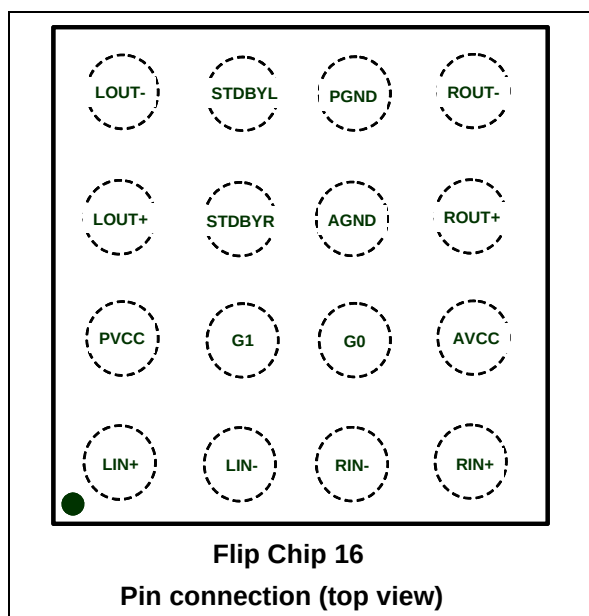


## Filter-free Flip Chip stereo 2 x 2.5 W class D audio power amplifier

Datasheet - production data



### Features

- Operates from  $V_{CC} = 2.5$  to  $5.5$  V
- Dedicated standby mode active low for each channel
- Output power per channel: 1.15 W at 5 V or 0.63 W at 3.6 V into  $8\ \Omega$  with 1% THD+N max.
- Output power per channel: 1.85 W at 5 V into  $4\ \Omega$  with 1% THD+N max.
- Output short-circuit protection
- Four gain setting steps: 6, 12, 18, 24 dB
- Low current consumption
- PSSR: 63 dB typ. at 217 Hz.
- Fast startup phase: 7.8 ms
- Thermal shutdown protection
- Flip Chip 16 bump lead-free package

**Table 1. Device summary**

| Order code | Temperature range | Package      | Packing       | Marking |
|------------|-------------------|--------------|---------------|---------|
| TS2012EIJT | - 40 °C to +85 °C | Flip Chip 16 | Tape and reel | K0      |

### Applications

- Cellular phones
- PDA

### Description

The TS2012EI is a fully-differential stereo class D power amplifier able to drive up to 1.15 W into an  $8\ \Omega$  load at 5 V per channel. It achieves better efficiency compared to typical class AB audio amps.

The device has four different gain settings utilizing two digital pins: G0 and G1.

Pop and click reduction circuitry provides low on/off switch noise while allowing the device to start within 8 ms.

Two standby pins (active low) allow each channel to be switched off separately.

The TS2012EI is available in a Flip Chip 16 bump lead-free package.

# Contents

|          |                                                            |           |
|----------|------------------------------------------------------------|-----------|
| <b>1</b> | <b>Absolute maximum ratings and operating conditions</b>   | <b>3</b>  |
| <b>2</b> | <b>Typical application</b>                                 | <b>5</b>  |
| <b>3</b> | <b>Electrical characteristics</b>                          | <b>7</b>  |
| 3.1      | Electrical characteristics tables                          | 7         |
| 3.2      | Electrical characteristic curves                           | 13        |
| <b>4</b> | <b>Application information</b>                             | <b>21</b> |
| 4.1      | Differential configuration principle                       | 21        |
| 4.2      | Gain settings                                              | 21        |
| 4.3      | Common mode feedback loop limitations                      | 21        |
| 4.4      | Low frequency response                                     | 22        |
| 4.5      | Decoupling of the circuit                                  | 23        |
| 4.6      | Wake-up time ( $t_{WU}$ ) and shutdown time ( $t_{STBY}$ ) | 23        |
| 4.7      | Consumption in shutdown mode                               | 25        |
| 4.8      | Single-ended input configuration                           | 25        |
| 4.9      | Output filter considerations                               | 26        |
| 4.10     | Short-circuit protection                                   | 26        |
| 4.11     | Thermal shutdown                                           | 27        |
| <b>5</b> | <b>Package information</b>                                 | <b>28</b> |
| <b>6</b> | <b>Revision history</b>                                    | <b>31</b> |

# 1 Absolute maximum ratings and operating conditions

**Table 2. Absolute maximum ratings**

| Symbol     | Parameter                                             | Value                             | Unit |
|------------|-------------------------------------------------------|-----------------------------------|------|
| $V_{CC}$   | Supply voltage <sup>(1)</sup>                         | 6                                 | V    |
| $V_{in}$   | Input voltage <sup>(2)</sup>                          | GND to $V_{CC}$                   | V    |
| $T_{oper}$ | Operating free air temperature range                  | -40 to + 85                       | °C   |
| $T_{stg}$  | Storage temperature                                   | -65 to +150                       | °C   |
| $T_j$      | Maximum junction temperature                          | 150                               | °C   |
| $R_{thja}$ | Thermal resistance junction to ambient <sup>(3)</sup> | 200                               | °C/W |
| $P_d$      | Power dissipation                                     | Internally limited <sup>(4)</sup> |      |
| ESD        | HBM: human body model <sup>(5)</sup>                  | 2                                 | kV   |
|            | MM: machine model <sup>(6)</sup>                      | 200                               | V    |
| Latch-up   | Latch-up immunity                                     | 200                               | mA   |
| $V_{STBY}$ | Standby pin maximum voltage                           | GND to $V_{CC}$                   | V    |
|            | Lead temperature (soldering, 10sec)                   | 260                               | °C   |
|            | Output short-circuit protection <sup>(7)</sup>        |                                   |      |

1. All voltage values are measured with respect to the ground pin.
2. The magnitude of the input signal must never exceed  $V_{CC} + 0.3 \text{ V}$  / GND - 0.3 V.
3. The device is protected in case of over temperature by a thermal shutdown active at 150°C.
4. Exceeding the power derating curves during a long period will cause abnormal operation.
5. Human body model: 100 pF discharged through a 1.5 kΩ resistor between two pins of the device, done for all couples of pin combinations with other pins floating.
6. Machine model: a 200 pF cap is charged to the specified voltage, then discharged directly between two pins of the device with no external series resistor (internal resistor < 5 Ω), done for all couples of pin combinations with other pins floating.
7. Implemented short-circuit protection protects the amplifier against damage by short-circuit between positive and negative outputs of each channel and between outputs and ground.

Table 3. Operating conditions

| Symbol     | Parameter                                                                             | Value                                                           | Unit                 |
|------------|---------------------------------------------------------------------------------------|-----------------------------------------------------------------|----------------------|
| $V_{CC}$   | Supply voltage                                                                        | 2.5 to 5.5                                                      | V                    |
| $V_{in}$   | Input voltage range                                                                   | GND to $V_{CC}$                                                 | V                    |
| $V_{ic}$   | Input common mode voltage <sup>(1)</sup>                                              | GND+0.5V to $V_{CC}$ -0.9V                                      | V                    |
| $V_{STBY}$ | Standby voltage input <sup>(2)</sup><br>Device ON<br>Device in STANDBY <sup>(3)</sup> | $1.4 \leq V_{STBY} \leq V_{CC}$<br>$GND \leq V_{STBY} \leq 0.4$ | V                    |
| $R_L$      | Load resistor                                                                         | $\geq 4$                                                        | $\Omega$             |
| $V_{IH}$   | GO, G1 - high level input voltage <sup>(4)</sup>                                      | $1.4 \leq V_{IH} \leq V_{CC}$                                   | V                    |
| $V_{IL}$   | GO, G1 - low level input voltage                                                      | $GND \leq V_{IL} \leq 0.4$                                      | V                    |
| $R_{thja}$ | Thermal resistance junction to ambient <sup>(5)</sup>                                 | 90                                                              | $^{\circ}\text{C/W}$ |

1.  $|V_{oo}| \leq 40$  mV max with all differential gains except 24 dB. For 24 dB gain, input decoupling capacitors are mandatory.
2. Without any signal on standby pin, the device is in standby (internal 300 k $\Omega$  +/-20% pull-down resistor).
3. Minimum current consumption is obtained when  $V_{STBY} = GND$ .
4. Between GO, G1 pins and  $GND$ , there is an internal 300 k $\Omega$  (+/-20%) pull-down resistor. When pins are floating, the gain is 6 dB. In full standby (left and right channels OFF), these resistors are disconnected (HiZ input).
5. With a 4-layer PCB.

## 2 Typical application

Figure 1. Typical application schematics

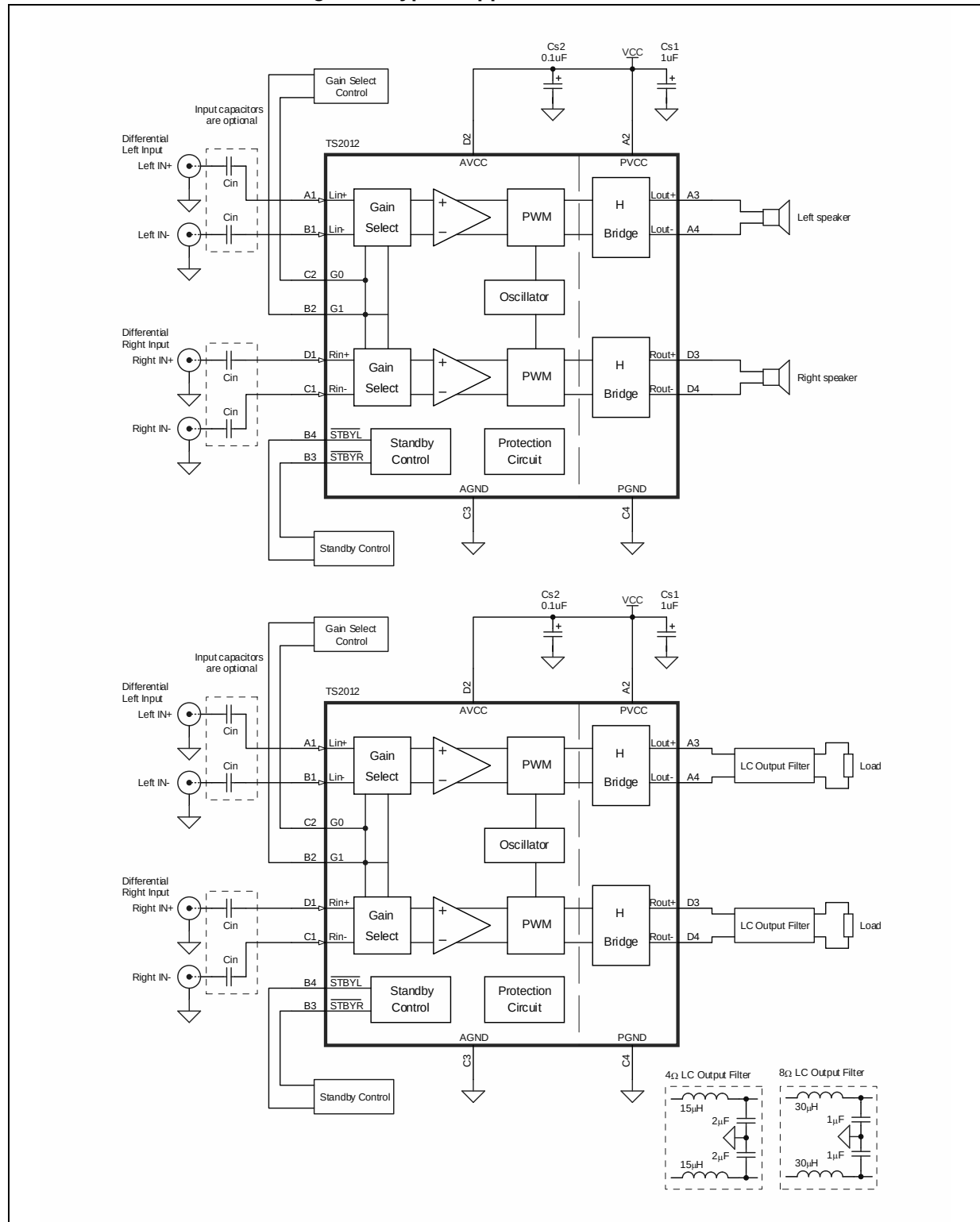


Table 4. External component description

| Components       | Functional description                                                                                                                                                                                                                                                                    |
|------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $C_{S1}, C_{S2}$ | Supply capacitor that provides power supply filtering.                                                                                                                                                                                                                                    |
| $C_{in}$         | Input coupling capacitors (optional) that block the DC voltage at the amplifier input terminal. The capacitors also form a high pass filter with $Z_{in}$<br>$(F_{cl} = 1 / (2 \times \pi \times Z_{in} \times C_{in}))$ . Be aware that value of $Z_{in}$ is changing with gain setting. |

