Optimizing the input stage of the DCH preamplifiers

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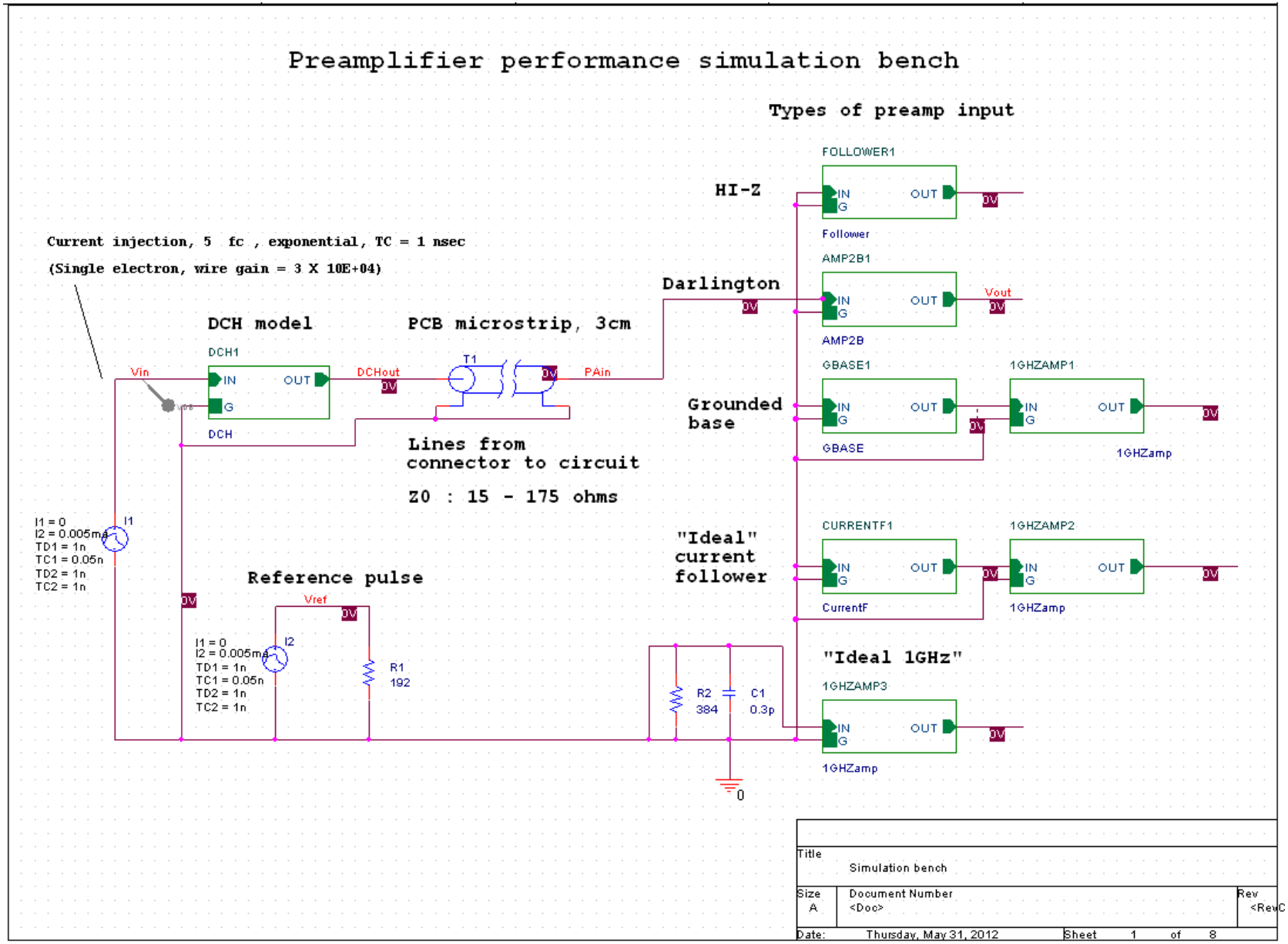
Summary

- SPICE model of the DCH elements
- Performances with various type of impedance terminations (using ideal amplifiers)
  - High Z buffers (superior S/N ratio)
  - 50 ohm systems (commercial RF gain block chips)
  - Low Z current followers (common base amplifiers) for their low sensitivity to environmental noise.
- Performances with real components
- Prototypes for beam tests


Preamplifier performance simulation bench
Types of preamp input
HI-Z
FOLLOWER1
IN
G
OUT
0V
Follower
Darlington
AMP2B1
Vout
AMP2B
Current injection, 5 fc , exponential, TC = 1 nsec
(Single electron, wire gain = 3 X 10E+04)
DCH model
PCB microstrip, 3cm
DCH1
Vin
DCHout
T1
PAin
DCH
Lines from
connector to circuit
Z0 : 15 - 175 ohms
Grounded
base
GBASE1
1GHZAMP1
GBASE
1GHZamp
I1 = 0
I2 = 0.005ma
TD1 = 1n
TC1 = 0.05n
TD2 = 1n
TC2 = 1n
I1
"Ideal"
current
follower
CURRENTF1
1GHZAMP2
CurrentF
Reference pulse
Vref
I2
R1
192
R2
384
C1
0.3p
"Ideal 1GHz"
1GHZAMP3
0
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Simulation bench
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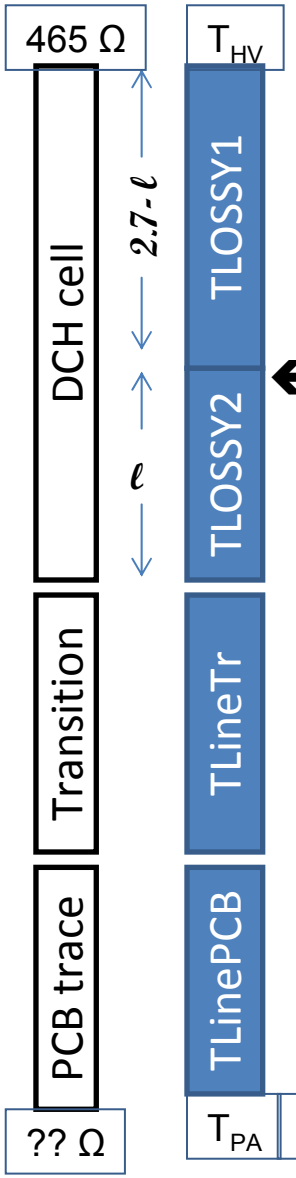
MODEL ELEMENTS for the DCH



DCH cell:
Coax line approximation
Inner wire dia. : 25 microns
Outer diameter 15 mm.

