Power Matters

IEEE802.3bt 4-Pair Power over Ethernet Task Force

Updating RDSON min and max in Table G1 Adhoc data base

(updated presentation data from November 2014)

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Rev005

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Objectives

- This is a short version of November IEEE meeting with more data for the below objectives that was accepted by the group. See http://www.ieee802.org/3/bt/public/nov14/darshan_07_1114.pdf
  - More MOSFETS data from different vendors were cheeked.
  - Addressing thermal effects
  - Table G1 was updated per group approval from November 2014.
- ----------
- Updating RDSON_MIN and RDSON_MAX values in Table G1 of End to End P2PRUNB adhoc data base.
  - RDSON is a parameter used in our unbalanced analysis and will be not be a requirement at IEEE standard.
- It will help us to reduce system P2PRUNB by introducing lower RDSON differences than initially assumed.

RDSON Current data in Table G1

#	Parameter	Data set 1	Data set 2
10	PSE output resistance	Rsense 0.25 RDSON_min=0.1 Ω RDSON_max=0.2 Ω	Rsense 0.25 RDSON_min=0.05 Ω RDSON_max=0.1 Ω

- Current data suggests 100% difference between max and min value
- See Complete existing data base table in Annex G1 and G2.

RDSON Suggested new data for Table G1

#	Parameter	Data set 1	Data set 2
10	PSE output resistance	Rsense 0.25 RDSON_max=0.1 Ω RDSON_min=0.7*RDSON_max	Rsense 0.25 RDSON_max=0.05 Ω RDSON_min=0.7*RDSON_max

- Based on:
  - Lab tests of Mosfets (See annex B1, B2)
  - Data sheet analysis (See annex C1, C2 and C3)
  - Other supportive tests not shown (with other MOSFETS and system unbalance lab tests)

Conclusions

- 14% maximum measured Rmax-Rmin from single P/N with 20 samples (Annex B1 and B2)
  - (This test alone is not sufficient to draw conclusions however with the addition of datasheets analysis and other supportive tests we can draw conclusions)

- Runb=30% maximum between several part numbers per their data sheets (Annex C1, C2)
  - Probability factors cause using lower than Rdiff_max. i.e. ~30% max
  - Datasheet min/max range > Measured Min/Max as expected.

- Summary
  - Existing data in Table G1 is too aggressive.
  - 30% maximum difference of Rmax-Rmin is more realistic worst case range.

Summary

- Propose to update Table G1 accordingly.
  - RDSON_min=0.7*RDSON_max for Table G1
    - E.g. Rdson max=0.1 Ω. RDSON_min=0.07 Ω
- Proposed change was accepted by the group on November IEEE meeting.
  - See meeting minutes

Thank You

Backup Slides

Annex B1: MOSFET RDSON Differences - Lab Tests

(all test at room temperature, all MOSFETS get the same case temperature)

Test conditions:

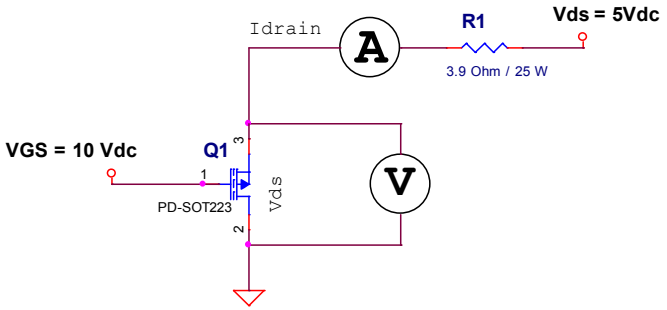
VGS= 10Vdc, VDS=5Vdc, Ambient Temp= 23° C

MosFET	Vds [mV]	Idrain [A]	$R_{DS(ON)}$ [mΩ]
1	265	1.125	235.556
2	235	1.142	205.779
3	245	1.131	216.622
4	239	1.136	210.387
5	242	1.128	214.539
6	234	1.138	205.624
7	232	1.132	204.947
8	242	1.131	213.970
9	246	1.133	217.123
10	242	1.134	213.404
11	245	1.131	216.622
12	261	1.128	231.383
13	251	1.12	224.107
14	246	1.132	217.314
15	250	1.128	221.631
16	246	1.132	217.314
17	253	1.132	223.498
18	263	1.128	233.156
19	254	1.131	224.580
20	242	1.132	213.781

