Analog Devices' Engineering University—Why YOU Should Attend

By Ryan Fletcher and Scott Wayne

Introduction

Throughout its history, Analog Devices has always been committed to education, as exemplified by its highly trained applications engineers, online EngineerZone community, and extensive portfolio of textbooks, circuit notes, and magazine articles. Unfortunately, in this age of "digital everything," many university students feel that digital electronics seem modern and exciting, while analog electronics appear boring and outmoded. Worse yet, many university curriculums have modeled the interests of their students, boosting their offerings in digital technology, while deemphasizing analog design skills.

The world, however, is analog. Light, sound, temperature, pressure, and acceleration are all analog quantities, so analog sensors, signal conditioning, and data converters will always be required. In addition, although broadcast communications are progressively heading into the digital domain, their RF signals require analog receivers, transmitters, and low-noise amplifiers. Furthermore, as energy efficiency and a "green" Earth become increasingly important, analog power-management techniques are needed more than ever.

Rather than fading out, analog technology is flourishing. In fact, more analog circuitry is found in a state-of-the-art high-definition TV than in a traditional analog TV; cardiac monitoring uses precision analog signal processing to detect small signals buried in noise; modern cell phones require analog power-management circuitry to prolong battery life; automobiles use microelectromechanical systems (MEMS) accelerometers and gyroscopes in electronic stabilization systems; and satellite communications use RF transmitters to broadcast digital signals in an analog realm. So, rather than being quaint, analog technology is now needed more than ever.

Recognizing the gap between the curriculums commonly found at universities and the industry's need for engineers trained in analog circuit design techniques, Analog Devices announced its Engineering University Program in March 2012. Aimed at revolutionizing the way engineering students learn analog circuit design, the program provides engineering students and professors with an affordable portable analog design kit that will enhance their educational experience by allowing them to experiment with advanced technologies, building, and testing real-world analog circuits anytime and anywhere.

In addition to engineering students, the Engineering University Program is ideal for practicing engineers who may be well versed in software development or digital technology but find themselves lacking some of the fundamentals of analog circuit design, technicians who want to improve their understanding of analog circuitry, and hobbyists and inventors who look to acquire new design skills.

The comprehensive program includes a textbook, which features exercises, labs, and homework; software for control, simulation, and analysis; and a design kit that enables hands-on learning. An online community facilitates communication between students, professors, and practicing engineers. As of January 2013, Circuits 1, the first semester course, is available. Future courses, including Circuits 2, Electronics 1, and Electronics 2 are in the works.

Textbook

The well-organized textbook includes homework and labs. Each chapter begins with an introduction and a list of objectives. Worked examples and exercises for the reader are interspersed throughout the text, and section summaries reinforce the lessons learned. The first semester course—Real Analog: Circuits 1—comprises 12 chapters (which are also presented as a series of videos and downloadable lecture slides):

1. **Circuit Analysis Fundamentals**
   This chapter introduces fundamental concepts of voltage, current, and power; basic circuit components including ideal sources and resistors; and analysis techniques such as Kirchhoff's voltage law, Kirchhoff's current law, and Ohm's law. The labs provide the first hint of real-world behavior: resistance varies around the ideal value of a resistor—and the first real-world application of analog circuitry: using a thermistor to measure temperature.

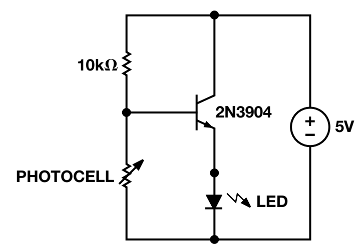


Figure 1. Chapter 1 lab: dawn-to-dusk lighting circuit.

2. **Circuit Reduction**
   This chapter employs the techniques presented in Chapter 1 to analyze series and parallel combinations of resistors and their use as voltage and current dividers. Nonideal sources and nonideal measurement devices provide further examples of real-world behavior.

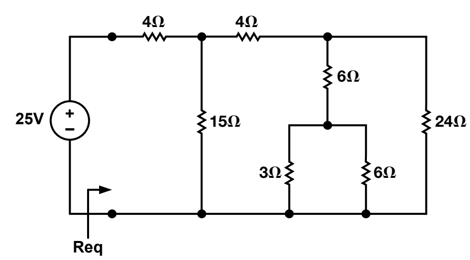


Figure 2. Chapter 2 homework: find the equivalent resistance, Req, and the current provided by the source.

