

# RADPAL POWER-ON-RESET VDD RAMP RATE CHARACTERIZATION REPORT

4/24/98

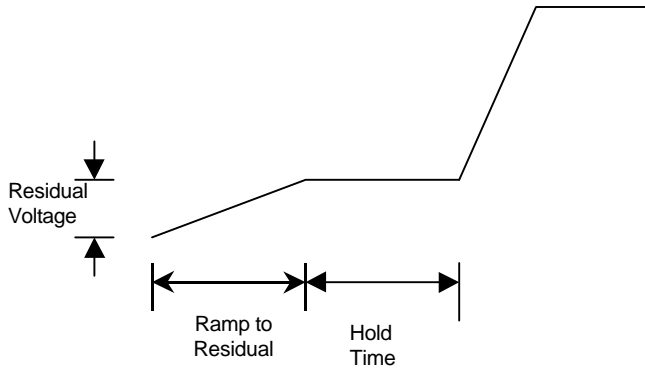
## Introduction

The RADPAL can power up in a test mode rather than the user mode if there is a small residual voltage on VDD or if the VDD ramp rate is extremely slow. A specification for VDD power up was developed stating that "VDD must begin at zero volts and reach one volt at a rate greater than 0.1 volt/second. It must then rise continuously to 3 volts and be monotonic thereafter". Appendix B contains the original problem description.

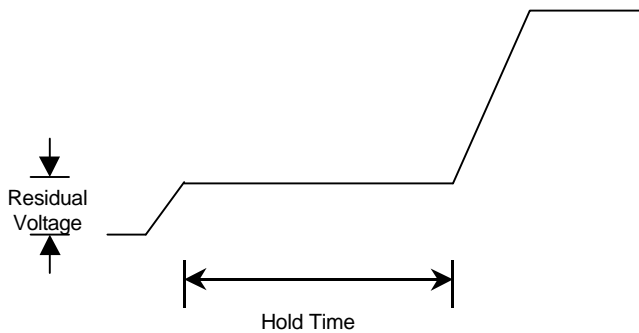
A concern was raised that the power up requirements might shift as the part ages and/or after radiation. It was also necessary to determine the maximum residual voltage that could be tolerated. A plan was developed to further characterize the RADPAL power-up requirements to answer these questions.

## Characterization Plan

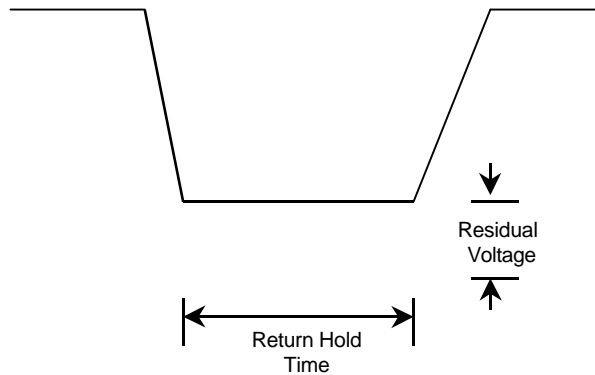
A set of three different VDD power up ramp conditions was developed to screen the parts for ramp rate failures. Waveforms for the tests are shown below.



Test 1: VDD slow ramp to residual voltage, hold before continuing power-up.



Test 2: VDD fast ramp to residual voltage, hold before continuing power-up.



Test 3: VDD return to residual voltage after power-up.

VDD ramp rates and hold times used for Test 1 are shown on page 5. A set of 30 RADPAL units were selected from various production lots. The parts were programmed with a test code that uses registered outputs and then tested according to the schedule shown below. In addition to the 30 UTMC units, four parts that had failed in a customer's system were tested following the same procedure as the 30 UTMC units.

