

## Switching Effects of OCEM Power Supplies III

Briant Lam and Achim Weidemann

(Power Conversion & Magnetic Measurements, SLAC)

### 1. Introduction

This memo continues the investigation of switching effects in the O.C.E.M. power supply which first was described in a memo of March 29, 2006( at <http://www-group.slac.stanford.edu/met/MagMeas/MAGDATA/ILC/OCEM-PS/2006-03/ocem-ps.pdf> or .odt or .doc or .html) and another memo (dated May 31, 2006, but with data of April26) <http://www-group.slac.stanford.edu/met/MagMeas/MAGDATA/ILC/OCEM-PS/2006-04/ocem-ps2.pdf> or .odt or .doc)..

In the latter memo it was shown that voltage, current and field of the attached dipole magnet return to a value undistinguishable from their pre-switching value within after switching occurs within about 200 milliseconds.

However, when we demonstrated this on April 27, 2006, the oscilloscope traces showed to our surprise, that the magnetic field does return only to an obviously lower value than that before switching. After much gnashing of teeth, this was shown due to an effect of the power supply on the Hall probe: When the cart with the Hall probe power supply and amplifier was close to the power supply, apparently the Hall probe's unshielded leads or connectors picked some EMF depressing its (small  $\sim 2\text{mV}$ ) signal; this effect disappeared when the cart was moved to the side, of the rack with the power supply, as shown in Figure 1 below.

Nevertheless, we decided to repeat these measurements with a additional probe, namely a F.W. Bell/Sypris 7010 Gauss/Teslameter.[1], and this note shows data taken by both the Hall probe previously used, and the additional one.

### 2. Results

As in the previous note, data were recorded with a Tektronics TDS 3014B 'eScope'. The Hall Voltage from the previously used probe (Channel 2), a voltage from the additional Gauss/Teslameter (Ch.3), both proportional to the magnetic field, the current (Ch. 1), and the voltage (Ch.4) were measured, in a 1000 ms time window, with  $\sim 100$  ms before, and  $\sim 900$  ms after the trigger for the switching. The oscilloscope records 10,000 data points in this 1000ms time window.

As before, the data were averaged in 100ms segments; the average over the first segment preceding the switching trigger provides a nominal value for the measured quantity.

Dividing these averages by the nominal value, multiplying by 100 and subtracting 100, one obtains then a percent deviation from the nominal value, which is shown in the tables below.

For an error estimate on this percent deviation, I take the standard deviation for each segment average, and scale it by  $100/(\text{nominal value})$ .

Appendix A shows tables for these averages and percent average deviations from the nominal values.

All data were taken using the 25Hz version of the board.



**Fig. 1** Measurement Setup: Cart with Hall Probe Power Supply, Amplifier at left; O.C.E.M. Power Supply in rack at right. In this position, the Hall Probe signal is not depressed when switching occurs. If the cart is moved to the front and closer to the rack, the Hall probe signal after switching is depressed.

Data were taken with switching the power supply at currents of 150 A, 75 A, and 25A; we also recorded 1000 ms at 150 A in which no switching occurred. All four data sets are shown as figures and tables in Appendix A.

The previously-used Hall probe and the new Gauss/Teslameter were not aligned perpendicular to the magnetic field of the dipole; hence the absolute values of the fields shown in 'Data as measured' in the table are offset by a scale factor.--

From looking at the tables and figures in the appendix, we notice the following:

- Withing 300ms after switching, the magnetic field, measured by either probe, has returned to a value undistinguishable from the pre-trigger value.
- Considering the percentage-deviation values, both magnetic field probes follow each other closely, indicating consistency, even if the absolute values might differ, due to relative position and rotation.
- We note the following anomaly: For the 150A and 75A data, the voltage after switching, returns to a value  $\sim(3.3 \pm 1.6)\%$  and  $\sim(6\pm 4)\%$  above the pre-trigger voltage, the currents correspondingly to  $\sim(0.17\pm 0.08)\%$  and  $\sim(0.4\pm 0.13)\%$  above the pre-trigger value. While bigger than previously observed, this current increase is within the (averaging) error previously observed (Data Files 7-10 of 'Switching Effects .. II' of May 31, 2006 had 0.2% and 0.4% current averageing error).

The corresponding increase in B, if linear, ~5Gauss in both cases, is of the order of the measurement error.

Thus we conclude that this study confirms that of the memo ('Switching Effects .. II') of May 31, 2006, namely that the field, current and voltage return to the pre-switching values, without need for re-standardization of the magnet.

