# DTE Power via MDI task Force.

## AC disconnect detection ad-hoc

Rev 001

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All the files containing the work of the ad hoc group located at:

http://grouper.ieee.org/groups/802/3/af/public/may02/index.html

(May 2002, 802.3af site area)

# 1. Scope of work

To demonstrate technical and economical feasibility of PSE based ac disconnect detection and determined if there is impact on previous functions in the draft.

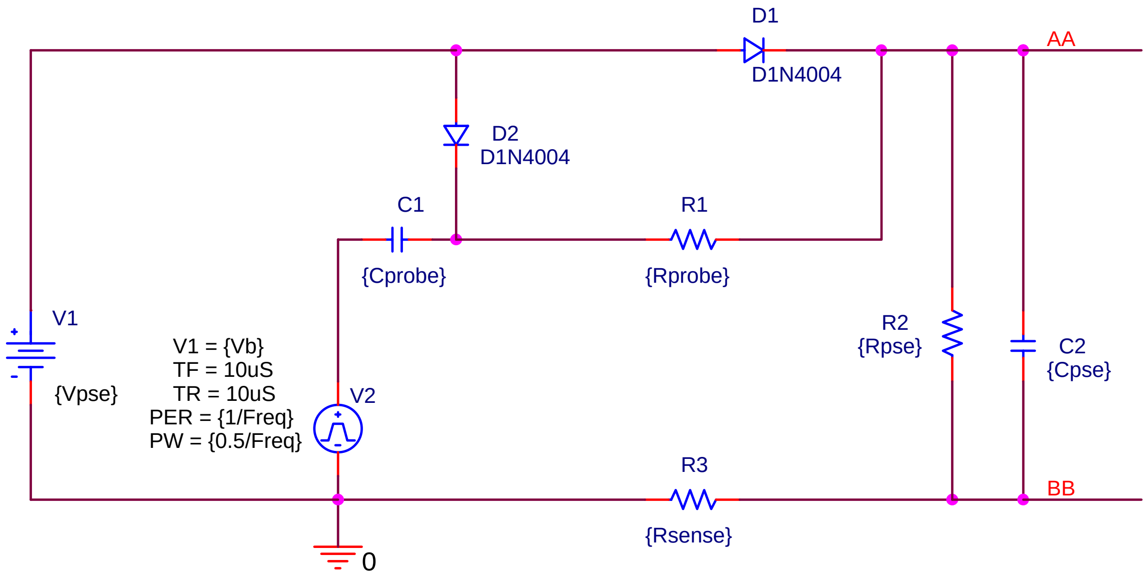
# 2. Tests List/ A.I (done)

