

## **AN-1603 LM274X Reference Designs**

---

### **ABSTRACT**

This application note presents several reference designs that implement the LM274X synchronous buck controller. The designs address various applications in a wide variety of configurations. The design reference will give an engineer a head start on their project, with designs encompassing sequencing, tracking, synchronizing multiple power supplies, DDR termination, buck-boost, low PCB real estate, and high efficiency point of load designs.

### **Contents**

1	LM274X Feature Set .....	2
2	LM2745 and LM2747 Sequencing Requirement & Frequency Synchronization .....	3
3	Performance Characteristics .....	6
4	LM2743 High Efficiency Design .....	8
5	LM2747 Small Solution Size and Low Output Voltage Noise .....	10
6	LM274X Buck Boost Design .....	12
7	LM2744 DDR2 Application Design .....	14
8	PCB Layout Considerations .....	15
	8.1 Separate Power Ground and Signal Ground .....	15
	8.2 Low Impedance Power Path .....	15
	8.3 Minimize the Switch Node Copper .....	16
	8.4 Kelvin Traces for Sense Lines .....	16
9	References .....	16

### **List of Figures**

1	Schematic .....	4
2	LM2743 $V_{IN} = 3.3V$ , $V_{OUT} = 1.0V$ , $I_{LOAD} = 15A$ , $f_{SW} = 300$ kHz .....	9
3	LM2747 $V_{IN} = 12V$ , $V_{OUT} = 1.2V$ , $I_{LOAD} = 9A$ , $f_{SW} = 1$ MHz .....	11
4	Buck Boost Schematic .....	13
5	From File: DDR .....	14

### **List of Tables**

1	Bill of Materials # 1 $V_{IN} = 5V$ , $V_{OUT1} = 1.5V$ , $I_{LOAD1} = 3A$ , $f_{SW} = 600$ kHz .....	4
2	Bill of Materials #2 $V_{IN} = 5V$ , $V_{OUT2} = 2.5V$ , $I_{LOAD2} = 6.5A$ , $f_{SW} = 600$ kHz.....	5
3	Bill of Materials #3 .....	9
4	Bill of Materials #4 .....	11
5	Bill of Materials #5.....	13
6	Bill of Materials #6.....	15

## 1 LM274X Feature Set

The LM274X family of products are high-speed synchronous buck regulator controllers. The use of adaptive non-overlapping MOSFET gate drivers helps avoid potential shoot-through problems while maintaining high efficiency. The IC is designed for the more cost-effective option of driving only N-channel MOSFETs in both the high-side and low-side positions. It senses the low-side switch voltage drop for providing a simple, adjustable current limit.

The LM274X family features a fixed-frequency voltage-mode PWM control architecture which is adjustable from 50 kHz to 2 MHz with one external resistor. This wide switching frequency range gives the power supply designer flexibility to make tradeoffs between component size, cost, and efficiency.

Features include soft-start, input under-voltage lockout (UVLO) and Power Good (based on both under-voltage and over-voltage detection). In addition, the shutdown pin of the IC can be used for providing startup delay, and the tracking feature provides precise tracking for the purpose of sequencing with respect to an external rail during soft-start.

The table below summarizes the distinctions of all seven of the LM274X products.

Parameter	LM2742	LM2743	LM2744	LM2745	LM2746	LM2747	LM2748
Analog $V_{IN}$ Range	4.5V - 5.5V	3V - 6V	3V - 6V	3V - 6V	3V - 5.5V	3V - 6V	3V - 6V
Power $V_{IN}$ Range	1.0V - 16V	1.0V - 16V	1.0V - 16V	1.0V - 14V	1.0V - 16V	1.0V - 14V	1.0V - 14V
Min $V_{OUT}$	0.6V	0.6V	0.5V	0.6V	0.6V	0.6V	0.6V
Operating Frequency	50 kHz to 2 MHz	50 kHz to 1 MHz	50 kHz to 1 MHz	50 kHz to 1 MHz	50 kHz to 1 MHz	50 kHz to 1 MHz	50 kHz to 1 MHz
Prebias Operation	No	No	No	Yes	No	Yes	Yes
Tracking	No	Yes	Yes	Yes	Yes	Yes	Yes
Frequency Synchronization	No	No	No	Yes 250 kHz to 1 MHz	No	Yes 250 kHz to 1 MHz	No
Package	TSSOP-14	TSSOP-14	TSSOP-14	TSSOP-14	TSSOP-14	TSSOP-14	TSSOP-14
Reference Accuracy	+/- 1.5% -0 to 125°C  +1.5% / -1.83% -40 to 125°C	+/- 2% -40 to 125°C	External Ref	+/- 1.5% -40 to 125°C	+/- 1.0% -25 to 125°C  +/- 1.33% -40 to 125°C	+/- 1.0% -40 to 125°C	+/- 1.5% -40 to 125°C

The LM274X family provides:

- High current driving and step down capabilities from wide input voltages between 1V and 16V to an adjustable output voltage as low as 0.6V
- High power density solutions with internal synchronous drivers with top and bottom N-channel MOSFET driving capability
- Simplified heat sinking and thermal management design
- Improved conversion efficiency compared to asynchronous solutions due to synchronous control
- The flexibility to optimize control loop design with external compensation thereby decreases line and load transient response time and voltage overshoot amplitude
- A high performance system solution with a control architecture where the MOSFETs and compensation components are external

This combination of complex-load-specific features and precision allows designers powering Application-Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs), and Digital Signal Processors (DSPs) to use a single LM274X controller to achieve best-in-class performance with minimal footprint.

## 2 LM2745 and LM2747 Sequencing Requirement & Frequency Synchronization

### Application Power Requirement:

$$V_{IN} = 5V$$

$$V_{OUT1} = 1.5V \text{ (Processor Core Voltage)}$$

$$I_{LOAD1} = 3A$$

$$V_{OUT2} = 2.5V \text{ (I/O Load)}$$

$$I_{LOAD2} = 6.5A$$

$$f_{SW} = 600 \text{ kHz}$$

$$* T_{AMBIENT} = -40^{\circ}C \text{ to } 85^{\circ}C$$

Due to the high load current and different output rails, two switch mode power supplies (SMPSs) are required to power a processor core voltage and the I/O circuit block. Both SMPS inputs will share the same distribution bus. When two or more power supplies share the same input voltage bus with non-synchronized SMPSs, the sum and difference between both switching frequencies will develop a beat frequency. The power supplies will reflect beat noise to the input bus and conduct into any electrical circuit connected to it, such as other intermediate points of loads (POLs).

The beat noise may be found at low frequencies and mitigate may result impractical; such mitigation includes additional filtering at the front end of each switching regulator, increasing the loop gain sufficiently at the beat frequency in order to reject the input to output noise transfer, or one of the switching frequencies can be set to switch at two times higher the lower switching frequency (Hong Huang, July 2003). These solutions will increase the size and will require more design time for the solution. All these mitigation techniques are avoided if the SMPS oscillators are synchronized. Synchronizing will eliminate beat noise and relieve conducted noise interaction to each others load; additionally synchronizing keeps the generated EMI to a predictable set of frequencies.

Either LM2745 or LM2747 can be used for the design since they both feature the ability to synchronize the internal oscillator to an external clock.

In this example, the processor voltage ( $V_{OUT1}$ ) must power up 30 ms before the I/O load ( $V_{OUT2}$ ) powers up and  $V_{OUT2}$  must power down 30 ms before  $V_{OUT1}$  rail powers down. The LM3880 will solve the sequencing requirement and will be used in this example design.

