OAK RIDGE National Laboratory

Electronics Bench Testing and Outcomes

Chuck Britton, Nance Ericson, Kyle Reed, Emma Brown, Leah Broussard, Austin Nelson, Andrew Hagemeier

8 Feb 2023

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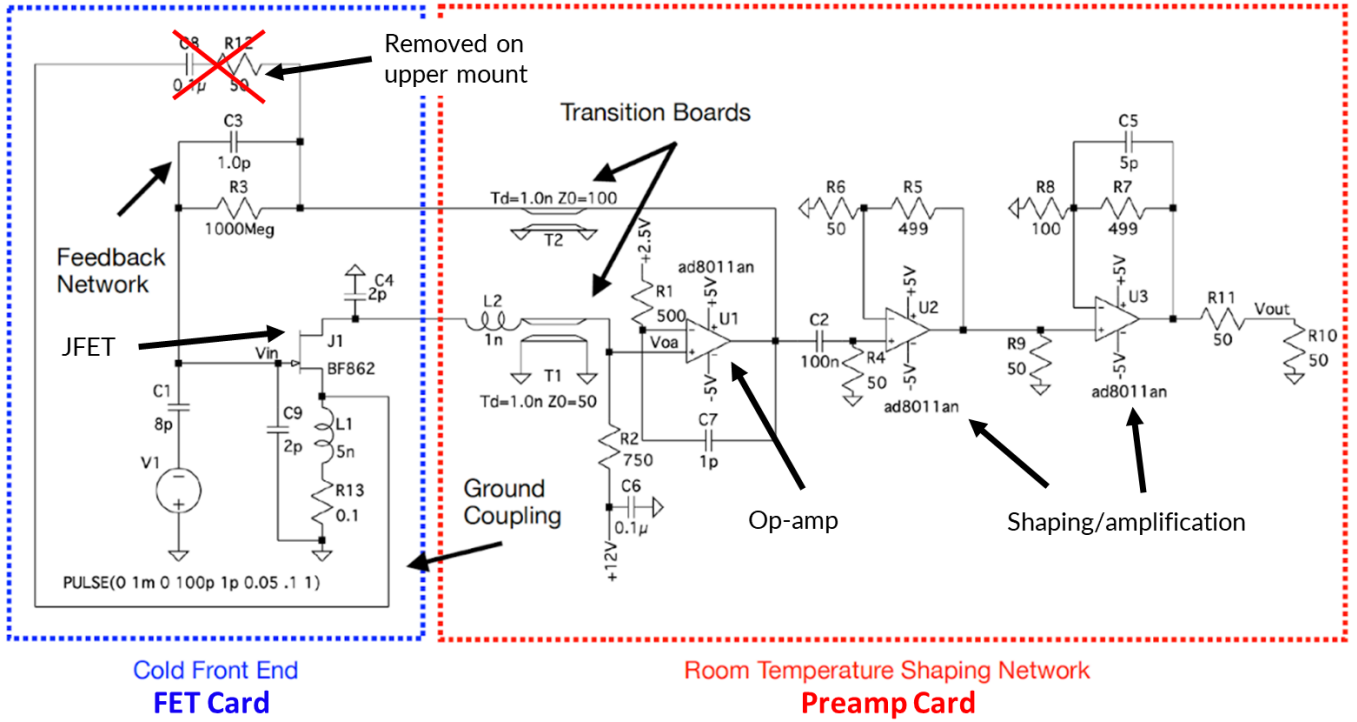
U.S. DEPARTMENT OF ENERGY

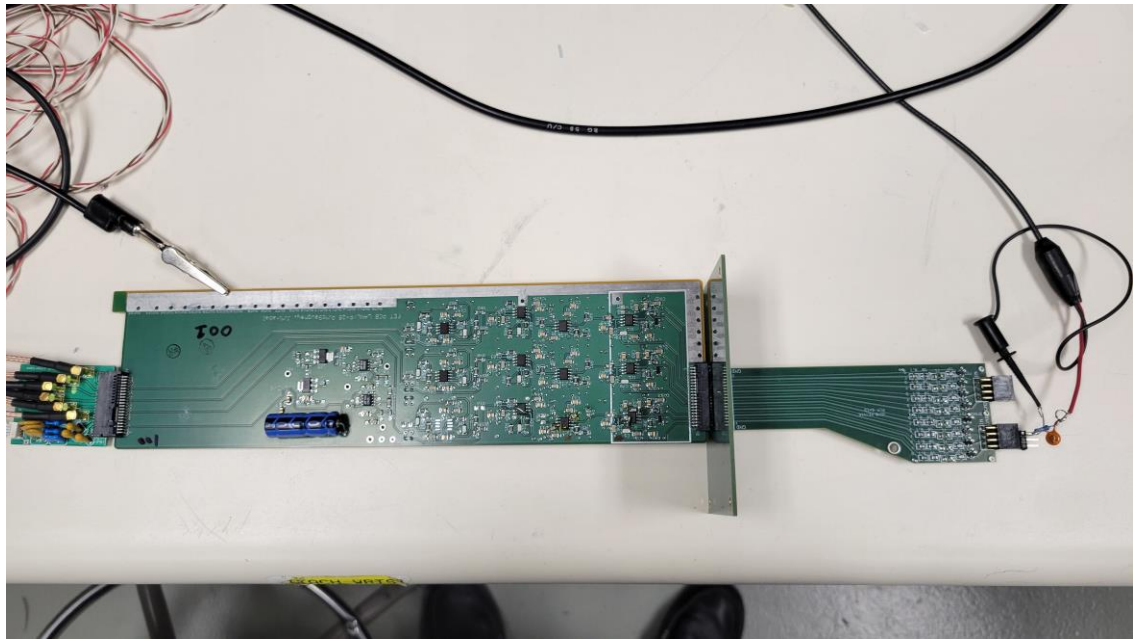
REVIEW: We have performed some benchtop testing on a single channel of the preamplifier board

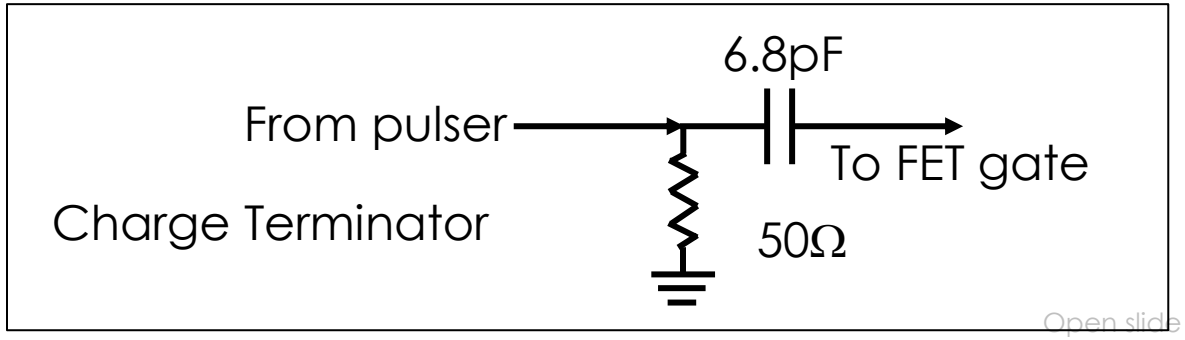
- Limited scope:
  - To understand actual waveshape response and stability with 2nd order Loop Transmission measurement (*not to determine waveshape suitability for the experiment*)
  - To measure power
  - To compare response to SPICE simulations
  - To attempt to create oscillations
  - To examine effects of minor circuit modifications



REVIEW: Board was setup with power supplies and 1GHz oscilloscope

- Used FET board, adapter board and power connections board from SNS
- Made a charge terminator with 6.8pF input capacitance for signal injection (~5nS risetime)
- +/-7V, +12V supplies were used

