

Using TPS5410/20/30/31/50 With Aluminum/Ceramic Output Capacitors

Ning Tang

High Performance Analog

ABSTRACT

As internally compensated devices, the wide input step-down SWIFT™ DC/DC converters, including TPS5410/5420/5430/5431/5450, have the advantages of less external part count and reduced design complexity, as well as limited output capacitor selection. By adding a few external components into the standard circuitry, these devices generally work well with aluminum/ceramic output capacitors. This application report shows the step-by-step design procedures when using aluminum/ceramic output capacitors with the wide input SWIFT™ DC/DC converters. Two design examples are provided to better understand both procedures.

Contents

1	Introduction	2
2	Design Procedure for Aluminum Output Capacitors	3
3	Design Procedure for Ceramic Output Capacitors	7
4	Conclusion	11
Appendix A	Related RC Networks and Their Simplified Transfer Functions	12
Appendix B	References	13

List of Figures

1	TPS5430EVM-136 Schematic	2
2	Measured Loop Response for TPS5430EVM-136, Vin=10.8 V	2
3	Application Circuit 1 Using Aluminum Output Capacitor	3
4	Measured Loop Responses for Application Circuit 1, Io = 3 A	6
5	Measured Output Ripple for Application Circuit 1, Vin = 12 V and Vo = 5 V/3 A	6
6	Measured Load Transient Response for Application Circuit 1, Vin = 12 V	7
7	Application Circuit 2 Using Ceramic Output Capacitors	7
8	Measured Loop Responses for Application Circuit 2, Io = 3 A.....	10
9	Measured Output Ripple for Application Circuit 2, Vin = 12 V and Vo = 5 V/3 A.....	10
10	Measured Load Transient Response for Application Circuit 2, Vin = 12 V.....	11

List of Tables

1	Bill of Materials for Application Circuit 1	5
2	Bill of Materials for Application Circuit 2	9

SWIFT is a trademark of Texas Instruments.
POSCAP, OS-CON are trademarks of Sanyo Electric Company, Ltd..

1 Introduction

The internally compensated wide input SWIFT™ product family was specifically designed for high-performance applications using high-quality output capacitors such as POSCAP™ (solid electrolytic capacitors with polymerized organic semiconductor), OS-CON™ (aluminum solid capacitors with organic semiconductor electrolyte), tantalum, and super-low-impedance aluminum capacitors, etc. Adopted from the TPS5430EVM-136 3-A, SWIFT™ Regulator Evaluation Module User's Guide (SLVU149), [Figure 1](#) shows the schematic of TPS5430EVM-136 using 10TPB220M (POSCAP) and [Figure 2](#) shows the measured loop-response characteristics at $V_{in}=10.8\text{ V}$ and 5-V/3-A output. Additional details in this user's guide illustrate the performance of the design using POSCAP.

