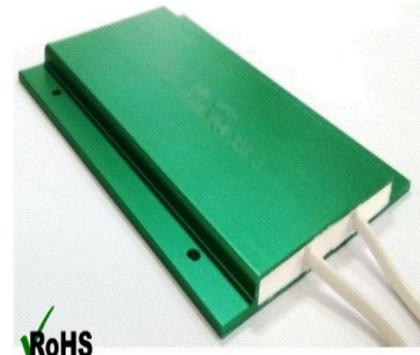


LPR Pulse Test

Pulse Test Results-LPR50, 55-60J

- Capacitor discharge pulses at the following pulse-widths:
1s, 0.1s, 0.01s
- 1 minute break between pulses
- Parts under test:
LPR50 1K (55J) and LPR50 500R (60J)



Samp ID	DSGN	OHMS INIT Resistance	sec Time	μF capacitance	Energy Joules	P. Power WATTS	P. Voltage VOLTS	P. Current AMPS	OHMS INIT Resistance	OHMS FINAL Resistance	%ΔR 10 pulses
7	LPR50 1K	998.9	0.01	10	55	10785	3282.2	3.29	998.9	1005.3	0.64%
5	LPR50 1K	1005.4	0.1	102	55	1,077	1040.7	1.04	1005.4	1005.5	0.01%
4	LPR50 1K	1003.7	1	994	55	110	332.7	0.33	1003.7	1003.9	0.02%
6	LPR50 500R	501.6	0.01	22	60	10,806	2328.1	4.64	501.6	502.9	0.26%
3	LPR50 500R	503.7	0.1	203	60	1,174	768.9	1.53	503.7	503.7	0.00%
2	LPR50 500R	502.7	1	1,994	60	120	245.3	0.49	502.7	502.9	0.04%

Remarks: The 1k ohm and 500 ohm showed <2% ΔR after discharge pulses. For each pulse width, a new sample was tested, there were no repeating samples for this experiment. The 1k ohm parts were pulsed with 55J, the 500 ohm with 60J.

Pulse Test Results-LPR50, 10xP and 15xP

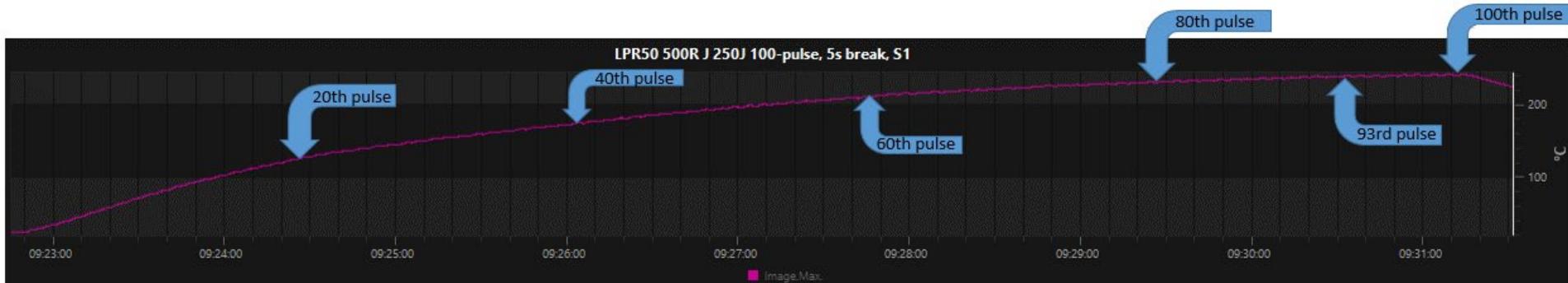
- Capacitor discharge pulses at the following pulse-widths:
0.5s and 1s
- Parts under test:
LPR50 500R

Samp ID	DSGN	OHMS INIT Resistance	sec Time	µF Capacitance	Energy Joules	P. Power WATTS	P. Voltage VOLTS	P. Current AMPS	OHMS INIT Resistance	OHMS FINAL	%ΔR 10 pulses	DESC
2	LPR50 500R	502.8	0.5	994	125	500	501.5	1.00	502.8	502.9	0.02%	10xP, 1 min break
3	LPR50 500R	503.7	0.5	994	188	749	614.2	1.22	503.7	504.0	0.06%	15xP, 1 min break
8	LPR50 500R	503.7	0.5	994	188	749	614.2	1.22	503.7	505.4	0.34%	15xP, 5s break
2	LPR50 500R	503.0	1	1994	375	748	613.3	1.22	503.0	502.8	-0.04%	15xP, 1 min break

Remarks: The 500 ohm resistors showed <2% ΔR after discharge pulses.

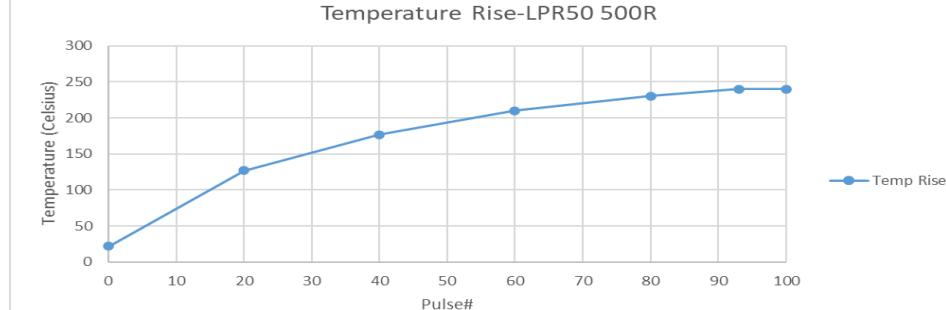
Pulse Test Results-LPR50, 100 discharge pulses

OHMITE



Samp ID	DSGN	OHMS INIT Resistance	sec Time	μF Capacitance	Energy Joules	P. Power WATTS	P. Voltage VOLTS	P. Current AMPS	OHMS INIT Resistance	OHMS FINAL	%ΔR 100
1	LPR50 500R	502.2	0.5	994	250	1002	709	1.41	502.2	511.8	1.91%

- 100 discharge pulses, 5s break
- 250 J at 0.5s pulse-width
- 50W average power
- 240C max temperature at 100th pulse (~218C temp rise)



Remarks: The 500 ohm resistor showed <2% ΔR after 100 discharge pulses with 5s break between pulses.

