National Semiconductor

# 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/$\sqrt{Hz}$ in the flat band and rises to only 3.5 nV/$\sqrt{Hz}$ at 10 Hz. The A grades offer guaranteed specifications of 25 μV offset voltage and 0.3 μV/°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.

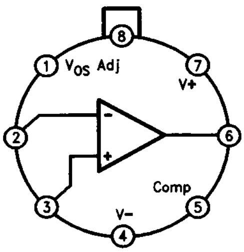
Other enhancements of the LM627/LM637 include a guaranteed 600Ω load drive capability over temperature: ±10V output swing at voltage gains over one million. Bias current has been reduced to 10 nA for the A and B grades and 25 nA for the C grade. Furthermore the LM627 may be overcompensated to allow it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

## Features

- Low Noise — 3 nV/$\sqrt{Hz}$@1 kHz; 3.5 nV/$\sqrt{Hz}$@ 10 Hz
- Low $V_{OS}$ — 25 μV Max
- Low Drift — 0.3 μV/°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* 600Ω drive over temperature
- Wide Power Supply Range — ±4V to ±18V
- Overcompensation Pin — Allows driving high $C_L$

## Connection Diagrams

**Metal Can Package**

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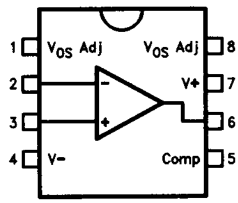
**Top View**

**DIP Packages**

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## Ordering Information

**LM627**

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

**LM637**

| Package | Temperature Range | | NSC Drawing |
|---|---|---|---|
| | Military | Commercial | |
| TO-99 | LM637AMH<br>LM637BMH | LM637ACH<br>LM637BCH<br>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 pF, $R_{ZAP}$ = 1.5 kΩ | |

## Operating Ratings

| | |
|---|---|
| Temperature Range (Note 8) | |
| AM and BM grades | $-55°C \le T_J \le +125°C$ |
| AC, BC, and C grades | $-25°C \le T_J \le +85°C$ |

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

## Electrical Characteristics (Continued)

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

## 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 | LM627AC LM637AC Tested Limit (Note 5) | LM627AC LM637AC Design Limit (Note 6) | LM627BC LM637BC Tested Limit (Note 5) | LM627BC LM637BC Design Limit (Note 6) | LM627C LM637C Tested Limit (Note 5) | LM627C LM637C Design Limit (Note 6) | Units |
|---|---|---|---|---|---|---|---|---|---|
| Input Offset Voltage | (Note 2) | 15 | 25<br>**50** | | 50<br>**110** | | 100 | **210** | µV Max |
| Input Offset Voltage Drift | (Note 3) | 0.2 | **0.6** | | **1.0** | | | **1.8** | µV/°C Max |
| Input Offset Voltage Long Term Stability | (Note 4) | 0.2 | | | | | | | µV/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 Hz<br>f = 30 Hz<br>f = 1 kHz | 3.5<br>3.1<br>3.0 | 5.5<br>4.5<br>3.8 | | 5.5<br>4.5<br>3.8 | | | 8.0<br>5.6<br>4.5 | $nV/\sqrt{Hz}$ Max |
| Input Noise Current Density | f = 10 Hz<br>f = 30 Hz<br>f = 1 kHz | 1.7<br>1.0<br>0.4 | | | | | | | $pA/\sqrt{Hz}$ Max |
| Input Resistance | Common Mode | 20 | | | | | | | GΩ |
| Input Voltage Range | | ±12 | ±11 | **±10.3** | ±11 | **±10.3** | ±11 | **±10.3** | V Min |
| Common-Mode Rejection Ratio | $V_{CM} = \pm 11V$<br>**$V_{CM} = \pm 10V$** | 140 | 126 | **120** | 126 | **120** | 120 | **116** | dB Min |
| Power Supply Rejection Ratio | $V_S = \pm 4V$ to $\pm 18V$<br>**$V_S = \pm 4.5V$ to $\pm 18V$** | 140 | 120 | **117** | 120 | **117** | 110 | **108** | dB Min |

