



LM627/LM637 Precision Operational Amplifiers

General Description

The LM627/LM637 series feature extremely low noise and excellent precision along with high speed. Voltage noise is a low 3 nV/ $\sqrt{\text{Hz}}$ in the flat band and rises to only 3.5 nV/ $\sqrt{\text{Hz}}$ at

10 Hz. The A grades offer guaranteed specifications of 25 μV offset voltage and 0.3 $\mu\text{V}/^\circ\text{C}$ drift, and their *guaranteed* 126 dB CMRR, 120 dB PSRR and voltage gain of 5 Million ensure an ultra-low V_{OS} under all conditions.

The unity-gain stable LM627 is nearly twice as fast as the OP-27 with a slew rate of 4.5 V/ μs and a 14 MHz gain-bandwidth product. Stable at gains of 5 or more, the decompensated LM637 is considerably faster.

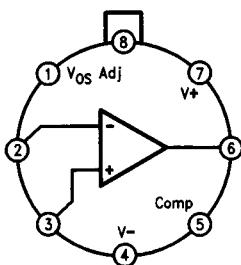
Other enhancements of the LM627/LM637 include a guaranteed 600 Ω load drive capability over temperature: $\pm 10\text{V}$ output swing at voltage gains over one million. Bias current has been reduced to 10 nA for the A and B grades and 25 nA for the C grade. Furthermore the LM627 may be overcompensated to allow it to drive capacitive loads up to 2000 pF while maintaining its superb dc specs.

Features

- Low Noise 3 nV/ $\sqrt{\text{Hz}}$ @1 kHz
3.5 nV/ $\sqrt{\text{Hz}}$ @ 10 Hz
- Low V_{OS} 25 μV Max
- Low Drift 0.3 $\mu\text{V}/^\circ\text{C}$ Max
- Offset Drift 100% Tested (A and B grades)
- Noise Voltage 100% Tested (A and B grades)
- High Gain 5 Million Min
- High CMRR 126 dB Min
- High PSRR 120 dB Min
- High Speed
- LM627: 14 MHz Gain-Bandwidth
4.5 V/ μs Slew Rate
- LM637: 65 MHz Gain-Bandwidth
14 V/ μs Slew Rate
- *Guaranteed* 600 Ω drive over temperature
- Wide Power Supply Range $\pm 4\text{V}$ to $\pm 18\text{V}$
- Overcompensation Pin Allows driving high C_L

Connection Diagrams

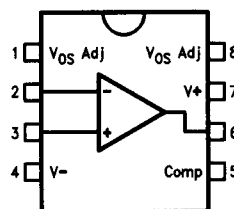
Metal Can Package



Top View

TL/H/9212-1

DIP Packages



TL/H/9212-2

Ordering Information

LM627

Package	Temperature Range		NSC Drawing
	Military	Commercial	
TO-99	LM627AMH LM627BMH	LM627ACH LM627BCH LM627CH	H08C
8-Pin Molded DIP		LM627CN	N08E

LM637

Package	Temperature Range		NSC Drawing
	Military	Commercial	
TO-99	LM637AMH LM637BMH	LM637ACH LM637BCH LM637CH	H08C
8-Pin Molded DIP		LM637CN	N08E



Absolute Maximum Ratings (Note 1)

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

Differential Input Overdrive Current (Note 7)	± 25 mA
Supply Voltage	44V
Input Voltage	Supply Voltage
Output Short Circuit to Gnd	Continuous
Power Dissipation (Note 8)	
Molded DIP	1300 mW
Metal Can	830 mW

Storage Temperature Range	-65°C to +150°C
Lead Temperature (Soldering, 5 sec.)	260°C
Maximum Junction Temperature	150°C
ESD Rating	3 kV
$C_{ZAP} = 100 \text{ pF}$, $R_{ZAP} = 1.5 \text{ k}\Omega$	

Operating Ratings

Temperature Range (Note 8)	
AM and BM grades	-55°C ≤ T _J ≤ +125°C
AC, BC, and C grades	-25°C ≤ T _J ≤ +85°C

Electrical Characteristics All limits guaranteed for T_J = 25°C, V_{CM} = 0, V_O = 0 and ±15V supplies unless otherwise specified. **Boldface limits apply at operating temperature extremes.**

