

# Contents

|          |                                          |           |
|----------|------------------------------------------|-----------|
| <b>1</b> | <b>Block diagram</b>                     | <b>6</b>  |
| <b>2</b> | <b>Pin description</b>                   | <b>7</b>  |
| 2.1      | Connection diagram                       | 7         |
| 2.2      | Pin list                                 | 7         |
| <b>3</b> | <b>Electrical specification</b>          | <b>8</b>  |
| 3.1      | Absolute maximum ratings                 | 8         |
| 3.2      | Electrical characteristics               | 8         |
| <b>4</b> | <b>Description of the audioprocessor</b> | <b>12</b> |
| 4.1      | Input stages                             | 12        |
| 4.2      | AutoZero                                 | 12        |
| 4.3      | Loudness                                 | 13        |
| 4.3.1    | Attenuation                              | 13        |
| 4.3.2    | Peak frequency                           | 13        |
| 4.3.3    | Low and high frequency boost             | 14        |
| 4.3.4    | Flat mode                                | 14        |
| 4.4      | SoftMute                                 | 14        |
| 4.5      | SoftStep volume                          | 15        |
| 4.6      | Bass                                     | 15        |
| 4.6.1    | Attenuation                              | 15        |
| 4.6.2    | Center frequency                         | 16        |
| 4.6.3    | Quality factors                          | 16        |
| 4.6.4    | DC mode                                  | 16        |
| 4.7      | Middle                                   | 17        |
| 4.7.1    | Attenuation                              | 17        |
| 4.7.2    | Center frequency                         | 17        |
| 4.7.3    | Quality factors                          | 17        |
| 4.8      | Treble                                   | 18        |
| 4.8.1    | Attenuation                              | 18        |
| 4.8.2    | Center frequency                         | 18        |
| 4.9      | Speaker attenuator                       | 18        |

---

|          |                                               |           |
|----------|-----------------------------------------------|-----------|
| 4.10     | Subwoofer attenuator .....                    | 18        |
| 4.11     | MUX output .....                              | 19        |
| 4.12     | Audioprocessor testing .....                  | 19        |
| <b>5</b> | <b>I<sup>2</sup>C bus specification .....</b> | <b>20</b> |
| 5.1      | Interface protocol .....                      | 20        |
| 5.1.1    | Receive mode .....                            | 20        |
| 5.1.2    | Transmission mode .....                       | 20        |
| 5.1.3    | Reset condition .....                         | 20        |
| 5.2      | Subaddress (receive mode) .....               | 21        |
| 5.3      | Data byte specification .....                 | 22        |
| <b>6</b> | <b>Package information .....</b>              | <b>27</b> |
| <b>7</b> | <b>Revision history .....</b>                 | <b>28</b> |

## List of tables

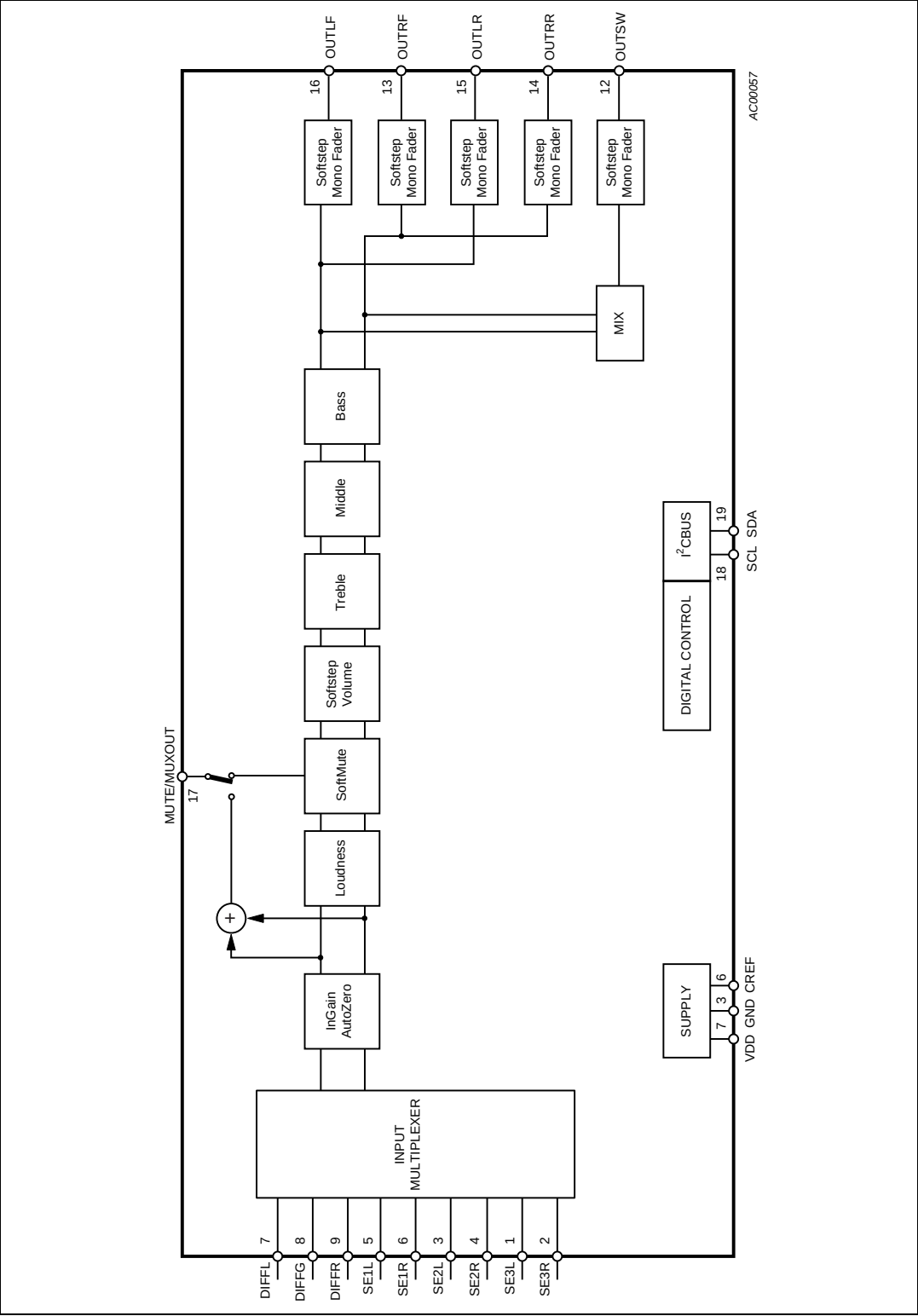
|           |                                                       |    |
|-----------|-------------------------------------------------------|----|
| Table 1.  | Device summary . . . . .                              | 1  |
| Table 2.  | Pin list . . . . .                                    | 7  |
| Table 3.  | Absolute maximum ratings . . . . .                    | 8  |
| Table 4.  | Electrical characteristics . . . . .                  | 8  |
| Table 5.  | Registers of all subaddresses. . . . .                | 20 |
| Table 6.  | Subaddress (receive mode) . . . . .                   | 21 |
| Table 7.  | Input selector /gain (0) . . . . .                    | 22 |
| Table 8.  | Loudness (1). . . . .                                 | 22 |
| Table 9.  | Volume / speaker attenuation (2,7,8,9,10,11). . . . . | 23 |
| Table 10. | Treble filter (3) . . . . .                           | 23 |
| Table 11. | Middle filter (4) . . . . .                           | 24 |
| Table 12. | Bass filter (5). . . . .                              | 25 |
| Table 13. | Middle / bass Fc select (6) . . . . .                 | 25 |
| Table 14. | Soft mute and soft step time (12) . . . . .           | 26 |
| Table 15. | Testing audio processor (13) . . . . .                | 26 |
| Table 16. | Document revision history . . . . .                   | 28 |

## List of figures

|            |                                                                      |    |
|------------|----------------------------------------------------------------------|----|
| Figure 1.  | Block diagram . . . . .                                              | 6  |
| Figure 2.  | Pin out. . . . .                                                     | 7  |
| Figure 3.  | Input stage . . . . .                                                | 12 |
| Figure 4.  | Loudness attenuation @ $f_C = 400\text{Hz}$ . . . . .                | 13 |
| Figure 5.  | Loudness center frequencies @ Attn. = 15dB . . . . .                 | 13 |
| Figure 6.  | Loudness attenuation, $f_C = 2.4\text{kHz}$ . . . . .                | 14 |
| Figure 7.  | Softmute timing . . . . .                                            | 14 |
| Figure 8.  | SoftStep timing . . . . .                                            | 15 |
| Figure 9.  | Bass control @ $f_C = 80\text{Hz}$ , $Q = 1$ . . . . .               | 15 |
| Figure 10. | Bass center frequencies @ Gain = 15dB, $Q = 1$ . . . . .             | 16 |
| Figure 11. | Bass quality factors @ Gain = 14dB, $f_C = 80\text{Hz}$ . . . . .    | 16 |
| Figure 12. | Bass normal and DC mode @ Gain = 14dB, $f_C = 80\text{Hz}$ . . . . . | 16 |
| Figure 13. | Middle control @ $f_C = 1\text{kHz}$ , $Q = 1$ . . . . .             | 17 |
| Figure 14. | Middle center frequencies @ Gain = 14dB, $Q = 1$ . . . . .           | 17 |
| Figure 15. | Bass quality factors @ Gain = 14dB, $f_C = 1\text{kHz}$ . . . . .    | 17 |
| Figure 16. | Treble control @ $f_C = 17.5\text{kHz}$ . . . . .                    | 18 |
| Figure 17. | Treble center frequencies @ Gain = 14dB . . . . .                    | 18 |
| Figure 18. | MUX output configuration . . . . .                                   | 19 |
| Figure 19. | SO20 mechanical data and package dimensions. . . . .                 | 27 |

