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## LM613 Dual Operational Amplifiers, Dual Comparators, and Adjustable Reference

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### FEATURES

#### OP AMP

- **Low Operating Current (Op Amp): 300  $\mu$ A**
- **Wide Supply Voltage Range: 4V to 36V**
- **Wide Common-Mode Range:  $V^-$  to  $(V^+ - 1.8V)$**
- **Wide Differential Input Voltage:  $\pm 36V$**
- **Available in Plastic Package Rated for Military Temp. Range Operation**

#### REFERENCE

- **Adjustable Output Voltage: 1.2V to 6.3V**
- **Tight Initial Tolerance Available:  $\pm 0.6\%$**
- **Wide Operating Current Range: 17  $\mu$ A to 20 mA**
- **Tolerant of Load Capacitance**

### APPLICATIONS

- **Transducer Bridge Driver**
- **Process and Mass Flow Control Systems**
- **Power Supply Voltage Monitor**
- **Buffered Voltage References for A/D's**

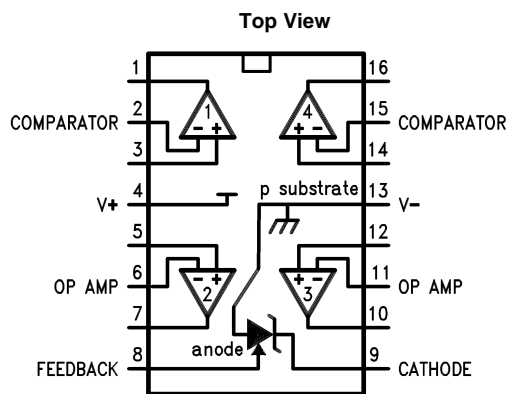
### DESCRIPTION

The LM613 consists of dual op-amps, dual comparators, and a programmable voltage reference in a 16-pin package. The op-amps out-performs most single-supply op-amps by providing higher speed and bandwidth along with low supply current. This device was specifically designed to lower cost and board space requirements in transducer, test, measurement, and data acquisition systems.

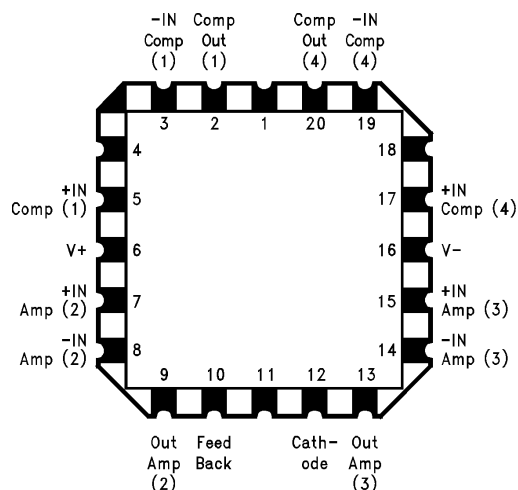
Combining a stable voltage reference with wide output swing op-amps makes the LM613 ideal for single supply transducers, signal conditioning and bridge driving where large common-mode-signals are common. The voltage reference consists of a reliable band-gap design that maintains low dynamic output impedance (1 $\Omega$  typical), excellent initial tolerance (0.6%), and the ability to be programmed from 1.2V to 6.3V via two external resistors. The voltage reference is very stable even when driving large capacitive loads, as are commonly encountered in CMOS data acquisition systems.

As a member of TI's Super-Block™ family, the LM613 is a space-saving monolithic alternative to a multi-chip solution, offering a high level of integration without sacrificing performance.

### Connection Diagrams



**Figure 1. CDIP and SOIC Packages**  
See Package Numbers NFE0016A and DW0016B



**Figure 2. E Package Pinout**



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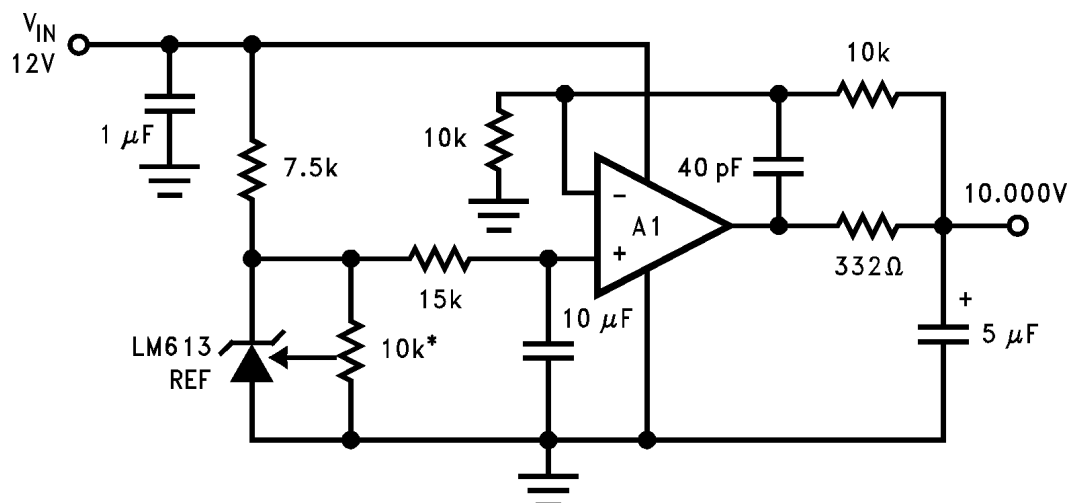
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## LM613



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\*10k must be low  
t.c. trimpot

**Figure 3. Ultra Low Noise, 10.00V Reference**  
Total Output Noise is Typically 14  $\mu\text{V}_{\text{RMS}}$



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

### Absolute Maximum Ratings<sup>(1)(2)</sup>

Voltage on Any Pin Except $V_R$ (referred to $V^-$ pin)	See <sup>(3)</sup>	36V (Max)
	See <sup>(4)</sup>	–0.3V (Min)
Current through Any Input Pin & $V_R$ Pin		±20 mA
Differential Input Voltage	Military and Industrial	±36V
	Commercial	±32V
Storage Temperature Range		–65°C ≤ $T_J$ ≤ +150°C
Maximum Junction Temperature <sup>(5)</sup>		150°C
Thermal Resistance, Junction-to-Ambient <sup>(6)</sup>	N Package	100°C/W
	DW0016B Package	150°C/W
Soldering Information (10 Sec.)	N Package	260°C
	DW0016B Package	220°C
ESD Tolerance <sup>(7)</sup>		±1 kV

- (1) Absolute maximum ratings indicate limits beyond which damage to the component may occur. Electrical specifications do not apply when operating the device beyond its rated operating conditions.
- (2) If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/ Distributors for availability and specifications.
- (3) Input voltage above  $V^+$  is allowed. As long as one input pin voltage remains inside the common-mode range, the comparator will deliver the correct output.
- (4) More accurately, it is excessive current flow, with resulting excess heating, that limits the voltages on all pins. When any pin is pulled a diode drop below  $V^-$ , a parasitic NPN transistor turns ON. No latch-up will occur as long as the current through that pin remains below the Maximum Rating. Operation is undefined and unpredictable when any parasitic diode or transistor is conducting.
- (5) Simultaneous short-circuit of multiple comparators while using high supply voltages may force junction temperature above maximum, and thus should not be continuous.
- (6) Junction temperature may be calculated using  $T_J = T_A + P_D \theta_{JA}$ . The given thermal resistance is worst-case for packages in sockets in still air. For packages soldered to copper-clad board with dissipation from one comparator or reference output transistor, nominal  $\theta_{JA}$  is 90°C/W for the N package, and 135°C/W for the DW0016B package.
- (7) Human body model, 100 pF discharged through a 1.5 kΩ resistor.

### Operating Temperature Range

LM613AI, LM613BI	–40°C to +85°C
LM613AM, LM613M	–55°C to +125°C
LM613C	0°C ≤ $T_J$ ≤ +70°C

## LM613

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### Electrical Characteristics

These specifications apply for  $V^- = \text{GND} = 0\text{V}$ ,  $V^+ = 5\text{V}$ ,  $V_{\text{CM}} = V_{\text{OUT}} = 2.5\text{V}$ ,  $I_{\text{R}} = 100\text{ }\mu\text{A}$ , FEEDBACK pin shorted to GND, unless otherwise specified. Limits in standard typeface are for  $T_{\text{J}} = 25^\circ\text{C}$ ; limits in **bold face type** apply over the **Operating Temperature Range**.

Parameter		Test Conditions	Typ <sup>(1)</sup>	LM613AM LM613AI Limits <sup>(2)</sup>	LM613M LM613I LM613C Limits <sup>(2)</sup>	Units
I <sub>S</sub>	Total Supply Current	R <sub>LOAD</sub> = ∞, 4V ≤ V <sup>+</sup> ≤ 36V (32V for LM613C)	450 550	940 1000	1000 1070	μA (Max) μA (Max)
V <sub>S</sub>	Supply Voltage Range		2.2 2.9	2.8 3	2.8 3	V (Min) V (Min)
			46 43	36 36	32 32	V (Max) V (Max)
OPERATIONAL AMPLIFIERS						
V <sub>OS1</sub>	V <sub>OS</sub> Over Supply	4V ≤ V <sup>+</sup> ≤ 36V (4V ≤ V <sup>+</sup> ≤ 32V for LM613C)	1.5 2.0	3.5 6.0	5.0 7.0	mV (Max) mV (Max)
V <sub>OS2</sub>	V <sub>OS</sub> Over V <sub>CM</sub>	V <sub>CM</sub> = 0V through V <sub>CM</sub> = (V <sup>+</sup> − 1.8V), V <sup>+</sup> = 30V, V <sup>−</sup> = 0V	1.0 1.5	3.5 6.0	5.0 7.0	mV (Max) mV (Max)
$\frac{V_{OS3}}{\Delta T}$	Average V <sub>OS</sub> Drift	See <sup>(2)</sup>	15			μV/°C (Max)
I <sub>B</sub>	Input Bias Current		10 11	25 30	35 40	nA (Max) nA (Max)
I <sub>OS</sub>	Input Offset Current		0.2 0.3	4 5	4 5	nA (Max) nA (Max)
$\frac{I_{OS1}}{\Delta T}$	Average Offset Current		4			pA/°C
R <sub>IN</sub>	Input Resistance	Differential	1000			MΩ
C <sub>IN</sub>	Input Capacitance	Common-Mode	6			pF
e <sub>n</sub>	Voltage Noise	f = 100 Hz, Input Referred	74			nV/√Hz
I <sub>n</sub>	Current Noise	f = 100 Hz, Input Referred	58			fA/√Hz
CMRR	Common-Mode Rejection Ratio	V <sup>+</sup> = 30V, 0V ≤ V <sub>CM</sub> ≤ (V <sup>+</sup> − 1.8V) CMRR = 20 log (ΔV <sub>CM</sub> /ΔV <sub>OS</sub> )	95 90	80 75	75 70	dB (Min) dB (Min)
PSRR	Power Supply Rejection Ratio	4V ≤ V <sup>+</sup> ≤ 30V, V <sub>CM</sub> = V <sup>+</sup> /2, PSRR = 20 log (ΔV <sup>+</sup> /V <sub>OS</sub> )	110 100	80 75	75 70	dB (Min) dB (Min)
A <sub>V</sub>	Open Loop Voltage Gain	R <sub>L</sub> = 10 kΩ to GND, V <sup>+</sup> = 30V, 5V ≤ V <sub>OUT</sub> ≤ 25V	500 50	100 40	94 40	V/mV (Min)
SR	Slew Rate	V <sup>+</sup> = 30V <sup>(3)</sup>	0.70 0.65	0.55 0.45	0.50 0.45	V/μs
GBW	Gain Bandwidth	C <sub>L</sub> = 50 pF	0.8 0.5			MHz MHz
V <sub>O1</sub>	Output Voltage Swing High	R <sub>L</sub> = 10 kΩ to GND, V <sup>+</sup> = 36V (32V for LM613C)	V <sup>+</sup> − 1.4 V <sup>+</sup> − 1.6	V <sup>+</sup> − 1.7 V <sup>+</sup> − 1.9	V <sup>+</sup> − 1.8 V <sup>+</sup> − 1.9	V (Min) V (Min)
V <sub>O2</sub>	Output Voltage Swing Low	R <sub>L</sub> = 10 kΩ to V <sup>+</sup> , V <sup>+</sup> = 36V (32V for LM613C)	V <sup>−</sup> + 0.8 V <sup>−</sup> + 0.9	V <sup>−</sup> + 0.9 V <sup>−</sup> + 1.0	V <sup>−</sup> + 0.95 V <sup>−</sup> + 1.0	V (Max) V (Max)
I <sub>OUT</sub>	Output Source Current	V <sub>OUT</sub> = 2.5V, V <sup>+</sup> <sub>IN</sub> = 0V, V <sup>−</sup> <sub>IN</sub> = −0.3V	25 15	20 13	16 13	mA (Min) mA (Min)
I <sub>SINK</sub>	Output Sink Current	V <sub>OUT</sub> = 1.6V, V <sup>+</sup> <sub>IN</sub> = 0V, V <sup>−</sup> <sub>IN</sub> = 0.3V	17 9	14 8	13 8	mA (Min) mA (Min)
I <sub>SHORT</sub>	Short Circuit Current	V <sub>OUT</sub> = 0V, V <sup>+</sup> <sub>IN</sub> = 3V, V <sup>−</sup> <sub>IN</sub> = 2V	30 40	50 60	50 60	mA (Max) mA (Max)
		V <sub>OUT</sub> = 5V, V <sup>+</sup> <sub>IN</sub> = 2V, V <sup>−</sup> <sub>IN</sub> = 3V	30 32	60 80	70 90	mA (Max) mA (Max)

