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<tr>
<td>Abstract</td>
<td>This document contains application information for the TDA1562Q class H amplifier.</td>
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**Contact information**

For additional information, please visit: [http://www.semiconductors.philips.com](http://www.semiconductors.philips.com)

For sales office addresses, please send an email to: sales.addresses@www.semiconductors.philips.com
1. Introduction

1.1 Amplifier description

The TDA1562Q is a mono BTL amplifier, capable of delivering 70W into a 4 Ω load at a supply voltage of 14.4 V, without the need to use an external DC-DC converter to achieve a higher supply voltage. The high output power is achieved by means of a Class H circuit, which enables the amplifier to almost double its supply voltage at moments when more than 20W output power is needed. Since the supply voltage will only be raised when it is necessary, the TDA1562Q will dissipate less power than a comparable Class AB amplifier operating at a constant high supply voltage.

Although originally designed for automotive applications, the high efficiency, high output power and simple application make the TDA1562Q very suitable for applications where high output powers and small size are important, such as active loudspeakers or small Hi-Fi sets.

This document describes how the TDA1562Q class H amplifier can best be applied. Information will be given about the principle and advantages of class H amplifiers and the properties and features of the amplifier will be explained. Furthermore, information will be given about the design of an application that will achieve the best possible performance with the device.

1.2 The Class H principle

Class H is basically a further development of the class G concept.

A class G amplifier uses two separate power supplies, one with a relatively low voltage and one with a high output voltage.

As long as the signal is at a low level, only the low supply voltage is used. Only when more output power is needed than the amplifier can deliver with the low supply voltage, the amplifier is connected to the high supply voltage.

Music signals consist for a great part of low level signals, so with a music signal, the amplifier is mainly using the low supply voltage.

The main advantage of this principle is that the power dissipation of the amplifier is lower than that of an amplifier which is constantly connected to a high supply voltage, since the supply voltage is one of the main factors which determine the power dissipation in an amplifier.

In a car, only one supply voltage is available, 14.4V, so for higher output powers than 25W into 4 Ω the supply voltage must be raised artificially. This is often done by means of DC–DC converters. These circuits have a number of disadvantages. First of all, a number of extra components are needed. Secondly, most DC–DC converters use high switching frequencies which may cause interference, so the correct design of a DC-DC converter is a difficult task. Since the supply lifting circuitry in the TDA1562Q follows the input signal, no extremely high frequencies will occur in the supply.
The class H amplifier uses an internal circuit to create its own high supply voltage. The only additional components necessary to create this high supply voltage are two electrolytic capacitors with a sufficient capacitance to store energy for low frequency operation.

The schematic in fig.1 shows how the class H amplifier is built up.

Principally, the output stage is a normal class AB BTL output stage. The special feature of the class H amplifier lies in the way the supply is connected to the output stage.

In a normal class AB amplifier the collectors of output transistors T1 and T3 would be directly connected to the positive supply rail. The output stage of the class H amplifier however, is connected to the power supply (by means of power diodes D1 and D2) and the + terminals of the lifter capacitors C1 and C2.

When the output power that is required is below 10W, transistors T7 and T8 will be driven, connecting the negative terminal of the lifter capacitors C1 and C2 to ground. This allows the lifter capacitors to be charged to near the supply voltage level.

When more output power is required, transistors T7 and T8 will be shut down, and transistors T5 and T6 will start conducting, lifting the negative terminal of the lifter capacitors to a higher voltage. The negative terminals of the lifter capacitors can be lifted to approximately the supply voltage.

When the negative terminal of the lifter capacitors is lifted, the voltage at the positive terminal of the lifter capacitors will be lifted above the supply voltage, so the lifter capacitors will start acting as power supply for the power transistors. By this mechanism, the supply voltage of the output stage can effectively be lifted to nearly twice the supply voltage coming from the battery.

While the supply voltage of the output stage is lifted above the actual supply voltage, the amplifier relies on the energy stored in the capacitors. This means that especially for low frequencies the capacitors must be able to store much energy. For proper operation at low frequencies it is therefore necessary that large lifter capacitors are used.
Figure 2 shows the equivalent circuits for when the lifter capacitors are being charged (charge cycle) and for when the supply is lifted maximally.

During the charge cycle, the total supply current consists of the sum of the charge current for the lifter capacitor (Clift) and the audio current. The charge current is controlled by the lift/recharge control circuitry in such a manner that the power dissipation in the charging circuitry will never exceed the maximum safe level. The maximum value of the charge current is approximately 5A.

When the power supply is lifted, the lifter capacitors will provide the audio current, so the power that can be delivered by the amplifier fully depends on the energy stored in the lifter capacitors.

Since the supply voltage of the output stage can be lifted to almost twice the standard supply voltage, the output power of this amplifier can become almost 4 times as high as that of a standard class AB BTL amplifier which would be between 80 and 100W at a THD of 10% with a supply voltage of 14.4V. In practice there are some additional voltage losses in the supply line, so the actual output power at 14.4V and a THD of 10% will be 70W.
1.3 Block diagram

Fig 3. Block diagram of the TDA1562
1.4 Pinning

Table 1: Pinning of the TDA1562Q

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>PIN</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>IN+</td>
<td>1</td>
<td>Signal input (positive)</td>
</tr>
<tr>
<td>IN-</td>
<td>2</td>
<td>Signal input (negative)</td>
</tr>
<tr>
<td>C1-</td>
<td>3</td>
<td>Negative terminal of lift electrolytic capacitor 1</td>
</tr>
<tr>
<td>MODE</td>
<td>4</td>
<td>Mode select input</td>
</tr>
<tr>
<td>C1+</td>
<td>5</td>
<td>Positive terminal of lift electrolytic capacitor 1</td>
</tr>
<tr>
<td>PGND1</td>
<td>6</td>
<td>Power ground 1</td>
</tr>
<tr>
<td>OUT+</td>
<td>7</td>
<td>Positive output</td>
</tr>
<tr>
<td>DIAG</td>
<td>8</td>
<td>Diagnostic output (open collector)</td>
</tr>
<tr>
<td>Vp1</td>
<td>9</td>
<td>Supply voltage 1</td>
</tr>
<tr>
<td>Vp2</td>
<td>10</td>
<td>Supply voltage 2</td>
</tr>
<tr>
<td>OUT-</td>
<td>11</td>
<td>Negative output</td>
</tr>
<tr>
<td>PGND2</td>
<td>12</td>
<td>Power ground 2</td>
</tr>
<tr>
<td>C2+</td>
<td>13</td>
<td>Positive terminal of lift electrolytic capacitor 2</td>
</tr>
<tr>
<td>Vref</td>
<td>14</td>
<td>Internal reference voltage</td>
</tr>
<tr>
<td>C2-</td>
<td>15</td>
<td>Negative terminal of lift electrolytic capacitor 2</td>
</tr>
<tr>
<td>STAT</td>
<td>16</td>
<td>Status I/O</td>
</tr>
<tr>
<td>SGND</td>
<td>17</td>
<td>Signal ground</td>
</tr>
</tbody>
</table>
1.5 Quick reference data

