

2.75-W FIXED GAIN MONO FILTER-FREE CLASS-D AUDIO POWER AMPLIFIER

FEATURES

- **Maximize Battery Life and Minimize Heat**
 - 0.5- μ A Shutdown Current
 - 3-mA Quiescent Current
 - High Efficiency Class-D
 - 88% at 400mW at 8 Ω
 - 80% at 100mW at 8 Ω
- **Short Circuit Auto-recovery**
- **Gain of 2 V/V (6dB)**
- **Only One External Component Required**
 - Internal Matched Input Gain and Feedback Resistors for Excellent PSRR and CMRR
 - Optimized PWM Output Stage Eliminates LC Output Filter
 - PSRR (–75 dB) and Wide Supply Voltage (2.5 V to 5.5 V) Eliminates Need for a Dedicated Voltage Regulator
 - Fully Differential Design Reduces RF Rectification and Eliminates Bypass Capacitor
 - CMRR (–69 dB) Eliminates Two Input Coupling Capacitors
- **Thermal and Short-Circuit Protection**
- **Pinout Similar to the TPA2010D1**
- **Wafer Chip Scale Packaging (WCSP)**
 - NanoFree™ (YZF)

APPLICATIONS

- **Wireless Handsets, PDAs, and other mobile devices**

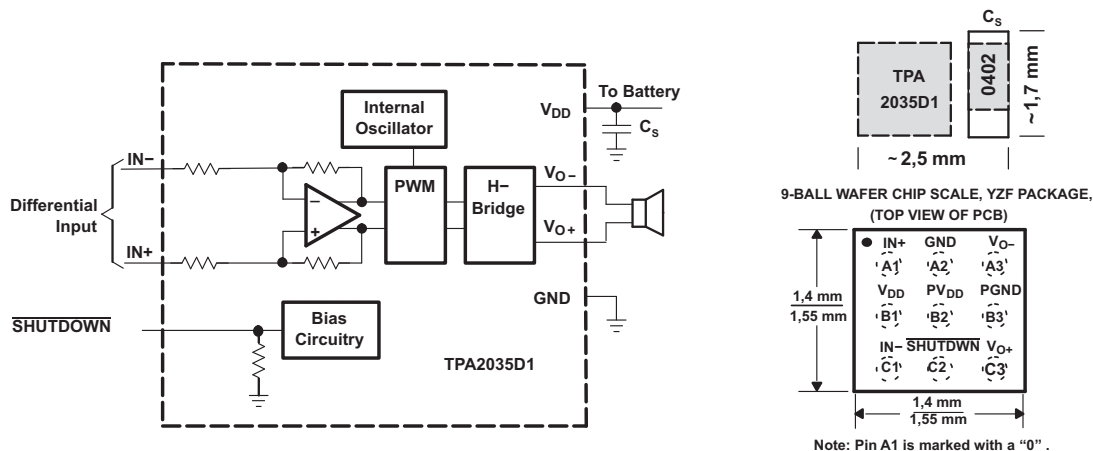
DESCRIPTION

The TPA2035D1 is a 2.75-W high efficiency filter-free class-D audio power amplifier in an approximately 1.5-mm x 1.5-mm wafer chip scale package (WCSP) that requires only one external component. The pinout is the same as the TPA2010D1 (SLOS417) except that the external gain setting input resistors required by the TPA2010D1 are integrated into the fixed gain of the TPA2035D1.

Features like –75dB PSRR and improved RF-rectification immunity with a small PCB footprint (WCSP amplifier plus single decoupling cap) make the TPA2035D1 ideal for wireless handsets. A fast start-up time of 3.2 ms with minimal pop makes the TPA2035D1 ideal for PDA applications.

In wireless handsets, the earpiece, speaker phone, and melody ringer can each be driven by the TPA2035D1. The TPA2035D1 has a low 27- μ V noise floor, A-weighted.

APPLICATION CIRCUIT



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These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

ORDERING INFORMATION

| T _A | PACKAGE (YZF) ⁽¹⁾ | PART NUMBER | SYMBOL |
|----------------|---|-----------------------------|--------|
| –40°C to 85°C | 9 balls, 1.5 mm × 1.5 mm WCSP (0.05/-0.1 mm tolerance) | TPA2035D1YZF ⁽²⁾ | CGD |

- (1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI website at www.ti.com.
- (2) The YZF package is only available taped and reeled. To order add the suffix *R* to the end of the part number for a reel of 3000, or add the suffix *T* to the end of the part number for a reel of 250 (e.g. TPA2035D1YZFR).

ABSOLUTE MAXIMUM RATINGS

over operating free-air temperature range unless otherwise noted⁽¹⁾

| | | | TPA2035D1 |
|------------------|---|--------------------------------------|-----------------------------------|
| V _{DD} | Supply voltage | In active mode | –0.3 V to 6 V |
| | | In $\overline{\text{SHUTDOWN}}$ mode | –0.3 V to 7 V |
| V _I | Input voltage | | –0.3 V to V _{DD} + 0.3 V |
| | Continuous total power dissipation | | See Dissipation Rating Table |
| T _A | Operating free-air temperature | | –40°C to 85°C |
| T _J | Operating junction temperature | | –40°C to 125°C |
| T _{stg} | Storage temperature | | –65°C to 150°C |
| ESD | Electro-Static Discharge Tolerance - Human Body Model (HBM) for all pins ⁽²⁾ | | 2KV |

- (1) Stresses beyond those listed under *absolute maximum ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *recommended operating conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) The output pins Vo– and Vo+ are tolerant to 1.5KV HBM ESD

RECOMMENDED OPERATING CONDITIONS

| | | | MIN | NOM | MAX | UNIT |
|-----------------|---------------------------------|--------------------------------|-----|-----|----------------------|------|
| V _{DD} | Supply voltage | | 2.5 | | 5.5 | V |
| V _{IH} | High-level input voltage | $\overline{\text{SHUTDOWN}}$ | 1.3 | | V _{DD} | V |
| V _{IL} | Low-level input voltage | $\overline{\text{SHUTDOWN}}$ | 0 | | 0.35 | V |
| V _{IC} | Common mode input voltage range | V _{DD} = 2.5 V, 5.5 V | 0.5 | | V _{DD} –0.8 | V |
| T _A | Operating free-air temperature | | –40 | | 85 | °C |

PACKAGE DISSIPATION RATINGS

| PACKAGE | DERATING FACTOR (1 / θ_{JA}) | T _A ≤ 25°C POWER RATING | T _A = 70°C POWER RATING | T _A = 85°C POWER RATING |
|---------|---|---------------------------------------|---------------------------------------|---------------------------------------|
| YZF | 4.8 mW/°C ⁽¹⁾ | 480 mW | 264 mW | 192 mW |
| YZF | 7.5 mW/°C ⁽²⁾ | 750 mW | 412 mW | 300 mW |

- (1) Derating factor measured with JEDEC Low-K board; 1S0P - One signal layer and zero plane layers.
- (2) Derating factor measured with JEDEC High K board; 1S2P - One signal layer and two plane layers. Please see JEDEC Standard 51-3 for Low-K board, JEDEC Standard 51-7 for High-K board, and JEDEC Standard 51-12 for using package thermal information. Please see JEDEC document page for downloadable copies: <http://www.jedec.org/download/default.cfm>.

