

LM2593HV Evaluation Board

National Semiconductor
Application Note 1207
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Specifications of the Board

The board is designed for a nominal DC input of 48V, but can safely withstand up to 60V. The regulated DC output is 12V 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 therefore 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 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.

Component Selection

We set

$$V_{IN} = 48V$$

$$V_O = 12V$$

$$I_O = 2A$$

INDUCTOR

We define 'D' as the Duty Cycle and 'r' the ripple current ratio $\Delta I/I_O$. See Application Note AN-1197 for more details on the terms and equations used here.

We choose r to be 0.3 here as per the design procedure inductor nomographs in the LM2593HV datasheet as well as the guidelines in the referenced Application Note. 'r' is related to the inductance through the equation

$$r = \frac{Et}{L \cdot I_{DC}}$$

where 'Et' is the applied Voltµsecs, I_{DC} is the maximum rated load in Amps, and L is the inductance in µH.

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 ($\cong 0.5V$), and V_{SW} is the drop across the switch when it is ON, plus any parasitics ($\cong 1.5V$). So

$$D = \frac{12 + 0.5}{48 - 1.5 + 0.5} = 0.27$$

The switch ON-time is

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

$$t_{ON} = 1.77 \mu\text{s}$$

So the Voltµseconds 'Et' is

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

$$Et = 61.1 \text{ V}\mu\text{s}$$

Estimated inductance is therefore

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

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

$$L = 101.8 \mu\text{H}$$

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 40V, as it does here, we need to evaluate the inductor further to ensure that the converter withstands damage if the outputs are overloaded/shorted. Here we have chosen a 100 µH/1.8A drum core type (large inherent air gap) from Coilcraft, which saturates above 3A. It is designed for a 40°C rise in temperature at a maximum ambient of 85°C. We have accepted its use 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.

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 50V maximum rating, and their inherent surge current limitations (which are always of concern especially at high input voltages). We have chosen a 63V aluminum electrolytic SMT capacitor from Panasonic, sized to handle the RMS current as calculated below:

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

$$I_{RMS_IN} = 2 \cdot \sqrt{0.27 \cdot \left[1 - 0.27 + \frac{0.3^2}{12} \right]} = 0.89 \text{ A}$$

The capacitor we chose is 100 µF with an RMS current rating of 1.02A at 100 kHz.

Component Selection (Continued)

OUTPUT CAPACITOR

We have chosen a capacitor type similar to the input capacitor mainly for logistic reasons. It was initially sized simply to handle the RMS current as calculated below, 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:

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

$$I_{\text{RMS_OUT}} = 2 \cdot \frac{0.3}{\sqrt{12}} = 0.17 \text{ A}$$

The capacitor we chose is 47 $\mu\text{F}/16\text{V}$ with an RMS current rating of 0.24A at 100 kHz and an ESR of 0.36 Ω .

CATCH DIODE

The Voltage rating must be higher than the input voltage. We have picked a 60V Schottky diode here. The average current in the catch diode is

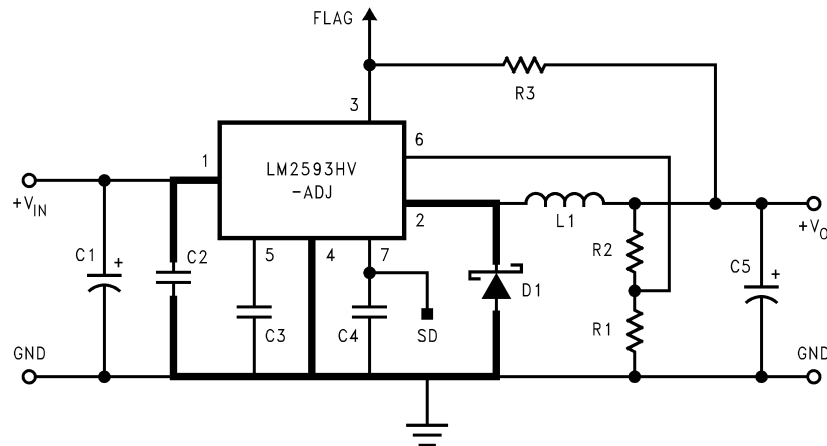
$$I_{\text{AVG_D}} = I_O \cdot (1-D)$$

$$I_{\text{AVG_D}} = 2 \cdot (1-0.27) = 1.47\text{A}$$

Usually the average current would be a starting point for the diode selection. But 60V 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, we wanted to consider a diode with a 'hot-drop' (the forward drop with the diode hot) of no greater than 0.5V (at an instantaneous forward current of about 2A). This meant using a 3A/60V Schottky diode from International Rectifier.

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 0V. The 'Flag' pin output is also available and it goes high (pulled up by R3 to the 12V 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 12V/21K=0.6 mA. The maximum voltage on the Flag pin should not exceed 45V and the current into it should not be higher than 3 mA. Therefore in our case it cannot be connected directly to the input voltage rail. The resistors R1 and R2 from a simple voltage divider designed to give 1.23V at the feedback pin when the output is at 12V.



Layout Suggestions

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

FIGURE 1.