(1) Typical values in standard typeface are for  $T_{\text{J}} = 25^\circ\text{C}$ ; values in **bold face type** apply for the full operating temperature range. These values represent the most likely parametric norm.

(2) All limits are ensured at room temperature (standard type face) or at operating temperature extremes (**bold type face**).

(3) Slew rate is measured with the op amp in a voltage follower configuration. For rising slew rate, the input voltage is driven from 5V to 25V, and the output voltage transition is sampled at 10V and @ 20V. For falling slew rate, the input voltage is driven from 25V to 5V, and the output voltage transition is sampled at 20V and 10V.

## Electrical Characteristics (continued)

These specifications apply for  $V^- = \text{GND} = 0\text{V}$ ,  $V^+ = 5\text{V}$ ,  $V_{\text{CM}} = V_{\text{OUT}} = 2.5\text{V}$ ,  $I_{\text{R}} = 100\text{ }\mu\text{A}$ , FEEDBACK pin shorted to GND, unless otherwise specified. Limits in standard typeface are for  $T_{\text{J}} = 25^\circ\text{C}$ ; limits in **boldface type** apply over the **Operating Temperature Range**.

Parameter	Test Conditions	Typ <sup>(1)</sup>	LM613AM LM613AI Limits <sup>(2)</sup>	LM613M LM613I LM613C Limits <sup>(2)</sup>	Units
<b>COMPARATORS</b>					
$V_{\text{OS}}$	Offset Voltage	$4\text{V} \leq V^+ \leq 36\text{V}$ (32V for LM613C), $R_{\text{L}} = 15\text{ k}\Omega$	1.0 <b>2.0</b>	3.0 <b>6.0</b>	5.0 <b>7.0</b> mV (Max) mV (Max)
$V_{\text{OS}}$ $V_{\text{CM}}$	Offset Voltage over $V_{\text{CM}}$	$0\text{V} \leq V_{\text{CM}} \leq 36\text{V}$ $V^+ = 36\text{V}$ , (32V for LM613C)	1.0 <b>1.5</b>	3.0 <b>6.0</b>	5.0 <b>7.0</b> mV (Max) mV (Max)
$\frac{V_{\text{OS}}}{\Delta T}$	Average Offset Voltage Drift		<b>15</b>		$\mu\text{V}/^\circ\text{C}$ (Max)
$I_{\text{B}}$	Input Bias Current		5 <b>8</b>	25 <b>30</b>	35 <b>40</b> nA (Max) nA (Max)
$I_{\text{OS}}$	Input Offset Current		0.2 <b>0.3</b>	4 <b>5</b>	4 <b>5</b> nA (Max) nA (Max)
$A_{\text{V}}$	Voltage Gain	$R_{\text{L}} = 10\text{ k}\Omega$ to 36V (32V for LM613C) $2\text{V} \leq V_{\text{OUT}} \leq 27\text{V}$	500 <b>100</b>		V/mV V/mV
$t_{\text{r}}$	Large Signal Response Time	$V_{\text{IN}}^+ = 1.4\text{V}$ , $V_{\text{IN}}^- = \text{TTL Swing}$ , $R_{\text{L}} = 5.1\text{ k}\Omega$	1.5 <b>2.0</b>		$\mu\text{s}$ $\mu\text{s}$
$I_{\text{SINK}}$	Output Sink Current	$V_{\text{IN}}^+ = 0\text{V}$ , $V_{\text{IN}}^- = 1\text{V}$ , $V_{\text{OUT}} = 1.5\text{V}$ $V_{\text{OUT}} = 0.4\text{V}$	20 <b>13</b>	10 <b>8</b>	10 <b>8</b> mA (Min) mA (Min)
			2.8 <b>2.4</b>	1.0 <b>0.5</b>	0.8 <b>0.5</b> mA (Min) mA (Min)
$I_{\text{LEAK}}$	Output Leakage Current	$V_{\text{IN}}^+ = 1\text{V}$ , $V_{\text{IN}}^- = 0\text{V}$ , $V_{\text{OUT}} = 36\text{V}$ (32V for LM613C)	0.1 <b>0.2</b>	10	10 $\mu\text{A}$ (Max) $\mu\text{A}$ (Max)
<b>VOLTAGE REFERENCE</b>					
$V_{\text{R}}$	Voltage Reference	See <sup>(4)</sup>	1.244	1.2365 1.2515 ( $\pm 0.6\%$ )	1.2191 1.2689 ( $\pm 2\%$ ) V (Min) V (Max)
$\frac{\Delta V_{\text{R}}}{\Delta T}$	Average Temp. Drift	See <sup>(5)</sup>	<b>10</b>	<b>80</b>	<b>150</b> ppm/ $^\circ\text{C}$ (Max)
$\frac{\Delta V_{\text{R}}}{\Delta T_{\text{J}}}$	Hysteresis	See <sup>(6)</sup>	<b>3.2</b>		$\mu\text{V}/^\circ\text{C}$
$\frac{\Delta V_{\text{R}}}{\Delta I_{\text{R}}}$	$V_{\text{R}}$ Change with Current	$V_{\text{R}}(100\text{ }\mu\text{A}) - V_{\text{R}}(17\text{ }\mu\text{A})$	0.05 <b>0.1</b>	1 <b>1.1</b>	1 <b>1.1</b> mV (Max) mV (Max)
		$V_{\text{R}}(10\text{ mA}) - V_{\text{R}}(100\text{ }\mu\text{A})$ See <sup>(7)</sup>	1.5 <b>2.0</b>	5 <b>5.5</b>	5 <b>5.5</b> mV (Max) mV (Max)
R	Resistance	$\Delta V_{\text{R}}(10 \rightarrow 0.1\text{ mA})/9.9\text{ mA}$ $\Delta V_{\text{R}}(100 \rightarrow 17\text{ }\mu\text{A})/83\text{ }\mu\text{A}$	<b>0.2</b> <b>0.6</b>	<b>0.56</b> <b>13</b>	<b>0.56</b> <b>13</b> $\Omega$ (Max) $\Omega$ (Max)
$\frac{V_{\text{R}}}{\Delta V_{\text{RO}}}$	$V_{\text{R}}$ Change with High $V_{\text{RO}}$	$V_{\text{R}}(V_{\text{RO}} = V_{\text{R}}) - V_{\text{R}}(V_{\text{RO}} = 6.3\text{V})$ (5.06V between Anode and FEEDBACK)	2.5 <b>2.8</b>	7 <b>10</b>	7 <b>10</b> mV (Max) mV (Max)
$\frac{V_{\text{R}}}{\Delta V_{\text{+}}}$	$V_{\text{R}}$ Change with $V_{\text{ANODE}}$ Change	$V_{\text{R}}(V_{\text{+}} = 5\text{V}) - V_{\text{R}}(V_{\text{+}} = 36\text{V})$ ( $V^+ = 32\text{V}$ for LM613C)	0.1 <b>0.1</b>	1.2 <b>1.3</b>	1.2 <b>1.3</b> mV (Max) mV (Max)
		$V_{\text{R}}(V_{\text{+}} = 5\text{V}) - V_{\text{R}}(V_{\text{+}} = 3\text{V})$	0.01 <b>0.01</b>	1 <b>1.5</b>	1 <b>1.5</b> mV (Max) mV (Max)
$I_{\text{FB}}$	FEEDBACK Bias Current	$V_{\text{ANODE}} \leq V_{\text{FB}} \leq 5.06\text{V}$	22 <b>29</b>	35 <b>40</b>	50 <b>55</b> nA (Max) nA (Max)

(4)  $V_{\text{R}}$  is the Cathode-to-feedback voltage, nominally 1.244V.

(5) Average reference drift is calculated from the measurement of the reference voltage at  $25^\circ\text{C}$  and at the temperature extremes. The drift, in ppm/ $^\circ\text{C}$ , is  $10^6 \cdot \Delta V_{\text{R}} / (V_{\text{R}}[25^\circ\text{C}] \cdot \Delta T_{\text{J}})$ , where  $\Delta V_{\text{R}}$  is the lowest value subtracted from the highest,  $V_{\text{R}}[25^\circ\text{C}]$  is the value at  $25^\circ\text{C}$ , and  $\Delta T_{\text{J}}$  is the temperature range. This parameter is ensured by design and sample testing.

(6) Hysteresis is the change in  $V_{\text{R}}$  caused by a change in  $T_{\text{J}}$ , after the reference has been "dehysteresized". To dehysteresize the reference; that is minimize the hysteresis to the typical value, its junction temperature should be cycled in the following pattern, spiraling in toward  $25^\circ\text{C}$ :  $25^\circ\text{C}$ ,  $85^\circ\text{C}$ ,  $-40^\circ\text{C}$ ,  $70^\circ\text{C}$ ,  $0^\circ\text{C}$ ,  $25^\circ\text{C}$ .

(7) Low contact resistance is required for accurate measurement.

## LM613



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### Electrical Characteristics (continued)

These specifications apply for  $V^- = \text{GND} = 0\text{V}$ ,  $V^+ = 5\text{V}$ ,  $V_{\text{CM}} = V_{\text{OUT}} = 2.5\text{V}$ ,  $I_{\text{R}} = 100\text{ }\mu\text{A}$ , FEEDBACK pin shorted to GND, unless otherwise specified. Limits in standard typeface are for  $T_{\text{J}} = 25^\circ\text{C}$ ; limits in **boldface type** apply over the **Operating Temperature Range**.