3. **Nodal and Mesh Analysis**
   This chapter introduces the idea of circuit nodes and meshes—including reference nodes, dependent nodes, super nodes, and constrained meshes—offering an easy way to analyze circuit voltages and currents.

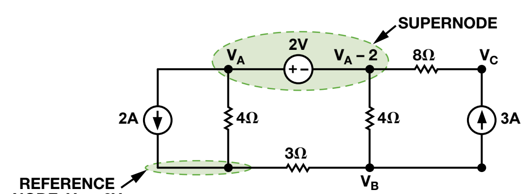


Figure 3. Worked example from Chapter 3 shows reference and super nodes.

4. Systems and Network Theorems

This chapter presents a system-level approach to circuit analysis, representing a conceptual circuit as a real system with inputs and outputs. It defines the mathematical concept of linearity, explains how to use superposition to analyze linear systems, and introduces the powerful Thévenin and Norton theorems that allow complex circuits to be modeled as simpler equivalent circuits. The lab demonstrates how power is transferred from a source to a load and how to match the load to maximize the power transfer.

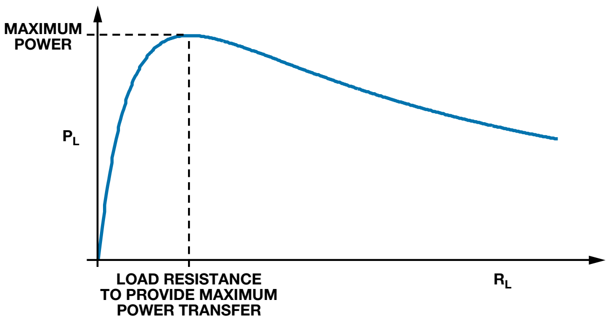


Figure 4. Plot from Chapter 4 shows load power versus load resistance.

5. Operational Amplifiers

This chapter introduces operational amplifiers (op amps), so named because they perform mathematical operations such as addition, integration, and exponentiation. Starting with ideal behavior, which allows easy analysis of inverting, noninverting, and differential circuits, it also explains the effects of real-world behavior, including finite gain, finite input impedance, nonzero output impedance, and nonzero offset voltage. The labs use op amps to improve the temperature measurement system.

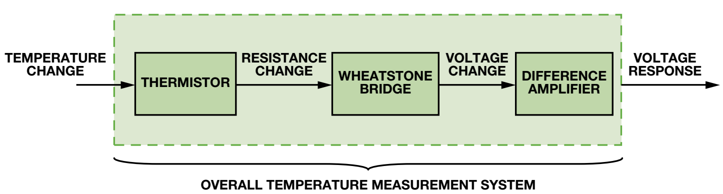


Figure 5. Block diagram from Chapter 5 lab: temperature measurement system design.

6. Energy Storage Elements

This chapter introduces capacitors and inductors, their role as energy storage elements, and their real-world behavior. While all circuits presented in earlier chapters could be analyzed using algebraic equations, these dynamic circuit elements are governed by differential equations. The text defines transient and steady-state responses, and mathematical concepts such as unit-step and decaying exponential functions. The labs generate and observe time-varying waveforms.

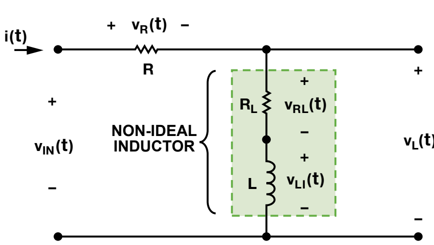


Figure 6. Circuit from Chapter 6 shows nonideal model of an inductor.

7. First-Order Circuits

This chapter features first-order circuits—those that include a single independent energy storage element and are characterized by first-order differential equations. It analyzes the natural response of circuits containing resistors and a single capacitor or inductor, as well as their response to a step change of the input voltage or current. The labs demonstrate how to measure the time constant and step response of active RC circuits.

