

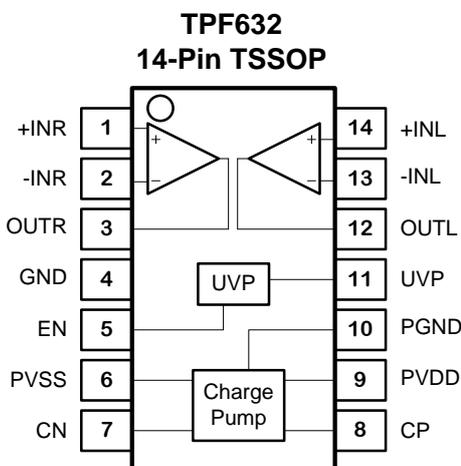
### Features

- 2- $V_{RMS}$  Output into 2.5k $\Omega$  Load with 3.3V Supply
- Integrated Charge Pump Generates Negative Supply Rail
- 0-V DC Voltage at Output
- Low Noise:  $V_N = 4.3\mu V_{RMS}$  at 20Hz to 20kHz
- Low THD+N: 0.001%
- Drives 600 $\Omega$  Load
- Stable with 220pF Capacitive Load
- Pop-Free Under-Voltage Protection
- Pop-Free Enable Control
- -40°C to 85°C Operation Range
- Robust 8kV (Output) HBM ESD Rating
- Robust 2kV CDM ESD Rating
- Green, TSSOP-14 Package

### Applications

- Set-Top Box
- Blu-ray and HD DVD Players
- PDP TV and LCD TV
- Home Theater in a Box

### Pin Configuration (Top View)



### Description

The 3PEAK INCORPORATED TPF632 are 2- $V_{RMS}$  pop-free stereo line drivers with the integrated charge pump generating the negative supply rail which allows the removal of the output DC-blocking capacitors. The devices are capable of driving 2- $V_{RMS}$  into a 2.5-k $\Omega$  load with single 3.3V supply voltage. The device has differential inputs, and can use external resistors for flexible gain setting.

The TPF632 has built-in enable/shutdown control for pop-free on/off control. The device has an external under-voltage detector that mutes the output when monitored voltage drop below set value. Using the TPF632 in audio products can reduce component count considerably compared to traditional methods of generating a 2- $V_{RMS}$  output.

The device needs only a single 3.3V supply to generate 5.6- $V_{PP}$  output while a traditional op-amp requires a split-rail power supply to achieve same. The device is ideal for single-supply electronics where size and cost are critical design parameters.

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### Audio Line Drivers

| Part Number | Package    | Remarks                                      |
|-------------|------------|----------------------------------------------|
| TPF632      | TSSOP-14   | 3.3V, Differential inputs                    |
| TPF603      | TSSOP-14   | 5V/3.3V, Differential inputs                 |
| TPF605      | MSOP-10-EP | 5V/3.3V, Single-ended inputs                 |
| TPF607      | MSOP-10    | 5V/3.3V, Single-ended inputs, no UVP control |

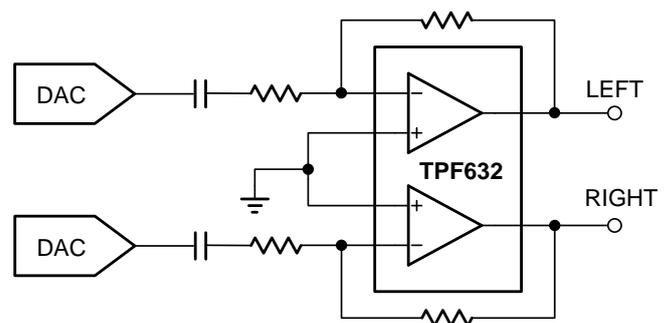


Figure 1. Typical Application Circuit of TPF632

# TPF632

## 2- $V_{RMS}$ Audio Line Driver with Integrated Charge Pump

### Order Information

| Model Name | Order Number | Package      | Transport Media, Quantity | Marking Information |
|------------|--------------|--------------|---------------------------|---------------------|
| TPF632     | TPF632-TR    | 14-Pin TSSOP | Tape and Reel, 3000       | TPF632              |