ELECTRICAL CHARACTERISTICS

 $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|--|-------------------------|-----|-----|---------------|
| $ V_{OS} $ Output offset voltage (measured differentially) | Inputs AC grounded, $V_{DD} = 2.5\text{ V to }5.5\text{ V}$ | | 5 | 25 | mV |
| PSRR Power supply rejection ratio | $V_{DD} = 2.5\text{ V to }5.5\text{ V}$ | | –75 | –61 | dB |
| CMRR Common mode rejection ratio | $V_{IC} = 0.5\text{ V to } (V_{DD} - 0.8\text{ V})$ | $V_{DD} = 2.5\text{ V}$ | –69 | –52 | dB |
| | | $V_{DD} = 3.6\text{ V}$ | –69 | –52 | |
| | | $V_{DD} = 5.5\text{ V}$ | –69 | –52 | |
| $ I_{IH} $ High-level input current | $V_{DD} = 5.5\text{ V}$, $V_I = 5.8\text{ V}$ | | | 50 | μA |
| $ I_{IL} $ Low-level input current | $V_{DD} = 5.5\text{ V}$, $V_I = -0.3\text{ V}$ | | | 5 | μA |
| $I_{(Q)}$ Quiescent current | $V_{DD} = 5.5\text{ V}$, no load | | 4 | 5.7 | mA |
| | $V_{DD} = 3.6\text{ V}$, no load | | 3 | | |
| | $V_{DD} = 2.5\text{ V}$, no load | | 2.2 | 3.7 | |
| $I_{(SD)}$ Shutdown current | $V_{(SHUTDOWN)} = 0.35\text{ V}$, $V_{DD} = 2.5\text{ V to }5.5\text{ V}$ | | 0.5 | 0.8 | μA |
| $r_{DS(on)}$ Static drain-source on-state resistance | $V_{DD} = 2.5\text{ V}$ | | 550 | | m Ω |
| | $V_{DD} = 3.6\text{ V}$ | | 420 | | |
| | $V_{DD} = 5.0\text{ V}$ | | 350 | | |
| Output impedance in SHUTDOWN | $V_{(SHUTDOWN)} \leq 0.35\text{ V}$ | | 2 | | k Ω |
| $f_{(sw)}$ Switching frequency | $V_{DD} = 2.5\text{ V to }5.5\text{ V}$ | 240 | 300 | 400 | kHz |
| Gain | $V_{DD} = 2.5\text{ V to }5.5\text{ V}$ | 5.5 | 6 | 6.5 | dB |
| R_{PD} Resistance of internal pulldown resistor from shutdown pin to GND | | | 300 | | k Ω |

OPERATING CHARACTERISTICS

 $T_A = 25^\circ\text{C}$, $R_L = 8\ \Omega$ (unless otherwise noted)

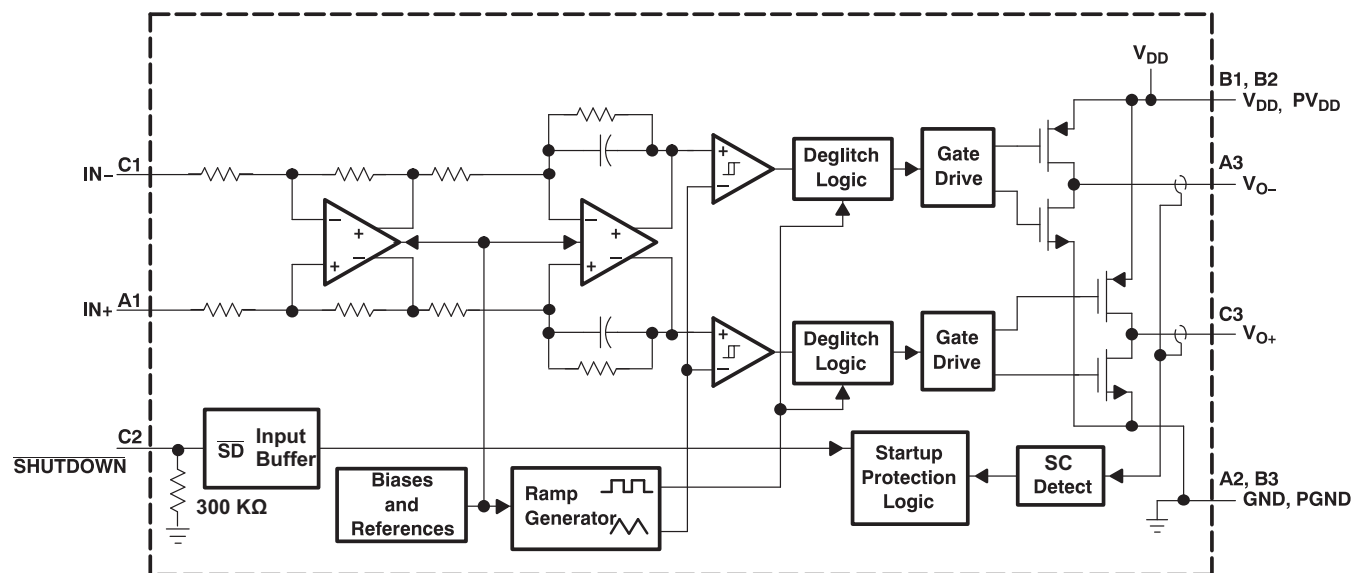
| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|--|---|-------|-----|---------------------|
| P_O Output power | $R_L = 4\ \Omega$, THD + N = 10%, $f = 1\text{ kHz}$ | $V_{DD} = 5\text{ V}$ | 2.75 | | W |
| | | $V_{DD} = 3.6\text{ V}$ | 1.35 | | |
| | | $V_{DD} = 2.5\text{ V}$ | 0.59 | | |
| | $R_L = 4\ \Omega$, THD + N = 1%, $f = 1\text{ kHz}$ | $V_{DD} = 5\text{ V}$ | 2.25 | | W |
| | | $V_{DD} = 3.6\text{ V}$ | 1.12 | | |
| | | $V_{DD} = 2.5\text{ V}$ | 0.48 | | |
| | $R_L = 8\ \Omega$, THD + N = 10%, $f = 1\text{ kHz}$ | $V_{DD} = 5\text{ V}$ | 1.68 | | W |
| | | $V_{DD} = 3.6\text{ V}$ | 0.85 | | |
| | | $V_{DD} = 2.5\text{ V}$ | 0.38 | | |
| | $R_L = 8\ \Omega$, THD + N = 1%, $f = 1\text{ kHz}$ | $V_{DD} = 5\text{ V}$ | 1.37 | | W |
| | | $V_{DD} = 3.6\text{ V}$ | 0.68 | | |
| | | $V_{DD} = 2.5\text{ V}$ | 0.31 | | |
| THD+N Total harmonic distortion plus noise | $V_{DD} = 5\text{ V}$, $P_O = 1\text{ W}$, $R_L = 8\ \Omega$, $f = 1\text{ kHz}$ | | 0.18% | | |
| | $V_{DD} = 3.6\text{ V}$, $P_O = 0.5\text{ W}$, $R_L = 8\ \Omega$, $f = 1\text{ kHz}$ | | 0.11% | | |
| | $V_{DD} = 2.5\text{ V}$, $P_O = 200\text{ mW}$, $R_L = 8\ \Omega$, $f = 1\text{ kHz}$ | | 0.10% | | |
| k_{SVR} Supply ripple rejection ratio | $V_{DD} = 3.6\text{ V}$, Inputs AC grounded with $C_I = 1\ \mu\text{F}$ | $f = 217\text{ Hz}$, $V_{(RIPPLE)} = 200\text{ mV}_{pp}$ | –73 | | dB |
| SNR Signal-to-noise ratio | $V_{DD} = 5\text{ V}$, $P_O = 1\text{ W}$, $R_L = 8\ \Omega$, A weighted noise | | 100 | | dB |
| V_n Output voltage noise | $V_{DD} = 3.6\text{ V}$, $f = 20\text{ Hz to }20\text{ kHz}$, Inputs AC grounded with $C_I = 1\ \mu\text{F}$ | No weighting | 35 | | μV_{RMS} |
| | | A weighting | 27 | | |
| CMRR Common mode rejection ratio | $V_{DD} = 3.6\text{ V}$, $V_{IC} = 1\text{ V}_{pp}$, $V_{Cm} = 1.8\text{ V}$ | $f = 217\text{ Hz}$ | –69 | | dB |