| Item | Test Description | Owner | Status | Ends By |
|---|---|---|---|---|
| 1 | Test Setup Circuits and general requirements | | | |
| 1.1 | Send over the reflector to ad-hoc members the standard circuit for all testing | Yair, Dave, Thong | Done | |
| 1.2 | To prepare a specifications for ac disconnect to be used later in the spec or in test setup definitions | Yair | Initial version Done | April 30, 2002 |
| 1.3 | Tests will done in order to confirm Table 12 by checking min/max parameters | All | | April 30, 2002 |
| 2 | Sensitivity Analysis, Setting Parameters Range | | | |
| 2.1 | To define the pulse spectrum of the ac signal<br>(Resources: Simulations, single port) | Yair | Done | April 30, 2002 |
| 2.2 | Effect on feedback loop of SMPS<br>(Resources: 1 port, Simulations) | Yair | Done | April 30, 2002 |
| 2.3 | To analyze the PD input ac impedance without DC current (Resources: Simulations, confirm with 2-3 phones, single port)<br>Zac max over a freq band and the dc bias it is tested at, we need this with 37v-57v spec This should take into account the min/max L, C per table 12. | Yair, Dave,Fred | Done | April 30, 2002 |
| 2.4 | To set the optimum probing frequency range (narrow the range)<br>To perform sensitivity Analysis for the probing frequency and define the tolerance required (Resources: Simulations, confirm with 2-3 phones, single port ) | Yair, Dave,Fred | Done | April 30, 2002 |
| 3 | Audio Interference tests | | | |
| 3.1 | Audio interference with existing phones, LCD | Roger, Scott | Done | April 30, 2002 |
| 3.2 | –Immunity tests - check specifically at line frequency<br>(Resources: Phone and/or high power PD, Single port PSE) | Yair, Roger | Done | April 30, 2002 |
| 3.3 | Sensitivity to line frequency and ringing interference with CAT 3 cable (Use florescent turn on/turn off to test sensitivity) (Resources: Phones, Ring generators, 1 ports PSE min) | Yair | Done | April 30, 2002 |
| 3.4 | How port-to-port cross regulation, cross-talk affected by the ac circuit.<br>(Resources: Lab tests, 3 port min look at the centered one) | Yair | Done | April 30, 2002 |
| 4 | RF interference | | | |
| 4.1 | RF interference<br>(Resources: Phone, Single port PSE) | Roger, Scott | Done | April 30, 2002 |
| 4.2 | –EFT test<br>(Resources: 2 port tests) | Roger | Done | April 30, 2002 |
| 4.3 | EN55024<br>Need to specify the relevant tests<br>(Resources: 2 port tests) | Scott | Done | April 30, 2002 |
| 4.4 | EN55022/CISPR22/FCC NB30/MPT 1570<br>Need to specify the relevant tests<br>(Resources: 4 port tests) | Roger, Yair | Done | April 30, 2002 |
| 5 | Effects on other 802.3af functions | | | |
| 5.1 | Test how over-current affected by the ac disconnect pulses<br>(Resources: Simulations, Lab tests, single port) | Yair, Dave | Done | April 30, 2002 |
| 5.2 | Effects of PD load transient.<br>(Resources: Lab test, single port) | Yair | Done | April 30, 2002 |
| 5.3 | Test for PSE output voltage step<br>Resources: Simulations, single port ) | Dave, Yair, Thong | Done | April 30, 2002 |
| 5.4 | To supply PD DC/DC Vout/Vin Ripple rejection ration as function of frequency | Yair | Done | April 30, 2002 |
| 6 | Other tests | | | |
| 6.1 | Evaluate the impact of two Midspan PSE's with ac disconnect scheme. | Dan Dove | working | April 30, 2002 |
| 6.2 | Roger tasks for 1000BT (Roger to pass to Broadcom?) | Roger | Done | April 30, 2002 |
| 6.3 | Checking data impairment when PSE is trying periodically to detect another PSE. If the results will be OK, than they are OK for ac disconnect too.<br>Parameters to consider: Frequency, Tr/Tf, Amplitude | Yair, Roger | Done | April 30, 2002 |
| 6.4 | Economical feasibility study | All | Done | April 30, 2002 |

# Item 1.1- Test Setup Circuits and general requirements

<u>Circuit # 1.</u>

Description: The hardware to be used to inject the ac disconnect probing signal across PSE port. The circuit does not include the sensing hardware, which is implementation specific.




PARAMETERS:

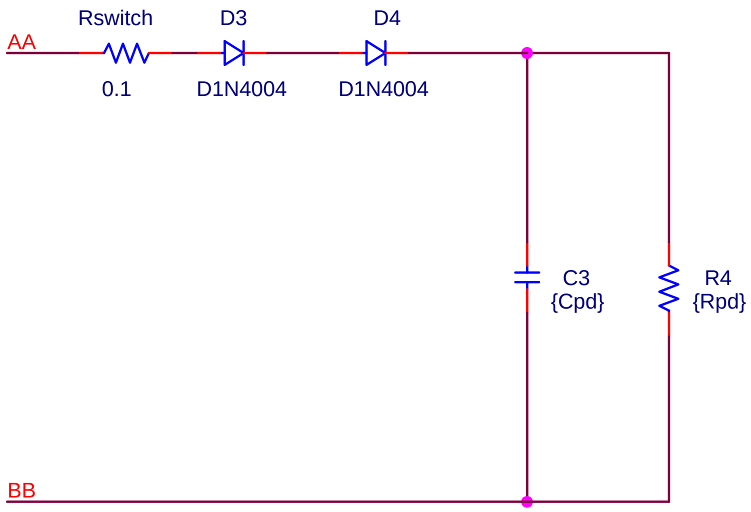
| | |
|---|---|
| Vb = 3.3 | See suggested specifications |
| Rpse = 200k | Implementation specific |
| Cpse = 0.52uF | Can be from zero to 0.52uF |
| Rprobe = 6.8K | See suggested specifications |
| Cprobe = 22uF | Implementation specific |
| Rsense = 2 | Implementation specific |
| Freq = 77 | See suggested specifications |
| Vpse = 50 | Implementation specific |

D1,D2 can be any equivalent diode that's meets port voltage/current stress.

