CLASSIC ARTICLES PAGE

The article(s) listed below fall into the category of materials which have enjoyed continued interest over the years since their original publication. This list has recently been restored/updated (as of March 2015).

- **1977:** As a preface to the 1977 *The Audio Amateur* series 'Slewing Induced Distortion in Audio Amplifiers', Walt authored a guest editorial for issue 1/1977, pp. 3, titled 'The Impossible Void'. This was a hopeful expression towards bridging the gap between measurements and listening tests, with SID/TIM measurements as a case in point. Looking back after 38 years of time, there may be some question if this void has been narrowed.

  SID/TIM Guest Editorial

- **1977:** The 1977 *The Audio Amateur* series 'Slewing Induced Distortion in Audio Amplifiers', was co-authored in part with Mark L. Stephens and Craig C. Todd. This long series featured five parts in the four 1977 issues of the magazine, and goes into great detail on measurements and testing of IC op amps for distortion characteristics. It was later to give rise to two major spin offs, described just below. Although many of the ICs discussed have since disappeared, the basics are just as true today as they were back in the 70s.

  Slewing Induced Distortion – TAA 1977 – Part 1

  Slewing Induced Distortion – TAA 1977 – Part 2a

  Slewing Induced Distortion – TAA 1977 – Part 2b

  Slewing Induced Distortion – TAA 1977 – Part 3

  Slewing Induced Distortion – TAA 1977 – Part 4

- **1977:** The paper 'Slewing Induced Distortion and Its Effect on Audio Amplifier Performance — With Correlated Measurement/Listening Results' was co-authored along with Mark L. Stephens and Craig C. Todd. It was presented at the May 1977 AES convention, and published as AES preprint 1252.

  Slewing Induced Distortion – AES Preprint #1252

- **1979:** The 'An Overview of SID and TIM' article series was co-authored with Mark L. Stephens and Craig C. Todd. It appeared in *Audio* in three parts, in June – August of 1979. This series of articles had prior roots in the above 1977 AES presentation as well as the earlier 1977 series within The Audio Amateur.

  Overview of SID and TIM Part 1

  Overview of SID and TIM Part 2

  Overview of SID and TIM Part 3

There is an ironic footnote here. Although the 1977 AES paper was rejected for inclusion in the Journal, yours truly received an AES fellowship, in November of 1979. It was cited as:

> "for his publications on the subjects of audio applications of integrated circuit operational amplifiers and the analysis of distortion".

Walt Jung AES Fellowship

1980: 'Picking Capacitors, Part 1', was co-authored with Dick Marsh, and was published in *Audio*, in February of 1980. This two part article examined a number of capacitor types for performance characteristics relevant within audio applications. 'Picking Capacitors, Part 2', was also co-authored with Dick Marsh, and it was published in *Audio*, in March of 1980.

Picking Capacitors, Part 1

Picking Capacitors, Part 2

1985: 'A Real-Time Signal Test for Capacitor Quality', authored by John Curl and Walt Jung, was published in *The Audio Amateur*, in issue 4 of 1985. This article illustrated a simple differential comparison test between a sample capacitor and a like-value high quality reference capacitor.

A Real-Time Signal Test for Capacitor Quality

In response to numerous requests from readers over the last few years, the following archive set describes various design approaches to audio line driver stages. While some of the articles have been stand-alone pieces, others have been in the context of a larger work, such as the Analog Devices seminar notes of 1992, 1993 and 2002.

This archival set is a series of individual articles, each focused on using op amps optimally as audio line driver stages. This article series is evolutionary, beginning with the first from 1992 and progressing with the most recent entries, from 2002. The basic topology used is a combination of two op amps, each optimized for either the input or output stage function. Thus, it can be referred to as a composite amplifier, since the two amplifier combination serves functionally as a single driver amplifier. The intent of this combination is to employ the best of their individual specs, to form a unique resultant. In this case, the target goal is a low distortion audio line driver, with ample output power to drive either long lines or headphones, for example. At the input side, a low distortion FET input device is typically used, to offer minimal loading to the source (and thus lowest distortion).