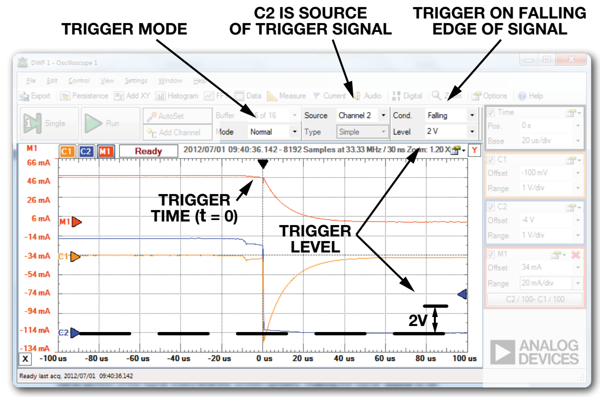


Figure 7. Control panel from Chapter 7 demonstrates trigger time and level.

8. Second-Order Circuits

This chapter expands upon the concepts presented in the previous chapter to analyze second-order circuits— those that include two independent energy storage elements and are characterized by second-order differential equations. While the step response of first-order circuits decays exponentially with time, that of second-order circuits can oscillate, so this chapter introduces the concepts of natural frequency and damping ratio, and relates them to the circuit's rise time, overshoot, and steady-state response. The labs measure the step response of an RLC circuit and analyze why real behavior differs from the ideal calculations.

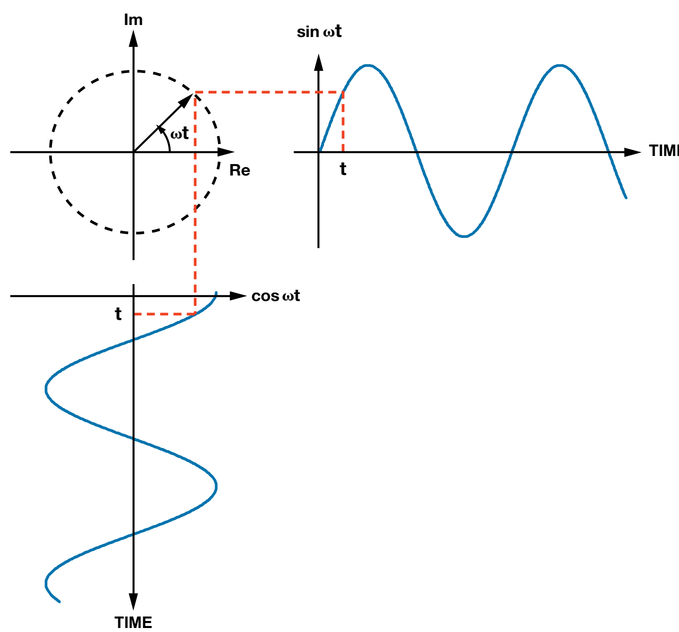


Figure 8. Illustration from Chapter 8 shows relationship between sin ωt, cos ωt, and $e^{j\omega t}$.

9. Introduction to State-Variable Models

This chapter introduces state-variable modeling, which establishes the state of the system using the voltages across the capacitors and the currents through the inductors. The state completely characterizes the system at each instant of time, so knowing the state at any time and the system inputs at all subsequent times allows the output to be determined at any subsequent time. The chapter shows how state-variable modeling enables numerical simulations to determine the system response. The labs in this chapter compare measured results with MATLAB® or Octave simulations.

$$\begin{bmatrix} \dot{x}_1(t) \\ \dot{x}_2(t) \\ \dot{x}_3(t) \end{bmatrix} = \begin{bmatrix} 0 & 0 & -1/L_1 \\ 0 & -R/L_2 & 1/L_2 \\ 1/C & -1/C & 0 \end{bmatrix} \begin{bmatrix} x_1(t) \\ x_2(t) \\ x_3(t) \end{bmatrix} + \begin{bmatrix} 1/L_1 \\ 0 \\ 0 \end{bmatrix} u(t)$$

Figure 9. Matrix algebra from Chapter 9 demonstrates state-variable analysis of third-order circuit.

10. Steady-State Sinusoidal Analysis

This chapter focuses on the steady-state behavior of dynamic systems with sinusoidal inputs, ignoring the system's transient response. It shows how sinusoidal signals can be represented in complex exponential and phasor forms, defines impedance and admittance, and explains how the system's frequency response expresses the relationship between input and output signals. The labs measure the gain and phase of amplifier circuits.

