

LSTM Reference Example

Submission #85 · LSTM · Phillip Kollmeyer, McMaster University

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[See reference example description](#)

WEIGHTED ERROR

2.73 %

official leaderboard score

ALL CELLS RMSE

2.76 %

test 1, every blinded cycle

MAX ERROR

40.3 %

worst instantaneous error

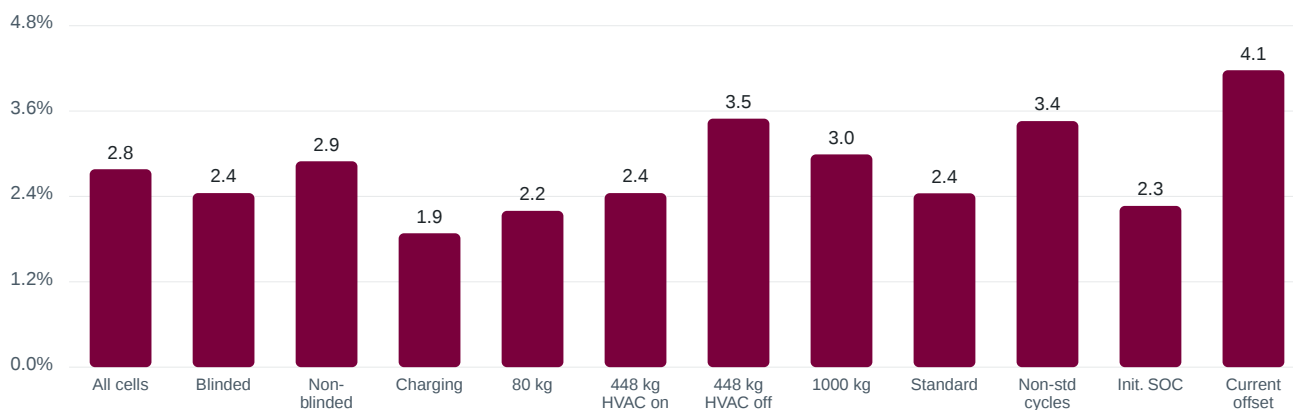
COMPLEXITY

8 ±1

Very high

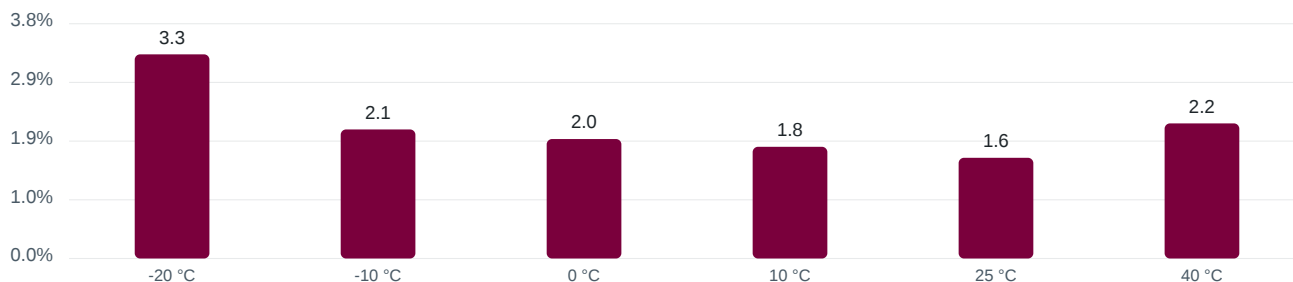
Error by test case

Average RMSE (% SOC) per blinded test case. Lower is better.



Error vs. ambient temperature

Test 9 — m80 cell at each chamber temperature.



All test cases

Weights as configured by the benchmark administrators at the time of this report (sum to 1); test 1 is weighted 0 because every other test is a subset of it.

