



Backfeed voltage during 2, 3 and 4 pair operating modes

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Rev006

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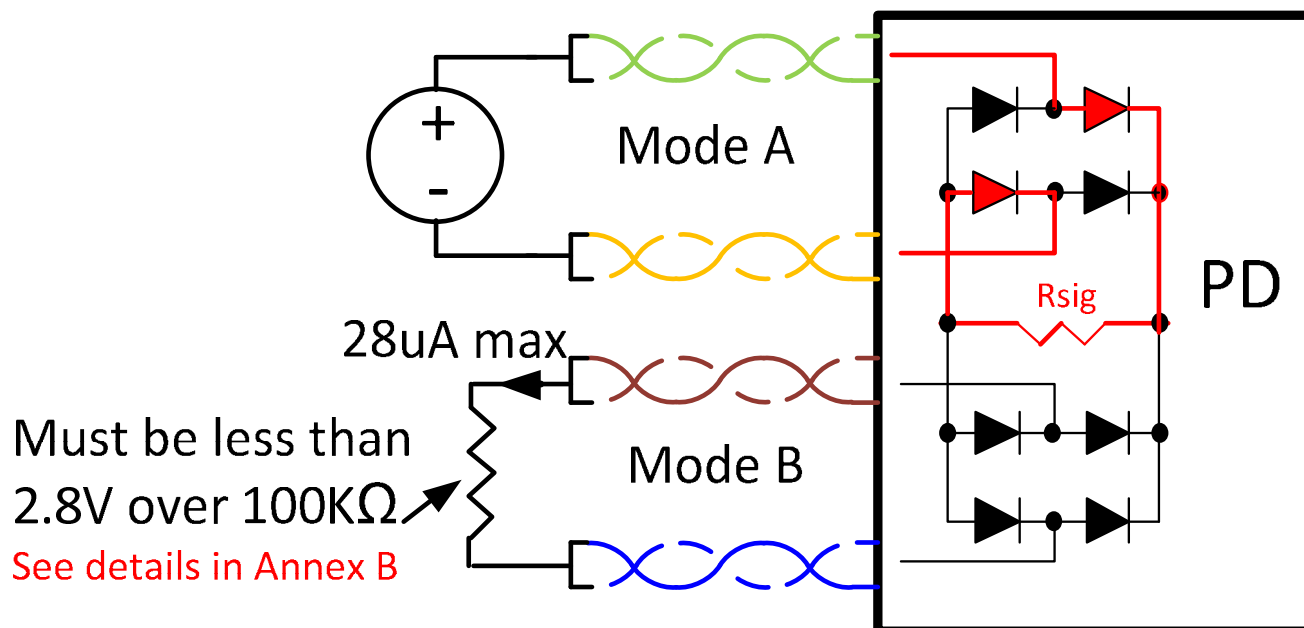
Objectives

- To investigate the effect of excluding backfeed requirements for 3-pair mode.
- To check if and in which parts, the IEEE802.3bt D3.4 need to be updated as a result.

Backfeed requirement.....1

145.3.8.8 Backfeed voltage

“When any voltage in the range of 0 V to $V_{Port_PD-2P\ max}$ is applied across the PI at either polarity specified on the conductors of either Mode A or Mode B¹ according to Table 145–20¹, the voltage measured across the PI for the other Mode with a 100 k Ω load resistor connected across that other Mode shall not exceed V_{bfd} as defined in Table 145–29.”



(1) “.. on the conductors of either Mode A or Mode B..”
is 2-pair or **3-pair** per Table 145-20

Backfeed requirement.....2

- The backfeed specification¹ in D3.4 applies for 2-pair and 3-pair mode per Table 145-20 in the 2-pair mode section.

1. Originally came from 802.3af/at for 2-pair PSEs

In addition:

There is a requirement: **“PD shall not source power to the PD PI”**

-Added to the spec to cover auxiliary PD power supply connection that its voltage and current capacity are not limited/specified by the spec.

-We need to ensure that the above shall will not be affected or confused with backfeed.

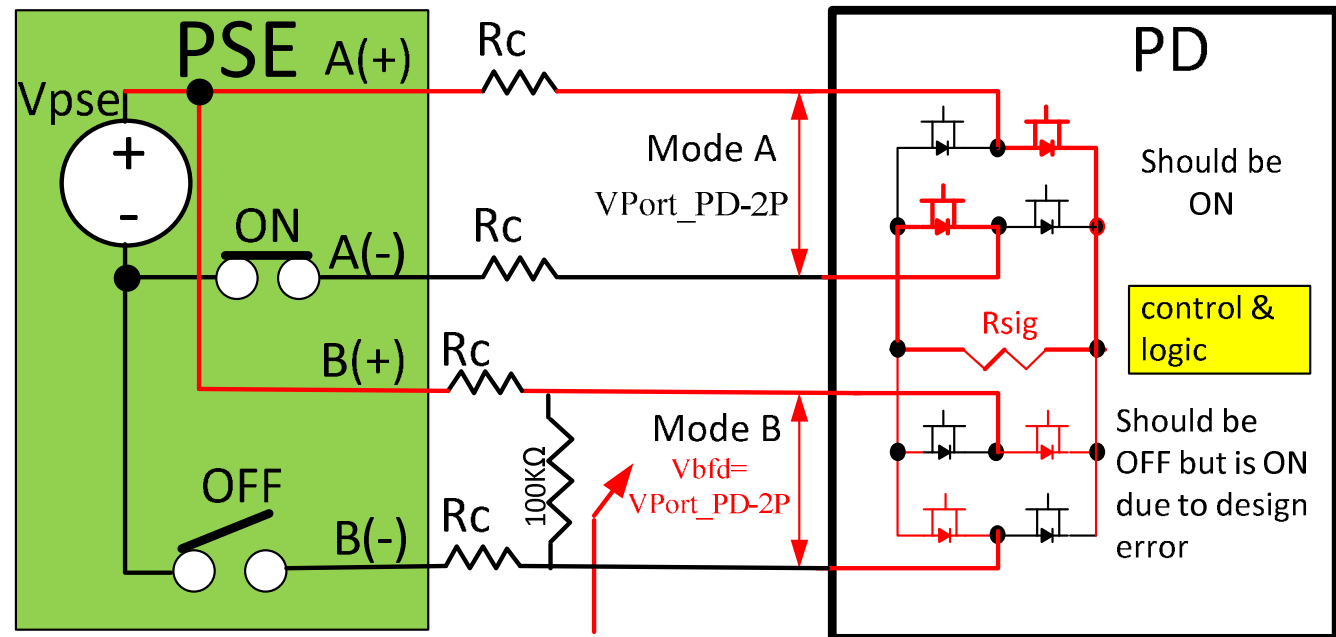
Table 145-20—PD input power configurations

Pairsets	Mode A		Mode B	
	Pair 1	Pair 2	Pair 3	Pair 4
Conductor	1 and 2	3 and 6	4 and 5	7 and 8
Valid 2-pair configurations				
	P	N	—	—
	N	P	—	—
	—	—	P	N
	—	—	N	P
	P	N	P	—
	P	N	—	P
	N	P	P	—
	N	P	—	P
	P	—	P	N
	—	P	P	N
	P	—	N	P
	—	P	N	P
Valid 4-pair configurations				
	N	P	N	P
	N	P	P	N

Problem #1 with the existing text vs. existing legacy and pre 802.3bt standard PDs implementations

- Some **Ideal diode bridges** in the market used with Type 1 and 2 PDs and pre-802.3bt SSPDs will fail to meet the backfeed requirement when operated in 3-pair mode¹.
- in most 4-pair PSE implementations, all positive leads are tied together and only the negative leads are switched. This results in 3-pair mode when a 4-pair PSE is powering over 2-pair

Note 1: Found during the last Plug Fest when pre-standard 802.3bt PDs where connected to pre-standard 802.3bt PSEs. Designers didn't verify that these specific implementations doesn't 100% match diode bridge behavior (which doesn't have the backfeed issue in 3-pair).