The LM2745 and the LM2747 ICs provides the correct solution with the highest performance and smallest solution size and either one can be substituted for the other depending on application DC reference tolerance requirement.

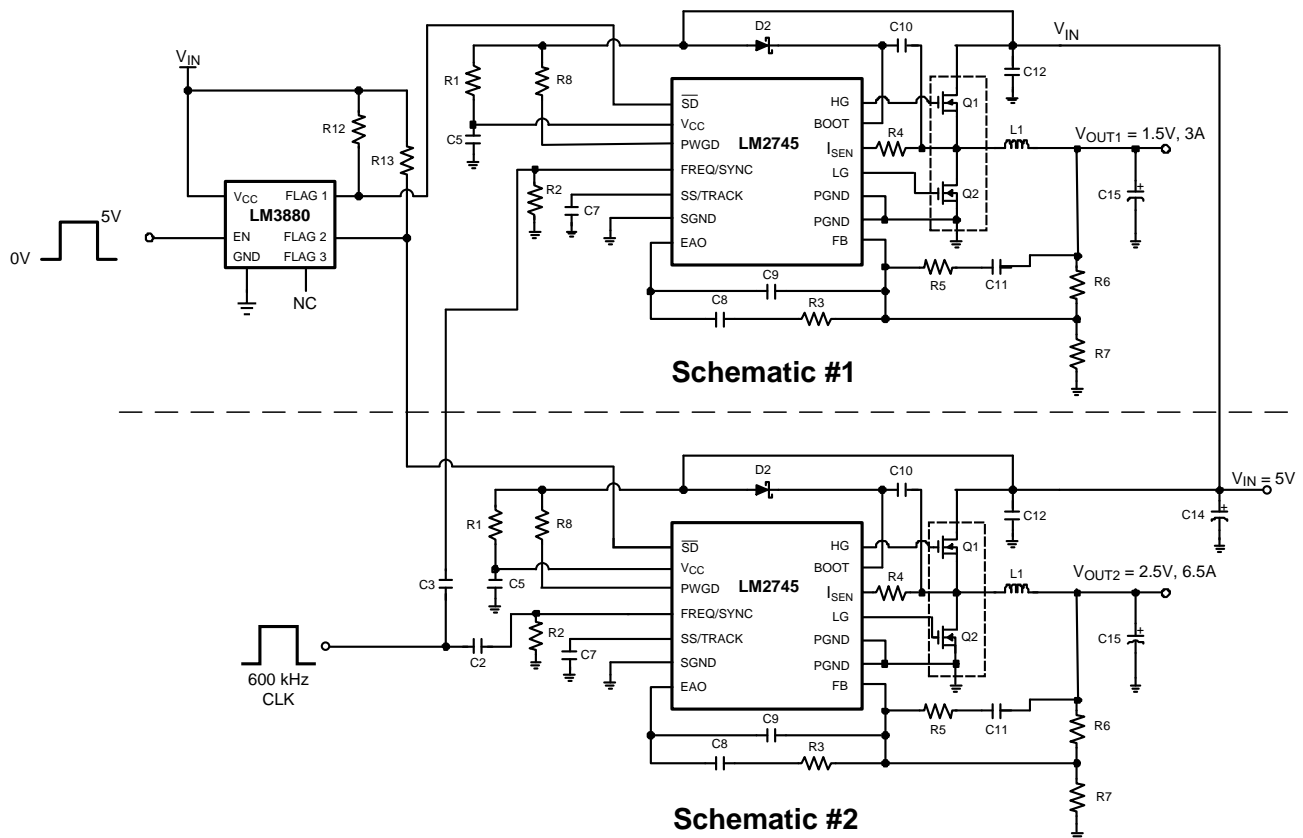


Figure 1. Schematic

**Table 1. Bill of Materials # 1**  
 $V_{IN} = 5V$ ,  $V_{OUT1} = 1.5V$ ,  $I_{LOAD1} = 3A$ ,  $f_{SW} = 600\text{ kHz}$ 

Designator	Function	Part Description	Part Number
U1	Buck Switching Controller	Synchronous Controller TSSOP14	Texas Instruments LM2745
U2	Sequencer IC	Simple Sequencer SOT23-6	Texas Instruments LM3880
C3	Shut Down Cap	Cer Cap 0.1 $\mu$ F 0805	Vishay VJ0805Y104KXX
C5	$V_{CC}$ Decoupling	Cer Cap 1 $\mu$ F 10V 0805	AVX 0805ZC105KAT
C7	Soft Start Cap	Cer Cap 12 nF 0603	Vishay VJ0603Y123KXX
C8	Comp Cap	Cer Cap 1 nF 0603	Vishay VJ0603Y102KXX
C9	Comp Cap	Cer Cap 12 pF 0603	Vishay VJ0603A120KAA
C10	Cboot	Cer Cap 0.1 $\mu$ F 0805	Vishay VJ0805Y104KXX
C11	Comp Cap	Cer Cap 2.7 nF 0603	Vishay VJ0603Y272KXX
C12	Input Filter Cap	Cer Cap 22 $\mu$ F 10V 1210	AVX 1210ZD226MAT
C15	Output Filter Cap	470 $\mu$ F, 2.5V, 18 m $\Omega$ , POScap	Sanyo 2R5TPE470MI
R1	Filter Resistor	Res 10 $\Omega$ 0603	Vishay CRCW060310R0F
R2	Frequency Adjust	Res 42.2 k $\Omega$ 0603	Vishay CRCW06034222F
R3	Comp Res	Res 38.3 k $\Omega$ 0603	Vishay CRCW06033832F
R4	Current Limit Res	Res 1.91 k $\Omega$ 0603	Vishay CRCW06031911F
R5	Comp Res	Res 3.74 k $\Omega$ 0603	Vishay CRCW06033741F
R6	Res Divider, upper	Res 10 k $\Omega$ 0603	Vishay CRCW06031002F

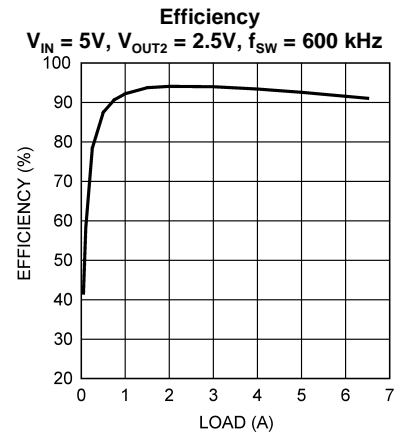
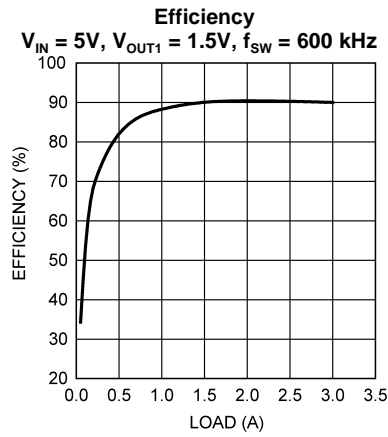
**Table 1. Bill of Materials # 1**  
 **$V_{IN} = 5V$ ,  $V_{OUT1} = 1.5V$ ,  $I_{LOAD1} = 3A$ ,  $f_{SW} = 600\text{ kHz}$  (continued)**

