AN–1207 LM2593HV Evaluation Board

1 Specifications of the Board

The board is designed for a nominal DC input of 48 V, but can safely withstand up to 60 V. The regulated DC output is 12 V at a maximum load current of 2A. It uses the adjustable version of the LM2593HV in 7 lead Surface Mount Package (TO263). Relying on careful layout, it eliminates the need for a snubber across the diode and uses a minimum number of components. It has shutdown capability and error flag output available on the board. It incorporates soft-start and delayed output error signaling and has an overall efficiency higher than 85%.

The board uses no external heatsinks, or through-hole parts and is suitable for a fully automatic production process. It requires only 1.7 x 2.0 x 0.7 cu. inches of space. The printed circuit board (PCB) is standard 1.6 mm thick (62 mils) ‘1/2 oz' double-sided FR4 laminate, with additional cooper plating, totaling a little over 1 oz of copper (“1 oz” is 1.4 mils/35 µm thick). The traces have been left unmasked to allow solder to deposit on the traces during reflow, so as to aid thermal dissipation. The converter is designed for continuous operation at rated load under natural convection up to a maximum ambient of 40°C.

2 Component Selection

We set:

V_{IN} = 48 V

V_O = 12 V

I_O = 2A

2.1 Inductor

‘D' is defined as the duty cycle and ‘r' is defined as the ripple current ratio $\Delta I/I_O$. For more details on the terms and equations used in this document, see *AN-1197 Selecting Inductors for Buck Converters* (SNVA038).

r was chosen to be 0.3 in this document as per the design procedure inductor nomographs in the *LM2593HV Simple SWITCHERPower Converter 150 kHz 2A Step-Down Voltage Regulator, With Features Data Sheet* (SNVS082) as well as the guidelines in the refer*AN-1197 Selecting Inductors for Buck Converters* (SNVA038). ‘r' is related to the inductance through Equation 1:

$$r = \frac{Et}{L \cdot I_{DC}} \quad (1)$$

where

- 'Et' is the applied Voltµsecs
- I_{DC} is the maximum rated load in Amps
- L is the inductance in µH

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The duty cycle is:

$$D = \frac{V_O + V_D}{V_{IN} - V_{SW} + V_D}$$

where

- V_D is the diode forward voltage drop (≅0.5 V)
- V_{SW} is the drop across the switch when it is ON, plus any parasitics (≅1.5 V).

$$D = \frac{12 + 0.5}{48 - 1.5 + 0.5} = 0.27 \quad (2)$$

The switch ON-time is:

$$t_{ON} = \frac{D}{f} = \frac{(12 + 0.5) \times 10^6}{(48 - 1.5 + 0.5) \times 150000} \mu secs$$

- t_{ON} = 1.77 µs (3)

So the Voltµseconds 'Et' is:

$Et = (V_{IN} - V_{SW} - V_O) \times t_{ON} = (48-1.5-12) \times 1.77$ Vµs

where

- Et = 61.1 Vµs (4)

Estimated inductance is:

$$L = \frac{Et}{r \times I_O} \mu H$$

$$L = \frac{61.1}{0.3 \times 2.0} \mu H$$

where

- L = 101.8 µH (5)

The first pass selection of the inductor is usually on the basis of the inductance calculated above and the max load current. But, if the input voltage exceeds 40 V, as it does here, evaluate the inductor further to ensure that the converter withstands damage if the outputs are overloaded/shorted. A 100 µH/1.8A drum core type (large inherent air gap) was chosen from Coilcraft, which saturates above 3A. It is designed for a 40°C rise in temperature at a maximum ambient of 85°C. Its use is accepted at a load current slightly higher than its continuous rating since the maximum ambient temperature for the demo-board is only 40°C not 85°C, and since we also know it does not saturate at the maximum load current.