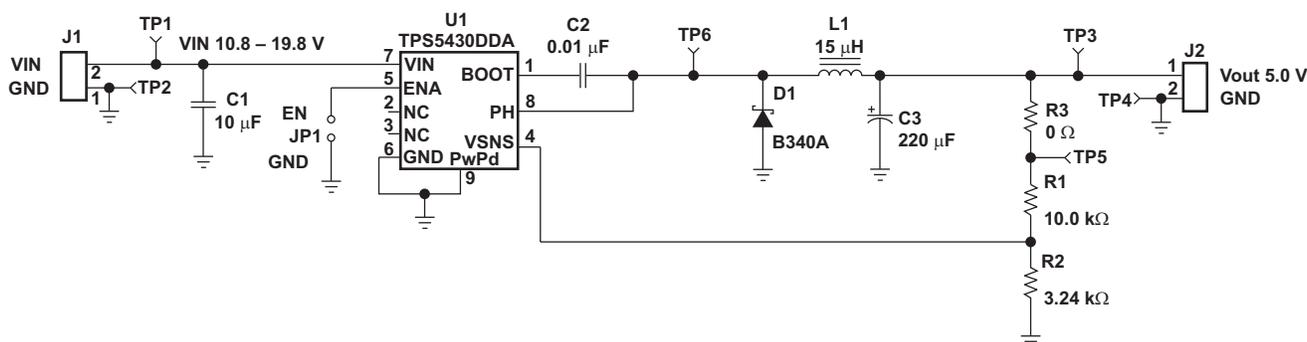


Figure 1. TPS5430EVM-136 Schematic

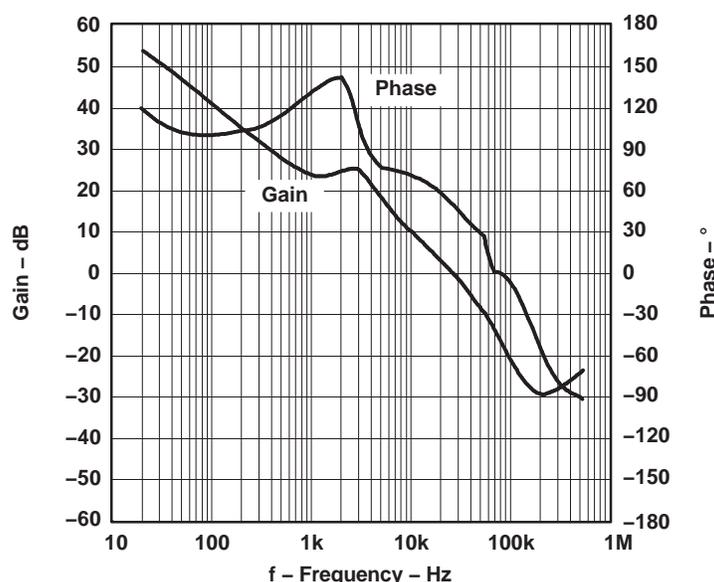


Figure 2. Measured Loop Response for TPS5430EVM-136, $V_{in}=10.8\text{ V}$

The ESR (equivalent series resistance) value of output capacitors plays an important role in the system stability of step-down DC/DC converters because of the resulting ESR zero in the power-stage frequency response. The ESR zero, which could be as low as 1 kHz for aluminum capacitors and as high as 5 MHz for ceramic capacitors, impacts both the gain response and the phase response. This makes it difficult for the fixed internal compensation network to work with a broad range of various aluminum/ceramic output capacitors. However, this does not preclude applications with aluminum/ceramic output capacitors. By simply adding two or three more external small resistors and capacitors, which are usually referred as RC networks, flexible designs generally can be done.

The basic idea of the external RC networks is to re-shape the frequency response so that the system stability is improved. For advanced users, see Appendix A, *Related RC Networks and Their Transfer Functions*.

Two design procedures are discussed in this application report: one is for applications using aluminum output capacitors and the other is for applications using ceramic output capacitors. For other design procedures, including the use of an output inductor, see the application sections of relevant data sheets. This application report focuses only on designing the additional RC network.

2 Design Procedure for Aluminum Output Capacitors

Figure 3 shows a TPS5430 application circuit using an aluminum output capacitor. Compared to Figure 1, a typical TPS5430 design, Figure 3 shows that two external components C12 and R7 have been added. Using application circuit 1 as an example, the following design procedure shows how to select component values for C12 and R7.

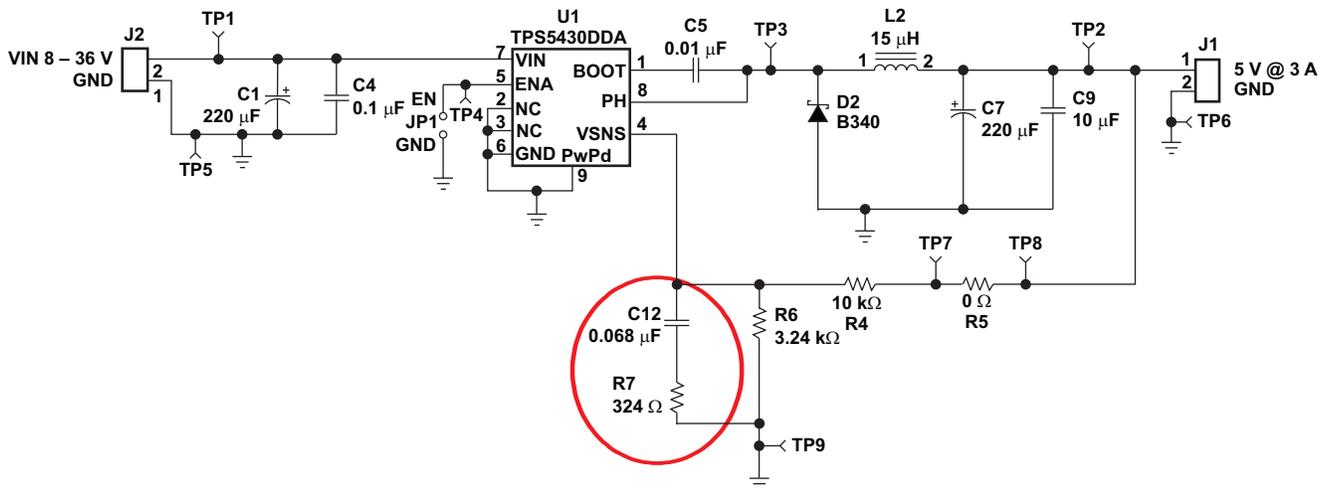


Figure 3. Application Circuit 1 Using Aluminum Output Capacitor

2.1 Design Parameters

- Input voltage range (V_{in}): 8 V - 36 V
- Output voltage (V_o): 5 V
- Output current rating (I_o): 3 A
- Operating switching frequency (f_s): 500 kHz

Following the routine design practice, DR125-150 from Coiltronics is selected as L2.