Circuit # 2.

Description: The hardware to be used to emulate the PD during normal powering mode. (Normal powering mode is the mode, which the PD is receiving power after successful detection and classification phase.

The circuit contains a switch at its input to be used for PD disconnection emulations.




PARAMETERS:

Cpd = 5uF Can vary from 5uF and up.

Rpd = 5K Can vary from Vport^2/12.95 to 5.7K

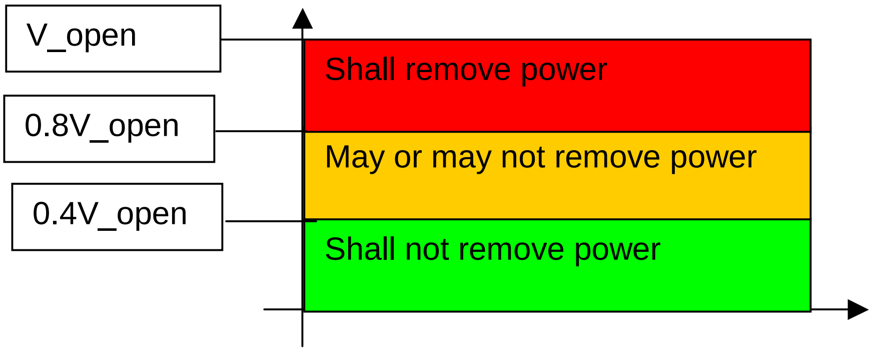
Rswitch represent phisical switch for simulation of connected or not connected PD

D3,D4 can be any equivalent diode that's meets port voltage/current stress.

# Item 1.2 - AC Disconnect black-box suggested specifications

| PSE side | | | | | | |
|---|---|---|---|---|---|---|
| # | Parameter | Sym | Unit | Min | Max | Notes |
| 1 | Pulse parameters | | | | | |
| 1.1 | Port disconnect probing ac voltage when PD is disconnected | V_open | Vpp | Op1- 1.5<br>Op2- 2.5 | 4.4 | 1, 33 |
| 1.2 | AC probing signal frequency | Fp | Hz | 10 | 500 | 35 |
| 1.3 | AC probing signal pulse width | pw | ms | 1 | | 34 |
| 1.4 | AC probing signal slew rate | SR | V/Us | | 0.1 | 7 |
| 2 | Ac source output impedance | | | | | |
| 2.1 | AC probing signal source output resistance | R_sac | KΩ | 5 | | 3 |
| 2.2 | PSE port impedance during AC disconnect function or during resistor detection when measured form the link to the PSE port. | R_rev | KΩ | 70 | | 4 |
| 3 | PSE port voltage during ac disconnect detection | | | | | |
| 3.1 | Port ac voltage when PD is Connected | | Vpp | | 0.5 | 2 |
| 3.2 | Port dc voltage when PD is disconnected | Vport | Vp | 44 | 60 | 1 |
| 4 | Disconnect detection thresholds | | | | | |
| 4.1 | "Shall not remove power from the port" | | Vpp | | 0.4V_open | 5 |
| 4.2 | "May or May not Remove power" | | Vpp | 0.4V_open | 0.8V_open | 5,36 |
| 4.3 | "Shall remove power from the port" | | | 0.8V_open | | 5 |
| 4.2 | Disconnect detection time | Tpmdo1 | ms | 300 | 400 | 6 |
| | | | | | | |
| PD side | | | | | | |
| | No additional definitions required | | | | | |
| | | | | | | |
| | | | | | | |

