

# LM1770 Design Reference

National Semiconductor  
Application Note 1414  
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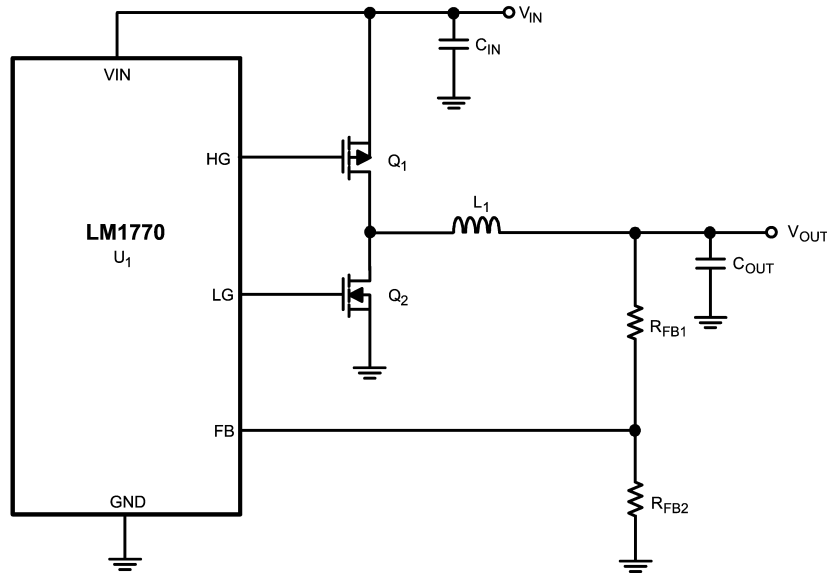
## Introduction

The LM1770 is a high efficiency synchronous buck controller which drives an external high side PFET and low side NFET. The controller utilizes a constant on-time control scheme which eliminates the need for external compensation components, allowing the power supply designer to minimize necessary board space and reduce costs.

This application note presents several reference designs that can be used to implement the LM1770 Synchronous Buck Controller in a wide variety of configurations. Input

voltages range from 3.3V to 5V, and the designs encompass common output voltages between 0.8V and 3.3V. Maximum output currents of 2A, 3A and 4A are demonstrated. Switching frequencies range between 242kHz and 1.5MHz depending on the operating conditions and the LM1770 timing option (see the LM1770 datasheet for more information on how to determine switching frequency). Included with an explanation of each design is a bill-of-materials as well as efficiency, output ripple, and transient measurements.

## 5V to 3.3V Conversion at 1 MHz (2A Max $I_{OUT}$ )



20170501

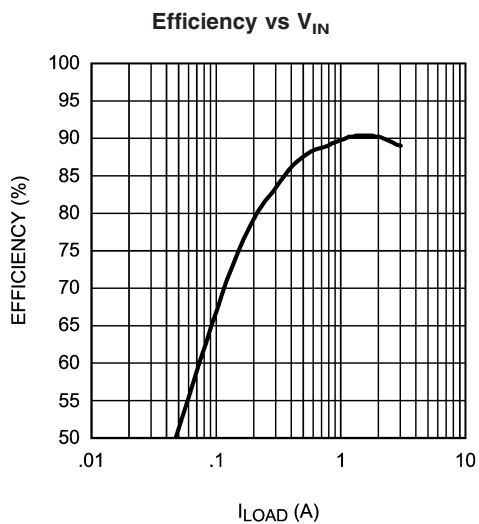
This higher frequency design enables the use of a small valued inductor (1  $\mu$ H) and a 68  $\mu$ F OSCON output capacitor, reducing component size. A stable design is possible without the use of a feed-forward capacitor, further reducing necessary board space. For the PFET and the NFET, the

SI3867DV and the SI3460DV are chosen due to their desirable  $R_{DS(on)}$  specifications, current handling capabilities and small footprints. The 1000 ns LM1770 timing option is used to implement the 1 MHz frequency.

Bill of Materials for 5V to 3.3V at 1 MHz

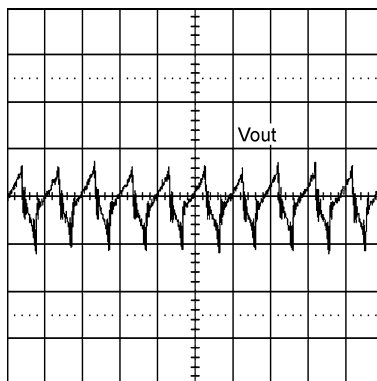
ID	Part Number	Type	Size	Parameters	Vendor	Qty
U <sub>1</sub>	LM1770T	Synchronous Buck Controller	SOT23-5	1000 ns	NSC	1
C <sub>IN</sub>	GRM32ER60J476ME20B	Input Capacitor	1210	47 $\mu$ F/X5R/6.3V	muRata	1
C <sub>OUT</sub>	10SVPA68MAA	Output Capacitor	C6	68 $\mu$ F/OSCON/10V	Sanyo	1
L	DO1608C-102MLC	Inductor		1 $\mu$ H	Coilcraft	1
R <sub>FB1</sub>	CRCW08052551	Resistor	0805	2.55 k $\Omega$ $\pm$ 1%	Dale	1
R <sub>FB2</sub>	CRCW08058060	Resistor	0805	806 $\Omega$ $\pm$ 1%	Dale	1
Q <sub>1</sub>	SI3867DV	PFET	TSOP-6	SI3867DV	Siliconix	1
Q <sub>2</sub>	SI3460DV	NFET	TSOP-6	SI3460DV	Siliconix	1

# 5V to 3.3V Conversion at 1 MHz (2A Max $I_{OUT}$ ) (Continued)



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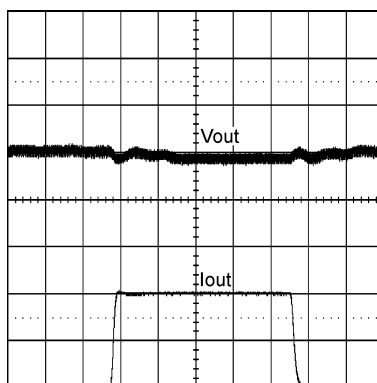
**Output Ripple with  $I_{OUT} = 3A$**