Lossy transmission line parameters:
C = 8.68 pf/meter
L = 1279 nHy/meter
R= 250 ohms/meter
Z = 384 ohms

Current pulse injection, at ℓ meter from the sense wire output

Section representing the crimp pin sockets, from the faceplate to the Motherboard PCB.
Modeled as a transmission line with 2 mm inner wire diameter and 15 mm OD. Z0 = 120 ohms, l = 1 cm

Section representing the PCB traces from the motherboard to the preamplifier Input.
Z0: tunable from 10 ohms to 175 ohms (line width, distance from GND plane)
l : up to 3 cm.

Ideal amplifier

Current pulse injection

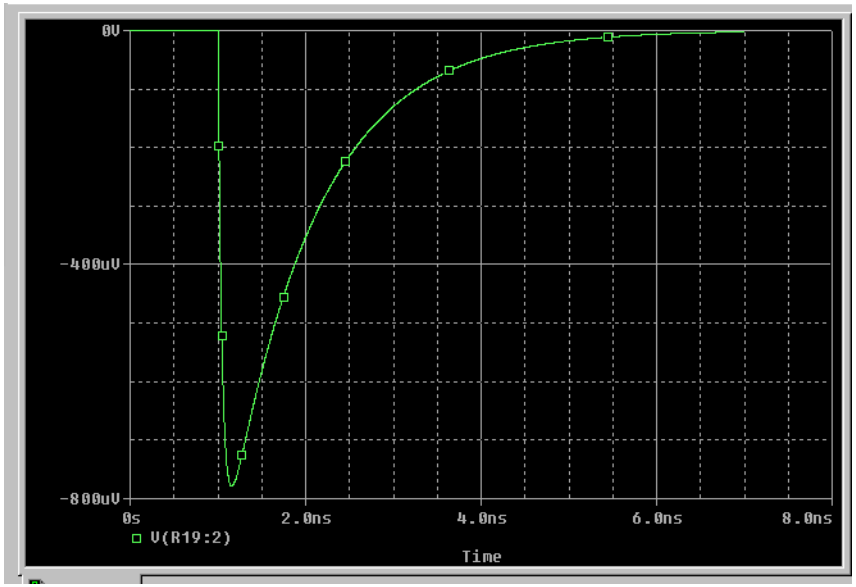
Choice:simple shape approximating the first few nanoseconds of the electron and ion current on the sense wire:

=> Current pulse shape: double exponential
with T1 = 0.05 nsec. (leading edge)
T2 = 1.0 nsec. (falling edge)
current amplitude (A) = 0.005 ma.
Injected charge:

$$\int Ae^{-t/T}\,dt = 5\,fC$$

(one electron at gain = 30,000)

