

## LM833 Dual Audio Operational Amplifier

Check for Samples: [LM833-N](#)

### FEATURES

- Wide dynamic range: >140dB
- Low input noise voltage:  $4.5\text{nV}/\sqrt{\text{Hz}}$
- High slew rate:  $7\text{ V}/\mu\text{s}$  (typ);  $5\text{ V}/\mu\text{s}$  (min)
- High gain bandwidth:  $15\text{MHz}$  (typ);  $10\text{MHz}$  (min)
- Wide power bandwidth:  $120\text{KHz}$
- Low distortion:  $0.002\%$
- Low offset voltage:  $0.3\text{mV}$
- Large phase margin:  $60^\circ$
- Available in 8 pin MSOP package

### DESCRIPTION

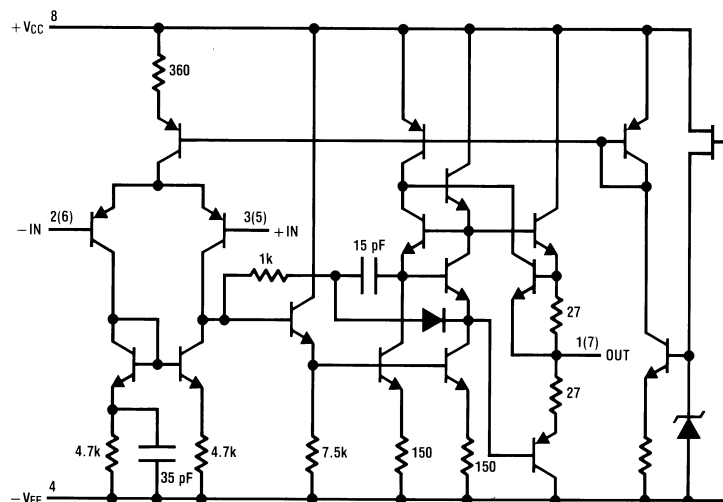
The LM833 is a dual general purpose operational amplifier designed with particular emphasis on performance in audio systems.

This dual amplifier IC utilizes new circuit and processing techniques to deliver low noise, high speed and wide bandwidth without increasing external components or decreasing stability. The LM833 is internally compensated for all closed loop gains and is therefore optimized for all preamp and high level stages in PCM and HiFi systems.

The LM833 is pin-for-pin compatible with industry standard dual operational amplifiers.

### Schematic Diagram

(1/2 LM833)



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## Connection Diagram

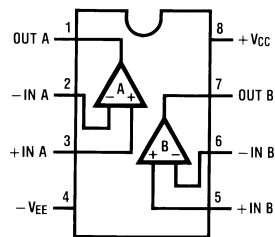


Figure 1.



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)</sup>

|                                                                         |                         |
|-------------------------------------------------------------------------|-------------------------|
| Supply Voltage $V_{CC}-V_{EE}$                                          | 36V                     |
| Differential Input Voltage <sup>(2)</sup> $V_I$                         | $\pm 30V$               |
| Input Voltage Range <sup>(2)</sup> $V_{IC}$                             | $\pm 15V$               |
| Power Dissipation <sup>(3)</sup> $P_D$                                  | 500 mW                  |
| Operating Temperature Range $T_{OPR}$                                   | $-40 \sim 85^{\circ}C$  |
| Storage Temperature Range $T_{STG}$                                     | $-60 \sim 150^{\circ}C$ |
| Soldering Information<br>Dual-In-Line Package<br>Soldering (10 seconds) | 260°C                   |
| Small Outline Package<br>(SOIC and MSOP)                                |                         |
| Vapor Phase (60 seconds)                                                | 215°C                   |
| Infrared (15 seconds)                                                   | 220°C                   |
| ESD tolerance <sup>(4)</sup>                                            | 1600V                   |

- (1) *Absolute Maximum Ratings* indicate limits beyond which damage to the device may occur. *Operating Ratings* indicate conditions for which the device is functional, but do not guarantee specific performance limits. *Electrical Characteristics* state DC and AC electrical specifications under particular test conditions which guarantee specific performance limits. This assumes that the device is within the Operating Ratings. Specifications are not guaranteed for parameters where no limit is given, however, the typical value is a good indication of device performance.
- (2) If supply voltage is less than  $\pm 15V$ , it is equal to supply voltage.
- (3) This is the permissible value at  $T_A \leq 85^{\circ}C$ .
- (4) Human body model, 1.5 k $\Omega$  in series with 100 pF.

## DC Electrical Characteristics

(1)(2)

( $T_A = 25^\circ\text{C}$ ,  $V_S = \pm 15\text{V}$ )

