

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 **1.0W** output power

Applications

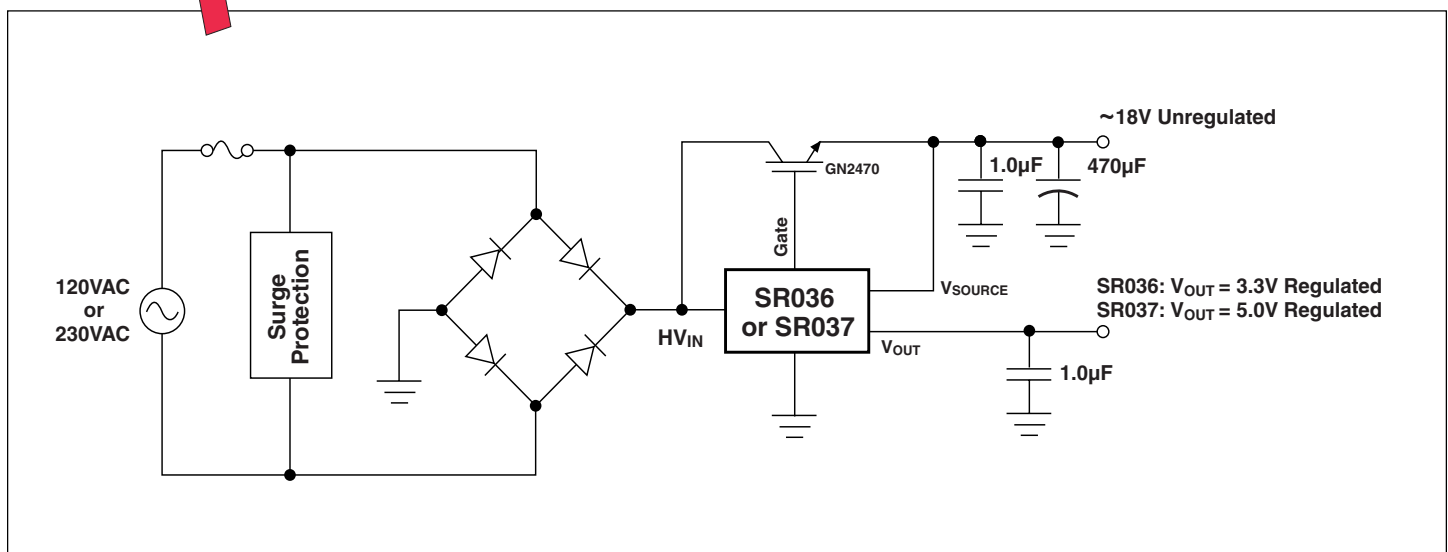
- ❑ 3.3V or 5.0V power supplies
- ❑ SMPS house keeping power supplies
- ❑ White goods
- ❑ Appliances
- ❑ Stand off low voltage power supplies
- ❑ Lighting controls

General Description

The Supertex SR036 and SR037 are inductorless, dual output off-line controllers, providing up to **1.0W** of output power. 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 4V, the external transistor is turned-on allowing it to charge an external capacitor connected to V_{SOURCE} . An unregulated DC output will develop on V_{SOURCE} . Once V_{SOURCE} reaches 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 ensure adequate safety precautions are in place to protect the end user from electrical shock.

SR03x Typical Application Circuit



Ordering Information

V _{OUT}	Package Options	
	MSOP-8	SO-8 w/ Heat Slug
3.3V	SR036MG*	SR036SG
5.0V	SR037MG*	SR037SG

* Product supplied on 2500 piece carrier tape reel.

Absolute Maximum Ratings*

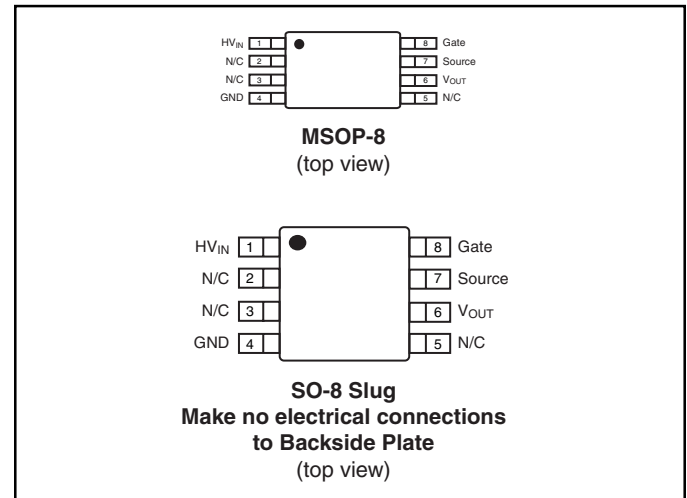
V _{IN} , High Voltage Input	+700V
V _{OUT} , Low Voltage Output	+6.0V
Storage Temperature	-65°C to +150°C
Soldering Temperature	+300°C
Power Dissipation, MSOP-8	300mW
Power Dissipation, SO-8 slug	1.50W ¹

* 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



Electrical Characteristics

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

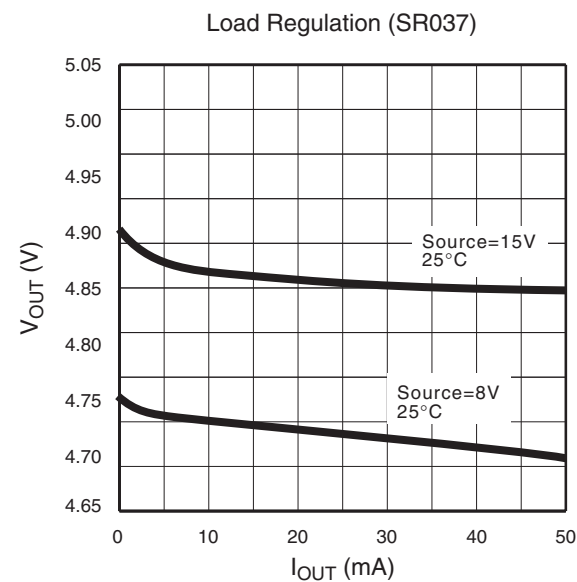
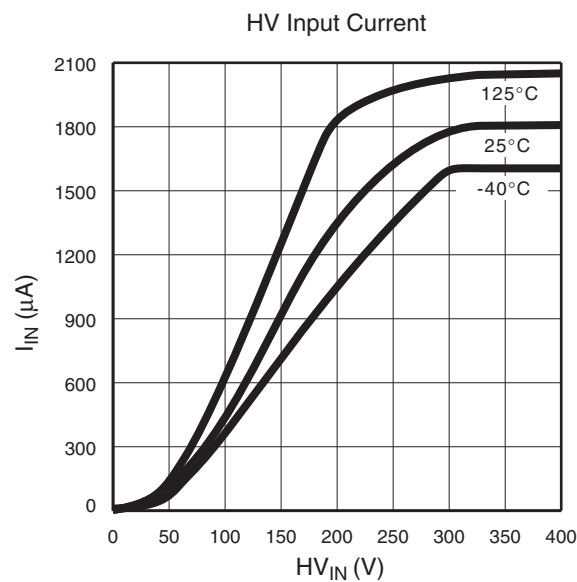
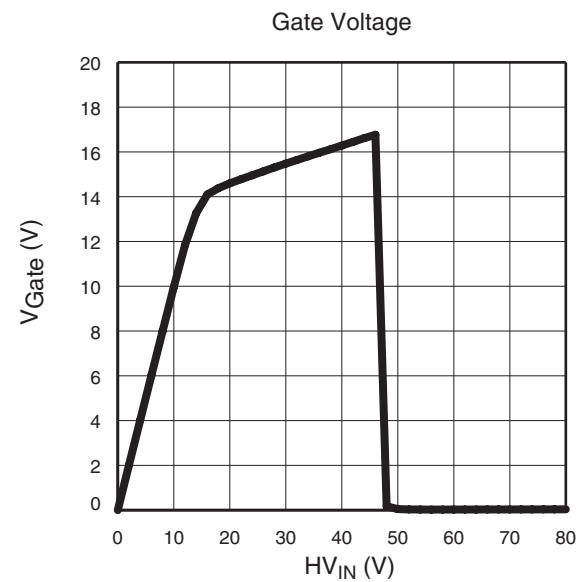
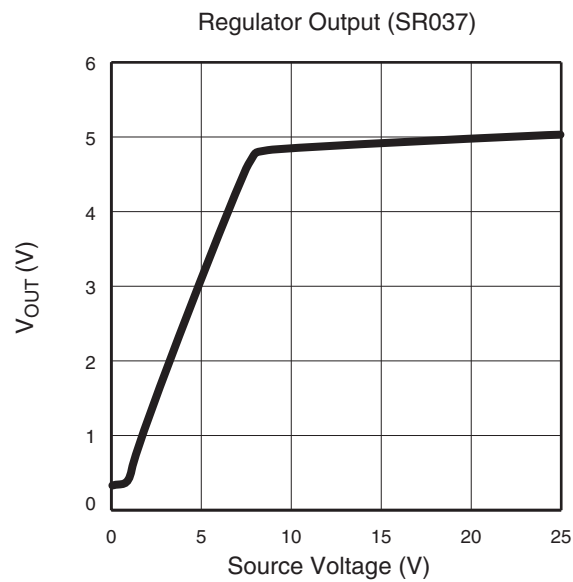
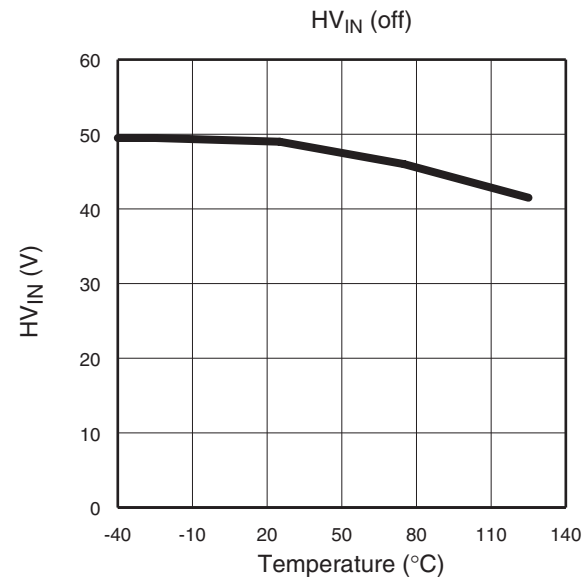
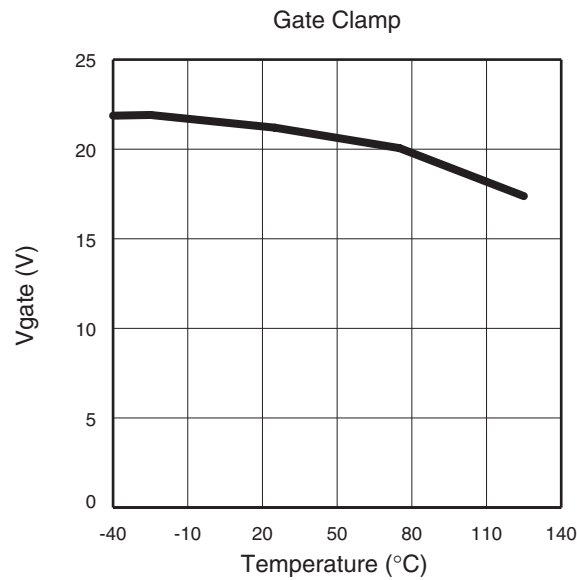
Symbol	Parameter	Min	Typ	Max	Units	Conditions
HV _{IN}	Input voltage			700	V	Peak transient voltage
				407		Peak rectified AC voltage
V _{TH}	HV _{IN} voltage when Gate is pulled to ground	40	45	50	V	
V _{GS}	Gate to source clamp voltage	±10	±15	±20	V	I _{GS} = ±100μA
V _{GATE}	Gate to ground clamp voltage	18	20	24	V	
V _{OUT}	Regulated output voltage for the SO-8 with heat slug	SR036	2.97	3.30	V	V _{SOURCE} = 10V
		SR037	4.5	5.00		V _{SOURCE} = 10V
ΔV _{OUT}	V _{OUT} load regulation		20	120	mV	V _{SOURCE} = 10V, I _{Load} = 0 to 50mA (1)
Freq	Input AC frequency	40		100	Hz	

