The Power to Amaze.

IMPROVE SYSTEM EFFICIENCY AND RELIABILITY FOR LED LIGHTING APPLICATIONS

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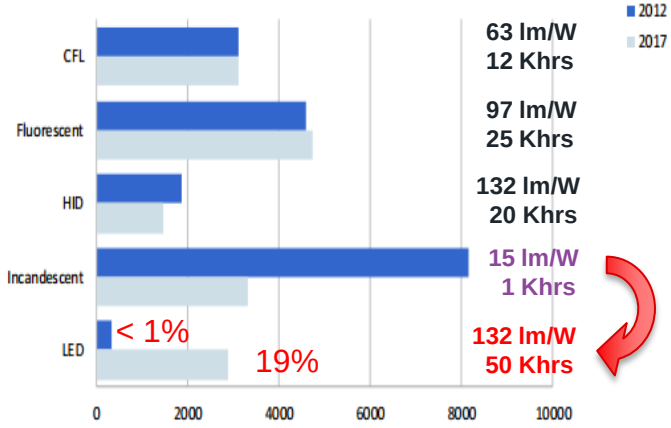
Lighting market trend

- Phase out incandescent bulbs
  (US: 100W/bulb in '12, 75W/bulb in '13, 40~60W/bulb in '14)
  (EU: 100W/bulb in '09, 40W/bulb in '12)

The World Market for Lighting By Product

Units Shipped (Billion Units)



The World Market for LED Lighting By Product & Power Rating

Revenues ($ Million), Units Shipped (Million Units), ASP $

		2011	2012	2013	2014	2015	2016	2017	CAGR 12 - 17
LED Lamps/Luminaires									
Low Power (<25W)	ASP	35.83	25.96	20.48	14.59	11.98	10.06	9.12	-18.9%
	Units	135.1	295.8	519.3	1,143.0	1,825.9	2,433.2	2,683.2	55.4%
	Revenues	4,841.3	7,679.6	10,637.0	16,672.0	21,877.8	24,482.0	24,466.5	26.1%
Medium Power (25-59W)	ASP	308.3	215.1	176.3	147.2	117.5	103.6	98.3	-14.5%
	Units	8.9	16.5	25.8	39.8	63.8	89.5	108.0	45.6%
	Revenues	2,754.4	3,547.7	4,548.2	5,855.0	7,498.2	9,273.6	10,618.5	24.5%
High Power (60W +)	ASP	734.1	611.7	510.0	408.6	323.9	285.6	258.3	-15.8%
	Units	6.1	10.1	16.4	25.7	39.2	58.1	82.9	52.3%
	Revenues	4,513.7	6,184.0	8,342.8	10,507.3	12,705.4	16,579.1	21,411.2	28.2%
Power Supply/Driver/Ballast									
Low Power (<25W)	ASP	1.75	1.63	1.55	1.44	1.39	1.36	1.35	-3.6%
	Units	155.6	338.4	629.5	1,343.4	2,012.8	2,585.8	2,779.8	52.4%
	Revenues	271.5	550.5	972.7	1,929.7	2,788.8	3,510.6	3,762.0	46.9%
Medium Power (25-59W)	ASP	13.2	10.8	9.9	9.8	9.4	9.1	9.2	-3.1%
	Units	10.7	20.0	31.9	47.5	72.6	97.9	115.7	42.0%
	Revenues	140.7	216.6	315.1	466.2	679.1	889.9	1,069.5	37.6%
High Power (60W +)	ASP	34.3	31.5	28.8	26.9	25.5	24.3	24.2	-5.1%
	Units	7.5	11.7	17.6	27.7	41.3	60.3	85.0	48.8%
	Revenues	259.0	366.6	505.9	744.8	1,051.8	1,466.6	2,057.4	41.2%

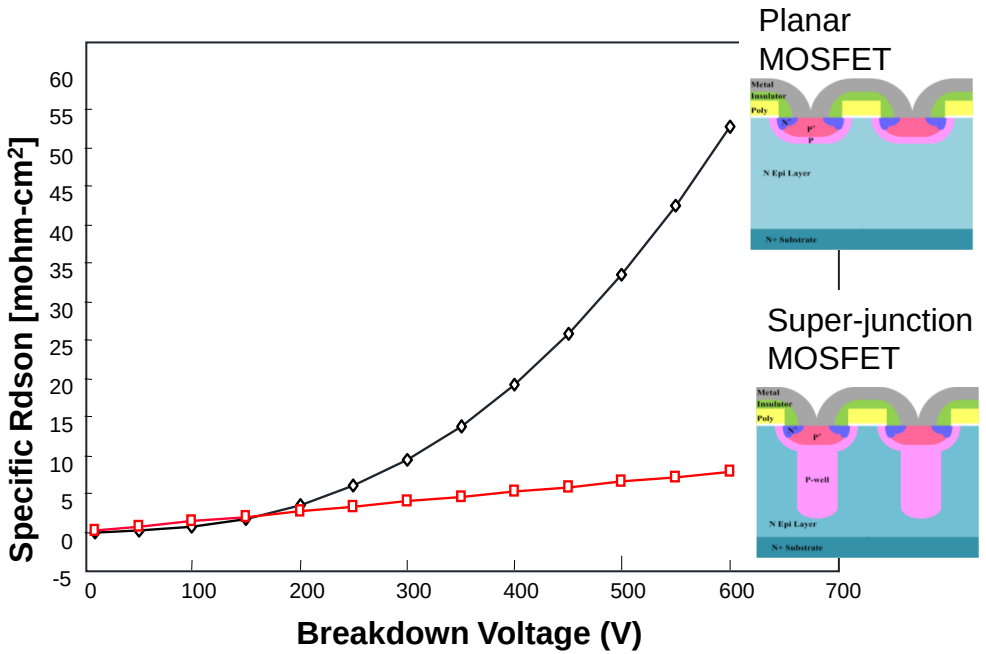
[From IHS Sep. '13]