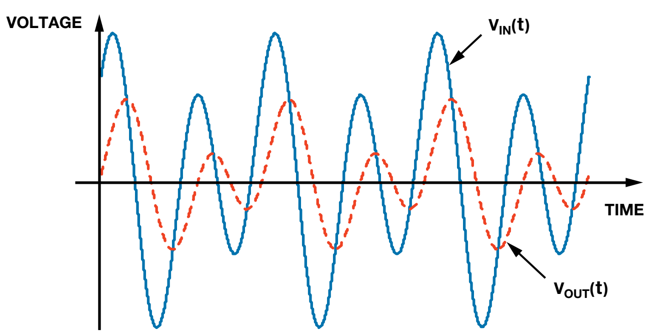


Figure 10. Plot from Chapter 10 shows system response to two-tone input signal.

11. Frequency Response and Filtering

This chapter describes how a system's frequency response can be used as a design and analysis tool and how signals can be represented in terms of their frequency content. It introduces the concepts of signal conditioning, focusing on low-pass and high-pass filters, and shows how Bode plots can illustrate a system's amplitude and phase behavior. The labs include conditioning the output of a MEMS microphone in an audio application and the output of a vibration sensor to measure mechanical stress.

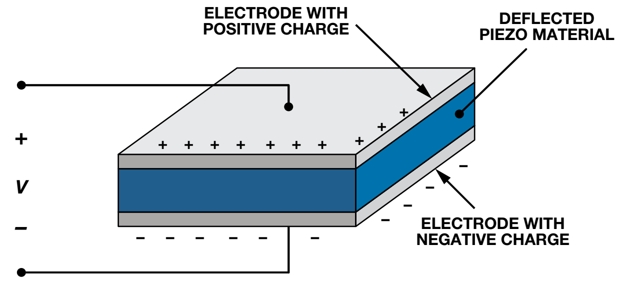


Figure 11. Vibration sensor from Chapter 11 lab project.

12. Steady-State Sinusoidal Power

This chapter covers power transmission using sinusoidal signals and introduces concepts of instantaneous, average, and reactive power. It then shows how to correct the power factor from an inductive load.

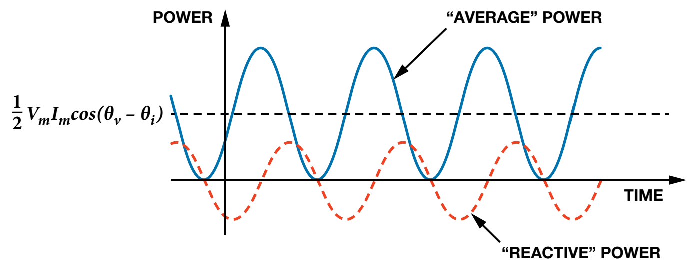


Figure 12. Plot from Chapter 12 shows components of instantaneous power.

Hardware

In addition to theory, the textbook provides practical circuits, discusses nonideal operation, and provides hands-on experience through its lab exercises, but the real fun comes from the design kits. The Analog Discovery™ design kit provides a 2-channel oscilloscope, a 2-channel arbitrary waveform generator, a 16-channel logic analyzer, a 16-channel pattern generator, a 2-channel voltmeter, a network analyzer, and two power supplies, making it a complete, portable, USB-powered analog design lab that enables students to experiment whenever and wherever they have an idea.

Figure 13. Analog Discovery design kit.

The design kit is paired with the Analog Parts Kit, which includes resistors, capacitors, diodes, transistors, sensors, op amps, convertors, regulators, and more—plus, a solderless breadboard, screwdriver, and assorted lead wires.

Figure 14. Analog parts kit.

The design kit uses WaveForms™, a powerful suite of virtual instruments that provides a clean, easy-to-use graphical interface for each instrument, making it simple to acquire, store, analyze, produce, and reuse analog and digital signals.

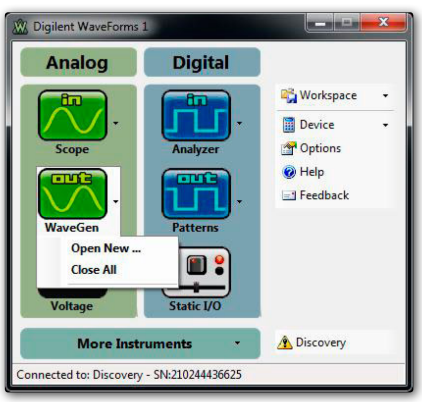


Figure 15. Waveforms software.

