

## Low power JFET quad operational amplifier

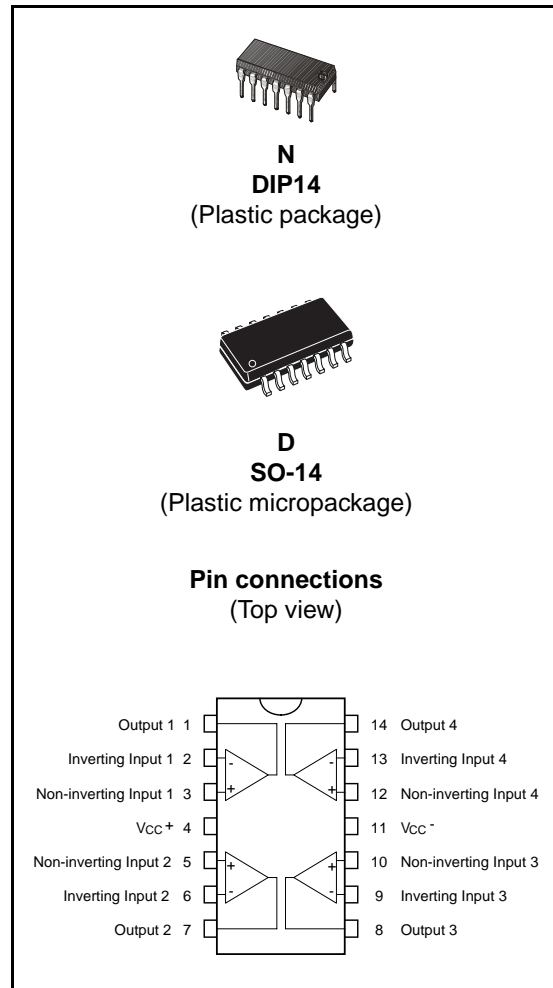
### Features

- Very low power consumption: 200  $\mu$ A
- Wide common-mode (up to  $V_{CC^+}$ ) and differential voltage ranges
- Low input bias and offset currents
- Output short-circuit protection
- High input impedance JFET input stage
- Internal frequency compensation
- Latch up free operation
- High slew rate: 3.5 V/ $\mu$ s

### Description

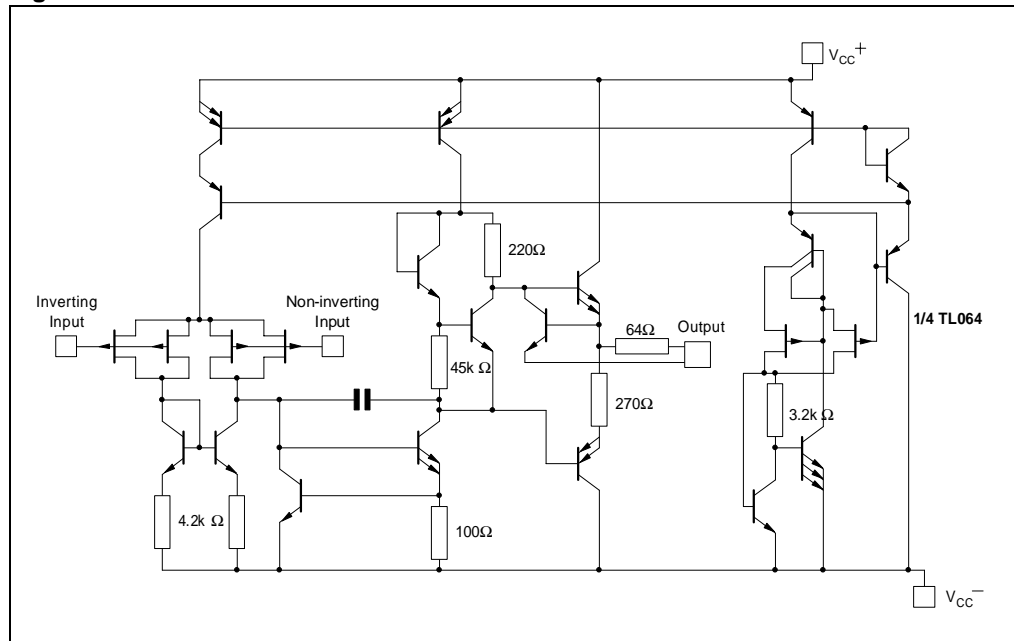
The TL064, TL064A and TL064B are high-speed JFET input single operational amplifiers. Each of these JFET input operational amplifiers incorporates well matched, high-voltage JFET and bipolar transistors in a monolithic integrated circuit.

The devices feature high slew rates, low input bias and offset currents, and low offset voltage temperature coefficient.



