

## LM168/LM268/LM368 Precision Voltage Reference

### General Description

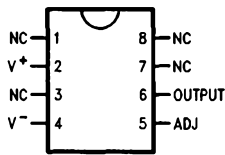
The LM168/LM368 are precision, monolithic, temperature-compensated voltage references. The LM168 makes use of thin-film technology enhanced by the discrete laser trimming of resistors to achieve excellent Temperature coefficient (Tempco) of  $V_{OUT}$  (as low as 5ppm/°C), along with tight initial tolerance, (as low as 0.02%). The trim scheme is such that individual resistors are cut open rather than being trimmed (partially cut), to avoid resistor drift caused by electromigration in the trimmed area. The LM168 also provides excellent stability vs. changes in input voltage and output current (both sourcing and sinking). This device is available in output voltage options of 5.0V and 10.0V and will operate in both series or shunt mode. Also see the LM368-2.5 data sheet for a 2.5V output. The devices are short circuit proof when sourcing current. A trim pin is made available for fine trimming of  $V_{OUT}$  or for obtaining intermediate values without greatly affecting the Tempco of the device.

### Features

- 300  $\mu$ A operating current
- Low output impedance
- Excellent line regulation (.0001%/V typical)
- Single-supply operation
- Externally trimmable
- Low temperature coefficient
- Operates in series or shunt mode
- 10.0V or 5.0V
- Excellent initial accuracy (0.02% typical)

### Connection Diagram

Dual-In-Line Package (N)  
or S.O. Package (M)

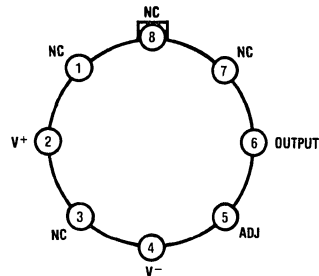


Top View

Order Number LM368N-5.0  
or LM268BYN-5.0  
See NS Package Number N08E

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Metal Can Package



Top View

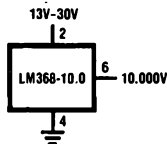
\*case connected to V-

Order Number LM168BYH-10, LM168BYH-5.0,  
LM268BYH-10, LM268BYH-5.0,  
LM368YH-10, LM368YH-5.0, LM368H-10, LM368H-5.0  
See NS Package Number H08C

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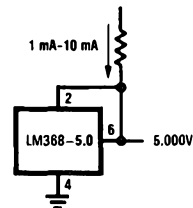
### Typical Applications

Series Regulator



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Shunt Regulator



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**Absolute Maximum Ratings** (Note 8)

Input Voltage (Series Mode)	35V
Reverse Current (Shunt Mode)	50 mA
Power Dissipation	600 mW
Storage Temperature Range	-60°C to +150°C
Operating Temperature Range	
LM168	-55°C to +125°C
LM268	-40°C to +85°C
LM368	0°C to +70°C

