# Backfeed voltage during 2, 3 and 4 pair operating modes

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# Objectives

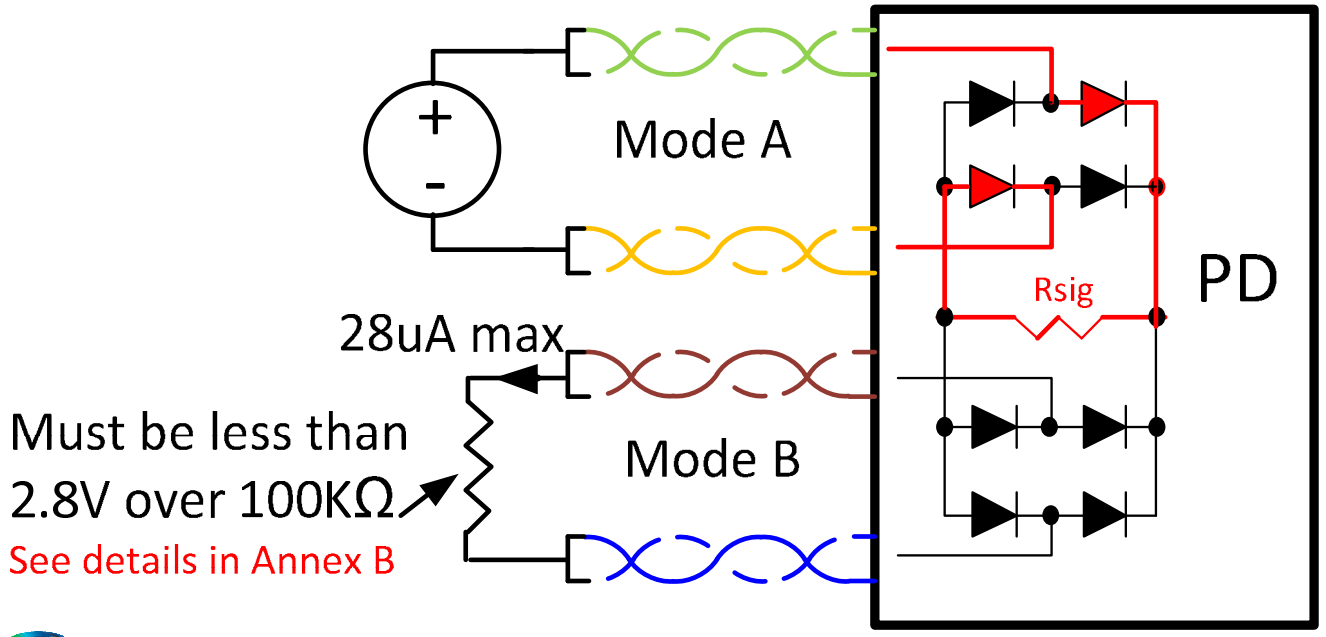
- To investigate the effect of excluding backfeed requirements for 3-pair mode.

- 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 VPort_PD-2P max is applied across the PI at either polarity specified on the conductors of either Mode A or Mode B[1] according to Table 145–20[1], the voltage measured across the PI for the other Mode with a 100 kΩ load resistor connected across that other Mode shall not exceed Vbfd 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 specification[1] 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.

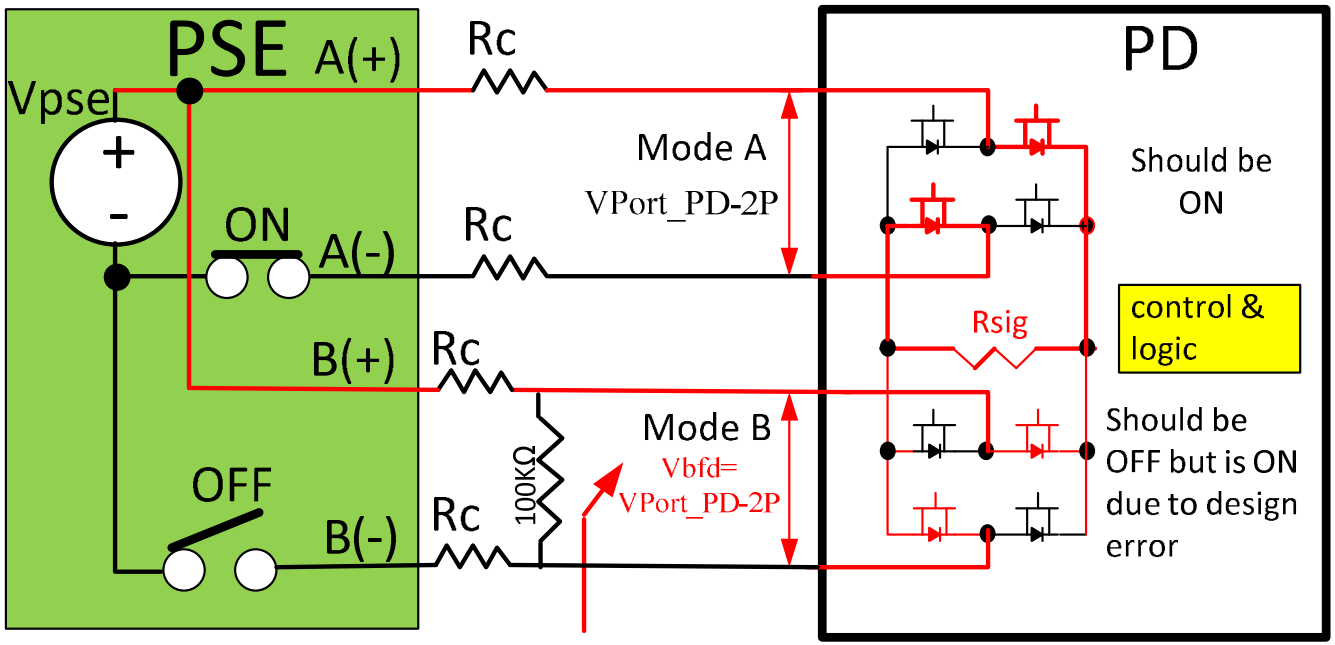
**Table 145–20—PD input power configurations**

| Pairsets | Mode A | | Mode B | |
|---|---|---|---|---|
| Pairs | 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 mode[1].
- 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) Vbfd 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 including initial condition of invalid signature/open circuit. | To be discussed |
| 13 | Pollution of classification 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 DSPDs[1].~~

