MOLLER Magnet Power Supply Factory Acceptance Test at OCEM

Below is the summary of activities performed on-site at OCEM in Italy for the magnet power supply (MPS) to be used for the downstream 3 (DS3) Torus.

Much of the testing was based on the existing factory acceptance test (FAT) document (UT-RP-0686) generated by OCEM, along with JLAB provided tests.

Andrea Segalini from OCEM coordinated resources. All tests were performed by Filippo Burini and Riccardo Casalini from OCEM and witnessed by Brian Eng and Onish Kumar from JLAB.

Monday, 11/13

Section 8.1 of FAT – Local Controls – OK

- Attempting to set current ramp rate at anything greater than or equal to 10 A/s would result in an Unknown Parameter error on the display, however set point was saved, verified with ramping supply and remote readout – FIXED in firmware update
- Maximum of three faults can be displayed on the screen
- Flow meter output was measured at terminal blocks

Section 8.2 of FAT – Remote Controls – OK

- Python script was used to check read and write functionality
    - Write testing of script limited to testing elevated permissions; should prevent altering values unless logged in – OK
    - Read testing found several commands that had different formatting from manual
        - MIG, MIAX – both missing # character from response
        - UPMODE:LIST – missing : character as separator in response
- Found that MRT response doesn't match documentation, namely it isn't temp_1:temp_x, but rather max_cabinet:cabinet_1:cabinet_2:shunt
- After logging in with PASSWORD command when manually testing all write commands, although none of the MWG commands, it was found that setting current ramp rate (MSRI) could be done remotely despite being in local mode – FIXED in firmware update
    - All other commands properly reported NAK error code 15
    - Verified again on 11/14

Section 8.3 of FAT – Capacitor Discharge and Door Key Release – OK

- There is no external indication for the ground switches. If left closed and power supply is ramped shows up as a charging timeout fault.

Section 8.4 of FAT – Interlocks – OK

- There are two fault states: L1 and L2
    - L1 turns off the output with no ramp as well as opens the disconnect switch
    - L2 turns off the output with a ramp (~30 kA/s)
- Power module interlock testing could only be performed with an OCEM development board
- Found that the Interlock # Name fields could be changed remotely, but local display wasn't updated with the new name – FIXED in firmware update

Tuesday, 11/14

Section 8.6 of FAT – Ground Fault Calibration – OK

- Tested at 200 mA and lowered ground fault limit to trip at 240 A output

Section 8.7 of FAT – Voltage Accuracy – Skipped

- Supply will only be operated in constant current mode so voltage accuracy tests skipped due to time

Section 8.8 of FAT – Current Accuracy – OK

Setpoint (A)	Readback (A)	Difference (mA)	Error (ppm)
80	80.01597	15.97	199.6
500	500.00082	0.82	1.6
900	899.98755	12.45	13.8
1300	1299.99117	8.83	6.8
1700	1699.96692	33.08	19.5
2100	2099.96196	38.04	18.1
2500	2499.94554	54.46	21.8
2700	2699.93421	65.79	24.4

- 80 A setpoint out of spec, however due to low load not high enough to be well regulated

Section 8.9 of FAT – Current Sharing – OK
Section 8.11 of FAT – Current Ripple – OK