Current pulse in a purely resistive load (Z/2 = 192 ohms) ➔

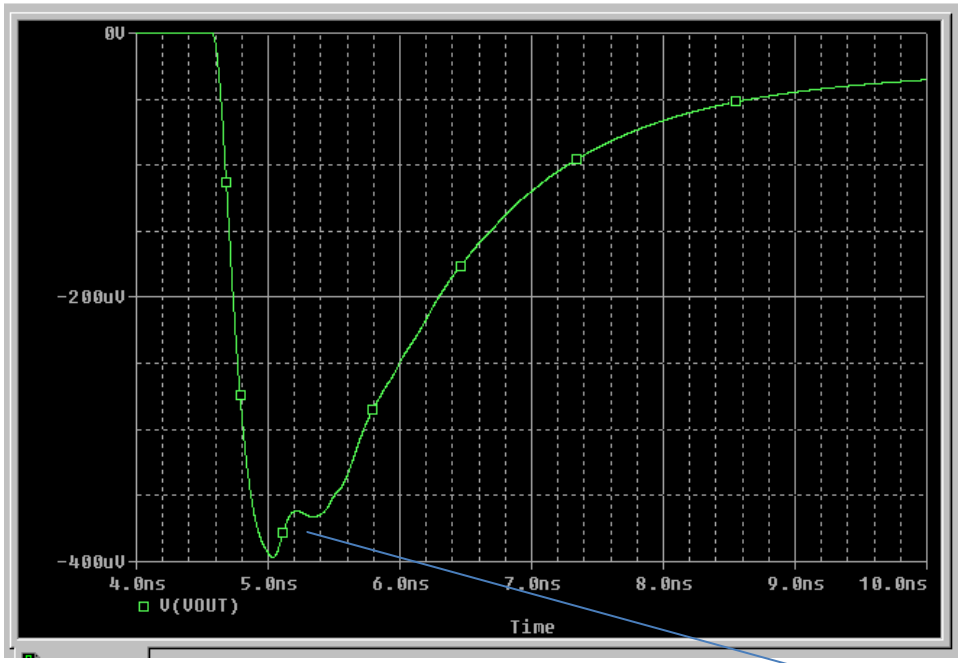


Simulations with the “ideal” 1 GHz bandwidth unity gain preamplifier

Note: in the following slides, S/N = Output Amplitude / 3 * RMSnoise

Scenario 1A, matching to the drift chamber impedance

- Board trace = 3 cm; 175 ohms, (0.2 nsec delay
- Termination 384 ohms

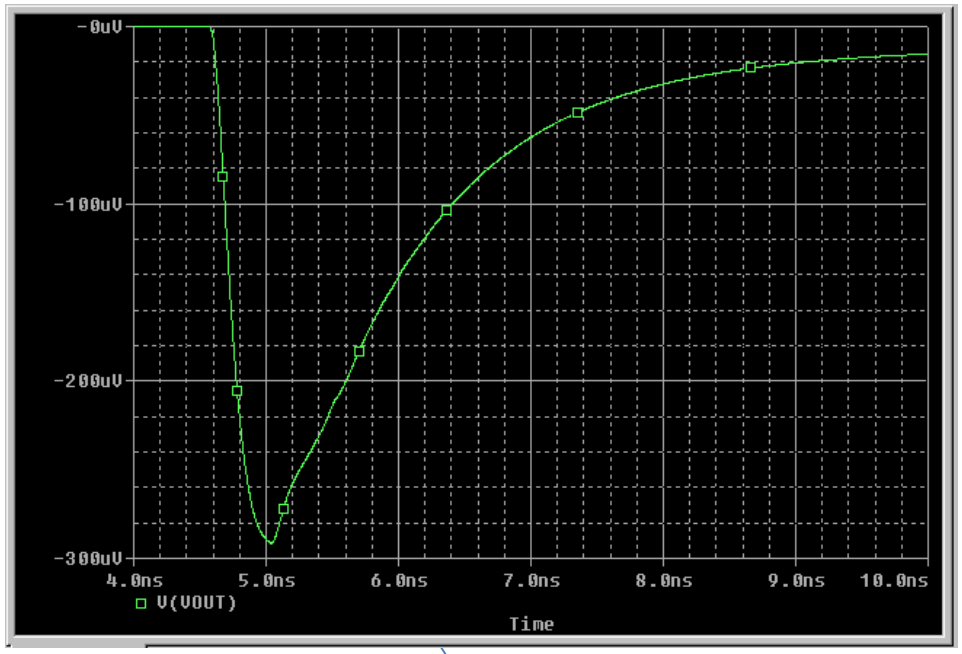


Pulse amplitude :
396 (375)
Peaking time :
0.44 nsec (55)
RMS noise @ 1 GHz BW:
29.02 microvolts
S/N 4.30

Reflection from PCB stripline

Scenario 1B, matching to the microstrip impedance;

- Board trace = 3 cm; 175 ohms, (0.2 nsec delay)
- Termination = 175 ohms

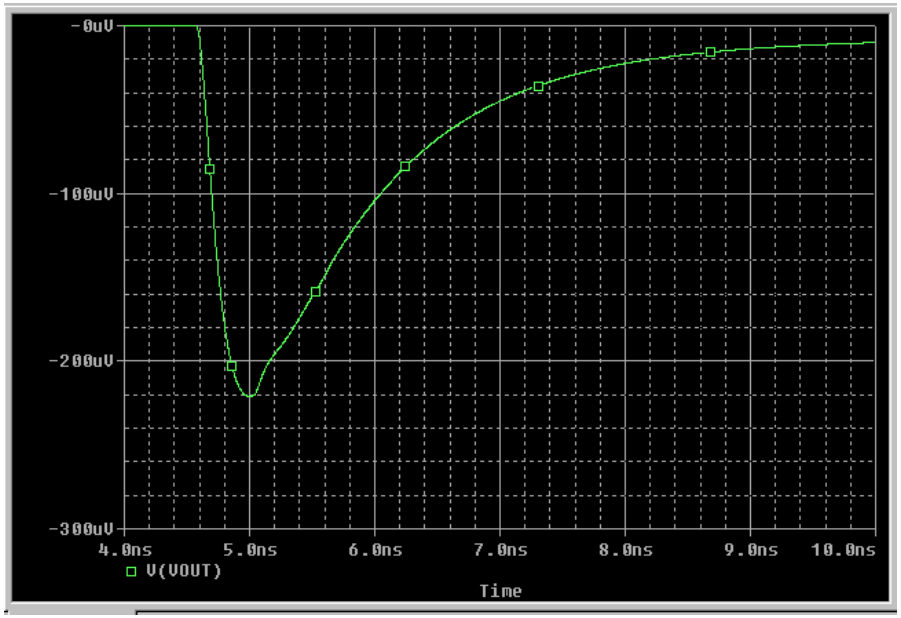


Pulse amplitude :
291 microvolts
Peaking time :
0.403 nsec
RMS noise @ 1 GHz BW:
27.75 microvolts
S/N 3.50

Less effects from the reflection

Scenario 1C, matching the microstrip and termination to the transition section;

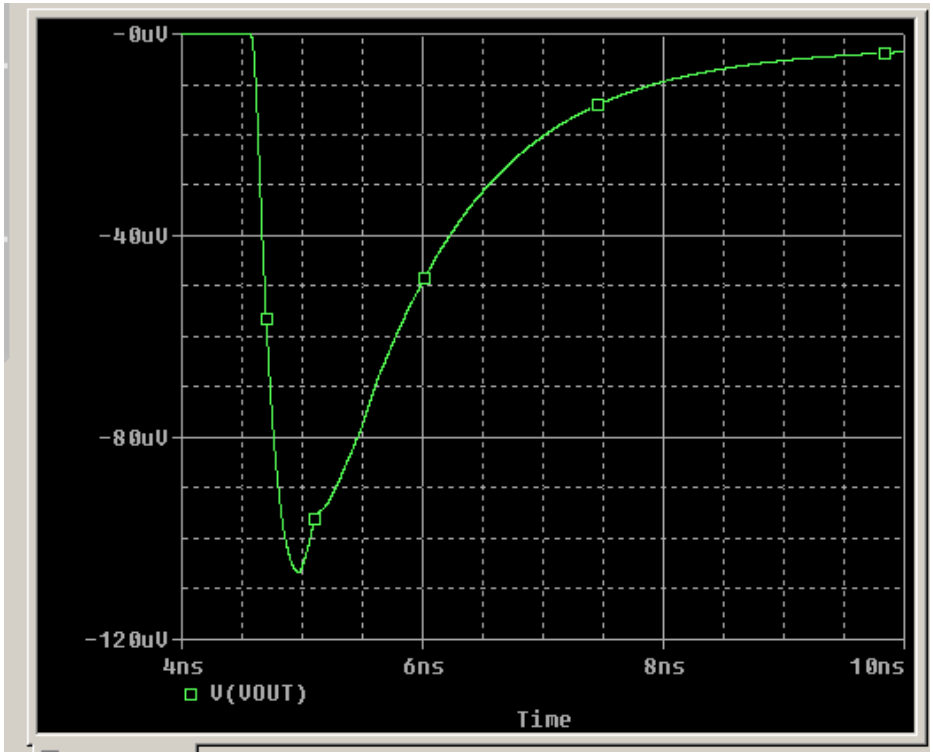
- Board trace = 3 cm; 120 ohms, (0.2 nsec delay)
- Termination = 120 ohms



Pulse amplitude :
221 microvolts
Peaking time :
0.40 nsec
RMS noise @ 1 GHz BW:
25.06 microvolts
S/N 2.93

Scenario 2, 50 ohms system;