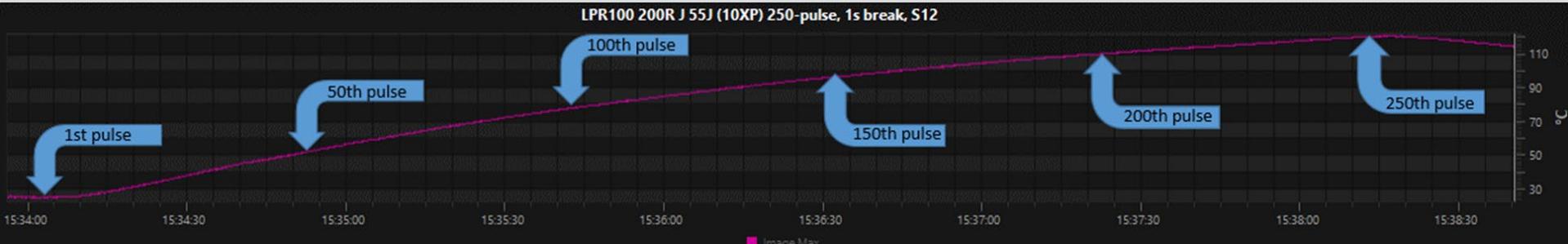
Pulse Test Results-LPR100, 650J

- 650J for the following intervals or until failure: 1s, 0.1s, 0.01s, 0.001s
- 1 minute break between pulses
- If it passes 0.1s pulse test, 10XP (1s break) until temperature stabilizes or 250 pulses
- Parts under test: LPR100 200R

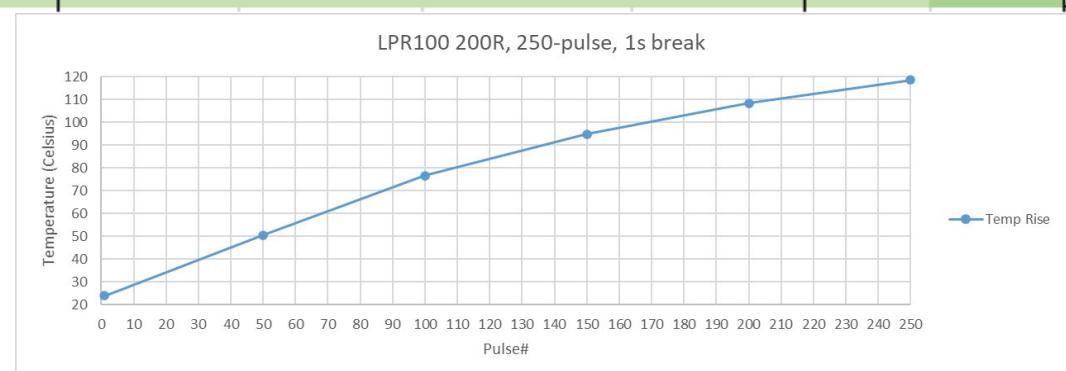
Samp	DSGN	OHMS INIT	sec	μ F	Energy	P. Power	P. Voltage	P. Current	OHMS INIT	OHMS	% Δ R
11	LPR100 200R	192.58	1	4783	650	1411	521	2.71	192.6	192.29	-0.15%
11	LPR100 200R	192.29	0.1	518.5	650	13039	1583	8.23	192.3	192.99	0.36%
11	LPR100 200R	192.99	0.01	43.66	650	154285	5457	28.27	193.0	open	

Remarks: The 200 ohm resistor showed <2% for the 1s and 0.1s pulse-widths but failed open on the first 0.01s pulse. The next experiment will be of the 10xP with 1s break, see next slide .

Pulse Test Results—LPR100, 250 pulse discharge pulses



- 250 discharge pulses
- 10xP, 55J at 0.1s pulse-width
- ~55W average power
- 118.6°C max temp at 250th pulse (~97°C temp rise)



Remarks: The 200 ohm resistor showed 0.01% ΔR after 250 discharge pulses with 1s break between pulses.

Pulse Test Results—LPR100, 650J

- 650J for the following intervals or until failure: 1s, 0.1s, 0.01s, 0.001s
- 1 minute break between pulses
- Parts under test: LPR100 25R

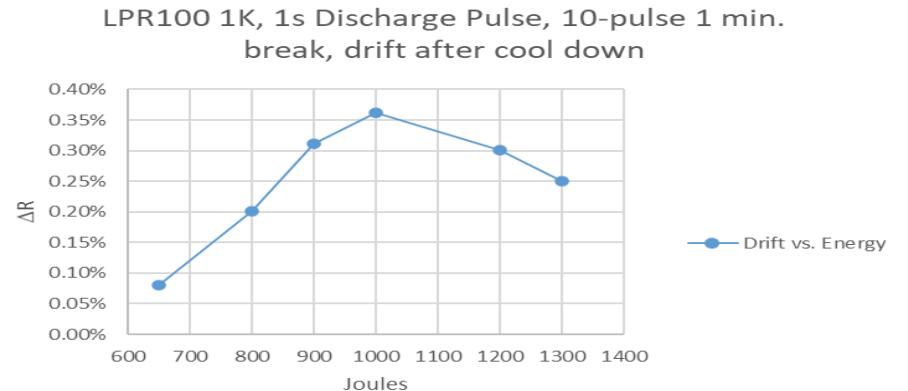
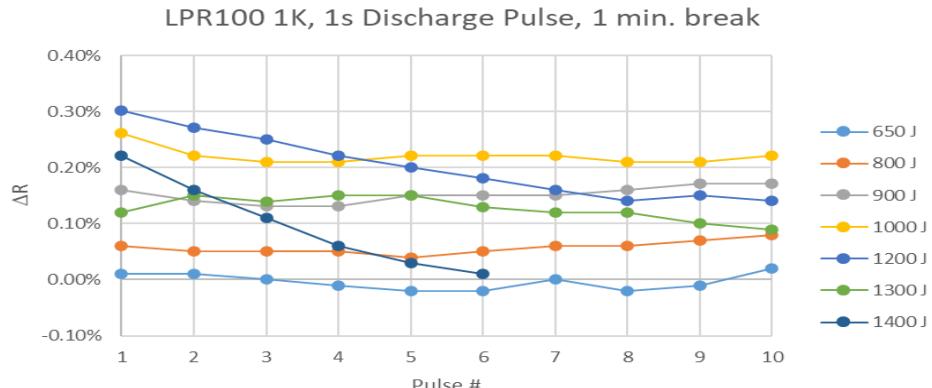
DSGN	OHMS INIT Resistance	sec Time	µF Capacitance	Energy Joules	P. Power WATTS	P. Voltage VOLTS	P. Current AMPS	OHMS INIT Resistance	OHMS FINAL	%ΔR 10 pulses
LPR100 25R	24.75	1	40760	650	1289	179	7.22	24.75	24.79	0.16%
LPR100 25R	24.78	0.1	4094	650	12814	564	22.74	24.78	24.79	0.04%
LPR100 25R	24.69	0.01	310	650	169848	2048	82.94	24.69	24.63	-0.24%

DSGN	OHMS INIT Resistance	sec Time	µF Capacitance	Energy Joules	P. Power WATTS	P. Voltage VOLTS	P. Current AMPS	OHMS INIT Resistance	OHMS FINAL
LPR100 25R	24.63	0.001	50	400	649614	4000	162.40	24.63	fail open

DSGN	OHMS INIT Resistance	sec Time	µF Capacitance	Energy Joules	P. Power WATTS	P. Voltage VOLTS	P. Current AMPS	OHMS INIT Resistance	OHMS FINAL	%ΔR 10 pulses
LPR100 25R	24.78	0.001	50	200	322841	2828	114.14	24.78	24.75	-0.12%
LPR100 25R	24.78	0.001	50	300	484262	3464	139.79	24.78	24.79	0.04%

Remarks: The 25 ohm resistor passed 650J for 1s, 0.1s, and 0.01s pulse-widths. At 0.001s, the part failed open at 400J.

