Inductorless, Dual Output Off-Line Regulators

Features

- Accepts peak input voltages up to 700V
- Operates directly off of rectified 120V AC or 230V AC
- Integrated linear regulator
- Minimal power dissipation
- No high voltage capacitors required
- No transformers or inductors required
- Up to 1.5W output power

Applications

- 3.3V or 5.0V power supplies
- SMPS house keeping power supplies
- White goods
- Appliances
- Small off-line low voltage power supplies
- Lighting controls

General Description

The Supertex SR036 and SR037 are inductorless, dual output off-line controllers. They do not require any transformers, inductors, or high voltage input capacitors. The input voltage, HV$_{in}$, is designed to operate from an unfiltered full wave rectified 120V or 230V AC line. It is designed to control an external N-channel MOSFET or IGBT. When HV$_{in}$ is less than 45V, the external transistor is turned-on allowing it to charge an external capacitor connected to V$_{source}$. An unregulated DC voltage will develop on V$_{source}$. Once HV$_{in}$ is above 45V, the transistor is turned off. The maximum gate voltage for the external transistor is 24V. The unregulated voltage is approximately 18V. The SR036 also provides a regulated 3.3V whereas the SR037 provides a regulated 5.0V.

WARNING!!! Galvanic isolation is not provided. Dangerous voltages are present when connected to the AC line. It is the responsibility of the designer to assure adequate safeguards are in place to protect the end user from electrical shock.

SR03x Typical Application Circuit
### Ordering Information

<table>
<thead>
<tr>
<th>$V_{\text{OUT}}$</th>
<th>Package Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.3V</td>
<td>SR036MG*</td>
</tr>
<tr>
<td>5.0V</td>
<td>SR037MG*</td>
</tr>
<tr>
<td></td>
<td>SR036SG</td>
</tr>
<tr>
<td></td>
<td>SR037SG</td>
</tr>
</tbody>
</table>

*Product supplied on 2500 piece carrier tape reel.

### Absolute Maximum Ratings*

- **$V_{\text{IN}}$, High Voltage Input**: +700V
- **$V_{\text{OUT}}$, Low Voltage Output**: +6.0V
- **Storage Temperature**: -65°C to +150°C
- **Soldering Temperature**: +300°C
- **Power Dissipation, MSOP-8**: 300mW
- **Power Dissipation, SO-8 slug**: 1.50W

*All voltages are referenced to GND.

1 When underside plate soldered to 2cm² of exposed copper.

*Absolute Maximum Ratings are those values beyond which damage to the device may occur. Functional operation under these conditions is not implied. Continuous operation of the device at the absolute rating level may affect device reliability. All voltages are referenced to device ground.

### Pin Configuration

#### MSOP-8 (top view)

#### SO-8 Slug

Make no electrical connections to Backside Plate (top view)

### Electrical Characteristics

(Over operating supply voltages unless otherwise specified, $T_a = 0°C$ to +125°C)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>$HV_{\text{IN}}$</td>
<td>Input voltage</td>
<td>700</td>
<td>407</td>
<td>V</td>
<td>Peak transient voltage</td>
<td></td>
</tr>
<tr>
<td>$V_{\text{TH}}$</td>
<td>$HV_{\text{IN}}$ voltage when Gate is pulled to ground</td>
<td>40</td>
<td>45</td>
<td>50</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>$V_{\text{GS}}$</td>
<td>Gate to source clamp voltage</td>
<td>±10</td>
<td>±15</td>
<td>±20</td>
<td>V</td>
<td>$I_{\text{GS}} = \pm 100\mu$A</td>
</tr>
<tr>
<td>$V_{\text{GATE}}$</td>
<td>Gate to ground clamp voltage</td>
<td>18</td>
<td>20</td>
<td>24</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>$V_{\text{OUT}}$</td>
<td>Regulated output voltage for the SO-8 with heat slug</td>
<td>SR036</td>
<td>2.97</td>
<td>3.30</td>
<td>3.63</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SR037</td>
<td>4.5</td>
<td>5.00</td>
<td>5.50</td>
<td>V</td>
</tr>
<tr>
<td>$\Delta V_{\text{OUT}}$</td>
<td>$V_{\text{OUT}}$ load regulation</td>
<td>120</td>
<td>mV</td>
<td>$V_{\text{SOURCE}} = 10V$, $I_{\text{Load}} = 0$ to 50mA (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freq</td>
<td>Input AC frequency</td>
<td>40</td>
<td>100</td>
<td>Hz</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) Load current on the regulated output must not cause SR03 power dissipation to exceed max ratings. Worst case power dissipation is given by:

$$P = \frac{V_{\text{IN}}^2}{185k\Omega} + (16V - V_{\text{OUT}}) \times I_{\text{OUT}}$$