### Absolute Maximum Ratings <sup>Note 1</sup>

Supply Voltage:  $V^+ - V^-$  .....4.0V  
Input Voltage.....  $V^- - 0.3$  to  $V^+ + 0.3$   
Input Current: +IN, -IN, SHDN <sup>Note 2</sup>.....  $\pm 10$ mA  
EN Pin Voltage..... $V^-$  to  $V^+$   
Output Current: OUT.....  $\pm 20$ mA

Output Short-Circuit Duration <sup>Note 3</sup>..... Indefinite  
Operating Temperature Range..... $-40^\circ\text{C}$  to  $125^\circ\text{C}$   
Maximum Junction Temperature.....  $150^\circ\text{C}$   
Storage Temperature Range.....  $-65^\circ\text{C}$  to  $150^\circ\text{C}$   
Lead Temperature (Soldering, 10 sec) .....  $260^\circ\text{C}$

**Note 1:** Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

**Note 2:** The inputs are protected by ESD protection diodes to each power supply. If the input extends more than 500mV beyond the power supply, the input current should be limited to less than 10mA.

**Note 3:** A heat sink may be required to keep the junction temperature below the absolute maximum. This depends on the power supply voltage and how many amplifiers are shorted. Thermal resistance varies with the amount of PC board metal connected to the package. The specified values are for short traces connected to the leads.

### ESD, Electrostatic Discharge Protection

| Pin    | Symbol | Parameter                | Condition                  | Minimum Level | Unit |
|--------|--------|--------------------------|----------------------------|---------------|------|
| Output | HBM    | Human Body Model ESD     | MIL-STD-883H Method 3015.8 | 8             | kV   |
| Others | HBM    | Human Body Model ESD     | MIL-STD-883H Method 3015.8 | 4             | kV   |
| All    | CDM    | Charged Device Model ESD | JEDEC-EIA/JESD22-C101E     | 2             | kV   |

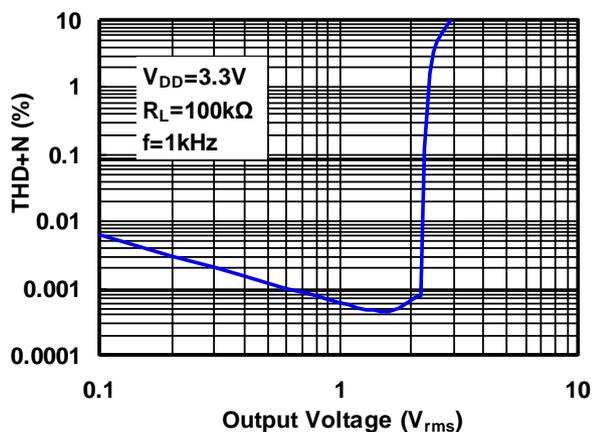
### 3V Electrical Characteristics

Specifications are at  $T_A = 27^\circ\text{C}$ .  $V_{DD} = 3.3\text{V}$ ,  $R_L = 2.5\text{k}\Omega$ ,  $C_{PUMP} = C_{PVSS} = 1\mu\text{F}$ ,  $C_{IN} = 10\mu\text{F}$ ,  $R_{IN} = 10\text{k}\Omega$ ,  $R_{FB} = 20\text{k}\Omega$ , unless otherwise noted.