Should we include (limit to 2.8V/28uA) or exclude (allow up to 57V with ILIM-2P) V_{bfd} requirements for 3-pair mode?

Topics that we already discussed

#	Subject	Annex
1	References for backfeed specifications	A
2	Why backfeed is 2.8V/28uA max	B
3	The reasons for backfeed specification	C1, C2
4	List of issues to resolve/investigate	D
5	Potential damage to detection circuitry during Detection to legacy Endspan/Midspan configurations and existing 4-pair PSEs	E
6	Endspan/Midspan configuration	F
7	PSE is connected to SSPD through crossed cable	G1, G2
8	Increasing PSE susceptibility to cross leakage current issues between pairs/ports in a multiport systems	H1, H2, H3
9	Examples of specifying system requirements of multiport systems	I
10	Addressing dual-signature PDs	J
11	PDs with wall adaptor	K1, K2
12	Pollution of detection at the detection voltage range	To be discussed
13	Pollution of detection at the classification voltage rang	To be discussed

Reasons to include 3-pair mode in backfeed spec

- “Worry Free” and It keeps the same intent we had for true 2-pair mode
 - It is, after all, “2-pair” mode with reinforced positive leads...
 - Prevents wrong Ideal diode bridge designs which need to have identical behavior to diode based designs (with improved efficiency only).
 - Prevents potential damage or improper operation or interoperability issues (will be addressed case by case if it is a valid concern. See Table summary and annexes for research results)
 - ~~Prevents confusion when using rectifier designs intended for SSPDs with DSPDs where they will violate the spec in DSPDs⁴.~~

(1) This argument may be weak since we can make the spec more clear that DSPDs need to meet both valid signature and backfeed requirements on each pair.....

Reasons to **exclude** 3-pair mode in backfeed spec

- ~~Allow some low cost Ideal Diode Bridge designs.~~
 - This argument is weak. Can be fixed and stay low cost....
- *Existing Legacy 802.3af/at and pre 802.3bt standard already exhibit high back feeding voltage under 3-pair mode. Compliant Type 3 and 4 PSEs may need to deal with it anyway.*
- 4-pair PSE that operates over 4-pair and is connected to **single-signature PD** will not be affected by backfeed.
 - POWER_UP on both pair sets will occur long after CC and detection/classification over each pairset are done, hence a 4-pair PSE is capable of handling the high backfeed voltage.
- Dual-signature PDs will have to meet backfeed requirements in 2-pair, 3-pair and 4-pair modes, otherwise detection will fail.

Solution: Option 1 (preferred, lower risks)

- Allows PSEs to support PDs with 3-pair backfeed issue
- Prevents propagating risks to the standard (and to PSEs and PDs) for new PDs to have backfeed issue at 3-pair mode (***unless group will focus on finding issues and address them which in this case we may go to solution 2***)
- **PD spec:**
 - Keep the text as is. It requires Type 3 and 4 PDs to meet backfeed in 2-pair, 3-pairs and also covers DSPDs.
- **PSE spec:**
 - To require Type 3 and 4 PSEs to support PDs that doesn't meet backfeed in 3-pair mode.
- System work (problem #2) : To continue to check if Type 3 and 4 PSEs may experience issues when exposed to backfeed of VPort_PD-2P max=57V and no current limit¹ compared to 28uA current limit as it was.
 - Update PSE spec and PD spec accordingly

Note 1: The current is limited by ILIM-2P at the powered pair

Solution: Option 2

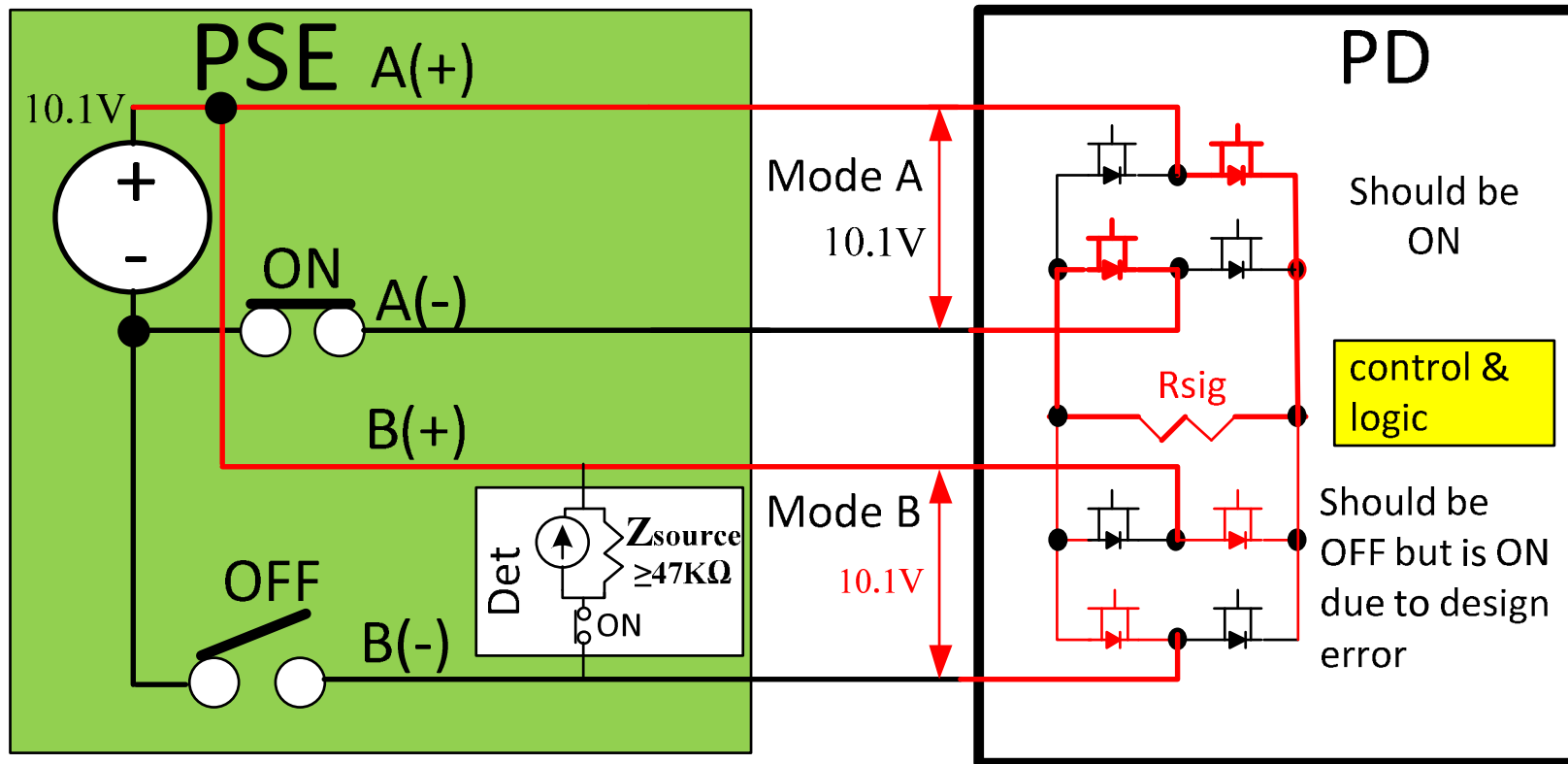
- Allow PSEs to support PDs with 3-pair backfeed issue
- Allows PDs with backfeed issues in 3-pair mode. This can only be possible if the whole group ***will focus on finding issues and address them so we will not create bigger problems otherwise we will have to go to option 1)***
- PD spec:
 - Exclude 3-pair from backfeed requirement for SSPDs.
 - Ensure that dual-sig is covered with a new text for DSPDs.
 - Make sure that PD shall not source power at any condition and to clearly differentiate it from backfeed.
- PSE spec:
 - To require Type 3 and 4 PSEs to support PDs that doesn't meet backfeed in 3-pair mode.
- System work (problem #2) : To continue to check if Type 3 and 4 PSEs may experience issues when exposed to backfeed of VPort_PD-2P max=57V and no current limit¹ compared to 28uA current limit as it was.
 - Update PSE spec and PD spec accordingly

Note 1: The current is limited by ILIM-2P at the powered pair

New issues – Detection pollution

Why to include backfeed in 3-pair for up to 10.1V?

