

Upgrading IEEE802.3at and Non-Standard High Power PSE System to IEEE802.3bt Compliant System

Penny Xu & PSIL (Power Interface)

Agenda

- **TPS23861 to TPS2388 Migration**
 - **Feature Differences**
 - **Hardware Differences**
 - **Software Differences**
- Introduction to IEEE802.3bt standard
- **TPS2388 to TPS23880 Migration**
 - Feature Differences
 - Hardware Differences
 - Software Differences
- **Nonstandard High Power Solution to TI BT Solution**
 - UPoE
 - PoE++
 - PoH

TPS23861→TPS2388

TPS23861

- Autonomous mode without I2C
- 4 channel
- Capacitance measurement
- 1 bit fast shutdown
- Software programmable I2C address

TPS2388

- IEEE 802.3at Compliance
- I2C communication
- One 14-bit A/D per port
- ROM only

- Host control is required
- 8 channel
- Port remapping
- 1 bit / 3 bit fast shutdown
- Hardware programmable I2C address
- I2C registers can be access via 8 bit commands(address port 1-4 &5-8 separately) or 16 bit commands(address port 1-8 at the same time)

TPS23861 → TPS2388 Hardware Change

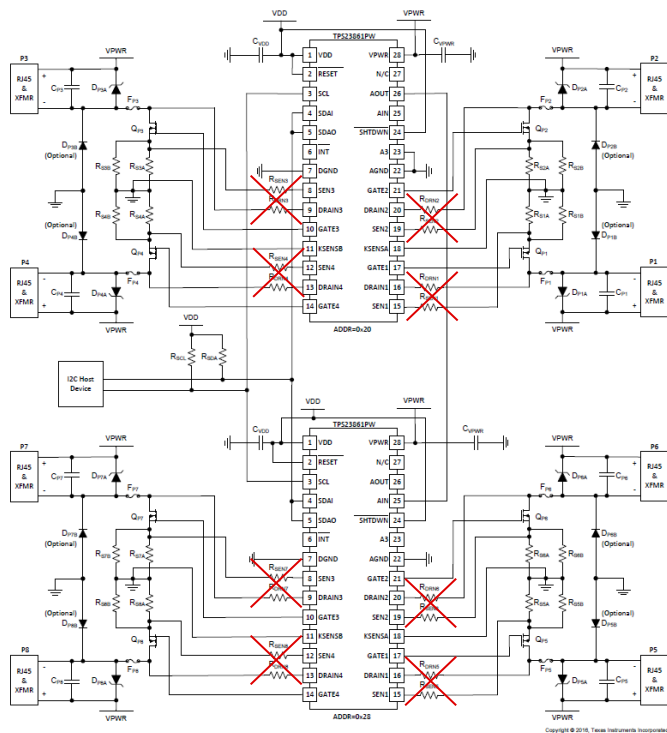


Figure 50. Eight Port Semi-Auto Mode Application

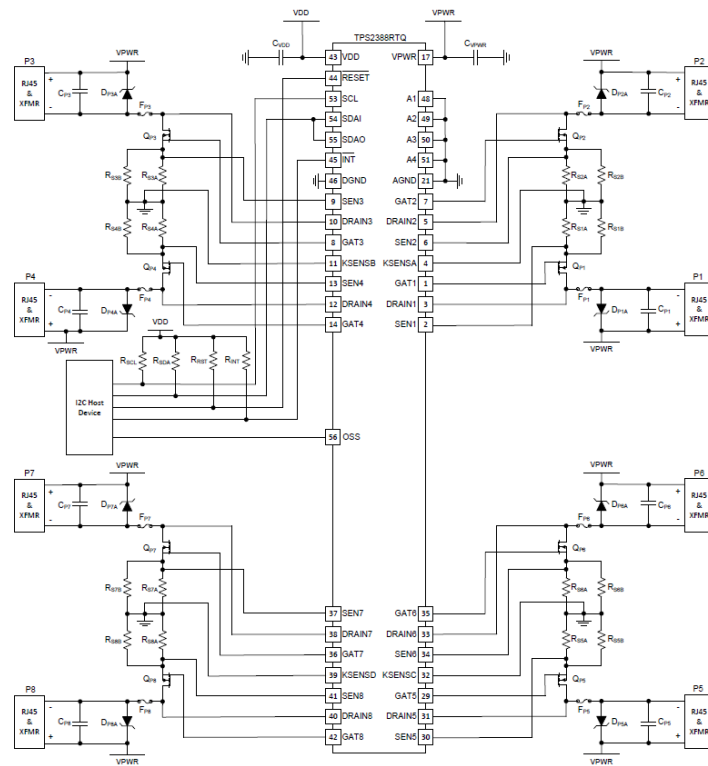


Figure 71. Eight Port Semiauto Mode Application

Note: TPS23861 requires power on sequence to ensure proper operation.

TPS23861 → TPS2388 Software Change

Register	TPS23861	TPS2388
11h	One physical I2C address pin A3 Use daisy chain to configure	4 physical I2C address pin A1-A4
15h	Configure 4 ports fast shutdown priority	Use OSS bit to configure shutdown priority Can disable ICUT fault
17h	Select A/D conversion rate 800/960 Select sense resistor 250/255	Configure I2C address bit 8/16 Configure OSS shutdown 1/3 bit Enable class or detect change indicator
1E/1Fh	RESERVED	Configure ICUT current
20h	Enable legacy detection	RESERVED
21h	Enable two-event classification for class4	RESERVED
23h	RESERVED	IEEE turn on button after one good detect and class
24h/25h	RESERVED	Indicate detect and class fault after IEEE power on
26h	RESERVED	Re-map port logically due to board constraint
27h	Add delay to no-critical interrupt	Configure shutdown priority using 3-bit OSS(27/28h)
2A/2Bh	Configure ICUT current	RESERVED

TPS23861 → TPS2388 MSP430 Reference Code

system_init.h

```
60 //user configurable parameter
61 #define TPS2388 1 //Device selection 1: TPS2388 is selected
62 #define TPS23861 0 //Device selection 1: TPS23861 is selected
63 #define TYPE2_TURN_ON 1 //Choose Type 2 for port 1-4
64 #define TYPE1_TURN_ON 0 //Choose Type 1 for port 1-4
65 #define NUM_OF_TPS238x 2 // device number in system
66 #define VMARK_WORKAROUND 1 // set 1 if TPS23861 has the mark voltage drop
67 #define NORMAL_OPERATING 0 // set 1 if TPS23861 doesn't have the mark voltage drop
68 #define PRINT_STATUS 0 // set 1 if wanting to print port status through uart
69 #define DETAILED_STATUS 0 // set 1 if wanting to print detailed status through uart
70 #define PM_POWER_MONITOR_TIMER 20 //20 = 1s
71 #define PM_DETECT_CLASS_RESTART_TIMER 60 //20 = 1s
72
73 #define PM_NUM_OF_PORT 4 // port count in one PSE
```



Device selection. Once one device is selected, the other device related function will be disabled.

TPS238x.h and TPS238x.c

```
2568 uint8_t tps_GetPortILIM(uint8_t systemPortNum)
2569 {
2570
2571 uint8_t value;
2572 uint8_t portBit = tps_GetDevicePortNum(systemPortNum);
2573
2574 tps_ReadI2CReg (tps_GetDeviceI2CAddress(systemPortNum), TPS238X_POE_PLUS_COMMAND, &value);
2575
2576
2577 return((value>>(3*portBit)) & 0x01);
2578 }
2579
2580
2581 #if(TPS23861 == 1)
2582 uint8_t tps_SetDeviceTwoEventEnable (uint8_t device_i2c_address,TPS238x_Two_Event_t twoEvent1,TPS238x_Two_Event_t twoEvent2,TPS238x_Two_Event_t twoEvent3,TPS238x_Two_Event_t twoEvent4)
2583 {
2584 {
2585 uint8_t rtn;
2586 uint8_t value;
2587
2588 value = (twoEvent4 << 6) | (twoEvent3 << 4) | (twoEvent2 << 2) | twoEvent1;
2589 rtn = tps_WriteI2CReg (device_i2c_address, TPS238X_TWO_EVENT_CLASSIFICATION_COMMAND, value);
2590
2591 return (rtn);
2592 }
2593 #endif
```



Select TPS2388 then the code related to TPS23861 will be disabled.

