IEEE 802.3dg Task Force

100BASE-T1L MDI Circuit Suggestions

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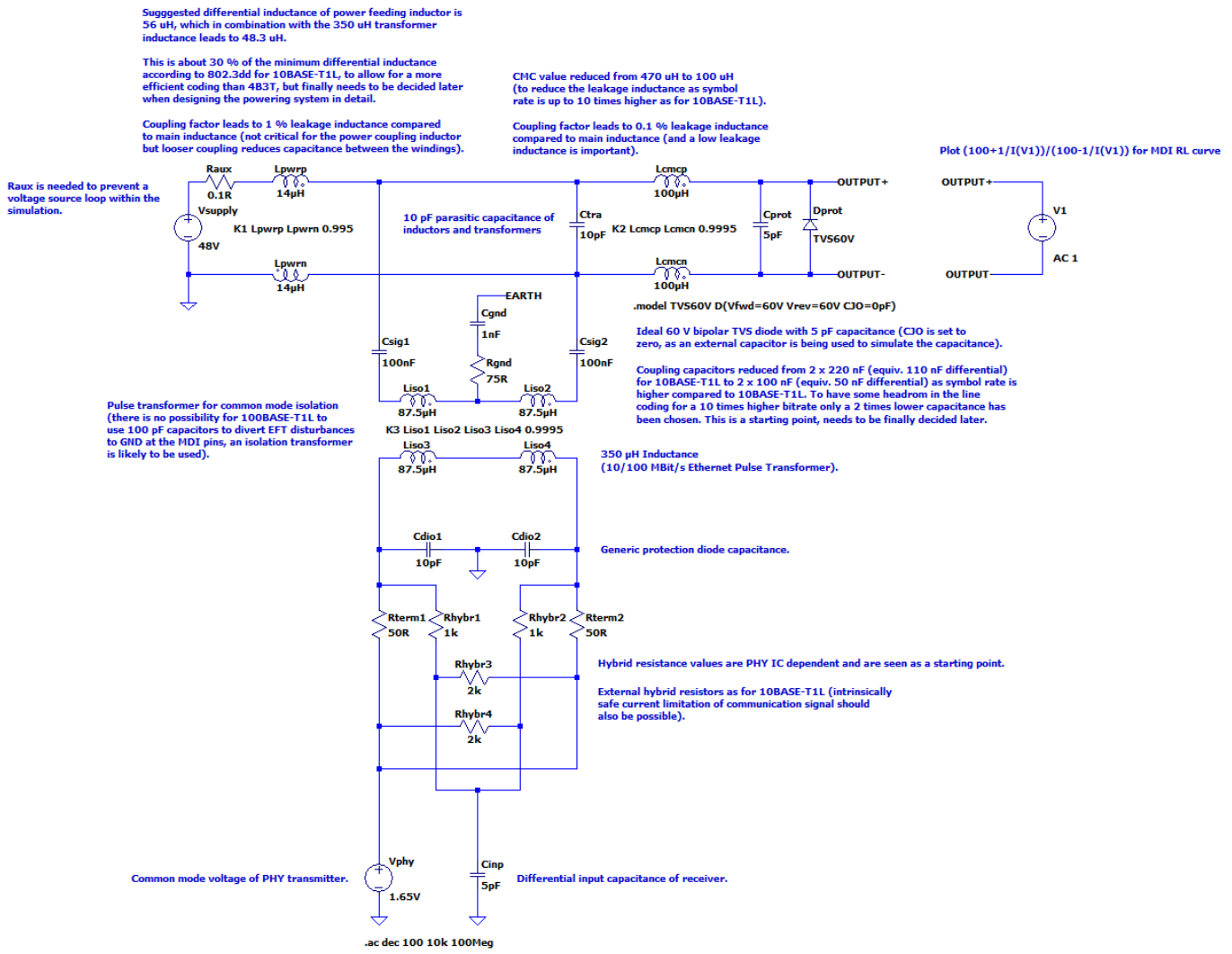
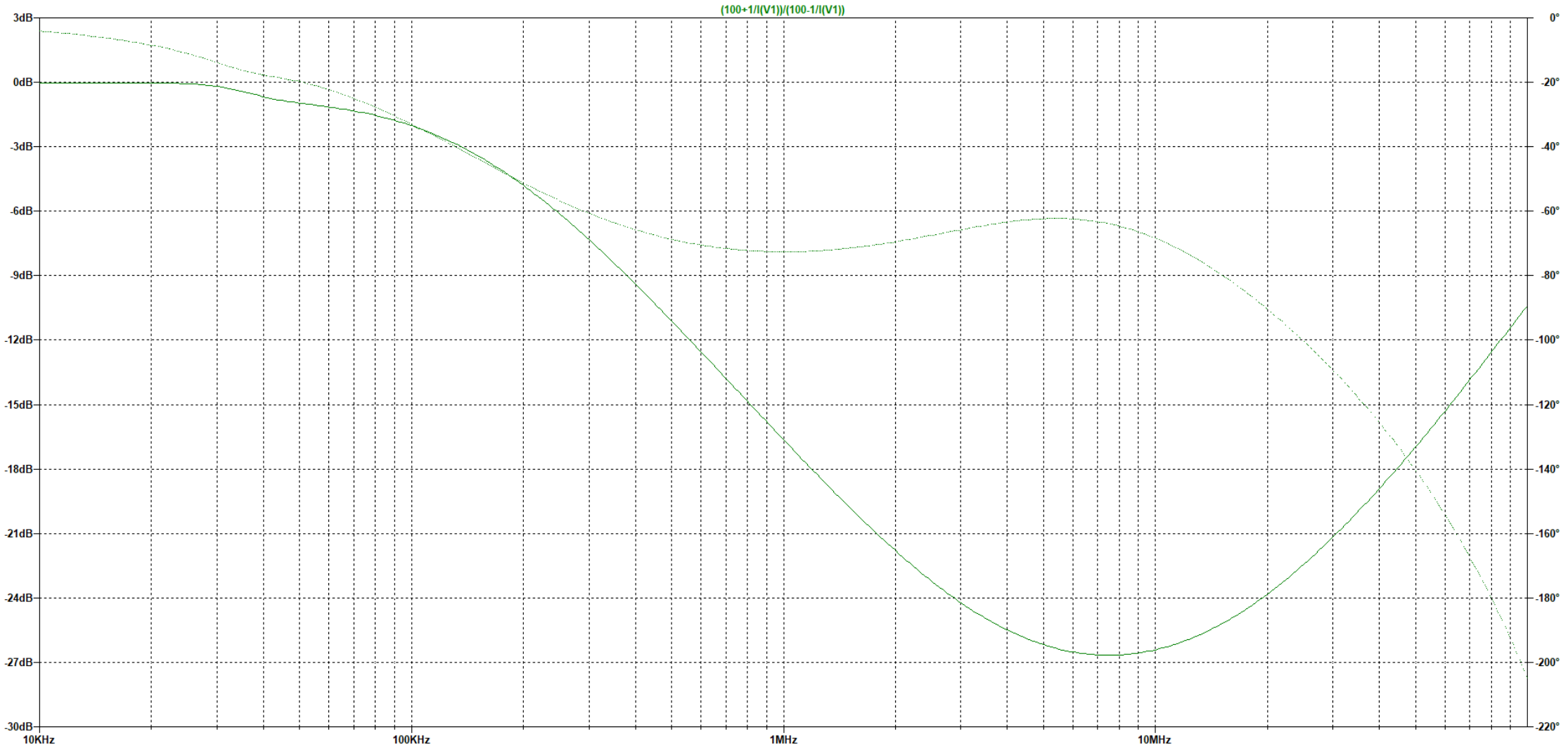
Introduction