	<u>Completion Date</u>
Automate Test Procedure	2/6/98
Determine Temperature Capability on HP4062	2/13/98
DOE to determine critical parameters	2/20/98
Simulate critical conditions determined by DOE	2/23/98
Test parts over temperature	2/26/98
- 34 parts from various wafers and assembly lots	
500 hour life test at 150C, 5.5 volts	3/19/98
Test parts over temperature	3/24/98
Radiate parts - CO60, 1M Rad-Si	4/7/98
- include part that is failing	
Test parts over temperature	4/10/98

### Characterization Result Summary

All of the testing was completed according to plan with 34 units consisting of the 30 UTMC units and 4 customer units. Only one of the 30 units (unit #40) failed before life test. It failed Test 1 and Test 2 at 125C. See the attached chart (page 6) summarizing all the failures and conditions. The summary data in the chart shows the first failure to occur for each part with the designated test and temperature. The ramp rates shown are the fastest ramp-rates to fail, the residual voltages shown are the lowest voltage to fail, and the hold times are the shortest times to fail. Detailed data for all of the parts is attached in Appendix A.

### Pre Life Test Results

Three of the four customer parts failed Test 1 at room temperature before life test. One of those units also failed Test 2. UTMC was unable to get unit 242 to fail before life test, even with a much wider range of ramp rates and hold times than used for the other parts.

None of the parts failed Test 3 under any conditions during any of the characterization steps. One of the parts UTMC used to develop the three tests from an earlier group of parts failed Test 3. That one part had been through an earlier life test so is not included in the data. It was radiation tested with the other UTMC parts.

### Post Life Test Results

Two of the 30 units failed after life test. Unit 40 failed Test 1 at 125C just as it did pre-life, but it no longer failed Test 2 after the life test. Unit 192 failed Tests 1 and 2 after life test. Unit 192 failed Test 1 at room temperature but not at hot.

All of the customer parts failed Test 1 post-life and 3 of the 4 failed Test 2.

### Post Radiation Test Results

There were no failures in any of the parts after radiation. Radiation "cured" all of the parts that failed previously, including the unit UTMC had tested exhaustively while developing the three test waveforms.

### Conclusions

One conclusion is very clear: radiation alleviates the VDD power-up ramp rate problem. This was expected because radiation causes the N-channel threshold to decrease and the P-channel threshold to increase in magnitude. This lowers the switch point of the logic gates, allowing the gates between the security fuse and the security latch to operate at lower voltages and hold the security latch in the reset state. Also, the POR pulse will be stronger and the switch point of the POR latch will be lower to help reset the security latch.

There is some evidence that parts get worse with life test but this was not dramatic or consistent and is statistically inconclusive. One UTMC part failed after life test that did not fail before. One of the four customer parts passed before life test but failed after life. Contrary to that pattern, one customer part (#240) and one UTMC part (#40) failed Test 2 before life test but passed after life. UTMC's experience is that shifts in device parameters with age are very minor (for example, thresholds shift only a few millivolts) so they have almost insignificant impact on power-up performance.

Parts failed Test 1, the ramp-rate test, at room temperature much more than at 125C but failed Test 2, the residual voltage test, most often at 25C. This is consistent with HSPICE results. Test 1 is dominated by AC parameters including the magnitude of the POR pulse, capacitance imbalance in the Security module POR latch, and timing skews between the mode 1 latch and the signal generated by the security fuse. The residual voltage failures, Test 2, are dominated by the DC switching threshold of the logic gates which are directly affected by temperature. Temperature will have a different effect on the AC circuit parameters compared to the DC circuit parameters.

The residual voltage levels were lower on some parts than previously observed in the lab or in simulation. The lowest failing voltage level was 50mV on unit #40 when held for at least 4 seconds. The failing residual voltage window was very narrow, from as little as 25mV to a maximum of 125mV on this group of parts.

Hold time had no effect on the ramp rate test results. If the part passed with a hold time of 0 seconds, it passed with a longer hold time and, if the part failed with 0 second hold, holding at a residual voltage did not make it any worse or better. For the residual voltage test, all of the first failures were with hold times between 4 and 8 seconds. This means that VDD must hold at the residual voltage for at least 4 seconds to cause a problem.

