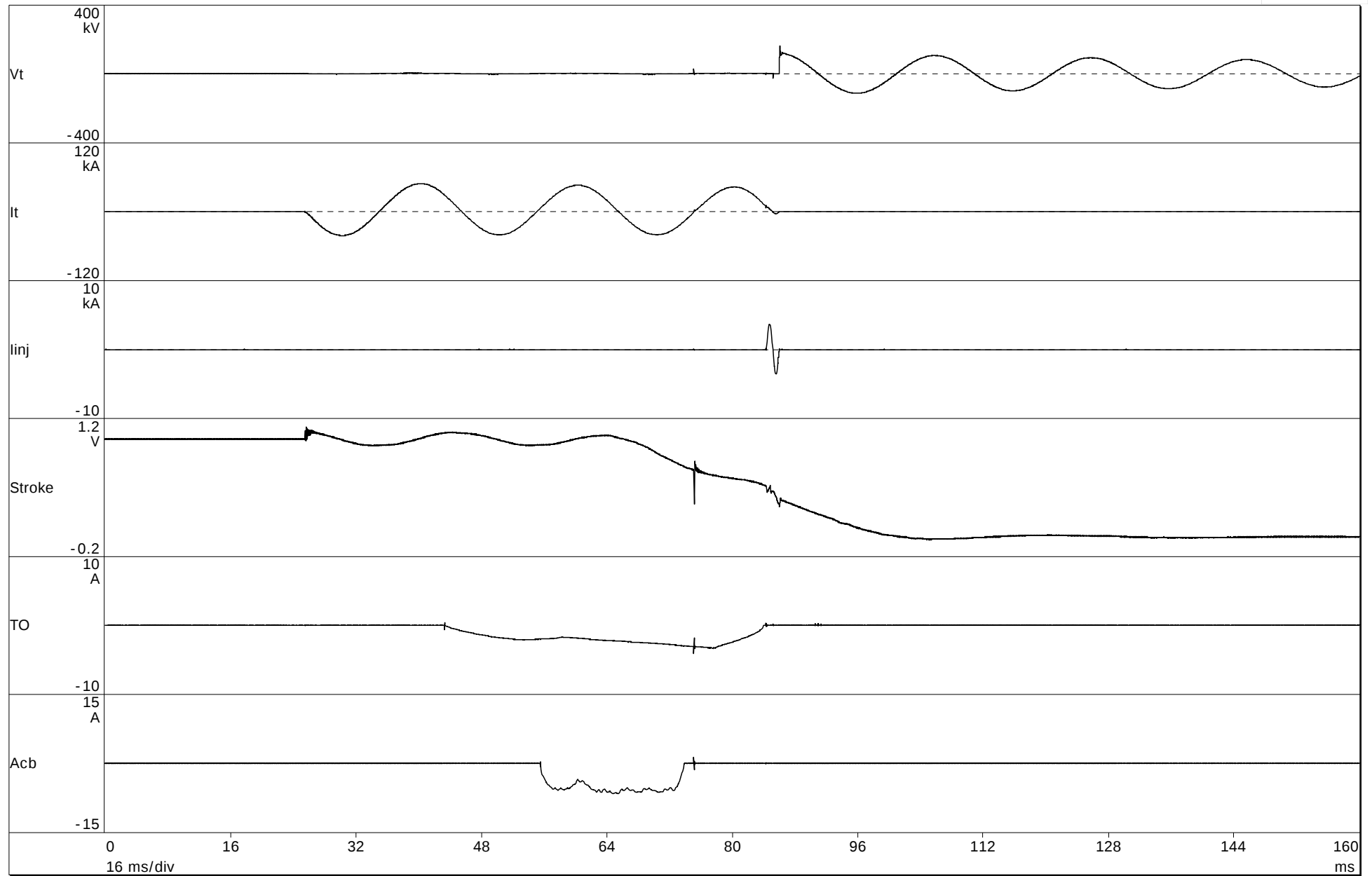
## HPC 1104 - 124



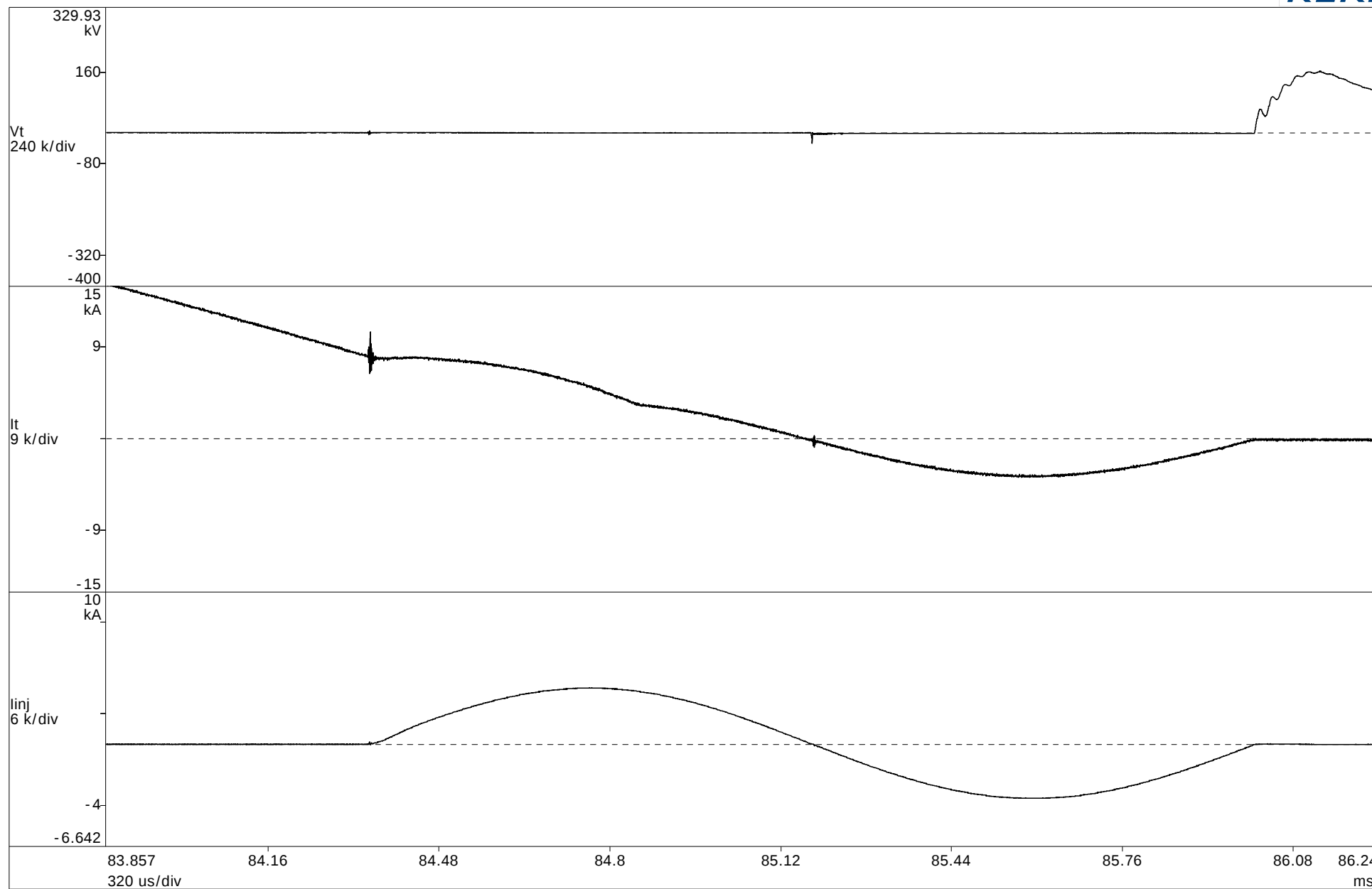
## HPC 1104 - 124



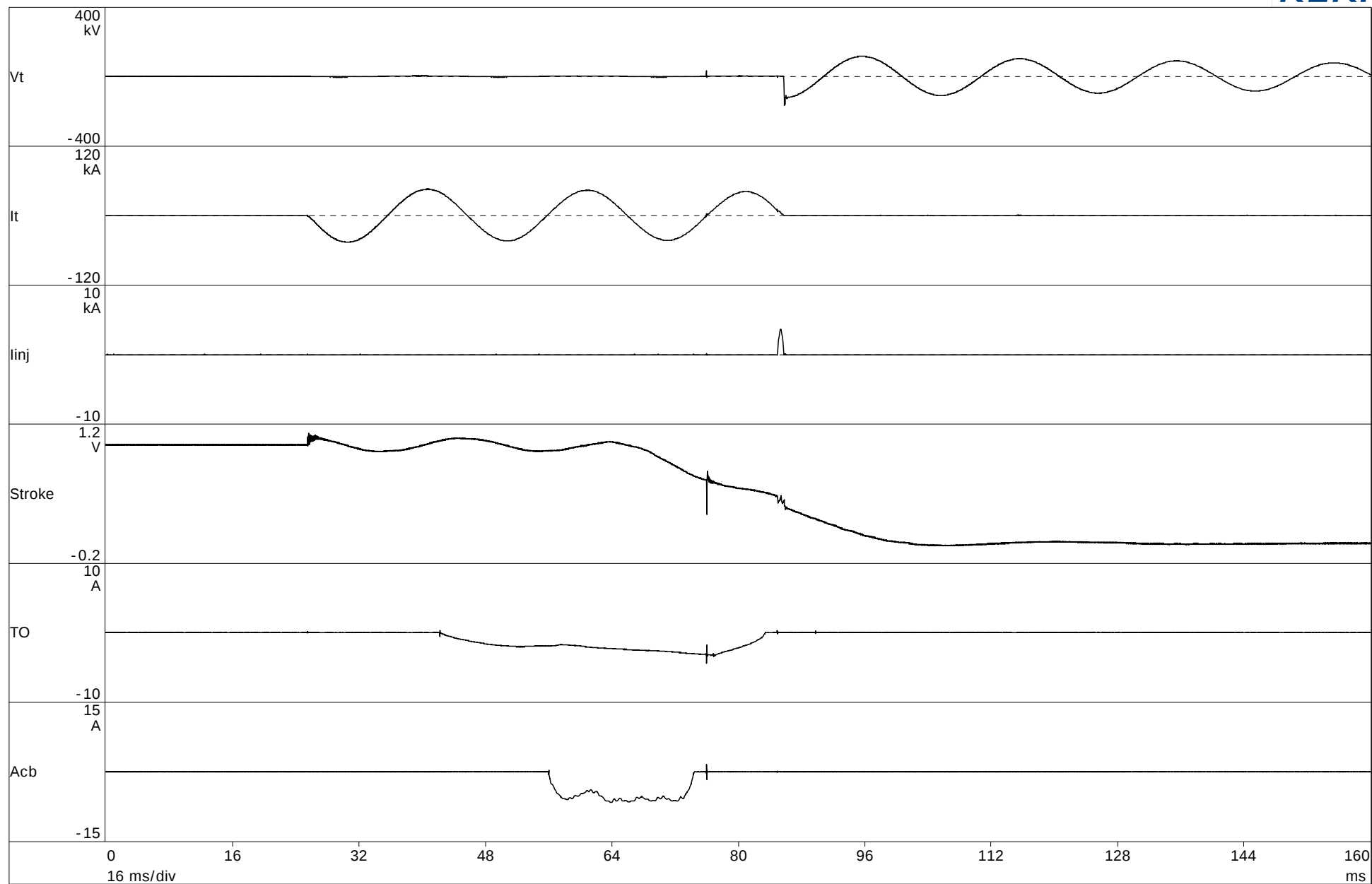
## HPC 1104 - 125



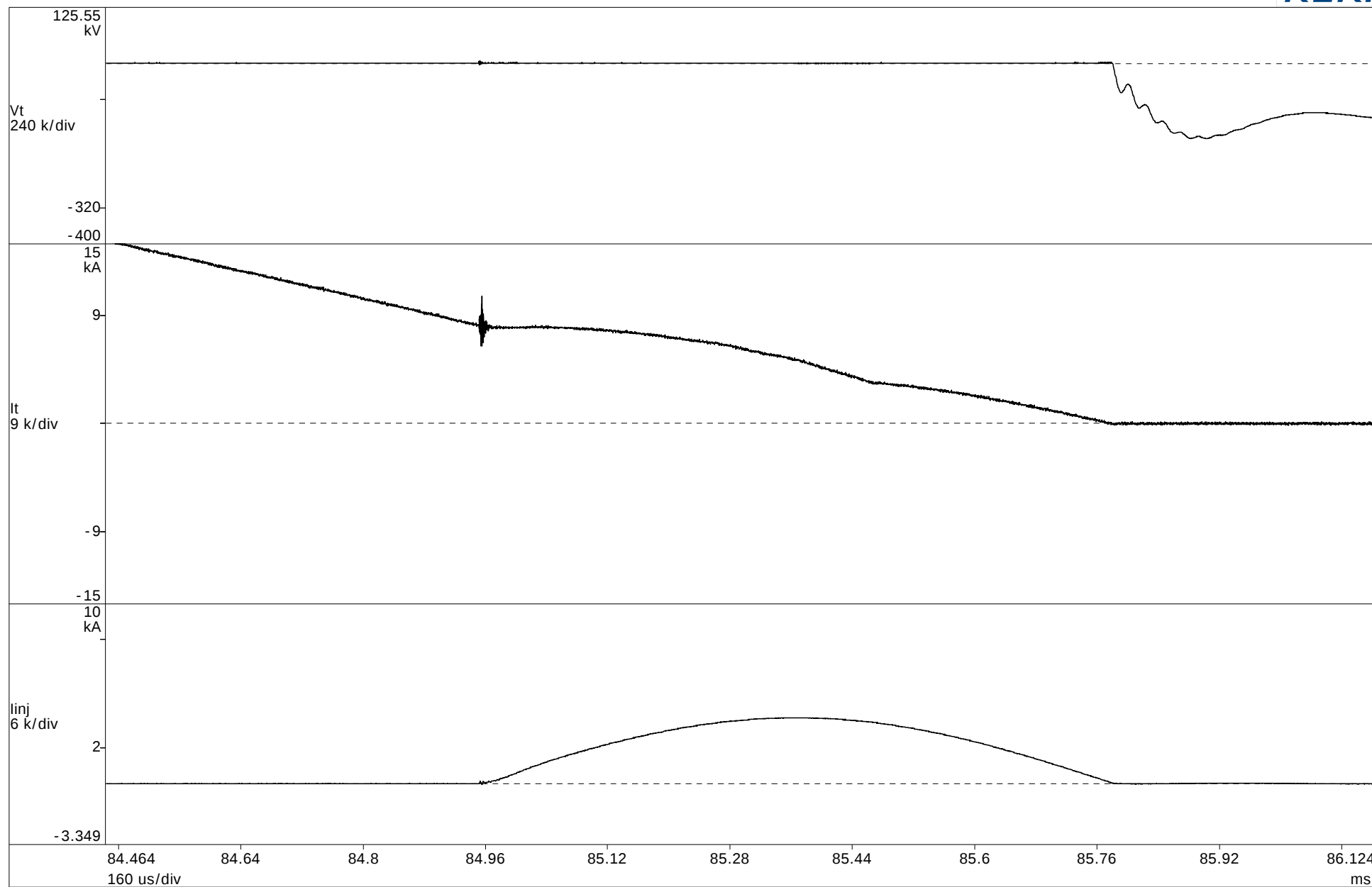
## HPC 1104 - 125



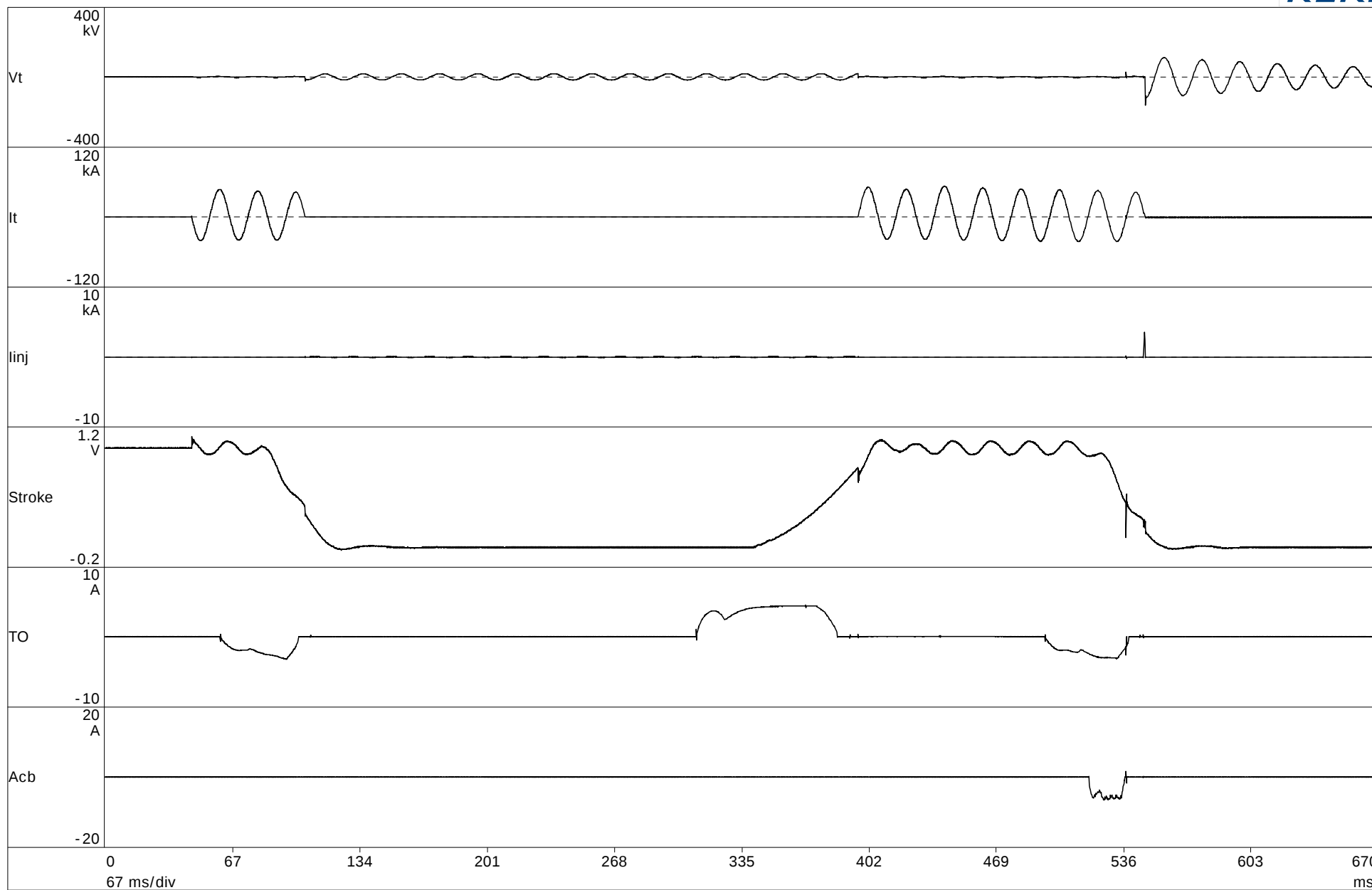
## HPC 1104 - 126



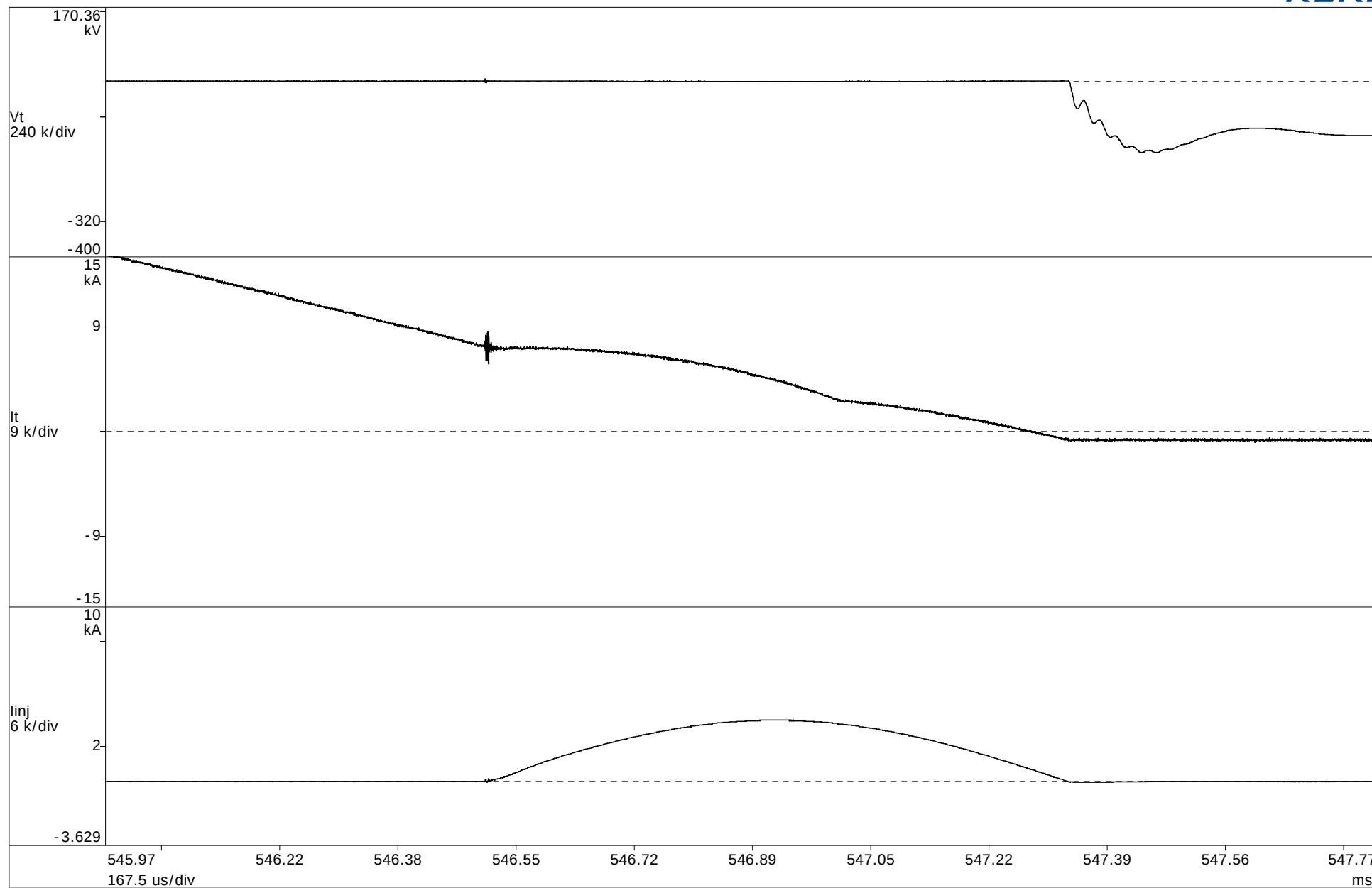
## HPC 1104 - 126



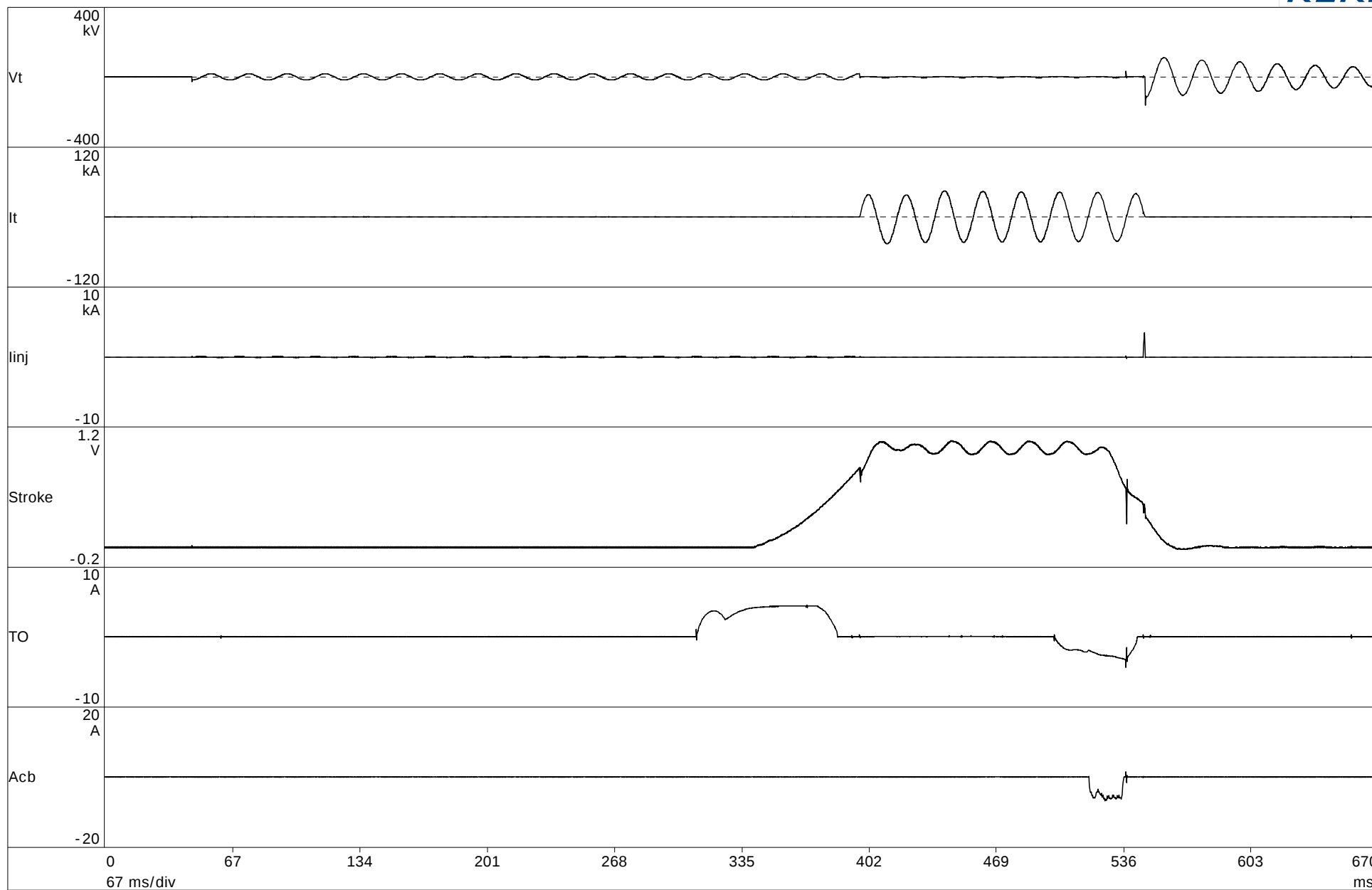
## HPC 1104 - 130



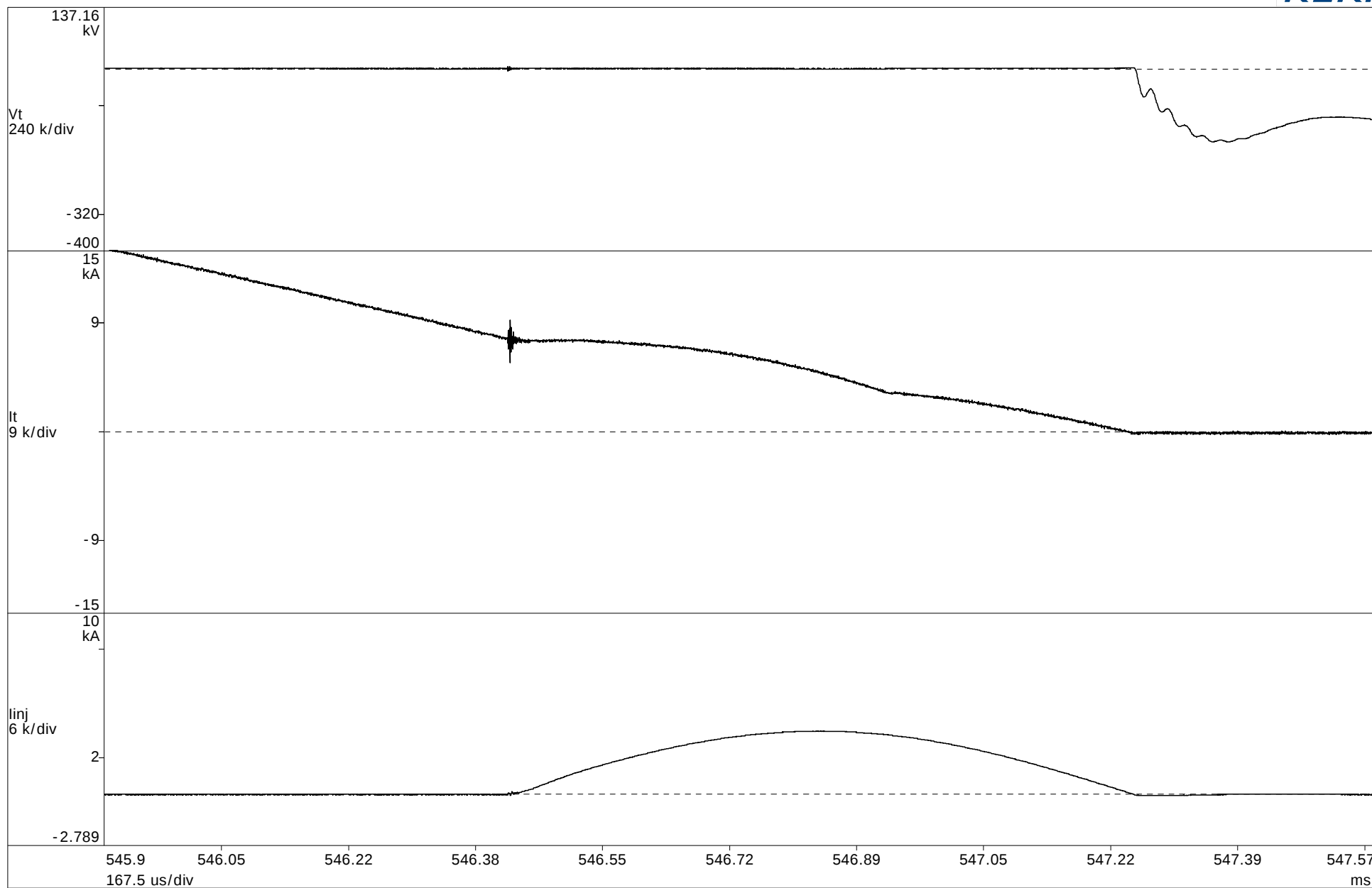
## HPC 1104 - 130



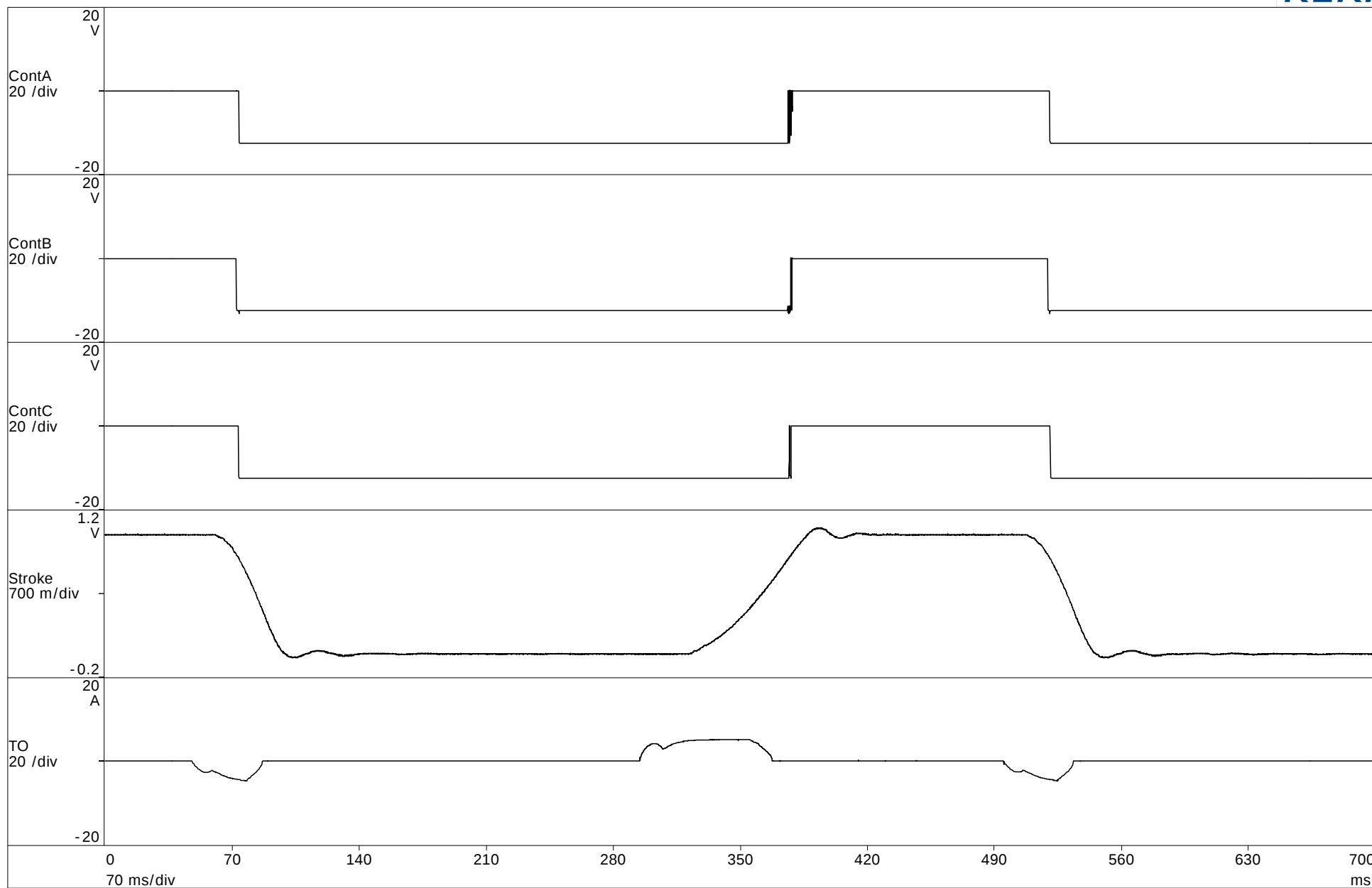
## HPC 1104 - 131



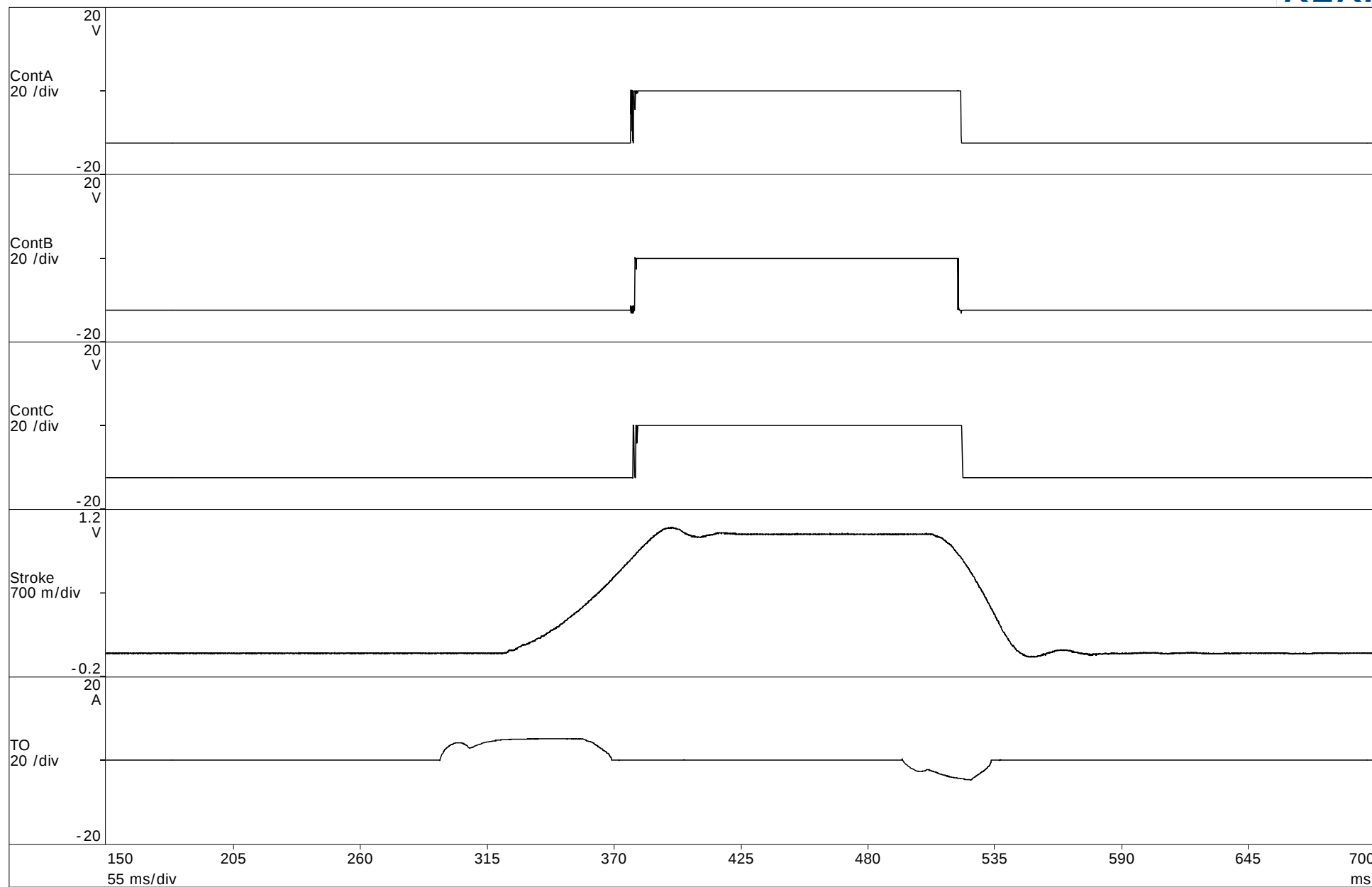