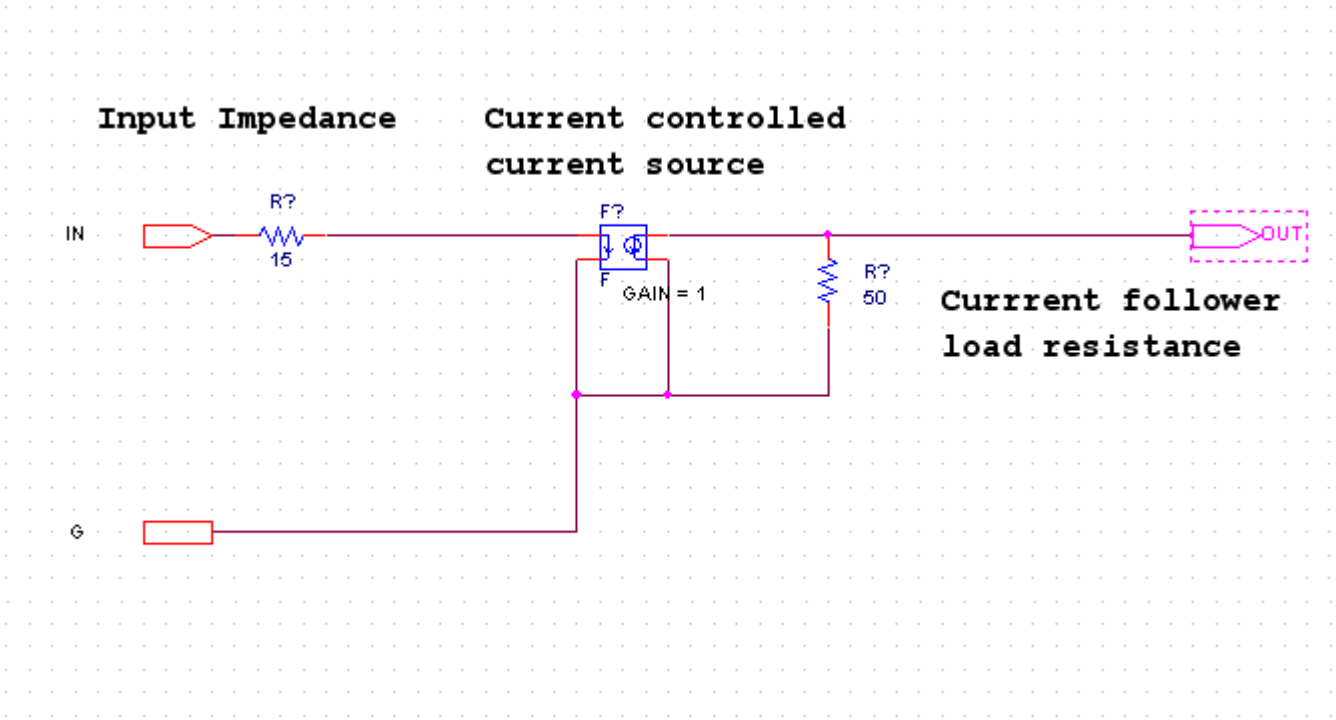
- Board trace = 3 cm; 50 ohms, (0.2 nsec delay)
- Termination = 50 ohms



Pulse amplitude :
107 microvolts
Peaking time :
0.37 nsec
RMS noise @ 1 GHz BW:
18.73 microvolts
S/N 1.90

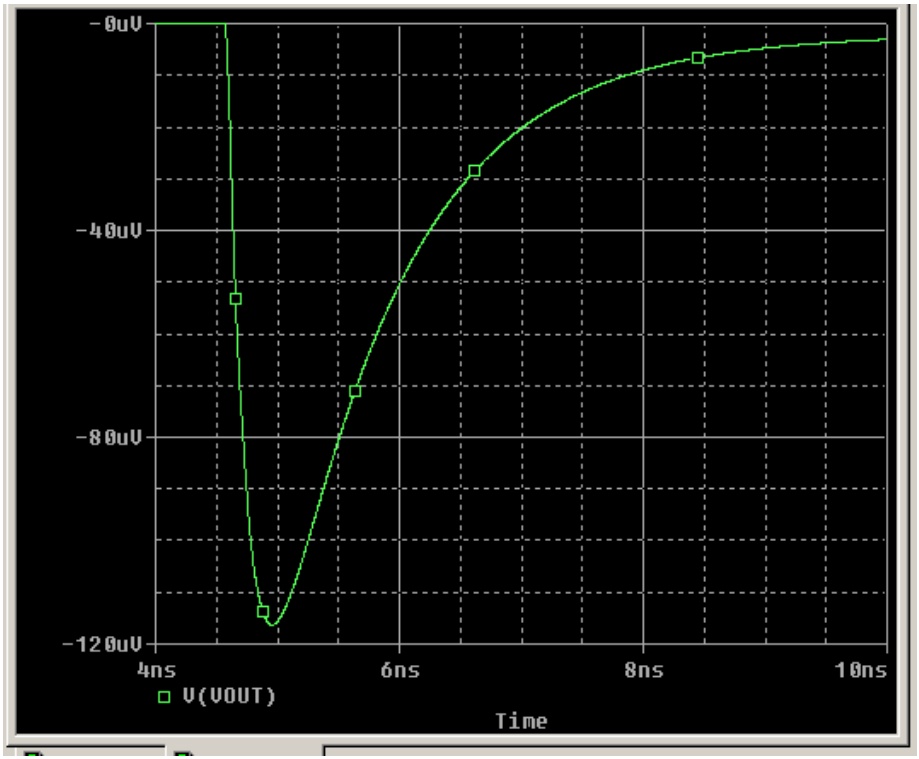
Scenario 3: low impedance current follower
(similar to a grounded base transistor input circuit)

MODEL:



Scenario 3, low impedance current follower

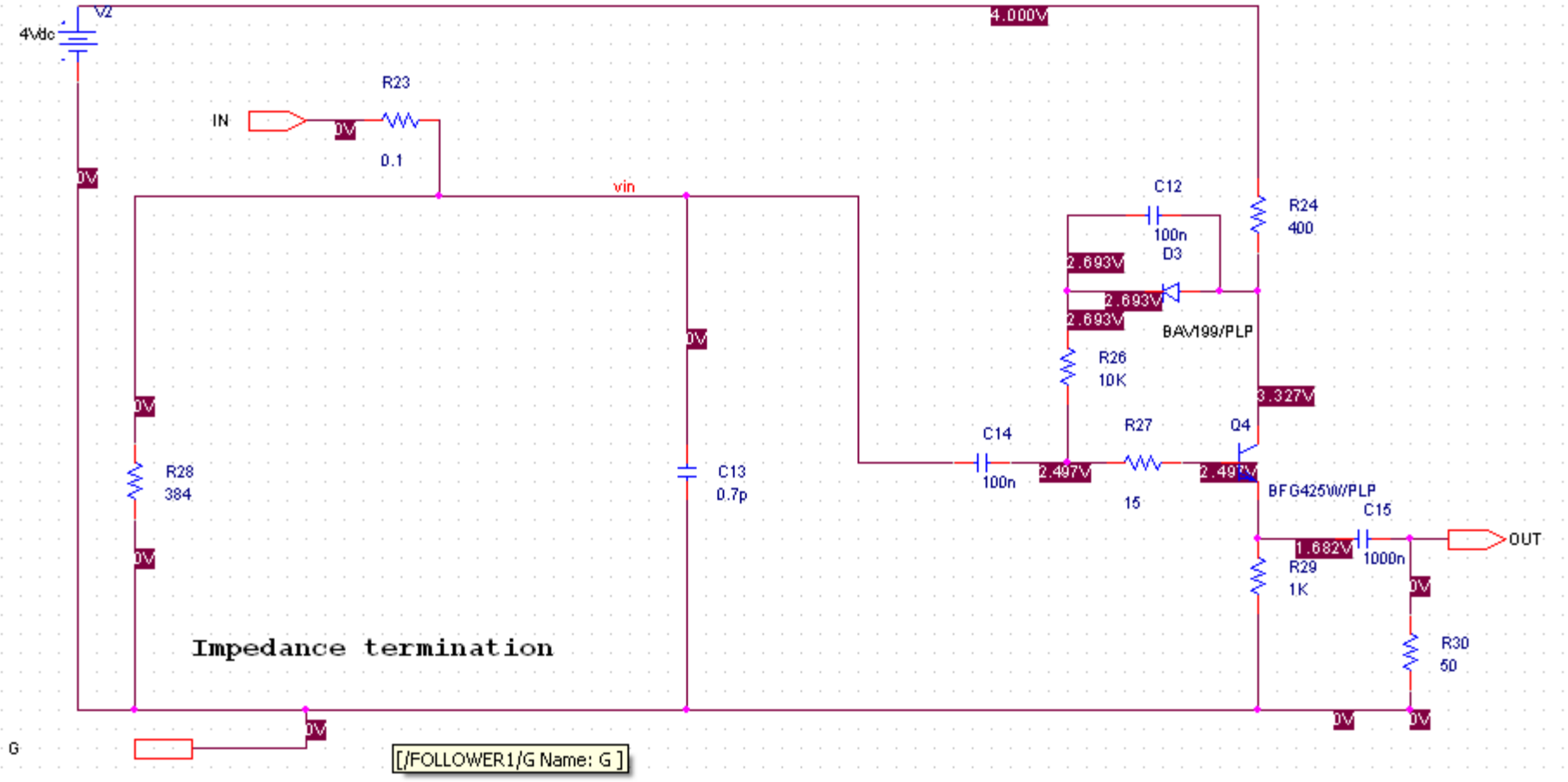
- Board trace = 3 cm; 15 ohms, (0.2 nsec delay)
- Termination = 15 ohms (input impedance of current follower)
- Output impedance: 50 ohms
- Assuming ideal preamp with 1 GHz bandwidth



Pulse amplitude :
116 microvolts
Peaking time :
0.36 nsec
RMS noise @ 1 GHz BW:
36.56 microvolts
S/N 1.06

Simulations with physical devices

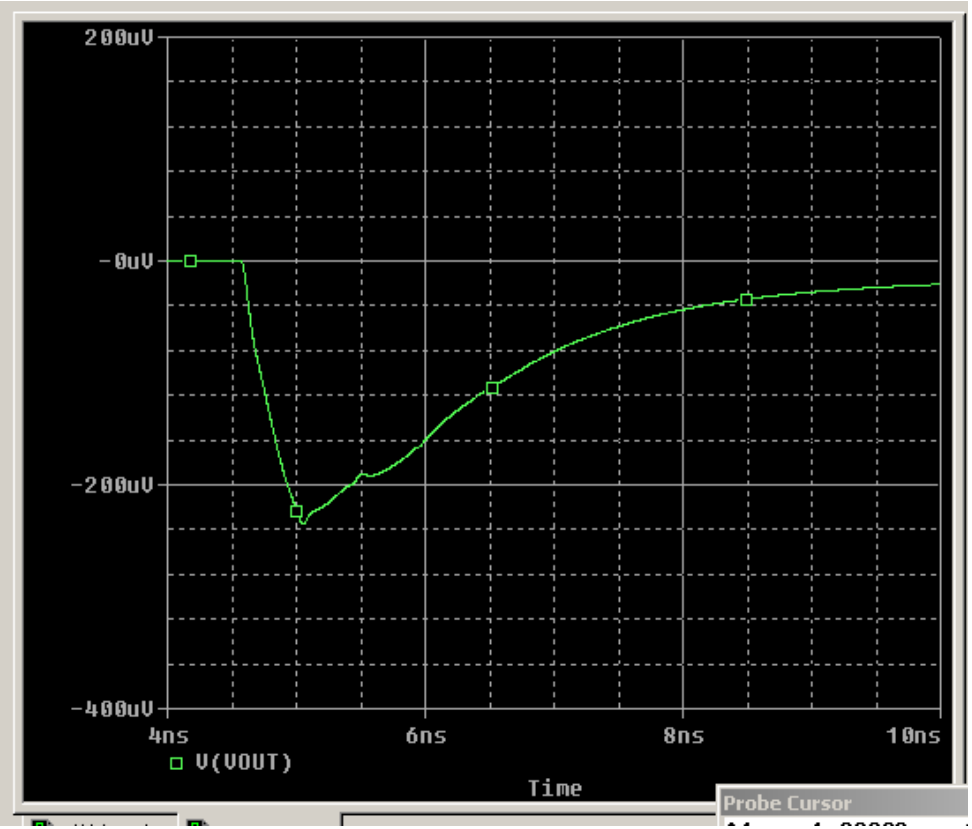
Voltage follower circuit driving 50 ohms



