Analog Book Reviews

New Op Amp Books For The Designer.

As far as standard ICs are concerned, op amps are probably the most universally used active part. Capable of far more than ever imagined back in the 60's when they first appeared, IC op amps are now used for a very wide array of tasks. Op amp books abound on my shelf, about 40 such titles in fact, and that's just for books dedicated *solely* to op amps. While the ones I use most often number ten or less, nevertheless good new analog books are always welcome. Which brings us to a case in point with this column's subject.

One of the more prolific writers of op amp books and applications that use them is Jerry Graeme. Graeme was an expert designer with Burr-Brown for many years, and is now a Principal Engineer with Gain Technology Corp. of Tucson, Ariz. Of course, he's no stranger to *Electronic Design* readers, having written numerous design articles in the past few years. Among the first op amp books I ever bought was *Operational Amplifiers: Design and Applications*, by Gene Tobey, Jerry Graeme, and Lawrence Huelsman, published by McGraw-Hill back in 1971. Since then, Graeme has published a number of other op amp books. The most recent include a book on photodiode applications using op amps, and a just-published one on optimizing op amp performance. This column focuses on these two books as analog design aids.

Photodiode Amplifiers: Op Amp Solutions, McGraw-Hill, 1996, ISBN 0-07-024247-X, is a 6-in. by 9-in. hardback book with a price of $49. Contact the publisher at (800) 2-MCGRAW or *http://www.mcgraw-hill.com*

Co-published with the author's company, Gain Technology Corp., the book features 272 pages and 105 illustrations within 10 chapters, plus a glossary and index.

This book should be a valuable aid to anyone using photodiode transducer circuitry for the wealth of information it contains. In the 10 chapters, Graeme starts from photodiode basics, and goes through amplifier-related considerations for noise, stability, bandwidth, gain, power supply effects, external noise effects, and such specialized applications as position-sensing photodiodes.

While the basic topology of a photodiode amplifier is one of an I/V converter with a photodiode as a current source transducer, extracting maximum performance from this setup is far from trivial. Various factors impact performance in terms of noise, bandwidth, and sensitivity, turning what appears from the surface as a somewhat straightforward circuit into a design challenge. Both the amplifier selection as well as the surrounding environment of the I/V stage often can have a major impact on performance— detrimentally!


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Graeme explores thoroughly this amplifier topology from general standpoints, and shows various modifications to enhance certain performance aspects, such as high gain operation, revisiting topics he has covered in past *Electronic Design* pages. For example, by exploiting the "Tee" feedback network[1] to eliminate the usual $10^9\ \Omega$ feedback resistor needed for 1-V/nA sensitivity, high I/V stage gain now can be realized with more normal component values.

This step avoids susceptibility to contamination and leakage paths such as with the $10^9\ \Omega$ resistor. Among other such enhancements addressed are bootstrapping the photodiode for greater bandwidth, dark current compensation, and multiple amplifier configurations.

While the general treatment of this book toward the applications is excellent, it could use some detail in terms of typical op amp part numbers. It turns out that an optimum amplifier for wide dynamic range, high bandwidth photodiode I/V applications is a somewhat rare animal within the op amp universe. Generally speaking, it will be a low voltage noise, low input current, low input capacitance, wideband FET input op amp. This is not something you find just lying around in your junkbox, and you'll typically pay a premium for such performance.

All in all however, this is a book that can easily be recommended. It will serve the photodiode amplifier designer quite well, and also will serve as a single reference source for the occasional user of these configurations.

Optimizing Op Amp Performance McGraw-Hill, 1997, ISBN 0-07-024522-3, is a 6-in. by 9-in. hardback, priced at $55. Also co-published with Gain Technology Corporation, this brand new book includes 300 pages and 150 illustrations within six chapters, plus a glossary and index.

While photodiode applications tend to be a bit specialized, general op amp feedback considerations certainly aren't—in fact, they are universal to all feedback circuits. And that is one of the major strengths of this book, the new insights it opens into more sophisticated feedback setups and their analysis. The first two chapters deal with feedback and its analysis, with titles of: "Performance Analysis, Feedback, and Stability," and "Feedback Modeling and Analysis." The first of these is more of a refresher, but nevertheless, it makes some excellent points. These include such things as general stability requirements related to the Bode diagram open/closed loop rate-of-closure, and the surrounding circuit and op amp parasitic effects on stability.