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PoE IEEE Standard History



PSE = 15.4W
PD = 13W



Type2

Type1



PSE = 30W
PD = 25.5W

PSE = 15.4W
PD = 13W

Type2

Type1



Class4:
PSE = 30W
PD = 25.5W

Class0-3:
PSE = 15.4W
PD = 13W

Class8: PSE = 90W
PD = 71W
Class7: PSE = 75W
PD = 62W

Class6: PSE = 60W
PD = 51W
Class5: PSE = 45W
PD = 40W

Class1-Class4

Type4

Type3

IEEE 802.3af
2003

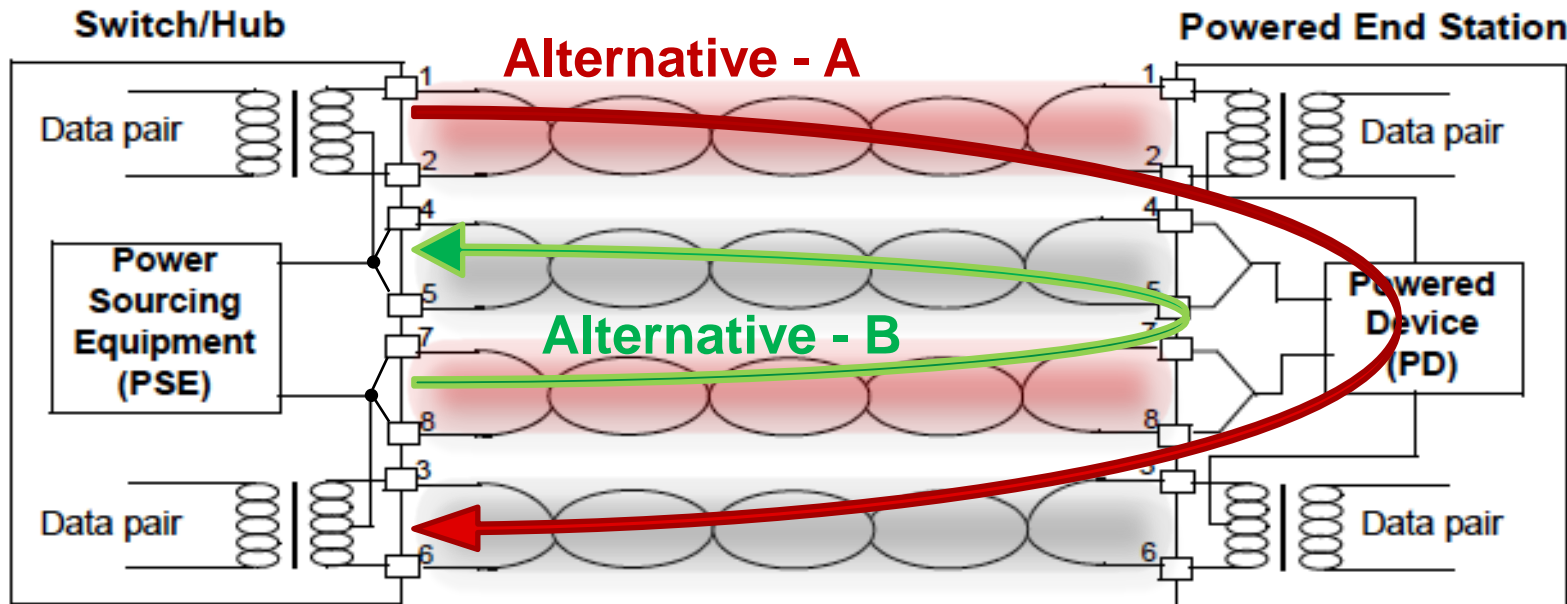
IEEE 802.3at
2009

IEEE 802.3bt
2018



IEEE 802.3bt New Features – 4 Pair PoE

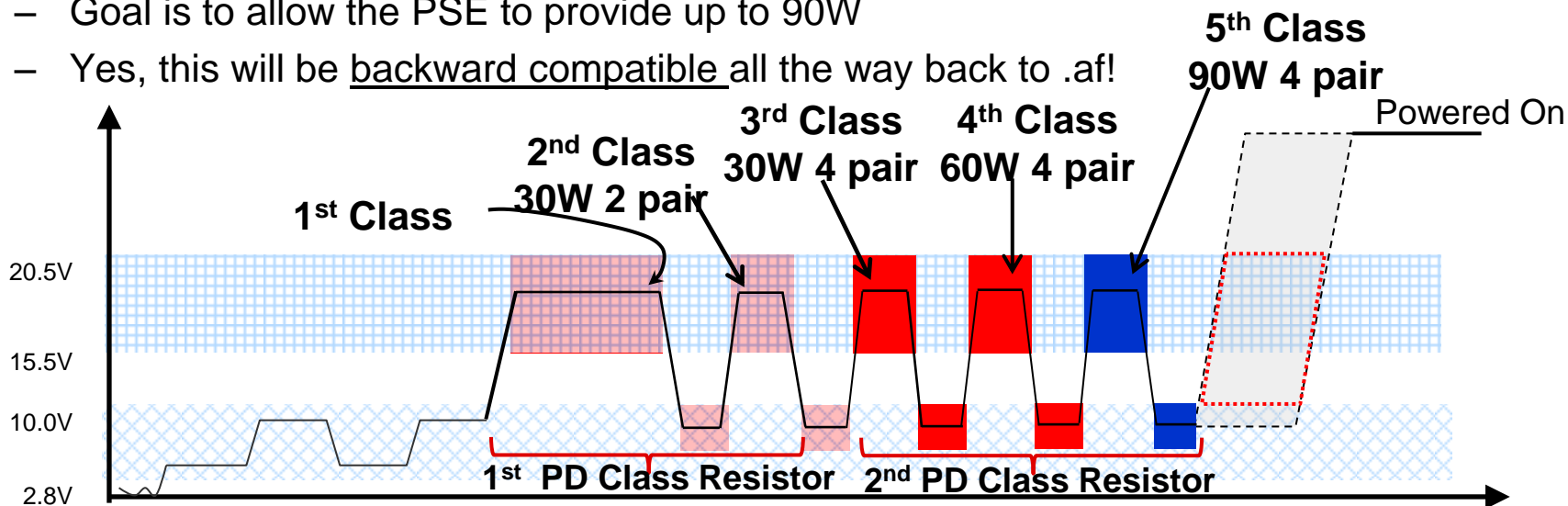
- Power over 4-Pair reduces cable loss and increase the overall system efficiency.
- 4-pair power delivery is **allowed** for all power levels in Type 3 and Type 4, but it is **required** for power >30W.



IEEE 802.3bt New Features – Mutual ID

IEEE 802.3bt Mutual ID

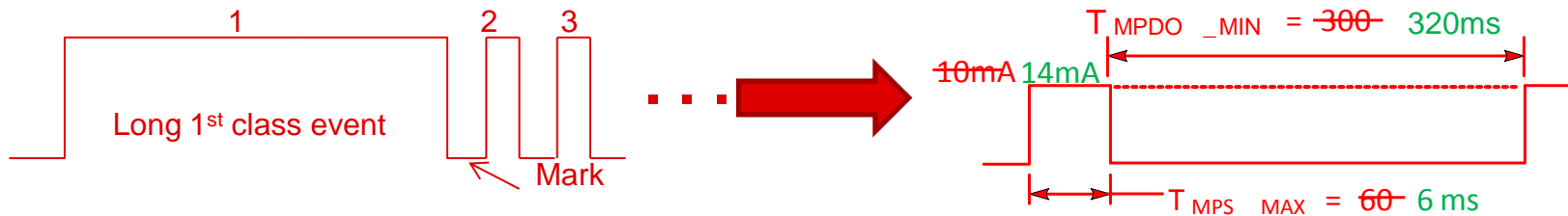
- New long 1st class finger “informs” PD that the PSE will support the new MPS timings.
- Goal is to allow the PSE to provide up to 90W
- Yes, this will be backward compatible all the way back to .af!



IEEE 802.3bt New Features – New MPS

New maintain power signature(MPS)

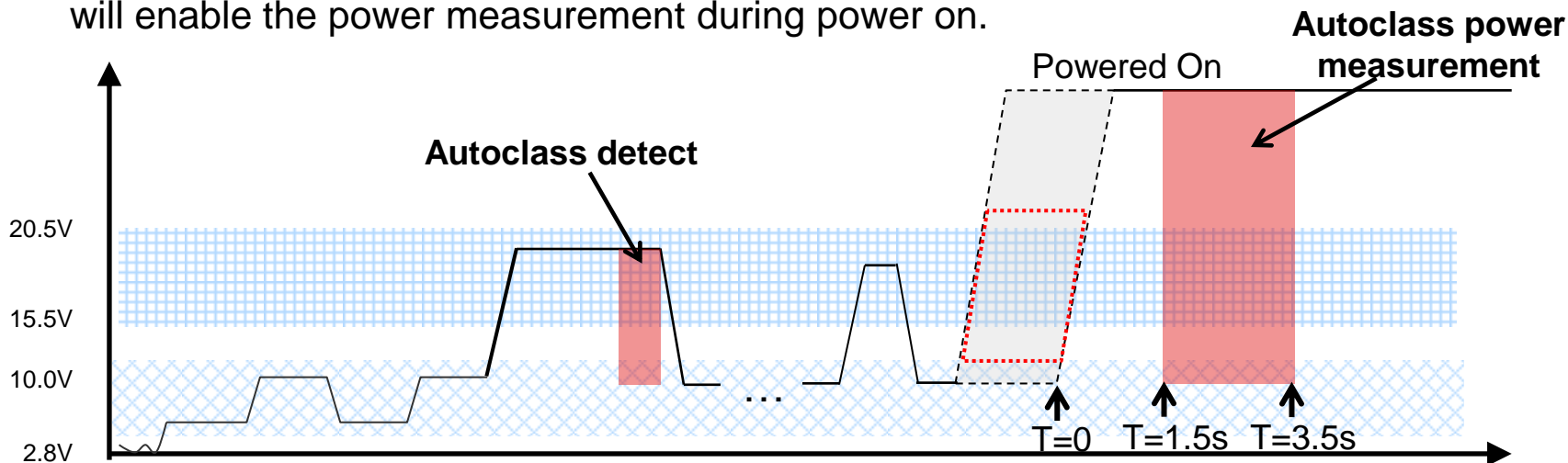
- “New” Lower Maintain Power Signature timings adopted in order to enable much lower standby power
 - PSE T_{MPS} max \Rightarrow 6ms (used to be 60ms).
 - PSE T_{MPDO} min \Rightarrow 320ms (used to be 300ms).
- A long first class event has been defined in order for the PSE to tell the PD it can use the new MPS timings.



IEEE 802.3bt New Features – Autoclass

Autoclass

- Autoclass is a new feature that allows PSE to measure the PD's maximum power during power on.
- At the end of first long finger, PD sends Autoclass signal (if capable) to PSE and PSE will enable the power measurement during power on.



IEEE 802.3bt New Features – Power Demotion

5. Multi Event Power Demotion

- Power demotion is anytime that PD gets the power lower than it's requesting (power will be only demoted to **Type boundary**).
- We are doing this today: class 4 PD gets powered at 15W.
- With the new Types introduced to the new standard, power demotion is extended to Type3 and Type4.
- For example, if the PSE is set to Type4 class 7, but the PD is Type 4 class 8. Obviously, the PSE is not able to provide the power that PD requests. Then PSE will demote the power to Type 3, 60W.
- The PD side only sees the classification event. Since Class 7 and class 8 both have 5 finger classification, the PD can't tell whether the PSE is able to output 75W or 90W. The PSE will demote the power to Type 3 (4 finger classification) which PD is able to recognize.