Voltage follower/50 ohms driver

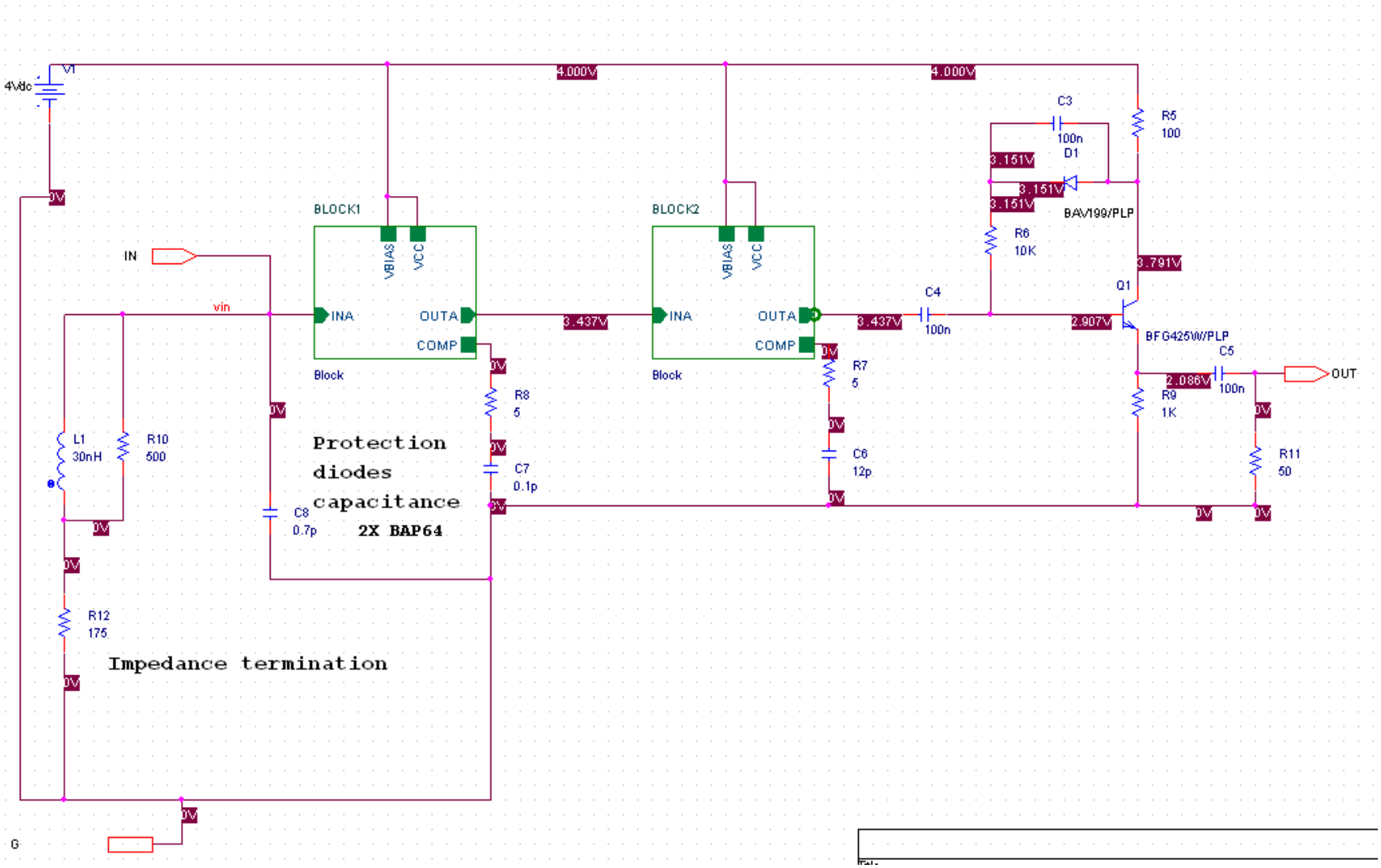
Board trace = 3 cm; 175 ohms, (0.2 nsec delay)

