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Power Supply Ripple and MDI Return Loss Modifications

GITESH BHAGWAT

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PSE and PD Power Supply Ripple

- PSE ripple voltage is measured using the test fixture shown here
- The Input impedance of the differential probe is given as:
  - $Z_{in}(f) = (100 \pm 0.1\% \times \frac{\sqrt{f^2 + {f_1}^2}}{f})$
- The Transfer function of the probe is given as:
  - $H_1(f) = \frac{f}{\sqrt{f^2 + {f_1}^2}}$
  - This high pass filter emulates the high pass effect of the data coupling capacitors
- For ripple measured at the MDI, a $100mV_{p\text{-}p}$ limit is specified in Table 104-4 item 4a.
- For ripple seen at the PHY input, a $10mV_{p\text{-}p}$ limit is specified in Table 104-4 item 4b.
  - To compare against this value, the measured ripple voltage is further post processed with the transfer given as:
  - $H_2(f) = \frac{f}{\sqrt{f^2 + {f_2}^2}}$
  - This high pass filter emulates the high pass filter in the PHY

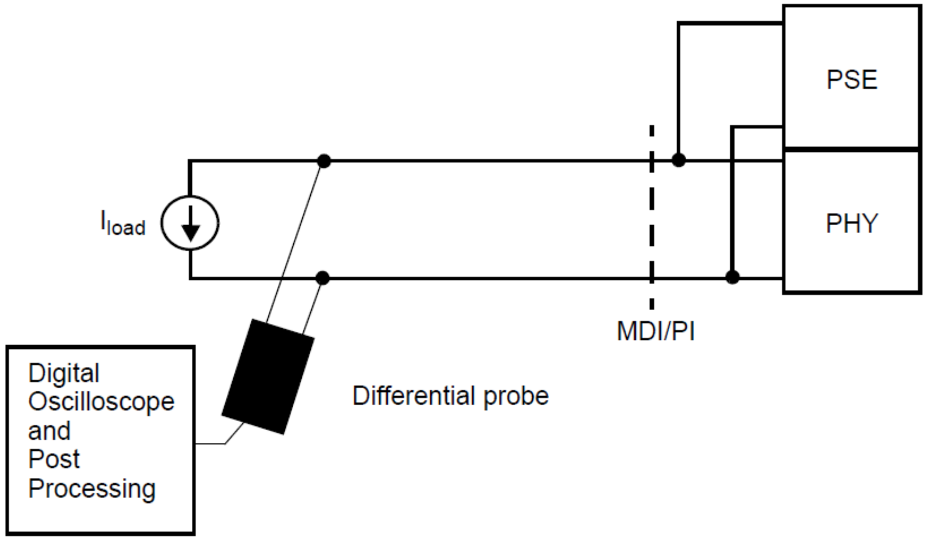


Figure 104–7—PSE ripple voltage test fixture

PSE and PD Power Supply Ripple

- The filter pole frequencies and the peak-to-peak ripple voltage values are shown below

PoDL Type	Data Speed	Modulation Scheme	Baud Rate	Ripple Filter Pole	
				f1	f2
Type E	10Mbps	PAM3	7.5 MBd	3.18 kHz ± 1%	0.1 MHz ± 1%
Type A, C	100Mbps	PAM3	66.66 MBd	31.8 kHz ± 1%	1 MHz ± 1%
Type B	1000Mbps	PAM3	750 MBd	318 kHz ± 1%	10 MHz ± 1%
Type F	2500Mbps	PAM4	1406.25 MBd	318 kHz ± 1%	10 MHz ± 1%
	5000Mbps		2812.5 MBd	318 kHz ± 1%	10 MHz ± 1%
	10000Mbps		5625 MBd	318 kHz ± 1%	10 MHz ± 1%

4	Power feeding ripple and noise:							
4a	1 kHz<f<10 MHz		$V_{p\text{-}p}$	—	0.1	All	All	See 104.4.6.3
4b	1 kHz<f<10 MHz			—	0.01	All	All	

PSE and PD Power Supply Ripple

- PAM4 (0.66V step) instead of PAM 3 (1V step)
  - Need more stringent PSE ripple specifications for NGAUTO systems
  - Scale peak ripple values from 0.1V to 0.066V for 4a and 0.01V to 0.0066V for 4b
- Coupling network in 1000BASE-T1 assumes a 3uH inductor and a10nF capacitor (gardner_3bu_2_0915.pdf)
  - Consider coupling network for NGAUTO with 2uH inductor and 10nF capacitor
  - Since ripple is measured at MDI, the HPF cutoff frequency determined by the RC pole and should remain same
  - f_1 = 318kHz
- Internal PHY filter cutoff – do not shift this frequency for higher baud rate
  - Consider same PHY pole as 1000BASE-T1 for all NGAUTO speeds
- Conclusion:
  - More stringent power supply specifications:
  - Lower peak to peak ripple voltage is allowed
  - PHY filter is retained same as 1000BASE-T1 system
- Similar changes can be applied to PD ripple specifications

PSE Power Supply Ripple – Text Changes

- Change Table 104-4 to add the new ripple voltage levels for Type F PSEs as shown below:

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	~~All~~ A,B,C,D,E	See 104.4.6.3
					0.066		F	
4b	1 kHz<f<10 MHz			-	0.01	All	~~All~~ A,B,C,D,E	
					0.0066		F	
…	…	…	…	…	…	…	…	…

