

## Power Supply Output Supervisory Circuit

### GENERAL DESCRIPTION

The XR-1543/2543/3543 are monolithic integrated circuits that contain all the functions necessary to monitor and control the output of a power supply system. Included in the 16-Pin dual-in-line package is a voltage reference, an operational amplifier, voltage comparators, and a high-current SCR trigger circuit. The functions performed by this device include over-voltage sensing, under-voltage sensing and current limiting, with provisions for triggering an external SCR "crowbar."

The internal voltage reference on the XR-1543 is guaranteed for an accuracy of  $\pm 1\%$  to eliminate the need for external potentiometers. The entire circuit may be powered from either the output that is being monitored or from a separate bias voltage.

### FEATURES

- Over-Voltage Sensing Capability
- Under-Voltage Sensing Capability
- Current Limiting Capability
- Reference Voltage Trimmed  $\pm 1\%$
- SCR "Crowbar" Drive 300 mA
- Programmable Time Delays
- Open Collector Outputs
- and Remote Activation Capability
- Total Standby current Less than 10 mA

### APPLICATIONS

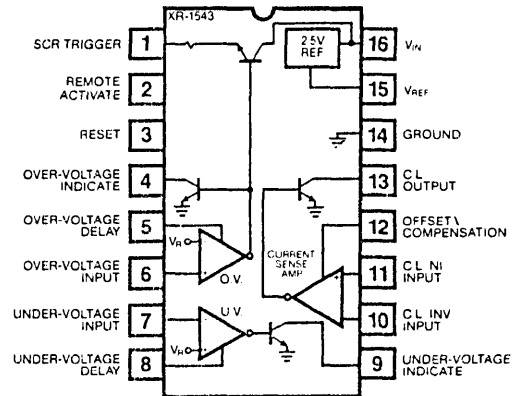
- DC/DC Converters
- Switch Mode Power Supplies
- Power Line Monitors
- Linear Power Supplies

### ABSOLUTE MAXIMUM RATINGS

Input Supply Voltage, $V_{IN}$	40V
Sense Inputs	$V_{IN}$
SCR Trigger Current (Note 1)	300 mA
Indicator Output Voltage	40V
Indicator Output Sink Current	50 mA
Power Dissipation (Ceramic)	1000 mW
Derate Above $T_A = +25^\circ\text{C}$	8 mW/ $^\circ\text{C}$
Power Dissipation (Plastic)	625 mW
Derate Above $T_A = +25^\circ\text{C}$	5 mW/ $^\circ\text{C}$
Operating Junction Temperature ( $T_J$ )	+150 $^\circ\text{C}$
Storage Temperature Range	-65 $^\circ\text{C}$ to +150 $^\circ\text{C}$

Note 1: At higher input voltages, a dissipation limiting resistor,  $R_G$ , is required.

### FUNCTIONAL BLOCK DIAGRAM



### ORDERING INFORMATION

Part Number	Package	Operating Temperature
XR-1543M	Ceramic	-55 $^\circ\text{C}$ to +125 $^\circ\text{C}$
XR-2543N	Ceramic	-25 $^\circ\text{C}$ to +85 $^\circ\text{C}$
XR-3543N	Ceramic	0 $^\circ\text{C}$ to +70 $^\circ\text{C}$
XR-3543P	Plastic	0 $^\circ\text{C}$ to +70 $^\circ\text{C}$

### SYSTEM DESCRIPTION

An output supervisory circuit, such as the XR-1543, is used to control and monitor the performance of a power supply. In many systems, it is crucial that the supply voltage is always within some minimum and maximum level, to guarantee proper performance, and to prevent damage to the system. If the supply voltage is out of tolerance, it is often desirable to shut down the system or to have some form of indication to the operator or system controller. As well as protecting the system, the power supply sometimes needs to be protected under short circuit and current overload situations. By providing an SCR "crowbar" on the output of a power supply, it can be shut off under certain fault conditions as well.

The over-voltage sensing circuit (O.V.) can be used to monitor the output of a power supply and provide triggering of an SCR, when the output goes above the prescribed voltage level. The under-voltage sensing circuit (U.V.) can be used to monitor either the output of a power supply or the input line voltage.

