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Inductorless Switching Off-line Power Supply Demoboard

Introduction:

The Supertex SR087DB1 is an inductorless switching power supply intended for operation directly from a 120/230VAC line. Two outputs, 12.6V and 5.0V are provided.

The operating principle is to turn on a pass transistor when the rectified AC input is below the output voltage, and to turn it off when the output storage capacitor is charged up to the regulation point. Since the output capacitor charges up on the rising edge of a sine wave, reasonable efficiencies can be obtained without the use of magnetics.

Instructions on page 2 and 3 describe how the demoboard may be modified to better suit applications that are not satisfied by the board as provided. For a full description of the SR087, see the SR087 datasheet.

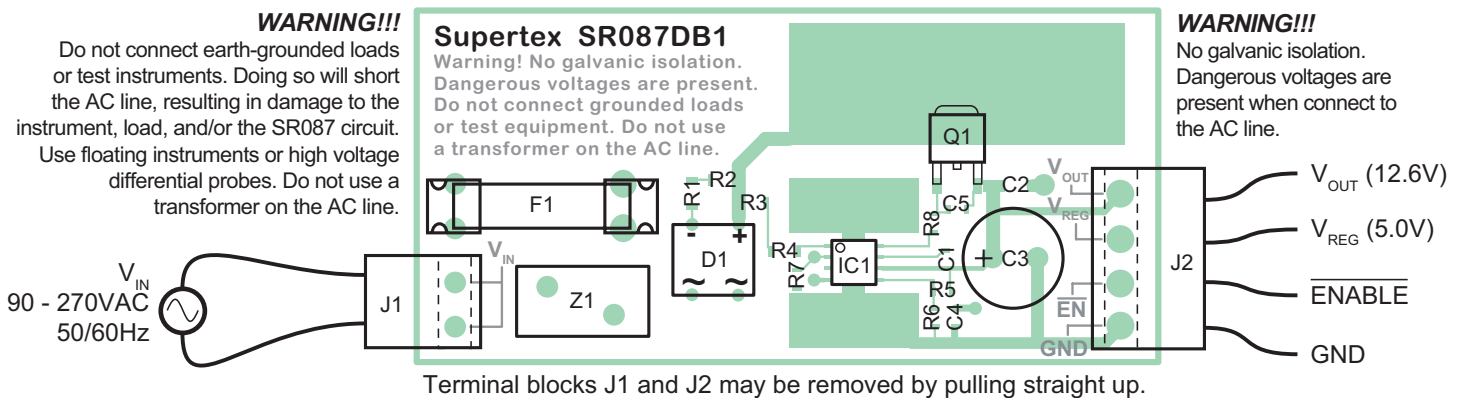
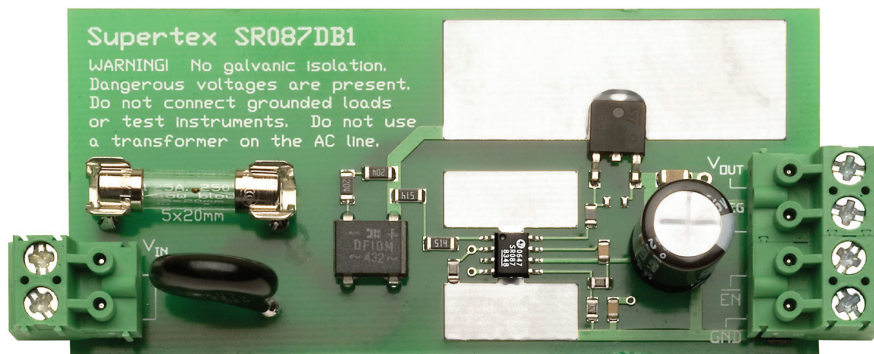
Specifications

Parameter	Value	
AC Input (V_{IN}):	90 to 270VAC 45Hz to 65Hz	
Output voltages: V_{OUT} (no load) V_{REG}	12.6V \pm 8% ¹ 5.0V \pm 5%	
Output current, max: I_{REG} $I_{OUT} + I_{REG}$	120VAC 60mA 100mA	230VAC 60mA 60mA
Efficiency, typ. ² (full load):	52%	44%
Standby power, typ. (no load):	62mW	200mW

Notes:

1. Adjustable from 9.0V to 50V.
2. Referenced to V_{OUT}

Board Layout and Connection Diagram



Connections:

V_{IN} - Connect to a 120/230VAC line. The AC input is protected by a 275V metal oxide varistor (MOV) and a 1.25A slow-blow fuse.

Do not use a transformer on the input line. The high inductance creates inductive kickback, which can overload the MOV.

The SR087DB1 will not operate from uninterruptible power supplies having a square wave output. This type of output is usually referred to as “modified sine wave”.

GND - Circuit common. Since galvanic isolation is not provided, connecting this point to an earth-grounded instrument, (such as an oscilloscope), will short the AC line, resulting in circuit and/or instrument damage.