Table 5. Pin description

| Pin number | Pin name | Description                                       |
|------------|----------|---------------------------------------------------|
| A1         | Lin+     | Left channel positive differential input          |
| A2         | PVCC     | Power supply voltage                              |
| A3         | Lout+    | Left channel positive output                      |
| A4         | Lout-    | Left channel negative output                      |
| B1         | Lin-     | Left channel negative differential input          |
| B2         | G1       | Gain select pin (MSB)                             |
| B3         | STBYR    | Standby pin (active low) for right channel output |
| B4         | STBYL    | Standby pin (active low) for left channel output  |
| C1         | Rin-     | Right channel negative differential input         |
| C2         | G0       | Gain select pin (LSB)                             |
| C3         | AGND     | Analog ground                                     |
| C4         | PGND     | Power ground                                      |
| D1         | Rin+     | Right channel positive differential input         |
| D2         | AVCC     | Analog supply voltage                             |
| D3         | Rout+    | Right channel positive output                     |
| D4         | Rout-    | Right channel negative output                     |

### 3 Electrical characteristics

#### 3.1 Electrical characteristics tables

**Table 6.  $V_{CC} = +5\text{ V}$ ,  $GND = 0\text{ V}$ ,  $V_{ic} = 2.5\text{ V}$ ,  $T_{amb} = 25^\circ\text{ C}$  (unless otherwise specified)**

| Symbol     | Parameters and test conditions                                                                                                                                                                                                                                 | Min.                        | Typ.                       | Max.                        | Unit          |
|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|----------------------------|-----------------------------|---------------|
| $I_{CC}$   | Supply current<br>No input signal, no load, both channels                                                                                                                                                                                                      |                             | 5                          | 7                           | mA            |
| $I_{STBY}$ | Standby current<br>No input signal, $V_{STBY} = GND$                                                                                                                                                                                                           |                             | 1                          | 2                           | $\mu\text{A}$ |
| $V_{oo}$   | Output offset voltage<br>Floating inputs, $G = 6\text{ dB}$ , $R_L = 8\ \Omega$                                                                                                                                                                                |                             |                            | 25                          | mV            |
| $P_o$      | Output power<br>THD + N = 1% max, $f = 1\text{ kHz}$ , $R_L = 4\ \Omega$<br>THD + N = 1% max, $f = 1\text{ kHz}$ , $R_L = 8\ \Omega$<br>THD + N = 10% max, $f = 1\text{ kHz}$ , $R_L = 4\ \Omega$<br>THD + N = 10% max, $f = 1\text{ kHz}$ , $R_L = 8\ \Omega$ |                             | 1.85<br>1.15<br>2.5<br>1.6 |                             | W             |
| THD + N    | Total harmonic distortion + noise<br>$P_o = 0.8\text{ W}$ , $G = 6\text{ dB}$ , $f = 1\text{ kHz}$ , $R_L = 8\ \Omega$                                                                                                                                         |                             | 0.5                        |                             | %             |
| Efficiency | Efficiency per channel<br>$P_o = 1.85\text{ W}$ , $R_L = 4\ \Omega + 15\ \mu\text{H}$<br>$P_o = 1.16\text{ W}$ , $R_L = 8\ \Omega + 15\ \mu\text{H}$                                                                                                           |                             | 78<br>88                   |                             | %             |
| PSRR       | Power supply rejection ratio with inputs grounded<br>$C_{in} = 1\ \mu\text{F}$ <sup>(1)</sup> , $f = 217\text{ Hz}$ , $R_L = 8\ \Omega$ , Gain = 6 dB,<br>$V_{ripple} = 200\text{ mV}_{pp}$                                                                    |                             | 65                         |                             | dB            |
| Crosstalk  | Channel separation<br>$P_o = 0.9\text{ W}$ , $G = 6\text{ dB}$ , $f = 1\text{ kHz}$ , $R_L = 8\ \Omega$                                                                                                                                                        |                             | 90                         |                             | dB            |
| CMRR       | Common mode rejection ratio<br>$C_{in} = 1\ \mu\text{F}$ , $f = 217\text{ Hz}$ , $R_L = 8\ \Omega$ , Gain = 6 dB,<br>$\Delta V_{ICM} = 200\text{ mV}_{pp}$                                                                                                     |                             | 63                         |                             | dB            |
| Gain       | Gain value with no load<br>$G1 = G0 = V_{IL}$<br>$G1 = V_{IL}$ and $G0 = V_{IH}$<br>$G1 = V_{IH}$ and $G0 = V_{IL}$<br>$G1 = G0 = V_{IH}$                                                                                                                      | 5.5<br>11.5<br>17.5<br>23.5 | 6<br>12<br>18<br>24        | 6.5<br>12.5<br>18.5<br>24.5 | dB            |
| $Z_{in}$   | Single-ended input impedance<br>Referred to ground<br>Gain = 6 dB<br>Gain = 12 dB<br>Gain = 18 dB<br>Gain = 24 dB                                                                                                                                              | 24<br>24<br>12<br>6         | 30<br>30<br>15<br>7.5      | 36<br>36<br>18<br>9         | k $\Omega$    |
| $F_{PWM}$  | Pulse width modulator base frequency                                                                                                                                                                                                                           | 190                         | 280                        | 370                         | kHz           |

**Table 6.  $V_{CC} = +5\text{ V}$ ,  $GND = 0\text{ V}$ ,  $V_{IC} = 2.5\text{ V}$ ,  $T_{amb} = 25^\circ\text{ C}$  (unless otherwise specified) (continued)**

| Symbol     | Parameters and test conditions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Min. | Typ.                                         | Max. | Unit                |
|------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|----------------------------------------------|------|---------------------|
| SNR        | Signal to noise ratio (A-weighting)<br>$P_0 = 1.1\text{ W}$ , $G = 6\text{ dB}$ , $R_L = 8\ \Omega$                                                                                                                                                                                                                                                                                                                                                                                                                    |      | 99                                           |      | dB                  |
| $t_{WU}$   | Total wake-up time <sup>(2)</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 9    | 13                                           | 16.5 | ms                  |
| $t_{STBY}$ | Standby time <sup>(2)</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 11   | 15.8                                         | 20   | ms                  |
| $V_N$      | Output voltage noise $f = 20\text{ Hz}$ to $20\text{ kHz}$ , $R_L = 8\ \Omega$<br>Unweighted (filterless, $G = 6\text{ dB}$ )<br>A-weighted (filterless, $G = 6\text{ dB}$ )<br>Unweighted (with LC output filter, $G = 6\text{ dB}$ )<br>A-weighted (with LC output filter, $G = 6\text{ dB}$ )<br>Unweighted (filterless, $G = 24\text{ dB}$ )<br>A-weighted (filterless, $G = 24\text{ dB}$ )<br>Unweighted (with LC output filter, $G = 24\text{ dB}$ )<br>A-weighted (with LC output filter, $G = 24\text{ dB}$ ) |      | 61<br>31<br>59<br>31<br>87<br>52<br>87<br>53 |      | $\mu\text{V}_{RMS}$ |

1. Dynamic measurements -  $20 \cdot \log(\text{rms}(V_{out})/\text{rms}(V_{ripple}))$ .  $V_{ripple}$  is the superimposed sinus signal to  $V_{CC}$  at  $f = 217\text{ Hz}$ .
2. See [Section 4.6: Wake-up time \( \$t\_{WU}\$ \) and shutdown time \( \$t\_{STBY}\$ \) on page 23](#).

Table 7.  $V_{CC} = +3.6\text{ V}$ ,  $GND = 0\text{ V}$ ,  $V_{ic} = 1.8\text{ V}$ ,  $T_{amb} = 25^\circ\text{ C}$  (unless otherwise specified)

| Symbol     | Parameter                                                                                                                                                                                                                                                      | Min.                        | Typ.                       | Max.                        | Unit          |
|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|----------------------------|-----------------------------|---------------|
| $I_{CC}$   | Supply current<br>No input signal, no load, both channels                                                                                                                                                                                                      |                             | 3.5                        | 5.5                         | mA            |
| $I_{STBY}$ | Standby current<br>No input signal, $V_{STBY} = GND$                                                                                                                                                                                                           |                             | 0.7                        | 2                           | $\mu\text{A}$ |
| $V_{oo}$   | Output offset voltage<br>Floating inputs, $G = 6\text{ dB}$ , $R_L = 8\ \Omega$                                                                                                                                                                                |                             |                            | 25                          | mV            |
| $P_o$      | Output power<br>THD + N = 1% max, $f = 1\text{ kHz}$ , $R_L = 4\ \Omega$<br>THD + N = 1% max, $f = 1\text{ kHz}$ , $R_L = 8\ \Omega$<br>THD + N = 10% max, $f = 1\text{ kHz}$ , $R_L = 4\ \Omega$<br>THD + N = 10% max, $f = 1\text{ kHz}$ , $R_L = 8\ \Omega$ |                             | 0.96<br>0.63<br>1.3<br>0.8 |                             | W             |
| THD + N    | Total harmonic distortion + noise<br>$P_o = 0.45\text{ W}$ , $G = 6\text{ dB}$ , $f = 1\text{ kHz}$ , $R_L = 8\ \Omega$                                                                                                                                        |                             | 0.35                       |                             | %             |
| Efficiency | Efficiency per channel<br>$P_o = 0.96\text{ W}$ , $R_L = 4\ \Omega + 15\ \angle H$<br>$P_o = 0.63\text{ W}$ , $R_L = 8\ \Omega + 15\ \angle H$                                                                                                                 |                             | 78<br>88                   |                             | %             |
| PSRR       | Power supply rejection ratio with inputs grounded<br>$C_{in} = 1\ \mu\text{F}$ <sup>(1)</sup> , $f = 217\text{ Hz}$ , $R_L = 8\ \Omega$ , Gain = 6 dB,<br>$V_{ripple} = 200\text{ mV}_{pp}$                                                                    |                             | 65                         |                             | dB            |
| Crosstalk  | Channel separation<br>$G = 6\text{ dB}$ , $f = 1\text{ kHz}$ , $R_L = 8\ \Omega$                                                                                                                                                                               |                             | 90                         |                             |               |
| CMRR       | Common mode rejection ratio<br>$C_{in} = 1\ \mu\text{F}$ , $f = 217\text{ Hz}$ , $R_L = 8\ \Omega$ , Gain = 6 dB,<br>$\Delta V_{ICM} = 200\text{ mV}_{pp}$                                                                                                     |                             | 62                         |                             | dB            |
| Gain       | Gain value with no load<br>$G1 = G0 = V_{IL}$<br>$G1 = V_{IL}$ and $G0 = V_{IH}$<br>$G1 = V_{IH}$ and $G0 = V_{IL}$<br>$G1 = G0 = V_{IH}$                                                                                                                      | 5.5<br>11.5<br>17.5<br>23.5 | 6<br>12<br>18<br>24        | 6.5<br>12.5<br>18.5<br>24.5 | dB            |
| $Z_{in}$   | Single-ended input impedance<br>Referred to ground<br>Gain = 6 dB<br>Gain = 12 dB<br>Gain = 18 dB<br>Gain = 24 dB                                                                                                                                              | 24<br>24<br>12<br>6         | 30<br>30<br>15<br>7.5      | 36<br>36<br>18<br>9         | k $\Omega$    |
| $F_{PWM}$  | Pulse width modulator base frequency                                                                                                                                                                                                                           | 190                         | 280                        | 370                         | kHz           |
| SNR        | Signal-to-noise ratio (A-weighting)<br>$P_o = 0.6\text{ W}$ , $G = 6\text{ dB}$ , $R_L = 8\ \Omega$                                                                                                                                                            |                             | 96                         |                             | dB            |
| $t_{WU}$   | Total wake-up time <sup>(2)</sup>                                                                                                                                                                                                                              | 7.5                         | 11.3                       | 15                          | ms            |

Table 7.  $V_{CC} = +3.6\text{ V}$ ,  $GND = 0\text{ V}$ ,  $V_{IC} = 1.8\text{ V}$ ,  $T_{amb} = 25^\circ\text{ C}$  (unless otherwise specified) (continued)

| Symbol     | Parameter                                                                     | Min. | Typ. | Max. | Unit                |
|------------|-------------------------------------------------------------------------------|------|------|------|---------------------|
| $t_{STBY}$ | Standby time <sup>(2)</sup>                                                   | 10   | 13.8 | 18   | ms                  |
| $V_N$      | Output voltage noise $f = 20\text{ Hz to } 20\text{ kHz}$ , $R_L = 8\ \Omega$ |      |      |      | $\mu\text{V}_{RMS}$ |
|            | Unweighted (filterless, $G = 6\text{ dB}$ )                                   |      | 54   |      |                     |
|            | A-weighted (filterless, $G = 6\text{ dB}$ )                                   |      | 28   |      |                     |
|            | Unweighted (with LC output filter, $G = 6\text{ dB}$ )                        |      | 52   |      |                     |
|            | A-weighted (with LC output filter, $G = 6\text{ dB}$ )                        |      | 27   |      |                     |
|            | Unweighted (filterless, $G = 24\text{ dB}$ )                                  |      | 80   |      |                     |
|            | A-weighted (filterless, $G = 24\text{ dB}$ )                                  |      | 50   |      |                     |
|            | Unweighted (with LC output filter, $G = 24\text{ dB}$ )                       |      | 79   |      |                     |
|            | A-weighted (with LC output filter, $G = 24\text{ dB}$ )                       |      | 49   |      |                     |

- Dynamic measurements -  $20 \cdot \log(\text{rms}(V_{out})/\text{rms}(V_{ripple}))$ .  $V_{ripple}$  is the superimposed sinus signal to  $V_{CC}$  at  $f = 217\text{ Hz}$ .
- See [Section 4.6: Wake-up time \( \$t\_{WU}\$ \) and shutdown time \( \$t\_{STBY}\$ \) on page 23](#).