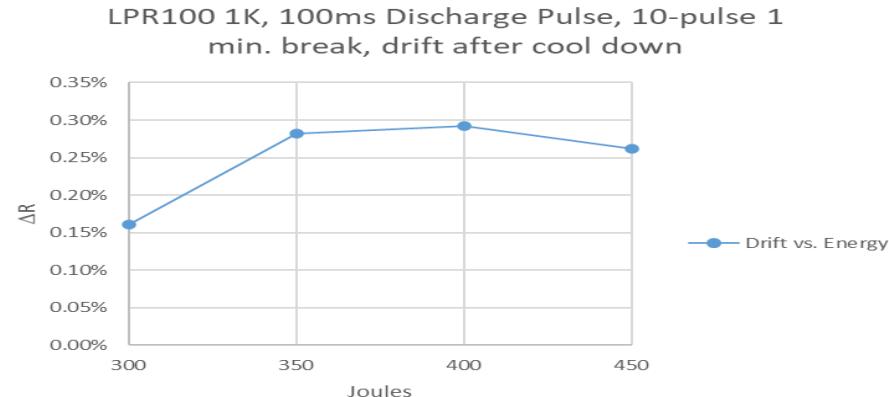
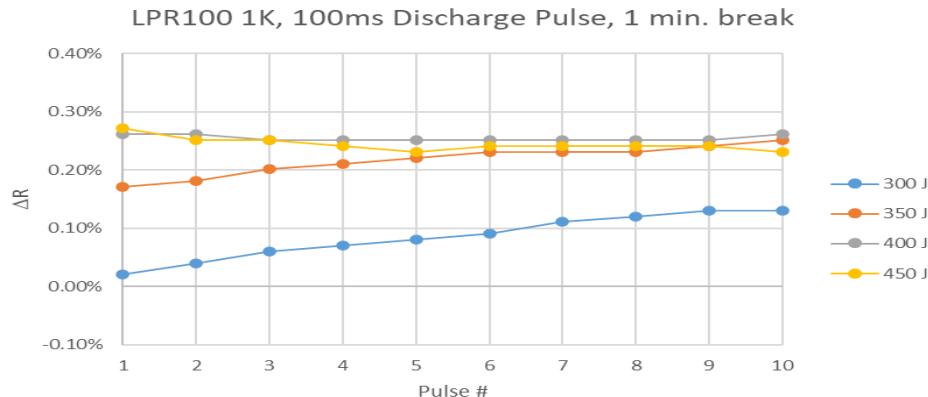
LPR100 1K Test Results– 1s pulse



- The LPR100 1K is pulsed with 10 capacitor discharges with 1 min. break
- The LPR100 1K failed on the 7th pulse at 1400J
- Passed up to 1300J, 0.25% ΔR

1s pulse							
Energy	650	800	900	1000	1200	1300	1400
Pulse#	%ΔR	%ΔR	%ΔR	%ΔR	%ΔR	%ΔR	%ΔR
1	0.01%	0.06%	0.16%	0.26%	0.30%	0.12%	0.22%
2	0.01%	0.05%	0.14%	0.22%	0.27%	0.15%	0.16%
3	0.00%	0.05%	0.13%	0.21%	0.25%	0.14%	0.11%
4	-0.01%	0.05%	0.13%	0.21%	0.22%	0.15%	0.06%
5	-0.02%	0.04%	0.15%	0.22%	0.20%	0.15%	0.03%
6	-0.02%	0.05%	0.15%	0.22%	0.18%	0.13%	0.01%
7	0.00%	0.06%	0.15%	0.22%	0.16%	0.12%	open
8	-0.02%	0.06%	0.16%	0.21%	0.14%	0.12%	
9	-0.01%	0.07%	0.17%	0.21%	0.15%	0.10%	
10	0.02%	0.08%	0.17%	0.22%	0.14%	0.09%	
after cool	0.08%	0.20%	0.31%	0.36%	0.30%	0.25%	

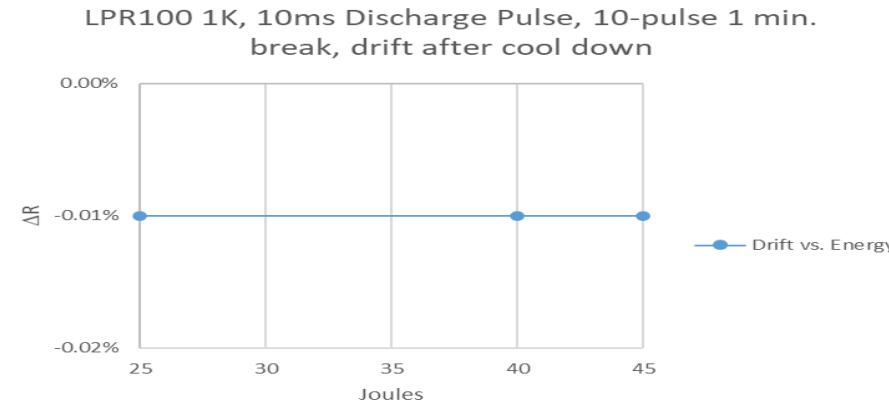
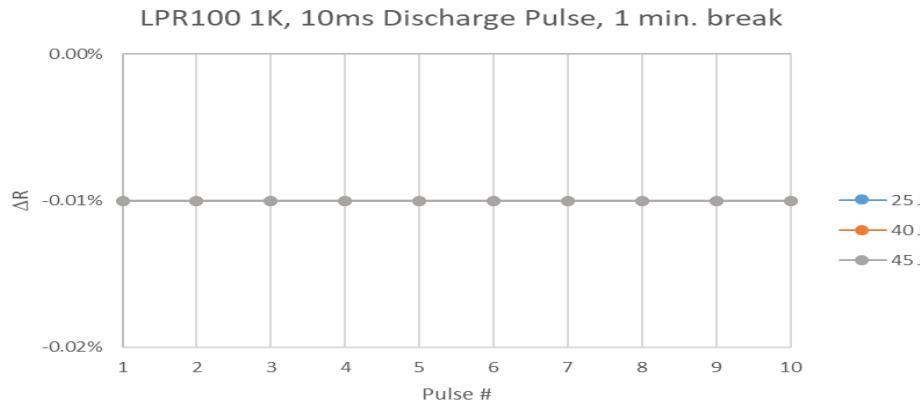
LPR100 1K Test Results – 100ms pulse



- The LPR100 1K is pulsed with 10 capacitor discharges with 1 min. break
- The LPR100 1K failed on the 1st pulse at 500J
- Passed up to 450J, 0.26% ΔR

100ms pulse					
Energy	300	350	400	450	500
Pulse#	% ΔR				
1	0.02%	0.17%	0.26%	0.27%	open
2	0.04%	0.18%	0.26%	0.25%	
3	0.06%	0.20%	0.25%	0.25%	
4	0.07%	0.21%	0.25%	0.24%	
5	0.08%	0.22%	0.25%	0.23%	
6	0.09%	0.23%	0.25%	0.24%	
7	0.11%	0.23%	0.25%	0.24%	
8	0.12%	0.23%	0.25%	0.24%	
9	0.13%	0.24%	0.25%	0.24%	
10	0.13%	0.25%	0.26%	0.23%	
after cool	0.16%	0.28%	0.29%	0.26%	

