802.3 Powering & MPoE

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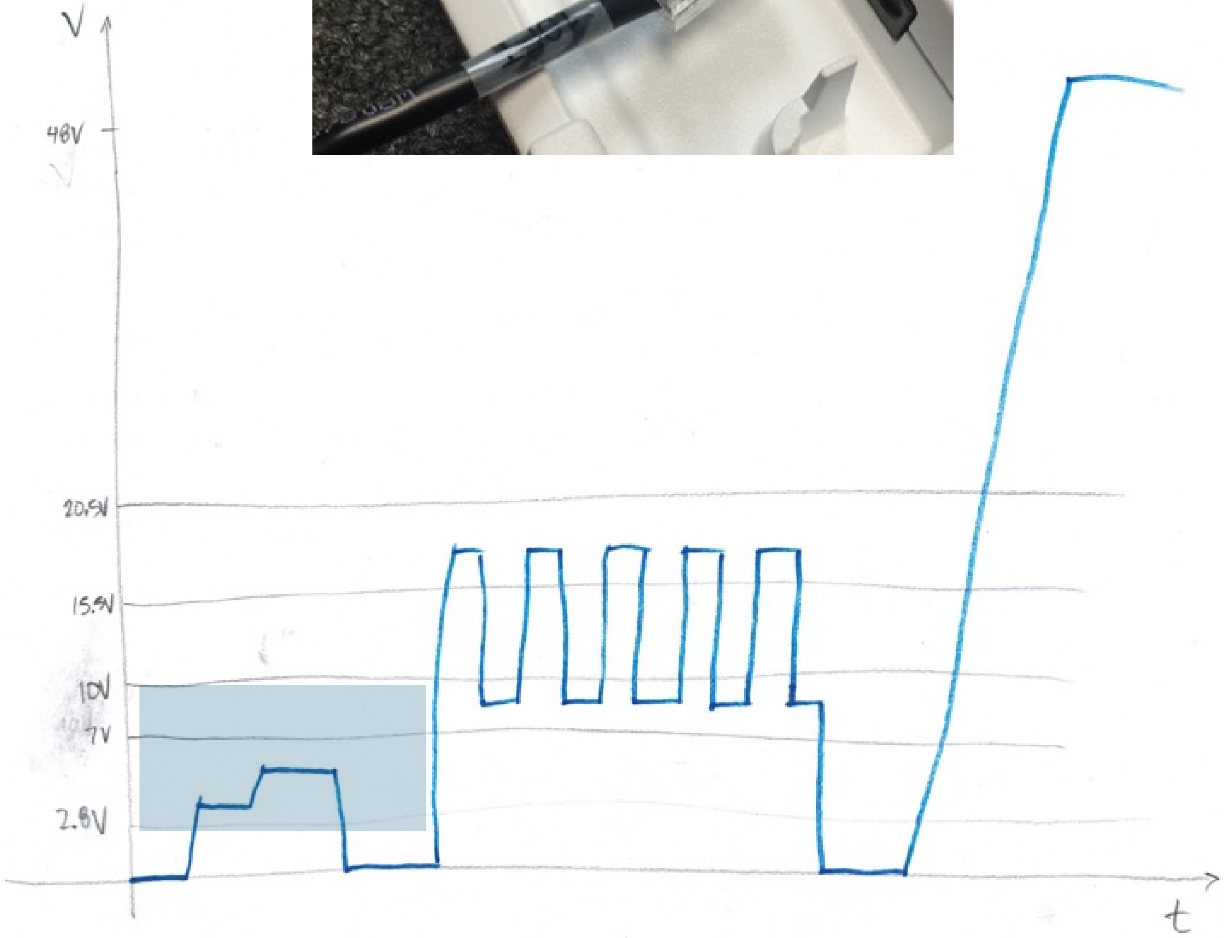
IEEE 802.3 PoE Basics (from Clause 33/145) Credit to Chad Jones

