Freescale Technology Forum

Design Innovation.

Nov, 2008

ESwitch: Design Considerations for Robustness and Reliability

PA103

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Author - **Steven Everson**

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Agenda

- Overview of eXtreme Switches
- Key Features and Added Value
- Proven Reliability
- Making EMC Happen
- Supporting Parts
- A Few Thoughts About Layout

Overview of eXtreme Switches

The eXtreme Switch products are high-side switches (N-channel MOSFET) with ultra low on-resistance (i.e. 2m Ohms), packaged in a Power QFN (PQFN) surface mount power package

The switches integrate:

- Overload protection
- Over-current detection
- Short-circuit protection
- Over-temperature protection
- High-voltage survivability
- Under-voltage and over-voltage shutdown with hysteresis

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Overview of eXtreme Switches (cont)

The devices also provide:

- Configuration and diagnostic feedback via a serial protocol interface (SPI)
- Proportional load current sense
- Configurable slew rate
- Electrostatic discharge protection (ESD)
- Active negative voltage clamp for fast de-energizing of wire harness inductive loads
- Loss of ground protection
- Open load diagnostic
- Reverse battery protection

They also have a very low quiescent current in sleep mode

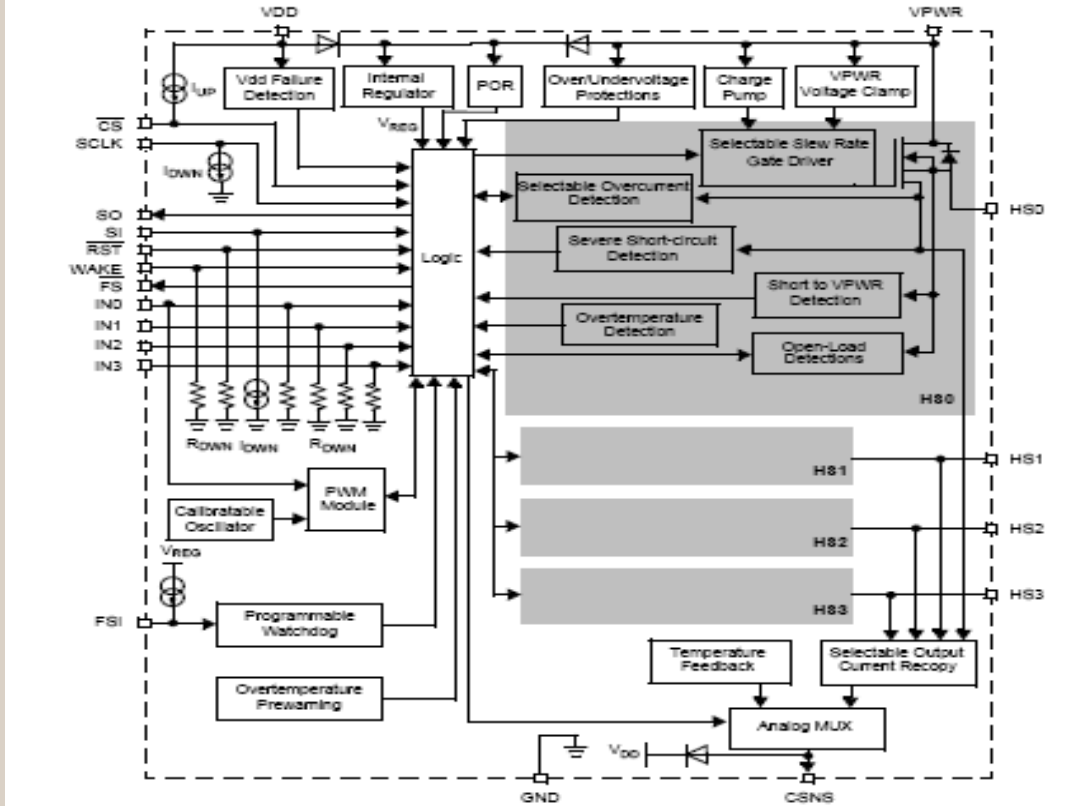
SPQ1012 / SPQ1035 / SPQ35 / SPQ15

Key characteristics

Operating voltage	**6 - 20 V**
Extended range	**4.5 – 28 V**
$R_{DS(ON)\ SPQ1012}$	**2x10-2x12mOhm**
$R_{DS(ON)\_SPQ1035}$	**2x10-2x35mOhm**
$R_{DS(ON)\_SPQ35}$	**4x35mOhm**
$R_{DS(ON)\_SPQ15}$	**4x15mOhm**
PWM frequency	**60 – 400Hz**
DC current	**6A /3A nom**
Sleep Current	**< 5µA**

Features

- 16-bit SPI with daisy chain capability
- PWM module with external or internal clock
- Smart overcurrent shutdown
- Overtemperature protections
- Auto-retry on most protections
- Fail-Safe mode in case of MCU damage
- Open-Load detection for bulbs or LEDs
- Short to Battery detection.
- Analog current and temperature feedback



12x12 PQFN

Application

- Halogen, Xenon, LED

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KEY FEATURES AND ADDED VALUE

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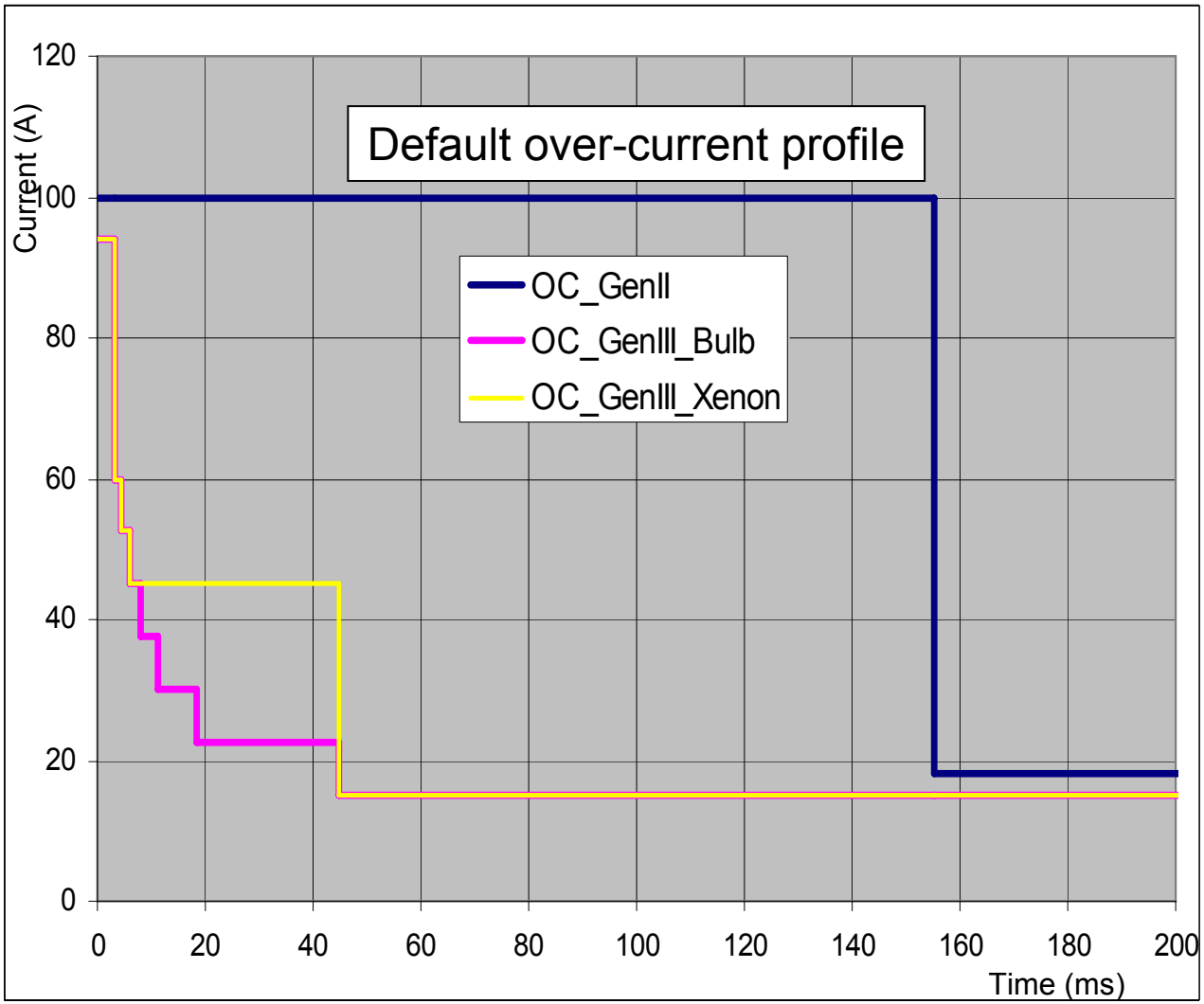
Gen II versus Gen III



- 9V to 27V –> 6V to 28V
- Over-current **blanking window replaced by inrush** over-current **profile** to control the bulb in PWM mode.
- GenIII has a multi-step over-current protection which can be programmed to be **compliant with 55/65W or Xenon lights**.
- In case of short-circuit, the **ΔT is drastically reduced** to a value which does not affect the device's reliability.

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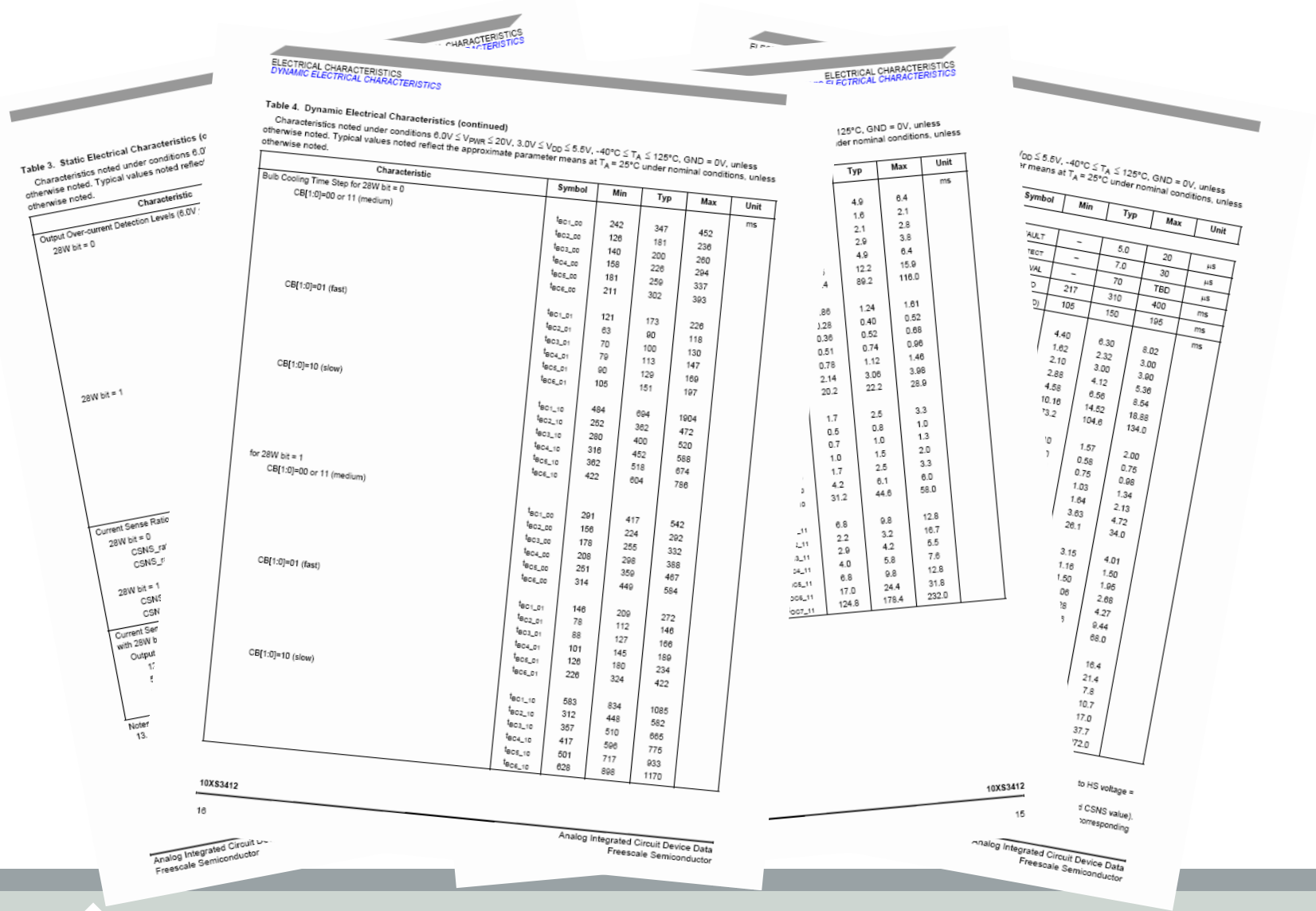
Gen III Over Current Limits



