SNS Injection Kicker PS Measurements

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How the PS Current follows the Down Ramp V_{ref} for Three Styles of Down Ramps

The SNS injection kicker magnet on December 27 and December 30, 2002.
The measurements on December 27 were taken without the ceramic beam tube.

The up ramps were identical in all cases. The current was ramped from 0 A to 1230 A in 2 ms using a slightly rounded start and end, (Rounding parameters: F1u = 0.1, F2u = 0.05). Then there was a flat top of 1 ms.

The down ramps were of the following three types:

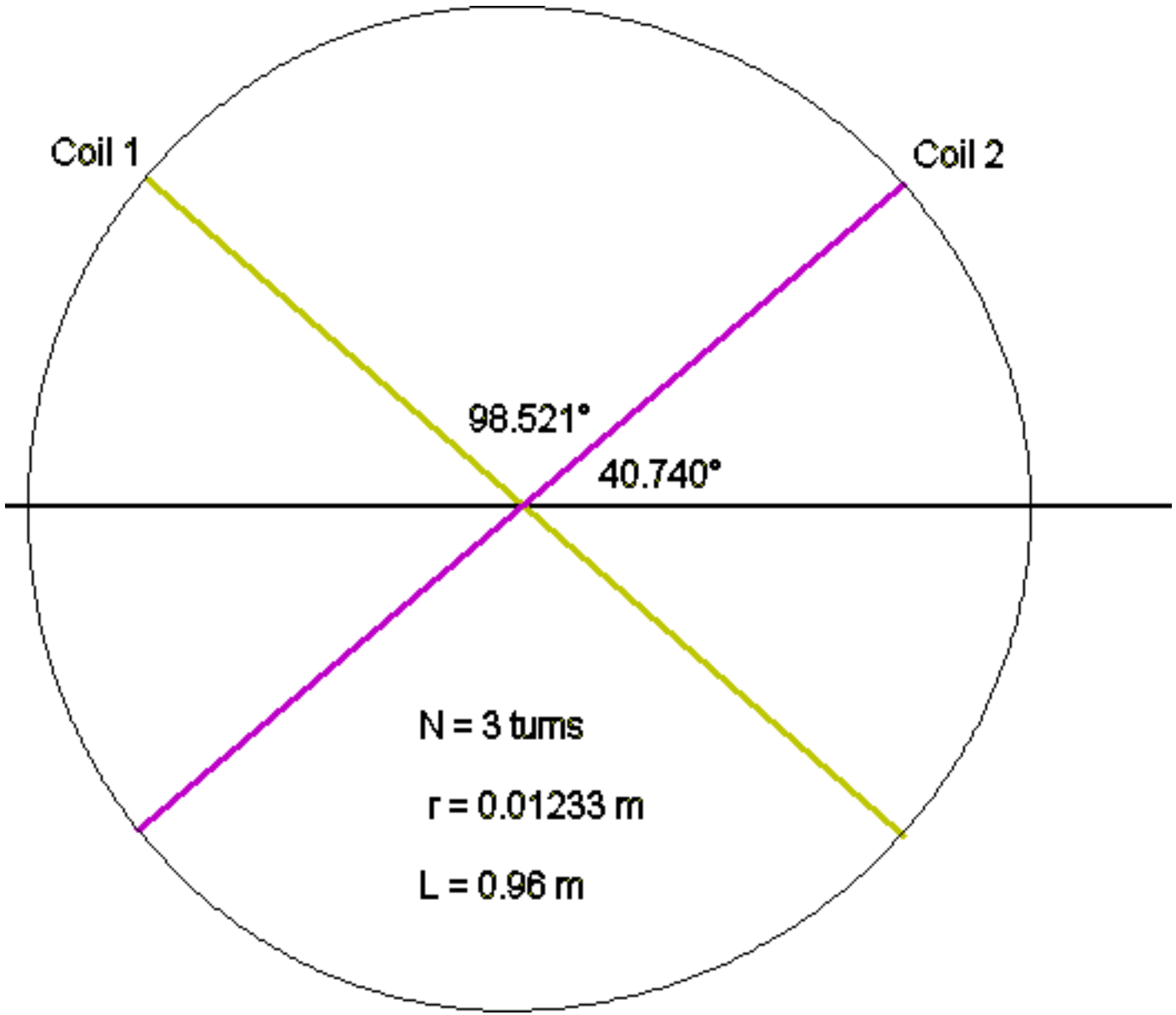
- Smoothed Linear (with slight rounding, F1d = 0.1, F2d = 0.05) with differing down ramp times.

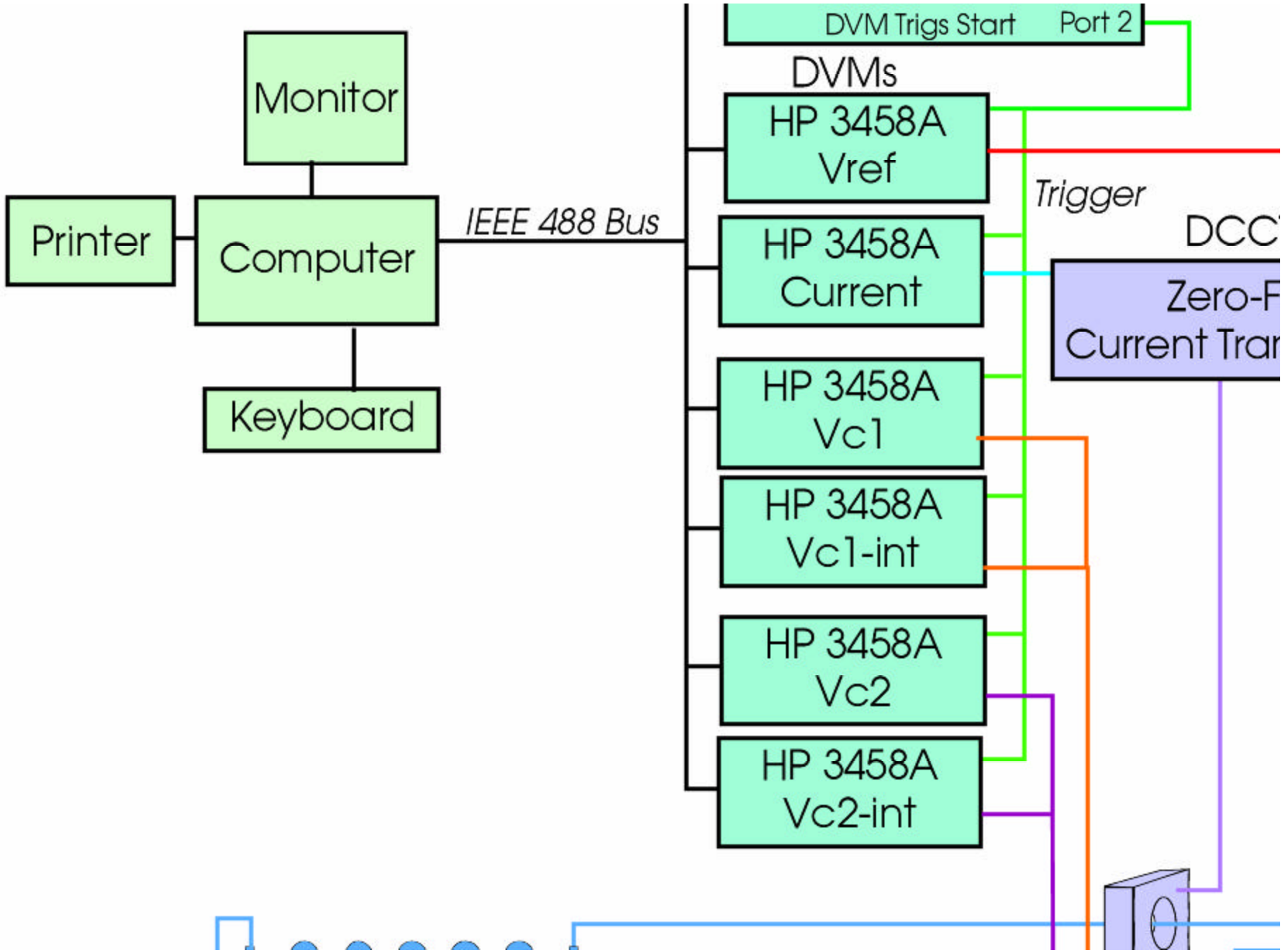
- Exponential Drop. The values used for τ were 0.15 ms to 0.30 ms in 0.05 ms steps.