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

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

Where I_{OUT} is the load on the regulated output

Typical Performance Curves



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 $HV_{IN(off)}$. Output voltage (V_{unreg}) 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.

Functional Block Diagram

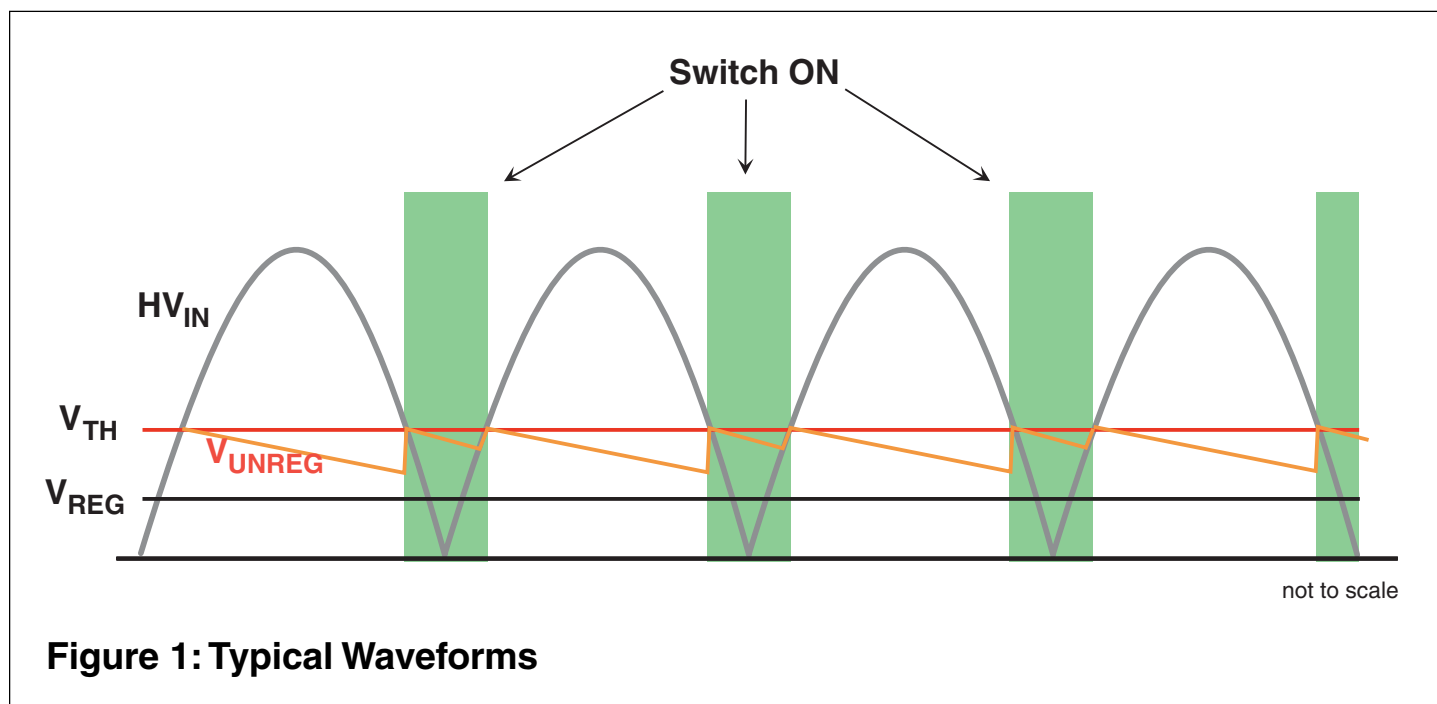
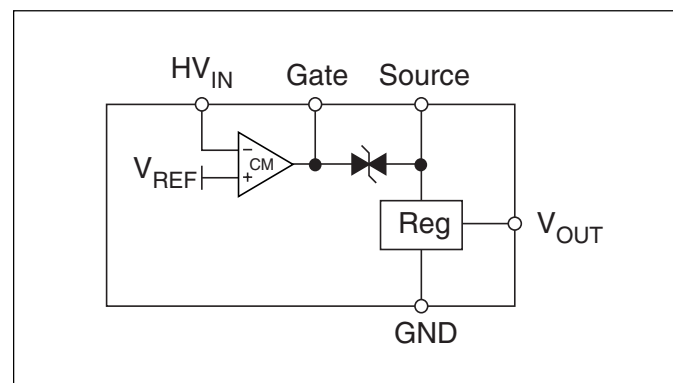


Figure 1: Typical Waveforms

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 $P_{BIAS} = V_{IN}^2 / 185k\Omega$ 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 $P_{REG} = (16V - V_{OUT}) * I_{REG}$, 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 2cm² of exposed copper area on the PCB.

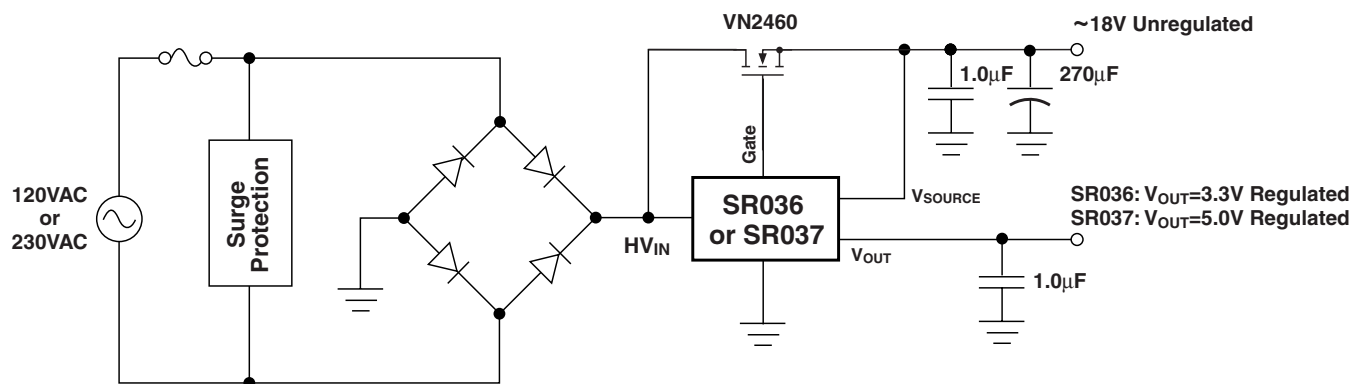
Power is also dissipated by the pass transistor. Power dissipated by the transistor will be $(16V * I_{TOTAL}) * (1/Eff - 1)$ where I_{TOTAL} is the sum of the load currents on the regulated and unregulated outputs and Eff is the converter efficiency (see Efficiency Graph next page). The transistor should be soldered to at least 5cm² of exposed copper area on the PCB for heatsinking.

Transformers

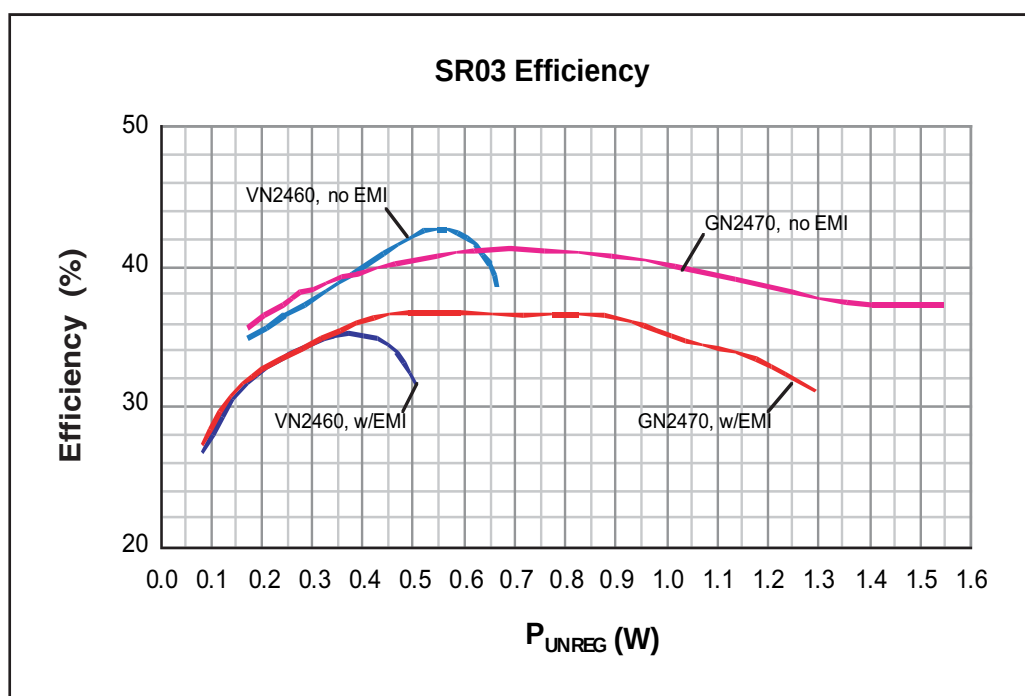


Do not use a transformer – either fixed or variable – on the AC line. The inductance of the transformer interferes with the normal operation of the SR03x.

