User Guide
SLUU231 –September 2005

# Using the TPS40074

## A 12V Input, 1.5V Output, 15A Synchronous Buck Controller

System Power Management – DC/DC Controllers

# 1 INTRODUCTION

The TPS40074EVM-001 evaluation module (EVM) is a synchronous buck converter providing a fixed 1.5V output at up to 15A from a 12V input bus. The EVM is designed to start up from a single supply, so no additional bias voltage is required for start-up. The module uses the TPS40074 High Frequency Controller with remote sense.

## 1.1 DESCRIPTION

TPS40074EVM-001 is designed to use a regulated 12V (10V-14V) bus to produce a high current, regulated 1.5V output at up to 15A of load current. The TPS40074EVM-001 is design to demonstrate the TPS40074 in a typical regulated bus to low-voltage application while providing a number of test points to evaluate the performance of the TPS40074 in a given application. The EVM can be modified to support output voltages from 0.9V to 3.3V by changing a single resistor. The TPS40074EVM-001 has been built to the Sample Application used in the TPS40074 Datasheet except the switching frequency has been lowered to 400kHz to reduce switching losses in the Power FETs, and the RKFF resistor (R10) increased to maintain the UVLO level.

## 1.2 APPLICATIONS

- Non-Isolated Medium Current Point of Load and low voltage bus converters.
- Merchant Power Modules
- Networking Equipment
- Telecommunications Equipment
- DC Power Distributed Systems

## 1.3 FEATURES

- 10V - 14V input range
- 1.5V fix output, adjustable with single resistor
- 15Adc Steady State Output Current
- 400kHz switching frequency
- Single Main Switch MOSFET and Single Synchronous Rectifier MOSFET
- Single Component Side, surface mount design on a 3” x 3” evaluation board
- Four Layer PCB with all components on top side
- Convenient test points for probing critical waveforms and non-invasive loop response testing

# 2 TPS40074EVM-001 ELECTRICAL PERFORMANCE SPECIFICATIONS

| Parameter | Notes and Conditions | | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| **INPUT CHARACTERISTICS** | | | | | | |
| Input Voltage Range | | | 10 | | 14 | V |
| Max Input Current | $V_{IN}$ = 10V, $I_{OUT}$ = 15A | | | 2.75 | | A |
| No-Load Input Current | $V_{IN}$ = 14V, $I_{OUT}$ = 0A | | | 45 | | mA |
| **OUTPUT CHARACTERISTICS** | | | | | | |
| Output Voltage | R6 = 9.53k R5 = 105k | | 1.45 | 1.50 | 1.55 | V |
| Output Voltage Regulation | Line Regulation (10V<$V_{IN}$<14V, $I_{OUT}$ = 5A)<br>Load Regulation (0A<$I_{OUT}$<15A, $V_{IN}$ = 12V) | | | | 1<br>1 | %<br>% |
| Output Voltage Ripple | $V_{IN}$ = 14V, $I_{OUT}$ = 15A | | | 25 | 50 | mVpp |
| Output Load Current | | | 0 | | 15 | A |
| Output Over Current | | | | 23 | | A |
| **SYSTEM CHARACTERISTICS** | | | | | | |
| Switching Frequency | | | 360 | 400 | 440 | kHz |
| Peak Efficiency | $V_{OUT}$ = 1.5V, 8A<$I_{OUT}$<12A | $V_{12V_IN}$ = 10V<br>$V_{12V_IN}$ = 12V<br>$V_{12V_IN}$ = 14V | | 87<br>85<br>83 | | %<br>% |
| Full Load Efficiency | $V_{OUT}$ = 1.5V, $I_{OUT}$ = 15A | $V_{12V_IN}$ = 10V<br>$V_{12V_IN}$ = 12V<br>$V_{12V_IN}$ = 14V | | 84<br>83<br>81 | | %<br>% |