2.2 Aluminum Output Capacitors

In order for users to obtain good performance from the aluminum output capacitors they select, the following guidelines are recommended:

1. The resonant frequency f_{LC} in Equation (1) of the output filter should be no more than 5 kHz

$$f_{LC} = \frac{1}{2\pi \times \sqrt{L_o \times C_o}} \quad (1)$$

Where L_o is the output inductance and C_o is the output capacitance

So

$$C_o \geq C_{o, \min} = \frac{1}{(2\pi \times 5k)^2 \times L_o} \quad (2)$$

2. The equivalent maximum ESR of the aluminum output capacitors R_{esr} should yield an output ripple less than 5% of the output voltage which means the R_{esr} should be less than the ESR_{max} defined in Equation (3)

$$ESR_{max} = \frac{V_o \times 5\%}{I_{opp}} \quad (3)$$

Where

$$I_{\text{opp}} = \frac{(V_{\text{in,max}} - V_o)}{f_s \times L_o} \times \frac{V_o}{V_{\text{in,max}}} \quad (4)$$

In this design, $L_o = L_2 = 15 \mu\text{H}$, $V_{\text{in,max}} = 36 \text{ V}$, $f_s = 500 \text{ kHz}$, then

$$C_o \geq C_{o,\text{min}} = \frac{1}{(2\pi \times 5\text{k})^2 \times 15 \mu\text{H}} = 67.5 \mu\text{F} \quad (5)$$

$$I_{\text{opp}} = \frac{(36 - 5)}{500\text{k} \times 15\mu} \times \frac{5}{36} = 0.574 \text{ A} \quad (6)$$

$$\text{ESR}_{\text{max}} = \frac{5 \times 5\%}{0.574} = 435 \text{ m}\Omega \quad (7)$$

Therefore, aluminum capacitors with greater than $67.5 \mu\text{F}$ equivalent capacitance and less than $435 \text{ m}\Omega$ of total ESR should yield good performance. The design example uses EEVFK0J221P with a maximum ESR of $360 \text{ m}\Omega$ from Panasonic for C7. C9 is a $10\text{-}\mu\text{F}$ ceramic bypass capacitor.

2.2.1 C12 and R7 Calculation

Perform the following steps to determine the values of C12 and R7:

1. Calculate the resonant frequency f_{LC} of the output filter by [Equation 1](#) and the ESR zero f_{z0} of the output capacitor by [Equation 8](#)

$$f_{z0} = \frac{1}{2\pi \times C_o \times \text{Resr}} \quad (8)$$

In this case, $L_o = L_2 = 15 \mu\text{H}$, $C_o = C_7 = 220 \mu\text{F}$, $\text{Resr} = 360 \text{ m}\Omega$, therefore

$$f_{\text{LC}} = \frac{1}{2\pi \times \sqrt{15\mu \times 220\mu}} = 2.77 \text{ kHz} \quad (9)$$

$$f_{z0} = \frac{1}{2\pi \times 220\mu \times 360\text{m}} = 2.01 \text{ kHz} \quad (10)$$

2. Select the output voltage divider.

The output voltage V_o is set by the resistor divider of R4 and R6. R4 should be fixed at $10 \text{ k}\Omega$. Calculate R6 value for 5-V output voltage using [Equation 11](#):

$$R_6 = \frac{R_4 \times 1.221}{V_o - 1.221} \quad (11)$$

R6 is then $3.24 \text{ k}\Omega$.

3. Calculate C12 and R7

As shown in Appendix A, *Related RC Networks and Their Transfer Functions*, the network composed of R4, R6, C12, and R7 has one pole f_{p1} and one zero f_{z2} . Determine the pole and zero by the following equations:

$$f_{p1} = \text{maximum} \left(0.3\text{k} \times \frac{f_{z0} \times V_o}{f_{\text{LC}}} \text{Hz}, 1 \text{ kHz} \right) \quad (12)$$

$$f_{z2} = \text{minimum} (7.5 \times f_{p1}, 10 \text{ kHz}) \quad (13)$$

Then, C12 and R7 can be calculated by [Equation 14](#) and [Equation 15](#),

$$C_{12} = \frac{1}{2\pi \times f_{p1} \times (R_4 // R_6)} \quad (14)$$

$$R_7 = \frac{1}{2\pi \times f_{z2} \times C_{12}} \quad (15)$$

Where $R_4 // R_6$ is the equivalent resistance when R4 and R6 are in parallel

For this design,

$$f_{p1} = \text{maximum}\left(0.3k \times \frac{2.01k \times 5}{2.77k} \text{Hz}, 1 \text{ kHz}\right) = \text{maximum}(1.09 \text{ kHz}, 1 \text{ kHz}) = 1.09 \text{ kHz}$$

$$f_{z2} = \text{minimum}(7.5 \times 1.09 \text{ kHz}, 10 \text{ kHz}) = \text{minimum}(8.17 \text{ kHz}, 10 \text{ kHz}) = 8.17 \text{ Hz} \quad (16)$$

Then

$$C_{12} = \frac{1}{2\pi \times 1.09k \times 2.45k} = 0.06 \mu\text{F} \quad (17)$$

$$R_7 = \frac{1}{2\pi \times 8.17k \times 0.06 \mu} = 325 \Omega \quad (18)$$

Select the next highest standard value for C12 and the closest standard value for R7, respectively; then, C12 is 0.068 μF and R7 is 324 Ω .