(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 limit[1] 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

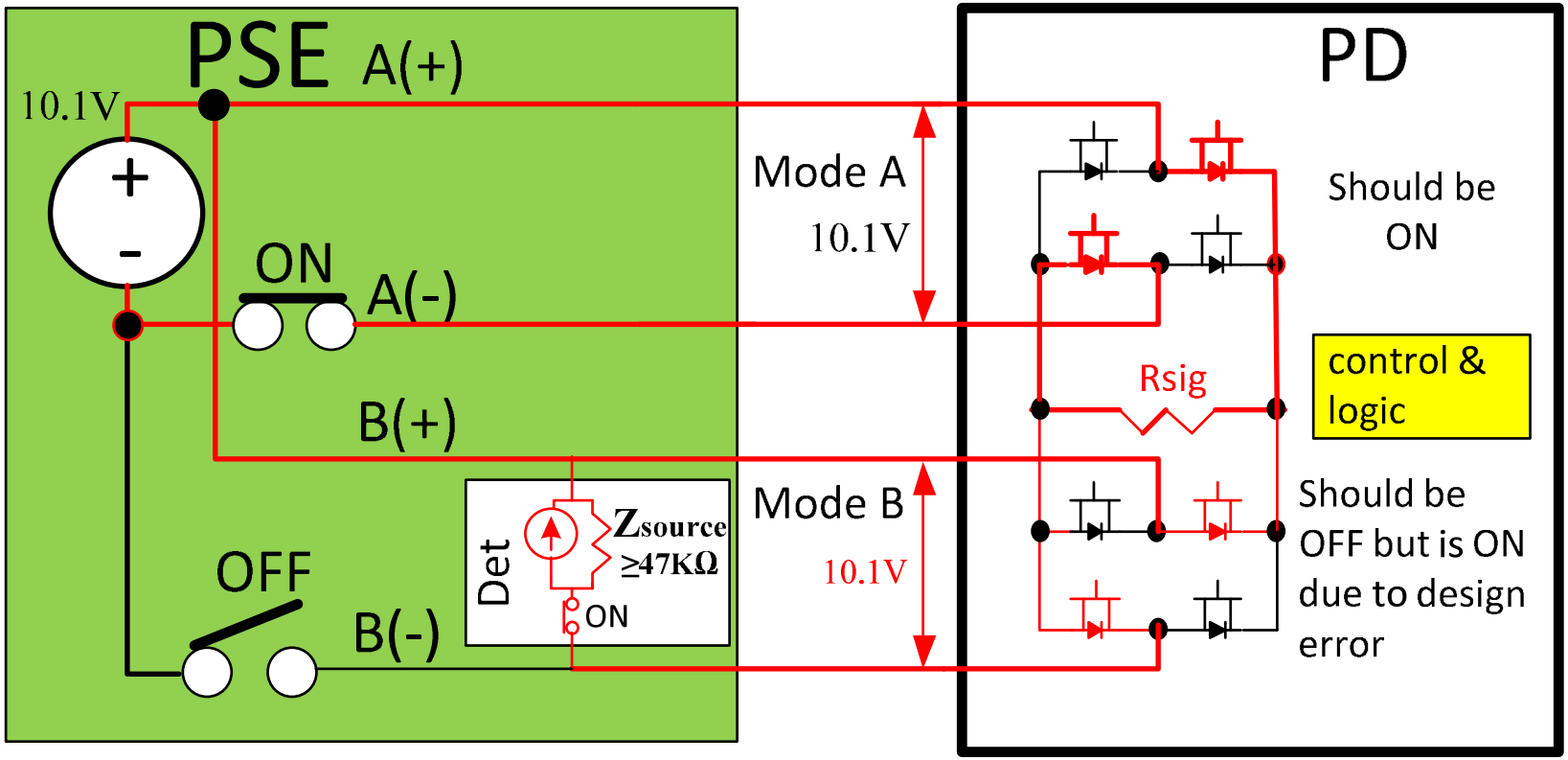
- Allow PSEs to support PDs with 3-pair backfeed issue
- Allows PDs with backfeed issues in 3-pair mode. This can only possible if the whole group ***will focus on finding issues and address them so we will not create bigger problems otherwise we will have to go to option 1)***
- PD spec:
  - Exclude 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 limit[1] 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 Zsource (Figure 145-19) in the detection circuitry.
- Zsource will be in parallel to Rsig ➔ 45K||(25K*0.95)=15.35K < 19K ➔ Fail.
- Solution: To require meeting backfeed for at least 10.1V OR meeting valid or invalid detection signature with the presence of Zsource hence PD will know what to do e.g. meeting old backfeed requirement in this region without forcing implementation.



