PowerSync Analyzer

Application Note

Ripple and Noise Testing with the PSA-3000

Sifos® Technologies

Ripple and Noise in IEEE 802.3 PoE

Since the original 802.3af (Clause 33) PoE specification, the requirement limiting common mode "Power feeding ripple and noise" has been present and was never altered for 802.3at (updated Clause 33) or for 802.3bt (new Clause 145). This requirement restricts the amount of AC noise that PSE's may output while powering PD's. In the case of 4-Pair powering PSE's in 802.3bt, the requirement is applicable to each powered pairset.

The requirement is stated as follows in both 802.3 clauses (33 and 145):

Item	Parameter	Unit	Min	Max
3 (Cl 33) 4 (Cl 145)	Power feeding ripple and noise:			
	f < 500 Hz	Vpp		0.500
	500 Hz to 150 KHz			0.200
	150 KHz to 500 KHz			0.150
	500 KHz to 1 MHz			0.100

The implication of this specification is that when a PSE is powering a PD, the output of the PSE should not exceed any of the peak-to-peak (Max) voltages when measured in the stated frequency bands. This further implies that the required measurement apparatus would be a spectrum analyzer capable of reporting peak-to-peak voltage amplitudes in frequency bands up to at least 1MHz. The measurement would be performed between the two wire pairs, or pairset, that receive DC power from the PSE port.

Conceptually, ripple and noise are of a concern because any conversion of that noise from common mode to differential could be detrimental to LAN signaling and also because they represent a form of RF emissions. Further, very high amplitudes of noise may have adverse impact on Powered Device functioning.

Ripple and Noise measurements, as performed by the Sifos PSA-3000 PowerSync Analyzer and incorporated into the 2-Pair and 4-Pair PSE Conformance Test Suites, were designed after consideration of three factors:

1. Specification Ambiguity
2. Economic Cost
3. Practical Requirements

Specification Ambiguity

The 802.3 PoE specifications clearly indicate that Ripple and Noise is only of concern when a PSE is powering a Powered Device (PD). As diagramed in Figure 1, the PD is drawing DC power (and current **Iport**) from the PSE while also presenting a capacitive load, **Cport**. The PSE ports also embed a source resistance, **Rs**. Ripple and Noise are measured as peak-to-peak voltage, **Vpp**, at the output of the PSE.

Cport, the capacitive load of powered pairset in the PD, is specified by 802.3 to be a minimum of 5 µF. This has the potential then to be a major factor affecting **Vpp**. The impedance of a 5 µF capacitor at several frequencies is presented in the following table.

Frequency	Zcap
150 KHz	0.21 Ω
500 KHz	0.06 Ω
1 MHz	0.03 Ω

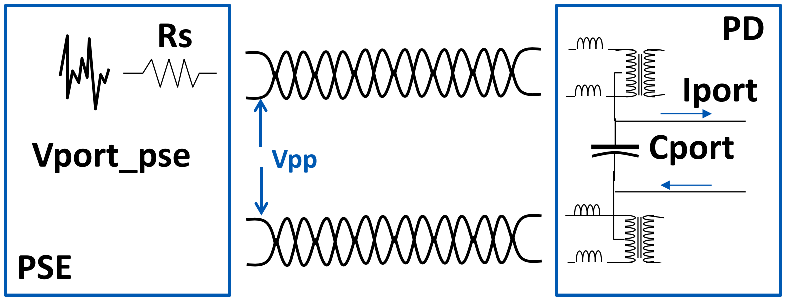

Figure 1. PSE Port Powering a PD

So at first glance, **Cport** in the PD will effectively short circuit frequencies above 500 KHz and will place a substantial load on frequencies in the 100 KHz range. That effect is reduced given a long cabling connection between PSE and PD where the loop DC resistance could reach as high as 12.5 Ω. In all cases, higher frequencies above 100 KHz will experience no higher than 12.7 Ω of load impedance meaning that the effective source impedance of the AC noise must be very low in order for **Vpp** to measure much above 0 Vpp.

Another potential factor affecting load impedance at high frequencies would be the common mode chokes in the PD Ethernet magnetics. Those would have the effect of adding to the impedance and reducing the common mode AC load, however, the frequency ranges where those chokes block transmission would typically be well above the 1 MHz maximum frequency in the Ripple and Noise specification.

The source impedance of the PSE port, **Rs**, also potentially plays a role in resultant **Vpp** values. PSE's typically must connect and disconnect PoE power using silicon switches (MOSFETS) and also may require sense elements for monitoring current and power. The DC voltage dropped across **Rs** depends on the PD DC load (**Iport**) while the AC (noise) voltage dropped across **Rs** depends on the PD effective AC input impedance including effects of **Cport**.

DC loading the PD can also have a direct impact on measured **Vpp**. For example, a switching power supply inside a PSE may generate more noise when the DC load increases and/or approaches the maximum capacity of that supply. So any testing of **Vpp** may need to be performed at extremes (low and high) of DC power loading.

One other factor affecting Vpp would be PD states where **Cport** might not be present. For example, a PD that receives power and delays activation of its DC-DC converters would present a much lower **Cport**, perhaps on the order of 50 to 100 nF for a period of time. That higher input impedance would then support a higher **Vpp** value at the PSE output.

Summarizing, the specification is very clear on **Vpp** values and frequency ranges but is very vague about the appropriate testing conditions for assessing **Vpp**.

