National Semiconductor

LM134/LM234/LM334 3-Terminal Adjustable Current Sources

General Description

The LM134/LM234/LM334 are 3-terminal adjustable current sources featuring 10,000:1 range in operating current, excellent current regulation and a wide dynamic voltage range of 1V to 40V. Current is established with one external resistor and no other parts are required. Initial current accuracy is ±3%. The LM134/LM234/LM334 are true floating current sources with no separate power supply connections. In addition, reverse applied voltages of up to 20V will draw only a few dozen microamperes of current, allowing the devices to act as both a rectifier and current source in AC applications.

The sense voltage used to establish operating current in the LM134 is 64 mV at 25°C and is directly proportional to absolute temperature (°K). The simplest one external resistor connection, then, generates a current with ≈ +0.33%/°C temperature dependence. Zero drift operation can be obtained by adding one extra resistor and a diode.

Applications for the new current sources include bias networks, surge protection, low power reference, ramp generation, LED driver, and temperature sensing. The LM134-3/LM234-3 and LM134-6/LM234-6 are specified as true temperature sensors with guaranteed initial accuracy of ±3°C and ±6°C, respectively. These devices are ideal in remote sense applications because series resistance in long wire runs does not affect accuracy. In addition, only 2 wires are required.

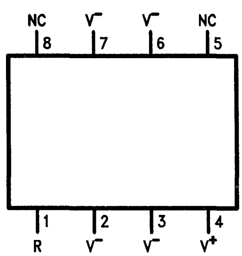
The LM134 is guaranteed over a temperature range of −55°C to +125°C, the LM234 from −25°C to +100°C and the LM334 from 0°C to +70°C. These devices are available in TO-46 hermetic, TO-92 and SO-8 plastic packages.

Features

- Operates from 1V to 40V
- 0.02%/V current regulation
- Programmable from 1 μA to 10 mA
- True 2-terminal operation
- Available as fully specified temperature sensor
- ±3% initial accuracy

Connection Diagrams

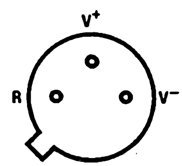
SO-8
Surface Mount Package



TL/H/5697-24

Order Number LM334M
See NS Package Number M08A

TO-46
Metal Can Package



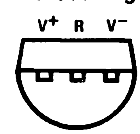
TL/H/5697-12

Bottom View

Pin 3 is electrically connected to case.

Order Number LM134H, LM134H-3, LM134H-6, LM234H, LM234H-3, LM234H-6, or LM334H
See NS Package Number H03H

TO-92
Plastic Package



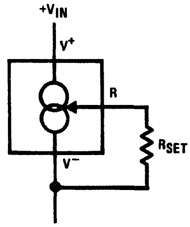
TL/H/5697-10

Bottom View

Order Number LM334Z, LM234Z-3 or LM234Z-6
See NS Package Number Z03A

Typical Application

Basic 2-Terminal Current Source



TL/H/5697-1

Absolute Maximum Ratings

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

V^+ to V^- Forward Voltage	
LM134/LM234	40V
LM334/LM134-3/LM134-6/LM234-3/LM234-6	30V
V^+ to V^- Reverse Voltage	20V
R Pin to V^- Voltage	5V
Set Current	10 mA
Power Dissipation	400 mW

Operating Temperature Range (Note 4)	
LM134/LM134-3/LM134-6	−55°C to +125°C
LM234/LM234-3/LM234-6	−25°C to +100°C
LM334	0°C to +70°C
Soldering Information	
TO-92 Package (10 sec.)	260°C
TO-46 Package (10 sec.)	300°C
SO Package	
Vapor Phase (60 sec.)	215°C
Infrared (15 sec.)	220°C

See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" (Appendix D) for other methods of soldering surface mount devices.

Electrical Characteristics (Note 1)

