

# 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.

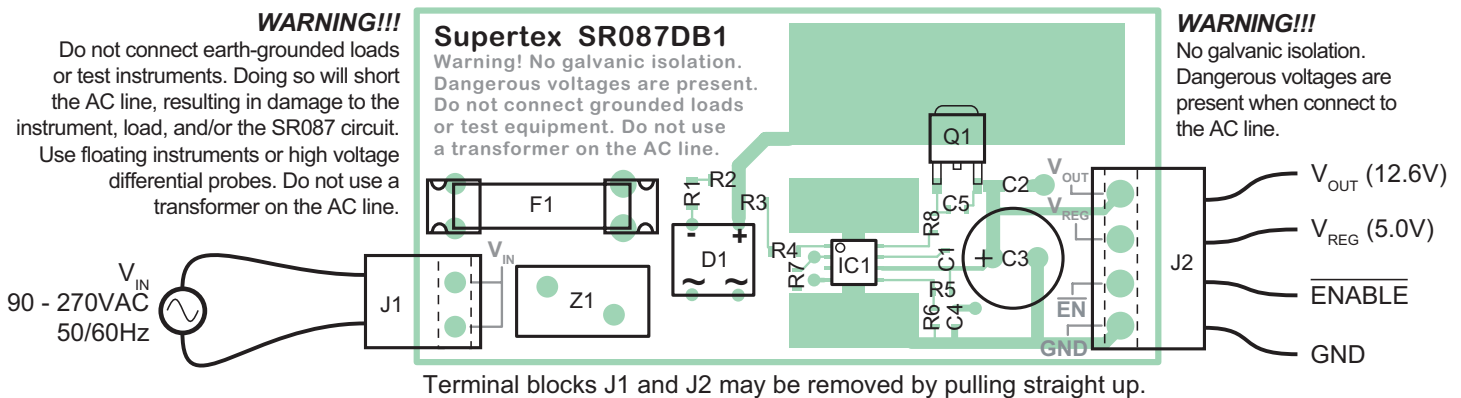
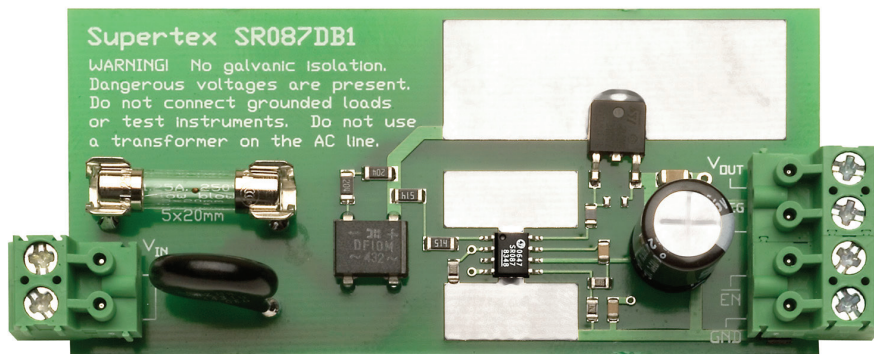
## Specifications

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

**Notes:**

- Adjustable from 9.0V to 50V.
- Referenced to  $V_{OUT}$

## Board Layout and Connection Diagram



## Connections:

**V<sub>IN</sub>** - 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<sub>OUT</sub>** - The main output. No-load output voltage is 12.6V. Because the V<sub>OUT</sub> 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<sub>OUT</sub> 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.