# 1 Schematic diagram

Figure 1. Circuit schematics



## 2 Absolute maximum ratings and operating conditions

**Table 1. Absolute maximum ratings**

| Symbol            | Parameter   | Value          |                |                | Unit |
|-------------------|---|----------------|----------------|----------------|------|
|                   |   | TL064M, AM, BM | TL064I, AI, BI | TL064C, AC, BC |      |
| V <sub>CC</sub>   | Supply voltage <sup>(1)</sup>                             | ±18            |                |                | V    |
| V <sub>i</sub>    | Input voltage <sup>(2)</sup>                              | ±15            |                |                | V    |
| V <sub>id</sub>   | Differential input voltage <sup>(3)</sup>                 | ±30            |                |                | V    |
| P <sub>tot</sub>  | Power dissipation   | 680            |                |                | mW   |
| R <sub>thja</sub> | Thermal resistance junction to ambient <sup>(4) (5)</sup> |                |                |                | °C/W |
|                   | SO-14<br>DIP14  | 105<br>80      |                |                |      |
| R <sub>thjc</sub> | Thermal resistance junction to case <sup>(4) (5)</sup>    |                |                |                | °C/W |
|                   | SO-14<br>DIP14  | 31<br>33       |                |                |      |
|                   | Output short-circuit duration <sup>(6)</sup>              | Infinite       |                |                |      |
| T <sub>oper</sub> | Operating free-air temperature range                      | -55 to +125    | -40 to +105    | 0 to +70       | °C   |
| T <sub>stg</sub>  | Storage temperature range                                 | -65 to +150    |                |                | °C   |
| ESD               | HBM: human body model <sup>(7)</sup>                      | 900            |                |                | V    |
|                   | MM: machine model <sup>(8)</sup>                          | 200            |                |                |      |
|                   | CDM: charged device model <sup>(9)</sup>                  | 1500           |                |                |      |

- All voltage values, except differential voltage, are with respect to the zero reference level (ground) of the supply voltages where the zero reference level is the midpoint between V<sub>CC</sub><sup>+</sup> and V<sub>CC</sub><sup>-</sup>.
- The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 volts, whichever is less.
- Differential voltages are the non-inverting input terminal with respect to the inverting input terminal.
- Short-circuits can cause excessive heating and destructive dissipation.
- R<sub>th</sub> are typical values.
- The output may be shorted to ground or to either supply. Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.
- Human body model: 100pF discharged through a 1.5kΩ resistor between two pins of the device, done for all couples of pin combinations with other pins floating.
- Machine model: a 200pF cap is charged to the specified voltage, then discharged directly between two pins of the device with no external series resistor (internal resistor < 5Ω), done for all couples of pin combinations with other pins floating.
- Charged device model: all pins plus package are charged together to the specified voltage and then discharged directly to the ground.

**Table 2. Operating conditions**

| Symbol            | Parameter                            | TL064M, AM, BM | TL064I, AI, BI | TL064C, AC, BC | Unit |
|-------------------|--------------------------------------|----------------|----------------|----------------|------|
| V <sub>CC</sub>   | Supply voltage range                 | 6 to 36        |                |                | V    |
| T <sub>oper</sub> | Operating free-air temperature range | -55 to +125    | -40 to +105    | 0 to +70       | °C   |

### 3 Electrical characteristics

Table 3.  $V_{CC} = \pm 15V$ ,  $T_{amb} = +25^{\circ}C$  (unless otherwise specified)

| Symbol    | Parameter   | TL064M     |            |           | TL064I     |            |           | TL064C   |            |           | Unit              |
|-----------|---|------------|------------|-----------|------------|------------|-----------|----------|------------|-----------|-------------------|
|           |   | Min.       | Typ.       | Max.      | Min.       | Typ.       | Max.      | Min.     | Typ.       | Max.      |                   |
| $V_{io}$  | Input offset voltage ( $R_S = 50\Omega$ )<br>$T_{amb} = +25^{\circ}C$<br>$T_{min} \leq T_{amb} \leq T_{max}$                          |            | 3          | 6<br>15   |            | 3          | 6<br>9    |          | 3          | 15<br>20  | mV                |
| $DV_{io}$ | Temperature coefficient of input offset voltage ( $R_S = 50\Omega$ )  |            | 10         |           |            | 10         |           |          | 10         |           | $\mu V/^{\circ}C$ |
| $I_{io}$  | Input offset current <sup>(1)</sup><br>$T_{amb} = +25^{\circ}C$<br>$T_{min} \leq T_{amb} \leq T_{max}$                                |            | 5          | 100<br>20 |            | 5          | 100<br>10 |          | 5          | 200<br>5  | pA<br>nA          |
| $I_{ib}$  | Input bias current <sup>(1)</sup><br>$T_{amb} = +25^{\circ}C$<br>$T_{min} \leq T_{amb} \leq T_{max}$                                  |            | 30         | 200<br>50 |            | 30         | 200<br>20 |          | 30         | 400<br>10 | pA<br>nA          |
| $V_{icm}$ | Input common mode voltage range   | $\pm 11.5$ | +15<br>-12 |           | $\pm 11.5$ | +15<br>-12 |           | $\pm 11$ | +15<br>-12 |           | V                 |
| $V_{opp}$ | Output voltage swing, $R_L = 10k\Omega$<br>$T_{amb} = +25^{\circ}C$<br>$T_{min} \leq T_{amb} \leq T_{max}$                            | 20<br>20   | 27         |           | 20<br>20   | 27         |           | 20<br>20 | 27         |           | V                 |
| $A_{vd}$  | Large signal voltage gain<br>$R_L = 10k\Omega$ , $V_o = \pm 10V$ ,<br>$T_{amb} = +25^{\circ}C$<br>$T_{min} \leq T_{amb} \leq T_{max}$ | 4<br>4     | 6          |           | 4<br>4     | 6          |           | 3<br>3   | 6          |           | V/mV              |
| GBP       | Gain bandwidth product<br>$T_{amb} = +25^{\circ}C$ , $R_L = 10k\Omega$ ,<br>$C_L = 100pF$   |            | 1          |           |            | 1          |           |          | 1          |           | MHz               |
| $R_i$     | Input resistance  |            | $10^{12}$  |           |            | $10^{12}$  |           |          | $10^{12}$  |           | $\Omega$          |
| CMR       | Common mode rejection ratio<br>$R_S = 50\Omega$   | 80         | 86         |           | 80         | 86         |           | 70       | 76         |           | dB                |
| SVR       | Supply voltage rejection ratio<br>$R_S = 50\Omega$  | 80         | 95         |           | 80         | 95         |           | 70       | 95         |           | dB                |
| $I_{CC}$  | Supply current, no load<br>$T_{amb} = +25^{\circ}C$ , no load, no signal  |            | 200        | 250       |            | 200        | 250       |          | 200        | 250       | $\mu A$           |
| $P_D$     | Total power consumption<br>$T_{amb} = +25^{\circ}C$ , no load, no signal  |            | 120        |           |            | 120        |           |          | 120        |           | dB                |
| SR        | Slew rate<br>$V_i = 10V$ , $R_L = 10k\Omega$ , $C_L = 100pF$ ,<br>$A_v = 1$   |            | 6          | 7.5       |            | 6          | 7.5       |          | 6          | 7.5       | mW                |
| $t_r$     | Rise time<br>$V_i = 20mV$ , $R_L = 10k\Omega$ ,<br>$C_L = 100pF$ , $A_v = 1$  |            | 0.2        |           |            | 0.2        |           |          | 0.2        |           | $\mu s$           |

