Analog Designers

Save Design Time and Improve Design Quality

Discover What's Been Missing!

Learn how to get more useful answers
with less work in

MIDDLEBROOK'S

STRUCTURED ANALOG DESIGN

COURSE

Presented in the USA and internationally,
both publicly and in-house

Question most often asked:

My boss thinks I should have learned this in college. How can I convince him that the knowledge gained at this course will save the company money on design time because I will be more efficient?

Answer:

You did learn the material in college, but how to use it in design probably received little or no attention. This course emphasizes just that: how to get maximum benefit from what you know already, and increase your design productivity.

Show your boss the comments from previous attendees.

Check our Web Page **http://www.ardem.com** for Course dates and locations, or talk to **Val** at:

Ardem Associates, 210 Calle Solana, San Dimas, CA 91773
Tel: (909) 592-0317 Fax: (909) 592-0698 e-mail: val@ardem.com

Who will benefit from this course?

Are you a manager/supervisor of analog designers who has to accept technical reports at face value because the results are expressed in equations that don't tell you anything?

In this course you can find out about Low-Entropy Expressions, so you can encourage your engineers to present their results in forms that expose not only the nature of the result, but the relative importance of the contributions from the various components. Then, you can provide useful guidance to increase the productivity of your engineers.

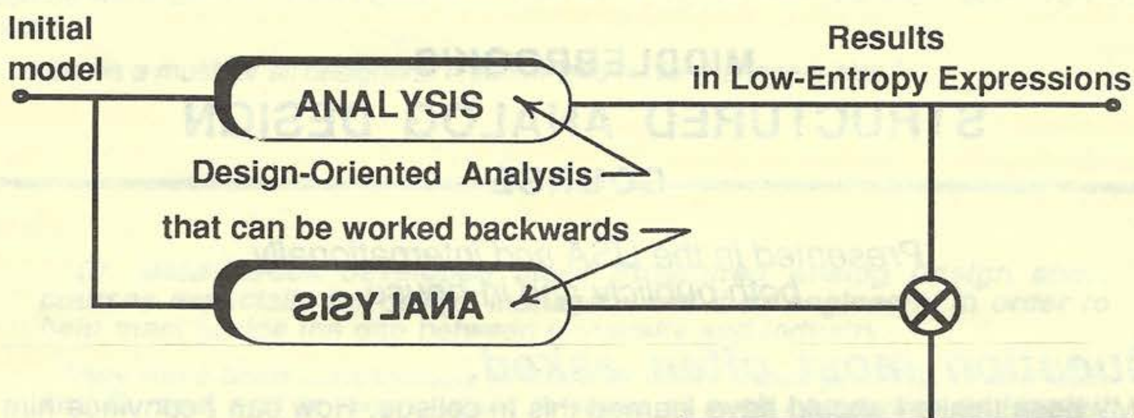
Are you an analog designer who thinks most of what you were taught in college hasn't been much use on the job?

This course shows you how those half-forgotten theorems and principles can really be put to good use.

Are you an analog circuit designer who has all but abandoned analysis because the algebra always seems to get out of hand?

In this course you can learn how to make the algebra work **for you** ***instead of against you, by applying Methods of Design-Oriented Analysis to get more quantitative answers with less work.***

The Design Feedback Loop:



What are Low-Entropy Expressions and Design-Oriented Analysis?

Design is the reverse of analysis: one starts with the Answer (the Specification), and one has to work back to the beginning (circuit configuration and element values). Therefore, only analysis that <u>can</u> be worked backwards is worth doing. This is Design-Oriented Analysis.

Design-Oriented Analysis is the process of guiding and controlling the algebra so that the result is a ***Low-Entropy Expression***, defined as one in which the terms are ordered, or grouped, so that additional insight is obtained into the relative importance of the various contributions to the result. This is the source of the additional information needed for design, and substitutes for the missing equations that would be needed to solve formally for the number of unknowns.

What Part 1 is about:

Analog circuits are often considered difficult, time-consuming and costly to design to specifications, because they are ill-defined in the sense that there are never nearly enough equations to solve for the number of unknowns.

Still, as engineers, we have to solve the problem anyway.

In this course you will learn about Dr. Middlebrook's positive approach: how to solve "real-life" design problems by keeping the algebra under control.