- Detection
- Classification
- Power Up
- Normal Operation
- Power Removal

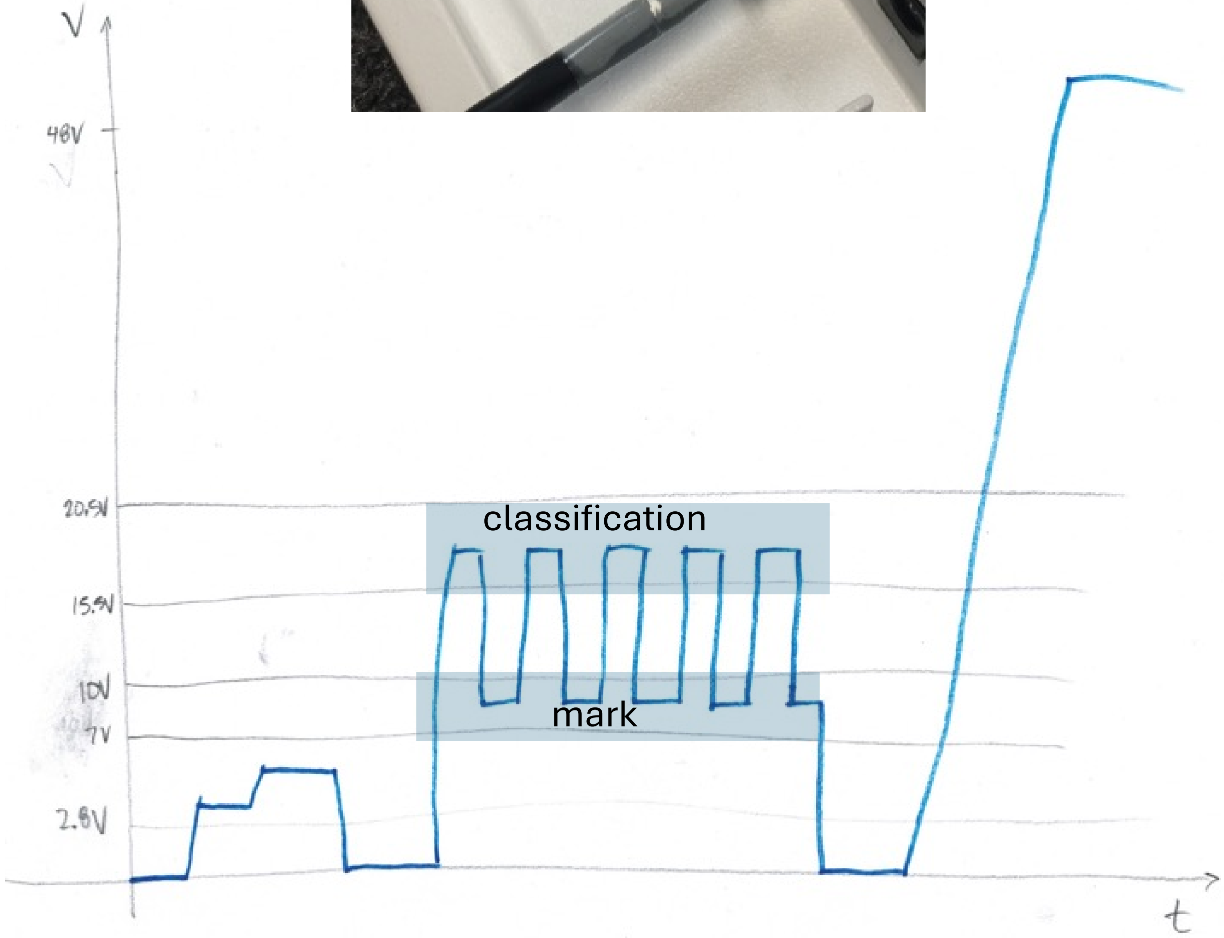
PD Detection

- No power is available at the PSE port without a PD connected
- Detection occurs in a range between 2.8V and 10V
- Open circuit limit of 30V and 5mA for detection
- Detection is looking for a 24.9k resistance