Table 3.  $V_{CC} = \pm 15V$ ,  $T_{amb} = +25^{\circ}C$  (unless otherwise specified) (continued)

| Symbol   | Parameter  | TL064M |      |      | TL064I |      |      | TL064C |      |      | Unit                   |
|----------|--|--------|------|------|--------|------|------|--------|------|------|------------------------|
|          |  | Min.   | Typ. | Max. | Min.   | Typ. | Max. | Min.   | Typ. | Max. |                        |
| $K_{ov}$ | Overshoot factor (see <a href="#">Figure 17</a> )<br>$V_i = 20mV$ , $R_L = 10k\Omega$ ,<br>$C_L = 100pF$ , $A_v = 1$ |        | 10   |      |        | 10   |      |        | 10   |      | %                      |
| $e_n$    | Equivalent input noise voltage<br>$R_S = 100\Omega$ , $f = 1KHz$   |        | 42   |      |        | 42   |      |        | 42   |      | $\frac{nV}{\sqrt{Hz}}$ |

1. The input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive. Pulse techniques must be used that will maintain the junction temperature as close to the ambient temperature as possible.

Table 4.  $V_{CC} = \pm 15V$ ,  $T_{amb} = +25^{\circ}C$  (unless otherwise specified)

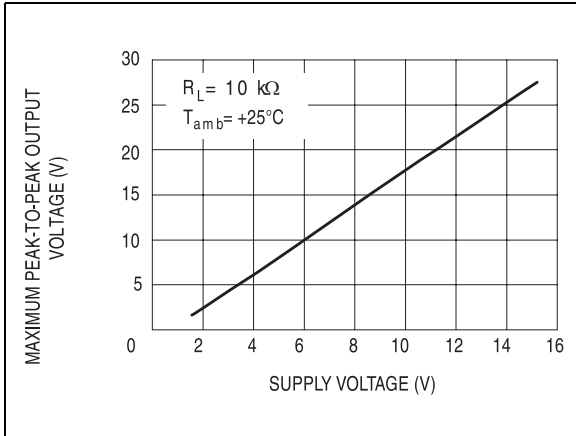
| Symbol    | Parameter   | TL064AC, AI, AM |            |          | TL064BC, BI, BM |            |          | Unit              |
|-----------|---|-----------------|------------|----------|-----------------|------------|----------|-------------------|
|           |   | Min.            | Typ.       | Max.     | Min.            | Typ.       | Max.     |                   |
| $V_{io}$  | Input offset voltage ( $R_S = 50\Omega$ )<br>$T_{amb} = +25^{\circ}C$<br>$T_{min} \leq T_{amb} \leq T_{max}$                      |                 | 3          | 6<br>7.5 |                 | 2          | 3<br>5   | mV                |
| $DV_{io}$ | Temperature coefficient of input offset voltage<br>( $R_S = 50\Omega$ )   |                 | 10         |          |                 | 10         |          | $\mu V/^{\circ}C$ |
| $I_{io}$  | Input offset current <sup>(1)</sup><br>$T_{amb} = +25^{\circ}C$<br>$T_{min} \leq T_{amb} \leq T_{max}$                            |                 | 5          | 100<br>3 |                 | 5          | 100<br>3 | $\mu A$<br>nA     |
| $I_{ib}$  | Input bias current <sup>(1)</sup><br>$T_{amb} = +25^{\circ}C$<br>$T_{min} \leq T_{amb} \leq T_{max}$                              |                 | 30         | 200<br>7 |                 | 30         | 200<br>7 | $\mu A$<br>nA     |
| $V_{icm}$ | Input common mode voltage range   | $\pm 11.5$      | +15<br>-12 |          | $\pm 11.5$      | +15<br>-12 |          | V                 |
| $V_{opp}$ | Output voltage swing ( $R_L = 10k\Omega$ )<br>$T_{amb} = +25^{\circ}C$<br>$T_{min} \leq T_{amb} \leq T_{max}$                     | 20<br>20        | 27         |          | 20<br>20        | 27         |          | V                 |
| $A_{vd}$  | Large signal voltage gain, $R_L = 10k\Omega$ , $V_o = \pm 10V$<br>$T_{amb} = +25^{\circ}C$<br>$T_{min} \leq T_{amb} \leq T_{max}$ | 4<br>4          | 6          |          | 4<br>4          | 6          |          | V/mV              |
| GBP       | Gain bandwidth product<br>$T_{amb} = +25^{\circ}C$ , $R_L = 10k\Omega$ , $C_L = 100pF$  |                 | 1          |          |                 | 1          |          | MHz               |
| $R_i$     | Input resistance  |                 | $10^{12}$  |          |                 | $10^{12}$  |          | $\Omega$          |
| CMR       | Common mode rejection ratio<br>$R_S = 50\Omega$   | 80              | 86         |          | 80              | 86         |          | dB                |
| SVR       | Supply voltage rejection ratio<br>$R_S = 50\Omega$  | 80              | 95         |          | 80              | 95         |          | dB                |
| $I_{CC}$  | Supply current, no load<br>$T_{amb} = +25^{\circ}C$ , no load, no signal  |                 | 200        | 250      |                 | 200        | 250      | $\mu A$           |