Lab tests:

FQT7N10L

100V LOGIC N-Channel MOSFET

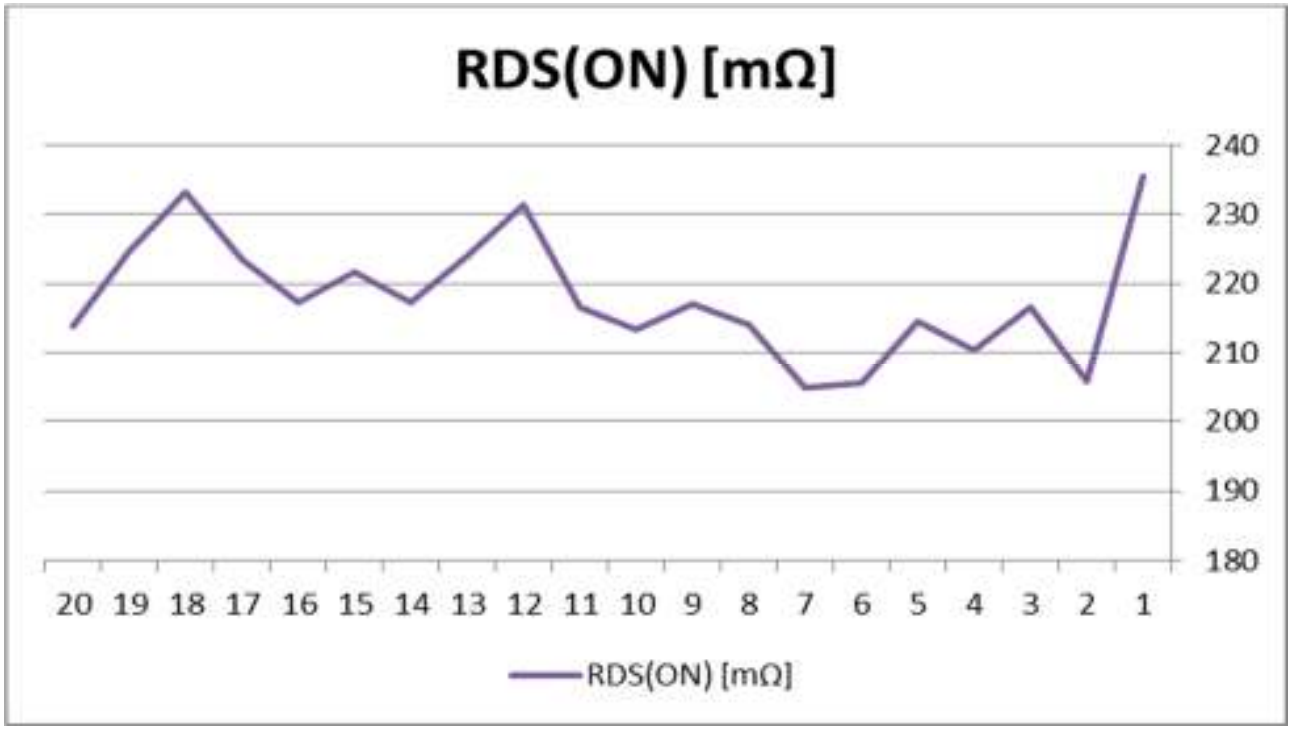


RDSON min [ohm]	205
RDSON max [ohm]	235.6
RDSON DIFF [ohm] (Rmax-Rmin)	30.6
RDSON unb (Rmax-Rmin)/(Rmax+Rmin)	**6.95%**
RDSON_Rdiff/Rtype	**13.9%**
Rmin/Rmax[%]	**87%**

Updating RDSON min and max in Table G1 Adhoc data base rev005. Yair Darshan , January 2015

Annex B2: MOSFET RDSON Differences - Lab Tests

(all test at room temperature, all MOSFETS get the same case temperature)



- **FQT7N10LTF**
- **RDSon variations at 23degC of 20 units sample.**
  - Similar results with other part numbers used for PoE applications

Annex C1:MOSFET RDSON Differences- Data Sheet Analysis

(Data is at room temperature. For temperature effect see annex C3)

- Checking 12 MOSFETS datasheet used in PoE. Only 5 are shown below.