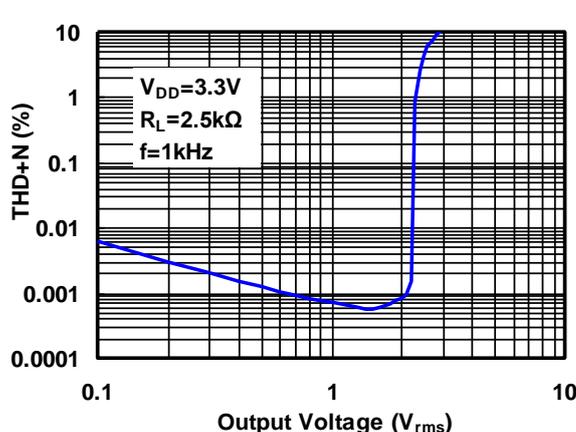
| SYMBOL       | PARAMETER                                           | CONDITIONS                                                        | MIN  | TYP   | MAX  | UNITS                  |
|--------------|-----------------------------------------------------|-------------------------------------------------------------------|------|-------|------|------------------------|
| $V_{DD}$     | Supply Voltage Range                                |                                                                   | 3.0  | 3.3   | 3.63 | V                      |
| $V_{OS}$     | Output Offset Voltage                               | Input grounded, unity gain.                                       | -4   |       | 4    | mV                     |
| $I_Q$        | Quiescent Current                                   | No load                                                           |      | 5.2   |      | mA                     |
| $I_{Q(off)}$ | Supply Current in Shutdown                          |                                                                   |      |       | 0.2  | mA                     |
| $V_O$        | Output Voltage                                      | $V_{DD} = 3.3\text{V}$ , $f = 1\text{kHz}$ , $\text{THD} = 1\%$   | 2.05 |       |      | $V_{RMS}$              |
| THD+N        | Total Harmonic Distortion Plus Noise                | $V_O = 2V_{RMS}$ , $f = 1\text{kHz}$                              |      | 0.001 |      | %                      |
| $X_{TALK}$   | Crosstalk                                           | $V_O = 2V_{RMS}$ , $f = 1\text{kHz}$                              |      | -110  |      | dB                     |
| $I_{SC}$     | Short Circuit Current                               | $V_{DD} = 3.3\text{V}$                                            |      | 20    |      | mA                     |
| $R_{IN}$     | Input Resistor Range                                |                                                                   | 1    | 10    | 47   | $\text{k}\Omega$       |
| SR           | Slew Rate                                           |                                                                   |      | 5     |      | $\text{V}/\mu\text{s}$ |
| $C_L$        | Maximum Capacitive Load                             |                                                                   |      |       | 220  | pF                     |
| $V_N$        | Noise Output Voltage                                | $\text{BW} = 20\text{Hz}$ to $20\text{kHz}$                       |      | 4.3   |      | $\mu\text{V}_{RMS}$    |
| SNR          | Signal to Noise Ratio                               | $V_O = 3V_{RMS}$ , $f = 1\text{kHz}$ , $\text{BW} = 20\text{kHz}$ |      | 117   |      | dB                     |
| GBW          | Unity Gain Bandwidth                                | No load                                                           |      | 10    |      | MHz                    |
| $A_{VOL}$    | Open-Loop Voltage Gain                              | No load                                                           |      | 130   |      | dB                     |
| $V_{UVP}$    | External Under-voltage Detection                    |                                                                   |      | 1.23  |      | V                      |
| $I_{HYS}$    | External Under-voltage Detection Hysteresis Current |                                                                   |      | 4.7   |      | $\mu\text{A}$          |
| $f_{CP}$     | Charge Pump Frequency                               |                                                                   |      | 330   |      | kHz                    |

