Application Report

SNVA133A–November 2005–Revised April 2013

AN-1414 LM1770 Design Reference

ABSTRACT

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

Contents

List of Figures

List of Tables

1 Introduction

The LM1770 is a high efficiency synchronous buck controller that 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.

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 (for more information on how to determine switching frequency, see *LM1770 Low-Voltage SOT23 Synchronous Buck Controller With No External Compensation* (SNVS403)). Included with an explanation of each design is a bill-of-materials as well as efficiency, output ripple, and transient measurements.

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

This higher frequency design enables the use of a small valued inductor (1 µH) and a 68 µF 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.

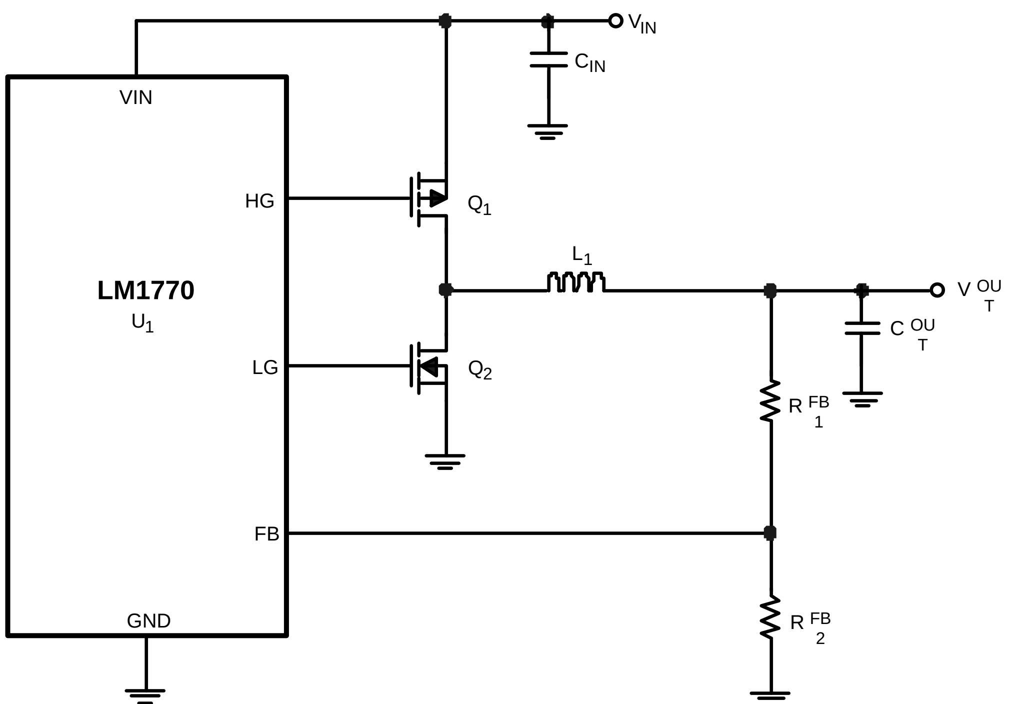

Figure 1. 5V to 3.3V Conversion at 1 MHz (2A Max I_{OUT})

Table 1. Bill of Materials (5V to 3.3V Conversion at 1 MHz)

ID	Part Number	Type	Size	Parameters	Vendor	Qty
U_1	LM1770T	Synchronous Buck Controller	SOT23-5	1000 ns	Texas Instruments	1
C_{IN}	GRM32ER60J476ME20B	Input Capacitor	1210	47 µF/X5R/6.3V	muRata	1
C_{OUT}	10SVPA68MAA	Output Capacitor	C6	68 µF/OSCON/10V	Sanyo	1
L	DO1608C-102MLC	Inductor		1 µH	Coilcraft	1
R_{FB1}	CRCW08052551	Resistor	0805	2.55 kΩ ±1%	Dale	1
R_{FB2}	CRCW08058060	Resistor	0805	806Ω ±1%	Dale	1
Q_1	SI3867DV	PFET	TSOP-6	SI3867DV	Siliconix	1
Q_2	SI3460DV	NFET	TSOP-6	SI3460DV	Siliconix	1

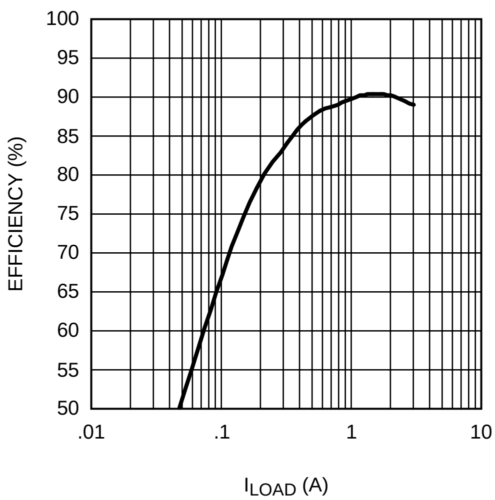

Figure 2. Efficiency vs V_{IN}

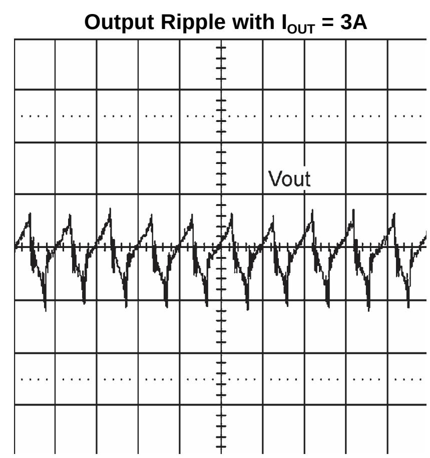

Figure 3. V_{OUT}: Output Ripple Voltage, 20mV AC/div

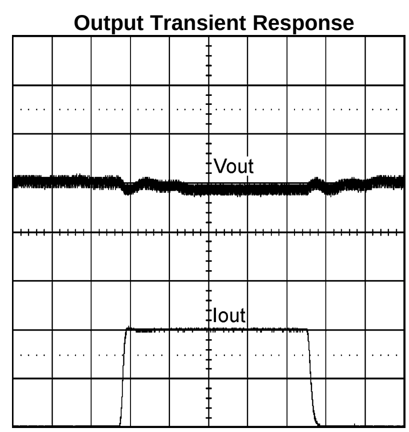

Figure 4. V_{OUT}: Output Voltage, 200mV AC/div
I_{OUT}: Load Current, 1A/div

3 5V to 3.3V Conversion at 500 kHz (4A Max I_{OUT})

This design operates at 500 kHz and utilizes larger valued components to enable a high maximum output current. A 2.2 µH inductor and a 150 µF 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 µF 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.