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>MIN.</th>
<th>TYP.</th>
<th>MAX.</th>
<th>UNIT</th>
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<tr>
<td>Vp</td>
<td>supply voltage</td>
<td>operating; note 1</td>
<td>8</td>
<td>14.4</td>
<td>18</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>non-operating</td>
<td>–</td>
<td>–</td>
<td>30</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>load dump</td>
<td>–</td>
<td>–</td>
<td>45</td>
<td>V</td>
</tr>
<tr>
<td>Iq</td>
<td>quiescent current</td>
<td>on and mute; RL = open circuit</td>
<td>–</td>
<td>110</td>
<td>150</td>
<td>mA</td>
</tr>
<tr>
<td>Isb</td>
<td>standby current</td>
<td>standby</td>
<td>–</td>
<td>3</td>
<td>50</td>
<td>μA</td>
</tr>
<tr>
<td></td>
<td>output offset voltage</td>
<td>on and mute</td>
<td>–</td>
<td>–</td>
<td>100</td>
<td>mV</td>
</tr>
<tr>
<td></td>
<td>delta output offset voltage</td>
<td>on ↔ mute</td>
<td>–</td>
<td>–</td>
<td>30</td>
<td>mV</td>
</tr>
<tr>
<td>Gv</td>
<td>voltage gain</td>
<td></td>
<td>25</td>
<td>26</td>
<td>27</td>
<td>dB</td>
</tr>
<tr>
<td></td>
<td>differential input impedance</td>
<td></td>
<td>90</td>
<td>150</td>
<td>–</td>
<td>kΩ</td>
</tr>
<tr>
<td>Po</td>
<td>output power</td>
<td>THD = 0.5%</td>
<td>45</td>
<td>55</td>
<td>–</td>
<td>W</td>
</tr>
<tr>
<td></td>
<td></td>
<td>THD = 10%</td>
<td>60</td>
<td>70</td>
<td>–</td>
<td>W</td>
</tr>
<tr>
<td>THD</td>
<td>total harmonic distortion</td>
<td>P0 = 1 W</td>
<td>–</td>
<td>0.03</td>
<td>–</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P0 = 20 W</td>
<td>–</td>
<td>0.06</td>
<td>–</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DDD active</td>
<td>–</td>
<td>2.1</td>
<td>–</td>
<td>%</td>
</tr>
</tbody>
</table>
2. Features and Diagnostics

The TDA 1562Q is equipped with three pins with which a number of functions and features can be controlled and which can give information about the status of the device.

2.1 The Mode select pin

First of all, the Mode Select pin controls switching on and off of the device. By controlling the voltage at the mode select pin, the device can be switched into the mute condition and into the operating condition. The transition levels (thresholds) specified in the data sheet are maximum and minimum values. For instance when the threshold for stand-by to mute is specified at 2V (maximum) and the threshold for mute to stand-by is specified at 1V (minimum), the actual values will be between 1 and 2 V. Between the two threshold levels there is a hysteresis of 200 mV. For example, when the device switches from stand-by to mute at 1.6 V, switching from mute to stand-by will occur when the mode select voltage drops below 1.4 V (see also fig.7 of the data sheet). This hysteresis is built in to prevent that the device will come into an undefined state when the mode select voltage is increased or decreased very slowly.

With the maximum and minimum values for the different thresholds, the mode select voltage ranges where the device is guaranteed to be in a certain condition, can be determined.

- The device is guaranteed in stand-by when the mode select voltage is below 1V
- When the mode select voltage is between 2V and 3.3V, the device is in the mute condition.
- When the mode select voltage is between 4.2V and Vp, the device is in the operating condition.

The mute function which is controlled by the mode select voltage is a zero-cross mute. The mute function will only engage or disengage when the signal passes through 0V. This way, the mute operation will cause as little unwanted noise as possible.

2.2 The Status I/O pin

The Status I/O pin (pin 16) can be used as an input pin as well as an output pin. Using the Status I/O pin as an input pin is done by forcing an external voltage on this pin. The levels and thresholds at pin 16 are the same as those for the mode select pin, only the functions controlled by the status I/O voltage are different.

- When the voltage at pin 16 is 0V to 1V, the device is muted. This mute function is a fast mute, so it will cut off the signal, regardless of the output level at the moment of muting. The fast mute may cause a plop-like sound when it is engaged at a high output level, but in some situations a fast mute is required.
- When the voltage at pin 16 is between 2 and 3.3V, the device will only work in class AB mode, class H operation will be disabled.

- When the voltage at pin 16 is higher than 4.2V, the device will be forced in class H mode.

**Warning:** In this condition, the device will not switch from class H to class B mode when the heatsink temperature reaches 120°C. Especially when the device is driven so hard that the lifter capacitors are discharged completely, there is a risk that the device will be damaged by excessive heat, so this is a mode of operation which preferably should not be used for other purposes than testing.

When the Status I/O pin is used as an output pin, the voltage level at this pin will give information about the operating mode of the device. When the voltage is between 0 and 0.5V, the device is muted, when the voltage is between 2 and 3 V, the device is in the class B operating mode. This will be the case when the heatsink temperature is 120°C or higher. When the voltage is between (Vp-2.5) and Vp, the device is in class H operation. The Status I/O pins of several devices (maximum 8) can be tied together. In such a setup, the device which has the lowest Status I/O voltages controls the Status I/O voltage of all devices. For example, as long as one of the devices is muted, all other devices will stay muted too. This way, all devices will switch from mute to operating at exactly the same moment.

When the status I/O pin is not used, it should be left floating.

### 2.3 The diagnostic pin

The diagnostic pin (pin 8) is an open collector output pin which should be connected to an external voltage through a pull-up resistor. The maximum current the diagnostic pin can sink is 1.5mA.

The following conditions are indicated by the diagnostic output:

1. **Clipping of the output stages:**
   - When clipping occurs, the diagnostic output will remain low as long as the output signal is clipping.

2. **Short circuits to Gnd, Vp or across the load:**
   - A short circuit to ground or to Vp will cause the diagnostic pin to go continuously low.
   - A short circuit across the load will cause the diagnostic output to go low for 20ms, then high for 50µs and then low for 20ms etc.. This will be repeated until the short circuit is removed.

3. **High temperature detection:**
   - Just before the temperature protection becomes active, the diagnostic output will go low continuously.

4. **Load detection:**
   - When the device is switched from stand-by to mute or on, a built in detection circuit checks whether a load is connected to the outputs. The result of this check can be seen at the diagnostic output when the device is muted by means of the voltage at the mode select pin. When the diagnostic output is high, a load has been detected. When it is low, no load has been detected.
In chapter xx.x a description is find for an external circuit that should be used in order to detect large loudspeakers with a very large selfinductance, like double voice coil subwoofers of which the coils are used in series.

**Note:** The load detection circuit has been designed to be used in a production environment, it was not designed to be used in a permanent diagnostic system. No guarantees can be given that the detection circuitry will work properly at low temperatures and low supply voltages.

The following figures show the relationships between the voltages at the three pins:

Figure 4 contains all information about the relationship between the status I/O pin and the mode select pin. When the amplifier is switched on by means of the mode select voltage the reference voltage (Vref) at pin 14 will rise gradually to Vp/2. When the status I/O pin is used as an output, the voltage at this pin will remain low until Vref reaches the threshold value of …V. When Vref reaches the threshold, the voltage at the status I/O pin will rise to it’s normal value. As long as the case temperature is below 120°C the voltage at the status I/O will be between Vp-2.5v and Vp. When the case temperature reaches 120°C, the status I/O voltage will drop to 2 to 3V. Finally, when the device is muted, the status I/O voltage will be between 0 and 0.5V.

When the status I/O pin is used as an input pin, the device can be forced into class H operation, class AB operation or fast mute.
Figure 5 shows the waveforms that appear at the diagnostic pin during different (fault) conditions.

First, the diagnostic pin will be low when the amplifier is muted and no load was detected during switching on.

When a load was detected during switching on, the diagnostic pin will stay high while the device is muted.

During clipping, the diagnostic output will be low as long as the output signal is clipping, so the width and frequency of the pulses at the diagnostic pin depend on the signal frequency and how far the amplifier is driven into clipping.

When one of the outputs is shorted either to ground or to the supply, the diagnostic pin will be permanently low.

Finally, when there is a short across the load (between the two outputs), the diagnostic pin will go low for 20ms, and then up for 50µs as long as the short circuit is present.
Finally, the diagnostic pin and the status I/O pin will give information, regarding the case temperature and the die temperature.

Figure 6 shows the behavior of the output, the diagnostic pin and the status I/O pin, when that pin is used as an output.