OPERATING CHARACTERISTICS (continued)
 $T_A = 25^\circ\text{C}$, $R_L = 8\ \Omega$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-----------------------------------|--------------------------|-----|------|-----|------------|
| R_I Input impedance | $A_V = 2\ \text{V/V}$ | | 30.2 | | k Ω |
| Start-up time from shutdown | $V_{DD} = 3.6\ \text{V}$ | | 3.2 | | ms |
| Short circuit detection threshold | $V_{DD} = 3.6\ \text{V}$ | | 1.7 | | A |

Terminal Functions

| TERMINAL | | I/O | DESCRIPTION |
|-----------|-----|-----|---|
| NAME | YZF | | |
| IN– | C1 | I | Negative differential audio input |
| IN+ | A1 | I | Positive differential audio input |
| V_{O-} | A3 | O | Negative BTL audio output |
| V_{O+} | C3 | O | Positive BTL audio output |
| GND | A2 | I | Analog ground terminal. Must be connected to same potential as PGND using a direct connection to a single point ground. |
| PGND | B3 | | High-current Analog ground terminal. Must be connected to same potential as GND using a direct connection to a single point ground. |
| V_{DD} | B1 | I | Power supply terminal. Must be connected to same power supply as PV_{DD} using a direct connection. Voltage must be within values listed in Recommended Operating Conditions table. |
| PV_{DD} | B2 | I | High-current Power supply terminal. Must be connected to same power supply as V_{DD} using a direct connection. Voltage must be within values listed in Recommended Operating Conditions table. |
| SHUTDOWN | C2 | I | Shutdown terminal. When terminal is low the device is put into Shutdown mode. |

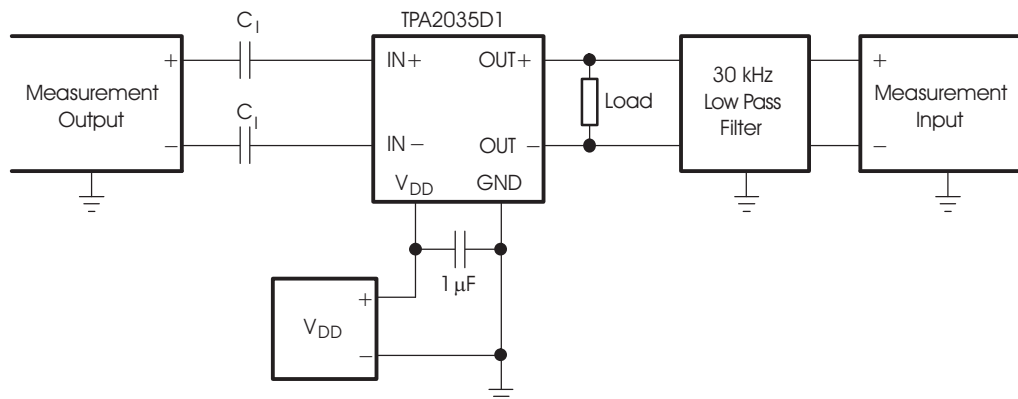
FUNCTIONAL BLOCK DIAGRAM

TYPICAL CHARACTERISTICS

TABLE OF GRAPHS

| | | | FIGURE |
|----------------|--------------------------------------|------------------------------|------------------------------------|
| Efficiency | vs Output power | | 1, 2 |
| P_D | Power dissipation | vs Output power | 3, 4 |
| Supply current | vs Output power | | 5, 6 |
| I_{DD} | Supply current | vs Supply voltage | 7 |
| $I_{(SD)}$ | Shutdown current | vs Shutdown voltage | 8 |
| P_O | Output power | vs Load resistance | 9, 10 |
| | | vs Supply voltage | 11 |
| THD+N | Total harmonic distortion plus noise | vs Output power | 12, 13 |
| | | vs Frequency | 14, 15, 16, 17 |
| | | vs Common-mode input voltage | 18 |
| K_{SVR} | Supply voltage rejection ratio | vs Frequency | 19, 20, 21, 22, 23, 24, 25, 26, 27 |
| | GSM power supply rejection | vs Time | 28 |
| | | vs Frequency | 29 |
| K_{SVR} | Supply voltage rejection ratio | vs Common-mode input voltage | 30, 31, 32 |
| CMRR | Common-mode rejection ratio | vs Frequency | 33 |
| | | vs Common-mode input voltage | 34 |

TEST SET-UP FOR GRAPHS



- (1) C_1 was shorted for any common-mode input voltage measurement. All other measurements were taken with a 1- μ F C_1 (unless otherwise noted).
- (2) A 33- μ H inductor was placed in series with the load resistor to emulate a small speaker for efficiency measurements.
- (3) The 30-kHz low-pass filter is required, even if the analyzer has an internal low-pass filter. An RC low-pass filter (100 Ω , 47-nF) is used on each output for the data sheet graphs.

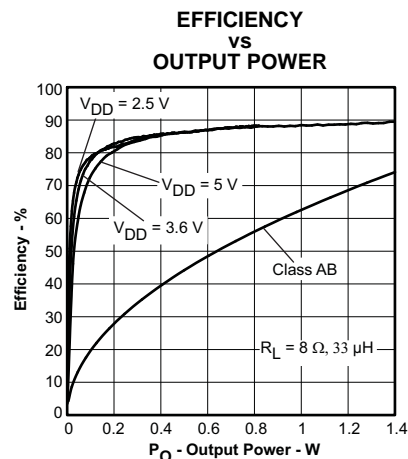


Figure 1.

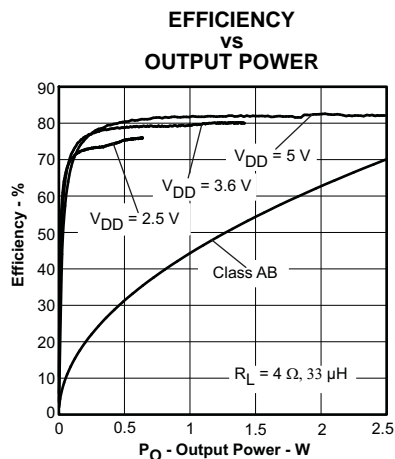


Figure 2.

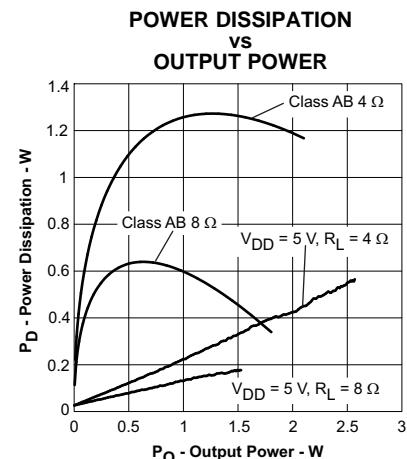


Figure 3.

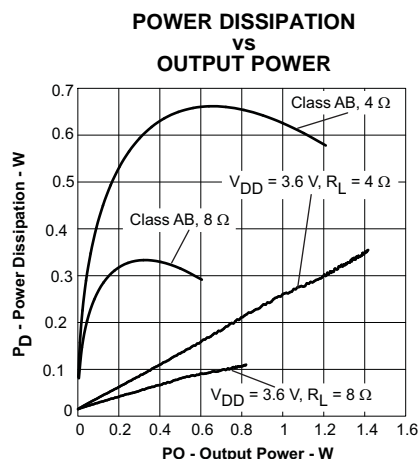


Figure 4.

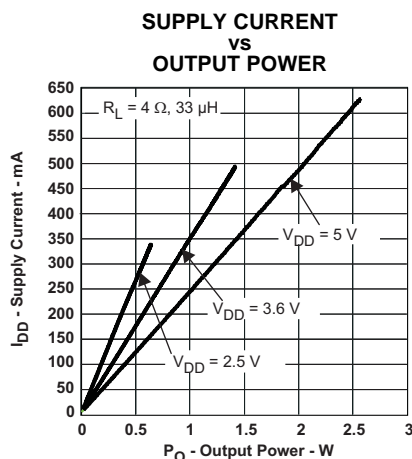


Figure 5.