| Notes | |
|---|---|
| 1 | Safety standards defined a DC voltage as a voltage that has 10% max ripple content. To meet 60V max for SELV requirements the ac contents must not exceed 10% therefore 10% of 44Vdc is 4.4Vpp max.<br>The 3V min was derived from the following reasons:<br>a- If PSE and PD generate low frequency noise OF 0.5Vpp each, in phase that the total could be 1Vpp.<br>b- The PD specified with 2V offset (2 diodes in series at low temperature). In order to forward bias them without the PSE DC bias, we need 2V min.<br>The worst case from the above is 2V min. Having 0.5Vpp min margin for the detection action, adds up to 2.5Vpp |
| 2 | 0.5Vpp as specified in table 5, draft 3. |
| 3 | To set a minimum resistance in order to limit the ac current at short circuit condition |
| 4 | To be equivalent to Resistor Detection output source impedance, in order to limit DC current to ground from external DC source connected to the port. Meant to keep compatibility to Resistor detection interface. |
| 5 | Initial value. To be optimized. |
| 6 | As specified by TPMDO at table 5, draft 3. |
| 7 | According to A.I. 2.1 |
| 8 | At PD input voltage from 37V to 57V |
| 9 | To get stabilization due to PD load changes, PSE port voltage transients etc. |
| 10 | Tested. Non-issue. Should be designed according to the IEEE802.3af spec. |
| 33 | Op1: Option 1, which is technically good enough and due to the fact that it is minimum value, it is allow supporting op2 and yet leave the flexibility to the designer.<br>Op2: Option 2, which is technically OK and force to be OK from the "other issue"<br>TO BE DISCUSSED WITH THE GROUP |
| 34 | Final work shows that min pulse width is the important parameter and along with frequency it sets the duty cycle so no need to defined duty cycle. The pulse width is depend on PSE time constant when PD is disconnected. |
| 35 | Frequency range was set according the lab tests and theoretical analysis with large margin and keeping enough flexibility to the designer. Max 500Hz was set to limit the signal spectrum. 10Hz limit was set to allow 50Hz with ±30% tolerance + margin.<br>In addition, 20Hz value can be practical if we want 2 pulses minimum within 100ms to support the 300ms min 400ms max disconnect time. |
| 36 | To be OK with the "other" issue threshold should be located above the value of actual Vac_close (PD is connected) with out DC bias. This value is depend on PSE circuit parameters and frequency. |



# Item 1.3- Confirmation of table 12 with ac-disconnect spec.

All the following A.I. results confirm table 12 parameters as it is defined in draft 3 of IEEE802.3af.

For more details see all A.I. reports include in this document.

# Item 2 - Sensitivity Analysis, Setting Parameters Range

## Item 2.1 – defining the pulse spectrum of the ac disconnect probing signal

The pulse parameters of the ac disconnect signal has been specified:

See item 1.2 above for pulse parameters.

For more details see the following documents:

> See document “AC Disconnect probing signal spectrum analysis - AD-HOC item 2_1” For pulse parameter calculations.
> See document “Optimizing disconnect detection ac probing signal Detection AD-HOC item 2_4 rev 001”

See document “When PSE is periodically detecting A_I 6_3” that confirms the selected pulse spectrum with lab tests.

## Item 2.2 - Effect on feedback loop of SMPS

Based on the work of item 5.4, it is obvious that there is no effect on the ability of PD power supply to handle 10-20mV ac up to 500Hz when PD is connected.
For more details see “PD power supply vout to vin noise rejection ratio - AD-HOC item 5_4” document.

## Item 2.3 – Analyzing PD ac input impedance.

PD input impedance has been analyzed within the limits of table 12.
The main conclusions were:

- No need to change table 12 in IEEE802.3af draft.
- AC signal across the port is immune to external noise.
- Verified design equations suggested for PD input impedance in order to simplify and optimize PSE sc disconnect circuit parameters.
- Lab tests, simulations and equations support the above conclusions

For more details see “PD Input impedance - sensitivity analysis AD-HOC  item 2_3” document

## Item 2.4 – To set the optimum probing signal frequency and tolerance.

The purpose of this action item was to check if the frequency range can be narrowed or if there are concerns regarding the detected ac signal as function of frequency variations.

