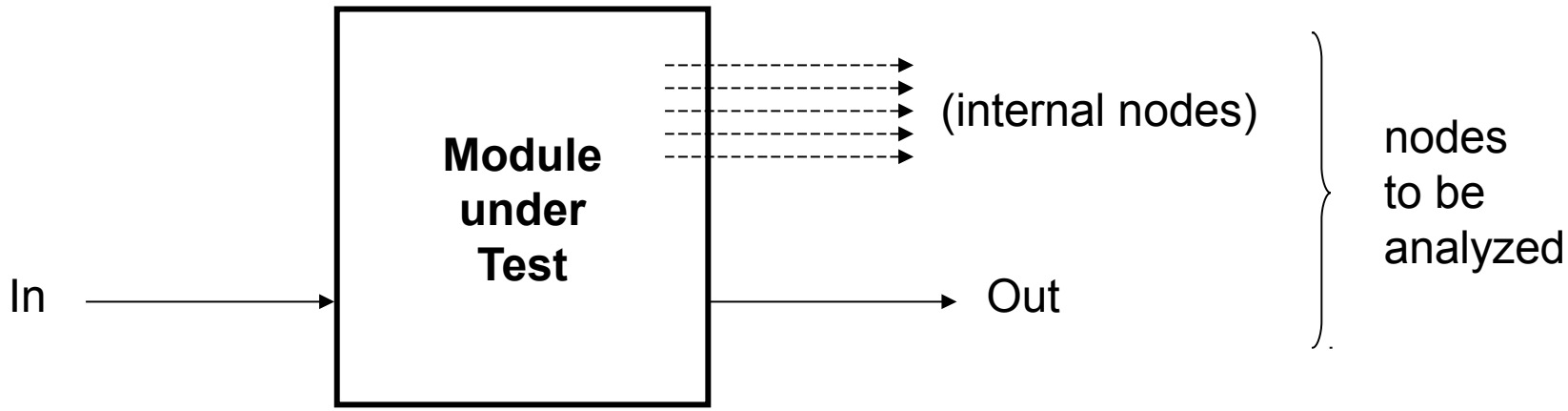
# Determination of the Worst Peak Output Voltage in a Linear Time Invariant Circuit

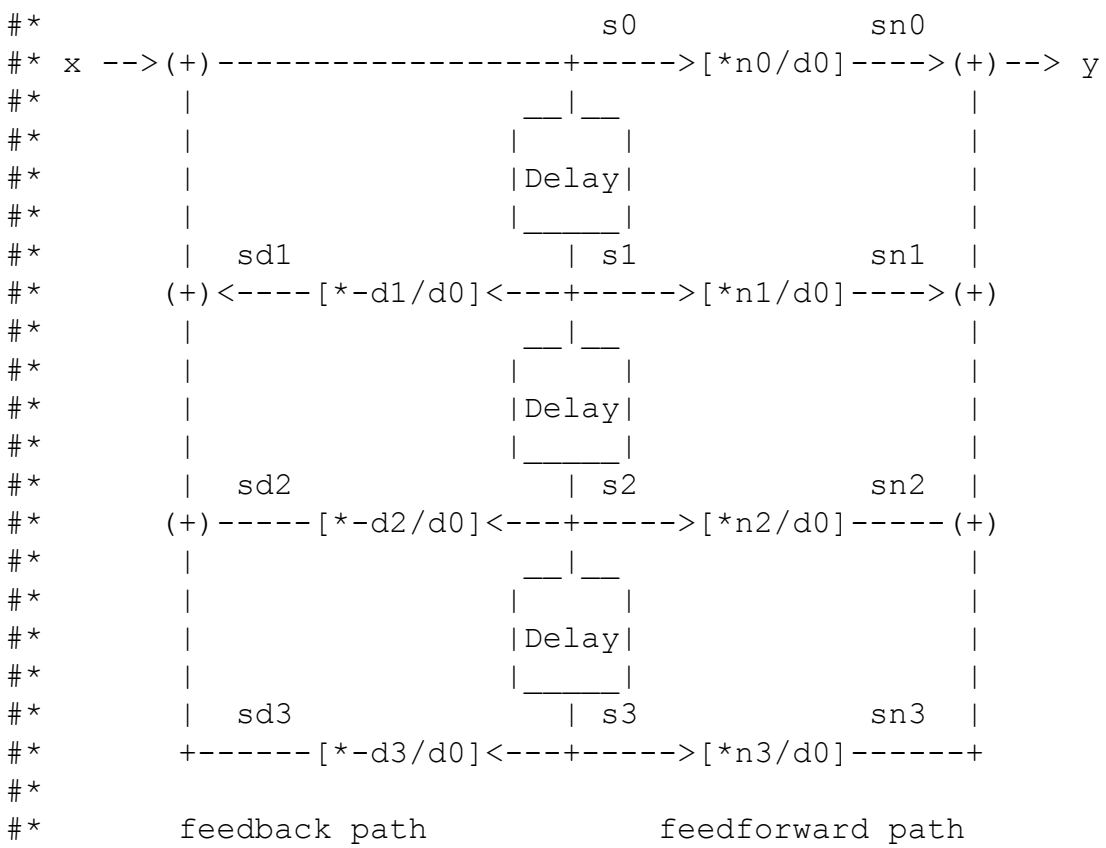
*based on the Step Response*

Yves Leduc, 2007




Hypothesis:

- Input is bounded  Lmin <= In <= Lmax
- Module is causal, LINEAR and time-invariant




We will apply the method to an example:

**the Output of this High Pass IIR Analog Filter**

Lmin = 0.0
Lmax = 1.0

# Local Extrema of the IIR Transfer Function

*NAPA netlist*

```
header <napatool.hdr>

title  "transfer function of IIR filter"

fs           48.0e3

ivar   npts   POWEROF2(20)

directive    REPEAT  25

node   in     noise    0.0 1.0
node   out    generator  hpf3      <iir>    "f3.dat"     in

tool   tf     "tf.out"    in 1.0   out 1.0   5.0e3    npts          // transfer function

terminate    TOOL_INDEX >= 1
```