1 Block diagram

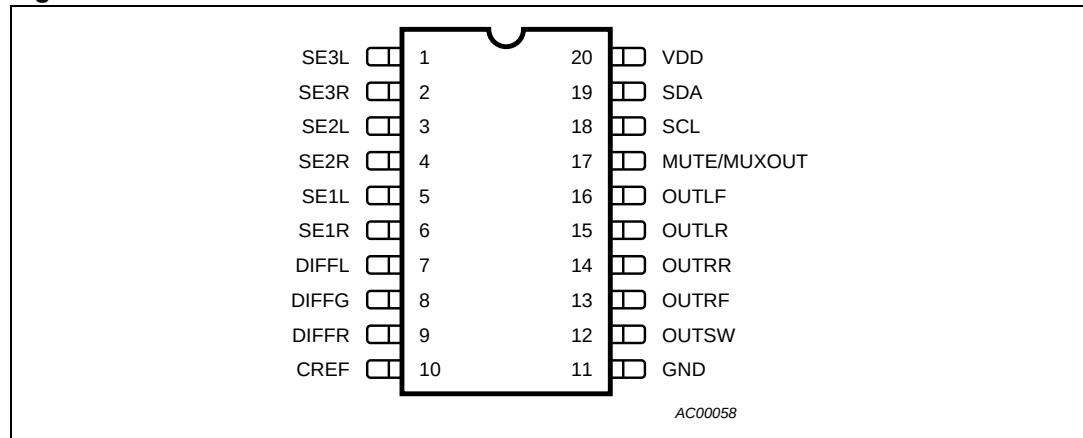
Figure 1. Block diagram



## 2 Pin description

### 2.1 Connection diagram

Figure 2. Pin out



### 2.2 Pin list

Table 2. Pin list

| No. | Pin Name      | Description                             | I/O |
|-----|---------------|-----------------------------------------|-----|
| 1   | SE3L          | Single-ended input 3 left channel       | I   |
| 2   | SE3R          | Single-ended input 3 right channel      | I   |
| 3   | SE2L          | Single-ended input 2 left channel       | I   |
| 4   | SE2R          | Single-ended input 2 right channel      | I   |
| 5   | SE1L          | Single-ended input 1 left channel       | I   |
| 6   | SE1R          | Single-ended input 1 Right channel      | I   |
| 7   | DIFFL         | Pseudo differential stereo input left   | I   |
| 8   | DIFFG         | Pseudo differential stereo input common | I   |
| 9   | DIFFR         | Pseudo differential stereo input right  | I   |
| 10  | CREF          | Reference capacitor                     | O   |
| 11  | GND           | Ground                                  | S   |
| 12  | OUTSW         | Subwoofer output                        | O   |
| 13  | OUTRF         | Front right output                      | O   |
| 14  | OUTRR         | Rear right output                       | O   |
| 15  | OUTLR         | Rear left output                        | O   |
| 16  | OUTLF         | Front left output                       | O   |
| 17  | MUTE / MUXOUT | External mute pin / MUX output          | I   |
| 18  | SCL           | I <sup>2</sup> C bus clock              | I   |
| 19  | SDA           | I <sup>2</sup> C bus data               | I/O |
| 20  | VDD           | Supply                                  | S   |

## 3 Electrical specification

### 3.1 Absolute maximum ratings

**Table 3. Absolute maximum ratings**

| Symbol    | Parameter                                           | Value                                  | Unit |
|-----------|-----------------------------------------------------|----------------------------------------|------|
| $V_S$     | Supply voltage for $V_{CC}^{(1)}$<br>for other pins | -0.4 to 10.2<br>-0.4 to $V_{CC} + 0.4$ | V    |
| $T_{op}$  | Operating temperature range                         | -40 to +85                             | °C   |
| $T_{stg}$ | Storage temperature                                 | -55 to +150                            | °C   |
| $V_{ESD}$ | ESD protection (Human Body Model)                   | ±2000                                  | V    |
| $V_{ESD}$ | ESD protection (Machine Model)                      | ±200                                   | V    |
| $V_{ESD}$ | ESD protection (Change Device Model)                | ±750                                   | V    |

1. Reference level is GND.

### 3.2 Electrical characteristics

**Table 4. Electrical characteristics**

$V_S = 8.5$  V;  $T_{amb} = 25$  °C;  $R_L = 10$  kΩ; all gains = 0 dB;  $f = 1$  kHz; unless otherwise specified

| Symbol                            | Parameter                      | Test condition            | Min. | Typ. | Max. | Unit      |
|-----------------------------------|--------------------------------|---------------------------|------|------|------|-----------|
| <b>Supply</b>                     |                                |                           |      |      |      |           |
| $V_S$                             | Supply voltage                 |                           | 8    | 8.5  | 10   | V         |
| $I_S$                             | Supply current                 |                           | 18   | 25   | 32   | mA        |
| <b>Input selector</b>             |                                |                           |      |      |      |           |
| $R_{in}$                          | Input resistance               | All single ended inputs   | 70   | 100  | 130  | kΩ        |
| $V_{CL}$                          | Clipping level                 |                           | 1.8  | 2    |      | $V_{RMS}$ |
| $S_{IN}$                          | Input separation               |                           | 80   | 100  |      | dB        |
| $G_{IN MIN}$                      | Min. input gain                |                           | -0.5 | 0    | 0.5  | dB        |
| $G_{IN MAX}$                      | Max. input gain                |                           | 14   | 15   | 16   | dB        |
| $G_{STEP}$                        | Step resolution                |                           | 0.5  | 1    | 1.5  | dB        |
| $V_{DC}$                          | DC steps                       | Adjacent gain steps       | -5   | 1    | 5    | mV        |
|                                   |                                | $G_{MIN}$ to $G_{MAX}$    | -30  | 4    | 30   | mV        |
| $V_{offset}$                      | Remaining offset with AutoZero |                           |      | 0.5  |      | mV        |
| <b>Differential stereo inputs</b> |                                |                           |      |      |      |           |
| $R_{in}$                          | Input resistance               | Differential              | 70   | 100  | 130  | kΩ        |
| CMRR                              | Common mode rejection ratio    | $V_{CM}=1 V_{RMS}@ 1kHz$  | 40   | 60   |      | dB        |
|                                   |                                | $V_{CM}=1 V_{RMS}@ 10kHz$ | 40   | 60   |      | dB        |

**Table 4. Electrical characteristics (continued)** $V_S = 8.5\text{ V}$ ;  $T_{\text{amb}} = 25\text{ }^{\circ}\text{C}$ ;  $R_L = 10\text{ k}\Omega$ ; all gains = 0 dB;  $f = 1\text{ kHz}$ ; unless otherwise specified

| Symbol               | Parameter                       | Test condition                     | Min. | Typ. | Max. | Unit |
|----------------------|---------------------------------|------------------------------------|------|------|------|------|
| e <sub>No</sub>      | Output noise @ speaker outputs  | 20Hz-20kHz,flat;<br>all stages 0dB |      | 12   | 20   | μV   |
| Loudness control     |                                 |                                    |      |      |      |      |
| A <sub>MAX</sub>     | Max. attenuation                |                                    | -16  | -15  | -14  | dB   |
| A <sub>STEP</sub>    | Step resolution                 |                                    | 0.5  | 1    | 1.5  | dB   |
| f <sub>Peak</sub>    | Peak frequency <sup>(1)</sup>   | f <sub>P1</sub>                    | 360  | 400  | 440  | Hz   |
|                      |                                 | f <sub>P2</sub>                    | 720  | 800  | 880  | Hz   |
|                      |                                 | f <sub>P4</sub>                    | 2.1  | 2.4  | 2.7  | kHz  |
| Volume control       |                                 |                                    |      |      |      |      |
| G <sub>MAX</sub>     | Max. gain                       |                                    | 14   | 15   | 16   | dB   |
| A <sub>MAX</sub>     | Max. attenuation                |                                    | -84  | -79  | -74  | dB   |
| A <sub>STEP</sub>    | Step resolution                 |                                    | 0.5  | 1    | 1.5  | dB   |
| E <sub>A</sub>       | Attenuation set error           | G = -20 to +15dB                   | -1   | 0    | 1    | dB   |
|                      |                                 | G = -79 to -20dB                   | -4   | 0    | 3    | dB   |
| E <sub>T</sub>       | Tracking error                  |                                    |      |      | 2    | dB   |
| V <sub>DC</sub>      | DC steps                        | Adjacent Attenuation Steps         | -3   | 0.1  | 3    | mV   |
|                      |                                 | From 0dB to G <sub>MIN</sub>       | -10  | 0.5  | 10   | mV   |
| Soft mute            |                                 |                                    |      |      |      |      |
| A <sub>MUTE</sub>    | Mute attenuation                |                                    | 80   | 100  |      | dB   |
| T <sub>D</sub>       | Delay time                      | T1                                 |      | 0.48 |      | ms   |
|                      |                                 | T2                                 |      | 0.96 |      | ms   |
|                      |                                 | T3                                 |      | 123  |      | ms   |
| V <sub>TH Low</sub>  | Low threshold for SM pin        |                                    |      |      | 0.7  | V    |
| V <sub>TH High</sub> | High threshold for SM pin       |                                    | 2.7  |      |      | V    |
| R <sub>PU</sub>      | Internal pull-up resistor       |                                    | 32   | 45   | 58   | kΩ   |
| V <sub>PU</sub>      | Internal pull-up voltage        |                                    |      | 3.3  |      | V    |
| Bass control         |                                 |                                    |      |      |      |      |
| fc                   | Center frequency <sup>(1)</sup> | f <sub>C1</sub>                    | 54   | 60   | 66   | Hz   |
|                      |                                 | f <sub>C2</sub>                    | 72   | 80   | 88   | Hz   |
|                      |                                 | f <sub>C3</sub>                    | 90   | 100  | 110  | Hz   |
|                      |                                 | f <sub>C4</sub>                    | 180  | 200  | 220  | Hz   |



