

The G4OEP: A Flea-Powered Headphone Amp

This low-power amp design gives new meaning to the word “simple.”

Would you believe me if I raved about the audiophile qualities of a car audio chip? I cannot blame you if you didn't. Last spring I constructed a headphone amplifier using a pair of TDA2003 ICs, and this is how it came about.

Since January 2006, I've subscribed to the British magazine *SPRAT*, which, as some of you may know, is an amateur radio quarterly published by the G-QRP club and edited by the Reverend George Dobbs (call sign G3RJV). Its pages are “devoted to low power communication.” Some club members have established radio contacts over a distance of 10,000 miles using intelligent software, *very* slow Morse code, and just 0.5mW of power! Others have called their ham friends in another city using a lemon as the only power source.

CIRCUIT FEATURES

Occasionally there are more down-to-earth articles in *SPRAT*. In the summer 2006 issue, Dr. Andrew Smith (call sign G4OEP) wrote “High Performance Headphone Amplifier,”¹ which described a circuit based on a well-known car audio chip, the TDA2003 (**Fig. 1**). This simple circuit comes straight from the datasheet², but some component values have been altered in order to reduce the voltage gain (from 100 to 18), and reduce the output power (from 4W to 0.01W).

You can easily reach both goals by increasing the overall feedback ratio, with the additional benefit of a 25-fold reduction in harmonic distortion. Gain is determined by the ratio of R2 over R1 (**Fig. 1**). In the standard application, R2 is 220Ω and R1 is 2.2Ω, resulting in a voltage gain of about 100. In Dr. Smith's circuit, R2 is 2k2 and R1 is 130Ω, so

that the gain is lowered to $(2200/130)+1 = 18$.

High-frequency cutoff (F3) is determined by C5 and R2, according to the formula:

$$F3 = 1/(2 * \pi * R2 * C5)$$

Thus, when C5 = 2.2nF and R2 = 2k2, F3 is set to 33kHz. Low-frequency cutoff is mainly determined by C6 and the impedance of the headphones.

**TABLE 1A: PARTS LIST
(FOR ONE AMPLIFIER CHANNEL)**

R1	130Ω 0.25W
R2, R3	2k2 0.25W
R4	1Ω 1W
C1	10μF 100V radial electrolytic
C2, C6	470μF 40V axial electrolytic
C3	0.22μF 100V MKT
C4	1000μF 40V axial electrolytic
C5	2.2nF 100V MKT
C7	0.1μF 100V MKT

IC1 TDA2003 (SGS Thomson). Heatsink not necessary.

NB: There is a discrepancy between the article in *SPRAT* and the schematic published on the G4OEP website⁴. In the *SPRAT* article, R3 has a value of 2k2, but in the posting on the web this resistor is 330Ω2. The latter value will result in larger bandwidth but also in greater risk of instability.

**TABLE 1B: POWER SUPPLY
(ONE FOR EACH AMPLIFIER CHANNEL)**

C8-C11	10nF 400V ceramic (not absolutely necessary)
C12	1000μF 40V (in my prototype 2 × 470μF 40V radial electrolytic, in parallel)
C13, C14	0.1μF foil cap
D1-D4	1N4002 (I used SY330/2, which are 200V 0.5A fast rectifiers from the former GDR)
IC2	L7812CV (SGS Thomson). Heatsink not necessary
S1	Mains switch (dual-pole dual-throw)
Tr1	Transformer 230V: 2 × 12V, PCB type, 10VA minimum

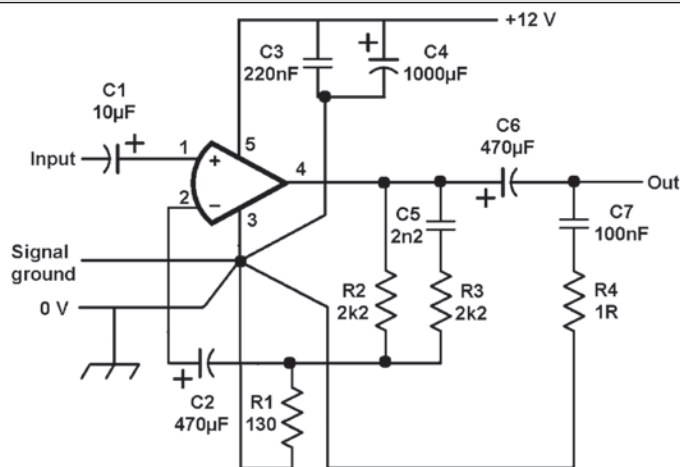


FIGURE 1: Amplifier schematic (one channel). There is a 30k log potentiometer (volume control) at the input (not shown).