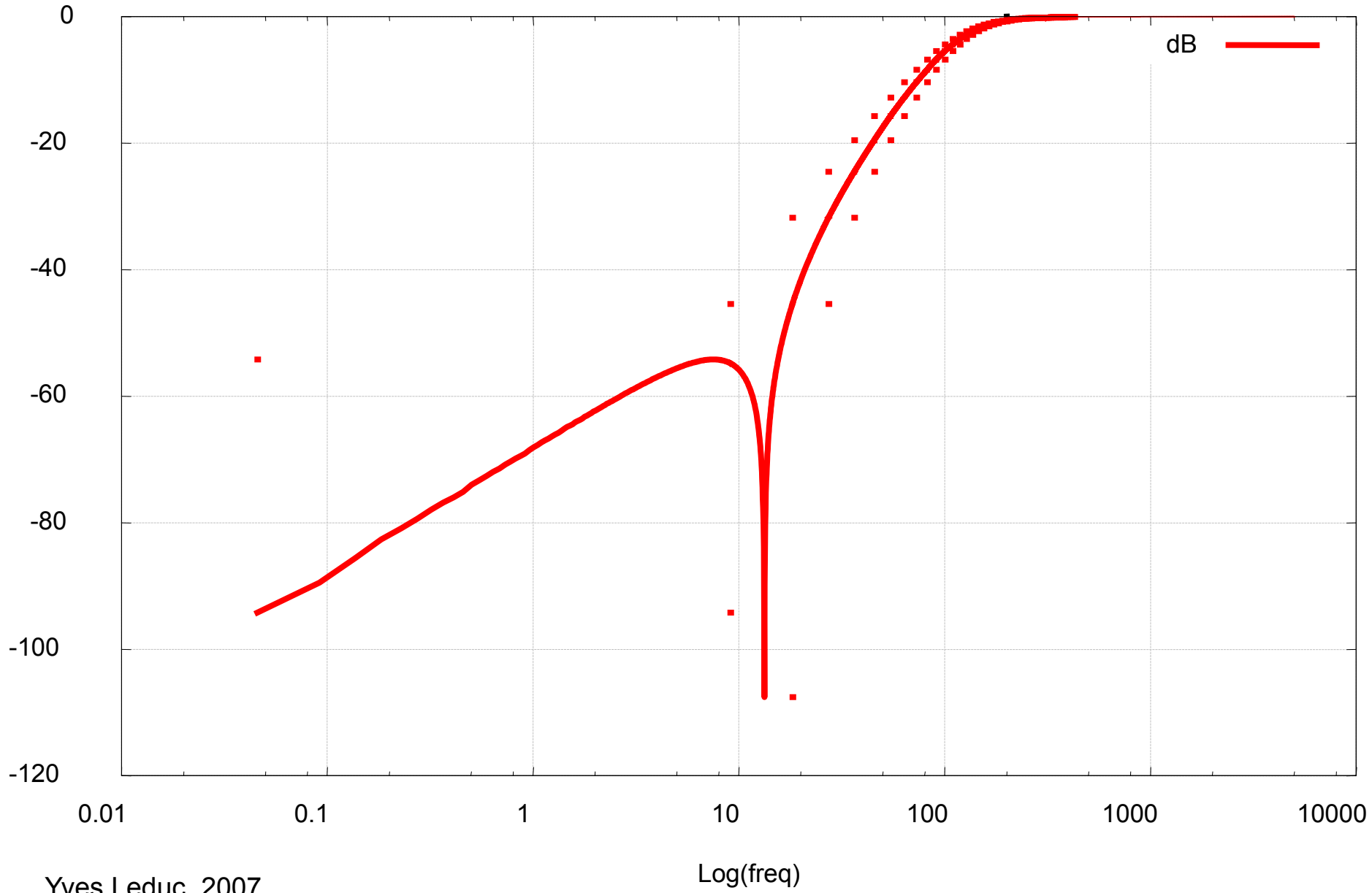
*file "f3.dat"*

```
## IIR filter,  High Pass.
#       numerator      denominator
0      -0.986961       1.000000
1       2.960880      -2.973750
2      -2.960880       2.947840
3       0.986961      -0.974089
```

```
cell interface     $y  $dummy  $x
declare (analog)   $x

# feedforward path coefficients
dvar $n0  -9.86961000000000e-001
dvar $n1   2.96088000000000e+000
dvar $n2  -2.96088000000000e+000
dvar $n3   9.86961000000000e-001
# feedback path coefficients
dvar $d1  -2.97375000000000e+000
dvar $d2   2.94784000000000e+000
dvar $d3  -9.74089000000000e-001
# signal path
node $s1  delay   $s0
node $s2  delay   $s1
node $s3  delay   $s2

node $sd1  gain  -$d1  $s1
node $sd2  gain  -$d2  $s2
node $sd3  gain  -$d3  $s3
node $sn0  gain   $n0  $s0
node $sn1  gain   $n1  $s1
node $sn2  gain   $n2  $s2
node $sn3  gain   $n3  $s3

node $s0    sum   $sd1  $sd2  $sd3  $x
node $y     sum   $sn0  $sn1  $sn2  $sn3
```

*file “tf.out”*

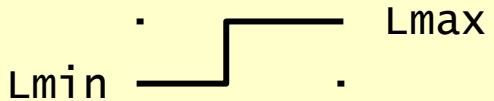
# IIR Filter Transfer Function




Yves Leduc, 2007

We will use this IIR filter to show the method of determination of the worst case of peak.