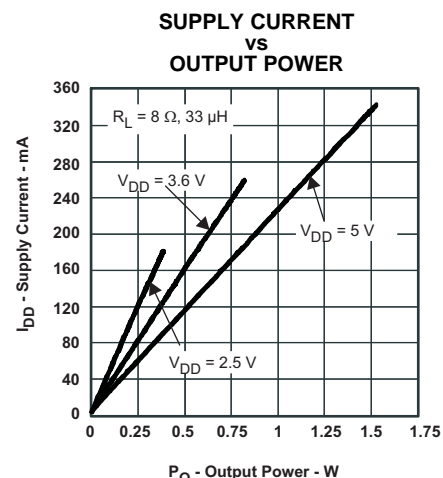


Figure 6.

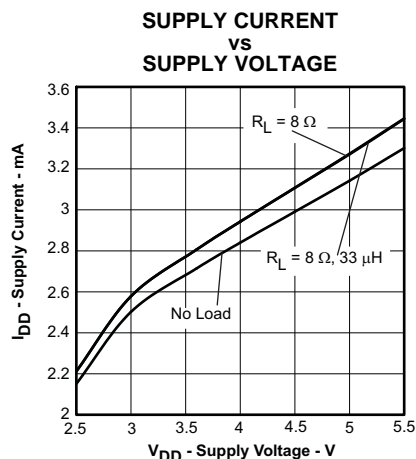


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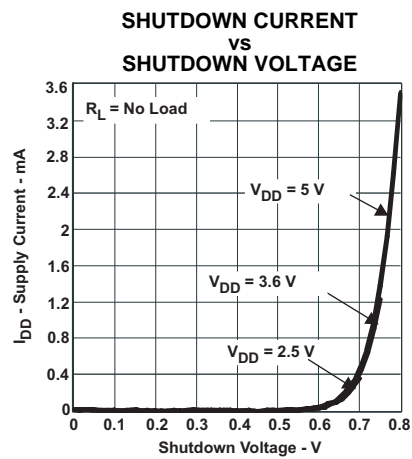


Figure 8.

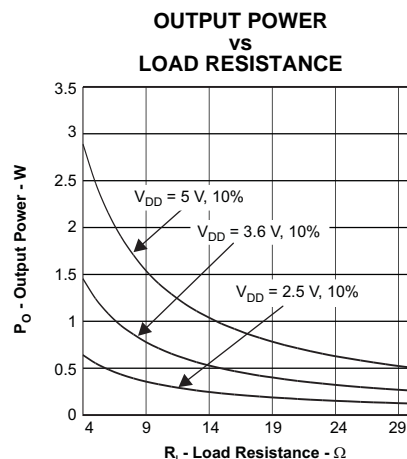


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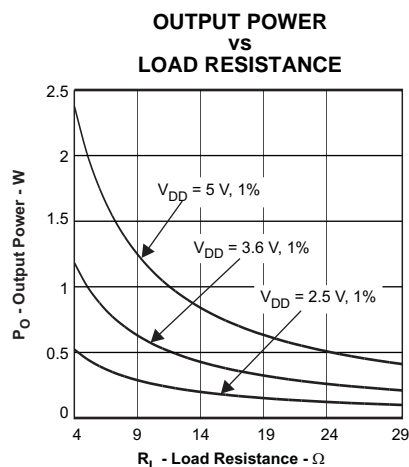


Figure 10.

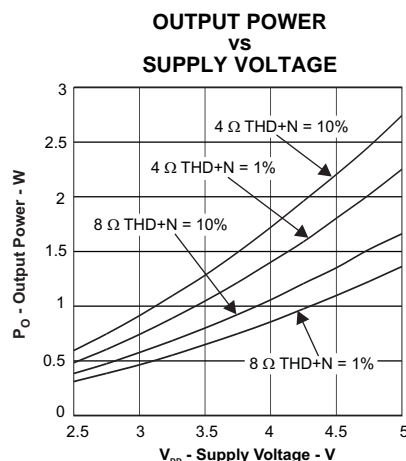


Figure 11.

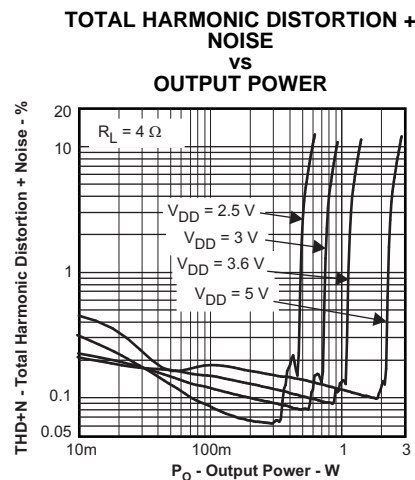


Figure 12.

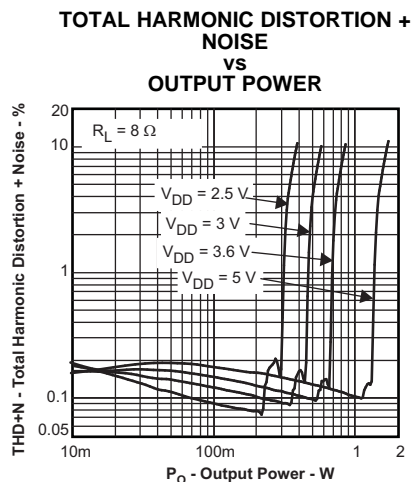


Figure 13.

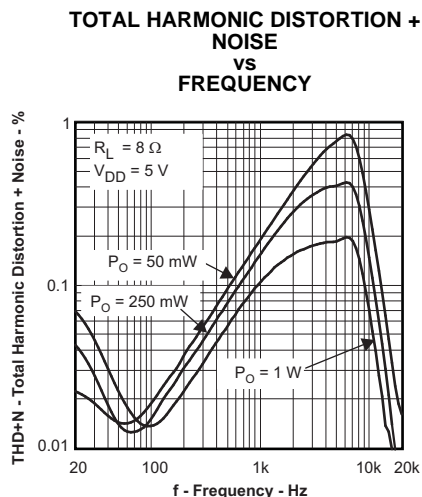


Figure 14.

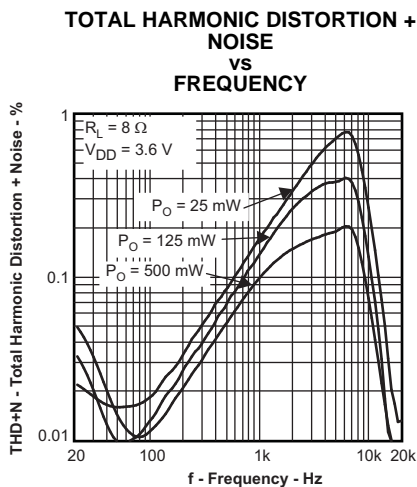


Figure 15.

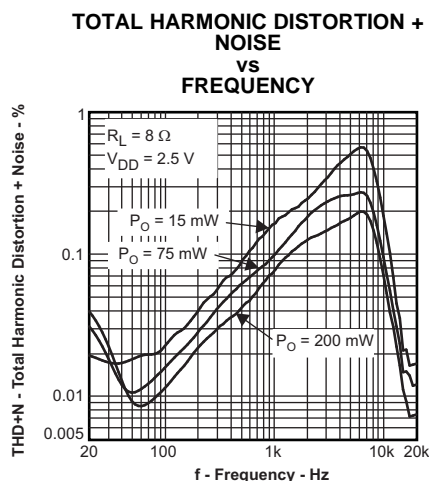


Figure 16.

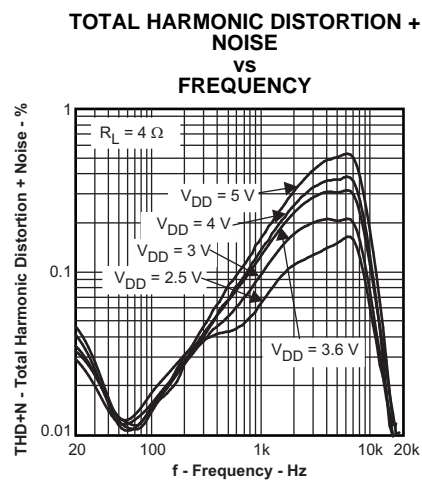


Figure 17.