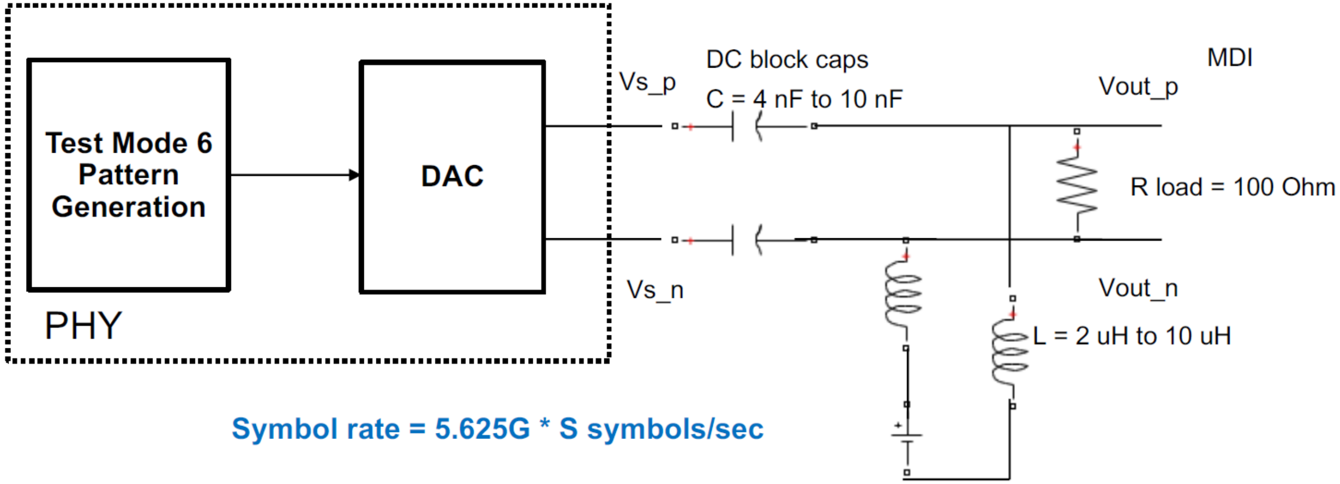
PD Power Supply Ripple – Text Changes

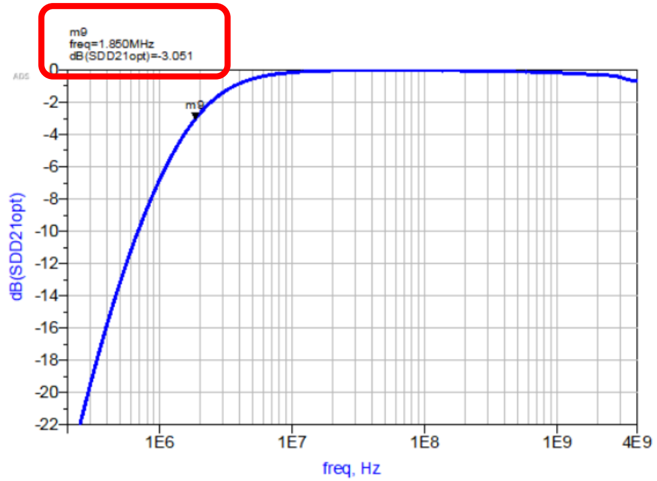
- Change Table 104-7 to add the new ripple voltage levels for Type F PDs as shown below:

Item	Parameter	Symbol	Unit	Min	Max	PD Type	Additional Information
…	…	…	…	…	…	…	…
3	Ripple voltage						
3a	1 kHz<f<10 MHz		V_{p-p}	-	0.1	~~All~~ A,B,C,D,E	See 104.5.6.4
					0.066	F	
3b	1 kHz<f<10 MHz			-	0.01	~~All~~ A,B,C,D,E	
					0.0066	F	
…	…	…	…	…	…	…	…

Low Frequency MDI Return Loss and Transmitter Droop

- Transmitter droop was specified considering a 2uH inductance and 10nF capacitance per transmitter output (souvignier_3ch_02_0319.pdf)
  - This yields an insertion loss 3dB HPF pole at 1.85MHz
- Having different inductance requirement from droop and low frequency return loss is confusing to system designers
- Should adjust MDI return loss mask to align with the coupling network used for droop
  - Same Insertion loss 3dB pole



