1 Scope

The scope of this application note is to provide an indication how to strip the buck boost reference design to reach the minimum bill of materials for a CISPR25 Class 3 compliant 6W solution.

2 Operating conditions

This application is designed for 6 rebels in series at 350mA (~ 6W).
Functional between VBAT = 9 and 16V

3 EMC tests

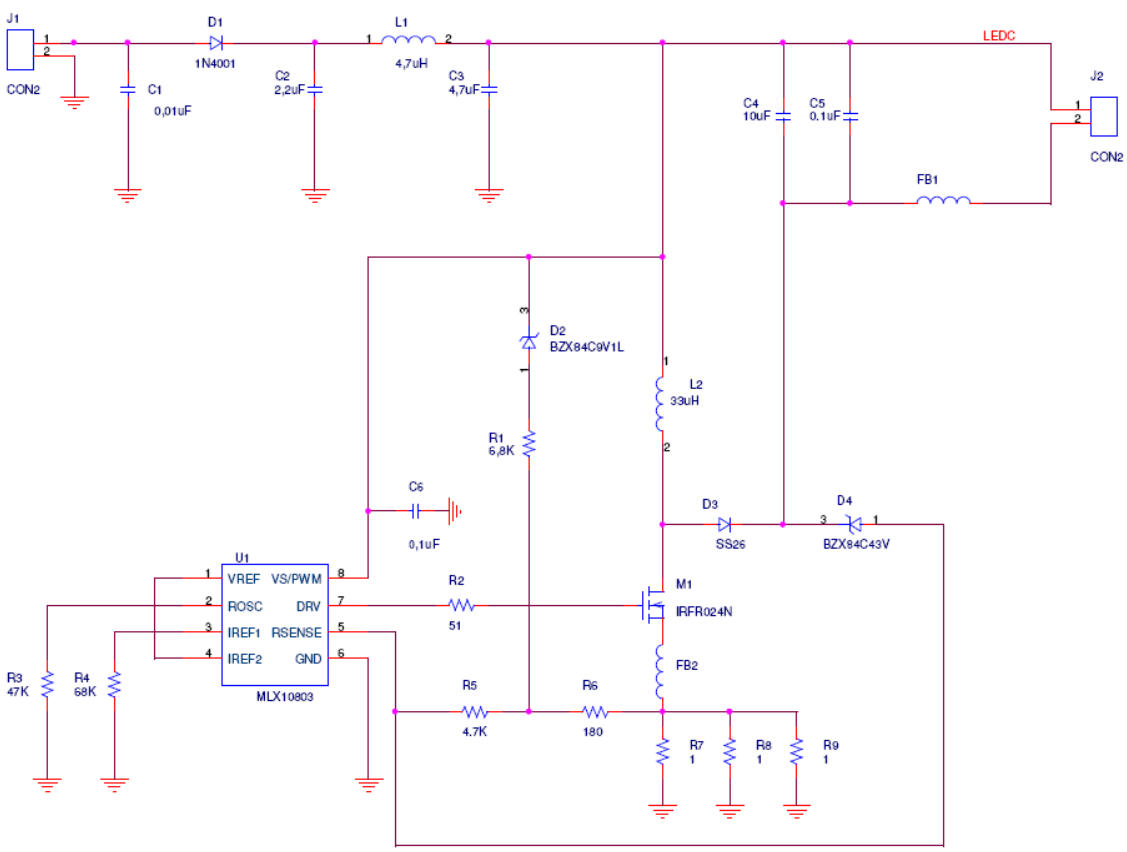
This design is targeted for lowest cost Class 3 compliancy.
Actual EMC tests may be executed in the future. At that point the applications note will be updated.