- Captured with external oscilloscope, not attached here, but in detailed report

Section 8.12 and 8.13 of FAT – Input Measurement & Efficiency – OK

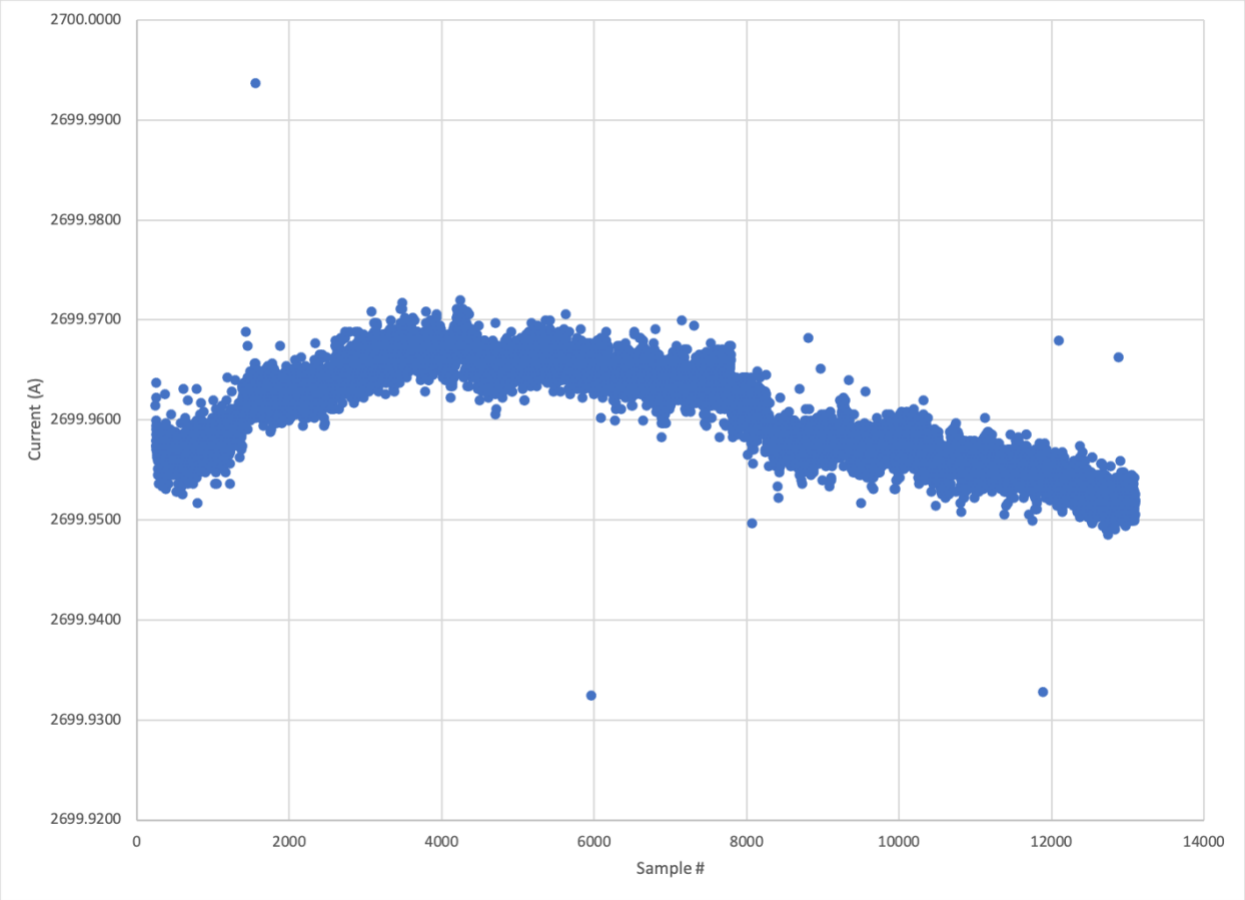
- Retested on 11/16, see table in that entry

Wednesday, 11/15

Section 8.10 of FAT – Long Term Stability – OK

- Keithly 2002 DMM set to 10 NLPC (200-ms sample), 1 sec trigger
- Ran for approximately 7 hrs when AC mains fault to OCEM tripped supply