# New issues – Detection pollution (at 30V range)

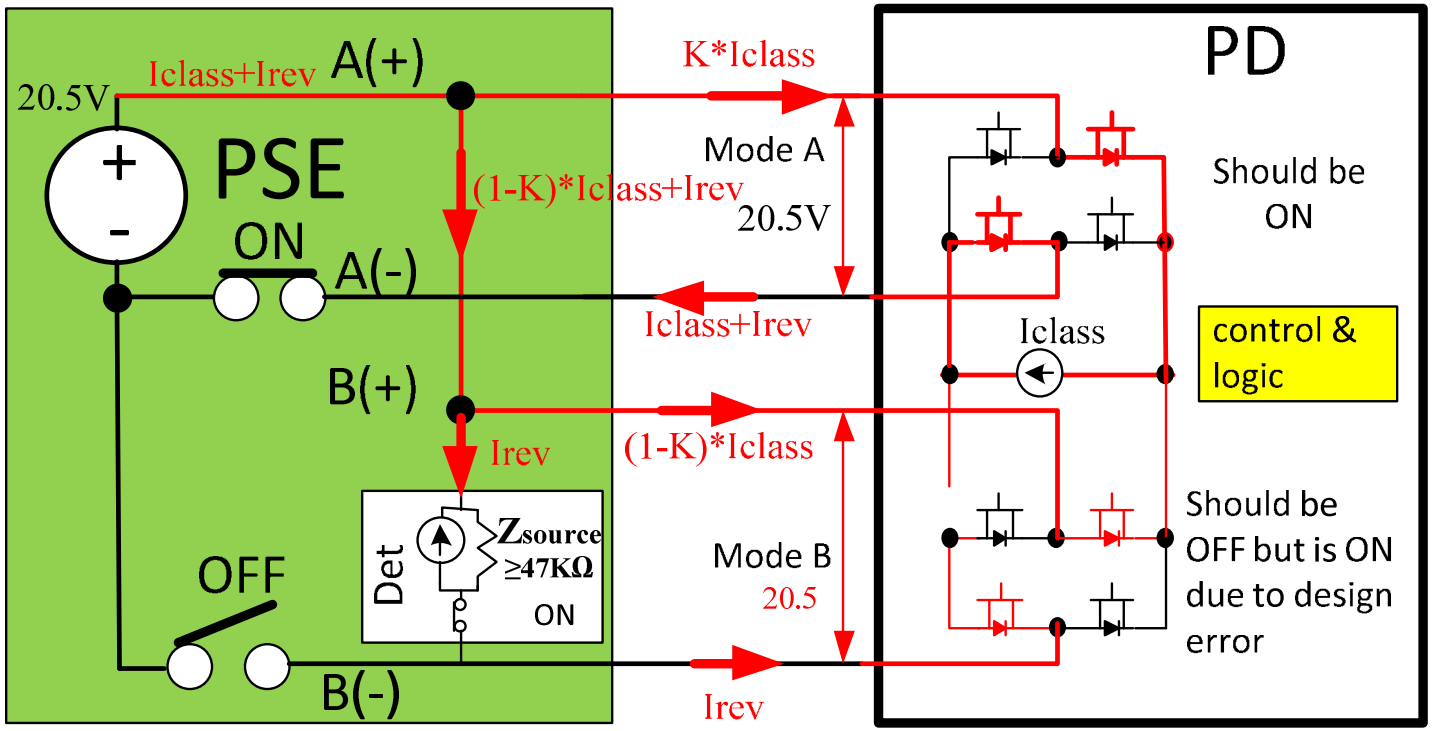
- When PD doesn't require power he need to present invalid signature which includes open circuit or high value of resistance.
- As a result, PSE detection voltages may reach 30V.
- Now if both ideal diode bridge are ON at 30V, they may stay on due to the fact that they latched and remembers that last operating mode.
- Now, if PD requires power and present valid signature which brings PSE PI voltage to <10.1V, signature will be polluted per the previous example.

- **Solutions:**
- Required PD to meet backfeed up to 30V **OR**
- Allow PD to faill detection on the first attempt since on the second attempt the PD must reset all its functionality below 2.8V and now the initial conditions is that signature is already valid and it will pass detection.

# 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/Rsource_min=0.436mA (or Irev) 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 Irev=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!

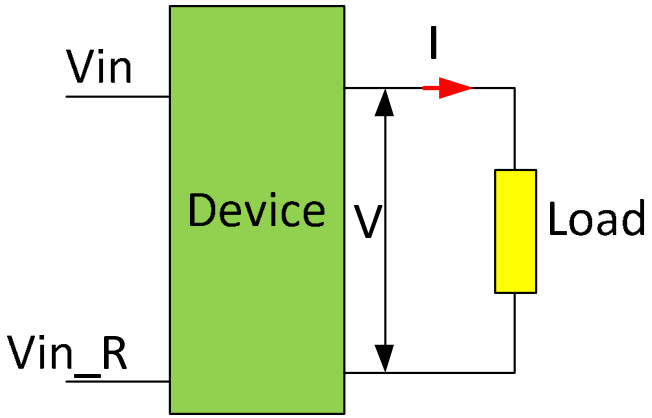



Solution:

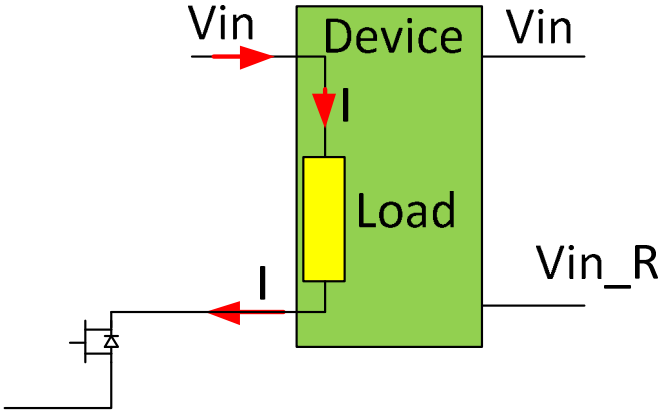
1. To require meeting backfeed in 3-pair for at least 20.5V+margin **OR**
2. Limit Irev to 0.5mA at the range of 10.1V to 21V.

# Source current vs.. sink current

Current sourcing
(current flows out of device)