**Table 1: TPS40074EVM-001 Electrical & Performance Specifications**

# 3 SCHEMATIC

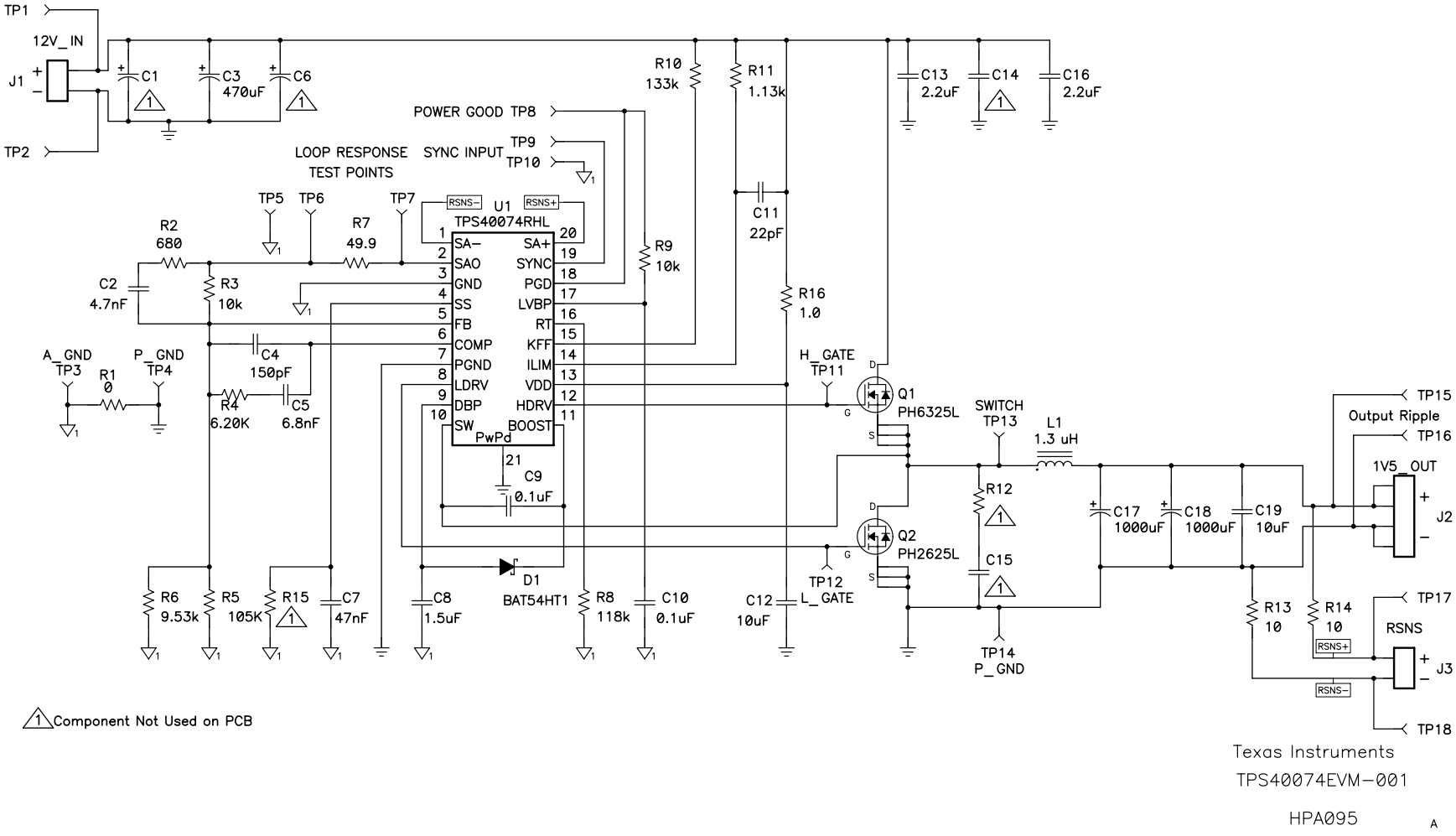



**Figure 1: TPS40074EVM-001 Power Stage / Control Schematic**

**For Reference Only, See Table 3: Bill of Materials for Specific Values**

## 3.1 ADJUSTING OUTPUT VOLTAGE (R5 & R6)

The regulated output voltage can be adjusted within a limited range by changing the ground resistor in the feedback resistor divider (R6 & R5). The output voltage is given by the formula

$$V_{VOUT} = V_{VREF} \times \frac{R5+R6+R3}{R5+R6}$$

Where $V_{VREF}$ = 0.700V and R3 = 10.0KΩ

Table 2 contains common values for R6 to generate popular output voltages with R5 open R5 can be used to increase the accuracy that can be obtained without using more expensive resistors. TPS40074EVM-001 is stable through these output voltages but the efficiency may suffer as the power stage is optimized for the 1.5V output.

| $V_{OUT}$ | R16 |
|---|---|
| 3.3V[1] | 2.67K |
| 2.5V[1] | 3.83K |
| 2.2V[1] | 4.64K |
| 2.0V[1] | 5.36K |
| 1.8V | 6.34K |
| 1.5V | 8.66K |
| 1.2V | 14.0K |

**Table 2: Adjusting $V_{1V5_OUT}$ with R14**

## 3.2 USING REMOTE SENSE (J3)

TPS40074EVM-001 provides the user with remote sense capabilities through the connector J3. When remote sense is used, J3 should be connected at the load to provide more accurate load regulation by compensating for losses over the terminal connections and load wire connections. When remote sense is connected the output voltage measured between TP15 and TP16 may show a positive load regulation characteristic (increasing output voltage with increasing load). This is the result of the controller's compensation of resistive losses between the local sense voltage (TP15 and TP16) and the remote sense connection (J3). TP17 and TP18 are connected to the remote sense lines and thus will show the voltage at the load when remote sense is connected.

Excessive phase shift from inductive components in the load or remote sense connections can cause instability if care is not taken to minimize these parasitic effects in the remote sense line. A twisted pair of insulated cables from the load connection to J3 is preferred to minimize noise injection and inductance in the remote sense line. In a device layout care should be taken to shield the remote sense line from high-noise, high-current or digital signals to limit noise injection into the feedback path and provide the most accurate regulation possible.

## 3.3 5V Input Operation[1] (R10 and R15)

To operate with a 5V input, two resistors need to be changed. R10 (RKFF) sets the voltage ramp amplitude and needs to be reduced to 53.6kΩ to lower the UVLO to 3.9V for 5V operation. In addition, a 330kΩ resistor should be added at R15 to prevent an internal race condition during soft-start.

[1] Due to higher duty cycles associated with higher output voltages or lower input voltages, output current should be limited to 10A when operating with output voltages greater than 2.0V or input voltages below 6V to reduce conduction losses in the main switching FET (Q1). Under these conditions a lower $R_{dsON}$ FET would normally be selected.

# TEST SET UP

## *3.4 EQUIPMENT*

### 3.4.1 VOLTAGE SOURCE

$V_{12V_IN}$
The input voltage source ($V_{12V_IN}$) should be a 0-15V variable DC source capable of 5Adc. Connect $V_{12V_IN}$ to J1 as shown in Figure 3.