ELECTRICAL CHARACTERISTICS
DYNAMIC ELECTRICAL CHARACTERISTICS

Table 4. Dynamic Electrical Characteristics (continued)

Characteristics noted under conditions $6.0V \le V_{PWR} \le 20V$, $3.0V \le V_{DD} \le 5.5V$, $-40°C \le T_A \le 125°C$, GND = 0V, unless otherwise noted. Typical values noted reflect the approximate parameter means at $T_A = 25°C$ under nominal conditions, unless otherwise noted.

Characteristic	Symbol	Min	Typ	Max	Unit
Bulb Cooling Time Step for 28W bit = 0					ms
CB[1:0]=00 or 11 (medium)	t_{EC1_00}	242	347	452	
	t_{EC2_00}	126	181	236	
	t_{EC3_00}	140	200	260	
	t_{EC4_00}	158	226	294	
	t_{EC5_00}	181	259	337	
	t_{EC6_00}	211	302	393	
CB[1:0]=01 (fast)	t_{EC1_01}	121	173	226	
	t_{EC2_01}	63	90	118	
	t_{EC3_01}	70	100	130	
	t_{EC4_01}	79	113	147	
	t_{EC5_01}	90	129	169	
	t_{EC6_01}	105	151	197	
CB[1:0]=10 (slow)	t_{EC1_10}	484	694	1904	
	t_{EC2_10}	262	362	472	
	t_{EC3_10}	280	400	520	
	t_{EC4_10}	316	452	588	
	t_{EC5_10}	362	518	674	
	t_{EC6_10}	422	604	786	
for 28W bit = 1					
CB[1:0]=00 or 11 (medium)	t_{EC1_00}	291	417	542	
	t_{EC2_00}	156	224	292	
	t_{EC3_00}	178	255	332	
	t_{EC4_00}	208	298	388	
	t_{EC5_00}	251	359	467	
	t_{EC6_00}	314	449	584	
CB[1:0]=01 (fast)	t_{EC1_01}	146	209	272	
	t_{EC2_01}	78	112	146	
	t_{EC3_01}	88	127	166	
	t_{EC4_01}	101	145	189	
	t_{EC5_01}	126	180	234	
	t_{EC6_01}	226	324	422	
CB[1:0]=10 (slow)	t_{EC1_10}	583	834	1085	
	t_{EC2_10}	312	448	582	
	t_{EC3_10}	357	510	665	
	t_{EC4_10}	417	596	775	
	t_{EC5_10}	501	717	933	
	t_{EC6_10}	628	898	1170	

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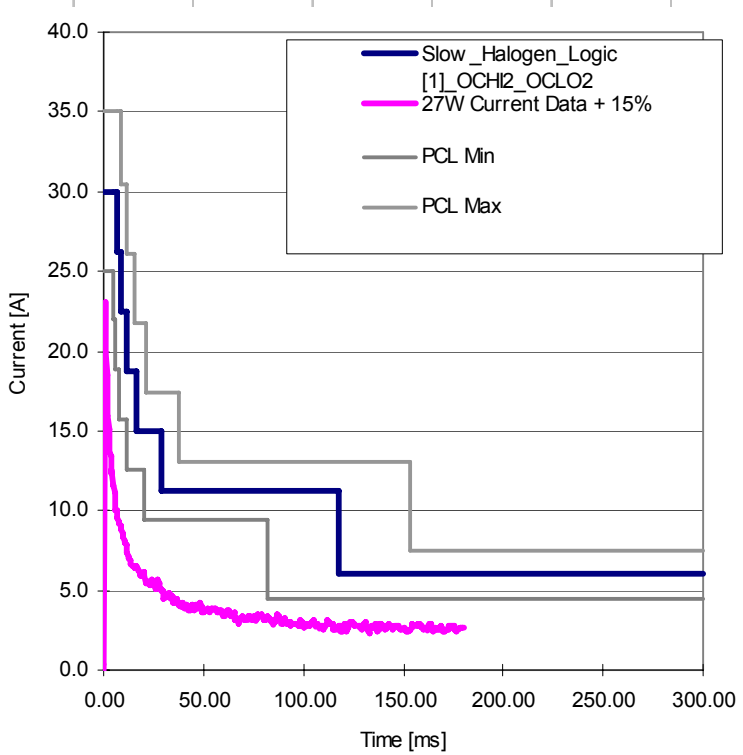
Gen III Overcurrent Selection

Register Settings

	Profile Speed	Xenon	28W Bit	OCHI	Steady State	Profile Name:
Click & Select =	Slow	Halogen	Logic [1]	OCHI2	OCLO2	Slow_Halogen_Logic [1]_OCHI2_OCLO2

Over Current Level		Typ		Min + Min		Max + Max	
		Time [ms]	Current Limit [A]	Time [ms]	Current Limit [A]	Time [ms]	Current Limit [A]
tOC1_00	0	0.00	30.0	0.00	25.0	0.00	35.0
	tOC1_00	4.90	30.0	3.40	25.0	6.40	35.0
tOC2_00	tOC1_00	4.90	30.0	3.40	25.0	6.40	35.0
	tOC2_00	6.50	30.0	4.50	25.0	8.50	35.0
tOC3_00	tOC2_00	6.50	26.2	4.50	22.0	8.50	30.5
	tOC3_00	8.60	26.2	5.90	22.0	11.30	30.5
tOC4_00	tOC3_00	8.60	22.5	5.90	18.9	11.30	26.1
	tOC4_00	11.50	22.5	7.90	18.9	15.10	26.1
tOC5_00	tOC4_00	11.50	18.7	7.90	15.7	15.10	21.8
	tOC5_00	16.40	18.7	11.30	15.7	21.50	21.8
tOC6_00	tOC5_00	16.40	15.0	11.30	12.6	21.50	17.4
	tOC6_00	28.60	15.0	19.80	12.6	37.40	17.4
tOC7_00	tOC6_00	28.60	11.2	19.80	9.4	37.40	13.1
	tOC7_00	117.80	11.2	82.20	9.4	153.40	13.1
Steady State	tOC7_00	117.80	6.0	82.20	4.5	153.40	7.5
	500	300.00	6.0	300.00	4.5	300.00	7.5



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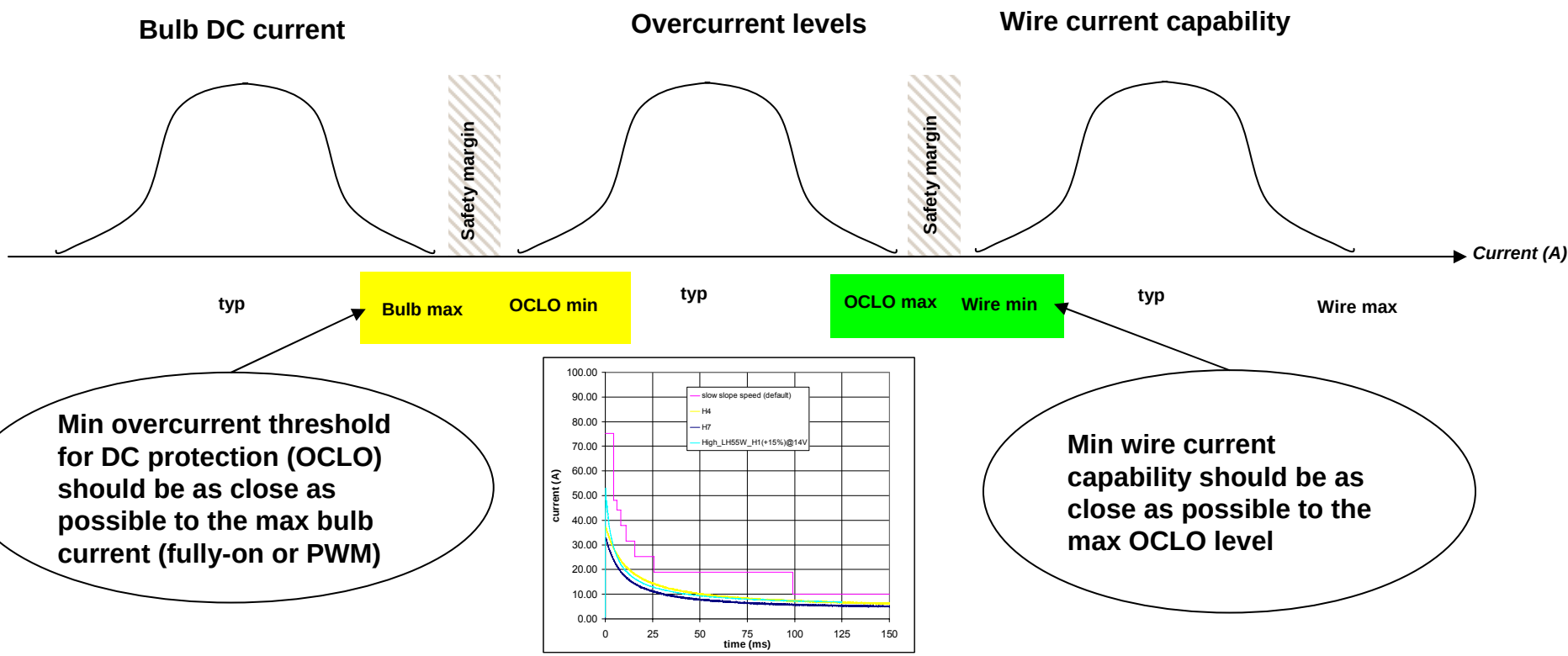
DC Overcurrent Protection