| Symbol   | Parameter                    | Conditions                                        | Min      | Typ        | Max  | Units |
|----------|------------------------------|---------------------------------------------------|----------|------------|------|-------|
| $V_{OS}$ | Input Offset Voltage         | $R_S = 10\Omega$                                  |          | 0.3        | 5    | mV    |
| $I_{OS}$ | Input Offset Current         |                                                   |          | 10         | 200  | nA    |
| $I_B$    | Input Bias Current           |                                                   |          | 500        | 1000 | nA    |
| $A_V$    | Voltage Gain                 | $R_L = 2\text{ k}\Omega$ , $V_O = \pm 10\text{V}$ | 90       | 110        |      | dB    |
| $V_{OM}$ | Output Voltage Swing         | $R_L = 10\text{ k}\Omega$                         | $\pm 12$ | $\pm 13.5$ |      | V     |
|          |                              | $R_L = 2\text{ k}\Omega$                          | $\pm 12$ | $\pm 13.4$ |      | V     |
| $V_{CM}$ | Input Common-Mode Range      |                                                   | $\pm 12$ | $\pm 14.0$ |      | V     |
| CMRR     | Common-Mode Rejection Ratio  | $V_{IN} = \pm 12\text{V}$                         | 80       | 100        |      | dB    |
| PSRR     | Power Supply Rejection Ratio | $V_S = 15 \sim 5\text{V}$ , $-15 \sim -5\text{V}$ | 80       | 100        |      | dB    |
| $I_Q$    | Supply Current               | $V_O = 0\text{V}$ , Both Amps                     |          | 5          | 8    | mA    |

- (1) *Absolute Maximum Ratings* indicate limits beyond which damage to the device may occur. *Operating Ratings* indicate conditions for which the device is functional, but do not guarantee specific performance limits. *Electrical Characteristics* state DC and AC electrical specifications under particular test conditions which guarantee specific performance limits. This assumes that the device is within the Operating Ratings. Specifications are not guaranteed for parameters where no limit is given, however, the typical value is a good indication of device performance.
- (2) All voltages are measured with respect to the ground pin, unless otherwise specified.

## AC Electrical Characteristics

( $T_A = 25^\circ\text{C}$ ,  $V_S = \pm 15\text{V}$ ,  $R_L = 2\text{ k}\Omega$ )

| Symbol   | Parameter                                          | Conditions                              | Min | Typ | Max | Units            |
|----------|----------------------------------------------------|-----------------------------------------|-----|-----|-----|------------------|
| SR       | Slew Rate                                          | $R_L = 2\text{ k}\Omega$                | 5   | 7   |     | V/ $\mu\text{s}$ |
| GBW      | Gain Bandwidth Product                             | $f = 100\text{ kHz}$                    | 10  | 15  |     | MHz              |
| $V_{NI}$ | Equivalent Input Noise Voltage (LM833AM, LM833AMX) | RIAA, $R_S = 2.2\text{ k}\Omega$<br>(1) |     |     | 1.4 | $\mu\text{V}$    |

- (1) RIAA Noise Voltage Measurement Circuit

## Design Electrical Characteristics

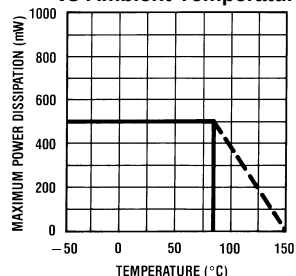
( $T_A = 25^\circ\text{C}$ ,  $V_S = \pm 15\text{V}$ )

The following parameters are not tested or guaranteed.

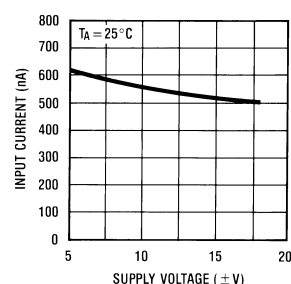
| Symbol                   | Parameter                                               | Conditions                                                                                        | Typ   | Units                          |
|--------------------------|---------------------------------------------------------|---------------------------------------------------------------------------------------------------|-------|--------------------------------|
| $\Delta V_{OS}/\Delta T$ | Average Temperature Coefficient of Input Offset Voltage |                                                                                                   | 2     | $\mu\text{V}/^\circ\text{C}$   |
| THD                      | Distortion                                              | $R_L = 2\text{ k}\Omega$ , $f = 20\sim 20\text{ kHz}$<br>$V_{OUT} = 3\text{ V}_{rms}$ , $A_V = 1$ | 0.002 | %                              |
| $e_n$                    | Input Referred Noise Voltage                            | $R_S = 100\Omega$ , $f = 1\text{ kHz}$                                                            | 4.5   | $\text{nV} / \sqrt{\text{Hz}}$ |
| $i_n$                    | Input Referred Noise Current                            | $f = 1\text{ kHz}$                                                                                | 0.7   | $\text{pA} / \sqrt{\text{Hz}}$ |
| PBW                      | Power Bandwidth                                         | $V_O = 27\text{ V}_{pp}$ , $R_L = 2\text{ k}\Omega$ , $\text{THD} \leq 1\%$                       | 120   | kHz                            |
| $f_U$                    | Unity Gain Frequency                                    | Open Loop                                                                                         | 9     | MHz                            |
| $\Phi_M$                 | Phase Margin                                            | Open Loop                                                                                         | 60    | deg                            |
|                          | Input Referred Cross Talk                               | $f = 20\sim 20\text{ kHz}$                                                                        | -120  | dB                             |

## Typical Performance Characteristics

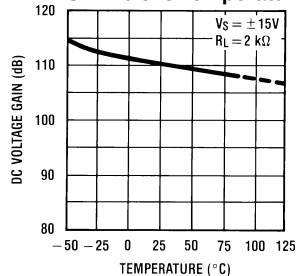
**Maximum Power Dissipation vs Ambient Temperature**