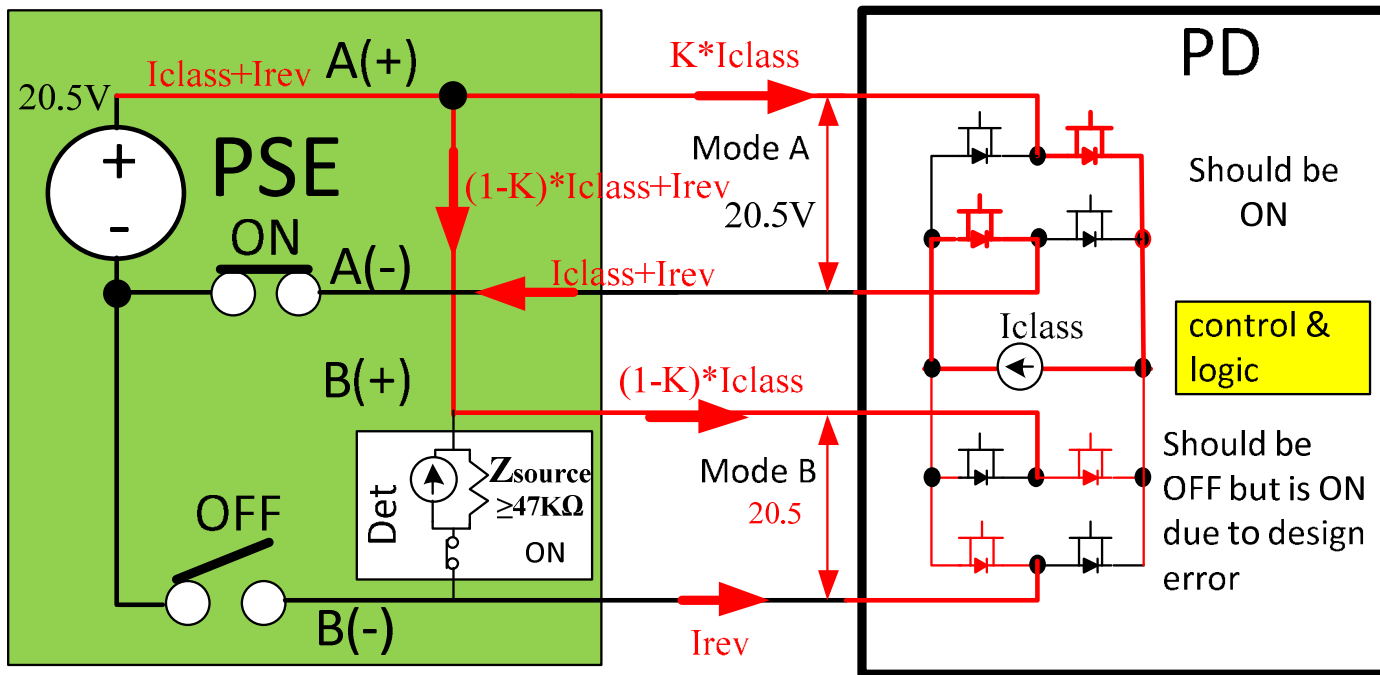
- Detection will be polluted if we allow ideal diode bridge to be ON in SSPDs during detection by the other alternative Z_{source} (Figure 145-19) in the detection circuitry.
- Z_{source} will be in parallel to R_{sig} .
- Solution: To require meeting backfeed for at least 10.1V (Preferred 20.5V for classification or better 30V since detection open voltage can reach 30V. See next slide).



New issues – Classification pollution

Why to include backfeed in 3-pair for up to (20.5V+margin?)

- In SSPDs we have single classification signature
 - Classification current may be changed by $20.5V/R_{source_min}=0.436mA$ (or I_{rev}) which will require tighter accuracy measurement
 - e.g. instead of 3mA margin between class 0 to class 1 and class 1 to class 2 we will have to meet $(3mA-0.436mA)$ margin (and it is worse since $I_{rev}=1.3mA$ max)
- If the legacy ideal diode bridges ALSO violates backfeed during the 30V range then it is a major design mistake and we should not allow it!



Solution:

To require meeting backfeed in 3-pair for at least 20.5V+margin (preferred 30V. See next slide)

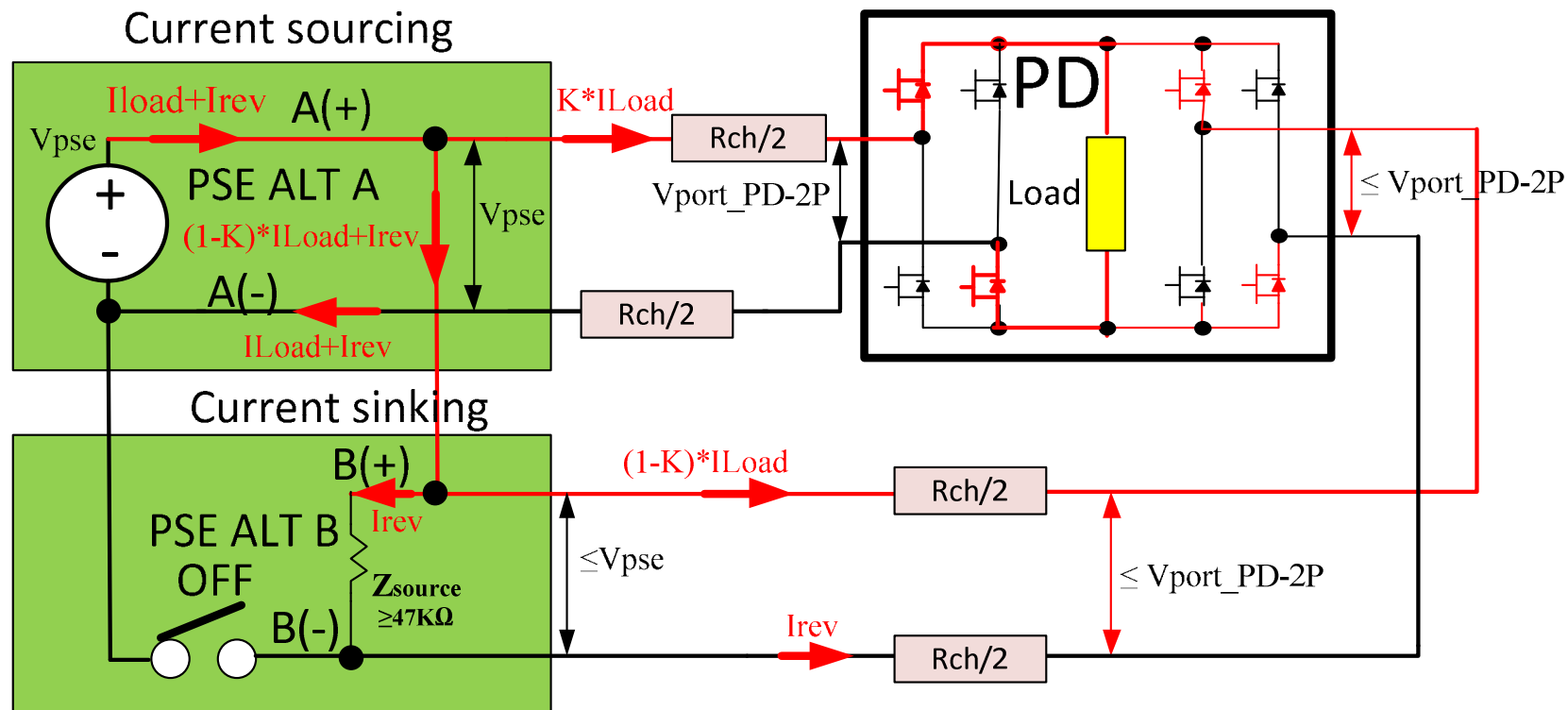
New issues – Classification pollution

Why to include backfeed in 3-pair for up to 30V

- It is the PD OFF voltage where below it PD should be OFF
- Detection voltage may reach 30V when the signature resistor is OFF. In this case if the ideal diode bridge is on both modes in 3-pair mode, the other mode can't due detection even if it want too.