Designator	Function	Part Description	Part Number
R7	Res Divider, lower	Res 6.65 k $\Omega$ 0603	Vishay CRCW06036651F
R8	PWGD Pull-Up	Res 100 k $\Omega$ 0603	Vishay CRCW06031003F
R12	Pull-Up Resistor	Res 10 k $\Omega$ 0603	Vishay CRCW06031002F
R13	Pull-Up Resistor	Res 10 k $\Omega$ 0603	Vishay CRCW06031002F
D2	Bootstrap Diode	Schottky Diode, SOD-123	MBR0520LTI
L1	Output Filter Inductor	2.0 $\mu$ H, 5.4Arms, 15 m $\Omega$	Cooper FP3-2R0
Q1 & Q2	Dual N-MOSFET Top & Bottom MOSFET	Top 14.6 m $\Omega$ @4.5V, 7.4 nC Bottom 9.1m $\Omega$ @4.5V, 15 nC	IRF9910

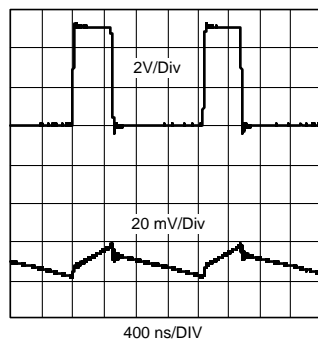
**Table 2. Bill of Materials #2**  
 **$V_{IN} = 5V$ ,  $V_{OUT2} = 2.5V$ ,  $I_{LOAD2} = 6.5A$ ,  $f_{SW} = 600\text{ kHz}$**

Designator	Function	Part Description	Part Number
U1	Buck Switching Controller	Synchronous Controller TSSOP14	Texas Instruments LM2745
C2	AC Coupling Cap	Cer Cap 68 pF 0603	Vishay VJ0603A680KAA
C3	AC Coupling Cap	Cer Cap 68 pF 0603	Vishay VJ0603A680KAA
C4	Shut Down Cap	Cer Cap 0.1 $\mu$ F 0805	Vishay VJ0805Y104KXX
C5	$V_{CC}$ Decoupling	Cer Cap 1 $\mu$ F 10V 0805	AVX 0805ZC105KAT
C7	Soft Start Cap	Cer Cap 12 nF 0603	Vishay VJ0603Y123KXX
C8	Comp Cap	Cer Cap 1 nF 0603	Vishay VJ0603Y102KXX
C9	Comp Cap	Cer Cap 15 pF 0603	Vishay VJ0603A150KAA
C10	Cboot	Cer Cap 0.1 $\mu$ F 0805	Vishay VJ0805Y104KXX
C11	Comp Cap	Cer Cap 2.2 nF 0603	Vishay VJ0603Y222KXX
C12	Input Filter Cap	Cer Cap 22 $\mu$ F 10V 20% 1210	AVX 1210ZD226MAT
C14	Input Filter Cap	Al-elec Cap 470 $\mu$ F 10V	Sanyo 10CE470WG
C15	Output Filter Cap	470 $\mu$ F, 4V, 12 m $\Omega$ , POScap	Sanyo 4TPE470MCL
R1	Filter Resistor	Res 10 $\Omega$ 0603	Vishay CRCW060310R0F
R2	Frequency Adjust	Res 42.2 k $\Omega$ 0603	Vishay CRCW06034222F
R3	Comp Res	Res 33.2 k $\Omega$ 0603	Vishay CRCW06033322F
R4	Current Limit Res	Res 1.82 k $\Omega$ 0603	Vishay CRCW06031821F
R5	Comp Res	Res 2.67 k $\Omega$ 0603	Vishay CRCW06032671F
R6	Res Divider upper	Res 10.0 k $\Omega$ 0603	Vishay CRCW06031002F
R7	Res Divider lower	Res 3.16 k $\Omega$ 0603	Vishay CRCW06033161F
R8	PWGD Pull-Up	Res 100 k $\Omega$ 0603	Vishay CRCW06031003F
D2	Bootstrap Diode	Schottky Diode, SOD-123	MBR0520LTI
L1	Output Filter Inductor	1.15 $\mu$ H, 8.5 Arms, 11 m $\Omega$	Würth Elektronik 744 310 115
Q1 & Q2	Dual N-MOSFET Top & Bottom MOSFET	Top 14.6 m $\Omega$ @4.5V, 7.4 nC Bottom 9.1m $\Omega$ @4.5V, 15 nC	IRF9910

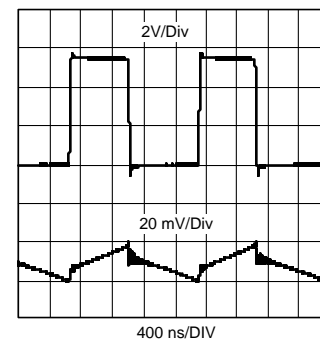
### 3 Performance Characteristics



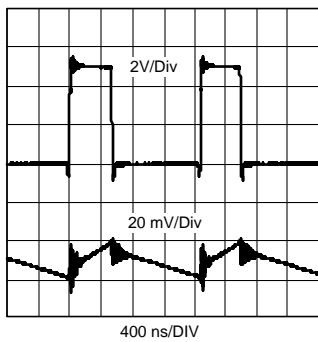
**Switch Node and Output Voltage Ripple**  
 $V_{IN} = 5V, V_{OUT1} = 1.5V, I_{LOAD1} = 0A$



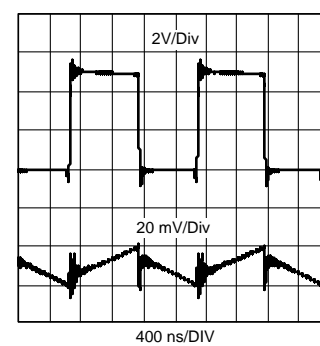
**Switch Node and Output Voltage Ripple**  
 $V_{IN} = 5V, V_{OUT2} = 2.5V, I_{LOAD2} = 0A$



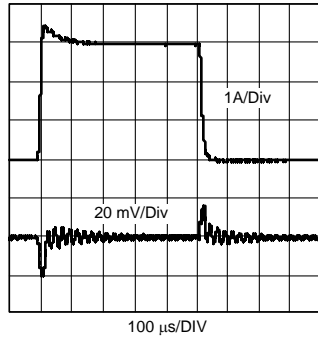
**Switch Node and Output Voltage Ripple**  
 $V_{IN} = 5V, V_{OUT1} = 1.5V, I_{LOAD1} = 3A$



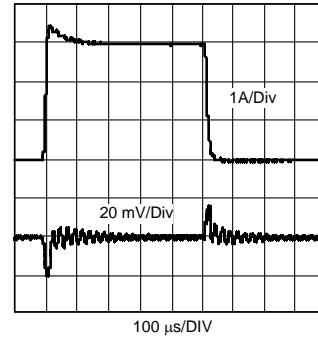
**Switch Node and Output Voltage Ripple**  
 $V_{IN} = 5V, V_{OUT2} = 2.5V, I_{LOAD2} = 6.5A$



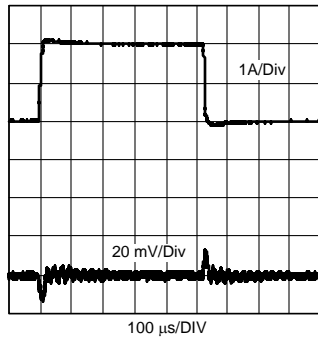
**Load Transient Response**  
 $V_{IN} = 5V, V_{OUT1} = 1.5V, I_{LOAD1} = 0A \text{ to } 3A$



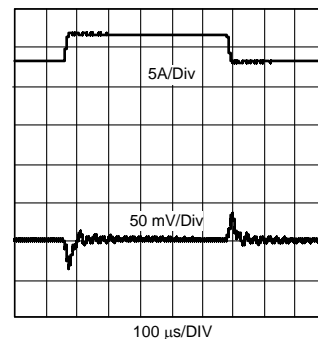
**Load Transient Response**  
 $V_{IN} = 5V, V_{OUT2} = 2.5V, I_{LOAD2} = 0A \text{ to } 6.5A$



