# AN-1193 LM3477 Evaluation Board

## 1 Introduction

The LM3477 is a current mode, high-side N channel FET controller. It is most commonly used in buck configurations, as shown in Figure 1. All the power conducting components of the circuit are external to the LM3477, so a large variety of inputs, outputs, and loads can be accommodated by the LM3477.

The LM3477 evaluation board comes ready to operate at the following conditions:

$4.5\ V \leq V_{IN} \leq 15\ V$

$V_{OUT} = 3.3\ V$

$0A \leq I_{OUT} \leq 1.6A$

The circuit and BOM for this application are given in Figure 1 and Table 1.

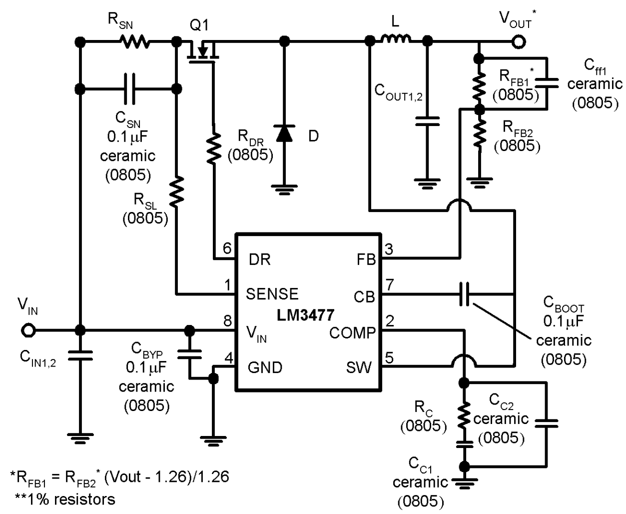


**Figure 1. LM3477 Buck Converter**

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**Table 1. Bill of Materials (BOM)**

| Component | Value | Part Number |
|---|---|---|
| $C_{IN1}$ | 120 µF/20 V | 594D127X0020R2 |
| $C_{IN2}$ | No connect | |
| $C_{OUT1}$ | 22 µF/10 V | LMK432BJ226MM (Taiyo Yuden) |
| $C_{OUT2}$ | 22 µF/10 V | LMK432BJ226MM (Taiyo Yuden) |
| L | 10 µH, 3.8A | DO3316P-103 (Coilcraft) |
| $R_C$ | 1.8 kΩ | CRCW08051821FRT1 (Vitramon) |
| $C_{C1}$ | 12 nF/50 V | VJ0805Y123KXAAT (Vitramon) |
| $C_{C2}$ | No connect | |
| Q1 | 5A, 30 V | IRLMS2002 (IRF) |
| D | 100 V, 3A | MBRS340T3 (Motorola) |
| $R_{DR}$ | 20 Ω | CRCW080520R0FRT1 (Vitramon) |
| $R_{SL}$ | 1 kΩ | CRCW08051001FRT1 (Vitramon) |
| $R_{FB1}$ | 16.2 kΩ | CRCW08051622FRT1 (Vitramon) |
| $R_{FB2}$ | 10.0 kΩ | CRCW08051002FRT1 (Vitramon) |
| $C_{FF}$ | 470 pF | VJ0805Y471KXAAT (Vitramony) |
| $R_{SN}$ | 0.03 Ω | WSL 2512 0.03 Ω ±1% (Dale) |

## 2 Performance

The following are some benchmark data taken from the circuit above on the LM3477 evaluation board. This evaluation board can also be used to evaluate a buck regulator circuit optimized for a different operating point, or to evaluate a trade-off between cost and some performance parameter. For example, the conversion efficiency may be increased by using a lower $R_{DS(ON)}$ MOSFET, ripple voltage may be lowered with lower ESR output capacitors, and the hysteretic threshold may be changed as a function of the $R_{SN}$ and $R_{SL}$ resistors.

The conversion efficiency can be increased by using a lower $R_{DS(ON)}$ MOSFET, however it drops as input voltage increases. The efficiency reduces because of increased diode conduction time and increased switching losses. Switching losses are due to the Vds*Id transition losses and to the gate charge losses, both of which can be lowered by using a FET with low gate capacitance. At low duty cycles, where most of the power loss in the FET is from the switching losses, trading off higher $R_{DS(ON)}$ for lower gate capacitance will increase efficiency.