20170503

$V_{OUT}$ : Output Ripple Voltage, 20mV AC/div

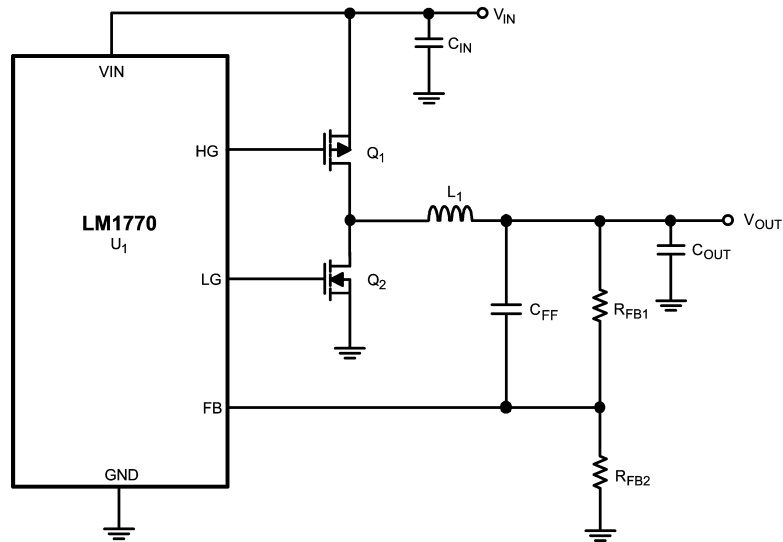
**Output Transient Response**



20170504

$V_{OUT}$ : Output Voltage, 200mV AC/div  
 $I_{OUT}$ : Load Current, 1A/div

## 5V to 3.3V Conversion at 500 kHz (4A Max $I_{OUT}$ )



20170505

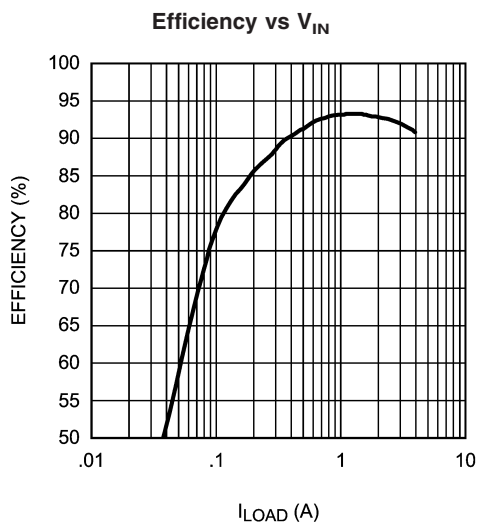
This design operates at 500 kHz and utilizes larger valued components to enable a high maximum output current. A 2.2  $\mu$ H inductor and a 150  $\mu$ F POSCAP output capacitor are used to generate the necessary ripple at the output and a 1 nF feed-forward capacitor is used to help stabilize the design. Due to the large current being switched on the board, a

larger 150  $\mu$ F electrolytic input capacitor is used. The SI9433BDY PFET and SI4894DY NFET provide the necessary power handling capabilities to switch the large output current in this design, and the 2000 ns LM1770 timing option operates at 500 kHz in this configuration.

**Bill of Materials for 5V to 3.3V at 500KHz**

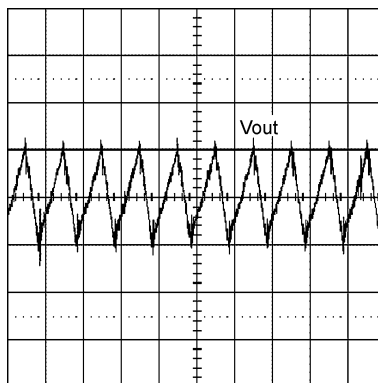
ID	Part Number	Type	Size	Parameters	Manufacturer	Qty
U <sub>1</sub>	LM1770U	Synchronous Buck Controller	SOT23-5	2000 ns	NSC	1
C <sub>FF</sub>	VJ0805Y102KXXM	Capacitor	0805	1 nF/X7R/25V	Vitramon	1
C <sub>IN</sub>	EEUFC0J151	Capacitor		150 $\mu$ F/Electrolytic/6.3V	Panasonic	1
C <sub>OUT</sub>	4TPB150MC	Capacitor	C	150 $\mu$ F/POSCAP/4V	Sanyo	1
L	DO3316P-222ML	Inductor		2.2 $\mu$ H	Coilcraft	1
Q <sub>1</sub>	SI9433BDY	PFET	SO-8	SI9433BDY	Siliconix	1
Q <sub>2</sub>	SI4894DY	NFET	SO-8	SI4894DY	Siliconix	1
R <sub>FB1</sub>	CRCW08052492	Resistor	0805	24.9 k $\Omega$ $\pm$ 1%	Dale	1
R <sub>FB2</sub>	CRCW08058061	Resistor	0805	8.06 k $\Omega$ $\pm$ 1%	Dale	1

# 5V to 3.3V Conversion at 500 kHz (4A Max $I_{OUT}$ ) (Continued)



20170506

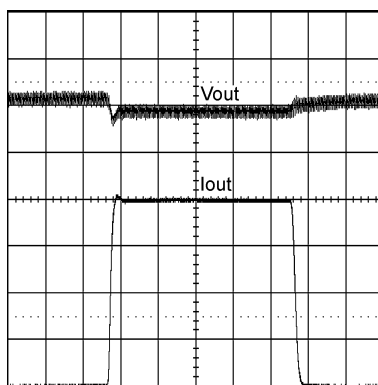
## Output Ripple with $I_{OUT} = 4A$



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$V_{OUT}$ : Output Voltage, 20mV AC/div

