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# DATA SHEET

## **TDA8924** **2 × 120 W class-D power amplifier**

Objective specification

2003 Jul 28

**2 × 120 W class-D power amplifier****TDA8924**

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**2 × 120 W class-D power amplifier****TDA8924****1 FEATURES**

- High efficiency (~90 %)
- Operating voltage from  $\pm 12.5$  V to  $\pm 30$  V
- Very low quiescent current
- Low distortion
- Usable as a stereo Single-Ended (SE) amplifier or as a mono amplifier in Bridge-Tied Load (BTL)
- Fixed gain of 28 dB in SE and 34 dB in BTL
- High output power
- Good ripple rejection
- Internal switching frequency can be overruled by an external clock
- No switch-on or switch-off plop noise
- Short-circuit proof across the load and to the supply lines
- Electrostatic discharge protection
- Thermally protected.

**2 APPLICATIONS**

- Television sets
- Home-sound sets
- Multimedia systems
- All mains fed audio systems
- Car audio (boosters).

**3 GENERAL DESCRIPTION**

The TDA8924 is a high efficiency class-D audio power amplifier with very low dissipation. The typical output power is 2 × 120 W.

The device comes in a HSOP24 power package with a small internal heatsink. Depending on supply voltage and load conditions a very small or even no external heatsink is required. The amplifier operates over a wide supply voltage range from  $\pm 12.5$  V to  $\pm 30$  V and consumes a very low quiescent current.

**4 QUICK REFERENCE DATA**

| SYMBOL                                      | PARAMETER               | CONDITIONS  | MIN.       | TYP.     | MAX.     | UNIT |
|---|-------------------------|---|------------|----------|----------|------|
| <b>General; <math>V_P = \pm 24</math> V</b> |                         |   |            |          |          |      |
| $V_P$                                       | supply voltage          |   | $\pm 12.5$ | $\pm 24$ | $\pm 30$ | V    |
| $I_{q(\text{tot})}$                         | total quiescent current | no load connected; note 1                               | –          | 100      | –        | mA   |
| $\eta$                                      | efficiency              | $P_o = 240$ W BTL mode                                  | –          | 83       | –        | %    |
| <b>Stereo single-ended configuration</b>    |                         |   |            |          |          |      |
| $P_o$                                       | output power            | $R_L = 2 \Omega$ ; THD = 10 %; $V_P = \pm 24$ V; note 2 | –          | 120      | –        | W    |
| <b>Mono bridge-tied load configuration</b>  |                         |   |            |          |          |      |
| $P_o$                                       | output power            | $R_L = 4 \Omega$ ; THD = 10 %; note 2                   | –          | 240      | –        | W    |
|   |                         | $V_P = \pm 24$ V  | –          | 175      | –        | W    |
|   |                         | $V_P = \pm 20$ V  | –          |          | –        | W    |

**Notes**

1. Quiescent current in application; value strongly depends on circuitry connected to the output pin. This also means that quiescent dissipation of the chip is lower than the  $V_P \times I_q$ .
2. Output power is measured indirectly; based on  $R_{DSon}$  measurement.

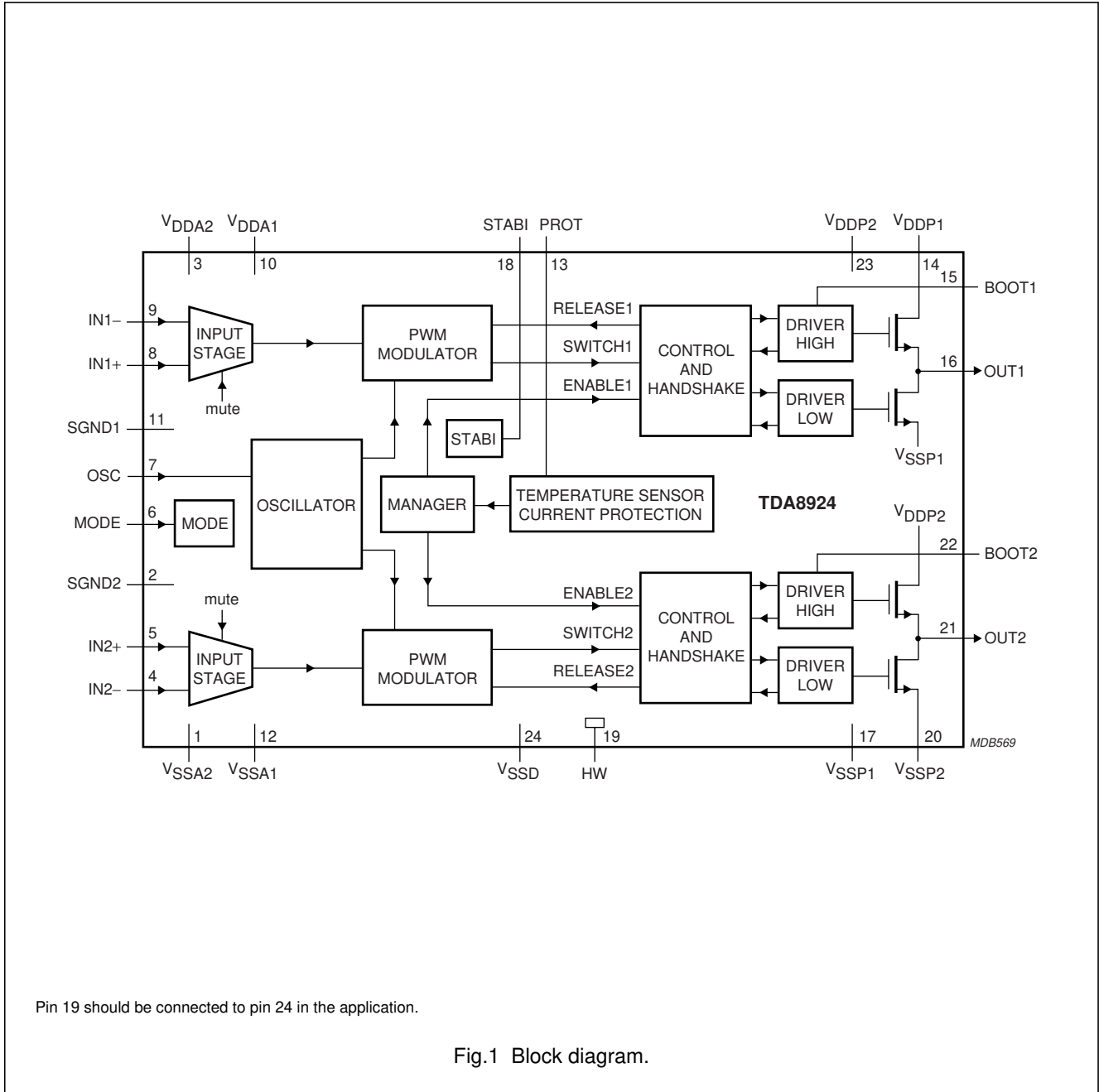
**5 ORDERING INFORMATION**

| TYPE NUMBER | PACKAGE |  |          |
|-------------|---------|--|----------|
|             | NAME    | DESCRIPTION  | VERSION  |
| TDA8924TH   | HSOP24  | plastic thermal enhanced small outline package; 24 leads; low stand-off height; heatsink | SOT566-3 |

2 × 120 W class-D power amplifier

TDA8924

6 BLOCK DIAGRAM

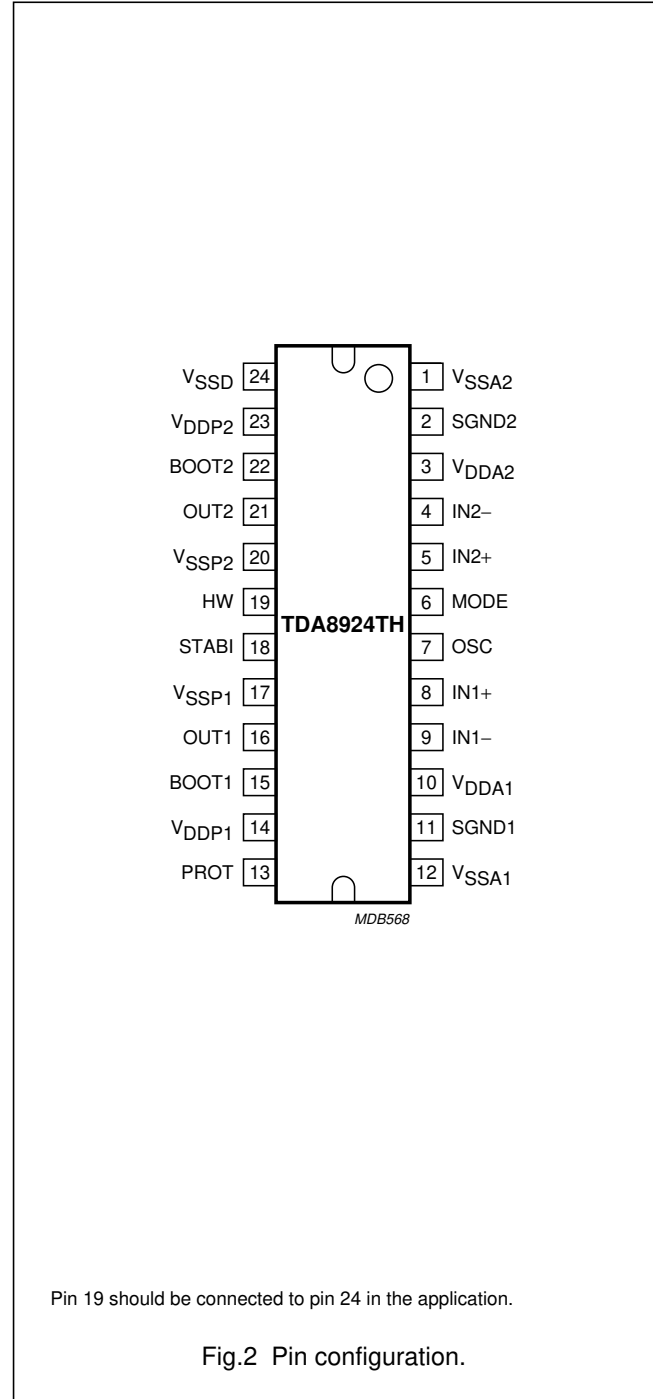


2 × 120 W class-D power amplifier

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7 PINNING

| SYMBOL            | PIN | DESCRIPTION                                       |
|-------------------|-----|---|
| V <sub>SSA2</sub> | 1   | negative analog supply voltage for channel 2      |
| SGND2             | 2   | signal ground channel 2                           |
| V <sub>DDA2</sub> | 3   | positive analog supply voltage for channel 2      |
| IN2-              | 4   | negative audio input for channel 2                |
| IN2+              | 5   | positive audio input for channel 2                |
| MODE              | 6   | mode select input (standby/mute/operating)        |
| OSC               | 7   | oscillator frequency adjustment or tracking input |
| IN1+              | 8   | positive audio input for channel 1                |
| IN1-              | 9   | negative audio input for channel 1                |
| V <sub>DDA1</sub> | 10  | positive analog supply voltage for channel 1      |
| SGND1             | 11  | signal ground for channel 1                       |
| V <sub>SSA1</sub> | 12  | negative analog supply voltage for channel 1      |
| PROT              | 13  | time constant capacitor for protection delay      |
| V <sub>DDP1</sub> | 14  | positive power supply for channel 1               |
| BOOT1             | 15  | bootstrap capacitor for channel 1                 |
| OUT1              | 16  | PWM output from channel 1                         |
| V <sub>SSP1</sub> | 17  | negative power supply voltage for channel 1       |
| STABI             | 18  | decoupling internal stabilizer for logic supply   |
| HW                | 19  | handle wafer; must be connected to pin 24         |
| V <sub>SSP2</sub> | 20  | negative power supply voltage for channel 2       |
| OUT2              | 21  | PWM output from channel 2                         |
| BOOT2             | 22  | bootstrap capacitor for channel 2                 |
| V <sub>DDP2</sub> | 23  | positive power supply voltage for channel 2       |
| V <sub>SSD</sub>  | 24  | negative digital supply voltage                   |



## 2 × 120 W class-D power amplifier

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### 8 FUNCTIONAL DESCRIPTION

#### 8.1 General

The TDA8924 is a two channel audio power amplifier using class-D technology. A typical application diagram is illustrated in Fig.38. A detailed application reference design is given in Section 16.8.