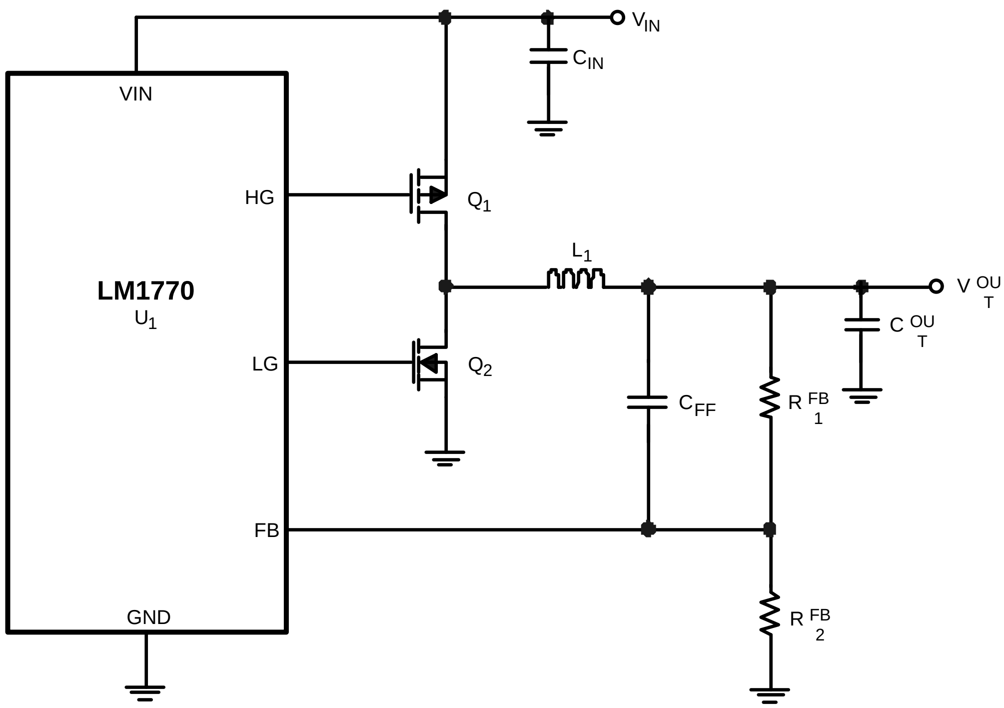

Figure 5. 5V to 3.3V Conversion at 500 kHz (4A Max I_{OUT})

Table 2. Bill of Materials (5V to 3.3V Conversion at 500 kHz)

ID	Part Number	Type	Size	Parameters	Manufacturer	Qty
U_1	LM1770U	Synchronous Buck Controller	SOT23-5	2000 ns	Texas Instruments	1
C_{FF}	VJ0805Y102KXXM	Capacitor	0805	1 nF/X7R/25V	Vitramon	1
C_{IN}	EEUFC0J151	Capacitor		150 µF/Electrolytic/6.3V	Panasonic	1
C_{OUT}	4TPB150MC	Capacitor	C	150 µF/POSCAP/4V	Sanyo	1
L	DO3316P-222ML	Inductor		2.2 µH	Coilcraft	1
Q_1	SI9433BDY	PFET	SO-8	SI9433BDY	Siliconix	1
Q_2	SI4894DY	NFET	SO-8	SI4894DY	Siliconix	1
R_{FB1}	CRCW08052492	Resistor	0805	24.9 kΩ ±1%	Dale	1
R_{FB2}	CRCW08058061	Resistor	0805	8.06 kΩ ±1%	Dale	1

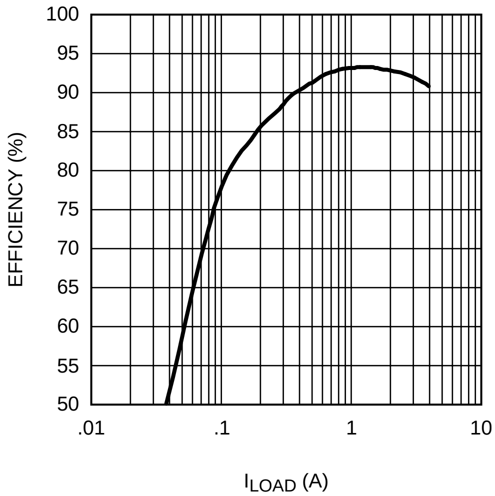

Figure 6. Efficiency vs V_{IN}

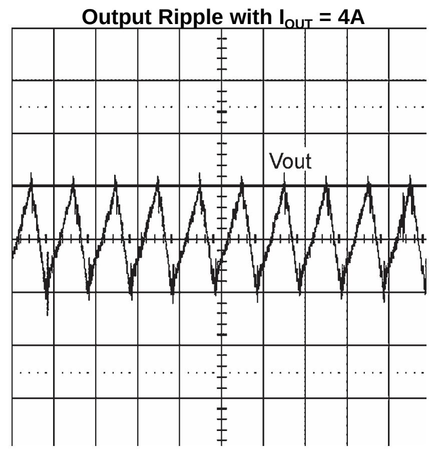

Figure 7. V_{OUT}: Output Voltage, 20mV AC/div

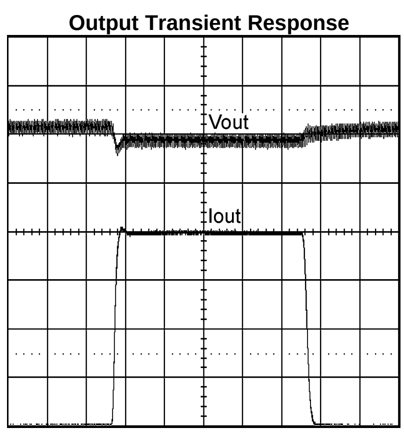

Figure 8. V_{OUT}: Output Voltage, 200mV AC/div
I_{OUT}: Load Current, 1A/div

4 5V to 2.5V Conversion at 1.5 MHz (3A Max I_{OUT})

The use of a small valued inductor (1.5 µH) is made possible by the high frequency operation. A 68 µF, low profile, POSCAP 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.