### 3.4.2 METERS

A1: 0-5Adc, ammeter
V1: $V_{12V_IN}$, 0-15V voltmeter
V2: $V_{1V5_OUT}$ 0-5V voltmeter

### 3.4.3 LOADS

LOAD1
The Output Load (LOAD1) should be an Electronic Constant Current Mode Load capable of 0-15Adc @ 1.5V

### 3.4.4 Recommended Wire Gauge

$V_{12V_IN}$ to J1
The connection between the source voltage, $V_{12V_IN}$ and J1 of HPA095 can carry as much as 3 Adc. The minimum recommended wire size is AWG #16 with the total length of wire less than 4 feet (2 feet input, 2 feet return).
J2 to LOAD1 (Power)
The power connection between J2 of HPA095 and LOAD1 can carry as much as 15Adc. The minimum recommended wire size is 2x AWG #16, with the total length of wire less than 4 feet (2 feet output, 2 feet return).
J3 to LOAD1 (Remote Sense)
If remote sense is used, the remote sense connection between J3 of HPA095 and LOAD1 can carry less than 1Adc. The minimum recommended wire size is AWG #22, with the total length of wire less and 4 feet (2 feet output, 2 feet return).

### 3.4.5 OTHER

FAN
This evaluation module includes components that can get hot to the touch, because this EVM is not enclosed to allow probing of circuit nodes, a small fan capable of 200-400 lfm is required to reduce component surface temperatures to prevent user injury. The EVM should not be left unattended while powered or probed while the fan is not running.
OSCILLOSCOPE
A 60MHz or faster Oscilloscope can be used to determine the ripple voltage on 1V5_OUT. The Oscilloscope should be set for 1MΩ impedance, AC coupling, 1μs/division horizontal resolution, 20mV/division vertical resolution for taking output ripple measurements. TP 15 and TP 16 can be used to measure the output ripple voltage by placing the oscilloscope probe tip through TP 15 and holding the ground barrel to TP 16 as shown in Figure 3. For a hands free approach, the loop in TP 16 can be cut and opened to cradle the probe barrel. Using a leaded ground connection may induce additional noise due to the large ground loop area.

## *3.5 EQUIPMENT SETUP*

Shown in Figure 3 is the basic test set up recommended to evaluate the TPS40074EVM-001. Please note that although the return for J1 and J2 are the same, the connections should remain separate as shown in Figure 2.

### 3.5.1 Procedure

1. Working at an ESD workstation, make sure that any wrist straps, bootstraps or mats are connected referencing the user to earth ground before power is applied to the EVM. Electrostatic smock and safety glasses should also be worn.
2. Prior to connecting the DC input source, $V_{12V_IN}$, it is advisable to limit the source current from $V_{12V_IN}$ to 5.0A maximum. Make sure $V_{12V_IN}$ is initially set to 0V and connected as shown in Figure 2.
3. Connect the ammeter A1 (0-5A range) between $V_{12V_IN}$ and J1as shown in Figure 2.
4. Connect voltmeter V1 to TP1 and TP2 as shown in Figure 2.
5. Connect LOAD1 to J2 as shown in Figure 1. Set LOAD1 to constant current mode to sink 0Adc before $V_{12V_IN}$ is applied.
6. Connect voltmeter, V2 across TP17 and TP18 as shown in Figure 2.
7. Connect Oscilloscope probe to TP16 and TP15 as shown in Figure 3.
8. Place Fan as shown in Figure 2 and turn on, making sure air is flowing across the EVM.