Also note that GND may be at a higher potential with respect to earth ground, even if the AC is switched off. **Use caution!**

V_{OUT} - The main output. No-load output voltage is 12.6V. Because the V_{OUT} storage capacitor (C3) recharges twice per input cycle, this output will have a certain amount of 100/120Hz ripple, depending upon the load. The SR087

regulates the peak output voltage, not the average, thus the average voltage will decrease under load.

V_{OUT} is adjustable from 9.0 to 50V. See the modifications section on page 3. A source-only external voltage may be applied to this output.

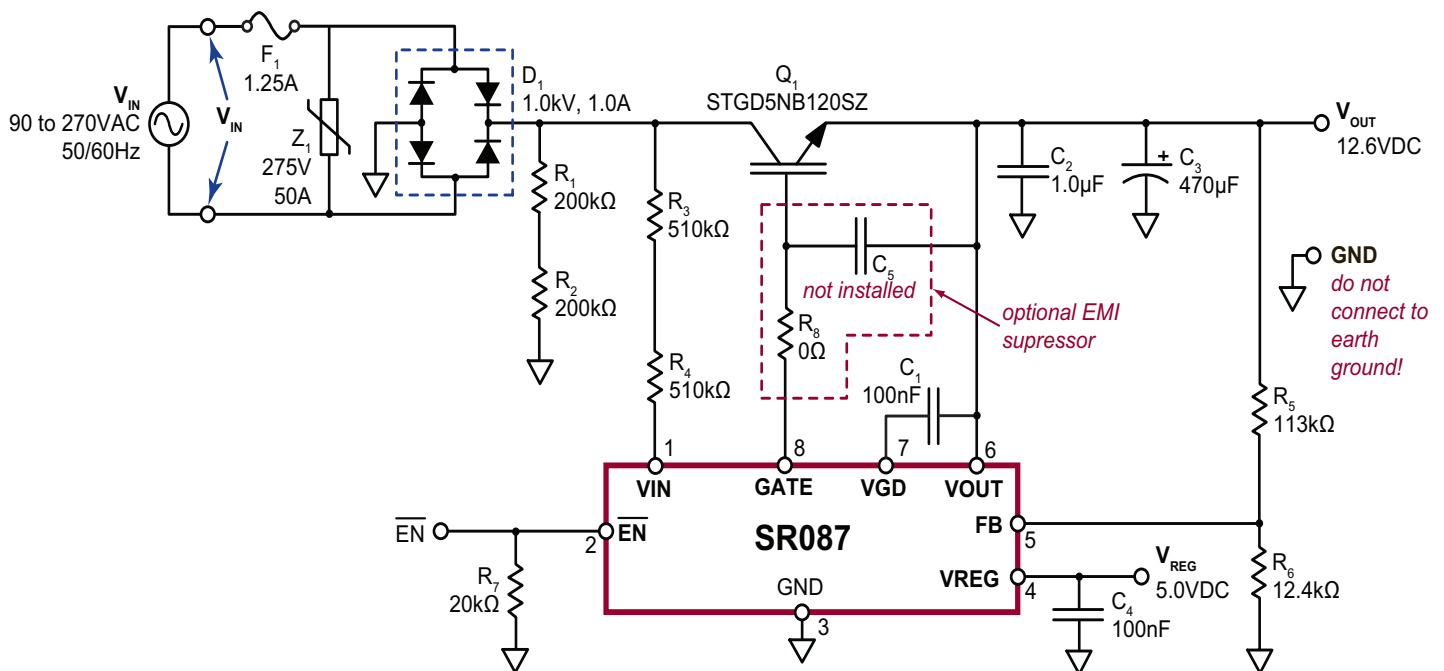
Do not connect earth-grounded loads or instruments!

V_{REG} - The regulated output, 5.0V nominal output voltage. V_{REG} is the output of a linear regulator internal to the SR087, which in turn is supplied by V_{OUT}. Thus any load on V_{REG} is effectively a load on V_{OUT}. V_{REG} requires at least 4.0V of headroom to operate. Being a linear regulator, the SR087 will dissipate power as I_{REG} is increased, up to 460mW at 60mA.

Enable - A logic low (<0.2V) enables Q₁ switching. A logic high (>0.75 • V_{REG}) disables Q₁, shutting down V_{OUT} and thus V_{REG}. However, if an external voltage is applied to V_{OUT} when disabled, V_{REG} will continue to function and provide a 5.0V output.

The input has 20kΩ pull-down. If unused, **Enable** should be left unconnected or connected to ground.

Schematic



Modifications

Output Voltage

V_{OUT} may be adjusted in the range of 9.0 to 50V¹ by changing feedback resistor R_5 according to the following equation. Keep in mind that the peak output voltage is regulated, not the average, therefore the average output voltage will decrease (and ripple increase) with increased loads.

$$R_5 = R_6 \cdot [(V_{OUT}/1.25V) - 1] \quad \text{EQ. 1}$$

Leave R_6 at 12.4k Ω - it assures a minimum 100 μ A load required for the proper operation of the SR087. Change R_3 and R_4 according to the equation 4. It may be necessary to replace C_2 and C_3 with capacitors having a higher voltage rating. For C_3 , use a low ESR capacitor with an adequate ripple current rating (800mArms). Use ceramic for C_2 .