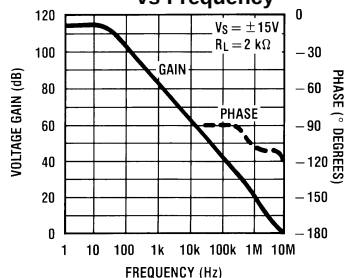
**Input Bias Current vs Supply Voltage**



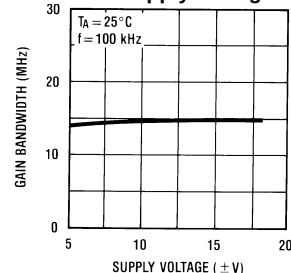
**DC Voltage Gain vs Ambient Temperature**



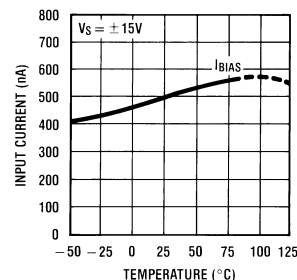
**Voltage Gain & Phase vs Frequency**



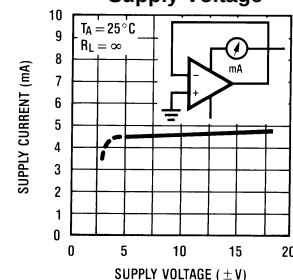
**Gain Bandwidth vs Supply Voltage**



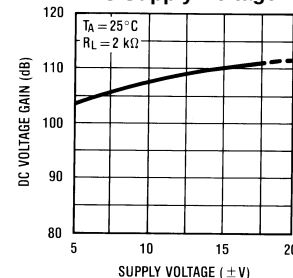
**Input Bias Current vs Ambient Temperature**



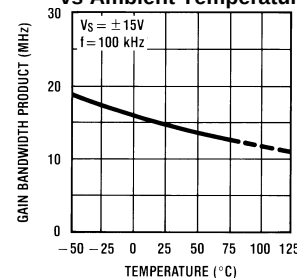
**Supply Current vs Supply Voltage**



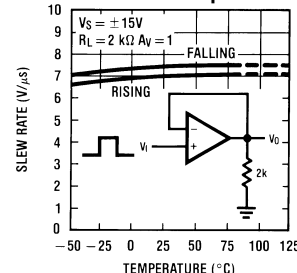
**DC Voltage Gain vs Supply Voltage**



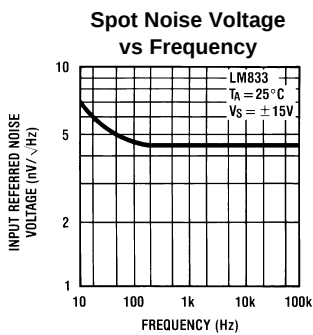
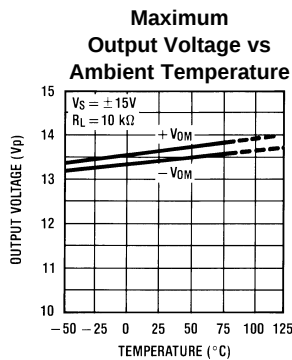
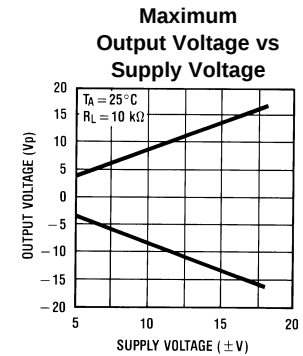
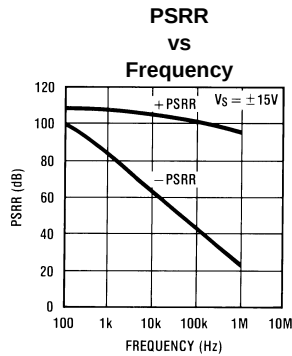
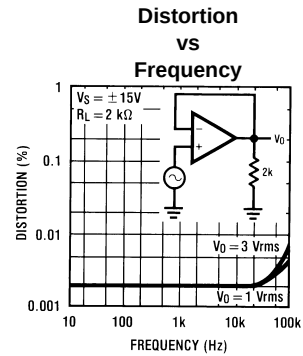
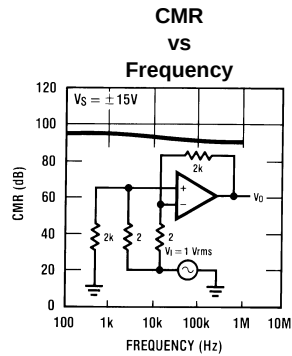
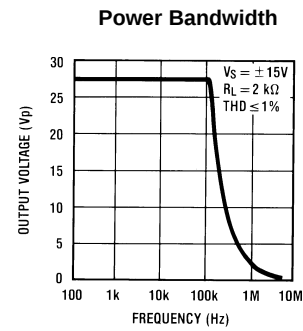
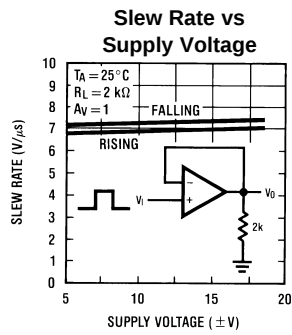
**Gain Bandwidth Product vs Ambient Temperature**



