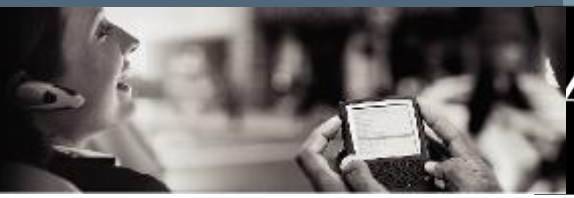
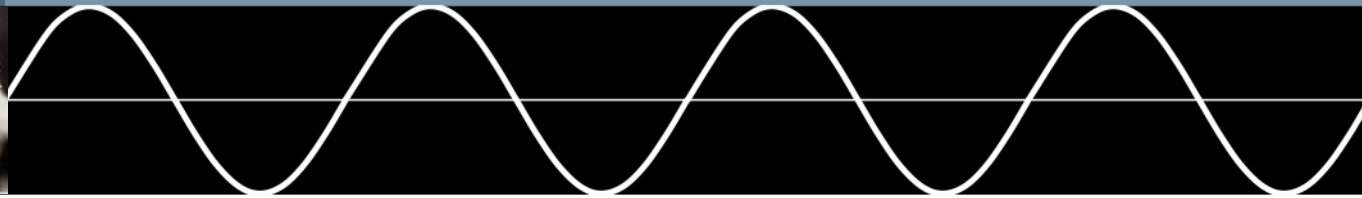
IEEE802.3bt
Cable Balance Ad-Hoc

PSE & PD Powered Interface (PI) Specifications Models, Values and Current Balance Results
Rev 1.26

J. Heath – Linear Technology



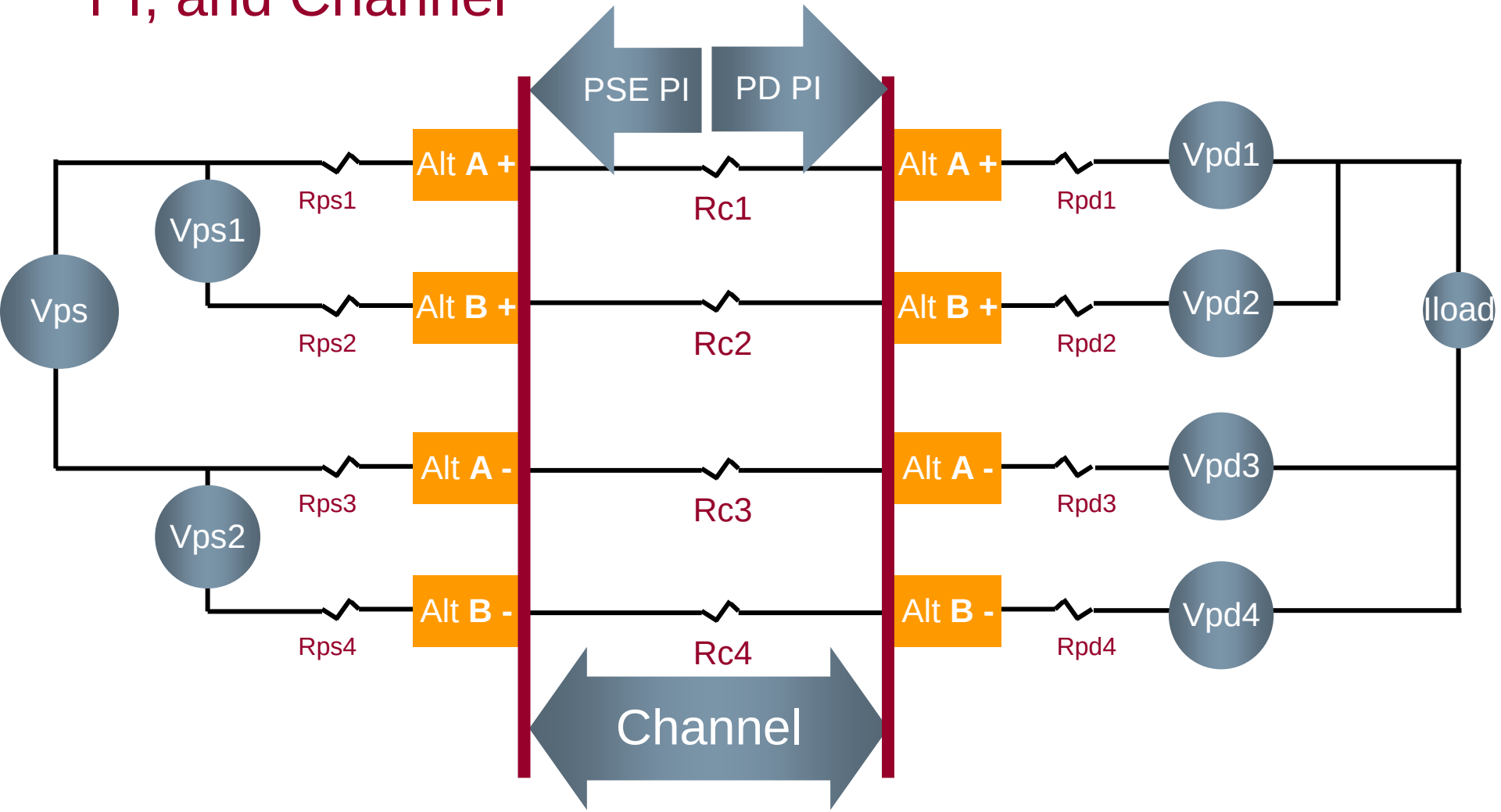


LINEAR TECHNOLOGY

PSE & PD PI Definition and Current Imbalance Method

- Determine reasonable Thevenin values for the PSE PI and PD PI based on current PSE design knowledge base
- Goal: Provide implementation independent and testable PI interfaces for the PSE & PD that ensure interoperability
- Simulate all 3 system components (the two PIs and the “link segment” or channel) with careful selection of worst case values at multiple current levels.
  - ***The proposed ad-hoc products are the highest individual pair current vs power level and the PSE PI and PD PI.***
  - ***(Not a % current imbalance number)***

End to End Current Model including PSE PI, PD PI, and Channel



Channel Imbalance

- Maximum Channel 2 pair Resistance 100m
  - Cat5 Channel 12.5 ohms (TBR)
  - Cat6 Close to Cat5 (TBD)
  - Wayne Larsen is suggesting lesser 100m Channel Resistance
- Pair to Pair Imbalance
  - Greater of (7% of total channel resistance) or .2 ohms (TBR)
- Model under review.

Simplified Cable Resistance and Rimbalance CAT5e vs. Length

Channel

			Length (m)	Channel Rmax	Channel Rmin	Calculated Rchannel	Imbalance	If By %	
Max Length	100	m	1	*0.200*	0.000	0.063	0.200	0.004	ohms
Max 2 Pair PoE Round Trip Channel Resistance	12.5	ohms	2	*0.200*	0.000	0.125	0.200	0.009	
Max 1 Pair Resistance (one way)	6.25	ohms	5	0.313	0.113	0.313	0.200	0.022	
Ratio Imbalance	7%	ohms/ohm	10	0.625	0.425	0.625	0.200	0.044	
Min Imbalance	0.2	ohms	20	1.250	1.050	1.250	0.200	0.088	
			30	1.875	1.675	1.875	0.200	0.131	
			40	2.500	2.300	2.500	0.200	0.175	
			50	3.125	2.906	3.125	0.219	0.219	
			60	3.750	3.488	3.750	0.263	0.263	
			70	4.375	4.069	4.375	0.306	0.306	
			80	5.000	4.650	5.000	0.350	0.350	
			90	5.625	5.231	5.625	0.394	0.394	
			100	6.250	5.813	6.250	0.438	0.438	

Special Case

Starting Point is Maximum Pair Resistance for Max Pair

Max – Min => Imbalance

LINEAR TECHNOLOGY

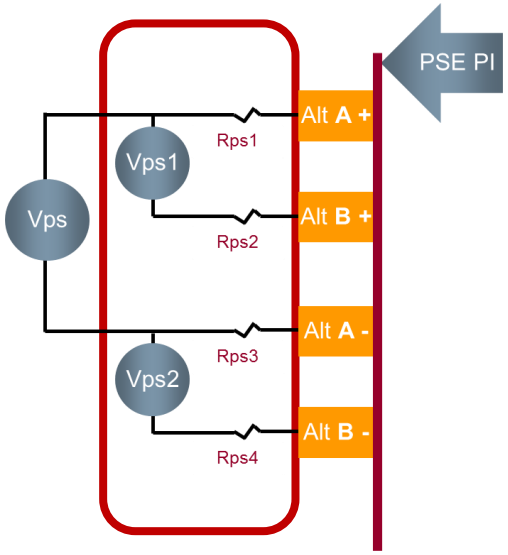
Keeping the PSE & PI Definitions Implementation Independent

- Delta resistance values and delta voltage values are the best way to keep the PI definition implementation independent
- PI definition does not include total resistance, just delta resistance
- We are NOT attempting to telling the OEMs how much resistance they can have in a PSE or PD
- (A single point PI measurement cannot fully characterize a PSE or PI.)

PSE PI Values and Simulation Support Information

- (Included DCMPS & ACMPS for now)

	PI Spec	DCMPS	ACMPS		System Simulation Support	DCMPS	ACMPS	
Rps1,Rps2	abs(Rps1 - Rps2)	0.095	0.145	ohms	Rps1,Rps2 Max	0.330	0.380	ohms
				ohms	Rps1,Rps2 Min	0.120	0.120	ohms
Vps1	abs(Maximum)	0.050	0.150	Volts	Vps1max	0.050	0.750	Volts
					Vps1min	0.000	0.300	
Rps3,Rps4	abs(Rps3 - Rps4)	0.202	0.252	ohms	Rps3, Rps4 Max	1.080	1.130	ohms
				ohms	Rps3, Rps4 Min	0.240	0.290	ohms
Vps2	abs(Maximum)	0.050	0.150	Volts	Vps2 Max	0.050	0.750	Volts
					Vps2 Min	0.000	0.300	Volts
Vps	*See Simulation Schematic*				Vps Max	57.000		Volts
					Vps Min	50.000		Volts
	ACMPS Diodes							
	Rps1 -> 4 Max		0.050	ohms	Rps1 -> 4 Max		0.050	ohms
	Vps1,2		0.100	Volts	Vps1,2 Max		0.700	Volts
					Vps1,2 Min		0.300	Volts



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Vps1	ABS(Maximum)	0.050	0.150	Volts	Vps1max	0.050	0.750	Volts
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Rps3,Rps4	abs(Rps3 - Rps4)	0.202	0.252	ohms	Rps3, Rps4 Max	1.080	1.130	ohms
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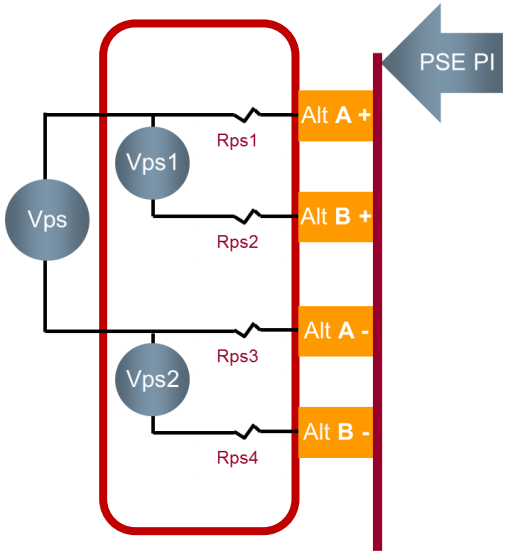
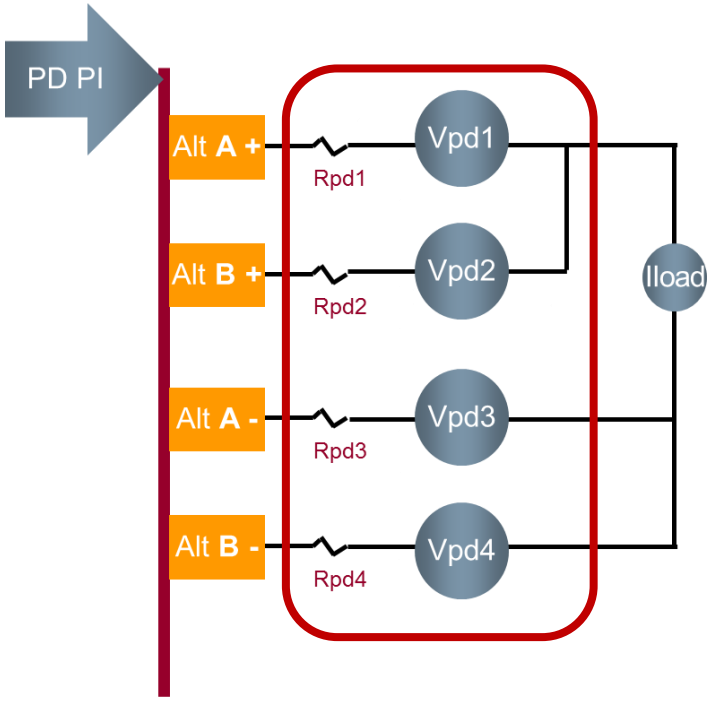
Vps2	ABS(Maximum)	0.050	0.150	Volts	Vps2 Max	0.050	0.750	Volts
					Vps2 Min	0.000	0.300	Volts
Vps	See Simulation Schematic				Vps Max	57.000		Volts
					Vps Min	50.000		Volts
	ACMPS Diodes		0.050	ohms			0.050	ohms
			0.100	Volts	Max		0.700	Volts
					Min		0.300	Volts