Where $I_{\text{OUT}}$ is the load on the regulated output.
Typical Performance Curves

Gate Clamp

Temperature (°C)

Vgate (V)

HV Input Current

Source Voltage (V)

Regulator Output (SR037)

VOUT (V)

Gate Voltage

HV IN (V)

Load Regulation (SR037)

VOUT (V)

Source=15V

Source=8V

25°C

-40°C

-125°C

HV IN (V)

IIN (µA)

0 5 10 15 20 25

0 5 10 15 20

-40 -10 20 50 80 110 140

-40 -10 20 50 80 110 140

-40 -10 20 50 80 110 140

-40 -10 20 50 80 110 140

0 1 2 3 4 5 6

0 1 2 3 4 5 6

0 1 2 3 4 5 6

0 1 2 3 4 5 6

0 10 20 30 40 50 60

0 10 20 30 40 50 60

0 10 20 30 40 50 60

0 10 20 30 40 50 60

Source=15V 25°C

Source=8V 25°C

0 50 100 150 200 250 300 350 400

0 50 100 150 200 250 300 350 400

0 50 100 150 200 250 300 350 400

0 50 100 150 200 250 300 350 400

2100 1800 1500 1200 900 600 300 0

2100 1800 1500 1200 900 600 300 0

2100 1800 1500 1200 900 600 300 0

2100 1800 1500 1200 900 600 300 0

4.65 4.70 4.75 4.80 4.85 4.90 4.95 5.00

4.65 4.70 4.75 4.80 4.85 4.90 4.95 5.00

4.65 4.70 4.75 4.80 4.85 4.90 4.95 5.00

4.65 4.70 4.75 4.80 4.85 4.90 4.95 5.00

0 5 10 15 20 25

0 5 10 15 20 25

0 5 10 15 20 25

0 5 10 15 20 25

125°C 25°C -40°C

125°C 25°C -40°C

125°C 25°C -40°C

125°C 25°C -40°C
Applications Information

Operating Principle

The SR03x operates by controlling the conduction angle of the external MOSFET or IGBT as shown in Figure 1. When the rectified AC voltage is below the $V_{th}$ threshold, the pass transistor is turned on. The pass transistor is turned off when the rectified AC is above $HV_{in}$, Output voltage (Vunreg) decays during the periods when the switch is off and when the rectified AC is below the output voltage. The amount of decay is determined by the load and the value of C1. Since the switch only conducts with low voltages across it, power dissipation is minimized.

Figure 1: Typical Waveforms

Power Dissipation

Power dissipation in the SR03 is from 2 sources. The first is due to the bias current (or overhead) required to operate the device. This may be calculated from $P_{bias} = \frac{V_{in}^2}{185k\Omega}$ where $V_{in}$ is the input voltage in $V_{RMS}$. The second source of power dissipation is the 3.3/5V linear regulator and may be calculated from $P_{reg} = (16V - V_{out}) \times I_{reg}$, where $V_{out}$ is 3.3V or 5V, and $I_{reg}$ is the load current on the 3.3/5V output. The total power dissipated by the SR03x is the sum of these two: $P_{bias} + P_{reg}$. (These equations are conservative – actual dissipation may be less.)

To adequately dissipate the power, the underside plate of the SR03xSG should be soldered to at least 2cm$^2$ of exposed copper area on the PCB.

Power is also dissipated by the pass transistor. Power dissipated by the transistor will be $(16V \times I_{total}) \times (1/\text{Eff} - 1)$ where $I_{total}$ is the sum of the load currents on the regulated and unregulated outputs and Eff is the converter efficiency (see Efficiency Graph next page). The transistor should be soldered to at least 5cm$^2$ of exposed copper area on the PCB for heatsinking.
Using a MOSFET in place of an IGBT

SRO3 Efficiency

Efficiency and EMI Test Circuit
SR03 Circuit using VN2460 (with EMI Suppression Circuit)

120VAC/60Hz  Limits per 47CFR15.107 for Class B devices.  45mA total load.