### Typical Performance Characteristics

Total Harmonic Distortion + Noise vs. Output Voltage

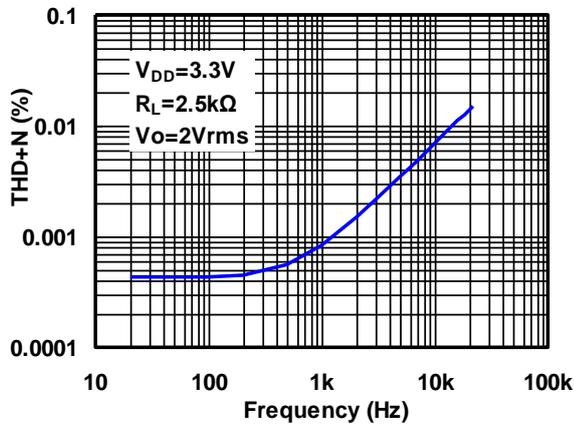


Total Harmonic Distortion + Noise vs. Output Voltage

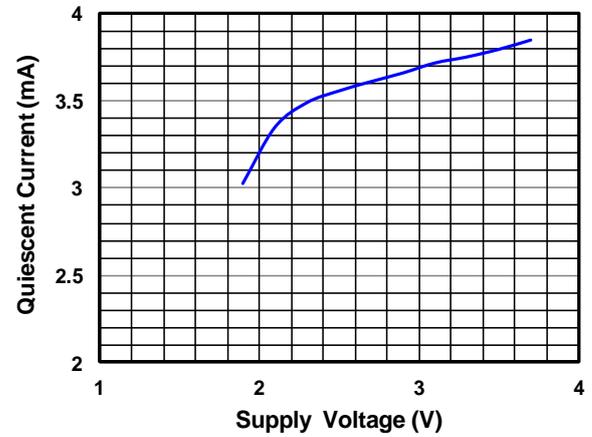


### Typical Performance Characteristic

Total Harmonic Distortion + Noise vs. Frequency



Quiescent Current vs. Supply Voltage



### Pin Functions

| PIN  |        | I/O | Description                                             |
|------|--------|-----|---------------------------------------------------------|
| Name | Number |     |                                                         |
| +INR | 1      | I   | Positive input of the right channel OPAMP               |
| -INR | 2      | I   | Negative input of the right channel OPAMP               |
| OUTR | 3      | O   | Output of the right channel OPAMP                       |
| GND  | 4      | P   | Ground                                                  |
| EN   | 5      | I   | Enable                                                  |
| PVSS | 6      | P   | Negative supply generated with integrated charge pump   |
| CN   | 7      | I/O | Negative terminal of the flying capacitor of the charge |
| CP   | 8      | I/O | Positive terminal of the flying capacitor of the charge |
| PVDD | 9      | P   | Positive supply                                         |
| PGND | 10     | P   | Ground for charge pump                                  |
| UVP  | 11     | I   | Under-voltage protection input                          |
| OUTL | 12     | O   | Output of the left channel OPAMP                        |
| -INL | 13     | I   | Negative input of the left channel OPAMP                |
| +INL | 14     | I   | Positive input of the left channel OPAMP                |