Parameter	Conditions	LM134/LM234			LM334			Units
		Min	Typ	Max	Min	Typ	Max	
Set Current Error, $V^+ = 2.5V$, (Note 2)	$10\ \mu A \leq I_{SET} \leq 1$ mA			3			6	%
	$1\ mA < I_{SET} \leq 5$ mA			5			8	%
	$2\ \mu A \leq I_{SET} < 10\ \mu A$			8			12	%
Ratio of Set Current to V^- Current	$100\ \mu A \leq I_{SET} \leq 1$ mA	14	18	23	14	18	26	
	$1\ mA \leq I_{SET} \leq 5$ mA		14			14		
	$2\ \mu A \leq I_{SET} \leq 100\ \mu A$		18	23		18	26	
Minimum Operating Voltage	$2\ \mu A \leq I_{SET} \leq 100\ \mu A$		0.8			0.8		V
	$100\ \mu A < I_{SET} \leq 1$ mA		0.9			0.9		V
	$1\ mA < I_{SET} \leq 5$ mA		1.0			1.0		V
Average Change in Set Current with Input Voltage	$2\ \mu A \leq I_{SET} \leq 1$ mA							
	$1.5 \leq V^+ \leq 5V$		0.02	0.05		0.02	0.1	%/V
	$5V \leq V^+ \leq 40V$		0.01	0.03		0.01	0.05	%/V
	$1\ mA < I_{SET} \leq 5$ mA							
	$1.5V \leq V \leq 5V$		0.03			0.03		%/V
	$5V \leq V \leq 40V$		0.02			0.02		%/V
Temperature Dependence of Set Current (Note 3)	$25\ \mu A \leq I_{SET} \leq 1$ mA	0.96T	T	1.04T	0.96T	T	1.04T	
Effective Shunt Capacitance			15			15		pF

Note 1: Unless otherwise specified, tests are performed at $T_j = 25°C$ with pulse testing so that junction temperature does not change during test.

Note 2: Set current is the current flowing into the V^+ pin. It is determined by the following formula: $I_{SET} = 67.7\ mV/R_{SET}$ (@ 25°C). Set current error is expressed as a percent deviation from this amount. I_{SET} increases at 0.336%/°C @ $T_j = 25°C$.

Note 3: I_{SET} is directly proportional to absolute temperature (°K). I_{SET} at any temperature can be calculated from: $I_{SET} = I_o\ (T/T_o)$ where I_o is I_{SET} measured at T_o (°K).

Note 4: For elevated temperature operation, T_j max is:

LM134	150°C
LM234	125°C
LM334	100°C

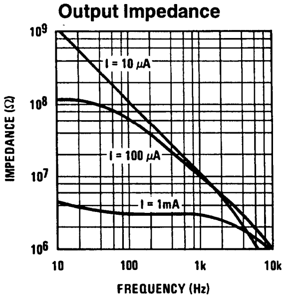
Thermal Resistance	TO-92	TO-46	SO-8
θ_{ja} (Junction to Ambient)	180°C/W (0.4″ leads) 160°C/W (0.125″ leads)	440°C/W	165°C/W
θ_{jc} (Junction to Case)	N/A	32°C/W	N/A

Electrical Characteristics (Note 1) (Continued)

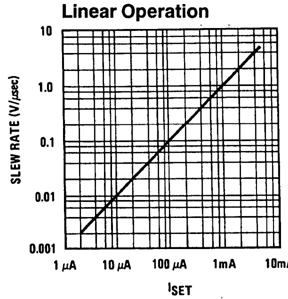
Parameter	Conditions	LM134-3, LM234-3			LM134-6, LM234-6			Units
		Min	Typ	Max	Min	Typ	Max	
Set Current Error, $V^+ = 2.5V$, (Note 2)	$100\ \mu A \le I_{SET} \le 1\ mA$ $T_j = 25°$			±1			±2	%
Equivalent Temperature Error				±3			±6	°C
Ratio of Set Current to V^- Current	$100\ \mu A \le I_{SET} \le 1\ mA$	14	18	26	14	18	26	
Minimum Operating Voltage	$100\ \mu A\ I_{SET} \le 1\ mA$		0.9			0.9		V
Average Change in Set Current with Input Voltage	$100\ \mu A \le I_{SET} \le 1\ mA$ $1.5 \le V^+ \le 5V$ $5V \le V^+ \le 30V$		 0.02 0.01	 0.05 0.03		 0.02 0.01	 0.01 0.05	 %/V %/V
Temperature Dependence of Set Current (Note 3) and	$100\ \mu A \le I_{SET} \le 1\ mA$	0.98T	T	1.02T	0.97T	T	1.03T	
Equivalent Slope Error				±2			±3	%
Effective Shunt Capacitance			15			15		pF

