Application Note ANI-23

Fault Tolerance Testing

Introduction

RS-485 / RS-422 Transceivers with ±60V fault tolerance provide rugged solutions for the real world where equipment can get installed incorrectly, wiring is incorrect or accidentally gets pinched resulting in shorts from ±60V to ground.

There are no industry standard tests, procedures or conditions stated in industry's datasheets for the ±60V specification. So let's put some devices from various vendors to the test. We took 11 different parts from MaxLinear and 4 other vendors and submitted them to two types of tests summarized in Table 1 to evaluate fault tolerance performance. An overview of device specifications is given in Table 2. In addition, a long term test was conducted on the MaxLinear parts, more of a real world scenario.

Test #	Test	Description	Comments
1	Transient Fault Voltage Test	Transient fault voltage applied to Y/Z outputs at 5V increments Vcc = VL = 5V; DI = H or DI = L. Record when failure occurs.	Passed up to ±60V
2	Transient Fault Voltage Test	Same as Test 1, except ±61V transient fault voltage applied to Y/Z outputs and sample size increased	Passed up to ±61V
3	Sweep Voltage Test	Vcc = VL = 5V Connect Y/Z outputs to power supply, slowly sweep voltage from 0V to +80 (and 0V to -80V). Record when failure occurs.	Passed up to ±70V
4	Long Term Fault Short Test	Vcc = VL = 0V Connect Y/Z outputs to fault voltage Power On device with Vcc = VL = 5V Record when failure occurs or stop at 36 hours.	Passed up to ±61V for 36 hours

Table 1: Summary of Fault Tolerance Testing

Function		MaxLinear XR33156	MaxLinear XR33053	MaxLinear XR33158	MaxLinear XR33152	Vendor A Device 1	Vendor A Device 2	Vendor B Device 1	Vendor B Device 2	Vendor C Device 1	Vendor D Devices 1, 2, 3
Fault Protection (V)		±60	±60	±60	±60	±60	±60	±60	±60	±70	±80 /±60*
Common Mode (V)		±25	±25	±25	±25	±25	±25	±25	±25	-20 to +25	-7 to +12
Supply (V)		3.0 - 5.0	3.0 - 5.0	3.0 - 5.0	3.0 - 5.0	4.5 - 5.5	4.5 - 5.5	3.0 - 5.5	3.0 - 5.5	4.5 - 5.5	4.5 - 5.5
Speed (bps)		20Mbps	1Mbps	20Mbps	250kbps	1Mbps	15Mbps	20Mbps	250Kbps	115Kbps	250Kbps 10Mbps
VL pin		Yes	No	No	No	No	No	No	No	No	No
Cable Invert		Yes	No	Yes	Yes	No	No	No	No	No	No
Fail Safe		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Duplex		Full	Full	Half	Half	Full	Full	Full	Full	Full	Half
Unit Load		1/2.5	1/10	1/2.5	1/10	1/4	1/4	1/8	1/8	1/8	1/4
Devices on bus		80	320	80	320	128	128	256	256	256	128
ESD (HBM)	Bus	±15KV	±15KV	±15KV	±15KV	±2KV	±15KV	±15KV	±15KV	±16KV	±15KV
	Other	±4KV	±4KV	±4KV	±4KV	±2KV	±8KV	±8KV	±8KV	±4KV	?
Temperature Grades (°C)		-40 to 85, -40 to 105	-40 to 85, -40 to 105	-40 to 85, -40 to 105	-40 to 85, -40 to 105	-40 to 85	-40 to 85	0 to 70, -40 to 85, -40 to 125	0 to 70, -40 to 85, -40 to 125	-40 to 105	-40 to 105
Packages		SOIC-8	SOIC-14	SOIC-8	SOIC-8	SOIC-14	SOIC-14, MSOP-10	SOIC-14, DFN-10	SOIC-14, DFN-10	SOIC-14	SOIC-14, SOIC-8

Table 2: Specification Comparison

Test 1: Transient Fault Voltage test to output Y/Z

Test Setup:

Application evaluation board with Vcc = VL = 5.0V, VL with 0.1uF, Vcc with 0.1uF and 10uF on VL.

HP6236B DC-Tripple outputs supply for fault transient testing voltage.

HP E3631A DC Power supply for Vcc = VL = 5V.

Test Procedure:

1. Power on device with Vcc = VL = 5V
2. First fault voltage with DI = H (+25V)
3. Retest the device with another setup. Making sure the device is still functional after the transient test.
4. Second fault voltage with DI = L (+25V)
5. Retest the device with another setup. Making sure the device is still functional after the transient test.
6. Third fault voltage with DI = H (-25V)
7. Retest the device with another setup. Making sure the device is still functional after the transient test.
8. Fourth fault voltage with DI = L (-25V)
9. Repeat the process from step 2 to step 8, at 5V interval until part failure occurs.
10. Record the fault voltage when failure occurs.