Table 8.  $V_{CC} = +2.5\text{ V}$ ,  $GND = 0\text{ V}$ ,  $V_{IC} = 1.25\text{ V}$ ,  $T_{amb} = 25\text{ }^{\circ}\text{C}$  (unless otherwise specified)

| Symbol     | Parameter                                                                                                                                                                                                                                                                              | Min.                        | Typ.                       | Max.                        | Unit             |
|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|----------------------------|-----------------------------|------------------|
| $I_{CC}$   | Supply current<br>No input signal, no load, both channels                                                                                                                                                                                                                              |                             | 2.8                        | 4                           | mA               |
| $I_{STBY}$ | Standby current<br>No input signal, $V_{STBY} = GND$                                                                                                                                                                                                                                   |                             | 0.45                       | 2                           | $\mu\text{A}$    |
| $V_{oo}$   | Output offset voltage<br>Floating inputs, $G = 6\text{ dB}$ , $R_L = 8\text{ }\Omega$                                                                                                                                                                                                  |                             |                            | 25                          | mV               |
| $P_o$      | Output power<br>THD + N = 1% max, $f = 1\text{ kHz}$ , $R_L = 4\text{ }\Omega$<br>THD + N = 1% max, $f = 1\text{ kHz}$ , $R_L = 8\text{ }\Omega$<br>THD + N = 10% max, $f = 1\text{ kHz}$ , $R_L = 4\text{ }\Omega$<br>THD + N = 10% max, $f = 1\text{ kHz}$ , $R_L = 8\text{ }\Omega$ |                             | 0.45<br>0.3<br>0.6<br>0.38 |                             | W                |
| THD + N    | Total harmonic distortion + noise<br>$P_o = 0.2\text{ W}$ , $G = 6\text{ dB}$ , $f = 1\text{ kHz}$ , $R_L = 8\text{ }\Omega$                                                                                                                                                           |                             | 0.2                        |                             | %                |
| Efficiency | Efficiency per channel<br>$P_o = 0.45\text{ W}$ , $R_L = 4\text{ }\Omega + 15\text{ }\mu\text{H}$<br>$P_o = 0.3\text{ W}$ , $R_L = 8\text{ }\Omega + 15\text{ }\mu\text{H}$                                                                                                            |                             | 78<br>87                   |                             | %                |
| PSRR       | Power supply rejection ratio with inputs grounded<br>$C_{in} = 1\text{ }\mu\text{F}$ <sup>(1)</sup> , $f = 217\text{ Hz}$ , $R_L = 8\text{ }\Omega$ , Gain = 6 dB,<br>$V_{ripple} = 200\text{ mV}_{pp}$                                                                                |                             | 65                         |                             | dB               |
| Crosstalk  | Channel separation<br>$G = 6\text{ dB}$ , $f = 1\text{ kHz}$ , $R_L = 8\text{ }\Omega$                                                                                                                                                                                                 |                             | 90                         |                             |                  |
| CMRR       | Common mode rejection ratio<br>$C_{in} = 1\text{ }\mu\text{F}$ , $f = 217\text{ Hz}$ , $R_L = 8\text{ }\Omega$ , Gain = 6 dB,<br>$\Delta V_{ICM} = 200\text{ mV}_{pp}$                                                                                                                 |                             | 62                         |                             | dB               |
| Gain       | Gain value with no load<br>$G1 = G0 = V_{IL}$<br>$G1 = V_{IL}$ and $G0 = V_{IH}$<br>$G1 = V_{IH}$ and $G0 = V_{IL}$<br>$G1 = G0 = V_{IH}$                                                                                                                                              | 5.5<br>11.5<br>17.5<br>23.5 | 6<br>12<br>18<br>24        | 6.5<br>12.5<br>18.5<br>24.5 | dB               |
| $Z_{in}$   | Single-ended input impedance<br>Referred to ground<br>Gain = 6 dB<br>Gain = 12 dB<br>Gain = 18 dB<br>Gain = 24 dB                                                                                                                                                                      | 24<br>24<br>12<br>6         | 30<br>30<br>15<br>7.5      | 36<br>36<br>18<br>9         | $\text{k}\Omega$ |
| $F_{PWM}$  | Pulse width modulator base frequency                                                                                                                                                                                                                                                   | 190                         | 280                        | 370                         | kHz              |
| SNR        | Signal-to-noise ratio (A-weighting)<br>$P_o = 0.28\text{ W}$ , $G = 6\text{ dB}$ , $R_L = 8\text{ }\Omega$                                                                                                                                                                             |                             | 93                         |                             | dB               |
| $t_{WU}$   | Total wake-up time <sup>(2)</sup>                                                                                                                                                                                                                                                      | 3                           | 7.8                        | 12                          | ms               |

Table 8.  $V_{CC} = +2.5\text{ V}$ ,  $GND = 0\text{ V}$ ,  $V_{ic} = 1.25\text{ V}$ ,  $T_{amb} = 25\text{ °C}$  (unless otherwise specified) (continued)

| Symbol     | Parameter                                                                     | Min. | Typ. | Max. | Unit          |
|------------|-------------------------------------------------------------------------------|------|------|------|---------------|
| $t_{STBY}$ | Standby time <sup>(2)</sup>                                                   | 8    | 12   | 16   | ms            |
| $V_N$      | Output voltage noise $f = 20\text{ Hz to } 20\text{ kHz}$ , $R_L = 8\ \Omega$ |      |      |      | $\mu V_{RMS}$ |
|            | Unweighted (filterless, $G = 6\text{ dB}$ )                                   |      | 51   |      |               |
|            | A-weighted (filterless, $G = 6\text{ dB}$ )                                   |      | 26   |      |               |
|            | Unweighted (with LC output filter, $G = 6\text{ dB}$ )                        |      | 49   |      |               |
|            | A-weighted (with LC output filter, $G = 6\text{ dB}$ )                        |      | 26   |      |               |
|            | Unweighted (filterless, $G = 24\text{ dB}$ )                                  |      | 77   |      |               |
|            | A-weighted (filterless, $G = 24\text{ dB}$ )                                  |      | 49   |      |               |
|            | Unweighted (with LC output filter, $G = 24\text{ dB}$ )                       |      | 76   |      |               |
|            | A-weighted (with LC output filter, $G = 24\text{ dB}$ )                       |      | 48   |      |               |

1. Dynamic measurements -  $20 \cdot \log(\text{rms}(V_{out})/\text{rms}(V_{ripple}))$ .  $V_{ripple}$  is the superimposed sinus signal to  $V_{CC}$  at  $f = 217\text{ Hz}$ .
2. See [Section 4.6: Wake-up time \( \$t\_{WU}\$ \) and shutdown time \( \$t\_{STBY}\$ \) on page 23](#).

### 3.2 Electrical characteristic curves

The graphs shown in this section use the following abbreviations.

- $R_L + 15\ \mu\text{H}$  or  $30\ \mu\text{H}$  = pure resistor + very low series resistance inductor.
- Filter = LC output filter ( $1\ \mu\text{F} + 30\ \mu\text{H}$  for  $4\ \Omega$  and  $0.5\ \mu\text{F} + 15\ \mu\text{H}$  for  $8\ \Omega$ ).

All measurements are done with  $C_{S1}=1\ \mu\text{F}$  and  $C_{S2}=100\ \text{nF}$  (Figure 2), except for the PSRR where  $C_{S1}$  is removed (Figure 3).