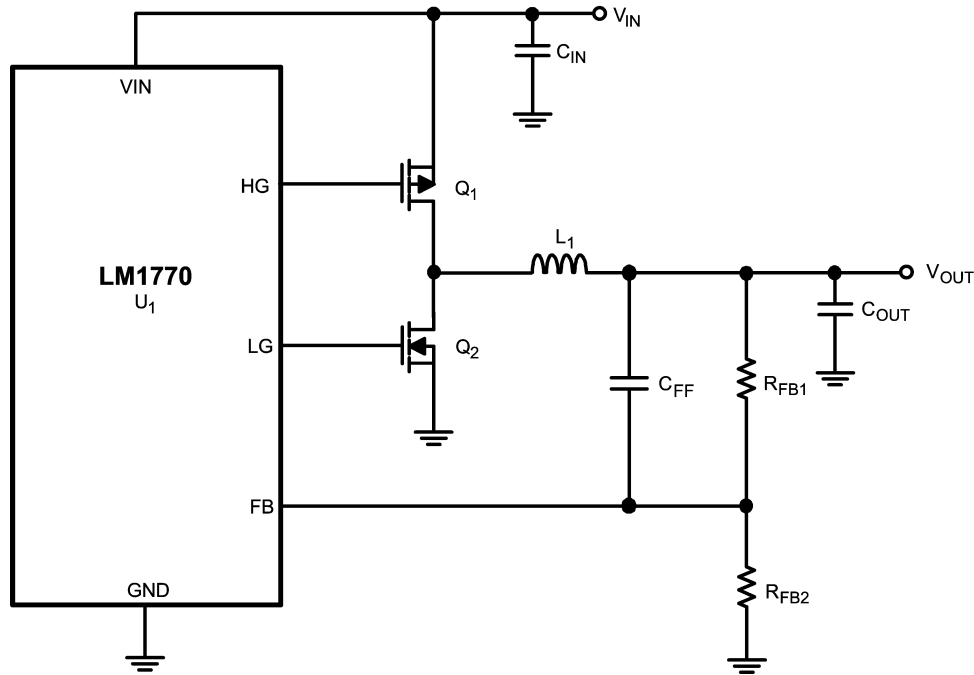
## Output Transient Response



20170508

$V_{OUT}$ : Output Voltage, 200mV AC/div  
 $I_{OUT}$ : Load Current, 1A/div

## 5V to 2.5V Conversion at 1.5 MHz (3A Max $I_{OUT}$ )



20170505

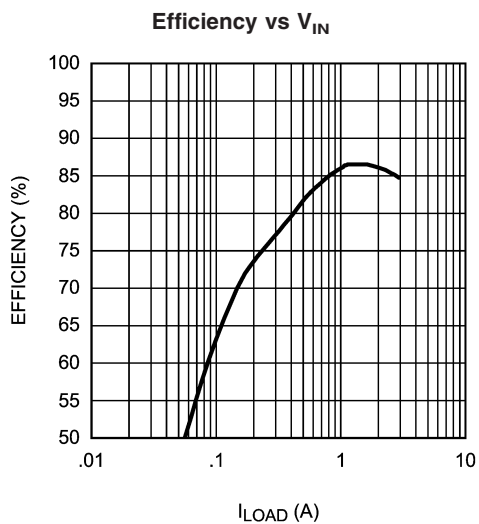
The use of a small valued inductor (1.5  $\mu\text{H}$ ) is made possible by the high frequency operation. A 68  $\mu\text{F}$ , low profile, POS-CAP output capacitor is used, along with a 10 nF ceramic feed-forward capacitor, to ensure stability. The 500 ns

LM1770 timing option allows for the 1.5 MHz switching frequency, and again the SI3867DV and SI3460DV FETs are used.

Bill of Materials for 5V to 2.5V at 1.5MHz

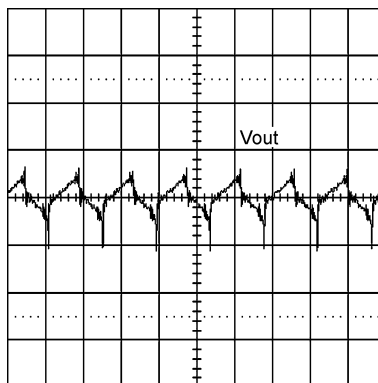
ID	Part Number	Type	Size	Parameters	Vendor	Qty
U <sub>1</sub>	LM1770S	Synchronous Buck Controller	SOT23-5	500 ns	NSC	1
C <sub>OUT</sub>	4TB68M	Capacitor	B2	68 $\mu\text{F}$ /POSCAP/4V	Sanyo	1
C <sub>FF</sub>	VJ0805Y103KXXM	Capacitor	0805	10 nF/X7R/25V	Vitramon	1
C <sub>IN</sub>	GRM32ER61A226KA65B	Capacitor	1210	22 $\mu\text{F}$ /X5R/10V	muRata	1
C <sub>OUT</sub>	4TB68M	Capacitor	B2	68 $\mu\text{F}$ /POSCAP/4V	Sanyo	1
L	DO3316P-152ML	Inductor		1.5 $\mu\text{H}$	Coilcraft	1
Q <sub>1</sub>	SI3867DV	PFET	TSOP-6	SI3867DV	Siliconix	1
Q <sub>2</sub>	SI3460DV	NFET	TSOP-6	SI3460DV	Siliconix	1
R <sub>FB1</sub>	CRCW08051692	Resistor	0805	16.9 k $\Omega$ $\pm$ 1%	Dale	1
R <sub>FB2</sub>	CRCW08058061	Resistor	0805	8.06 k $\Omega$ $\pm$ 1%	Dale	1

# 5V to 2.5V Conversion at 1.5 MHz (3A Max $I_{OUT}$ ) (Continued)



20170510

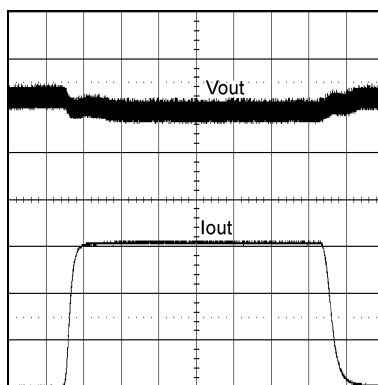
## Output Ripple with $I_{OUT} = 3A$



20170511

$V_{OUT}$ : Output Voltage, 50mV AC/div

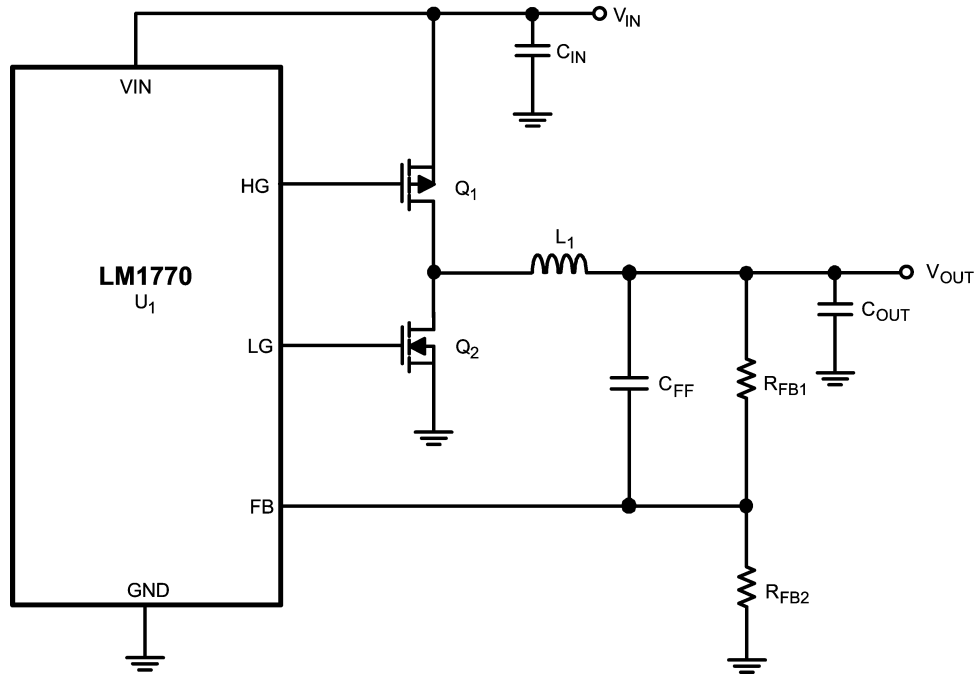
## Output Transient Response



20170512

$V_{OUT}$ : Output Voltage, 100mV AC/div  
 $I_{OUT}$ : Load Current, 1A/div

## 5V to 2.5V Conversion at 378 kHz (2A Max $I_{OUT}$ )



20170505

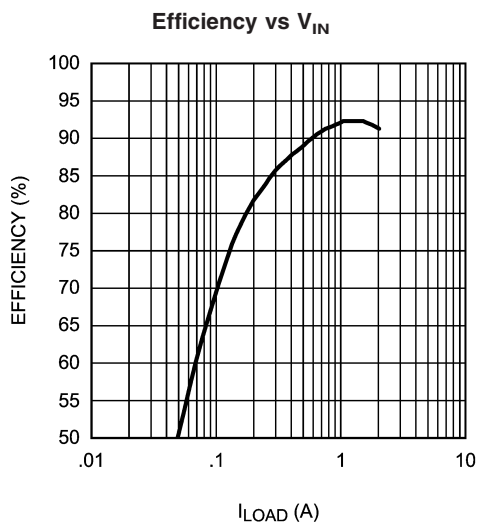
This design utilizes small components allowing a minimally sized complete power supply solution. A 5.0  $\mu\text{H}$ , small footprint inductor is used along with a 47  $\mu\text{F}$  POSCAP output capacitor to minimize component size. A 10 nF ceramic feed-forward capacitor helps improve stability, and again the