The audio input signal is converted into a digital Pulse Width Modulated (PWM) signal via an analog input stage and PWM modulator. To enable the output power transistors to be driven, this digital PWM signal is applied to a control and handshake block and driver circuits for both the high side and low side. In this way a level shift is performed from the low power digital PWM signal (at logic levels) to a high power PWM signal which switches between the main supply lines.

A 2nd-order low-pass filter converts the PWM signal to an analog audio signal across the loudspeaker.

The TDA8924 one-chip class-D amplifier contains high power D-MOS switches, drivers, timing and handshaking between the power switches and some control logic. For protection a temperature sensor and a maximum current detector are built-in.

Each of the two audio channels of the TDA8924 contains a PWM, an analog feedback loop and a differential input stage. The TDA8924 also contains circuits common to both channels such as the oscillator, all reference sources, the mode functionality and a digital timing manager.

The TDA8924 contains two independent amplifier channels with high output power, high efficiency (90 %), low distortion and a low quiescent current. The amplifier channels can be connected in the following configurations:

- Mono Bridge-Tied Load (BTL) amplifier
- Stereo Single-Ended (SE) amplifiers.

The amplifier system can be switched in three operating modes with pin MODE:

- Standby mode; with a very low supply current
- Mute mode; the amplifiers are operational, but the audio signal at the output is suppressed
- Operating mode; the amplifiers are fully operational with output signal.

An example of a switching circuit for driving pin MODE is illustrated in Fig.3.

For suppressing plop noise the amplifier will remain automatically in the mute mode for approximately 150 ms before switching to the operating mode (see Fig.4). During this time, the coupling capacitors at the input are fully charged.

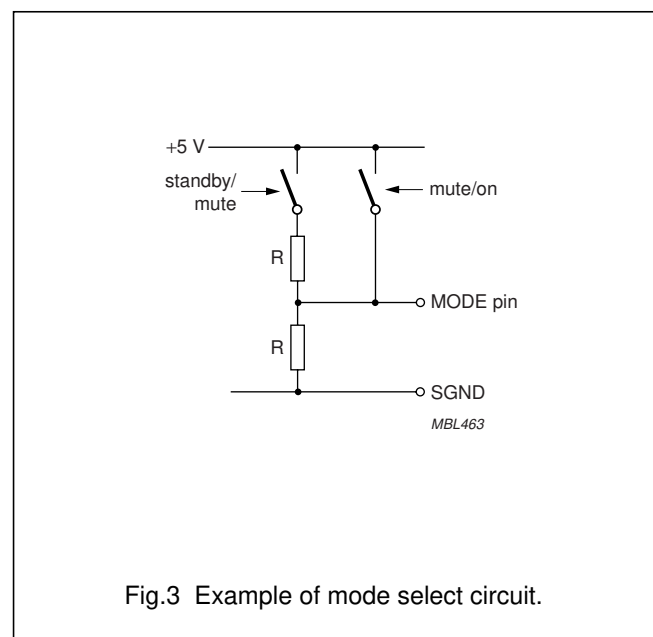
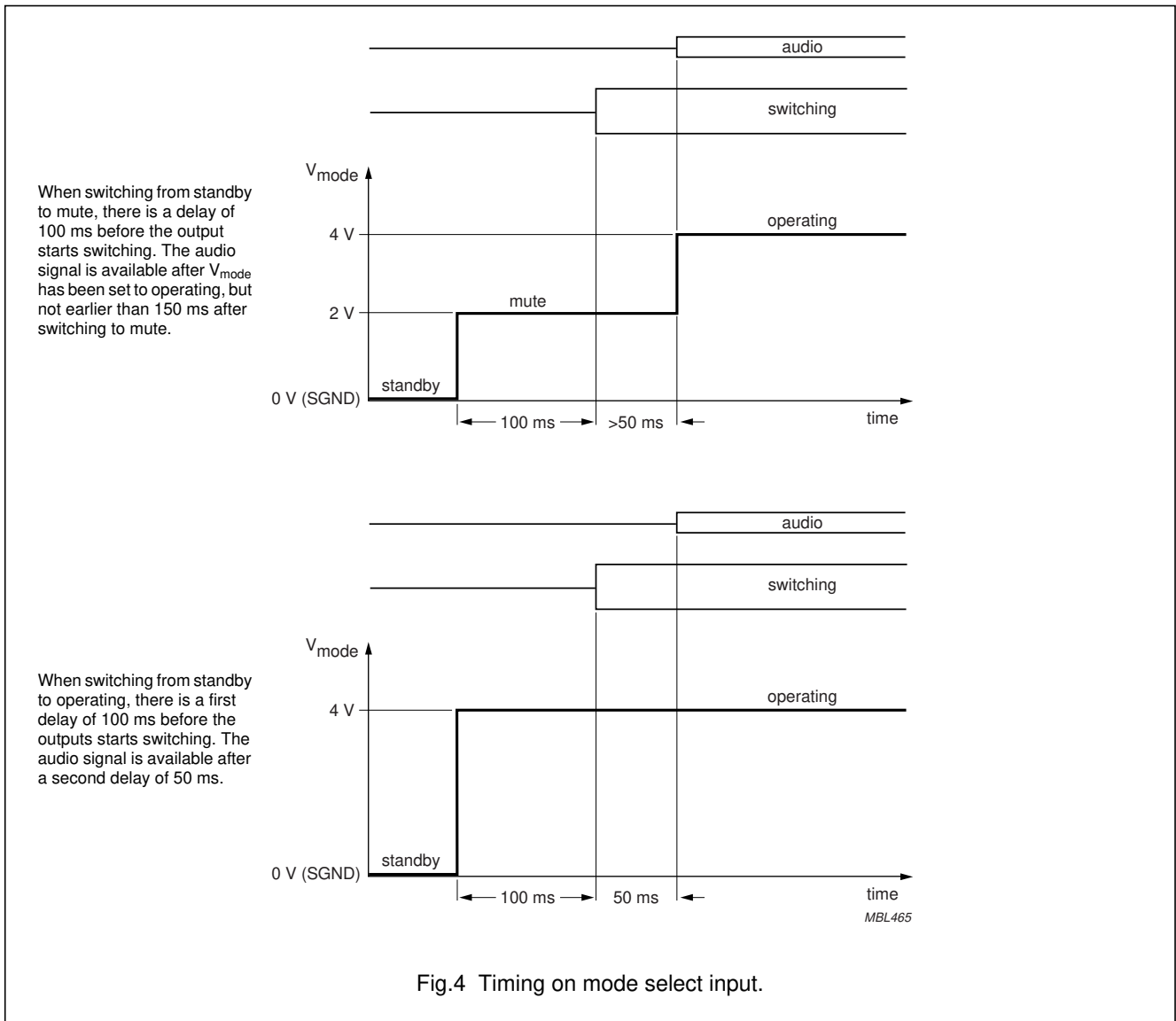


Fig.3 Example of mode select circuit.

2 × 120 W class-D power amplifier

TDA8924



8.2 Pulse width modulation frequency

The output signal of the amplifier is a PWM signal with a carrier frequency of approximately 350 kHz. Using a 2nd-order LC demodulation filter in the application results in an analog audio signal across the loudspeaker. This switching frequency is fixed by an external resistor  $R_{OSC}$  connected between pin OSC and  $V_{SSA}$ . With the resistor value given in the schematic diagram of the reference design, the carrier frequency is typical 350 kHz. The carrier frequency can be calculated using the

following equation:  $f_{osc} = \frac{9 \times 10^9}{R_{OSC}} \text{ Hz}$

If two or more class-D amplifiers are used in the same audio application, it is advisable to have all devices operating at the same switching frequency.

This can be realized by connecting all OSC pins together and feed them from an external central oscillator. Using an external oscillator it is necessary to force pin OSC to a DC-level above SGND for switching from internal to an external oscillator. In this case the internal oscillator is disabled and the PWM will be switched to the external frequency. The frequency range of the external oscillator must be in the range as specified in the switching characteristics; see Chapter 13.



## 2 × 120 W class-D power amplifier

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In an application circuit:

- Internal oscillator:  $R_{OSC}$  connected from pin OSC to  $V_{SS}$
- External oscillator: connect oscillator signal between pin OSC and SGND; delete  $R_{OSC}$  and  $C_{OSC}$ .

### 8.3 Protections

Temperature, supply voltage and short-circuit protection sensors are included on the chip. In the event that the maximum current or maximum temperature is exceeded the system will shut down.

#### 8.3.1 OVER-TEMPERATURE

If the junction temperature ( $T_j$ ) exceeds 150 °C, then the power stage will shut down immediately. The power stage will start switching again if the temperature drops to approximately 130 °C, thus there is a hysteresis of approximately 20 °C.

#### 8.3.2 SHORT-CIRCUIT ACROSS THE LOUDSPEAKER TERMINALS AND TO SUPPLY LINES

When the loudspeaker terminals are short-circuited or if one of the demodulated outputs of the amplifier is short-circuited to one of the supply lines this will be detected by the current protection. If the output current exceeds the maximum output current of 12 A, then the power stage will shut down within less than 1  $\mu$ s and the high-current will be switched off. In this state the dissipation is very low. Every 100 ms the system tries to restart again. If there is still a short-circuit across the loudspeaker load or to one of the supply lines, the system is switched off again as soon as the maximum current is exceeded. The average dissipation will be low because of this low duty cycle.