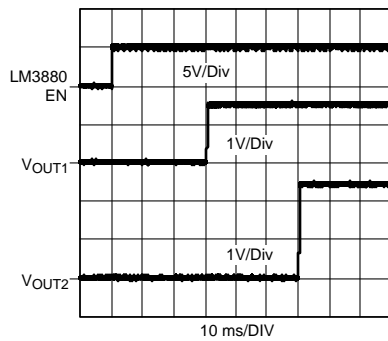
**Load Transient Response**  
 $V_{IN} = 5V, V_{OUT1} = 1.5V, I_{LOAD1} = 1A \text{ to } 3A$



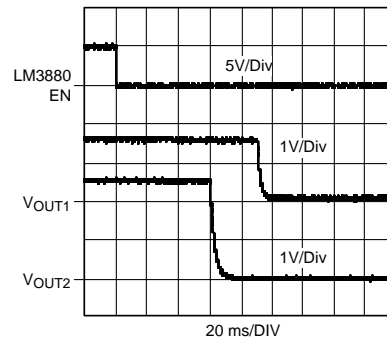
**Load Transient Response**  
 $V_{IN} = 5V, V_{OUT2} = 2.5V, I_{LOAD2} = 3A \text{ to } 6.5A$



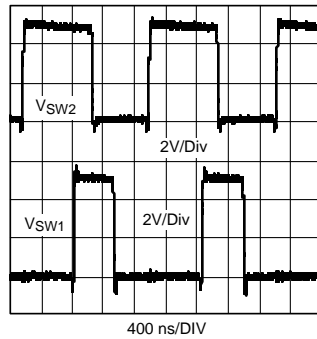
**Sequencing**  
 $V_{IN} = 5V, \text{Turn-on}$



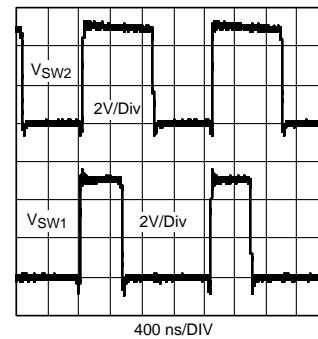
**Sequencing**  
 $V_{IN} = 5V, \text{Turn-off}$



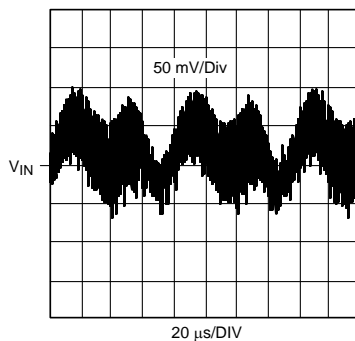
**Synchronizing (Not Synchronized)**  
 $V_{IN} = 5V$ ,  $V_{OUT1} = 1.5V$ ,  $V_{OUT2} = 2.5V$   
 $I_{LOAD1} = 3A$ ,  $I_{LOAD2} = 6.5A$



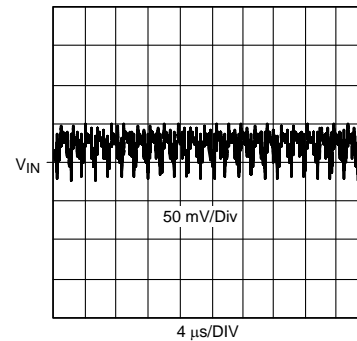
**Synchronizing (Synchronized)**  
 $V_{IN} = 5V$ ,  $V_{OUT1} = 1.5V$ ,  $V_{OUT2} = 2.5V$   
 $I_{LOAD1} = 3A$ ,  $I_{LOAD2} = 6.5A$



**Synchronizing (Not Synchronized)**  
 $V_{IN} = 5V$ ,  $V_{OUT1} = 1.5V$ ,  $V_{OUT2} = 2.5V$   
 $I_{LOAD1} = 3A$ ,  $I_{LOAD2} = 6.5A$



**Synchronizing (Synchronized)**  
 $V_{IN} = 5V$ ,  $V_{OUT1} = 1.5V$ ,  $V_{OUT2} = 2.5V$   
 $I_{LOAD1} = 3A$ ,  $I_{LOAD2} = 6.5A$



## 4 LM2743 High Efficiency Design

### Application Power Requirement:

$$V_{IN} = 3.3V$$

$$V_{OUT} = 1.0V$$

$$I_{LOAD} = 15A$$

$$f_{SW} = 300 \text{ kHz}$$

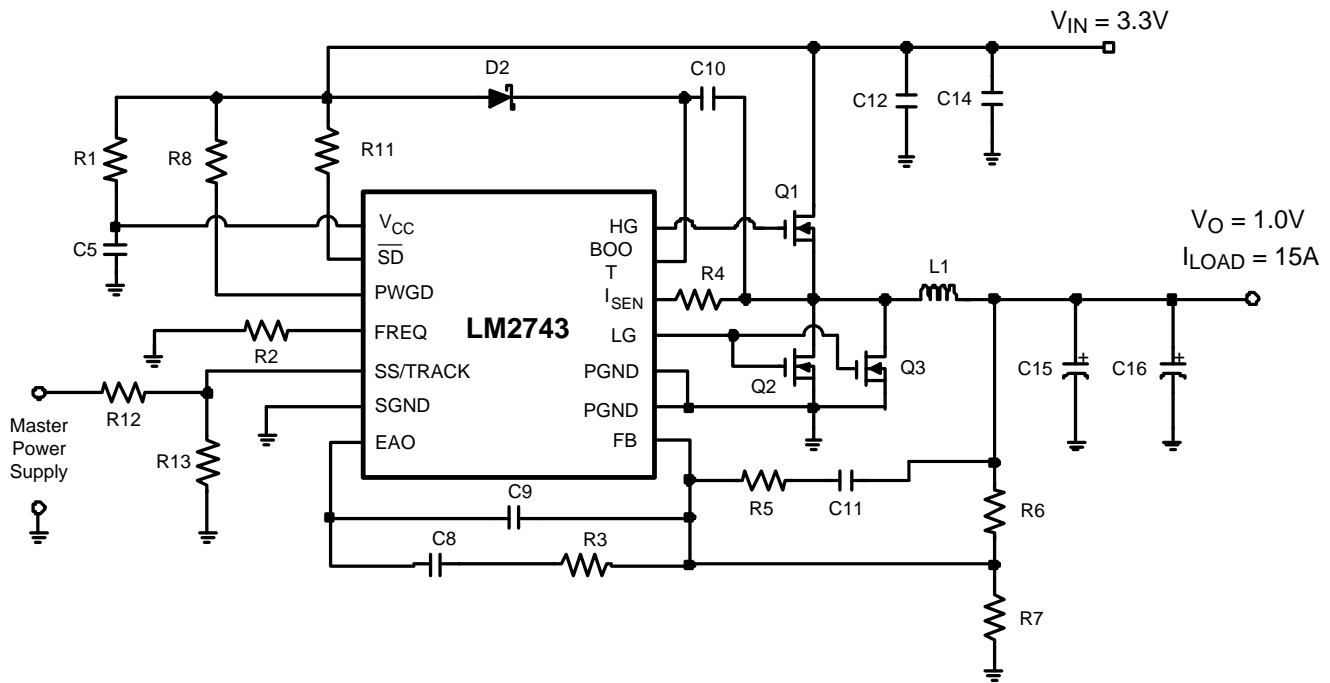
$$* T_{AMBIENT} = -40^{\circ}C \text{ to } 85^{\circ}C$$

The LM2743 through LM2748 can track the output of a master power supply during soft-start by connecting a resistor divider to the SS/TRACK pin. In this way, the output voltage slew rate of the LM2743/4/5/6/7/8 will be controlled by the master supply for loads that require precise sequencing. Two ways of using the tracking features is to design the resistor divider to track an equal slew rate or an equal rise time, further information is provided in the respective datasheet. Your system requirement will direct which option is the right solution for your load.