As long as the case temperature is below 120°C, the amplifier will be operating in full class H mode, the lift circuits are enabled. When the case temperature reaches 120°C the device will disable the class H circuits when the status I/O pin is open. When the status I/O pin is forced high, the class H circuits will not be disabled and the amplifier will continue working in class H mode. This type of operation is risky, since the class H circuits will now be stressed more severely than they were meant to be.

When the status I/O pin is left floating or it is used as a diagnostic output, the voltage at the status I/O pin will drop to between 2 and 3V.

When the case temperature continues rising after class H operation is disabled, the overall temperature protection will be activated when the case temperature reaches 150°C. The thermal protection will reduce the output power until the case temperature has sunk below 150°C again.

Just before the thermal protection becomes active, at a case temperature of 145°C, the diagnostic pin will go low indicating a too high temperature.
2.4 Differential inputs

The TDA1562Q has differential (symmetrical) inputs. A symmetrical input has the advantage that common mode interference that is picked up in the input lines is effectively suppressed.

Especially in an automotive application where there is much interference by external sources, the suppression of noise is very important.

3. Switch on/off behavior

When the amplifier is switched on, it should be kept in the mute condition long enough to ensure that the input capacitors are fully biased. When the amplifier is switched from
When the amplifier is switched off, it should be muted as fast as possible, in order to minimize the risk of switching noise from circuits in front of the amplifier being amplified. So unless these circuits are switched off later, here it would be best to use the status I/O pin to mute the amplifier.

The optimum switch-off sequence is as follows:

### Table 3: Switch-off sequence

<table>
<thead>
<tr>
<th>Operating</th>
<th>Operating to stand-by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode select pin</td>
<td>$V_{mode} &gt; 4.5V$</td>
</tr>
<tr>
<td>Status I/O pin</td>
<td>Floating</td>
</tr>
</tbody>
</table>

During engine starts, the Supply voltage may drop to values below 5V. The TDA1562Q is equipped with a so-called “Low Vp Mute circuit” which will mute the amplifier when the supply voltage drops to values below 7V, the amplifier will be automatically muted.

**When the supply voltage drops very rapidly, the negative terminals of the lifter capacitors will be pulled down and the voltage at these pins can become lower than the substrate voltage, this may cause plops.**

As long as the amplifier is muted, an internal circuit will prevent the negative terminals of the lifter capacitors from being pulled below substrate level.
The best method to prevent plops during engine start procedures is to switch the amplifier to mute during engine start (as soon as the supply voltage drops rapidly) and switch the amplifier on again, using the switch-on sequence described in Table 2, after the supply voltage has returned to its normal value.

When the amplifier is in stand-by mode, the internal circuitry which prevents the negative terminals being pulled below substrate level will not work. So despite the amplifier being switched off, this may still cause plops during engine start. In this condition, plops can be prevented by connecting Schottky diodes between the negative terminals of the lift capacitors and ground.

4. Protections and overstress conditions

Apart from the thermal protection circuitry which is mentioned in paragraph 2.3, the TDA1562Q is also equipped with short circuit protections.
The TDA 1562Q has two separate circuits, protecting it against short circuits to the ground, the supply voltage and across the load.

The first protection circuit, the **missing current protection** will switch off the amplifier in case of a short circuit to ground or to the supply. The missing current protection compares the current flowing into the supply pins with the current flowing out of the power ground pins. As soon as the difference between the two measured values exceeds 1.5A the amplifier is switched off. Such a situation will occur as soon as one of the outputs is shorted to either ground or to the supply.

The second short circuit protection is called the **maximum current protection**. This protection is activated as soon as the current in the output stage exceeds 7.5A. This will happen when there is a short between the two outputs. For this protection to be activated, it is necessary that there is a signal at the output of the amplifier, otherwise no current will be flowing between the outputs.

When a too low impedance is connected to the amplifier (2Ω) this protection can also be activated when the amplifier is driven hard and cause “audio holes”.

In the situations described above, the amplifier will be protected against damage by the protection circuits.

There are, however, some conditions which will damage the device. Generally, double fault conditions and fault conditions under more extreme circumstances may damage the device.

Examples of double faults are:

- Short circuit of one of the outputs to ground while the power ground is disconnected. (also known as loss of ground condition)
- Short circuit of one of the outputs to the supply while the supply is disconnected.

During operation at supply voltages higher than 16V, the charge circuits for the lifter capacitors and the voltage lifting circuits will heat up considerably, especially when the amplifier is driven by a signal with a large low frequency content.

In extreme conditions (continuous clipping signal), the charging and/or lifting circuits may overheat after prolonged operation.

A number of other conditions that are known to have caused damage to the TDA1562Q are:

1. Driving the amplifier into thermal protection while the device is forced into class H mode by means of the status I/O pin. Normally, when the status I/O pin is floating, the thermal protection will disable class H operation when a heatsink temperature of 120°C is reached (approximately 145°C junction temperature). When this protection is overruled by connecting the status I/O pin to the supply, there is a serious risk of overheating the lifting circuitry.

   Driving the device so hard that the overall thermal shutdown is activated will in this situation cause overheating of the lifting circuitry, possibly resulting in permanent damage to the lifting circuits.

2. Shorting an output to the Vsupply while the corresponding lifter capacitor is fully discharged.

   This situation can occur when a device is switched on instantaneously after the power supply is connected, with an input signal so high, that the amplifier is forced into Class H mode immediately. This can only occur when the mode select pin is high at the moment that the supply is connected to the amplifier. Normally when
there is only a small delay between connection of the supply and switching the amplifier to the “on” condition the lifter capacitors will be charged, and the risk of this condition occurring is minimal.

When a very inductive load is connected to the TDA1562Q and the device is driven with a signal containing a high amount of high frequency components (>3kHz) the risk exists that the protection circuits of the device will be activated when the input level exceeds 1.2Vrms. This may cause interruptions of the audio output signal.

Clamping the input signal to a maximum value of 1.2Vrms will prevent this

**Warning:** When the device is switched into the stand-by mode, the lifter capacitors remain charged. So even when the supply is disconnected, some parts of the circuit will still be at supply voltage level. Normally, this will not cause any problems, not even when the supply pin of the device is connected to ground. However, when either pin 5 or pin 13 is shorted to an adjacent pin, the charge remaining in the lifter capacitors may cause damage.

When, in extreme conditions, the supply voltage drops rapidly and this voltage drop exceeds 1V the negative terminals of the lifter capacitors will be pulled down to voltages below the substrate level.

When this occurs, the amplifier can be temporarily switched off, causing plops in the music signal.

This can be prevented by ensuring that the supply voltage will never drop more than 1V, by using components in the supply line with a sufficiently low series resistance.

In many cases however, the series resistance in the supply line cannot be controlled, or is a given value. For these cases, the best solution is to connect Schottky diodes between the – terminal of the lifter capacitors and the power ground. The anodes of the diodes should be connected to the power ground and the cathodes of the diodes should be connected to the – terminals of the lifter capacitors (see fig.7).

With this set-up, the – terminals of the lifter capacitors will never be pulled more than 0.4V below the substrate level, which will prevent the amplifier from switching off.

5. Application description

5.1 Application schematic
Figure 7 shows the basic application diagram of the TDA1562.

With the exception of the components connected to pins 3 and 5 and 13 and 15 it is the schematic of any class AB BTL amplifier with a symmetrical input. In this paragraph, the different components in the application will be discussed.
The input capacitors $C_{in1}$ and $C_{in2}$:

These capacitors are necessary to obtain a DC separation between the inputs and the signal source. The capacitance of the input capacitors, combined with the input impedance of the amplifier determines the low frequency roll-off point.

In the standard application a value of 100nF is used for these capacitors, higher capacitances will result in a lower roll-off frequency (see also fig.8). It is advised to use capacitors with a low DC leakage (film capacitors) for this purpose, since any DC leakage at the inputs will result in a DC offset at the outputs. Electrolytic capacitors usually have a relatively high DC leakage current, so they should not be used as input capacitors.