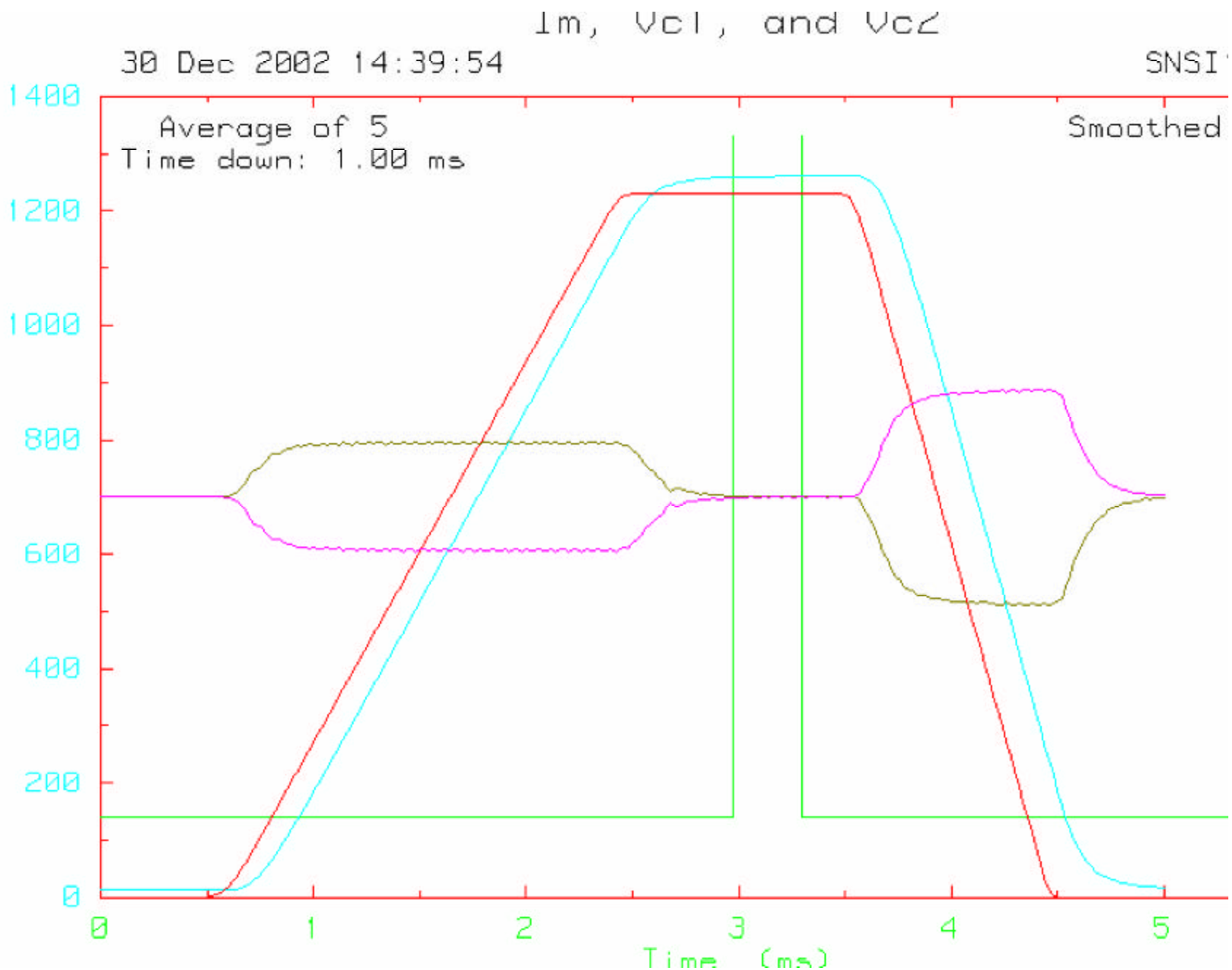
$$I_{\max} e^{-\frac{t}{t}} \quad \text{for t} < 7t, \text{ then } 0.$$

- Square Root Drop. For this down-ramp type, the values of τ used were 0.10 ms to 1.10 ms in 0.20 ms steps.

$$I_{\max}\left(1 - \sqrt{\frac{t}{t}}\right) \quad \text{for t} < t, \text{ then } 0.$$