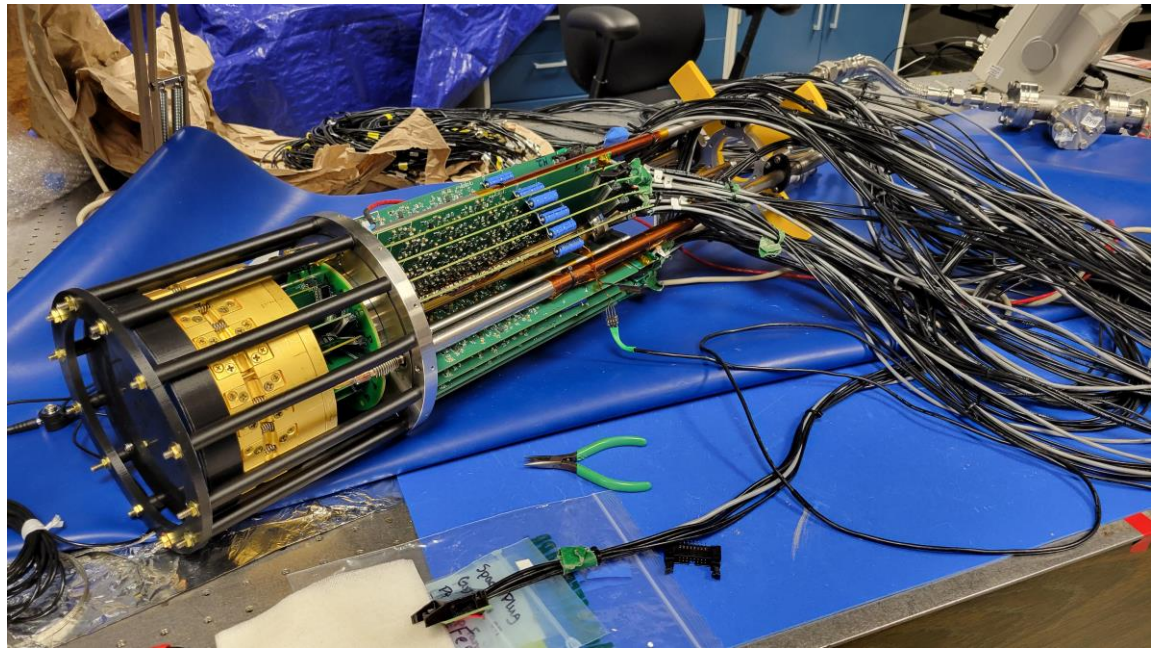


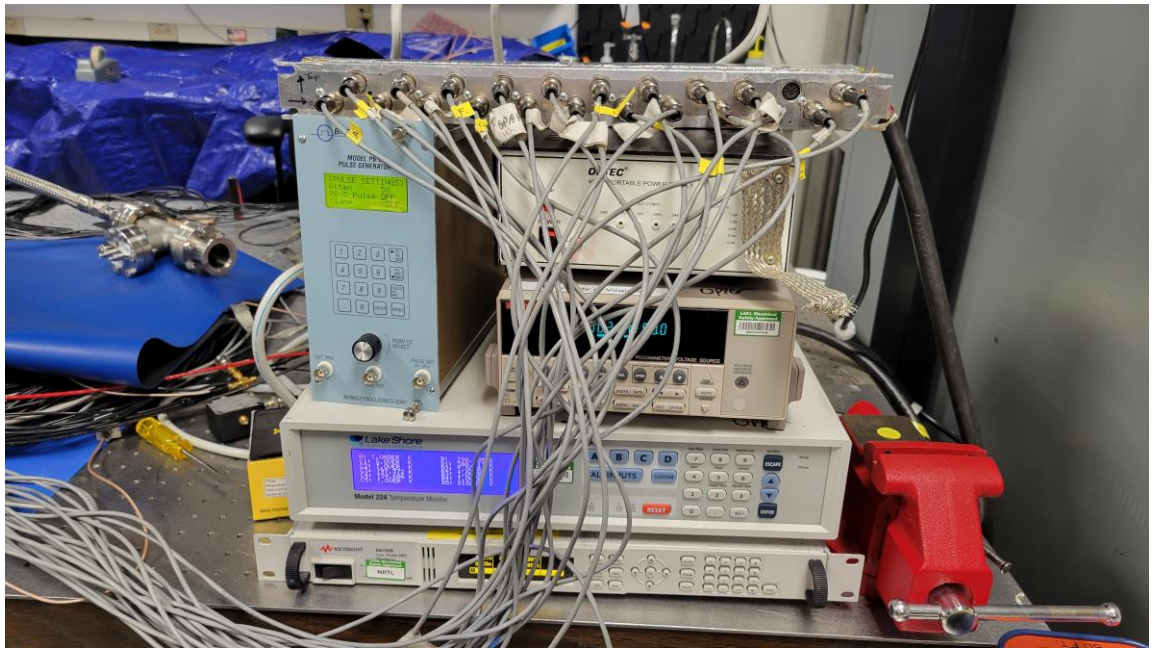


Single Board summary to date

- Preamplifier/driver waveshape is good, stability is excellent
- SPICE Simulation model is poor likely due to AD8011 model
  - Underpredicts bandwidth
  - Overpredicts phase margin
- Oscillations show system tends to oscillate with various grounding configurations
- Circuits are OK, system is bad
- Board Layout needs to be improved

System has been set up in 5800, D210





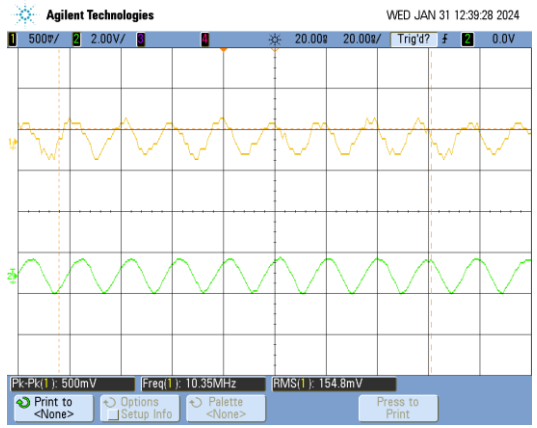
Summary of testing

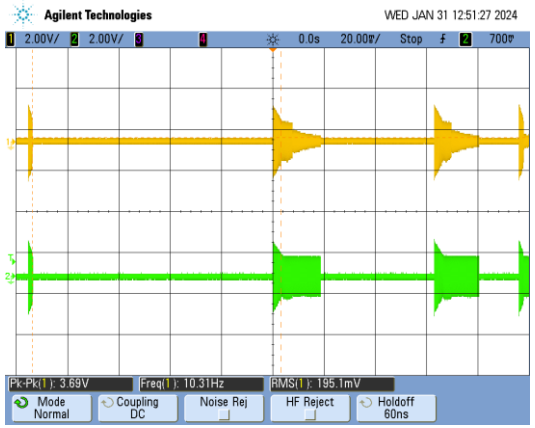
- There were a couple of boards that didn't work. These were replaced
  - Capacitor (C31) blew. Shorted to the frame.
- System began oscillating immediately
  - Needed to remove 2 boards to maintain stability.
  - Which boards didn't really matter.
  - Didn't matter whether boards had warmed up or just started cold.
- We worked from the cable end of the assembly to systematically remove grounding
  - Included mechanical grounds
  - Bias and pulser tee grounds on vacuum feed
  - Both grounded and insulated preamp board "foot"
    - Added aluminum foil to improve ground since the foot does not fit tightly.
    - Insulated with Kapton tape.
  - Disconnected bias tee board at detector end
  - Disconnected ground tabs on FET cards
  - Removed gold endcap and left FET boards intact

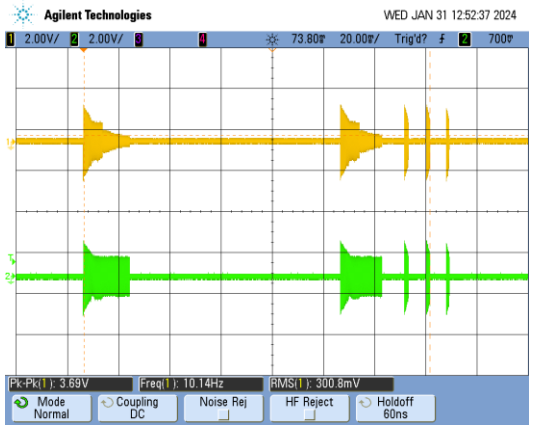
Results

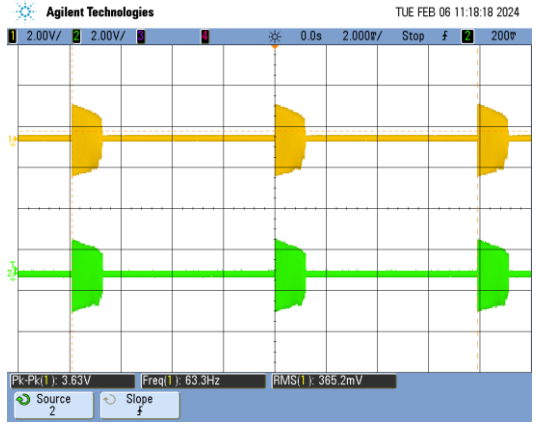
- Changes seemed to have little effect if any
- Oscillation stopped if 2-3 boards were removed
- Oscillation bursts
  - Appeared to be 50MHz with irregular noise mixed
  - Burst length started at ~1.25ms period and 600us duration
  - After system reassembled period appears to be several 10s of ms and duration of ~ 20mS
  - Now burst ~4ms

