

TFA9874B

High Efficiency Class-D Audio Amplifier

Rev. 1 — 14 August 2018

Product data sheet

1 General description

The TFA9874B is a high efficiency 10.0 V boosted class-D audio amplifier. It can deliver up to 10.0 W peak output power into an 8 Ω speaker and up to 11.8 W peak output power into a 6 Ω speaker, at a supply voltage of 4.0 V. The internal adaptive DC-to-DC converter raises the supply voltage up to 10.0 V, providing ample headroom for major improvements in sound quality.

Internal adaptive DC-to-DC conversion boosts the supply rail to provide additional headroom and power output. The supply voltage is only raised when necessary. This maximizes the output power of the class-D audio amplifier while limiting quiescent power consumption.

The device can be configured to drive either a hands-free speaker (4 Ω to 8 Ω) for audio playback, or a receiver speaker (32 Ω), for handset playback, allowing it to be embedded in platforms supporting both a hands-free speaker and a handset speaker. The maximum output power and the noise levels are lower in handset call use case than in hands-free call use case.

The TFA9874B also incorporates battery protection. By limiting the supply current when the battery voltage is low, it prevents the audio system from drawing excessive load currents from the battery, which could cause a system under voltage. This circuitry minimizes the impact of a falling battery voltage by preventing unexpected device switch off due to excessive current drawn from the battery.

The device features low RF susceptibility because it has a digital input interface that is insensitive to clock jitter. The second order closed loop architecture used in a class-D audio amplifier provides excellent audio performance and high supply voltage ripple rejection. The audio input interface is TDM and the control settings are communicated via an I²C-bus interface.

The TFA9874B is available in a 36-bump WLCSP (Wafer Level Chip-Size Package) with a 400 μ m pitch.

2 Features and benefits

- High output power: 5.6 W (average) into 8 Ω at 4.0 V supply voltage (THD = 1 %)
- Supports handset (16 Ω or 32 Ω) and hands-free (4 Ω to 8 Ω) speaker configurations
- High efficiency, low power dissipation and low-noise speaker driver
- Adaptive DC-to-DC converter increases the supply voltage smoothly when switching between Fixed Boost and Adaptive Boost modes, preventing large battery supply spikes and limiting quiescent power consumption
- Wide supply voltage range (fully operational from 2.7 V to 5.5 V)
- Very low noise output voltage <15 μ V (with -60 dBFS input at f_s = 48 kHz)
- Low battery current consumption <125 mA (P_o = 380 mW, average music power)
- I²C-bus control interface (400 kHz)



- Speaker current and voltage monitoring (via the TDM-bus) for Acoustic Echo Cancellation (AEC) at the host
- 16 kHz/32 kHz/44.1 kHz/48 kHz sample frequencies supported
- Ultrasonic support via TDM running at 96 kHz
- Programmable interrupt control via a dedicated interrupt pin
- Low RF susceptibility
- Thermal foldback and overtemperature protection
- 15 kV system-level ESD protection without external components on amplifier output

3 Applications

- Mobile phones and Tablets
- Portable Navigation Devices (PND)
- Notebooks/Netbooks
- Internet of Things applications embedding high quality audio

4 Quick reference data

Table 1. Quick reference data

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|------------------|------------------------|---|------|-----|------|------|
| V _{BAT} | battery supply voltage | on pin VBAT V _{BAT} must not be lower than V _{DDD} in application | 2.7 | - | 5.5 | V |
| V _{DDD} | digital supply voltage | on pin VDDD | 1.65 | 1.8 | 1.95 | V |
| V _{DDP} | power supply voltage | on pin VDDP | 2.7 | - | 10.0 | V |
| R _L | load resistance | | 3.2 | - | 38 | Ω |
| I _{BAT} | battery supply current | Active state on pin VBAT; Operating mode with load R _L = 6 Ω; DC-to-DC in Adaptive Boost mode, P _o = 380 mW, (average music power), V _{BAT} = 4.0 V, V _{BST} = 10 V | - | 120 | - | mA |
| | | Idle state on pin VBAT; Operating mode with load R _L = 6 Ω; DC-to-DC in Adaptive Boost mode, P _o = 0 mW, V _{BAT} = 4.0 V, V _{BST} = 10 V | - | 2.5 | - | mA |
| | | Power-down state | - | 1 | - | μA |
| I _{DDD} | digital supply current | Active state on pin VDDD; Operating mode with load R _L = 6 Ω; DC-to-DC in Adaptive Boost mode, P _o = 380 mW, (average music power), V _{BAT} = 4.0 V, V _{BST} = 10 V | - | 5.2 | - | mA |
| | | Idle state on pin VDDD; Operating mode with load R _L = 6 Ω; DC-to-DC in Adaptive Boost mode, P _o = 0 mW, V _{BAT} = 4.0 V, V _{BST} = 10 V | - | 3.6 | - | mA |
| | | Power-down state | 1.6 | 3 | 19 | μA |

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|-------------|----------------------|---|-----|-----|-----|------|
| $P_{o(AV)}$ | average output power | THD+N = 1 %; ($R_L = 8 \Omega$; $L_L = 44 \mu H$); $V_{BST} = 10.0 V$; $V_{BAT} = 4.0 V$; $V_{DDD} = 1.8 V$ | 5.3 | 5.6 | - | W |
| | | THD+N = 1 %; ($R_L = 6 \Omega$; $L_L = 32 \mu H$); $V_{BST} = 10.0 V$; $V_{BAT} = 4.0 V$; $V_{DDD} = 1.8 V$ | 5.8 | 6.1 | - | W |
| | | THD+N = 1 %; ($R_L = 4 \Omega$; $L_L = 30 \mu H$); $V_{BST} = 9.0 V$; $V_{BAT} = 4.0 V$; $V_{DDD} = 1.8 V$ | 6 | 6.2 | - | W |

5 Ordering information

Table 2. Ordering information

| Type number | Package | | |
|---------------|---------|---|-----------|
| | Name | Description | Version |
| TFA9874UK/N1 | WLCSP36 | wafer level chip-scale package; 36 bumps; 2.62 mm x 2.51 mm x 0.5 mm body | SOT1780-5 |
| TFA9874BUK/N1 | WLCSP36 | wafer level chip-scale package; 36 bumps; 2.62 mm x 2.51 mm x 0.525 mm body (backside coating included) | SOT1780-4 |