## Applications Information

### Typical Application Circuit

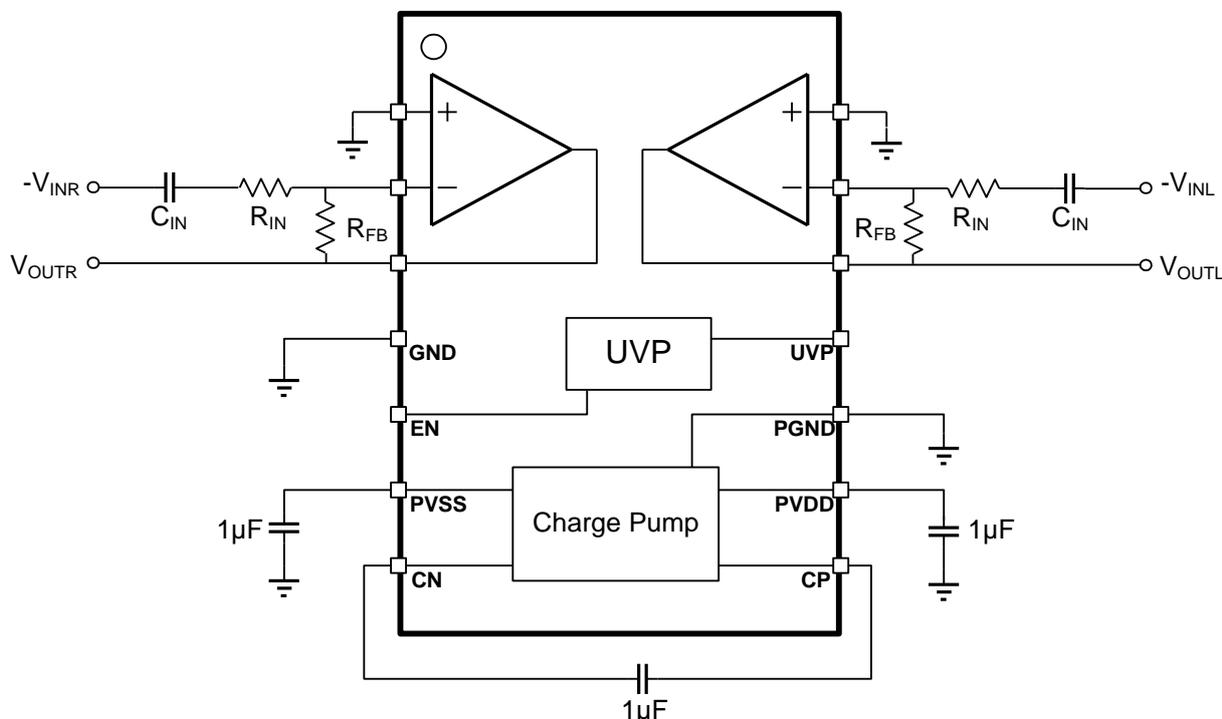


Figure 2 Typical Application Circuit of TPF632

Typical application circuits are shown as above. TPF632 operates from a single supply voltage PVDD. Its integrated charge pump generates a negative supply  $-PVDD$  at the PVSS pin. The line driving amplifiers work with dual supplies: PVDD and  $-PVDD$ . Therefore, the DC level of the audio output can be designed to be 0V. A DC-blocking capacitor typically seen in a single-supplied driver is not necessary.

The supply range of the TPF632 is 3.0V to 3.63V. For a  $2V_{RMS}$  output, the recommended supply voltage is 3.3V.  $R_{IN}$  of  $2.5k\Omega$  and  $R_{FB}$  of  $5k\Omega$  set the inverting gain of 2. Because of the exceptional noise performance of TPF632, the dominant noise source is actually from  $R_{IN}$ . To get better noise performance, lower input resistance and feedback resistance may be used.

### Integrated Charge Pump

The integrated charge pump in TPF632 generates negative power supply from a single supply PVDD. A flying capacitor for the charge pump shall be applied between CP and CN. At the same time a decoupling capacitor shall be applied between PVSS and ground. Typical value for the flying capacitor is  $1\mu F$ . Typical value of the decoupling capacitor shall be same as or larger than that of the flying capacitor. Low-ESR capacitors are recommended for the flying capacitor and the decoupling capacitor.

### Audio Signal Amplification Gain Setting

The main application of the TPF632 is to amplify/buffer audio signals and drive audio lines with very low distortion. Typical application circuits with inverting gain are shown in Figure 3.

Non-inverting amplification of audio signals is also possible with same low distortion.

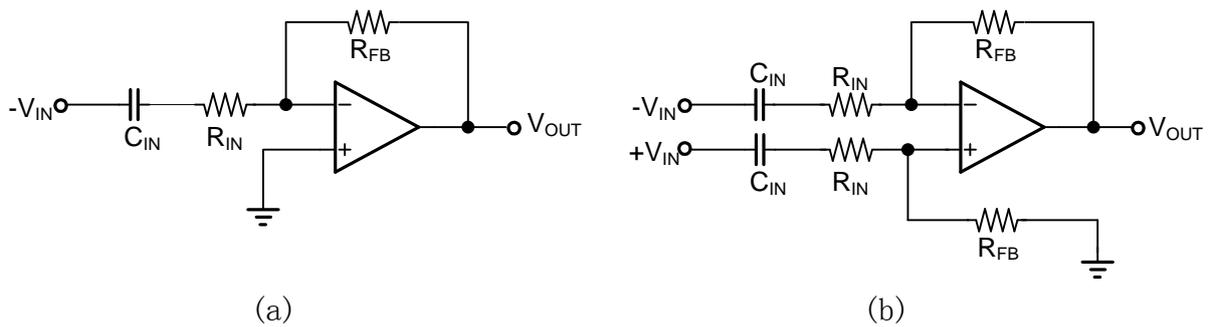


Figure 3 Typical Application Circuit of TPF632

### AC-Coupling Input Capacitors

Because of the integrated charge pump that generates negative rail, TP632 may be used to amplify audio signal so the output DC voltage is 0V. This usually requires the DC voltage of the input signal to be 0V. If the input signal has a DC level other than 0V, an AC-coupling capacitor is necessary to block the DC voltage.

