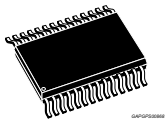
# TDA7721

## 5 band car audio processor

**Datasheet - production data**



**TSSOP28**

## Features

- Input multiplexer
  - QD1 to QD2: quasi-differential stereo input
  - SE1 to SE3: stereo single-ended input
- InGain
  - 6 dB with 1 dB steps
- Loudness
  - 2nd order frequency response
  - Programmable center frequency (400 Hz / 800 Hz / 2400 Hz)
  - 15 dB with 1 dB steps
  - Selectable high frequency boost
  - Selectable flat-mode (constant attenuation)
- Volume
  - +23 dB to -79 dB with 1 dB step resolution
  - SoftStep control with programmable blend times
- EQ1
  - 2nd order frequency response
  - Center frequency programmable in 4 steps (63 Hz / 80 Hz/ 100 Hz /125 Hz)
  - Q programmable in 4 steps (1.0/1.25/1.5/2.0)
  - -15 to 15 dB range with 1 dB resolution
- EQ2
  - 2nd order frequency response
  - Center frequency programmable in 4 steps (200 Hz/ 250 Hz/ 315 Hz/ 400 Hz)
  - Q programmable in 4 steps (1.0/1.25/1.5/2.0)
  - -15 to 15 dB range with 1 dB resolution
- EQ3
  - 2nd order frequency response
  - Center frequency programmable in 4 steps (630 Hz/ 800 Hz/ 1 kHz/ 1.25 kHz)
  - Q programmable in 4 steps (0.75/1.0/1.25/2)
  - -15 to 15 dB range with 1 dB resolution
- EQ4
  - 2nd order frequency response
  - Center frequency programmable in 4 steps (2 kHz/ 2.5 kHz/ 3.15 kHz/ 4 kHz)
  - Q programmable in 4 steps (0.75/1.0/1.25/2)
  - -15 to 15 dB range with 1 dB resolution
- EQ5
  - 2nd order frequency response
  - Center frequency programmable in 4 steps (6.3 kHz/ 8 kHz / 10 kHz/ 12.5 kHz)
  - Q programmable in 4 steps (0.75/1.0/1.25/2)
  - -15 to 15 dB range with 1 dB resolution
- Highpass
  - 2nd order frequency response
  - Center frequency programmable in 5 steps (63 Hz / 100 Hz / 120 Hz / 150 Hz/ 180 Hz)
- Subwoofer
  - 2nd order low pass filter
  - Programmable cut off frequency
  - (55 Hz / 85 Hz / 120 Hz / 160 Hz)
- Speaker
  - 6 independent soft step speaker controls
  - +15 dB to -79 dB with 1 dB steps
  - Three selectable output DC level
  - Direct mute
- Mute functions
  - Direct mute
  - Digitally controlled SoftMute with 4 programmable mute-times
  - (0.48 ms / 0.96 ms / 8 ms / 16 ms)
- Offset detection
  - Offset voltage detection circuit for on-board power amplifier failure diagnosis

**Table 1. Device summary**

| Order code | Package | Packing |
|---|---|---|
| TDA7721 | TSSOP28 | Tube |
| TDA7721TR | TSSOP28 | Tape and reel |



This is information on a product in full production. www.st.com

# Contents


**1 Description and block diagram . . . . . 6**

1.1 Description . . . . . 6

1.2 Block diagram . . . . . 6

**2 Pin connections and description . . . . . 7**

2.1 Pin connections . . . . . 7

**3 Electrical specifications . . . . . 9**

3.1 Thermal data . . . . . 9

3.2 Absolute maximum ratings . . . . . 9

3.3 Electrical characteristics . . . . . 9

**4 Description of audioprocessor . . . . . 16**

4.1 Input stage . . . . . 16

4.1.1 Single-ended stereo input (SE1, SE2, SE3) . . . . . 16

4.1.2 Quasi-differential stereo Input (QD1,QD2) . . . . . 16

4.1.3 Fast charge . . . . . 16

4.2 Input gain . . . . . 16

4.3 Loudness . . . . . 16

4.3.1 Loudness attenuation . . . . . 16

4.3.2 Peak frequency . . . . . 17

4.3.3 High frequency boost . . . . . 17

4.3.4 Flat mode . . . . . 17

4.4 SoftMute . . . . . 18

4.5 Volume . . . . . 18

4.6 EQ1 . . . . . 19

4.6.1 EQ1 attenuation . . . . . 19

4.6.2 Center frequency . . . . . 19

4.6.3 EQ1 quality factor . . . . . 20

4.7 EQ2 . . . . . 20

4.7.1 EQ2 attenuation . . . . . 20

4.7.2 EQ2 center frequency . . . . . 21

4.7.3 EQ2 quality factor . . . . . 21

4.8 EQ3 . . . 22
4.8.1 EQ3 attenuation . . . 22
4.8.2 Center frequency . . . 22
4.8.3 EQ3 quality factor . . . 23
4.9 EQ4 . . . 23
4.9.1 EQ4 attenuation . . . 23
4.9.2 Center frequency . . . 24
4.9.3 EQ4 quality factor . . . 24
4.10 EQ5 . . . 25
4.10.1 EQ5 attenuation . . . 25
4.10.2 Center frequency . . . 25
4.10.3 EQ5 quality factor . . . 26
4.11 Highpass filter . . . 26
4.12 Subwoofer filter . . . 27
4.13 SoftStep control . . . 28
4.14 DC offset detector . . . 29
4.15 Output stage . . . 30
4.16 Audioprocessor testing . . . 30

**5 $I^2C$ bus specification . . . 31**
5.1 Interface protocol . . . 31
5.2 $I^2C$ bus electrical characteristics . . . 31
5.2.1 Receive mode . . . 32
5.2.2 Transmission mode . . . 32
5.2.3 Reset condition . . . 33
5.3 Data byte specification . . . 34

**6 Package information . . . 49**

**7 Revision history . . . 50**

# List of tables

Table 1. Device summary . . . 1
Table 2. Pin description . . . 7
Table 3. Thermal data . . . 9
Table 4. Absolute maximum ratings . . . 9
Table 5. Electrical characteristics . . . 9
Table 6. $I^2C$ bus electrical characteristics . . . 31
Table 7. Subaddress (receive mode) . . . 33
Table 8. Main selector (0) . . . 34
Table 9. Output level / Highpass / EQ5 (1) . . . 35
Table 10. EQ2 (2) . . . 35
Table 11. EQ4 (3) . . . 36
Table 12. SoftMute / others (4) . . . 37
Table 13. SoftStep I (5) . . . 38
Table 14. SoftStep II / DC-detector (6) . . . 39
Table 15. Loudness (7) . . . 40
Table 16. Volume (8) . . . 41
Table 17. EQ5 (9) . . . 42
Table 18. EQ3 (10) . . . 42
Table 19. EQ1 (11) . . . 43
Table 20. Subwoofer / EQ3/ EQ1 (12) . . . 44
Table 21. Speaker attenuation (FL/FR/RL/RR/SWL/SWR) (13-18) . . . 44
Table 22. Testing audio processor 1 (19) . . . 45
Table 23. Testing audio processor 2 (20) . . . 46
Table 24. Testing audio processor 3 (21) . . . 47
Table 25. InGain & EQ2, EQ4 (22) . . . 48
Table 26. Document revision history . . . 50

# List of figures

Figure 1. Block diagram . . . 6
Figure 2. Pin connections (top view) . . . 7
Figure 3. Loudness attenuation @ $f_P$ = 400 Hz . . . 16
Figure 4. loudness center frequencies @ attn. = 15 dB . . . 17
Figure 5. Loudness attenuation, $f_c$ = 2.4 kHz . . . 17
Figure 6. SoftMute timing . . . 18
Figure 7. EQ1 gain control @ $f_c$ = 125 Hz, Q = 1 . . . 19
Figure 8. EQ1 center frequencies @ gain = 14 dB . . . 19
Figure 9. EQ1 quality factors @ $f_c$ = 125 Hz . . . 20
Figure 10. EQ2 gain control @ $f_c$ = 400 Hz, Q = 1 . . . 20
Figure 11. EQ2 center frequency @ gain = 14 dB . . . 21
Figure 12. EQ2 quality factors @ $f_c$ = 400 Hz . . . 21
Figure 13. EQ3 gain control @ $f_c$ = 1.25 kHz, Q = 1 . . . 22
Figure 14. EQ3 center frequencies @ gain = 14 dB . . . 22
Figure 15. EQ3 quality factors @ $f_c$ = 1.25 kHz . . . 23
Figure 16. EQ4 gain control @ $f_c$ = 4 kHz, Q = 1 . . . 23
Figure 17. EQ4 center frequencies @ gain = 14 dB . . . 24
Figure 18. EQ4 quality factors @ $f_c$ = 4 kHz . . . 24
Figure 19. EQ5 gain control @ $f_c$ = 12.5 kHz . . . 25
Figure 20. EQ5 center frequencies @ gain = 14 dB . . . 25
Figure 21. EQ5 quality factors @ $f_c$ = 12.5 kHz . . . 26
Figure 22. Highpass cut frequencies . . . 26
Figure 23. Subwoofer cut frequencies . . . 27
Figure 24. DC offset detection circuit (simplified) . . . 29
Figure 25. Test circuit . . . 30
Figure 26. $I^2C$ bus interface protocol . . . 31
Figure 27. $I^2C$ bus data . . . 32
Figure 28. TSSOP28 mechanical data and package dimensions . . . 49

# 1 Description and block diagram

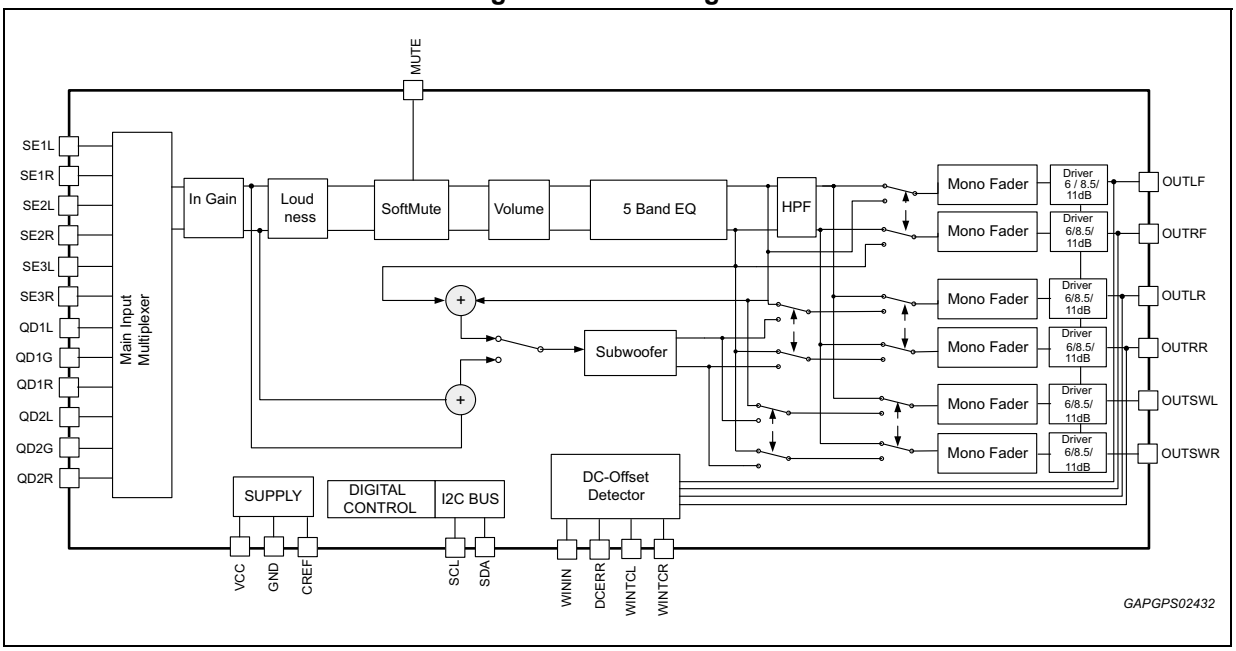
## 1.1 Description

The TDA7721 is a high performance signal processor specifically designed for car radio applications.

The device includes a high performance audio processor with fully integrated audio filters and new SoftStep architecture. The digital control allows programming in a wide range of filter characteristics.

## 1.2 Block diagram

**Figure 1. Block diagram**



# 2 Pin connections and description

## 2.1 Pin connections

**Figure 2. Pin connections (top view)**

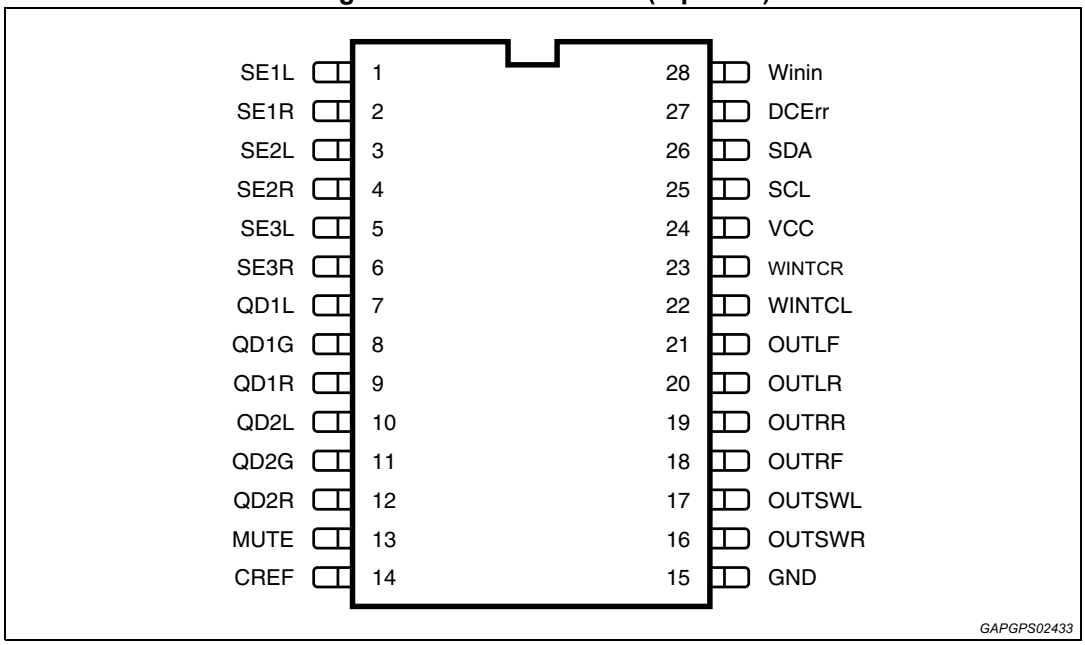



**Table 2. Pin description**

| N# | Pin name | Description | I/O |
|---|---|---|---|
| 1 | SE1L | Single-end input left | I |
| 2 | SE1R | Single-end input right | I |
| 3 | SE2L | Single-end input left | I |
| 4 | SE2R | Single-end input right | I |
| 5 | SE3L | Single-end input left | I |
| 6 | SE3R | Single-end input right | I |
| 7 | QD1L | Quasi-differential stereo inputs left | I |
| 8 | QD1G | Quasi-differential stereo inputs common | I |
| 9 | QD1R | Quasi-differential stereo inputs right | I |
| 10 | QD2L | Quasi-differential stereo inputs left | I |
| 11 | QD2G | Quasi-differential stereo inputs common | I |
| 12 | QD2R | Quasi-differential stereo inputs right | I |
| 13 | MUTE | External mute pin | I |
| 14 | CREF | Reference capacitor | O |
| 15 | GND | Ground | S |