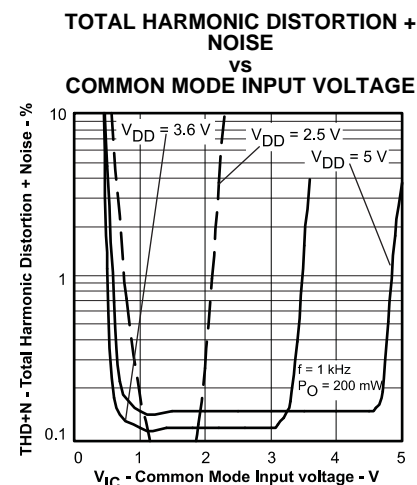


Figure 18.

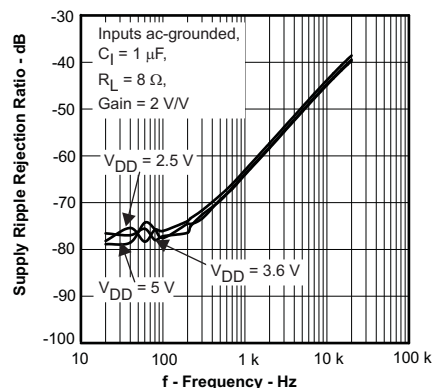
**SUPPLY RIPPLE REJECTION RATIO
VS
FREQUENCY**


Figure 19.

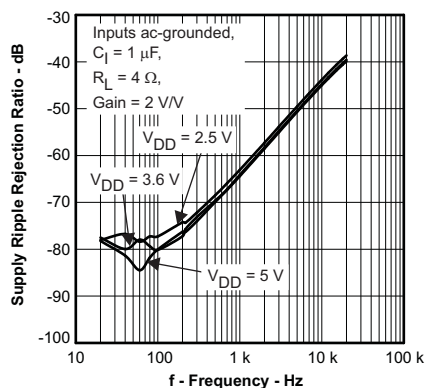
**SUPPLY RIPPLE REJECTION RATIO
VS
FREQUENCY**


Figure 20.

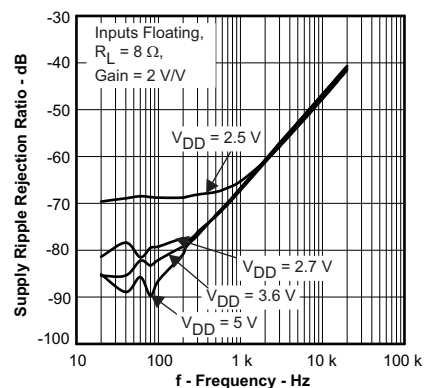
**SUPPLY RIPPLE REJECTION RATIO
VS
FREQUENCY**


Figure 21.

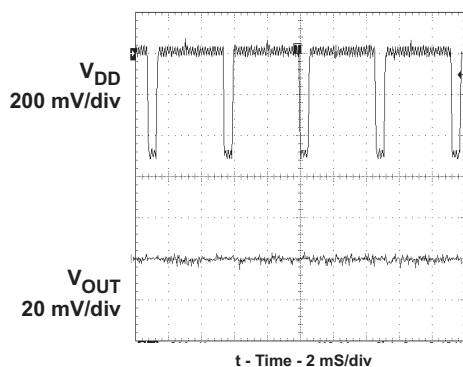
**GSM POWER SUPPLY REJECTION
VS
TIME**


Figure 22.

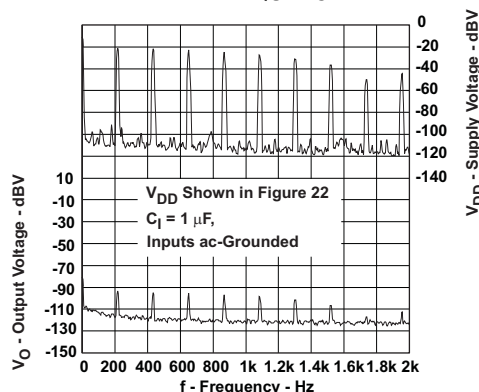
**GSM POWER SUPPLY REJECTION
VS
FREQUENCY**


Figure 23.

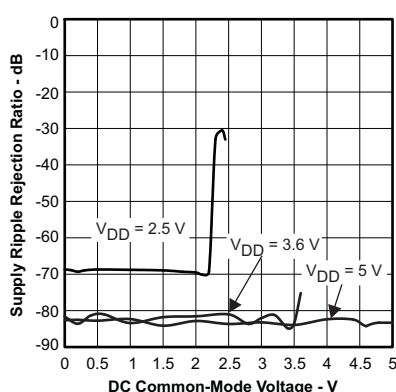
**SUPPLY RIPPLE REJECTION RATIO
VS
DC COMMON MODE VOLTAGE**


Figure 24.

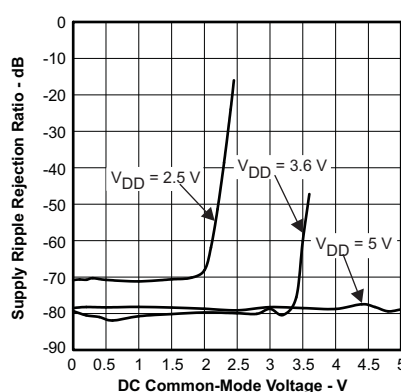
**SUPPLY RIPPLE REJECTION RATIO
VS
DC COMMON MODE VOLTAGE**


Figure 25.

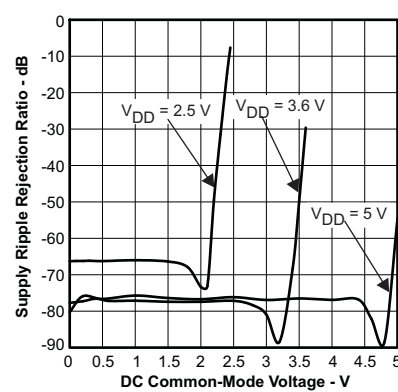
**SUPPLY RIPPLE REJECTION RATIO
VS
DC COMMON MODE VOLTAGE**


Figure 26.

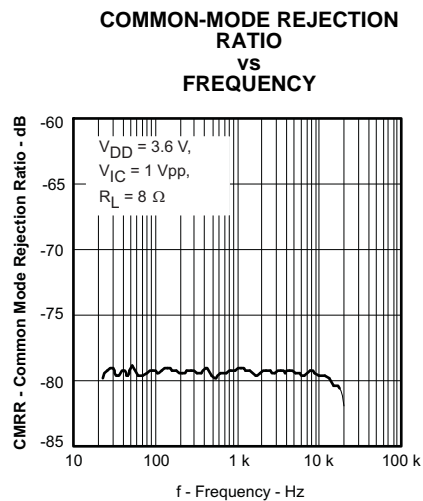


Figure 27.

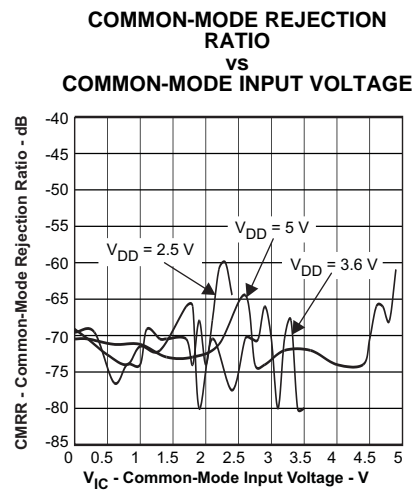


Figure 28.