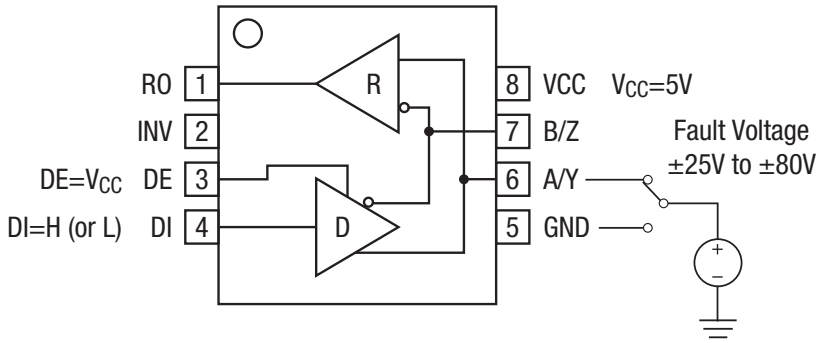

Figure 1: XR33152 / XR33158 Test Setup

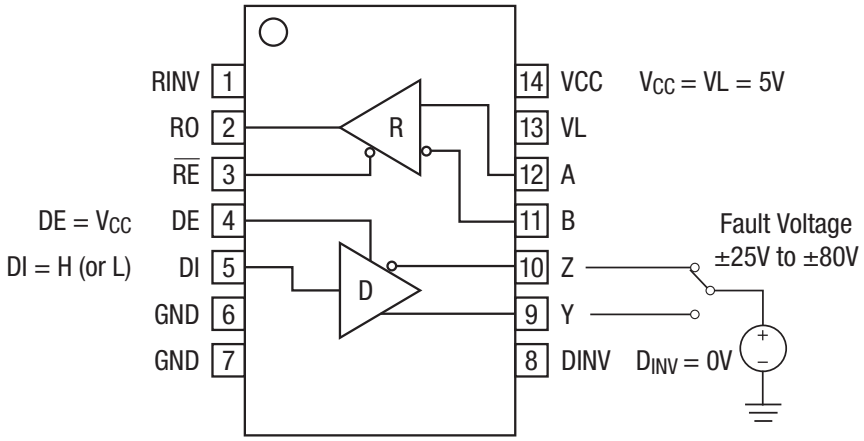

Figure 2: XR33156 / XR33053 Test Setup

Part[1] /Fault (V)		25	-25	30	-30	35	-35	40	-40	45	-45	50	-50	55	-55	60	-60	65	-65	70	-70	75	-75	80	-80
DI=		H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
		L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
Vendor Device 1	1	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P									
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	F									
Vendor Device 1	2	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P									
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	F									
Vendor Device 2	1	P	P	P	P	P	P	P	P	P	P	P													
		P	P	P	P	P	P	P	P	P	P	F													
Vendor Device 2	2	P	P	P	P	P	P	P	P	P	P	P													
		P	P	P	P	P	P	P	P	P	P	F													
Vendor B Device 1	1	P	P	F																					
		P	P																						
Vendor B Device 1	2	P	P	F																					
		P	P																						
Vendor B Device 2	1	P	P	P	P	P	P	F																	
		P	P	P	P	P	P																		
Vendor B Device 2	2	P	P	P	P	P	P	P																	
		P	P	P	P	P	P	P	F																
Vendor C Device 1	1	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F				
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P					
Vendor C Device 1	2	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P					
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F					
Vendor D Device 1	1	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F			
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P				
Vendor D Device 1	2	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P				
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P				
Vendor D Device 2	1	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F					
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P						
Vendor D Device 2	2	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P				
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F				
Vendor D Device 3	1	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P				
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P				
Vendor D Device 3	2	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P				
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P				
XR33152	1	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F	Fail 65.2						
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P							
XR33152	2	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F	Fail 65.6						
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P							
XR33152	3	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P		Fail -66.4						
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F							
XR33156	1	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	Fail 68.1						
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P							
XR33156	2	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F	Fail 65.5						
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P							
XR33156	3	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P		Fail -66.1						
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F							
XR33158	1	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F	Fail 65.5						
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P							
XR33158	2	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	Fail -66.2						
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F							
XR33158	3	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F	Fail 65.43						
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P							
XR33053	1	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F	Fail 65.6						
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P							
XR33053	2	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F	Fail 65.7						
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P							
XR33053	3	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F	Fail 65.2						
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P							