Table 2. Pin description (continued)

| N# | Pin name | Description | I/O |
|---|---|---|---|
| 16 | OUTSWR | Subwoofer right output | O |
| 17 | OUTSWL | Subwoofer left output | O |
| 18 | OUTRF | Front right output | O |
| 19 | OUTRR | Rear right output | O |
| 20 | OUTLR | Rear left output | O |
| 21 | OUTLF | Front left output | O |
| 22 | WINTCL | DC offset detector filter output left channel | O |
| 23 | WINTCR | DC offset detector filter output right channel | O |
| 24 | VCC | Supply | S |
| 25 | SCL | $I^2C$ bus clock | I |
| 26 | SDA | $I^2C$ bus data | I/O |
| 27 | DCERR | DC offset detector output | O |
| 28 | WININ | DC offset detector input | I |

# 3 Electrical specifications

## 3.1 Thermal data

**Table 3. Thermal data**

| Symbol | Description | Value | Unit |
|---|---|---|---|
| $R_{th\text{-}jamb}$ | Thermal resistance junction-to-ambient | 114 | °C/W |

## 3.2 Absolute maximum ratings

**Table 4. Absolute maximum ratings**

| Symbol | Parameter | Value | Unit |
|---|---|---|---|
| $V_S$ | Operating supply voltage | 13 | V |
| $V_{in_max}$ | Maximum voltage for signal input pins | 7 | V |
| $T_{amb}$ | Operating ambient temperature | -40 to 85 | °C |
| $T_{stg}$ | Storage temperature range | -55 to 150 | °C |

## 3.3 Electrical characteristics

$V_s$ =11.5 V; $T_{amb}$ = 25 °C; $R_L$ = 10 kΩ; all gains = 0 dB; f = 1 kHz; Output gain = 6 dB; Input = SE1; unless otherwise specified

**Table 5. Electrical characteristics**

| Symbol | Parameter | Test condition | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| **Supply** | | | | | | |
| Vs | Supply voltage | - | 4.5 | 8.5 | 13 | V |
| Is | Supply current | - | 33 | 40 | 47 | mA |
| **Input selector** | | | | | | |
| $R_{in}$ | Input resistance clipping level | All single ended inputs | 70 | 100 | 130 | kΩ |
| $V_{CL}$ | | Input gain = 0dB, when $V_{CC} \geq 5$ V THD = 1% | 0.9 | 1.06 | - | $V_{RMS}$ |
| | | Input gain = 0dB, when $V_{CC}$ = 4.5 V THD = 1% | 0.6 | 0.707 | | $V_{RMS}$ |
| $S_{IN}$ | Input separation | - | 80 | 100 | | dB |
| $V_{ib}$ | Input bias voltage | All single-ended and differential stereo inputs | 2.3 | 2.5 | 2.7 | V |
| **Differential stereo inputs** | | | | | | |
| $R_{in}$ | Input resistance | Differential | 70 | 100 | - | kΩ |

Table 5. Electrical characteristics (continued)

| Symbol | Parameter | Test condition | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| CMRR | Common mode rejection ratio for main source | $V_{CM}$ = 1 $V_{RMS}$ @ 1 kHz | 46 | 60 | - | dB |
| | | $V_{CM}$ = 1 $V_{RMS}$ @ 10 kHz | 46 | 60 | - | dB |
| **Loudness control** | | | | | | |
| $A_{MAX}$ | Max attenuation | - | 14 | 15 | 16 | dB |
| $A_{STEP}$ | Step resolution | - | 0.5 | 1 | 1.5 | dB |
| $f_{Peak}$ | Peak frequency(1) | $f_{P1}$ | - | 400 | - | Hz |
| | | $f_{P2}$ | - | 800 | - | Hz |
| | | $f_{P3}$ | - | 2400 | - | Hz |
| **IN gain** | | | | | | |
| $G_{MAX}$ | Max Gain(2) | - | 5 | 6 | 7 | dB |
| $A_{STEP}$ | Step resolution | - | 0.5 | 1 | 1.5 | dB |
| $E_T$ | Tracking error | - | | | 2 | dB |
| $V_{DC}$ | DC steps | Adjacent gain steps | -5 | 0.5 | 5 | mV |
| **Volume control** | | | | | | |
| $G_{MAX}$ | Max gain(2) | - | 21 | 23 | 25 | dB |
| $A_{MAX}$ | Max attenuation | - | -83 | -79 | -75 | dB |
| $A_{STEP}$ | Step resolution | - | 0.5 | 1 | 1.5 | dB |
| $E_A$ | Attenuation set error | G = -20 to +23 dB | -0.75 | 0 | +0.75 | dB |
| | | G = -20 to -79 dB | -4 | 0 | 3 | dB |
| $E_T$ | Tracking error | - | | | 2 | dB |
| $V_{DC}$ | DC steps | Adjacent attenuation steps | -3 | 0.1 | 3 | mV |
| | | Adjacent gain step from +23dB to +15dB | -15 | - | 15 | mV |
| | | Adjacent gain step From +15dB to 0dB | -5 | - | 5 | mV |
| **Soft mute** | | | | | | |
| $A_{MUTE}$ | Mute attenuation | - | 80 | 100 | - | dB |
| $T_D$ | Delay time | $T_1$ | 0.36 | 0.48 | 0.6 | ms |
| | | $T_2$ | 0.84 | 0.96 | 1.08 | ms |
| | | $T_3$ | 0.3 | 7.6 | 7.9 | ms |
| | | $T_4$ | 14 | 15.3 | 16.8 | ms |
| $V_{TH_Low}$ | Low threshold for MUTE pin(3) | - | - | - | 1 | V |
| $V_{TH_High}$ | High threshold for MUTE pin(3) | - | 2.5 | - | - | V |
| RPU | Internal pull-up resistor for MUTE pin(3) | - | 32 | 45 | 58 | k |

**Table 5. Electrical characteristics (continued)**

| Symbol | Parameter | Test condition | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| VPU | Internal pull-up Voltage for MUTE Pin(3) | - | - | 3.3 | - | V |
| **EQ1 control** | | | | | | |
| $C_{RANGE}$ | Control range(2) | - | 14 | 15 | 16 | dB |
| $A_{STEP}$ | Step resolution | - | 0.5 | 1 | 1.5 | dB |
| $F_c$ | Center frequency(1) | $f_{C1}$ | - | 63 | - | Hz |
| | | $f_{C2}$ | - | 80 | - | Hz |
| | | $f_{C3}$ | - | 100 | - | Hz |
| | | $f_{C4}$ | - | 125 | - | Hz |
| Q1 | Quality factor(1) | Q1 | - | 1.0 | - | - |
| | | Q2 | - | 1.25 | - | - |
| | | Q3 | - | 1.5 | - | - |
| | | Q4 | | 2 | - | - |
| **EQ2 control** | | | | | | |
| $C_{RANGE}$ | Control range(2) | - | 14 | 15 | 16 | dB |
| $A_{STEP}$ | Step resolution | - | 0.5 | 1 | 1.5 | dB |
| $F_c$ | Center frequency(1) | $f_{C1}$ | - | 200 | - | Hz |
| | | $f_{C2}$ | - | 250 | - | Hz |
| | | $f_{C3}$ | - | 315 | - | Hz |
| | | $f_{C4}$ | - | 400 | - | Hz |
| Q2 | Quality factor(1) | Q1 | - | 1.0 | - | - |
| | | Q2 | - | 1.25 | - | - |
| | | Q3 | - | 1.5 | - | - |
| | | Q4 | - | 2 | - | - |
| **EQ3 control** | | | | | | |
| $C_{RANGE}$ | Control range(2) | - | 14 | 15 | 16 | dB |
| $A_{STEP}$ | Step resolution | - | 0.5 | 1 | 1.5 | dB |
| $F_c$ | Center frequency(1) | $f_{C1}$ | - | 630 | - | Hz |
| | | $f_{C2}$ | - | 800 | - | Hz |
| | | $f_{C3}$ | - | 1 | - | kHz |
| | | $f_{C4}$ | - | 1.25 | - | kHz |

Table 5. Electrical characteristics (continued)

| Symbol | Parameter | Test condition | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| Q3 | Quality factor(1) | Q1 | - | 0.75 | - | - |
| | | Q2 | - | 1.0 | - | |
| | | Q3 | - | 1.25 | - | - |
| | | Q4 | - | 2.0 | - | - |
| **EQ4 control** | | | | | | |
| $C_{RANGE}$ | Control range(2) | - | 14 | 15 | 16 | dB |
| $A_{STEP}$ | Step resolution(1) | - | 0.5 | 1 | 1.5 | dB |
| $F_c$ | Center frequency(1) | $f_{C1}$ | - | 2 | - | kHz |
| | | $f_{C2}$ | - | 2.5 | - | kHz |
| | | $f_{C3}$ | - | 3.15 | - | kHz |
| | | $f_{C4}$ | - | 4 | - | kHz |
| $Q_4$ | Quality factor | Q1 | - | 0.75 | - | - |
| | | Q2 | - | 1.0 | - | - |
| | | Q3 | - | 1.25 | - | - |
| | | Q4 | - | 2.0 | - | - |
| **EQ5 control** | | | | | | |
| $C_{RANGE}$ | Control range(2) | - | 14 | 15 | 16 | dB |
| $A_{STEP}$ | Step resolution | - | 0.5 | 1 | 1.5 | dB |
| $F_c$ | Center frequency(1) | $f_{C1}$ | - | 6.3 | - | kHz |
| | | $f_{C2}$ | - | 8 | - | kHz |
| | | $f_{C3}$ | - | 10 | - | kHz |
| | | $f_{C4}$ | - | 12.5 | - | kHz |
| $Q_5$ | Quality factor(1) | Q1 | - | 0.75 | - | - |
| | | Q2 | - | 1.0 | - | - |
| | | Q3 | - | 1.25 | - | - |
| | | Q4 | - | 2.0 | - | - |
| **Speaker attenuators** | | | | | | |
| $G_{MAX}$ | Max gain(2) | - | 14 | 15 | 16 | dB |
| $A_{MAX}$ | Max attenuation | - | -83 | -79 | -75 | dB |
| $A_{STEP}$ | Step resolution | - | 0.5 | 1 | 1.5 | dB |
| $A_{MUTE}$ | Mute attenuation | - | 80 | 90 | | dB |
| $E_A$ | Attenuation set error | G = -20 to +15 dB | -0.75 | 0 | +0.75 | dB |
| | | G = -20 to -79 dB | -4 | 0 | 3 | dB |

**Table 5. Electrical characteristics (continued)**

| Symbol | Parameter | Test condition | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| $V_{DC}$ | DC Steps | Adjacent attenuation steps | -5 | 0.1 | 5 | mV |
| | | Adjacent gain steps | -10 | 0.5 | 10 | |
| **HPF** | | | | | | |
| $F_{HP}$ | Highpass corner frequency(1) | $f_{HP1}$ | - | 63 | - | Hz |
| | | $f_{HP2}$ | - | 100 | - | Hz |
| | | $f_{HP3}$ | - | 120 | - | Hz |
| | | $f_{HP4}$ | - | 150 | - | Hz |
| | | $f_{HP5}$ | - | 180 | - | Hz |
| **Audio outputs** | | | | | | |
| $V_{CL}$ | Clipping level | THD = 1%; $V_{CC}$ = 6 V option1 | 1.9 | 2.0 | - | $V_{RMS}$ |
| | | THD = 1%; $V_{CC}$ = 8.2 V option2 | 2.5 | 2.6 | - | $V_{RMS}$ |
| | | THD = 1%; $V_{CC}$ = 11.5 V option3 | 3.3 | 3.6 | - | $V_{RMS}$ |
| | | THD = 1%; $V_{CC}$ = 4.5 V option1 | 0.8 | 0.92 | - | $V_{RMS}$ |
| | | THD = 1%; $V_{CC}$ = 4.5 V option2 | 0.15 | 0.21 | - | $V_{RMS}$ |
| $R_{OUT}$ | Output impedance | - | - | 30 | 100 | Ω |
| $R_L$ | Output load resistance | - | 2 | - | - | kΩ |
| $C_L$ | Output load capacitor | - | - | - | 10 | nF |
| $V_{DC}$ | Output DC level | Option1: Output level = 3 V | 2.85 | 3 | 3.15 | V |
| | | Option2: Output level = 4 V | 3.8 | 4 | 2 | V |
| | | Option3: Output level = 5.75 V; $V_{CC}$ > 6.5 V | 5.5 | 5.75 | 6 | V |
| $G_{OUT}$ | Output gain | Option1:Output level/gain = 3 V/6 dB | 5 | 6 | 7 | dB |
| | | Option2: Output level/gain = 4 V/8.5 dB | 7.5 | 8.5 | 9.5 | dB |
| | | Option3: Output level/gain = 5.75V/11dB | 10 | 11 | 12 | dB |
| **Subwoofer lowpass** | | | | | | |
| $f_{LP}$ | Lowpass corner frequency(1) | $f_{LP1}$ | - | 55 | - | Hz |
| | | $f_{LP2}$ | - | 85 | - | Hz |
| | | $f_{LP3}$ | - | 120 | - | Hz |
| | | $f_{LP4}$ | - | 160 | - | Hz |
| **DC offset detection circuit** | | | | | | |
| $V_{th}$ | Zero comp window size | $V_1$ | ±15 | ±30 | ±45 | mV |
| | | $V_2$ | ±20 | ±45 | ±65 | mV |
| | | $V_3$ | ±30 | ±60 | ±90 | mV |
| | | $V_4$ | ±60 | ±90 | ±120 | mV |

**Table 5. Electrical characteristics (continued)**

| Symbol | Parameter | Test condition | | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|---|
| $\tau_{sp}$ | Max rejected spike length | - | | - | 11 | - | µs |
| | | - | | - | 22 | - | µs |
| | | - | | - | 33 | - | µs |
| | | - | | - | 44 | - | µs |
| $I_{CHDCErr}$ | DCErr charge current | - | | 3.5 | 5 | 6.5 | µA |
| $I_{DISDCErr}$ | DCErr discharge current | - | | 3.5 | 5 | 8 | mA |
| $V_{OutH}$ | DCErr high voltage | - | | 3.1 | 3.3 | 3.5 | V |
| $V_{OutH}$ | DCErr low voltage | - | | 0 | 100 | 300 | mV |
| $V_{TH_Low}$ | Low threshold for WinIn Pin(3) | - | | - | - | 1 | V |
| $V_{TH_High}$ | High threshold for WinIn Pin(3) | - | | 2.5 | - | - | V |
| RPU | Internal pull-up resistor for WinIn Pin | - | | 35 | 50 | 65 | kΩ |
| VPU | Internal pull-up voltage for WinIn Pin | - | | 3.1 | 3.3 | 3.5 | V |
| **General** | | | | | | | |
| $e_{NO}$ | Output Noise | BW = 20 Hz-20 kHz A-Weighted, all gain = 0 dB, HPF = OFF, Input = SE/QD | Output level/gain = 3 V/6 dB | - | 20 | 25 | µV |
| | | | Output level/gain = 4 V/8.5 dB | - | 27 | 30 | µV |
| | | | Output level/gain = 5.75 V/11 dB | - | 36 | 40 | µV |
| | | BW = 20 Hz-20kHz A-Weighted, Output muted | Output level/gain = 3 V/6 dB | - | 6.6 | 10 | µV |
| | | | Output level/gain = 4 V /8.5 dB | - | 8 | 12 | µV |
| | | | Output level/gain =5.75V/11dB | - | 10 | 15 | µV |
| S/N | Signal to noise ratio | all gain = 0dB, A-weighted; | Output level/gain = 3 V/6 dB | 98 | 100 | - | dB |
| | | | Output level/gain = 4 V/8.5 dB | 98 | 100 | - | dB |
| | | | Output level/gain=5.75V/11dB | 98 | 100 | - | dB |

**Table 5. Electrical characteristics (continued)**

| Symbol | Parameter | Test condition | | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|---|
| D | Distortion | VIN=0.5$V_{RMS;}$ all gain = 0dB, HPF=OFF | Output level/gain=3V/6dB(5V) | - | 0.01 | 0.1 | % |
| | | | Output level/gain=4V/8.5dB(6V) | - | 0.01 | 0.1 | % |
| | | | Output level/gain=5.75V/11dB(8.5V) | - | 0.01 | 0.1 | % |
| $S_C$ | Channel separation left/right | - | | 75 | 90 | - | dB |

1. Value guaranteed by measuring correlated parameter.
2. Measure performed in DC.
3. Verified only in characterization.

# 4 Description of audioprocessor

## 4.1 Input stage

Two quasi-differential stereo input and three single-ended inputs are available.