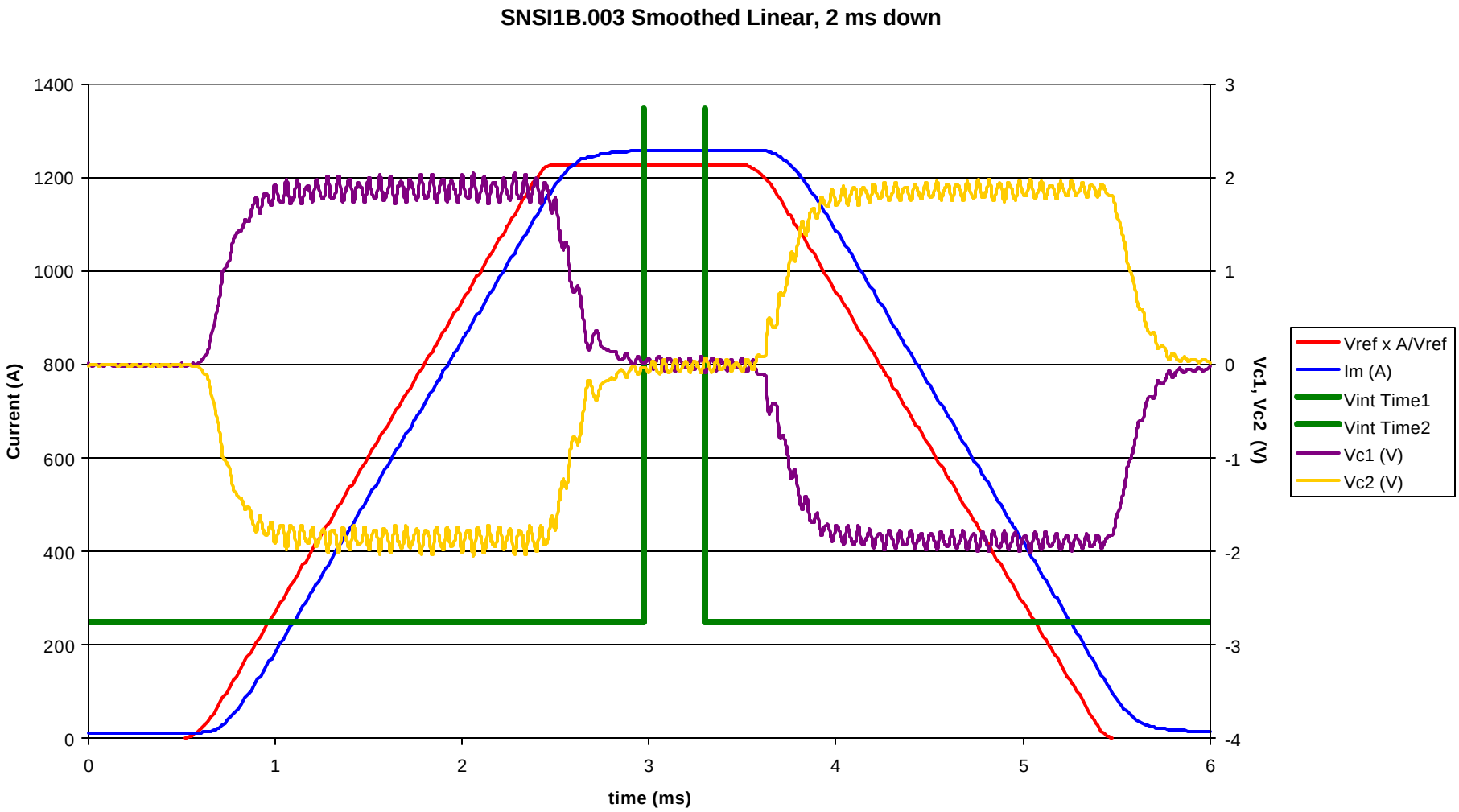

Coil 1
Coil 2
98.521°
40.740°
N = 3 turns
r = 0.01233 m
L = 0.96 m

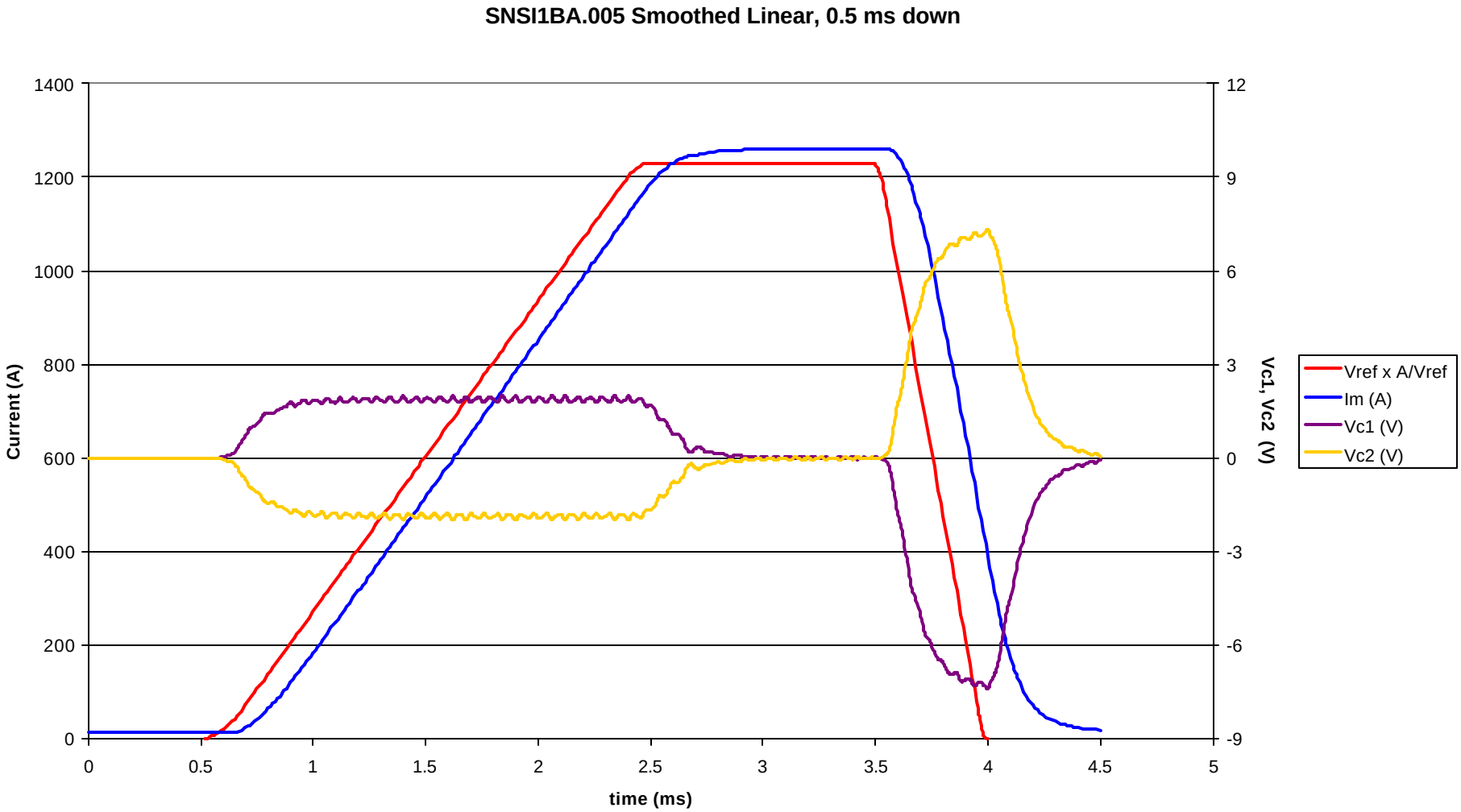

Monitor
Printer
Computer
Keyboard
IEEE 488 Bus
DVM Trigs Start
Port 2
DVMs
HP 3458A
Vref
HP 3458A
Current
HP 3458A
Vc1
HP 3458A
Vc1-int
HP 3458A
Vc2
HP 3458A
Vc2-int
Trigger
DCC
Zero-F
Current Trar

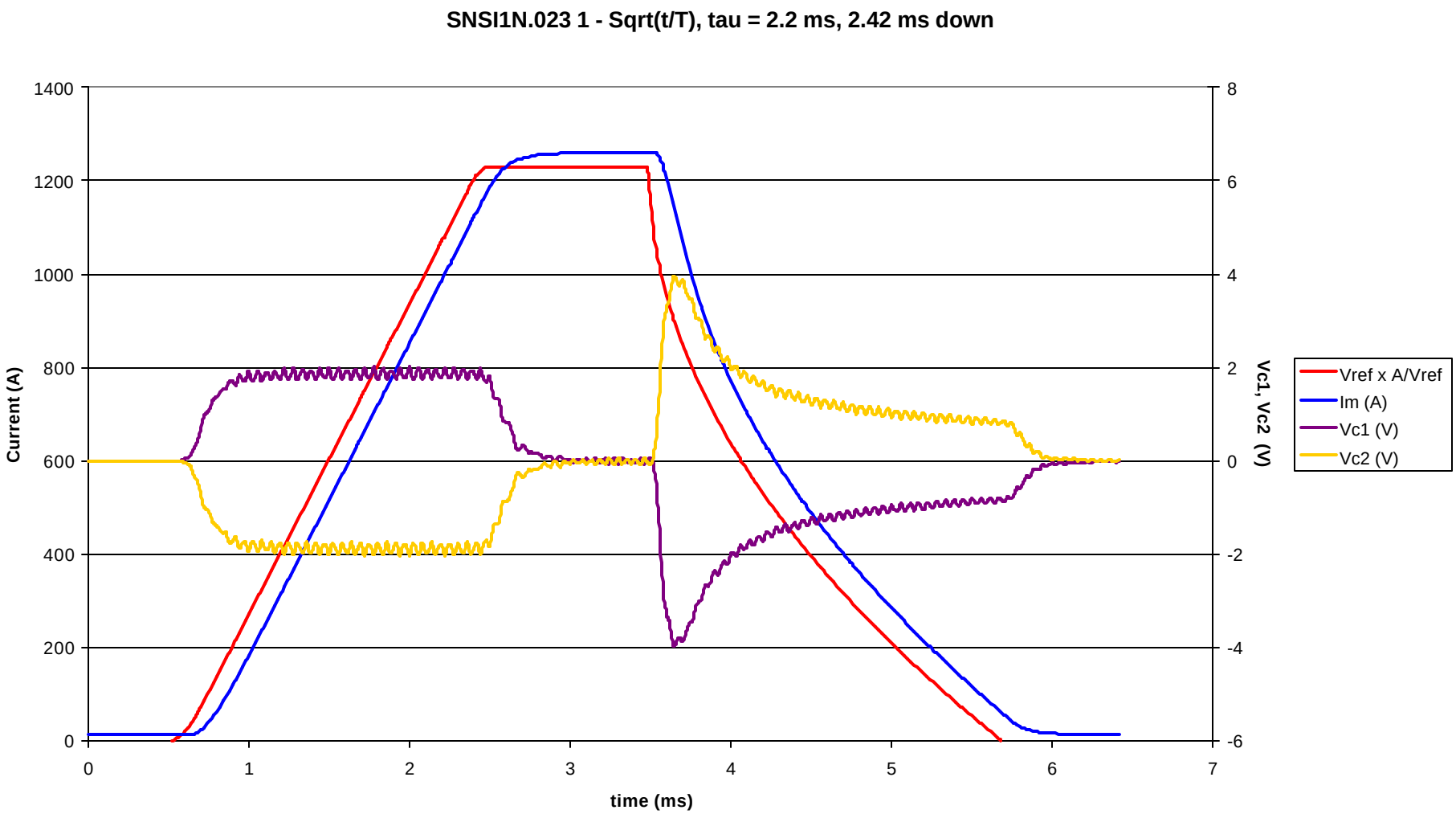

Im, Vc1, and Vc2
30 Dec 2002 14:39:54
SNSI
Average of 5
Time down: 1.00 ms
Smoothed
1400
1200
1000
800
600
400
200
0
0
1
2
3
4
5
Time (ms)