**Slew Rate vs Ambient Temperature**

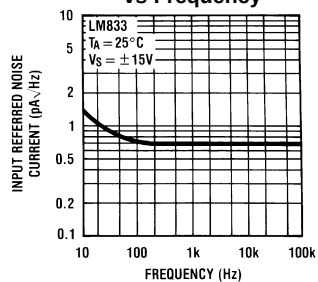


## Typical Performance Characteristics (continued)

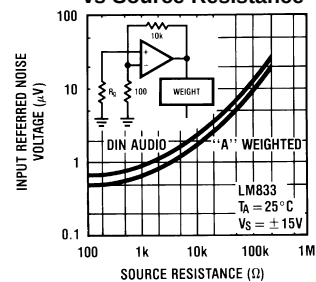


## Typical Performance Characteristics (continued)

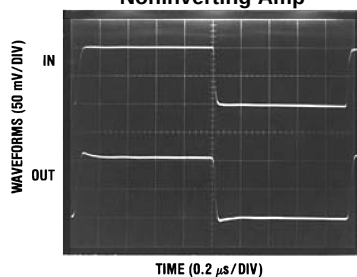
**Spot Noise Current  
vs Frequency**



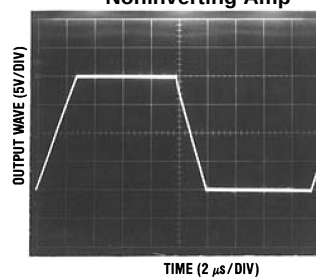
**Input Referred Noise Voltage  
vs Source Resistance**



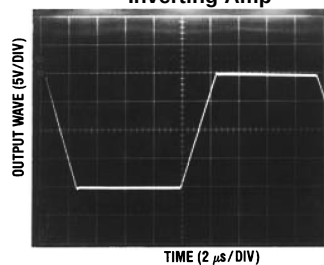
**Noninverting Amp**



**Noninverting Amp**



**Inverting Amp**

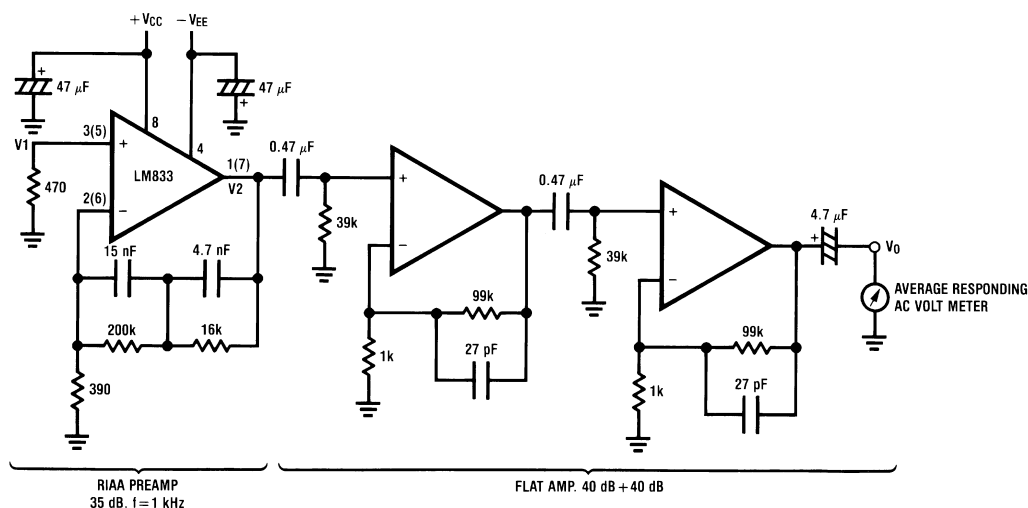


## Application Hints

The LM833 is a high speed op amp with excellent phase margin and stability. Capacitive loads up to 50 pF will cause little change in the phase characteristics of the amplifiers and are therefore allowable.

Capacitive loads greater than 50 pF must be isolated from the output. The most straightforward way to do this is to put a resistor in series with the output. This resistor will also prevent excess power dissipation if the output is accidentally shorted.

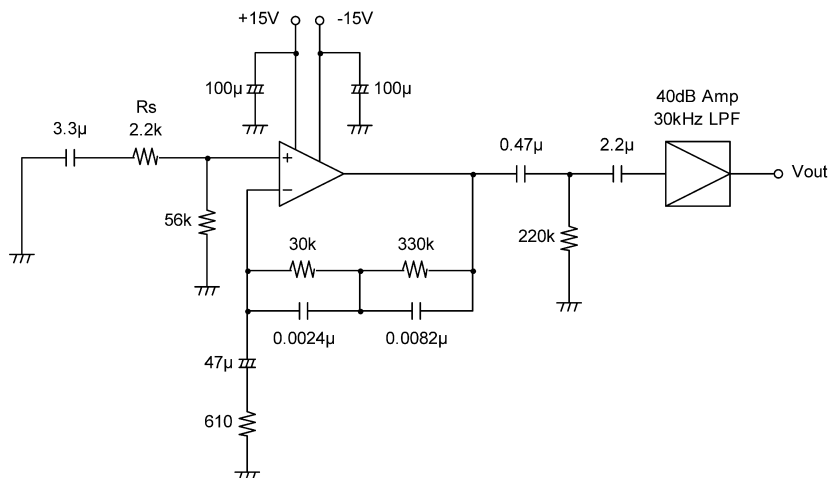
## Noise Measurement Circuit



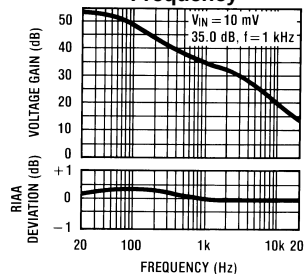
Complete shielding is required to prevent induced pick up from external sources. Always check with oscilloscope for power line noise.