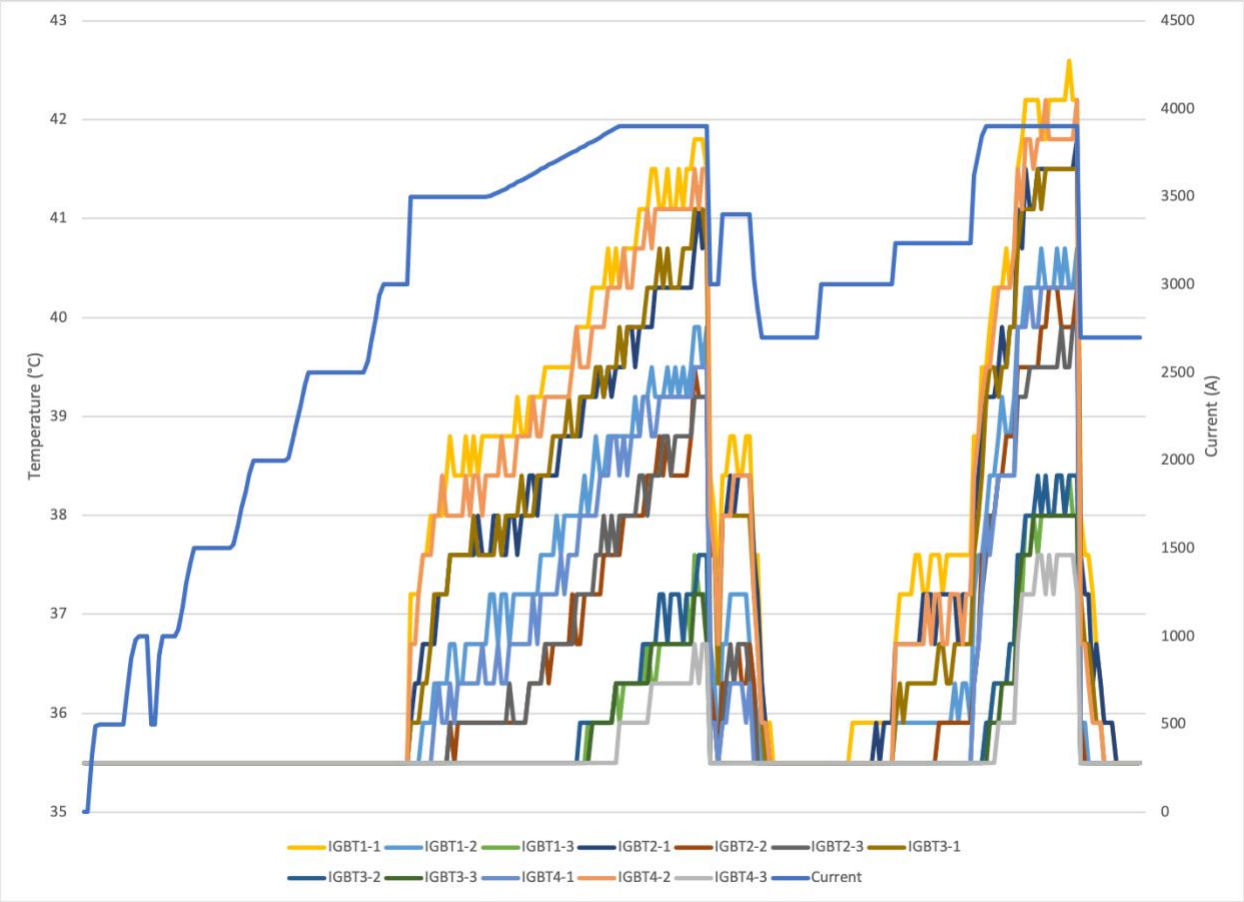
	Current (A)
Min	2699.9325
Max	2699.9937
pk-pk	0.0612
Average	2699.9607
σ	0.0048



Thursday, 11/16

Load changed in order to get full 3900 A output (software limited to 3940 A) of supply (previous load limited to 2700 A)

- Six cables in parallel were used to connect load – General Cavi FG17 1x240
    - Rated for 490 A each, became noticeably warm during test
- Generally speaking, the warmest IGBT temperatures were on #1 which is near the water output and the coolest were on #3, which is on the inlet
    - ~5°C difference between #1 & #3 (except for power module 2, which was 1.5°C)