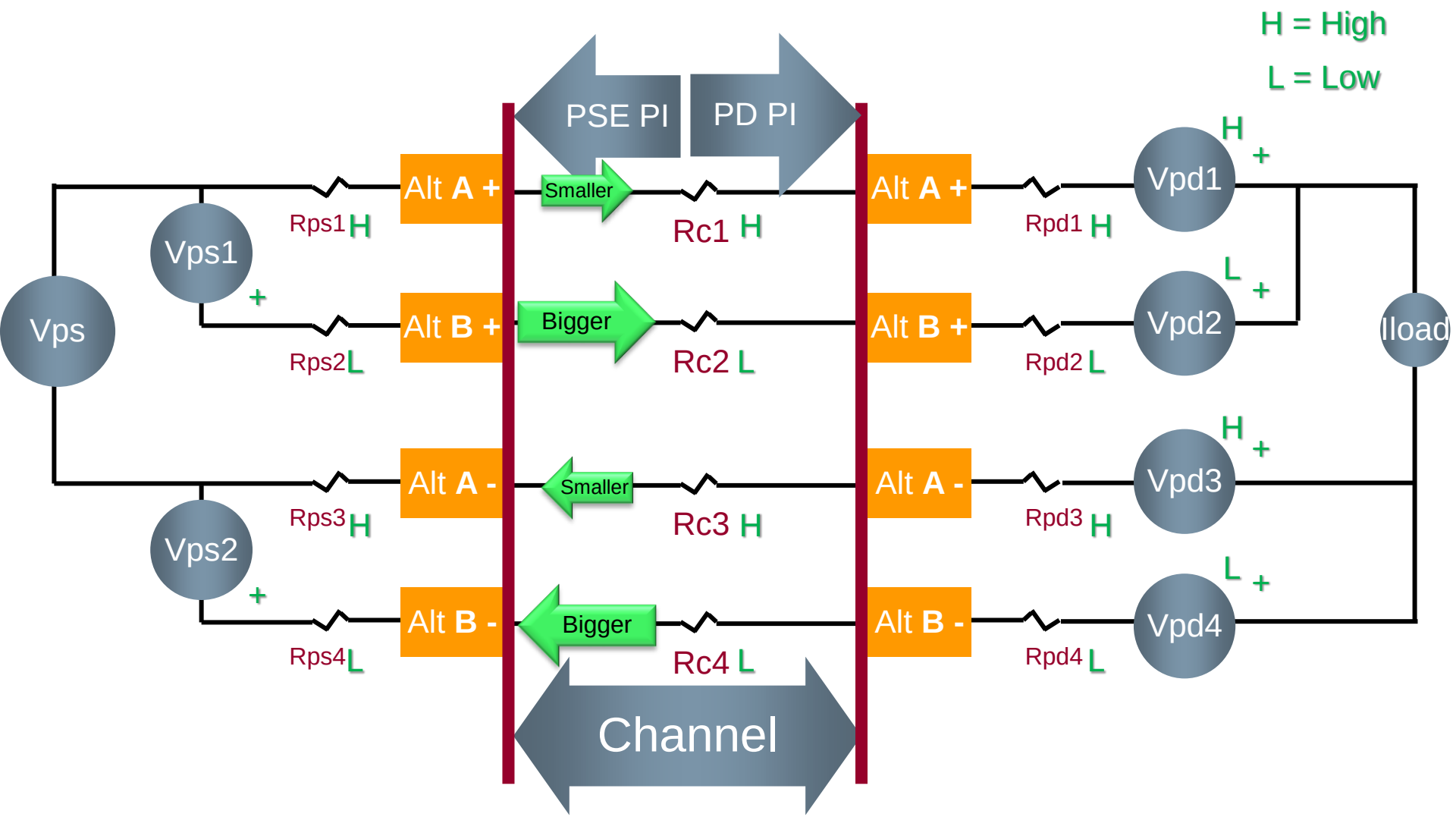
PD PI Values and Simulation Support Information

	PI Spec	DCMPS		
Rpd1,Rpd2	abs(Rpd1 - Rpd2)	0.195		ohms
				ohms
Vpd1,Vpd2	abs(Vpd1-Vpd2)	0.100		Volts
Rpd3,Rpd4	abs(Rpd3 - Rpd4)	0.295		ohms
				ohms
Vpd3,Vpd4	abs(Vpd3 - Vpd4)	0.100		Volts

System Simulation Support	DCMPS	
Rpd1,Rpd2 Max	0.780	ohms
Rpd1,Rpd2 Min	0.320	ohms
Vpd1,Vpd2 Max	0.800	Volts
Vpd1,Vpd2 Min	0.300	
Rpd3, Rpd4 Max	1.180	ohms
Rpd3, Rpd4 Min	0.340	ohms
Vpd3,Vpd4 Max	0.800	Volts
Vpd3,Vpd4 Min	0.300	Volts

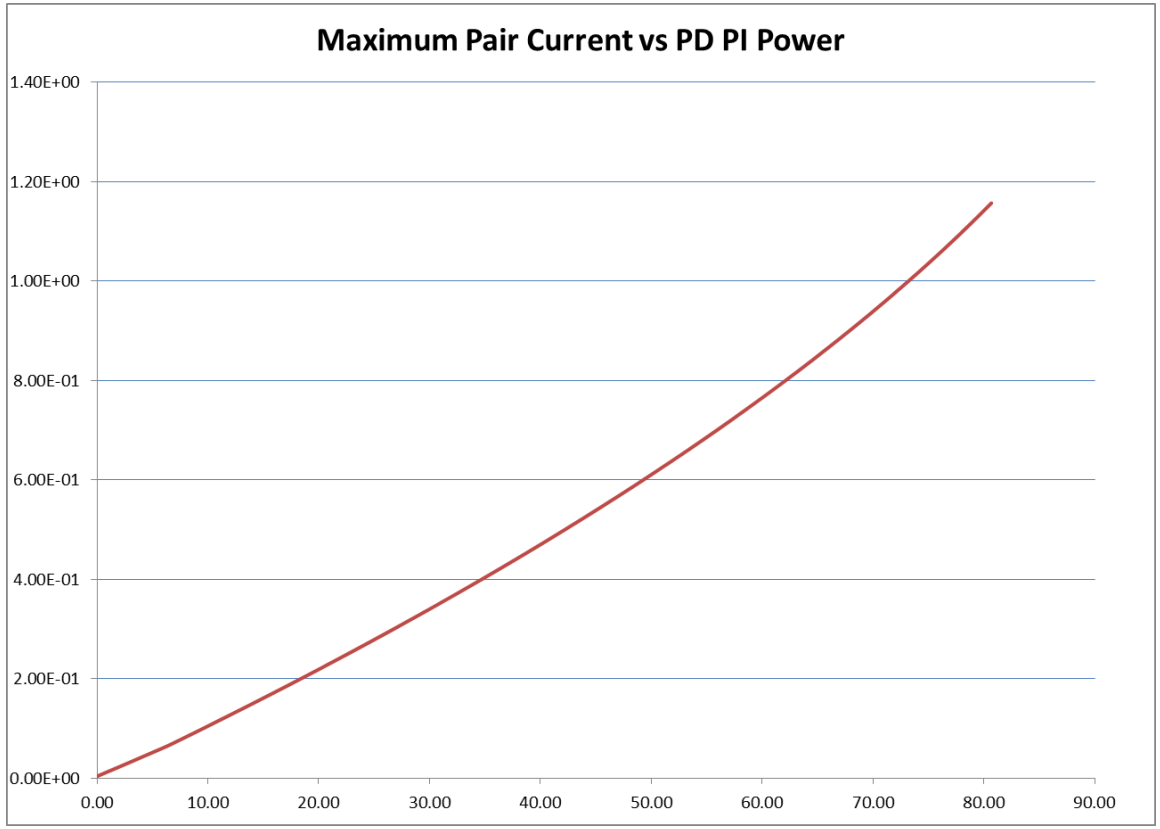


System Simulation Schematic 'Worst Case'



Maximum Pair System Current vs Power

Today's Results



PD Power (W)	Short Channel I (mA)	Long Channel I (mA)	Mair Max (mA)
6	93	49	93
13	147	141	147
25.5	236	278	278
51	425	629	629
75	604	1039	1039

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Values and Results

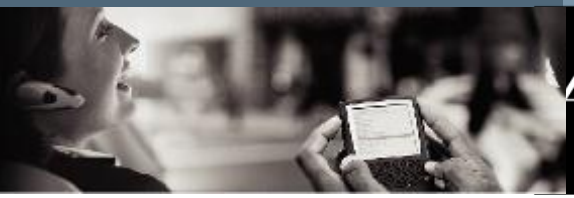
- Values are simulated in LTSpice
- Maximum “pair current” reported in each simulation condition and then the maximum of these maximums is reported
- Re-simulation will be required as values continue to change

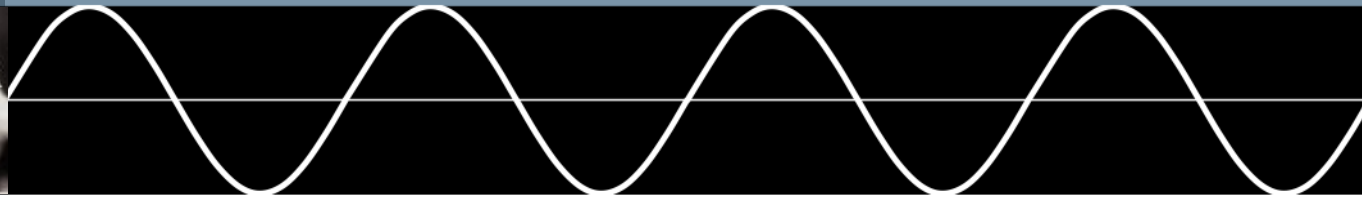
To Do

- Follow the continuing resistance and voltage parameters as they evolve and re-simulate
- Add AC disconnect diodes to the PSE PI and adjust PSE PI values and re-simulate
- Simulate the 4 channel length resistances for 0.15m, 4m, 23m, 100m Wayne is suggesting using his values.
- Create a different and more realistic PSE and PD that could be useful for looking at the upcoming DC disconnect discussions