**Soldering Information**

DIP (N) Package, 10 sec.	+260°C
TO-5 (H) Package, 10 sec.	+300°C
SO (M) 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	LM168/LM268/LM368			
		Typical	Tested Limit (Note 2)	Design Limit (Note 3)	Units (Max. unless noted)
$V_{OUT}$ Error: LM168B, LM268B LM368		$\pm 0.02$ $\pm 0.02$	$\pm 0.05$ $\pm 0.1$		% %
Line Regulation	$(V_{OUT} + 3V) \leq V_{IN} \leq 30V$	$\pm 0.0001$	$\pm 0.0005$		%/V
Load Regulation (Note 4)	$0 \text{ mA} \leq I_{SOURCE} \leq 10 \text{ mA}$ $-10 \text{ mA} \leq I_{SINK} \leq 0 \text{ mA}$	$\pm 0.0003$ $\pm 0.003$	$\pm 0.001$ $\pm 0.008$		%/mA %/mA
Thermal Regulation	$T = 20 \text{ mS}$ (Note 5)	$\pm 0.005$	$\pm 0.01$		%/100 mW
Quiescent Current		250	350		$\mu\text{A}$
Change of Quiescent Current vs. $V_{IN}$	$(V_{OUT} + 3V) \leq V_{IN} \leq 30V$	3	5		$\mu\text{A}/V$
Temperature Coefficient of $V_{OUT}$ (see graph): LM168BY (Note 6) LM268BY LM368Y LM368	$-55^\circ\text{C} \leq T_A \leq 125^\circ\text{C}$ $-40^\circ\text{C} \leq T_A \leq 85^\circ\text{C}$ $0^\circ\text{C} \leq T_A \leq 70^\circ\text{C}$ $0^\circ\text{C} \leq T_A \leq 70^\circ\text{C}$	$\pm 5$ $\pm 7.5$ $\pm 11$ $\pm 15$	$\pm 10$ $\pm 15$ $\pm 20$	$\pm 30$	ppm/ $^\circ\text{C}$ ppm/ $^\circ\text{C}$ ppm/ $^\circ\text{C}$ ppm/ $^\circ\text{C}$
Short Circuit Current	$V_{OUT} = 0$	30	70	100	mA
Noise:					
10.0V: 0.1 - 10Hz		30			$\mu\text{Vp-p}$
100Hz - 10 kHz		1100			$\text{nV}/\sqrt{\text{Hz}}$
6.2V: 0.1 - 10Hz		20			$\mu\text{Vp-p}$
100Hz - 10 kHz		700			$\text{nV}/\sqrt{\text{Hz}}$
5.0V: 0.1 - 10Hz		16			$\mu\text{Vp-p}$
100Hz - 10 kHz		575			$\text{nV}/\sqrt{\text{Hz}}$
$V_{OUT}$ Adjust Range: 10.000V 5.000V	$0V \leq V_{PIN5} \leq V_{OUT}$	4.5-17.0 4.4-7.0		6.0-15.5 4.5-6.0	V min. V min.

**Note 1:** Unless otherwise noted, these specifications apply:  $T_A = 25^\circ\text{C}$ ,  $V_{IN} = 15V$ ,  $I_{LOAD} = 0$ ,  $0 \leq C_L \leq 200 \text{ pF}$ , Circuit is operating in Series Mode. Or, circuit is operating in Shunt Mode,  $V_{IN} = +15V$  or  $V_{IN} = V_{OUT}$ ,  $T_A = +25^\circ\text{C}$ ,  $I_{LOAD} = -1.0 \text{ mA}$ ,  $0 \leq C_L \leq 200 \text{ pF}$ .

**Note 2:** Tested Limits are guaranteed and 100% tested in production.

**Note 3:** Design Limits are guaranteed (but not 100% production tested) over the indicated temperature and supply voltage ranges. These limits are not used to calculate outgoing quality levels.

**Note 4:** The LM168 has a Class B output, and will exhibit transients at the crossover point. This point occurs when the device is asked to sink approximately 120  $\mu\text{A}$ . In some applications it may be advantageous to preload the output to either  $V_{IN}$  or Ground, to avoid this crossover point.

**Note 5:** Thermal Regulation is defined as the change in the output Voltage at a time T after a step change in power dissipation of 100 mW.

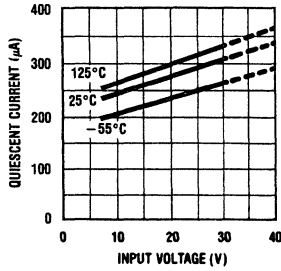
**Note 6:** Temperature Coefficient of  $V_{OUT}$  is defined as the worst case  $\Delta V_{OUT}$  measured at Specified Temperatures divided by the total span of the Specified Temperature Range (See graphs). There is no guarantee that the Specified Temperatures are exactly at the minimum or maximum deviation.