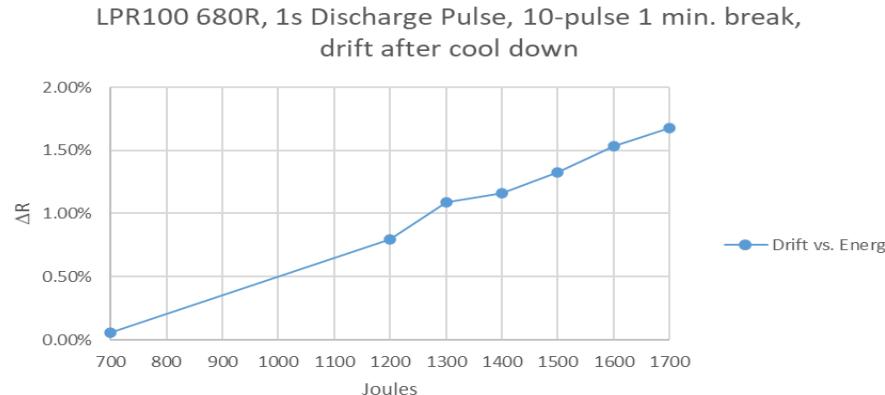
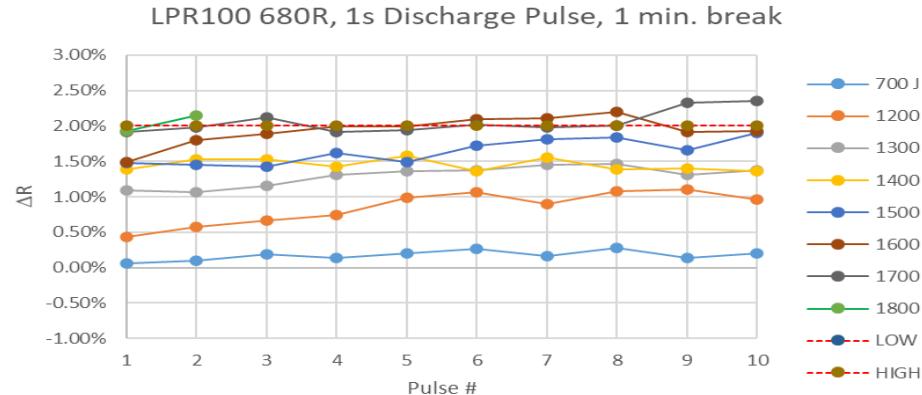
LPR100 1K Test Results– 10ms pulse



- The LPR100 1K is pulsed with 10 capacitor discharges with 1 min. break
- The LPR100 1K failed on the 1st pulse at 50J
- Passed up to 45J, -0.01% ΔR

10ms pulse				
Energy	25	40	45	50
Pulse#	% ΔR	% ΔR	% ΔR	% ΔR
1	-0.01%	-0.01%	-0.01%	-0.01%
2	-0.01%	-0.01%	-0.01%	-0.01%
3	-0.01%	-0.01%	-0.01%	-0.01%
4	-0.01%	-0.01%	-0.01%	-0.01%
5	-0.01%	-0.01%	-0.01%	-0.01%
6	-0.01%	-0.01%	-0.01%	-0.01%
7	-0.01%	-0.01%	-0.01%	-0.01%
8	-0.01%	-0.01%	-0.01%	-0.01%
9	-0.01%	-0.01%	-0.01%	-0.01%
10	-0.01%	-0.01%	-0.01%	-0.01%
after cool	-0.01%	-0.01%	-0.01%	-0.01%

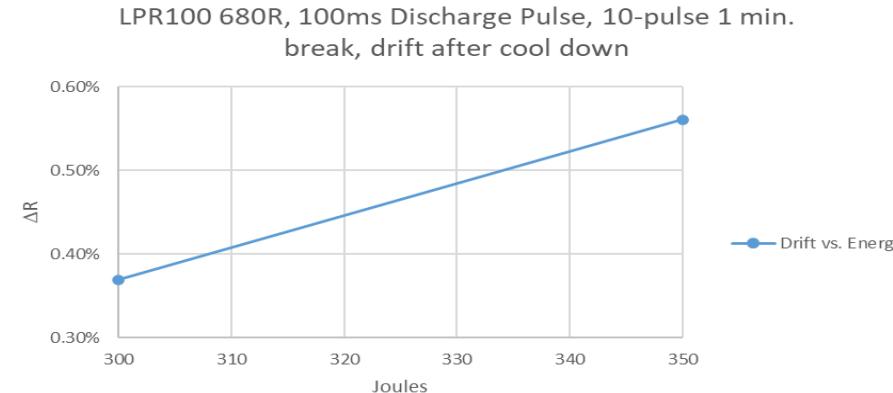
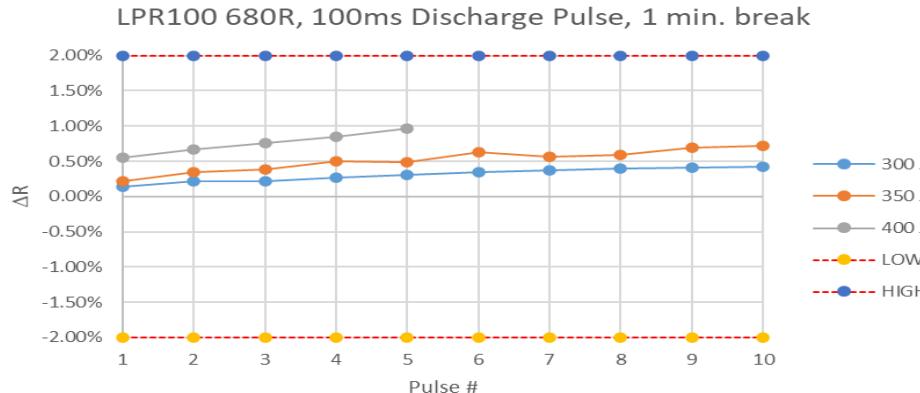
LPR100 680R Test Results– 1s pulse



- The LPR100 680R is pulsed with 10 capacitor discharges with 1 min. break
- The LPR100 680R failed on the 3rd pulse at 1800J
- Passed up to 1700J, 1.68% ΔR

1s Pulse								
Energy	700	1200	1300	1400	1500	1600	1700	1800
Pulse#	%ΔR							
1	0.06%	0.43%	1.09%	1.39%	1.47%	1.49%	1.92%	1.93%
2	0.10%	0.57%	1.06%	1.53%	1.44%	1.80%	1.98%	2.15%
3	0.19%	0.66%	1.15%	1.53%	1.43%	1.89%	2.12%	open
4	0.13%	0.74%	1.31%	1.43%	1.62%	1.99%	1.92%	
5	0.21%	0.99%	1.36%	1.58%	1.49%	1.99%	1.95%	
6	0.27%	1.06%	1.37%	1.36%	1.72%	2.09%	2.02%	
7	0.16%	0.90%	1.44%	1.55%	1.81%	2.11%	1.98%	
8	0.28%	1.08%	1.46%	1.39%	1.84%	2.20%	2.00%	
9	0.13%	1.11%	1.31%	1.40%	1.65%	1.92%	2.33%	
10	0.21%	0.96%	1.37%	1.36%	1.90%	1.93%	2.36%	
after cool	0.06%	0.80%	1.09%	1.16%	1.33%	1.53%	1.68%	