6 Block diagram

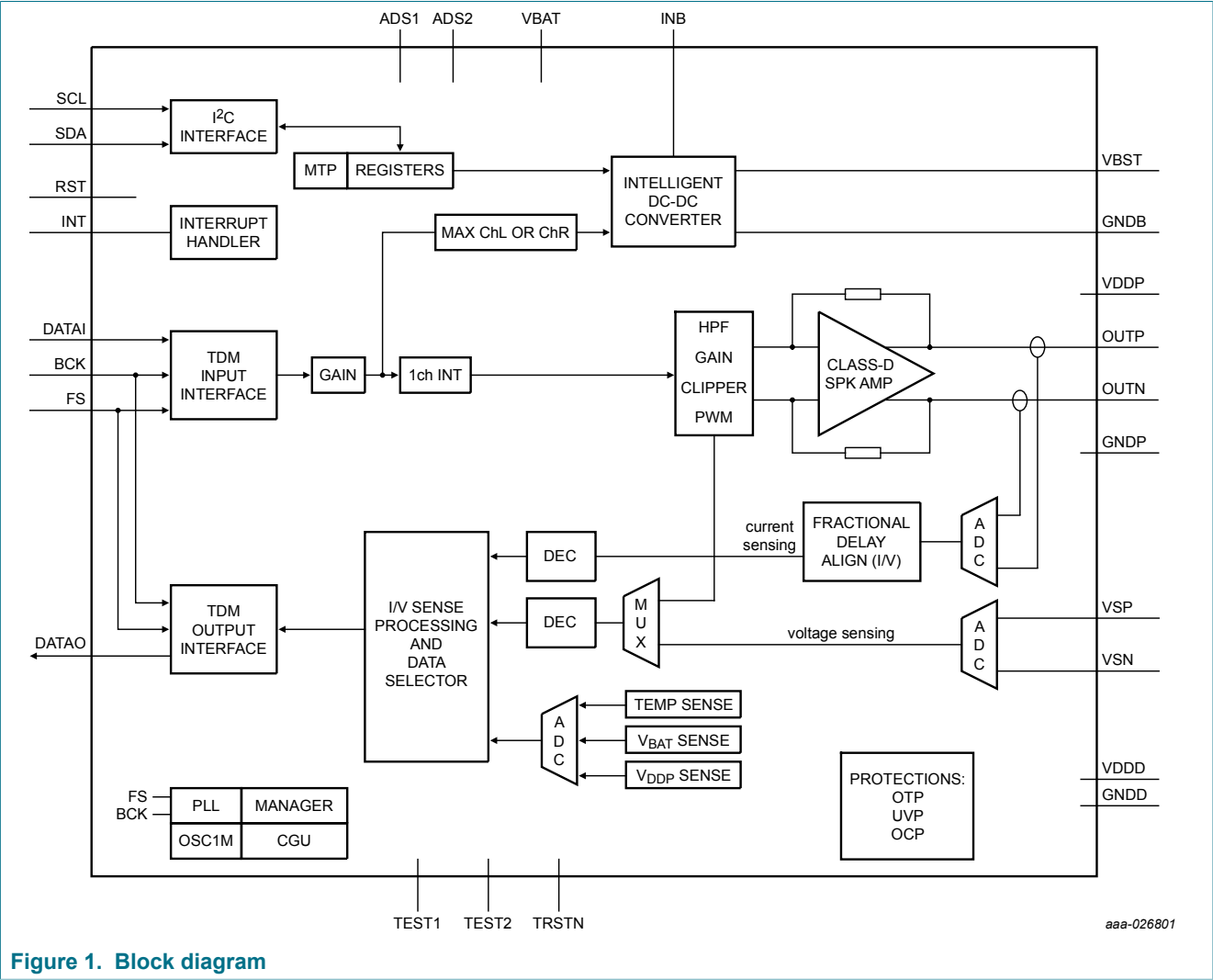


Figure 1. Block diagram

7 Pinning information

7.1 Pinning

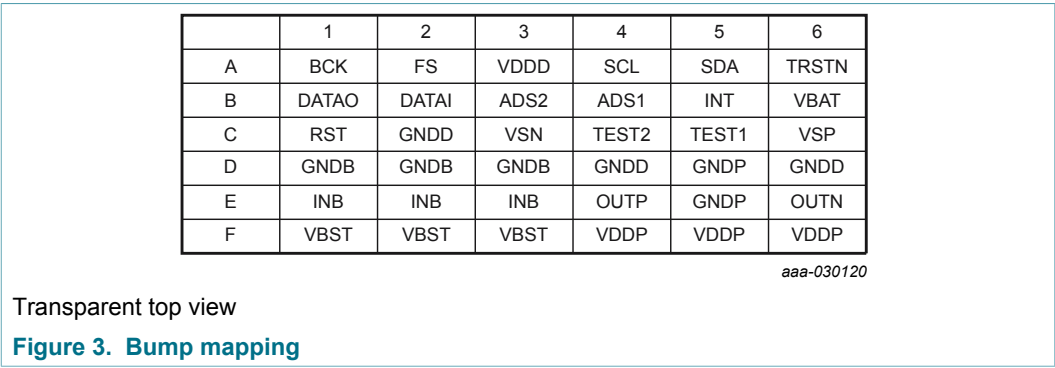
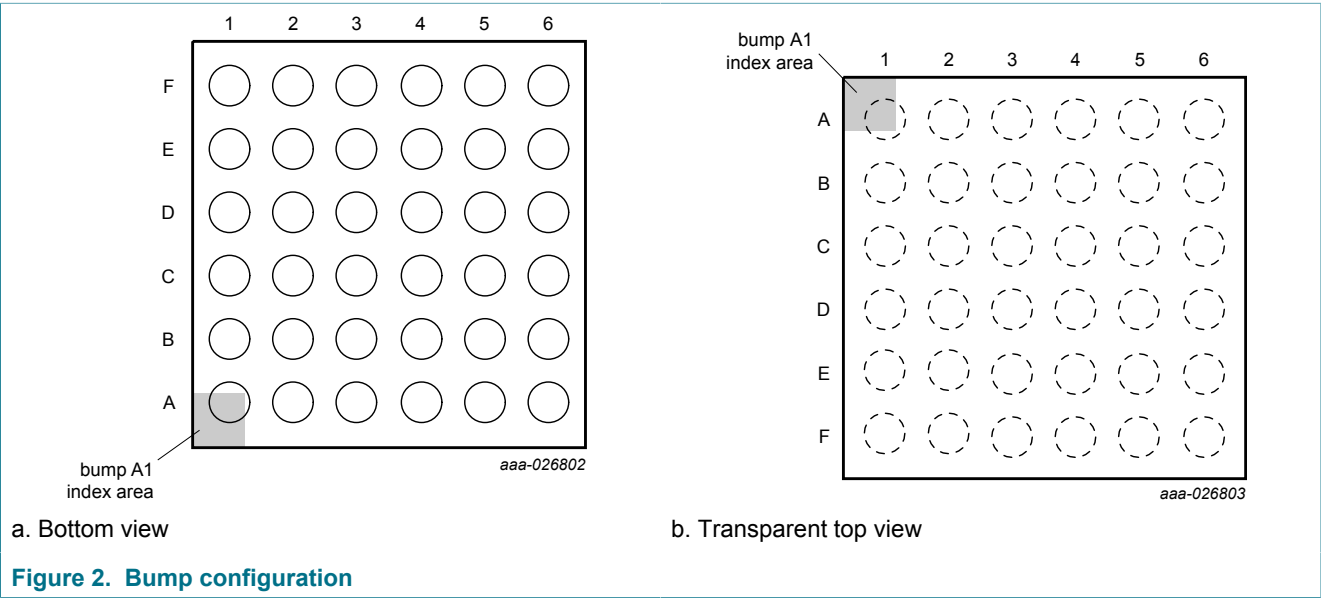