Layout and Bill of Material

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

TABLE 1. Bill of Material

Designator	Description	Manufacturer	Part Number	Quantity
U1	LM2593HVS-ADJ	National Semiconductor	LM2593HVS-ADJ	1
D1	3A/60V Schottky	International Rectifier	MBRS360TR	1
L1	100 μ H/1.8A	Coilcraft	DO5022-104	1
C1	100 μ F/63V	Panasonic	EEVFC1J101Q	1
C2, C3, C4	0.1 μ F/100V	Vishay-Vitramon	VJ1206Y104KXBA	3
C5	47 μ F/16V	Panasonic	EEVFK1C470P	1
R1	2.37K/1%	Vishay	CRCW12062371F	1
R2, R3	21K/1%	Vishay	CRCW12062102F	2

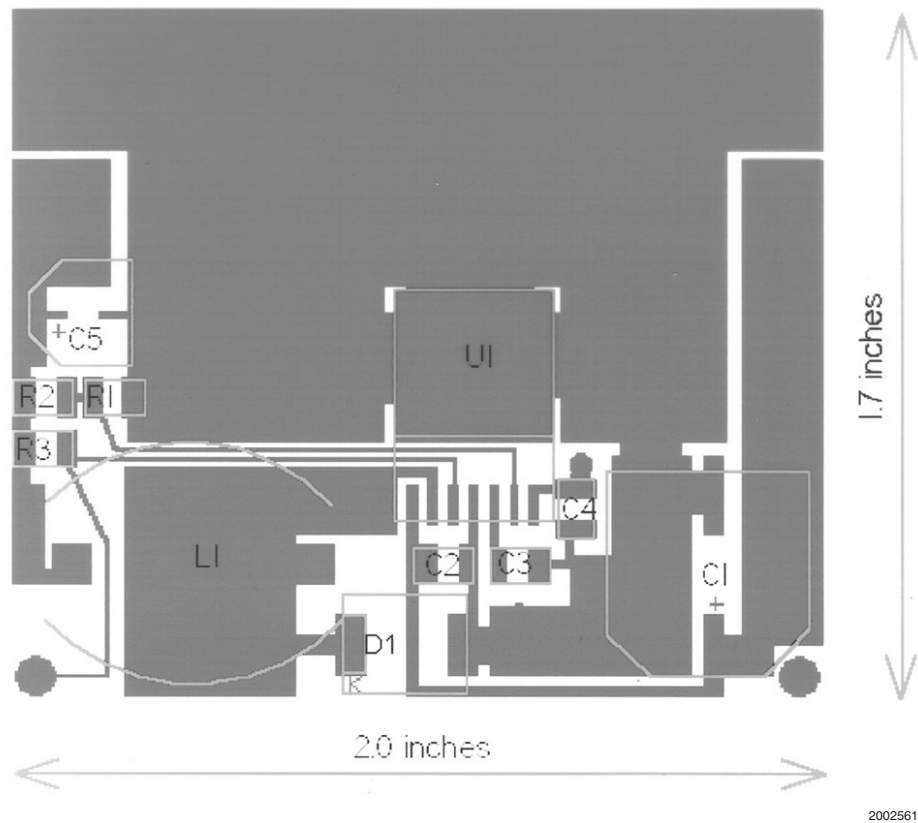
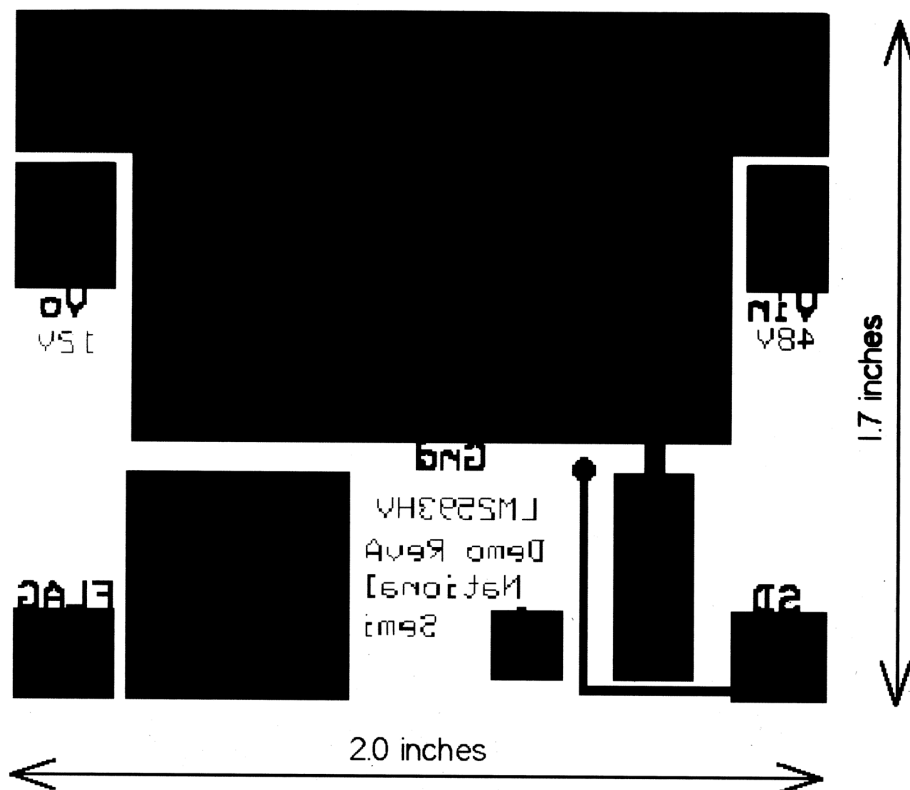


FIGURE 2. Top Side (Component Side) of PCB

Layout and Bill of Material (Continued)



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FIGURE 3. Bottom Side of PCB Viewed from Top

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