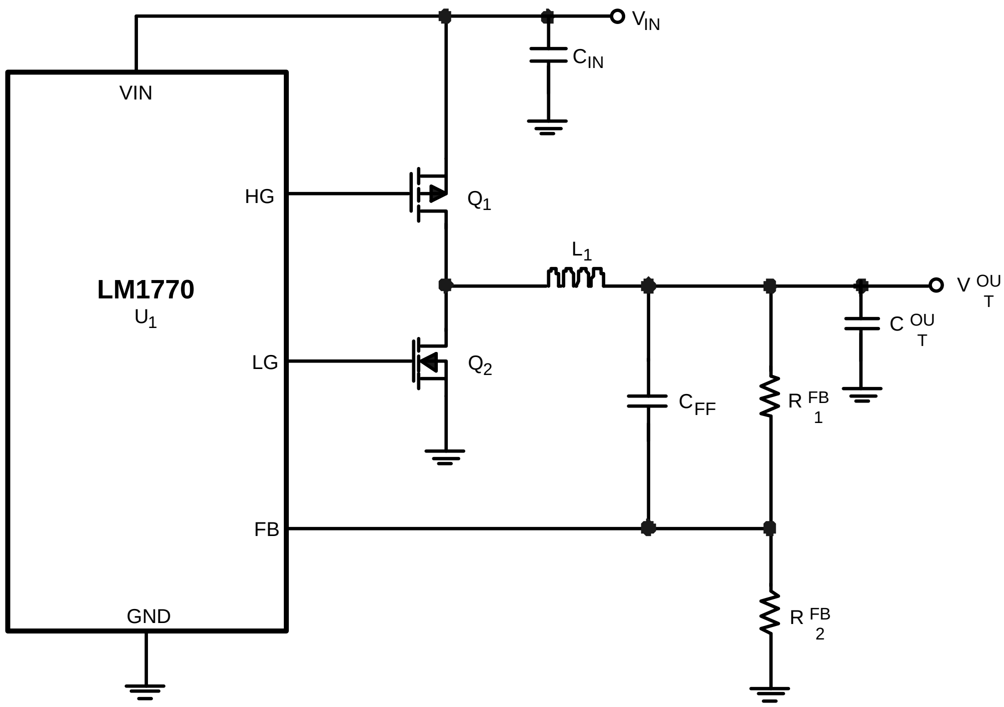

Figure 9. 5V to 2.5V Conversion at 1.5 MHz (3A Max I_{OUT})

Table 3. Bill of Materials (5V to 2.5V Conversion at 1.5 MHz)

ID	Part Number	Type	Size	Parameters	Vendor	Qty
U_1	LM1770S	Synchronous Buck Controller	SOT23-5	500 ns	Texas Instruments	1
C_{OUT}	4TB68M	Capacitor	B2	68 µF/POSCAP/4V	Sanyo	1
C_{FF}	VJ0805Y103KXXM	Capacitor	0805	10 nF/X7R/25V	Vitramon	1
C_{IN}	GRM32ER61A226KA65B	Capacitor	1210	22 µF/X5R/10V	muRata	1
C_{OUT}	4TB68M	Capacitor	B2	68 µF/POSCAP/4V	Sanyo	1
L	DO3316P-152ML	Inductor		1.5 µH	Coilcraft	1
Q_1	SI3867DV	PFET	TSOP-6	SI3867DV	Siliconix	1
Q_2	SI3460DV	NFET	TSOP-6	SI3460DV	Siliconix	1
R_{FB1}	CRCW08051692	Resistor	0805	16.9 kΩ ±1%	Dale	1
R_{FB2}	CRCW08058061	Resistor	0805	8.06 kΩ ±1%	Dale	1

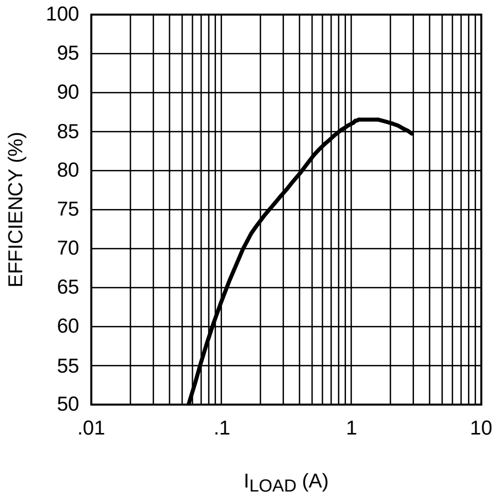

Figure 10. Efficiency vs V_{IN}

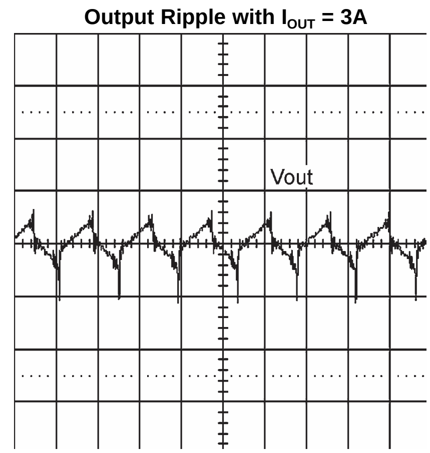

Figure 11. V_{OUT}: Output Voltage, 50mV AC/div

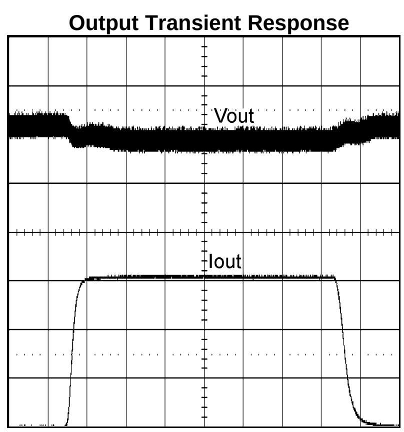

Figure 12. V_{OUT}: Output Voltage, 100mV AC/div
I_{OUT}: Load Current, 1A/div

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

This design utilizes small components allowing a minimally sized complete power supply solution. A 5.0 µH, small footprint inductor is used along with a 47 µF 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 the *AN-1400 LM1770 Evaluation Board User's Guide* (SNVA125).

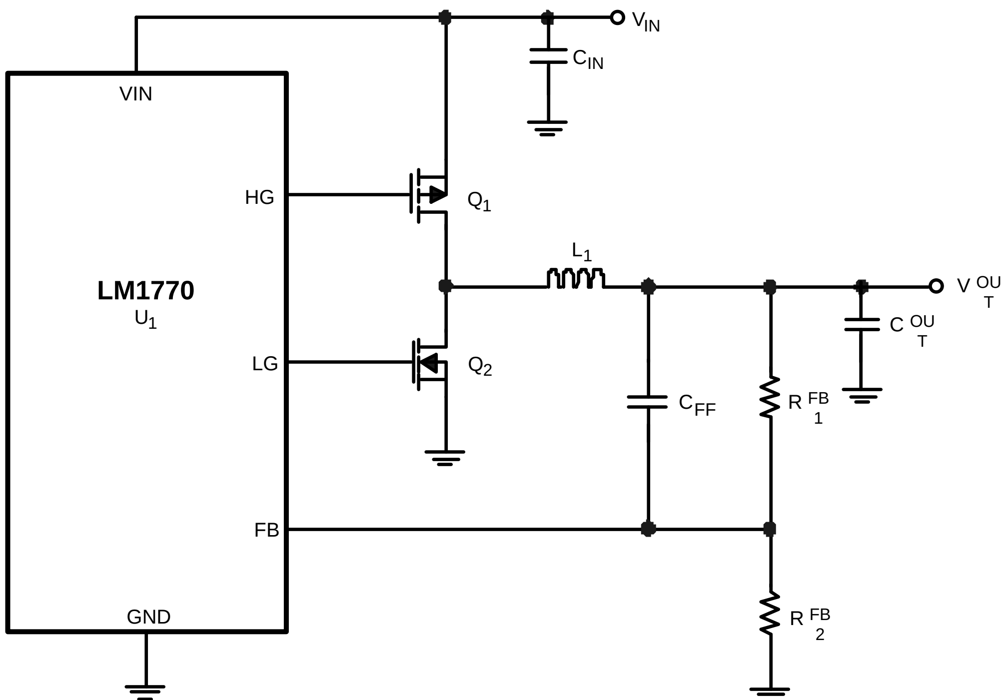

Figure 13. 5V to 2.5V Conversion at 378 kHz (2A Max I_{OUT})