## HPC 1104 - 131



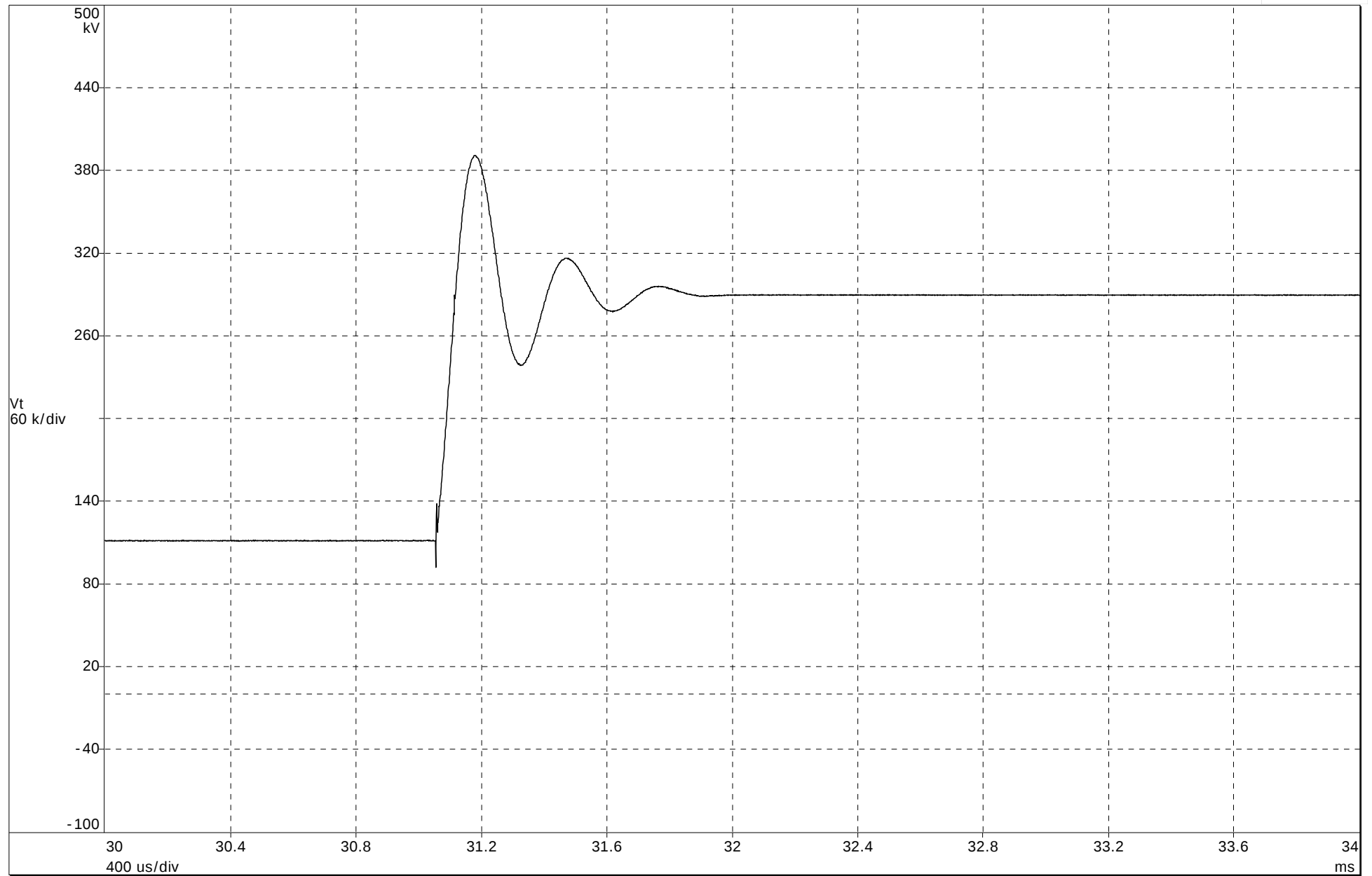
## HPC 1104 - 132



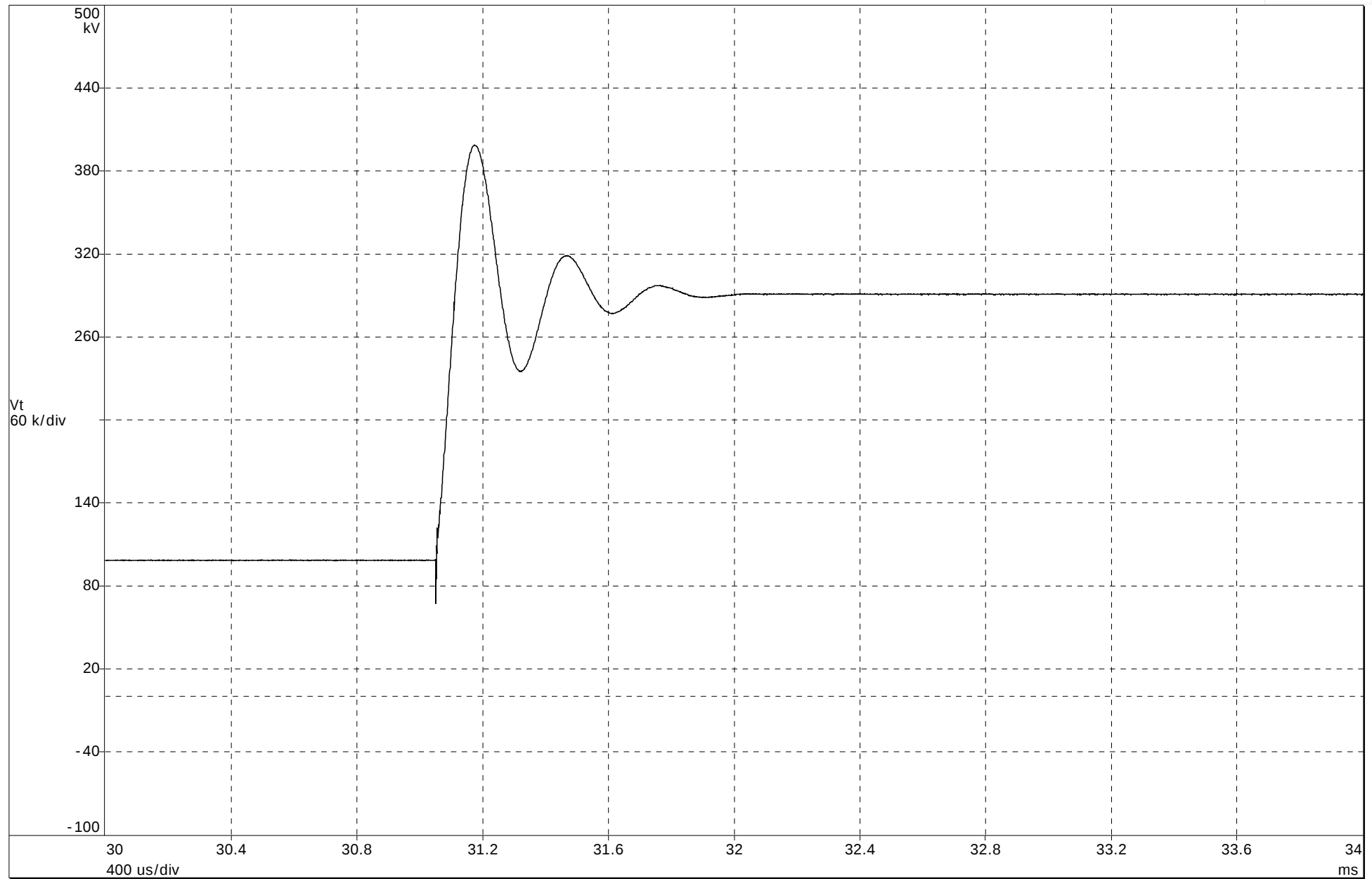
## HPC 1104 - 133



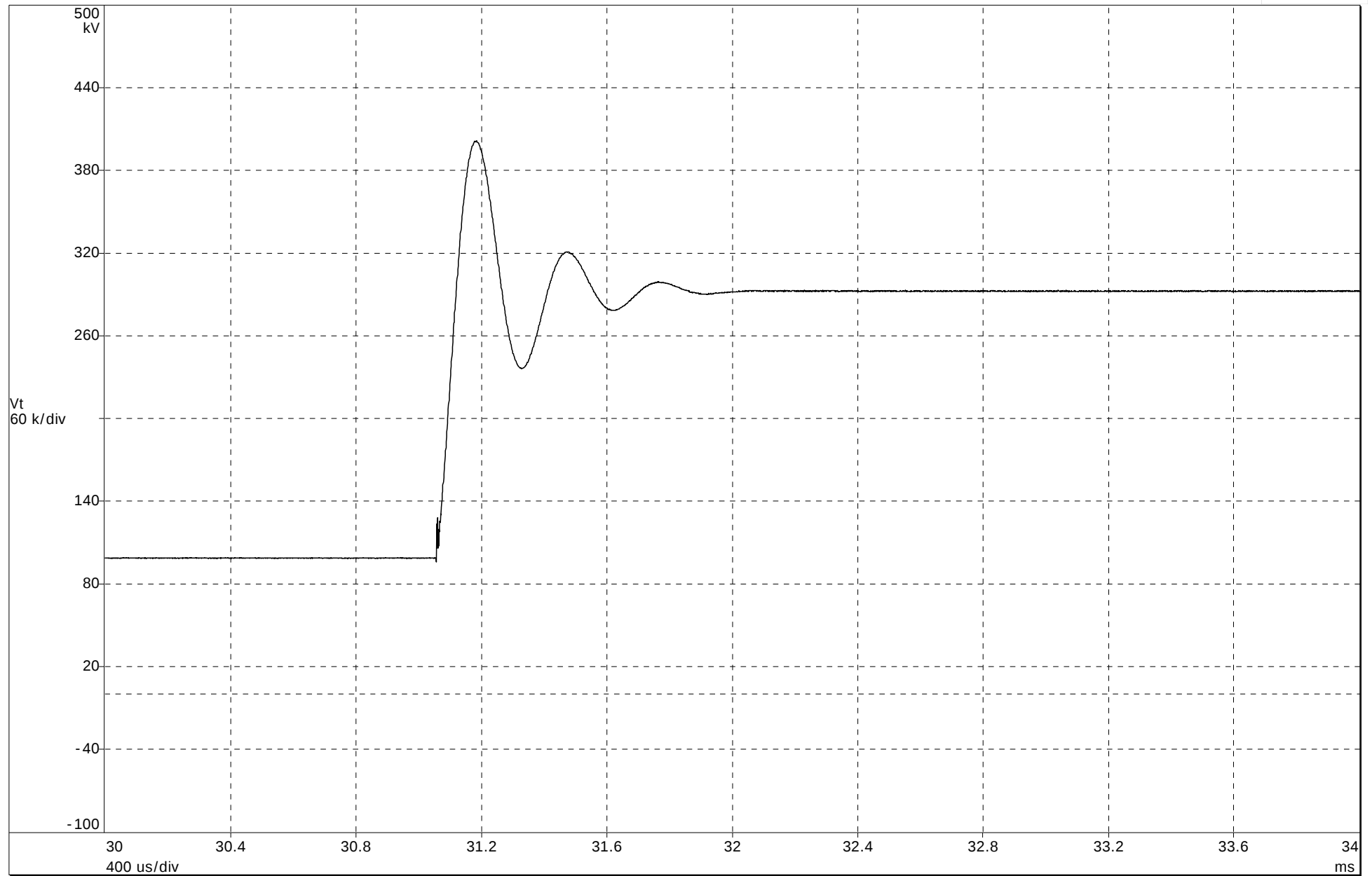
HPC 1104 - 144



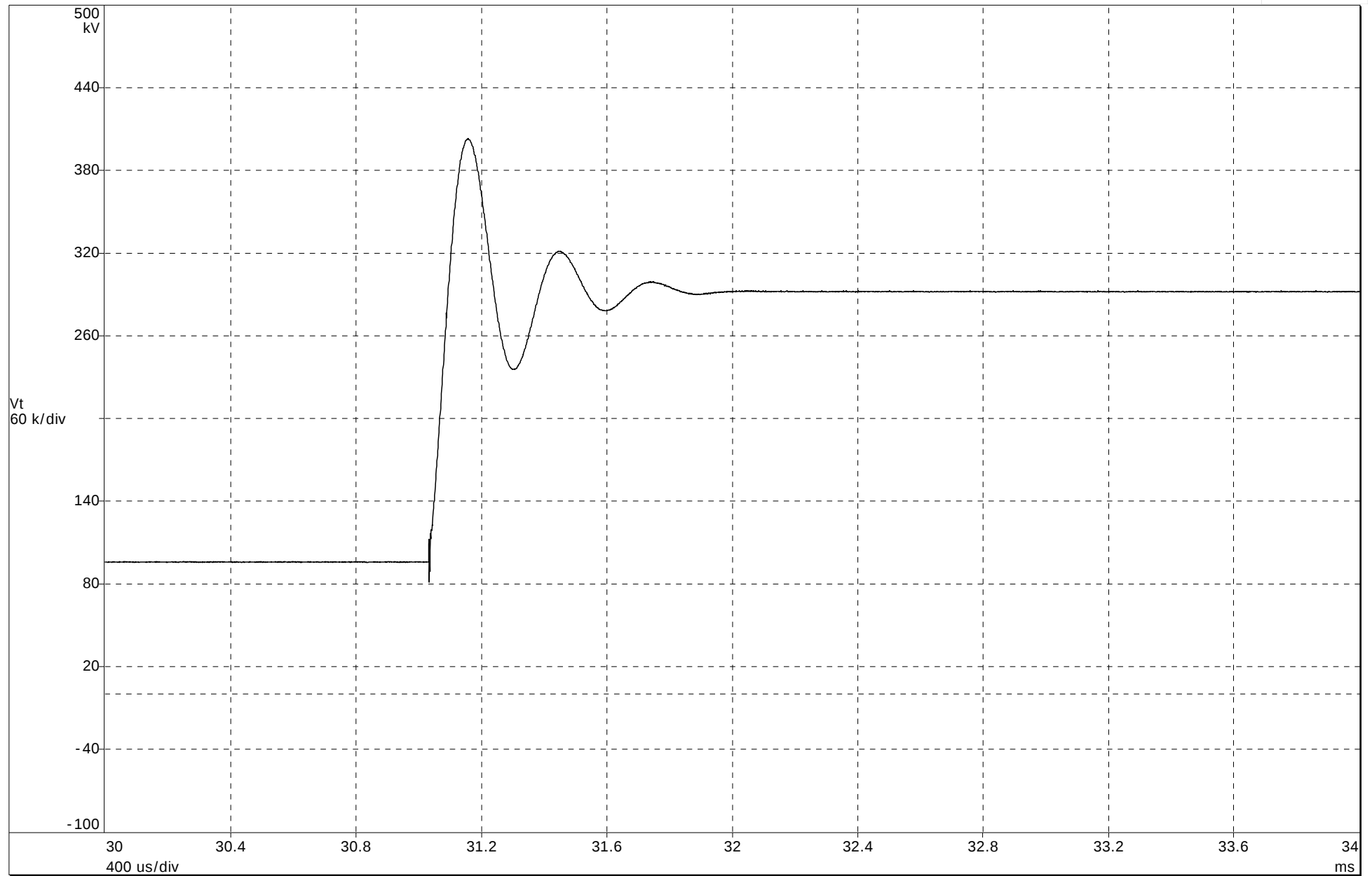
HPC 1104 - 145



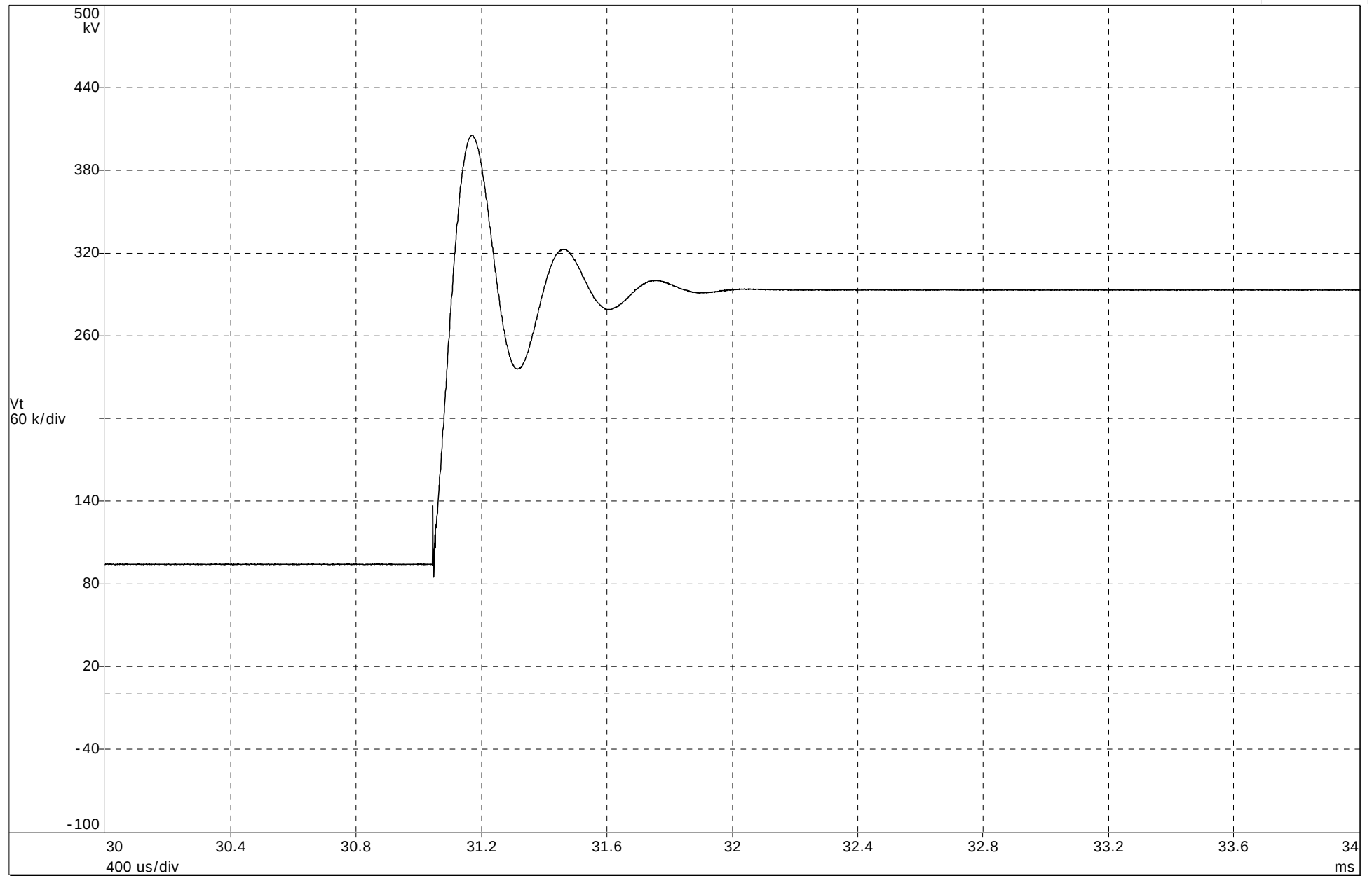
HPC 1104 - 146



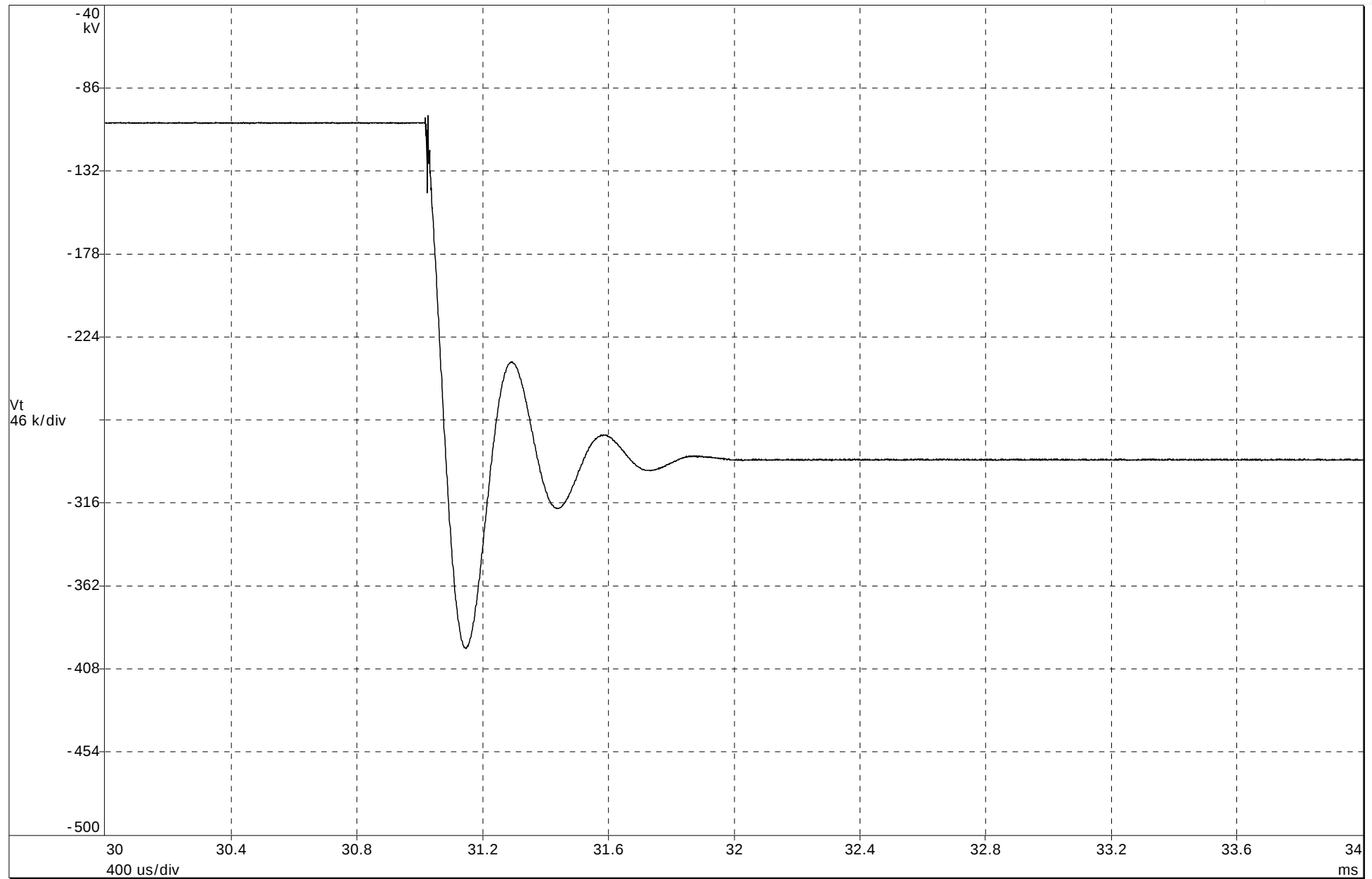
HPC 1104 - 147



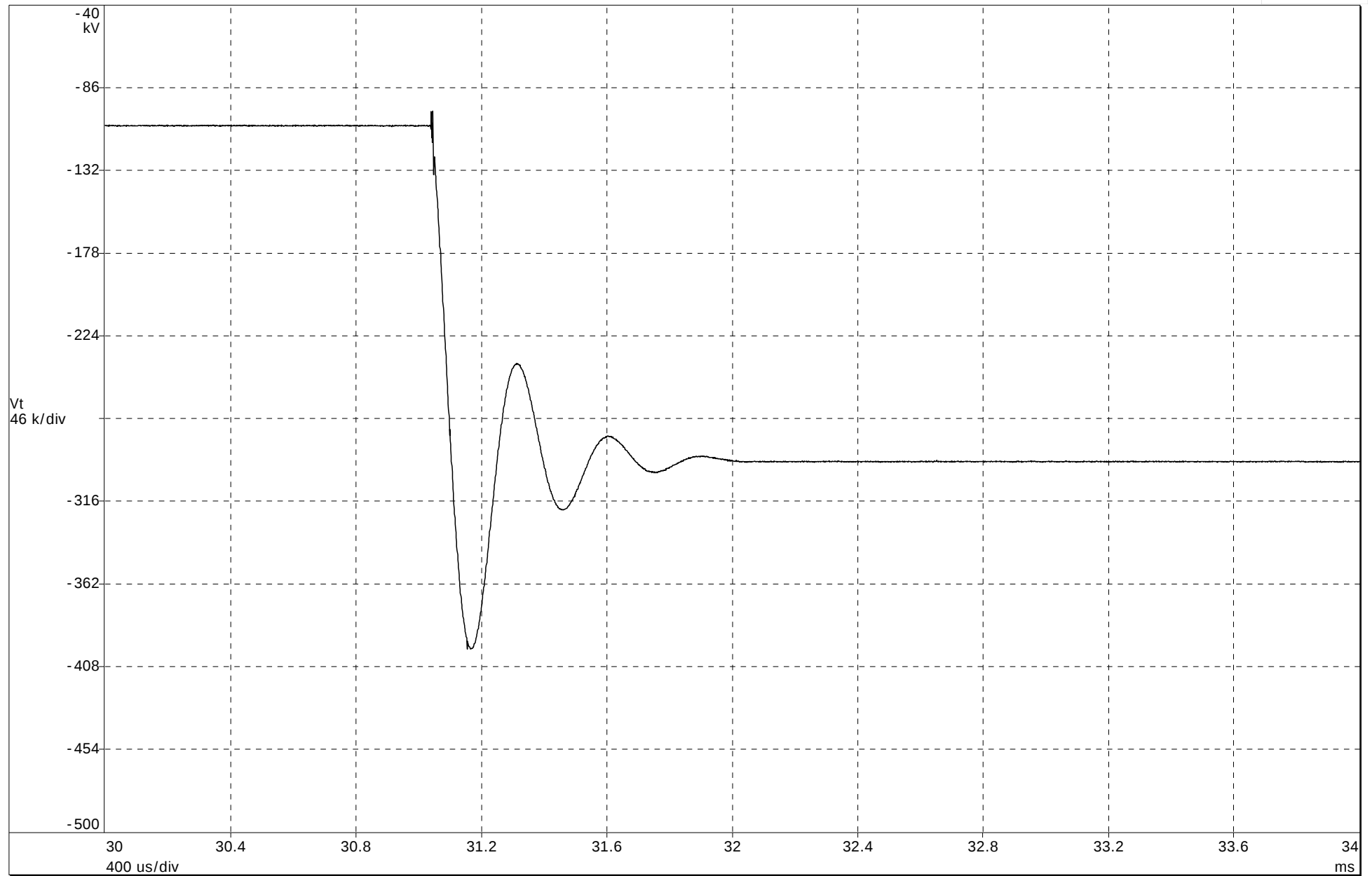
HPC 1104 - 148



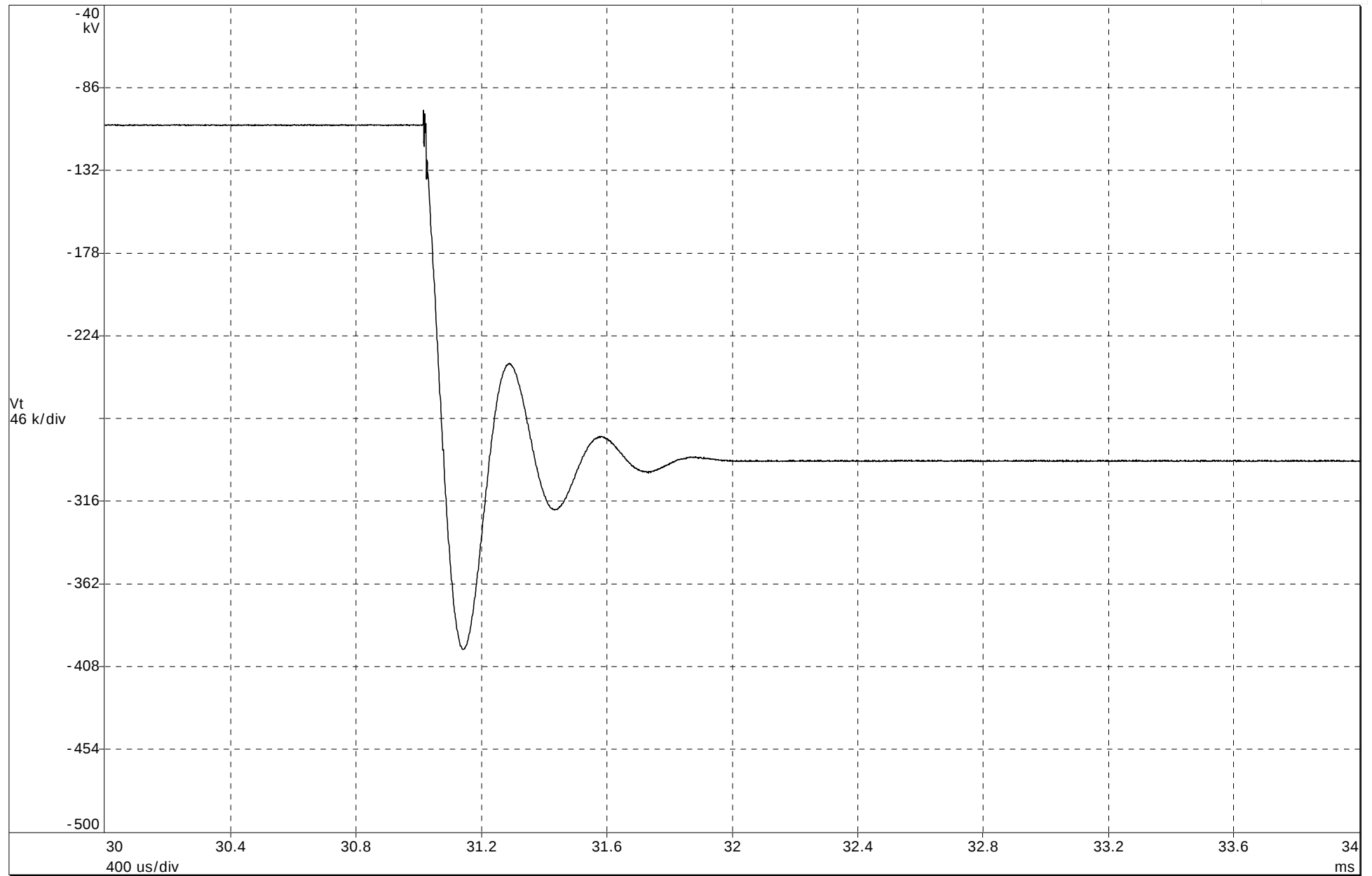
HPC 1104 - 149



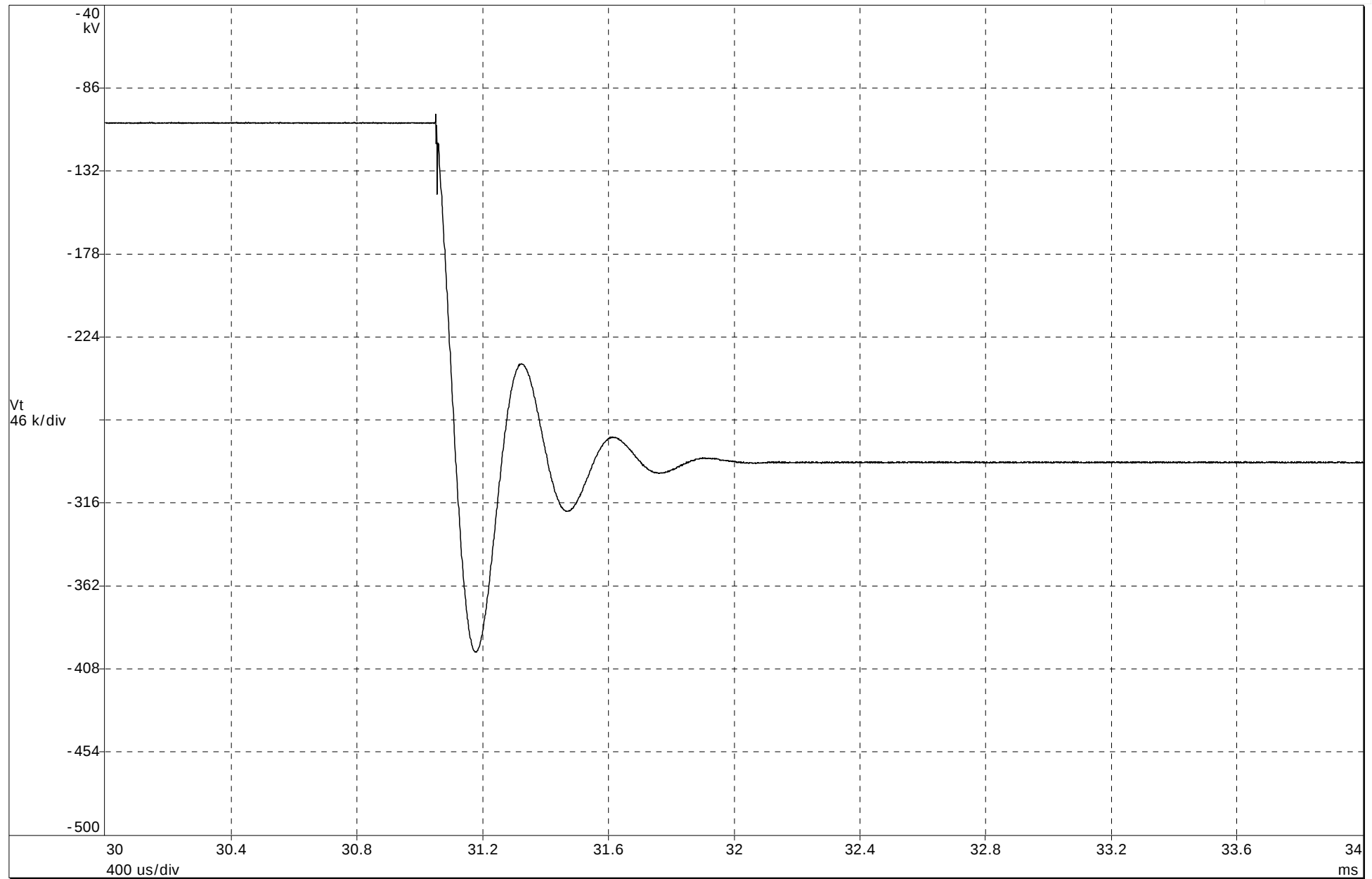
HPC 1104 - 150



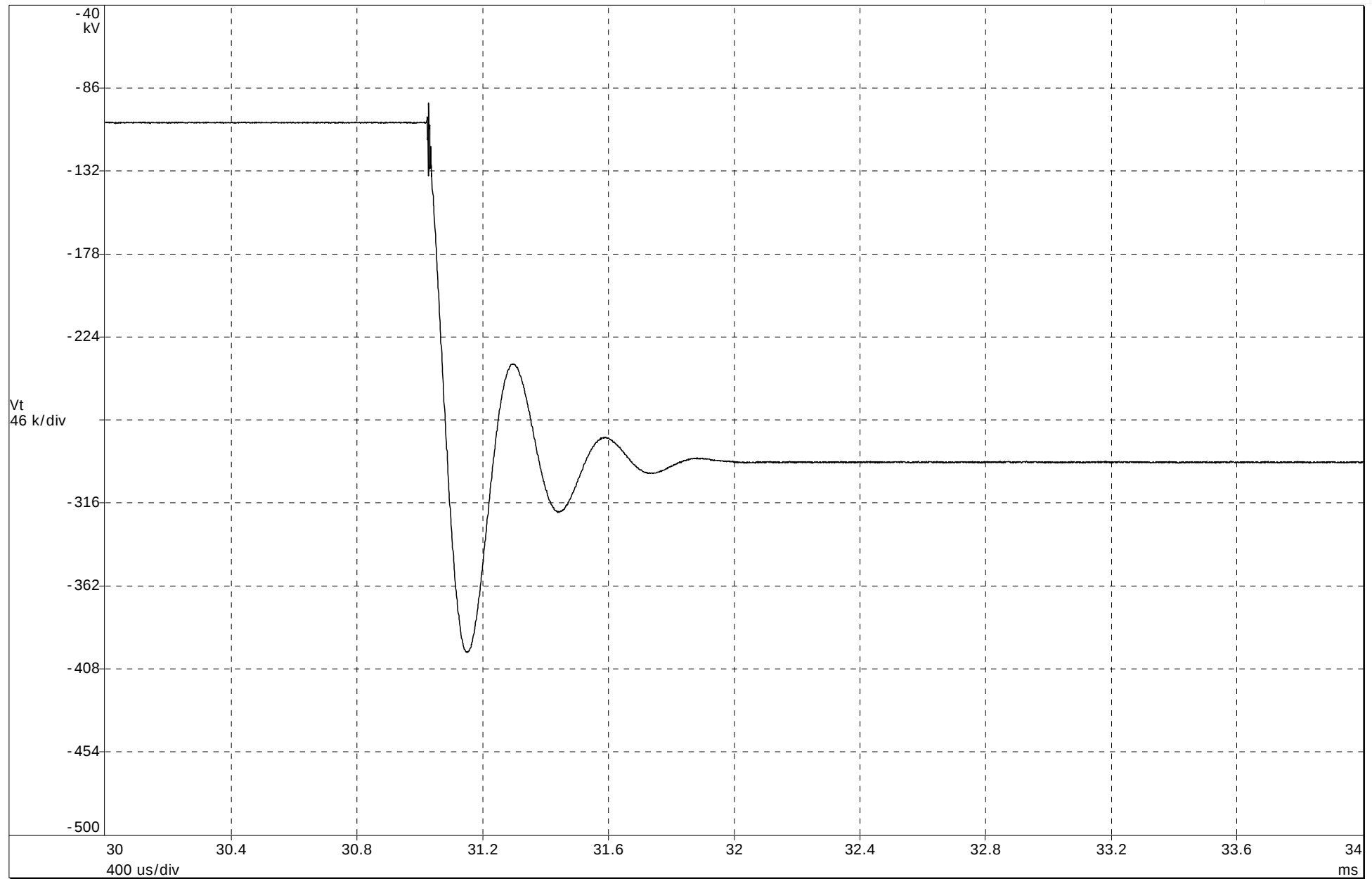
HPC 1104 - 151



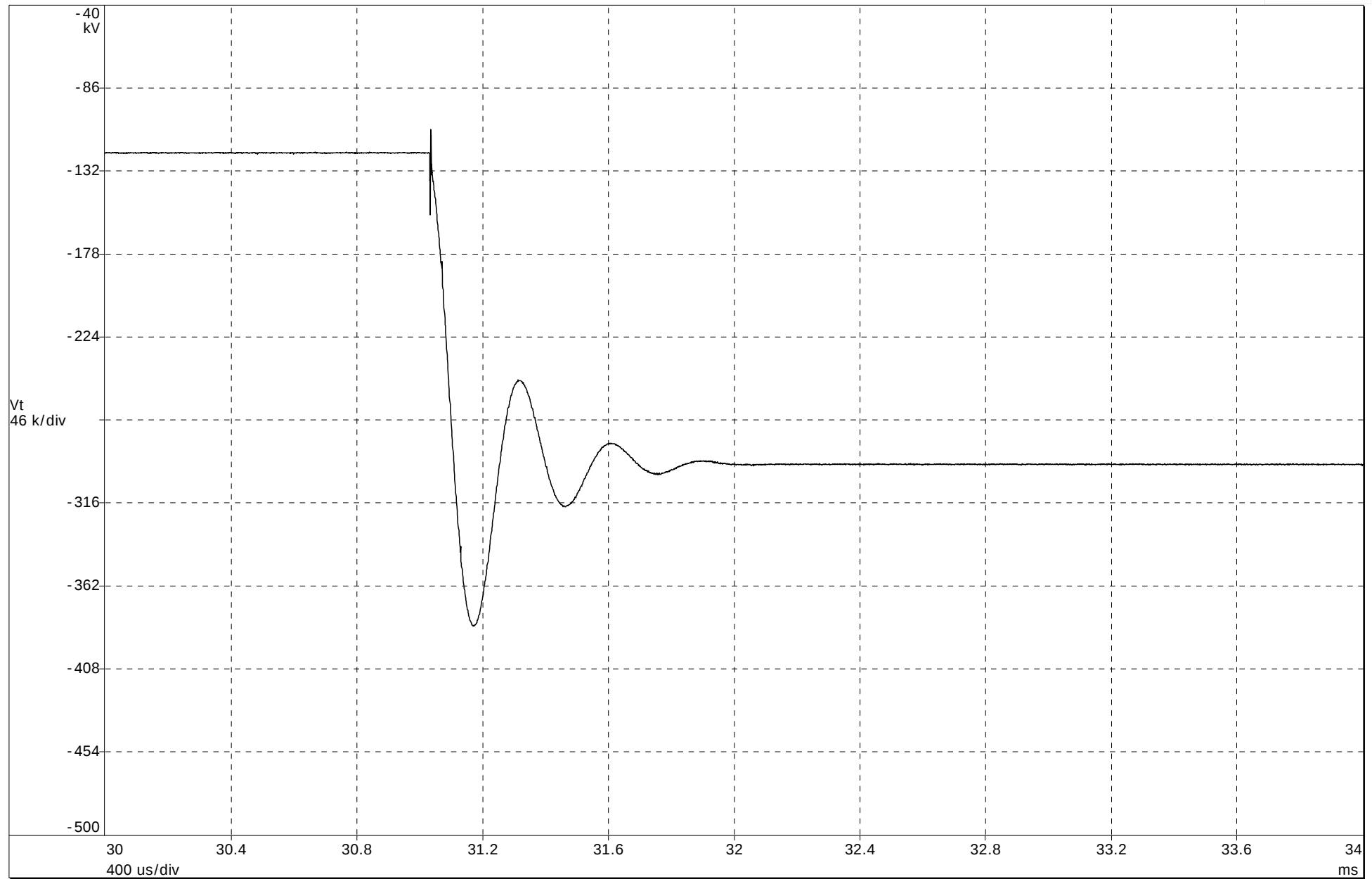