**Figure 2. Total Gain: 115 dB @f = 1 kHz**  
**Input Referred Noise Voltage:  $e_n = V_0/560,000$  (V)**

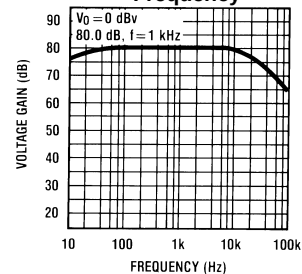
## RIAA Noise Voltage Measurement Circuit



**RIAA Preamp Voltage Gain, RIAA  
Deviation  
vs  
Frequency**

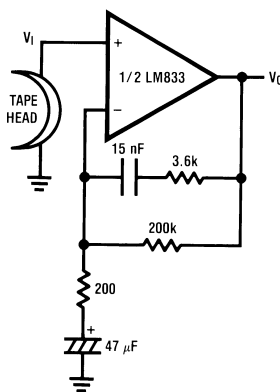


**Flat Amp Voltage Gain vs  
Frequency**



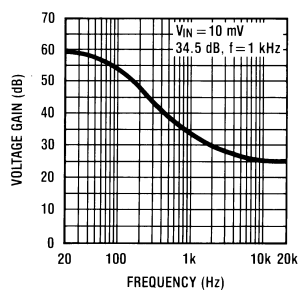
## Typical Applications

**Figure 3. NAB Preamp**

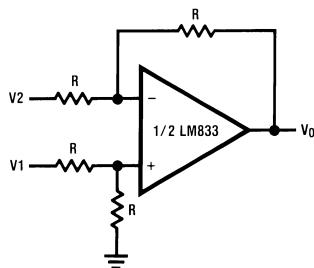


$A_V = 34.5$   
 $F = 1 \text{ kHz}$   
 $E_n = 0.38 \mu\text{V}$   
 A Weighted

**Figure 4. NAB Preamp Voltage Gain  
vs Frequency**

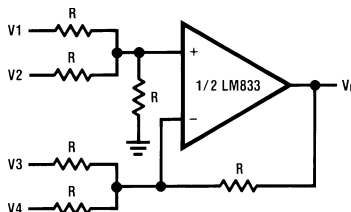


**Figure 5. Balanced to Single Ended Converter**



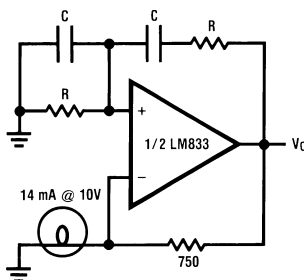
$$V_O = V_1 - V_2$$

**Figure 6. Adder/Subtractor**



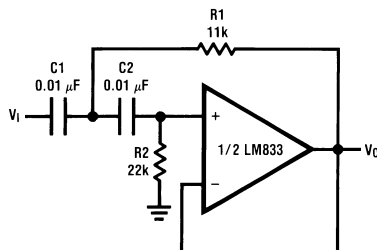
$$V_O = V_1 + V_2 - V_3 - V_4$$

**Figure 7. Sine Wave Oscillator**



$$f_o = \frac{1}{2\pi RC}$$

**Figure 8. Second Order High Pass Filter (Butterworth)**

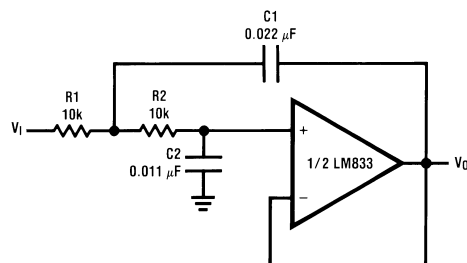


$$\text{if } C_1 = C_2 = C$$

$$R_1 = \frac{\sqrt{2}}{2\omega_o C}$$

$$R_2 = 2 \cdot R_1$$

Illustration is  $f_o = 1 \text{ kHz}$

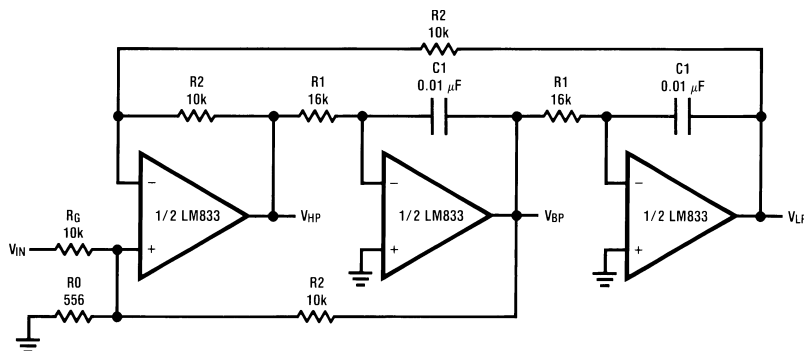
**Figure 9. Second Order Low Pass Filter (Butterworth)**

if  $R_1 = R_2 = R$

$$C_1 = \frac{\sqrt{2}}{\omega_0 R}$$

$$C_2 = \frac{C_1}{2}$$

Illustration is  $f_0 = 1 \text{ kHz}$

**Figure 10. State Variable Filter**

$$f_0 = \frac{1}{2\pi C_1 R_1}, Q = \frac{1}{2} \left( 1 + \frac{R_2}{R_0} + \frac{R_2}{R_G} \right), A_{BP} = Q A_{LP} = Q A_{LH} = \frac{R_2}{R_G}$$