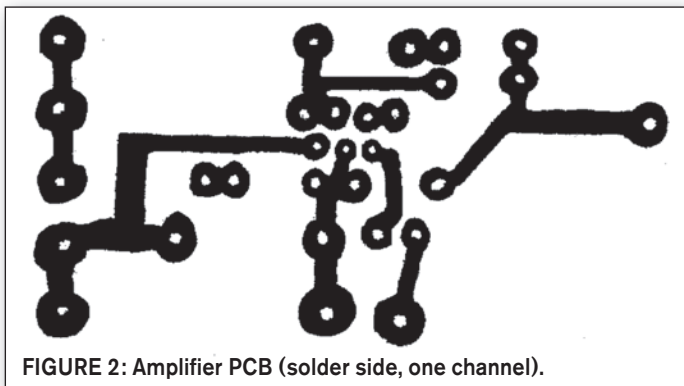


FIGURE 2: Amplifier PCB (solder side, one channel).

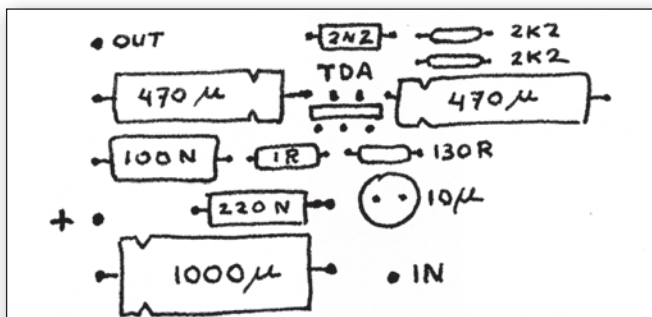


FIGURE 3: Parts placement (one amplifier channel, seen from solder side).

In my prototype, I measured a -3dB low-frequency cutoff frequency of 13Hz (left channel) and 14Hz (right channel), using a 32Ω load. When you use headphones with higher impedance (such as the 85Ω Sennheiser HD25SP of Dr. Smith) the low-frequency cutoff will be shifted to 10Hz (Table 2), and even less in the case of AKG or Beyer dynamic.

According to Dr. Smith, "Objectively the performance of this amplifier is flawless, and it also sounds sweet." The circuit "gives excellent performance, equal to the very best commercial designs costing hundreds of pounds¹." I found this hard to believe, because the TDA2003 is a Class B amplifier, and the proposed circuit makes liberal use of negative feedback. Both aspects seem incompatible with good sound. However, I considered the following:

- (a) At the small amount of power required by sensitive headphones, the TDA2003 will operate continuously in Class A.
- (b) Well-designed op amp circuits with overall negative feedback can sound good, as Dieter Burmester³ has proven.
- (c) My junkbox contains several

TDA2003 ICs that I bought in Germany for only 38 Eurocents apiece (www.pollin.de). For such a small price, you can run the risk and perform some tests! Thus, I decided to give the G4OEP circuit a try.

APPLICATION

From experience I know that the TDA2003 chip can be a difficult animal—it is prone to oscillation if the circuit wiring is poorly laid out. The *SPRAT* article warns: "To avoid instability problems, a rigorous single-point earthing scheme should be used. The common earth point should be as close

to pin 3 as possible¹."

Following this advice, I designed a simple PCB in which R1 and R4 are very close to pin 3. I ensured that the input and output pins of the circuit were at opposite corners of the board, i.e., at a great distance from each other (Figs. 2 and 3). Dimensions of the PCB (3.5 × 2", or 9 × 5cm) are based on the use of 40V axial electrolytic capacitors from Philips (HP-LL-M), which, in my opinion, have an excellent price-performance ratio. My parts placement is indicated in Fig. 3.