# XR-15/25/3543

## ELECTRICAL CHARACTERISTICS

Test Conditions:  $V_{IN} = 10V$ ,  $T_A$  = full operating temperature range, unless otherwise specified. Refer to Figure 9 for component designation.

PARAMETERS	XR-1543/2543			XR-3543			UNIT	CONDITIONS
	MIN	TYP	MAX	MIN	TYP	MAX		
Input Voltage Range	4.5		40	4.5		40	V	$T_A = 25^\circ C$ to max $T_A = \text{min to max}$ $T_A = 25^\circ C$ , $V_{IN} = 40V$
Input Voltage Range	4.7		40	4.7		40	V	
Supply Current		7	10		7	10	mA	
<b>REFERENCE VOLTAGE SECTION (Pins 15 and 16)</b>								
Output Voltage	2.48	2.50	2.52	2.45	2.50	2.55	V	$T_A = 25^\circ C$ $T_A = \text{min to max}$ $V_{IN} = 5$ to 30V $I_{ref} = 0$ to 10 mA $V_{ref} = 0V$
Output Voltage	2.45		2.55	2.40		2.60	V	
Line Regulation		1	5		1	5	mV	
Load Regulation		1	10		1	10	mV	
Short Circuit Current		15			15		mA	
Temperature Stability		50			50		ppm/ $^\circ C$	
<b>SCR TRIGGER SECTION (Pins 1, 2, and 3)</b>								
Peak Output Current	100	200	400	100	200	400	mA	$V_{IN} = 5V$ , $R_G = 0\Omega$ , $V_O = 0$ $V_{IN} = 15V$ , $I_O = 100$ mA $V_{IN} = 40V$ Pin 2 = GND Pin 2 = Open Pin 2 = GND, Pin 3 = GND Pin 2 = GND, Pin 3 = Open $T_J = 25^\circ C$ , $R_L = 50\Omega$ , $C_D = 0$ $T_J = 25^\circ C$ , $R_L = 50\Omega$ $C_D = 0$ , Pin 2 = 0.4V $T_J = 25^\circ C$ , $R_L = 50\Omega$ , $C_D = 0$ , Pin 6 = 2.7V
Peak Output Voltage	12	13		12	13		V	
Output OFF Voltage		0	0.1		0	0.1	V	
Remote Activate Current		0.4	0.8		0.4	0.8	mA	
Remote Activate Voltage		2	6		2	6	V	
Reset Current		0.4	0.8		0.4	0.8	mA	
Reset Voltage		2	6		2	6	V	
Output Current Slew Rate		400			400		mA/ $\mu s$	
Propagation Delay Time (From Pin 2)		300			300		nsec	
Propagation Delay Time (From Pin 6)		500			500		nsec	
<b>COMPARATOR SECTIONS (Pins 4, 5, 6, 7, 8, and 9)</b>								
Input Threshold (Input Voltage Rising on Pin 6 and Falling on Pin 7)	2.45	2.50	2.55	2.40	2.50	2.60	V	$T_J = \text{min to max}$ $T_J = 25^\circ C$
Input Hysteresis	2.40	25	2.60	2.35	25	2.65	mV	
Input Bias Current		0.3	1.0		0.3	1.0	$\mu A$	Sense input = 0V
Delay Saturation		0.2	0.5		0.2	0.5	V	
Delay High Level		6	7		6	7	V	$V_D = 0V$ $I_L = 10$ mA $V_{out} = 40V$ $C_D = 0$ Pin 6 = 2.7V Pin 7 = 2.3V $T_J = 25^\circ C$
Delay Charging Current	200	250	300	200	250	300	$\mu A$	
Indicate Saturation Voltage		0.2	0.5		0.2	0.5	V	
Indicate Leakage Current		0.01	1.0		0.01	1.0	$\mu A$	
Propagation Delay Time		400			400		nsec	
Propagation Delay Time		10			10		msec	
<b>CURRENT LIMIT AMPLIFIER SECTION (Pins 10, 11, 12, and 13)</b>								
Input Voltage Range	0		$V_{IN} - 3V$	0		$V_{IN} - 3V$	V	Pin 12 = Open, $V_{CM} = 0V$ Pin 12 = Open, $V_{CM} = 0V$ Pin 12 = 10 k $\Omega$ to GND $V_{IN} = 15V$ , $0 \leq$ $V_{CM} \leq 12V$ $V_{CM} = 0V$ , Pin 12 = Open $I_L = 10$ mA $V_{out} = 40V$ $T_J = 25^\circ C$ , $A_v = 0$ dB $T_J = 25^\circ C$ , $V_{overdrive} = 100$ mV
Input Bias Current		0.3	1.0		0.3	1.0	$\mu A$	
Input Offset Voltage		0	10		0	15	mV	
Input Offset Voltage	80	100	120	70	100	130	mV	
Common Mode	60	70		60	70		dB	
Rejection Ratio							dB	
Open Loop Gain	72	80		72	80		dB	
Output Saturation Voltage		0.2	0.5		0.2	0.5	V	
Output Leakage Current		0.01	1.0		0.01	1.0	$\mu A$	
Small Signal Bandwidth		5			5		MHz	
Propagation Delay Time		200			200		nsec	