Typical Performance Characteristics

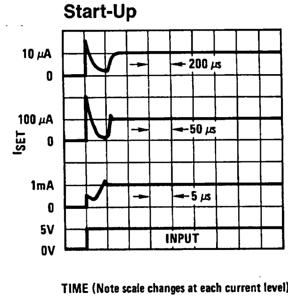
Output Impedance



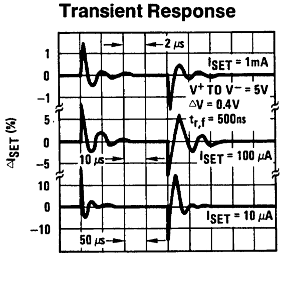
Maximum Slew Rate for Linear Operation



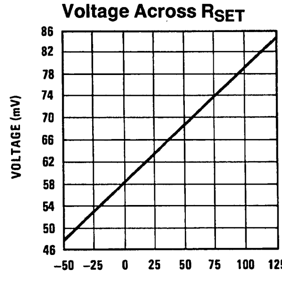
Start-Up



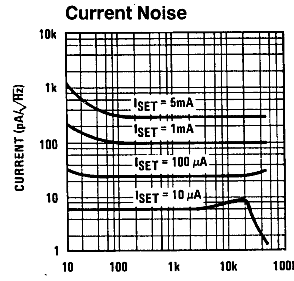
Transient Response



Voltage Across R_{SET}



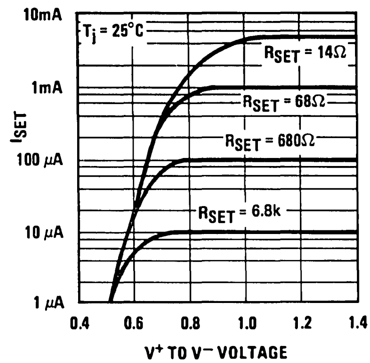
Current Noise



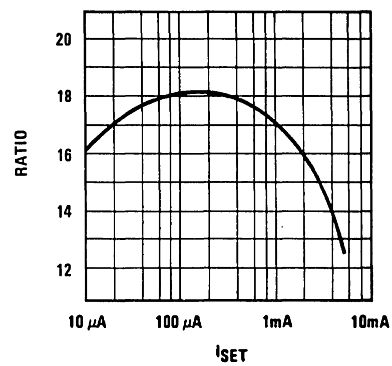
TL/H/5697–2

Typical Performance Characteristics (Continued)

Turn-On Voltage



Ratio of I_{SET} to V^- Current



TL/H/5697-3

Application Hints

The LM134 has been designed for ease of application, but a general discussion of design features is presented here to familiarize the designer with device characteristics which may not be immediately obvious. These include the effects of slewing, power dissipation, capacitance, noise, and contact resistance.

SLEW RATE

At slew rates above a given threshold (see curve), the LM134 may exhibit non-linear current shifts. The slewing rate at which this occurs is directly proportional to I_{SET}. At I_{SET} = 10 µA, maximum dV/dt is 0.01V/µs; at I_{SET} = 1 mA, the limit is 1V/µs. Slew rates above the limit do not harm the LM134, or cause large currents to flow.

THERMAL EFFECTS

Internal heating can have a significant effect on current regulation for I_{SET} greater than 100 µA. For example, each 1V increase across the LM134 at I_{SET} = 1 mA will increase junction temperature by ≈ 0.4°C in still air. Output current (I_{SET}) has a temperature coefficient of ≈0.33%/°C, so the change in current due to temperature rise will be (0.4)(0.33) = 0.132%. This is a 10:1 degradation in regulation compared to true electrical effects. Thermal effects, therefore, must be taken into account when DC regulation is critical and I_{SET} exceeds 100 µA. Heat sinking of the TO-46 package or the TO-92 leads can reduce this effect by more than 3:1.

SHUNT CAPACITANCE

In certain applications, the 15 pF shunt capacitance of the LM134 may have to be reduced, either because of loading problems or because it limits the AC output impedance of the current source. This can be easily accomplished by buffering the LM134 with an FET as shown in the applications. This can reduce capacitance to less than 3 pF and improve regulation by at least an order of magnitude. DC characteristics (with the exception of minimum input voltage), are not affected.

NOISE

Current noise generated by the LM134 is approximately 4 times the shot noise of a transistor. If the LM134 is used as an active load for a transistor amplifier, input referred noise will be increased by about 12 dB. In many cases, this is acceptable and a single stage amplifier can be built with a voltage gain exceeding 2000.