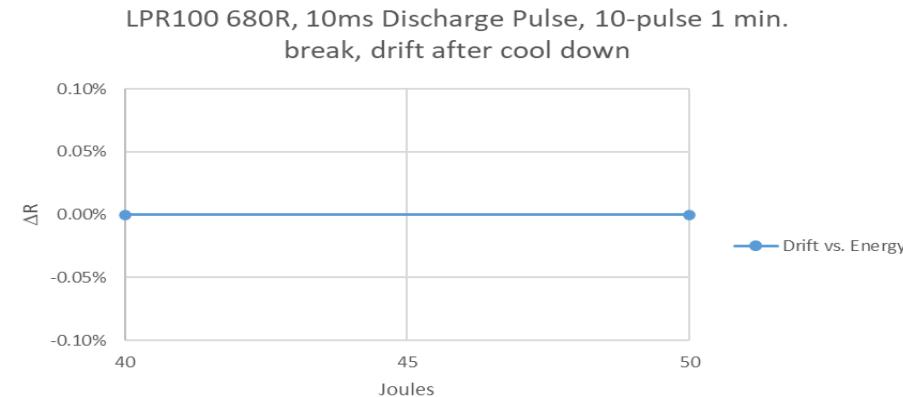
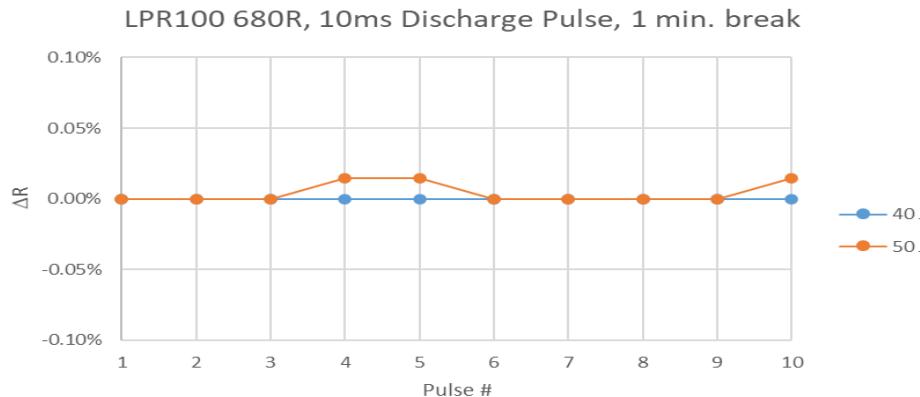
LPR100 680R Test Results – 100ms pulse



- The LPR100 680R is pulsed with 10 capacitor discharges with 1 min. break
- The LPR100 680R failed on the 6th pulse at 400J
- Passed up to 350J, 0.56% ΔR

100ms Pulse			
Energy	300	350	400
Pulse#	% ΔR	% ΔR	% ΔR
1	0.13%	0.22%	0.55%
2	0.22%	0.34%	0.66%
3	0.22%	0.38%	0.75%
4	0.27%	0.50%	0.84%
5	0.31%	0.49%	0.96%
6	0.34%	0.63%	open
7	0.37%	0.56%	
8	0.40%	0.59%	
9	0.41%	0.69%	
10	0.43%	0.72%	
after cool	0.37%	0.56%	

LPR100 680R Test Results– 10ms pulse

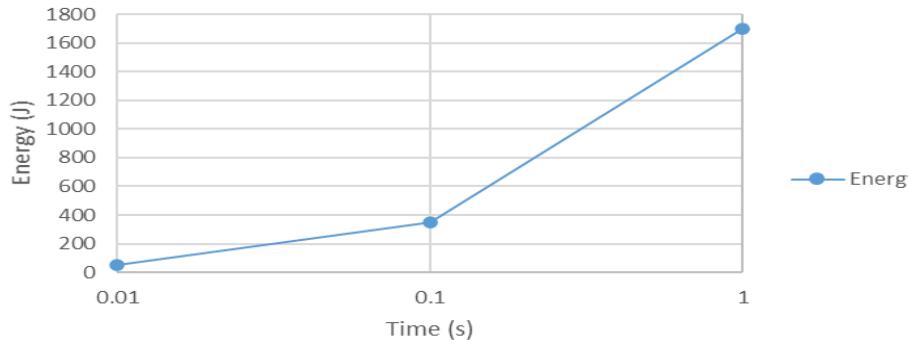


- The LPR100 680R is pulsed with 10 capacitor discharges with 1 min. break
- The LPR100 680R failed on the 1st pulse at 55J
- Passed up to 50J, 0% ΔR

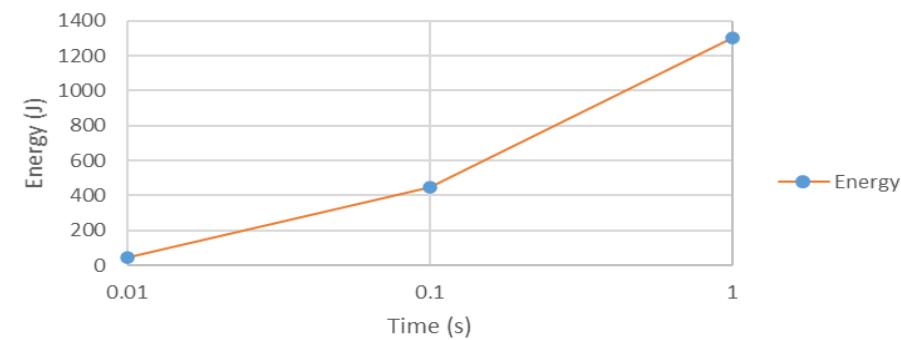
10ms Pulse			
Energy	40	50	55
Pulse#	% ΔR	% ΔR	% ΔR
1	0.00%	0.00%	open
2	0.00%	0.00%	
3	0.00%	0.00%	
4	0.00%	0.01%	
5	0.00%	0.01%	
6	0.00%	0.00%	
7	0.00%	0.00%	
8	0.00%	0.00%	
9	0.00%	0.00%	
10	0.00%	0.01%	
after cool	0.00%	0.00%	