For example, the tracking feature is useful for FPGAs core and I/O voltages, for the differential must be minimized during power up. Monotonic ramping with equal slew rates will prevent latch-up, bus contention, and undesirable transistor logic states (Altera Corporation, February 2007).

For further Altera design solutions and guidance refer to the *Power Management for Altera Quick Reference Guide* and for Xilinx® design solutions and guidance refer to the *Xilinx FPGA Power Management Reference Guide*.





**Figure 2. LM2743  $V_{IN} = 3.3V$ ,  $V_{OUT} = 1.0V$ ,  $I_{LOAD} = 15A$ ,  $f_{SW} = 300\text{ kHz}$**

**Table 3. Bill of Materials #3**

Designator	Function	Part Description	Part Number
U1	Buck Switching Controller	Synchronous Controller TSSOP14	Texas Instruments LM2743
C5	$V_{CC}$ Decoupling	Cer Cap 1 $\mu F$ 10V 0805	AVX 0805ZC105KAT
C8	Comp Cap	Cer Cap 820 pF 0603	Vishay VJ0603Y821KXX
C9	Comp Cap	Cer Cap 33 pF 0603	Vishay VJ0603A330KAA
C10	Cboot	Cer Cap 0.1 $\mu F$ 0805	Vishay VJ0805Y104KXX
C11	Comp Cap	Cer Cap 2.2 nF 0603	Vishay VJ0603Y222KXX
C12	Input Filter Cap	Cer Cap 100 $\mu F$ 6.3V 1812	AVX 1812D107MAT
C14	Input Filter Cap	Cer Cap 100 $\mu F$ 6.3V 1812	AVX 1812D107MAT
C15	Output Filter Cap	470 $\mu F$ , 2.5V, 8 m $\Omega$ , POScap	Sanyo 2.5TPLF470M8
C16	Output Filter Cap	470 $\mu F$ , 2.5V, 8 m $\Omega$ , POScap	Sanyo 2.5TPLF470M8
R1	$V_{CC}$ Filter Resistor	Res 10 $\Omega$ 0805	Vishay CRCW080510R0F
R2	Frequency Adjust Res	Res 97.6 k $\Omega$ 0603	Vishay CRCW06039762F
R3	Comp Res	Res 30.9 k $\Omega$ 0603	Vishay CRCW06033092F
R4	Current Limit Res	Res 2.32 k $\Omega$ 0603	Vishay CRCW06032321F
R5	Comp Res	Res 2.37 k $\Omega$ 0603	Vishay CRCW06032371F
R6	Res Divider, upper	Res 10 k $\Omega$ 0603	Vishay CRCW06031002F
R7	Res Divider, lower	Res 15 k $\Omega$ 0603	Vishay CRCW06031502F
R8	PWGD Pull-Up	Res 100 k $\Omega$ 0603	Vishay CRCW06031003F
R11	Shut Down Pull-Up	Res 100 k $\Omega$ 0603	Vishay CRCW06031003F
R12	Tracking Res	Res 35.7 $\Omega$ 0603	Vishay CRCW060335R7F
R13	Tracking Res	Res 150 $\Omega$ 0603	Vishay CRCW06031500F
D1	Bootstrap Diode	Schottky Diode, SOD-123	MBR0520LTI

**Table 3. Bill of Materials #3 (continued)**

Designator	Function	Part Description	Part Number
D2	Rectifier Diode	Schottky Diode SMB	Central Semi CSMH3-20M
L1	Output Filter Inductor	680 nH, 22Arms, 1.9mΩ	WE 744 313 068
Q1	Top MOSFET	Single N-MOSFET, 7.5mΩ@2.5V, 36nC	Vishay Si4442DY
Q2	Bottom MOSFET	Single N-MOSFET, 7.5mΩ@2.5V, 36nC	Vishay Si4442DY
Q3	Bottom MOSFET	Single N-MOSFET, 7.5mΩ@2.5V, 36nC	Vishay Si4442DY

## 5 LM2747 Small Solution Size and Low Output Voltage Noise

Application Power Requirement:

$$V_{IN} = 12V$$

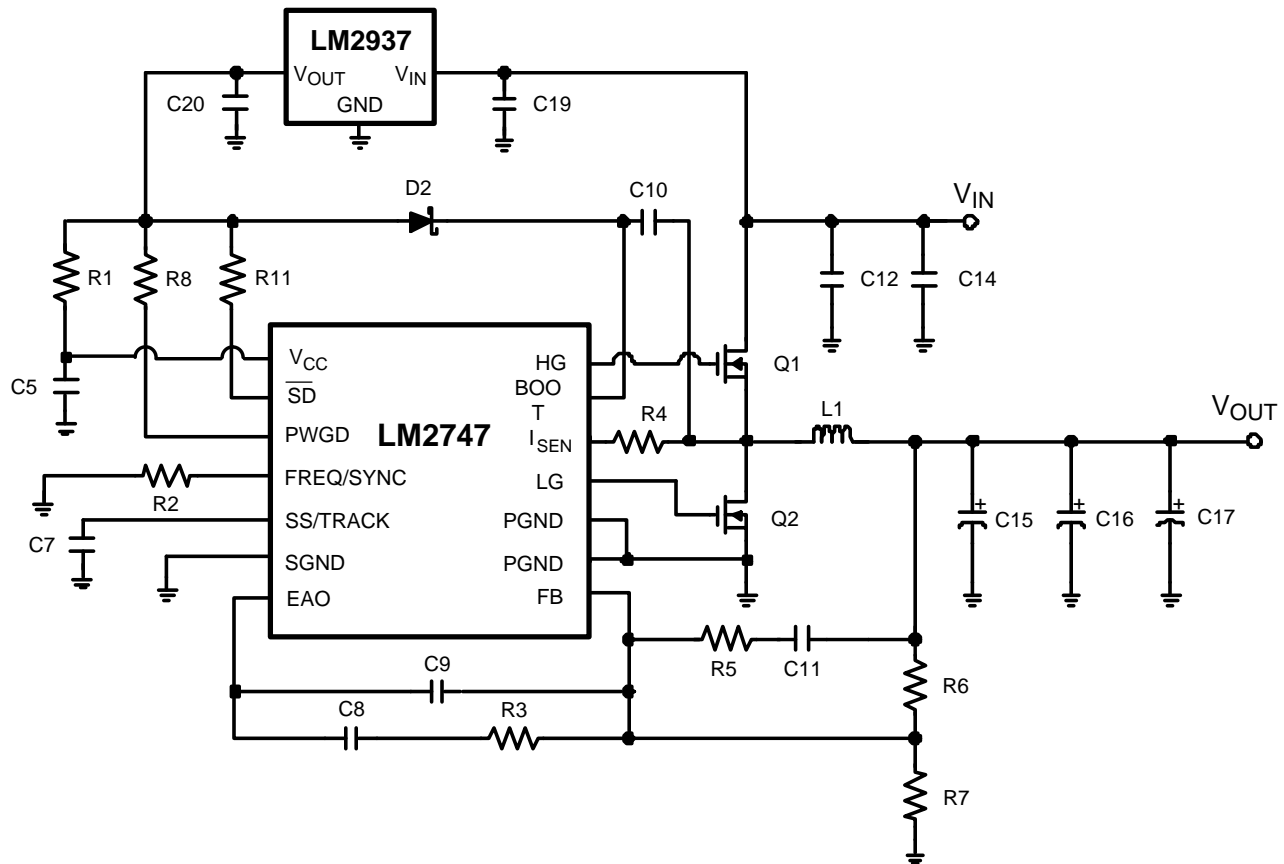
$$V_{OUT} = 1.2V$$

$$I_{LOAD} = 9A$$

$$f_{SW} = 1 \text{ MHz}$$

$$* T_{AMBIENT} = -40^{\circ}C \text{ to } 85^{\circ}C$$

The switching frequency of the LM274X is user programmable within the range of 50 kHz to 2 MHz. In this application example the switching frequency is set to 1 MHz, thereby reduces the input filter capacitance and output filter inductance and capacitance, but will sacrifice efficiency. Multilayer ceramic capacitors (MLCCs) were selected for output filtering. The low ESR and ESL of the MLCC provide low output voltage ripple and low noise generation. This application example also values high output voltage tolerance, thus the LM2747 device is chosen.


**Figure 3. LM2747  $V_{IN} = 12V$ ,  $V_{OUT} = 1.2V$ ,  $I_{LOAD} = 9A$ ,  $f_{SW} = 1\text{ MHz}$** 
**Table 4. Bill of Materials #4**

Designator	Function	Part Description	Part Number
U1	Buck Switching Controller	Synchronous Controller TSSOP14	Texas Instruments LM2747
U2	Linear Regulator	5V, 500mA, SOT-223	Texas Instruments LM2937IMP-5.0
C5	$V_{CC}$ Decoupling	Cer Cap 1 $\mu$ F 10V 0805	AVX 0805ZC105KAT
C7	Soft Start Cap	Cer Cap 12nF 0603	Vishay VJ0603Y123KXX
C8	Comp Cap	Cer Cap 2.7nF 0603	Vishay VJ0603Y272KXX
C9	Comp Cap	Cer Cap 47pF 0603	Vishay VJ0603A470KAA
C10	Cboot	Cer Cap 0.1 $\mu$ F 0805	Vishay VJ0805Y104KXX
C11	Comp Cap	Cer Cap 1.5 nF 0603	Vishay VJ0603Y152KXX
C12	Input Filter Cap	Cer Cap 22 $\mu$ F 25V 1812	TDK C4532X7R1E226M
C14	Input Filter Cap	Cer Cap 22 $\mu$ F 25V 1812	TDK C4532X7R1E226M
C15	Output Filter Cap	100 $\mu$ F, 4V, MLCC, X5R	AVX 12104D107MAT
C16	Output Filter Cap	100 $\mu$ F, 4V, MLCC, X5R	AVX 12104D107MAT
C17	Output Filter Cap	100 $\mu$ F, 4V, MLCC, X5R	AVX 12104D107MAT
C19	LDO Input Filter Cap	470 nF, 25V, 1206	Vishay VJ1206Y474KXXA
C20	LDO Output Filter Cap	22 $\mu$ F, 6.3V, X5R, 1206, 20%	AVX 12066D226MAT
R1	Filter Resistor	Res 10 $\Omega$ 0603	Vishay CRCW060310R0F

**Table 4. Bill of Materials #4 (continued)**

Designator	Function	Part Description	Part Number
R2	Frequency Adjust Res	Res 24.9 kΩ 0603	Vishay CRCW06032492F
R3	Comp Res	Res 5.36 kΩ 0603	Vishay CRCW06035361F
R4	Current Limit Res	Res 1 kΩ 0603	Vishay CRCW06031001F
R5	Comp Res	Res 215Ω 0603	Vishay CRCW06032150F
R6	Res Divider, upper	Res 10 kΩ 0603	Vishay CRCW06031002F
R7	Res Divider, lower	Res 10 kΩ 0603	Vishay CRCW06031002F
R8	PWGD Pull-Up	Res 100 kΩ 0603	Vishay CRCW06031003F
R11	Shut Down Pull-Up	Res 100 kΩ 0603	Vishay CRCW06031003F
D2	Bootstrap Diode	Schottky Diode, SOD-123	MBR0530LTI
L1	Output Filter Inductor	680 nH, 9.72Arms, 4.63 mΩ	Cooper FP3-R68
Q1	Single Top MOSFET	9.5 mΩ@ 4.5V, 9.3nC	International Rectifier IRF7821
Q2	Single Bottom MOSFET	3.4mΩ@ 4.5V, 33 nC	Renesas HAT2165H

## 6 LM274X Buck Boost Design

Application Power Requirement:

$$V_{IN} = 3.0V \text{ to } 5.7V$$

$$V_{OUT} = 3.3V$$

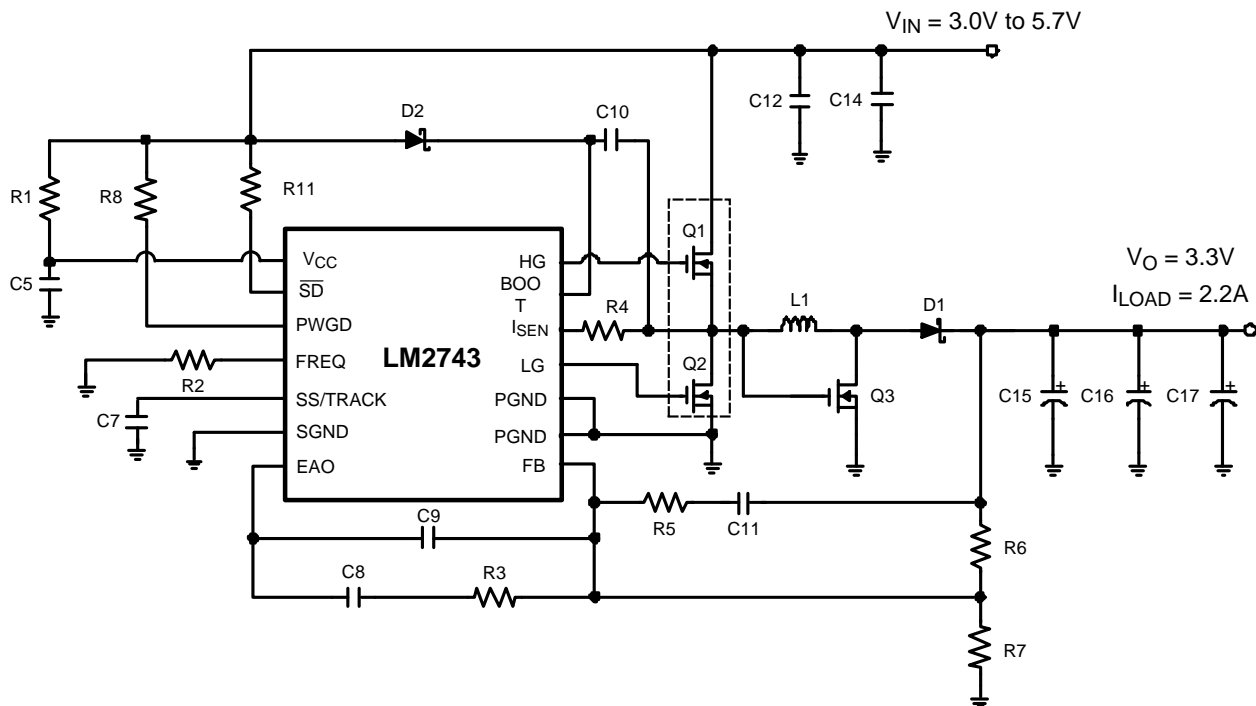
$$f_{SW} = 250 \text{ kHz}$$

$$I_{OUT} = 2.2A$$

$$* T_{AMBIENT} = -40^{\circ}C \text{ to } 85^{\circ}C$$

The LM274X satisfies handheld portable application with lithium-ion, multi-cell alkaline or NiMH batteries, whose required output load voltage is within the battery charge and discharged range. A popular power converter solution to this requirement is a SEPIC, but its low efficiency, two large inductors, and a DC blocking capacitor in the power stage demands a large board area.