### References

1. Sypris Test & Measurement, Orlando, FL; Sypris 7010 Gauss/Teslameter, [http://www.sypris.com/stm/content.asp?page\\_id=271](http://www.sypris.com/stm/content.asp?page_id=271)

### Appendix A:

For each of the 4 data sets,

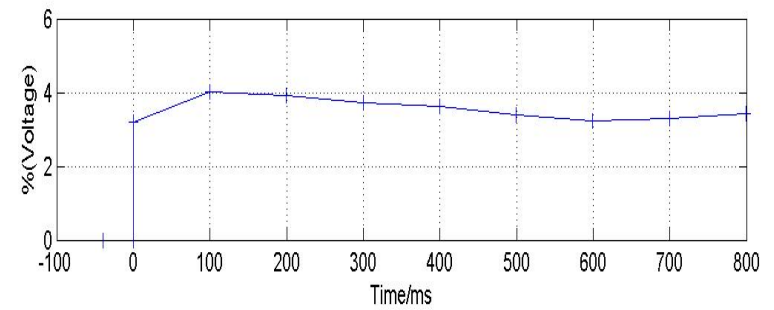
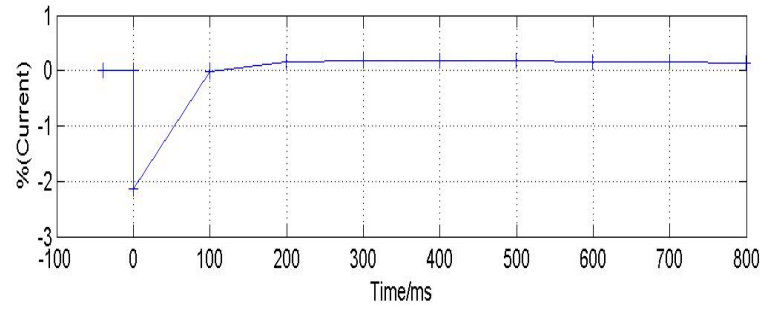
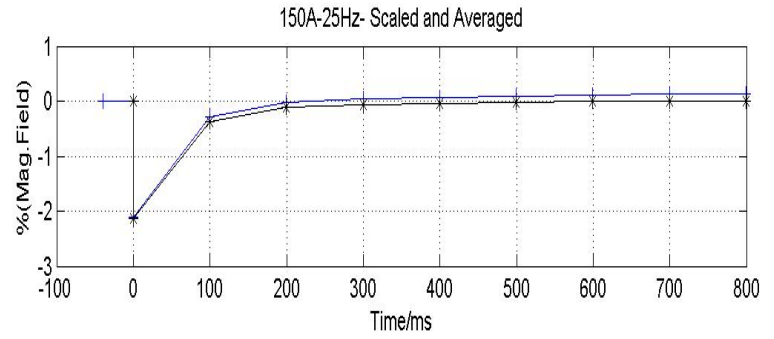
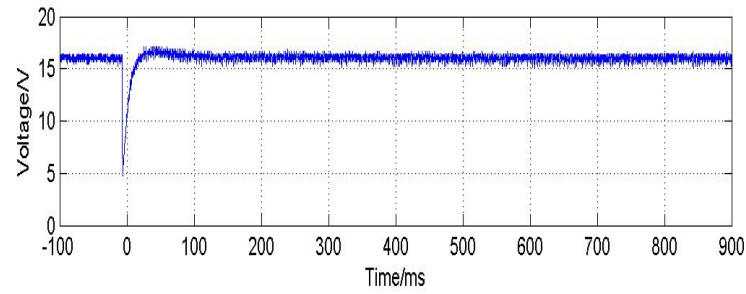
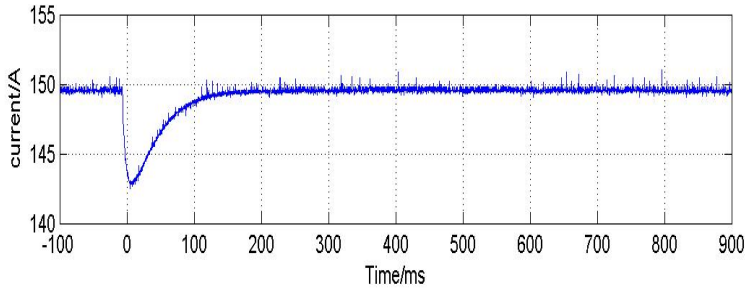
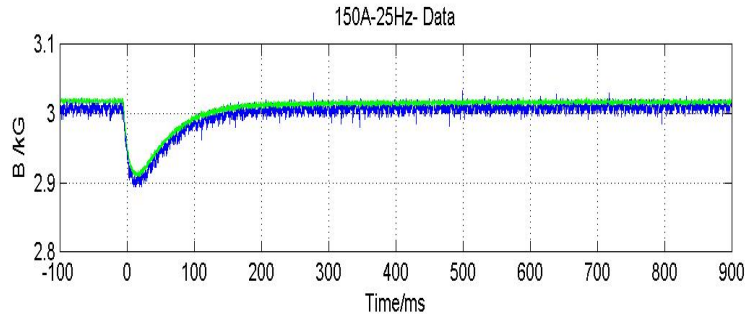
- the figure on the left shows the original data,
- the figure on the right the percentage deviation from the nominal value.
- Top row: magnetic field (blue trace: Hall probe, green or upper trace: Sypris 7010 Gauss/Teslameter);
- middle row: current;
- bottom row: voltage.