- This presentation provides suggestions for a 100BASE-T1L MDI circuit or combined 10/100BASE-T1L MDI circuits:
  - *100BASE-T1L only MDI*
  - *10/100BASE-T1L MDI*
  - *10/100BASE-T1L MDI (switch side) for intrinsically safe applications*
  - *10/100BASE-T1L MDI (field device side) for intrinsically safe applications*
- The models are provided as LTSpice models and are for simulation purposes only.
- For real life hazardous area applications, special care and effort must be taken to fulfill all relevant requirements of the applicable safety standards (e.g. IEC 60079 series of standards or equivalent) and to fulfill all other applicable health, environmental and safety regulations.
- The simulation models in this presentation are a very first starting point and need to be improved over time.
- Additional input is highly welcome and recommended.

100BASE-T1L only MDI



100BASE-T1L only MDI Return Loss

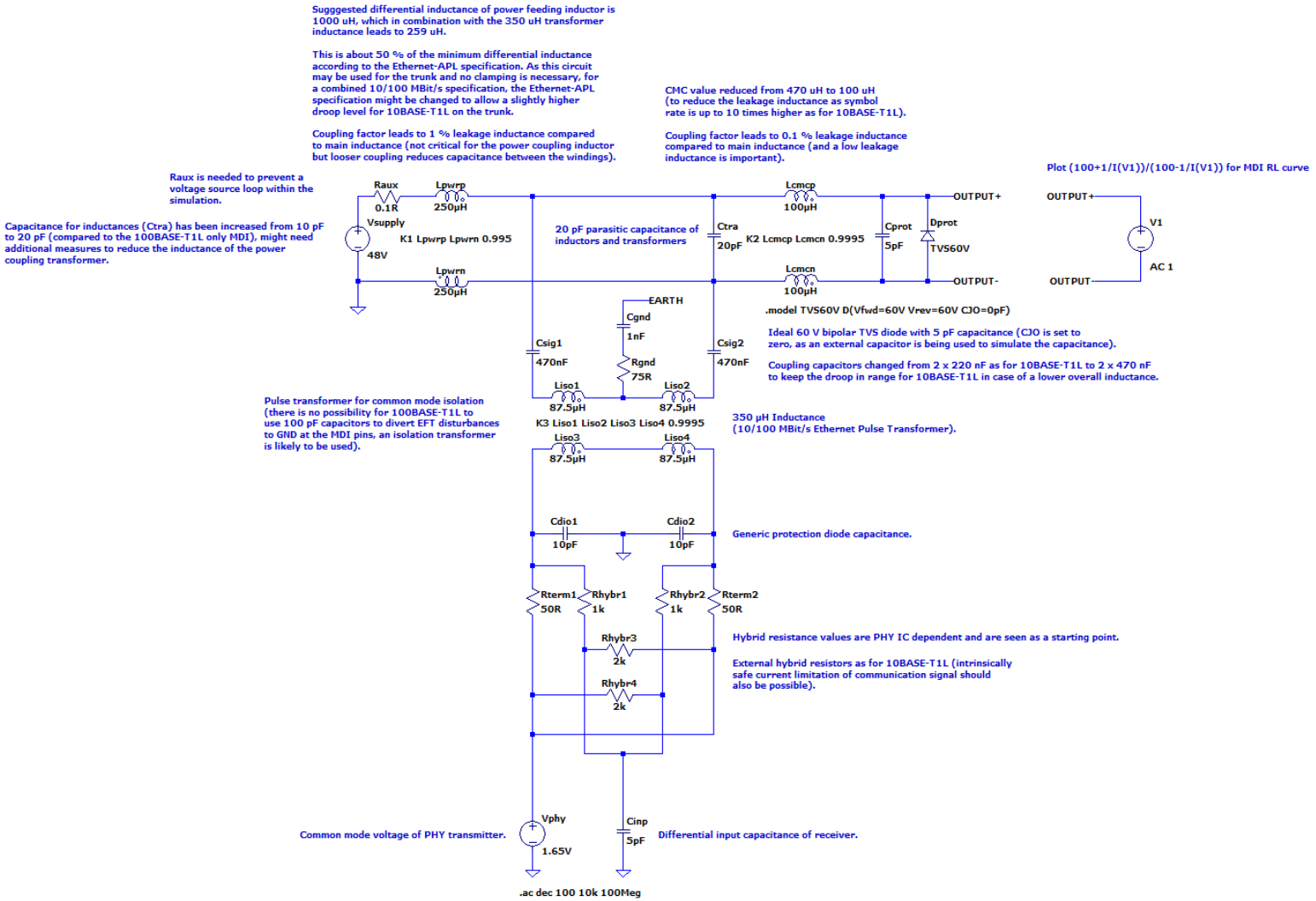


100BASE-T1L only MDI

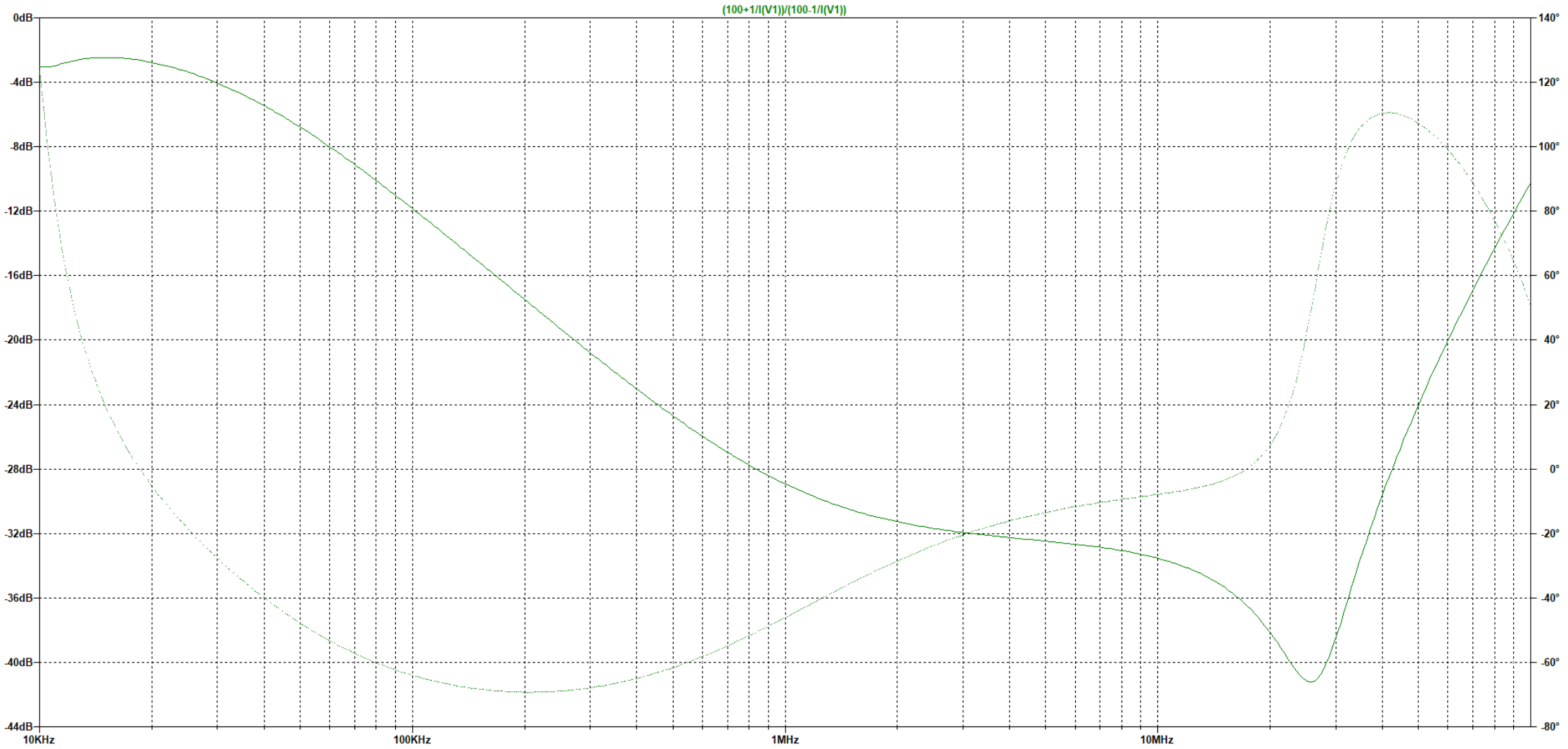
- Suggested typical circuit parameters for 100BASE-T1L only MDI circuit:

  - *Power coupling inductance: 56 uH (14 uH per winding)*
  - *Signal coupling transformer: 350 uH (standard 10/100 Mbit/s single pair Ethernet-Pulse transformer), leakage inductance 350 nH*
  - *Common mode choke: 100 uH inductance per winding, leakage inductance 100 nH*
  - *Signal coupling capacitors: 100 nF (in each line on primary side of transformer)*
  - *Parasitic capacitance for transformers: 10 pF (needs feedback from component manufacturers, what is possible or if we need to increase this value)*
  - *Low capacitance ESD/Surge protection: 5 pF*
  - *50 Ω termination resistance in each signal line*
  - *External hybrid resistors for PHY IC*

10/100BASE-T1L MDI



10/100BASE-T1L MDI Return Loss



10/100BASE-T1L MDI

- Needs to be compatible to 100BASE-T1L and 10BASE-T1L (including 802.3dd modifications).
- Needs to be compatible to Ethernet-APL (as the overall inductance is lower, for Ethernet-APL there might be need to allow a higher droop for the trunk).
- Potentially the power coupling inductance can be further reduced, to get non-IS Ethernet-APL closer to the 802.3dd limits.

- Suggested typical circuit parameters for 10/100BASE-T1L MDI circuit:

  - *Power coupling inductance: 1000 uH (250 uH per winding)*
  - *Signal coupling transformer: 350 uH (standard 10/100 Mbit/s single pair Ethernet-Pulse transformer), leakage inductance 350 nH*
  - *Common mode choke: 100 uH inductance per winding, leakage inductance 100 nH*
  - *Signal coupling capacitors: 470 nF (in each line on primary side of transformer)*
  - *Parasitic capacitance for transformers: 20 pF (doubled compared to 100BASE-T1L only MDI, needs feedback from component manufacturers, what is possible)*
  - *Low capacitance ESD/Surge protection: 5 pF*
  - *50 Ω termination resistance in each signal line*
  - *External hybrid resistors for PHY IC*