LEAD RESISTANCE

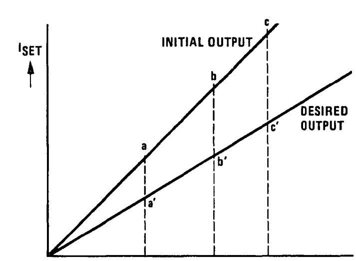
The sense voltage which determines operating current of the LM134 is less than 100 mV. At this level, thermocouple or lead resistance effects should be minimized by locating the current setting resistor physically close to the device. Sockets should be avoided if possible. It takes only 0.7Ω contact resistance to reduce output current by 1% at the 1 mA level.

SENSING TEMPERATURE

The LM134 makes an ideal remote temperature sensor because its current mode operation does not lose accuracy over long wire runs. Output current is directly proportional to absolute temperature in degrees Kelvin, according to the following formula:

$$I_{SET} = \frac{(227\mu V/°K)(T)}{R_{SET}}$$

Calibration of the LM134 is greatly simplified because of the fact that most of the initial inaccuracy is due to a gain term (slope error) and not an offset. This means that a calibration consisting of a gain adjustment only will trim both slope and zero at the same time. In addition, gain adjustment is a one point trim because the output of the LM134 extrapolates to zero at 0°K, independent of R_{SET} or any initial inaccuracy.



TL/H/5697-4

This property of the LM134 is illustrated in the accompanying graph. Line abc is the sensor current before trimming.

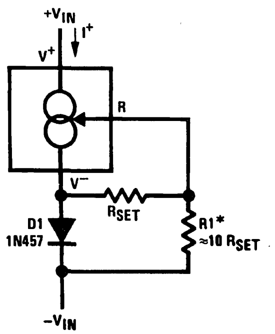
Application Hints (Continued)

Line a'b'c' is the desired output. A gain trim done at T2 will move the output from b to b' and will simultaneously correct the slope so that the output at T1 and T3 will be correct. This gain trim can be done on R_{SET} or on the load resistor used to terminate the LM134. Slope error after trim will normally be less than ±1%. To maintain this accuracy, however, a low temperature coefficient resistor must be used for R_{SET}.

A 33 ppm/°C drift of R_{SET} will give a 1% slope error because the resistor will normally see about the same temperature variations as the LM134. Separating R_{SET} from the LM134 requires 3 wires and has lead resistance problems, so is not normally recommended. Metal film resistors with less than 20 ppm/°C drift are readily available. Wire wound resistors may also be used where best stability is required.

Typical Applications (Continued)

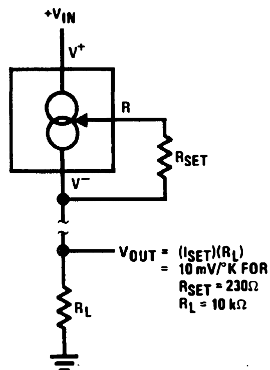
Zero Temperature Coefficient Current Source



TL/H/5697-13

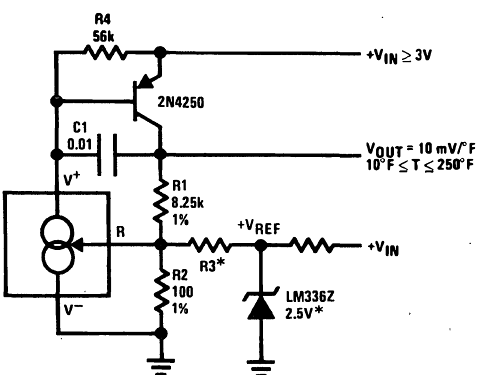
*Select ratio of R1 to R_{SET} to obtain zero drift. $I^+ \approx 2 I_{SET}$

Terminating Remote Sensor for Voltage Output



TL/H/5697-14

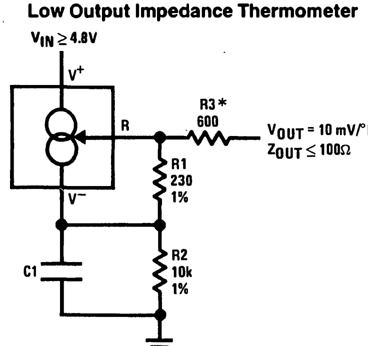
Ground Referred Fahrenheit Thermometer



TL/H/5697-15

*Select R3 = V_{REF}/583 μA. V_{REF} may be any stable positive voltage ≥ 2V
Trim R3 to calibrate