1. Apply a step function




2. Use the step response to compute the worst case of peak using the theorem of superposition for linear systems

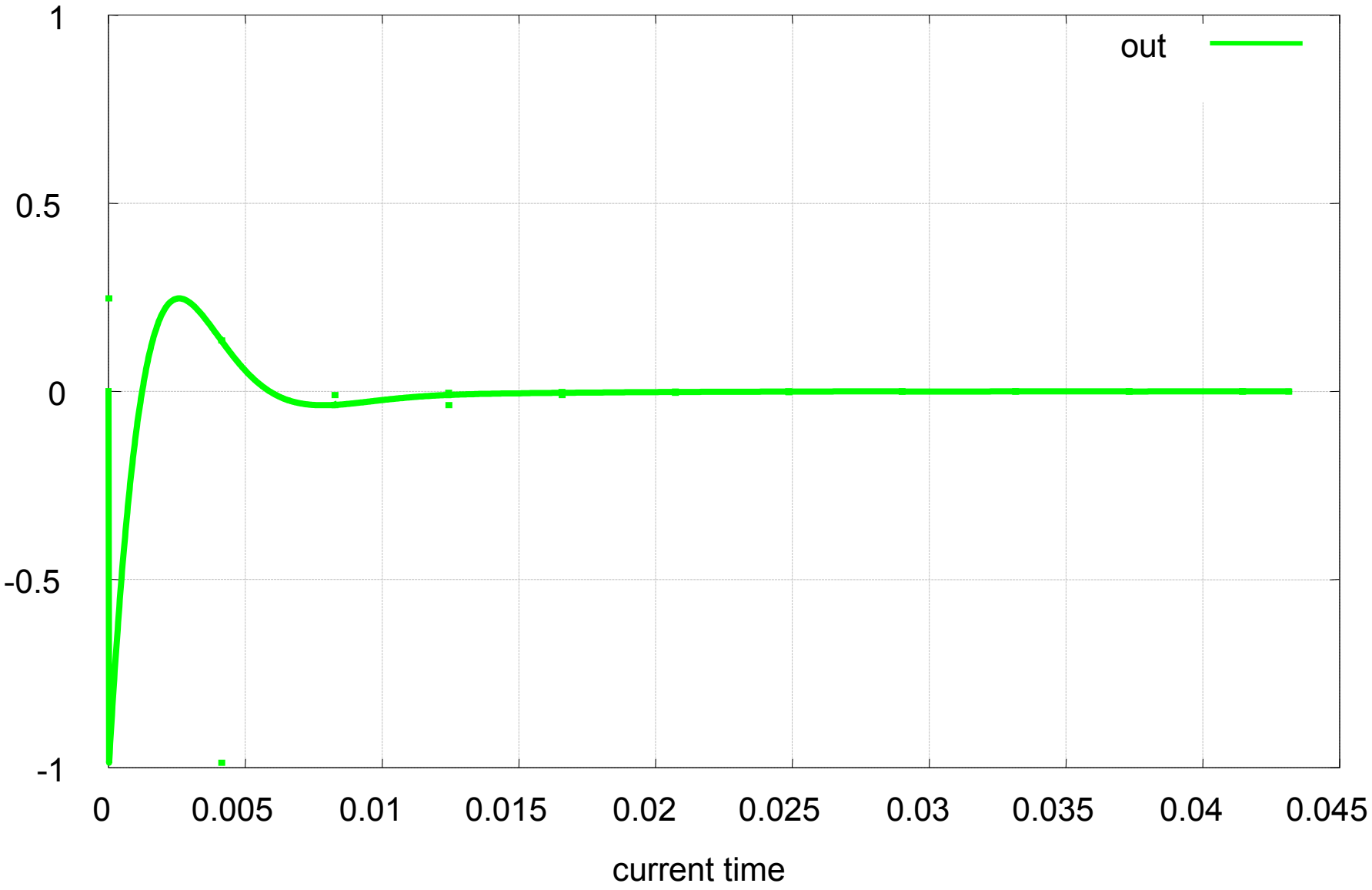
# IIR Filter Step Response

*NAPA netlist*

```
header <napatool.hdr>

fs          48.0e3

title  "Step Response of IIR Filter"

node   in   step  0.0  1.0  1.0e-6
node   out  generator  hpf3  <iir>   "f3.dat"  in

node   stb  iuser stable out 10   1.0e-6       // check for signal stabilization

output "resp.out"  in  out                      // step response

terminate   (LOOP_INDEX >= 5000) || stb
```

*file “resp.out”*

# IIR Filter Step Response

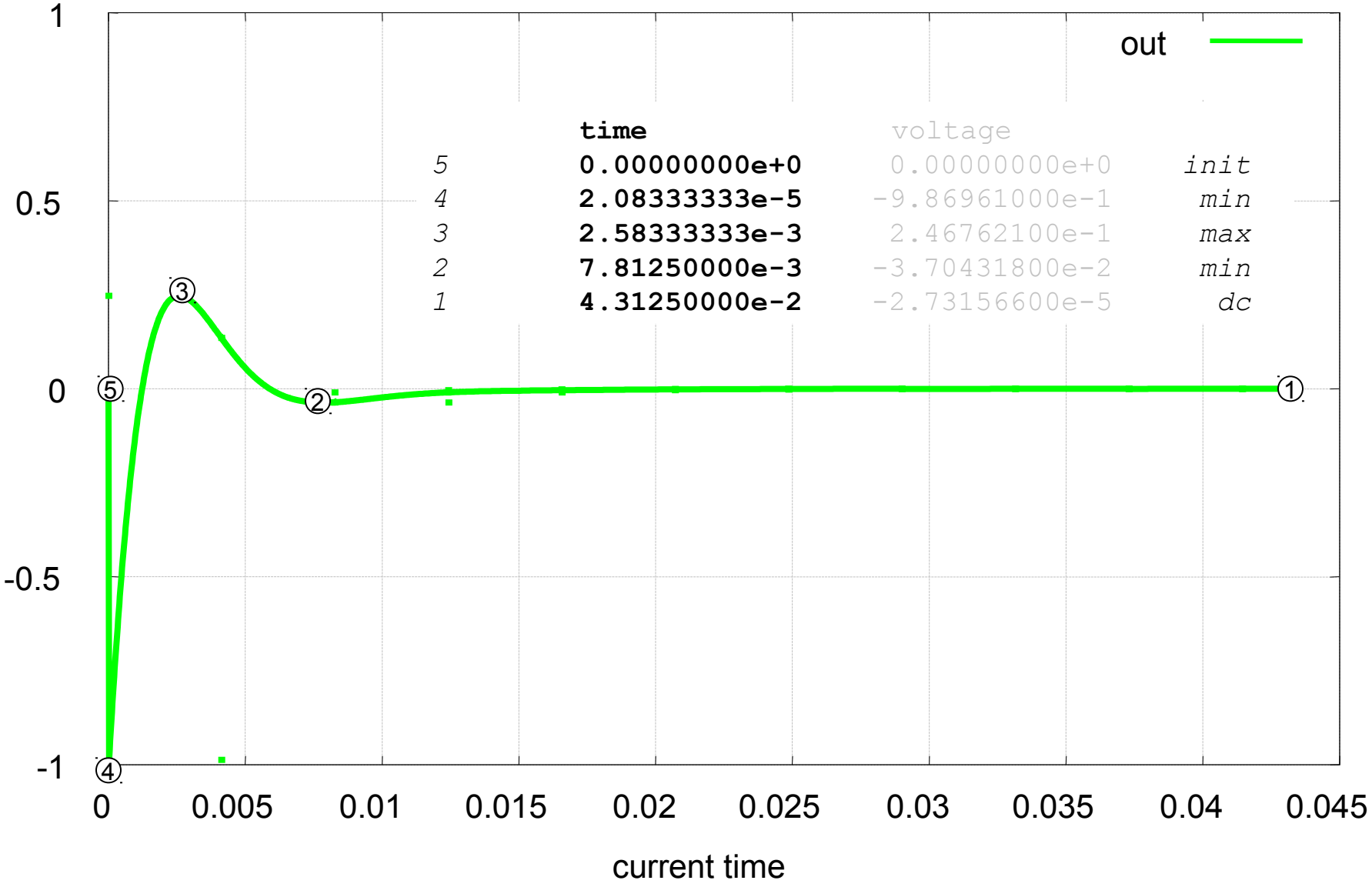


# Local Extrema of the IIR Filter Step Response

*NAPA netlist*

```
header <napatool.hdr>

fs          48.0e3

title  "Local Extrema of the IIR Filter Step Response"

node    in    step  0.0  1.0  1.0e-6
node    out   generator  hpf3  <iir>   "f3.dat"  in

node    stb   iuser stable out 10   1.0e-6          // check for signal stabilization

output "resp.out"  in  out                          // step response
post    extrema "ext.out" 0  2  (short)             // list of extrema

terminate    (LOOP_INDEX >= 5000) || stb
```