TEST	NAME	DATA	WEIGHT	RMSE %
1	All cells	All four cells, all blinded drive cycles. The single headline accuracy value; weighted 0 in the final score because every other test is a subset of it.	0.000	2.76
2	Blinded cell (m448)	The m448 cell, for which no characterization or drive-cycle data is released — a true generalisation test.	0.100	2.43
3	Non-blinded cells	m80, m448-N and m1000 cells, blinded drive cycles only.	0.100	2.87
4	Charging	CC-CV charge profiles for the m80 cell.	0.100	1.87
5	80 kg payload	Range of loads — single-passenger vehicle model (m80 cell, HVAC on).	0.033	2.18
5	448 kg payload, HVAC on	Range of loads — maximum rated payload with cabin HVAC (m448 cell).	0.067	2.43
6	448 kg payload, HVAC off	Range of loads — maximum rated payload without cabin HVAC (m448-N cell).	0.067	3.47
5	1000 kg payload	Range of loads — towing a small trailer (m1000 cell). Highest current demand.	0.033	2.97
7	Standard drive cycles	UDDS, HWFET, LA92 and US06 for the m1000 cell.	0.100	2.43
8	Non-standard drive cycles	HWCUST and HWGRADE highway / mountain-pass cycles for the m1000 cell.	0.100	3.44
9	-20 °C	m80 cell at -20 °C ambient. Resistance is ~10× higher than at 40 °C.	0.017	3.34
9	-10 °C	m80 cell at -10 °C ambient.	0.017	2.11
9	0 °C	m80 cell at 0 °C ambient.	0.017	1.96
9	10 °C	m80 cell at 10 °C ambient.	0.017	1.83
9	25 °C	m80 cell at 25 °C ambient.	0.017	1.65
9	40 °C	m80 cell at 40 °C ambient.	0.017	2.21
10	Initial SOC error	The estimator is started with the true SOC at 90 %, 60 % and 30 % instead of 100 %, emulating an unknown initial state.	0.100	2.25
11	Current sensor offset	Constant offsets of ±0.1 A and ±0.3 A are added to the measured current.	0.100	4.14

Weighted error = sum over tests of (weight × RMSE) = 2.73 %

How this score is computed

Definitions of every metric and the exact arithmetic behind the numbers in this report, so results can be checked by hand.

Model interface

Your function is called once per measured sample, in order, with $X = [\text{current (A), voltage (V), temperature (}^{\circ}\text{C)}]$ and its own state z from the previous call; it returns the SOC estimate for that sample (0–1) and the updated state. Every cycle is preceded by one hour of rest at constant conditions so stateful models can settle; that hour is excluded from all metrics.

Per-cycle errors (Per-cycle errors table)

For each blinded drive cycle the estimate is compared with the reference SOC measured in the laboratory: $\text{RMSE} = \sqrt{\text{mean}((\text{SOC_est} - \text{SOC_ref})^2)}$, $\text{MAE} = \text{mean}(|\text{SOC_est} - \text{SOC_ref}|)$, $\text{max error} = \max(|\text{SOC_est} - \text{SOC_ref}|)$, all in % SOC over the samples of that cycle (excluding the padding).

Test cases 1–8

Each test case is the arithmetic mean of the per-cycle RMSE values of the cycles that belong to it (all cells; the blinded m448 cell; the three non-blinded cells; the charging profiles; the m80 / m448 / m448-N / m1000 payload conditions; the standard UDDS/HWFET/LA92/US06 cycles; the non-standard HWCUST/HWGRADE cycles).

Test 9 — temperature

For the m80 cell, the mean per-cycle RMSE at each chamber temperature (-20, -10, 0, 10, 25, 40 °C) is reported as six separate entries.

Test 10 — initial-SOC error

Three blinded cycles are re-run with the model started at a wrong initial SOC of 90 %, 60 % and 30 % (instead of 100 %). The nine RMSE values are averaged with weights 3 : 2 : 1 for the 90 / 60 / 30 % starts, so the smaller, more realistic offsets count more.

Test 11 — current-sensor offset

Blinded cycles are re-run with a constant offset added to the measured current (± 0.05 , ± 0.1 and ± 0.3 A); the test value is the mean RMSE of the offset runs that count towards the score (the ± 0.1 A and ± 0.3 A cases).

Complexity

Wall-clock time per sample of your model, divided by the time per sample of a plain coulomb counter measured on the same machine (the calibration constant), then placed into one of ten bins one third of a decade wide. It is informational and does not enter the weighted error.