2.3 Bill of Materials

Table 1 is the bill of materials for the key components in application circuit 1.

Table 1. Bill of Materials for Application Circuit 1

Count	RefDes	Value	Description	Size	Part Number	MFR
1	C1	220 μF	Capacitor, Aluminum, 220- μF , 50-V, 20%	0.457 \times 0.406	EEVFK1H221P	Panasonic
1	C4	0.1 μF	Capacitor, Ceramic, 50-V, X7R, 10%	0603	Std	TDK
1	C5	0.01 μF	Capacitor, Ceramic, 50-V, X7R, 10%	0603	Std	TDK
1	C7	220 μF	Capacitor, Aluminum, 6.3-V, 220- μF , 20%, 360-m Ω	0.260 \times 0.276 inch	EEVFK0J221P	Panasonic
1	C9	10 μF	Capacitor, Ceramic, 10- μF , 16-V, X5R, 20%	1210	Std	TDK
1	C12	0.068 μF	Capacitor, Ceramic, 50-V, X7R, 10%	0603	Std	TDK
1	D2		Diode, Schottky, 3-A, 40-V	SMC	B340	Motorola
1	L2	15 μH	Inductor, SMT,4.27-A, 29.8-m Ω	0.492 sq inch	DR125-150	Coiltronics
1	R4	10.0k Ω	Resistor, Chip, 1/16-W, 1%	0603	Std	Std
1	R5	0 Ω	Resistor, Chip, 1/16-W, 1%	0603	Std	Std
1	R6	3.24k Ω	Resistor, Chip, 1/16-W, 1%	0603	Std	Std
1	R7	324 Ω	Resistor, Chip, 1/16-W, 1%	0603	Std	Std
1	U1		IC, Switching Step-Down Regulator, 5.5-V - 36-V, 3-A	SO8 [DDA]	TPS5430DDA	TI

2.4 Performance Graphs

To illustrate how well the application circuit 1 operates, Figure 4 shows the loop responses for $V_{in} = 12 \text{ V}$ and $V_{in} = 36 \text{ V}$. Figure 5 shows the output ripple, and Figure 6 shows the transient response.

2.5 Tips

To fine tune the values of C12 and R7 manually, keep in mind that decreasing C12 results in higher crossover frequency which means faster transient response and increasing R7 will boost the phase margin which means better system stability.

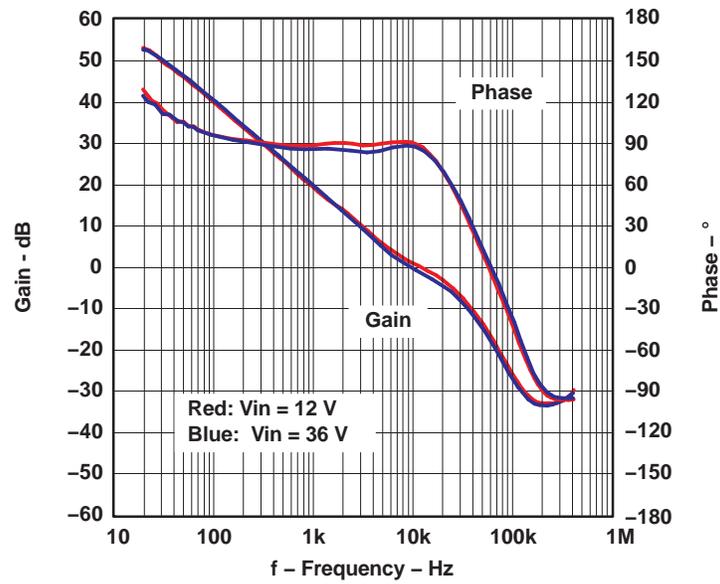


Figure 4. Measured Loop Responses for Application Circuit 1, $I_o = 3\text{ A}$

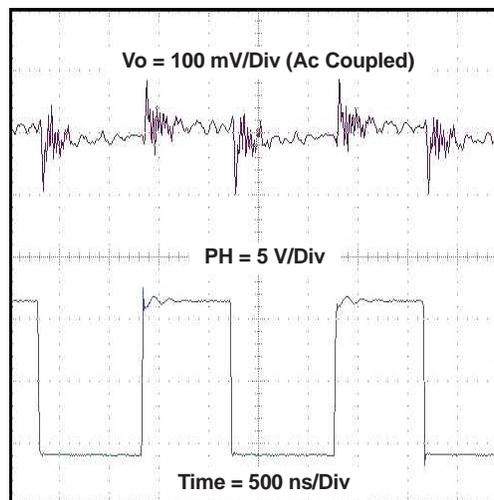


Figure 5. Measured Output Ripple for Application Circuit 1, $V_{in} = 12\text{ V}$ and $V_o = 5\text{ V}/3\text{ A}$