# Local Extrema of the IIR Filter Step Response

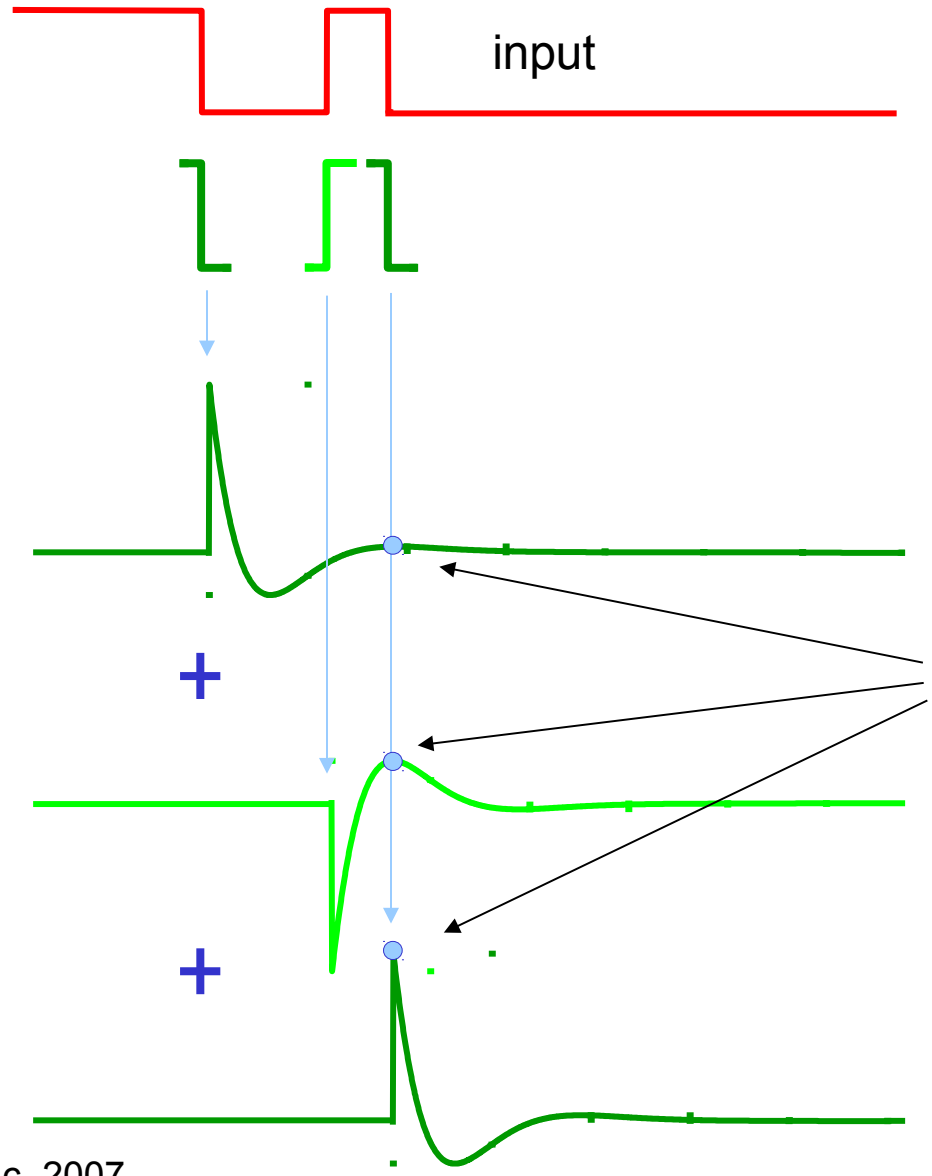


# Method A

- *Indirect Method* -

Use Time Position of Local Extrema
of the IIR Filter Step Response
to build activations leading to
the Worst Case Peak voltage.

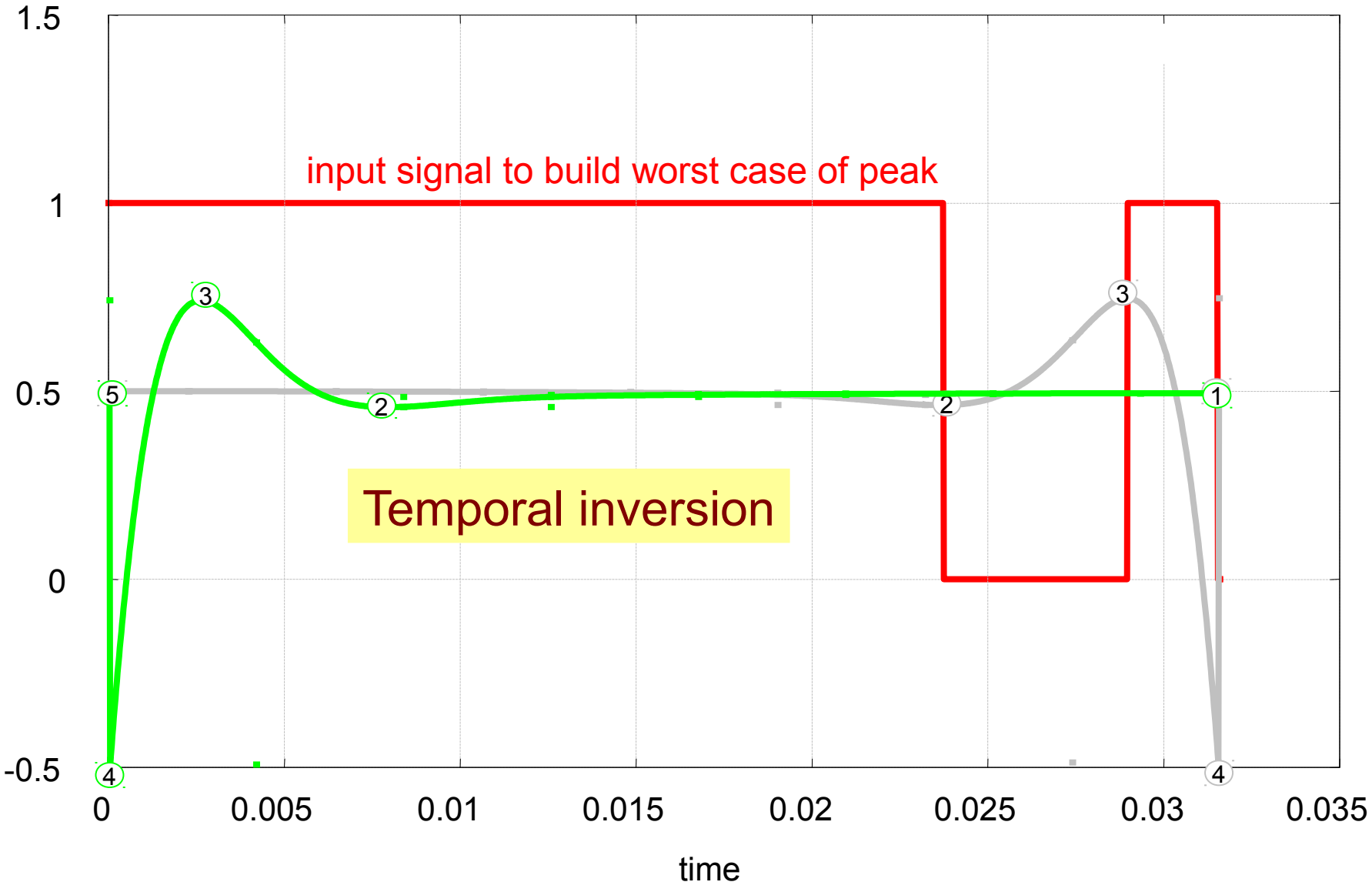
# Method A: Use Time Position of Local Extrema of the IIR Filter Step Response




Build an activation in such a way that all maximums occur at the same time.