The columns in the tables 'Data as measured' are:

- Time Interval [ms]: The time interval of ~100ms over which the data were averaged,
- Ch1 [A] : The current,
- Ch2 [kG]: The magnetic field, in kiloGauss, as measured by the Hall probe,
- Ch3 [kG]: The magnetic field, in kiloGauss, as measured by the Gauss/Teslameter.
- Ch4 [V]: The Voltage output by the power supply,

The 'Percent difference from 100' shows the differences to 100% of the corresponding quantities rescaled to 100% = average to pre-trigger (-100 to -0.2 ms) average.

**Data File 1: 150 A**



Data File 1: 150A continued:

Results for C:\achim\MM\OCEM-PS\2006-04-28-Data\150A.CSV .

9 segments.

---- Data as measured : -----

Time interval [ms]	ch1 [A]	ch2 [kG]	ch3 [kG]	ch4 [V]
-100.00 - -0.20	149.304 +/- 1.007	3.006 +/- 0.010	3.017 +/- 0.009	15.502 +/- 2.102
0.10 - 99.90	146.121 +/- 1.964	2.943 +/- 0.028	2.952 +/- 0.027	15.998 +/- 1.130
100.00 - 199.80	149.281 +/- 0.234	2.998 +/- 0.008	3.006 +/- 0.006	16.123 +/- 0.259
199.90 - 299.70	149.526 +/- 0.109	3.006 +/- 0.005	3.013 +/- 0.002	16.109 +/- 0.253
299.80 - 399.60	149.564 +/- 0.115	3.008 +/- 0.005	3.015 +/- 0.002	16.081 +/- 0.251
399.70 - 499.50	149.571 +/- 0.117	3.008 +/- 0.005	3.016 +/- 0.002	16.062 +/- 0.260
499.60 - 599.40	149.565 +/- 0.100	3.009 +/- 0.005	3.016 +/- 0.002	16.026 +/- 0.246
599.50 - 699.30	149.551 +/- 0.118	3.010 +/- 0.005	3.017 +/- 0.002	16.001 +/- 0.269
699.40 - 799.20	149.549 +/- 0.120	3.010 +/- 0.005	3.017 +/- 0.002	16.010 +/- 0.249
799.30 - 899.10	149.522 +/- 0.110	3.011 +/- 0.005	3.017 +/- 0.002	16.035 +/- 0.256

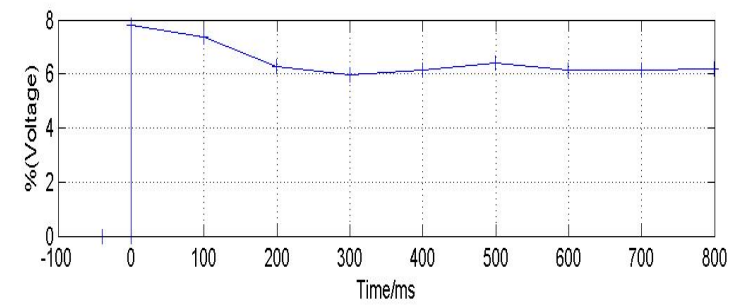
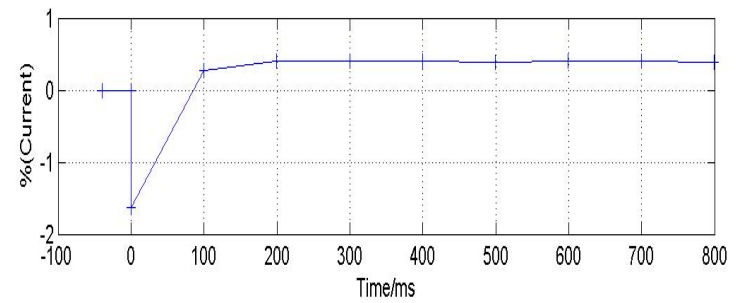
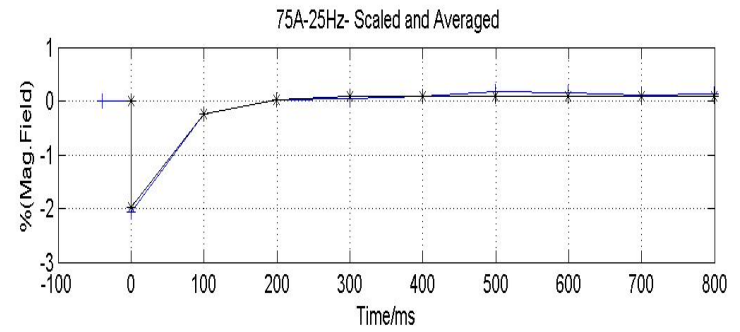
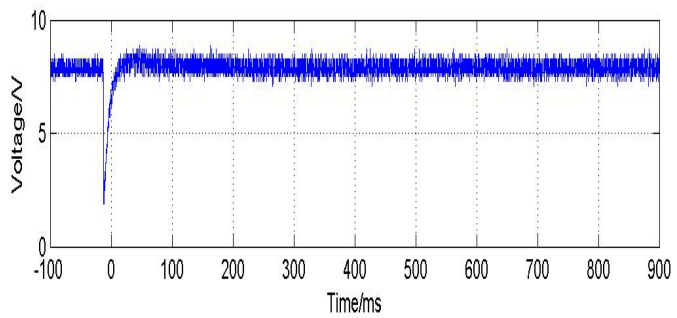
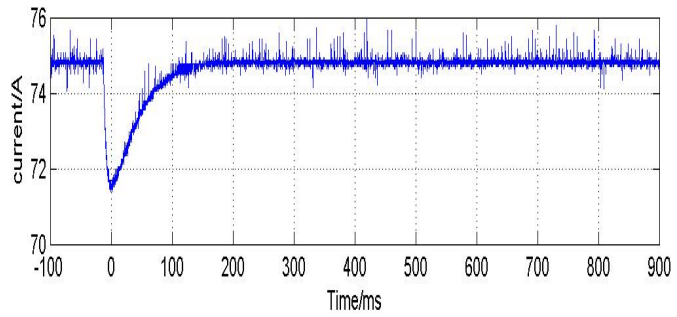
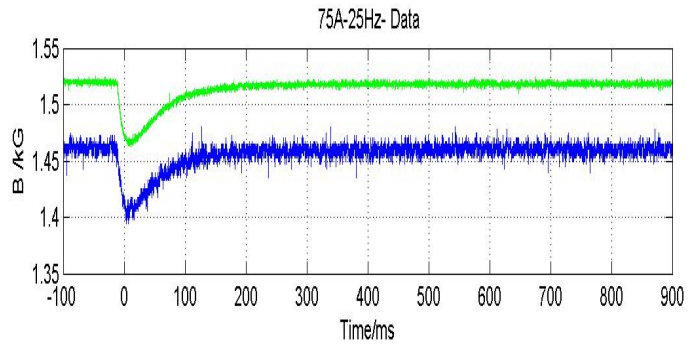
----Percent difference from 100:

----((chxave(i)/chxave(first seg)\*100 -100) with scaled errors): -----

Time interval [ms]	ch1	ch2	ch3	ch4
-100.00 - -0.20	0.000 +/- 0.675	0.000 +/- 0.329	0.000 +/- 0.291	0.000 +/- 13.560
0.10 - 99.90	-2.132 +/- 1.315	-2.113 +/- 0.925	-2.132 +/- 0.879	3.199 +/- 7.291
100.00 - 199.80	-0.015 +/- 0.157	-0.286 +/- 0.259	-0.363 +/- 0.194	4.005 +/- 1.671
199.90 - 299.70	0.149 +/- 0.073	-0.012 +/- 0.167	-0.112 +/- 0.064	3.918 +/- 1.631
299.80 - 399.60	0.174 +/- 0.077	0.044 +/- 0.174	-0.063 +/- 0.058	3.735 +/- 1.618
399.70 - 499.50	0.179 +/- 0.078	0.059 +/- 0.174	-0.037 +/- 0.063	3.612 +/- 1.674
499.60 - 599.40	0.175 +/- 0.067	0.080 +/- 0.163	-0.015 +/- 0.062	3.382 +/- 1.588
599.50 - 699.30	0.165 +/- 0.079	0.105 +/- 0.166	-0.003 +/- 0.064	3.220 +/- 1.734
699.40 - 799.20	0.164 +/- 0.080	0.125 +/- 0.169	-0.002 +/- 0.063	3.280 +/- 1.603
799.30 - 899.10	0.146 +/- 0.073	0.138 +/- 0.156	-0.003 +/- 0.061	3.437 +/- 1.652

----Done with file no. 1 -----

Data File 2: 75 A



Data File 2: 75A continued:

Results for C:\achim\MM\OCEM-PS\2006-04-28-Data\75A.CSV .

9 segments.