2.2 Input Capacitor

The voltage rating of the input capacitor must be higher than the DC Input. Tantalum capacitors were not considered suitable here due to their 50 V maximum rating, and their inherent surge current limitations (which are always of concern especially at high input voltages). A 63 V aluminum electrolytic SMT capacitor was chosen from Panasonic, sized to handle the RMS current as calculated in Equation 6:

$$I_{RMS\_IN} = I_O \cdot \sqrt{D \cdot \left[1 - D + \frac{r^2}{12}\right]} \text{ A}$$

$$I_{RMS\_IN} = 2 \cdot \sqrt{0.27 \cdot \left[1 - 0.27 + \frac{0.3^2}{12}\right]} = 0.89 \text{ A} \quad (6)$$

The capacitor that was chosen is 100 µF with an RMS current rating of 1.02A at 100 kHz.

2.3 Output Capacitor

A capacitor type was chosen similar to the input capacitor mainly for logistic reasons. It was initially sized simply to handle the RMS current as calculated in Equation 7 , and with a voltage rating just higher than the output voltage. Subsequently, a Bode plot for the feedback loop confirmed that the phase margin was acceptable at around 40°. This validated the initial selection. The required RMS rating of the output capacitor is:

$$I_{RMS\_OUT} = I_O \cdot \frac{r}{\sqrt{12}} \text{ A}$$

$$I_{RMS\_OUT} = 2 \cdot \frac{0.3}{\sqrt{12}} = 0.17 \text{ A} \quad (7)$$

The capacitor that was chosen is 47 µF/16 V with an RMS current rating of 0.24A at 100 kHz and an ESR of 0.36 Ω.

2.4 Catch Diode

The voltage rating must be higher than the input voltage. A 60 V Schottky diode was chosen here. The average current in the catch diode is:

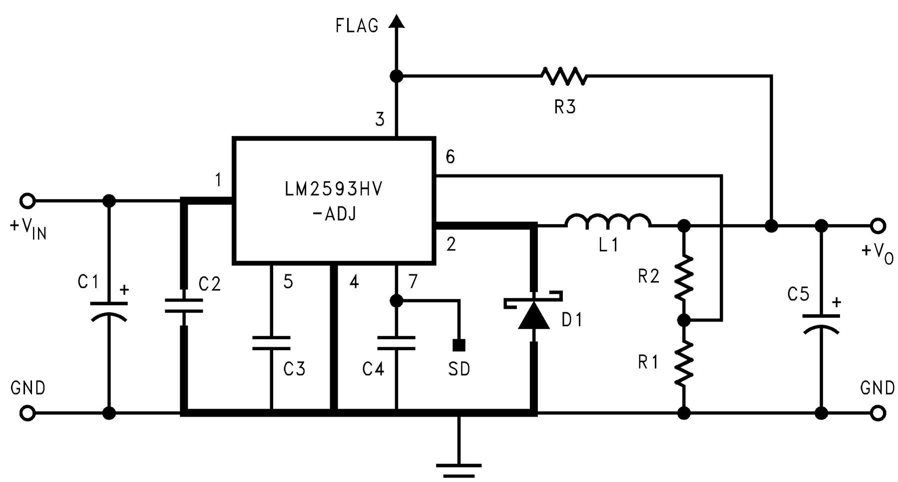
$$I_{AVG\_D} = I_O \bullet (1-D)$$

$$I_{AVG\_D} = 2 \bullet (1-0.27) = 1.47\text{A} \quad (8)$$

Usually the average current would be a starting point for the diode selection. But 60 V Schottky diodes have a higher forward voltage drop than low voltage Schottkys, unless they are ‘over-sized' in terms of their current rating. So to force good efficiency, a diode with a ‘hot-drop' (the forward drop with the diode hot) was considered of no greater than 0.5 V (at an instantaneous forward current of about 2A). This meant using a 3A/60V Schottky diode from International Rectifier.