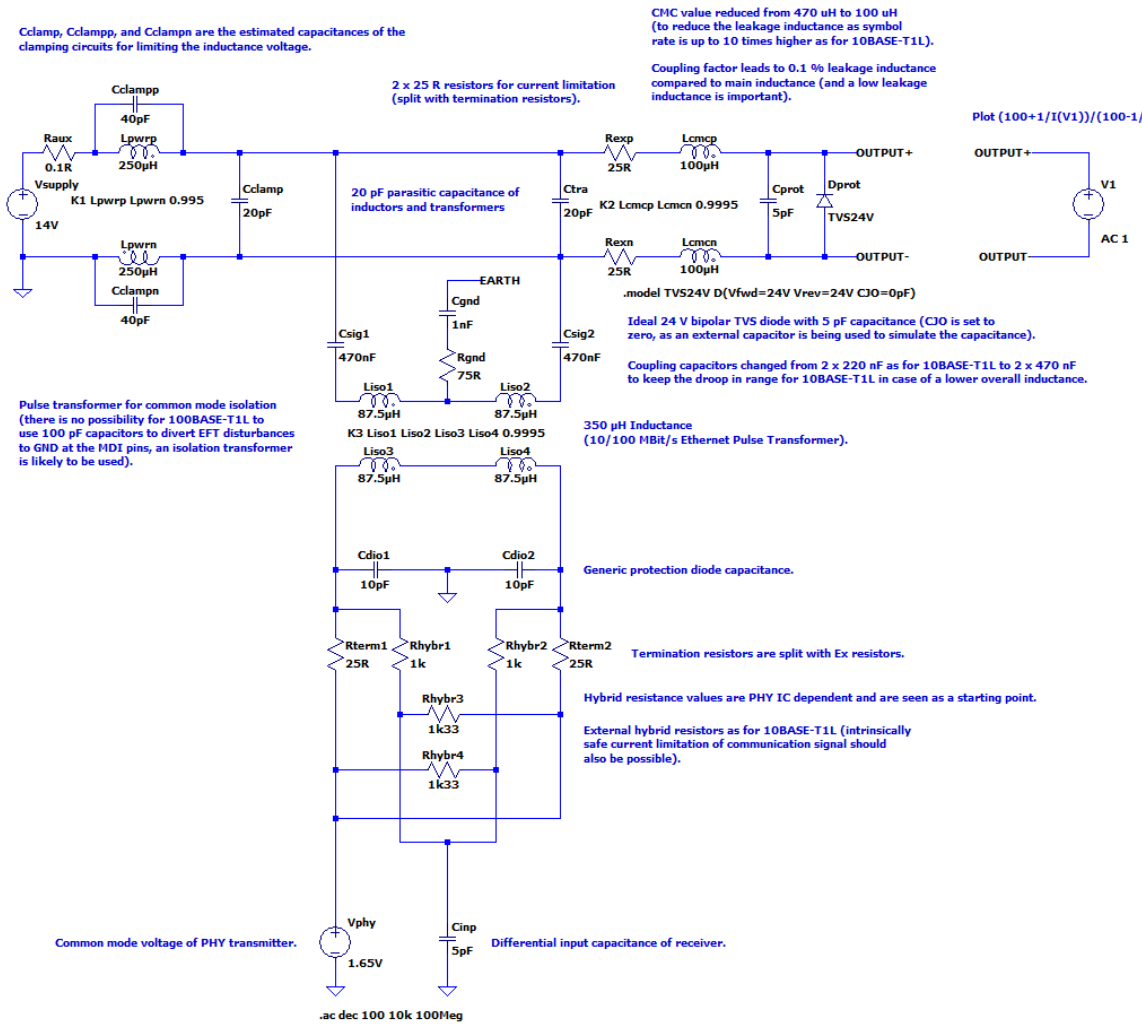
10/100BASE-T1L MDI (Switch Side, Intrinsically Safe)

Sugggested differential inductance of power feeding inductor is 1000 uH, which in combination with the 350 uH transformer inductance leads to 259 uH.

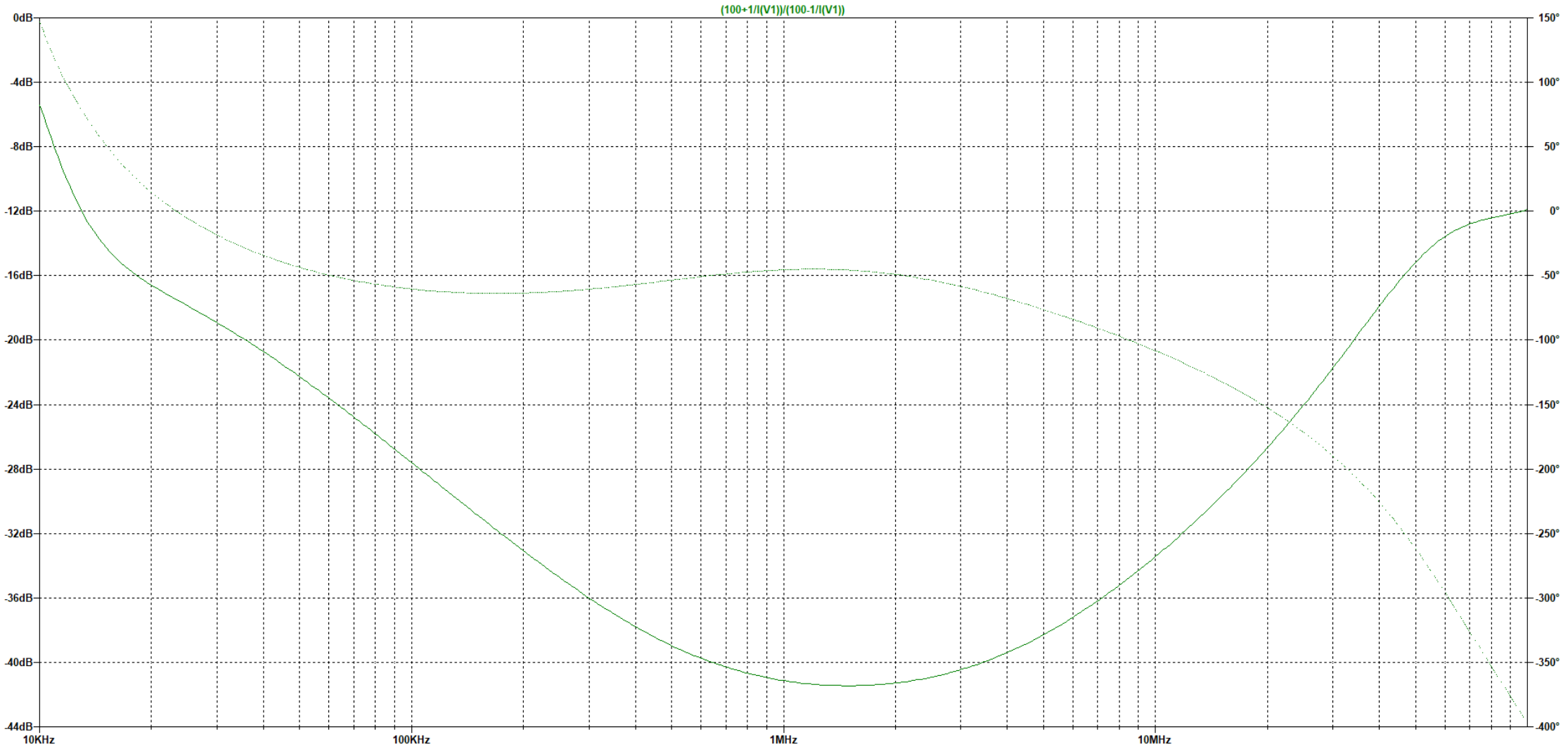
This is about 50 % of the minimum differential inductance according to the Ethernet-APL specification. As this circuit may be used for the trunk and no clamping is necessary, for a combined 10/100 MBit/s specification, the Ethernet-APL specification might be changed to allow a slightly higher droop level for 10BASE-T1L on the trunk.