The conclusions of this work item were:

- Vac_close and Vac_open are not sensitive to frequency change with in wide range +/-30% and more (less than 50mVpp) for a given set of PSE circuit's parameter values and frequency.
- Vac_close without DC bias is kept within narrow limits as function of PD load changes (250mVpp max)
- Threshold points should be set by PSE vendor according to his implementation and Vac_open value, probing frequency, ac source impedance etc.
- Successful Disconnect Detection has been achieved with 3 different PDs
- Good parameters tracking has been demonstrated for 3 different PDs

Bottom line:

- Sensitivity of ac probing voltage to its frequency is low enough to allow low cost implementation.
    - Tested for 50Hz to 150Hz span for a given set of PSE circuit's parameter values.
- Optimum nominal frequency should be selected according to PSE circuit parameters only.
- 500Hz should be absolute max value.

<u>For more details see: "Optimizing disconnect detection ac probing signal Detection AD HOC item 2_4 rev 001" document</u>

# Item 3 - Audio Interference tests

## Item 3.1 Audio Interference tests

The purpose of this A.I. was to test the effect of audio noise and other effects on PD performance due to ac disconnect detection signal and to confirms theoretical and simulated predictions.

The conclusions were:

No issue for ac disconnect probing signal at frequencies up to 500Hz
No issue for PSE power supply output ripple at 500mV/500Hz

Other report received with similar conclusion:

Three different sets tested.

Conditions:

1. AC disconnect probing signal injected using circuit #1 of Item 1.1.
2. Signal pairs (1,2 and 3,6) and spare pairs (4,5 and 7,8) tested.
3. Zero loops.

Tests and Results:

1. Routine Functional tests - all passed.
2. LCD visual inspection - no noticeable effects.
3. Audio subjective test - no noticeable effects.
4. Audio spectral analysis - no noticeable effects.

For more details see the following documents:
“Audio Interference AD HOC item 3_1”
“Described in “PD power supply Vout to Vin noise rejection ratio - AD HOC item 5_4”

## Items 3.2, 3.3 Immunity tests for line frequency and ringing signals.

The objective of these A.I.s were to check the following:

Sensitivity of Vac_close to low-frequency electrical field
Sensitivity of Vac_close to Telecom Ringing frequency
Testing the immunity of the ac-disconnect detection concept to false disconnect detection

The conclusions of these tests were:

With the suggested spec parameters:

Very low Sensitivity of Vac_close to low-frequency electrical field (24mVpp max for 240Vrms over 100m cable)
Very low Sensitivity of Vac_close to Ringing voltages/Frequency (24mVpp max for 240Vrms over 100m cable)
AC-Disconnect detection concept is not generating false disconnect detection

For more details see “Immunity tests AD HOC item 3_2 and 3_3” document.

## Item 3.4 Cross Talk as function of ac disconnect signal.

Objectives

To verify that a port located between two other ports is not affected by ac disconnect signal.

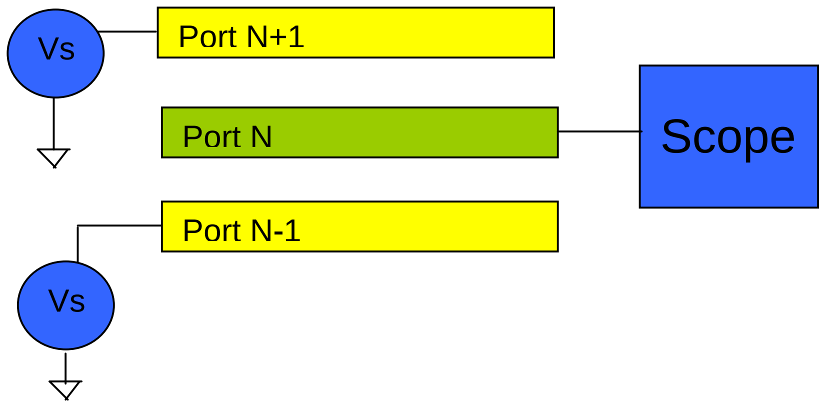
To test the following conditions:

- Port N is ON and ports N+1, N-1 are connected to Vs
- Port N is OFF and ports N+1, N-1 are connected to Vs

Test setup and conditions

AC signal: 60Vpp, square wave 50% duty cycle, tr=tf=250us.
AC signal was connected to the port through 5K resistors.
PSE port capacitance=0uf
Cable length: 0.1m to 140m
Load at the end of the cable: 0, 100 Ohm, 5K, 70K.