208VAC/60Hz  (230VAC/50Hz not available) Limits per CISPR 14-1 for household appliances.  23mA total load.
SR03 Circuit using GN2470 (no EMI Suppressor)

120VAC/60Hz  Limits per 47CFR15.107 for Class B devices. 50mA total load.

208VAC/60Hz  (230VAC/50Hz not available). Limits per CISPR 14-1 for household appliances. 25mA total load.
SR03 Circuit using GN2470 (no EMI Suppressor)

120VAC/60Hz  Limits per 47CFR15.107 for Class B devices. 100mA total load.
Applications Information, continued

**Figure 2: Example Circuit with Enable Control**

Figure 2 is an example circuit using the SR036 or SR037 along with a Supertex GN2470 IGBT to generate an unregulated voltage of approximately 18V and a regulated voltage of 3.3V for the SR036 or 5.0V for the SR037. The combined total output current is typically 50mA. The TN2106K1 in series with a 1KΩ resistor can be added for applications requiring an enable control.

**Figure 3: Generating Two Regulated Voltages**

For applications requiring two regulated voltages, an inexpensive discrete linear regulator can be added to regulate the unregulated output as show in Figure 3. The discrete linear regulator consists of a Zener diode, a resistor and a bipolar transistor. The regulated voltage, Vout1, is determined by the Zener diode voltage minus the base-to-emitter voltage drop of 0.6V. Figure 3 uses a 5.6V Zener diode to obtain a 5.0V output. Different Zener diode voltages can be used to obtain different regulated output voltages.
Applications Information, *continued*

The circuit shown in Figure 4 uses the SR036 to supply a regulated 3.3V for the logic control circuitry while the unregulated voltage is used to drive a 12V relay coil. The operating voltage for a 12V relay coil is typically very wide and can therefore operate directly from the unregulated line.

The circuit shown in Figure 5 uses the SR037 to supply a regulated 5.0V for the logic control circuitry while the unregulated voltage is used to drive a 5.0V coil relay. To overcome the voltage variation of the unregulated line, a bipolar transistor is used to drive the coil with a constant current. The resistor value from the emitter to ground sets the desired coil current. For an arbitrary coil current of 40mA, the resistor value can be calculated as:

\[
R = \frac{5.0V - \frac{40mA}{\beta}1K\Omega - V_{be}}{\frac{40mA}{\beta}}, \text{ where } V_{be} = 0.6V \text{ and } \beta = 100
\]

\[
= 100\Omega
\]
Applications Information, continued

Figure 6: Driving 5V Relay Coils with Zener Diode Clamp

The circuit shown in Figure 6 uses the SR037 to supply a regulated 5.0V for the logic control circuitry. A 5.1V Zener diode is used in parallel with the 5.0V relay coil to ensure that the relay coil’s maximum operating voltage is not exceeded. The Zener diode also acts as the catch diode when the coil is switched to the off state. An external series resistor is used to limit the amount of Zener current.

Figure 7: Driving LEDs from 120VAC

The circuit shown in Figure 7 uses the SR036 or SR037 to drive 12 high efficiency red LEDs from an AC line. The average LED current is approximately 20mA.
Applications Information, continued

**Figure 8:**
Precision current drive for LED String from AC Line

**Features:**
1. Precision Current Regulator
2. Zener Voltage Boost
3. PWM Dimming (optional)
4. EMI Filter (optional)

The circuit uses the SR037 or SR036 and GN2470 to drive a string of LEDs from AC power line. The LED current is regulated at up to 40mA. The LED string voltage can be up to AC line voltage (120V for 120Vac / 230V for 230VAC).

**Figure 9:**
Simple current drive for LED String from AC Line

**Features:**
1. Simple Current Regulator
2. Automatic Voltage Boost
3. Zener Boost Voltage Limit (optional)
4. EMI Filter (optional)

The circuit uses the SR037 or SR036 and GN2470 to drive a string of LEDs from AC power line. The LED current is regulated at up to 40mA. The LED string voltage can be up to AC line voltage (120V for 120Vac / 230V for 230VAC).
8-Lead MSOP Package Outline (MG)

Note: Circle (e.g. B) indicates JEDEC Reference.

Measurement Legend = Dimensions in Inches
(Dimensions in Millimeters)
8-LEAD SMALL OUTLINE PACKAGE WITH HEAT SLUG (SG)

Measurement Legend = Dimensions in Inches
(Dimensions in Millimeters)

Dimensions do not include end flash, mold flash material protrusion.