Table 4. Bill of Materials (5V to 2.5V Conversion at 378 kHz)

ID	Part Number	Type	Size	Parameters	Vendor	Qty
U_1	LM1770U	Synchronous Buck Controller	SOT23-5	2000 ns	Texas Instruments	1
C_{FF}	VJ0603Y103KXXA	Capacitor	0603	10 nF/X7R/25V	Vitramon	1
C_{IN}	GRM21BR60J226ME39B	Capacitor	0805	22 µF/X5R/6.3V	muRata	1
C_{OUT}	4TPC47M	Capacitor	B1	47 µF/POSCAP/4V	Sanyo	1
L	MSS7341-502NX	Inductor		5.0 µH	Coilcraft	1
Q_1	SI3867DV	PFET	TSOP-6	SI3867DV	Siliconix	1
Q_2	SI3460DV	NFET	TSOP-6	SI3460DV	Siliconix	1
R_{FB1}	CRCW06032102F	Resistor	0603	21 kΩ ±1%	Dale	1
R_{FB2}	CRCW06031002	Resistor	0603	10 kΩ ±1%	Dale	1

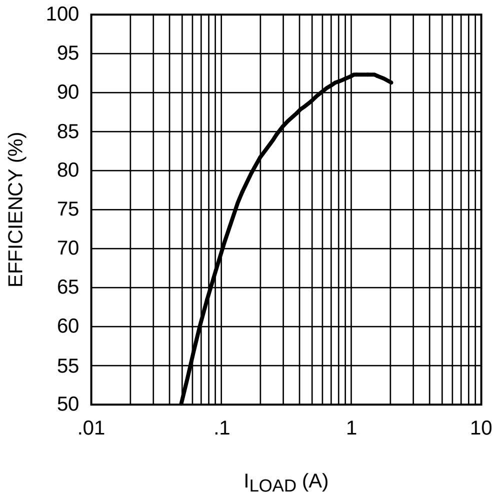

Figure 14. Efficiency vs V_{IN}

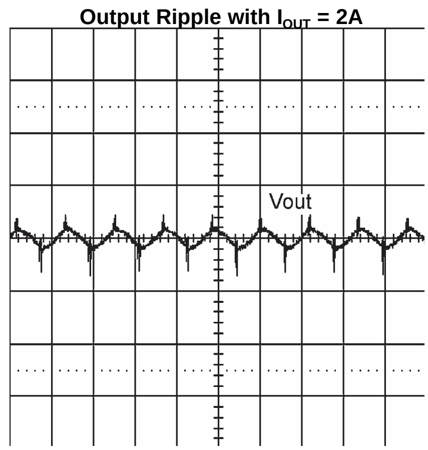

Figure 15. V_{OUT}: Output Voltage, 50mV AC/div

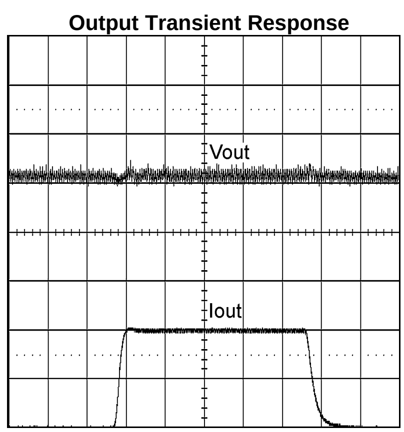

Figure 16. V_{OUT}: Output Voltage, 100mV AC/div
I_{OUT}: Load Current, 1A/div

6 5V to 1V Conversion at 303 kHz (3A Max I_{OUT})

This design illustrates the LM1770's performance at a low frequency of operation as well as a low output voltage. A 6.8 µH inductor is used along with a low ESR 68 µF 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.

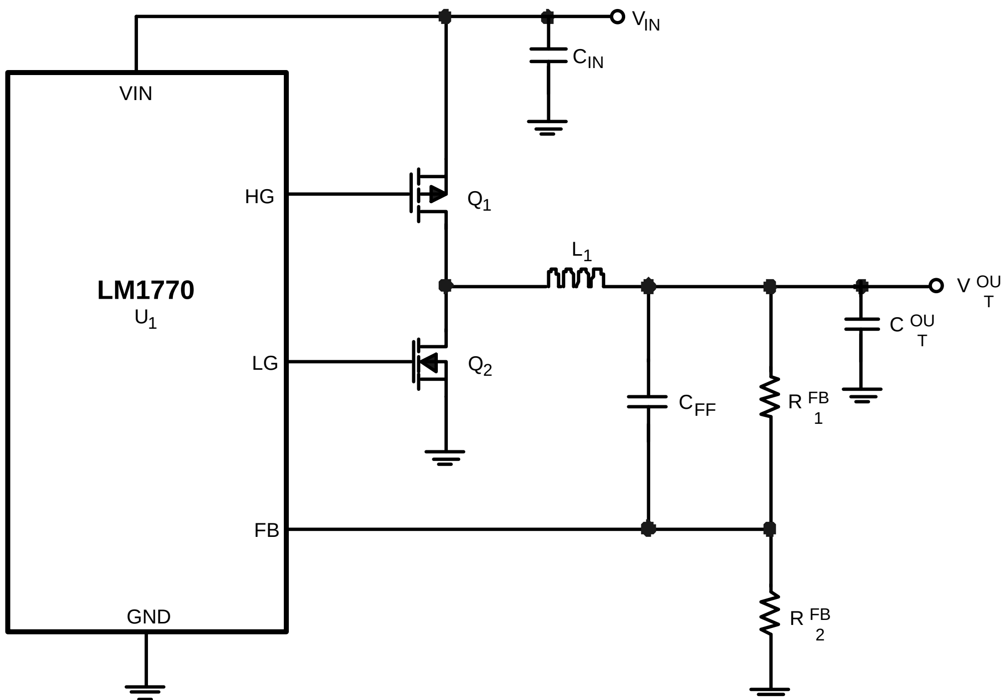

Figure 17. 5V to 1V Conversion at 303 kHz (3A Max I_{OUT})

Table 5. Bill of Materials (5V to 1V Conversion at 303 kHz)