The second chapter is one of the book's major highlights, as it develops new feedback analysis approaches to extend the classic non-inverting feedback model to more general uses including inverting and differential cases. For example, it is a very interesting treatment to see how Graeme develops $\beta+$ and $\beta-$ models into a net β, for use in the feedback calculations. The chapter includes examples of composite amplifiers and other complex feedback structures to illustrate the analysis points. To me, this chapter alone is worth the admission price. Readers should find it helpful when seeking maximum performance from op amps that use the classic voltage feedback architecture.

Chapter 3, "Power-Supply Bypass," details design methods for optimizing the power supply system of an op amp to minimize spurious resonances and noise components. This chapter draws upon the themes of a couple of recent Graeme-Baker articles from *Electronic Design,* [2,3] illustrating graphically how noise components in the supply system interact with the amplifier's response, how resonances can occur in bypasses, steps to take for damping, etc. While this coverage is generally excellent, it would be even better with the use of actual part number examples, for instance as were used in previous articles.[2,3]

Chapter 4, "Phase Compensation," shows how to counteract destabilizing loads as well as other parasitic effects around amplifier configurations. Chapter 5, "Reducing Radiated Interference," shows methods of reducing electrostatic coupling by means of impedance control and balance, and controlling magnetic interference by shielding, minimizing loop area, along with effective common mode rejection.

Chapter 6, "Distortion and Its Measurement," is one of the more interesting, yet puzzling, chapters of the book. Quantifying op-amp distortion is one of the more important measurement tasks facing a designer today, and toward this goal, sound measurement and analysis techniques are really invaluable. In this chapter, a number of useful op amp measurement hookups are suggested toward separating and scaling op amp input and output signals, thus leading to isolation of the op amp's distortion component(s), while minimizing sensitivity to the analyzer's limits.

Unfortunately, one of this section's weak points is that there are no complete in-context measurement examples to flesh out the concepts. So, one simply cannot judge whether a given approach will allow measurements of –80 dB or –100 dB. Or, better yet, how op amp topologies differ in their distortion.

Pre-process filter instrumentation such as described in another article[4] can enhance FFT dynamic range to well above 100 dB, allowing harmonics to be captured at –130 to –140 dB levels. Standard bench instrumentation such as the Audio Precision System 1 analyzer[5], allows both digital and analog domain signal tests. This instrument has a 20Hz-20kHz THD+N system spec limit of 0.0015% + 3µV for a 22Hz-80kHz measurement bandwidth (note: 0.0015% is equivalent to –96.5 dB). This can be extended with pre-processing, as noted above. Combining the power of this instrumentation and the Chapter 6 techniques can result in some powerful distortion analysis tools.

Despite some relatively minor caveats, I would recommend this book to anyone using op amps. The book's strengths are certainly the treatment of advanced feedback analysis, but there are plenty of other useful concepts for the designer within the covers.

TIP: Your analog design tool kit can be usefully enhanced by both of these books. Enjoy!

References:

1. Jerald Graeme, "The Tee-Feedback Factor in Photodiode Amplifiers," *Electronic Design Analog Special Issue*, June 26, 1995.
2. Jerald Graeme, Bonnie Baker, "Design Equations Help Optimize Supply Bypassing for Op Amps," *Electronic Design Analog Special Issue, June 24, 1996.*
3. Jerald Graeme, Bonnie Baker, "Fast Op Amps Demand More Than a Single-Capacitor Bypass," *Electronic Design Analog Special Issue, Nov. 18, 1996.*
4. Tom Mintner, "Pre-Process Audio With Notch Filter to Improve FFT Dynamic Range," *Electronic Design Analog Special Issue, Nov. 18, 1996.*
5. Audio Precision System One, Audio Precision, P.O. Box 2209, Beaverton, OR, 97075-3070; (800) 231-7350.
6. Distortion measurement techniques and results are discussed in Chapter 2 of Walter G. Jung, *Audio IC Op Amp Applications, 3d Ed.* Sams, 1987.

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