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

The input-impedance at each input is 100 kΩ.

### 4.1.2 Quasi-differential stereo Input (QD1,QD2)

The QD input is implemented as a buffered quasi-differential stereo stage with 100 kΩ input-impedance at each input. There is 0 dB attenuation at QD input stage.

### 4.1.3 Fast charge

Each differential input pin features a "fast-charge" switch allowing to quickly charge any external large coupling capacitors upon power-on of the device. When the device is powered-on, the "fast-charge" switches are automatically turned on, for normal operations these switches need to be released by any programming of byte_0. After that, the "fast-charge" switches can be turned on/off by setting "fast charge = on/off".

## 4.2 Input gain

A 0~6dB input gain is selectable to compensate the different input signal.

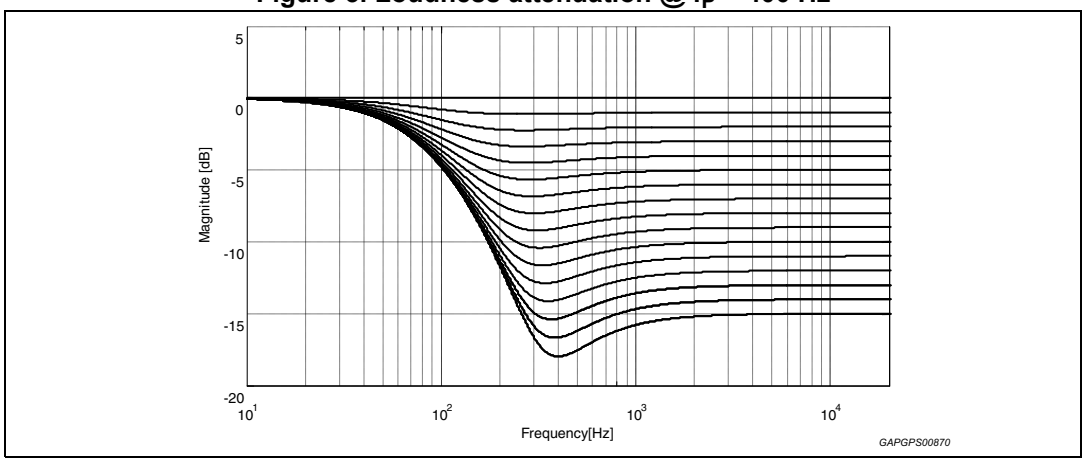
## 4.3 Loudness

There are four parameters programmable in the loudness stage.

### 4.3.1 Loudness attenuation

*Figure 3* shows the attenuation as a function of frequency at $f_P$ = 400 Hz

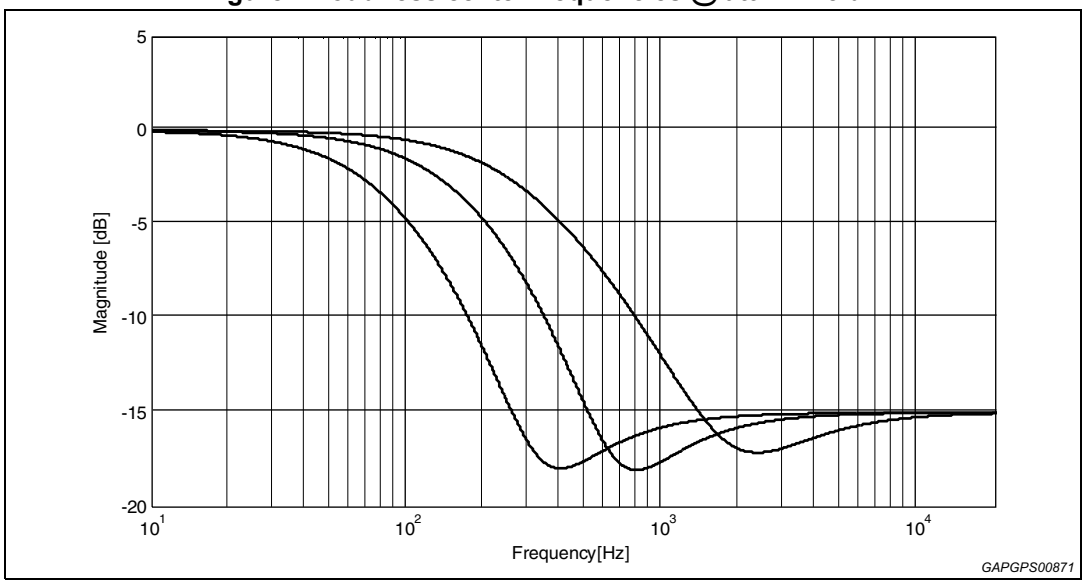
**Figure 3. Loudness attenuation @ $f_P$ = 400 Hz**



### 4.3.2 Peak frequency

*Figure 4* shows the four possible peak-frequencies at 400, 800 and 2400 Hz

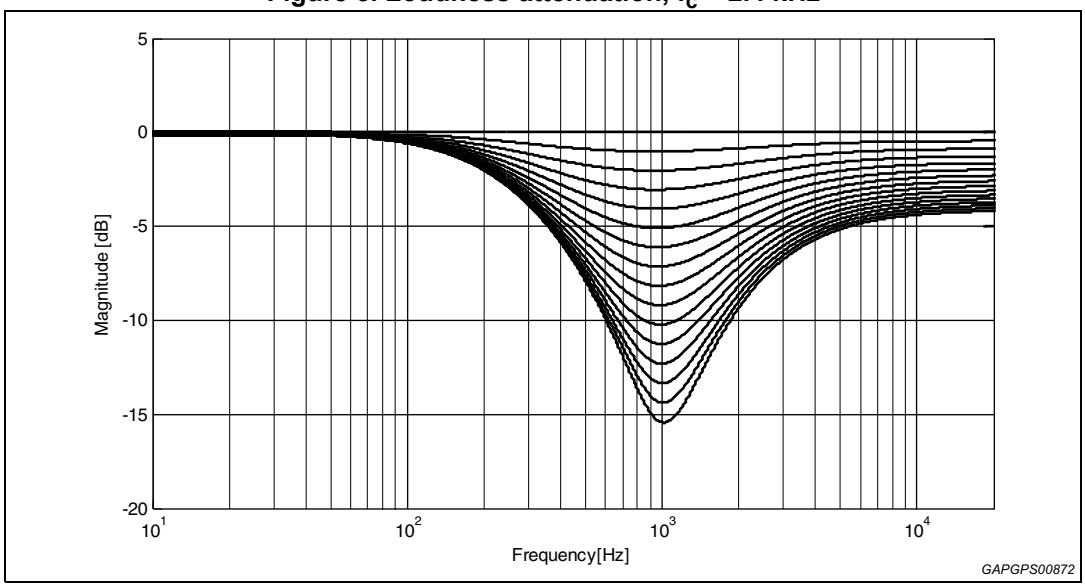
**Figure 4. loudness center frequencies @ attn. = 15 dB**




### 4.3.3 High frequency boost

*Figure 5* shows the different loudness shapes in low & high frequency boost.

**Figure 5. Loudness attenuation, $f_c$ = 2.4 kHz**




### 4.3.4 Flat mode

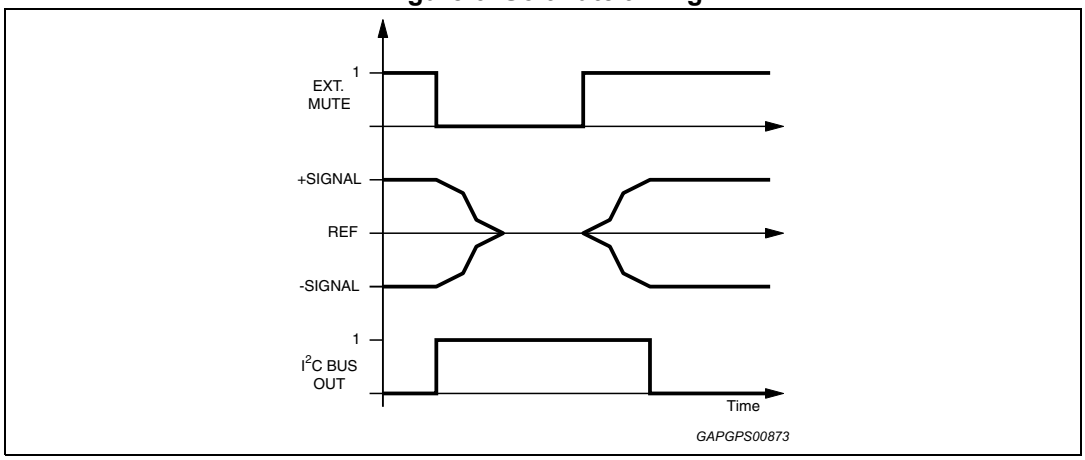
In flat mode the loudness stage works as a 0 dB to -15 dB attenuator.

## 4.4 SoftMute

The digitally controlled SoftMute stage allows muting/demuting the signal with a $I^2C$ bus programmable slope. The mute process can be activated either 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 6*).

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 6. SoftMute timing**




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

## 4.5 Volume

When the volume-level is changed audible clicks could appear at the output. The root cause of those clicks could be either a DC-Offset before the volume-stage or the sudden change in 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. The blend-time from one step to the next is programmable as 5 ms or 10 ms. The SoftStep control is described in detail in *Section 4.13*.

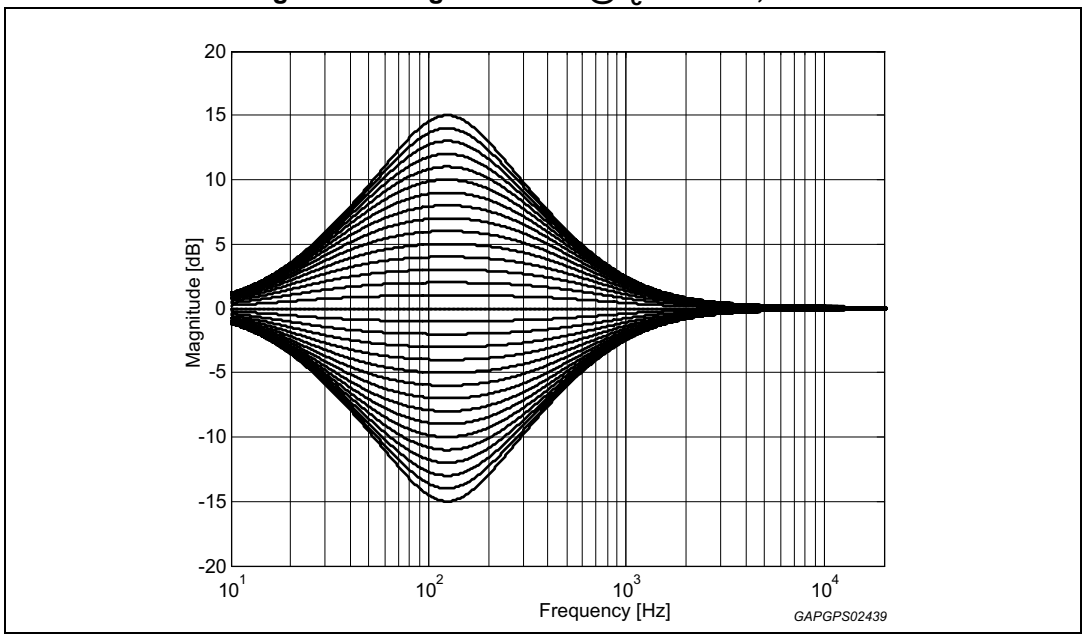
## 4.6 EQ1

There are three parameters programmable in the EQ1 stage.

### 4.6.1 EQ1 attenuation

*Figure 7* shows the attenuation as a function of frequency at 125 Hz.

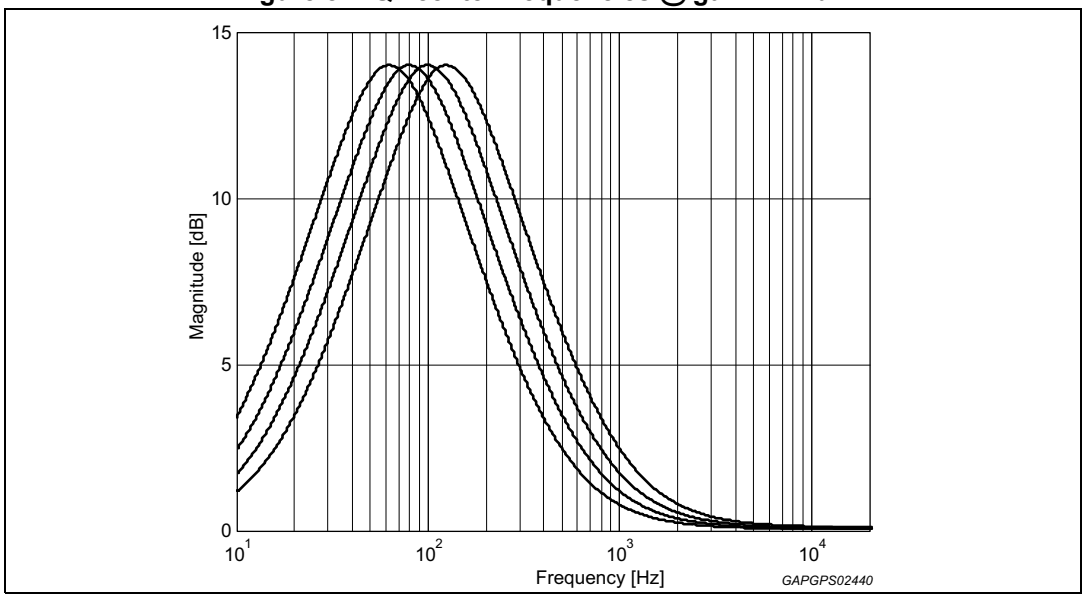
**Figure 7. EQ1 gain control @ $f_c$ = 125 Hz, Q = 1**




### 4.6.2 Center frequency

*Figure 8* shows the four possible center frequencies 63 Hz/ 80 Hz / 100 Hz/ 125 Hz.