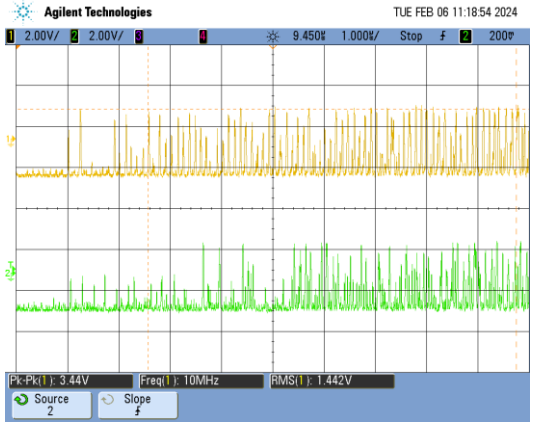
Different Oscillation Modes Boards M and U, Ch1 (board T out)

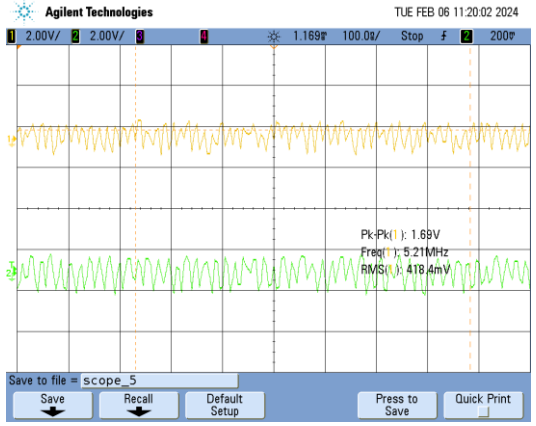












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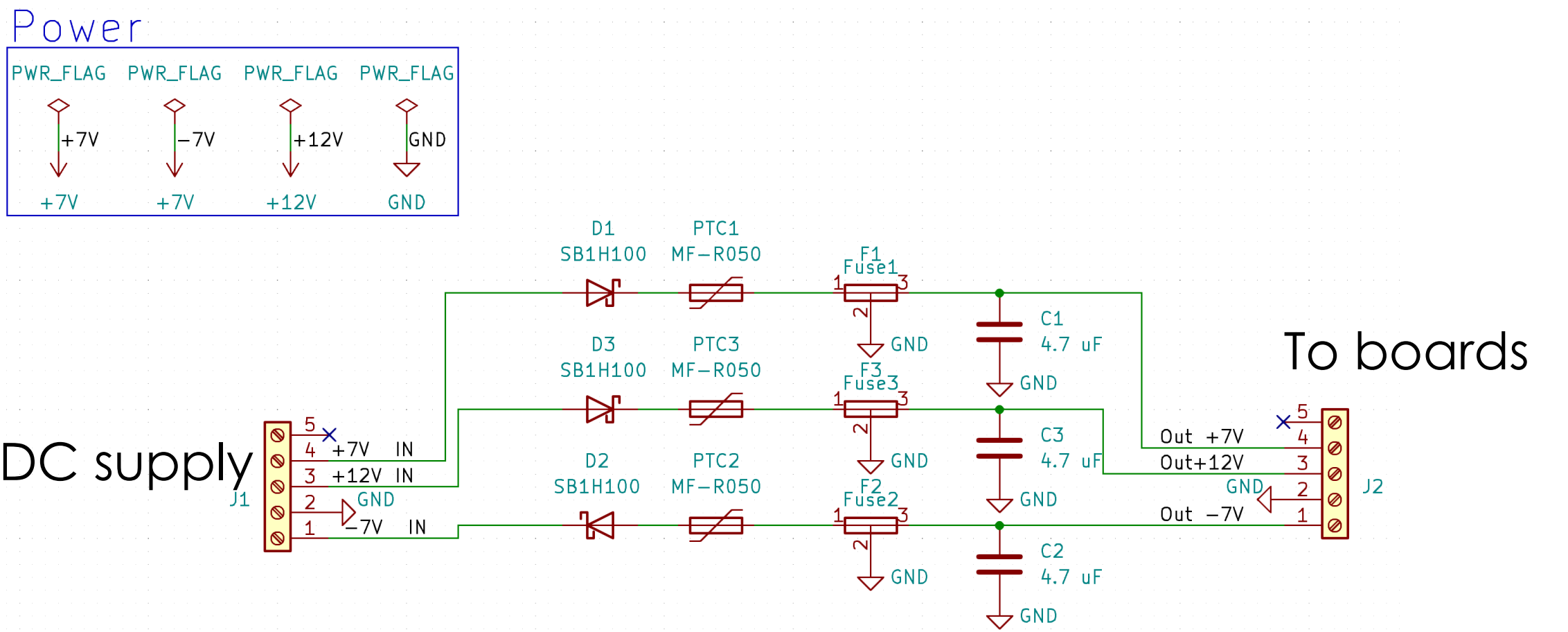
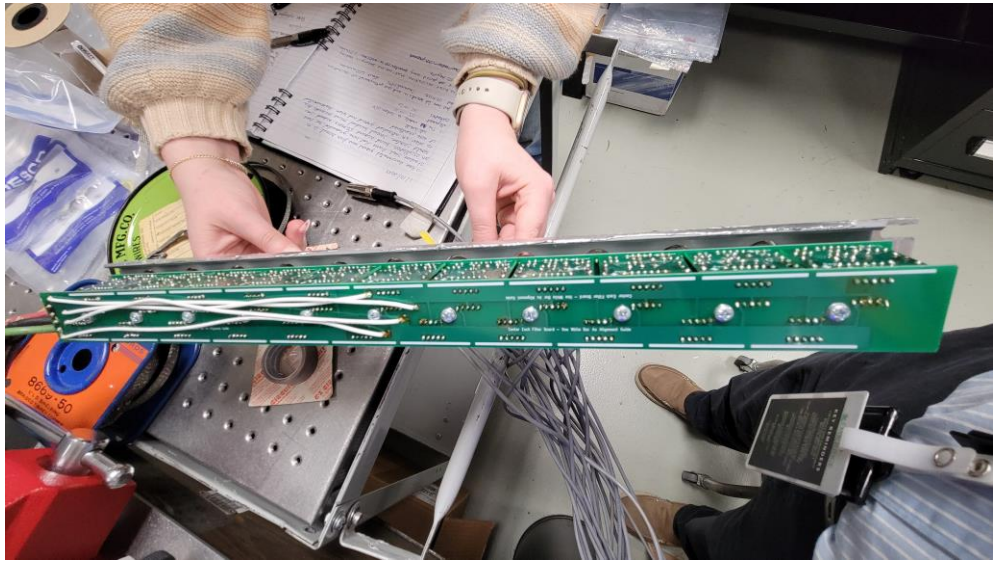
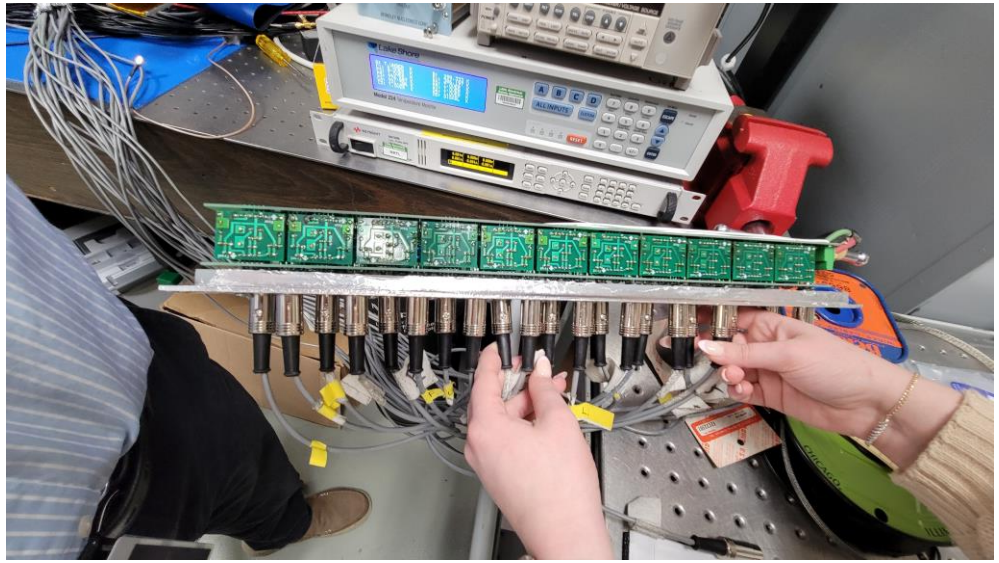
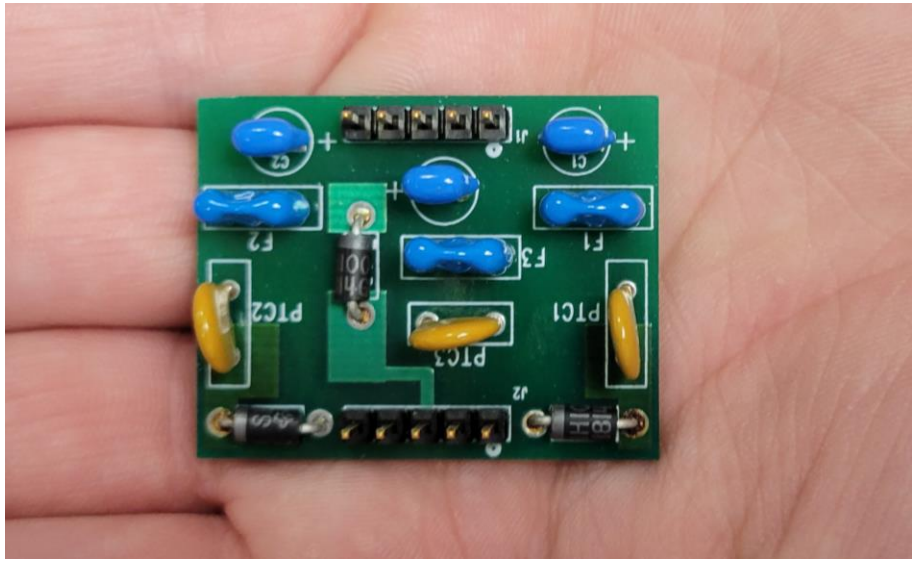
Power Distribution Channel