Table 3. Pinning

| Symbol | Pin | Type | Description |
|--------|-----|------|--|
| BCK | A1 | I | digital audio bit clock input for TDM interface |
| FS | A2 | I | digital audio frame sync input for TDM interface |
| VDDD | A3 | I | digital supply voltage |
| SCL | A4 | I | digital I ² C-bus clock input |
| SDA | A5 | I/O | digital I ² C-bus data input/output |
| TRSTN | A6 | I | test signal input TRSTN, connect to PCB ground |
| DATAO | B1 | I/O | digital audio data output for TDM interface |
| DATAI | B2 | I | digital audio data input for TDM interface |

| Symbol | Pin | Type | Description |
|--------|-----|------|--|
| ADS2 | B3 | I | digital address select input 2 |
| ADS1 | B4 | I | digital address select input 1 |
| INT | B5 | O | digital interrupt output |
| VBAT | B6 | P | battery supply voltage |
| RST | C1 | I | reset input |
| GNDD | C2 | P | digital ground |
| VSN | C3 | I/O | voltage sense negative input |
| TEST2 | C4 | I/O | test signal input 2; for test purposes only; connect to PCB ground, or connect via a capacitor to PCB ground |
| TEST1 | C5 | I/O | test signal input 1; for test purposes only; connect to PCB ground, or connect via a capacitor to PCB ground input |
| VSP | C6 | I/O | voltage sense positive |
| GNDB | D1 | P | boosted ground |
| GNDB | D2 | P | boosted ground |
| GNDB | D3 | P | boosted ground |
| GNDD | D4 | P | digital ground |
| GNDP | D5 | P | power ground |
| GNDD | D6 | P | digital ground |
| INB | E1 | P | DC-to-DC boost converter input |
| INB | E2 | P | DC-to-DC boost converter input |
| INB | E3 | P | DC-to-DC boost converter input |
| OUTP | E4 | O | non-inverting output |
| GNDP | E5 | P | power ground |
| OUTN | E6 | O | inverting output |
| VBST | F1 | O | boosted supply voltage output |
| VBST | F2 | O | boosted supply voltage output |
| VBST | F3 | O | boosted supply voltage output |
| VDDP | F4 | P | power supply voltage |
| VDDP | F5 | P | power supply voltage |
| VDDP | F6 | P | power supply voltage |

8 Functional description

The TFA9874B is a highly efficient Bridge Tied Load (BTL) class-D audio amplifier as depicted in block diagram; see [Figure 1](#).

TFA9874B contains a TDM input/output interface for communicating with the audio host. It also offers the possibility of providing an ultrasonic path to the speaker.

At low battery voltage levels, the gain (from TDM interface to speaker output) is automatically reduced to limit battery current (when battery safeguard is enabled).

The digital audio stream is converted into two Pulse Width Modulated (PWM) signals which are then injected into the class-D audio amplifier. The 3-level PWM scheme supports filterless speaker drive.

An adaptive DC-to-DC converter boosts the output voltage to the level that is required by the ClassD amplifier.

9 Limiting values

Table 4. Limiting values

In accordance with the Absolute Maximum Rating System (IEC 60134).

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|------------------|---------------------------------|--|------|-----|--------------------|------|
| V _{BAT} | battery supply voltage | on pin VBAT | -0.3 | - | +6 | V |
| V _{BST} | booster output voltage | on pin VBST | -0.3 | - | +12 ^[1] | V |
| V _{INB} | booster input voltage | on pin INB | -0.3 | - | +12 ^[1] | V |
| V _{DDP} | power supply voltage | on pin VDDP | -0.3 | - | +12 ^[1] | V |
| V _O | output voltage | on speaker connections; pins OUTP, OUTN | -0.3 | - | +12 ^[1] | V |
| V _{DDD} | digital supply voltage | on pin VDDD | -0.3 | - | +2.5 | V |
| V _{low} | low voltage | on pins TEST1/TEST2 | -0.3 | - | +2.5 | V |
| T _j | junction temperature | | - | - | +125 | °C |
| T _{stg} | storage temperature | | -55 | - | +150 | °C |
| T _{amb} | ambient temperature | | -40 | - | +85 | °C |
| V _{ESD} | electrostatic discharge voltage | according to Human Body Model (HBM) | -2 | - | +2 | kV |
| | | according to Charge Device Model (CDM) | -500 | - | +500 | V |

[1] Using NXP demo board, with a 1 mm wire/PCB track length on INB pin, AC pulses between -6 V and +15 V can be observed without damaging the device, as these spikes do not end up inside the actual device.

10 Thermal characteristics

Table 5. Thermal characteristics

| Symbol | Parameter | Conditions | Typ | Max | Unit |
|----------------------|---|---------------------------|-----|-----|------|
| R _{th(j-a)} | thermal resistance from junction to ambient | 4-layer application board | 49 | - | K/W |

11 Characteristics

11.1 DC characteristics

Table 6. DC characteristics

All parameters are guaranteed for $V_{BAT} = 3.6\text{ V}$; $V_{DDD} = 1.8\text{ V}$; $V_{DDP} = V_{BST} = 10.0\text{ V}$, adaptive boost mode; $L_{BST} = 1\text{ }\mu\text{H}^{[1]}$; $R_L = 8\text{ }\Omega^{[1]}$; $L_L = 44\text{ }\mu\text{H}^{[1]}$; $f_i = 1\text{ kHz}$; $f_s = 48\text{ kHz}$; $T_{amb} = 25\text{ }^\circ\text{C}$; default settings, unless otherwise specified.

| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit |
|---|----------------------------------|--|-----|------------------------|-----|---------------------|------|
| V _{BAT} | battery supply voltage | on pin VBAT V _{BAT} must not be lower than V _{DDD} | | 2.7 | - | 5.5 | V |
| I _{BAT} | battery supply current | Active state: On pin VBAT; Operating mode with load R _L = 6 Ω; DC-to-DC in Adaptive Boost mode; P _o = 380 mW, (average music power), V _{BAT} = 4.0 V | | - | 120 | - | mA |
| | | Idle state: On pin VBAT; Operating mode with load R _L = 6 Ω and no output signal (idle); DC-to-DC converter in Adaptive Boost mode; V _{BAT} = 4.0 V | | - | 2.5 | - | mA |
| | | Power-down state: On pin VBAT; DC-to-DC in Power-down mode; T _j = 25 °C; no clock | | - | 1 | - | μA |
| V _{DDP} | power supply voltage | on pin VDDP | | 2.7 | - | 10.0 | V |
| V _{DDD} | digital supply voltage | on pin VDDD | | 1.65 | 1.8 | 1.95 | V |
| I _{DDD} | digital supply current | Active state | | - | 5.2 | - | mA |
| | | Idle state | | - | 3.6 | - | mA |
| | | Power-down state | | 1.6 | 3 | 19 | μA |
| Pins FS, BCK, DATAI, ADS1, ADS2, SCL, SDA, RST, TRSTN | | | | | | | |
| V _{IH} | HIGH-level input voltage | | | 0.7V _{DDD} | - | V _{DDD} | V |
| V _{IL} | LOW-level input voltage | | | - | - | 0.3V _{DDD} | V |
| C _{in} | input capacitance | | [2] | - | - | 3 | pF |
| I _{LI} | input leakage current | 1.8 V on input pin | | - | - | 0.1 | μA |
| Pins DATAO, INT, push-pull output stages | | | | | | | |
| V _{OH} | HIGH-level output voltage | | | V _{DDD} – 0.4 | - | - | V |
| V _{OL} | LOW-level output voltage | | | - | - | 400 | mV |
| Pins SDA, open-drain outputs, external 10 kΩ resistor to V _{DDD} | | | | | | | |
| V _{OH} | HIGH-level output voltage | | | V _{DDD} – 0.4 | - | - | V |
| V _{OL} | LOW-level output voltage | I _{OL} = 4 mA | | - | - | 400 | mV |
| Pins OUTP, OUTN | | | | | | | |
| R _{DSon} | drain-source on-state resistance | PMOS+NMOS transistors | | - | 430 | 520 | mΩ |

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---------------------------|---|---|--------------------|-----|------|------|
| Protection | | | | | | |
| $T_{act(th_prot)}$ | thermal protection activation temperature | | 130 | - | - | °C |
| $V_{ovp(VBAT)}$ | overvoltage protection on pin VBAT | | 5.6 | - | 6.0 | V |
| $V_{uvp(VBAT)}$ | undervoltage protection on pin VBAT | | 2.3 | - | 2.7 | V |
| $I_{O(ocp)}$ | overcurrent protection output current | | 2.5 | - | - | A |
| DC-to-DC converter | | | | | | |
| V_{BST} | voltage on pin VBST | DCVOS = 111111; Boost mode (after trim) | ^[3] 9.8 | 10 | 10.2 | V |

[1] L_{BST} = boost converter inductance; R_L = load resistance; L_L = load inductance (speaker).