**Table 4. Electrical characteristics (continued)** $V_S = 8.5\text{ V}$ ;  $T_{\text{amb}} = 25\text{ }^{\circ}\text{C}$ ;  $R_L = 10\text{ k}\Omega$ ; all gains = 0 dB;  $f = 1\text{ kHz}$ ; unless otherwise specified

| Symbol             | Parameter                       | Test condition             | Min. | Typ. | Max. | Unit |
|--------------------|---------------------------------|----------------------------|------|------|------|------|
| Q <sub>BASS</sub>  | Quality factor <sup>(1)</sup>   | Q <sub>1</sub>             | 0.9  | 1    | 1.1  |      |
|                    |                                 | Q <sub>2</sub>             | 1.1  | 1.25 | 1.4  |      |
|                    |                                 | Q <sub>3</sub>             | 1.3  | 1.5  | 1.7  |      |
|                    |                                 | Q <sub>4</sub>             | 1.8  | 2    | 2.2  |      |
| C <sub>RANGE</sub> | Control range                   |                            | ±14  | ±15  | ±16  | dB   |
| A <sub>STEP</sub>  | Step resolution                 |                            | 0.5  | 1    | 1.5  | dB   |
| DC <sub>GAIN</sub> | Bass-DC-gain                    | DC = off                   |      | 0    |      | dB   |
|                    |                                 | DC = on                    | 3.5  | 4.4  | 6    | dB   |
| Middle control     |                                 |                            |      |      |      |      |
| C <sub>RANGE</sub> | Control range                   |                            | ±14  | ±15  | ±16  | dB   |
| A <sub>STEP</sub>  | Step resolution                 |                            | 0.5  | 1    | 1.5  | dB   |
| fc                 | Center frequency <sup>(1)</sup> | f <sub>C1</sub>            | 400  | 500  | 600  | Hz   |
|                    |                                 | f <sub>C2</sub>            | 0.8  | 1    | 1.2  | kHz  |
|                    |                                 | f <sub>C3</sub>            | 1.2  | 1.5  | 1.8  | kHz  |
|                    |                                 | f <sub>C4</sub>            | 2    | 2.5  | 3    | kHz  |
| Q <sub>BASS</sub>  | Quality factor <sup>(1)</sup>   | Q <sub>1</sub>             | 0.45 | 0.5  | 0.55 |      |
|                    |                                 | Q <sub>2</sub>             | 0.65 | 0.75 | 0.85 |      |
|                    |                                 | Q <sub>3</sub>             | 0.9  | 1    | 1.1  |      |
|                    |                                 | Q <sub>4</sub>             | 1.1  | 1.25 | 1.4  |      |
| Treble control     |                                 |                            |      |      |      |      |
| C <sub>RANGE</sub> | Clipping level                  |                            | ±14  | ±15  | ±16  | dB   |
| A <sub>STEP</sub>  | Step resolution                 |                            | 0.5  | 1    | 1.5  | dB   |
| fc                 | Center frequency <sup>(1)</sup> | f <sub>C1</sub>            | 8    | 10   | 12   | kHz  |
|                    |                                 | f <sub>C2</sub>            | 10   | 12.5 | 15   | kHz  |
|                    |                                 | f <sub>C3</sub>            | 12   | 15   | 18   | kHz  |
|                    |                                 | f <sub>C4</sub>            | 14   | 17.5 | 21   | kHz  |
| Speaker attenuator |                                 |                            |      |      |      |      |
| G <sub>MAX</sub>   | Max. gain                       |                            | 14   | 15   | 16   | dB   |
| A <sub>MAX</sub>   | Max. attenuation                |                            | -84  | -79  | -74  | dB   |
| A <sub>STEP</sub>  | Step resolution                 |                            | 0.5  | 1    | 1.5  | dB   |
| A <sub>MUTE</sub>  | Mute attenuation                |                            | 80   | 90   |      | dB   |
| E <sub>E</sub>     | Attenuation set error           |                            |      |      | 2    | dB   |
| V <sub>DC</sub>    | DC steps                        | Adjacent attenuation steps | -5   | 0.1  | 5    | mV   |

**Table 4. Electrical characteristics (continued)** $V_S = 8.5\text{ V}$ ;  $T_{\text{amb}} = 25\text{ }^{\circ}\text{C}$ ;  $R_L = 10\text{ k}\Omega$ ; all gains = 0 dB;  $f = 1\text{ kHz}$ ; unless otherwise specified

| Symbol                      | Parameter                     | Test condition                                   | Min. | Typ.  | Max.  | Unit             |
|-----------------------------|-------------------------------|--------------------------------------------------|------|-------|-------|------------------|
| <b>Audio outputs</b>        |                               |                                                  |      |       |       |                  |
| $V_{\text{CL}}$             | Clipping level                | $d = 0.3\%$                                      | 1.8  | 2     |       | $V_{\text{RMS}}$ |
| $R_{\text{OUT}}$            | Output impedance              |                                                  |      | 30    | 100   | $\Omega$         |
| $R_L$                       | Output load resistance        |                                                  | 2    |       |       | $\text{k}\Omega$ |
| $C_L$                       | Output load capacitor         |                                                  |      |       | 10    | nF               |
| $V_{\text{DC}}$             | DC voltage level              |                                                  | 3.8  | 4.0   | 4.2   | V                |
| <b>Subwoofer attenuator</b> |                               |                                                  |      |       |       |                  |
| $G_{\text{MAX}}$            | Max. gain                     |                                                  | 14   | 15    | 16    | dB               |
| $A_{\text{MAX}}$            | Max. attenuation              |                                                  | -84  | -79   | -74   | dB               |
| $A_{\text{STEP}}$           | Step resolution               |                                                  | 0.5  | 1     | 1.5   | dB               |
| $A_{\text{MUTE}}$           | Mute attenuation              |                                                  | 80   | 90    |       | dB               |
| $E_E$                       | Attenuation set error         |                                                  |      |       | 2     | dB               |
| $V_{\text{DC}}$             | DC steps                      | Adjacent attenuation steps                       | -5   | 0.1   | 5     | mV               |
| <b>General</b>              |                               |                                                  |      |       |       |                  |
| $e_{\text{NO}}$             | Output noise                  | BW=20Hz to 20 kHz all gain = 0dB                 |      | 12    | 20    | $\mu\text{V}$    |
| S/N                         | Signal to noise ratio         | all gain = 0dB flat; $V_o=2V_{\text{RMS}}$       |      | 100   |       | dB               |
| D                           | Distortion                    | $V_{\text{IN}}=1V_{\text{RMS}}$ ; all stages 0dB |      | 0.005 | 0.100 | %                |
| $S_C$                       | Channel separation left/right |                                                  | 80   | 90    |       | dB               |

1. Min. and max. values are calculated according to simulation results; functionality is guaranteed by measuring a directly correlated parameter.

## 4 Description of the audioprocessor

### 4.1 Input stages

In the basic configuration, one stereo pseudo differential (programmable as single-ended input) and three single-ended stereo inputs are available.

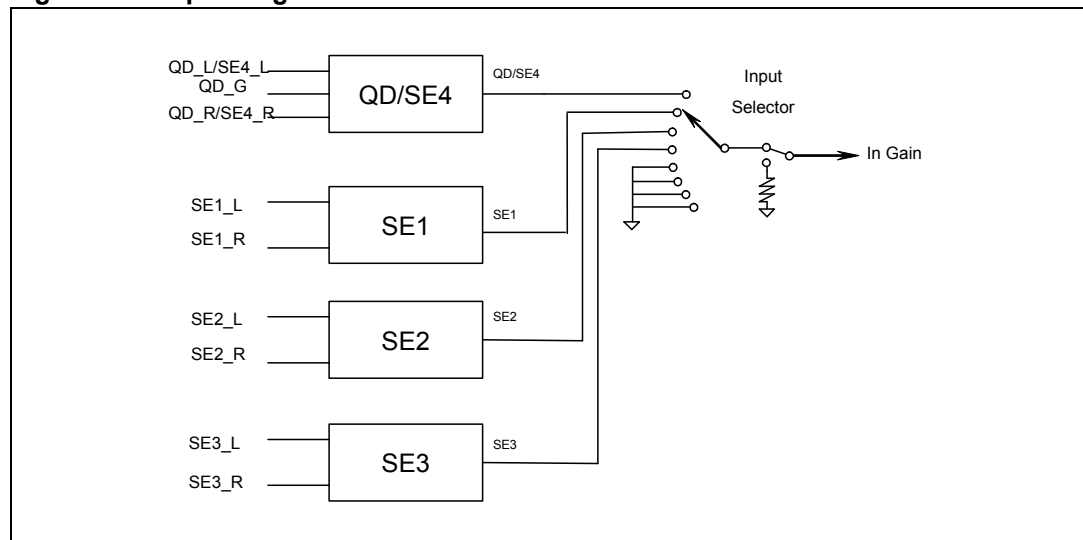
#### Pseudo differential stereo input (PD/SE4)

The PD input is implemented as a buffered pseudo differential stereo stage with 100k $\Omega$  input-impedance at each input. The attenuation is fixed to -3dB in order to adapt the incoming signal level. It is also configurable as single-ended input.

#### Single-ended stereo input (SE1, SE2, SE3)

The input-impedance at each input is 100k $\Omega$  and the attenuation is fixed to -3dB for incoming signals.

**Figure 3. Input stage**



### 4.2 AutoZero

The AutoZero allows a reduction of the number of pins as well as external components by canceling any offset generated by or before the In-Gain-stage (Please notice that externally generated offsets, e.g. generated through the leakage current of the coupling capacitors, are not canceled).

The auto-zeroing is started every time the input source is changed and needs max. 0.6ms for the alignment. To avoid audible clicks the Audio processor is muted before the loudness stage during this time.

#### AutoZero-remain

In some cases, for example if the  $\mu$ P is executing a refresh cycle of the IIC-Bus-programming, it is not useful to start a new AutoZero-action because no new source is

selected and an undesired mute would appear at the outputs. For such applications, it can be switched in the AutoZero-Remain-Mode (Bit 6 of the subaddress-byte). If this bit is set to high, the AutoZero will not be invoked and the old adjustment-value remains.