- Assuming .7 pf of protection diode capacitance
- Termination = 384 ohms

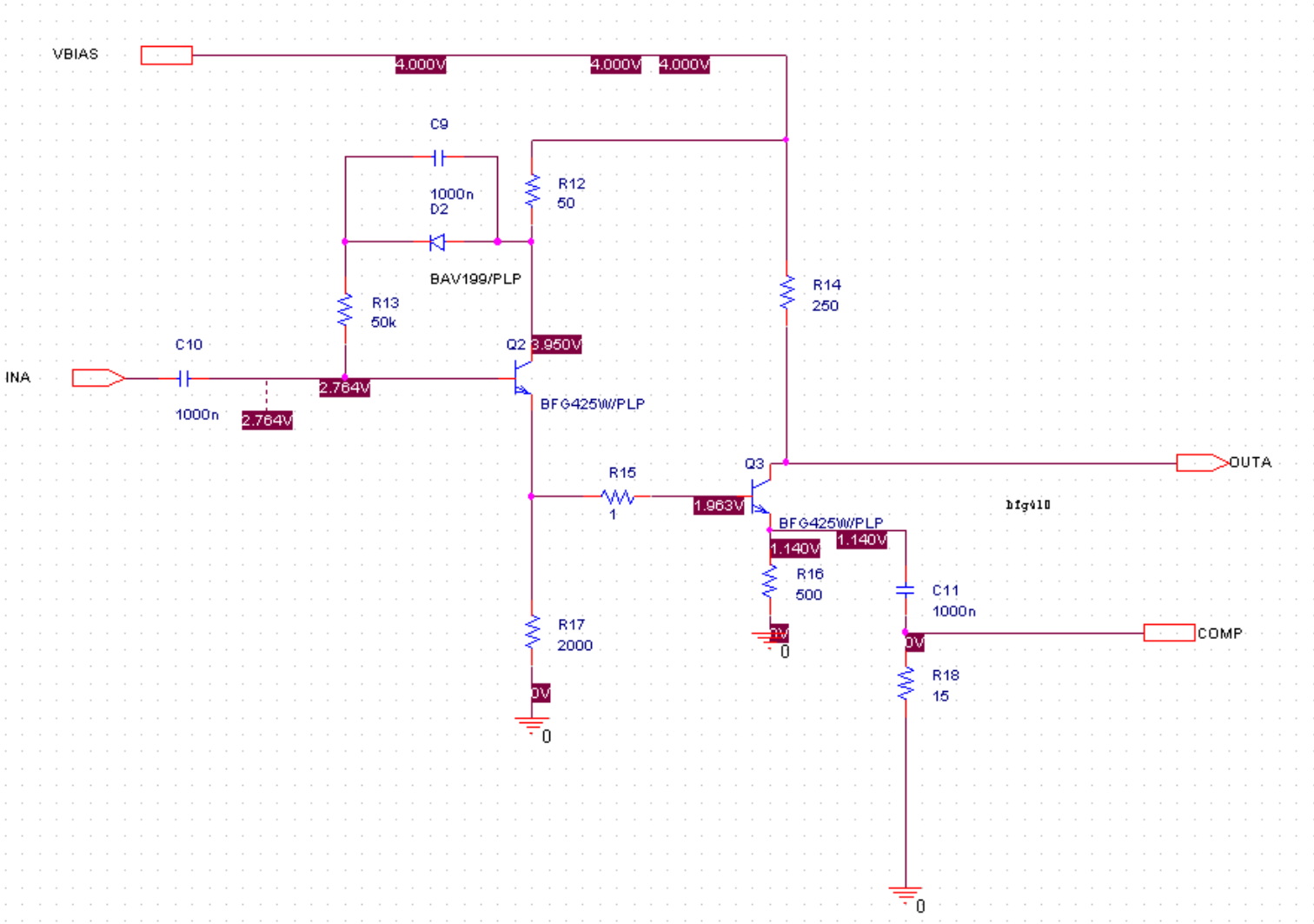


Pulse amplitude :
235 microvolts
Peaking time :
0.50 nsec
RMS noise @ 1 GHz BW:
27.31 microvolts
S/N 2.87

Darlington preamplifier top level



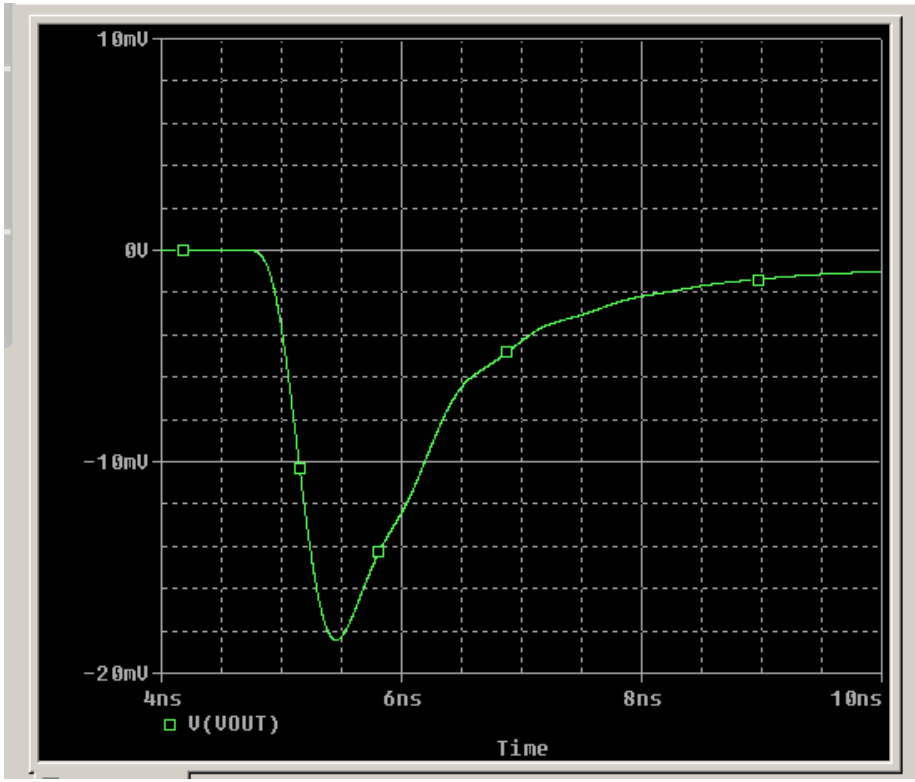
Darlington preamplifier gain block



Darlington preamplifier with 2 gain blocks

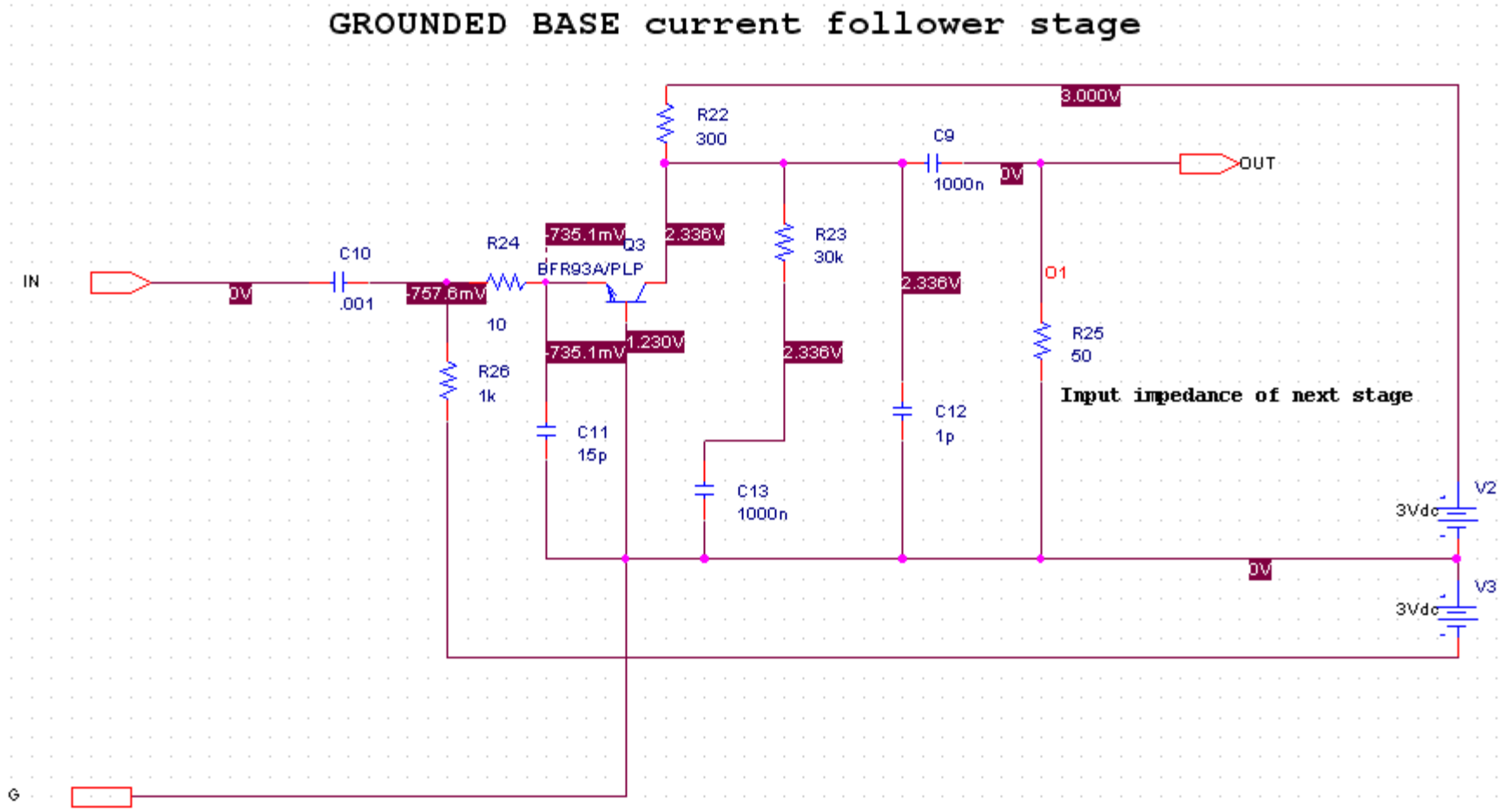
Board trace = 3 cm; 175 ohms, (0.2 nsec delay)