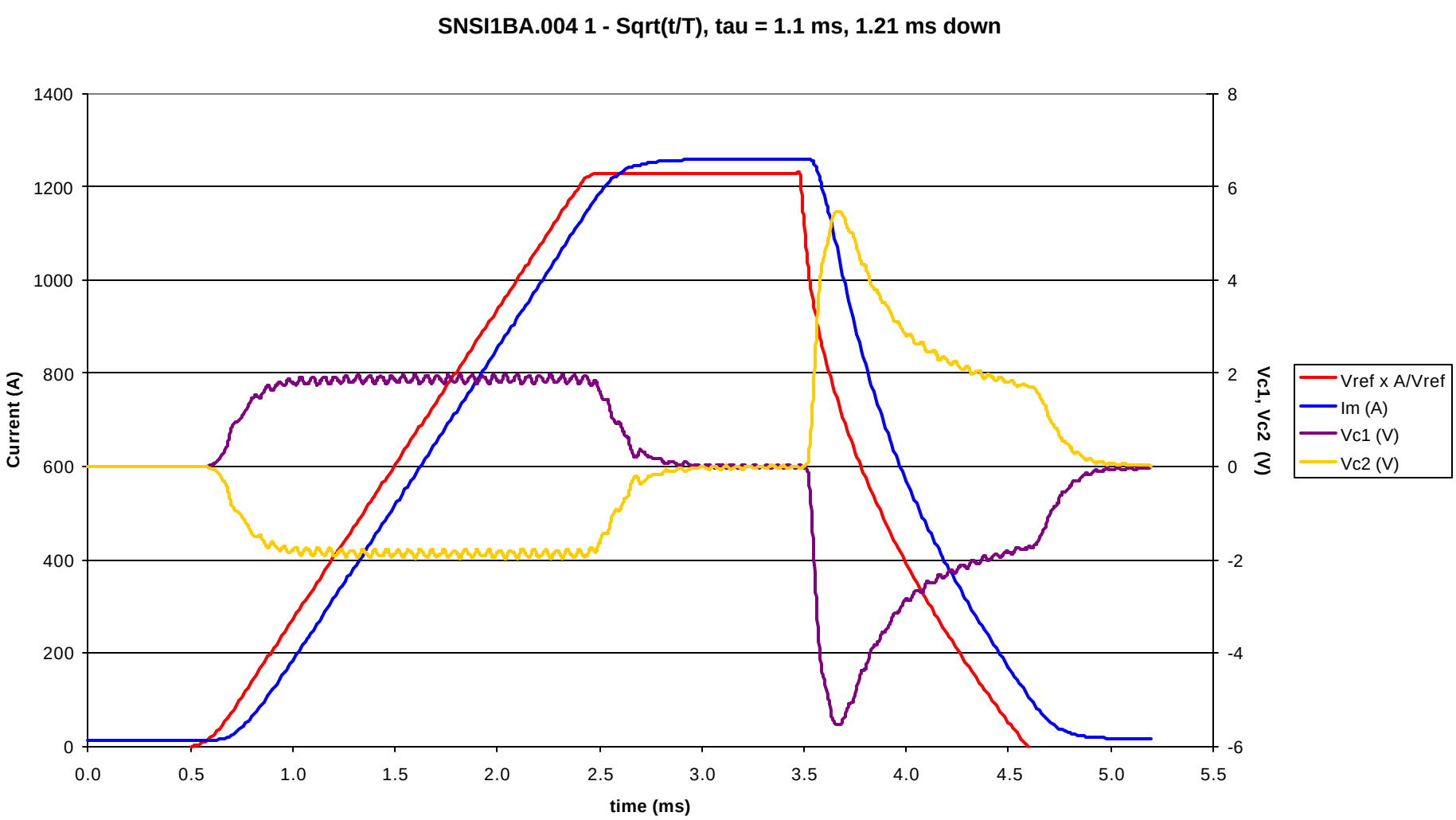
14:44:14 SNSI1BA **Up Ramp** Aperture =1.E-5
n:\raw\SNSinj\SNSI1BA.002 Exponential Drop
Time down: 1.40 ms tau = 0.20
Imax = +1260.81 A Imin = +13.13 A
Integration time = .00538 s
Idiff = -1247.500 Max Idot = 667840 A/s
Ips2 = +1260.69 A Ips1 = +13.19 A
Idiff2 = +1247.551 Max Idot = 667840 A/s
Theta is -0.29° CW dB = (775,776)(779,778)(774,774)
Vc1 Max +1.90954 V Min -0.00934 V
Integral: +3.49136 mV-s **Aperture: 2.97 ms +3.48639 mV-s**
Offset Corrected Integral: +3.50738 mV-s
Vc2 Max +0.00716 V Min -1.89380 V
Integral: -3.46379 mV-s **Aperture: 2.97 ms -3.45722 mV-s**
Offset Corrected Integral: -3.47531 mV-s