Parameter	Conditions	Typ	LM627AM LM637AM		LM627BM LM637BM		Units
			Tested Limit (Note 5)	Design Limit (Note 6)	Tested Limit (Note 5)	Design Limit (Note 6)	
Input Offset Voltage	(Note 2)	15	25 55		50 110		μV Max
Input Offset Voltage Drift	(Note 3)	0.2	0.3		0.6		μV/°C Max
Input Offset Voltage Long Term Stability	(Note 4)	0.2					μV/mo Max
Input Bias Current		3	10 20		10 20		nA Max
Input Offset Current		2	10 20		10 20		nA Max
Input Noise Voltage	0.1 to 10Hz	0.08		0.18		0.18	μV p-p Max
Input Noise Voltage Density	f = 10Hz f = 30Hz f = 1kHz	3.5 3.1 3.0	5.5 4.5 3.8		5.5 4.5 3.8		nV/√Hz Max
Input Noise Current Density	f = 10Hz f = 30Hz f = 1kHz	1.7 1.0 0.4					pA/√Hz Max
Input Resistance	Common-Mode	20					GΩ
Input Voltage Range		±12	±11 ±10.3		±11 10.3		V Min
Common-Mode Rejection Ratio	V _{CM} = ±11V V_{CM} = ±10V	140	126 120		126 120		dB Min
Power Supply Rejection Ratio	V _S = ±4V to ±18V V_S = ±4.5V to ±18V	140	120 117		120 117		dB Min
Large-Signal Voltage Gain	V _O = ±12V R _L ≥ 2 kΩ	10000	5000 3000		5000 2000		V/mV Min
	V _O = ±10V R _L ≥ 1 kΩ	7000	4000 2000		3500 1500		
	R _L ≥ 600Ω V _O = ±10V	6000	3000 1500		2000 1000		

Electrical Characteristics (Continued)

Parameter	Conditions	Typ	LM627AM LM637AM		LM627BM LM637BM		Units
			Tested Limit (Note 5)	Design Limit (Note 6)	Tested Limit (Note 5)	Design Limit (Note 6)	
Output Voltage Swing	$R_L \geq 2 \text{ k}\Omega$	± 13.8	± 13 ± 12.5		± 13 ± 12.5		V Min
	$R_L \geq 600\Omega$	± 12.5	± 11 ± 10.5		± 11 ± 10.5		
Slew Rate	LM627 LM637 $R_L = 2\text{k}$	4.5 14		3 10		3 10	V/ μs Min
	LM627 LM637 $f = 10 \text{ kHz}$	14 65		10 45		10 45	MHz Min
Output Resistance	Open Loop	50					Ω
Supply Current		3	4.5 5.5		4.5 5.5		mA Max
Offset Adjust Range	$R_P \geq 10 \text{ k}\Omega$	± 2					mV

Electrical Characteristics All limits guaranteed for $T_J = 25^\circ\text{C}$, $V_{CM} = 0$, $V_O = 0$ and $\pm 15\text{V}$ supplies unless otherwise specified. **Boldface limits apply at operating temperature extremes.**

Parameter	Conditions	Typ	LM627AC LM637AC		LM627BC LM637BC		LM627C LM637C		Units
			Tested Limit (Note 5)	Design Limit (Note 6)	Tested Limit (Note 5)	Design Limit (Note 6)	Tested Limit (Note 5)	Design Limit (Note 6)	
Input Offset Voltage	(Note 2)	15	25 50		50 110		100	210	μV Max
Input Offset Voltage Drift	(Note 3)	0.2	0.6		1.0			1.8	$\mu\text{V}/^\circ\text{C}$ Max
Input Offset Voltage Long Term Stability	(Note 4)	0.2							$\mu\text{V}/\text{mo}$ Max
Input Bias Current		3	10	20	10	20	25	50	nA Max
Input Offset Current		2	10	20	10	20	25	50	nA Max
Input Noise Voltage	0.1 to 10 Hz	0.08		0.18		0.18		0.25	μV p-p Max
Input Voltage Noise Density	$f = 10 \text{ Hz}$	3.5	5.5		5.5			8.0	$\text{nV}/\sqrt{\text{Hz}}$ Max
	$f = 30 \text{ Hz}$	3.1	4.5		4.5			5.6	
	$f = 1 \text{ kHz}$	3.0	3.8		3.8			4.5	
Input Noise Current Density	$f = 10 \text{ Hz}$	1.7							$\text{pA}/\sqrt{\text{Hz}}$ Max
	$f = 30 \text{ Hz}$	1.0							
	$f = 1 \text{ kHz}$	0.4							
Input Resistance	Common Mode	20							$\text{G}\Omega$
Input Voltage Range		± 12	± 11	± 10.3	± 11	± 10.3	± 11	± 10.3	V Min
Common-Mode Rejection Ratio	$V_{CM} = \pm 11\text{V}$ $V_{CM} = \pm 10\text{V}$	140	126	120	126	120	120	116	dB Min
Power Supply Rejection Ratio	$V_S = \pm 4\text{V to } \pm 18\text{V}$ $V_S = \pm 4.5\text{V to } \pm 18\text{V}$	140	120	117	120	117	110	108	dB Min