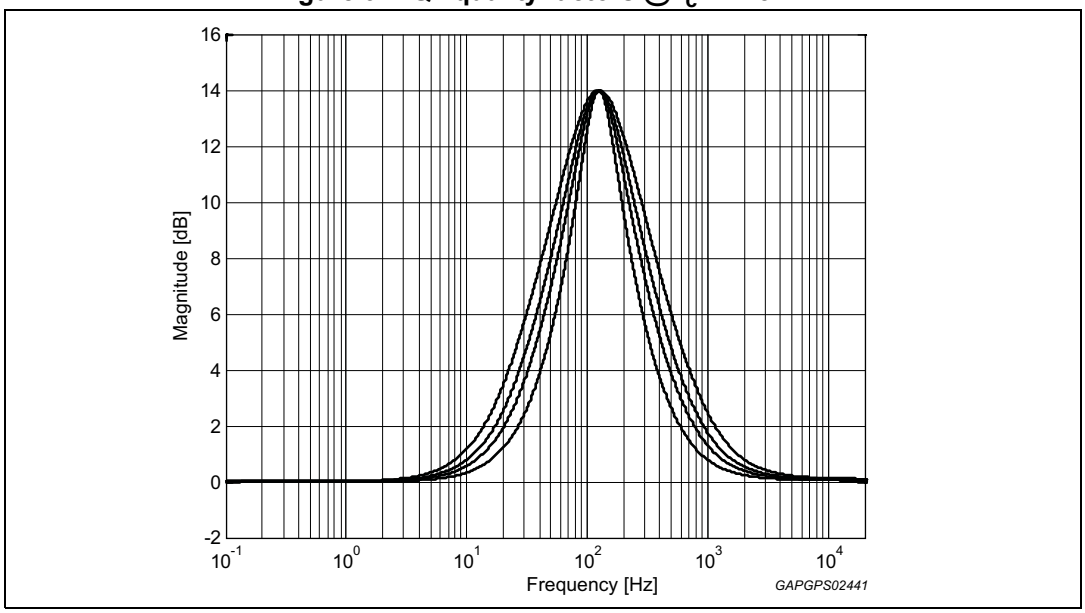
**Figure 8. EQ1 center frequencies @ gain = 14 dB**



### 4.6.3 EQ1 quality factor

*Figure 9* shows the four possible quality factors (1.0/1.25/1.5/2) when $f_c$ is 125 Hz.

**Figure 9. EQ1 quality factors @ $f_c$ = 125 Hz**



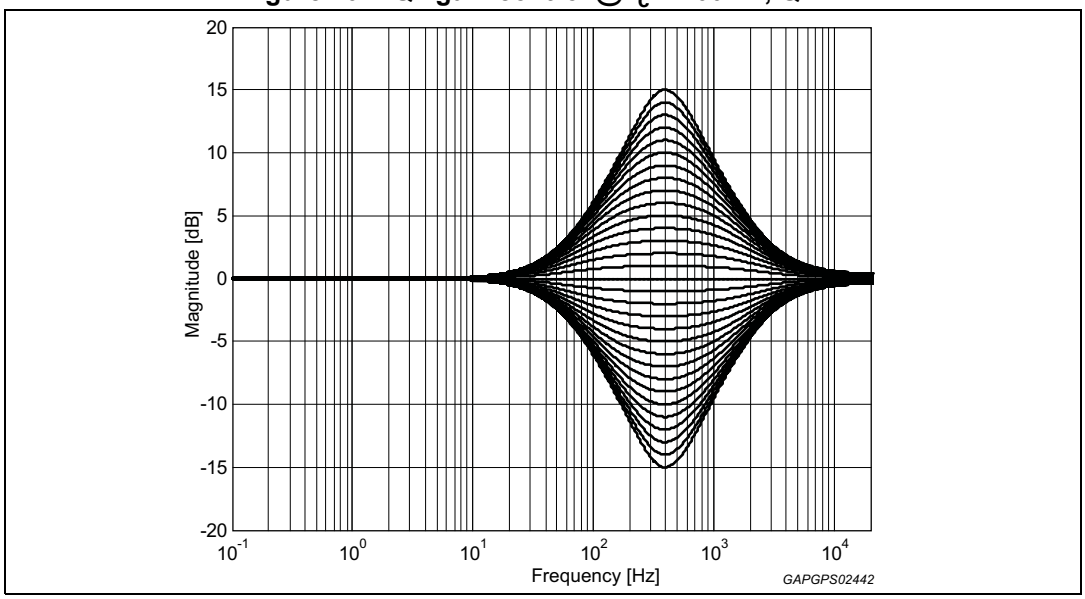

## 4.7 EQ2

There are three parameters programmable in the EQ2 stage.

### 4.7.1 EQ2 attenuation

*Figure 10* shows the attenuation as a function of frequency at 400 Hz when Q = 1.

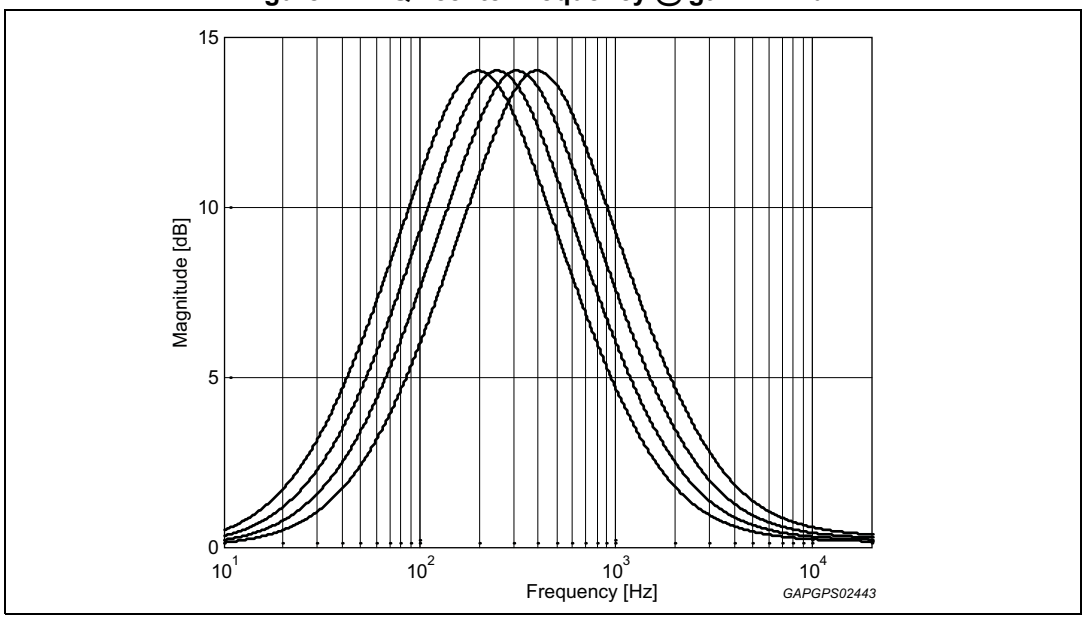
**Figure 10. EQ2 gain control @ $f_c$ = 400 Hz, Q = 1**



### 4.7.2 EQ2 center frequency

*Figure 11* shows the four possible center frequencies 200/250/315/400 Hz.

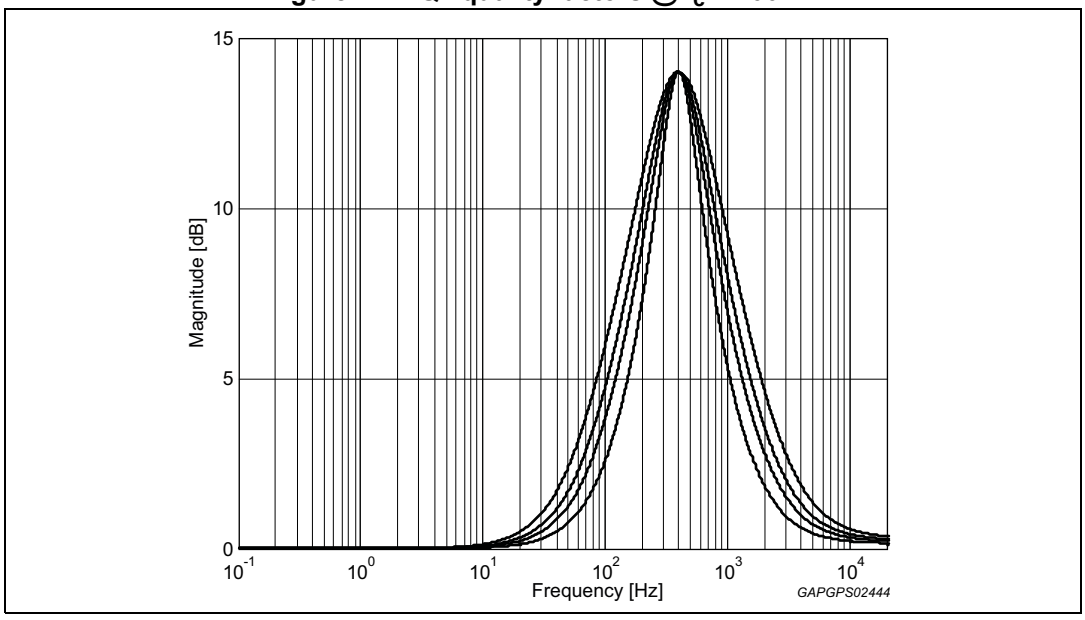
**Figure 11. EQ2 center frequency @ gain = 14 dB**




### 4.7.3 EQ2 quality factor

*Figure 12* shows the four possible quality factors (1.0/1.25/1.5/2) when $f_c$ is 400 Hz.

**Figure 12. EQ2 quality factors @ $f_c$ = 400 Hz**



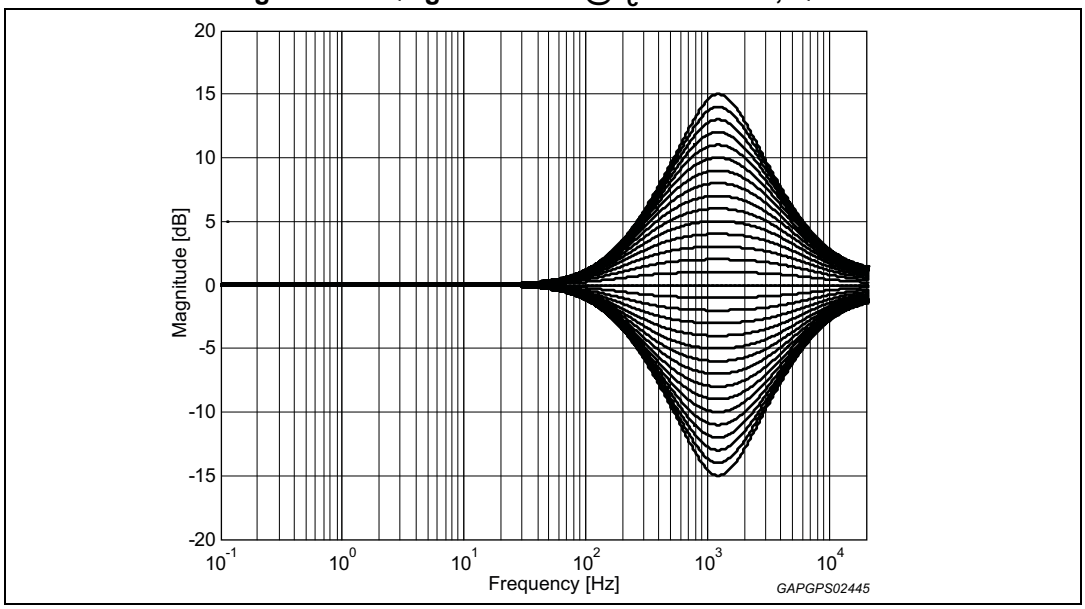
## 4.8 EQ3

There are three parameters programmable in the EQ3 stage.

### 4.8.1 EQ3 attenuation

*Figure 13* shows the attenuation as a function of frequency at a center frequency of 1.25kHz.

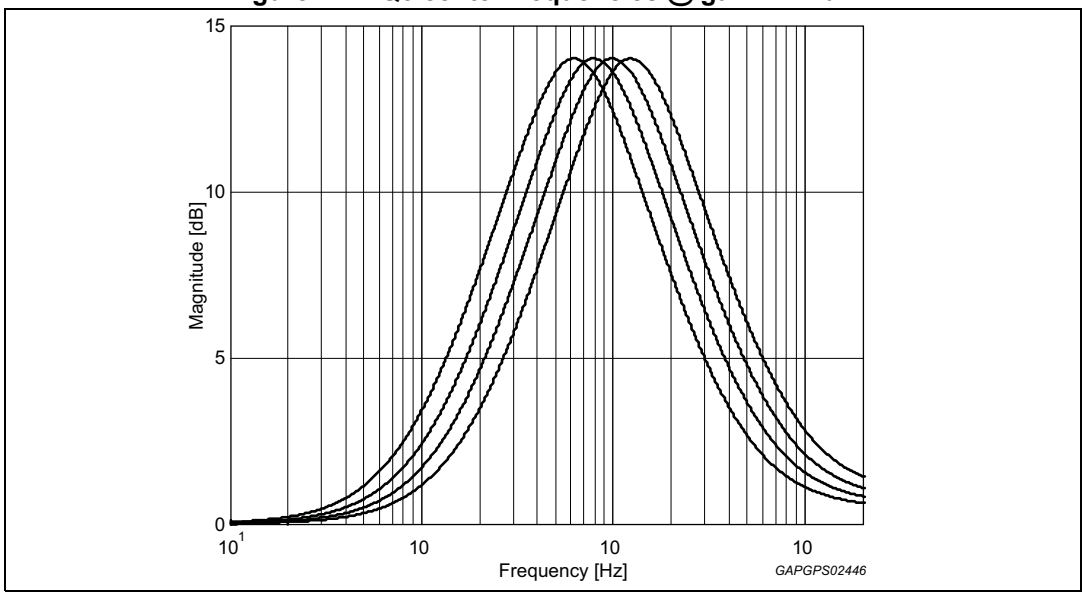
**Figure 13. EQ3 gain control @ $f_c$ = 1.25 kHz, Q = 1**




### 4.8.2 Center frequency

*Figure 14* shows the four possible center frequencies 630 Hz, 800 Hz, 1 kHz, 1.25 kHz.