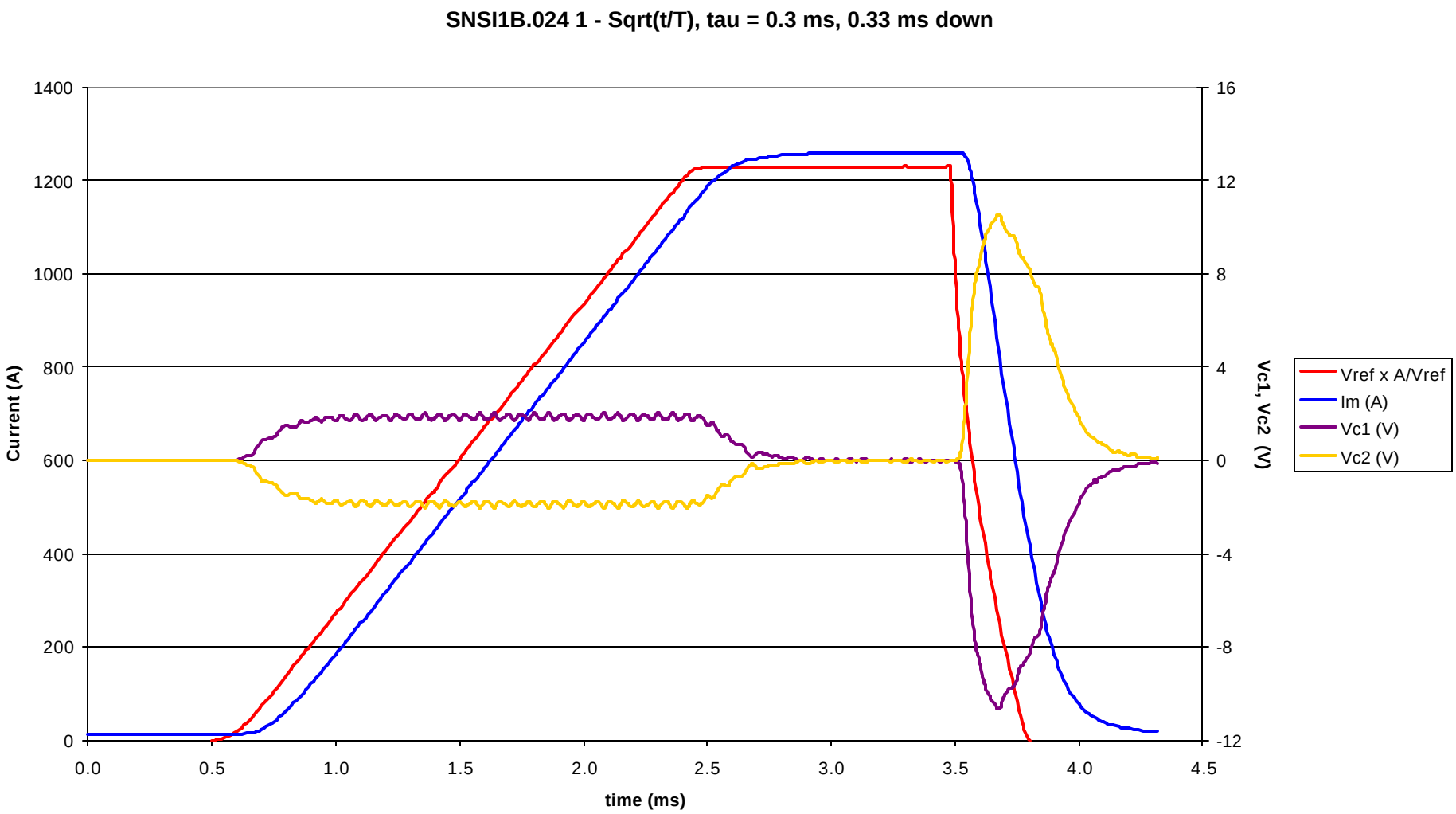
14:44:14 SNSI1BA **Down Ramp** Aperture =1.E-5
n:\raw\SNSinj\SNSI1BA.002 Exponential Drop
Time down: 1.40 ms tau = 0.20
Imax = +1260.81 A Imin = +13.13 A
Integration time = .00538 s
Idiff = +1247.023 Max Idot = -559260 A/s
Ips2 = +13.73 A Ips1 = +1260.75 A
Idiff2 = -1247.065 Max Idot = -559260 A/s
Theta is -0.24° CW dB = (775,775)(776,776)(776,775)
Vc1 Max +0.01856 V Min -8.58445 V
Integral: -3.49034 mV-s **Aperture: 2.97 ms -3.49130 mV-s**
Offset Corrected Integral: -3.49416 mV-s
Vc2 Max +8.49675 V Min -0.02142 V
Integral: +3.46070 mV-s **Aperture: 2.97 ms +3.46252 mV-s**
Offset Corrected Integral: +3.46748 mV-s

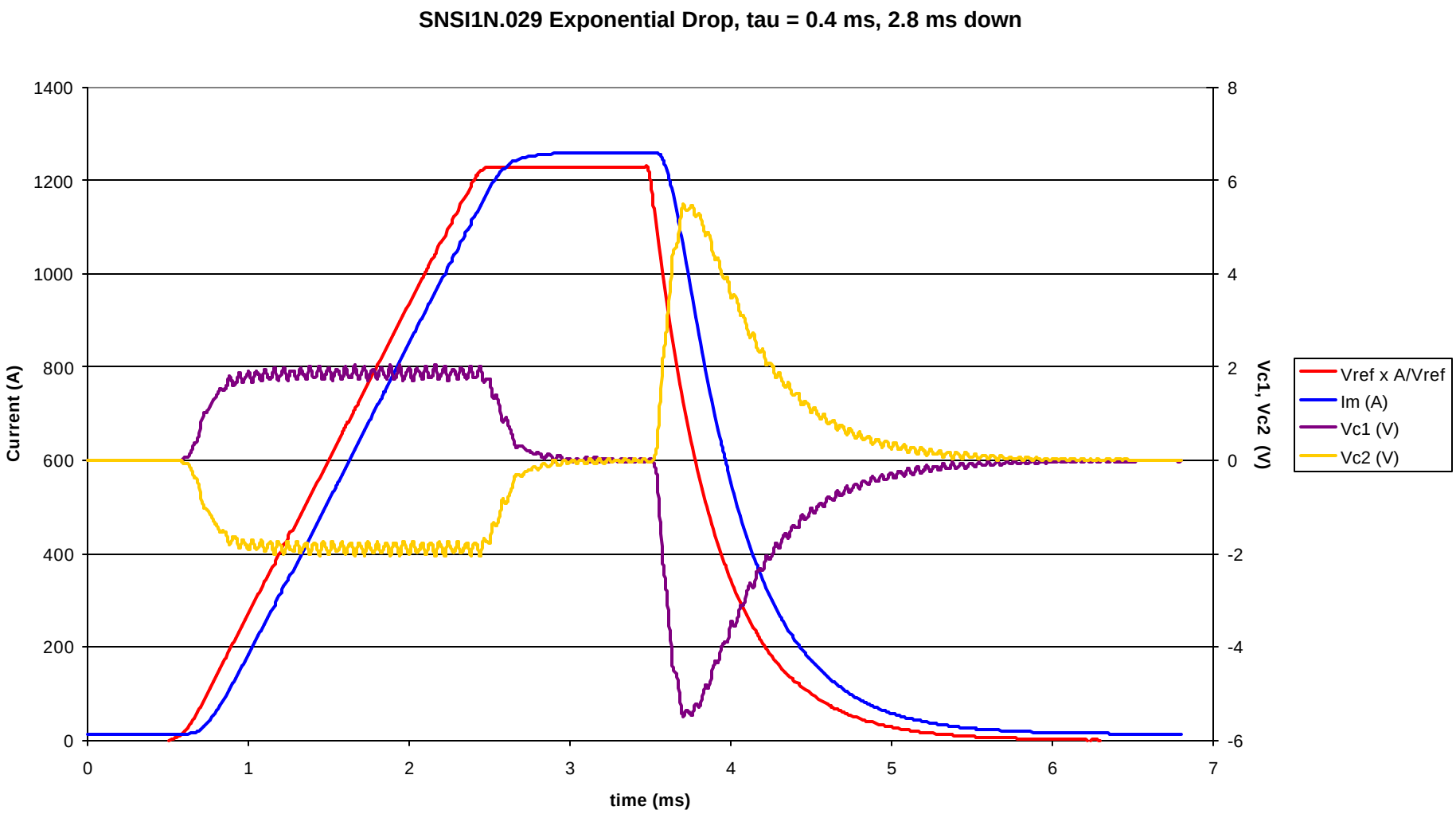

SNSI1B.003 Smoothed Linear, 2 ms down
Current (A)
Vc1, Vc2 (V)
time (ms)
1400
1200
1000
800
600
400
200
0
3
2
1
0
-1
-2
-3
-4
0
1
2
3
4
5
6
Vref x A/Vref
Im (A)
Vint Time1
Vint Time2
Vc1 (V)
Vc2 (V)