The AC-coupling capacitor essentially forms a high-pass filter at the input. The cut-off frequency of the filter has to be low enough not to distort the input audio signal. For an inverting amplifier shown in Figure 4 the cut-off frequency may be calculated as following:

$$f_c = \frac{1}{2\pi R_{IN} C_{IN}} \tag{1}$$

If the required maximum cut-off frequency is known, the minimum AC-coupling capacitance can be determined:

$$C_{IN} \geq \frac{1}{2\pi R_{IN} f_c} \tag{2}$$

### Adding Low-Pass Filtering to the Gain

If low-pass filtering is necessary in addition to the audio signal amplification, a second-order filter can be implemented as shown in Figure 4. Choice of  $C_3$ ,  $R_1$ ,  $R_2$ , and  $R_3$  is based on the gain setting requirement and AC-coupling cut-off frequency as discussed above.  $C_1$ ,  $C_2$  and  $C_4$  may be calculated depending on the bandwidth. Example choices of R and C are listed in Table 1. If first-order filtering satisfies performance requirements, simply remove the  $C_2$  and  $C_4$  to lower the component counts.

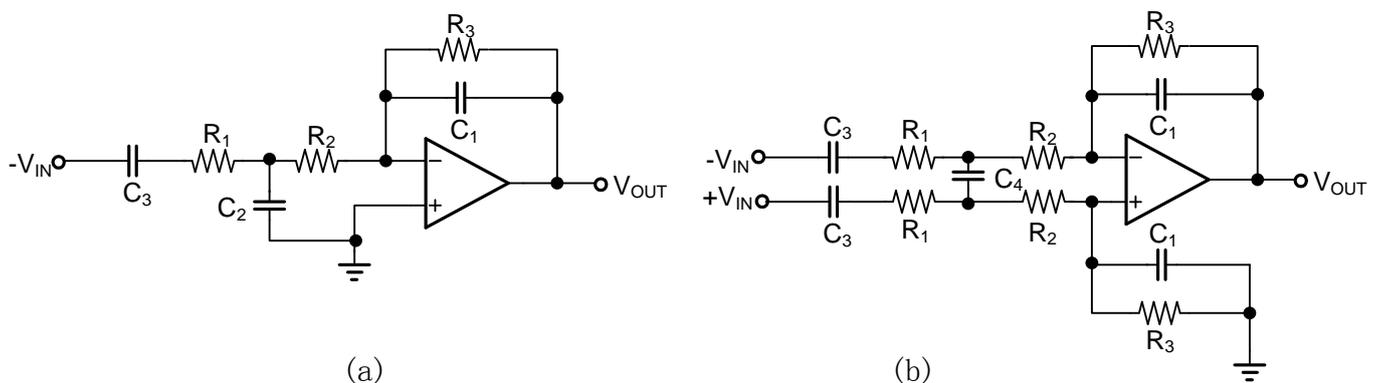


Figure 4 Second-order filter with gain: (a) Single-ended input; (b) Differential input

Table 1 Example RC setting at different gains

| Gain   | R <sub>1</sub> | R <sub>2</sub> | R <sub>3</sub> | C <sub>1</sub> | C <sub>2</sub> | C <sub>3</sub> | C <sub>4</sub> |
|--------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| G=2    | 2.5kΩ          | 2.5kΩ          | 10kΩ           | 120pF          | 1nF            | 2.2uF          | 360pF          |
| G=2.5  | 2.4kΩ          | 2.4kΩ          | 12kΩ           | 91pF           | 750pF          | 2.2uF          | 390pF          |
| G=3.75 | 2kΩ            | 2kΩ            | 15kΩ           | 75pF           | 750pF          | 4.7uF          | 390pF          |

### Pop-Free Power Up and Power Down

During power up or power down, the input device that provide audio source may experience significant DC level shift. Charging of the input capacitor due to DC shift will cause pop noise. It is recommended that TPF632 is disabled (EN low) during power up and power down and kept disabled until charging of the input capacitor is complete. The sequence of EN control is illustrated below.