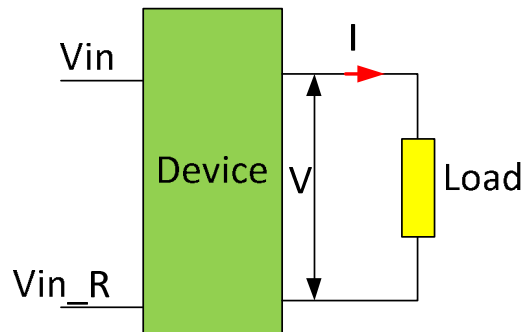
Source current vs.. sink current

- When ideal diode bridge is not meeting backfeed under 3-pair condition it will cause the PSE Alternative that is OFF or detecting to **consume** up to $57V/45K=1.3mA$.
- A device when it is OFF, cannot source current. It can only sink/draw current.
- Alternative A PSE is powered, delivering power to the PD and the PD backfeed voltage to ALT B PSE that is OFF and cause Z_{source} to dissipate power.
- Therefore, PSE ALT B is drawing current and not sourcing current

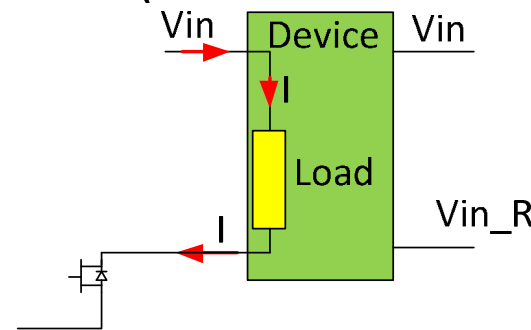


Source current vs.. sink current – proposed text

Current sourcing
(current flows out of device)



Current sinking
(current flows into device)



As a result, change the proposed text to:

When a 4-pair capable PSE provides power in 2-pair mode, whereby two pairs are connected to the positive VPSE, and one pair is connected to the negative VPSE, a single-signature PD may reflect a voltage of up to VPSE back onto the unpowered pairset. See 145.3.8.8. The PSE shall not source a current higher than I_{rev} on the unpowered negative pair, as defined in Table 145-20, on the negative pair of a pairset when the voltage of that pairset is equal to or lower than the voltage of the other pairset.

This text was deleted since Table 145-20 doesn't address I_{rev} and doesn't supply any other relevant info with the current order of the text description.

This text was deleted since it means that if the voltage is higher we can draw more current...

New issue – Reflected voltage must be $\leq V_{port_PD-2P}$

- If we allow excluding backfeed in 3-pair mode, we must request that the reflected voltage shall be $\leq V_{port_PD-2P}$
 - This request is obvious and expected to be implemented correctly
 - No PD vendor is expected to boost the voltage from V_{port_PD-2P} at the powered Mode to a voltage $> V_{port_PD-2P}$ at the unpowered mode
 - however since we have to specify the PD PI we must prevent this case in the spec otherwise if $V_{pse}=50V$ and $V_{port_PD-2P}>50V$, PSE may be damaged or behave incorrectly.
- Discussion?
- Do we have this already covered in the proposed text?
- It is sufficient to limit the reflected voltage at the PD input to V_{port_PD-2P}

Summary of concerns and proposed solutions

PSE section



#	Concern	Results	Recommendations
1	Damage to existing 4-pair designs during detection. Spec limits to 30V. Now they will be exposed to 57V max.	2 vendor tested. No issues.	To require PSE to meet reflected voltage (was backfeed) of 0-57V in 3-pair for all operating states with: <ul style="list-style-type: none"> - limiting the current flow (or draw) to 1.3mA - Applicable for SSPDs
2	Susceptibility to increased leakage current generated by common mode voltage generated at the termination block that pollutes detection on adjacent unpowered pairs/port. Normally, backfeed is 57V max with 28uA current limit. If we exclude 3-pair, it will be 25V up to 57V with ILIM-2P limit which is unlimited leakage source.	2 vendor tested. Leakage current was increased as expected but still low.	Simulation results showed that there is issue of increased sensitivity to detection pollution however it depends solely on PSE termination isolation design and MOSFET Roff_min. No need to add text to PSE for this issue. See Annex H1, H2, H3 for details
3			
4			

Summary of concerns and proposed solutions PD section

#	Concern	Results	Recommendations
1	PDs that equipped with auxiliary power supply per 145.3 page 186 line 43-44 with no spec that limits its voltage and current which now may source voltage/power and damage PSE, PD and violates safety specs.		The current statement -“PDs shall not source power to the PI” is sufficient as long as we differentiate between sourcing power and backfeed i.e. backfeed is not sourcing power. Backfeed is reflected power.
2	Pollution of detection by the 2 nd pair when the 1 st pair is doing detection		To required meeting backfeed in 3-pair mode up 10.1V
3	Pollution of classification by the 2 nd pair when the 1 st pair is doing classification.		To required meeting backfeed in 3-pair mode up to (20.5V+margin)
4	Pollution of detection by the 2 nd pair when the 1 st pair is doing detection		To required meeting backfeed in 3-pair mode up 30V. Need to be verified.
5			

Next steps/Recommendations/Discussion



- To include backfeed for
 - detection
 - classification (20.5V+margin or 30V ?)
- Which option solution to go?
 - In my opinion (Yair)
 - option 1 is safe and has no risks.
 - Option 2 may be OK if we will cover all potential issues. I don't know if we cover all the unknowns yet.
 - We need the group/system vendors to help with finding issues in 3-pair backfeed and suggest solution in a form of additional text to be added to PSE and/or PD sections to prevent damage/safety or interoperability issues if 3-pair is excluded from backfeed.

Annexes

Annex A – References for backfeed specifications

- http://www.ieee802.org/3/af/comments/d4.2/P802_3af_D4_2_all_page_line.pdf
comments 10 and 12 page 11 addressing the question why we need backfeed spec. Comment in comment 10 I showed the field report for why backfeed is a must.
- The backfeed requirement was added at the last cycle of the 802.3af meeting after a field report results. In addition, a note was added (to complete the info as shown in comment #101 page 23 at:
http://www.ieee802.org/3/af/comments/d4.1/P802_3af_D4_1_all_by_page.pdf