Instead of simultaneous solution of multiple loop or node equations, which automatically leads to a useless High-Entropy result, a Low-Entropy result is obtained by *sequential, simple, circuit reduction steps*: "Divide and Conquer."

In-class exercises demonstrate many specific useful techniques:

Low-Entropy Algebra
How to get more useful quantitative answers with less work (the best kind of algebra is no algebra at all).

The Quadratic Equation
How to overcome the two basic defects of the conventional formula, and get a Low-Entropy formula that gives both roots with equal numerical accuracy (very simple useful results that hardly anyone knows).

Inverted poles and zeros
Take advantage of the horizontal symmetry of dB vs log frequency asymptote sketches.

The Input/Output Impedance theorem
How to find input and output impedances (even in feedback systems) with only a line or two of algebra, if you already know the gain.

The Extra Element Theorem (EET)
If you've done all the work to find the gain of a system, and then you decide to add another element to the model, a line or two of algebra lets you find the new gain from the old gain without having to start from scratch with the new model.

The Feedback Theorem
A lower-entropy version of the conventional formula for a single-loop feedback system lets you express the closed-loop gain merely in terms of the specification and the loop gain; the open-loop (forward) gain, which isn't needed in the answer, and is often hard to calculate anyway, is eliminated.

How much Phase Margin is necessary?
Wrong question. The right question is: What's the relation between phase margin and system performance?

Loop Gain by Closed-Loop Signal Injection
Loop gain measurement by applying a test signal to a broken loop can be tedious and inaccurate if the dc operating point has constantly to be monitored and restored. Instead, injection of a test signal into a loop that remains closed permits totally painless measurements.

The **Course Notes** fully document the course contents, and are a valuable reference for later follow-up study.

What Part 2 is about:

Part 2 is built around a review of the Design-Oriented Analysis techniques of Part 1, plus additional new material, conducted in more of a workshop environment.

More time is spent on in-class solutions to exercises, leading into a broader discussion of how to apply the concepts of Design-Oriented Analysis in terms of Low-Entropy Expressions to more complex, more realistic problems.

This is the crucial step in bridging the gap between "academic" analysis methods and "real-life" design problems that are more complicated by at least an order of magnitude, the hurdle over which many design engineers trip.

Specific Additional topics include:

The quadratic equation revisited:
Improved Low-Entropy expressions when real roots are close together.

The Two Extra Element Theorem (2EET):
Efficient ways of calculating properties of circuits with two reactances, which have quadratic responses. Is it possible to get complex roots (having peaked response)?

Low (High) frequency response of a transistor amplifier
Take into account the coupling/bypass (collector/emitter) capacitances using the Low-Entropy 2EET formulas. Can the low (high) frequency response be peaked?

General relation between phase margin and closed-loop gain
If all you know about the loop gain is the phase margin, how can you tell if the closed-loop response has a peak?

Phase Margin and Transient Response
Transient response is an accurate indicator of phase margin, right? Maybe -- depends on which transient reponse: input-to-output, or load-to-output.

The Extended Feedback Theorem
How to account for direct forward transmission through the feedback path (ignored in the conventional formula). Main use: how to check that this effect is negligible.

Real-Life Examples, 1
An active low-pass filter: (a) How do you design the feedback network to satisfy the gain specification? (b) How do you design the loop gain (and the crossover frequency and phase margin) to achieve this specification within the required tolerance?

Real-Life Examples, 2
A complicated three-stage video-bandwidth feedback amplifier. How to get simple, Design-Oriented, Low-Entropy expressions for the loop gain and the closed-loop gain; how to account in a simple way for the low-frequency loop-gain response due to 13 coupling, bypass, and decoupling capacitors.

What will I learn that will make me more productive in my work?

This question and more are best answered by Managers and Design Engineers who have already taken the course:

Analog Circuit Design Engineers learn new and useful tools:

"This has been a great course. I now can go back and tackle problems I have left unsolved, or have misunderstood, because of 'the algebra'."

"The material will be very helpful. I had given up on using equations for complex circuits, and this will allow me to do a better job in analysis. The material was presented with simplicity in mind, and was thoroughly explained with very practical examples. "

"I got much more than I expected, especially in the new techniques of circuit design/analysis."