APPLICATION INFORMATION

FULLY DIFFERENTIAL AMPLIFIER

The device is a fully differential amplifier with differential inputs and outputs. The fully differential amplifier consists of a differential amplifier and a common-mode amplifier. The differential amplifier ensures that the amplifier outputs a differential voltage on the output that is equal to the differential input times the gain. The common-mode feedback specifies that the common-mode voltage at the output is biased around $V_{DD}/2$ regardless of the common-mode voltage at the input. The fully differential TPA2035D1 can still be used with a single-ended input; however, the TPA2035D1 should be used with differential inputs when in a noisy environment, like a wireless handset, to ensure maximum noise rejection.

Advantages of Fully Differential Amplifiers

- Input-coupling capacitors not required:
 - The fully differential amplifier allows the inputs to be biased at voltage other than mid-supply. The inputs of the TPA2035D1 can be biased anywhere within the common mode input voltage range listed in the Recommended Operating Conditions table. If the inputs are biased outside of that range, input-coupling capacitors are required.
- Midsupply bypass capacitor, $C_{(BYPASS)}$, not required:
 - The fully differential amplifier does not require a bypass capacitor. Any shift in the midsupply affects both positive and negative channels equally and cancels at the differential output.
- Better RF-immunity:
 - GSM handsets save power by turning on and shutting off the RF transmitter at a rate of 217 Hz. The transmitted signal is picked-up on input and output traces. The fully differential amplifier cancels the signal better than the typical audio amplifier.

SHORT CIRCUIT AUTO-RECOVERY

When a short circuit event happens, the TPA2035D1 goes to shutdown mode and tries to reactivate itself after 20 μ s. This auto-recovery will continue until the short circuit event stops. This feature can protect the device without affecting the device's long term reliability.

COMPONENT SELECTION

Figure 29 shows the TPA2035D1 typical schematic with differential inputs, while Figure 30 shows the TPA2035D1 with differential inputs and input capacitors. Figure 31 shows the TPA2035D1 with a single-ended input.

Decoupling Capacitor (C_S)

The TPA2035D1 is a high-performance class-D audio amplifier that requires adequate power supply decoupling to ensure the efficiency is high and total harmonic distortion (THD) is low. For higher frequency transients, spikes, or digital hash on the line, a good low equivalent-series-resistance (ESR) ceramic capacitor, typically 1 μ F, placed as close as possible to the device V_{DD} lead works best. Placing this decoupling capacitor close to the TPA2035D1 is important for the efficiency of the class-D amplifier, because any resistance or inductance in the trace between the device and the capacitor can cause a loss in efficiency. For filtering lower-frequency noise signals, a 10 μ F or greater capacitor placed near the audio power amplifier would also help, but it is not required in most applications because of the high PSRR of this device. Typically, the smaller the capacitor's case size, the lower the inductance and the closer it can be placed to the TPA2035D1.

Input Capacitors (C_I)

The TPA2035D1 does not require input coupling capacitors if the design uses a differential source that is biased within the common-mode input voltage range. That voltage range is listed in the Recommended Operating Conditions table. If the input signal is not biased within the recommended common-mode input range, such as in needing to use the input as a high pass filter, shown in Figure 30, or if using a single-ended source, shown in Figure 31, input coupling capacitors are required. The same value capacitors should be used on both IN+ and IN– for best pop performance.

$$f_c = \frac{1}{(2\pi R_I C_I)} \quad (1)$$

The value of the input capacitor is important to consider as it directly affects the bass (low frequency) performance of the circuit. Speaker response may also be taken into consideration when setting the corner frequency using input capacitors.

Equation 2 is reconfigured to solve for the input coupling capacitance.

$$C_I = \frac{1}{(2\pi R_I f_c)} \quad (2)$$

If the corner frequency is within the audio band, the capacitors should have a tolerance of $\pm 10\%$ or better, because any mismatch in capacitance causes an impedance mismatch at the corner frequency and below.

For a flat low-frequency response, use large input coupling capacitors ($1\ \mu\text{F}$ or larger).

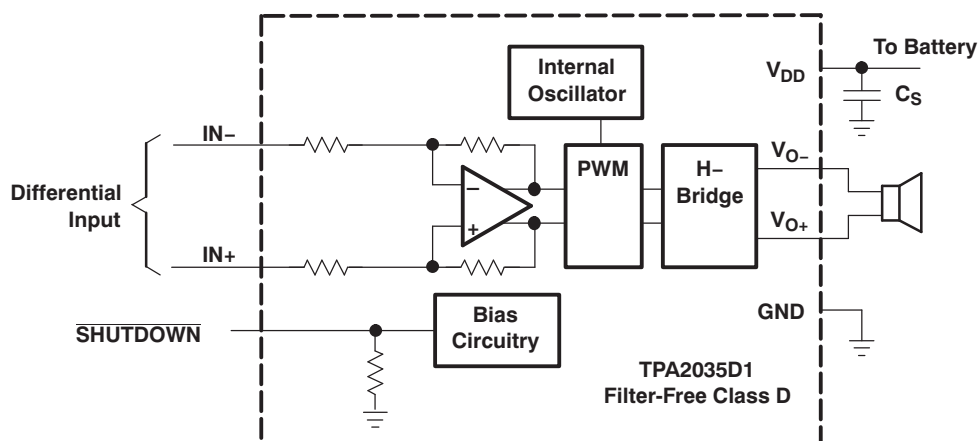


Figure 29. Typical TPA2035D1 Application Schematic With Differential Input for a Wireless Phone

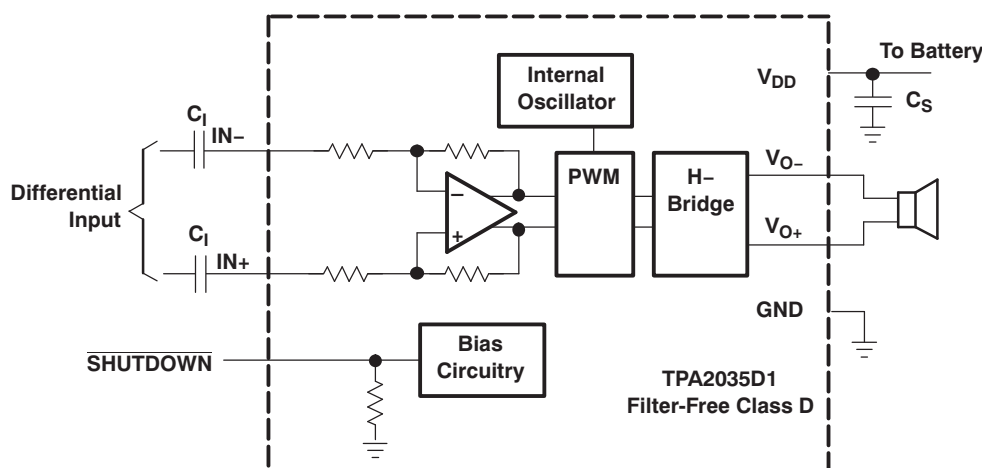


Figure 30. TPA2035D1 Application Schematic With Differential Input and Input Capacitors

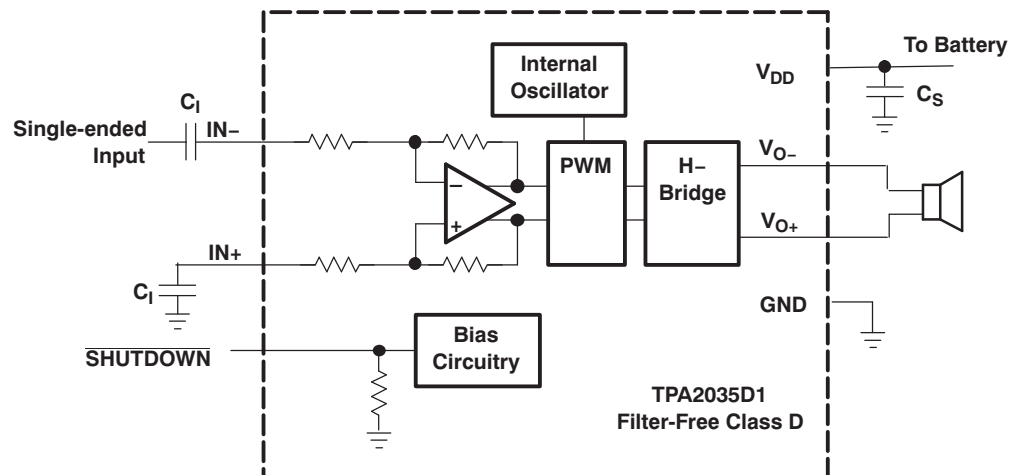


Figure 31. TPA2035D1 Application Schematic With Single-Ended Input

BOARD LAYOUT

In making the pad size for the WCSP balls, it is recommended that the layout use nonsolder mask defined (NSMD) land. With this method, the solder mask opening is made larger than the desired land area, and the opening size is defined by the copper pad width. Figure 32 and Table 1 show the appropriate diameters for a WCSP layout. The TPA2035D1 evaluation module (EVM) layout is shown in the next section as a layout example.