# XR-15/25/3543

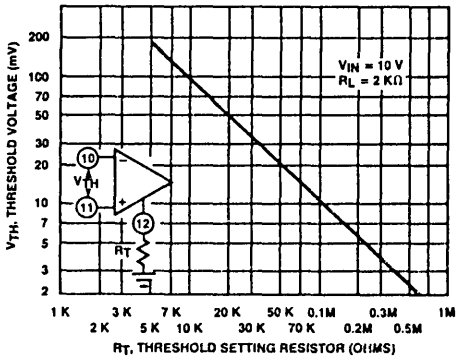


Figure 1. Typical Current Threshold ( $V_{TH}$ ) vs. Threshold Setting Resistor ( $R_T$ )

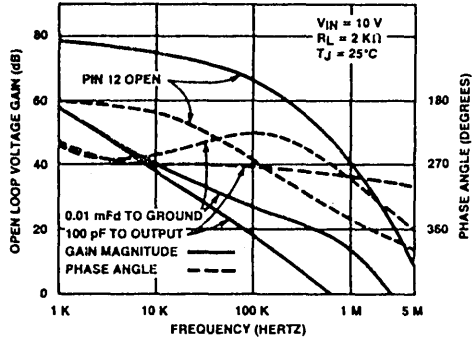


Figure 2. Current Limiting Amplifier—Frequency Response

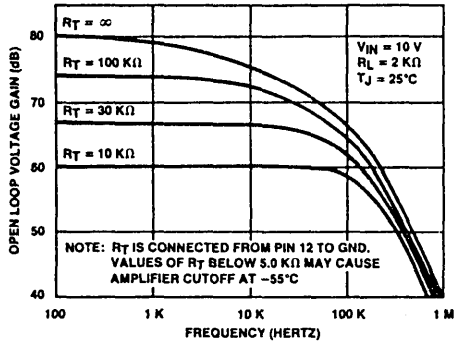


Figure 3. Current Limiting Amplifier Gain vs. Threshold Setting Resistor ( $R_T$ )