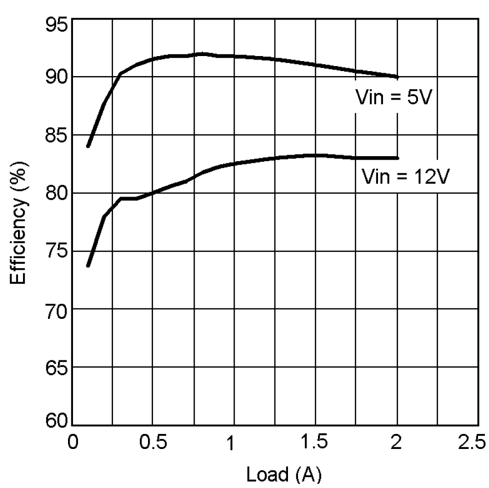



**Figure 2. Efficiency vs Load $V_{OUT}$ = 3.3 V**

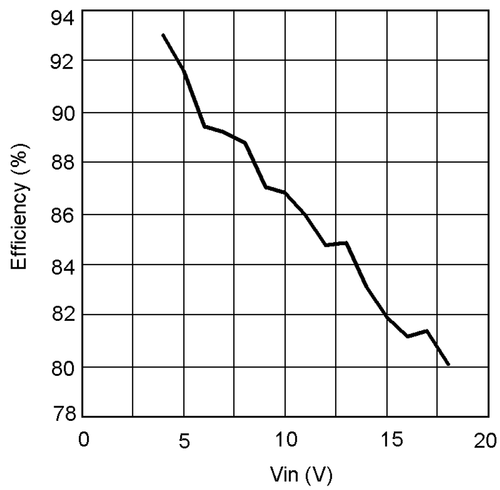
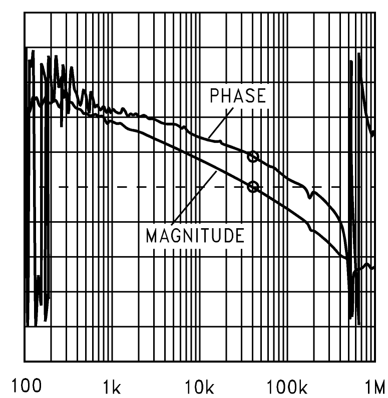



**Figure 3. Efficiency vs $V_{IN}$**
**$V_{OUT}$ = 3.3 V, $I_{OUT}$ = 2A**

Figure 5 shows a bode plot of LM3477 open loop frequency response using the external components listed in Table 1.




(1) Magnitude = 20 dB/Decade Bandwidth = 39.8kHz
Phase = 45°/Decade Phase Margin = 41°

**Figure 4. Open Loop Frequency Response**
**$V_{IN}$ = 5 V, $V_{OUT}$ = 3.3 V, $I_{OUT}$ = 1.5A**

## 3 Hysteretic Mode

As the load current is decreased, the LM3477 will eventually enter a 'hysteretic' mode of operation. When the load current drops below the hysteretic mode threshold, the output voltage rises slightly. The over voltage protection (OVP) comparator senses this rise and causes the power MOSFET to shut off. As the load pulls current out of the output capacitor, the output voltage drops until it hits the low threshold of the OVP comparator and the part begins switching again. This behavior results in a lower frequency, higher peak-to-peak output voltage ripple than with the normal pulse width modulation scheme. The magnitude of the output voltage ripple is determined by the OVP threshold levels, which are referred to the feedback voltage and are typically 1.25 V to 1.31 V. For more information, see the *Electrical Characteristics* table in the *LM3477 High Efficiency High-Side N-Channel Controller for Switching Regulator Data Sheet* (SNVS141). In the case of a 3.3 V output, this translates to a regulated output voltage between 3.27 V and 3.43 V. The hysteretic mode threshold point is a function of $R_{SN}$ and $R_{SL}$. Figure 5 shows the Hysteretic Threshold vs. $V_{IN}$ for the LM3477 evaluation board with and without $R_{SL}$.

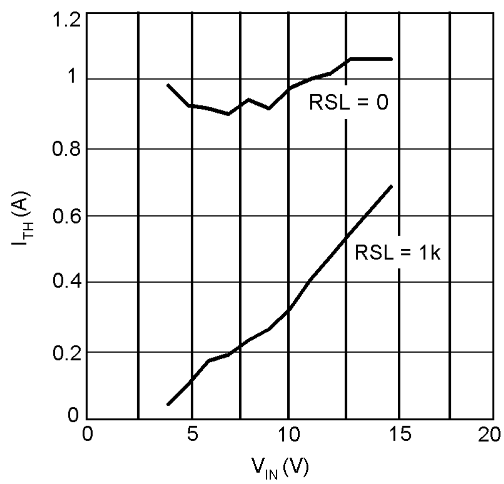



**Figure 5. $I_{TH}$ vs $V_{IN}$**

## 4 Increasing Current Limit

The $R_{SL}$ resistor offers flexibility in choosing the ramp of the slope compensation. Slope compensation affects the minimum inductance for stability (see the *Slope Compensation* section in the *LM3477 High Efficiency High-Side N-Channel Controller for Switching Regulator Data Sheet* (SNVS141), but also helps determine the current limit and hysteretic threshold. As an example, $R_{SL}$ can be disconnected and replaced by a 0 ohm resistor so that no extra slope compensation is added to the current sense waveform to increase the current limit. A more conventional way to adjust the current limit is to change $R_{SN}$. $R_{SL}$ is used here to change current limit for the sake of simplicity and to demonstrate the dependence of current limit to $R_{SL}$. By changing $R_{SL}$ to 0 ohm, the following conditions may be met:

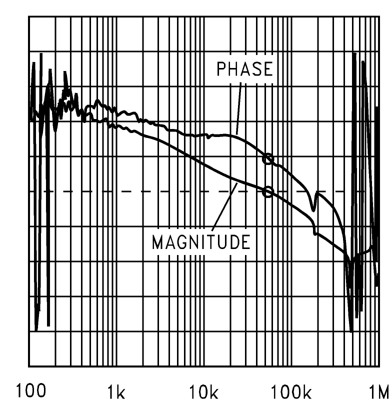
$4.5\text{ V} \leq V_{IN} \leq 15\text{ V}$

$V_{OUT} = 3.3\text{ V}$

$0\text{A} \leq I_{OUT} \leq 3\text{A}$

The current limit is a weak function of slope compensation and a strong function of the sense resistor. By decreasing $R_{SL}$, slope compensation is decreased, and as a result the current limit increases. The hysteretic mode threshold will also increase to about 1A (see Figure 5).