Power Boards







- BACKUP SLIDES

OAK RIDGE National Laboratory

Electronic Board Bench Test Status

Chuck Britton, Nance Ericson, Kyle Reed

Electronics and Embedded Systems

7 Dec 2023

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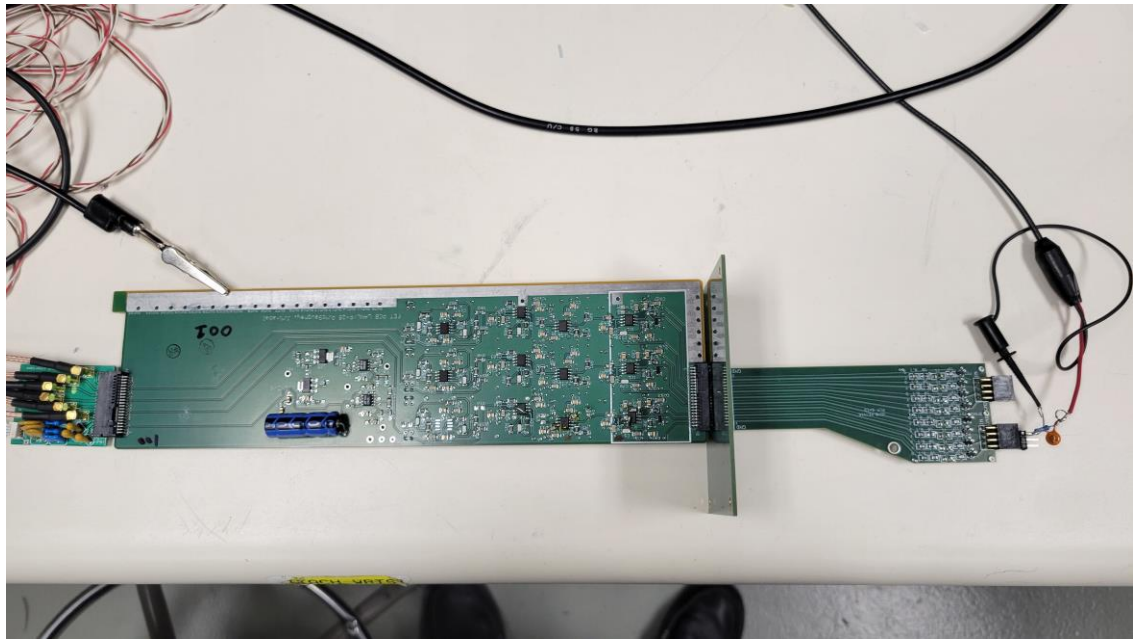
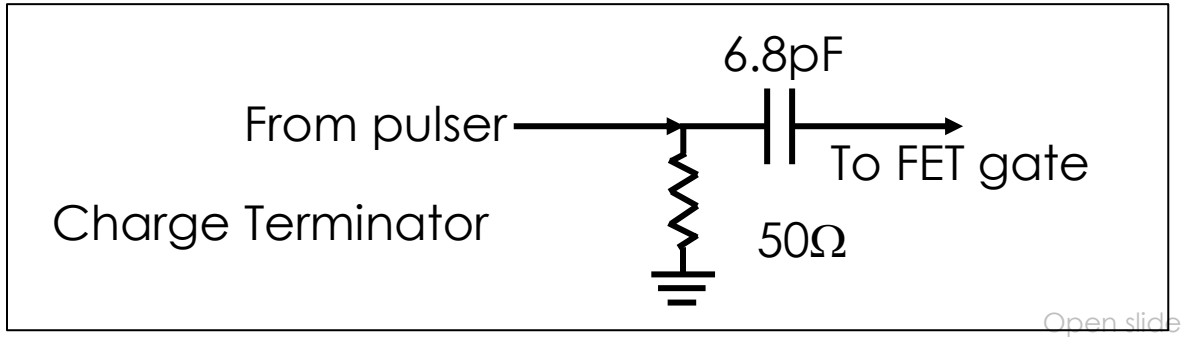
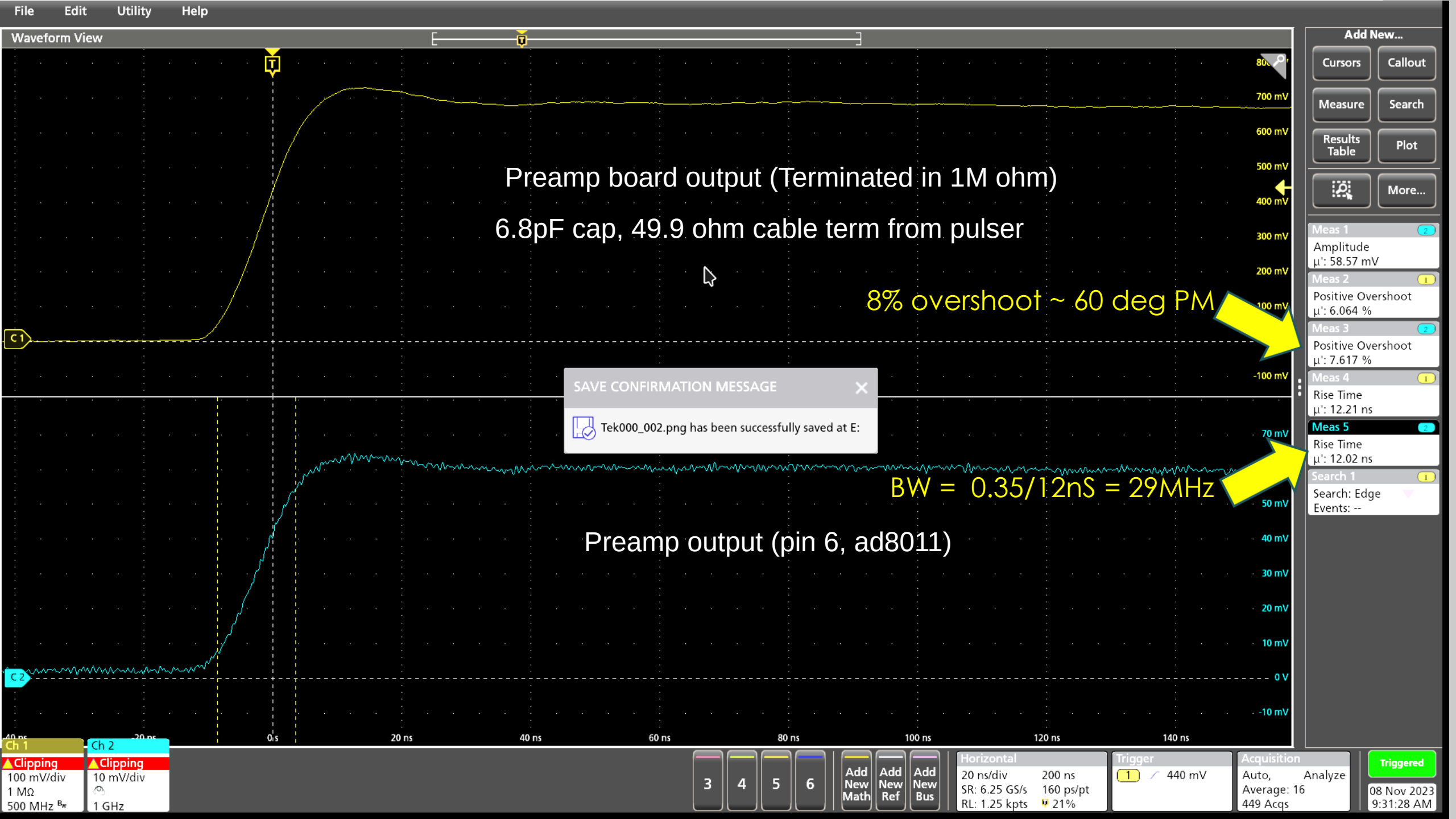