- Assuming .7 pf of protection diode capacitance
- Termination = 175 ohms



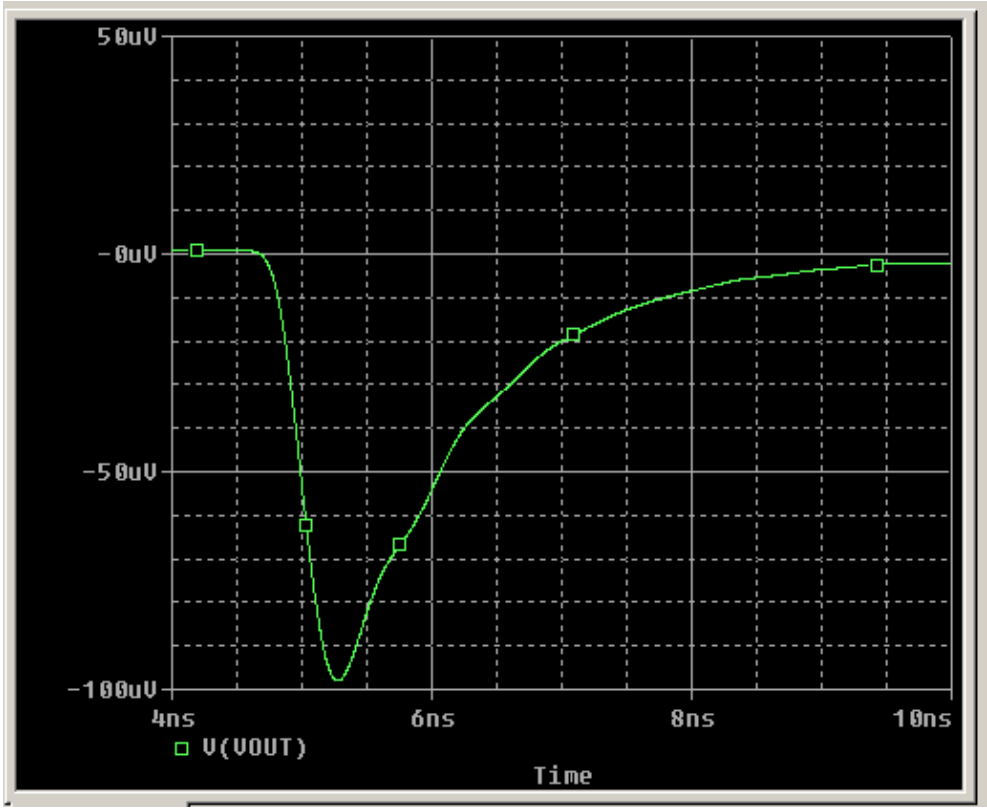
Pulse amplitude :
18.43 millivolts
Peaking time :
0.65 nsec
RMS noise @ 1 GHz BW:
2.31 millivolts
S/N 2.66

Common base circuit, real components



Grounded base transistor circuit

- Board trace = 3 cm; Z=**30 ohms**, (0.2 nsec delay)
- Output impedance: 50 ohms
- Assuming ideal preamp with 1 GHz bandwidth



Pulse amplitude :
98.1 microvolts
Peaking time :
0.37 nsec
RMS noise @ 1 GHz BW:
39.19 microvolts
S/N 0.83

CONCLUSIONS

Summary of the simulations

Scenario	Signal amplitude (millivolts)	Peaking time (nanosec.)	RMS noise (millivolts)	S/N
Ideal				
1A:Term. = Z0 chamber	0.396	0.44	0.029	4.30
1B: Term = stripline	0.291	0.40	0.028	3.50
1C: Term = stripline=transition	0.221	0.40	0.025	2.93
2: Term = 50 ohms	0.107	0.37	0.019	1.90
3: Current follower/50 ohms	0.116	0.36	0.037	1.06
Physical devices				
1A: Follower (384 ohms)	0.235	0.50	0.027	2.87
with 2 AD 8354 (4.2dB NF)	23.500	-----	4.300	1.82
1B: Darlington (175 ohms)	18.430	0.65	2.310	2.66
2: 50 ohms (2 AD8354)	10.700	-----	3.078	1.16
3: Grounded base transistor	0.098	0.39	0.039	0.83

Short term plans

- Build 3 single channel prototypes of each:
  - Follower + 2 AD8354 circuits
  - Darlington circuit
  - 50 ohms system
- Beam tests in July at TRIUMF on single wire test chamber