HPC 1104 - 152



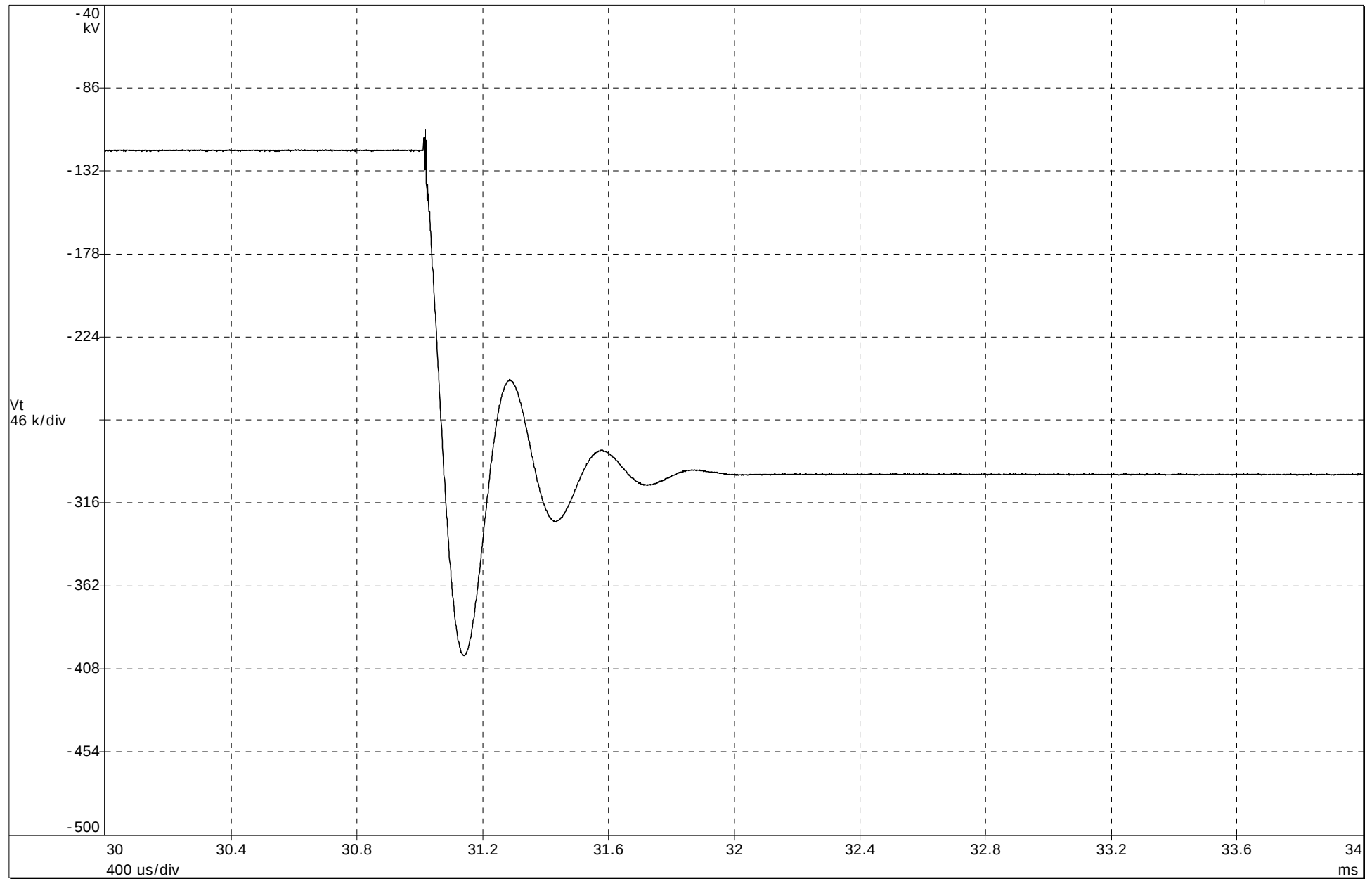
HPC 1104 - 153



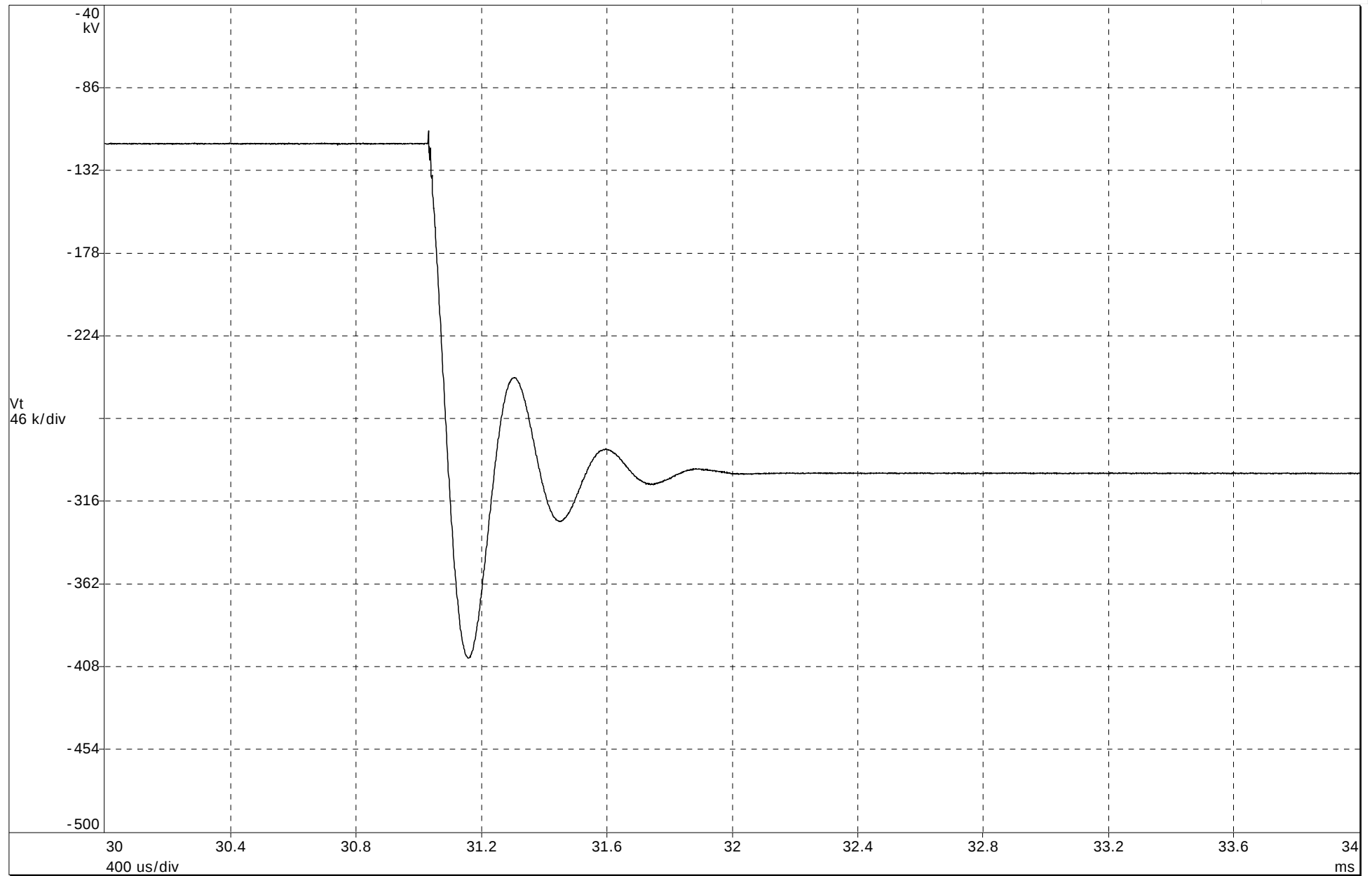
HPC 1104 - 154



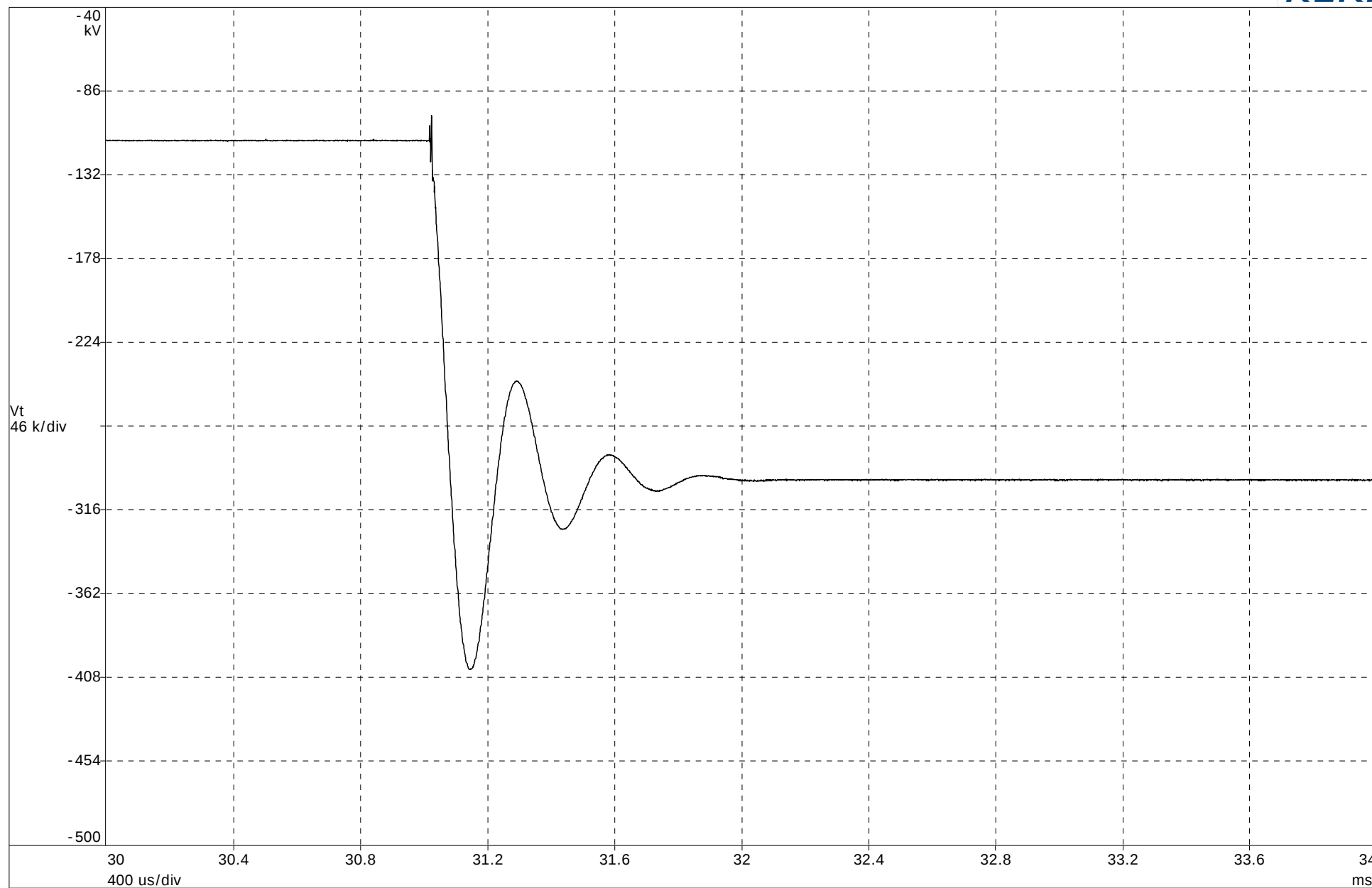
HPC 1104 - 155



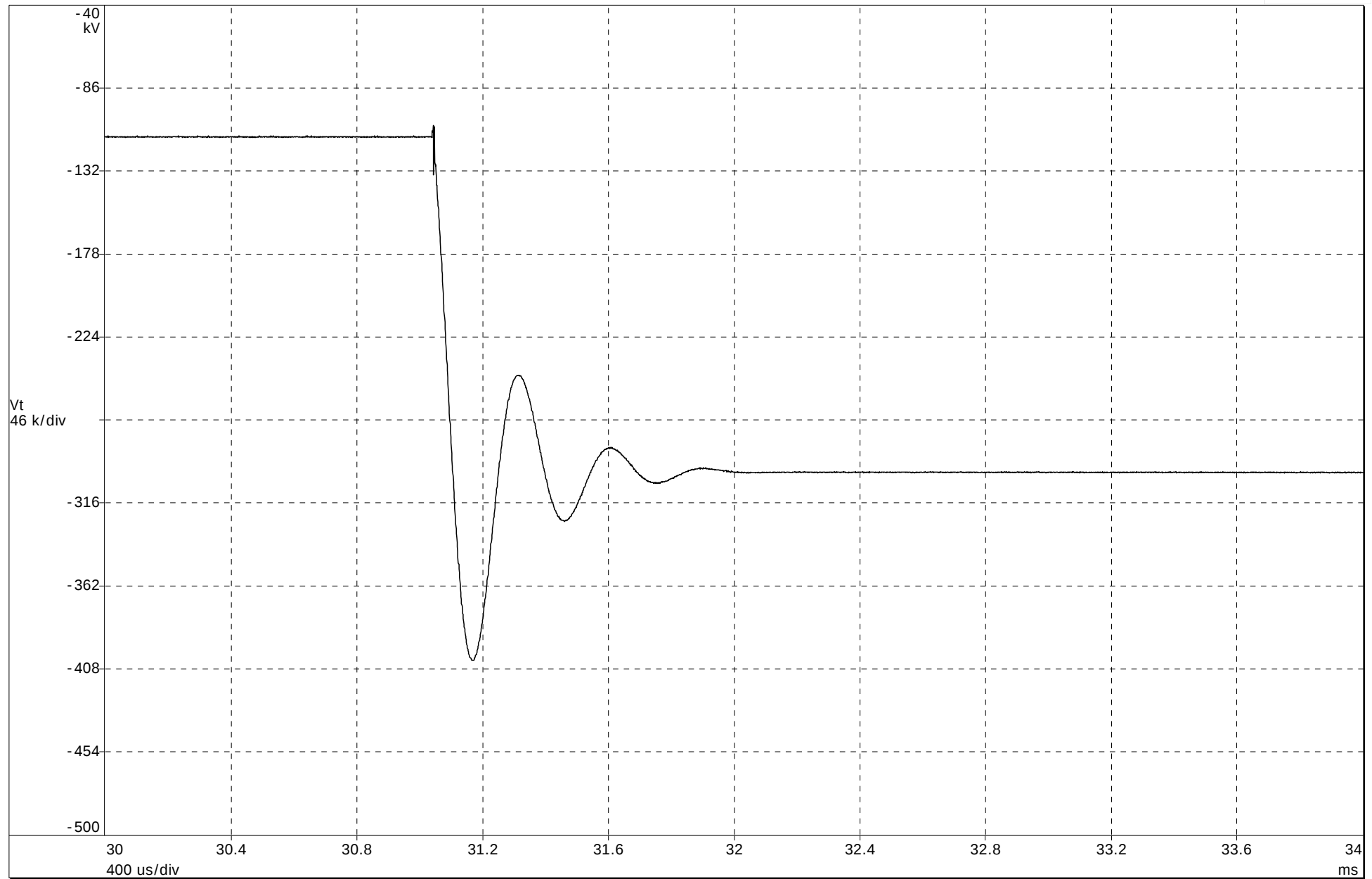
HPC 1104 - 156



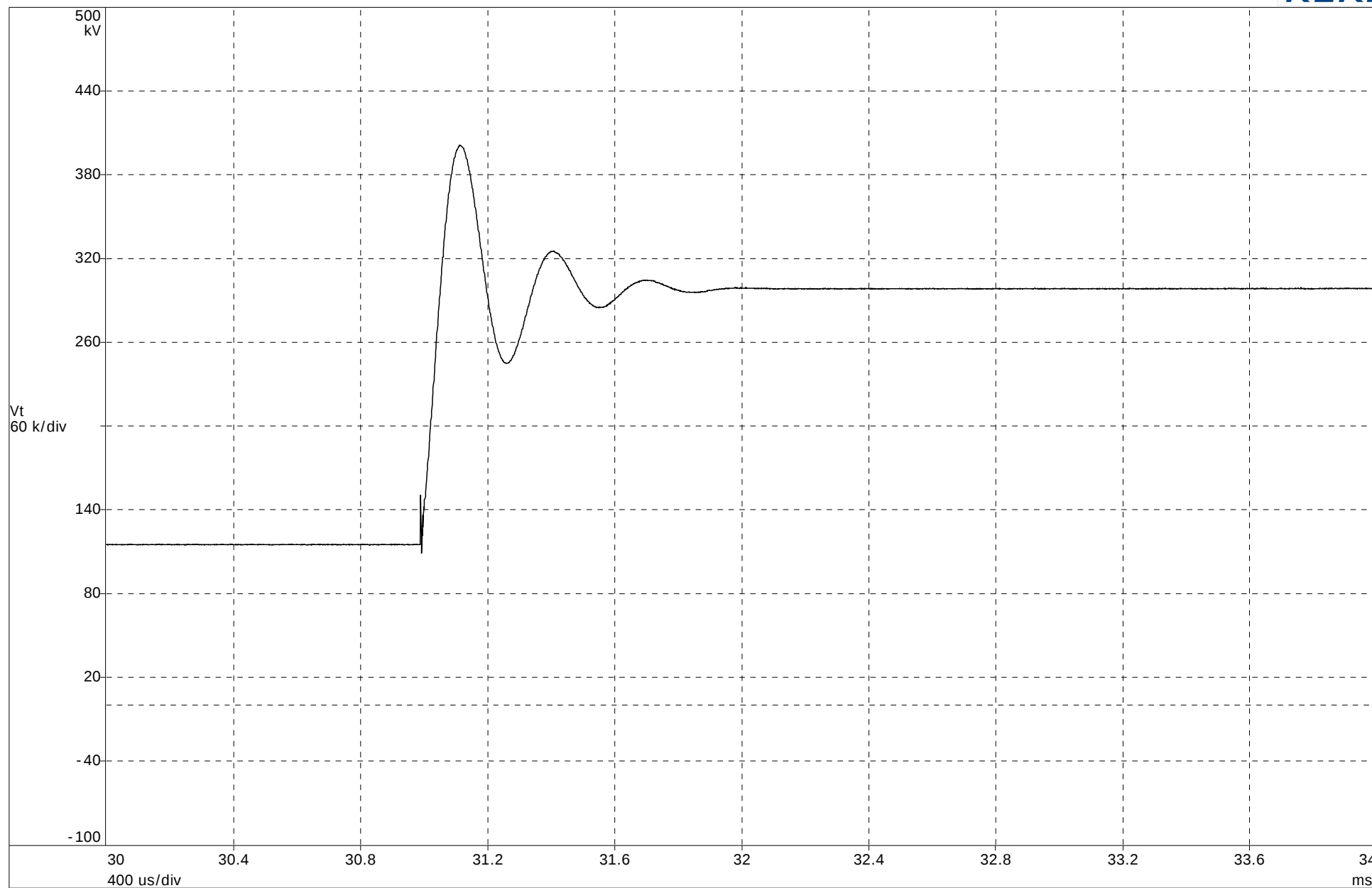
HPC 1104 - 157



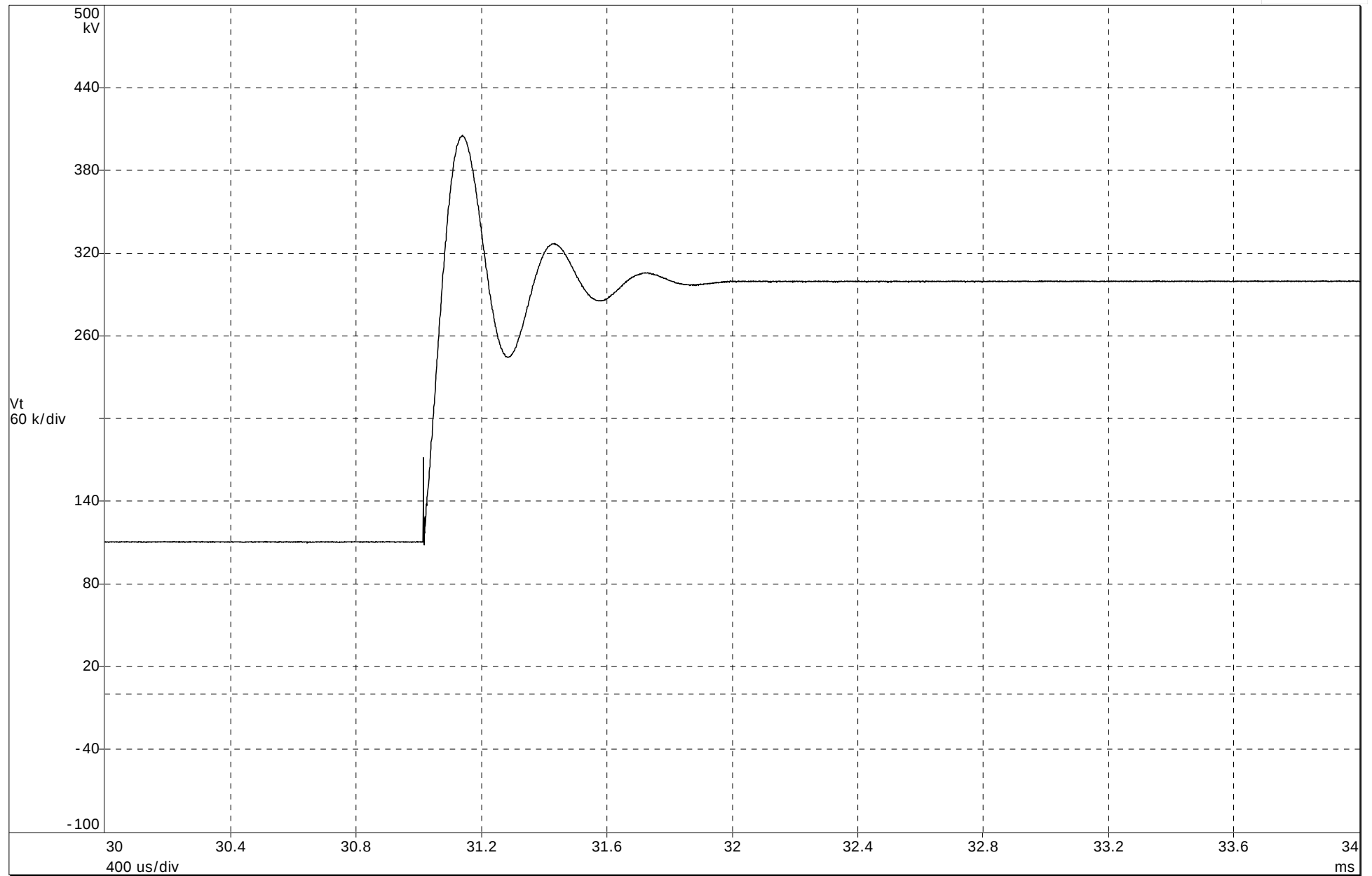
HPC 1104 - 158



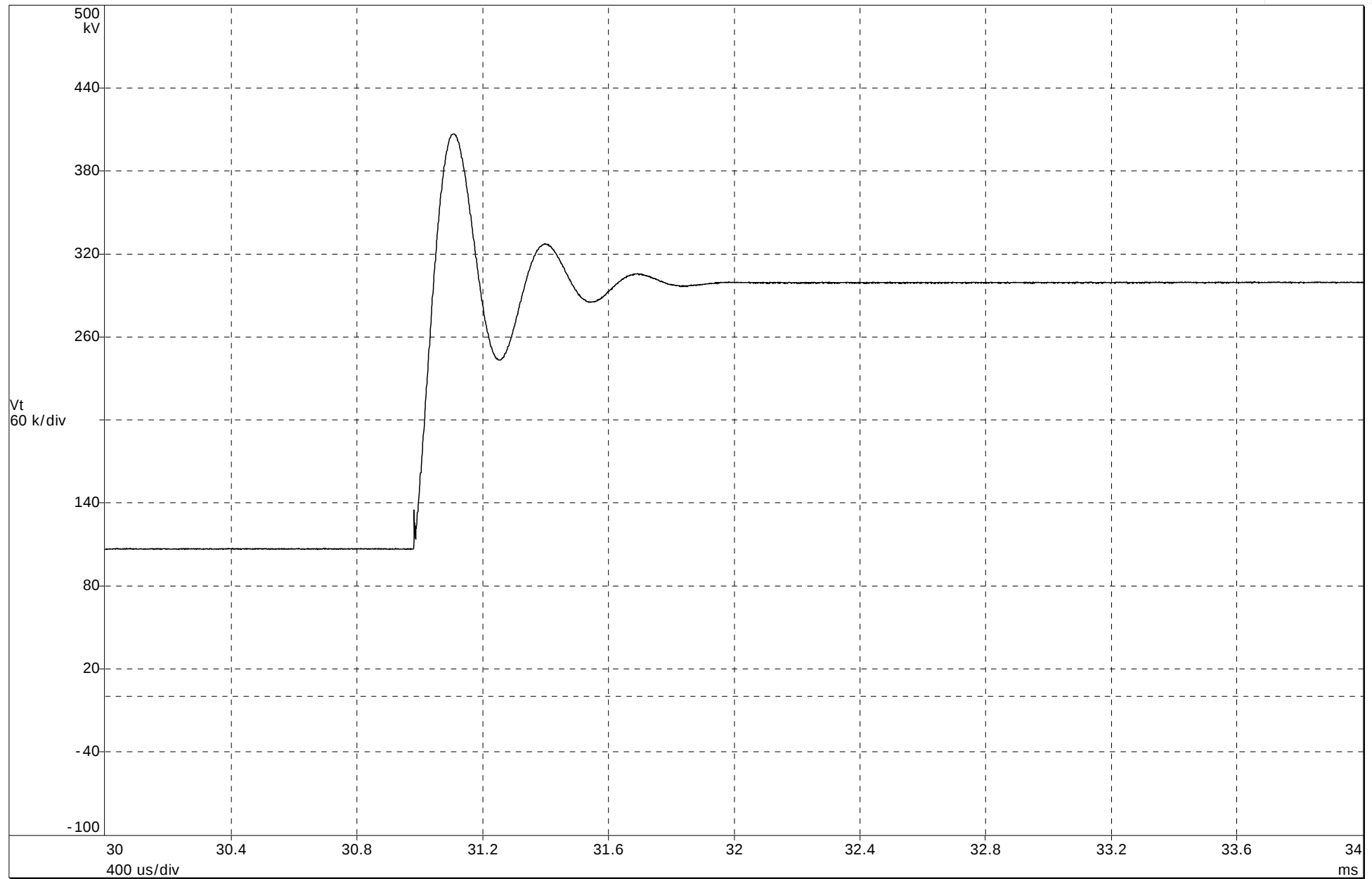
HPC 1104 - 159



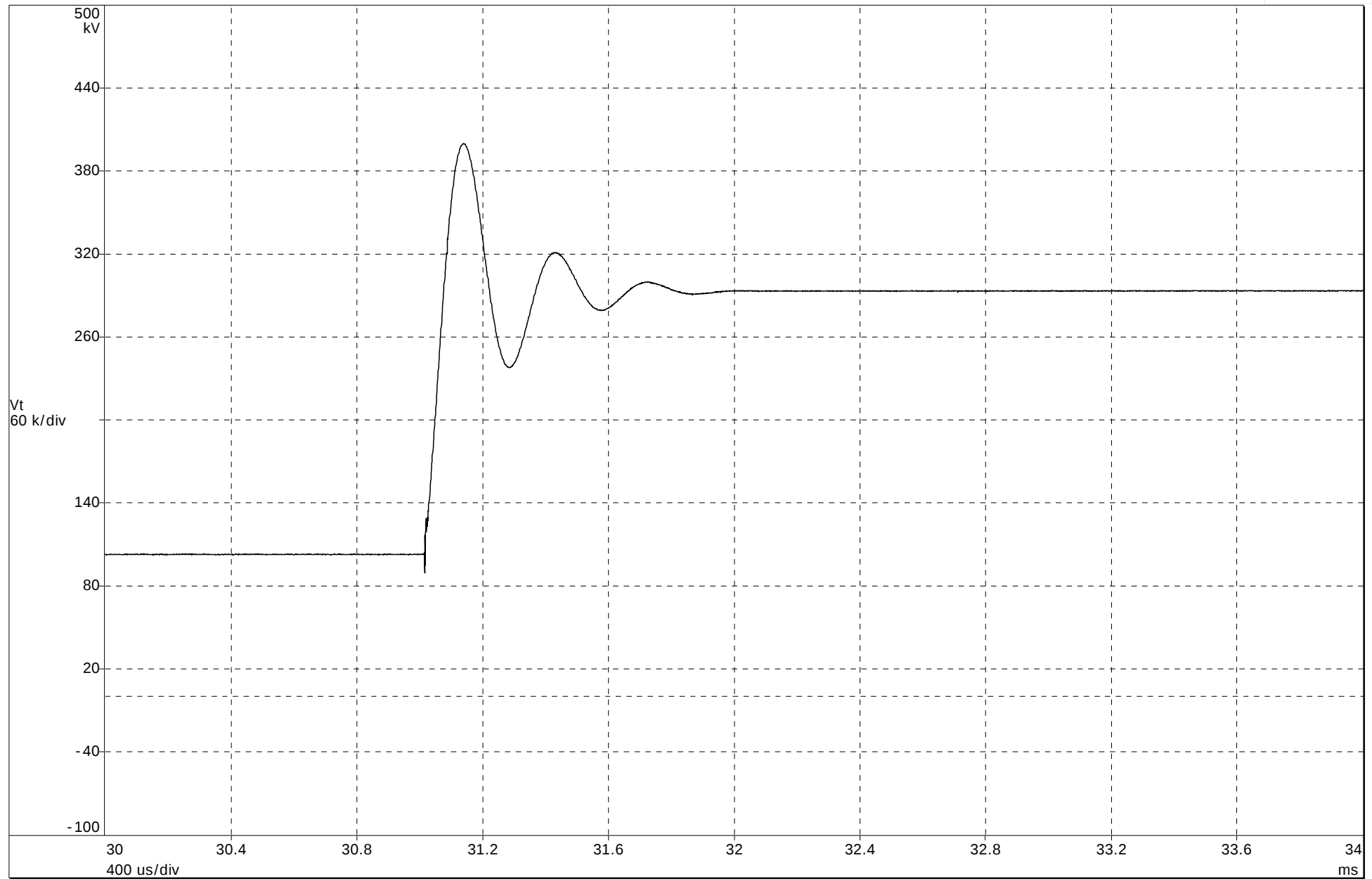
HPC 1104 - 160



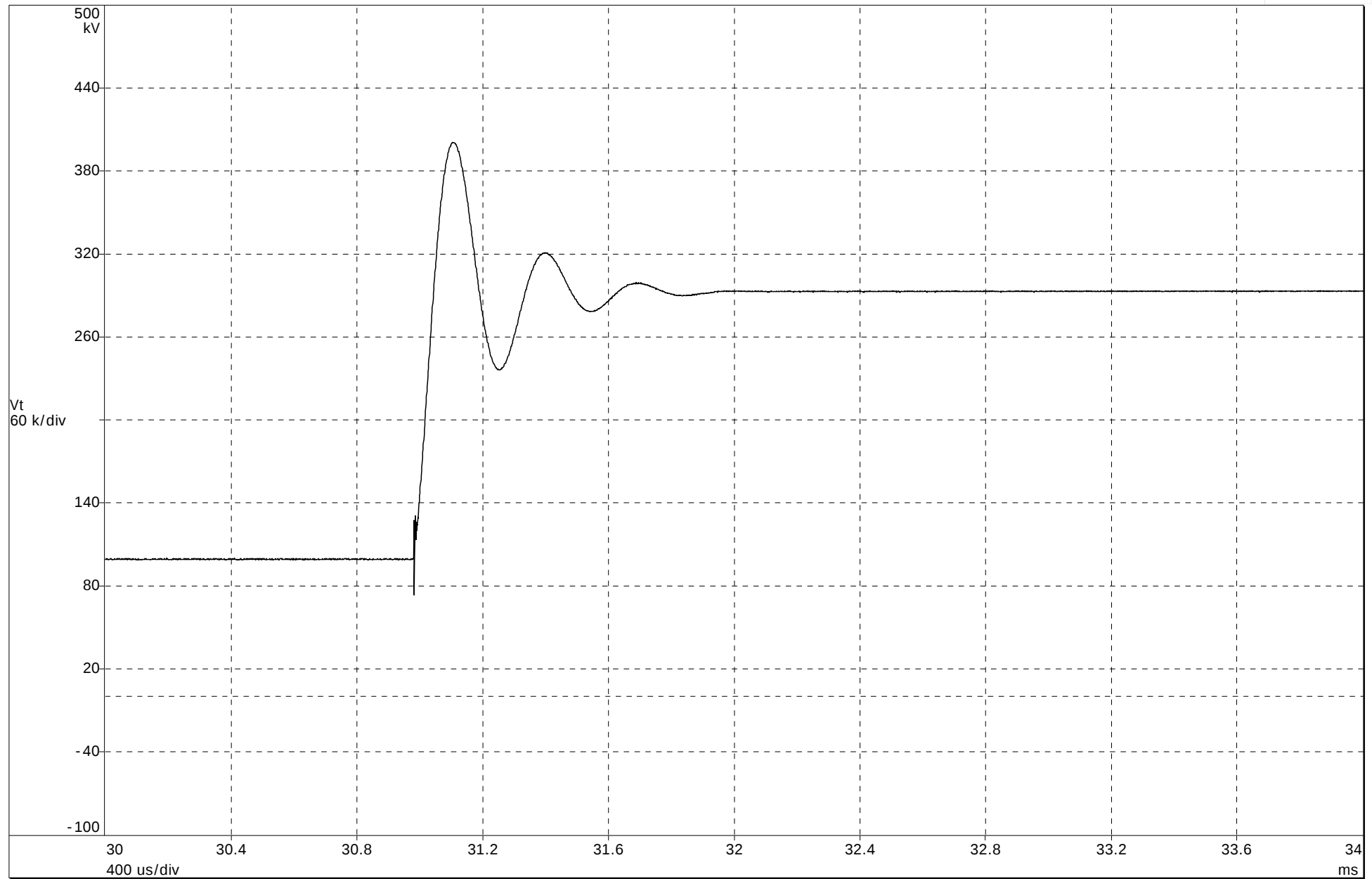
HPC 1104 - 161



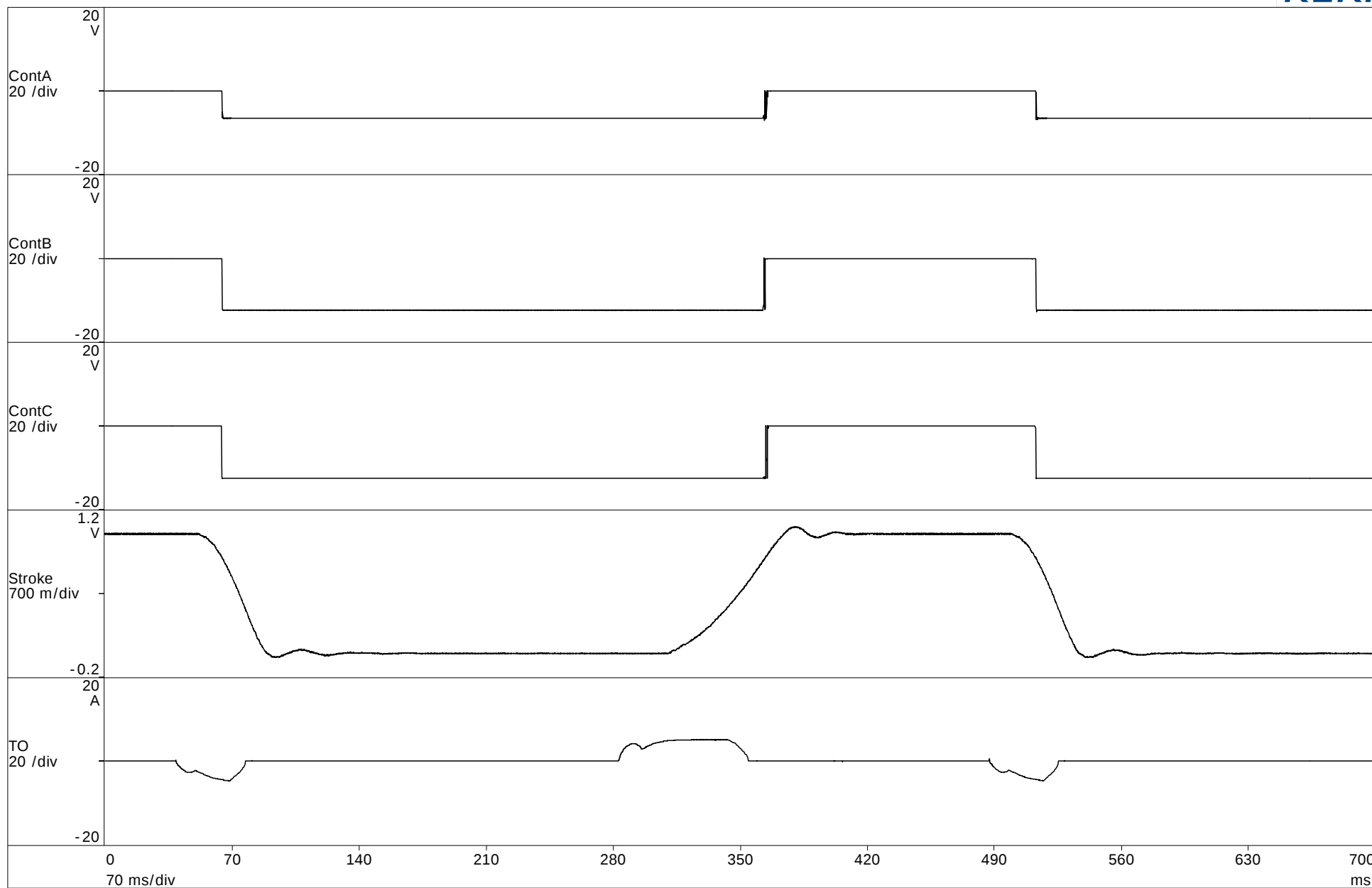
HPC 1104 - 162