---- Data as measured : -----

Time interval [ms]	ch1 [A]	ch2 [kG]	ch3 [kG]	ch4 [V]
-100.00 - -0.20	74.510 +/- 0.862	1.458 +/- 0.012	1.517 +/- 0.010	7.439 +/- 1.170
0.10 - 99.90	73.292 +/- 0.930	1.428 +/- 0.015	1.487 +/- 0.014	8.020 +/- 0.419
100.00 - 199.80	74.717 +/- 0.129	1.455 +/- 0.006	1.513 +/- 0.003	7.986 +/- 0.301
199.90 - 299.70	74.804 +/- 0.088	1.459 +/- 0.005	1.517 +/- 0.002	7.905 +/- 0.294
299.80 - 399.60	74.806 +/- 0.091	1.459 +/- 0.005	1.518 +/- 0.001	7.883 +/- 0.299
399.70 - 499.50	74.813 +/- 0.098	1.460 +/- 0.005	1.518 +/- 0.002	7.898 +/- 0.291
499.60 - 599.40	74.803 +/- 0.084	1.461 +/- 0.005	1.518 +/- 0.002	7.916 +/- 0.297
599.50 - 699.30	74.812 +/- 0.089	1.461 +/- 0.005	1.518 +/- 0.002	7.896 +/- 0.300
699.40 - 799.20	74.809 +/- 0.098	1.460 +/- 0.005	1.518 +/- 0.002	7.895 +/- 0.288
799.30 - 899.10	74.802 +/- 0.087	1.460 +/- 0.005	1.518 +/- 0.002	7.900 +/- 0.301

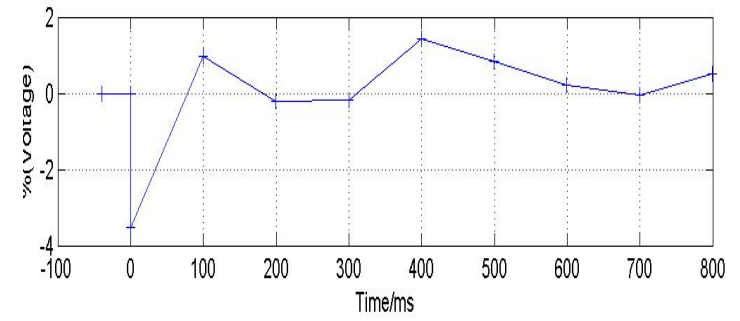
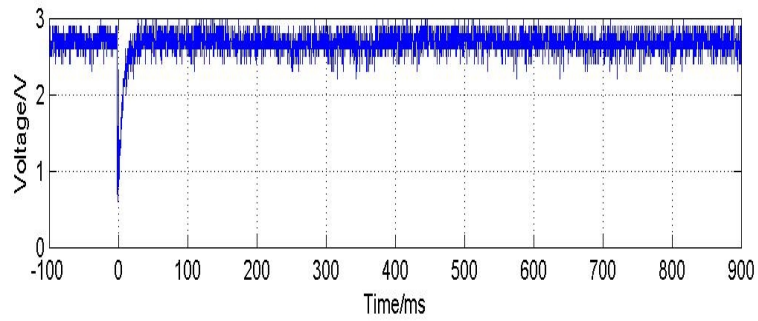
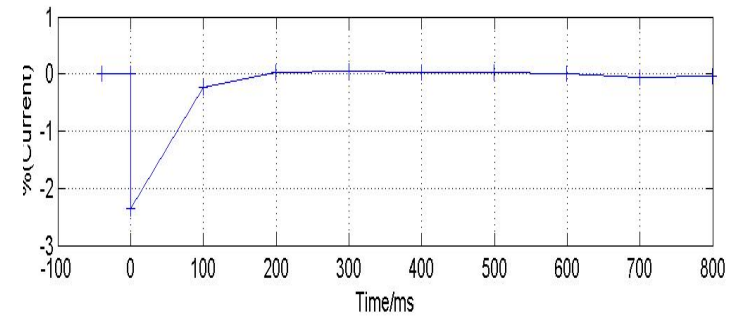
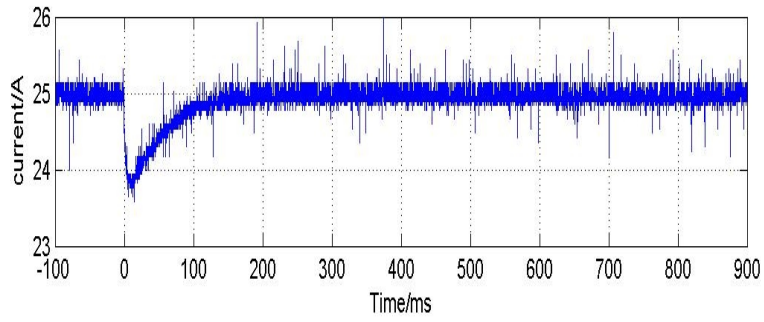
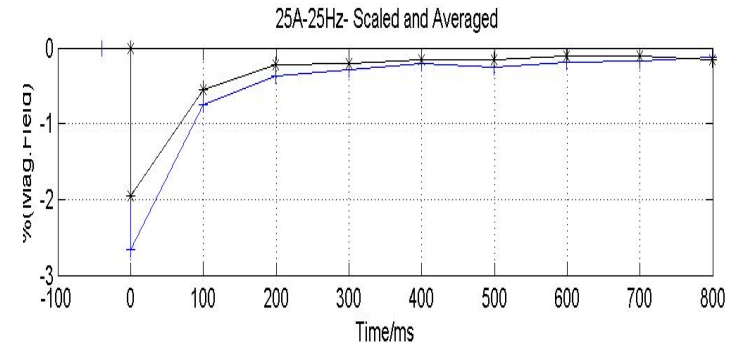
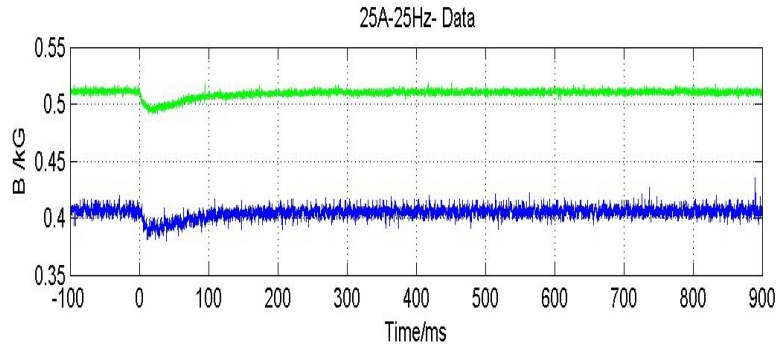
----Percent difference from 100:

----((chxave(i)/chxave(first seg)\*100 -100) with scaled errors): -----

Time interval [ms]	ch1	ch2	ch3	ch4
-100.00 - -0.20	0.000 +/- 1.157	0.000 +/- 0.790	0.000 +/- 0.664	0.000 +/- 15.734
0.10 - 99.90	-1.636 +/- 1.249	-2.070 +/- 1.026	-1.985 +/- 0.901	7.802 +/- 5.639
100.00 - 199.80	0.277 +/- 0.173	-0.248 +/- 0.380	-0.251 +/- 0.191	7.355 +/- 4.052
199.90 - 299.70	0.394 +/- 0.118	0.015 +/- 0.323	0.021 +/- 0.101	6.260 +/- 3.957
299.80 - 399.60	0.397 +/- 0.123	0.042 +/- 0.332	0.079 +/- 0.097	5.969 +/- 4.019
399.70 - 499.50	0.407 +/- 0.131	0.090 +/- 0.327	0.082 +/- 0.103	6.163 +/- 3.914
499.60 - 599.40	0.393 +/- 0.113	0.175 +/- 0.316	0.086 +/- 0.106	6.402 +/- 3.986
599.50 - 699.30	0.404 +/- 0.119	0.159 +/- 0.319	0.089 +/- 0.104	6.136 +/- 4.034
699.40 - 799.20	0.400 +/- 0.132	0.107 +/- 0.331	0.098 +/- 0.100	6.128 +/- 3.868
799.30 - 899.10	0.391 +/- 0.117	0.131 +/- 0.311	0.095 +/- 0.103	6.190 +/- 4.047

----Done with file no. 2 -----

Data File 3: 25 A





Data File 3: 25A continued:

Results for C:\achim\MM\OCEM-PS\2006-04-28-Data\25A.CSV .

9 segments.

---- Data as measured : -----

Time interval [ms]	ch1 [A]	ch2 [kG]	ch3 [kG]	ch4 [V]
-100.00 - -0.20	24.960 +/- 0.106	0.407 +/- 0.004	0.511 +/- 0.002	2.679 +/- 0.224
0.10 - 99.90	24.370 +/- 0.313	0.396 +/- 0.005	0.501 +/- 0.004	2.584 +/- 0.360
100.00 - 199.80	24.903 +/- 0.104	0.404 +/- 0.004	0.508 +/- 0.002	2.704 +/- 0.117
199.90 - 299.70	24.966 +/- 0.104	0.405 +/- 0.004	0.510 +/- 0.002	2.673 +/- 0.111
299.80 - 399.60	24.973 +/- 0.109	0.406 +/- 0.004	0.510 +/- 0.002	2.674 +/- 0.126
399.70 - 499.50	24.969 +/- 0.103	0.406 +/- 0.004	0.510 +/- 0.002	2.717 +/- 0.116
499.60 - 599.40	24.966 +/- 0.104	0.406 +/- 0.004	0.510 +/- 0.002	2.701 +/- 0.114
599.50 - 699.30	24.959 +/- 0.101	0.406 +/- 0.004	0.511 +/- 0.002	2.684 +/- 0.118
699.40 - 799.20	24.947 +/- 0.104	0.406 +/- 0.004	0.511 +/- 0.001	2.677 +/- 0.116
799.30 - 899.10	24.952 +/- 0.106	0.406 +/- 0.004	0.510 +/- 0.002	2.692 +/- 0.117