Electrical Characteristics (Continued)

Parameter	Conditions	Typ	LM627AC LM637AC		LM627BC LM637BC		LM627C LM637C		Units
			Tested Limit (Note 5)	Design Limit (Note 6)	Tested Limit (Note 5)	Design Limit (Note 6)	Tested Limit (Note 5)	Design Limit (Note 6)	
Large-Signal Voltage Gain	$V_O = \pm 12V$ $R_L \geq 2\text{ k}\Omega$ $V_O = \pm 10V$ $R_L \geq 1\text{ k}\Omega$ $R_L \geq 600\Omega$	10000	5000	3000	5000	3000	4000	2500	V/mV Min
		7000	4000	2500	3500	2000	2500	1500	
		6000	3000	2000	2000	1500	1500	1000	
Output Voltage Swing	$R_L \geq 2\text{ k}\Omega$ $R_L \geq 600\Omega$	± 13.8 ± 12.5	± 13 ± 11	± 12.5 ± 10.5	± 13 ± 11	± 12.5 ± 10.5	± 13 ± 10.5	± 12.5 ± 10	V Min
Slew Rate	LM627 LM637 $R_L = 2k$	4.5		3		3		3	V/ μ s Min
		14		10		10		10	
Gain-Bandwidth Product	LM627 LM637 $f = 10\text{ kHz}$	14 65		10 45		10 45		10 45	MHz Min
Output Resistance	Open Loop	50							Ω
Supply Current		3	4.5	5	4.5	5	4.8	5.2	mA Max
Offset Adjust Range	$R_P \geq 10\text{ k}\Omega$	± 2							mV

Note 1: Absolute maximum ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed.

Note 2: Input offset voltage for A and B grades is tested and guaranteed with the device fully warmed up. See Figure 1 in the Application Hints for test circuit. Warmup drift is typically $5\text{ }\mu\text{V}$ settling out in 5 minutes. The LM627C/LM637C offset voltage is measured by automated test equipment within 200 ms of applying power.

Note 3: Input offset voltage drift is defined as $(V_{OS}(85^\circ\text{C}) - V_{OS}(-25^\circ\text{C}))/110^\circ\text{C}$ for the industrial temperature range. For the military temperature range, the input offset voltage drift is measured from room temperature to both extremes: both $(V_{OS}(25^\circ\text{C}) - V_{OS}(-55^\circ\text{C}))/80^\circ\text{C}$ and $(V_{OS}(125^\circ\text{C}) - V_{OS}(25^\circ\text{C}))/100^\circ\text{C}$.

Note 4: Input offset voltage long term stability refers to the average trend line of V_{OS} vs. time over extended periods of time after the first 30 days of operation. Excluding the initial hour of operation, changes in V_{OS} during the first 30 days are typically $2\text{ }\mu\text{V}$.

Note 5: Guaranteed and 100% production tested. These limits are used to calculate outgoing quality levels.

Note 6: Guaranteed but not 100% production tested. These limits are not used to calculate outgoing quality levels.

Note 7: Inputs are protected by back-to-back diodes to prevent zener breakdown of the input transistors. Series limiting resistors have not been included since they degrade noise performance. Excessive current may flow if a differential voltage in excess of 0.7V is applied.