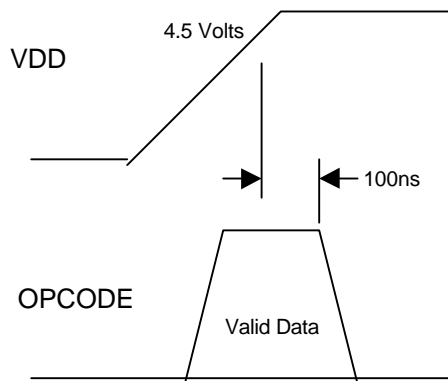
All of the parts exhibiting a problem, post-life, were tested before being irradiated with each of the op-code fixes. All passed with op-codes for modes (0,2-6) on the inputs.

### Specification Update

Based on this data, the power-up specification should be updated as follows. The minimum ramp rate allowed should be changed from 0.1V/s to 0.2V/s. This provides adequate margin over the fastest ramp rate failure of 0.123V/s. Previously we stated that VDD must begin its ramp at 0 volts. We can now define 0 volts more precisely as a maximum residual voltage of 40mV, providing some margin over the worst data observed.

The RADPAL will always power up in user mode if inputs 1-10 are in the following states:

- Input (1): logic 1
- Inputs (2-9): any of the hex codes DC, DE, DF, E0, E1, E2 (input 9 is msb)
- Input (10): logic 1



Opcode Fix Timing Specification

The inputs must be in the state defined above for at least 100ns after VDD reaches its operating voltage. If this condition is met, VDD ramp rate and residual voltage are not limited.

Vern Schnathorst  
Product Development Mgr

Alan Oliver  
Standard Product Design Engineer

**Appendix A**  
**PAL Characterization Data**

Pre Burnin Ramp Test (Test 1)				
Part #	Fastest Ramp Time Failure		Lowest Voltage Failure	
	25C	125C	25C	125C
192	NF	NF	NF	NF
40	NF	0.123V/s @ .20V	NF	.10V @ 0.035V/s
240	0.014V/s @ .20V	NF	.20V @ 0.014V/s	NF
241	0.026V/s @ .25V	NF	.25V @ 0.026V/s	NF
242	NF	NF	NF	NF
243	0.035V/s @ .35V	NF	.35V @ 0.035V/s	NF

Post Burnin Ramp Test (Test 1)			
Fastest Ramp Time Failure		Lowest Voltage Failure	
25C	125C	25C	125C
0.055V/s @ .15V	NF	.15V @ 0.055V/s	NF
NF	0.123V/s @ .20V	NF	.10V @ 0.035V/s
0.020V/s @ .20V	NF	.20V @ 0.020V/s	NF
0.035V/s @ .25V	NF	.20V @ 0.020V/s	NF
0.020V/s @ .20V	NF	.15V @ 0.011V/s	NF
0.055V/s @ .35V	0.123V/s @ .20V	.30V @ 0.020V/s	.10V @ 0.035V/s

Pre Burnin Residual Test (Test 2)				
Part #	Residual Voltage Failure		Shortest Hold Time Failure	
	25C	125C	25C	125C
192	NF	NF	NF	NF
40	NF	.05V	NF	4.0s
240	.20V	NF	8.0s	NF
241	NF	NF	NF	NF
242	NF	NF	NF	NF
243	NF	NF	NF	NF

Post Burnin Residual Test (Test 2)			
Residual Voltage Failure		Shortest Hold Time Failure	
25C	125C	25C	125C
NF	.10V	NF	4.0s
NF	NF	NF	NF
NF	NF	NF	NF
NF	.20V	NF	6.0s
NF	.15V	NF	6.0s
NF	.075V	NF	6.0s

Ramp Test Conditions for parts 192 and 40  
Ramp = .10V to .50V in steps of .05V  
Ramp Rate = .017V/s to .123V/s in 6 steps  
Hold = 0s to 2s in steps of 2s

Residual Test Conditions for parts 192 and 40  
Residual = .05V to .45V in steps of .025V  
Hold = 2s to 4s in steps of 2s

Ramp Test Conditions for parts 240 - 243  
Ramp = .10V to .50V in steps of .05V  
Ramp Rate = .017V/s to .123V/s in 6 steps  
Hold = 0s to 2s in steps of 2s

Residual Test Conditions for parts 240-243  
Residual = .05V to .45V in steps of .025V  
Hold = 6s to 10s in steps of 2s