IEEE 802.3bt New Features – Power Demotion

- Examples

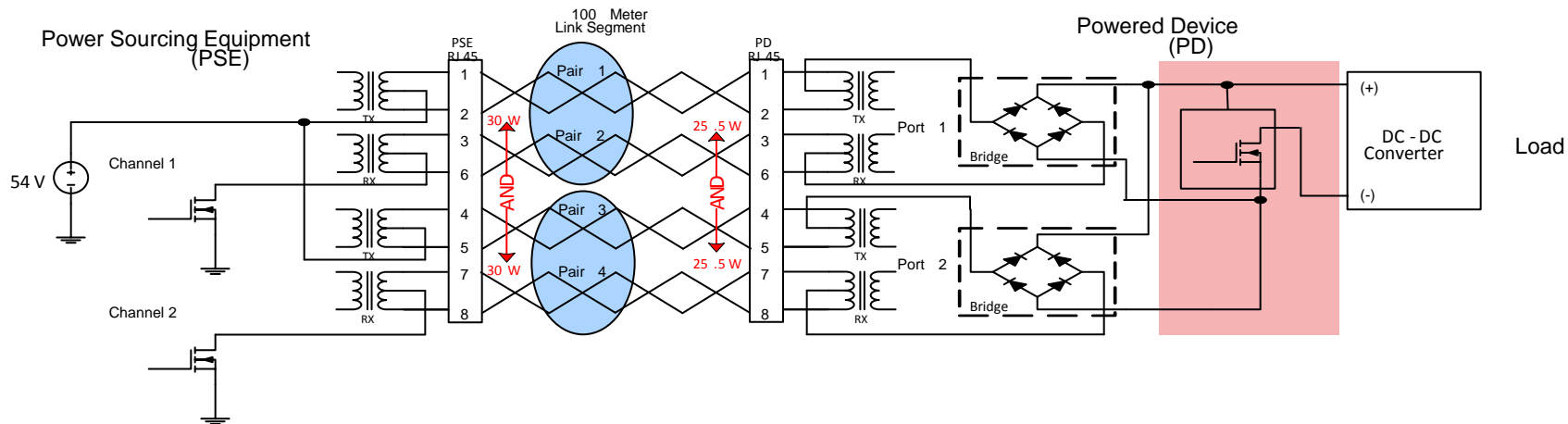
PSE Allocated Power	PD(30W) Requested	PD(45W) Requested	PD(60W) Requested	PD(75W) Requested	PD(90W) Requested
15W	Power up at 15W	Power up at 15W	Power up at 15W	Power up at 15W	Power up at 15W
30W		Power up at 30W	Power up at 30W	Power up at 30W	Power up at 30W
45W			Power up at 30W	Power up at 30W	Power up at 30W
60W				Power up at 60W	Power up at 60W
75W					Power up at 60W

IEEE 802.3bt New Features – Connection Check

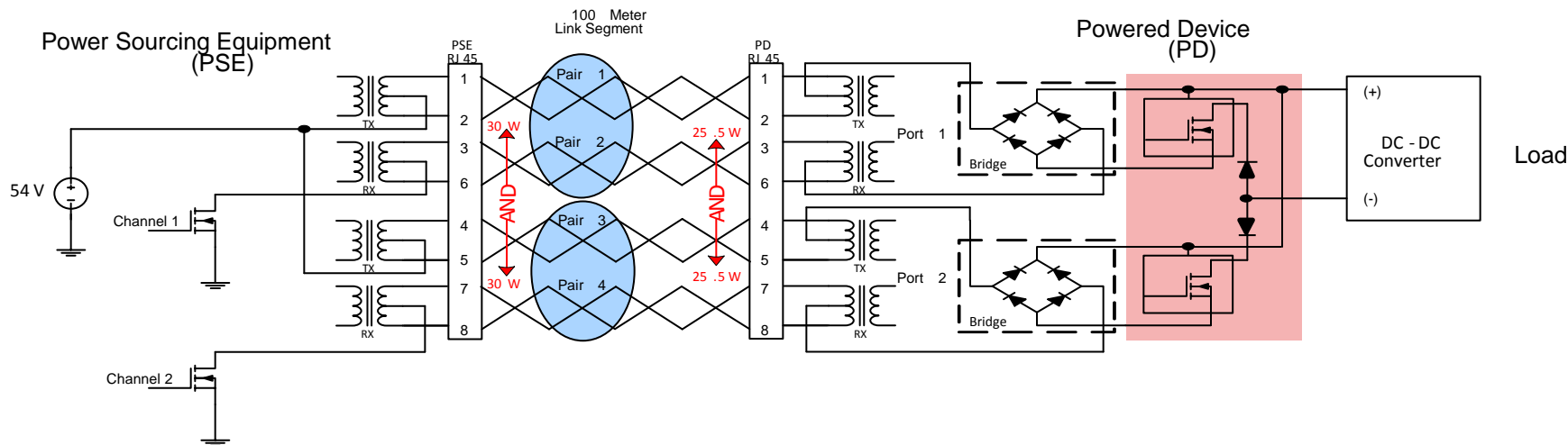
6. Connection Check

- IEEE802.3bt is adopting both single signature and dual signature PDs.
- For 4 pair port, connection check becomes a part of detection operation.
- After connection check, PSE should determine whether a single signature PD, dual signature PD is connected to the port.

Single Signature PD Structure

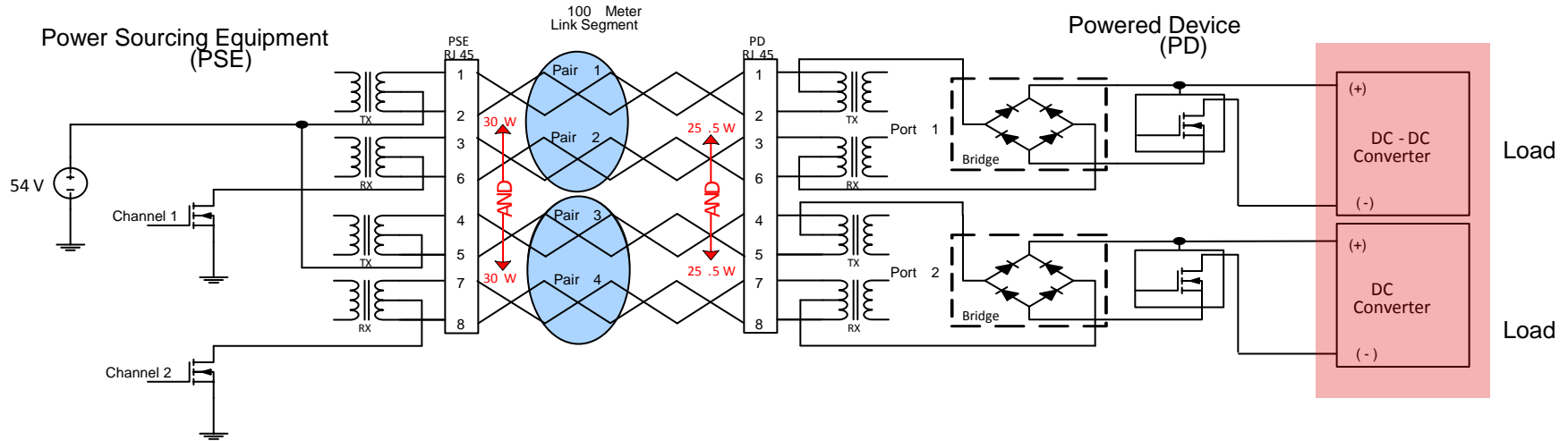


Dual Signature PD Structure I



****PD should allow both PSE channels to finish inrush before going to normal operation.**

Dual Signature PD Structure II



TPS23880 Mutual ID Table: Single Signature PDs

This table demonstrates how the PSE recognizes the PD class by **class current**.

PSE Type		1 st class finger	Power Sourced	PD Class	Finger 1 (I _{CLASS})	Finger 2 (I _{CLASS})	Finger 3 (I _{CLASS})	Finger 4 (I _{CLASS})	Finger 5 (I _{CLASS})
Power Level Indicated by Finger					2/4-Pair 15W	2/4-Pair 30W	4-Pair 30W	4-Pair Up to 60W	4-Pair 90W
1	AF/AT	Short	< 15W	0-3	0-3	NA	NA	NA	NA
3	BT	Long	< 15W	1-3	1-3	NA	NA	NA	NA
2	AT	Short	30W	4	4	4	NA	NA	NA
3	BT	Long	30W	4	4	4	4	NA	NA
3	BT	Long	45W	5	4	4	0	0	NA
3	BT	Long	60W	6	4	4	1	1	NA
4	BT	Long	75W	7	4	4	2	2	2
4	BT	Long	90W	8	4	4	3	3	3

Class Level	I _{CLASS} Range (mA)
0	0 – 4
1	9 – 12
2	17 – 20
3	26 – 30
4	36 - 44
PSE 3 rd finger is permitted	

*All power levels referenced to PSE PI.

TPS23880 Mutual ID Table: Dual Signature PDs

This table demonstrates how the PSE recognizes the PD class by **class current**.

PD Class	Power Sourced	Finger 1 (I _{CLASS})	Finger 2 (I _{CLASS})	Finger 3 (I _{CLASS})	Finger 4 (I _{CLASS})	Comments
Power Level Indicated by Finger		15W	30W	30W	45W	
0	15.4 W	0				Not defined in IEEE bt standard. Not a Four Pair Capable PD.
1	4 W	1	1	0		
2	7 W	2	2	0		
3	15.4 W	3	3	0		
4	30.0 W	4	4	0		IEEE Defined Four Pair Capable PD
		4	4	4		Not a Compliant Four Pair PD
5	45.0 W	4	4	3	3	

Class Level	I _{CLASS} Range (mA)
0	0 – 4
1	9 – 12
2	17 – 20
3	26 – 30
4	36 - 44

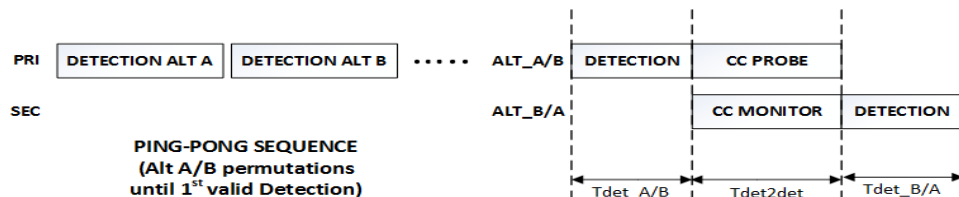
Dual Signature PDs are also permitted to present unique classification signatures per PSE pair set.