SI3867DV and SI3460DV FETs are used. The 2000 ns LM1770 timing option sets the operating frequency at 378 kHz. This design is identical to the LM1770 Demo Board, and more information on the general design as well as the layout of the PCB is available in Application Note AN-1400.

**Bill of Materials for 5V to 2.5V at 378KHz**

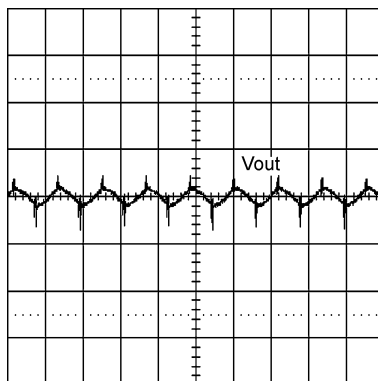
ID	Part Number	Type	Size	Parameters	Vendor	Qty
U <sub>1</sub>	LM1770U	Synchronous Buck Controller	SOT23-5	2000 ns	NSC	1
C <sub>FF</sub>	VJ0603Y103KXXA	Capacitor	0603	10 nF/X7R/25V	Vitramon	1
C <sub>IN</sub>	GRM21BR60J226ME39B	Capacitor	0805	22 $\mu\text{F}$ /X5R/6.3V	muRata	1
C <sub>OUT</sub>	4TPC47M	Capacitor	B1	47 $\mu\text{F}$ /POSCAP/4V	Sanyo	1
L	MSS7341-502NX	Inductor		5.0 $\mu\text{H}$	Coilcraft	1
Q <sub>1</sub>	SI3867DV	PFET	TSOP-6	SI3867DV	Siliconix	1
Q <sub>2</sub>	SI3460DV	NFET	TSOP-6	SI3460DV	Siliconix	1
R <sub>FB1</sub>	CRCW06032102F	Resistor	0603	21 k $\Omega$ $\pm$ 1%	Dale	1
R <sub>FB2</sub>	CRCW06031002	Resistor	0603	10 k $\Omega$ $\pm$ 1%	Dale	1

# 5V to 2.5V Conversion at 378 kHz (2A Max $I_{OUT}$ ) (Continued)



20170514

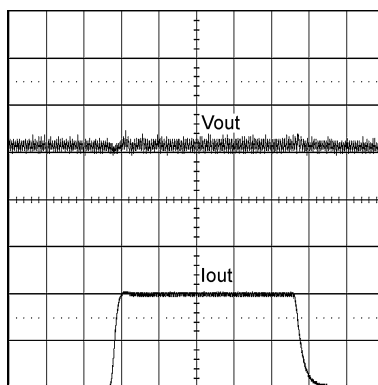
## Output Ripple with $I_{OUT} = 2A$



20170515

$V_{OUT}$ : Output Voltage, 50mV AC/div

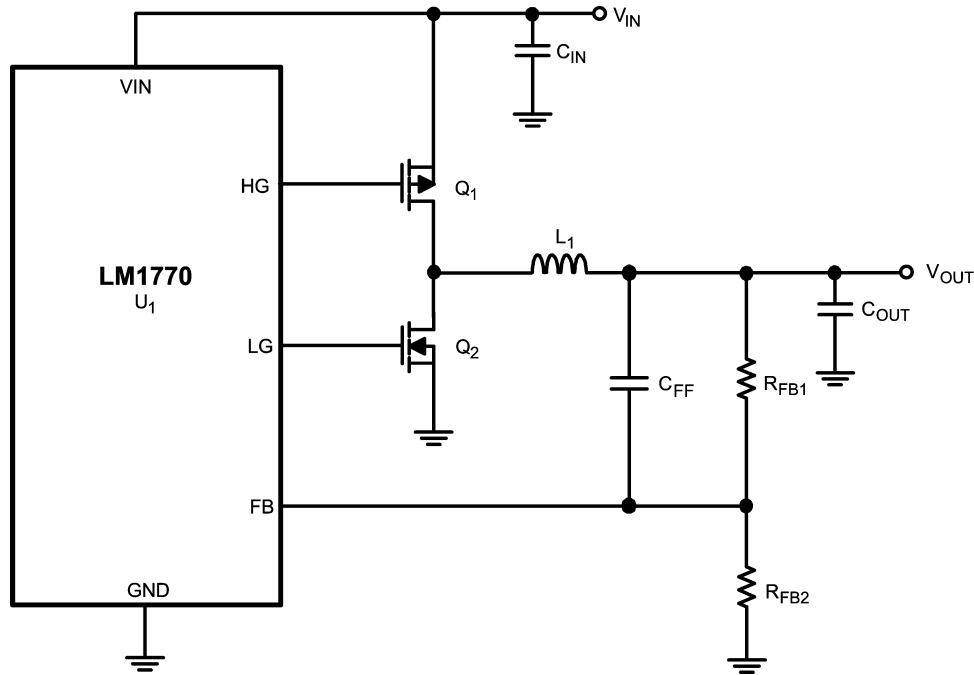
## Output Transient Response



20170516

$V_{OUT}$ : Output Voltage, 100mV AC/div  
 $I_{OUT}$ : Load Current, 1A/div

## 5V to 1V Conversion at 303KHz (3A Max $I_{OUT}$ )



20170505

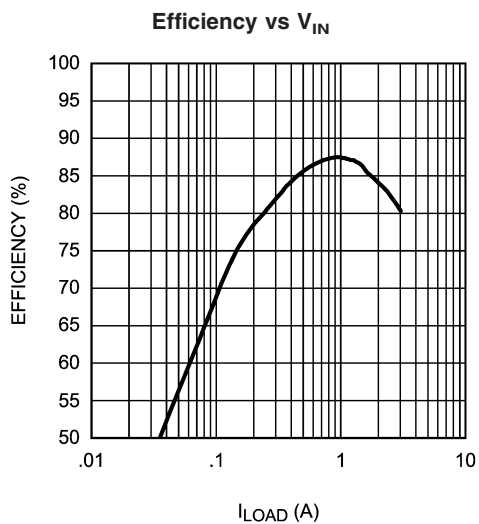
This design illustrates the LM1770's performance at a low frequency of operation as well as a low output voltage. A 6.8  $\mu$ H inductor is used along with a low ESR 68  $\mu$ F OSCON output capacitor to minimize the voltage ripple at the output,

while still ensuring stability. A 10 nF feed forward capacitor is also used, along with the SI3867DV PFET and the SI3460DV NFET. The 2000 ns LM1770 provides the 303 kHz switching frequency.