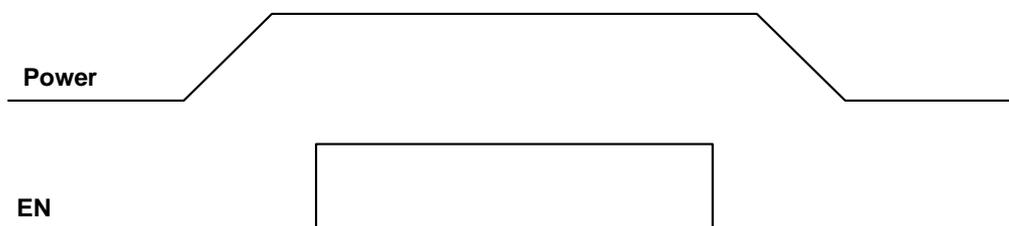


Figure 5 The Sequence of EN Control

### Under-voltage Protection

When unexpected power off happens, the host may not have enough time to disable TPF632 before pop noise is generated. The integrated under-voltage protection circuits can be used to mute and disable TPF632 when the monitored supply voltage drops below certain voltage.

The recommended connection is shown below.  $V_{supply}$  is the monitored supply voltage. The threshold voltage at the UVP pin is 1.23V.  $R_3$  sets the hysteresis voltage and is usually much larger than  $R_1$  and  $R_2$ . The turn on threshold and hysteresis can be calculated:

$$V_{TH} = 1.23V \times (R_1 + R_2) / R_2 \tag{3}$$

$$\text{Hysteresis} = 4.7\mu A \times R_3 \times (R_1 + R_2) / R_2 \tag{4}$$

$$\text{when } R_3 \gg R_1, R_2 \tag{5}$$

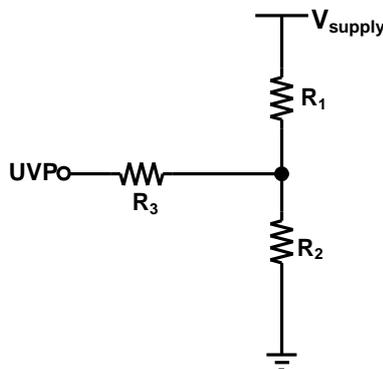


Figure 6 Under-voltage Protection Circuits

### ESD

TPF632 has reverse-biased ESD protection diodes on all inputs and outputs. Input and out pins can not be biased more than 300mV beyond either supply rail.

### Driving Large Capacitive Load

TPF632 is designed to drive large capacitive loads up to 220pF directly. When driving larger capacitive loads with the TPF632, a small series resistor at the output ( $R_{ISO}$  in Figure 7 ) improves the feedback loop's phase margin and stability by making the output load resistive at higher frequencies. Usually  $R_{ISO}$  of 50 $\Omega$  is sufficient.

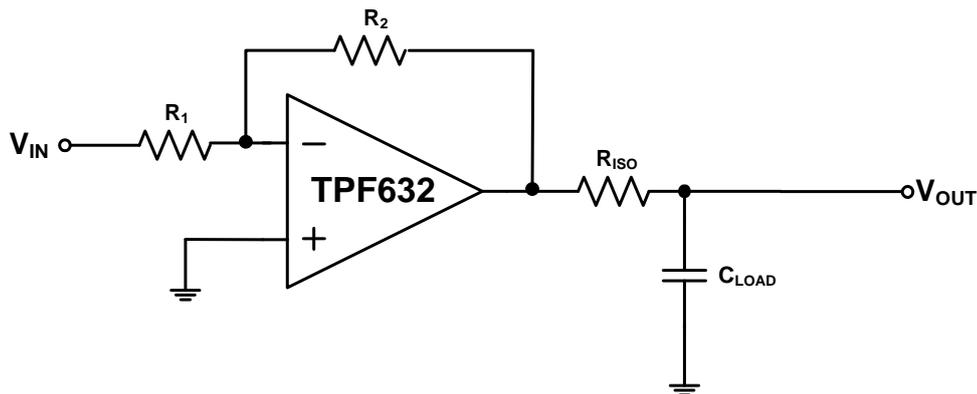


Figure 7 Driving Circuits

### Power Supply Layout and Bypass

The power supply pin of TPF632 should have a local bypass capacitor (i.e., 0.01 $\mu$ F to 0.1 $\mu$ F) within 2mm for good high frequency performance. It can also use a bulk capacitor (i.e., 1 $\mu$ F or larger) within 100mm to provide large, slow currents. This bulk capacitor can be shared with other analog parts.