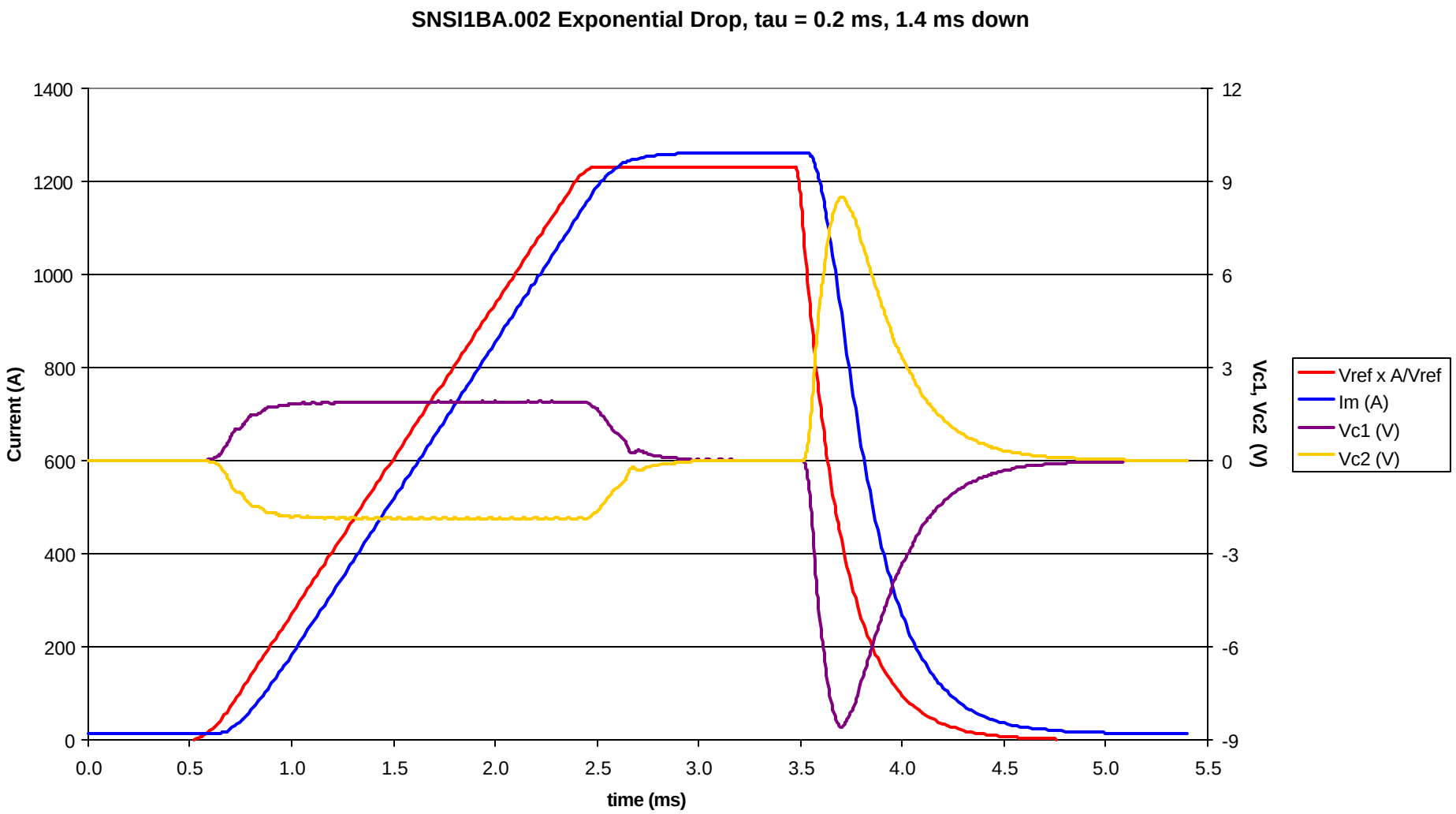

SNSI1BA.005 Smoothed Linear, 0.5 ms down
Current (A)
Vc1, Vc2 (V)
time (ms)
1400
1200
1000
800
600
400
200
0
12
9
6
3
0
-3
-6
-9
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Vref x A/Vref
Im (A)
Vc1 (V)
Vc2 (V)

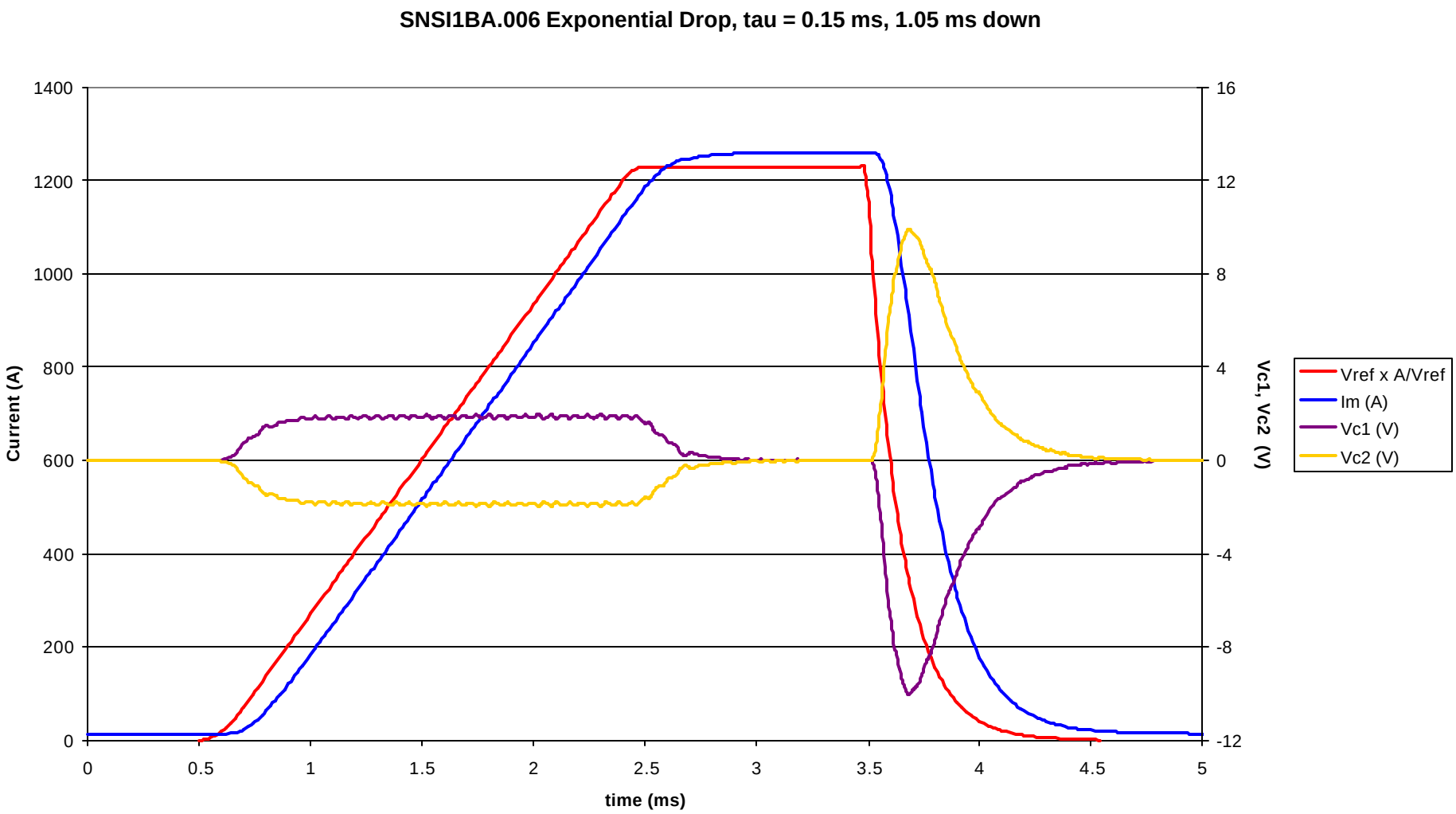

SNSI1N.023 1 - Sqrt(t/T), tau = 2.2 ms, 2.42 ms down
Current (A)
Vc1, Vc2 (V)
time (ms)
1400
1200
1000
800
600
400
200
0
8
6
4
2
0
-2
-4
-6
0
1
2
3
4
5
6
7
Vref x A/Vref
Im (A)
Vc1 (V)
Vc2 (V)