As already mentioned, the TDA1562 has a symmetrical input. In order to achieve the highest possible suppression of common mode interference, the two input capacitors should be well matched. Especially at low frequencies the difference in impedance between two nominally equal capacitors may cause a deterioration of the CMRR (common mode rejection ratio). Fig. 9 shows the effect of the input capacitors on the CMRR.

![Gain vs Freq](image.png)

- **A**: 100nF input capacitors
- **B**: 220nF input capacitors
- **C**: 470nF input capacitors

Fig 8. Low frequency roll off with different values of input capacitors
**A: Ideal input capacitors (“infinite” capacitance”)**

**B: 470nF input capacitors, randomly selected**

**C: 100nF capacitors, matched values (difference < 0.1%)**

**D: 100nF capacitors, randomly selected (difference 5%)**

**Fig 9. The influence of input capacitors on the Common Mode Ripple Rejection**

Fig. 9 clearly shows the influence of the input capacitors on the CMRR. At low frequencies the impedance of the input capacitors will increase and any difference in the impedance between the two input capacitors will immediately be translated to a worse CMRR. When a very high CMRR is required it is therefore best to use input capacitors with a high capacitance, preferably matched or 1% accuracy types.

- **The reference decoupling capacitor Cref:**
  This capacitor at pin 14 serves to stabilize the internal voltage reference, and during switching on of the amplifier it is used as a timing device. A recommended value for this capacitor is 10µF. Using a smaller capacitor than this may result in worse supply voltage ripple rejection and possibly malfunction of the load detection circuit during start-up.

- **The supply decoupling capacitors Csup1 and Csup2:**
  Csup1 is the supply decoupling electrolytic capacitor. This capacitor acts as a buffer in order to reduce supply voltage ripple when high currents are drawn from the power supply. The bigger the capacitance of this capacitor, the better the supply ripple reduction. The standard value for this capacitor is 2200µF/16V. Csup2 is the HF decoupling capacitor for the power supply. The main purpose of this capacitor is to suppress high frequency oscillations at the supply lines. This capacitor should be placed as close as possible to the Vp and Gnd pins of the device. The standard value for this component is 100nF. Usually a film capacitor or a good quality surface mount ceramic capacitor is used. Choosing a smaller value than 100nF could lead to oscillations in the supply lines.
• **The lift capacitors Clift:**
The lift capacitors are used to store the energy which is needed to lift the supply voltage when the output power exceeds 10W.
The capacitance of the capacitors will determine the continuous output power at low frequencies.
The larger the capacitance, the higher the continuous output power at low frequencies.

Optimum performance can be achieved with 22000 µF lifter capacitors. Higher values do not contribute noticeably to higher output powers at low frequencies.

Apart from the capacitance, the ESR (Equivalent Series Resistance) of the capacitors is important.
The influence of the capacitance and the ESR of the lift capacitors is illustrated in fig.10.

![Fig 10. The influence of ESR and capacitance of the lift capacitors on the output power](image_url)

When the ESR is high, the power losses in the capacitors will be high too, resulting in a reduction of output power. In fig. 10 it is visible that using Low ESR capacitors instead of standard multi purpose electrolytics will result in a considerably higher output power at frequencies above 100Hz. It is also visible that the standard capacitors will run out of energy at 35Hz, causing the output power to drop very sharply. Raising the capacitance of the lifter capacitors will result in a higher output power at low frequencies.

Especially when proper operation at extremely low temperatures is required, the choice of the lift capacitors is very important. At low temperatures, the ESR of a capacitor will increase, while the capacitance will decrease. It depends on what type of capacitor is used, how much the ESR will increase and the capacitance will decrease, but for applications where extremely low operating temperatures (below
Since the lift capacitors will be charged up to a voltage nearly equal to the supply voltage, the voltage rating of these capacitors should be equal to that of the supply capacitors, so in an automotive application that would be 16V.

- **The Schottky diodes at pins 3 and 15:**
  The two Schottky diodes at pins 3 and 5 are necessary when it is expected that the supply voltage will dip more than 1 V during loud music fragments. When this happens, it is possible that the amplifier will temporarily mute. The Schottky diodes will prevent that the negative terminals of the lift capacitors are pulled below substrate level more than 0.4V, thus preventing this phenomenon. Also during engine start situations the Schottky diodes prevent that the negative terminals of the lift capacitors are pulled below substrate level, which may cause plops.

- **The diagnostic LED:**
  The TDA1562 has a diagnostic output pin. This pin is an open collector output, so it should be connected to an external voltage through a pull-up resistor. When the diagnostic pin is activated the voltage at pin 8 (diagnostic) will be pulled down. In the standard application PCB the diagnostic pin is connected to the supply voltage through a 1kΩ resistor and a LED, so that when the diagnostic is activated, the LED will light up.

- **The mode select circuit:**
  The mode select pin (pin 4) is connected to the supply through a switch and an RC circuit which ensures that the voltage at the mode select pin rises gradually, ensuring a plop-free switch-on.

- **The EMI filtering capacitors (C-emi) and Boucherot (Zobel) networks**
  In many applications small capacitors (1-10nF) to ground are are placed near the loudspeaker connector. The purpose of these capacitors is to filter out any HF interference coming into the amplifier. The TDA1562Q is very sensitive to capacitive loads to ground, so a small capacitor from one of the outputs to ground could cause instability. The risk of instability exists when the value of the EMI capacitors exceeds 100pF. When EMI filtering capacitors are used which have a higher capacitance than 100pF stability can only be maintained by placing Boucherot (Zobel) networks close to the output pins of the amplifier. Best results have been obtained with a combination of a 47nF capacitor and a 10Ω resistor.

### 5.2 Dimensioning of the Class H application

Since the amplifier relies on the energy stored in the lift capacitors for operation in class H mode, the amount of energy stored in these capacitors is crucial for proper class H operation.

Proper class H operation requires that the amplifier is able to replenish the amount of energy that is delivered into the speaker during operation. When the amount of energy which is drawn from the lift capacitors is higher than the amount of energy the charge circuitry can deliver to the capacitors, the lift capacitors will be drained and the amplifier will deliver no more output power than a conventional BTL automotive amplifier.
Especially at low frequencies, the time that the lift capacitor must act as power supply is long, so when the amplifier is operating at low frequencies the risk of the lift capacitors being discharged is highest.

Although operating the amplifier with discharged lift capacitors causes high distortion, there is no further risk of damage.

Figure 3 shows the charge current vs. the voltage across the lift capacitor. As long as the voltage is below 5V, the charge current will be limited to approximately 1A. As soon as the voltage is higher than 5V, the charge current will increase to its maximum value of 5A. This has been done to limit the dissipation and heat production in the charge circuitry to prevent overheating of the charge circuits.

This figure also shows the limitations of the charge circuit. When the lift capacitors are fully discharged, it will take some time (in the case of 10000μF capacitors approx. 60ms) for the voltage to reach 5V. For a fully discharged 10000μF lift capacitor, it takes approximately 100ms to be recharged.

The next figures show the relationship between output signal (Vout, measured at the output of the audio analyser), charge current (Icharge) and the voltage across the lift capacitor (Vlift).

The measurements were taken at a supply voltage of 14.4V, with a 4Ω load, a signal frequency of 30Hz and lift capacitors of 10000μF.
Fig. 4 shows the situation at a moderate output level (approx. 40W). The sine wave is not clipping yet. The voltage across the lift capacitor is shown for the positive output so during the positive half of the sinewave, $V_{\text{lift}}$ drops and it is visible that current is drawn from the lift capacitor ($I_{\text{charge}}$ going negative). During the negative half of the sinewave, the lift capacitor is recharged.

Fig 12. Charge current, output signal and lift capacitor voltage at $P_o=40W$, $f=30Hz$
Fig. 5 shows the voltages and the charge current while the output signal is clipping. It is visible now that the charge current is at its maximum value almost all the time during the recharging of the lift capacitor. The lift capacitor voltage almost drops to 5V. In this situation the charge circuit is only just able to maintain the charge in the lift capacitor.