Ground layout improves performance by decreasing the amount of stray capacitance and noise at the OPA's inputs and outputs. To decrease stray capacitance, minimize PC board lengths and resistor leads, and place external components as close to the op amps' pins as possible.

### Proper Board Layout

To ensure optimum performance at the PCB level, care must be taken in the design of the board layout. To avoid leakage currents, the surface of the board should be kept clean and free of moisture. Coating the surface creates a barrier to moisture accumulation and helps reduce parasitic resistance on the board.

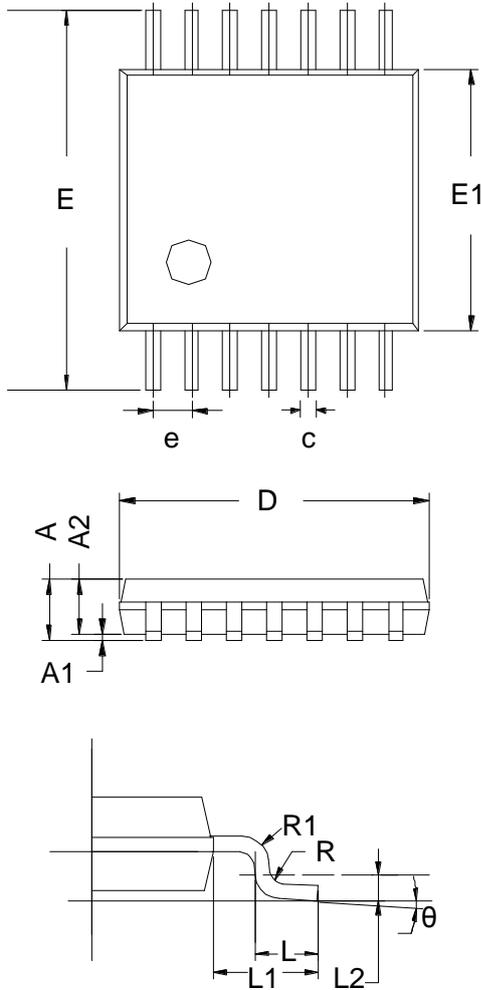
Keeping supply traces short and properly bypassing the power supplies minimizes power supply disturbances due to output current variation, such as when driving an ac signal into a heavy load. Bypass capacitors should be connected as closely as possible to the device supply pins. Stray capacitances are a concern at the outputs and the inputs of the amplifier. It is recommended that signal traces be kept at least 5mm from supply lines to minimize coupling.

A variation in temperature across the PCB can cause a mismatch in the Seebeck voltages at solder joints and other points where dissimilar metals are in contact, resulting in thermal voltage errors. To minimize these thermocouple effects, orient resistors so heat sources warm both ends equally. Input signal paths should contain matching numbers and types of components, where possible to match the number and type of thermocouple junctions. For example, dummy components such as zero value resistors can be used to match real resistors in the opposite input path. Matching components should be located in close proximity and should be oriented in the same manner. Ensure leads are of equal length so that thermal conduction is in equilibrium. Keep heat sources on the PCB as far away from amplifier input circuitry as is practical.

The use of a ground plane is highly recommended. A ground plane reduces EMI noise and also helps to maintain a constant temperature across the circuit board.

**Package Outline Dimensions**

TSSOP-14



| Symbol | Dimensions<br>In Millimeters |      |      |
|--------|------------------------------|------|------|
|        | MIN                          | TYP  | MAX  |
| A      | -                            | -    | 1.20 |
| A1     | 0.05                         | -    | 0.15 |
| A2     | 0.90                         | 1.00 | 1.05 |
| b      | 0.20                         | -    | 0.28 |
| c      | 0.10                         | -    | 0.19 |
| D      | 4.86                         | 4.96 | 5.06 |
| E      | 6.20                         | 6.40 | 6.60 |
| E1     | 4.30                         | 4.40 | 4.50 |
| e      | 0.65 BSC                     |      |      |
| L      | 0.45                         | 0.60 | 0.75 |
| L1     | 1.00 REF                     |      |      |
| L2     | 0.25 BSC                     |      |      |
| R      | 0.09                         | -    | -    |
| theta  | 0°                           | -    | 8°   |