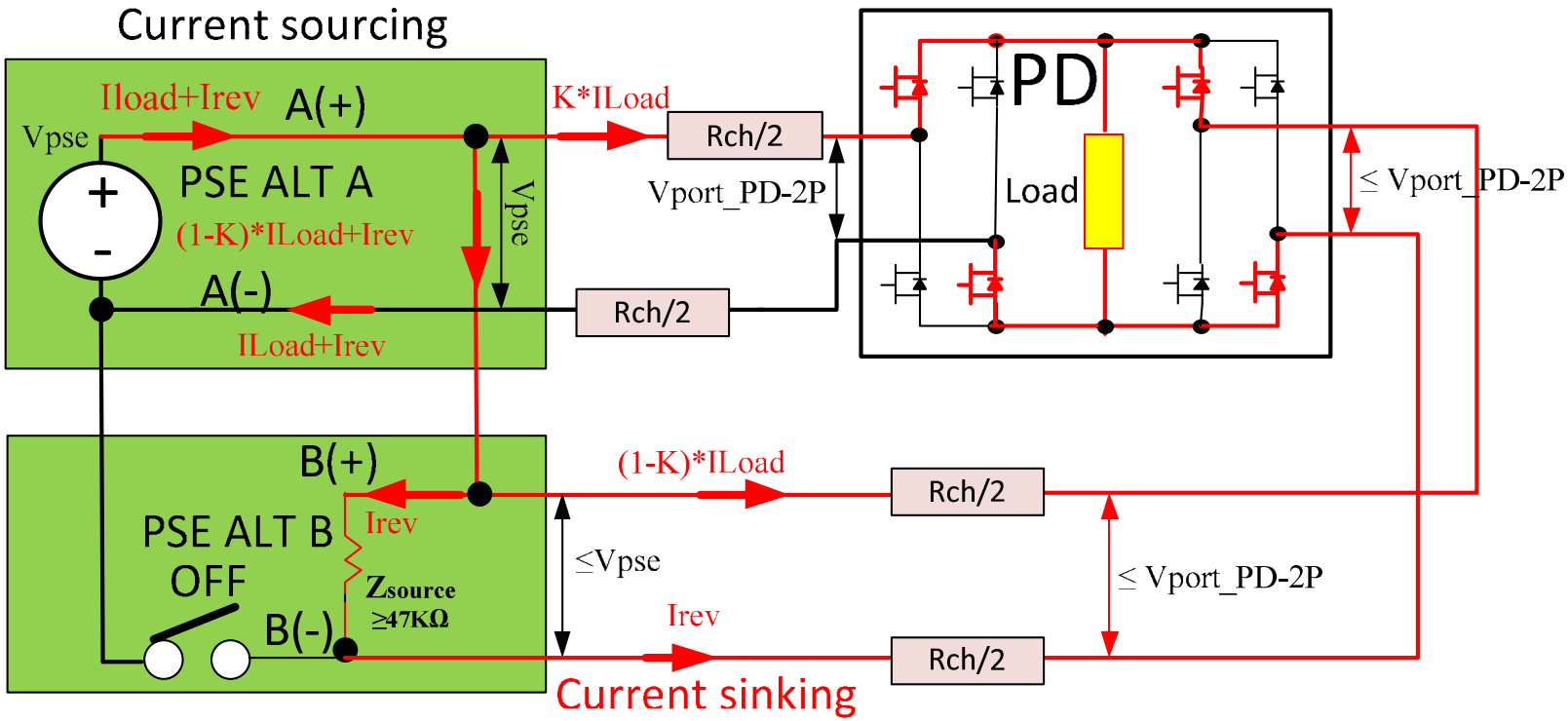



Current sinking
(current flows into device)



# Source current vs.. Sink/draw 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 or ~0.5mA during classification operating voltage range.
- A device when it is OFF, can't source current. It can only be additional load to other active load.
- Alternative A PSE is powered, delivering power to the PD and the PD backfeed voltage to ALT B PSE that is OFF and cause Zsource to dissipate power.
- Therefore, PSE ALT B negative pair is drawing current.



# Source current vs.. sink current – proposed text

As a result, change the proposed text to:

**145.2.10.3a Reflected voltage**

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. This can cause a reverse current to flow, named Irev, defined in Table 145–16. Reverse current is current flowing out of the PSE on a negative pair.

The PSE shall not ~~source~~ cause a current higher than Irev, as defined in Table 145–16, to flow on the negative pair. This requirement holds only when no power is being sourced into the PSE.

# Annexes

# 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:<br>- limiting the current flow (or draw) to 1.3mA at Vpse>21V and to 0.5mA between 10.1V and 21V.<br>- 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.<br>See Annex H1, H2, H3 for details |
| 3 | | | |
| 4 | | | |