Weighted error

weighted error = $\sum (\text{weight}_i \times \text{RMSE}_i)$ over the test cases listed on the previous page. Test 1 (all cells) carries weight 0 because every other test is a subset of it. The weights sum to 1 and were set by the benchmark administrators (see the change log on the site).

This submission

TEST CASE	RMSE %	WEIGHT	WEIGHT × RMSE
1. All cells	2.763	0.0000	0.0000
2. Blinded cell (m448)	2.430	0.1000	0.2430
3. Non-blinded cells	2.874	0.1000	0.2874
4. Charging	1.869	0.1000	0.1869
5. 80 kg payload	2.182	0.0333	0.0727
5. 448 kg payload, HVAC on	2.430	0.0667	0.1620
6. 448 kg payload, HVAC off	3.469	0.0667	0.2313
5. 1000 kg payload	2.970	0.0333	0.0990
7. Standard drive cycles	2.427	0.1000	0.2427
8. Non-standard drive cycles	3.435	0.1000	0.3435
9. -20 °C	3.341	0.0167	0.0557
9. -10 °C	2.112	0.0167	0.0352
9. 0 °C	1.955	0.0167	0.0326
9. 10 °C	1.828	0.0167	0.0305
9. 25 °C	1.648	0.0167	0.0275
9. 40 °C	2.211	0.0167	0.0368
10. Initial SOC error	2.251	0.1000	0.2251
11. Current sensor offset	4.145	0.1000	0.4145
Sum = weighted error			2.726 %

Stored headline score: 2.726 % (matches the sum above to rounding).

Complexity: measured 8 ± 1 on a 1–10 scale (Very high). Max error: 40.3 % is the largest instantaneous $|\text{SOC_est} - \text{SOC_ref}|$ over every blinded cycle.

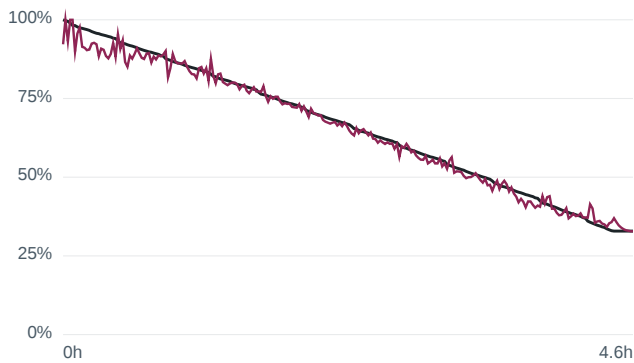
Time-domain results

Estimated vs. reference SOC on representative blinded cycles (down-sampled). One hour of padding precedes every cycle and is excluded from the metrics.