Fig. 14 shows the voltages and the charge current while the lift capacitor is fully discharged, f=30Hz.

Fig 13. Charge current, output signal and lift capacitor voltage at Po=70W, f=30Hz

Fig 14. Charge current, output signal and lift capacitor voltage while lift capacitor is fully discharged, f=30Hz
Fig. 6 shows what happens when the amplifier is driven so hard that the lift capacitors are fully discharged. This situation usually only occurs when the amplifier is driven into hard clipping with a low frequency signal, because a low frequency signal contains considerably more energy than a signal with a higher frequency.

During the negative half of the sinewave, the charge circuit will attempt to recharge the lift capacitor, but as long as the voltage across the lift capacitor is below 5V, the charge current will be limited to 1A to protect the internal charge transistor. As long as the input signal is not reduced to below 14W, the lift capacitor cannot be recharged sufficiently to allow proper class H operation.

These pictures show that the TDA1562 can only function properly, with low distortion, as long as sufficient energy can be stored in the lift capacitors. Two conditions are vital for this:

1: The amount of energy drawn form the lift capacitors during lifting should preferably not exceed the energy which the charge circuit can “put back” into the lift capacitors during charging.

2: The signal should be “dynamic” enough to ensure that the lift capacitors can be recharged after they have been discharged.

Condition 1 shows that it is important that the amount of energy which can be stored in the lift capacitors should be sufficient. When the amplifier should mainly drive low frequency signals, the lift capacitors should be large enough to store sufficient energy for the expected signal. For frequencies down to 20Hz a capacitance of 22000µF is recommended.

Condition 2 shows that driving the amplifier very hard with a signal with a low crest factor will result in discharging the lift capacitors. Then, because of the low crest factor, the lift capacitors cannot be recharged, resulting in much more distortion and a lower SPL.

Driving the amplifier into severe clipping with a noise signal with a crest factor of 2:1 will only result in the lift capacitors being discharged and staying discharged simply because the charge circuit will not be able to recharge the capacitors. Testing should be carried out with a signal with sufficient dynamics to allow the charge circuits to recharge the lift capacitors in case they are fully discharged. Therefore a noise signal with a crest factor of 4:1 should be used.

The situation can get even worse when two amplifiers are used to drive a dual voice coil speaker. When the lift capacitors of one of the amplifiers are discharged, an unbalance will arise between the two voice coils. Since the two voice coils will work as a kind of transformer, the amplifier that is still lifting may induce voltage spikes onto the outputs of the amplifier that is no longer lifting. This may eventually result in damage to the amplifiers.
5.3 Minimum load impedance

Philips strongly advises against load impedances lower than 4Ω because the output stage was designed for 4Ω loads. The maximum repetitive output current for which the TDA1562 output stage is designed is 8A. To ensure that no damage can be caused by too high output currents the maximum output current protection activates at an output current of 7.5A.

The maximum peak output voltage at a supply voltage of 14.4V is 24V. The minimum impedance to achieve a current of 7.5A at a peak voltage of 24V is 24/7.5= 3.2Ω, which is 4Ω - 20%.

Usually, amplifiers are designed so that they will be able to drive loads which are 20% below the nominal load impedance without problems, so the nominal minimum load impedance for the TDA1562 is 4Ω.

When a lower impedance than 3.2Ω is connected to the TDA1562, the current protection will activate frequently, causing severe distortion. Also no guarantee can be given for the long term reliability of the device, since reliability guarantees are given for operation with the nominal load impedance. Prolonged operation with a lower load impedance may eventually result in overstress of parts.

5.4 Recommendations

From the information given in the previous paragraphs the following conclusions can be drawn:

1: The TDA1562 was not designed for operation with loads lower than 3.2Ω and should not be used with lower load impedances.

2: Noise testing should be carried out with a signal with a crest factor of 4:1, and not 2:1 because a signal with a crest factor of 2: does not have a sufficient dynamic range to allow the lift capacitors to recharge.

3: Especially for driving subwoofers, the capacitance of the lift capacitors should be as high as possible, it should be at least 10000µF, but preferably 22000µF. The higher the value of the lift capacitors, the lower the risk of distortion while driving low frequency signals.
5.5 Used components

Table 4: Used components

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
<th>Comment</th>
<th>Purpose</th>
<th>Effect when value is changed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schottky diode</td>
<td>BYV10-40</td>
<td>Schottky diode</td>
<td>To prevent that the negative terminal of the lifter capacitors is pulled below substrate level when the supply voltage drops.</td>
<td>Without Schottkys: In stand-by: Possibly plops In operating: Possibly “audio holes”</td>
</tr>
<tr>
<td>Cin1, Cin2</td>
<td>100nF</td>
<td>MKT</td>
<td>Input DC coupling</td>
<td>Lower: Low frequency rolloff will shift to higher frequency. Higher: Low frequency rolloff will shift to lower frequency.</td>
</tr>
<tr>
<td>Csup1</td>
<td>2200µF/16V</td>
<td>Electrolytic capacitor</td>
<td>Buffer capacitor</td>
<td>Lower value: Worse SVRR</td>
</tr>
<tr>
<td>Csup2</td>
<td>100nF</td>
<td>SMD, NPO or X7R material</td>
<td>HF decoupling of the supply</td>
<td>Lower value: possibly oscillations in the supply</td>
</tr>
<tr>
<td>Cref</td>
<td>10µF/16V</td>
<td>Electrolytic capacitor</td>
<td>Decoupling of internal reference voltage, timing for load detection circuit.</td>
<td>Lower value: Worse SVRR and possibly malfunction of load detection circuit</td>
</tr>
<tr>
<td>Clift</td>
<td>4700µF/16V</td>
<td>Electrolytic capacitor</td>
<td>Supply lift capacitors</td>
<td>Lower value: Less power at low frequencies ESR influences maximum output power.</td>
</tr>
<tr>
<td>C-emi</td>
<td>&lt; 100pF</td>
<td>EMI capacitor</td>
<td>Filter out EMI from external sources</td>
<td>Lower value: less EMI suppression Higher value: possible instability of the amplifier. When higher values than 100pF are used, Boucherot (Zobel) filters (10Ω, 47nF) should be placed near the outputs.</td>
</tr>
</tbody>
</table>

These are the components which are advised for the standard TDA1562 application.
When the amplifier is mainly used for driving a subwoofer, increasing the size of the lift capacitors is strongly advised.
5.6 PCB lay out

To get the best possible performance from the TDA 1562Q a number of rules must be observed during the lay-out of the PCB.
- The copper tracks to the lift capacitors should be kept as short as possible, and the surface of the loops enclosed by these tracks should be as small as possible, in order to prevent radiation from these loops.
- The signal ground and power ground tracks should be connected together at the location where the power ground is connected to the PCB (Star grounding). It must be prevented that high supply currents will run through signal ground or reference ground tracks, since ripple on these tracks will cause unnecessary distortion.
- The high frequency decoupling capacitor (100 nF) should be mounted as close as possible to the supply pins.
- Keep the tracks of the + and – inputs and the signal ground pin as close together as possible, this way the surface of the loop which could pick up interference will be as small as possible.
- Because high currents will be running through the supply tracks and the output tracks, it is advisable to make these tracks as wide as possible, and use PCB material with a 70 µm copper layer.

The following figures show the PCB lay-out of the application PCB of the TDA 1562Q.

![PCB lay-out figures](image)

**Fig 15. Top view of the TDA1562Q PCB**

a. PCB components top view  
b. PCB copper top view
a. Bottom side component view

b. Bottom side copper layer

Fig 16. Bottom view of the TDA1562Q PCB (as seen from above).
5.7 Thermal behavior

5.7.1 Power dissipation

In order to calculate a suitable heatsink for the TDA1562Q it is necessary to know the power dissipation in the amplifier.