Table 4.  $V_{CC} = \pm 15V$ ,  $T_{amb} = +25^{\circ}C$  (unless otherwise specified) (continued)

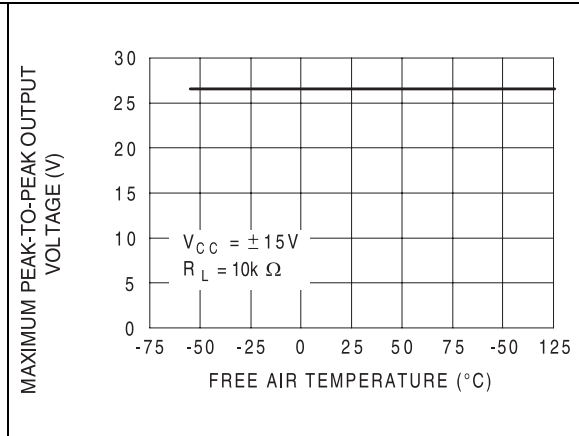
| Symbol   | Parameter   | TL064AC, AI, AM |      |      | TL064BC, BI, BM |      |      | Unit                   |
|----------|---|-----------------|------|------|-----------------|------|------|------------------------|
|          |   | Min.            | Typ. | Max. | Min.            | Typ. | Max. |                        |
| $P_D$    | Total power consumption<br>$T_{amb} = +25^{\circ}C$ , no load, no signal  |                 | 120  |      |                 | 120  |      | dB                     |
| SR       | Slew rate<br>$V_i = 10V$ , $R_L = 10k\Omega$ , $C_L = 100pF$ , $A_v = 1$  | 1.5             | 3.5  |      | 1.5             | 3.5  |      | V/ $\mu s$             |
| $t_r$    | Rise time<br>$V_i = 20mV$ , $R_L = 10k\Omega$ , $C_L = 100pF$ , $A_v = 1$   |                 | 0.2  |      |                 | 0.2  |      | $\mu s$                |
| $K_{ov}$ | Overshoot factor (see <a href="#">Figure 17</a> )<br>$V_i = 20mV$ , $R_L = 10k\Omega$ , $C_L = 100pF$ , $A_v = 1$ |                 | 10   |      |                 | 10   |      | %                      |
| $e_n$    | Equivalent input noise voltage<br>$R_S = 100\Omega$ , $f = 1KHz$  |                 | 42   |      |                 | 42   |      | $\frac{nV}{\sqrt{Hz}}$ |

1. The input bias currents of a FET-input operational amplifier are normal junction reverse currents, which are temperature sensitive. Pulse techniques must be used that will maintain the junction temperature as close to the ambient temperature as possible.

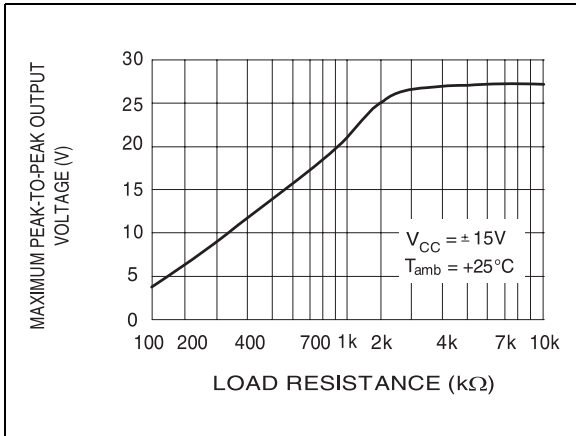
**Figure 2. Maximum peak-to-peak output voltage versus supply voltage**



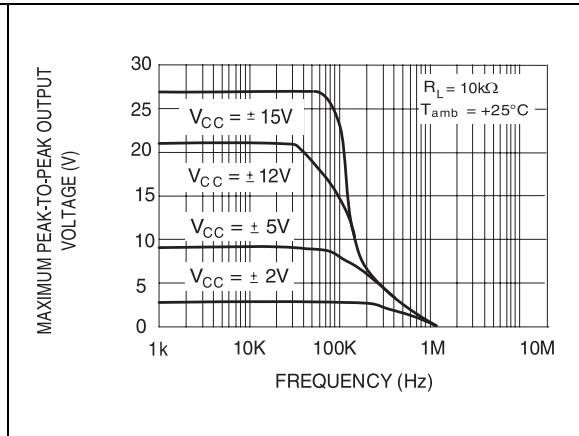
**Figure 3. Maximum peak-to-peak output voltage versus free air temp**



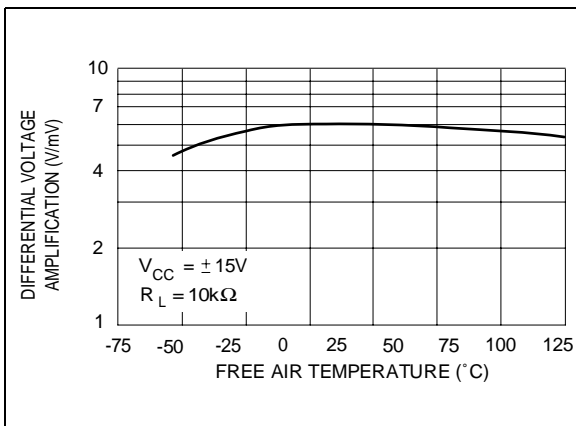
**Figure 4. Maximum peak-to-peak output voltage versus load resistance**