LPR100 1K Graph – Energy vs. Time

LPR100 680R, Energy vs. Time

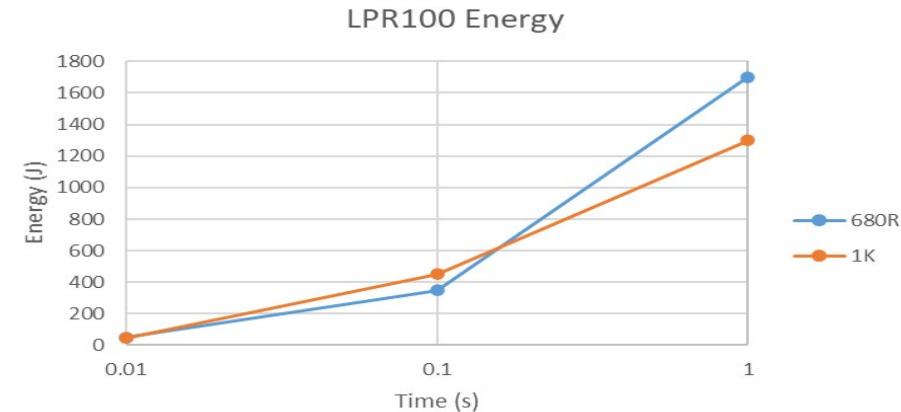


LPR100 1K, Energy vs. Time

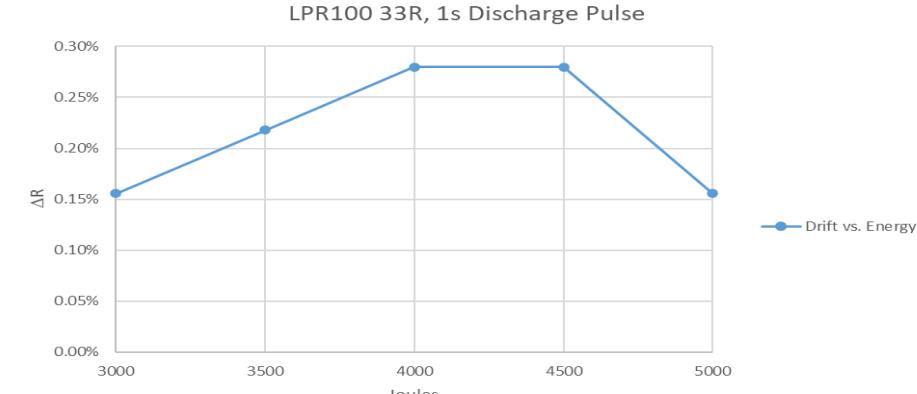
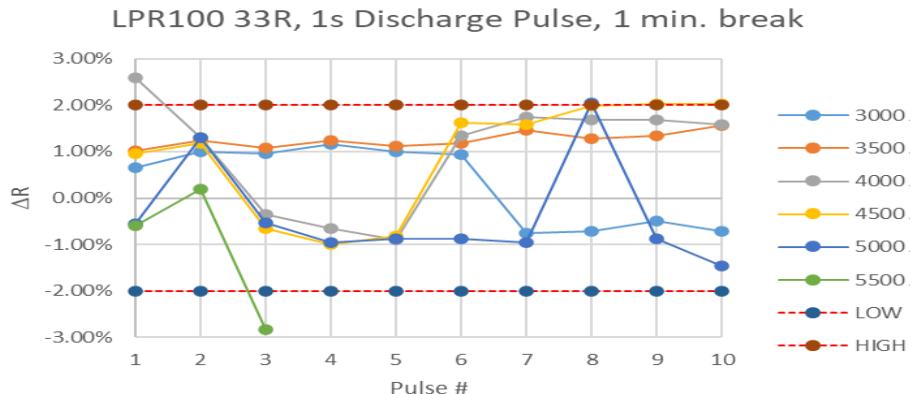


- The graphs show the passing energy after a 10-pulse experiment
- Passing is $\Delta R < 2\%$

	680R	1K
time (s)	energy (J)	
0.01	50	45
0.1	350	450
1	1700	1300



LPR100 33R Test Results– 1s pulse

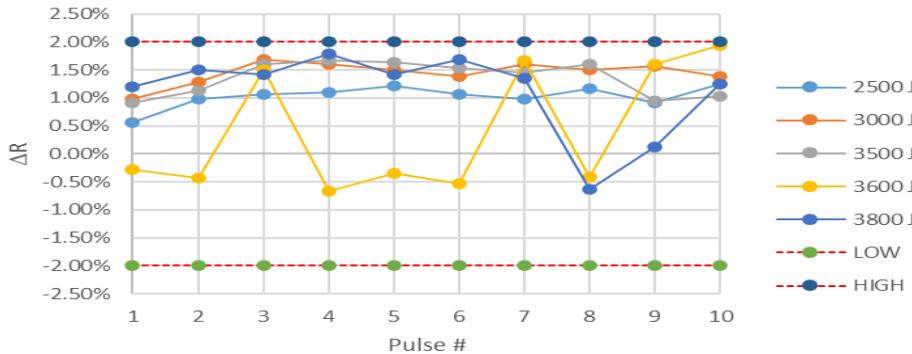


- The LPR100 33R is pulsed with 10 capacitor discharges with 1 min. break
- The LPR100 33R failed on the 4th pulse at 5500 J
- Passed up to 5000 J, 0.16% ΔR

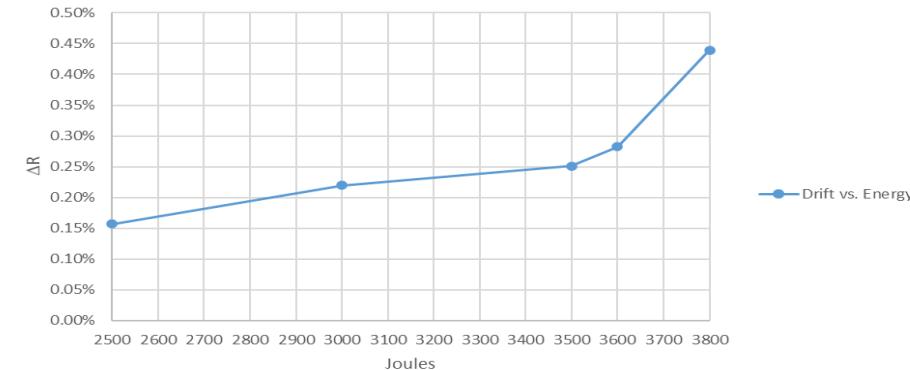
Watts	6665	7776	8887	9998	11109	12220
Joules	3000	3500	4000	4500	5000	5500
Pulse#	%ΔR	%ΔR	%ΔR	%ΔR	%ΔR	%ΔR
1	0.65%	1.03%	2.58%	0.96%	-0.56%	-0.59%
2	1.00%	1.24%	1.31%	1.18%	1.31%	0.19%
3	0.96%	1.09%	-0.34%	-0.65%	-0.53%	-2.83%
4	1.15%	1.24%	-0.65%	-1.00%	-0.96%	open
5	1.00%	1.12%	-0.90%	-0.81%	-0.87%	
6	0.93%	1.18%	1.34%	1.62%	-0.87%	
7	-0.75%	1.46%	1.74%	1.59%	-0.96%	
8	-0.72%	1.28%	1.68%	1.99%	2.05%	
9	-0.50%	1.34%	1.68%	2.02%	-0.87%	
10	-0.72%	1.56%	1.59%	2.02%	-1.46%	
after cool	0.16%	0.22%	0.28%	0.28%	0.16%	

LPR100 33R Test Results – 500ms pulse

LPR100 33R, 500ms Discharge Pulse, 1 min. break



LPR100 33R, 500ms Discharge Pulse

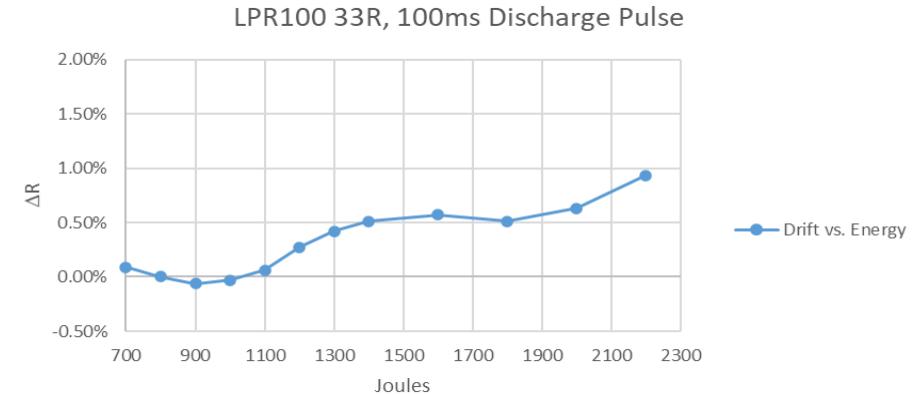
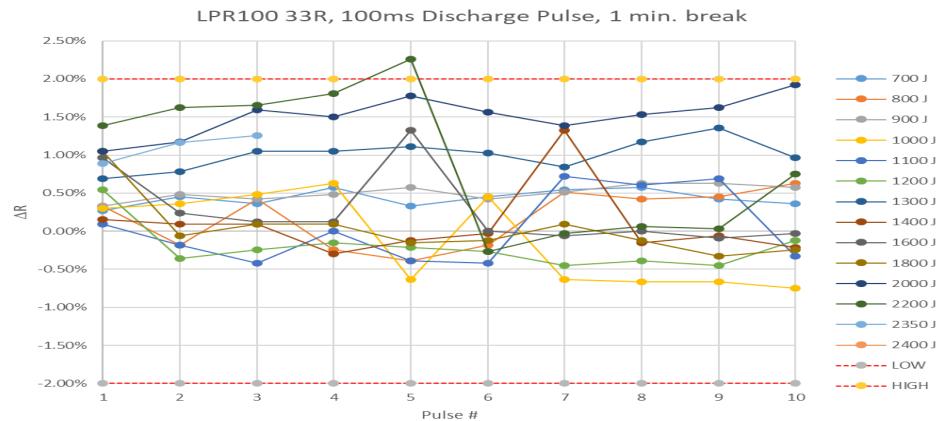