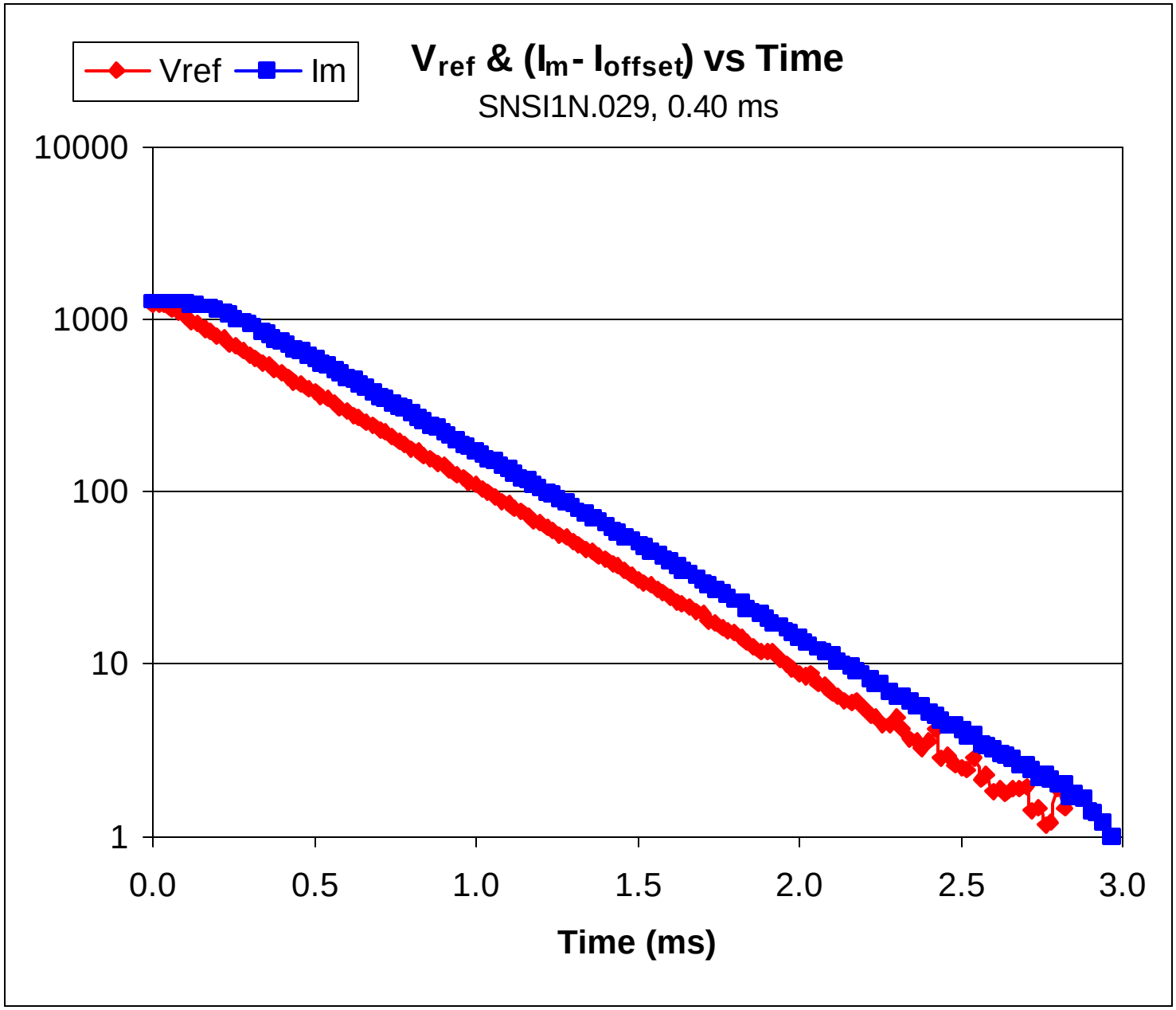

SNSI1BA.004 1 - Sqrt(t/T), tau = 1.1 ms, 1.21 ms down
Current (A)
Vc1, Vc2 (V)
time (ms)
1400
1200
1000
800
600
400
200
0
8
6
4
2
0
-2
-4
-6
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Vref x A/Vref
Im (A)
Vc1 (V)
Vc2 (V)

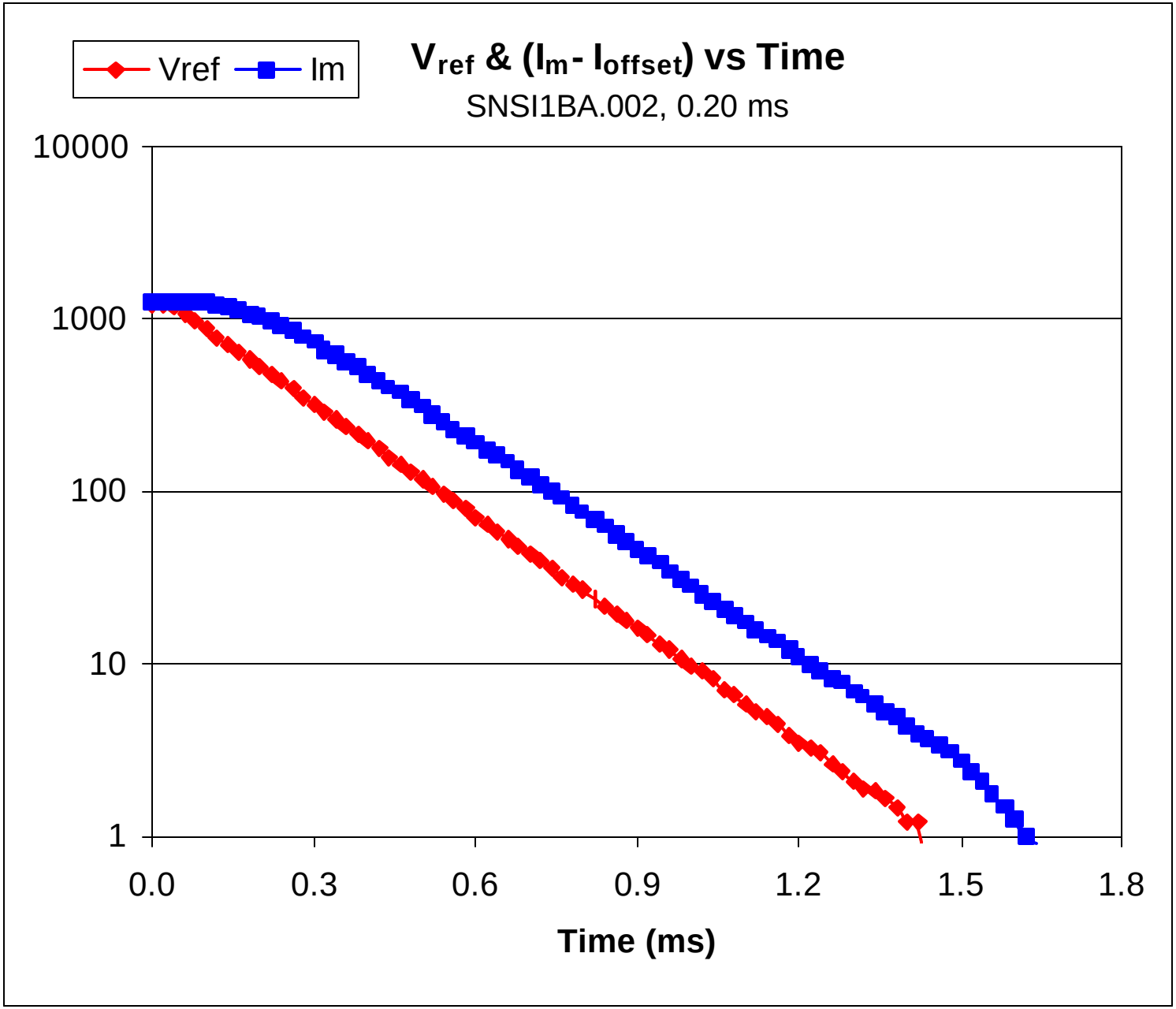

SNSI1B.024 1 - Sqrt(t/T), tau = 0.3 ms, 0.33 ms down
Current (A)
Vc1, Vc2 (V)
time (ms)
1400
1200
1000
800
600
400
200
0
16
12
8
4
0
-4
-8
-12
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Vref x A/Vref
Im (A)
Vc1 (V)
Vc2 (V)