*All power levels referenced to PSE PI per pair set.

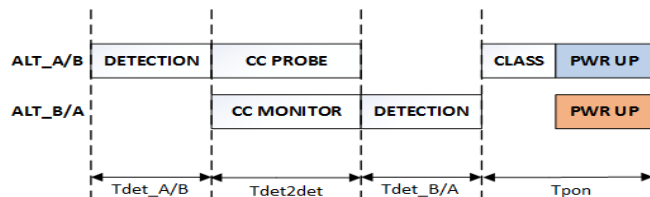
4-Pair Discovery & Turn On Sequence

- Single signature PD

Discovery Sequence

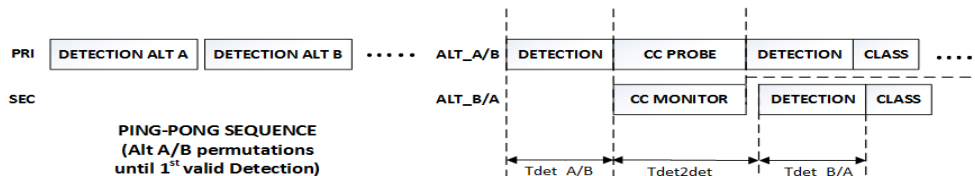


Turn On Sequence

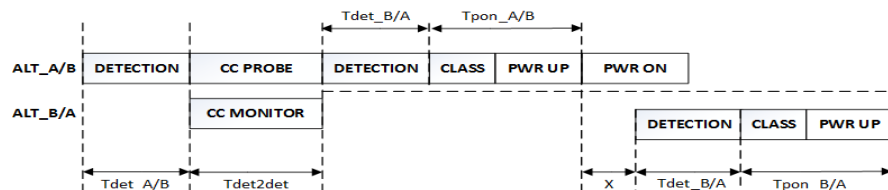


- Dual signature PD

Discovery Sequence



Turn On Sequence



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IEEE802.3bt PSE Solution-TPS23880

SRAM based 8-port PSE

Samples available

Features

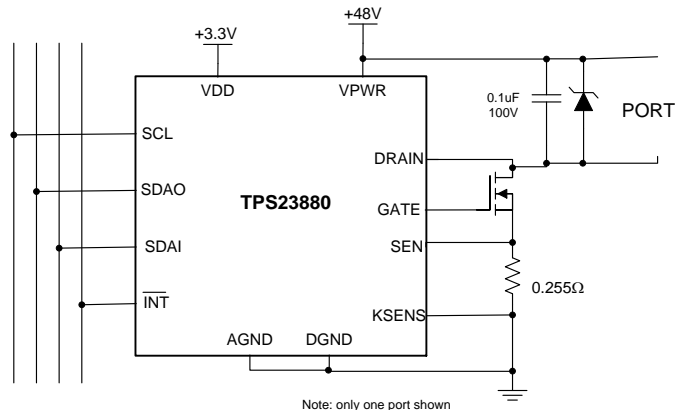
- Fully IEEE 802.3bt Compliant
- 2-Pair (up to 30W) & 4-Pair (up to 90W) Configurable
- **I2C Programmable SRAM**
- Autoclass Detection and Power Measurement
- Programmable Port Power Allocation Limiting w/ Power Demotion
- Port Re-Mapping Capability
- Sequenced Turn On in Semi Auto Mode
- Fast port shutdown input w/ up to 8 priority settings
- Short-Circuit Protection with Foldback
- 0.255 Ω Sense Resistor with Kelvin Sensing
- **1 A2D per port**
- 14-Bit Port Current and Voltage Monitoring

Applications

- Ethernet Switches and Routers
- UPOE
- Pass-through Systems
- SOHO Routers
- Ethernet Hubs
- Lighting

Benefits

- Firmware Upgradability for Flexible Solution
- Parallel programmability via global I2C write
- Simple PCB design and power architecture
- Robust and Efficient Design.

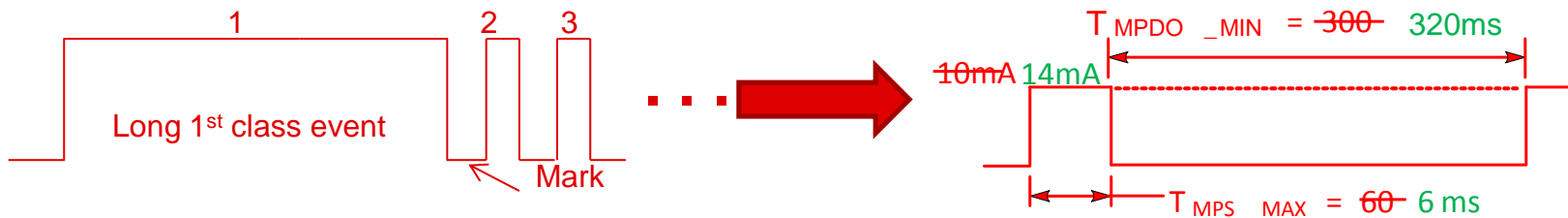


8 x 8 mm, 56-pin
QFN package

IEEE802.3bt Maintain Power Signature Concerns

“New” IEEE802.3bt Maintain Power Signature (MPS)

- Timings adopted in order to enable much lower standby power
 - PSE $T_{MPS_max} \Rightarrow 6ms$ (used to be 60ms).
 - PSE $T_{MPDO_min} \Rightarrow 320ms$ (used to be 300ms).
- A long first class event has been defined in order for the PSE to tell the PD it can use the new MPS timings.



1 A/D vs. 8 A/D for Maintaining Power

- The MPS signature may be lost when sharing 1 A/D converter for all ports due to the shortened IEEE802.3bt MPS timings.
 - For example, when a PSE with 1 A/D provides power to all 8-channels the A/D is required to measure the current through each channel to ensure the MPS signal is received (which could take a significantly long time to process).
 - With 1 A/D monitoring 8-channels, the PSE may remove power even if a PD is providing the desired MPS signature.
 - Loss of the MPS signature will turn the port power off and power will not be provided until classification & detection reoccurs.
 - With TI solution having 8 A/D converters, there is no such concern.

TPS2388→TPS23880

TPS2388

- ROM only
- Current policing only
- IEEE 802.3at Compliance

TPS23880

- I2C communication required
- One 14-bit A/D per port
- Hardware programmable I2C address
- Pinout and package
- 8 Channel
- Port remapping
- 1 bit / 3 bit fast shutdown
- Auto mode
- SRAM programmable
- Capacitance measurement
- IEEE 802.3bt Compliance
- Alternative foldback
- Current policing + power policing

TPS2388 → TPS23880 Hardware Change(2 pair)

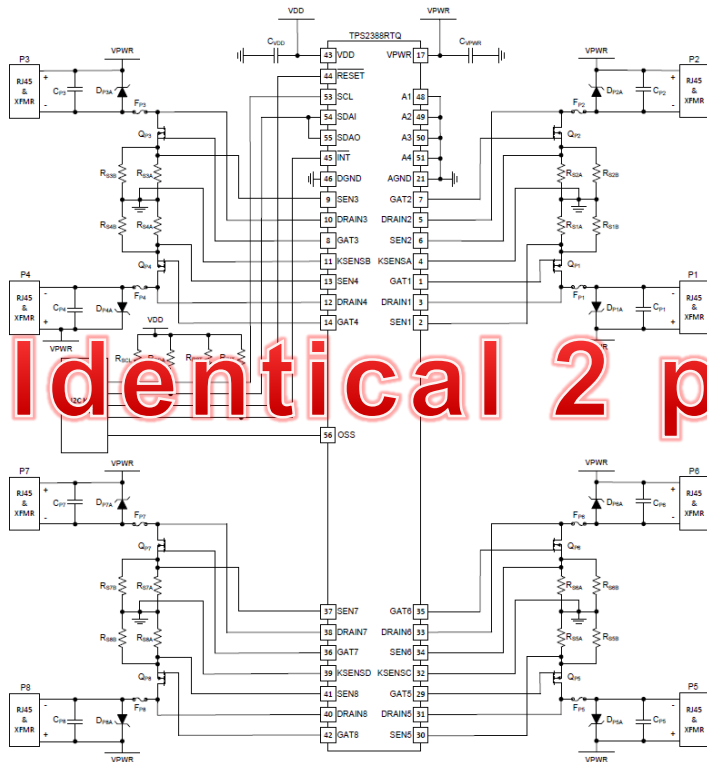


Figure 71. Eight Port Semi-auto Mode Application

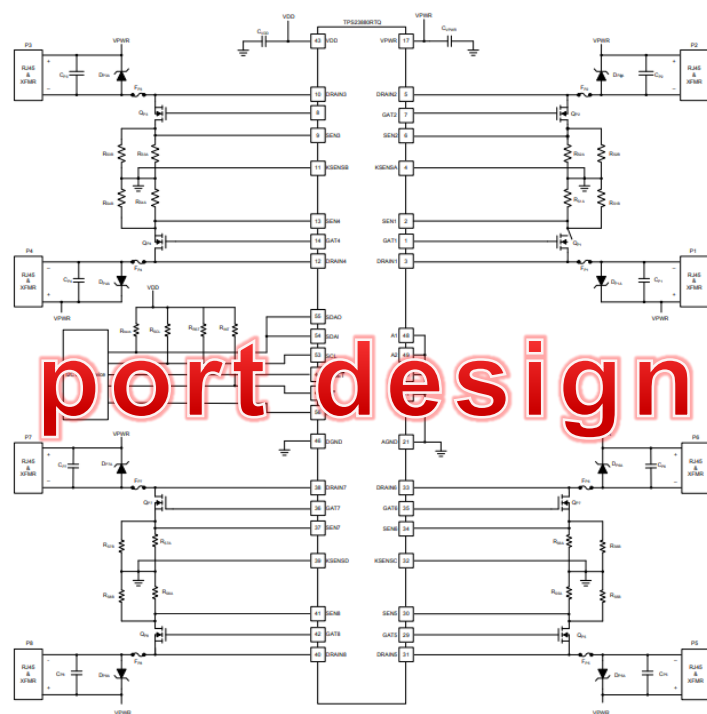


Figure 73. Eight 2-Pair Port Application

TPS2388 → TPS23880 Hardware Change(4 pair)