**Figure 2. Test diagram for measurements**

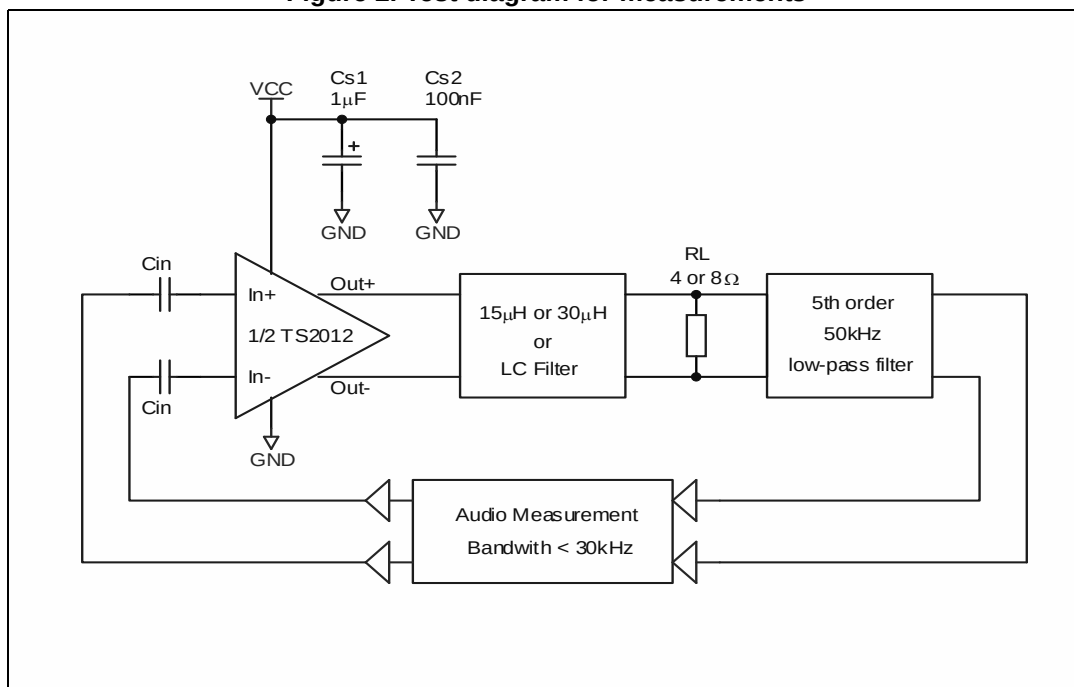


Figure 3. Test diagram for PSRR measurements

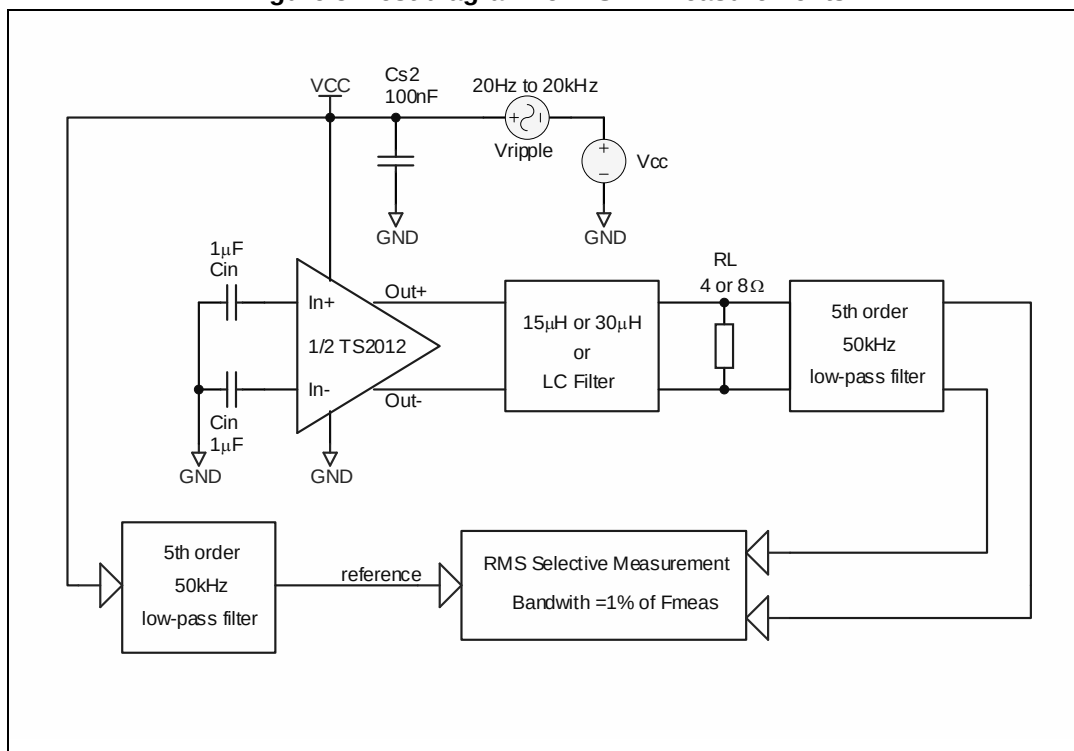


Figure 4. Current consumption vs. power supply voltage

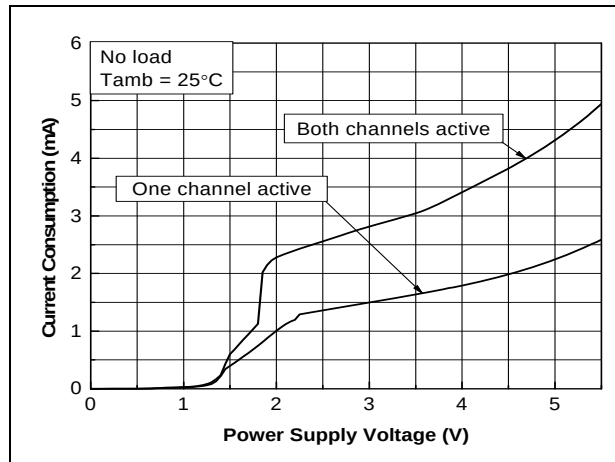


Figure 5. Current consumption vs. standby voltage (one channel)

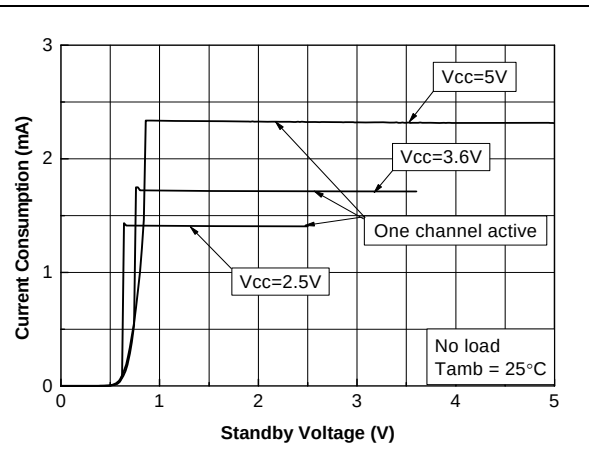


Figure 6. Efficiency vs. output power (one channel)

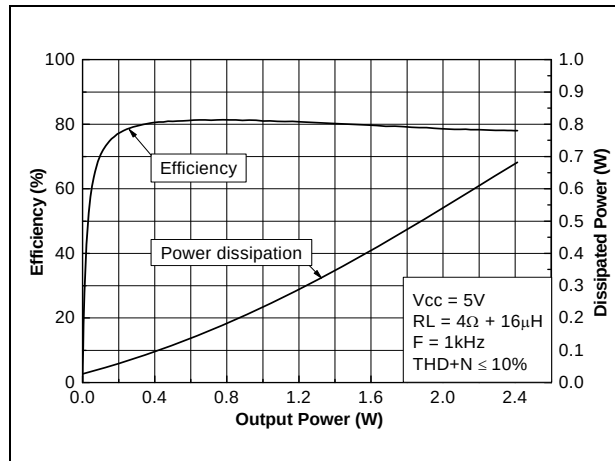


Figure 7. Efficiency vs. output power (one channel)

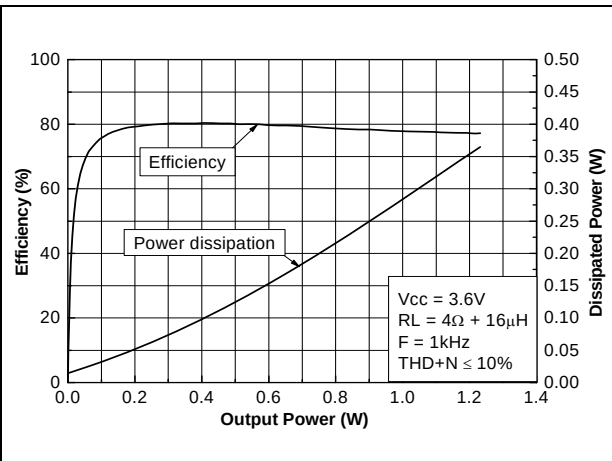


Figure 8. Efficiency vs. output power (one channel)

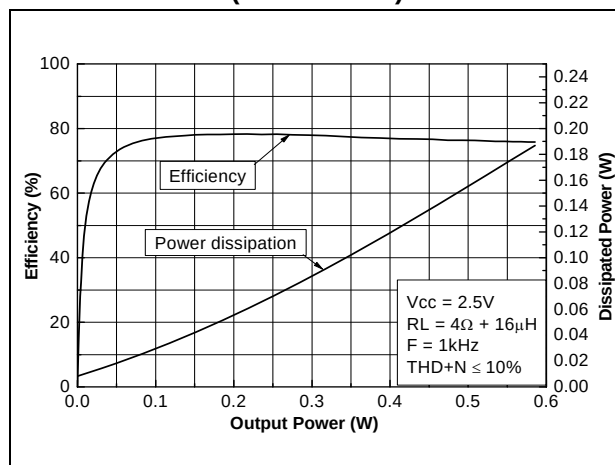


Figure 9. Efficiency vs. output power (one channel)

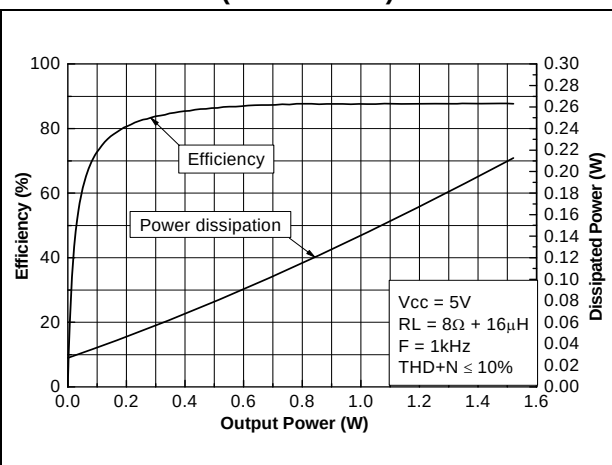


Figure 10. Efficiency vs. output power  
(one channel)

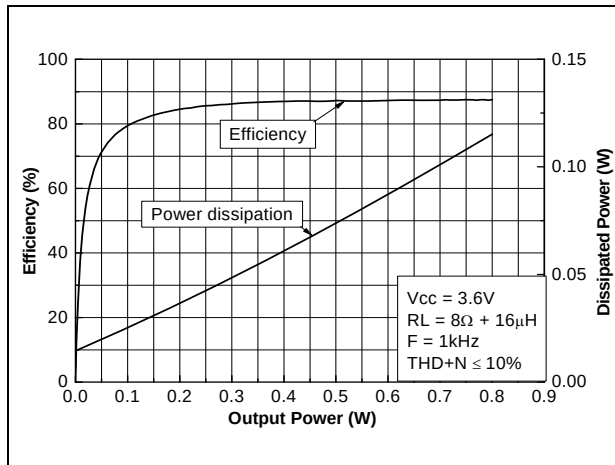


Figure 11. Efficiency vs. output power  
(one channel)