NF=No Failure

**Pre Life**

**Post Life**

part=240		temp=25			part=240		temp=25		
test=por1	Output	Ramp Voltage	Ramp Time	Hold Time	test=por1	Output	Ramp Voltage	Ramp Time	Hold Time
						5.0	0.20	9.77	0
						5.0	0.25	12.23	0
						5.0	0.30	14.66	0
						5.0	0.35	17.11	0
						5.0	0.40	19.58	0
						5.0	0.45	22.04	0
						5.0	0.50	24.47	0
						5.0	0.20	11.81	0
						5.0	0.25	14.77	0
						5.0	0.30	17.75	0
						5.0	0.35	20.68	0
						5.0	0.40	23.65	0
						5.0	0.45	26.60	0
						5.0	0.50	29.55	0
	5.0	0.2	13.88	0		5.0	0.20	13.88	0
						5.0	0.25	17.34	0
						5.0	0.30	20.76	0
						5.0	0.35	24.28	0
						5.0	0.40	27.77	0
						5.0	0.45	31.19	0
						5.0	0.50	34.63	0
	5.0	0.2	15.87	0		5.0	0.20	15.91	0
						5.0	0.25	19.89	0
						5.0	0.30	23.85	0
						5.0	0.35	27.83	0
						5.0	0.40	31.85	0
	5.0	0.45	35.80	0					
	5.0	0.20	17.93	0					
	5.0	0.25	22.48	0					
	5.0	0.35	31.41	0					
	5.0	0.45	40.39	0					
	5.0	0.20	7.78	2					
	5.0	0.20	9.76	2					
	5.0	0.20	11.81	2					
	5.0	0.20	13.88	2					
	5.0	0.20	15.90	2					
	5.0	0.35	27.83	2					
	5.0	0.50	39.78	2					
	5.0	0.20	17.97	2					
	5.0	0.25	22.41	2					
	5.0	0.35	31.41	2					
	5.0	0.50	44.89	2					







5.0	0.40	27.74	0
5.0	0.45	31.20	0
5.0	0.50	34.66	0
5.0	0.20	15.88	0
5.0	0.25	19.87	0
5.0	0.30	23.87	0
5.0	0.35	27.88	0
5.0	0.40	31.84	0
5.0	0.45	35.80	0
5.0	0.50	39.78	0
5.0	0.15	13.45	0
5.0	0.20	17.94	0
5.0	0.25	22.45	0
5.0	0.30	26.91	0
5.0	0.35	31.39	0
5.0	0.40	35.90	0
5.0	0.45	40.40	0
5.0	0.50	44.87	0
5.0	0.20	5.73	2
5.0	0.20	7.72	2
5.0	0.15	7.35	2
5.0	0.20	9.79	2
5.0	0.25	12.23	2
5.0	0.30	14.67	2
5.0	0.35	17.14	2
5.0	0.40	19.57	2
5.0	0.45	22.02	2
5.0	0.15	8.84	2
5.0	0.20	11.81	2
5.0	0.25	14.74	2
5.0	0.30	17.76	2
5.0	0.35	20.69	2
5.0	0.40	23.65	2
5.0	0.45	26.60	2
5.0	0.50	29.56	2
5.0	0.15	10.40	2
5.0	0.20	13.86	2
5.0	0.25	17.30	2
5.0	0.30	20.85	2
5.0	0.35	24.24	2
5.0	0.40	27.71	2
5.0	0.45	31.21	2
5.0	0.50	34.68	2
5.0	0.15	11.93	2
5.0	0.20	15.92	2
5.0	0.25	19.88	2
5.0	0.30	23.86	2
5.0	0.35	27.85	2