Allows wire harness optimization
Reduces weight and cost



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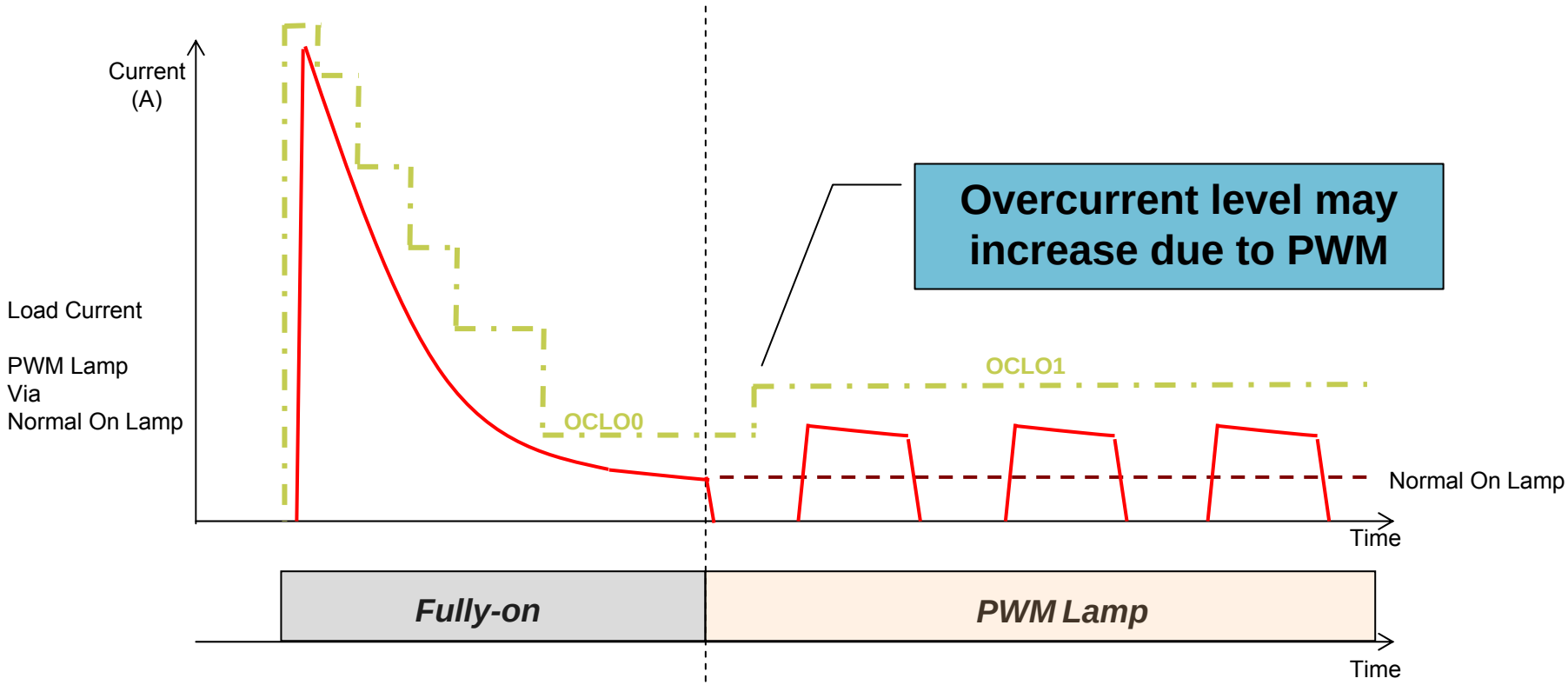
Driving Lamps in PWM

Drive in fully-on to heat the lamp filament during 150msec
Control in PWM to increase the life-time of the lamp



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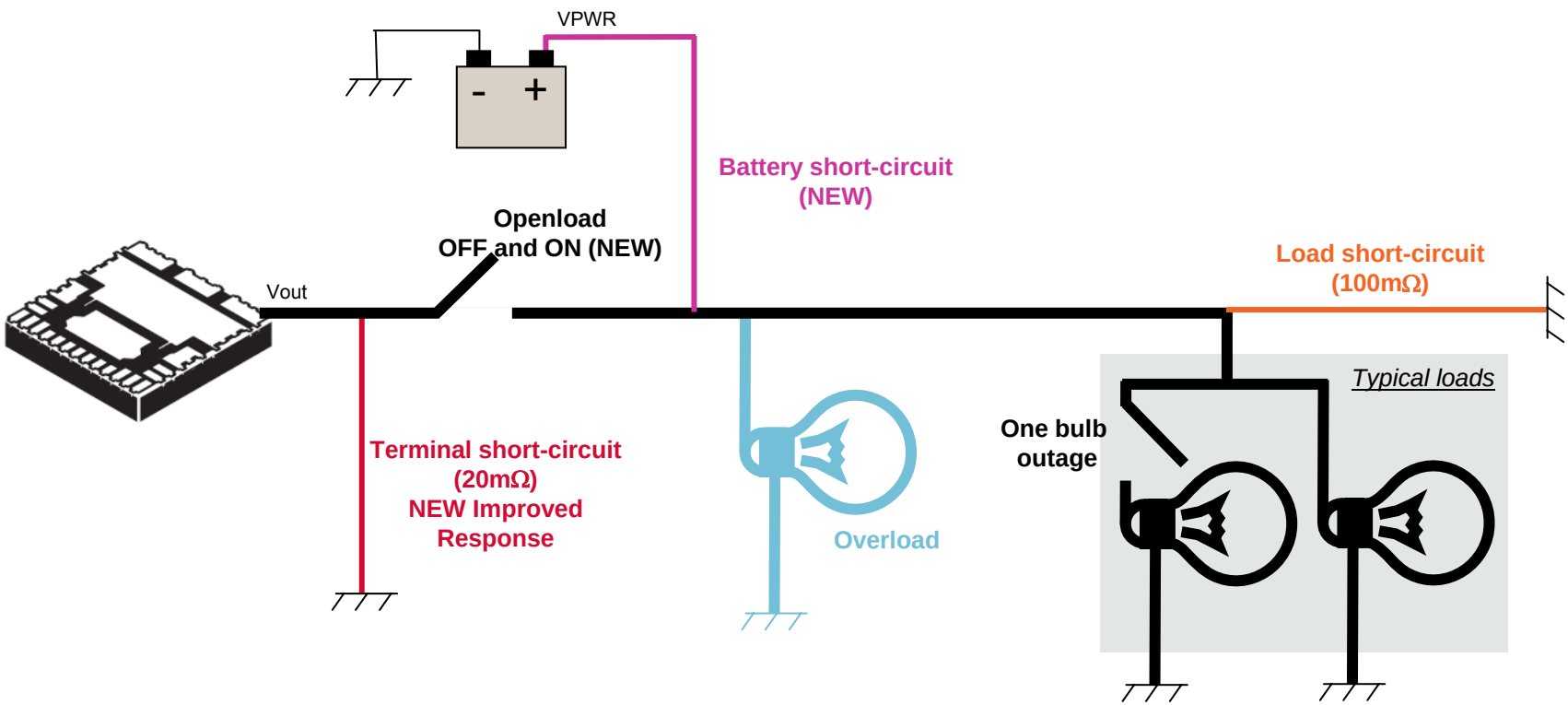
Lighting Behavior Monitoring



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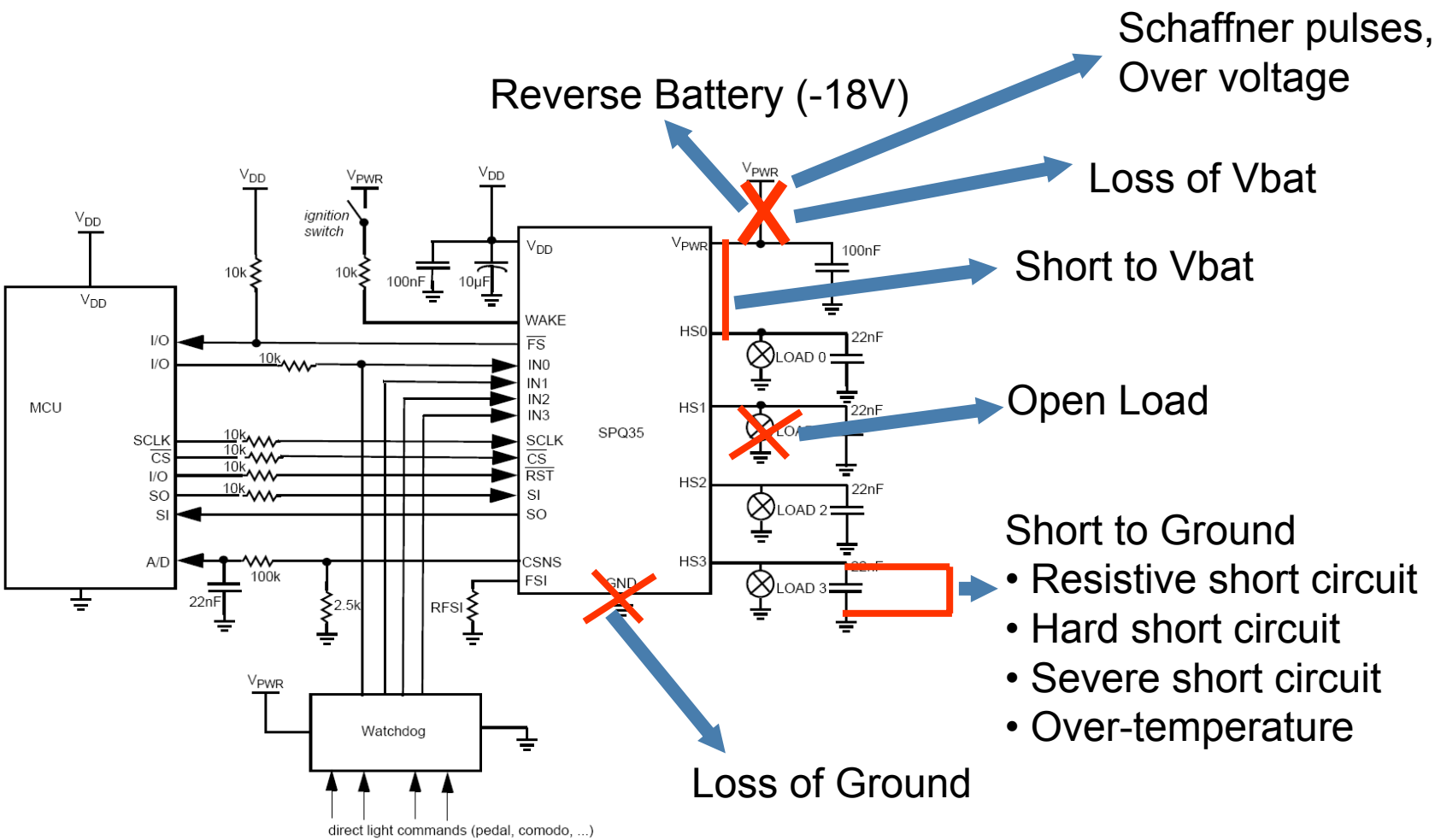
Protections - External Fault and Transients