Backup Material

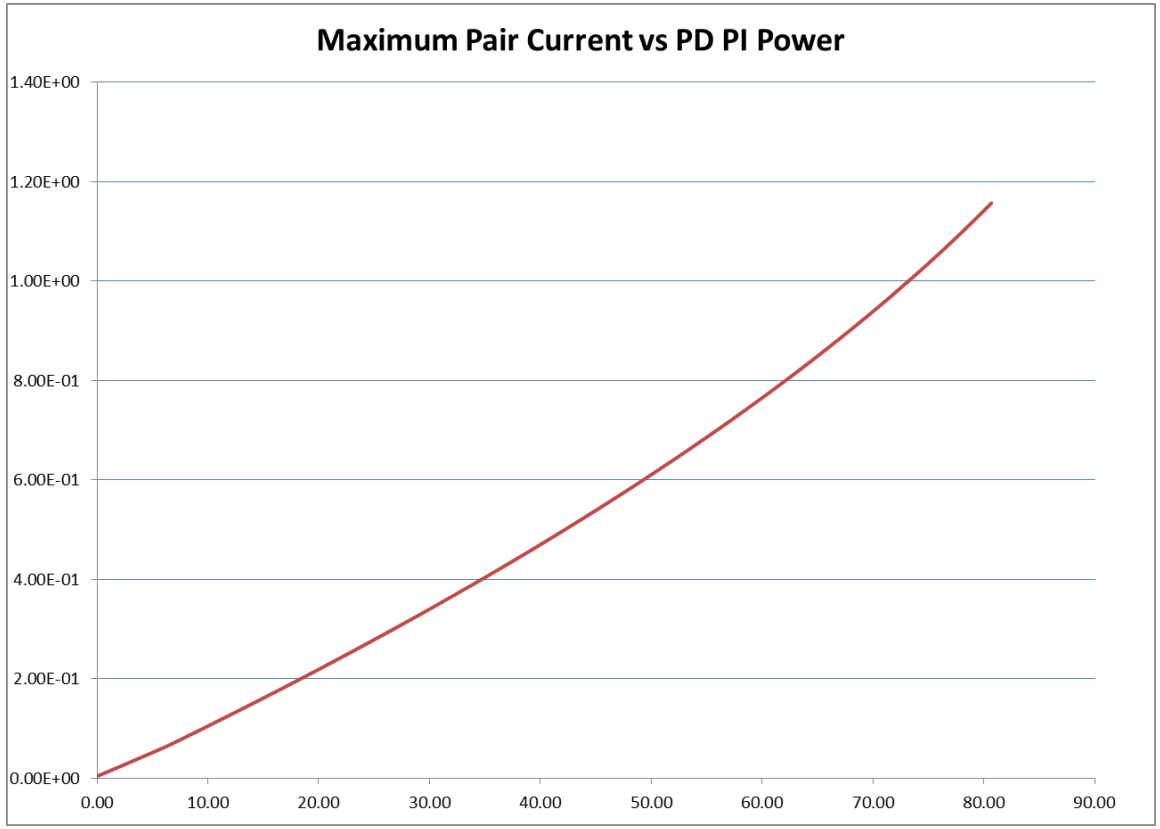
J. Heath





Maximum Pair System Current vs Power

Today's Results



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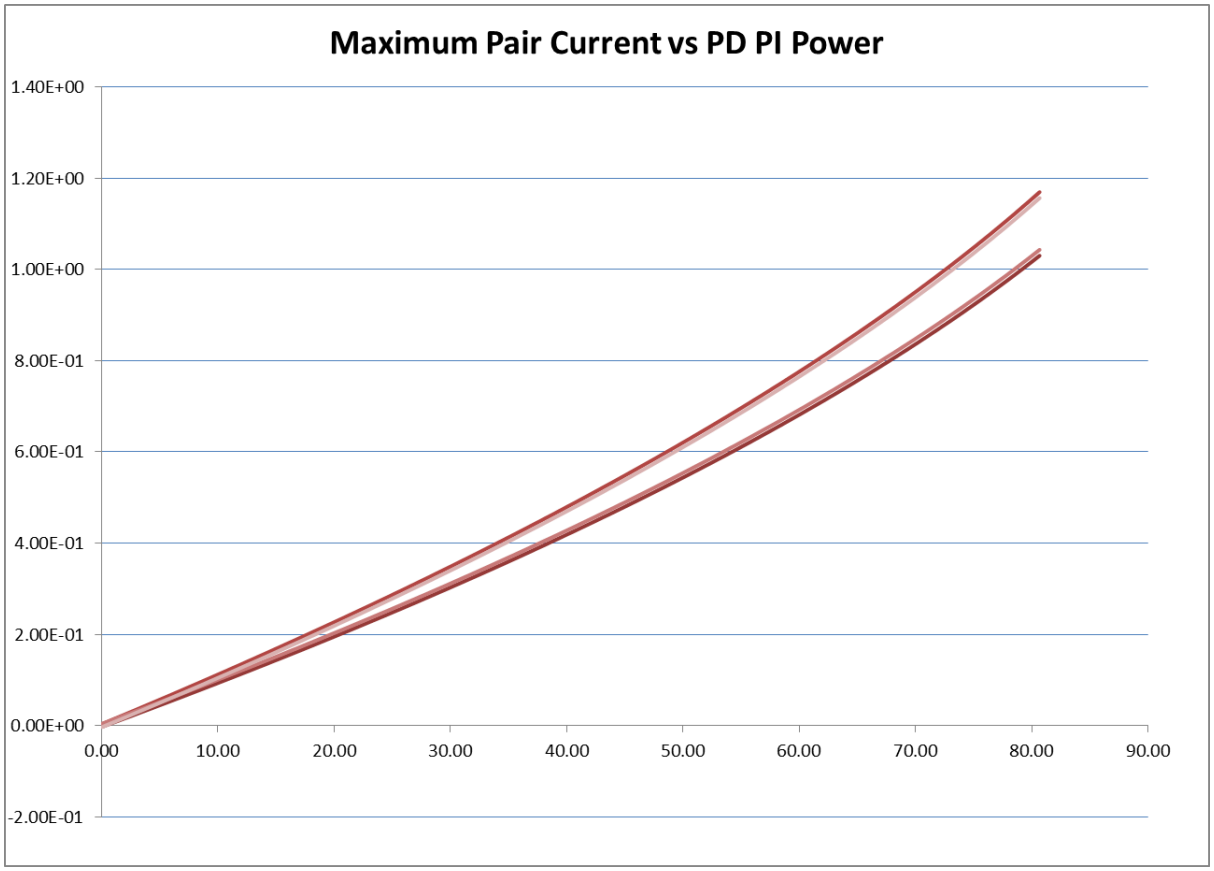
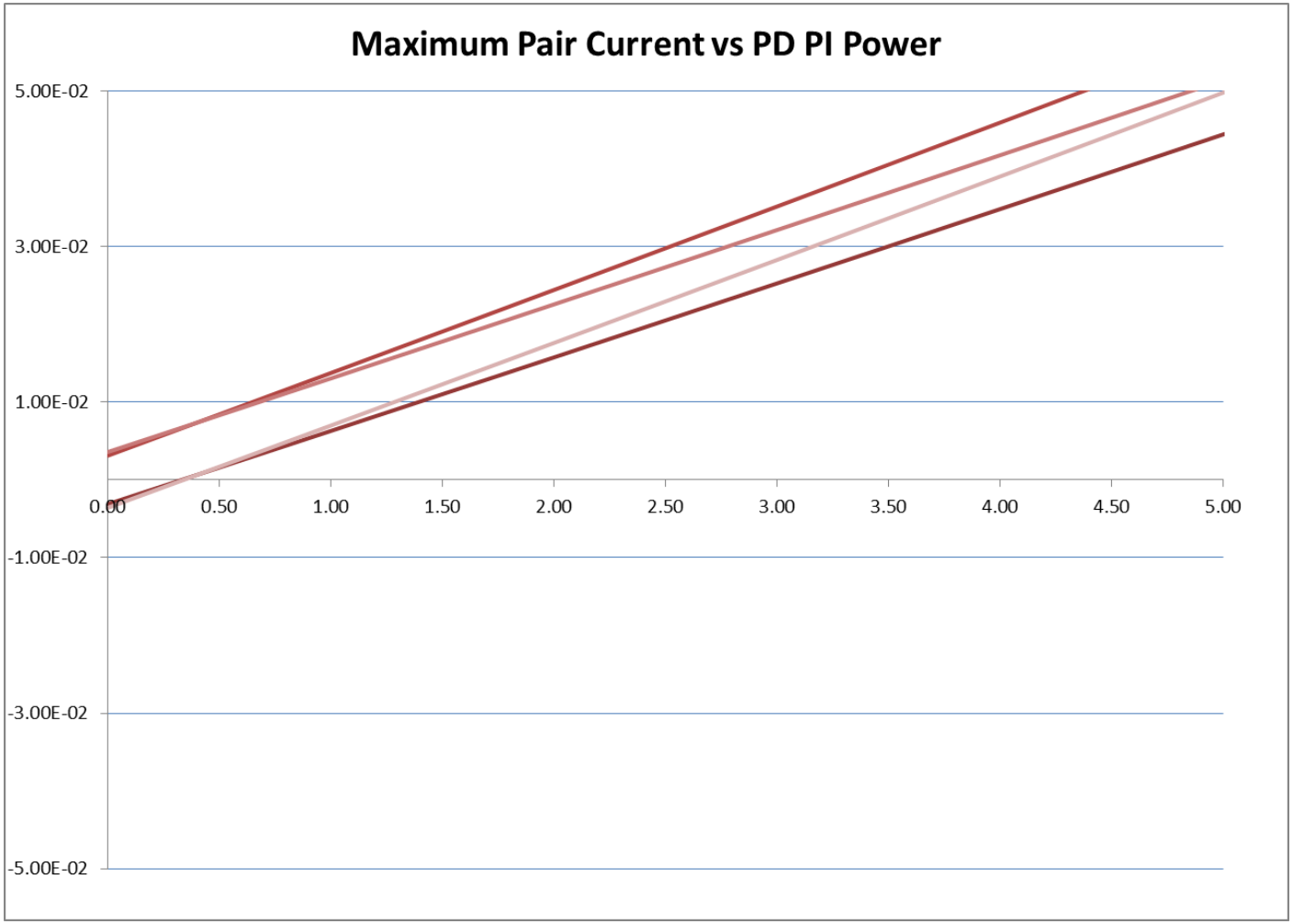
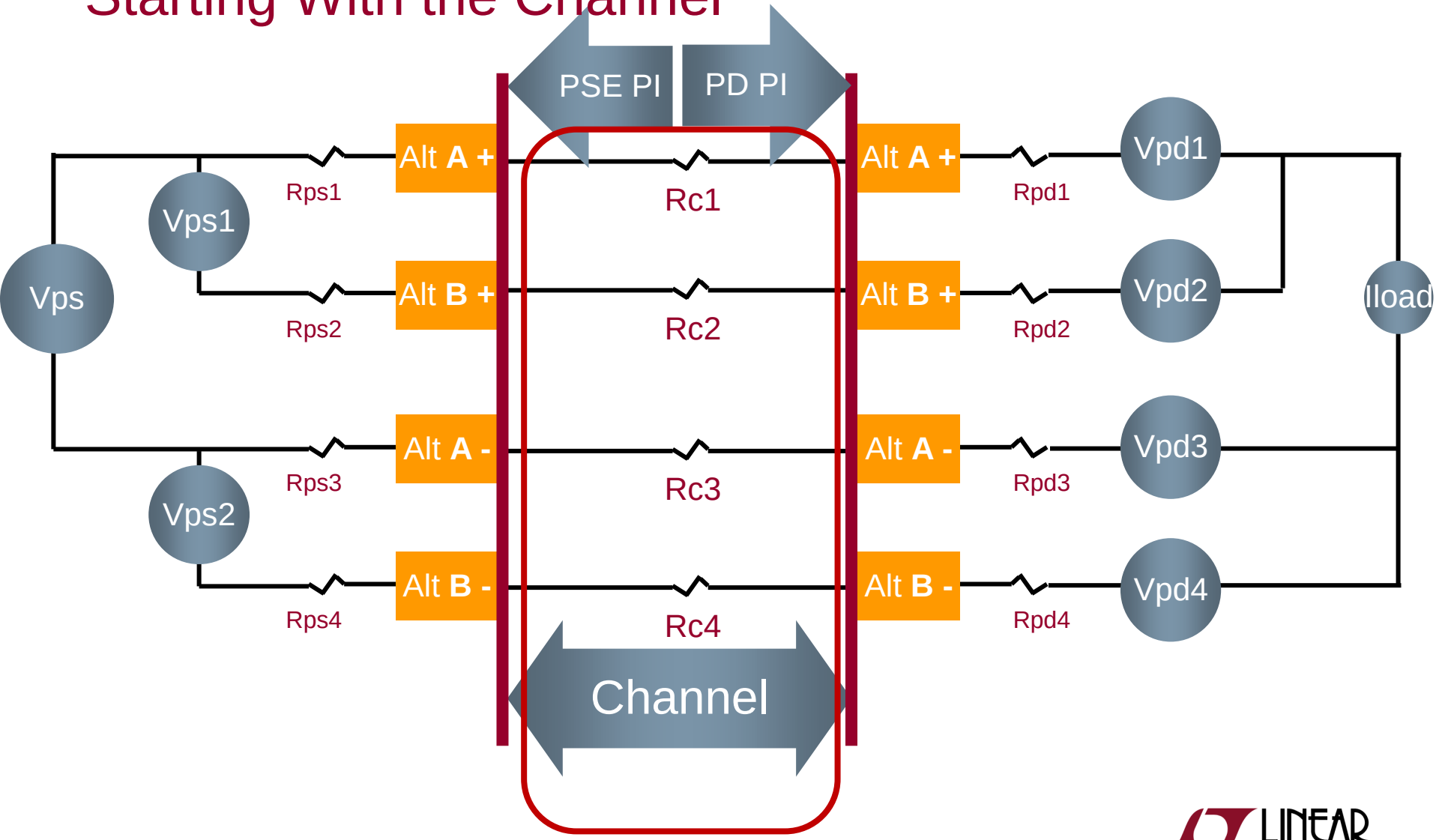