### 3.5.2 Diagram

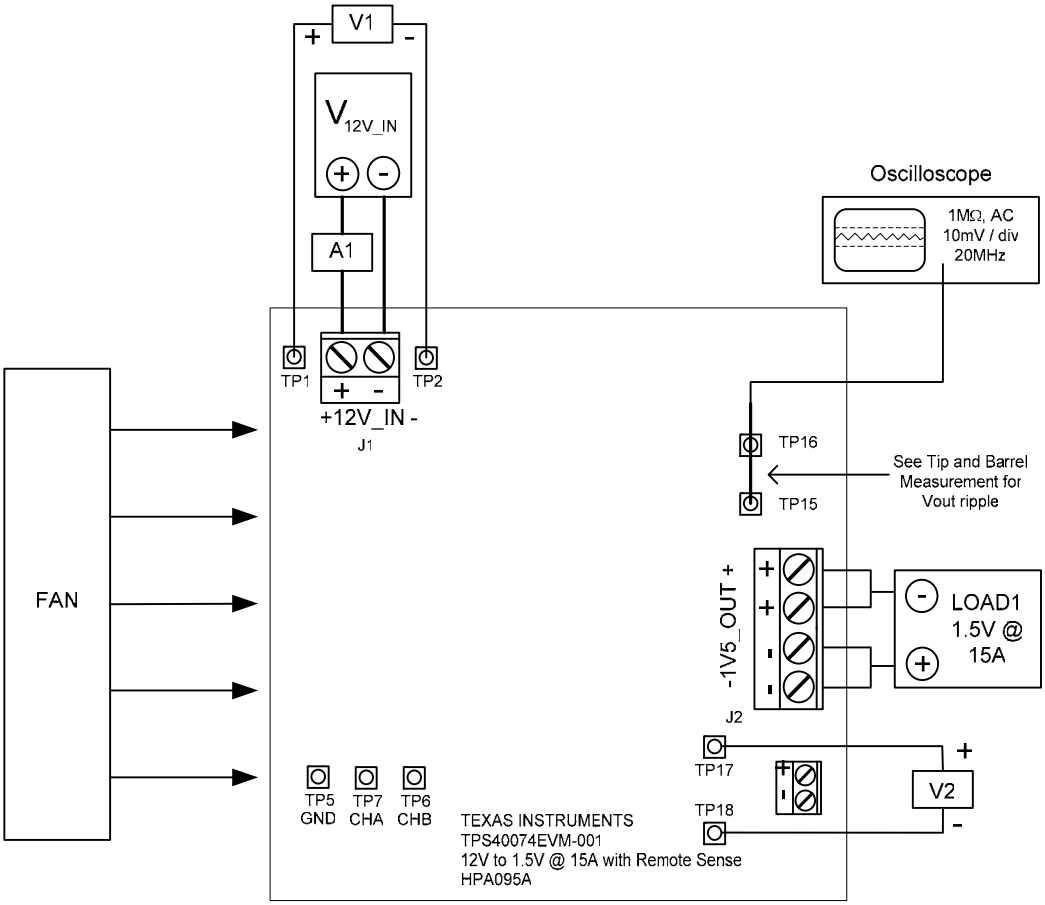



**Figure 2: TPS40074EVM-001 Recommended Test Set-Up**

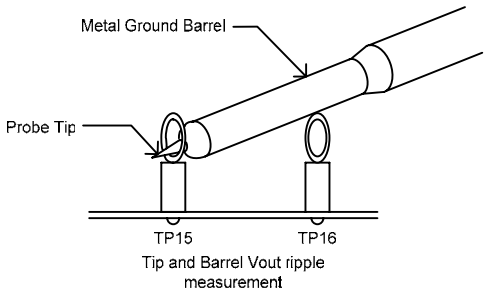



**Figure 3: Output Ripple Measurement - Tip & Barrel using TP15 and TP16**

## *3.6 START UP / SHUT DOWN PROCEDURE*

1. Increase $V_{12V_IN}$ (V1) from 0V to 10Vdc.
2. Vary LOAD1 from 0 – 10Adc
3. Vary $V_{12V_IN}$ (V1) from 10Vdc to 14Vdc
4. Decrease LOAD1 to 0A.
5. Decrease $V_{12V_IN}$ to 0V.

## *3.7 EQUIPMENT SHUTDOWN*

1. Shut Down Oscilloscope
2. Shut down LOAD1
3. Shut down $V_{12V_IN}$
4. Shut down FAN

# 4 TPS40074EVM TYPICAL PERFORMANCE DATA & CHARACTERISTIC CURVES

Figure 4 through Figure 7 present typical performance curves for the TPS40074EVM-001. Since actual performance data can be affected by measurement techniques and environmental variables, these curves are presented for reference and may differ from actual field measurements.