With this home-made PCB, TDA2003 chips from SGS-Thomson,

TABLE 2: AMPLIFIER MEASUREMENTS

(by Dr. A. Smith)

Voltage gain: 18

Nominal power output: 10mW

Maximum output reached at: 200mV input

Harmonic distortion: 0.006% (at 1V peak out in 85Ω)

Spectrum of distortion (1V peak in 85Ω at 1kHz):

Only 2nd and 3rd harmonic visible

2nd at -90dB

3rd < -88dB

Noise: -100dB

Hum: -84dB (dependent on PSU circuit and layout)

Frequency response: 10Hz - 50kHz (-3dB) in 85Ω

(my measurements)

Frequency response: 14Hz - > 30kHz (-3dB) in 32Ω

Quiescent current: about 40mA at +12V

(the 85Ω load consisted of Sennheiser HD25SP headphones)

(the 32Ω load consisted of Grado SR125 headphones)

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LISTENING TESTS

During the listening tests, I was impressed by the audio quality of the following CDs:

1. Tielman Susato, "Dansereye" (1551). New London Consort. Philip Pickett, conductor. Decca 436-131 2 [Producer: Peter Wadland, engineers: Jonathan Stokes and Neil Hutchinson, recorded 1991, released 1998].

A collection of Renaissance dances performed on a great variety of instruments, including such exotic items as hurdy-gurdy, rebec, cittern, sackbuts, serpent, crumhorn, curtals, shawms, racketts, sordins, rommel-pot, and regal. Although originating from the early 16th century (probably even from medieval times), several of these melodies can still be heard in folk music today (listen, e.g., to recordings of the Flemish ensemble Het Kliekske on CBS). My favorites are "Hoboeckendans" (track 16), Pavane La Battaille (i.e., The Fight, track 26), and Entre du Fol (i.e., Entry of the Fool, track 37). The disk is delightful, although occasionally there is some stridence in loud passages, and the performance may be a tad too polished for this repertoire.

2. "Wim van Beek plays the organ of the Dutch Reformed Church in Kantens." Works of Sweelinck, Scheidt, Van den Kerckhoven, Böhm, Buxtehude, Pachelbel, and anonymous 16th century composers. Orgelcommissie Kantens, WBK2001 [CD released in 2001, engineer: Jan Willem van Willigen. Can be ordered via the Internet, www.groningenorgelland.nl/cd.htm Price 10 Euros].

This is a marvelous CD in every respect, capable of converting even die-hard organ haters. The 17th century organ at the village church of Kantens is a beautiful and unique instrument. The music is joyful, easy on the ear, well played, and very well recorded. Until his retirement, Wim van Beek was organ teacher at The Royal Conservatory in The Hague and the Conservatory in Groningen.

3. Jacob van Eyck, "Der Fluyten Lusthof" [The Flute's Garden of Delight]. Played by Erik Bosgraaf on various recorders. With Izhar Elias, baroque guitar, and Inmaculada Muñoz Jiménez, pandereta. Brilliant Classics 93391 [Box of three CDs released in 2007, engineer: Peter Arts, producer: Thiemo Wind] See www.brilliantclassics.com, www.jacobvaneyck.info and www.erikbosgraaf.com.

www.jacobvaneyck.info and www.erikbosgraaf.com.

Jacob van Eyck (1589-1657), the blind city carillonneur of Utrecht, played his recorder on summer evenings in the Janskerkhof. The public, strolling in the churchyard, was overwhelmed by his virtuosic art. The solo variations, preludes, and fantasias (based on British, French, Italian, Dutch, and German folk songs, besides some melodies from the Geneva psalter) were printed during van Eyck's lifetime in "Der Fluyten Lusthof." For this recording, Erik Bosgraaf selected 69 of the 150 published works. He plays this music very well, with great freedom of timing and dynamic expression. The CDs are also well-recorded (in a chapel at Warmond, near the city of Leiden). The accompanying booklet is written by Thiemo Wind, who recently defended a doctoral dissertation about van Eyck. For several weeks, this recording occupied the no. 1 position of the Top 50 of classical music releases on Radio Netherlands. Highly recommended!