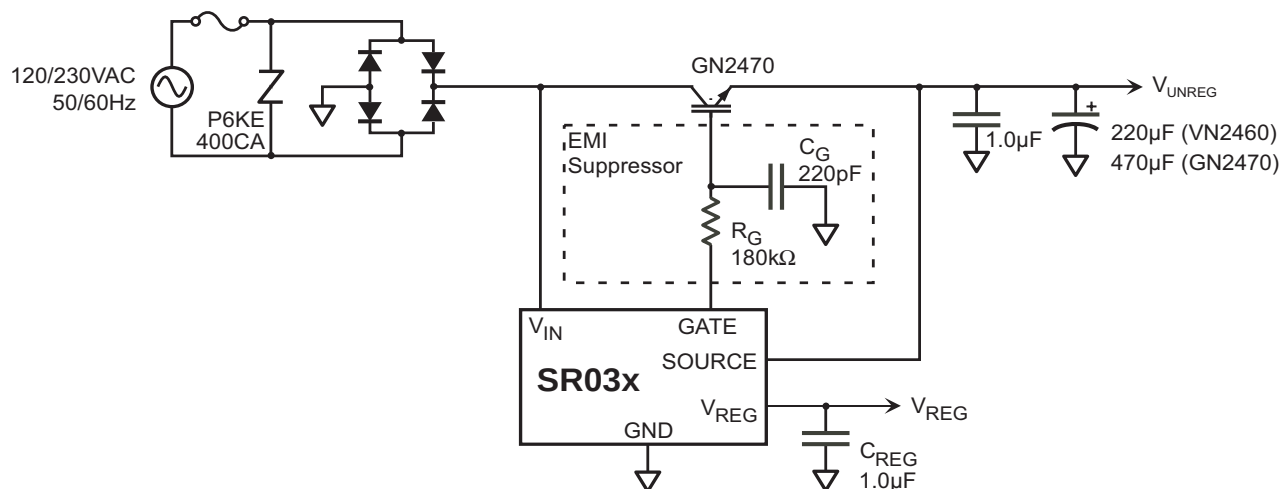
Using a MOSFET in place of an IGBT



SRO3 Efficiency

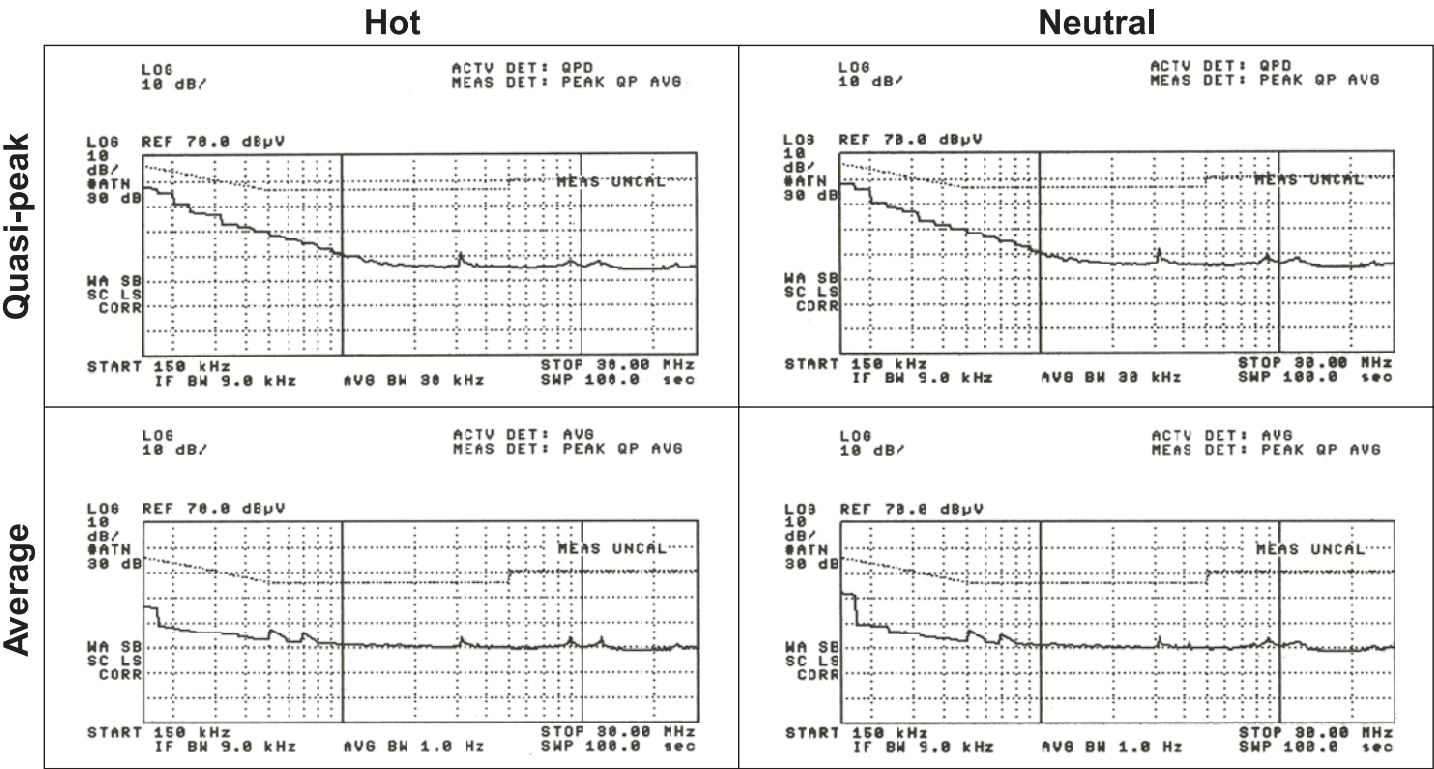


Efficiency and EMI Test Circuit

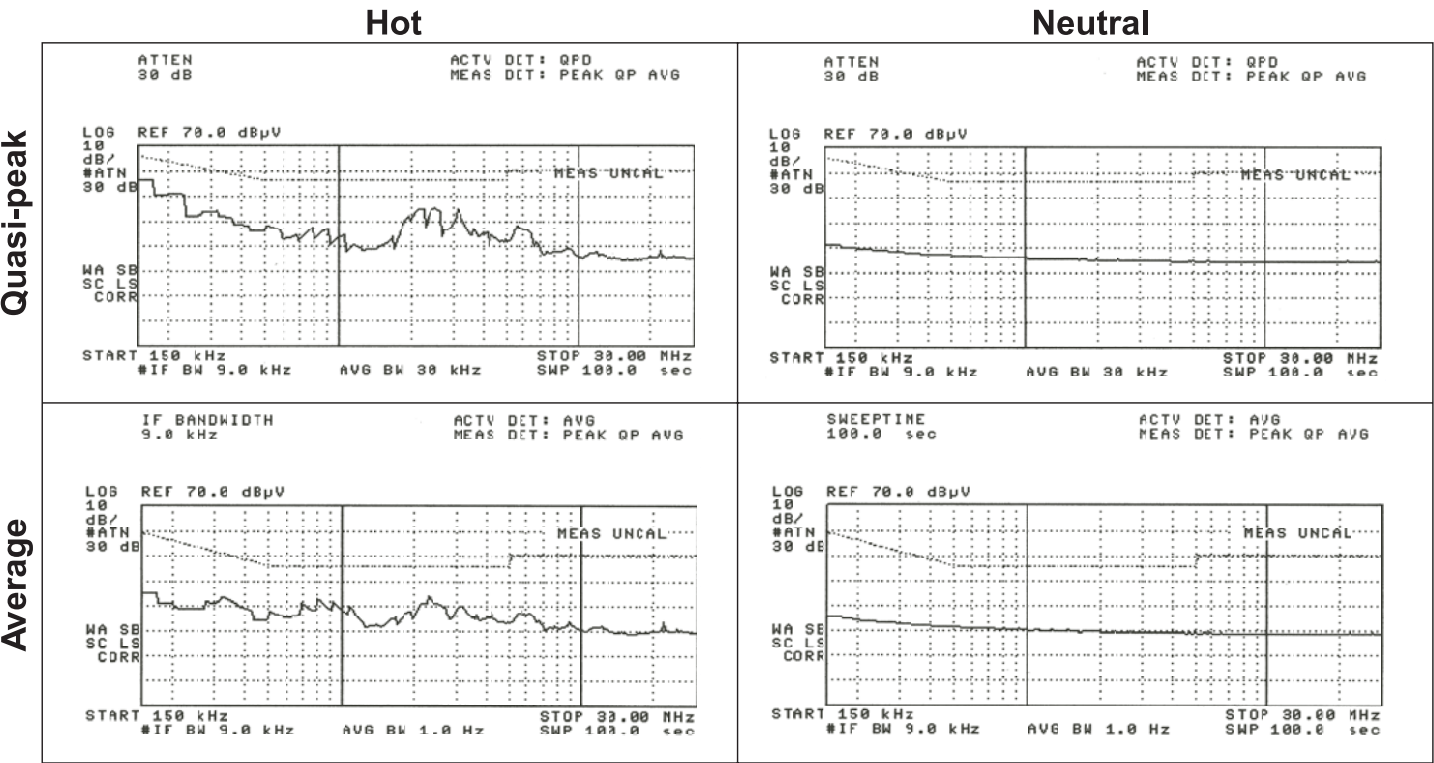


SR03 Circuit using VN2460
(with EMI Suppression Circuit)