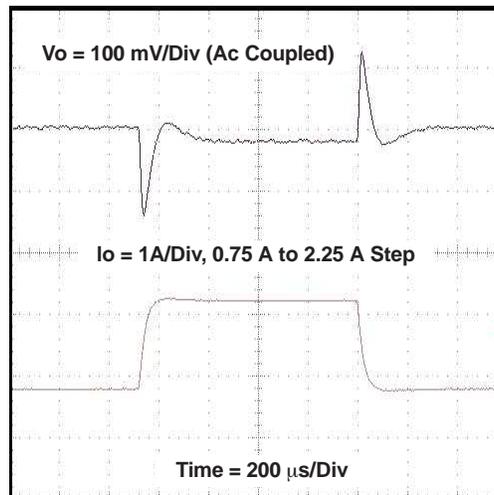


Figure 6. Measured Load Transient Response for Application Circuit 1, $V_{in} = 12\text{ V}$

3 Design Procedure for Ceramic Output Capacitors

Figure 7 shows application circuit 2, similar to application circuit 1 shown in Figure 3, but this circuit uses ceramic rather than aluminum output capacitors. The only differences between the two circuits are the output capacitors C7 and C9 and the external RC network C11, C12, C13 and R7. Using application circuit 2 as the example, the following design procedure shows how to select component values for C11, C12, C13 and R7.

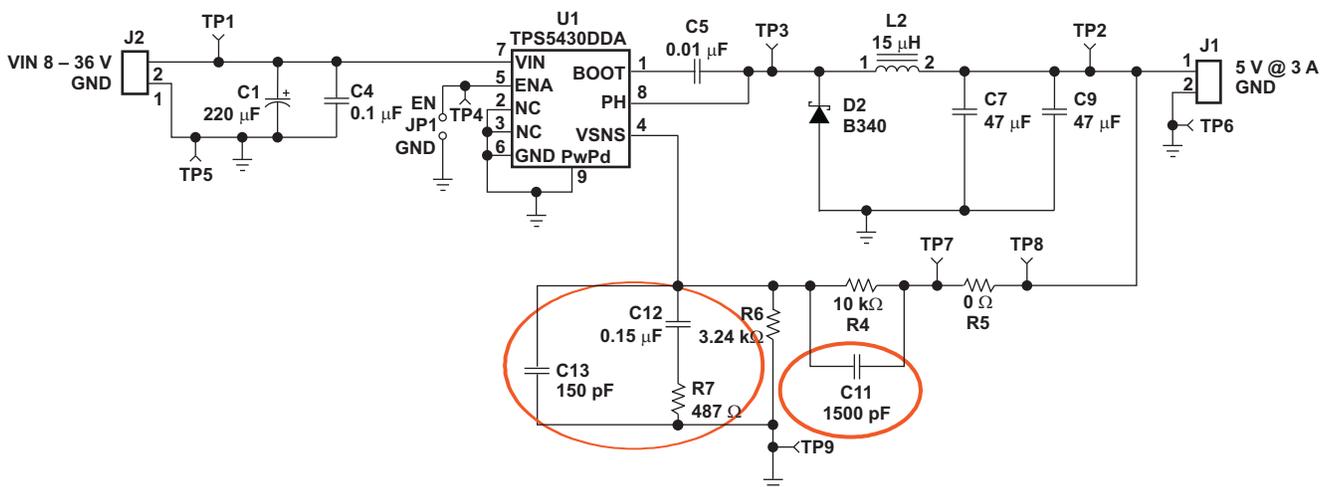


Figure 7. Application Circuit 2 Using Ceramic Output Capacitors

3.1 Design Parameters

- Input voltage range (V_{in}): 8 V - 36 V
- Output voltage (V_o): 5 V
- Output current rating (I_o): 3 A
- Operating switching frequency (f_s): 500 kHz

Following routine design practice, DR125-150 from Coiltronics is selected for L2.

3.2 Ceramic Output Capacitors

In order for users to obtain good performance from the ceramic output capacitors they select, it is recommended that the resonant frequency f_{LC} of the output filter is no more than 6 kHz, i.e.,

$$C_o \geq C_{o, \min} = \frac{1}{(2\pi \times 6k)^2 \times L_o} \quad (19)$$

In this example, $L_o = L_2 = 15 \mu\text{H}$, then

$$C_o \geq C_{o, \min} = \frac{1}{(2\pi \times 6k)^2 \times 15 \mu\text{H}} = 46.9 \mu\text{F} \quad (20)$$

Therefore, ceramic capacitors with more than 46.9 μF equivalent capacitance should yield good performance. The design example uses C4532X5R1A476M from TDK as C7 and C9.