4. La Bella Noeva: Les Chants de la Terre. [Madrigals of Giulio Caccini, Alessandro

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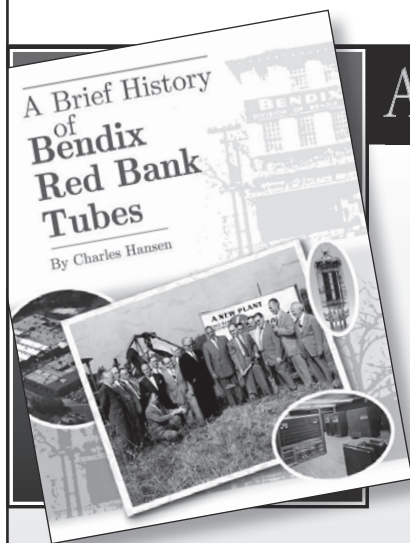
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Grandi, Biagio Marini, Claudio Monteverdi, Giovanni Stefani, and an anonymous Italian composer.] Marco Beasley, tenor. Ensemble Accordone. Guido Morini, organ/harpsichord/artistic direction. Alpha 508 [recorded and released in 2003, engineer Hugues Deschaux, see www.alpha-prod.com].

A technically and musically perfect rendering of early 17th century Italian love songs. [I may be biased because I am a great fan of Marco Beasley and his ensemble]. The music is full of emotional expression. "La Bella Noeva" means "good news," and the different love stories are told in a very lively way. The disk finishes with a madrigal based on the biblical Song of Songs, a short version of the Laudate Dominum (setting of Psalm 150), and an alleluia.

5. G.F.Händel, Gloria (World Premiere Recording), Dixit Dominus. Emma Kirkby, soprano, Royal Academy of Music Baroque Orchestra, Laurence Cummings, conductor (Gloria), Hillevi Martinpelto, soprano, Anne Sofie von Otter, alto, Stockholm Bach Choir, Drottningholm Baroque Ensemble, Anders Öhrwall, conductor. BIS CD1235. [Released in 2001, engineers Ingo Petry and Robert von Bahr].

In 2001, the manuscript of Händel's Gloria was rediscovered in the library of the Royal Academy of Music at London. This CD contains the world premiere recording of this unknown work, besides an excellent performance of the Dixit Dominus, a Latin setting of Psalm 110. The acoustics of Duke's Hall at the Royal Academy of Music (Gloria) are rather dry, those of the Adolf Fredrik Church in Stockholm (Dixit Dominus) are more resonant. The voices of soloists and choir are well recorded, with naturally sounding sibilants. And Händel's music is very beautiful.

6. Friedrich Hartmann Graf, "Out of the Shadow of the Masters." Sonata in e for flute and basso continuo; trio in D for flute, violin, and cello; quartet in G for flute, violin, viola, and cello; quartet no. 2 in D for two flutes, viola, and cello; quintet in Eb. Ensemble Schönbrunn. Globe GLO 5212 [Producer: Paul Janse, engineer: Paul Peter Polak, recorded in 2004, released in 2005, see www.globerecords.nl].

This disk contains what probably are the first recordings of several unpublished works by F.H. Graf, a contemporary of Joseph Haydn. The manuscripts are in the Gjedde Collection at the Royal Danish Library in

Copenhagen. They were "rediscovered" by Martin Root, flute player and leader of the Schönbrunn Ensemble. Graf's music is surprisingly diverse: some of his works resemble pieces by Johann Christian Bach or Joseph Haydn, the quintet is more in the style of the later chamber music of Schubert. There are many unusual innovations in Graf's scores, but the outcome is always interesting and pleasing to the ear. The Schönbrunn Ensemble (consisting of eight musicians from Great Britain, Germany, and Holland) plays with great virtuosity and musical perfection, and the recording is excellent. Strongly recommended for anyone who can appreciate music not belonging to the "iron repertoire."

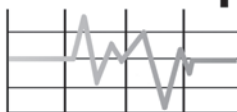
7. F.Mendelssohn-Bartholdy, Paulus (oratorio opus 36). Melanie Diener, soprano, Annette Markert, mezzo-soprano, James Taylor, tenor, Matthias Görne, bass, Choeur de La Chapelle Royale, Collegium Vocale Gent, Orchestre des Champs Elysées, Philippe Herreweghe, conductor. Harmonia Mundi HMC 901584.85 [2 CDs] Live recording, Auditorium Stravinsky, Montreux 1995 [released in 1996].