**Figure 5. Maximum peak-to-peak output voltage versus frequency**



**Figure 6. Differential voltage amplification versus free air temperature**



**Figure 7. Large signal differential voltage amplification and phase shift versus frequency**

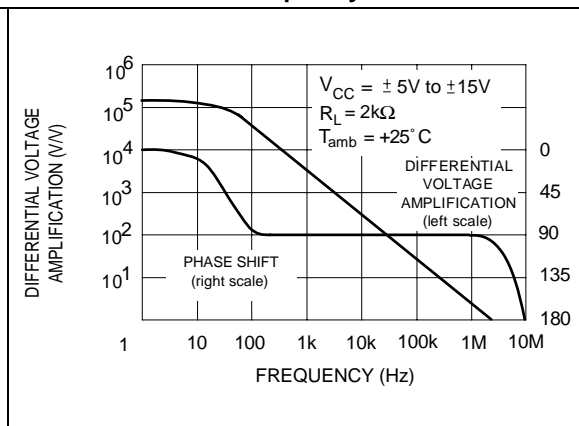


Figure 8. Supply current per amplifier versus supply voltage

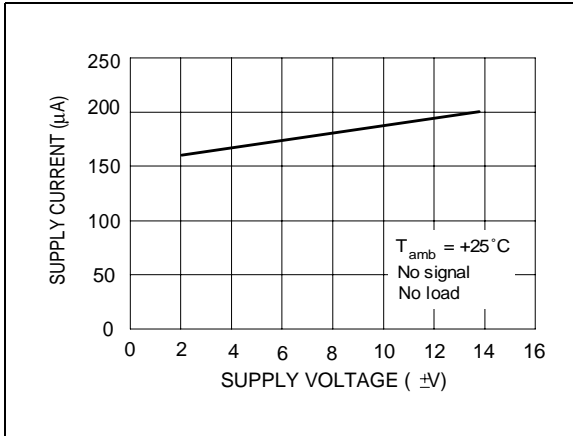


Figure 9. Supply current per amplifier versus free air temperature

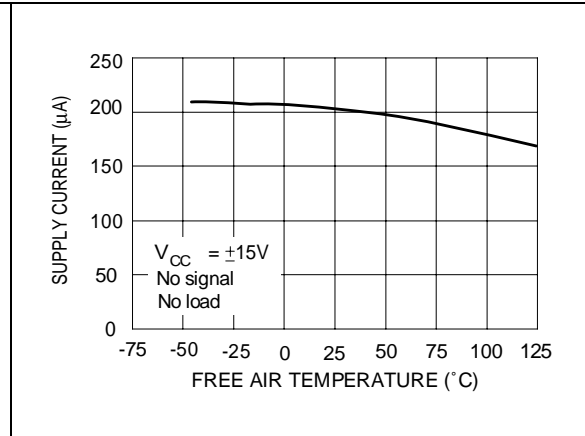


Figure 10. Total power dissipated versus free air temperature

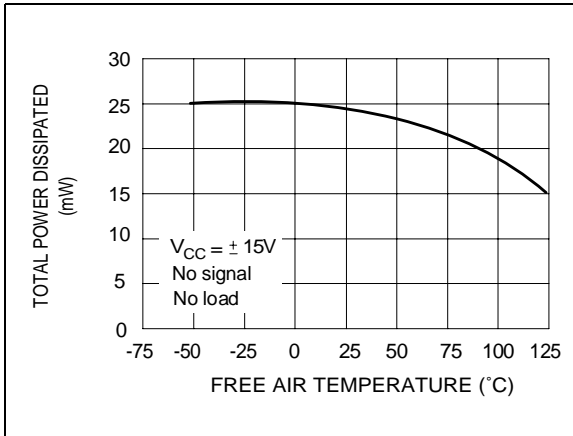


Figure 11. Common mode rejection ratio versus free air temperature

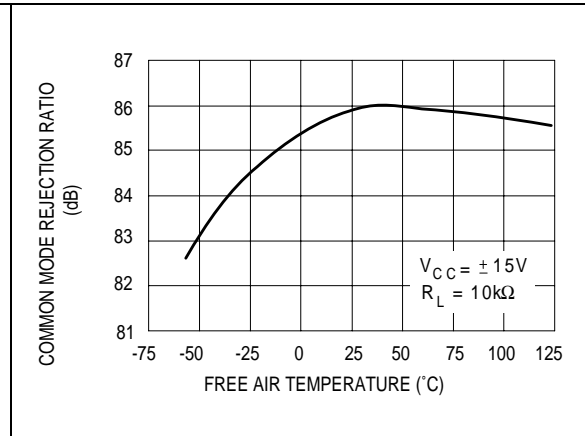


Figure 12. Normalized unity gain bandwidth, slew rate, and phase shift versus temperature