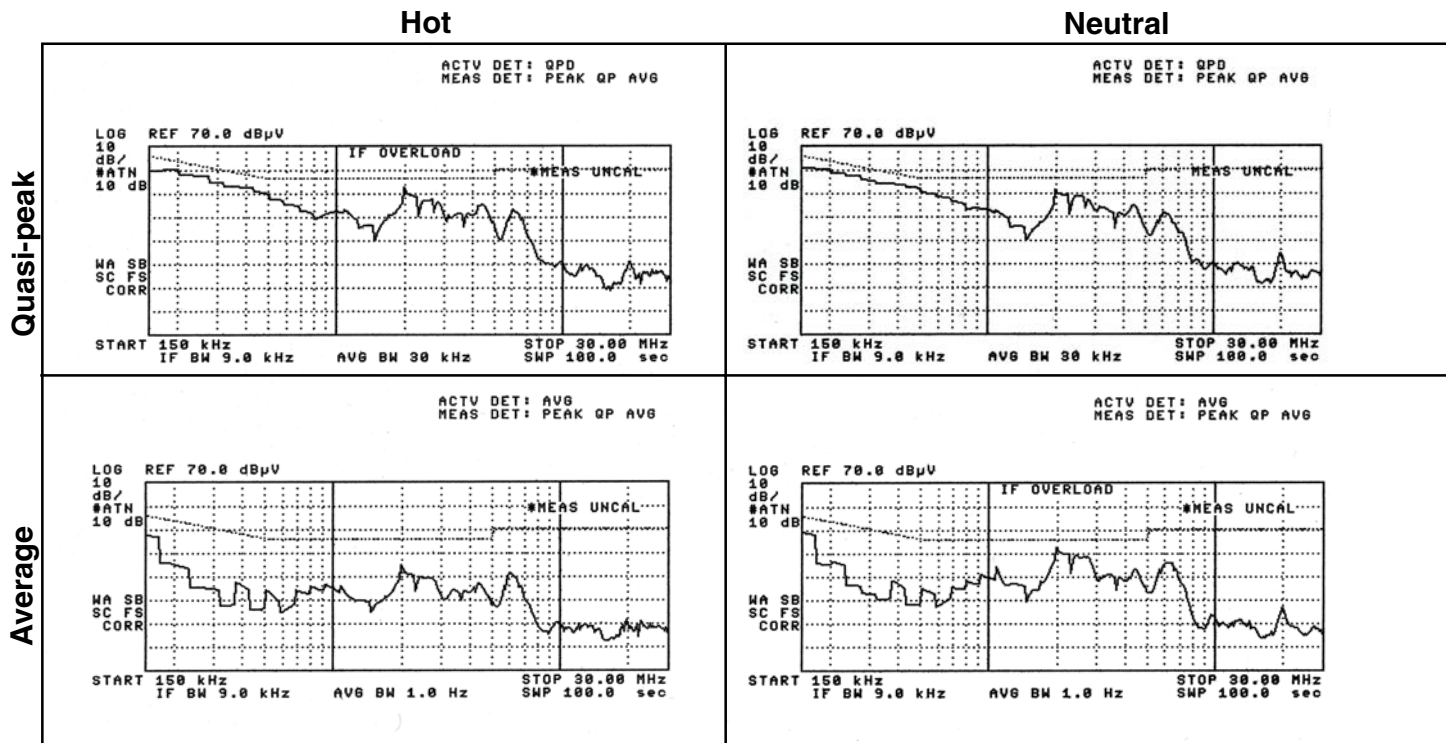
120VAC/60Hz Limits per 47CFR15.107 for Class B devices. 45mA total load.



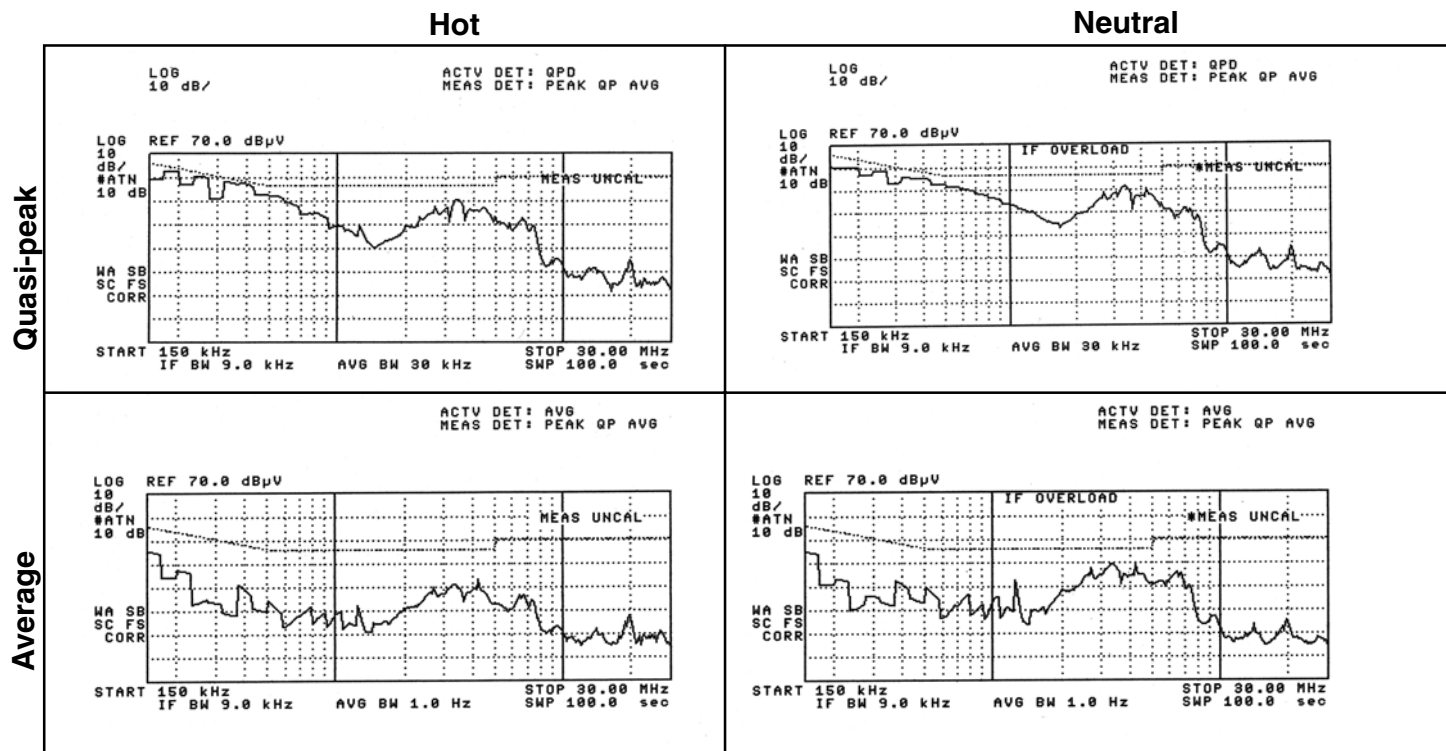
208VAC/60Hz (230VAC/50Hz not available) Limits per CISPR 14-1 for household appliances. 23mA total load.



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

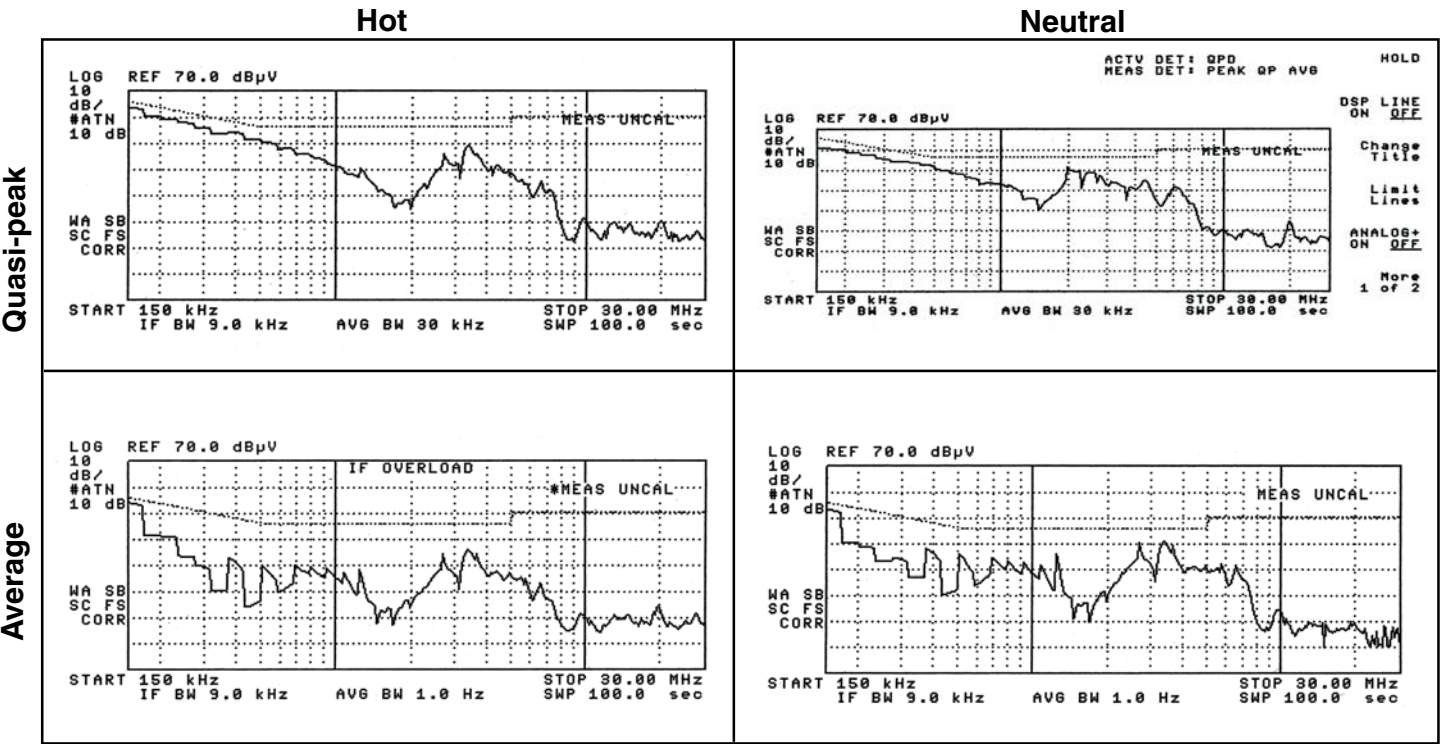


208VAC/60Hz (230VAC/50Hz not available). Limits per CISPR 14-1 for household appliances. 25mA total load.