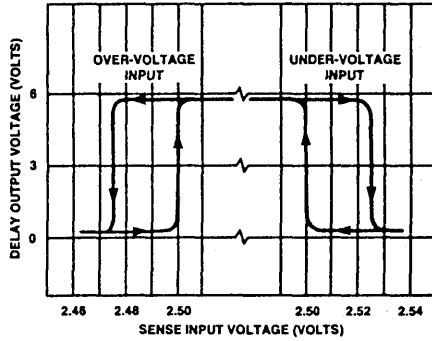


Figure 4. Over-Voltage and Under-Voltage Comparator Hysteresis

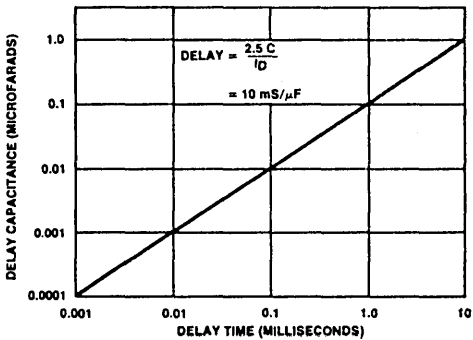


Figure 5. Comparator Activation Delay vs. Capacitor Value

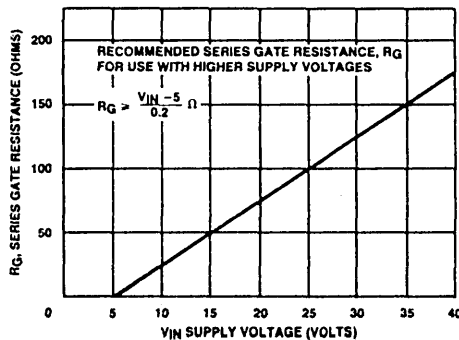


Figure 6. SCR Trigger—Series Gate Resistance ( $R_G$ ) vs. Input Voltage

# XR-15/25/3543

## PRINCIPLES OF OPERATION

The internal control blocks of the XR-1543 operate as follows:

### Voltage Reference Section

The internal voltage reference circuit of the XR-1543 is based on the well-known "band-gap reference" with a nominal output voltage of 2.50 volts, internally trimmed to give an accuracy of  $\pm 1\%$  at 25°C. It is capable of providing a stable output voltage over a wide input voltage range. Furthermore, its performance is guaranteed for changes in line and load conditions. The accuracy of the output voltage is guaranteed to  $\pm 2\%$  maximum for the XR-1543/2543, and  $\pm 4\%$  maximum for the XR-3543, over the entire operating temperature range.

The output of the reference circuit is capable of providing up to 10 mA of current for use as a reference for external circuitry. The primary function of this circuit is to provide a very accurate and stable reference input for the under-voltage and over-voltage comparators, thereby enabling very precise monitoring of line and output voltages without potentiometers.

### Comparator Section

The under-voltage and over-voltage sensing comparators of the XR-1543 are identical except for the input polarities. Each section is made up of two comparators in series whose inputs are referenced to 2.50 volts. The delay terminal between the comparators requires an external capacitor to ground for programmable time delays on the output.

When an out-of-tolerance situation occurs, the first comparator activates a current source which then charges the external capacitor at a constant rate. This ramp voltage is then compared to the reference voltage by the second comparator which activates the output indicating circuit. With no external capacitor, the overall time delay from sense input to output is approximately 0.5  $\mu$ sec. The charging current for the capacitor,  $C_D$ , is approximately 250  $\mu$ A which results in the following relationship:

$$\text{Time delay} = 10 C_D \text{ (msec)}$$

where  $C_D$  is in  $\mu$ F.

The output npn transistors are capable of sinking 10 mA with saturation voltage of less than 0.4 volts. The outputs can be "wired OR'd" to provide a single output indicator.

### Current Sensing Amplifier

The operational amplifier used in the XR-1543 is a high-gain, externally compensated amplifier with open collector outputs. The pnp input stage provides for a wide

input common mode range extending from ground to approximately 3 volts below the positive supply. With a 2 k $\Omega$  pull-up resistor, the open-loop voltage gain is 72 dB minimum with a unity gain bandwidth beyond 5 MHz. The operational amplifier may be used as a comparator or, if linear amplification is required, external compensation may be added for stable performance over a wide frequency range.

The input offset voltage of this amplifier is specified for 10 mV maximum; however, it may be programmed externally for thresholds up to 200 mV. By connecting a resistor,  $R_T$ , from Pin 12 to ground, the input threshold voltage can be varied. For most current sensing applications, the required threshold polarity calls for a positive voltage on the inverting input. Reducing the impedance on Pin 12 also lowers the overall voltage gain of the amplifier, which makes this pin a convenient point to apply frequency compensation. This can be accomplished by either connecting  $C_1$  to the output, or  $C_2$  to ground as shown in Figure 8. The diode,  $D_1$ , and the resistor,  $R_C$ , are used only if it is necessary to increase the frequency response by operating the output at a higher current and/or isolating the load from  $R_C$  and  $C_1$ , when the amplifier is off.

### SCR Trigger Section

The SCR trigger section of the XR-1543 is connected to the output of the over-voltage comparator and is capable of handling 300 mA. The circuit also provides for remote activation of the output as well as a reset terminal. When an over-voltage situation occurs, the output of the sensing comparator goes low, turning "on" the over-voltage indicate transistor. At the same time, the comparator drives an npn Darlington pair which provides 300 mA to activate an external SCR crowbar.