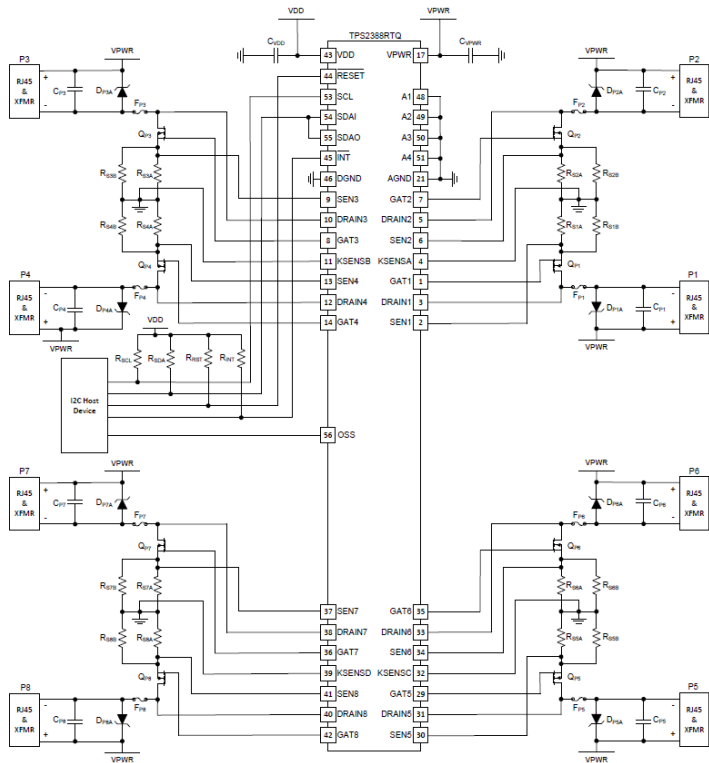


Figure 71. Eight Port Semiauto Mode Application

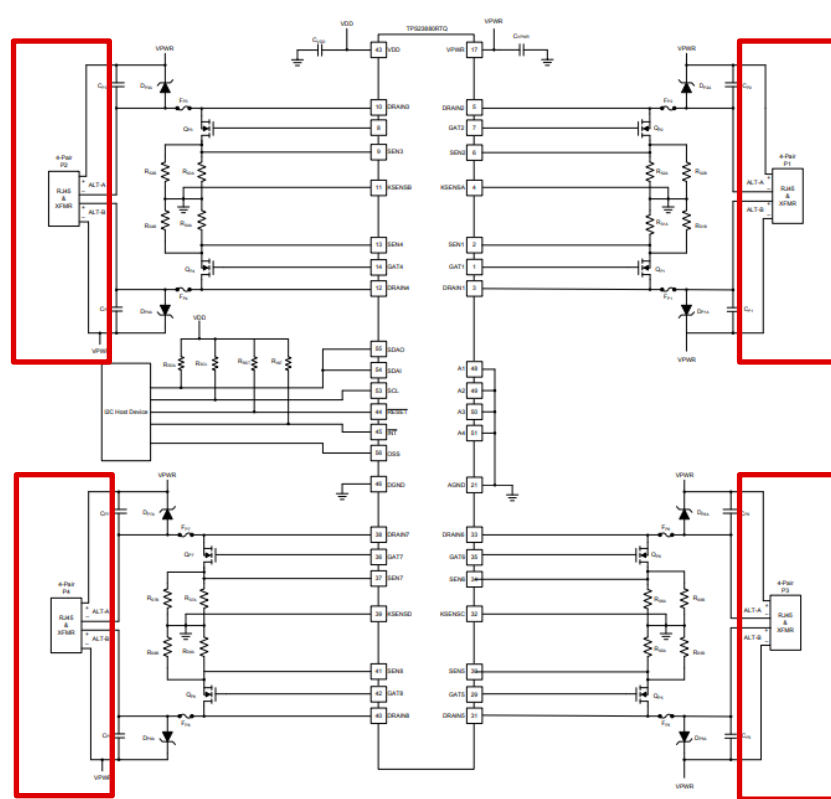
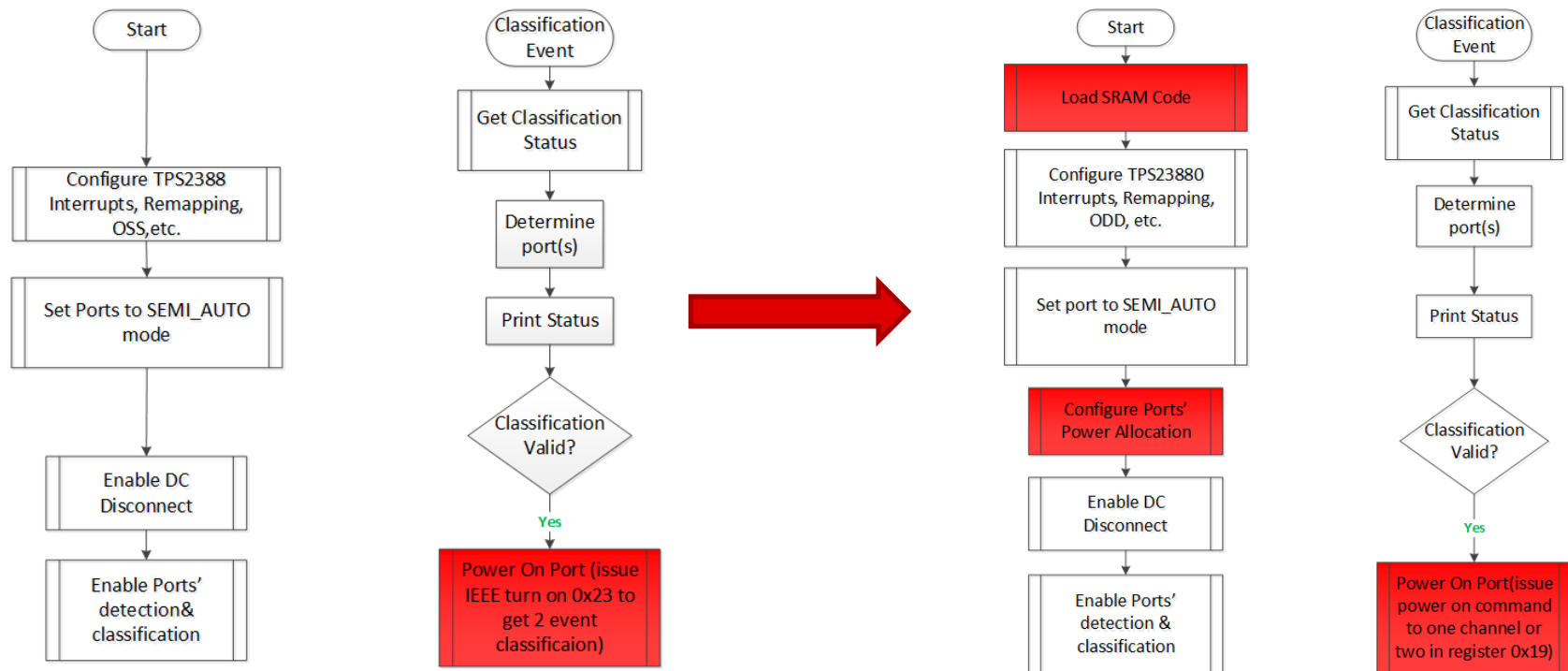


Figure 74. Four 4-Pair Port Application

TPS2388 → TPS23880 Software Change

Register	TPS2388	TPS23880
1Ch	RESERVED	Auto class enabling and connection check status
1Eh/1Fh 20h/21h	ICUT configurations (20mA/1W resolution for Type 1;40mA/2W resolution for Type 2)	2 pair PCUT configurations (0.5W resolution)
23h	Power on button after one good detect and class	RESERVED
29h	RESERVED	Power allocation,2pair/4pair configuration
2A/2Bh	RESERVED	4 pair PCUT configurations (0.5W resolution)
4Ch-4Fh	RESERVED	Assigned class
50h	RESERVED	Auto class Control(manual and auto measurement)
51h-54h	RESERVED	Auto class power measurement results
55h	RESERVED	Alternative foldback selection

TPS2388 → TPS23880 Software Change



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Nonstandard High Power Solution Summary