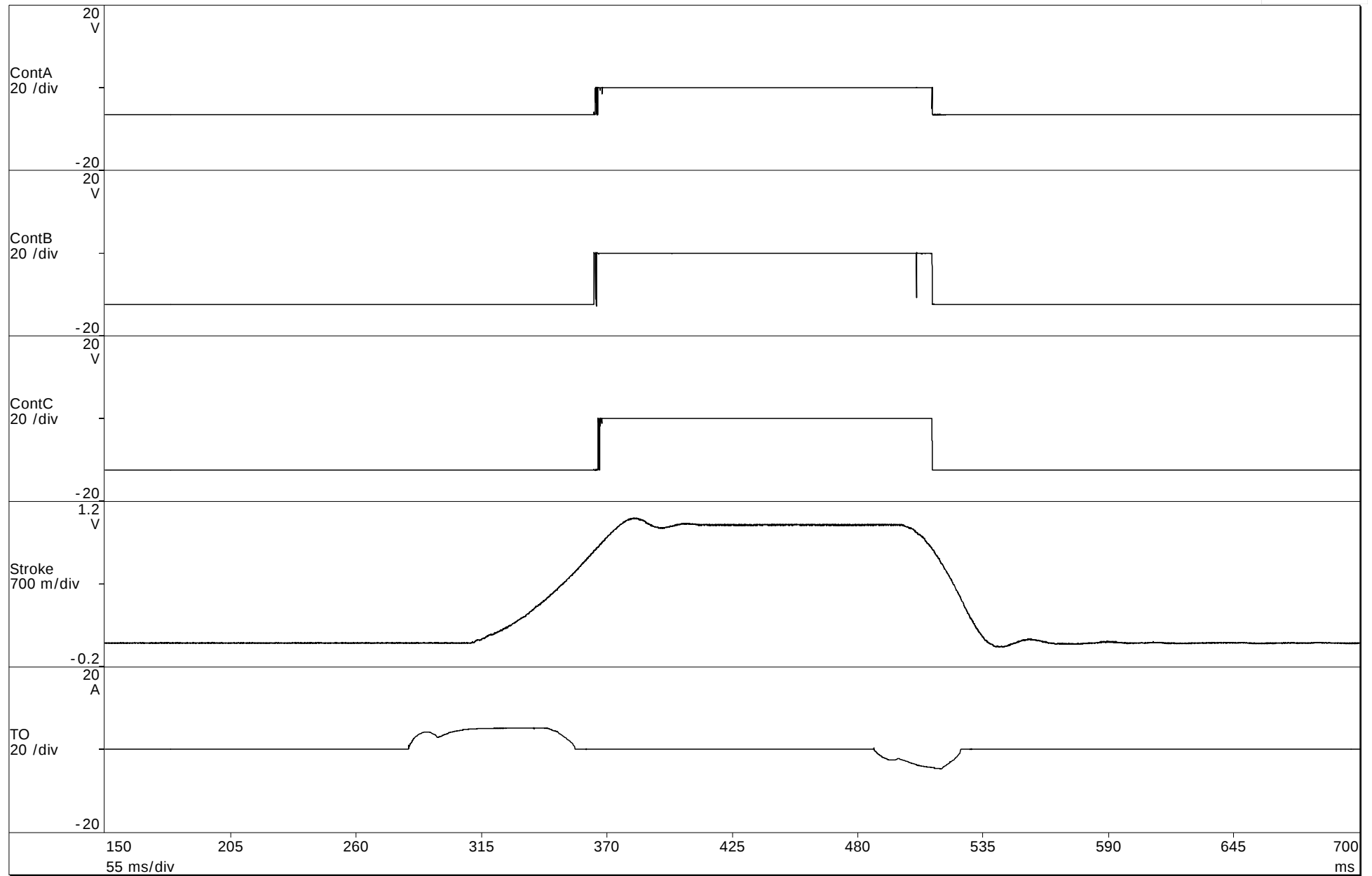
HPC 1104 - 163



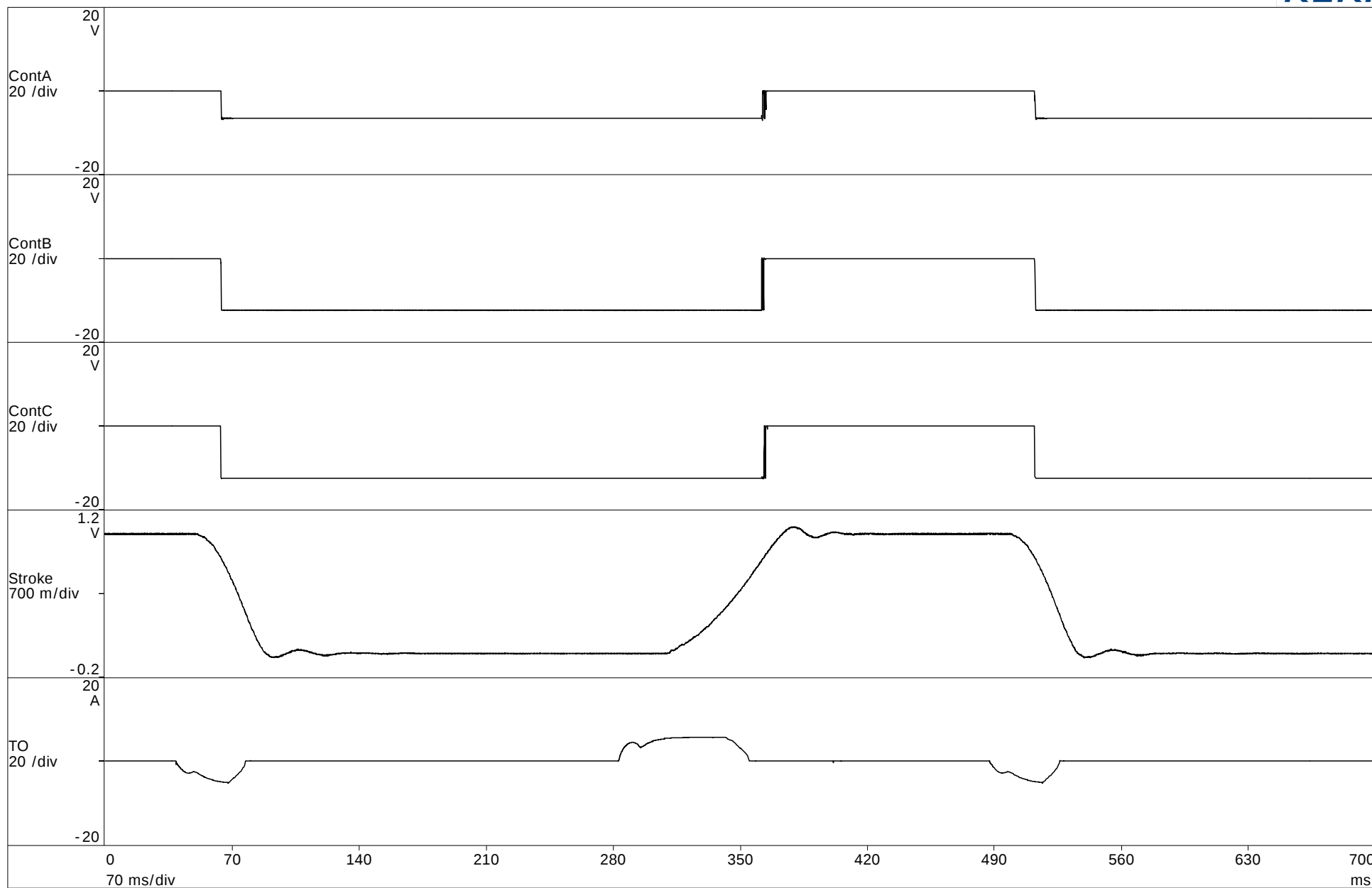
## HPC 1104 - 164



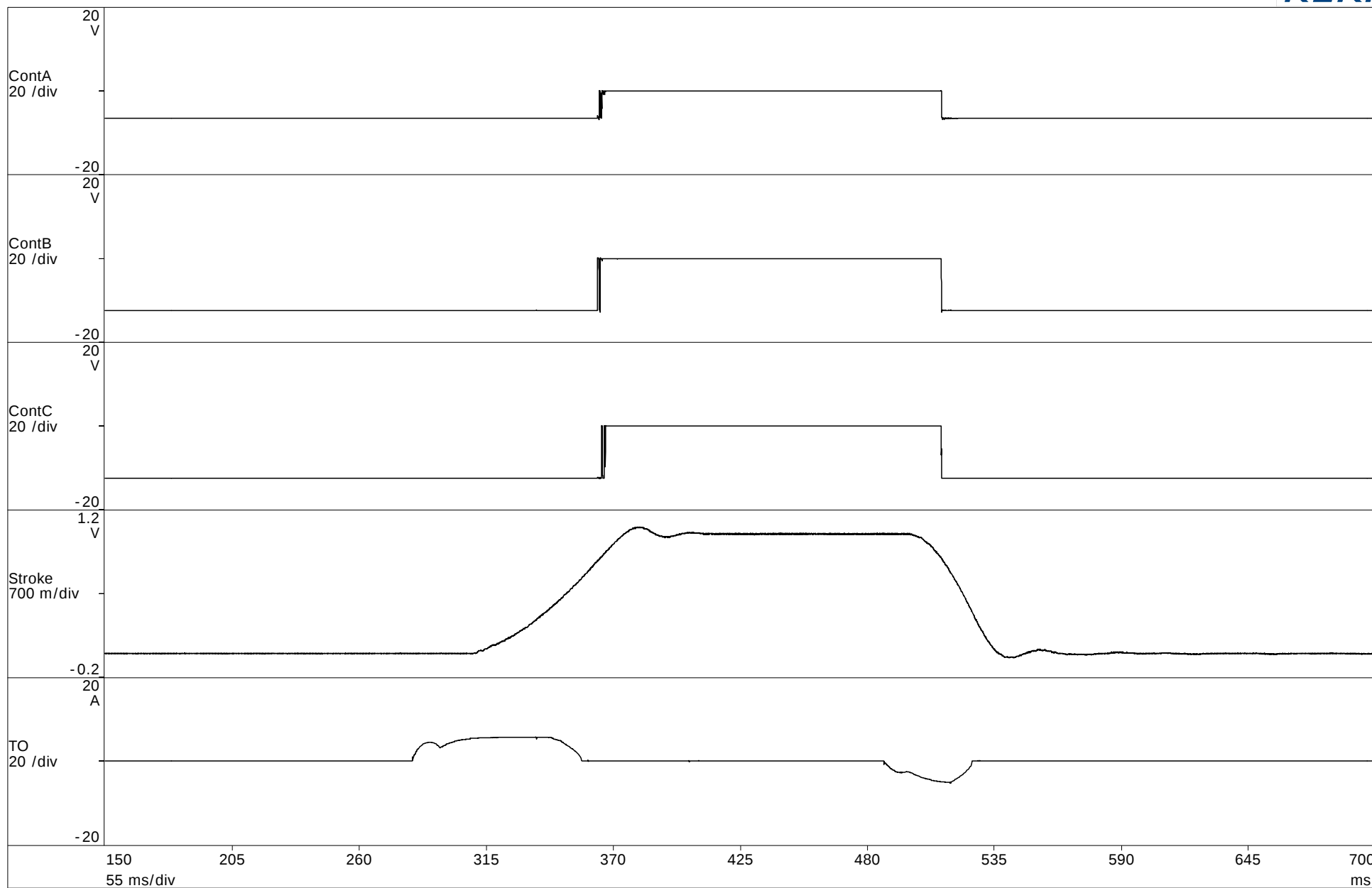
## HPC 1104 - 165



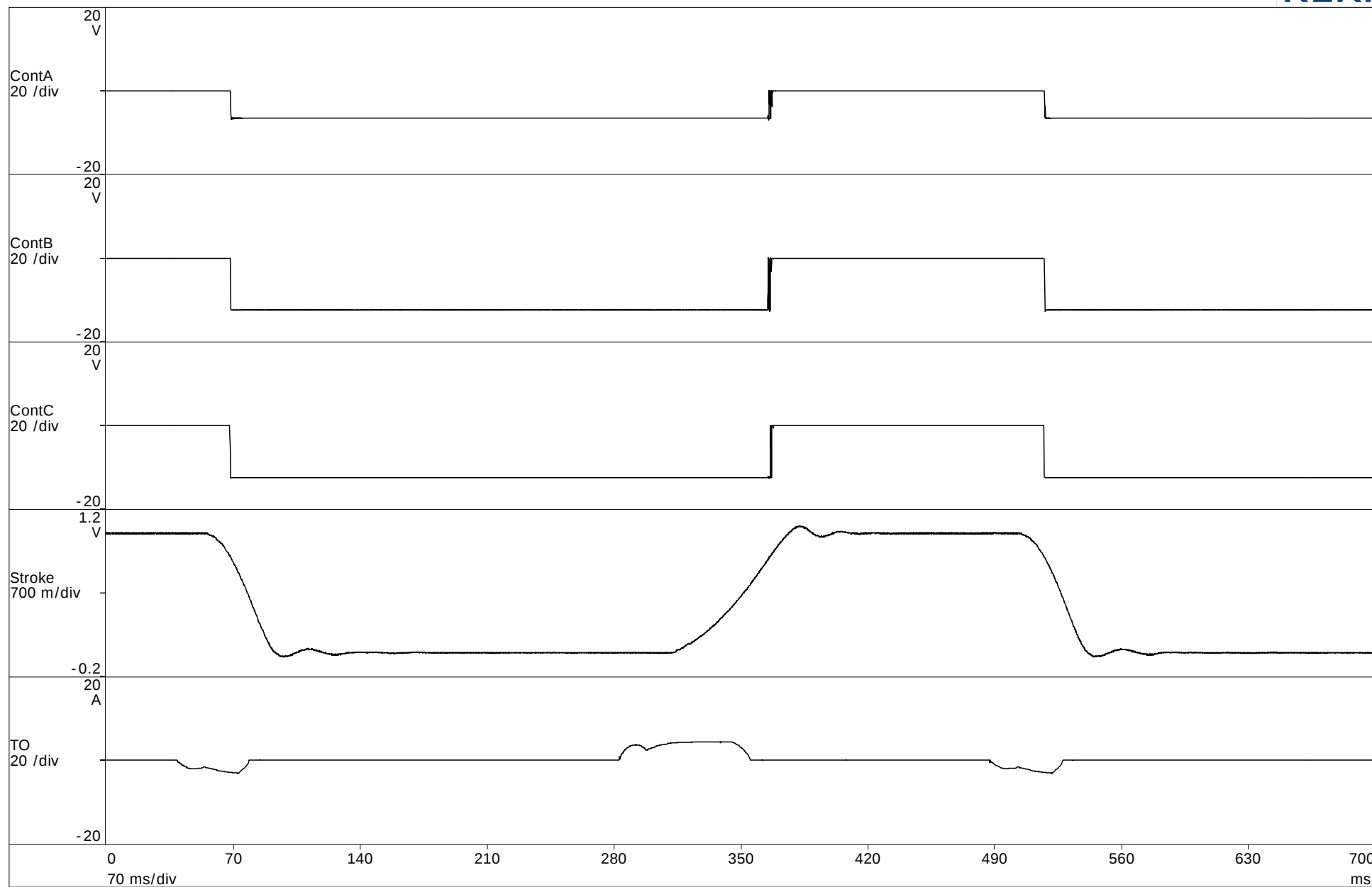
## HPC 1104 - 166



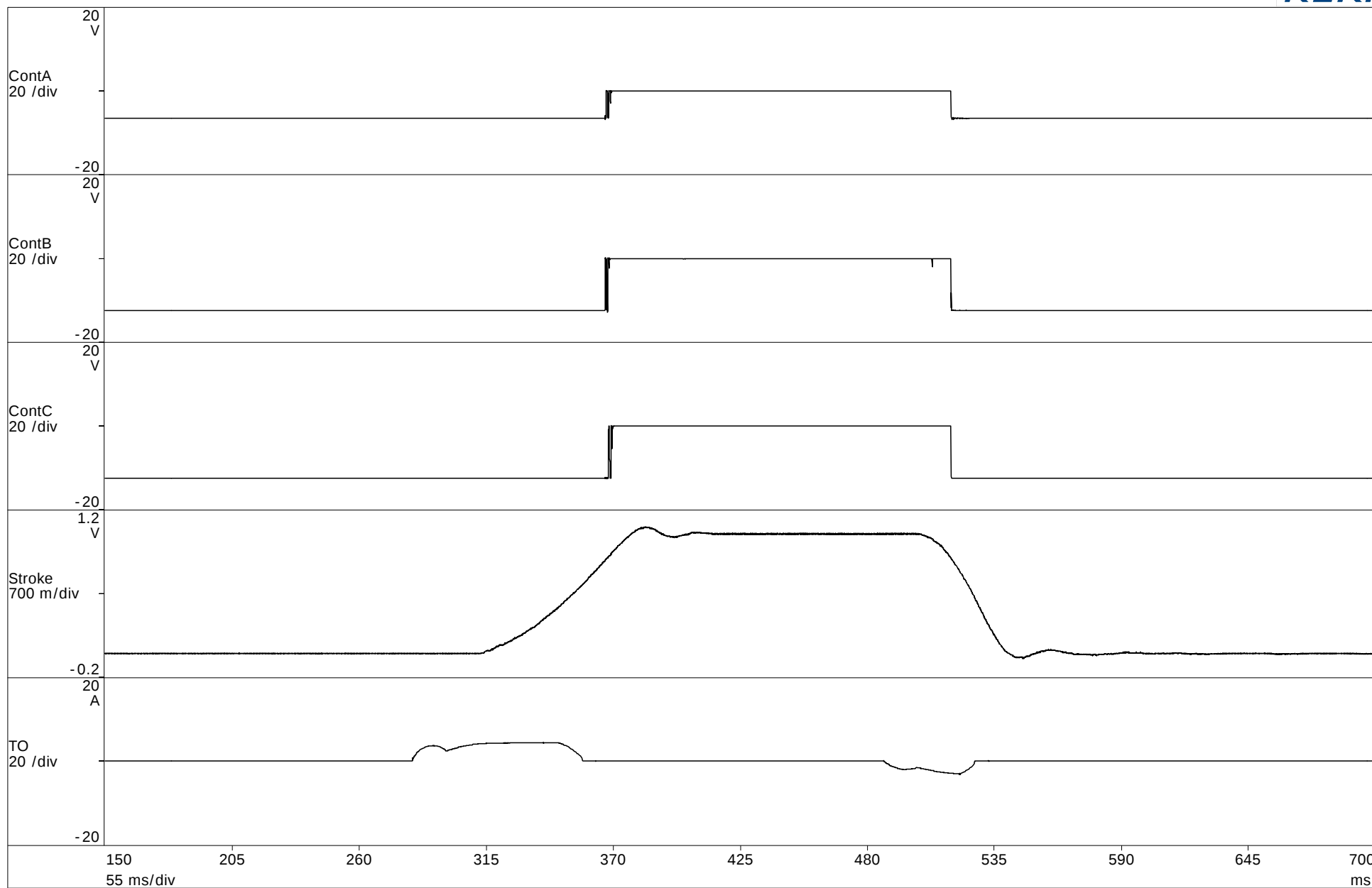
## HPC 1104 - 167



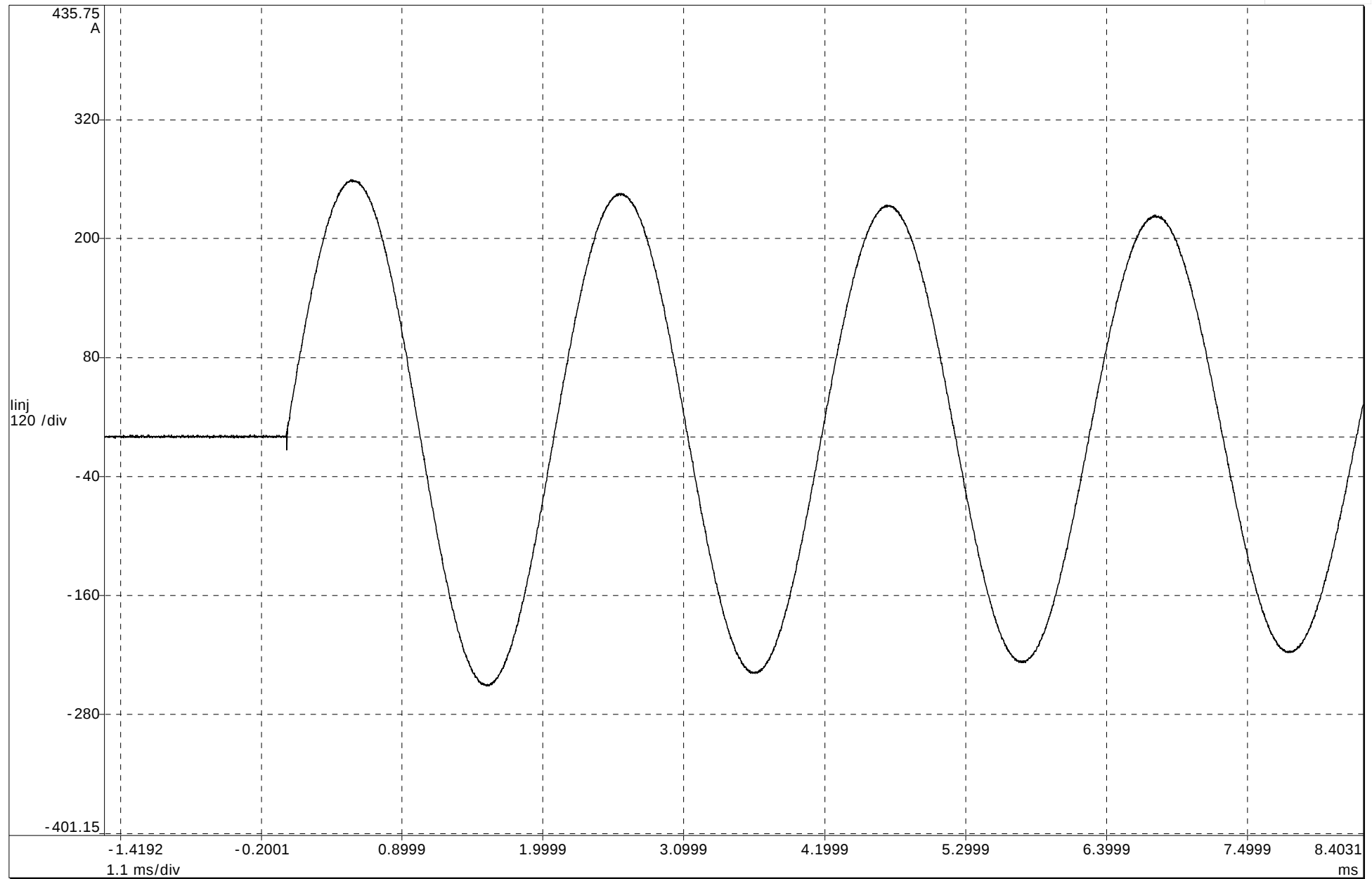
## HPC 1104 - 168



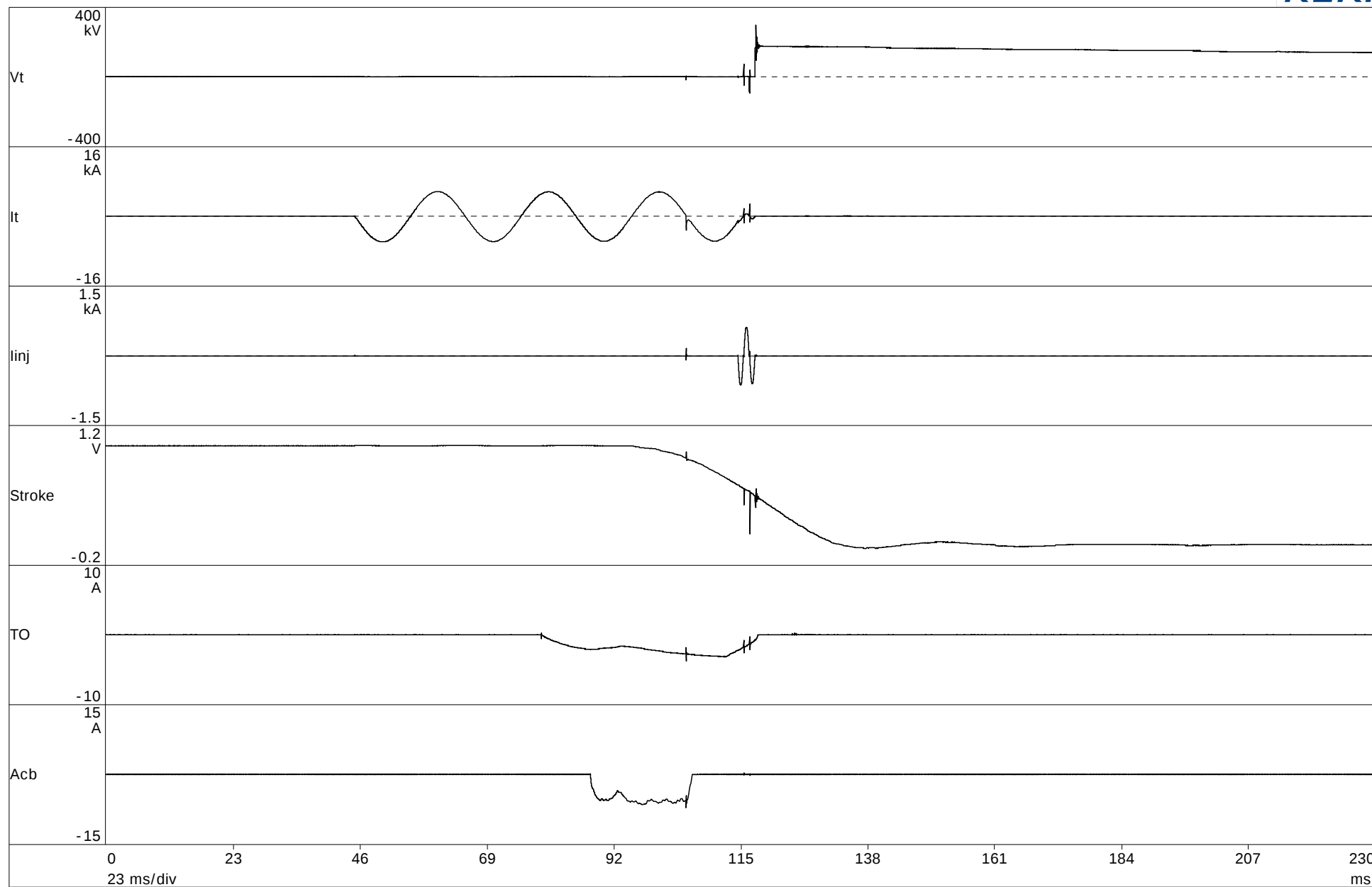
## HPC 1104 - 169



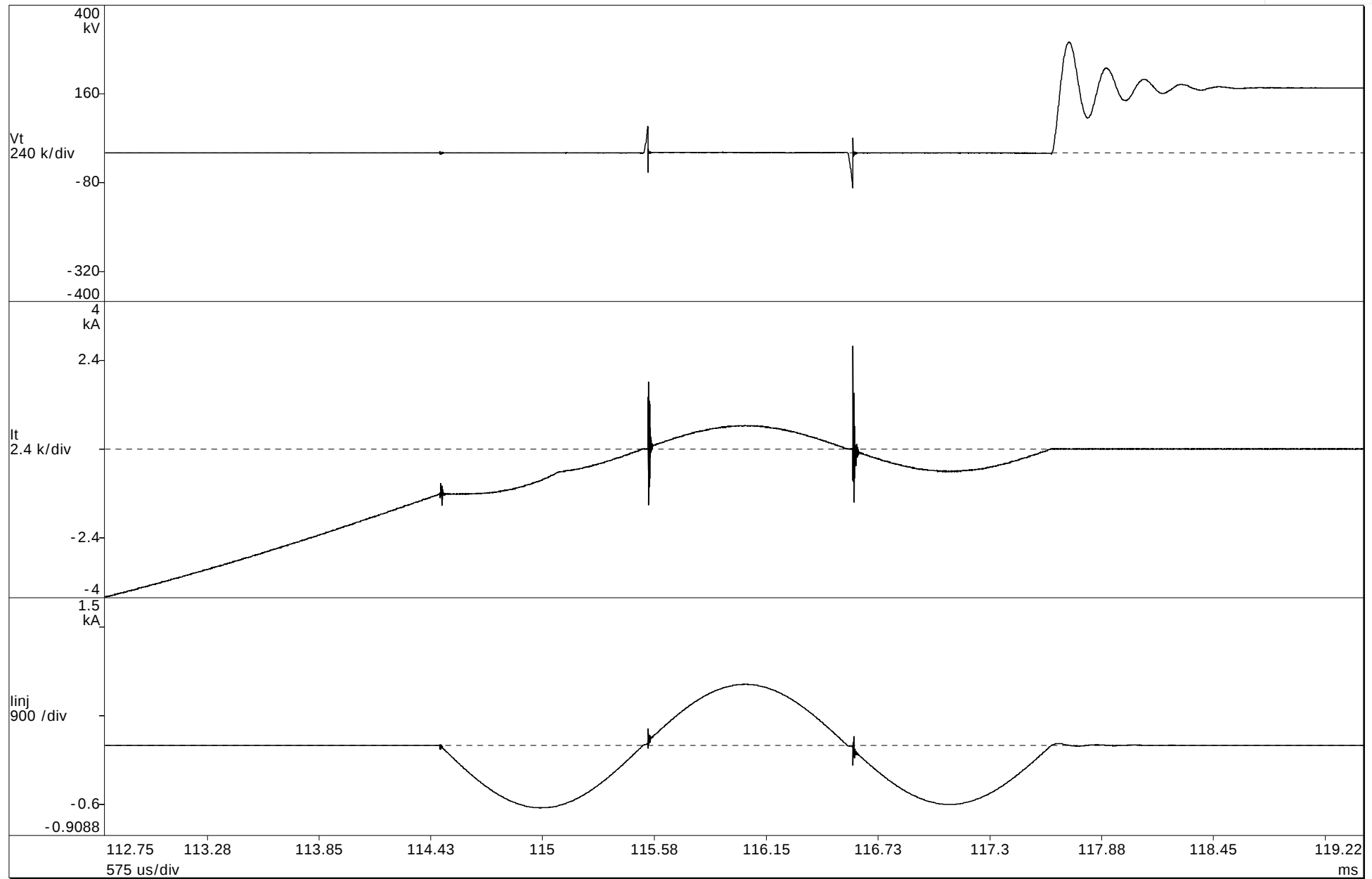
HPC 1104 - 174



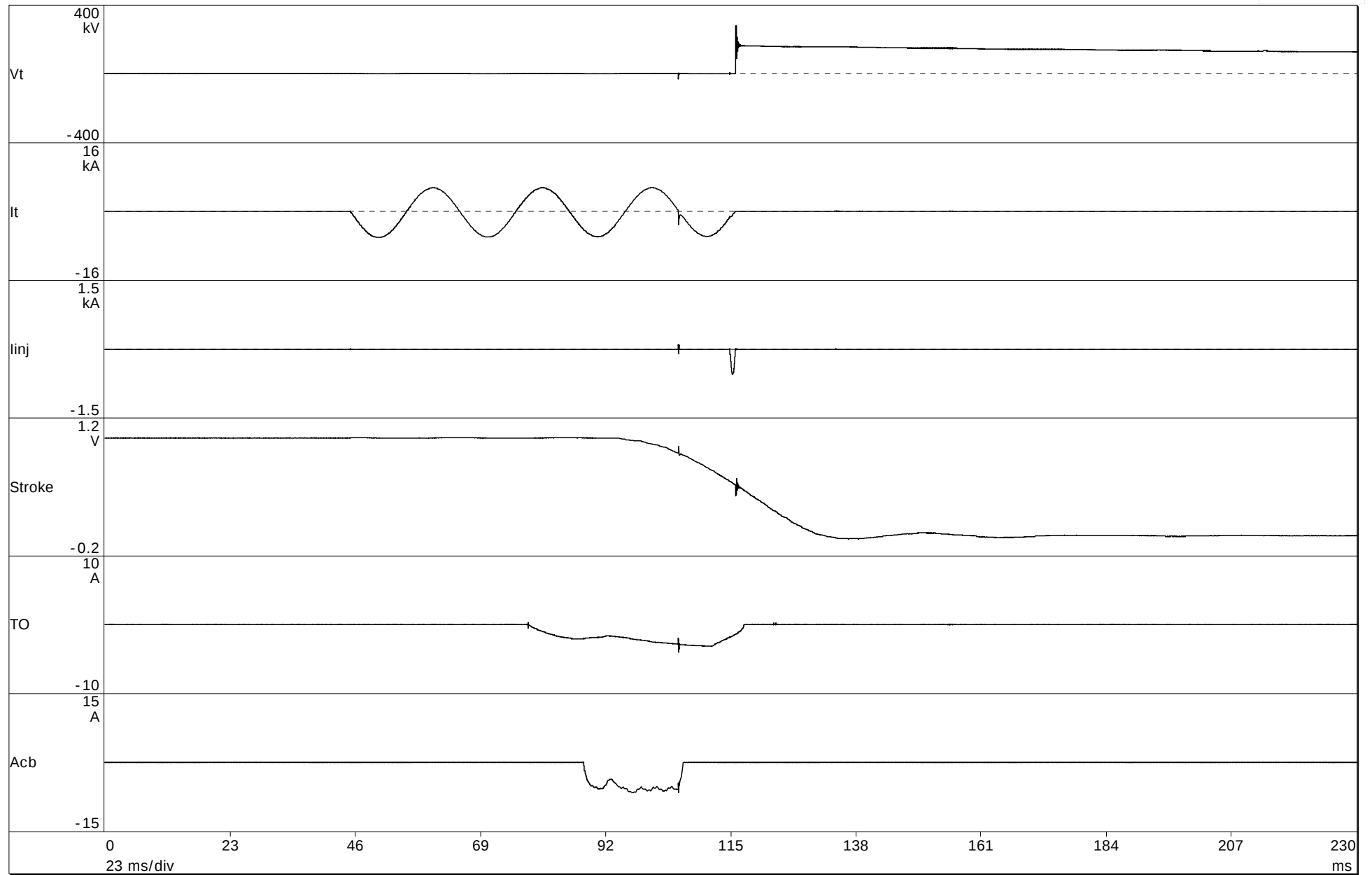
HPC 1104 - 179



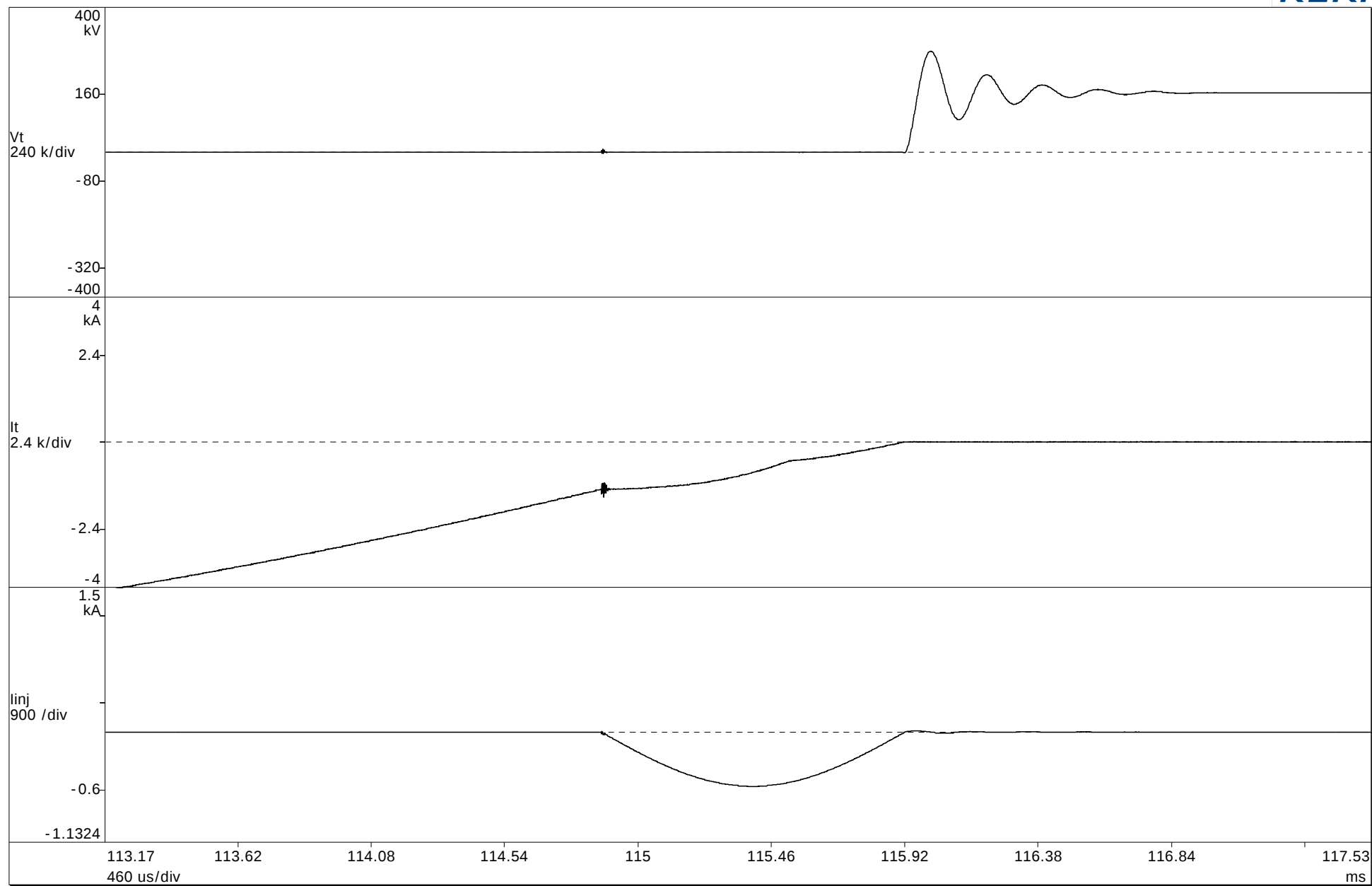
## HPC 1104 - 179



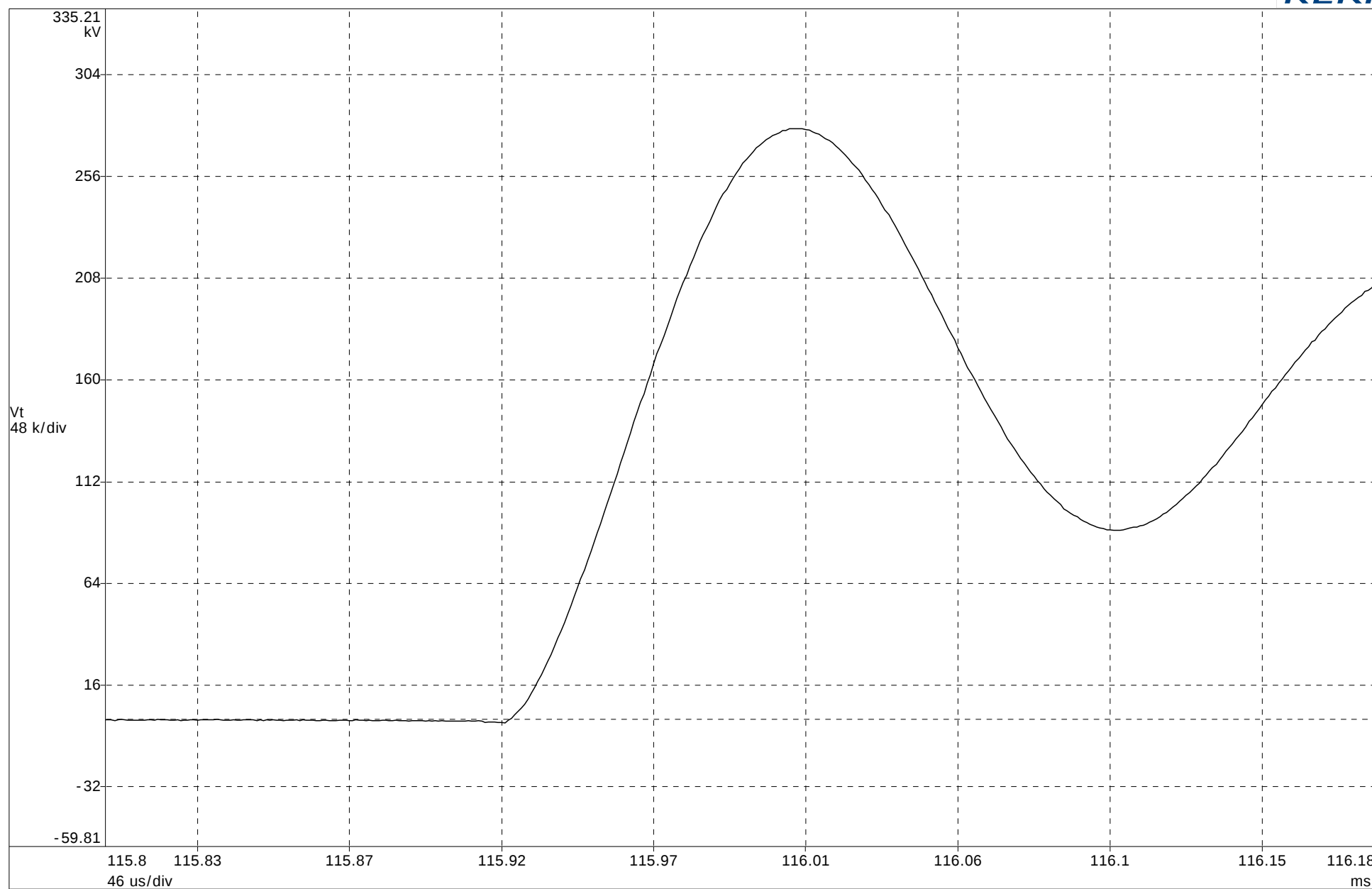