Bill of Materials for 5V to 1V at 303 kHz

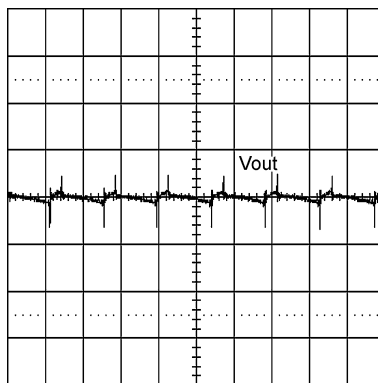
ID	Part Number	Type	Size	Parameters	Vendor	Qty
U <sub>1</sub>	LM1770T	Synchronous Buck Controller	SOT23-5	1000 ns	NSC	1
C <sub>FF</sub>	VJ0805Y103KXXM	Capacitor	0805	10 nF/X7R/25V	Vitramon	1
C <sub>IN</sub>	GRM43SR60J107ME20B	Capacitor	1812	100 $\mu$ F/X5R/6.3V	muRata	1
C <sub>OUT</sub>	6SVPC100M	Capacitor	B6	100 $\mu$ F/OSCON/6.3V	Sanyo	1
L	DO3316P-682ML	Inductor		6.8 $\mu$ H	Coilcraft	1
Q <sub>1</sub>	SI3867DV	PFET	TSOP-6	SI3867DV	Siliconix	1
Q <sub>2</sub>	SI3460DV	NFET	TSOP-6	SI3460DV	Siliconix	1
R <sub>FB1</sub>	CRCW08052001	Resistor	0805	2 k $\Omega$ $\pm$ 1%	Dale	1
R <sub>FB2</sub>	CRCW08058061	Resistor	0805	8.06 k $\Omega$ $\pm$ 1%	Dale	1

# 5V to 1V Conversion at 303KHz (3A Max $I_{OUT}$ ) (Continued)



20170518

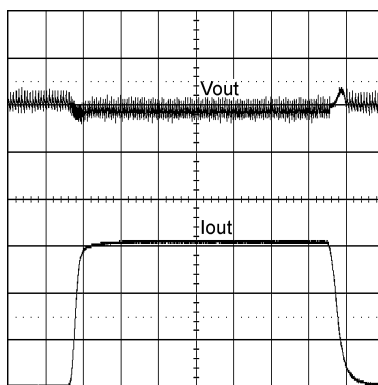
## Output Ripple with $I_{OUT} = 3A$



20170519

$V_{OUT}$ : Output Voltage, 20mV AC/div

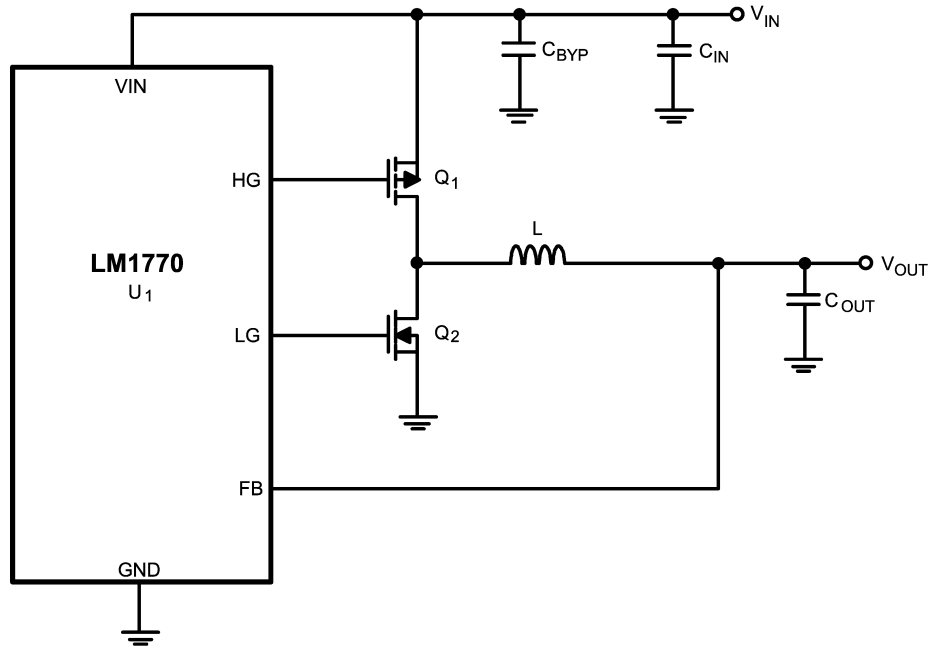
## Output Transient Response



20170520

$V_{OUT}$ : Output Voltage, 50mV AC/div  
 $I_{OUT}$ : Load Current, 1A/div

### 3.3V to 0.8V Conversion at 242KHz (2A Max $I_{OUT}$ )



20170521

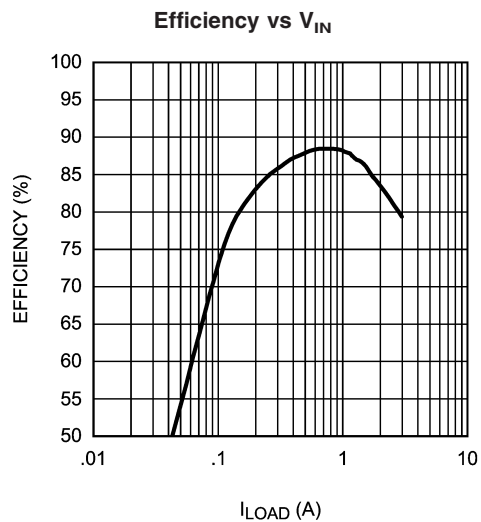
This design regulates the output at the LM1770's reference voltage. There are no feedback resistors necessary for this design as the output voltage is connected directly to the feedback pin. A 6.8  $\mu$ H inductor and a 150  $\mu$ F POSCAP

output capacitor are used to create enough ripple at the output to ensure stability. No feedforward capacitor is necessary and the SI3867DV and SI3460DV FETs are used.