Parameter		Test Conditions	Typ <sup>(1)</sup>	LM613AM LM613AI Limits <sup>(2)</sup>	LM613M LM613I LM613C Limits <sup>(2)</sup>	Units
$e_n$	$V_{\text{R}}$ Noise	10 Hz to 10 kHz, $V_{\text{RO}} = V_{\text{R}}$	30			$\mu\text{V}_{\text{RMS}}$

### Simplified Schematic Diagrams

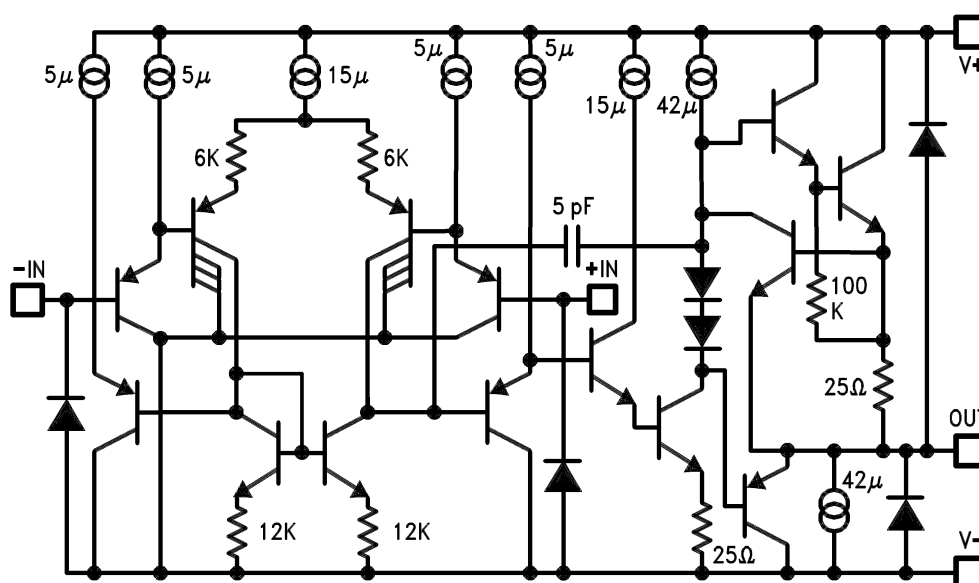
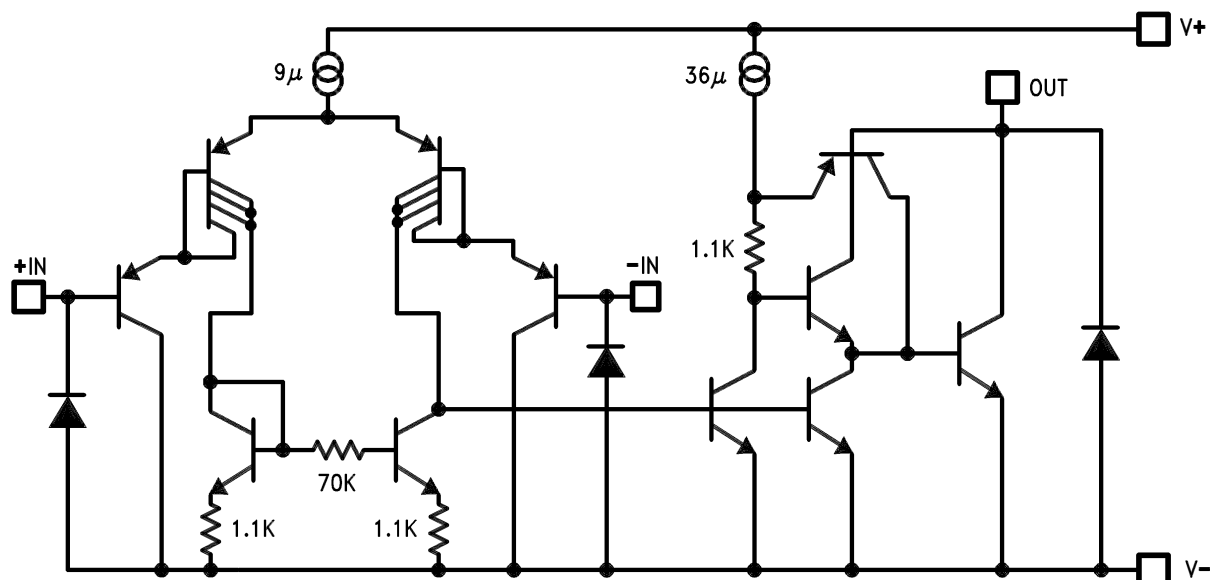
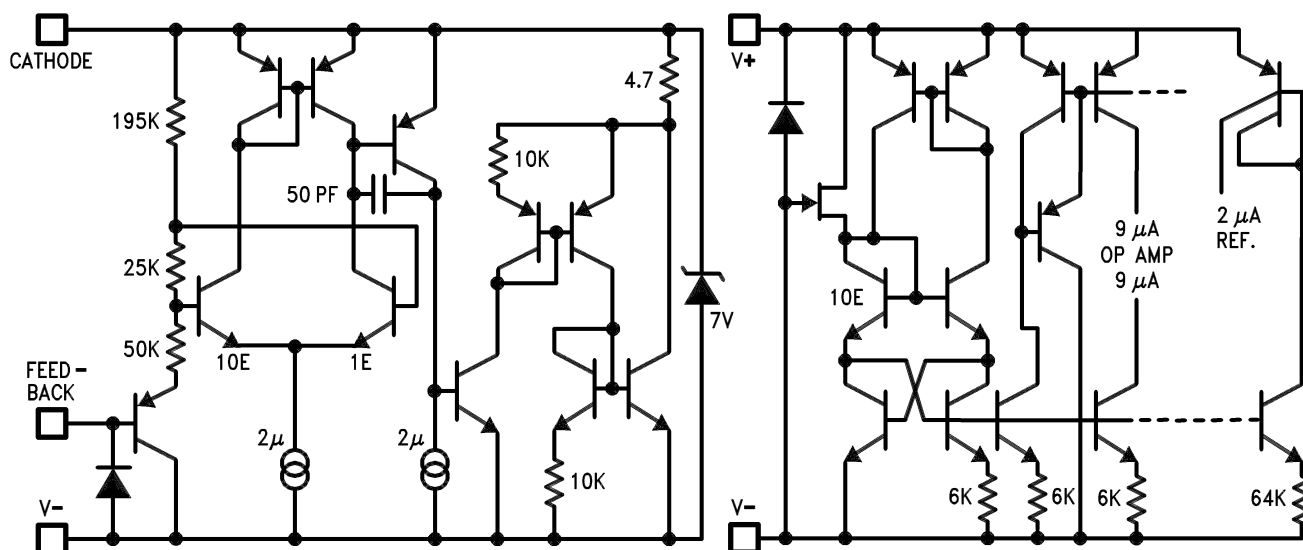


Figure 4. Op Amp



**Figure 5. Comparator**



**Figure 6. Reference/Bias**



## TYPICAL PERFORMANCE CHARACTERISTICS (Reference)

$T_J = 25^\circ\text{C}$ , FEEDBACK pin shorted to  $V^- = 0\text{V}$ , unless otherwise noted

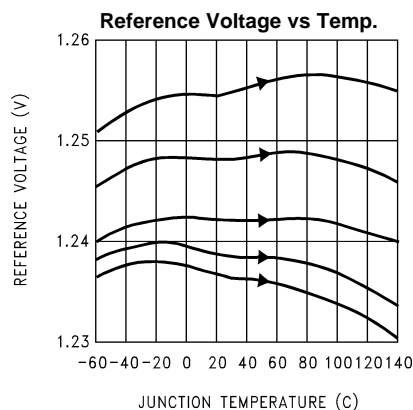


Figure 7.

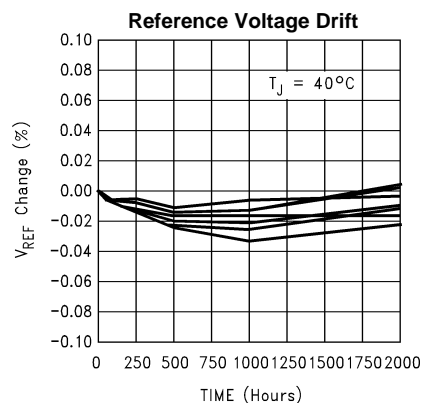


Figure 8.

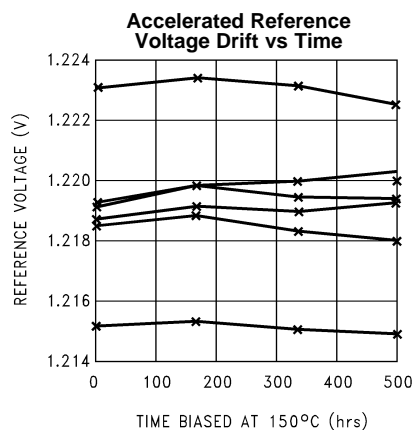


Figure 9.

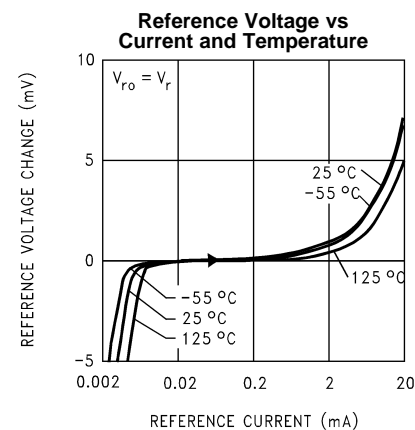


Figure 10.

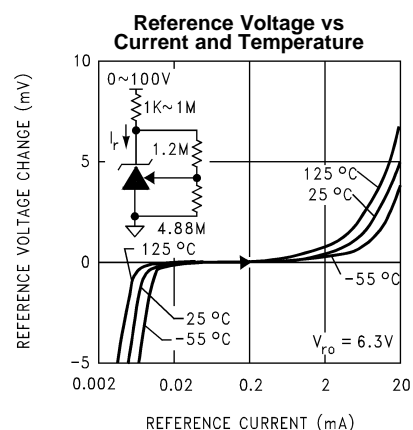


Figure 11.

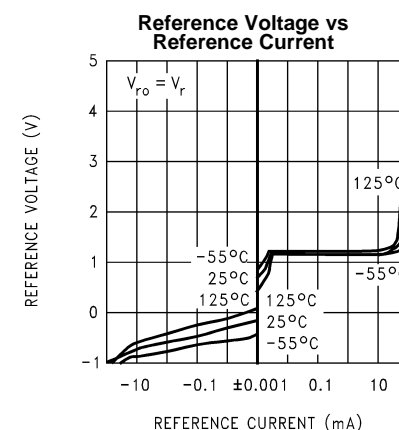
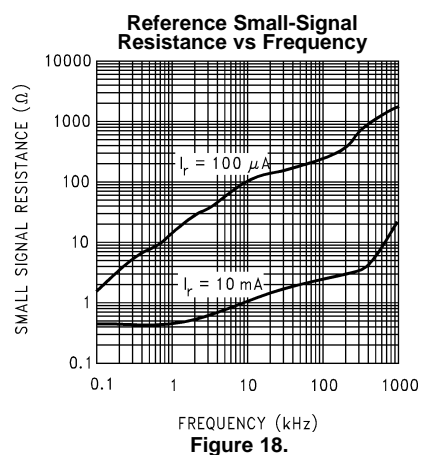
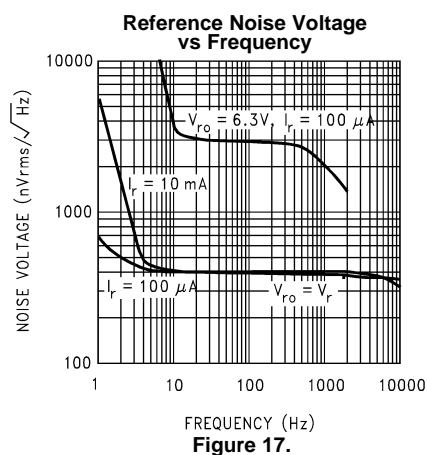
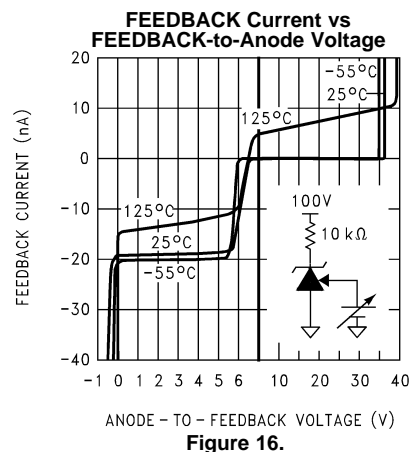
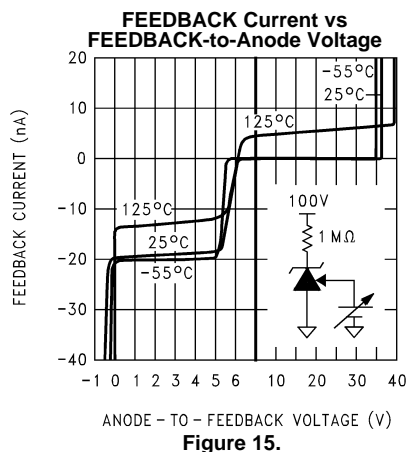
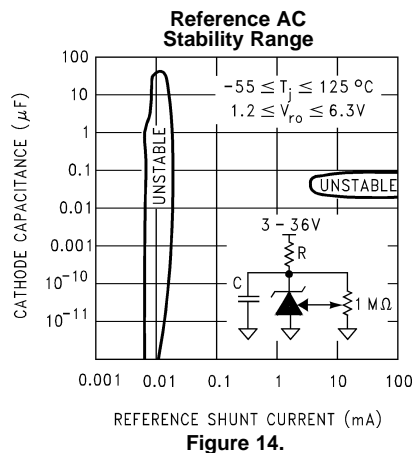
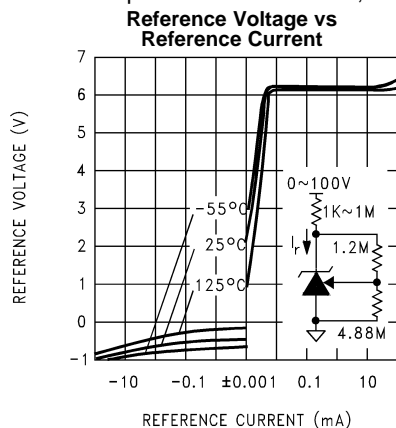


Figure 12.