#### 8.3.3 START-UP SAFETY TEST

During the start-up sequence, when the mode pin is switched from standby to mute, the condition at the output terminals of the power stage are checked. In the event of a short-circuit at one of the output terminals to  $V_{DD}$  or  $V_{SS}$  the start-up procedure is interrupted and the system waits for open-circuit outputs. Because the test is done before enabling the power stages, no large currents will flow in the event of a short-circuit. This system protects for short-circuits at both sides of the output filter to both supply lines. When there is a short-circuit from the power PWM output of the power stage to one of the supply lines (before the demodulation filter) it will also be detected by the start-up safety test. Practical use of this test feature can be found in detection of short-circuits on the printed-circuit board.

**Remark:** This test is only operational prior to or during the start-up sequence, and not during normal operation.

During normal operation the maximum current protection is used to detect short-circuits across the load and with respect to the supply lines.

#### 8.3.4 SUPPLY VOLTAGE ALARM

If the supply voltage falls below  $\pm 12.5$  V the undervoltage protection is activated and the system shuts down correctly. If the internal clock is used, this switch-off will be silent and without pop noise. When the supply voltage rises above the threshold level the system is restarted again after 100 ms. If the supply voltage exceeds  $\pm 32$  V the overvoltage protection is activated and the power stages shut down. They are re-enabled as soon as the supply voltage drops below the threshold level.

It has to be stressed that the overvoltage protection only protects against damage due to supply pumping effects; see Section 16.7. Apart from the power stages, the rest of the circuitry remains connected to the power supply. This means, that the supply itself should never exceed 30 V.

An additional balance protection circuit compares the positive ( $V_{DD}$ ) and the negative ( $V_{SS}$ ) supply voltages and is triggered if the voltage difference between them exceeds a certain level. This level depends on the sum of both supply voltages. An expression for the unbalanced threshold level is as follows:  $V_{th(ubn)} \sim 0.15 \times (V_{DD} + V_{SS})$ .

**Example:** With a symmetrical supply of  $\pm 30$  V the protection circuit will be triggered if the unbalance exceeds approximately 9 V; see also Section 16.7.

### 8.4 Differential audio inputs

For a high common mode rejection ratio and a maximum of flexibility in the application, the audio inputs are fully differential. By connecting the inputs anti-parallel the phase of one of the channels can be inverted, so that a load can be connected between the two output filters. In this case the system operates as a mono BTL amplifier and with the same loudspeaker impedance an approximately four times higher output power can be obtained.

The input configuration for mono BTL application is illustrated in Fig.5; for more information see Chapter 16.

In the stereo single-ended configuration it is also recommended to connect the two differential inputs in anti-phase. This has advantages for the current handling of the power supply at low signal frequencies.

2 × 120 W class-D power amplifier

TDA8924

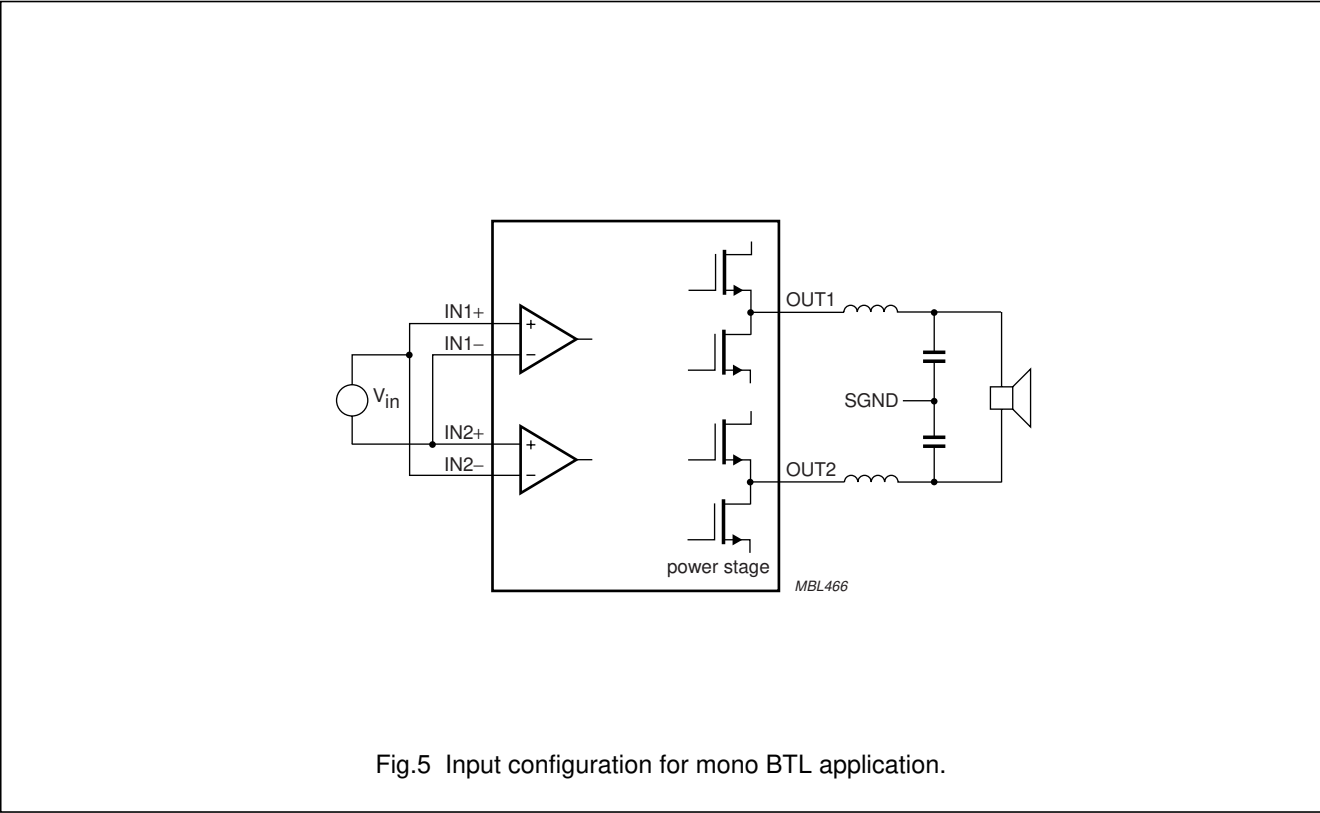


Fig.5 Input configuration for mono BTL application.

**2 × 120 W class-D power amplifier****TDA8924****9 LIMITING VALUES**

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

| SYMBOL            | PARAMETER                             | CONDITIONS           | MIN. | MAX. | UNIT |
|-------------------|---------------------------------------|----------------------|------|------|------|
| V <sub>P</sub>    | supply voltage                        |                      | –    | ±30  | V    |
| V <sub>MODE</sub> | input voltage on pin MODE             | with respect to SGND | –    | 5.5  | V    |
| V <sub>sc</sub>   | short-circuit voltage on output pins  |                      | –    | ±30  | V    |
| I <sub>ORM</sub>  | repetitive peak current in output pin | note 1               | –    | 11.3 | A    |
| T <sub>stg</sub>  | storage temperature                   |                      | –55  | +150 | °C   |
| T <sub>amb</sub>  | ambient temperature                   |                      | –40  | +85  | °C   |
| T <sub>vj</sub>   | virtual junction temperature          |                      | –    | 150  | °C   |

**Note**

1. See also Section 16.6.

**10 THERMAL CHARACTERISTICS**

| SYMBOL               | PARAMETER                                   | CONDITIONS          | VALUE | UNIT |
|----------------------|---|---------------------|-------|------|
| R <sub>th(j-a)</sub> | thermal resistance from junction to ambient | in free air; note 1 | 35    | K/W  |
| R <sub>th(j-c)</sub> | thermal resistance from junction to case    | note 1              | 1.3   | K/W  |

**Note**

1. See also Section 16.5.

**11 QUALITY SPECIFICATION**

In accordance with “SNW-FQ611-part D” if this type is used as an audio amplifier.

$2 \times 120$  W class-D power amplifier

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**12 STATIC CHARACTERISTICS** $V_P = \pm 24$  V;  $T_{amb} = 25$  °C; measured in Fig.9; unless otherwise specified.

| SYMBOL  | PARAMETER                              | CONDITIONS                       | MIN.       | TYP.     | MAX.     | UNIT    |
|---|--|----------------------------------|------------|----------|----------|---------|
| <b>Supply</b>                                       |  |                                  |            |          |          |         |
| $V_P$   | supply voltage                         | note 1                           | $\pm 12.5$ | $\pm 24$ | $\pm 30$ | V       |
| $I_{q(tot)}$  | total quiescent current                | no load connected                | –          | 100      | –        | mA      |
| $I_{stb}$   | standby supply current                 |                                  | –          | 100      | 500      | $\mu$ A |
| <b>Mode select input: pin MODE</b>                  |  |                                  |            |          |          |         |
| $V_{MODE}$  | input voltage                          | note 2                           | 0          | –        | 5.5      | V       |
| $I_{MODE}$  | input current                          | $V_{MODE} = 5.5$ V               | –          | –        | 1000     | $\mu$ A |
| $V_{stb}$   | input voltage for standby mode         | notes 2 and 3                    | 0          | –        | 0.8      | V       |
| $V_{mute}$  | input voltage for mute mode            | notes 2 and 3                    | 2.2        | –        | 3.0      | V       |
| $V_{on}$  | input voltage for operating mode       | notes 2 and 3                    | 4.2        | –        | 5.5      | V       |
| <b>Audio inputs: pins IN2–, IN2+, IN1+ and IN1–</b> |  |                                  |            |          |          |         |
| $V_I$   | DC input voltage                       | note 2                           | –          | 0        | –        | V       |
| <b>Amplifier outputs: pins OUT1 and OUT2</b>        |  |                                  |            |          |          |         |
| $ V_{OO(SE)} $                                      | SE output offset voltage               | operating and mute               | –          | –        | 150      | mV      |
| $ \Delta V_{OO(SE)} $                               | SE variation of output offset voltage  | operating $\leftrightarrow$ mute | –          | –        | 80       | mV      |
| $ V_{OO(BTL)} $                                     | BTL output offset voltage              | operating and mute               | –          | –        | 215      | mV      |
| $ \Delta V_{OO(BTL)} $                              | BTL variation of output offset voltage | operating $\leftrightarrow$ mute | –          | –        | 115      | mV      |
| <b>Stabilizer: pin STABI</b>                        |  |                                  |            |          |          |         |
| $V_{o(stab)}$                                       | stabilizer output voltage              | operating and mute; note 4       | 11         | 13       | 15       | V       |
| <b>Temperature protection</b>                       |  |                                  |            |          |          |         |
| $T_{prot}$  | temperature protection activation      |                                  | 150        | –        | –        | °C      |
| $T_{hys}$   | hysteresis on temperature protection   |                                  | –          | 20       | –        | °C      |

**Notes**

1. The circuit is DC adjusted at  $V_P = \pm 12.5$  V to  $\pm 30$  V.
2. With respect to SGND (0 V).
3. The transition regions between standby, mute and operating mode contain hysteresis (see Fig.6).
4. With respect to  $V_{SSP1}$ .