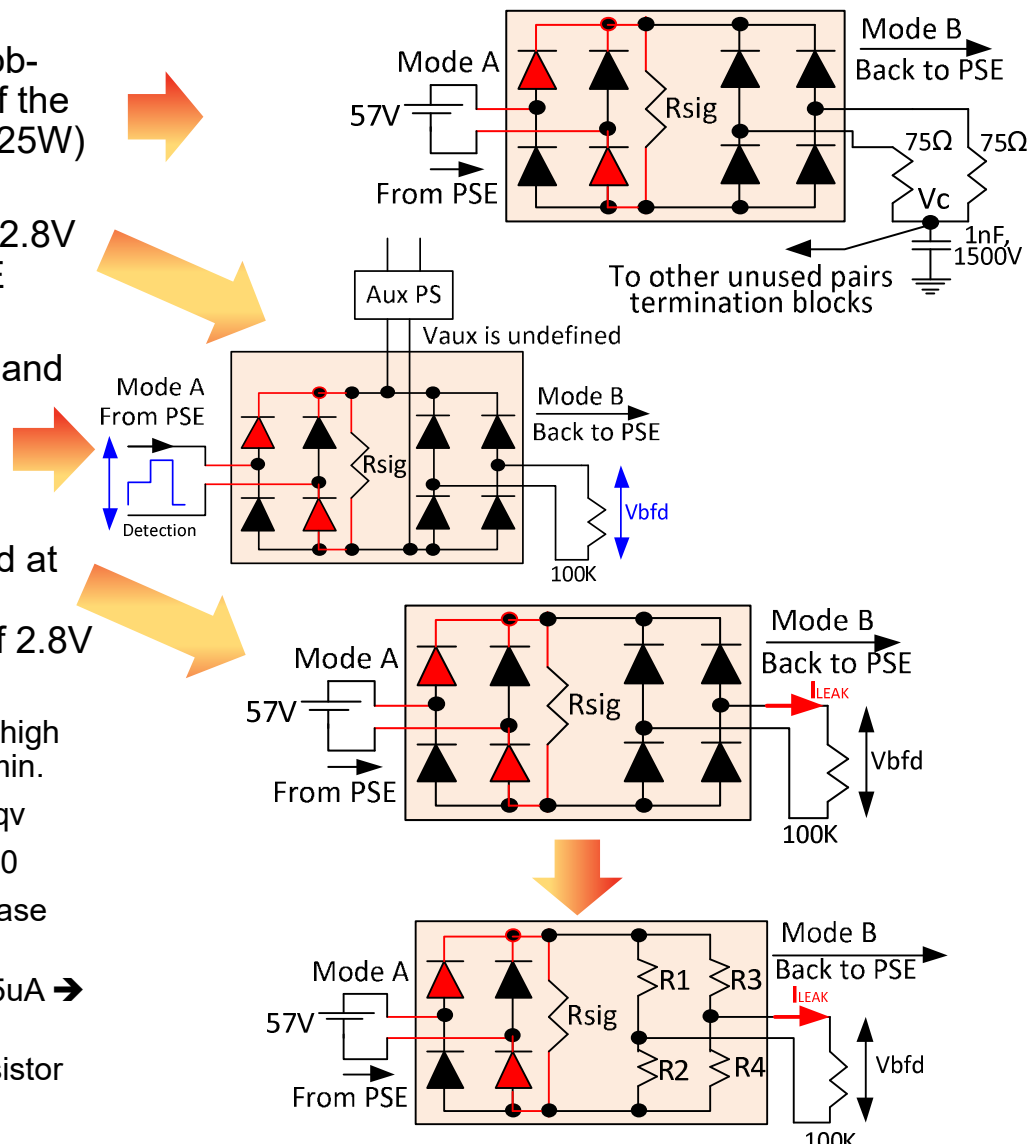
Annex B – Why backfeed parameters are 2.8V, 28uA, 100K

Why 2.8V?

- To limit the voltage in order not to damage Bob-smith terminations in a Switch. The resistor of the termination was limited to 0805 package (0.125W) → $2.8V^2 / (2 * 75) = 0.052W < 0.125W$.
- PD auxiliary power supply will not generate >2.8V on an unpowered mode in order to allow PSE detection.
- In addition, 2.8V is minimum detection range and PSE OFF voltage, resulting with well defined behavior in all PD and PSE operating modes

Why 28uA?

- 28uA is the maximum leakage current allowed at worst case PD operating conditions on an unpowered mode that will create maximum of 2.8V over 100K test resistor.
- All Mode B diodes are reversed bias represented by high resistances R1, R2, R3 and R4 with $R = R_{min} = 1M\Omega$ min.
- $I_{LEAK_max} = (57V * (R4 / (R3 + R4) - R2 / (R1 + R2))) / R_{eqv}$
- $I_{LEAK_max} = 0$ If all diodes equal, else $I_{LEAK_max} > 0$
- With $R4 = 10 * R3 = 10 * R$ and $R1 = 10 * R2 = 10 * R$ (worst case assumption) →
 - $V_{eqv} = 57 * 9 / 11$, $R_{eqv} = 2 * 10 * R / 11$, $I_{leak_max} = 25.65uA$ → rounding up to 28uA
 - Convert I_{leak_max} to voltage with 100K sense resistor → 2.8V as needed.

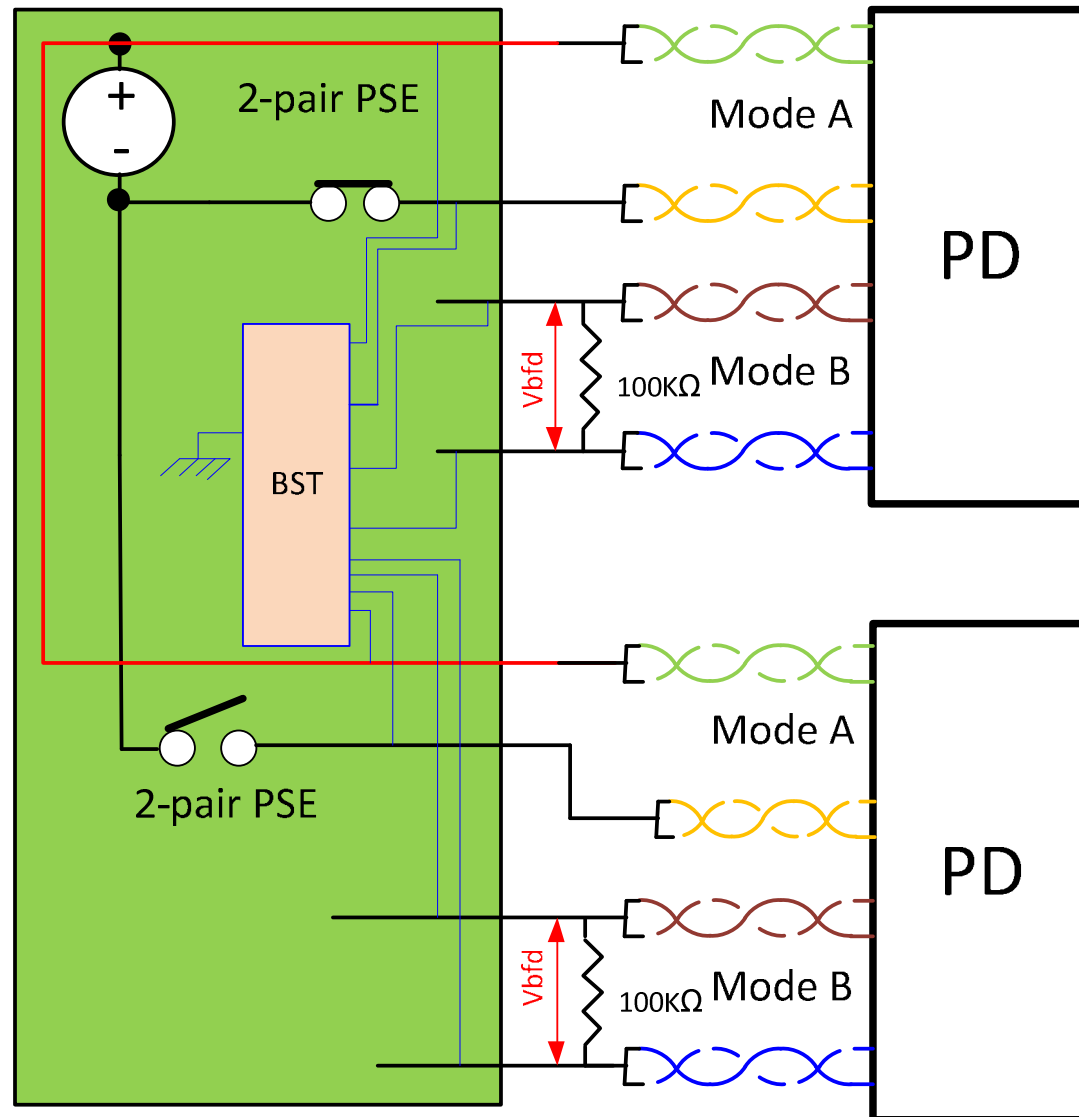


Annex C1 :The reasons for backfeed specification

- To prevent pollution of adjacent PSE ports
 - In some PSEs, poorly DC-isolated Bob Smith terminations can couple PD Backfeed to adjacent ports, resulting in corruption of the detection signature
- To prevent damage to non PSE pairs with low impedance terminations
- To set a well-defined behavior of an unpowered PD mode
 - Backfeed should be below the PSE minimum OFF/detection voltage value.
- To meet “**The PD shall not source power on its PI** ”
 - To handle PD auxiliary power supply with no limits on its voltage/current
- To prevent damage to Endspan or Midspan configuration when one of them is OFF.