## *4.1 EFFICIENCY*

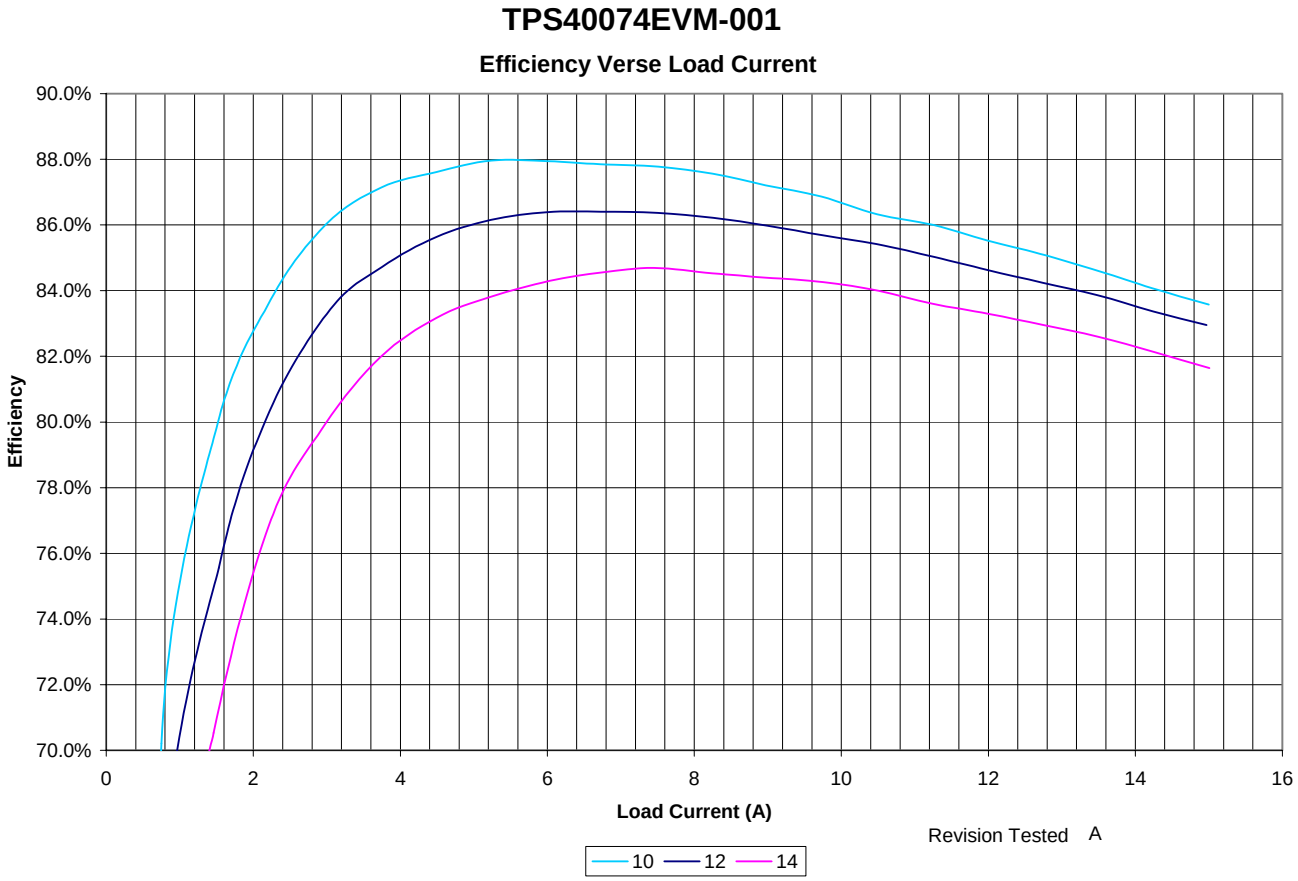



**Figure 4: TPS40074EVM-001 Efficiency**

**$V_{12V_IN}$ =10-14V, $V_{1V5_OUT}$ = 1.5V $I_{1V5_OUT}$ = 0-15A**

## 4.2 LINE & LOAD REGULATION

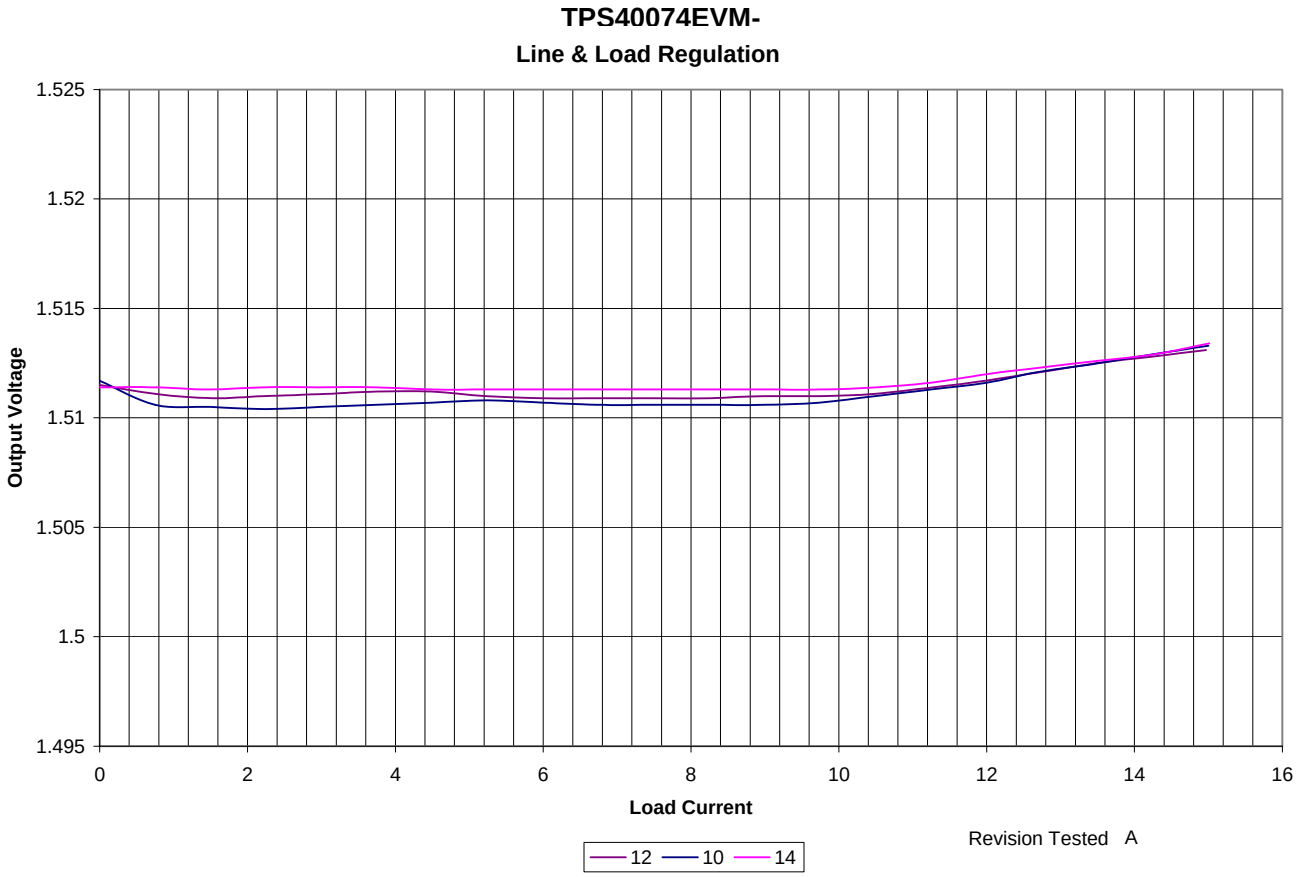



**Figure 5: TPS40074EVM-001 Line & Load Regulation – ±1% Window**

# 5 EVM ASSEMBLY DRAWINGS AND LAYOUT

The following figures (Figure 6 through 11) show the design of the TPS40074EVM-001 printed circuit board. The EVM has been designed using a 4-layer, 2oz copper-clad circuit board 3.0" x 3.0" with all components on the top side to allow the user to easily view, probe and evaluate the TPS40074 control IC in a practical application. Moving components to both sides of the PCB or using additional internal layers can offer additional size reduction for space constrained systems.