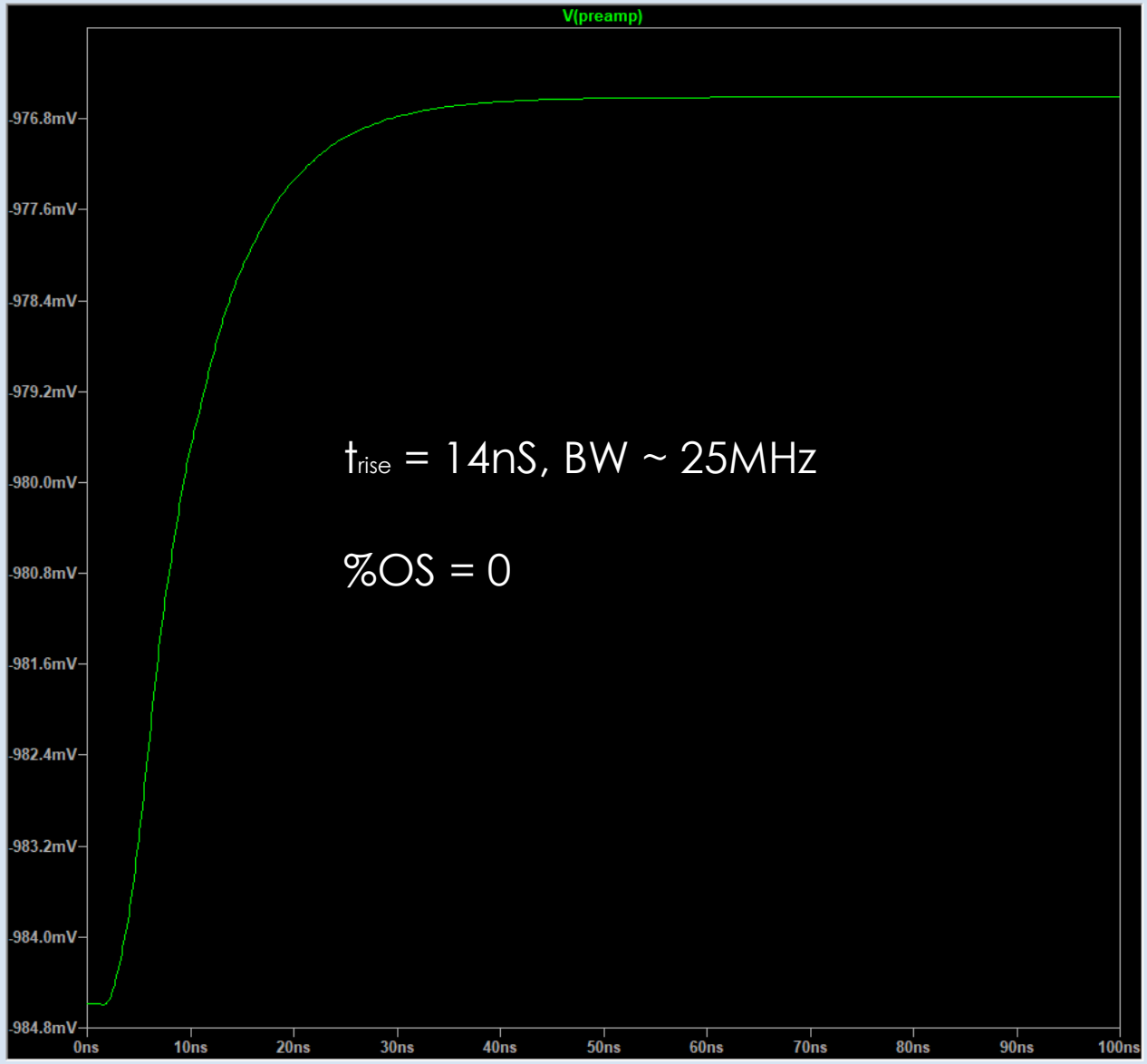

File
Edit
Utility
Help
Waveform View
Preamp board output (Terminated in 1M ohm)
6.8pF cap, 49.9 ohm cable term from pulser
8% overshoot ~ 60 deg PM
SAVE CONFIRMATION MESSAGE
Tek000_002.png has been successfully saved at E:
BW = 0.35/12nS = 29MHz
Preamp output (pin 6, ad8011)
Add New...
Cursors
Callout
Measure
Search
Results Table
Plot
More...
Meas 1
Amplitude
μ': 58.57 mV
Meas 2
Positive Overshoot
μ': 6.064 %
Meas 3
Positive Overshoot
μ': 7.617 %
Meas 4
Rise Time
μ': 12.21 ns
Meas 5
Rise Time
μ': 12.02 ns
Search 1
Search: Edge
Events: --
Ch 1
Clipping
100 mV/div
1 MΩ
500 MHz
Ch 2
Clipping
10 mV/div
1 GHz
Add New Math
Add New Ref
Add New Bus
Horizontal
20 ns/div
200 ns
SR: 6.25 GS/s
160 ps/pt
RL: 1.25 kpts
21%
Trigger
440 mV
Acquisition
Auto, Analyze
Average: 16
449 Acqs
Triggered
08 Nov 2023
9:31:28 AM

LTspice XVII - AD8011_With_Parasitics.asc

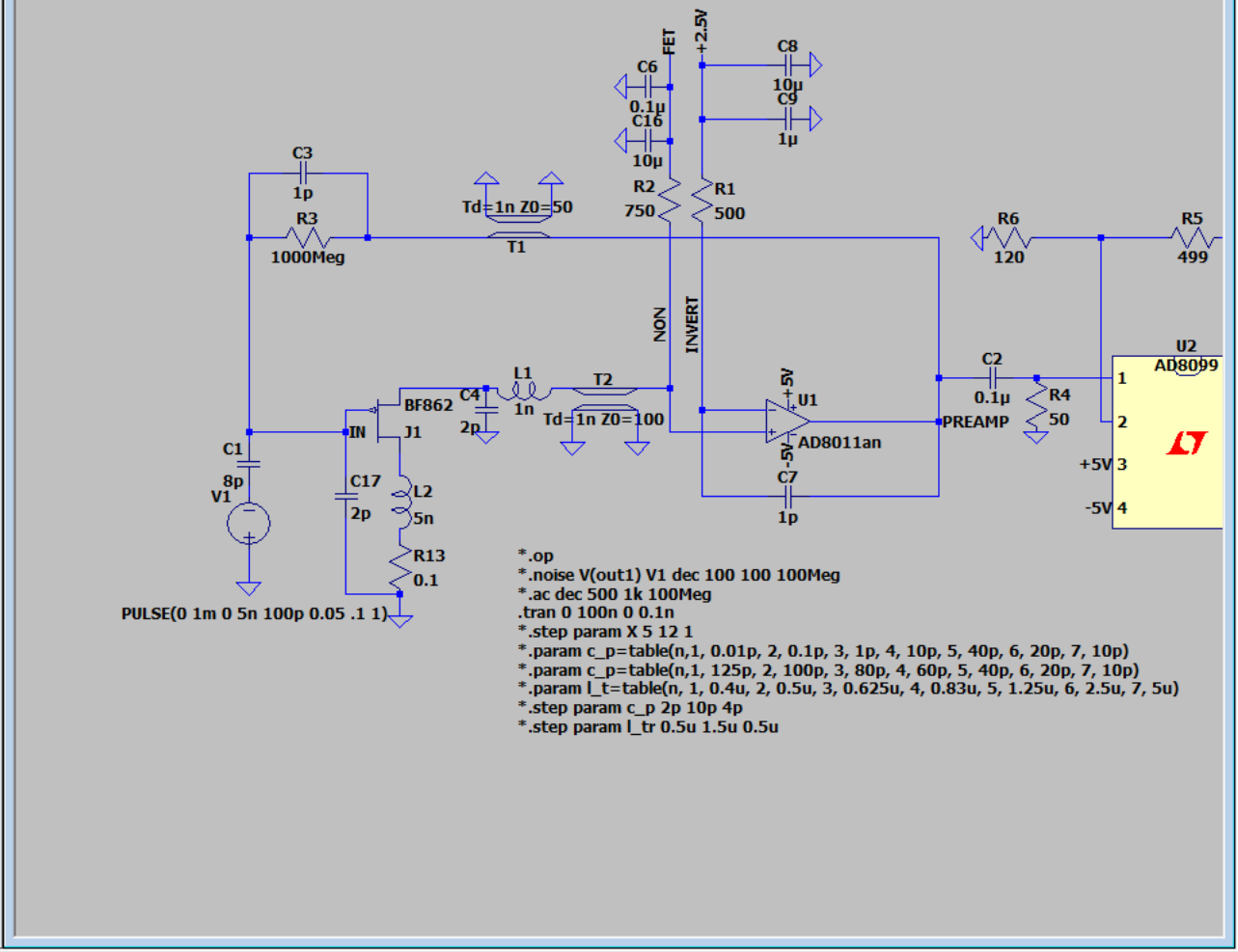
File Edit Hierarchy View Simulate Tools Window Help