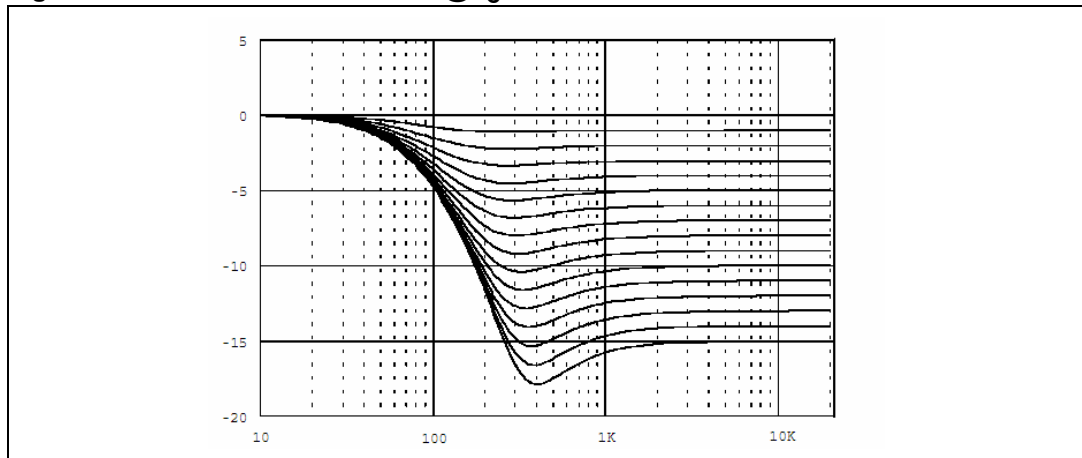
## 4.3 Loudness

There are four parameters programmable in the loudness stage:

### 4.3.1 Attenuation

*Figure 4* shows the attenuation as a function of frequency at  $f_C = 400\text{Hz}$

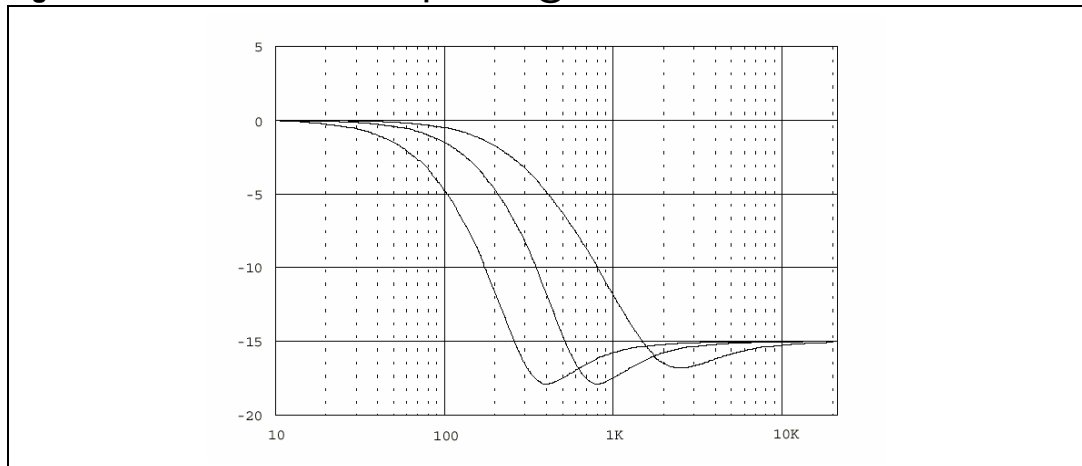
**Figure 4. Loudness attenuation @  $f_C = 400\text{Hz}$ .**



### 4.3.2 Peak frequency

*Figure 5* shows the four possible peak-frequencies at 400, 800 and 2400Hz

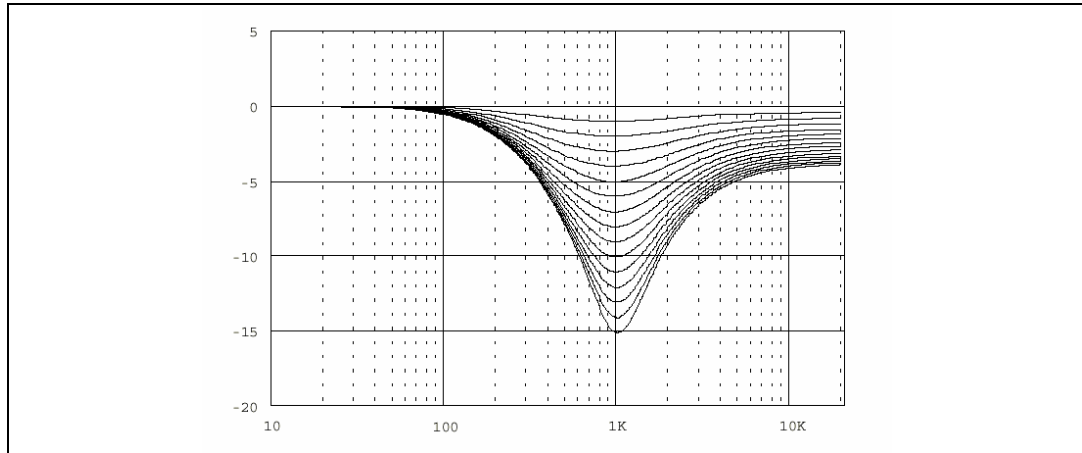
**Figure 5. Loudness center frequencies @ Attn. = 15dB**



### 4.3.3 Low and high frequency boost

*Figure 6* shows the different Loudness shapes in low & high frequency boost.

**Figure 6. Loudness attenuation,  $f_c = 2.4\text{kHz}$**



### 4.3.4 Flat mode

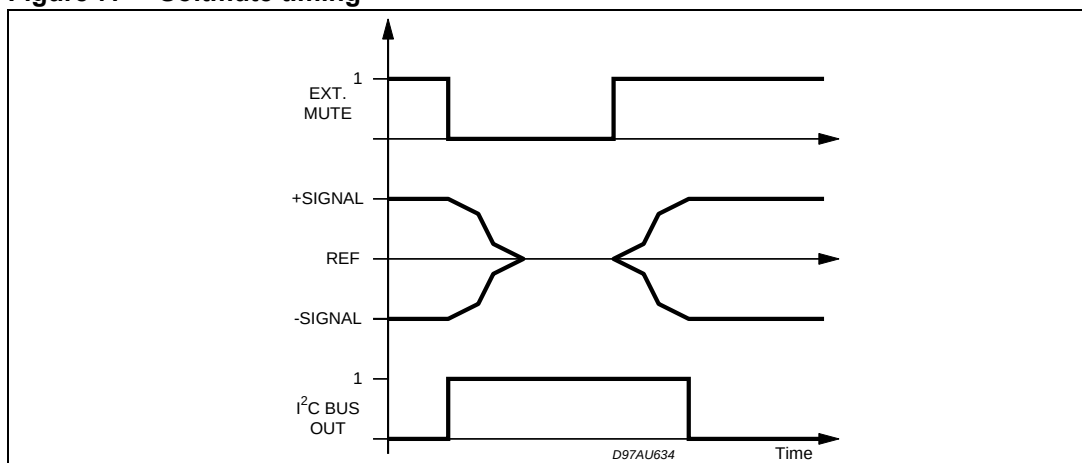
In flat mode the loudness stage works as a 0dB to -15dB attenuator.

## 4.4 SoftMute

The digitally controlled SoftMute stage allows muting/demuting the signal with a  $I^2C$ -bus programmable slope. The mute process can either be activated by the SoftMute pin or by the  $I^2C$ -bus. This slope is realized in a special S-shaped curve to mute slow in the critical regions (see *Figure 7*).

For timing purposes the Bit0 of the  $I^2C$ -bus output register is set to 1 from the start of muting until the end of demuting.

**Figure 7. Softmute timing**



1. Please notice that a started Mute-action is always terminated and could not be interrupted by a change of the mute-signal

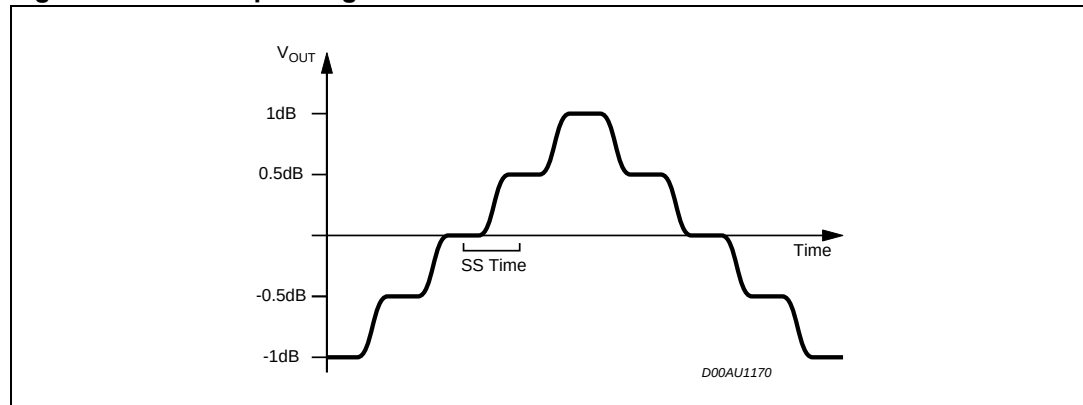
## 4.5 SoftStep volume

When the volume-level is changed audible clicks could appear at the output. The root cause of those clicks

could either be a DC-Offset before the volume-stage or the sudden change of the envelope of the audio signal. With the SoftStep-feature both kinds of clicks could be reduced to a minimum and are no more audible.

Eight programmable softstep time from one step to the next are user selectable.

**Figure 8. SoftStep timing**



1. For steps more than 1dB the SoftStep mode should be deactivated because it could generate 1dB error step during the blend-time.