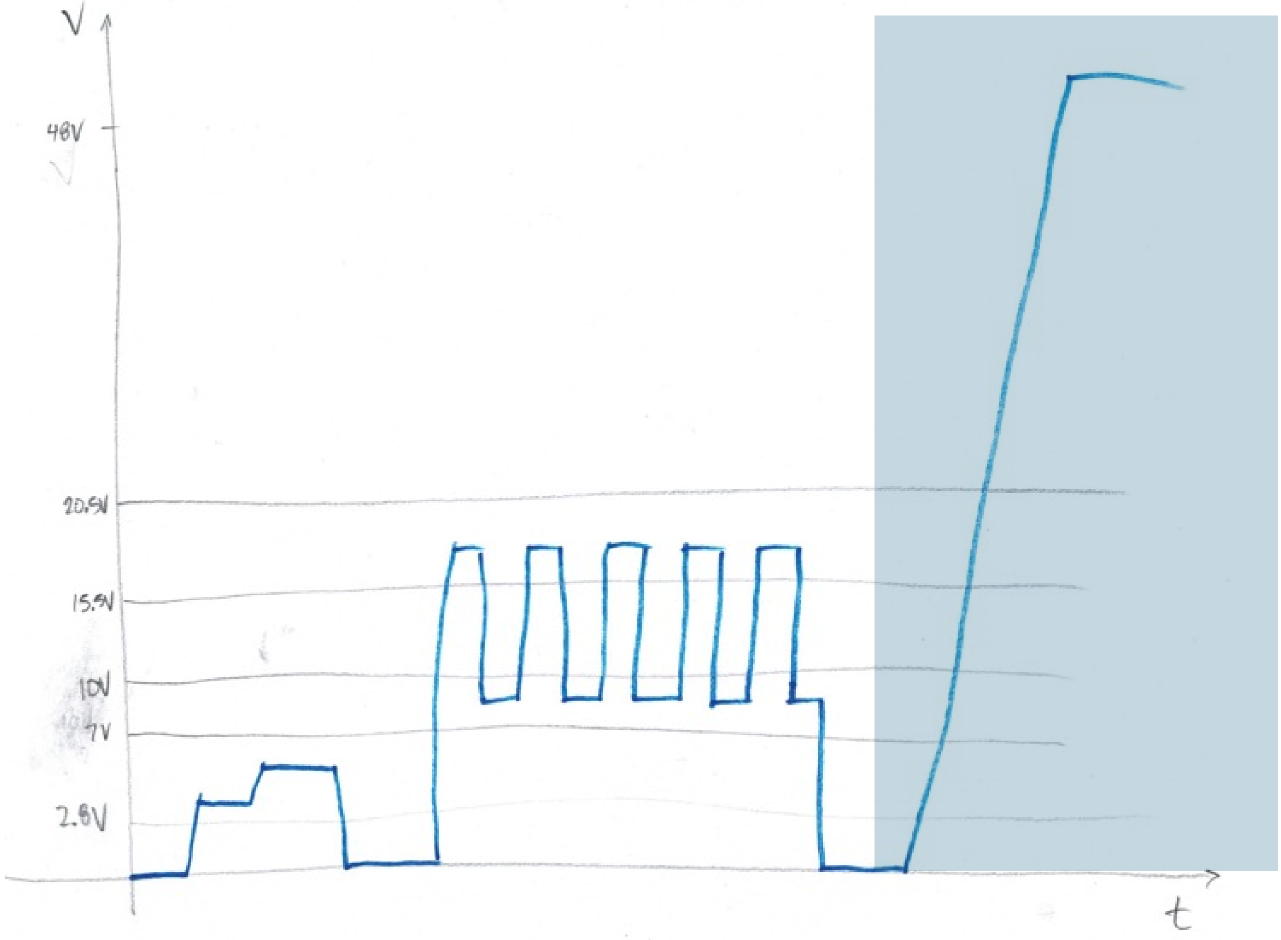
PD Classification

- Once a PD is detected, the PSE moves to classification
- A voltage between 15.5V and 20.5V is applied and the current is measured
- Each classification event is followed by a mark event in the range of 7-10V



PD Power Up

- Only once the PD is successfully detected and classified can power be applied
- PSE port voltage during power on is 44V, 50V, or 52V min (dependent on PSE Type)
- PSE max port voltage is 57V for all Types



Power Removal

- Disconnecting the PD will cause power removal. PSE returns to detection probing.
- Power removal for overcurrent is a complex set of equations and an upper/lower bound template
- Lowerbound template sets the minimums a PSE must provide to guarantee powering compliant PDs
- Upperbound template sets limits to protect the PSE and cabling from overcurrent

Power Removal Continued

- Worst case fault conditions that turn PSE power off:
  - 1.75A per pair for 75ms
  - 1.3A per pair for 4s
  - Greater than 0.96A per pair longer than 4s
    - These numbers are for Class 8 and are per pairset specifications
- Real PSEs will remove power before any of these conditions are met

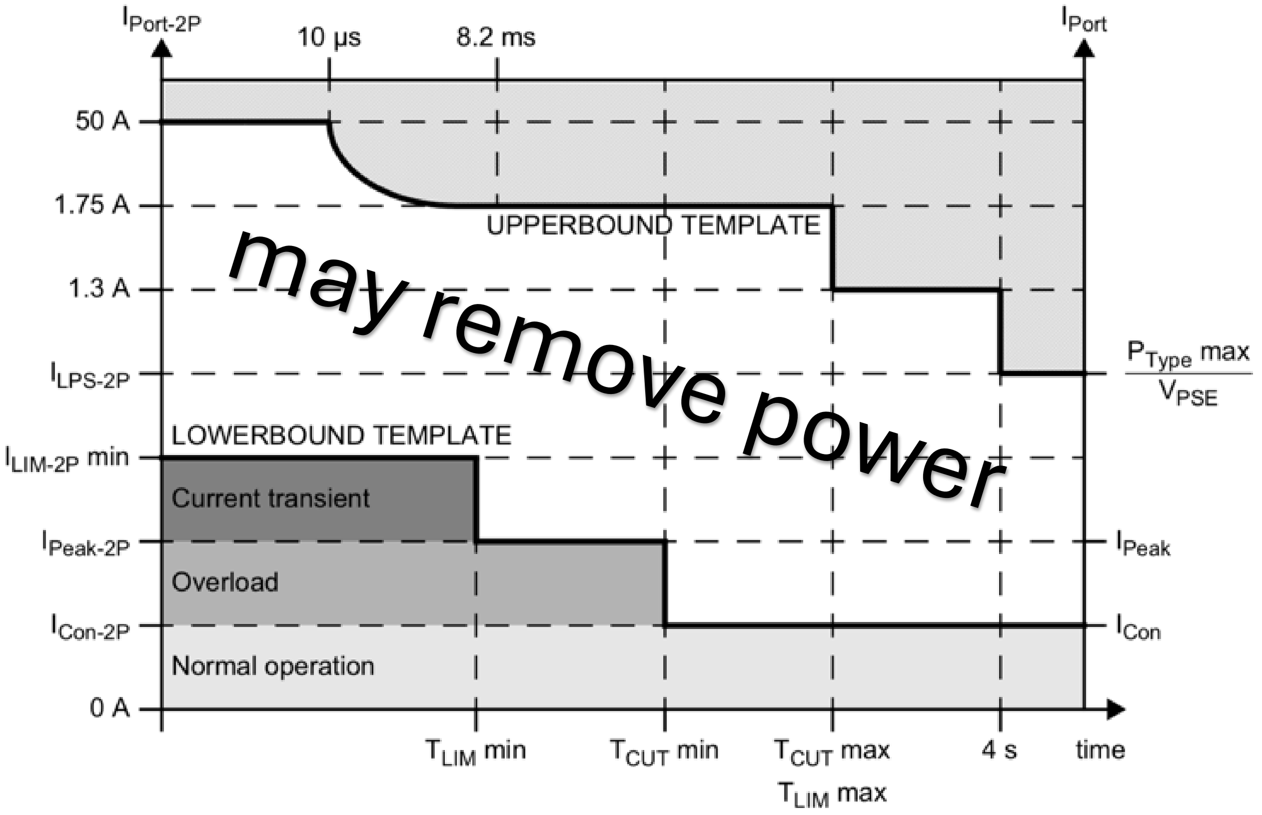
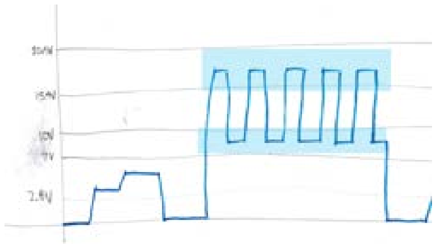
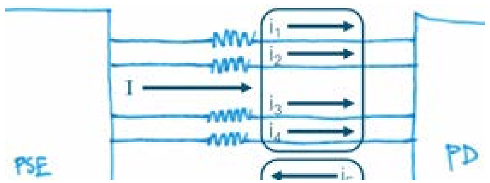