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## 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 | $V_O = \pm 12V$<br>$R_L \geq 2\ k\Omega$ | 10000 | 5000 | **3000** | 5000 | **3000** | 4000 | **2500** | V/mV Min |
| | $V_O = \pm 10V$<br>$R_L \geq 1\ k\Omega$ | 7000 | 4000 | **2500** | 3500 | **2000** | 2500 | **1500** | |
| | $R_L \geq 600\Omega$ | 6000 | 3000 | **2000** | 2000 | **1500** | 1500 | **1000** | |
| Output Voltage Swing | $R_L \geq 2\ k\Omega$ | ±13.8 | ±13 | **±12.5** | ±13 | **±12.5** | ±13 | **±12.5** | V Min |
| | $R_L \geq 600\Omega$ | ±12.5 | ±11 | **±10.5** | ±11 | **±10.5** | ±10.5 | **±10** | |
| Slew Rate | LM627 $R_L = 2k$ | 4.5 | | 3 | | 3 | | 3 | V/μs Min |
| | LM637 | 14 | | 10 | | 10 | | 10 | |
| Gain-Bandwidth Product | LM627 f = 10 kHz | 14 | | 10 | | 10 | | 10 | MHz Min |
| | LM637 | 65 | | 45 | | 45 | | 45 | |
| Output Resistance | Open Loop | 50 | | | | | | | Ω |
| Supply Current | | 3 | 4.5 | **5** | 4.5 | **5** | 4.8 | **5.2** | mA Max |
| Offset Adjust Range | $R_P \geq 10\ k\Omega$ | ±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 μV 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°C) − $V_{OS}$(−25°C))/110°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°C) − $V_{OS}$(−55°C))/80°C and ($V_{OS}$(125°C) − $V_{OS}$(25°C))/100°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 μV.

**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.

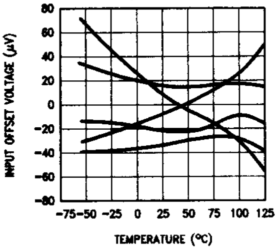
**Note 8:** For operation above 25°C, the maximum power dissipation specification must be derated. Typical junction-to-ambient thermal resistance of the molded DIP is 105°C/W. The metal can package has a typical junction-to-ambient thermal resistance of 150°C/W and a typical junction-to-case thermal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

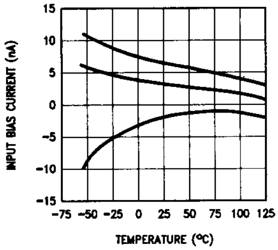
## Typical DC Performance Characteristics (LM627, LM637)

$V_S = \pm 15V$, $T_A = 25°C$, $R_L = 2k$ unless othewise indicated.

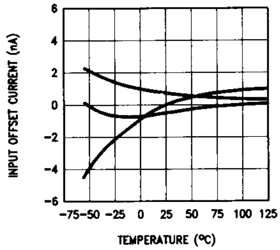
**Input Offset Voltage of 5 Representative Units vs Temperature (Note 9)**