## TYPICAL PERFORMANCE CHARACTERISTICS (Reference) (continued)

$T_J = 25^\circ\text{C}$ , FEEDBACK pin shorted to  $V^- = 0\text{V}$ , unless otherwise noted



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## TYPICAL PERFORMANCE CHARACTERISTICS (Reference) (continued)

$T_J = 25^\circ\text{C}$ , FEEDBACK pin shorted to  $V^- = 0\text{V}$ , unless otherwise noted

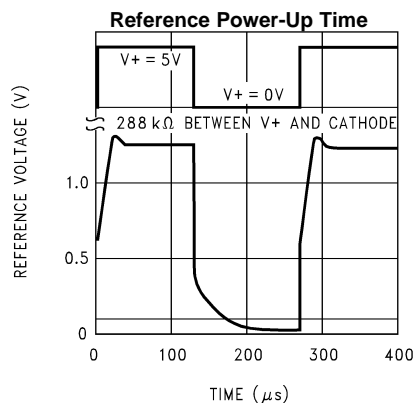


Figure 19.

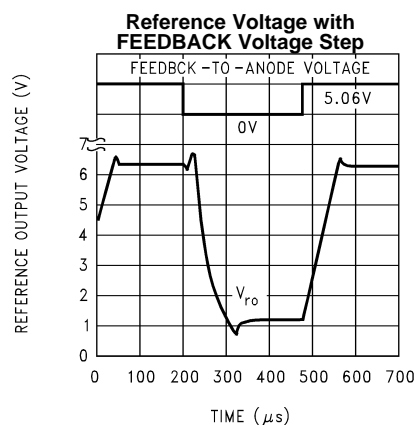


Figure 20.

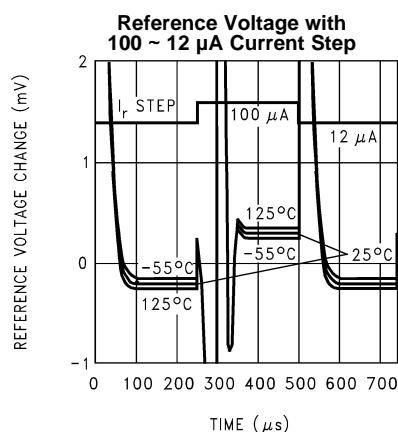


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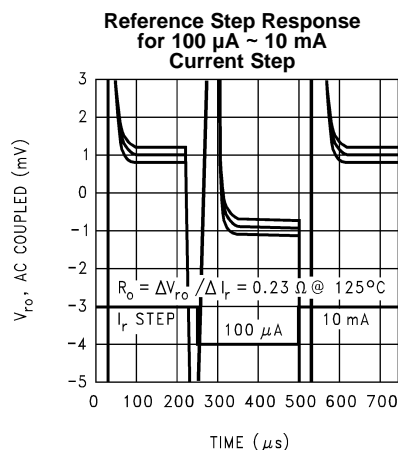


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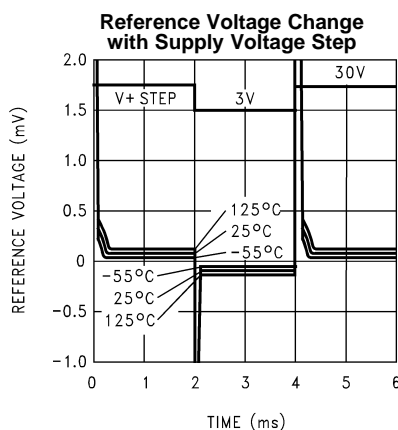


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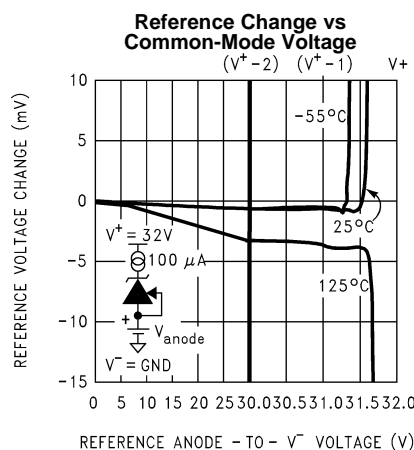


Figure 24.

## TYPICAL PERFORMANCE CHARACTERISTICS (Op Amps)

$V^+ = 5V$ ,  $V^- = GND = 0V$ ,  $V_{CM} = V^+/2$ ,  $V_{OUT} = V^+/2$ ,  $T_J = 25^\circ C$ , unless otherwise noted

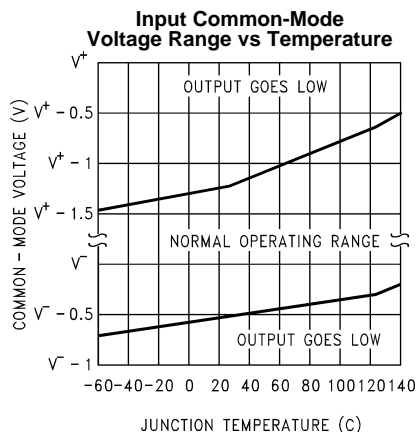


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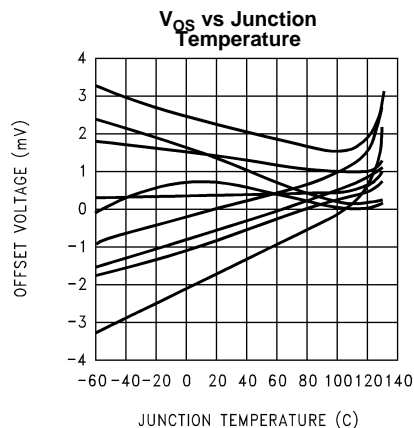


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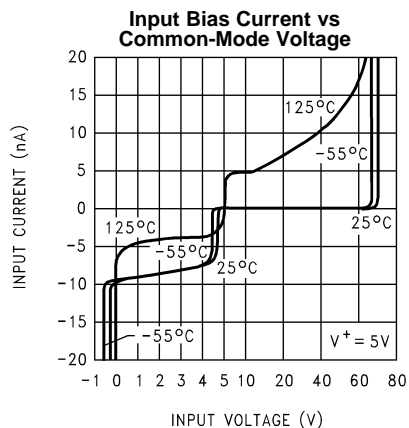


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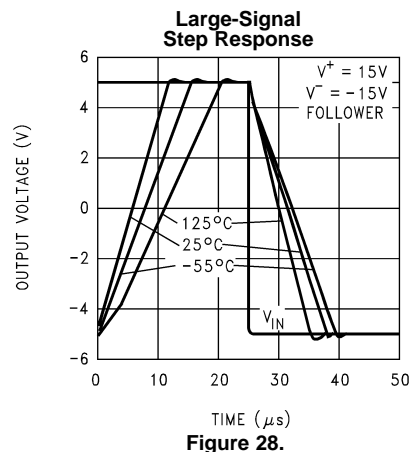


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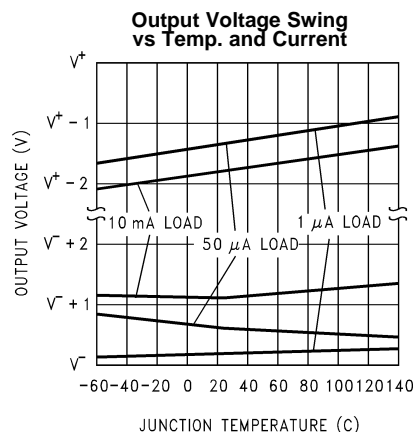


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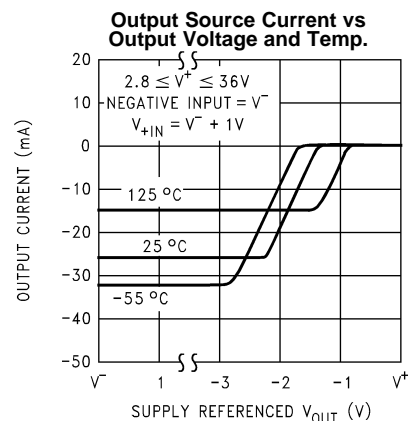


Figure 30.

# LM613

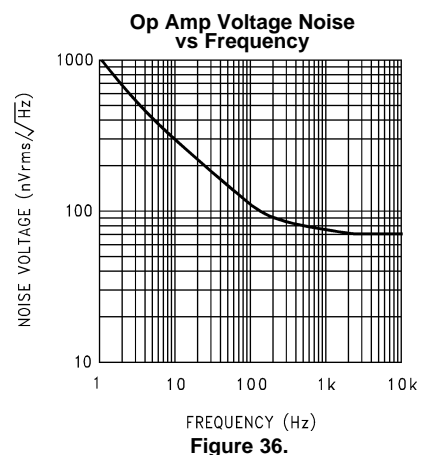
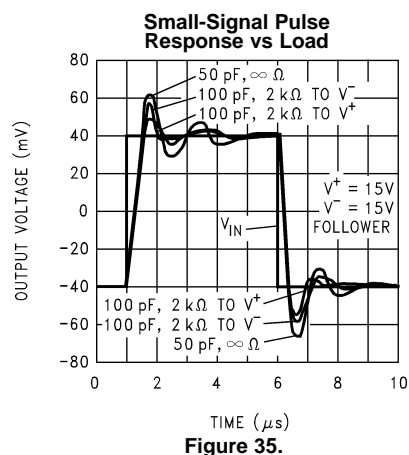
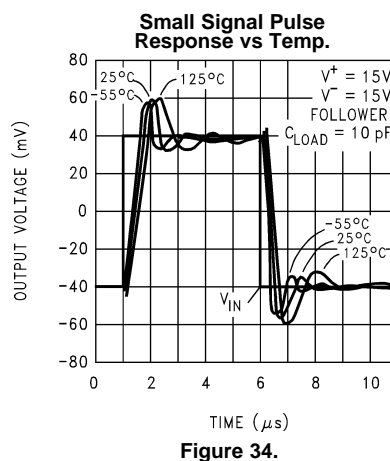
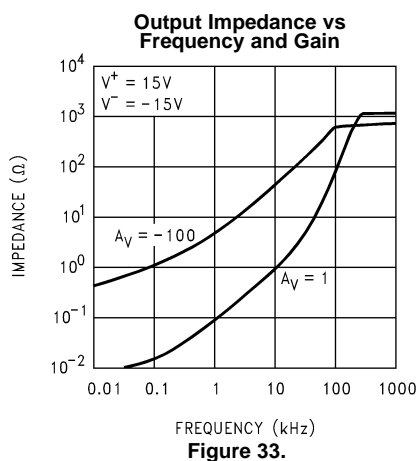
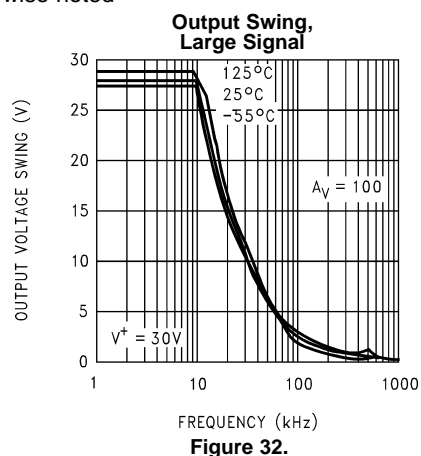
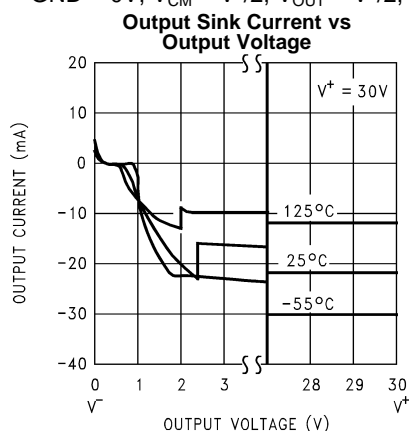