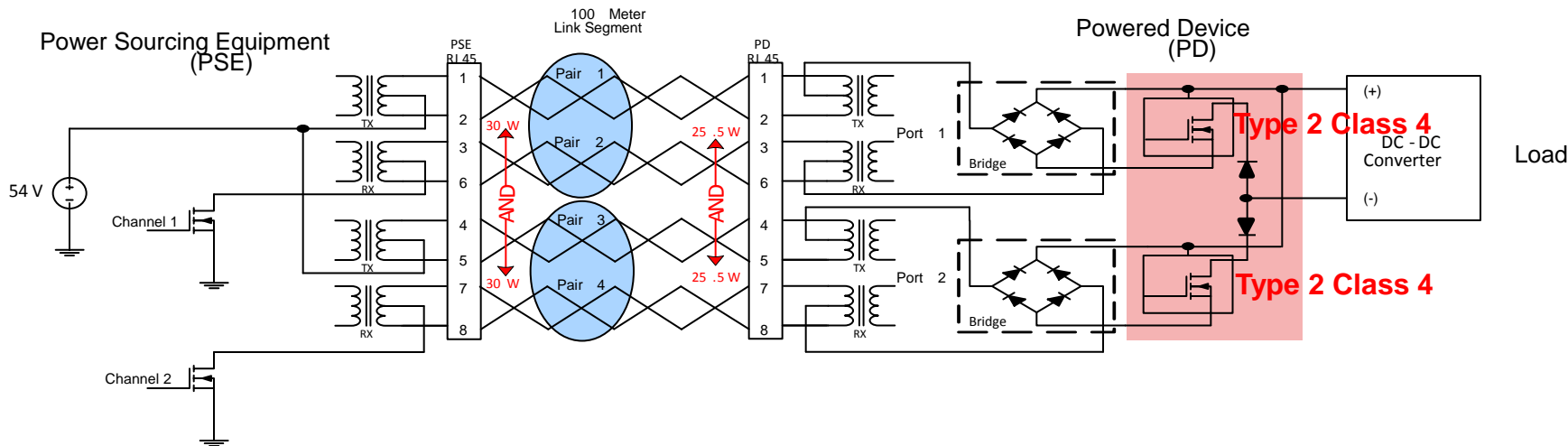
	Customers	Max Power Sourced
UPoE	Enterprise Switch, Small cell	60W
PoE++	Wireless backhaul, Small cell	120W
PoH	Consumer customers(like audio systems)	95W

TPS23880 + UPoE PD LLDP

- LLDP is implemented in the data link layer
- Minor changes will be needed to upgrade from existing UPoE LLDP solution to 90W LLDP solution due to register change in PSE device.

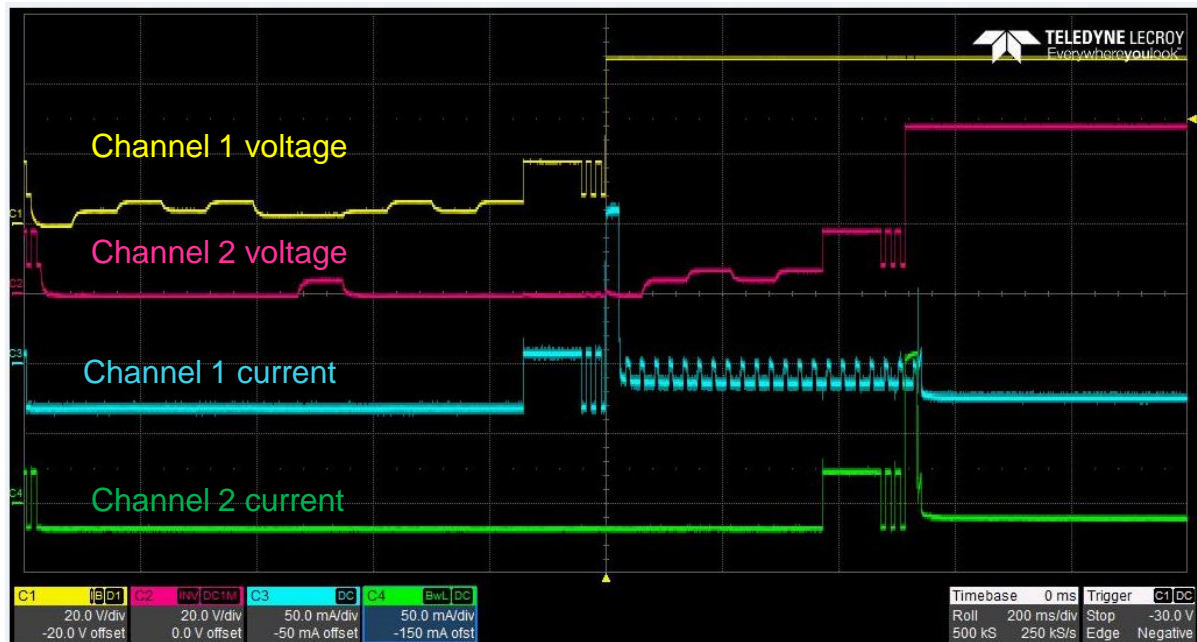
TPS23880 + UPoE PD Forced

- TPS23880 can recognize forced UPoE as a dual signature PD(class 4 on both channels) and output 60W from one 4-pair port.



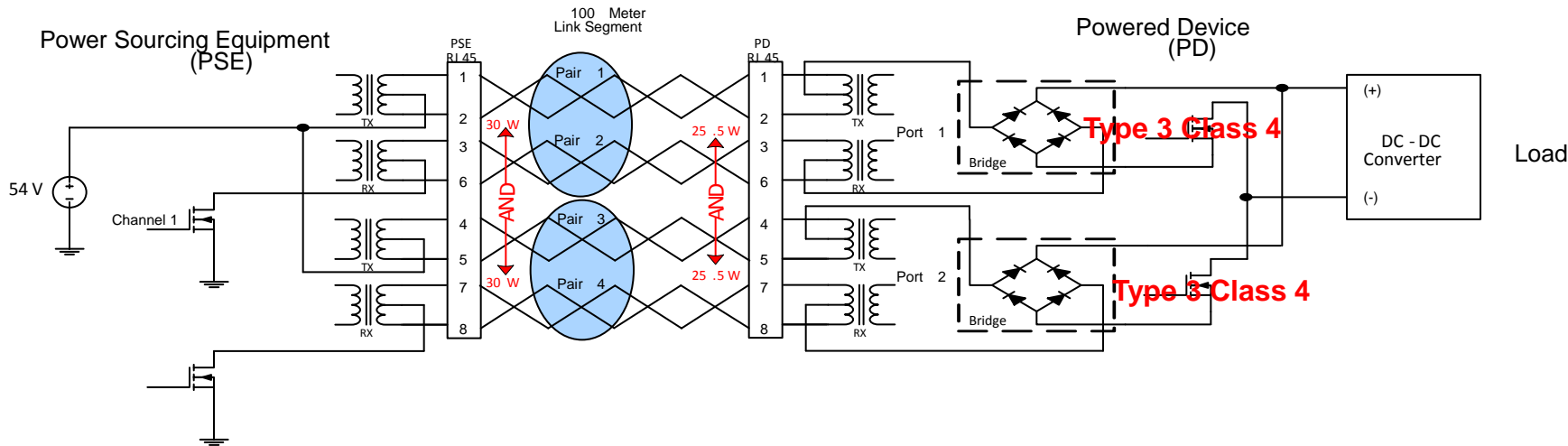
TPS23880 + UPoE PD Forced

TPS2378EVM-602

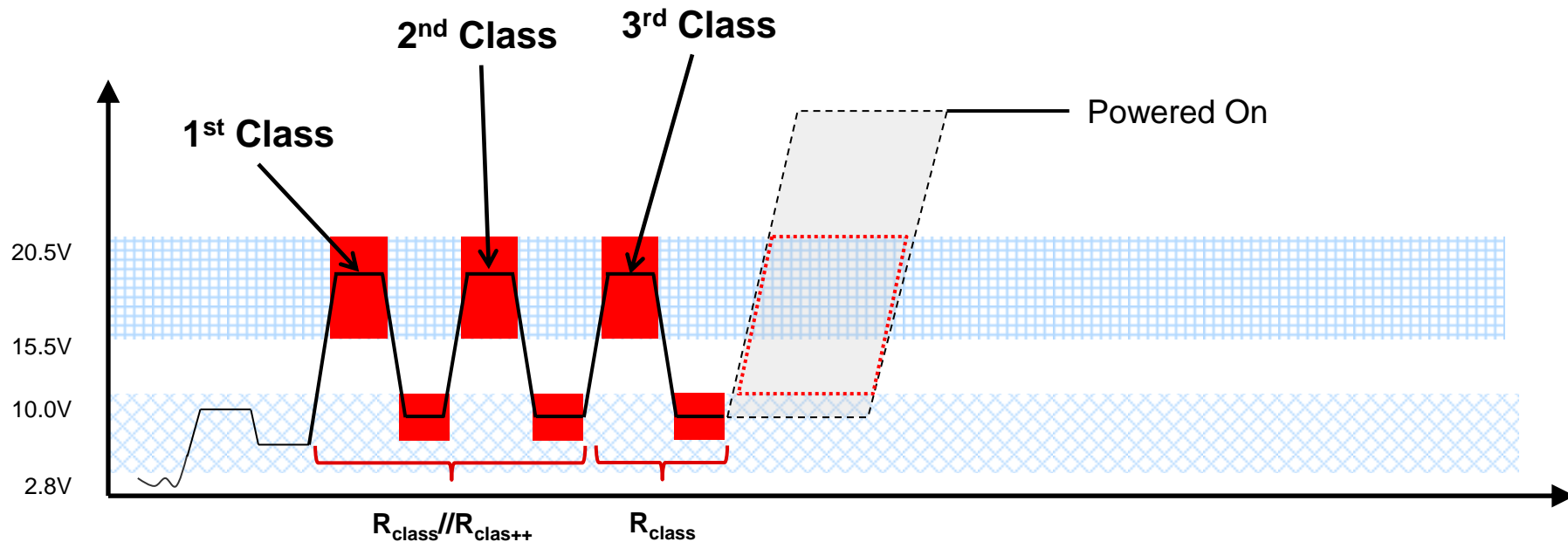


UPoE PSE + TPS2372/TPS2373

- If using LLDP, the BT PD only need to be set for class 4 like AT PDs.
- If using Forced UPoE, we need to set both PD to class 4 as UPoE PSE can only identify class 4 PDs.