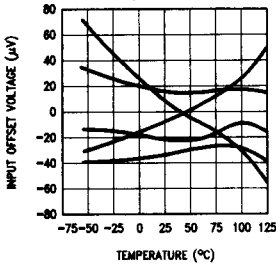
Note 8: For operation above 25°C , the maximum power dissipation specification must be derated. Typical junction-to-ambient thermal resistance of the molded DIP is $105^\circ\text{C}/\text{W}$. The metal can package has a typical junction-to-ambient thermal resistance of $150^\circ\text{C}/\text{W}$ and a typical junction-to-case thermal resistance of $17^\circ\text{C}/\text{W}$.

Note 9: These units selected to illustrate the types of variations that may be encountered. (This note refers to particular curves within the Typical Performance Characteristics.)

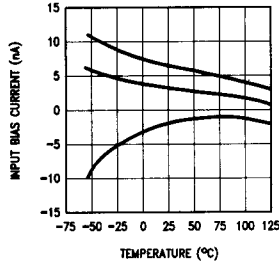
Typical DC Performance Characteristics (LM627, LM637)

$V_S = \pm 15V$, $T_A = 25^\circ C$, $R_L = 2k$ unless otherwise indicated.

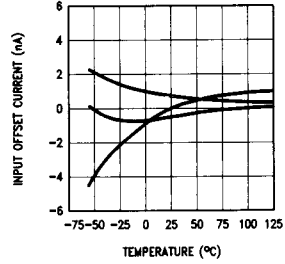
Input Offset Voltage of 5 Representative Units vs Temperature (Note 9)



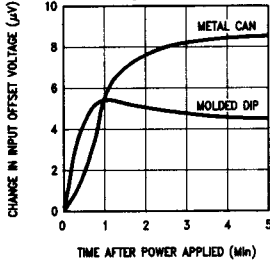
Input Bias Current of 3 Representative Units vs Temperature (Note 9)



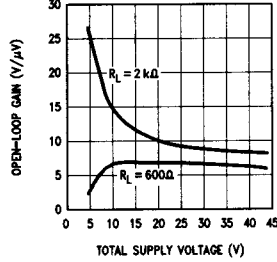
Input Offset Current of 3 Representative Units vs Temperature (Note 9)



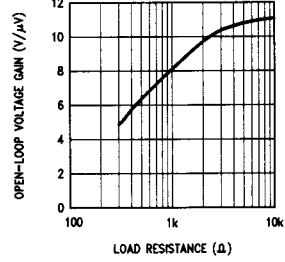
Warmup Drift



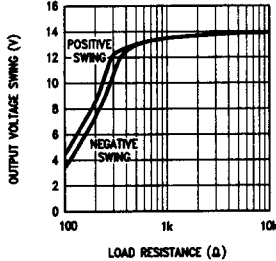
Open Loop Gain vs Supply Voltage



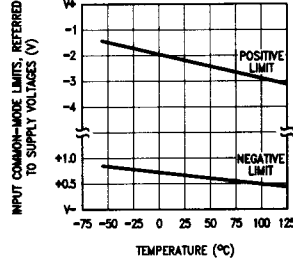
Open Loop Gain vs Load Resistance



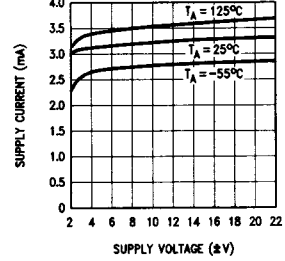
Output Voltage Swing vs Load Resistance



Input Common-Mode Limits vs Temperature



Supply Current vs Supply Voltage

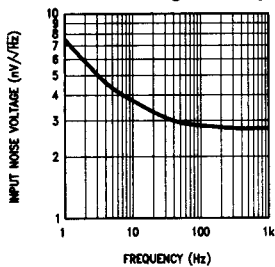


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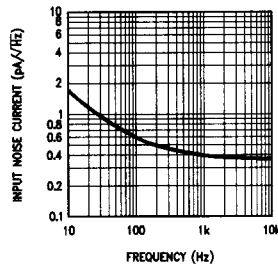
Typical Noise Characteristics (LM627, LM637)