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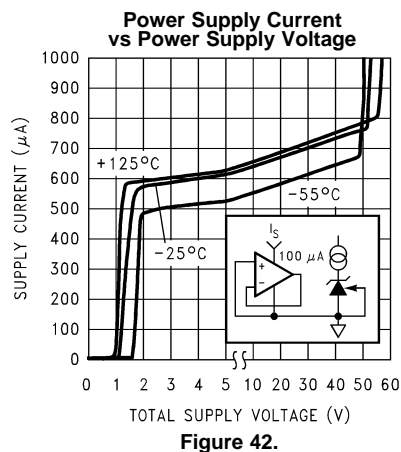
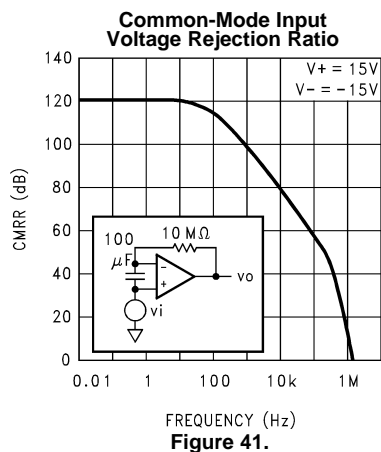
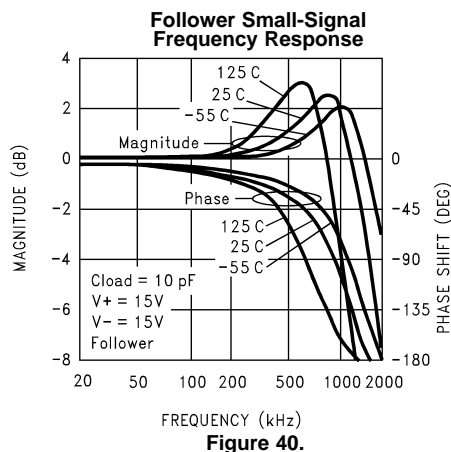
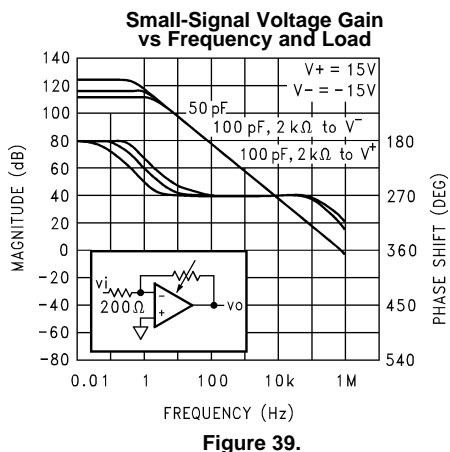
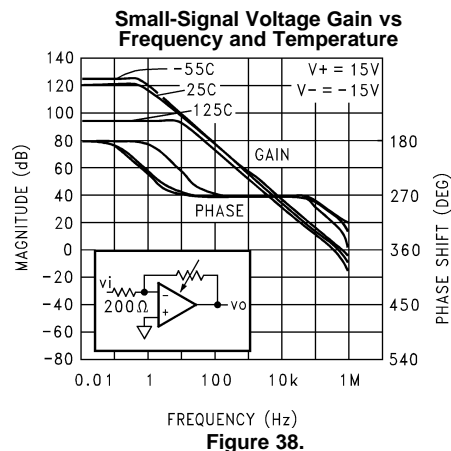
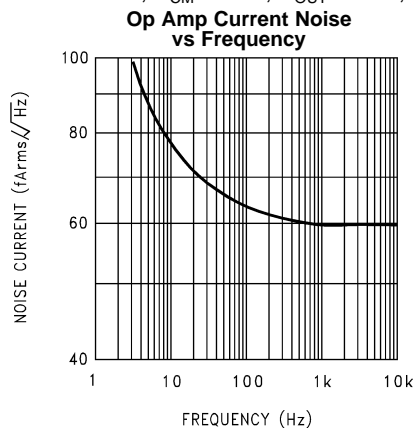
## TYPICAL PERFORMANCE CHARACTERISTICS (Op Amps) (continued)

$V^+ = 5V$ ,  $V^- = GND = 0V$ ,  $V_{CM} = V^+/2$ ,  $V_{OUT} = V^+/2$ ,  $T_J = 25^\circ C$ , unless otherwise noted



## TYPICAL PERFORMANCE CHARACTERISTICS (Op Amps) (continued)

$V^+ = 5V$ ,  $V^- = GND$ ,  $V_{CM} = V^+/2$ ,  $V_{OUT} = V^+/2$ ,  $T_J = 25^\circ C$ , unless otherwise noted



## LM613

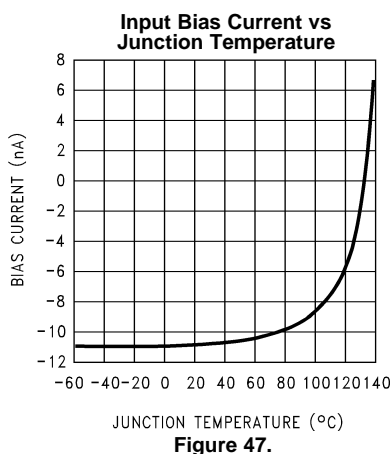
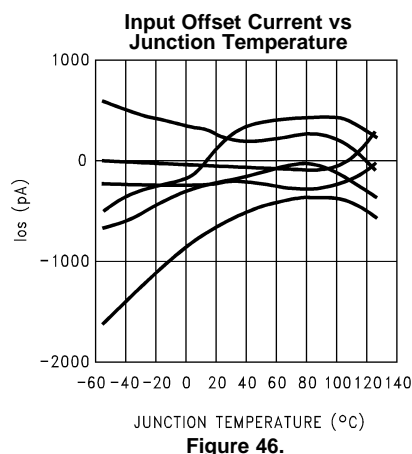
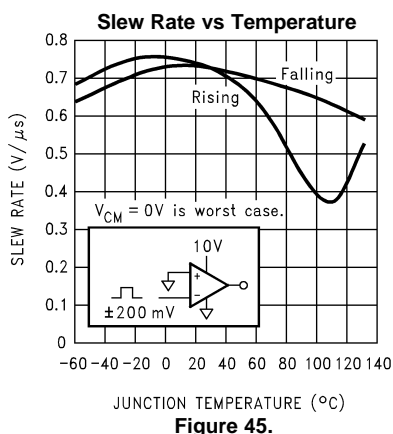
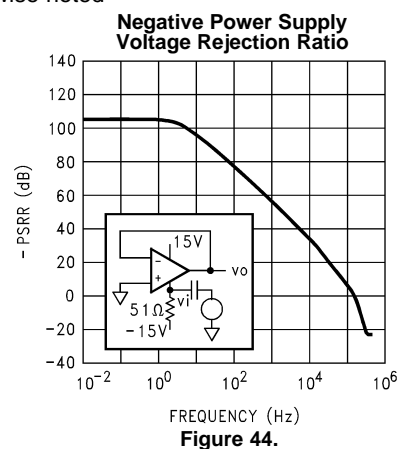
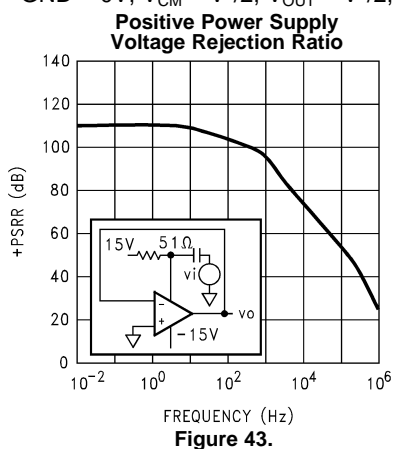


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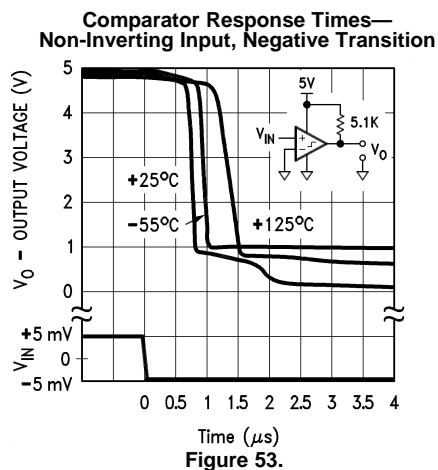
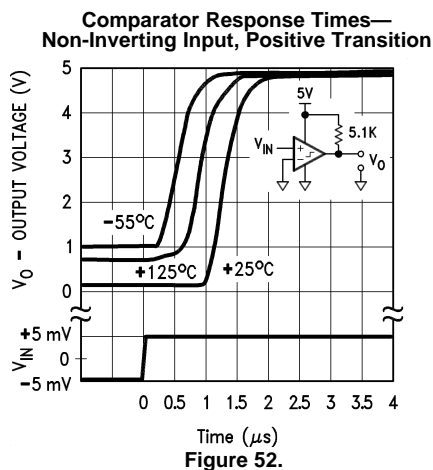
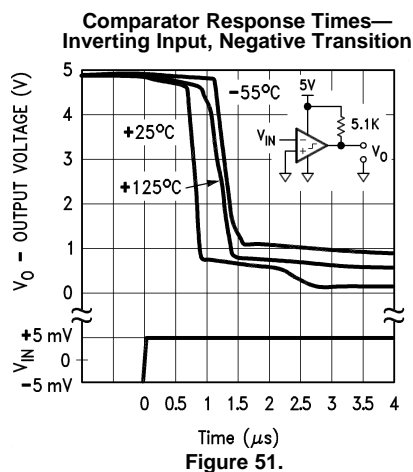
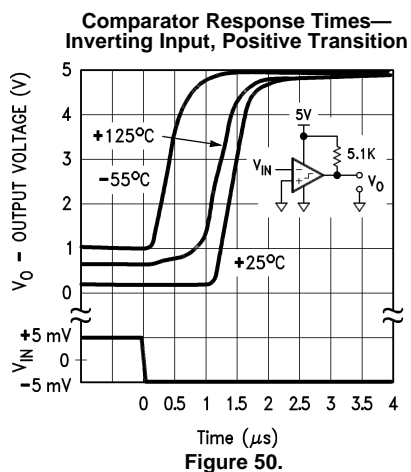
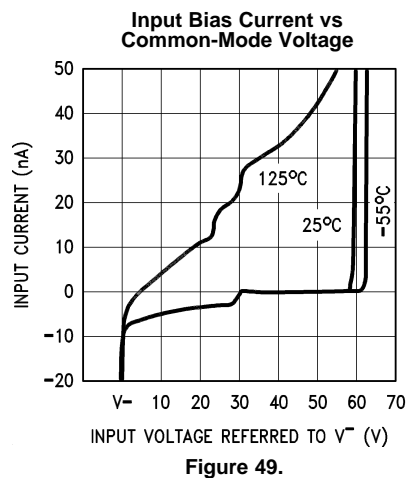
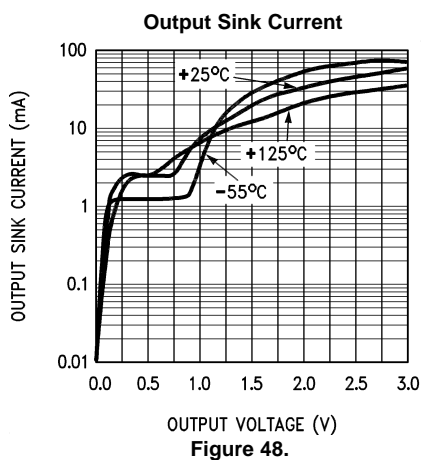
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### TYPICAL PERFORMANCE CHARACTERISTICS (Op Amps) (continued)