How PoE++ Works for High Power



PoE++ & 802.3bt Mutual ID Conflicts

PD Class	Finger 1 (I _{CLASS})	Finger 2 (I _{CLASS})	Finger 3 (I _{CLASS})	Finger 4 (I _{CLASS})	Finger 5 (I _{CLASS})		802.3bt IEEE Power	PoE ++ Power
0	0	NA	NA	NA	NA		15.4W	15.4W
1	1	NA	NA	NA	NA		4W	4W
2	2	NA	NA	NA	NA		7W	7W
3	3	NA	NA	NA	NA		15.4W	15.4W
4	4	4	4	NA	NA		30W	30W
5	4	4	0	0	NA		45W	45W
6	4	4	1	1	NA		60W	65W
7	4	4	2	2	2		75W	90W
8	4	4	3	3	3		90W	120W

Class Level	I _{CLASS} Range (mA)
0	0 – 4
1	9 – 12
2	17 – 20
3	26 – 30
4	36 - 44

• PoE++ Mutual ID Compliance Issues

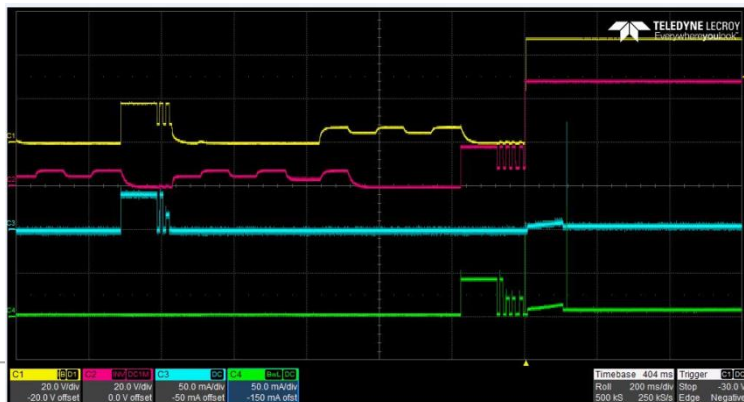
- Although the “3rd finger” classification levels used for PoE++ equipment align with the IEEE 5-finger Mutual ID, the power levels associated with these PDs **do not match**
- For a 802.3bt compliant PSE, this conflict will result in existing PoE++ equipment being detected as lower power IEEE802.3bt equipment

TPS23880 + PoE++ PD

PoE++ PD Class 5



PoE++ PD Class 7



PoE++ PD Class 6



PoE++ PD Class 8

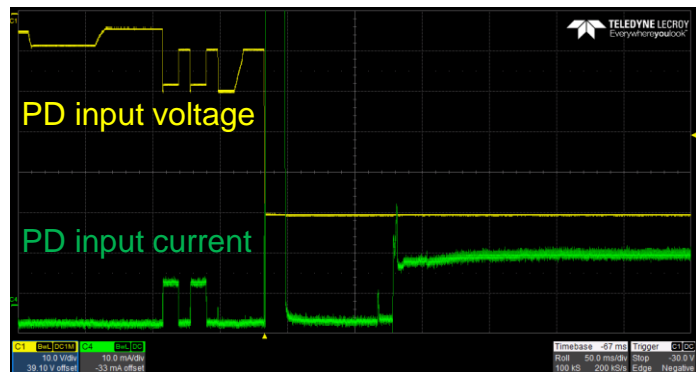


TPS23880 + PoE++ PD

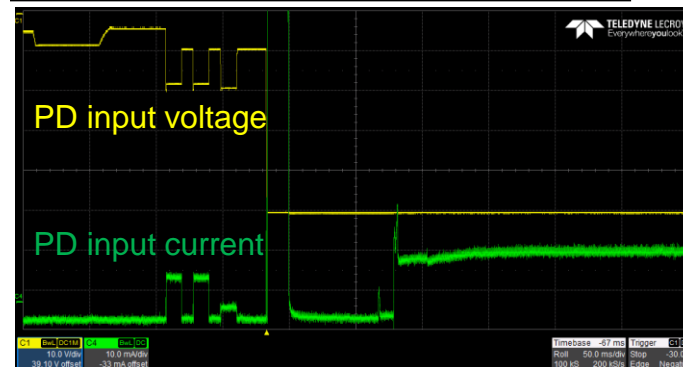
- TPS23880 is able to recognize PoE++ PD as high power and classify them from class 5-8.
- The power level definition is different between PoE++ and .bt standard. PoE ++ PSE can output higher power for class 6 to class 8.
- TPS23880 is able to deliver high power based on the power allocation defined in .bt standard.
- In order to be fully compliant to PoE++ PD at power levels, extra commands are required to increase the PCUT limit.
- PoE++ >100W violates IEEE and UL specs.
- No PSE can distinguish PoE++ PD and .bt PD.

PoE++ PSE + TPS2372/3

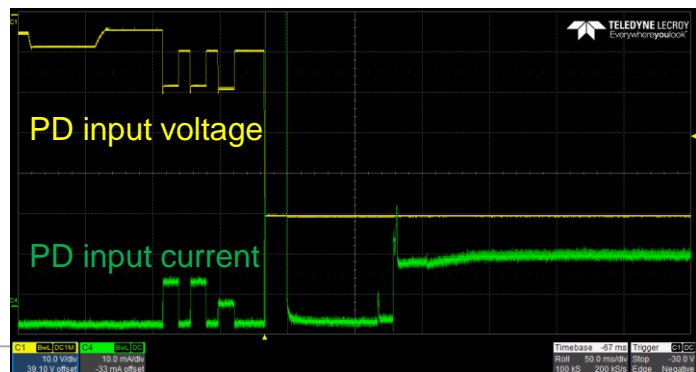
PoE++ PSE 45W TPS2373-4 class 5



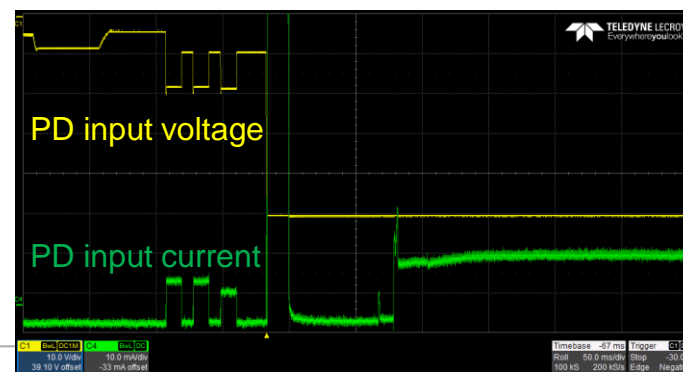
PoE++ PSE 65W TPS2373-4 class 6



PoE++ PSE 90W TPS2373-4 class 7



PoE++ PSE 120W TPS2373-4 class 8



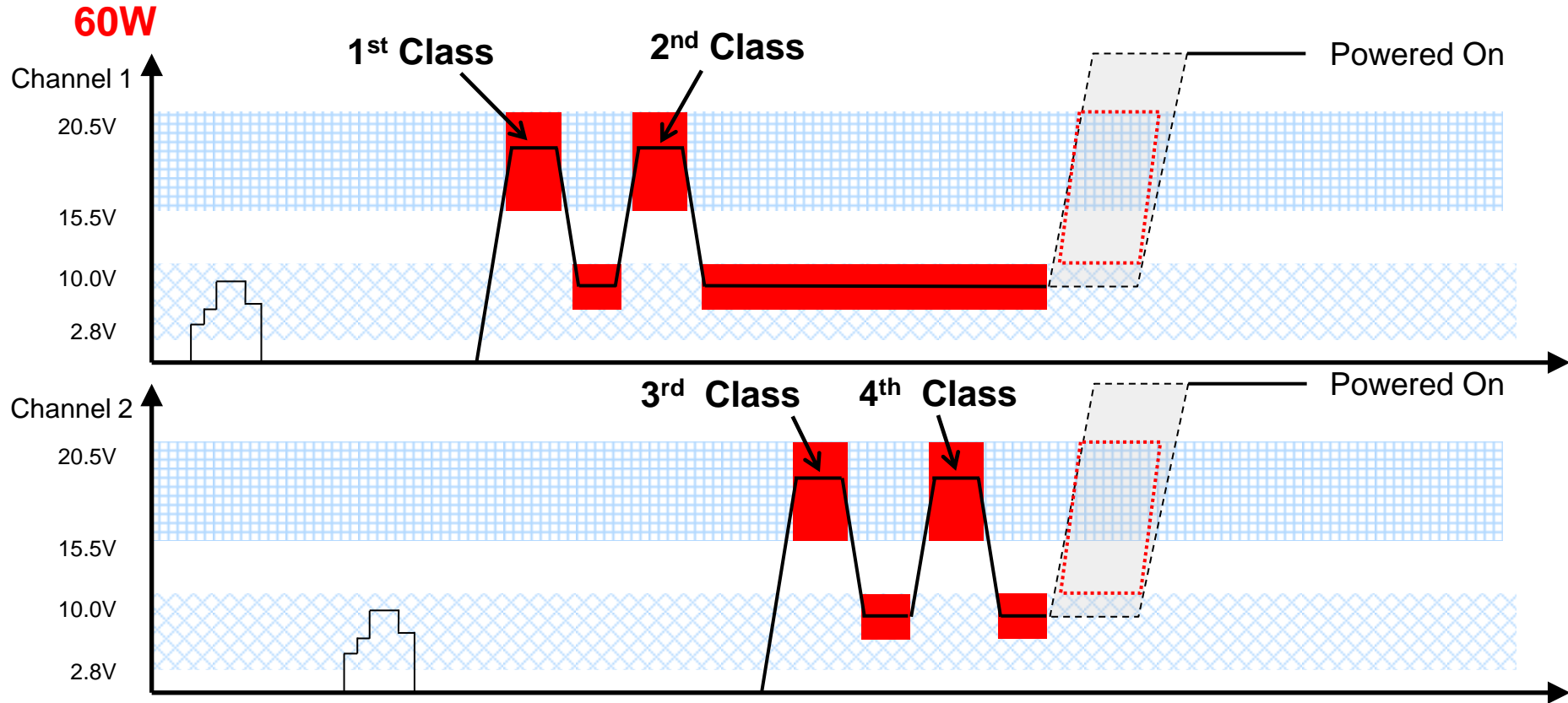
PoE++ PSE + TPS2372/3

- TPS2372/3 can be successfully classified by PoE++ PSE for all class levels.
- BT PD can't handle PoE++ class 8 power (120W).
- TPS2372/3 shows TPH(Low), TPL(Low) and BT (High) when connecting to PoE++ PSE which is different from BT PSE.
- TPS2372/3 can distinguish PoE++ PSE and BT PSE.
- PoE++ PD can't distinguish between PoE++ PSE and BT PSE.