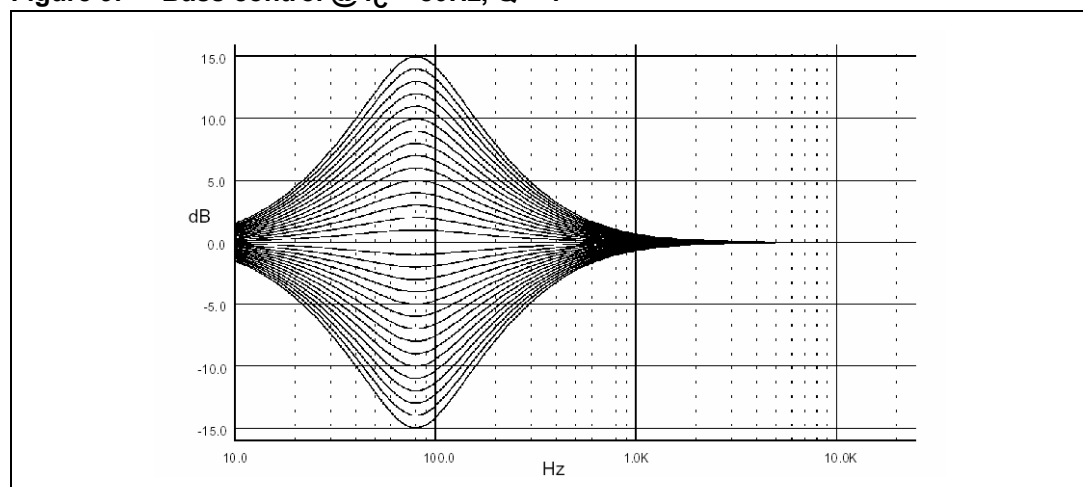
## 4.6 Bass

There are four parameters programmable in the bass stage:

### 4.6.1 Attenuation

*Figure 9* shows the attenuation as a function of frequency at a center frequency of 80Hz.

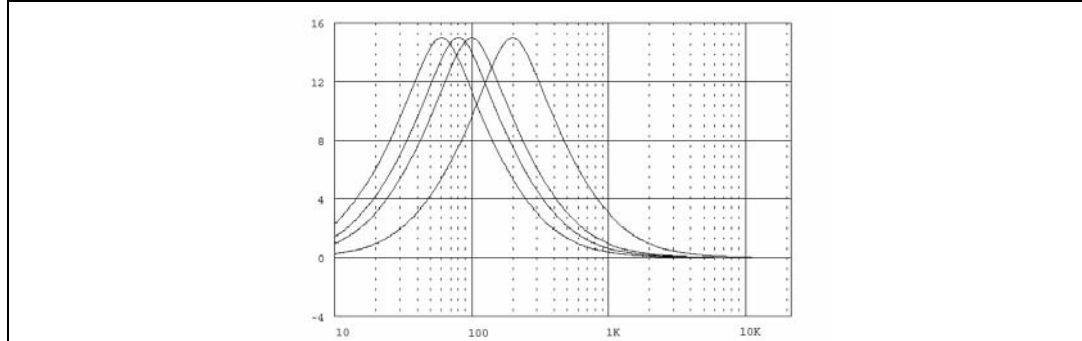
**Figure 9. Bass control @  $f_c = 80\text{Hz}$ ,  $Q = 1$**



### 4.6.2 Center frequency

Figure 10 shows the four possible center frequencies 60, 80, 100 and 200Hz.

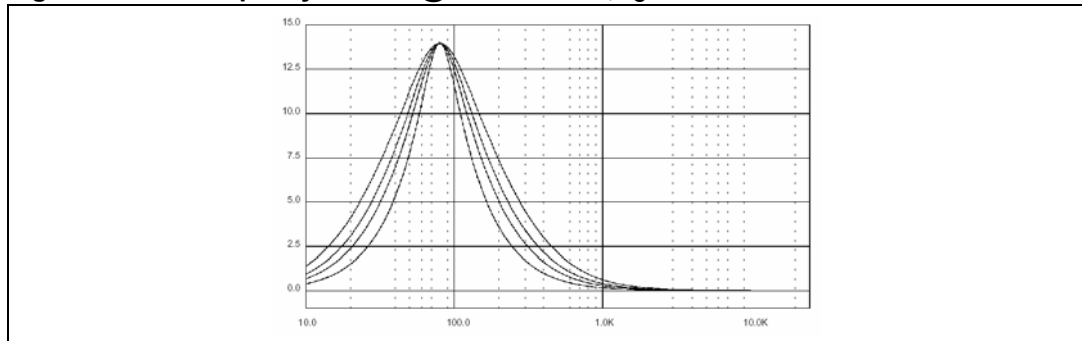
Figure 10. Bass center frequencies @ Gain = 15dB, Q = 1



### 4.6.3 Quality factors

Figure 11 shows the four possible quality factors 1, 1.25, 1.5 and 2.

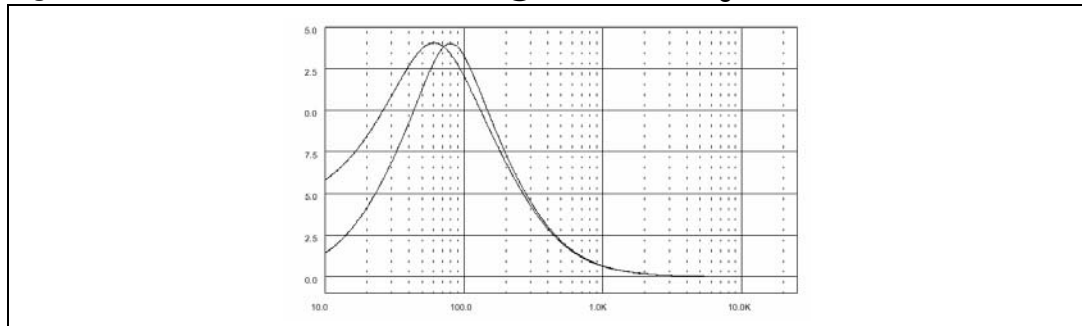
Figure 11. Bass quality factors @ Gain = 14dB,  $f_c = 80\text{Hz}$



### 4.6.4 DC mode

In this mode the DC-gain is increased by 4.4dB. In addition the programmed center frequency and quality factor is decreased by 25% which can be used to reach alternative center frequencies or quality factors.

Figure 12. Bass normal and DC mode @ Gain = 14dB,  $f_c = 80\text{Hz}$



1. The center frequency, Q and DC-mode can be set fully independently.

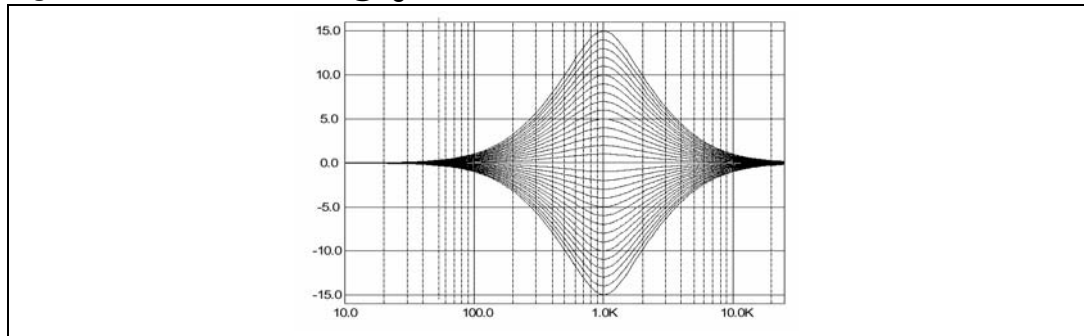
## 4.7 Middle

There are three parameters programmable in the middle stage:

### 4.7.1 Attenuation

*Figure 13* shows the attenuation as a function of frequency at a center frequency of 1kHz.

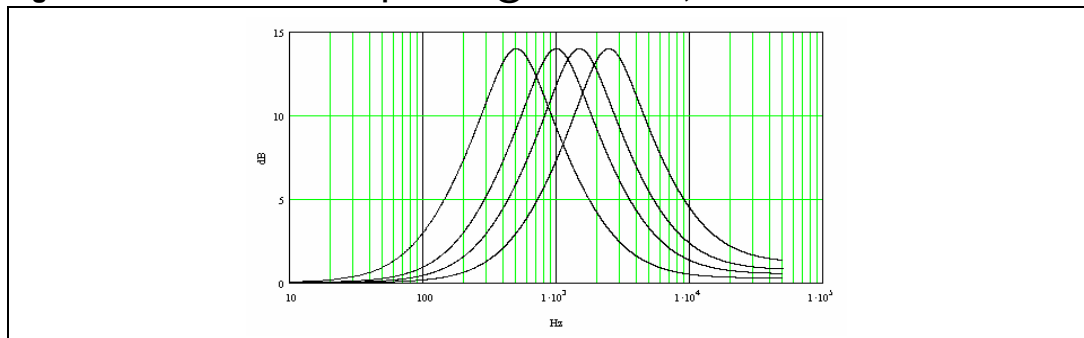
**Figure 13. Middle control @  $f_C = 1$  kHz,  $Q = 1$**



### 4.7.2 Center frequency

*Figure 14* shows the four possible center frequencies 500Hz, 1kHz, 1.5kHz and 2.5kHz.

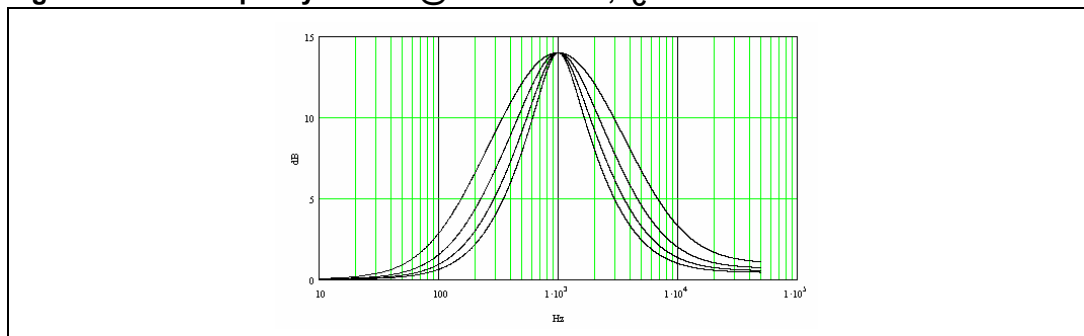
**Figure 14. Middle center frequencies @ Gain = 14dB,  $Q = 1$**



### 4.7.3 Quality factors

*Figure 15* shows the four possible quality factors 0.5, 0.75, 1 and 1.5.