Figure 145–24—Power on states, per pairset operating current template for Type 4 PSEs

Image Source: IEEE 802.3bt



The Classes



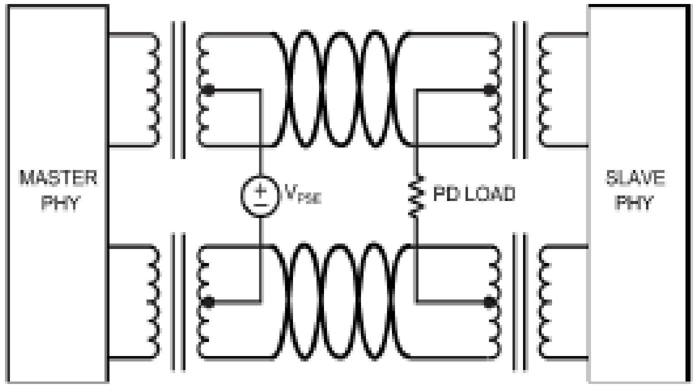
PD Class	# of PD Classification Events	P_{PSE}	P_{PD}	I_{CABLE} MAX	Max Rated Current Per Conductor	
					2 Pair	4 Pair
1	1	4W	3.84W	91mA	45mA	20mA
2	1	7W	6.49W	159mA	80mA	35mA
3	1	15.4W	13W	350mA	175mA	77mA
4	2	30W	25.5W	600mA	300mA	150mA
5	4	45W	40W	900mA	NA	225mA
6	4	60W	51W	1200mA	NA	300mA
7	5	75W	62W	1442mA	NA	361mA
8	5	90W	71.3W	1731mA	NA	433mA

PoE is a Constant Power System

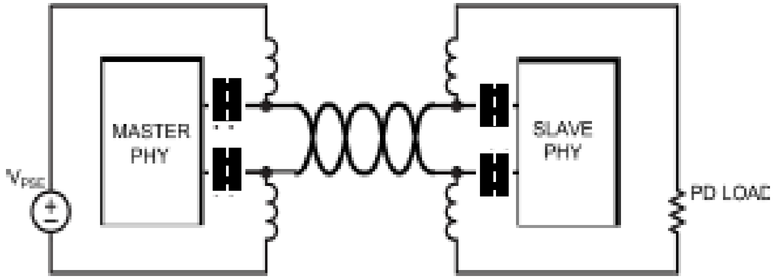
- Recall the equation for $$I_{cable} = \frac{V_{PSE} - \sqrt{V_{PSE}^2 - 4 * R_{cable} * P_{PD}}}{2 * R_{cable}}$$
- The currents presented on the previous slide are the worst case rated currents
- These are derived from the minimum V_{pse} and max P_{pd} and R_{cable}
- Real systems don’t operate at the mins and maxes
- PDs are ‘constant power’, the power consumption of the PD does not change if any of the three variables change
- A change in any one results in a reduction of cable current

Translating that to Single Pair: PoDL/SPoE & MPoE

Following in the Footsteps of PoE – Power is an Enabler for IoT



Power over Ethernet (PoE)



Power over Data Lines (PoDL)

- Single-pair powering for Ethernet was introduced in IEEE Std 802.3bu is now Clause 104 in IEEE Std 802.3
  - Clause 104 is often called "PoDL" (power over data line), more currently, SPoE (Single-pair Power over Ethernet)
- New protocol for Multidrop & bussed power: MPoE in 802.3da
- SPoE/MPoE applies power across the differential single pair, just like the data voltage (unlike PoE)
  - SPoE "PoDL" separates by frequency, with a highpass/lowpass filters, uses variant of Maxim OneWire for classification
  - PoE separates the power and data because power is 'common mode' or across the average voltage of 2 pairs , uses voltage pulses - mark and low events for classification
  - MPoE separates by frequency, but uses PoE-like classification

PoDL/SPoE clause 104 power classes

Class	0	1	2	3
Ppd (Watts min)	0.5	1	3	5
Vpse (Volts max)	18	18	18	18
Ipi (mA max)	101	227	249	471
Loop resistance (ohms max)	6	6	6.5	6.5