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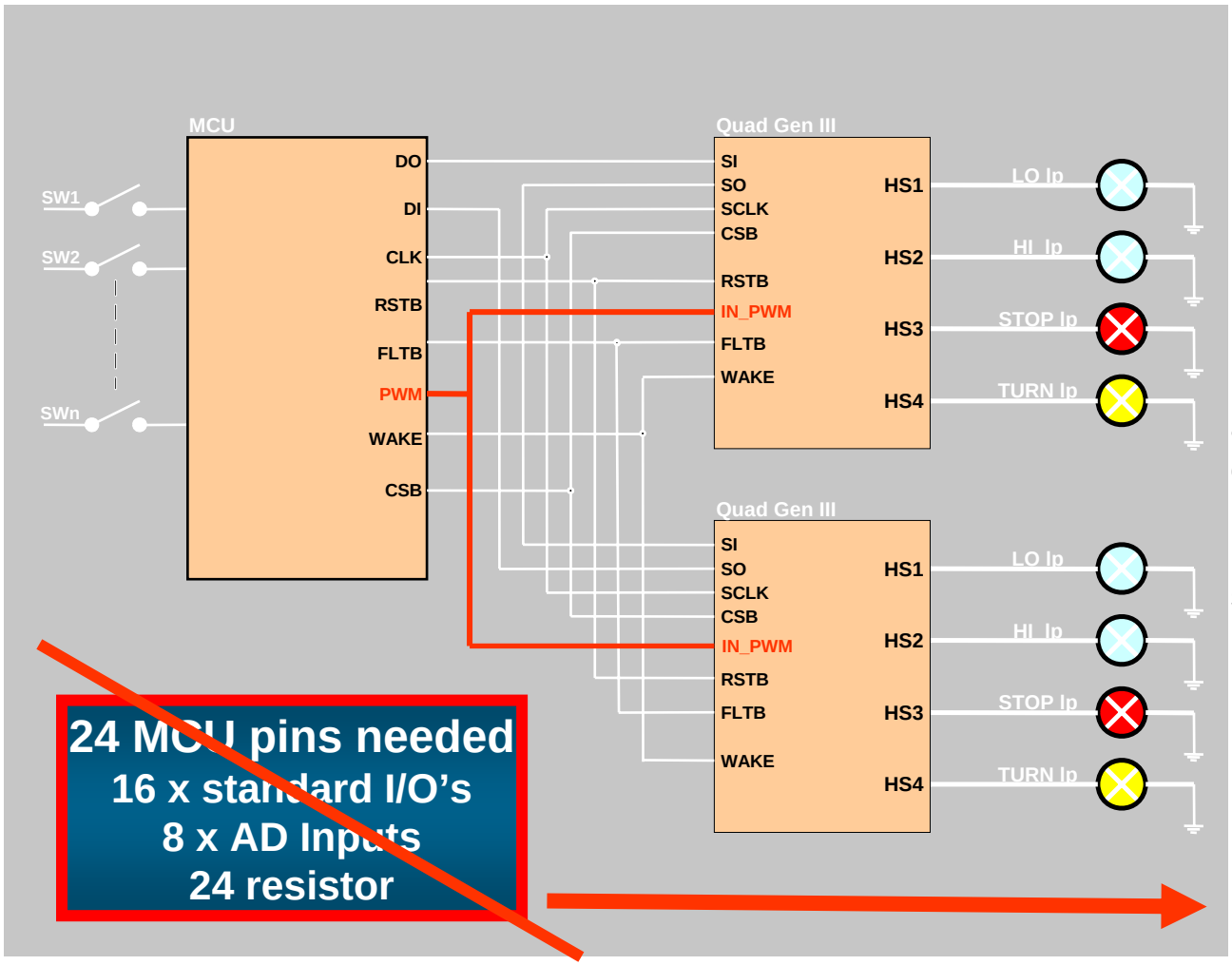
Gen III Example
Using eXtremeSwitch Quad Devices



- One PWM signal only
- Low MCU resources: Duty cycle and phase shift managed by the eXtremeSwitch (SPI)
- Fault management need NOT be synchronized to the signal

8 MCU pins needed
7 x standard I/O's
1 x AD Inputs
15 resistors

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PROVEN RELIABILITY

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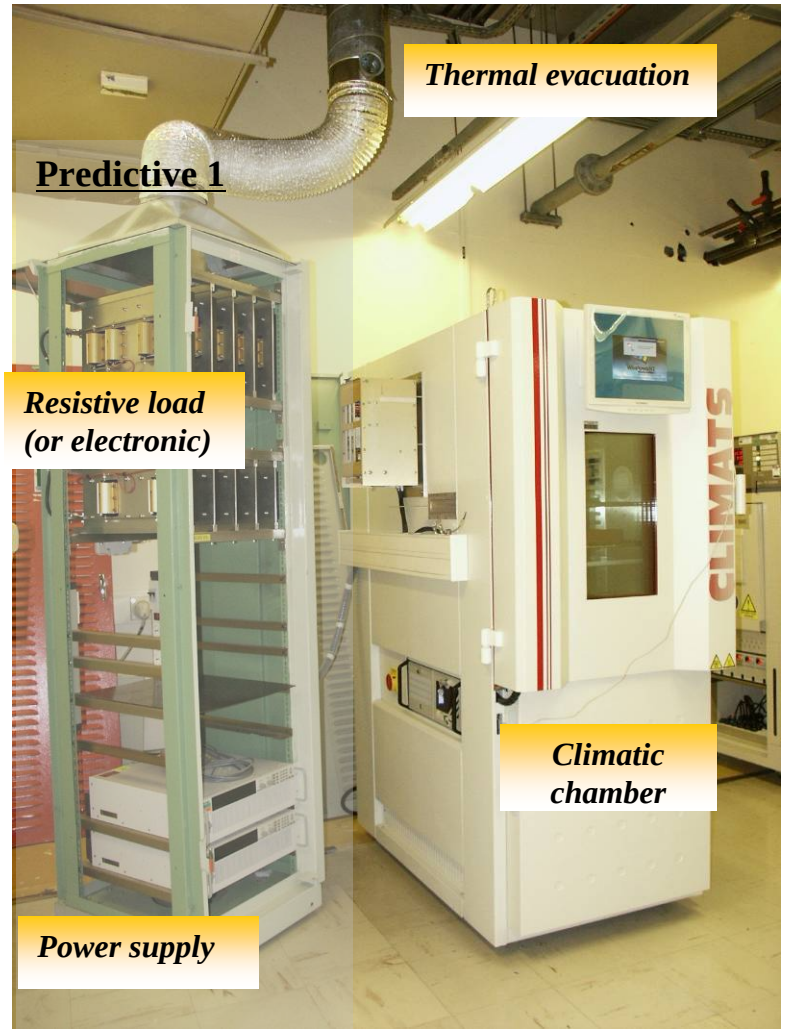
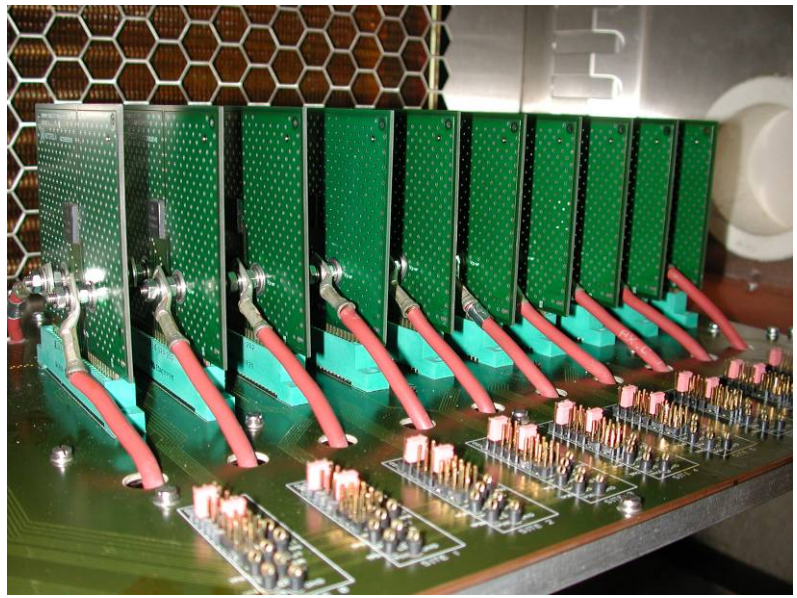
HPRA Test Bench



High Power Reliability Assessment

Power supply	Xantrec Xdc 30V-200A
Clim chamber	-40°C 180°C
Driver	Synergie CAD IOL Gen III P1 v1.0
Load	RS Power load
Mother board	Predictive mother board Rev1.0
Coupon	FSL eSwitch Gen III Rev1.0



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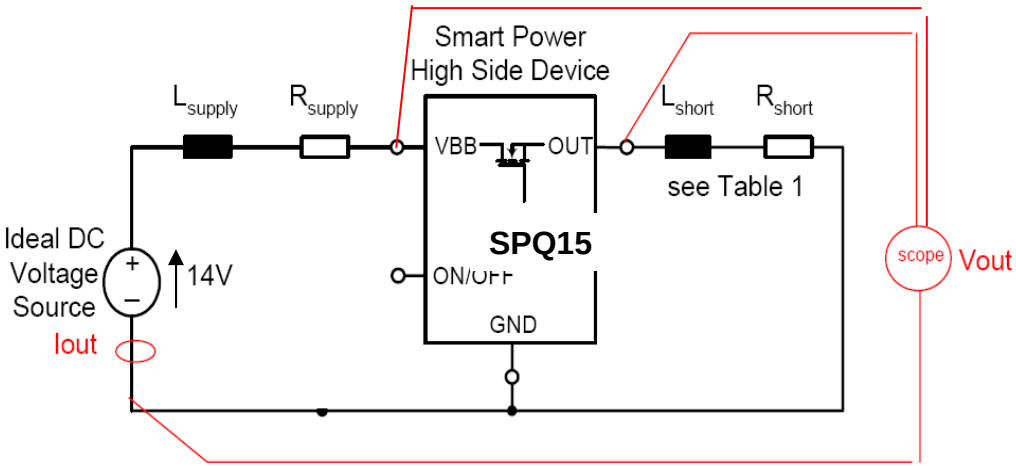
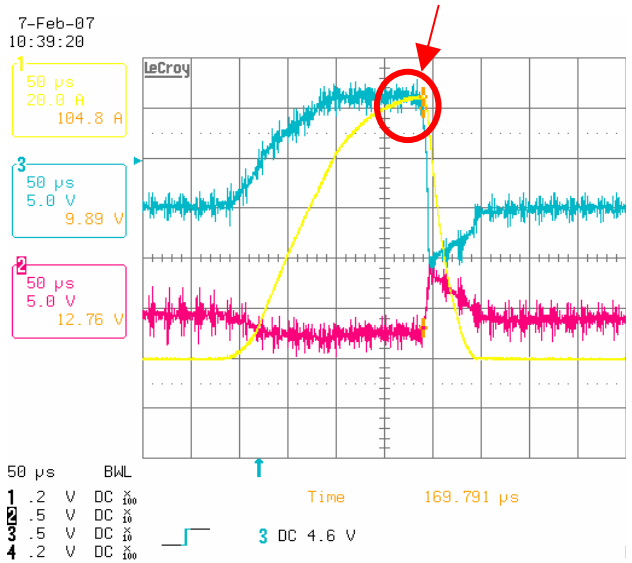
Electrical Characterization Set Up : -40° C and 100mOhm short circuit condition