SR03 Circuit using GN2470 (no EMI Suppressor)

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



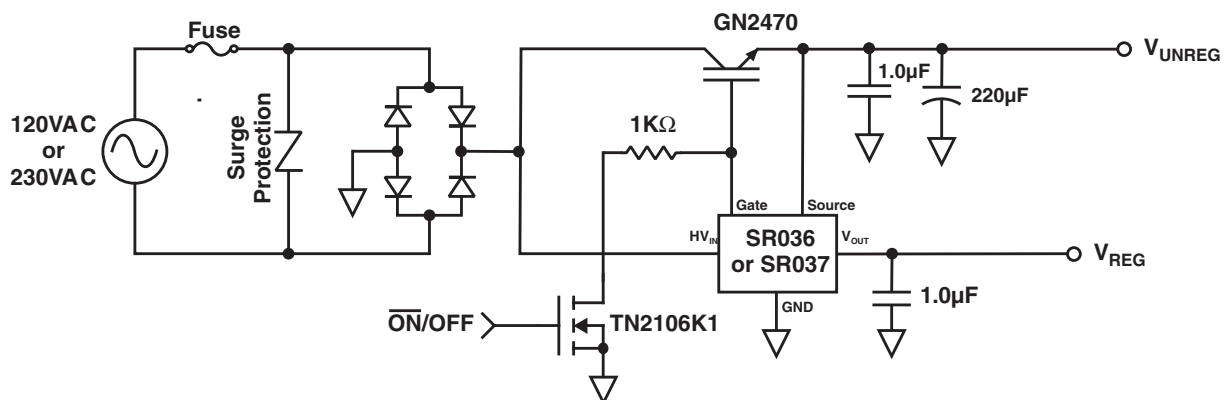
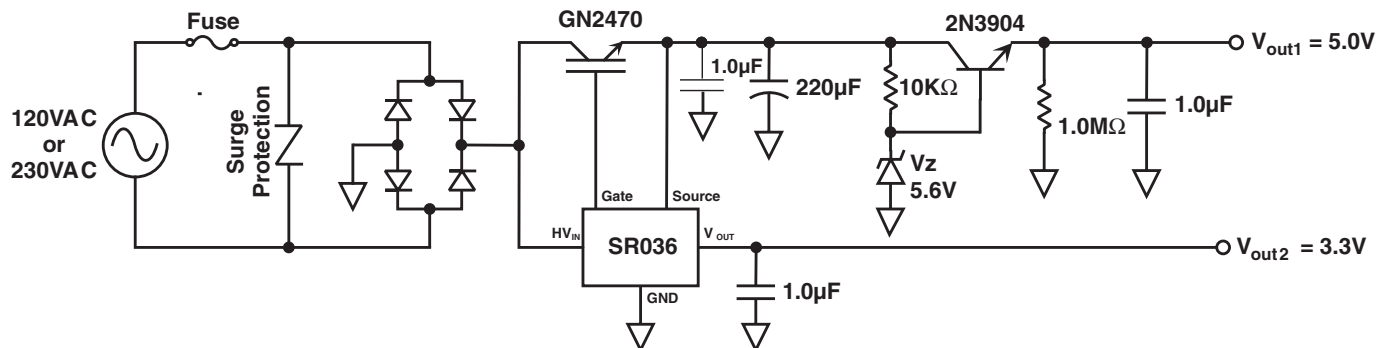
Applications Information, *continued***Figure 2: Example Circuit with Enable Control**

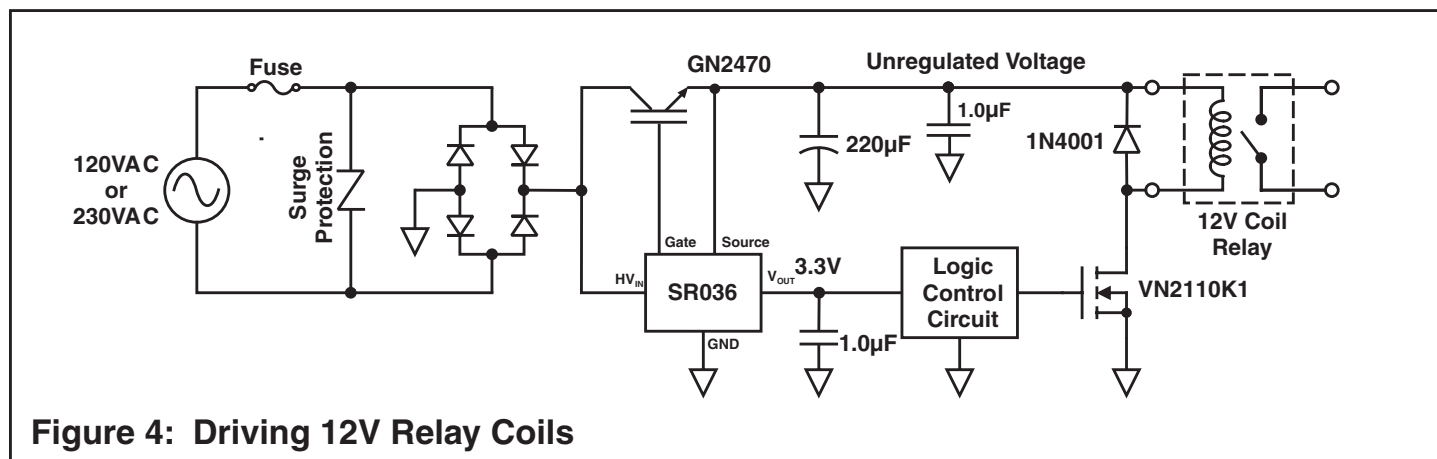
Figure 2 is an example circuit using the SR036 or SR037 along with a Supertex GN2470 IGBT to generate an unregulated voltage of approximately 18V and a regulated voltage of 3.3V for the SR036 or 5.0V for the SR037. The combined total output

current is typically 50mA. The TN2106K1 in series with a 1K Ω resistor can be added for applications requiring an enable control.

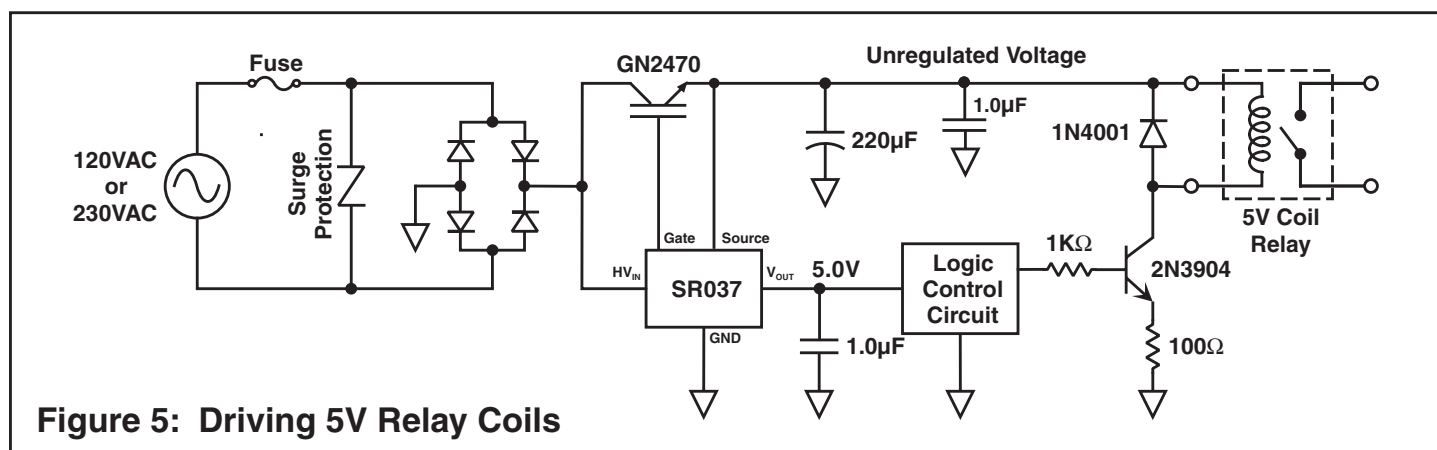
**Figure 3: Generating Two Regulated Voltages**

For applications requiring two regulated voltages, an inexpensive discrete linear regulator can be added to regulate the unregulated output as shown in Figure 3. The discrete linear regulator consists of a Zener diode, a resistor and a bipolar transistor. The regulated voltage, V_{out1} , 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.

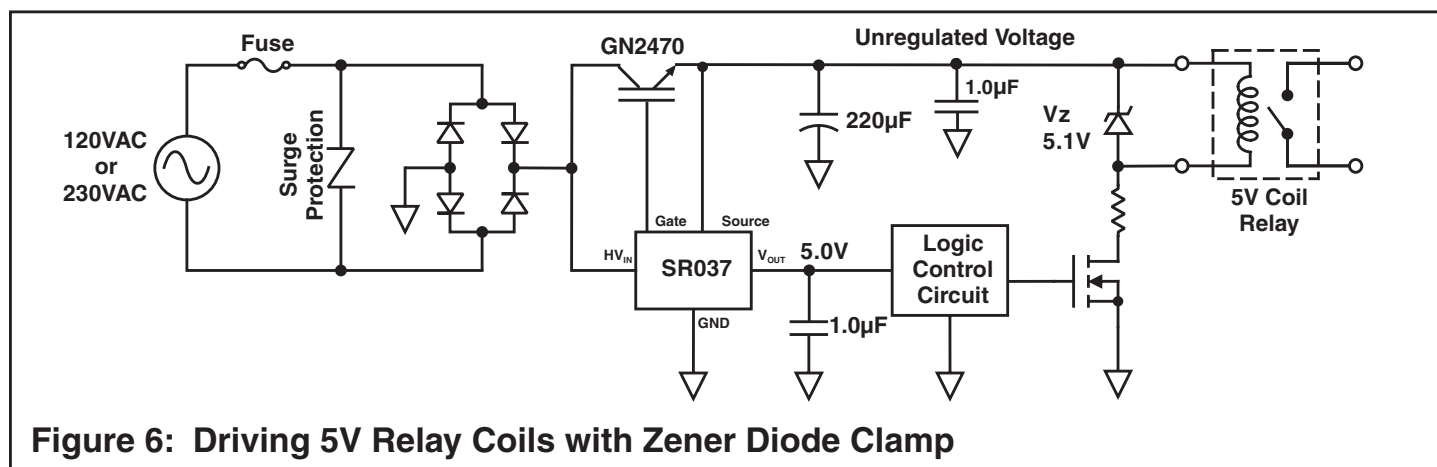
Applications Information, *continued*

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.