Usually, the power dissipation of an amplifier is determined by driving the amplifier to a certain output power, and then measuring the total power delivered by the power supply. The dissipated power can then be calculated by subtracting the output power from the total power.

Generally, a sine wave signal is used to measure the power dissipation. For a conventional class AB amplifier, the worst case power dissipation with a sine wave signal will occur at approximately 50% of the clipping level, so for a 20W amplifier that would be at approximately 10W. The power dissipation will then be approximately 10W. An 80W amplifier will have a worst case power dissipation (with sine wave signal) of approximately 40W.

A rule of thumb is that the power dissipation with a music signal is 50% of the worst case power dissipation, measured with a sine wave signal. For an 80W amplifier this would then be approximately 20W.

These rules only apply for amplifiers with a constant supply voltage. For high efficiency amplifiers, the test method using sine wave signals is inadequate for calculating a realistic heatsink. In this case not a sine wave signal, but a music signal or a music-like signal should be used.

A signal which is very similar to a music signal is a pink noise signal which is filtered through an IEC 60268 filter. The schematic diagram for this filter is shown in figure 17.

![Fig 17. IEC 60268 filter](image)

A pink noise signal, filtered through this filter will give a good representation of a music signal. The great advantage of this signal, compared to a music signal, is that it is reproducible.
5.7.2 Power dissipation curves.

Figures 18 and 19 show the results of power dissipation measurements carried out on a TDA1562 and a comparable class AB amplifier. For this test the supply voltage of the class AB amplifier was regulated so that the output power at a THD of 10% would be 70W. Figure 18 shows the test results when a 1kHz sine wave signal is used. Figure 19 shows the test result with an IEC 60268 filtered pink noise signal.

The curves in figure 18 clearly show the difference between the TDA1562Q and the normal class AB amplifier.

The curve for the class AB amplifier is the characteristic curve for such a device. The power dissipation rises steeply at low output powers and slowly reduces after the maximum power dissipation has been reached at approximately 33W.

For the TDA1562Q the situation is different. Up to output power levels of 11W the amplifier behaves like a single channel BTL amplifier, driving a 4Ω load at a supply voltage of 14.4V. Then the lifting circuitry becomes active, and the power dissipation increases steadily. In the TDA1562Q there is no significant reduction of the dissipated power after the output power has reached 50W. Above 70W there even is an increase. The additional power dissipation in this device is caused by the lifting and charging circuitry, which will dissipate more and more power as the output power increases.
The curves in figure 18 do not show the advantage in power dissipation the TDA1562Q has when it is driven with a music signal. This advantage can only be illustrated by measuring the power dissipation with a music signal or a music-like signal, as it is done in fig. 19.

When the power dissipation is measured with a music-like signal, it is very clear that the TDA1562Q has a great advantage over a conventional class AB amplifier. Only at extremely high levels, when the amplifier is clipping very heavily, the power dissipation will equal that of the class AB amplifier.

To calculate an appropriate heatsink for the amplifier, it is necessary to know the power dissipation. As already mentioned, for class AB amplifiers this is usually done by measuring the worst case power dissipation with a sine wave signal and then taking 50% of that value as a value for the power dissipation with music.

From fig. 18 we can see that in this case the worst case power dissipation for the class AB amplifier is 35W, so the heatsink should be calculated for a power dissipation of 17.5W. The next step is to take this result to the curves measured with the noise signal (fig.19). When we draw a line down from the point where the power dissipation in the class AB amplifier is 17.5W to the curve of the TDA1562Q, we see that at that output level the power dissipation of the TDA1562Q is only 9.3W. this means that the heatsink for the TDA1562Q can be considerably smaller than that of the normal class AB amplifier.
5.7.3 Heatsink calculation

Figure 20 shows the thermal equivalent circuits for the TDA1562Q and the class AB amplifier.

For the TDA1562Q the maximum allowable case temperature before any thermal protection is activated is 120°C, so the external heatsink should be calculated so that the case temperature will not exceed this value.

For the class AB amplifier a maximum junction temperature of 150°C will be used as criterion for the calculations.

For this calculation we have assumed the thermal resistance from junction to case (Rth j-c) for both devices to be 0.5K/W and thermal resistance from the case to the external heatsink (Rth c-hs) to be 0.1K/W (thermal compound used).

When we assume that the maximum ambient temperature will be 65°C we can calculate the thermal resistance for the external heatsinks for the TDA1562Q and for the class AB amplifier.

For the TDA1562Q the thermal resistance for the external heatsink can be calculated as follows:

\[ \Delta T_{c-a} = T_{case} - T_{ambient} \]

\[ P_d = 9.3W \]
\[ R_{th j-c} = 0.5K/W \]
\[ R_{th c-hs} = 0.1K/W \]
\[ P_d = 17.5W \]
\[ R_{th j-c} = 0.5K/W \]
\[ R_{th c-hs} = 0.1K/W \]
\[ \Delta T_{j-a} = T_{junction} - T_{ambient} \]
R\text{th hs-a} = \frac{\partial T_{c-a}}{Pd} - R\text{th}_{c-hs} = \frac{120 - 65}{9.3} - 0.1 = 5.8 \text{ K/W}

For the class AB amplifier the calculation is as follows:

R\text{th hs-a} = \frac{T_{i-a}}{Pd} - R\text{th}_{hs-a} - R\text{th}_{f-c} = \frac{150 - 65}{17.5} - 0.1 - 0.5 = 4.25 \text{ K/W}

There is a difference of 1.65 K/W between the heatsink the TDA1562Q needs and the heatsink the class AB amplifier needs.

Although 1.65 K/W does not seem to be a big difference, it usually means a considerable increase in heatsink size, as is illustrated in figure 21.

Figure 21 shows a standard heatsink (Fischer Elektronik SK178) which can be used for cooling an amplifier. To achieve a thermal resistance of 5.8K/W the heatsink needs to have a length of approximately 50mm. To achieve a thermal resistance of 4.25K/W the length of the heatsink should be approximately 100mm, so the class AB amplifier would need a heatsink \textit{twice} the size of the heatsink of the TDA1562.

This example shows that the TDA1562Q can be used with a considerably smaller heatsink than a comparable class AB amplifier.
6. Typical waveforms

Since the class H principle is based on the principle that the supply voltage is raised at moments that the output power may exceed 20W into 4Ω, the waveforms that can be observed at the outputs are different from waveforms which can normally be observed at the output of an amplifier.

Usually, the output signal of an amplifier is a symmetrical sine wave signal (see fig. 22). In the TDA1562 this is only the case up to the point where the supply voltage starts lifting. When the supply voltage starts lifting, the shape of the signal at each output will no longer be symmetrical. The following figures show that the sine wave is expanded upwards, so that the top half of the sine wave will become “sharper” than the bottom half of the sine wave. However, when the signal is measured across the load (between the two outputs). The distortion will be compensated and the signal between the two outputs will still be a sine wave.

![Fig 22. Output signals before lifting](image-url)

When the lift circuits are not yet active, the signals at both outputs are ordinary sinewaves. Across the load the two outputs are added, resulting in a sine wave with twice the amplitude of the two output signals (BTL principle).

When the input voltage is increased to a level which would cause a normal class AB amplifier to start clipping, the lift circuits will activate and the supply voltage of the output stages will be lifted. The result of this is that the sinewave output signal will expand upwards.
The lower half of the sinewave at each output will start clipping, as is illustrated in figs. 23 and 24.

![Fig 23. Output signals at low level lifting (f=1kHz)](image)

Figure 23 shows the shape of the signals at both outputs when the amplifier just starts lifting the supply. It is visible that the tops of the sine waves are becoming slightly “sharper” and it is also visible that the bottom part of the sinewaves starts “flattening”

![Fig 24. Output signals at high lifting level (f=1kHz)](image)
slightly due to the onset of clipping. The voltage across the load remains a perfect sinewave shape.