Although this is a live recording, voices sound natural and the strings are very sweet. Mendelssohn's oratorio (based on the biblical Book of Acts) contains several well-known (Lutheran) hymn melodies. The performances by the four soloists, the double choir, and orchestra are excellent. The album has an informative booklet. Buy this cheap release if you can, you will not be disappointed.

8. Bach after Bach. Famous works of J.S. Bach transcribed by Max Reger for piano 4-hands (Brandenburg Concertos nos. 2 and 6, Orchestral Suite no.3, Toccata and Fugue in d). Wyneke Jordans and Leo van Doeselaar, fortepiano. Challenge Classics CC 72070 [Recorded and released in 1998, producer: Marcel Schopman, engineer: Jörn Mineur].

To most modern listeners, transcriptions of Bach's music in a late Romantic style are anathema. But any doubts you may have are dispelled after the first few notes. Wyneke Jordans and Leo van Doeselaar (a married couple) play with such joy and vitality that you *must* listen to the music. The sound of the Bechstein piano is very well recorded. A truly remarkable production. ■

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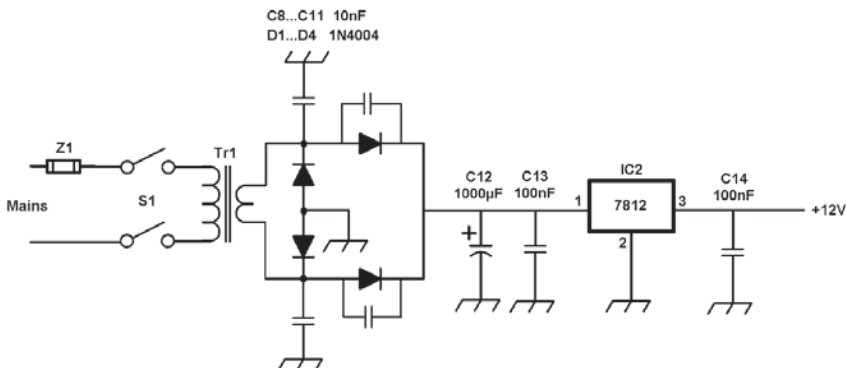


FIGURE 4: Power supply (one channel).

and the wiring scheme of **Photo 1**, there is no instability. Each channel of the prototype has its own power supply (**Fig. 4**). The transformer is shared between the channels, but because it has two independent secondaries, the PSU is a dual-mono construction. The supply is very simple and based on L7812CV voltage regulators⁴.

For listening, I mainly used a Grado SR125 (32Ω), occasionally also using a Sennheiser HD465 (60Ω). A Sony Discman and a Marantz CD80 player were the digital audio sources. It turned out that the claims of G4OEP are absolutely correct. The amp is very

quiet. There is no audible hum and noise during operation. Take care with the orientation of the power transformer: a 90° rotation can make the difference between slight hum and no hum at all.

Switching transients during power-on or power-off are minor. It sounds both sweet and precise. Differences in recording quality or in the acoustics of different recording venues are immediately evident. Percussion instruments and sudden transients are well-reproduced, indicating good control of the headphone by the amplifier. Sibilants are not artificially emphasized,