— Reference SOC — Estimated SOC

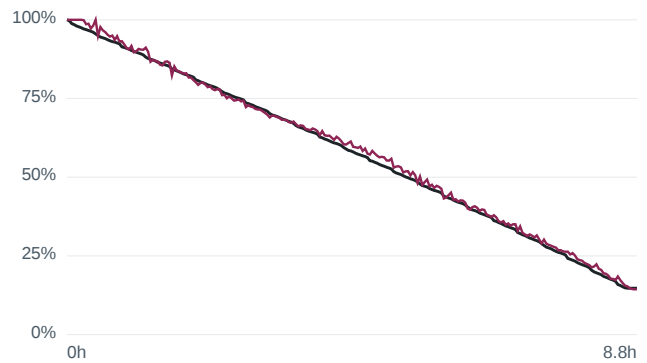
m80 UDDS at -20 °C

RMSE 2.32 %



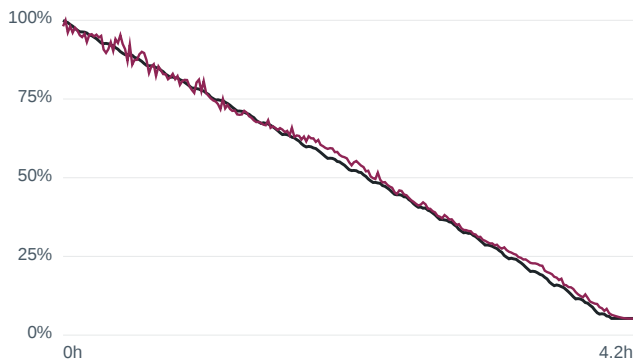
m80 UDDS at 0 °C

RMSE 1.39 %



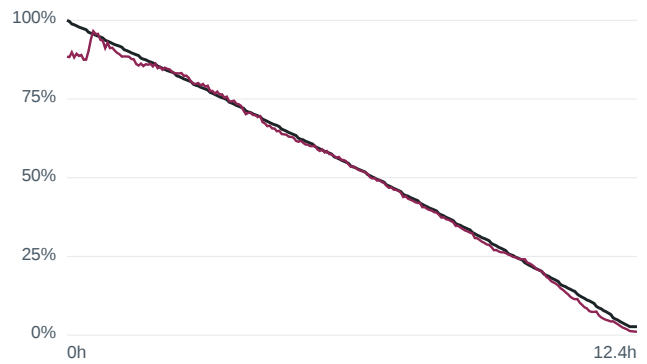
m80 US06 at 25 °C

RMSE 1.73 %



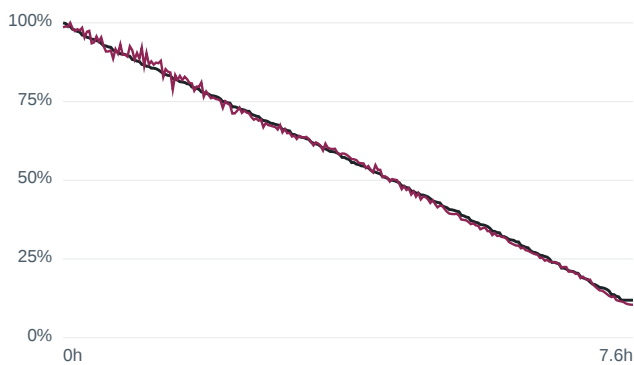
m80 UDDS at 40 °C

RMSE 2.28 %



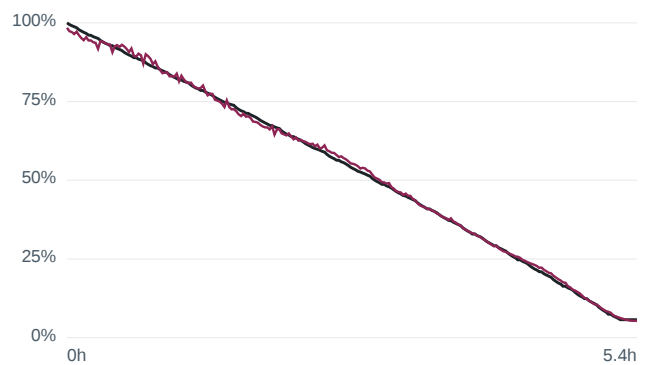
m448 LA92 at 10 °C

RMSE 1.19 %



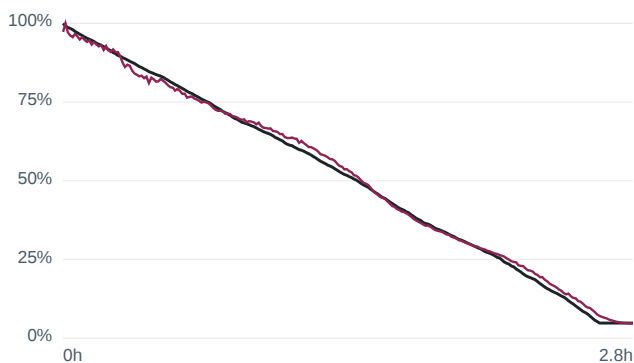
m1000 HWFET at 25 °C

RMSE 1.04 %



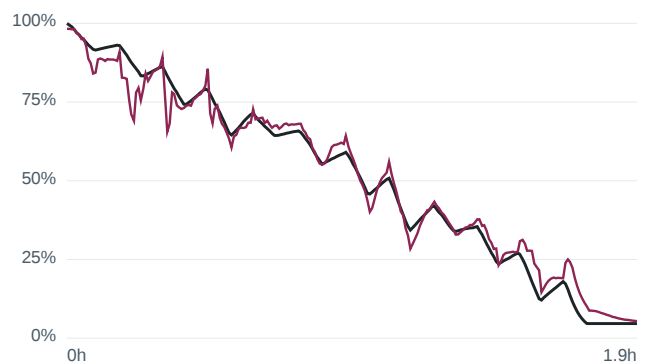
m1000 HWCUST at 25 °C

RMSE 1.56 %



m1000 HWGRADE at 25 °C

RMSE 4.23 %



Per-cycle errors

All 144 blinded drive cycles: RMSE, MAE and maximum error (% SOC).