When the input signal is increased further, the output signals will look as in figure 24. The bottom parts of the sinewaves are clipping heavily and the tops of the sinewaves are extended. Across the load, however, the signal is still a sinewave.

Finally, when the input level is increased even more, the tops of the output waveforms will also start clipping. When this level is reached, the signal across the load will also start clipping, as is illustrated in fig. 25.

At low signal frequencies the tops of a clipping signal will slope down (fig. 26). This sloping down of the signal is caused by the energy being “drained” from the lift capacitors. As long as not too much energy is drained from the lift capacitors, the voltage will be sustained. At low signal frequencies, much energy is drained from the lift capacitors, which will cause the voltage across the lift capacitors to decrease.

When the amplifier is driven into clipping at very low frequencies, it may happen that the lift capacitors are fully drained. In such a situation the lift capacitors will remain discharged as long as the input signal is high, since there is only very little time for recharging. The amplifier will then deliver the same output power as a normal class AB amplifier would. As soon as the signal drops below the level where the outputs are lifted, the lift capacitors will be recharged and the amplifier will be able to deliver its full output power again.
Fig 26. Waveforms during clipping at low frequencies (40Hz)
The wave forms which can be observed at the lift capacitors also illustrate the way the TDA1562 works and its limitations.

When the amplifier starts lifting, the voltage at the negative terminal of the lift capacitors will be lifted, thus lifting the voltage at the positive terminal. Figure 27 shows the waveforms at the + and – terminals of one of the lift capacitors during lifting. The lowest voltage level at the – terminal is slightly above 0V, which is the saturation voltage of transistors T7 and T8 (see fig. 1). The lowest voltage level at the + terminal will be approximately one diode forward voltage below the supply voltage (due to diodes D1 and D2).

Since there are two output stages, there are two lift capacitors, each taking care of one half of the sine wave. This is illustrated in figure 28.
Driving the amplifier hard at low frequencies will eventually result in the lift capacitors being drained, so that the capacitors will no longer be able to sustain the high supply voltage.

Fig. 29 shows what happens when the amplifier is driven so hard that the lift capacitors can no longer sustain the high supply voltage. In this figure it is visible that the lift voltage at both lift capacitors decreases. As a result of that the total output voltage swing also decreases. Since the lift capacitors can no longer be recharged sufficiently, the lift voltage will eventually be reduced to 0V.

Figures 30 to 32 show the currents in the + terminal of the lift capacitors.

In figure 30 the amplifier is lifting moderately at a signal frequency of 1kHz. The charging of the capacitor takes place while the other channel is lifting. In this case, at an output power of 40W the charge current (I charge) does not exceed 2.5A.

As soon as the output starts lifting, current is drawn from the lift capacitor, resulting in a negative current (I audio) at the + terminal of the lift capacitor. The energy stored in the lift capacitor is sufficient to sustain the signal during the complete sine wave.

At an output power of 55W (figure 31) the amplifier is clipping, the charge current increases to values up to 4A and the current drawn from the lift capacitor increases too. The lift capacitor is still capable of storing enough energy to sustain the signal during the complete sine wave.
Fig 30. Current waveform during lifting (Po=40W @ f=1kHz)

Fig 31. Current waveform during clipping (Po=55W @ f=1kHz)
At a signal frequency of 1kHz, the lift capacitors (8200 µF) can store sufficient energy to sustain the sinewave even during heavy clipping (at Po=75W), which is shown in fig.32. With smaller lift capacitors it might happen that the lift capacitors are drained.

![Current waveform during hard clipping](image)

**Fig 32. Current waveform during hard clipping**

At an output level of 75W @ 1kHz the charge current for the lift capacitors reaches the maximum value of 5A. As long as sufficient energy can be stored in the lift capacitors, the amplifier will be able to sustain a continuous sine wave signal.

At low frequencies, the lift capacitors must deliver much more energy than at higher frequencies, so at low frequencies the risk of “draining” the lift capacitors is much greater than at high frequencies. Also, the charge circuitry is stressed much harder when low frequency signals are amplified.
7. Measurement curves

In this final chapter some additional measurement curves will be shown to show the performance that can be expected with a properly designed application.

![](image_url)

**Fig 33. Output power vs. THD at a supply voltage of 14.4V, with a 4Ω load**

The Po vs. THD curves show the performance of the TDA1562 at frequencies of 100Hz, 1kHz and 10kHz. The “bump” at 10W output powers shows the level at which the lifting circuitry becomes active. The notch in the 100Hz and 1kHz curves is caused by internal circuitry.
At a constant output power of 1W the TDA1562 behaves like any class AB BTL amplifier. The THD (+noise) increases with the signal frequency as a result of crossover distortion.

Below 10W, most of the THD+noise figures are caused by noise and crossover distortion. Since these are constant numbers, the THD+noise ratio decreases as the output power increases.

Above 10W, artifacts from the lifter circuitry are responsible for increased THD numbers.
Fig 35. Pout vs. Vp at constant THD levels

A: THD=10%
B: THD=0.5%

f=1kHz
Rl=4ohms
Clift=8200uF/16V
Fig 36. Supply voltage ripple rejection

- $V_{p}=14.4\text{V}$
- $R_{load}=4\text{ohms}$
- $R_{in}=0$
- $V_{ripple}=2V_{p-p}$
8. Driving a dual voice coil speaker

Driving a dual voice coil subwoofer with two TDA1562 amplifiers may cause a number of fault conditions which could damage the amplifier.

The next paragraphs will explain which fault conditions may occur and give suggestions on how the amplifiers can be protected against these fault conditions.

8.1 Pulses below substrate level at the outputs

When one of the two amplifiers is driven so hard that the lift capacitors are fully discharged, it may occur that the other amplifier will induce voltage pulses into the output of this amplifier, due to the cross coupling between the two loudspeaker coils.

One possible condition which has been observed is that pulses below substrate level occur at the output of the amplifier. As soon as the voltage at the output is pulled more than 0.7V below substrate (ground) level, a parasitic diode in the output stage (see fig.37) will start conducting. When the current through this parasitic diode exceeds approx.3.5A, damage to the output stage will occur.

![Fig 37. One output stage of the TDA1562 with negative pulse](image-url)
As long as the current through the parasitic diode does not exceed 3 A, no damage will be done, but when it exceeds 3.5A, the output stage will be damaged. This is visible in fig.38 A and B. The energy contained in the negative pulse is an important factor. As long as the current in the parasitic diode doesn’t flow for more than 50µs, the current may be much higher.

To protect the parasitic diode from too high currents, a schottky diode can be connected externally between the output and ground, as shown in fig.39. The schottky diode will conduct most of the current during a negative voltage pulse.
The schottky diode will conduct most of the current, thus protecting the parasitic diode. Fig.40 shows the current distribution between the schottky diode and the parasitic diode. The yellow trace shows the current through the parasitic diode at 5A/division and the magenta trace shows the current through the schottky diode at 10A/division.
Fig 40. Current distribution between Schottky and parasitic diode

With a ROHM RSX301L schottky diode (3A) it was not possible to damage the amplifier down to pulse voltages of –30V (which was the limiting value of the test setup used) with a pulse duration of 50ms. Fig. 4 also shows that the current through the parasitic diode may exceed 3.5A with a considerable amount, as long as the duration is no more than 50µs.

This setup was tested for 4 hours with a pulse signal with a pulse duration of 50ms and a duty cycle of 50%. After the test the device was still undamaged.

The conclusion of this test is that a 3A schottky diode should be sufficient to protect the device against negative voltage pulses.

8.2 Positive voltage pulses at the outputs

Beside negative voltage pulses at the outputs, it is also possible that positive pulses occur at the outputs.

To check the effect of positive pulses at the outputs, a number of tests was carried out on the TDA1562.

First of all, test were carried out with the amplifier operating normally with the lift capacitors charged.