A remote activation circuit is included to allow the user to activate the SCR crowbar in other than an over-voltage situation. When this terminal, Pin 2, is grounded, it forces the output of the comparator low which activates the output circuitry in the same manner as the over-voltage comparator does.

Another function of this circuit is to provide the capability to latch the O.V. indicate and SCR trigger outputs "on", after a fault is sensed. This is done by connecting the remote activate terminal (Pin 2) to the O.V. indicating terminal (Pin 4). When an O.V. condition occurs, Pin 2 is pulled low, which in turn holds the outputs in the "on" condition until the reset terminal is externally grounded, removing the latch and turning "off" the outputs. If the external connection is not made, the high current output will be activated only as long as a fault condition exists. When the fault condition disappears, the outputs will be disabled. The thresholds for both remote activation and reset terminals are approximately 1.2 volts.

# XR-15/25/3543

## EQUIVALENT SCHEMATIC DIAGRAM

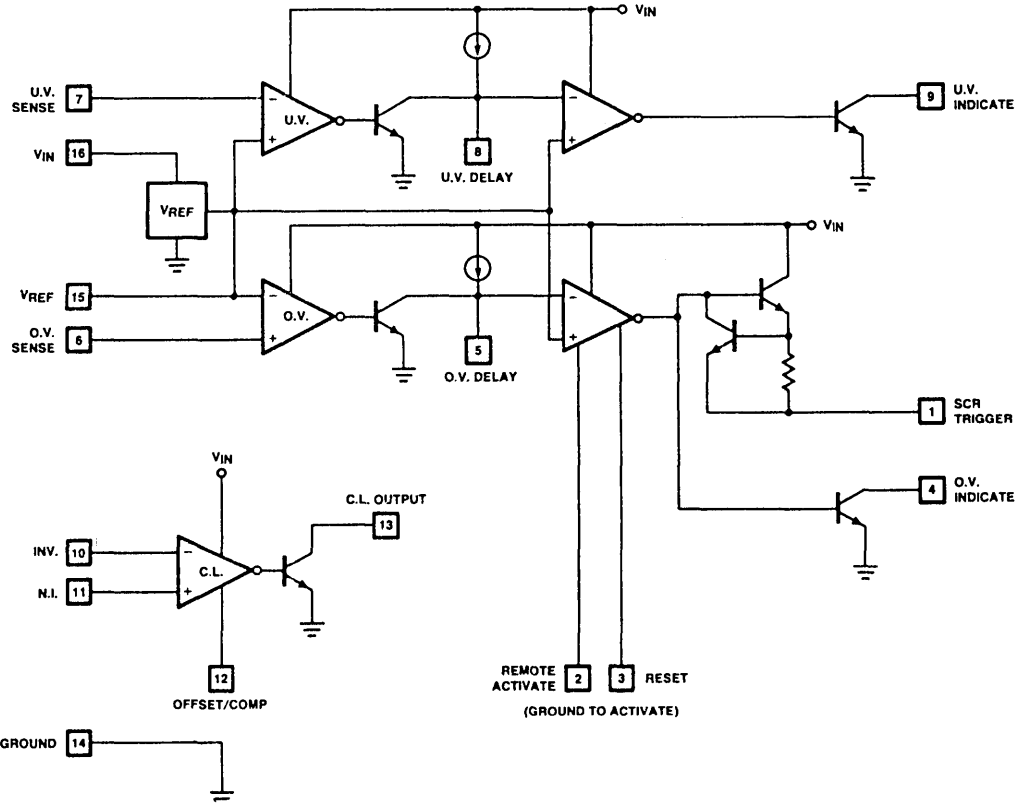
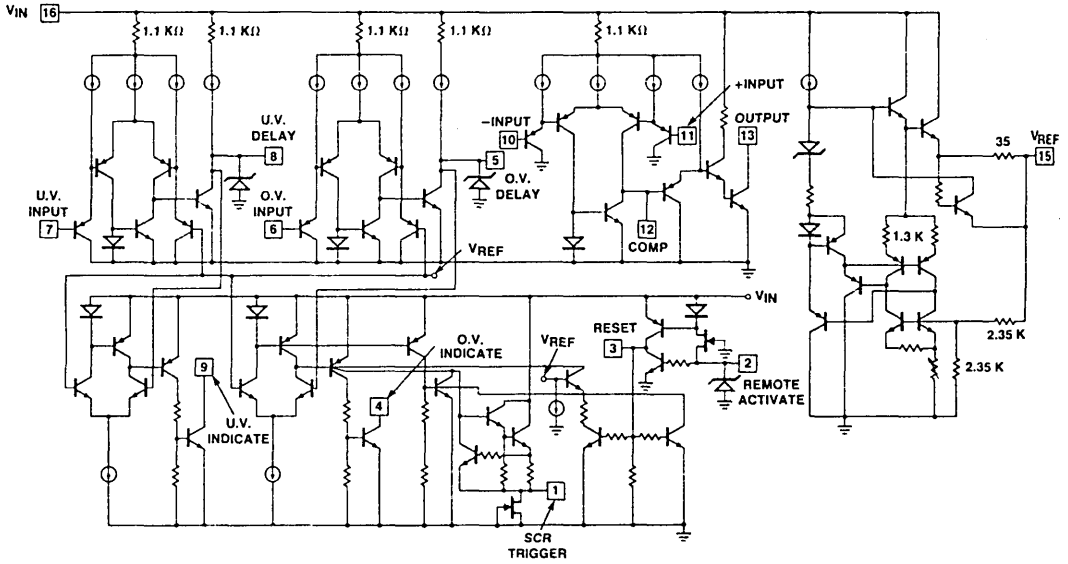