3.2.1 C11, C12, C13 and R7 Calculation

Perform the following the steps to determine the values of C11, C12, and R7:

1. Calculate the resonant frequency f_{LC} of the output filter by [Equation 1](#). In this case, $L_o = L_2 = 15 \mu\text{H}$, $C_o = C_7 // C_9 = 94 \mu\text{F}$, then

$$f_{LC} = \frac{1}{2\pi \times \sqrt{15\mu \times 94\mu}} = 4.24 \text{ kHz} \quad (21)$$

2. Select the output voltage divider.

As mentioned previously, R4 should be fixed at 10 k Ω ; R6 is calculated to be 3.24 k Ω for a 5-V output voltage using [Equation 11](#).

3. Calculate C11, C12, and R7

As shown in Appendix A, *Related RC Networks and Their Transfer Functions*, the network, composed of R4, R6, C11, C12, and R7, has two poles f_{p1} and f_{p4} and two zeros f_{z2} and f_{z3} . Determine the poles and zeros by the following equations:

$$f_{p1} = 0.5 \text{ M} \times \frac{V_o}{f_{LC}} \quad (22)$$

$$f_{z2} = 0.7 \times f_{LC} \quad (23)$$

$$f_{z3} = 2.3 \times f_{LC} \quad (24)$$

f_{z4} is usually located at too high a frequency to be concerned with. Then, C11, C12, and R7 can be calculated by [Equation 25](#), [Equation 26](#), and [Equation 27](#).

$$C_{12} = \frac{1}{2\pi \times f_{p1} \times (R_4 // R_6)} \quad (25)$$

$$R_7 = \frac{1}{2\pi \times f_{z2} \times C_{12}} \quad (26)$$

$$C_{11} = \frac{1}{2\pi \times f_{z3} \times R_4} \quad (27)$$

Where $R_4 // R_6$ is the equivalent resistance when R4 and R6 are in parallel

For this design,

$$f_{p1} = 0.5 \text{ M} \times \frac{5}{4.24k} = 589.62 \text{ Hz}$$

$$f_{z2} = 0.7 \times 4.24k = 2.97 \text{ kHz}$$

$$f_{z3} = 2.3 \times 4.24k = 9.75 \text{ kHz} \quad (28)$$

Then,

$$C12 = \frac{1}{2\pi \times 589.62 \times 2.45k} = 0.11 \mu\text{F}$$

$$R7 = \frac{1}{2\pi \times 2.97k \times 0.11\mu} = 487 \Omega$$

$$C11 = \frac{1}{2\pi \times 9.75k \times 10k} = 1633 \text{ pF} \tag{29}$$

Select the next highest standard value for C12 and the closest standard value for C11 and R7, respectively; then, C11 is 1500 pF, C12 is 0.15 μF, and R7 is 487 Ω.

C13 is recommended to improve the load regulation performance. Since C13 is effectively in parallel with C11 to determine the location of fp4, C13 should be much smaller than C11 to be negligible. C13 must be less than the 1/10 value of C11. In this example, 150pF works well.

3.3 Bill of Materials

Table 2 is the bill of materials for the key components in application circuit 2.

Table 2. Bill of Materials for Application Circuit 2

Count	RefDes	Value	Description	Size	Part Number	MFR
1	C1	220 μF	Capacitor, Aluminum, 220-μF, 50-V, 20%	0.457 × 0.406	EEVFK1H221P	Panasonic
1	C4	0.1 μF	Capacitor, Ceramic, 50-V, X7R, 10%	0603	Std	TDK
1	C5	0.01 μF	Capacitor, Ceramic, 50-V, X7R, 10%	0603	Std	TDK
2	C7, C9	47 μF	Capacitor, Ceramic, 10-V, X5R, 20%	1812	C4532X5R1A476M	TDK
1	C11	1500 pF	Capacitor, Ceramic, 50-V, X7R, 10%	0603	Std	TDK
1	C12	0.15 μF	Capacitor, Ceramic, 50-V, X7R, 10%	0603	Std	TDK
1	C13	150 pF	Capacitor, Ceramic, 50-V, X7R, 10%	0603	Std	TDK
1	D2		Diode, Schottky, 3-A, 40-V	SMC	B340	Motorola
1	L2	15 μH	Inductor, SMT, 4.27-A, 29.8-mΩ	0.492 sq inch	DR125-150	Coiltronics
1	R4	10.0kΩ	Resistor, Chip, 1/16-W, 1%	0603	Std	Std
1	R5	0Ω	Resistor, Chip, 1/16-W, 1%	0603	Std	Std
1	R6	3.24 kΩ	Resistor, Chip, 1/16-W, 1%	0603	Std	Std
1	R7	487Ω	Resistor, Chip, 1/16-W, 1%	0603	Std	Std
1	U1		IC, Switching Step-Down Regulator, 5.5-V - 36-V, 3A	SO8 [DDA]	TPS5430DDA	TI

3.4 Performance Graphs

To illustrate how well the application circuit 2 operates, Figure 8 shows the loop responses for Vin = 12 V and Vin = 36 V. Figure 9 shows the output ripple, and Figure 10 shows the transient response.