# Summary of concerns and proposed solutions PD section

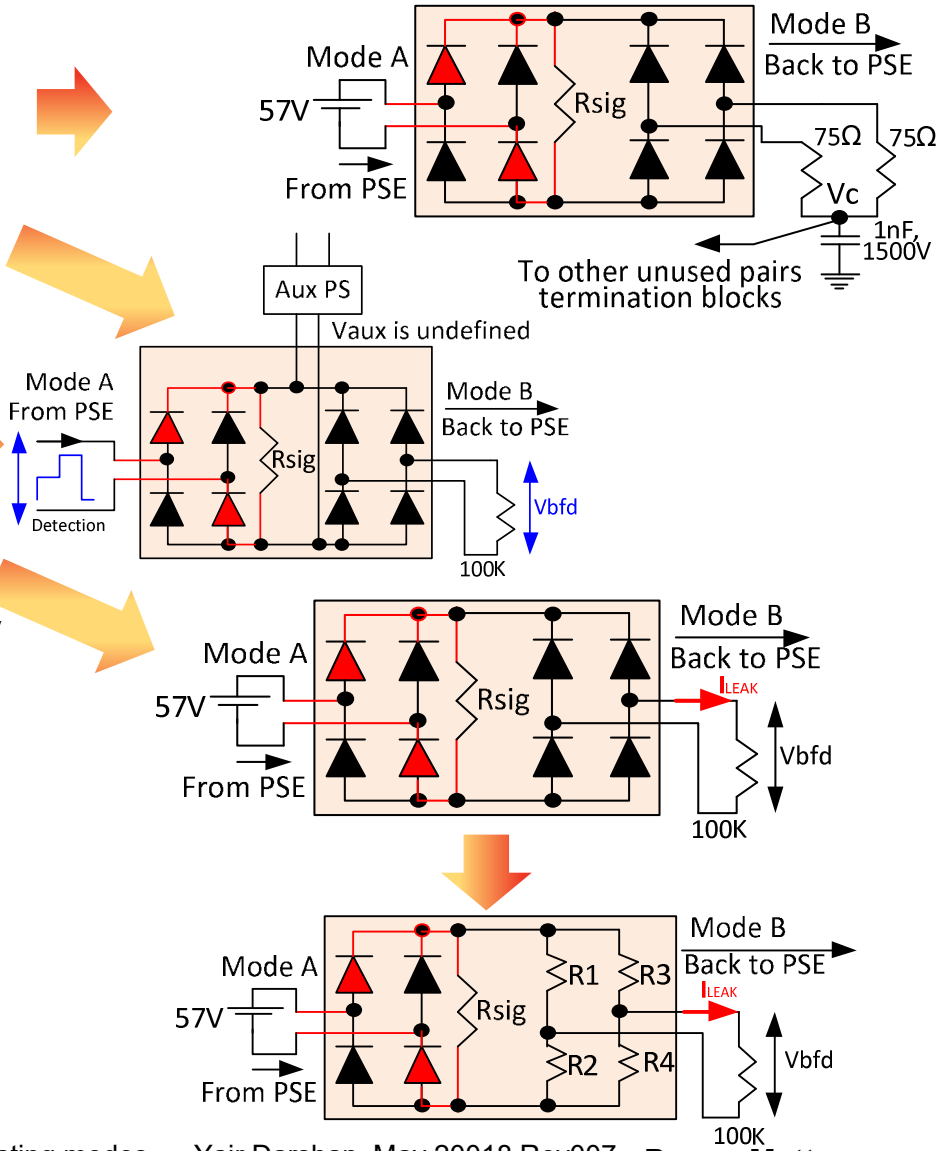
| # | Concern | Results | Recommendations |
|---|---|---|---|
| 1 | PDs that equipped with auxiliary power supply per 145.3 page 186 line 43-44 with no spec that limits its voltage and current which now may source voltage/power and damage PSE, PD and violates safety specs. | | The current statement -"PDs 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 2nd pair when the 1st pair is doing detection | | To required meeting backfeed in 3-pair mode up 10.1V or meet valid/invalid signature with the presence of Zsource on the unpowered mode. |
| 3 | Pollution of classification by the 2nd pair when the 1st pair is doing classification. | | To required meeting backfeed in 3-pair mode up to (20.5V+margin) or meet classification requiremetnts with the presence of Zsource. |
| 4 | Pollution of detection by the 2nd pair when the 1st pair is doing detection and the PD signature is open. | | To required meeting backfeed in 3-pair mode up 30V or allow detection failure on the 1st trial since on the second detection attempt the detection will pass. |
| 5 | | | |

# 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=Rmin=1MΩ min.
  - ILEAK_max=(57V*(R4/(R3+R4) – R2/(R1+R2) ))/Reqv
  - ILEAK_max=0 If all diodes equal, else ILEAK_max >0
  - With R4=10*R3=10*R and R1=10*R2=10*R (worst case assumption) ➔
    - Veqv=57*9/11. Reqv=2*10*R/11, Ileak_max=25.65uA ➔ rounding up to 28uA
    - Convert Ileak_max to voltage with 100K sense resistor ➔2.8V as needed.



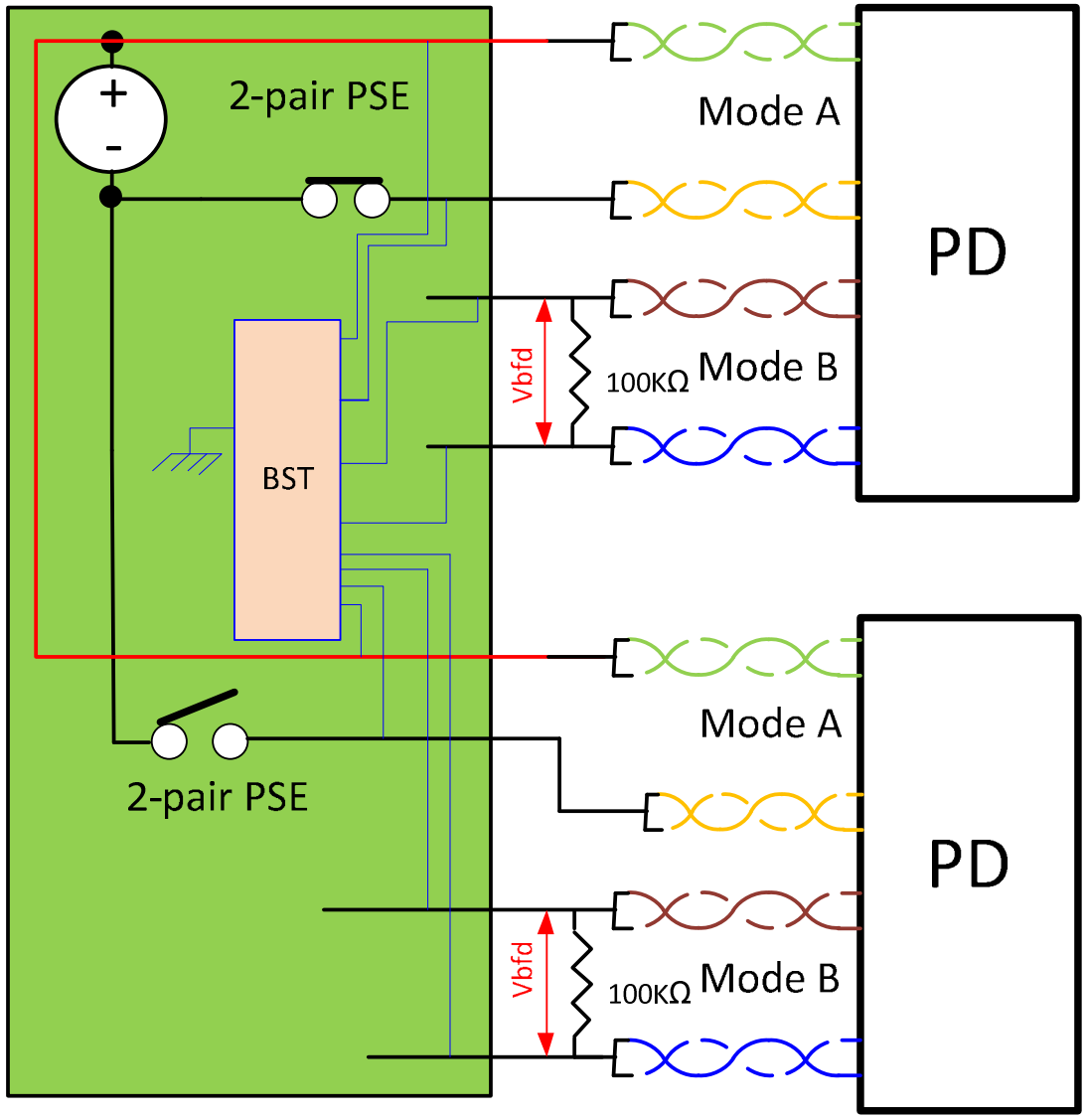
# Annex C1 :The reasons for backfeed specification