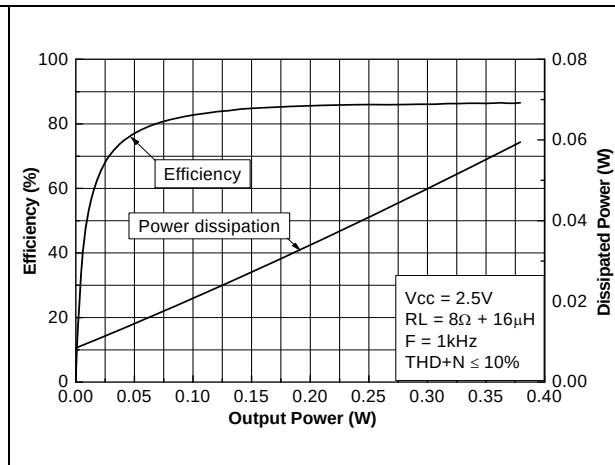


Figure 12. PSRR vs. frequency

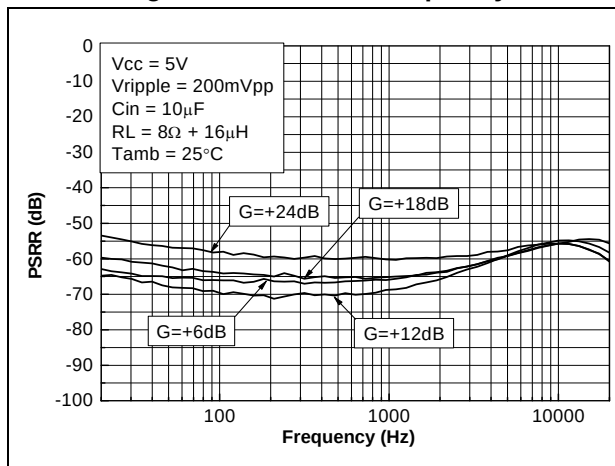


Figure 13. PSRR vs. frequency

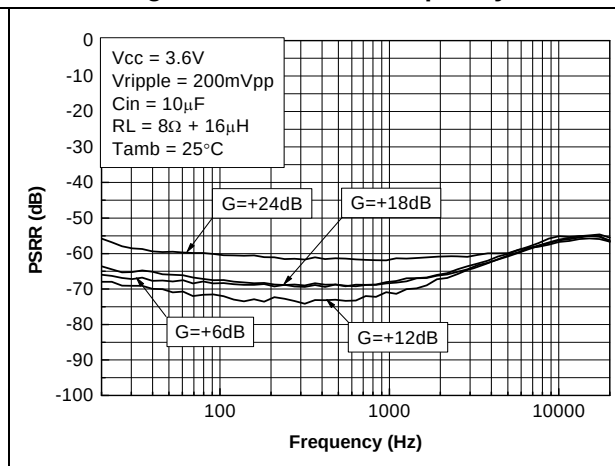


Figure 14. PSRR vs. frequency

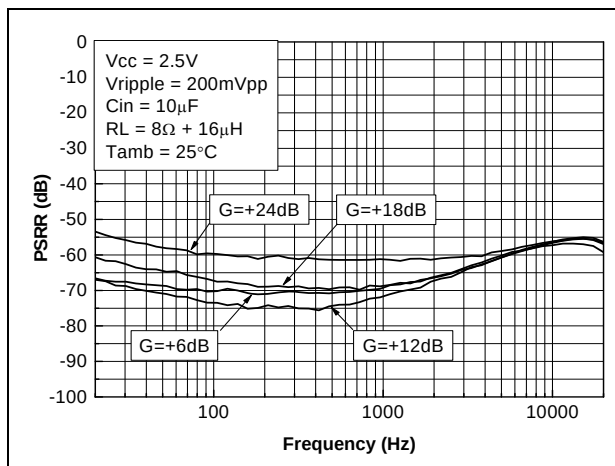


Figure 15. PSRR vs. common mode input  
voltage

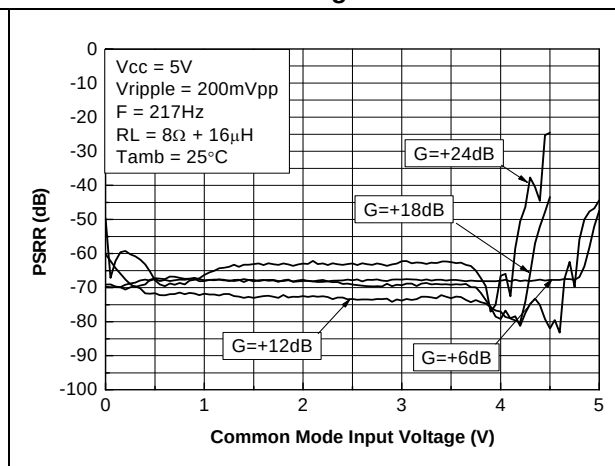


Figure 16. PSRR vs. common mode input voltage

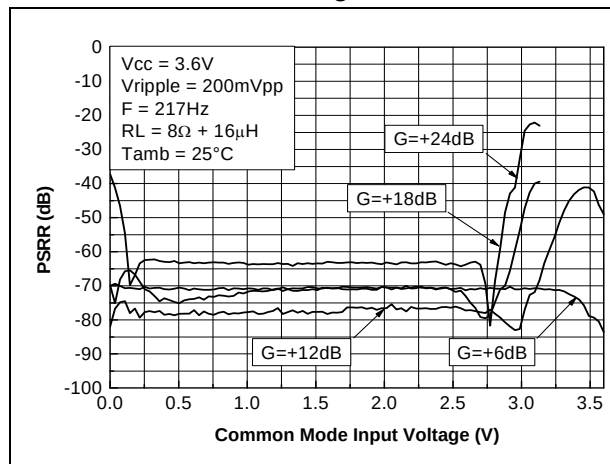


Figure 17. PSRR vs. common mode input voltage

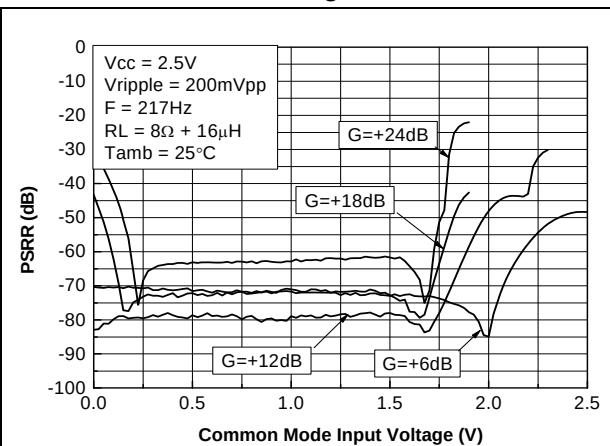


Figure 18. CMRR vs. frequency

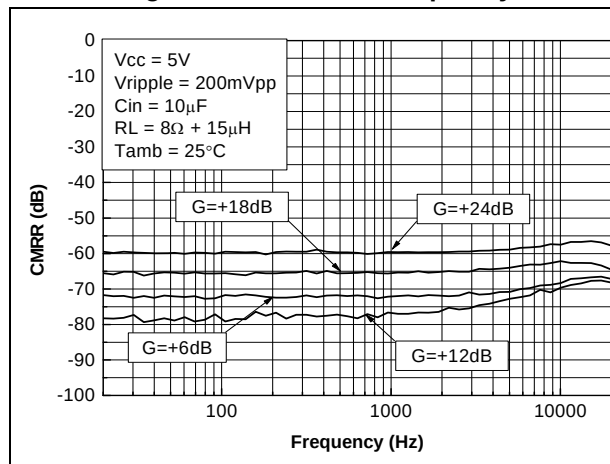


Figure 19. CMRR vs. frequency

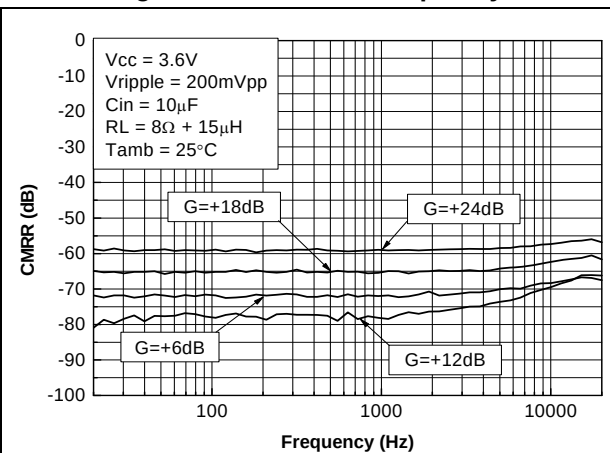


Figure 20. CMRR vs. frequency

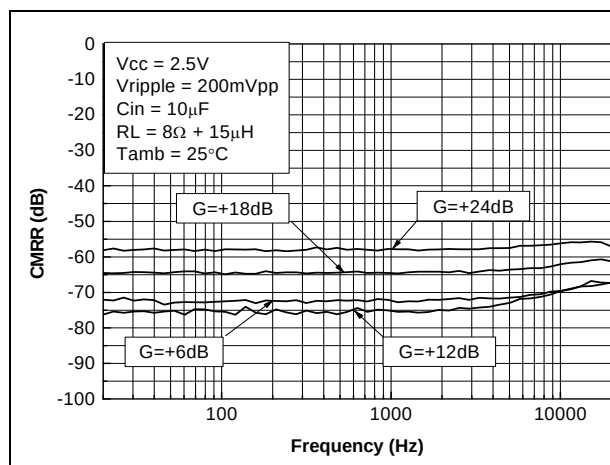


Figure 21. CMRR vs. common mode input voltage

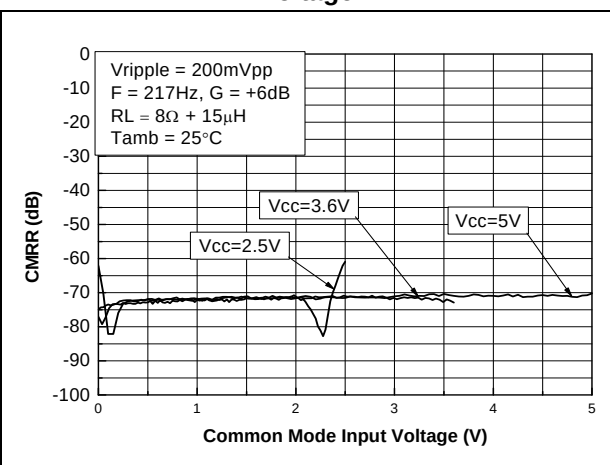


Figure 22. CMRR vs. common mode input voltage

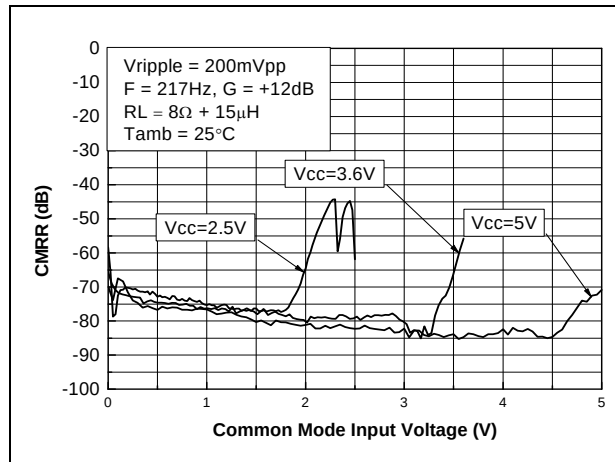


Figure 23. CMRR vs. common mode input voltage

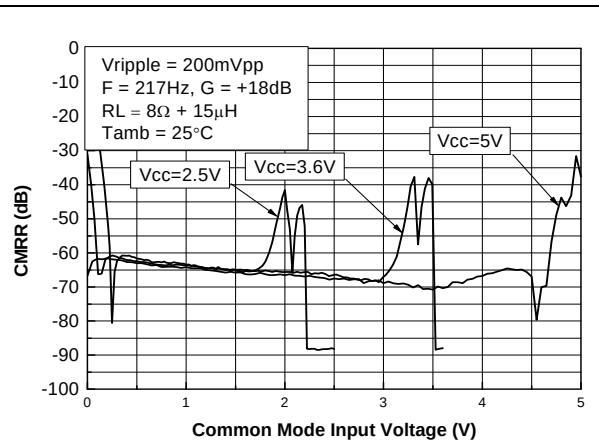


Figure 24. CMRR vs. common mode input voltage

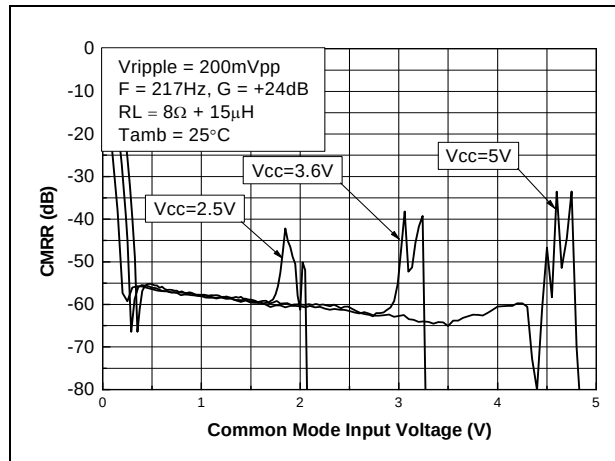


Figure 25. THD+N vs. output power

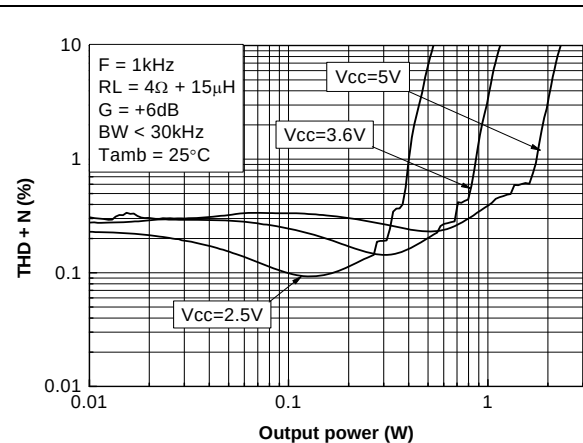


Figure 26. THD+N vs. output power

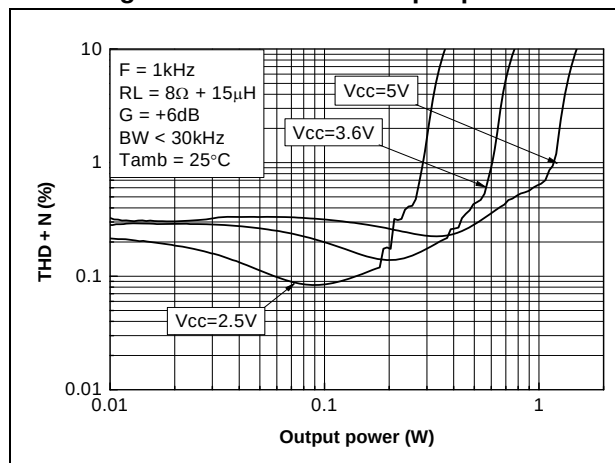


Figure 27. THD+N vs. frequency

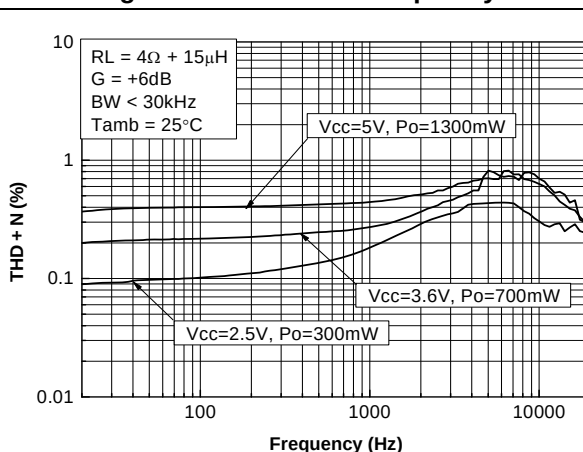


Figure 28. THD+N vs. frequency

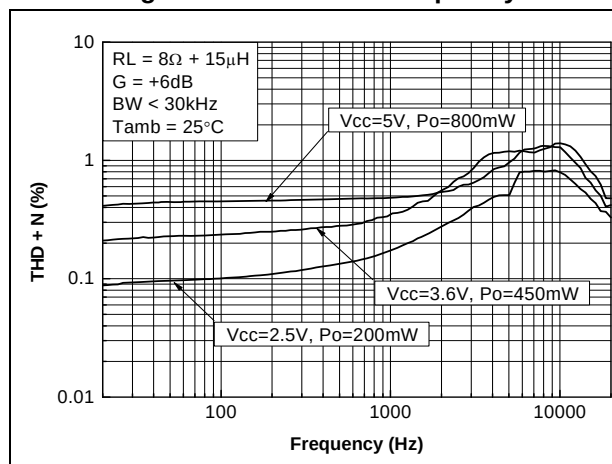


Figure 29. Crosstalk vs. frequency

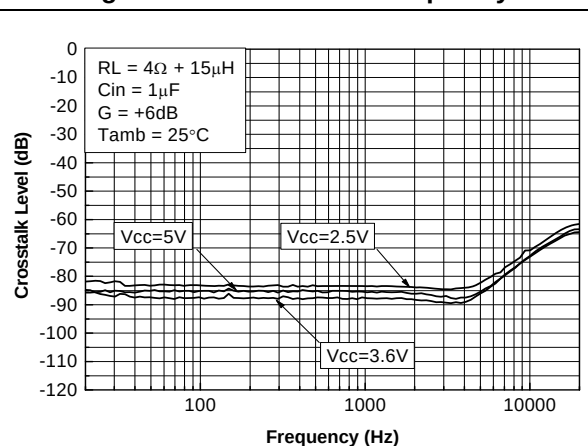


Figure 30. Crosstalk vs. frequency

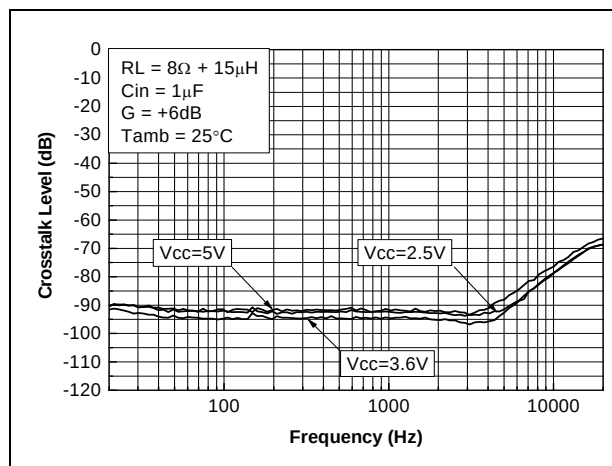


Figure 31. Output power vs. power supply voltage

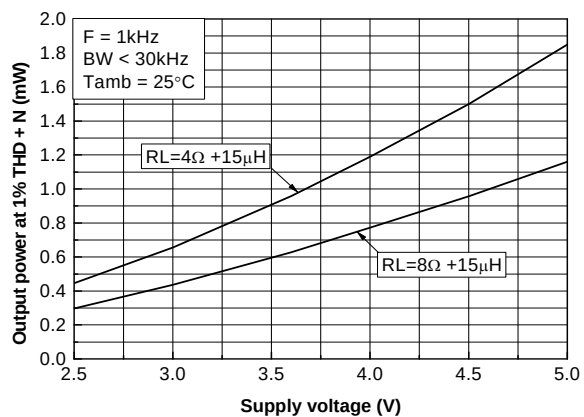


Figure 32. Output power vs. power supply voltage

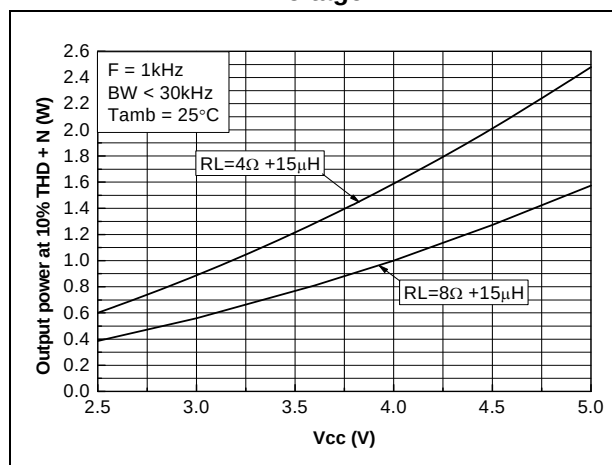


Figure 33. Power derating curves

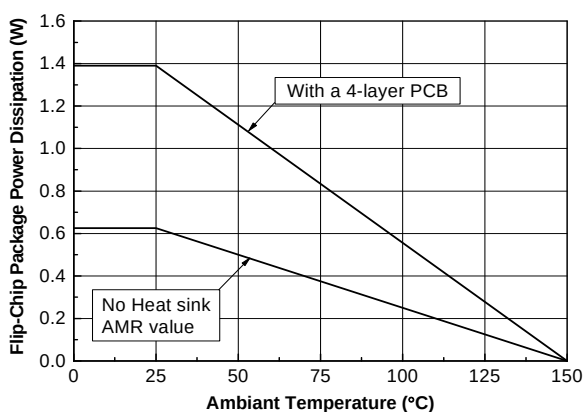


Figure 34. Startup and shutdown phase  
 $V_{CC} = 5\text{ V}$ ,  $G = 6\text{ dB}$ ,  $C_{in} = 1\text{ }\mu\text{F}$ , inputs grounded

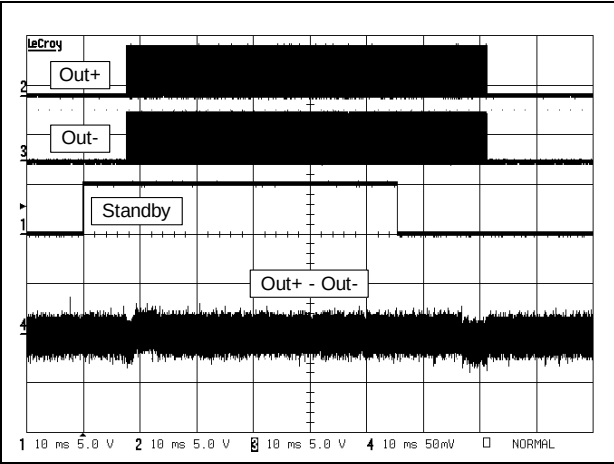
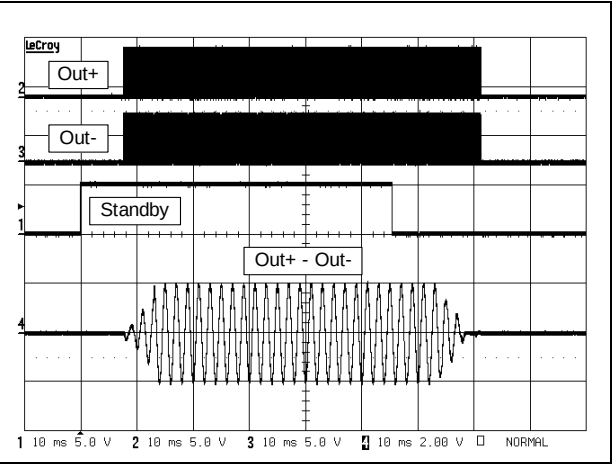


Figure 35. Startup and shutdown phase  
 $V_{CC} = 5\text{ V}$ ,  $G = 6\text{ dB}$ ,  $C_{in} = 1\text{ }\mu\text{F}$ ,  $V_{in} = 2\text{ V}_{pp}$ ,  
 $F = 500\text{ Hz}$



## 4 Application information

### 4.1 Differential configuration principle

The TS2012EI is a monolithic fully-differential input/output class D power amplifier. The TS2012EI also includes a common-mode feedback loop that controls the output bias value to average it at  $V_{CC}/2$  for any DC common mode input voltage. This allows the device to always have a maximum output voltage swing, and by consequence, maximize the output power. Moreover, as the load is connected differentially compared with a single-ended topology, the output is four times higher for the same power supply voltage.