Simplified Diode Model Results at Low Currents Suggest a Better Model Would be Useful



Starting With the Channel



Some Channel Imbalance Values from Wayne Larsen for Simulations

	9.38	14	rnom connector	60
	5.00%	5.00%	Rimbalnce connector	30
	cable length	cordage length	total length	connectors
A	0	0.15	0.15	0
B	3	1	4	2
C	15	8	23	4
D	90	10	100	4
	max channel resistance	min channel resistance	channel unbalance, Ohms	channel unbalance %
A	0.021	0.019	0.002	5.00%
B	0.541	0.441	0.100	10.19%
C	2.767	2.406	0.361	6.97%
D	10.082	9.025	1.057	5.53%

Channel Imbalance

- Maximum Channel 2 pair Resistance 100m
  - Cat5 12.5 ohms (TBR)
  - Cat6 Close to Cat5 (TBD)
- Pair to Pair Imbalance
  - Greater of (6% of total channel resistance) or .2 ohms (TBR)

Cable Resistance and Rimbalance CAT5e vs. Length

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			Length (m)	Channel Rmax	Channel Rmin	Calculated Rchannel	Imbalance	If By %	
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Min Imbalance	0.2	ohms	20	1.250	1.050	1.250	0.200	0.088	
			30	1.875	1.675	1.875	0.200	0.131	
			40	2.500	2.300	2.500	0.200	0.175	
			50	3.125	2.906	3.125	0.219	0.219	
			60	3.750	3.488	3.750	0.263	0.263	
			70	4.375	4.069	4.375	0.306	0.306	
			80	5.000	4.650	5.000	0.350	0.350	
			90	5.625	5.231	5.625	0.394	0.394	
			100	6.250	5.813	6.250	0.438	0.438	

Special Case

Starting Point is Maximum Pair Resistance for Max Pair

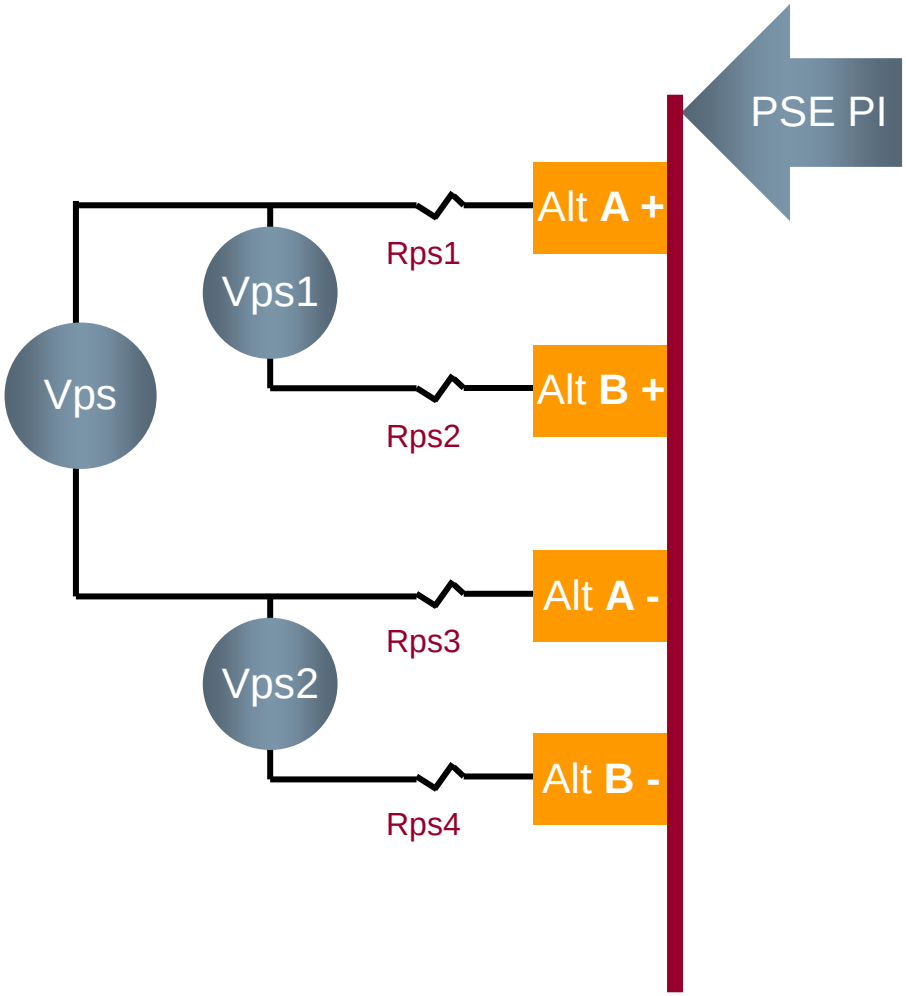
Max – Min => Imbalance

LINEAR TECHNOLOGY

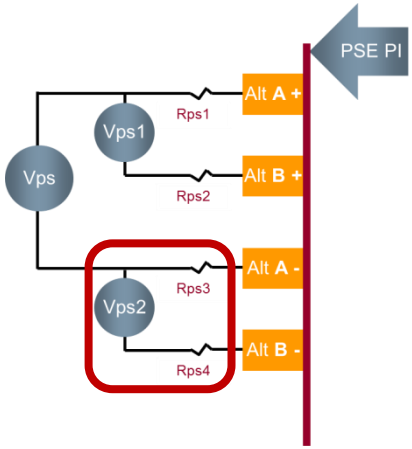
Why Separate PSE & PD PI definitions and System Simulation Values?

- *To stay away from implementation*
- *At the PSE & PD PI it is the differences between resistances and between voltages that cause current imbalance*
  - *Delta resistance and voltage values cause current imbalance*
  - *Large 'nominal' resistances will ballast delta voltage values within the PSE and PD PIs.*
- PSE and PD PI definitions can be specified in terms of worst case differences
- For system level simulations, separate High/Low values are determined and used for end to end simulation to calculate worst case current in any pair.

PSE PI



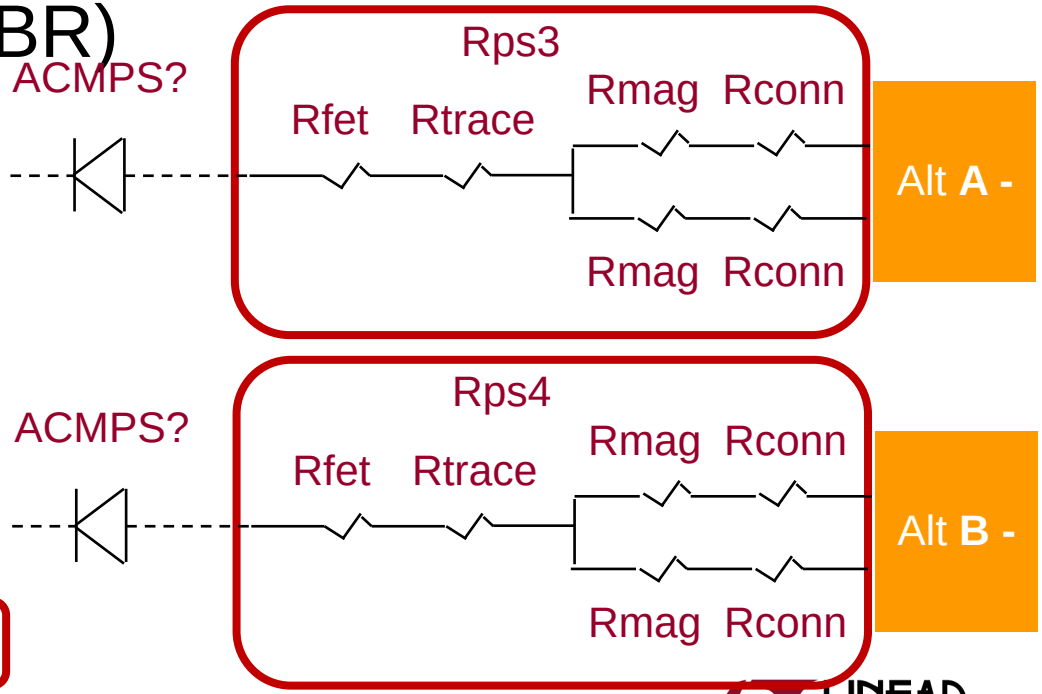
PSE PI Low Side Value Selection



- Assumes not ACMPS for now
  - (we need to talk about this)
- With no ACMPS, V1 is just set to a reasonable non-zero value
  - Suggest 0.05V (TBR)

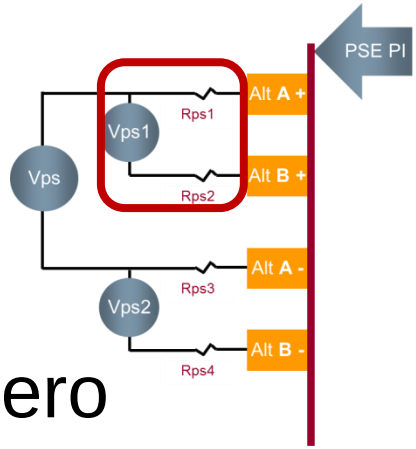
Vps2

			Nominal System Simulation Support		
Rps3, Rps4	Imbalance		Max	Min	
Rfet (High R)	0.100		0.400		ohms
Rfet (Low R)				0.020	ohms
Rsense(High)	0.007		0.350		ohms
Rsense(Low)				0.100	ohms
Rtrace	0.000		0.000	0.000	ohms
Rmag	0.080		0.130	0.090	ohms
Rconn	0.015		0.200	0.030	ohms
	PI Spec				
Totals	0.202		1.080	0.240	ohms