## HPC 1104 - 180



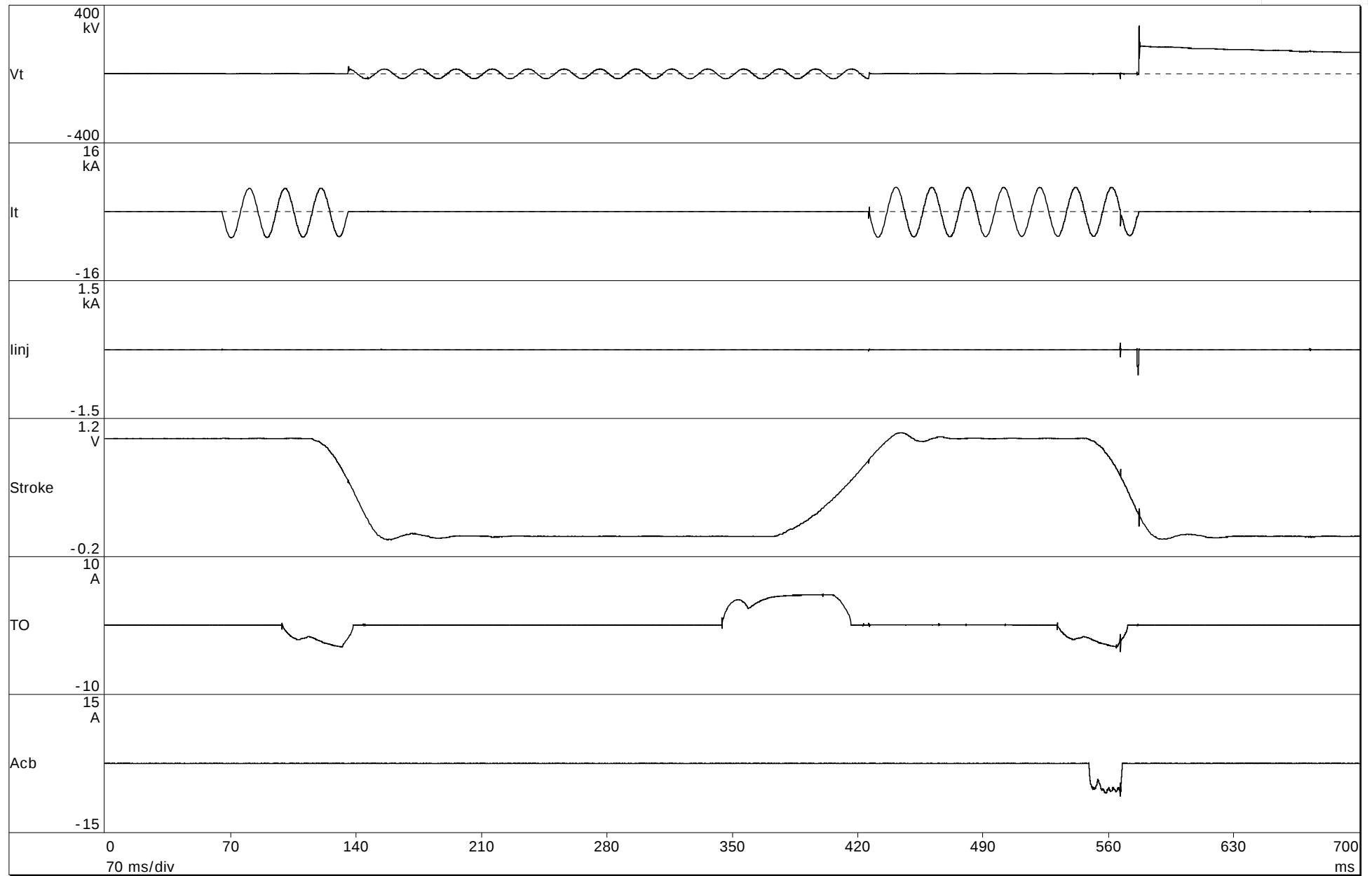
## HPC 1104 - 180



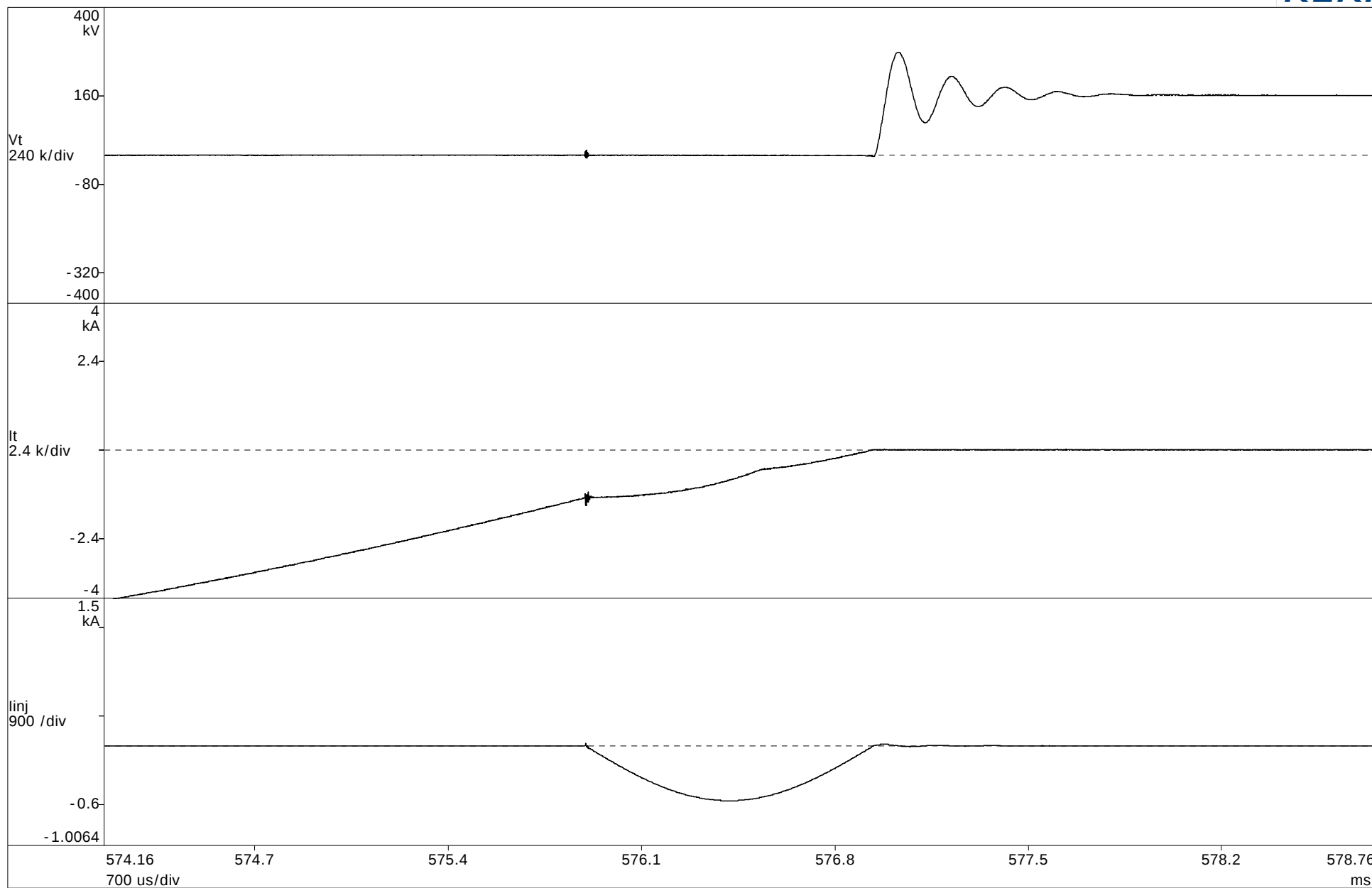
## HPC 1104 - 180



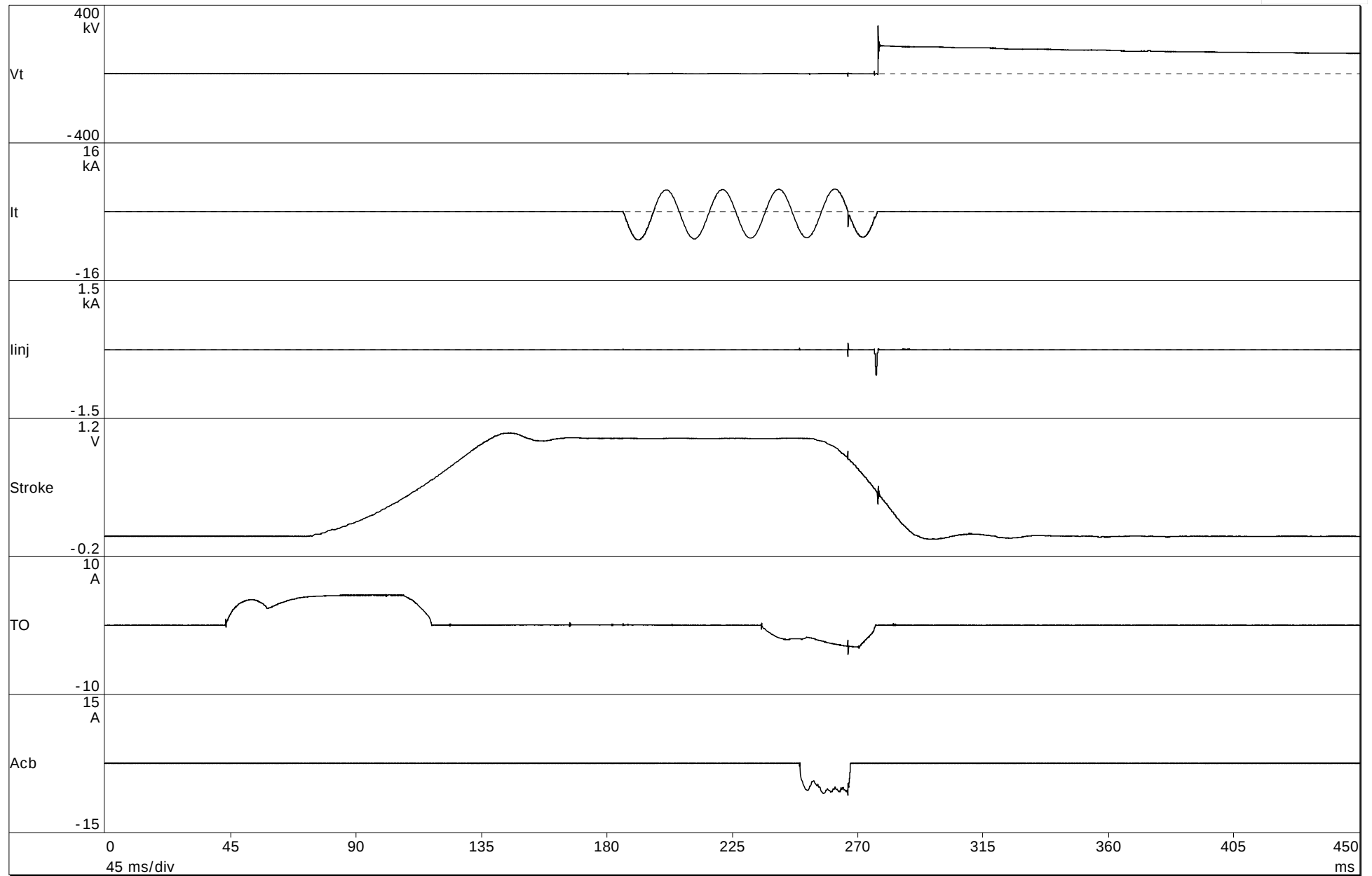
HPC 1104 - 183



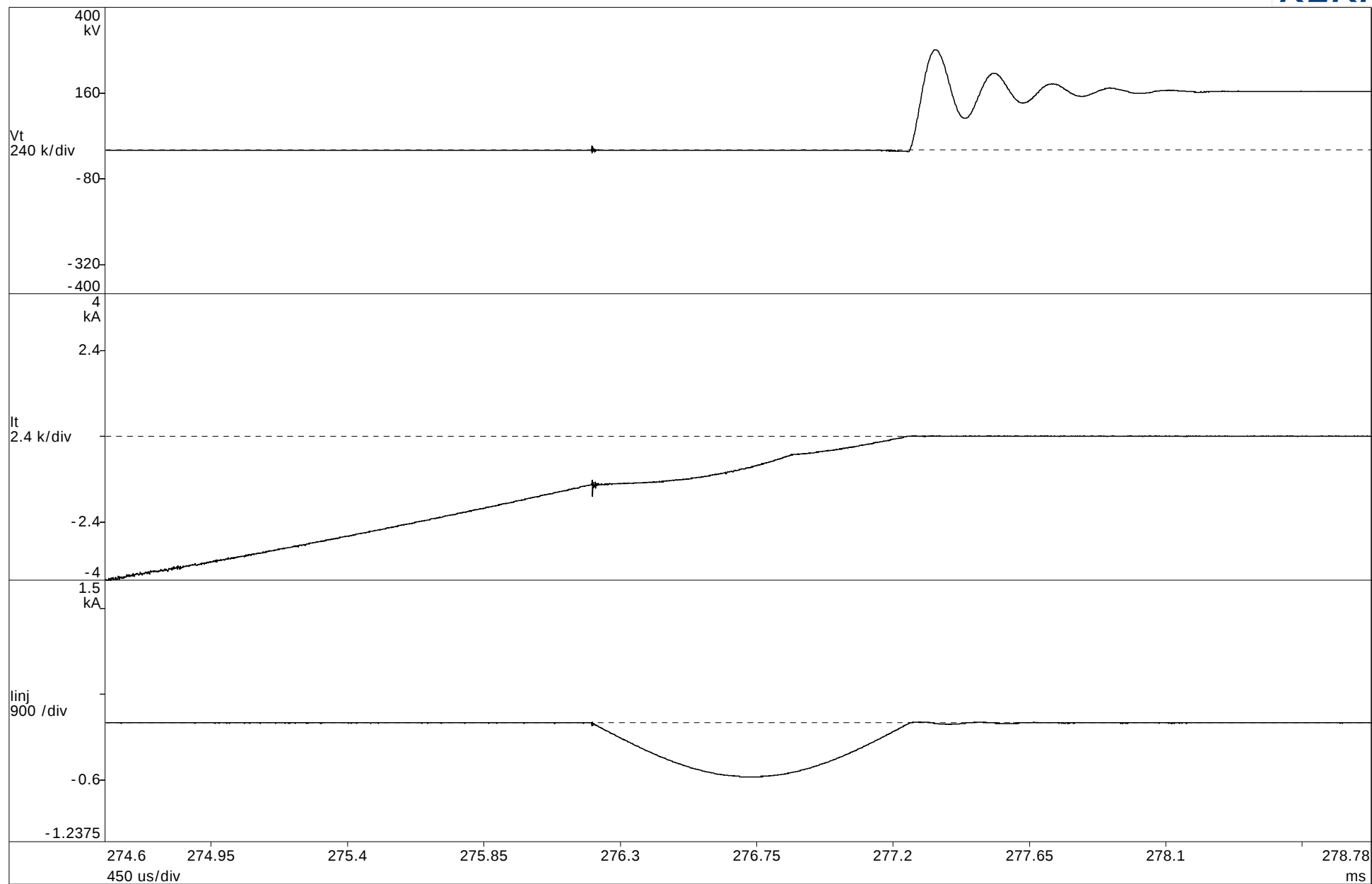
HPC 1104 - 183



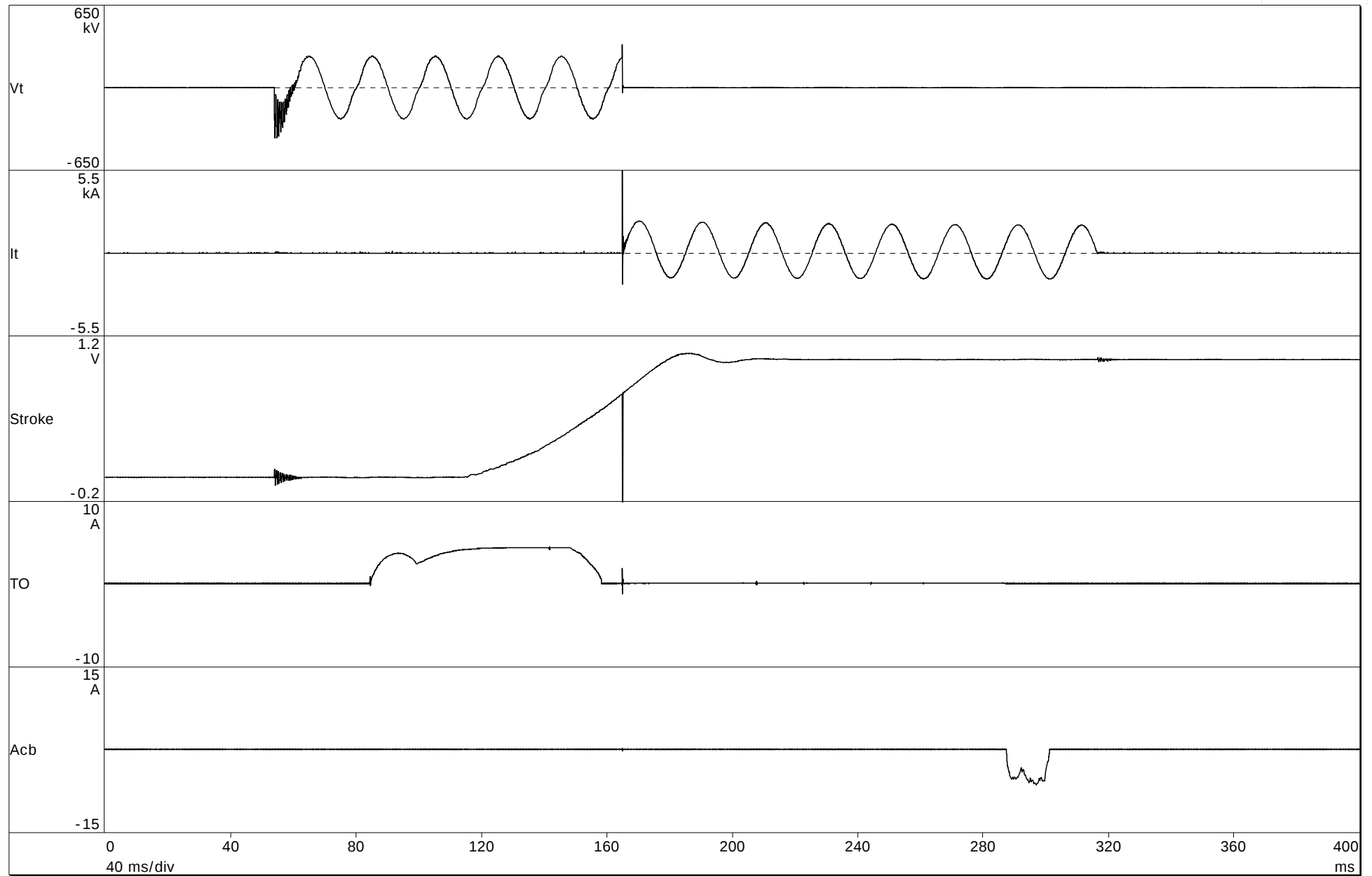
HPC 1104 - 184



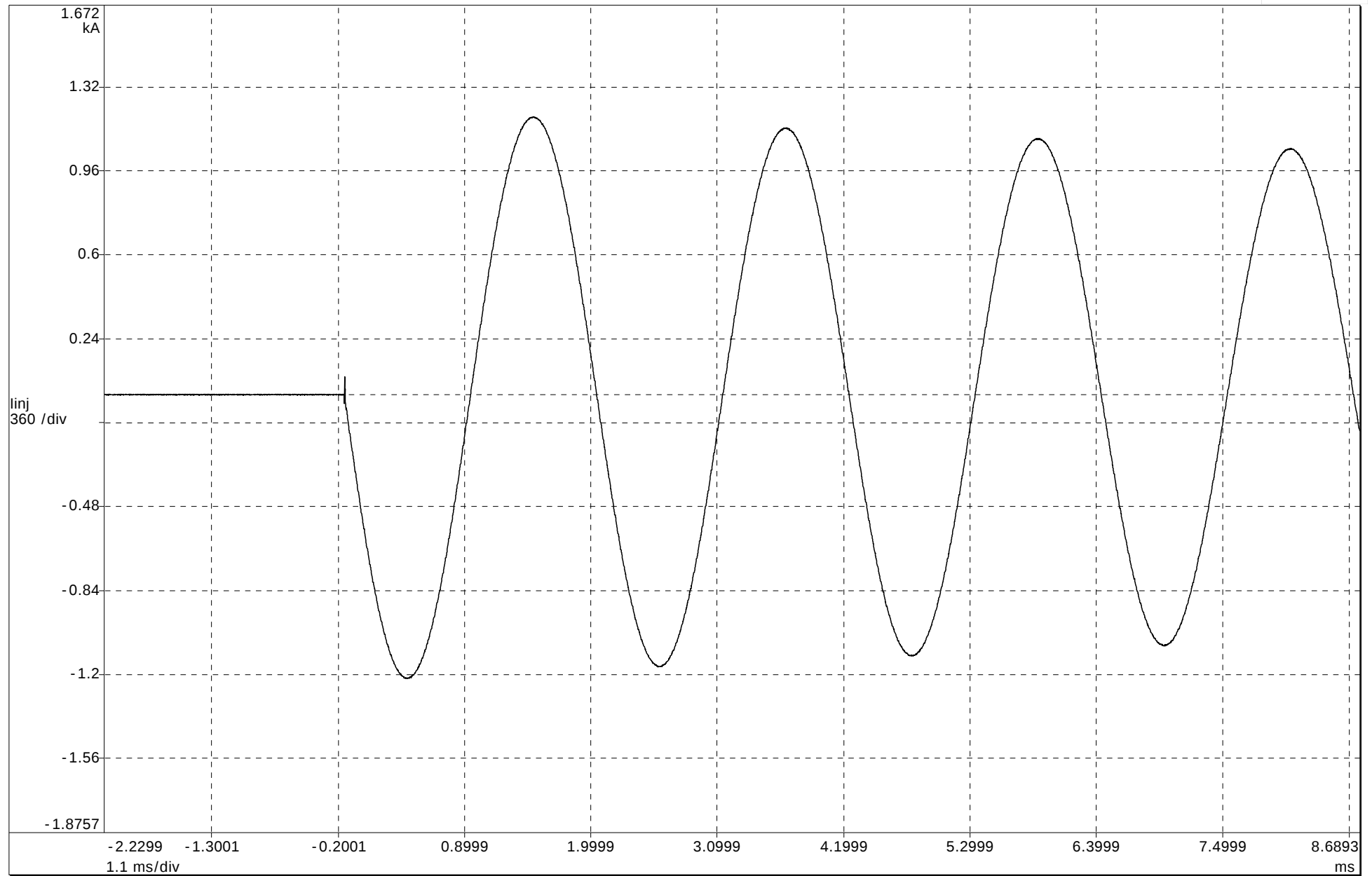
## HPC 1104 - 184



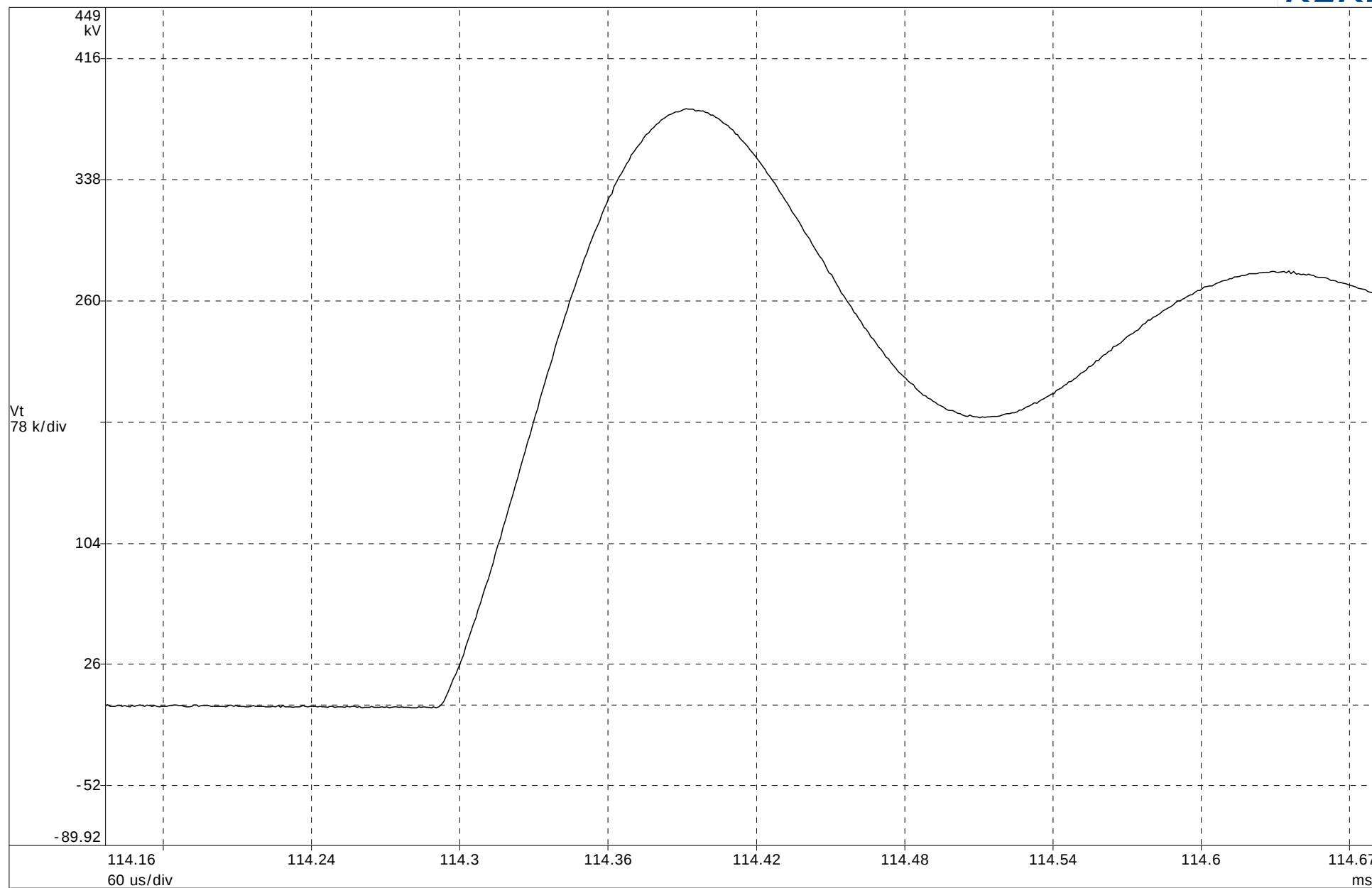
HPC 1104 - 188



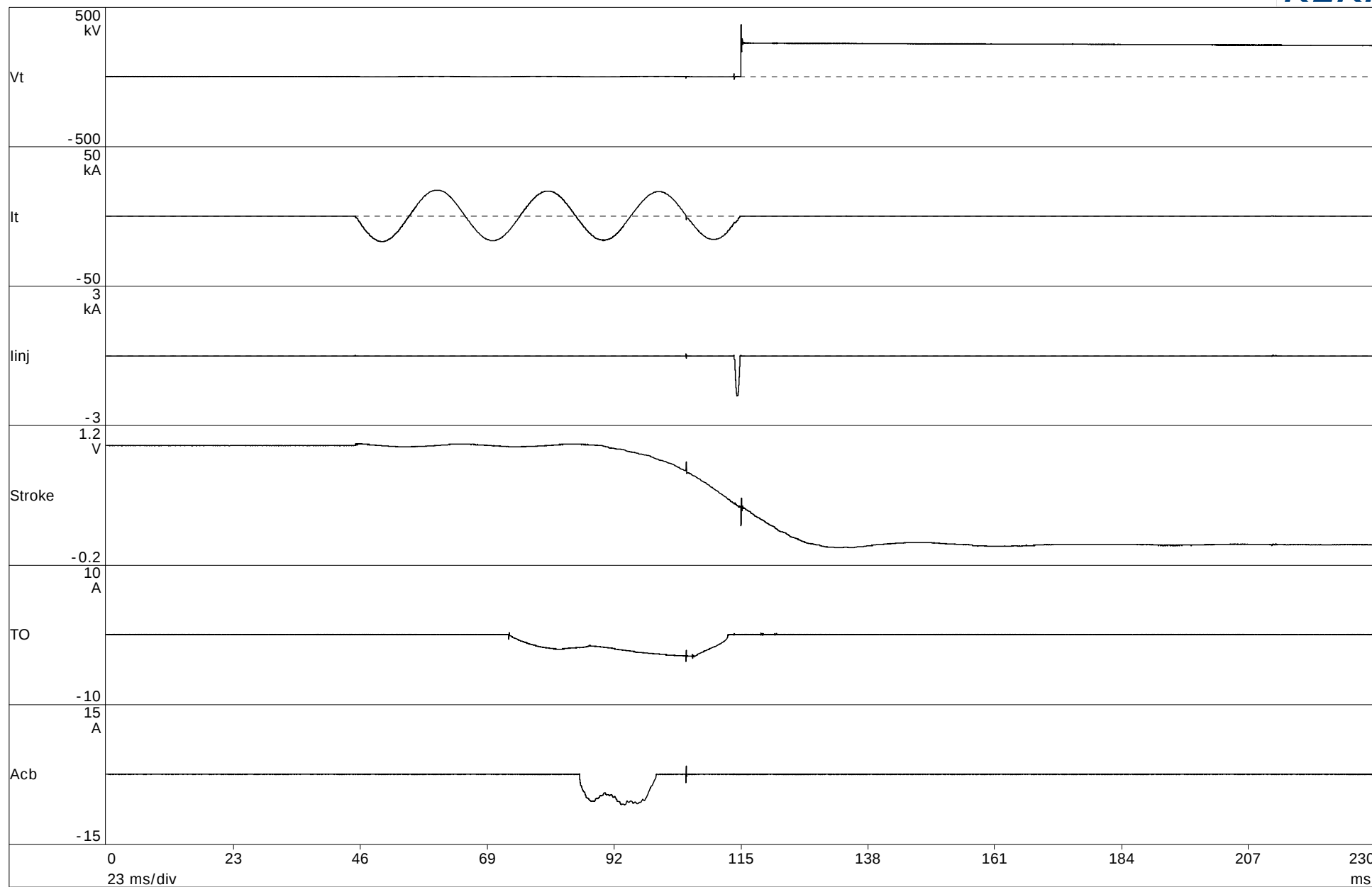
HPC 1104 - 190



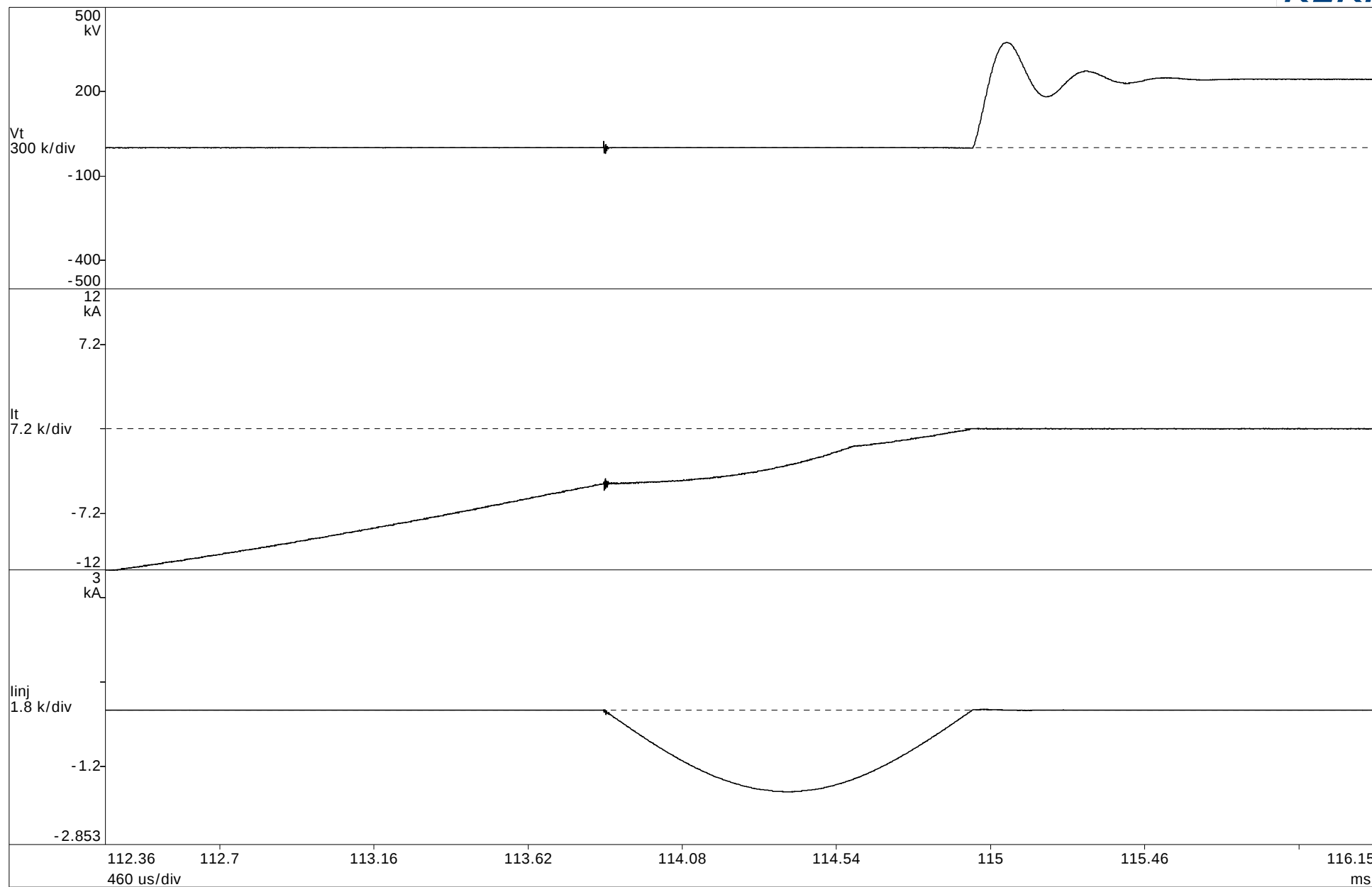
HPC 1104 - 194



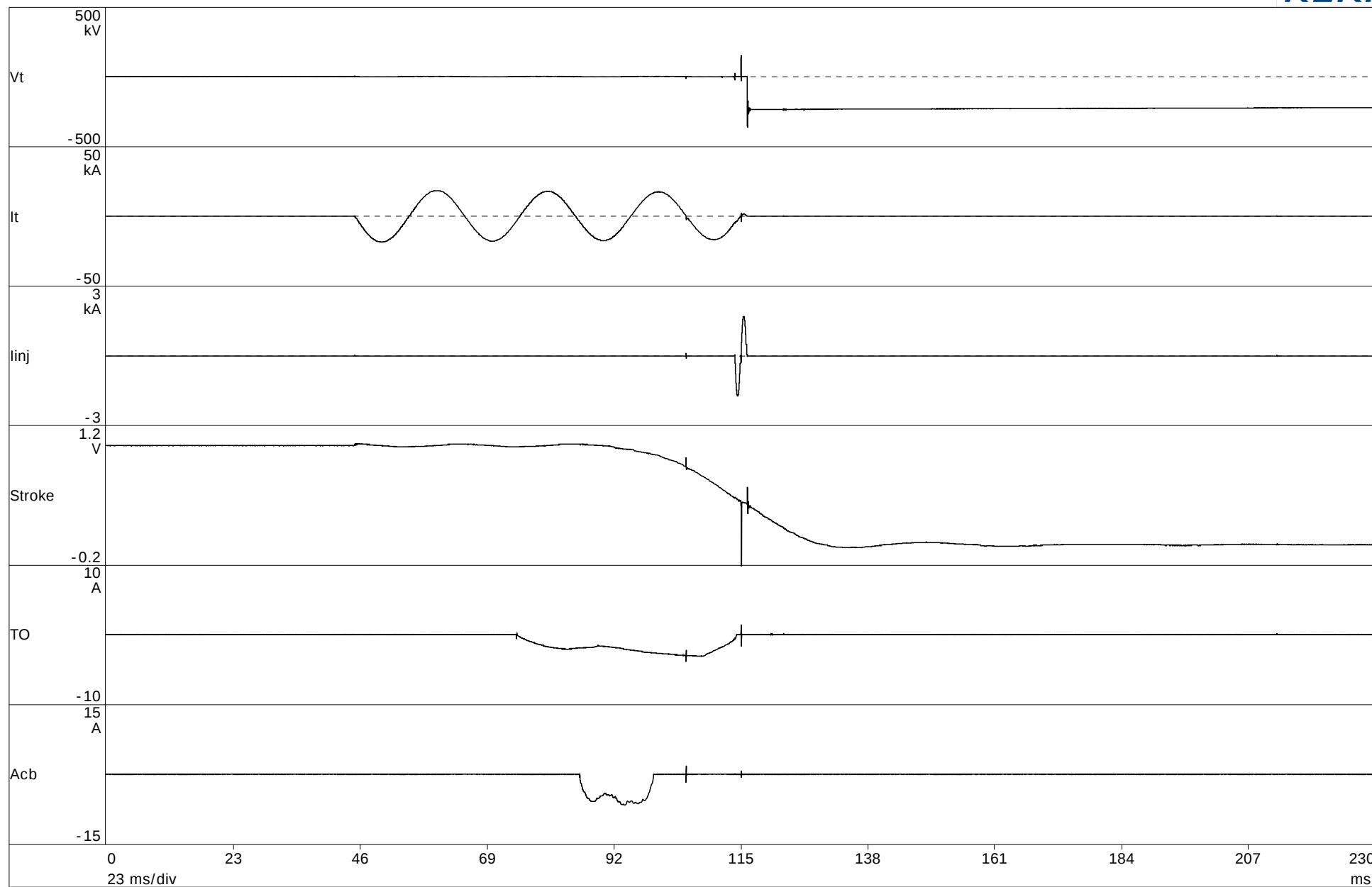
