Application Note AN2202:
AS2533...6
Single Chip “Speakerphone”
with 8Ω-Loudspeaker Amplifier

1. Scope
This application note describes a low-cost add-on circuit for driving an 8Ω-Loudspeaker to get a simple loudhearing (“Speakerphone”) Telephone.
To possible ways of supplying the amplifier are shown:

AN2202a: Amplifier supply in shunt transistor path
AN2202b: Amplifier supply by power extraction circuit (AN3020)

It can be added to any AS253x application without interfering PTT-relevant parameters, like AC-impedance, Sidetone cancellation or DC-mask.
For detailed description of the AS2533...6 circuit please refer to application note AN2201 (single chip telephone demo board).

2. Key Features
⇒ Low cost additional circuit enables use of loudhearing function
⇒ Full duplex “handsfree” operation via handset microphone and loudspeaker (at distances <2m between telephone and user)
⇒ Can be added to any AS253x- application
⇒ Enables use of low cost 8Ω - Loudspeaker
⇒ High output power with low distortion
⇒ Entirely powered from the telephone line
⇒ No influence of loudspeaker amplifier in AC-impedance, sidetone cancellation or DC-mask
⇒ Excellent sidetone cancellation of AS253x circuits enables high loudspeaker volume without howling between handset microphone and loudspeaker

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3. Other applicable documents and papers

1. Data Sheet AS2533/4B/5/6 Multi-Standard CMOS Single Chip Telephone with Dual Soft Clipping
2. Data Sheet AS2520/1 Telephone Speech Circuit with Loudhearing and Handsfree
3. Application Note AN2201: Single Chip Telephone demo board
4. Application Note AN2203: SCT with on-hook dialing, loudhearing and music-on-hold with auto-release
5. Application Note AN3020: Power extraction for external loads

3.1 Further Applications

Applications based on the AS2533...6 are continuously updated. Ask your local distributor or Austria Mikro Systeme sales office for the latest revisions or visit our home-page: http://www.vertical-global.com.

4. Revision status

AN2202      Application Note (this document) Rev.: A01
AN2202LS    Loudspeaker Amplifier Schematic Rev.: A00

5. General description

The amplifier is a simple, low cost add-on circuit to the AS253x single chip telephone family. It is supplied by the line current and amplifies the receive signal, taken from RO (Receive output), see Fig.1. Compared to more complex “real” handsfree circuits (like AS2520/1) there is no channel switching or anti-larsen circuit implemented, therefore the receive and transmit gains must be lower to avoid howling.

However, at short distances between user and telephone (<2m, which is adequate for normal office work) there is even full duplex “handsfree” operation possible, when the handset is placed next to the telephone with the microphone facing to the user.

Due to the excellent sidetone cancellation of the AS253x circuits, howling between handset microphone and loudspeaker will only occur, when both are put very close to each other. In normal operation, no howling will occur, even with maximum loudspeaker volume.

Due to the unique structure of the AS253x family’s line adaption, adding the amplifier has no influence on the important PTT related parameters, like AC-impedance, DC-mask, etc. (see Pt. 5.1 below).

Note: all subsequent component numbering refers to the schematic, shown in Pt. 9!

5.1 Amplifier supply: Comparison of AN2202a and AN2202b:

The following table describes the difference between the two types of amplifier supply: while the simple AN2202a supply shows slight influence in maximum sending level and “Make”-resistance in pulse dialing, the AN2202b (3 extra components) supply has no influence in these parameters and a more stable maximum output driving capability at high line currents (see Fig.4 & 5).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>AN2202a (Shunt path supply)</th>
<th>AN2202b (Power extraction)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC impedance</td>
<td>no influence</td>
<td>no influence</td>
</tr>
<tr>
<td>off-hook DC mask</td>
<td>no influence</td>
<td>no influence</td>
</tr>
<tr>
<td>Tx-/Rx-gains</td>
<td>no influence</td>
<td>no influence</td>
</tr>
<tr>
<td>“Make”-resistance in pulse dialing</td>
<td>&lt;2300Ω @ 20mA</td>
<td>&lt;1600Ω @ 20mA</td>
</tr>
<tr>
<td>max. sending level (soft clip level = 4Vpp)</td>
<td>no influence for I_{line} &lt;40mA &lt;4Vpp for I_{line} &gt;40mA (see Fig.3)</td>
<td>no influence; soft clip level</td>
</tr>
<tr>
<td>max. 8Ω output power; THD &lt;2%</td>
<td>≈26mW</td>
<td>≈27mW</td>
</tr>
<tr>
<td>max. 8Ω output power; THD &lt;3%</td>
<td>≈32mW</td>
<td>≈34mW</td>
</tr>
<tr>
<td>number of extra components</td>
<td>none</td>
<td>3parts:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 transistor,1diode,1resistor</td>
</tr>
</tbody>
</table>
6. Block diagram

Fig. 1 shows the block diagram of the speech paths: the transmitted signal is fed to the line via the 2-4 wire interface and the receive signal coming from line is fed to the Rx amplifier. The same Rx signal passes an attenuator for volume control and is then amplified by the loudspeaker amplifier.