Annex C2: The reasons for backfeed specification: Detection pollution

- **Example** with 2-pair multiport PSE (get worsen when the number of ports increase)
- “BST” is a termination module, contributing to port to port cross-leakage
- If BST is poorly designed, the 2nd PSE will not be able to detect and powerup.
- “From clause 33 and 145: “In a multiport system, the implementer should maintain DC isolation through the termination circuitry to eliminate cross-port leakage currents. “



Annex D: List of issues to resolve/investigate

List of issues to address in order to resolve problem #2

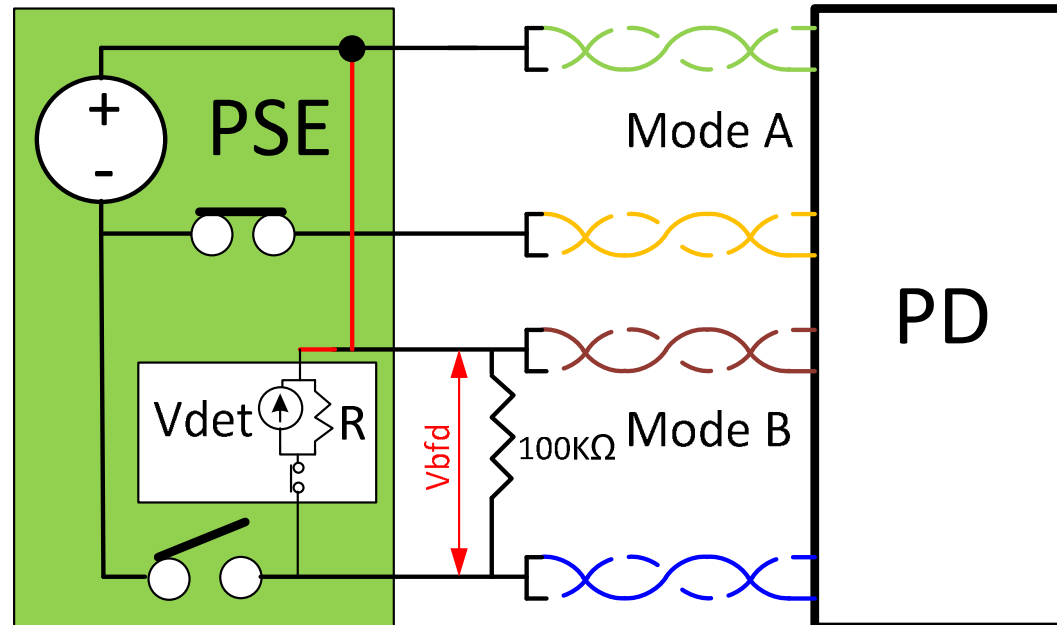
- Test conditions: Applying high backfeed voltage (VPort_PD-2P) to the unpowered pair of a 4-pair PSE when connected **to an ideal diode bridge from a schematic that was supplied to me¹**, in the following cases and checking for:
 - damage to existing 4-pair PSE detection circuitry that was used to see up to 30V during detection and backfeed voltage up to 2.8V and now may see backfeed voltages up to 57V.
 - PDs using wall adapters. If excluding 3-pair, PSE or PD or bot will be damaged since maximum voltage and current are not specified.
 - Damage or interoperability issues in a typical Endspan/Midspan configuration
 - When a PSE is connected to a SSPD through crossed cable: Damage to the detection diode across the PI due to reverse polarity¹?

When a PSE is connected to SSPD through crossed cable: safety (>60V) between the two modes¹?

- increasing PSE susceptibility to cross leakage current issues that will prevent successful detection on adjacent pairs/ports (now leakage may be higher by $57V/2.8V \approx 20$)
- Effects of backfeed violation on detection and classification
- **Other? Group/system vendors need to check for other use cases to ensure we are not creating problems in such late stages of the standard.**

Annex E: Potential damage to detection circuitry during Detection to legacy Endspan/Midspan configurations and existing 4-pair PSEs

- Detection circuitry has to handle up to 57V and not 30V as in typical diode based bridge designs.
- Vendor1 results: PSE ok at 57V and power dissipation for any duration.
 - Details: $R_{dson} \cdot I_{port}^2 > 57^2/R$ per port → No issues
 - R is the PSE output resistance across the PI during OFF/DETECTION state
 - Increasing R has no significant value compared lowest possible R. The minimum value of R (R_{min}) must be $R_{min} \geq 45K$ to meet spec. See note 1.



Note 1:

having R close to $R_{min} \geq 45K$ during OFF/Detection states is advantage compared to $R > R_{min}$ since it allows fast discharge of PD input caps and make PD ready for next new detection faster.

Solution: to add to the PSE spec:

PSE to handle reverse voltages from 0V to 57V with maximum of $I_{rev} = 1.3mA$

Annex F: Endspan/Midspan configuration

- Since a Midspan, when connected to Endspan, breaks the DC continuity over at least one positive pair, ***the 3-pair mode is avoided*** which results in true 2-pair mode operation, which meets the backfeed requirement.
- **Conclusions: No issues with Endspan/Midspan configurations if we exclude backfeed requirements in 3-pair mode.**

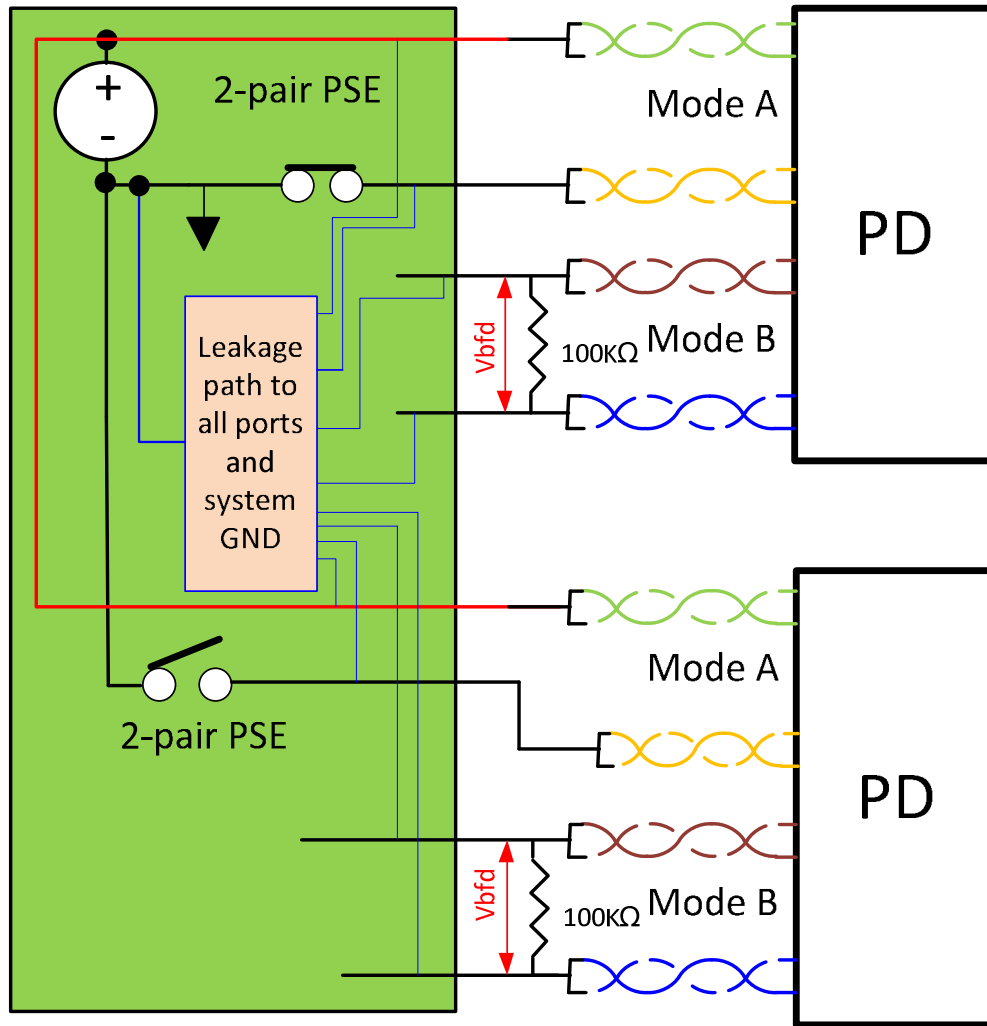
Annex G1: PSE is connected to SSPD through crossed cable