2 × 120 W class-D power amplifier

TDA8924

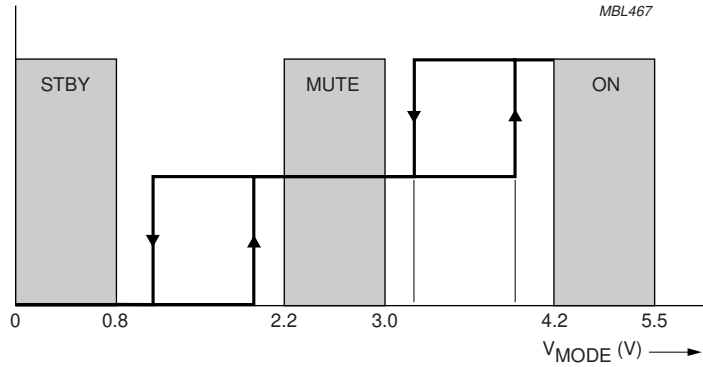


Fig.6 Behaviour of mode selection pin MODE.

13 SWITCHING CHARACTERISTICS

V<sub>DD</sub> = ±24 V; T<sub>amb</sub> = 25 °C; measured in Fig.9; unless otherwise specified.

| SYMBOL   | PARAMETER  | CONDITIONS                 | MIN.       | TYP.       | MAX.     | UNIT |
|--|--|----------------------------|------------|------------|----------|------|
| <b>Internal oscillator; note 1</b>               |  |                            |            |            |          |      |
| f <sub>osc(typ)</sub>                            | typical oscillator frequency   | R <sub>OSC</sub> = 30.0 kΩ | 290        | 317        | 344      | kHz  |
| f <sub>osc</sub>                                 | oscillator frequency   |                            | 210        | –          | 600      | kHz  |
| <b>External oscillator or frequency tracking</b> |  |                            |            |            |          |      |
| V <sub>OSC</sub>                                 | voltage on pin OSC   |                            | SGND + 4.5 | SGND + 5   | SGND + 6 | V    |
| V <sub>OSC(trip)</sub>                           | trip level for tracking at pin OSC                                     |                            | –          | SGND + 2.5 | –        | V    |
| f <sub>track</sub>                               | frequency range for tracking   |                            | 210        | –          | 600      | kHz  |
| V <sub>P(OSC)(ext)</sub>                         | minimum symmetrical supply voltage for external oscillator application |                            | 15         | –          | –        | V    |

Note

1. Frequency set with R<sub>OSC</sub>, according to the formula in Section 8.2.

**2 × 120 W class-D power amplifier****TDA8924****14 DYNAMIC AC CHARACTERISTICS (STEREO AND DUAL SE APPLICATION)**

$V_P = \pm 24$  V;  $R_L = 2$   $\Omega$ ;  $f_i = 1$  kHz;  $f_{osc} = 310$  kHz;  $R_{sL} < 0.1$   $\Omega$  (note 1);  $T_{amb} = 25$  °C; measured in Fig.9; unless otherwise specified.

| SYMBOL         | PARAMETER                       | CONDITIONS   | MIN. | TYP. | MAX. | UNIT       |
|----------------|---------------------------------|--|------|------|------|------------|
| $P_o$          | output power                    | $R_L = 4$ $\Omega$ ; $V_P = \pm 27$ V; THD = 0.5 %; note 2 | –    | 70   | –    | W          |
|                |                                 | $R_L = 4$ $\Omega$ ; $V_P = \pm 27$ V; THD = 10 %; note 2  | –    | 90   | –    | W          |
|                |                                 | $R_L = 3$ $\Omega$ ; $V_P = \pm 27$ V; THD = 0.5 %; note 2 | –    | 93   | –    | W          |
|                |                                 | $R_L = 3$ $\Omega$ ; $V_P = \pm 27$ V; THD = 10 %; note 2  | –    | 115  | –    | W          |
|                |                                 | $R_L = 2$ $\Omega$ ; $V_P = \pm 24$ V; THD = 0.5 %; note 2 | –    | 95   | –    | W          |
|                |                                 | $R_L = 2$ $\Omega$ ; $V_P = \pm 24$ V; THD = 10 %; note 2  | –    | 120  | –    | W          |
| THD            | total harmonic distortion       | $P_o = 1$ W; note 3  | –    | 0.05 | –    | %          |
|                |                                 | $f_i = 1$ kHz  | –    | 0.07 | –    | %          |
|                |                                 | $f_i = 10$ kHz   | –    | –    | –    | –          |
| $G_{V(cl)}$    | closed loop voltage gain        |  | –    | 28   | –    | dB         |
| $\eta$         | efficiency                      | $P_o = 125$ W; note 4                                      | –    | 83   | –    | %          |
| SVRR           | supply voltage ripple rejection | operating; $f_i = 100$ Hz; note 5                          | –    | 55   | –    | dB         |
|                |                                 | operating; $f_i = 1$ kHz; note 6                           | 40   | 50   | –    | dB         |
|                |                                 | mute; $f_i = 100$ Hz; note 5                               | –    | 55   | –    | dB         |
|                |                                 | standby; $f_i = 100$ Hz; note 5                            | –    | 80   | –    | dB         |
| $ Z_i $        | input impedance                 |  | 45   | 68   | –    | k $\Omega$ |
| $V_{n(o)}$     | noise output voltage            | operating; $R_s = 0$ $\Omega$ ; note 7                     | –    | 200  | 400  | $\mu$ V    |
|                |                                 | operating; $R_s = 10$ k $\Omega$ ; note 8                  | –    | 230  | –    | $\mu$ V    |
|                |                                 | mute; note 9   | –    | 220  | –    | $\mu$ V    |
| $\alpha_{cs}$  | channel separation              | note 10  | –    | 70   | –    | dB         |
| $ \Delta G_V $ | channel unbalance               |  | –    | –    | 1    | dB         |
| $V_{o(mute)}$  | output signal in mute           | note 11  | –    | –    | 400  | $\mu$ V    |
| CMRR           | common mode rejection ratio     | $V_{i(CM)} = 1$ V (RMS)                                    | –    | 75   | –    | dB         |

**Notes**

- $R_{sL}$  = series resistance of inductor of low-pass LC filter in the application.
- Output power is measured indirectly; based on  $R_{DS(on)}$  measurement.
- Total harmonic distortion is measured in a bandwidth of 22 Hz to 22 kHz. When distortion is measured using a lower order low-pass filter a significantly higher value is found, due to the switching frequency outside the audio band. Maximum limit is guaranteed but may not be 100 % tested.
- Output power measured across the loudspeaker load.
- $V_{ripple} = V_{ripple(max)} = 2$  V (p-p);  $f_i = 100$  Hz;  $R_s = 0$   $\Omega$ .
- $V_{ripple} = V_{ripple(max)} = 2$  V (p-p);  $f_i = 1$  kHz;  $R_s = 0$   $\Omega$ .
- $B = 22$  Hz to 22 kHz;  $R_s = 0$   $\Omega$ ; maximum limit is guaranteed but may not be 100 % tested.
- $B = 22$  Hz to 22 kHz;  $R_s = 10$  k $\Omega$ .
- $B = 22$  Hz to 22 kHz; independent of  $R_s$ .
- $P_o = 1$  W;  $R_s = 0$   $\Omega$ ;  $f_i = 1$  kHz.
- $V_i = V_{i(max)} = 1$  V (RMS); maximum limit is guaranteed but may not be 100 % tested.

**2 × 120 W class-D power amplifier****TDA8924****15 DYNAMIC AC CHARACTERISTICS (MONO BTL APPLICATION)**

$V_P = \pm 24$  V;  $R_L = 4 \Omega$ ;  $f_i = 1$  kHz;  $f_{osc} = 310$  kHz;  $R_{sL} < 0.1 \Omega$  (note 1);  $T_{amb} = 25$  °C; measured in Fig.9; unless otherwise specified.

| SYMBOL               | PARAMETER                       | CONDITIONS   | MIN. | TYP.  | MAX. | UNIT       |
|----------------------|---------------------------------|--|------|-------|------|------------|
| P <sub>o</sub>       | output power                    | $R_L = 3 \Omega$ ; $V_P = \pm 20$ V; THD = 0.5 %; note 2 | –    | 160   | –    | W          |
|                      |                                 | $R_L = 3 \Omega$ ; $V_P = \pm 20$ V; THD = 10 %; note 2  | –    | 205   | –    | W          |
|                      |                                 | $R_L = 4 \Omega$ ; $V_P = \pm 20$ V; THD = 0.5 %; note 2 | –    | 135   | –    | W          |
|                      |                                 | $R_L = 4 \Omega$ ; $V_P = \pm 20$ V; THD = 10 %; note 2  | –    | 175   | –    | W          |
|                      |                                 | $R_L = 4 \Omega$ ; $V_P = \pm 24$ V; THD = 0.5 %; note 2 | –    | 200   | –    | W          |
|                      |                                 | $R_L = 4 \Omega$ ; $V_P = \pm 24$ V; THD = 10 %; note 2  | –    | 240   | –    | W          |
| THD                  | total harmonic distortion       | $P_o = 1$ W; note 3<br>$f_i = 100$ Hz                    | –    | 0.015 | –    | %          |
|                      |                                 | $f_i = 1$ kHz  | –    | 0.015 | 0.05 | %          |
|                      |                                 | $f_i = 10$ kHz   | –    | 0.015 | –    | %          |
| G <sub>v(cl)</sub>   | closed loop voltage gain        |  | –    | 34    | –    | dB         |
| $\eta$               | efficiency                      | $P_o = 240$ W; note 4                                    | –    | 83    | –    | %          |
| SVRR                 | supply voltage ripple rejection | operating; $f_i = 100$ Hz; note 5                        | –    | 49    | –    | dB         |
|                      |                                 | operating; $f_i = 1$ kHz; note 6                         | 36   | 44    | –    | dB         |
|                      |                                 | mute; $f_i = 100$ Hz; note 5                             | –    | 49    | –    | dB         |
|                      |                                 | standby; $f_i = 100$ Hz; note 5                          | –    | 80    | –    | dB         |
| Z <sub>i</sub>       | input impedance                 |  | 22   | 34    | –    | k $\Omega$ |
| V <sub>n(o)</sub>    | noise output voltage            | operating; $R_s = 0 \Omega$ ; note 7                     | –    | 280   | 560  | $\mu$ V    |
|                      |                                 | operating; $R_s = 10$ k $\Omega$ ; note 8                | –    | 300   | –    | $\mu$ V    |
|                      |                                 | mute; note 9   | –    | 280   | –    | $\mu$ V    |
| V <sub>o(mute)</sub> | output signal in mute           | note 10  | –    | –     | 500  | $\mu$ V    |
| CMRR                 | common mode rejection ratio     | V <sub>i(CM)</sub> = 1 V (RMS)                           | –    | 75    | –    | dB         |

**Notes**

1.  $R_{sL}$  = series resistance of inductor of low-pass LC filter in the application.
2. Output power is measured indirectly; based on  $R_{DSon}$  measurement.
3. Total harmonic distortion is measured in a bandwidth of 22 Hz to 22 kHz. When distortion is measured using a low order low-pass filter a significant higher value will be found, due to the switching frequency outside the audio band. Maximum limit is guaranteed but may not be 100 % tested.
4. Output power measured across the loudspeaker load.
5.  $V_{ripple} = V_{ripple(max)} = 2$  V (p-p);  $f_i = 100$  Hz;  $R_s = 0 \Omega$ .
6.  $V_{ripple} = V_{ripple(max)} = 2$  V (p-p);  $f_i = 1$  kHz;  $R_s = 0 \Omega$ .
7.  $B = 22$  Hz to 22 kHz;  $R_s = 0 \Omega$ ; maximum limit is guaranteed but may not be 100 % tested.
8.  $B = 22$  Hz to 22 kHz;  $R_s = 10$  k $\Omega$ .
9.  $B = 22$  Hz to 22 kHz; independent of  $R_s$ .
10.  $V_i = V_{i(max)} = 1$  V (RMS);  $f_i = 1$  kHz; maximum limit is guaranteed but may not be 100 % tested.