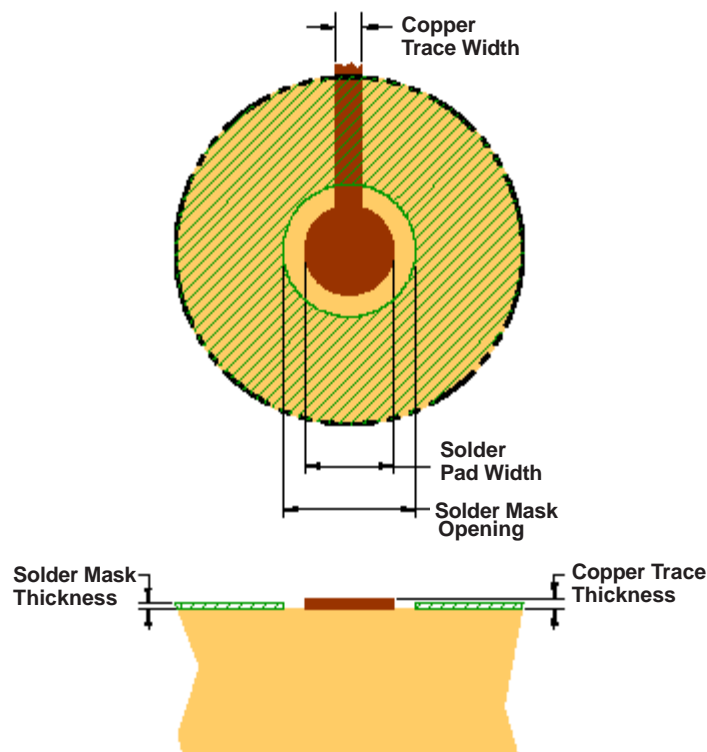


Figure 32. Land Pattern Dimensions

Table 1. Land Pattern Dimensions

| SOLDER PAD DEFINITIONS | COPPER PAD | SOLDER MASK OPENING | COPPER THICKNESS | STENCIL OPENING | STENCIL THICKNESS |
|-------------------------------|--|--|------------------------------|--|-------------------------|
| Nonsolder mask defined (NSMD) | 275 μm (0.0, –25 μm) | 375 μm (0.0, –25 μm) | 1 oz max (32 μm) | 275 μm x 275 μm Sq. (rounded corners) | 125 μm thick |

NOTES:

1. Circuit traces from NSMD defined PWB lands should be 75 μm to 100 μm wide in the exposed area inside the solder mask opening. Wider trace widths reduce device stand off and impact reliability.
2. Recommended solder paste is Type 3 or Type 4.
3. Best reliability results are achieved when the PWB laminate glass transition temperature is above the operating range of the intended application.
4. For a PWB using a Ni/Au surface finish, the gold thickness should be less 0.5 μm to avoid a reduction in thermal fatigue performance.
5. Solder mask thickness should be less than 20 μm on top of the copper circuit pattern.
6. Best solder stencil performance is achieved using laser-cut stencils with electro polishing. Use of chemically etched stencils results in inferior solder paste volume control.
7. Trace routing away from WCSP device should be balanced in X and Y directions to avoid unintentional component movement due to solder wetting forces.

Component Location

Place all the external components very close to the TPA2035D1. Placing the decoupling capacitor, C_S , close to the TPA2035D1 is important for the efficiency of the class-D amplifier. Any resistance or inductance in the trace between the device and the capacitor can cause a loss in efficiency.

Trace Width

Recommended trace width at the solder balls is 75 μm to 100 μm to prevent solder wicking onto wider PCB traces. [Figure 33](#) shows the layout of the TPA2035D1 evaluation module (EVM).

For high current pins (V_{DD} , GND V_{O+} , and V_{O-}) of the TPA2035D1, use 100- μm trace widths at the solder balls and at least 500- μm PCB traces to ensure proper performance and output power for the device.

For input pins (IN–, IN+, and SHUTDOWN) of the TPA2035D1, use 75- μm to 100- μm trace widths at the solder balls. IN– and IN+ traces need to run side-by-side to maximize common-mode noise cancellation.

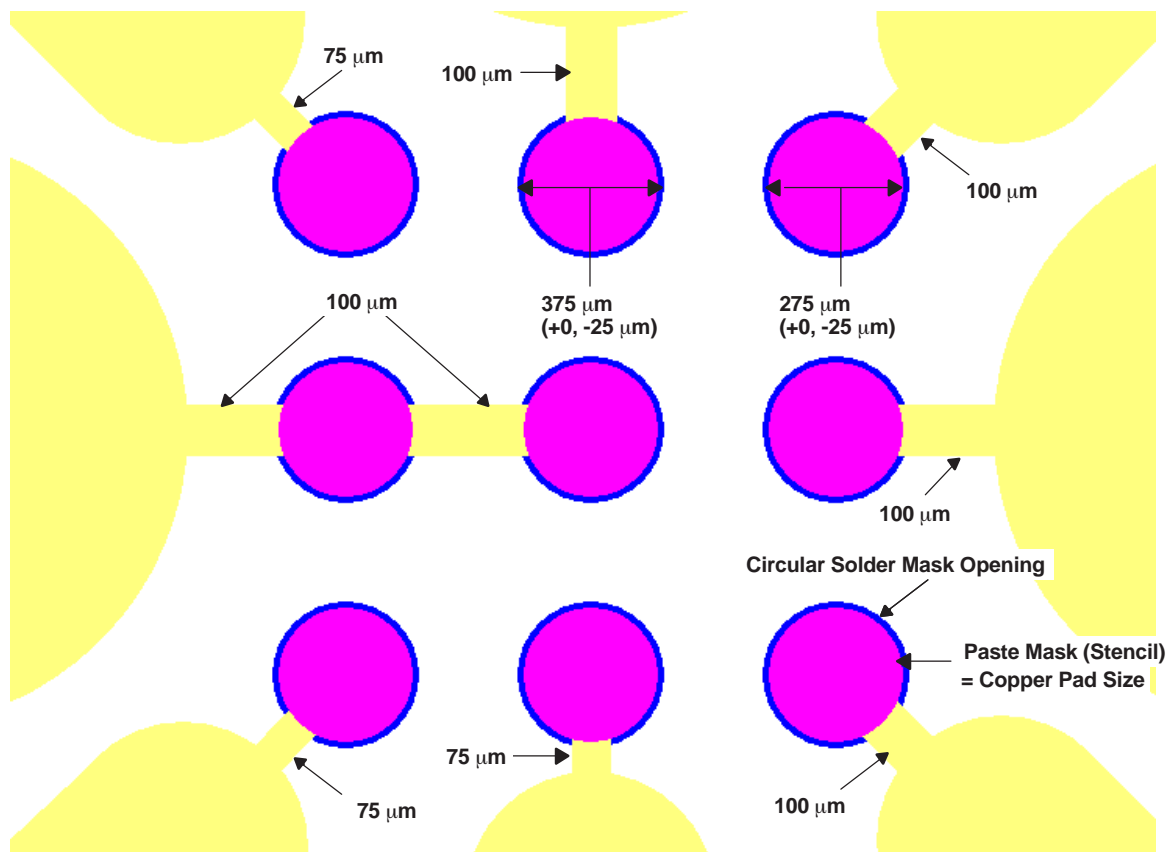


Figure 33. Close Up of TPA2035D1 Land Pattern

EFFICIENCY AND THERMAL INFORMATION

The maximum ambient temperature depends on the heat-sinking ability of the PCB system. The derating factor for the YZF package is shown in the dissipation rating table. Converting this to θ_{JA} :