[2] This parameter is not tested during production; the value is guaranteed by design and checked during product validation.

[3] Boost switching frequency = 2 MHz in PWM mode.

11.2 AC characteristics

Table 7. AC characteristics

All parameters are guaranteed for $V_{BAT} = 3.6$ V; $V_{DDD} = 1.8$ V; $V_{DDP} = V_{BST} = 10.0$ V, adaptive boost mode; $L_{BST} = 1$ μ H^[1]; $R_L = 8$ Ω ^[1]; $L_L = 44$ μ H^[1]; $f_i = 1$ kHz; $f_s = 48$ kHz; $T_{amb} = 25$ °C; default settings, unless otherwise specified.

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|--|-----------------------|--|-----|-----|-----|------|
| Amplifier output power | | | | | | |
| $P_{O(AV)}$ | average output power | Hands-free speaker, THD+N = 1 %; $V_{DDD} = 1.8$ V | | | | |
| | | $R_L = 8$ Ω ; $L_L = 44$ μ H; $f_s = 48$ kHz, $V_{BST} = 10.0$ V, $V_{BAT} = 4.0$ V | 5.3 | 5.6 | - | W |
| | | $R_L = 6$ Ω ; $L_L = 32$ μ H; $f_s = 48$ kHz, $V_{BST} = 10.0$ V, $V_{BAT} = 4.0$ V | 5.8 | 6.1 | - | W |
| | | $R_L = 4$ Ω ; $L_L = 30$ μ H; $f_s = 48$ kHz, $V_{BST} = 9.0$ V, $V_{BAT} = 4.0$ V | 6 | 6.2 | - | W |
| | | Receiver speaker; THD+N = 1 %; $V_{BST} = 10.0$ V | | | | |
| | | $R_L = 32$ Ω ; Voice mode | - | 0.2 | - | W |
| | | $R_L = 32$ Ω ; Audio mode | - | 1.5 | - | W |
| Amplifier output pins (OUTP and OUTN) | | | | | | |
| $ V_{O(offset)} $ | output offset voltage | absolute value, after trimming; $V_{DDP} = 3.4$ V to 10.0 V, $V_{BAT} = 3.4$ V to 5 V | - | - | 1.0 | mV |

| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit |
|------------------------|--------------------------------------|--|-----|------|-----|------|---------------|
| Amplifier performances | | | | | | | |
| η_{po} | output power efficiency | On pin VBAT; Operating mode with load $R_L = 6\ \Omega$; DC-to-DC in Adaptive Boost mode, $P_o = 380\text{ mW}$, (average music power), $V_{BAT} = 4.0\text{ V}$ | [2] | - | 82 | - | % |
| | | On pin VBAT; input: 100 Hz sine wave, $R_L = 8\ \Omega$; DC-to-DC in Tracking Boost mode, $V_{BAT} = 4.0\text{ V}$, $P_o = 600\text{ mW}$ | [2] | - | 91 | - | % |
| | | On pin VBAT; Input: 100 Hz sine wave, $R_L = 8\ \Omega$; DC-to-DC in Tracking Boost mode, $V_{BAT} = 4.0\text{ V}$, $P_o = 4\text{ W}$ | [2] | - | 84 | - | % |
| THD+N | total harmonic distortion-plus-noise | $V_{DDP} > 9\text{ V}$, $P_o = 2.0\text{ W}$, $R_L = 8\ \Omega$ | [3] | - | - | 0.05 | % |
| | | $V_{DDP} > 9\text{ V}$, $P_o = 2.0\text{ W}$, $R_L = 4\ \Omega$ | [3] | - | - | 0.09 | % |
| $V_{n(o)}$ | output noise voltage | A-weighted; no input signal; Low Noise mode; $f_s = 48\text{ kHz}$ | [2] | - | 14 | 18 | μV |
| | | A-weighted; no input signal; Low Noise mode; $f_s = 16\text{ kHz}$, 32 kHz | [2] | - | - | 50 | μV |
| | | A-weighted; no input signal; Low Noise mode; $f_s = 44.1\text{ kHz}$ | [2] | - | 15 | 18 | |
| DR | dynamic range | A-weighted; $V_{BAT} = 3.4\text{ V}$ to 5 V ; S/ N = maximum signal (at THD = 1 %); output noise voltage ($V_{n(o)}$); NO signal applied | [2] | 110 | 114 | - | dB |
| S/N | signal-to-noise ratio | A-weighted, $V_{BAT} = 3.4\text{ V}$ to 5 V , maximum signal at THD = 1 % | [2] | 100 | - | - | dB |
| PSRR | power supply rejection ratio | from V_{BAT} ; booster in follower mode ($V_{DDP} = V_{BAT}$) $f_{\text{ripple}} = 217\text{ Hz}$ square wave, $V_{\text{ripple}} = 50\text{ mV}_{(p-p)}$, $V_{BAT} = 4.0\text{ V}$ | | 60 | 80 | - | dB |
| | | from V_{BAT} ; booster in follower mode ($V_{DDP} = V_{BAT}$) $f_{\text{ripple}} = 20\text{ Hz}$ to 1 kHz sine wave, $V_{\text{ripple}} = 200\text{ mV (RMS)}$, $V_{BAT} = 3.4\text{ V}$ to 5.0 V Low Power AND Low Noise modes on | | 60 | 80 | - | dB |
| | | from V_{BAT} ; booster in follower mode ($V_{DDP} = V_{BAT}$) $f_{\text{ripple}} = 1\text{ kHz}$ to 20 kHz sine wave, $V_{\text{ripple}} = 200\text{ mV (RMS)}$, $V_{BAT} = 3.4\text{ V}$ to 5.0 V | | 55 | 60 | - | dB |
| $\Delta G/\Delta f$ | gain variation with frequency | BW = 20 Hz to 15 kHz , $V_{BAT} = 3.4\text{ V}$ to 5 V | | -0.1 | - | +0.7 | dB |
| V_{POP} | pop noise voltage | At mode transition and gain change. | | - | - | 2 | mV |

| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit |
|---|---|--|-----|------|-----|------|------|
| R _L | load resistance | | | 3.2 | 8 | 38 | Ω |
| C _L | load capacitance | | | - | - | 200 | pF |
| f _{sw} | switching frequency | directly coupled to the TDM input frequency | | 256 | - | 384 | kHz |
| G _(TDM-VO) | TDM to V _O gain | INPLEV = 0 dB | | 6 | - | 21 | dB |
| Amplifier power-up, power-down and propagation delays | | | | | | | |
| t _{d(on)PLL} | PLL turn-on delay time | PLL locked on BCK, f _s = 48 kHz | | - | 2 | - | ms |
| t _{d(on)amp} | amplifier turn-on delay time | f _s = 48 kHz | | - | 1 | - | ms |
| t _{d(off)} | turn-off delay time | | | - | 32 | - | μs |
| t _{d(alarm)} | alarm delay time | | | - | 200 | - | ms |
| t _{PD} | propagation delay | Delta Propagation delay between L & R in stereo application = 1.625 FS | | | | | |
| | | f _s = 16 kHz | | - | - | 850 | μs |
| | | f _s = 16 kHz HP | | - | - | 850 | μs |
| | | f _s = 32 kHz | | - | - | 750 | μs |
| | | f _s = 44.1 kHz | | - | - | 650 | μs |
| | | f _s = 48 kHz | | - | - | 700 | μs |
| | | f _s = 96 kHz | | - | - | 600 | μs |
| Booster Inductance | | | | | | | |
| L _{bst} | boost inductance | | | 0.33 | 1.0 | 2.2 | μH |
| Voltage and Current-sensing performance | | | | | | | |
| S/N | signal-to-noise ratio | I _O = 1.1 A (peak); A-weighted | | 62 | 65 | - | dB |
| ΔV _{sense} /I _{sense} | V _{sense} /I _{sense} ratio mismatch | Pilot tone -40 dBFS | [4] | - | 2 | - | % |
| THD+N | total harmonic distortion-plus-noise | f _i = 20 Hz to 20 kHz, V _i = -12 dBFS | | - | - | 0.75 | % |

[1] L_{BST} = boost converter inductance; R_L = load resistance; L_L = load inductance (speaker).