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16 APPLICATION INFORMATION

16.1 BTL application

When using the power amplifier in a mono BTL application (for more output power), the inputs of both channels must be connected in parallel; the phase of one of the inputs must be inverted; see Fig.5. In principle the loudspeaker can be connected between the outputs of the two single-ended demodulation filters.

16.2 Pin MODE

For correct operation the switching voltage at pin MODE should be debounced. If pin MODE is driven by a mechanical switch an appropriate debouncing low-pass filter should be used. If pin MODE is driven by an electronic circuit or microcontroller then it should remain at the mute voltage level for at least 100 ms before switching back to the standby voltage level.

16.3 Output power estimation

The output power in several applications (SE and BTL) can be estimated using the following expressions:

$$SE: P_{o(1\%)} = \frac{\left[ \frac{R_L}{R_L + 0.6} \times V_P \times (1 - t_{min} \times f_{osc}) \right]^2}{2 \times R_L}$$

Maximum current:

$$I_{o(peak)} = \frac{V_P \times (1 - t_{min} \times f_{osc})}{R_L + 0.6} \text{ should not exceed 12 A.}$$

$$BTL: P_{o(1\%)} = \frac{\left[ \frac{R_L}{R_L + 1.2} \times 2V_P \times (1 - t_{min} \times f_{osc}) \right]^2}{2 \times R_L}$$

Maximum current:

$$I_{o(peak)} = \frac{2V_P \times (1 - t_{min} \times f_{osc})}{R_L + 1.2} \text{ should not exceed 12 A.}$$

Legend:

$R_L$  = load impedance

$f_{osc}$  = oscillator frequency

$t_{min}$  = minimum pulse width (typical 190 ns)

$V_P$  = single-sided supply voltage (so if supply  $\pm 30$  V symmetrical, then  $V_P = 30$  V)

$P_{o(1\%)}$  = output power just at clipping

$P_{o(10\%)}$  = output power at THD = 10 %

$P_{o(10\%)} = 1.25 \times P_{o(1\%)}$ .

16.4 External clock

The minimum required symmetrical supply voltage for external clock application is  $\pm 15$  V (equally, the minimum asymmetrical supply voltage for applications with an external clock is 30 V).

When using an external clock the duty cycle of the external clock has to be between 47.5 % and 52.5 %.

A possible solution for an external clock oscillator circuit is illustrated in Fig.7.

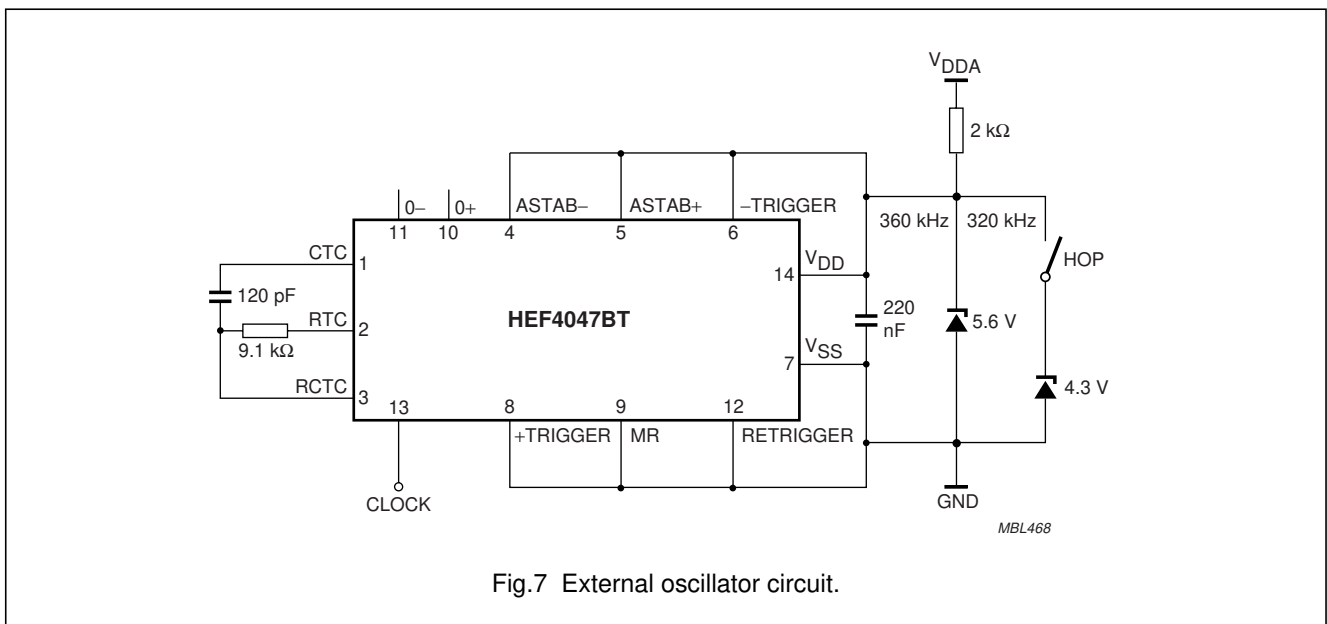


Fig.7 External oscillator circuit.



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16.5 Heatsink requirements

Although the TDA8924 is a class-D amplifier a heatsink is required. Reason is that though efficiency is high, the output power is high as well, resulting in heating up of the device. The relation between temperatures, dissipation and thermal behaviour is given below.

$$R_{th(j-a)} = \frac{T_{j(max)} - T_A}{P_{diss}}$$

$P_{diss}$  is determined by the efficiency ( $\eta$ ) of the TDA8924. The efficiency measured in the TDA8924 as a function of output power is given in Figs. 17 and 18. The power dissipation can be derived as function of output power; see Figs. 15 and 16.

The derating curves (given for several values of the  $R_{th(j-a)}$ ) are illustrated in Fig.8. A maximum junction temperature  $T_j = 150\text{ }^\circ\text{C}$  is taken into account. From Fig.8 the maximum allowable power dissipation for a given heatsink size can be derived or the required heatsink size can be determined at a required dissipation level.

Example:

$$P_o = 2 \times 100\text{ W into } 2\ \Omega$$

$$T_{j(max)} = 150\text{ }^\circ\text{C}$$

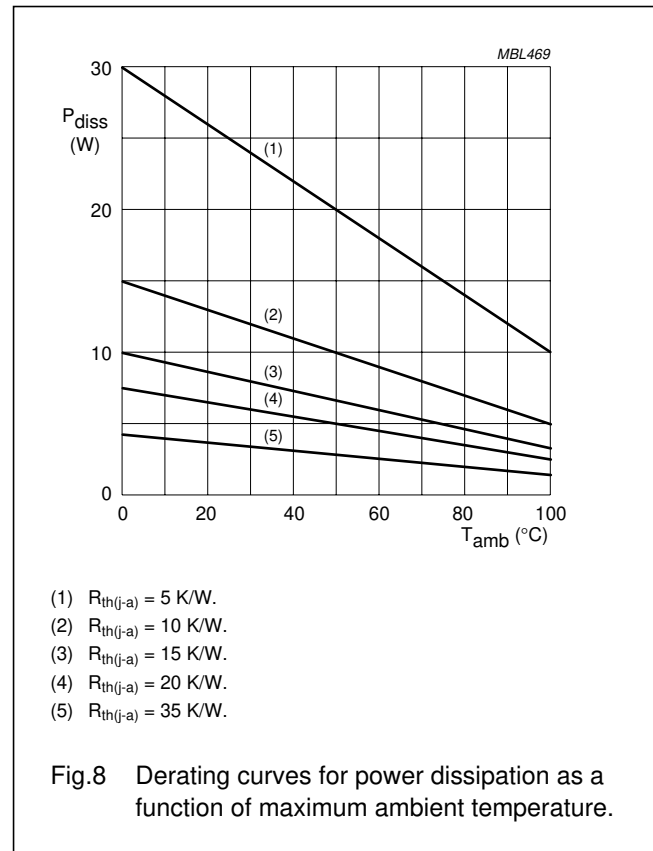
$$T_{amb} = 60\text{ }^\circ\text{C}$$

$$P_{diss(tot)} = 37\text{ W (see Fig.15).}$$

The required  $R_{th(j-a)} = 2.43\text{ K/W}$  can be calculated.

The  $R_{th(j-a)}$  of the TDA8924 in free air is 35 K/W; the  $R_{th(j-c)}$  of the TDA8924 is 1.3 K/W, thus a heatsink of 1.13 K/W is required for this example.

This example demonstrates that one might end up with unrealistically low  $R_{th(j-a)}$  figure. It has to be kept in mind that in actual applications, other factors such as the average power dissipation with a music source (as opposed to a continuous sine wave) will determine the size of the heatsink required.



16.6 Output current limiting

To guarantee the robustness of the class-D amplifier the maximum output current which can be delivered by the output stage is limited. An overcurrent protection is included for each output power switch. When the current flowing through any of the power switches exceeds a defined internal threshold (e.g. in case of a short-circuit to the supply lines or a short-circuit across the load), the amplifier will shut down immediately and an internal timer will be started. After a fixed time (e.g. 100 ms) the amplifier is switched on again. If the requested output current is still too high the amplifier will switch-off again. Thus the amplifier will try to switch to the operating mode every 100 ms. The average dissipation will be low in this situation because of this low duty cycle. If the overcurrent condition is removed the amplifier will remain operating.

Because the duty cycle is low the amplifier will be switched off for a relatively long period of time, which will be noticed as a so-called audio-hole; an audible interruption in the output signal.

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To trigger the maximum current protection in the TDA8924, the required output current must exceed 12 A. This situation occurs in case of:

- Short-circuits from any output terminal to the supply lines ( $V_{DD}$  or  $V_{SS}$ )
- Short-circuit across the load or speaker impedances or a load impedance below the specified values of 2 Ω and 4 Ω.

Even if load impedances are connected to the amplifier outputs which have an impedance rating of 4 Ω, this impedance can be lower due to the frequency characteristic of the loudspeaker; practical loudspeaker impedances can be modelled as an RLC network which will have a specific frequency characteristic: the impedance at the output of the amplifier will vary with the input frequency. A high supply voltage in combination with a low impedance will result in large current requirements.