Class	4	5	6	7	8	9
Ppd (Watts min)	1	3	5	10	30	50
Vpse (Volts max)	36	36	36	36	60	60
Ipi (mA max)	97	339	215	461	735	1360
Loop resistance (ohms max)	6.5	6.5	6.5	6.5	6.5	6.5

Class	10	11	12	13	14	15
Ppd (Watts min)	1.23	3.2	8.4	7.7	20	52
Vpse (Volts max)	30	30	30	58	58	58
Ipi (mA max)	92	240	632	231	600	1579
Loop resistance (ohms max)	65	25	9.5	65	25	9.5

Clause 104 supports classification at:

- 5 nominal supply voltages (12, 24, 30, 48, 58 Volts)
- 5 loop resistances, but 4 nominally:
  ~6, 9.5, 25, 65 ohms
- 13 power levels, but 8 nominally:
  0.5, 1, 3,5, 8, 10, 20, 50 Watts
- Classification is performed by serial communication (SCCP)
- EITHER: detect a signature resistance and have no classification (class is implied to be hard-coded)
- OR: implement the SCCP classification protocol

Noise from the PSE/PD

- Specified at PSE & PD:
  - up to 10 MHz with 2 different HP filters (items a & b);
  - assumed minimal > 10 MHz

- PSE: Table 104-7 items 4a & b
- PD: Table 104-11 items 3a & b

Table 104–7—PSE output requirements *(continued)*

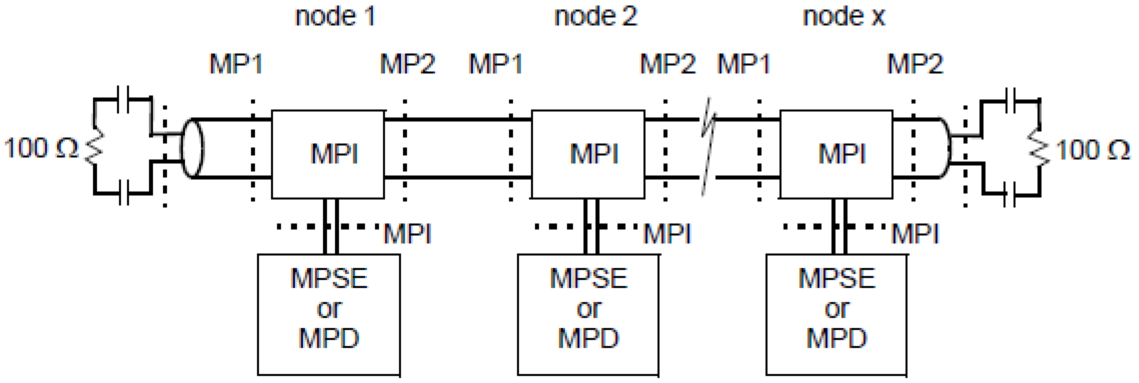
Item	Parameter	Symbol	Unit	Min	Max	Class	Type	Additional information
4	Power feeding ripple and noise:							
4a	1 kHz < f < 10 MHz		V_{p-p}	—	0.1	All	A, B, C, D, E	See 104.4.7.3
					0.066		F	
4b	1 kHz < f < 10 MHz			—	0.01	All	A, B, C, D, E	
					0.0066		F	

Table 104–11—PD power supply limits *(continued)*

Item	Parameter	Symbol	Unit	Min	Max	PD Type	Additional information
3	Ripple voltage						
3a	1 kHz < f < 10 MHz		V_{p-p}	—	0.1	A, B, C, D, E	See 104.5.7.4
					0.066	F	
3b	1 kHz < f < 10 MHz			—	0.01	A, B, C, D, E	
					0.0066	F	

High-level description of MPoE

- Defines an MPSE and an MPD (similar to a PSE and a PD in PoE)
- Generally only one MPSE per mixing segment
  - More than one MPSE isn't disallowed, but is out of scope
- Can have one or more MPDs on the wiring
  - PSE provides no power until at least one MPD is detected
- Devices on the mixing segment may or may not take power (supports non-MPDs)
- Defines the MPI (Multidrop power interface) which can be the TCI (data interface)
- Defines unit loading for MPD power consumption



NOTE – The MPI may not be exposed. If it is not exposed, specified values are calculated from values observed at MP1 and MP2.

Figure 189–1—Mixing segment and reference points for power

Two Power System Types

- One for 60V (dry), one for 30V (damp) – both class 2 (NFPA70)
- Each MPSE can provide 16 "unit loads" of power
- Each MPD can consume an integer number of unit loads of power

Table 189–1—System power types

	30 V Max MPSE (Type 0)	57 V Max MPSE (Type 1)	Units
V_{MPSE} max	30	57	V
V_{MPSE} min	21.6	45	V
V_{MPD} min	16	35.5	V
I_{MPSE} min	1100	1750	mA
P_{MPSE} min	23.76	78.75	W
P_{MPD_1U} max	1.1	4	W
NOTE—Multiplying the minimum MPD voltage and current does not yield the required MPSE power because the power calculations for multidrop systems are not linear equations. As power is delivered to each MPD along the mixing segment, the current through the remaining portion of the mixing segment is reduced. In systems with fewer than 16 unit loads, values such as V_{MPD} and the power available to the MPD(s) will rise.			