Design Challenge

- **Voltage margin**
- **Thermal / Efficiency**
- **Volume Space**
- **Reliability**
- **Lifetime**
- **Cost**
- **Supply Chain with Multiple Vendors**

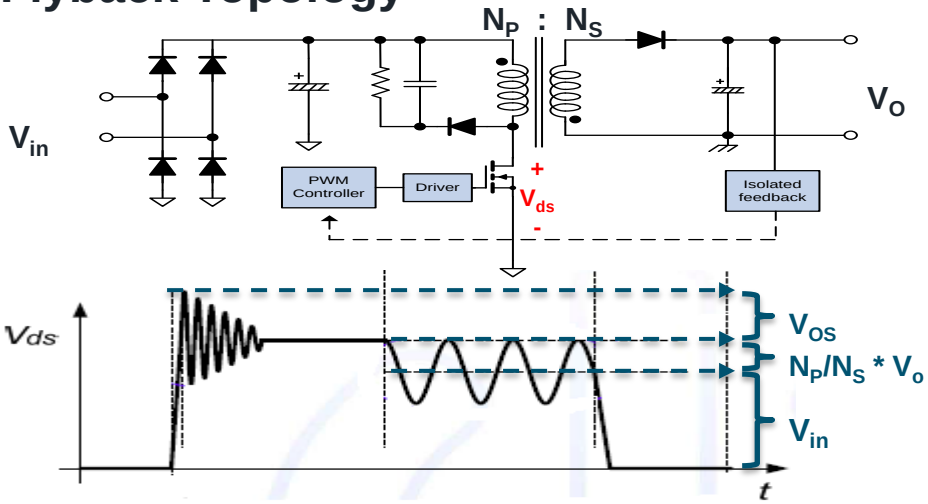
Overview of Super-junction MOSFET

- Provides lower conduction and switching losses
- Enables high power density and efficiency for power conversion systems
- Consumes less and reduces component costs
- Robust and better body diode Performance



Why 800V MOSFET?

Flyback Topology

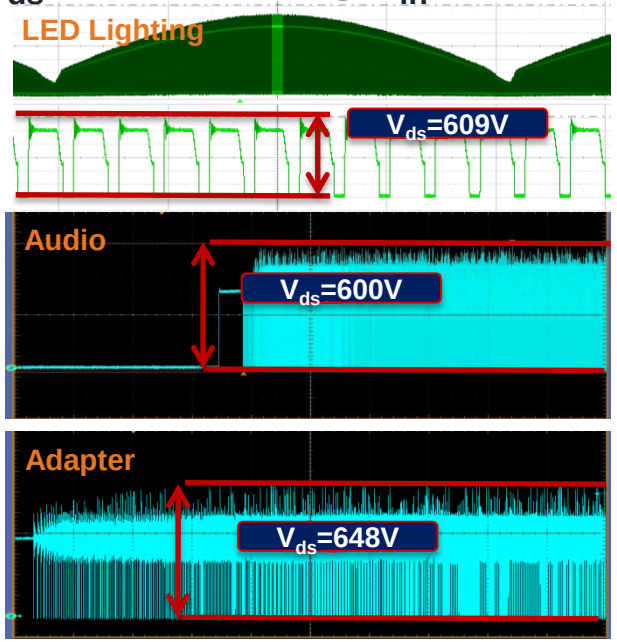


$$V_{ds}, V_{MOSFET(off)} = V_{in} + N_P/N_S * V_o + V_{os}$$

Input voltage (Vac)	Turn ratio of transformer	Output voltage	Voltage overshoot

eg.) 264Vac*1.414 + 2.5*63V + 70V = 600.8V
→ 600.8V + 20% margin = 721V

V_{ds} waveforms @V_{in}=264Vac



• Normally, set makers request 20% derating voltage margin for main switch. Therefore, 800V MOSFET is suitable for this application.

800V SuperFET® II MOSFET Features & Benefits

Key Feature

- Higher breakdown voltage over 800 V
- Industry's lowest specific on-resistance (specific $R_{DS(on)}$)
- Excellent figure of merit (FOM = $R_{DS(on)}$ x Qg)
- Least stored energy in output capacitance (Eoss)
- 100% avalanche tested
- Best-in-class robust body diode
- Zener diode included

Benefits

- Give design flexibility for voltage margin
- Minimize conduction loss

- Decrease driving loss
- Minimize switching loss, enables higher frequency

- Guarantee high reliability
- Provide ruggedness in bridge circuit operation
- Provide built-in ESD protection

All the reduced power loss leads to higher efficiency,
Lowest Rsp allows smaller package, and may eliminate a heatsink, for tiny form factors

800V SuperFET® II MOSFET Line-Up

$R_{DS(on)}$ (Max.) [mΩ]	TO-247	D2-Pak	TO-220	TO-220F	D-Pak (TO-252)	I-Pak (TO-251)
4,300				FCPF4300N80Z		FCU4300N80Z
3,400					FCD3400N80Z	FCU3400N80Z
2,250				FCPF2250N80Z	FCD2250N80Z	FCU2250N80Z
1,300				FCPF1300N80Z FCPF1300N80ZYD*	FCD1300N80Z	
850			FCP850N80Z (Release : Q2 '15)	FCPF850N80Z	FCD850N80Z	FCU850N80Z
650			FCP650N80Z (Release : Q2 '15)	FCPF650N80Z		
400			FCP400N80Z (Release : Q2 '15)	FCPF400N80Z FCPF400N80ZL1*		
290		FCB290N80	FCP290N80 (Release : Q2 '15)	FCPF290N80 (Release : Q2 '15)		
220			FCP220N80 (Release : Q2 '15)	FCPF220N80		
85	FCH085N80_F155 (Release : Q2 '15)					
60	FCH060N80_F155 (Release : Q2 '15)					