-40°C and 100mOhm Short circuit condition



L_{supply}	4µH
R_{supply}	5m Ω
L_{short}	3µH
R_{short}	**87 + 17m Ω**

Shutdown due to Overcurrent High detection after 200us



During turn On: => Energy = 84mJ in 200µs

During turn Off: => Energy = 50mJ in 50µs

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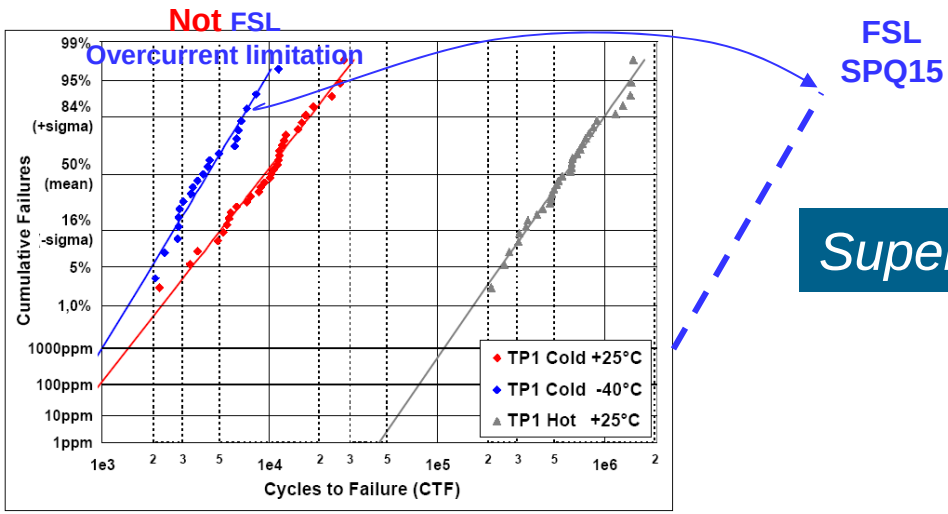
AECQ100-12 cold short circuit preliminary results

Grade	# Cycles	Lots/Samples per lot	# Fails
A	>1,000,000	3/10	0
B	>300,000 – 1,000,000	3/10	0
C	>100,000 – 300,000	3/10	0
D	>30,000 – 100,000	3/10	0
E	>10,000 – 30,000	3/10	0
F	>3,000 – 10,000	3/10	0
G	>1,000 – 3,000	3/10	0
H	300 – 1,000	3/10	0
O	< 300	3/10	0

-40° C, 100mOhm on 10 samples:

After 1 M cycles:

- **Rdson deviation < 5%**
- **CSNS deviation < 10%**
- **All Devices fully functional**



Superior robustness & reliability

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Over Current Protection Strategies

FSL devices		MC33888	MC33982 MC33984 MC33981	PC33580	Custom ICs	10XS3412* 15XS3400* 35XS3400*
Protection features		current limitation, unlatched overtemp	latched over-current, unlatched over temp	latched over-current, latched over temp	latched over-current, latched over temp, severe short-circuit, unlimited auto-restart	latched over-current profile, latched over-temp, severe short-circuit, limited auto-retry
Cold Repetitive short-circuit Short pulse	Terminal short-circuit	current limitation	OT unlatched (low Rds(on))	OT latched	SC latched	SC latched
	Load short-circuit	current limitation	latched over-current	latched over-current	OT latched	OC profile + OT latched
Cold Repetitive short-circuit Long pulse	Terminal short-circuit	current limitation	OT unlatched (low Rds(on))	OT latched	SC latched	SC latched
	Load short-circuit	current limitation	latched over-current	latched over-current	OT latched	OC profile + OT latched
Hot Repetitive short-circuit	Terminal short-circuit	OT unlatched	OT unlatched	OT + OC latched	No auto-retry in case of SC/OT	Limited auto-retry
	Load short-circuit	OT unlatched	OT unlatched	OT + OC latched	Unlimited auto-retry	Limited auto-retry

Ranking of potential test failure:

*GEN3

high

medium

low

no risk

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HPRA Preliminary Results

Table 1. Test Results Summary

Test Name	Ambient Temperature	Cycle Definition	OCHI level Configured	Fault Detected	Number of Cycles Passed Before the First Failure
Load short-circuit	-40° C	ON 10ms OFF 990ms	OCHI1	Latched over-current for 90A at 250 µ sec	1M cycles drain / source shorted together
Load short-circuit	+40° C	ON 10ms OFF 990ms	OCHI1	Latched over-current for 90A at 250 µ sec	382k cycles drain / source shorted together
Load short-circuit	+85° C	ON 10ms OFF 990ms	OCHI1	Latched over-current for 90A at 250 µ sec	on-going
Load short-circuit	+85° C	ON 10ms OFF 990ms	OCHI2	Latched over-current for 65A at 250 µ sec	> 1.2M cycles
Over-load	+40° C	ON 900ms OFF 9s	OCHI1	Latched over-current for 40A at 95msec	> 1M cycles
Terminal short-circuit	+85° C	ON 1ms OFF 99ms	OCHI1	Latched severe short-circuit for 40A at 100 µ sec	> 1M cycles

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MAKING EMC HAPPEN!

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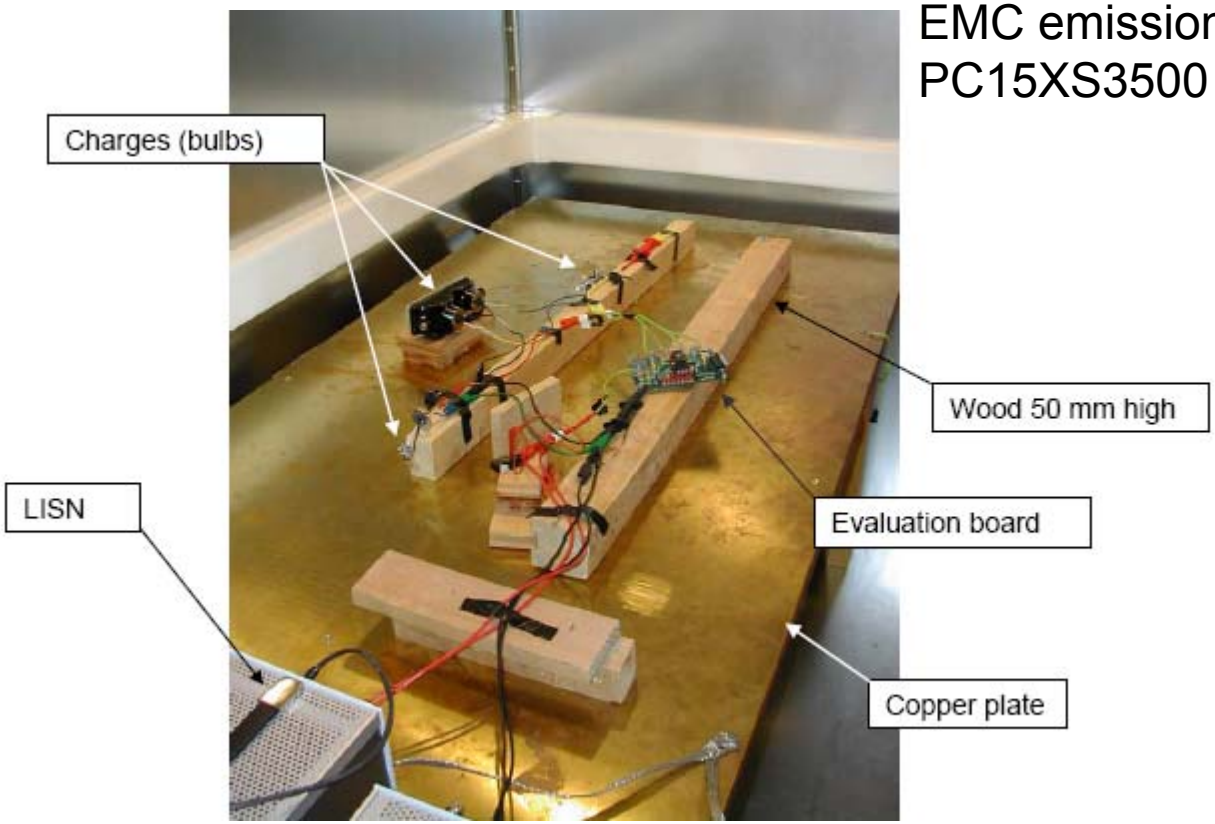
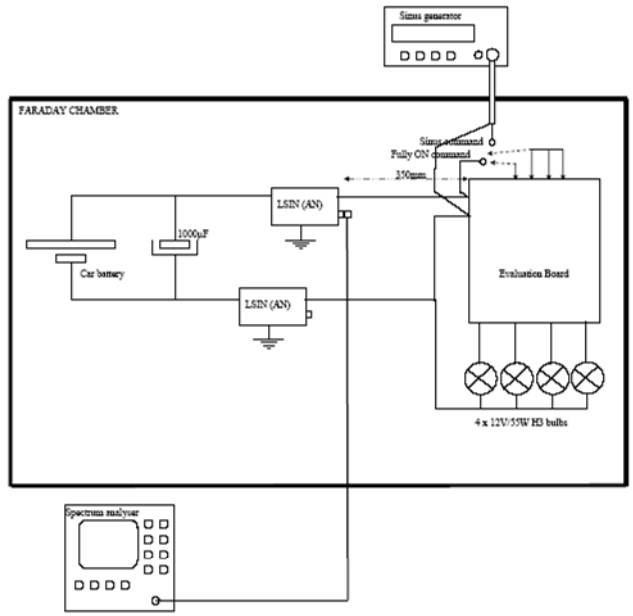
SPQ15 Conducted Emission

- **Conducted emissions tests were carried out in accordance with the CISPR25 standard**