**Bill of Materials for 3.3V to 0.8V at 242 kHz**

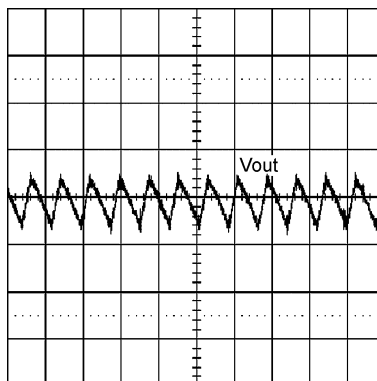
ID	Part Number	Type	Size	Parameters	Vendor	Qty
U <sub>1</sub>	LM1770T	Synchronous Buck Controller	SOT23-5	1000ns	NSC	1
C <sub>BYP</sub>	VJ0805Y104KXXM	Capacitor	0805	100 nF/X7R/25V	Vitramon	1
C <sub>IN</sub>	GRM32ER60J476ME20B	Capacitor	1210	47 $\mu$ F/X5R/6.3V	muRata	1
C <sub>OUT</sub>	4TPB150MC	Capacitor	C	150 $\mu$ F/POSCAP/6.3V	Sanyo	1
L	DO3316P-682ML	Inductor		6.8 $\mu$ H	Coilcraft	1
Q <sub>1</sub>	SI3867DV	PFET	TSOP-6	SI3867DV	Siliconix	1
Q <sub>2</sub>	SI3460DV	NFET	TSOP-6	SI3460DV	Siliconix	1

### 3.3V to 0.8V Conversion at 242KHz (2A Max $I_{OUT}$ ) (Continued)



20170522

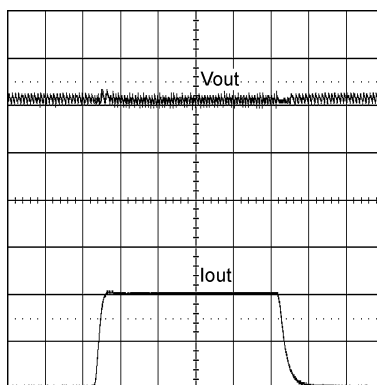
**Output Ripple with  $I_{OUT} = 2A$**



20170523

$V_{OUT}$ : Output Voltage, 20mV AC/div

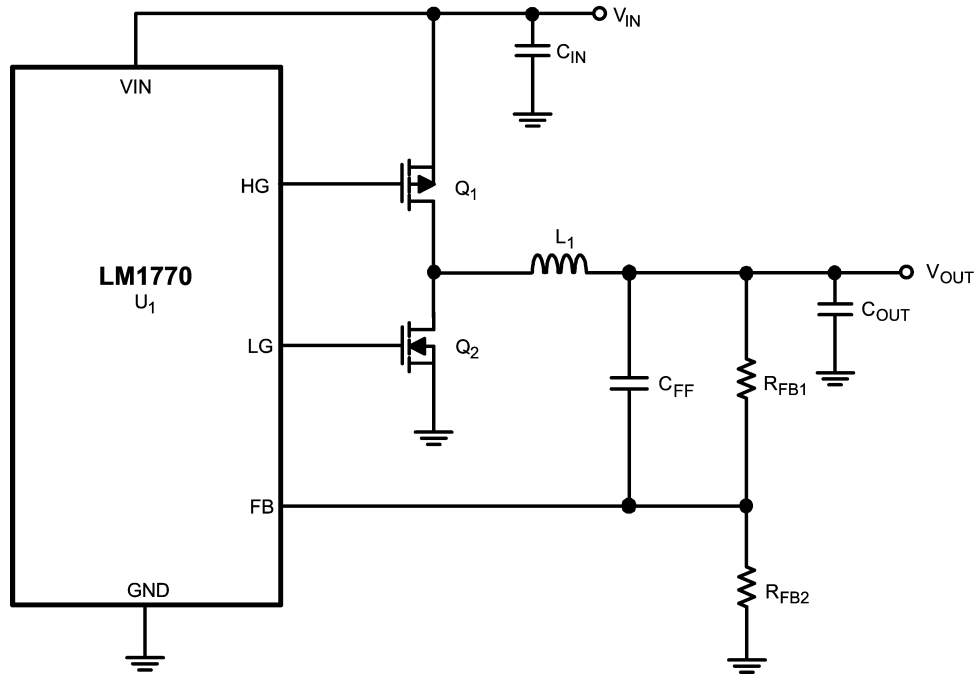
**Output Transient Response**



20170524

$V_{OUT}$ : Output Voltage, 100mV AC/div  
 $I_{OUT}$ : Load Current, 2A/div

### 3.3V to 0.9V Conversion at 545 kHz (3A Max $I_{OUT}$ ) DDR2 Application



20170505

This design operates at a higher frequency as compared to the 0.8V design above. This facilitates the use of a smaller 3.3  $\mu$ H inductor which allows the complete power supply to fit on the LM1770 evaluation board PCB. The output is set at 0.9V to provide a VTT voltage for use in DDR2 applications.

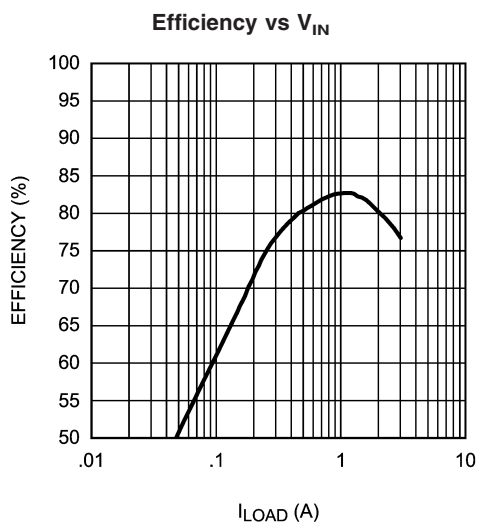
The design is capable of both sinking and sourcing current. A 100  $\mu$ F POSCAP is used as the output capacitor, and again the SI3867DV and SI3460DV FETs are used. The 500 ns LM1770 timing option operates at 545 kHz for this application.

**Bill of Materials for 3.3V to 0.9V at 545 kHz**

ID	Part Number	Type	Size	Parameters	Vendor	Qty
U <sub>1</sub>	LM1770S	Synchronous Buck Controller	SOT23-5	500 ns	NSC	1
C <sub>FF</sub>	VJ0603Y102KXXM	Capacitor	0603	1 nF/X7R/25V	Vitramon	1
C <sub>IN</sub>	GRM21BR60J226ME39B	Capacitor	0805	22 $\mu$ F/X5R/6.3V	muRata	1
C <sub>OUT</sub>	6TPB100MA	Capacitor	B2	100 $\mu$ F/POSCAP/6.3V	Sanyo	1
L	MSS7341-332NX	Inductor		3.3 $\mu$ H	Coilcraft	1
Q <sub>1</sub>	SI3867DV	PFET	TSOP-6	SI3867DV	Siliconix	1
Q <sub>2</sub>	SI3460DV	NFET	TSOP-6	SI3460DV	Siliconix	1
R <sub>FB1</sub>	CRCW06031001	Resistor	0603	1 k $\Omega$ $\pm$ 1%	Dale	1
R <sub>FB2</sub>	CRCW06038061	Resistor	0603	8.06 k $\Omega$ $\pm$ 1%	Dale	1