**Note 7:** In metal can (H),  $\theta_{J-C}$  is  $75^\circ\text{C}/W$  and  $\theta_{J-A}$  is  $150^\circ\text{C}/W$ . In plastic DIP,  $\theta_{J-A}$  is  $160^\circ\text{C}/W$ . In SO-8,  $\theta_{J-A}$  is  $180^\circ\text{C}/W$ , in TO-92,  $\theta_{J-A}$  is  $160^\circ\text{C}/W$ .

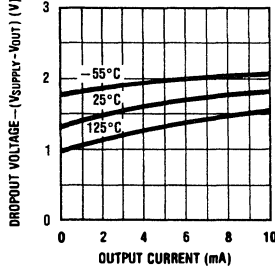
**Note 8:** Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its Rated Operating Conditions (see Note 1 and Conditions).

# Typical Performance Characteristics (Note 1)

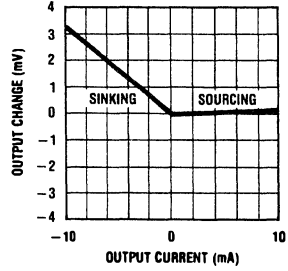
**Quiescent Current vs. Input Voltage and Temperature**



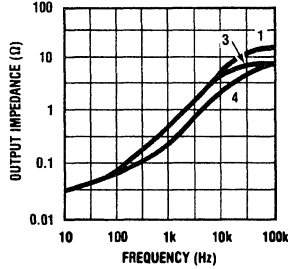
**Dropout Voltage vs. Output Current (Series Mode Sourcing Current)**



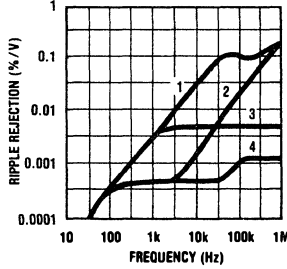
**Output Change vs. Output Current**



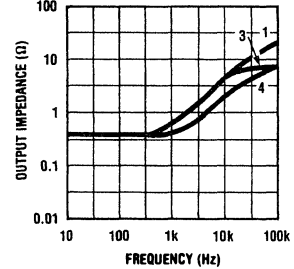
**Output Impedance vs. Frequency (Sourcing Current)**



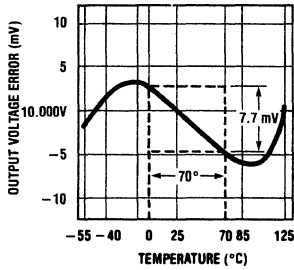
**Ripple Rejection vs. Frequency**



**Output Impedance vs. Frequency (Sinking Current)**

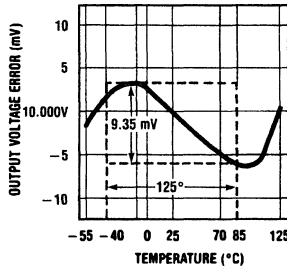


**Temperature Coefficient: LM368-10 (Curve A)**



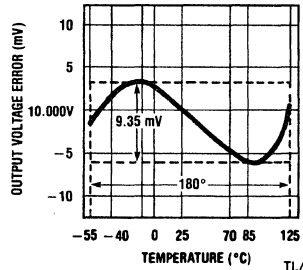
Typical Temperature Coefficient Calculations:  
 LM368-10 (see Curve A)  
 $T.C. = 7.7 \text{ mV} / (70^\circ \times 10\text{V})$   
 $= 11 \times 10E-6 = 11 \text{ ppm}/^\circ\text{C}$

**Temperature Coefficient: LM268-10 (Curve B)**



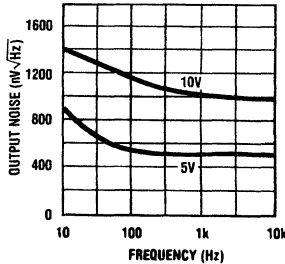
LM268-10 (see Curve B)  
 $T.C. = 9.35 \text{ mV} / (125^\circ \times 10\text{V})$   
 $= 7.5 \times 10E-6 = 7.5 \text{ ppm}/^\circ\text{C}$