EMC emission tests on SPQ15-PC15XS3500 device driving H3-55W bulbs



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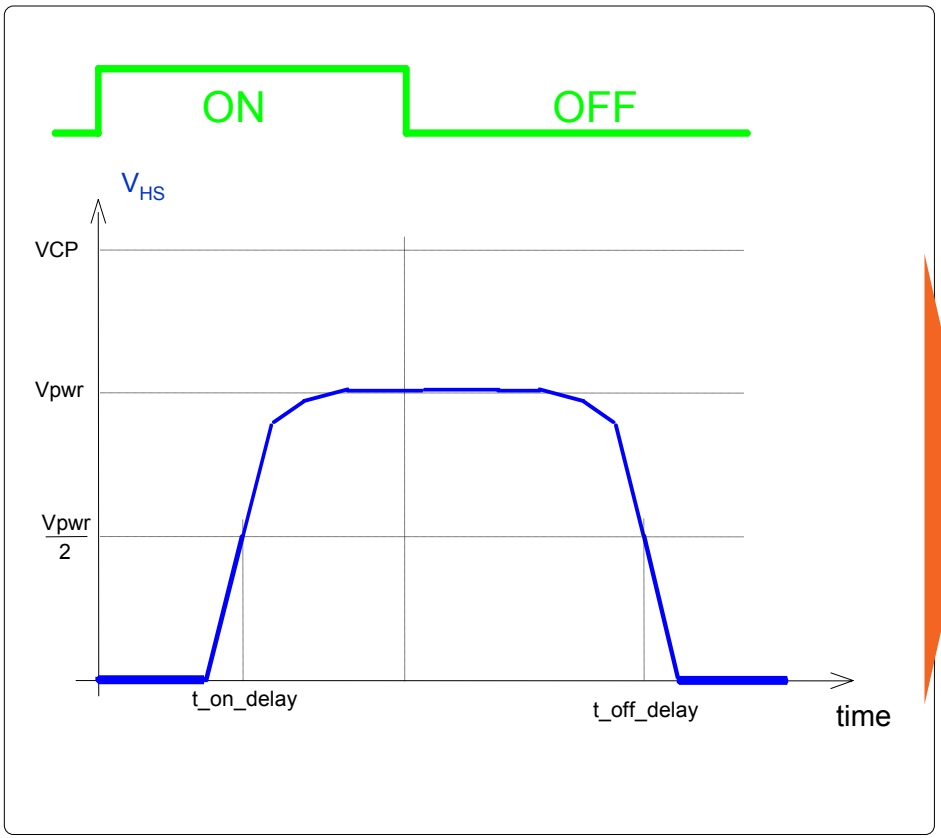
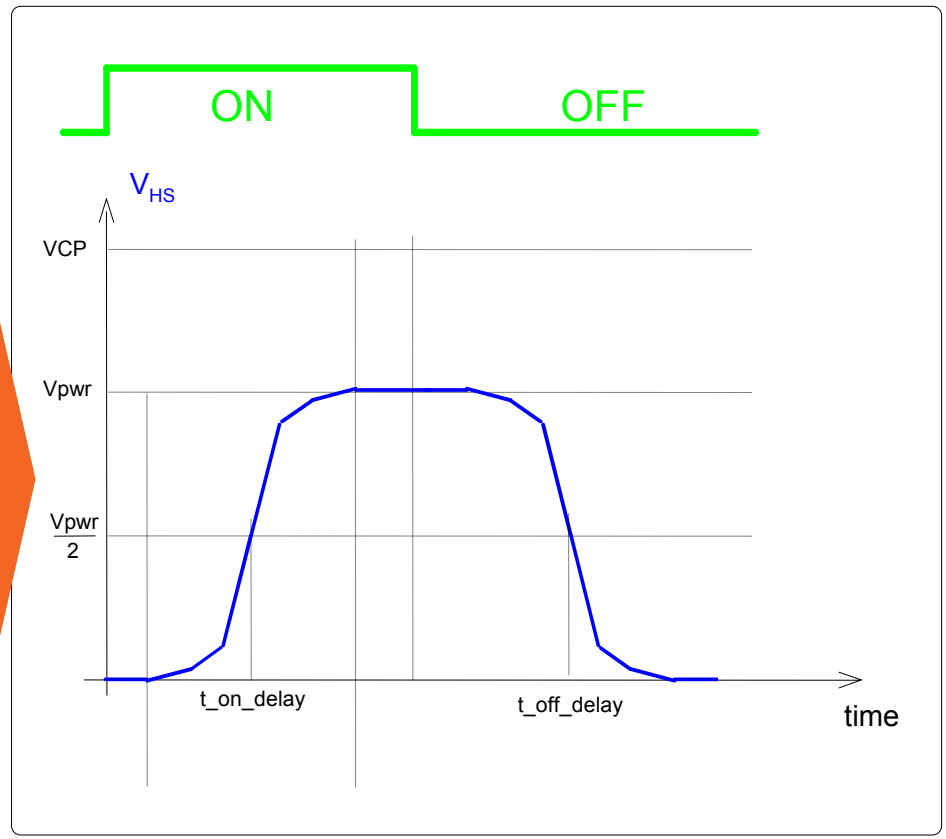
Output Switching

Gen II – MC33580



Gen III – 15XS3400



Main improvements:
EMC and PWM duty-cycle resolution < 1%

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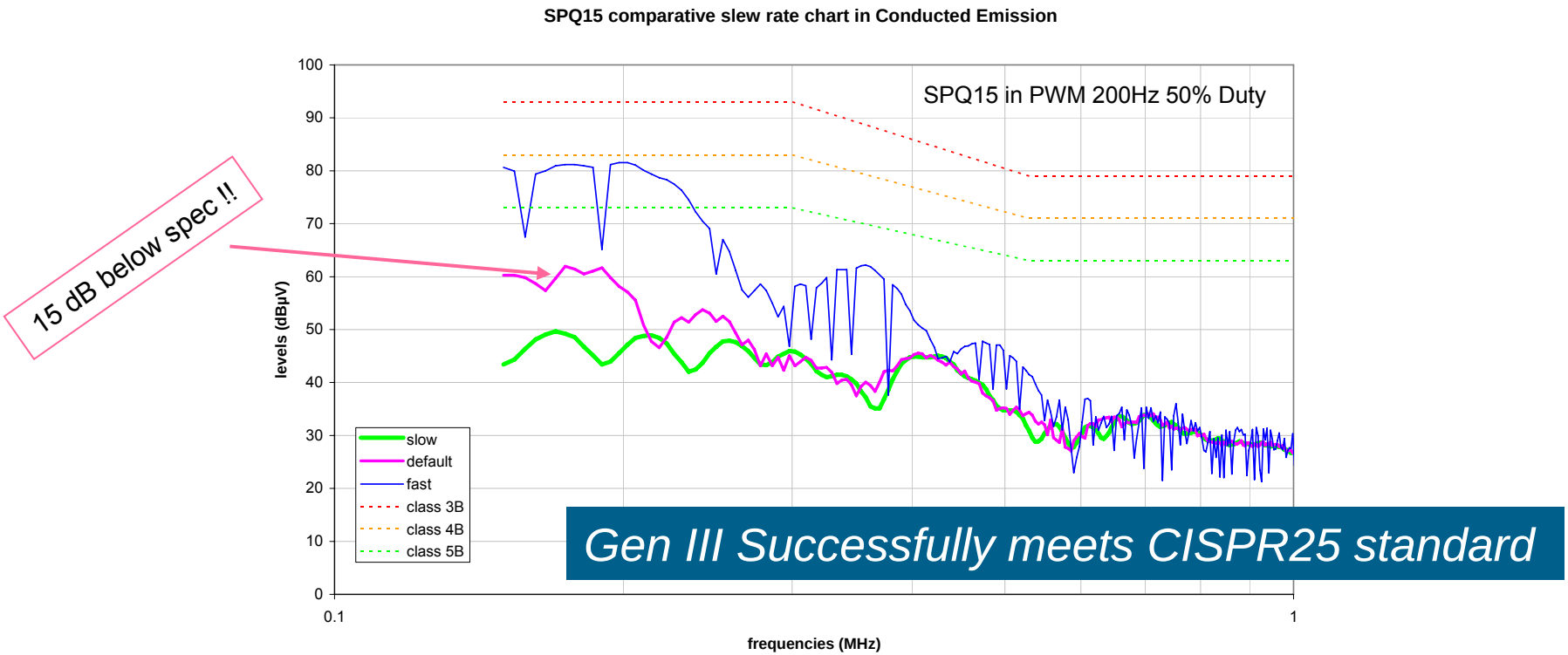
SPQ15 Conducted Emission Results

The Gen III device has been characterized for automotive lighting application (using Quad 15m Ohms).

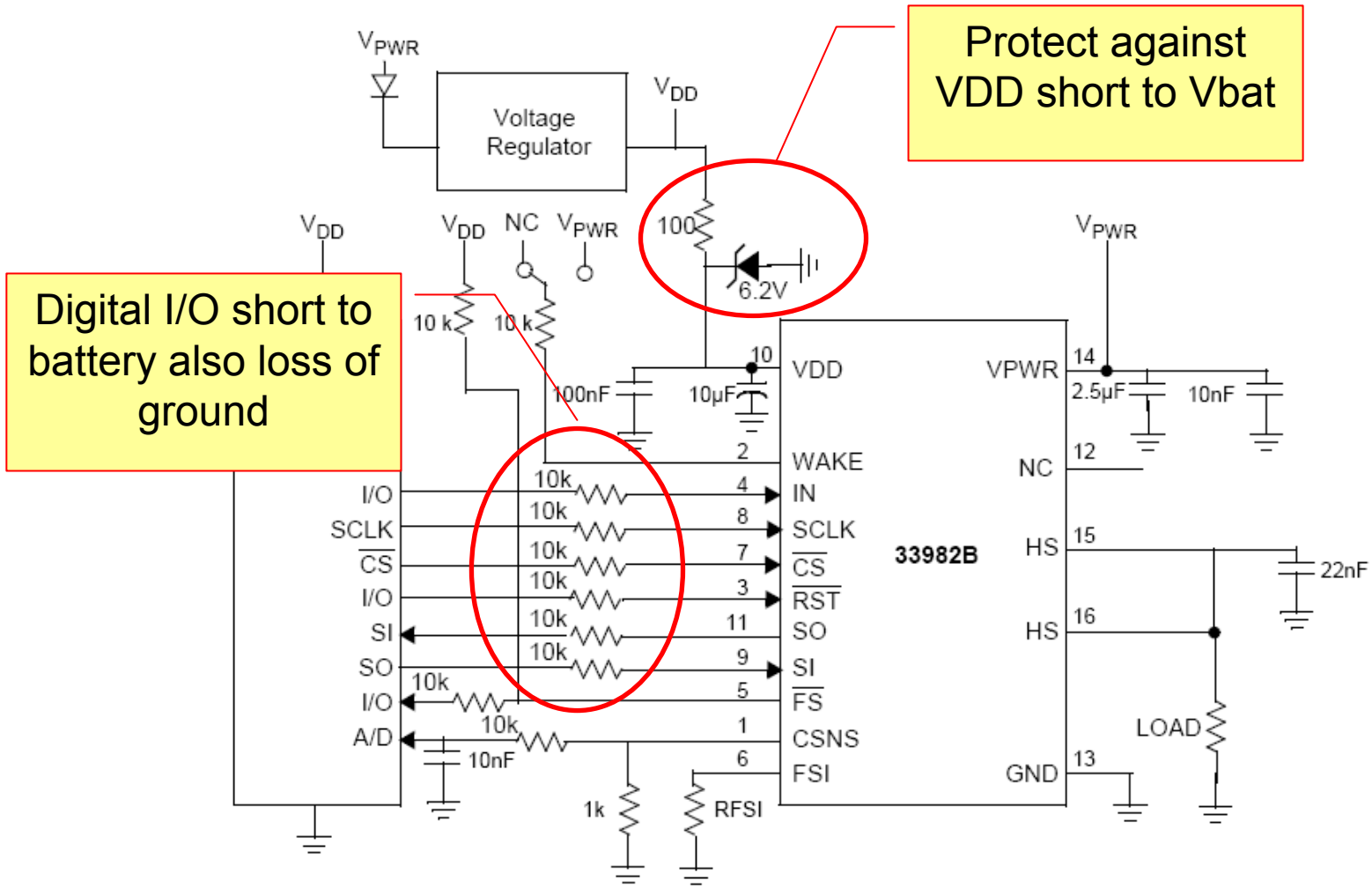


Decoupling capacitors used:

- on VPWR: 22nF located to the supply connector and 1nF closed to the IC,
- for each output: 22nF located to the output connector.