AD8011_With_Parasitics.asc AD8011_With_Parasitics.raw

AD8011_With_Parasitics.raw



AD8011_With_Parasitics.asc



Type here to search

37°F Mostly cloudy

10:46 AM 12/5/2023

LTspice XVII - AD8011_With_Parasitics-LOOP-T.raw

File View Plot Settings Simulation Tools Window Help

AD8011_With_Parasitics-LOOP-T.asc AD8011_With_Parasitics-LOOP-T.raw

AD8011_With_Parasitics-LOOP-T.raw

V(preamp) V(return)

60dB 54dB 48dB 42dB 36dB 30dB 24dB 18dB 12dB 6dB 0dB -6dB -12dB

180° 160° 140° 120° 100° 80° 60° 40° 20° 0°

1KHz 10KHz 100KHz 1MHz 10MHz 100MHz

PM = 87 deg , Overdamped

AD8011_With_Parasitics-LOOP-T.asc

.nodeset V(nc_01)= 0
+V(n022): 0
+V(+5v): 5
+V(-5v): -5
V(+2.5v): 2.5
+V(invert): 2.48428
+V(non): 2.48095
+V(fet): 10
+V(n009): -2.00005e-006
+V(preamp): -1.94521

V6 FET 10
V2 +5V 5
V3 5 -5V
V4 +2.5V 2.5
C3 1p
R3 1000Meg
Td=1n Z0=50 T1
C6 0.1µ
C16 10µ
C8 10µ
C9 1µ
R2 750
R1 500
RETURN
C18 1e10
V7 AC 1
L3 1e20
R6 120
R5 499
NON
INVERT
C2 0.1µ
R4 50
PREAMP
U2 AD8099
U1 AD8011an
L1 1n
T2 Td=1n Z0=100
BF862 J1
C4 2p
C1 8p
V1
C17 2p
L2 5n
R13 0.1
C7 1p
PULSE(0 1m 0 5n 100p 0.05 .1 1)

AD8011_With_Parasitics-LOOP-T.raw

Cursor 1
V(preamp)
Freq: 18.756577MHz Mag: 61.175494mdB
Phase: 87.097508°
Group Delay: 509.67485ps

Cursor 2
Freq: -- N/A-- Mag: -- N/A--
Phase: -- N/A--
Group Delay: -- N/A--

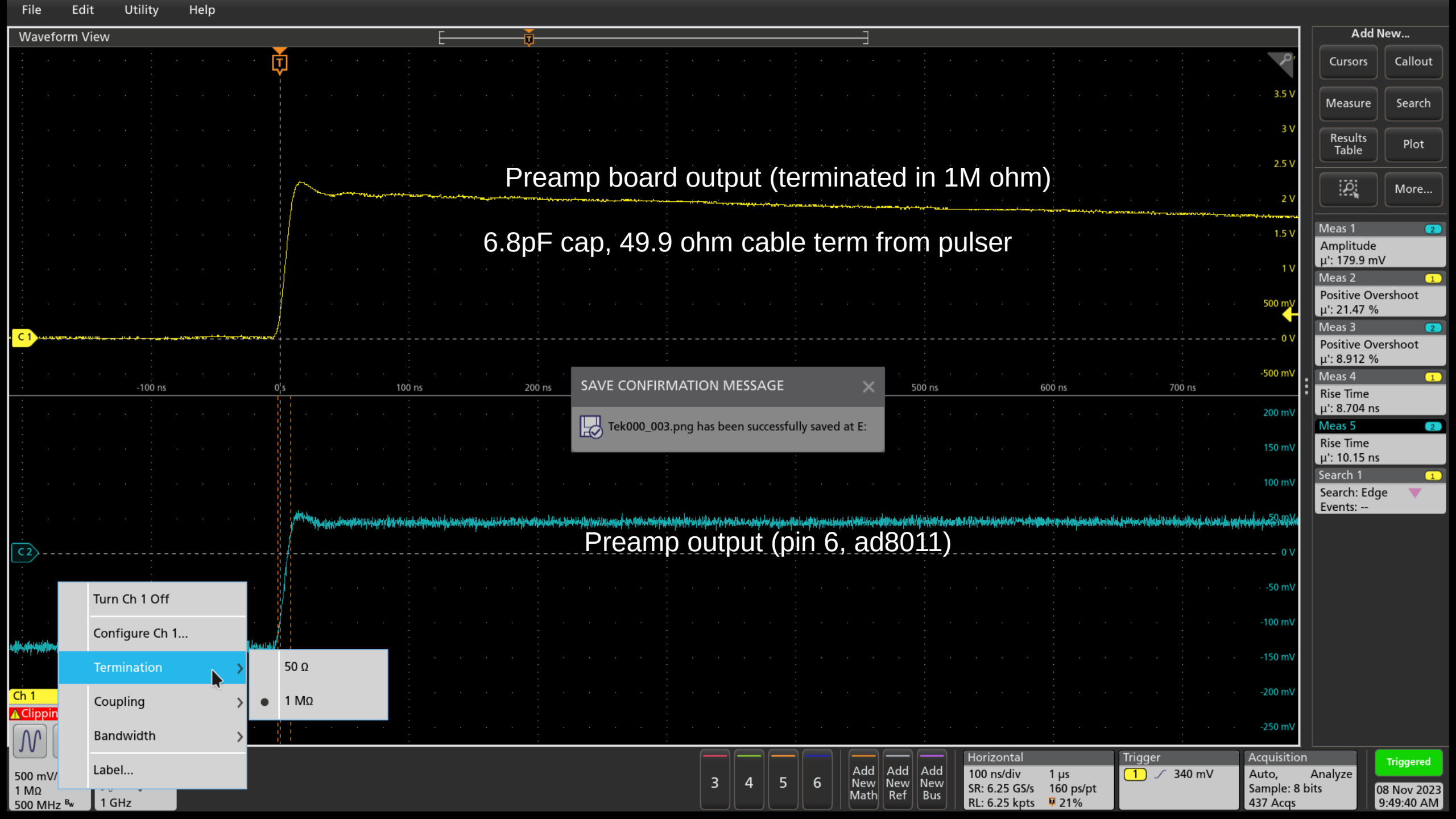
Ratio (Cursor2 / Cursor1)
Freq: -- N/A-- Mag: -- N/A--
Phase: -- N/A--
Group Delay: -- N/A--