P/N	Min[1]	Typ[2]	Max[2]	Runb[3]	Rdiff[%] [4]	Probability ➔0[5] Rmin/Rmax[%]	Probability ➔>0[6] Rtype/Rmax= Rmin/Rtyp[%]
A	0.12	0.14	0.16	14.29%	28.57%	75.00%	87.50%
B	0.2	0.275	0.35	27.27%	54.55%	57.14%	78.57%
C	0.22	0.3	0.38	26.67%	53.33%	57.89%	78.95%
D	0.088	0.124	0.16	29.03%	58.06%	**55.00%**	**77.50%**
E	0.074	0.092	0.11	19.57%	39.13%	67.27%	83.64%
Average				**23.36%**	**46.73%**	**62.46%**	**81.23%**
						Rmin=0.55*Rmax	**Rmin=0.77*Rmax**

Notes:

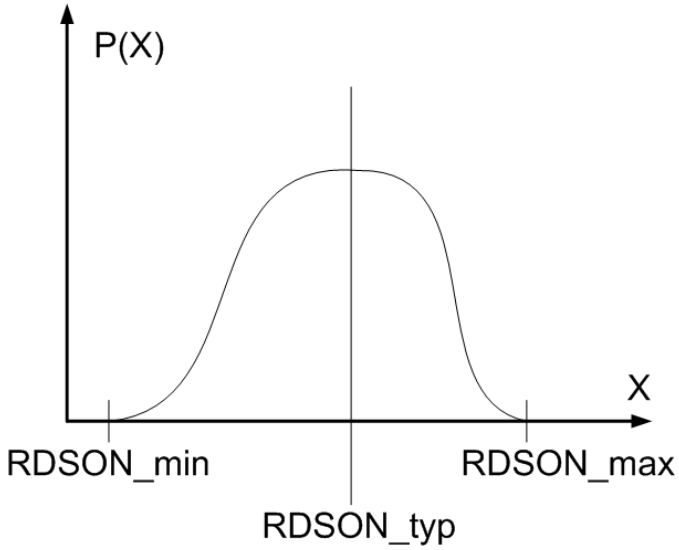
1. Calculated value from Typ, Max values
2. Data sheet values
3. Runb=(Max-Typ)/Type=(Max-Min)/(Max+Min)
4. Rdiff[%]=(Max-Min)/Typ=Rdiff[%pp]
5. The probability that Rmax and Rmin will be exist at the same port is close to zero. See annex C2.
6. The probability that Rdson will be at the range of Rmin, Rtype or Rtype Rmax is >0 and more realistic. As a result, RDSONmin=0.77*RDSONmax. Rounding it down to RDSONmin=0.7*RDSONmax for additional margin.

Annex C2:MOSFET RDSON Differences- Data Sheet Analysis

(Data is at room temperature. For temperature effect see annex C3)

- Rmin=0.7*Rmax was chosen to be more realistic choice (still worst case) based on the fact that the probability that for the same part number and vendor we will get RDSon_max and RDSON_min at the same port and at the same manufacturing time is close to zero (probability of ~10^-11)

- As a result, Rdiff=Rmax-Rmin per datasheet component characterization is lower than Rdiff_max e.g. 2sigma around the mean=~70% of 10^6 units.
  - Moreover, Rdson_diff is compensated by Rsense_diff (2% max), Transformer resistance (~8.3% max) and connectors (<25% max) which practically filters out Rmin area.



Annex C3:MOSFET RDSON Differences- Data Sheet Analysis (Addressing RDSON as function of temperature)

- The thermal coefficients (resistance vs. temperature) of Rsense, Transformer wire resistance, connectors, PCB traces and cables are better than RDSON thermal coefficient variations between MOSFETs.
- As a result, RDSon variations between Mosfets due to different RDSON thermal coefficients are compensated in part so net results is significantly lower than RDSON alone.
- In system level, we saw that thermal variation has small effect on PSE PI pair to pair resistance unbalance on negative pairs and even lower in positive pairs were only pure resistive elements are used with no silicon.
- There is available RDSON min/max variations vs temperature lab tests contribution done by MOSFET vendor and will be addressed in separate contribution.