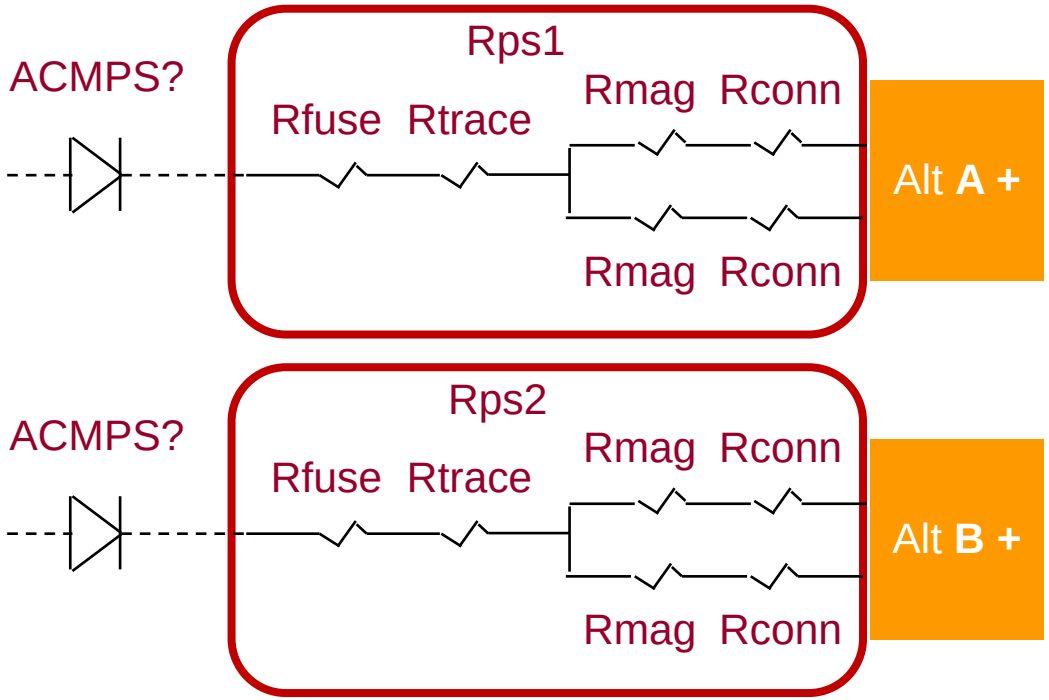


PSE PI High Side Values

- Assumes not ACMPS for now
  - Welcome input here
- With no ACMPS, V1 is just set to non-zero value
- Vps1
  - Suggest 0.05V



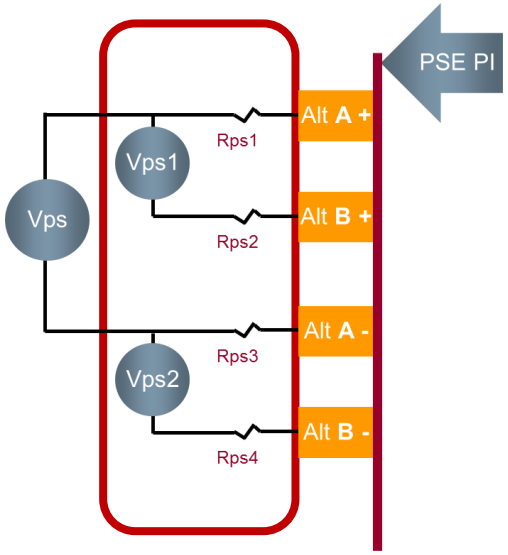
			Nominal System Simulation Support		
Rps1, Rps2	Imbalance		Max	Min	
Rfuse	0		0.000	0.000	ohms
Rtrace	0		0.000	0.000	ohms
Rmag	0.08		0.130	0.090	ohms
Rconn	0.015		0.200	0.030	ohms
	PI Spec				
Totals	0.095		0.330	0.120	ohms



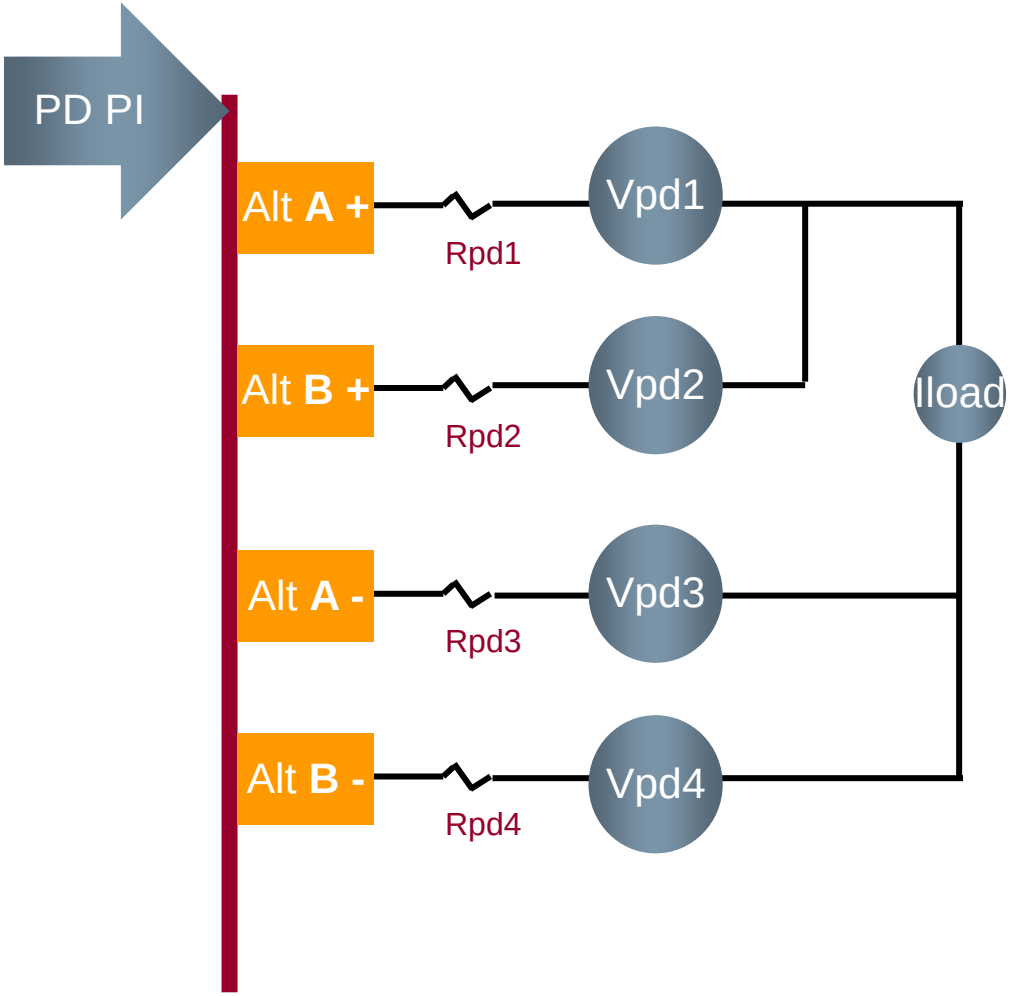
PSE PI Values and Simulation Support Information

- (Included DCMPS & ACMPS for now)

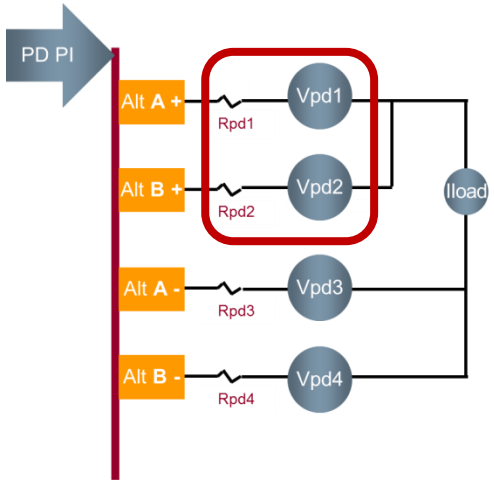
	PI Spec	DCMPS	ACMPS		System Simulation Support	DCMPS	ACMPS	
Rps1,Rps2	abs(Rps1 - Rps2)	0.095	0.145	ohms	Rps1,Rps2 Max	0.330	0.380	ohms
				ohms	Rps1,Rps2 Min	0.120	0.120	ohms
Vps1	abs(Maximum)	0.050	0.150	Volts	Vps1max	0.050	0.750	Volts
					Vps1min	0.000	0.300	
Rps3,Rps4	abs(Rps3 - Rps4)	0.202	0.252	ohms	Rps3, Rps4 Max	1.080	1.130	ohms
				ohms	Rps3, Rps4 Min	0.240	0.290	ohms
Vps2	abs(Maximum)	0.050	0.150	Volts	Vps2 Max	0.050	0.750	Volts
					Vps2 Min	0.000	0.300	Volts
Vps	*See Simulation Schematic*				Vps Max	57.000		Volts
					Vps Min	50.000		Volts
	ACMPS Diodes							
	Rps1 -> 4 Max		0.050	ohms	Rps1 -> 4 Max		0.050	ohms
	Vps1,2		0.100	Volts	Vps1,2 Max		0.700	Volts
					Vps1,2 Min		0.300	Volts



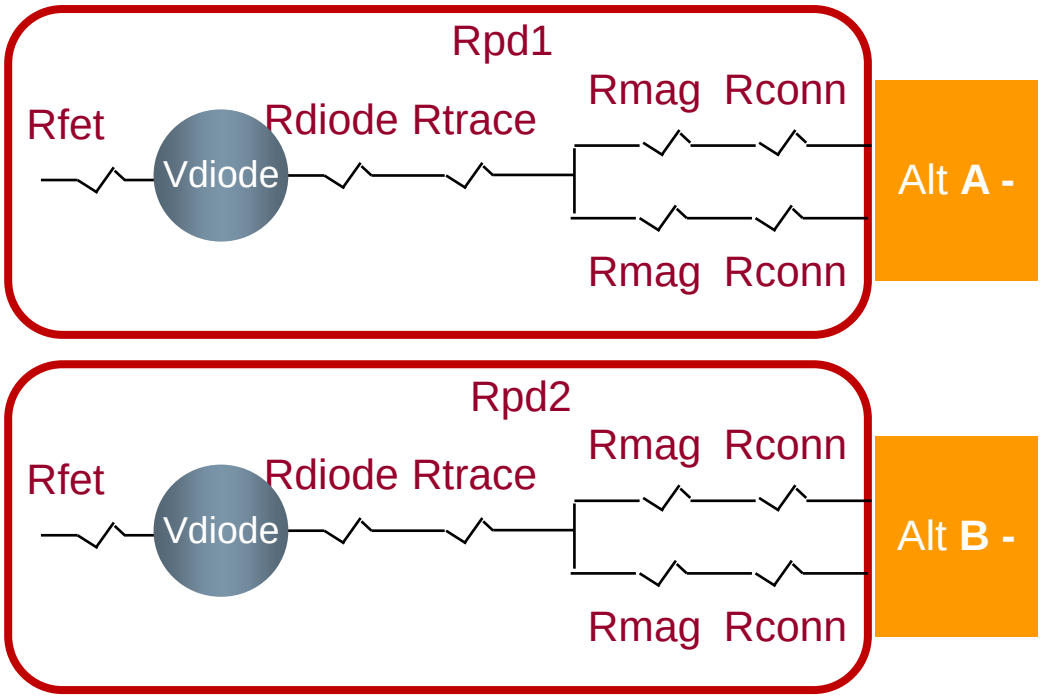
PD PI


PD PI
Alt A +
Rpd1
Vpd1
Alt B +
Rpd2
Vpd2
Iload
Alt A -
Rpd3
Vpd3
Alt B -
Rpd4
Vpd4

PD PI High Side Values



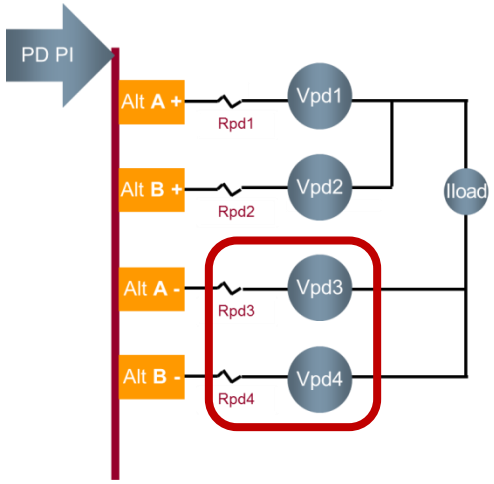
			System Simulation Support		
Rpd1, Rpd2	Imbalance		Max	Min	
Rtrace	0		0.000	0.000	ohms
Rmag	0.08		0.130	0.090	ohms
Rconn	0.015		0.200	0.030	ohms
Rdoide(High)	0.100		0.450		ohms
Rdiode(Low)				0.200	ohms
	PI Spec				
Totals	0.195		0.780	0.320	ohms
Vpd1,Vpd2					
Vdiode	0.100		0.300	0.800	Volts