Coupling factor leads to 1 % leakage inductance compared to main inductance (not critical for the power coupling inductor but looser coupling reduces capacitance between the windings).

Capacitance for inductances (Ctra) has been increased from 10 pF to 20 pF (compared to the 100BASE-T1L only MDI), might need additional measures to reduce the inductance of the power coupling transformer.



10/100BASE-T1L MDI (Switch Side, Intrinsically Safe) RL



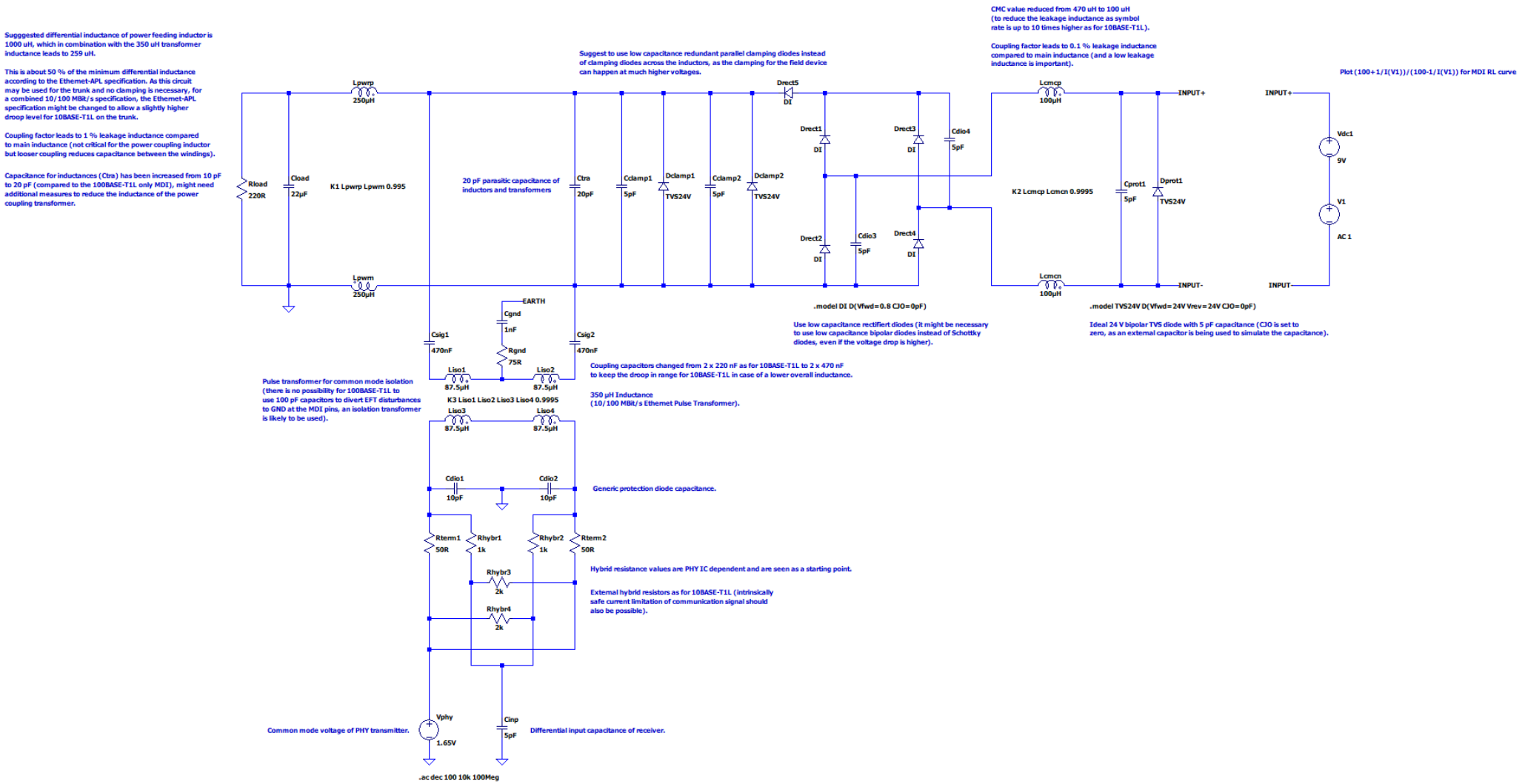
10/100BASE-T1L MDI (Switch Side, Intrinsically Safe)