(*: suffix "YD" is Y form of outlead and "L1" is narrow outlead)

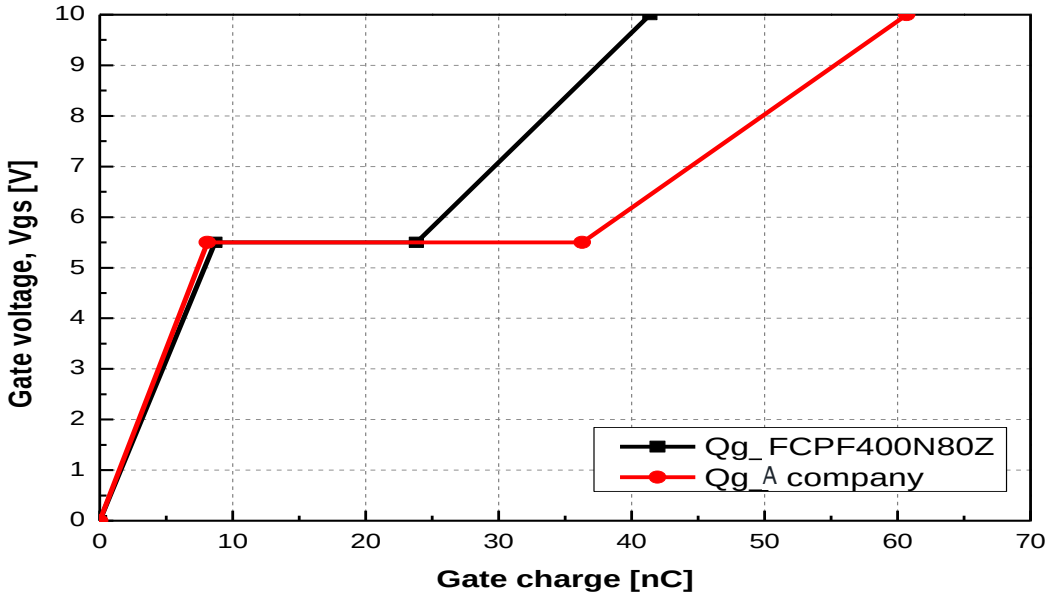
FCPF400N80Z Bench Mark for Mid-Power LED Lighting

FCPF400N80Z - Key Parameters

Parameter comparison table based on datasheet

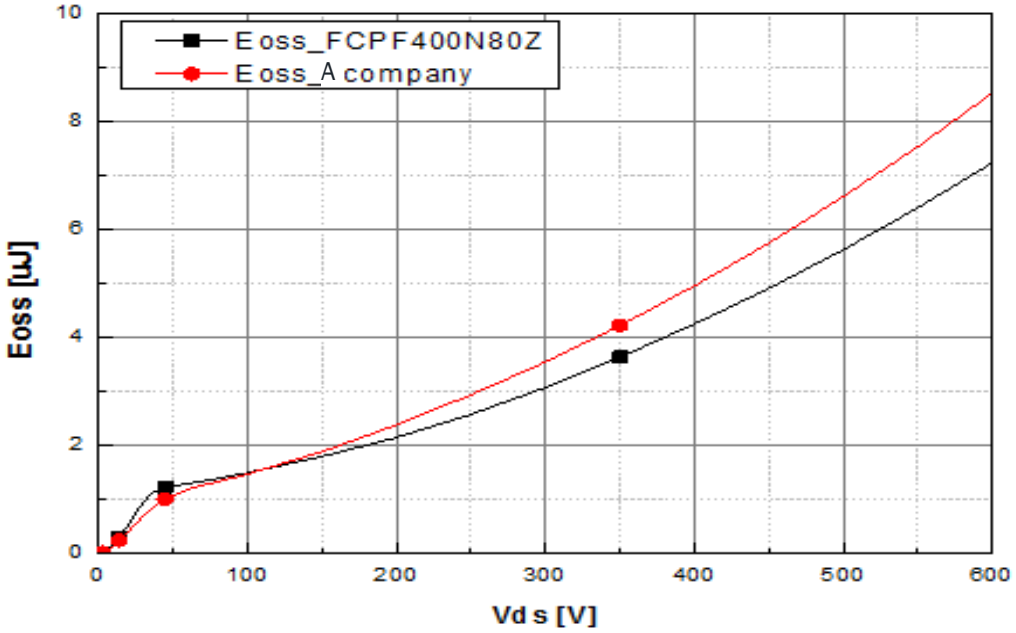
Parameter	FCPF400N80Z (Fairchild SuperFET® II MOSFET)	A company (Super Junction MOS)
BV_{DSS}	800 V	800 V
I_D	11 A	11 A
$V_{GS(th)}$	2.5 ~ 4.5 V	2.1 ~ 3.9 V
$R_{DS(on)}$ (Max.)	**400 mohm**	450 mohm
Q_g (Typ.)	**43 nC**	64 nC
FOM $[R_{DS(on)} \times Q_g]$	**17.2 Ω ·nC**	28.8 Ω · nC
Q_{gs} (Typ.)	8.6 nC	8.0 nC
Q_{gd} (Typ.)	17.0 nC	30.0 nC
E_{OSS} at 400V	**4.25 µJ**	4.96 µJ
Zener diode b/w gate and source	**Exist**	None

FCPF400N80Z
- Gate Charge



P/N \ Item	Qg [nC]	Qgs [nC]	Qgd [nC]
	@V_{DS} = 480V, I_D=11A		
FCPF400N80Z	41.4	8.67	15.1
A company	60.7	8.1	28.2