Source: IEEE P802.3da D3p2

Multidrop Power over Ethernet (MPoE)

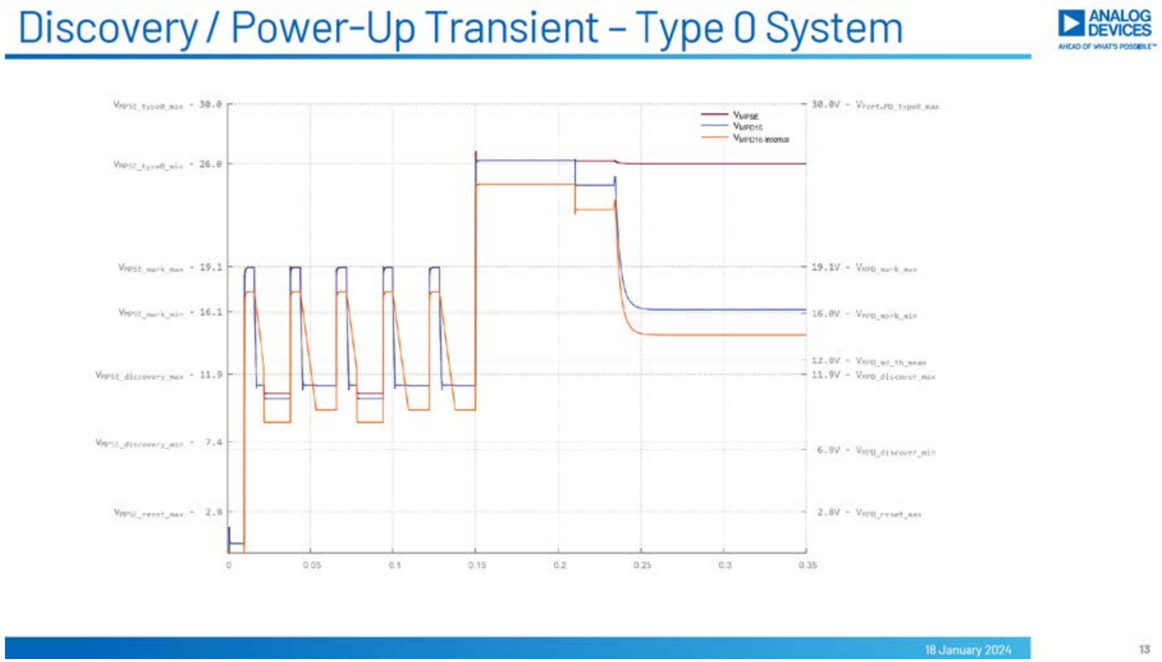
- Specifies:
  - The characteristics of an MPSE to add power to the cabling system.
  - The characteristics of an MPD's load on the power source and the cabling.
  - A method for determining the presence of one or more MPDs prior to applying power.
  - A method for applying and removing power from the mixing segment in a controlled manner.
  - A method for scaling supplied power back to the idle level when power is no longer requested or required.
  - A method for MPDs and MPSEs to negotiate and allocate power.
  - Power fault sensing and recovery.
  - Requirements for adding an MPD to an already powered mixing segment.

System Types, Unit Loads, and "Cold Power"

- Two System Types (30V and 50V)
  - MPSEs and MPDs may be 30V, 50V, or "Mixed" (capable of either)
- Each mixing segment supports at least 16 "unit loads"
  - A PD has a positive integer number of unit loads
  - MPSEs provide at least 1W current when powering
  - The unit load for a 30V system is 1W, and for a 50V system is 2W
- MPSEs provide "Cold Power" – no powering voltage unless PDs are present and identified
  - MPDs provide a "Transmit Power Signature"(TPS) similar to PoE's "Maintain Power Signature" (MPS)
  - MPSEs remove power in the absence of any MPD TPS
- MPSEs (also) remove power for faults (overload or short), or on command

Discovery

- An MPSE discovers and classifies types of MPDs present through a sequence of high & low states
  - Presenting a High "Mark" voltage low current, followed by
  - Measuring current draw at a Lower voltage with a higher current limit
- MPDs respond with:
  - Minimal current at the Mark states
  - Current draw at the low state depending on the state number and the MPD type
- All MPDs are measured at once



https://www.ieee802.org/3/da/public/0124/Paul_da_01_20240124.pdf

Isolated and non-isolated systems

- Isolated: recommended if the system crosses a ground reference boundary
- Grounded: for systems within a continuous ground domain