3 Schematic

The board schematic is presented in Figure 1. The key layout suggestions are also indicated on the schematic. Shutdown capacity is available and the pinout marked ‘SD' on the board can be taken low to cause the output of the converter to fall to 0 V. The ‘Flag' pin output is also available and it goes high (pulled up by R3 to the 12 V rail) to indicate that the output is well-regulated. When the output is ‘not OK', this pin is pulled down internally by the IC and in this condition it sinks 12 V/21K = 0.6 mA. The maximum voltage on the Flag pin should not exceed 45 V and the current into it should not be higher than 3 mA. Therefore, in this case it cannot be connected directly to the input voltage rail. The resistors R1 and R2 from a simple voltage divider designed to give 1.23 V at the feedback pin when the output is at 12 V.



A Traces shown in BOLD need to be short (not wide) as they pass high frequency current pulses. Wide copper planes with switching current/voltage can radiate excessively.

B Trace to Feedback Pin (Pin 6) should not pass directly under L1 (to avoid pickup). b)

Figure 1. Layout Suggestions

4 Layout and Bill of Material (BOM)

The two sides of the board are presented in Figure 2 Figure 3. The Bill of Material is presented in Table 1.

Table 1. Bill of Material

Designator	Description	Manufacturer	Part Number	Quantity
U1	LM2593	Texas Instruments	LM2593	1
D1	3A/60V Schottky	International Rectifier	MBRS360TR	1
L1	100 µH/1.8A	Coilcraft	DO5022-104	1
C1	100 µF/63 V	Panasonic	EEVFC1J101Q	1
C2, C3, C4	0.1 µF/100 V	Vishay-Vitramon	VJ1206Y104KXBA	3
C5	47 µF/16 V	Panasonic	EEVFK1C470P	1
R1	2.37K/1%	Vishay	CRCW12062371F	1
R2, R3	21K/1%	Vishay	CRCW12062102F	2