Another factor which must be taken into account is the ripple current which will also flow through the output power switches. This ripple current depends on the inductor values which are used, supply voltage, oscillator frequency, duty factor and minimum pulse width. The maximum available output current to drive the load impedance can be calculated by subtracting the ripple current from the maximum repetitive peak current in the output pin, which is 11.3 A for the TDA8924.

As a rule of thumb the following expressions can be used to determine the minimum allowed load impedance without generating audio holes:

$$Z_L \geq \frac{V_P(1 - t_{\min} f_{\text{osc}})}{I_{\text{ORM}} - I_{\text{ripple}}} - 0.6 \quad \text{for SE application.}$$

$$Z_L \geq \frac{2V_P(1 - t_{\min} f_{\text{osc}})}{I_{\text{ORM}} - I_{\text{ripple}}} - 1.2 \quad \text{for BTL application.}$$

Legend:

$Z_L$  = load impedance

$f_{\text{osc}}$  = oscillator frequency

$t_{\min}$  = minimum pulse width (typical 190 ns)

$V_P$  = single-sided supply voltage (if the supply = ±30 V symmetrical, then  $V_P = 30$  V)

$I_{\text{ORM}}$  = maximum repetitive peak current in output pin; see also Chapter 9

$I_{\text{ripple}}$  = ripple current.

Output current limiting goes with a signal on the protection pin (pin PROT). This pin is HIGH under normal operation. It goes LOW when current protection takes place.

This signal could be used by a signal processor. In order to filter the protection signal a capacitor can be connected between pin PROT and  $V_{SS}$ . However, this capacitor slows down the protective action as well as it filters the signal. Therefore, the value of the capacitor should be limited to a maximum value of 47 pF.

For a more detailed description of the implications of output current limiting see also the application notes (tbf).

### 16.7 Pumping effects

The TDA8924 class-D amplifier is supplied by a symmetrical voltage (e.g.  $V_{DD} = +24$  V,  $V_{SS} = -24$  V). When the amplifier is used in a SE configuration, a so-called 'pumping effect' can occur. During one switching interval energy is taken from one supply (e.g.  $V_{DD}$ ), while a part of that energy is delivered back to the other supply line (e.g.  $V_{SS}$ ) and visa versa. When the voltage supply source cannot sink energy the voltage across the output capacitors of that voltage supply source will increase: the supply voltage is pumped to higher levels.

The voltage increase caused by the pumping effect depends on:

- Speaker impedance
- Supply voltage
- Audio signal frequency
- Capacitor value present on supply lines
- Source and sink currents of other channels.

The pumping effect should not cause a malfunction of either the audio amplifier and/or the voltage supply source. For instance, this malfunction can be caused by triggering of the undervoltage or overvoltage protection or unbalance protection of the amplifier. The overvoltage protection is only meant to prevent the amplifier from supply pumping effects.

For a more detailed description of this phenomenon see the application notes (tbf).

### 16.8 Reference design

The reference design for the single-chip class-D audio amplifier using the TDA8924 is illustrated in Fig.9. The Printed-Circuit Board (PCB) layout is shown in Fig.10. The Bill Of Materials (BOM) is given in Table 1.

2 × 120 W class-D power amplifier

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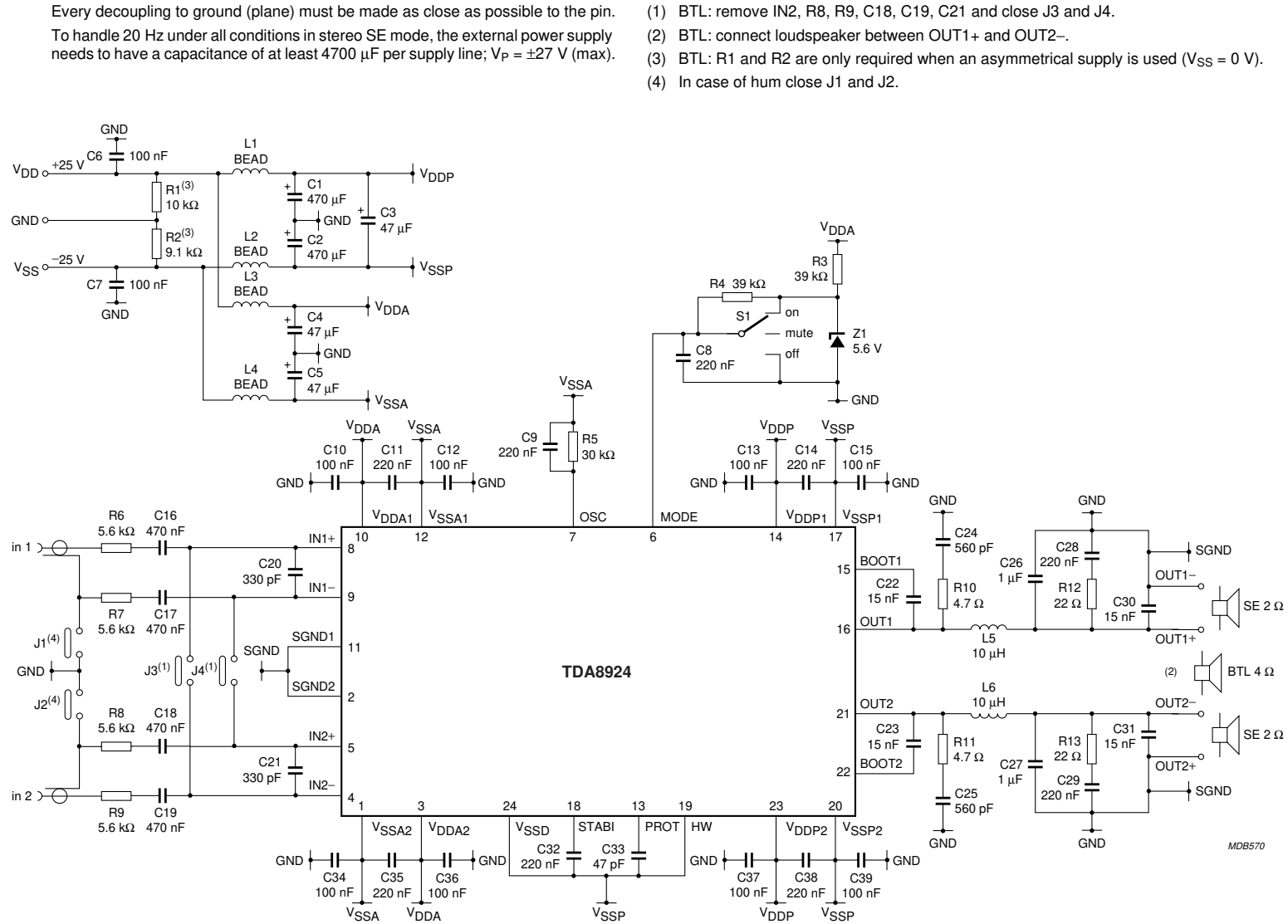


Fig.9 Single-chip class-D audio amplifier application diagram.

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**2 × 120 W class-D power amplifier****TDA8924**

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**16.9 PCB information for HSOP24 encapsulation**

The size of the printed-circuit board is 74.3 × 59.10 mm, dual-sided 35 µm copper with 121 metallized through holes.

The standard configuration is a symmetrical supply (typical ±24 V) with stereo SE outputs (typical 2 × 4 Ω).

The printed-circuit board is also suitable for mono BTL configuration (1 × 8 Ω) also for symmetrical supply and for asymmetrical supply.

It is possible to use several different output filter inductors such as 16RHBP or EP13 types to evaluate the performance against the price or size.

**16.10 Classification**

The application shows optimized signal and EMI performance.

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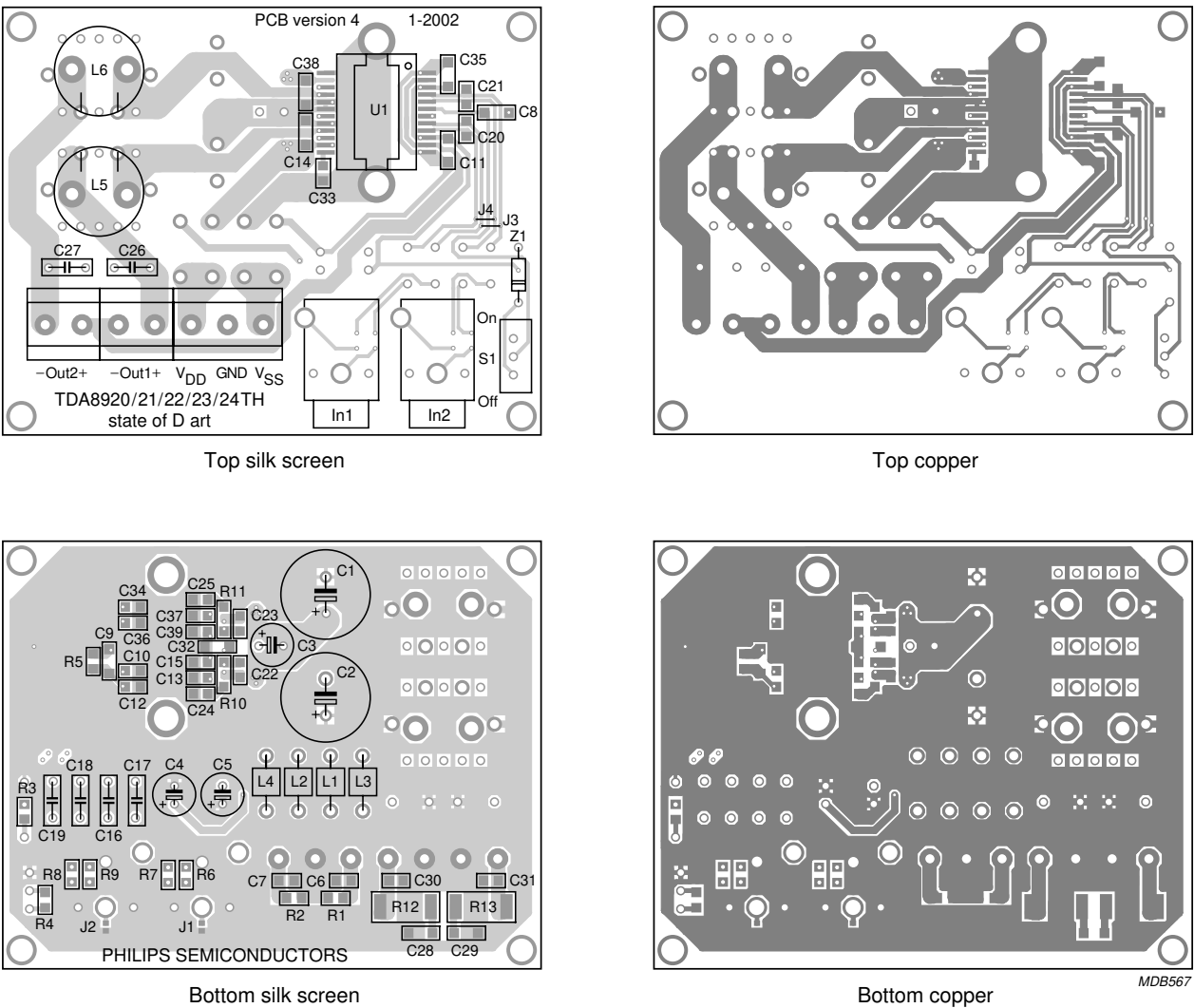


Fig.10 Printed-circuit board layout for the TDA8924TH (some of the components showed on the top silk side have to be mounted on the bottom side for a proper heatsink fitting).