FCPF400N80Z
- Coss Stored Energy : Eoss



P/N \ Item	Eoss [uJ]			
	@V_{DS} 100V	@V_{DS} 200V	@V_{DS} 400V	@V_{DS} 600V
FCPF400N80Z	1.50	2.15	4.25	7.24
A company	1.47	2.38	4.96	8.53

FCPF400N80Z
- UIS, Body diode di/dt and ESD immunity

- Measured data

Parameter	FCPF400N80Z (Fairchild SuperFET® II)	A company (Super Junction MOS)	Remark
UIS : Ias (@ L=1mH)	11 A	10 A	Similar
Body diode reverse recovery ruggedness : Body diode di/dt (@ Isd=11A, Vdd=600V)	**1280 A / us**	340 A / us	3.8 times superior
ESD immunity : HBM	**3.6 KV**	2.0 KV	1.8 times superior

FCPF400N80Z
- Application Evaluation

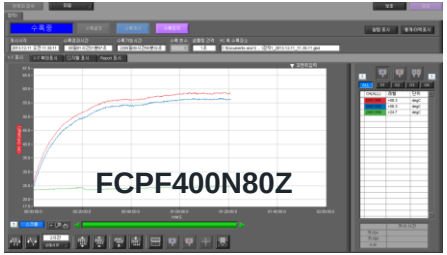
- **PCB Model : Mid-Power LED Lighting board (Flyback)**
- **Test Condition**

  Vin : 100Vac / 60Hz,

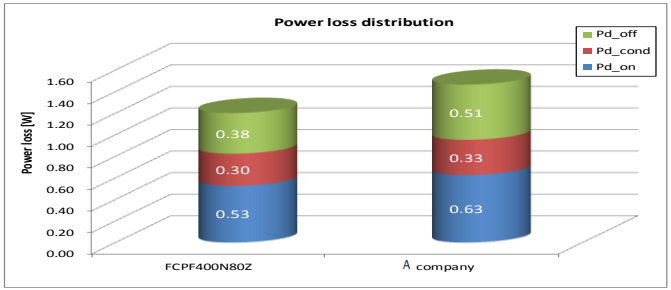
  Pin : 100W

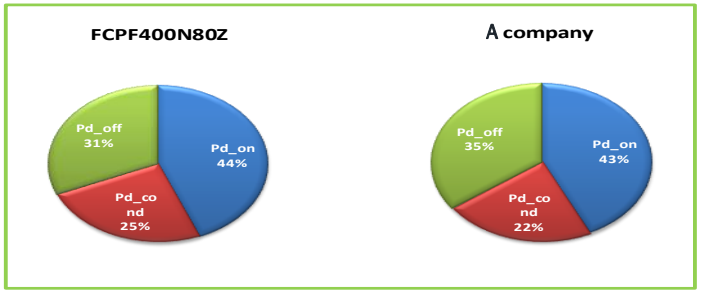
  Rg.on = 100Ω+L_{bead}, Rg.off = 10Ω +L_{bead}
- **Test Results**

• Temp. profile



Item / P/N	PKG	Case Temp. of MOSFET [℃]	Power Loss [W]				AC & DC Test data (Measured data)					
			Pon	Pcond	Poff	Total	BV [V]	Int. Rg [Ω]	Vth [V]	$R_{DS(on)}$ [mΩ]	Qg [nC]	Qgd [nC]
FCPF400N80Z	TO-220F	**58.4**	0.53	0.3	0.38	1.20	898	1.14	3.53	**326@5.0A**	41.4	15.1
A company	TO-220F	66.1	0.63	0.33	0.51	1.47	898	1.10	3.09	343@5.0A	60.7	28.2