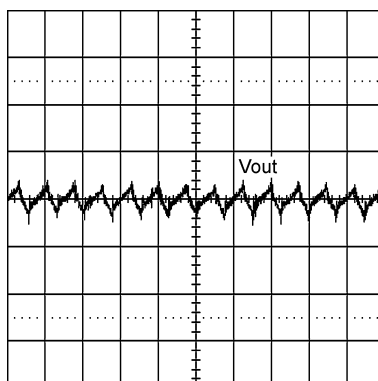
# 3.3V to 0.9V Conversion at 545 kHz (3A Max $I_{OUT}$ ) DDR2 Application

(Continued)



20170526

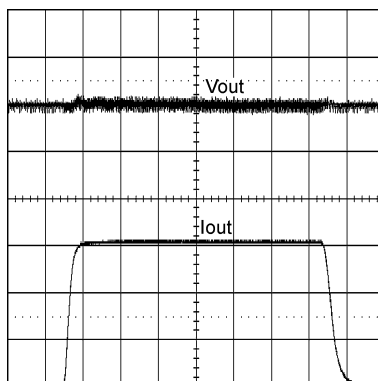
**Output Ripple with  $I_{OUT} = 3A$**



20170527

$V_{OUT}$ : Output Voltage, 20mV AC/div

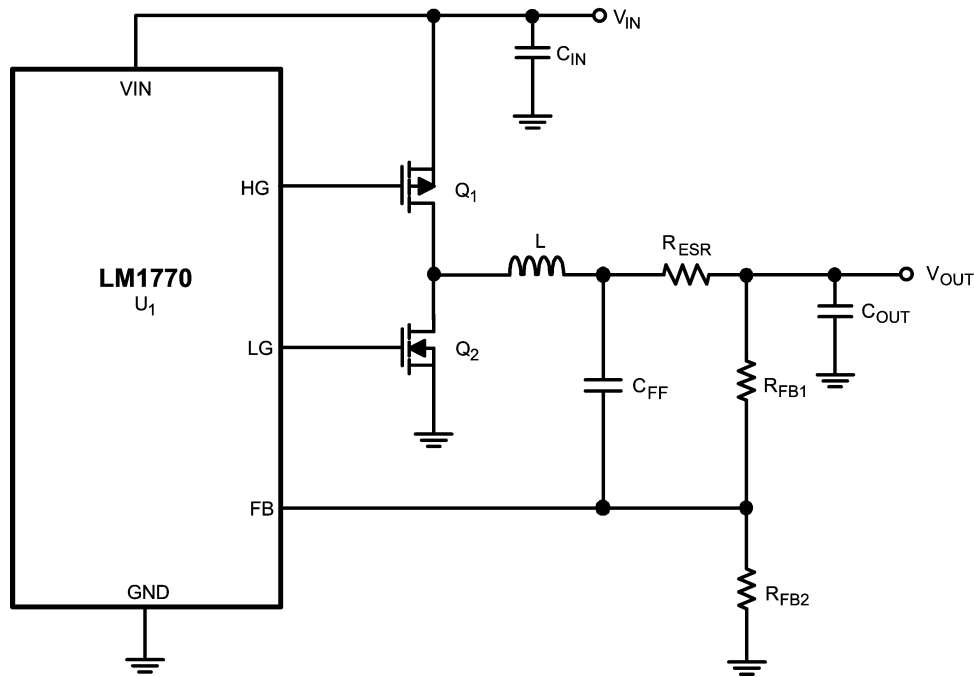
**Output Transient Response**



20170528

$V_{OUT}$ : Output Voltage, 100mV AC/div  
 $I_{OUT}$ : Load Current, 1A/div

### 3.3V to 1.8V Conversion at 272 kHz (2A Max $I_{OUT}$ ) All Ceramic Application



20170529

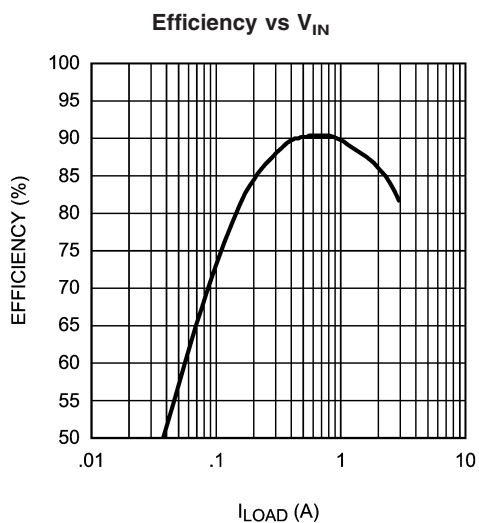
This design incorporates a 22  $\mu$ F ceramic output capacitor. Due to the lack of ESR on ceramic capacitors, a separate 50 m $\Omega$  resistor is used for creating sufficient ripple at the output. A 3.3  $\mu$ H inductor value is used along with a 10 nF feed-

forward capacitor to help ensure stability. The SI3867DV and SI3460DV FETs are again used as the high side and low side switches, respectively. The 2000 ns LM1770 timing option accommodates 272 kHz operation.

ID	Part Number	Type	Size	Parameters	Vendor	Qty
U <sub>1</sub>	LM1770U	Synchronous Buck Controller	SOT23-5	2000 ns	NSC	1
C <sub>FF</sub>	VJ0805Y103KXXA	Capacitor	0805	10 nF/X7R/25V	Vitramon	1
C <sub>IN</sub>	GRM32ER60J476ME20B	Capacitor	1210	47 $\mu$ F/X5R/6.3V	muRata	1
C <sub>OUT</sub>	GRM32ER61A226KA65B	Capacitor	1210	22 $\mu$ F/X5R/10V	muRata	1
L	DO3316P-332ML	Inductor		3.3 $\mu$ H	Coilcraft	1
Q <sub>1</sub>	SI3867DV	PFET	TSOP-6	SI3867DV	Siliconix	1
Q <sub>2</sub>	SI3460DV	NFET	TSOP-6	SI3460DV	Siliconix	1
R <sub>ESR</sub>	WSL-1206	Resistor	1206	.05 $\Omega$ $\pm$ 1%	Dale	1
R <sub>FB1</sub>	CRCW08051241	Resistor	0805	1.24 k $\Omega$ $\pm$ 1%	Dale	1
R <sub>FB2</sub>	CRCW08051001	Resistr	0805	1.00 k $\Omega$ $\pm$ 1%	Dale	1

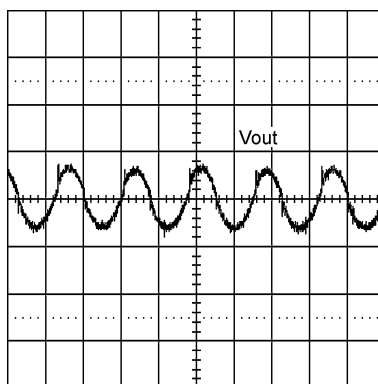
# 3.3V to 1.8V Conversion at 272 kHz (2A Max $I_{OUT}$ ) All Ceramic Application

(Continued)