- The LPR100 33R is pulsed with 10 capacitor discharges with 1 min. break
- The LPR100 33R failed on the 1st pulse at 4000 J
- Passed up to 3800 J, 0.44% ΔR

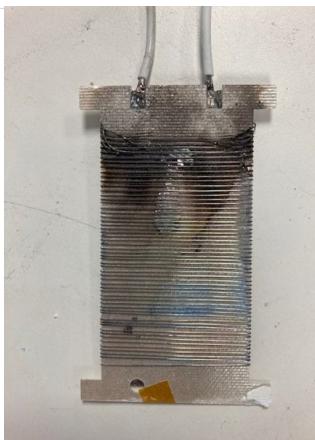


Watts	10456	12547	14638	15056	15893	16729
Joules	2500	3000	3500	3600	3800	4000
Pulse#		%ΔR	%ΔR	%ΔR	%ΔR	%ΔR
1		0.56%	0.97%	0.91%	-0.28%	1.19%
2		0.97%	1.29%	1.13%	-0.44%	1.51%
3		1.07%	1.69%	1.60%	1.51%	1.41%
4		1.10%	1.60%	1.66%	-0.66%	1.79%
5		1.22%	1.51%	1.63%	-0.35%	1.41%
6		1.07%	1.38%	1.54%	-0.53%	1.69%
7		0.97%	1.60%	1.44%	1.66%	1.35%
8		1.16%	1.51%	1.60%	-0.41%	-0.63%
9		0.91%	1.57%	0.94%	1.60%	0.13%
10		1.25%	1.38%	1.04%	1.94%	1.25%
after cool		0.16%	0.22%	0.25%	0.28%	0.44%

LPR100 33R Test Results – 100ms pulse

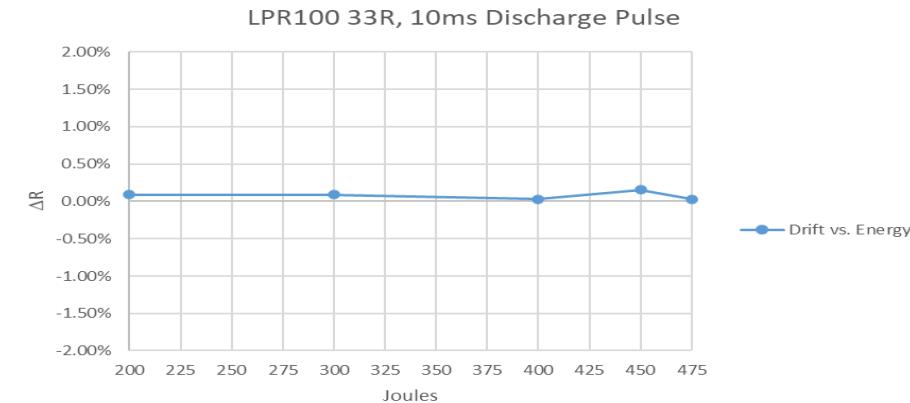
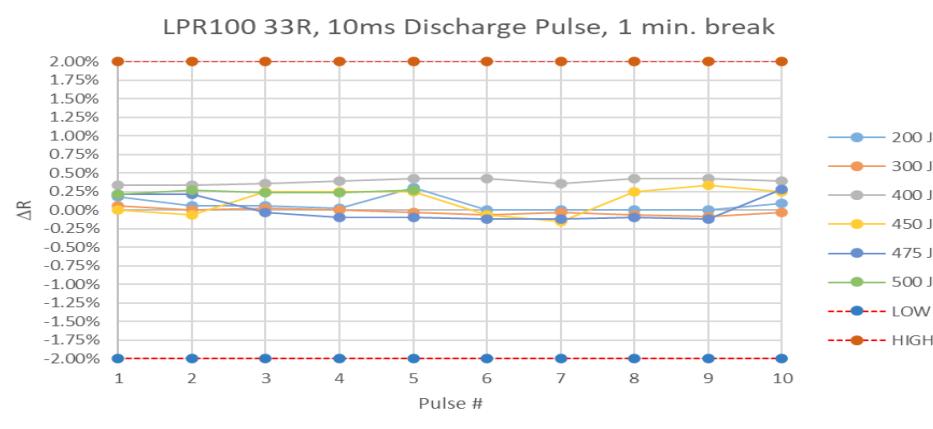


- The LPR100 33R is pulsed with 10 capacitor discharges with 1 min. break
- The LPR100 33R failed on the 4th pulse at 2350 J, loud explosive noise.
- Passed up to 2200 J, 0.56% ΔR



Watts	14629	16718	18808	20898	22988	25078	27168	29257	33437	37617	41796	45976	49998
Joules	700	800	900	1000	1100	1200	1300	1400	1600	1800	2000	2200	2350
Pulse#	% ΔR												
1	0.27%	0.33%	0.33%	0.30%	0.09%	0.54%	0.69%	0.15%	0.96%	1.05%	1.05%	1.38%	0.89%
2	0.45%	-0.18%	0.48%	0.36%	-0.18%	-0.36%	0.78%	0.09%	0.24%	-0.06%	1.17%	1.63%	1.16%
3	0.36%	0.42%	0.42%	0.48%	-0.42%	-0.24%	1.05%	0.09%	0.12%	0.09%	1.59%	1.66%	1.26%
4	0.57%	-0.24%	0.48%	0.63%	0.00%	-0.15%	1.05%	-0.30%	0.12%	0.09%	1.50%	1.81%	open
5	0.33%	-0.39%	0.57%	-0.63%	-0.39%	-0.21%	1.11%	-0.12%	1.32%	-0.15%	1.78%	2.26%	
6	0.45%	-0.18%	0.42%	0.45%	-0.42%	-0.27%	1.02%	-0.03%	0.00%	-0.12%	1.56%	-0.27%	
7	0.54%	0.51%	0.51%	-0.63%	0.72%	-0.45%	0.84%	1.32%	-0.06%	0.09%	1.38%	-0.03%	
8	0.57%	0.42%	0.63%	-0.66%	0.60%	-0.39%	1.17%	-0.15%	0.00%	-0.12%	1.53%	0.06%	
9	0.42%	0.45%	0.63%	-0.66%	0.69%	-0.45%	1.35%	-0.06%	-0.09%	-0.33%	1.63%	0.03%	
10	0.36%	0.63%	0.57%	-0.75%	-0.33%	-0.12%	0.96%	-0.21%	-0.03%	-0.24%	1.93%	0.75%	
after cool	0.09%	0.00%	-0.06%	-0.03%	0.06%	0.27%	0.42%	0.51%	0.57%	0.51%	0.63%	0.93%	