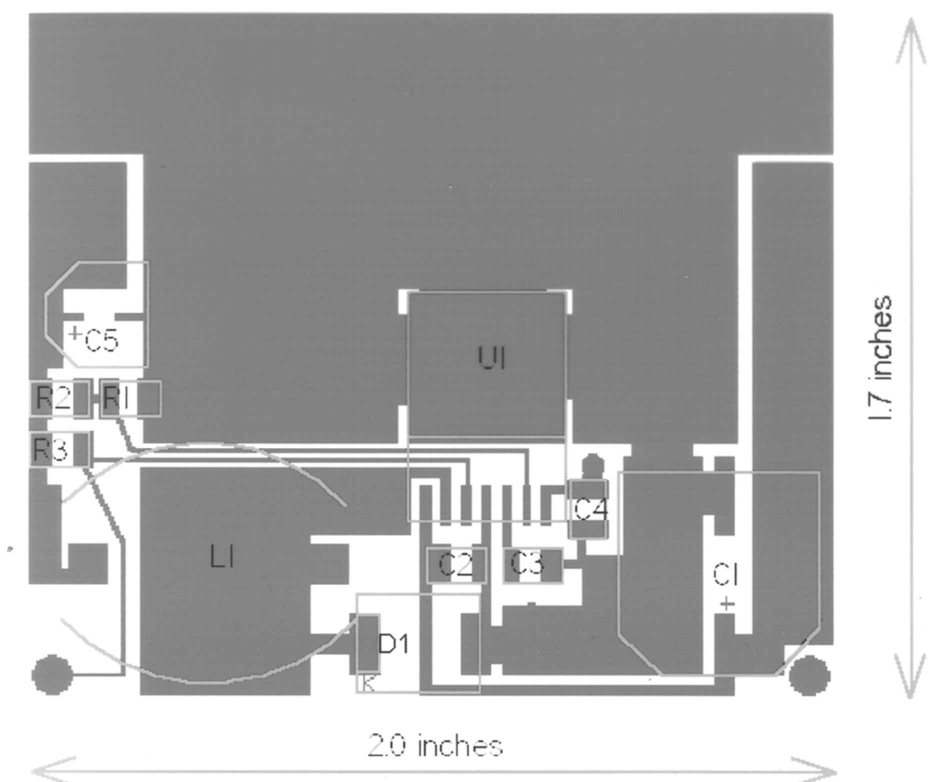


Figure 2. Top Side (Component Side) of PCB

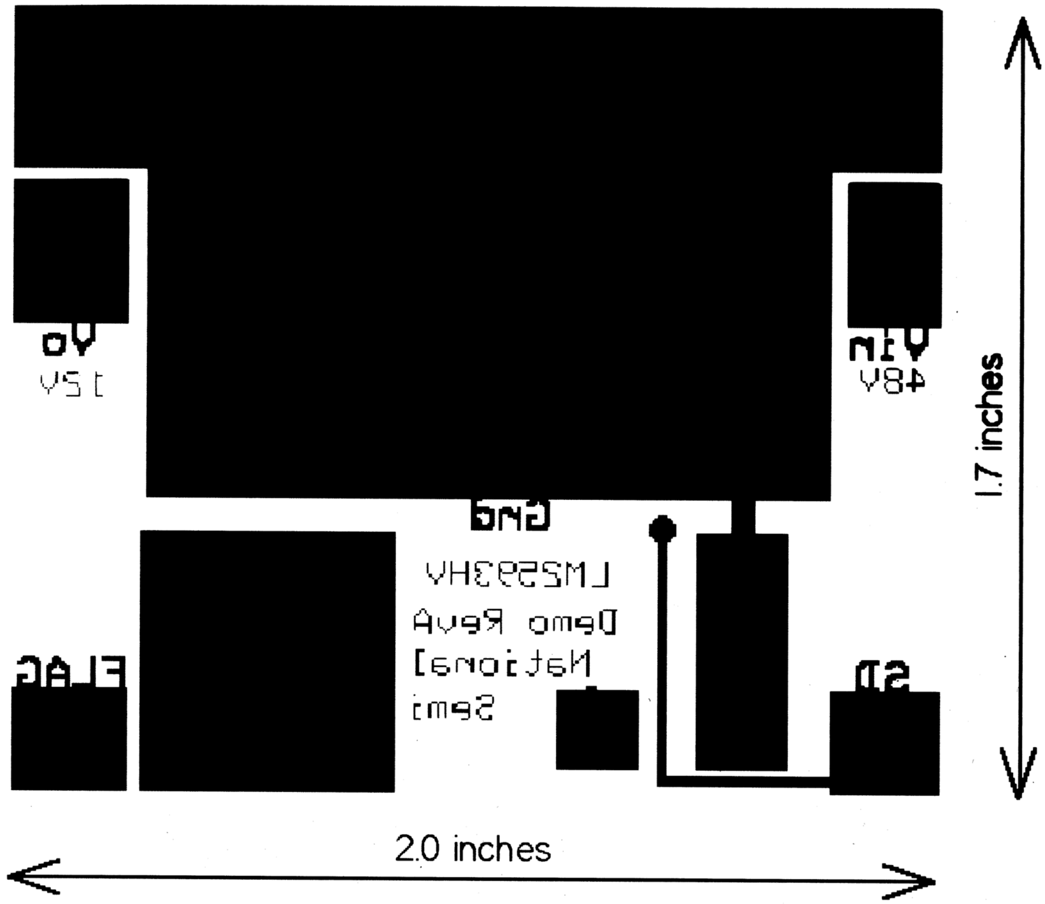


Figure 3. Bottom Side of PCB Viewed From Top

5 References

- *AN-1197 Selecting Inductors for Buck Converters* (SNVA038)
- *LM2593HV Simple SWITCHERPower Converter 150 kHz 2A Step-Down Voltage Regulator, With Features Data Sheet* (SNVS082)

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