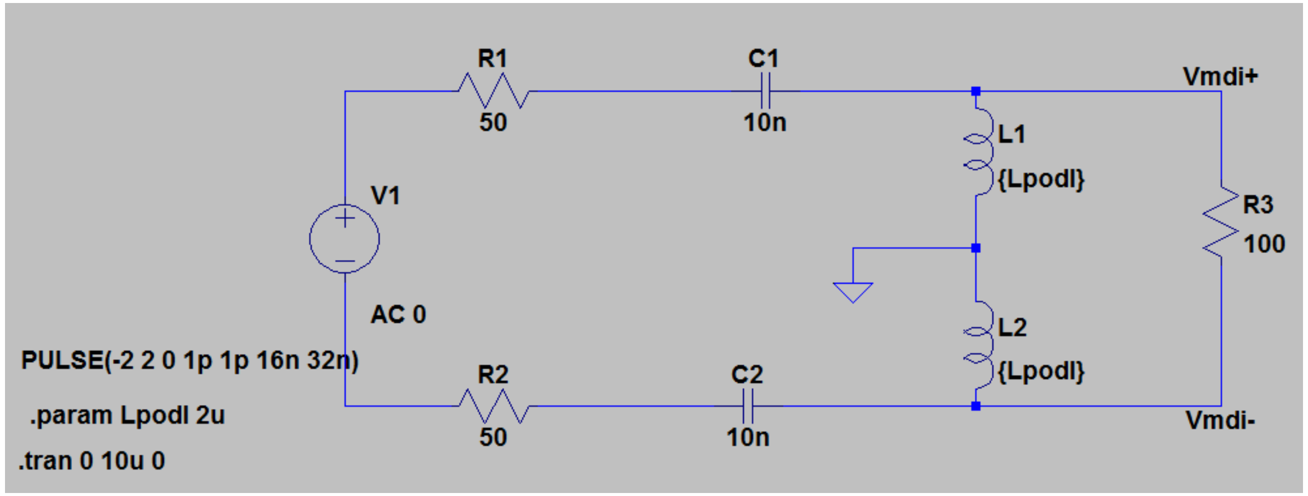


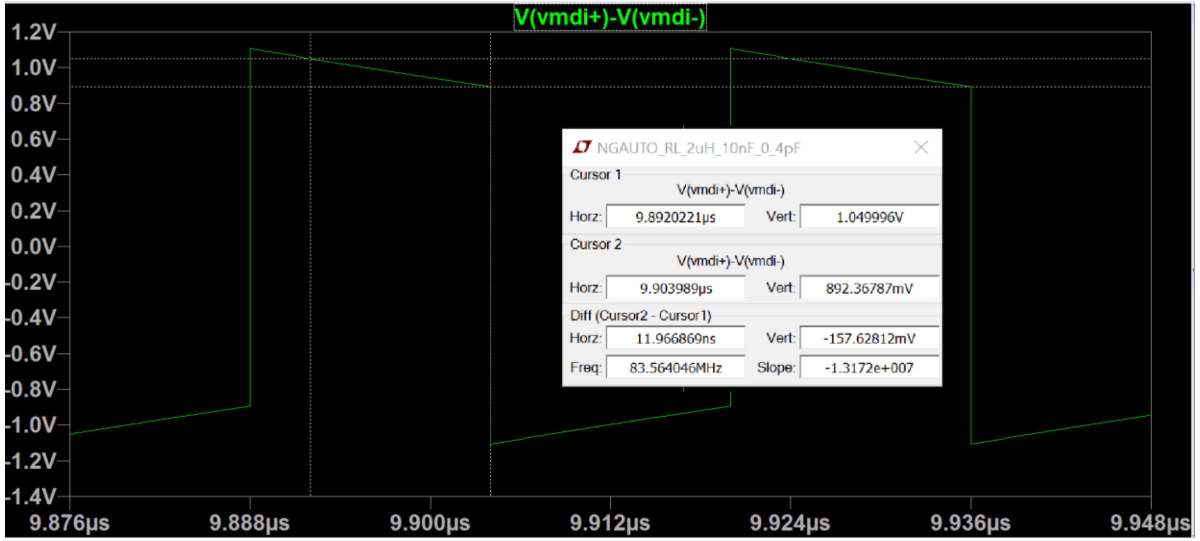
DC cap = **10 nF**
L = 2 uH , 0.15 pF internal parasitic cap
R load = 100 Ohm
R source = 100 Ohm
Board Trace = 1 inch
Connector = Rosenberger H-MTD

Droop = 15 %
HighPass_3dB = 1.85 MHz

Low Frequency MDI Return Loss and Transmitter Droop

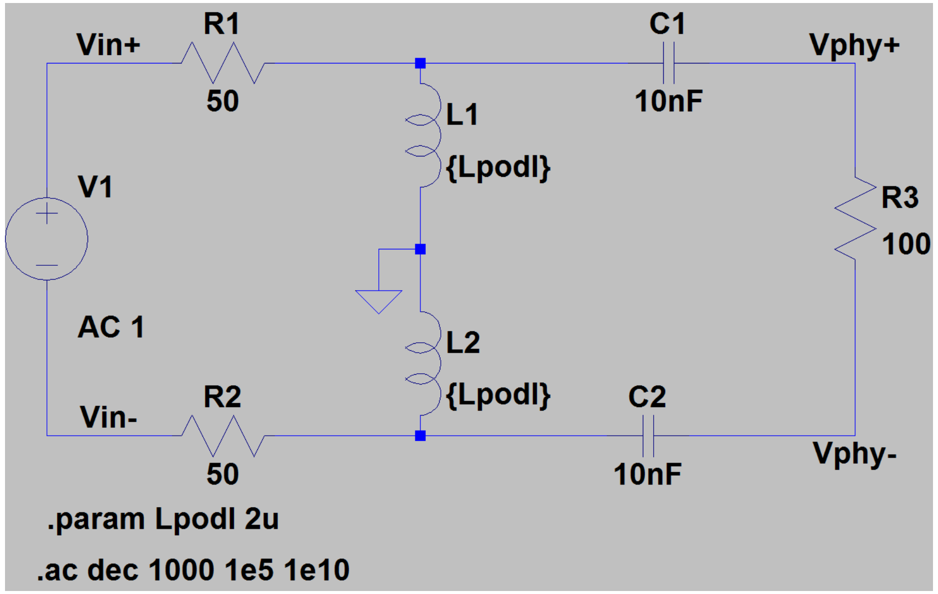
- Coupling circuit for droop simulation:
  - 2uH coupling inductor
  - 10nF coupling capacitor
- Droop calculated = 15%
  - Droop = $\frac{(1.0499-0.89236)V}{1.0499V} \times 100$ in 12ns
- Verify insertion loss HPF pole at 1.85Mhz
- Measure low frequency return loss for these values