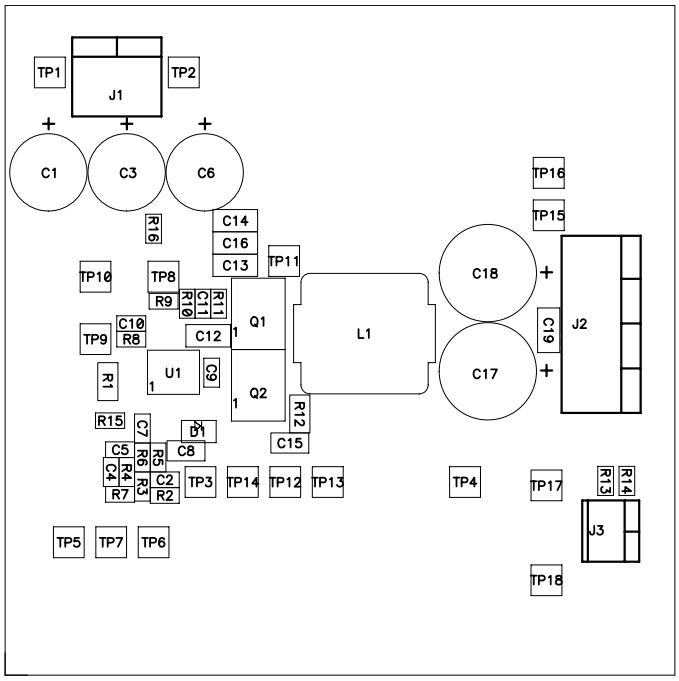



**Figure 6: TPS40074EVM-001 Component Placement (Viewed from Top)**

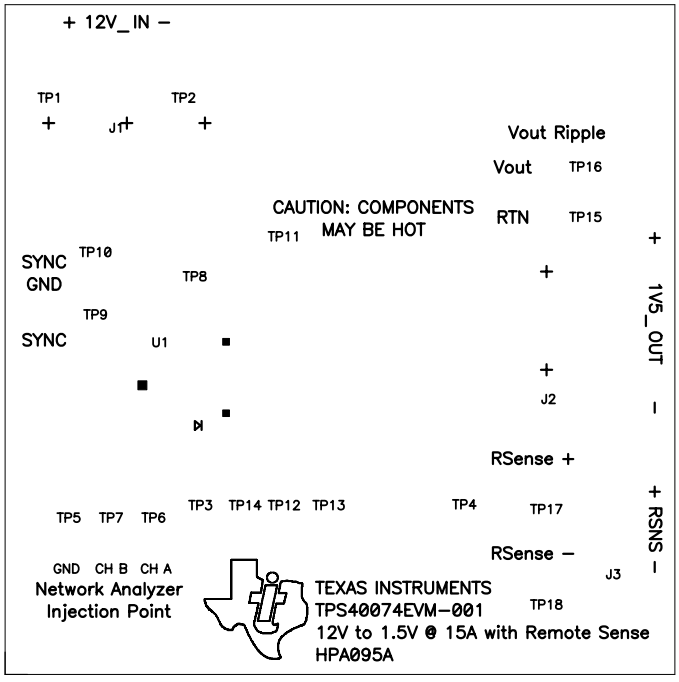



**Figure 7: TPS40074EVM-001 Silkscreen (Viewed from Top)**

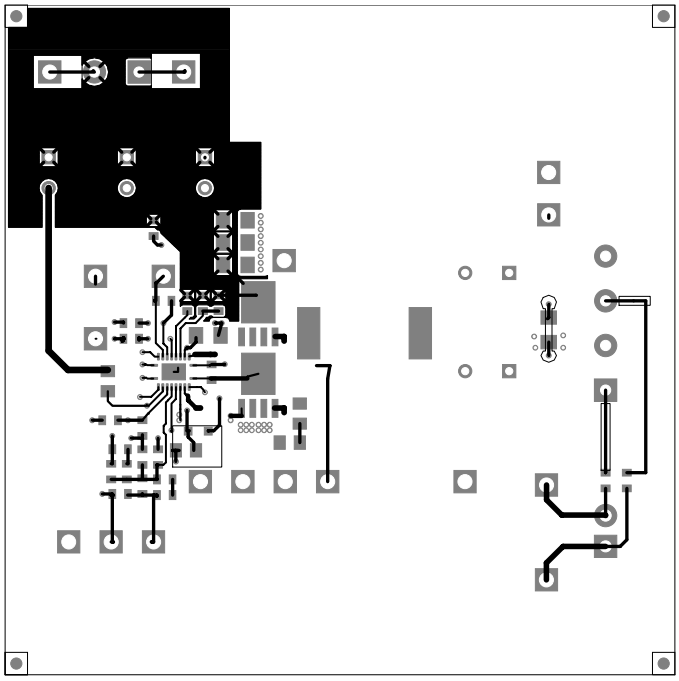


**Figure 8: TPS40074EVM-001 Top Copper (Viewed from Top)**

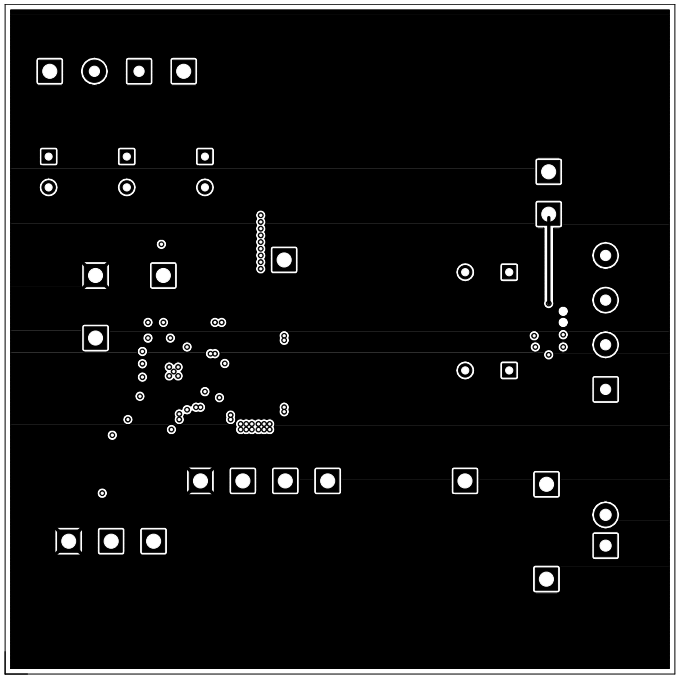