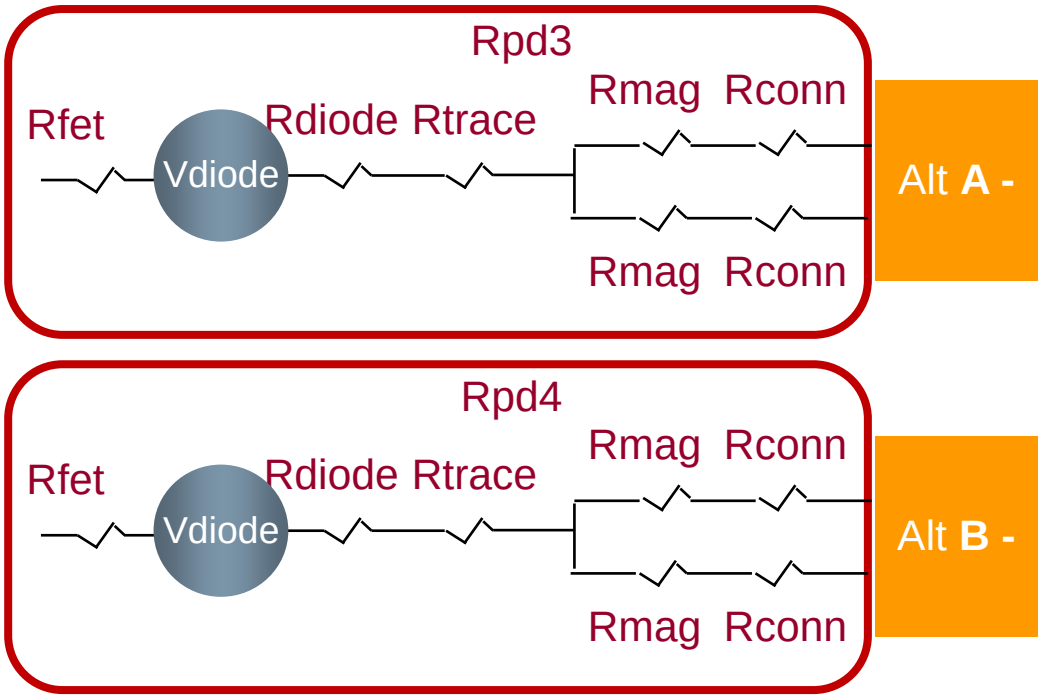
PD PI Notes

- High Side MOSFET PDs exist
  - Need to consider the possible impact if any on Maximum Current.

PD PI Low Side Values



			System Simulation Support		
Rpd3,Rpd4	Imbalance		Max	Min	
Rdoide(High)	0.100		0.450		ohms
Rdiode(Low)				0.200	ohms
Rtrace	0.000		0.000	0.000	ohms
Rmag	0.080		0.130	0.090	ohms
Rconn	0.015		0.200	0.030	ohms
Rfet (High R)	0.100		0.400		ohms
Rfet (Low R)				0.020	ohms
	PI Spec				
Totals	0.295		1.180	0.340	ohms
Vpd3,Vpd4					
Vdiode	0.100		0.300	0.800	Volts

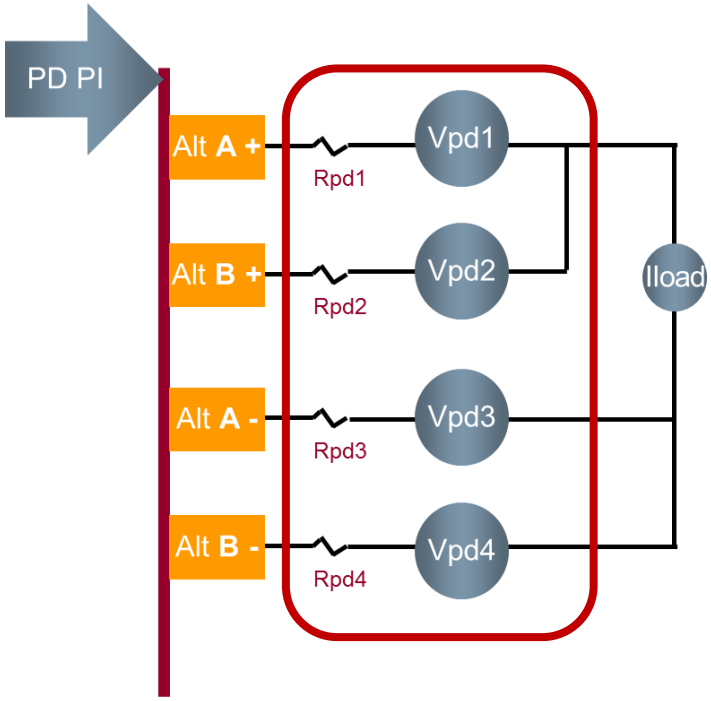


LINEAR TECHNOLOGY

PD PI Values and Simulation Support Information

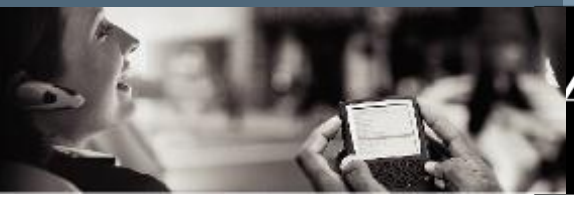
	PI Spec	DCMPS		
Rpd1,Rpd2	abs(Rpd1 - Rpd2)	0.195		ohms
				ohms
Vpd1,Vpd2	abs(Vpd1-Vpd2)	0.100		Volts
Rpd3,Rpd4	abs(Rpd3 - Rpd4)	0.295		ohms
				ohms
Vpd3,Vpd4	abs(Vpd3 - Vpd4)	0.100		Volts

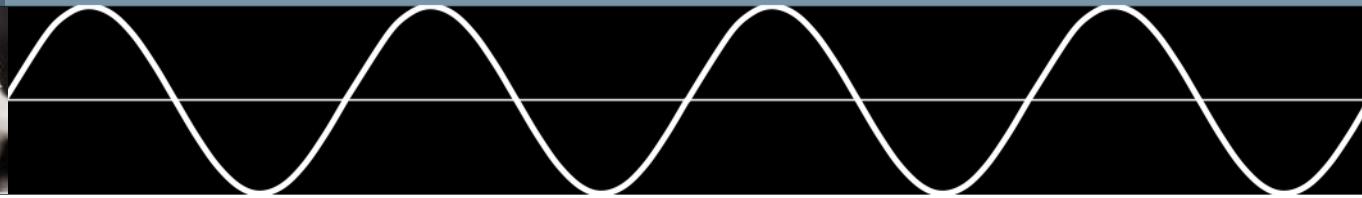
System Simulation Support	DCMPS	
Rpd1,Rpd2 Max	0.780	ohms
Rpd1,Rpd2 Min	0.320	ohms
Vpd1,Vpd2 Max	0.800	Volts
Vpd1,Vpd2 Min	0.300	
Rpd3, Rpd4 Max	1.180	ohms
Rpd3, Rpd4 Min	0.340	ohms
Vpd3,Vpd4 Max	0.800	Volts
Vpd3,Vpd4 Min	0.300	Volts