Superposition of maximums

# Method A: Use Time Position of Local Extrema of the IIR Filter Step Response

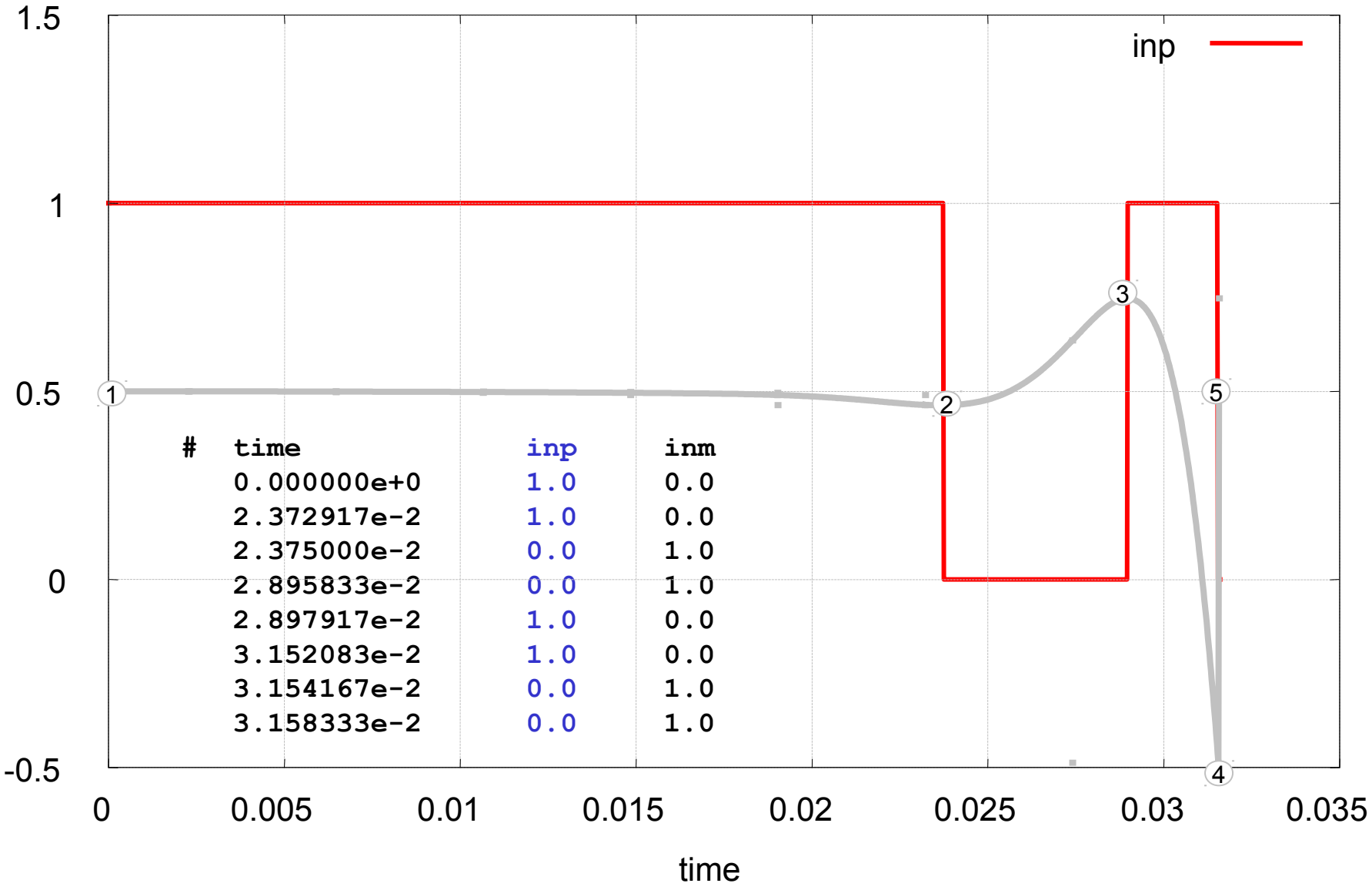


# Method A: Use Time Position of Local Extrema of the IIR Filter Step Response

*NAPA netlist*

```
header <napatool.hdr>

fs          48.0e3

title  "Build activation for Worst Case of Peak of IIR filter"

debug  WCPK_PWL

node   in   step  0.0  1.0  1.0e-6
node   out  generator  hpf3  <iir>   "f3.dat"  in

node   stb  iuser stable out 10   1.0e-6     // check for signal stabilization

output "resp.out"  in  out                    // step response
post   wcpk_pwl "wcpk_pwl.out" 0  2           // compute the 2 activations to be used
                                              // to get this worst case of peak
terminate    (LOOP_INDEX >= 5000) || stb
```

# Method A: Use Time Position of Local Extrema of the IIR Filter Step Response




| # time | inp | inm |
|---|---|---|
| 0.000000e+0 | 1.0 | 0.0 |
| 2.372917e-2 | 1.0 | 0.0 |
| 2.375000e-2 | 0.0 | 1.0 |
| 2.895833e-2 | 0.0 | 1.0 |
| 2.897917e-2 | 1.0 | 0.0 |
| 3.152083e-2 | 1.0 | 0.0 |
| 3.154167e-2 | 0.0 | 1.0 |
| 3.158333e-2 | 0.0 | 1.0 |