## HPC 1104 - 195



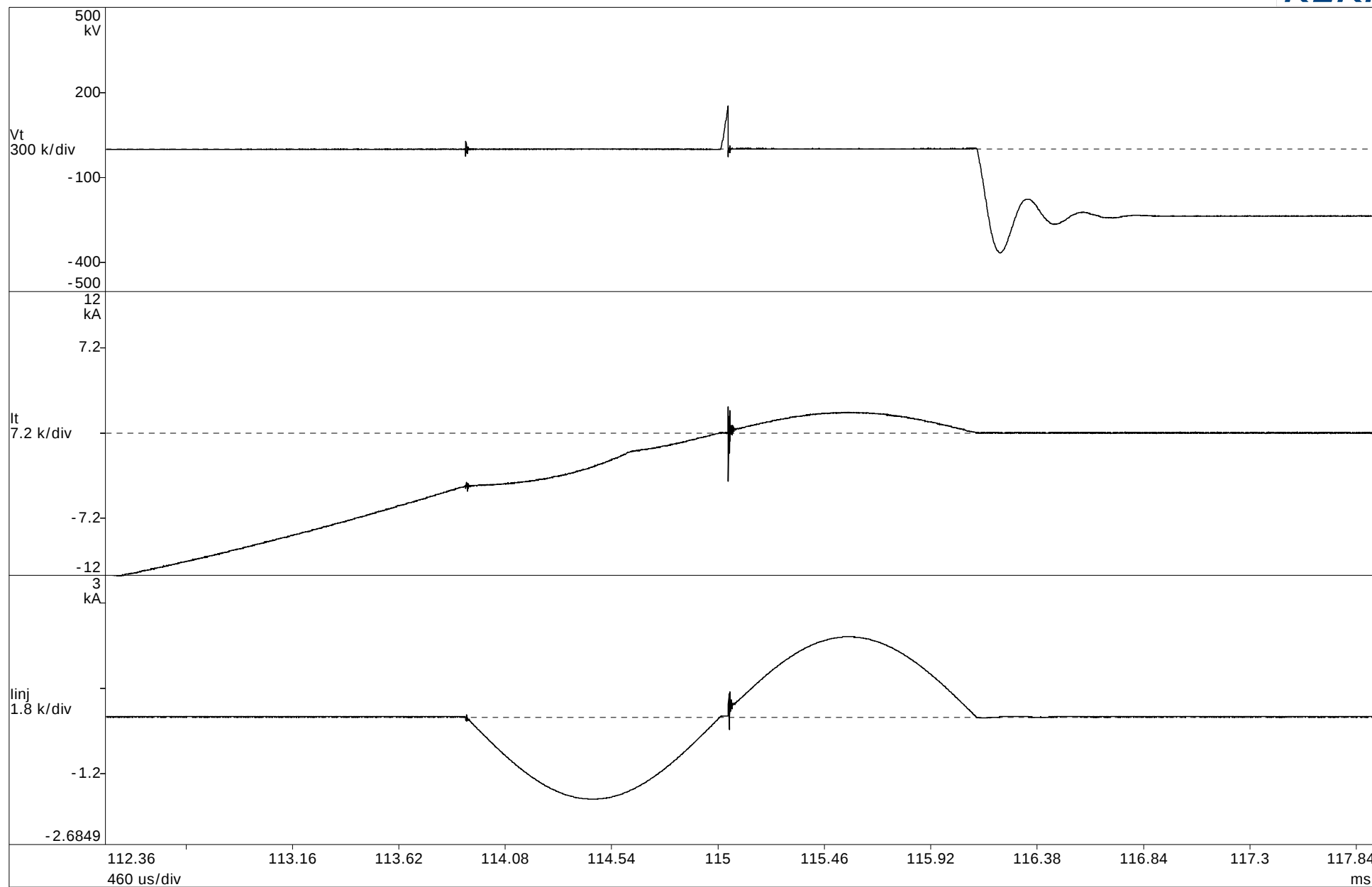
## HPC 1104 - 195



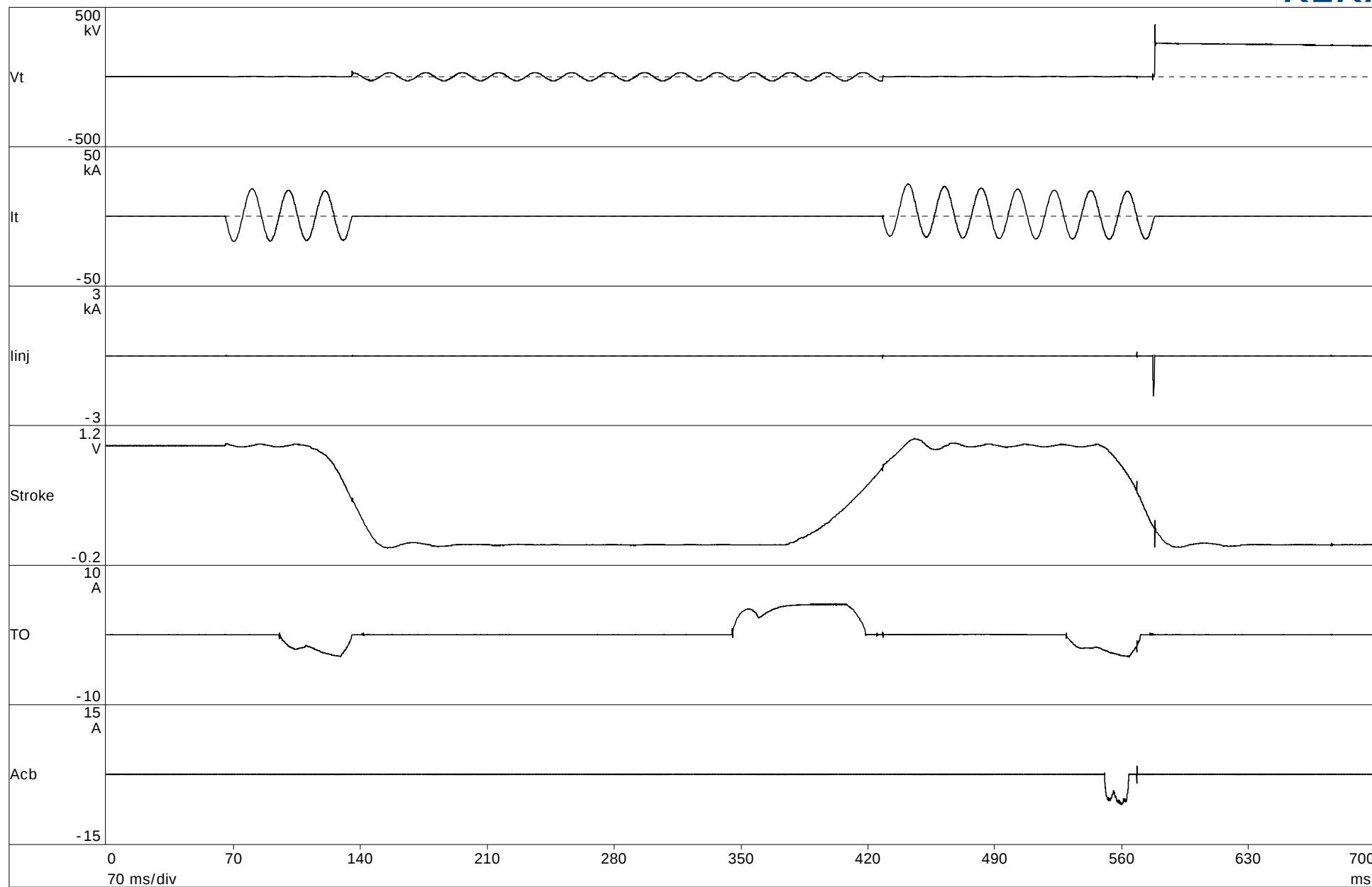
## HPC 1104 - 196



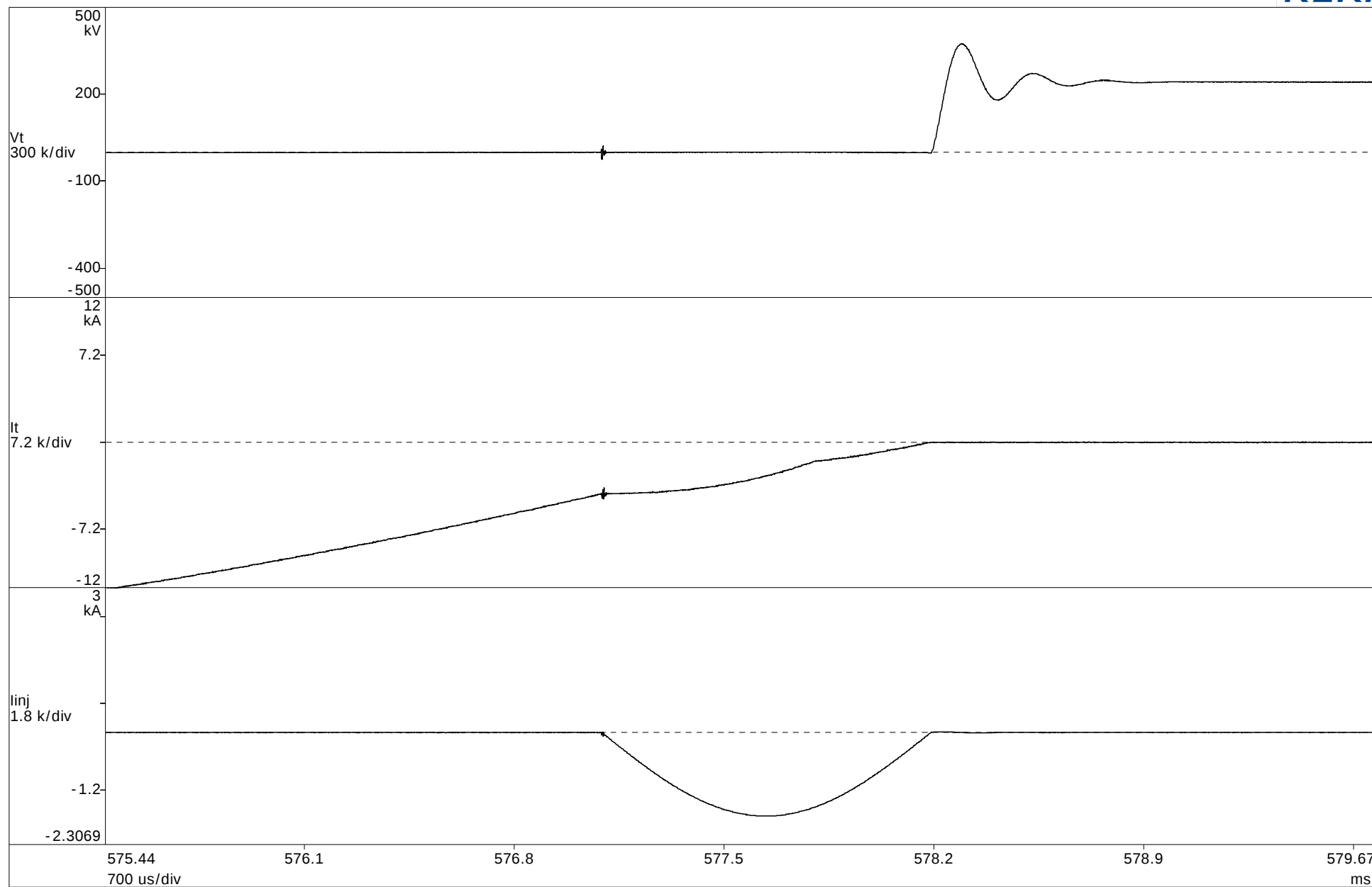
## HPC 1104 - 196



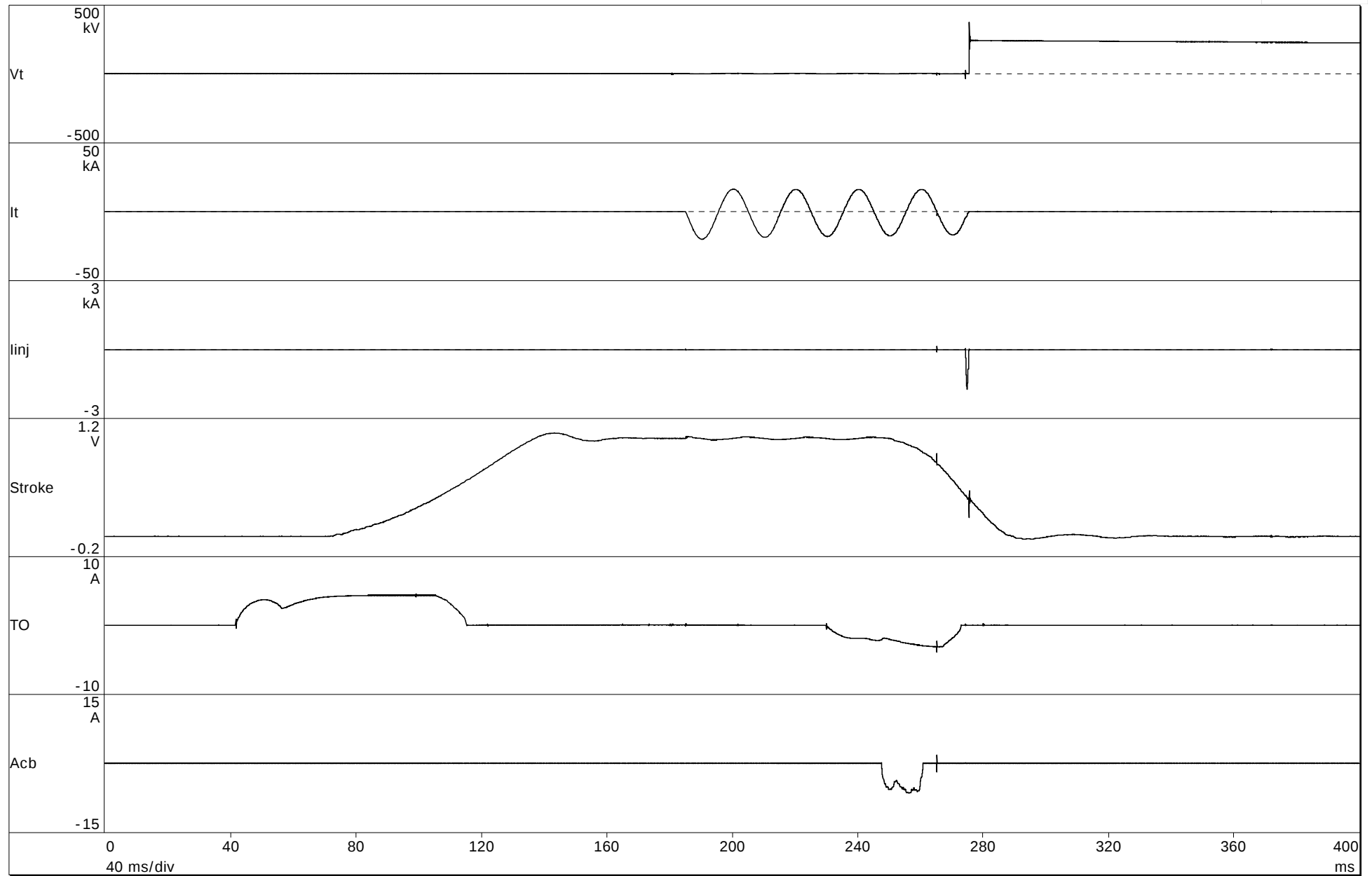
HPC 1104 - 198



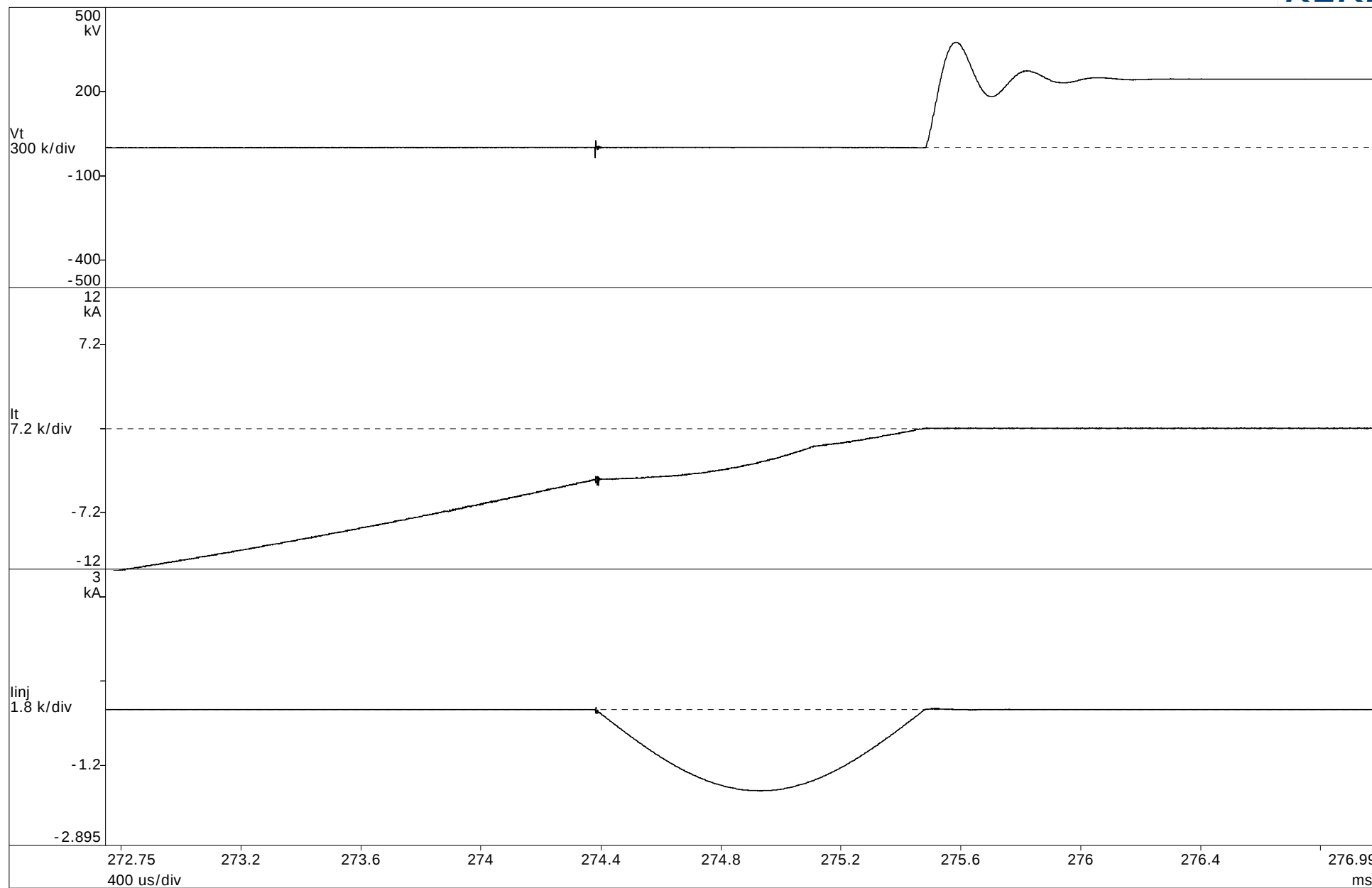
## HPC 1104 - 198



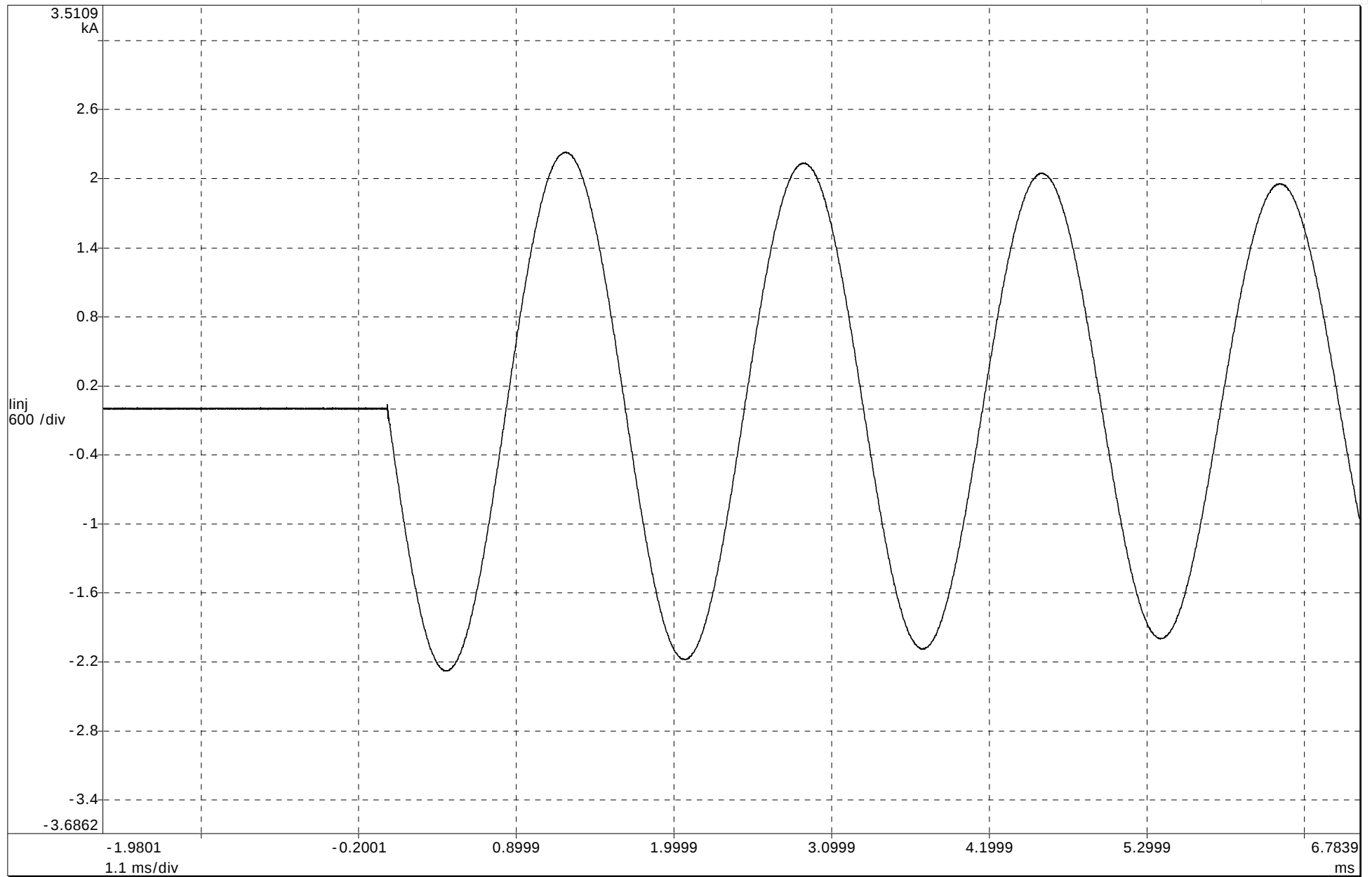
HPC 1104 - 199



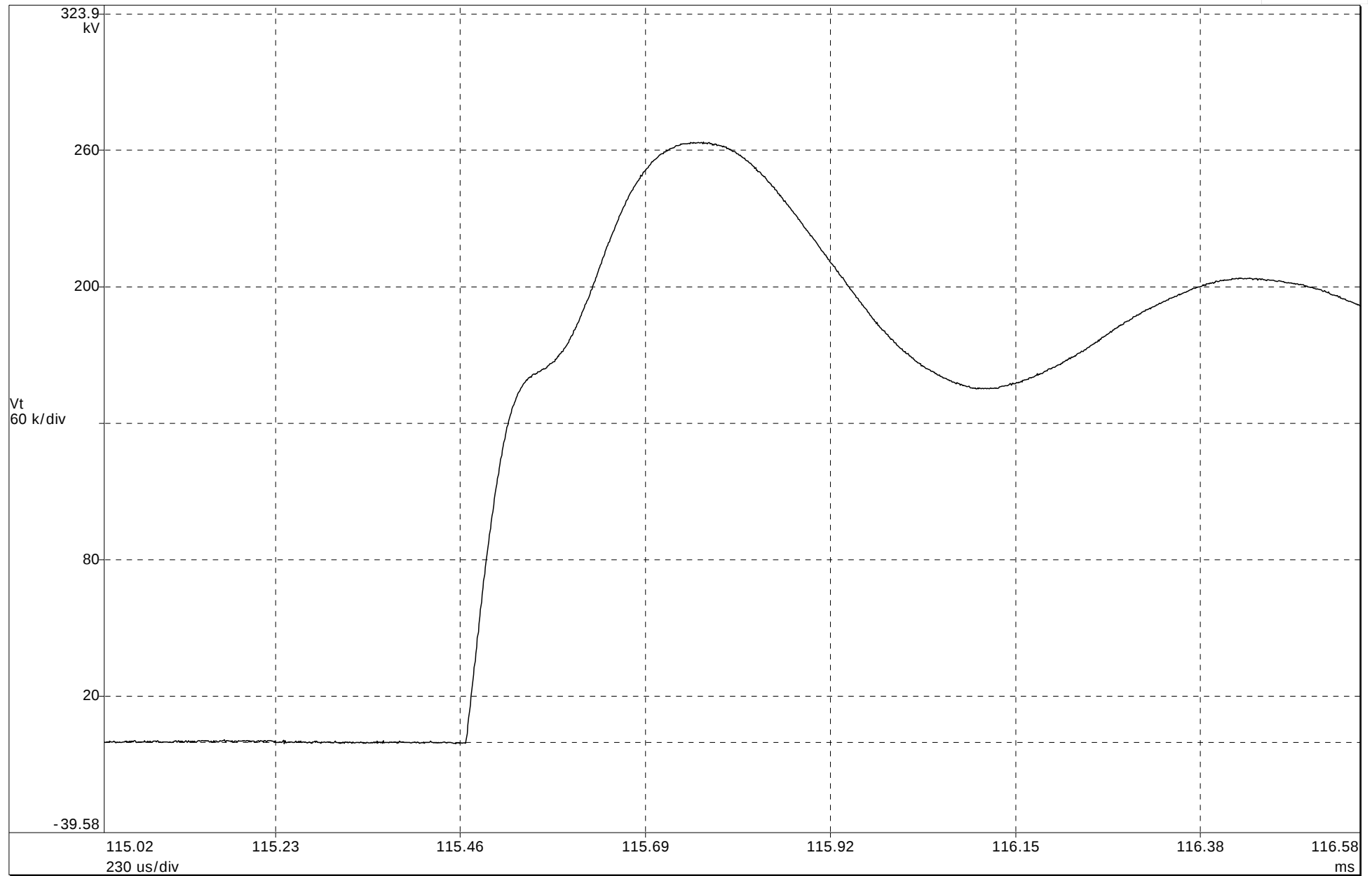
## HPC 1104 - 199



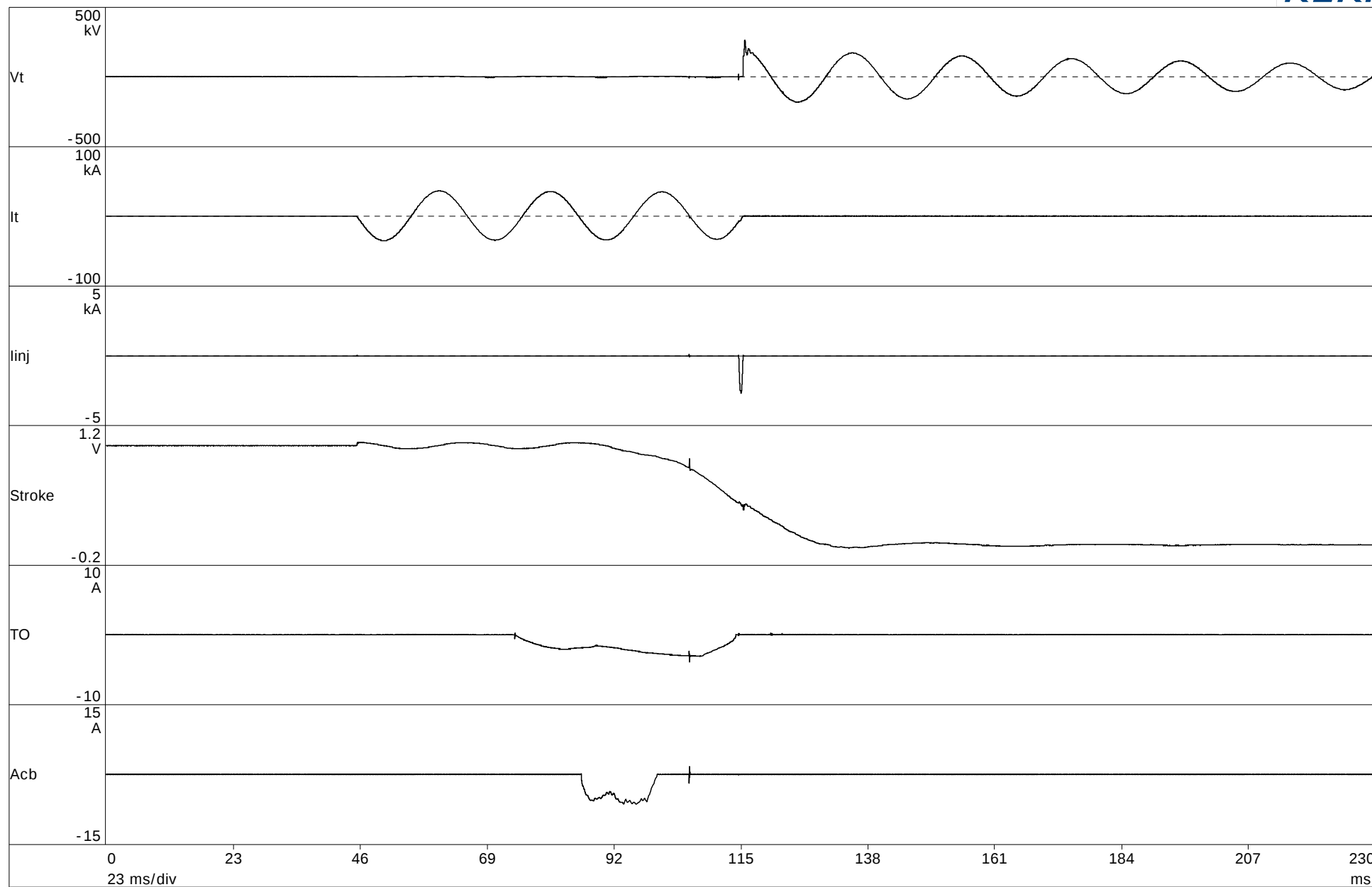
HPC 1104 - 200



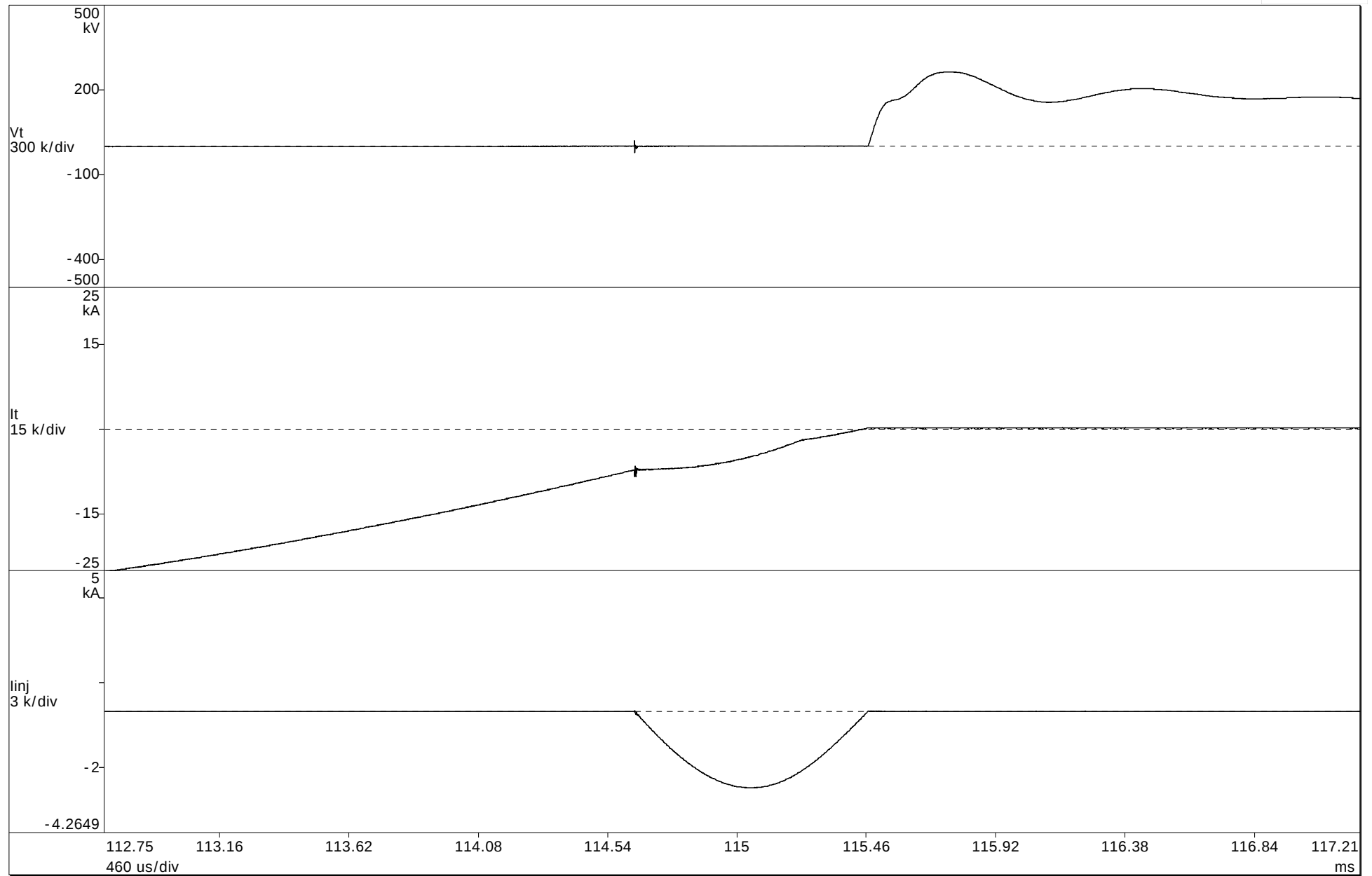
HPC 1104 - 204



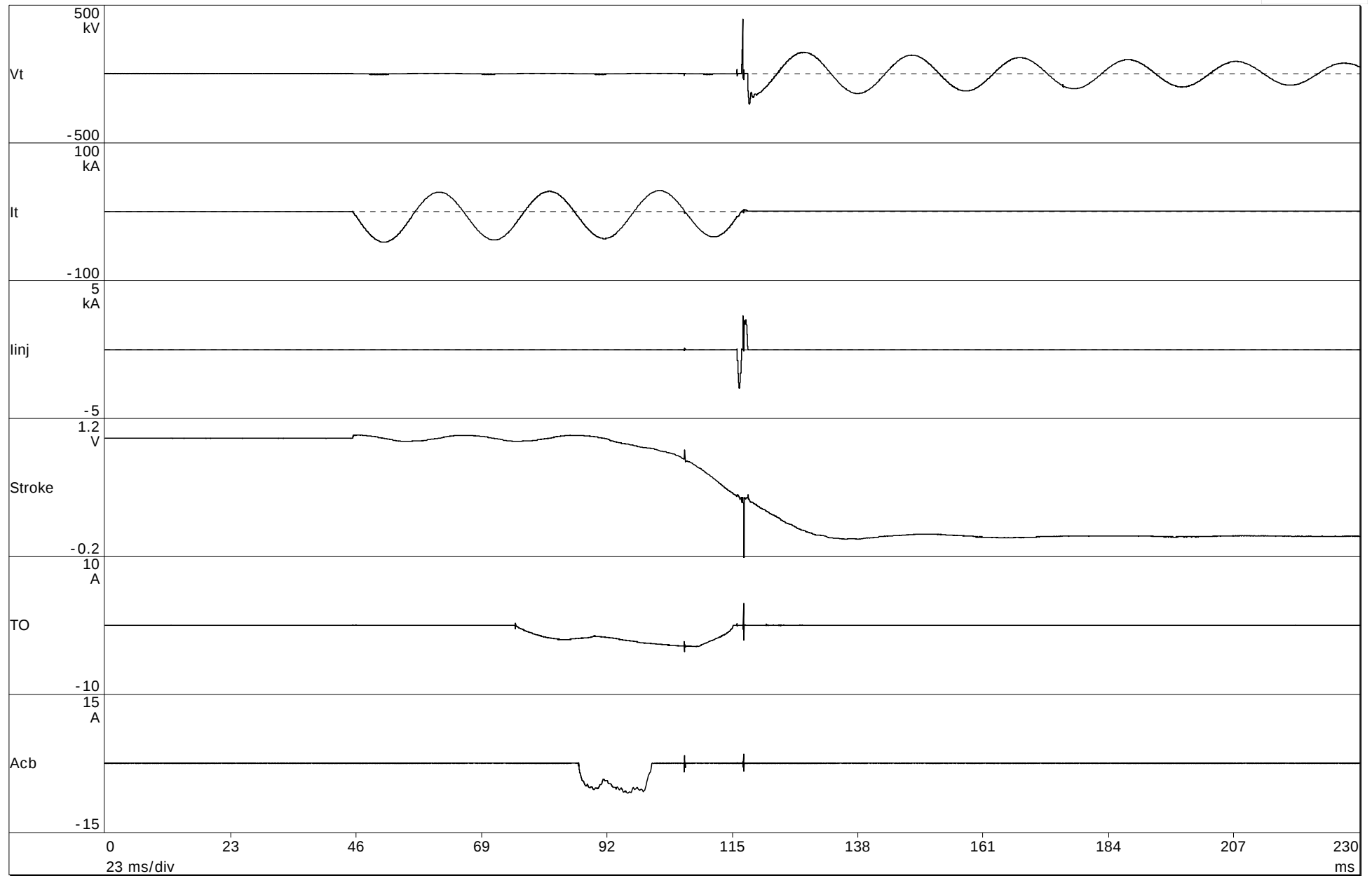
## HPC 1104 - 204



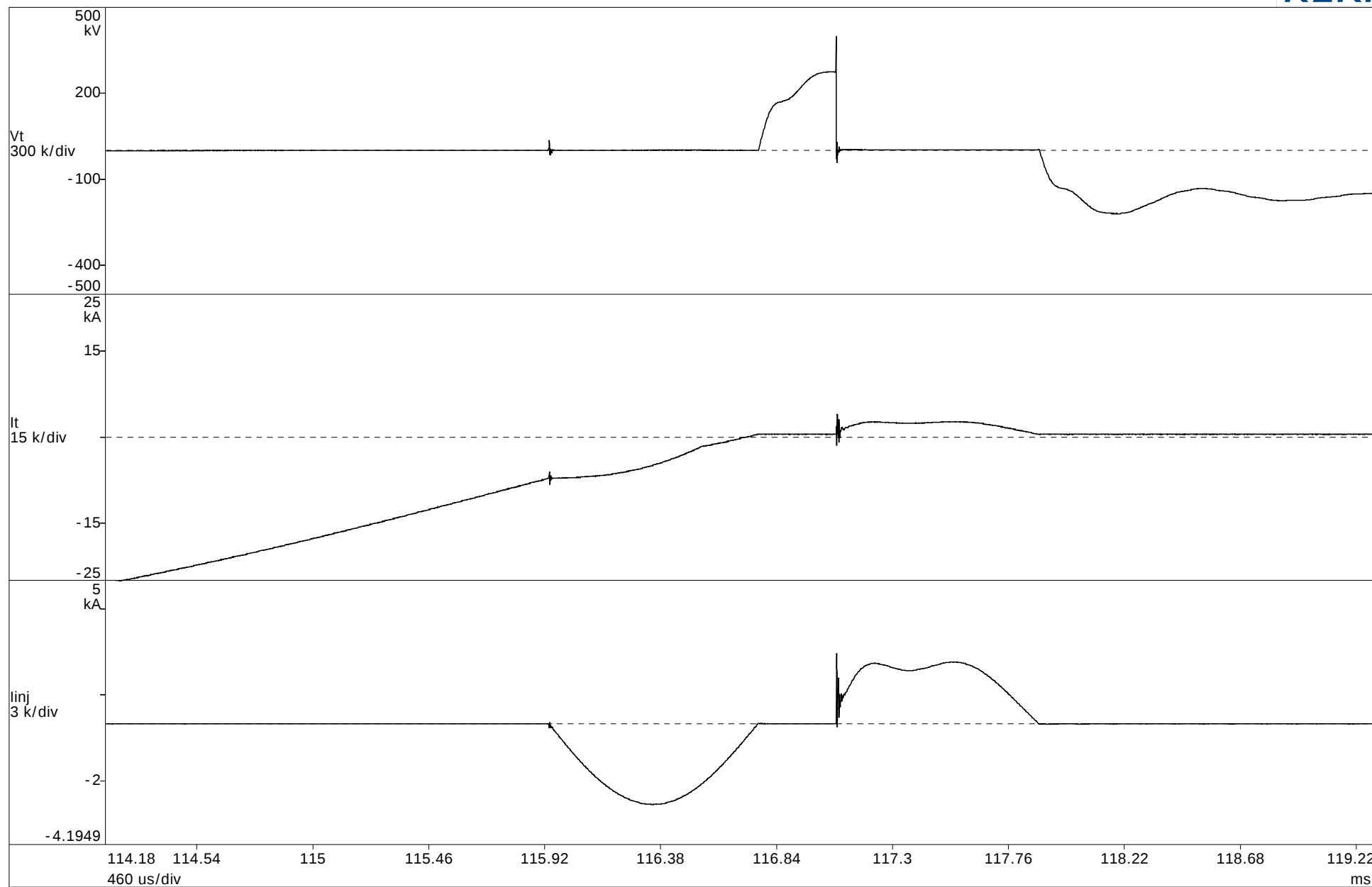