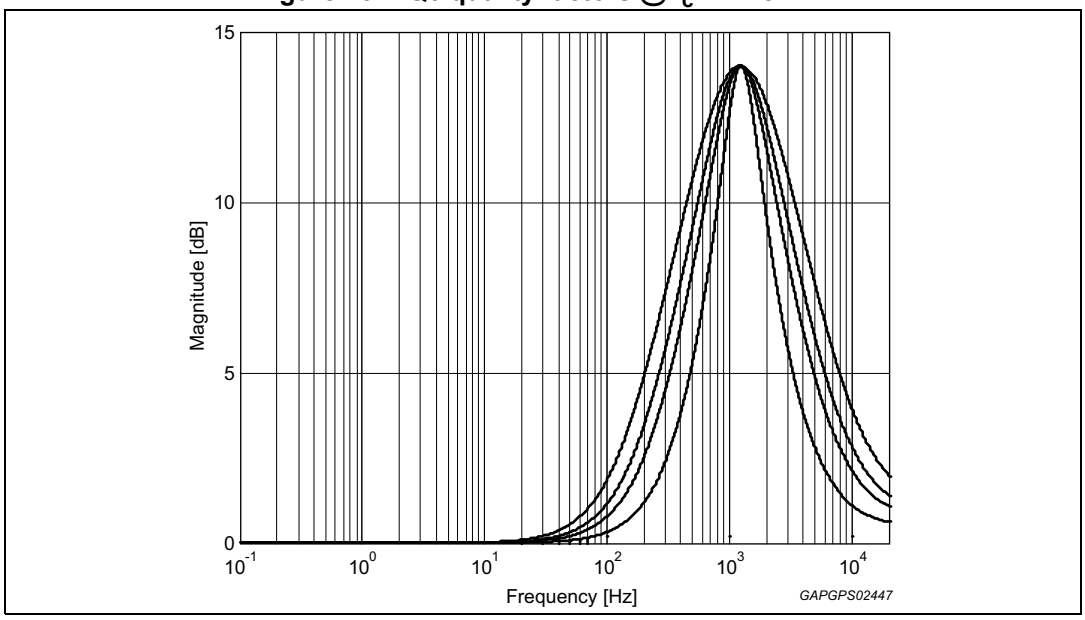
**Figure 14. EQ3 center frequencies @ gain = 14 dB**



### 4.8.3 EQ3 quality factor

*Figure 15* shows the four possible quality factors (0.75/1.0/1.25/2.0) when $f_c$ is1.25 kHz.

**Figure 15. EQ3 quality factors @ $f_c$ = 1.25 kHz**



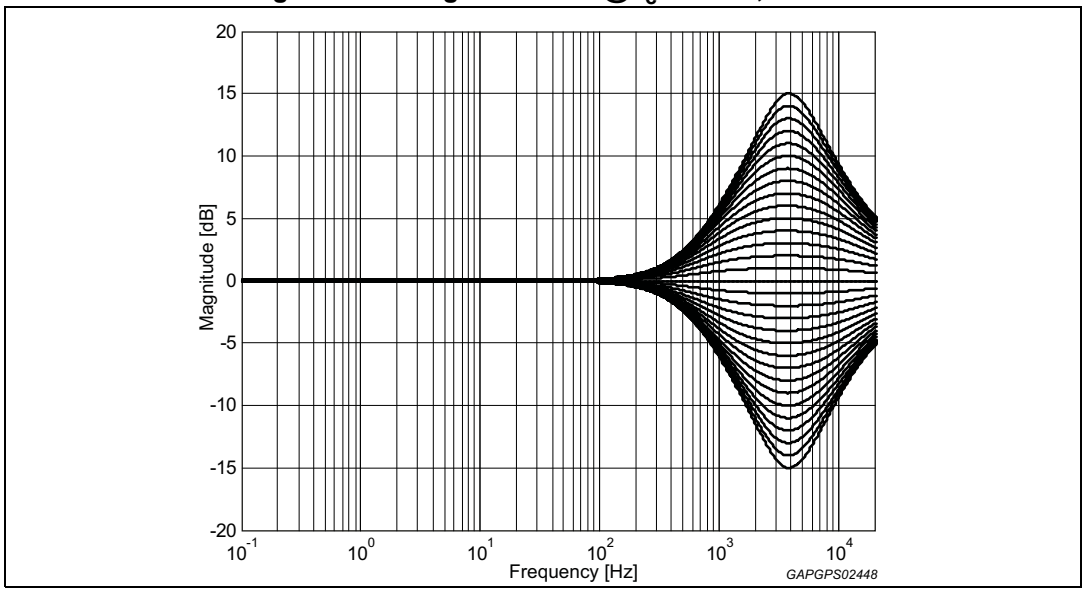

## 4.9 EQ4

There are three parameters programmable in the EQ4 stage.

### 4.9.1 EQ4 attenuation

*Figure 16* shows the attenuation as a function of frequency at a center frequency of 4 kHz.

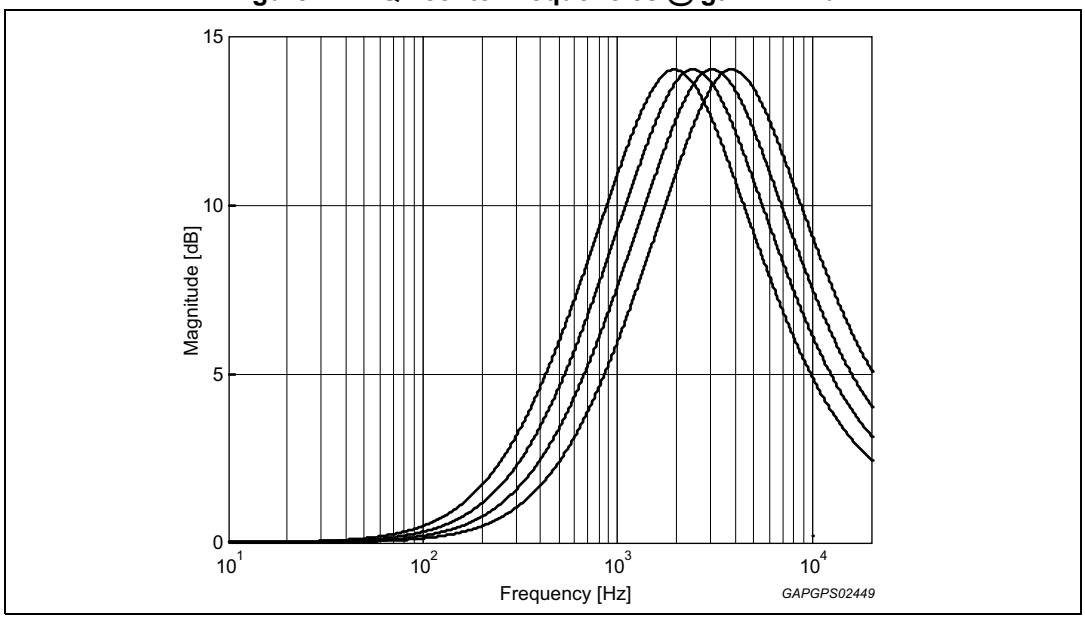
**Figure 16. EQ4 gain control @ $f_c$ = 4 kHz, Q = 1**



### 4.9.2 Center frequency

*Figure 17* shows the four possible center frequencies 2/2.5/3.15/4kHz.

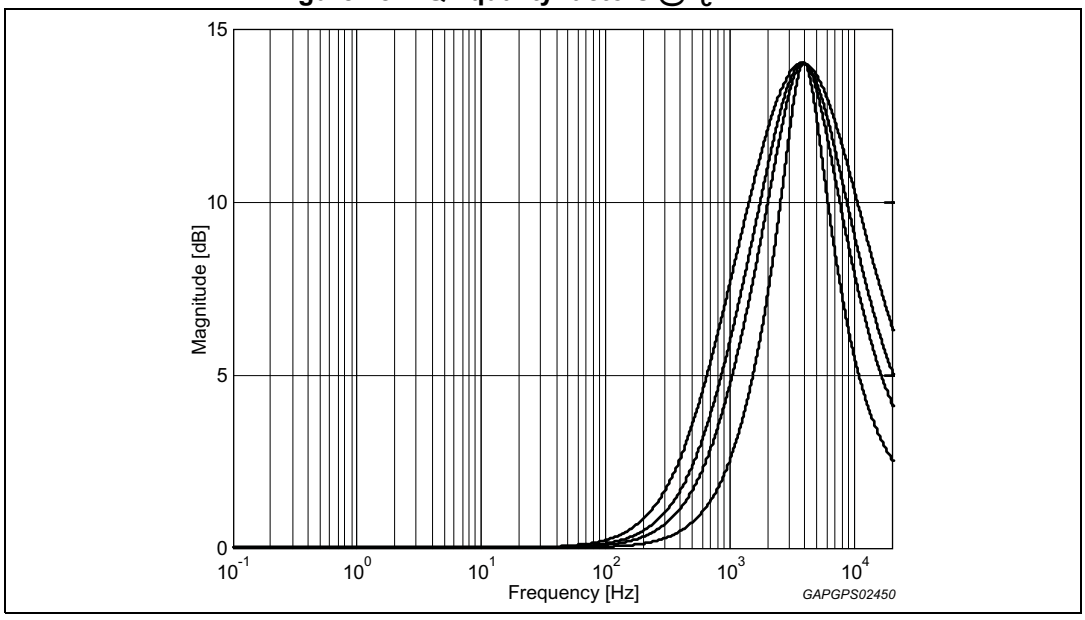
**Figure 17. EQ4 center frequencies @ gain = 14 dB**




### 4.9.3 EQ4 quality factor

*Figure 18* shows the four possible quality factors(0.75/1.0/1.25/2) when $f_c$ is 4 kHz.

**Figure 18. EQ4 quality factors @ $f_c$ = 4 kHz**



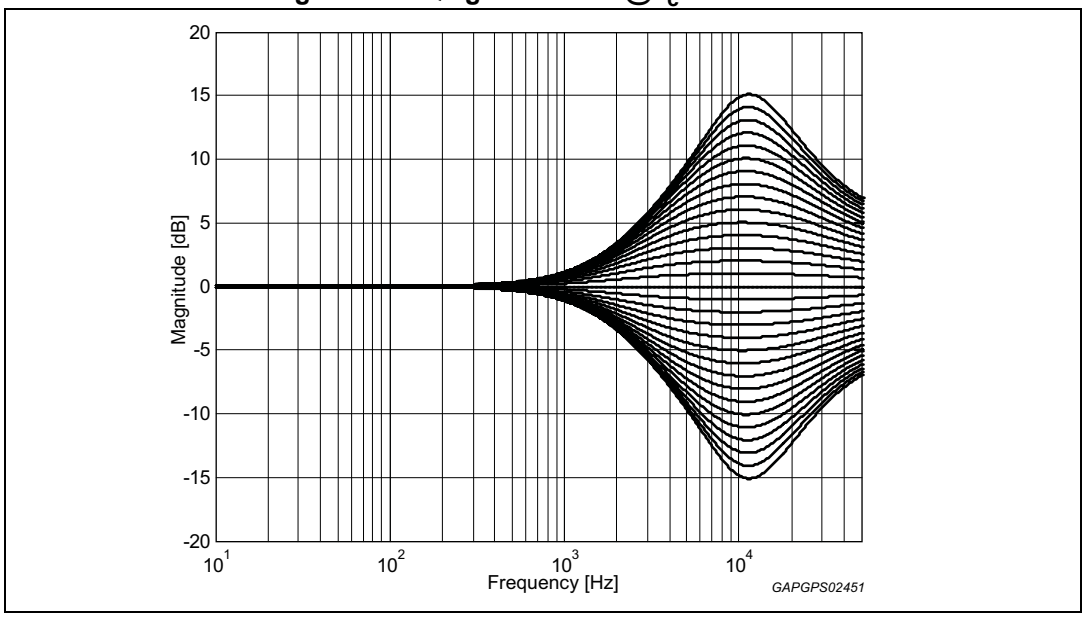
## 4.10 EQ5

There are three parameters programmable in the EQ5 stage.

### 4.10.1 EQ5 attenuation

*Figure 19* shows the attenuation as a function of frequency at a center frequency of 12.5 kHz.

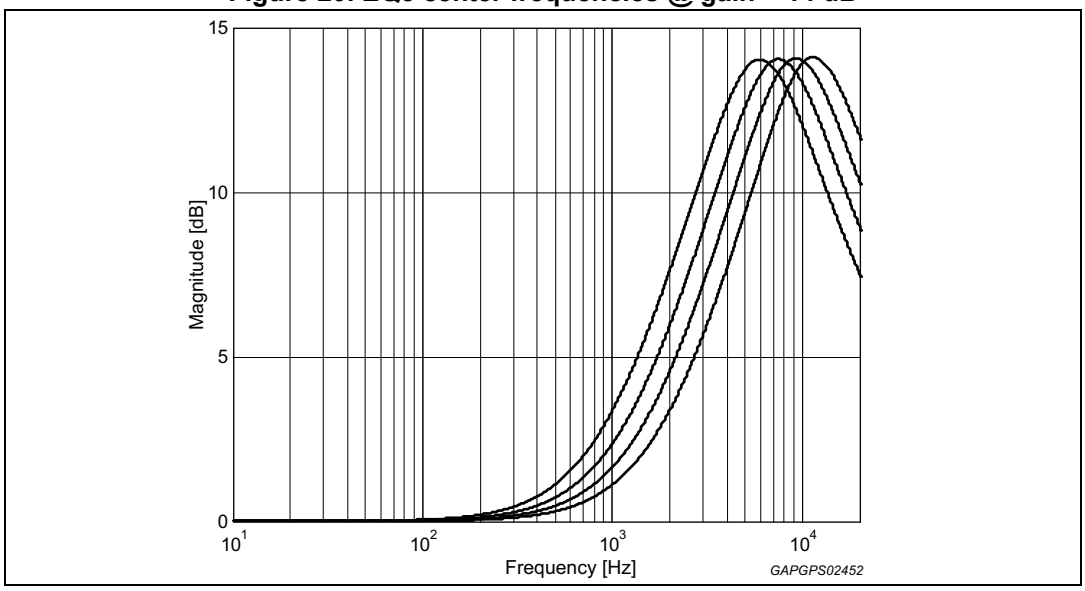
**Figure 19. EQ5 gain control @ $f_c$ = 12.5 kHz**




### 4.10.2 Center frequency

Figure 20 shows the four possible center frequencies 6.3/8/10/12.5 kHz.

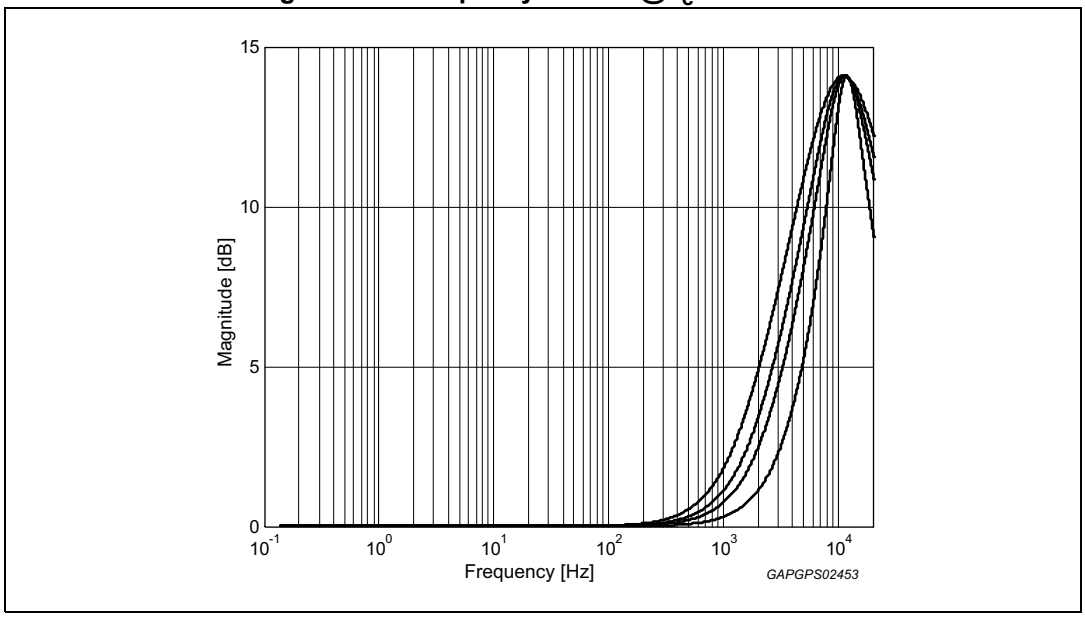
**Figure 20. EQ5 center frequencies @ gain = 14 dB**



### 4.10.3 EQ5 quality factor

*Figure 21* shows the four possible quality factors(0.75/1.0/1.25/2) when $f_c$ is12.5 kHz.