$V^+ = 5V$ ,  $V^- = GND$ ,  $V_{CM} = V^+/2$ ,  $V_{OUT} = V^+/2$ ,  $T_J = 25^\circ C$ , unless otherwise noted



## TYPICAL PERFORMANCE CHARACTERISTICS (Comparators)





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### TYPICAL PERFORMANCE CHARACTERISTICS (Comparators) (continued)

**Comparator Response Times—  
Inverting Input, Positive Transition**

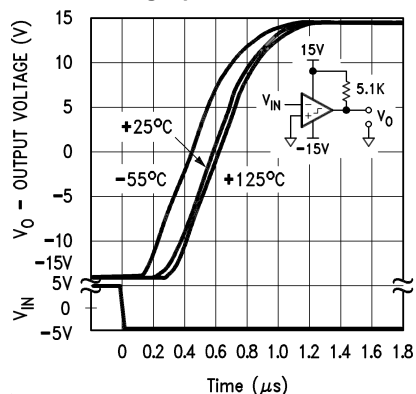


Figure 54.

**Comparator Response Times—  
Inverting Input, Negative Transition**

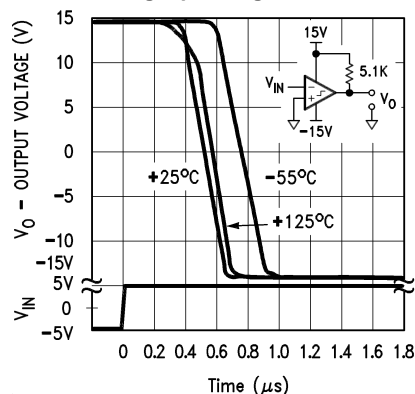


Figure 55.

**Comparator Response Times—  
Non-Inverting Input, Positive Transition**

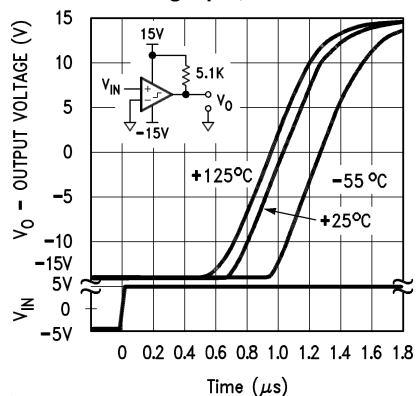


Figure .

**Comparator Response Times—  
Non-Inverting Input, Negative Transition**

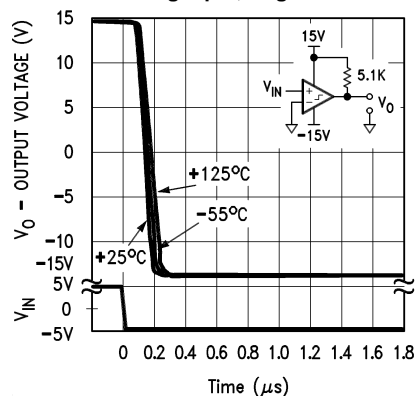


Figure 56.

## TYPICAL PERFORMANCE DISTRIBUTIONS

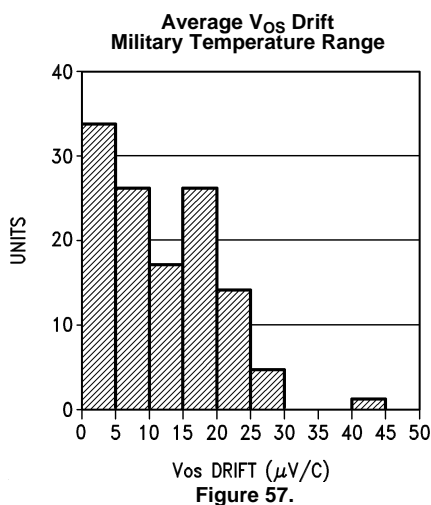


Figure 57.

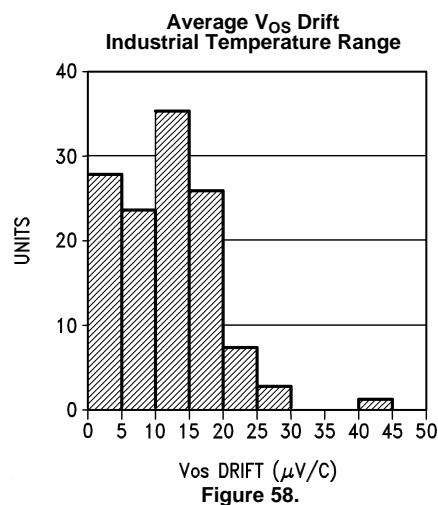


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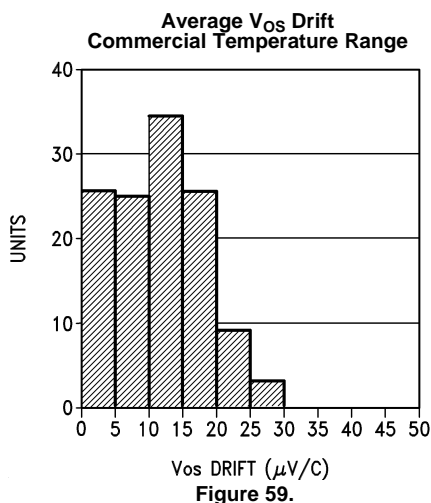


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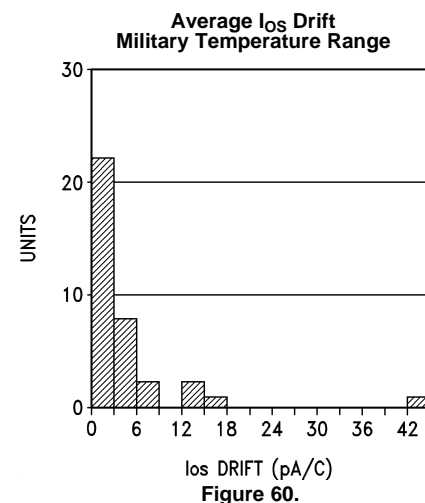


Figure 60.

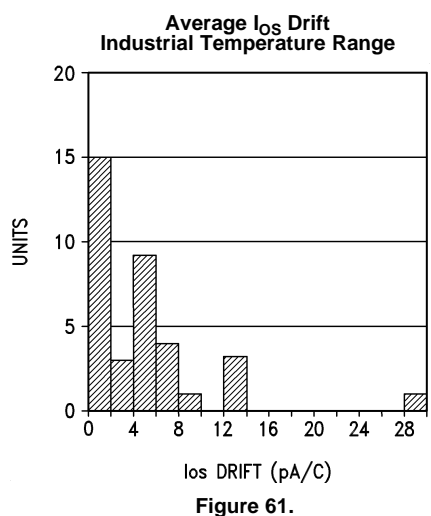


Figure 61.

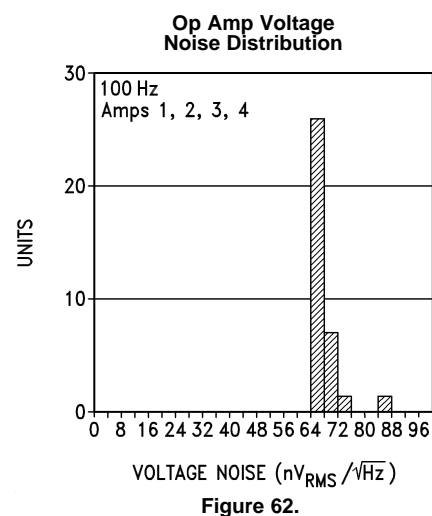


Figure 62.

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### TYPICAL PERFORMANCE DISTRIBUTIONS (continued)

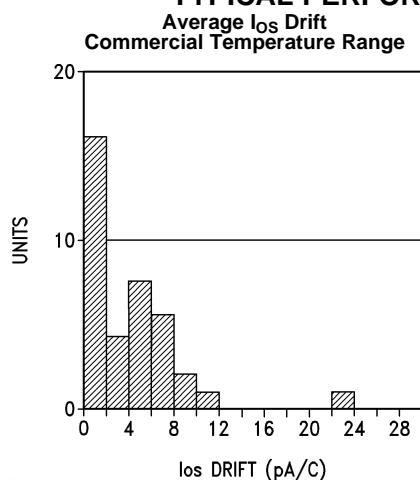


Figure 63.

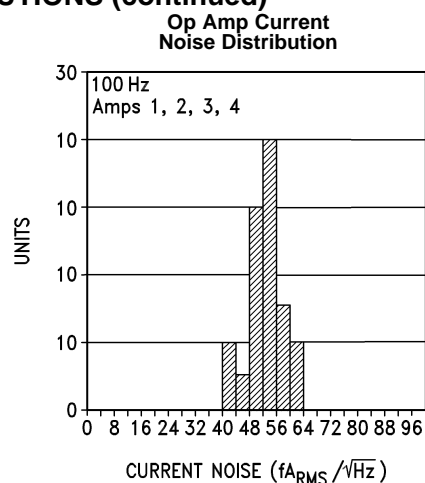


Figure 64.

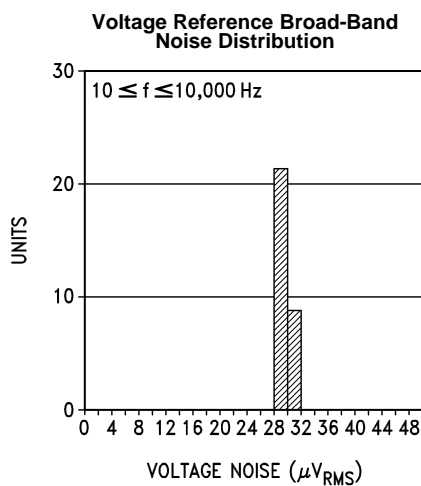


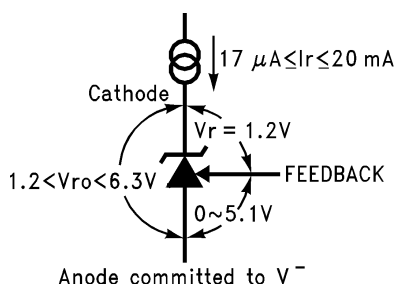
Figure 65.