- To verify that when a crossed cable is used, the unpowered PSE alternative doesn't experience reversed voltage that could damage the detection diode across the PI (Figure 145-19 and 145-20).
- **Analysis results:** per the specific ideal diode bridge schematic that I have received, which generates backfeed (VPort_PD-2P) in 3-pair mode:
 - The root cause of the high backfeed voltage on the unpowered pair is that the two control circuits of the two Ideal diode bridges get the positive pair voltage since they are both tied together at the PSE. This causes the relevant negative side MOSFET in the ideal diode bridge to be ON, on the unpowered pair which in turn generates the high backfeed voltage (instead of staying OFF as it would in a diode bridge implementation).
 - The bridge still determine its polarity only as a function of its input voltage independent of the 2nd bridge, resulting in the correct backfeed voltage polarity at the unpowered PSE alternative.
- **Conclusions:** No issues with crossed cable if we exclude backfeed requirements in 3-pair mode.

Annex G2: PSE is connected to SSPD through crossed cable

- To verify that when a crossed cable is used, the unpowered PSE alternative doesn't experience reversed voltage which would cause >60V between the modes in Midspan/Endspan configurations
- **Analysis results**
- **3 arguments that each alone is sufficient to claim NO ISSUES:**
- There is no risk of >60V between modes when the PD is single-signature, since any pairs of the same polarity are clamped to each other by the PD diodes.
- In addition, there is no reverse polarity issue in the mentioned ideal diode bridge behavior.
- Since a Midspan, when connected to Endspan, breaks the DC continuity over at least one positive pair, ***the 3-pair mode is avoided*** which results in true 2-pair mode operation which meets the backfeed requirement.

Annex H1: increasing PSE susceptibility to cross leakage current issues between pairs/ports in a multiport systems.



- Allowing high backfeed voltage up to 57V may increase existing 4-pair design and legacy 2-pair design susceptibility to cross-leakage current by a factor of up to ~20 (57V/2.8V) and may prevent successful detection on adjacent pairs/ports.
- *I checked Vendor1 system and leakage current is still sufficiently low at 57V so detection is not polluted.*
- **See simulation results next slide**

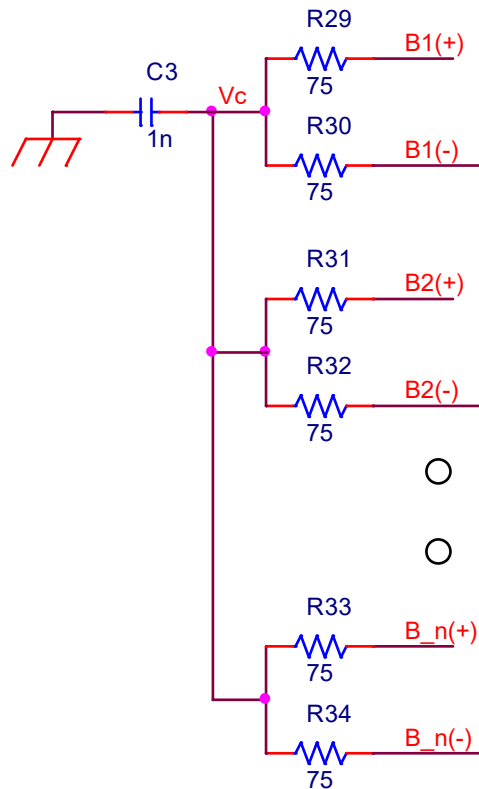
Annex H2: increasing PSE susceptibility to cross leakage current issues between pairs/ports in a multiport systems.

Simulation results: What if excluding backfeed ?

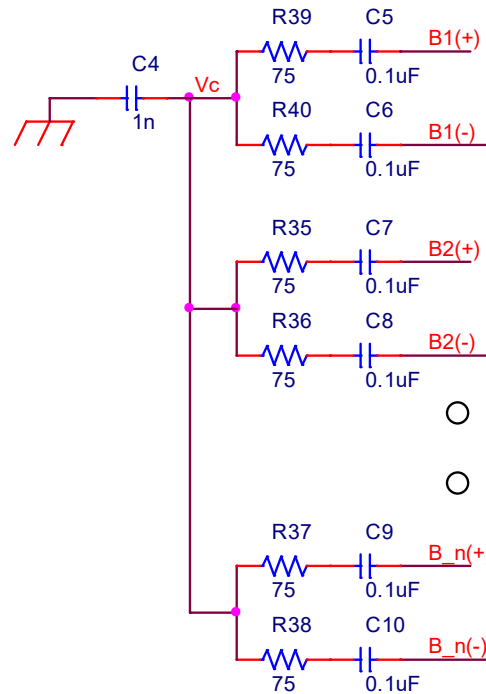
#	PSE Config	Termination Config. (See Annex H2)	Results
1	2 pair only (Type 1 or Type 2 PSEs)	A	<p>Conditions: -Alt A on 1st port is ON. -Alt B on with typical diode bridge ($V_{bfd} \leq 2.8V$, $I_{bfd} \leq 28\mu A$)</p> <p>Results: Failure to detect on the N port ($V_c = V_{pse}/2$ to V_{pse}, $V_{sig} > 2.8V$)</p> <p>Conclusion: -Move to Termination config B -Meet backfeed in 2-pair</p>
1	2 pair only (Type 1 or Type 2 PSEs)	A	<p>Conditions: Alt A on 1st port is ON. -Alt B on 1st port ideal diode bridge in ON ($V_{bfd} \gg 2.8V$, $I_{bfd} \gg 28\mu A$)</p> <p>Results: Damage to termination resistors. Failure to detect on the 2nd port ($V_c = 25.11V$, $V_{sig} = 24.46V$)</p> <p>Conclusion: -Move to Termination config B -Meet backfeed in 2-pair</p>
2	3-Pair Type 3/4 PSE operating over 2-pair (3-pair mode)	B	<p>Conditions: -Alt A on 1st port is ON. -Alt B on 1st port ideal diode bridge in ON ($V_{bfd} \gg 2.8V$, $I_{bfd} \gg 28\mu A$)</p> <p>Results: $V_c = 42.9V$, $V_{sig} = 1.081V < 2.8V$ when only one port is ON. $V_c = 31.296V$, $V_{sig} = 1.1347V < 2.8V$ when 3 ports are ON and one is OFF. Each port that is ON increase V_{sig} by 17.66mV with cap leakage resistance=10MEG. -will pass detection until the 97 port is ON.</p> <p>Conclusion: -we can exclude backfeed in 3-pair as long as Termination config B is carefully used and MOSFET $R_{off} \gg R_{sig}$.</p>

Annex H3: increasing PSE susceptibility to cross leakage current issues between pairs/ports in a multiport systems.