SUPPORTING PARTS

A Typical Safe Application Schematic



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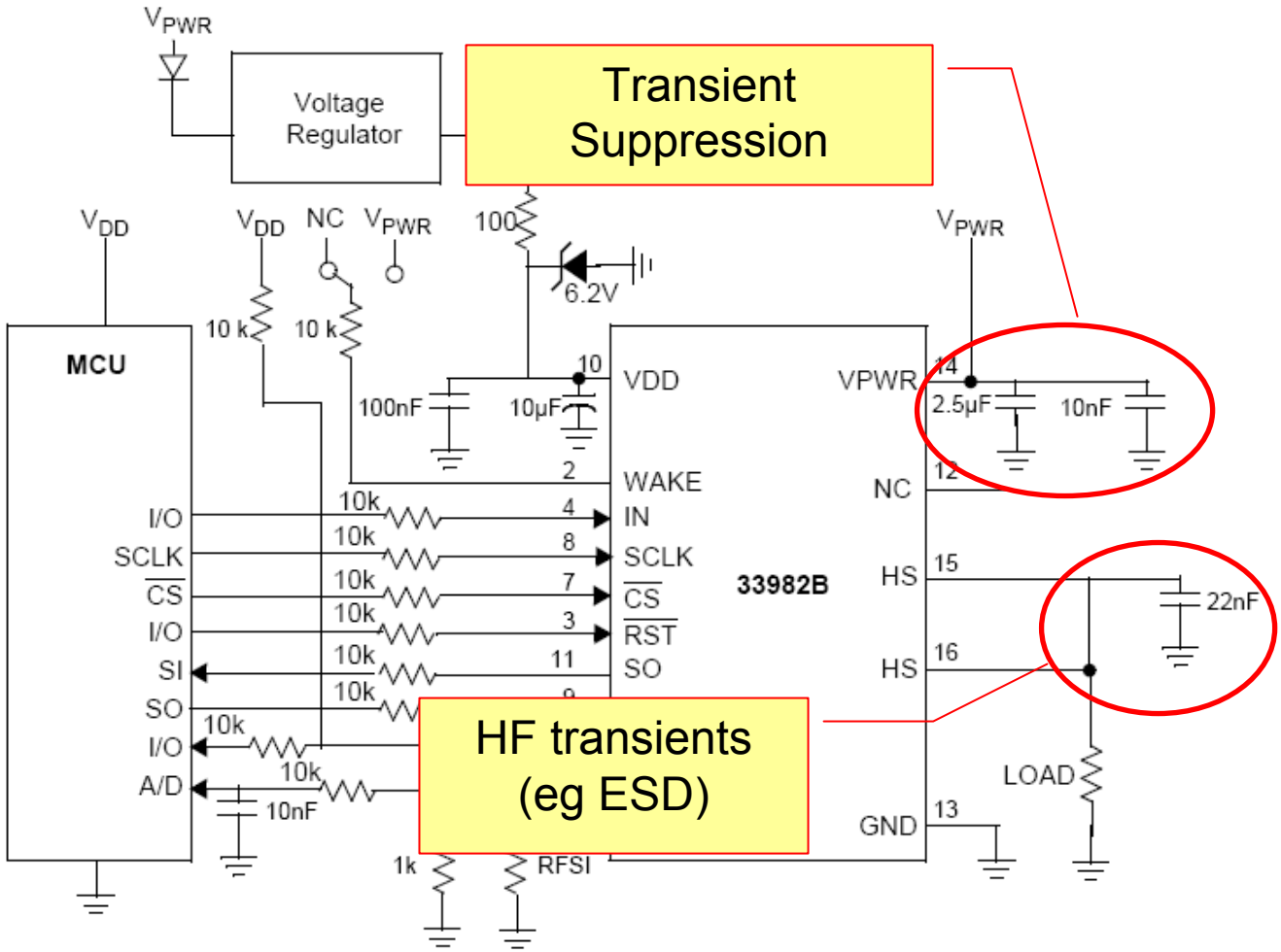
A Typical Safe Application Schematic



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A FEW THOUGHTS ON LAYOUT

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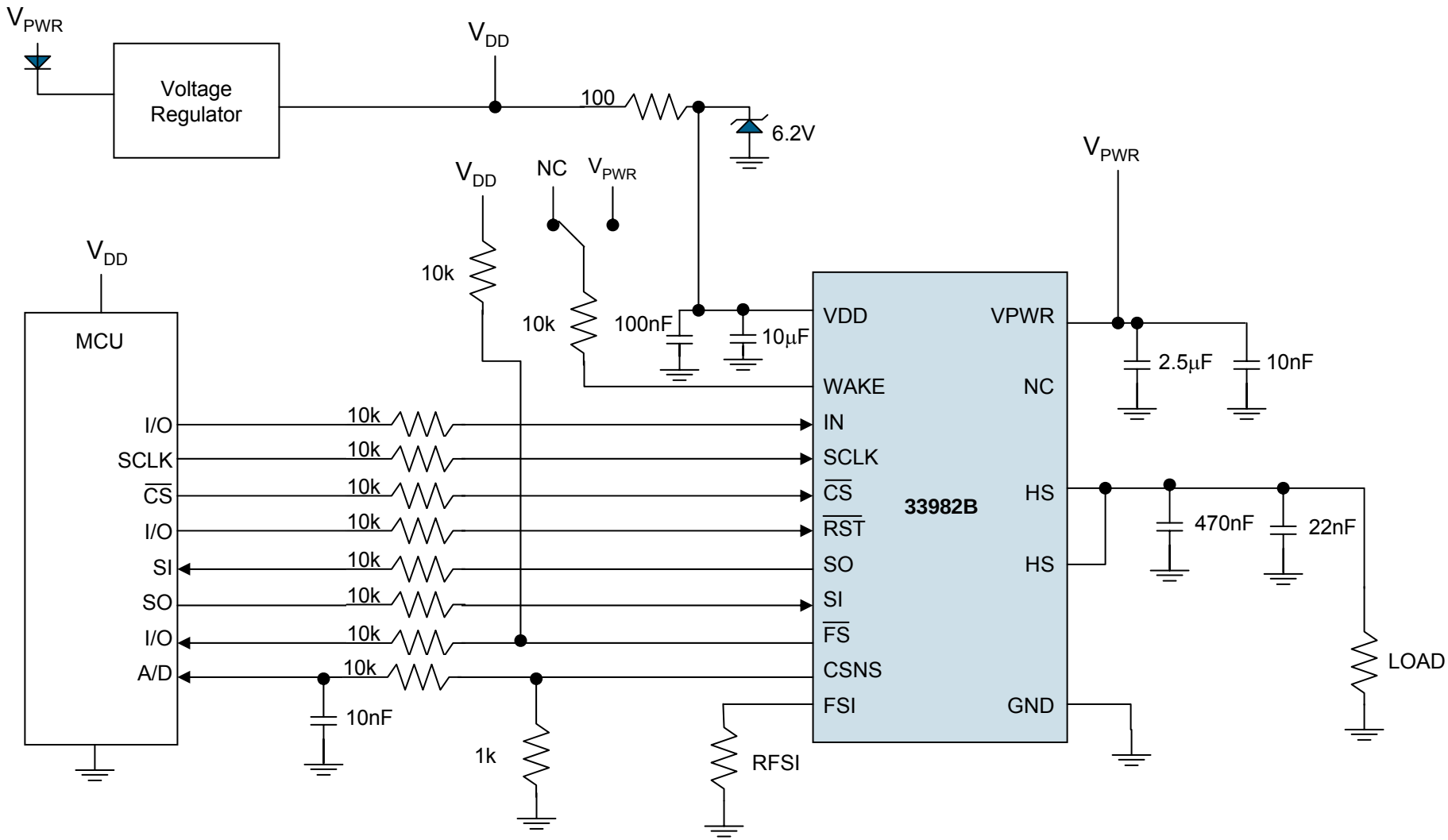
Component Placement



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Layout Considerations

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Application Note

AN2467
Rev. 4.0, 4/2007

Power Quad Flat No-Lead (PQFN) Package

1 Purpose

This document provides guidelines for Printed Circuit Board (PCB) design and assembly. Package performance attributes such as Moisture Sensitivity Level (MSL) rating, board level reliability and Thermal Resistance data are included as reference.

2 Scope

This document is written to generically encompass several different Power Quad Flat No-Lead (PQFN) packages assembled at Freescale internal assembly sites and external subcontractor sites. It should be noted that device specific information is not provided. This document serves only as a guideline to assist in the development of user specific solutions. Development effort will still be required by end users to optimize PCB mounting processes and board design.

Contents

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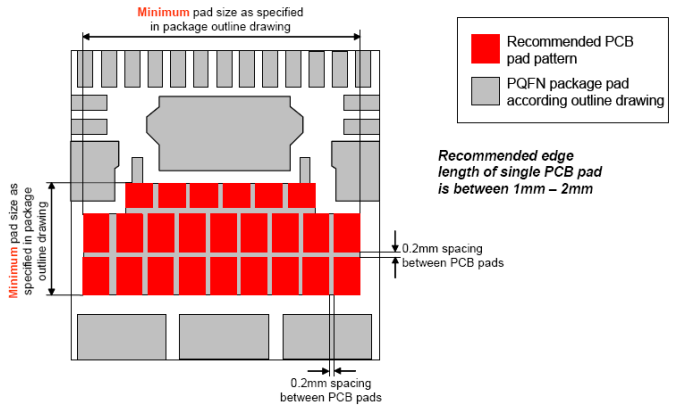
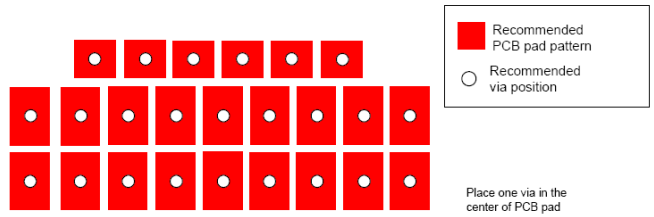


Figure 13. PCB Pad Design



Recommended via diameter is 0.5mm.
PTH (plated through hole) via must be plugged/ filled with epoxy or solder mask in order minimize void formation and to avoid any solder wicking into the via.