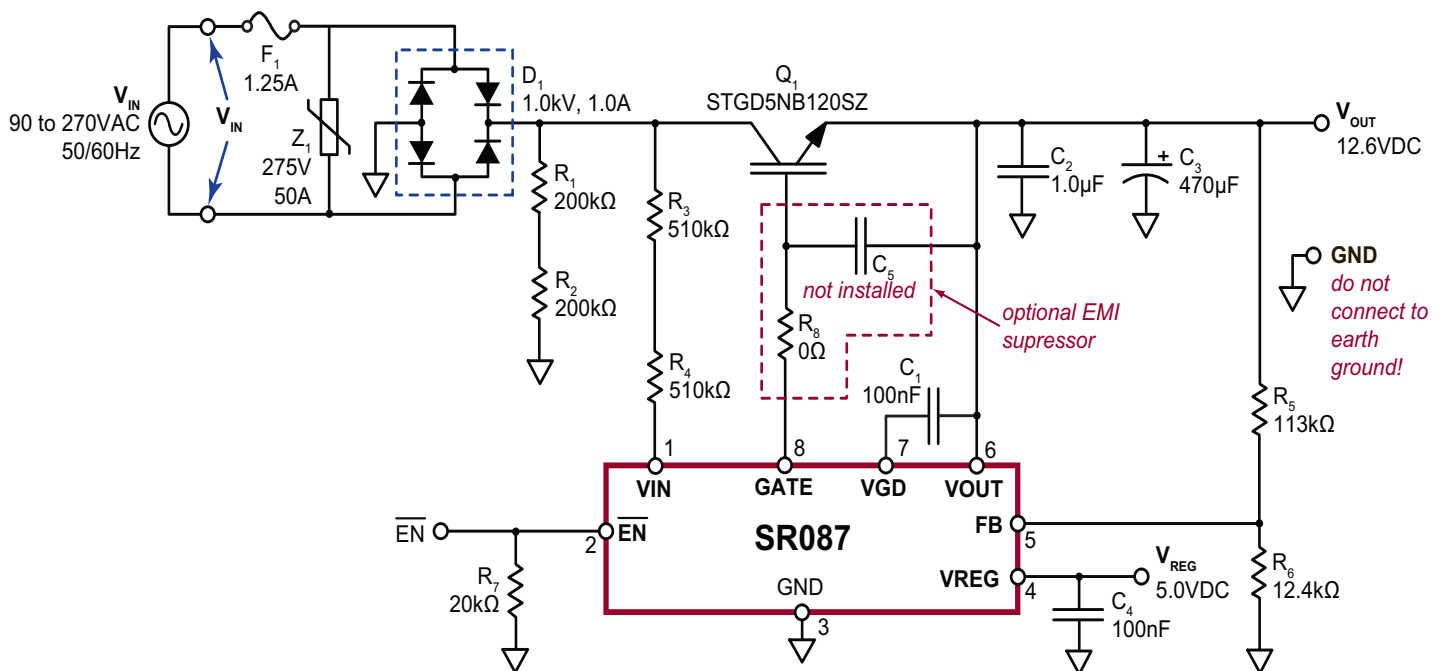
**Do not connect earth-grounded loads or instruments!**

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

**Enable** - A logic low (<0.2V) enables Q<sub>1</sub> switching. A logic high (>0.75 • V<sub>REG</sub>) disables Q<sub>1</sub>, shutting down V<sub>OUT</sub> and thus V<sub>REG</sub>. However, if an external voltage is applied to V<sub>OUT</sub> when disabled, V<sub>REG</sub> 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 50V<sup>1</sup> 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 $\Omega$  - it assures a minimum 100 $\mu$ 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<sub>P-P</sub> 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 $\Omega$ .

$R_2$  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 $\Omega$  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:

- $V_{REG}$  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 $\Omega$  | 5%  | 200V                    | 1206                 | any          | -                          |
| R3, R4 | Resistor                | 510k $\Omega$  | 5%  | 200V                    | 1206                 | any          | -                          |
| R5     | Resistor                | 113k $\Omega$  | 1%  | -                       | 0805                 | any          | -                          |
| R6     | Resistor                | 12.4k $\Omega$ | 1%  | -                       | 0805                 | any          | -                          |
| R7     | Resistor                | 20k $\Omega$   | 1%  | -                       | 0805                 | any          | -                          |
| R8     | <i>not installed</i>    | 0 $\Omega$     | -   | -                       | 0805                 | any          | -                          |
| C1     | Capacitor, cer X7R      | 100nF          | 10% | 25V                     | 0805                 | any          | -                          |
| C2     | Capacitor, cer X7R      | 1.0 $\mu$ F    | 10% | 25V                     | 1206                 | any          | -                          |
| C3     | Capacitor, alum, lo ESR | 470 $\mu$ F    | 20% | 25V, 800mA <sup>1</sup> | -                    | Nichicon     | UHE1E471MPD6               |
| C4     | Capacitor, cer X7R      | 100 $\mu$ 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<br>8-Lead SOIC | Supertex     | SR087SG-G                  |

## Note:

1. At 100/120Hz

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