$V_S = \pm 15V$, $T_A = 25^\circ C$

Noise Voltage vs Frequency



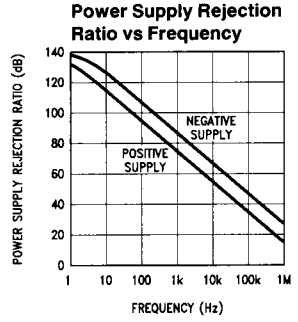
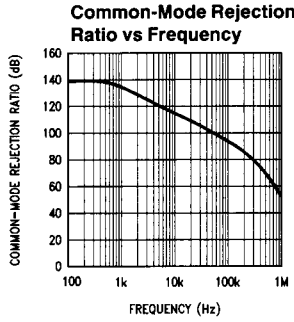
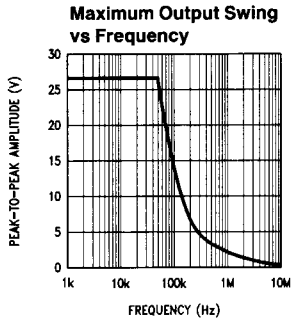
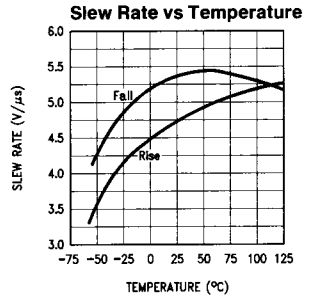
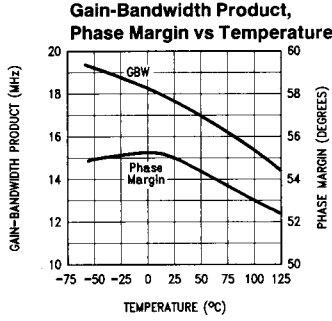
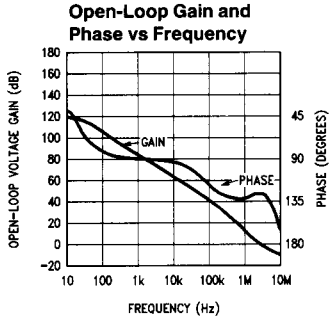
Noise Current vs Frequency



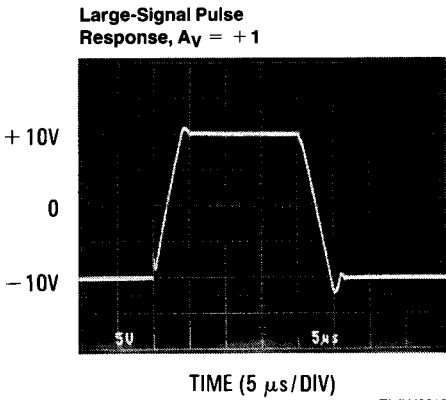
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Typical AC Performance Characteristics (LM627)

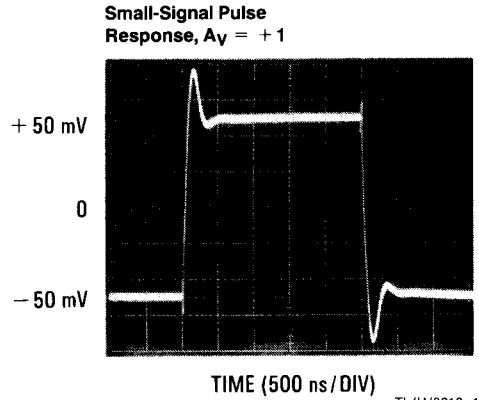
$V_S = \pm 15V, T_A = 25^\circ C, R_L = 2k$