CELL	TEMP	CYCLE	DURATION	RMSE	MAE	MAXE
m1000	-20 °C	HWCUST	1.37 h	3.62	3.38	7.72
m1000	-20 °C	HWFET	2.27 h	2.32	1.72	15.66
m1000	-20 °C	HWGRADE	1.22 h	11.03	9.07	34.21
m1000	-20 °C	LA92	3.20 h	5.04	4.40	15.26
m1000	-20 °C	UDDS	4.31 h	3.15	2.46	13.48
m1000	-20 °C	US06	1.74 h	10.69	9.46	24.11
m1000	-10 °C	HWCUST	1.67 h	1.67	1.27	5.36
m1000	-10 °C	HWFET	2.91 h	1.75	1.44	9.92
m1000	-10 °C	HWGRADE	1.20 h	7.52	6.13	29.28
m1000	-10 °C	LA92	4.23 h	2.48	1.79	12.71
m1000	-10 °C	UDDS	5.91 h	1.98	1.43	10.93
m1000	-10 °C	US06	2.09 h	4.51	3.68	14.76
m1000	0 °C	HWCUST	2.05 h	1.74	1.55	3.29
m1000	0 °C	HWFET	3.70 h	1.63	1.33	6.82
m1000	0 °C	HWGRADE	1.36 h	4.31	3.43	17.36
m1000	0 °C	LA92	5.60 h	1.79	1.31	9.69
m1000	0 °C	UDDS	8.09 h	1.66	1.29	8.28
m1000	0 °C	US06	2.66 h	2.40	1.72	10.38
m1000	10 °C	HWCUST	2.41 h	1.25	1.05	3.08
m1000	10 °C	HWFET	4.37 h	1.71	1.21	8.37
m1000	10 °C	HWGRADE	1.52 h	4.52	3.70	14.61
m1000	10 °C	LA92	7.06 h	1.43	1.10	7.21
m1000	10 °C	UDDS	10.51 h	1.12	0.86	6.66
m1000	10 °C	US06	3.11 h	1.75	1.34	8.54
m1000	25 °C	HWCUST	2.83 h	1.53	1.27	4.07
m1000	25 °C	HWFET	5.37 h	1.06	0.82	4.90
m1000	25 °C	HWGRADE	1.90 h	4.27	3.03	18.91
m1000	25 °C	LA92	9.30 h	1.21	0.90	6.66
m1000	25 °C	UDDS	14.69 h	1.41	1.17	5.99
m1000	25 °C	US06	3.79 h	1.96	1.58	8.00
m1000	40 °C	HWCUST	2.91 h	1.91	1.39	11.50
m1000	40 °C	HWFET	5.15 h	1.98	1.22	11.44
m1000	40 °C	HWGRADE	2.17 h	3.87	2.88	12.33
m1000	40 °C	LA92	8.33 h	2.03	1.27	11.65
m1000	40 °C	UDDS	11.69 h	2.28	1.50	11.97
m1000	40 °C	US06	3.89 h	2.32	1.59	11.66
m448	-20 °C	HWCUST	1.39 h	1.48	1.19	8.25
m448	-20 °C	HWFET	2.34 h	2.71	2.27	14.16
m448	-20 °C	HWGRADE	1.23 h	6.53	5.18	18.49
m448	-20 °C	LA92	3.46 h	3.45	2.86	13.52
m448	-20 °C	UDDS	4.56 h	2.64	2.01	11.16
m448	-20 °C	US06	1.80 h	6.94	6.08	17.68
m448	-10 °C	HWCUST	1.69 h	1.52	1.15	5.56
m448	-10 °C	HWFET	3.01 h	1.46	1.10	7.91
m448	-10 °C	HWGRADE	1.22 h	5.27	4.20	20.02
m448	-10 °C	LA92	4.59 h	2.39	1.76	11.36
m448	-10 °C	UDDS	6.23 h	2.13	1.64	10.04
m448	-10 °C	US06	2.25 h	3.66	2.99	12.37
m448	0 °C	HWCUST	2.09 h	1.16	0.97	3.28
m448	0 °C	HWFET	3.83 h	1.31	1.04	5.10
m448	0 °C	HWGRADE	1.51 h	3.45	2.70	10.54
m448	0 °C	LA92	6.16 h	1.80	1.27	9.75