[2] This parameter is not tested during production; the value is guaranteed by design and checked during product validation.

[3] L_{BST} = boost converter inductor; R_L = load resistance; L_L = load inductance (speaker).

[4] Intended for Speaker protection. In combination with NXP Speaker protection a speaker temperature accuracy of ± 10 °C can be realized.

11.3 TDM timing characteristics

Table 8. TDM bus interface characteristics

All parameters are guaranteed for $V_{BAT} = 3.6\text{ V}$; $V_{DDD} = 1.8\text{ V}$; $V_{DDP} = V_{BST} = 10.0\text{ V}$, adaptive boost mode; $L_{BST} = 1\text{ }\mu\text{H}^{[1]}$; $R_L = 8\text{ }\Omega^{[1]}$; $L_L = 44\text{ }\mu\text{H}^{[1]}$; $f_i = 1\text{ kHz}$; $f_s = 48\text{ kHz}$; $T_{amb} = 25\text{ }^\circ\text{C}$; default settings, unless otherwise specified.

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|-----------|-----------------------|-----------------------------|-------------|-----|----------|------|
| f_s | sampling frequency | on pin WS, audio mode | [2] 16 | - | 48 | kHz |
| | | on pin WS, ultrasonic mode | - | - | 96 | kHz |
| f_{clk} | clock frequency | on pin BCK, audio mode | [2] $32f_s$ | - | $384f_s$ | kHz |
| | | on pin BCK, ultrasonic mode | - | - | $96f_s$ | MHz |
| t_{su} | set-up time | WS edge to BCK HIGH | [3] 10 | - | - | ns |
| | | DATA edge to BCK HIGH | 10 | - | - | ns |
| t_h | hold time | BCK HIGH to WS edge | [3] 10 | - | - | ns |
| | | BCK HIGH to DATA edge | 10 | - | - | ns |
| t_j | external clock jitter | PLL locked on BCK | [4] - | 1 | 2 | ns |
| | | PLL locked on FS | [5] - | - | 20 | ns |

[1] L_{BST} = boost converter inductance; R_L = load resistance; L_L = load inductance.

[2] The TDM bit clock input (BCK) is used as a clock input for the amplifier and the DC-to-DC converter. Note that both the BCK and WS signals need to be present for the clock to operate correctly.

[3] This parameter is not tested during production; the value is guaranteed by design and checked during product validation.

[4] When the PLL is locked on BCK, amplifier output noise can deteriorate when clock jitter > 1 ns; performance is guaranteed up to jitter = 2 ns.

[5] The system is less sensitive to jitter when the PLL is locked on FS.

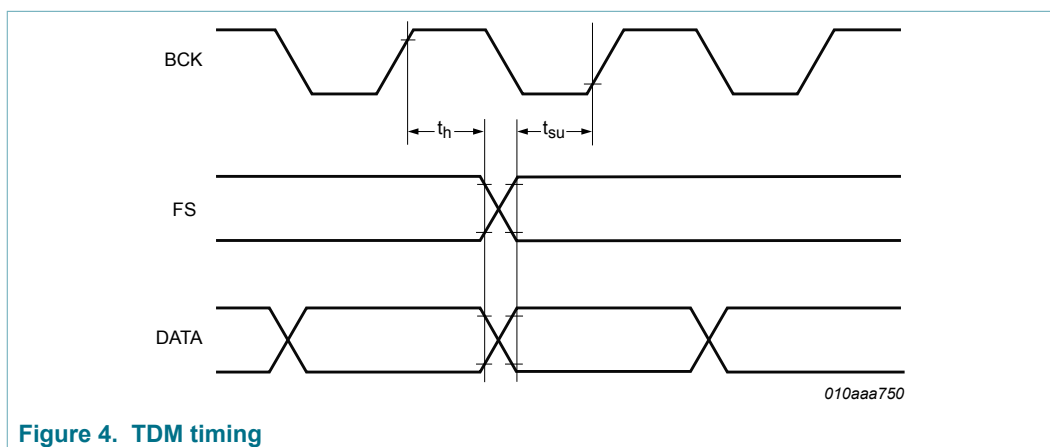


Figure 4. TDM timing

11.4 I²C timing characteristics

Table 9. I²C-bus interface characteristics; see Figure 15

All parameters are guaranteed for $V_{BAT} = 3.6\text{ V}$; $V_{DDD} = 1.8\text{ V}$; $V_{DDP} = V_{BST} = 10.0\text{ V}$, adaptive boost mode; $L_{BST} = 1\text{ }\mu\text{H}^{[1]}$; $R_L = 8\text{ }\Omega^{[1]}$; $L_L = 44\text{ }\mu\text{H}^{[1]}$; $f_i = 1\text{ kHz}$; $f_s = 48\text{ kHz}$; $T_{amb} = 25\text{ }^\circ\text{C}$; default settings, unless otherwise specified.

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|--------------|---|---------------------|-------------------------------|-----|-----|---------------|
| f_{SCL} | SCL clock frequency | | - | - | 400 | kHz |
| t_{LOW} | LOW period of the SCL clock | | 1.3 | - | - | μs |
| t_{HIGH} | HIGH period of the SCL clock | | 0.6 | - | - | μs |
| t_r | rise time | SDA and SCL signals | ^[2] $20 + 0.1 C_b$ | - | - | ns |
| t_f | fall time | SDA and SCL signals | ^[2] $20 + 0.1 C_b$ | - | - | ns |
| $t_{HD;STA}$ | hold time (repeated) START condition | | ^[3] 0.6 | - | - | μs |
| $t_{SU;STA}$ | set-up time for a repeated START condition | | 0.6 | - | - | μs |
| $t_{SU;STO}$ | set-up time for STOP condition | | 0.6 | - | - | μs |
| t_{BUF} | bus free time between a STOP and START condition | | 1.3 | - | - | μs |
| $t_{SU;DAT}$ | data set-up time | | 100 | - | - | ns |
| $t_{HD;DAT}$ | data hold time | | 0 | - | - | μs |
| t_{SP} | pulse width of spikes that must be suppressed by the input filter | | ^[4] 0 | - | 50 | ns |
| C_b | capacitive load for each bus line | | - | - | 400 | pF |

[1] L_{BST} = boost converter inductance; R_L = load resistance; L_L = load inductance (speaker).

[2] C_b is the total capacitance of one bus line in pF. The maximum capacitive load for each bus line is 400 pF.

[3] After this period, the first clock pulse is generated.

[4] To be suppressed by the input filter.