Current Imbalance Simulations

Jeff Heath





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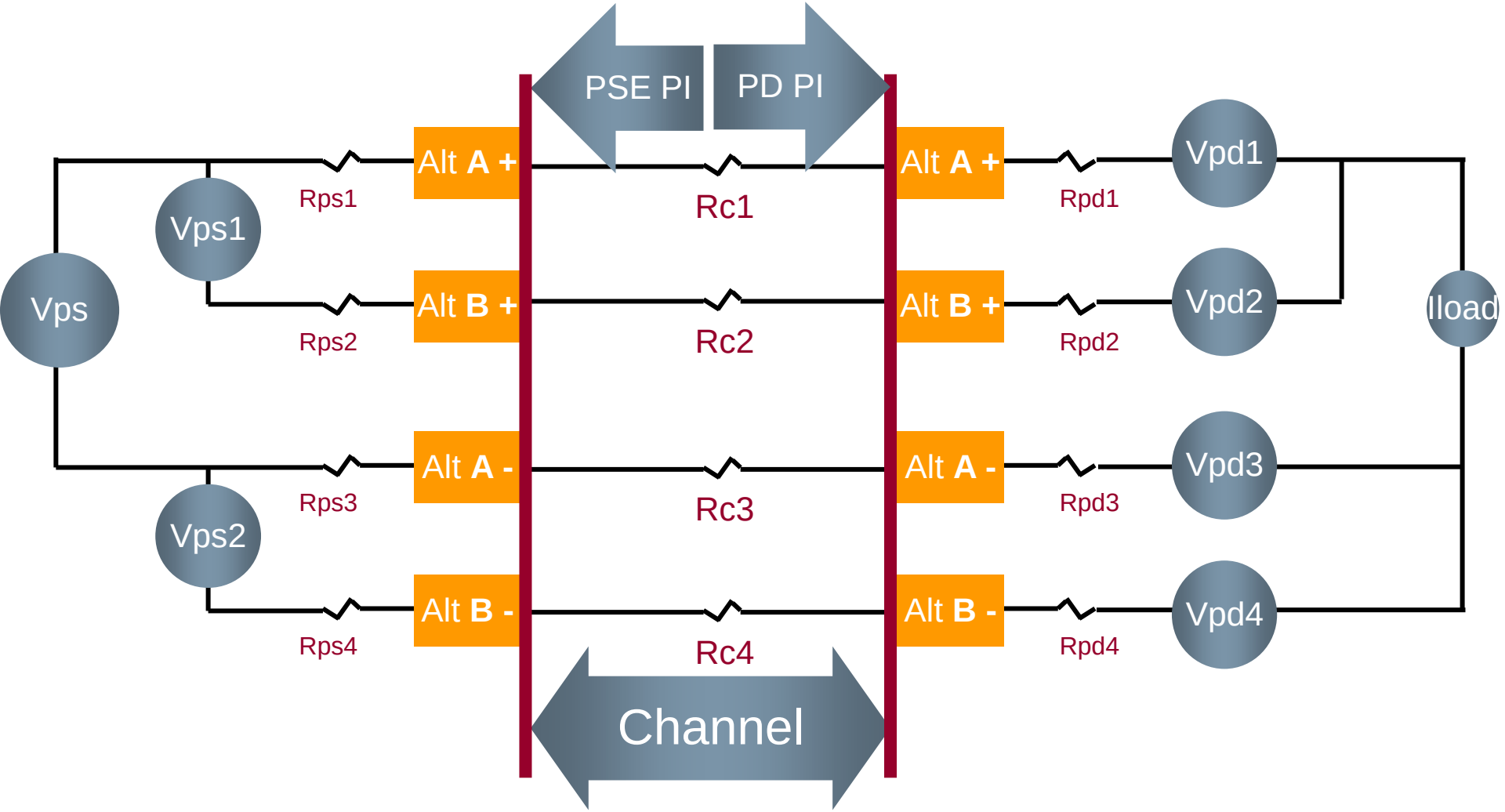
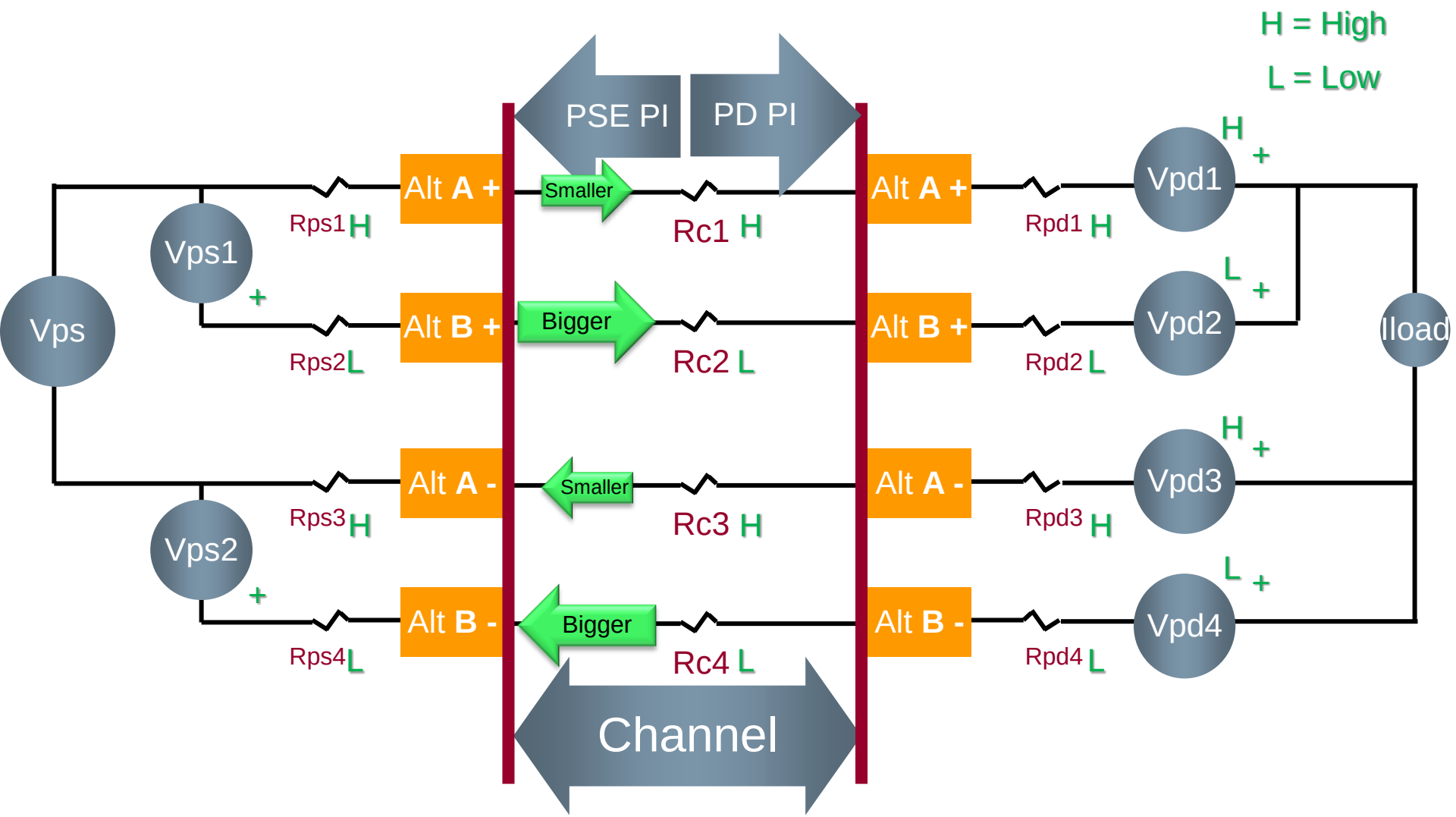
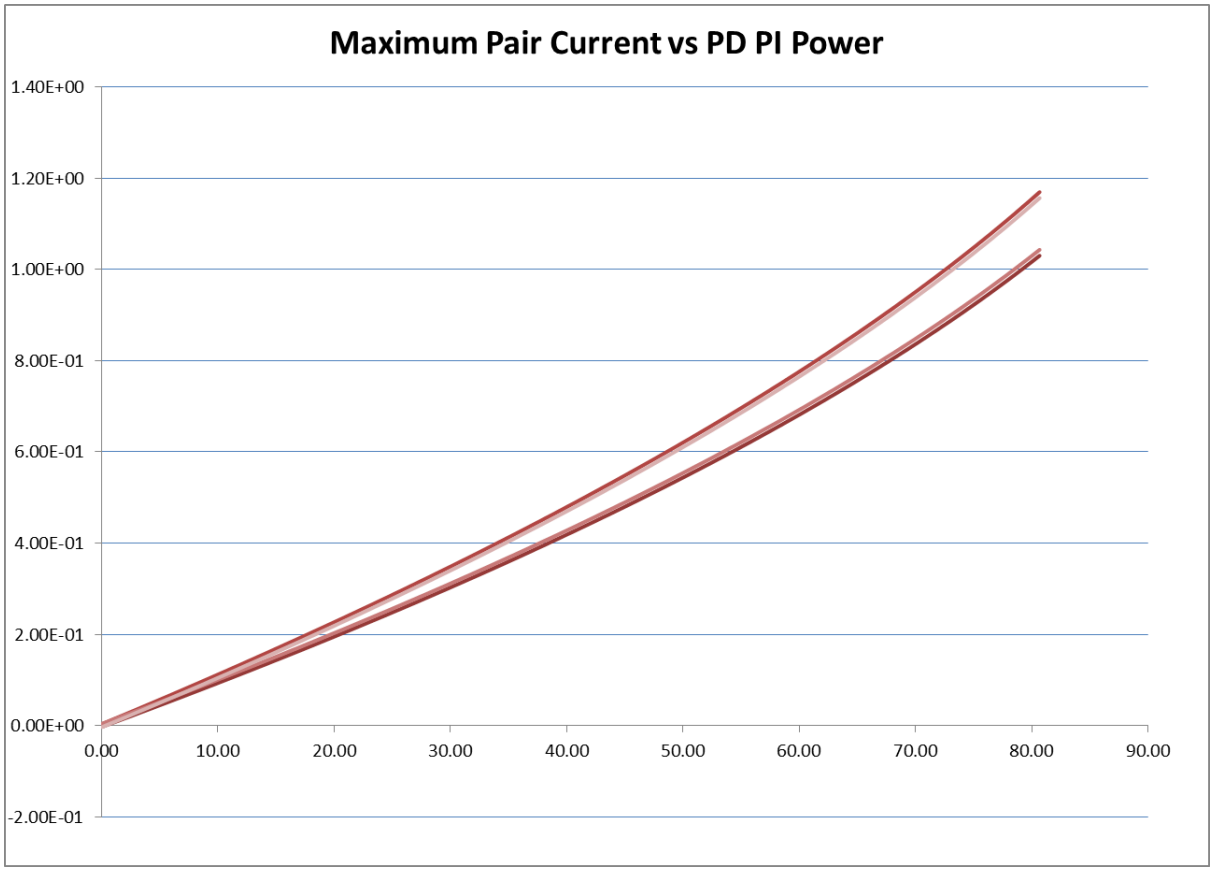
System Simulation Schematic



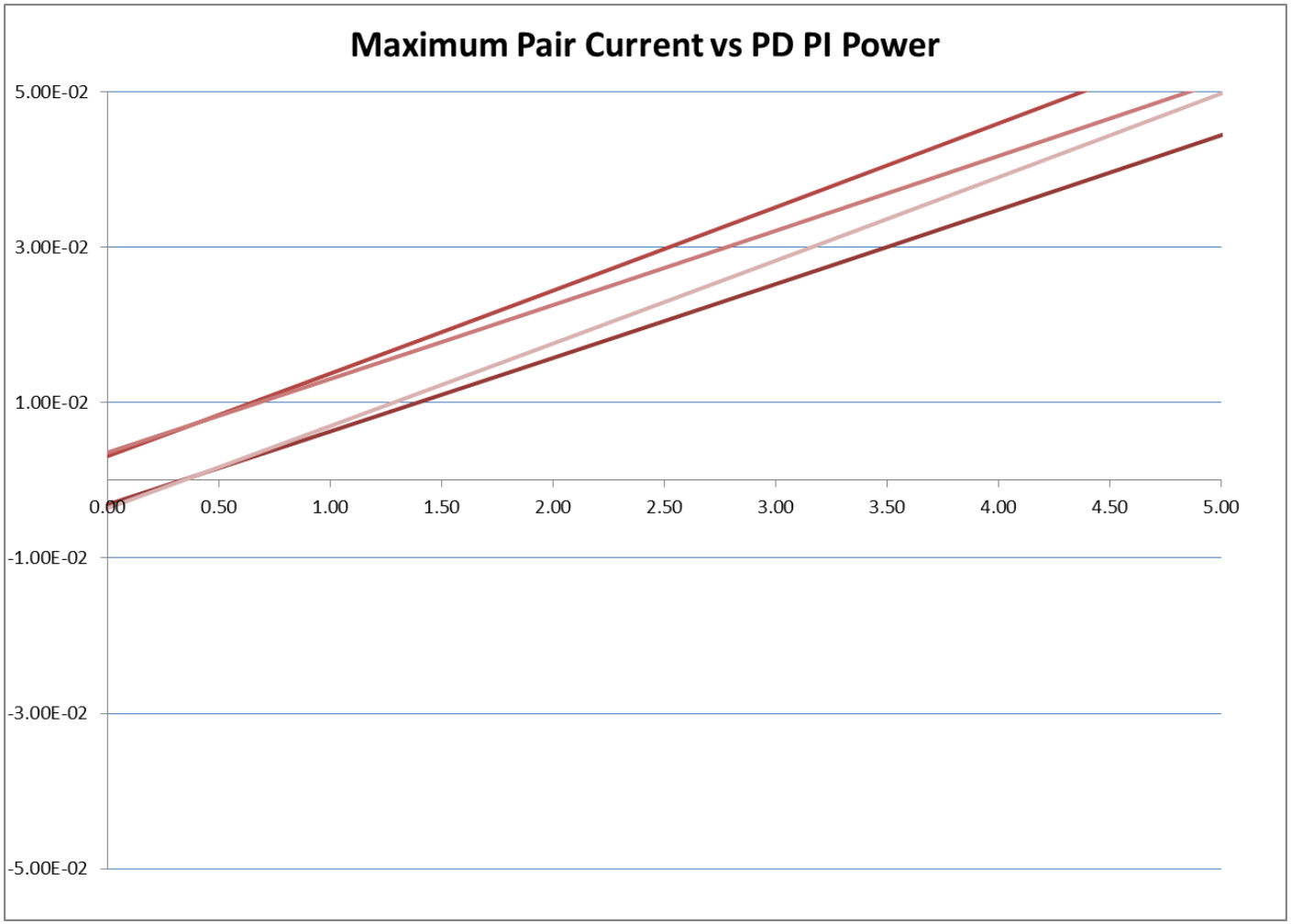
System Simulation Schematic 'Worst Case'



Maximum Pair System Current vs Power



Simplified Diode Model Results at Low Currents



Long Channel Simulation Values

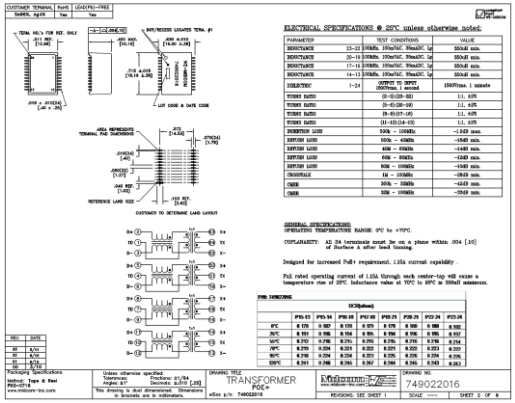
Long Channel Values										
PSE Values				PD Values						
								Channel Values	Rc1,Rc3	Rc2,Rc4
Rps1,Rps2 Max	0.330	ohms		Rpd1,Rpd2 Max	0.780	ohms		Length(m)	Channel Rmax	Channel Rmin
abs(Rps1 - Rps2)	0.095	ohms		abs(Rpd1 - Rpd2)	0.195	ohms		100	6.250	5.813
Rpse1	**0.330**	**ohms**		**Rpd1**	**0.780**	**ohms**				
Rpse2	**0.235**	**ohms**		**Rpd2**	**0.585**	**ohms**				
Rps3, Rps4 Max	1.080	ohms		Rpd3, Rpd4 Max	1.180	ohms				
abs(Rps3 - Rps4)	0.202	ohms		abs(Rpd3 - Rpd4)	0.295	ohms				
Rpse3	**1.080**	**ohms**		**Rpd3**	**1.180**	**ohms**				
Rpse4	**0.878**	**ohms**		**Rpd4**	**0.885**	**ohms**				
				Vpd1	**0.900**	**Volts**				
Vpse				Vpd1,Vpd2 Max	0.800	Volts				
VPSE out Min	**50.000**	**Volts**		abs(Vpd1-Vpd2)	0.100	Volts				
Vpse1				**Vpd2**	**0.800**	**Volts**				
abs(delta)	**0.050**	**Volts**		Vpd1,Vpd2 Max	0.800					
Vpse2										
abs(delta)	**0.050**	**Volts**		**Vpd3**	**0.900**	**Volts**				
				Vpd3,Vpd4 Max	0.800					
VRpse1	*49.950*	*Volts*		abs(Vpd3 - Vpd4)	0.100					
Vrpse2	*50.000*	*Volts*								
Vrpse3	*0.050*	*Volts*		**Vpd4**	**0.800**	**Volts**				
Vrpse4	*0.000*	*Volts*		Vpd3,Vpd4 Max	0.800					