5.0	0.40	31.81	2
5.0	0.45	35.78	2
5.0	0.50	39.80	2
5.0	0.15	13.45	2
5.0	0.20	17.93	2
5.0	0.25	22.43	2
5.0	0.30	26.92	2
5.0	0.35	31.44	2
5.0	0.40	35.91	2
5.0	0.45	40.40	2
5.0	0.50	44.86	2

test=por2	
-----------	--

test=por2	Output	Voltage Step	Hold Time	
	5.0	0.15	6	
	5.0	0.15	8	
	5.0	0.15	10	
	5.0	0.175	10	

test=por3		
part=242	temp=125	
test=por1		
test=por2		
test=por3		

test=por3		
part=242	temp=125	
test=por1		
test=por2		
test=por3		

part=243		temp=25		
test=por1	Output	Ramp Voltage	Ramp Time	Hold Time
	5.0	0.35	9.96	0
	5.0	0.40	11.42	0
	5.0	0.45	12.88	0
	5.0	0.50	14.36	0
	5.0	0.35	13.51	0
	5.0	0.40	15.48	0
	5.0	0.45	17.45	0
	5.0	0.50	19.36	0
	5.0	0.35	17.12	0
	5.0	0.40	19.57	0
	5.0	0.45	22.01	0

part=243		temp=25		
test=por1	Output	Ramp Voltage	Ramp Time	Hold Time
	5.0	0.35	6.37	0
	5.0	0.40	7.30	0
	5.0	0.45	8.16	0
	5.0	0.50	9.21	0
	5.0	0.30	8.58	0
	5.0	0.35	10.01	0
	5.0	0.40	11.43	0
	5.0	0.45	12.86	0
	5.0	0.50	14.27	0
	5.0	0.30	11.60	0
	5.0	0.35	13.53	0
	5.0	0.40	15.50	0
	5.0	0.45	17.41	0
	5.0	0.50	19.33	0
	5.0	0.30	14.66	0
	5.0	0.35	17.11	0
	5.0	0.40	19.56	0
	5.0	0.45	22.02	0

5.0	0.50	24.46	0
5.0	0.35	20.69	0
5.0	0.40	23.67	0
5.0	0.45	26.61	0
5.0	0.50	29.55	0
5.0	0.35	24.21	0
5.0	0.40	27.69	0
5.0	0.45	31.15	0
5.0	0.50	34.67	0
5.0	0.35	27.81	0
5.0	0.40	31.82	0
5.0	0.45	35.80	0
5.0	0.50	39.76	0
5.0	0.35	31.40	0
5.0	0.40	35.89	0
5.0	0.45	40.39	0
5.0	0.50	44.87	0
5.0	0.35	9.98	2
5.0	0.40	11.42	2
5.0	0.45	12.84	2
5.0	0.50	14.32	2
5.0	0.35	13.54	2
5.0	0.40	15.46	2
5.0	0.45	17.46	2
5.0	0.50	19.42	2
5.0	0.35	17.12	2
5.0	0.40	19.58	2
5.0	0.45	22.02	2
5.0	0.50	24.46	2
5.0	0.35	20.69	2
5.0	0.40	23.64	2
5.0	0.45	26.63	2
5.0	0.50	29.62	2
5.0	0.35	24.31	2
5.0	0.40	27.74	2

5.0	0.50	24.44	0
5.0	0.30	17.69	0
5.0	0.35	20.67	0
5.0	0.40	23.62	0
5.0	0.45	26.59	0
5.0	0.50	29.56	0
5.0	0.30	20.78	0
5.0	0.35	24.24	0
5.0	0.40	27.72	0
5.0	0.45	31.18	0
5.0	0.50	34.63	0
5.0	0.30	23.87	0
5.0	0.35	27.85	0
5.0	0.40	31.80	0
5.0	0.45	35.83	0
5.0	0.50	39.81	0
5.0	0.30	26.88	0
5.0	0.35	31.42	0
5.0	0.40	35.90	0
5.0	0.45	40.38	0
5.0	0.50	44.89	0
5.0	0.30	5.42	2
5.0	0.35	6.35	2
5.0	0.40	7.35	2
5.0	0.45	8.18	2
5.0	0.50	9.15	2
5.0	0.30	8.57	2
5.0	0.35	10.01	2
5.0	0.40	11.38	2
5.0	0.45	12.85	2
5.0	0.50	14.30	2
5.0	0.30	11.66	2
5.0	0.35	13.55	2
5.0	0.40	15.47	2
5.0	0.45	17.42	2
5.0	0.50	19.41	2
5.0	0.30	14.67	2
5.0	0.35	17.13	2
5.0	0.40	19.57	2
5.0	0.45	22.01	2
5.0	0.50	24.46	2
5.0	0.30	17.73	2
5.0	0.35	20.73	2
5.0	0.40	23.63	2
5.0	0.45	26.63	2
5.0	0.50	29.55	2
5.0	0.30	20.78	2
5.0	0.35	24.29	2
5.0	0.40	27.70	2