Figure 7. XR-1543 Block Diagram

# XR-15/25/3543

## APPLICATIONS INFORMATION

A typical application of the XR-1543 is to monitor a single power supply output voltage as shown in Figure 9. In this circuit, both over- and under-voltage sensing and current-limiting functions are performed. The circuit shown is powered from an external bias capable of supplying 10 mA in addition to the activation current for the SCR trigger. With Pin 2 tied to Pin 4, a latch has been provided such that when an over-voltage situation occurs, the o.v. indicator and SCR trigger are activated and held until the reset terminal is externally grounded.

In powering an SCR from supply voltages greater than 5 volts, an external resistor,  $R_G$ , is required on Pin 1 to limit the power dissipation for the XR-1543. Although the XR-1543 is capable of handling 300 mA of current, its power dissipation must be kept below the absolute maximum ratings.

In this circuit, current-limiting is performed by sensing the voltage drop across the resistor,  $R_{SC}$ , in the positive supply line. The threshold for the amplifier is externally set by the resistor,  $R_T$ .

The values of the external components used in Figure 9 are calculated as follows:

1. Current limiting threshold,  $V_{TH} \approx \frac{1000}{R_T}$

2.  $C_1$  is determined by the loop dynamics.

3. Peak current to load,

$$I_p \approx \frac{V_{TH}}{R_{SC}} + \frac{V_O}{R_{SC}} \left( \frac{R_2}{R_2 + R_3} \right)$$

4. Short circuit current,

$$I_{SC} = \frac{V_{TH}}{R_{SC}}$$

5. Low output voltage limit,

$$V_O (\text{low}) = \frac{2.5(R_4 + R_5 + R_6)}{R_5 + R_6}$$

6. High output voltage limit,

$$V_O (\text{high}) = \frac{2.5(R_4 + R_5 + R_6)}{R_6}$$

7. Voltage sensing delay,  $T_D = 10,000 C_D$

8. SCR trigger power limiting resistor,

$$R_G > \frac{V_{IN} - 5}{0.2}$$

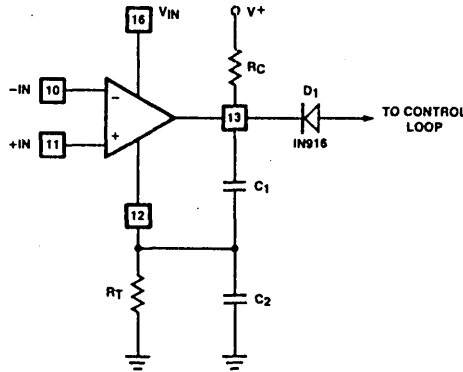


Figure 8. Current Limiting Amplifier Connections for Threshold Control and Frequency Compensation