Illustration is  $f_0 = 1 \text{ kHz}$ ,  $Q = 10$ ,  $A_{BP} = 1$

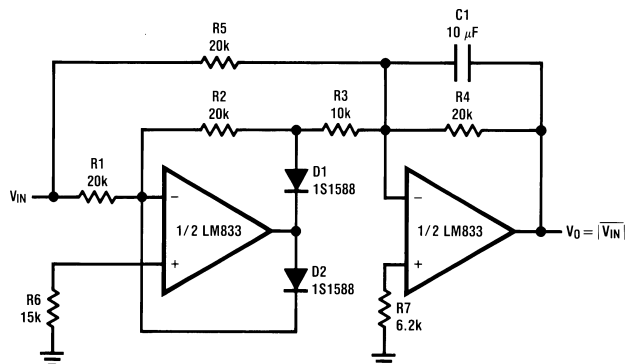
**Figure 11. AC/DC Converter**

Figure 12. 2 Channel Panning Circuit (Pan Pot)

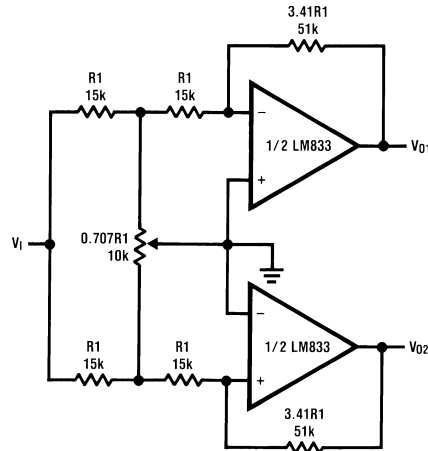


Figure 13. Line Driver

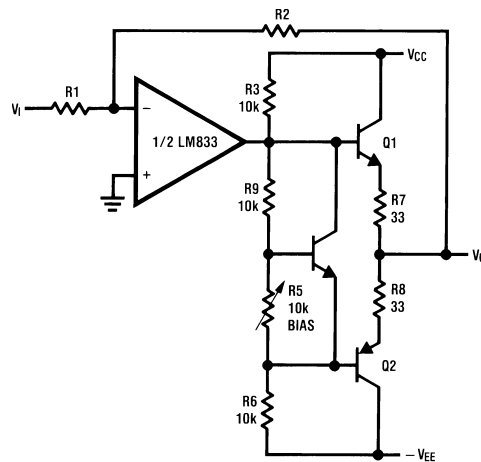
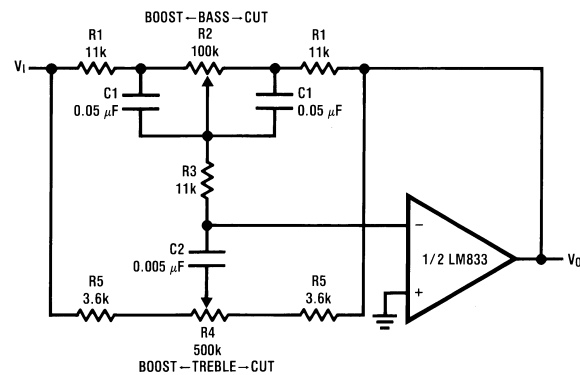


Figure 14. Tone Control



$$f_L = \frac{1}{2\pi R_2 C_1}, f_{LB} = \frac{1}{2\pi R_1 C_1}$$

$$f_H = \frac{1}{2\pi R_5 C_2}, f_{HB} = \frac{1}{2\pi (R_1 + R_5 + 2R_3) C_2}$$

Illustration is:

$$f_L = 32 \text{ Hz}, f_{LB} = 320 \text{ Hz}$$

$$f_H = 11 \text{ kHz}, f_{HB} = 1.1 \text{ kHz}$$

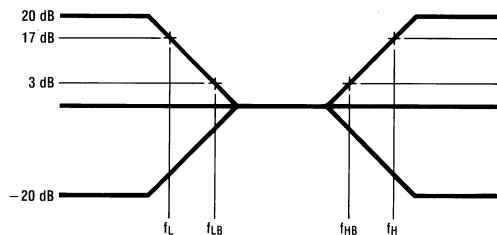
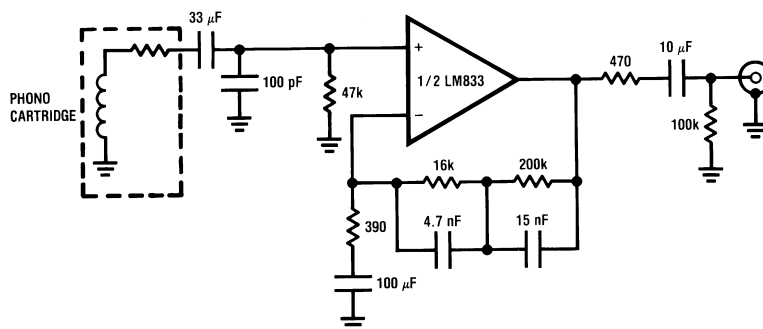
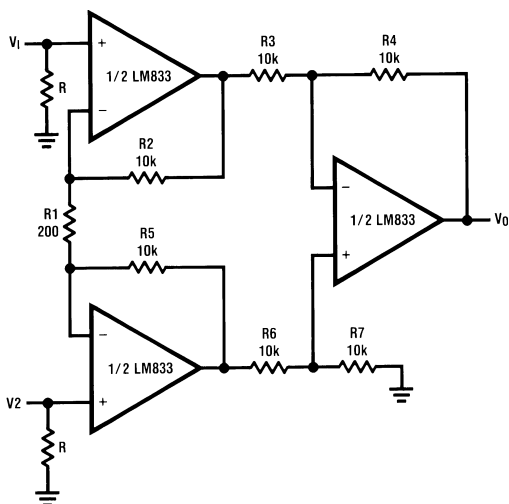