A Buck-Boost power converter as seen in [Figure 4](#), has a higher efficiency, requires only one inductor, does not require a large power burning sense resistor, and its power stage transfer function is a degree less complicated in contrast with a SEPIC configuration, thereby reduces solution size, cost, design time, and prolongs battery life.


**Figure 4. Buck Boost Schematic**
**Table 5. Bill of Materials #5**

Designator	Function	Part Description	Part Number
U1	Buck Switching Controller	Synchronous Controller TSSOP14	Texas Instruments LM2743
C5	V <sub>CC</sub> Decoupling	Cer Cap 1 μF 10V 0805	AVX 0805ZD105MAT
C7	Soft Start Cap	Cer Cap 12 nF 0603	Vishay VJ0603Y123KXX
C8	Comp Cap	Cer Cap 33 nF 0603	Vishay VJ0603Y333KXX
C9	Comp Cap	Cer Cap 330 pF 0603	Vishay VJ0603A331KAA
C10	Cboot	Cer Cap 0.1 μF 0805	Vishay VJ0805Y104KXX
C11	Comp Cap	Cer Cap 8.2 nF 0603	Vishay VJ0603Y822KXX
C12	Input Filter Cap	Cer Cap 22 μF 10V 1210	AVX 1210ZD226MAT
C14	Input Filter Cap	AL-Elec 220 μF, 10V	Sanyo 10ME220WX
C15	Output Filter Cap	100μF, 4V, MLCC, X5R	AVX 12104D107MAT
C16	Output Filter Cap	100μF, 4V, MLCC, X5R	AVX 12104D107MAT
C17	Output Filter Cap	100μF, 4V, MLCC, X5R	AVX 12104D107MAT
R1	V <sub>CC</sub> Input Filter	Res 10.0Ω 0603	Vishay CRCW060310R0J
R2	Frequency Adjust Res	Res 121 kΩ 0603	Vishay CRCW06031213F
R3	Comp Res	Res 3.16 kΩ 0603	Vishay CRCW06033161F
R4	Current Limit Res	Res 2.55 kΩ 0603	Vishay CRCW06032551F
R5	Comp Res	Res 36.5Ω 0603	Vishay CRCW06033650F
R6	Res Divider, upper	Res 10 kΩ 0603	Vishay CRCW06031002F
R7	Res Divider, lower	Res 2.22 kΩ 0603	Vishay CRCW06032221F
R8	PWGD Pull-Up	Res 100 kΩ 0603	Vishay CRCW06031003F
R11	Shut Down Pull-Up	Res 100 kΩ 0603	Vishay CRCW06031003F
D1	Output Diode	Schottky Diode 5A 25V D-Pak	Central Semi CSHD5-25L
D2	Bootstrap Diode	Schottky Diode, SOD-123	MBR0520LTI

**Table 5. Bill of Materials #5 (continued)**

Designator	Function	Part Description	Part Number
L1	Output Filter Inductor	3.3μH, 9.26Arms, 6.3 mΩ	Cooper DR125-3R3
Q1	Top and Bottom MOSFETs	Dual N-MOSFET, 24mΩ@2.5V, 11 nC	Vishay Si9926BDY
Q2	Single Bottom MOSFET	7.5mΩ@2.5V, 36nC	Vishay Si4442DY

## 7 LM2744 DDR2 Application Design

Application Power Requirement:

$$V_{IN} = 5V$$

$$V_{DD} = 1.8V$$

$$V_{TT} = 0.9V$$

$$f_{SW} = 500 \text{ kHz}$$

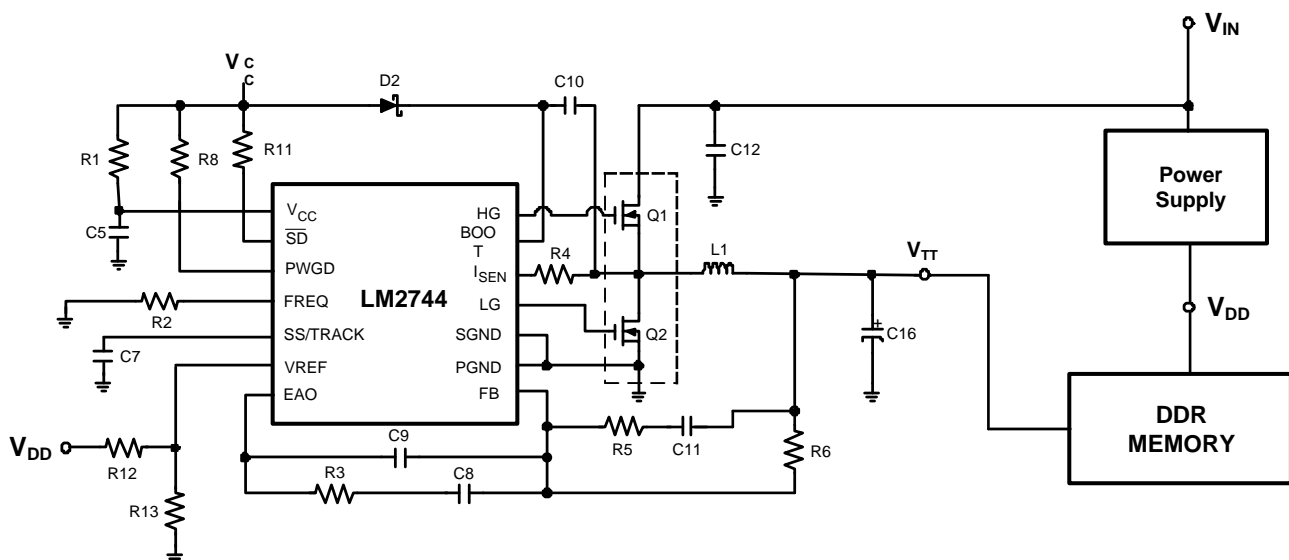
$$I_{LOAD} = 3A$$

$$* T_{AMBIENT} = -40^{\circ}\text{C to } 85^{\circ}\text{C}$$

The LM2744 has an externally adjustable reference voltage between 0.5V to 1.5V. This caters to double data rate synchronous dynamic random access memory (DDR) and DDR2 SDRAM termination power requirements.

DDR and DDR2 memory supply voltage is specified as  $V_{DD}$  and  $V_{TT}$ .  $V_{TT}$  is expected to equal  $V_{DD}/2$  and to track DC voltage variations of the memory supply with the ability to sink and source current. The memory supply voltage for DDR termination is specified as  $V_{DD} = V_{DDQ} = 1.8V$  with a DC tolerance of  $\pm 100mV$ . DC is defined as any signal less than or equal to 20 MHz. Peak-to-peak noise (non-common mode) on  $V_{REF}$  may not exceed  $\pm 1\%$  of the DC value. Peak-to-peak AC noise on  $V_{REF}$  must not exceed  $\pm 2\%$  of  $V_{REF}$  (DC). AC noise is defined as any noise over 20 MHz in frequency (Micron, June 2006).