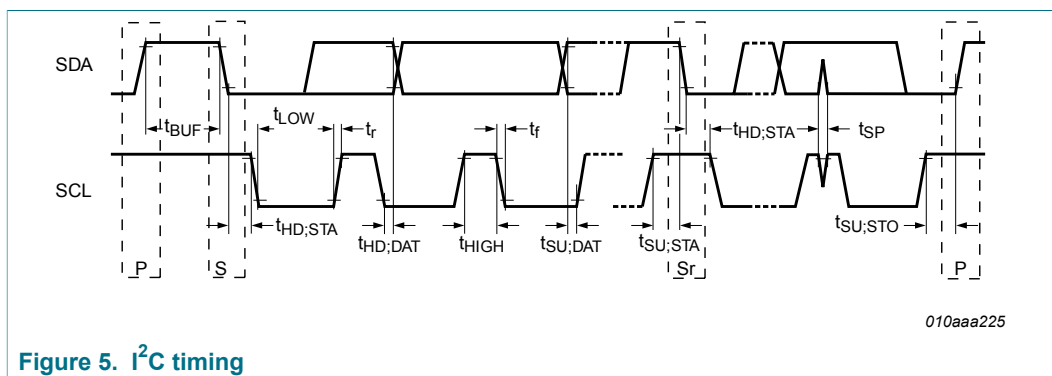


Figure 5. I²C timing

12 Application information

12.1 Application diagrams

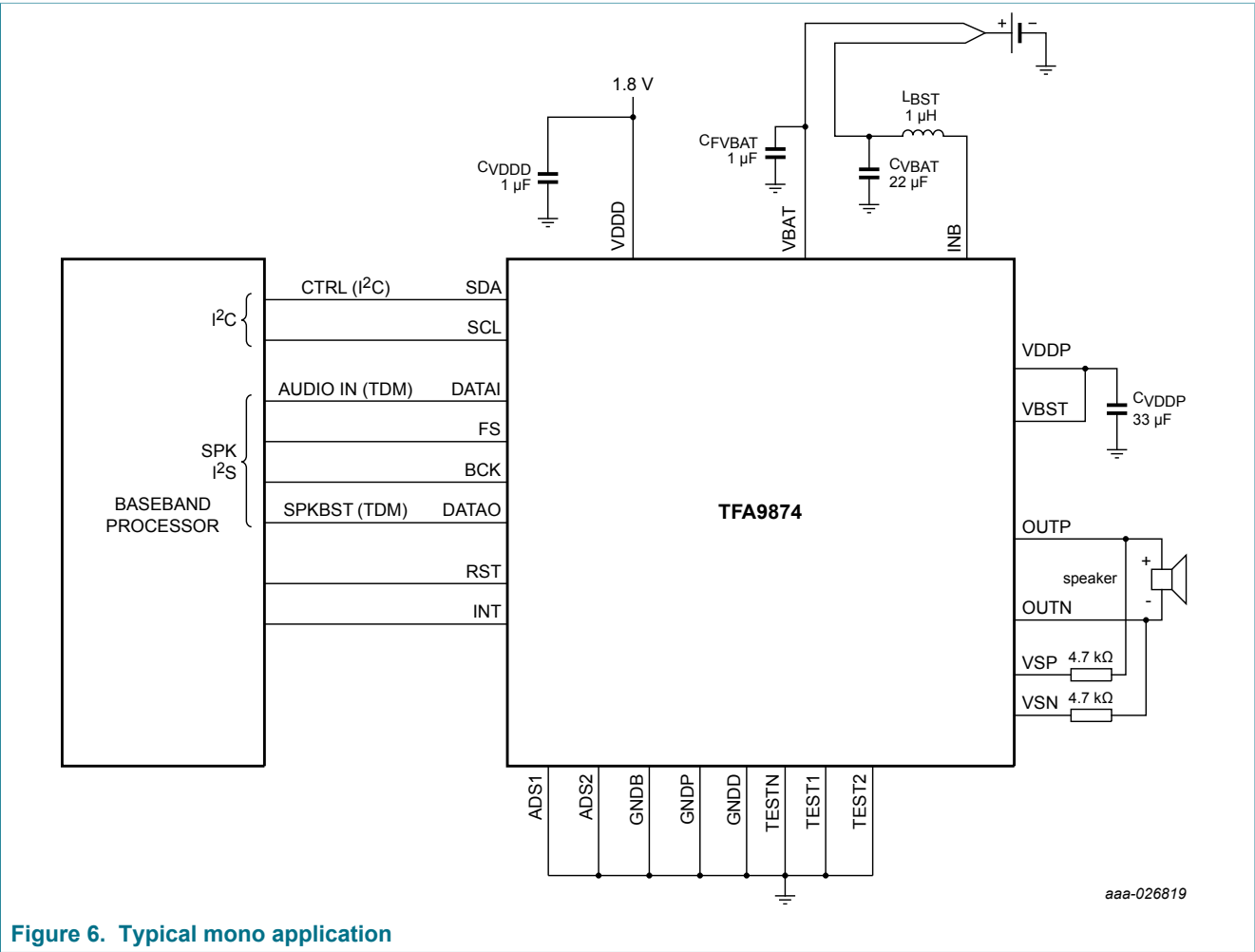


Figure 6. Typical mono application

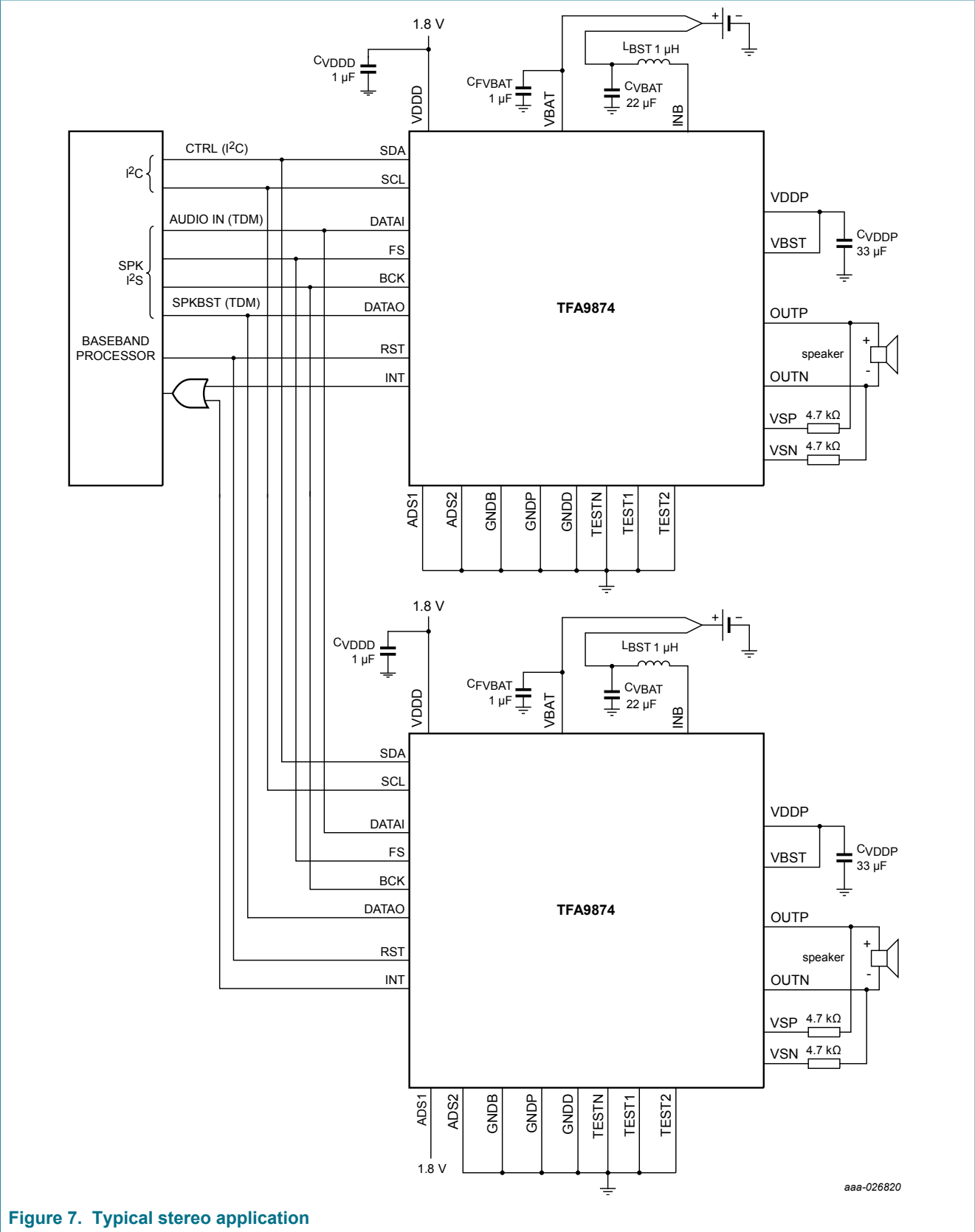


Figure 7. Typical stereo application

13 Package outline

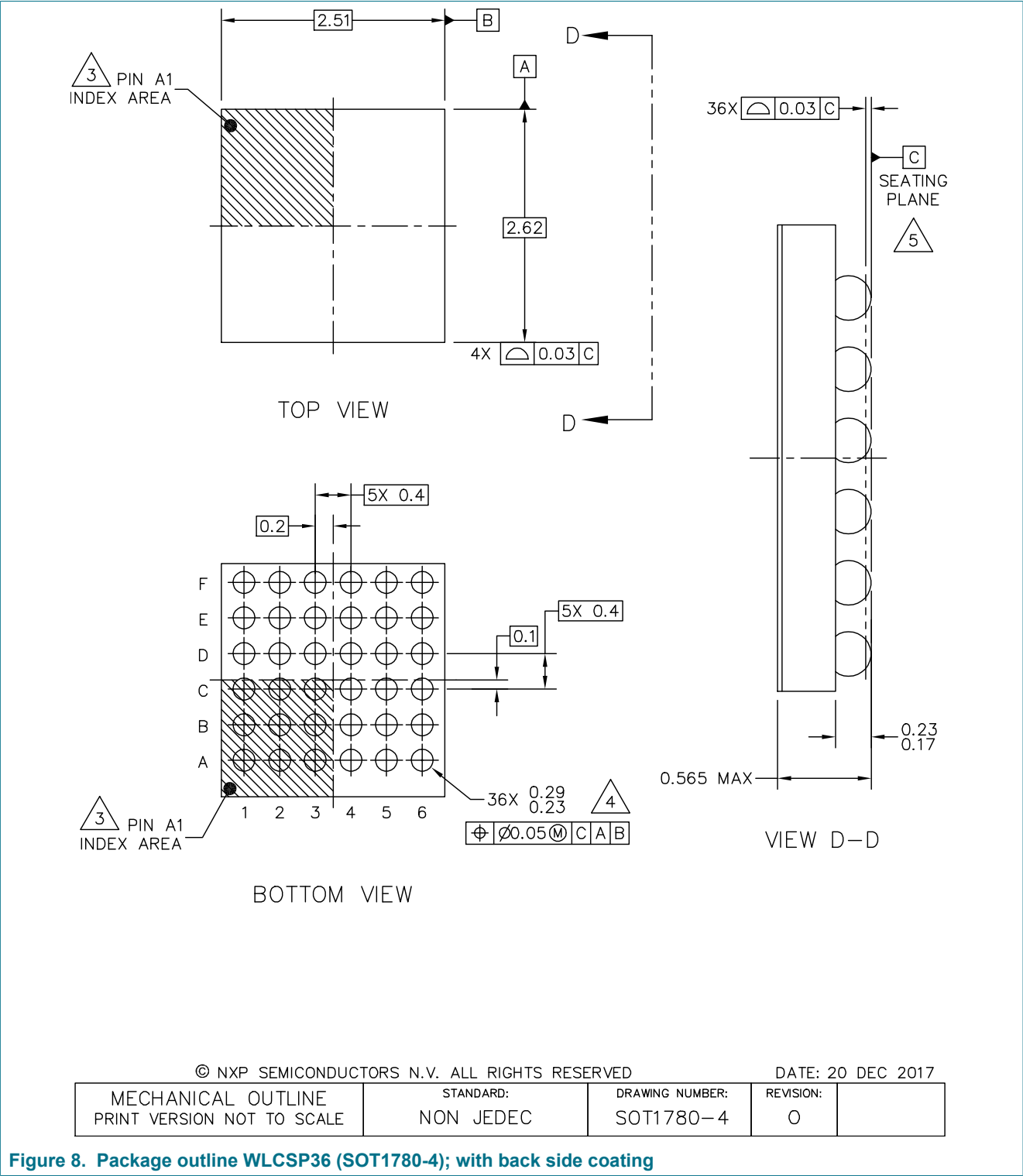


Figure 8. Package outline WLCSP36 (SOT1780-4); with back side coating

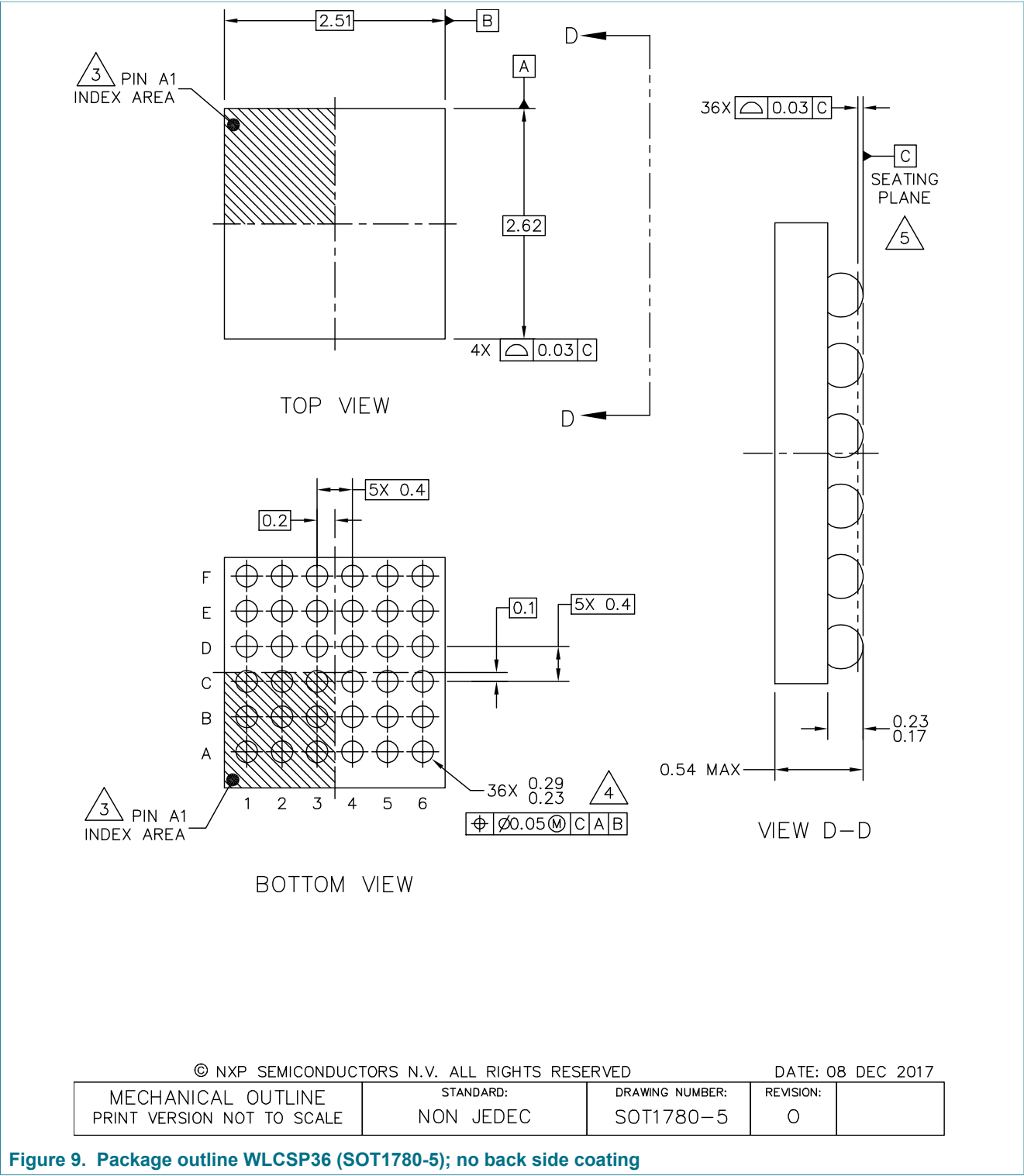


Figure 9. Package outline WLCSP36 (SOT1780-5); no back side coating

14 Soldering of WLCSP packages

14.1 Introduction to soldering WLCSP packages

This text provides a very brief insight into a complex technology. A more in-depth account of soldering WLCSP (Wafer Level Chip-Size Packages) can be found in application note *AN10439 "Wafer Level Chip Scale Package"* and in application note *AN10365 "Surface mount reflow soldering description"*.

Wave soldering is not suitable for this package.

All NXP Semiconductors WLCSP packages are lead-free.

14.2 Board mounting

Board mounting of a WLCSP requires several steps:

1. Solder paste printing on the PCB
2. Component placement with a pick and place machine
3. The reflow soldering itself

14.3 Reflow soldering

Key characteristics in reflow soldering are:

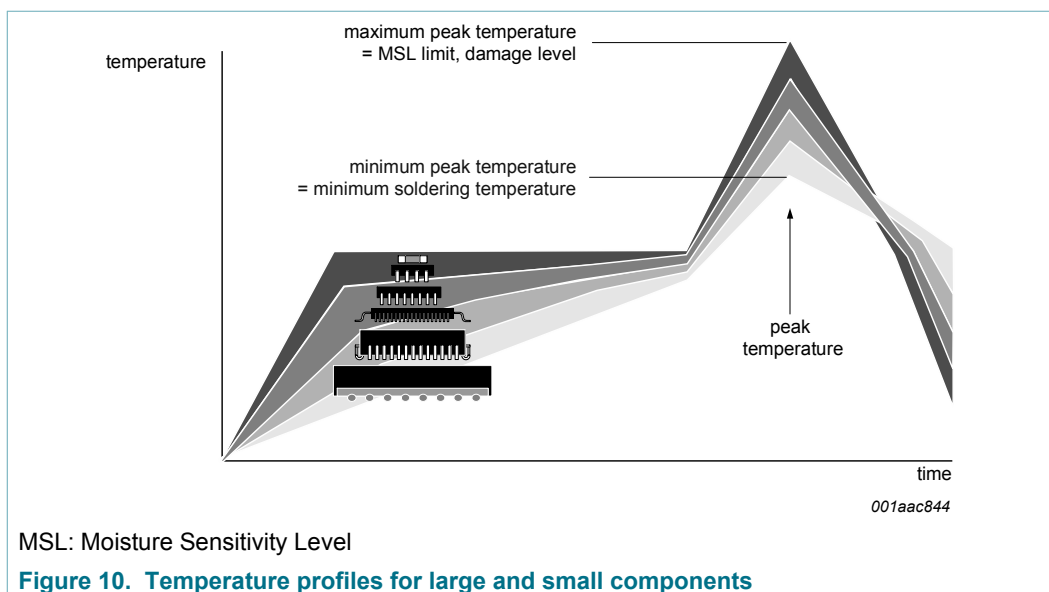
- Lead-free versus SnPb soldering; note that a lead-free reflow process usually leads to higher minimum peak temperatures (see [Figure 10](#)) than a SnPb process, thus reducing the process window
- Solder paste printing issues, such as smearing, release, and adjusting the process window for a mix of large and small components on one board
- Reflow temperature profile; this profile includes preheat, reflow (in which the board is heated to the peak temperature), and cooling down. It is imperative that the peak temperature is high enough for the solder to make reliable solder joints (a solder paste characteristic) while being low enough that the packages and/or boards are not damaged. The peak temperature of the package depends on package thickness and volume and is classified in accordance with [Table 10](#).