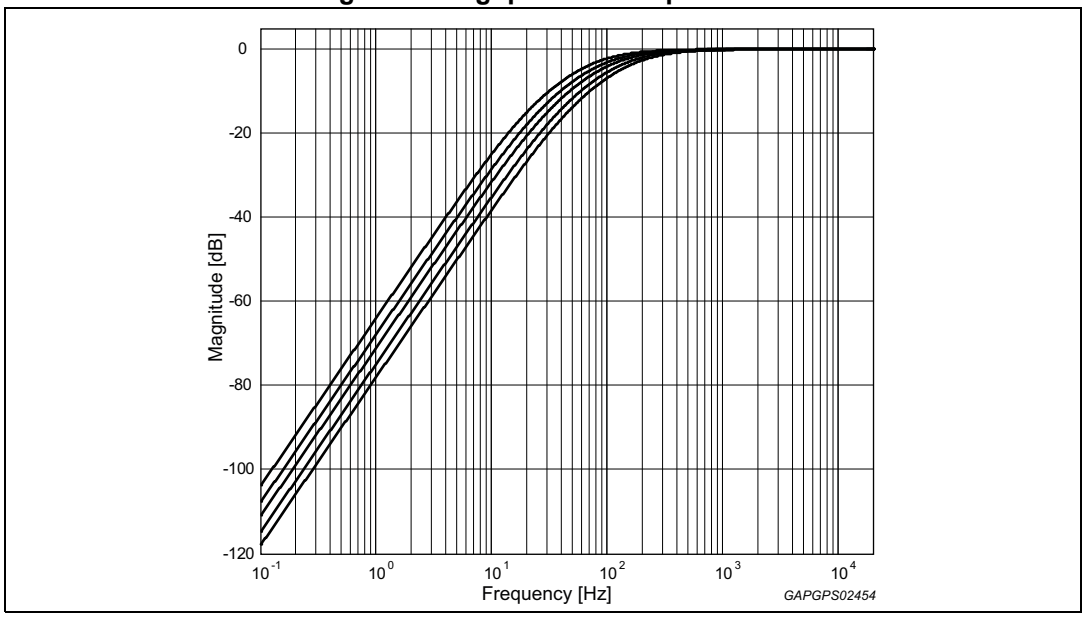
**Figure 21. EQ5 quality factors @ $f_c$ = 12.5 kHz**




## 4.11 Highpass filter

The 2nd order high pass filter has the programmable cut-off frequencies (63/100/120/150/180Hz).

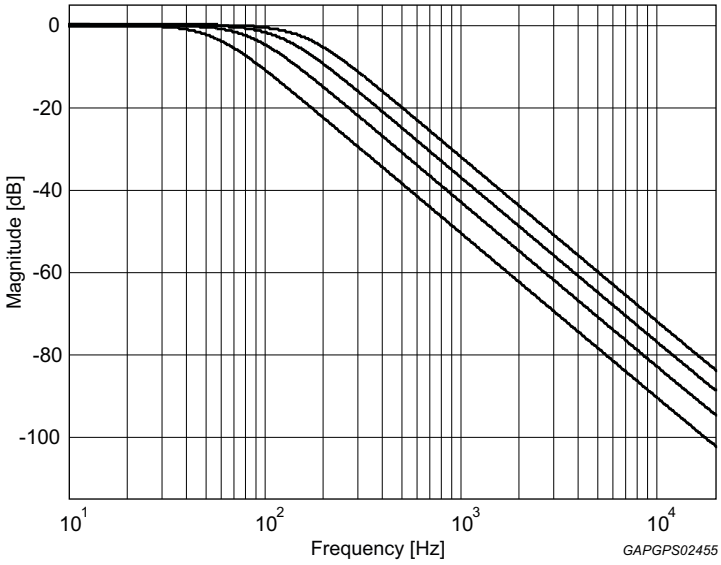
**Figure 22. Highpass cut frequencies**



## 4.12 Subwoofer filter

The subwoofer lowpass filter has Butterworth characteristics with programmable cut-off frequency (55 Hz / 85 Hz/ 120 Hz/ 160 Hz). The output phase can be selected between 0 deg and 180 deg. The input of subwoofer takes signal from EQ filter output or output of input MUX.

**Figure 23. Subwoofer cut frequencies**



## 4.13 SoftStep control

In this device, the SoftStep function is available for volume, speaker, loudness, EQ block. With SoftStep function, the audible noise of DC offset or the sudden change of signal can be avoided when adjusting gain setting of the block.

For each block, the SoftStep function is controlled by SoftStep on/off control bit in the control table. The SoftStep transient time selection (5 ms or 10 ms) is common for all blocks and it is controlled by SoftStep time control bit. The SoftStep operation of all blocks has a common centralized control. In this case, a new SoftStep operation will not be started before the completion of previous SoftStep.

There are two different modes to activate the SoftStep operation. The SoftStep operation can be started right after $I^2C$ data sending, or the SoftStep can be activated in parallel after data sending of several different blocks. The two modes are controlled by the 'act bit' (it is normally bit7 of the byte) of each byte. When act bit is '0', which means action, the SoftStep is activated right after the date byte is sent. When the act bit is '1', which means wait, the block goes to wait for SoftStep status. In this case, the block will wait for some other block to activate the operation. The SoftStep operation of all blocks in wait status will be done together with the block which activate the SoftStep. With this mode, all specific blocks can do the SoftStep in parallel. This avoids waiting when the SoftStep is operated one by one. Be noticed that if a block is set to 'gain1' with act bit = 1, later this block is set to 'gain2' with act bit = 0, in this case the block will do a SoftStep from present gain to 'gain2' but not from present gain to 'gain1' then to 'gain2'.

| Chip Addr | Sub Addr | 0xxxxxxx |
|---|---|---|

|← Soft-step start here

| Chip Addr | Sub Addr | 1xxxxxxx | 1xxxxxxx | ..... | 0xxxxxxx |
|---|---|---|---|---|---|

|← SoftStep start here for all

## 4.14 DC offset detector

Using the DC offset detection circuit (*Figure 24*) an offset voltage difference between the audio power amplifier and the APR's Front and Rear outputs can be detected, preventing serious damage to the loudspeakers. The circuit compares whether the signal crosses the zero level inside the audio power at the same time as in the speaker cell. The output of the zero-window-comparator of the power amplifier must be connected with the WinIn-input of the APR. The WinIn-input has a 50 kΩ internal pull-up resistor connected to 3.3 V. It is recommended to drive this pin with open-collector outputs only.

To compensate for errors at low frequencies the WinTC-pin is implemented, with external capacitors introducing the same delay $\tau$ = 22.5 kΩ * $C_{ext}$ as the AC-coupling introduced between the APR and the power amplifier. For the zero window comparators, the time constant for spike rejection as well as the threshold are programmable.

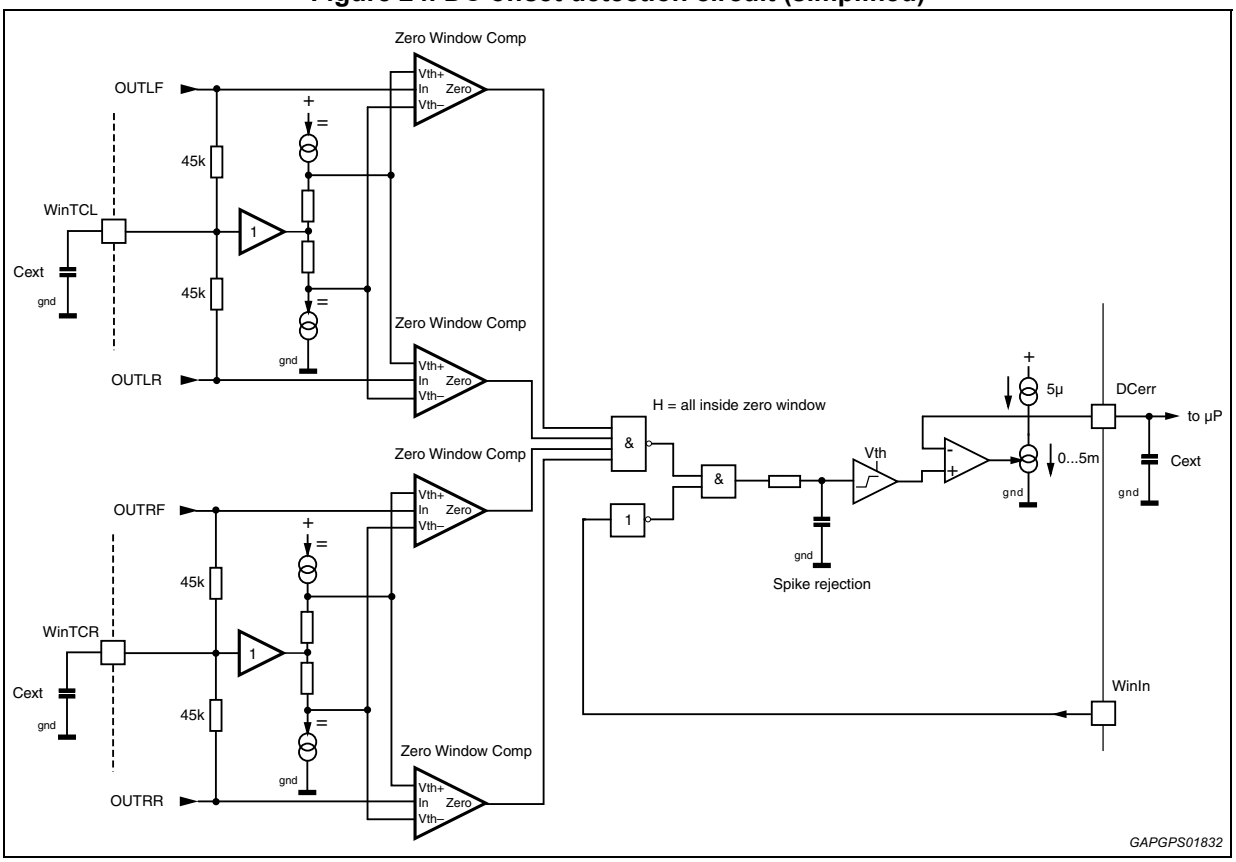
A low-active DC-offset error signal appears at the DCErr output if the next conditions are both true:

a) Front and rear outputs are inside zero crossing windows.

b) The Input voltage $V_{winin}$ is logic low whenever at least one output of the power amplifier is outside the zero crossing windows.

After power-on, the external attached capacitor is rapidly charged (fast-charge) to overcome a false indication.

**Figure 24. DC offset detection circuit (simplified)**



## 4.15 Output stage

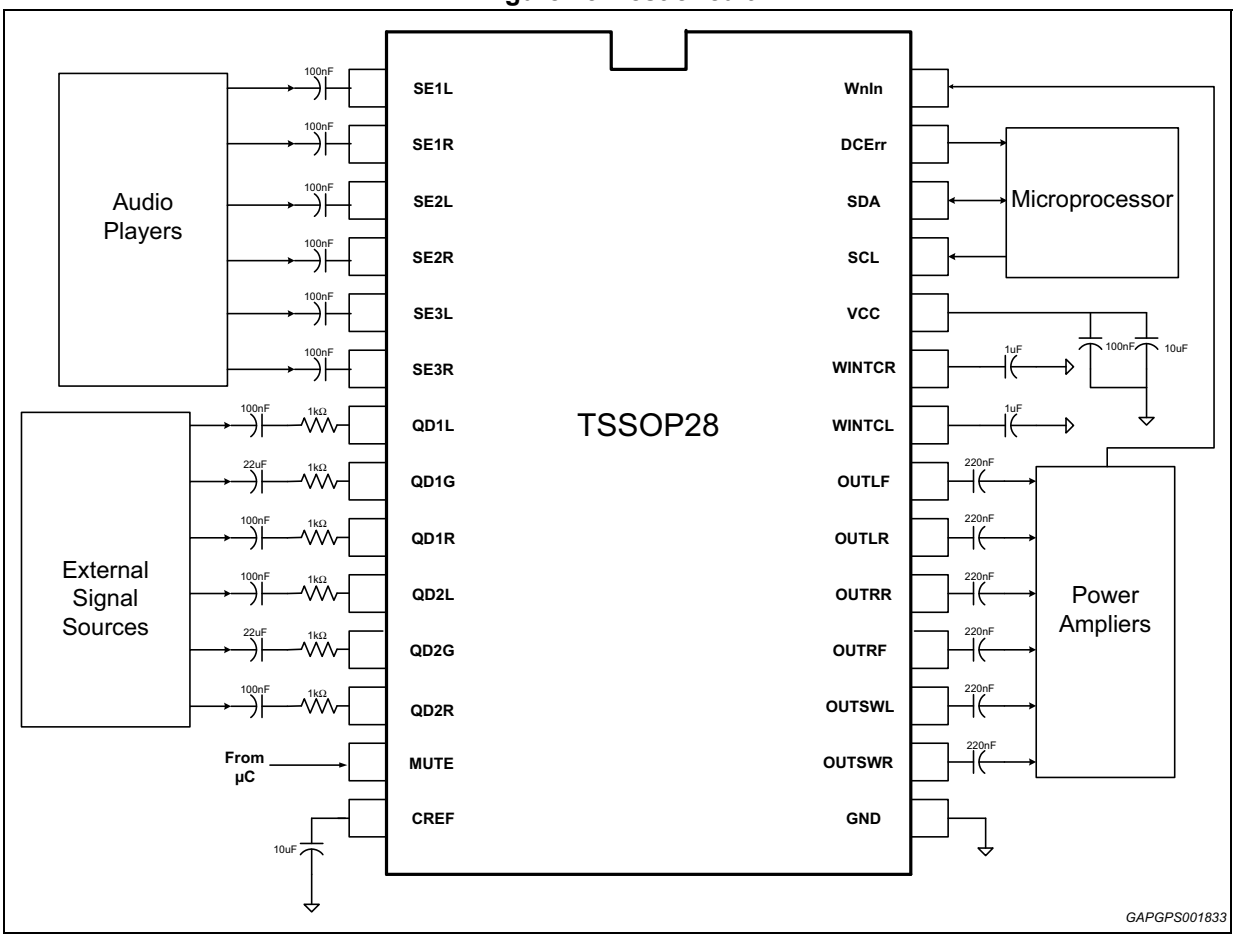
The output gain and output DC voltage are configurable by $I^2C$ to fit different application. The configuration is as follows:

- AC Gain = 6 dB, DC level = 3 V
- AC Gain = 8.5 dB, DC level = 4 V
- AC Gain = 11 dB, DC level = 5.75 V

## 4.16 Audioprocessor testing

In the test mode, which can be activated by setting bit D7 of the $I^2C$ subaddress byte and bit D0 of the testing audioprocessor byte, several internal signals are available at the QD2G pin. In this mode, the input resistance of 100 kΩ is disconnected from the pin. Internal signals available for testing are listed in the data-byte specification.