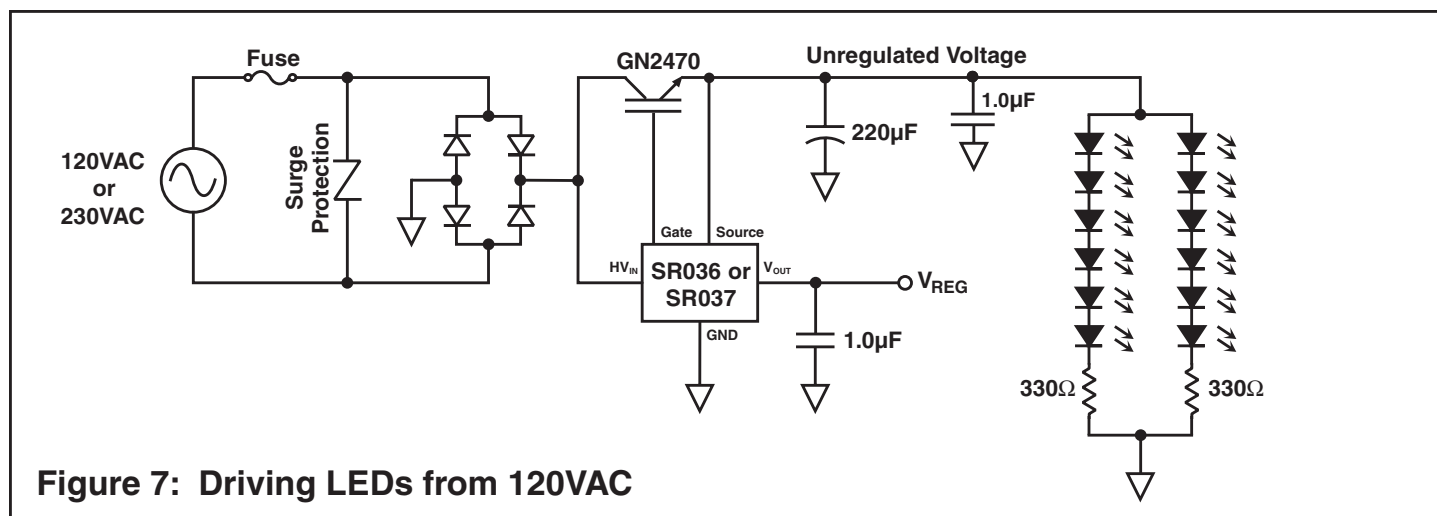
The circuit shown in Figure 5 uses the SR037 to supply a regulated 5.0V for the logic control circuitry while the unregulated voltage is used to drive a 5.0V coil relay. To overcome the voltage variation of the unregulated line, a bipolar transistor is used to

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:

Applications Information, *continued*

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.



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.

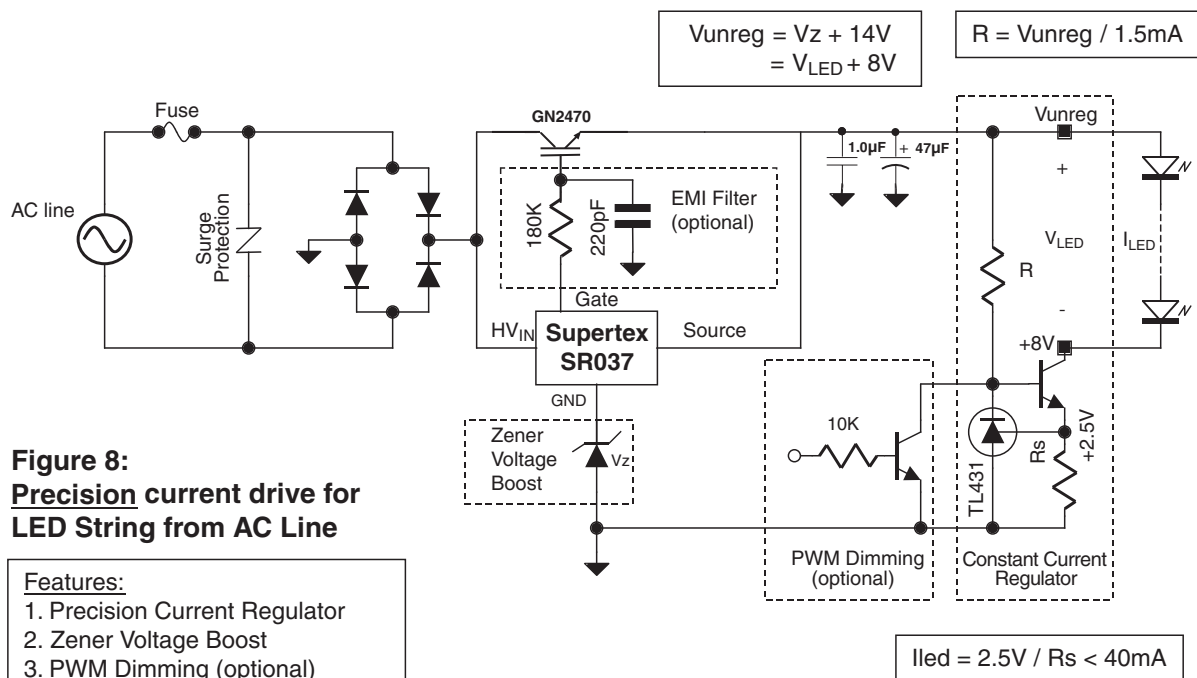


Figure 8:
Precision current drive for
LED String from AC Line

Features:

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

The circuit uses the SR037or 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).

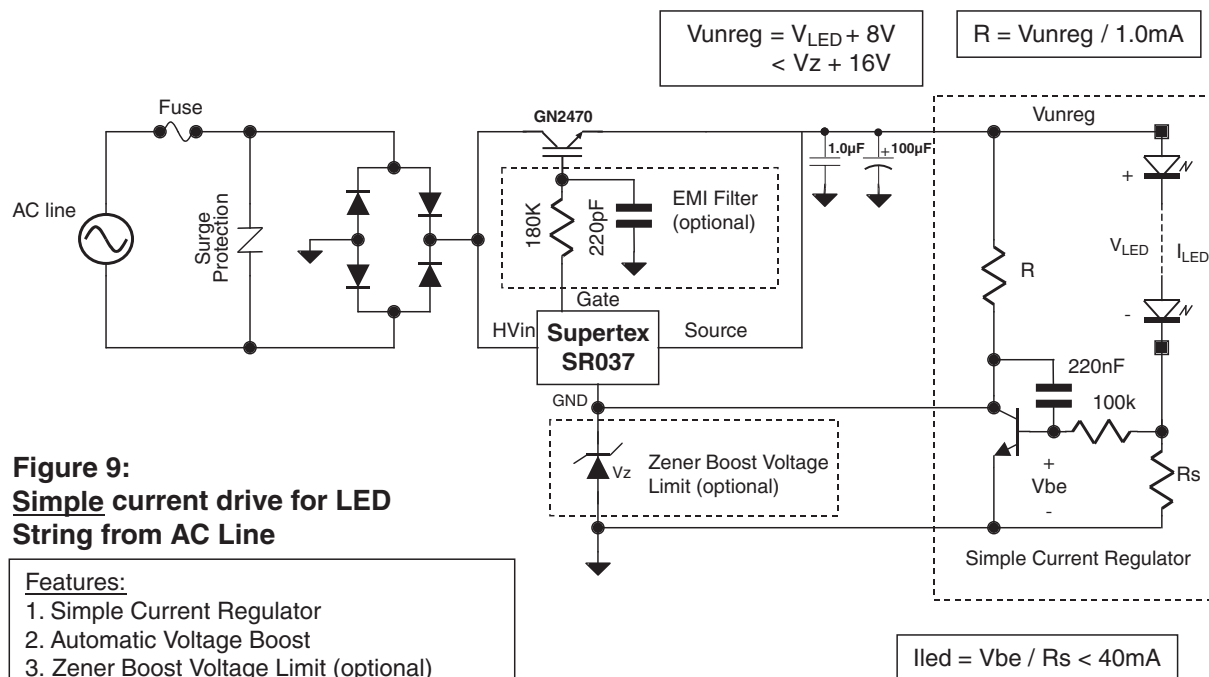


Figure 9: Simple current drive for LED String from AC Line

Features:

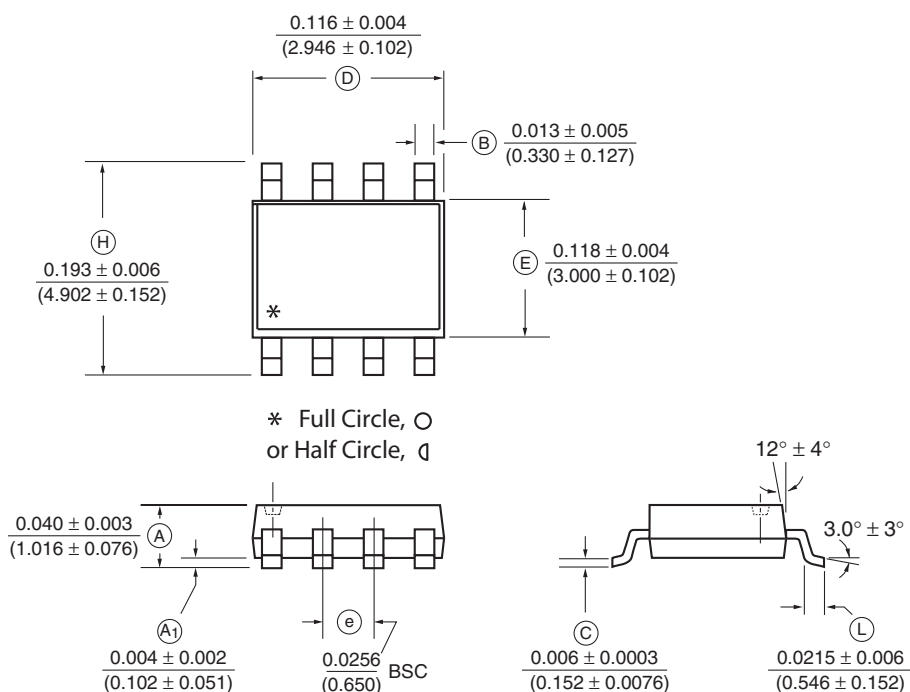
1. Simple Current Regulator
2. Automatic Voltage Boost
3. Zener Boost Voltage Limit (optional)
4. EMI Filter (optional)

The circuit uses the SR037 or SR036 and GN2470 to drive a string of LEDs from AC power line.