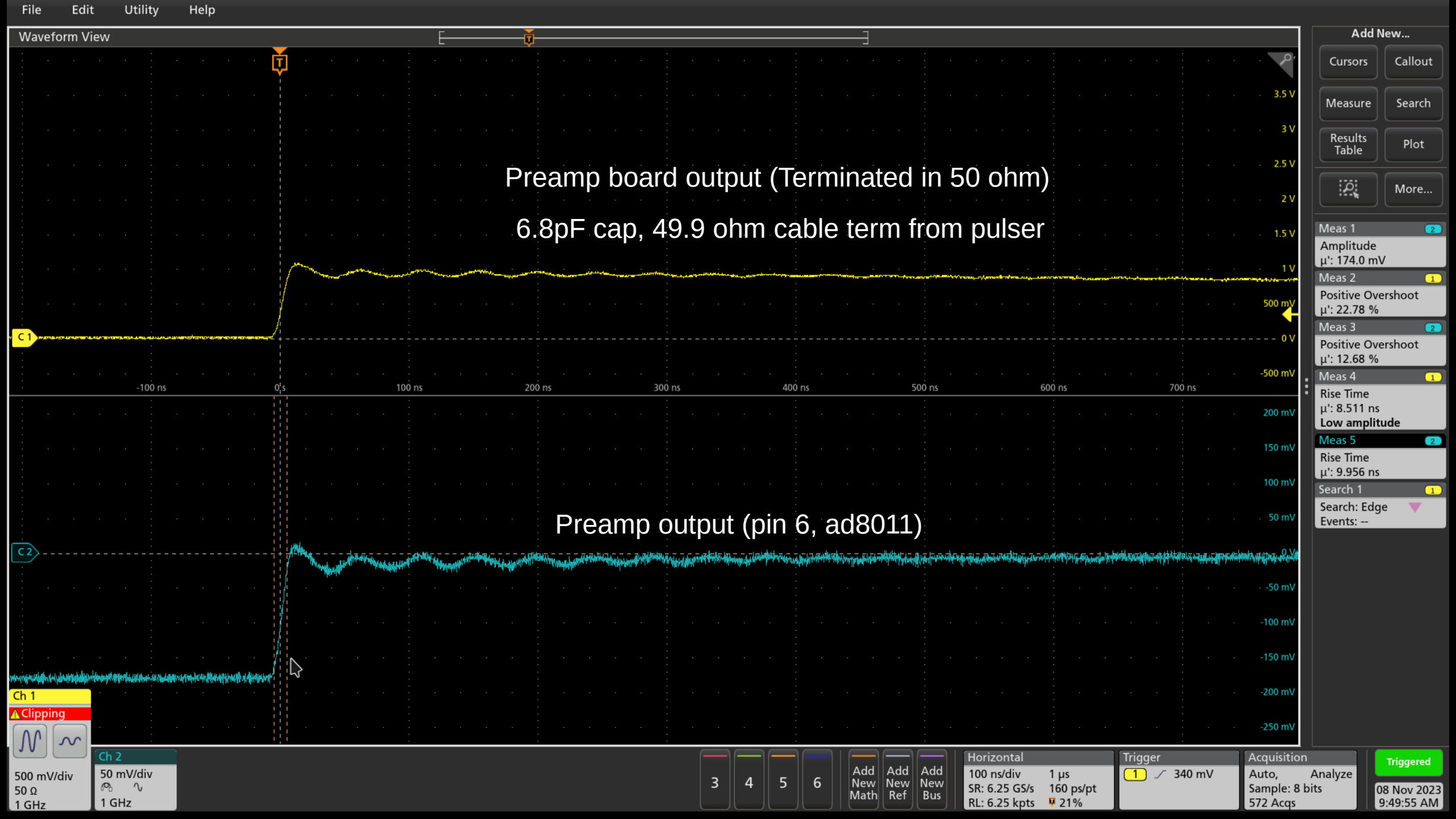
x = 100.000MHz y = 60.784dB, 181.959°

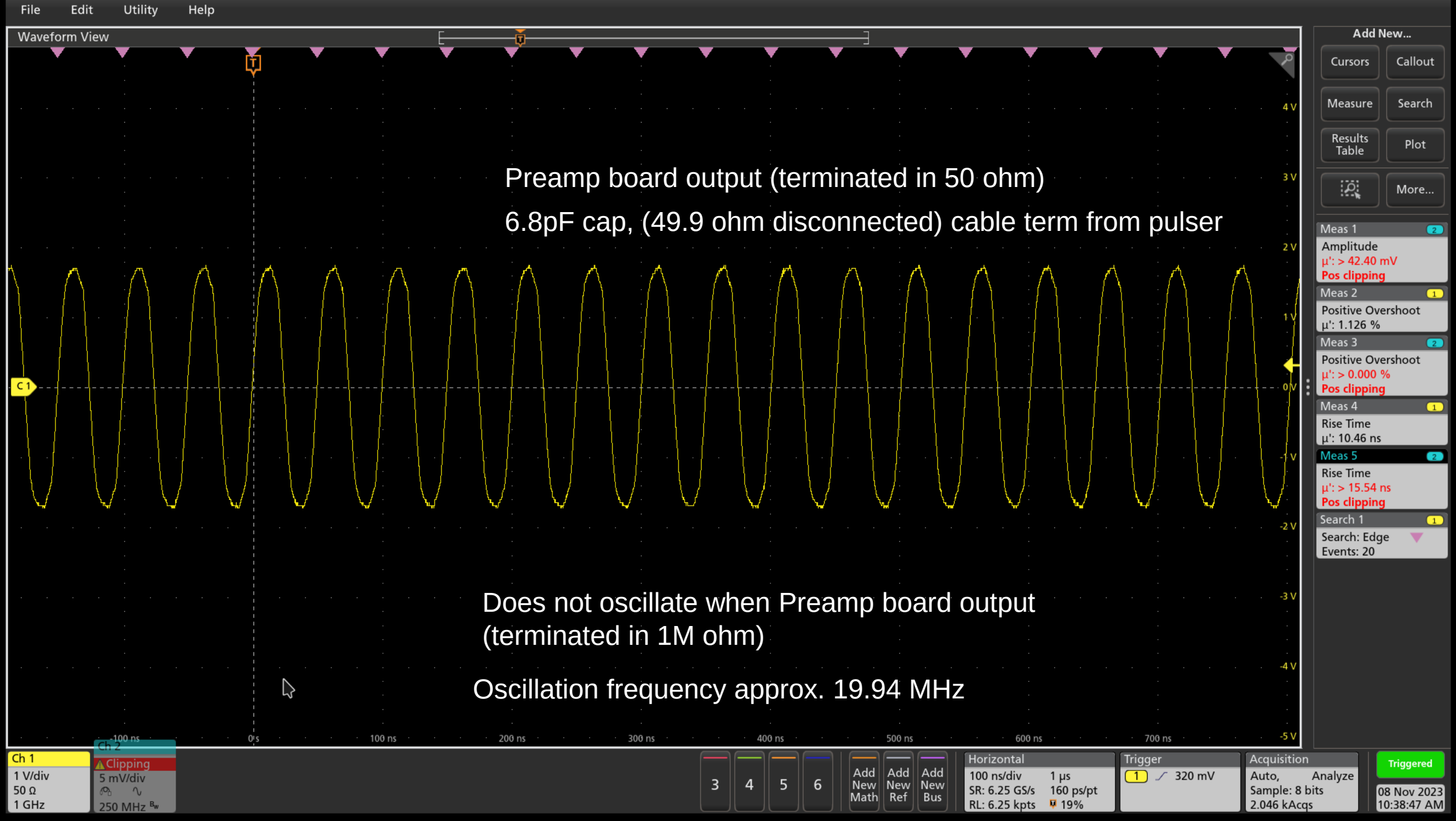
Type here to search

37°F Mostly cloudy

10:48 AM 12/5/2023


File
Edit
Utility
Help
Waveform View
Preamp board output (terminated in 1M ohm)
6.8pF cap, 49.9 ohm cable term from pulser
Preamp output (pin 6, ad8011)
C 1
C 2
3.5 V
3 V
2.5 V
2 V
1.5 V
1 V
500 mV
0 V
-500 mV
-100 ns
0 s
100 ns
200 ns
500 ns
600 ns
700 ns
200 mV
150 mV
100 mV
50 mV
0 V
-50 mV
-100 mV
-150 mV
-200 mV
-250 mV
SAVE CONFIRMATION MESSAGE
Tek000_003.png has been successfully saved at E:
Turn Ch 1 Off
Configure Ch 1...
Termination
Coupling
Bandwidth
Label...
50 Ω
1 MΩ
Ch 1
Clippin
500 mV/
1 MΩ
500 MHz
1 GHz
Add New...
Cursors
Callout
Measure
Search
Results Table
Plot
More...
Meas 1
Amplitude
μ': 179.9 mV
Meas 2
Positive Overshoot
μ': 21.47 %
Meas 3
Positive Overshoot
μ': 8.912 %
Meas 4
Rise Time
μ': 8.704 ns
Meas 5
Rise Time
μ': 10.15 ns
Search 1
Search: Edge
Events: --
3
4
5
6
Add New Math
Add New Ref
Add New Bus
Horizontal
100 ns/div
1 µs
SR: 6.25 GS/s
160 ps/pt
RL: 6.25 kpts
21%
Trigger
1
340 mV
Acquisition
Auto,
Analyze
Sample: 8 bits
437 Acqs
Triggered
08 Nov 2023
9:49:40 AM


File
Edit
Utility
Help
Waveform View
Preamp board output (Terminated in 50 ohm)
6.8pF cap, 49.9 ohm cable term from pulser
3.5 V
3 V
2.5 V
2 V
1.5 V
1 V
500 mV
0 V
-500 mV
C 1
-100 ns
0 s
100 ns
200 ns
300 ns
400 ns
500 ns
600 ns
700 ns
Preamp output (pin 6, ad8011)
200 mV
150 mV
100 mV
50 mV
0 V
-50 mV
-100 mV
-150 mV
-200 mV
-250 mV
C 2
Add New...
Cursors
Callout
Measure
Search
Results Table
Plot
More...
Meas 1
Amplitude
μ': 174.0 mV
Meas 2
Positive Overshoot
μ': 22.78 %
Meas 3
Positive Overshoot
μ': 12.68 %
Meas 4
Rise Time
μ': 8.511 ns
Low amplitude
Meas 5
Rise Time
μ': 9.956 ns
Search 1
Search: Edge
Events: --
Ch 1
Clipping
500 mV/div
50 Ω
1 GHz
Ch 2
50 mV/div
1 GHz
3
4
5
6
Add New Math
Add New Ref
Add New Bus
Horizontal
100 ns/div
1 μs
SR: 6.25 GS/s
160 ps/pt
RL: 6.25 kpts
21%
Trigger
1
340 mV
Acquisition
Auto,
Analyze
Sample: 8 bits
572 Acqs
Triggered
08 Nov 2023
9:49:55 AM