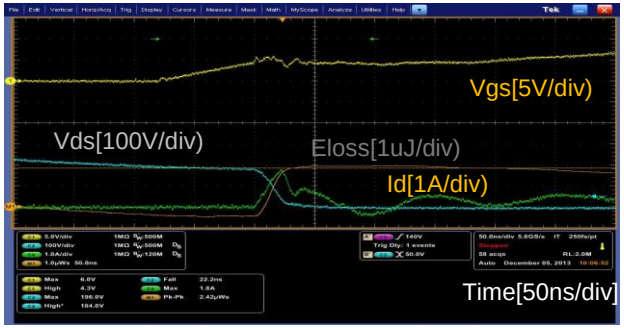




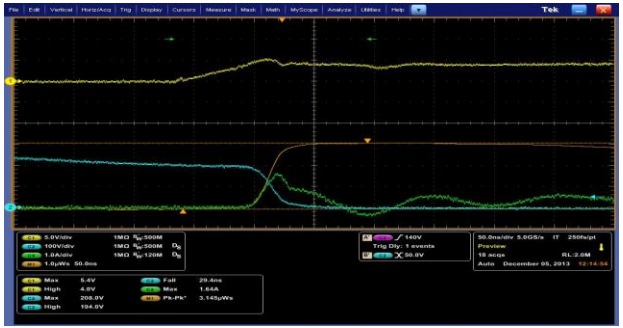
FCPF400N80Z
- Application Evaluation

I-V Waveforms

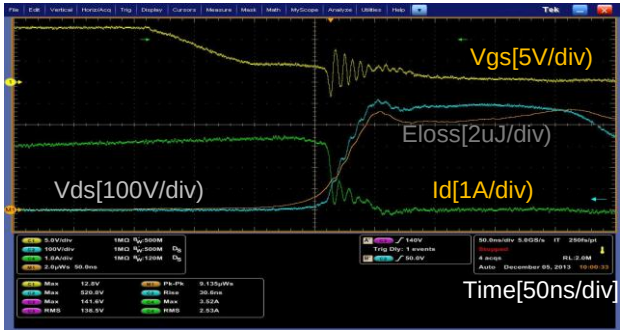
<FCPF400N80Z turn-on>



<A company turn-on>



<FCPF400N80Z turn-off>



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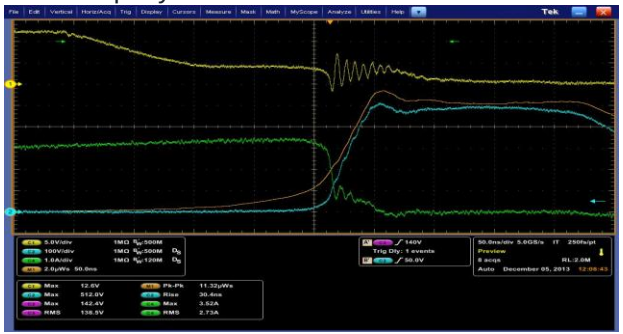


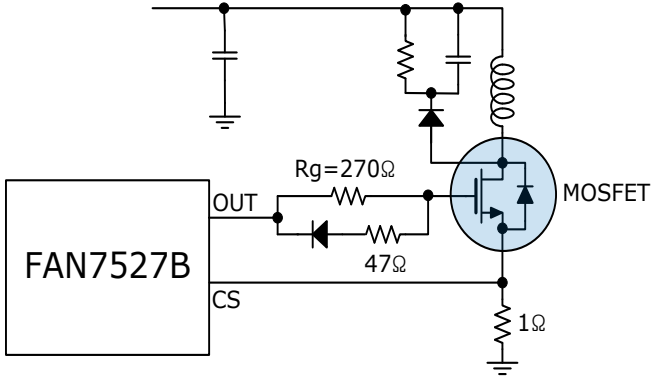
FCPF1300N80Z Bench Mark for Low Power LED Lighting

Spec. of Test Board

Existing
MOSFET :
FQPF8N80C

Board Spec.

- Input Voltage: 220 V_{AC} ~ 240 V_{AC}
- Output: 48 V / 600 mA (15 LEDs)
- Controller: FAN7527B (PFC IC)
- Topology: Single Stage SSR



FCPF1300N80Z - Key Parameters

- Parameter comparison table (based on datasheet)

Parameter	FCPF1300N80Z (Fairchild SuperFET® II MOSFET)	FQPF8N80C (Fairchild Planar MOSFET)	A company (Super Junction MOS)
BV_{DSS}	800 V	800 V	800 V
I_D	4 A	8 A	4 A
$V_{GS(th)}$	2.5 V ~ 4.5 V	3.0 V ~ 5.0 V	2.1 V ~ 3.9 V
$R_{DS(ON)}$ (Max.)	**1.3 ohm**	1.55 ohm	1.3 ohm
Qg (Max.)	**21 nC**	45 nC	31 nC
Qgs (Typ.)	3.5 nC	10 nC	3 nC
Qgd (Typ.)	**6.8 nC**	14 nC	12 nC
Zener diode b/w gate and source	**Exist**	None	None

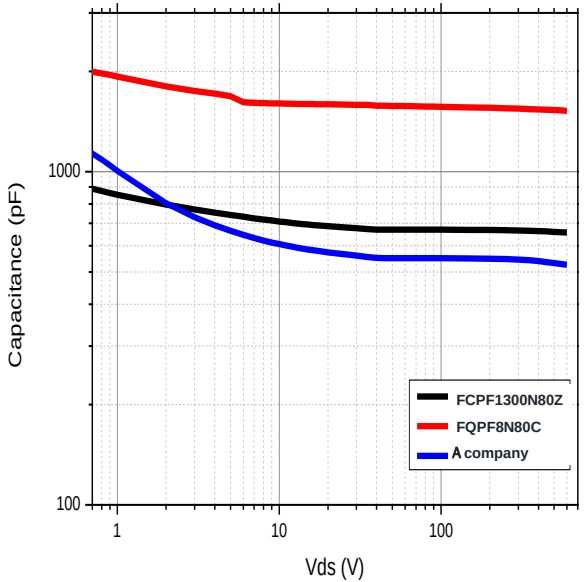
FCPF1300N80Z - Key Parameters

- Parameter comparison table (based on measured data)

Parameter	FCPF1300N80Z (Fairchild SuperFET® II MOSFET)	FQPF8N80C (Fairchild Planar MOSFET)	A company (Super Junction MOS)
$V_{GS(th)}$ (@0.4mA)	3.83 V	4.25 V	2.73 V
BV_{DSS} (@250uA)	944 V	870 V	907 V
$R_{DS(ON)}$ (Typ.)	**1.03 ohm**	1.2 ohm	0.98 ohm
Crss (@480V)	**4.3 pF**	5.7 pF	6.9 pF
Ciss (@480V)	660 pF	1531 pF	532 pF
Coss (@480V)	**15 pF**	39 pF	17 pF
Qg (tot)	**16.2 nC**	25.2 nC	30.6 nC

- The Qg and Crss of FCPF1300N80Z are lower than the others.
  - Drive loss is smaller than the others. → $P_{Drive} = f \times V_{th} \times Q_g$
- The Rds(on) of FCPF1300N80Z is lower than FQPF8N80C.