## HPC 1104 - 204



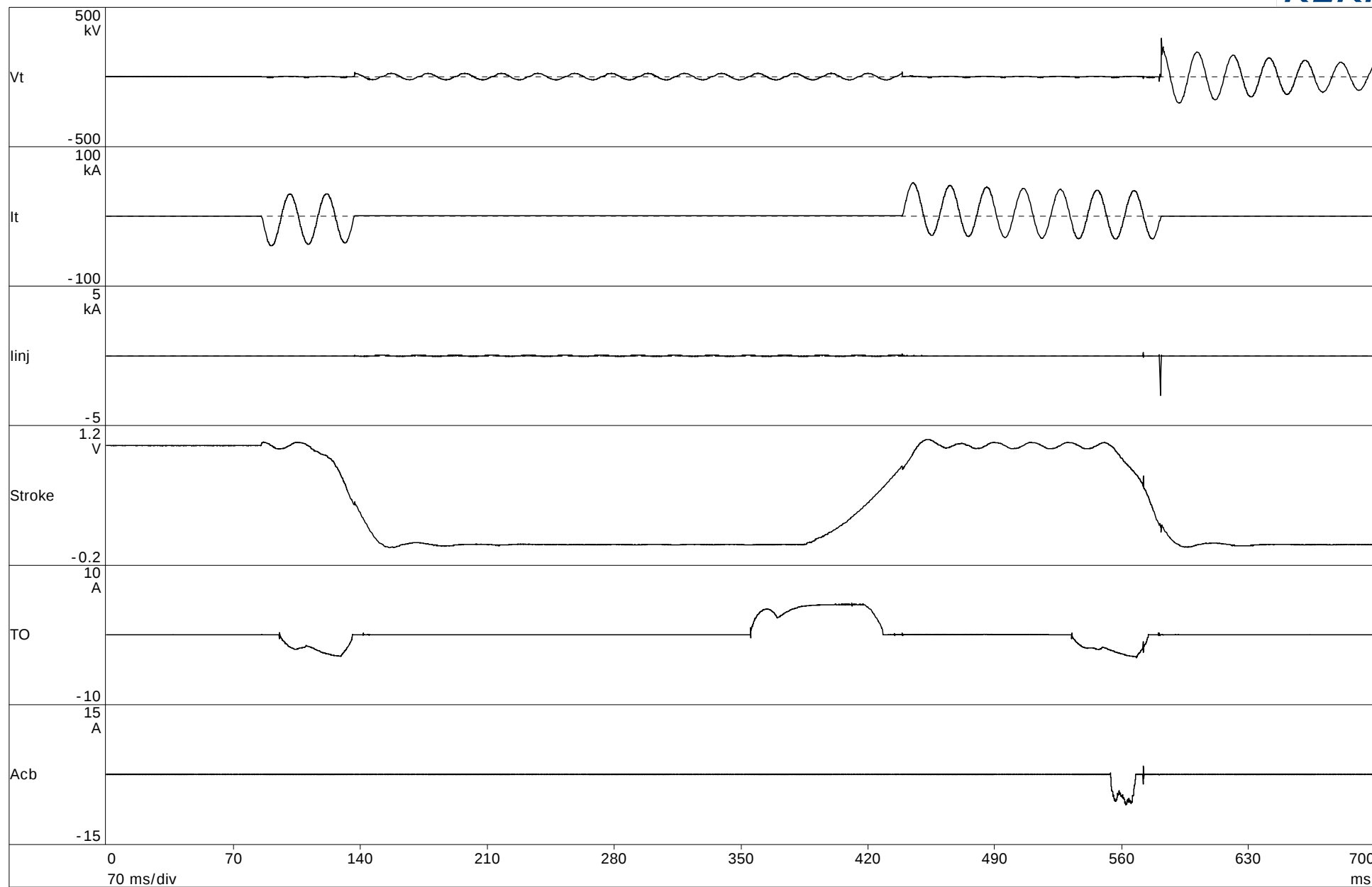
## HPC 1104 - 205



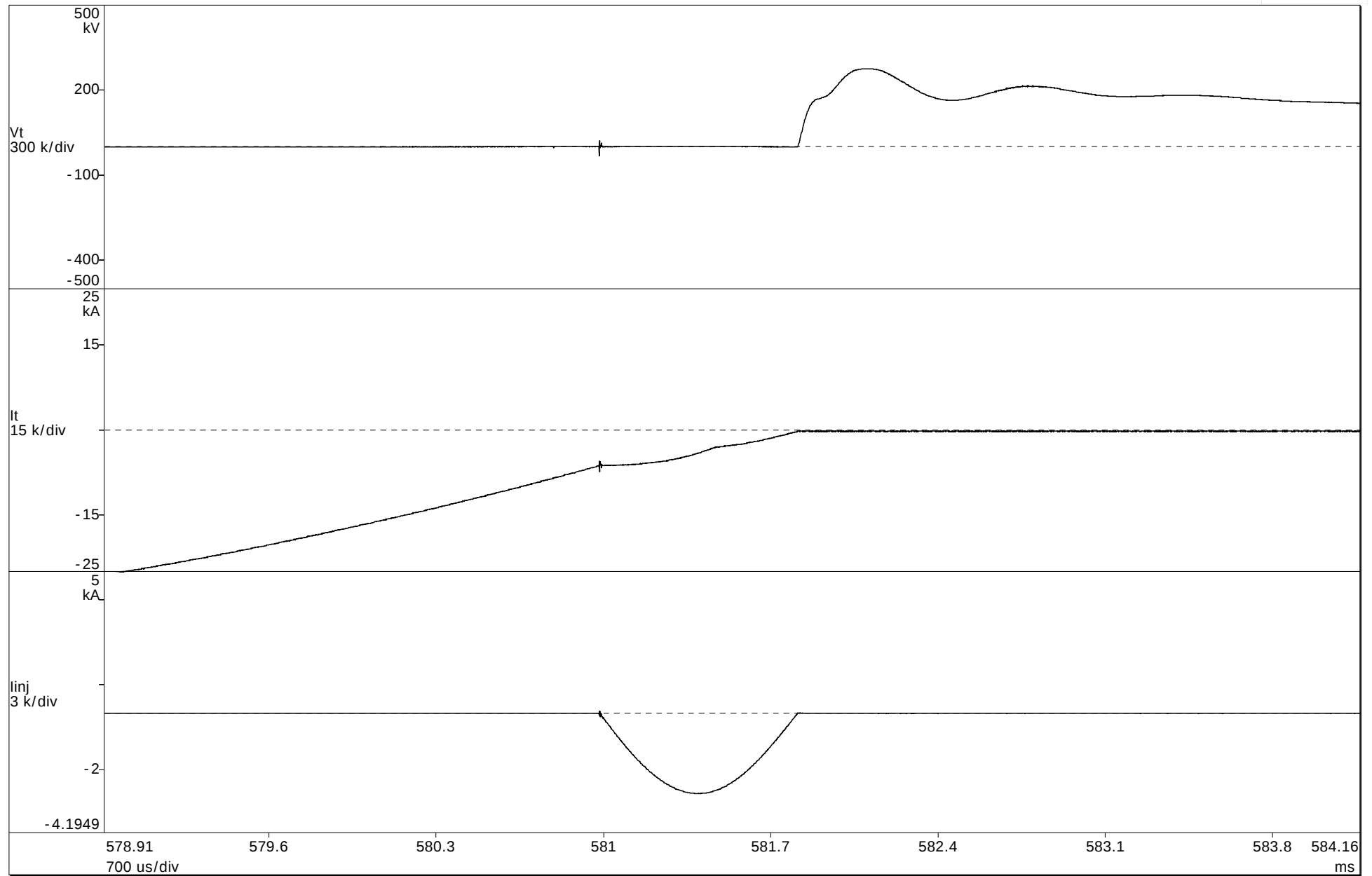
## HPC 1104 - 205



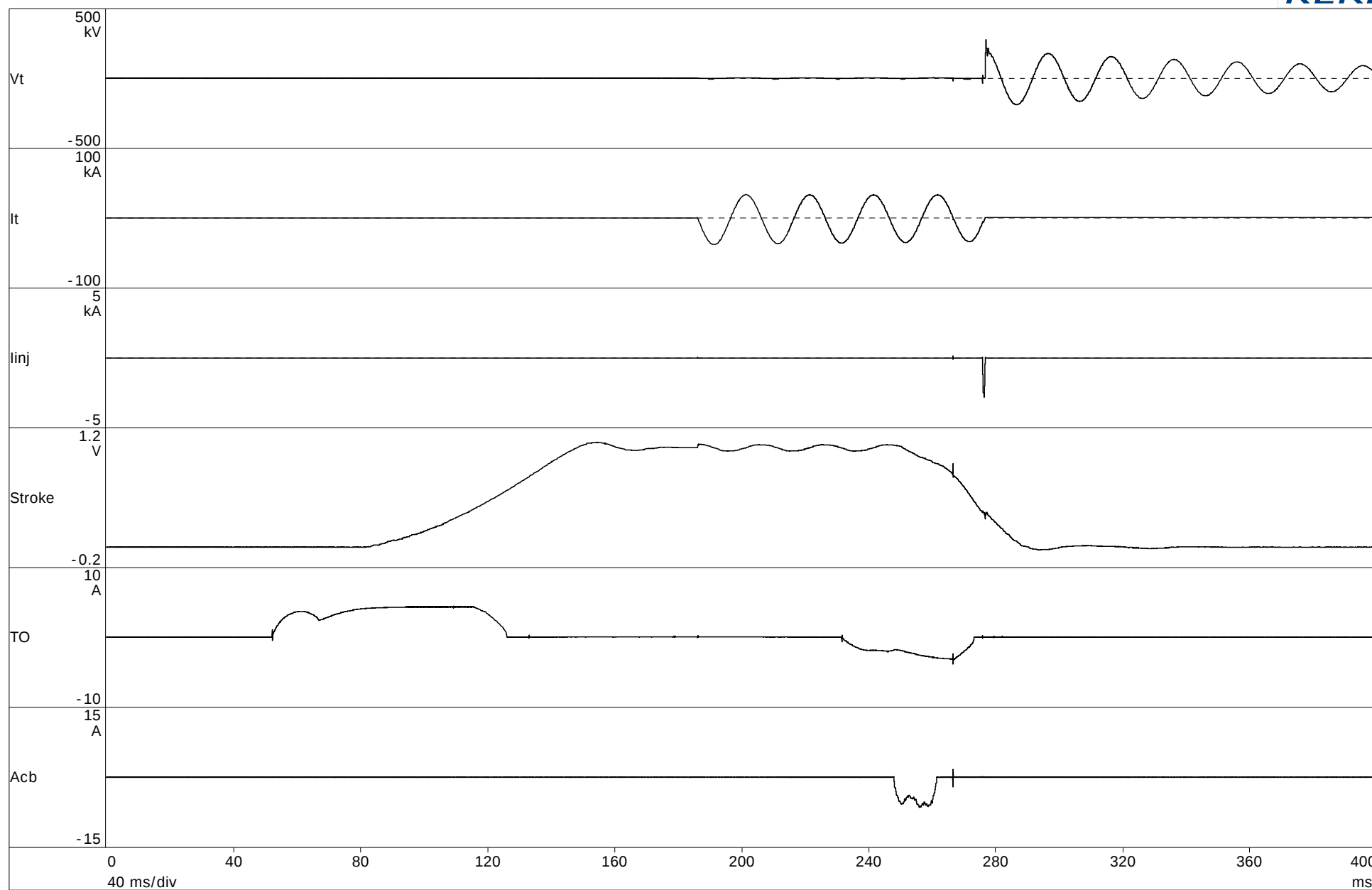
HPC 1104 - 207



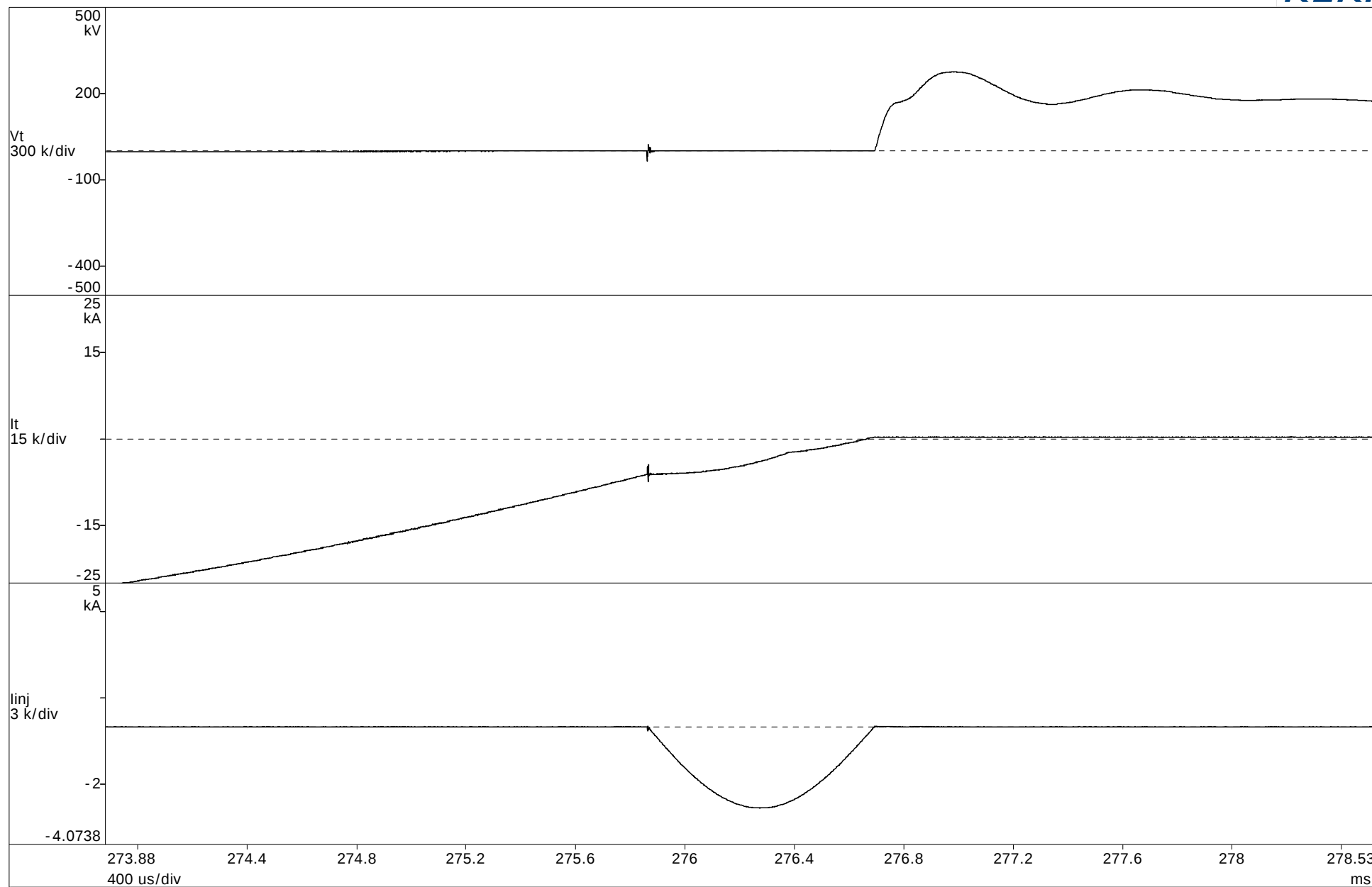
## HPC 1104 - 207



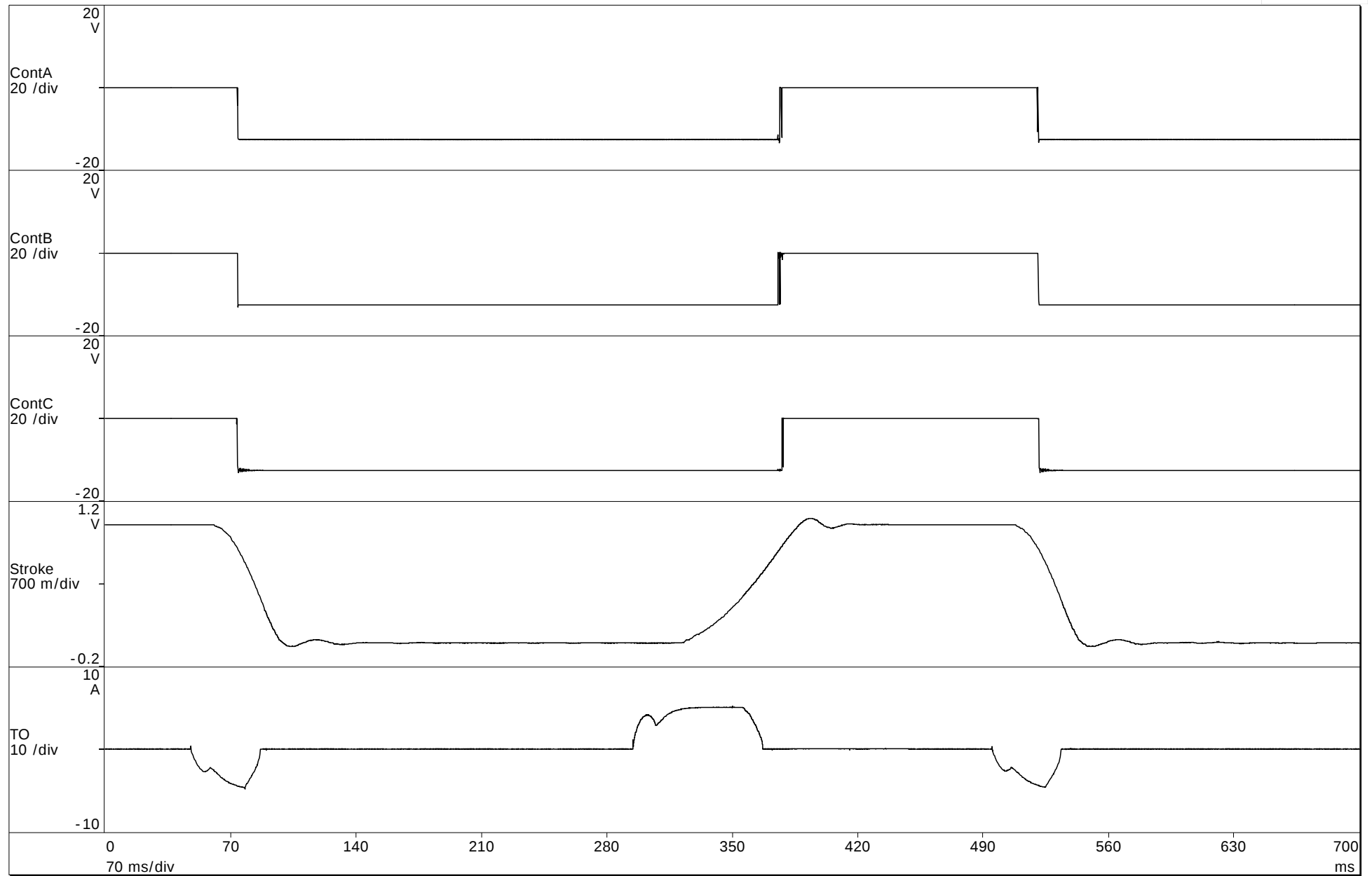
## HPC 1104 - 208



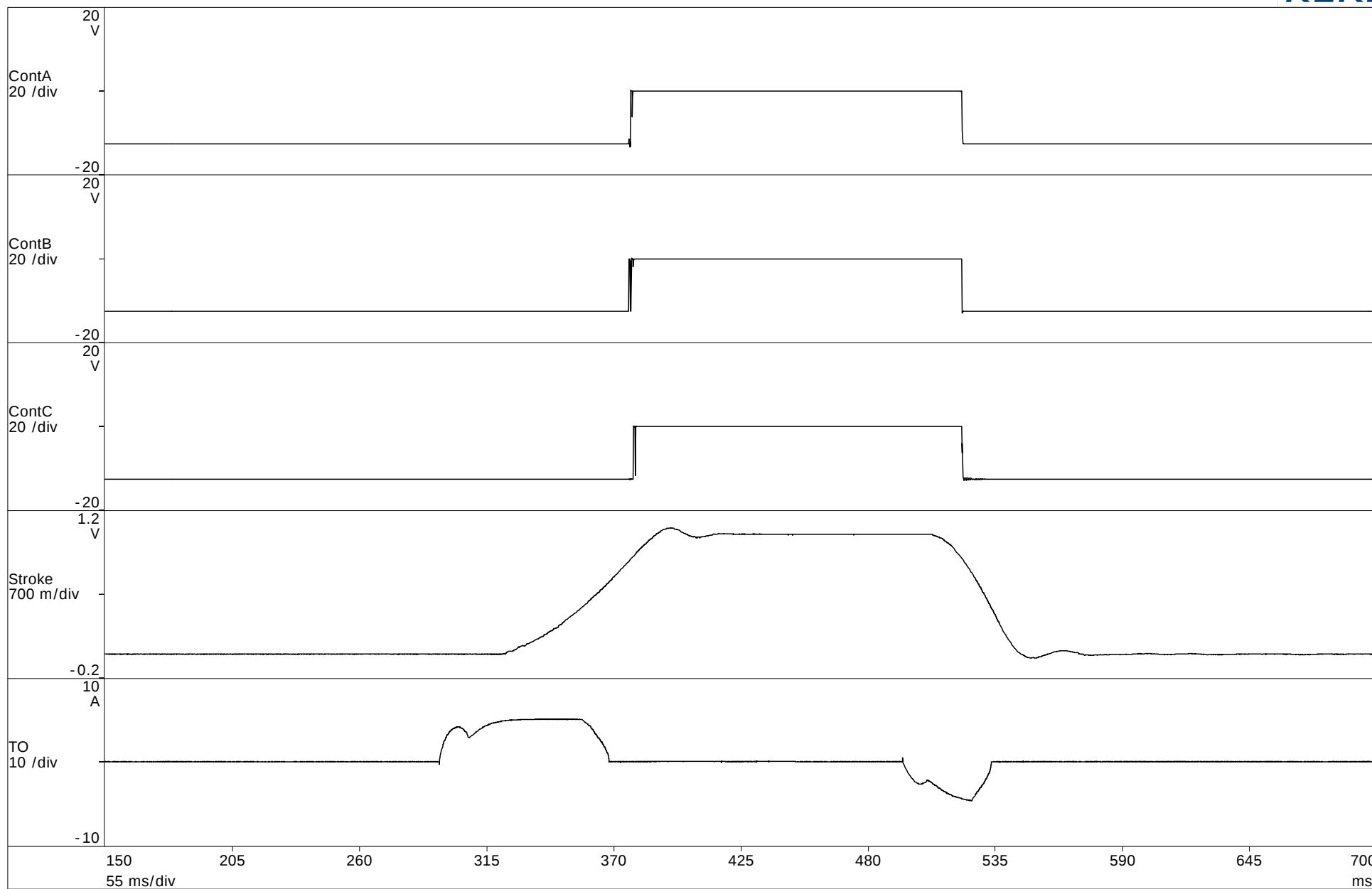
## HPC 1104 - 208



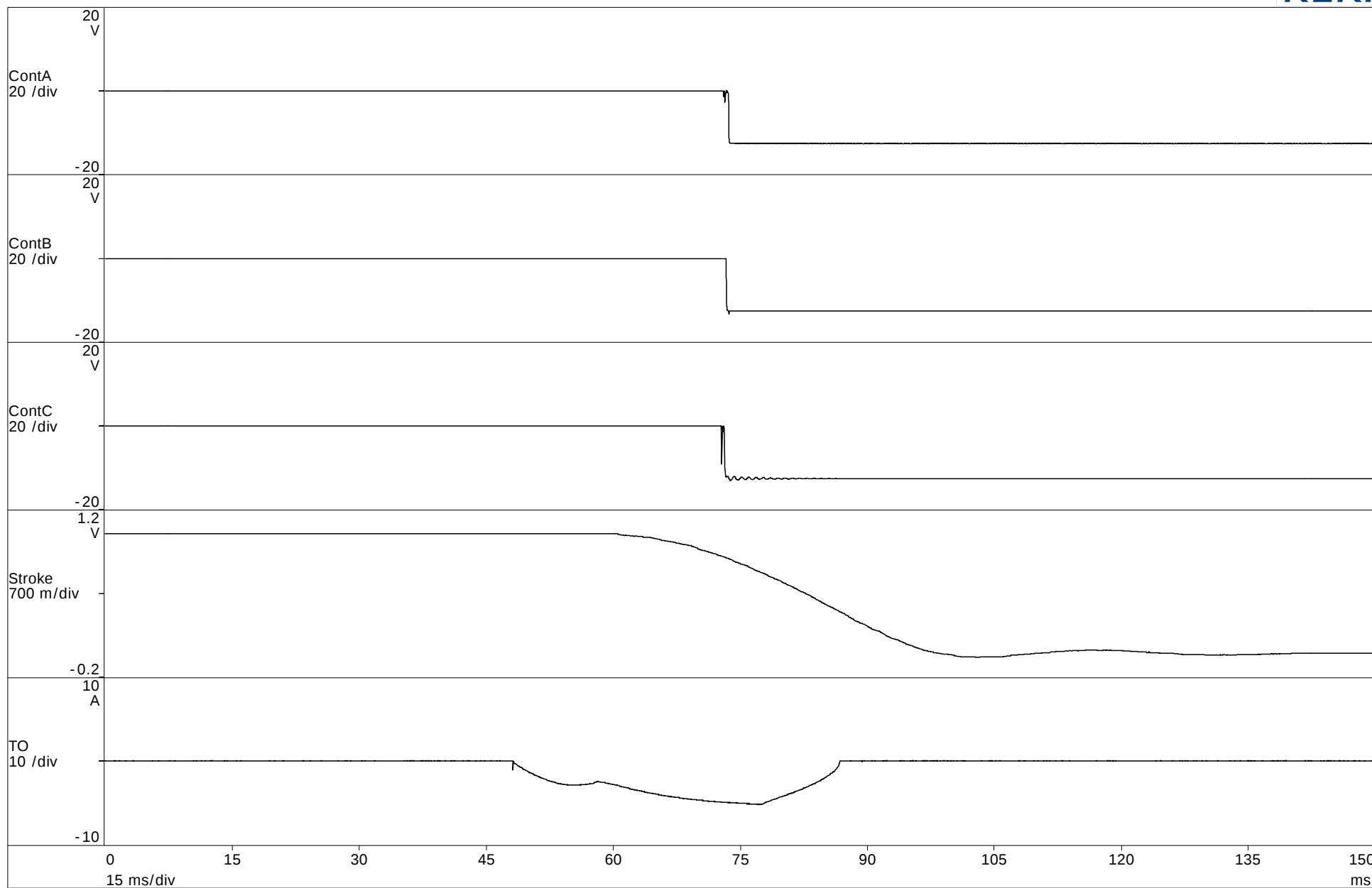
## HPC 1104 - 209



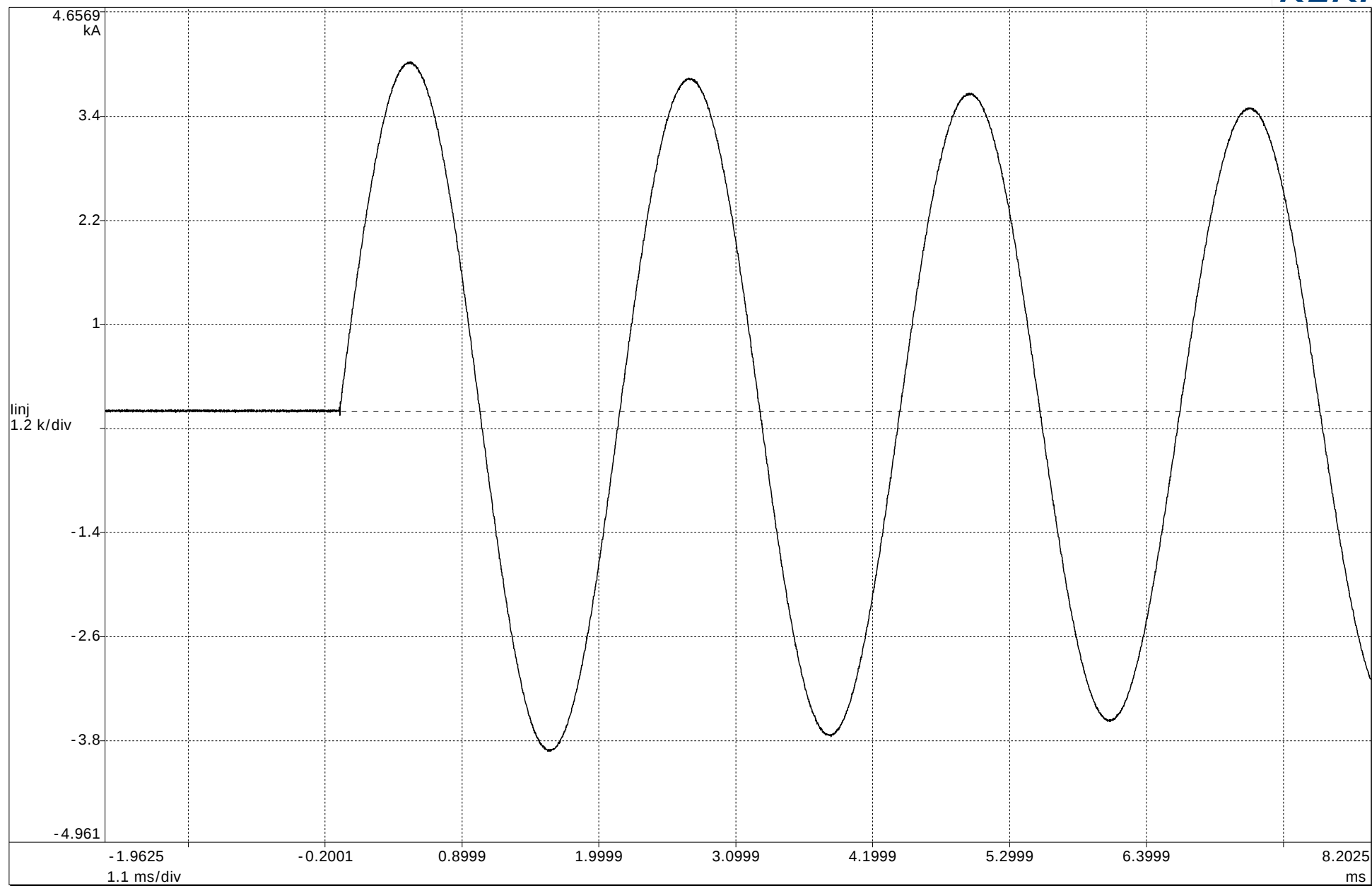
## HPC 1104 - 210



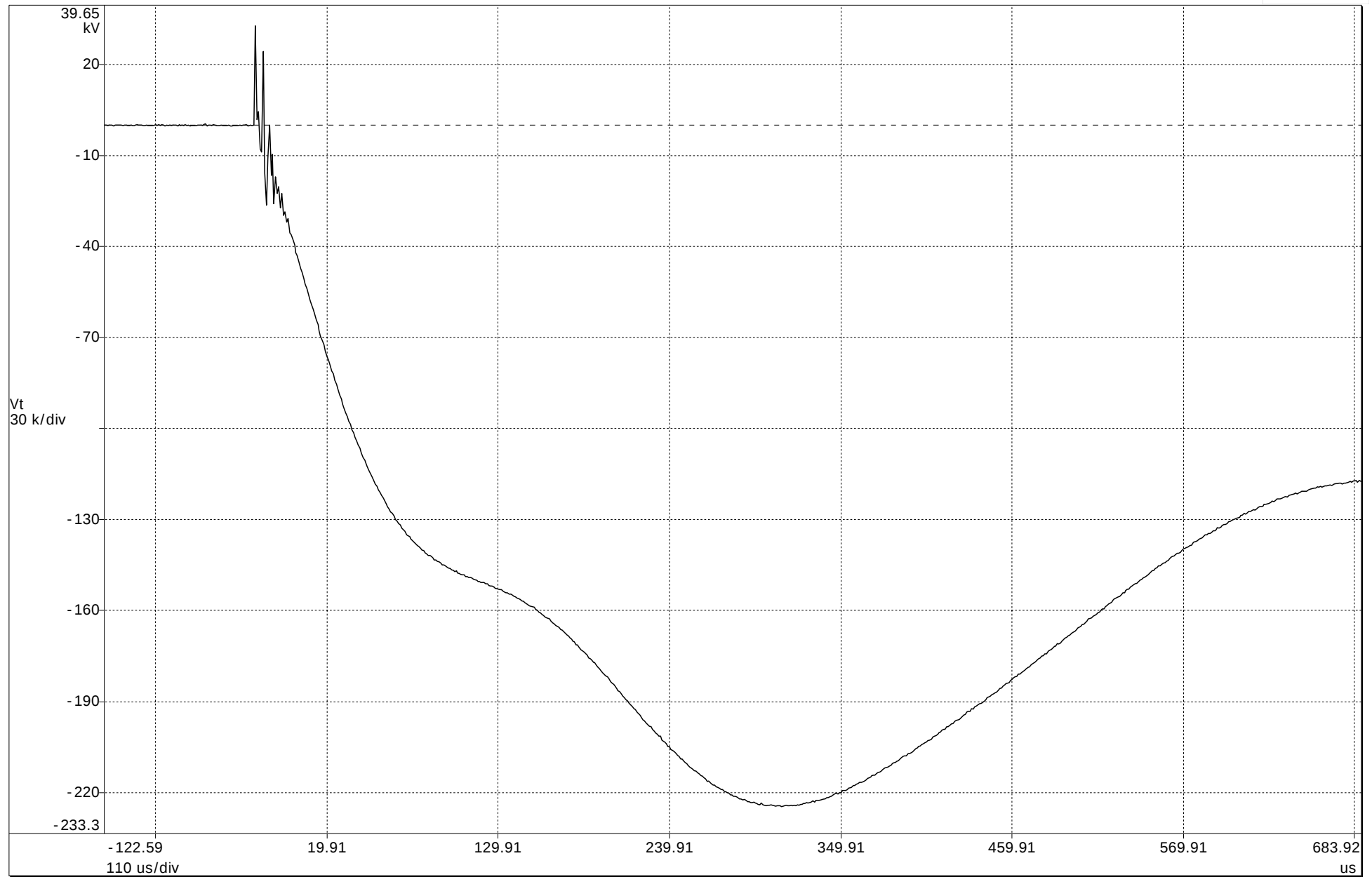
## HPC 1104 - 211



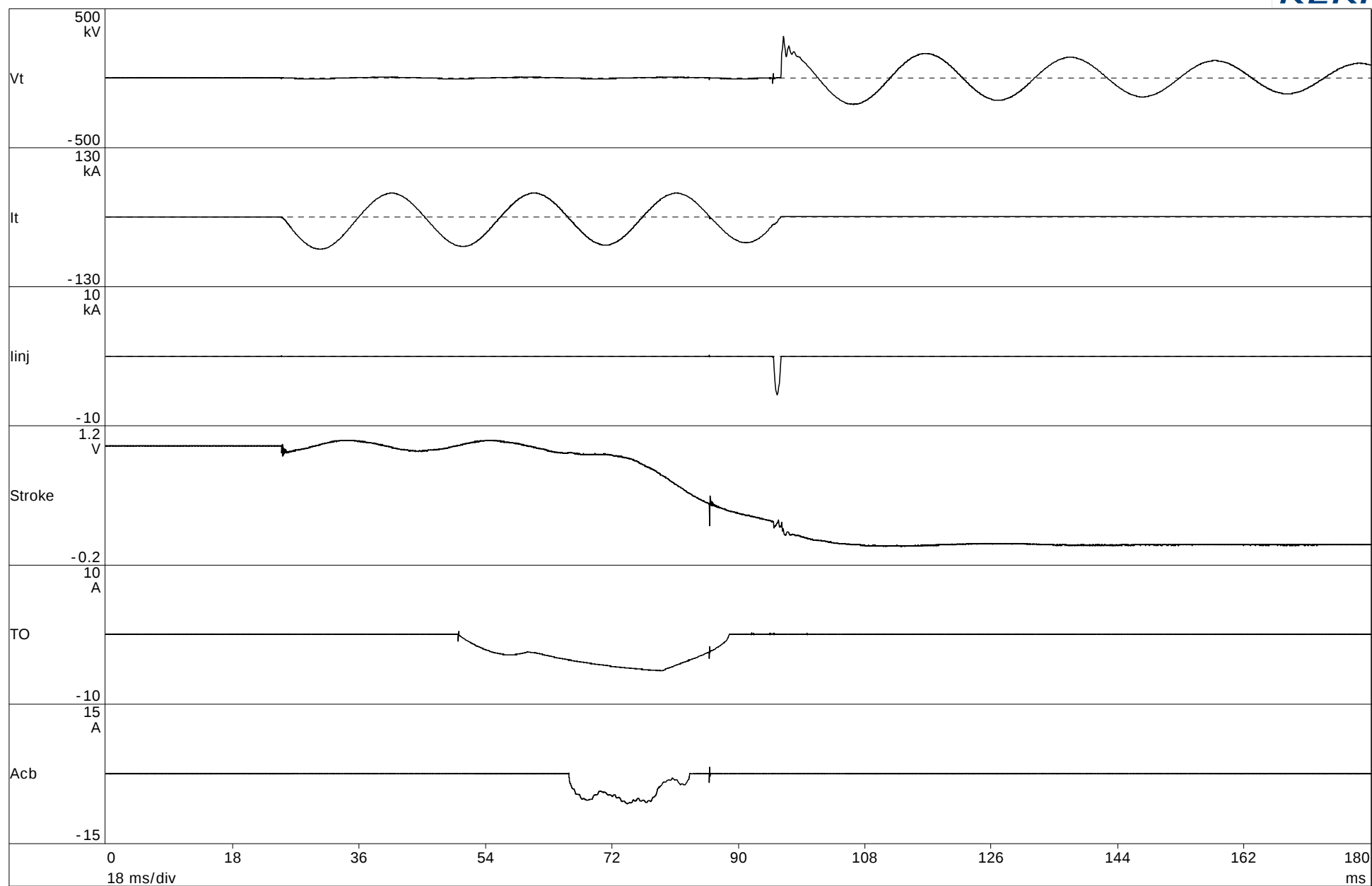