Test results: Can't be measured due too very low signal below noise level.




Conclusion:
Cross Talk is not an issue under the above conditions with very large margin.

## Item 3.4.1 Cross Regulation effects on ac disconnect signal.

The same results has been received with DC disconnect method. No effect on detected ac signal.

Conclusion:
All timing parameters as defined by Table 12 Draft 3, applicable to ac disconnect method. (Disconnect time 400ms max. Not remove power if interruptions are detected for less than 300ms.)

See also related topic A.I. 5.2 and 5.3

# Item 4- RF interference

It was demonstrated that the ac disconnect detection concept is immune to low frequency field.

High frequency field is not an issue due to the fact that it is out of ac disconnect signal band.

The effective impedance at the high frequency starting at 150Khz is much lower than the ac impedance at the low frequency field.

The following tests were considered:

| Standard | Subject | Relevancy for ac disconnect concept | Reasoning |
|---|---|---|---|
| EN55024 | Addressed the following list of tests | | |
| IEC 61000-4-2 | Electrostatic discharge | NA | Out of frequency band |
| IEC 61000-4-3 | Immunity to radiated electromagnetic field | NA | Out of frequency band |
| IEC 61000-4-4 | Immunity to EFT | NA | Out of frequency band |
| | | | |
| IEC 61000-4-6 | Immunity to conducted electromagnetic field | NA | Out of frequency band |
| IEC 61000-4-8 | Immunity to power low frequency modulated on electromagnetic field | NA | -Relevant to specific devices as listed in the standard.<br>- Out of frequency band |
| IEC 61000-4-11 | Immunity to voltage dips short interrupts etc. | Applicable only at ac signal band. | See other tests in this document that covers this requirement. |
| CISPR 22 | Radio disturbances | NA | Out of frequency band |

The above tests were conducted for the Resistor Detection concept and for DC disconnect method in which lower thresholds voltages are required and all tests passed successfully.

Conclusion:

Immunity to EMI or RF disturbances is not an issue.

# Item 5-Effects on other 802.3af functions

## 5.1 – "AC disconnect" Effect on current sensing

Objective:
To check the effect of AC Disconnect signal on current sense circuits Overload and Underload functions as specified by IEEE802.3af Draft 3, Table 12.

Test Setup

1. AC disconnects circuits integrated into single port PSE. The PSE was loaded with a PD with minimum and maximum load.

2. Verifying that the current sensing functions are not affected by the ac disconnect signal.

Prediction:

AC signal is specified to be 4.4Vpp through 5K minimum resistor.
Max current contributed by the ac signal is 4.4Vpp/5K <1mA.

% of measured current:

Min load: 1/10 ==> 10%
Max load: 1/350 ==> 0.3%

Test results:

| Load / Measure | Minimum load | Maximum load |
|---|---|---|
| Results | Threshold point was not changed | Threshold point was not changed |

Conclusion:

Current sensing circuits and Over-load / Under-load functions are not affected by the presence of AC disconnect probing signal of 4.4Vpp.
Sensitivity of the above functions is implementation specific and can easily achieved.

Confirmed by other report as well.

## Item 5.2, 5.3 – Effects of PD load and PSE voltage transients.

The objectives of these A.I. were to test for:

Immunity to load transients
Immunity to PSE voltage transients
Sensitivity of Vac_close to load changes
Sensitivity of Vac_close to PSE voltage transients

Summary

Stabilization time is similar to the results received in DC disconnect concept.
Timing vs. min/max load and
Timing vs. min/max capacitance and min load values as specified in table 12, are still valid.
Disconnect time =400ms max
Shall not remove power if Vac_open>Vth for < 300ms

For more information see:
"Immunity to load and PSE voltage transients AD HOC item 5_2 and 5_3" document.

## Item 5.4- PD DC/DC Vout/Vin Ripple rejection ratio as function of frequency.

Objective:
To check the following:

1. How the ac signal across the port will be attenuated by the PD power supply.
2. We spec the PSE port for 500mVpp at normal powering mode. Is it OK in terms of audio interference to the sensitive hardware in the PD?