**Figure 9: TPS40074EVM-001 Layer 2 (X-Ray View from Top)**

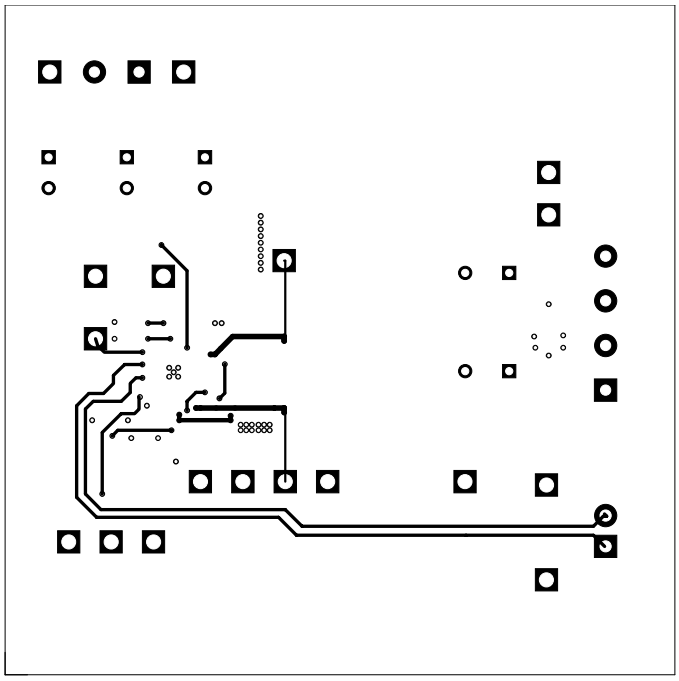


**Figure 10: TPS40074EVM-001 Layer 3 (X-Ray View from Top)**

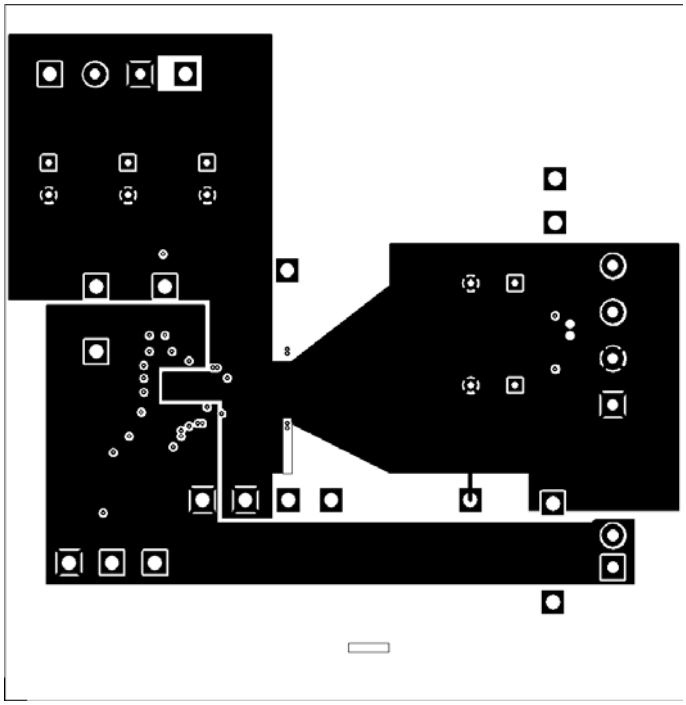


**Figure 11: TPS40074EVM-001 Bottom Copper (X-Ray View from Top)**

# 6 LIST OF MATERIALS

Table 3 lists the EVM components as configured according to the schematic shown in Figure 1 and Figure 2.