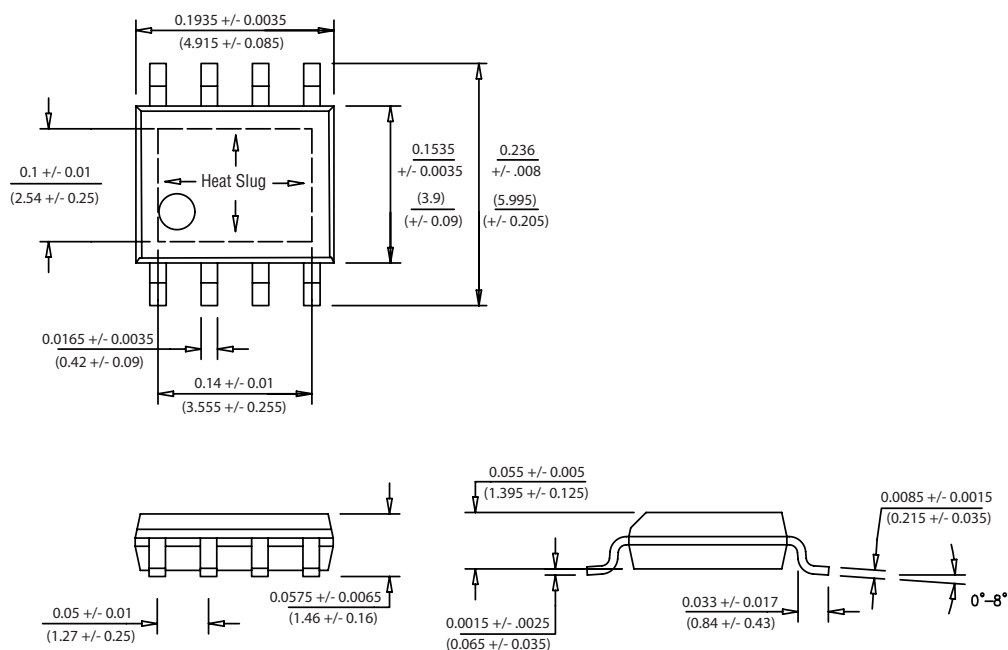
The LED current is regulated at up to 40mA.

The LED string voltage can be up to AC line voltage (120V for 120Vac / 230V for 230VAC).

8-Lead MSOP Package Outline (MG)



8-Lead MSOP (with heat slug) Package Outline (SG)



Measurement Legend = $\frac{\text{Dimensions in Inches}}{\text{(Dimensions in Millimeters)}}$

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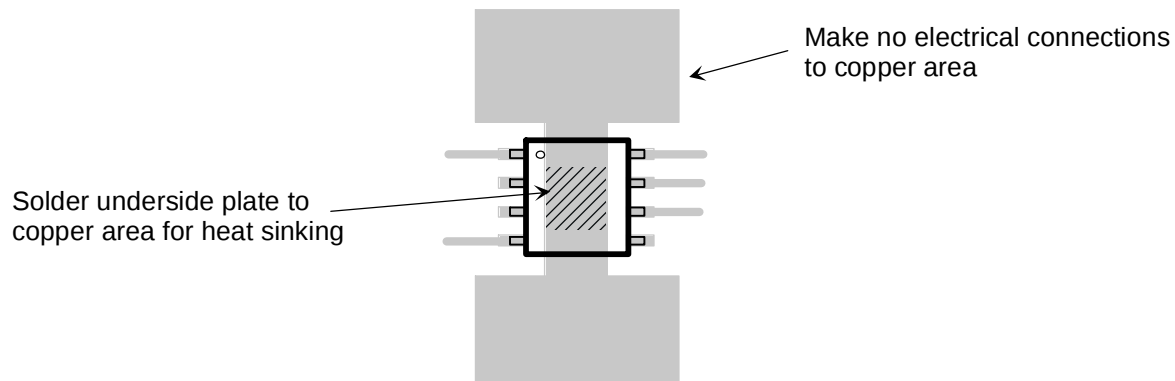
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Technical Bulletin: SR03x Plate Connections

This bulletin applies to the SR036 and SR037 in the SG (Power SO-8) package.

Increased efficiency and lower no-load power consumption of SR03x based regulator circuits can be achieved by assuring no electrical connections are made to the underside plate on the SR03x package. A copper area should still be employed to provide needed heat sinking, however, this copper area should be electrically floating. For maximum heat sinking capability, do not cover the copper area with solder mask.

Existing PCB layouts with the plate grounded should be corrected.

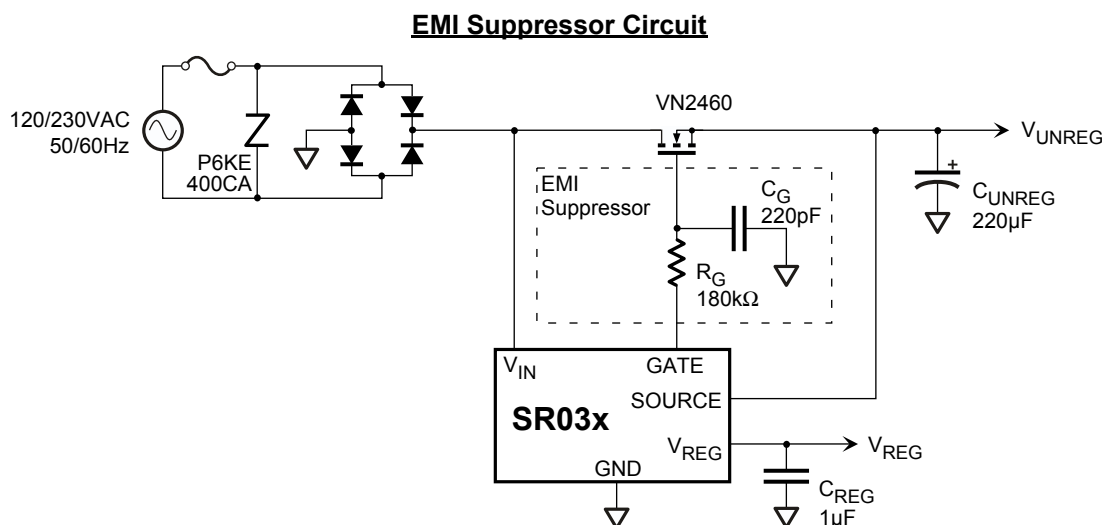


Early SR03x demo boards erroneously had the underside plate connected to ground. These boards will exhibit decreased efficiency and higher no load power. New, corrected demo boards may be ordered from Supertex's web site.

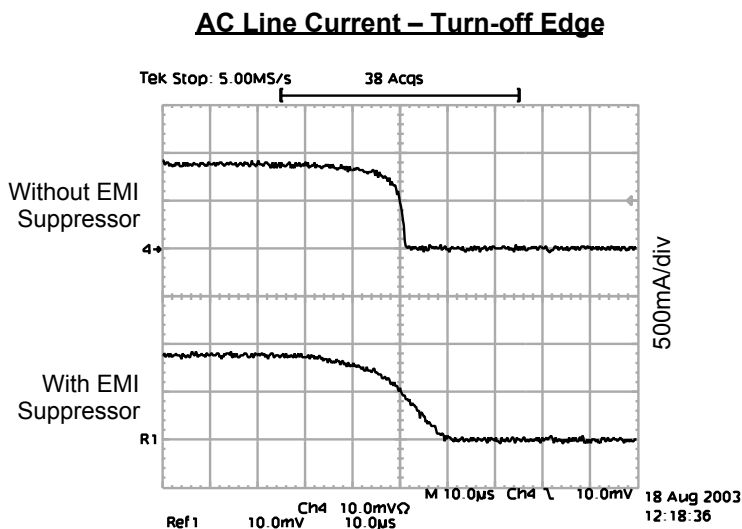
Technical Bulletin: SR03x EMI Reduction

SR03-based power supplies may create conducted EMI into the AC power line that exceeds FCC and CISPR requirements. This bulletin describes one technique to reduce EMI, allowing SR03-based supplies to comply with applicable requirements.

Conducted EMI is largely due to the short, high-current pulse imposed on the AC line when the pass MOSFET turns on. Smoothing out this current pulse reduces the harmonic content of the current drawn from the AC line, thus reducing conducted EMI. Placing a simple RC filter before the MOSFET gate smooths out the pulse.

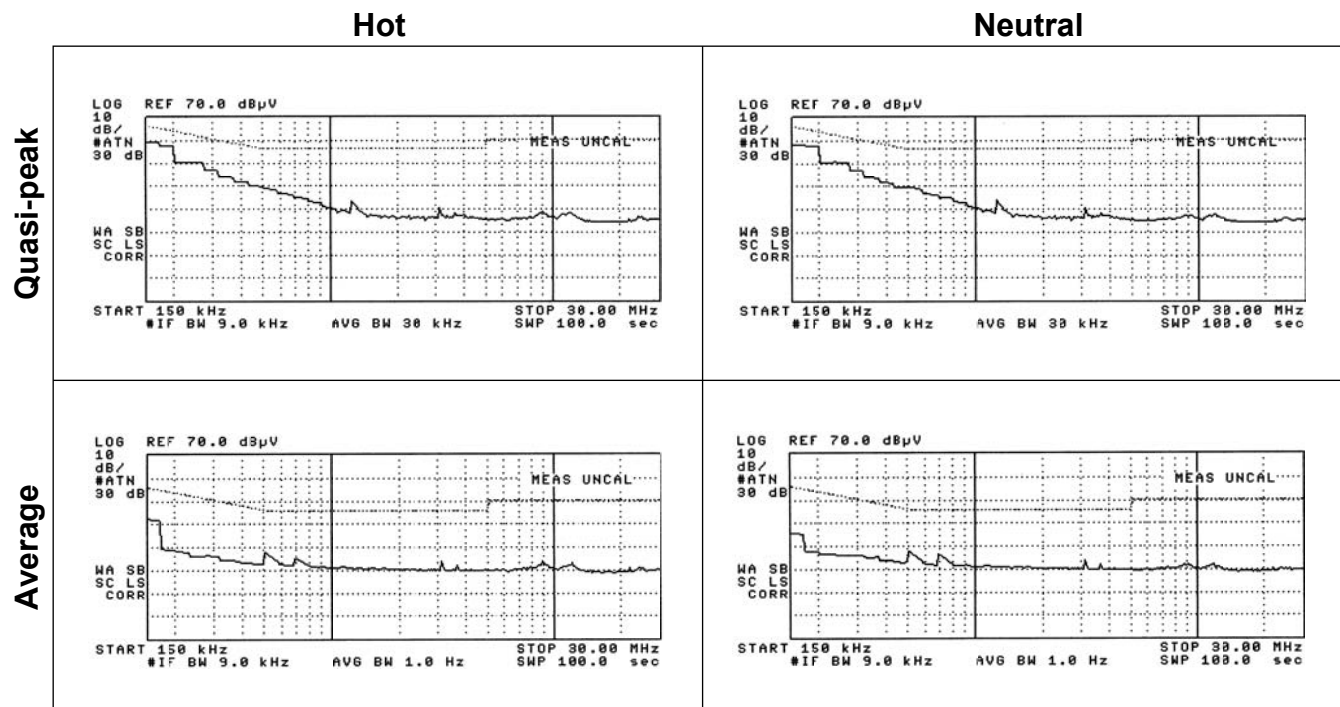


The values for R_G and C_G may need adjustment depending on the characteristics of the chosen MOSFET and the value of C_{UNREG} . (Higher values of C_{UNREG} generally produce higher EMI as capacitor recharge times are shorter.) The idea is to select values of R and C to soften the edges of the current pulse, as shown below. It may be tempting to forego C_G , relying instead on the MOSFETs' input capacitance. However, high dV/dt when power is first applied may cause the MOSFET to turn on due to C_{RSS} , damaging the FET. C_G protects against this possibility. Note that extending the turn-off time at the rising edge of the rectified AC increases the voltage drop across the FET, decreasing efficiency somewhat.