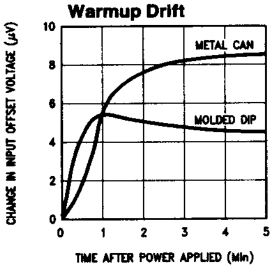

**Input Bias Current of 3 Representative Units vs Temperature (Note 9)**



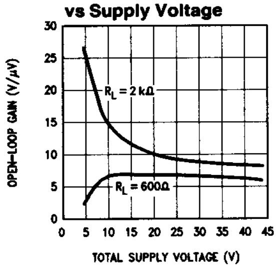

**Input Offset Current of 3 Representative Units vs Temperature (Note 9)**



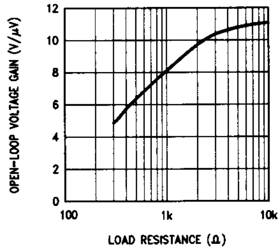

**Warmup Drift**



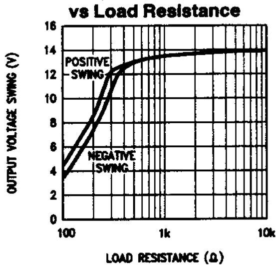

**Open Loop Gain vs Supply Voltage**



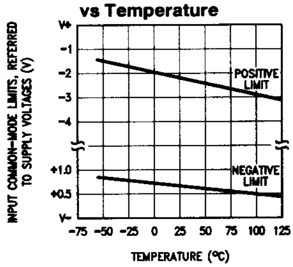

**Open Loop Gain vs Load Resistance**



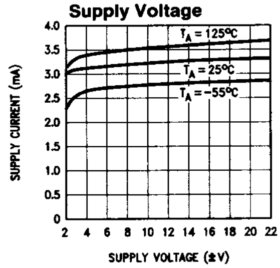

**Output Voltage Swing vs Load Resistance**




**Input Common-Mode Limits vs Temperature**




**Supply Current vs Supply Voltage**

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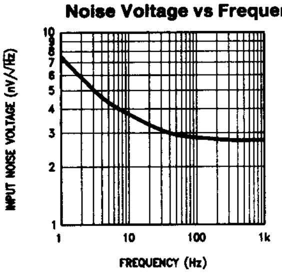
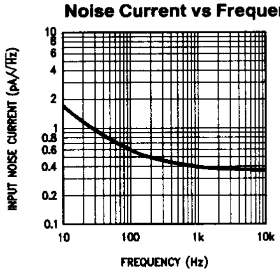
## Typical Noise Characteristics (LM627, LM637)

$V_S = \pm 15V$, $T_A = 25°C$

**Noise Voltage vs Frequency**




**Noise Current vs Frequency**

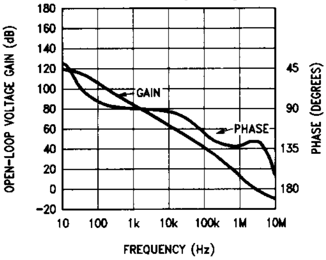



TL/H/9212-10

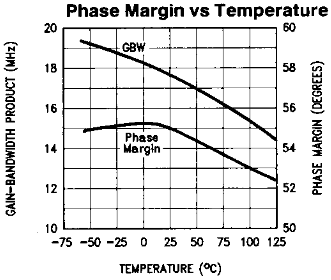
## Typical AC Performance Characteristics (LM627)

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

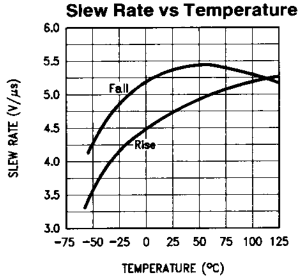
**Open-Loop Gain and Phase vs Frequency**