File: HPA095A_bom.xls EVM# TPS40074EVM-001
Date: 15-Apr-05 HPA# HPA095A

**Bill of Materials**

## TPS40074EVM-001

| Count | RefDes | Description | Size | Mfr | Part Number |
|---|---|---|---|---|---|
| 0 | C1, C6 | Capacitor, 470uF, 16V, 21 milliohm, 25% | 8mm | Panasonic | EEUFL1C470U |
| 1 | C3 | Capacitor, 470uF, 16V, 21 milliohm, 25% | 8mm | Panasonic | EEUFL1C470U |
| 1 | C2 | Capacitor, Ceramic, 4700 pF, 50V, X7R, 10% | 0603 | Std | Std |
| 1 | C4 | Capacitor, Ceramic, 150 pF, 50V, X7R, 10% | 0603 | Std | Std |
| 1 | C5 | Capacitor, Ceramic, 6800 pF, 50V, X7R, 10% | 0603 | Std | Std |
| 1 | C7 | Capacitor, Ceramic, 0.047 uF, 50V, X7R, 10% | 0603 | Std | Std |
| 1 | C8 | Capacitor, Ceramic, 1.5 uF, 16V, X7R, 20% | 0805 | TDK | C2012X7R1C115M |
| 2 | C9, C10 | Capacitor, Ceramic, 0.1uF, 50V, X7R, 20% | 0603 | Std | Std |
| 1 | C11 | Capacitor, Ceramic, 22 pF, 50V, NPO, 10% | 0603 | Std | Std |
| 1 | C12 | Capacitor, Ceramic, 10 uF, 16V, X7R, 20% | 1206 | TDK | C3216X7R1C106M |
| 2 | C13, C16 | Capacitor, Ceramic, 2.2 uF, 16V, X7R, 10% | 1206 | Std | Std |
| 0 | C14 | Capacitor, Ceramic, 2.2 uF, 16V, X7R, 10% | 1206 | Std | Std |
| 0 | C15 | Capacitor, Ceramic, 1000 pF, 25V, X7R, 20% | 0805 | Std | Std |
| 2 | C17, C18 | Capacitor, 1000 uF, 10V, 16milliohm, 25% | 8mm | Panasonic | EEUFL1A102U |
| 1 | C19 | Capacitor, Ceramic, 10 uF, 6.3V, X5R, 20% | 1206 | Std | Std |
| 1 | D1 | Diode, Schottky, 200-mA, 30-V | SOD323 | On-Semi | BAT54HT1 |
| 1 | J1 | Terminal Block, 2-pin, 15-A, 5.1mm | 0.40 x 0.35 | OST | ED1609 |
| 1 | J2 | Terminal Block, 4-pin, 15-A, 5.1mm | 0.80 x 0.35 | OST | ED2227 |
| 1 | J3 | Terminal Block, 2-pin, 6-A, 3.5mm | 0.27 x 0.25 | OST | ED1514 |
| 1 | L1 | Inductor, SMT, 1.3 uH, 26 A, 2 milliohm | 0.51 x 0.51 | Pulse | PG0077.142 |
| 1 | Q1 | Mosfet, N-Ch, 25V, 81.4A, 8.9 miliOhms | LFPAK | Philips | PH6325L |
| 1 | Q2 | Mosfet, N-Ch, 25V, 118A, 4.1miliOhms | LFPAK | Philips | PH2625L |
| 1 | R1 | Resistor, Chip, Zero Ohm Jumper, 1/10-W, 5% | 0805 | Std | Std |
| 1 | R2 | Resistor, Chip, 680 Ohms, 1/16-W, 1% | 0603 | Std | Std |
| 2 | R3,R9 | Resistor, Chip, 10k Ohms, 1/16-W, 1% | 0603 | Std | Std |
| 1 | R4 | Resistor, Chip, 6.20k Ohms, 1/16-W, 1% | 0603 | Std | Std |
| 1 | R5 | Resistor, Chip, 105K Ohms, 1/16-W, 1% | 0603 | Std | Std |
| 1 | R6 | Resistor, Chip, 9.53k Ohms, 1/16-W, 1% | 0603 | Std | Std |
| 1 | R7 | Resistor, Chip, 49.9 Ohms, 1/16-W, 1% | 0603 | Std | Std |
| 1 | R8 | Resistor, Chip, 118k Ohms, 1/16-W, 1% | 0603 | Std | Std |
| 1 | R10 | Resistor, Chip, 133k Ohms, 1/16-W, 1% | 0603 | Std | Std |
| 1 | R11 | Resistor, Chip, 1.13k Ohms, 1/16-W, 1% | 0603 | Std | Std |
| 0 | R12 | Resistor, Chip, 3.3 Ohms, 1/10-W, 1% | 0805 | Std | Std |
| 2 | R13, R14 | Resistor, Chip, 10 Ohms, 1/16-W, 1% | 0603 | Std | Std |
| 0 | R15 | Resistor, Chip, Ohms, 1/16-W, 1% | 0603 | N/A | N/A |
| 1 | R16 | Resistor, Chip, 1.0-Ohms, 1/16-W, 1% | 0603 | Std | Std |
| 3 | TP1, TP15, TP17 | Test Point, Red, Thru Hole | 0.125 x 0.125 | Keystone | 5010 |

| | | | | | |
|---|---|---|---|---|---|
| 8 | TP2, TP3, TP4, TP5, TP10, TP14, TP16, TP18 | Test Point, Black, Thru Hole | 0.125 x 0.125 | Keystone | 5011 |
| 7 | TP6, TP7, TP8, TP9, TP11, TP12, TP13 | Test Point, White, Thru Hole | 0.125 x 0.125 | Keystone | 5012 |
| 1 | U1* | IC, | QFN-20 | TI | TPS40074RHL |
| 1 | -- | PCB, 4-Layer FR4, 3.0" x 3.0" x 0.062" | 2.4" x 2.1" | Any | HPA095A |
| 4 | -- | Bumpon, Transparent | 0.44" x 0.2" | 3M | SJ5303 |

Notes:

1. These assemblies are ESD sensitive, ESD precautions shall be observed.
2. These assemblies must be clean and free from flux and all contaminants.
   Use of no clean flux is not acceptable.
3. These assemblies must comply with workmanship standards IPC-A-610 Class 2.
4. Install Bumpons on back side(unpopulated side) of PCB. Install one in each corner after cleaning.
5. Ref designators marked with an asterik " * " cannot be subsituted.
   All other components can be subsituted with equivalent MFG's components.

**Table 3: TPS40074EVM-001 Bill of Materials**