Given below is a bode plot of LM3477 open loop frequency response using the modified ($R_{SL} = 0\Omega$) components to achieve higher output current capability.




(1) Magnitude = 20 dB/Decade    Bandwidth = 55.3kHz
Phase = 45°/Decade    Phase Margin = 42°

**Figure 6. Open Loop Frequency Response**
**$V_{IN}$ = 5 V, $V_{OUT}$ = 3.3 V, $I_{OUT}$ = 3A**

## 5 Layout Fundamentals

Good layout for DC-DC converters can be implemented by following a few simple design guidelines:

1. Place the power components (catch diode, inductor, and filter capacitors) close together. Make the traces between them short.
2. Use wide traces between the power components and for power connections to the DC-DC converter circuit.
3. Connect the ground pins of the input and output filter capacitors and catch diode as close as possible using generous component-side copper fill as a pseudo-ground plane. Then, connect this to the ground-plane with several vias.
4. Arrange the power components so that the switching current loops curl in the same direction.
5. Route high-frequency power and ground return as direct continuous parallel paths.
6. Separate noise sensitive traces, such as the voltage feedback path, from noisy traces associated with the power components.
7. Ensure a good low-impedance ground for the converter IC.
8. Place the supporting components for the converter IC, such as compensation, frequency selection and charge-pump components, as close to the converter IC as possible but away from noisy traces and the power components. Make their connections to the Converter IC and it's pseudo-ground plane as short as possible.
9. Place noise sensitive circuitry, such as radio-modem IF blocks, away from the DC-DC converter, CMOS digital blocks, and other noisy circuitry.

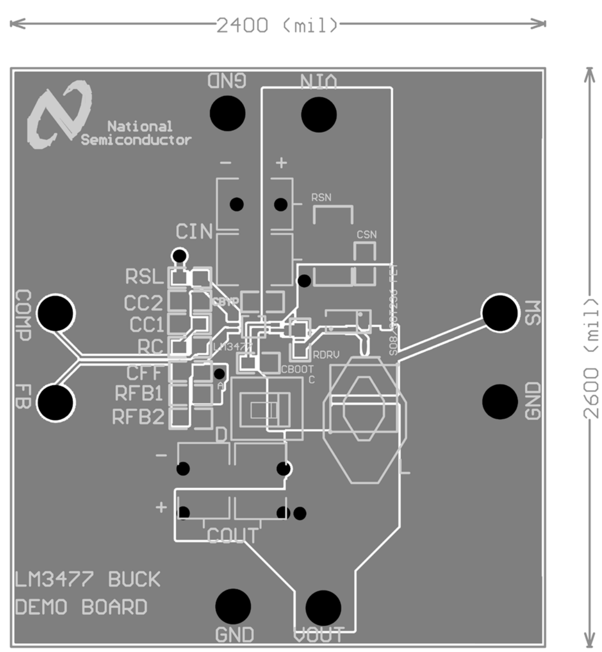



**Figure 7. LM3477 Evaluation Board PCB Layout (Top Side)**

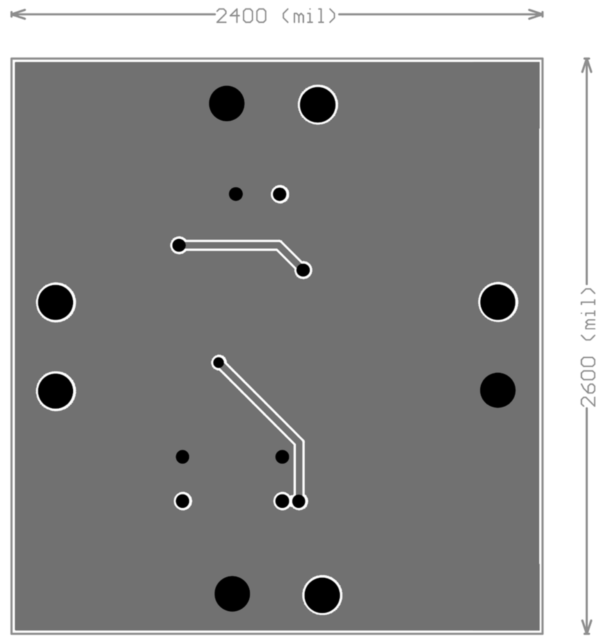



**Figure 8. LM3477 Evaluation Board PCB Layout (Bottom Side)**

# IMPORTANT NOTICE



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