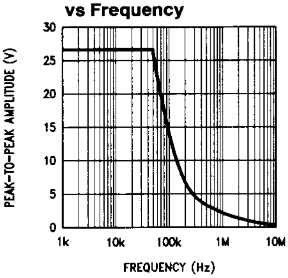

**Gain-Bandwidth Product, Phase Margin vs Temperature**



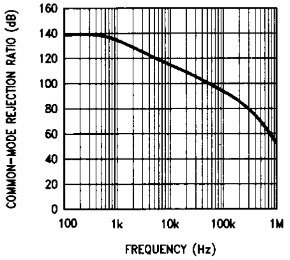

**Slew Rate vs Temperature**



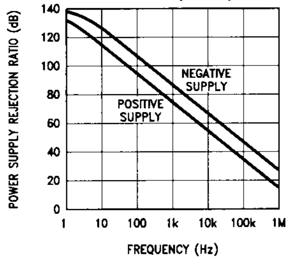

**Maximum Output Swing vs Frequency**




**Common-Mode Rejection Ratio vs Frequency**

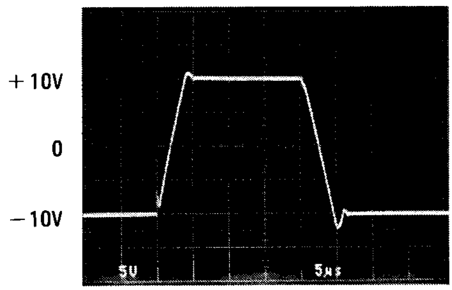



**Power Supply Rejection Ratio vs Frequency**




TL/H/9212-11

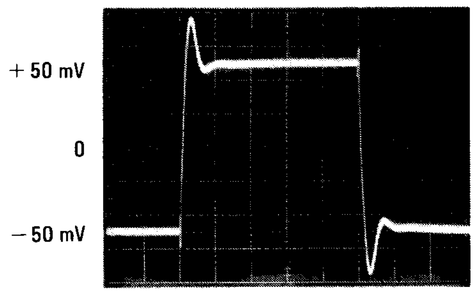
**Large-Signal Pulse Response, $A_V = +1$**




TIME (5 μs/DIV)

TL/H/9212-12

**Small-Signal Pulse Response, $A_V = +1$**



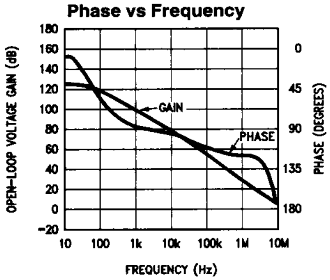

TIME (500 ns/DIV)

TL/H/9212-13

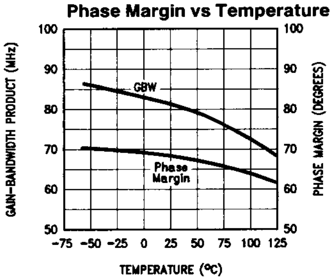
## Typical AC Performance Characteristics (LM637)

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

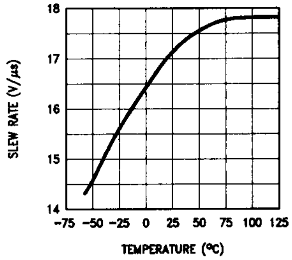
**Open-Loop Gain and Phase vs Frequency**




**Gain-Bandwidth Product, Phase Margin vs Temperature**




**Slew Rate vs Temperature**

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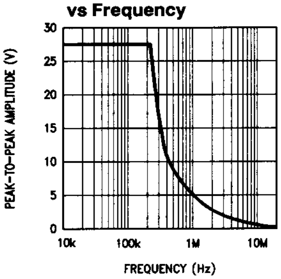
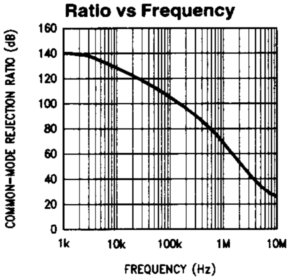
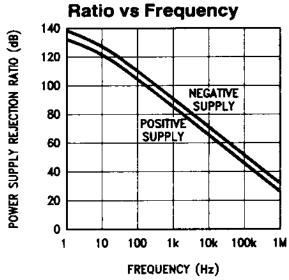
**Maximum Output Swing vs Frequency**