FCPF1300N80Z - Capacitance



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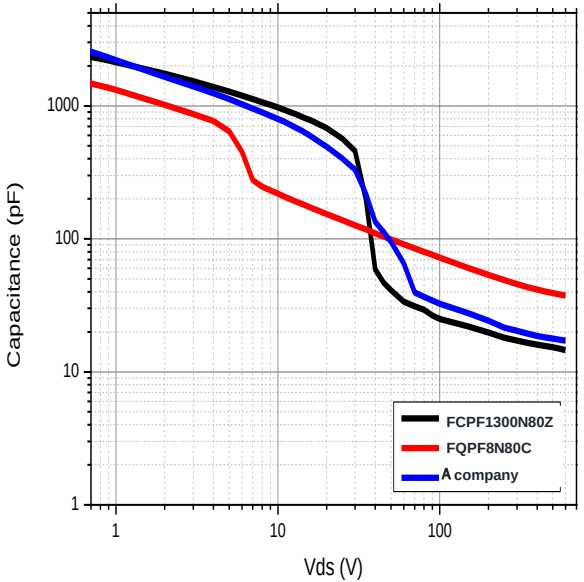

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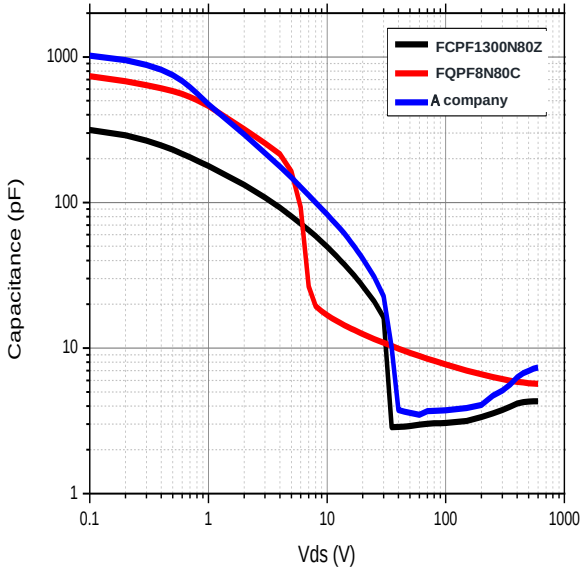


< Comparison Crss >

FCPF1300N80Z
- Gate Charge Test

FCPF1300N80Z

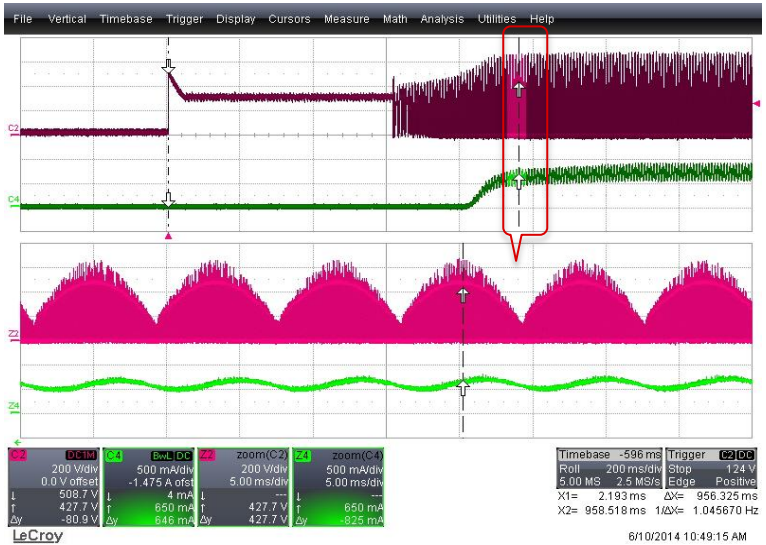
< FCPF1300N80Z >

< FQPF8N80C >

< A company >

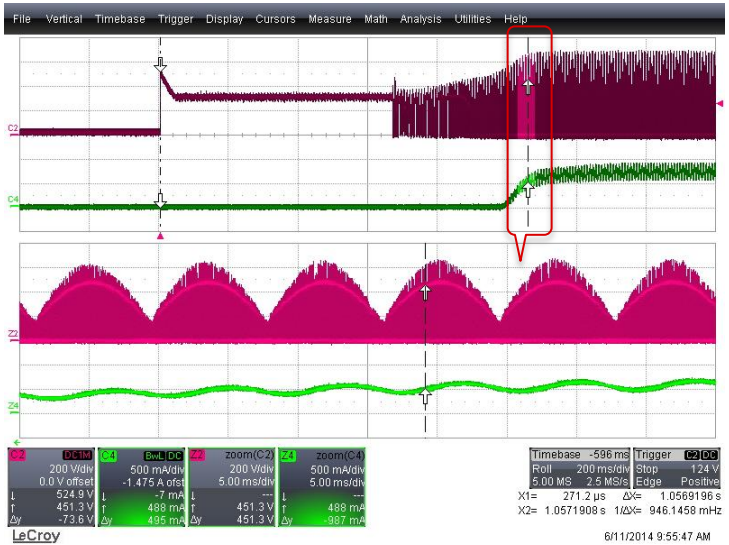
- Gate charging time is faster than the others.
  - On loss is smaller than the others.

FCPF1300N80Z
- Operation during Start-Up



Vds: 200 V / div

I_{OUT}: 500 mA / div



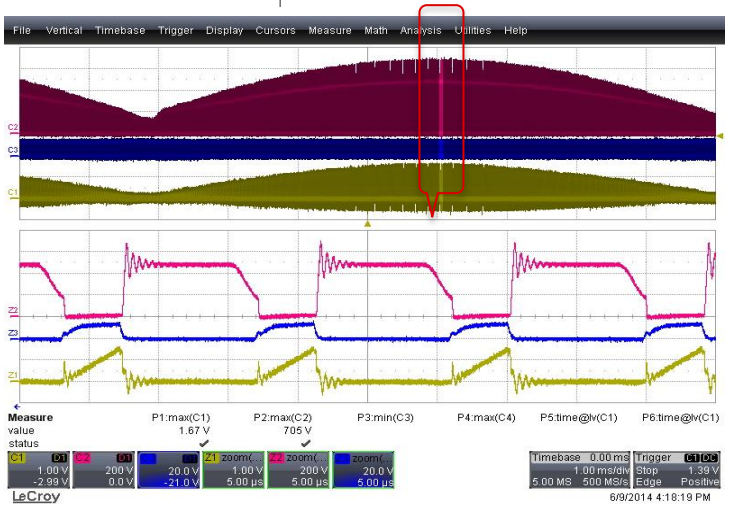
< V_{IN} = 230 V_{ac}, with FQPF8N80C >

- No problem.