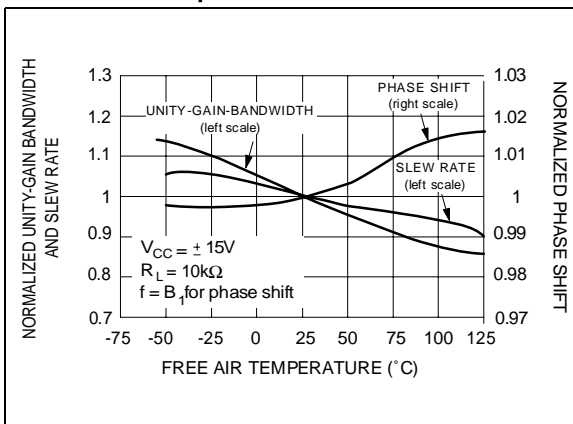


Figure 13. Input bias current versus free air temperature

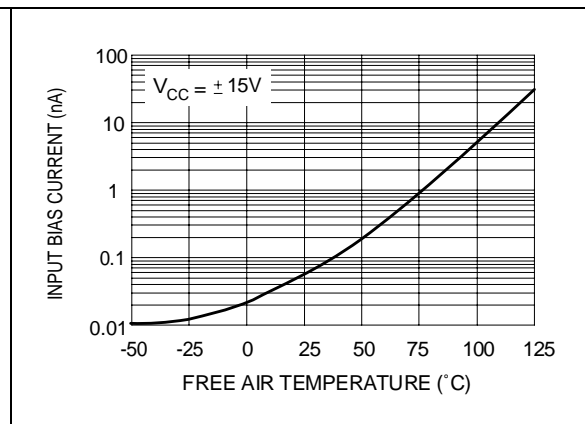




Figure 14. Voltage follower large signal pulse response

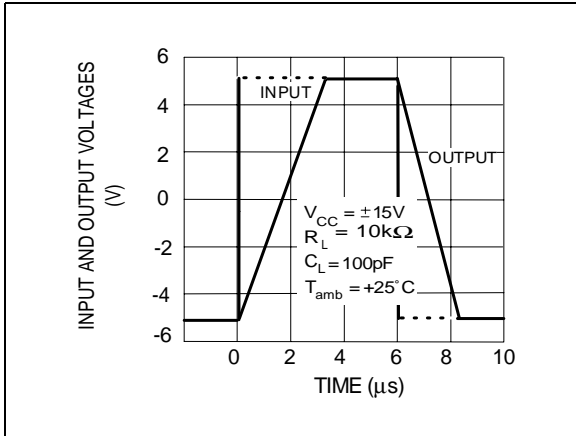


Figure 15. Output voltage versus elapsed time response

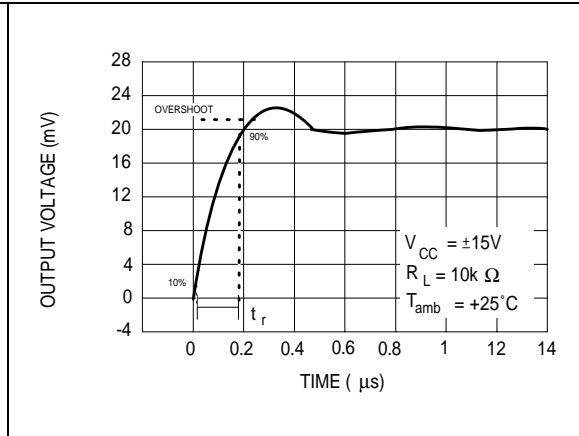
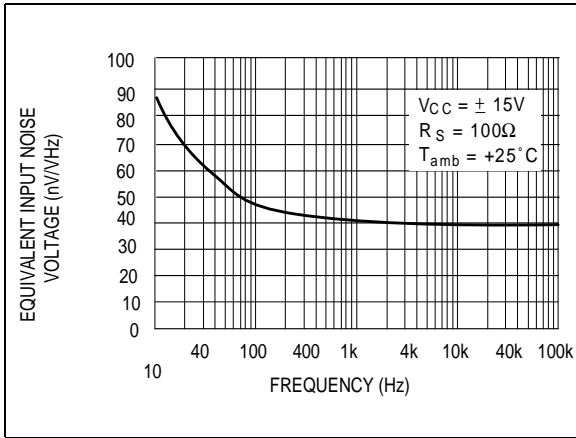