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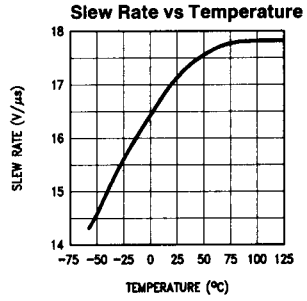
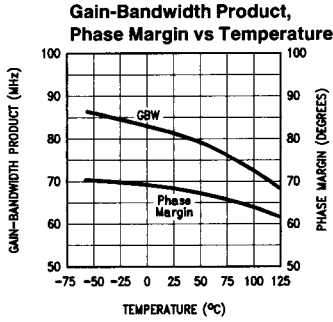
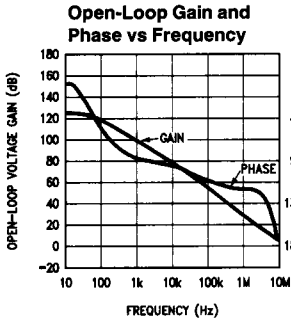
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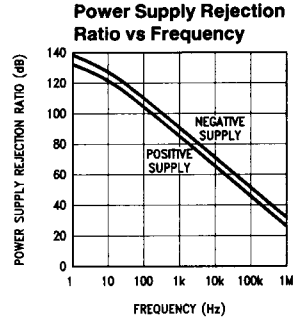
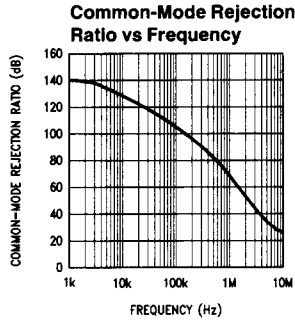
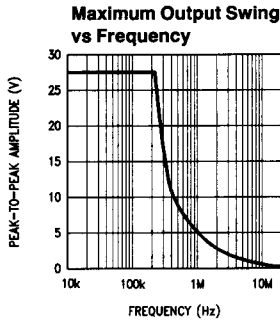
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Typical AC Performance Characteristics (LM637)

$V_S = \pm 15V, T_A = 25^\circ C, R_L = 2k$

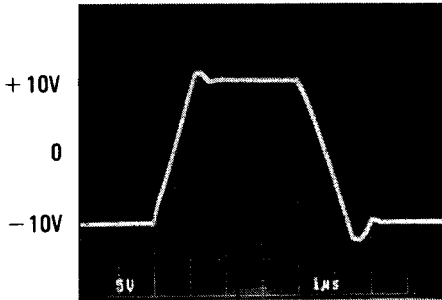


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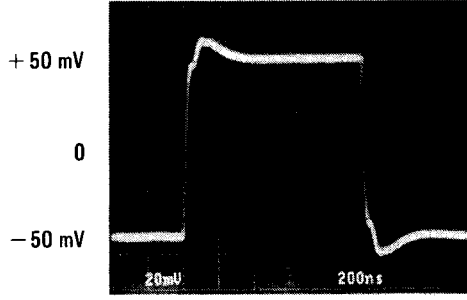
Large-Signal Pulse Response, $A_V = +5$



TIME (1 μs/DIV)

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Small-Signal Pulse Response, $A_V = +5$



TIME (200 ns/DIV)

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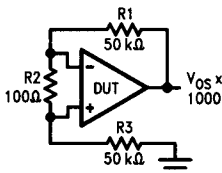
Application Hints

OFFSET VOLTAGE

Offset voltage of the LM627/637 is internally trimmed to a very low value. The data sheet V_{OS} specification applies at $T_J = 25^\circ\text{C}$, $V_{CM} = 0$ and $\pm 15\text{V}$ supplies. For other temperatures, common-mode voltages, and supply voltages, temperature drift, common-mode rejection and power-supply rejection errors must be taken into account.

Since the LM627/LM637C offset voltage is measured within 200 ms of applying power, the $5\ \mu\text{V}$ typical warmup drift is not accounted for in the measurement. Fortunately, the warmup drift is a small fraction of its $100\ \mu\text{V}$ max offset. For the $25\ \mu\text{V A}$ and $50\ \mu\text{V B}$ grades, the offset voltage is measured with the circuit of *Figure 1* approximately 5 minutes after applying power.

To measure V_{OS} with high accuracy, V_{OS} must be amplified right at the device as shown; otherwise the offset voltage can be obscured by noise and thermoelectric voltages. Thermocouples occur in the devices, the IC socket and the resistor across the device inputs (R2), all of which must be held isothermal. Usually best results are obtained by placing the circuit in a box or chamber to minimize airflow and employing a long thermal soak time. R2 should be mounted symmetrically with respect to potential thermal gradients: e.g. *not* perpendicular to the board but instead parallel to the board and the device socket. In addition, R2 should have low thermal EMF. Cermet or nichrome metal film types are acceptable; avoid tin-oxide resistors.