Summary

- Better than 30dB output/input rejection
- Typical 40-50dB rejection for 48V to 5V DC/DC converter.
- With 10-20mV ac disconnect input signals, No audio interference is expected.

For more details test results verifications, see the following documents:

1. PD power supply vout to vin noise rejection ratio - AD HOC item 5_4
2. Audio Interference AD HOC item 3_1

# Item 6- Other Tests

## Item 6.1- Evaluate the impact of Midspan with two PSE's connected to the same link. The 1st link section A is separated for the 2nd section B by isolating capacitor.

Will be presented by Dan Dove at the meeting.

## Item 6.2- Demonstration on 1G system

The purpose of this test is to confirm that ac disconnect signals are not affecting 10/100/1000MB/s

<u>The test results confirmed the following conclusions:</u>

AC disconnect signal as specified in the test setup is not affecting 1G system.

Resistor detection with 30Vp ac signal, continuous, periodic across the port is not affecting the system performance as per A.I. 6.3

<u>For more info see the following documents:</u>

1. AC disconnect detection- Demonstration on 1G system ad hoc item 6_2
2. When PSE is periodically detecting A_I 6_3

## Item 6.3 - Testing data when PSE is periodically detecting other PSE. Probing signal spectrum measurements and more.

Test objective:

Checking data impairment when PSE is trying periodically to detect another PSE. If the results will be OK, than they are OK for ac disconnect too.

Parameters to consider:
Frequency, Tr/Tf, Amplitude

To determine the signal spectrum limitations for zero data errors at the following operating modes:

AC disconnect detection probing signal
Resistor Detection probing signal
To confirm the calculated results as analyzed in A.I. 2.1.

Background:

In some implementations AC disconnect signal required to be applied to the port most of the time.
Resistor Detection uses min 2-point measurements, which is very low frequency ac signal constrained by other circuit parameters.

Resistor detection may run continuously generating up to 30Vpp low frequency signal across the port PSE is trying to detect other PSE/Non-compliant PD

The target of the following work is to support the theoretical analysis conclusions that implies that no data degradation is expected and we have huge margin.

Conclusions

Data integrity is kept, with large margin for the following conditions:
- 69Vpp/1MHz through 5K min
- Any practical cable length (1m to 120m tested)
- Loads from zero to 75K
- For dual voltage source or single voltage source

Suggested probing signal spectrum:
- Amplitude: 30V max as defined by IEEE802.3af
- Rise/Fall time: currently 10us specified, meets data error free requirements
  - o Changing to dv/dt<0.1V/us for no EMI.
- Frequency: up to 500Hz
- Periodically detecting (Signature or Disconnect) with the suggested probing signal spectrum is not generating data errors nor EMI.
- Suggested probing signal spectrum meets IEEE802.3 limits with huge margins

For more information see: “When PSE is periodically detecting A_I 6_3” document

# Item 6.4 - Economical feasibility

PD side:
No effect on PD cost.
----------------------------------------
PSE side:
Function of the approach taken:

Option 1:
Disconnect circuit is implemented per port.

Option 2:
Using part of the circuit to support few ports in parallel
----------------------------------------

Option 1 detail:
Signal source: a single pin from controller: 1-2 cents
Diode type 1: 5 cents
Diode type 2: 2 cents
Capacitor, Aluminum 1u – 10u/100V: 2-3 cents
Resistor: 1cent
Sensing circuit: 6 cents if it is additional part to the port, 0 cents if the port voltage is already monitored to support other functions.

Total: 10 cents to 18 cents as function of implementation

Option 2 details:

Number of ports in the group=N

For a group:
Signal source: a single pin from controller: 1-2 cents
Driver: 5 cents
Diode type 2: 2 cents
Capacitor, Aluminum 22 – 50u/100V: 4-5 cents

Total for a group: 14 cents

Per port:
Diode type 1: 5 cents
Resistor: 1cent
Sensing circuit: 6 cents if it is additional part to the port, 0 cents if the port voltage is already monitored to support other functions.
Total: 6 cents to 12 cents as function of implementation

Total per port: (6+14/N) to (12+14/N).
For multi port system: N>>1 ==> cost per port 6 to 12 cents max.