Figure 16. Equivalent input noise voltage versus frequency



### Parameter measurement information

Figure 17. Voltage follower

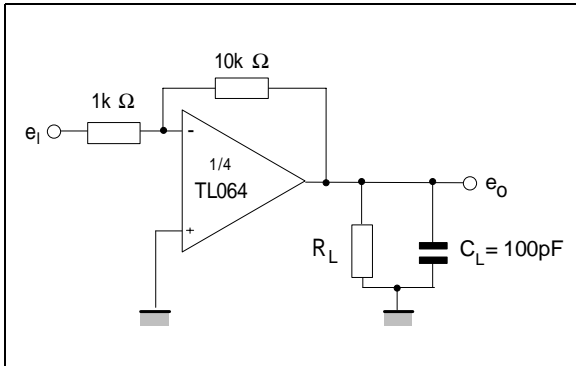
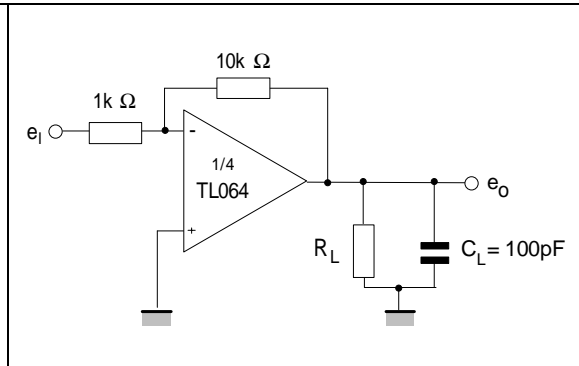
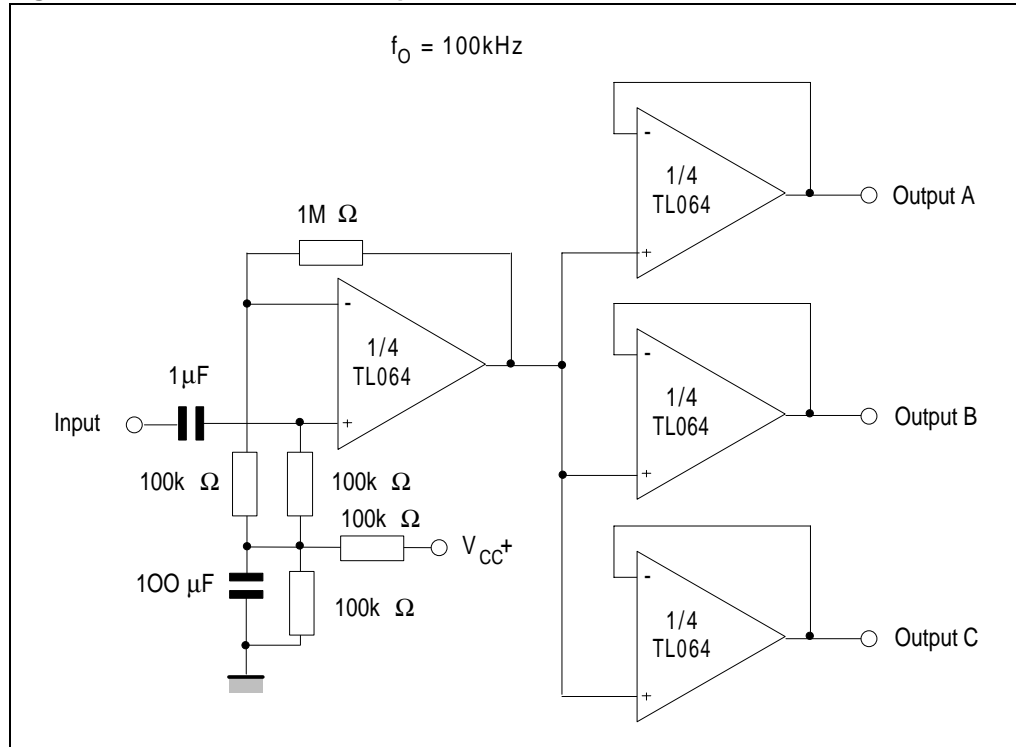


Figure 18. Gain-of-10 inverting amplifier



## 4 Typical applications

Figure 19. Audio distributor amplifier



## 5 Package information

In order to meet environmental requirements, ST offers these devices in ECOPACK® packages. These packages have a lead-free second level interconnect. The category of second level interconnect is marked on the package and on the inner box label, in compliance with JEDEC Standard JESD97. The maximum ratings related to soldering conditions are also marked on the inner box label. ECOPACK is an ST trademark. ECOPACK specifications are available at: [www.st.com](http://www.st.com).

Figure 20. DIP14 package mechanical data

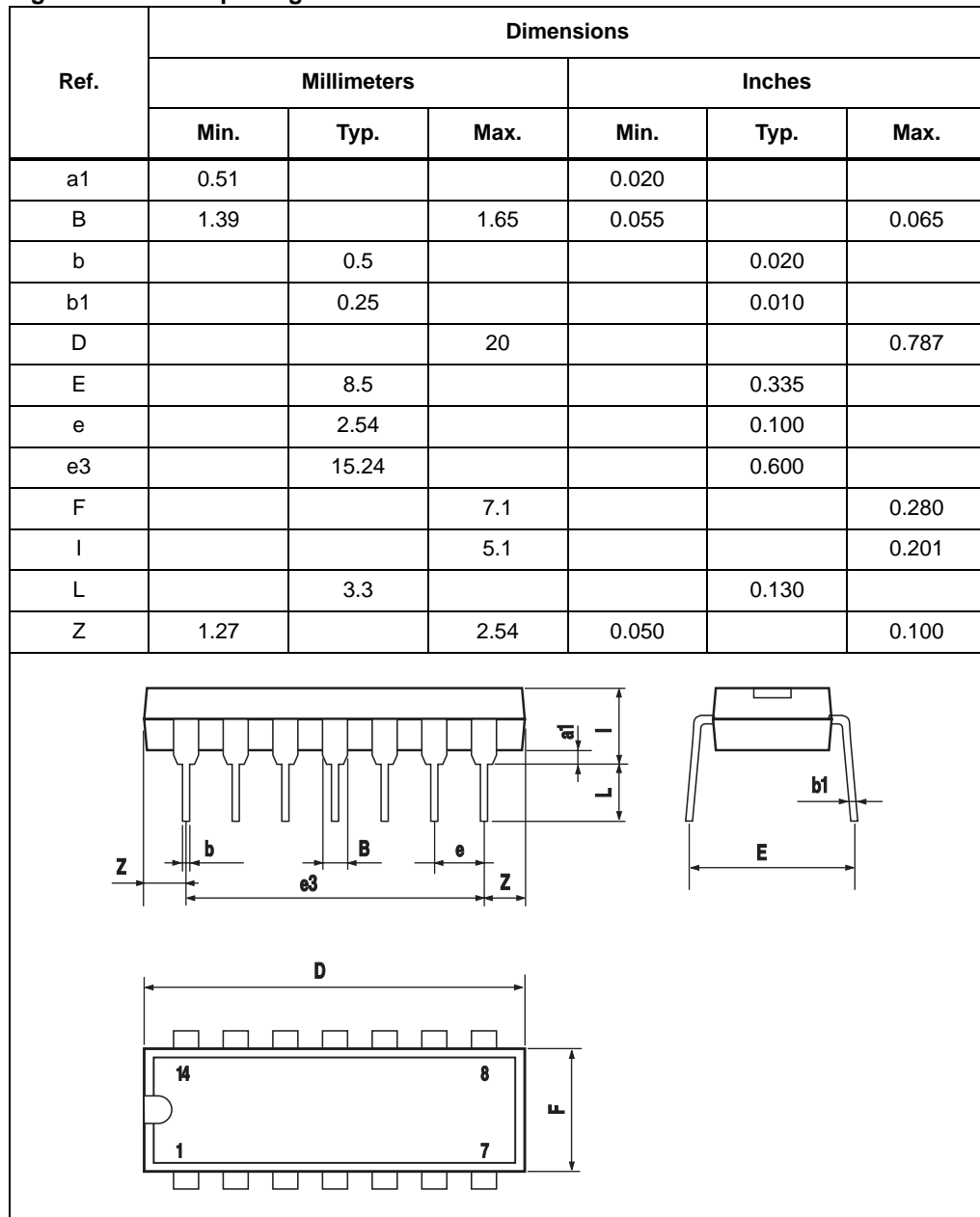
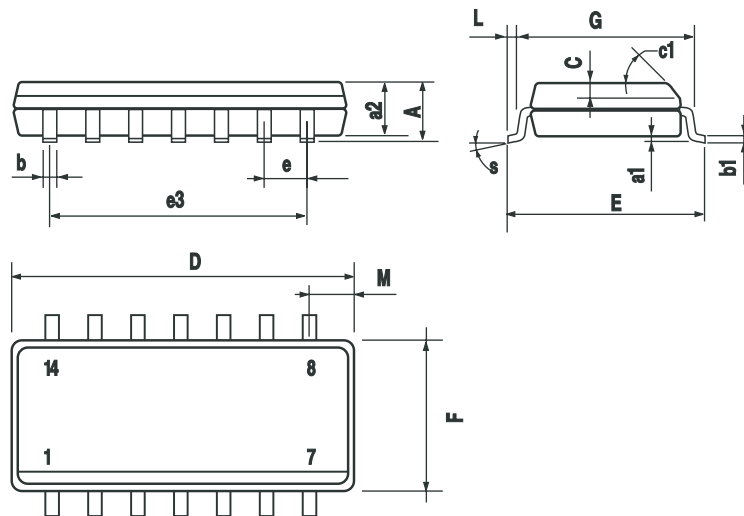