- 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

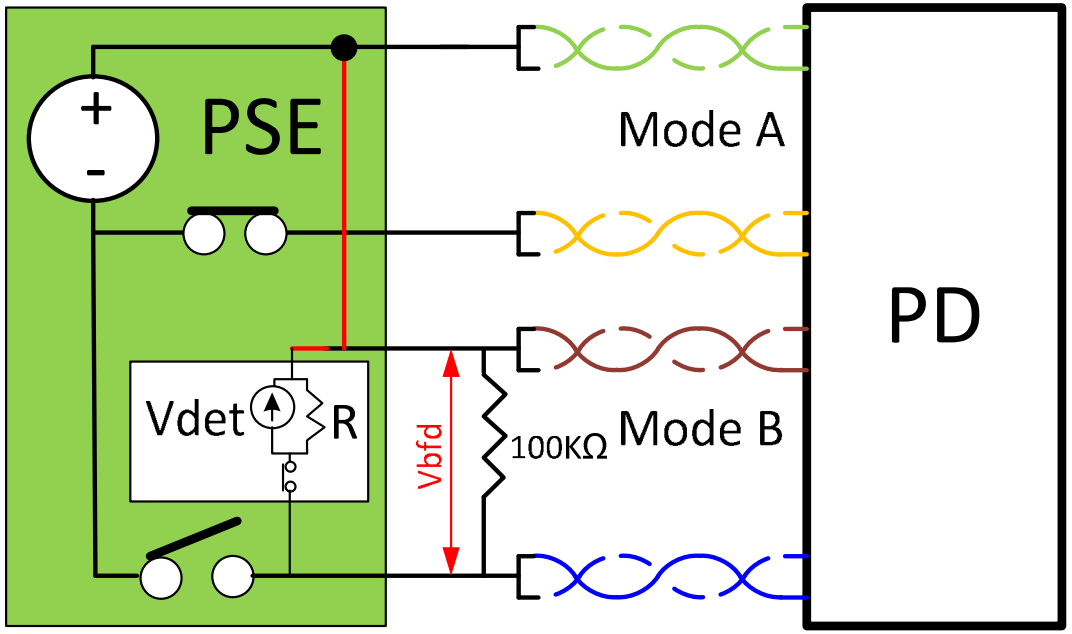
List of issues to address in order to resolve problem #2

- 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 me**[1], 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 polarity[1]?

    When a PSE is connected to SSPD through crossed cable: safety (>60V) between the two modes[1]?
  - 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=~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: Rdson*Iport^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 (Rmin) must be Rmin≥45K to meet spec. See note 1.




Note 1:

having R close to Rmin≥45K during OFF/Detection states is advantage compared to R>Rmin 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 Irev=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).

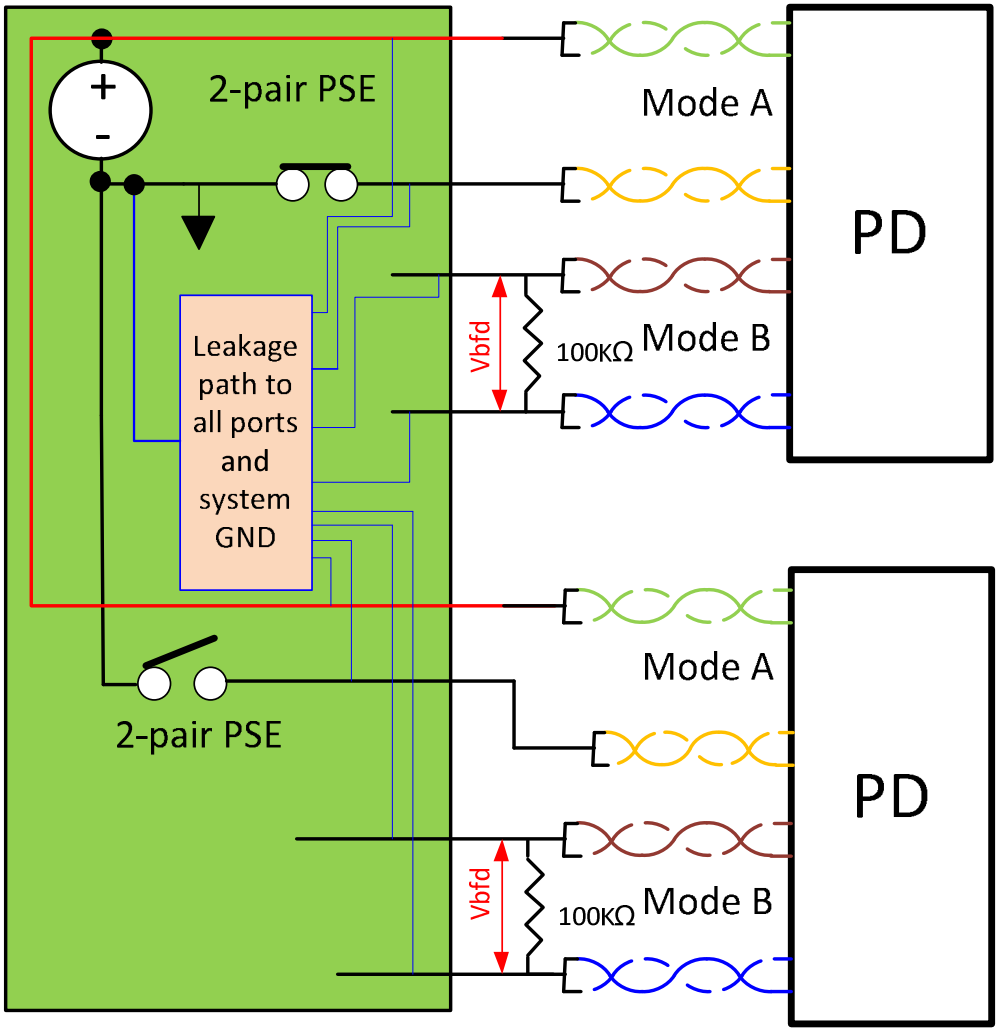
- Analysis results: per the specific ideal diode bridge schematic that I have received, which generates backfeed (VPort_PD-2P ) in 3-pair mode:
  - The root cause of the high backfeed voltage on the unpowered pair is that the two control circuits of the two Ideal diode bridges get the positive pair voltage 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**