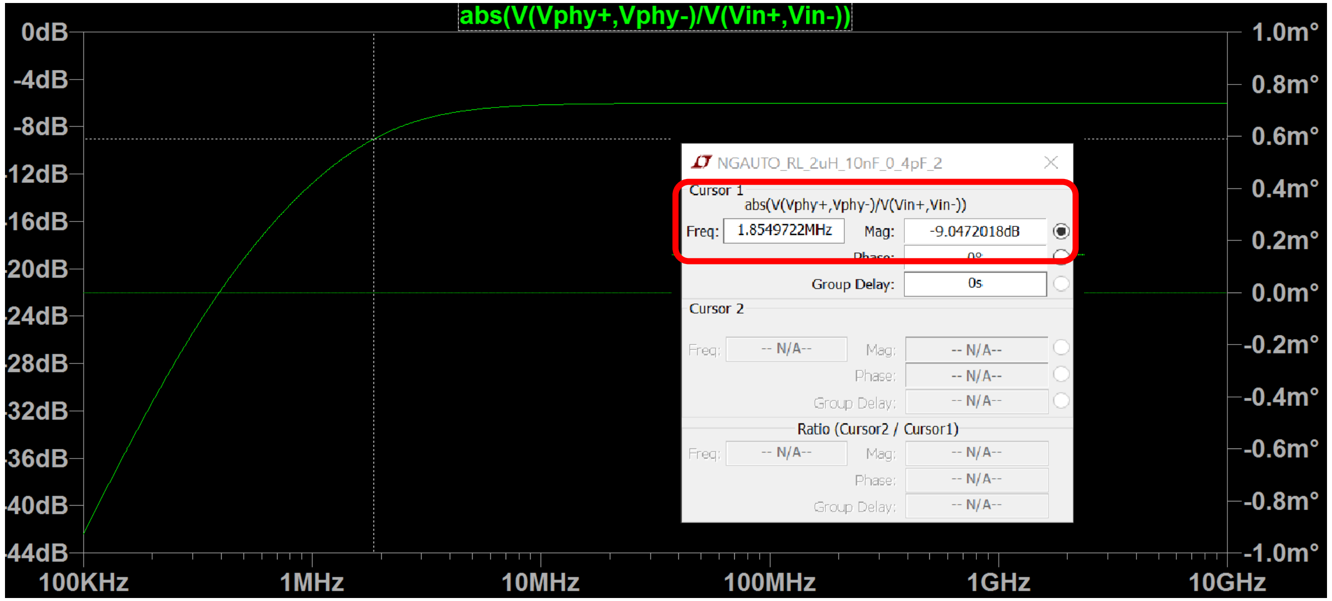


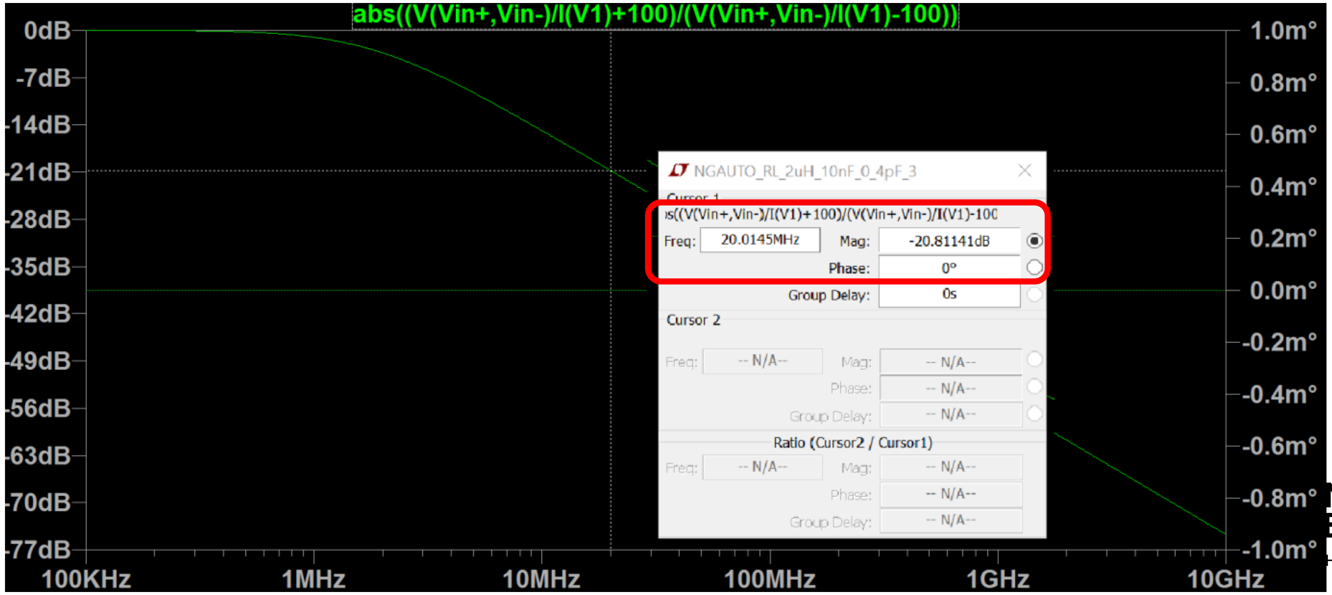


Low Frequency MDI Return Loss and Transmitter Droop

- HPF pole in insertion loss at 1.85 MHz verified
- Return Loss has a breakpoint of
  - -20dB at 20Mhz
- Change the low frequency MDI return loss breakpoint to align with this







Low Frequency MDI Return Loss Text Changes

- Change the edit to clause 149.8.2.1 MDI return loss to change the low frequency breakpoint
- **(P168, L2)** From:

$$MDI\_Return\_Loss(f) \le \begin{cases} 20 - 20\left(\log_{10}\frac{10}{f}\right) & 1 \le f < 10 \\ 20 & 10 \le f \le 500 \\ 12 - 10\log_{10}(f/3000) & 500 \le f \le 3000 \\ 12 - 20\log_{10}(f/3000) & 3000 \le f \le 4000 \end{cases} \text{ (dB)} \quad (149\text{–}27)$$

where

f is the frequency in MHz.

- To:

Return Loss ≥

- $\mathbf{20 - 20 \times Log_{10}(\frac{20}{f})}$ **for** $\mathbf{2 \le f \le 20}$
- $\mathbf{20}$ **for** $\mathbf{20 \le f \le 500}$
- $12 - 10 \times Log_{10}(\frac{f}{3000})$ for $500 \le f \le 3000$
- $12 - 20 \times Log_{10}(\frac{f}{3000})$ for $3000 \le f \le 4000$

where f is frequency in MHz

Impact of Low Frequency (LF) Return Loss (RL)

- http://ieee802.org/3/ch/public/jul19/vakilian_3ch_01_0719.pdf assumes 4.7uH inductors and a low frequency break point of 10Mhz
- As shown in http://ieee802.org/3/ch/public/sep18/bhagwat_3ch_01a_0918.pdf higher power coupling inductance comes at the cost of lower current
- Having different inductance requirement for droop and LF RL is confusing to system designers
- Previous work done in 1000BASE-T1 system design concluded that:

> **Summary**
>
> - PoDL inductor size is reduced and becomes more practical with relaxation of RL limit line.
> - Relaxing RL limit line degrades PHY performance by about 3dB when the lower corner frequency is at 40MHz.
> - Degradation in PHY performance is reasonable (less than 0.5dB at MSE of about -34dB) with limit line corner frequency not exceeding 20MHz.