Table 10. Lead-free process (from J-STD-020D)

| Package thickness (mm) | Package reflow temperature (°C) | | |
|------------------------|---------------------------------|--------------|---------|
| | Volume (mm ³) | | |
| | < 350 | 350 to 2 000 | > 2 000 |
| < 1.6 | 260 | 260 | 260 |
| 1.6 to 2.5 | 260 | 250 | 245 |
| > 2.5 | 250 | 245 | 245 |

Moisture sensitivity precautions, as indicated on the packing, must be respected at all times.

Studies have shown that small packages reach higher temperatures during reflow soldering, see [Figure 10](#).



For further information on temperature profiles, refer to application note *AN10365 "Surface mount reflow soldering description"*.

14.3.1 Stand off

The stand off between the substrate and the chip is determined by:

- The amount of printed solder on the substrate
- The size of the solder land on the substrate
- The bump height on the chip

The higher the stand off, the better the stresses are released due to TEC (Thermal Expansion Coefficient) differences between substrate and chip.

14.3.2 Quality of solder joint

A flip-chip joint is considered to be a good joint when the entire solder land has been wetted by the solder from the bump. The surface of the joint should be smooth and the shape symmetrical. The soldered joints on a chip should be uniform. Voids in the bumps after reflow can occur during the reflow process in bumps with high ratio of bump diameter to bump height, i.e. low bumps with large diameter. No failures have been found to be related to these voids. Solder joint inspection after reflow can be done with X-ray to monitor defects such as bridging, open circuits and voids.

14.3.3 Rework