3.5 Tips

The capacitance for MLCC (multilayer ceramic chip) capacitors not only depends on the temperature and operating hours, but also depends on the applied DC bias voltage. The actual capacitance could drop to less than 60% of the nominal capacitance at the rated voltage, depending on the dielectric, the case size, and the nominal capacitance [1] [2] [3]. Because the capacitance change may affect the performance and stability of the corresponding circuit, it is important to examine the capacitors under the actual operation conditions and verify the actual capacitance. The foregoing design procedure is based on nominal values. If the actual capacitance reduces by more than 25% of the nominal value in the application, the foregoing calculations should be based on the actual capacitance, but not the nominal capacitance.

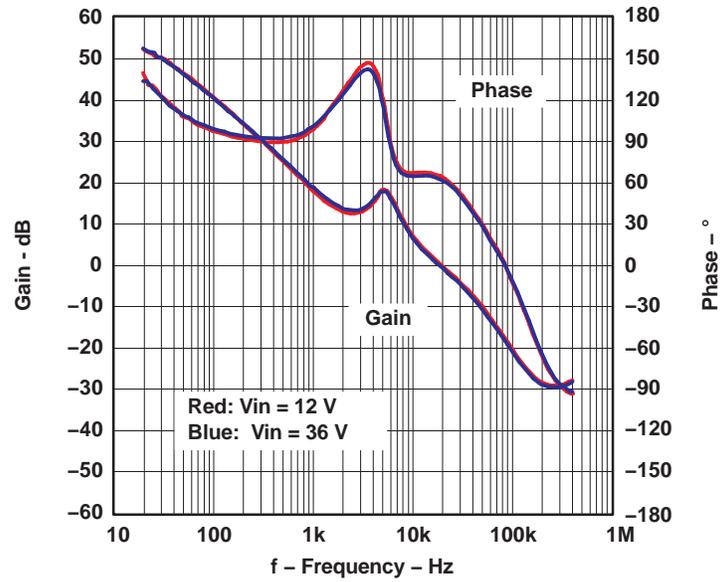


Figure 8. Measured Loop Responses for Application Circuit 2, $I_o = 3\text{ A}$

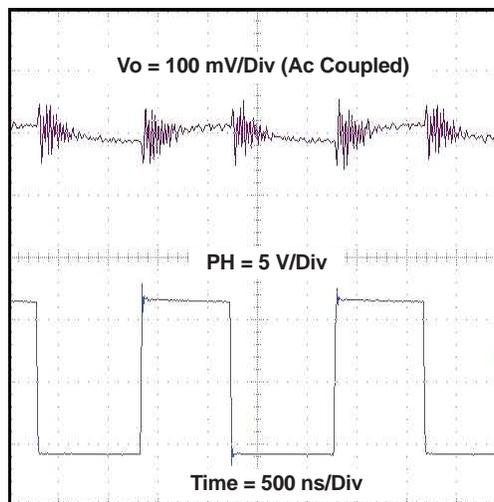


Figure 9. Measured Output Ripple for Application Circuit 2, $V_{in} = 12\text{ V}$ and $V_o = 5\text{ V}/3\text{ A}$

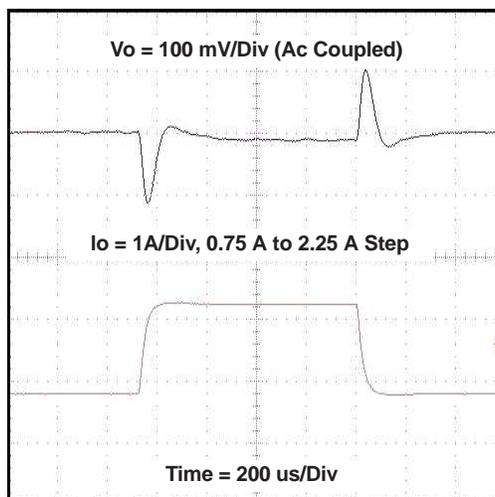
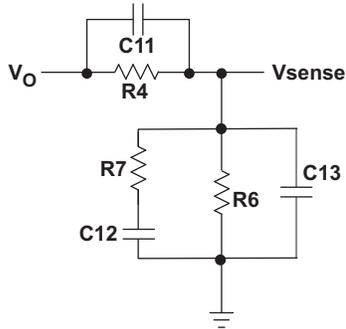
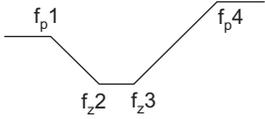
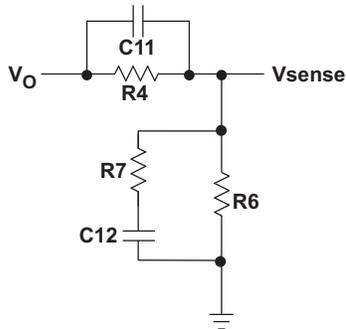
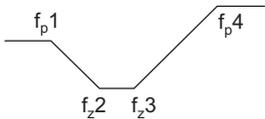
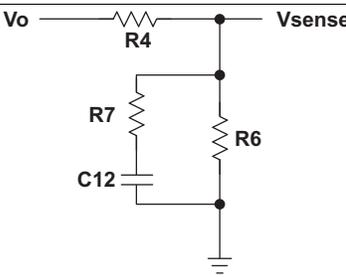
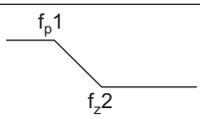