Termination Type A



Termination Type B



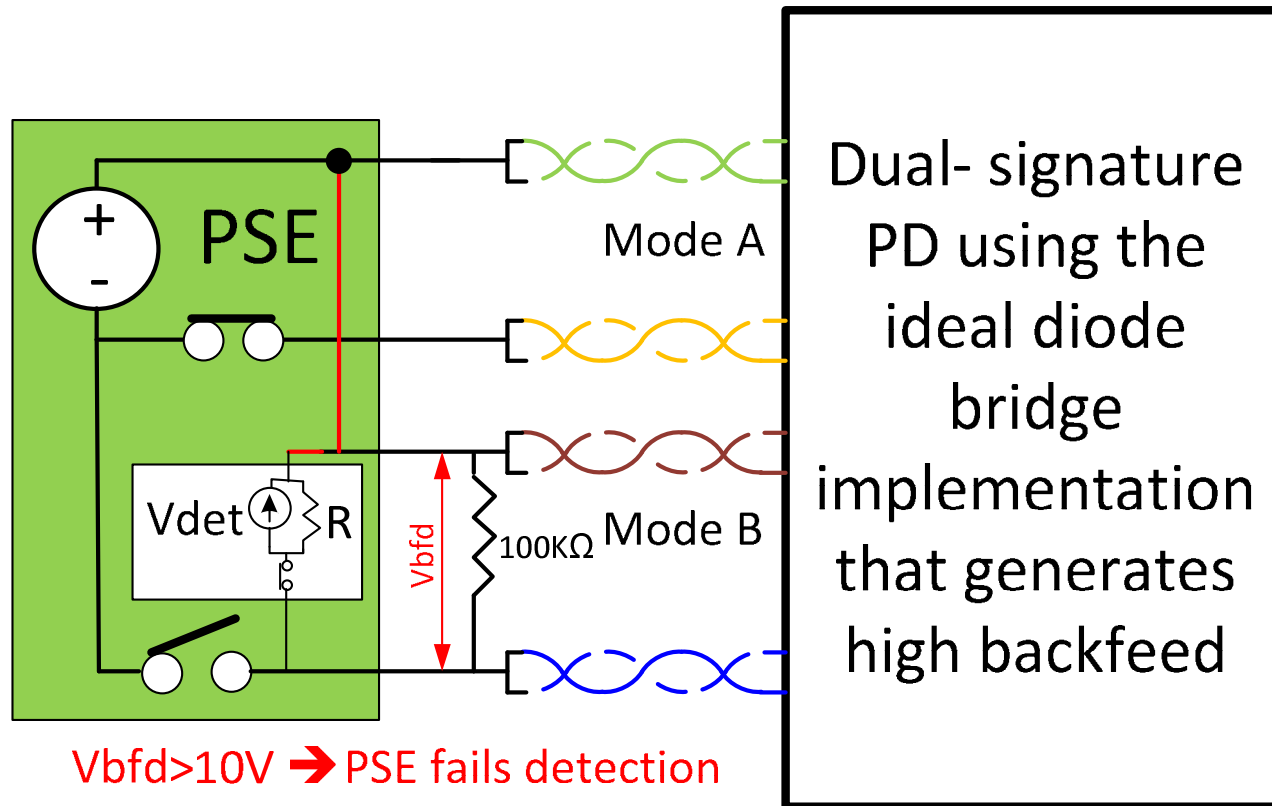
Note: Each cap has high resistance in parallel to represent leakage current

Annex I: Examples of specifying system requirements for multiport systems

- 145.4.1 Isolation (Page 221 line 36)
 - In a multiport system, the implementer should maintain DC isolation through the termination circuitry to eliminate cross-port leakage currents.
- 145.4.1.1.1 Environment A requirements (Page 222 line 10)
 - An Environment A multiport NID does not require electrical power isolation between link segments.

Annex J: Addressing dual-signature PDs

- The current text looks like it covers both single-signature and dual-signature PD, however dual-signature PDs must meet backfeed for any valid configuration in Table 145-20 (2-pair, 3-pair and 4-pair) and we need to ensure this in the final text of backfeed, if it is going to be changed.



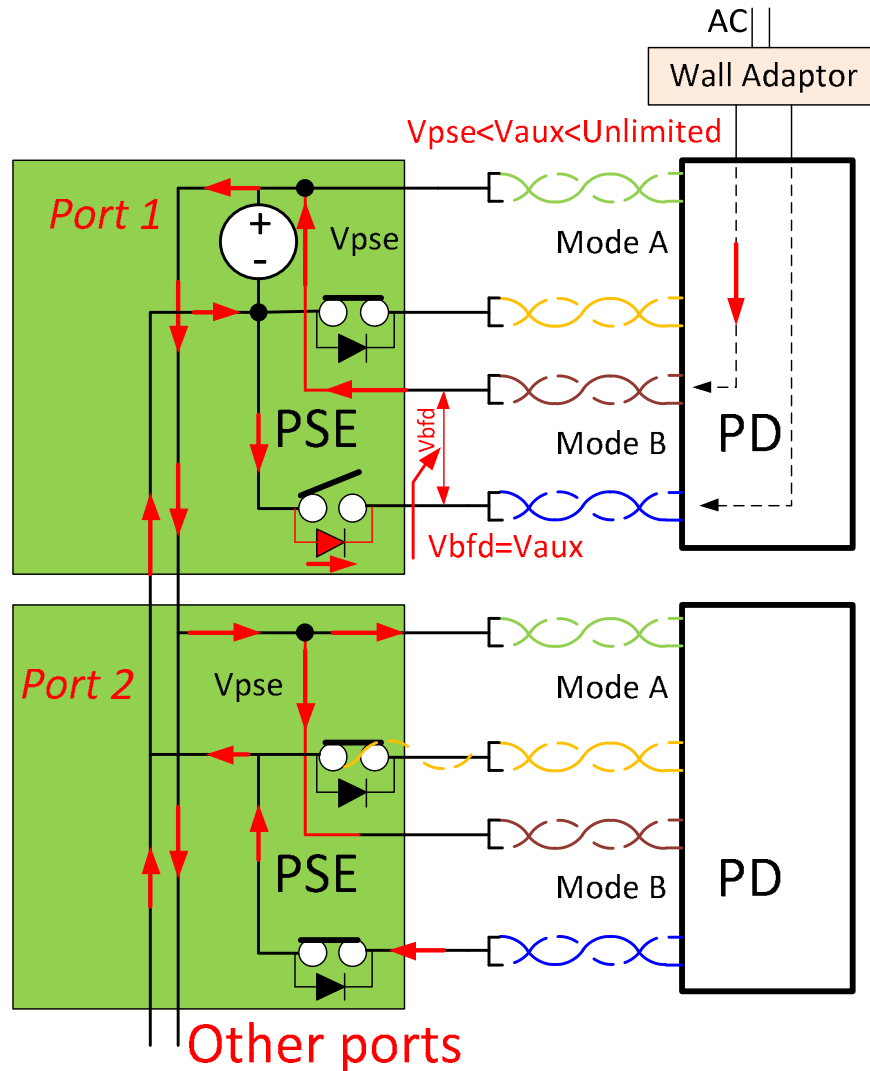
Solution:

If excluding backfeed from 3-pair, to do it only for SSPD and add new text to include backfeed requirements for dual-signature PDs in 2-pair, 3-pair and 4-pair modes.

Annex K1: PDs with wall adaptor

- The concern is that violation of PD back feeding has the same results as if PD is sourcing power which is ***not acceptable!***
 - PDs with aux power supply are allowed by the standard
 - Their maximum voltage and current limits are not specified
 - ***The concerns are:***
 - Voltage > V_{pse_min} . PD aux power supply will replace PSE PS and power all the ports and will damage the PD aux power supply
 - Voltage > 57.
 - It will damage PSE
 - Violate the safety spec (SELV).
 - PD aux power supply will replace PSE PS and power all the ports and will damage the PD aux power supply.
 - See problem and solution next slide

Annex K2: PDs with wall adaptor



- Risk of damaging:
 - PSE (If $V_{aux} > 57V$)
 - PSE MOSFET body diode of port #1 ALT B
 - PD (Aux supplies all the power to the 1KW PSE load....)
 - Other PSE connected instead of Aux

- Solution:

Need to keep the requirement that PD shall not source power and clarify in additional text that backfeed is not sourcing power.