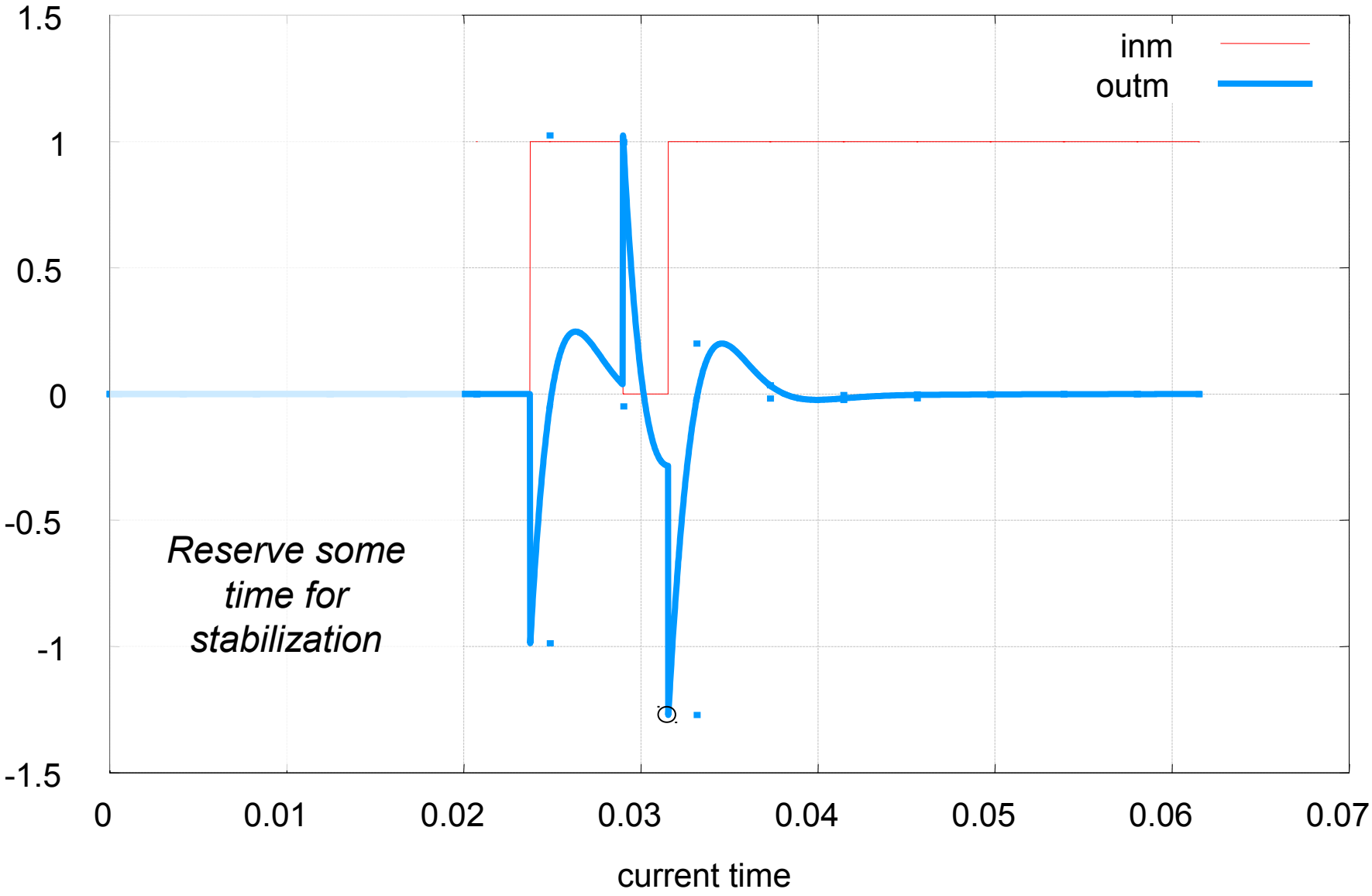
# Use Computed Activation to get the Worst Case of Peak

*NAPA netlist*

```
header <napatool.hdr>

title  "Use computed PWL to get the Worst Case of Peak"

fs           48.0e3                                  // same sampling frequency   !!!

debug  PWL

node   inp   duser pwl  "wcpk_pwl.out"   TIME  1  (aperiodic)
node   inm   duser pwl  "wcpk_pwl.out"   TIME  2  (aperiodic)
node   outp  generator    hpf3p  <iir>   "f3.dat"  inp
node   outm  generator    hpf3m  <iir>   "f3.dat"  inm

node   stbp  iuser stable  outp  100  1.0e-4
node   stbm  iuser stable  outm  100  1.0e-4

output "worst.out"  inp inm  outp outm

terminate    (LOOP_INDEX > 10000) || (stbm && stbp)
```