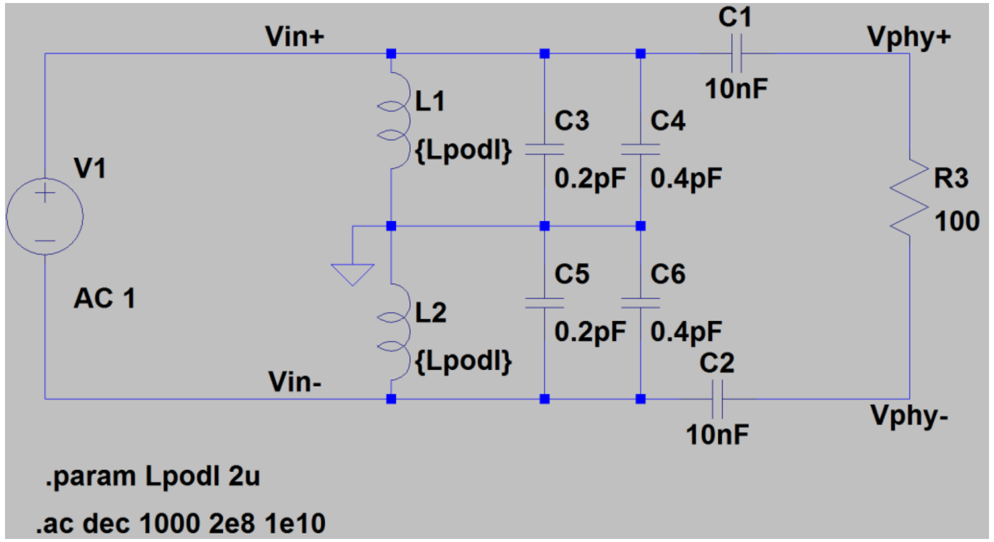
- Reference: www.ieee802.org/3/bp/public/jan16/chini_3bp_0116_01%20.pdf
- (Original) Conclusion:
  - Modifying LF RL mask corner to 20MHz shouldn’t have a significant impact on data transmission
    - Since baud rates are substantially higher than 1000BASE-T1 impact should be even smaller (?)

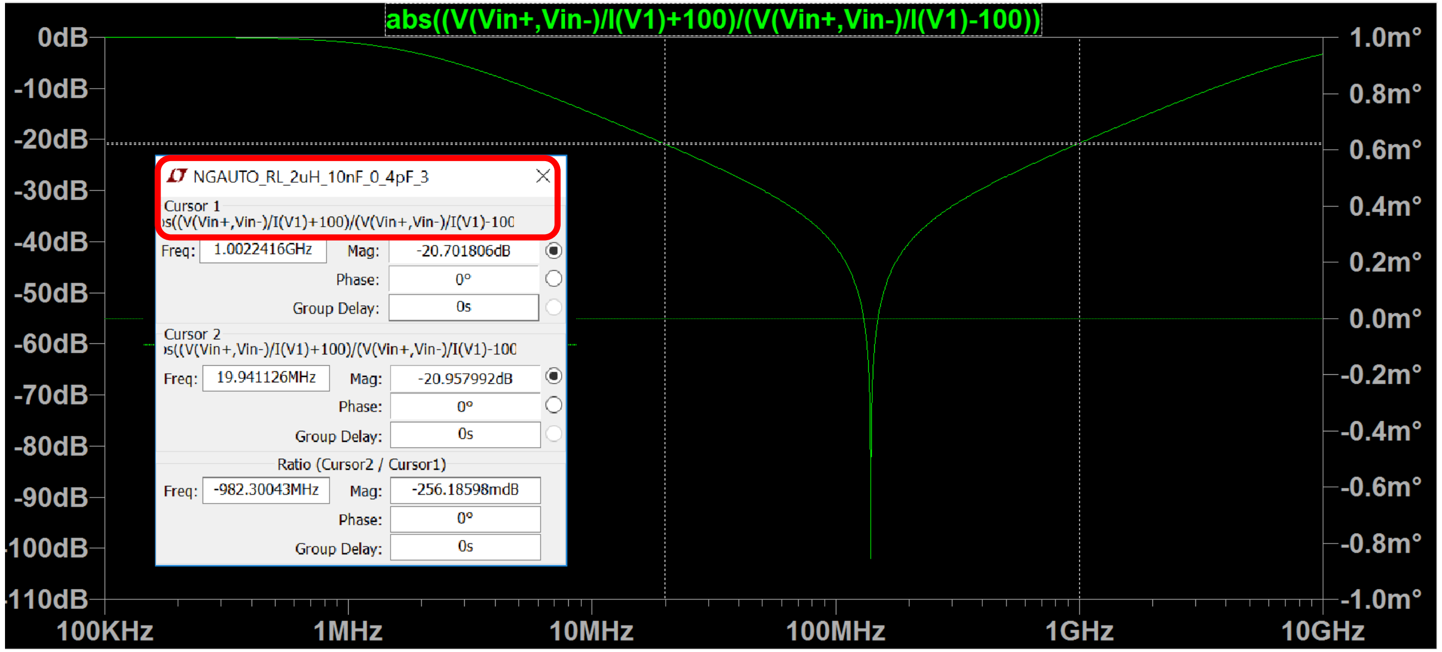
Impact of Low Frequency (LF) Return Loss (RL) - Updates from discussions in Vienna

- PHY designers feel the 20dB at 10Mhz corner frequency is required
  - Higher baud rate compared to 1000BASE-T1 systems requires changes in design approach
  - Lower corner allows an economically feasible PHY
- MDI Return Loss primarily determined by PHY requirements
- Impact on power coupling has been presented
- Droop and LF RL pointing towards same inductance beneficial for system design
- Conclusion:
  - If PHY designers believe this corner needs to be at 10MHz, we would like to withdraw proposed modification
  - Would further analyze this and propose a revised droop spec in alignment

High Frequency MDI Return Loss and ESD Protection Devices

- PHY devices may need additional protection using devices such as ESD clamping diodes
  - Consider additional capacitive loading of 0.4pF per output
- Coupling inductors have parasitic capacitance
  - Considering an SRF of about 250MHz, capacitance of 0.2pF per inductor
- This yields a high frequency return loss of -20dB at 1GHz
- Adding further margin for termination tolerance, trace inductance, package inductances etc.
  - Consider a breakpoint of -20dB at 500MHz
  - And a return loss of -5dB at 4000MHz





High Frequency MDI Return Loss Text Changes

- Change the edit to clause 149.8.2.1 MDI return loss to change the high frequency mask
- **(P168, L2)** From:

$$MDI\_Return\_Loss(f) \le \begin{cases} 20 - 20\left(\log_{10}\frac{10}{f}\right) & 1 \le f < 10 \\ 20 & 10 \le f \le 500 \\ 12 - 10\log_{10}(f/3000) & 500 \le f \le 3000 \\ 12 - 20\log_{10}(f/3000) & 3000 \le f \le 4000 \end{cases} \text{ (dB)} \quad (149\text{–}27)$$

where

f is the frequency in MHz.