ID	Part Number	Type	Size	Parameters	Vendor	Qty
U_1	LM1770T	Synchronous Buck Controller	SOT23-5	1000 ns	Texas Instruments	1
C_{FF}	VJ0805Y103KXXM	Capacitor	0805	10 nF/X7R/25V	Vitramon	1
C_{IN}	GRM43SR60J107ME20B	Capacitor	1812	100 µF/X5R/6.3V	muRata	1
C_{OUT}	6SVPC100M	Capacitor	B6	100 µF/OSCON/6.3V	Sanyo	1
L	DO3316P-682ML	Inductor		6.8 µH	Coilcraft	1
Q_1	SI3867DV	PFET	TSOP-6	SI3867DV	Siliconix	1
Q_2	SI3460DV	NFET	TSOP-6	SI3460DV	Siliconix	1
R_{FB1}	CRCW08052001	Resistor	0805	2 kΩ ±1%	Dale	1
R_{FB2}	CRCW08058061	Resistor	0805	8.06 kΩ ±1%	Dale	1

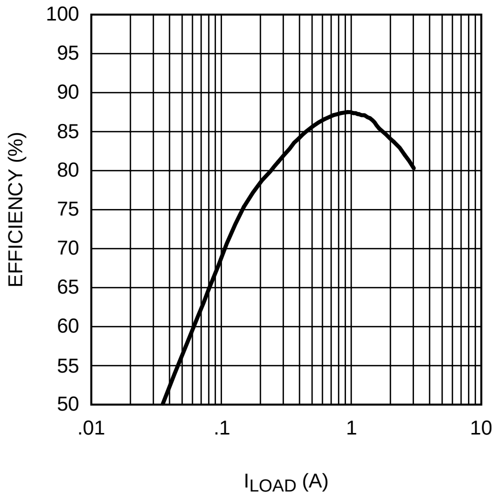

Figure 18. Efficiency vs V_{IN}

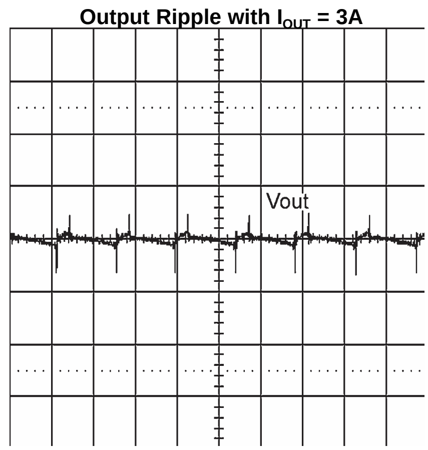

Figure 19. V_{OUT}: Output Voltage, 20mV AC/div

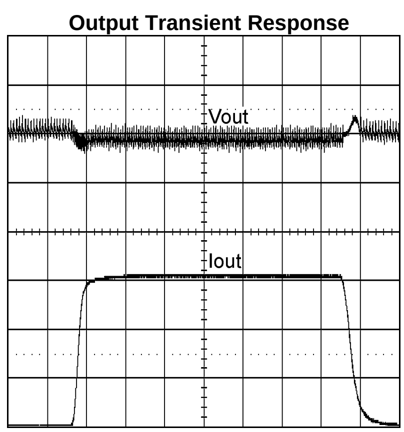

Figure 20. V_{OUT}: Output Voltage, 50mV AC/div
I_{OUT}: Load Current, 1A/div

7 3.3V to 0.8V Conversion at 242 kHz (2A Max I_{OUT})

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 µH inductor and a 150 µF 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.

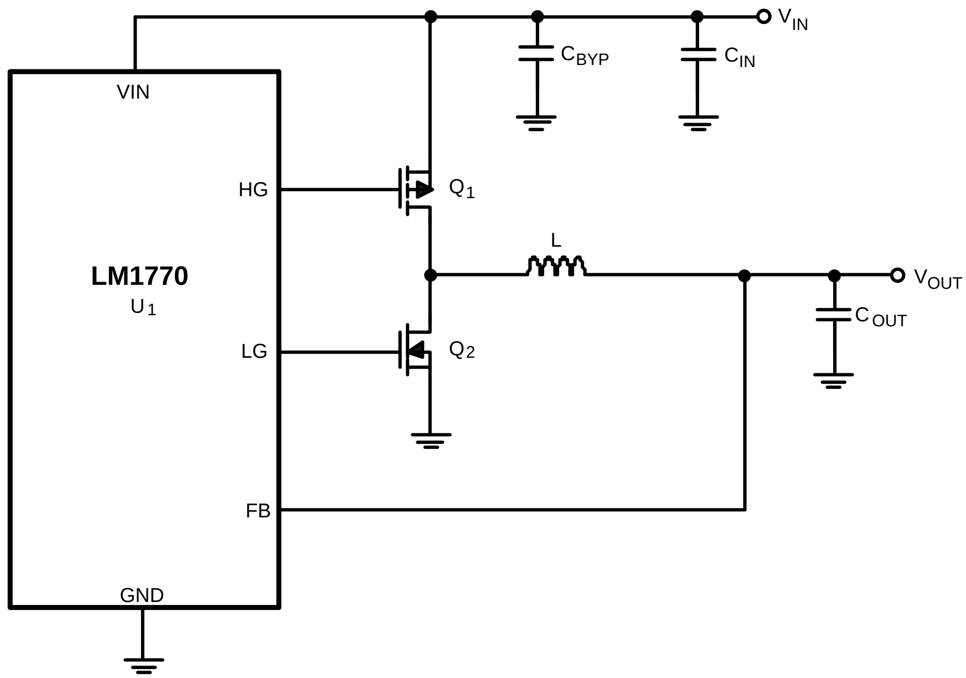

Figure 21. 3.3V to 0.8V Conversion at 242 kHz (2A Max I_{OUT})

Table 6. Bill of Materials (3.3V to 0.8V Conversion at 242 kHz)

ID	Part Number	Type	Size	Parameters	Vendor	Qty
U_1	LM1770T	Synchronous Buck Controller	SOT23-5	1000ns	Texas Instrument s	1
C_{BYP}	VJ0805Y104KXXM	Capacitor	0805	100 nF/X7R/25V	Vitramon	1
C_{IN}	GRM32ER60J476ME20B	Capacitor	1210	47 µF/X5R/6.3V	muRata	1
C_{OUT}	4TPB150MC	Capacitor	C	150 µF/POSCAP/6.3V	Sanyo	1
L	DO3316P-682ML	Inductor		6.8 µH	Coilcraft	1
Q_1	SI3867DV	PFET	TSOP-6	SI3867DV	Siliconix	1
Q_2	SI3460DV	NFET	TSOP-6	SI3460DV	Siliconix	1