In general, rework is not recommended. By rework we mean the process of removing the chip from the substrate and replacing it with a new chip. If a chip is removed from the substrate, most solder balls of the chip will be damaged. In that case it is recommended not to re-use the chip again.

Device removal can be done when the substrate is heated until it is certain that all solder joints are molten. The chip can then be carefully removed from the substrate without damaging the tracks and solder lands on the substrate. Removing the device must be done using plastic tweezers, because metal tweezers can damage the silicon. The

surface of the substrate should be carefully cleaned and all solder and flux residues and/or underfill removed. When a new chip is placed on the substrate, use the flux process instead of solder on the solder lands. Apply flux on the bumps at the chip side as well as on the solder pads on the substrate. Place and align the new chip while viewing with a microscope. To reflow the solder, use the solder profile shown in application note *AN10365 "Surface mount reflow soldering description"*.

14.3.4 Cleaning

Cleaning can be done after reflow soldering.

15 Revision history

Table 11. Revision history

| Document ID | Release date | Data sheet status | Change notice | Supersedes |
|------------------|--------------|--------------------|---------------|------------|
| TFA9874B_SDS v.1 | 20180814 | Product data sheet | - | - |

16 Legal information

16.1 Data sheet status

| Document status ^{[1][2]} | Product status ^[3] | Definition |
|-----------------------------------|-------------------------------|---|
| Objective [short] data sheet | Development | This document contains data from the objective specification for product development. |
| Preliminary [short] data sheet | Qualification | This document contains data from the preliminary specification. |
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