NOTE 1: VL nd V_{CC} with 0.1uF, V_{CC} = VL, Output Y nd 10 uF on VL

Table 3: Test 1 Fault Tolerance Test Results

Vendor	Device	Fault Tolerance Clain (±V)	Test 1 Summary	% of Claim
Exar	XR33152	60	60	100.0
	XR33156	60	60	100.0
	XR33158	60	60	100.0
	XR33053	60	60	100.0
Vendor A	1	60	45	75.0
	2	60	55	91.7
Vendor B	1	60	25	41.7
	2	60	35	58.3
Vendor C	1	70	65	92.9
Vendor D	1	80	70	87.5
	2	80	65	81.3
	3	80	70	87.5

Table 4: Summary of Test 1 Fault Tolerance Test Results

Test 2: Transient Fault Voltage Test to output Y and Z, ±61V on Exar Devices

Test Procedure:

Additional testing was performed to solidify the 4 MaxLinear parts. Test 1 was performed with fault voltage set at an increased ±61V with an increased sample size of 10 each of the XR33156, XR33053, XR33158 and XR33152.

Part(1)	Fault (V)	25	-25	30	-30	35	-35	40	-40	45	-45	50	-50	55	-55	61	-61	65	-65	70	-70
DI=		H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
		L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
XR33152	1															P	P				
																P	P				
XR33152	2															P	P				
																P	P				
XR33152	3															P	P				
																P	P				
XR33152	4															P	P				
																P	P				
XR33152	5															P	P				
																P	P				
XR33152	6															P	P				
																P	P				
XR33152	7															P	P				
																P	P				
XR33152	8															P	P				
																P	P				
XR33152	9															P	P				
																P	P				
XR33152	10															P	P				
																P	P				

NOTE 1: VL and VCC with 0.1uF, VCC = VL, Output Y and 10 uF on VL

Table 5: Half Duplex XR33152 Transient Test, DI = H / L, ±61V Fault Tolerance to Both Z or Y

Part[1]	Fault (V)	25	-25	30	-30	35	-35	40	-40	45	-45	50	-50	55	-55	61	-61	65	-65	70	-70
DI=		H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
		L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
XR33156	1															P	P				
																P	P				
XR33156	2															P	P				
																P	P				
XR33156	3															P	P				
																P	P				
XR33156	4															P	P				
																P	P				
XR33156	5															P	P				
																P	P				
XR33156	6															P	P				
																P	P				
XR33156	7															P	P				
																P	P				
XR33156	8															P	P				
																P	P				
XR33156	9															P	P				
																P	P				
XR33156	10															P	P				
																P	P				

NOTE 1: VL and V_{CC} with 0.1uF, V_{CC} = VL, Output Y and 10 uF on VL

Table 6: Full Duplex XR33156 Transient Test, DI = H / L, ±61V Fault Tolerance to Both Z or Y

Part[1]	Fault (V)	25	-25	30	-30	35	-35	40	-40	45	-45	50	-50	55	-55	61	-61	65	-65	70	-70
DI=		H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
		L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
XR33158	1															P	P				
																P	P				
XR33158	2															P	P				
																P	P				
XR33158	3															P	P				
																P	P				
XR33158	4															P	P				
																P	P				
XR33158	5															P	P				
																P	P				
XR33158	6															P	P				
																P	P				
XR33158	7															P	P				
																P	P				
XR33158	8															P	P				
																P	P				
XR33158	9															P	P				
																P	P				
XR33158	10															P	P				
																P	P				

NOTE 1: VL and V_{CC} with 0.1uF, V_{CC} = VL, Output Y and 10 uF on VL

Table 7: Half Duplex XR33158 Transient Test, DI = H / L, ±61V Fault Tolerance to Both Z or Y

Part[1]	Fault (V)	25	-25	30	-30	35	-35	40	-40	45	-45	50	-50	55	-55	61	-61	65	-65	70	-70
DI=		H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
		L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
XR33053	1															P	P				
																P	P				
XR33053	2															P	P				
																P	P				
XR33053	3															P	P				
																P	P				
XR33053	4															P	P				
																P	P				
XR33053	5															P	P				
																P	P				
XR33053	6															P	P				
																P	P				
XR33053	7															P	P				
																P	P				
XR33053	8															P	P				
																P	P				
XR33053	9															P	P				
																P	P				
XR33053	10															P	P				
																P	P				

NOTE 1: VL and V_{CC} with 0.1uF, V_{CC} = VL, Output Y and 10 uF on VL

Table 8: Full Duplex XR33053 Transient Test, DI = H / L, ±61V Fault Tolerance to Both Z or Y

Vendor	Device	Fault Tolerance Clain (±V)	Test 1,2 Summary	% of Claim
Exar	XR33152	60	61	101.7
	XR33156	60	61	101.7
	XR33158	60	61	101.7
	XR33053	60	61	101.7
Vendor A	1	60	45	75.0
	2	60	55	91.7
Vendor B	1	60	25	41.7
	2	60	35	58.3
Vendor C	1	70	65	92.9
Vendor D	1	80	70	87.5
	2	80	65	81.3
	3	80	70	87.5

Table 9: Updated Summary of Test 1 and Test 2 Fault Tolerance Test Results

Test 3: Sweep Voltage Test

Test Procedure:

1. Vcc = VL = 0V
2. Connect output Y (or Z) to DC power supply at 0V.
3. Power on device with Vcc = VL = 5V.
4. Set driver input DI = L (or H), slowly ramping-up voltage from (0 to ±80V).
5. Record when failure occurs.