**Figure 25. Test circuit**



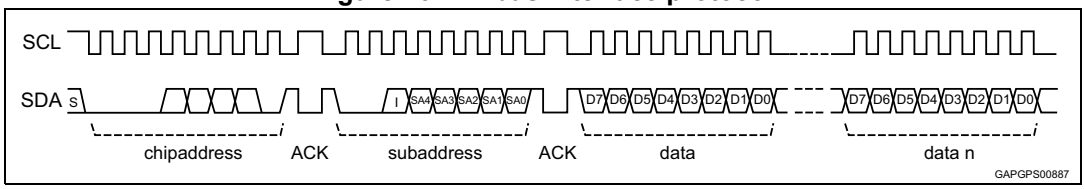
# 5 I²C bus specification

## 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 400kbits/s
- 3.3 V logic compatible

**Figure 26. I²C bus interface protocol**




S = Start

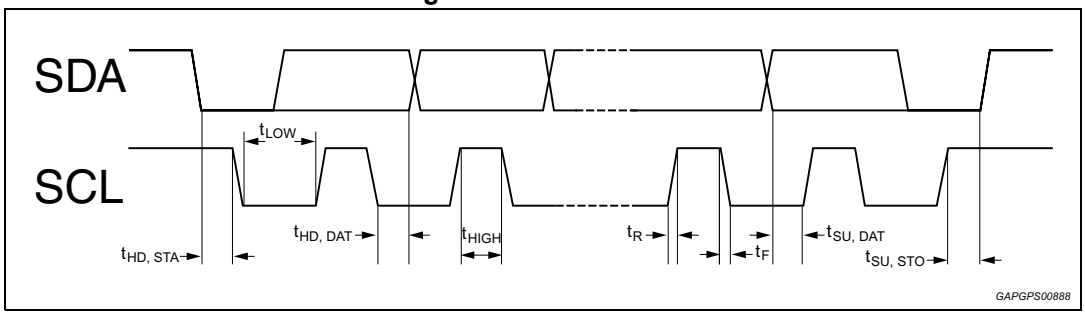
ACK = Acknowledge

## 5.2 I²C bus electrical characteristics

**Table 6. I²C bus electrical characteristics**

| Symbol | Parameter | Min | Max | Unit |
|---|---|---|---|---|
| $f_{SCL}$ | SCL clock frequency | - | 400 | kHz |
| $V_{IH}$ | High level input voltage | 2.4 | - | V |
| $V_{IL}$ | Low level input voltage | - | 0.8 | V |
| $t_{HD,STA}$ | Hold time for START | 0.6 | - | µs |
| $t_{SU,STO}$ | Setup time for STOP | 0.6 | - | µs |
| $t_{LOW}$ | Low period for SCL clock | 1.3 | - | µs |
| $t_{HIGH}$ | High period for SCL clock | 0.6 | - | µs |
| $t_F$ | Fall time for SCL/SDA | - | 300 | ns |
| $t_R$ | Rise time for SCL/SDA | - | 300 | ns |
| $t_{HD,DAT}$ | Data hold time | 0 | - | ns |
| $t_{SU,DAT}$ | Data setup time | 100 | - | ns |

Figure 27. I²C bus data




### 5.2.1 Receive mode

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

S = Start

R/W = "0" → Receive mode (Chip can be programmed by µP)

"1" → Transmission mode (Data could be received by µP)

ACK = Acknowledge

P = Stop

TS = Testing mode

AI = Auto increment

### 5.2.2 Transmission mode

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

SM = SoftMute activated for main channel

BZ = SoftStep busy (‘0’ = Busy)

X = Not used

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

### 5.2.3 Reset condition

A power-on-reset is invoked if the supply voltage is below than 3.5 V. After that the registers are initialized to the default data written in following tables.

**Table 7. Subaddress (receive mode)**

| MSB | | | | | | | LSB | Function |
|---|---|---|---|---|---|---|---|---|
| I2 | I1 | I0 | A4 | A3 | A2 | A1 | A0 | |
| 0<br>1 | - | - | - | - | - | - | - | **Testing mode**<br>Off<br>On |
| - | x | - | - | - | - | - | - | **Not used** |
| - | - | 0<br>1 | - | - | - | - | - | **Auto increment mode**<br>Off<br>On |
| - | - | - | 0 | 0 | 0 | 0 | 0 | Main selector/others |
| - | - | - | 0 | 0 | 0 | 0 | 1 | Output level / Highpass / EQ5 |
| - | - | - | 0 | 0 | 0 | 1 | 0 | EQ2 |
| - | - | - | 0 | 0 | 0 | 1 | 1 | EQ4 |
| - | - | - | 0 | 0 | 1 | 0 | 0 | Soft-mute / others |
| - | - | - | 0 | 0 | 1 | 0 | 1 | SoftStep I |
| - | - | - | 0 | 0 | 1 | 1 | 0 | SoftStep II / DC-detector |
| - | - | - | 0 | 0 | 1 | 1 | 1 | Loudness |
| - | - | - | 0 | 1 | 0 | 0 | 0 | Volume / output gain |
| - | - | - | 0 | 1 | 0 | 0 | 1 | EQ5 |
| - | - | - | 0 | 1 | 0 | 1 | 0 | EQ3 |
| - | - | - | 0 | 1 | 0 | 1 | 1 | EQ1 |
| - | - | - | 0 | 1 | 1 | 0 | 0 | Subwoofer / EQ3 / EQ1 |
| - | - | - | 0 | 1 | 1 | 0 | 1 | Speaker attenuator left front |
| - | - | - | 0 | 1 | 1 | 1 | 0 | Speaker attenuator right front |
| - | - | - | 0 | 1 | 1 | 1 | 1 | Speaker attenuator left rear |
| - | - | - | 1 | 0 | 0 | 0 | 0 | Speaker attenuator right rear |
| - | - | - | 1 | 0 | 0 | 0 | 1 | Subwoofer attenuator left |
| - | - | - | 1 | 0 | 0 | 1 | 0 | Subwoofer attenuator right |
| - | - | - | 1 | 0 | 0 | 1 | 1 | Testing audio processor 1 |
| - | - | - | 1 | 0 | 1 | 0 | 0 | Testing audio processor 2 |
| - | - | - | 1 | 0 | 1 | 0 | 1 | Testing audio processor 3 |
| - | - | - | 1 | 0 | 1 | 1 | 0 | InGain/EQ2/EQ4 |

## 5.3 Data byte specification

**Table 8. Main selector (0)**

| MSB | | | | | | | LSB | Function |
|---|---|---|---|---|---|---|---|---|
| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | |
| | | | | | | | | **Main source selector** |
| | | | | | 0 | 0 | 0 | SE1 |
| | | | | | 0 | 0 | 1 | SE3 |
| | | | | | 0 | 1 | 0 | QD1 |
| - | - | - | - | - | 0 | 1 | 1 | QD2 |
| | | | | | 1 | 0 | 0 | SE2 |
| | | | | | 1 | 0 | 1 | Mute |
| | | | | | 1 | 1 | 0 | Mute |
| | | | | | 1 | 1 | 1 | Mute |
| - | - | - | - | 0 | - | - | - | **EQ2 SoftStep** |
| | | | | 1 | | | | On |
| | | | | | | | | Off |
| - | - | - | 0 | - | - | - | - | **EQ4 SoftStep** |
| | | | 1 | | | | | On |
| | | | | | | | | Off |
| - | - | 0 | - | - | - | - | - | **Subwoofer flat** |
| | | 1 | | | | | | Off |
| | | | | | | | | On |
| - | 0 | - | - | - | - | - | - | **Subwoofer input source** |
| | 1 | | | | | | | Input MUX |
| | | | | | | | | EQ output |
| 0 | - | - | - | - | - | - | - | **Rear input source** |
| 1 | | | | | | | | Subwoofer output |
| | | | | | | | | EQ /HPF (depends on Byte1D4) |

**Table 9. Output level / Highpass / EQ5 (1)**

| MSB | | | | | | | LSB | Function |
|---|---|---|---|---|---|---|---|---|
| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | |
| - | - | - | - | - | - | | | **Output DC level** |
| | | | | | | 0 | 0 | 3 V (AC Gain = 6dB) |
| | | | | | | 0 | 1 | 4 V (AC Gain = 8.5dB) |
| | | | | | | 1 | x | 5.75 V (AC Gain = 11dB) |
| - | - | - | | - | - | - | - | **Highpass enable** |
| | | | 0 | | | | | Off (bypass) |
| | | | 1 | | | | | On |
| - | - | | - | | | - | - | **Highpass frequency** |
| | | 0 | | 0 | 0 | | | 100Hz |
| | | 0 | | 0 | 1 | | | 120Hz |
| | | 0 | | 1 | 0 | | | 150Hz |
| | | 0 | | 1 | 1 | | | 180Hz |
| | | 1 | | x | x | | | 63Hz |
| | | | | | | | | **EQ5 quality factor** |
| 0 | 0 | | | | | | | 0.75 |
| 0 | 1 | - | - | - | - | - | - | 1.0 |
| 1 | 0 | | | | | | | 1.25 |
| 1 | 1 | | | | | | | 2 |

**Table 10. EQ2 (2)**

| MSB | | | | | | | LSB | Function |
|---|---|---|---|---|---|---|---|---|
| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | |
| | | | | | | | | **Gain/Attenuation** |
| | | | 0 | 0 | 0 | 0 | 0 | -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 |
| | | | | | | | | **EQ2 center frequency** |
| | 0 | 0 | | | | | | 200Hz |
| - | 0 | 1 | - | - | - | - | - | 250Hz |
| | 1 | 0 | | | | | | 315Hz |
| | 1 | 1 | | | | | | 400Hz |
| | | | | | | | | **Soft step action** |
| 0 | - | - | - | - | - | - | - | act |
| 1 | | | | | | | | wait |

Table 11. EQ4 (3)

| MSB | | | | | | | LSB | Function |
|---|---|---|---|---|---|---|---|---|
| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | |
| | | | | | | | | **Gain/Attenuation** |
| | | | 0 | 0 | 0 | 0 | 0 | -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 |
| | | | | | | | | **EQ4 center frequency** |
| | | 0 | | | | | | 2kHz |
| - | - | 1 | - | - | - | - | - | 2.5kHz |
| | | 0 | | | | | | 3.15kHz |
| | | 1 | | | | | | 4kHz |
| | | | | | | | | **SoftStep action** |
| 0 | - | - | - | - | - | - | - | act |
| 1 | | | | | | | | wait |

**Table 12. SoftMute / others (4)**

| MSB | | | | | | | LSB | Function |
|---|---|---|---|---|---|---|---|---|
| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | |
| - | - | - | - | - | - | - | | **SoftMute** |
| | | | | | | | 0 | On |
| | | | | | | | 1 | Off |
| - | - | - | - | - | - | | | **Pin influence for mute** |
| | | | | | | 0 | - | Pin and IIC |
| | | | | | | 1 | | IIC |
| - | - | - | - | | | - | - | **SoftMute Time** |
| | | | | 0 | 0 | | | 0.48ms |
| | | | | 0 | 1 | | | 0.96ms |
| | | | | 1 | 0 | | | 7.68ms |
| | | | | 1 | 1 | | | 15.36ms |
| - | - | | | - | - | - | - | **Speaker-Ls/Rs input selection (OUTSWL & OUTSWR)** |
| | | 0 | 0 | | | | | High Pass filter |
| | | 0 | 1 | | | | | Subwoofer filter |
| | | 1 | 0 | | | | | High Pass filter |
| | | 1 | 1 | | | | | EQ filter |
| - | | - | - | - | - | - | - | **Fast charge** |
| | 0 | | | | | | | On |
| | 1 | | | | | | | Off |
| | - | - | - | - | - | - | - | **Anti-alias filter** |
| 0 | | | | | | | | On |
| 1 | | | | | | | | Off (bypass) |

Table 13. SoftStep I (5)

| MSB | | | | | | | LSB | Function |
|---|---|---|---|---|---|---|---|---|
| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | |
| - | - | - | - | - | - | - | 0<br>1 | **Loudness SoftStep**<br>On<br>Off |
| - | - | - | - | - | - | 0<br>1 | - | **Volume SoftStep**<br>On<br>Off |
| - | - | - | - | - | 0<br>1 | - | - | **EQ5 SoftStep**<br>On<br>Off |
| - | - | - | - | 0<br>1 | - | - | - | **EQ3 SoftStep**<br>On<br>Off |
| - | - | - | 0<br>1 | | - | - | - | **EQ1 SoftStep**<br>On<br>Off |
| - | - | 0<br>1 | - | - | - | - | - | **Speaker LF SoftStep**<br>On<br>Off |
| - | 0<br>1 | - | - | - | - | - | - | **Speaker RF SoftStep**<br>On<br>Off |
| 0<br>1 | - | - | - | - | - | - | - | **Speaker LR SoftStep**<br>On<br>Off |

**Table 14. SoftStep II / DC-detector (6)**

| MSB | | | | | | | LSB | Function |
|---|---|---|---|---|---|---|---|---|
| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | |
| - | - | - | - | - | - | - | 0<br>1 | **Speaker RR SoftStep**<br>On<br>Off |
| - | - | - | - | - | - | 0<br>1 | - | **Subwoofer left SoftStep**<br>On<br>Off |
| - | - | - | - | - | 0<br>1 | - | - | **Subwoofer right SoftStep**<br>On<br>Off |
| - | - | - | - | 0<br>1 | - | - | - | **SoftStep time**<br>5 ms<br>10 ms |
| - | - | 0<br>0<br>1<br>1 | 0<br>1<br>0<br>1 | - | - | - | - | **Zero-comparator window size**<br>± 90 mV<br>± 60 mV<br>± 45 mV<br>± 30 mV |
| 0<br>0<br>1<br>1 | 0<br>1<br>0<br>1 | - | - | - | - | - | - | **Spike rejection time constant**<br>11µs<br>22 µs<br>33 µs<br>44 µs |

**Table 15. Loudness (7)**

| 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 | **Attenuation**<br>0dB<br>-1dB<br>:<br>-14dB<br>-15dB |
| - | - | 0<br>0<br>1<br>1 | 0<br>1<br>0<br>1 | - | - | - | - | **Center frequency**<br>Flat<br>400Hz<br>800Hz<br>2400Hz |
| - | 0<br>1 | - | - | - | - | - | - | **High boost**<br>On<br>Off |
| 0<br>1 | - | - | - | - | - | - | - | **SoftStep action**<br>act<br>wait |