Figure 21. SO-14 package mechanical data

| Ref. | Dimensions  |      |      |        |       |       |
|------|-------------|------|------|--------|-------|-------|
|      | Millimeters |      |      | Inches |       |       |
|      | Min.        | Typ. | Max. | Min.   | Typ.  | Max.  |
| A    |             |      | 1.75 |        |       | 0.068 |
| a1   | 0.1         |      | 0.2  | 0.003  |       | 0.007 |
| a2   |             |      | 1.65 |        |       | 0.064 |
| b    | 0.35        |      | 0.46 | 0.013  |       | 0.018 |
| b1   | 0.19        |      | 0.25 | 0.007  |       | 0.010 |
| C    |             | 0.5  |      |        | 0.019 |       |
| c1   | 45° (typ.)  |      |      |        |       |       |
| D    | 8.55        |      | 8.75 | 0.336  |       | 0.344 |
| E    | 5.8         |      | 6.2  | 0.228  |       | 0.244 |
| e    |             | 1.27 |      |        | 0.050 |       |
| e3   |             | 7.62 |      |        | 0.300 |       |
| F    | 3.8         |      | 4.0  | 0.149  |       | 0.157 |
| G    | 4.6         |      | 5.3  | 0.181  |       | 0.208 |
| L    | 0.5         |      | 1.27 | 0.019  |       | 0.050 |
| M    |             |      | 0.68 |        |       | 0.026 |
| S    | 8° (max.)   |      |      |        |       |       |



## 6 Ordering information

Table 5. Order codes

| Part number                                   | Temperature range | Package | Packing                | Marking                         |
|---|-------------------|---------|------------------------|---------------------------------|
| TL064MN<br>TL064AMN<br>TL064BMN               | -55°C, +125°C     | DIP14   | Tube                   | TL064MN<br>TL064AMN<br>TL064BMN |
| TL064MD/MDT<br>TL064AMD/AMDT<br>TL064BMD/BMDT |                   | SO-14   | Tube or<br>tape & reel | 064M<br>064AM<br>064BM          |
| TL064IN<br>TL064AIN<br>TL064BIN               | -40°C, +105°C     | DIP14   | Tube                   | TL064IN<br>TL064AIN<br>TL064BIN |
| TL064ID/IDT<br>TL064AID/AIDT<br>TL064BID/BIDT |                   | SO-14   | Tube or<br>tape & reel | 064I<br>064AI<br>064BI          |
| TL064CN<br>TL064ACN<br>TL064BCN               | 0°C, +70°C        | DIP14   | Tube                   | TL064CN<br>TL064ACN<br>TL064BCN |
| TL064CD/CDT<br>TL064ACD/ACDT<br>TL064BCD/BCDT |                   | SO-14   | Tube or<br>tape & reel | 064C<br>064AC<br>064BC          |

## 7 Revision history

Table 6. Document revision history

| Date        | Revision | Changes   |
|-------------|----------|---|
| 13-Nov-2001 | 1        | Initial release.  |
| 25-Jul-2007 | 2        | Added $R_{thja}$ , $R_{thjc}$ and ESD values in <a href="#">Table 2: Operating conditions</a> .<br>Added <a href="#">Table 2: Operating conditions</a> .<br>Expanded <a href="#">Table 5: Order codes</a> .<br>Format update. |

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