*The articles and their original publication are briefly summarized below, as references **1)** through **8)** .*

1) Walt Jung, 'A High Performance Audio Composite Line Driver Stage', from "Applications for Amplifiers in Audio," Ch. 5 within Walt Kester, Editor, *1992 Amplifier Applications Guide*, Analog Devices, Inc., Norwood, MA, 1992, ISBN 0-916550-10-9, pp. 18 – 22.

A High Performance Audio Composite Line Driver Stage

Note: Although not cited as an author here, it should be noted that AD744 op amp designer Scott Wurcer provided the original inspiration for the two amplifier concept in use, which employed the AD744 and the AD811 as a composite driver.

2) Walt Jung, 'High Performance Audio Stages Using Transimpedance Amplifiers', within Gary Galo, "POOGE-5: Rite of Passage for the DAC960," *The Audio Amateur*, issue 2, 1992, pp. 15-18. This article appeared as a sidebar to Gary Galo's modification piece on the Philips DAC-960. It illustrated the basic composite line driver using the AD744 and the AD811 op amps. It also had some measurement discussions on DAC output levels, and showed a method of using a transimpedance (current feedback) type amplifier as an integrator in a DAC I/V stage.

High Performance Audio Stages Using Transimpedance Amplifiers

3) Walt Jung, Adolfo Garcia, "Op Amps in Line-Driver and Receiver Circuits, Part 2," *Analog Dialogue*, 27-1, 1993, pp. 14 – 17.

Op Amps in Line-Driver and Receiver Circuits, Pt 2

This article expanded upon the basic two amplifier concept, showed alternate line drivers, and discussed topics related to high performance line drivers.

4) Walt Jung, 'Audio Line Drivers', from "Audio Applications," Ch. 8 within Walt Kester, Editor, *1993 System Applications Guide*, Analog Devices, Inc., Norwood, MA, 1992, ISBN 0-916550-10-9, pp. 8-63 – 8-100.

Audio Line Drivers

This work expanded substantially on numbers 1 and 3 above. Also discussed are housekeeping details such as driving capacitive loads and bypassing. A special note here for page 8-64—the non-inductive bypasses should be film, not ceramic capacitor types, i.e., polyester or PPS would be examples. Other application examples are both single-ended and differential drivers, as well as transformer drivers with and without feedback. A useful measurement technique shown includes a non-inverting test to examine input stage non-linearity with regard to amplifier sensitivity to source impedance.

5) Walt Jung, "Composite Line Driver with Low Distortion", *Electronic Design Analog Special Issue*, June 24, 1996, pp. 78-80.

Composite Line Driver with Low Distortion

This article is a focused application of the two-amplifier line driver concept, suitable for headphone use or very high current line driving. It added impedance compensation to the input stage op amp for lowest distortion for a given source impedance. Interestingly, it also showed how thermal distortion can be generated by high current outputs, a phenomenon that is intrinsically addressed by use of the composite connection.

6) Walt Jung, "Walt's Tools & Tips: 'Op Amp Audio – Minimizing Input Errors (Part 4)'", *Electronic Design*, December 14, 1998, pp. 80-82.

Op Amp Audio – Minimizing Input Errors

This article, the final installment of Walt's Tools and Tips in Electronic Design (also the fourth in the Op Amp Audio series), showed a complete composite amplifier optimized for audio use. It employs the basic two-stage amplifier, but with stage one
modified to operate with lower open loop bandwidth via the use local feedback.

7) Walt Jung, 'Audio Buffers and Line Drivers', from section 6-1, "Audio Amplifiers"', within Walt Jung, Editor, *Op Amp Applications*, Analog Devices, Inc. 2002, ISBN 0-916550-26-5, pp. 6-48 – 6-78.

Audio Buffers and Line Drivers

This, the most recent work on this topic, expanded considerably on numbers 1, 3, and 4 above. Again discussed are housekeeping details such as driving capacitive loads and bypassing. Application examples are both single-ended and differential drivers, as well as new distortion canceling transformer drivers using feedback. The measurement technique using a non-inverting test to examine input stage non-linearity with regard to amplifier sensitivity to source impedance is expanded/updated with the performance of current devices.

8) The link following is the entire (210 page) chapter from *Op Amp Applications*, which contains this work. It is also recommended as a broad resource on amplifier techniques.

Chapter 6 from *Op Amp Applications*