Figure 15. RIAA Preamp



$A_v = 35 \text{ dB}$   
 $E_n = 0.33 \mu\text{V}$   
 $S/N = 90 \text{ dB}$   
 $f = 1 \text{ kHz}$   
 A Weighted  
 A Weighted,  $V_{IN} = 10 \text{ mV}$   
 @  $f = 1 \text{ kHz}$

Figure 16. Balanced Input Mic Amp



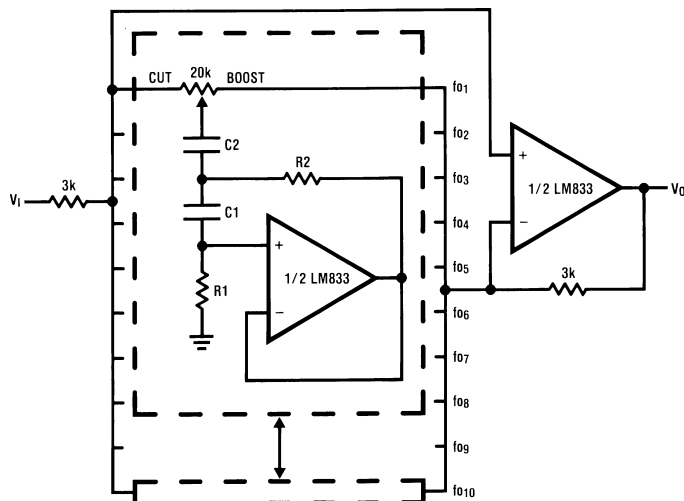
If  $R_2 = R_5$ ,  $R_3 = R_6$ ,  $R_4 = R_7$

$$V_0 = \left(1 + \frac{2R_2}{R_1}\right) \frac{R_4}{R_3} (V_2 - V_1)$$

Illustration is:

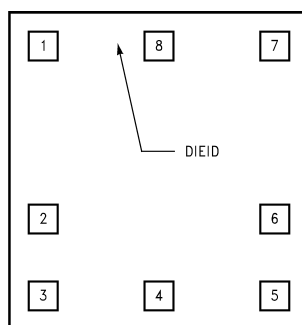
$$V_0 = 101(V_2 - V_1)$$

**Figure 17. 10 Band Graphic Equalizer**



| fo (Hz) | C <sub>1</sub> | C <sub>2</sub> | R <sub>1</sub> | R <sub>2</sub> |
|---------|----------------|----------------|----------------|----------------|
| 32      | 0.12μF         | 4.7μF          | 75kΩ           | 500Ω           |
| 64      | 0.056μF        | 3.3μF          | 68kΩ           | 510Ω           |
| 125     | 0.033μF        | 1.5μF          | 62kΩ           | 510Ω           |
| 250     | 0.015μF        | 0.82μF         | 68kΩ           | 470Ω           |
| 500     | 8200pF         | 0.39μF         | 62kΩ           | 470Ω           |
| 1k      | 3900pF         | 0.22μF         | 68kΩ           | 470Ω           |
| 2k      | 2000pF         | 0.1μF          | 68kΩ           | 470Ω           |
| 4k      | 1100pF         | 0.056μF        | 62kΩ           | 470Ω           |
| 8k      | 510pF          | 0.022μF        | 68kΩ           | 510Ω           |
| 16k     | 330pF          | 0.012μF        | 51kΩ           | 510Ω           |

**LM833 MDC MWC  
DUAL AUDIO OPERATIONAL AMPLIFIER**



**Figure 18. Die Layout (A - Step)**

**Table 1. Die/Wafer Characteristics**

| Fabrication Attributes      |                                    | General Die Information     |               |
|-----------------------------|------------------------------------|-----------------------------|---------------|
| Physical Die Identification | LM833A                             | Bond Pad Opening Size (min) | 110µm x 110µm |
| Die Step                    | A                                  | Bond Pad Metalization       | ALUMINUM      |
| Physical Attributes         |                                    | Passivation                 | VOM NITRIDE   |
| Wafer Diameter              | 150mm                              | Back Side Metal             | BARE BACK     |
| Dise Size (Drawn)           | 1219µm x 1270µm<br>48mils x 50mils | Back Side Connection        | Floating      |
| Thickness                   | 406µm Nominal                      |                             |               |
| Min Pitch                   | 288µm Nominal                      |                             |               |