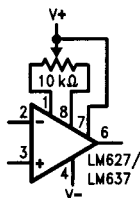


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FIGURE 1. Offset Voltage Test Circuit

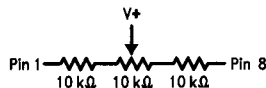
OFFSET NULLING

This is usually not required on the LM627/637 family since its offset voltage is internally trimmed. An offset adjust range of approximately $\pm 2\ \text{mV}$ is available using a single 10 or $20\ \text{k}\Omega$ potentiometer as shown in *Figure 2*. With these values, the adjustment is relatively linear over the entire range. If a $100\ \text{k}\Omega$ potentiometer is used, the adjustment becomes very coarse at the extremes (above $700\ \mu\text{V}$) but fine in the center, which makes it easier to precisely null the offset. For even more sensitivity, employ a pot in conjunction with two fixed resistors. The circuit of *Figure 3*, which uses this technique, has an adjustment range of $\pm 200\ \mu\text{V}$. Because adjusting the offset voltage of an LM627/637 will alter its offset voltage temperature drift, caution is advised.



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FIGURE 2. Offset Adjust Circuit



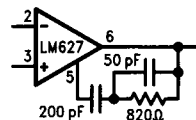
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FIGURE 3. Improved Sensitivity Offset Adjust

Every $100\ \mu\text{V}$ of offset will produce a $0.33\ \mu\text{V}/^\circ\text{C}$ drift component. For this reason the offset adjust potentiometer should not be used to null out a sensor offset if system temperature drift is important; rather a stable voltage reference must be added to the sensor voltage. Offset voltage drift is guaranteed by design for the LM627C either with or without external nulling. The higher precision A and B grades are 100% drift tested and guaranteed without nulling only.

OVERCOMPENSATION

Without any external compensation, the LM627 is stable at unity gain and up to $500\ \text{pF}$ load capacitance. It has a slew rate of $4.5\ \text{V}/\mu\text{s}$ and a gain-bandwidth product of $14\ \text{MHz}$. If desired, the amplifier may be overcompensated by adding external components as shown in *Figure 4*. This increases maximum capacitive loading to $2000\ \text{pF}$ while decreasing slew rate to $1.5\ \text{V}/\mu\text{s}$ and bandwidth to $1.5\ \text{MHz}$. If overcompensation of the LM627 (or the LM637) is not desired, pin 5 should be left open.

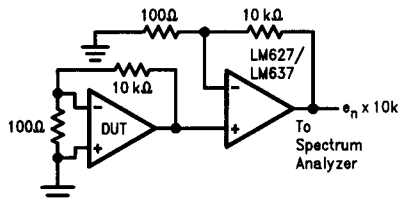


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FIGURE 4. Overcompensation

NOISE

When measuring spot noise voltage, a circuit as shown in *Figure 5* is recommended. The DUT running at a gain of 100 will not roll off until approximately $140\ \text{kHz}$. Adding the second gain of 100 amplifier brings total DUT-input-referred gain up to $10,000$, which minimizes to minimize sensitivity to EMI in the environment. When measuring spot noise at $30\ \text{Hz}$, it is recommended that the spectrum analyzer bandwidth be $20\ \text{Hz}$ or less to minimize pickup at line frequency.

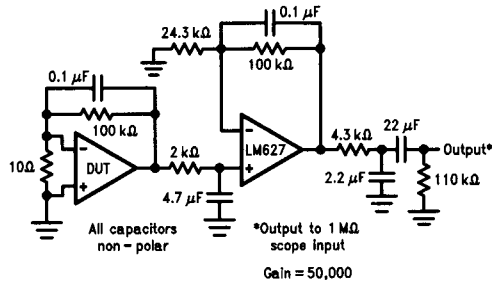


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FIGURE 5. Spot Noise Test Circuit

Application Hints (Continued)

The circuit used to measure peak-to-peak noise voltage in the 0.1 to 10 Hz range is shown in Figure 6. The device should be warmed up for about 2 minutes and shielded from air currents to minimize warmup drift and thermoelectric voltages. The test time should be limited to only 10 seconds, as this limits noise contributions below 0.1 Hz, as does the single zero rolloff. The measuring equipment must be flat down to 0.1 Hz. DC coupling must be employed to ensure this. Certain types of X-Y plotters may not be usable because of severe rolloff above a few Hz.



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FIGURE 6. 0.1 Hz to 10 Hz Noise Test Circuit