- Minimum IGBT temperature is reported as 35.5°C

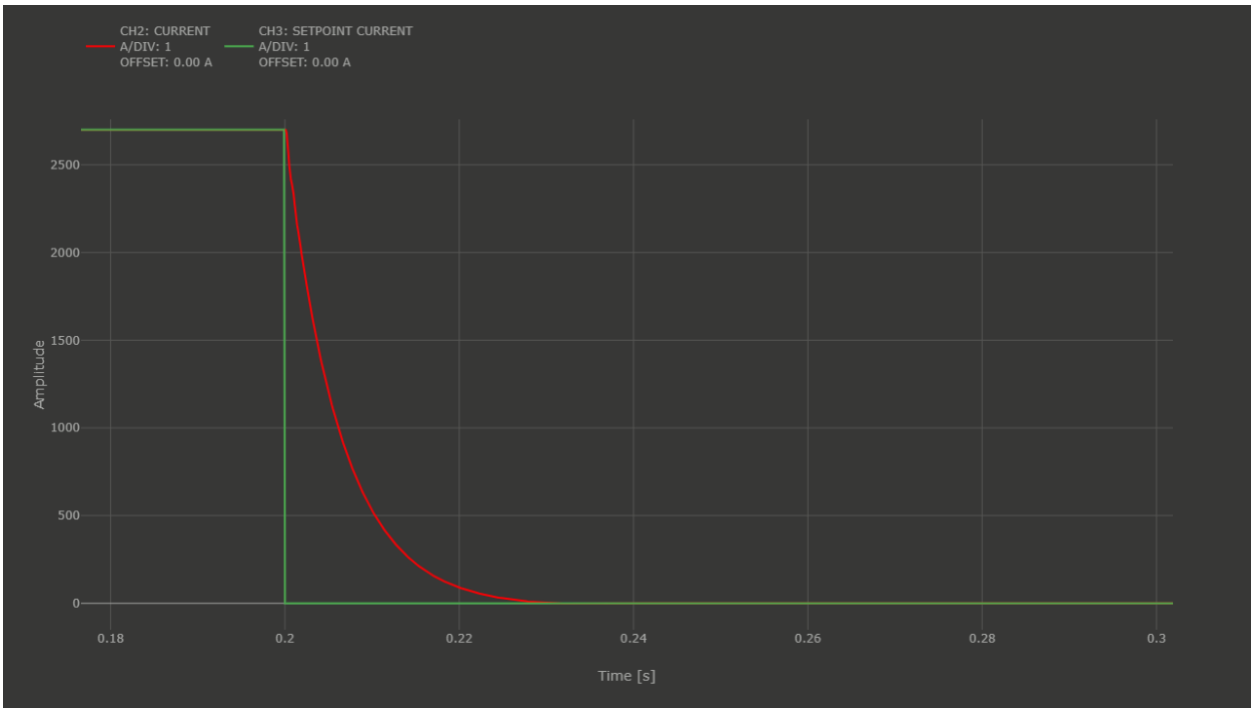
Re-ran Section 8.13 of FAT – Efficiency – OK

- Input measured with Fluke 434 Power Quality Analyzer, output from MPS

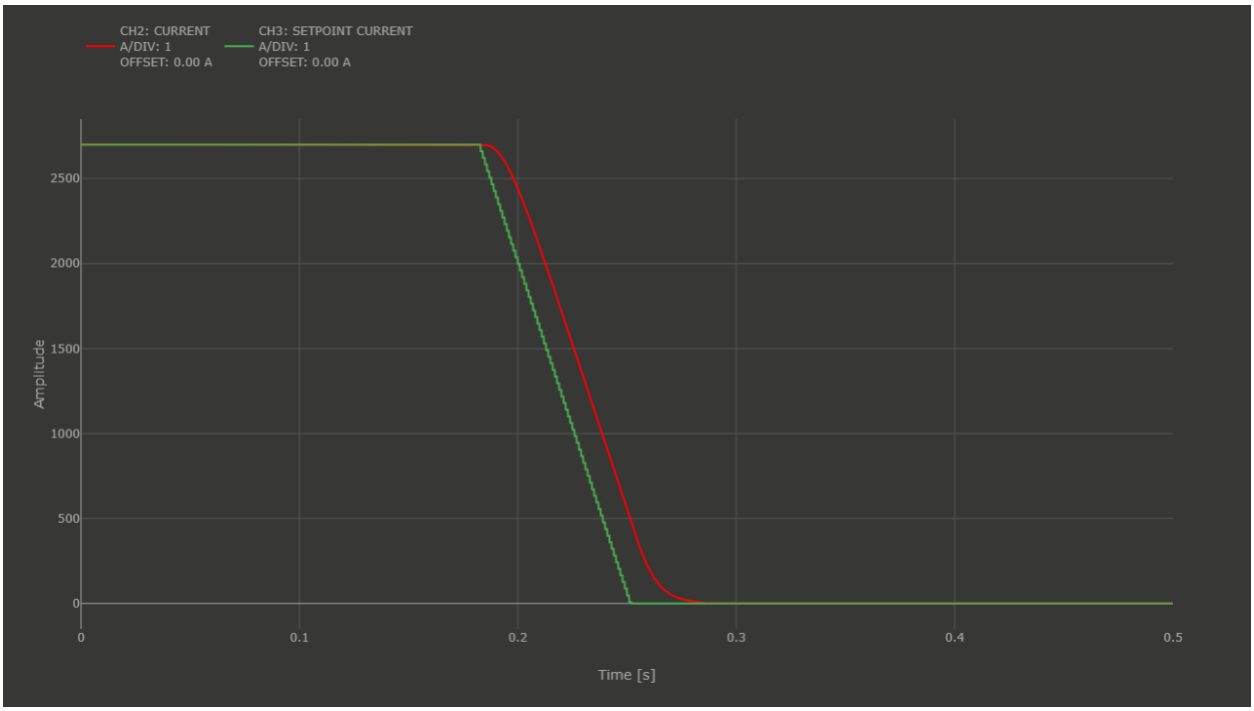
Input	Output			
Power (kW)	**Current (A)**	**Voltage (V)**	**Power (kW)**	**Efficiency**
1.9	80	1.76	0.14	7.42%
8	500	11.03	5.51	68.92%
21.5	900	19.99	17.99	83.70%
42.5	1300	29.11	37.84	89.03%
71.7	1700	38.59	65.61	91.51%
111.5	2100	49.19	103.29	92.64%
161.2	2500	59.99	149.98	93.04%
191.3	2700	65.90	177.92	93.01%