- Needs to be compatible to 100BASE-T1L and 10BASE-T1L.
- Needs to be compatible to Ethernet-APL (depending on the additional signal isolation transformer there might be a little higher droop, which is partly compensated by using larger signal coupling capacitors).

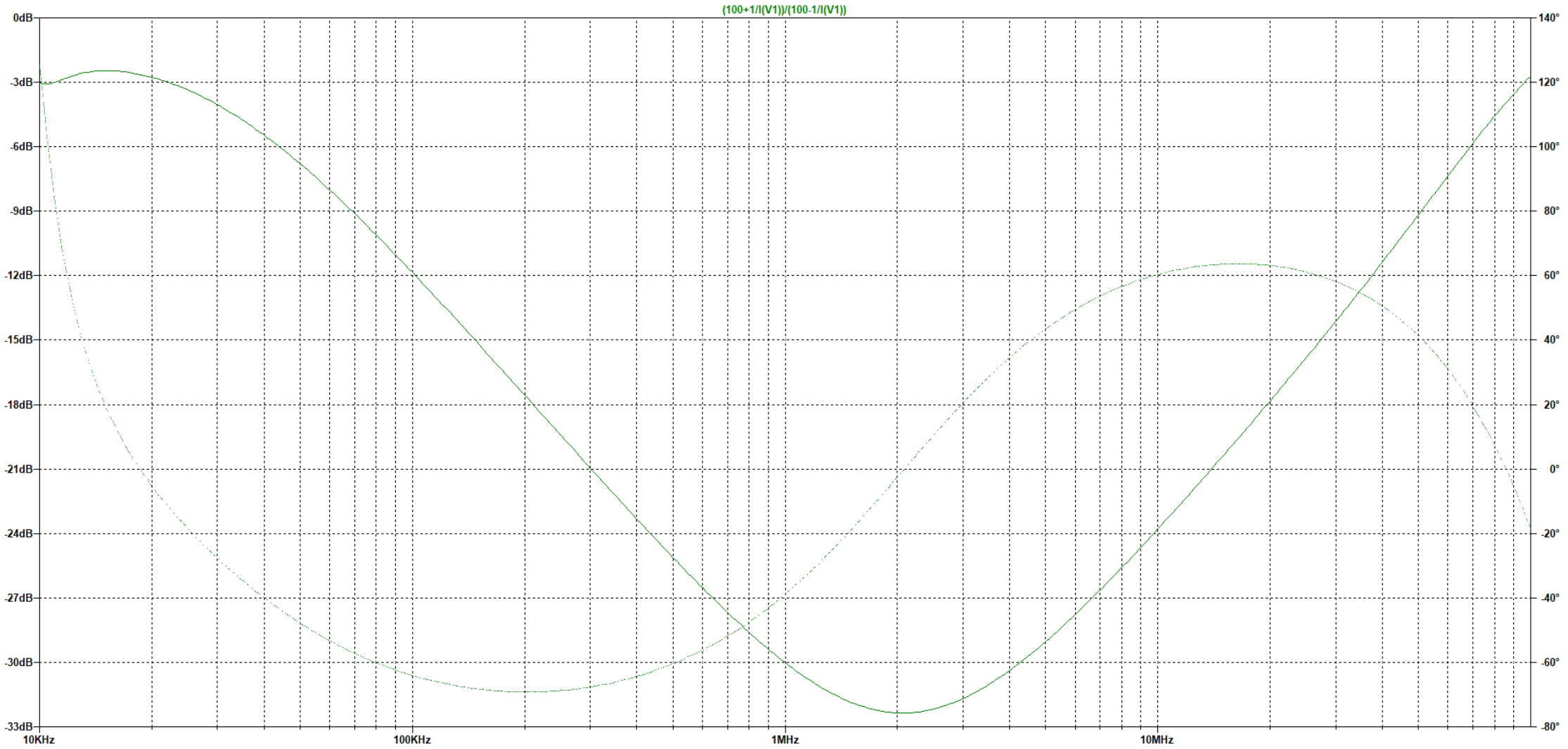
- Suggested typical circuit parameters for 10/100BASE-T1L MDI circuit:

  - *Power coupling inductance: 1000 uH (250 uH per winding)*
  - *Signal coupling transformer: 350 uH (standard 10/100 Mbit/s single pair Ethernet-Pulse transformer), leakage inductance 350 nH*
  - *Common mode choke: 100 uH inductance per winding, leakage inductance 100 nH*
  - *Signal coupling capacitors: 470 nF (in each line on primary side of transformer)*
  - *Parasitic capacitance for transformers: 20 pF (doubled compared to 100BASE-T1L only MDI, needs feedback from component manufacturers, what is possible)*
  - *Clamping diodes: 40 pF across each inductor winding and 20 pF across the signal lines (to prevent negative voltages)*
  - *25 Ω intrinsically safe current limitation resistance in each line (might slightly differ depending on implementation for resistive Ex ia current limitation, but might also go to zero in case of an electronic limitation circuit)*
  - *25 Ω (or more) remaining termination impedance in each signal line*
  - *Low capacitance ESD/Surge protection: 5 pF*
  - *External hybrid resistors for PHY IC*

10/100BASE-T1L MDI (Field Device Side, Intrinsically Safe)



10/100BASE-T1L MDI (Field Dev. Side, Intrinsically Safe) RL



10/100BASE-T1L MDI (Field Device Side, Intrinsically Safe)

- Needs to be compatible to 100BASE-T1L and 10BASE-T1L.
- Needs to be compatible to Ethernet-APL (depending on the additional signal isolation transformer there might be a little higher droop, which is partly compensated by using larger signal coupling capacitors).

- Suggested typical circuit parameters for 10/100BASE-T1L MDI circuit:

  - *Power coupling inductance: 1000 uH (250 uH per winding)*
  - *Signal coupling transformer: 350 uH (standard 10/100 Mbit/s single pair Ethernet-Pulse transformer), leakage inductance 350 nH*
  - *Common mode choke: 100 uH inductance per winding, leakage inductance 100 nH*
  - *Signal coupling capacitors: 470 nF (in each line on primary side of transformer)*
  - *Parasitic capacitance for transformers: 20 pF (doubled compared to 100BASE-T1L only MDI, needs to be checked with component manufacturers, what is possible)*
  - *Clamping diodes: use redundant (2 x 5 pF) low capacitance parallel clamping circuit (TVS diodes), as clamping only needs to protect the rectifier and thus allows much higher clamping voltage than for the switch port)*
  - *Rectifier diodes: use low capacitance diodes (e.g. 5 pF each), might omit the use of Schottky diodes and need the use for higher voltage drop bipolar diodes*
  - *50 Ω termination resistance in each signal line*
  - *Low capacitance ESD/Surge protection: 5 pF*
  - *External hybrid resistors for PHY IC*

Summary

- Going from 10BASE-T1L to 100BASE-T1L increases significantly the requirements for the MDI circuit.
  - *The symmetric 100 pF capacitors to ground close to the MDI connector used in 10BASE-T1L (providing a path for the EFT disturbances to ground) cannot be used anymore, as they provide a too low MDI impedance for the higher frequency range of 100BASE-T1L.*
  - *Thus to improve the EMC behavior likely a transformer coupling of the communication signal is necessary (similar as suggested for the unshielded version of 10BASE-T1L).*
  - *This additional transformer reduces the overall inductance within the system and also adds additional leakage inductance in the signal path, which needs to be minimized.*

- Additionally the clamping and rectifier circuits, needed for a 10/100 Mbit/s intrinsically safe MDI, add a significant capacitance to the MDI, which leads to higher reflections (worse MDI RL) and efforts must be taken to minimize this capacitance.
  - *Comparing the 100BASE-T1L MDI with a 10BASE-T1L MDI the "relative" capacitance value is higher, thus a careful design of the PSD mask, which requires a higher reduction of the transmit power above Nyquist frequency compared to the PSD mask for 10BASE-T1L might be necessary.*
  - *It would be good to get input from others, who are interested in intrinsically safe ports, about further data of the intended protection circuits.*

- The leakage inductance of the common mode choke and signal isolation transformer is crucial for 100BASE-T1L.
  - *Assuming an up to 10 times higher symbol rate, the leakage inductance needs to be much lower for 100BASE-T1L (for 10BASE-T1L up to about 1 uH is working well).*
  - *For a 10/100BASE-T1L combined port thus it is likely necessary to reduce the main inductance of the CMC.*
  - *A standard 10/100 Mbit/s Ethernet pulse transformer might be suitable for signal isolation, as these transformers are optimized for small leakage inductance.*

Thank you!