**Special Assembly Requirements:****Note:** Actual die size is rounded to the nearest micron.**Die Bond Pad Coordinate Locations (A - Step)**

(Referenced to die center, coordinates in µm) NC = No Connection

| SIGNAL NAME | PAD NUMBER | X/Y COORDINATES |      | PAD SIZE |   |     |
|-------------|------------|-----------------|------|----------|---|-----|
|             |            | X               | Y    | X        |   | Y   |
| OUTPUT A    | 1          | -476            | 500  | 110      | x | 110 |
| INPUT A-    | 2          | -476            | -212 | 110      | x | 110 |
| INPUT A+    | 3          | -476            | -500 | 110      | x | 110 |
| VEE-        | 4          | -0              | -500 | 110      | x | 110 |
| INPUT B+    | 5          | 476             | -500 | 110      | x | 110 |
| INPUT B-    | 6          | 476             | -212 | 110      | x | 110 |
| OUTPUT B    | 7          | 476             | 500  | 110      | x | 110 |
| VCC+        | 8          | 0               | 500  | 110      | x | 110 |

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**PACKAGING INFORMATION**

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package Qty | Eco Plan<br>(2)            | Lead/Ball Finish | MSL Peak Temp<br>(3) | Samples<br>(Requires Login) |
|------------------|---------------|--------------|--------------------|------|-------------|----------------------------|------------------|----------------------|-----------------------------|
| LM833M           | ACTIVE        | SOIC         | D                  | 8    | 95          | TBD                        | CU SNPB          | Level-1-235C-UNLIM   |                             |
| LM833M/NOPB      | ACTIVE        | SOIC         | D                  | 8    | 95          | Green (RoHS<br>& no Sb/Br) | CU SN            | Level-1-260C-UNLIM   |                             |
| LM833MM          | ACTIVE        | VSSOP        | DGK                | 8    | 1000        | TBD                        | CU SNPB          | Level-1-260C-UNLIM   |                             |
| LM833MM/NOPB     | ACTIVE        | VSSOP        | DGK                | 8    | 1000        | Green (RoHS<br>& no Sb/Br) | CU SN            | Level-1-260C-UNLIM   |                             |
| LM833MMX/NOPB    | ACTIVE        | VSSOP        | DGK                | 8    | 3500        | Green (RoHS<br>& no Sb/Br) | CU SN            | Level-1-260C-UNLIM   |                             |
| LM833MX          | ACTIVE        | SOIC         | D                  | 8    | 2500        | TBD                        | CU SNPB          | Level-1-235C-UNLIM   |                             |
| LM833MX/NOPB     | ACTIVE        | SOIC         | D                  | 8    | 2500        | Green (RoHS<br>& no Sb/Br) | CU SN            | Level-1-260C-UNLIM   |                             |
| LM833N           | ACTIVE        | PDIP         | P                  | 8    | 40          | TBD                        | Call TI          | Level-1-NA-UNLIM     |                             |
| LM833N/NOPB      | ACTIVE        | PDIP         | P                  | 8    | 40          | Green (RoHS<br>& no Sb/Br) | Call TI          | Level-1-NA-UNLIM     |                             |

<sup>(1)</sup> 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.

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

<sup>(2)</sup> 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)

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

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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 |
|---------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| LM833MM       | VSSOP        | DGK             | 8    | 1000 | 178.0              | 12.4               | 5.3     | 3.4     | 1.4     | 8.0     | 12.0   | Q1            |
| LM833MM/NOPB  | VSSOP        | DGK             | 8    | 1000 | 178.0              | 12.4               | 5.3     | 3.4     | 1.4     | 8.0     | 12.0   | Q1            |
| LM833MMX/NOPB | VSSOP        | DGK             | 8    | 3500 | 330.0              | 12.4               | 5.3     | 3.4     | 1.4     | 8.0     | 12.0   | Q1            |
| LM833MX       | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.5     | 5.4     | 2.0     | 8.0     | 12.0   | Q1            |
| LM833MX/NOPB  | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.5     | 5.4     | 2.0     | 8.0     | 12.0   | Q1            |

## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

| Device        | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|---------------|--------------|-----------------|------|------|-------------|------------|-------------|
| LM833MM       | VSSOP        | DGK             | 8    | 1000 | 203.0       | 190.0      | 41.0        |
| LM833MM/NOPB  | VSSOP        | DGK             | 8    | 1000 | 203.0       | 190.0      | 41.0        |
| LM833MMX/NOPB | VSSOP        | DGK             | 8    | 3500 | 349.0       | 337.0      | 45.0        |
| LM833MX       | SOIC         | D               | 8    | 2500 | 349.0       | 337.0      | 45.0        |
| LM833MX/NOPB  | SOIC         | D               | 8    | 2500 | 349.0       | 337.0      | 45.0        |

P (R-PDIP-T8)

PLASTIC DUAL-IN-LINE PACKAGE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - C. Falls within JEDEC MS-001 variation BA.

DGK (S-PDSO-G8)

PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 per end.
  - D. Body width does not include interlead flash. Interlead flash shall not exceed 0.50 per side.
  - E. Falls within JEDEC MO-187 variation AA, except interlead flash.

D (R-PDSO-G8)

PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - $\triangle C$  Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
  - $\triangle D$  Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
  - E. Reference JEDEC MS-012 variation AA.

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