- To:

Return Loss ≥

- $20 - 20 \times Log_{10}(\frac{10}{f})$ for $1 \le f \le 10$
- 20 for $10 \le f \le 500$
- $\mathbf{20{-}16.5 \times Log_{10}(\frac{f}{500})}$ **for** $\mathbf{500 \le f \le 4000}$

where f is frequency in MHz

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All MDI Return Loss Text Changes and Comparison

- Existing mask:

$$MDI\_Return\_Loss(f) \le \begin{Bmatrix} 20 - 20\left(\log_{10}\frac{10}{f}\right) & 1 \le f < 10 \\ 20 & 10 \le f \le 500 \\ 12 - 10\log_{10}(f/3000) & 500 \le f \le 3000 \\ 12 - 20\log_{10}(f/3000) & 3000 \le f \le 4000 \end{Bmatrix} \text{ (dB)} \quad (149\text{–}27)$$

where

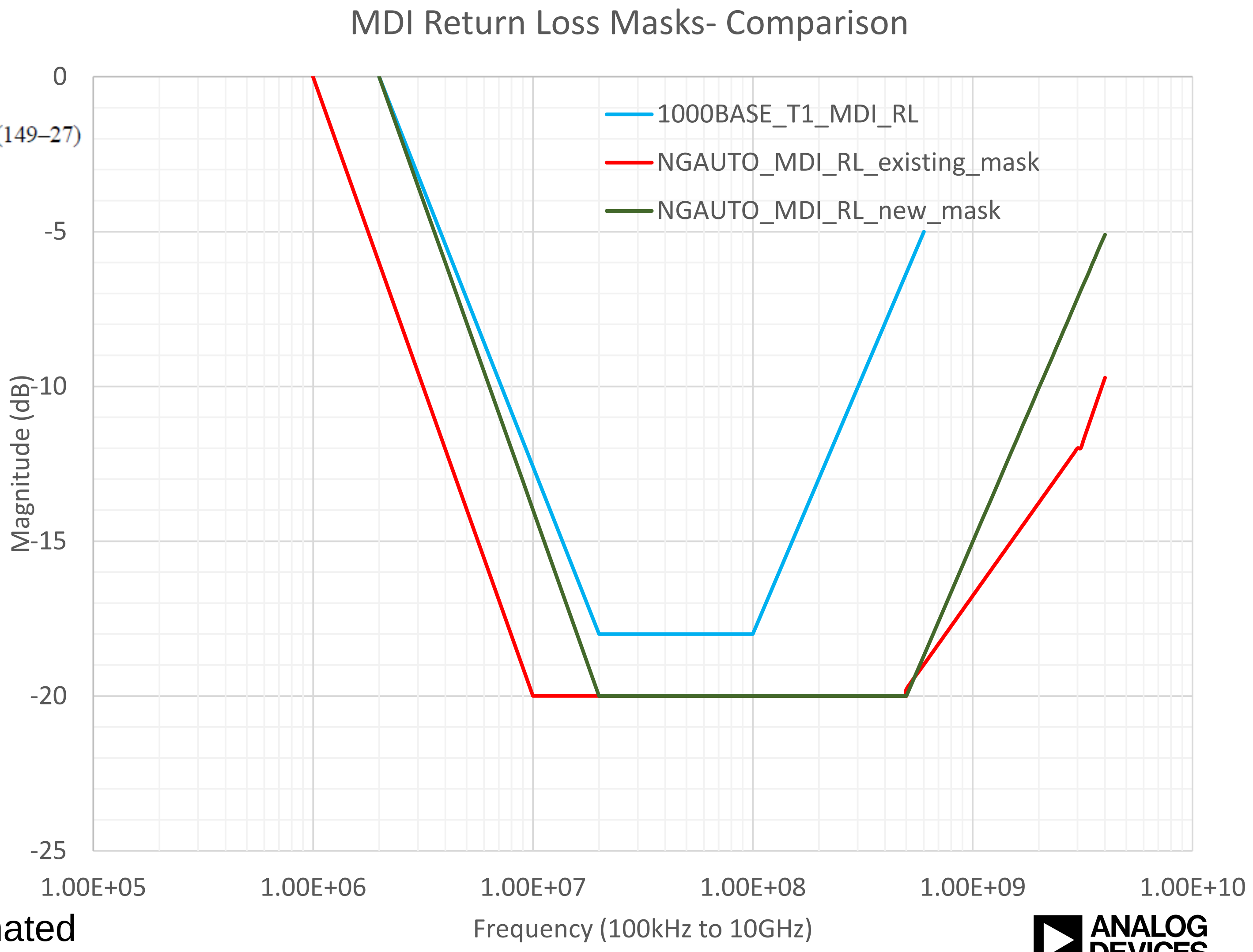
f is the frequency in MHz.

- Modified mask:

Return Loss ≥

- $20 - 20 \times Log_{10}(\frac{20}{f})$ for $2 \le f \le 20$
- 20 for $20 \le f \le 500$
- $20 - 16.5 \times Log_{10}(\frac{f}{500})$ for $500 \le f \le 4000$