CELL	TEMP	CYCLE	DURATION	RMSE	MAE	MAXE
m448	0 °C	UDDS	8.60 h	1.85	1.45	8.43
m448	0 °C	US06	2.87 h	2.23	1.59	9.36
m448	10 °C	HWCUST	2.42 h	1.39	1.21	4.35
m448	10 °C	HWFET	4.47 h	1.33	0.98	7.18
m448	10 °C	HWGRADE	1.68 h	3.73	3.09	11.33
m448	10 °C	LA92	7.60 h	1.18	0.91	6.96
m448	10 °C	UDDS	11.08 h	1.19	0.89	6.74
m448	10 °C	US06	3.35 h	1.65	1.27	8.40
m448	25 °C	HWCUST	2.86 h	1.69	1.36	3.48
m448	25 °C	HWFET	5.46 h	1.26	1.03	4.53
m448	25 °C	HWGRADE	2.19 h	3.38	2.59	15.96
m448	25 °C	LA92	10.06 h	1.20	0.86	6.87
m448	25 °C	UDDS	15.59 h	1.37	1.10	6.32
m448	25 °C	US06	4.07 h	1.96	1.63	7.54
m448	40 °C	HWCUST	2.92 h	2.10	1.49	11.39
m448	40 °C	HWFET	5.21 h	2.11	1.28	11.14
m448	40 °C	HWGRADE	2.32 h	3.42	2.58	11.41
m448	40 °C	LA92	8.79 h	1.97	1.19	11.67
m448	40 °C	UDDS	12.09 h	2.26	1.44	12.00
m448	40 °C	US06	4.06 h	2.31	1.55	11.96
m448-N	-20 °C	HWCUST	1.65 h	2.58	2.14	8.23
m448-N	-20 °C	HWFET	3.09 h	2.20	1.47	14.44
m448-N	-20 °C	HWGRADE	1.50 h	12.45	10.28	40.27
m448-N	-20 °C	LA92	5.21 h	6.93	5.99	22.34
m448-N	-20 °C	UDDS	8.67 h	7.54	6.46	22.25
m448-N	-20 °C	US06	2.23 h	10.35	9.28	24.14
m448-N	-10 °C	HWCUST	1.89 h	3.33	2.88	7.56
m448-N	-10 °C	HWFET	3.85 h	1.91	1.54	7.54
m448-N	-10 °C	HWGRADE	1.36 h	10.18	8.20	26.62
m448-N	-10 °C	LA92	6.66 h	4.01	3.33	16.25
m448-N	-10 °C	UDDS	10.80 h	4.59	3.90	16.39
m448-N	-10 °C	US06	2.70 h	5.79	4.99	16.19
m448-N	0 °C	HWCUST	2.31 h	1.24	0.96	3.88
m448-N	0 °C	HWFET	4.47 h	1.37	1.07	5.40
m448-N	0 °C	HWGRADE	1.65 h	4.93	4.04	13.87
m448-N	0 °C	LA92	7.99 h	2.44	1.82	11.83
m448-N	0 °C	UDDS	12.79 h	3.14	2.74	11.38
m448-N	0 °C	US06	3.22 h	2.97	2.27	11.02
m448-N	10 °C	HWCUST	2.53 h	1.33	1.11	4.61
m448-N	10 °C	HWFET	4.84 h	1.33	0.96	7.29
m448-N	10 °C	HWGRADE	1.79 h	4.01	3.22	13.67
m448-N	10 °C	LA92	8.80 h	1.26	0.88	8.08
m448-N	10 °C	UDDS	13.92 h	1.62	1.17	7.71
m448-N	10 °C	US06	3.56 h	1.99	1.47	9.82
m448-N	25 °C	HWCUST	2.86 h	1.68	1.35	3.43
m448-N	25 °C	HWFET	5.47 h	1.35	1.14	4.55
m448-N	25 °C	HWGRADE	2.30 h	3.30	2.48	16.26
m448-N	25 °C	LA92	10.09 h	1.21	0.90	6.68
m448-N	25 °C	UDDS	15.61 h	1.24	0.93	6.27
m448-N	25 °C	US06	4.08 h	2.05	1.73	7.29
m448-N	40 °C	HWCUST	3.13 h	2.05	1.45	11.29
m448-N	40 °C	HWFET	5.89 h	2.25	1.33	11.43
m448-N	40 °C	HWGRADE	2.48 h	3.35	2.50	11.61
m448-N	40 °C	LA92	11.03 h	2.16	1.22	11.81
m448-N	40 °C	UDDS	16.75 h	2.49	1.52	12.24