20170530

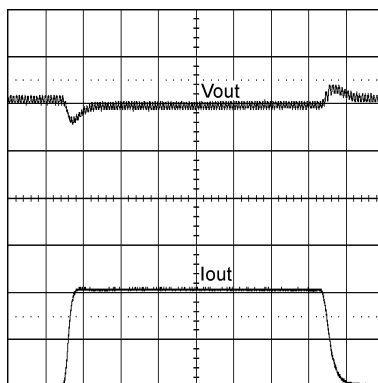
**Output Ripple with  $I_{OUT} = 2A$**



20170531

$V_{OUT}$ : Output Voltage, 20mV AC/div

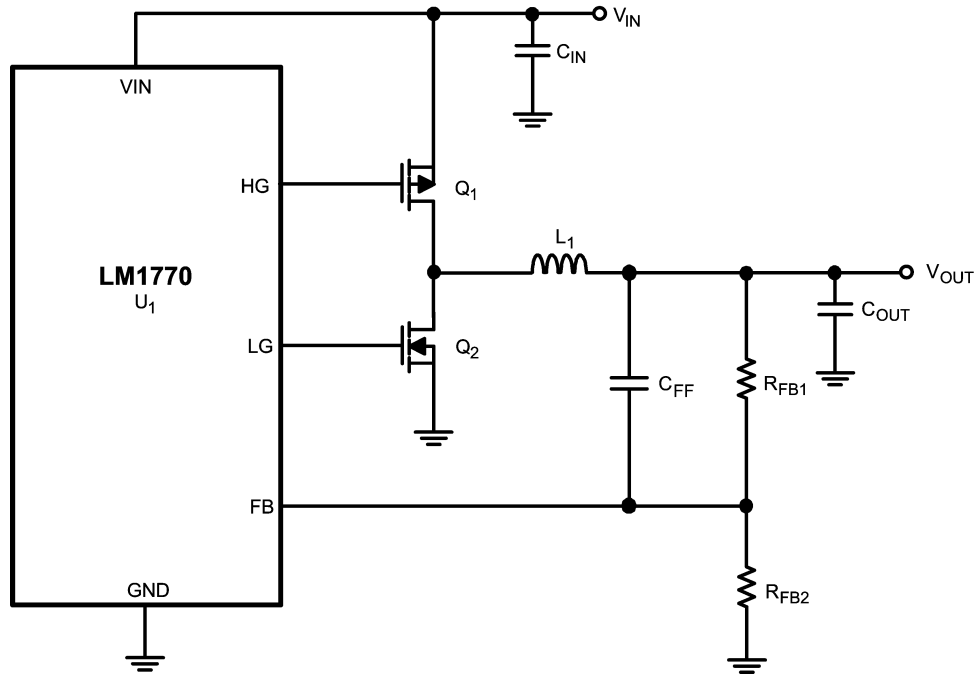
**Output Transient Response**



20170532

$V_{OUT}$ : Output Voltage, 200mV AC/div  
 $I_{OUT}$ : Load Current, 1A/div

### 3.3V to 1.8V Conversion at 545 kHz (2A Max $I_{OUT}$ )



20170505

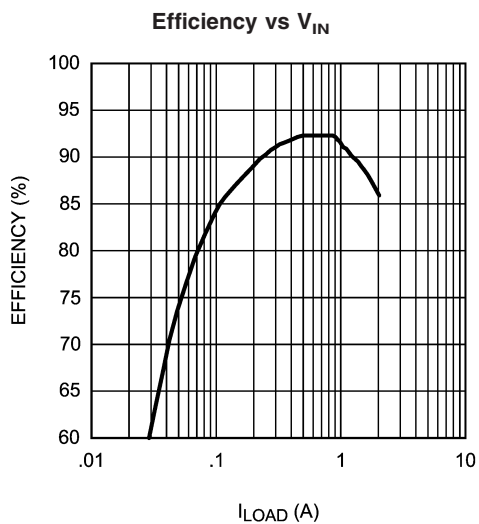
This is another design utilizing small sized components chosen to fit on the LM1770 evaluation board PCB. A 6.2  $\mu\text{H}$  inductor along with a 68  $\mu\text{F}$  POSCAP capacitor are used to implement the output filter, and a 10 nF feed-forward capaci-

tor is added to help improve stability. Again the SI3867DV and the SI3460DV FETs are used, and the 1000 ns LM1770 timing option accommodates the 545 kHz switching frequency.

Bill of Materials for 3.3V to 1.8V at 545 kHz

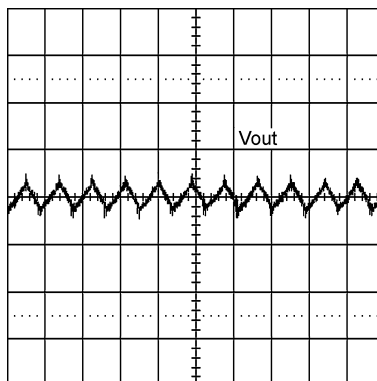
ID	Part Number	Type	Size	Parameters	Vendor	Qty
U <sub>1</sub>	LM1770T	Synchronous Buck Controller	SOT23-5	1000 ns	NSC	1
C <sub>FF</sub>	VJ0603Y103KXXM	Capacitor	0603	10 nF/X7R/25V	Vitramon	1
C <sub>IN</sub>	GRM32ER61A226KA65B	Capacitor	0805	22 $\mu\text{F}$ /X5R/6.3V	muRata	1
C <sub>OUT</sub>	4TPB68M	Capacitor	B2	68 $\mu\text{F}$ /POSCAP/4.0V	Sanyo	1
L	MSS7341-622NX	Inductor		6.2 $\mu\text{H}$	Coilcraft	1
Q <sub>1</sub>	SI3867DV	PFET	TSOP-6	SI3867DV	Fairchild	1
Q <sub>2</sub>	SI3460DV	NFET	TSOP-6	SI3460DV	Siliconix	1
R <sub>FB1</sub>	CRCW06031002	Resistor	0603	10 k $\Omega$ $\pm$ 1%	Dale	1
R <sub>FB2</sub>	CRCW06038061	Resistor	0603	8.06 k $\Omega$ $\pm$ 1%	Dale	1

### 3.3V to 1.8V Conversion at 545 kHz (2A Max $I_{OUT}$ ) (Continued)



20170534

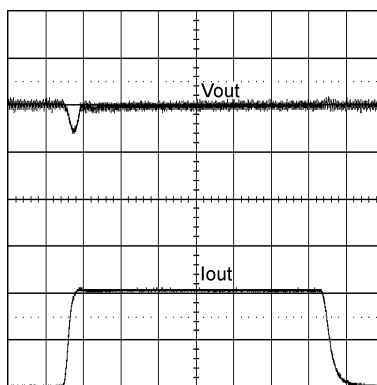
**Output Ripple with  $I_{OUT} = 2A$**



20170535

$V_{OUT}$ : Output Voltage, 20mV AC/div

**Output Transient Response**



20170536

$V_{OUT}$ : Output Voltage, 100mV AC/div  
 $I_{OUT}$ : Load Current, 1A/div

## Notes

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