## APPLICATION INFORMATION

### VOLTAGE REFERENCE

#### Reference Biasing

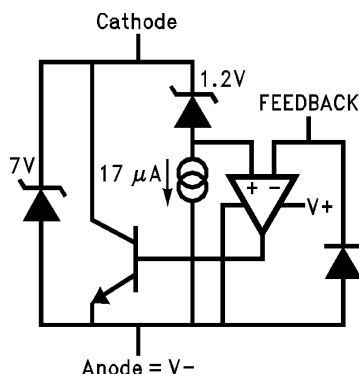
The voltage reference is of a shunt regulator topology that models as a simple zener diode. With current  $I_r$  flowing in the "forward" direction there is the familiar diode transfer function.  $I_r$  flowing in the reverse direction forces the reference voltage to be developed from cathode to anode. The cathode may swing from a diode drop below  $V^-$  to the reference voltage or to the avalanche voltage of the parallel protection diode, nominally 7V. A 6.3V reference with  $V^+ = 3V$  is allowed.



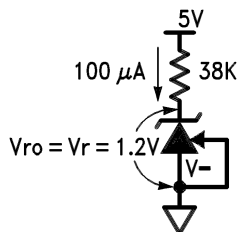
**Figure 66. Voltage Associated with Reference  
(current source  $I_r$  is external)**

The reference equivalent circuit reveals how  $V_r$  is held at the constant 1.2V by feedback, and how the FEEDBACK pin passes little current.

To generate the required reverse current, typically a resistor is connected from a supply voltage higher than the reference voltage. Varying that voltage, and so varying  $I_r$ , has small effect with the equivalent series resistance of less than an ohm at the higher currents. Alternatively, an active current source, such as the LM134 series, may generate  $I_r$ .



**Figure 67. Reference Equivalent Circuit**



**Figure 68. 1.2V Reference**

## LM613



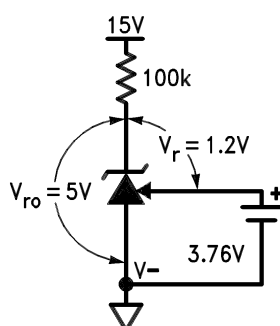
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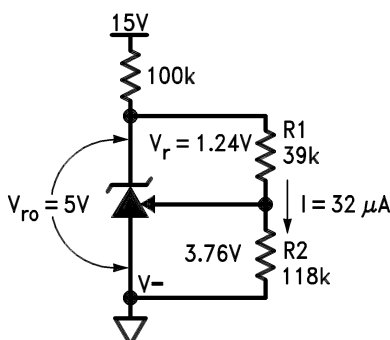
Capacitors in parallel with the reference are allowed. See the [Reference AC Stability Range](#) typical curve for capacitance values—from 20  $\mu\text{A}$  to 3 mA any capacitor value is stable. With the reference's wide stability range with resistive and capacitive loads, a wide range of RC filter values will perform noise filtering.

### Adjustable Reference

The FEEDBACK pin allows the reference output voltage,  $V_{ro}$ , to vary from 1.24V to 6.3V. The reference attempts to hold  $V_r$  at 1.24V. If  $V_r$  is above 1.24V, the reference will conduct current from Cathode to Anode; FEEDBACK current always remains low. If FEEDBACK is connected to Anode, then  $V_{ro} = V_r = 1.24\text{V}$ . For higher voltages FEEDBACK is held at a constant voltage above Anode—say 3.76V for  $V_{ro} = 5\text{V}$ . Connecting a resistor across the constant  $V_r$  generates a current  $I = R1/V_r$  flowing from Cathode into FEEDBACK node. A Thevenin equivalent 3.76V is generated from FEEDBACK to Anode with  $R2 = 3.76/I$ . Keep  $I$  greater than one thousand times larger than FEEDBACK bias current for  $<0.1\%$  error— $I \geq 32 \mu\text{A}$  for the military grade over the military temperature range ( $I \geq 5.5 \mu\text{A}$  for a 1% untrimmed error for a commercial part).



**Figure 69. Thevenin Equivalent of Reference with 5V Output**

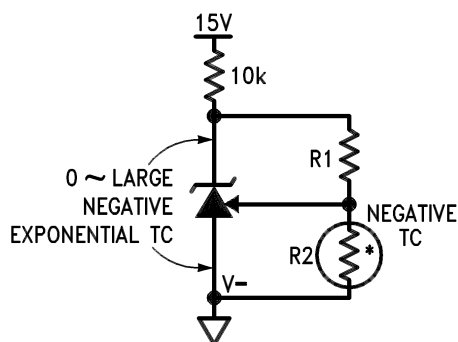


$$R1 = Vr/I = 1.24/32\mu = 39k$$

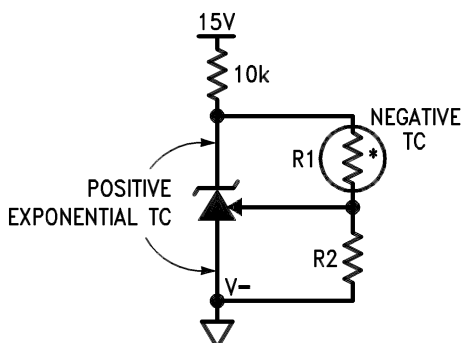
$$R2 = R1 \{ (Vro/Vr) - 1 \} = 39k \{ (5/1.24) - 1 \} = 118k$$

**Figure 70. Resistors R1 and R2 Program Reference Output Voltage to be 5V**

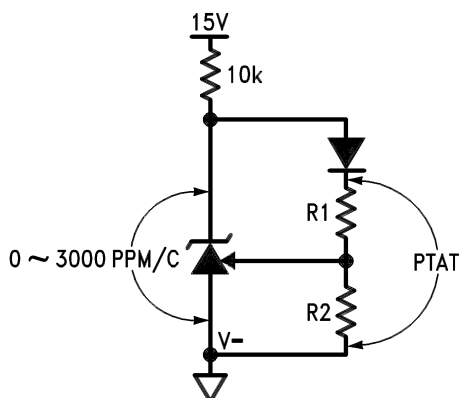
Understanding that  $V_r$  is fixed and that voltage sources, resistors, and capacitors may be tied to the FEEDBACK pin, a range of  $V_r$  temperature coefficients may be synthesized.



**Figure 71. Output Voltage has Negative Temperature Coefficient (TC) if R2 has Negative TC**



**Figure 72. Output Voltage has Positive TC if R1 has Negative TC**



**Figure 73. Diode in Series with R1 Causes Voltage Across R1 and R2 to be Proportional to Absolute Temperature (PTAT)**

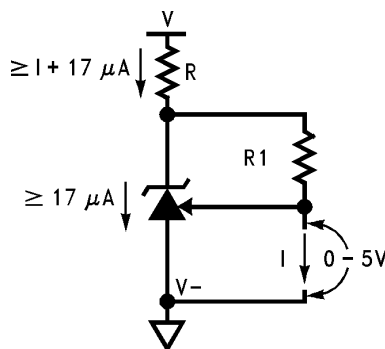
Connecting a resistor across Cathode-to-FEEDBACK creates a 0 TC current source, but a range of TCs may be synthesized.

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$$I = V_r/R1 = 1.24/R1$$

Figure 74. Current Source is Programmed by R1

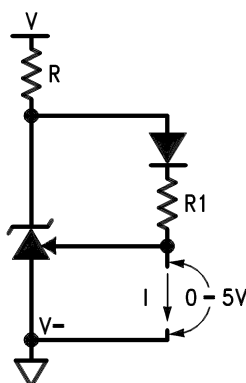


Figure 75. Proportional-to-Absolute-Temperature Current Source

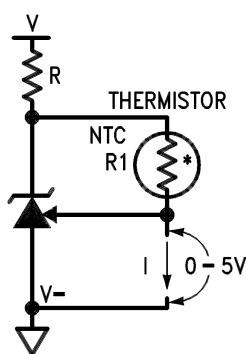


Figure 76. Negative-TC Current Source

### Reference Hysteresis

The reference voltage depends, slightly, on the thermal history of the die. Competitive micro-power products vary— always check the data sheet for any given device. Do not assume that no specification means no hysteresis.

## OPERATIONAL AMPLIFIERS AND COMPARATORS

Any amp, comparator, or the reference may be biased in any way with no effect on the other sections of the LM613, except when a substrate diode conducts, see <sup>(1)</sup> in [Electrical Characteristics](#). For example, one amp input may be outside the common-mode range, another amp may be operating as a comparator, and all other sections may have all terminals floating with no effect on the others. Tying inverting input to output and non-inverting input to  $V^-$  on unused amps is preferred. Unused comparators should have non-inverting input and output tied to  $V^+$ , and inverting input tied to  $V^-$ . Choosing operating points that cause oscillation, such as driving too large a capacitive load, is best avoided.

### Op Amp Output Stage

These op amps, like the LM124 series, have flexible and relatively wide-swing output stages. There are simple rules to optimize output swing, reduce cross-over distortion, and optimize capacitive drive capability:

1. Output Swing: Unloaded, the 42  $\mu\text{A}$  pull-down will bring the output within 300 mV of  $V^-$  over the military temperature range. If more than 42  $\mu\text{A}$  is required, a resistor from output to  $V^-$  will help. Swing across any load may be improved slightly if the load can be tied to  $V^+$ , at the cost of poorer sinking open-loop voltage gain.
2. Cross-Over Distortion: The LM613 has lower cross-over distortion (a 1  $V_{BE}$  deadband versus 3  $V_{BE}$  for the LM124), and increased slew rate as shown in the characteristic curves. A resistor pull-up or pull-down will force class-A operation with only the PNP or NPN output transistor conducting, eliminating cross-over distortion.
3. Capacitive Drive: Limited by the output pole caused by the output resistance driving capacitive loads, a pull-down resistor conducting 1 mA or more reduces the output stage NPN  $r_e$  until the output resistance is that of the current limit 25 $\Omega$ . 200 pF may then be driven without oscillation.

### Comparator Output Stage

The comparators, like the LM139 series, have open-collector output stages. A pull-up resistor must be added from each output pin to a positive voltage for the output transistor to switch properly. When the output transistor is OFF, the output voltage will be this external positive voltage.

For the output voltage to be under the TTL-low voltage threshold when the output transistor is ON, the output current must be less than 8 mA (over temperature). This impacts the minimum value of pull-up resistor.

The offset voltage may increase when the output voltage is low and the output current is less than 30  $\mu\text{A}$ . Thus, for best accuracy, the pull-up resistor value should be low enough to allow the output transistor to sink more than 30  $\mu\text{A}$ .

### Op Amp and Comparator Input Stage

The lateral PNP input transistors, unlike those of most op amps, have  $BV_{EBO}$  equal to the absolute maximum supply voltage. Also, they have no diode clamps to the positive supply nor across the inputs. These features make the inputs look like high impedances to input sources producing large differential and common-mode voltages.

(1) Absolute maximum ratings indicate limits beyond which damage to the component may occur. Electrical specifications do not apply when operating the device beyond its rated operating conditions.