The **advantages** of a full-differential amplifier are:

- high PSRR (power supply rejection ratio),
- high common mode noise rejection,
- virtually zero pop without additional circuitry, giving a faster start-up time compared to conventional single-ended input amplifiers,
- easier interfacing with differential output audio DACs,
- no input coupling capacitors required thanks to the common mode feedback loop.

### 4.2 Gain settings

In the flat region of the frequency-response curve (no input coupling capacitor or internal feedback loop + load effect), the differential gain can be set to 6, 12 18, or 24 dB, depending on the logic level of the G0 and G1 pins, as shown in [Table 9](#).

**Table 9. Gain settings with G0 and G1 pins**

| G1 | G0 | Gain (dB) | Gain (V/V) |
|----|----|-----------|------------|
| 0  | 0  | 6         | 2          |
| 0  | 1  | 12        | 4          |
| 1  | 0  | 18        | 8          |
| 1  | 1  | 24        | 16         |

*Note:* Between pins G0, G1 and GND there is an internal 300 k $\Omega$  (+/-20%) resistor. When the pins are floating, the gain is 6 dB. In full standby (left and right channels OFF), these resistors are disconnected (HiZ input).

### 4.3 Common mode feedback loop limitations

As explained previously, the common mode feedback loop allows the output DC bias voltage to be averaged at  $V_{CC}/2$  for any DC common mode bias input voltage.

Due to the  $V_{ic}$  limitation of the input stage (see [Table 3: Operating conditions on page 4](#)), the common mode feedback loop can fulfill its role only within the defined range.

## 4.4 Low frequency response

If a low frequency bandwidth limitation is required, it is possible to use input coupling capacitors. In the low-frequency region, the input coupling capacitor  $C_{in}$  starts to have an effect.  $C_{in}$  forms, with the input impedance  $Z_{in}$ , a first order high-pass filter with a -3 dB cut-off frequency (see [Table 6](#) to [Table 8](#)).

$$F_{CL} = \frac{1}{2 \cdot \pi \cdot Z_{in} \cdot C_{in}}$$

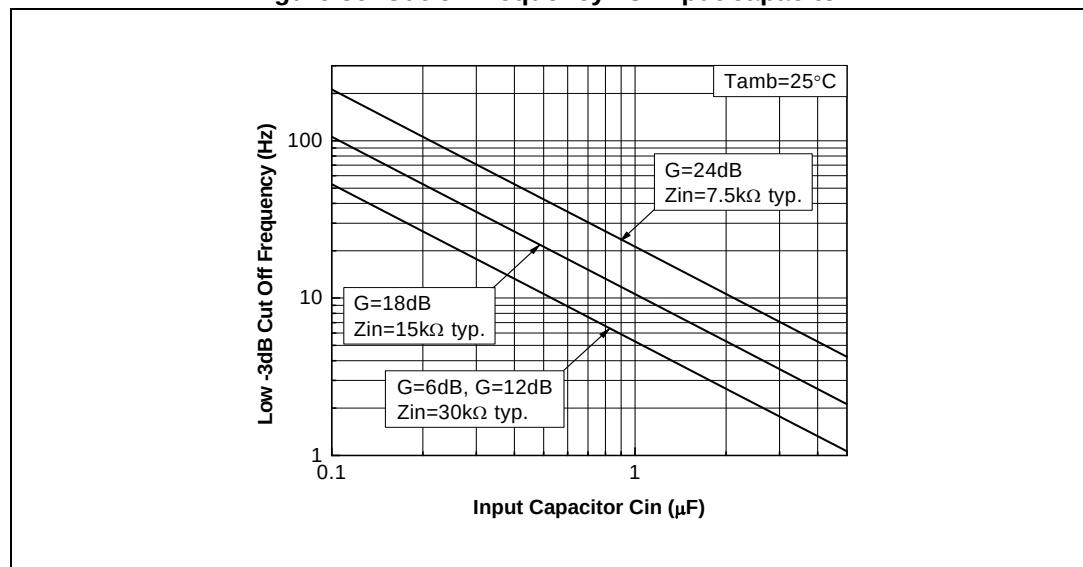
So, for a desired cut-off frequency  $F_{CL}$ ,  $C_{in}$  is calculated as follows.

$$C_{in} = \frac{1}{2 \cdot \pi \cdot Z_{in} \cdot F_{CL}}$$

with  $F_{CL}$  in Hz,  $Z_{in}$  in  $\Omega$  and  $C_{in}$  in F.

The input impedance  $Z_{in}$  is for the whole power supply voltage range and it changes with the gain setting. There is also a tolerance around the typical values (see [Table 6](#) to [Table 8](#)).

**Figure 36. Cut-off frequency vs. input capacitor**



## 4.5 Decoupling of the circuit

Power supply capacitors, referred to as  $C_{S1}$  and  $C_{S2}$ , are needed to correctly bypass the TS2012EI.