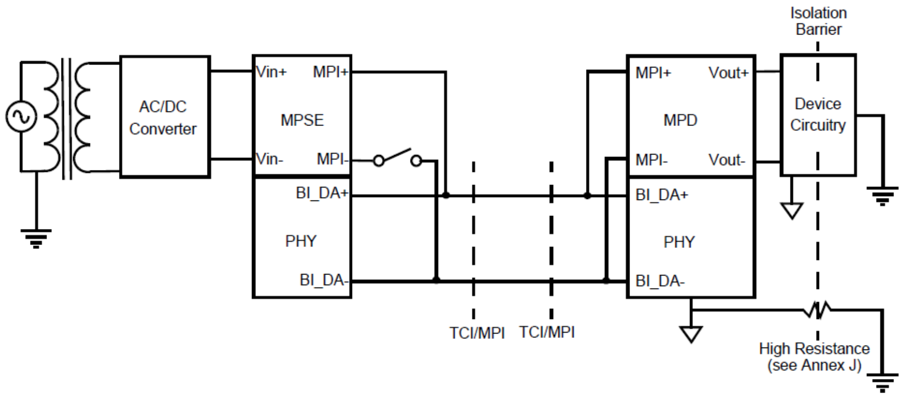


Figure 189–12—Isolated MPoE system diagram

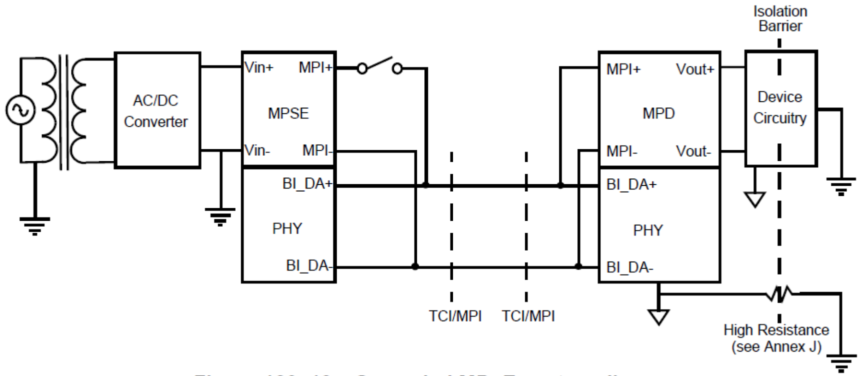


Figure 189–13—Grounded MPoE system diagram

Source: IEEE P802.3da D3p2

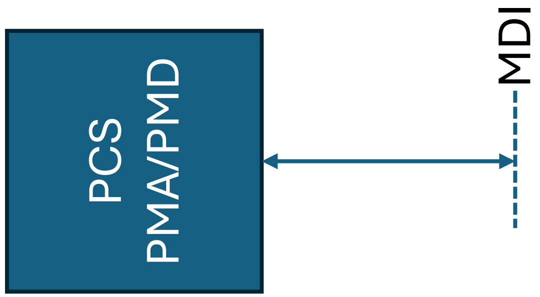
MPoE is defined to:

- Provide a multidrop power bus
  - With multidrop PHYs (and data on the same wires)
  - Without multidrop PHYs (with data on separate wires)
  - With or without management
- Be simpler than SPoE/PoDL but provide the same safety & management
  - Provide for detection of the power source voltage
  - Provide for management of the total load on the bus
- Proven implementation enabled by PoE (2/4pair)-like ‘mark/low event’ classification

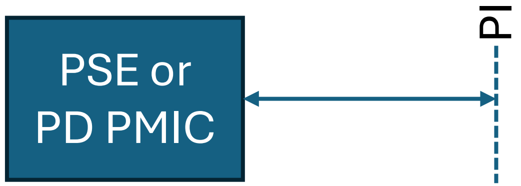
Missing from clause 189: Impact on PHYs

- Clause 189 leaves out ripple and noise directly
  - An oversight?
  - Clause 189 DOES have a dI/dt specification – similarly derived
    - See https://www.ieee802.org/3/da/public/0924/paul_02_da_202400916_v1.pdf
    - Very PHY dependent – conceived only for 10BASE-T1S & 10BASE-T1M
    - Translates to 12.8 mVpp over 1MHz to 40 MHz
  - Clauses 33/145, and 104 specify PSE and PD ripple & noise for different PHY types, differentiated by frequency content and levels
    - Clauses 33 & 145 identify this relative to the PHY (10 through 10GBASE-T)
    - Clause 104 makes these different power port types (A through H)
  - Need to specify noise and distortion onto the line for 802.3dm – doesn't necessarily have to be in the power clause

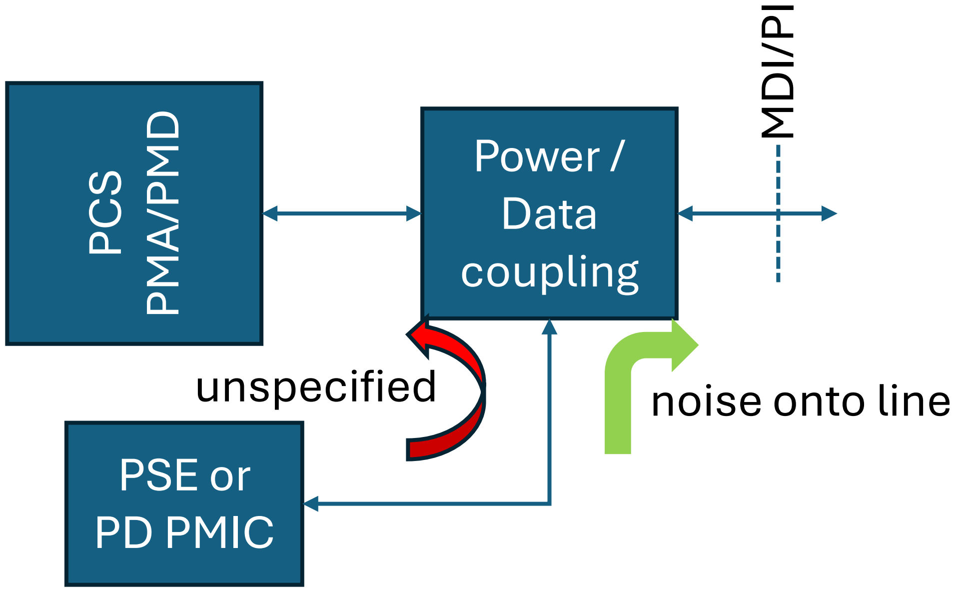
Specifying the Powered PHY



Without power, Droop, PSD, MDI RL, translate directly from the PMA/PMD to the MDI