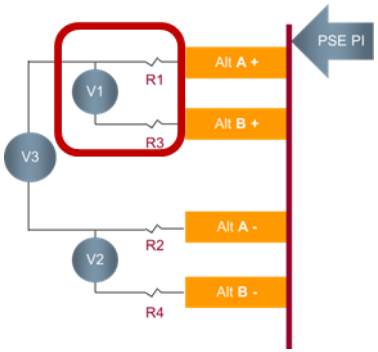
Short Channel Simulation Values

Short Channel Values										
PSE Values				PD Values						
								Channel Values	**Rc1,Rc3**	**Rc2,Rc4**
Rps1,Rps2 Min	0.120	ohms		Rpd1,Rpd2 Min	0.32	ohms		Length(m)	**Channel Rmax**	**Channel Rmin**
abs(Rps1 - Rps2)	0.095	ohms		abs(Rpd1 - Rpd2)	0.195	ohms		1	**0.2**	**0**
Rpse1	**0.120**	**ohms**		**Rpd1**	**0.320**	**ohms**				
Rpse2	**0.025**	**ohms**		**Rpd2**	**0.125**	**ohms**				
Rps3, Rps4 Min	0.240	ohms		Rpd3, Rpd4 Min	0.34	ohms				
abs(Rps3 - Rps4)	0.202	ohms		abs(Rpd3 - Rpd4)	0.295	ohms				
Rpse3	**0.240**	**ohms**		**Rpd3**	**0.340**	**ohms**				
Rpse4	**0.038**	**ohms**		**Rpd4**	**0.045**	**ohms**				
				Vpd1	**0.900**	**Volts**				
Vpse				Vpd1,Vpd2 Max	0.800	Volts				
VPSE out Min	**50.000**	**Volts**		abs(Vpd1-Vpd2)	0.100	Volts				
Vpse1				**Vpd2**	**0.800**	**Volts**				
abs(delta)	**0.050**	**Volts**		Vpd1,Vpd2 Max	0.800					
Vpse2										
abs(delta)	**0.050**	**Volts**		**Vpd3**	**0.900**	**Volts**				
				Vpd3,Vpd4 Max	0.800					
VRpse1	*49.950*	*Volts*		abs(Vpd3 - Vpd4)	0.100					
Vrpse2	*50.000*	*Volts*								
Vrpse3	*0.050*	*Volts*		**Vpd4**	**0.800**	**Volts**				
Vrpse4	*0.000*	*Volts*		Vpd3,Vpd4 Max	0.800					

Appendix A
PSE PI Magnetics check

- Minimum
  - Nominal: 0.09 ohms
  - Delta: 0.001 ohms
- Maximum
  - Nominal: 0.122 ohms
  - Delta: 0.001 ohms
- These Values differ from current assumptions
- I will use the new low nominal value and the existing high value
  - Low: 0.09 ohms
  - High: 0.13 ohms





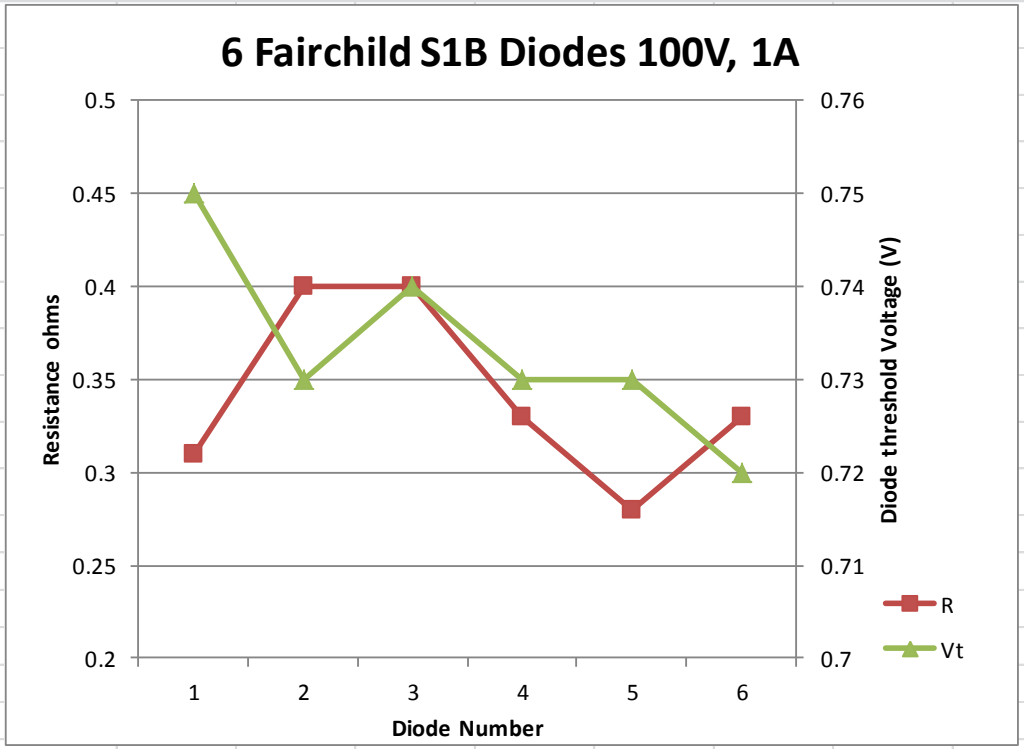
P/N: 749022016

DCR(ohms)	P15-13	P15-14	P16-18	P17-18	P19-21	P20-21	P22-24	P23-24
0°C	0.178	0.182	0.178	0.179	0.179	0.180	0.180	0.182
25°C	0.191	0.196	0.194	0.195	0.194	0.196	0.195	0.197
55°C	0.212	0.216	0.215	0.216	0.215	0.216	0.216	0.214
70°C	0.219	0.224	0.221	0.222	0.221	0.222	0.223	0.222
95°C	0.218	0.224	0.224	0.223	0.225	0.226	0.224	0.226
120°C	0.241	0.246	0.245	0.247	0.244	0.245	0.243	0.243

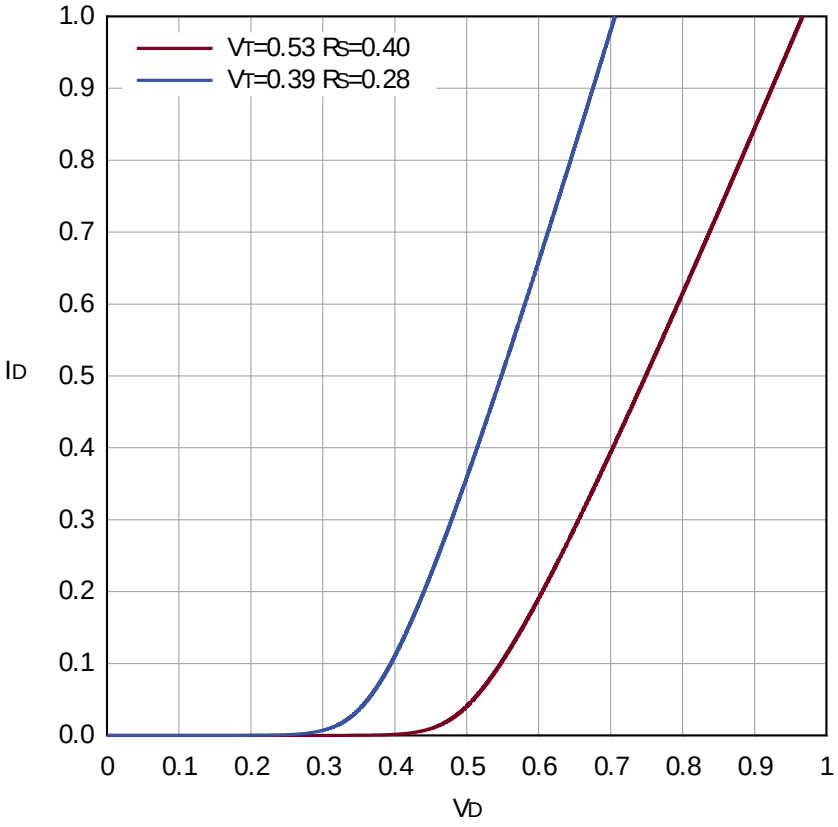
0C		Average	Parallel R
0.178	0.182	0.180	0.090
0.178	0.179	0.179	0.089
0.18	0.18	0.180	0.090
0.18	0.182	0.181	0.090
	Average	0.180	0.090
	Average	0.180	0.090
	Delta	0.003	0.001
120C			
0.241	0.246	0.244	0.122
0.245	0.247	0.246	0.123
0.244	0.245	0.245	0.122
0.243	0.243	0.243	0.122
	Average	0.244	0.122
	Delta	0.003	0.122
			0.001

Appendix B: Diode Mismatch Shows Much Larger Diode Resistance than Currently Being Modeled

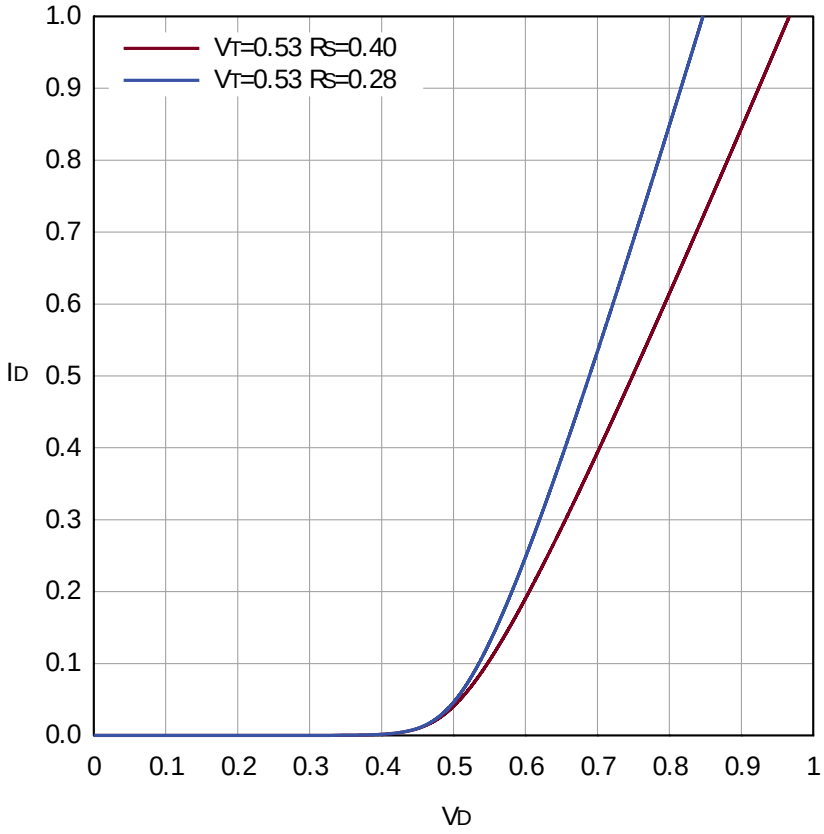
Diode	R	Vt
1	0.31	0.75
2	0.4	0.73
3	0.4	0.74
4	0.33	0.73
5	0.28	0.73
6	0.33	0.72
Mean	0.342	0.733
Min	0.280	0.720
Max	0.400	0.750
Delta	0.120	0.030



Current Diode Mismatch Parameters Seem Very Pessimistic. This is worth a discussion in the future



Current Diode Mismatch Model in this presentation.



Diode Mismatch Model w/ more realistic R and Vth Mismatch

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