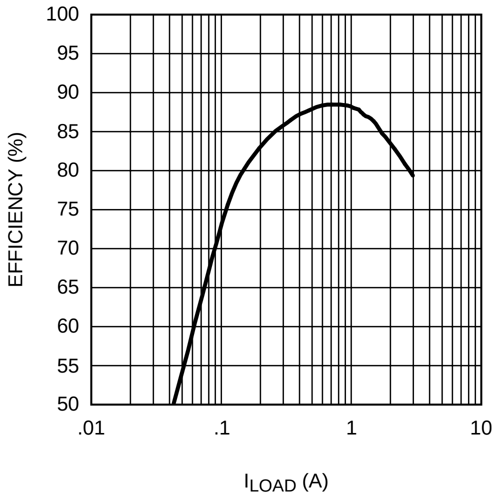

Figure 22. Efficiency vs V_{IN}

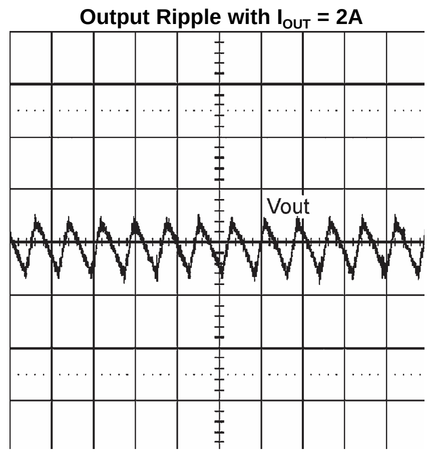

Figure 23. V_{OUT}: Output Voltage, 20mV AC/div

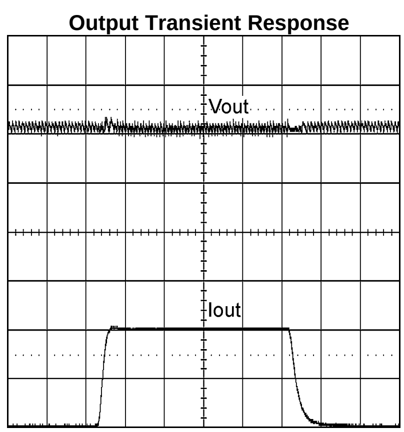

Figure 24. V_{OUT}: Output Voltage, 100mV AC/div
I_{OUT}: Load Current, 2A/div

8 3.3V to 0.9V Conversion at 545 kHz (3A Max I_{OUT}) DDR2 Application

This design operates at a higher frequency as compared to the 0.8V design above. This facilitates the use of a smaller 3.3 µH inductor that 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 µF 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.

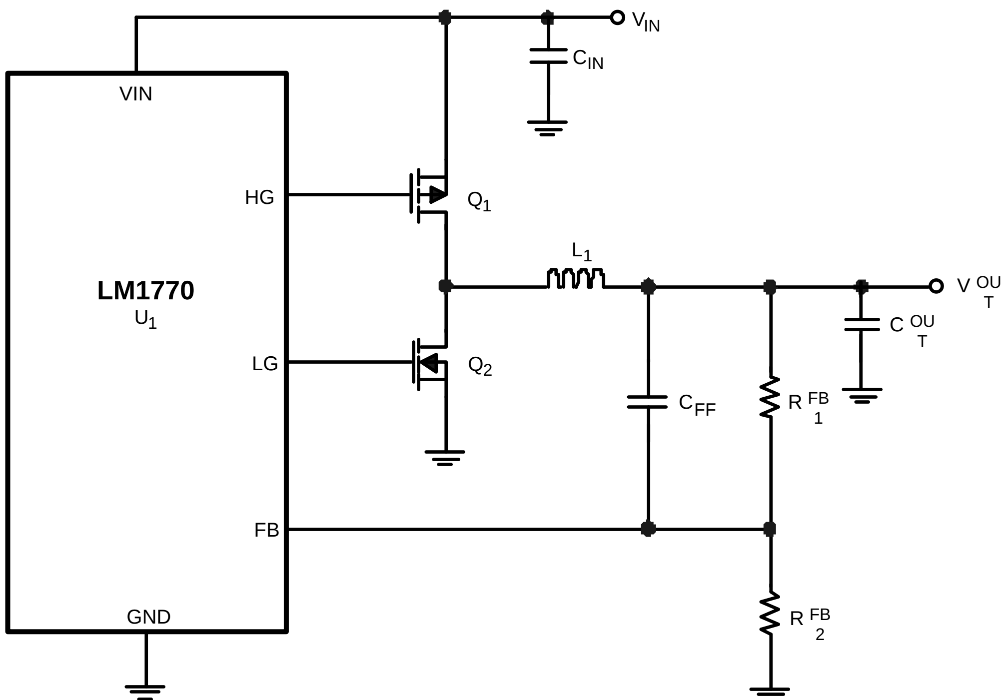

Figure 25. 3.3V to 0.9V Conversion at 545 kHz (3A Max I_{OUT}) DDR2 Application

Table 7. Bill of Materials (3.3V to 0.9V Conversion at 545 kHz)

ID	Part Number	Type	Size	Parameters	Vendor	Qty
U_1	LM1770S	Synchronous Buck Controller	SOT23-5	500 ns	Texas Instruments	1
C_{FF}	VJ0603Y102KXXM	Capacitor	0603	1 nF/X7R/25V	Vitramon	1
C_{IN}	GRM21BR60J226ME39B	Capacitor	0805	22 µF/X5R/6.3V	muRata	1
C_{OUT}	6TPB100MA	Capacitor	B2	100 µF/POSCAP/6.3V	Sanyo	1
L	MSS7341-332NX	Inductor		3.3 µH	Coilcraft	1
Q_1	SI3867DV	PFET	TSOP-6	SI3867DV	Siliconix	1
Q_2	SI3460DV	NFET	TSOP-6	SI3460DV	Siliconix	1
R_{FB1}	CRCW06031001	Resistor	0603	1 kΩ ±1%	Dale	1
R_{FB2}	CRCW06038061	Resistor	0603	8.06 kΩ ±1%	Dale	1