$2 \times 120$  W class-D power amplifier

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**16.11 Reference design: bill of materials****Table 1** Single-chip class-D audio amplifier printed-circuit board (version 4; 01-2002) for TDA8924TH (see Figs 9 and 10)

| BOM ITEM | QUANTITY | REFERENCE   | PART  | DESCRIPTION                     |
|----------|----------|---|---|---------------------------------|
| 1        | 1        | U1  | TDA8924TH   | Philips Semiconductors B.V.     |
| 2        | 2        | in1 and in2                                       | cinch inputs  | Farnell 152-396                 |
| 3        | 2        | out1 and out2                                     | output connector  | Augat 5KEV-02                   |
| 4        | 1        | V <sub>DD</sub> , GND and V <sub>SS</sub>         | supply connector  | Augat 5KEV-03                   |
| 5        | 2        | L5 and L6   | 10 $\mu$ H  | EP13 or 16RHBP (TOKO); note 1   |
| 6        | 4        | L1, L2, L3 and L4                                 | BEAD  | Murata BL01RN1-A62              |
| 7        | 1        | S1  | PCB switch  | Knitter ATE1E M-O-M             |
| 8        | 1        | Z1  | 5V6   | BZX 79C5V6 DO-35                |
| 9        | 2        | C1 and C2   | 470 $\mu$ F; 35 V   | Panasonic M series ECA1VM471    |
| 10       | 3        | C3, C4 and C5                                     | 47 $\mu$ F; 63 V  | Panasonic NHG series ECA1JHG470 |
| 11       | 6        | C16, C17, C18 and C19                             | 470 nF; 63 V  | MKT EPCOS B32529- 0474- K       |
| 12       | 9        | C8, C9, C11, C14, C28, C29, C32, C35 and C38      | 220 nF; 63 V  | SMD 1206                        |
| 13       | 10       | C6, C7, C10, C12, C13, C15, C34, C36, C37 and C39 | 100 nF; 50 V  | SMD 0805                        |
| 14       | 2        | C20 and C21                                       | 330 pF; 50 V  | SMD 0805                        |
| 15       | 4        | C22, C23, C30 and C31                             | 15 nF; 50 V   | SMD 0805                        |
| 16       | 2        | C24, C25  | 560 pF; 100 V   | SMD 0805                        |
| 17       | 1        | C33   | 47 pF; 25V  | SMD 0805                        |
| 18       | 2        | R3 and R4   | 39 k $\Omega$ ; 0.1 W   | SMD 0805                        |
| 19       | 1        | R5  | 30 k $\Omega$ ; 0.1 W   | SMD 1206                        |
| 20       | 1        | R1  | 10 k $\Omega$ ; 0.1 W; optional   | SMD 0805                        |
| 21       | 1        | R2  | 9.1 k $\Omega$ ; 0.1 W; optional  | SMD 0805                        |
| 22       | 4        | R6, R7, R8 and R9                                 | 5.6 k $\Omega$ ; 0.1 W  | SMD 0805                        |
| 23       | 2        | R12 and R13                                       | 22 $\Omega$ ; 1 W   | SMD 2512                        |
| 24       | 2        | R10 and R11                                       | 4.7 $\Omega$ ; 0.25 W   | SMD 1206                        |
| 25       | 2        | C26 and C27                                       | 1 $\mu$ F; 63V  | MKT                             |
| 26       | 1        | heatsink  | SK 174 50 mm (5 K/W) Fisher elektronik  |                                 |
| 27       | 1        | printed-circuit board material                    | 1.6 mm thick epoxy FR4 material, dual-sided 35 $\mu$ m copper; clearances 300 $\mu$ m; minimum copper track 400 $\mu$ m |                                 |

**Note**

1. EP13 or 16RHBP inductors have been used in the first demo boards. In these boards, they functioned properly. However current rating basically is too low. A better choice is the new TOKO DASM 998AM-105 inductor.

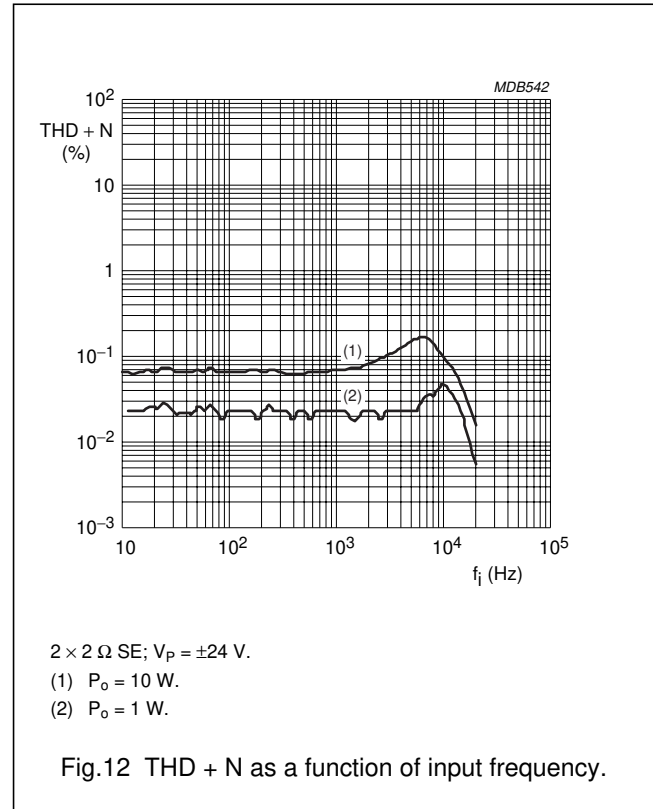
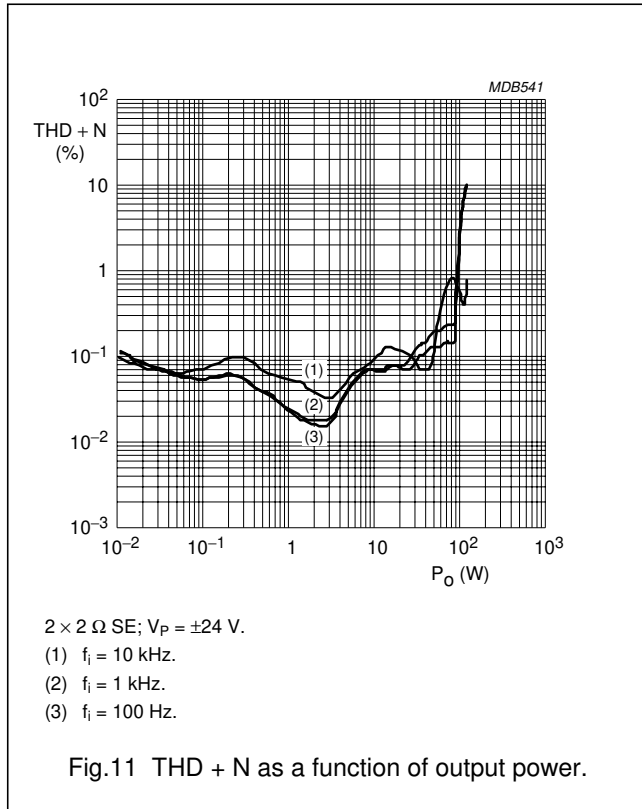
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16.12 Curves measured in the reference design