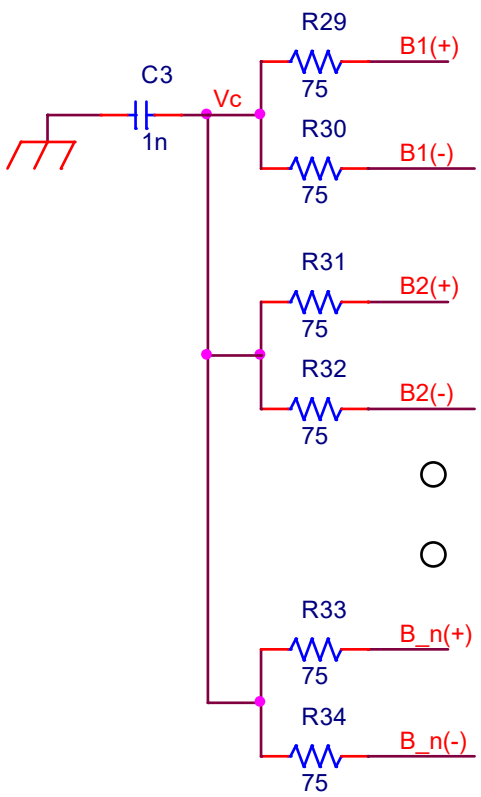
# Annex H2: increasing PSE susceptibility to cross leakage current issues between pairs/ports in a multiport systems.

## Simulation results: What if excluding backfeed ?

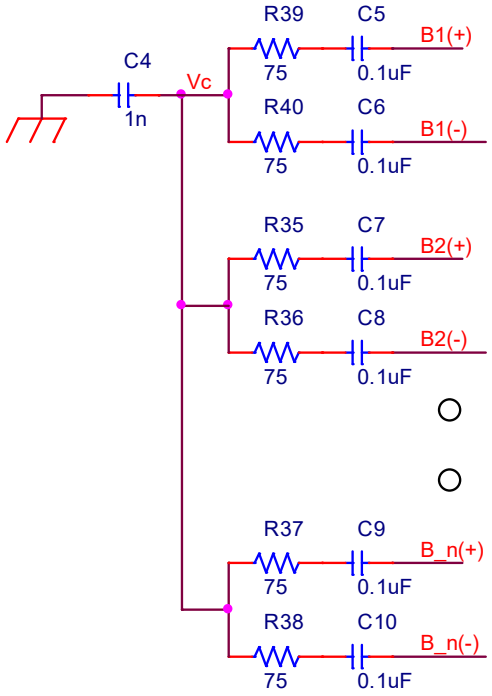
| # | PSE Config | Termination Config. (See Annex H2) | Results |
|---|---|---|---|
| 1 | 2 pair only (Type 1 or Type 2 PSEs) | A | **Conditions:**<br>-Alt A on 1st port is ON.<br>-Alt B on with **typical diode bridge** (Vbfd ≤ 2.8V, Ibfd ≤ 28uA)<br>**Results:**<br>Failure to detect on the N port (Vc=Vpse/2 to Vpse, Vsig>2.8V)<br>**Conclusion:**<br>-Move to Termination config B<br>-Meet backfeed in 2-pair |
| 1 | 2 pair only (Type 1 or Type 2 PSEs) | A | **Conditions:** Alt A on 1st port is ON. -Alt B on 1st port **ideal diode bridge** in ON (Vbfd>>2.8V, Ibfd>>28uA)<br>**Results:**<br>Damage to termination resistors. Failure to detect on the 2nd port (Vc=25.11V, Vsig=24.46V)<br>**Conclusion:**<br>-Move to Termination config B<br>-Meet backfeed in 2-pair |
| 2 | 3-Pair Type 3/4 PSE operating over 2-pair (3-pair mode) | B | Conditions: -Alt A on 1st port is ON.<br>-Alt B on 1st port ideal diode bridge in ON (Vbfd>>2.8V, Ibfd>>28uA)<br>**Results:**<br>Vc=42.9V, Vsig=1.081V <2.8V when only one port is ON.<br>Vc=31.296V, Vsig=1.1347V <2.8V when 3 ports are ON and one is OFF.<br>Each port that is ON increase Vsig by 17.66mV with cap leakage resistance=10MEG.<br>-will pass detection until the 97 port is ON.<br>**Conclusion:**<br>**-we can exclude backfeed in 3-pair as long as Termination config B is carefully used and MOSFET Roff >> Rsig.** |