Economic Cost

To perform the Ripple and Noise measurement as specified, requires an elaborate setup of test equipment including:

- Fixture to extract common mode voltage from the PSE output and then block DC voltage
- Fixture or instrument to get PSE to apply power and to provide a range of DC loads
- Spectrum Analyzer (or Digital Scope with spectral analysis features) to bound several frequency bands up to 1 MHz and then produce output as peak-to-peak voltage

Such an apparatus would likely cost many thousands of dollars and when fully implemented, would deliver just one parameter (Vpp) from the 802.3 clause 33 or clause 145 specifications.

Given the discussion regarding **Specification Ambiguity** above, this seems like an economically inefficient approach to the overall Ripple and Noise challenge.

Practical Requirements

In the **Specification Ambiguity** section above, it was suggested that AC Ripple and Noise appearing at the output of the PSE port would generally need to have a low source impedance in order to support the typical AC load conditions on that signal source. For practical purposes, it would need to originate in the PSE DC power supply(s) though there could be a scenario where gate control to the PSE MOSFET propagated noise.

The vast majority of PSE DC power supplies are switching supplies that would include switching frequencies in the range of 25 KHz to 500 KHz. Power supplies with higher switching frequencies, say 350 KHz to 1 MHz, are more apt to produce undesirable radiated emissions and as discussed above, frequencies in that range are more likely to get squelched by the powered PD connection.

Low frequencies in the vicinity of AC line inputs, i.e. 50 Hz or 60 Hz, might also find a path to the PSE output in some PSE implementations. Those low frequencies won't be as affected the AC load impedance of the PD so even though they may be small, they can appear even with a much higher source impedance.

Summarizing, areas of largest concern should be:

1. AC Line Frequencies (unaffected by PD AC load characteristics)
2. AC/DC Power Supply Switching Frequencies that are well below 500 KHz and are not properly filtered
3. AC noise present when PD **Cport** is at a theoretical minimum

Ripple and Noise Measurements in the PowerSync Analyzer (PSA)

Each PSA-3000 (PSA-3202, PSA-3102) test port includes an AC peak-to-peak detector. This detector is diagrammed in Figure 2.

Normally, the detector is fully disconnected from the PoE pairset lines. It is only connected during AC peak-to-peak measurements. When connected, the PoE DC voltage is blocked and a 0.05μF (**Cport**) capacitance is connected between the high side and the low side. The 0.05μF capacitance represents the minimum possible capacitance that a connected PD could present (prior to drawing DC load).

Passive filtering is then used to segregate low frequency ripple from higher frequency noise. The Low Pass (LP) filter passes 25 Hz to 325 Hz and will be mostly transparent to 50 Hz and 60 Hz. The Band Pass (BP) filter passes 2.5 KHz to 350 KHz with minimal attenuation in the 20 KHz to 250 KHz band. This measurement then supports observation of power supply switching frequencies.

The meter is therefore configured to recover "low band" or "high band" peak-to-peak voltage and includes sampling windows of either 2 seconds or 5 seconds.

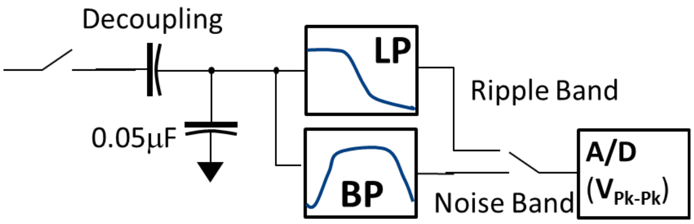

Figure 2. PowerSync Analyzer AC Peak Detector

Because the PSA test port is connected directly to the PSE port-under-test, as required generally for PSE conformance testing, there is no way for the measurement to simulate worst case cabling loop resistance of 12.5Ω. However, use of the 0.05μF load capacitance more than compensates that effect without completely short circuiting frequencies up to 500 KHz.

In the following table, the AC loading impact of a PD with 5μF **Cport** located 100M from the PSE port is compared to a PSA test port AC peak-to-peak meter connected directly at the PSE port. The comparison is performed at 100 KHz and 250 KHz.

Cabling Rchan	Cport	Frequency	AC Load Impedance
12.5 Ω (100M)	5.0 μF	250 KHz	12.50 Ω
0 Ω	0.05 μF	250 KHz	12.73 Ω
12.5 Ω (100M)	5.0 μF	100 KHz	12.50 Ω
0 Ω	0.05 μF	100 KHz	31.83 Ω

At 250 KHz, the effective test port AC meter load is very comparable to the worst case combination of a PD with **Cport** = 5 μF at the end of 100M of cabling. At 100 KHz, the test port presents a higher impedance that would cause the peak-to-peak noise to measure a bit higher than the worst case powered PD scenario depending upon the source impedance of that noise in the PSE.

Summary

The Ripple and Noise measurements performed by the PowerSync Analyzer should be regarded as a "**figure of merit**" as pertains to PSE output AC noise. Given the high ambiguity in the 802.3 specification and the low incremental cost in meter implementation, this metering solution represents a cost effective approach that will sort out PSE's sourcing excessive AC noise levels when providing DC power to a PD. The PSA test port can readily repeat these measurements with different DC power loads including minimum and maximum PSE supported loads.

EA Certified 2.0™

The Ethernet Alliance Gen2 (802.3bt) PSE certification test plan has accepted this approach as an alternative to the more elaborate and expensive measurements described earlier in **Economic Cost**.