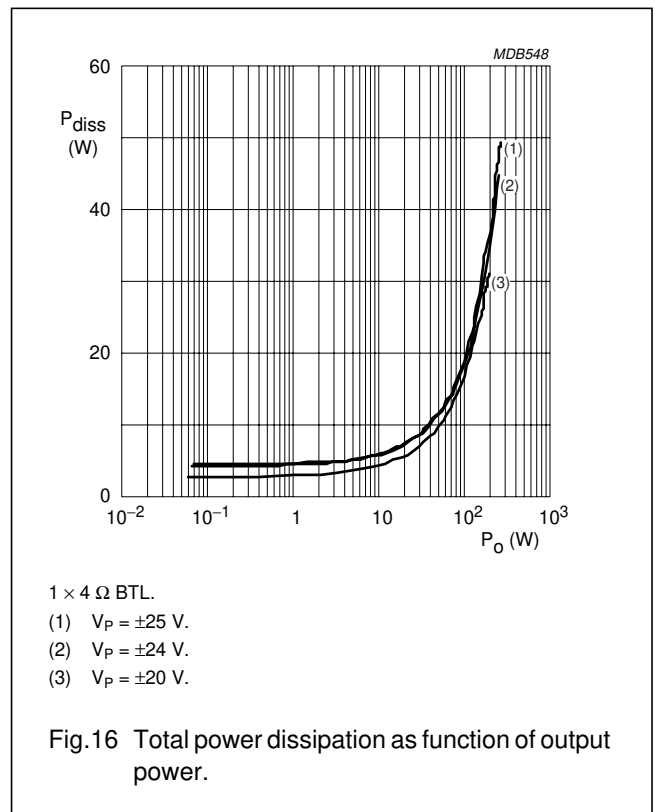
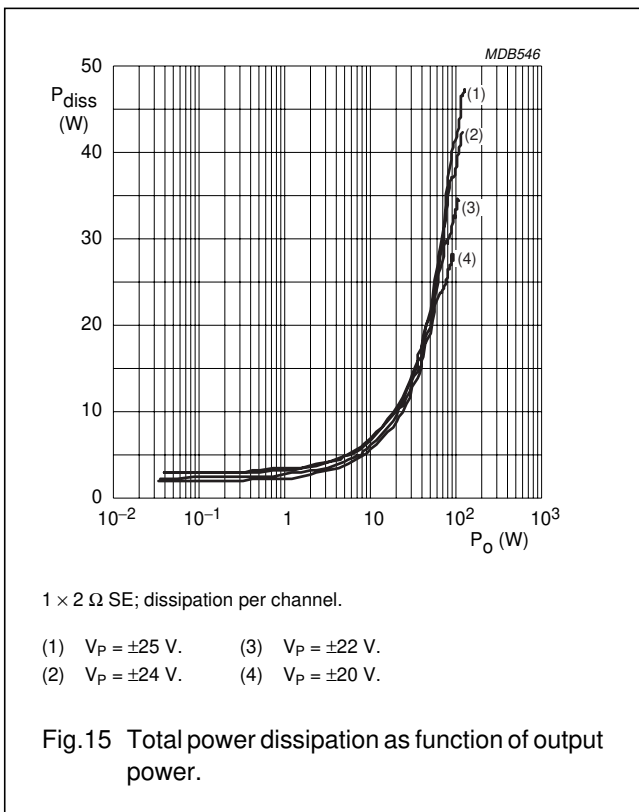
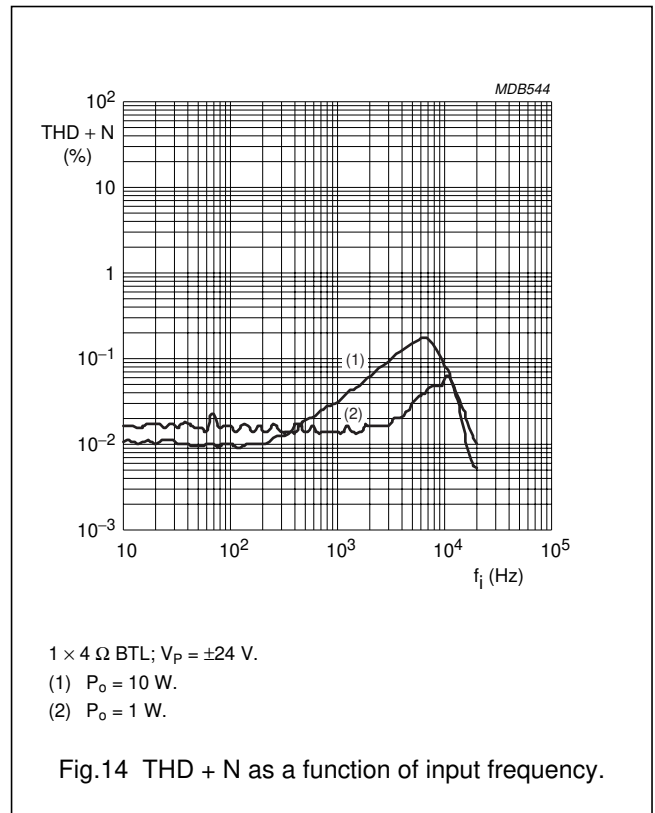
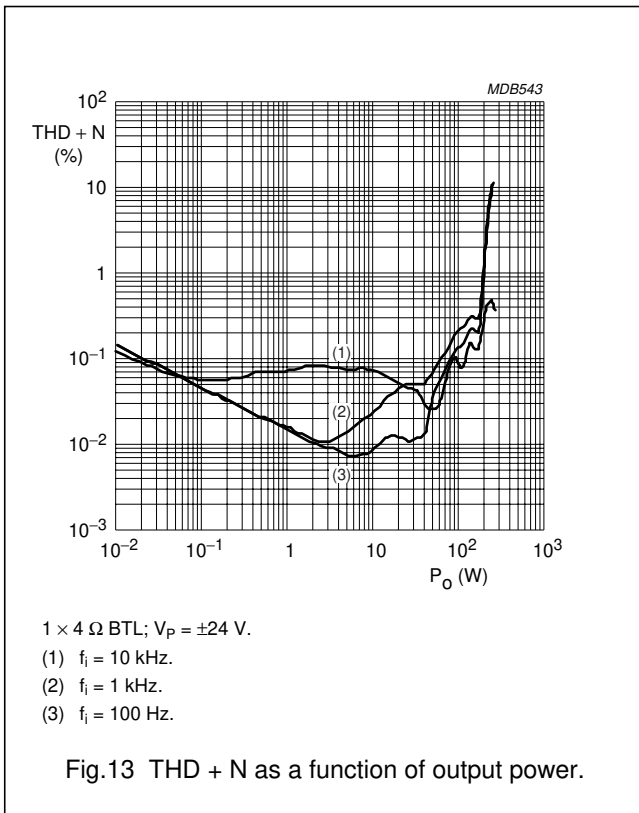
The curves illustrated in Figs 19 and 20 are measured with a resistive load impedance. Spread in  $R_L$  (e.g. due to the frequency characteristics of the loudspeaker) can trigger the maximum current protection circuit; see Section 16.6.

The curves illustrated in Figs 29 and 30 show the effects of supply pumping when only one single-ended channel is driven with a low frequency signal; see Section 16.7.



2 × 120 W class-D power amplifier

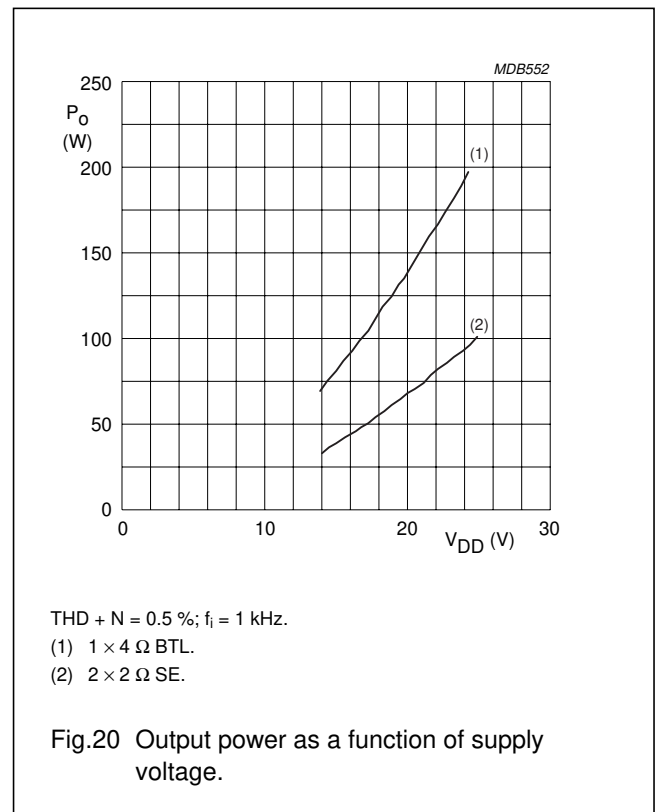
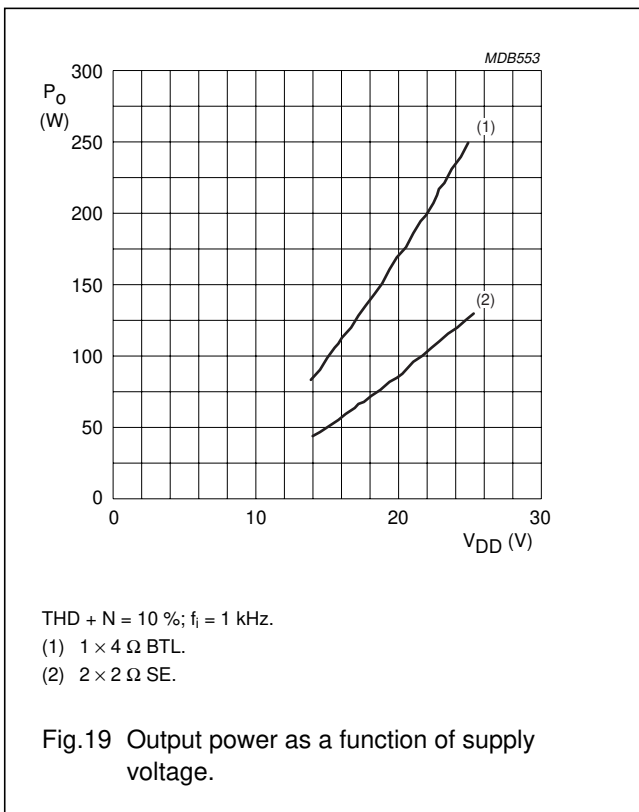
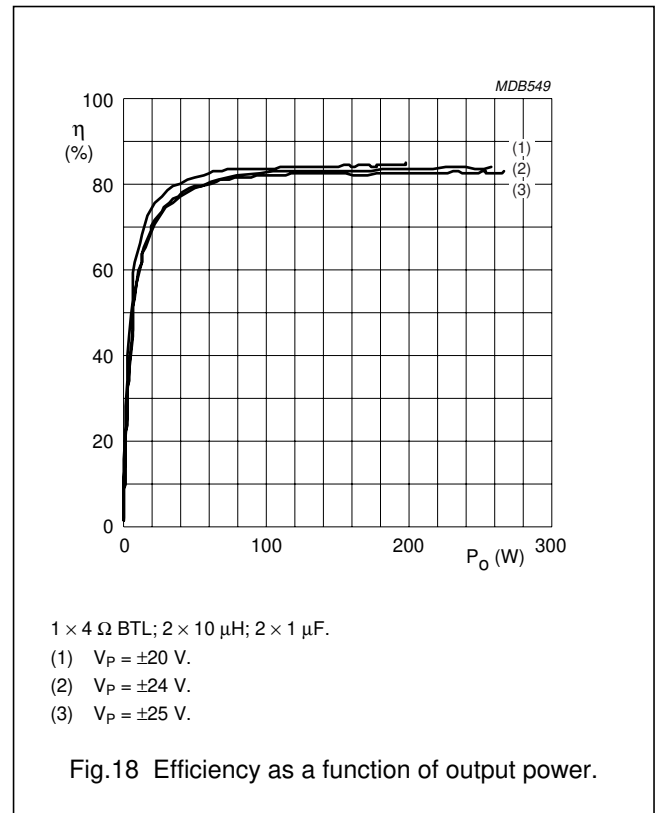
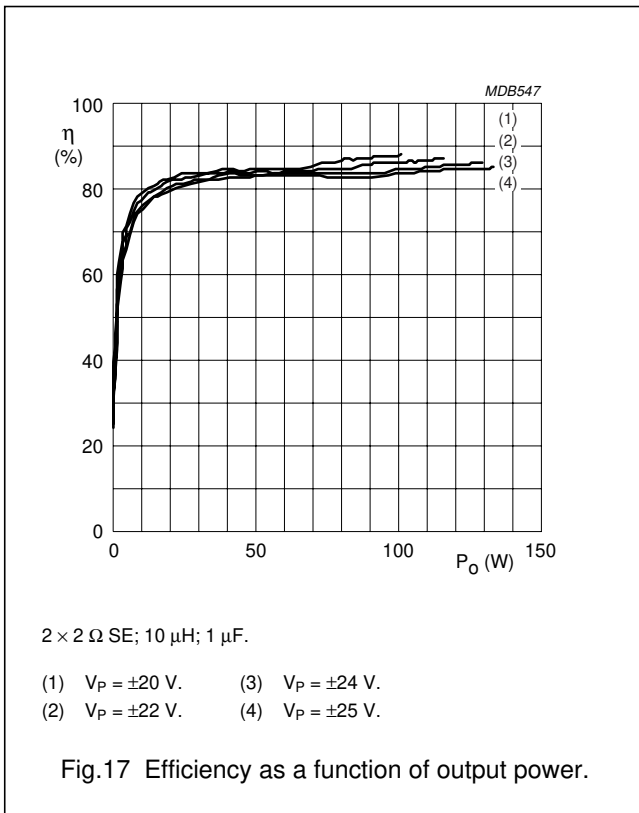
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2 × 120 W class-D power amplifier

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2 × 120 W class-D power amplifier

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