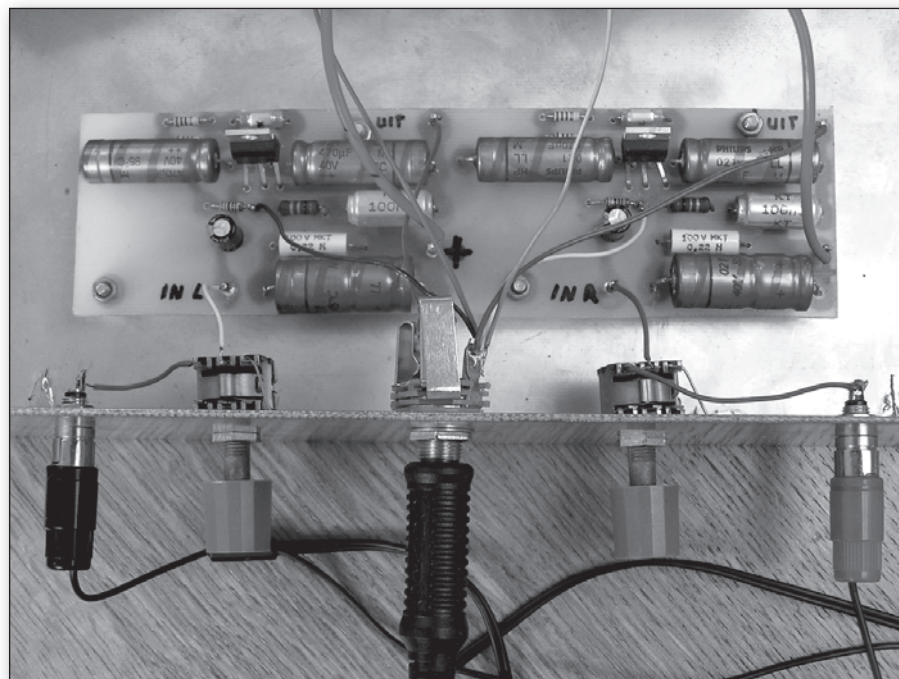


PHOTO 1: Prototype of amplifier built on a "chassis" made of double-sided PCB material. All signal earth and PSU ground wires run to the headphone jack which serves as a star ground.

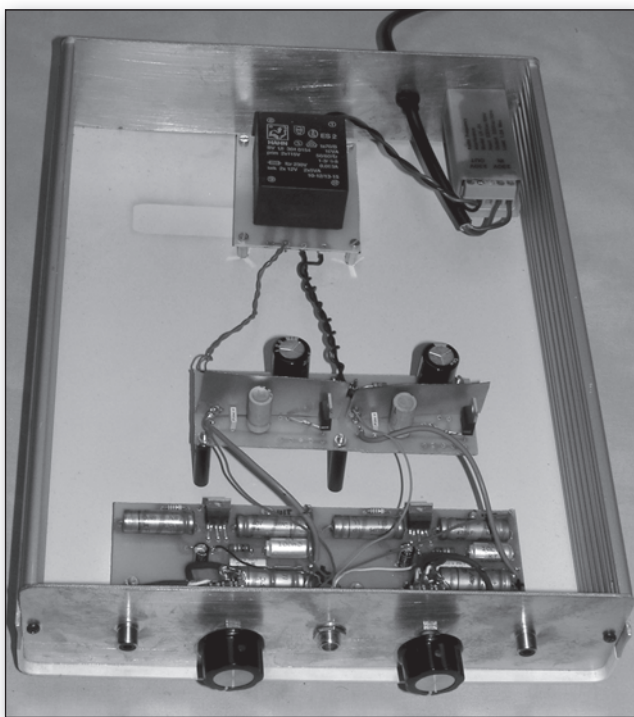


PHOTO 2: Amplifier built into metal cabinet.

and voices sound very natural when the recording is good (unfortunately, many recordings are rather poor in this respect). In conclusion: I love it and

POST SCRIPT

Since the writing of this article, I have placed the headphone amp with power supply in a spacious metal cab-

will soon place it in a nice-looking cabinet!

This novel design is known as "The G4OEP Headphone Amplifier" after its inventor, but also as "Il Semplice." This Italian expression means "the simple one." I can't think of a headphone amplifier simpler than this! Semplice is also a musical term, meaning "simple, unaffected, without embellishments." The musical presentation of the G4OEP headphone amplifier is like that: very clean and without any evident flaw.

inet which was originally intended to house a computer modem (Photo 2). I added a mains filter to the 230V AC power supply line. Screening of the amplifier by the metal cabinet and the addition of the filter resulted in a small improvement of the sound. *ax*

REFERENCES

1. Dr. Andrew Smith, "High Performance Headphone Amplifier," *SPRAT* 127:27-28, 2006.
2. SGS-Thomson, TDA2003: 10W Car Radio Audio Amplifier. You can download the datasheet from: <http://eu.st.com/stonline/books/pdf/docs/1449.pdf>.
3. Dieter Burmester is the owner and chief engineer of the company Burmester Audiosysteme, a German manufacturer of high-end audio equipment, based in Berlin (www.burmester.de). Many of his preamp designs use op-amp circuits.
4. SGS-Thomson, L7800 Series Positive Voltage Regulators. You can download the datasheet from: <http://eu.st.com/stonline/books/pdf/docs/2143.pdf>.
5. G4OEP website: <http://g4oep.atSPACE.com>, see especially the page: <http://g4oep.atSPACE.com/headamp/headamp.htm>.

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