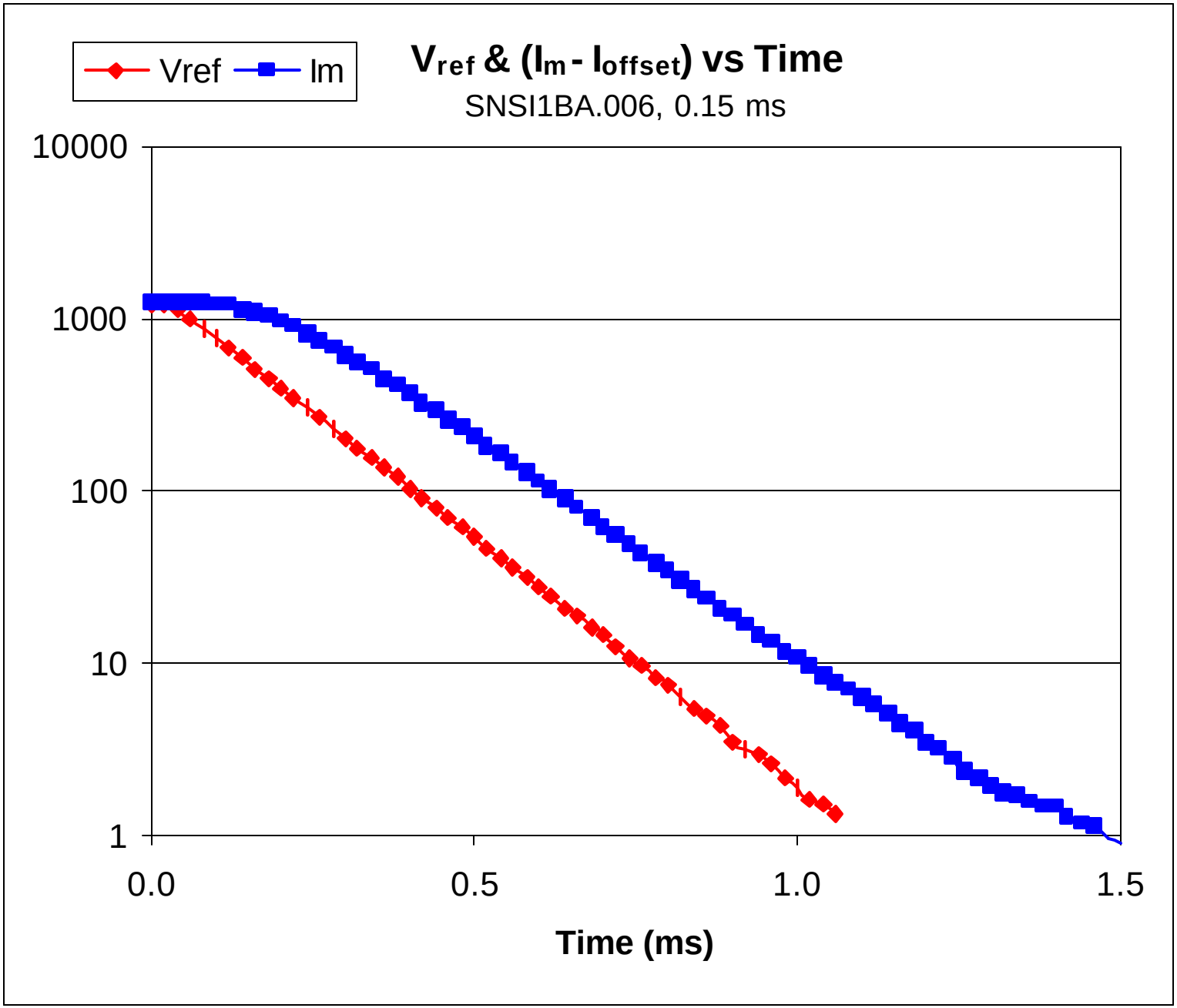

SNSI1N.029 Exponential Drop, tau = 0.4 ms, 2.8 ms down
Current (A)
Vc1, Vc2 (V)
time (ms)
1400
1200
1000
800
600
400
200
0
8
6
4
2
0
-2
-4
-6
0
1
2
3
4
5
6
7
Vref x A/Vref
Im (A)
Vc1 (V)
Vc2 (V)


SNSI1BA.002 Exponential Drop, tau = 0.2 ms, 1.4 ms down
Current (A)
Vc1, Vc2 (V)
time (ms)
1400
1200
1000
800
600
400
200
0
12
9
6
3
0
-3
-6
-9
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Vref x A/Vref
Im (A)
Vc1 (V)
Vc2 (V)


SNSI1BA.006 Exponential Drop, tau = 0.15 ms, 1.05 ms down
Current (A)
Vc1, Vc2 (V)
time (ms)
1400
1200
1000
800
600
400
200
0
16
12
8
4
0
-4
-8
-12
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Vref x A/Vref
Im (A)
Vc1 (V)
Vc2 (V)


Vref
Im
V_{ref} & (I_m - I_{offset}) vs Time
SNSI1N.029, 0.40 ms
10000
1000
100
10
1
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Time (ms)


Vref
Im
V_{ref} & (I_m - I_{offset}) vs Time
SNSI1BA.002, 0.20 ms
10000
1000
100
10
1
0.0
0.3
0.6
0.9
1.2
1.5
1.8
Time (ms)


Vref
Im
V_{ref} & (I_m - I_{offset}) vs Time
SNSI1BA.006, 0.15 ms
10000
1000
100
10
1
0.0
0.5
1.0
1.5
Time (ms)

The fit of Im was restricted to the points in the region which looked linear in a plot of ln(Im) vs. time.

The power supply reference voltage was such as to give a top current of 1230 A, but the actual current observed was 1260 A. However, the DCCT used has not been recently calibrated.

The PS current lags the reference voltage by about 0.150 ms, but part of this lag could be due to the DCCT.

(DCCTs generally have a slewing rate of about 25 V/ms. Full scale is 10 V. The bandwidth for a DCCT is about 10 kHz for small signals.)

The PS current doesn't initially drop exponentially.
It isn't until the current is in the range of 700 ot 900 A that the drop becomes exponential.

Values from Fit of Ln(I_m - I_{offset}) vs. Time Using the Linear Region Only

Expected Time Constant		**0.15**	**0.20**	**0.25**	**0.30**	**0.40**
I_m Values	**t** (ms)	0.171	0.213	0.260	0.307	0.402
	I_{offset} (A)	13.5	13.7	13.5	13.2	13.0

I_{offset} was the value found by Excel Solver that minimized the residual sum of squares for the straight line fit of Ln(I_m - I_{offset}) vs. Time for the region that visually appeared to be linear.
The straight line fit was done using the Excel array formula LINEST.

Exponential Drop Ramps, Comparison of Time Constant for the Measured Reference Voltage to that of the Magnet Current

4-Parameter Fits
(Minimizing residual sum of squares)

$Y_{fit} = Y_{min} + (Y_{max} - Y_{min}) * Exp [- (t - t_{delay}) / \tau]$,
for $t > t_{delay}$; $Y_{fit} = Y_{max}$ for $t < t_{delay}$.

Expected Time Constant (ms)		**0.15**	**0.20**	**0.25**	**0.30**	**0.40**
V_{ref} Values	**t** (ms)	0.150	0.200	0.250	0.300	0.400
	V_{ref} max (A_{equiv})	1229	1229	1229	1229	1229
	V_{ref} min (A_{equiv})	0	0	0	0	0
	t_{delay} (ms)	0.030	0.030	0.030	0.030	0.030
I_m Values	**t** (ms)	0.184	0.233	0.280	0.318	0.414
	I_m max (A)	1244	1263	1235	1298	1189
	I_m min (A)	10	8	8	10	11
	t_{delay} (ms)	0.175	0.174	0.183	0.180	0.215