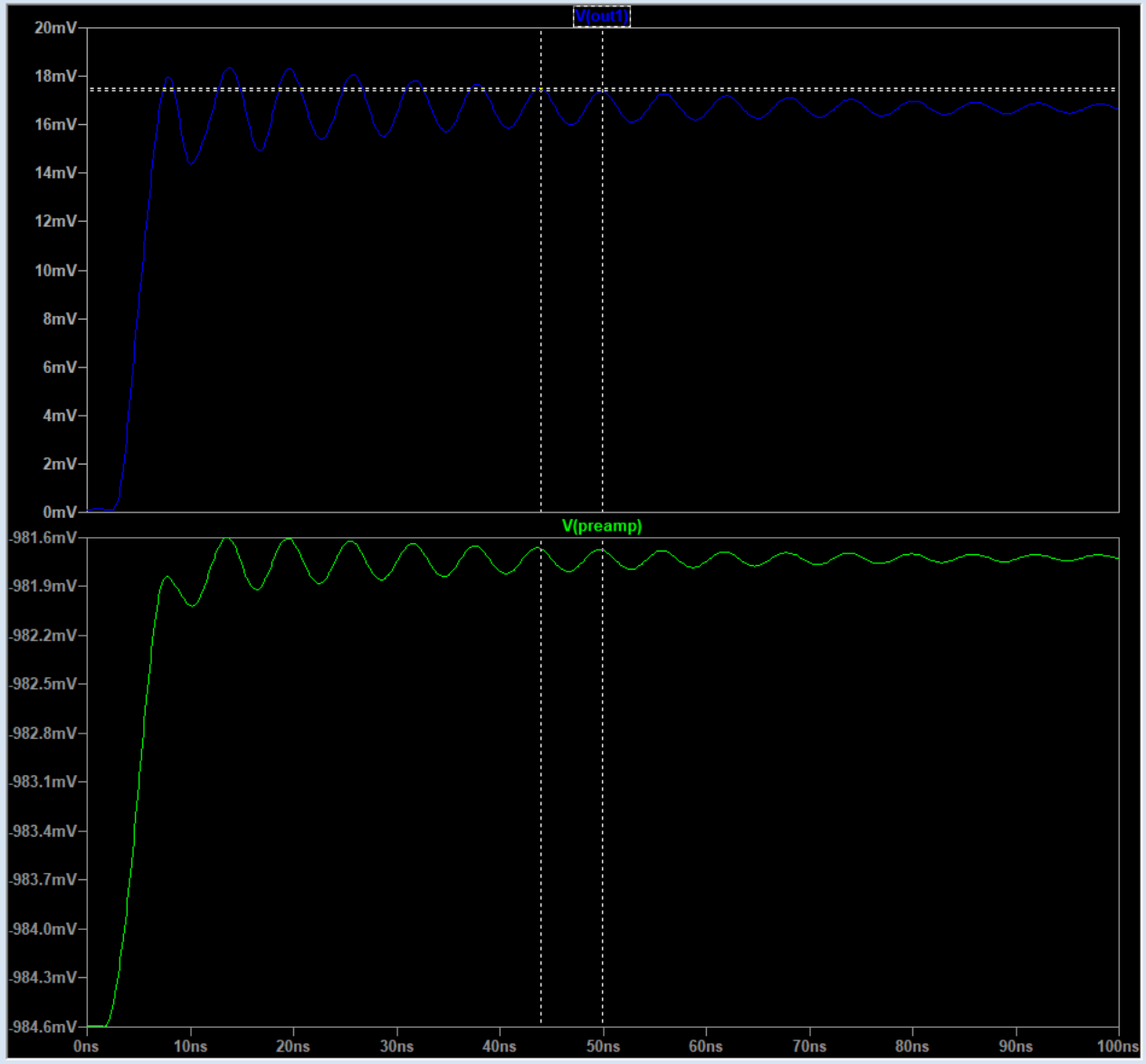

File
Edit
Utility
Help
Waveform View
Add New...
Cursors
Callout
Measure
Search
Results Table
Plot
More...
Meas 1
Amplitude
μ': > 42.40 mV
Pos clipping
Meas 2
Positive Overshoot
μ': 1.126 %
Meas 3
Positive Overshoot
μ': > 0.000 %
Pos clipping
Meas 4
Rise Time
μ': 10.46 ns
Meas 5
Rise Time
μ': > 15.54 ns
Pos clipping
Search 1
Search: Edge
Events: 20
Preamp board output (terminated in 50 ohm)
6.8pF cap, (49.9 ohm disconnected) cable term from pulser
C 1
4 V
3 V
2 V
1 V
0 V
-1 V
-2 V
-3 V
-4 V
-5 V
-100 ns
0 s
100 ns
200 ns
300 ns
400 ns
500 ns
600 ns
700 ns
Does not oscillate when Preamp board output
(terminated in 1M ohm)
Oscillation frequency approx. 19.94 MHz
Ch 1
1 V/div
50 Ω
1 GHz
Ch 2
Clipping
5 mV/div
250 MHz
3
4
5
6
Add New Math
Add New Ref
Add New Bus
Horizontal
100 ns/div
1 µs
SR: 6.25 GS/s
160 ps/pt
RL: 6.25 kpts
19%
Trigger
1
320 mV
Acquisition
Auto,
Analyze
Sample: 8 bits
2.046 kAcqs
Triggered
08 Nov 2023
10:38:47 AM

LTspice XVII - AD8011_With_Parasitics.asc

File Edit Hierarchy View Simulate Tools Window Help

AD8011_With_Parasitics.asc AD8011_With_Parasitics.raw

AD8011_With_Parasitics.raw



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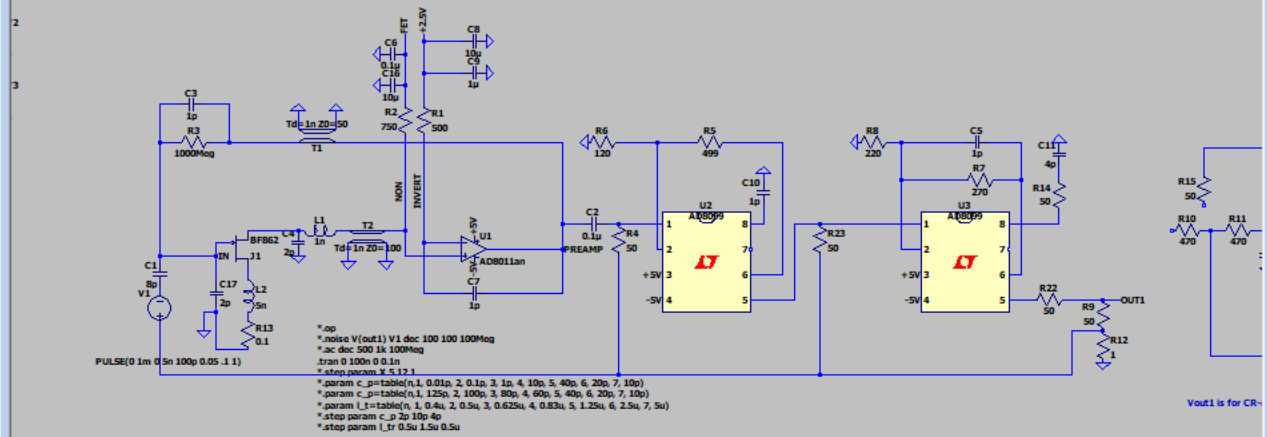

Splitting ground at the front end can cause an oscillation.

AD8011_With_Parasitics.raw

Cursor 1	V(out1)		
Horz:	43.976608ns	Vert:	17.507353mV
Cursor 2	V(out1)		
Horz:	49.94152ns	Vert:	17.389156mV
Diff (Cursor2 - Cursor1)			
Horz:	5.9649123ns	Vert:	-118.19772µV
Freq:	167.64706MHz	Slope:	-19815.5

x = 59.06ns y = 20.50mV

Type here to search

Near record

11:43 AM 12/6/2023

Summary of observations

- As received
  - Stable
    - with1M termination
  - Marginally stable
    - with 50Ω term on 'scope.
  - Unstable with
    - with 50Ω term on 'scope AND
    - 50Ω term disconnected at charge terminator
  - Power
    - +7V = 303mA
    - -7V = 278mA
    - +12V = 75mA
  - Oscillation Freq ~ 20MHz

- Modified
  - Inserted 10Ω and 22Ω resistors and 0.1uF and 1uF on supply pins of 1st three stage opamps.
    - **No effect**
  - Replaced output stage with AD8011.
    - **Oscillation increased to 27MHz**

Final summary to date

- Preamplifier/driver waveshape is good, stability is excellent
- SPICE Simulation model is poor likely due to AD8011 model
  - Underpredicts bandwidth
  - Overpredicts phase margin
- Oscillations show system tends to oscillate with various grounding configurations
- Going forward - Barkhousen Criteria for a sustained oscillation
  - Loop gain must be equal to 1
  - Phase shift around loop must be 0 deg.
  - (T=1 + j0)
- My overall opinion – circuits are good, system is bad
- Next moves include grounding map