4 Application schematic

4.1 Starter values

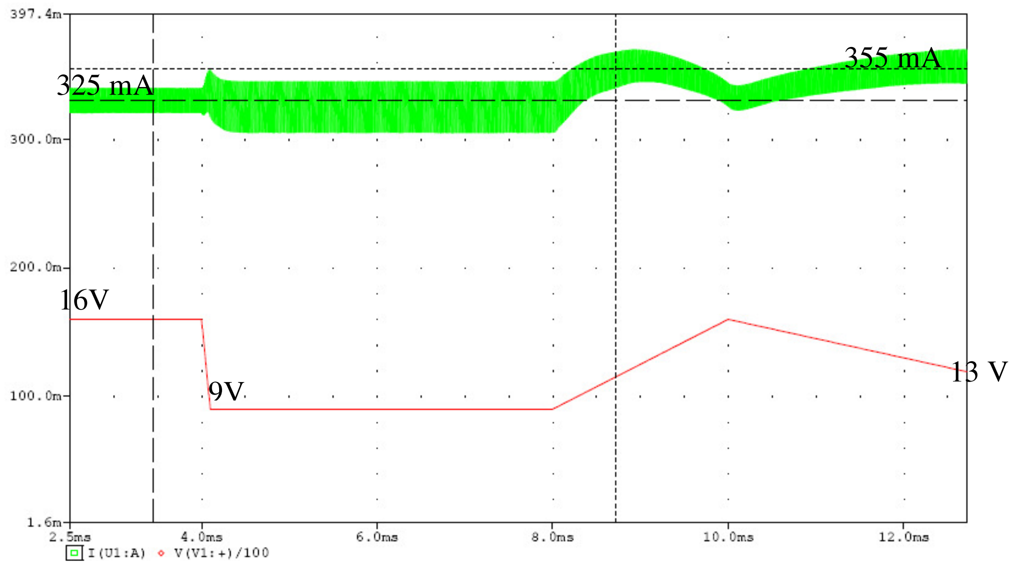
INPUT DATA		OUTPUT DATA	
Min. supply, VS	9	I coil_peak (VSmin) , A	2.24
Nom. supply, VS	13	I coil_peak (VSnom) , A	1.91
Max. supply, VS	16	I coil_peak (VSmax) , A	1.78
LED Forward Voltage, VF	3.2	Rosc, Kohm	68
Number of LEDs in series	6	Rsense, Ohm	0.17
Average current: LED , mA	350	Rshunt_CM, Ohm	0.21
Tmonoflop, uS	4.1	Min. switching frequency, kHz	81
L (the Coil), uH	33	Nom. switching frequency, kHz	112
		Max. switching frequency, kHz	129
		Avg. current FET (Vsmin), A	1.68
		Nom Output Capacitor Co, uF	8.9

4.2 Application schematic



4.3 Tolerances

- Zener D2 as feedforward compensation for changes in VBAT of the average LED current.
- The simulation does not include the reverse polarity diode



LED current(green) varies+/- 3.5% as a function of VS
355mA @13V, 330mA @9V and @16V

5 BOM

Q-ty	Ref.	Part	Part Spec.	Package	Manuf.
1	C1	0,01uF	X7R,+/-10%,50V	1206	
1	C2	2,2uF	X7R,+/-10%,50V	1210	
1	C3	4,7uF	X7R,+/-10%,50V	1210	
1	C4	10uF	X7R,+/-10%,50V	1210	
2	C5,C6	0,1uF	X7R,+/-10%,50V	805	
1	D1	1N4001	diode		
1	D2	SS26	Shottky diode		
1	D3	BZX84C43V	Zener diode	SOT-23	
1	D4	BZX84C9V1	Zener diode	SOT-23	
2	FB1,FB2	BLM18PG331	ferrite bead	603	Murata
1	L1	4,7uH	CDRH8D28N-4R7N		Sumida
1	L2	33uH	CDRH104R-330N		Sumida
1	M1	PMV213SN	100V, MOSFET	SOT-23	Philips
1	R1	6,8K	1/8W,+/- 5%,50V	805	
1	R2	51	1/4W,+/- 5%,50V	805	
1	R3	47K	1/8W,+/- 5%,50V	805	
1	R4	68K	1/4W,+/- 5%,50V	805	
1	R5	4,7K	1/4W,+/- 5%,50V	805	
1	R6	180	1/8W,+/- 5%,50V	805	
3	R7..R9	1	1/8W,+/- 1%,50V	805	
1	U2	MLX10803	LED driver	SO-8	Melexis

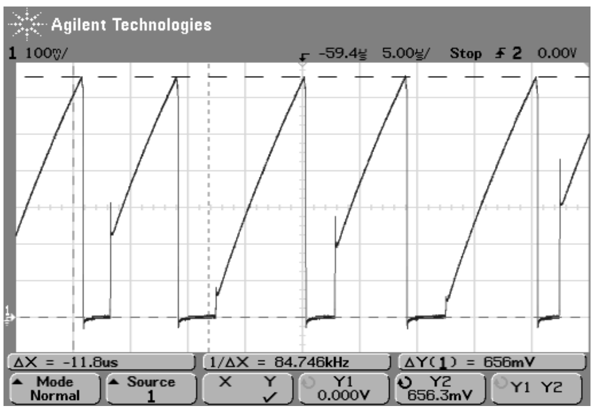
Cost reduction remarks:

- Capacitor C4 minimizes the ripple on the LED current. As calculated a 8.9uF should limit the ripple to max +/-10% at VS =13V. If supply ripple is not important this component can be reduced even to 100nF.
- FB1 may be removed if there is margin in the FM radio band.
- C5 may be removed if there is margin in the 10MHz band
- Rshunt: 333 mOhm is the highest recommended Rshunt value in order to set the overcurrent protection, and set the Zener compensation network. Also for efficiency it is not recommended to increase the shunt value.