Since V_{REG} is a linear regulator supplied from V_{OUT} , the maximum current available from V_{REG} is reduced as V_{OUT} is increased due to power considerations.

$$I_{REG(MAX)} = \frac{1.5W}{V_{OUT} - 3.3V} \quad \text{EQ. 2}$$

or 60mA, whichever is less.

Output Ripple

Storage capacitor C_3 was sized to provide about 2V_{P-P} ripple at 100mA combined load ($I_{OUT} + I_{REG}$). For lighter loads, C_3 may be reduced. Conversely, C_3 may be increased for lower ripple. Use a low ESR capacitor with an adequate ripple current rating (measure using a current probe). Efficiency and output current capability may drop with increased capacitance because of a smaller conduction angle associated with lower ripple. Due to feedback hysteresis, ripple cannot be reduced below 4%.

$$V_{RIPPLE(P-P)} \approx \frac{I_{OUT} + I_{REG}}{2f_{IN} C_3} \quad \text{EQ. 3}$$

Input Voltage

To reduce standby power for 230VAC-only applications, or for supply voltages less than 90Vrms, R_1 and R_4 should be changed according to equation 4 below. R_1 + R_2 should remain at 400k Ω .

R_2 and R_4 are employed to ensure adequate creepage distances and resistor voltage ratings for 230VAC operation. For 120VAC-only applications they may be omitted (replaced with shorts), with $R_1 = 1.0M\Omega$ and $R_3 = 430k\Omega$.

Conducted EMI

As supplied, the SR087DB1 meets 47CFR Part 15 Class B and CISPR 14-1 requirements for conducted emissions at combined load currents ($I_{OUT} + I_{REG}$) of less than 20mA. For higher load currents, an RC network (R_8 & C_5) can be used before the IGBT gate to slow down the falling edge. This has the effect of reducing harmonics, lowering conducted EMI. Suggested values of 22k Ω and 390pF allow the SR087DB1 to meet EMI requirements at combined load currents of 60mA for 120VAC and 40mA for 230VAC.

Slowing down the falling edge results in the output voltage overshooting the intended regulation point, causing the peak V_{OUT} voltage to be higher than expected. This may be compensated for by entering a slightly lower value for V_{OUT} into equation 1 when selecting feedback resistors. Slowing down the falling edge also increases switching losses, resulting in slightly decreased efficiency.

$R_3 + R_4$ Equation

$$(R3 + R4) < \frac{\sqrt{2V_{IN}^2 - V_x^2} - V_x \cos^{-1}\left(\frac{V_x}{\sqrt{2} V_{IN}}\right)}{\pi \cdot 25\mu A} \quad \text{Eq. 4}$$

$$\text{where } V_x = V_{OUT} + 15V$$

Use the minimum anticipated RMS value for V_{IN} . Take resistor tolerance into account, selecting the next lower standard value. Choosing a lower value has no effect other than slightly higher standby power.

Note:

1. V_{REG} requires at least 4.0V of headroom to provide 3.3V. Therefore V_{OUT} including ripple and tolerance, must not fall below 7.3V.

Bill of Materials

Item #	Description	Value	Tol	Rating	Package	Manufacturer	Manufacturer's Part Number
F1	Fuse, slow-blow	1.25A	-	250V	5x20mm	any	-
Z1	MOV	275V	-	50A	14mm	any	-
D1	Diode bridge	-	-	1.0kV, 1.0A	-	any	-
R1, R2	Resistor	200k Ω	5%	200V	1206	any	-
R3, R4	Resistor	510k Ω	5%	200V	1206	any	-
R5	Resistor	113k Ω	1%	-	0805	any	-
R6	Resistor	12.4k Ω	1%	-	0805	any	-
R7	Resistor	20k Ω	1%	-	0805	any	-
R8	<i>not installed</i>	0 Ω	-	-	0805	any	-
C1	Capacitor, cer X7R	100nF	10%	25V	0805	any	-
C2	Capacitor, cer X7R	1.0 μ F	10%	25V	1206	any	-
C3	Capacitor, alum, lo ESR	470 μ F	20%	25V, 800mA ¹	-	Nichicon	UHE1E471MPD6
C4	Capacitor, cer X7R	100 μ F	10%	16V	0805	any	-
C5	<i>not installed</i>	-	-	-	0805	-	-
Q1	IGBT	-	-	1.2kV, 5.0A	D-pak	ST	STGD5NB120SZ
IC1	Power supply controller	-	-	-	Power 8-Lead SOIC	Supertex	SR087SG-G

Note:

1. At 100/120Hz

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