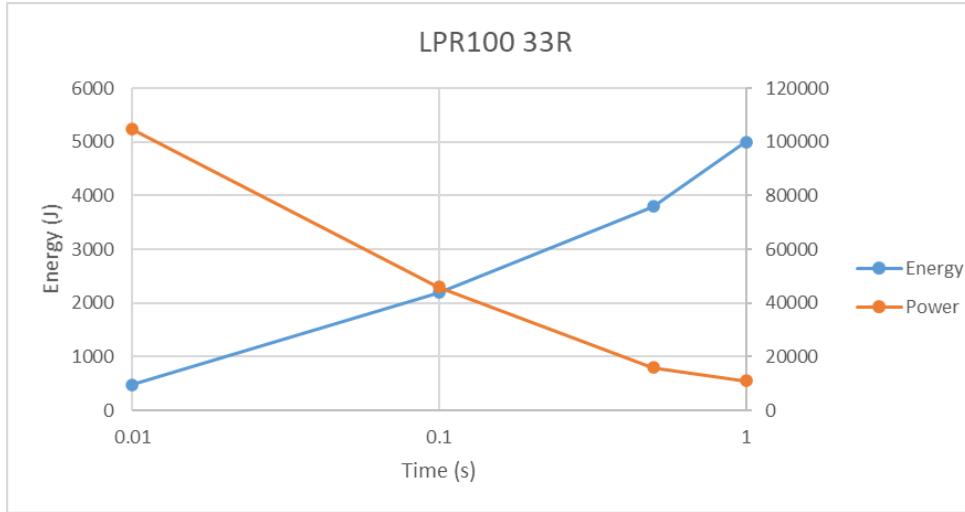
LPR100 33R Test Results– 10ms pulse



- The LPR100 33R is pulsed with 10 capacitor discharges with 1 min. break
- The LPR100 33R failed on the 6th pulse at 500 J
- Passed up to 475 J, 0.03% ΔR

Watts	43666	65264	87018	99185	104696	108773
Joules	200	300	400	450	475	500
Pulse#	% ΔR					
1	0.18%	0.06%	0.33%	0.00%	0.21%	0.21%
2	0.06%	0.00%	0.33%	-0.06%	0.21%	0.27%
3	0.06%	0.03%	0.36%	0.25%	-0.03%	0.24%
4	0.03%	0.00%	0.39%	0.25%	-0.09%	0.24%
5	0.30%	-0.03%	0.42%	0.25%	-0.09%	0.27%
6	0.00%	-0.06%	0.42%	-0.06%	-0.12%	open
7	0.00%	-0.03%	0.36%	-0.15%	-0.12%	
8	0.00%	-0.06%	0.42%	0.25%	-0.09%	
9	0.00%	-0.09%	0.42%	0.34%	-0.12%	
10	0.09%	-0.03%	0.39%	0.25%	0.28%	
after cool	0.09%	0.09%	0.03%	0.15%	0.03%	

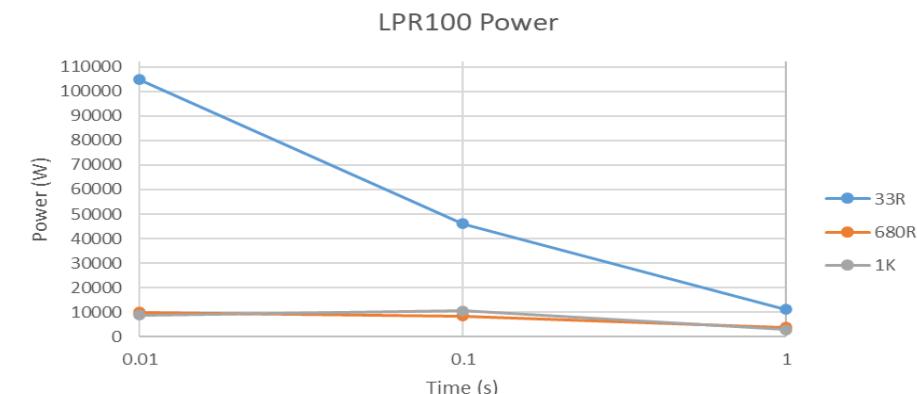
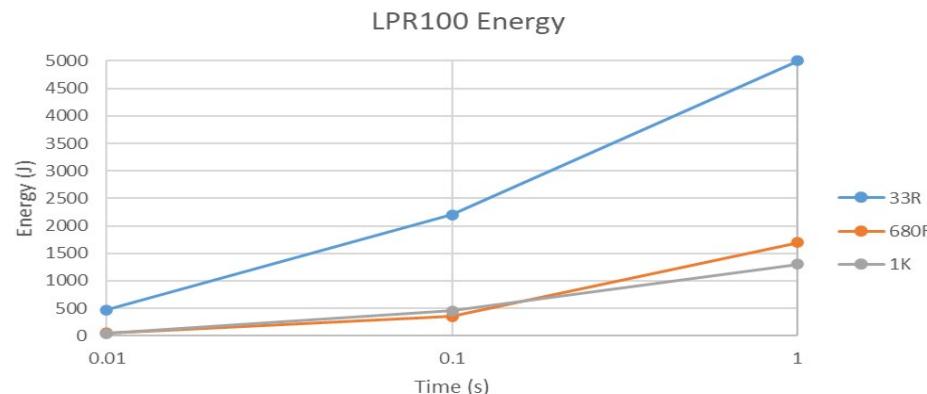
LPR100 33R Graphs – Energy & Power



Energy & Power, 33R				
time (s)	Joules	watts	volts	amps
0.01	475	104696	1849	56.6
0.1	2200	45976	1236	37.2
0.5	3800	15893	712	22.3
1	5000	11109	598	18.6

- The graphs show the passing energy and power after a 10-pulse experiment
- Passing is $\Delta R < 2\%$

LPR100 Graphs – Energy & Power



time (s)	Joules		
	33R	680R	1K
0.01	475	50	45
0.1	2200	350	450
1	5000	1700	1300

time (s)	Watts		
	33R	680R	1K
0.01	104696	10040	8834
0.1	45976	8475	10505
1	11109	3849	2845

- The graphs show the passing energy and power after a 10-pulse experiment
- Passing is $\Delta R < 2\%$

Conclusion



- The LPR50 1K passed 55J and the LPR50 500R passed 60J for 10ms, 100ms, and 1s. At these energy levels, the parts should not have any significant problems or failures.
- The LPR50 500R was pulsed 100 times, the average power of 50W, max temperature of 240C. This shows that the max temperature rating of 250C was not reached.
- The LPR100 was pulsed 250 times, average power of 55W, max temperature was ~119C. The calculated max temperature at 55W (55% of rated power) is ~116C.
- The LPR100 was pulse tested for 650J, the ohm value plays a role in whether it will pass or fail. The values tested were 25R, 200R, 680R and 1K. 25R passed 10ms, 100ms, 1s. 200R passed 100ms, 1s. 680R and 1K passed only 1s.
- The LPR100 33R was pulse tested to find the failures at 10ms, 100ms, 500ms and 1s.