![Speakerphone block diagram](image)

6.1 How to avoid howling

As can be seen on Fig.1, there is an acoustic loop from:

- loudspeaker $\Rightarrow$ acoustic feedback (determined by the mechanical distance between loudspeaker and handset microphone $\Rightarrow$ Tx amplifier $\Rightarrow$ sidetone $\Rightarrow$ LS amplifier).

Howling will occur, when the total loop gain is $\geq 1$ (equal to $\geq 0$ dB). Therefore the following conditions will have an effect in loop gain:

<table>
<thead>
<tr>
<th>Parameter:</th>
<th>measure to reduce howling</th>
<th>Note:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmit gain</td>
<td>reduce gain</td>
<td>must meet the SLR limits</td>
</tr>
<tr>
<td>Sidetone</td>
<td>increase sidetone</td>
<td>can be done by optimizing the sidetone network, the better the sidetone cancellation, the more gain can be given to the loudspeaker</td>
</tr>
<tr>
<td></td>
<td>cancellation</td>
<td></td>
</tr>
<tr>
<td>Loudspeaker volume</td>
<td>decrease loudspeaker</td>
<td>for good performance, a maximum of loudspeaker volume is desirable, therefore this should be the least step</td>
</tr>
<tr>
<td></td>
<td>volume</td>
<td></td>
</tr>
<tr>
<td>Loudspeaker frequency response</td>
<td>limit bandwidth</td>
<td>howling will occur with the frequency of the highest amplification. Therefore the frequency response curve should be as flat as possible and limited to the speech band ($\approx 300..3400Hz$)</td>
</tr>
<tr>
<td>acoustic coupling between</td>
<td>increase distance between</td>
<td>In normal operation, the distance can be down to a few centimeters, when the handset is put onto or off the cradle. The loop should be adjusted such that in normal speech mode there is no howling at distances $&gt;5..10$ cm. Additionally, the loudspeaker can be mounted away from the handset microphone position, like on the side or on the rear, if possible.</td>
</tr>
<tr>
<td>loudspeaker and handset</td>
<td>loudspeaker and handset</td>
<td></td>
</tr>
<tr>
<td>microphone</td>
<td>microphone</td>
<td></td>
</tr>
</tbody>
</table>
7. Circuit description

7.1 8Ω loudspeaker amplifier
The amplifier is a simple Class-A type amplifier. Gain is set by R28, the bandwidth is limited by C21 (avoid howling). Q6 and Q7 should be matched in gain (complementary types).

Nearly all the line current will flow through these transistors, independent of the signal output amplitude. The maximum power dissipation of Q6 and Q7 is

\[ P_{\text{tot}} = V_{\text{CE}} \times (I_{\text{Line}} - I_{\text{IC1}}) \]

where:

- \( V_{\text{CE,Q6}} = V_{\text{BE,Q6}} + U_{\text{D12}} \)
- \( V_{\text{CE,Q7}} = V_{\text{BE,Q7}} + U_{\text{D13}} \)

\( V_{\text{BE,Q6,Q7}} = 0.7 \text{V} \), \( V_{\text{TH,D12,D13}} = 0.52 \text{V} \).

\( I_{\text{IC1}} = \text{typ. 3mA (see data sheet)} \)

Power dissipation at \( I_{\text{line}} = 100 \text{mA} \):

\[ P_{\text{tot}} = (0.7+0.52) \times (0.1-0.003) = 118\text{mW} \]

In order to maintain no interference of the circuit to AC-impedance, DC-mask, maximum sending level, etc... the amplifiers’ supply voltage \( V_{\text{CC}} \) must be limited to <2.44V \(^1\). This is accomplished by

\[ V_{\text{CC}} = V_{\text{BE,Q6}} + V_{\text{TH,D12}} + V_{\text{TH,D13}} + V_{\text{BE,Q7}} \]

\[ V_{\text{CC}} = 0.68\text{V} + 0.5\text{V} + 0.5\text{V} + 0.68\text{V} = 2.36\text{V} \]

\(^1\) Critical for AN2202a configuration, not critical for AN2202b configuration.

VLI can range between 2.5...6.5V ⇒ 4.5V ± 2\( V_{\text{peak}} \) (max. sending level), the C-E saturation voltage of Q3 is assumed >60mV

To maintain full transmit swing (± 2\( V_{\text{peak}} \)) ⇒ \( VC(Q3) = V_{\text{CC}} = (2.5\text{V}-60\text{mV}) < 2.44\text{V} \)

7.2 Amplifier supply in shunt transistor path
This configuration requires no extra components. However, the maximum voltage of \( V_{pp} \) must be considered: If \( V_{pp} \) rises >2.44V, the maximum transmit level will be slightly distorted at the negative half-wave.