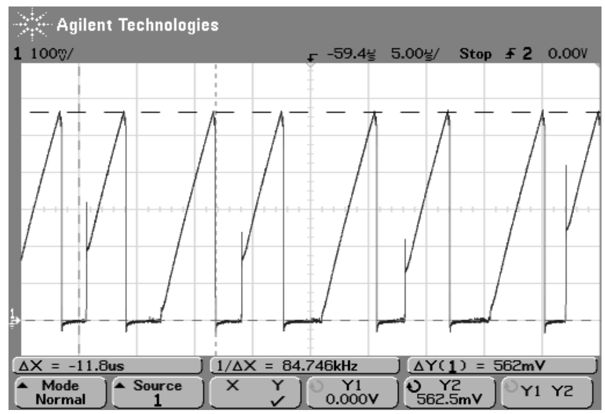
6 Measurement results

- Rosc = 47K => Tmon = 2,9 usec
- Rsense = 0.33 Ohm
- LED total Forward Voltage = 17,7V
- Applied coil = 33uH

Below plots show the operation in continuous conduction mode.



VS = 9V, Freq ~ 95kHz
Ipeak = 660mV/330mOhm = 2A



VS = 13V, Freq ~ 145kHz
Ipeak = 562mV/330mOhm = 1.70A

Measurement results (without reverse polarity diode):

VIN(V)	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
IIN(mA)	775	718	668	616	572	521	477	425
PIN(W)	6.98	7.82	7.35	7.39	7.44	7.29	7.16	6.8
PLED(W)	5.59	5.84	6.04	6.15	6.15	6.02	5.97	5.62
ILED(mA)	315	330	336	341	341	338	335	321
Efficiency	**80%**	**82%**	**82%**	**83%**	**83%**	**83%**	**83%**	**83%**
ILED Toler.	**7%**	**3%**	**2%**	**0%**	**0%**	**1%**	**2%**	**6%**

ILED tolerance is +/-5% from 9V to 16V. The tolerance can be reduced to +/-2% when using the current mirror compensation network as explained in the Buck boost reference design application note.

7 Comparison with 68uH for improved efficiency

INPUT DATA	
Min. supply, V	13
Max. supply, V	16
LED threshold, V	2.95
Number of LEDs in chanel	6
Average current: LED , mA	350
Tmonoflop, uS	2.9
L (the Coil), uH	33

OUTPUT DATA	
I coil_peak, A	1.62
Rosc, Kohm	47
Rsense, Ohm	0.23
Rshunt, Ohm	0.21
Min. switching frequency, kHz	142
Max. switching frequency, kHz	160
Avg. current MLX10801 or FET	1.38
Output Capacitor Co, uF	7.5

INPUT DATA	
Min. supply, V	13
Max. supply, V	16
LED threshold, V	2.95
Number of LEDs in chanel	6
Average current: LED , mA	350
Tmonoflop, uS	2.9
L (the Coil), uH	68

OUTPUT DATA	
I coil_peak, A	1.35
Rosc, Kohm	47
Rsense, Ohm	0.28
Rshunt, Ohm	0.21
Min. switching frequency, kHz	101
Max. switching frequency, kHz	116
Avg. current MLX10801 or FET	0.95
Output Capacitor Co, uF	12.9

Using the above calculated values, we find that

- For PLED = 6.2 W
- And assuming FET + shunt DC resistance value ~ 50+333 ~ 380 mOhm
- Using 33 uH => Dissipated power is 1.38^2*0.38 = 0.72W (12%)
- Using 68 uH => Dissipated power is 0.95^2*0.38 = 0.34W (6%)

In practice we measure an improvement of 5%.

Conclusion:
The efficiency increases significantly when applying a 68uH coil in stead of a 33uH coil. The main reason is the increased average current (through the FET and the shunt.
Reducing the shunt value to for instance 170mOhm will improve the efficiency with 5%.

Remark:
In the above example the monoflop time has not been optimized. The reduced switching frequency of the 68uH case implies a larger ripple and therefore the BB_coil calc suggests a larger output capacitor.