**Temperature Coefficient: LM168-10 (Curve C)**



LM168-10 (see Curve C)  
 $T.C. = 9.35 \text{ mV} / (180^\circ \times 10\text{V})$   
 $= 5.2 \times 10E-6 = 5.2 \text{ ppm}/^\circ\text{C}$

**Output Noise vs. Frequency**

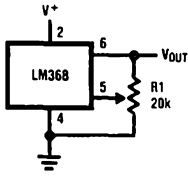


- (1) LM368 alone.
- (2) with 0.01 µf Mylar, Trim to Gnd.
- (3) with 10Ω in series with 10 µf, V<sub>OUT</sub> to Gnd.
- (4) with Both.

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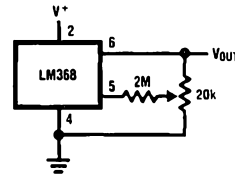
# Typical Applications

## Wide Range Trimmable Regulator



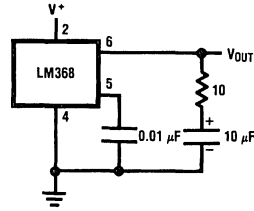
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## Narrow Range Trimmable Regulator ( $\pm 1\%$ min.)



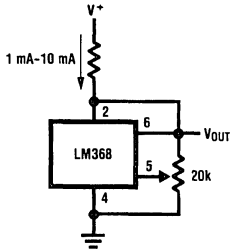
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## Improved Noise Performance



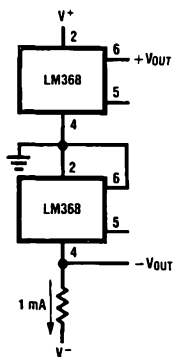
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## Adjustable Zener



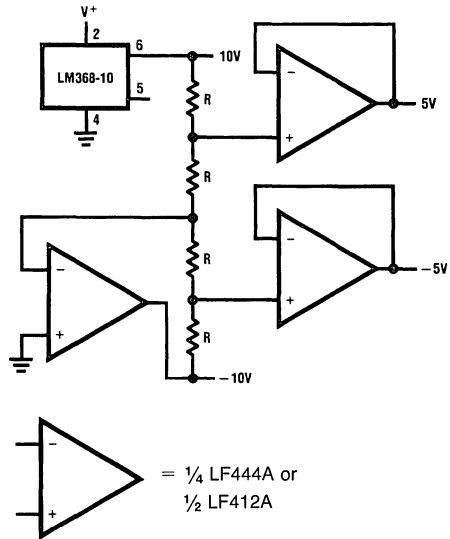
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## $\pm$ Reference



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## $\pm 10V, \pm 5V$ References

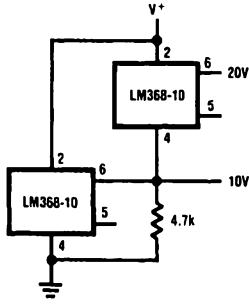


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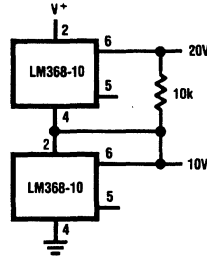
R = Thin Film Resistor Network,  
 $\pm 0.05\%$  Matching and 5ppm Tracking  
 (Beckman 694-3-R-10K-A),  
 (Caddock T-914-10K-100-05)  
 or similar.