Re-tested Interlocks to compare L1 and L2 faults

- Tested two each of L1 (E-Stop, IGBT Temperature) and L2 (overcurrent, overtemperature)
- Voltage reference to IGBT for each of the trips is attached, captured via web interface of MPS

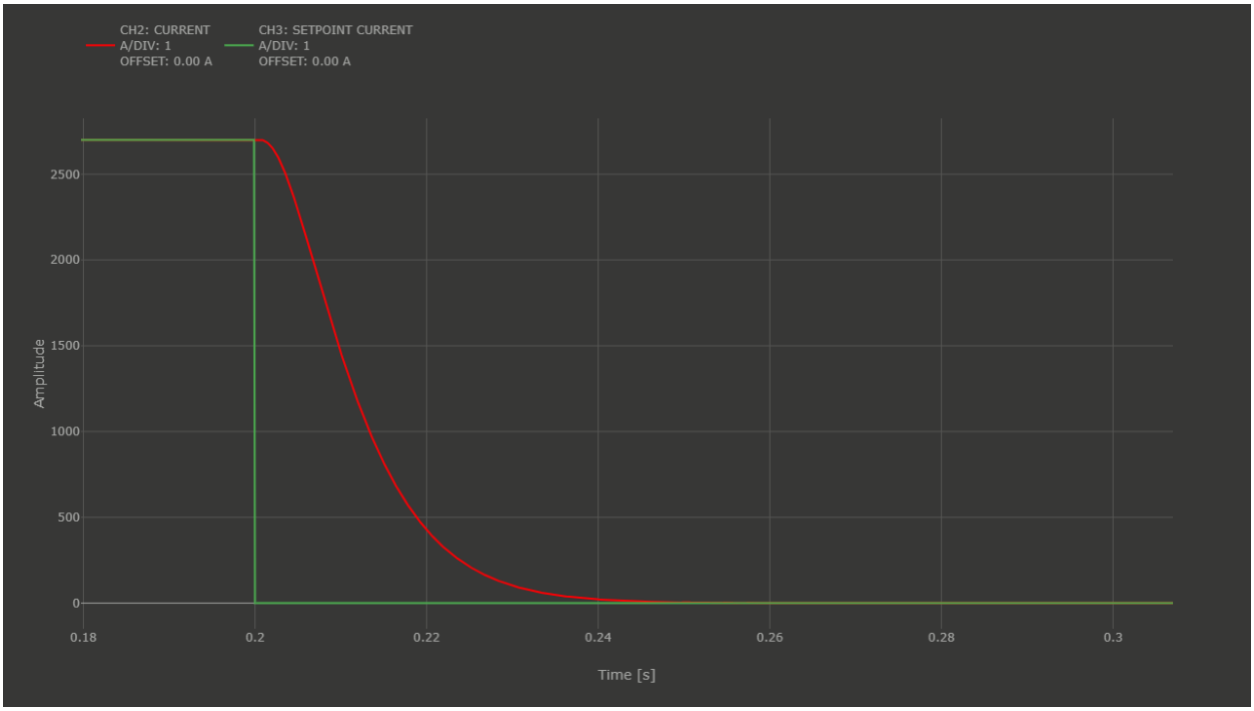


L1 Fault (no ramp to 0)