The following design satisfies the requirements found in the document.


**Figure 5. From File: DDR**

**Table 6. Bill of Materials #6**

Designator	Function	Part Description	Part Number
U1	Buck Switching Controller	Synchronous Controller TSSOP14	Texas Instruments LM2744
C5	V <sub>CC</sub> Decoupling	Cer Cap 1 $\mu$ F 10V 0805	AVX 0805 ZD105MAT
C7	Soft Start Cap	Cer Cap 12 nF 0603	Vishay VJ0603Y123KXX
C8	Comp Cap	Cer Cap 1.2 nF 0603	Vishay VJ0603Y122KXX
C9	Comp Cap	Cer Cap 18 pF 0603	Vishay VJ0603A180KAA
C10	Cboot	Cer Cap 0.1 $\mu$ F 0805	Vishay VJ0805Y104KXX
C11	Comp Cap	Cer Cap 2.2 nF 0603	Vishay VJ0603Y222KXX
C12	Input Filter Cap	Cer Cap 22 $\mu$ F 10V 1210	AVX 1210ZD226MAT
C15	Output Filter Cap	470 $\mu$ F, 2.5V, 12 m $\Omega$ , POScap	Sanyo 2R5TPE470MC
R1	V <sub>CC</sub> Input Filter	Res 10 $\Omega$ 0603	Vishay CRCW060310R0J
R2	Frequency Adjust Res	Res 56.2 k $\Omega$ 0603	Vishay CRCW06035622F
R3	Comp Res	Res 28.7 k $\Omega$ 0603	Vishay CRCW06032872F
R4	Current Limit Res	Res 3.16 k $\Omega$ 0603	Vishay CRCW06033161F
R5	Comp Res	Res 2.67 k $\Omega$ 0603	Vishay CRCW06032671F
R6	Res Divider, upper	Res 10 k $\Omega$ 0603	Vishay CRCW06031002F
R8	PWGD Pull-Up	Res 100 k $\Omega$ 0603	Vishay CRCW06031003F
R11	Shut Down Pull-Up	Res 100 k $\Omega$ 0603	Vishay CRCW06031003F
R12	Resistor Div	Res 10 k $\Omega$ 0603	Vishay CRCW06031002F
R13	Resistor Div	Res 10 k $\Omega$ 0603	Vishay CRCW06031002F
D2	Bootstrap Diode	Schottky Diode, SOD-123	MBR0520LTI
L1	Output Filter Inductor	1.5 $\mu$ H, 4.67Arms, 13 m $\Omega$	Cooper DR73-1R5
Q1 & Q2	Dual N-MOSFET Top & Bottom MOSFET	Top 27 m $\Omega$ @4.5V, 4.6 nC Bottom 21 m $\Omega$ @4.5V, 11 nC	Renesas HAT2218R

## 8 PCB Layout Considerations

To produce an optimal power solution with the LM274X and any other SMPS, good layout and design of the PCB are as important as component selection. The following are several guidelines to aid in creating a good layout for the LM274X devices. For an extensive PCB layout explanation refer to Application Note AN-1229.

### 8.1 Separate Power Ground and Signal Ground

Good layout techniques include a dedicated ground plane, preferably on an internal layer. Power level ground (PGND) copper should reside on the top level of the board. Power level components such as the input capacitors, low side MOSFET(s), and output capacitors must have their return paths through this PGND plane and avoid current flowing through the internal dedicated ground plane. Signal level components like the compensation and feedback resistors should be connected to a separate copper section called signal ground (SGND). The signal ground section and the power ground section should be connected to the internal dedicated ground plane and serve as the single point ground connection.

### 8.2 Low Impedance Power Path

The power path includes the input capacitors, power FETs, output inductor, and output capacitors. Keep these components on the same side of the PCB and connect them with thick traces or copper planes on the same layer. Vias add resistance and inductance to the power path and have high impedance connections to internal planes. If heavy switching currents must be routed through vias and/or internal planes, use multiple vias in parallel to reduce their resistance and inductance. The power components must be kept close together. The longer the paths that connect them, the more inductance, thus the more they act as antennas radiating unwanted EMI.

### 8.3 **Minimize the Switch Node Copper**

The plane that connects the power FETs and output inductor together radiates more EMI as it gets larger. Use just enough copper to give low impedance to the switching currents.

### 8.4 **Kelvin Traces for Sense Lines**

The feedback trace should connect the positive node of the output capacitor and connect to the top feedback resistor (R2). Keep this trace away from the switch node and from the output inductor. Make sure to keep the sense resistor as close as possible to the pin and keep the trace away from EMI radiating nodes and components.

\* PCB copper area must be satisfied per manufacturer datasheet in order to achieve maximum ambient temperature.

## 9 **References**

1. Hong Huang, Astec International Limited, July 2003, "Study of Beat Frequencies – Modeling and reducing the Effects in Switch-mode DC Power Conversion Systems"
2. Altera Corporation, February 2007, "Stratix III Power Management Design Guide", Application Note 448
3. Micron, June 2006, "DDR2 Power Solutions For Notebooks", Technical Note-47-05
4. Ravindra Ambatipudi, National Semiconductor Corporation, [No Date], "Simple Techniques Minimize Cross-Coupling in Distributed Power Systems"



## IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as "components") are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

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

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

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license 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 significant portions of TI 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. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

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

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI's goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or "enhanced plastic" are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have **not** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

### Products

Audio	<a href="http://www.ti.com/audio">www.ti.com/audio</a>
Amplifiers	<a href="http://amplifier.ti.com">amplifier.ti.com</a>
Data Converters	<a href="http://dataconverter.ti.com">dataconverter.ti.com</a>
DLP® Products	<a href="http://www.dlp.com">www.dlp.com</a>
DSP	<a href="http://dsp.ti.com">dsp.ti.com</a>
Clocks and Timers	<a href="http://www.ti.com/clocks">www.ti.com/clocks</a>
Interface	<a href="http://interface.ti.com">interface.ti.com</a>
Logic	<a href="http://logic.ti.com">logic.ti.com</a>
Power Mgmt	<a href="http://power.ti.com">power.ti.com</a>
Microcontrollers	<a href="http://microcontroller.ti.com">microcontroller.ti.com</a>
RFID	<a href="http://www.ti-rfid.com">www.ti-rfid.com</a>
OMAP Applications Processors	<a href="http://www.ti.com/omap">www.ti.com/omap</a>
Wireless Connectivity	<a href="http://www.ti.com/wirelessconnectivity">www.ti.com/wirelessconnectivity</a>

### Applications

Automotive and Transportation	<a href="http://www.ti.com/automotive">www.ti.com/automotive</a>
Communications and Telecom	<a href="http://www.ti.com/communications">www.ti.com/communications</a>
Computers and Peripherals	<a href="http://www.ti.com/computers">www.ti.com/computers</a>
Consumer Electronics	<a href="http://www.ti.com/consumer-apps">www.ti.com/consumer-apps</a>
Energy and Lighting	<a href="http://www.ti.com/energy">www.ti.com/energy</a>
Industrial	<a href="http://www.ti.com/industrial">www.ti.com/industrial</a>
Medical	<a href="http://www.ti.com/medical">www.ti.com/medical</a>
Security	<a href="http://www.ti.com/security">www.ti.com/security</a>
Space, Avionics and Defense	<a href="http://www.ti.com/space-avionics-defense">www.ti.com/space-avionics-defense</a>
Video and Imaging	<a href="http://www.ti.com/video">www.ti.com/video</a>

### TI E2E Community

[e2e.ti.com](http://e2e.ti.com)