HPC 1104 - 212



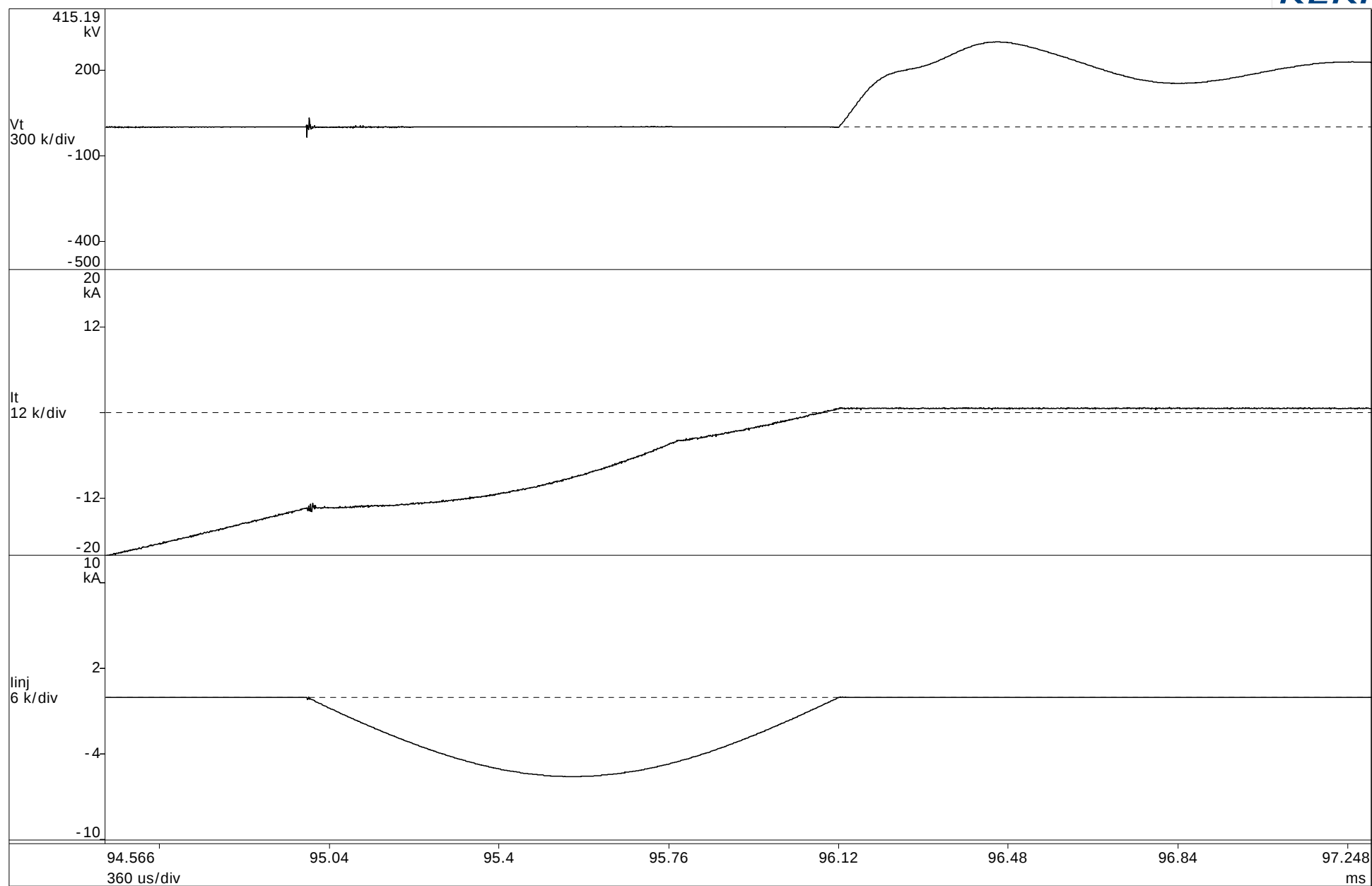
HPC 1104 - 213



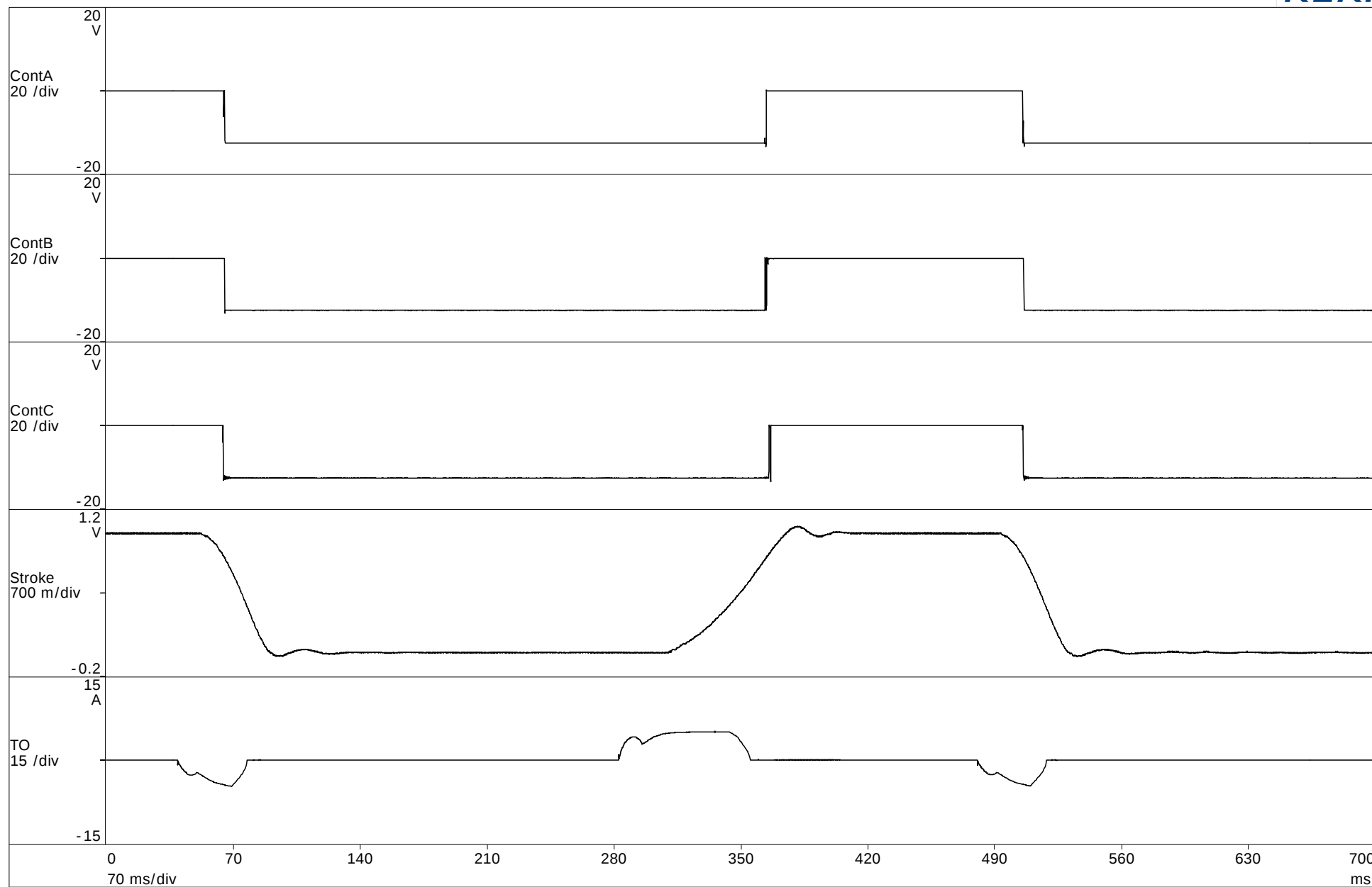
HPC 1104 - 216



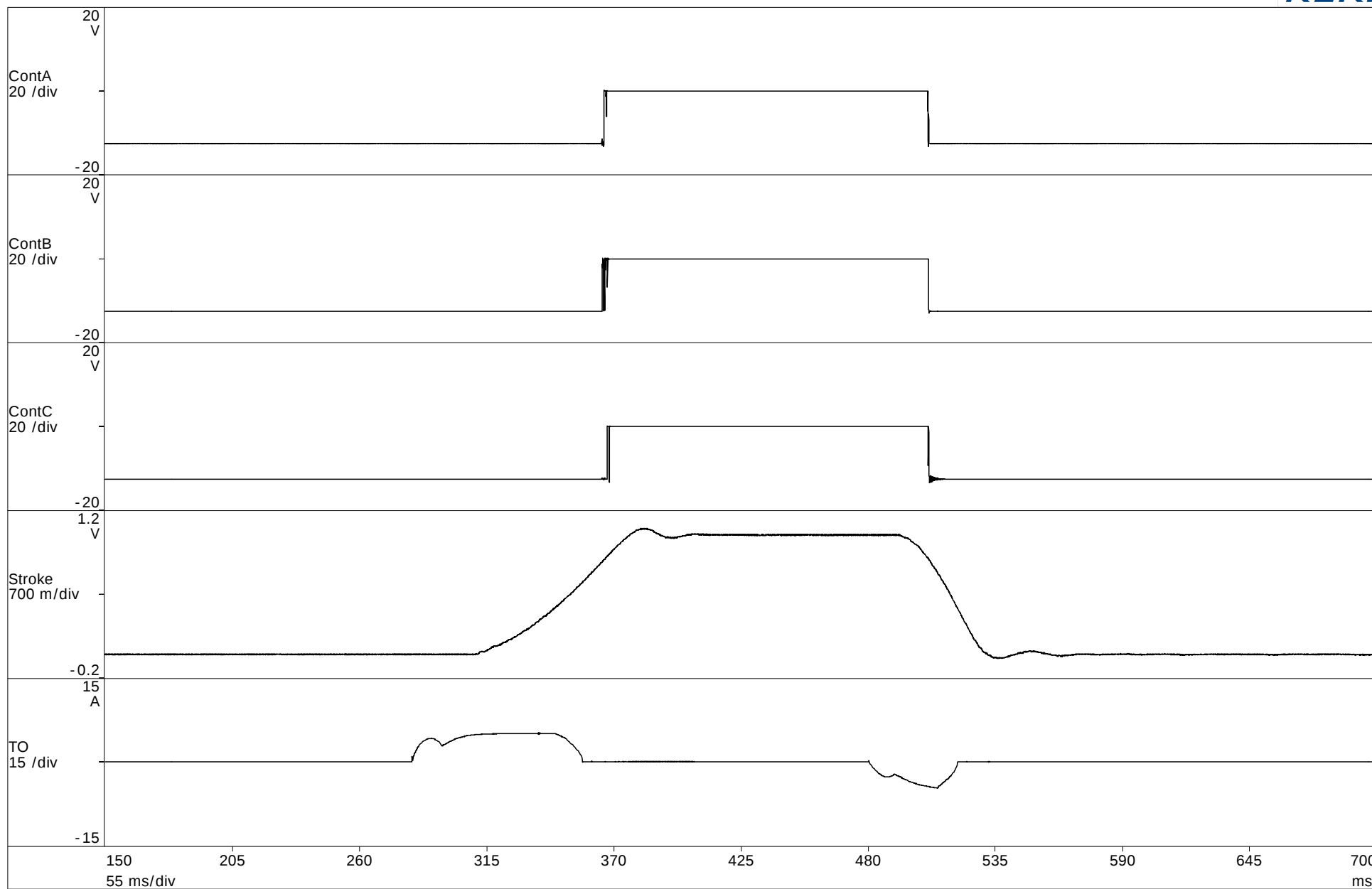
## HPC 1104 - 216



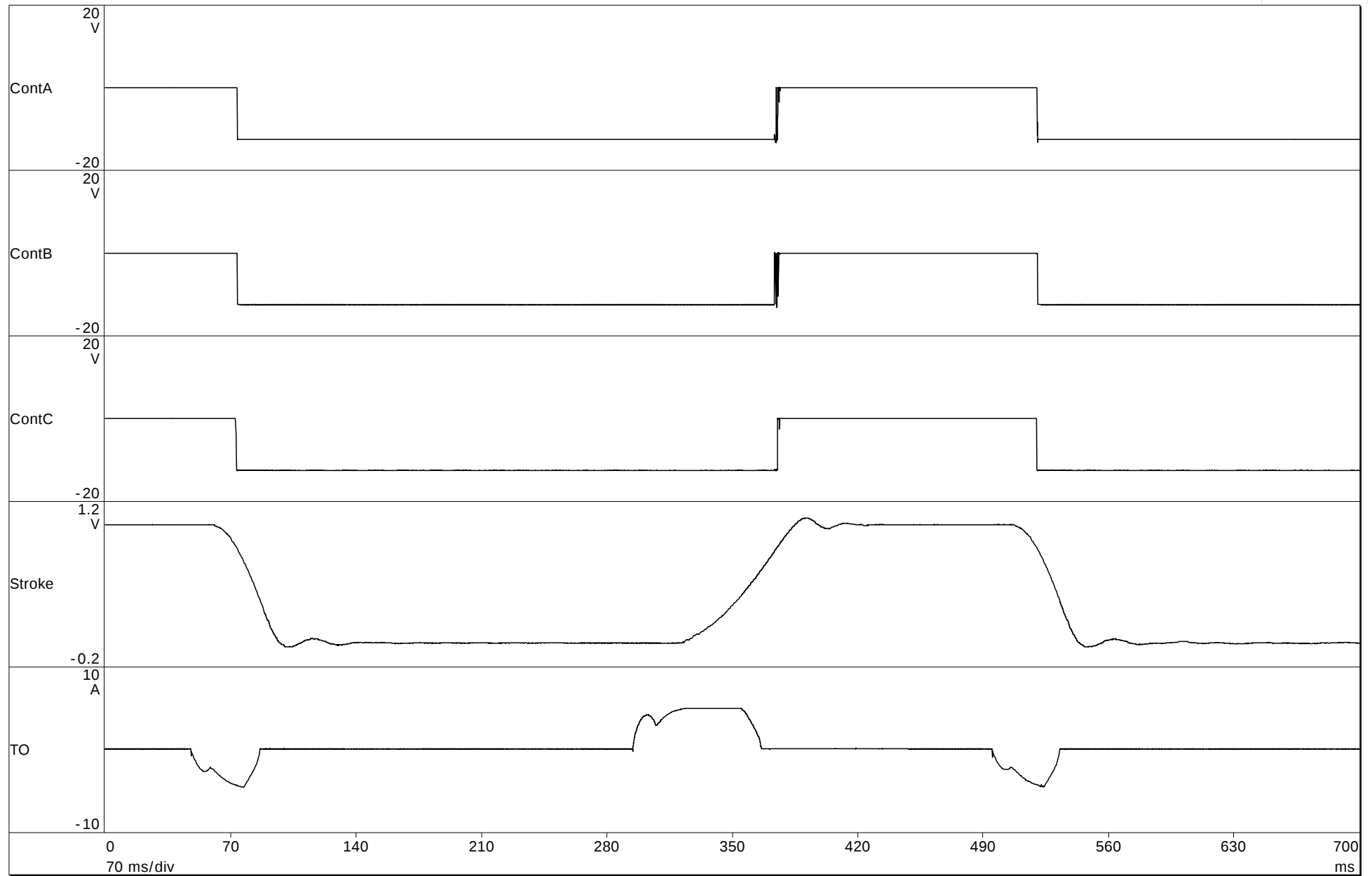
## HPC 1104 - 217



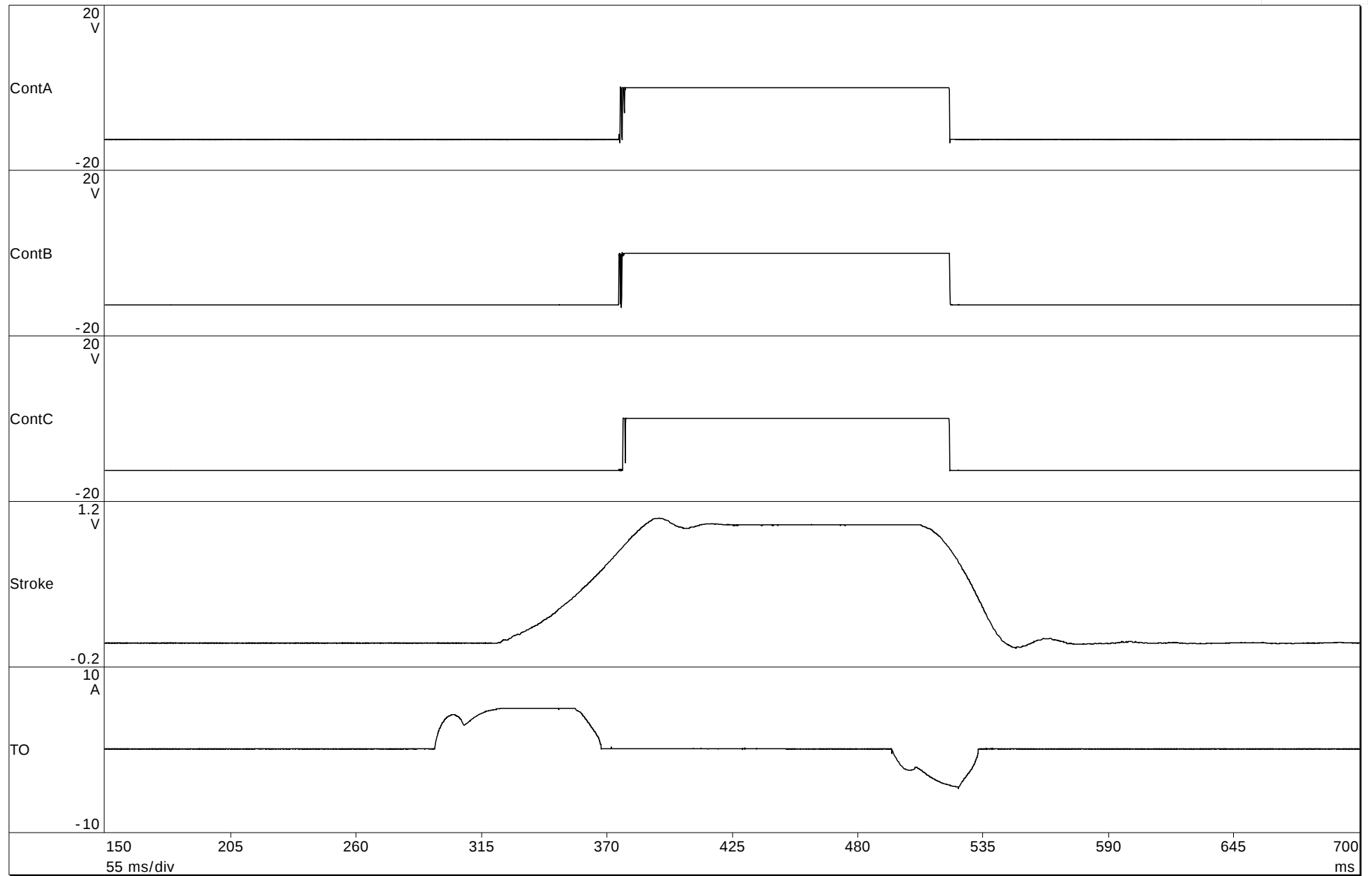
## HPC 1104 - 218



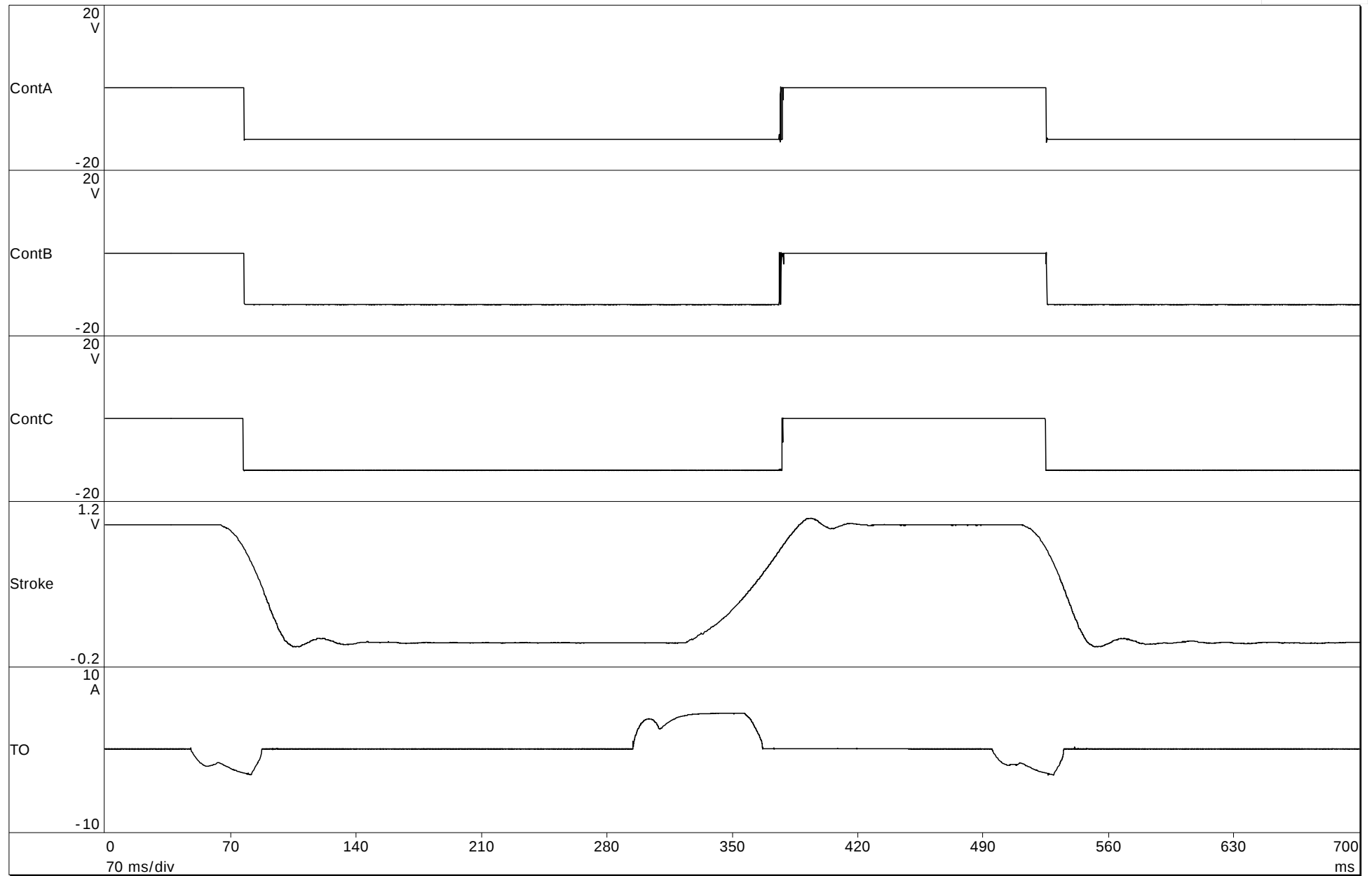
## HPC 1104 - 219



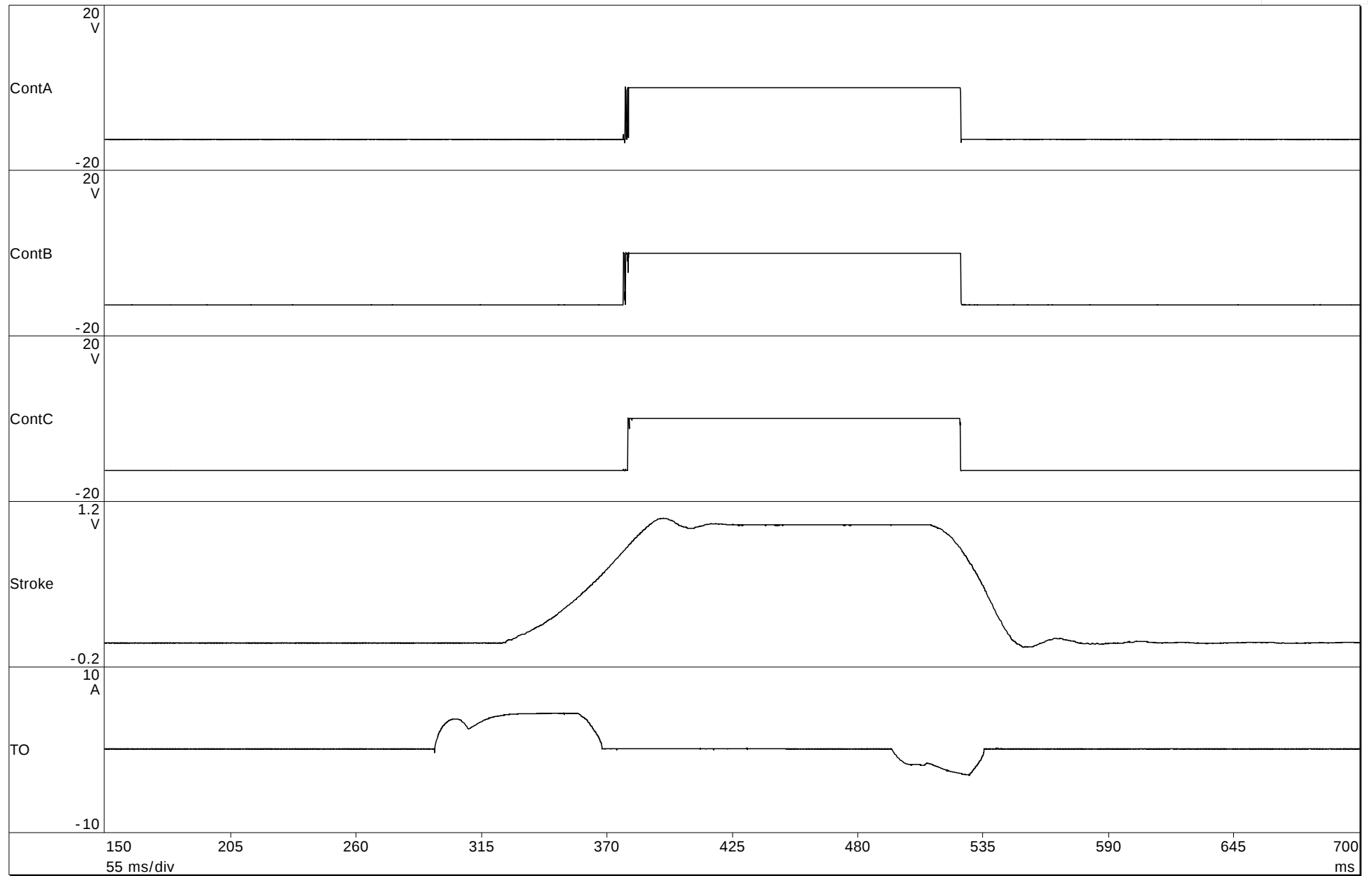
## HPC 1104 - 220



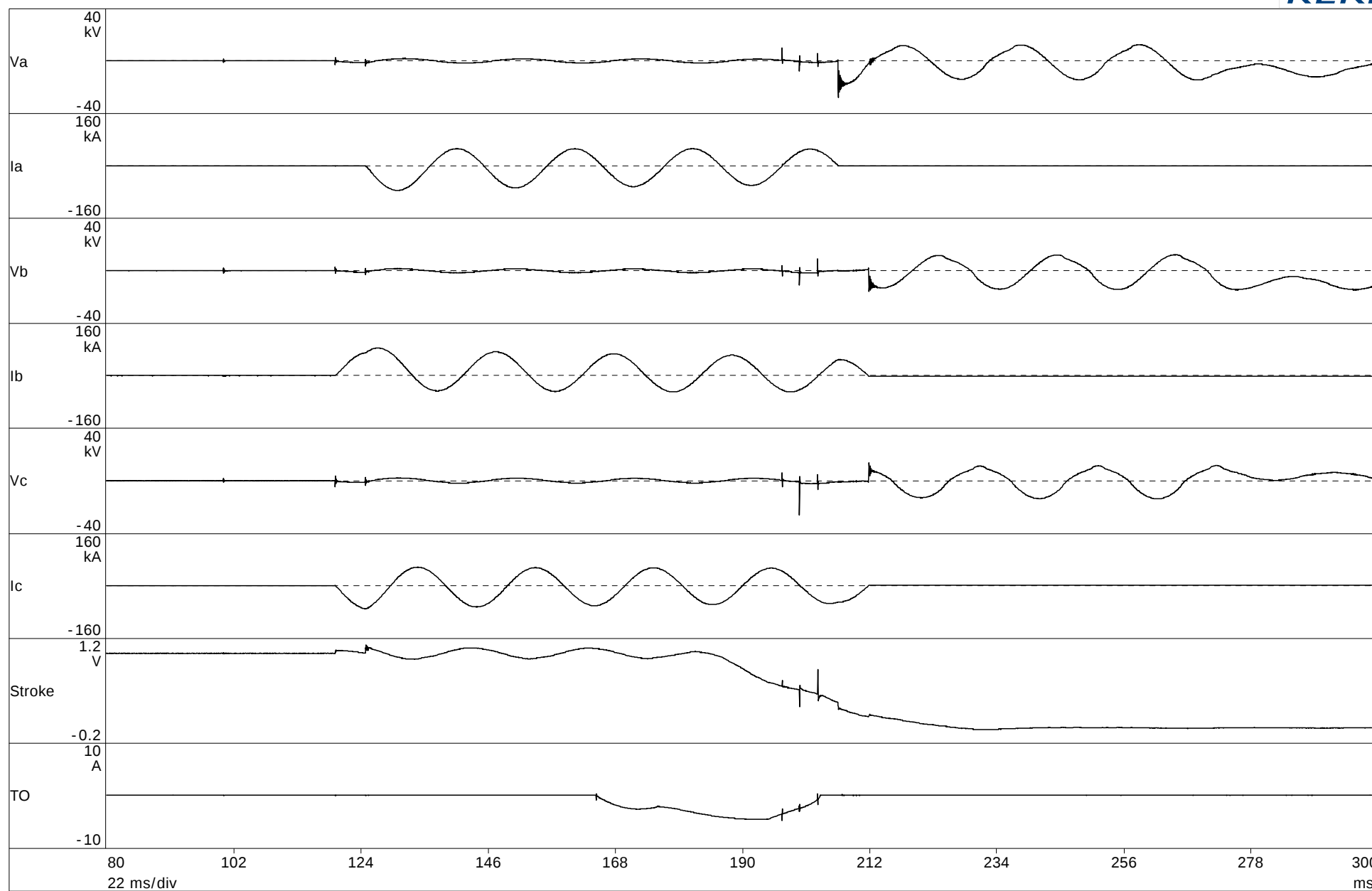
## HPC 1104 - 221



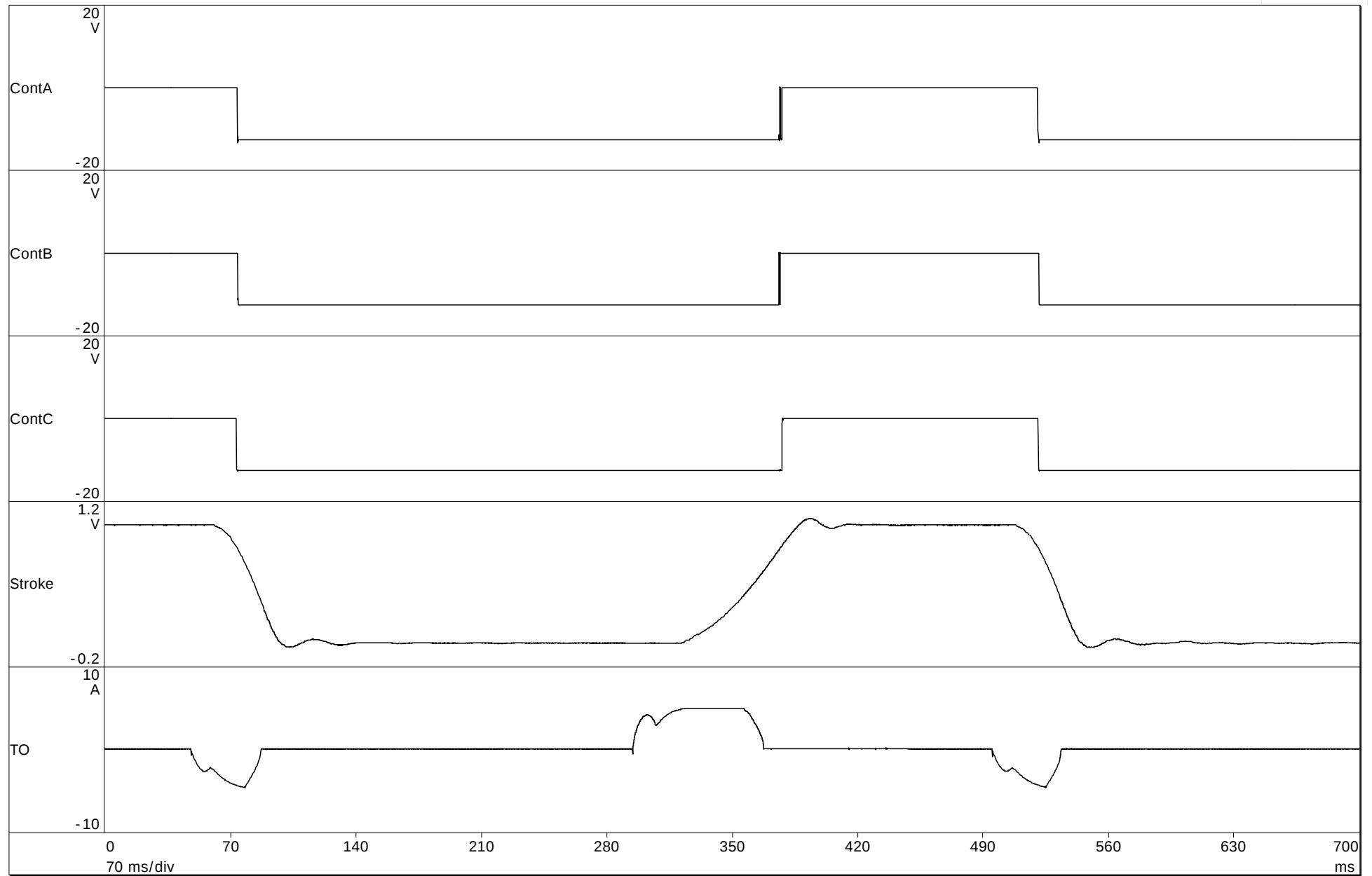
HPC 1104 - 222



HPC 1104 - 227



HPC 1104 - 228



HPC 1104 - 229