< V_{IN} = 230 V_{ac}, with FCPF1300N80Z >

- No problem.

FCPF1300N80Z
- Normal operation(1)

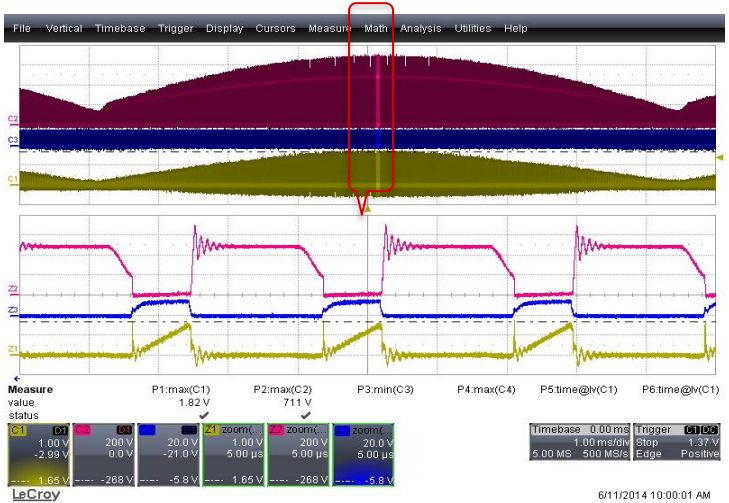


< V_{IN} = 230 V_{ac}, FQPF8N80C >

Vds: 200 V / div

Vgs: 20 V / div

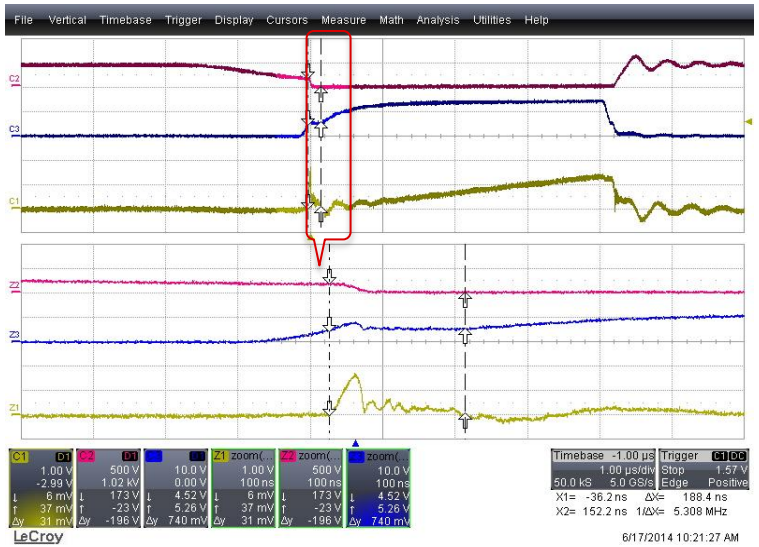
V_{CS}: 1 V / div



< V_{IN} = 230 V_{ac}, FCPF1300N80Z/ A company >

- The peak voltage and leading edge current are almost same.

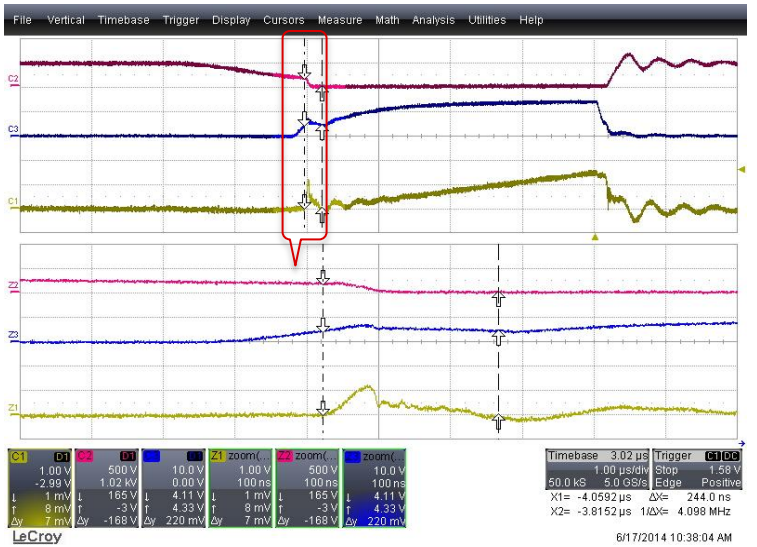
FCPF1300N80Z
- Normal operation(2)



