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NCV881930/NCV891930 - Mixed Capacitor Technology Filtering

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APPLICATION NOTE

Introduction

High output current applications subject to large load transients may be implemented with an all−ceramic technology output filtering solution. The bulk output capacitance requirement can become somewhat costly and occupy substantial PCB area. A lower cost solution is obtained through the use of mixed technology ceramic and aluminum polymer (or solid aluminum electrolytic) capacitors.

NCV881930 and NCV891930 Output Capacitor Filtering

NCV881930 (410 kHz) and NCV891930 (2 MHz) are low quiescent current automotive synchronous buck controllers having internal preset slope and feedback loop compensation. Preset internal compensation results in fixed current sense resistors and output filtering component values. IC internal compensations were optimized for designs having large load transients requiring larger value bulk output capacitor filters. Recommended current sense resistor and output filter components in Figure 1 are provided in Table 1 and Table 2 and for all−ceramic capacitor solutions.

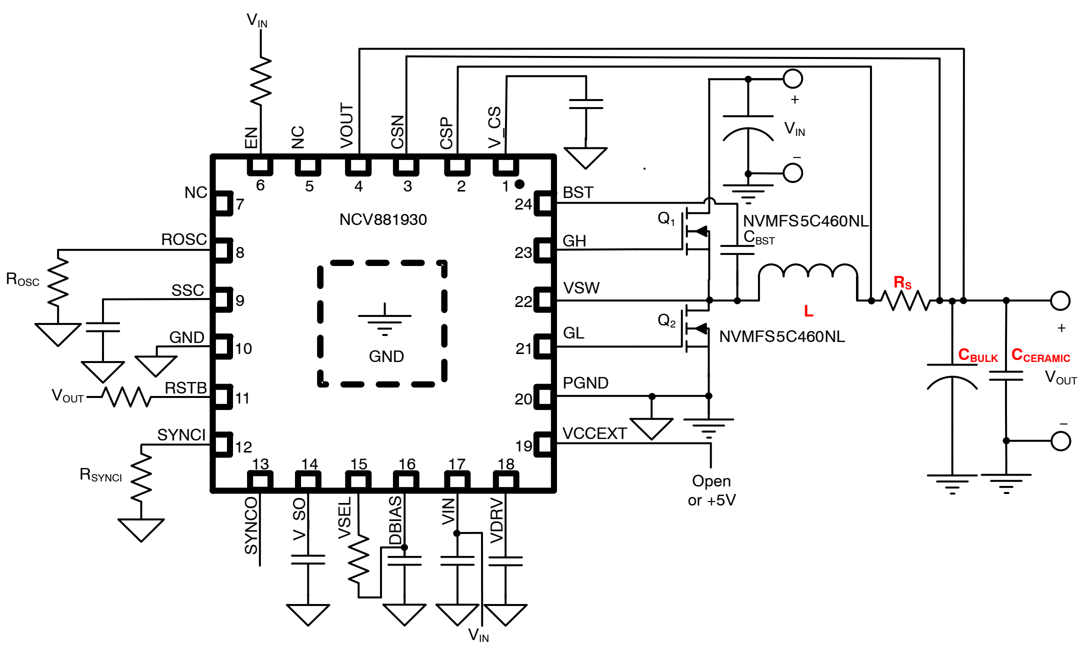

Figure 1. NCV881930 5 V Application Schematic Example

Table 1. 410 kHz NCV881930MW00R2G VALUE RECOMMENDATIONS

Output Current (A)	MOSFET	3.3 V Option			5 V Option		
		Inductor Value (µH)	Current Sense Resistor (Ω)	Output Capacitance (Ceramic) (µF)	Inductor Value (µH)	Current Sense Resistor (Ω)	Output Capacitance (Ceramic) (µF)
6	NVMFS5C460NL	3.3	(2x0.012) 0.006	(11x22) 242	4.7	(2x0.012) 0.006	(9x22) 198
7	NVMFS5C460NL	3.3	(2x0.011) 0.0055	(13x22) 286	3.3	(2x0.010) 0.005	(10x22) 220
8	NVMFS5C460NL	2.2	(2x0.009) 0.0045	(15x22) 330	3.3	(2x0.009) 0.0045	(12x22) 264
9	NVMFS5C460NL	2.2	(2x0.008) 0.004	(16x22) 352	3.3	(2x0.008) 0.004	(13x22) 286
10	NVMFS5C460NL	2.2	(2x0.007) 0.0035	(18x22) 396	2.2	(2x0.007) 0.0035	(13x22) 286

Table 2. 2 MHz NCV891930MW00R2G VALUE RECOMMENDATIONS

Output Current (A)	MOSFET	3.3 V Option			5 V Option		
		Inductor Value (µH)	Current Sense Resistor (Ω)	Output Capacitance (Ceramic) (µF)	Inductor Value (µH)	Current Sense Resistor (Ω)	Output Capacitance (Ceramic) (µF)
2	NVTFS5C478NL NVMFD5C470NL	2.2	0.028	(7x10) 70	3.3	0.028	(5x10) 50
3	NVTFS5C478NL NVMFD5C470NL	1.5	0.018	(11x10) 110	2.2	0.0195	(8x10) 80
4	NVTFS5C478NL	1.0	0.0135	(14x10) 140	1.5	0.0135	(11x10) 110
5	NVMFS5C468NL	0.80	0.011	(18x10) 180	1.2	0.011	(12x10) 120
6	NVMFS5C468NL	0.65	0.009	(22x10) 220	1.0	0.009	(15x10) 150

Minimum bulk capacitance requirement is dependent on output current, load transient amplitude and output voltage transient response from the application specifications. All−ceramic technology solutions may become cost prohibitive at higher current ratings. A technology mix of ceramic and aluminum polymer (or solid aluminum electrolytic) capacitors will result in a lower cost solution and occupy less PCB area. Mixed capacitor technology recommendations provided in Table 3 and Table 4 are based on an analysis for a ± 3% maximum voltage transient response for a load step current transient of 50% to 100% of rated current.