# Typical Applications (Continued)

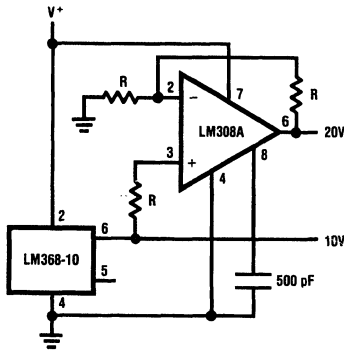
## Multiple Output Voltages



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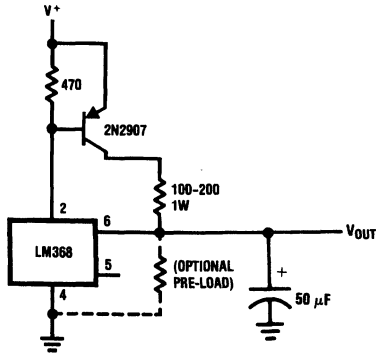
TL/H/5522-14



R = Thin Film Resistor Network  
 0.05% Matching and 5ppm Tracking  
 (Beckman 694-3-R-10K-A),  
 (Caddock T-914-10K-100-05)  
 or similar.

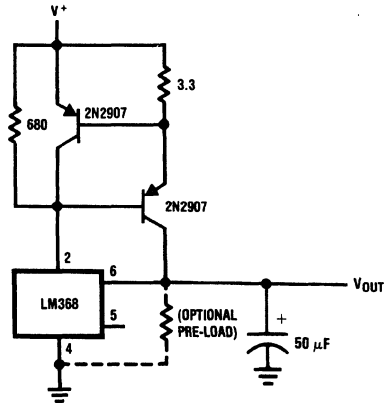
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## Reference with Booster



TL/H/5522-16

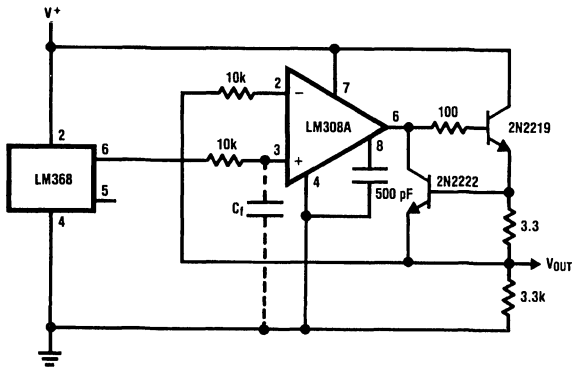
## 100 mA Boosted Reference



TL/H/5522-17

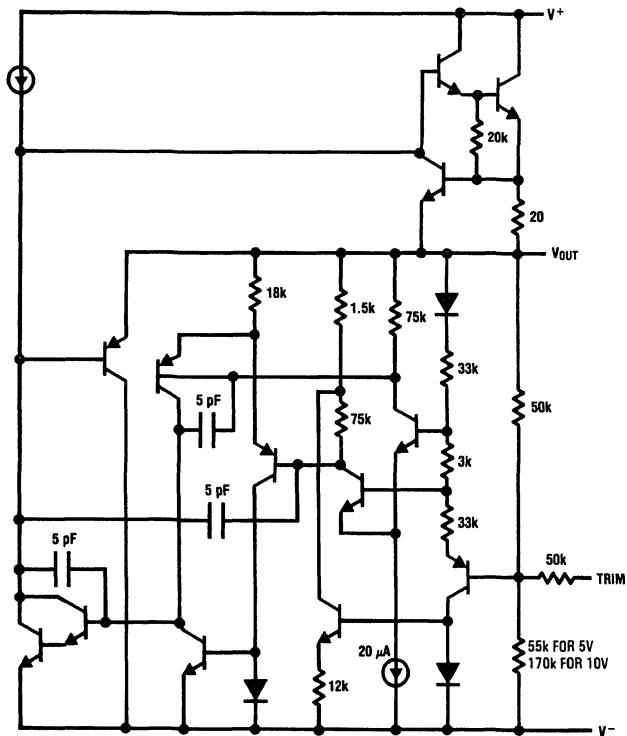
Typical Applications (Continued)

Buffered High-Current Reference with Filter



TL/H/5522-18

Simplified Schematic Diagram



TL/H/5522-6

\*Reg. U.S. Pat. Off.