5.0	0.20	3.71	2
5.0	0.35	6.41	2
5.0	0.40	7.34	2
5.0	0.35	10.01	2
5.0	0.50	14.26	2
5.0	0.45	17.42	2
5.0	0.30	14.69	2
5.0	0.40	19.57	2
5.0	0.25	14.78	2
5.0	0.30	17.73	2
5.0	0.35	20.67	2

5.0	0.35	2.86	2
5.0	0.40	3.28	2
5.0	0.45	3.65	2
5.0	0.50	4.05	2
5.0	0.10	1.82	2
5.0	0.15	2.76	2
5.0	0.20	3.63	2
5.0	0.25	4.59	2
5.0	0.30	5.45	2
5.0	0.35	6.39	2
5.0	0.40	7.29	2
5.0	0.45	8.21	2
5.0	0.50	9.13	2
5.0	0.10	2.85	2
5.0	0.15	4.28	2
5.0	0.20	5.70	2
5.0	0.25	7.19	2
5.0	0.30	8.57	2
5.0	0.35	9.99	2
5.0	0.40	11.43	2
5.0	0.45	12.85	2
5.0	0.50	14.30	2
5.0	0.10	3.87	2
5.0	0.15	5.82	2
5.0	0.20	7.72	2
5.0	0.25	9.65	2
5.0	0.30	11.59	2
5.0	0.35	13.52	2
5.0	0.40	15.52	2
5.0	0.45	17.43	2
5.0	0.50	19.35	2
5.0	0.15	7.36	2
5.0	0.20	9.76	2
5.0	0.25	12.24	2
5.0	0.30	14.68	2
5.0	0.35	17.12	2
5.0	0.40	19.56	2
5.0	0.45	22.02	2
5.0	0.50	24.47	2
5.0	0.10	5.93	2
5.0	0.15	8.86	2
5.0	0.20	11.85	2
5.0	0.25	14.79	2
5.0	0.30	17.73	2
5.0	0.35	20.66	2
5.0	0.40	23.63	2
5.0	0.45	26.58	2
5.0	0.50	29.55	2
5.0	0.15	10.39	2

5.0	0.20	13.87	2
5.0	0.35	24.29	2
5.0	0.40	27.76	2
5.0	0.20	15.89	2
5.0	0.45	35.81	2
5.0	0.35	31.41	2
5.0	0.40	35.89	2

test=por2

test=por3

5.0	0.20	13.89	2
5.0	0.25	17.30	2
5.0	0.30	20.81	2
5.0	0.35	24.24	2
5.0	0.40	27.72	2
5.0	0.45	31.16	2
5.0	0.50	34.70	2
5.0	0.15	11.92	2
5.0	0.20	15.91	2
5.0	0.25	19.90	2
5.0	0.30	23.86	2
5.0	0.35	27.83	2
5.0	0.40	31.83	2
5.0	0.45	35.82	2
5.0	0.50	39.78	2
5.0	0.15	13.45	2
5.0	0.20	17.94	2
5.0	0.25	22.44	2
5.0	0.30	26.93	2
5.0	0.35	31.40	2
5.0	0.40	35.90	2
5.0	0.45	40.43	2
5.0	0.50	44.88	2

test=por2	Output	Step Voltage	Hold Time
-----------	--------	--------------	-----------

5.0	0.075	6	
5.0	0.100	6	
5.0	0.125	6	
5.0	0.150	6	
5.0	0.175	6	
5.0	0.050	8	
5.0	0.075	8	
5.0	0.100	8	
5.0	0.125	8	
5.0	0.150	8	
5.0	0.175	8	
5.0	0.050	10	
5.0	0.075	10	
5.0	0.100	10	
5.0	0.125	10	
5.0	0.150	10	
5.0	0.175	10	

test=por3