A Student's Perspective

For a student project, I am currently prototyping a device to automatically evaporate condensation from bathroom mirrors. In the process, I have used components of the Analog Devices' Engineering University Program, including the Analog Discovery design kit, WaveForms software, analog parts kit, and online textbook. The vast resources of the program have been invaluable for my project, and other engineering students will surely be thrilled to have it available at their fingertips. Interested students can easily access, transport, and review the program's free online materials in any location. The Analog Discovery hardware design platform allows students to bring the functionality of a traditional lab anywhere. In my case, this versatility triggered an interest in analog circuitry, while encouraging innovation and spur-of-the-moment circuit creation. With these powerful resources at hand, students will be able to explore their deepest curiosities while supplementing the facts learned in their classes.

The online course materials provide some of the program's most intriguing resources. Topics presented in the Real Analog textbook are taught from the perspective of electrical engineers in the workplace, providing excellent insight into subjects traditionally written about by academic writers. Clearly articulated video lectures and PowerPoint slides supplement the written material; and the step-by-step laboratory work develops essential hands-on skills using real-world applications. Freely available online, ADI's Engineering University coursework is perfectly suited to supplement existing course content or as an excellent resource for independent study.

As intellectually stimulating as the online course materials are, perhaps the most useful resources will be those available via the virtual classroom. In this open forum, anyone can pose a question regarding the course materials, technical exercises, or design platforms. The virtual classroom, a key portion of ADI's Engineering University Program, is missing from most other educational packages. Regularly monitored by the professional staff at Analog Devices, this community is designed to encourage collaboration among students. Its ability to foster global communication while offering timely answers to questions will enhance the efficiency of many students.

For me, the most practical portion of the program was the Analog Discovery design kit. With this platform, along with the free WaveForms software, I implemented an oscilloscope, an arbitrary waveform generator, and a power supply—simultaneously from my computer—enabling a quick and easy start to my circuit design. Figure 16 shows a screenshot of the above functions running on my PC. Although I didn't use them for this project, the design kit offers many other features—including a logic analyzer, a pattern generator, static I/O, a voltmeter, and a network analyzer. The device's portability and ease of use will allow students to take creativity and innovation outside of the traditional lab setting and bring it to dormitories, common areas, and even home. Including hardware, which is rarely found as part of an educational package, is an ingenious idea to combine practical design skills with theoretical learning. I highly recommend the optional Analog Parts Kit, which proved to be incredibly useful, providing me with an array of components and saving me the time and hassle of ordering parts.

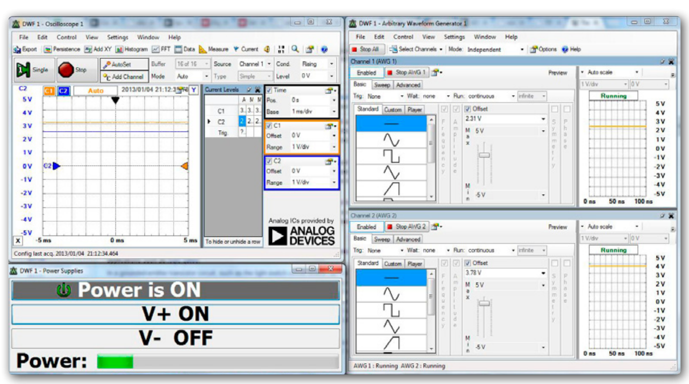


Figure 16. Running an oscilloscope, arbitrary waveform generator, and power supply from a computer.

Figure 17 shows how the Analog Discovery design kit can bring lab functionality anywhere, including the kitchen table. This newfound accessibility to lab tools encourages students to apply their knowledge more creatively, learning debugging techniques and other skills that cannot be taught in lecture. With its portability and ease of use, the design kit provides students with an elegant tool to apply their knowledge.

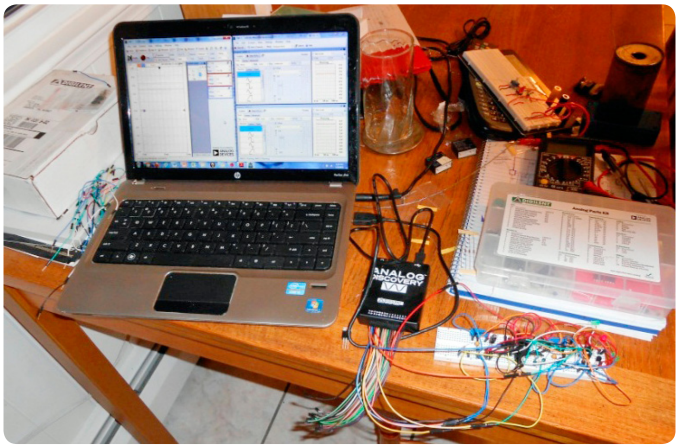


Figure 17. Analog Discovery can bring lab functionality anywhere, including the kitchen table.