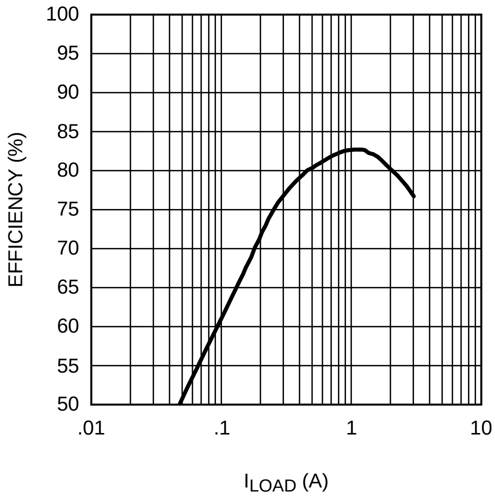

Figure 26. Efficiency vs V_{IN}

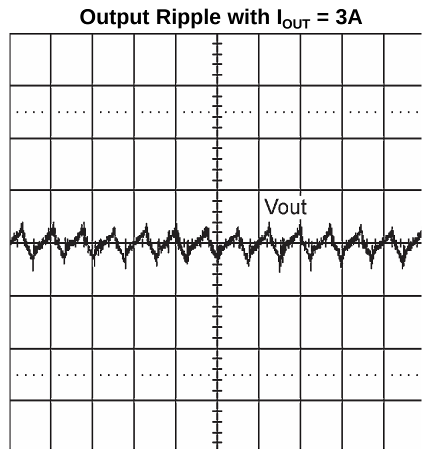

Figure 27. V_{OUT}: Output Voltage, 20mV AC/div

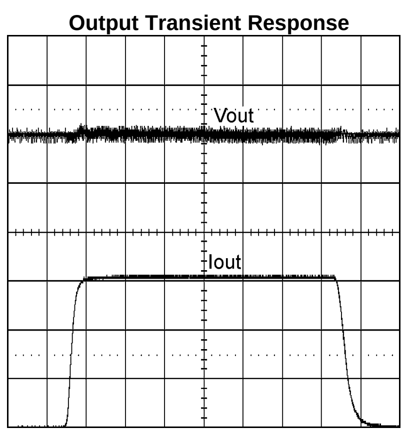

Figure 28. V_{OUT}: Output Voltage, 100mV AC/div
I_{OUT}: Load Current, 1A/div

9 3.3V to 1.8V Conversion at 272 kHz (2A Max I_{OUT}) All Ceramic Application

This design incorporates a 22 µF ceramic output capacitor. Due of the lack of ESR on ceramic capacitors, a separate 50 mΩ resistor is used for creating sufficient ripple at the output. A 3.3 µH 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.

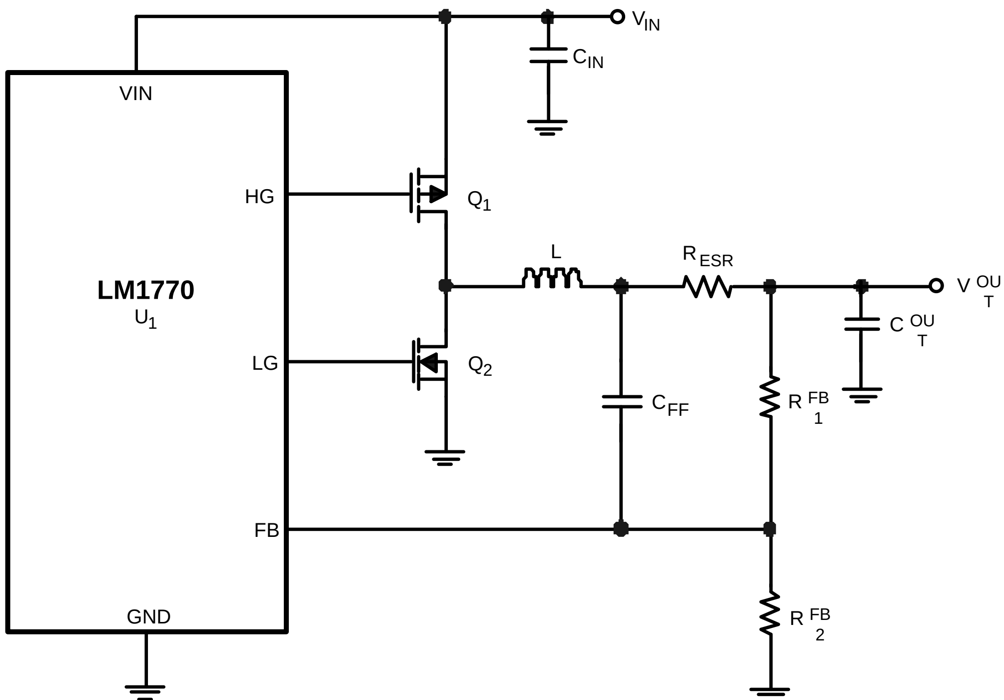

Figure 29. 3.3V to 1.8V Conversion at 272 kHz (2A Max I_{OUT}) All Ceramic Application

Table 8. Bill of Materials (3.3V to 1.8V Conversion at 272 kHz)

ID	Part Number	Type	Size	Parameters	Vendor	Qty
U_1	LM1770U	Synchronous Buck Controller	SOT23-5	2000 ns	Texas Instruments	1
C_{FF}	VJ0805Y103KXXA	Capacitor	0805	10 nF/X7R/25V	Vitramon	1
C_{IN}	GRM32ER60J476ME20B	Capacitor	1210	47 µF/X5R/6.3V	muRata	1
C_{OUT}	GRM32ER61A226KA65B	Capacitor	1210	22 µF/X5R/10V	muRata	1
L	DO3316P-332ML	Inductor		3.3 µH	Coilcraft	1
Q_1	SI3867DV	PFET	TSOP-6	SI3867DV	Siliconix	1
Q_2	SI3460DV	NFET	TSOP-6	SI3460DV	Siliconix	1
R_{ESR}	WSL-1206	Resistor	1206	.05Ω ±1%	Dale	1
R_{FB1}	CRCW08051241	Resistor	0805	1.24 kΩ ±1%	Dale	1
R_{FB2}	CRCW08051001	Resistor	0805	1.00 kΩ ±1%	Dale	1

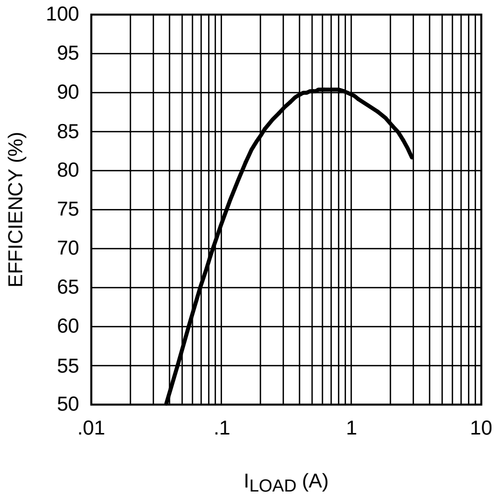

Figure 30. Efficiency vs V_{IN}

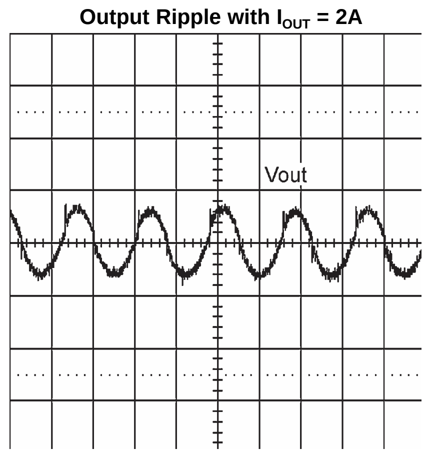

Figure 31. V_{OUT}: Output Voltage, 20mV AC/div

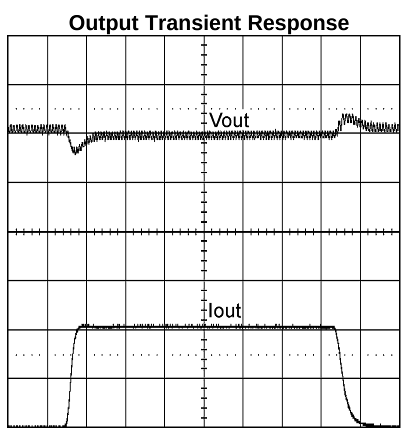

Figure 32. V_{OUT}: Output Voltage, 200mV AC/div
I_{OUT}: Load Current, 1A/div

10 3.3V to 1.8V Conversion at 545 kHz (2A Max I_{OUT})

This is another design utilizing small sized components chosen to fit on the LM1770 evaluation board PCB. A 6.2 µH inductor along with a 68 µF POSCAP capacitor are used to implement the output filter, and a 10 nF feed-forward capacitor 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.