Vds: 500 V / div

Vgs: 10 V / div

V_{CS}: 1 V / div

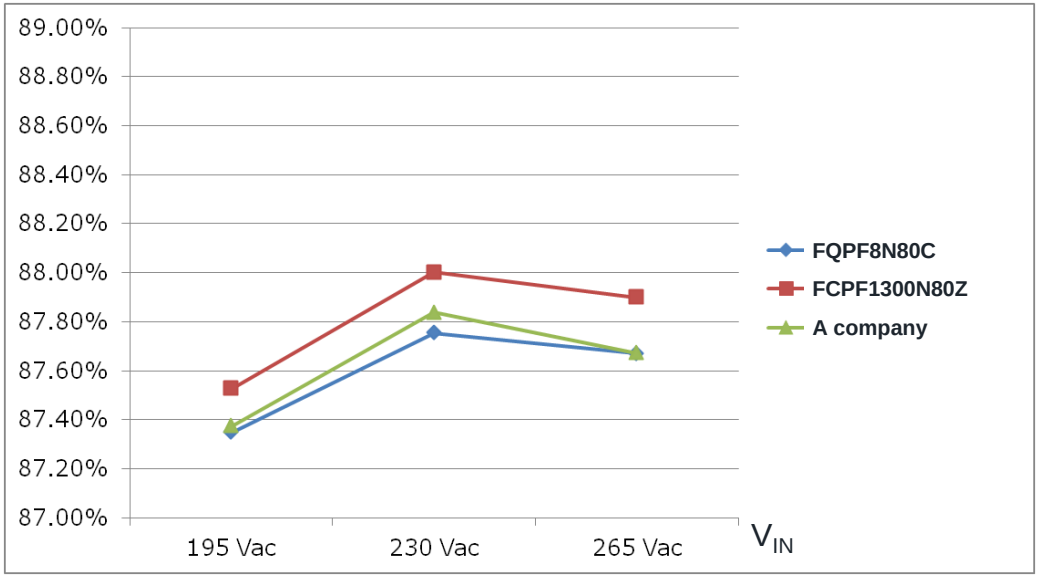


< Original w/ FCPF1300N80Z >

< Improved Circuit w/ FCPF1300N80Z >

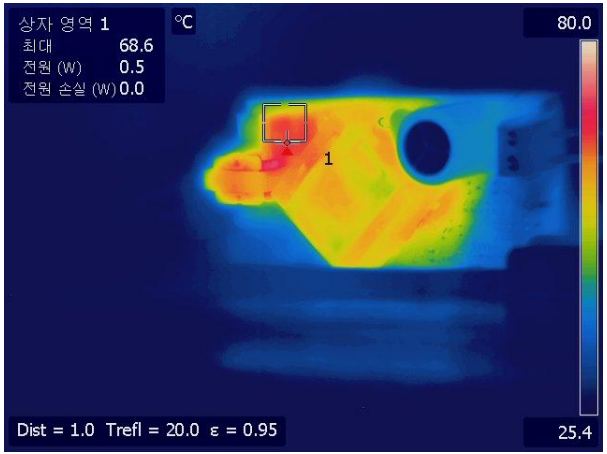
- When Rg is changed from 270 Ω to 510 Ω, the leading edge current is decreased.
  - The efficiency can be decreased due to increased switching loss.
  - EMI can be improved.

FCPF1300N80Z - Efficiency

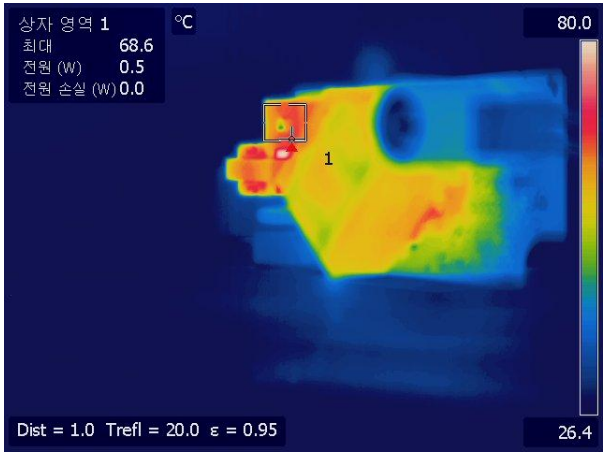


- Aging: 30 mins.
- The efficiency of FCPF1300N80Z is better than the others.

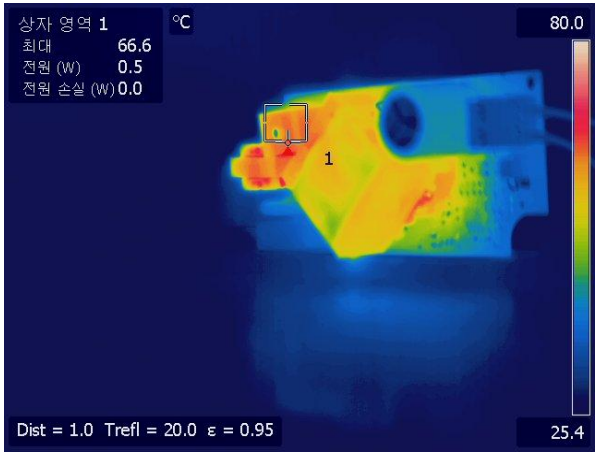
FCPF1300N80Z
- Operating Temperature



< V_{IN} = 230 V_{ac}, FQPF8N80C >



< V_{IN} = 230 V_{ac}, A company >



< V_{IN} = 230 V_{ac}, FCPF1300N80Z >

- Aging: 30 mins.
- The operating temperature of FCPF1300N80Z is better than the others.

800V SuperFET® II MOSFET Summary

- Higher breakdown voltage of 800 V → Design flexibility with voltage margin
- Lowest specific Rds(on) → Conduction loss ↓ → Improve efficiency & Small space of PCB
- Excellent figure of merit ($R_{DS(on)}$ x Qg) → Driving loss ↓ → Improve efficiency
- Lowest output capacitance (Coss) → Switching loss ↓ → Improve efficiency
- 100% Avalanche tested → High reliability
- Zener diode included → ESD protection
- Various package option → Variety of choice for thermal & mechanical design

For more information, please visit
- SuperFET II MOSFET landing page
- Product portfolio

THANK YOU