# XR-15/25/3543

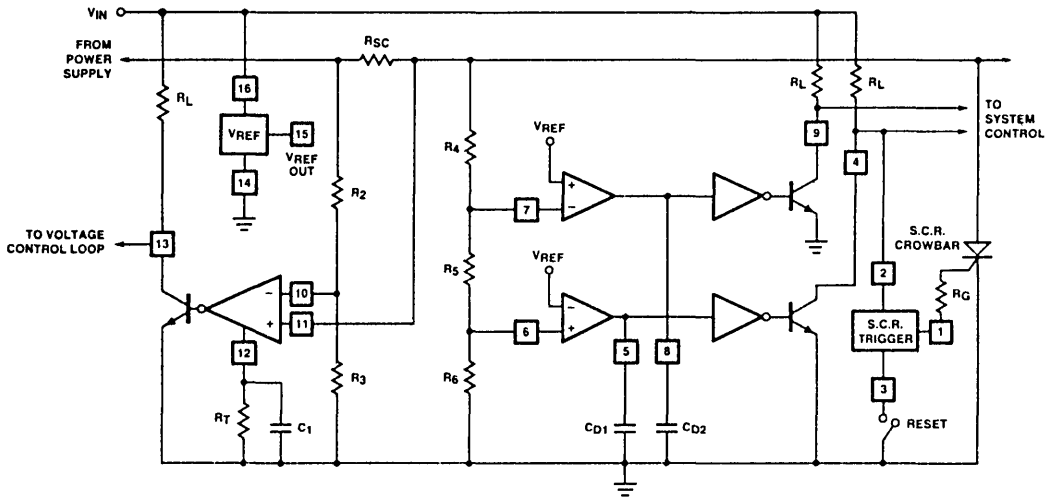


Figure 9. Typical Connection for Linear Foldback Current Limiting as well as Over-Voltage and Under-Voltage Protection.