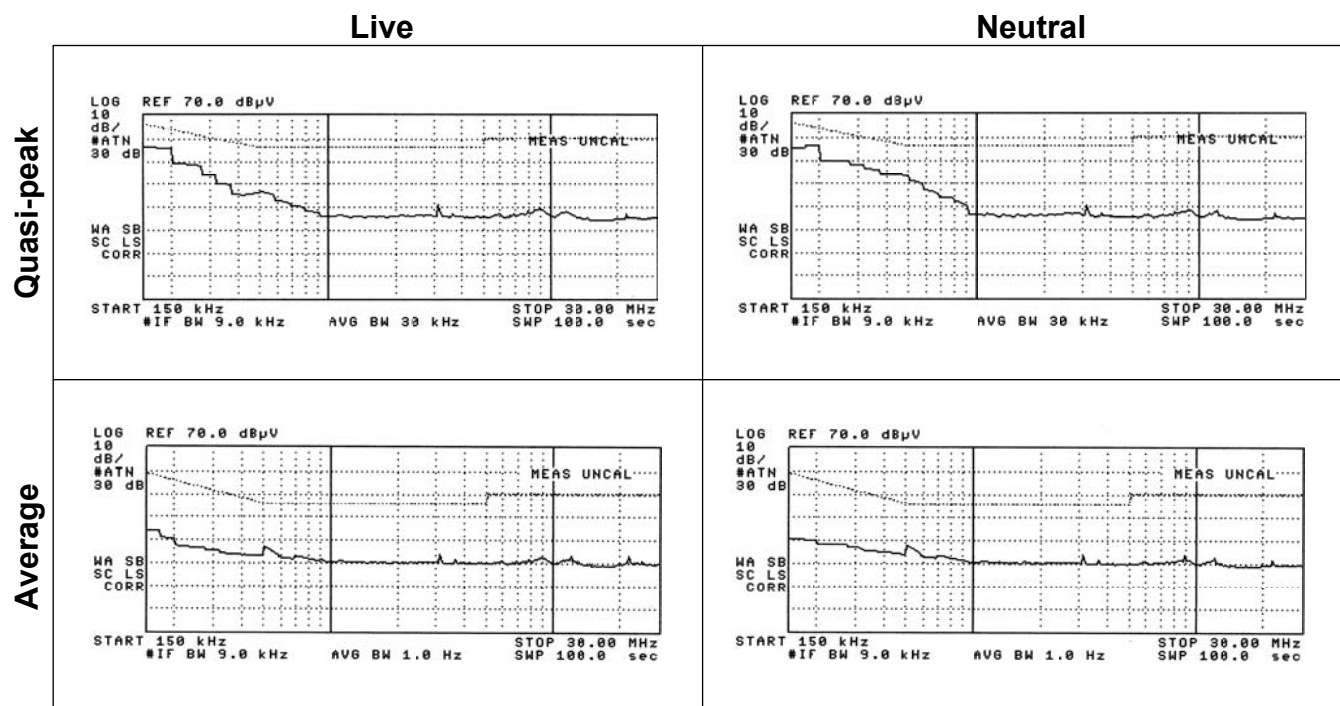


The following spectrums show the effect of the EMI suppression technique.

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

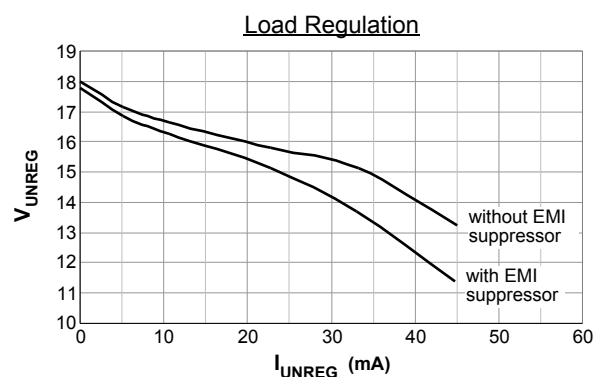
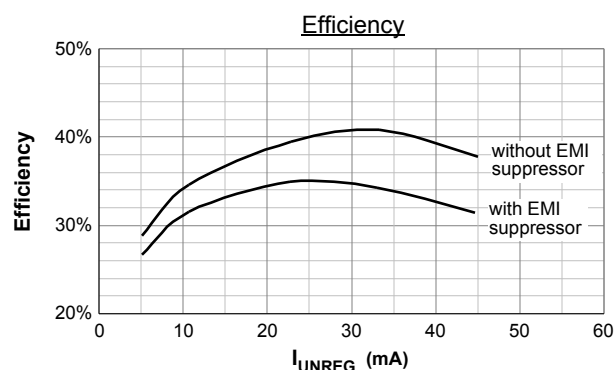


208VAC/60Hz (230VAC/50Hz not available) Limits per CISPR 14-1 for household appliances. 20mA total load.

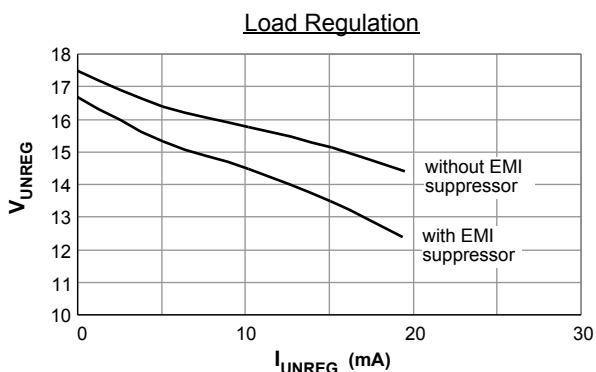
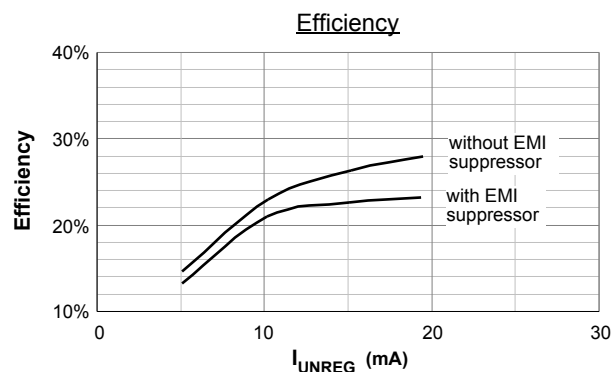


The EMI reduction technique has an effect on power supply performance, as illustrated in the following graphs.

120VAC/60Hz



208VAC/60Hz (230VAC/50Hz not available)



SR03x Power On Surge Protection

When power is first applied to an SR03x circuit near the peak of the input sine wave, there is an instantaneous step of voltage at the HV_{IN} terminal. The same step is applied to the pass element (MOSFET or IGBT). The parasitic capacitances in the pass element (MOSFET or IGBT) form a voltage divider circuit that applies an attenuated step to the gate of the pass element in the direction to turn on the pass element.

If the input step voltage is large enough, the pass element will be turned on. The high impedance gate drive of the SR03x is not strong enough to shut down the pass element in time. The pass element will conduct high current while there is a large voltage across it. This over heats the pass

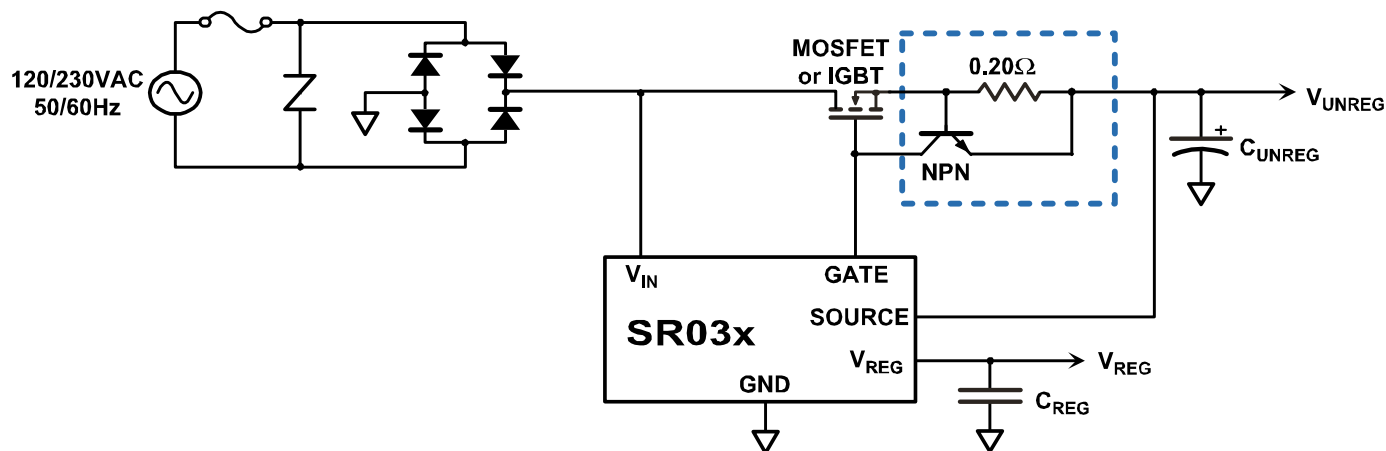
element and destroys it. In turn, the SR03x is also destroyed.

It has been reported that this power-on circuit destruction occurs frequently on 230VAC inputs and occasionally on 120VAC inputs.

The protection circuit, shown below, controls the gate drive and clamps the current through the pass element to approximately 3 Amperes (exact current not critical). This allows the SR03x enough time to shut down the pass element.

As shown in the circuit diagram, the surge protection requires only a resistor and a low cost NPN transistor (MPSA06 or equivalent).

Power On Surge Protection Circuit Diagram



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