Table 16. Volume (8)

| MSB | | | | | | | LSB | Function |
|---|---|---|---|---|---|---|---|---|
| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | |
| | | | | | | | | **Gain/attenuation** |
| | 0 | 0 | 0 | 0 | 0 | 0 | 0 | +0dB |
| | 0 | 0 | 0 | 0 | 0 | 0 | 1 | +1dB |
| | 0 | : | : | : | : | : | : | : |
| | 0 | 0 | 0 | 1 | 1 | 1 | 1 | +15dB |
| | 0 | 0 | 1 | 0 | 0 | 0 | 0 | +16dB |
| | 0 | : | : | : | : | : | : | : |
| | 0 | 0 | 1 | 0 | 1 | 1 | 1 | +23dB |
| | 0 | 0 | 1 | 1 | 0 | 0 | 0 | Not used |
| | 0 | : | : | : | : | : | : | : |
| | 0 | 0 | 1 | 1 | 1 | 1 | 1 | Not used |
| | 0 | 1 | 0 | 0 | 0 | 0 | 0 | -0dB |
| - | 0 | : | : | : | : | : | : | : |
| | 0 | 1 | 0 | 1 | 1 | 1 | 1 | -15dB |
| | 0 | : | : | : | : | : | : | : |
| | 0 | 1 | 1 | 1 | 1 | 1 | 0 | -30dB |
| | 0 | 1 | 1 | 1 | 1 | 1 | 1 | -31dB |
| | 1 | 0 | 0 | 0 | 0 | 0 | 0 | -32dB |
| | 1 | 0 | 0 | 0 | 0 | 0 | 1 | -33dB |
| | 1 | : | : | : | : | : | : | : |
| | 1 | 0 | 1 | 1 | 1 | 1 | 1 | -63dB |
| | 1 | 1 | 0 | 0 | 0 | 0 | 0 | -64dB |
| | : | : | : | : | : | : | : | : |
| | 1 | 1 | 0 | 1 | 1 | 1 | 1 | -79dB |
| | 1 | 1 | 1 | x | x | x | x | Mute |
| | | | | | | | | **SoftStep action** |
| 0 | - | - | - | - | - | - | - | act |
| 1 | | | | | | | | wait |

**Table 17. EQ5 (9)**

| MSB | | | | | | | LSB | Function |
|---|---|---|---|---|---|---|---|---|
| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | |
| | | | | | | | | **Gain/attenuation** |
| | | | 0 | 0 | 0 | 0 | 0 | -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 |
| | | | | | | | | **EQ5 center frequency** |
| | 0 | 0 | | | | | | 6.3kHz |
| - | 0 | 1 | - | - | - | - | - | 8kHz |
| | 1 | 0 | | | | | | 10.0kHz |
| | 1 | 1 | | | | | | 12.5kHz |
| | | | | | | | | **SoftStep action** |
| 0 | - | - | - | - | - | - | - | act |
| 1 | | | | | | | | wait |

**Table 18. EQ3 (10)**

| MSB | | | | | | | LSB | Function |
|---|---|---|---|---|---|---|---|---|
| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | |
| | | | | | | | | **Gain/attenuation** |
| | | | 0 | 0 | 0 | 0 | 0 | -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 |
| | | | | | | | | **EQ3 Quality factor** |
| | 0 | 0 | | | | | | 0.75 |
| - | 0 | 1 | - | - | - | - | - | 1.0 |
| | 1 | 0 | | | | | | 1.25 |
| | 1 | 1 | | | | | | 2 |
| | | | | | | | | **SoftStep action** |
| 0 | - | - | - | - | - | - | - | act |
| 1 | | | | | | | | wait |

Table 19. EQ1 (11)

| MSB | | | | | | | LSB | Function |
|---|---|---|---|---|---|---|---|---|
| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | |
| | | | | | | | | **Gain/attenuation** |
| | | | 0 | 0 | 0 | 0 | 0 | -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 |
| | | | | | | | | **EQ1 quality factor** |
| | 0 | 0 | | | | | | 1.0 |
| - | 0 | 1 | - | - | - | - | - | 1.25 |
| | 1 | 0 | | | | | | 1.5 |
| | 1 | 1 | | | | | | 2 |
| | | | | | | | | **SoftStep action** |
| 0 | - | - | - | - | - | - | - | act |
| 1 | | | | | | | | wait |

**Table 20. Subwoofer / EQ3/ EQ1 (12)**

| MSB | | | | | | | LSB | Function |
|---|---|---|---|---|---|---|---|---|
| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | |
| | | | | | | | | **Subwoofer cut-off frequency** |
| | | | | | | 0 | 0 | 55Hz |
| - | - | - | - | - | - | 0 | 1 | 85Hz |
| | | | | | | 1 | 0 | 120Hz |
| | | | | | | 1 | 1 | 160Hz |
| - | - | - | - | - | 0 | - | - | **Subwoofer output phase** |
| | | | | | 1 | | | 180 deg |
| | | | | | | | | 0 deg |
| | | | | | | | | **EQ3 Center Frequency** |
| | | | 0 | 0 | | | | 630Hz |
| - | - | - | 0 | 1 | - | - | - | 800Hz |
| | | | 1 | 0 | | | | 1000Hz |
| | | | 1 | 1 | | | | 1250Hz |
| | | | | | | | | **EQ1 Center Frequency** |
| | 0 | 0 | | | | | | 63Hz |
| - | 0 | 1 | - | - | - | - | - | 80Hz |
| | 1 | 0 | | | | | | 100Hz |
| | 1 | 1 | | | | | | 125Hz |
| | | | | | | | | **EQ Flat mode** |
| 0 | - | - | - | - | - | - | - | on |
| 1 | | | | | | | | off |

**Table 21. Speaker attenuation (FL/FR/RL/RR/SWL/SWR) (13-18)**

| MSB | | | | | | | LSB | Function |
|---|---|---|---|---|---|---|---|---|
| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | |
| | | | | | | | | **Gain/attenuation** |
| | 0 | 0 | 0 | 0 | 0 | 0 | 0 | +0dB |
| | 0 | 0 | 0 | 0 | 0 | 0 | 1 | +1dB |
| | : | : | : | : | : | : | : | : |
| | 0 | 0 | 0 | 1 | 1 | 1 | 1 | +15dB |
| - | 0 | 0 | 1 | 0 | 0 | 0 | 0 | -0dB |
| | 0 | 0 | 1 | 0 | 0 | 0 | 1 | -1dB |
| | : | : | : | : | : | : | : | : |
| | 1 | 0 | 1 | 1 | 1 | 1 | 0 | -78dB |
| | 1 | 0 | 1 | 1 | 1 | 1 | 1 | -79dB |
| | 1 | 1 | x | x | x | x | x | mute |
| | | | | | | | | **SoftStep action** |
| 0 | - | - | - | - | - | - | - | act |
| 1 | | | | | | | | wait |

**Table 22. Testing audio processor 1 (19)**

| MSB | | | | | | | LSB | Function |
|---|---|---|---|---|---|---|---|---|
| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | |
| - | - | - | - | - | - | - | 0<br>1 | **Audio processor testing mode**<br>Off<br>On |
| - | - | - | 0<br>0<br>0<br>0<br>0<br>0<br>0<br>0 | 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 | - | **Test multiplexer at QD2G** (1)<br>SSCLK<br>SMCLK<br>Clk200<br>SDCLK<br>REQ_Test<br>VDDa<br>VDDd<br>V2V |
| - | - | - | 1<br>1<br>1<br>1<br>1<br>1<br>1<br>1 | 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 | - | **Test multiplexer DCO** (1)<br>Vref<br>Vref<br>Vref<br>Vref<br>Vthp ref<br>Vthn ref<br>IntZeroErr<br>Vref |
| - | - | 0<br>1 | - | - | - | - | - | **Clock fast mode** (2)<br>On<br>Off |
| - | 0<br>1 | - | - | - | - | - | - | **Clock source**(2)<br>External (MUTE Pin)<br>Internal (200kHz) |
| 0<br>1 | - | - | - | - | - | - | - | **Attenuators gain clock control** (2)<br>On<br>Off |

1. The control bit needs both I²C test mode on & sub-address test mode on.
2. The control bit does not depend on test mode.

**Table 23. Testing audio processor 2 (20)**

| MSB | | | | | | | LSB | Function |
|---|---|---|---|---|---|---|---|---|
| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | |
| - | - | - | - | - | - | - | 0<br>1 | **Test architecture**(1)<br>Normal<br>Split |
| - | - | - | - | - | - | 0<br>1 | - | **Oscillator clock** (2)<br>400kHz<br>800kHz |
| - | - | - | - | - | 0<br>1 | - | - | **SoftStep curve**(2)<br>S-Curve<br>Linear curve |
| - | - | - | 0<br>0<br>1<br>1 | 0<br>1<br>0<br>1 | - | - | - | **Manual set busy signal** (1)<br>Auto<br>Auto<br>0<br>1 |
| - | - | - | 0<br>0<br>1<br>1 | 0<br>1<br>0<br>1 | - | - | - | **Request for clk generator** (1)<br>Allow<br>Allow<br>Stopped<br>Stopped |
| - | - | 0<br>1 | - | - | - | - | - | **No DCO spike rejection** (2)<br>On<br>Off |
| - | x | - | - | - | - | - | - | **Not used** |
| 0<br>1 | - | - | - | - | - | - | - | **EQ flat function**<br>Disable<br>Enable |

1. The control bit needs sub-address test mode on.
2. The control bit does not depend on test mode.

**Table 24. Testing audio processor 3 (21)**

| MSB | | | | | | | LSB | Function |
|---|---|---|---|---|---|---|---|---|
| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | |
| - | - | - | - | - | - | - | 0<br>1 | **Enable Clock for FL/FR/RL/RR/SWL/SWR**<br>On<br>Off |
| - | - | - | - | - | - | 0<br>1 | - | **Enable clock for InGain&EQ1**<br>On<br>Off |
| - | - | - | - | - | 0<br>1 | - | - | **Enable clock for volume&EQ2**<br>On<br>Off |
| - | - | - | - | 0<br>1 | - | - | - | **Enable clock for EQ3**<br>On<br>Off |
| - | - | - | 0<br>1 | - | - | - | - | **Enable clock for EQ4**<br>On<br>Off |
| - | - | 0<br>1 | - | - | - | - | - | **Enable clock for EQ5**<br>On<br>Off |
| - | 0<br>1 | - | - | - | - | - | - | **Enable test for InGain**<br>On<br>Off |
| x | | - | - | - | - | - | - | **Not used** |

**Table 25. InGain & EQ2, EQ4 (22)**

| MSB | | | | | | | LSB | Function |
|---|---|---|---|---|---|---|---|---|
| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | |
| - | - | - | - | 0<br>0<br>:<br>0<br>0<br>1 | 0<br>0<br>:<br>1<br>1<br>x | 0<br>1<br>:<br>1<br>1<br>x | 0<br>0<br>:<br>0<br>1<br>x | **InGain**<br>+0dB<br>+1dB<br>:<br>+6dB<br>Not used<br>Not used |
| - | - | 0<br>0<br>1<br>1 | 0<br>1<br>0<br>1 | - | - | - | - | **EQ2 quality factor**<br>1.0<br>1.25<br>1.5<br>2.0 |
| 0<br>0<br>1<br>1 | 0<br>1<br>0<br>1 | - | - | - | - | - | - | **EQ4 quality factor**<br>0.75<br>1.0<br>1.25<br>2 |

# 6 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK® packages, depending on their level of environmental compliance. ECOPACK® specifications, grade definitions and product status are available at: *www.st.com*.

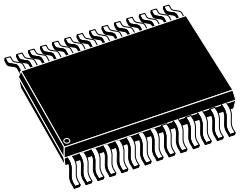
ECOPACK® is an ST trademark.

**Figure 28. TSSOP28 mechanical data and package dimensions**

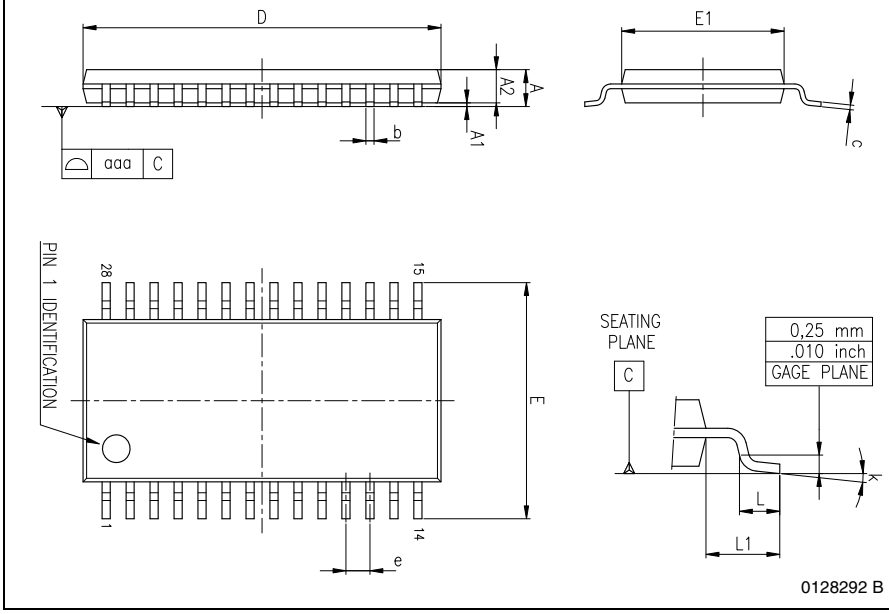
| DIM. | mm | | | inch | | |
|---|---|---|---|---|---|---|
| | MIN. | TYP. | MAX. | MIN. | TYP. | MAX. |
| A | | | 1.200 | | | 0.047 |
| A1 | 0.050 | | 0.150 | 0.002 | | 0.006 |
| A2 | 0.800 | 1.000 | 1.050 | 0.031 | 0.039 | 0.041 |
| b | 0.190 | | 0.300 | 0.007 | | 0.012 |
| c | 0.090 | | 0.200 | 0.004 | | 0.008 |
| D (1) | 9.600 | 9.700 | 9.800 | 0.378 | 0.382 | 0.386 |
| E | 6.200 | 6.400 | 6.600 | 0.244 | 0.252 | 0.260 |
| E1 (1) | 4.300 | 4.400 | 4.500 | 0.170 | 0.173 | 0.177 |
| e | | 0.650 | | | 0.026 | |
| L | 0.450 | 0.600 | 0.750 | 0.018 | 0.024 | 0.030 |
| L1 | | 1.000 | | | 0.039 | |
| k | 0° (min.), 8° (max.) | | | | | |
| aaa | | | 0.100 | | | 0.004 |

Note: 1. D and E1 does not include mold flash or protrusions. Mold flash or po trusions shall not exceed 0.1 5mm (.006inch) per side.

**OUTLINE AND MECHANICAL DAT A**



**TSSOP28**
**Thin Shrink Small Outline Package**
**JEDEC MO-153-AC**




GAPGPS00889

# 7 Revision history

Table 26. Document revision history

| Date | Revision | Changes |
|---|---|---|
| 24-Oct-2013 | 1 | Initial release. |
| 20-Dec-2013 | 2 | Updated *Figure 1: Block diagram on page 6*;<br>Modified *Table 5: Electrical characteristics* on page 11 and 12 (only $C_{RANGE}$ parameter name). |
| 08-Jan-2014 | 3 | Updated *Features on page 1*. |

**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.

© 2014 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**