Additionally, the “Make”-resistance in pulse dialing will be higher, because with CS being pulled to \( V_{SS} \), VLI cannot be shorted to \( V_{BE} \) (as in the standard application AN2201 with the collector of Q3 being connected to \( V_{SS} \)).

During pulse dialing, VLI will be 2.5V, thus increasing the total “ON”-resistance by

\[ \Delta R_{\text{ON}} = \frac{2.5\text{V} - 0.6\text{V}}{I_{\text{Line}} = 3\text{mA}} = 11.1\Omega (20\text{mA})...19.6\Omega (100\text{mA}) \]

7.3 Amplifier supply by power extraction circuit AN3020
This power extraction can be used to supply any external load by the available line current without affecting the performance of the single chip telephone. A detailed description of this circuit is given in application note AN3020.

“ON”-resistance in pulse dialing (compared to the standard application AN2201) is only increased by 10Ω (see. Fig. 6).
8. Measurement results & curves

8.1 Frequency response
Fig. 2 shows the frequency response curve of the loudspeaker amplifier. The curve shows the output level on an 8Ω resistor (solid line) and an 8Ω loudspeaker (dotted line; PHILIPS AD3371 series 80mm 8Ω speaker) measured with maximum volume and -10dBm Rx level on line. The peak at 200Hz is a resonant frequency of the specific loudspeaker type.

Gain of the amplifier is set by the resistors R27, R28 and the attenuation of P1. The bandwidth is adjusted by C21.

Fig. 2: Frequency response of loudspeaker amplifier (P\text{Line}=-10\text{dBm})

8.2 Maximum sending level
Fig.3 shows the maximum Transmit sending level, measured at Li vs. line current, assuming a total harmonic distortion (THD) of less than 1%.

AN2201a (dotted line): At line currents >40mA, VPP will rise up to 2.5V (@ 90mA) and sending level will be slightly distorted before it reaches the soft clip level ($\pm2V_{\text{peak}}$).

AN2202b (solid line): There is no influence in maximum sending level, the transmit signal can be up to the soft clip level at line currents of >12mA.

Fig. 3: Maximum sending level vs. line current (@ THD <1%)

8.3 Maximum output power
Fig.4 and Fig.5 show the maximum output power on an 8Ω loudspeaker at f=1kHz: the curves indicate the maximum output power with <2% and <3% total harmonic distortion.

AN2202a: The lower output drive capability at higher line currents results from nonlinearities at higher collector currents and mismatch in the complementary transistor types.

AN2202b: Maximum output power is not decreased with higher line currents.
8.4 On-resistance in pulse dialing

As described in Pt. 7.2 and 7.3, the ON-resistance (="Make"-resistance) in both applications is higher than with the standard application, AN2201. However, the ON-resistance in pulse dialing is generally low with AS253x - applications, this parameter allows a wide tolerance to meet the PTT specs. Germany's BAPT223 ZV5, for example, allows \( R_{ON} \leq 390 \Omega @ I_{Line} > 24\text{mA} \).

Fig. 6 shows the ON-resistance, measured on a-and b-terminals in pulse dialing with the AN2202 applications compared to the standard application AN2201.

Note: since the measurement is taken at a- and b-terminals, the overall resistance (including ON-resistance of line-transistor) will be measured.
9. Application schematic:
10. Related Standards

The product, AS25xx, is designed to be in compliance with ETSI standards for connection to the analogue PSTN of terminal equipment including voice telephony services or other voice band communication when installed into a properly designed system. The specification of the product is based on following standards and requirements:

- **NET 4** ETS 300 001, PSTN basic access; analogue terminal equipment general requirements, March 1996.
- **EN55022** EMC (Electro Magnetic Compatibility)
- **IEC 1000-4-3** Electromagnetic Irradiation (CE approval)

Note: Some national PTT authorities may have additional requirements exceeding the above standards and requirements. Such additional requirements have only been respected to the extent that they were known to Austria Mikro Systeme prior to designing the product. However, Austria Mikro Systeme shall not be liable to recipient or any third party in connection with the approval procedures of applications in which the AS25xx is used.

11. Approvals

Since the AS25xx is a component and not a complete system, it can not be approved as a stand alone part by the standards bodies. Hence, full conformance to above standards is depending on the application in which the AS25xx is being used, and therefore, approvals by the standards bodies are the responsibility of the customer and Austria Mikro Systeme will not have tested the product to meet the above standards.

12. General Liability Declaration

The information furnished here by Austria Mikro Systeme is believed to be correct and accurate. However, Austria Mikro Systeme shall not be liable to licensee or any third party for any damages, including but not limited to personal injury, property damage, loss of profits, loss of use, interruption of business or indirect, special, incidental or consequential damages, of any kind, in connection with or arising out of the furnishing, performance or use of the technical data. No obligation or liability to licensee or any third party shall arise or flow out of Austria Mikro Systeme rendering technical or other services.

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