Existing worst Case Data Base Table G1

Group response, IEEE meeting November 2014 : To accept Item 10 change

#	Parameter	Data set 1	Data set 2
1	Cordage resistivity[1]	0.14Ω/m	
		0.09262Ω/m for AWG#24 for worst case analysis	
2	Horizontal cable resistivity option 1[2] option 2[3]	11.7Ω/100m=(12.5Ω - 4*0.2Ω) / 100m which is the maximum resistance when tested with maximum Iport.	7.4Ω/100m (CAT6A, AWG23) This is to give us maximum P2PRunb
3		0.098Ω/m. Maximum value per TIA etc. Can't be used for worst case analysis.	
4	Unbalance parameters	• Cable Pair resistance unbalance: 2%. Channel pair resistance unbalance: 3% • Cable P2P Resistance Unbalance: 5%. • Channel P2P Resistance Unbalance: 0.1Ω/7.5% max which ever is greater	
5	Channel use cases to check. See figure 1 for what is a channel.	A. 6 inch (0.15 m) of cordage, no connectors. B. 4 m channel with 1 m of cordage, 3 m of cable, 2 connectors C. 23 m channel with 8 m of cordage, 15 m of cable, 4 connectors D. 100m channel with 10 m of cordage, 90 m of cable, 4 connectors	
6	End to End Channel[6]	The Channel per figure 1 + the PSE and PD PIs.	
7	Transformer winding resistance	120mOhm min, 130mOhm max	
8	Connector resistance[8]	40mOhm min, 60mOhm max	30mOhm min, 50mOhm max
9	Diode bridge[9] (Discreet Diodes)	0.39V+0.25Ω*Id min; 0.53V+0.25Ω*id max. (TBD)	
10	PSE output resistance [10]	Rsense 0.25 RDSON_min=0.1 Ω RDSON_min=0.7*RDSON_max	Rsense 0.25 RDSON_min=0.05 Ω RDSON_min=0.7*RDSON_max

Annex G2: Worst case data base Notes

1	Per standard. It is maximum value for solid and stranded wire. The maximum value is close to AWG#26 wire resistance/meter including twist rate effects. **See annex E1.** Due to the fact that patch cords may use AWG#24 cables with stranded (for mechanical flexibility) or solid wire (for improved performance), we will use the AWG#24A for worst case analysis as well. Cordage with AWG#24 wire has 0.0842Ω/m for solid wire and with 10% twist rate it will be 0.09262 Ω/m.
2	We need both data sets (data set 1 and data set 2) to find where is the worst condition for maximum current unbalance. **See Annex B curve and data** showing that at short channel we get maximum P2PRUNB but it may has less concern to us since the current is lower. We need to do all use cases calculation to see where is the maximum current over the pair; at short channel or long channel. The CAT6A cable with AWG#23 has 0.066 Ω/m. Including 12% increase on cable length due to twist rate, the effective cable resistance per meter will be 1.12*6.6 Ω/100m= 0.074 Ω/m. (with 20% twist rate it will be 0.0792 Ω/m)
3	Standard definition per Annex E1 for maximum resistance. We will check how results will be differ when AWG#23 is used for worst case results (lower resistance than standard definition for horizontal cable which is a maximum value.
4	
5	
6	PSE PI and PD PI includes: connector, transformer, resistors. PD PI includes diode bridge.
7	
8	Connector resistance was changed since the difference (60-30) milliohm is not representing Rdiff, it is representing maximum and minimum results of connector resistance of different connectors. To correct it, we change the numbers according to inputs from connector vendors and measured data. See Annex E1-E6 for confirmation.
9	Vf and Rd are worst case numbers of discrete diode which there is no control on Vf and Rd. It needs more investigation to verify that we are not over specify. (Christian is checking it). Normally match components (e.g. matched two diode bridges) are used for 4P operation. Any how ,PD PI spec. will eventually set the requirement.
10	PSE output resistance e.g. Rs_a/b=Rsense+Rdson in addition to winding resistance. See model I Annex F for reference.

Adhoc response, June 24, 2014. Adhoc accept this table

Source: Yair Darshan and Christian Beia

Thank You