Low Output Impedance Thermometer

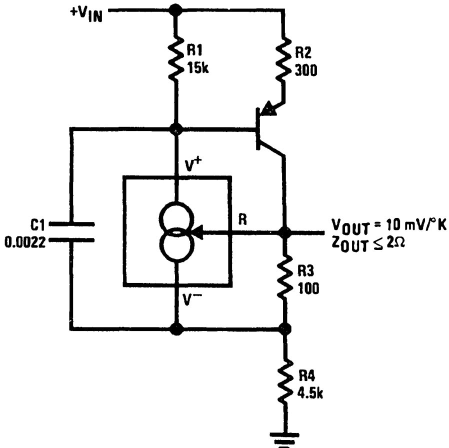


TL/H/5697-6

*Output impedance of the LM134 at the "R" pin is approximately $\frac{-R_o\Omega}{16}$ where R_o is the equivalent external resistance connected to the V^- pin. This negative resistance can be reduced by a factor of 5 or more by inserting an equivalent resistor in series with the output.

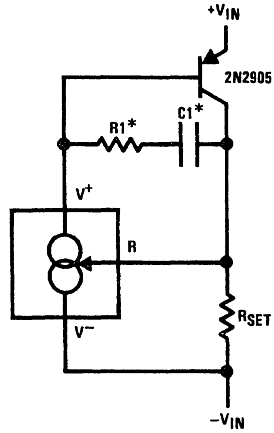
Typical Applications (Continued)

Low Output Impedance Thermometer



TL/H/5697-16

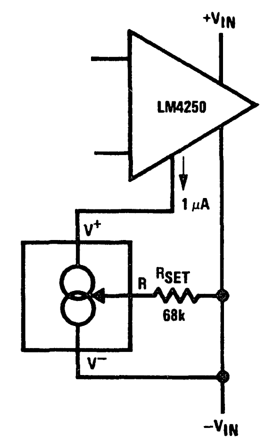
Higher Output Current



TL/H/5697-5

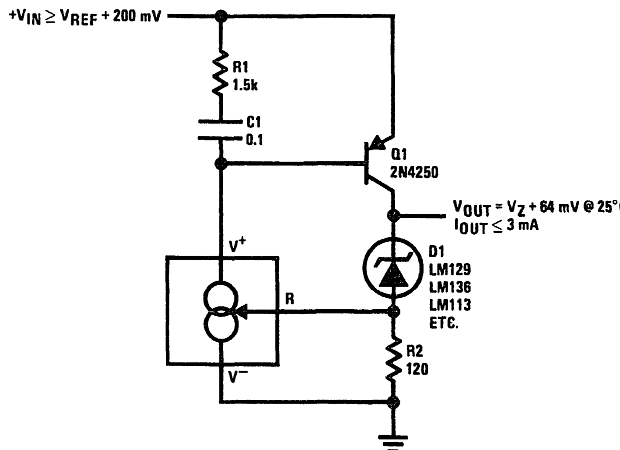
*Select R1 and C1 for optimum stability

Micropower Bias



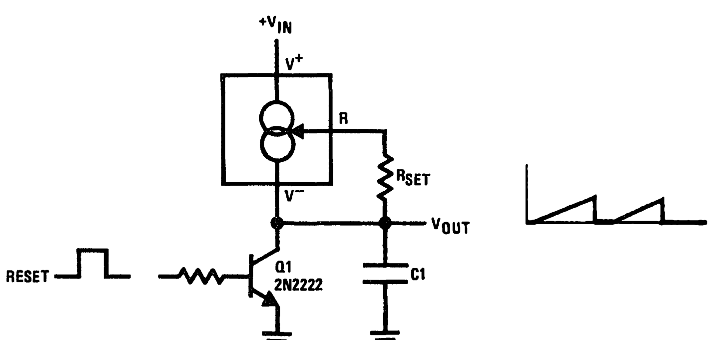
TL/H/5697-17

Low Input Voltage Reference Driver



TL/H/5697-18

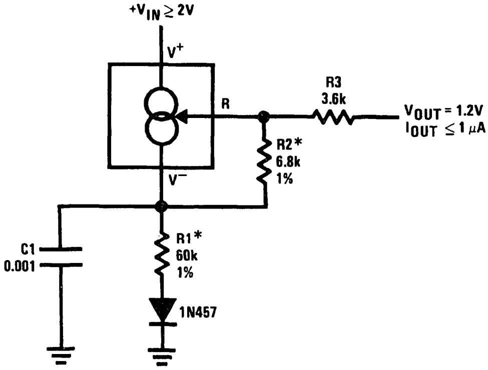
Ramp Generator



TL/H/5697-19

Typical Applications (Continued)