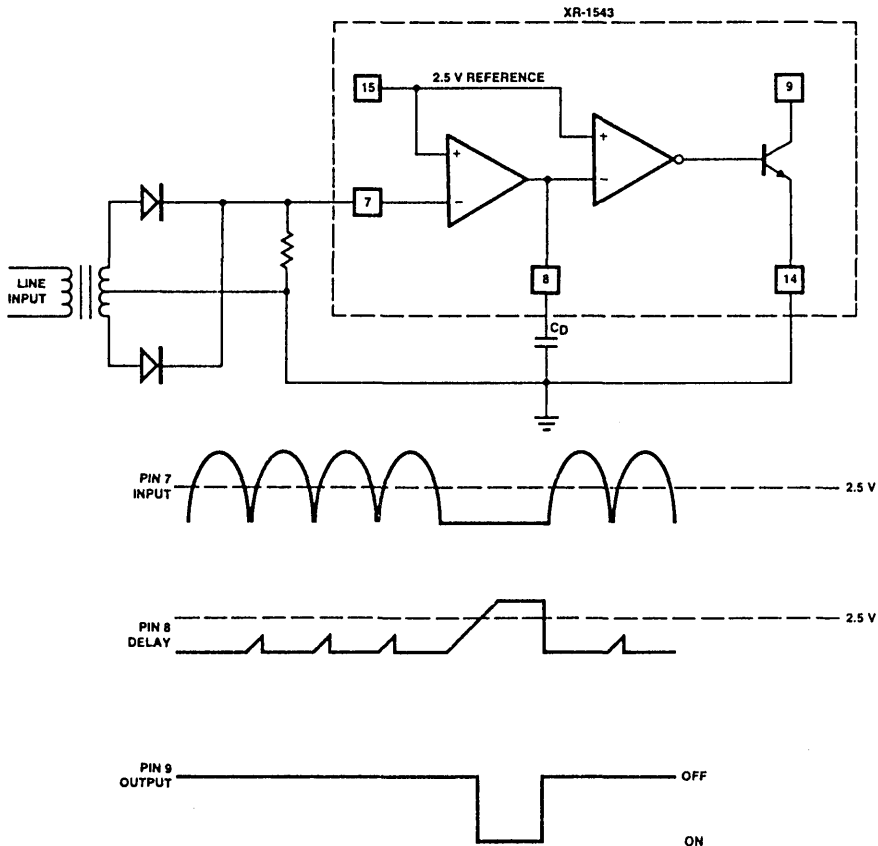


Figure 10. XR-1543—Input Line Monitor Circuit

# XR-15/25/3543

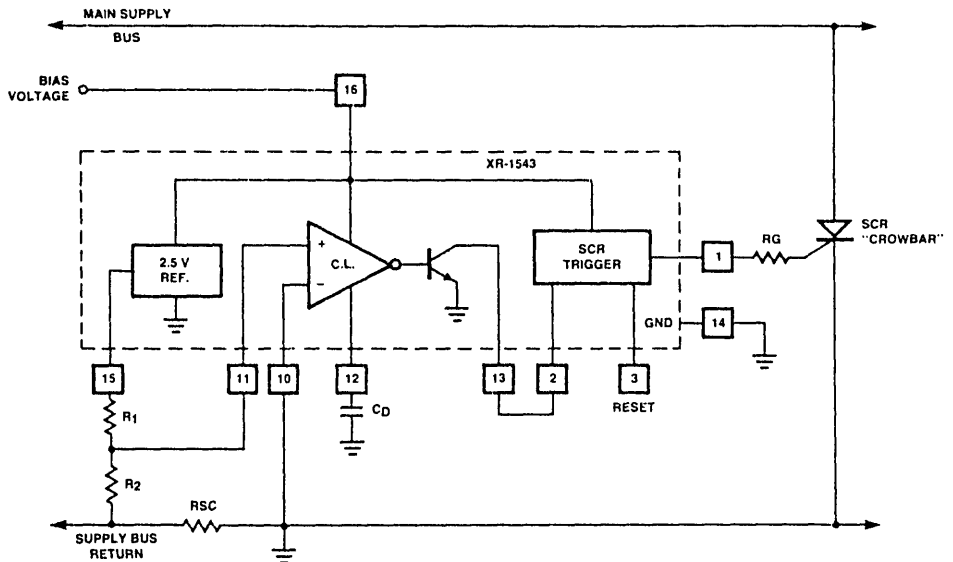


Figure 11. XR-1543—Over Current Shutdown Circuitry

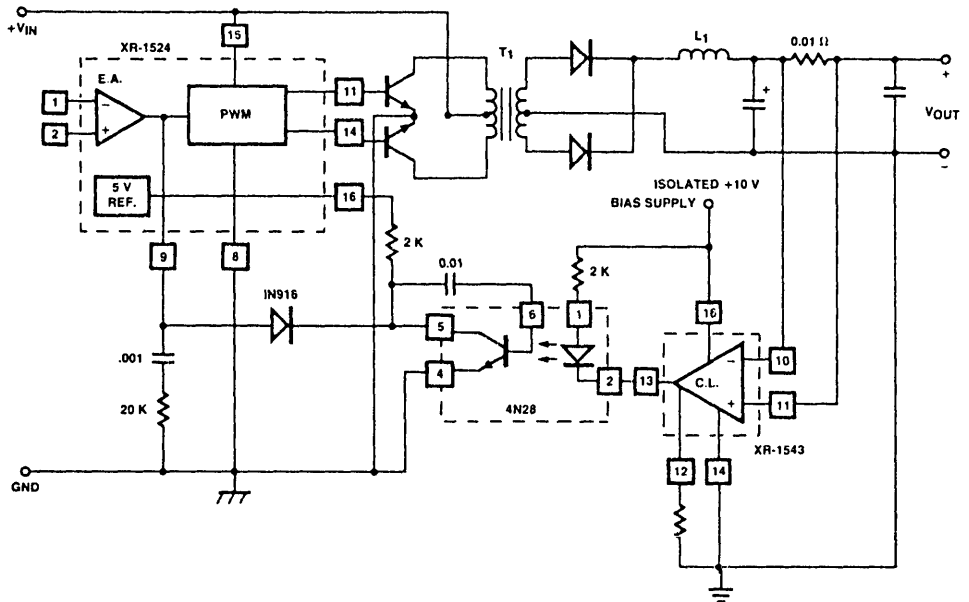


Figure 12. XR-1543 - DC Converter with Isolated Current Limiting