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

Termination Type A




Termination Type B



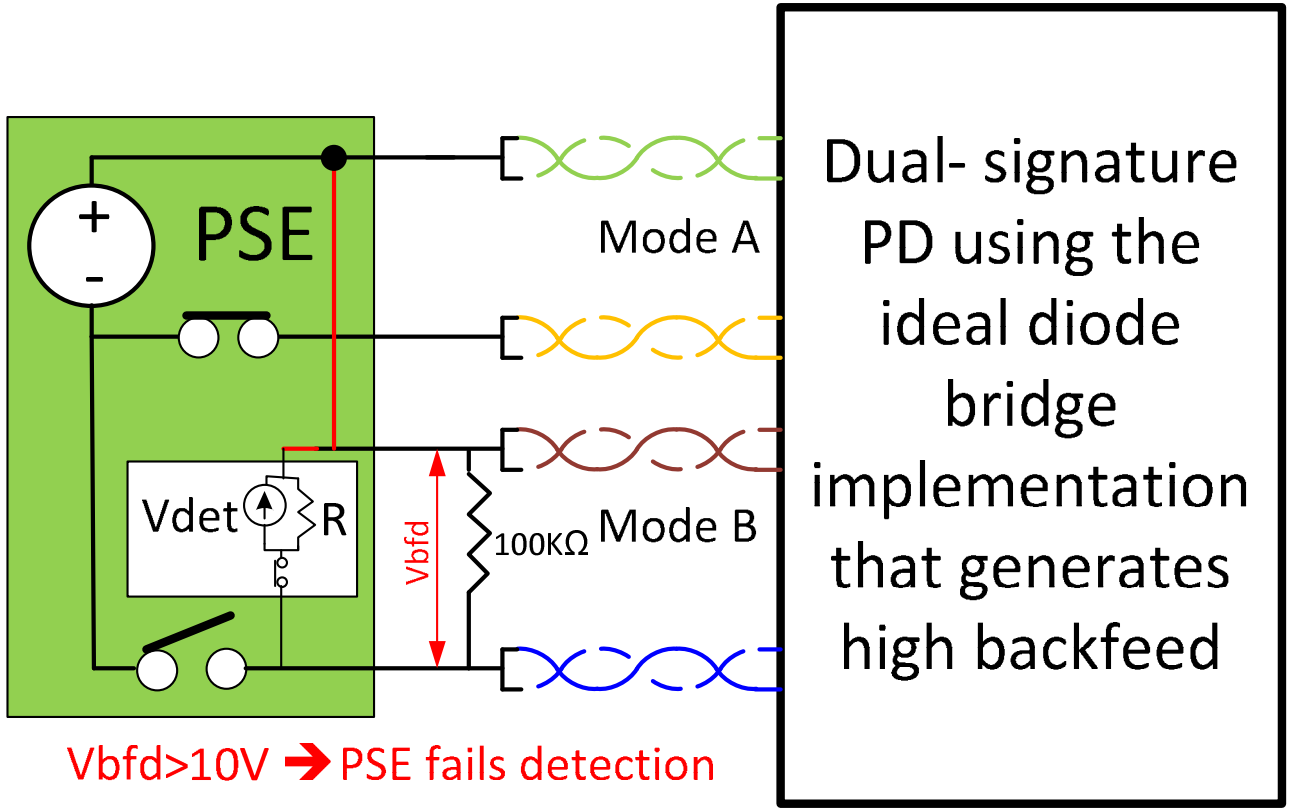

Note: Each cap has high resistance in parallel to represent leakage current

# 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.



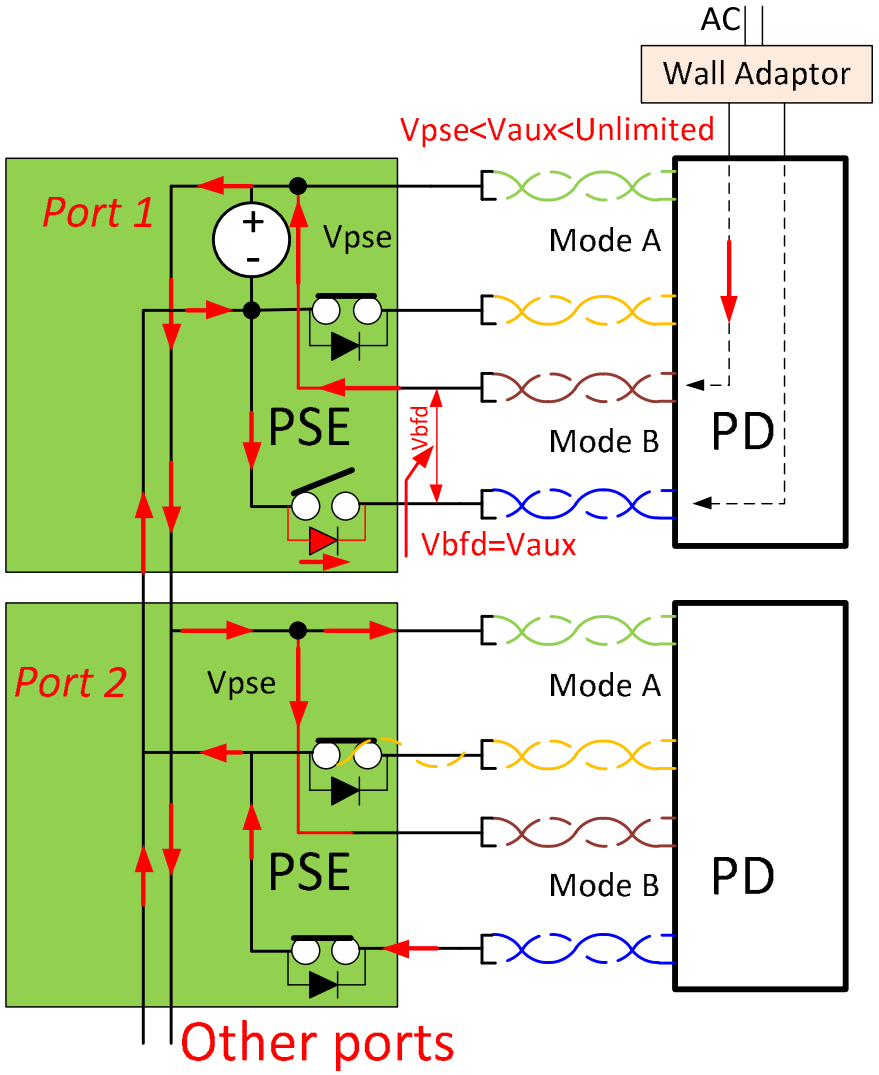

**Solution:**

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>Vpse_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 Vaux>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.