The TS2012EI has a typical switching frequency of 280 kHz and an output fall and rise time of approximately 5 ns. Due to these very fast transients, careful decoupling is mandatory.

A 1  $\mu$ F ceramic capacitor ( $C_{S1}$ ) between PVCC and PGND and one additional ceramic capacitor 0.1  $\mu$ F ( $C_{S2}$ ) are enough. A 1  $\mu$ F capacitor must be located as close as possible to the device PVCC pin in order to avoid any extra parasitic inductance or resistance created by a long track wire. Parasitic loop inductance, in relation with  $di/dt$ , introduces overvoltage that decreases the global efficiency of the device and may cause, if this parasitic inductance is too high, a breakdown of the TS2012EI. For filtering low-frequency noise signals on the power line, you can use a  $C_{S1}$  capacitor of 4.7  $\mu$ F or more.

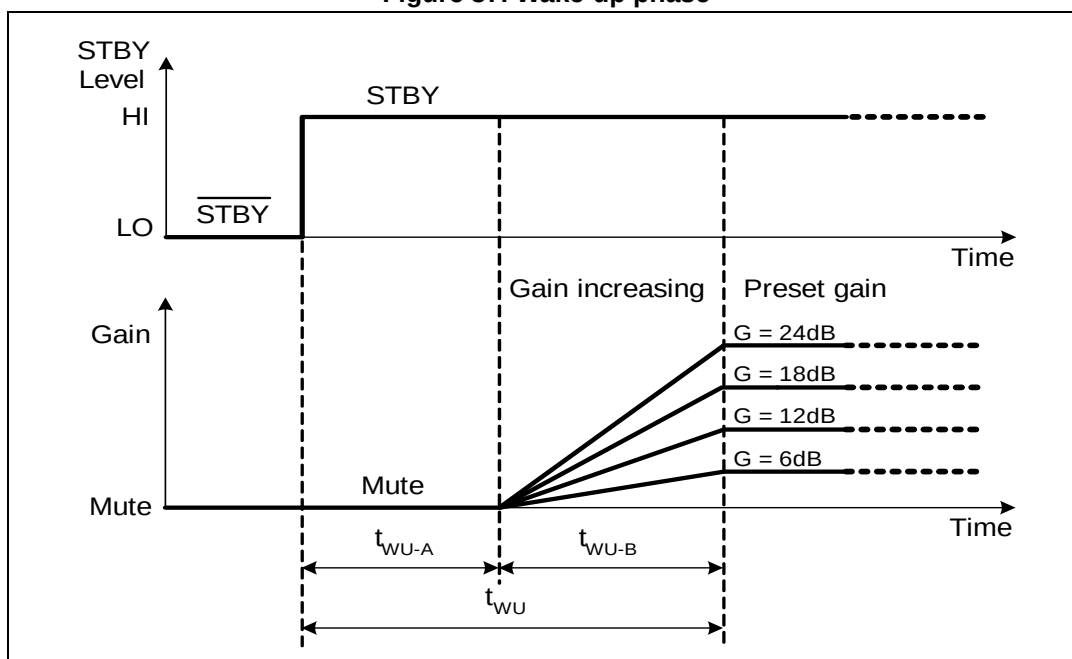
In addition, even if a ceramic capacitor has an adequate high frequency ESR (equivalent series resistance) value, its current capability is also important. A size of 0603 is a good compromise, particularly when a 4  $\Omega$  load is used.

Another important parameter is the rated voltage of the capacitor. A 1  $\mu$ F/6.3 V capacitor used at 5 V, loses about 50% of its value. With a power supply voltage of 5 V, the decoupling value, instead of 1  $\mu$ F, could be reduced to 0.5  $\mu$ F. As  $C_S$  has particular influence on the THD+N in the medium-to-high frequency region, this capacitor variation becomes decisive. In addition, less decoupling means higher overshoots, which can be problematic if they reach the power supply AMR value (6 V).

## 4.6 Wake-up time ( $t_{WU}$ ) and shutdown time ( $t_{STBY}$ )

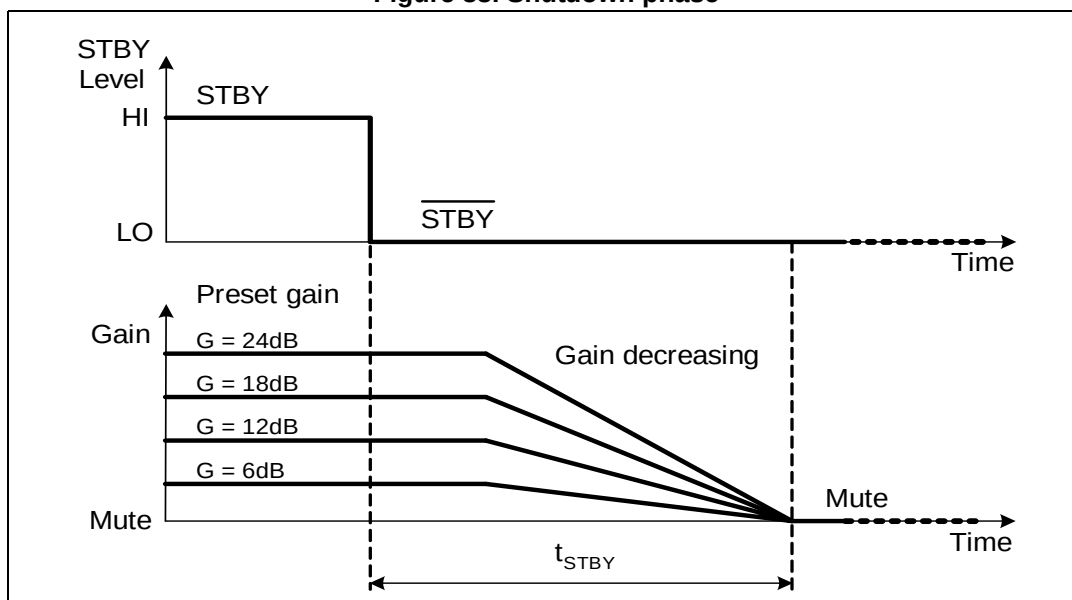
During the wake-up sequence when the standby is released to set the device ON, there is a delay. The wake-up sequence of the TS2012EI consists of two phases. During the first phase  $t_{WU-A}$ , a digitally-generated delay, mutes the outputs. Then, the gain increasing phase  $t_{WU-B}$  begins. The gain increases smoothly from the mute state to the preset gain selected by the digital pins G0 and G1. This startup sequence avoids any pop noise during startup of the amplifier. Refer to [Figure 37: Wake-up phase](#)

Figure 37. Wake-up phase



When the standby command is set, the time required to set the output stage to high impedance and to put the internal circuitry in shutdown mode is called the standby time. This time is used to decrease the gain from its nominal value set by the digital pins G0 and G1 to mute and avoid any pop noise during shutdown. The gain decreases smoothly until the outputs are muted ([Figure 38](#)).

Figure 38. Shutdown phase



## 4.7 Consumption in shutdown mode

Between the shutdown pin and GND there is an internal 300 k $\Omega$  (+/-20%) resistor. This resistor forces the TS2012EI to be in shutdown when the shutdown input is left floating.

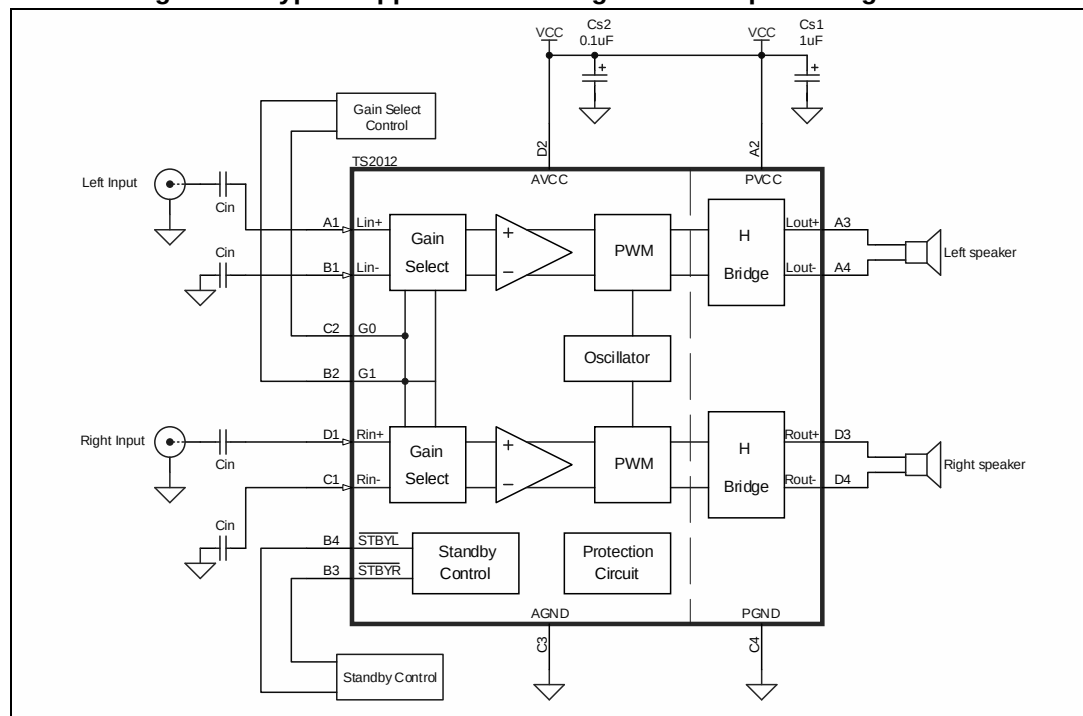
However, this resistor also introduces additional shutdown power consumption if the shutdown pin voltage is not at 0 V.

With a 0.4 V shutdown voltage pin for example, you must add  $0.4 \text{ V} / 300 \text{ k}\Omega = 1.3 \mu\text{A}$  typical ( $0.4 \text{ V} / 240 \text{ k}\Omega = 1.66 \mu\text{A}$  maximum) for each shutdown pin to the standby current specified in [Table 6](#) to [Table 8](#). Of course, this current will be provided by the external control device for the standby pins.

## 4.8 Single-ended input configuration

It is possible to use the TS2012EI in a single-ended input configuration. However, input coupling capacitors are mandatory in this configuration. [Figure 39](#) shows a typical single-ended input application.

**Figure 39. Typical application for single-ended input configuration**



## 4.9 Output filter considerations

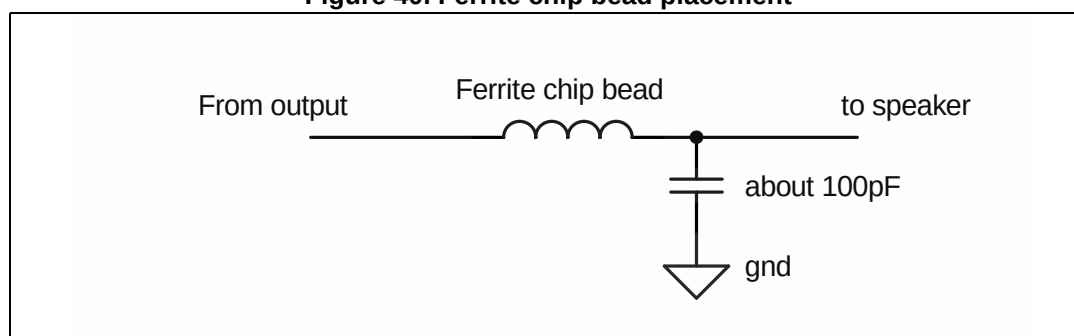
The TS2012EI is designed to operate without an output filter. However, due to very sharp transients on the TS2012EI output, EMI-radiated emissions may cause some standard compliance issues.

These EMI standard compliance issues can appear if the distance between the TS2012EI outputs and loudspeaker terminal are long (typically more than 50 mm, or 100 mm in both directions, to the speaker terminals). Because the PCB layout and internal equipment device are different for each configuration, it is difficult to provide a one-size-fits-all solution.

However, to decrease the probability of EMI issues, there are several simple rules to follow.

- Reduce, as much as possible, the distance between the TS2012EI output pins and the speaker terminals.
- Use a ground plane to "shield" sensitive wires.
- Place, as close as possible to the TS2012EI and in series with each output, a ferrite bead with a rated current of at least 2.5 A and an impedance greater than  $50\ \Omega$  at frequencies above 30 MHz. If, after testing, these ferrite beads are not necessary, replace them by a short-circuit.
- Allow extra footprint to place, if necessary, a capacitor to short perturbations to ground ([Figure 40](#)).