"I wouldn't want to miss any of it. The most unfamiliar part is the Extra Element Theorem: I want to master it, and use it."

"I expect the added ease in applying theory to design will save a substantial amount of time in doing circuiit analysis. I expect the Null Double Injection technique to be particularly useful, and the concept of Low-Entropy equations makes the final analysis easier to interpret."

"Material helped to put together fragmented knowledge previously learned, and [suggested] new approaches to old problems. The techniques and tricks will be added to my bag and will be used in the future."

..applicable to CAD:

"Most information will be very useful -- I periodically spend large chunks of time working through various topologies to attempt to develop a macromodel for an analog part for use in circuit simulation. Literally all of these tools are useful in that process!"

Design Engineers learn how to make better designs faster...

"When I read the Syllabus I was not quite sure if I needed this course because it appears that I had already covered the material at university. [However, the value was] more than I expected. The course material not only is useful, but will reduce the time I spend doing analysis."

"Contains very valuable insights and methods for all circuit analysis. Greatly refines the design process. Extremely clear presentation. Best course I've had."

"The course absolutely meets my expectations. The material will for sure help my design work in the future. I will highly recommend this course to my manager, colleagues, and subordinates."

"[Although] I consider myself a good analog designer with a good analytical background, I found this course to be very much worth my time, and the tools a useful addition to what I currently know."

The course material will be valuable because it will allow me to gain insight into the true causes and effects in my designs. I will share what I've learned with my coworkers who might appreciate these techniques."

"The course gives an added benefit to anyone who has been away from analog design for a while, by presenting analog concepts in a refreshing easy manner which seems to bring all the basic concepts back to mind without much work."

"This was the most useful circuit analysis course I have ever had. The results are very practical and should be readily applicable."

...appreciate and enjoy different viewpoints and approaches:

"I would award this course several 'lightbulbs' because many times a lightbulb would go on in my head as I either understood something new, saw a better way to use something I had known for years, found better and more complete expansions of formulae (like the quadratic) that I had never been entirely pleased with before, or thought of places where I would like to apply these things. (Or perhaps the award should be several 'forehead slaps' for all the times I wished I had known these things before."

"...it has been a very worthwhile three days spent learning, thinking, and reviewing. I guess I'm a convert because I want to tell others about this approach and its benefits (and I normally hate proselyters)."

"The material presented was an insightful look and review of some of the things I 'learned' in college. It presented circuit analysis in a different and more useful light, and the additional knowledge gained from the course will improve my circuit design and analysis."

"This is the best course I've ever taken. The material is fundamental but the viewpoints are all eye-openers. I didn't learn any subject I hadn't known before, but this course took a lot of misconcepts and confusion out of my mind. I wish I'd had this course years ago."

"This course was a real 'eye-opener' for me, especially with regard to the techniques which make an ac analysis intuitive (an understanding I have never had). It will forever change the way I approach ac circuits."

"This course is the best electronics course I have ever taken. I will highly recommend it to my colleagues."

Managers help their engineers to produce better results:

"I'm a systems engineer and, as such, do not directly do design work. However, I believe that this course will allow me to ask better questions of my project team and more effectively critique their work."

"This course is a must for all designers. I recommend it...for managers also."

Dr. Middlebrook developed these Structured Analog Design short courses especially for design managers and their engineers, in order to help them bridge the gap between university and industry.

They have been successfully presented many times publicly, in the USA and Europe, and in recent years in-house at such companies as Hewlett Packard, Litton, Boeing, AT&T, Ericsson, Motorola, Philips, and Chrysler.

Dr. R. David Middlebrook is Professor of Electrical Engineering at Caltech, USA, and a well-known author and lecturer. He is a Fellow of the IEEE, a Fellow of the IEE (UK), and a leading power electronics researcher. Practical, Design-Oriented Circuit Analysis and Measurement Techniques is his primary thrust in educating OEMs, system designers, and students.

He is a recipient of an I·R Award (1980), Excellence in Teaching Award (1982), the IEEE William E. Newell Power Electronics Award (1982) for outstanding achievement in power electronics, and the Edward Longstreth Medal of the Franklin Institute (1991).

Among his outside interests is Formula race car driving.