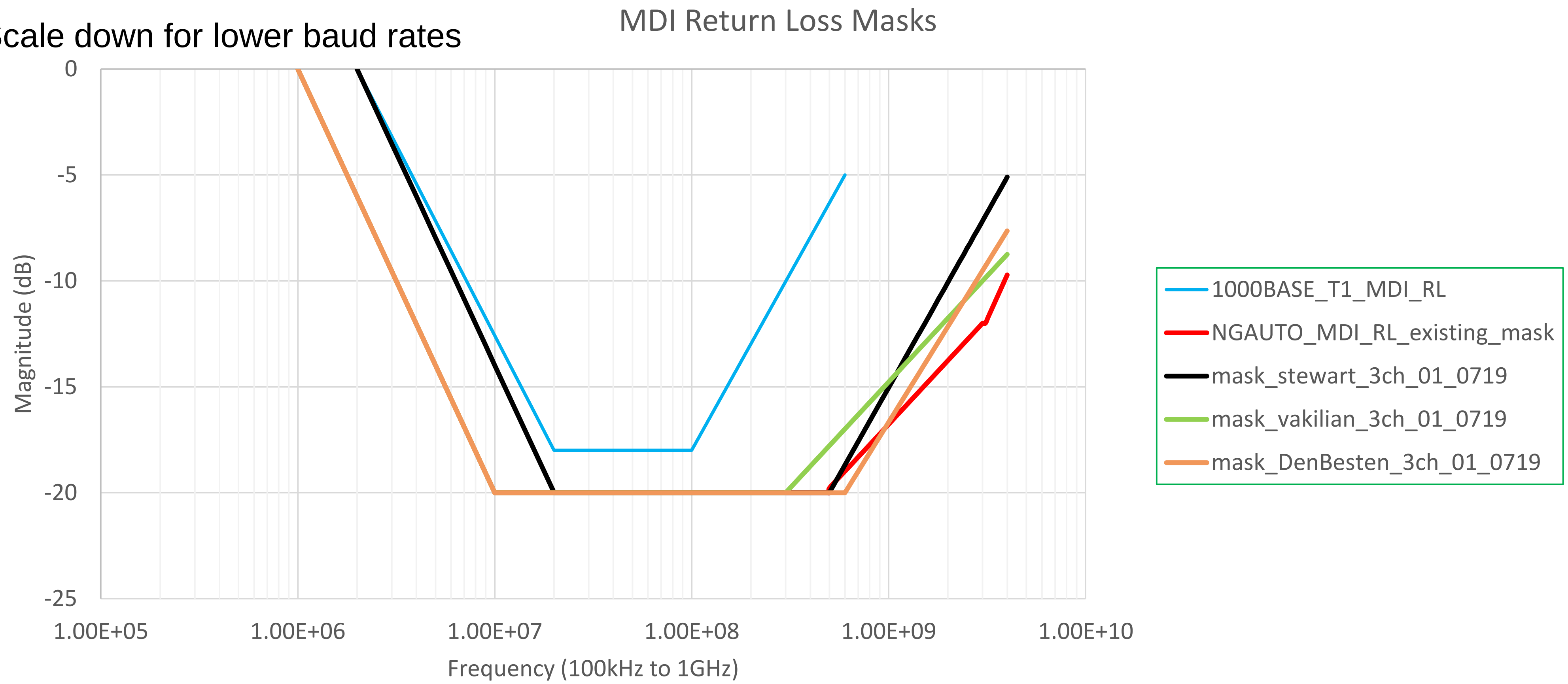
where f is frequency in MHz



- Note: discontinuity in previous mask has been eliminated

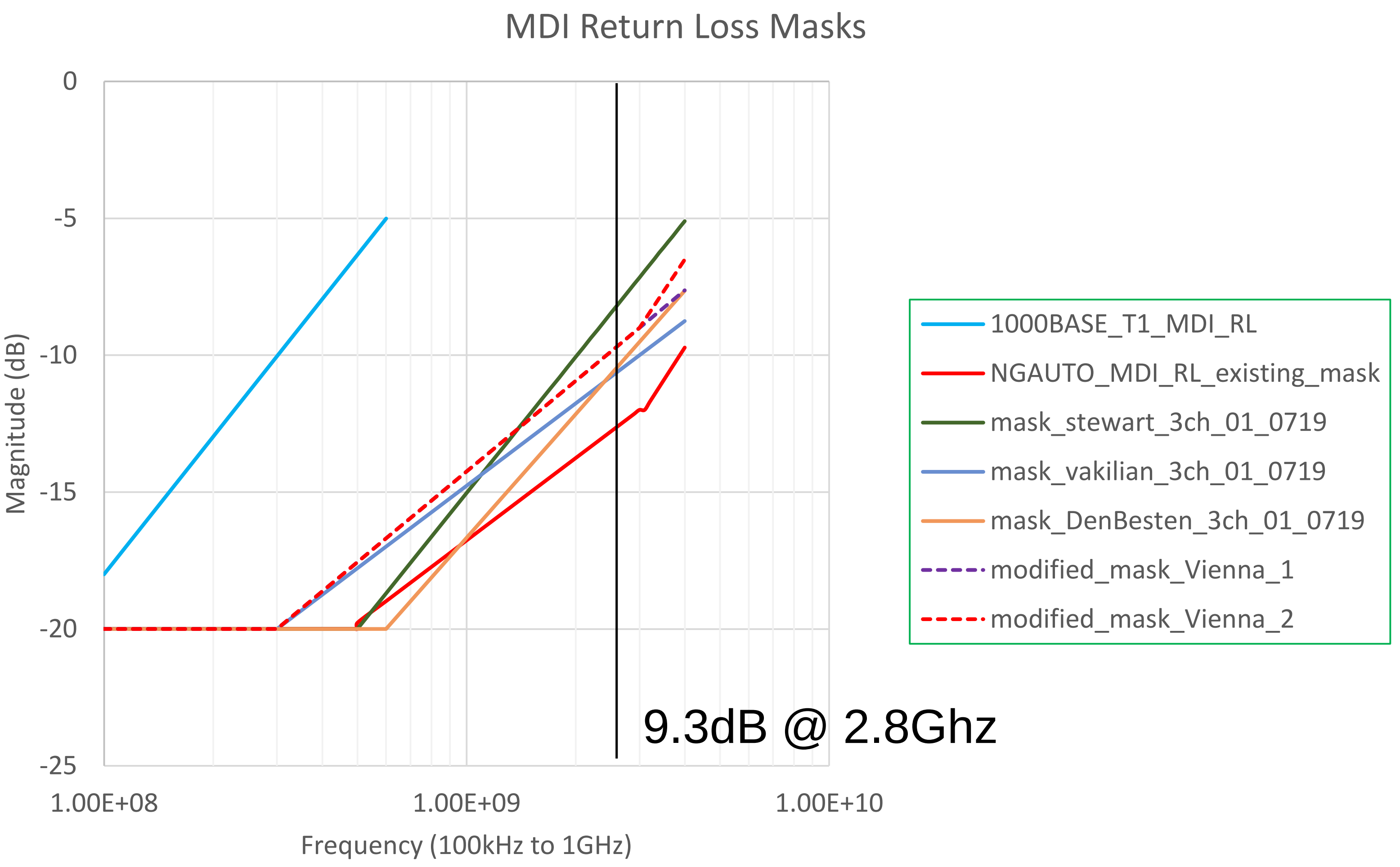
High Frequency (HF) Return Loss (RL) - Updates from discussions in Vienna