**Figure 40. Ferrite chip bead placement**



In the case where the distance between the TS2012EI output and the speaker terminals is too long, it is possible to have low frequency EMI issues due to the fact that the typical operating frequency is 280 kHz. In this configuration, it is necessary to use the output filter represented in [Figure 1 on page 5](#) as close as possible to the TS2012EI.

## 4.10 Short-circuit protection

The TS2012EI includes output short-circuit protection. This protection prevents the device from being damaged in case of fault conditions on the amplifier outputs.

When a channel is in operating mode and a short-circuit occurs between two outputs of the channel or between an output and ground, the short-circuit protection detects this situation and puts the appropriate channel into standby. To put the channel back into operating mode, it is necessary to put the channel's standby pin to logical LO, and then back again to logical HI and wake up the channel.

## 4.11 Thermal shutdown

The TS2012EI device has an internal thermal shutdown protection in the event of extreme temperatures to protect the device from overheating. Thermal shutdown is active when the device reaches 150° C. When the temperature decreases to safe levels, the circuit switches back to normal operation.

## 5 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK® packages, depending on their level of environmental compliance. ECOPACK® specifications, grade definitions and product status are available at: [www.st.com](http://www.st.com). ECOPACK® is an ST trademark.

Figure 41. Flip Chip 16 package mechanical drawing

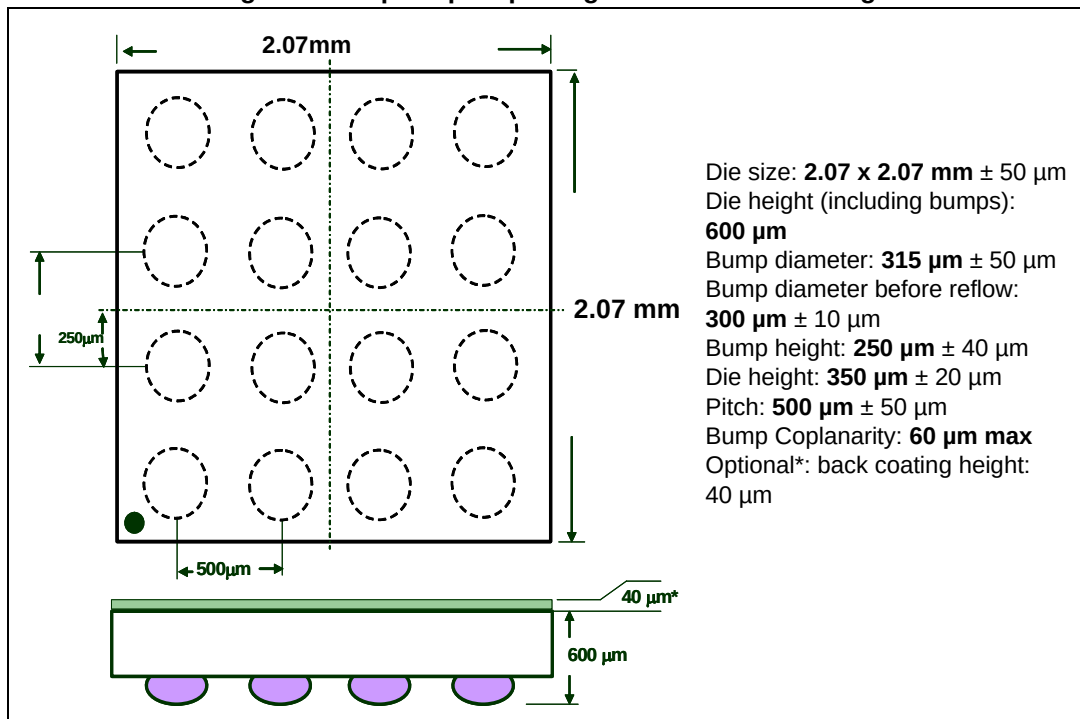


Figure 42. Pinout (top view)

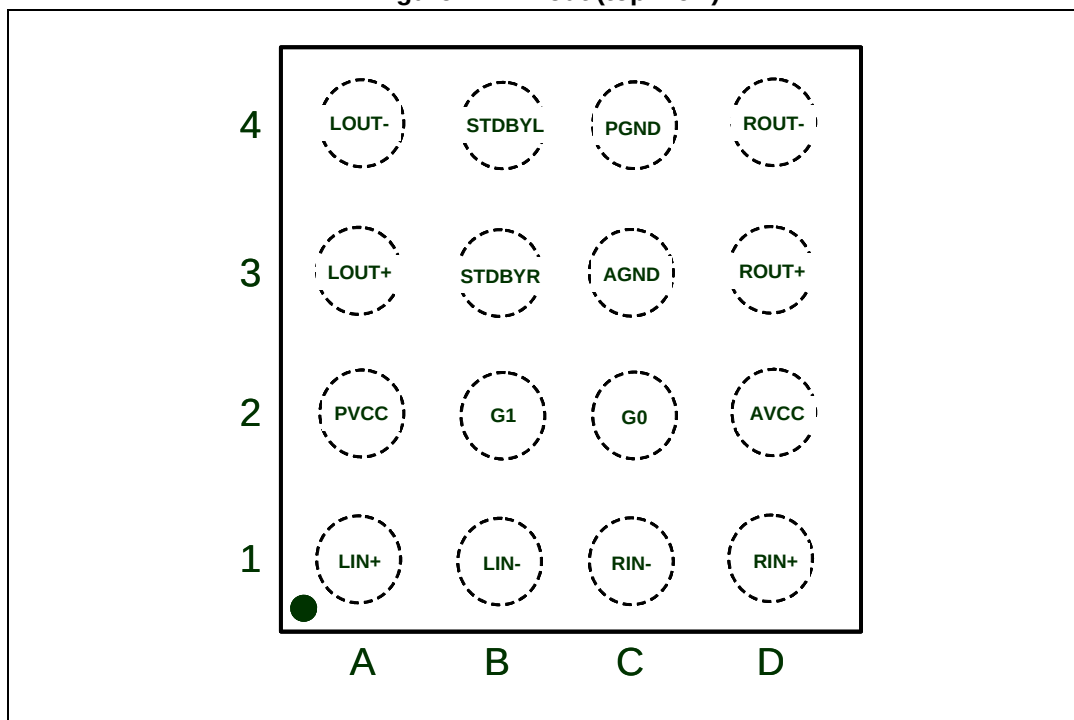


Figure 43. Marking (top view)

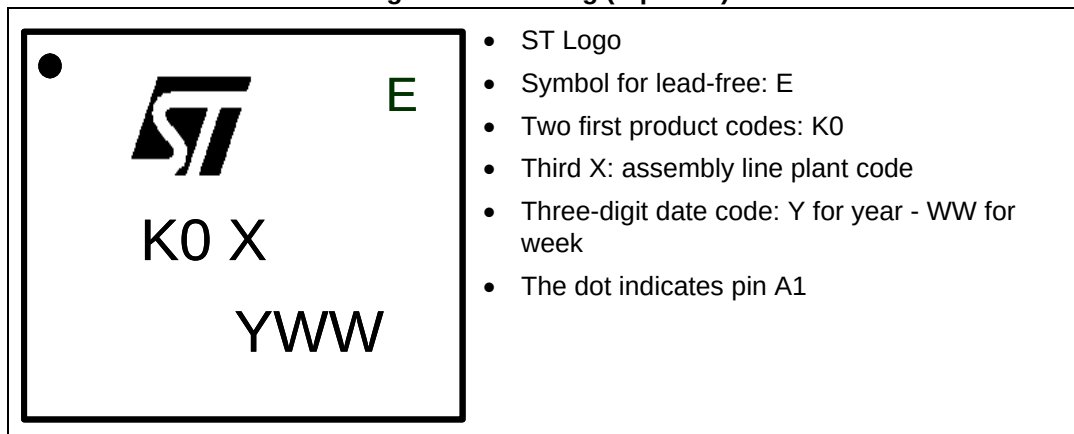


**Figure 44. Tape and reel schematics (top view)**

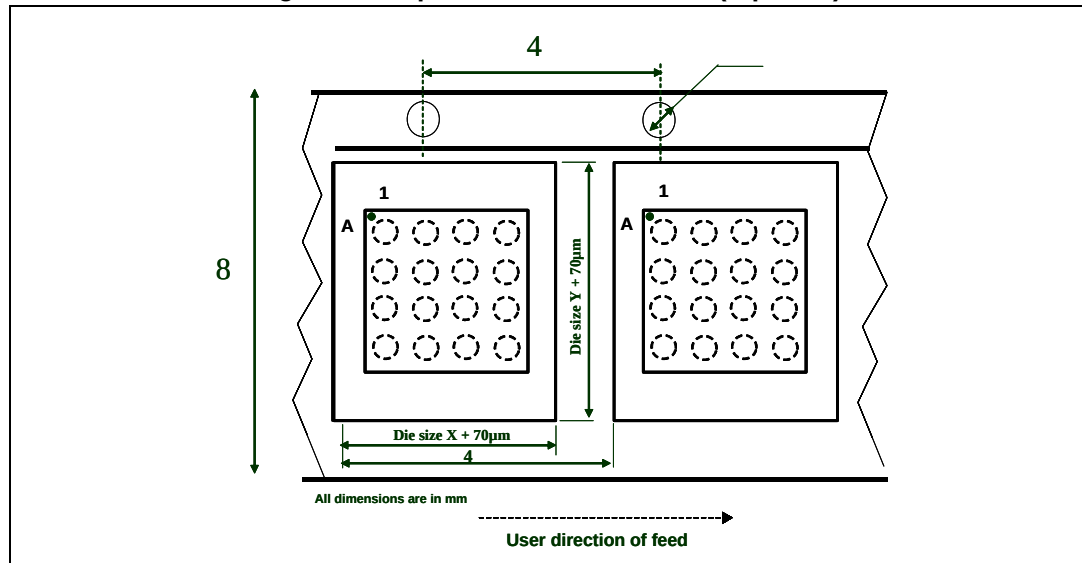
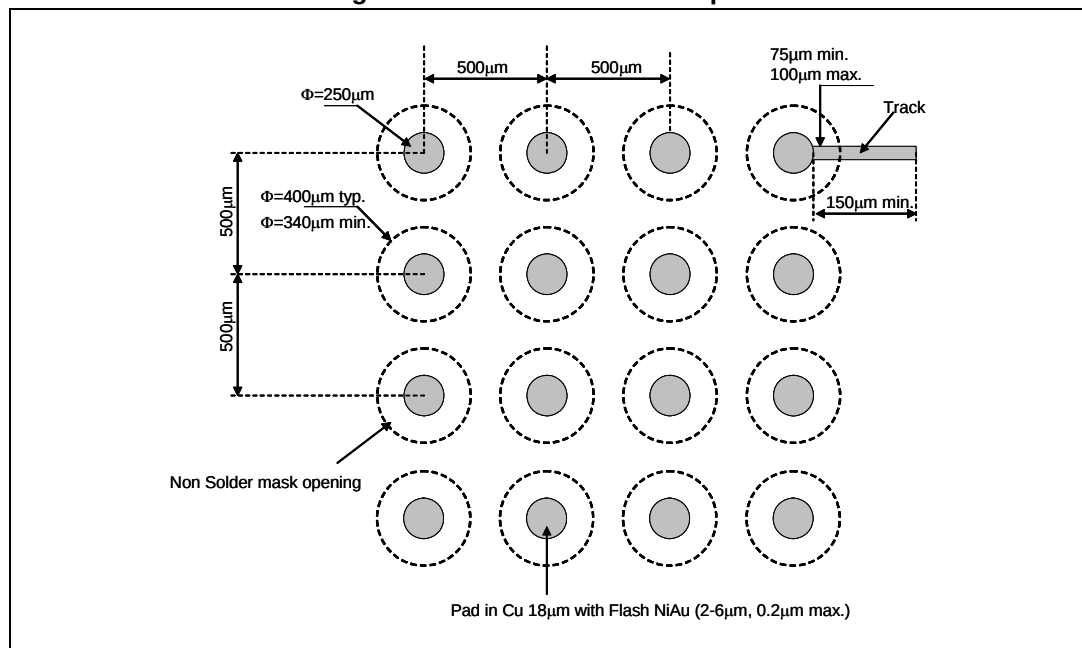


**Figure 45. Recommended footprint**



## 6 Revision history

**Table 10. Document revision history**

| Date        | Revision | Changes          |
|-------------|----------|------------------|
| 01-Apr-2014 | 1        | Initial release. |

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