**Figure 15. Bass quality factors @ Gain = 14dB,  $f_C = 1$  kHz**





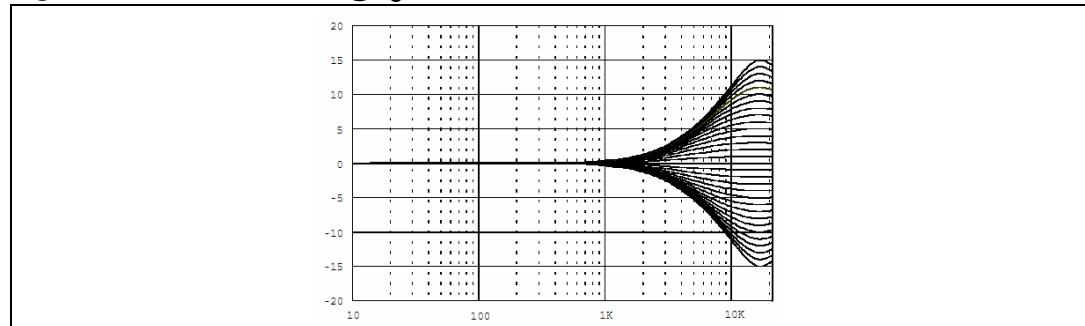
## 4.8 Treble

There are two parameters programmable in the treble stage:

### 4.8.1 Attenuation

*Figure 16* shows the attenuation as a function of frequency at a center frequency of 17.5kHz.

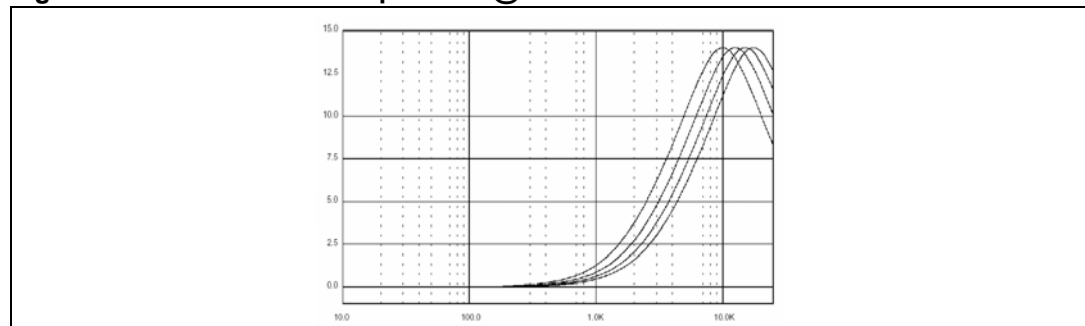
**Figure 16. Treble control @  $f_C = 17.5$  kHz**



### 4.8.2 Center frequency

*Figure 17* shows the four possible center frequencies 10k, 12.5k, 15k and 17.5kHz.

**Figure 17. Treble center frequencies @ Gain = 14dB**



## 4.9 Speaker attenuator

The four speakers have independent soft step speaker controls. And their attenuators can be adjusted from +15dB to -79dB with 1dB steps.

## 4.10 Subwoofer attenuator

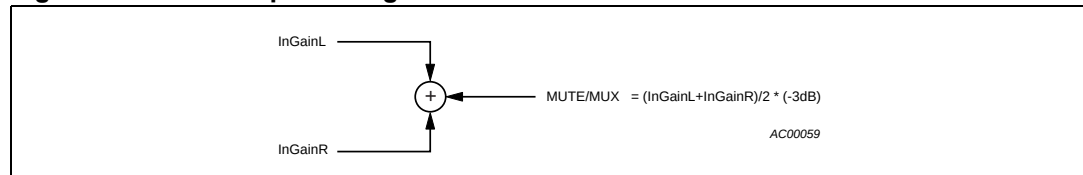
The Subwoofer output is a single ended mono output. The attenuator is exactly the same like the other speakers.

## 4.11 MUX output

It provides a mono signal output (before tone filters) at Mute/MUX pin, used for external level meter / spectrum analyzer.

The mute pin can be configured as MUX output (I<sup>2</sup>C Byte13\_D7D1). When it is configured as MUX output, the output voltage is  $(\text{InGainL} + \text{InGainR})/2$  with -3dB attenuation.

**Figure 18. MUX output configuration**



## 4.12 Audioprocessor testing

In the test mode, which can be activated by setting bit D7 of the IIC subaddress byte and bit D0 of the testing audioprocessor byte, several internal signals are available at the SE2R pin. In this mode, the input resistance of 100kOhm is disconnected from the pin. Internal signals available for testing are listed in the data-byte specification.

## 5 I<sup>2</sup>C bus specification

### 5.1 Interface protocol

The interface protocol comprises:

- a start condition (S)
- a chip address byte (the LSB determines read/write transmission)
- a subaddress byte
- a sequence of data (N-bytes + acknowledge)
- a stop condition (P)
- the max. clock speed is 500kbts/s

#### 5.1.1 Receive mode

|   |   |   |   |   |   |   |   |     |     |    |    |    |    |    |    |    |    |     |      |     |   |
|---|---|---|---|---|---|---|---|-----|-----|----|----|----|----|----|----|----|----|-----|------|-----|---|
| S | 1 | 0 | 0 | 0 | 1 | 0 | 0 | R/W | ACK | TS | AZ | AI | A4 | A3 | A2 | A1 | A0 | ACK | DATA | ACK | P |
|---|---|---|---|---|---|---|---|-----|-----|----|----|----|----|----|----|----|----|-----|------|-----|---|

S = Start

R/W = "0" -> Receive Mode (Chip can be programmed by  $\mu$ P)

"1" -> Transmission Mode (Data could be received by  $\mu$ P)

ACK = Acknowledge

P = Stop

TS = Testing mode

AZ = Auto zero remain

AI = Auto increment

#### 5.1.2 Transmission mode

|   |   |   |   |   |   |   |   |     |     |   |   |   |   |   |   |   |   |    |     |   |
|---|---|---|---|---|---|---|---|-----|-----|---|---|---|---|---|---|---|---|----|-----|---|
| S | 1 | 0 | 0 | 0 | 1 | 0 | 0 | R/W | ACK | X | X | X | X | X | X | X | X | SM | ACK | P |
|---|---|---|---|---|---|---|---|-----|-----|---|---|---|---|---|---|---|---|----|-----|---|

SM = Soft mute activated for main channel

X = Not Used

The transmitted data is automatic updated after each ACK. Transmission can be repeated without new chip address.

#### 5.1.3 Reset condition

A Power-On-Reset is invoked if the Supply-Voltage is below than 2.5V. After that the following data is written automatically into the registers of all subaddresses:

**Table 5. Registers of all subaddresses**

| MSB |   |   |   |   |   |   | LSB |
|-----|---|---|---|---|---|---|-----|
| 1   | 1 | 1 | 1 | 1 | 1 | 1 | 0   |

## 5.2 Subaddress (receive mode)

Table 6. Subaddress (receive mode)

| MSB    |        |        |    |    |    |    |    | LSB                                     | Function |
|--------|--------|--------|----|----|----|----|----|-----------------------------------------|----------|
| I2     | I1     | I0     | A4 | A3 | A2 | A1 | A0 |                                         |          |
| 0<br>1 |        |        |    |    |    |    |    | <b>Testing Mode</b><br>Off<br>On        |          |
|        | 0<br>1 |        |    |    |    |    |    | <b>Auto Zero Remain</b><br>Off<br>On    |          |
|        |        | 0<br>1 |    |    |    |    |    | <b>Auto Increment Mode</b><br>Off<br>On |          |
|        |        |        | 0  | 0  | 0  | 0  | 0  | Main Source Selector                    |          |
|        |        |        | 0  | 0  | 0  | 0  | 1  | Loudness                                |          |
|        |        |        | 0  | 0  | 0  | 1  | 0  | Volume                                  |          |
|        |        |        | 0  | 0  | 0  | 1  | 1  | Treble                                  |          |
|        |        |        | 0  | 0  | 1  | 0  | 0  | Middle                                  |          |
|        |        |        | 0  | 0  | 1  | 0  | 1  | Bass                                    |          |
|        |        |        | 0  | 0  | 1  | 1  | 0  | Middle/ Bass Fc Select                  |          |
|        |        |        | 0  | 0  | 1  | 1  | 1  | Speaker Attenuator Left Front           |          |
|        |        |        | 0  | 1  | 0  | 0  | 0  | Speaker Attenuator Left Rear            |          |
|        |        |        | 0  | 1  | 0  | 0  | 1  | Speaker Attenuator Right Rear           |          |
|        |        |        | 0  | 1  | 0  | 1  | 0  | Speaker Attenuator Right Front          |          |
|        |        |        | 0  | 1  | 0  | 1  | 1  | Subwoofer Attenuator                    |          |
|        |        |        | 0  | 1  | 1  | 0  | 0  | Soft Mute / Soft Step                   |          |
|        |        |        | 0  | 1  | 1  | 0  | 1  | Testing Audio Processor                 |          |

## 5.3 Data byte specification

Table 7. Input selector /gain (0)

| MSB    |                       |                       |                       |                       |                       |                       | LSB                   | Function                                                         |
|--------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|------------------------------------------------------------------|
| D7     | D6                    | D5                    | D4                    | D3                    | D2                    | D1                    | D0                    |                                                                  |
|        |                       |                       |                       |                       | 0<br>0<br>0<br>0<br>1 | 0<br>0<br>1<br>1<br>X | 0<br>1<br>0<br>1<br>X | <b>Source Selector</b><br>PD/SE4<br>SE1<br>SE2<br>SE3<br>mute    |
|        | 0<br>0<br>:<br>1<br>1 | 0<br>0<br>:<br>1<br>1 | 0<br>0<br>:<br>1<br>1 | 0<br>1<br>:<br>0<br>1 |                       |                       |                       | <b>Input Gain</b><br>0dB<br>1dB<br>:<br>14dB<br>15dB             |
| 0<br>1 |                       |                       |                       |                       |                       |                       |                       | <b>Diffin Mode</b><br>Single Ended Stereo<br>Differential Stereo |