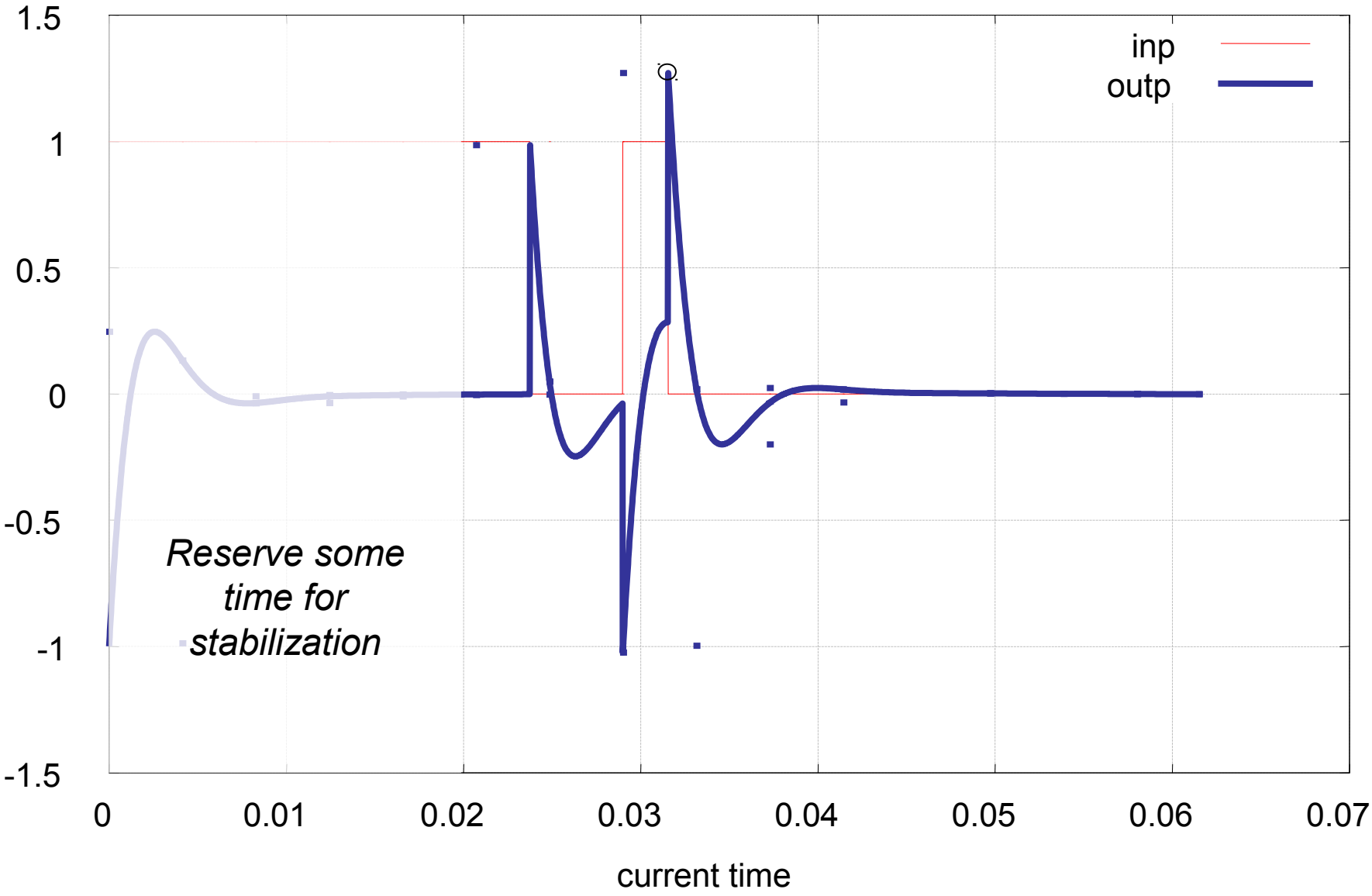
*file "worst.out"*

# Minimum Peak Voltage of IIR Filter



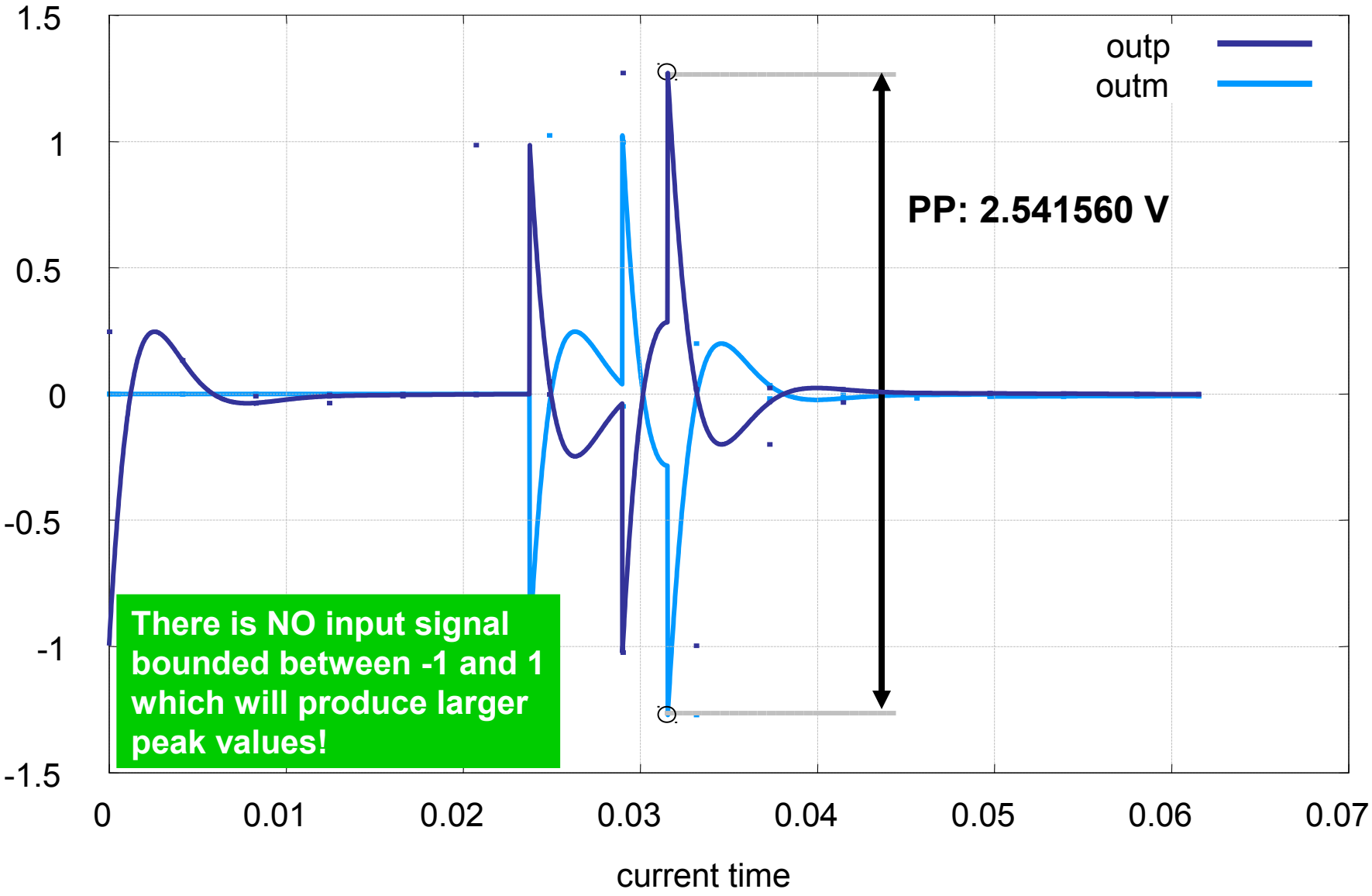
*file "worst.out"*

# Maximum Peak Voltage of IIR Filter



*file "worst.out"*

# Minimum and Maximum Peak Voltage of IIR Filter

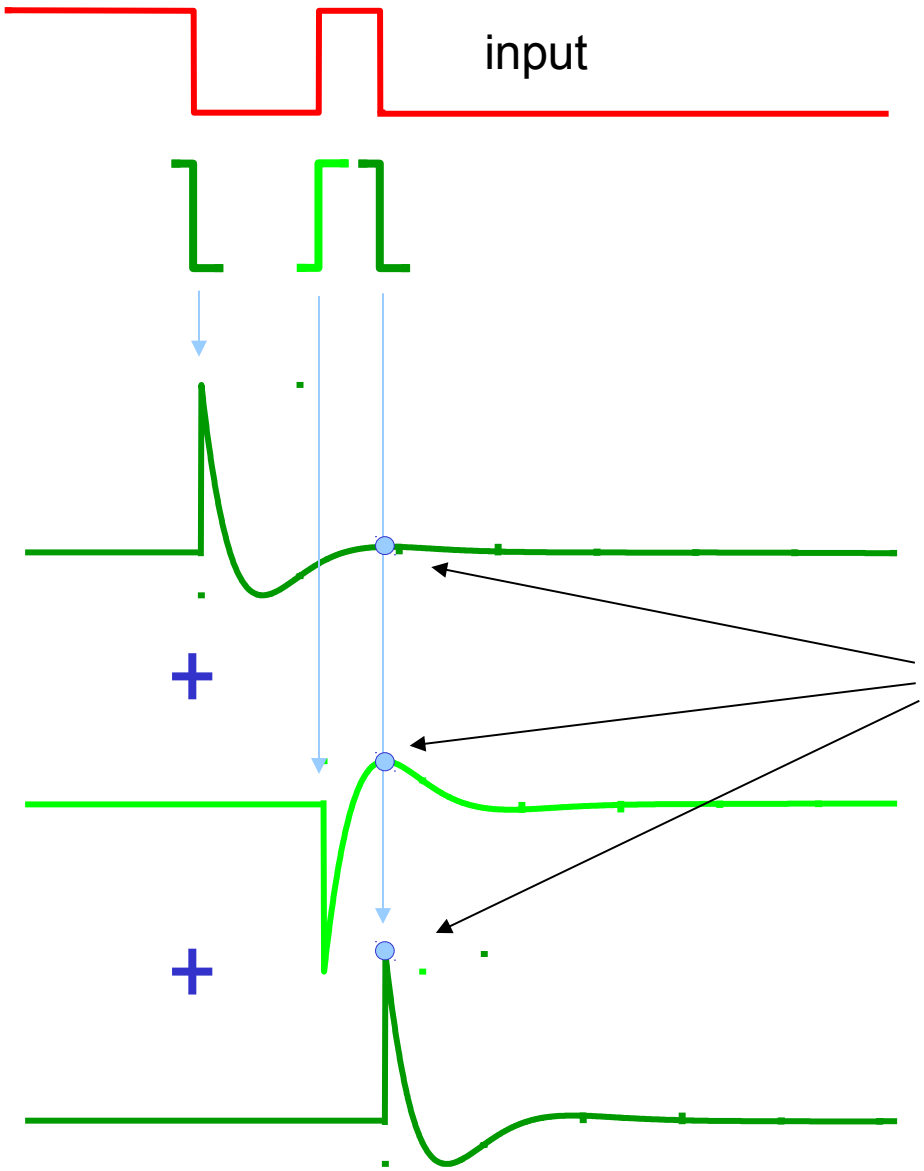


# Method B

- *Direct Method* -

Use Local Extremum Voltages
of the IIR Filter Step Response
to get directly the value of the
Worst Case Peaks.

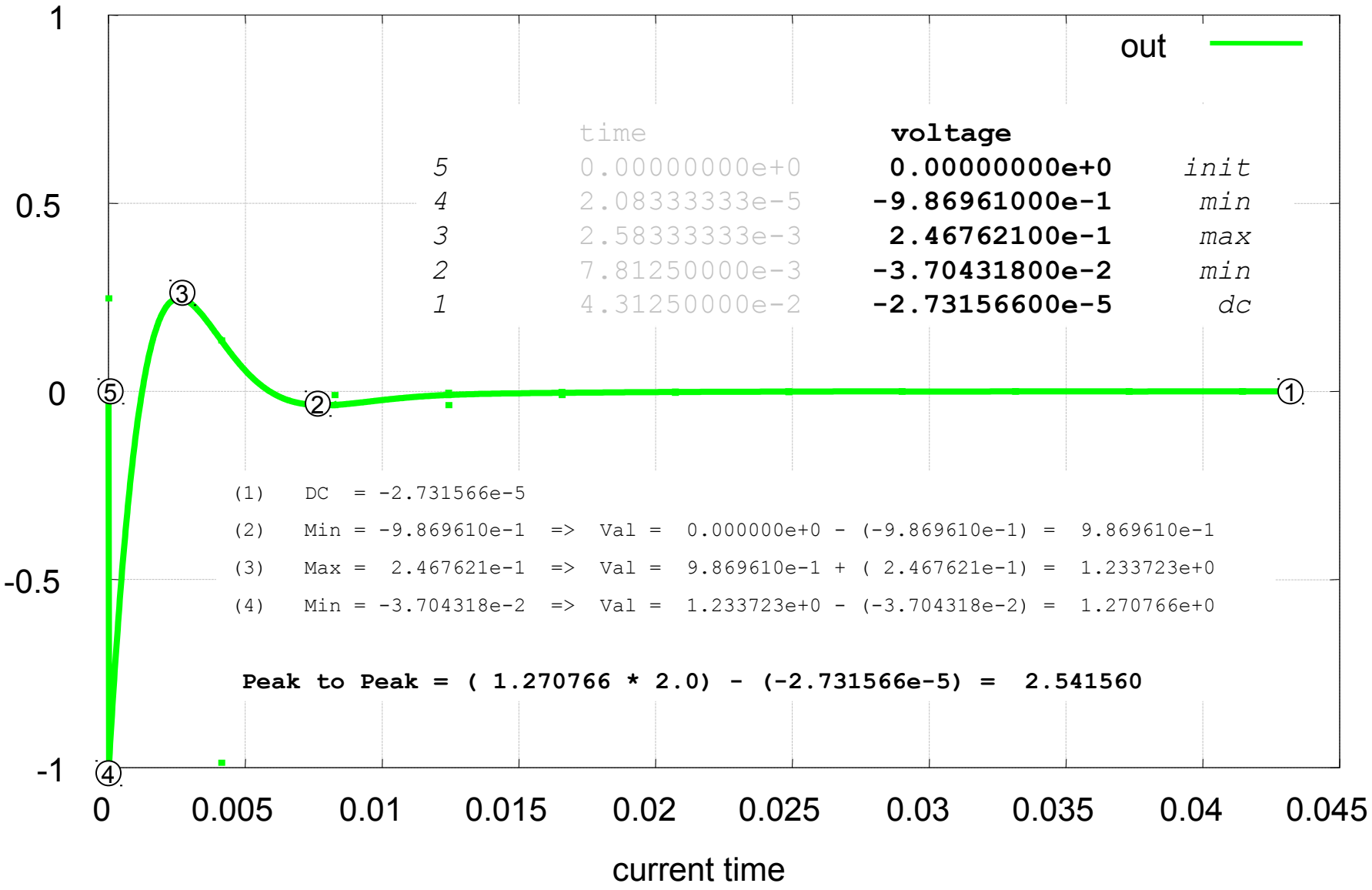
# Method B: Use Local Extremum Voltages of the IIR Filter Step Response




Superposition of maximums

Yves Leduc, 2007

# Method B: Use Local Extremum Voltages of the IIR Filter Step Response



# Method B: Use Local Extremum Voltages of the IIR Filter Step Response

*NAPA netlist*

```
header <napatool.hdr>

fs          48.0e3

title  "Direct Worst Case of Peak evaluation of IIR filter"

debug  WCPK

node   in   step  0.0  1.0  1.0e-6
node   out  generator  hpf3  <iir>   "f3.dat"  in

node   stb  iuser stable out 10   1.0e-6      // check for signal stabilization

output "resp.out"  in  out                     // step response
post    wcpk       "wcpk.out"  0  2            // compute the worst case of peak

terminate   (LOOP_INDEX >= 5000) || stb
```

*file “wcpk.out”*

```
# F3_D
# (tool                )  wcpk postprocessor applied on "resp.out"
# (compiler version    )  NAPA V2.81
# (source file         )  f3_d.mac
# (random seed         )  585223739
# (postprocessed file  )  resp.out
# (postprocessed column)  #1, #3
# (postprocessed tool  )  output
#
# (postprocessed signal)  current_time -> out
#
# [ Compute the WORST CASE OF PEAK from a Step Response ]
#
# Fri Feb 02 21:17:59 2007 by YVES LEDUC
#        min_peak             max_peak        peak_to_peak
   -1.270794e+000       1.270766e+000       2.541560e+000
# end of output file
```