Under these conditions it was only possible to damage the device by applying a DC voltage higher than 25V to the output.
The situation changes dramatically when the lift capacitors are discharged. In that situation the amplifier will already be damaged by a voltage pulse of 12V at one of the outputs. This is shown in fig. 41.

![Images showing current flowing into amplifier with positive pulse at output](Fig 41. Current flowing into amplifier with positive pulse at output, Ch2 (cyan): Voutput, Ch3 (magenta): current into device)

Normally, protecting an amplifier from voltage pulses at the outputs can be done by connecting a diode from each output to the supply rail. In the TDA1562 this method cannot be applied because during normal operation the output voltage can exceed the supply voltage.

Since in most cases the +terminal of the lift capacitors is the connection with the highest voltage in the application, the most effective way to protect the output against positive pulses seemed to be to connect a diode between the output and the +terminal of the lift capacitors.

This, however, did not give the desired effect. After more testing it was found that an additional Schottky diode between the negative terminal of the lift capacitor and the supply rail did give the desired results. The resulting circuit is shown in fig. 42.
Finally, adding a 50mΩ resistor between the output and the diode gave some more improvement.

The total circuitry needed for optimum reliability in dual voice coil applications is shown in fig.43.
In addition to the circuits shown in fig. 43 it is necessary to protect the lift capacitors from being discharged. The best way to do this is by using limiter circuit that limits the input voltage as soon as the output starts clipping. The clip detection circuitry of the TDA1562 can be used to trigger this limiting circuit.

**8.3 Protection circuits**

**8.3.1 Hard limiter**

The clipping information from the Diagnostic pin of the Class H IC can be used in a tight feedback loop, that instantaneously adjusts the audio input level or "Hard Limits" the maximum output volume.

The Hard Limiter will slow the THD from growing and also will prevent the Lifting Capacitors from ever fully discharging. If one of the lifting capacitors starts to ratchet down in voltage due to peculiar music content, the THD will fire the clip detector and hold the audio input level at precisely the correct amplitude that allows the lifting capacitor to remain charged.

Depending on the application for the Class H Amplifier, the Hard Limiter can be easily adjusted to accommodate any requirement. In a Subwoofer Application, Fast Attack times are critical at the expense of some additional THD and in the case of a full range application, very low THD can be heavily weighted.
Fig 44. Hard limiter circuit

R1 is the common pull-up resistor for the Open Collector Diagnostic output from any number of Class H channels. The clipping information is active low. When a clip occurs, D1 conducts and quickly discharges C1 through R3. The value of R3 sets the attack time and should not be smaller than 4.7k in order to limit Base Current of Q2. R2 sets the gain of the feedback loop and the steepness of the limiting knee. R4, R8, R9, R11 and C2 set up the DC bias and filtering for the Gate of Q1, the special Philips Semiconductor's FET. The FET is designed to be linear over a wide operating range and is used in tuners as the AM amplifier. The Drain of the FET is connected to the same reference voltage used by the audio op amp that inputs the audio signal into the TDA1562.

The Source of the FET is connected to the Input of the audio op amp and therefore is DC biased up to the reference voltage (4V). Since the FET is an N channel depletion mode FET, it is always fully ON and needs to be biased OFF. By raising the Source pin to the reference voltage (4V) and referencing the GATE through two parallel paths of 100k + 10k to ground, the GATE sees (-) Vref and is fully pinched off. Some of the audio signal is feed back to the GATE of the FET through C4 in order to linearize the transition area from Pinched Off to just start conducting, in order to linearize
the just becoming active region of the FET. This reduces the total THD of the Hard Limiter circuit by half.

As a clip starts to occur, and the FET GATE bias voltage starts to go above the Vref supply on it's SOURCE, the DRAIN to SOURCE resistance starts to fall and places the same Vref bias on the negative pin of the audio op amp as that on it's positive input. This effectively reduces the amplitude of the audio passing through the op amp limits the clipping.

When the clipping event is over, R7 recharges C1, which determines it's recovery time.

### 8.3.2 OVP circuit

![OVP circuit diagram](image)

When the battery voltage (Vp) reaches a level of 15.1V then Q3 will conduct and connects the status I/O pin (16) of the TDA1562 to pin 16 of TDA1562 (status I/O) via diode D2 to zener diode D5. This results in a voltage of about 3.2V on the status I/O pin, which means that the TDA1562 is forced into class AB mode, preventing the amplifier of going into class-H mode.

The OVP circuit should be connected via the ignition key switch in order to prevent the car battery from draining during the time that zenerdiode D4 is conducting.

A second TDA1562 can be connected by using another diode (D3).

### 8.4 Load detection for subwoofers with very large self inductance
The TDA1562 has a load detection circuit on board that was intentionally designed for ‘normal’ loudspeakers with an inductance <0.5mH, like full range speakers up till woofers to about 20cm in diameter.

But nowadays larger speakers are used by car manufacturers to give an even better bass response in the car. These speakers are called subwoofers. Some even have a double voice coil of which the coils are mounted in series. One can imagine that the inductance of these configurations can become quite high, from 1mH to several milli Henry’s.

If these kind of subwoofers are connected to the TDA1562, one should use an extra external circuit to get a proper load detection at the DIAG pin.

This external circuit creates a short time correction between the outputs of the amplifier during enabling of the mode pin, so when the amplifier is starting-up. It is only active for a very short time so no negative side effects occur during normal usage.

**Internal circuit**

The internal circuit works as follows:
After the TDA1562 is switched from standby to mute or on, the mode pin can be switched to mute to see if a load is present on the outputs.
So, when the mode pin is enabled by 5V (eg. a microcontroller) an internal switch is closed and the external Vref capacitor is charged via an internal 15kOhm resistor. Also an internal switch (from OUT- to ground) is closed so that a measuring current of 1mA will flow from the positive output (OUT+) through the loudspeaker, to the negative output (OUT-), through the internal switch to ground.

When the voltage on the Vref capacitor has reached a level of 1.4V, the upper comparator will flip-over and at voltage levels between 0mV and about 70mV on the positive output (OUT+) (caused by the impedance of the loudspeaker) the SR-flip flop will be set and will give a high value on its output. When the mute pin is still low, the state of the flip flop is available on the DIAG pin, proper load is detected.

If there is no load connected at the outputs, there's no voltage across the outputs (OUT+) and the flip flop is resetted. Now a “no load condition” is valid and the DIAG pin will remain low.

Subwoofers

Now, if the voltage swing on the output exceeds the level of 100mV the SR flip flop is reset, and a “no load detect” situation occurs (no mather if a load is connected to the outputs or not) unless the voltage crosses –30mV after the positive voltage swing. Then the SR flip flop is set again.

It is seen that a voltage swing of >100mV can occur on the output when a large (dual voice coil) subwoofer is connected to the amplifier outputs. This has everything to do with its large inductance that causes that large voltage swing, which will be even worse when the voice coils are connected in series.
In order to force the output voltage swing to a negative value that crosses –30mV an external network must be connected to the positive output (OUT+).
This circuit will connect a Boucherot to the output during a very short time which is long enough to dampen the voltage swing from rising above 100mV.
The time is determined by the values of the resistor R2 , R3 , the capacitor C2 and the voltage on the mode pin and equals about13mS for the shown component values.
(t=-20k*470nF*ln(1.2/5)=13mS)
If a logic 3.3V voltage is used on the mode pin instead of 5V, then the capacitor C2 should be changed to a value of 680nF.

With this external circuit it has become possible now, to detect subwoofers with an inductance of about > 0.5mH (at 1 kHz) at room temperature and Vp=14.4V.
9. Conclusion

When properly applied, with quality components, an amplifier equipped with the TDA1562 can deliver high power and very good performance with a high reliability.

The class H configuration enables customers to build a high power car amplifier without the need to use DC/DC converters to increase the supply voltage. Thanks to the high efficiency of the amplifier the heatsink needed for such an amplifier can be considerably smaller that that of a comparable class AB amplifier.
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