$$\theta_{JA} = \frac{1}{\text{Derating Factor}} \quad (3)$$

Given θ_{JA} (from the Package Dissipation ratings table), the maximum allowable junction temperature (from the Absolute Maximum ratings table), and the maximum internal dissipation (from Power Dissipation vs Output Power figures) the maximum ambient temperature can be calculated with the following equation. Note that the units on these figures are Watts RMS. Because of crest factor (ratio of peak power to RMS power) from 9–15 dB, thermal limitations are not usually encountered.

$$T_{A\text{Max}} = T_{J\text{Max}} - \theta_{JA} P_{D\text{max}} \quad (4)$$

The TPA2035D1 is designed with thermal protection that turns the device off when the junction temperature surpasses 150°C to prevent damage to the IC. Note that using speakers more resistive than 4-Ω dramatically increases the thermal performance by reducing the output current and increasing the efficiency of the amplifier. θ_{JA} is a gross approximation of the complex thermal transfer mechanisms between the device and its ambient environment. If the θ_{JA} calculation reveals a potential problem, a more accurate estimate should be made.

WHEN TO USE AN OUTPUT FILTER

Design the TPA2035D1 without an output filter if the traces from the amplifier to the speaker are short. Wireless handsets and PDAs are great applications for this class-D amplifier to be used without an output filter.

The TPA2035D1 passed FCC- and CE-radiated emissions testing with no shielding with speaker trace wires 100 mm long or less. For longer speaker trace wires, a ferrite bead can often be used in the design if failing radiated emissions testing without an LC filter; and, the frequency-sensitive circuit is greater than 1 MHz. If choosing a ferrite bead, choose one with high impedance at high frequencies, but very low impedance at low frequencies. The selection must also take into account the currents flowing through the ferrite bead. Ferrites can begin to lose effectiveness at much lower than rated current values. See the EVM User's Guide ([SLOU237](#)) for components used successfully by TI.

[Figure 34](#) shows a typical ferrite-bead output filter.

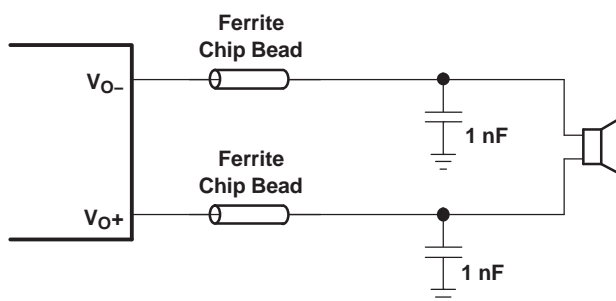


Figure 34. Typical Ferrite Chip Bead Filter

PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish | MSL Peak Temp (3) | Op Temp (°C) | Top-Side Markings (4) | Samples |
|------------------|---------------|--------------|-----------------|------|-------------|-------------------------|------------------|----------------------|--------------|--------------------------|-------------------------|
| TPA2035D1YZFR | ACTIVE | DSBGA | YZF | 9 | 3000 | Green (RoHS & no Sb/Br) | SNAGCU | Level-1-260C-UNLIM | -40 to 125 | CGD | Samples |
| TPA2035D1YZFT | ACTIVE | DSBGA | YZF | 9 | 250 | Green (RoHS & no Sb/Br) | SNAGCU | Level-1-260C-UNLIM | -40 to 125 | CGD | Samples |

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

TBD: The Pb-Free/Green conversion plan has not been defined.

Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

(4) Multiple Top-Side Markings will be inside parentheses. Only one Top-Side Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Top-Side Marking for that device.

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TAPE AND REEL INFORMATION


*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|---------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TPA2035D1YZFR | DSBGA | YZF | 9 | 3000 | 180.0 | 8.4 | 1.65 | 1.65 | 0.81 | 4.0 | 8.0 | Q1 |
| TPA2035D1YZFT | DSBGA | YZF | 9 | 250 | 180.0 | 8.4 | 1.65 | 1.65 | 0.81 | 4.0 | 8.0 | Q1 |

TAPE AND REEL BOX DIMENSIONS

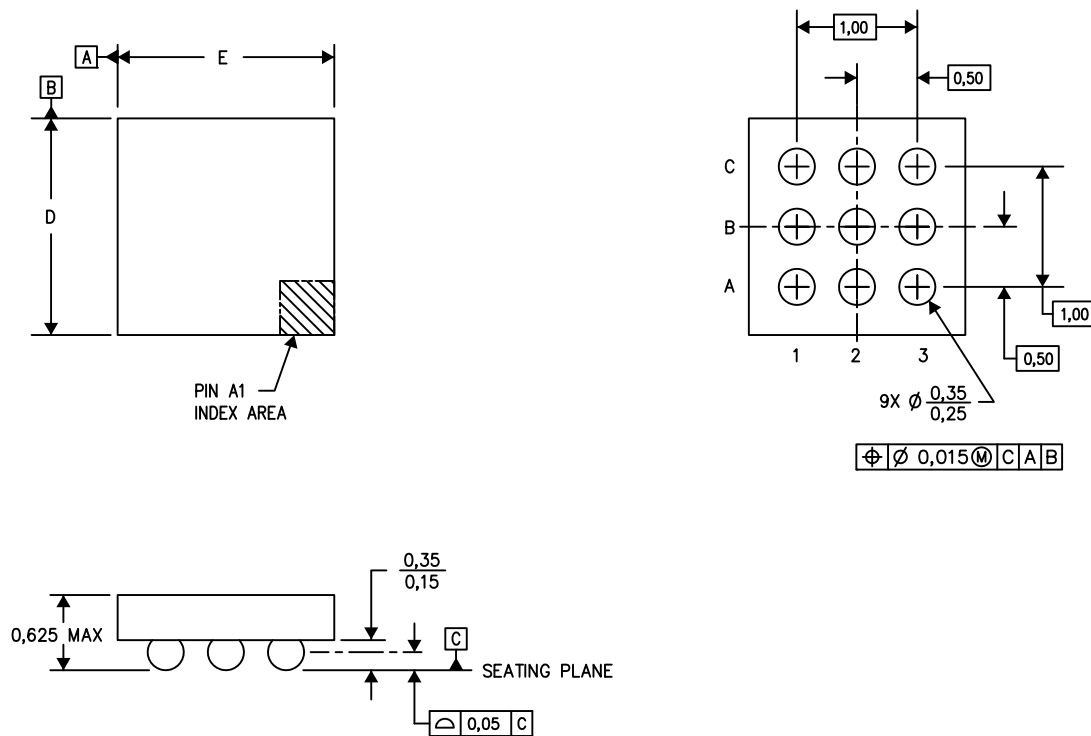


*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TPA2035D1YZFR | DSBGA | YZF | 9 | 3000 | 182.0 | 182.0 | 20.0 |
| TPA2035D1YZFT | DSBGA | YZF | 9 | 250 | 182.0 | 182.0 | 20.0 |

YZF (S-XBGA-N9)

DIE-SIZE BALL GRID ARRAY



D: Max = 1.51 mm, Min = 1.45 mm

E: Max = 1.51 mm, Min = 1.45 mm

4205058-4/P 07/13

- NOTES:
- All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
 - This drawing is subject to change without notice.
 - NanoFree™ package configuration.

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