Table 8. Loudness (1)

| MSB    |        |                  |                  |                       |                       |                       | LSB                   | Function                                                                                |
|--------|--------|------------------|------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------------------------------------------------------------------------|
| D7     | D6     | D5               | D4               | D3                    | D2                    | D1                    | D0                    |                                                                                         |
|        |        |                  |                  | 0<br>0<br>:<br>1<br>1 | 0<br>0<br>:<br>1<br>1 | 0<br>0<br>:<br>1<br>1 | 0<br>1<br>:<br>0<br>1 | <b>Attenuation</b><br>0dB<br>-1dB<br>:<br>-14dB<br>-15dB                                |
|        | 0      | 0<br>0<br>1<br>1 | 0<br>1<br>0<br>1 |                       |                       |                       |                       | <b>Filter/Center Frequency</b><br>Off (Flat) D6 must be = 0<br>400Hz<br>800Hz<br>2400Hz |
|        | 0<br>1 |                  |                  |                       |                       |                       |                       | <b>Shape</b><br>Low Boost<br>Low & HighBoost                                            |
| 0<br>1 |        |                  |                  |                       |                       |                       |                       | <b>Loudness Soft Step</b><br>on<br>off                                                  |

Table 9. Volume / speaker attenuation (2,7,8,9,10,11)

| MSB |    |    |    |    |    |    | LSB | Function         |
|-----|----|----|----|----|----|----|-----|------------------|
| D7  | D6 | D5 | D4 | D3 | D2 | D1 | D0  |                  |
|     | 0  | 0  | 0  | 1  | 1  | 1  | 1   | Gain/Attenuation |
|     | 0  | 0  | 0  | 1  | 1  | 1  | 0   | +15dB            |
|     | :  | :  | :  | :  | :  | :  | :   | +14dB            |
|     | 0  | 0  | 0  | 0  | 0  | 0  | 1   | :                |
|     | 0  | 0  | 0  | 0  | 0  | 0  | 0   | +1dB             |
|     | 0  | 0  | 1  | 0  | 0  | 0  | 0   | 0dB              |
|     | 0  | 0  | 1  | 0  | 0  | 0  | 1   | 0dB              |
|     | :  | :  | :  | :  | :  | :  | :   | -1dB             |
|     | 0  | 0  | 1  | 1  | 1  | 1  | 1   | :                |
|     | 0  | 1  | 0  | 0  | 0  | 0  | 0   | -15dB            |
|     | :  | :  | :  | :  | :  | :  | :   | -16dB            |
|     | 1  | 0  | 1  | 1  | 1  | 1  | 0   | :                |
|     | 1  | 0  | 1  | 1  | 1  | 1  | 1   | -78dB            |
|     | 1  | 1  | x  | x  | x  | x  | x   | -79dB            |
|     |    |    |    |    |    |    |     | Mute             |
| 0   |    |    |    |    |    |    |     | Volume Soft Step |
| 1   |    |    |    |    |    |    |     | on               |
|     |    |    |    |    |    |    |     | off              |

Table 10. Treble filter (3)

| MSB |    |    |    |    |    |    | LSB | Function                |
|-----|----|----|----|----|----|----|-----|-------------------------|
| D7  | D6 | D5 | D4 | D3 | D2 | D1 | D0  |                         |
|     |    |    | 0  | 0  | 0  | 0  | 0   | Gain/Attenuation        |
|     |    |    | 0  | 0  | 0  | 0  | 1   | -15dB                   |
|     |    |    | :  | :  | :  | :  | :   | -14dB                   |
|     |    |    | 0  | 1  | 1  | 1  | 0   | :                       |
|     |    |    | 0  | 1  | 1  | 1  | 1   | -1dB                    |
|     |    |    | 1  | 1  | 1  | 1  | 1   | 0dB                     |
|     |    |    | 1  | 1  | 1  | 1  | 0   | 0dB                     |
|     |    |    | :  | :  | :  | :  | :   | +1dB                    |
|     |    |    | 1  | 0  | 0  | 0  | 1   | :                       |
|     |    |    | 1  | 0  | 0  | 0  | 0   | +14dB                   |
|     |    |    |    |    |    |    |     | +15dB                   |
|     | 0  | 0  |    |    |    |    |     | Treble Center Frequency |
|     | 0  | 1  |    |    |    |    |     | 10.0kHz                 |
|     | 1  | 0  |    |    |    |    |     | 12.5kHz                 |
|     | 1  | 1  |    |    |    |    |     | 15.0kHz                 |
|     |    |    |    |    |    |    |     | 17.5kHz                 |
| 1   |    |    |    |    |    |    |     | Must be "1"             |

Table 11. Middle filter (4)

| MSB |    |    |    |    |    |    | LSB | Function                         |
|-----|----|----|----|----|----|----|-----|----------------------------------|
| D7  | D6 | D5 | D4 | D3 | D2 | D1 | D0  |                                  |
|     |    |    | 0  | 0  | 0  | 0  | 0   | <b>Gain/Attenuation</b><br>-15dB |
|     |    |    | 0  | 0  | 0  | 0  | 1   | -14dB                            |
|     |    |    | :  | :  | :  | :  | :   | :                                |
|     |    |    | 0  | 1  | 1  | 1  | 0   | -1dB                             |
|     |    |    | 0  | 1  | 1  | 1  | 1   | 0dB                              |
|     |    |    | 1  | 1  | 1  | 1  | 1   | 0dB                              |
|     |    |    | 1  | 1  | 1  | 1  | 0   | +1dB                             |
|     |    |    | :  | :  | :  | :  | :   | :                                |
|     |    |    | 1  | 0  | 0  | 0  | 1   | +14dB                            |
|     |    |    | 1  | 0  | 0  | 0  | 0   | +15dB                            |
|     | 0  | 0  |    |    |    |    |     | <b>Middle Q Factor</b><br>0.5    |
|     | 0  | 1  |    |    |    |    |     | 0.75                             |
|     | 1  | 0  |    |    |    |    |     | 1                                |
|     | 1  | 1  |    |    |    |    |     | 1.25                             |
| 0   |    |    |    |    |    |    |     | <b>Middle Soft Step</b><br>on    |
| 1   |    |    |    |    |    |    |     | off                              |

Table 12. Bass filter (5)

| MSB    |                  |                  |    |    |    |    | LSB | Function                                          |
|--------|------------------|------------------|----|----|----|----|-----|---------------------------------------------------|
| D7     | D6               | D5               | D4 | D3 | D2 | D1 | D0  |                                                   |
|        |                  |                  | 0  | 0  | 0  | 0  | 0   | <b>Gain/Attenuation</b><br>-15dB                  |
|        |                  |                  | 0  | 0  | 0  | 0  | 1   | -14dB                                             |
|        |                  |                  | :  | :  | :  | :  | :   | :                                                 |
|        |                  |                  | 0  | 1  | 1  | 1  | 0   | -1dB                                              |
|        |                  |                  | 0  | 1  | 1  | 1  | 1   | 0dB                                               |
|        |                  |                  | 1  | 1  | 1  | 1  | 1   | 0dB                                               |
|        |                  |                  | 1  | 1  | 1  | 1  | 0   | +1dB                                              |
|        |                  |                  | :  | :  | :  | :  | :   | :                                                 |
|        |                  |                  | 1  | 0  | 0  | 0  | 1   | +14dB                                             |
|        |                  |                  | 1  | 0  | 0  | 0  | 0   | +15dB                                             |
|        | 0<br>0<br>1<br>1 | 0<br>1<br>0<br>1 |    |    |    |    |     | <b>Bass Q Factor</b><br>1.0<br>1.25<br>1.5<br>2.0 |
| 0<br>1 |                  |                  |    |    |    |    |     | <b>Bass Soft Step</b><br>on<br>off                |

Table 13. Middle / bass Fc select (6)

| MSB |    |        |        |                  |                  |                  | LSB              | Function                                                            |
|-----|----|--------|--------|------------------|------------------|------------------|------------------|---------------------------------------------------------------------|
| D7  | D6 | D5     | D4     | D3               | D2               | D1               | D0               |                                                                     |
|     |    |        |        |                  |                  | 0<br>0<br>1<br>1 | 0<br>1<br>0<br>1 | <b>Middle Center Frequency</b><br>500Hz<br>1kHz<br>1.5kHz<br>2.5kHz |
|     |    |        |        | 0<br>0<br>1<br>1 | 0<br>1<br>0<br>1 |                  |                  | <b>Bass Center Frequency</b><br>60Hz<br>80Hz<br>100Hz<br>200Hz      |
|     |    |        | 0<br>1 |                  |                  |                  |                  | <b>Bass DC Mode</b><br>off<br>on                                    |
|     |    | 0<br>1 |        |                  |                  |                  |                  | <b>Smoothing Filter</b><br>off<br>on                                |
| X   | X  |        |        |                  |                  |                  |                  | Not used                                                            |



Table 14. Soft mute and soft step time (12)

| MSB |        |                                      |                                      |                                      |             |             | LSB    | Function                                                                                                |
|-----|--------|--------------------------------------|--------------------------------------|--------------------------------------|-------------|-------------|--------|---------------------------------------------------------------------------------------------------------|
| D7  | D6     | D5                                   | D4                                   | D3                                   | D2          | D1          | D0     |                                                                                                         |
|     |        |                                      |                                      |                                      |             |             | 0<br>1 | <b>Soft Mute</b><br>on<br>off                                                                           |
|     |        |                                      |                                      |                                      | 0<br>0<br>1 | 0<br>1<br>X |        | <b>Soft Mute Time</b><br>0.48ms<br>0.96ms<br>123ms                                                      |
|     |        | 0<br>0<br>0<br>0<br>1<br>1<br>1<br>1 | 0<br>0<br>1<br>1<br>0<br>0<br>1<br>1 | 0<br>1<br>0<br>1<br>0<br>1<br>0<br>1 |             |             |        | <b>Soft Step Time</b><br>0.16ms<br>0.32ms<br>0.64ms<br>1.28ms<br>2.56ms<br>5.12ms<br>10.24ms<br>20.48ms |
|     | 0<br>1 |                                      |                                      |                                      |             |             |        | <b>AZ function</b><br>off<br>on                                                                         |
| X   |        |                                      |                                      |                                      |             |             |        | Not used                                                                                                |