- Other HF RL masks proposed in this meeting
  - http://www.ieee802.org/3/ch/public/jul19/DenBesten_3ch_01_0719.pdf – (10G mask shown here)
  - http://www.ieee802.org/3/ch/public/jul19/vakilian_3ch_01_0719.pdf
- Desired 10dB Return Loss at Nyquist
- Scale down for lower baud rates



High Frequency (HF) Return Loss (RL)
- Updates from discussions in Vienna

- Using masks from vakilian_3ch_01_0719.pdf and DenBesten_3ch_01_0719.pdf



Version 1:

Return Loss ≥

- $20 - 20 \times Log_{10}(\frac{10}{f})$ for $1 \leq f \leq 10$
- 20 for $10 \leq f \leq 300$
- $\mathbf{20 - 11 \times Log_{10}(\frac{f}{300})}$ **for** $\mathbf{300 \leq f \leq 4000}$

where f is frequency in MHz

Version 2:

Return Loss ≥

- $20 - 20 \times Log_{10}(\frac{10}{f})$ for $1 \leq f \leq 10$
- 20 for $10 \leq f \leq 300$
- $\mathbf{20 - 11 \times Log_{10}(\frac{f}{300})}$ **for** $\mathbf{300 \leq f \leq 3000}$
- $\mathbf{9 - 20 \times Log_{10}(\frac{f}{3000})}$ **for** $\mathbf{3000 \leq f \leq 4000}$

where f is frequency in MHz

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Thank You!

QUESTIONS? FEEDBACK?

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Backup Slides

PSE Power Supply Ripple – Text Changes

- Change the edit to clause 104.4.6.3 to separate Type F and Type B PSEs and modify the cutoff frequencies:

(P62, L52) From:

“A digital oscilloscope or data acquisition module with a differential probe is used to observe the voltage at the MDI/PI of the PSE device under test (DUT) as shown in Figure 104–7. The input impedance, Zin(f), and transfer function, H1(f), of the differential probe are specified by Equation (104–1) and Equation (104–2), respectively. When measuring the ripple voltage for a Type A or Type C PSE as specified by Table 104–4 item (4a), f1 = 31.8 kHz ± 1%. When measuring the ripple voltage for a Type B or Type F PSE as specified in Table 104–4 item (4a), f1 = 318 kHz ± 1%.”

To:

A digital oscilloscope or data acquisition module with a differential probe is used to observe the voltage at the MDI/PI of the PSE device under test (DUT) as shown in Figure 104–7. The input impedance, Zin(f), and transfer function, H1(f), of the differential probe are specified by Equation (104–1) and Equation (104–2), respectively. When measuring the ripple voltage for a Type A or Type C PSE as specified by Table 104–4 item (4a), f1 = 31.8 kHz ± 1%. When measuring the ripple voltage for a Type B ~~or Type F~~ PSE as specified in Table 104–4 item (4a), f1 = 318 kHz ± 1%. When measuring the ripple voltage for a Type F PSE as specified in Table 104–4 item (4a), f1 = 318 kHz ± 1%.”

PSE Power Supply Ripple – Text Changes

- Change the edit to clause 104.4.6.3 to separate Type F and Type B PSEs and modify the cutoff frequencies:

(P63, L1) From:

"When measuring the ripple voltages for a Type B or Type F PSE as specified by Table 104–4 item (4b), the voltage observed at the MDI/PI with the differential probe where f1 = 318 kHz ± 1% is post-processed with transfer function H2(f) specified in Equation (104–3) where f2 = 10 MHz ± 1%"

To:

"When measuring the ripple voltages for a Type B ~~or Type F~~ PSE as specified by Table 104–4 item (4b), the voltage observed at the MDI/PI with the differential probe where f1 = 318 kHz ± 1% is post-processed with transfer function H2(f) specified in Equation (104–3) where f2 = 10 MHz ± 1%.

When measuring the ripple voltages for a Type F PSE as specified by Table 104–4 item (4b), the voltage observed at the MDI/PI with the differential probe where f1 = 318 kHz ± 1% is post-processed with transfer function H2(f) specified in Equation (104–3) where f2 = 10 MHz ± 1%"

PD Power Supply Ripple – Text Changes

- Change the edit to clause 104.5.6.4 to separate Type F and Type B PDs and modify the cutoff frequencies:

(P63, L41) From:

“When measuring the ripple voltage for a Type B or Type F PD as specified by Table 104–7 item (3a), f1 = 318 kHz ± 1%.”

To:

“When measuring the ripple voltage for a Type B ~~or Type F~~ PD as specified by Table 104–7 item (3a), f1 = 318 kHz ± 1%. When measuring the ripple voltage for a Type F PD as specified by Table 104–7 item (3a), f1 = 318 kHz ± 1%.”

(P63, L47) From:

“When measuring the ripple voltages for a Type B or Type F PD as specified by Table 104–7 item (3b), the voltage observed at the MDI/PI with the differential probe where f1 = 318 kHz ± 1% shall be post-processed with transfer function H2(f) specified in Equation (104–3) where f2 = 10 MHz ± 1%.”

To:

“When measuring the ripple voltages for a Type B ~~or Type F~~ PD as specified by Table 104–7 item (3b), the voltage observed at the MDI/PI with the differential probe where f1 = 318 kHz ± 1% shall be post-processed with transfer function H2(f) specified in Equation (104–3) where f2 = 10 MHz ± 1%.

When measuring the ripple voltages for a Type F PD as specified by Table 104–7 item (3b), the voltage observed at the MDI/PI with the differential probe where f1 = 318 kHz ± 1% shall be post-processed with transfer function H2(f) specified in Equation (104–3) where f2 = 10 MHz ± 1%.”