Pros and Cons for PoE++

- Pros
 - Classification current is the same as .bt standard
- Cons
 - The power level is different than .bt standard
 - Class 5-8 can only be demoted to 30W or 15w if PSE can't supply the PD with >30W since PoE++ only has 3 finger classification for class5 ~ class 8
 - BT PSE could send 3 finger classification if demoted to class 4 while PoE++ PD still thinks the PSE can provide high power which will cause continues on-off scenarios
 - No PSE can distinguish PoE++ PD and .bt PD
 - PoE++ PD can't distinguish PoE++ PSE and .bt PSE
 - >100W violates IEEE standard and UL standard

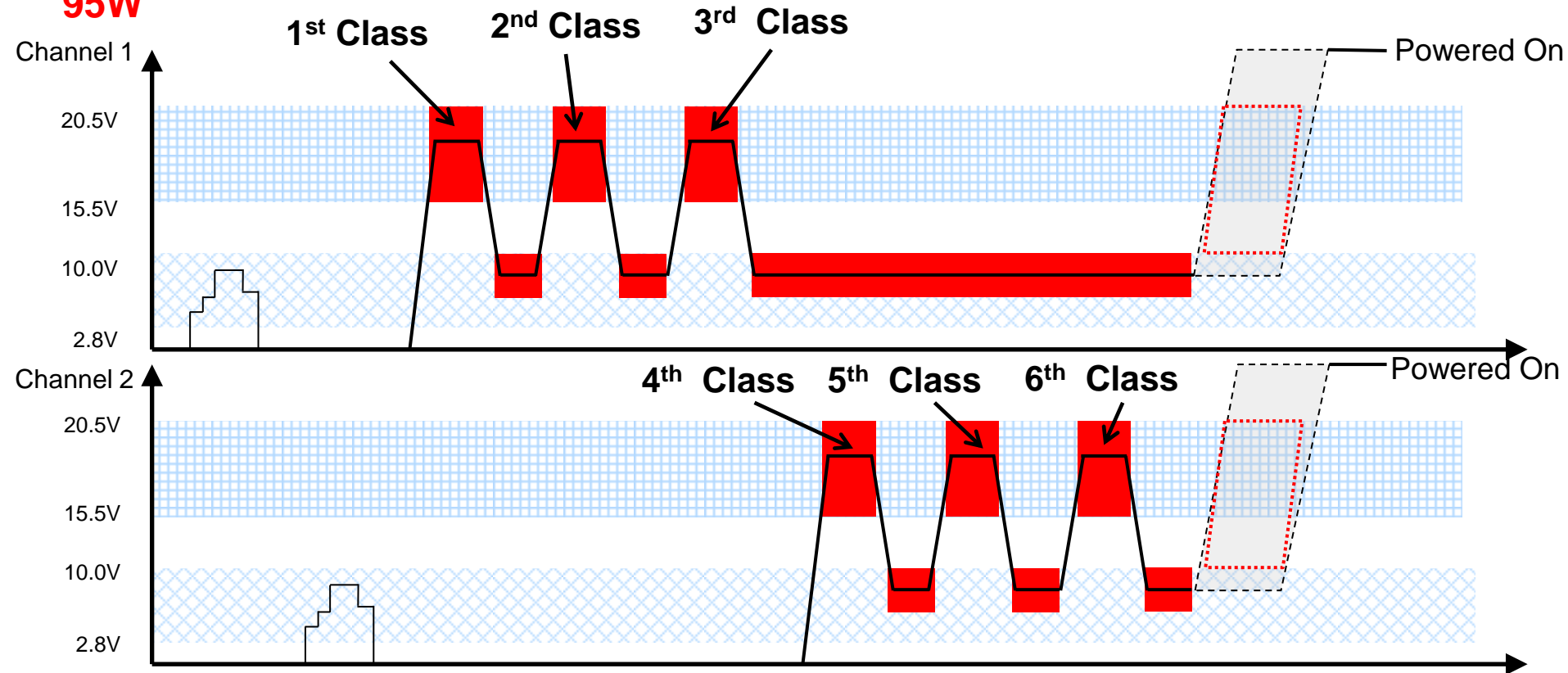
How PoH (HD BaseT) Works for High Power?



Proven through lab experiments

How does PoH (HD BaseT) Work for High Power?

95W



Proven through lab experiments

How PoH (HD BaseT) Works for High Power?

# of fingers (N-event classification)	SUPP_S1	SUPP_S2	AT_FLAG	HD_FLAG	4P_AT_FLAG	4P_HD_FLAG	Power Level
1	X	X	Hi Z	Hi Z	Hi Z	Hi Z	15W 2 Pair
2	H	L	0V	Hi Z	Hi Z	Hi Z	30W 2 Pair
2	L	H	0V	Hi Z	Hi Z	Hi Z	30W 2 Pair
2	H	H	0V	Hi Z	0V	Hi Z	60W 4 Pair
3	L	H	0V	0V	Hi Z	Hi Z	47.5W 2 Pair
3	H	L	0V	0V	Hi Z	Hi Z	47.5W 2 Pair
3	H	H	0V	0V	0V	Hi Z	60W 4 Pair

How PoH (HD BaseT) Works for High Power?

- PoH is one way negotiation instead of mutual identification which means there's no way for PD to tell PSE its power requirement.
- Once PSE is configured to output high power, it is always ready to output max power regardless of PD power requirement.
- PoH PD is always set for class 4 for high power applications.

TPS23880 + PoH PD

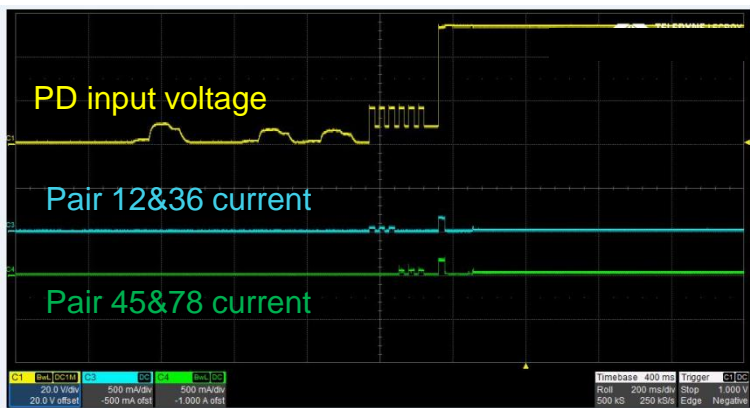


TPS23880 + PoH PD

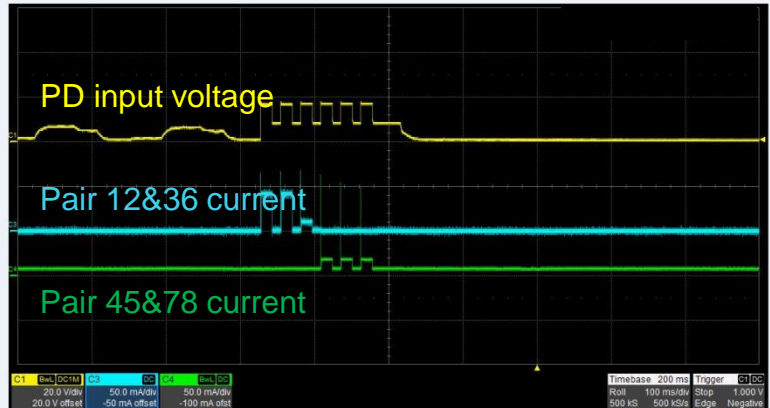
- TPS23880 is able to recognize PoH PD as a class 4 PD.
- PoH PD can recognize TPS23880 as 60W capable PSE.
- TPS23880 is able to deliver 30W to PoH PD by default.
- If wanting to deliver higher power(>30W), extra host commands are required and it is going to be proprietary solution.
- Because the PoH PD is blind to TPS23880's capability sending >60W, so there is interoperability conflicts to receive >51W on the PD side.
- TI doesn't know there's a way to do a BT compliant system and send 60W to PoH PD.

PoH PSE + TPS2372/3

PoH PSE 95W TPS2373-4 Class 4



PoH PSE 95W TPS2373-4 Class 6



PoH PSE + TPS2372/3

- Only class 4 .bt PD can be turned on since PoH can't do mutual identification and can't recognize class 5-8.
- TPS2372/3 shows TPH(Low), TPL(Low) and \overline{BT} (High) which is different from standard PSE.
- Reminder: PoH is a one way communication. This means:
 - If the PoH PSE is set to 95W, BT PD can receive full power(74W).
 - If the PoH PSE is set to 60W, BT PD can only receive 51W.
 - If the PoH PSE is set to 30W, BT PD can only receive 25W.
 - This means the PD has no means to change the PSE's mind.

PoH Summary Pros and Cons

- Pros
 - Can go >90W, 95W
- Cons
 - No Power demotion
 - One way communication, there's no way for PSE to know the PD power level and it 's hard to do port power budgeting at PSE system level
 - PD is not required to do current limit. If the PSE is configured for 95W and a class 4 .at PD connects to the PoH port, during a fault, the PD can go as high as 95W which could damage the PD as the PoH PSE can't adjust the current limit based on PD's power level.

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Power Over Ethernet (PoE) Solutions



PoE Powered Devices (PD)

A PD-only device manages and protects the POE Power system at the load, VIN= VOUT. A PD+DC/DC does all that and performs the DC/DC conversion to provide the required load voltages.



Power Sourcing Equipment (PSE)

PSE Devices protect and manage the power as it is being put into the CAT-5 cable. Classification, identification, and overload protection are among the standard functions.



Ethernet Alliance (EA) Certified Designs

In 2018 the Ethernet Alliance began granting licenses to PoE designs which pass a test suite to demonstrate compliance to the IEEE802.3 standard. TI has multiple licensed designs and was the first

Check out **TI.com/poe** to find our entire PD/PSE portfolio and relevant support



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