L2 Fault (reference ramped to 0)

- Also tested issuing the MWI command (which doesn't use a ramp rate) to go to 0 A output; looks similar to an L1 fault

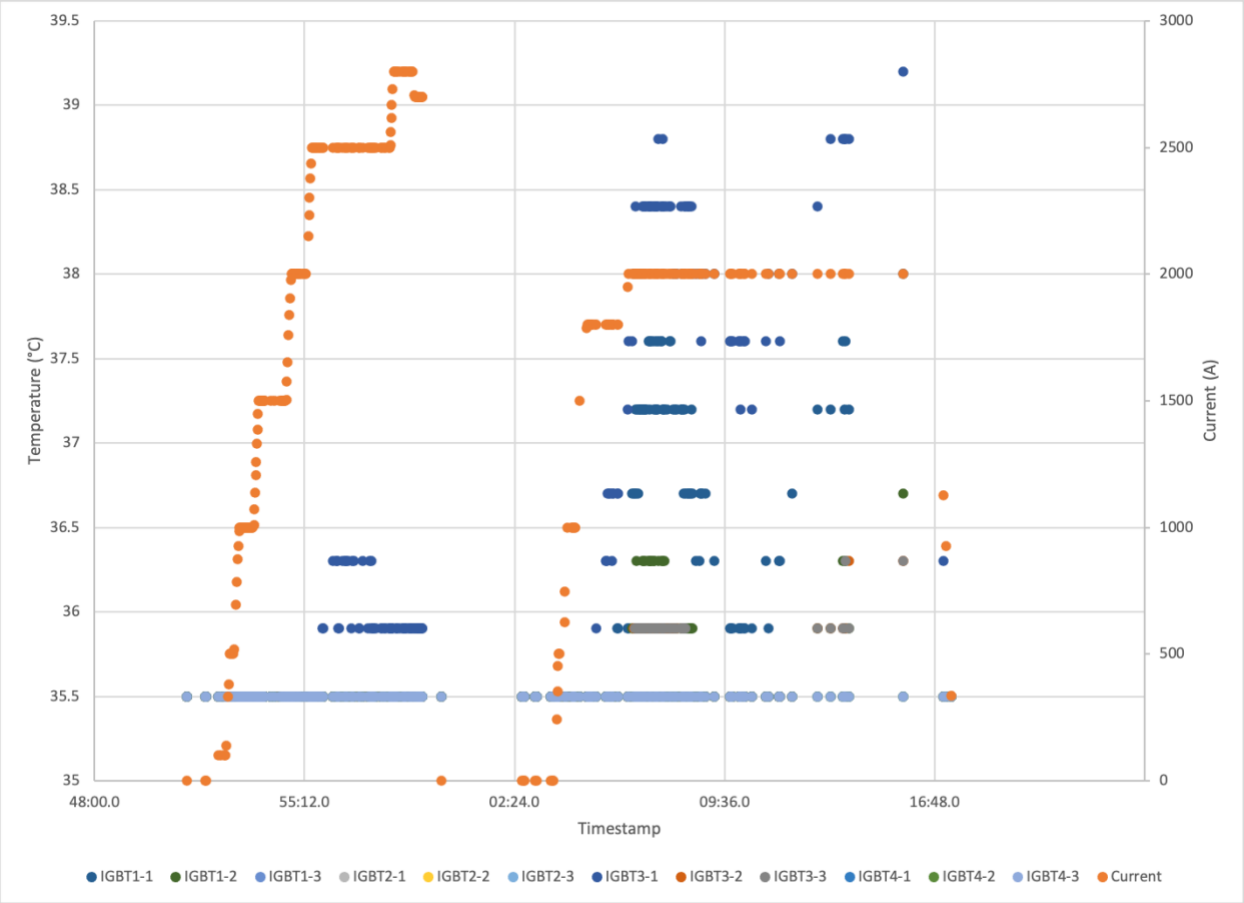


MWI set to 0 A

JLAB should always use MWIR command to set current output, and use MWI 0 for faults