Part[1]	Fault (±V)	0	5	10	15	20	25	30	35	40	45	50	55	55	60	65	70	75	80	85
DI=		L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
		H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Vendor A Device 1	1	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F				
		P	P	P	P	P	P	P	P	P	P	P	P	P	P					
Vendor A Device 2	1	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P				
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	F				
Vendor B Device 1	1	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P				
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	F				
Vendor B Device 2	1	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P				
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	F				
Vendor C Device 1	1	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F		
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P			
Vendor C Device 1	2	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P		
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F		
Vendor D Device 1	1	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P		
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F		
Vendor D Device 2	1	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F		
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P			
Vendor D Device 3	1	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	
XR33152	1	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F	Fail 73.4	
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P			
XR33152	2	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F	Fail 72.8	
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P			
XR33152	3	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P		Fail -72.7	
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F		
XR33156	1	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	Fail -70.5	
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F		
XR33156	2	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F	Fail 71.1	
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P			
XR33158	1	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P		Fail -72.8	
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F		
XR33158	2	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F	Fail 73.2	
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P			
XR33053	1	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F	Fail 70.5	
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P			
XR33053	2	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F	Fail 71.5	
		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P			

Table 10: Sweep Voltage Test Results

Vendor	Device	Fault Tolerance Clain (±V)	Test 1 Summary	% of Claim	Test 3 Summary	% of Claim
Exar	XR33152	60	61	101.7	70	116.7
	XR33156	60	61	101.7	70	116.7
	XR33158	60	61	101.7	70	116.7
	XR33053	60	61	101.7	70	116.7
Vendor A	1	60	45	75.0	60	100.0
	2	60	55	91.7	60	100.0
Vendor B	1	60	25	41.7	60	100.0
	2	60	35	58.3	60	100.0
Vendor C	1	70	65	92.9	70	100.0
Vendor D	1	80	70	87.5	70	87.5
	2	80	65	81.3	70	87.5
	3	80	70	87.5	80	100.0

Table 11: Summary of Test 3 Results Added to Tests 1 and 2

Test 4: Long Term Fault Short Test

Test Procedure:

Performed on XR33156 Full Duplex and XR33152 Half Duplex devices.

1. Device is powered off (Vcc = 0V), DI = 1Mbps input.
2. Connect Y and Z outputs to +61V
3. Power on device (Vcc = 5V). Record elapse time.
4. Power off device. Remove fault voltage.
5. Test Y/Z outputs (making sure that it is still functional after long term test).
6. Repeat Step 1 to Step 5 for -61V.

XR33156	Voltage		Time	Note
Number	Start	End	Elapsed	
38	61V	61V	36 hours	Both Y and Z are functional after 36 hrs
38	-61V	-61V	36 hours	Both Y and Z are functional after 36 hrs
39	61V	61V	36 hours	Both Y and Z are functional after 36 hrs
39	-61V	-61V	36 hours	Both Y and Z are functional after 36 hrs

Table 12: XR33156 Long Term Fault Short Test Results

XR33152	Voltage		Time	Note
Number	Start	End	Elapsed	
40	61V	61V	36 hours	Both Y and Z are functional after 36 hrs
40	-61V	-61V	36 hours	Both Y and Z are functional after 36 hrs
41	61V	61V	36 hours	Both Y and Z are functional after 36 hrs
41	-61V	-61V	36 hours	Both Y and Z are functional after 36 hrs

Table 13: XR33152 Long Term Fault Short Test Results

Conclusion

The other vendors must be using the Sweep Voltage Testing to claim the fault tolerance capabilities of their devices. The MaxLinear parts pass the Sweep Voltage Test at +/- 70V, 116.7% of the +/-60V specification. However the results of the testing suggest that other vendors either just meet their spec and some do not meet it. The MaxLinear parts had similar results to Vendor D in the Sweep Voltage Tests, even though their device is rated higher.

The Sweep Voltage Test is easier, as can be seen by the voltages achieved in all of the test results. However, the Fault Voltage of Tests 1 and 2 is more realistic of conditions that will occur in the real usage of the devices. The MaxLinear devices were the only ones that met and exceeded the claimed fault voltage specification under all test conditions. The MaxLinear devices passed the Long Term Short Tests as well.

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