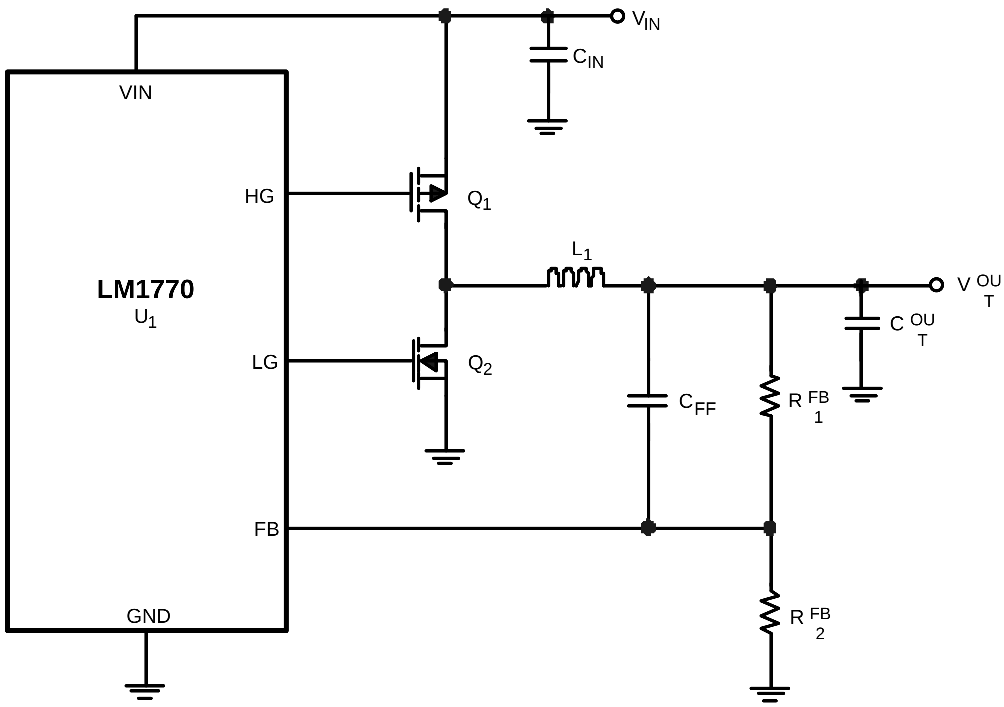

Figure 33. 3.3V to 1.8V Conversion at 545 kHz (2A Max I_{OUT})

Table 9. Bill of Materials (3.3V to 1.8V Conversion at 545 kHz)

ID	Part Number	Type	Size	Parameters	Vendor	Qty
U_1	LM1770T	Synchronous Buck Controller	SOT23-5	1000 ns	Texas Instruments	1
C_{FF}	VJ0603Y103KXXM	Capacitor	0603	10 nF/X7R/25V	Vitramon	1
C_{IN}	GRM32ER61A226KA65B	Capacitor	0805	22 µF/X5R/6.3V	muRata	1
C_{OUT}	4TPB68M	Capacitor	B2	68 µF/POSCAP/4.0V	Sanyo	1
L	MSS7341-622NX	Inductor		6.2 µH	Coilcraft	1
Q_1	SI3867DV	PFET	TSOP-6	SI3867DV	Fairchild	1
Q_2	SI3460DV	NFET	TSOP-6	SI3460DV	Siliconix	1
R_{FB1}	CRCW06031002	Resistor	0603	10 kΩ ±1%	Dale	1
R_{FB2}	CRCW06038061	Resistor	0603	8.06 kΩ ±1%	Dale	1

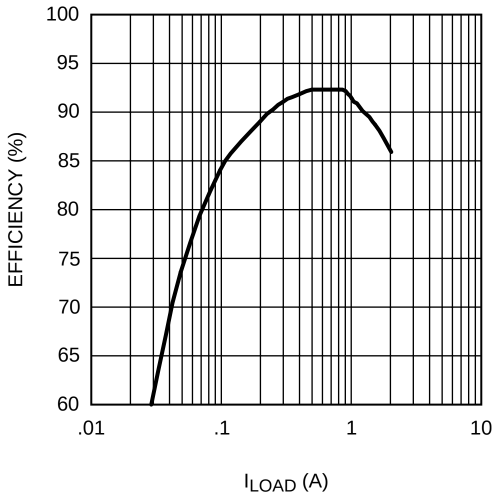

Figure 34. Efficiency vs V_{IN}

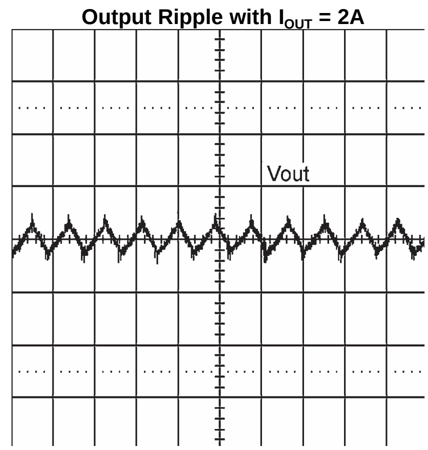

Figure 35. V_{OUT}: Output Voltage, 20mV AC/div

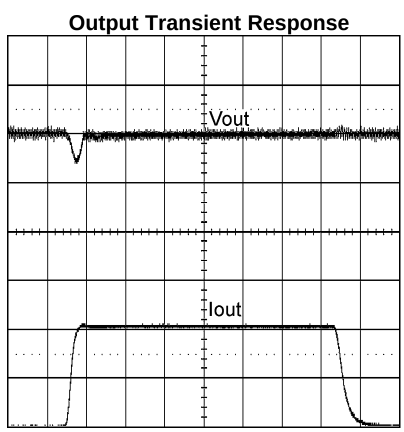

Figure 36. V_{OUT}: Output Voltage, 100mV AC/div
I_{OUT}: Load Current, 1A/div

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