Figure 10. Measured Load Transient Response for Application Circuit 2, $V_{in} = 12\text{ V}$

4 Conclusion

The design procedures described in this application report have shown that it is easy to design with aluminum/ceramic output capacitors using the wide input step-down SWIFT™ DC/DC converters. The experimental measurements also have illustrated the feasibility of the design procedures.

Appendix A Related RC Networks and Their Simplified Transfer Functions

NETWORK	SIMPLIFIED TRANSFER FUNCTION	COMMENTS
	$\frac{V_{sense}(s)}{V_o(s)} = \frac{R_6}{R_4 + R_6} \times \frac{(1 + s \times C_{11} \times R_4) \times (1 + s \times C_{12} \times R_7)}{[1 + s \times (C_{11} + C_{13}) \times (R_6 // R_7)] \times [1 + s \times C_{12} \times (R_4 // R_6 + R_7)]}$	 $f_{p1} = \frac{1}{2\pi \times C_{12} \times [(R_4 // R_6) + R_7]}$ $f_{z2} = \frac{1}{2\pi \times C_{12} \times R_7}$ $f_{z3} = \frac{1}{2\pi \times C_{11} \times R_4}$ $f_{p4} = \frac{1}{2\pi \times (C_{11} + C_{13}) \times (R_6 // R_7)}$
	$\frac{V_{sense}(s)}{V_o(s)} = \frac{R_6}{R_4 + R_6} \times \frac{(1 + s \times C_{11} \times R_4) \times (1 + s \times C_{12} \times R_7)}{[1 + s \times C_{11} \times (R_6 // R_7)] \times [1 + s \times C_{12} \times (R_4 // R_6 + R_7)]}$	 $f_{p1} = \frac{1}{2\pi \times C_{12} \times [(R_4 // R_6) + R_7]}$ $f_{z2} = \frac{1}{2\pi \times C_{12} \times R_7}$ $f_{z3} = \frac{1}{2\pi \times C_{11} \times R_4}$ $f_{p4} = \frac{1}{2\pi \times C_{11} \times (R_6 // R_7)}$
	$\frac{V_{sense}(s)}{V_o(s)} = \frac{R_6}{R_4 + R_6} \times \frac{(1 + s \times C_{12} \times R_7)}{[1 + s \times C_{12} \times (R_4 // R_6 + R_7)]}$	 $f_{p1} = \frac{1}{2\pi \times C_{12} \times [(R_4 // R_6) + R_7]}$ $f_{z2} = \frac{1}{2\pi \times C_{12} \times R_7}$

Appendix B References

1. George M. Harayda, Akira Omi, and Axel Yamamoto, *Improve Your Designs with Large Capacitance Value Multi-Layer Ceramic Chip (MLCC) Capacitors*, Panasonic Industrial Company.
2. Technical Data, *Capacitance and Dissipation Factor Measurement of Chip Multilayer Ceramic Capacitors*, Murata Manufacturing Co., Ltd.
3. Technical Update, *Comparison of Ceramic and Tantalum Capacitors*, KEMET Electronics Corp.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products

Amplifiers	amplifier.ti.com
Data Converters	dataconverter.ti.com
DSP	dsp.ti.com
Interface	interface.ti.com
Logic	logic.ti.com
Power Mgmt	power.ti.com
Microcontrollers	microcontroller.ti.com
Low Power Wireless	www.ti.com/lpw

Applications

Audio	www.ti.com/audio
Automotive	www.ti.com/automotive
Broadband	www.ti.com/broadband
Digital Control	www.ti.com/digitalcontrol
Military	www.ti.com/military
Optical Networking	www.ti.com/opticalnetwork
Security	www.ti.com/security
Telephony	www.ti.com/telephony
Video & Imaging	www.ti.com/video
Wireless	www.ti.com/wireless

Mailing Address: Texas Instruments
Post Office Box 655303 Dallas, Texas 75265