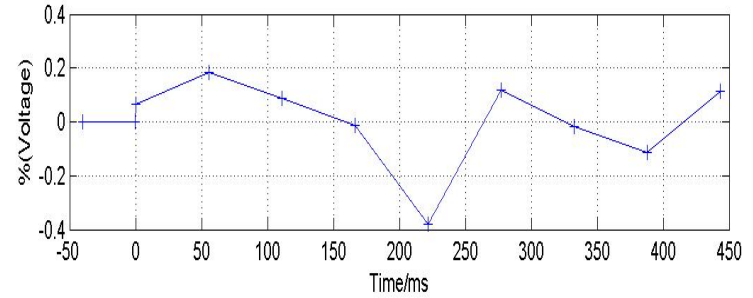
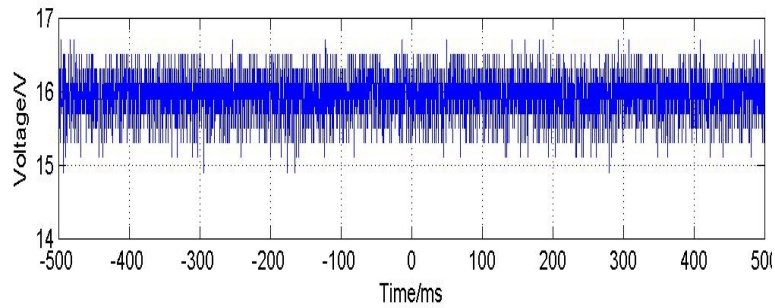
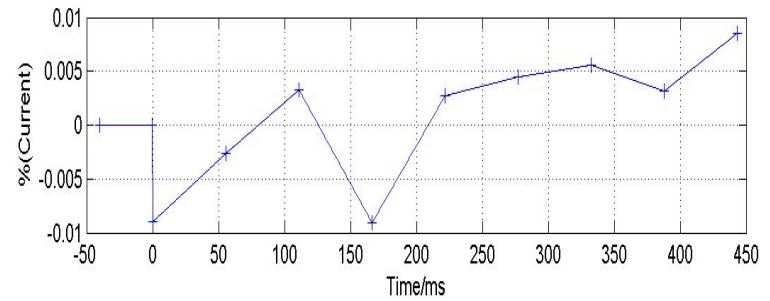
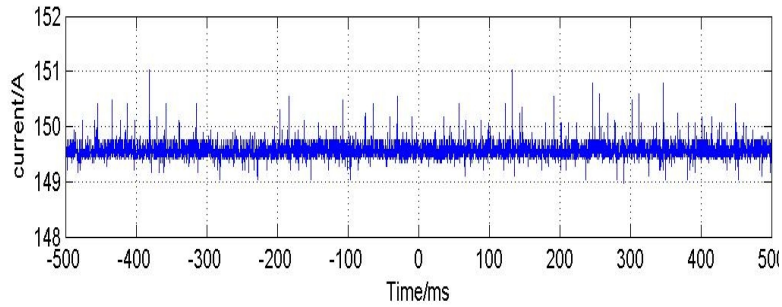
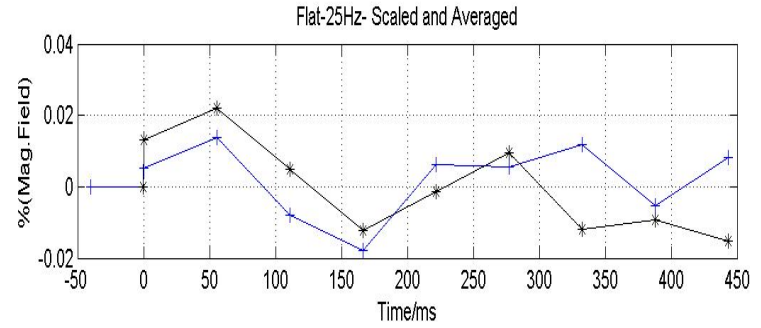
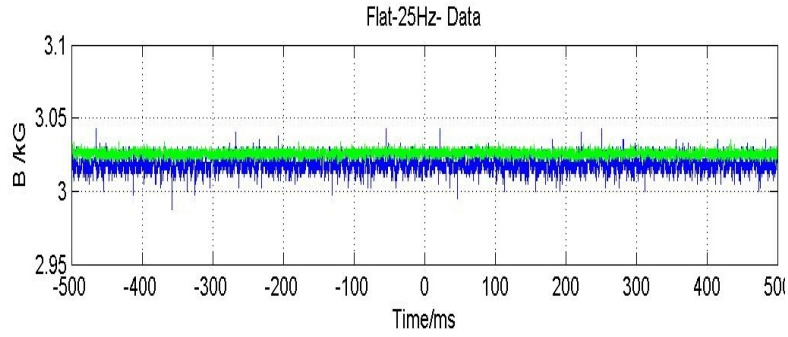
----Percent difference from 100:

----((chxave(i)/chxave(first seg)\*100 -100) with scaled errors): -----

Time interval [ms]	ch1	ch2	ch3	ch4
-100.00 - -0.20	0.000 +/- 0.426	0.000 +/- 0.881	0.000 +/- 0.299	0.000 +/- 8.375
0.10 - 99.90	-2.362 +/- 1.253	-2.660 +/- 1.266	-1.958 +/- 0.810	-3.535 +/- 13.453
100.00 - 199.80	-0.225 +/- 0.415	-0.757 +/- 0.867	-0.550 +/- 0.329	0.953 +/- 4.379
199.90 - 299.70	0.025 +/- 0.416	-0.367 +/- 0.885	-0.223 +/- 0.294	-0.206 +/- 4.142
299.80 - 399.60	0.054 +/- 0.438	-0.294 +/- 0.894	-0.200 +/- 0.299	-0.176 +/- 4.705
399.70 - 499.50	0.038 +/- 0.412	-0.209 +/- 0.907	-0.157 +/- 0.305	1.439 +/- 4.348
499.60 - 599.40	0.025 +/- 0.417	-0.251 +/- 0.919	-0.150 +/- 0.297	0.833 +/- 4.266
599.50 - 699.30	-0.002 +/- 0.405	-0.193 +/- 0.876	-0.112 +/- 0.300	0.209 +/- 4.411
699.40 - 799.20	-0.052 +/- 0.416	-0.169 +/- 0.870	-0.101 +/- 0.290	-0.052 +/- 4.316
799.30 - 899.10	-0.030 +/- 0.424	-0.131 +/- 0.916	-0.159 +/- 0.303	0.505 +/- 4.379

----Done with file no. 3 -----

Data File 4: 150A No switching -Flat Line



Data File 4: 150A - No Switching - Flat Line continued:  
 Results for C:\achim\MM\OCEM-PS\2006-04-28-Data\FlatLine.CSV .

---- Data as measured : -----

Time interval [ms]	ch1 [A]	ch2 [kG]	ch3 [kG]	ch4 [V]
-500.00 - -0.20	149.553 +/- 0.112	3.018 +/- 0.005	3.026 +/- 0.002	15.945 +/- 0.263
0.10 - 55.40	149.540 +/- 0.100	3.019 +/- 0.005	3.026 +/- 0.002	15.956 +/- 0.262
55.50 - 110.80	149.549 +/- 0.111	3.019 +/- 0.005	3.027 +/- 0.002	15.975 +/- 0.261
110.90 - 166.20	149.558 +/- 0.128	3.018 +/- 0.005	3.026 +/- 0.002	15.960 +/- 0.273
166.30 - 221.60	149.539 +/- 0.107	3.018 +/- 0.005	3.026 +/- 0.002	15.943 +/- 0.258
221.70 - 277.00	149.557 +/- 0.122	3.019 +/- 0.005	3.026 +/- 0.002	15.885 +/- 0.269
277.10 - 332.40	149.560 +/- 0.120	3.019 +/- 0.005	3.026 +/- 0.002	15.964 +/- 0.251
332.50 - 387.80	149.561 +/- 0.123	3.019 +/- 0.005	3.026 +/- 0.002	15.943 +/- 0.256
387.90 - 443.20	149.558 +/- 0.110	3.018 +/- 0.005	3.026 +/- 0.002	15.927 +/- 0.265
443.30 - 498.60	149.566 +/- 0.112	3.019 +/- 0.005	3.025 +/- 0.002	15.963 +/- 0.262

----Percent difference from 100:  
 ----((chxave(i)/chxave(first seg)\*100 -100) with scaled errors): -----

Time interval [ms]	ch1	ch2	ch3	ch4
-500.00 - -0.20	0.000 +/- 0.075	0.000 +/- 0.160	0.000 +/- 0.068	0.000 +/- 1.651
0.10 - 55.40	-0.009 +/- 0.067	0.005 +/- 0.150	0.013 +/- 0.063	0.066 +/- 1.640
55.50 - 110.80	-0.003 +/- 0.074	0.014 +/- 0.152	0.022 +/- 0.065	0.184 +/- 1.638
110.90 - 166.20	0.003 +/- 0.085	-0.008 +/- 0.161	0.005 +/- 0.066	0.089 +/- 1.715
166.30 - 221.60	-0.009 +/- 0.071	-0.018 +/- 0.159	-0.012 +/- 0.066	-0.013 +/- 1.620
221.70 - 277.00	0.003 +/- 0.082	0.006 +/- 0.164	-0.001 +/- 0.069	-0.380 +/- 1.686
277.10 - 332.40	0.004 +/- 0.080	0.005 +/- 0.160	0.010 +/- 0.064	0.116 +/- 1.577
332.50 - 387.80	0.006 +/- 0.083	0.012 +/- 0.159	-0.012 +/- 0.065	-0.017 +/- 1.608
387.90 - 443.20	0.003 +/- 0.073	-0.005 +/- 0.155	-0.009 +/- 0.071	-0.115 +/- 1.664
443.30 - 498.60	0.008 +/- 0.075	0.008 +/- 0.157	-0.015 +/- 0.065	0.112 +/- 1.640

----Done with file no. 4 -----