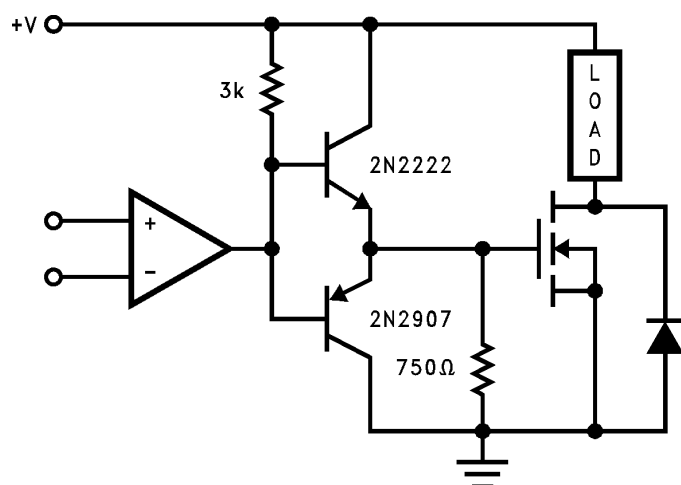
## LM613



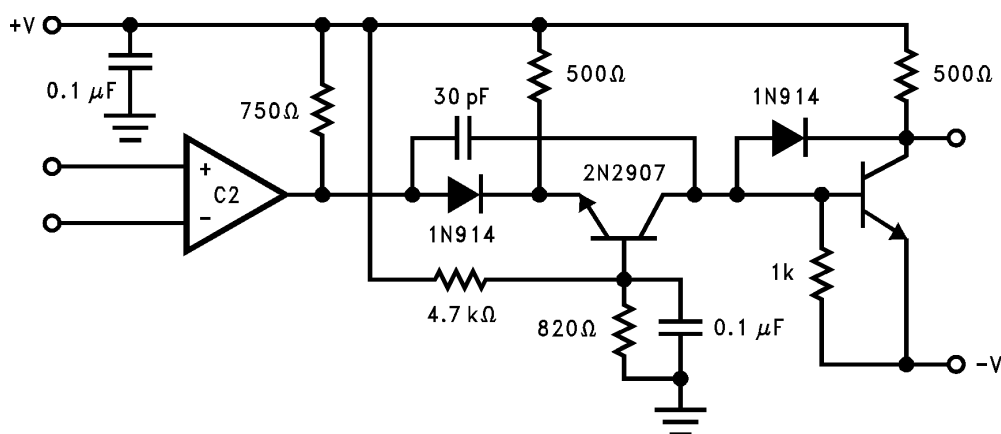
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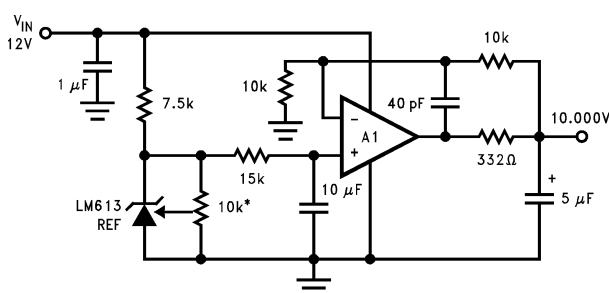
### Typical Applications



**Figure 77. High Current, High Voltage Switch**

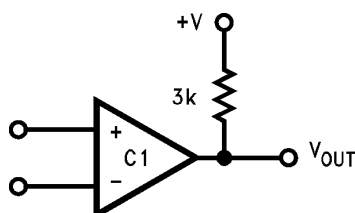


**Figure 78. High Speed Level Shifter. Response Time is Approximately 1.5 μs, Where Output is Either Approximately +V or -V.**

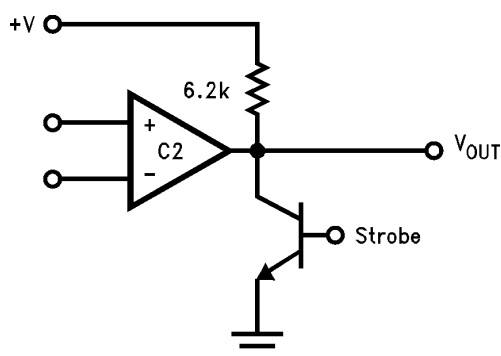


\*10k must be low  
t.c. trimpot

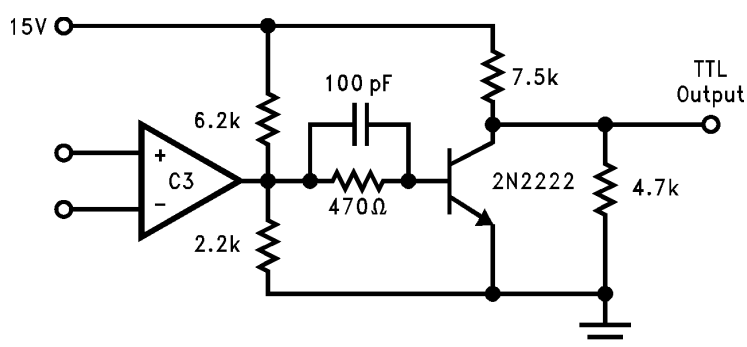
**Figure 79. Ultra Low Noise, 10.00V Reference. Total Output Noise is Typically 14 μV<sub>RMS</sub>.**



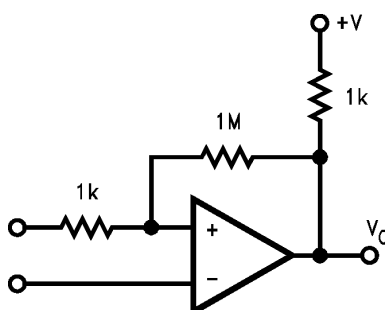
**Figure 80. Basic Comparator**



**Figure 81. Basic Comparator with External Strobe**



**Figure 82. Wide-Input Range Comparator with TTL Output**



**Figure 83. Comparator with Hysteresis ( $\Delta V_H = +V(1k/1M)$ )**

## REVISION HISTORY

Changes from Revision A (March 2013) to Revision B	Page
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|--|--------------------|
| • Changed layout of National Data Sheet to TI format ..... | <a href="#">25</a> |
|--|--------------------|



PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LM613IWM	NRND	SOIC	DW	16	45	TBD	Call TI	Call TI	-40 to 85	LM613IWM	
LM613IWM/NOPB	ACTIVE	SOIC	DW	16	45	Green (RoHS & no Sb/Br)	CU SN	Level-3-260C-168 HR	-40 to 85	LM613IWM	<a href="#">Samples</a>
LM613IWMX	NRND	SOIC	DW	16	1000	TBD	Call TI	Call TI	-40 to 85	LM613IWM	
LM613IWMX/NOPB	ACTIVE	SOIC	DW	16	1000	Green (RoHS & no Sb/Br)	CU SN	Level-3-260C-168 HR	-40 to 85	LM613IWM	<a href="#">Samples</a>

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "-" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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**PACKAGE OPTION ADDENDUM**

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1-Nov-2013

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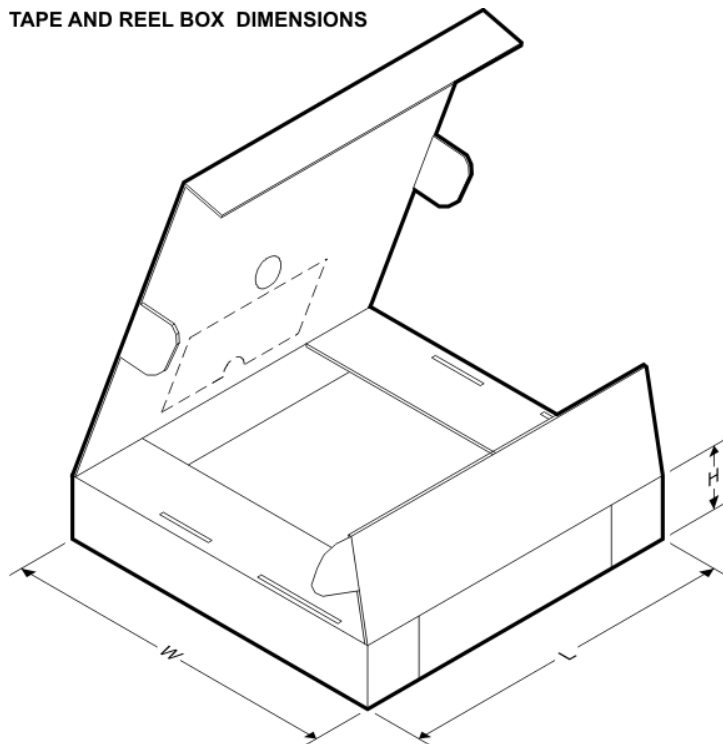
### TAPE AND REEL INFORMATION



\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LM613IWMX	SOIC	DW	16	1000	330.0	16.4	10.9	10.7	3.2	12.0	16.0	Q1
LM613IWMX/NOPB	SOIC	DW	16	1000	330.0	16.4	10.9	10.7	3.2	12.0	16.0	Q1

**TAPE AND REEL BOX DIMENSIONS**



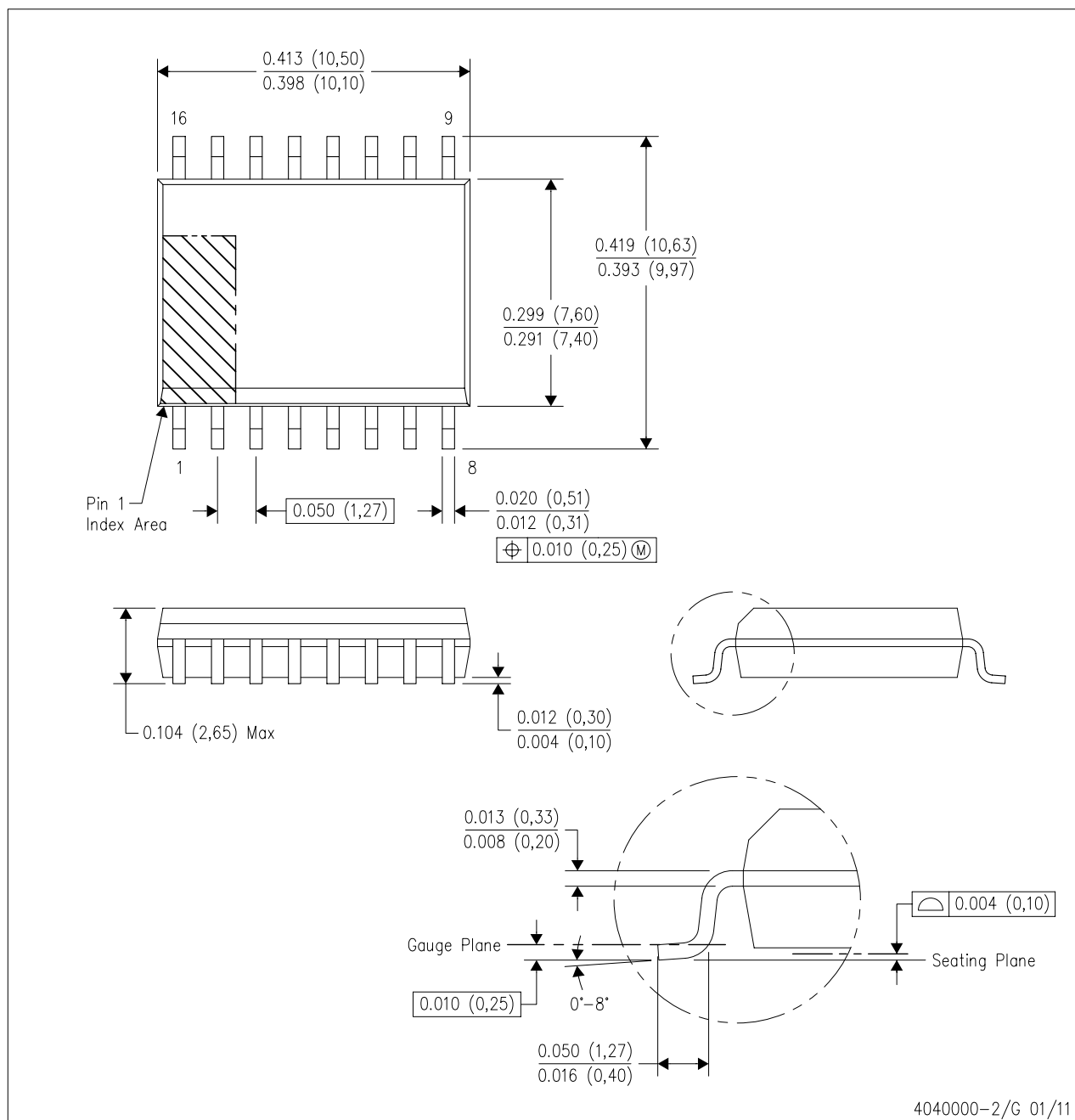
\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM613IWMX	SOIC	DW	16	1000	367.0	367.0	38.0
LM613IWMX/NOPB	SOIC	DW	16	1000	367.0	367.0	38.0

## MECHANICAL DATA

DW (R-PDSO-G16)

PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in inches (millimeters). Dimensioning and tolerancing per ASME Y14.5M-1994.
  - B. This drawing is subject to change without notice.
  - C. Body dimensions do not include mold flash or protrusion not to exceed 0.006 (0,15).
  - D. Falls within JEDEC MS-013 variation AA.



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