Ceramic capacitor component deratings are described in the NCV881930 and NCV891930 IC datasheet's application note section. Aluminum−polymer capacitance initial derating of 20% were included for the analysis; additional derating may need to be considered.

Bulk Capacitor Filter Analysis

There is limited literature available for practical guidelines for selecting mixed technology capacitor values for output filtering. The approach used in this application note is as follows:

- Determine a minimum ceramic capacitor value based on steady−state output current operation to meet ripple and noise filtering requirements [1] using equation 1.
- Determine a minimum bulk capacitor value for the load transient [2] using equation 3 which includes bulk capacitor ESR.

$$C_{ceramic} = \frac{1}{(2\,\pi\,f_o)^2 \cdot L} \qquad \text{(eq. 1)}$$

where

$$f_o = \frac{f_s}{\pi} \cdot \sqrt{\frac{2\,\Delta V_{ripple}}{(1 - D_{min}) \cdot V_{out}}} \; \text{(Hz)} \qquad \text{(eq. 2)}$$

L = output inductor (H)
f_s = switching frequency (Hz)
D_{min} = minimum duty ratio
ΔV_{ripple} = steady state ripple voltage (V)

$$C_{out\_minimum} = \frac{1}{2\,\pi\,f_c} \cdot \frac{1}{phasemargin_{factor} \cdot \frac{\Delta V_{transient}}{\Delta I_{loadstep}} - ESR_{Cout}} \quad (eq.\ 3)$$

where
f_c = power supply bandwidth (Hz)
$\Delta V_{transient}$ = maximum load transient voltage (V)
$\Delta I_{loadstep}$ = load transient current (A)
ESR_{Cout} = bulk capacitor ESR (Ω)

$$phasemargin_{factor} = \sqrt{1 - 2\cos(phasemargin)}$$

Table 3. NCV881930MW00 RECOMMENDED MIXED TECHNOLOGY CAPACITORS

Iout (A)	Technology	NCV881930MW00	
		3.3 V	5 V
6	Ceramic	2 x 22 μF	2 x 22 μF
	Alum Poly	2 x 120 μF	2 x 100 μF
8	Ceramic	2 x 22 μF	2 x 22 μF
	Alum Poly	2 x 180 μF	2 x 120 μF
10	Ceramic	2 x 22 μF	2 x 22 μF
	Alum Poly	2 x 220 μF	2 x 180 μF
14	Ceramic	–	3 x 22 μF
	Alum Poly	–	2 x 220 μF
20	Ceramic	–	3 x 22 μF
	Alum Poly	–	3 x 220 μF

Table 4. NCV891930MW00 RECOMMENDED MIXED TECHNOLOGY CAPACITORS

Iout (A)	Technology	NCV891930MW00	
		3.3 V	5 V
2	Ceramic	1 x 10 μF	1 x 10 μF
	Alum Poly	2 x 33 μF	1 x 56 μF
4	Ceramic	1 x 10 μF	1 x 10 μF
	Alum Poly	2 x 68 μF	2 x 56 μF
6	Ceramic:	1 x 10 μF	1 x 10 μF
	Alum Poly	2 x 120 μF	2 x 68 μF
8	Ceramic	2 x 10 μF	2 x 10 μF
	Alum Poly	2 x 180 μF	2 x 100 μF

Capacitors from Table 3 and Table 4 are described in Table 5:

Table 5. CAPACITOR INFORMATION

Capacitor	Technology	ESR (mΩ)
10 μF/10V X7R 1210	Ceramic	2.9
22 μF/10V X7R 1210	Ceramic	4.0
33 μF/6.3V 2917	Aluminum Polymer	28
56 μF/6.3V 2917	Aluminum Polymer	28
68 μF/6.3V 2917	Aluminum Polymer	28
100 μF/6.3V 2917	Aluminum Polymer	18
120 μF/6.3V 2917	Aluminum Polymer	15
180 μF/6.3V 2917	Aluminum Polymer	15
220 μF/6.3V 2917	Aluminum Polymer	15

Additional low value output noise ceramic decoupling capacitors are recommended (e.g. 0.1 μF, 1 nF).

Bulk capacitors having different ESR values may be considered subject to transient load response requirements. For a given load step current, a larger bulk capacitor ESR value results in an increased amplitude of the output voltage transient response.

Reference:

[1] C. Basso, “Switch−Mode Power Supplies – SPICE Simulations and Practical Designs”, McGraw−Hill, 2014.

[2] F. Mueller, “Predicting the Load Transient Response of Switch Mode Power Supplies”, www.bodospower.com, June 2015.

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