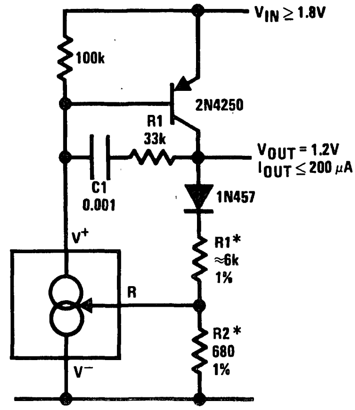
1.2V Reference Operates on 10 μA and 2V



TL/H/5697-20

*Select ratio of R1 to R2 to obtain zero temperature drift

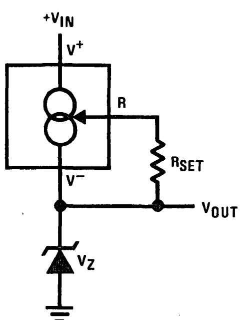
1.2V Regulator with 1.8V Minimum Input



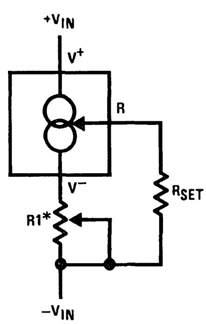
TL/H/5697-7

*Select ratio of R1 to R2 for zero temperature drift

Zener Biasing

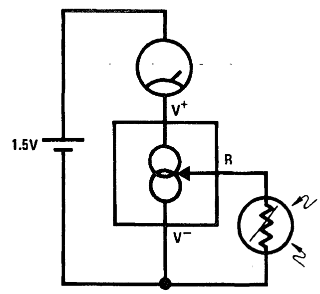


Alternate Trimming Technique



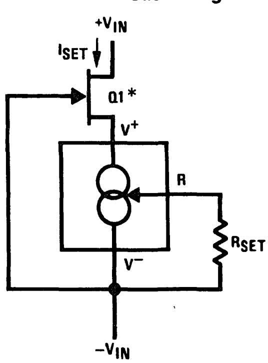
*For ±10% adjustment, select R_{SET} 10% high, and make R1 ≈ 3 R_{SET}

Buffer for Photoconductive Cell

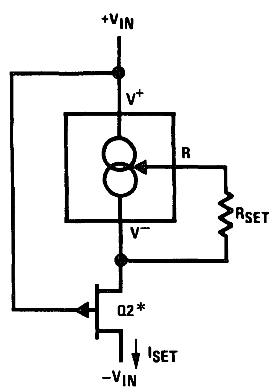


TL/H/5697-8

FET Cascoding for Low Capacitance and/or Ultra High Output Impedance



TL/H/5697-21

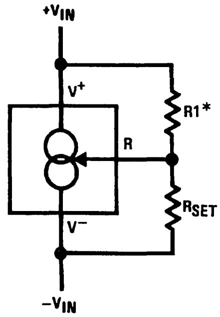


TL/H/5697-22

*Select Q1 or Q2 to ensure at least 1V across the LM134. $V_p (1 - I_{SET}/I_{DSS}) \geq 1.2V$.

Typical Applications (Continued)

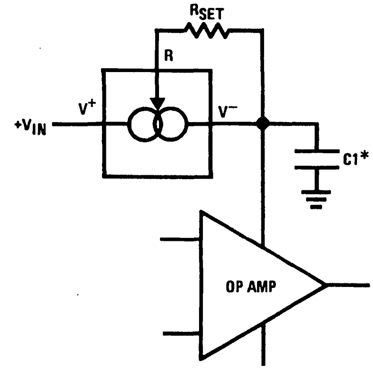
Generating Negative Output Impedance



TL/H/5697-23

*$Z_{OUT} \approx -16 \bullet R1$ ($R1/V_{IN}$ must not exceed I_{SET})

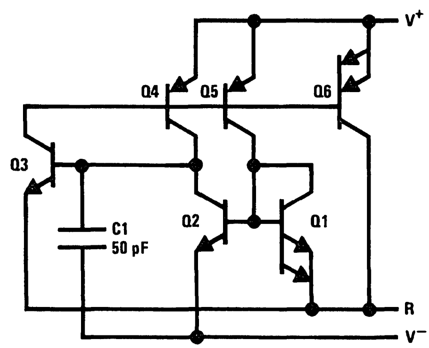
In-Line Current Limiter



TL/H/5697-9

*Use minimum value required to ensure stability of protected device. This minimizes inrush current to a direct short.

Schematic Diagram



TL/H/5697-11