**Common-Mode Rejection Ratio vs Frequency**

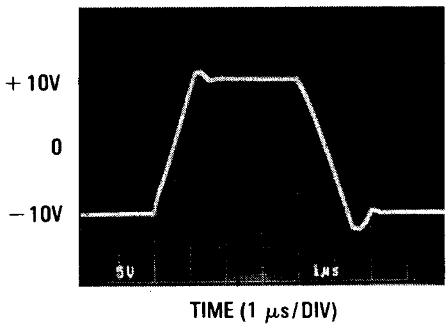



**Power Supply Rejection Ratio vs Frequency**




TL/H/9212-15

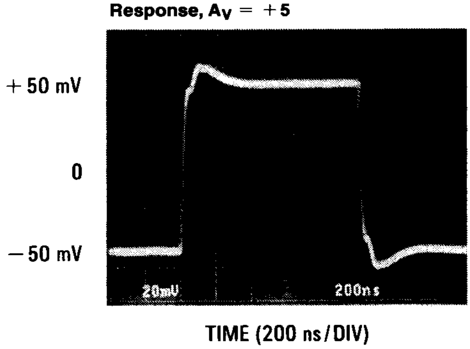
**Large-Signal Pulse Response, $A_V = +5$**




TIME (1 μs/DIV)

TL/H/9212-16

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




TIME (200 ns/DIV)

TL/H/9212-17

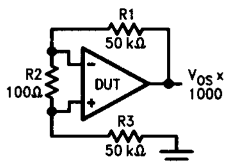
## Application Hints

### OFFSET VOLTAGE

Offset voltage of the LM627/637 is internally trimmed to a very low value. The data sheet $V_{OS}$ specification applies at $T_J = 25°C$, $V_{CM} = 0$ and ±15V 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 μV typical warmup drift is not accounted for in the measurement. Fortunately, the warmup drift is a small fraction of its 100 μV max offset. For the 25 μV A and 50μV 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.




TL/H/9212-3

**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 ±2 mV is available using a single 10 or 20 kΩ potentiometer as shown in *Figure 2*. With these values, the adjustment is relatively linear over the entire range. If a 100 kΩ potentiomer is used, the adjustment becomes very coarse at the extremes (above 700 μV) 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 ±200 μV. Because adjusting the offset voltage of an LM627/637 will alter its offset voltage temperature drift, caution is advised.

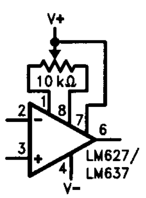



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**FIGURE 2. Offset Adjust Circuit**

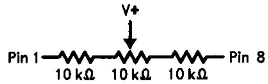


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**FIGURE 3. Improved Sensitivity Offset Adjust**

Every 100μV of offset will produce a 0.33 μV/°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 pF load capacitance. It has a slew rate of 4.5 V/μs and a gain-bandwidth product of 14 MHz. If desired, the amplifier may be overcompensated by adding external components as shown in *Figure 4*. This increases maximum capacitive loading to 2000 pF while decreasing slew rate to 1.5 V/μs and bandwidth to 1.5 MHz. If overcompensation of the LM627 (or the LM637) is not desired, pin 5 should be left open.

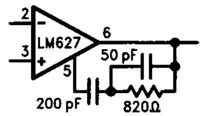


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**FIGURE 4. Overcompensation**

### 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 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 Hz, it is recommended that the spectrum analyzer bandwidth be 20 Hz or less to minimize pickup at line frequency.

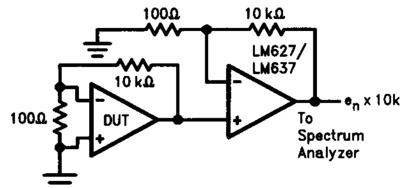


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**FIGURE 5. Spot Noise Test Circuit**

## 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.

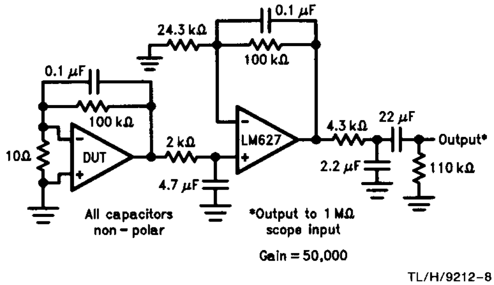


**FIGURE 6. 0.1 Hz to 10 Hz Noise Test Circuit**

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