Table 15. Testing audio processor (13)

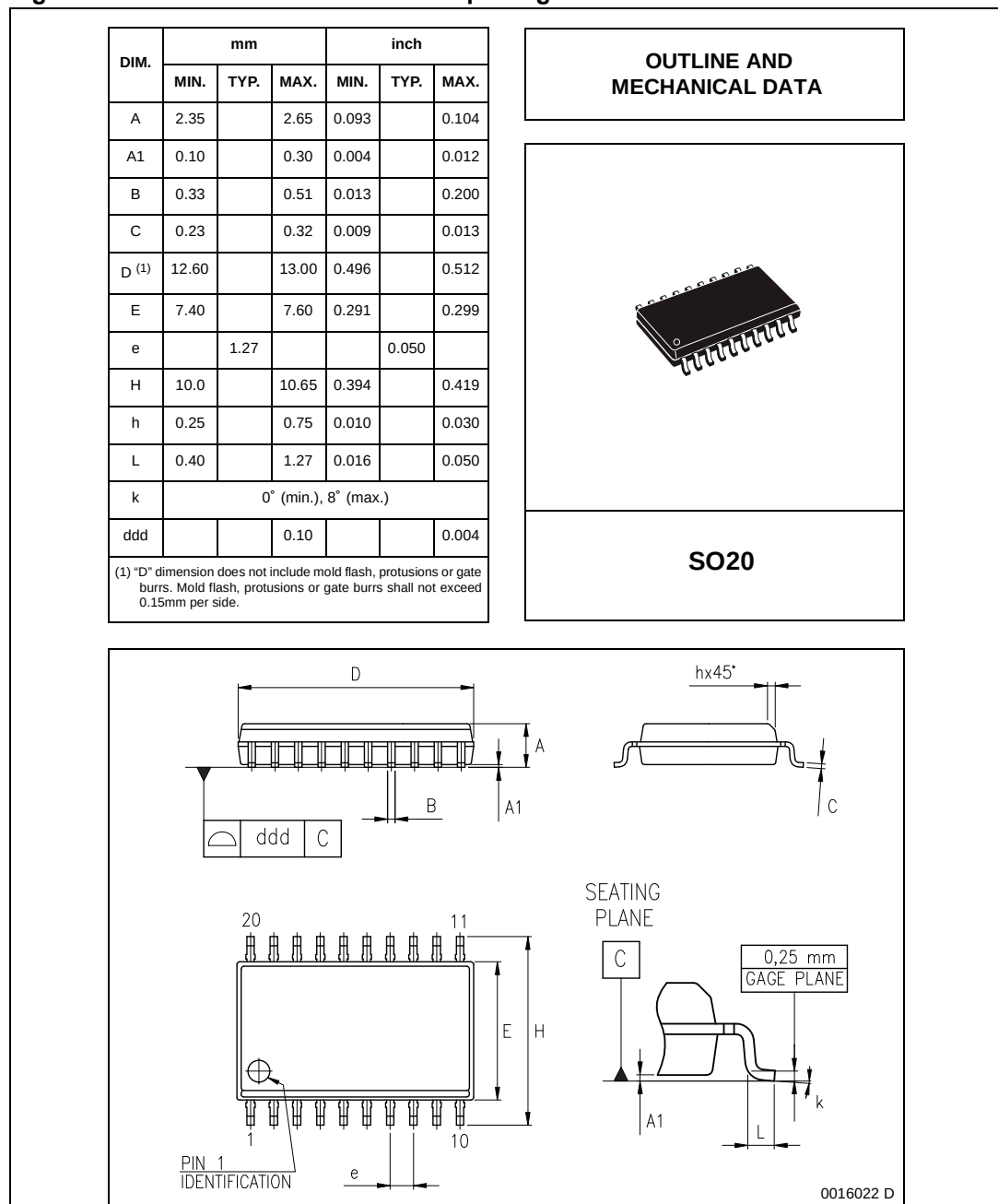
| MSB         |        |    |                                      |                                      |                                      |             | LSB    | Function                                                                                                           |
|-------------|--------|----|--------------------------------------|--------------------------------------|--------------------------------------|-------------|--------|--------------------------------------------------------------------------------------------------------------------|
| D7          | D6     | D5 | D4                                   | D3                                   | D2                                   | D1          | D0     |                                                                                                                    |
|             |        |    |                                      |                                      |                                      |             | 0<br>1 | <b>Audio Processor Testing Mode</b><br>off<br>on                                                                   |
|             |        |    | 0<br>0<br>0<br>0<br>1<br>1<br>1<br>1 | 0<br>0<br>1<br>1<br>0<br>0<br>1<br>1 | 0<br>1<br>0<br>1<br>0<br>1<br>0<br>1 |             |        | <b>Test Multiplexer</b><br>InMuxOutR<br>LoudOutR<br>VolumeOutR<br>VBG1.26<br>REF5V5<br>SSCLK<br>SMCLK<br>Clk200kHz |
|             |        | x  |                                      |                                      |                                      |             |        | Not Used                                                                                                           |
|             | 0<br>1 |    |                                      |                                      |                                      |             |        | <b>Schlock</b><br>Normal<br>Fast Mode                                                                              |
| 0<br>1<br>1 |        |    |                                      |                                      |                                      | x<br>0<br>1 |        | <b>MUTE Pin Config.</b><br>MUX output<br>External clock<br>Mute (normal)                                           |

## 6 Package information

In order to meet environmental requirements, ST (also) offers these devices in ECOPACK® packages. ECOPACK® packages are lead-free. The category of second Level Interconnect is marked on the package and on the inner box label, in compliance with JEDEC Standard JESD97. The maximum ratings related to soldering conditions are also marked on the inner box label.

ECOPACK is an ST trademark. ECOPACK specifications are available at: [www.st.com](http://www.st.com).

**Figure 19. SO20 mechanical data and package dimensions**



## 7 Revision history

**Table 16. Document revision history**

| Date        | Revision | Changes                                                                   |
|-------------|----------|---------------------------------------------------------------------------|
| 15-Feb-2007 | 1        | Initial release.                                                          |
| 23-Oct-2008 | 2        | Updated <a href="#">Table 6: Subaddress (receive mode) on page 21</a> .   |
| 03-Nov-2008 | 3        | Corrected <a href="#">Table 6: Subaddress (receive mode) on page 21</a> . |
| 23-Sep-2013 | 4        | Updated Disclaimer.                                                       |

**Please Read Carefully:**

Information in this document is provided solely in connection with ST products. STMicroelectronics NV and its subsidiaries ("ST") reserve the right to make changes, corrections, modifications or improvements, to this document, and the products and services described herein at any time, without notice.

All ST products are sold pursuant to ST's terms and conditions of sale.

Purchasers are solely responsible for the choice, selection and use of the ST products and services described herein, and ST assumes no liability whatsoever relating to the choice, selection or use of the ST products and services described herein.

No license, express or implied, by estoppel or otherwise, to any intellectual property rights is granted under this document. If any part of this document refers to any third party products or services it shall not be deemed a license grant by ST for the use of such third party products or services, or any intellectual property contained therein or considered as a warranty covering the use in any manner whatsoever of such third party products or services or any intellectual property contained therein.

**UNLESS OTHERWISE SET FORTH IN ST'S TERMS AND CONDITIONS OF SALE ST DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY WITH RESPECT TO THE USE AND/OR SALE OF ST PRODUCTS INCLUDING WITHOUT LIMITATION IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE (AND THEIR EQUIVALENTS UNDER THE LAWS OF ANY JURISDICTION), OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT.**

**ST PRODUCTS ARE NOT DESIGNED OR AUTHORIZED FOR USE IN: (A) SAFETY CRITICAL APPLICATIONS SUCH AS LIFE SUPPORTING, ACTIVE IMPLANTED DEVICES OR SYSTEMS WITH PRODUCT FUNCTIONAL SAFETY REQUIREMENTS; (B) AERONAUTIC APPLICATIONS; (C) AUTOMOTIVE APPLICATIONS OR ENVIRONMENTS, AND/OR (D) AEROSPACE APPLICATIONS OR ENVIRONMENTS. WHERE ST PRODUCTS ARE NOT DESIGNED FOR SUCH USE, THE PURCHASER SHALL USE PRODUCTS AT PURCHASER'S SOLE RISK, EVEN IF ST HAS BEEN INFORMED IN WRITING OF SUCH USAGE, UNLESS A PRODUCT IS EXPRESSLY DESIGNATED BY ST AS BEING INTENDED FOR "AUTOMOTIVE, AUTOMOTIVE SAFETY OR MEDICAL" INDUSTRY DOMAINS ACCORDING TO ST PRODUCT DESIGN SPECIFICATIONS. PRODUCTS FORMALLY ESCC, QML OR JAN QUALIFIED ARE DEEMED SUITABLE FOR USE IN AEROSPACE BY THE CORRESPONDING GOVERNMENTAL AGENCY.**

Resale of ST products with provisions different from the statements and/or technical features set forth in this document shall immediately void any warranty granted by ST for the ST product or service described herein and shall not create or extend in any manner whatsoever, any liability of ST.

ST and the ST logo are trademarks or registered trademarks of ST in various countries.

Information in this document supersedes and replaces all information previously supplied.

The ST logo is a registered trademark of STMicroelectronics. All other names are the property of their respective owners.

© 2013 STMicroelectronics - All rights reserved

STMicroelectronics group of companies

Australia - Belgium - Brazil - Canada - China - Czech Republic - Finland - France - Germany - Hong Kong - India - Israel - Italy - Japan - Malaysia - Malta - Morocco - Philippines - Singapore - Spain - Sweden - Switzerland - United Kingdom - United States of America

[www.st.com](http://www.st.com)