As with every educational package, ADI's Engineering University Program has its strengths and weaknesses. Beginning with its strongest points, the courseware is easily accessible and free of charge. Written by individuals who fully understand the content, the online materials leave little room for confusion or misinterpretation. The integration of theory with practical applications provides a near perfect combination of reading and hands-on learning. In addition, the online content blends the components necessary for a complete understanding of the topics, including video lectures, PowerPoint slides, textbook, and reinforcing homework assignments, making the program an exceptional resource for learning about analog circuitry.

The program contains room for improvement, however. The homework lacks sufficient quantity and depth to provide a greater understanding of the material, and the virtual classroom suffers from a lack of participation. The textbook contains some minor formatting inconsistencies and grammatical errors, although these do not hinder the ability of the text to convey information. Lastly, to avoid confusion, Digilent® should include directions to download WaveForms and a manual with the Analog Discovery kit (I had to figure out which software to download and search for documentation that explains the full usage of the package).

For readers who are curious about my project, the device evaporates condensation from bathroom mirrors using a homemade clear thin-film heater, senses the relative humidity and temperature using the AD22100 temperature sensor, and controls the heater with a circuit consisting of comparators and simple transistor logic. Figure 18 shows the breadboard used to prototype and debug the circuit, measure voltages, and simulate the sensor input. ADI's Engineering University Program is proving to be a valuable tool; in the future, I plan to use more of the online course materials to study analog circuitry.

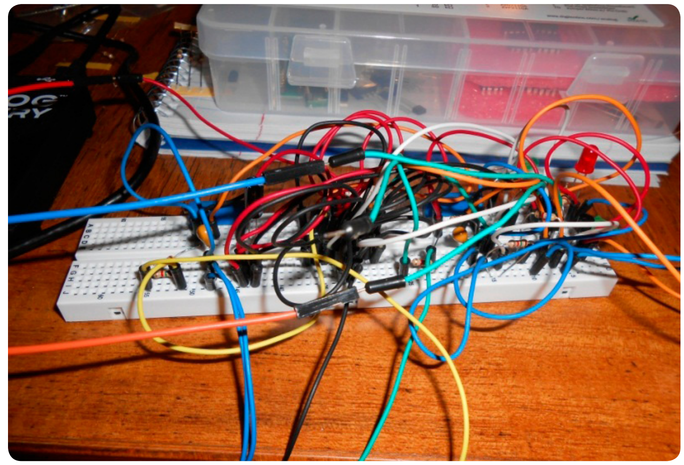


Figure 18. The prototyped circuit on a breadboard.

Conclusion

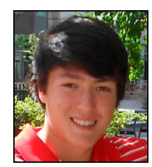
ADI's Engineering University Program provides an excellent resource for learning about analog circuitry. The textbook, video lectures, and labs teach analog theory to a high standard, seeding student curiosity; the virtual classroom facilitates international communication, question posing, and remote assistance; and the hardware design platforms have superb functionality that inspire students to innovate.

References

Revolutionizing How Engineering Students Learn Analog Circuit Design.

Video about Analog Devices University Program.

Authors



Ryan Fletcher [rfletcher@wpi.edu] is a student at the Massachusetts Academy of Math & Science at Worcester Polytechnic Institute, where his interests include electrical and robotic engineering, mathematics, and business. He is a member of various clubs, including debate, ultimate Frisbee, and recreational skiing. In his spare time, Ryan enjoys cycling, mountain biking, and snowboarding.

Scott Wayne [scott.wayne@analog.com] joined Analog Devices as a design engineer in 1978. Before transferring to the *Analog Dialogue* staff, he designed a variety of precision analog-to-digital and digital-to-analog converters using modular, hybrid, and monolithic technologies. Scott holds an SBEE from MIT and continues his education through their edX program. He is the author of several articles and holds two patents. In his free time, Scott enjoys hiking, bicycling, and kayaking.