Figure 14. Via Design

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Layout Considerations

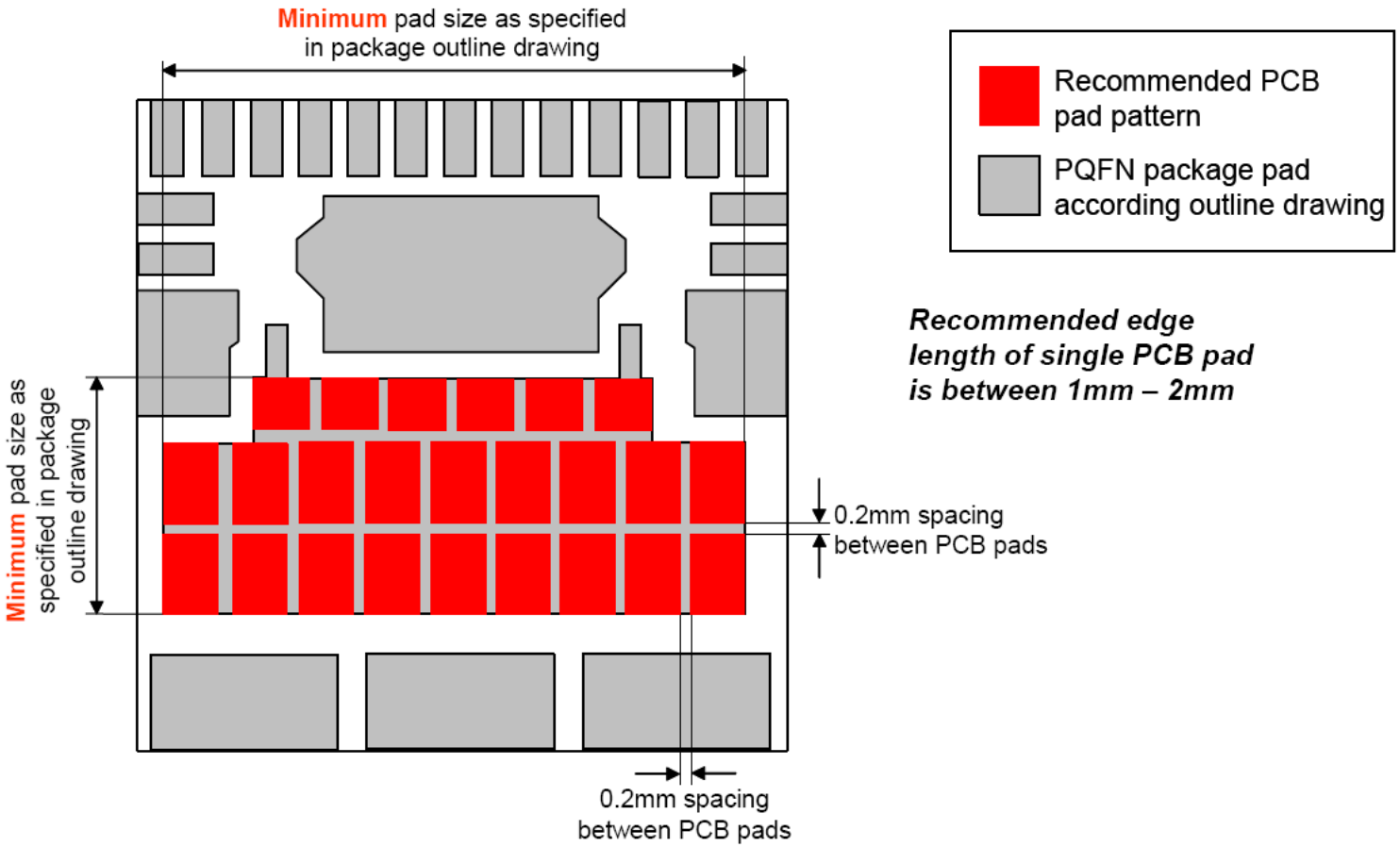

Figure 13. PCB Pad Design

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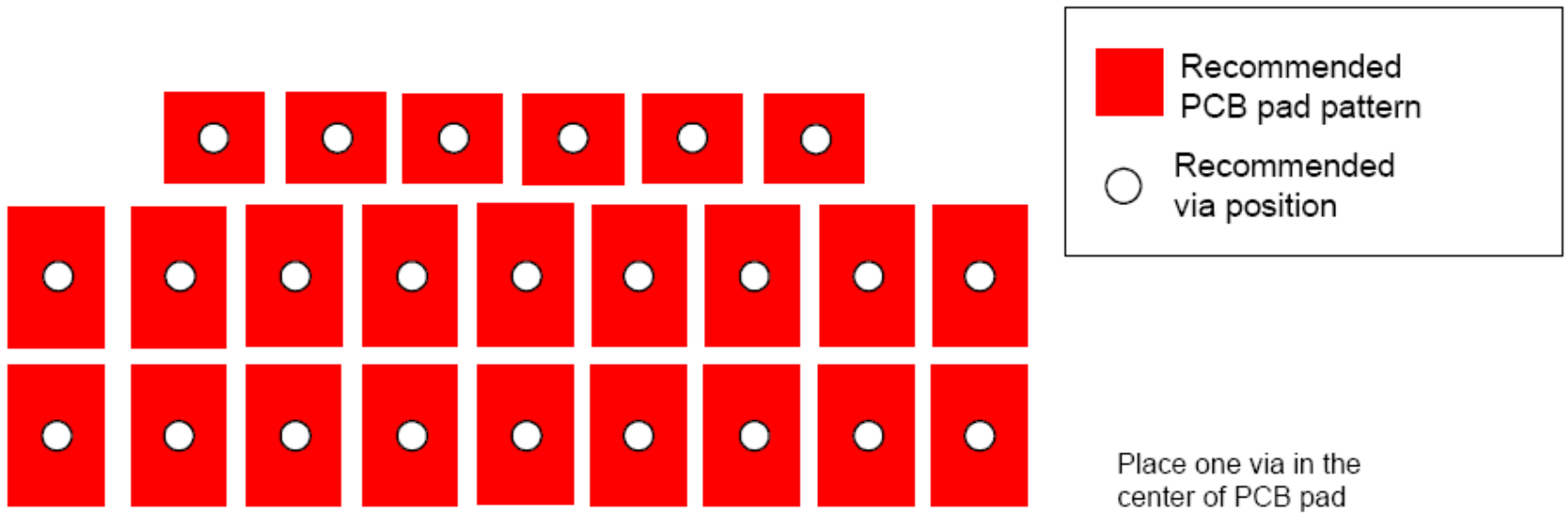
Layout Considerations



Recommended via diameter is 0.5mm.
PTH (plated through hole) via must be plugged/ filled with epoxy or solder mask in order minimize void formation and to avoid any solder wicking into the via.

Figure 14. Via Design

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Layout Considerations

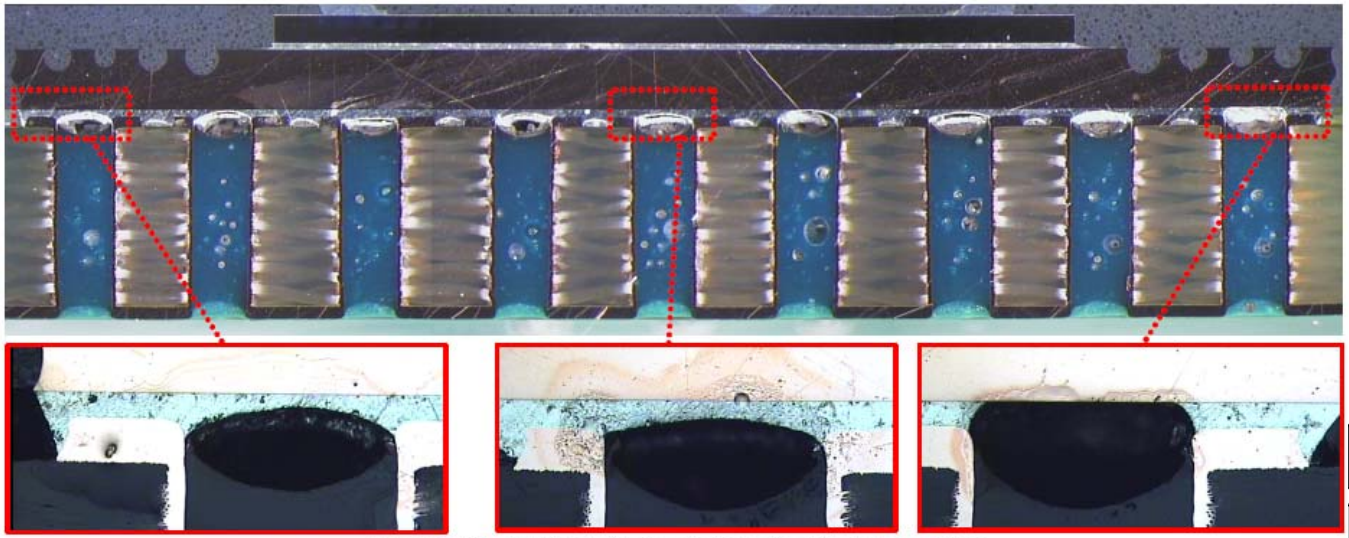

Figure 17. Typical Appearance in Cross-section

Typical appearance of the completed solder joint of the large exposed pad. Fully wetted pads with non-wetted via area.

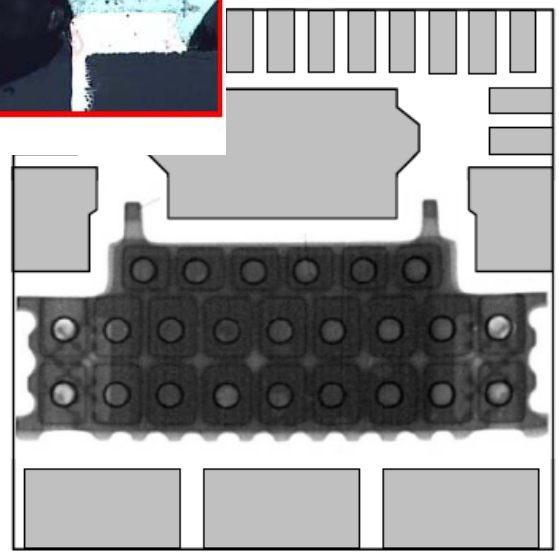

Figure 16. Typical Appearance of Assembly in X-ray

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Available Tools

• Datasheets	☑ Available
• Thermal datasheets	Under preparation (Jan 08)
• Power dissipation Calculator	☑ Available
• Transient Overcurrent Profile Selector	☑ Available
• PQFN Application Note (AN2467) & Footprint Proposal	☑ Available
• eXtreme Switch Protection Guidelines (AN3274)	☑ Available
• EMC, Shaffner reports and ESD Engineering Bulletin	☑ Available
• AECQ100-12 test preliminary Engineering Bulletin	☑ Available
• EVB	☑ Available*

*small quantities, upon request

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Related Session Resources

Session Location – Online Literature Library

http://www.freescale.com/webapp/sps/site/homepage.jsp?nodeId=052577903644CB

Sessions

Session ID	Title

Demos

Pedestal ID	Demo Title

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