CELL	TEMP	CYCLE	DURATION	RMSE	MAE	MAXE
m448-N	40 °C	US06	4.44 h	2.23	1.47	12.14
m80	-20 °C	HWCUST	1.37 h	2.56	2.31	7.88
m80	-20 °C	HWFET	2.34 h	4.92	4.30	14.90
m80	-20 °C	HWGRADE	1.25 h	4.44	3.42	14.63
m80	-20 °C	LA92	3.54 h	2.17	1.58	9.86
m80	-20 °C	UDDS	4.62 h	2.17	1.58	10.42
m80	-20 °C	US06	1.86 h	3.78	3.07	12.11
m80	-10 °C	HWCUST	1.69 h	2.30	2.10	4.41
m80	-10 °C	HWFET	3.02 h	2.75	2.38	9.01
m80	-10 °C	HWGRADE	1.24 h	2.84	2.20	12.64
m80	-10 °C	LA92	4.74 h	1.47	1.11	7.65
m80	-10 °C	UDDS	6.32 h	1.32	1.02	6.53
m80	-10 °C	US06	2.30 h	2.00	1.56	7.39
m80	0 °C	HWCUST	2.08 h	2.31	2.06	4.87
m80	0 °C	HWFET	3.84 h	1.88	1.50	5.67
m80	0 °C	HWGRADE	1.64 h	2.97	2.47	8.54
m80	0 °C	LA92	6.39 h	1.39	1.08	6.28
m80	0 °C	UDDS	8.75 h	1.39	1.14	5.08
m80	0 °C	US06	2.93 h	1.80	1.43	6.56
m80	10 °C	HWCUST	2.42 h	1.72	1.35	4.38
m80	10 °C	HWFET	4.49 h	1.61	1.24	6.44
m80	10 °C	HWGRADE	1.80 h	3.29	2.65	8.63
m80	10 °C	LA92	7.88 h	1.49	1.10	6.70
m80	10 °C	UDDS	11.32 h	1.40	0.95	6.36
m80	10 °C	US06	3.42 h	1.46	1.16	5.69
m80	25 °C	HWCUST	2.86 h	1.73	1.41	3.42
m80	25 °C	HWFET	5.52 h	1.17	0.96	4.75
m80	25 °C	HWGRADE	2.33 h	2.96	2.32	13.90
m80	25 °C	LA92	10.58 h	1.15	0.86	5.72
m80	25 °C	UDDS	16.13 h	1.14	0.89	5.63
m80	25 °C	US06	4.22 h	1.73	1.45	5.39
m80	40 °C	HWCUST	2.95 h	2.05	1.44	11.66
m80	40 °C	HWFET	5.41 h	2.04	1.21	11.52
m80	40 °C	HWGRADE	2.73 h	2.90	2.11	11.46
m80	40 °C	LA92	9.07 h	1.90	1.06	11.72
m80	40 °C	UDDS	12.40 h	2.17	1.27	11.94
m80	40 °C	US06	4.17 h	2.22	1.46	12.00