Without data, power ripple & noise goes straight to the PI (at the line interface)

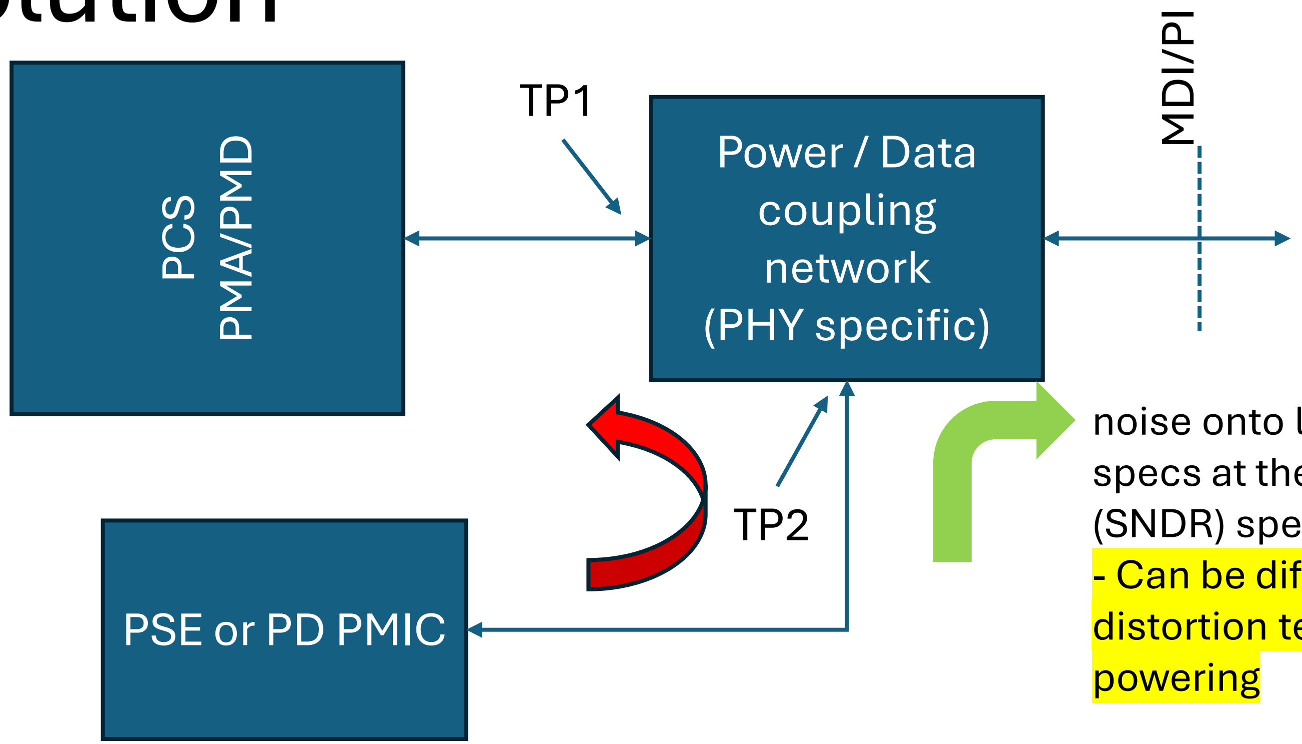


With power, Droop, PSD, MDI RL, are impacted by the loading and filtering of the power coupling circuitry between the PMA/PMD and the MDI

Similarly, the power specifications are presented as seen through the power coupling circuitry (this usually helps the PMIC filter out noise)

Noise from PMIC into local receiver PMA/PD is unspecified

Possible solution



noise onto line (specified by ripple specs at the PI & the TX distortion (SNDR) spec of the PHY)
- Can be difficult to test if the TX distortion test is done without line powering

IF we want this specified, specify aspects of the power/data coupling:

- Board designer controls the transfer function & impedance from MDI/PI to TP1 (and reverse)
  - * At a minimum, document the assumptions which impact the PHY droop, PSD, and MDI RL
- The local PMIC noise to the PMA receiver is within the board designer's control (no need for TP2 to the PMA/PCS)
- Need to consider how to test PMIC noise onto the line when the local PHY is active

What do we have to use?

- Specifications for noise from the PMIC (PSE or PD)
  - PSE: Items 4a & 4b in Table 104-7, measured as 104.4.7.3
  - PD: Items 3a & 3b in Table 104-11, measured as 104.5.7.4
  - High speed ACT (and TDD) should be able to use Type F, Low speed ACT should be OK with Type A (100BASE-T1, similar but less bandwidth, more sensitive to noise)
  - Need to check that this is consistent with TX SNDR specification
- Relaxation of droop and MDI RL specifications for the PHY:
  - High speed ACT & TDD – do we need relaxation?
    - Clause 149 doesn’t have one
  - Low speed ACT – need model of coupling circuitry to determine needs

Questions?
Thank you.