Removed PWM signal to power modules to simulate a fault

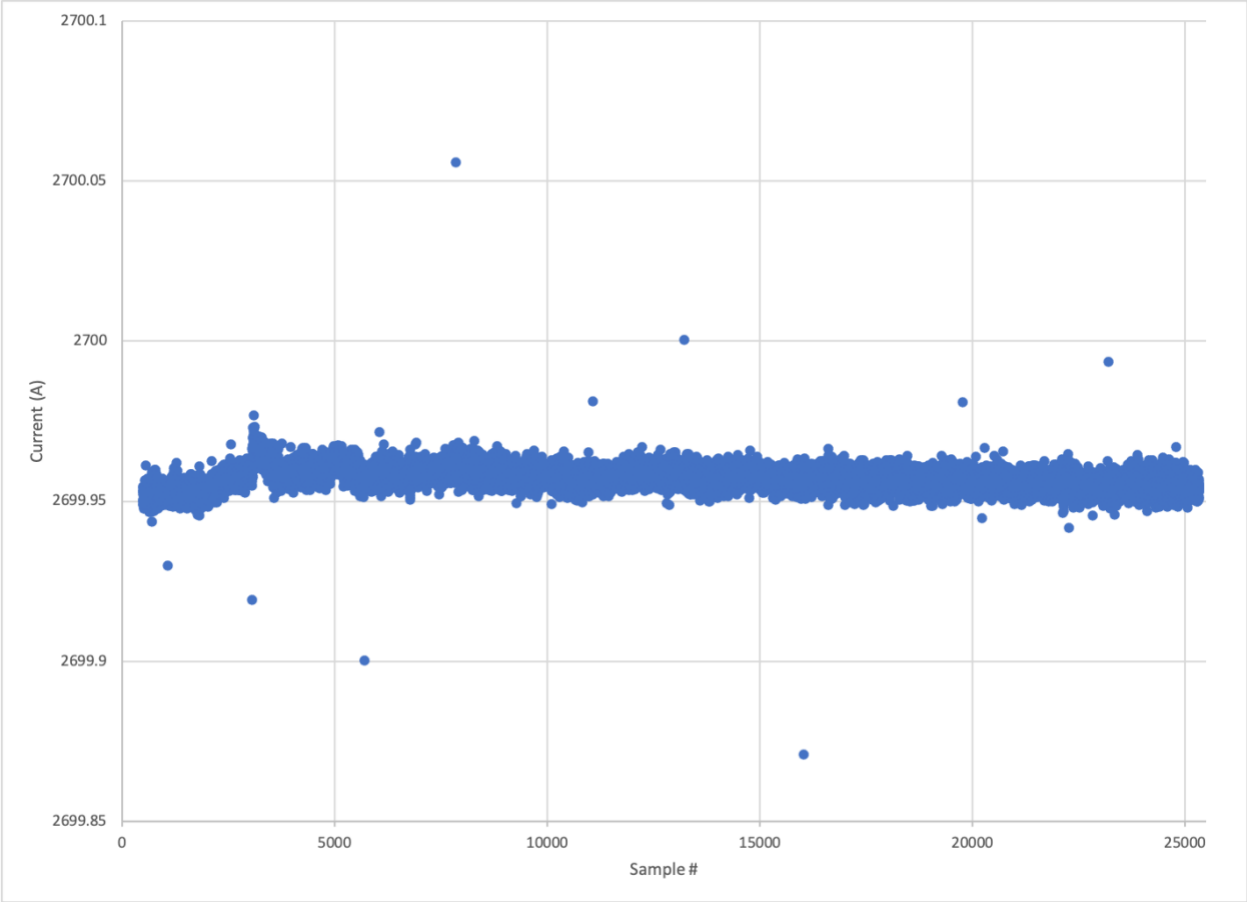
- Removed from 1 module and ran at 2800 A
- Removed from 2 modules and ran at 2000 A
- IGBT temperature difference not large enough to be used to indicate a fault



Re-ran Section 8.10 of FAT – Long Term Stability – OK

- Lowered NLPC to 5 on Keithley 2002, trigger at 500 ms
- Ran for approximately 3.5 hrs then shut down due to lack of safety personnel (COB)

	Current (A)
Min	2699.8710
Max	2700.0558
pk-pk	0.1848
Average	2699.9570
σ	0.0033



Friday, 11/17

Review of data and documents, generate plots